FAST Facility for Accelerated Service Testing — TECHNICAL NOTE

TTC 033(FAST-TN85) September 1986

GREASE EVALUATIONS USING THE HI-RAIL LUBRICATION SYSTEM AT FAST

ABSTRACT

Previous testing of lubrication systems at the Facility for Accelerated Service Testing (FAST) have stimulated a general interest in grease performance. The hi-rail grease test was conducted to evaluate four types of lubricant when used with a hi-rail track lubricator. In this test, the grease evaluation criteria were:

- o The effect of initial lubrication on dry rail conditions;
- o The change in lubrication effectiveness during drydown;
- o The position-in-curve lubrication level.

The testing suggests the conclusion that development of a grease specifically for use in a hi-rail lubrication system could provide 30-35 laps of service without wheel-slip problems.

INTRODUCTION

This report supplements a previous study, Hi-Rail Lubrication System on FAST, Report No. TTC-007 (FAST-TN85), which was concerned with the general performance of the lubricator and two test greases. The reader should review that report in order to have a better understanding of the data presented in this supplement.

The initial hi-rail tests showed that adequate lubrication was obtainable for the first 10 to 15 trains after grease application. However, the following problems were indicated:

1. The initial grease application was so profuse that the lubricant migrated over the top of the rail, causing wheel-slip problems.

2. The expected fuel savings were not obtained for this test. In test runs of 30-35 trains, the last 10-20 trains were run under a marginal-to-dry mode. This condition resulted in high energy consumption overall and, thus, small fuel savings over that of dry rail operation.

The first hi-rail report recommended that additional tests be performed using other lubricants. Subsequent tests were run with three additional lubricants, along with the grease used in the original test. These three lubricants were selected after consultation with the Burlington Northern Railroad, supplier of the hi-rail lubricator.

TEST DESCRIPTION

Tests were run to evaluate the three additional grease products on the FAST track. The major differences between this test and the original were that only the outside rail curves of FAST were lubricated, that section 07 on the FAST loop remained dry for metallurgy tests, and that ambient temperatures were somewhat warmer for this sequence due to the season.

The four lubricants tested were:

	Referred to in report as	Description
1.	No. 1	A high-graphite grease supplied by BN.
2.	No. 2	A 12% graphite lubricant that was used in the original test. It is most commonly used in trackside lubricators, and was tested again to provide a control baseline.
3.	No. 3	A metaloid fusion lubricant that was also tested in the trackside lubricator test.
4.	No. 4	An open gear lubricant whose carrier evaporated after application, leaving a "dry film" of lubricant.

As an exact replication of the original test was not possible, no effort should be made to draw direct comparisons between the two tests. The performance relationship between the greases studied, however, is valid in terms of temperature differentials and wheel forces, when adjustments are made for the differences in the test conditions.

TEST DATA

The three "standard" data-gathering systems that were used on other lubrication tests were also used for this study. The data for this report were obtained by the following means:

1. "Goop gauge:" This is a simple visual indicator used to check grease levels on track (see Figure 1). An "optimum" level is between "0" and "+10" (on an arbitrary scale). Any value over "+10" is undesirable because it indicates grease on the rail top, and any value below "0" indicates less-than-adequate lubrication of the gauge face. Table 1 shows six "goop gauge" readings and their relationships to the other two measurements.

2. Rail-head temperature rise: This is an indicator of how the rail temperature is affected by frictional forces from a passing train. This measurement is made on the rail head by small thermocouples. Testing was done on Section 03 of FAST, which is the primary location for comparing all lubricants. This section contains a 5° curve with 4" of superelevation with a normal train speed of 45 mph. Again, Table 1 compares various lubrication ranges with corresponding temperature rises.

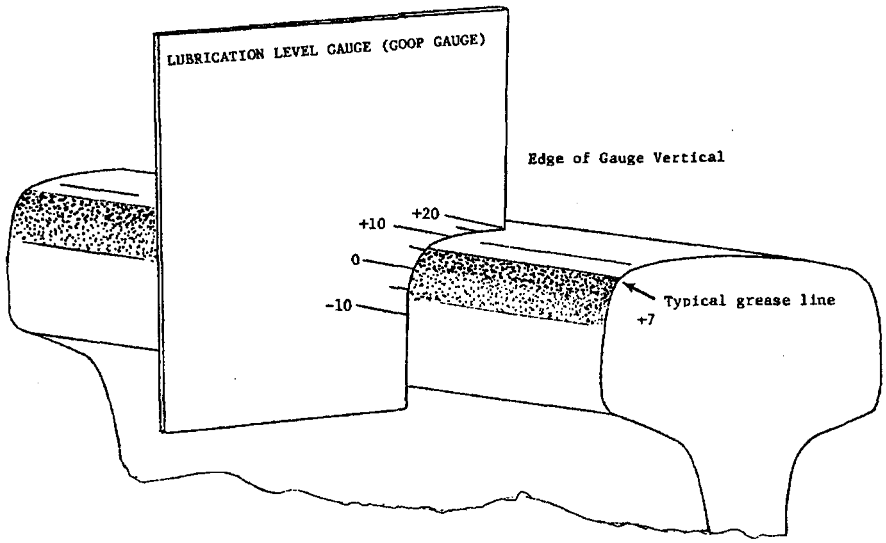

FIGURE 1. "GOOP GAUGE."

TABLE 1. LUBRICATION DATA.

Condition of Rail Lubrication	Temperature Rise	Wheel Force*	"Goop Gauge"
Dry - metal flakes	12° or more	12 or more	-10
Dry - no effective lubrication	9° to 12°	9 to 12	-10
Marginal	7° to 9°	7 to 9	-10 to -5
Low	5.5° to 7°	5 to 7	-5 to 0
Lubricated (gauge face only)	2° to 5.5°	2 to 5	0 to +10
Over-lubricated (grease on top of rail)	0° to 2°	0 to 2	Greater than +10

*Values shown are in 1000 lb ft (KFPS) of axle torque. To convert to longitudinal force (KIPS), divide by 1.5.

3. Wheel Forces: Longitudinal wheel force, as measured by an instrumented axle, is also an excellent indicator of lubrication. Table 1 shows the values of wheel forces at various lubrication levels.

The wheel force data is missing from the first test run (made with the No. 4 grease) due to a failure of the T-8 data collection car. Otherwise, all lubricants contain data from the "goop gauge," rail temperature rise, and wheel force collection systems.

Appendices A through D contain plots of the parameter values versus the number of laps operated after hi-rail application of each test grease.

TEST RESULTS

The lubricant test data have been reduced and are shown in Table 2. Each column in the table summarizes grease performance under one of the criteria stated previously. Performance may be judged by:

1. The effect of initial lubrication on dry rail conditions. The dry-to-lubricated reduction in temperature and wheel force readings is an indication of how much improvement was made by application of that particular lubricant. When interpreting the data in Table 2 attention should be paid to the fact that the rail temperature figures represent the temperature rise differential between "dry" and "lubricated" rail. Higher rail temperature and wheel force differential values indicate better lubrication.

2. The change in lubrication effectiveness during drydown. This is a measure of the change in effectiveness 10, 15, 20, and 30 laps <u>after</u> application. Beginning-of-curve data indicate how long the grease lasts after application. A smaller net change indicates a lubricant that lasts longer.

3. The position-in-curve lubrication level. This data is an indication of how well the lubricant can stay in place; that is, the resistance to migration around a curve. A high beginning-to-end of curve value indicates that the lubricant is being removed from the beginning-of-curve and transported to the end. This means that the beginning-of-curve is drying out much faster than the end. Thus, a low net change in data is best.

ANALYSIS OF TEST RESULTS

The data summarized in Table 2 are provided in Appendices A through D for examination. Because the analysis of Table 2 data was complicated by the lack of wheel force information from the first test run using the No. 4 grease, the rail temperature measurements provide the most reliable means of evaluating the performance of the grease. The second No. 4 lubricant test run was made immediately following the first. However, the temperature data from the first run should be used for comparisons, because the buildup of grease on the wheels could influence the product performance during a second run.

The first criteria, "Effect of Initial Lubrication," evaluates the improvement in wheel force and rail temperature readings after the application of grease on a dry rail. The No. 2 and No. 4 lubricants performed identically in rail

TABLE 2. RESULTS OF GREASE TEST.

DATA FROM FAST SECTION 03 - BEGINNING-OF-CURVE DATA IN BLOCKS 1 & 2

	1. Effect of Initial Lubrication on Dry Rail Conditions (Differential Values)		2. Change in Lubrication Effectiveness During Drydown								3. Position-in-Curve Lubrication Level					
			Wheel Force				Rail Temp				Wheel Force			Rail Temp		
			Laps After Application				Laps After Application				Laps After Application			Laps After Application		
Grease Type	W/Force	Rail Temp	10	15	20	30	10	15	20	30	1	10	30	1	10	30
No. 1	9	8°	3.5	5	8.5	10*	1.5°	3.5°	7°	7°	1	2.5	4	0°	1°	6°
No. 2	8.5	7°	1	2	2	5.5	1°	2°	3°	3°	1	1	1.5	1°	1°	**
No. 3	13	9°	1.5	2.5	4	5.5	0.5°	1°	2°	3°	1	0	0	0°	1°	1°
No. 4 1st Test	No Data	7°	No Data				1°	2°	3°	5°	No Data			1°	1°	4°
No. 4 2nd Test	11.5	10°	1	2	2	3	0°	0°	0°	1°	0	0	0	0°	1.5°	3°

*Projected by 4 laps
**Missing Data

Wheel force data is in values of torque - 1000 lb ft of torque (KFPS) temperature differential. It should be noted that the rail temperature recording equipment failed several times during testing of all greases. The missing wheel force data also restricted the evaluation and forced the use of beginning-of-curve improvement figures rather than the preferred average calculated from mid-curve measures.

The second criteria, "Drydown Lubrication Effectiveness," uses the beginning-of-curve data to assess staying power because end-of-curve measures would be biased by grease that was transferred from the beginning of the curve. A lubricant that spreads too readily should be rated lower due to migration away from the beginning of the curve. Comparison shows, for example, that the No. 2 and No. 3 greases have similar drydown lives for the 30-lap examination period, while No. 1 allowed substantially higher temperature and wheel force gains twenty laps after application.

The third measurement criteria, "Position-in-Curve Lubrication Level," evaluates the uniformity of the lubricant level throughout the curve just after application and again after 10 and 30 train passes. A grease that is long lasting and does not migrate too readily should retain its effectiveness uniformly around the curve. Low number at 30 laps indicate good uniformity in the curve.

The No. 3 grease demonstrated a very uniform lubrication level (see Appendix C, No. 3 grease "goop gauge" plots). For this test, well over 40 laps were required before large differences in wheel force measurements were recorded between the beginning and the end of the curve.

PERFORMANCE ANALYSIS

At the outset of this discussion it should be noted that the application mode, amount of grease applied, and prevailing climatic conditions must be considered when interpreting the test data. Also, the following summaries of grease performance should be weighed prior to using any of the results.

1. No. 1 grease: This high graphite grease was supplied by the BN railroad. The high graphite content provided good initial lubrication, but the grease did not demonstrate good retention qualities. Apparently, the high amount of graphite was adequate for bulk lubrication effectiveness, but the carrier medium moved rapidly off the gauge corner. This can be verified by examining the "goop gauge" plots which show the rapid disappearance of visible lubrication (see Appendix A).

2. No. 2 grease: This grease was used during the initial hi-rail tests. Its persistance on the rail, based on goop gauge readings, was very similar to that of the No. 3 lubricant. An examination of Appendices B and C (Section 03 "goop gauge" plots), will verify that similar drydown traits were exhibited. However, the entire curve differentials were higher for the No. 2 grease.

3. No. 3 grease: The No. 3 grease was so "slippery" that the hi-rail application method wasted at least 50% of the product during application. Immediately after application, more than half of the grease rolled off the gauge side and fell to the base of the rail. In the author's judgment, if all the grease applied had "stuck" to the rail, a much longer

test run would have been required to dry off the rail. However, the fact that some of the grease migrated to the rail head suggested that the presence of more grease might have led to locomotive wheel slip problems. The No. 3 grease is discussed in Trackside Lubricator Grease Test, AAR report No. R-632.

4. No. 4 grease. This is an open gear lubricant that was selected as a "dry film" test product for the hi-rail. Its low-viscosity carrier evaporates rapidly and leaves a tacky lubricant film on the rail. This formulation makes this grease more pumpable than most greases in cold weather. During testing the lubricant tended to stay where it was applied and was one of the few lubricants used in the lubrication test series that did not readily migrate to the top of the rail. The "goop gauge" log indicates that there were a few laps of +30 grease before the lubricant level retreated to more acceptable readings in the +10 range.

   Certain problems encountered in testing the No. 4 grease were not necessarily due to the lubricant itself; the inherent free play of the hi-rail applicator may have contributed. The spray nozzle is mounted on the end of a rubber hose that vibrated during application, and the grease had a tendency to stay where the nozzle deposited it. (Appendix D, Figures D1 and D2, show the No. 4 lubricant just after application. Further evaluation of this grease is discussed in Report No. TTC-029 (FAST-TN85), Spray and Roller Type Locomotive-Mounted Lubrication Systems.

Lubrication Application Rate

The amount of grease applied for each grease tested is shown in Table 3. The amount of No. 3 grease applied was not measured because there was not enough test grease remaining to run a pump test with the hi-rail vehicle. The grease application rate was determined as follows:

1. The grease barrel was weighed (including pump).

2. The hi-rail pump was operated for 10 minutes.

3. The barrel was reweighed (including pump).

4. A computation based on a vehicle test speed of 15 mph was made to determine amount applied.

TABLE 3. GREASE PUMPED PER CURVE MILE.

Grease	Amount Pumped During 10 Minutes	Equivalent lbs/mile @ 15 mph
No. 1	15 lbs 4 oz	6 lbs 2 oz
No. 2	19 lbs 3 oz	7 lbs 10 oz
No. 3	Not measured	---
No. 4	22 lbs 2 oz	8 lbs 14 oz

Due to waste and dropoff, Table 3 does not indicate how much lubricant was actually applied. Some of the waste may have been eliminated and the test results altered by readjusting the hi-rail nozzle system and the spray nozzle configuration. Also, it should be noted that this test was run during late summer, when ambient temperatures reach 95°F. Lower temperatures will change the flow characteristics of most greases.

The results presented for all greases should be considered "worst case." With the exception of No. 4, all test analysis was based on a single application of each grease. The second application of No. 4 provided results superior in all areas to the initial application. Wheel force data from the second run show excellent dry-to-lubed condition improvement, good lubrication effectiveness during drydown, and excellent position-in-curve lubrication level.

Comparison to Trackside Lubrication Tests

Table 3 gives the basis for an approximate comparison of the hi-rail and trackside grease applicators. At FAST, a high level of lubrication was maintained by two trackside lubricators, each set to apply 4-6 oz of grease per train pass. Taking into consideration the use of only the outside rail for the tests, the grease application for 30 trains is comparable (see Table 5). No. 2 grease was used as the control-base lubricant for this and previous FAST lubrication tests.

TABLE 5. 30-TRAIN COMPARISON.

Trackside:	5 oz/train/lubricator	18 lbs 12 oz for 30 trains
Hi-rail:	7 lbs 11 oz/curve mile @ 2.2 miles of curve	16 lbs 15 oz for 30 trains

For a 30-train reapplication cycle, the hi-rail applicator deposits slightly less grease (1 lb 13 oz) than a trackside system. Based on past data, however, the trackside system supplied a more uniform, constant level of lubrication. The data in this report indicate that, in spite of the fact that the No. 3 grease performed better than the previously tested No. 2 grease, the adequate lubrication level (rail temperature rise of less than 5.5° or wheel force less than 3350 lbs) did not extend more than 20-25 laps after application. During a fully-lubricated period with the trackside system, all train passes were made with wheel force and rail temperature rises of less than 3350 lbs and 5°, respectively.

CONCLUSIONS

Testing the four lubricants showed that each product has its positive and negative performance characteristics when used with the hi-rail device. This fact suggests the need to develop a specialty lubricant designed to surmount the problems and last for 30-35 laps after application without the adverse effects of wheel slip.

Single-application testing with one device may not fully characterize a lubricant. Some experimentation with application systems and a full scale, multi-run test, when the same grease is tested for 4 or 5 consecutive runs (reapplied every 30 to 35 laps for 4 or 5 cycles) is necessary to properly evaluate a grease for performance. The FAST Lubrication Studies have underscored the need for and value of extensive product evaluation.

NOTICE

This report has been prepared from test results produced at the Transportation Test Center (TTC) of the Association of American Railroads (AAR) under contract to the Federal Railroad Administration (FRA). The reported information is distributed by the FRA in the interest of information exchange. No portion of this report may be regarded as an endorsement by the AAR, TTC, Burlington Northern Railroad, or the FRA.

APPENDIX A

NO. 1 GREASE

"Goop Gauge" - 2 plots, Sections 3, 13

Wheel Force - 2 plots, Sections 3, 13

Rail Temperature Rise - 2 plots, Sections 3, 13

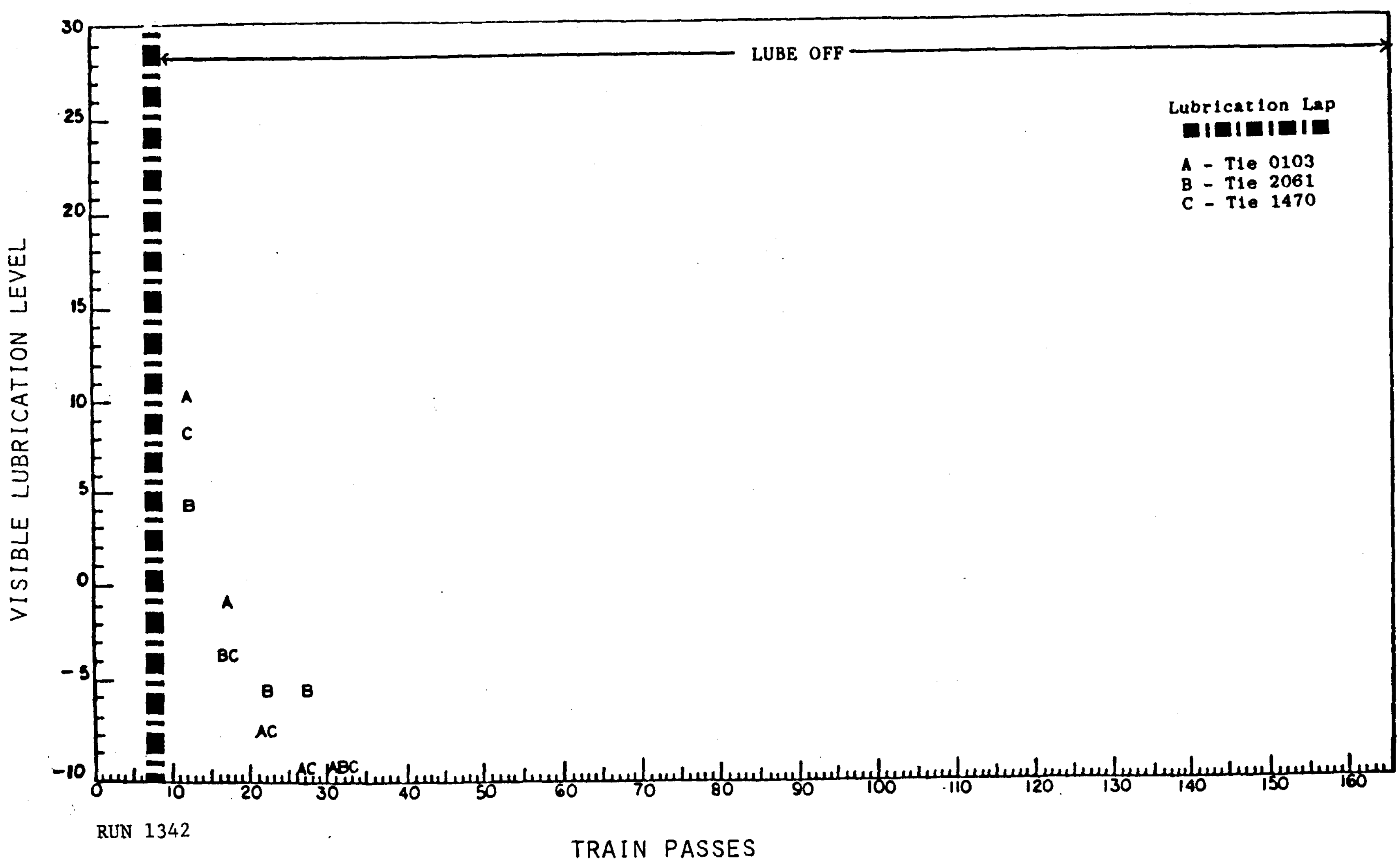

FIGURE A-1. NO. 1 GREASE "GOOP GAUGE" READINGS, SECTION 03.

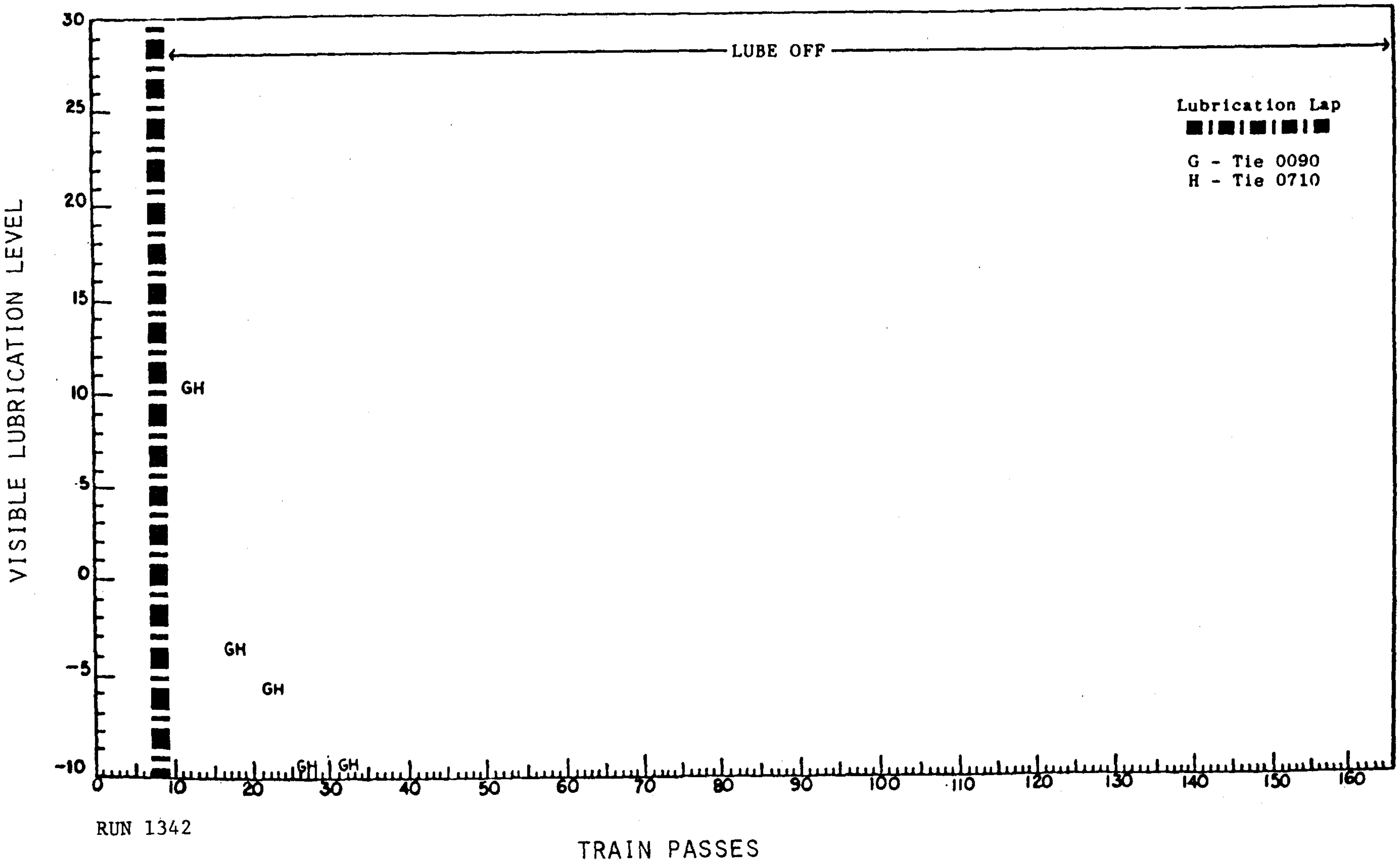

FIGURE A-2. NO. 1 GREASE "GOOP GAUGE" READINGS, SECTION 13.

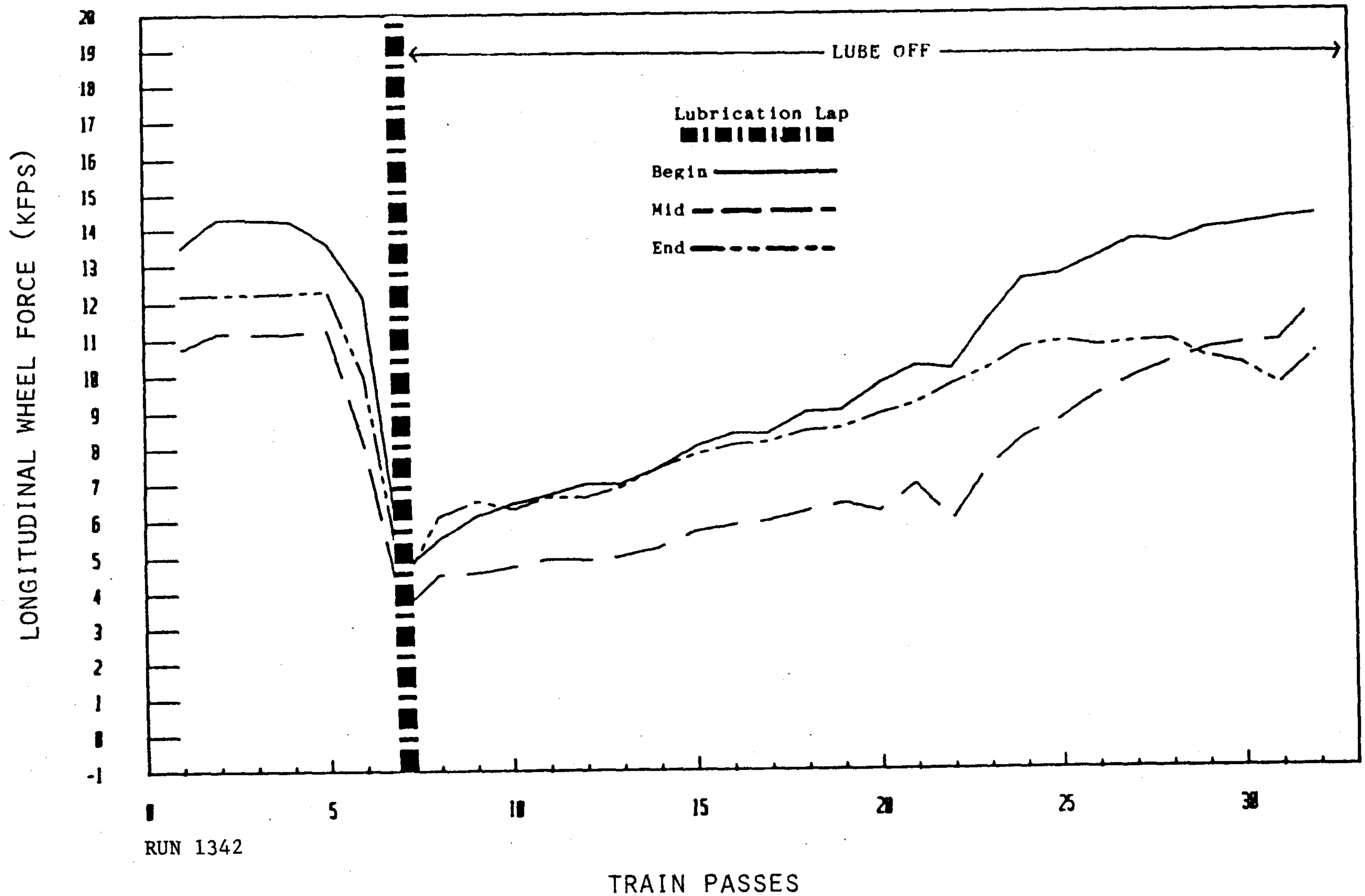

FIGURE A-3. NO. 1 GREASE WHEEL FORCE DATA, SECTION 03.

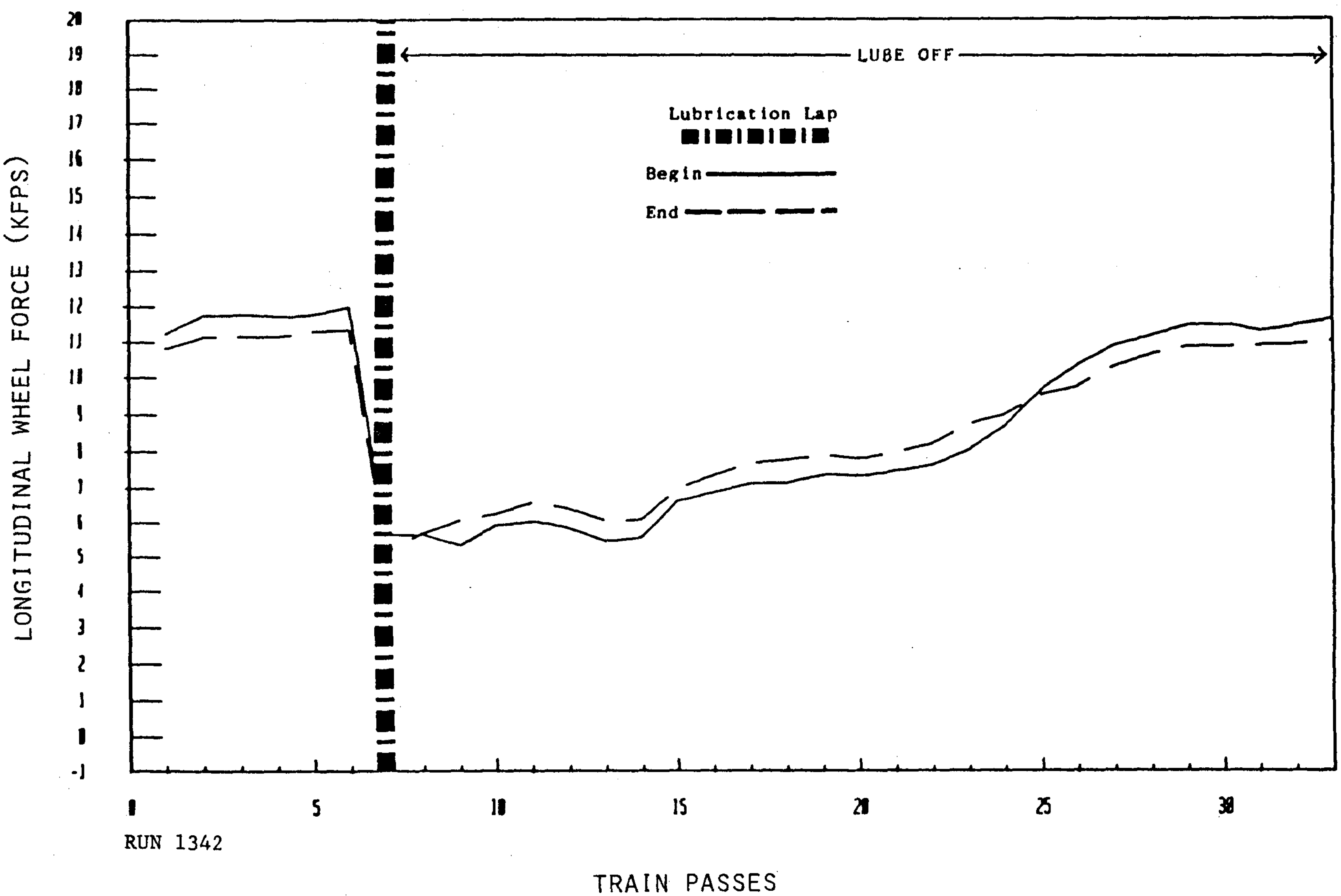

FIGURE A-4. NO. 1 GREASE WHEEL FORCE DATA, SECTION 13.

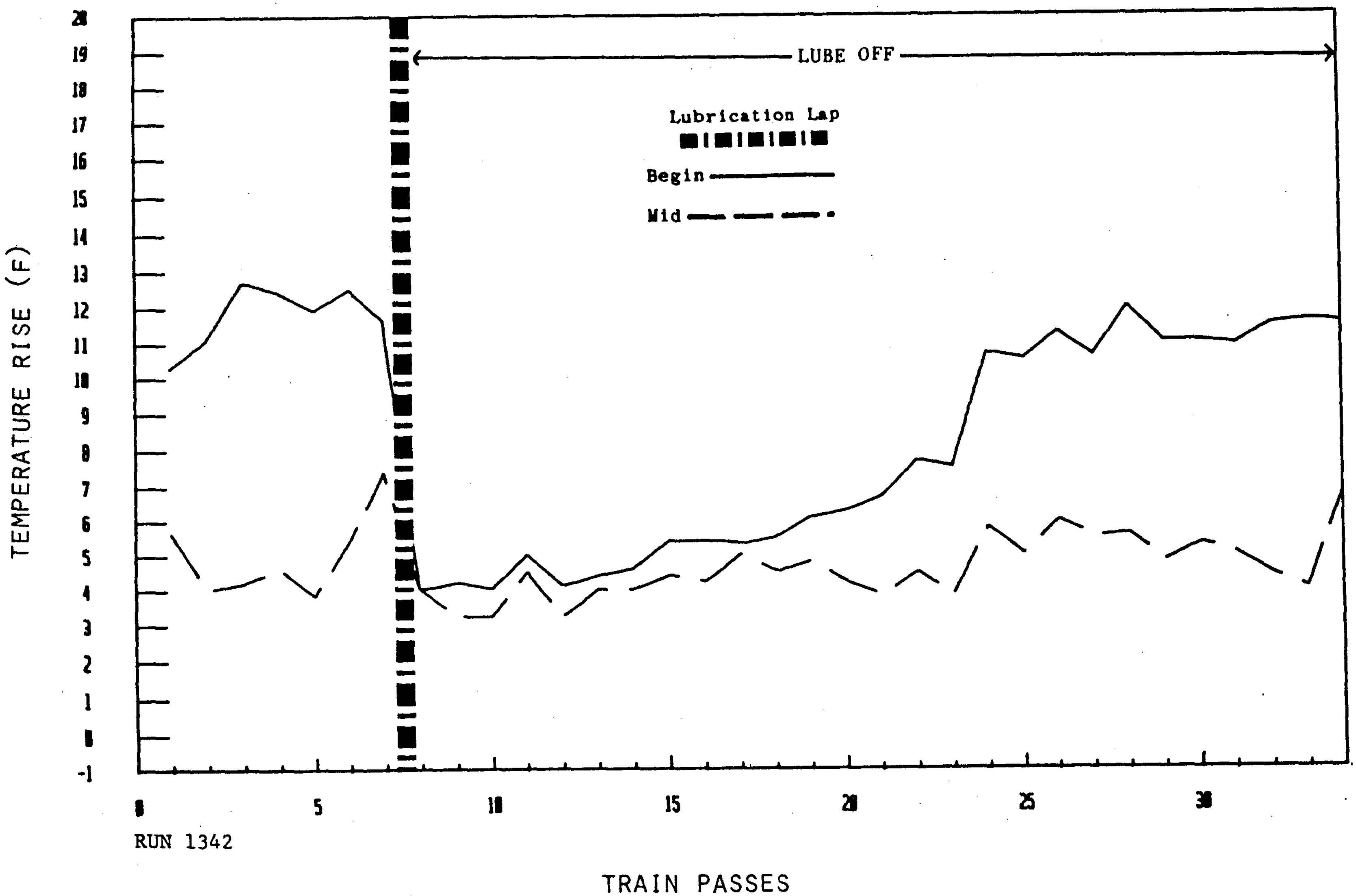

FIGURE A-5. NO. 1 GREASE RAIL TEMPERATURE VARIATION, SECTION 03.

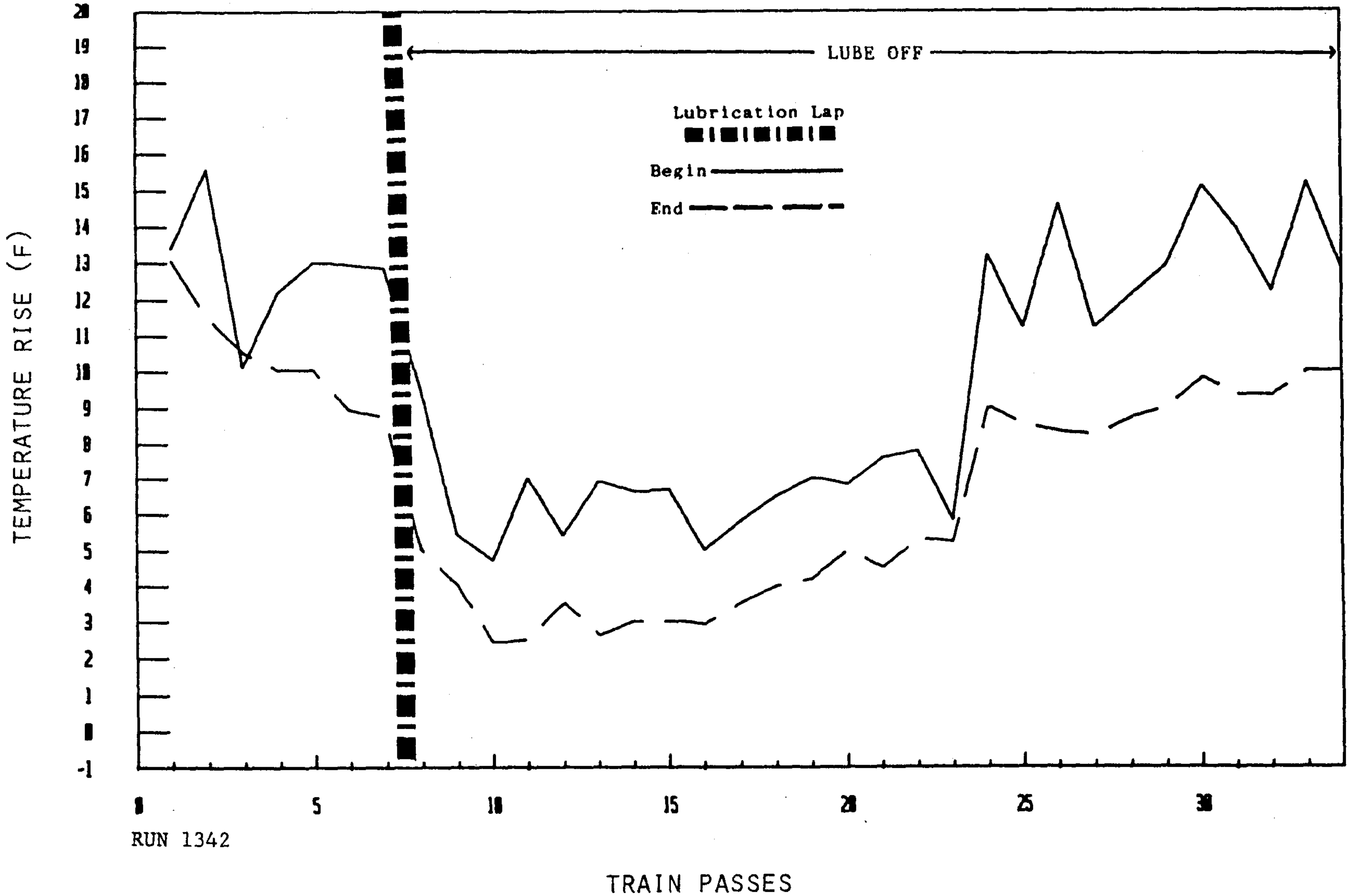

FIGURE A-6. NO. 1 GREASE RAIL TEMPERATURE VARIATION, SECTION 13.

APPENDIX B

NO. 2 GREASE

"Goop Gauge" - 2 plots, Sections 3, 13

Wheel Force - 2 plots, Sections 3, 13

Rail Temperature Rise - 2 plots, Sections 3, 13

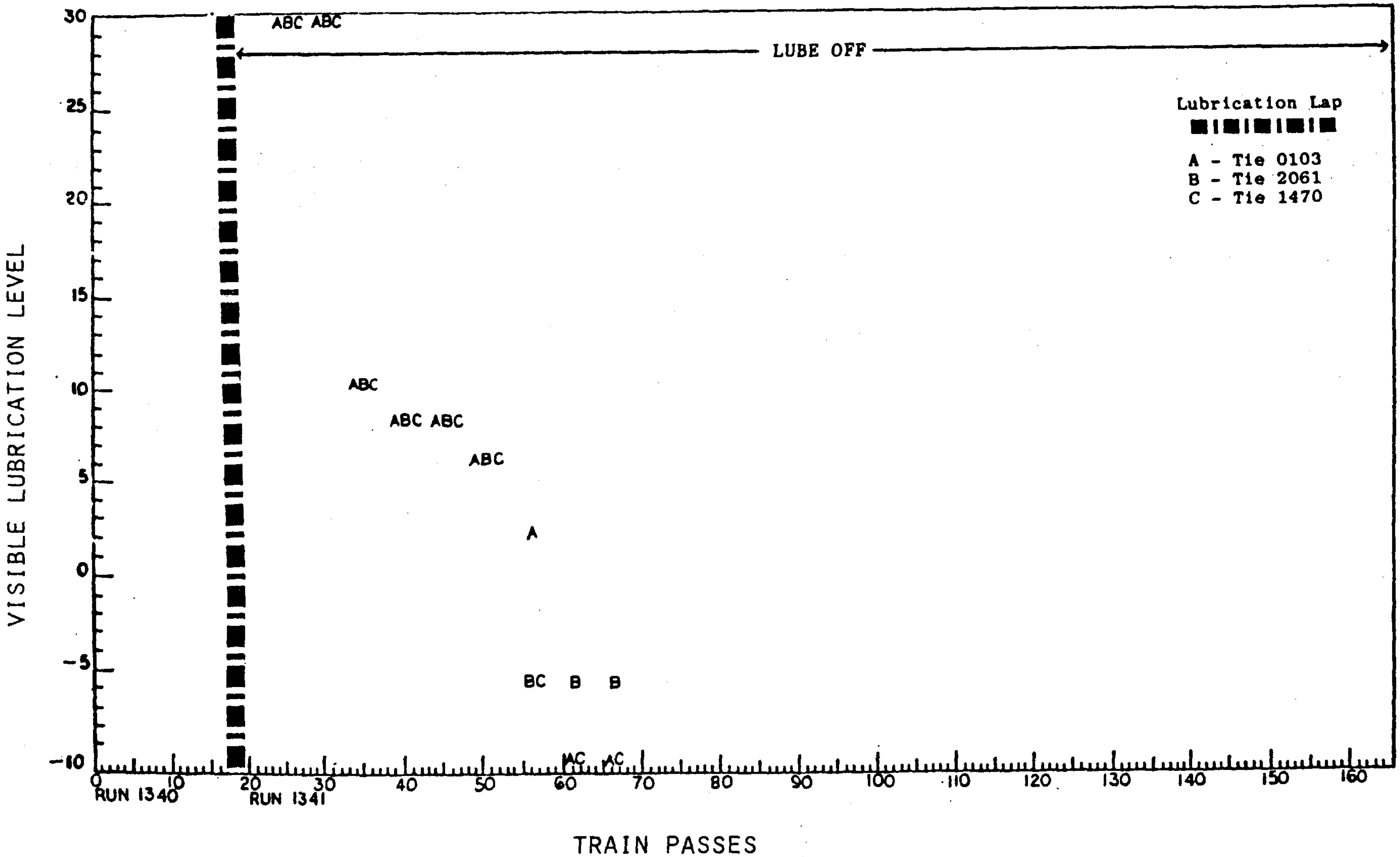

FIGURE B-1. NO. 2 GREASE "GOOP GAUGE" READINGS, SECTION 03.

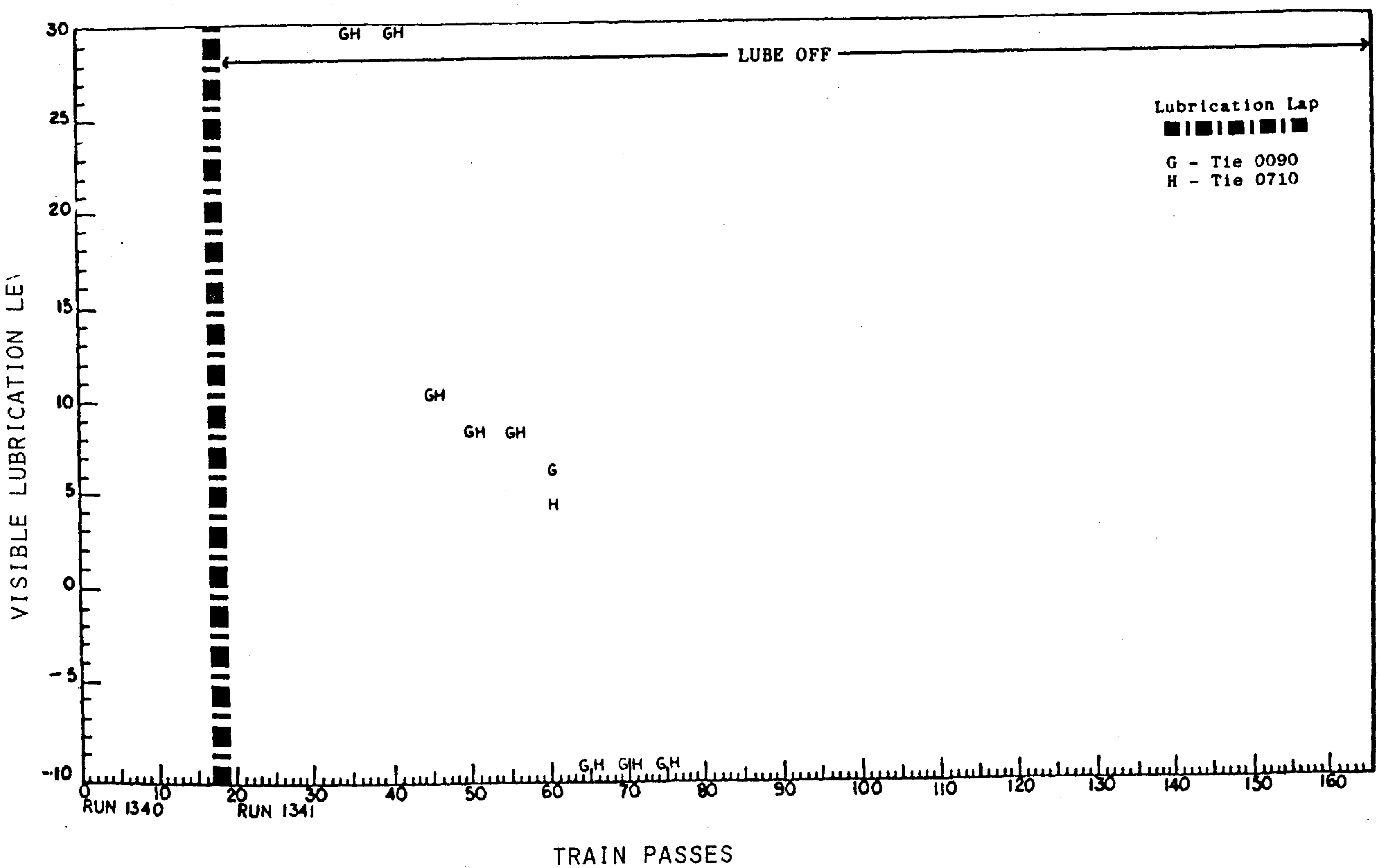

FIGURE B-2. NO. 2 GREASE "GOOP GAUGE" READINGS, SECTION 13.

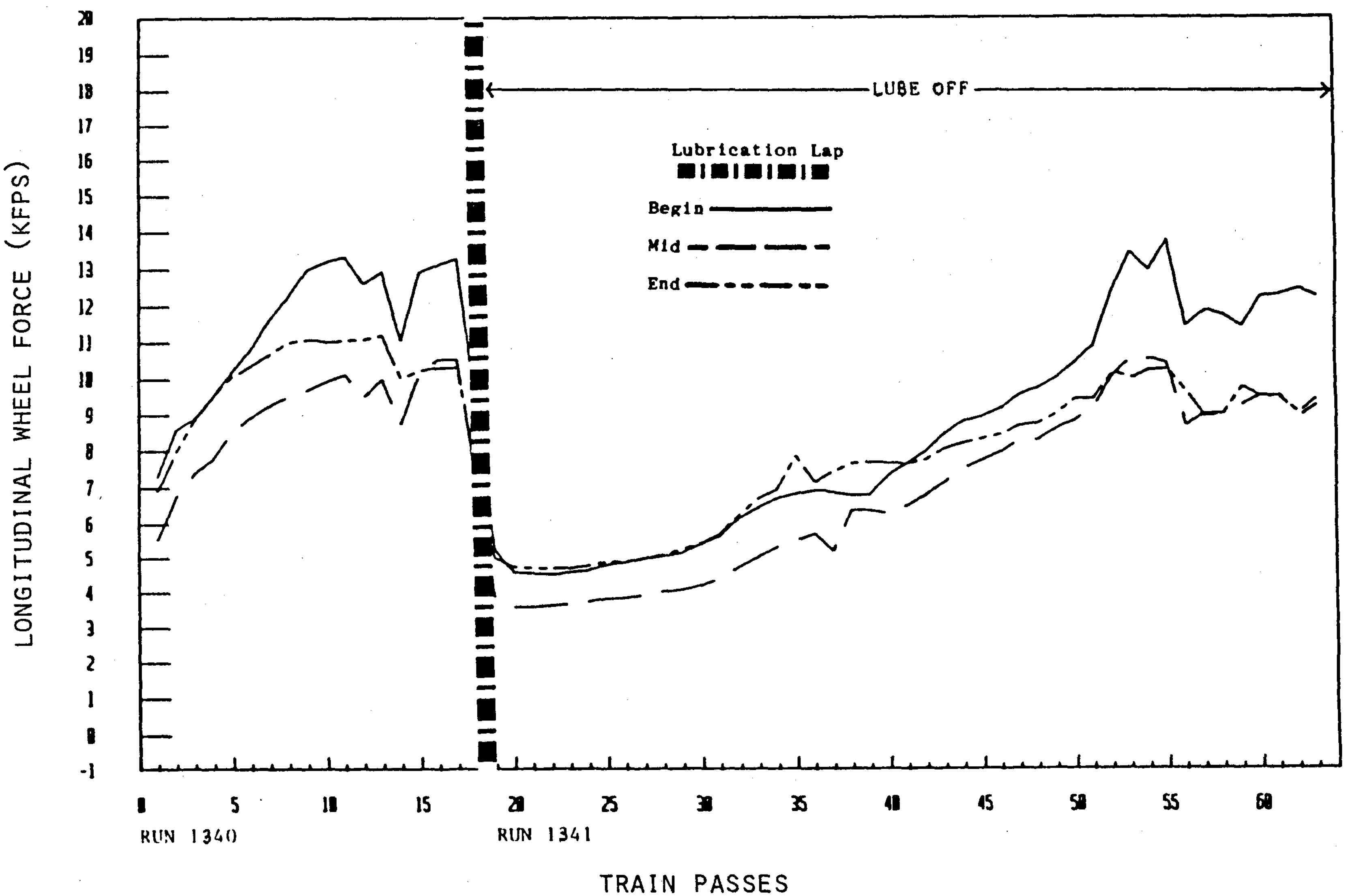

FIGURE B-3. NO. 2 GREASE WHEEL FORCE DATA, SECTION 03.

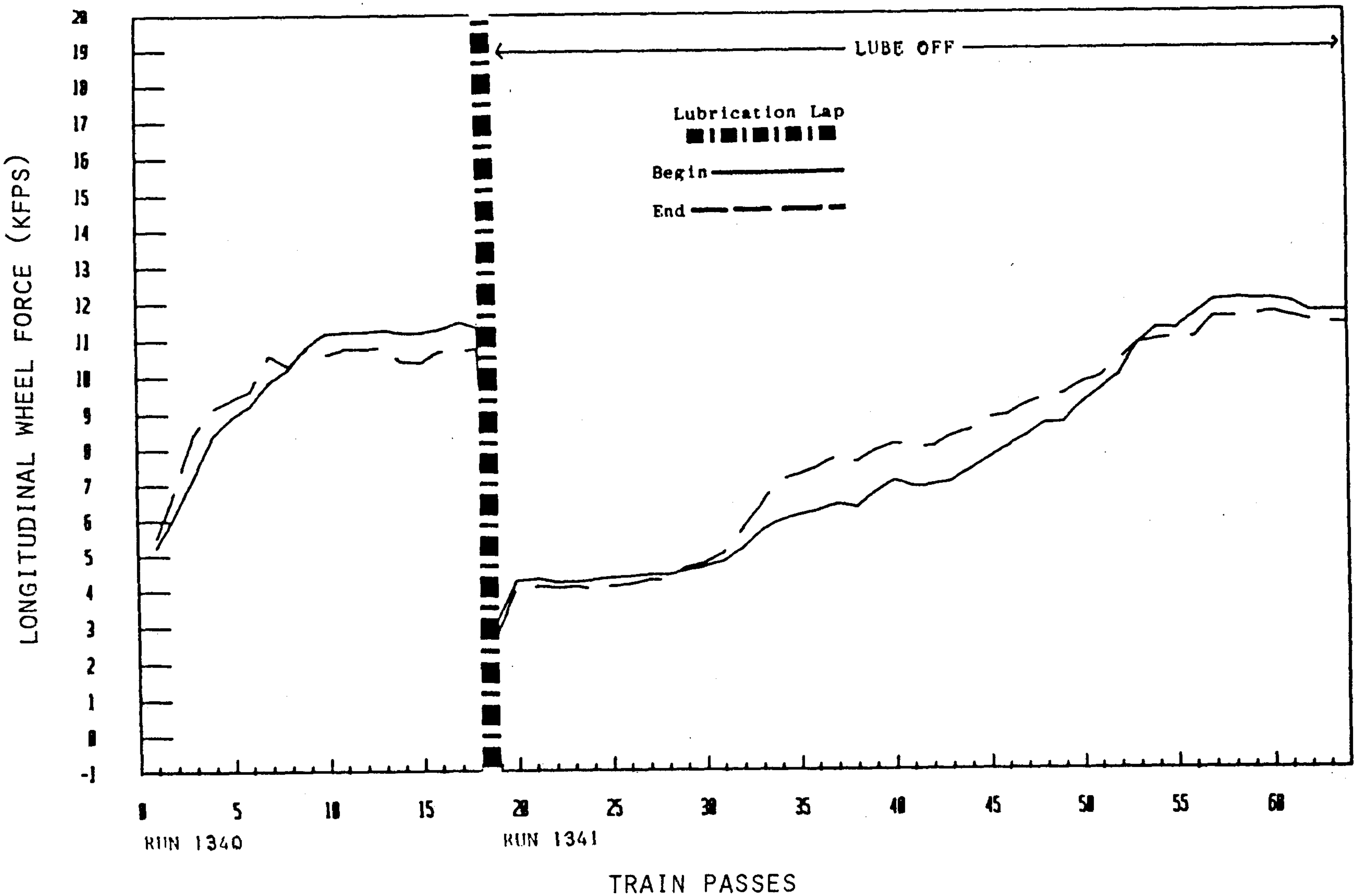

FIGURE B-4. NO. 2 GREASE WHEEL FORCE DATA, SECTION 13.

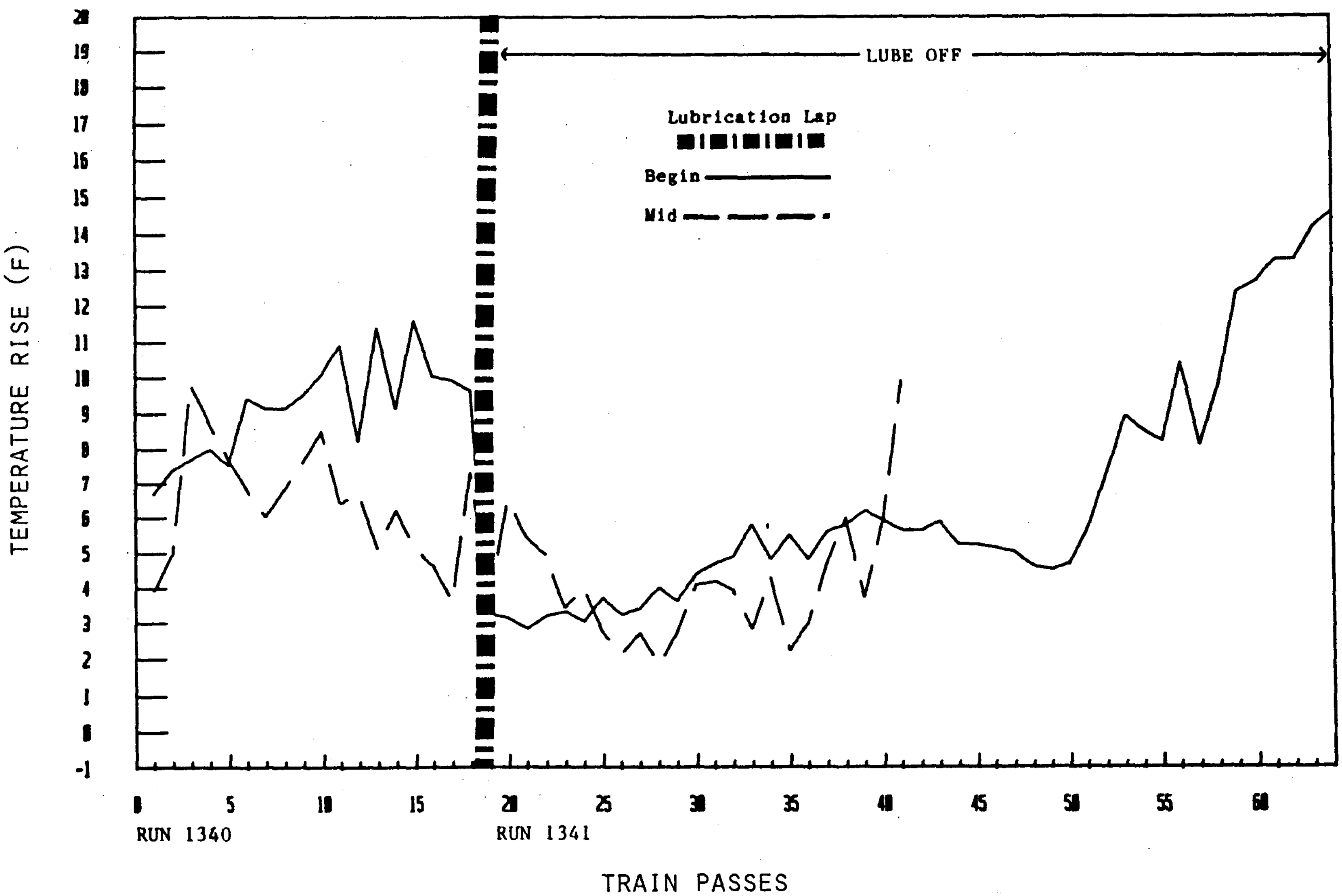

FIGURE B-5. NO. 2 GREASE RAIL TEMPERATURE VARIATION, SECTION 03.

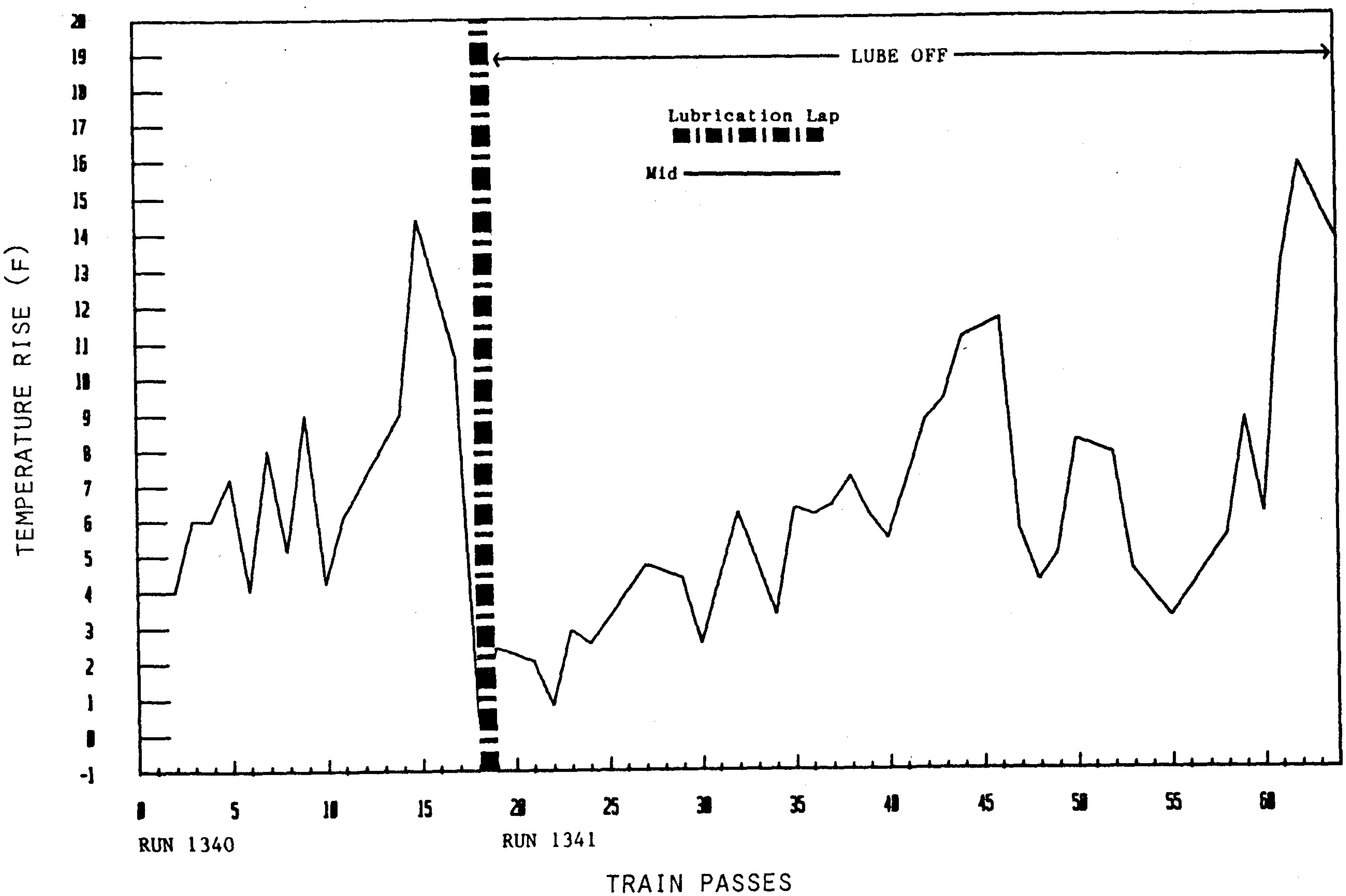

FIGURE B-6. NO. 2 GREASE RAIL TEMPERATURE VARIATION, SECTION 13.

APPENDIX C

NO. 3 GREASE

"Goop Gauge" - 2 plots, Sections 3, 13

Wheel Force - 2 plots, Sections 3, 13

Rail Temperature Rise - 2 plots, Sections 3, 13

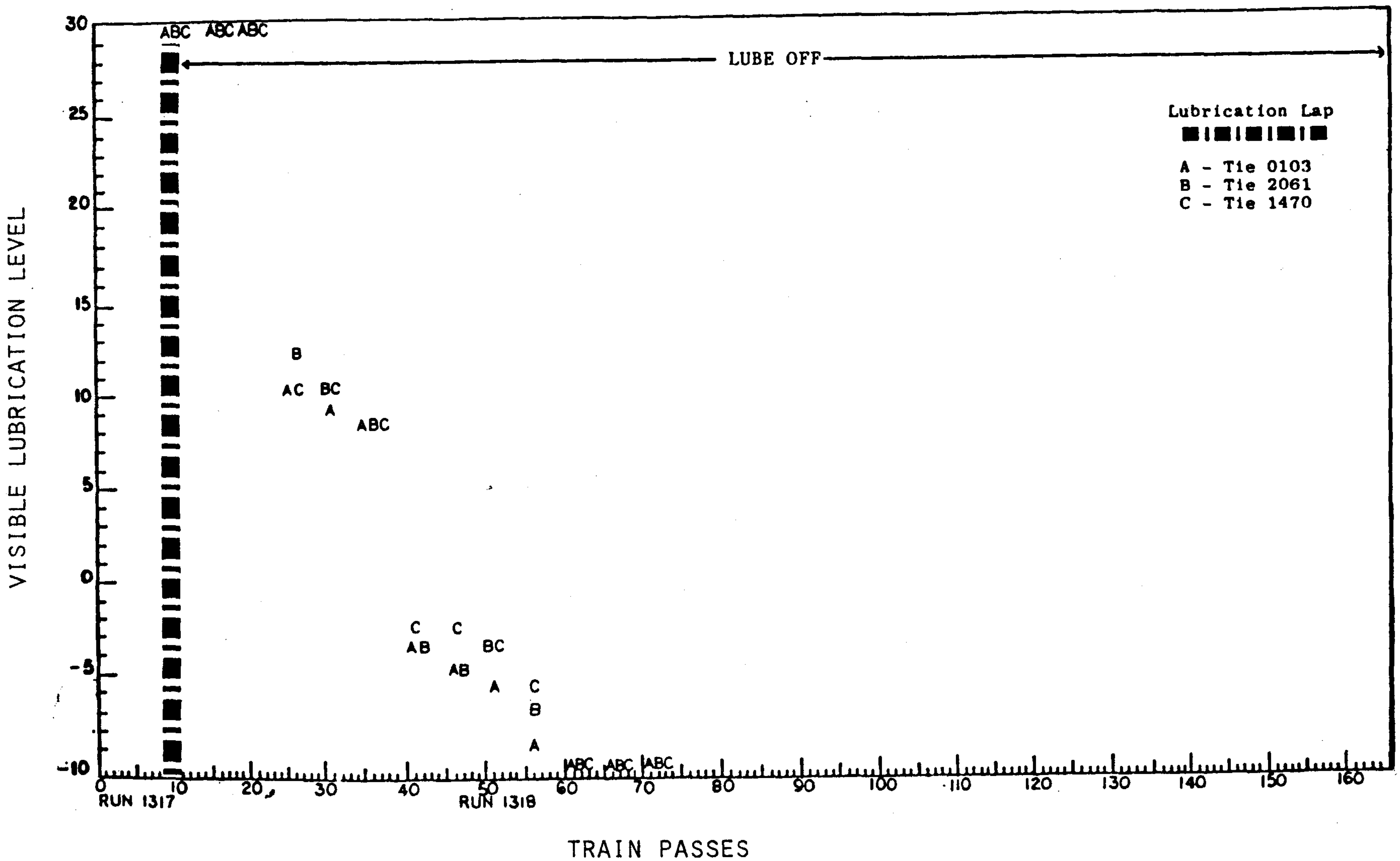

FIGURE C-1. NO. 3 GREASE "GOOP GAUGE" READINGS, SECTION 03.

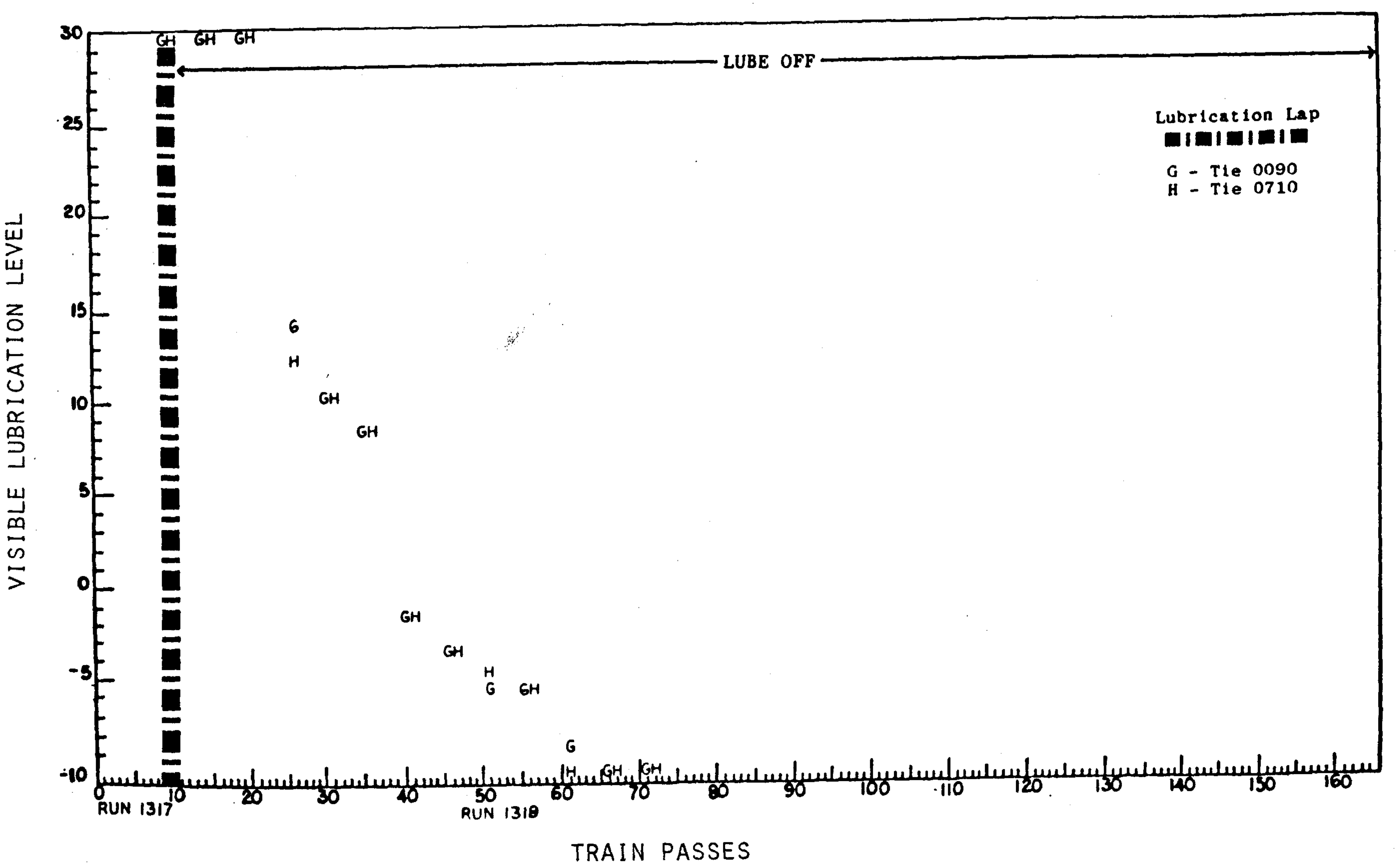

FIGURE C-2. NO. 3 GREASE "GOOP GAUGE" READINGS, SECTION 13.

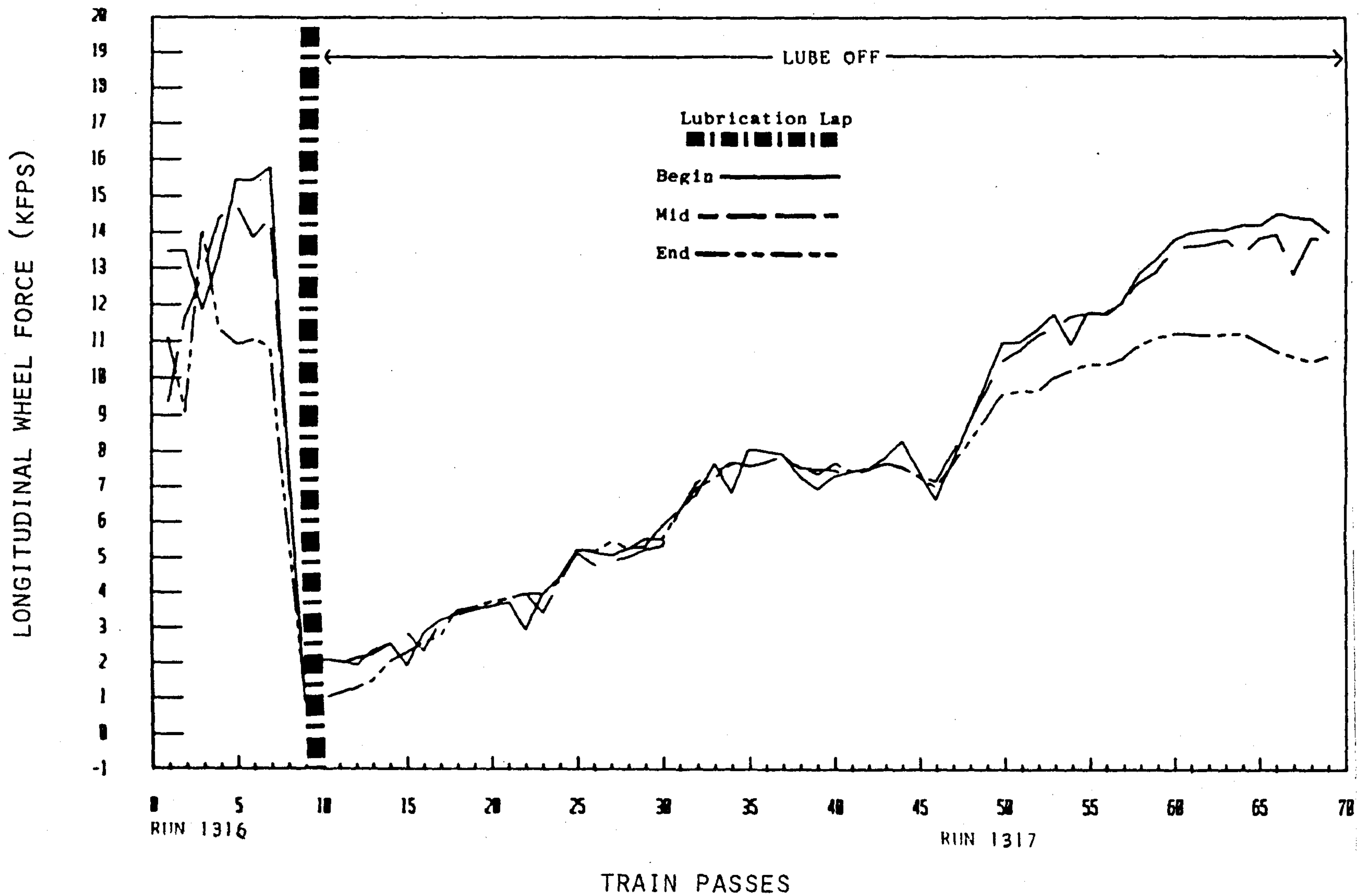

FIGURE C-3. NO. 3 GREASE WHEEL FORCE DATA, SECTION 03.

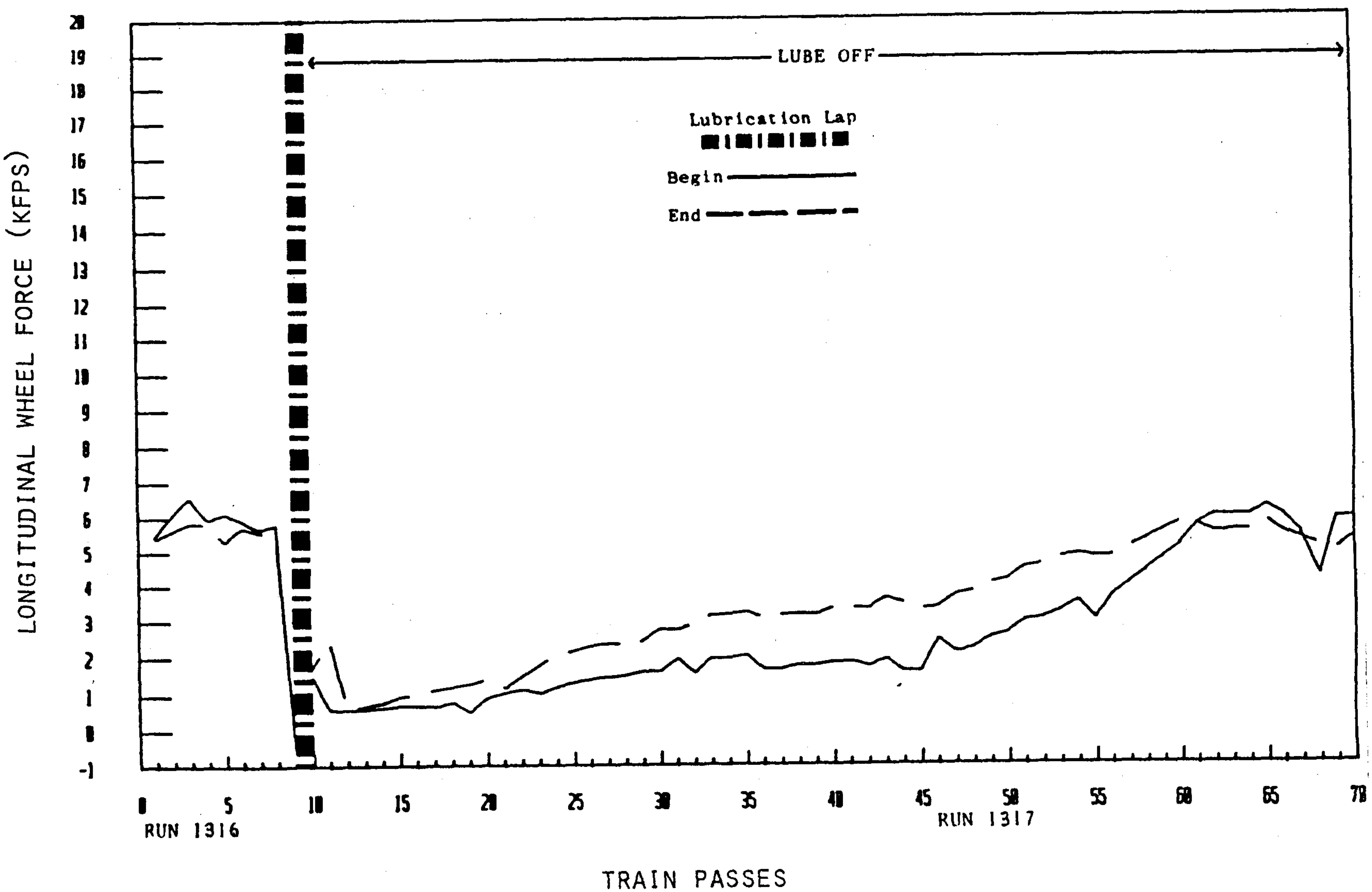

FIGURE C-4. NO. 3 GREASE WHEEL FORCE DATA, SECTION 13.

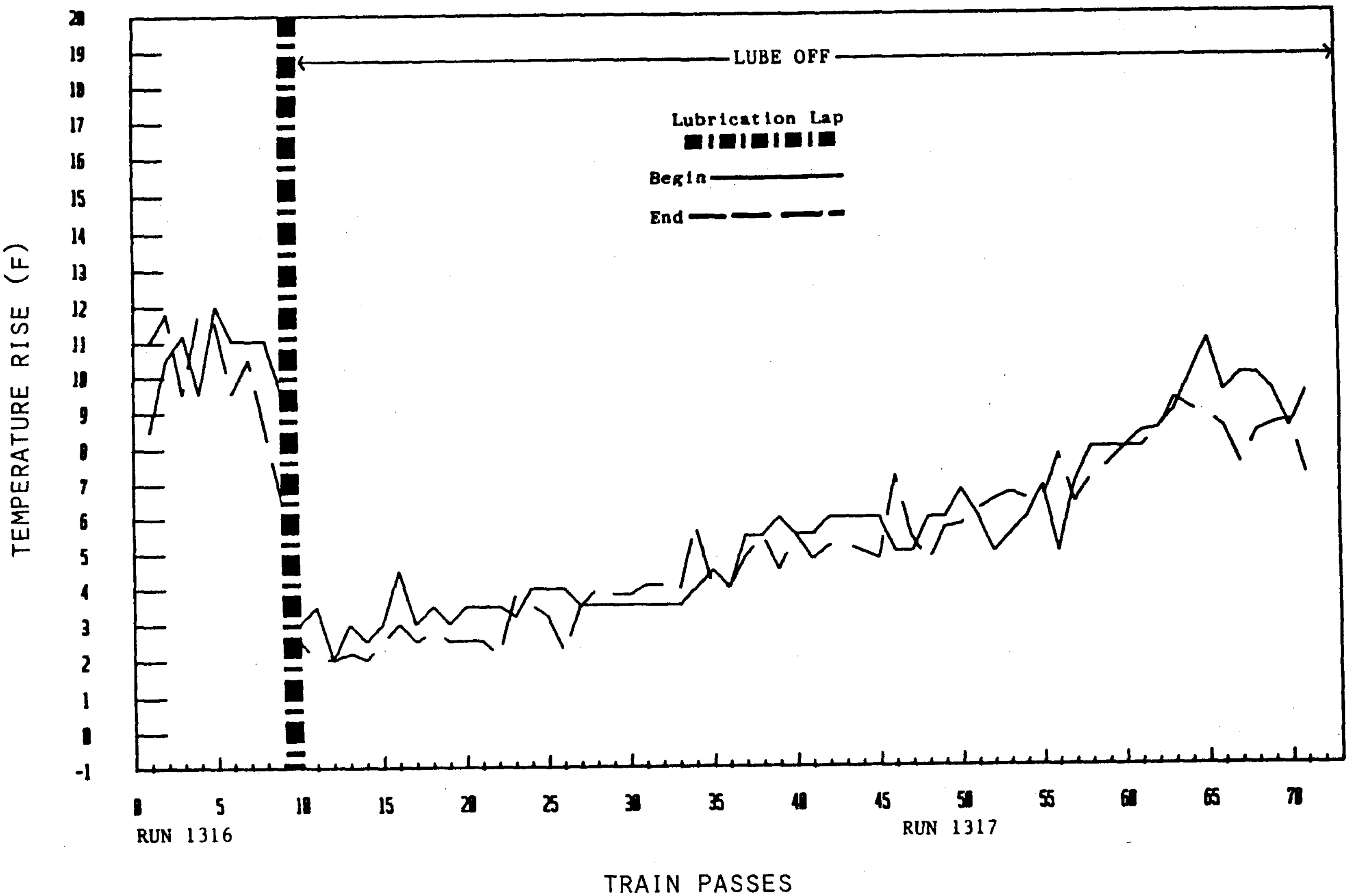

FIGURE C-5. NO. 3 GREASE RAIL TEMPERATURE VARIATION, SECTION 03.

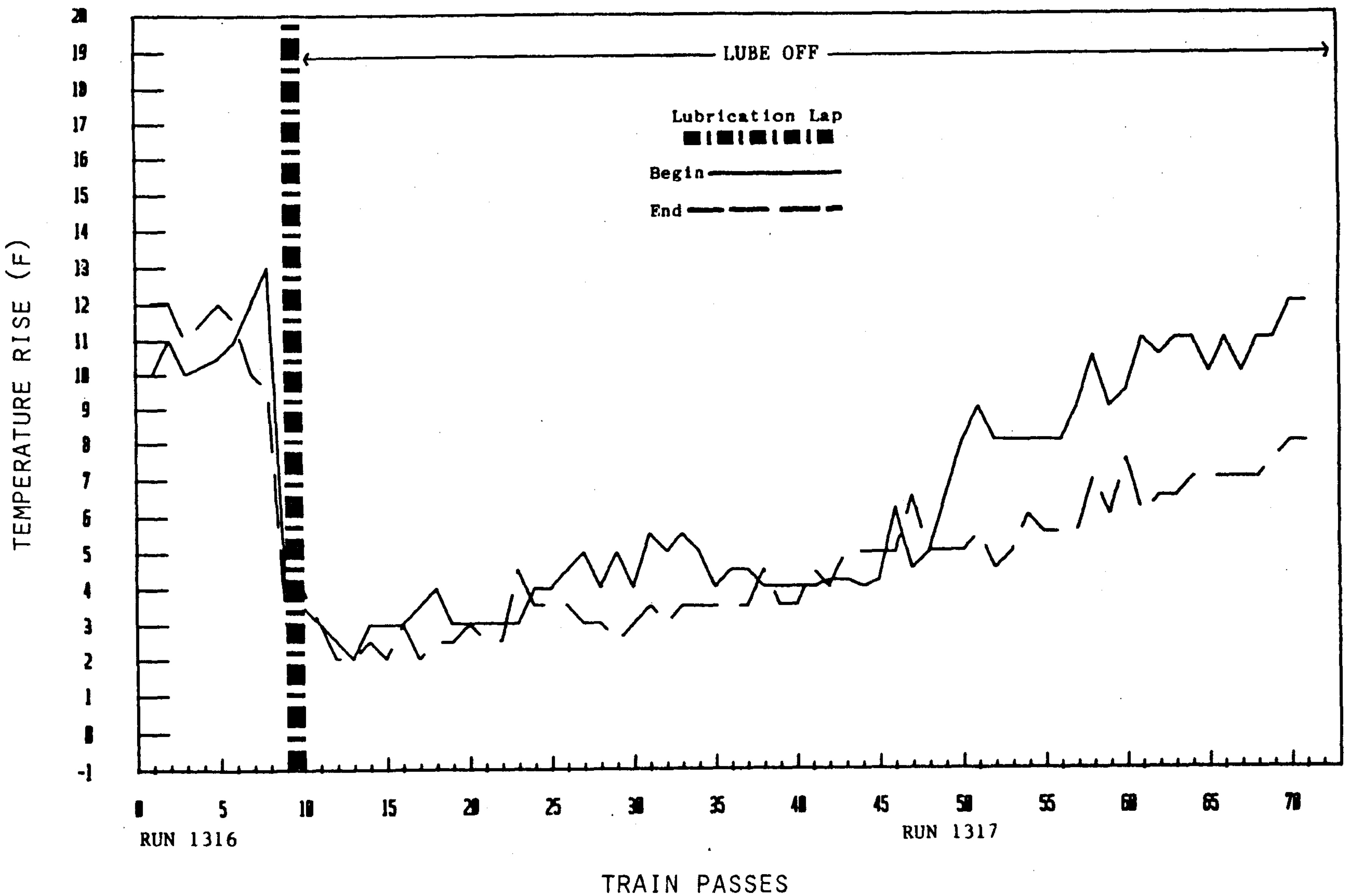

FIGURE C-6. NO. 3 GREASE RAIL TEMPERATURE VARIATION, SECTION 13.

APPENDIX D

NO. 4 GREASE

Run 1 "Goop Gauge" - 2 plots, Sections 3, 13

Run 1 Rail Temperature Rise - 2 plots, Sections 3, 13

Run 2 "Goop Gauge" - 2 plots, Sections 3, 13

Run 2 Rail Temperature Rise - 2 plots, Sections 3, 13

Run 2 Wheel Force Data - 2 plots, Sections 3, 13

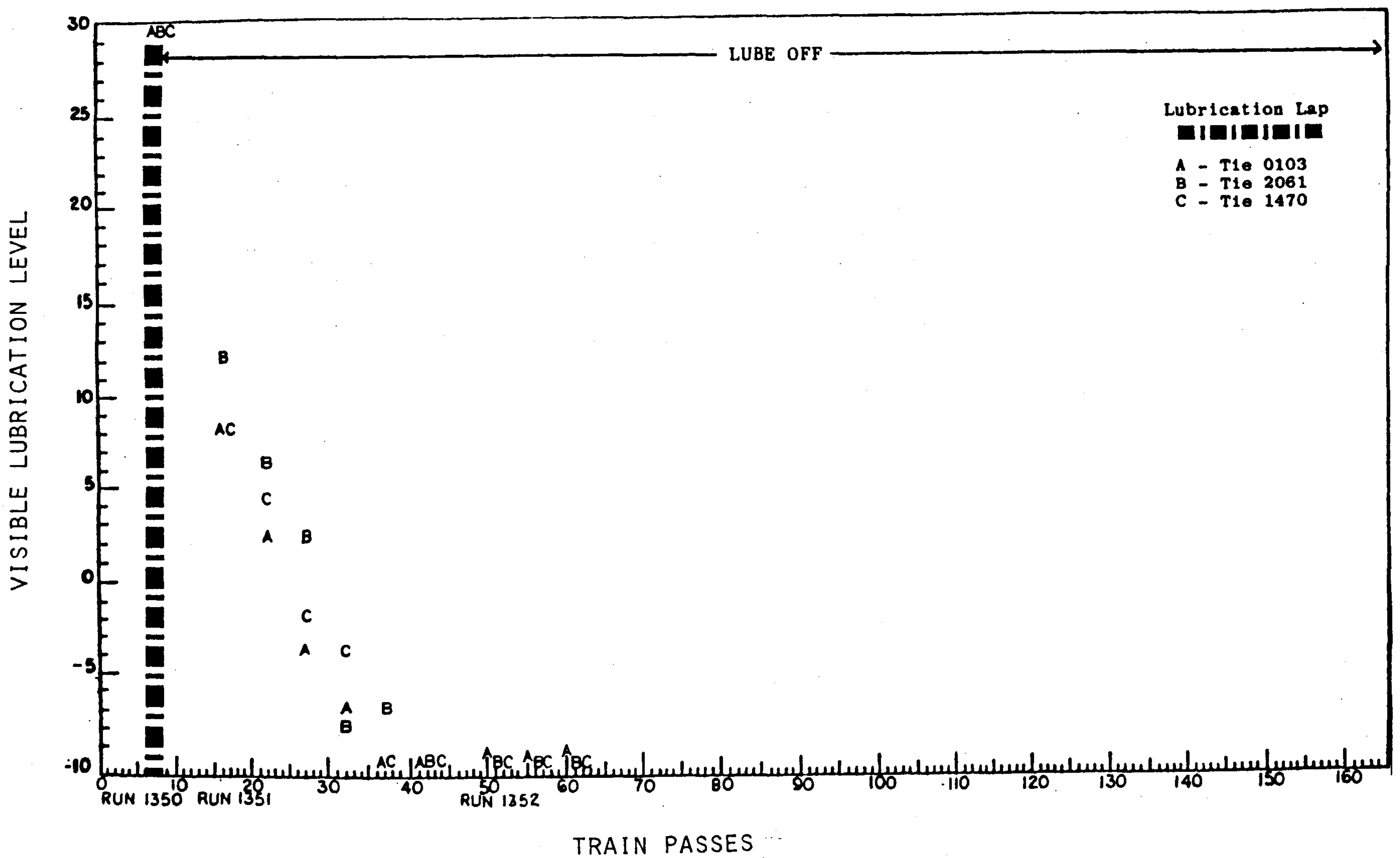

FIGURE D-1. NO. 4 GREASE "GOOP GAUGE" READINGS, RUN #1, SECTION 03.

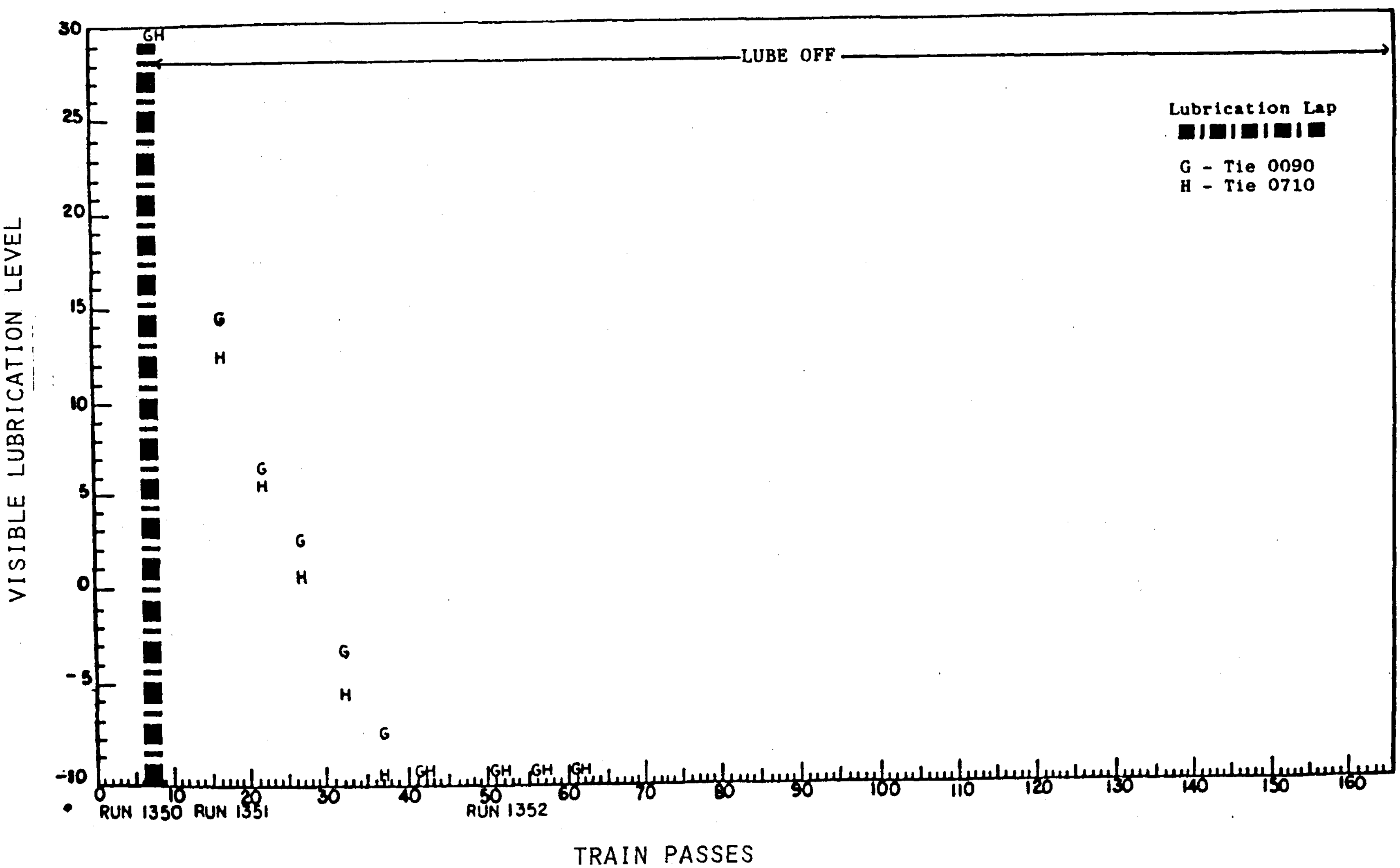

FIGURE D-2. NO. 4 GREASE "GOOP GAUGE" READINGS, RUN #1, SECTION 13.

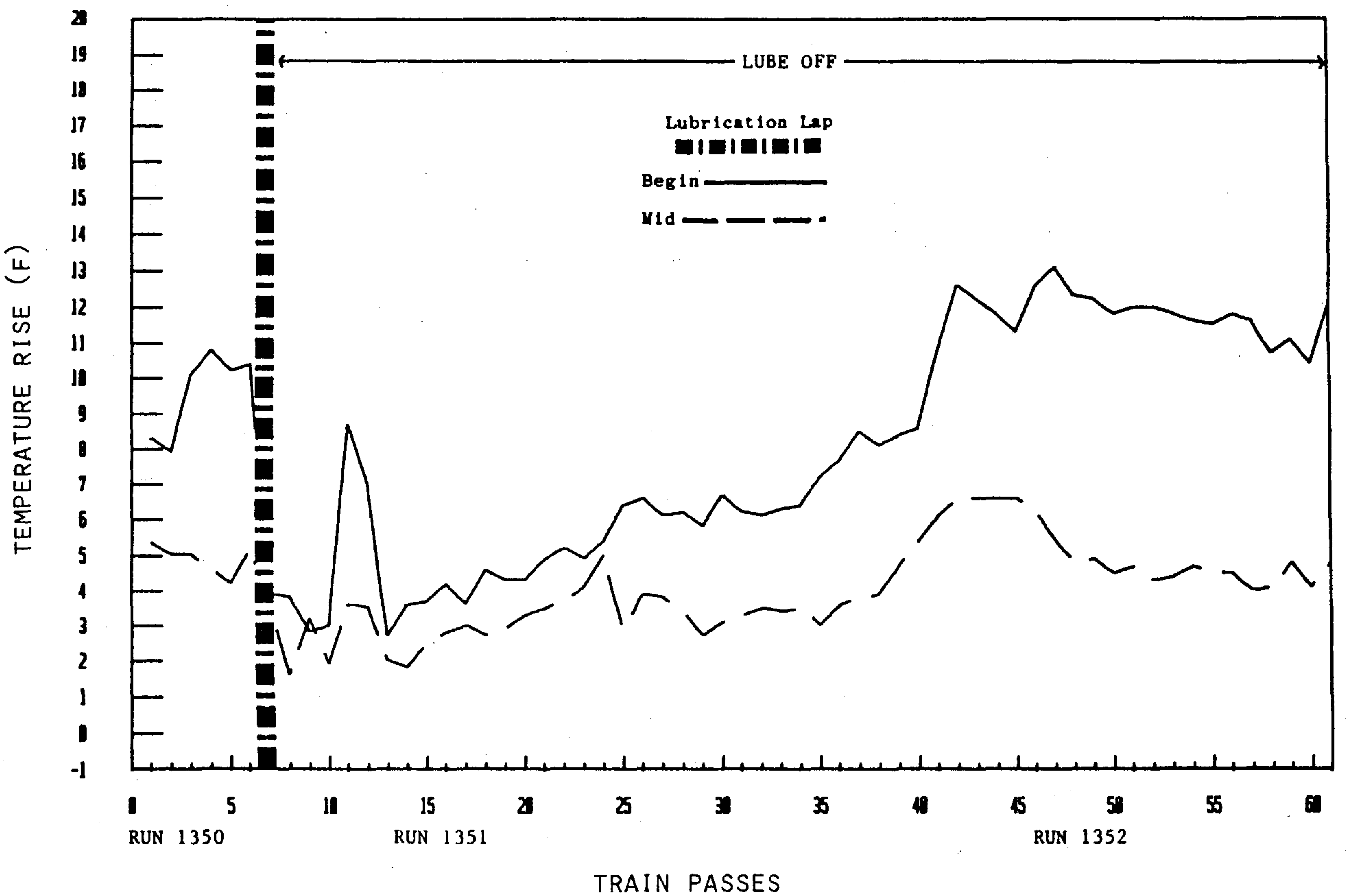

FIGURE D-3. NO. 4 GREASE RAIL TEMPERATURE VARIATION, RUN #1, SECTION 03.

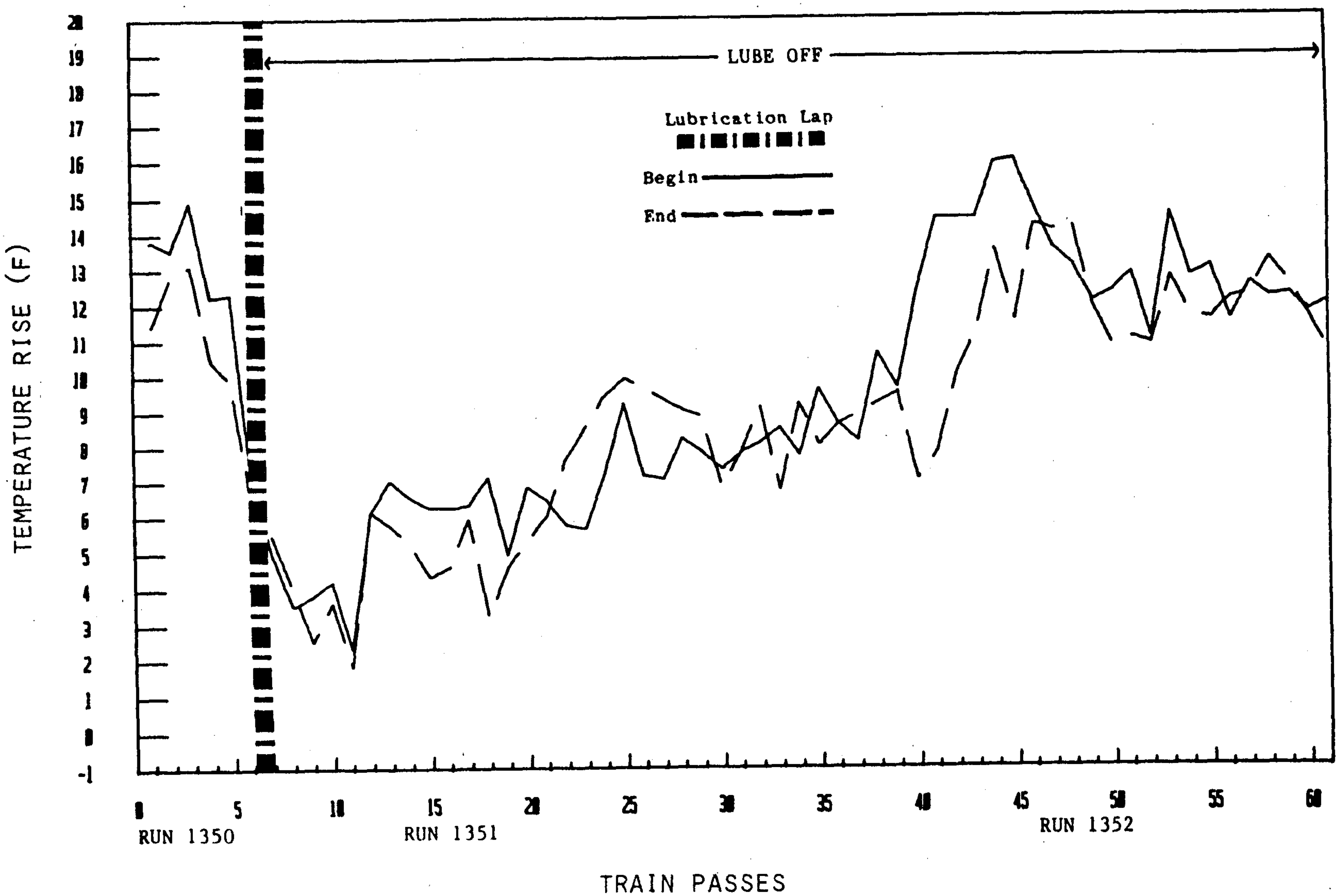

FIGURE D-4. NO. 4 GREASE RAIL TEMPERATURE VARIATION, RUN #1, SECTION 13.

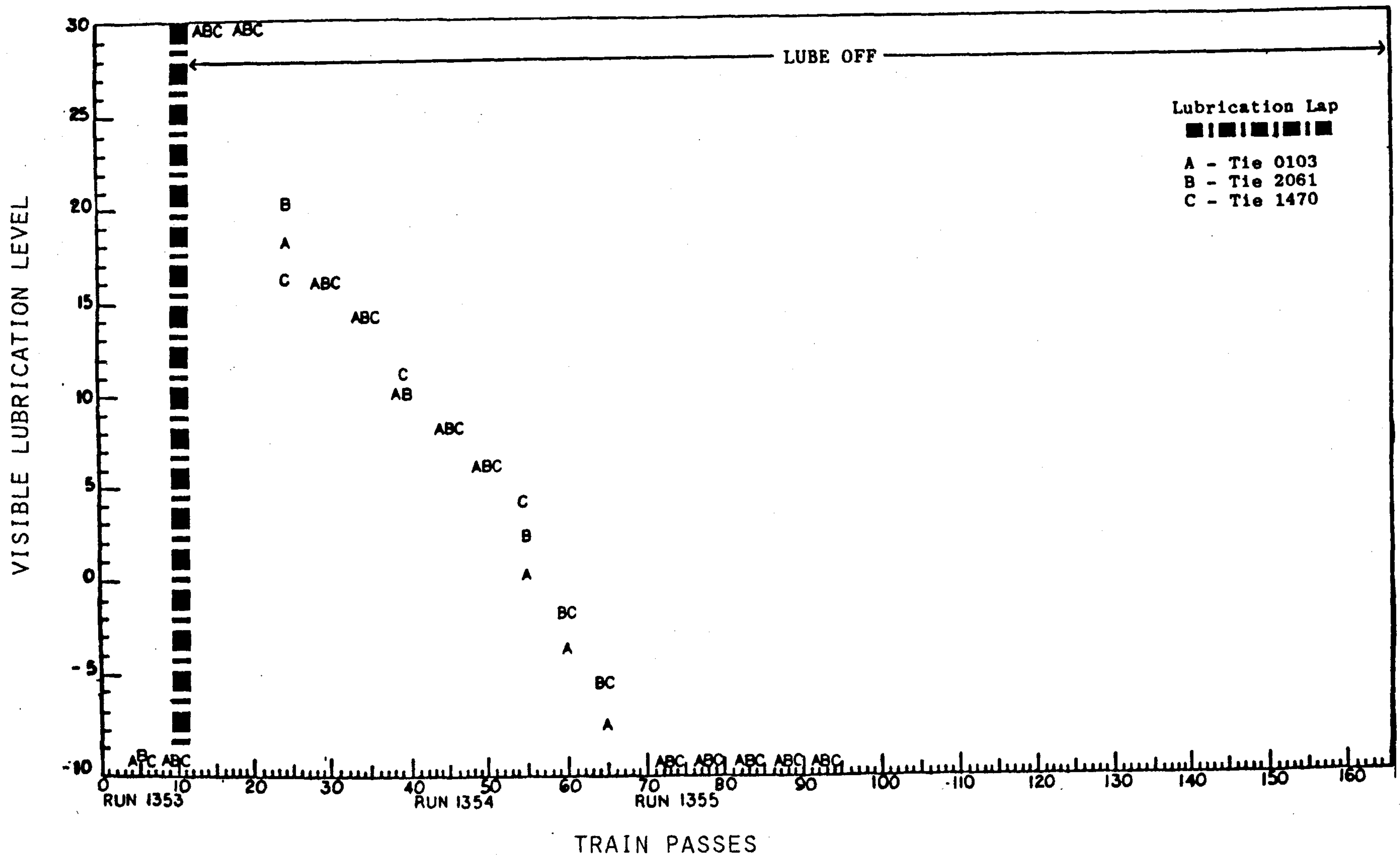

FIGURE D-5. NO. 4 GREASE "GOOP GAUGE" READINGS, RUN #2, SECTION 03.

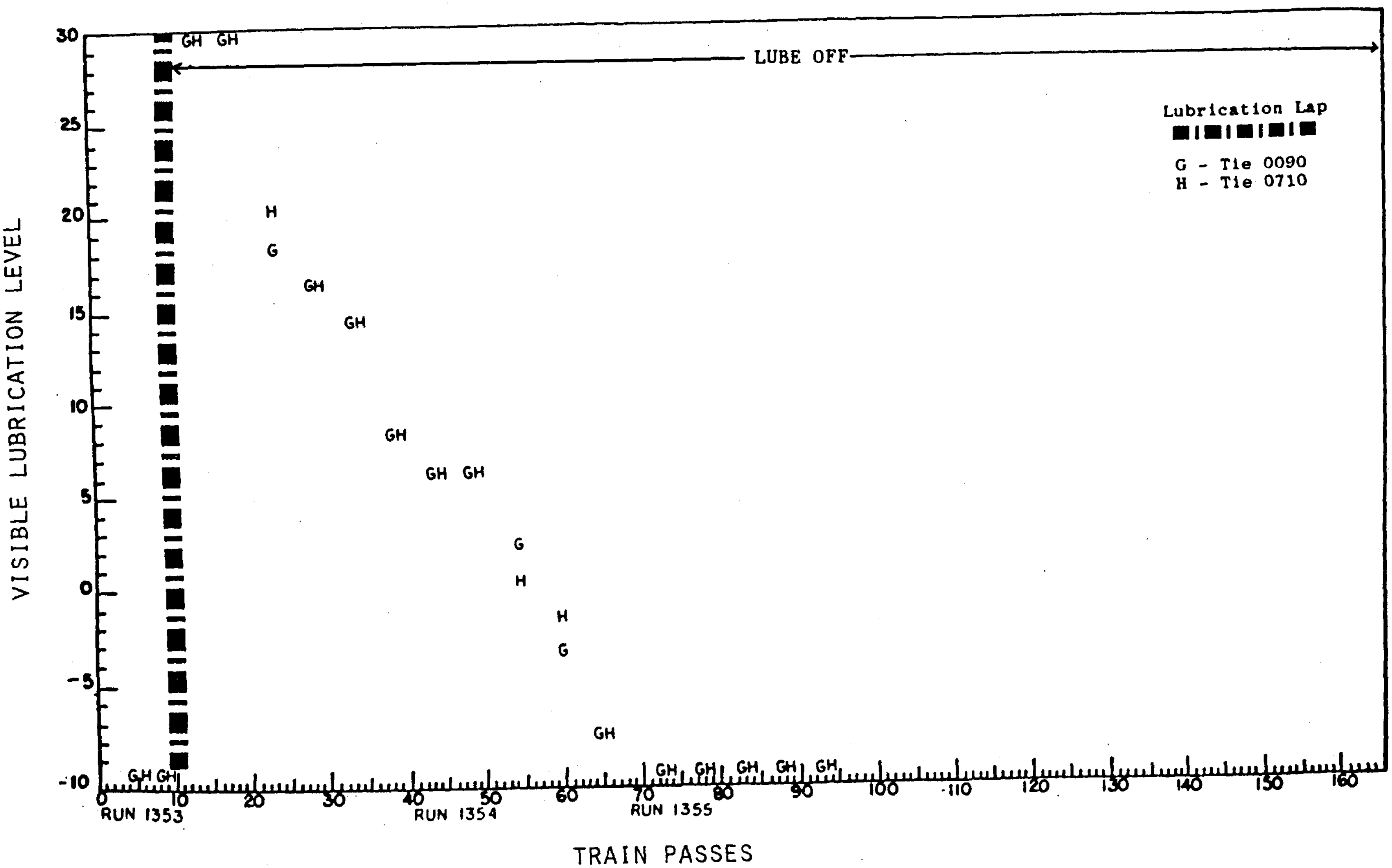

FIGURE D-6. NO. 4 GREASE "GOOP GAUGE" READINGS, RUN #2, SECTION 13.

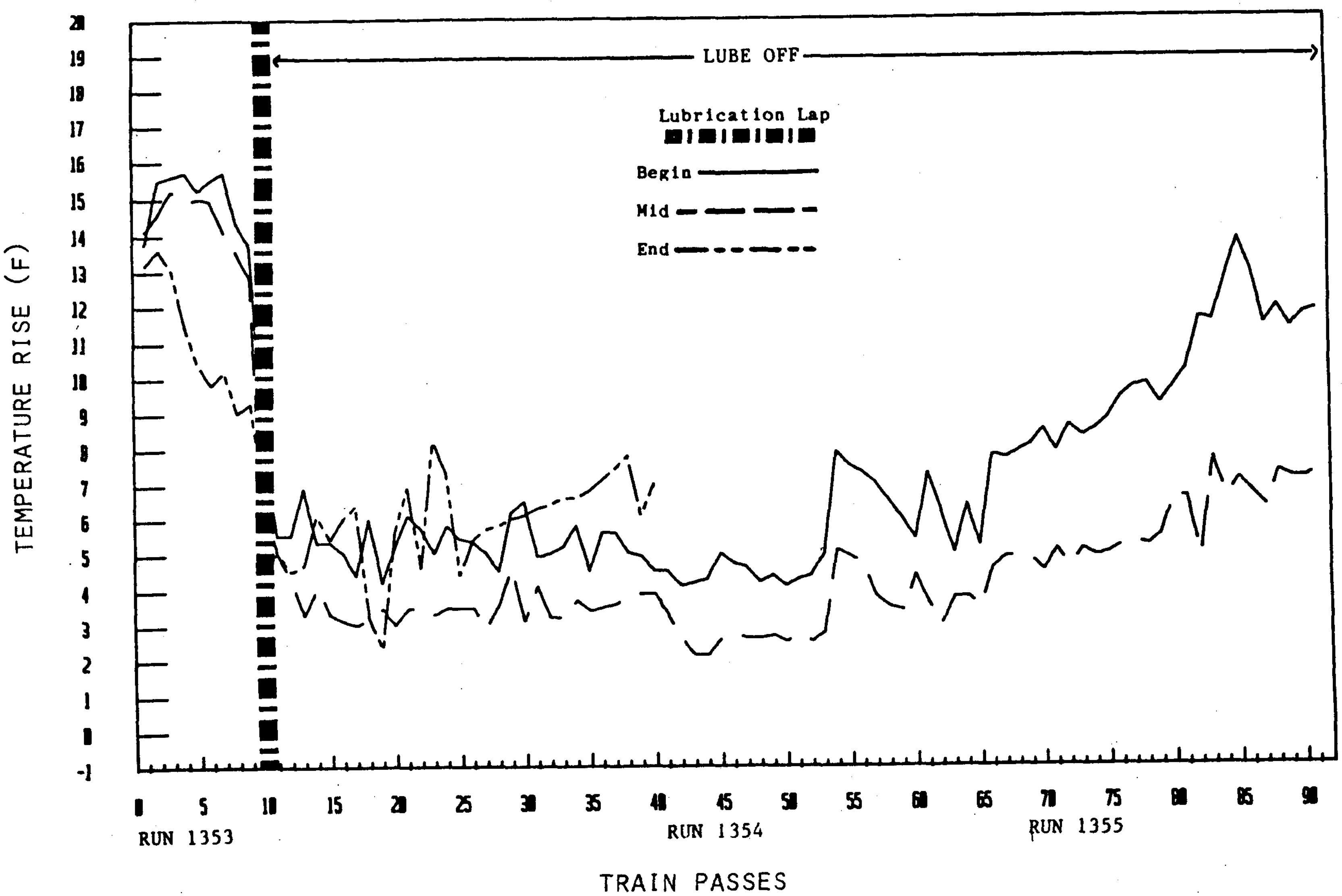

FIGURE D-7. NO. 4 GREASE RAIL TEMPERATURE VARIATION, RUN #2, SECTION 03.

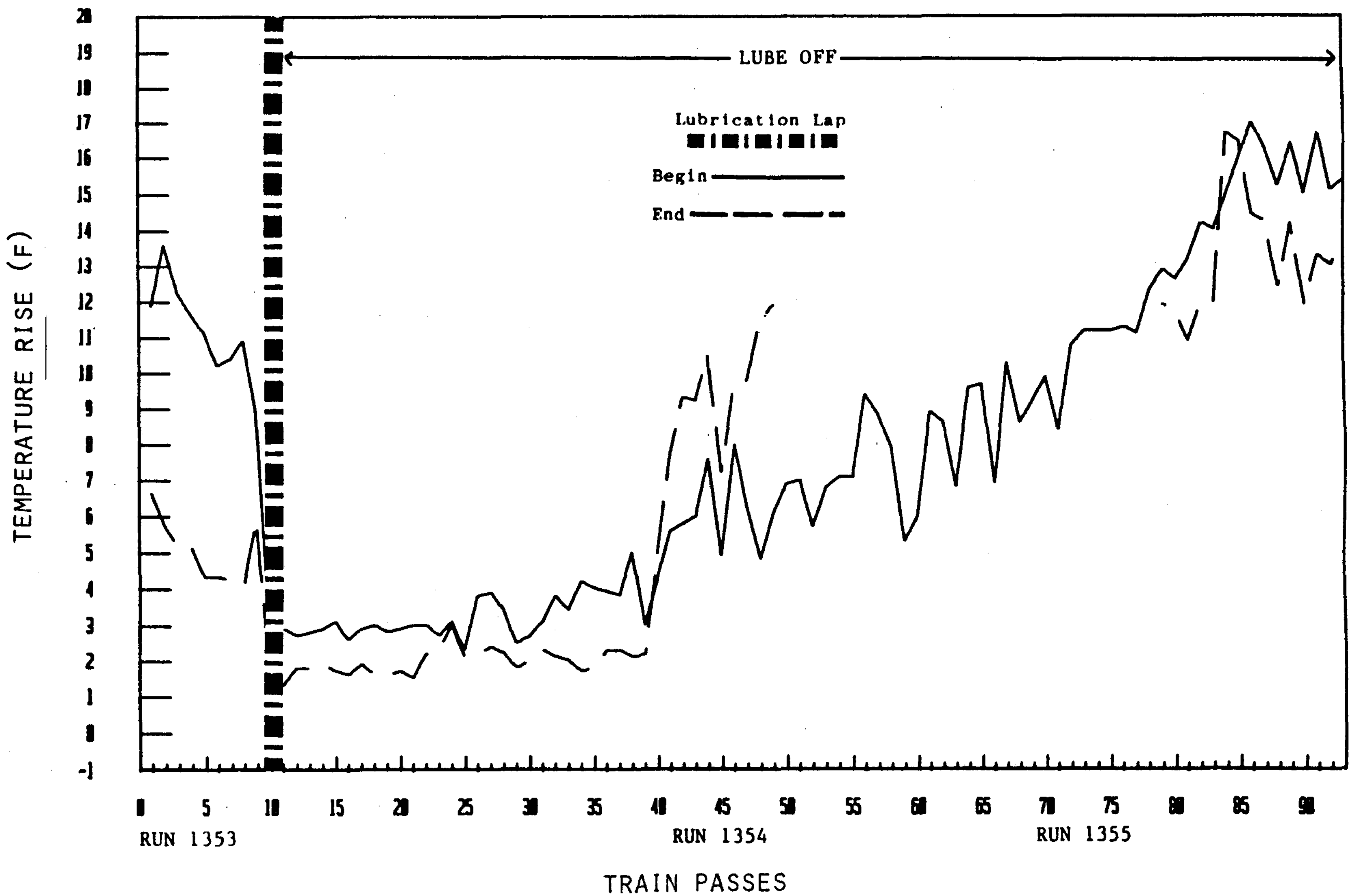

FIGURE D-8. NO. 4 GREASE RAIL TEMPERATURE VARIATION, RUN #2, SECTION 13.

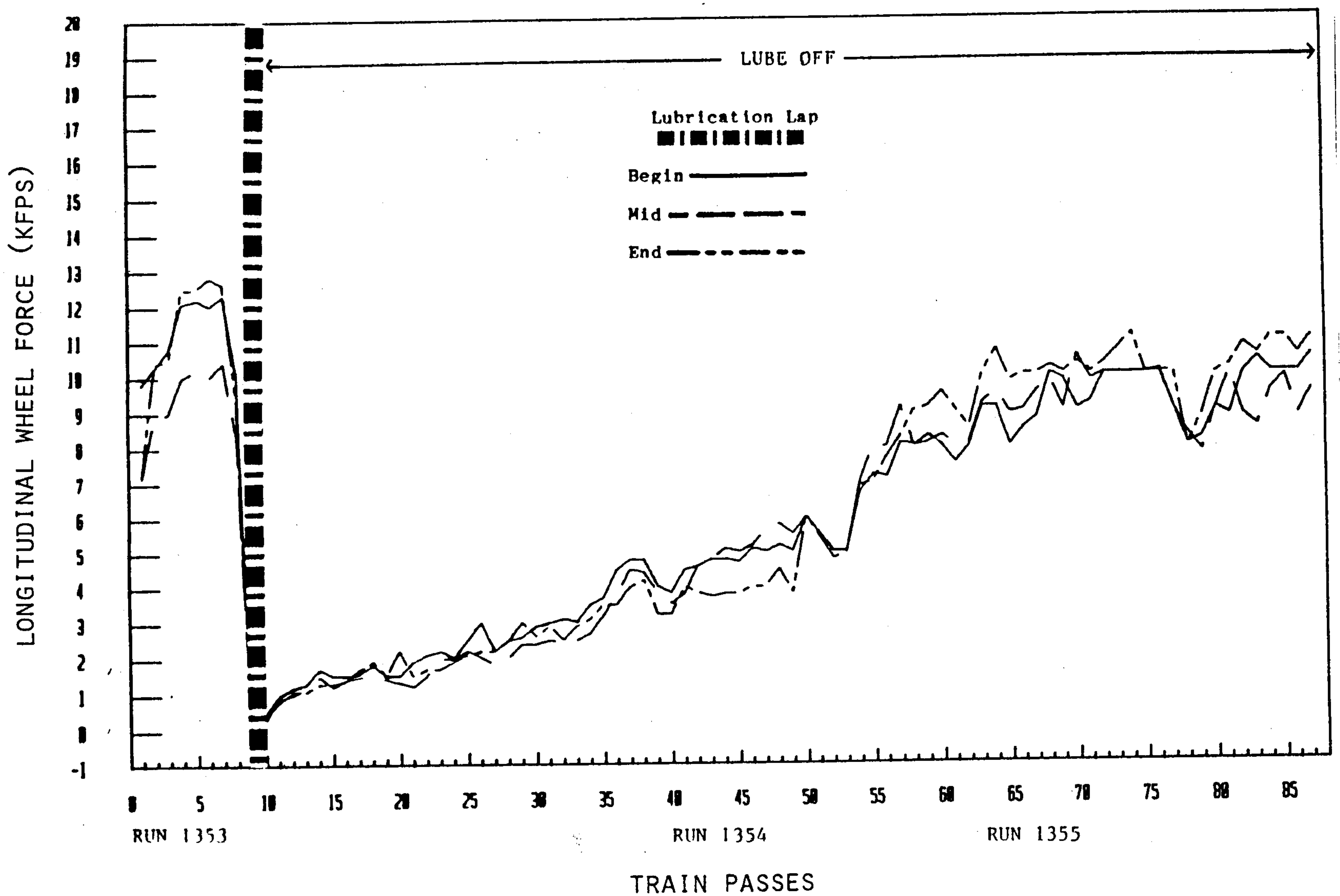

FIGURE D-9. NO. 4 GREASE WHEEL FORCE DATA, SECTION 03.

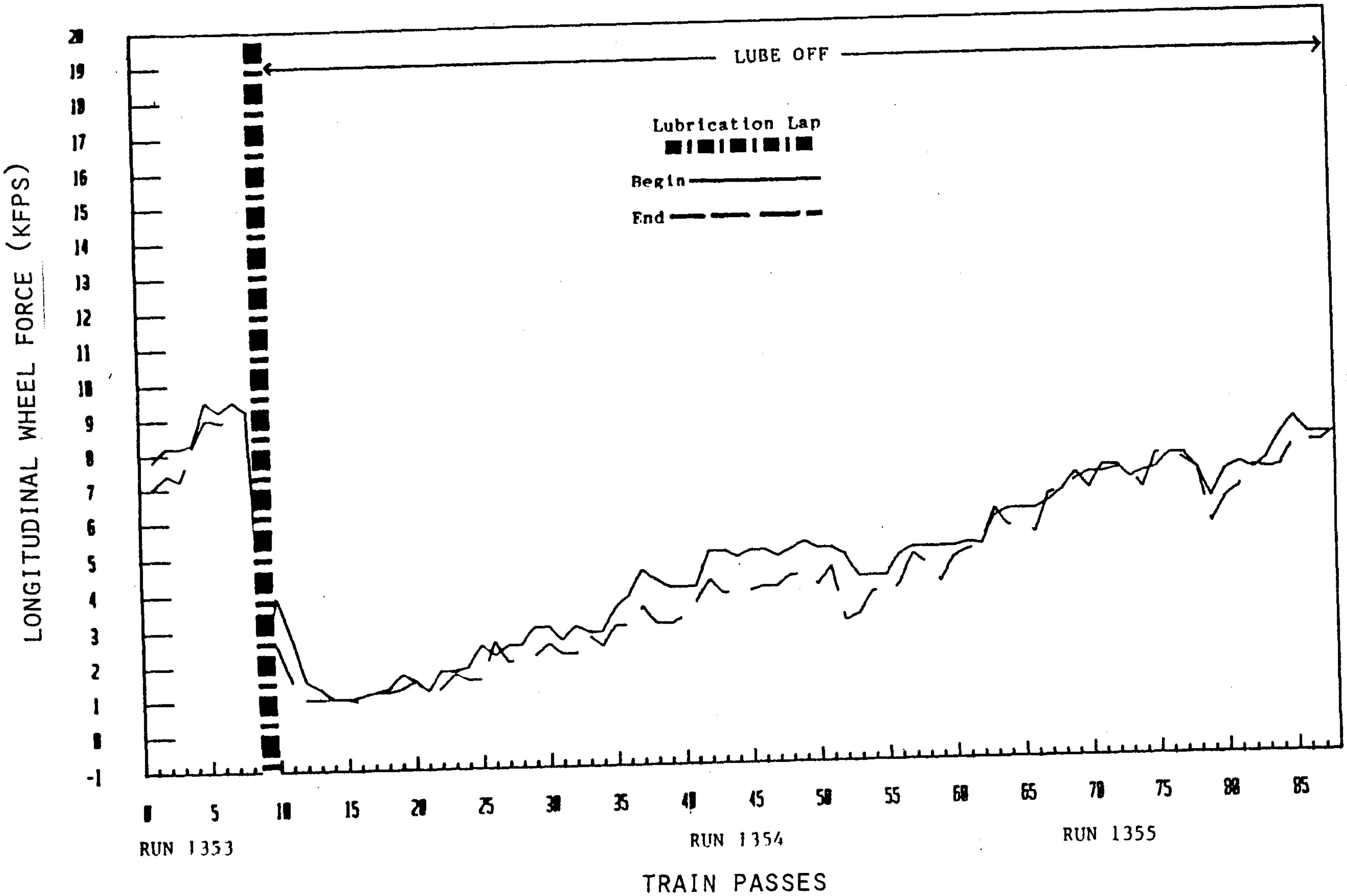

FIGURE D-10. NO. 4 GREASE WHEEL FORCE DATA, SECTION 13.