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Facility for Accelerated Service Testing

TECHNICAL NOTE

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A Study of Trackside Lubricator Greases on FAST

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INTRODUCTION

The FAST program has used lubrication during specific periods to extend rail life in various metallurgy tests conducted since 1976. During this time, the gage-face wear rate of standard carbon rail has been used as a "baseline" for measuring comparative life of alternative premium rails. The importance of closely controlling lubrication was not fully recognized until data from early tests indicated vast differences in wear rates of identical rails during various periods of the FAST experiment. The Lubrication Study at FAST was designed to address a number of questions that resulted from early experiments, including how to apply, measure, and control lubrication of the rail.

The Lubrication Study was planned in July, 1983, and was scheduled to begin in October of that year. An AAR Ad Hoc Committee recommended that the experiment investigate the implications for

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various materials and their associated wear patterns demonstrated by earlier experiments.

The FAST Lubrication Study had five major objectives:

- o To develop methods for measuring the effectiveness of lubrication;
- o To develop performance criteria for various types of lubricants, location and methods of application, and configuration of lubrication systems;
- o To maintain and evaluate reliability and maintenance histories of various trackside lubricator systems;
- o To evaluate the energy savings potential of various lubrication systems.
- o To develop ideas for better lubricators for the unique FAST environment.

This report concerns only the first three objectives.

The lack of track-grease performance standards has often resulted in the user selecting a "curve grease" on the basis of low cost rather than superior lubrication performance. In the past, the specifics of grease composition and performance have been the province of the grease manufacturers. Recently, the reduction of train resistance through better lubrication has been realized. Thus, the ability of specific greases to transfer, spread, persist, and lubricate are of great current interest.

This report studies several performance indices of lubrication performance made for eight lubricants at the Facility for Accelerated Service Testing (FAST). The railroad industry is encouraged to use these results in assessing qualifications for lubricant selection and in setting up their own lubricant qualification programs. The results of this test may not entirely address user operating requirements as this data was derived entirely from FAST tests.

This report will review FAST test results showing how various lubricants differ in the following situations:

- o speed of application;
- o spreadability;
- o reaction to hot wheels;
- o reaction to sand on the rail;
- o residual effectiveness after application is stopped;
- o effect of cold and warm temperatures.

METHOD AND PROCEDURES

All field tests were made on the FAST Track (Figure 1) with the test train operated in a counterclockwise direction. All lubrication was applied on the outside rail in Section 22. This location is approximately 2,200 ft. in advance of the 5-deg. curve in Section 03.

A Moore & Steele trackside lubricator with four M & S blades was used for all tests. Test grease was placed in the tank, the tests runs were performed, and the tank was replaced with another tank containing a different test grease.

The test sequence for most greases was run first in the winter at temperatures of from 20 to 25 deg. F and then in the summer at temperatures of from 89 to 96 deg. F.

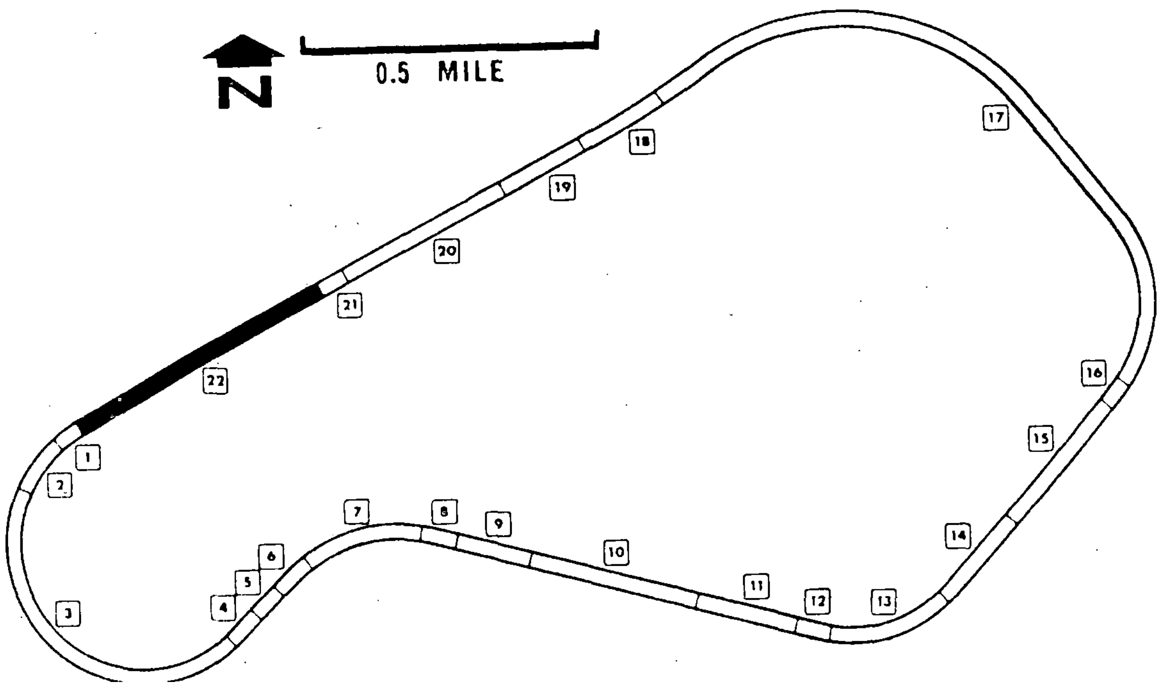

Figure 1. FAST Track Loop: The FAST Track layout with Section 22 identified.

The FAST train was operated for eight-hour shifts, during which the lubricator was turned on or off as required. The rail was dried between grease tests by operating the train for a number of laps until data indicated a "dry" or unlubricated rail.

Data Measurements

Specific databases were created to assess the comprehensive performance of the grease products on three specific types of measurements used to monitor grease effectiveness:

1. The "goop gauge" is a simple visual indicator used to check grease levels on track. In the past, FAST has tried numerous methods of monitoring lubrication levels. Grease output meters were installed in the trackside lubricator hoses, but frequent clogging, freezing weather, and erratic readings led to the abandonment of this system. The "goop gauge", Figure 2, has been utilized for several years to measure and control the level of visible grease on the rail. During recent lubrication studies, FAST personnel attempted to maintain lubricant levels of no lower than +0 and no higher than +10, based on "goop gauge" values. These levels indicate a grease coverage restricted to only the gage surface. A trackman periodically inspected the spread of lubricant on test curves and adjusted the lubricators to maintain grease at the desired level.

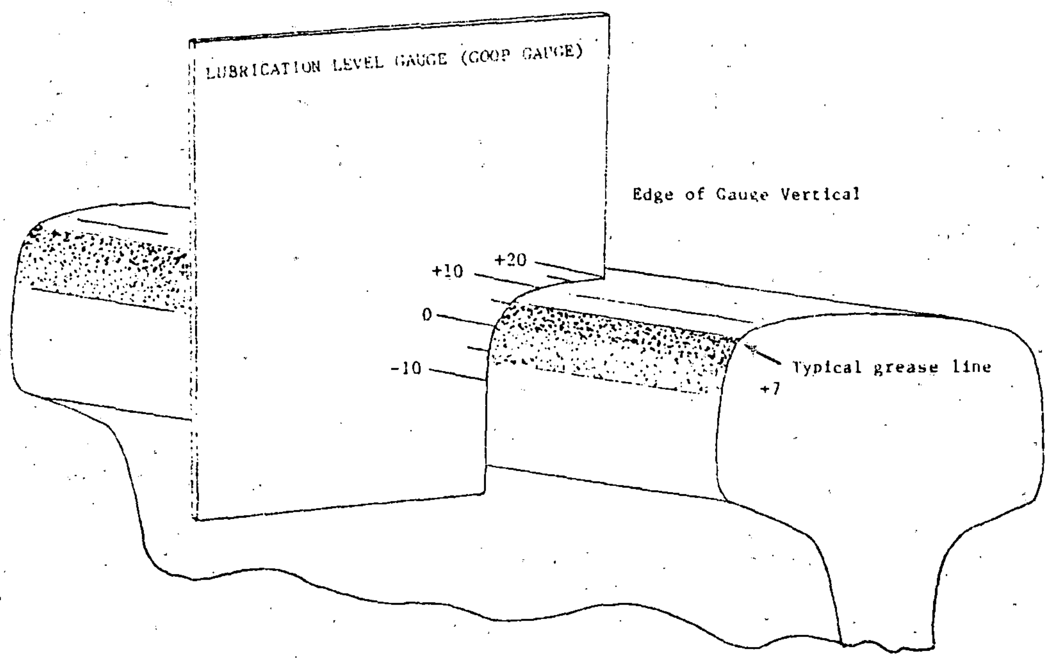

Figure 2. Goop Gauge: The "Goop Gauge" is used to measure the spread of lubrication at the gage surface.

While the "goop gauge" is a useful tool for monitoring the visible level of lubricant, it does not indicate the effectiveness of lubrication of the wheel flange-to-rail interface.

2. Rail-head temperature-rise is an indicator of the frictional forces from a passing train affecting rail temperature. It is measured by small thermocouples attached to the head and base of the rail. Frictional forces are present during the flanging action on the high rail as a train negotiates a curve. These result in heat at the rail-flange interface. The amount of heat produced by a passing train is a function of many factors - curvature, speed, superelevation, truck characteristics, train weight, and lubrication. At FAST, it is possible to control these variables; during the lubrication experiment, all these items except lubrication were kept constant. Thus, the resulting temperature-rises were an excellent indication of lubrication-effectiveness.

The field side of the high rail is used for temperature measurements because the results will facilitate use of portable systems by the railroad industry.

3. Longitudinal wheel/rail forces are determined by measuring the torsional strain in the axle. These forces are a function of the longitudinal slippage that takes place between wheel and rail. Forces on the two wheels of the axle are equal and opposite and steer the axle. If the torquemeter output is divided by the wheel radius, it can be called a longitudinal force that retards train motion. On a curve, the torquemeter provides a very uniform means of comparing forces for dry and lubricated rail. These forces are monitored by a specially instrumented wheelset, mounted in a standard truck (leading axle)

under a 100-ton car. The torque measurements are made at midtrain and recorded by the data-collection vehicle. At FAST, on a 5-deg. curve at 45 m.p.h., a "dry" or unlubricated rail will result in axle torque values of 5,500 to 8,500 lb. ft. Adequate lubrication on the same curve will result in axle torque values of 1,500 to 2,500 lb. ft. Consistent torque values are observed between these two extremes at intermediate lubrication levels.

Figure 3 shows the benefits of lubrication as measured by rail temperature rise. The lower line on the temperature graph indicates ambient rail temperature of a short length of 136-lb. rail situated adjacent to the track. Wheel forces and railhead temperature-rise information was collected as the FAST train negotiated the test curve and spread the lubricant around the loop.

Data for 5° curve, 4" elevation, 8500 ton train (75 cars) at 45 mph:

		DRY	LUBED
Longitudinal Forces	torque	15.0 ft kips	2.0 ft kips
Coop Gauge		-10	+10
Temperature Rise at Rail Head		18° F	3° F

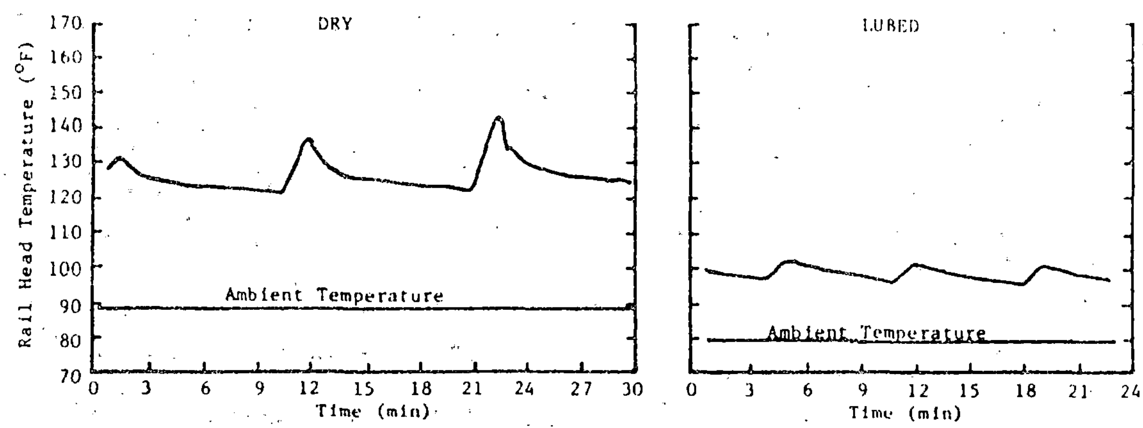

Figure 3. Lubrication Effectiveness Measurements

"Goop gauge", rail-temperature, and longitudinal wheel-force data were obtained at the following locations:

- o Section 3 (5-deg. curve): Measurements were made at the beginning, middle, and end of the curve.
- o Section 13 (4-deg. curve): Measurements were made at the beginning and end of the curve.

The "goop gauge" provided a visual measurement of the presence of grease after each passage of the train.

The rail-temperature measurements provided an indication of lubrication-effectiveness based upon the average friction due to flexing of the rails caused by the passing train.

The wheel-force data was collected at designated locations within the consist and was then averaged for a train 600 to 800 ft. long. This measurement is an indication of the lubrication level at a selected position in the train. For these tests, the wheel forces were measured near the middle of an 80-car train.

Data Presentation

Appendices A through J include a representative graph for each type of measurement utilized in this test. Run numbers represent a series of laps with similar test conditions. Lap numbers indicate single train passes over the test zones and are used for evaluating the retention of grease on rail and other pertinent lubrication data. "Goop gauge", rail temperature, and wheel-force readings have been plotted for each grease type and for each of the two test curves. A total of more than 140 plots were generated. A representative sample of each type has been included in the Appendix.

Rail temperature and wheel-force data were collected on a continuous basis for each lap. The "goop-gauge" readings were recorded in a log book by a track inspector walking the test zone.

Each plot is numbered A-1, B-3, etc., to permit easier cross-referencing of results. Section 03 track data shows the highest resolution and is used for rating greases. In many cases, Section 13 did not receive adequate lubrication because it is located more than 2 miles from the lubricator. This may also indicate that after about 180 deg. of curvature, effective lubrication at FAST was difficult to maintain with trackside application of the test lubricants.

An additional Appendix, L, presents the results of a laboratory test performed on the test greases.

Test Run Sequence

Each FAST train operation was recorded daily. All repetitive tests were identified by the same run number. Each test run used the following sequence:

1. Lubrication from the previous test run was removed by operating the train with the trackside lubricator turned off.
2. Concurrently, the lubricator site was prepared by installing another tank containing the new test grease. The pump, hoses, and tank were cleaned with solvent and then the system was primed and flushed to remove all traces of other lubricants.

3. After a "dry" track condition had reached a longitudinal force of 6,000 lb. ft. in the 5-deg. curve, and railhead temperature-rises of 10 deg. F for each lap of the train occurred, the lubricator was turned on for a period of up to 35 laps, as follows:
   - o 5-10 laps: lubricator on;
   - o 15-20 laps: lubricator on, wheel brakes applied, and measurement of wheel-tread temperatures;
   - o 5 laps: lubricator on, no braking, sanding through test zones;
   - o Lubricator off.
4. The train continued to operate to "dry down" the track for the next test sequence.
5. Data collected during the lubrication and dry-down laps provided changes in wheel force and temperature. "Goop-gauge" readings were also taken after each passage of the train. These data were used for all comparisons.
6. Lap designation for lube on, sanding, braking, etc., shown on the plots in the Appendices may be off by plus or minus 2 laps due to measuring devices being erroneously triggered at different times.
7. Results of lubrication applied by the hi-rail system are reported in the second hi-rail report.

Table 1A lists the cold weather test conditions and Table 1B pertains to warm weather testing. Each table specified the FAST run number, date(s) of test, designation of grease used during the run, ambient temperature and comments relative to applied lubrication, and test conditions. Therefore, these tables summarize the test environment and grease designation for all the data in the eight Appendices.

TABLE 1A

TEST RUN CONTROL LOG FOR COLD-WEATHER TESTS

FAST Run No.	Dates 1984	Test Grease	Ambient Deg. F.	Comments
1264	02/27-28	A	+20	Lube on, braking, sanding
1265	02/28-29	A	+25	Lube on
1266	02/30-03/01	B	+26	Lube on, braking
1267	03/01-03/02	B	+21	Lube on, braking, sanding, lube off
1268	03/02-03	C	+20	Lube on, braking
1269	03/05-06	C	+19	Lube on, braking, sanding, lube off
1270	03/06-07	D	+21	Lube on, braking
1271	03/07-08	D	+19	Lube on, braking, sanding, lube off
1272	03/08-09	E	+21	Lube on, braking, sanding
1273	03/09-10	E	+25	Lube on, sanding, lube off
1274	Other FAST Tests	None	+24	
1275	Other FAST Tests	None	+29	
1276	03/13-14	F	+26	Lube on, braking, sanding
1277	03/14-15	F	+26	Lube on, sanding, lube off
1278	03/15-16	G	+25	Lube on, braking, sanding
1279	03/16-17	G	+25	Lube on, sanding, lube off

TABLE 1B

TEST RUN CONTROL LOG FOR WARM-WEATHER TESTS

FAST Run No.	Dates 1984	Test Grease	Ambient Deg. F.	Comments
1316	06/06	C	+89	(Hi-rail) lube lap
1317	06/07	C	+91	Dry-down
1318	06/12	A	+92	Lube on, braking
1319	06/13	A	+92	Lube on, sanding, lube off
1320	06/14	A	+91	Lube off
1321	06/26	A	+90	Lube off
1322	06/29	E	+93	Lube on
1323	07/02	E	+95	Lube on, braking, sanding, be off
1324	07/05	E	+94	Braking
1325	07/06	E	+96	Sanding, lube off
1326*	07/10	B	+92	Lube on
1327*	07/11	B	+94	Lube on, braking, sanding, lube off
1328	07/12	B	+93	Lube off
1329	07/17	D	N/A	Dry-down
1330	07/18	D	N/A	Lube on, braking
1331	07/19	D	N/A	Sanding, lube off
1332	07/20	D	N/A	Lube off
1333	07/24	D	N/A	Lube off
1334	07/25	B	N/A	Lube on, braking, sanding
1335	07/26	B	N/A	Lube off
1336	07/30	G	N/A	Lube on, braking, sanding, lube off
1337	08/01	C	N/A	Lube on, braking, sanding, lube off
1338	08/02	F	N/A	Lube on, braking, sanding
1339	08/10	F	N/A	Lube off
1340**	08/14	H	N/A	Lube (hi-rail) on
1341**	08/15	H	N/A	Dry-down
1342**	08/16	I	N/A	Lube (hi-rail) on 1 lap, lube off
1343	08/21	J	N/A	Lube on
1344	08/22	J	N/A	Lube on, braking, sanding, lube off
1345	08/23	J	N/A	Lube off
1350**	09/07	K	N/A	Lube (hi-rail) on
1351**	09/10	K	N/A	Dry-down
1352**	09/11	K	N/A	Dry-down
1353**	09/12	K	N/A	Lube (hi-rail) on
1354**	09/13	K	N/A	Dry-down
1355**	09/14	K	N/A	Dry-down
1356**	09/22	K	N/A	Dry-down

* Invalid data. Rerun as runs 1334, 1335

** Data to be addressed in other reports

Lubricant Selection

The AAR Ad Hoc Committee on Rail Lubrication was responsible for the overall test plan. This committee, which was made up primarily of railroad engineering personnel, selected the following test lubricants:

A. Standard FAST grease used in the past having a calcium soap base and 12% graphite;

B. A petroleum lubricant with carbon black and synthetic polymer thickness;

C. A metaloid fusion lubricant with tetrafluoroethylene (Teflon) additive;

D. A petroleum lubricant with lithium soap base and graphite and molybdenum disulfide additive;

E. A special formula for CN/CP with calcium soap base and 11.5% graphite with 2.5% molybdenum disulfide additive.

These five lubricants provided a range of "standard" greases. Three additional lubricants that were tested are:

F. A petroleum lubricant with calcium soap base thickener and molybdenum disulfide additive;

G. A petroleum lubricant with lithium soap base thickener and no graphite;

J. A tetrafluoroethylene and lithium soap base lubricant.

To eliminate contamination between grease types and limit handling, a separate reservoir was filled with each grease and placed on site. The same pump was cleaned with a solvent and used for each grease. All samples for lab analysis were obtained directly from the reservoir used on site, not from the original grease barrel.

RESULTS

The data-analysis section of this report is divided into two parts. The first segment is a comparison of each of the eight greases with itself to discern any differences in effectiveness when applied during cold and warm periods. The second section is a comparison between different grease types during the cold and warm tests.

In the harsh environment of railroad service, the physical performance of a grease is as important as is its ability to reduce friction. That is, effective lubrication depends on the presence and persistence of lubricant at the wheel-rail interface. Thus, each set of results ranks grease performance on:

- o initial spreadability on dry track;
- o resistance to power braking;
- o resistance to the effects of sanding;
- o ability to survive on the rail after application stops.

The analysis for each grease is based on the observed change in a parameter (wheel force or rail temperature-rise) that results after each activity. For example, a dry-rail axle torque of 6,500 lb. ft. changing to a 2,000 lb. ft. after five lubricated laps shows a net reduction (improvement) of 4,500 lb. ft. This may be compared to a different grease providing an improvement of only 2,500 lb. ft. "Goop-gauge" logs are provided in the Appendices for information purposes to show the level of visible grease present for each test.

In reference to a number of "rail temperature" plots analyzed, it is indicated that power braking heated the train wheels, as intended, and transmitted a significant amount of heat to the rails. This can be confirmed by examining rail-temperature plots and concurrent wheel-force plots for each test. In most cases, the wheel forces indicate little or no change due to hotter wheels; the rail-temperature plots invariably indicate a significant rise in temperature. (The instrumented wheelsets had all brakes removed; thus, no effect of brake shoe force is shown.) For purposes of data analysis, the effects of power braking on lubrication-effectiveness can be assessed by examining the wheel-force data plots.

Table 2 contains a brief summary of grease behavior noted during testing. These results were based on field observations, wheel-force data, railhead temperature-rise, "goop-gauge" readings, and test control logs.

A major concern of some railroads represented on the FAST Ad Hoc Lubrication Committee was the problem of grease burning off wheels on long downgrades where wheel temperatures can exceed 600 deg. F. To simulate this environment, the wheel temperatures at FAST were raised by power braking for a distance of about 1.5 mi. per lap, leaving the locomotive power in run 8 (throttle position) for the entire 4.7 mi. loop. A maximum wheel temperature of 350 deg. F was reached after 15 to 20 repeated braking laps, so the braking tests should not be considered conclusive evidence of lubrication effectiveness on hot wheels.

Although wheel force and rail temperature data were collected for all runs, the automatic rail-temperature data-collection system did not always perform as intended. Thus, much of the analysis is based on wheel-force data.

TABLE 2

OBSERVED PERFORMANCE OF GREASES UNDER TYPICAL CONDITIONS

Grease Type	Difference, Cold to Warm Weather	Effect of Sanding	Effect of Braking
A	Spread faster during warm weather. Did not last as long in cold weather.	Adversely affected only during cold weather	No effect
B	Very poor cold-weather effectiveness; did not transfer from blade to wheels.	Slight adverse effect	No effect
C	Appeared to have poor cold-temperature pumpability. Disappeared rapidly.	Adversely affected	No effect
D	Spread faster during warm weather. Did not last as long as in cold weather.	No effect	No effect
E	Spread faster during warm weather.	Adversely Affected more during warm weather than during cold weather	Adversely affected during warm periods
F	Better cold-temperature curve differential.	Some adverse effect	No effect
G	Better uniformity during cold weather. Lasted longer during warm weather. More rapid application during warm weather.	Adversely affected in both cold and warm weather, more so during warm weather	No effect
J	Not tested in cold weather. Low uniformity during warm weather.	Some adverse effect in warm weather	No effect

Note: Data from tests on greases H, I, and K will be addressed in other reports.

Test Results by Grease Type

The figures referred to in the following discussions are TTC file numbers for plotted data. Due to the large number of plots taken, only representative ones for each grease are in the Appendix.

Grease Type A

Grease A is a calcium soap base and 12% graphite additive. It was selected for testing because it had been used at the FAST track for several years. All plots for grease A are prefixed with "A".

Figure A-3 shows cold weather rail temperatures with varying lubrication. Figure A-5 presents the wheel-force data for cold weather. In test Section 03, grease A performed somewhat better during the warmer period than during the cold period.

During the warm weather test, the overall difference in temperature-rise for a dry-rail condition (10 to 13 deg. F) compared to lubricated rail (2 to 3 deg. F) was about the same as during the cold test, although the drop was more rapid during the warm test. After about five laps of lubricated operation, a relatively consistent temperature-rise of 3 deg. F was observed.

The wheel-force data indicated a better overall effectiveness during the warm weather. It was also noted that periods of power braking had no effect on lubrication efficiency. Sanding operations, during cold ambient temperatures, slightly reduced effectiveness.

Grease Type B

Grease B did not contain any graphite or any molybdenum disulfide as additives. This petroleum-based grease has carbon black and synthetic polymers added to thicken the product.

During the cold temperature test, little or no grease reached the rails. This was verified through "goop-gauge" logs and statements from the test crew. The lubricator pump was examined several times during the test; although fresh grease was always present at the application blade parts, the grease did not transfer to the passing wheel flanges. At the conclusion of the cold-temperature run, a large amount of lubricant was piled on the ballast adjacent to the blades (Figure 4).

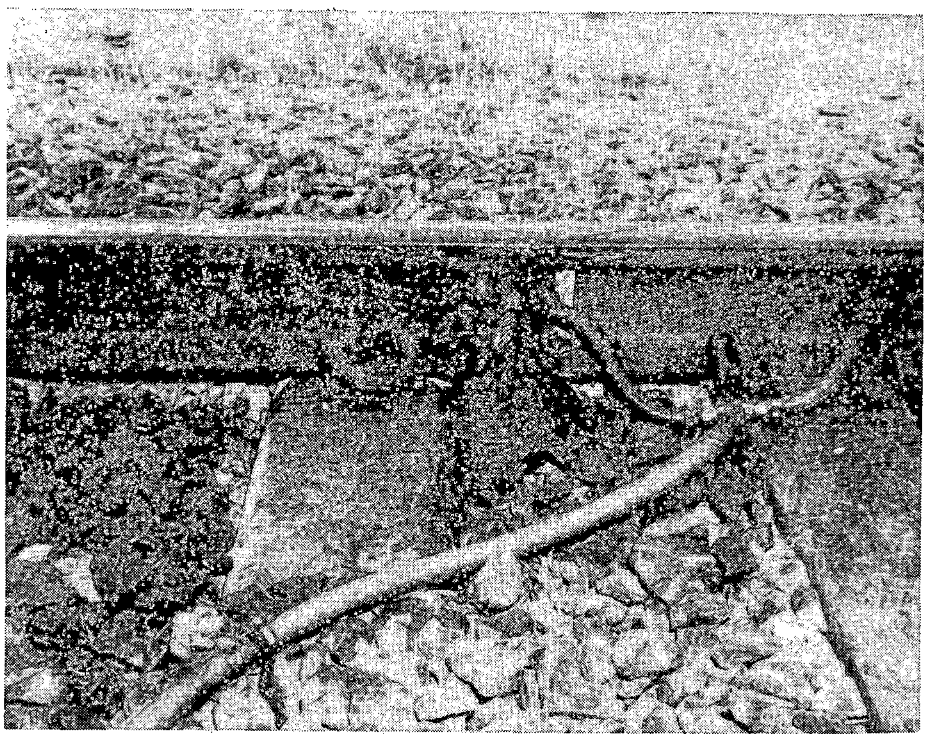

Figure 4. Lubricant "B" on Ballast: During cold weather, lubricant "B" poorly transferred grease to wheel flange.

The same grease was tested during warm weather. The grease required six train passes prior to uniform effectiveness being observed at both ends of the curve. No adverse effect due to braking was observed; however, sanding did produce a very mild adverse effect.

Grease Type C

Grease C was the initial "nonconventional" lubricant selected by the Ad Hoc Committee. This grease is a metaloid fusion lubricant with tetrafluoroethylene, and its selection resulted from interest in the effect of the additive on the rail-wheel contact surface. Since this grease contains no graphite, there is no graphite "mess" as is often the case with conventional lubricants.

The cold temperature tests proved somewhat disappointing. Although rail temperature and wheel force data (Figures C-3 and C-5, respectively) indicated that lubrication effectiveness continued to improve after the lubricator was turned on, the grease stopped flowing around lap 35 to 40. The "goop gauge" indicated a loss of lubricant, and test logs indicated that no grease was being pumped. The pump was inspected and the grease puddled, eliminating an air pocket, but another pocket developed rapidly.

Data plots indicated that the performance of grease C was affected adversely by both braking and sanding. This conclusion is difficult to support because after 35 laps, there was only a small amount of grease present on the rail, and this was due to the lubricant pump failure. It should be noted that effectiveness of the grease, as measured by wheel force (Figure C-5), was good until the pumping failure occurred. The same pump was used for the next test with no adjustment or repair, and no pumping problems were encountered.

The warm temperature wheel-force data indicated a higher beginning-to-end-of-curve effectiveness differential than during cold temperatures. While no effect was noticed due to braking, sanding appeared to lessen the grease effectiveness. The effect that the lubricant had upon wheel force decreased quite rapidly after turning off the lubricator.

Worthy of note is the effect of rain on wheel force data. Observation determined that the rail was dry after the termination of the test; however, the data also showed that rain apparently caused well-lubricated rail toward test-end at approximately lap 51.

Although application (lube on) data showed good effectiveness, rapid lubricant disappearance was also indicated. One problem observed during runs with the grease was that it was apparently unable to adhere to the rail (the grease was sprayed through a nozzle onto the rail from a moving truck). Much of the grease fell or slid from the rail immediately after being applied. The MFL base appeared to provide good lubrication effectiveness, especially during colder temperature testing, but the carrier is not optimized for pumpability and staying power in the railroad environment. A photo of the lubricator site after application of grease C is shown in Figure 5.

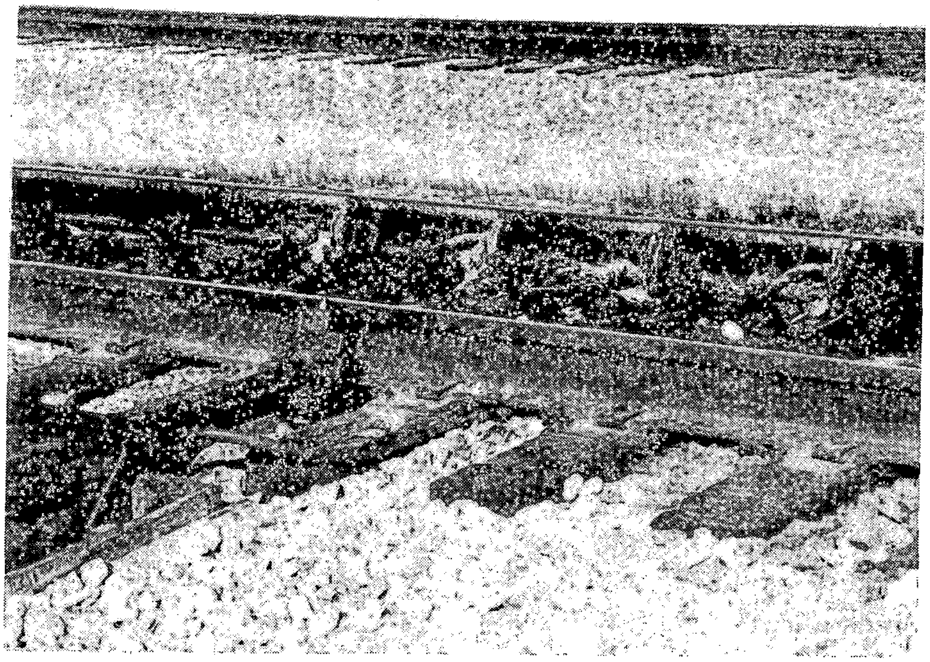

Figure 5. Lubricated Site For Grease "C". Note that the grease has slipped from the gage point of the rail.

Grease Type D

Grease D utilizes a lithium soap base thickener for the carrier, with molybdenum disulfide added as a friction-reducing agent.

During cold temperatures, the rail temperature-rise data indicated a gradual increase and uniformity of effectiveness from the beginning to the end of the curves, with about 14 to 15 laps required to reach its most efficient level (Appendix D, Figures D-3 and D-4). No effect on rail temperature was observed due to sanding.

The wheel force data indicated more rapid improvement in lubrication effectiveness during the warm temperature test as compared to the cold temperature test. Little or no effect due to braking or sanding was observed.

During the cold temperature test, the beginning of Section 03 started to lose lubricant effectiveness quite rapidly. Wheel forces reached 3,500 lb. ft. about nine laps after the lubricator was turned off.

Grease Type E

Grease E has a calcium soap base to maintain viscosity and 11.5% graphite and 2.5% molybdenum disulfide. It was selected for testing because it was designed for cold weather use at the request of the Canadian railroads.

Wheel-force data for Section 03 (Figure E-5) indicate a slower effectiveness factor during cold temperatures; there was a slight adverse effect due to sanding. During warm temperatures, the effectiveness of application was faster, but an adverse effect due to hot wheels from braking was observed. This lower effectiveness value was carried on through the sanding operations. Two data-collection runs were made with this lubricant during warm weather because of instrumentation problems.

Grease Type F

Grease F was an experimental calcium soap thickener grease with graphite and molybdenum additives.

Wheel-force plot (F-5) indicates better cold temperature performance. The beginning-to-end-of-curve differential was much less, and the overall level of lubrication was better during the cold-temperature tests. Sanding was slightly detrimental to effectiveness in both temperature ranges.

Grease Type G

Grease G has a lithium soap thickener with pure synthetic oils and traces of elemental lead and copper included as additives.

Wheel-force data (plot G-5) indicate a more uniform effectiveness during cold temperatures than during warm temperatures. This was noticed during the initial lube-on period when the beginning-to-end-of-curve differential for Section 03 was less during the cold period. During the warm-temperature test, the improvement in effectiveness levels at all positions in the curve was more rapid; however, the beginning-to-end-of-curve differentials were higher. The effect of sanding was adverse during both temperature periods, but a larger loss of effectiveness was noted during the warm test.

After turning the lubricator off, the loss of grease effectiveness was faster during the cold test than during the warm test.

Grease Type J

Grease J contained tetrafluoroethylene (TFE) and lithium soap base thickners. It was not selected for testing until after the cold weather tests had been completed. The manufacturer pointed out that the TFE additive was designed to work into the metal surfaces to provide longer-lasting lubrication effects. In a single test run on the FAST Track, long-term effects of residual TFE could not be detected. There was some prolonged effectiveness, as indicated by the wheel force plots for Sections 03 and 13. Figure J-5 indicates a larger beginning-to-end-of-curve differential in wheel forces, and a slight adverse effect from sanding.

Grease Ranking

The most often-sought information from this study was a comprehensive ranking of the lubricants based upon test-specific and overall performance. Table 3 is a summary of cold and warm temperature wheel-force data that addresses the following questions:

1. What amount of improvement, over existing conditions, can be obtained in wheel-force data after five to six train passes?

The information was collected about 3,800 ft. from the lubricator in the middle of the 5-deg. curve.

2. What was the largest wheel force differential observed within the curve after five to six laps of operations?

Columns 1 and 3 of Table 3 contain both cold and warm temperature data that show the net reduction in wheel force due to lubrication at midcurve for each grease tested. A high reduction in wheel force is advantageous.

Columns 2 and 4 contain both cold and warm temperature beginning-to-end-of-curve wheel-force differential data. A grease with good, uniform spreading characteristics would produce very nearly the same wheel force value at all positions in the curve. Therefore, the lower the differential value the better the lubrication performance.

Wheel force values after five to six train passes were selected for analysis, because later tests were operated for five to six laps prior to braking, and the initial grease response was preferred. During the test, by leaving the lubricator on for 10 to 15 laps, so much grease often would be applied that little difference could be determined between grease types. Due to this, the values for Table 3 should be regarded as plus or minus 1, since it was difficult to pinpoint exact wheel forces.

TABLE 3

WHEEL FORCE DIFFERENTIAL DATA FROM
COLD AND WARM WEATHER TESTS

Data were taken 5 to 6 laps after the lubricator was turned on. All wheel-force values are expressed in 1,000 lb. ft.

	Cold Temperature		Warm Temperature	
Grease Type	Net Midcurve Improvement from Dry to Lubricated k lb.ft.	Beginning-to-End-of-Curve Differential k lb.ft.	Net Midcurve Improvement from Dry to Lubricated k lb.ft.	Beginning-to-End-of-Curve Differential k lb.ft.
A	4	3	9	2
E	4	1	10.5	2
B	1.5*	1*	7	5
D	2.5	0.5	8	1
C	2	1.5	5	3.5
G	2.5	2	6.5	2
F	3	2.5	4	5
J	**	**	2.5	3

*Briefly, for only one lap. No effective lubrication was obtained during the cold-weather test.

Table 4 shows wheel force dry-down data for each test grease. The figures indicate the number of train passes required to raise wheel forces by 3,500 lb. ft. after lubrication was terminated. Although this was an effort to quantify how long each grease would last, it is important to note that conditions varied widely from one lubricant test to another.

TABLE 4

DRY-DOWN DATA

Shows number of laps required to increase the wheel force 3,500 lb. ft. after the lubricator was turned off. Data were collected in midcurve, Section 03 of FAST.

Grease Type	Cold-Weather Test No. of Laps	Warm-Weather Test No. of Laps
A	25+	45
E	21	6*
B	**	13
D	***	70
C	**	8
G	16	20
F	6	10
J	****	22

* Questionable data
** Adequate lubrication never obtained
*** Insufficient data; data-collection stopped after 10 laps
**** Not tested

Due to budget constraints, not all lubricants started their dry-down period after the same number of grease application laps. The result is that different amounts of grease were applied to the rail prior to dry-down. In addition, because the dry-down immediately followed the sanding operations, the effect of sand influenced how long the grease would last on the rail. Therefore, the lubricants were not ranked on their durability.

Table 5 ranks each product using the tabulated data in Table 3 for an application guide. The lubricants were ranked according to their ability to be applied rapidly and uniformly. Each grease was ranked in one of the following performance categories: high, medium, or low. It should be kept in mind that the lubricants were ranked on the basis of results at FAST. Highly disparate conditions such as higher curvature, colder or warmer operating temperatures may influence ranking under actual railroad operating conditions.

TABLE 5

GREASE RANKING ON ABILITY TO BE APPLIED RAPIDLY AND UNIFORMLY APPLIED

Performance	Cold-Weather Test	Warm-Weather Test
High	E A	E A D*
Medium	F D G C	B G C
Low	B	F J

*Only grease adversely affected by braking

Laboratory Tests

ASTM and other laboratory test results are often supplied by lubricant manufacturers with their products. No one test has been deemed an acceptable standard for use on rail lubricators; this is witnessed by the wide variety of different tests used by various manufacturers.

TTC performed a series of laboratory tests based on a report entitled "Laboratory Tests Stable Polytetrafluoroethylene Colloids as Lubricating Additives" by F. G. Reick (American Laboratory for June, 1977). The test setup shown in Figures 6 and 7 consisted of a conventional drill press, a flat-bottom 3/8-in. drill bit (machined flat with a 3/16-in. hole in the center), and a section of polished rail. An 8-lb. counter-weight (using a 1-gal. milk jug) on a lever arm was used to force the drill bit down on the rail sample (Figure 7). The rail temperature was recorded and plotted every 5 min. using a TTC portable thermocouple meter and a magnetically attached probe. All tests were performed at a room temperature of 65 to 78 deg. A drill press speed of 1,500 r.p.m. was used for all tests.

The test sequence for each plot was as follows:

1. Obtain a machined flat-bottom drill bit with the prescribed hole.
2. Place 3 c.c. of test grease where the drill bit will contact the rail.
3. Place bit in the drill chuck, start motor, and manually lower the bit until it just makes contact with the railhead, then let the weight apply the correct force.
4. Continue the test until a rail temperature of 250 deg. F is reached or 2 hours has passed.

Where possible, two or three additional test runs were made for each test grease.

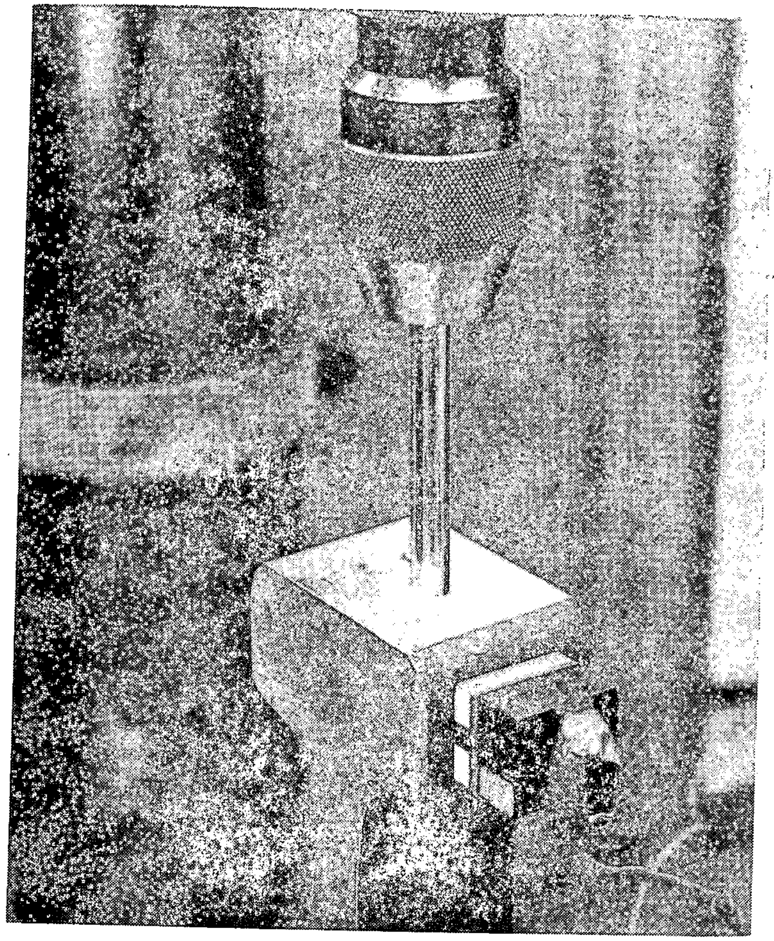

Figure 6. Lab Test Setup. Drill rod is against section.

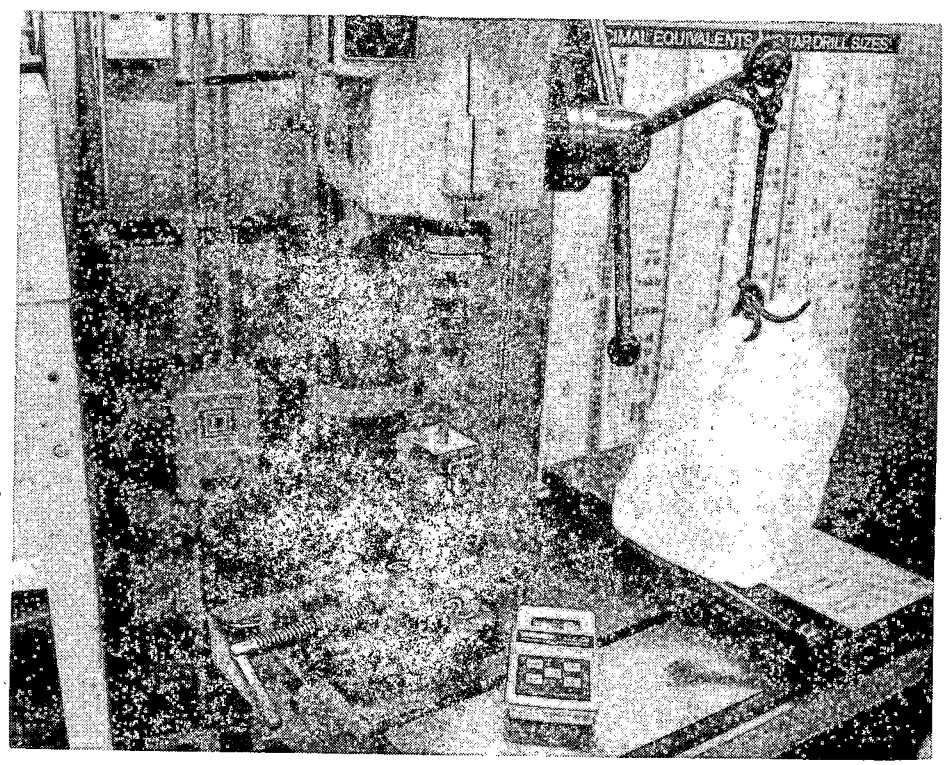

Figure 7. Lab Test Measurement.

Table 6 shows rail temperature readings after specified time intervals. Appendix L contains log-sheet plots of temperature readings for each grease tested plus results of a dry (no grease) test. Of special interest was the similarity of results between test lubricants, especially during the initial 15-min. intervals. Although some greases did not perform well on the additional test runs, the average value of temperature for each time interval, as shown in Table 6, indicates that this type of test is probably not very useful for determining applicability of lubricants under railroad trackside lubricator conditions.

The laboratory tests indicate that all lubricants have very similar traits under these test conditions. The wide range of results from field tests show that the effects of wheel flange movement in picking up the lubricant from a stationary blade and spreading it along the rail requires more complex test simulation conditions than were available from the laboratory testing.

TABLE 6

LABORATORY TEST: RAIL TEMPERATURE READINGS (DEG. F) AT SPECIFIED TIME INTERVALS

Grease Type	Time in Test (Mins.) 5	10	15	60	120
Dry	185	266	---	---	---
A	90	105	120	185	225
E	90	102	112	155	155
B	95	112	127	175	250
D	95	110	125	165	165
C	90	105	118	150	150
G	90	108	120	175	175
F	90	112	125	175	195
J	90	105	115	150	145

SUMMARY

It is not surprising that the highest-ranking test greases are similar to those now commonly used in the railroad industry. These lubricants have passed the field acceptance tests of actual railroad operation, unofficial though they may be. Since these lubricants do not provide optimum coverage at all times, why isn't there wider application of new, unconventional anti-friction additives such as tetrafluoroethylene? The test results explain some of the reasons.

In the always harsh (especially at the wheel-rail interface) railroad environment, the carrier, or thickener, plays an important role in track lubricant performance. In the case of unconventional additives, the anti-friction agents are effective, but the base carrier apparently does not survive pre-application and post-application variables. Therefore, having been either mechanically displaced from the rail-flange contact area or dissipated by some other means, the carrier is no longer available to deliver its product-graphite or molybdenum disulfide, for example, where it is needed.

The trackside lubricator system is, itself, subjected to an extreme temperature range of minus 25 to plus 120 deg. F. Grease dispensed by this system may be contaminated by dirty lubricator blades, and it must then be picked up by wheels traveling at speeds up to 70 mph. The grease is then carried on the wheel flange and transferred to the rail for distances of more than a mile. Finally, it is transferred from the wheel flange to the side of a rail so that it may begin working to reduce friction.

Even the greases that ranked highest did not perform the remote lubrication as well as desired. Grease still migrated to the railhead, reducing traction and causing locomotive wheel slip. The migrated grease is shown by the +20 to +30 "goop- gauge" readings on most plots. This happens even after initial efforts were directed toward applying the grease only to the flange of the wheel. In order to reach curves distant from a lubricator, trackmen were forced to increase lubricator output, causing excessive lubrication at nearby curves. If effective levels of lubrication are to be maintained during cold and warm periods, lubricator operation must be monitored to ensure uniform application and spreadability.

Future research into lubricant additives and carriers (bases) will be required to optimize grease performance. A joint effort between the petroleum and the lubricator manufacturers would be beneficial in developing application systems and lubricants that are optimized to work together.

ACKNOWLEDGMENTS

A test of this size requires the participation and cooperation of a number of persons. Special thanks are directed to the lubricant manufacturers and suppliers who assisted.

Data-collection efforts onboard the TTC test car were the responsibility of Ms. Judy Stadler and Mr. Alex Harrell, both of whom deserve credit for recording vast quantities of data. Mr. Ira Kalb was responsible for transferring and monitoring the various lubricants, as well as for ensuring a properly operating lubricator. Mr.

Carl McGraw and Mr. Manuel Perez contributed much effort to recording "goop-gauge" readings throughout each test. Test coordination was performed by Mr. Bernard Kreusch. Data-reduction and plotting were performed by Ms. Bea Rael.

APPENDIX

GRAPHS OF MEASURED TEST DATA PLOTTED VS. LAP NUMBER
AND LABORATORY TEST DATA

GREASE LUBRICATION TEST

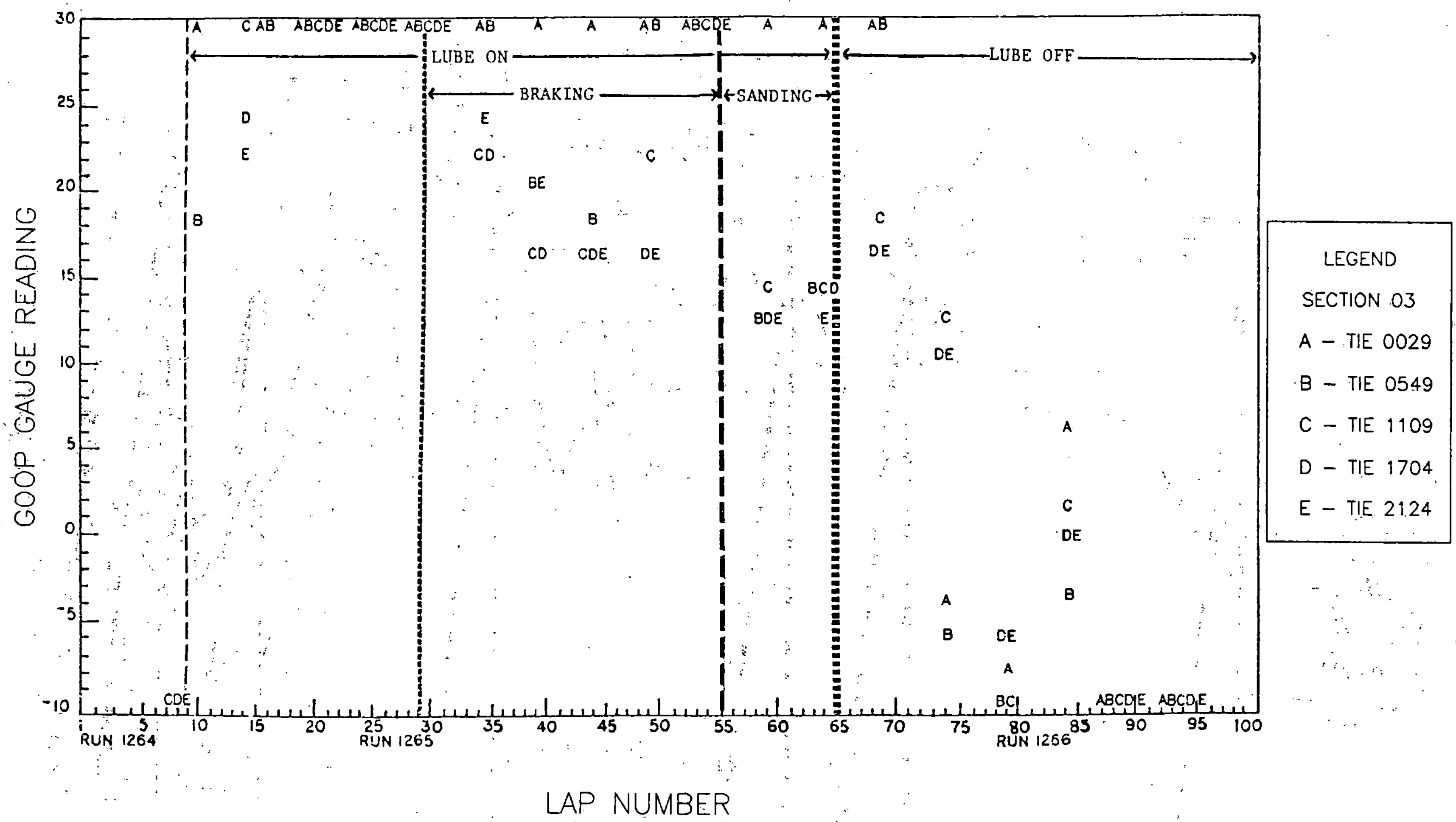

Figure A–1. Grease "A", Goop Gauge Reading, Section 03, Cold Weather

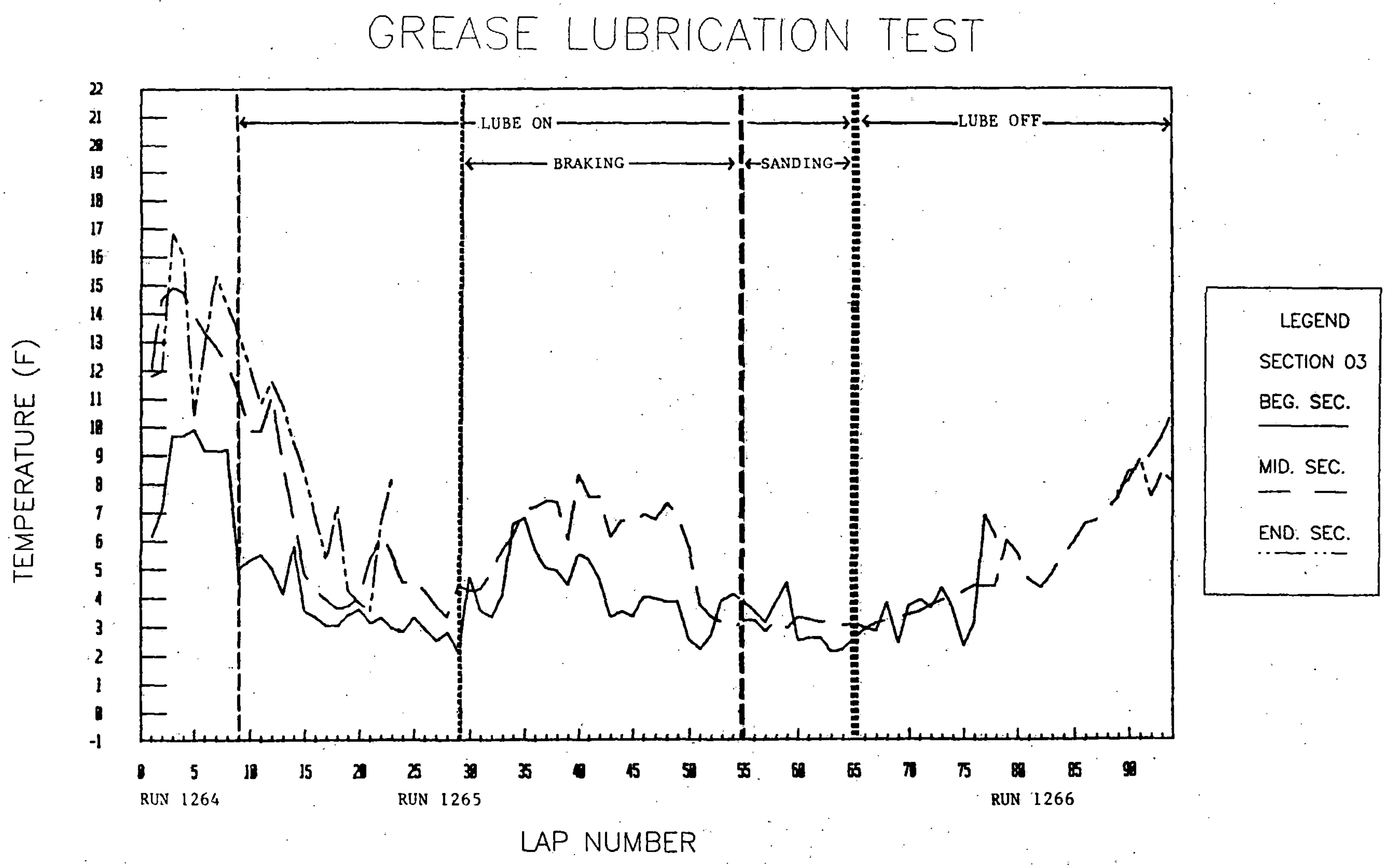

Figure A–3. Grease "A", Rail Temperature Rise, Section 03, Cold Weather

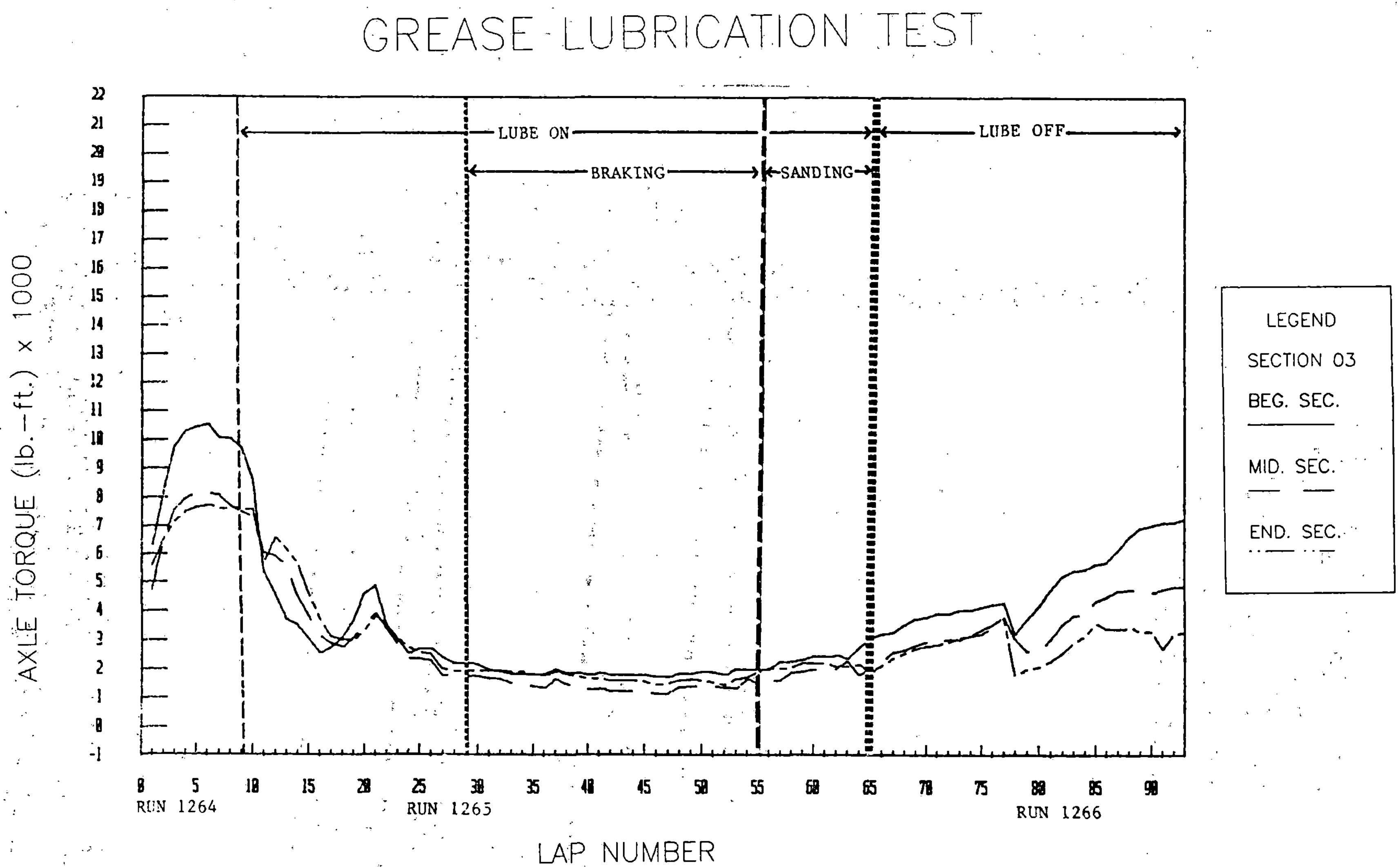

Figure A-5. Grease "A", Axle Torque Data, Section 03, Cold Weather.

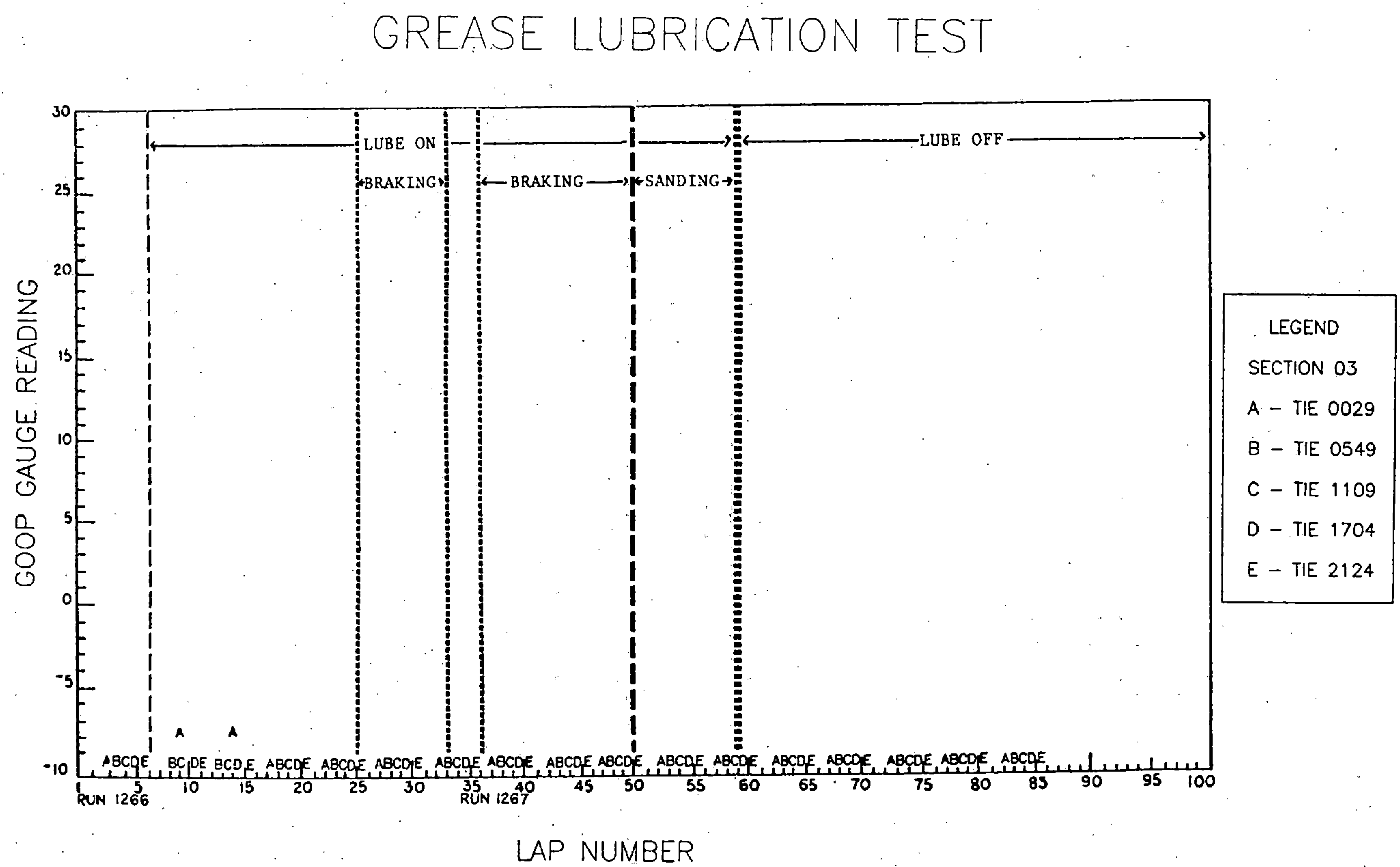

Figure B–1. Grease "B", Goop Gauge Reading, Section 03, Cold Weather.

GREASE LUBRICATION TEST

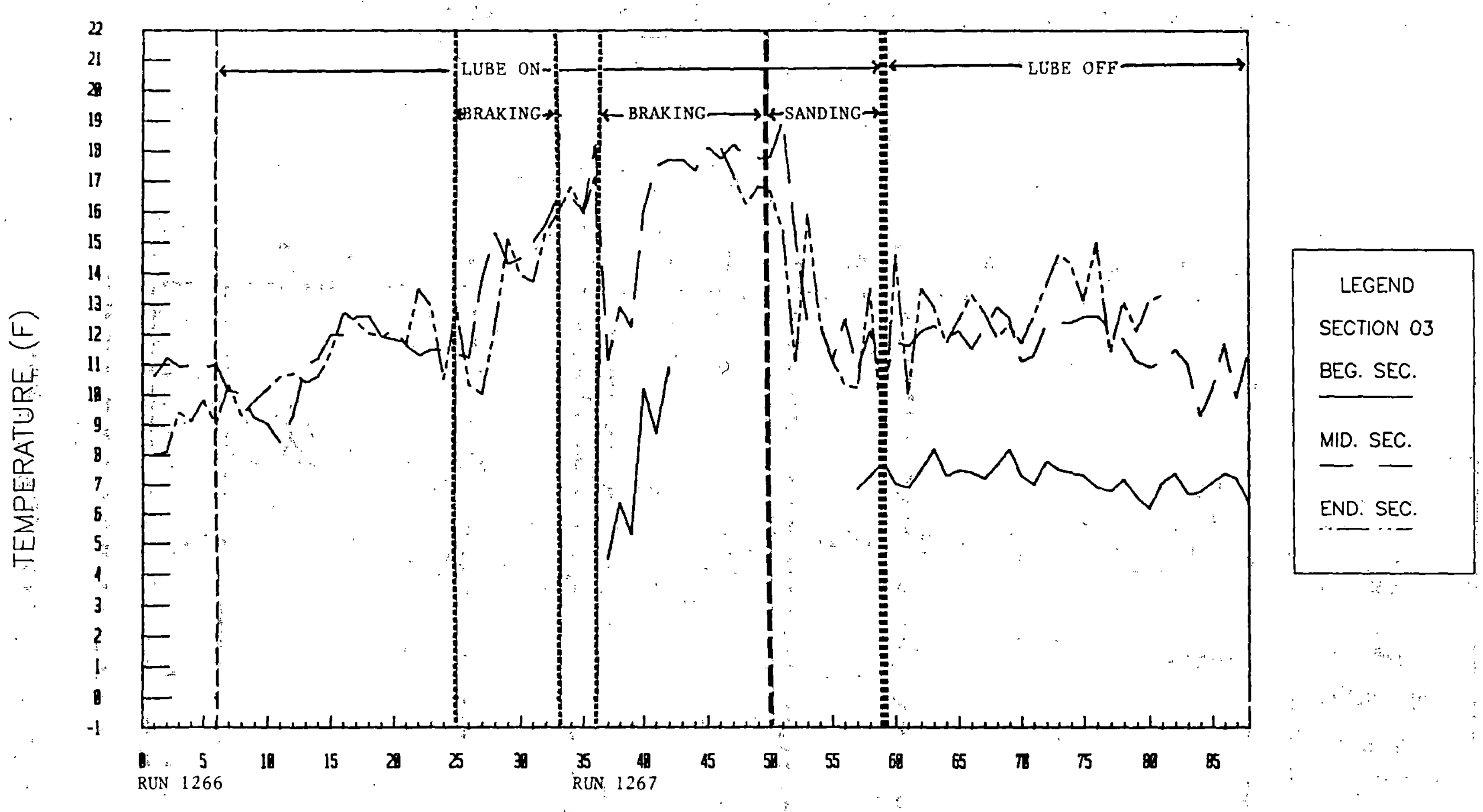

Figure B–3. Grease "B", Rail Temperature Rise, Section 03, Cold Weather.

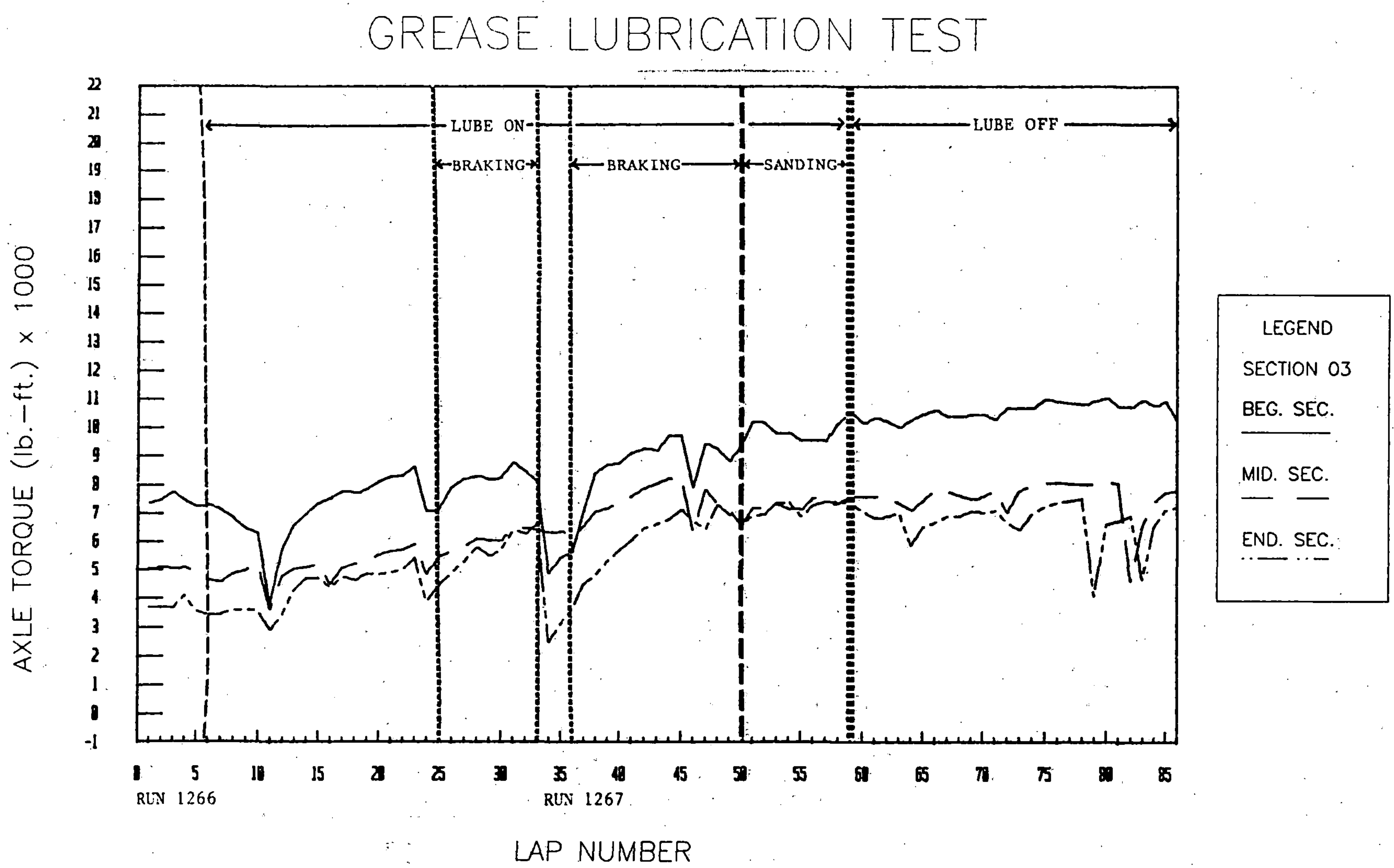

Figure B–5. Grease "B", Axle Torque Data, Section 03, Cold Weather.

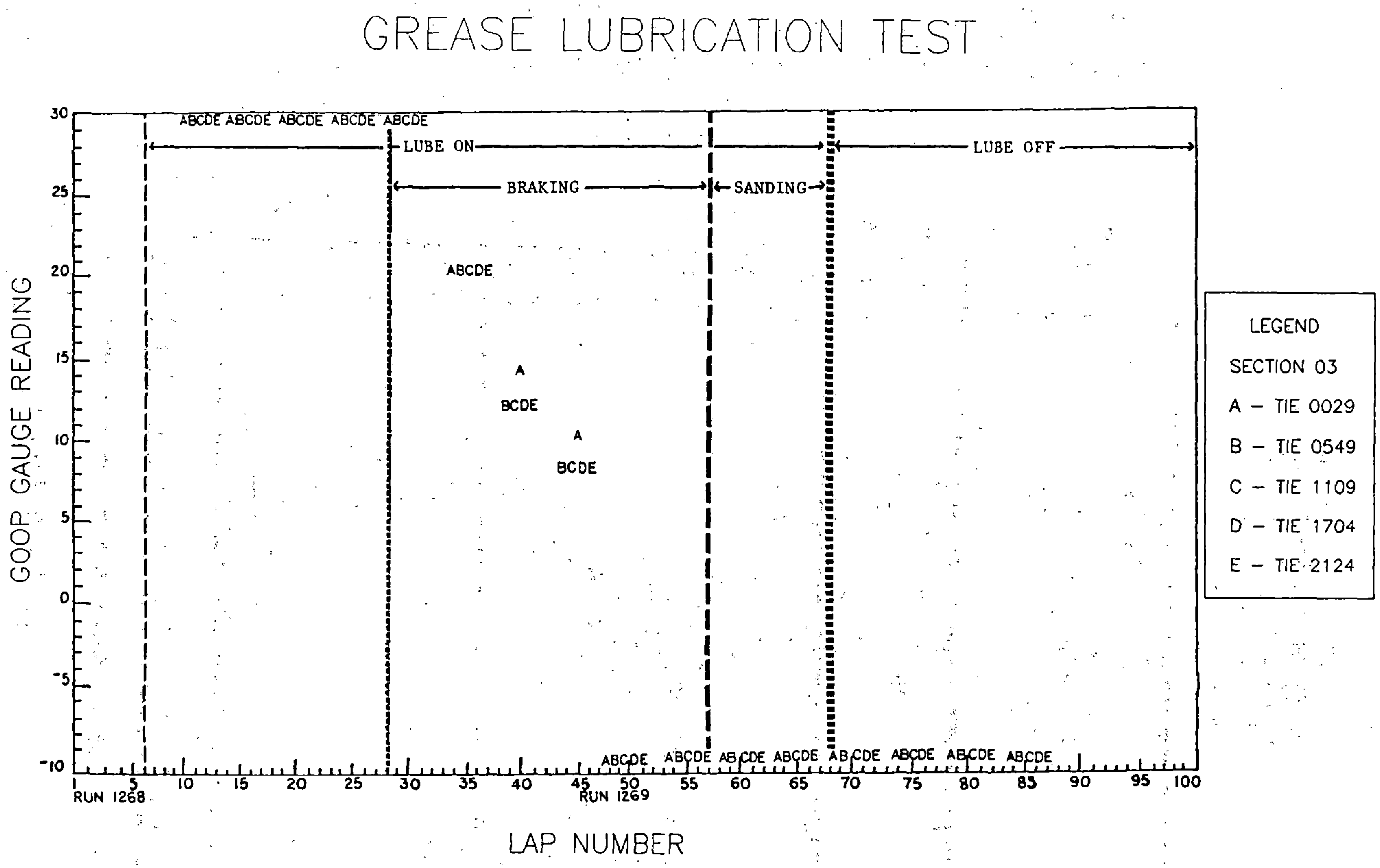

Figure C–1. Grease "C", Goop Gauge Reading, Section 03, Cold Weather.

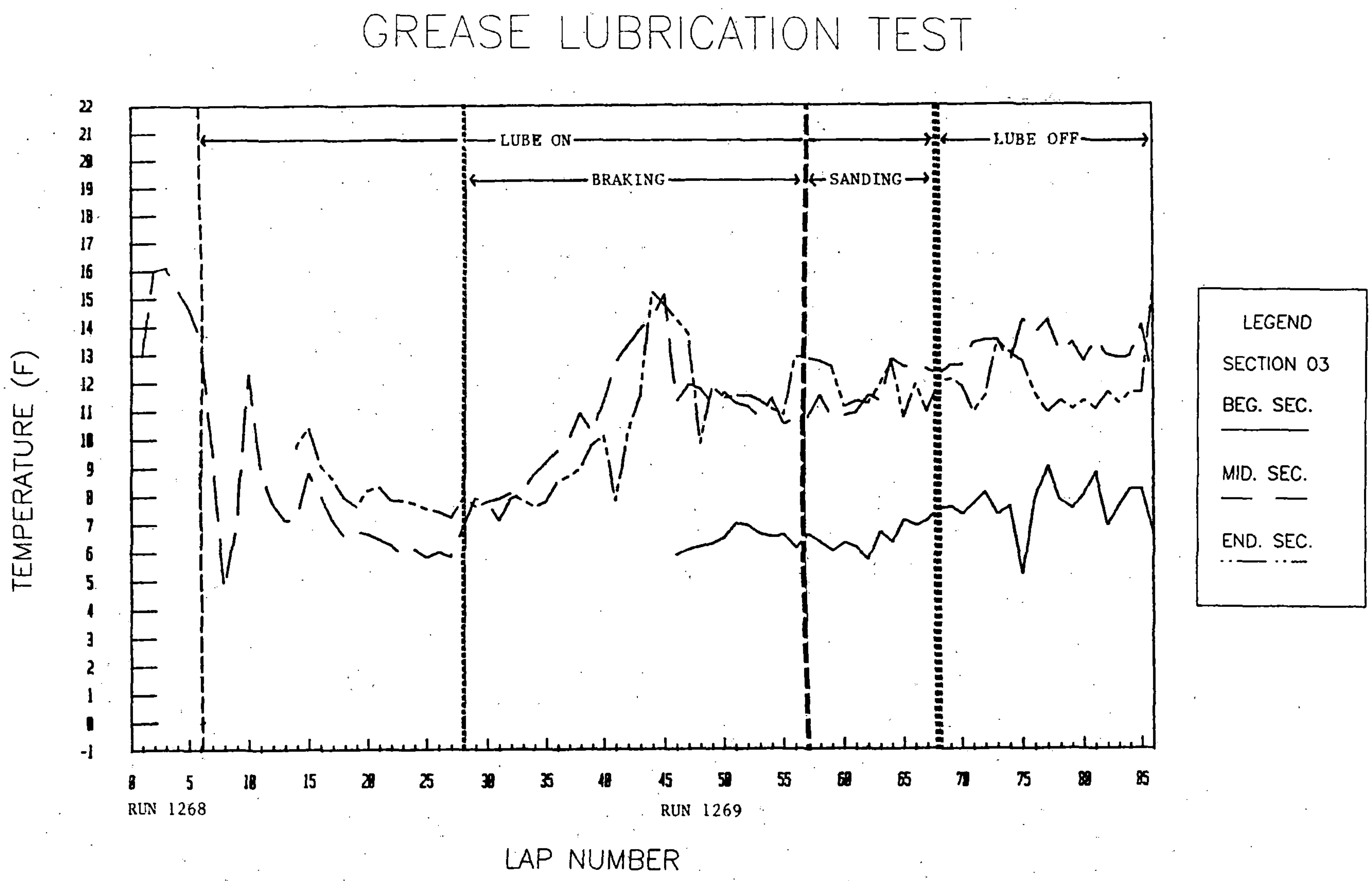

Figure C-3. Grease "C", Rail Temperature Rise, Section 03, Cold Weather.

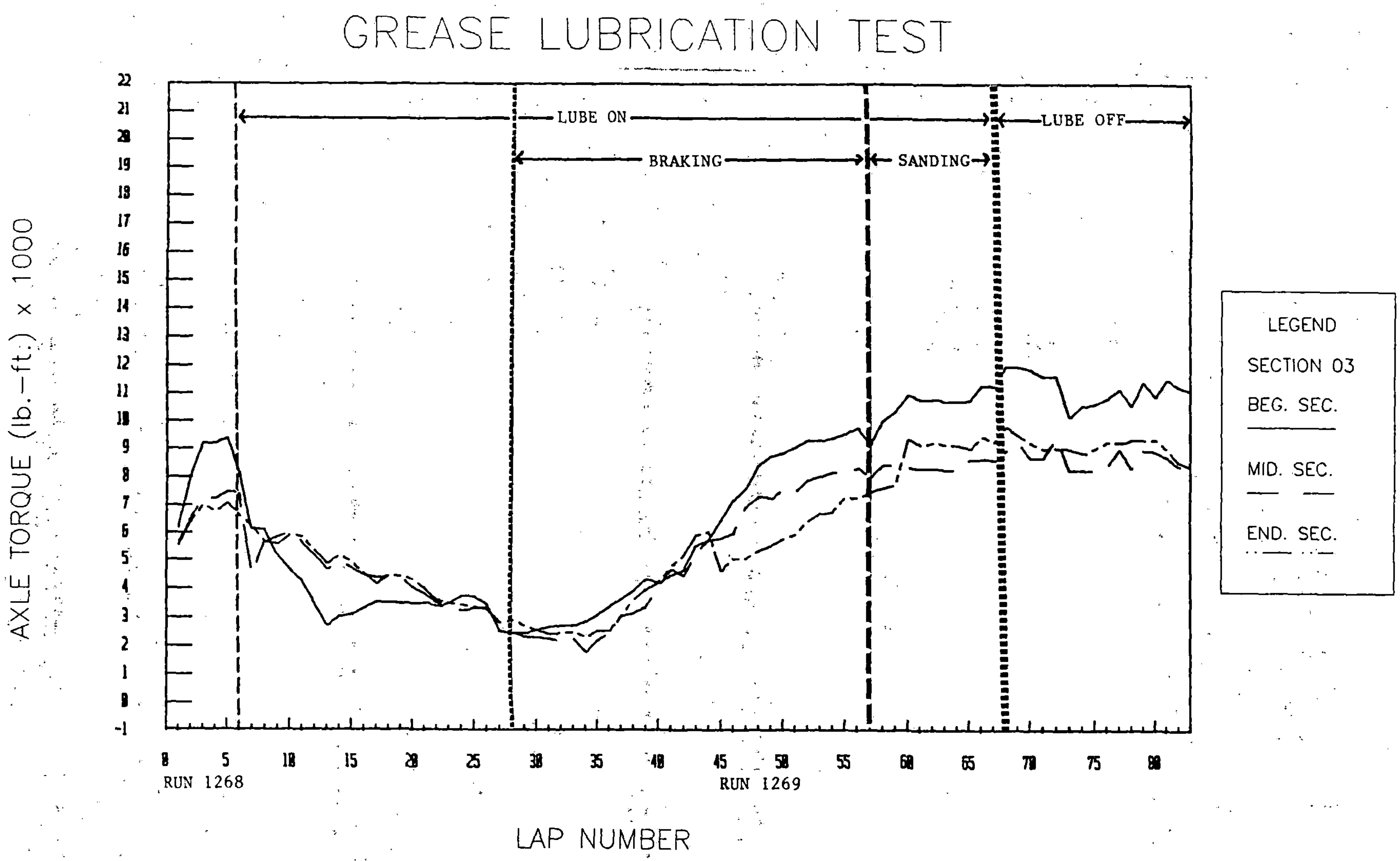

Figure C-5. Grease "C", Axle Torque Data, Section 03, Cold Weather.

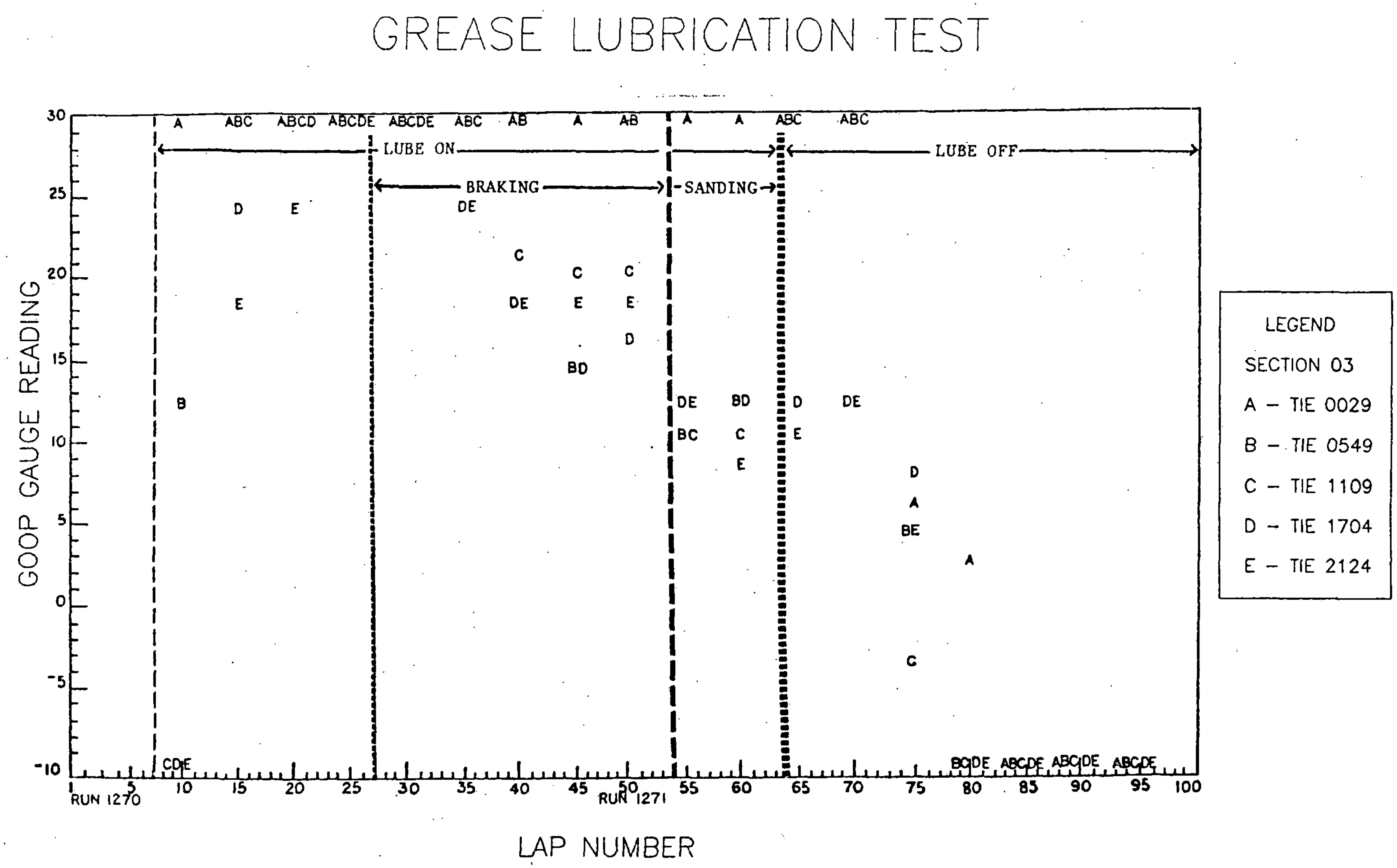

Figure D–1. Grease "D", Goop Gauge Reading, Section 03, Cold Weather.

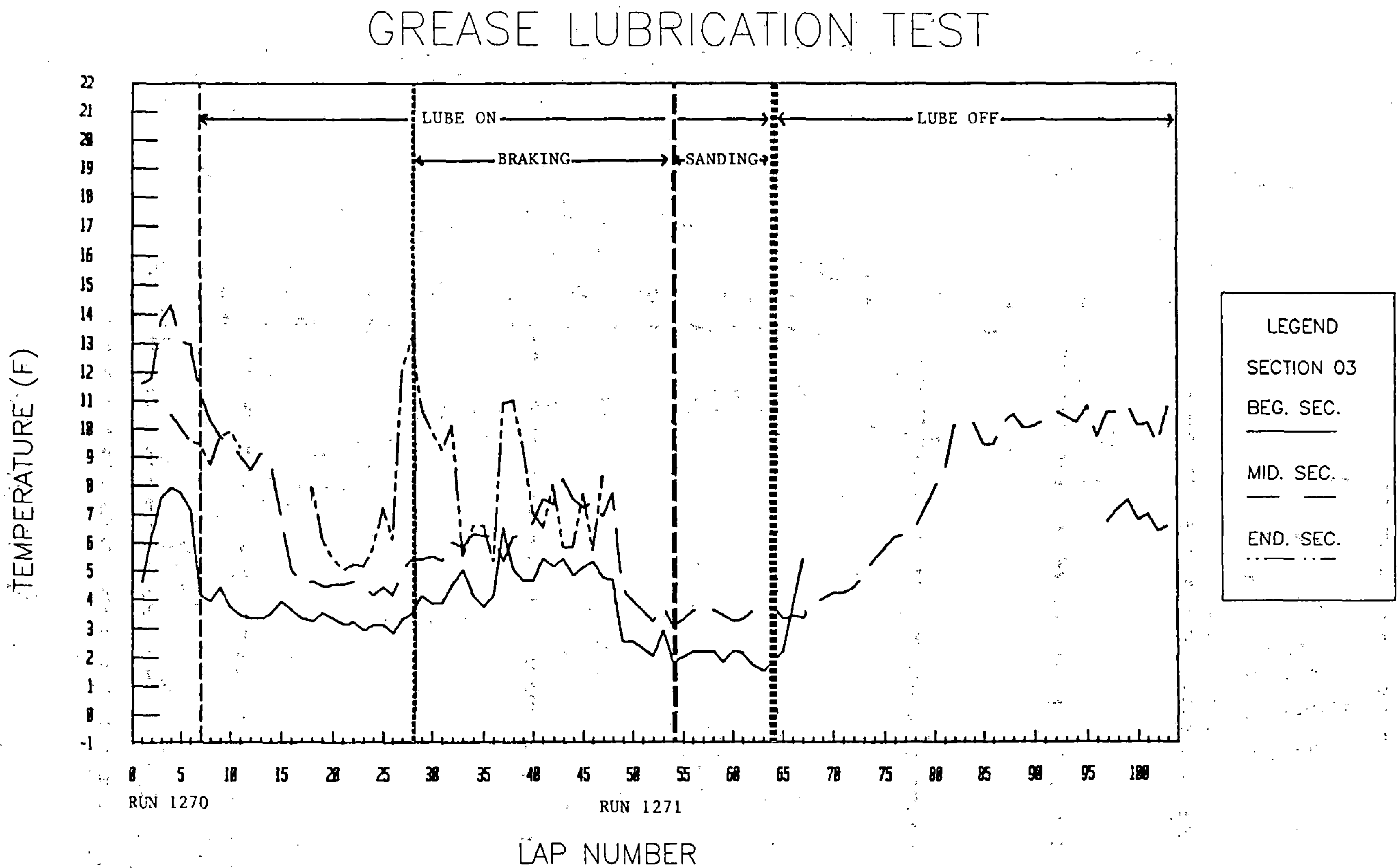

Figure D-3. Grease "D", Rail Temperature Rise, Section 03, Cold Weather.

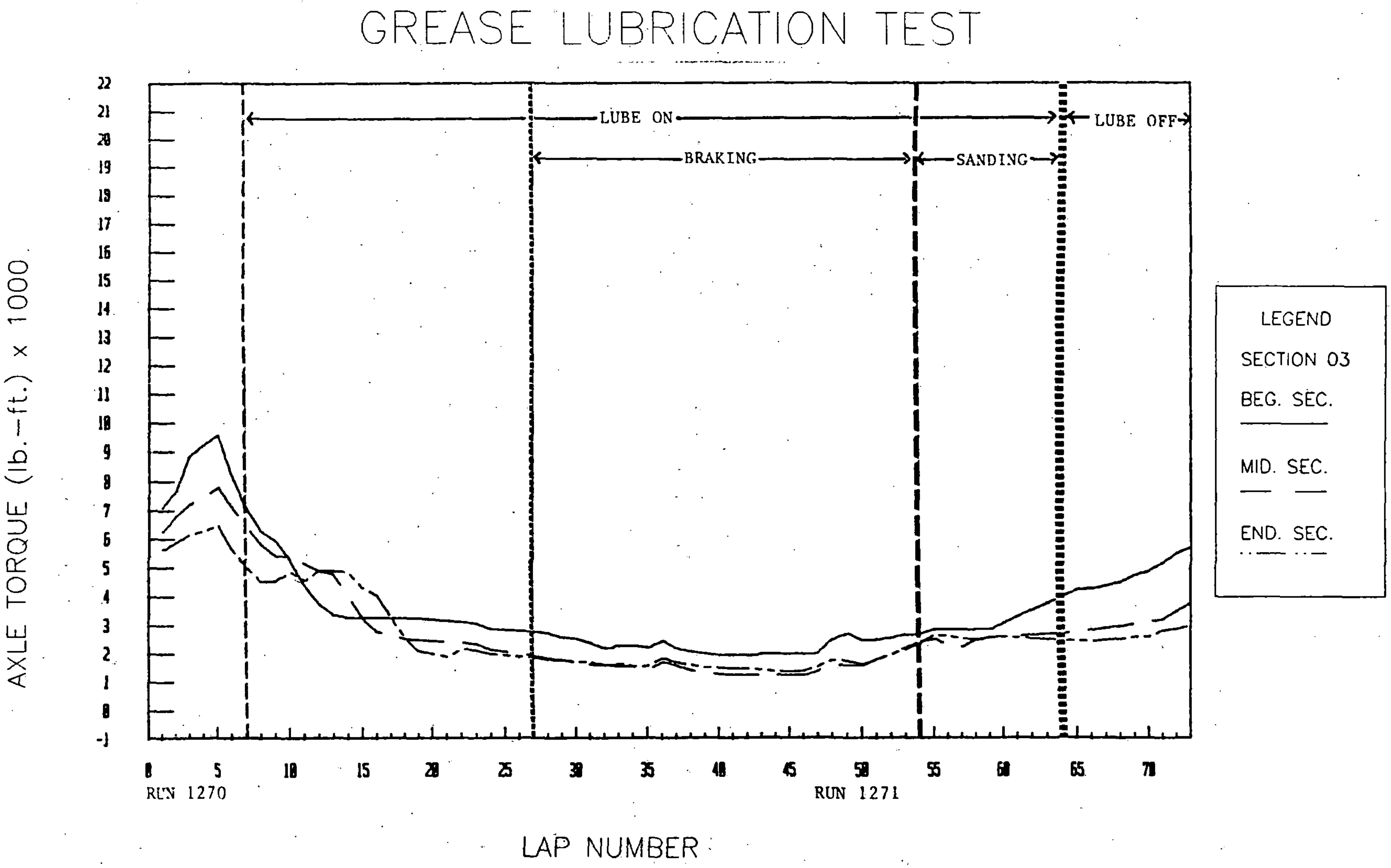

Figure D-5. Grease "D", Axle Torque Data, Section 03, Cold Weather.

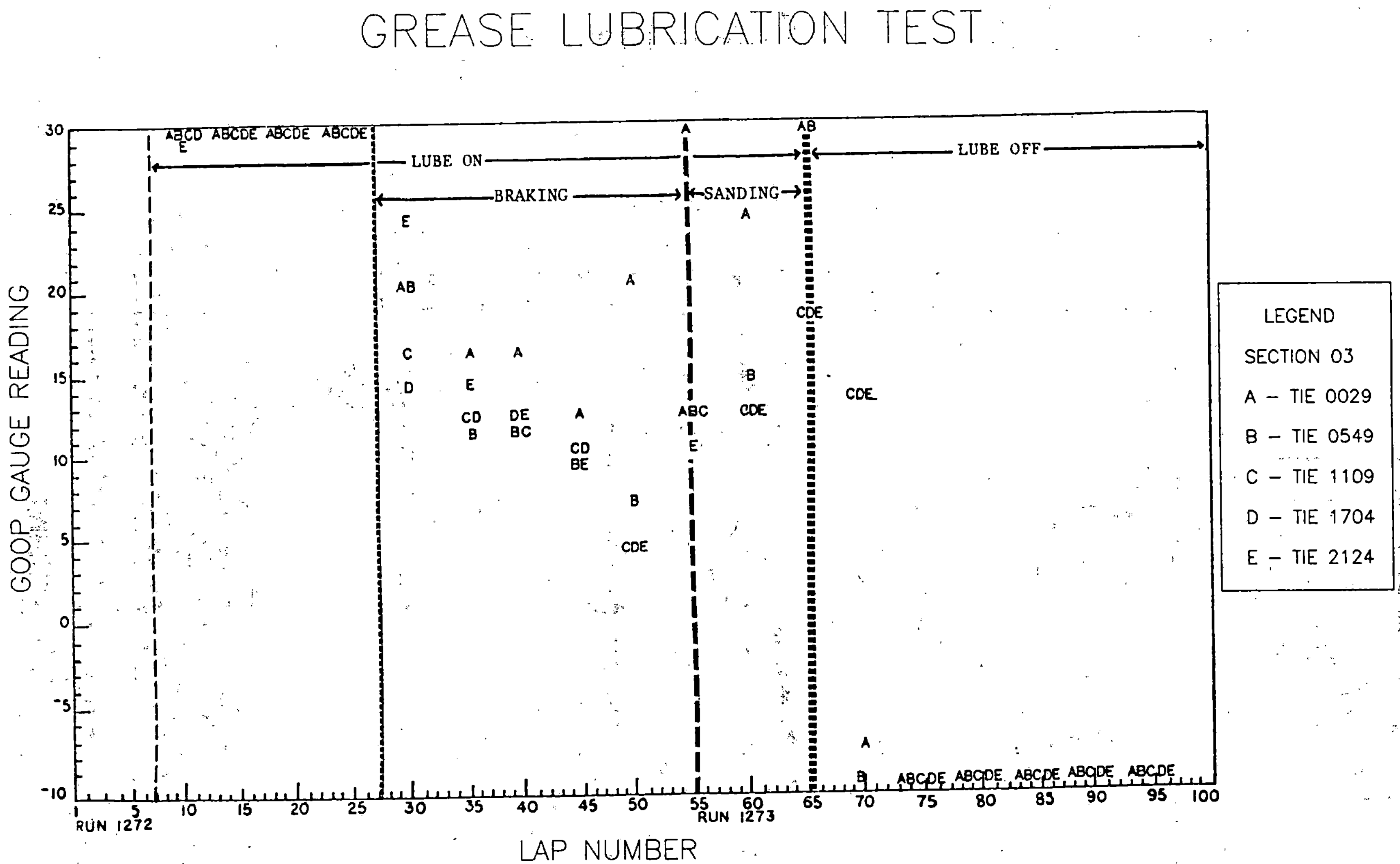

Figure E–1. Grease "E", Goop Gauge Reading, Section 03, Cold Weather.

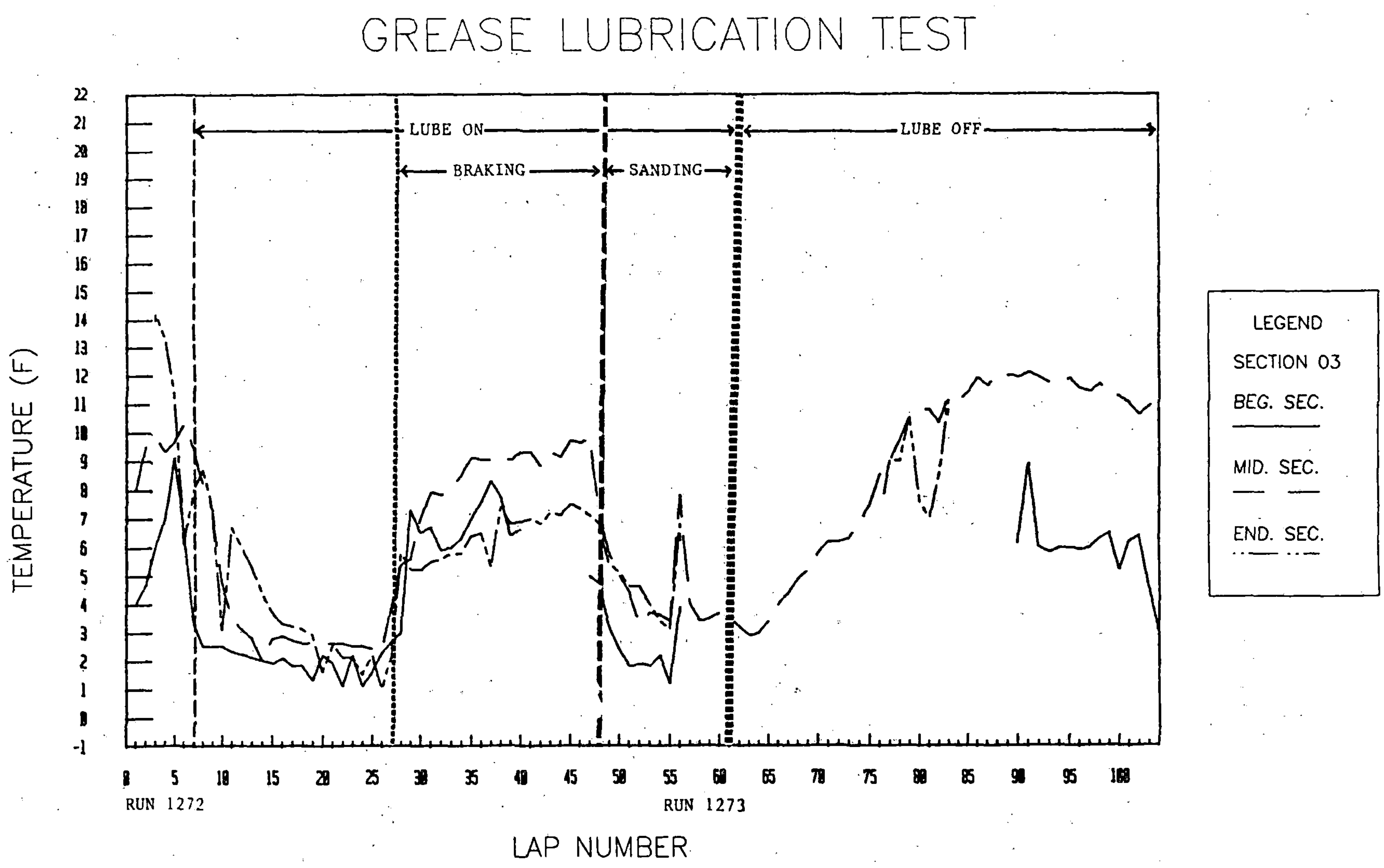

Figure E-3. Grease "E", Rail Temperature Rise, Section 03, Cold Weather.

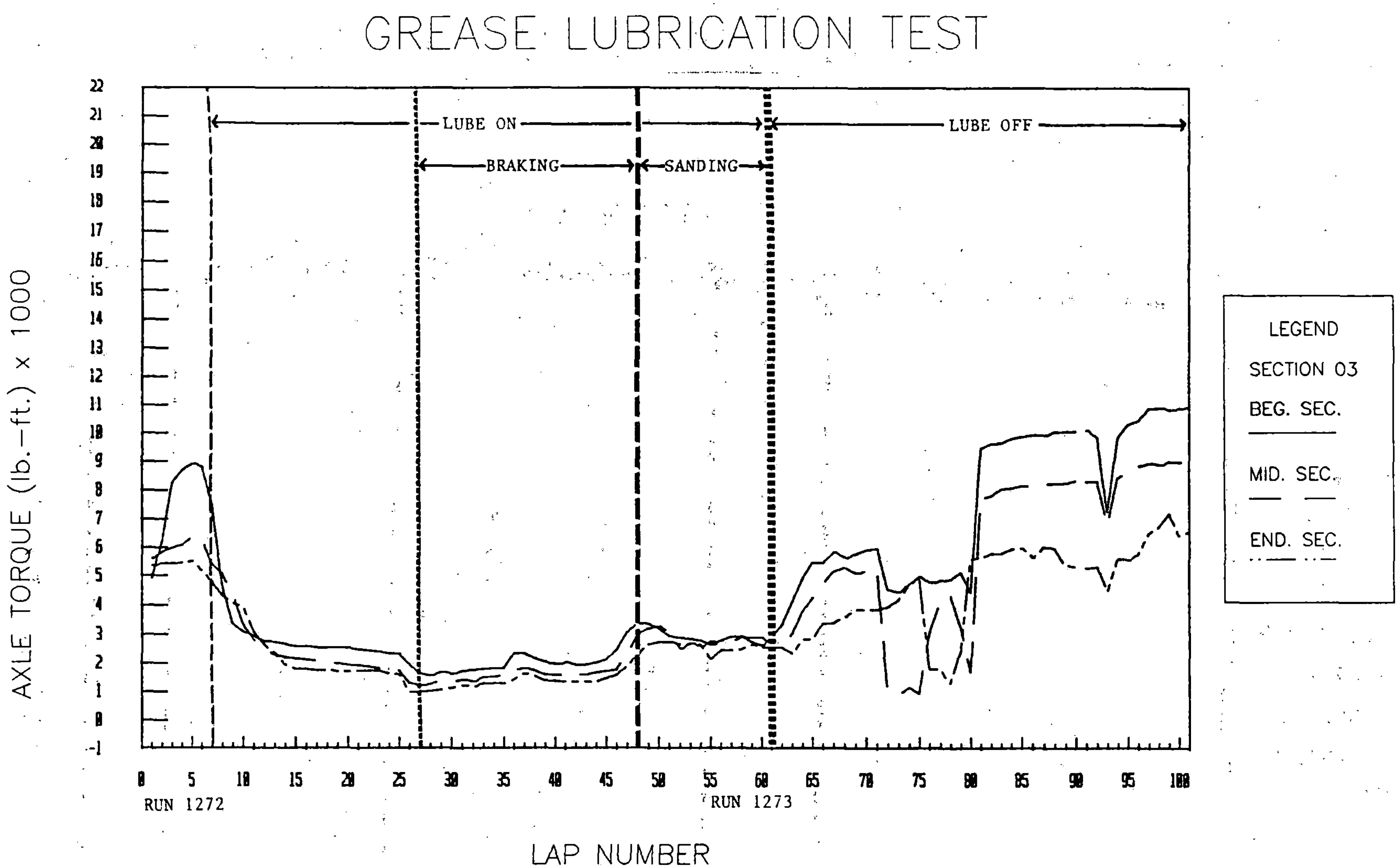

Figure E-5. Grease "E", Axle Torque Data, Section 03, Cold Weather.

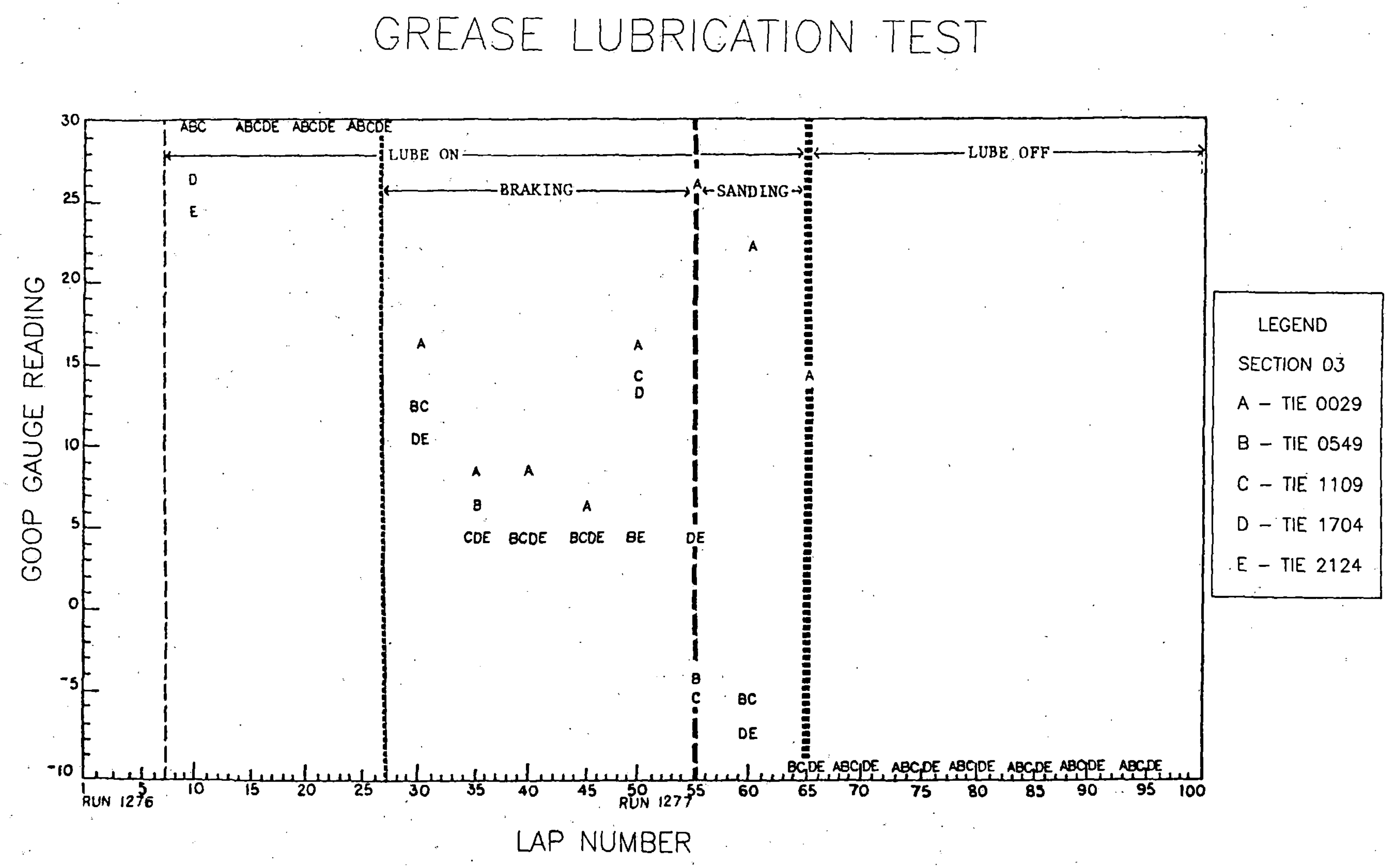

Figure F–1. Grease "F", Goop Gauge Reading, Section 03, Cold Weather.

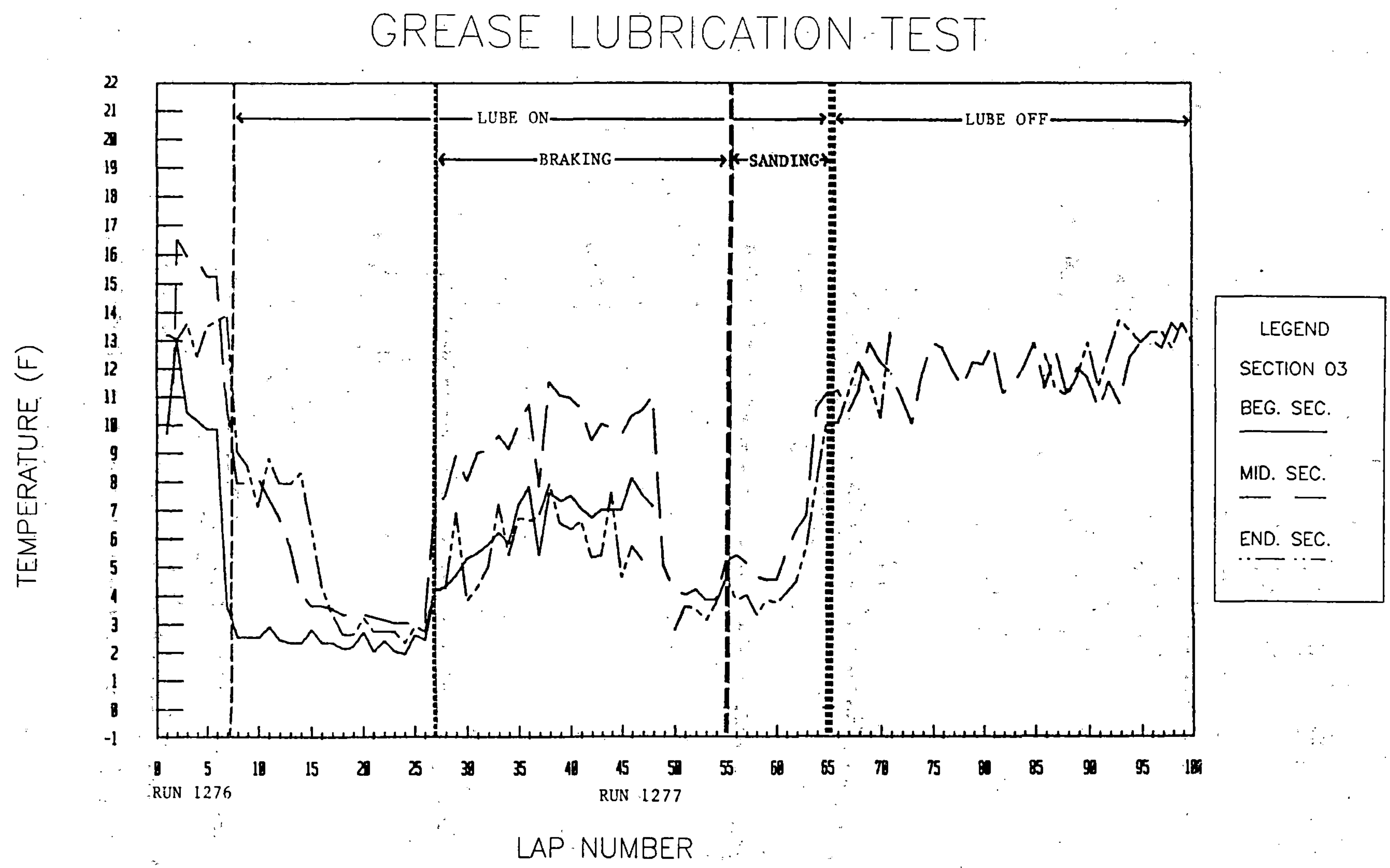

Figure F–3. Grease "F", Rail Temperature Rise, Section 03, Cold Weather.

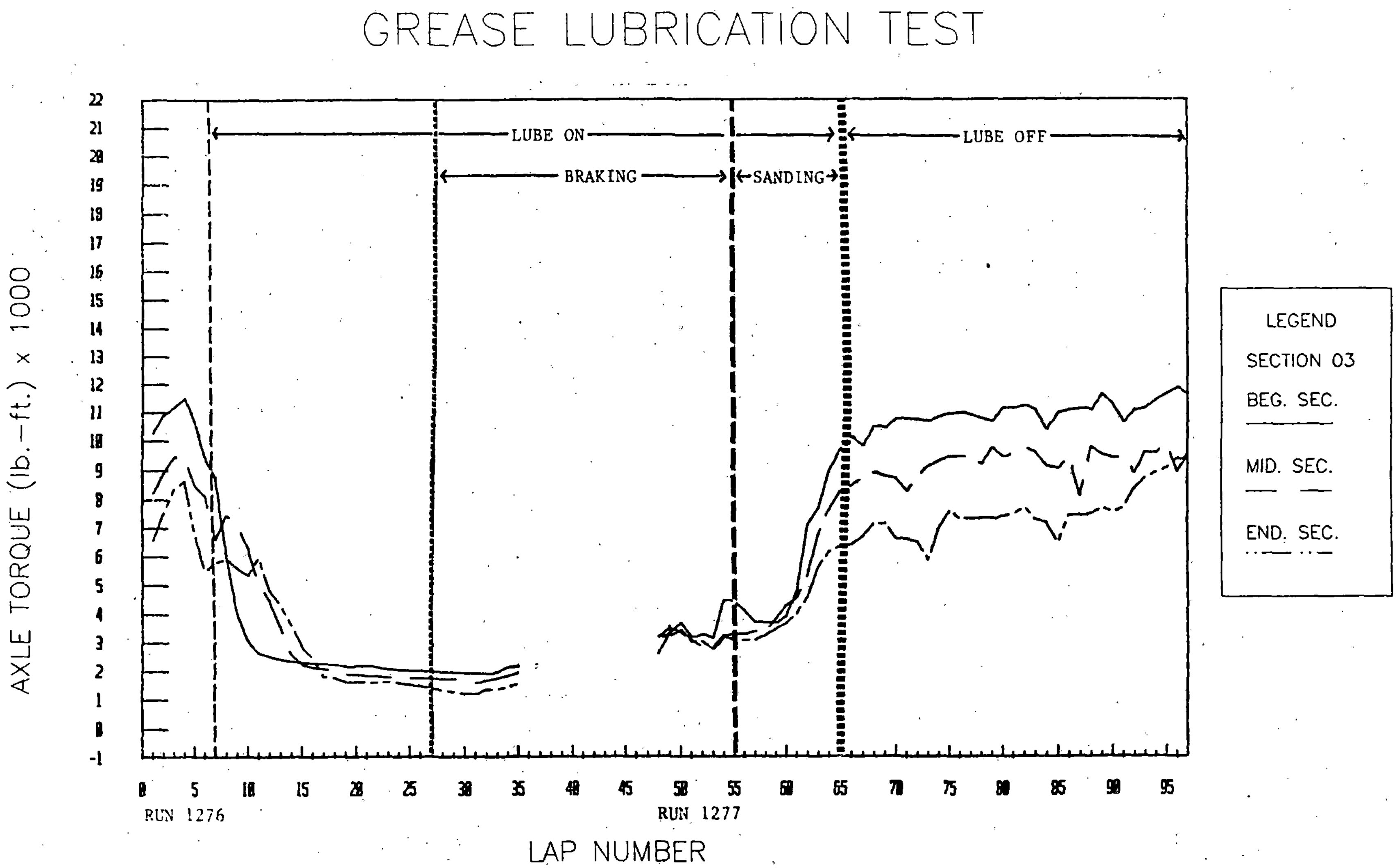

Figure F-5. Grease "F", Axle Torque Data, Section 03, Cold Weather.

GREASE LUBRICATION TEST

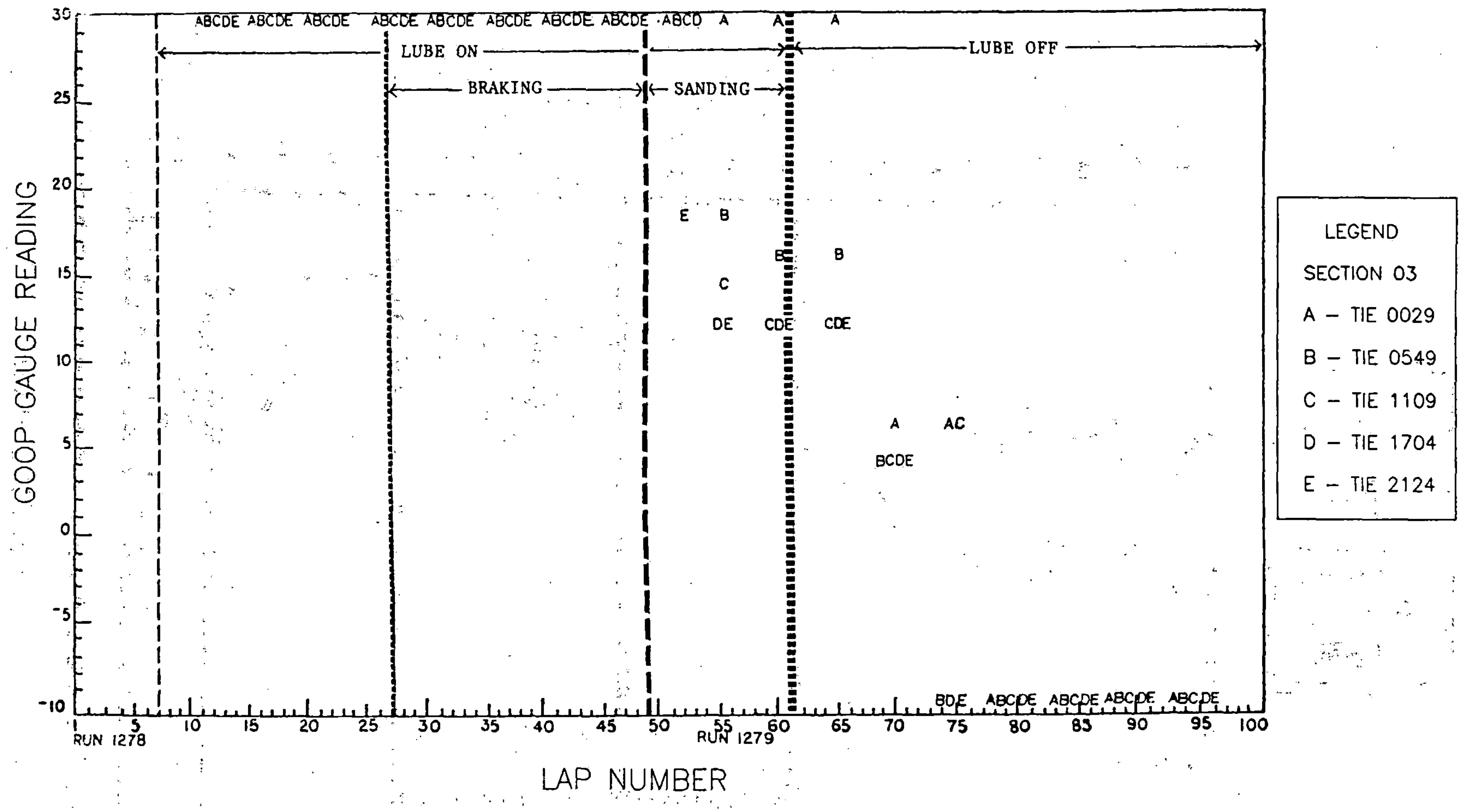

Figure G-1. Grease "G", Goop Gauge Reading, Section 03, Cold Weather.

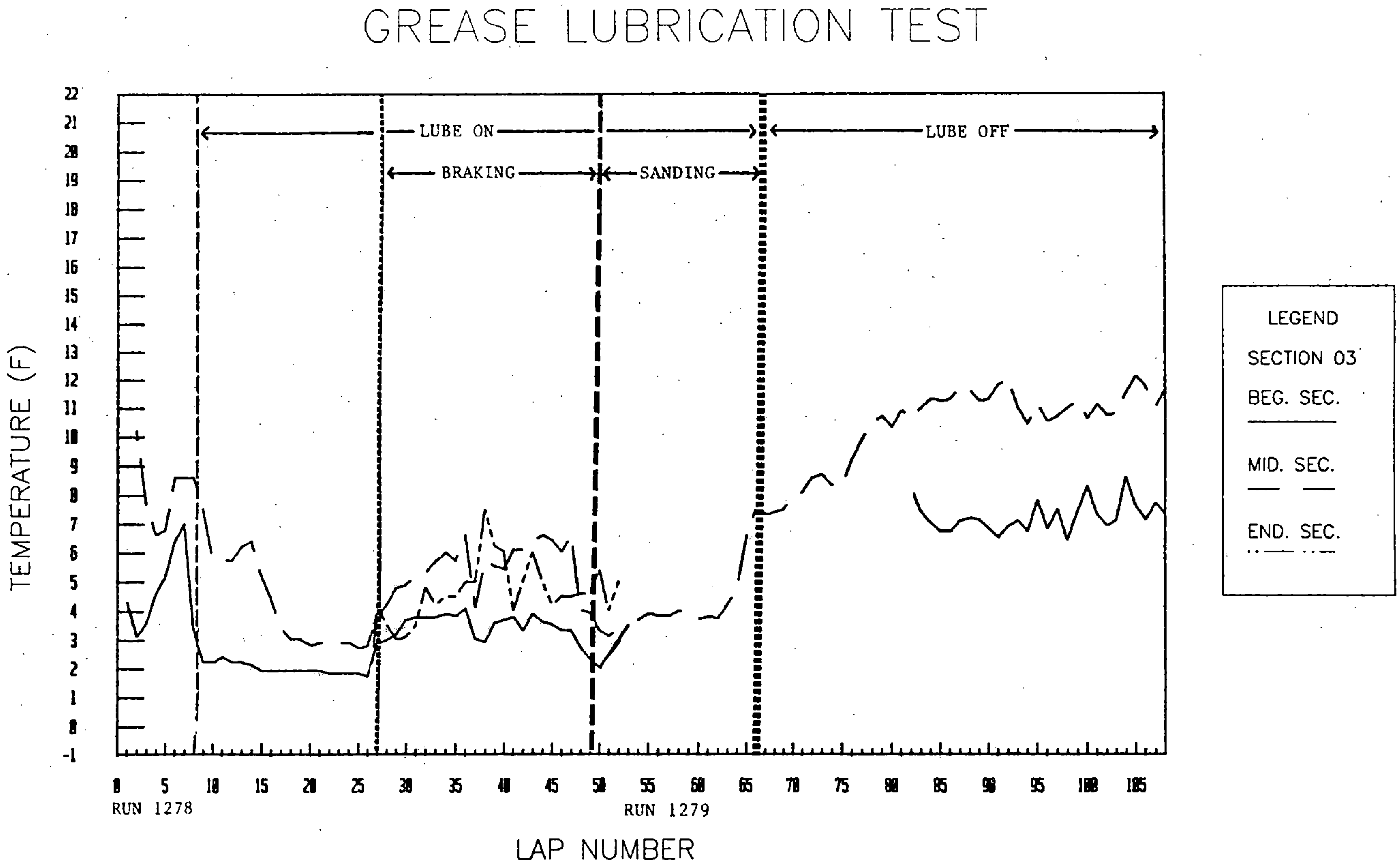

Figure G-3. Grease "G", Rail Temperature Rise, Section 03, Cold Weather.

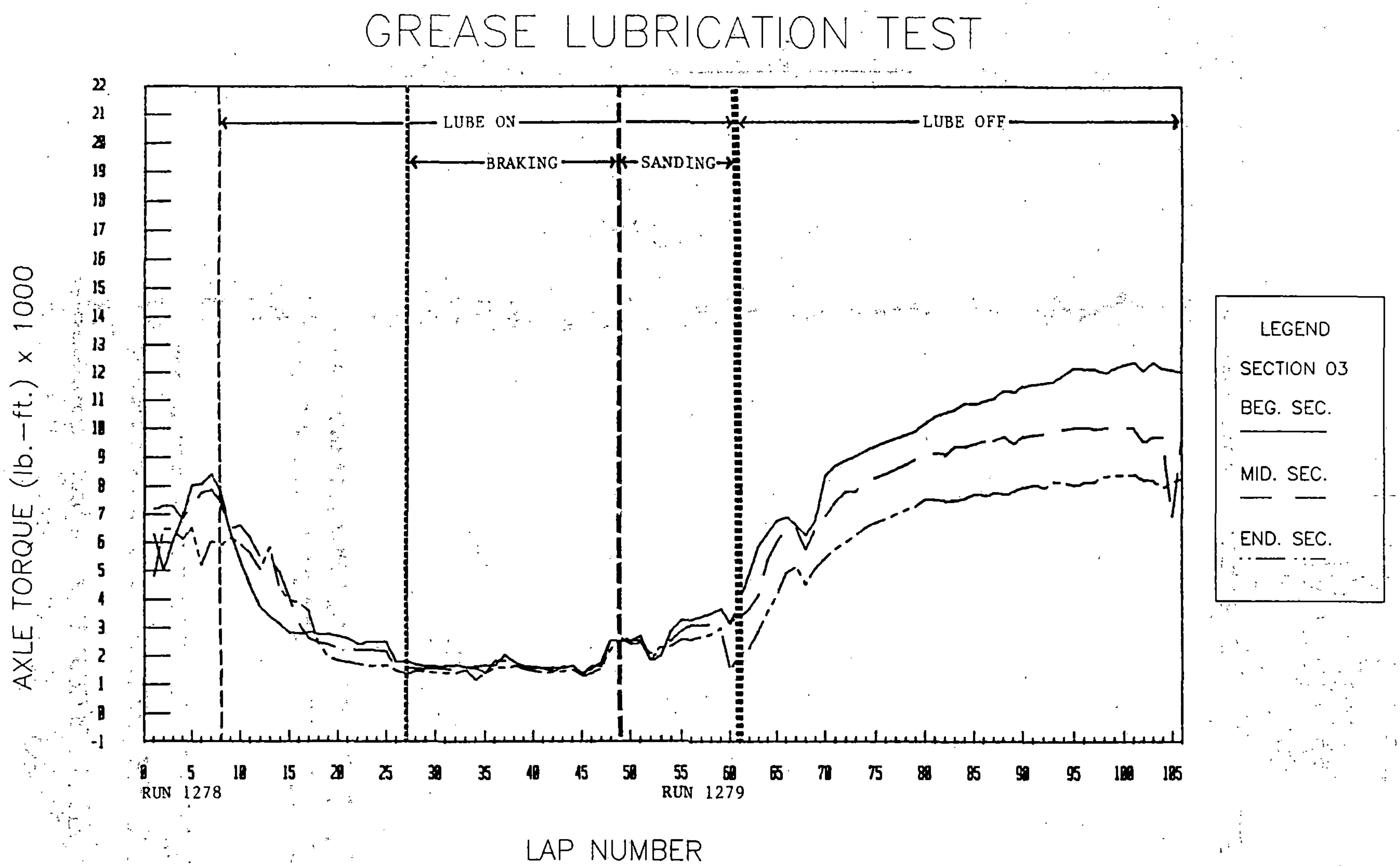

Figure G-5. Grease "G", Axle Torque Data, Section 03, Cold Weather.

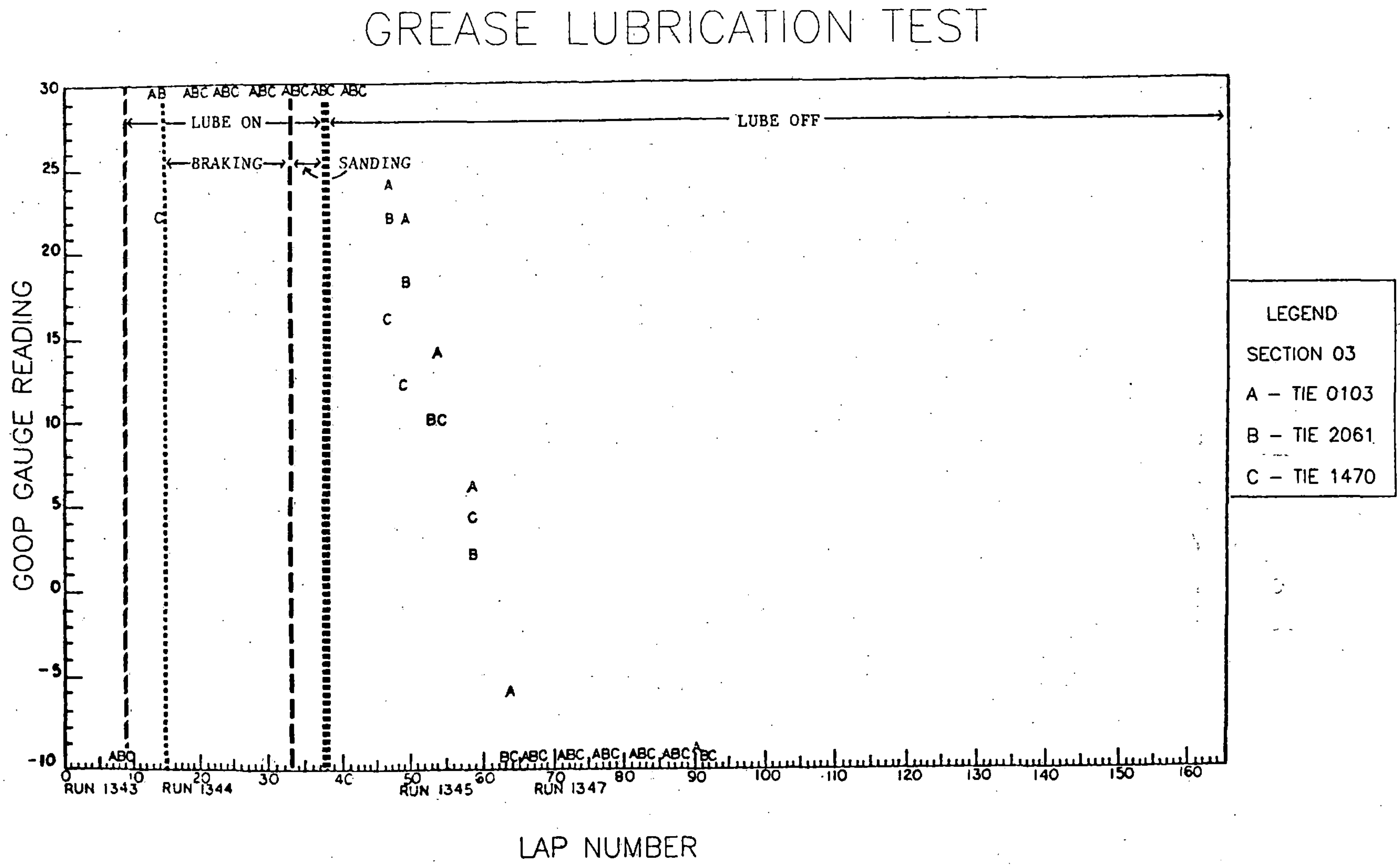

Figure J–1. Grease "J", Goop Gauge Reading, Section 03, Warm Weather.

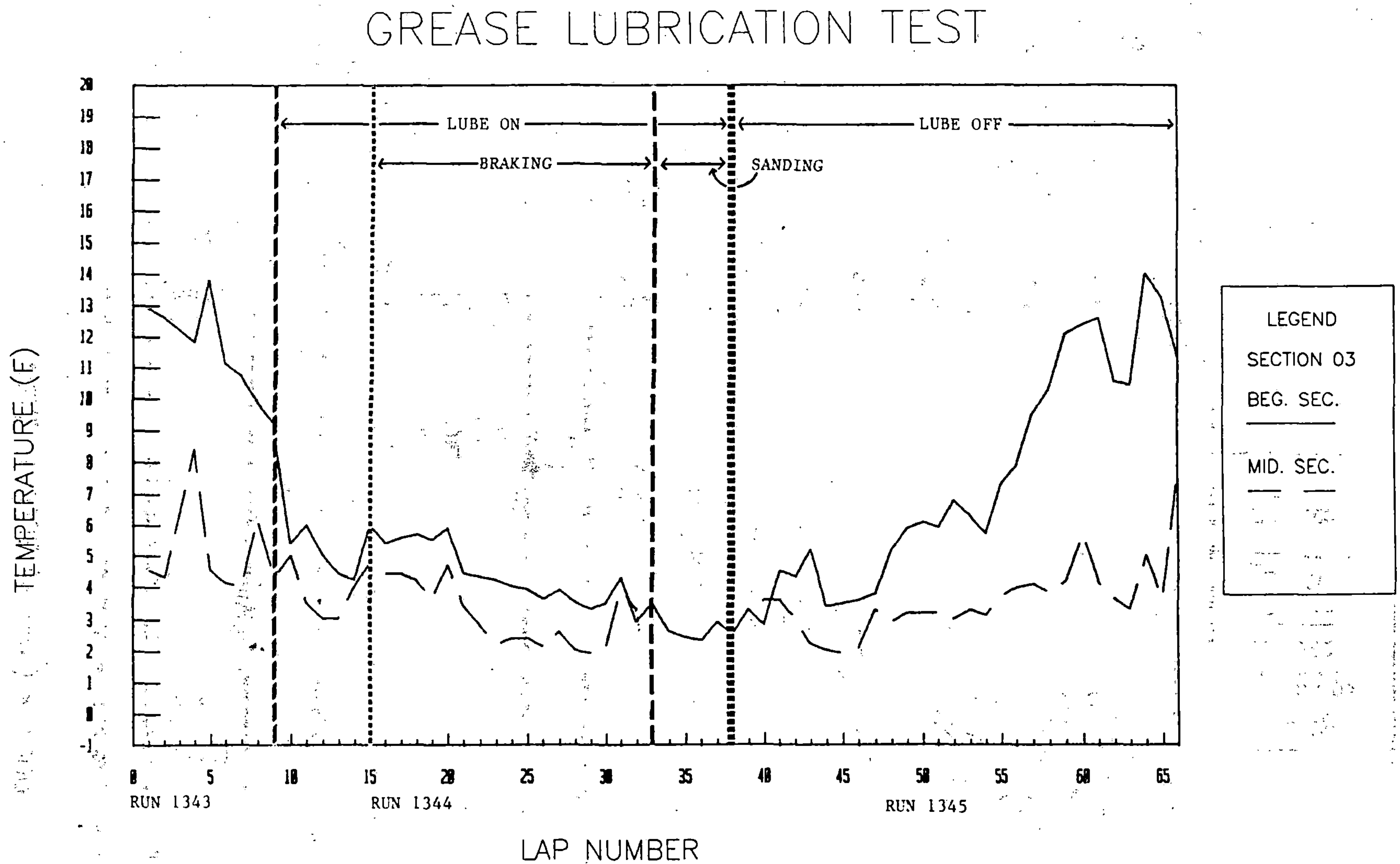

Figure J-3. Grease "J", Rail Temperature Rise, Section 03, Warm Weather.

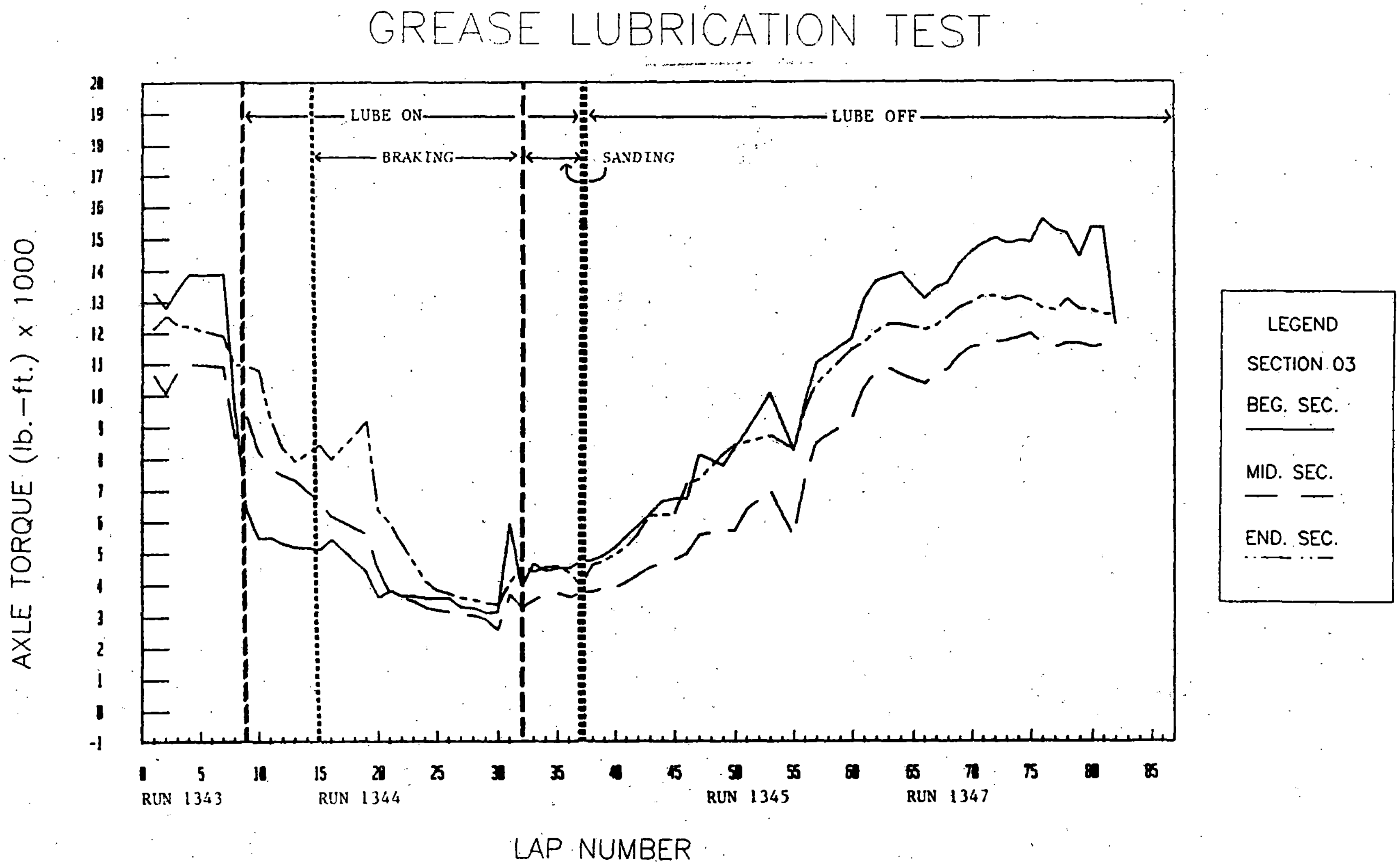

Figure J-5. Grease "J", Axle Torque Data, Section 03, Warm Weather.

A Study of Trackside Lubricator Greases on FAST, Technical Note, 1988
Richard P Reiff, FAST