PB92-129428

U.S. Department
of Transportation

Federal Railroad Administration

Performance of Degraded Roller Bearings

Office of Research and Development

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DOT/FRA/ORD-90/12

December 1990

ACKNOWLEDGEMENTS

A test program of this magnitude and complexity would not be possible without the help of many organizations and individuals. The authors wish to acknowledge the special contributions made by Mr. Robert Florum, AAR-TTC, for directing the extensive effort by TTC in preparing for and conducting the month-long test; Mr. Robert McCown for providing onboard test direction, real time data analysis and detailed test logs which are incorporated in this report; and Dr. Hermann Ernst for providing prototype low friction bearing seals for evaluation.

Special recognition goes to the Timken Company and Brenco, Inc., for providing the test bearings and to Servo Corporation of American and Harmon Industries, Inc. for providing wayside bearing evaluation systems.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. PB92-129428

2. REPORT DATE
18 December 1989
Revised: 12/28/90

3. REPORT TYPE AND DATES COVERED
Test Results 3/7/89 through 4/7/89

4. TITLE AND SUBTITLE
Performance of Degraded Roller Bearings

5. FUNDING NUMBERS

6. AUTHOR(S)
Kevin Kesler and Chris Tinto

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ENSCO, Inc.
Applied Technology and Engineering Division
5400 Port Royal Road
Springfield, VA 22151

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-FR-89-08

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Federal Railroad Administration
Department of Transportation
400 Seventh St., S.W.
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
FRA/ORD-90/12

11. SUPPLEMENTARY NOTES
Volume I contains the main body of the report including Appendices A, B, and C. Volume II contains Appendix D, supporting data for material reported in the main body of this report.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Volume I is available to the public from the National Technical Information Service, Springfield, VA 22161. Volume II is available from ENSCO, Inc., 5400 Port Royal Road, Springfield, VA 22151.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Concerns over railroad bearing failure prompted a test to be conducted to measure the rate at which degraded bearings overheat under service conditions. A test consist which included a locomotive, a data collection car and four test cars containing 24 subject bearings was utilized. The bearings under test had all been removed from railroad service due to overheating. Two bearings were grooved and the remaining had differing interference fits. By monitoring the thermal performance of the bearings, the maximum heating and cooling rates associated with roller bearing failure were determined to be 12.8 deg/min and 7.2 deg/min, respectively.

It was found that significant thermal gradients can exist across a given bearing, with temperature differences of 30 deg F between inboard and outboard races. In addition, the cones associated with bearings that had minimal interference fit were observed to rotate at rates varying from .04 to 1.6 percent slip.

14. SUBJECT TERMS
Roller Bearings
Degraded
Cone Rotation
Bearing Thermal Performance

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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PERFORMANCE OF DEGRADED ROLLER BEARINGS

1.0 BACKGROUND

Concerns for railroad roller bearing safety within the Federal Railroad Administration (FRA) were heightened in 1982 following two wheel loss incidents that year, caused by bearing failures on the New York Metro North Railroad's M-2 commuter coaches. The actions taken by the FRA at that time, and the results of investigations performed by the FRA and the Transportation Systems Center following that event are documented in a paper entitled "Grooving Failure in Railroad Axle and Bearing Systems" (O. Orringer -TSC). Excerpts from that paper are presented here as part of the background to this investigation.

Following the wheel loss incidents on Metro North, the Federal Railroad Administration restricted the M-2 fleet operating speed, increased the frequency of safety inspection, and established a failure investigation task force led and staffed by the Transportation Systems Center. The inspections identified additional wheelsets which showed signs of bearing overheat episodes. The railroad shopped these wheelsets for disassembly and examination by the task force. Ultimately, about 30 percent of the wheelsets in the fleet were found to have a groove being cut into the journal underneath a bearing. The task force established a progression for the groove cutting process and confirmed its association with bearing failure when the safety inspection program caught an imminent failure in a wheelset with a deeply grooved journal.

The M-2 coach is an atypical vehicle, in that it combines great weight on the rails (70 tons) with inboard-bearing axles that were originally tubular with a relatively large bore (89 mm diameter compared with the axle's nominal journal diameter of 157 mm). A survey of other U.S. rolling stock identified two similar but newer fleets: the Arrow-III coaches owned by New Jersey Transit Rail Operations; and the Southeastern Pennsylvania Transit Authority's fleet of Silverliner-IV coaches. The M-2, A-III, and S-IV fleets comprise 664 cars operated in high-speed intercity service covering the Philadelphia - New York - New Haven sector of the Northeast Corridor mainline.

In its final report, the task force concluded that a combination of marginal design and poor assembly quality control had caused the high incidence of journal grooving in the M-2 fleet, and also that the other fleets would experience similar problems at similar points in their service lives. The large axle bore and lack of an adequate specification for clamping the bearing were cited as factors contributing to the marginal character of the design. The role of the tubular cross sections was emphasized by the fact that the first 40 M-2 axles had solid sections, yet none of these were grooved despite their having accumulated the most service in the same assembly quality control environment as the rest of the fleet. Marginal bearing-to-axle interference fit resulting from poor control of diametral tolerances, improper application of outboard-bearing wheelset gage control procedures, and excessive time between bearing component inspection were cited as the main factors contributing to poor assembly quality control.

The task force recommended that the M-2 fleet be retrofitted with solid axles and that the industry specifications for diametral tolerances and clamping of inboard bearings be tightened. These measures were adopted in 1983, and the M-2 retrofit campaign was completed in 1984. Two A-III wheel loss incidents in 1984 prompted New Jersey Transit to start a similar retrofit campaign. The Federal Railroad Administration simultaneously undertook a safety research program in cooperation with New Jersey Transit, the vehicle builder, and the bearing suppliers. The A-III retrofit was completed in 1985, and after additional bearing seizures occurred in the S-IV fleet, the Southeastern Pennsylvania Transit Authority decided to switch from tubular to solid axles in the course of their scheduled overhaul program.

The immediate objective of the early FRA/TSC bearing safety research program was to establish the rates of journal grooving and bearing temperature increase. The task force had judged that groove depth and bearing temperature would increase steadily as a wheelset approached the point of bearing seizure. Hence, it should be possible to use the failure progression rates to define a minimum safe frequency for inspection to detect overheated wheelsets. Rational establishment of a safe inspection frequency was critically important because practical considerations permitted neither significant operating speed restriction nor inspection more frequent than the minimum essential to protect the A-III fleet.

During the investigation of the performance of commuter roller bearings the FRA and TSC became aware of incidents of axle grooving on freight cars. A test program, coordinated with the Association of American Railroads was developed to determine the effect of fit and clamp on the integrity of roller bearing installations in freight service.

Degraded bearings for the test were obtained by the AAR from a number of cooperative railroads. The test bearings were selected to determine the effect of fit and clamp force on the integrity of bearing installations.

Two test bearings included in the test had grooves caused by the inner race slipping. By monitoring the thermal performance of these and the other test bearings, the heating and cooling rates associated with a roller bearing failure could be determined. These results could be used to plan wayside hot box detector usage and provide better guidelines for the detection of overheated bearings by train crews.

2.0 TEST CONFIGURATION AND INSTRUMENTATION

2.1 Test Consist and Test Bearings

The consist for this test included a locomotive, test data acquisition car T-5, and four loaded 100-ton hopper cars (see Figure 2-1). A total of 24 bearings were evaluated. Each bearing was selected from actual service samples, based on its interference fit. The bearings were disassembled, inspected, and installed on test axles to achieve the combinations of fit and clamp indicated in the test matrix (see Figure 2-1).

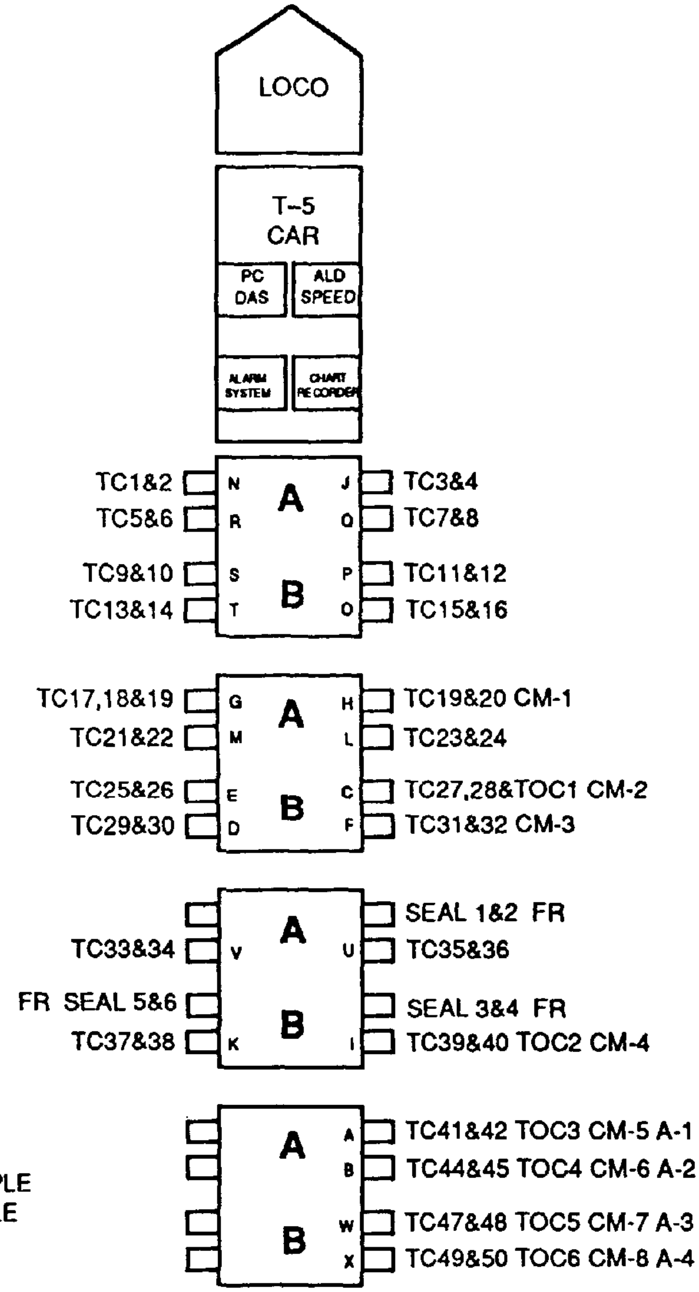
Two bearings, noted W and X, were installed with one separator bar cut from each cage. The loose bar was placed loosely inside the bearing in an attempt to simulate the effect of a broken roller separator.

2.2 Bearing Temperature Measurements

Two thermocouples were installed on each test bearing (see Figure 2-2). The thermocouples were installed over the inboard and outboard races.

A redundant alarm system was used to monitor each bearing which would alert the test crew any time a bearing overheated beyond a preselected temperature threshold. This threshold was set to 250° F.

A single thermocouple, bonded to the underside of car 2, was used to monitor ambient temperature. The thermal safety alarms for a given bearing were set at a fixed threshold based solely on the temperature above ambient. For the data analysis in this report, all bearing temperature data are presented as the temperature



CM = CONE MOTION SENSOR
TC = THERMOCOUPLE SENSOR
A = ACCELERATION SENSOR
TOC = TOP OF CUP THERMOCOUPLE
SEAL = SEAL CASE THERMOCOUPLE
FR = FLUID RING SEALS

CLAMP	INTERFERENCE FIT					
	GROOVED	ZERO	0.00075	0.0015	0.002	0.0045
ZONE			G,H	L,M		U,V
AS FOUND	A,B					
10-TON		C,D	I,J	N		
SPEC		E,F	K	P,Q		
SPEC				R,S	O,T	

NOTE: BEARINGS W&X HAVE CUT CAGES

FIGURE 2-1. TEST CONFIGURATION AND INSTRUMENTATION

BEARING THERMOCOUPLE LOCATION

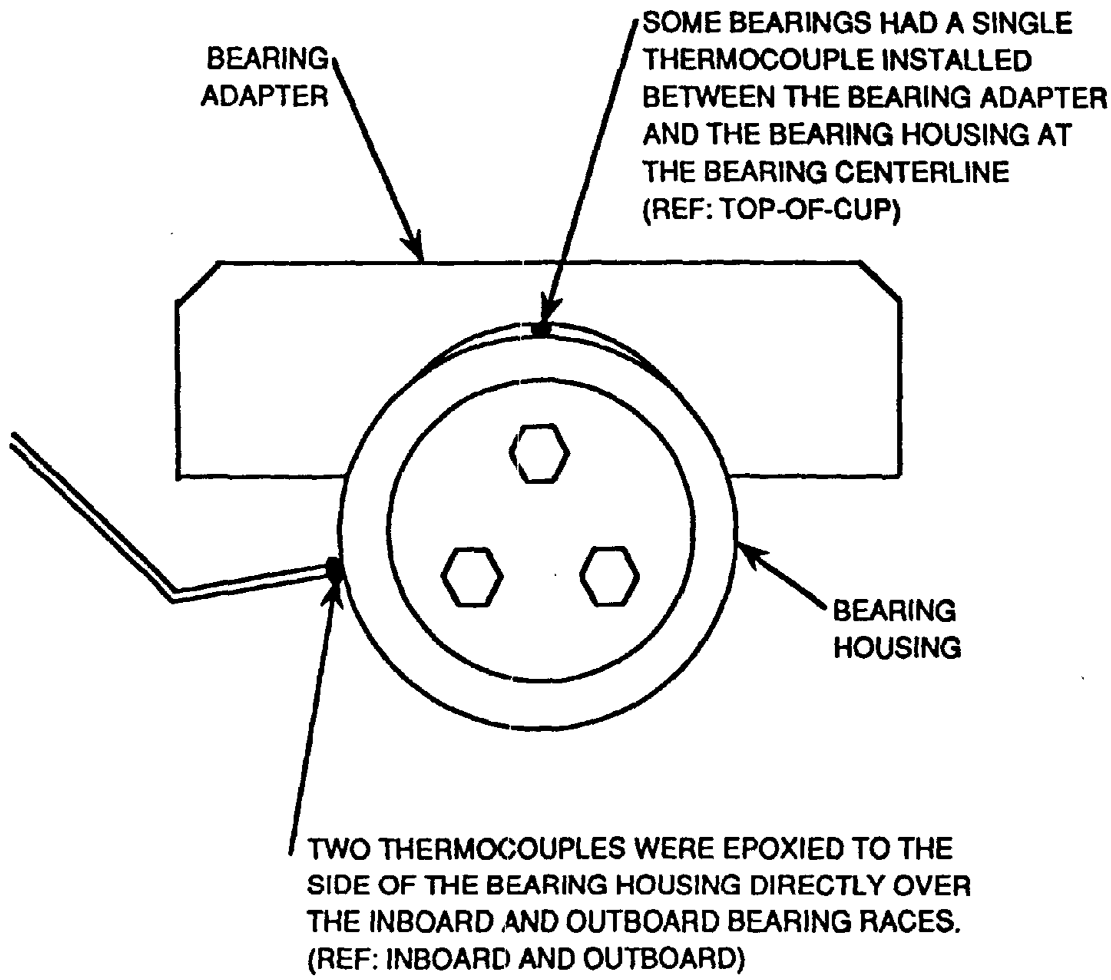


FIGURE 2-2. BEARING THERMOCOUPLE LOCATION

above ambient. This was accomplished by subtracting the measured ambient temperature from the measured bearing temperature for each channel of data.

2.3 Cone Motion Measurement

In order to determine if the inner races of the test bearings had begun to slip on the axle, a special cone motion measurement system was installed on the inner races of eight bearings which were considered most likely to fail.

A diagram of the measurement concept (as applied to an inboard bearing) is shown in Figure 2-3. Magnets were installed on the axle (reference magnet) and on the inner race of the bearing. Hall effect sensors, mounted in a nonrotating reference, detected the precise passage of two magnets as the axle rotates.

An encoder circuit driven by the axle produced a constant 500 pulses per axle revolution. A counter was used to total the number of pulses received from the encoder between the time the race-mounted magnet and the reference magnet are detected by their respective hall effect sensors. The number of encoder pulses detected between these two events should be constant unless the inner race is slipping on the axle.

For the purposes of this test, an encoder was mounted on the data collection car, T-5, which provided the reference pulses for all of the test axles. As long as all of the test cars were moving at the same speed and their wheels were not slipping, this provided good information regarding the angular displacement of each test axle. In the event of severe run-in/run-out or wheel slip, the data would be briefly invalid, since the speed of all of the test axles is not identical to the T-5 encoder axle. However, this is a momentary effect and the angular position of the inner races on each individual axle is disturbed only for a very short time (a few axle revolutions).

If a bearing race was gradually slipping relative to the axle, as some did, the number of encoder pulses encountered between the inner race magnet and reference magnet gradually grew. When the race slipped to the point where there were 500 pulses between magnets, indicating a full axle revolution, the output would be reset to zero and would start over again.

CONE MEASUREMENT CONCEPT

(SHOWN HERE ON AN INBOARD BEARING)

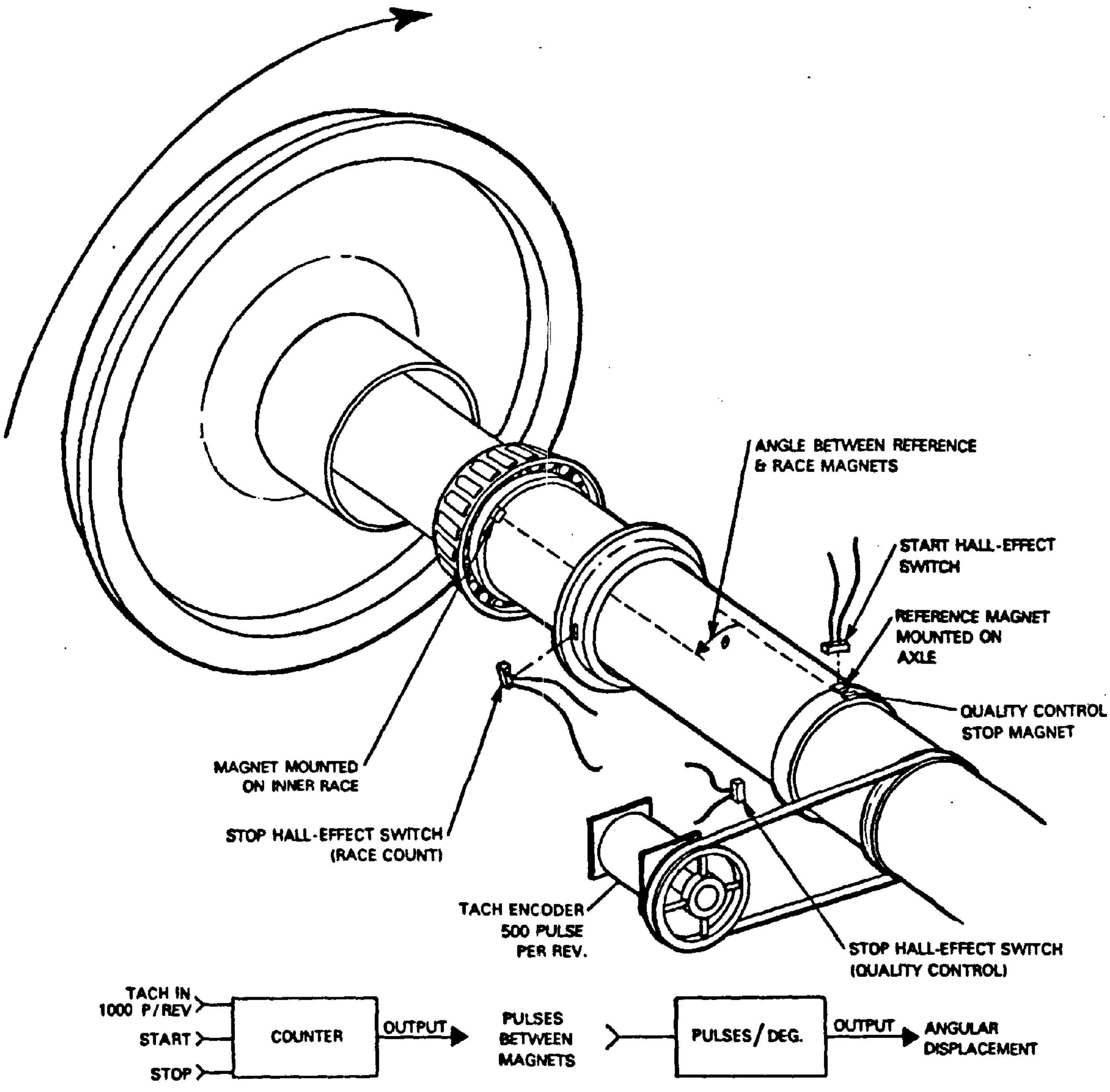


FIGURE 2-3. CONE MEASUREMENT CONCEPT

The data from a constantly slipping race would therefore be a "saw tooth" pattern, ramping up from 0 to 500 pulses and then resetting to 0. (Examples of this continuous slipping behavior are shown in Section 4.2 - Cone Motion Performance.)

3.0 TEST SCHEDULE AND TEST EVENTS SUMMARY

Test instrumentation was installed, calibrated, and checked out at the Transportation Test Center during January and February 1989. Actual testing was conducted between March 7 and April 7, 1989. Table 3-1 provides a summary of daily and major test events. Appendix A contains the detailed test log.

TABLE 3-1. TEST SCHEDULE AND TEST EVENT SUMMARY

Date	Miles Tested	Cumulative Miles	Max. Speed	Dir	Significant Events/Comments
3/7/89	40.5	40.5	40 mph	CW	Start test.
3/8/89	27.0	67.5	30	CW	- WABL committee visit. - Grooved bearings slipping and not overheating. - Some slippage on zero and light fit bearings. - Cut cage OK. - Failure of "special" seal observed. - 30 MPH max. speed.
3/9/89	NO TEST	67.5			Thermocouples bonded directly to bearing cup for improved response.
3/10/89	108	175.5	60	CCW	- Observed difference between temperatures at inboard and outboard cups of the same bearing. - Bearing 42R inner reached 245° F, 41R outer reached 240° at 60 mph. - Wayside detectors alarm on hot inner cup only. - Loud "squealing" reported from bearing 42R. - Thermal "runaway" occurs repeatedly on bearing 42R each time 60 mph is reached.
3/11/89 - 3/12/89					NO TEST

TABLE 3-1. TEST SCHEDULE AND TEST EVENT SUMMARY (CONT'D)

Date	Miles Tested	Cumulative Miles	Max. Speed	Dir	Significant Events/Comments
3/13/89	108.0	283.5	40	CCW	- Bearing 41R reaches 250° F at 30 mph, then reaches 260° F upon slowing to 20 mph. - Bearing 42R inboard cup hits 270° F at the top of cup (56° F ambient) after running 45 at 35 mph.
3/14/89	6.0	289.5		REV CCW	Move into shop. - Instrumentation checkout. - Thermocouple on bearing 41R outer found to read 12° F higher than actual due to offset.
3/15/89	122.5	412	50 mph	CCW	- Bearing 42R overheats at 50 mph; reaches 270° F after slowing to 30 mph. - Bearing 42R overheats to 486° F maximum at 40 mph. - Wheelsets 41 and 42 removed to allow higher test speeds.
3/16/89 - 3/19/89		NO TEST			
3/20/89	220.0	632.0	60 mph	CW	Cone motion noted for bearing 23-I at 189 counts (512 = 1 rev) and bearing 24-O at 324. Both started day near zero.
3/21/89	121.5	753.5	70 mph	CCW	Wayside alarm with no evidence of overheating on board.
3/22/89	148.5	902.0	70 mph	CW	- Generator failures delay testing. - Test cars weighed.

TABLE 3-1. TEST SCHEDULE AND TEST EVENT SUMMARY (CONT'D)

Date	Miles Tested	Cumulative Miles	Max. Speed	Dir	Significant Events/Comments
3/23/89	334.5	1,236.5	70 mph	CW	- Wayside alarm with no evidence of overheating. Problem found in wayside setup. - Cone motion 44RI reset. - Bearing cup vs. adapter slip observed from 0.7 to 4.7 inches on test bearings.
3/24/89	259.5	1,496.0	70 mph	CS	- No overheating. - Two onboard thermocouples fail and alarm. These are required.
3/25/89 to 3/27/89		NO TESTING			- Repair intermittent onboard thermocouples.
3/28/89	432.0	1,928.0	70 mph	CCW	Wayside alarm; no overheating apparent.
3/29/89	405.0	2,333.0	70 mph	CW	Wayside alarm; no overheating apparent.
3/30/89	310.5	2,643.5	70 mph	CW	- No alarms. - Cup indexing on bearing 21R, damages cone motion sensor.
3/31/89	270.0	2,913.5	70 mph	CW	- Wayside alarm, no overheating apparent. - Cone motion CM43I and CM21 are not functioning.
4/3/89	364.6	3,278.0	70 mph	CCW	- Cone motion CM21 repaired. - Lost ambient thermocouple.

TABLE 3-1. TEST SCHEDULE AND TEST EVENT SUMMARY (CONT'D)

Date	Miles Tested	Cumulative Miles	Max. Speed	Dir	Significant Events/Comments
4/4/89	434.0	3,739.0[1]	70 mph	CW	- Wayside false alarms traced to test car exhaust pipe. - Cone motion instrumentation problems.
4/5/89	445.5	4,184.5	70 mph	CCW	Repair cone motion, thermocouples, and acceleration.
4/6/89	405.0	4,598.5	70 mph	CW	
4/7/89	426.5[2]	5,016.0	70 mph	CW	Clockwise selected; appears to produce greater cone motion on right-side test bearings.

[1]Includes 27 miles run but overlooked in prior totals.
[2]Includes 21.5 miles switching.

4.0 <u>TEST RESULTS</u>

4.1 THERMAL PERFORMANCE

Plots of the bear ing temperature data from the test are contained in Appendix D. Appendix D is in a separate volume, available on request. All plots are displayed as temperatures above ambient in °F vs. sample number. **Sample number indicates cumulative test time at a sample rate of one sample every five seconds.**

Appendix D begins with an index and explanation that identifies the plots available and describes how to interpret the data contained in each temperature plot. The naming convention for all bearing-temperature plots indicates car number, axle number, left or right side, and inboard/outboard race or top of cup.

Examples:
11LO means car 1, axle 1, left outside.
41RTC means car 4, axle 1, right top of cup.

Examples of bearing thermal performance data for selected bearings have been compiled in the following sections as examples of normal, left side/right side differentials, inboard/outboard cup differential, curve vs. tangent bearing heating, top of cup vs. side of cup temperatures and thermal runaway (bearing failure).

On March 7th and 8th the bearing temperature probes were not in good contact with the bearings resulting in low readings. At the start of some test days the ambient temperature thermocouple warmed up with air temperature increases faster than the bearing mounted thermocouples which had greater thermal mass.

4.1.1 <u>Normal</u>

4.1.1.1 Normal Operating Temperature Ranges

The operating temperatures for each of the bearings for the entire 5,000-mile test are plotted together in Figure 4-1. The cyclic pattern evident in the data is typical of heating and cooling of the bearing at the beginning and end of the test day. The range of operating temperatures for the entire test for all "normally" operating bearings (normal meaning no thermal runaway) ranged between 65°F and 140°F (18° C and 60° C) above ambient at 70 mph with a full 100-ton load.

BEARING OPERATING TEMPERATURE ABOVE AMBIENT

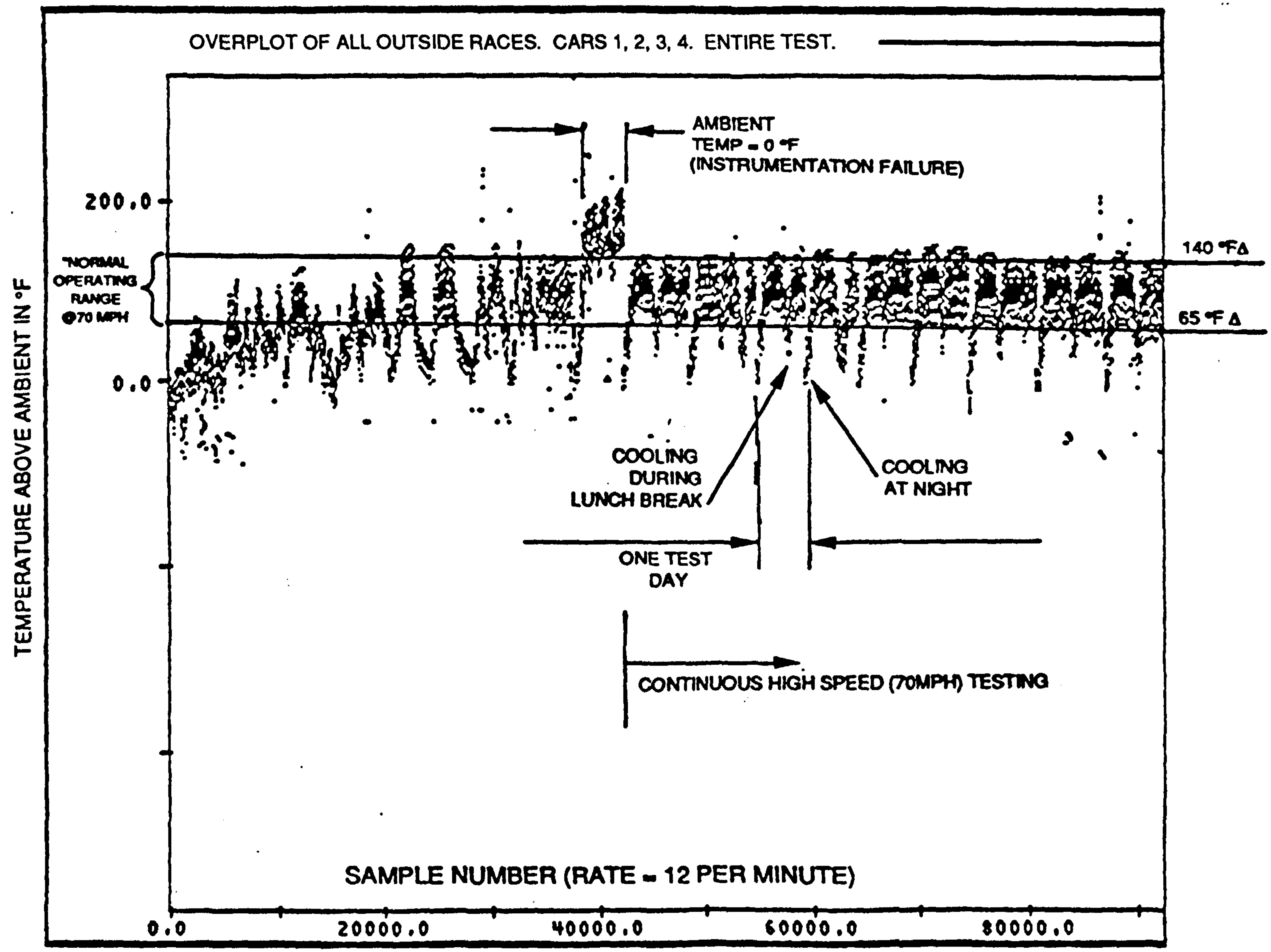


FIGURE 4-1

This is consistent with similar test data obtained for heavy self-propelled commuter cars (Jersey Arrow III coaches) during tests conducted in 1984. Results of these tests indicated typical normal bearing running temperatures of 50° F to 122° F (10° C to 50°C) above ambient for loaded operation at speeds of 100 mph.

4.1.1.2 Evaluation of Differences in Bearing Temperatures on the Same Axle, Right vs. Left

Plots of the difference in temperature between right and left side outboard races are shown in Figures 4-2 and Figure 4-3 for car 1, axles 1 and 2, respectively. The daily cyclic pattern evident in these plots is caused by the difference between temperatures for the bearing on the outside of the RTT loop (high rail) and the bearing on the inside of the RTT loop (low rail).

The mean of the cyclic pattern is indicative of the nominal difference between the left-side and right-side bearings under normal conditions.

During testing from March 28th on, test speeds ran at nearly 70 mph continuously. For these days the results for both of these axles indicate a marked difference of 15° to 20° F between high rail and low rail running (half-peak to peak of cycle). The "average" temperature difference for car 1, axle 2 appears to be just below zero (around -4° or -5° F), indicating the left side bearing is running nominally 4° or 5° F warmer than the right.

The corresponding average for car 1, axle 1 appears to be nearer to -8° to -10° F, indicating the left side bearing to be running warmer than the right side by 8 to 10° F.

4.1.1.3 Inboard vs. Outboard Race Temperatures for the Same Bearing

During the test it was observed that on some occasions when onboard bearing alarms sounded due to heating just over the alarm threshold, the wayside detectors did not alarm. Further investigation showed that significant temperature differences could exist between the inboard and outboard bearing cups on a single bearing.

The results show that the outboard race of this bearing ran about 30° F warmer than the inboard race at 70 mph. This result was observed on other bearings, though not on all, indicating that significant thermal gradients can exist across one bearing.

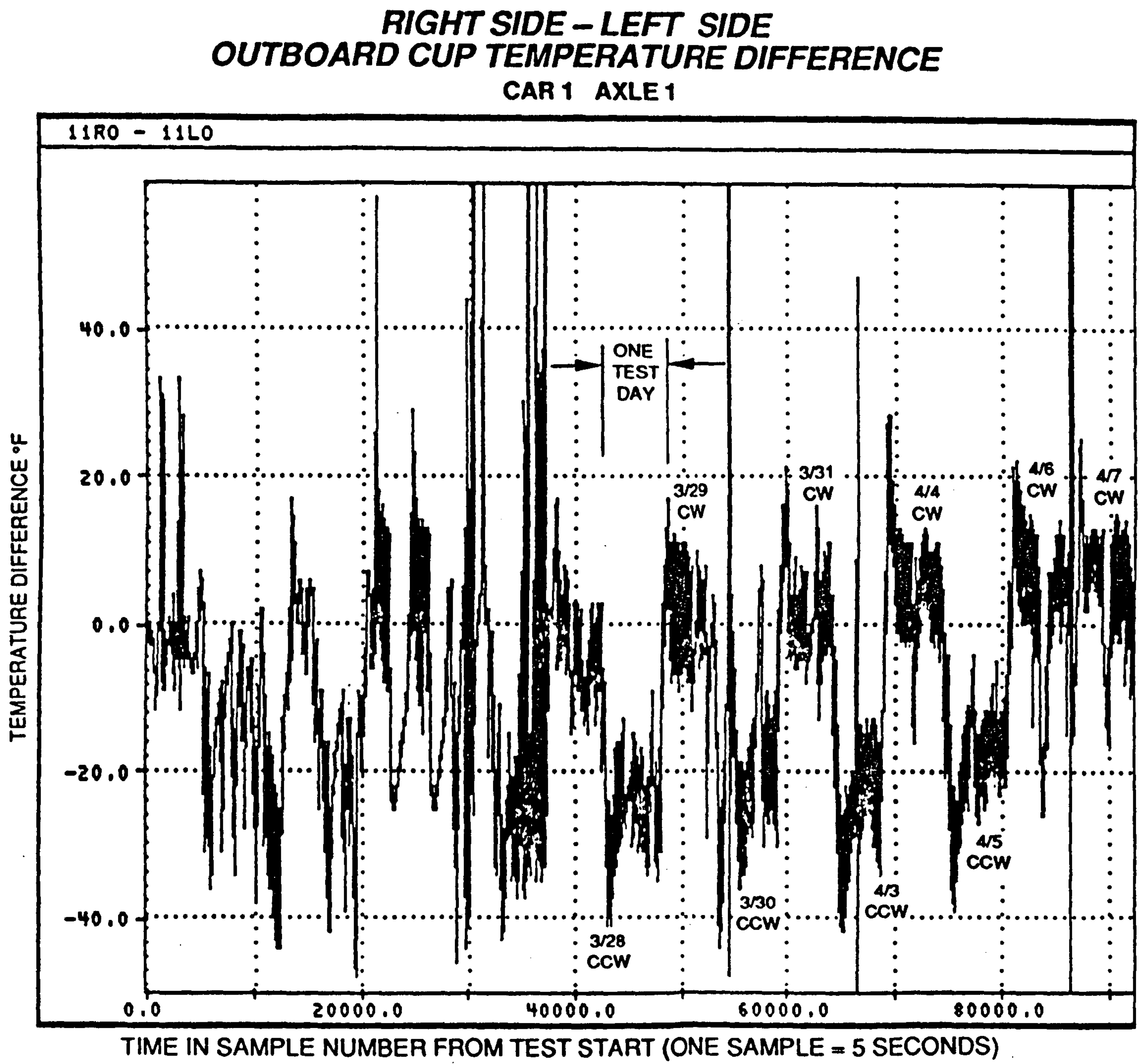

RIGHT SIDE – LEFT SIDE
OUTBOARD CUP TEMPERATURE DIFFERENCE
CAR 1 AXLE 1
11RO - 11LO
TEMPERATURE DIFFERENCE °F
40.0
20.0
0.0
-20.0
-40.0
ONE TEST DAY
3/28 CCW
3/29 CW
3/30 CCW
3/31 CW
4/3 CCW
4/4 CW
4/5 CCW
4/6 CW
4/7 CW
0.0
20000.0
40000.0
60000.0
80000.0
TIME IN SAMPLE NUMBER FROM TEST START (ONE SAMPLE = 5 SECONDS)

FIGURE 4-2

RIGHT SIDE – LEFT SIDE OUTSIDE CUP TEMPERATURE DIFFERENCE

CAR 1 AXLE 2

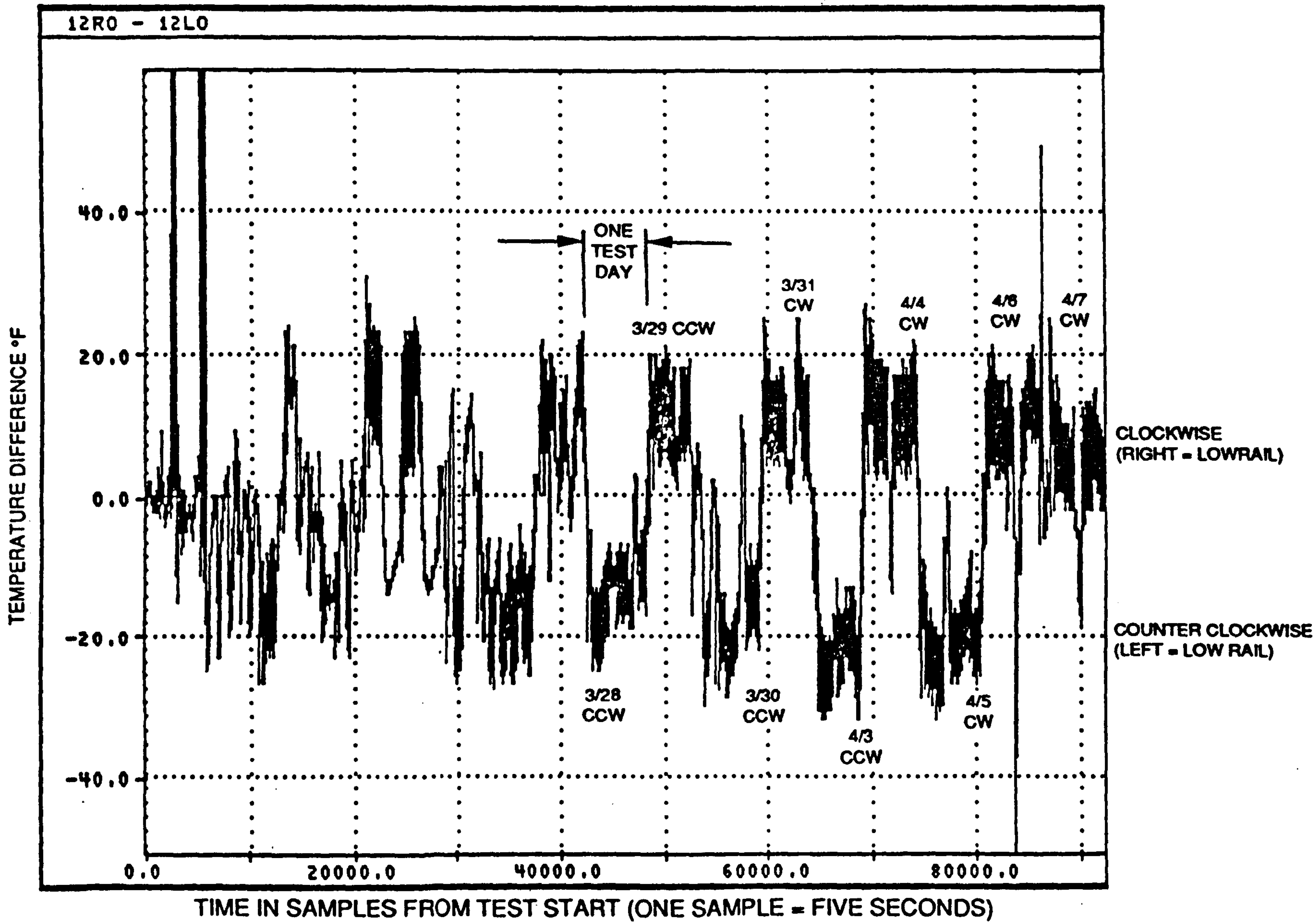


FIGURE 4-3

Figure 4-4 shows the temperatures above ambient for the inboard and outboard races on bearing 32R (car 3, axle 2, right side) for testing on 4/7/89.

4.1.1.4 Effect of Curve vs. Tangent

The variation in bearing temperature during one lap can be seen in Figure 4-5. This is the effect of curving. During curve negotiation, the inner and outer race of the bearing on car 2, axle 2, left side can be seen to heat up by as much as 10° F during one lap.

4.1.1.5 Top of Cup Temperatures

Temperatures were measured on the top of the bearing (between the bearing adapter and the bearing housing) on six bearings. Some difficulty was encountered in electrically isolating the thermocouples installed between the bearing adapter and the bearing housing. As a result, some of the top of cup temperature data is considered unreliable.

From the data that is available, the top of cup temperatures ran about 10° F warmer than the side of cup temperatures during normal operations, (See example Figure 4-6) showing the temperature difference between the top of cup and side of cup for normal conditions on car 2, axle 3, right side. Thermal plots are presented for the entire test, one day and one lap. Speed and location reference (ALD) data are also presented for the single lap in the figure. This data is significant because wayside overheated bearing detectors must measure temperature at points along the bottom and side of the bearing housing whereas the heat in a overheating bearing is primarily generated in the load zone at the top of the cup. Figure 4-11 (page 27) shows both top of cup and side of cup temperatures in an overheating condition, where the temperature difference is approximately 120° F.

4.1.2 Seal Temperatures - Experimental low friction

Experimental low friction seals were installed on three bearings. Seal temperature was recorded on each of these. Sample data plots of temperature above ambient for one seal on each of the bearings are shown in Figures 4-7, 4-8 and 4-9. These seals ran nominally 50° F to 70° F above ambient at 70 mph. While no seal temperature data are available from other bearings in the consist, this is significantly lower than the average 100° F to 110° F above ambient measured on the bearing housings of the other test bearings.

COMPARISON OF OPERATING TEMPERATURE ABOVE AMBIENT FOR THE INBOARD AND OUTBOARD RACES OF BEARING 32R — TEST DAY 4/7

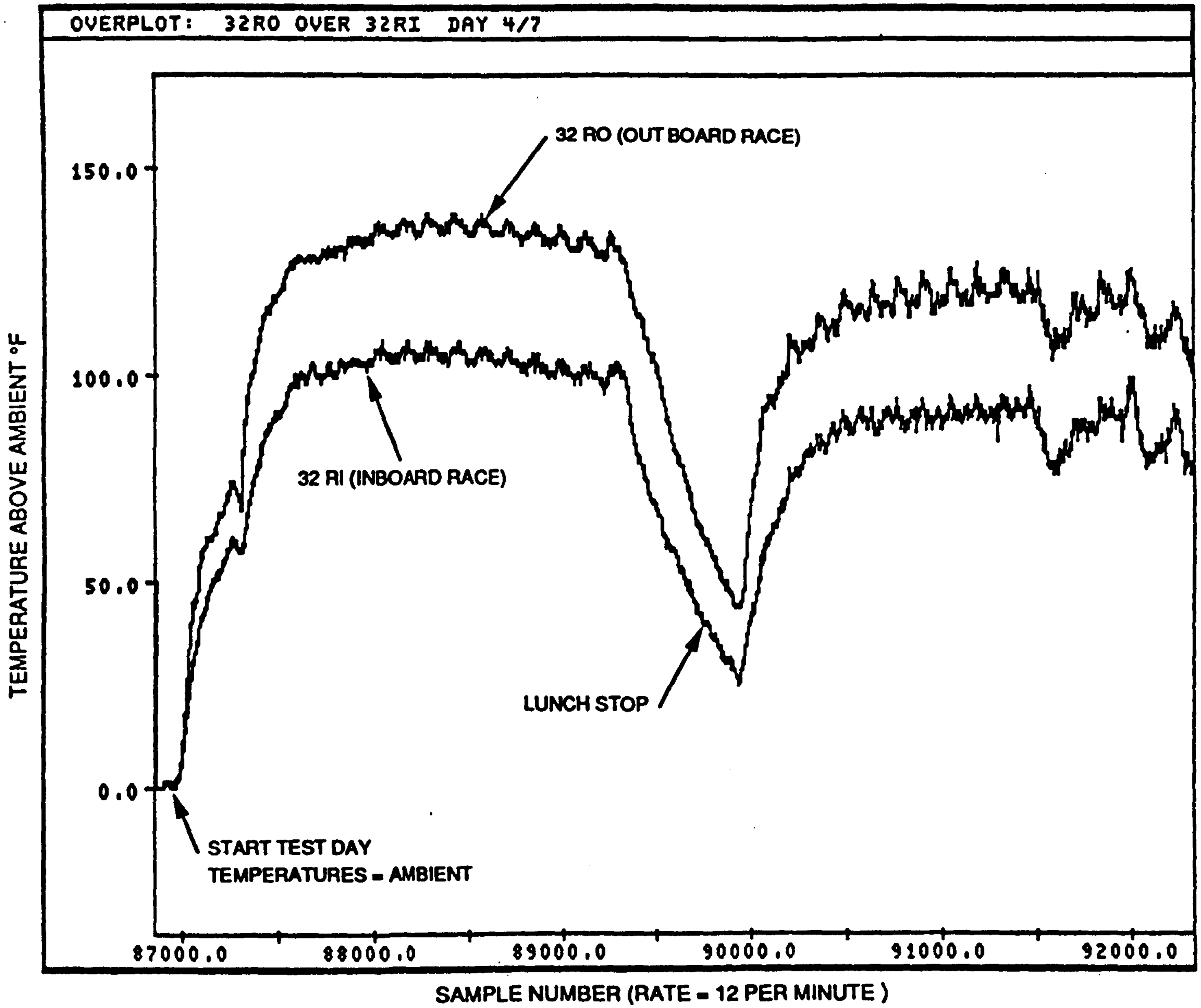


FIGURE 4-4

TEMPERATURE VARIATION WITHIN ONE LAP OF RTT LOOP AT CONSTANT SPEED

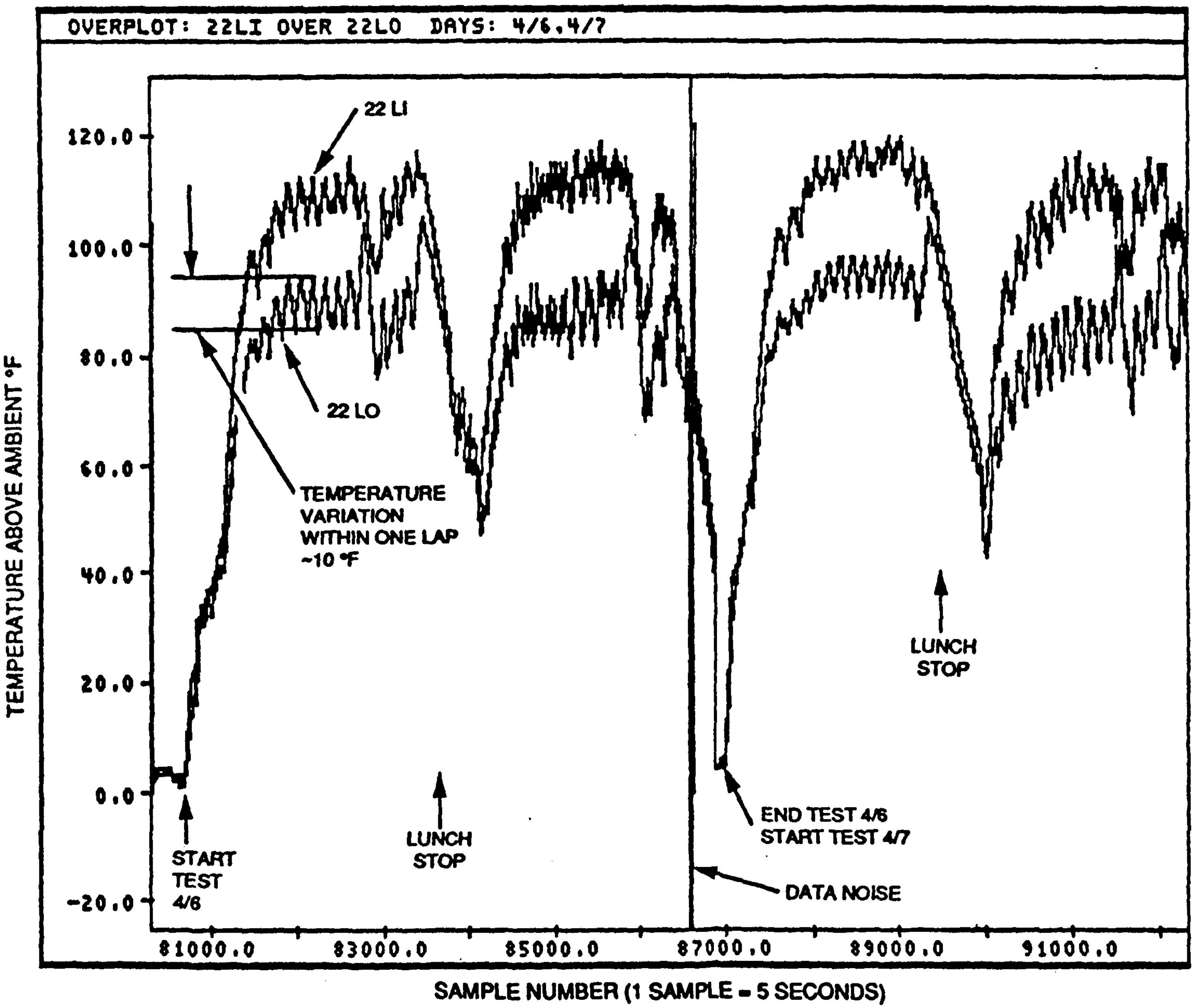


FIGURE 4-5

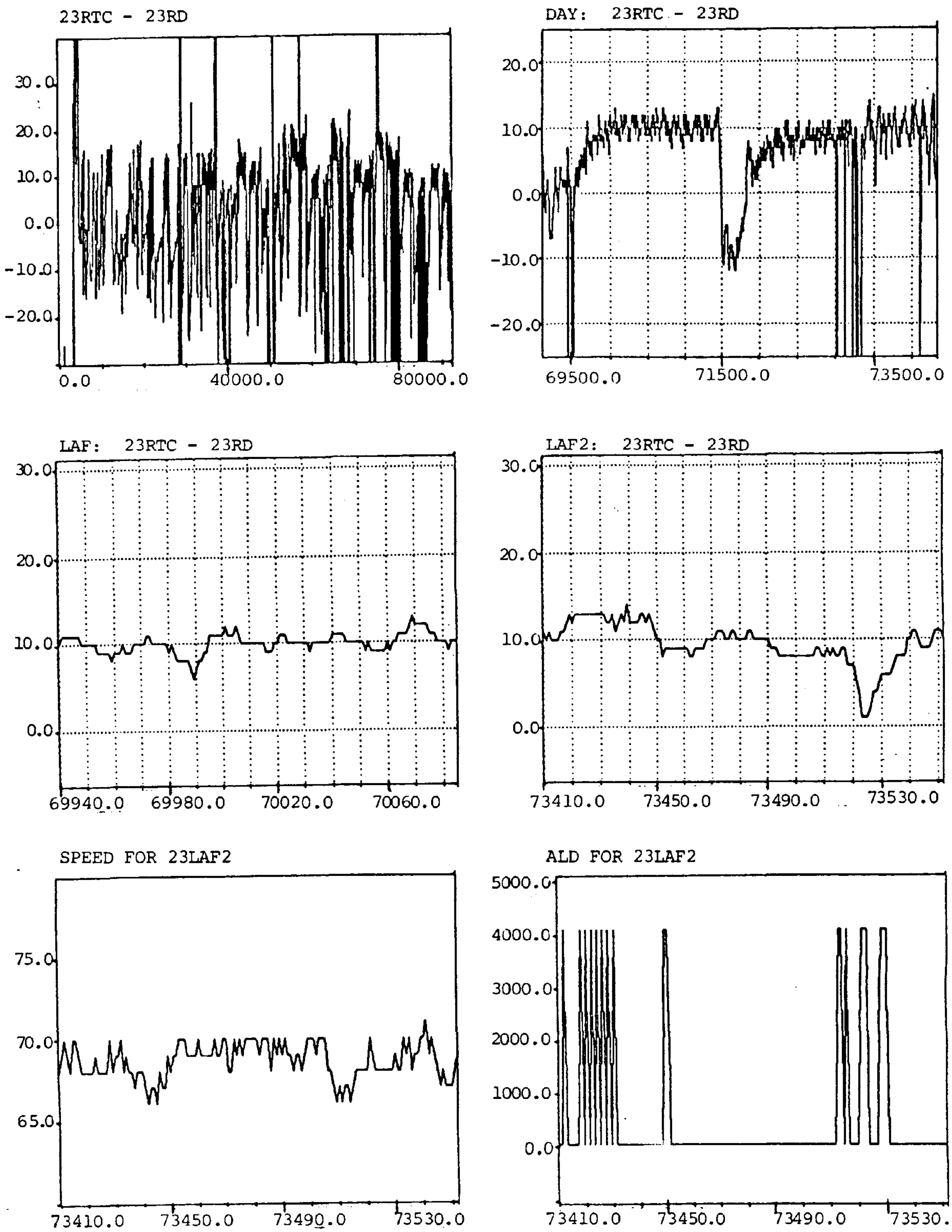
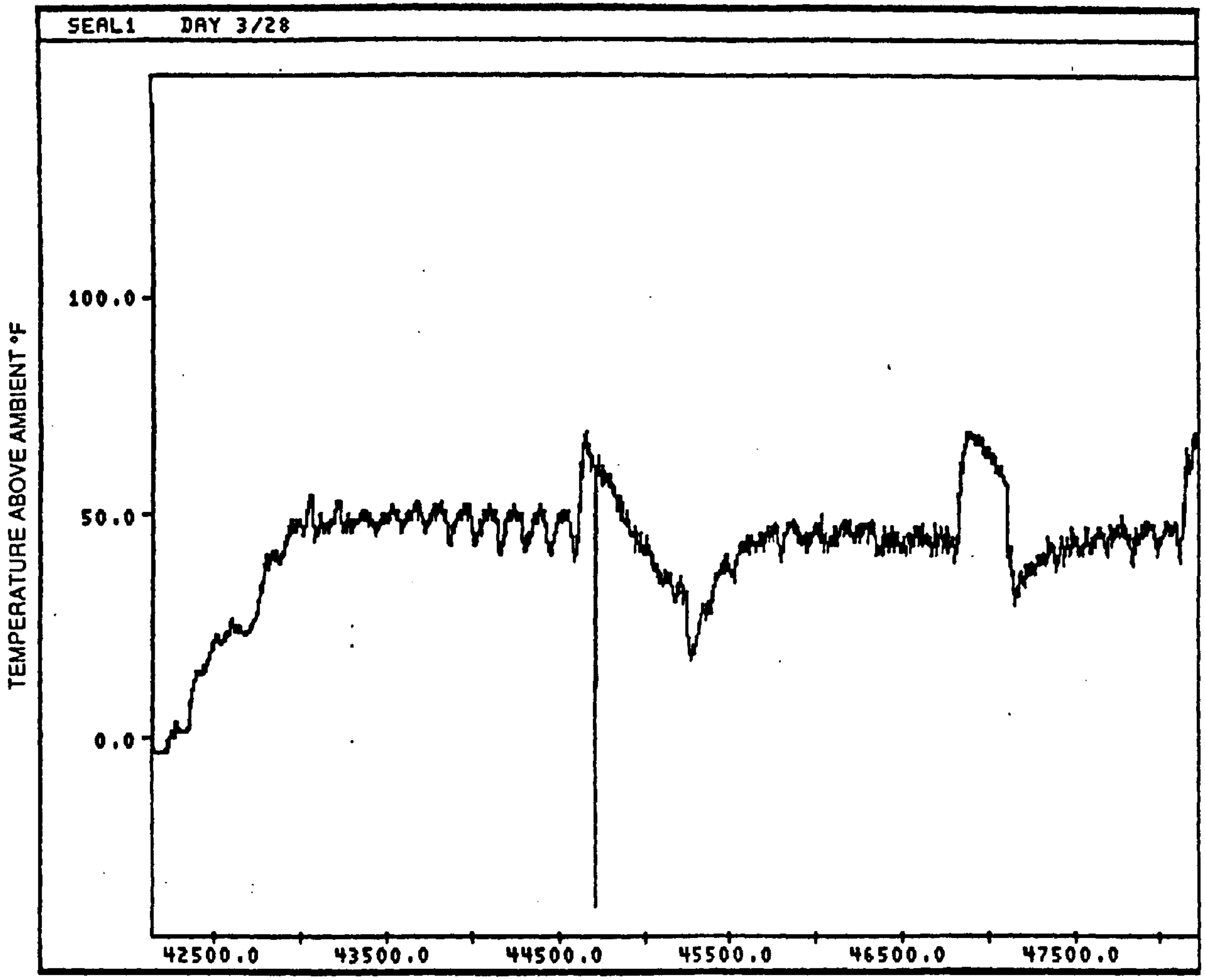


FIGURE 4-6. OUTBOARD VS. TOP OF CUP BEARING TEMPERATURE

TEMPERATURE ABOVE AMBIENT
EXPERIMENTAL SEAL NUMBER 1



SAMPLE NUMBER (1 SAMPLE = 5 SECONDS)

FIGURE 4-7

TEMPER TURE ABOVE AMBIENT (°F) EXPERIMENTAL SEAL NUMBER 3

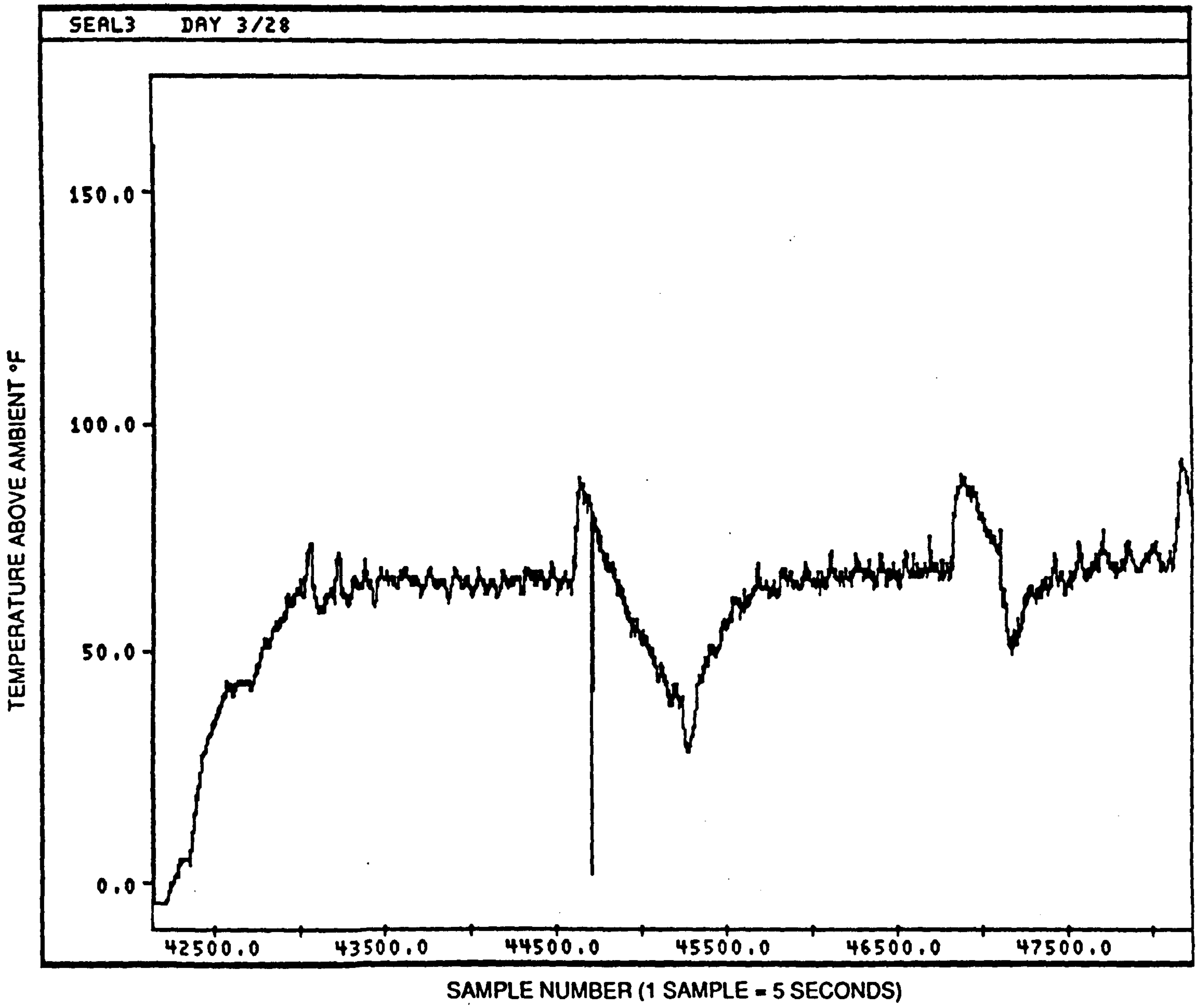


FIGURE 4-8

TEMPERATURE ABOVE AMBIENT (°F)
EXPERIMENTAL SEAL NUMBER 5

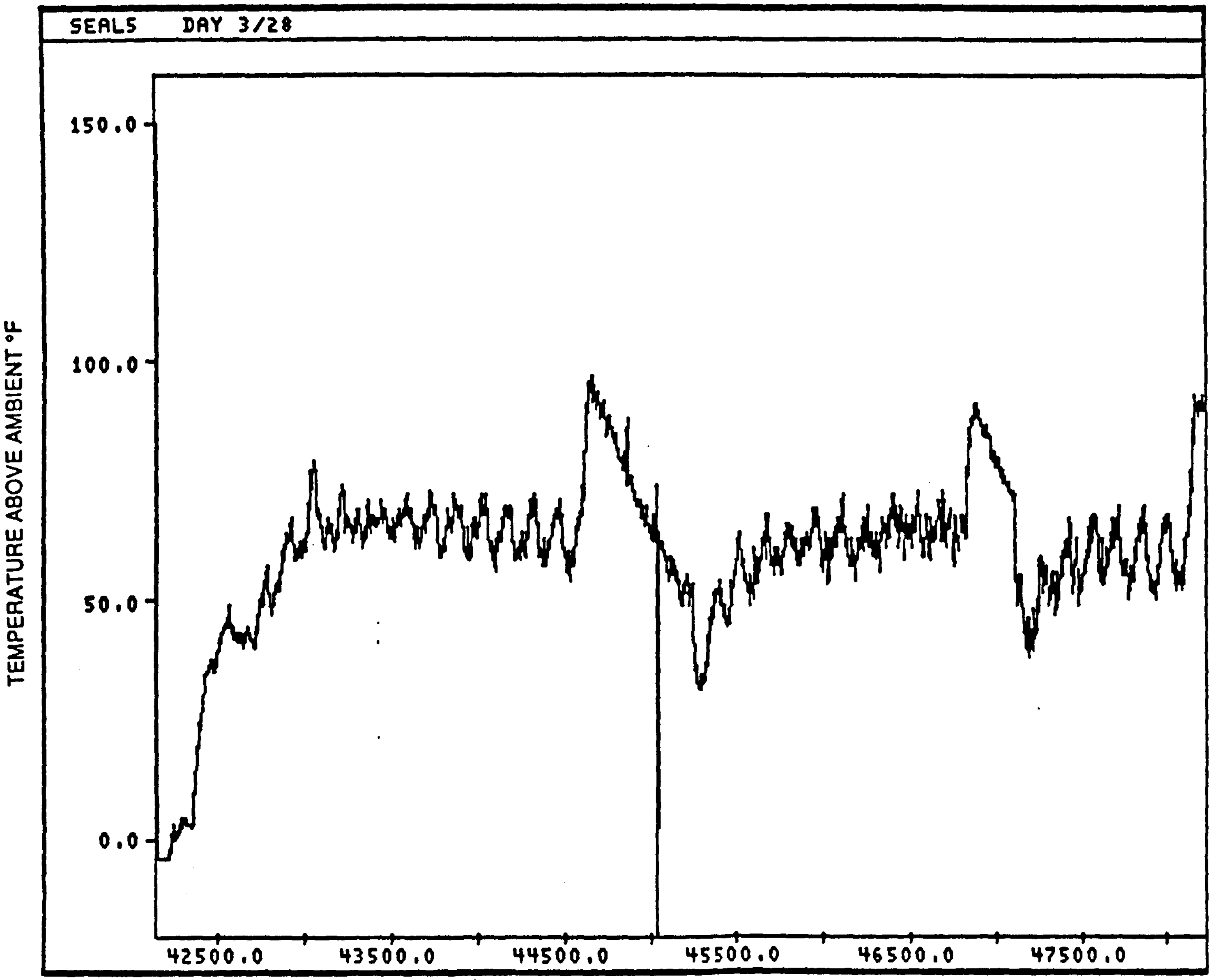


FIGURE 4-9

The primary questions to be addressed by running these bearings in the test were: how would wayside measurement systems measure their temperature and how would the data compare with normal bearings due to the reduction of seal friction. Wayside temperature data is not addressed in this report.

4.1.3. Bearings Approaching Failure

Two test bearings, one on car 4, axle 1 and one on car 4, axle 2, went into thermal failure during the test. Both of these bearings had grooved axles, due to race slipping, when they were selected for testing. At the beginning of the test the inner race on both bearings was observed to be slipping, but not overheating.

During the first and second days of testing, speeds were limited to 40 mph and 30 mph respectively. Runs both days were conducted in the clockwise direction.

On March 9th testing was delayed while the thermocouples were bonded to the bearings for better thermal conductivity.

On March 10th testing resumed in a counterclockwise direction, reaching a maximum speed of 60 mph. Based on real time observations during the test, overheating occurred for the first time when the inner race on bearing 42R (car 4, axle 2, right side) reached 245°F. The outer race on bearing 41R reached 240°F. Appendix B contains a complete set of reference plots for these bearings.

4.1.4 Performance and Failure of Bearing 42R

Plots of the temperature above ambient for bearing 42R are shown over the entire test in Figures 4-10 and 4-11 for the top of cup and outboard race respectively. On March 7th the consist ran for approximately forty minutes at 30 mph followed by 10 minutes of 40 mph running. The top of cup temperature reached just over 100°F above ambient on two successive laps. A total of 40 miles of testing was run.

On March 8th, 27 miles of testing was conducted. During this limited testing the bearing temperature on the top of the cup reached a maximum of about 60°- 65° above ambient.

On March 10th testing resumed after bonding the thermocouples to the bearing housings. A total of 175.5 miles of testing was conducted with speeds up to 60 mph.

TEMPERATURE ABOVE AMBIENT (°F)
CAR 4 AXLE 2 RIGHT OUTBOARD RACE (SIDE OF BEARING)

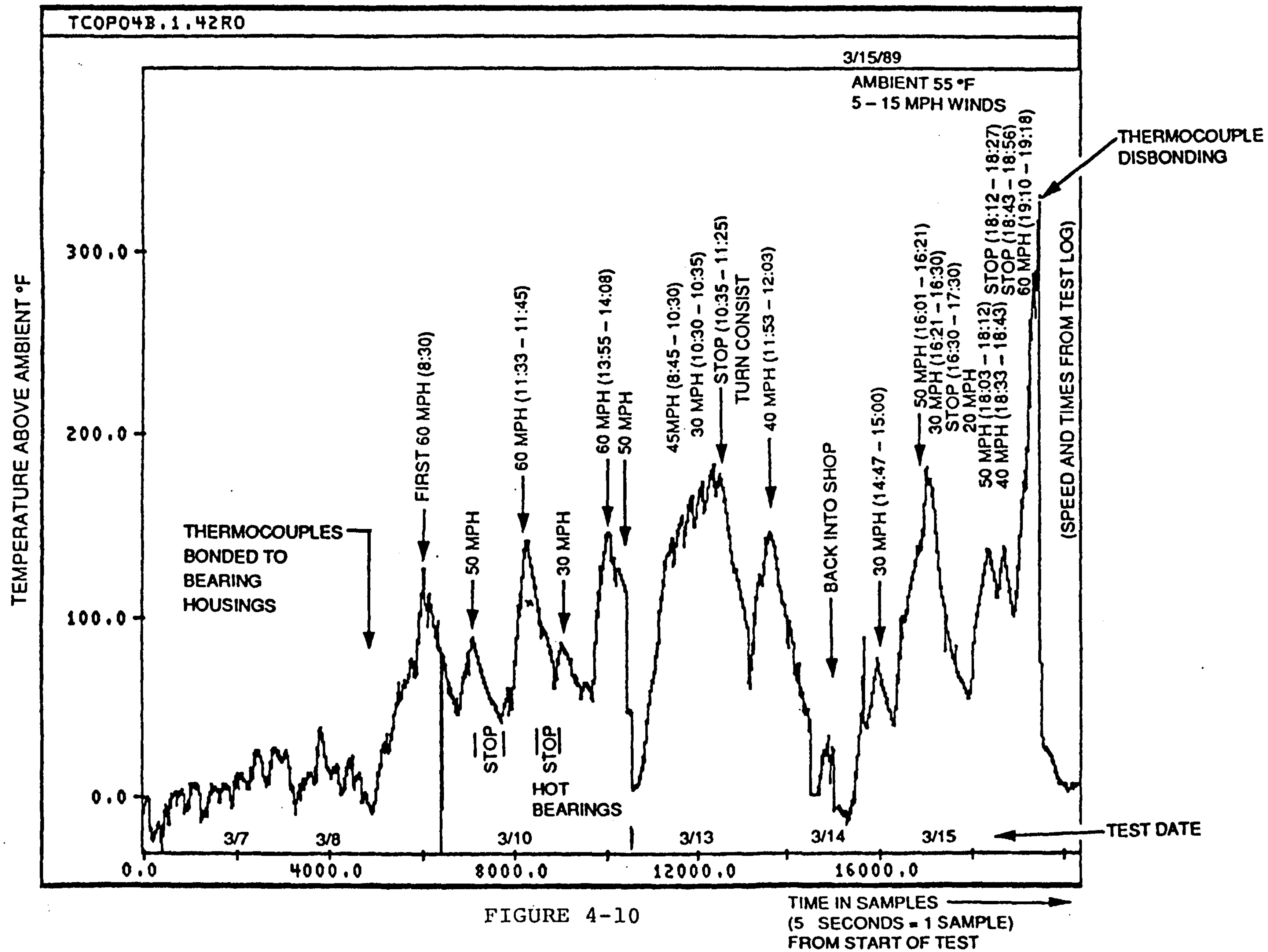


FIGURE 4-10

OVER PLOT OF TOP OF CUP AND SIDE OF CUP DURING OVERHEATING

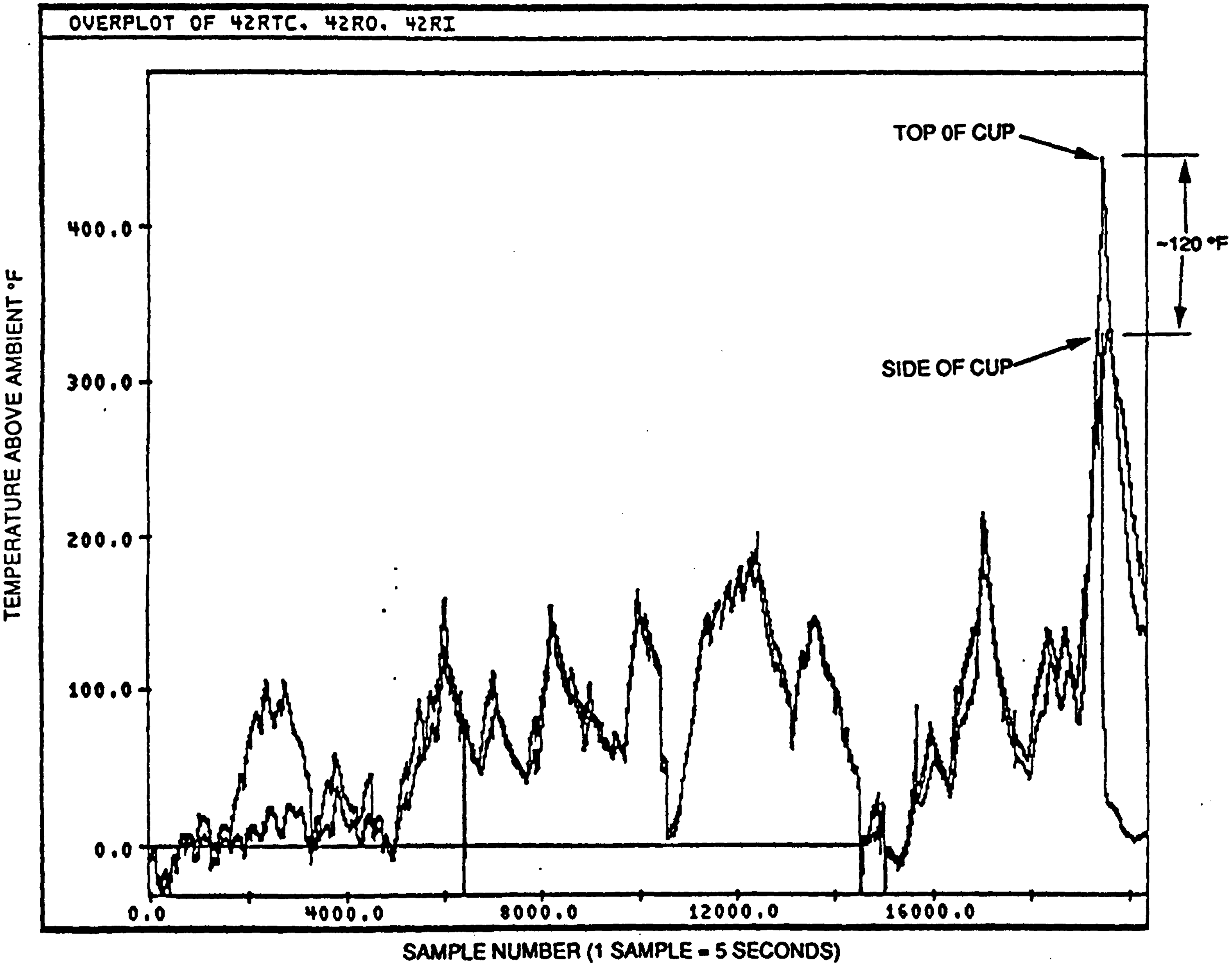


FIGURE 4-11

Figure 4-10 shows the temperature above ambient for the outboard thermocouple on bearing 42R. During operations on March 10th the bearing temperature rose quickly to around 130° over ambient each time 60 mph was attained, cooling rapidly upon stopping. On each subsequent period of 60 mph running the peak temperature above ambient increased slightly.

On March 13th the bearing 42R heated rapidly to around 130° F above ambient at 45 mph operations and continued to heat up when slowed to 30 mph. During this general warming trend, brief periods of warming during curve negotiation and cooling during tangent running were observed.

On March 14th no testing was performed; however, data were collected during a move into the shop.

On March 15th the bearing temperature rose sharply to around 180° F above ambient at the outboard race on the side of the bearing during 50 mph operation.

The bearing cooled rapidly during several stops and heated just as rapidly when testing resumed. When the test ended the bearing temperature measured 370° and 371° F on the inboard and outboard races of bearing 42R respectively. The top of the cup measured 486° F or 116° F hotter than the side of the cup at its peak.

4.1.5 Maximum Bearing Heating and Cooling Rates

One of the primary objectives of this test was to learn how quickly bearings overheat and how quickly they cool off. The heating rate has implications concerning the probability of detection by wayside detectors. The cooling rate defines just how long a train crew has to find an overheating bearing once detected by the wayside detector.

The maximum heating rate observed prior to removing the bearing from service was 12.8° F per minute. The maximum cooling rate was 7.2° F per minute.

At the above heating rate at 60 mph the bearing temperature could be expected to rise 256° F in 20 miles. At the above cooling rate with a 250° F alarm threshold a train crew would have about 7 minutes between the time a hot bearing was detected (250° F) and the bearing had cooled below 200° F, the temperature at which a melt-stick will indicate a hot bearing.

4.1.5.1 Bearing 42R

Maximum bearing overheating and cooling rates observed during the test occurred on March 15th. During testing at 50 mph and later at 60 mph on that day, two overheating events occurred for bearing 42R. The top of cup, inboard race and outboard race temperatures for bearing 42R on that day are shown in Figures 4-12, 4-13 and 4-14. The heating and cooling rates associated with each of these events are derived in Figures 4-15 through 4-20.

In these figures, the heating and cooling rates are the slopes of the time (number of samples) vs. temperature curves. Number of samples is converted to minutes through the relation:

1 sample = 5 seconds = 1/12 minutes.

Time (P-200) is the time elapsed in minutes to cool from the peak observed bearing temperature to 200° F.

Peak (temp) is the maximum temperature recorded in the bearing.

The maximum heating and cooling rates are as follows:

First overheating event on 3/15

(50 mph peak speed)

	Peak Temp.	Max. Heating Rate/min	Max. Cooling Rate/min.
Top of Cup	258°F	6.7	5.1
Outboard race	234°F	5.2	3.7
Inboard race	270°F	12.8	6.4

BEARING 42R TOP OF CUP TEMPERATURE VS TIME

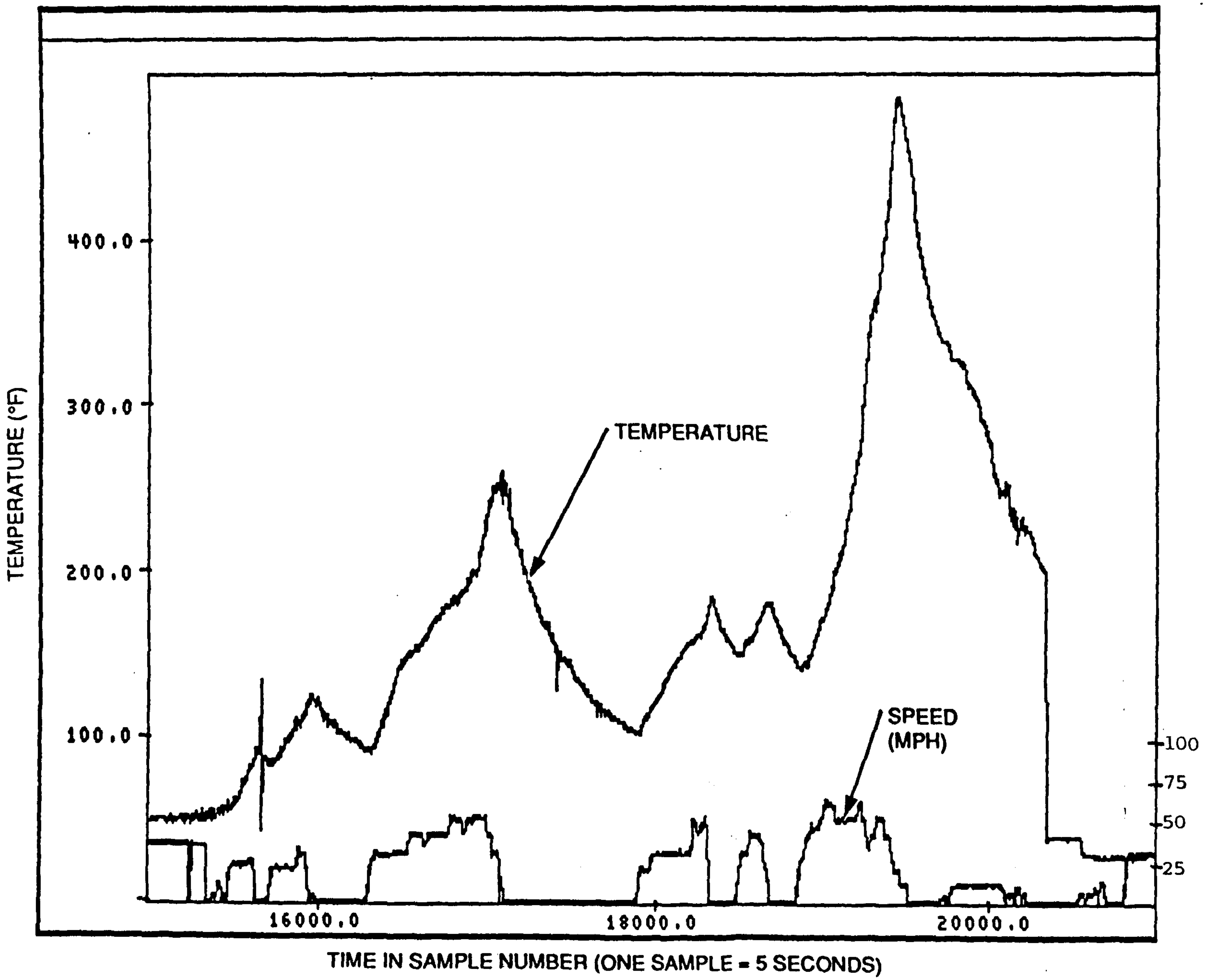


FIGURE 4-12

BEARING 42R INBOARD RACE TEMPERATURE VS TIME

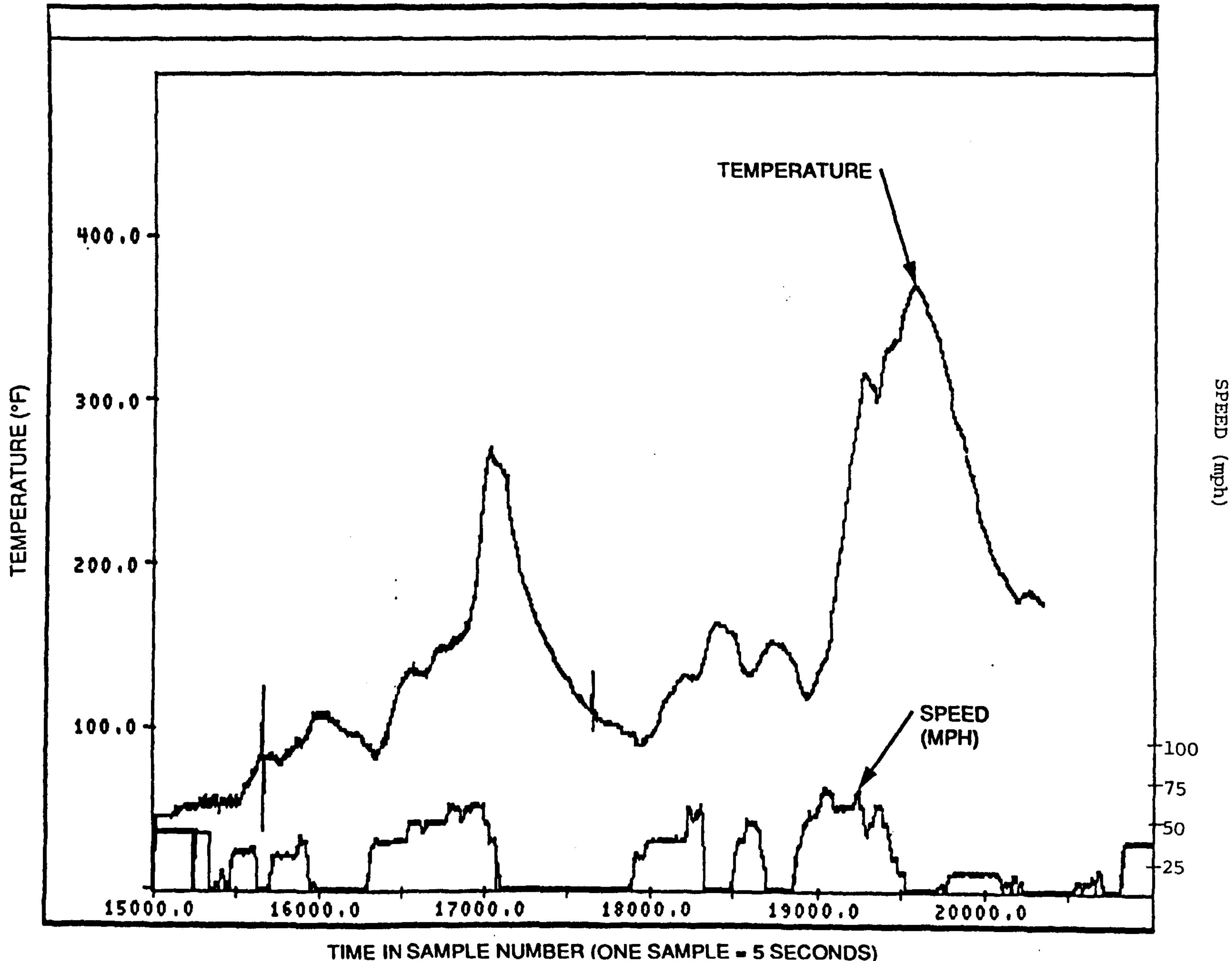


FIGURE 4-13

BEARING 42R OUTBOARD RACE TEMPERATURE VS TIME

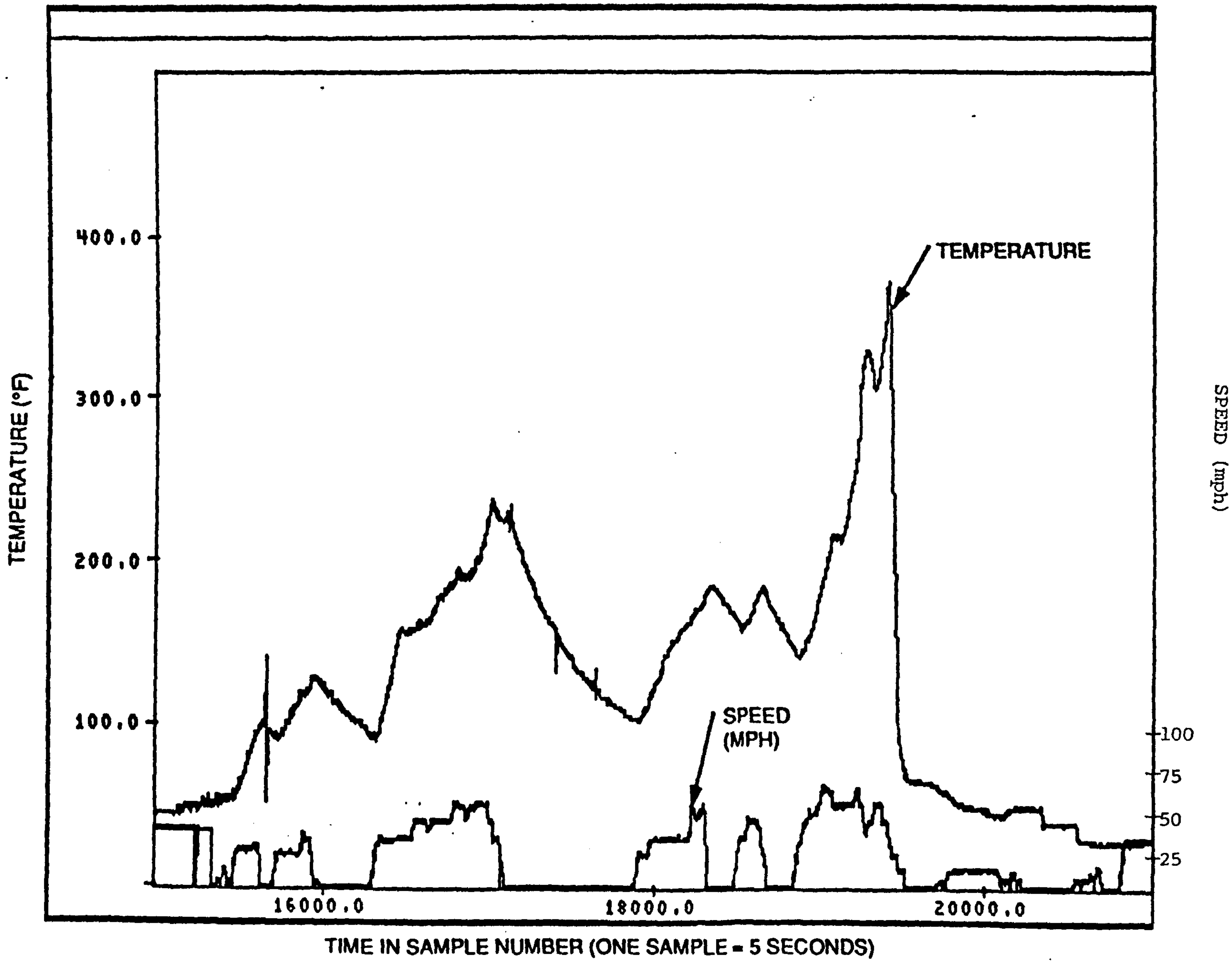


FIGURE 4-14

HEATING AND COOLING RATES BEARING 42R TOP OF CUP TEMPERATURE VS TIME

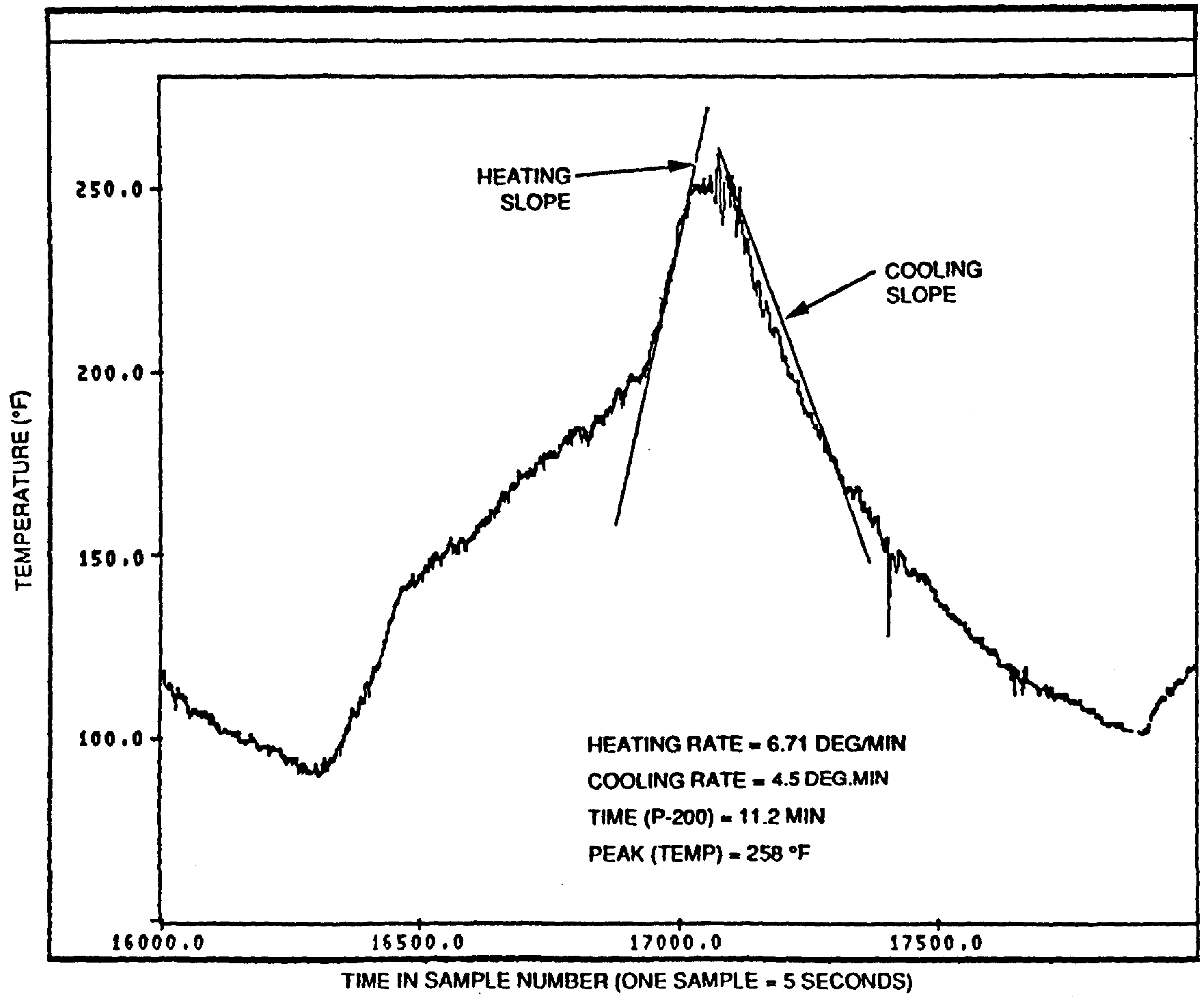


FIGURE 4-15

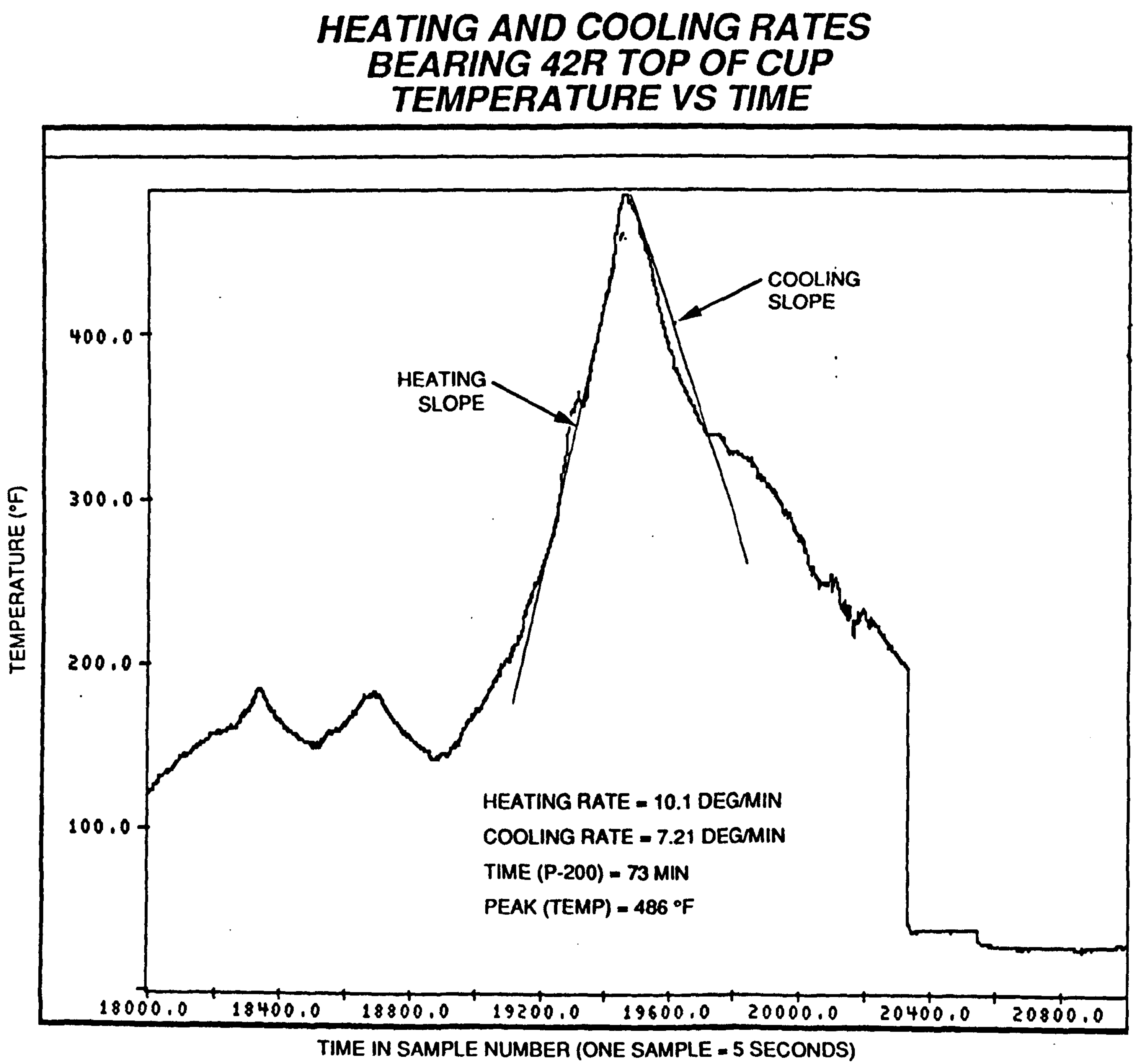

HEATING AND COOLING RATES
BEARING 42R TOP OF CUP
TEMPERATURE VS TIME
COOLING SLOPE
HEATING SLOPE
HEATING RATE = 10.1 DEG/MIN
COOLING RATE = 7.21 DEG/MIN
TIME (P-200) = 73 MIN
PEAK (TEMP) = 486 °F
TEMPERATURE (°F)
100.0
200.0
300.0
400.0
18000.0
18400.0
18800.0
19200.0
19600.0
20000.0
20400.0
20800.0
TIME IN SAMPLE NUMBER (ONE SAMPLE = 5 SECONDS)

FIGURE 4-16

HEATING AND COOLING RATES BEARING 42R INBOARD RACE TEMPERATURE VS TIME

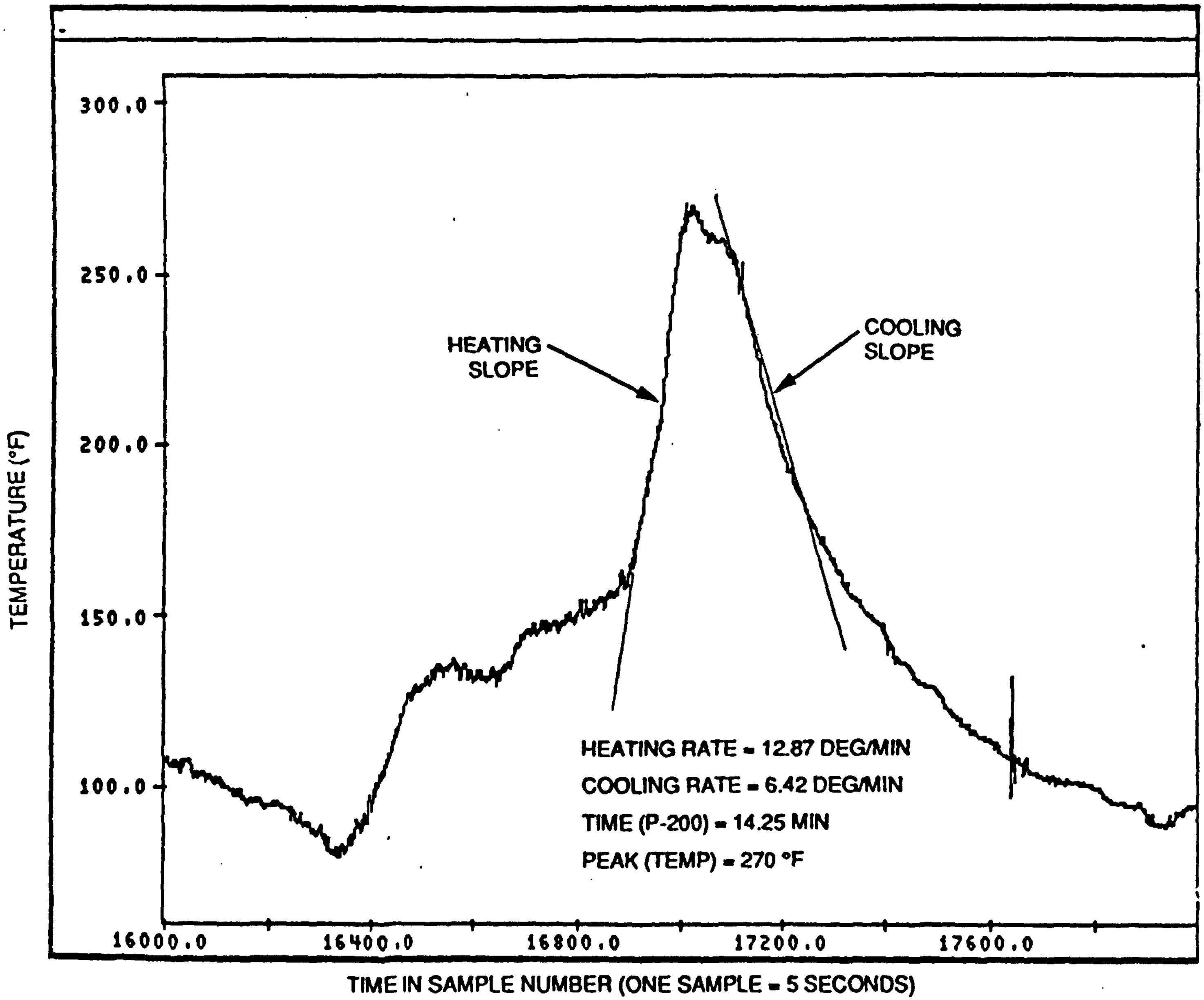


FIGURE 4-17

HEATING AND COOLING RATES BEARING 42R INBOARD RACE TEMPERATURE VS TIME

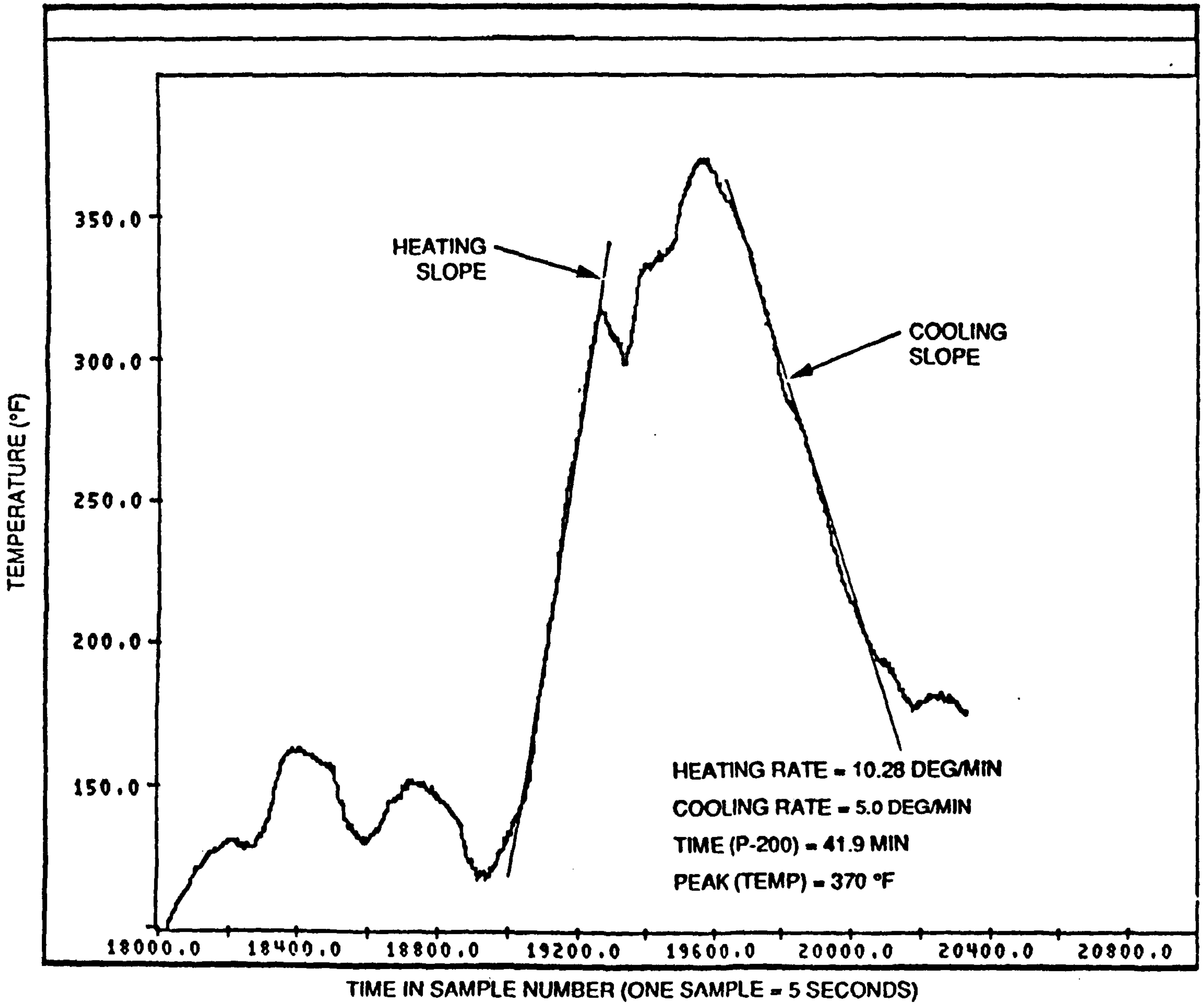


FIGURE 4-18

HEATING AND COOLING RATES BEARING 42R OUTBOARD RACE TEMPERATURE VS TIME

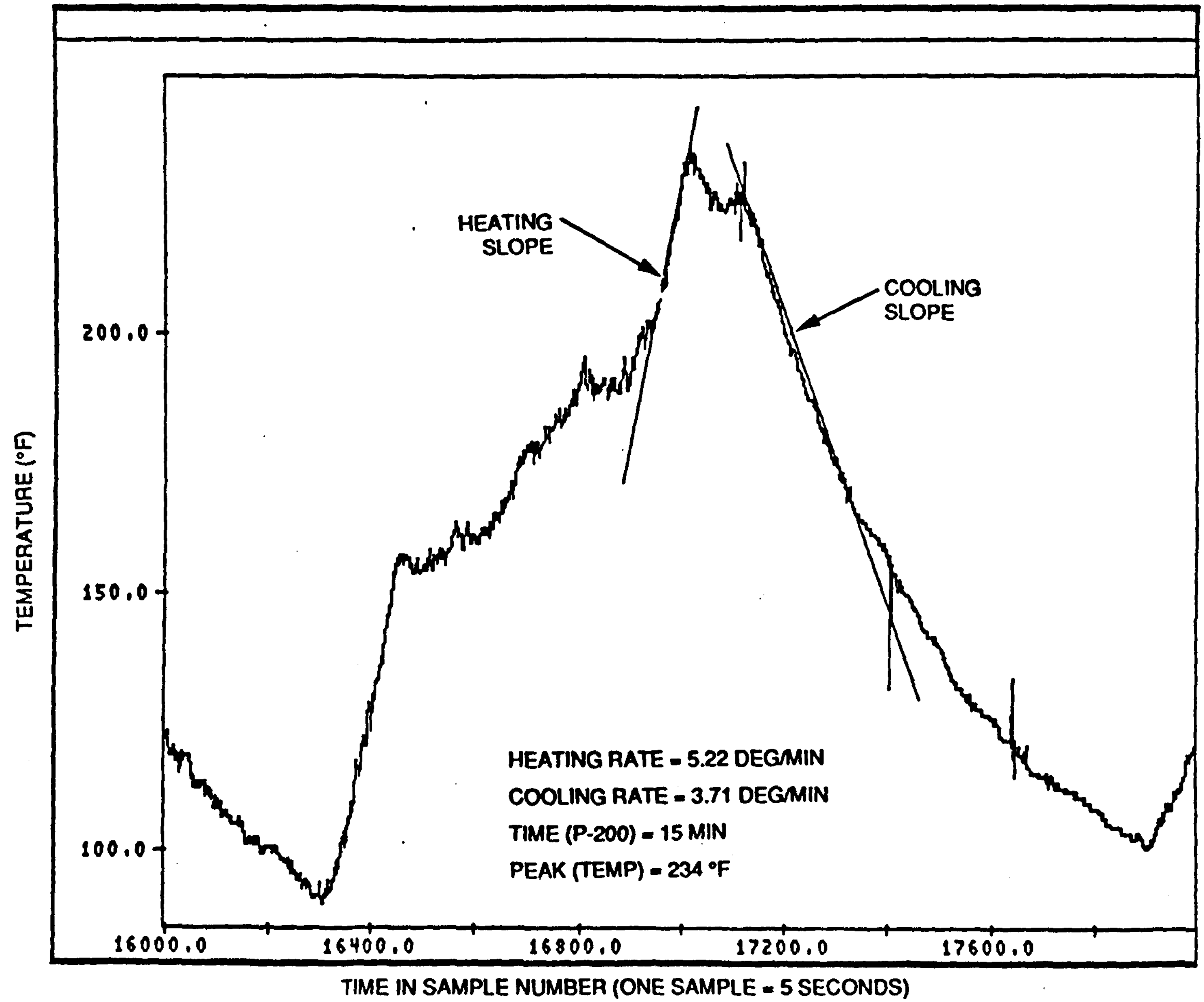


FIGURE 4-19

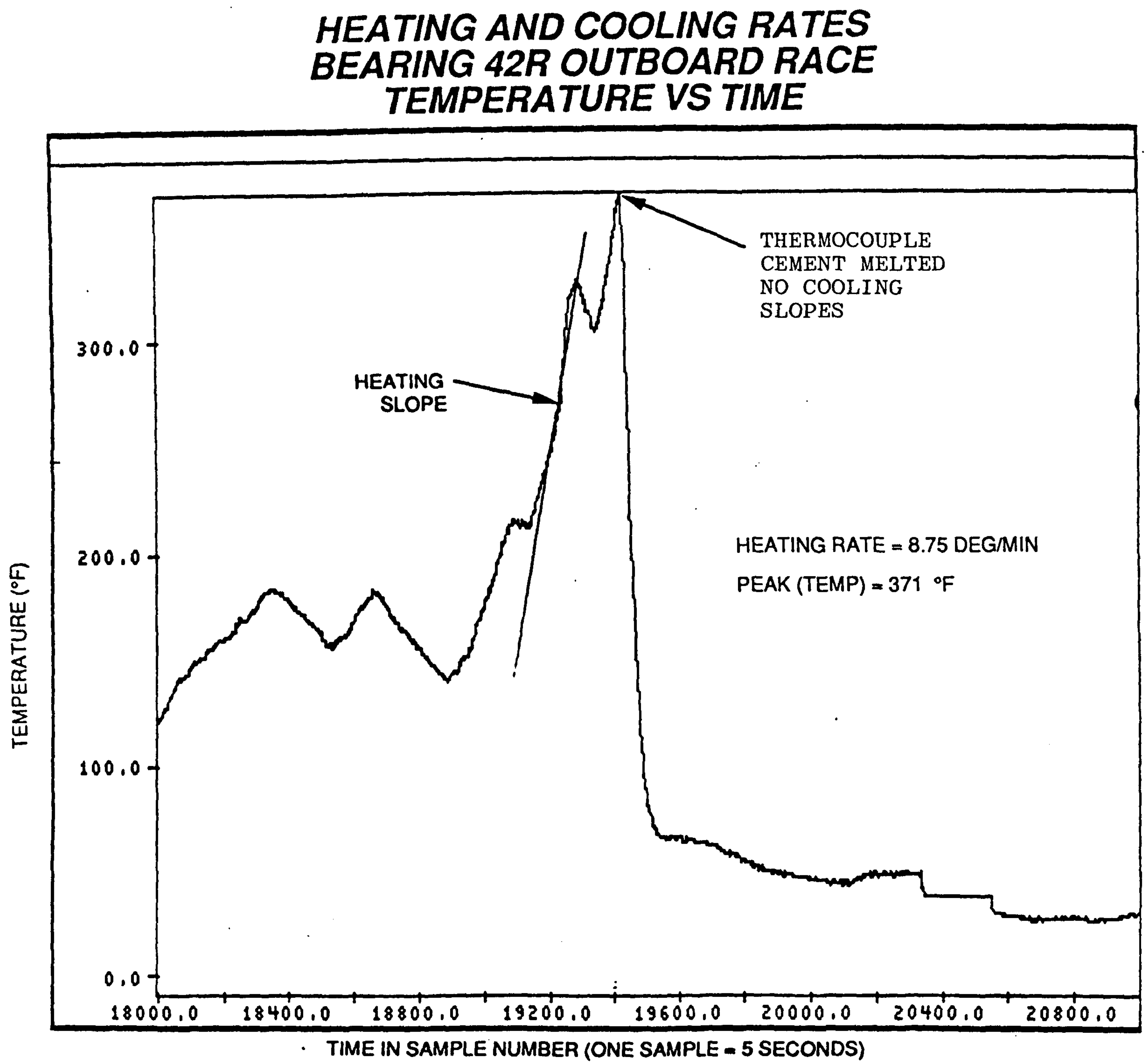

HEATING AND COOLING RATES
BEARING 42R OUTBOARD RACE
TEMPERATURE VS TIME
THERMOCOUPLE
CEMENT MELTED
NO COOLING
SLOPES
HEATING
SLOPE
HEATING RATE = 8.75 DEG/MIN
PEAK (TEMP) = 371 °F
300.0
200.0
100.0
0.0
18000.0
18400.0
18800.0
19200.0
19600.0
20000.0
20400.0
20800.0
TEMPERATURE (°F)
TIME IN SAMPLE NUMBER (ONE SAMPLE = 5 SECONDS)

FIGURE 4-20

Second overheating event on 3/15

(60 mph peak speed)

	Peak Temp.	Max. Heating Rate/min	Max. Cooling Rate/min.
Top of Cup	486° F	10.1	7.2
Outboard race	371° F	8.8	*
Inboard race	370° F	10.3	5.0

*Thermocouple disbonded.

Roller bearing lubricant has a dropping point of 325° F (Dropping point is the temperature at which grease changes from semi-solid to liquid state). At this point the lubricating ability of the grease is significantly reduced. The open cup flash point for the lubricant is 340° F.

At the inboard race on the side of the bearing, in the area seen by a wayside detector, the temperature increased at a rate of 10.3 degrees per minute. The flash point temperature of 340° F was reached first at the top of the cup. This temperature was reached after travelling 8.1 miles or 9.5 minutes beyond the time at which the inboard race first reached a temperature of 250° F. The inboard race did not reach the 340° F temperature until it had travelled 17.8 miles or 25.1 minutes.

For the particular bearing failure which occurred during this test, wayside detectors would have to have been spaced 8 miles apart to have detected this bearing overheating and prevent temperatures from exceeding the 340° F grease flash point. The wayside detector spacing recommended in a 1977 report prepared for the FRA by Shaker Research Corporation was 30 miles. That recommendation was based on an analysis of derailment statistics.

4.1.5.2 Bearing 41R

Bearing 41R was the only other test bearing to overheat during the test. On March 10th, at test speeds of 60 mph, bearing 41R reached nearly 260° F for brief periods. On the following test day the bearing reached nearly 280° F briefly during 50 mph operation. (See Figures 4-21, 4-22 and 4-23 for plots of the speed and temperature data for this bearing). The wheelset containing this bearing was removed from the test consist on March 15 to allow sustained high-speed running so that higher mileage could be accumulated on the other test bearings. The wheelset was held for future additional testing.

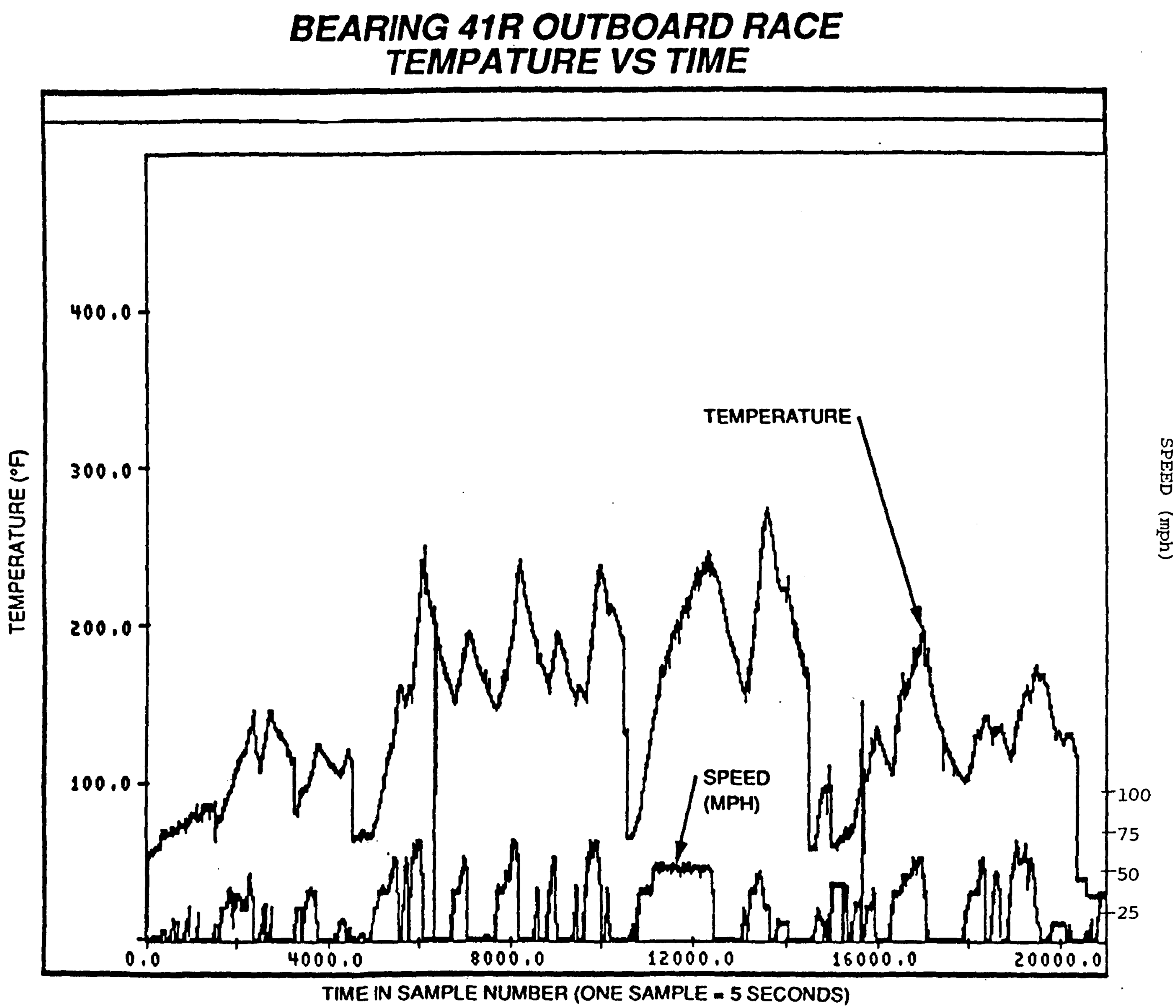
4.2 Cone Motion Performance

Cone motion sensors, as described in section 2.3, were installed on eight bearings which had minimal fit and/or clamp. These bearings were considered likely to spin on the axle. In fact, two bearings began the test with grooved axles (car 4, axles 1 and 2). These bearings were observed to slip from the beginning of the test. Other bearings or individual races began to slip during the test (see Table 4-1).

The slip rates expressed in percent slip, for the bearing with deeply grooved journals are as follows:

Bearing	Race	Rate
41R	Inside	1.60%
41R	Outside	0.11%
42R	Inside	1.28%
42R	Outside	0.04%

Appendix C contains plots for cone motion on each of the bearings so instrumented for the entire test and for representative test segments for the bearings slipping at high rates (41R and 42R).



BEARING 41R OUTBOARD RACE
TEMPATURE VS TIME
TEMPERATURE (°F)
400.0
300.0
200.0
100.0
TEMPERATURE
SPEED
(MPH)
SPEED (mph)
100
75
50
25
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
TIME IN SAMPLE NUMBER (ONE SAMPLE = 5 SECONDS)

FIGURE 4-21

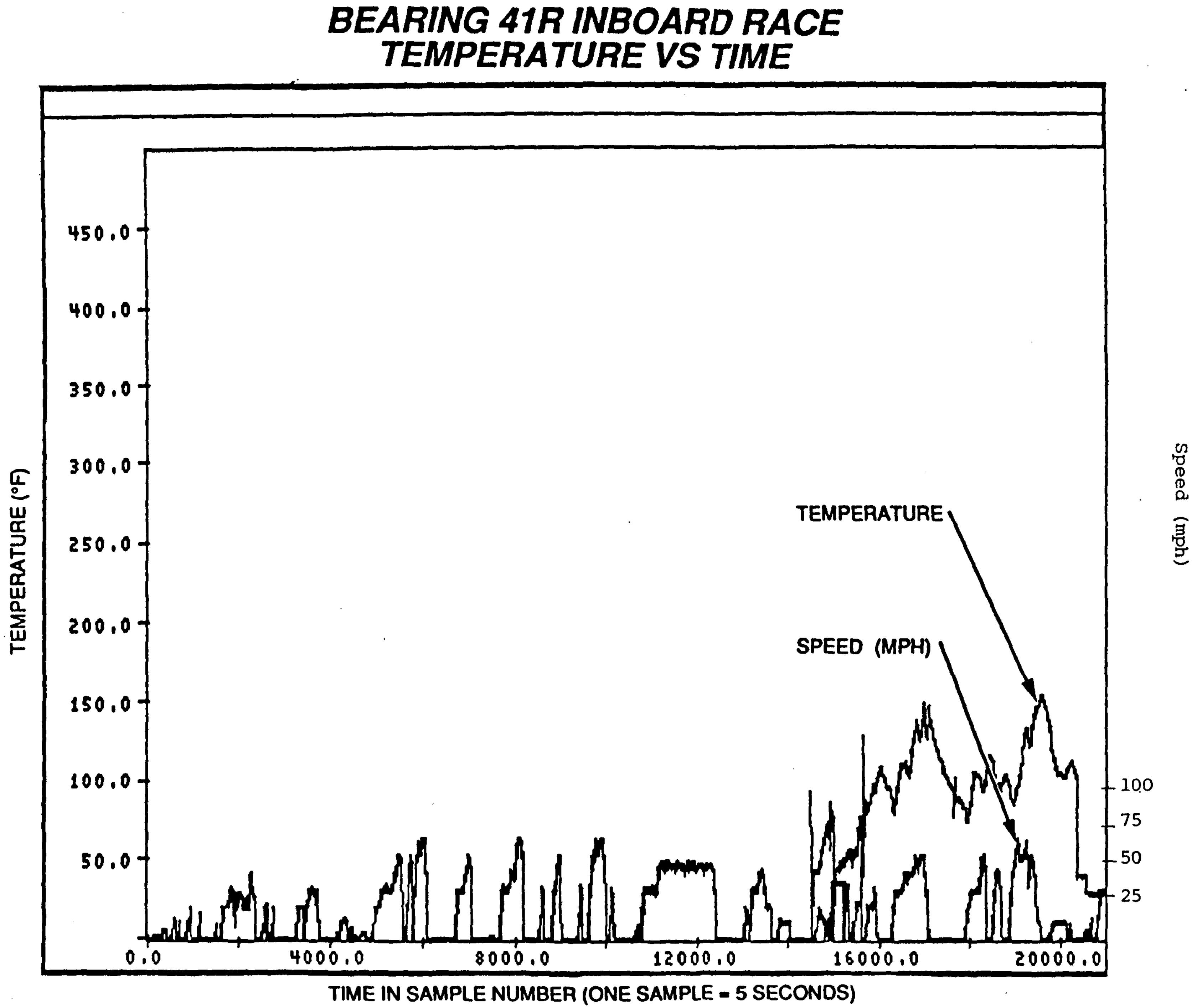

BEARING 41R INBOARD RACE
TEMPERATURE VS TIME
TEMPERATURE (°F)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
4000.0
8000.0
12000.0
16000.0
20000.0
TEMPERATURE
SPEED (MPH)
100
75
50
25
Speed (mph)
TIME IN SAMPLE NUMBER (ONE SAMPLE = 5 SECONDS)

FIGURE 4-22

Speed (mph)

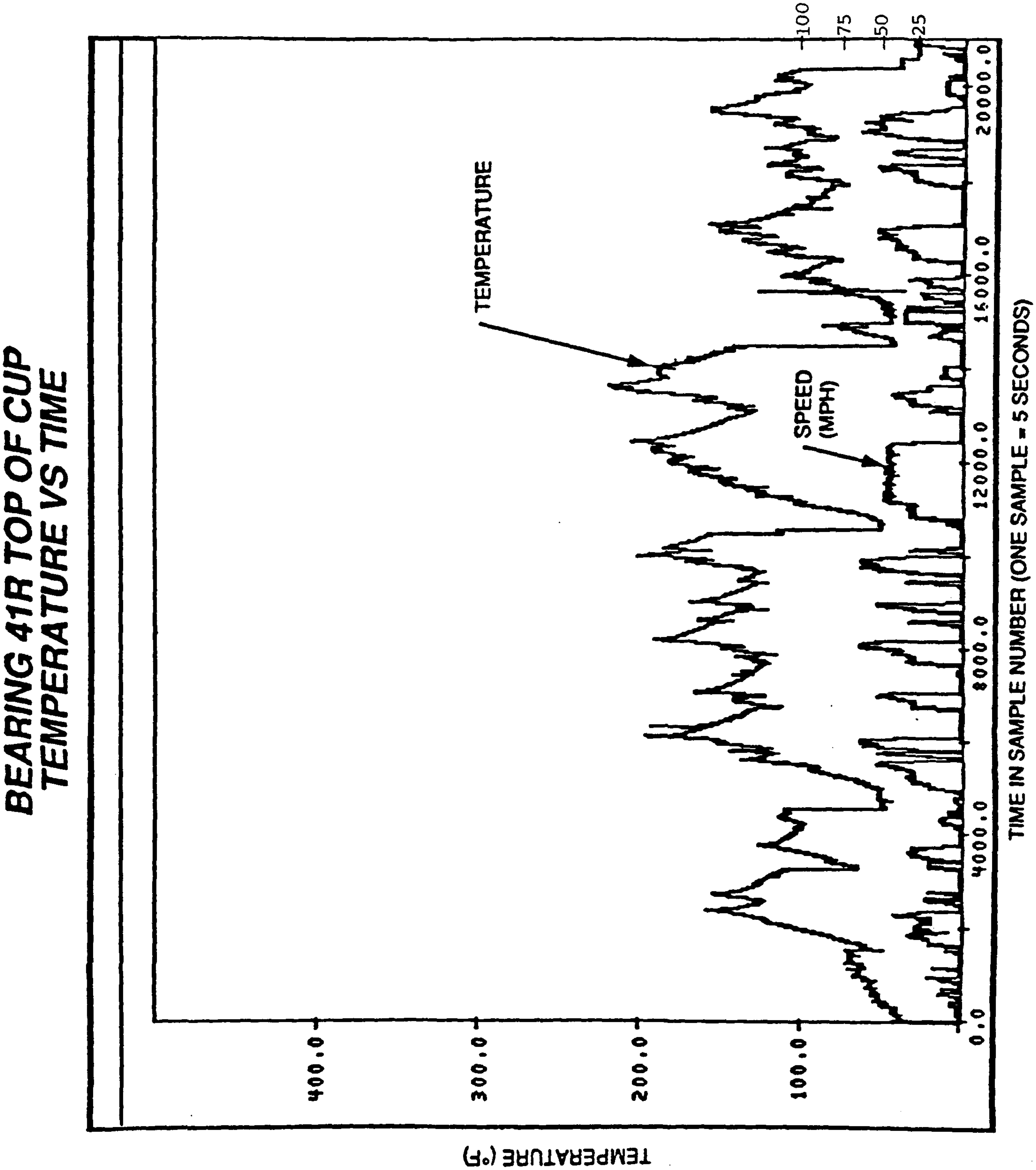


FIGURE 4-23

TABLE 4-1

CONE SLIP - NUMBER OF REVOLUTIONS FOR THE ENTIRE TEST

Bearing Position	Inboard Race	Outboard Race
21	3	3*
22	No slip	
23	3 1/8	2 1/2
24	4 1/2*	7 1/2
34	1/2**	small
41	continuous	continuous
42	continuous	continuous
43	1/4*	1/4*
44	3 1/2	2 1/4

* Projected - some data missing

**Began slipping on fourth test day

APPENDIX A

TEST LOG

TEST EVENTS REPORT

TO: Dr. Oscar Orringer, TSC May 1, 1989

FROM: Robert J. McCown, PE Robert McCown PE

SUBJECT: INFORMATION: FRA Defective Roller Bearing Test at TTC

This report of test events is furnished in accordance with the terms of Transportation Systems Center Purchase Order DTRS57-88-P-82014. Preparation of this report was begun on March 19, 1989, and completed on May 1, 1989. The report is based on notes taken by R. McCown and the test logs maintained by Wayne Stadler, TTC Test Controller and Alex Harrell, TTC Instrumentation Technician.

[Note: The referenced Purchase Order reflects test dates of July-August 1988. The test described in these reports is the same test as planned for July-August, but deferred until March-April, 1989.]

March 4-5, 1989 Saturday, Sunday

R.J. McCown from residence, Seabrook, MD, to Pueblo, CO, via POV. (1,740 miles)

March 6, 1989 Monday

Pre-test briefing in TTC Operations Building conference room. Attended by R. Florom, TTC Test Engineer, W. Stadler, TTC Test Controller, C. Chisholm and A. Harrell, TTC Instrumentation Technicians, T. Moser, ENSCO Senior Engineer, and R. McCown, TSC Technical Representative.

T. Moser reviewed the data collection package and cone motion monitoring instrumentation provided and installed by ENSCO, and the thermocouple units and wiring provided and installed by TTC. The ENSCO equipment includes a radio alarm system with receiver units for both the T-5 car and the locomotive. He reviewed the construction of the alarm system electronics and the troubleshooting aids provided. R. McCown reviewed prior FRA/TSC experience with the New Jersey Arrow test, which utilized similar instrumentation, with a particular view to the safety margins available in the event of a seized bearing. R. Florom reviewed the safety plan for the test, including the agreed level of 250 degrees F for a first safety limit, then 600 degrees F for subsequent special runs. In addition, at least two wayside detectors will be in service on the test loop. He also advised that additional personnel might visit the testing, including the inventor of the proprietary seals included in the test consist, and the AAR Wheels, Axles, Bearings, and Lubrication (WABL) Technical Committee on the morning of March 8.

Adjourned to SMB Building where entire consist was housed during instrumentation and during subsequent pauses in testing. Wiring was finalized. A diagram of the test consist as initially deployed is Attachment A.

March 7, 1989 Tuesday

Crew call 08:00. Operations delayed briefly by flat tire on vehicle bringing Servo personnel J. Bambara and two technicians to safety briefing. W. Stadler, Test Controller briefed all personnel involved. Servo personnel will man and monitor wayside Servo 9000 hotbox detector, upgraded to include acoustic detection, but wayside personnel must move back from track during train passage. Operations on 3/7 to be clockwise (CW) on RTT.

09:25 Difficulty encountered in getting PC data collection system to boot. Rolled consist outside building without data collection so that T-5 generator could be started. work on computer

10:10 Computer and ADIC tape up. Tape up T-5 sliding door where cables enter.

10:30 Slow roll out of SMB, check cabling loops, add slack; paint mark cups to detect indexing.

11:00 Lunch break.

11:50 Roll out North Wye toward RTT. Note that Car 4, Axle 1 (hereafter 41) cones are both already slipping per cone motion system. 42 outside maybe, 42 inside definitely slipping. 41 and 42 are the deeply grooved axle bearings.

12:05 Start required first "conditioning lap" on RTT at 10 mph. Speed not to exceed 30 during conditioning lap.

12:10 Radio alarm sounded for Car 3. Glitch in alarm system.

12:17 Restart.

12:20 Stop, radio alarm.

12:37 Passed wayside detectors at slow speed.

12:38 Request speed to 20 mph.

12:41 Stop. Tachometer problem with T-5 tach, which provides speed signal and drives cone motion system.

12:50 Restart

12:51 Stop, radio alarm. Restart, immediate stop, alarm again. Swap alarm circuit boards from Car 3 to Car 1 to isolate fault.

13:40 Restart conditioning lap.

13:55 Request speed to 30 mph.

14:00 First pass by "Talker" Harmon detector at "Rattlesnake Junction;" no defects.

14:08 Finished first lap.

14:35 Request speed to 40 mph.

14:45 Stop, alarm, tach problems.

14:50 Lost tach completely.

14:55 Start; 15:10 finished third lap.

15:13 Stopped train for day at Wayside Facility to accommodate WABL visit on 3/8/89.

16:00-18:00 R. Florom and R. McCown finalized presentation to WABL, and agreed that making a test run with the committee aboard would be inadvisable given the difficulties encountered on 3/7/89. Operating crew called for 12:00-20:30 for 3/8 to allow morning for WABL visit without impacting available test time. T. Moser and B. Stewart reworked T-5 tach system and set up meter to read out analog speed at operating position in T-5 forward reception area.

March 8, 1989 Wednesday

08:00-10:00 TTC Presentation to WABL Committee at Harris Hall, including overview of Defective Bearing Test by R. Florom. Interim results as of 3/7/89 presented: grooved bearings confirmed slipping but not overheating; some slippage already observed in Car 2 bearings with light or zero fits; cut cage bearings operating normally. Committee showed strong interest in presentation. Members invited to attend testing. Attendance list from WABL meeting is Attachment B.

10:30-11:00 WABL Committee visit to Wayside Detection Facility and Defective Bearing Test Consist. Consist had to be moved to clear up for Rail Garrison Test Train, so slow roll-by of worst bearings conducted for WABL members standing at wayside. Committee then toured T-5 to observe instrumentation.

11:00-15:00 Discovered channel assignment problem for cone motion; readings on PC not agreeing with readings on meters. T. Moser, K. Kesler, B. Stewart trouble shoot and correct. TTC personnel examining air brake problems on consist; T-5 not releasing, cars releasing too quickly. R. McCown pointed out that T-5 air brake set up for "graduated" release; corrected to "direct" release for compatibility with freight cars in consist. Car brake problems apparently due to lack of use of cars; cycling brakes repeatedly alleviated problems.

Special seal #6 had lost thermocouple (twisted off) on 3/7; seal enclosure apparently turned inside bearing cup. TTC car maintenance personnel pulled end cap and discovered that end cap had been driving seal enclosure, causing excessive heating and melting aluminum shims. R. Florom removed shims and end cap reinstalled (subsequently operated acceptably.)

15:00 On move; start track conditioning lap CW on RTT at 20 mph.

15:11 Stop to check inboard special seal #5, temp. had gone to 120 F. No apparent problem.

15:20 Request speed to 30 mph. Confirmed 41I, 41O, 42I, 42O all slipping.

15:35 Complete first lap.

15:40 Stopped at wayside to set out B. Stewart. K. Kesler used handheld Omega pyrometer to compare with data collection system values; determined up to 20 degree F difference between direct reading and data collection system (!!). Discussed situation with all parties; concluded necessary to remove thermocouple probes and substitute glued thermocouples for all bearings in consist. Probes were reading much closer to ambient than acceptable.

16:15 Back consist to SMB, arrive 16:50, end data collection.

16:50-19:15 R. Florom, C. Chisholm, K. Kesler, T. Moser, B. Stewart, R. McCown strip thermocouple probes from consist; strip wires and junctions out of probes for reinstallation on 3/9.

March 9, 1989 Thursday

08:00-15:30 C. Chisholm and A. Harrell gluing thermocouples to sides of bearing cups with dental cement. T. Moser and R. McCown reviewing PC software use.

15:30-19:30 T. Moser and R. McCown verifying thermocouples with heat gun; detected 10-20 degree discrepancy on Car 3. T. Moser and Brian Stewart diagnosed problem to different resistors used in construction of circuit board; corrected. Also installed "divide by 2" circuit in tach feed to cone motion system, since system would not properly indicate values greater than 1,000, and 1,024 counts had been observed on 3/7-8. Maximum counts on cone motion now 512, well within system capabilities. Covered all side-of-cup glued thermocouples with RTV silicone caulking compound to assure good insulation from ambient.

March 10, 1989 Friday

05:10 Instrumentation crew at SMB; begin setup.

06:00 Operating crew call at SMB.

06:22 Couple locomotive to consist and pull out; start T-5 generator.

06:35 Safety briefing.

06:40 Leave SMB; slow roll to check new wiring in curves.

07:02 On RTT, run CCW. NOTE: CCW running places the grooved bearings on the high side of all curves on the RTT. Swap wires on cone motion for axles 43, 44.

07:15 Begin conditioning lap at 20 mph.

07:25 Request speed to 30 mph.

07:45 Complete first lap. Request speed to 40 mph.

07:50 Thermocouple 12outer went open; other OK.

07:55 Speed to 50 mph.

08:02-08:12 Stop to fix 12o thermocouple; plug was intermittent at TAC80 module. On move; request 50 mph.

08:15 Complete 2nd lap.

08:20-08:25 Stop to fix intermittent thermocouple. On move to 50 mph.

08:30 Request speed to 60 mph. (First 60 mph for this consist.)

08:37 Bearing 42, Omega Channel 22 warming up, but not on PC. Bearing 41 warming up on PC, but not on Omega.

08:44 Reduce to 50 mph.

08:46 Reduce to 30 mph. Wayside detectors (Servo and others at Wayside Facility) alarm on Axle 42 only, not on Axle 41.

08:50 Stop. Record bearing cooling sequence. Bearing 42 inner reached about 245 degrees F; bearing 41 outer reached about 240. Uncertainty resulted from only one side of each bearing heating; appearance of crossed channels. Used handheld pyrometer, and opened each affected thermocouple on bearings 41 and 42 in turn; confirmed that wiring and channels were correct and that both bearings were hot. *NOTE*: This observed gradient effect across the width of the bearing cup is regarded as a very valuable product of this test to date. If this behavior occurs at other locations, significantly improved detection of defective bearings may result from increasing detector surveillance to *both* sides of the bearing cups, not only inner *or* outer as most detectors now perform.

09:41 On move to 30 mph.

09:54 W. Stadler (at wayside) reports loud squealing from bearing 42.

09:57 Request speed to 40 mph.

10:00 Request speed to 50 mph.

10:10 Stop; cone motion system disabled on bearing 44R; magnet had unscrewed from Delrin ring and damaged Hall effect sensors. Repair and take lunch break.

11:03 Resume at 30 mph.

11:15 No radio message from "Talker" detector at Rattlesnake Jct. Dispatch troubleshooter from TTC.

17

11:20 Request 40 mph. Audio impressions of bearings via accelerometers and headset: 41R sounds like "a flock of starlings (birds) twittering"; #42 quieter; #43 and 44 very quiet.

11:33 Request 60 mph.

11:41 Bearing 42, Omega channel 22, begins to rise out of "pack."

11:45 Stop for hot bearings. Ambient 82 F; wind reported at 5-15 mph from west. Handheld measurements (all taken within five minutes of stopping):

#41	2:00 position on front of cup, outside:	225 F
	2:00 position on front of cup, inside :	217 F
	Front of adapter:	178 F
	Outside end of cap screw:	187 F
	Face of end cap:	174 F
#42	2:00 position on front of cup, outside:	222 F
	10:00 position on rear of cup, inside:	224 F
	Front of adapter:	180 F
	Outside end of cap screw:	203 F
	Face of end cap:	166 F

Handheld readings taken on #44R (running nominally) for comparison:

10:00 position on front of cup, outside:	138 F
2:00 position on rear of cup:	134 F
Front of adapter:	132 F
Wheel hub close to axle:	105 F

Cup indexing was also checked (Note: Metal plates with some compression had been placed from truck frames to cup bottoms to impede cup indexing to protect instrumentation, per recommendation by Timken Co.): Bearing cup 41 R match mark on cup had moved about 0.75" CW; #43R about 0.5" CW; 42 and 44 no movement.

The banding strap holding the top-of-cup thermocouple on bearing 41R was observed to be loose and was tightened. Values on this thermocouple had been suspiciously closer to ambient than to the side-of-cup values.

12:13 Resume operation at 30 mph.

12:20-12:37 Stop to check cone motion on 42R.

12:44 Request speed to 50 mph.

12:50 Stop to pick up R. Florom; note antifreeze leak from T-5. Determined to be from second, unused generator system. Talker back on line.

13:00 Back to 50 mph. with J. Bambara, Servo, aboard T-5. He reports sound of #41R "like jingle bells."

13:35 Stop to change locomotive crews; check Omega channel 19.

13:46 Resume to 50 mph.

13:55 Request 60 mph.

14:00 Thermal runaway again occurring on 42R.

14:08 Reduce to 50 mph.

14:15 Stop. Handheld: 42 outside of cup 241 F; 41 is 199 F.

14:25-14:36 Resume to 50 max. to South Wye and to SMB.

14:36-15:00 Fuel T-5 and locomotive, consist into SMB.

15:00-17:00 T. Moser and R. McCown revise PC software to insure alarms can be reset. R. McCown write disk report from ADIC to diskettes to insure data integrity (approx. 30 minutes for 1/2 of full day's data.) Servo personnel left TTC.

March 12, 1989 Sunday

R. McCown imported first half of data from 3/10/89 into DADISP data processing program and printed, to confirm data integrity of PC data and suitability of DADISP for analyzing all data from test.

March 13, 1989 Monday

05:00 Instrumentation crew at SMB to set up.

06:05 Couple locomotive and pull consist out of SMB to start T-5 generator. Both Omega and PC come up OK. Alarm system 12V car battery on Car 3 discovered to be discharged over weekend. During delay, attempt to write report from PC and system goes down.

07:58 PC restored to proper data collection. Problem is apparently intermittent connector cable between PC and ADIC, aggravated because ADIC takes 2-4 minutes for every recycle.

08:00 Consist out on RTT; testing to be CCW.

08:10 Start track conditioning lap at 30 mph. Weather foggy and damp; bearings running much quieter than previously. Speculation on lubrication value of moisture in grease.

08:30 No message from "talker" detector.

08:45 Finished first lap, speed to 45 mph.

08:51 "No defects" from talker.

09:10 Noted that cone motion 24 inside probably not functioning; seems to be locked up at max. count of 512 and was at 1024 before divide-by-two was installed.

09:18 Triggered alarm light from wayside detectors. NOTE: Servo detector intentionally set to alarm at lower values than normal. Alarm on this pass probably based on 150 F over ambient; ambient approx. 40 F and bearings at 190 F. Consist operating at sustained 45 mph. Ambient thermocouple not attached to any thermal mass; showing wide and rapid swings with sunlight, shadow, wind conditions, etc.

09:36 Triggered alarm light from wayside.

10:00 Sustained 45 mph. Readings on PC: 41R, 42R outers both 224 F and rising slowly, continuously.

10:13 Triggered alarm light from wayside.

10:20 "No defects" per talker.

10:28 Onboard alarm sounded.

10:30 Reduced speed to 30 mph.

10:31 Triggered alarm light from wayside.

10:35 Stop; bearing 42 top-of-cup at 270 F. Lunch break. Handheld readings immediately after stopping:

Bearing 41R:

Side of cup inside truck frame: 210 F
Side of cup outside truck frame: 206 F
Face of adapter: 176 F

Bearing 42R:

Side of cup inside truck frame: 273 F
Side of cup outside truck frame: 238 F
Face of adapter: 210 F

Bearing 43R for comparison:

Side of cup inside truck frame: 127 F
Side of cup outside truck frame: 135 F
Face of adapter: 122 F

Melt-stick tester also applied to simulate procedures used by some railroads. Melt-stick rated at 200 F definitely indicated overtemperature condition on sides of cups on 41R and 42R by going liquid on application. Definite indication on adapter of 42R; questionable indication on adapter for 41R.

10:50 Data collection continued to get cooling information. Weather report: ambient 56 F, wind southwest 10 mph. R. McCown, R. Florom discussed situation and concur that turning train may provide useful indication of effects of high superelevation on RTT curves (6").

11:25 Turn consist on balloon loop, test direction now CW, grooved bearings on low side of curves.

11:35 Start CW at 30 mph.

11:53 Speed to 40 mph.

12:03 Bearing 41R at 250 F with onboard alarm; reduce to 30 mph.

12:05 No alarm light from wayside.

12:07 Reduce to 20 mph; 41R max. temp. 260 F.

Handheld readings:

Bearing 41R:

Side of cup outside truck frame:	254.8 F
Side of cup inside truck frame:	233.0 F
Face of adapter:	212.0 F
Surface of end cap:	199.2 F

Cup match mark indexed about 2"
Seal enclosure moved about 3"

Bearing 42R:

Side of cup outside truck frame:	210 F
Side of cup inside truck frame:	197 F
Face of adapter:	177 F
Surface of end cap:	162 F

Cup and seal positions not significantly changed from prior note.

12:23 Weather report: temperature 67 F, wind 14 mph from southeast.

12:52 End of test operations for 3/13. Parked consist on RTT at 501 switch to facilitate quicker startup.

13:30 End of data collection for 3/13.

13:30-17:35 R. McCown downloaded data from ADIC to disk files. R. Florom wiring all 41 and 42 thermocouples into PC for data collection and analysis. Metrabyte Board #1 in PC: channel 8(24) now reads "TMP, Alarm ON, 250 degrees, 41 I R", duplicating Omega channel 21; Board #1 channel 9(25) now reads "TMP, Alarm ON, 250 degrees, 42 I R", duplicating Omega channel 22. These channel assignments must be edited into PC data collection program each time PC is re-started, since they are not entered in the PC software defaults. Retightened all top-of-cup thermocouple bands and A. Harrell re-cemented thermocouple to band for 41R top-of-cup.

During 3/13 also notified Timken (Emil Popa), BRENCO (Don Jellie and Bob Lawrence), and AAR Chicago Technical Center (CTC) (Mike Fec) by telephone that failure was imminent on bearings 41R and 42R and invited attendance by their representatives at test.

Timken anticipates that George Solly will be at Pueblo 3/13 PM; left telephone numbers for R. McCown and R. Florom. BRENCO and AAR CTC determining who may be available to come.

March 14, 1989 Tuesday

06:00 R. Florom advises that BRENCO Service Engineer Larry Stricker will be available on 3/15 to observe test, and AAR CTC engineers Mike Fee and Bill Snead will also be available, bringing infrared television system to document thermal gradients across bearing cups. Timken's George Solly not heard from, although Pueblo motel says it "has been ringing his room" on the telephone. Eventually determined that Solly is in Washington State, not Colorado, and unavailable to attend testing. Consensus is to suspend testing until 3/15 so that BRENCO and AAR TTC personnel can attend, advise, and observe on intentional failure of bearings 41R and 42R, with temperatures to be allowed to approach 600 F.

07:30-08:45 Problems initializing PC and ADIC tape drive.

08:45 Back up CCW on RTT to yard and into SMB.

08:50 Omega chart recorder stopped scanning; ultimately had to turn line power off and back on to get scanning to resume.

09:12 Arrive SMB.

09:15-16:35 TTC photo personnel set up small black-and-white TV camera to monitor bearing 41R, with monitor and recorder on T-5.

Check all 41 and 42 thermocouple circuits with millivolt calibration source injected in lieu of thermocouple with results as follows:

Bearing/Posn.	Sim. Val.°F	PC Reads°F	Offset°F
41R Inside			
	200	196	-4
	400	396	-4
41R Outside			
	10	22	+12
	99	111	+12
	200	212	+12
	397	408	+11
41R Top-of-Cup			
	10	8	-2
	202	199	-3
	401	397	-4

42R Inside			
	199	196	-3
	399	396	-3
42R Outside			
	200	197	-3
	401	398	-3
42R Top-of-Cup			
	200	202	+2
	400	401	+1

Check on Omega for comparison:

Bearing/Posn.	Sim. Val. F	Omega Reads F	Offset F
21R Inside			
	200	201	+1
	400	400	0

Note: offsets appear to be constant across expected temperature range, and appear to be DC biases introduced by amplifier circuits at each car and at Omega and PC signal conditioning. Twelve degree difference on bearing 41R outside is maximum offset on consist. Note that this offset makes bearing 41R appear to be *warmer* than it actually is operating. This is consistent with observations made during operations aboard the consist, particularly when the entire consist had equalized at ambient.

R. McCown downloaded ADIC cartridges for 3/10 and 3/13 to hard disk and diskettes.

19:30-23:00 R. McCown process and import all PC data from 3/10 and 3/13 into DADISP. Print for handout to arriving representatives on 3/15. These packages of graphs plus 3/15 data forwarded to O. Orringer, TSC, by Federal Express on 3/17 AM.

March 15, 1989 Wednesday

Test start time set back to 13:00 to allow travel time for AAR CTC personnel and equipment.

10:00-13:00 R. McCown and R. Florom brief L. Stricker; copy results package from 3/10 and 3/13. In G. Spons absence from TTC, R. McCown telephoned R. Scharr, FRA, to approve distribution of results graphs to personnel attending test, provided marked "preliminary". C. Chisholm made divider and wired analog speed signal onto Omega Channel 26. M. Fec and W. Snead arrived from AAR CTC.

12:30 Set up T-5, computers OK.

13:45 Safety briefing, on move toward RTT for testing Counterclockwise. CCW direction selected to place expected failure bearings 41R and 42R on side of consist adjacent to right-of-way road along RTT for observation from vehicle, if needed.

14:11 On move on RTT. Weather conditions 55 F, winds 5-15 mph from southeast. Begin track conditioning lap at 20 mph.

14:25-14:37 Stop to fix open thermocouple on 41R, Omega channel 21.

14:47 Request speed to 30 mph.

15:00-15:23 Stop at wayside detectors to set up IR video camera. Maximum temperatures on 41R and 42R approximately 120 F.

15:27 Complete conditioning lap.

15:41 Speed to 40 mph. No radio message from talking Harmon detector on this pass.

15:52 Complete second full lap. Bearings warming gradually, no thermal events.

16:01 Speed to 50 mph.

16:10 Third full lap.

16:20 No message from Harmon detector.

16:21 Bearing 42R overheating. Reduce speed to 30 mph.

16:30 Pass wayside detectors at 30 mph with approximately 270 F on bearing 42R; little gradient across cup. Record IR video of hot bearing cup. Advised by radio by TTC maintenance personnel that Harmon detector has failed; at least two circuit boards fail self-test integrity check. No way to restore operation on 3/15 and uncertain as to when.

16:45-17:05 R. Florom, R. McCown, W. Stadler telephoned Paul Schwartz on mobile phone regarding failure of Harmon detector. R. McCown called R. Scharr, FRA, on same subject. All parties concurred that onboard instrumentation plus other wayside detector provided adequate safeguards for personnel and consist. Moved small TV camera from bearing 41R to 42R, providing real-time observation of end cap and outer end of cup from inside T-5.

17:30 Restart at 20 mph CCW on RTT.

17:42 Fourth full lap.

18:03 Speed to 50 mph.

18:08 Fifth full lap.

18:12-18:27 Stop to check bearing 42R. Cup outside truck frame 179 F; cup inside truck frame 163 F; end of cap screw 160 F; surface of end cap 143 F. Resume at 30 mph.

18:33 Speed to 40 mph.

18:43-18:56 Stop at wayside detectors to install halogen light to illuminate bearing 42R for TV camera. Resume at 40 mph with agreed consensus and intention that this will be "final lap" resulting in bearing failure on 42R.

19:02 Sixth full lap.

19:04 Speed to 45 mph.

19:08 Speed to 50 mph at location R-54.

19:10 Speed to 60 mph. Bearing 42R heating markedly.

19:18 Seventh full lap. Reduce speed to 50 mph.

19:24 Alarm sounds on 42R at 258 F but not rising markedly.

19:27 Request speed to 60 mph. Heating continues.

19:28 Reduce speed to 50.

19:31 Reduce speed to 40. Bearing 42R begins to cool.

19:34 Eighth full lap. Third lap since intention to begin "final lap." Request speed to 50 mph.

19:40 Outboard seal on 42R reported as moving in and out, as viewed on TV monitor. (Note: Later replay of video tape showed seal had not been moving; appearance of motin due to shadows from strong light source on rotating end cap.) Reduce speed to 40 mph. Bearing temperature exceeding 400 F. One side thermocouple loose and now reading ambient. Locomotive crew reports bearing smoking heavily (apparently due to cone motion sensors melting out of seal case, leaving openings for hot melted grease to escape from housing.) No flames or sparks observed by crew or by personnel on T-5. Discussion aboard T-5 of temperature and condition of axle, since heating sequence has covered extended time interval and axle is not instrumented. Temperature of bearing is rising at a faster, but not extremely fast, rate. TV clearly shows bearing smoking and cone motion sensors hanging loose, but end cap is rotating properly with no indication that axle is softening. Alternative of operating bearing until the axle is seen to extend (due to thermal softening) is offered but declined, since time to safely stop consist under this condition would be uncertain. Maximum temperature from instrumentation 486 F on cup of 42R.

19:43 Reduce to 30 mph.

19:44 Reduce to 20 mph.

19:47 W. Stadler requests that TTC Fire Department tour RTT road to make sure that test has not started any grass fires (none found.)

19:48 Ordered stop; then decided not to stop until closer to CSB, to minimize consist handling problems in case bearing seizes after stop. Reduced speed to 10 mph.

19:53 Stop at location R-26 to make manual observations of 42R. Both cone motion sensors melted out of seal enclosures. Both side-of-cup cemented thermocouples off cup, but top-of-cup thermocouple still operating. Handheld pyrometer readings immediately after stop (Note that Celsius readings were taken since temperatures exceeded 400 F maximum on Omega handheld pyrometer!):

Bearing 42R:

Wheel hub:	82.0 F
Axle between backing ring and hub:	124.0 F
Inboard seal case:	350.0 F
Surface of cup inside truck frame:	177 C = 350.6 F
Bearing adapter surface inside truck frame:	173 C = 343.4 F
Surface of cup outside of truck frame:	200 C = 392.0 F
Outboard seal case:	154 C = 309.2 F
Surface of end cap:	162 C = 323.6 F
Surface of cap screw:	180 C = 356.0 F
Outside face of end of adapter:	172 C = 341.6 F
Accelerometer mounting block welded to adapter:	168 C = 304.4 F

The 200 F melt stick was not applied, since all readily accessible points on the bearing exceeded 300 F and melting would definitely have occurred.

20:10 Started consist toward CSB at walking pace, with test personnel walking beside 42R for about 1,000 feet to observe noises and whether seizure occurred. Bearing operated smoothly with no apparent grinding or screeching. Routine noise of brake shoe rubbing wheel exceeded any noise made by bearing.

20:40 Ninth full lap for 3/15/89. Fourth full lap since intended "last lap".

20:50 Backed consist into CSB yard to change out wheelsets 41 and 42 on 3/16/89. Note that bearing 41R did not overheat on 3/15, but was removed in order to obtain higher test mileages to examine less extreme slipping cones.

21:10-21:55 R. McCown downloaded ADIC data to hard disk and diskette.

March 16, 1989 Thursday

08:00-10:00 TTC maintenance personnel remove 41 and 42 wheelsets. R. McCown printing data from 3/15 using DADISP and advising TSC and FRA of test results of 3/15. A. Harrell noted that generator water pump on T-5 was failing, precluding test operations until pump can be replaced.

10:00-16:00 Dismount bearing 42R at CSB and examine. No obvious damage beyond conditions observed prior to start of test. Some soft/liquid grease still in seal case at one end. Place bearing components in cleaning bath for detailed examination on 3/17. Discuss significance of results to date with L. Stricker, M. Fee, W. Snead.

March 17, 1989 Friday

09:00-10:00 R. McCown printing data, Federal Express graphs to TSC. R. Florom, L. Stricker, W. Stadler examining cleaned bearing components.

10:00-13:00 Complete examination and report on cleaned components. Copy of L. Stricker's BRENCO report is Attachment C.

13:00-19:30 Rewire consist to adjust for elimination of sensors on 41R and 42R. Attempt to eliminate TAC-80 modules for sensors no longer needed; attempt unsuccessful and ambient thermocouples installed instead. Thermocouples placed on seal enclosures (not cup) for replacement normal bearing 41R for comparison with other seal data.

March 18, 1989 Saturday

TTC maintenance personnel assisted by W. Stadler obtain and replace water pump on T-5 generator diesel.

March 20, 1989 Monday

06:45 Consist moving toward RTT. Omega chart stopped scanning. Tried all resets; had to unplug 120V line power to Omega to get recorder to start recording again.

07:05 Start track conditioning lap at 30 mph clockwise on RTT.

07:33 Radio alarm sounded; open thermocouple on nominal bearing replacement for axle 41.

07:38 Complete conditioning lap, speed to 60 mph.

07:55 Omega jammed again. Reset again by cycling 120V power.

08:02 TTC/OCC advised weather report: temperature 30 F, winds 30-39 mph, humidity 51%.

08:40 Sound of bearing 43R via accelerometer and headset: generally quiet, slight squeaking only on curves.

08:51 Omega jammed again. Reset again. Suspected very cold temperatures inside T-5, particularly around instrumentation racks located in doorway, as probable source of problems with Omega.

09:24 Omega alarm sounded; got warning light at Wayside detector. Omega alarm sounding strange pulsating note continuously and would not reset, even though no channels showing hot or cold beyond alarm limits. Stopped testing. Telephoned ENSCO and then Omega main office in Connecticut. Omega advised that jamming and alarm problems indicated that entire memory of unit would need to be cleared, and they didn't have programming sequence at hand to accomplish reset. Read onboard Omega manual in detail, located memory clear instructions, reset all memory. Alarm reset by clearing memory. Reprogrammed channels. Omega resumed proper operation.

11:00 Tried to turn on overhead electric heat in T-5, to warm up instrumentation rack area. Loading of heater (15KW) almost stalled single available T-5 generator; caused black smoke to belch from both stack and generator housing under car. This caused concern of possible fire in engine compartment. Terminated data collection on PC system and shut down generator to await TTC mechanical assistance. Generator restarted at 12:30. Maintenance personnel stated that fan blade for generator is not properly installed and needs work. Backed to Post 85 for crew change.

13:18 Resume testing at 60 mph.

13:50 Omega channel 21 on nominal 41R bearing went open and drifted and was turned off. Omega channel 24 on bearing 44R went open; kept running relying on top-of-cup and outside thermocouple which remained OK.

14:58 Conclude testing, back to SMB. Note that cone motion 23I is now at 0189, and 24O at 0324; both were near 0001 (reset) at start of testing on 3/20/89.

15:20 Start dumping ADIC data from morning run to disk file. Reload Omega paper. Completed dumping afternoon ADIC data at 16:15; discovered that afternoon disk files had overwritten morning files. ARC'ed off afternoon files to floppy disks.

March 21, 1989 Tuesday

06:13 Pull out of SMB; computers up OK; edited PC data collection format (per copies of printed reports produced from ADIC tape.)

06:25-06:35 Fix thermocouple on Seal #6.

06:44 Fix CM 24RI sensor.

06:58 Start conditioning lap counterclockwise on RTT.

07:30 Finish condition lap, speed to 60 mph.

08:00 Stop to fix 32RO thermocouple. Picked up R. Florom and B. Rajkumar. R. Florom proposed increasing test speed to 70 mph. All present agreed that this would allow earlier test completion and help to reduce lateral forces on bearings due to running at much less than approximately 90 mph balance speed of RTT curves.

09:01 Speed to 70 mph on a trial basis with instructions to engine crew to watch consist closely for evidence of truck hunting or other problems. (None observed.)

09:21, 09:35 Wayside detector alarmed. No evidence of hot bearings on consist.

10:00 Stopped to set out Florom and Rajkumar; lunch break. W. Stadler made walk-around inspection of consist in view of higher operating speed; detected cracked coupler head on trailing end of Car 2. Crack approximately 8" long along side of coupler head and extending around top of head; old break with evidence of new extensions of crack at ends.

11:25 Backed consist into CSB to avoid possible break-in-two if cracked coupler head failed completely. Break-in-two would severely damage cabling. Downloaded data from ADIC to disks. Decabled to allow uncoupling between Car 2 and Car 3. Replaced trailing coupler on Car 2. TTC maintenance personnel removed fan from T-5 generator at CSB, took to machine shop for repair. Personnel noted that fan belt on generator was excessively worn, but declined to replace it.

13:30 Returned consist to SMB. Re-assembled antenna for radio alarm system transmitter on Car 1; vibration of running consist had caused antenna assembly to come apart and fall into hopper of car leaving no effective antenna and causing almost continuous alarm on T-5.

14:30 Consist in SMB. Re-downloaded data from 3/20 AM run from ADIC to disks. Maintenance personnel re-installing generator fan. Re-wiring of Cars 2 and 3 completed at SMB.

March 22, 1989 Wednesday

06:31 Pulled out of SMB, all computers came up OK. Start conditioning lap at 06:42 clockwise on RTT.

07:08 Finish conditioning lap, speed to 70 mph.

07:50 T-5 generator fan belt broke, lost power, lost all data collection systems, lost all data because ADIC tape was improperly terminated. Confirmed source of problem was generator shutdown due to severe overtemperature condition.

08:50 Began rigging 120V power from small (750W) inverter on locomotive DOT 203 to feed data collection systems on T-5 so that consist could be moved to CSB. Also mounted small gasoline generator on Car 1 as additional backup.

09:40 On move with temporary power. Now no cone motion system data. Determined problem due to no 120V power to T-5 tachometer circuits. Rigged power to them.

09:52 Resume testing to 70 mph to get consist to SMB for generator repairs.

10:20 Weighed all test cars while enroute SMB. Weights as follows (pounds):

Car #:	ATK 11829	ATK 11809	ATK 11841	ATK 11818
A-end	130,600	132,200	131,400	129,300
B-end	130,100	129,800	130,950	129,950
Total	260,700	262,000	262,350	259,250

10:40 Consist in SMB to repair generator.

11:50 Pulled out of SMB.

12:35 Resume testing at 70 mph.

12:43 Lost tachometer signal from T-5. Replaced tach.

13:00 Crew change.

14:23 Arranged for slower speed past Harmon talker detector to allow collection of acoustic data by Harmon representative on-site.

14:52 Onboard sound of both 43R and 44R bearings: "rushing" noise, no pronounced squeaking.

15:30 Consist into SMB; downloaded data from 3/22 after generator failure.

<u>March 23, 1989 Thursday</u>

06:55 Pulled out of SMB, started computers OK. Onto RTT at 07:00; begin 30 mph conditioning lap counterclockwise.

07:30 Stop to check open thermocouple.

09:15, 09:29 Wayside detector alarmed. Detector tape showed consist axle 11 as hot. This would be a test bearing; no indication of heat from onboard sensors. Informed by R. Florom that problem lies in programming of Servo 9000 detector at wayside site.

09:40 Stopped for lunch and to confirm no bearings hot.

10:10-10:28 Used test consist to shove FAST train off RTT after one FAST locomotive failed.

11:20 Train struck antelope at R43 (no stop.)

11:36 Omega channel 21 open and drifting, turned off(now non-test bearing.)

11:46-11:56 CM 43I sensor appears defective, stop to check. Resume to 70 mph.

12:03-12:12 Stop to allow Fire Department to wash antelope off DOT 203.

12:45 Thermocouple 11LO open (no stop).

13:02-13:11 Crew change.

13:17 Slow to 30 mph for Harmon detector data collection.

13:20 CM 44RI reset from 0501 to 0001.

R.J. McCOWN TEST EVENTS REPORT ATTACHMENT E

POSITIONS OF CONES ON TEST BEARINGS AS MANUALLY NOTED ONBOARD BY R.J.M.

NOTE: Reading of 0500+ shifting to 0001 indicates reset after full rotation of slippage on axle.

	miles	21o	21i	23o	23i	24o	24i	34o	34i	43o	43i	44o	44i
3/22	753	146	112	458	253	412	408	235	301	180	147	278	384
3/23	902	316	188	19	361	42	38	244	316	183	150	358	478
3/24	1240	468	337	122	1	143	141	243	330	189	*	383	20
3/28	1496	*	468	217	174	265	263	242	347	196	*	460	139
3/29	1928	*	123	322	330	381	379	245	402	201	*	51	269
3/30	2333	*	277	457	1	503	499	244	450	214	*	147	396
4/3	2643	435	?	58	191	326	320	243	470	226	*	256	30
4/4	3278	1	280	125	285	71	68	246	489	238	*	316	112
4/5	3739	50	325	180	359	321	317	246	502	251	*	358	239
4/6	4185	107	412	260	468	39	36	250	28	276	*	484	455
4/7	4589	115	420	265	470	84	81	246	32	276	*	500	7
EOT	5016	151	457	301	1	242	238	249	44	286	*	81	278

13:25 CM 34RO blinking to 0500 occasionally.

13:55-14:09 Slowed consist to 30 mph to clear conflicting move on RTT.

15:00 Leave RTT, to SMB. Download data, note test bearing cup positions as follows: 21R: OD of cup slipped 4.7" clockwise under adapter; 23R: 0.5" CW; 24R: 1.75" CCW; 34R: no significant motion; 43R: 1.5" CW; 44R: 0.7" CCW. None of the Delrin rings carrying the cone motion magnets had appeared to slip significantly compared to their previous locations on the bearing end caps. It was noted that the cups of the bearings on the leading axle and the trailing axle of each truck seemed to slip in opposite directions.

March 24, 1989 Friday

06:00-06:30 Work on TAC-80's account going intermittent again. Pulled out of SMB. Begin conditioning lap clockwise on RTT at 07:24.

07:52 Complete conditioning lap, to 70 mph.

08:01, 08:14, 08:27 Slowed to 30, then 40, then 50 mph for Harmon detector data collection.

08:47-09:03 Stop for open thermocouple; resume to 70.

09:50-10:10 Stop for lunch and to pick up R. Florom and B. Smith. Resume to 70 mph.

11:09-11:51 Onboard alarm; stopped, repaired open thermocouple.

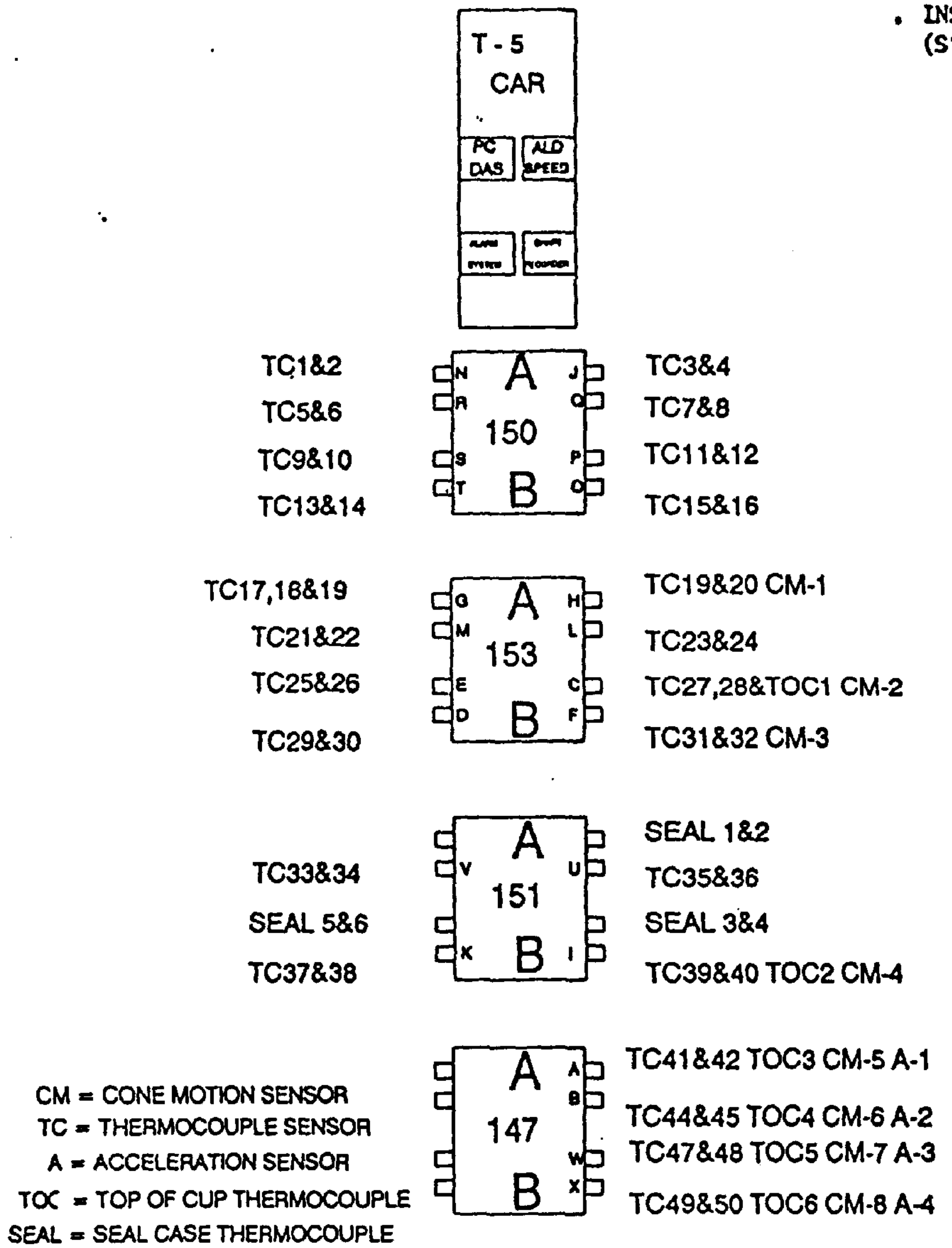
13:24 Run complete for day, into SMB. Downloaded data from ADIC.

This completes the test direction efforts and reporting conducted by R. J. McCown under Purchase Order DTRS57-88-P-82014. Additional test direction provided by R.J. McCown was conducted as a consultant to ENSCO, Inc., and will be reported separately.

#

R.J. McCOWN
TEST EVENTS REPORT

ATTACHMENT A
INSTRUMENTATION LAYOUT
(START OF TESTING)



CLAMP	INTERFERENCE FIT					
	GROOVED	ZERO	0.00075	0.0015	0.002	0.0045
ZERO			G,H	L,M		U,V
AS FOUND	A,B					
10-TON		C,D	I,J	N		
SPEC		E,F	K	P,Q		
SPEC				R,S	O,T	

WABL COMMITTEE

AAR WABL COMMITTEE MEETING @ TTC
VISITOR LOG

(Visit to FRA Defective Bearing Test & Other TTC Activities)

DATE March 3, 1989

PLEASE PRINT

NAME	COMPANY	TO SEE	TOUR	BUSINESS	DEPARTURE DATE	BADGE NO.
Tom Donkin	Amtrak		✓	AAR		
John Szilagyi	CN Nat Rlys		✓	AAR		
JOE CHAN	DM & IR Rly		"	"		
MIKE FEE	AAR		✓	AAR		
Brian Blackwell	AAR Wash.		✓	AAR		
TOM STAHURA	AAR "		✓	"		
ROBERT COMAND	CP RAIL		✓	AAR		
PAUL G. SPEETS	CONRAIL		✓	AAR		
Al Jones	AAR		✓	AAR		
Rick Collins	BN		✓	AAR		
G Hamilton	NS		✓	AAR		
Dave Schmidt	C&NW		✓	AAR		
Robert F. Breeze	AAR Chicago		✓	AAR		
[illegible]	SPTCo		✓	AAR WABL		
John [illegible]	AT&SF		✓	AAR		
Eric Wolf	TTX		✓	AAR		
Phil Schippert	CSXT		✓	AAR		

TOTAL VISITORS ________ TOURS ________

ATTACHMENT B Page 1/2

Transportation Test Center

WABL COMMITTEE

AAR WABL COMMITTEE MEETING @ TTC

VISITOR LOG

DATE March 8, 1989

PLEASE PRINT

NAME	COMPANY	TO SEE	TOUR	BUSINESS	DEPARTURE DATE	BADGE NO.
[illegible]	[illegible]					

TOTAL VISITORS ________ TOURS ________

Transportation Test Center

2 BRENCO BEARING INSPECTION REPORT

330457 Previous M.E. set-out at Santa Fe — Evening 147 R-3

PART 1 - EXTERNAL INSPECTION

TEST # 4-2-R IN 8 OUT

INSPECTION LOCATION: TTC - Pueblo Co — MONTH: 3 DAY: 16 YEAR: 89

CAR INITIAL: AT	CAR NUMBER: 322610	POSITION: R-1	TYPE OF CAR: 29828

BEARING SIZE: 12	SERIAL NUMBER	MONTH: N YEAR: 69 $

FIT OR MATCH or MX: N	JOURNAL BURN OFF: N	HOW DETECTED:	NFL: Y

SHROUD E/O: N	B/R: N	FIT B/R: Y	FIT APPL: N	B/R LOOSE: N	V/H CODE: 50

LATERAL: .095	TORQUE (0)(0)(0)	MOUNT BY: NT	MOUNT DATE:

AXLE SERIAL #: 178FT 647 W 215	AXLE MFG: ESCO	AXLE DATE: 9-68

WHEEL SERIAL #: 3355	CLASS: U	WHEEL MFG: SW	WHEEL DATE: 01-81

JOURNAL SIZE I.B. CONE: WR 6.1900	SPACER: 6.1904	O.B. CONE: WR 6.1905	UPSET:

ADAPTER CONDITION: HEATED

WHEEL CONDITION - OK

AXLE CONDITION - I.B. CONE SEAT SCORED 3/64" DEEP - O.B. CONE SEAT FRETTED - O.B. SEAT MEASURING 6.1890 AT CENTER OF SEAT -

PART 2 --INTERNAL INSPECTION

CUP REMANED: Y — TIMES: 2 - 3/74 ATSF 2-81 AT — CUP LAST REMANED ON: 2-81

CUP REMANED BY: AT — CUP REGROUND ON:

CUP CONDITION O.B. - Probable Etching Erupting to Spalls - HEAT - INDENTATIONS - HEAVY SMEARING.
Lube wt = .06 lb

I.B. - INDENTATIONS - HEAT - SMEARING - 1 Repairable Spall

CONE REMANED: N — TIMES — CONE LAST REMANED ON:

DATE CONE PLATED: N — CONE PLATED BY:

CONE I.B. - DATE: 66-1581 — COND. - BACK RIB WEAR - SPALLING NEAR BACK RIB - HEAVY SMEARING & HEAT - Prior Cage Damage (scored) Heaviest NEAT NEAR SPACER - BORE HIGHLY POLISHED.
.22 lb Lube 66-12976

O.B. - DATE: N-9-96 — COND. - 3 Spalled Rollers - Pitted & Smeared Rollers - Roller End-WEAR - Pitted, Smeared Race - Motion Sensor magnet Dislodged.
.14 lb Lube

SEALS I.B. - MFG: B — DATE: 5-88 — COND. - 1/8" UNEVEN WEAR. MOTION SENSOR TOUCHING CASE - DUST LIP BECOMING LOOSE (12 O'CLOCK)
.46 lb. Lube

O.B. - MFG: T — DATE: 5-88 — COND. - HEAT - NEARLY DRY - NO WEAR - MOTION SENSOR GOUGED CASE.
.14 lb Lube

V.R. I.B. - MFG: T — DATE: — COND. - Chipped - cracked - Face Wear - Heat! chip from prior Application

O.B. - MFG: T — DATE: — COND. - SEVERE HEAT.

SPACER CONDITION - HEAVY FACE WEAR - LOOSE ON JOURNAL .02 lb Lube

GREASE CONDITION - Dry O.B - OLD GREASE I.B.

COMMENTS/CONCLUSIONS - VERTICAL MOVEMENT I.B. - SOME ROUGHNESS IN BEARING - HEAVY HEAT DISCOLORATION ON JOURNAL - ORIGINAL BACKING RING WAS LOOSE. (NOT LOOSE THIS APPLICATION)

CAP SCREWS HAVE SOME FLATTENED Threads From Prior USE

BRENCO REP: Larry P. Stricker — RAILROAD REP: Bob Flowers, Rob McCowan — DATE: 3-17-89

TEST EVENTS REPORT

TO: J. Kevin Kesler, ENSCO May 1, 1989

FROM: Robert J. McCown, PE Robert J McCown PE

SUBJECT: INFORMATION: FRA Defective Roller Bearing Test at TTC

This report of test events is furnished in accordance with our consultant agreement. Preparation of this report was begun on May 1, 1989, and completed on May 1, 1989. The report is based on notes taken by R. McCown and the test logs maintained by Wayne Stadler, TTC Test Controller and Alex Harrell, TTC Instrumentation Technician.

March 27, 1989 Monday

No operation of test train. TTC Instrumentation personnel and B. Stewart, ENSCO, to rewiring TAC-80 modules to eliminate intermittent opening and drifting of thermocouple circuits. R.J. McCown off.

March 28, 1989 Tuesday

05:30 Relocate PC monitor and keyboard to T-5 table to reduce noise and vibration during monitoring. Troubleshoot intermittents in Car 4 channels. B. Stewart, ENSCO, riding consist to check out radio alarm.

06:47 Pull consist out of SMB. Start computers OK. Re-use (write over) ADIC tape from 3/22/89, since supply of blank ADIC tape cartridges is exhausted. Tape from 3/22 was unreadable due to generator failure on 3/22 AM.

06:55 Start conditioning lap counterclockwise on RTT at 30 mph.

07:27 Complete first lap, speed to 70 mph.

07:28 Radio alarm sounded, all channels OK.

07:56, 08:10, 08:22 Slowed to 30, 40, 50 mph for Harmon detector acoustic data collection at Rattlesnake Junction. Otherwise speed continuous at 70 mph.

08:28, 08:41 Wayside detector alarmed. No indications of hot bearing on onboard sensors. TTC Maintainer Ron Holcomb checking Servo 9000 detector at Wayside.

09:30 Wayside alarmed again. Holcomb calling Servo Company Main Office to diagnose problem.

10:07-10:57 Lunch stop. Walk around to check consist, OK. B. Stewart and A. Harrell checking radio alarm using UHF/VHF pocket scanner to listen to radio transmitter carrier and tones. Resume testing at 70 mph.

13:11-13:34 Crew change. Resume to 70 mph.

15:15 Backed into SMB. Downloaded ADIC data to hard disk and diskettes.

March 29, 1989 Wednesday

06:30 Pulled consist out of SMB. Computers up OK.

06:34 On RTT running conditioning lap clockwise on RTT.

07:07 Finished conditioning lap, speed to 70 mph.

08:18 Wayside detector alarmed. No indication of hot bearing on onboard sensors. Continued testing.

10:14-10:50 Lunch stop; check open thermocouple.

12:28-12:31 Turn consist on Balloon Loop to accommodate visit by AAR Car Construction Committee. Now running counterclockwise; resume to 70 mph.

12:46-13:54 Stop at Wayside for Car Committee observation of consist and wayside detectors. Slow roll consist through detectors to demonstrate laser targeting showing what location on bearing is actually scanned by each detector. Resume testing at 70 mph.

15:10 Back consist into SMB. Download ADIC data to hard disk and diskettes.

March 30, 1989 Thursday

06:36 Pull consist out of SMB, work on open thermocouple.

06:58 On RTT, start conditioning lap counterclockwise at 30 mph.

07:28 Complete conditioning lap, speed to 70 mph.

07:58, 08:14 Slow to 40, 50 mph for Harmon detector data collection.

10:09-11:03 Lunch stop. Resume to 70 mph.

13:10 Backed consist to CSB to jack bearing 21R; cup indexing had forced cone motion sensors up under bearing adapter, destroying wiring. Turned sensors back to prior position with weight jacked off wheelset.

March 31, 1989 Friday

06:30 Pull consist out of SMB. Start computers OK. Switched leads to CM 43I and 43O to confirm that magnet is not being seen, rather than wiring problem. Confirmed that magnet on CM 43I is not being seen; magnet on Cone 43I may be missing, destroyed, or out of view of sensor.

07:02 Start conditioning lap clockwise on RTT at 30 mph.

07:30 Finish conditioning lap, speed to 70 mph.

08:31 Wayside detector alarmed. No indication of hot bearings on consist on onboard sensors. No one at Wayside facility to check detector tape. Stopped train to make sure that non-test bearings (non-instrumented), and test car and locomotive bearings are OK.

09:30 Wayside alarmed again. No indication onboard. Continued testing.

10:03-10:34 Lunch stop. Repair leads to CM 21. Resume to 70 mph.

10:35-11:40 Stop consist; no cone motion data. Traced failure to short circuit. Disable CM 21 and resume testing to 70 mph.

13:25 Backed consist into SMB. Download ADIC data to hard disk and diskettes.

April 3, 1989 Monday

07:30 Arrive SMB. Wayside standby power failed during weekend. Waiting for locomotive so that generator can be started once T-5 can be pulled outside of building.

08:40 Pulled out of SMB. Computers up OK.

08:46 Start 30 mph conditioning lap counterclockwise on RTT.

09:10 Noted that CM21I, CM21O, and CM21REF are all showing readings consistent with reverse direction of travel, not forward direction.

09:15 Finish conditioning lap, speed to 70 mph.

09:16, 09:33 Reduce to 40, 50 mph for Harmon data collection.

11:23-11:57 Lunch stop. Backed consist about three car lengths to check cone motion sensors and system. Rewired CM21 "start" and "reference" Hall-effect switch leads, which had apparently been transposed during work on CM21 prior week. This corrected readings to correspond with forward direction of movement. Performed walk-around to check car condition, OK. Resume testing to 70 mph.

13:25 Radio alarm; ambient thermocouple open and drifting.

14:30 Lost thermocouple 22RO; continue testing.

14:43-14:56 CM 24O resetting from 500+ to 0001; held at 0001 throughout this interval (CM counters don't show 0000 during regular system operation; results in extended interval showing 0001 equivalent to interval for at least two or three counts for other settings of counter.)

14:50-15:03 CM 24I resetting from 500+ to 0001.

15:30 Back into SMB. Download ADIC data to hard disk and diskettes.

April 4, 1989 Tuesday

06:45 T-5 kitchen refrigerator failed; no luck attempting repairs. Pulled out of SMB. Computers up OK. Weather 33 F, damp, light snow in Pueblo.

07:04 Start 30 mph conditioning lap clockwise on RTT.

07:30 Finish conditioning lap. Speed to 70 mph. Onboard monitored sound on bearings 43R and 44R relatively quiet, neither squeaking, 43R somewhat louder than 44R.

07:34 Radio alarm; one top-of-cup thermocouple open. Continue testing.

07:48, 08:01 Slowed to 40, 50 mph for Harmon data collection.

09:00 Radio alarm again; continue testing.

09:43, 10:03 Wayside detector alarmed. No onboard indication of hot bearings. R. Florom enroute to check wayside detector.

10:17-10:47 Lunch stop. Spotted T-5 over Servo 9000 sensors at Wayside facility. Confirmed that diesel generator exhaust pipe on T-5 is being seen as a hot bearing by the detector. Exhaust pipe crosses above rail beside wheel at kitchen end of T-5, and lies in almost exactly the same position as the third bearing of a three-axle truck would lie. The pipe was bare steel, heated by the diesel exhaust to about 300 F. Jacketed pipe with insulation material. Resumed testing to 70 mph with many fewer false alarms from Wayside detectors.

10:50 Watched CM21O; stayed locked at 500+ for over 1.5 laps; no indication that magnet is being seen. CM 21I went open also about 12:50.

13:35 Onboard sound of 43R: like crickets chirping. 44R making typical "rushing" noise.

14:12 Parked consist on South Wye. Downloaded ADIC data to hard disk and diskettes.

April 5, 1989 Wednesday

06:15 Repair CM21O and CM21I Hall-effect sensors. Weather 29 F, clear, dry.

07:30 Start 30 mph conditioning lap counterclockwise on RTT.

07:50 Finish conditioning lap; speed to 70 mph.

07:53, 08:09 Slowed to 40, 50 mph for Harmon data collection.

08:25 Radio alarm; thermocouple open, continue testing.

09:15 Accelerometer on bearing 43R failed while being observed.

10:30-11:14 Lunch stop and work on thermocouples; restored accelerometer cable on bearing 43R.

11:50 CM 34I resetting to 0001.

13:27 Lost thermocouple on 34LI; continue testing.

13:50-14:07 Crew change. Resume to 70 mph.

15:30 Park on South Wye. Download ADIC data to hard disk and diskettes.

April 6, 1989 Thursday

06:40 Backed consist onto RTT and turned on Balloon Loop. Test direction clockwise for conditioning lap at 30 mph. Sheldon Apsell, President of MicroLogic, Inc., observing testing aboard T-5 per prior arrangement.

07:20 Finish conditioning lap, speed to 70 mph.

07:52, 08:05 Slowed to 40, 50 mph for Harmon data collection.

08:31 Radio alarm; thermocouple 44R top-of-cup open and drifting; other thermocouples on bearing OK; continue testing.

71

09:30-09:40 Stop to pick up G. Spons and R. Florom. Resume to 70 mph.

09:50 No message on passing Harmon detector.

10:01 Harmon detector restored to operation.

10:11 Lost thermocouple 14L0; continue testing.

10:30-11:27 Lunch stop; set out S. Apsell, G. Spons, R. Florom; fuel locomotive and T-5. Resume testing at 70 mph.

13:51-14:05 Crew change. Resume at 70 mph.

14:31 Locomotive trouble with DOT 203; running rough and flames from exhaust stack. Cut DOT 203 off consist and sent to CSB for repairs. DOT 001 brought back. Left consist on RTT overnight.

April 7, 1989 Friday (Last Day of Operation of This Test Sequence)

06:55 Started 30 mph clockwise track conditioning lap. NOTE: Clockwise direction selected to maximize cone motion observed on preceding days; clockwise direction with test bearings on low rail of curves seems to cause substantially greater cone motion per mile run.

07:22 Completed conditioning lap; speed to 70 mph.

07:54, 08:07 Slowed to 40, 50 mph for Harmon data collection.

09:47 Radio alarm sounded. No bearings showing hot onboard; alarm apparently due to overcharging battery by leaving charger plugged into 120V during running.

10:13-11:02 Stop for lunch and photographing of consist at Wayside detectors. Resume at 70 mph.

13:55-14:02 Crew change. Resume last lap at 70 mph.

14:30 Consist into SMB. Download ADIC tape to hard disk and diskettes. Remove R. McCown equipment from T-5.

End of Planned Short-Term Test Sequence.

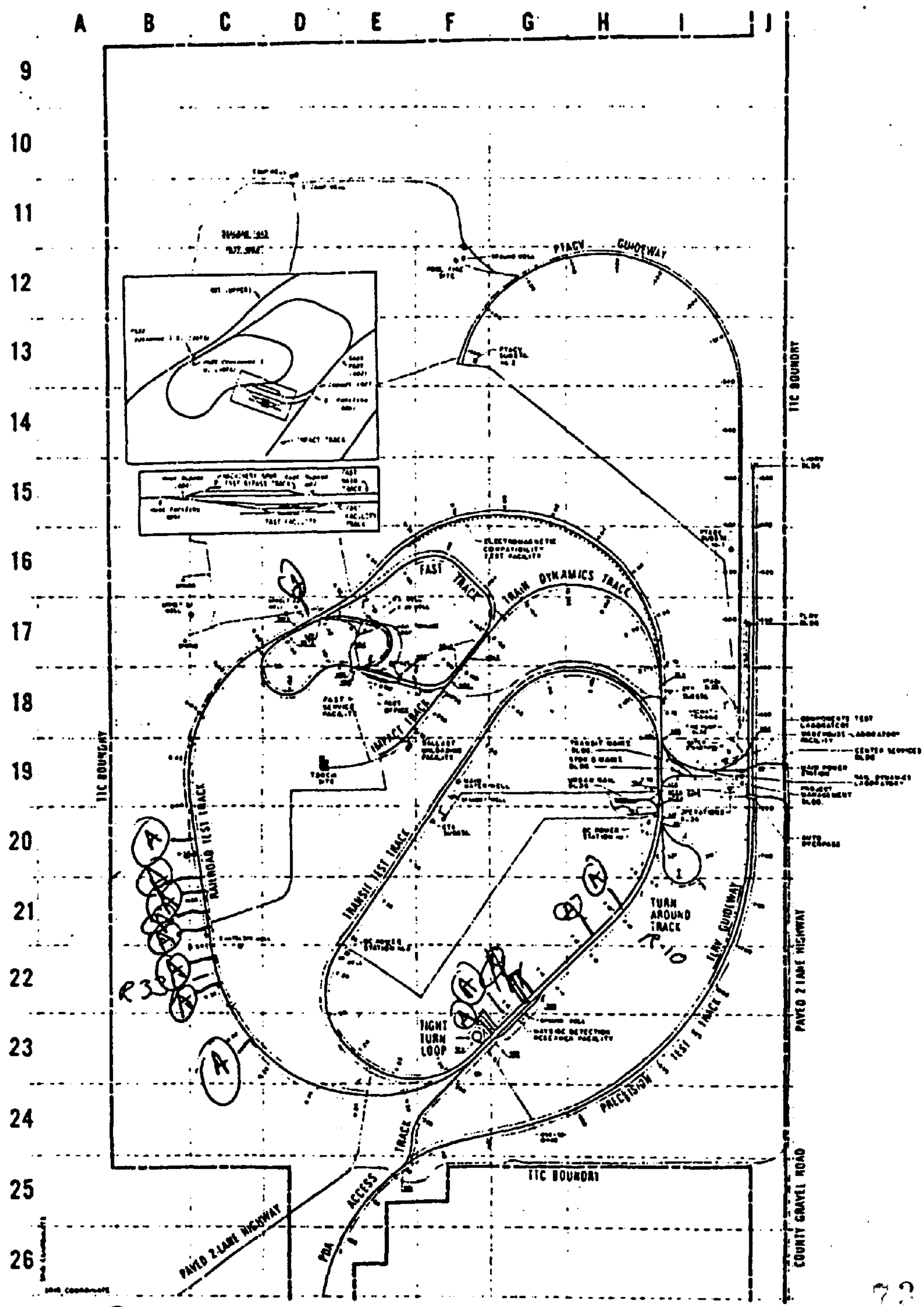
#

R.J. McCOWN TEST EVENTS REPORT ATTACHMENT D

LOCATIONS OF ALD'S RECORDING INTO PC DATA COLLECTION SYSTEM

TRANSPORTATION TEST CENTER

PUEBLO COLORADO

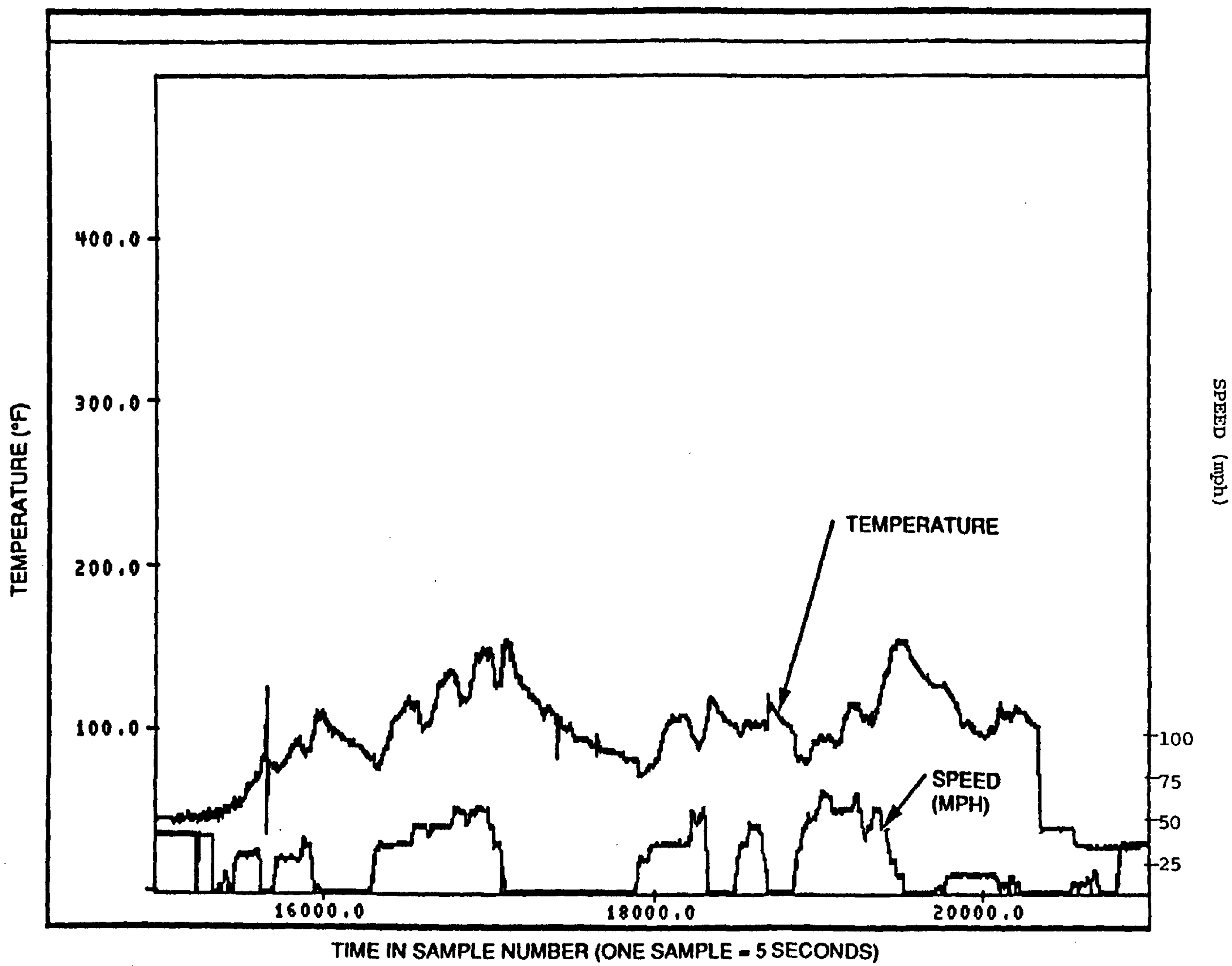


(A) = ALD LOCATION RECORDED ONTO ADIC

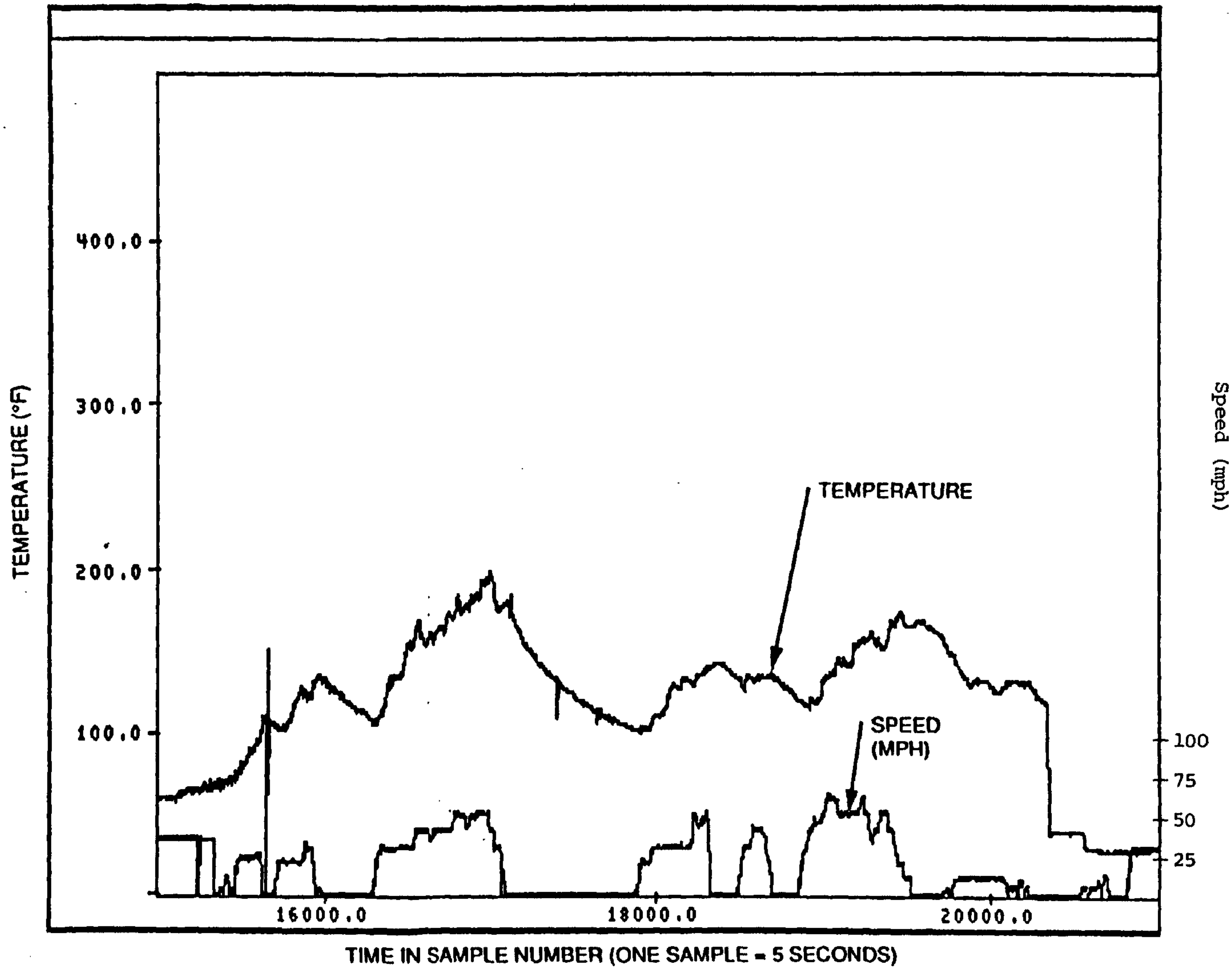
APPENDIX B

REFERENCE PLOTS FOR BEARING 41R AND 42R

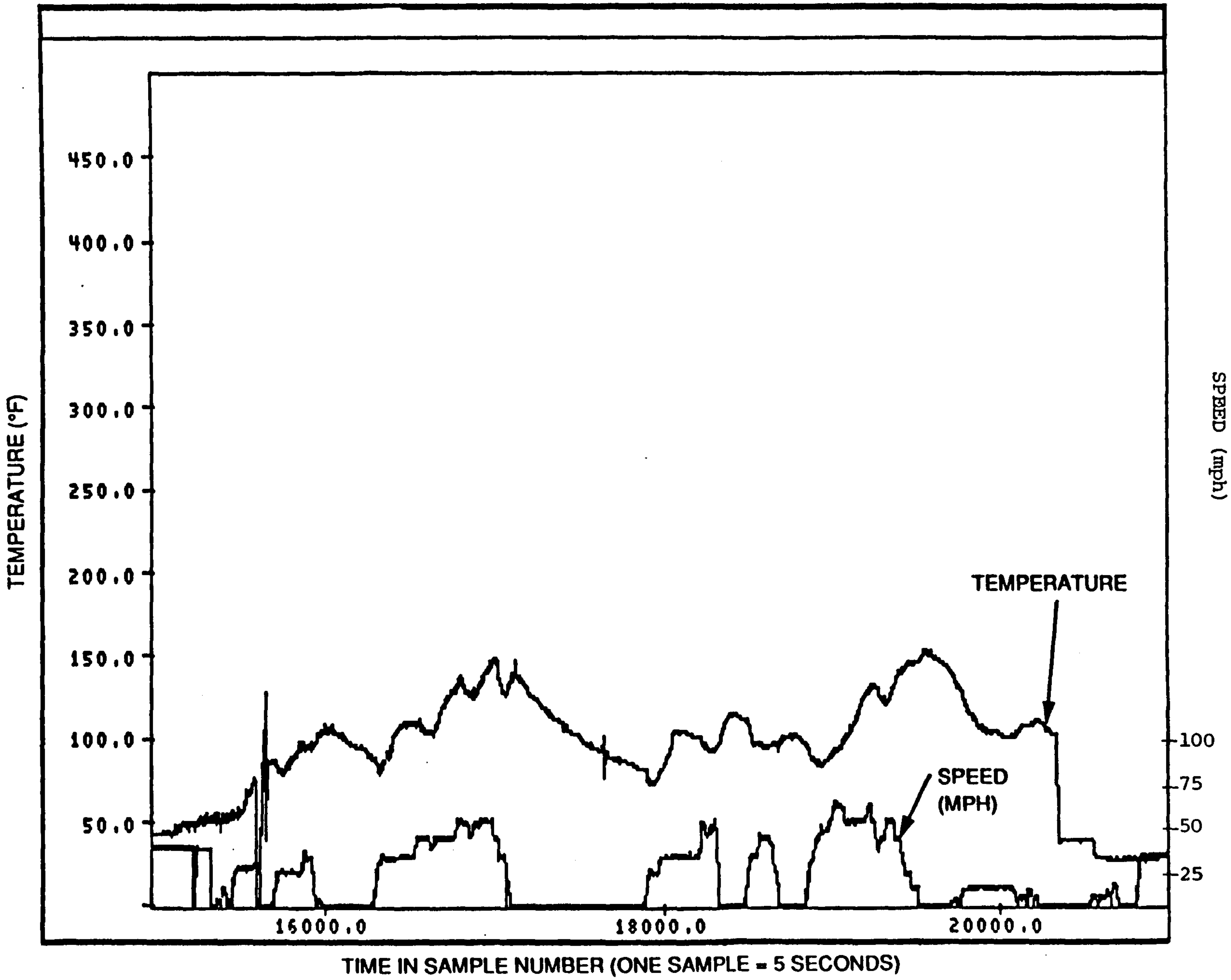
BEARING 41R TOP OF CUP TEMPERATURE VS TIME



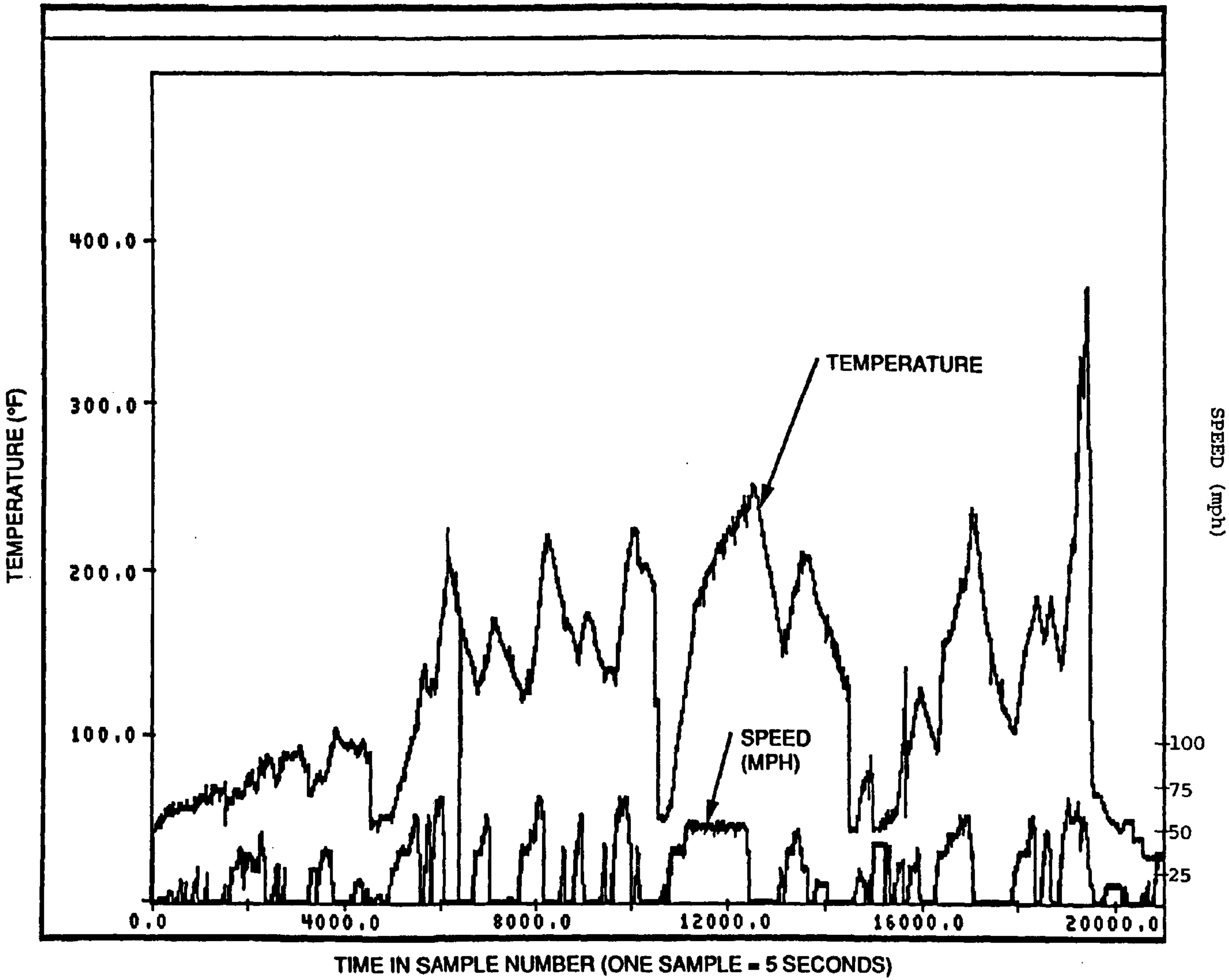
BEARING 41R OUTBOARD RACE
TEMPERATURE VS TIME



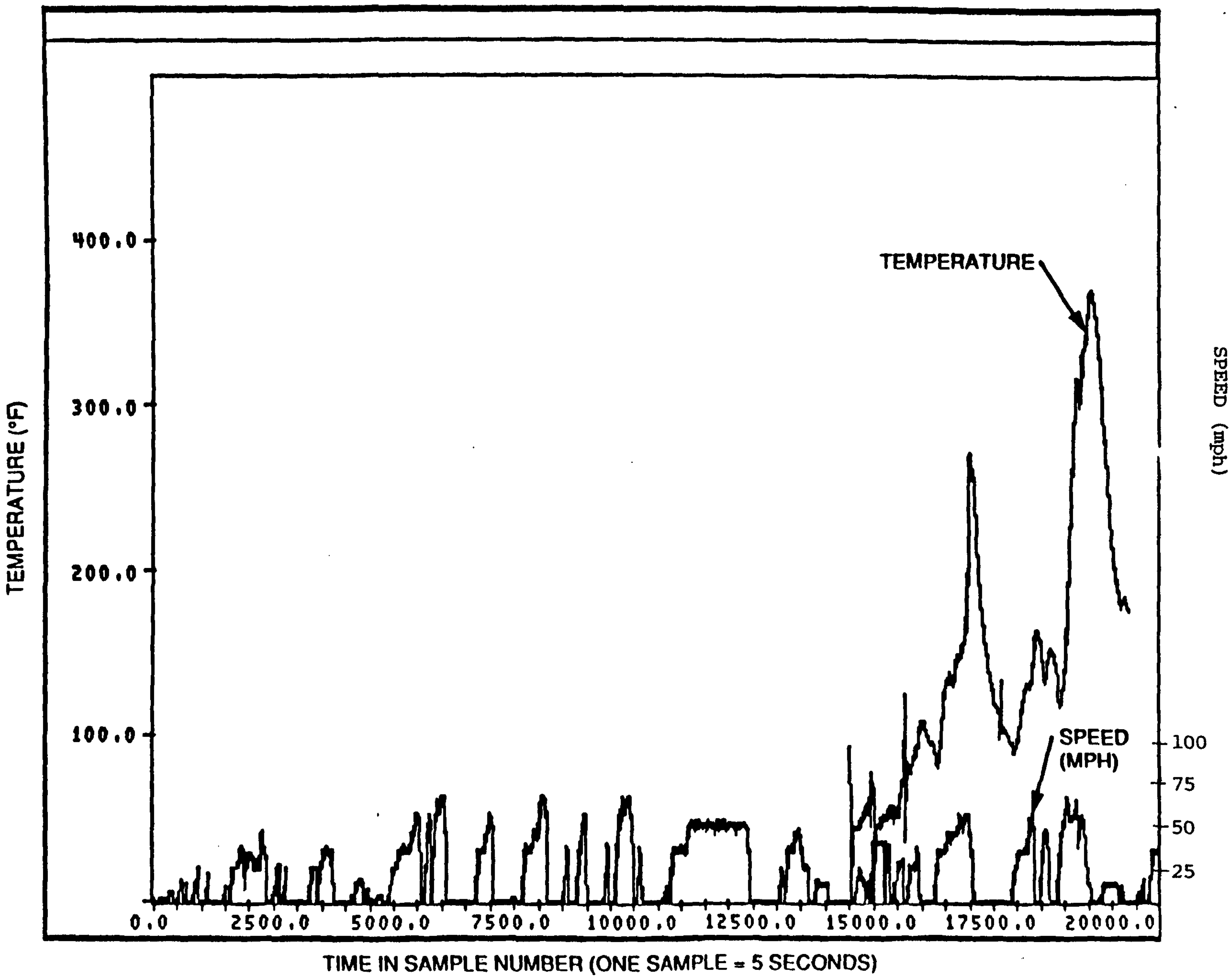
BEARING 41R INBOARD RACE TEMPERATURE VS TIME



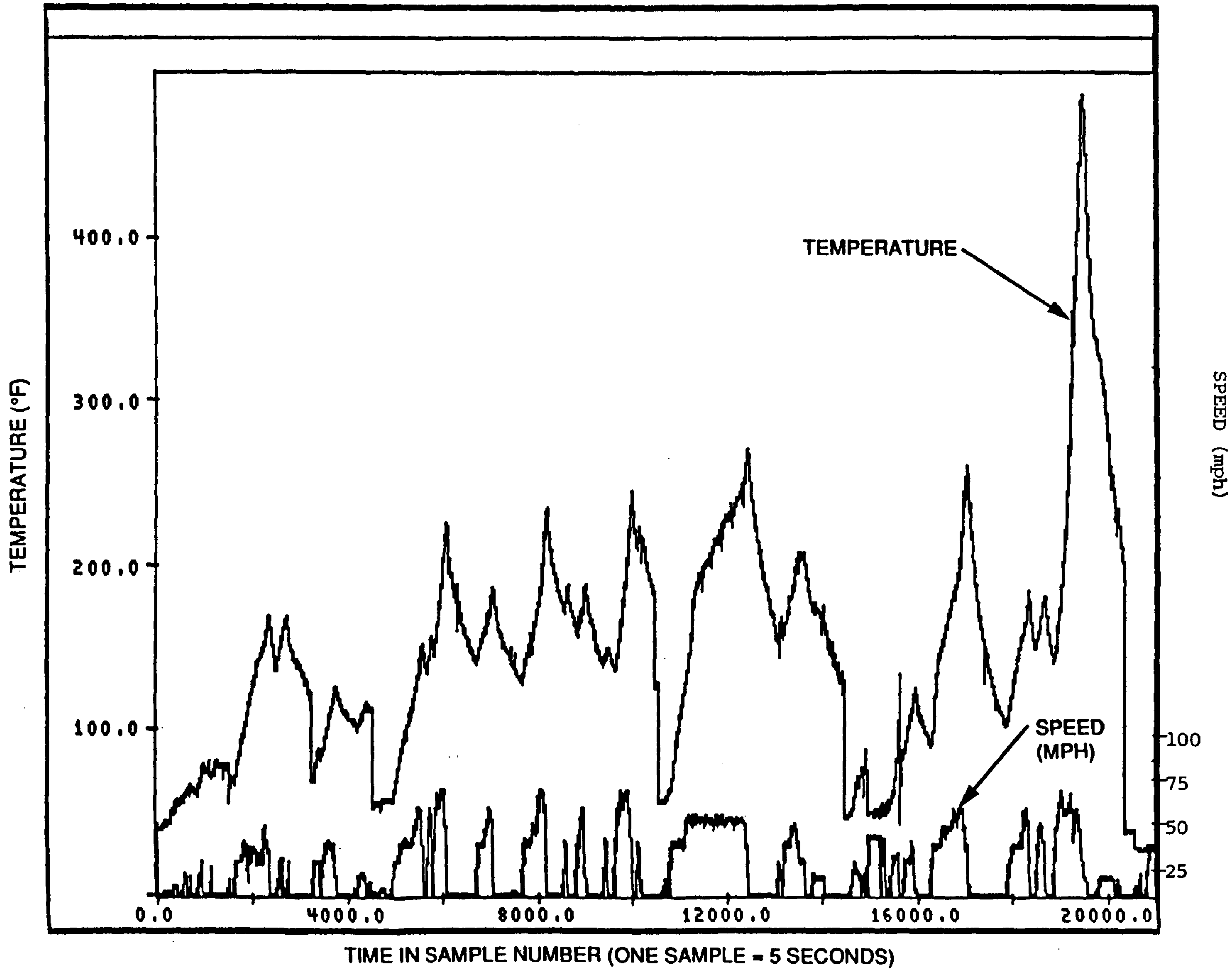
BEARING 42R OUTBOARD RACE TEMPERATURE VS TIME



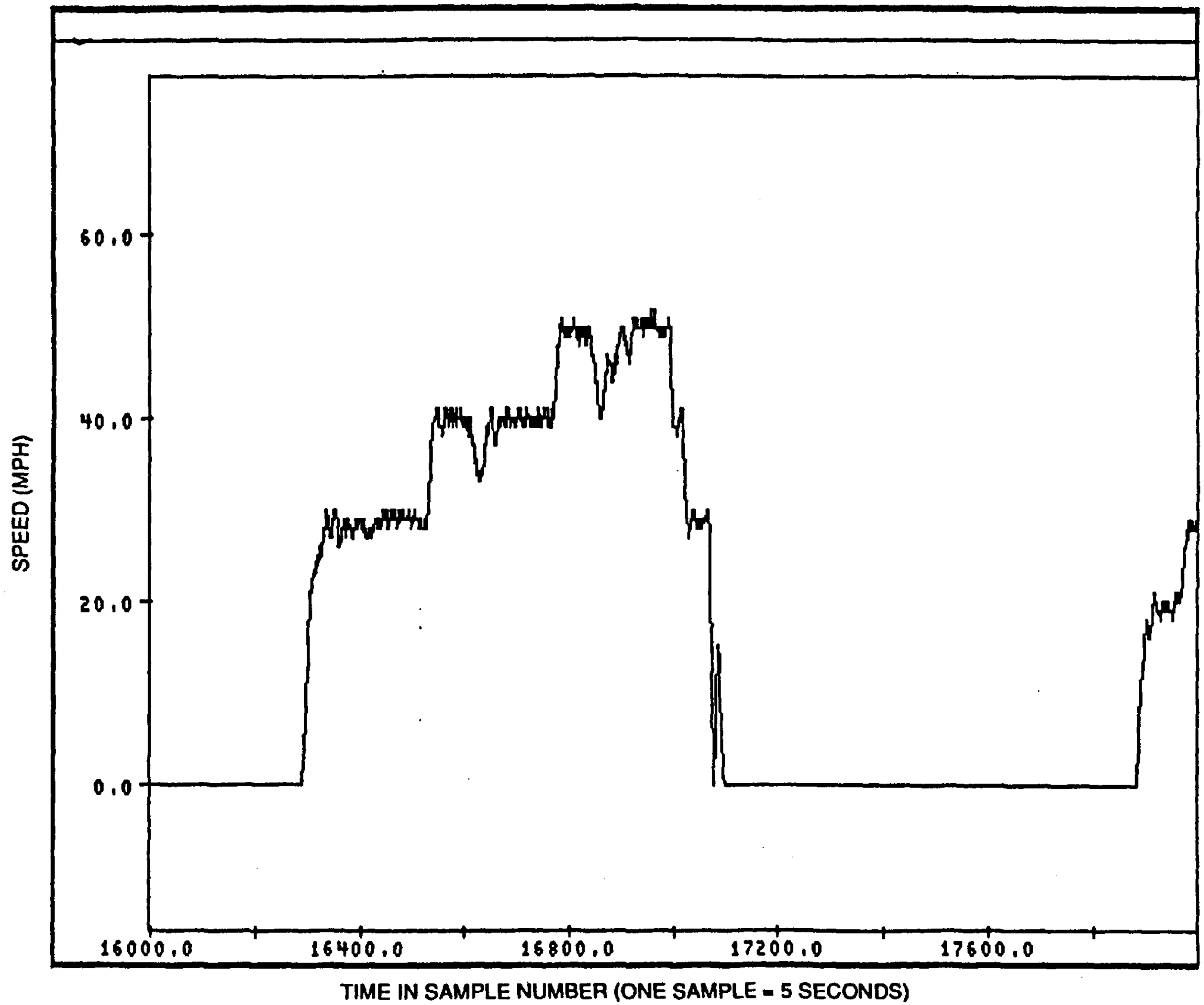
BEARING 42R INBOARD RACE TEMPERATURE VS TIME



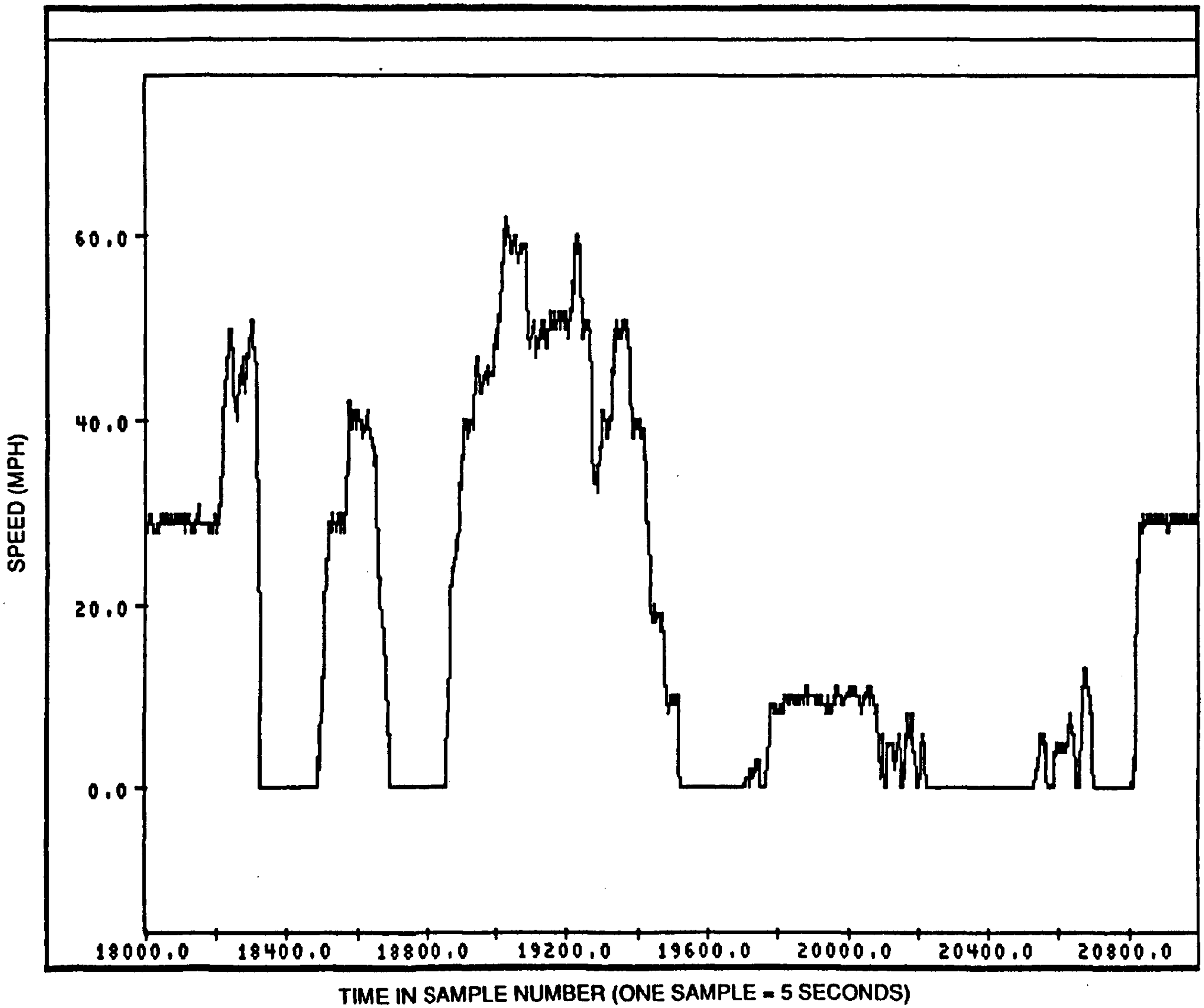
BEARING 42R TOP OF CUP TEMPERATURE VS TIME



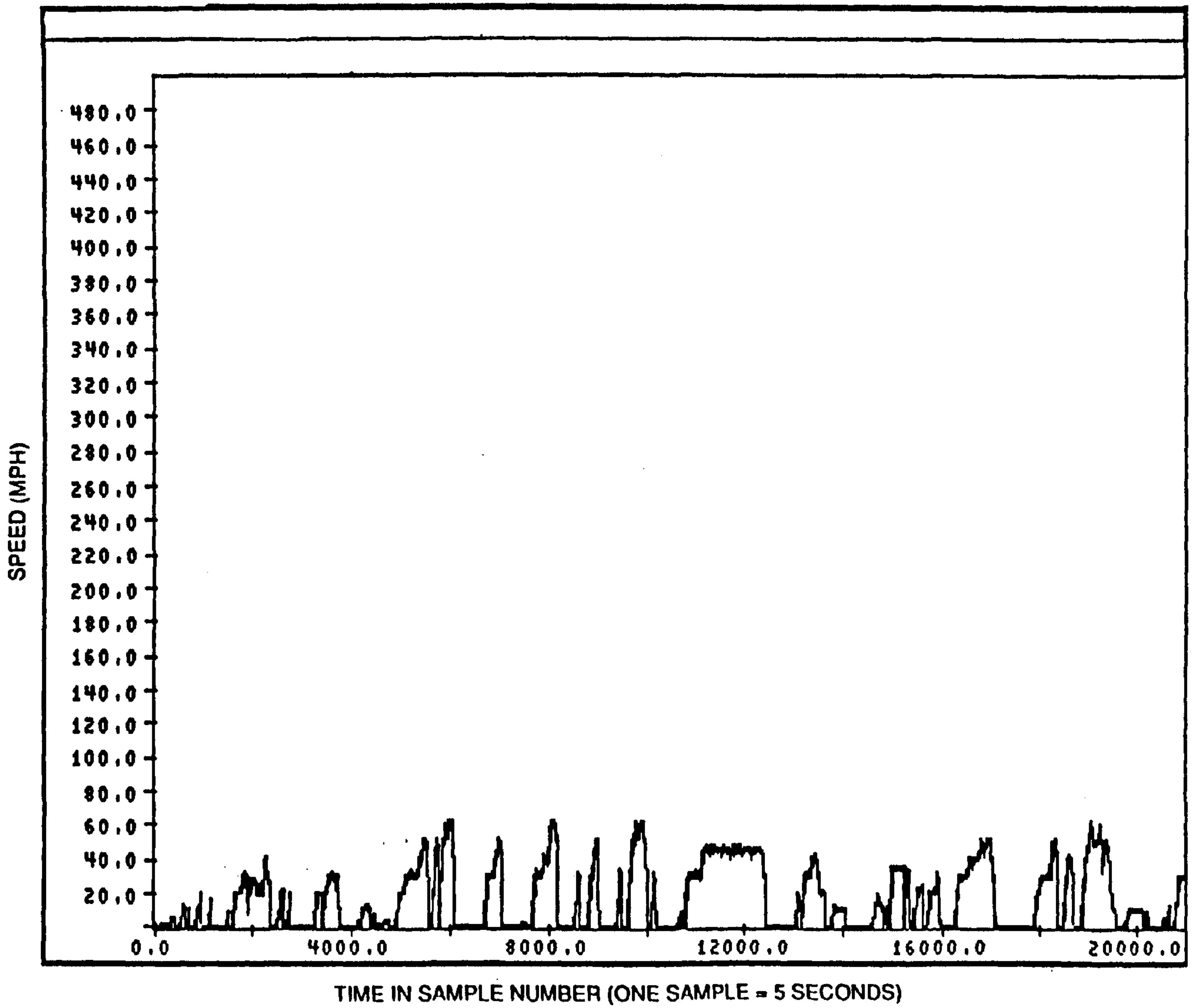
SPEED VS TIME



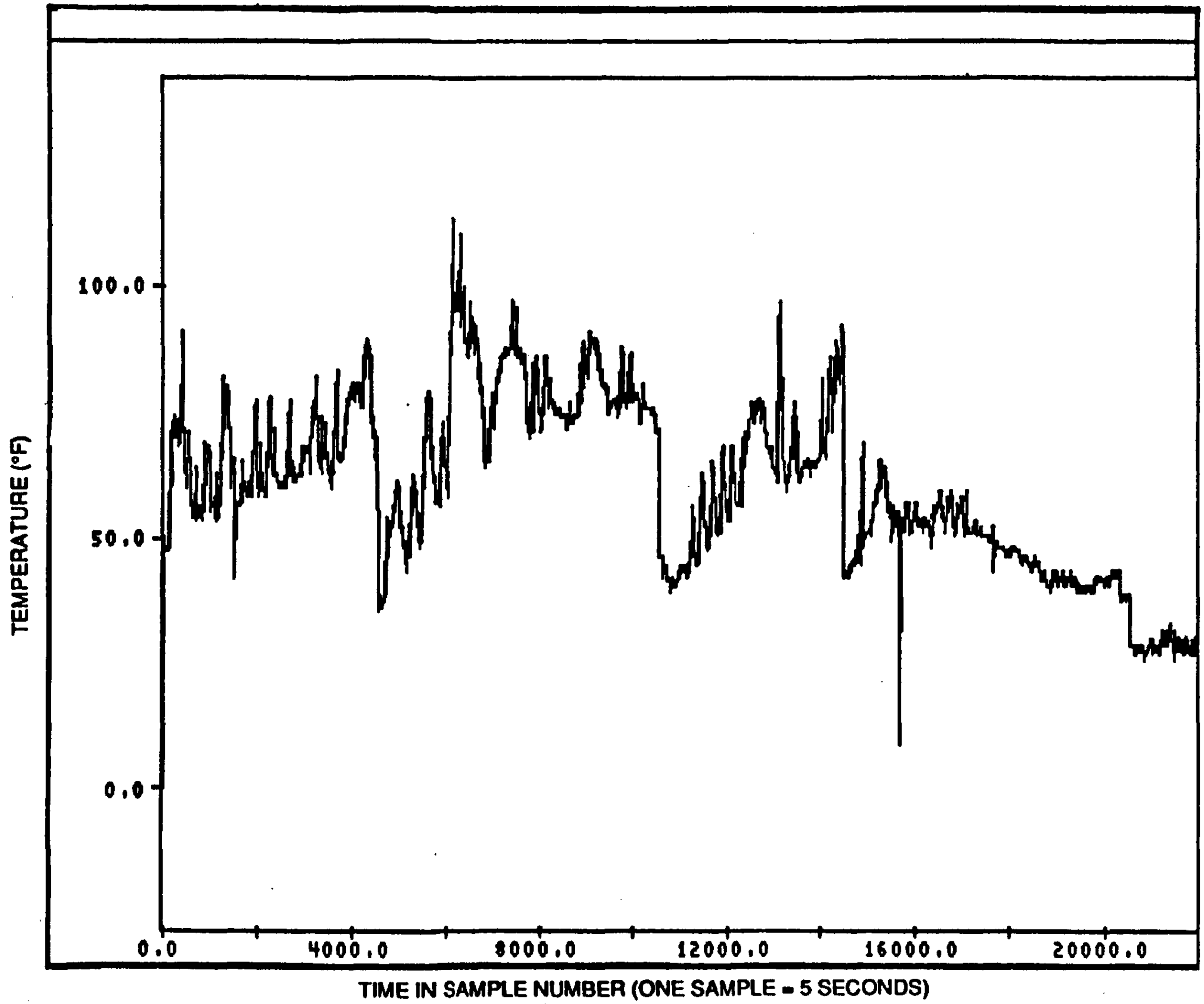
SPEED VS TIME



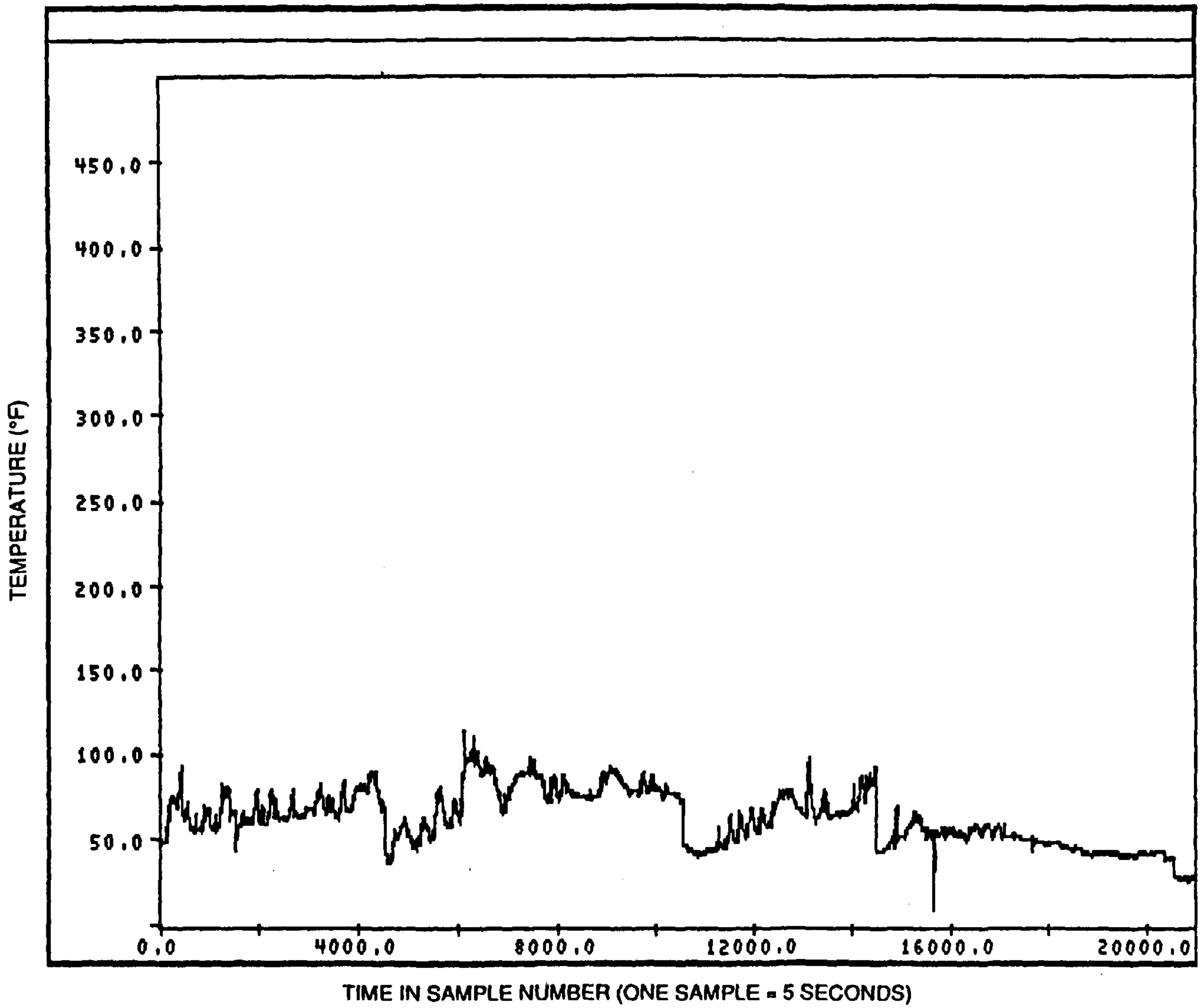
SPEED VS TIME



AMBIENT TEMPERATURE VS TIME

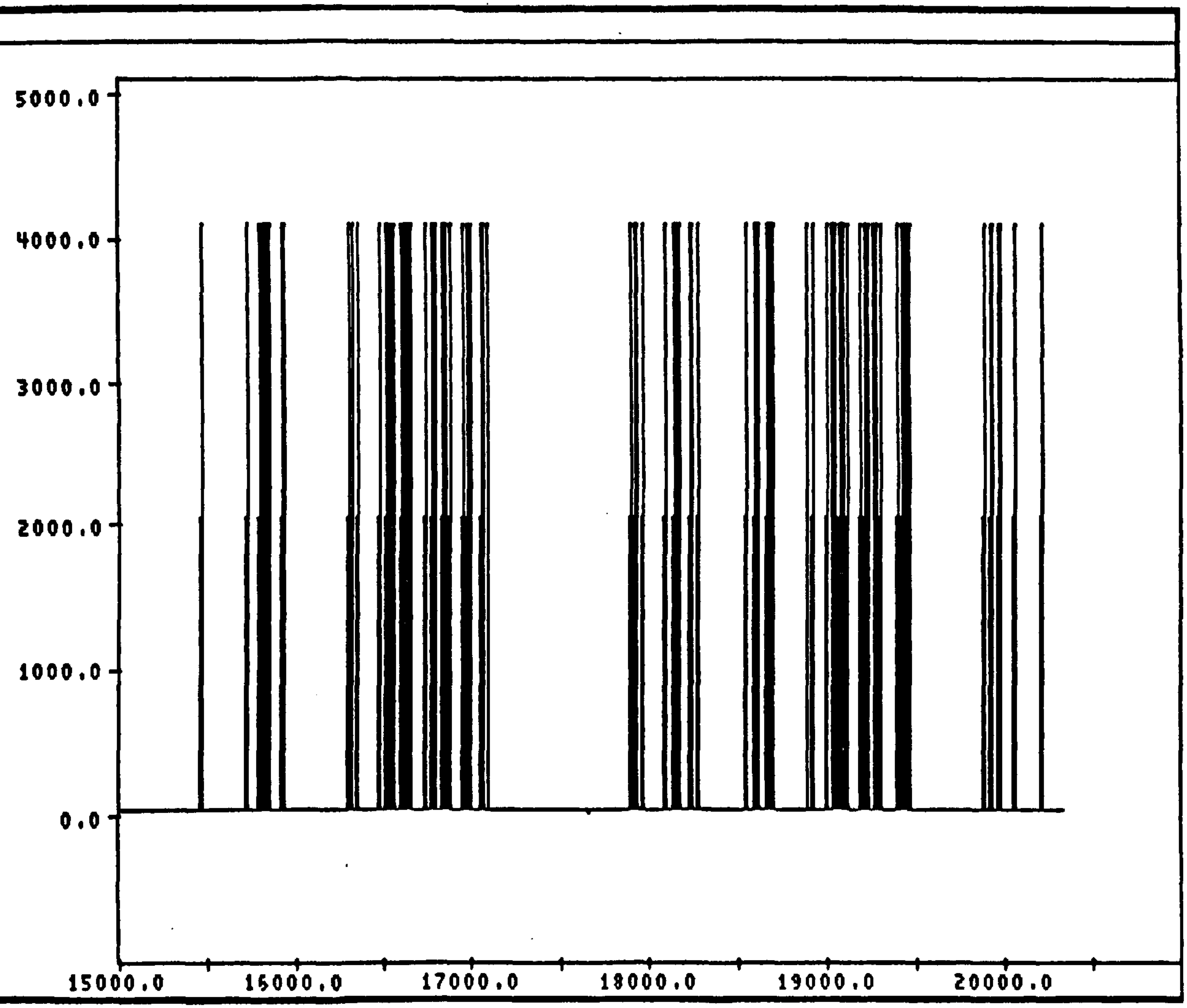


AMBIENT TEMPERATURE VS TIME



ALD FOR 3/15

14980L5356

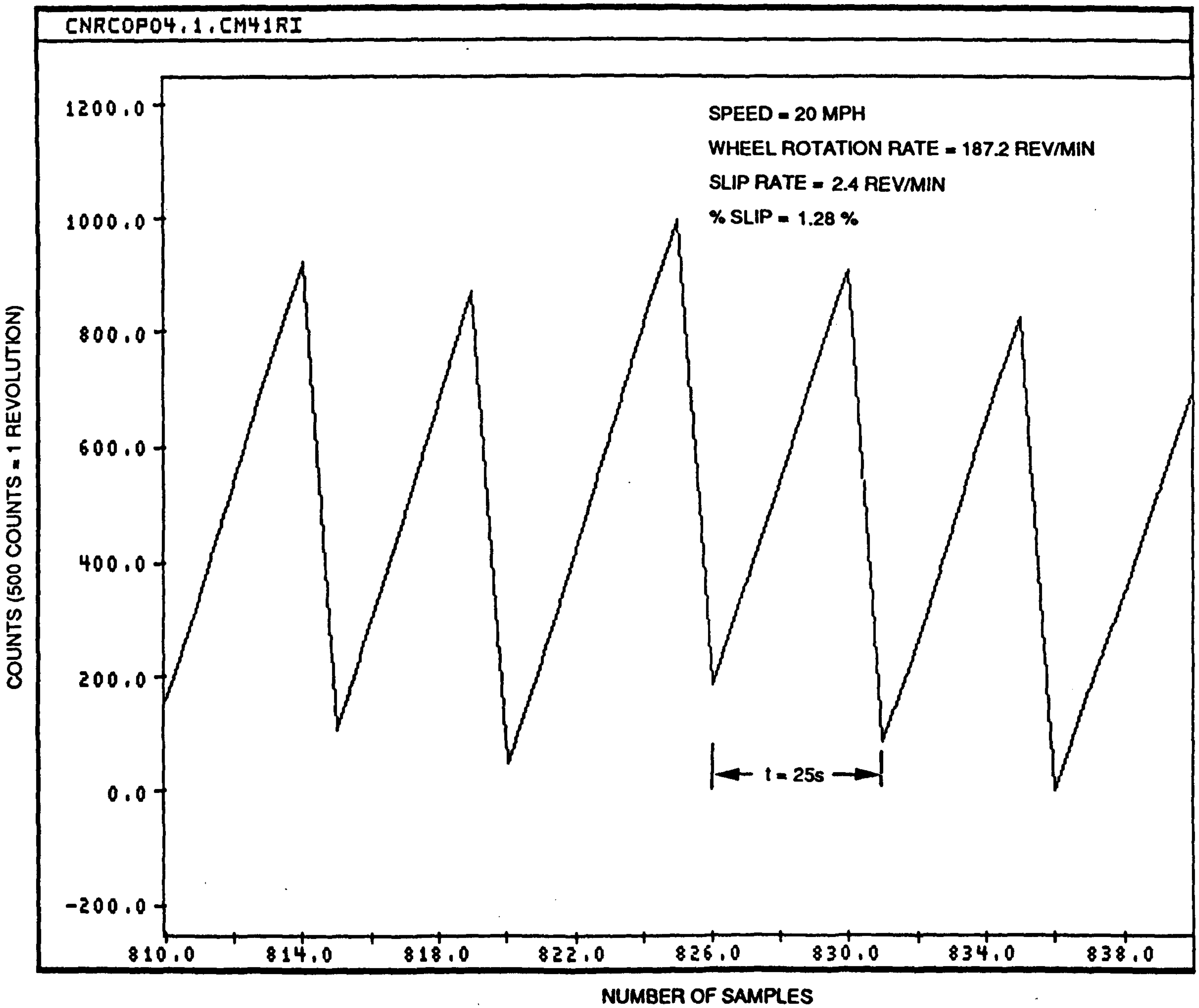


TIME IN SAMPLE NUMBER (ONE SAMPLE = 5 SECONDS)

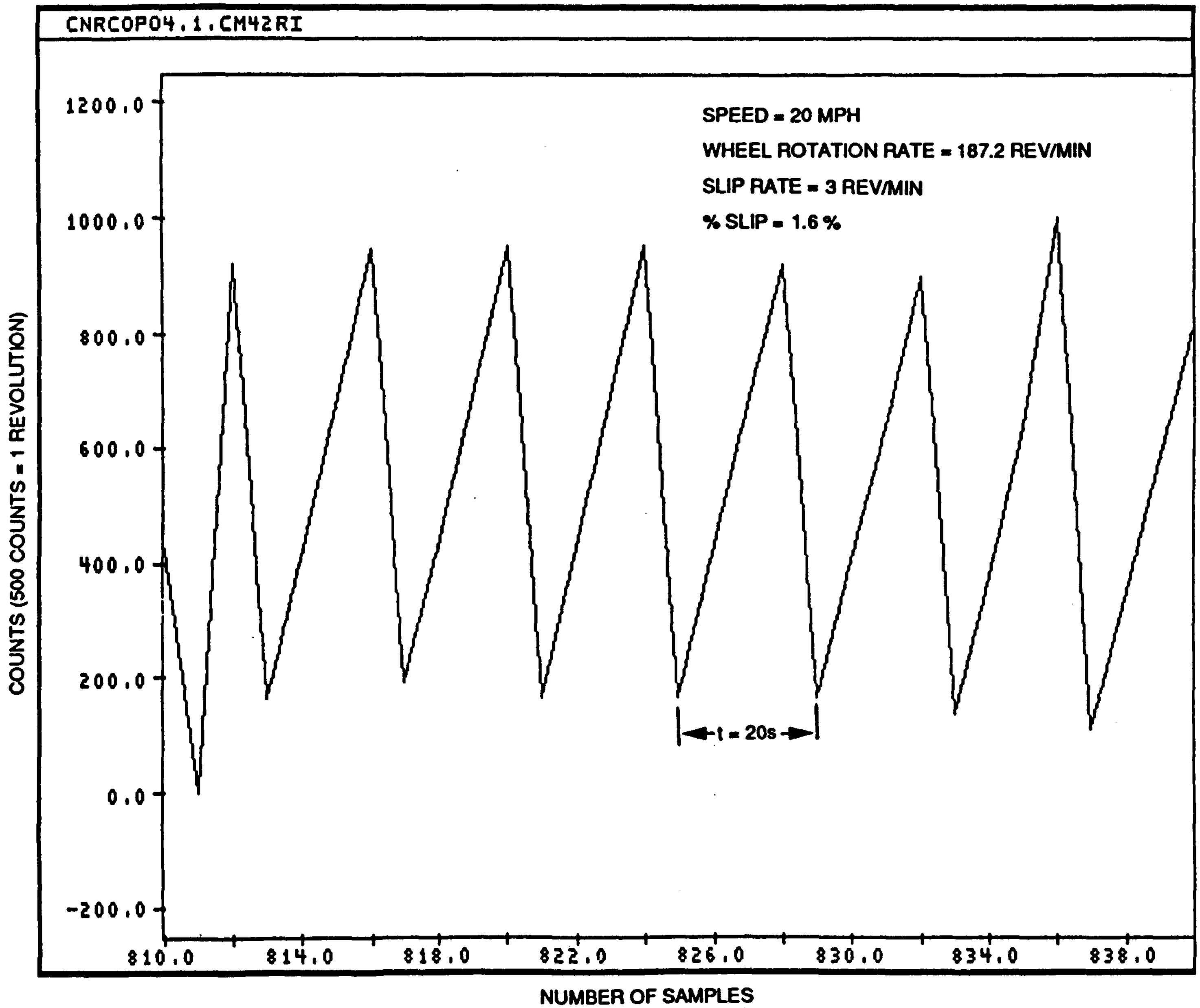
APPENDIX C

BEARING RACE ROTATION ANGLE (CONE MOTION)

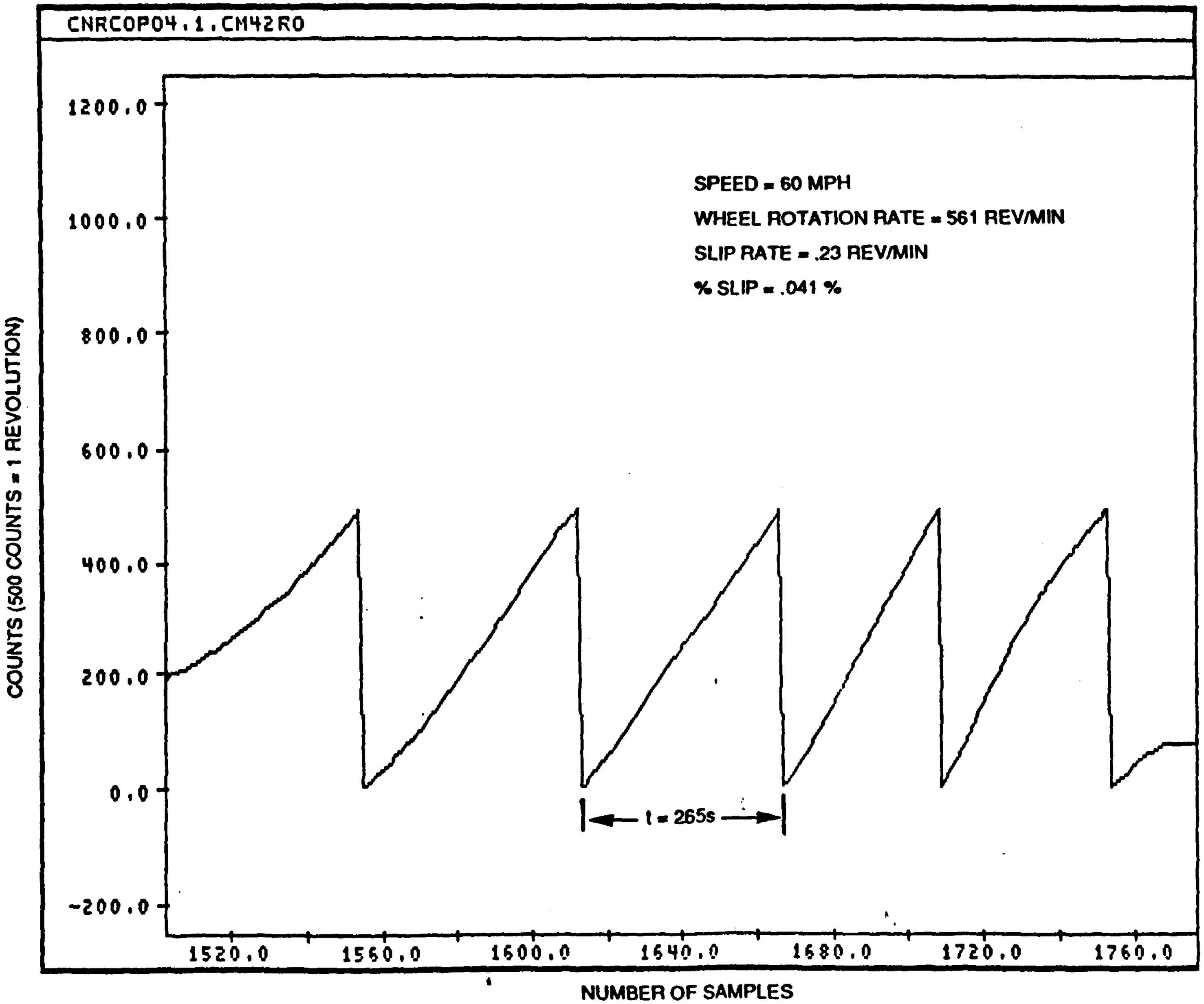
BEARING RACE ROTATION ANGLE
CAR 4 AXLE 1 RIGHT INSIDE



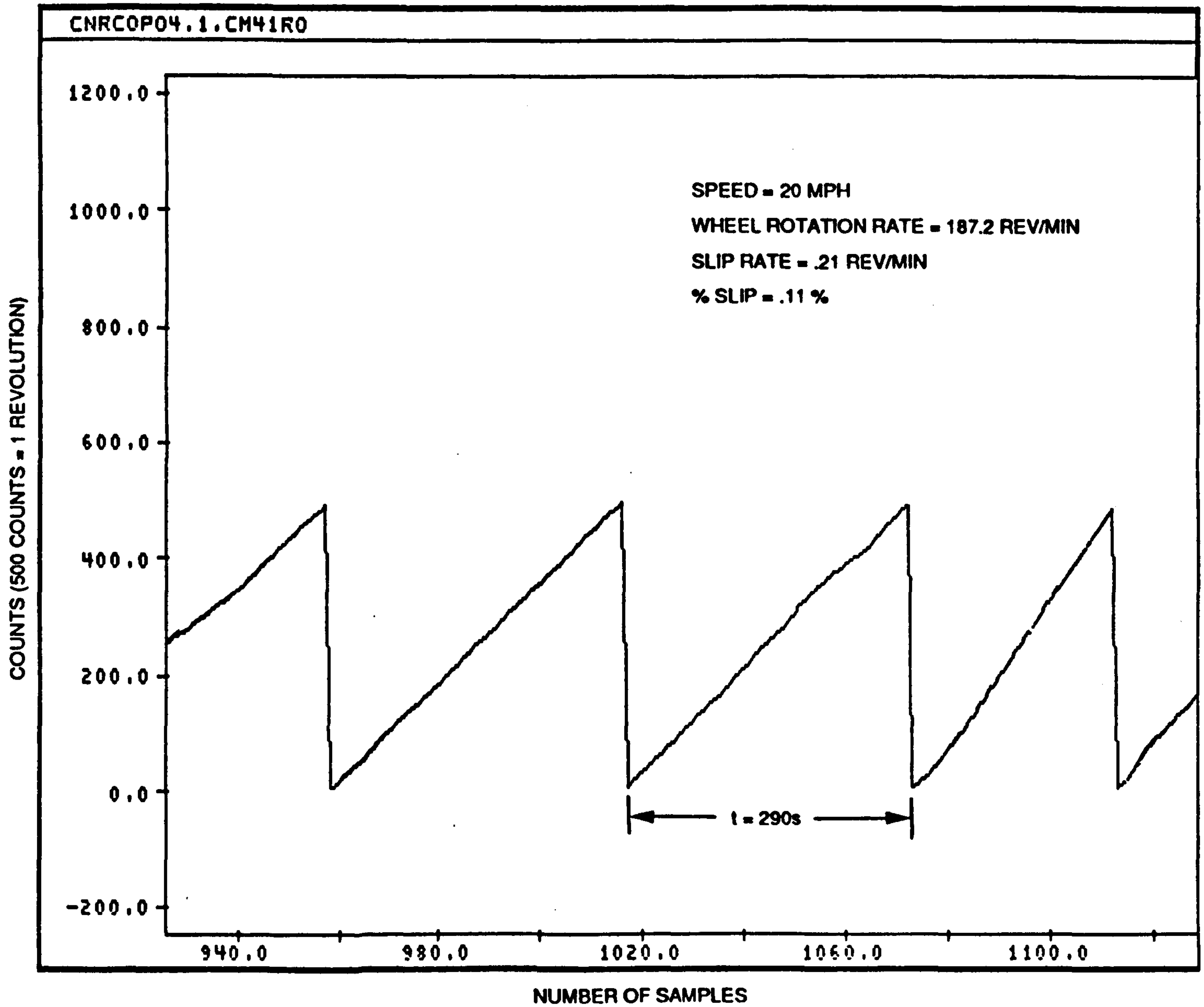
BEARING RACE ROTATION ANGLE
CAR 4 AXLE 2 RIGHT INSIDE



BEARING RACE ROTATION ANGLE
CAR 4 AXLE 2 RIGHT OUTSIDE

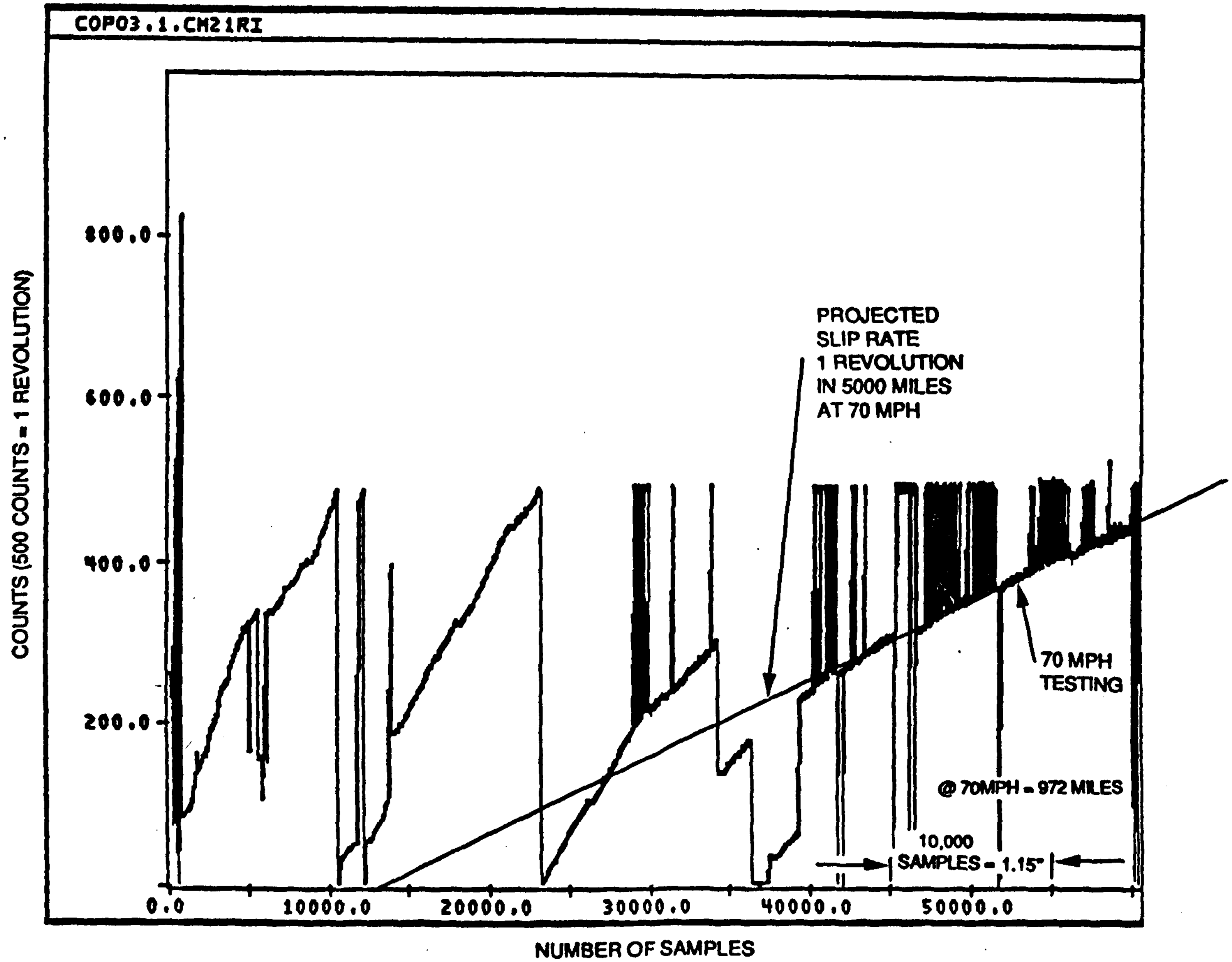


BEARING RACE ROTATION ANGLE
CAR 4 AXLE 1 RIGHT OUTSIDE

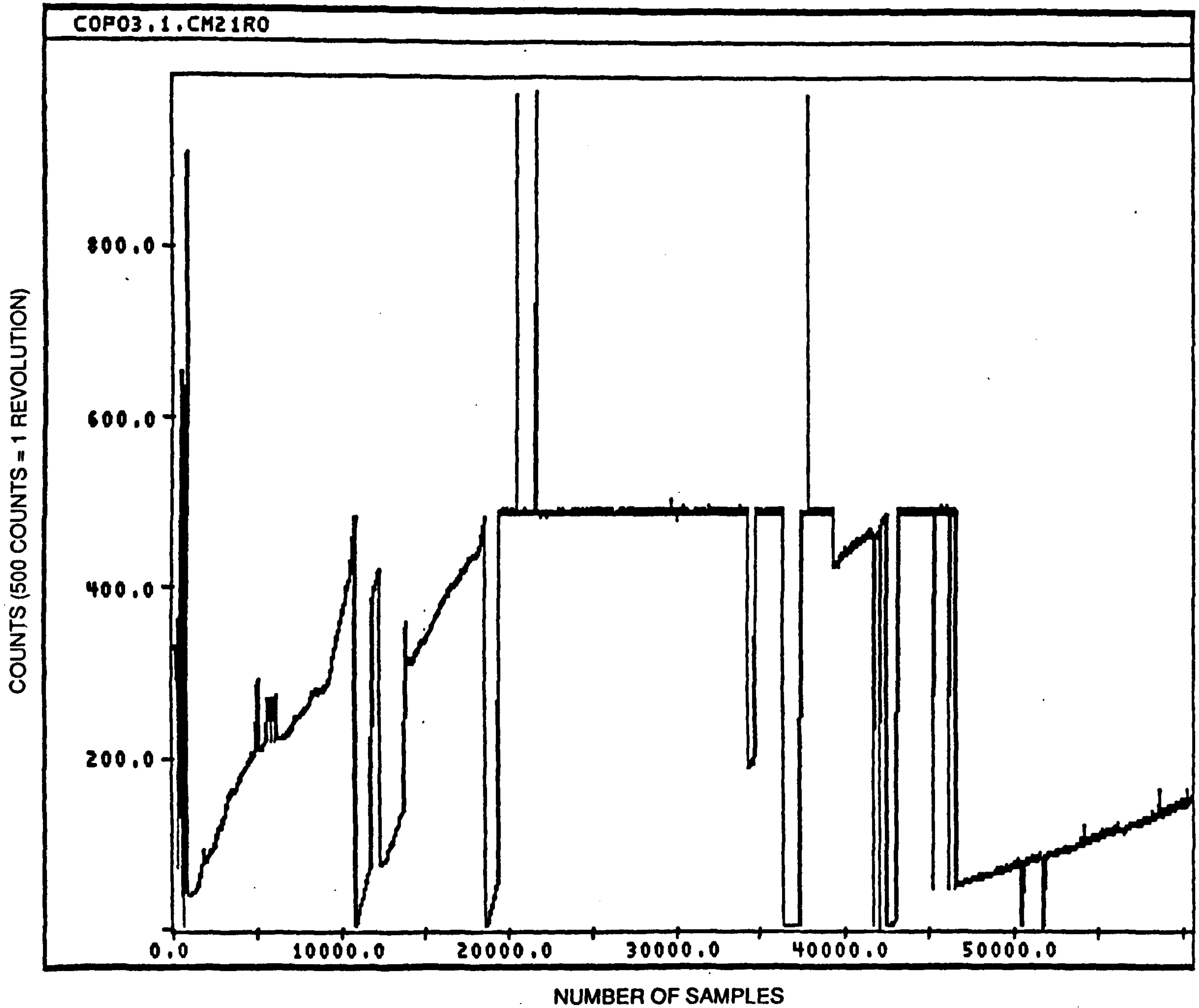


BEARING RACE ROTATION ANGLE

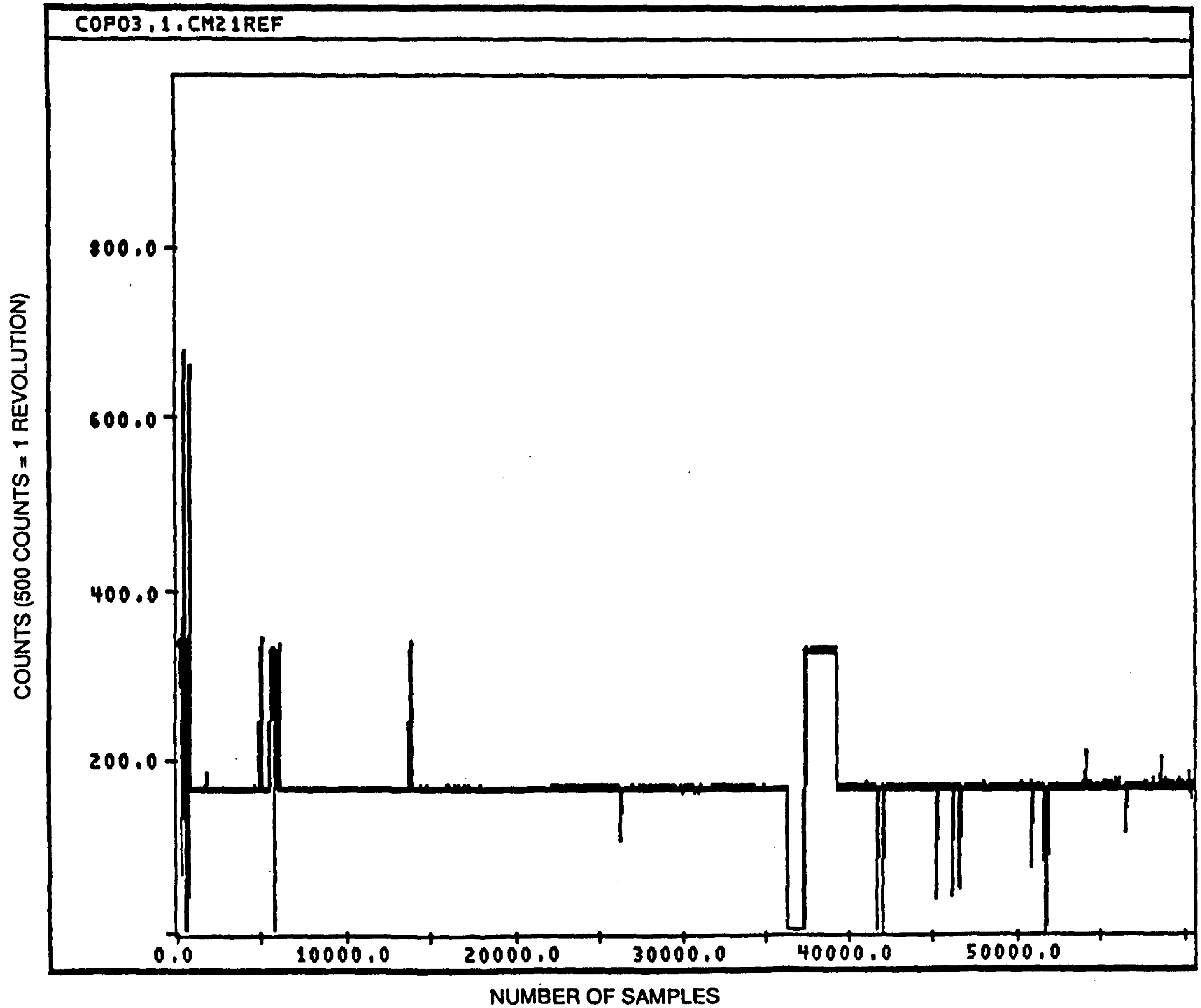
CAR 2 AXLE1 RIGHT INSIDE



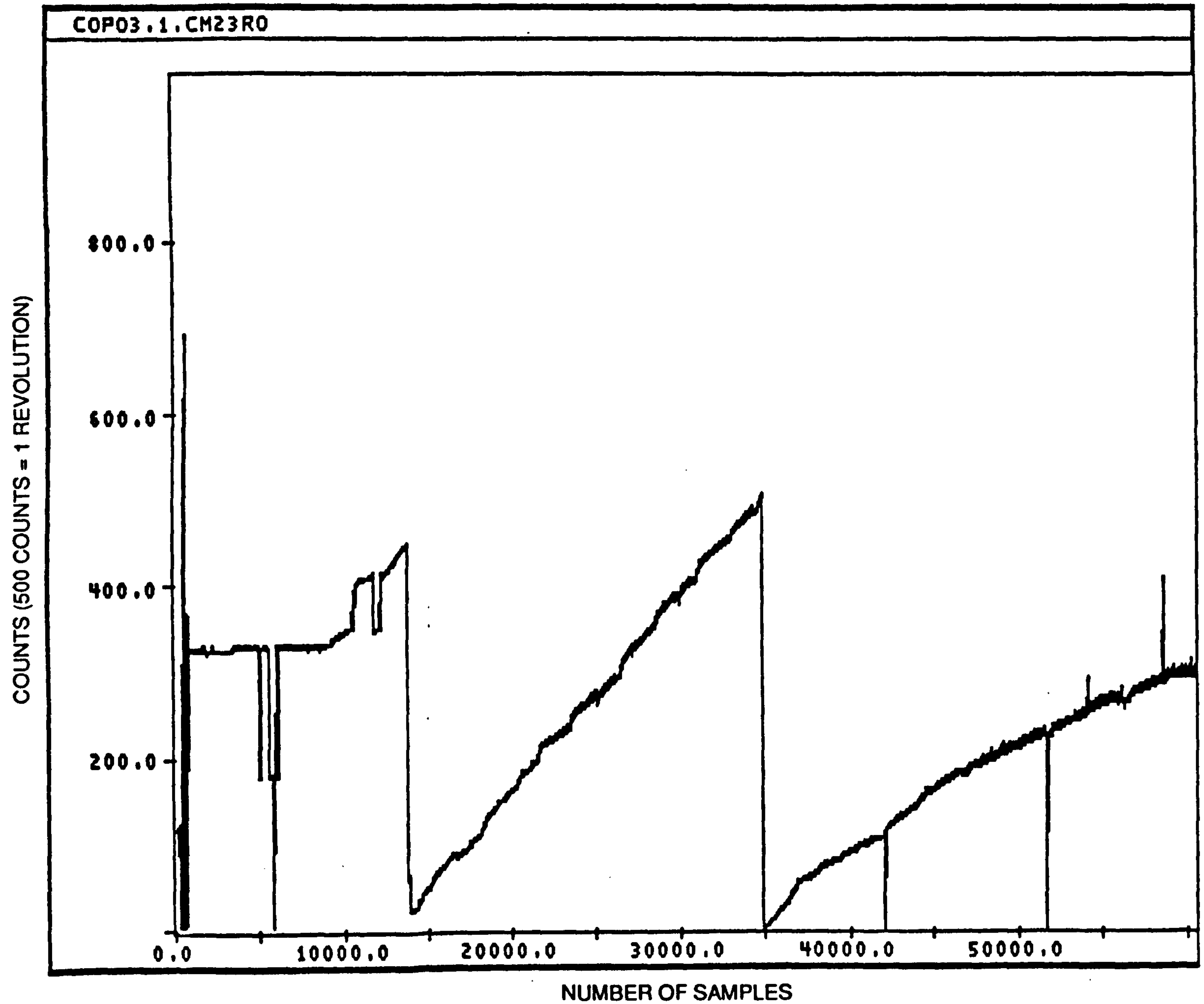
BEARING RACE ROTATION ANGLE
CAR 2 AXLE 1 RIGHT OUTSIDE



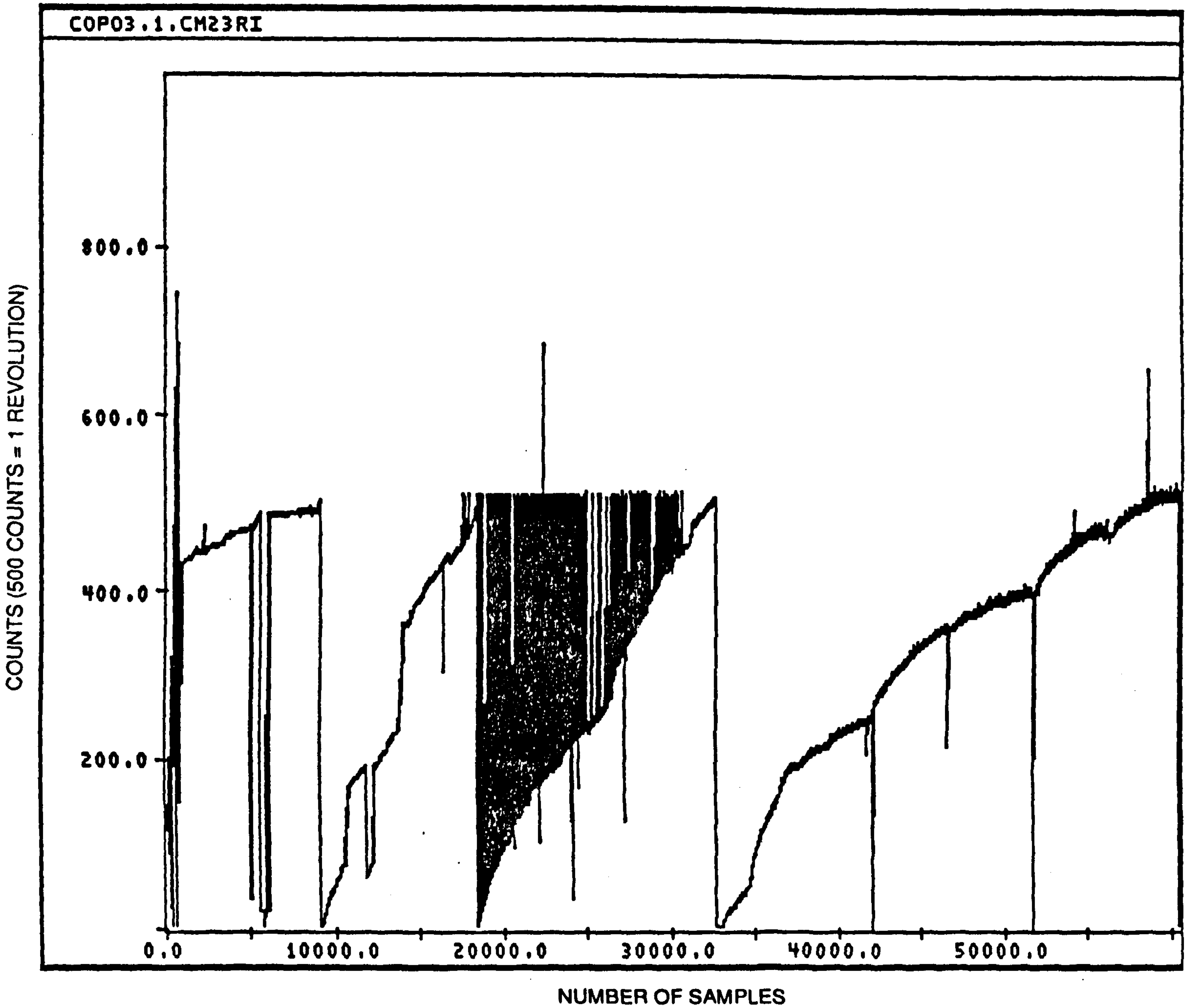
BEARING RACE ROTATION ANGLE
CAR 2   AXLE 1   REFERENCE



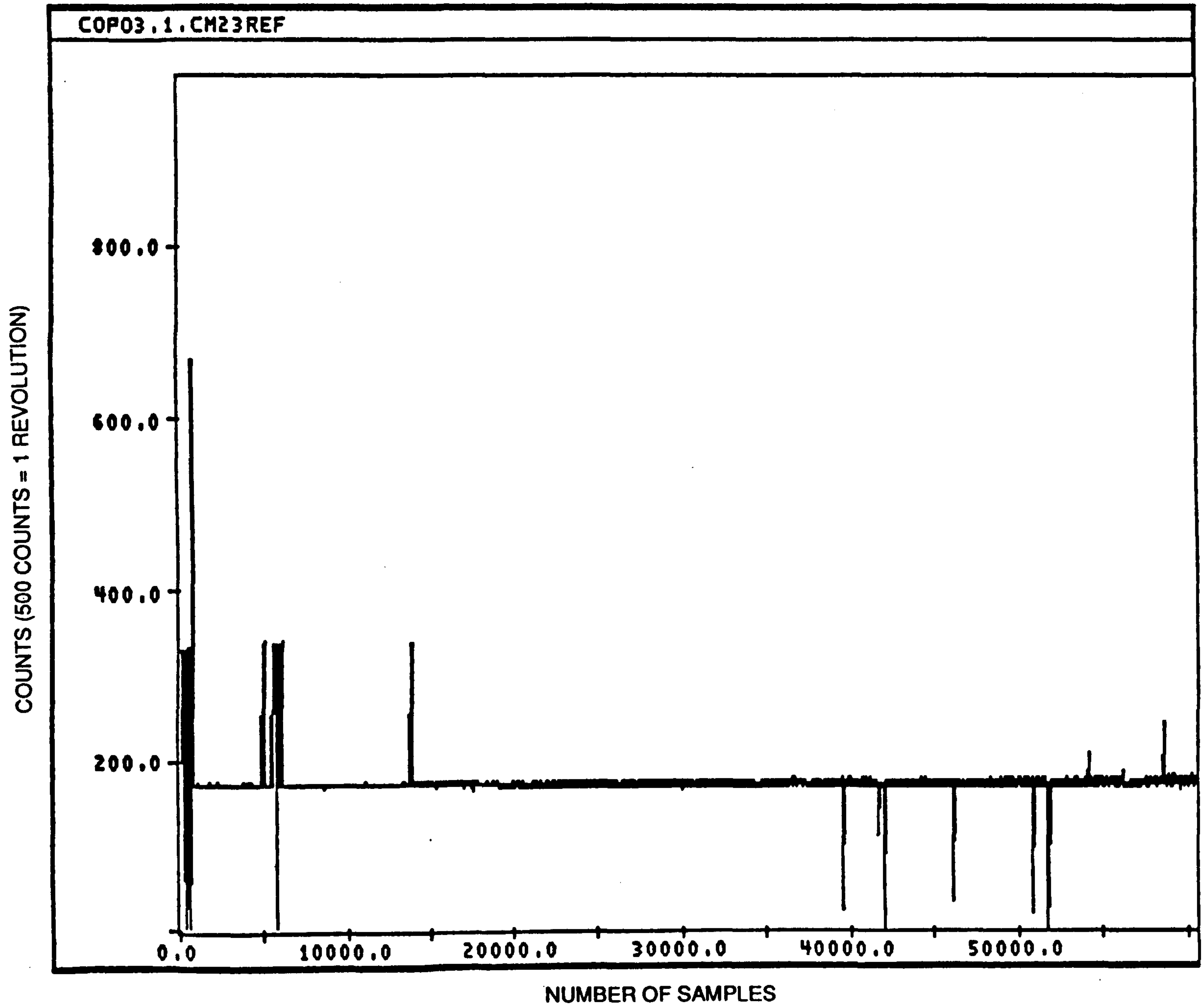
BEARING RACE ROTATION ANGLE
CAR 2 AXLE 3 RIGHT OUTSIDE



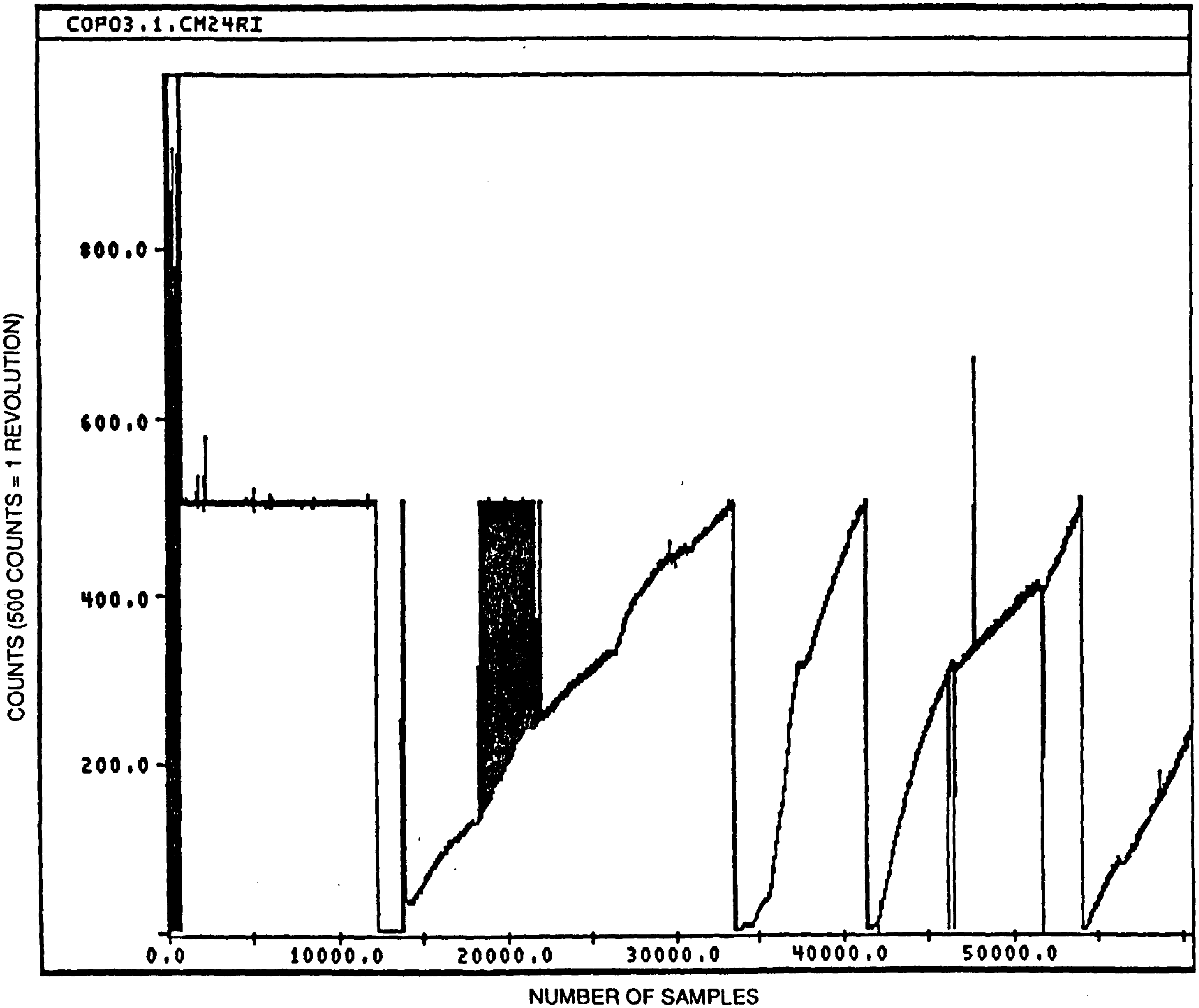
BEARING RACE ROTATION ANGLE
CAR 2 AXLE 3 RIGHT INSIDE



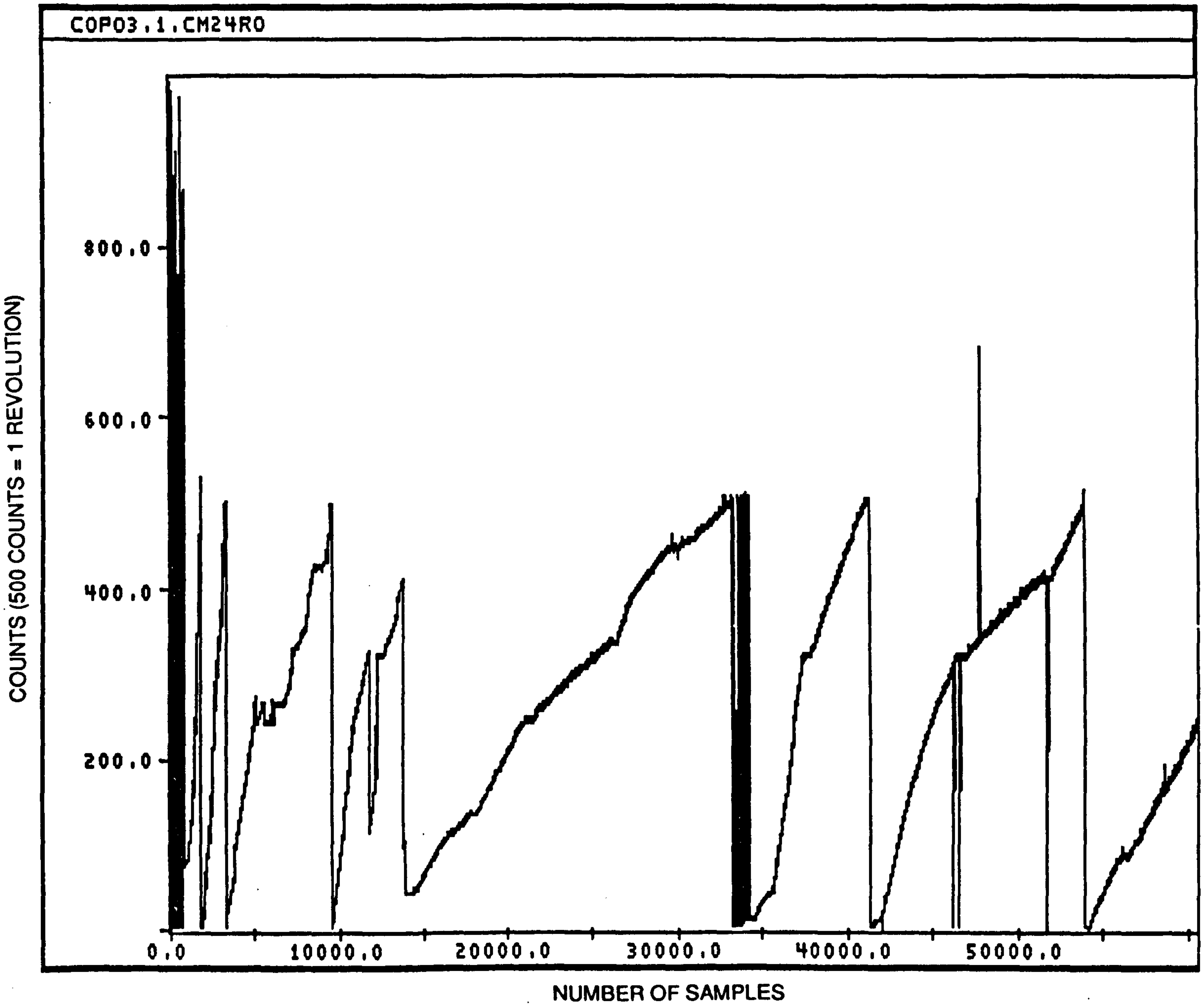
BEARING RACE ROTATION ANGLE
CAR 2 AXLE 3 REFERENCE



BEARING RACE ROTATION ANGLE
CAR 2 AXLE 4 RIGHT INSIDE

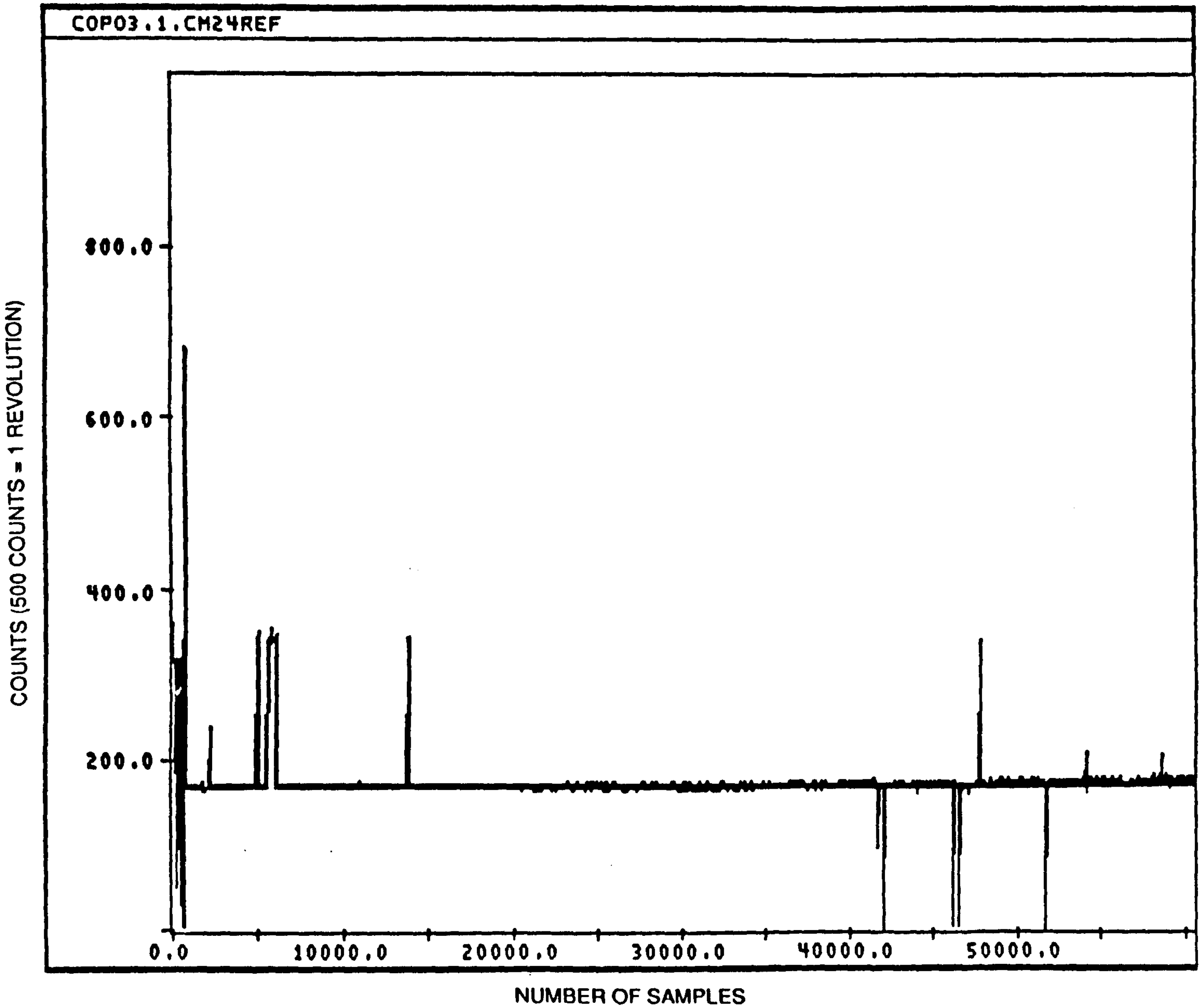


BEARING RACE ROTATION ANGLE
CAR 2 AXLE 4 RIGHT OUTSIDE



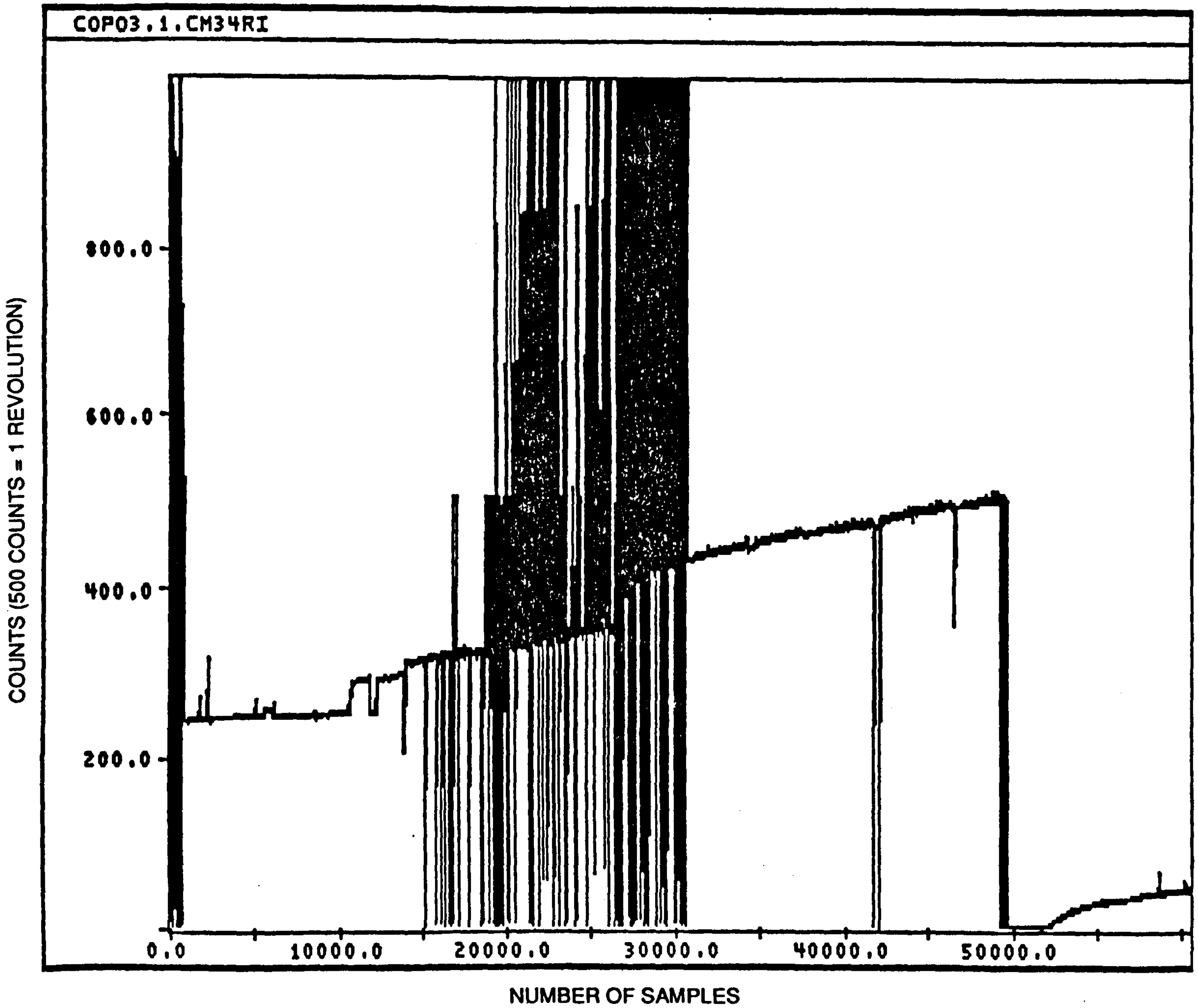
BEARING RACE ROTATION ANGLE

CAR 2 AXLE 4 REFERENCE

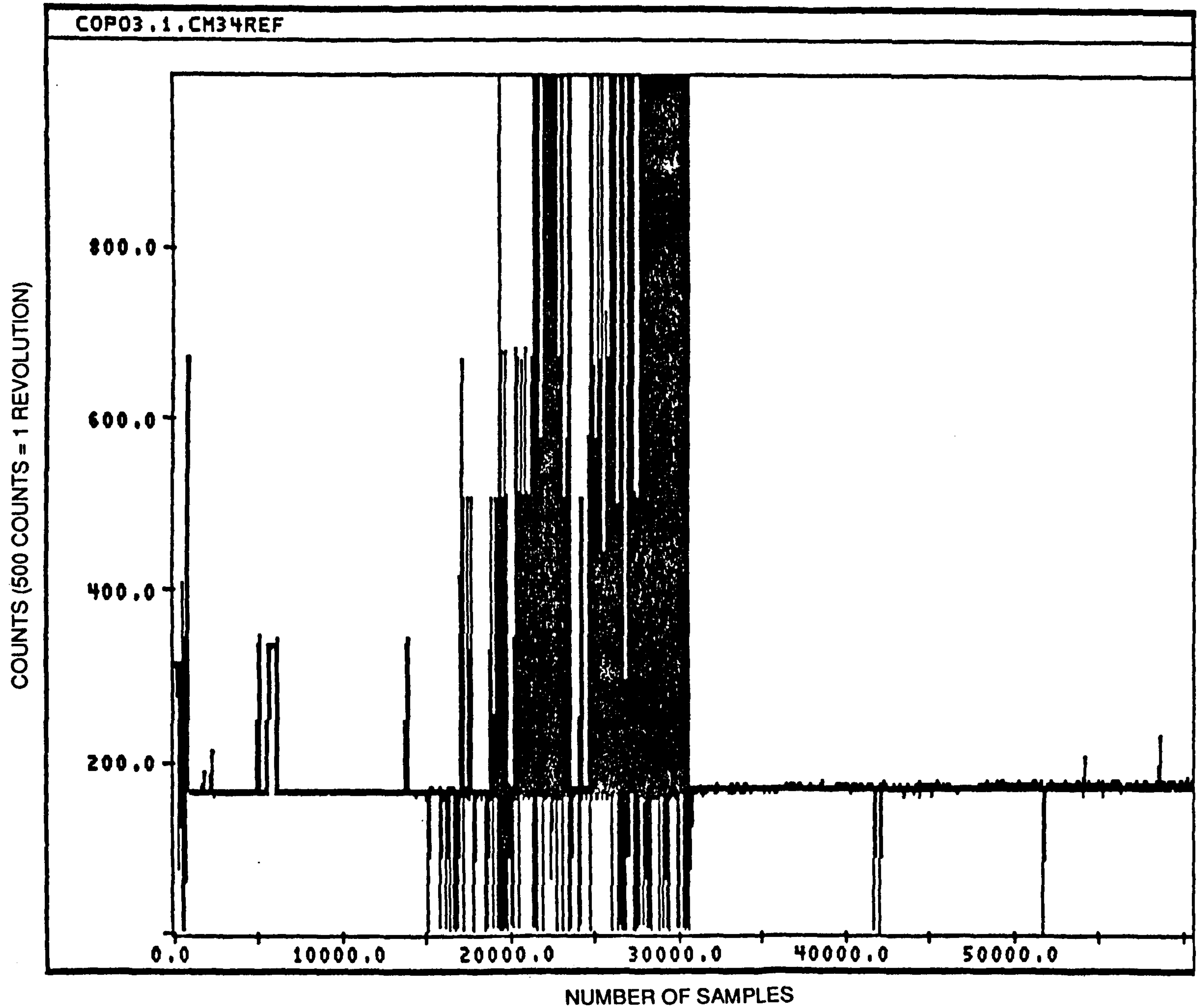


BEARING RACE ROTATION ANGLE

CAR 3 AXLE 3 RIGHT INSIDE

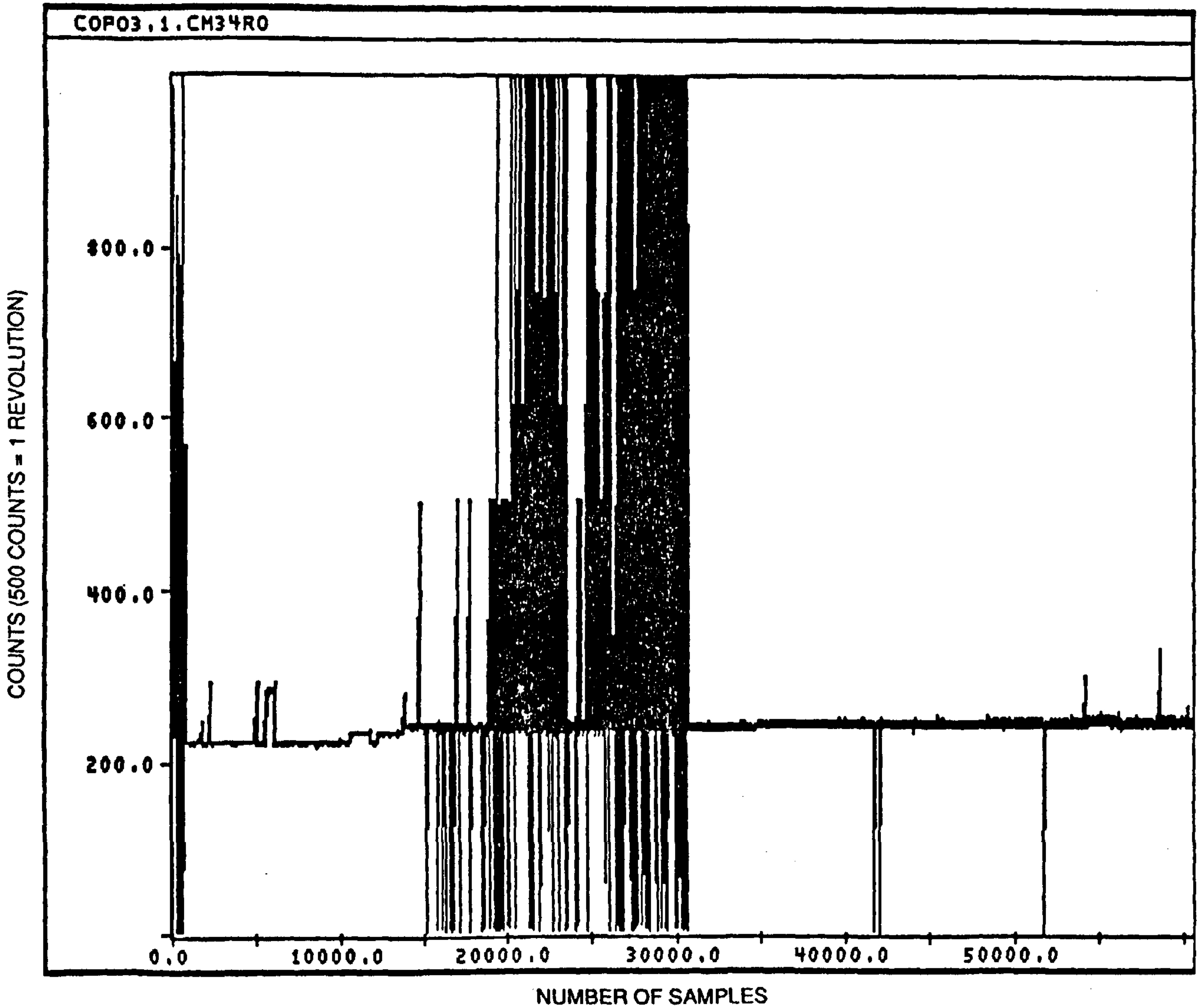


BEARING RACE ROTATION ANGLE
CAR 3 AXLE 4 REFERENCE



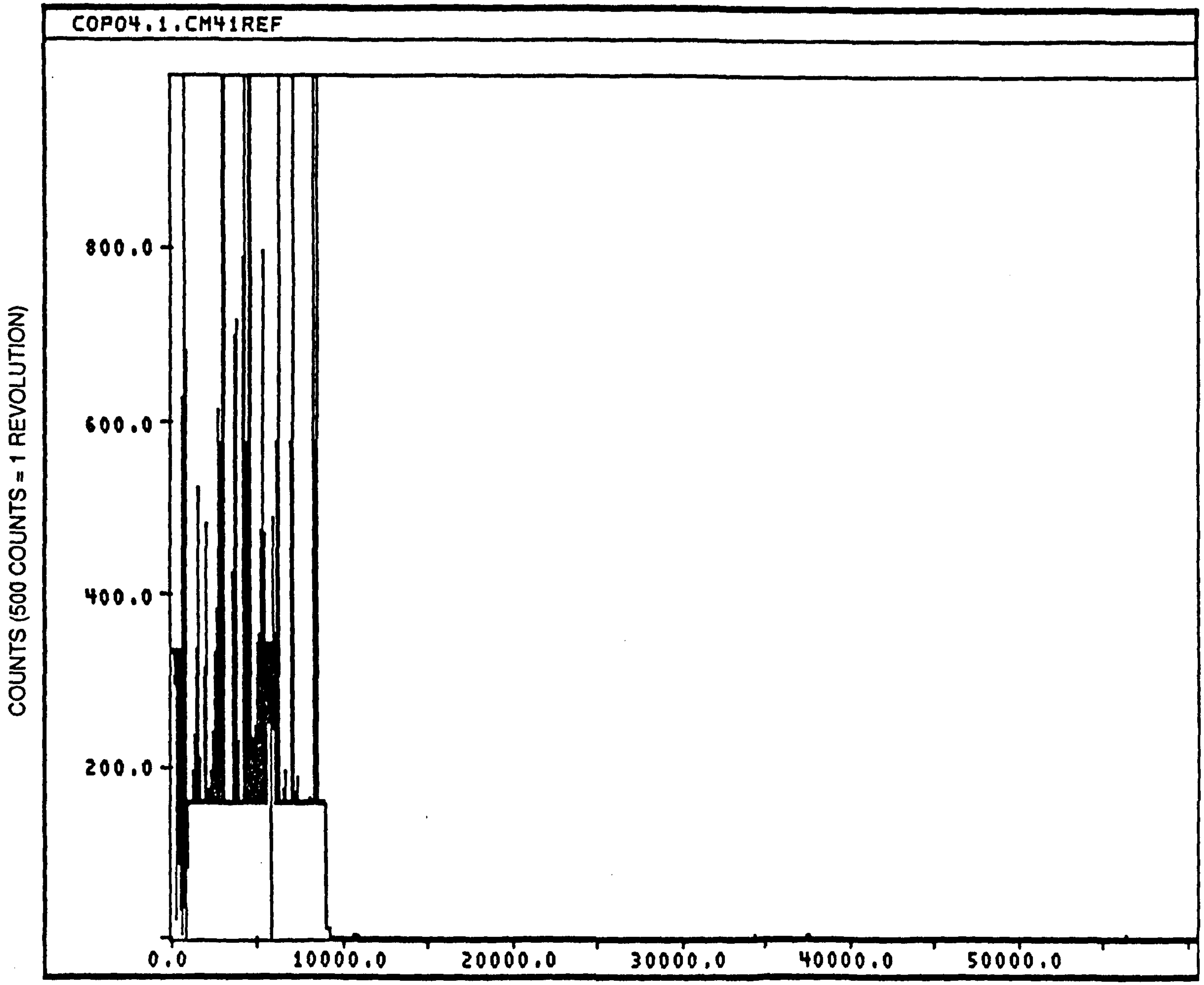
BEARING RACE ROTATION ANGLE

CAR 3 AXLE 4 RIGHT OUTSIDE



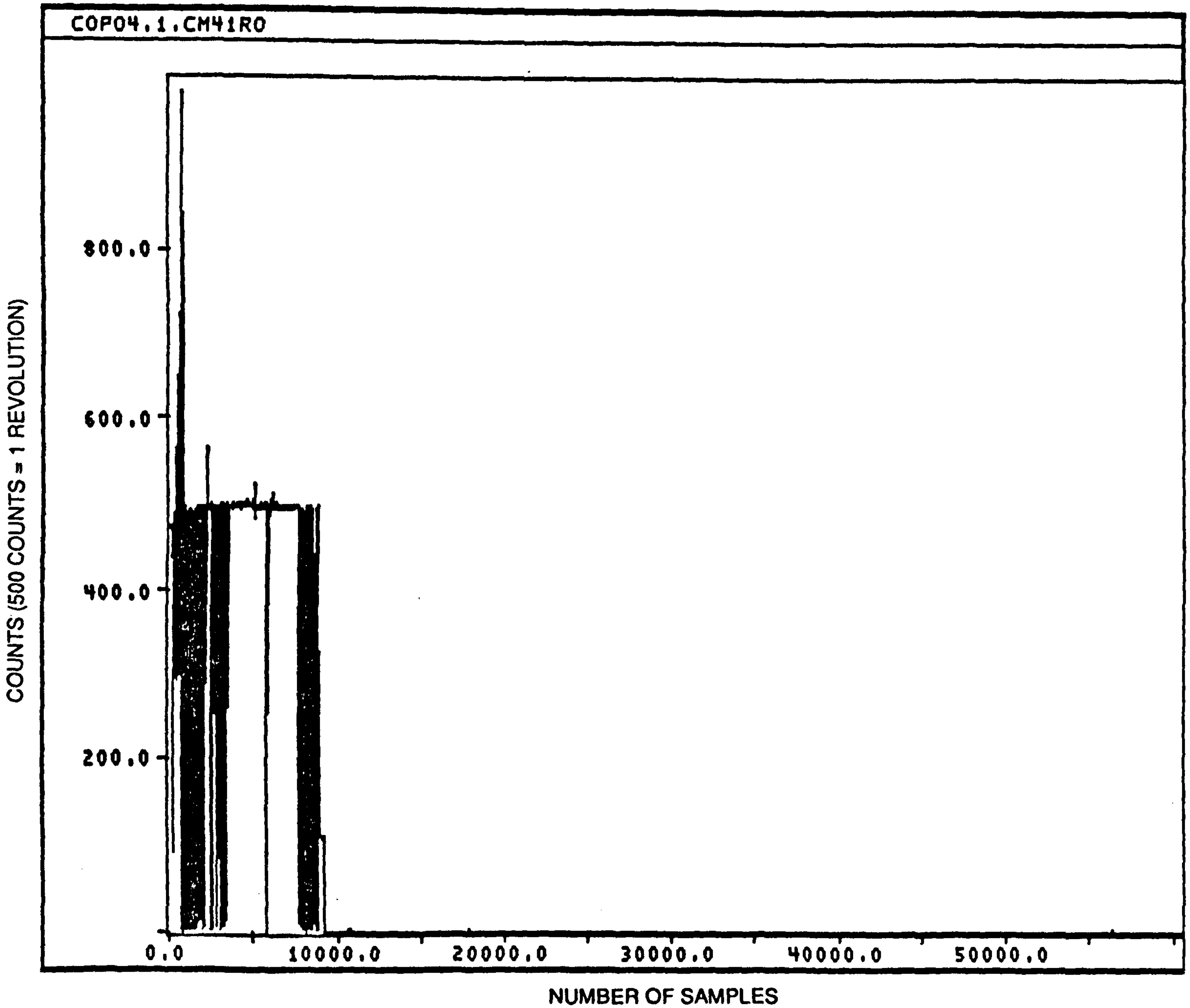
BEARING RACE ROTATION ANGLE

CAR 4 AXLE 1 REFERENCE

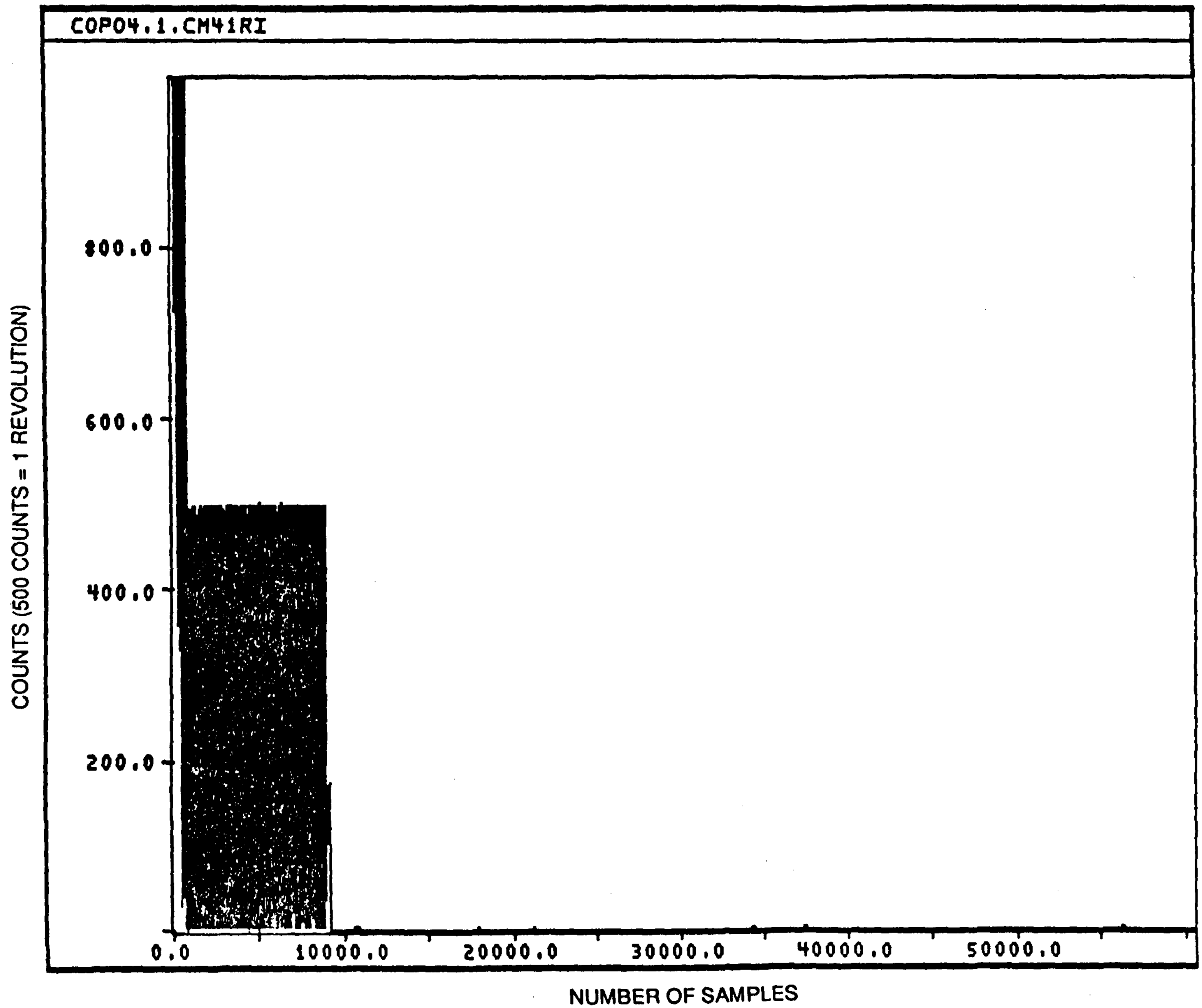


BEARING RACE ROTATION ANGLE

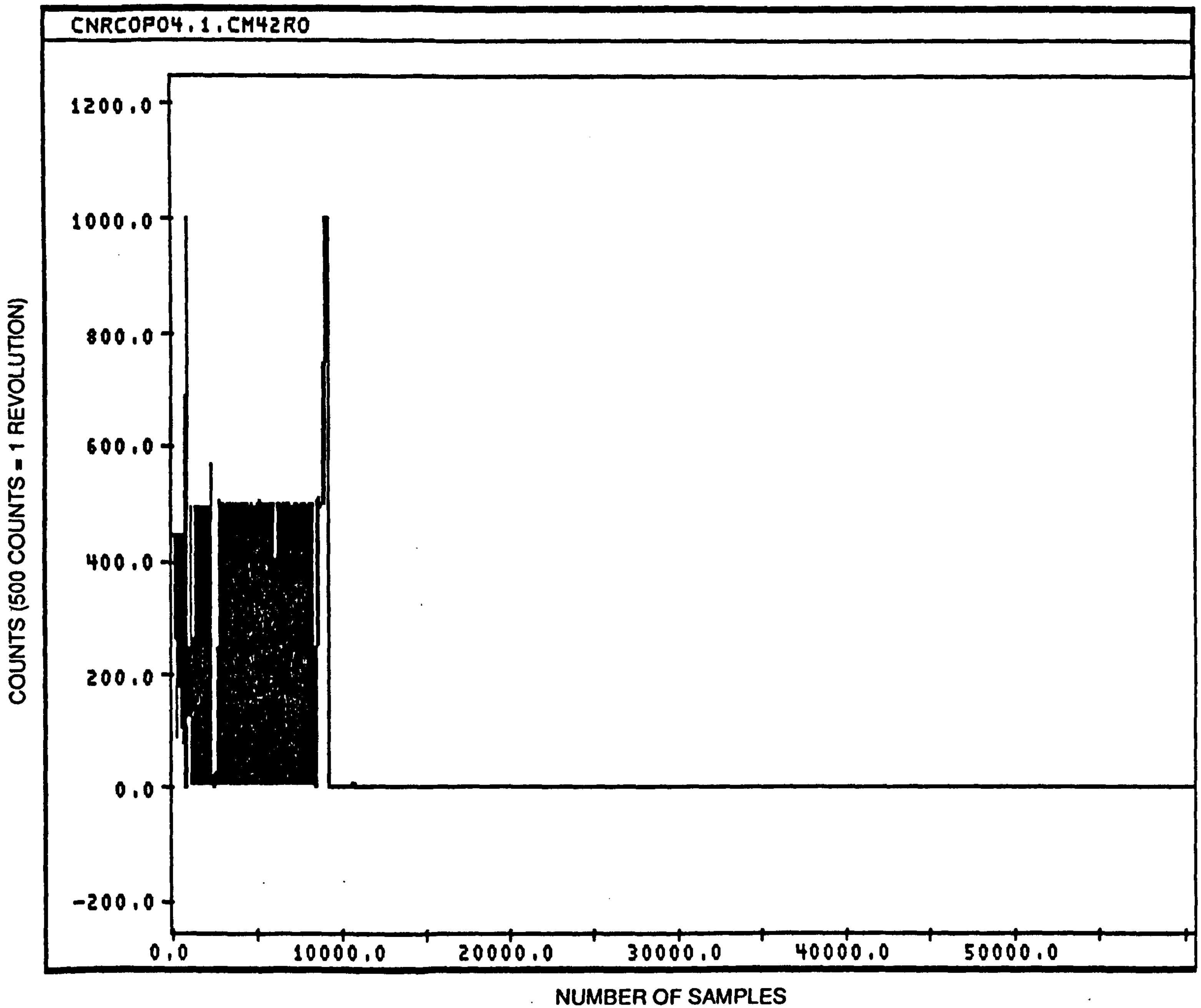
CAR 4 AXLE 1 RIGHT OUTSIDE



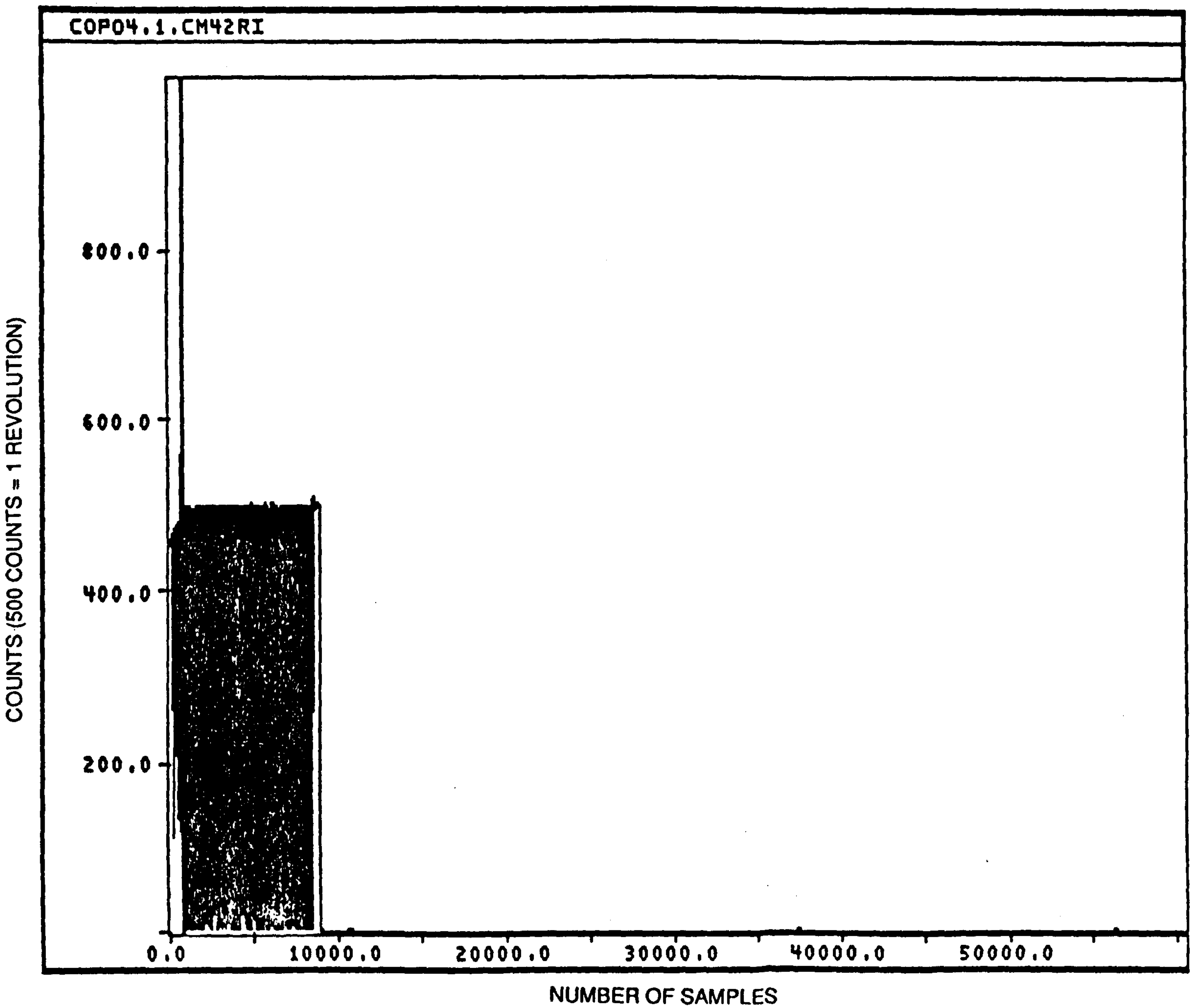
BEARING RACE ROTATION ANGLE
CAR 4 AXLE 1 RIGHT INSIDE



BEARING RACE ROTATION ANGLE
CAR 4 AXLE 2 RIGHT OUTSIDE

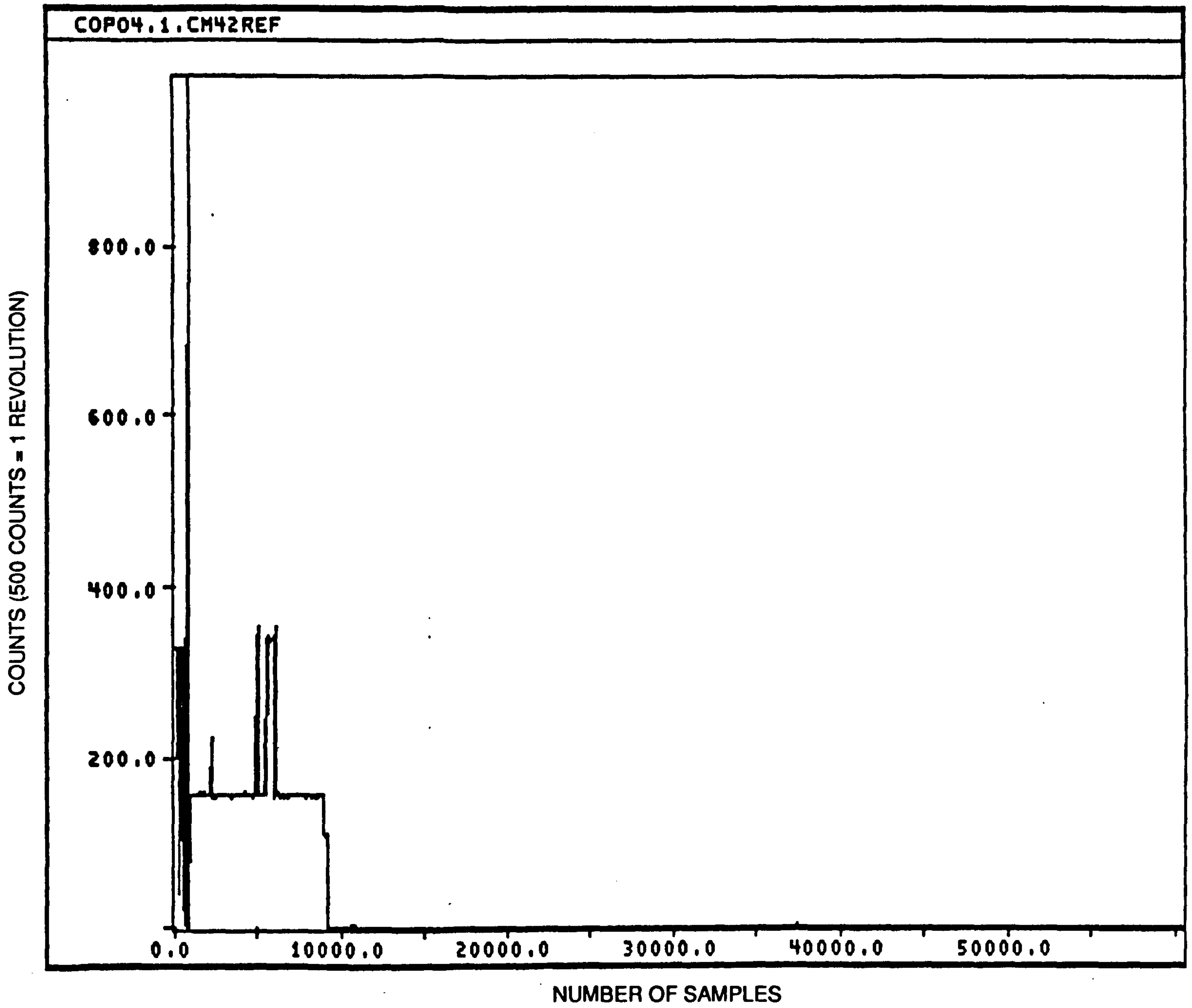


BEARING RACE ROTATION ANGLE
CAR 4 AXLE 2 RIGHT INSIDE

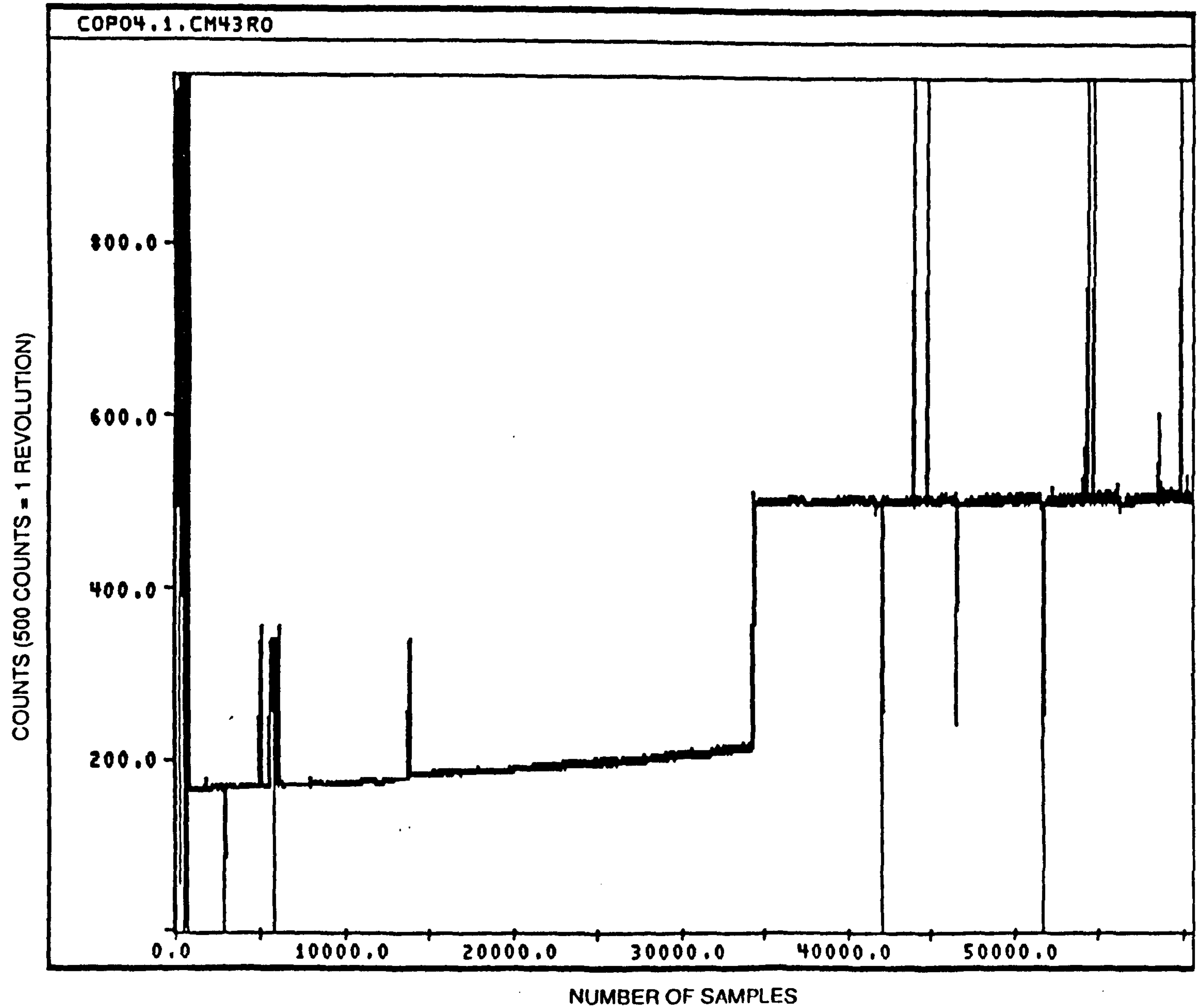


BEARING RACE ROTATION ANGLE

CAR 4 AXLE 2 REFERENCE

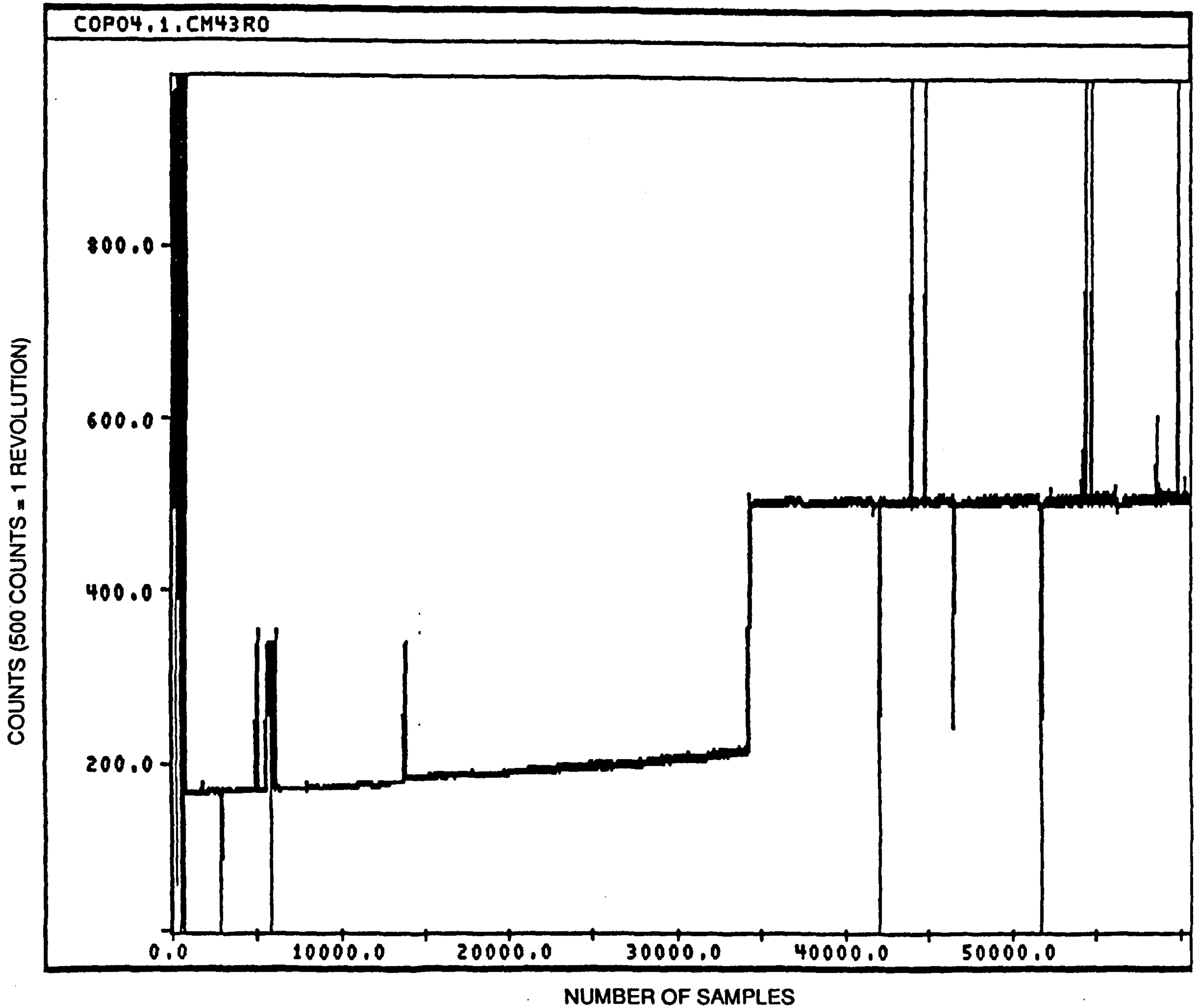


BEARING RACE ROTATION ANGLE
CAR 4 AXLE 3 RIGHT OUTSIDE

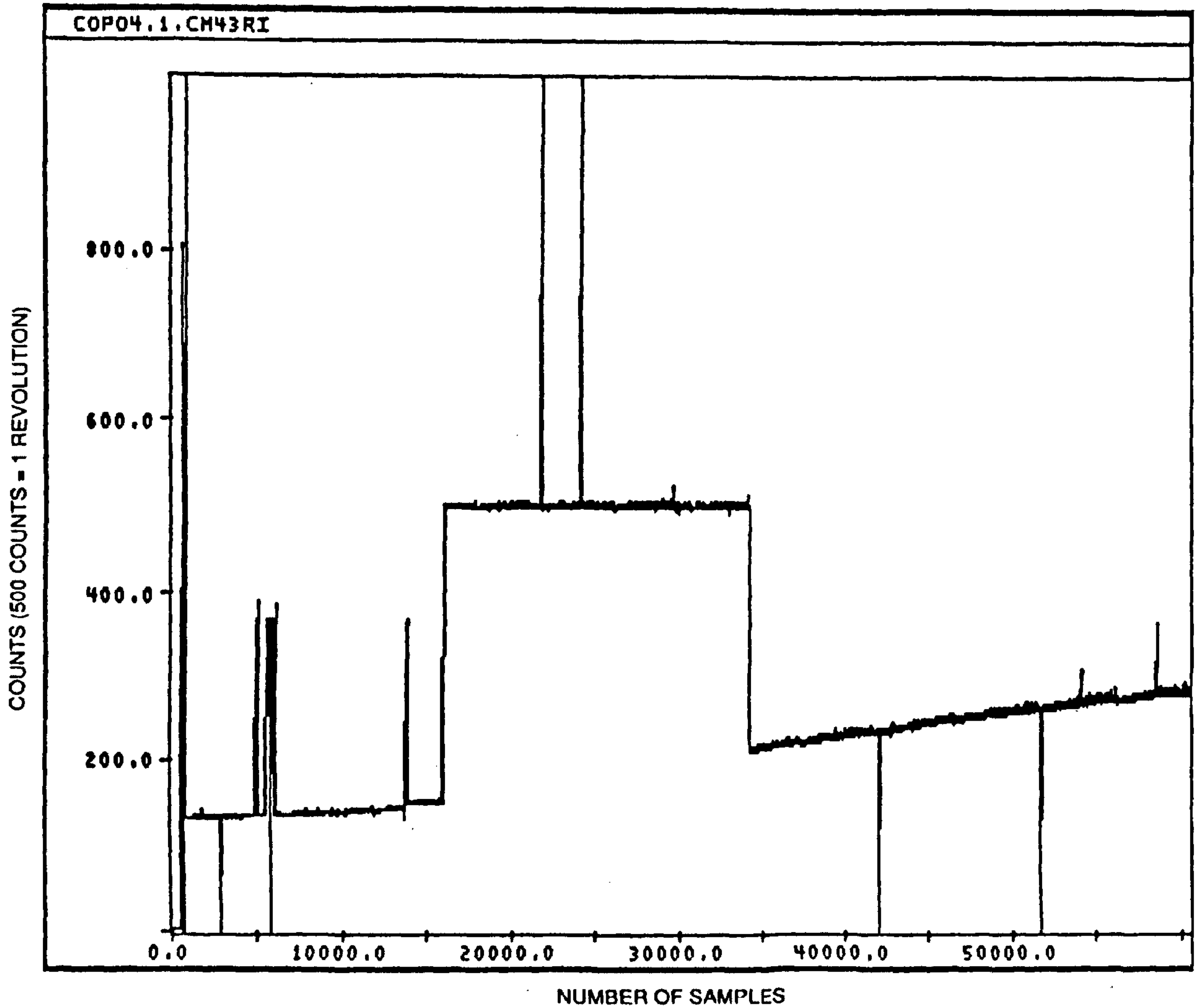


BEARING RACE ROTATION ANGLE

CAR 4 AXLE 3 RIGHT OUTSIDE

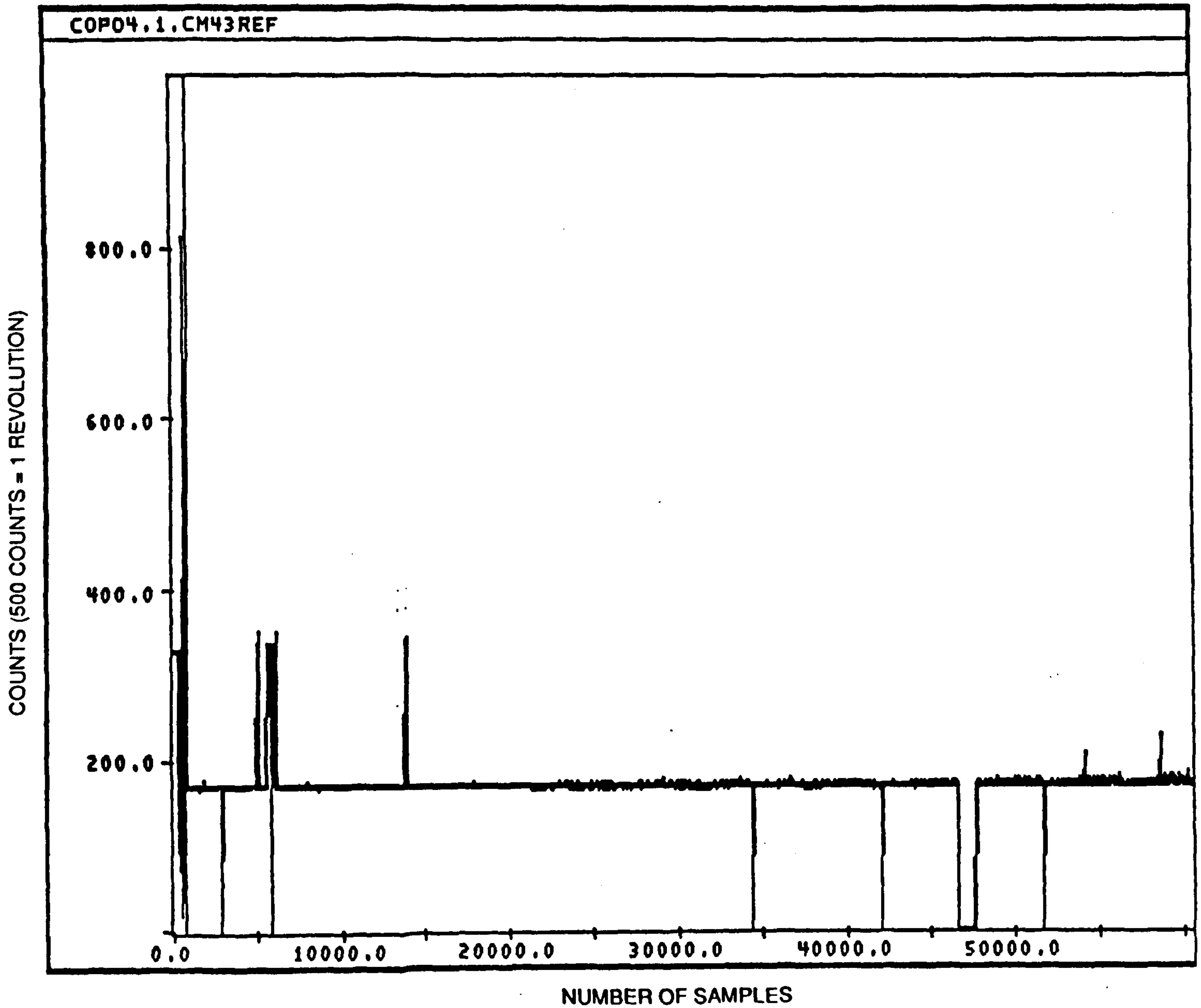


BEARING RACE ROTATION ANGLE
CAR 4 AXLE 3 RIGHT INSIDE



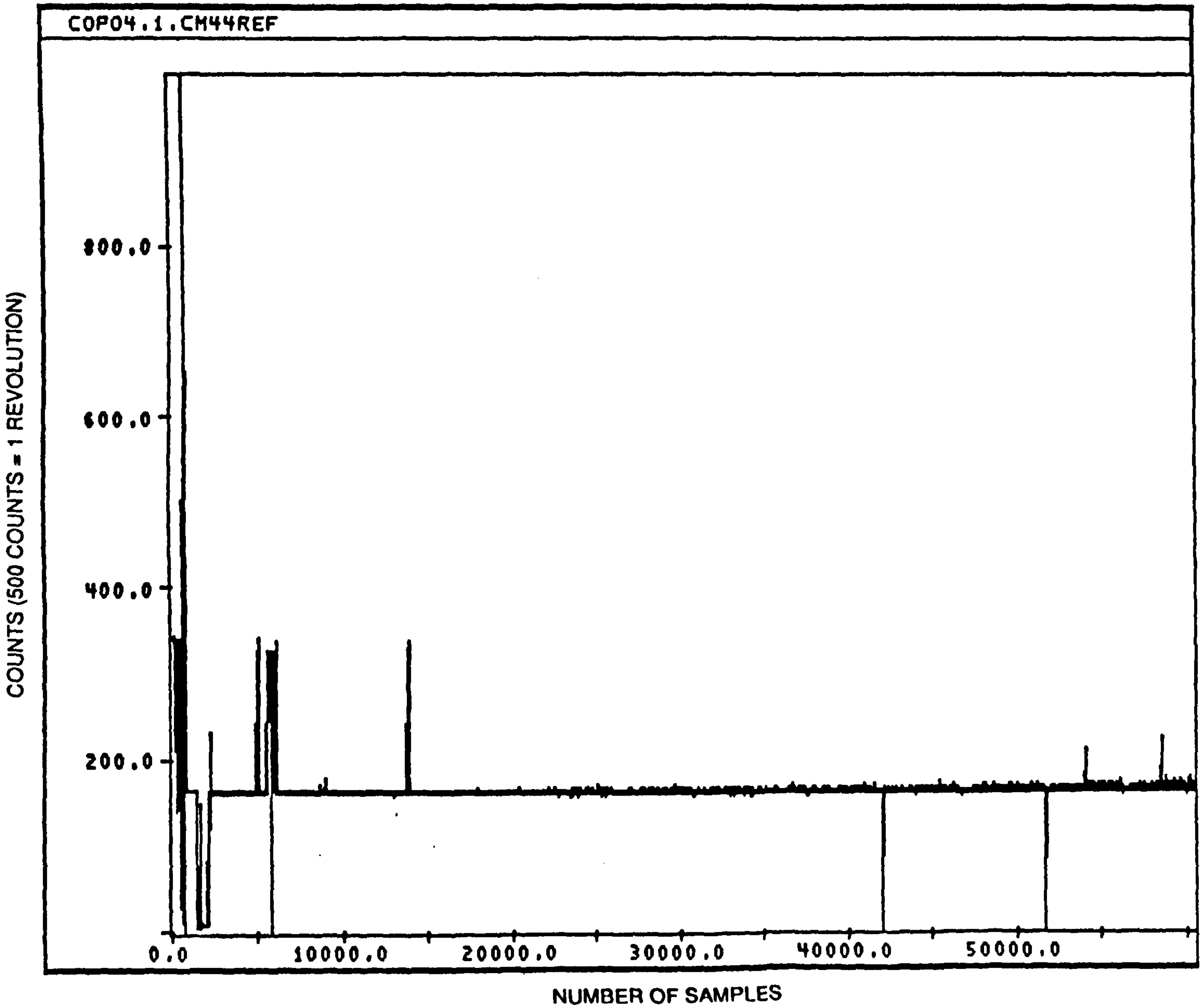
BEARING RACE ROTATION ANGLE

CAR 4 AXLE 3 REFERENCE

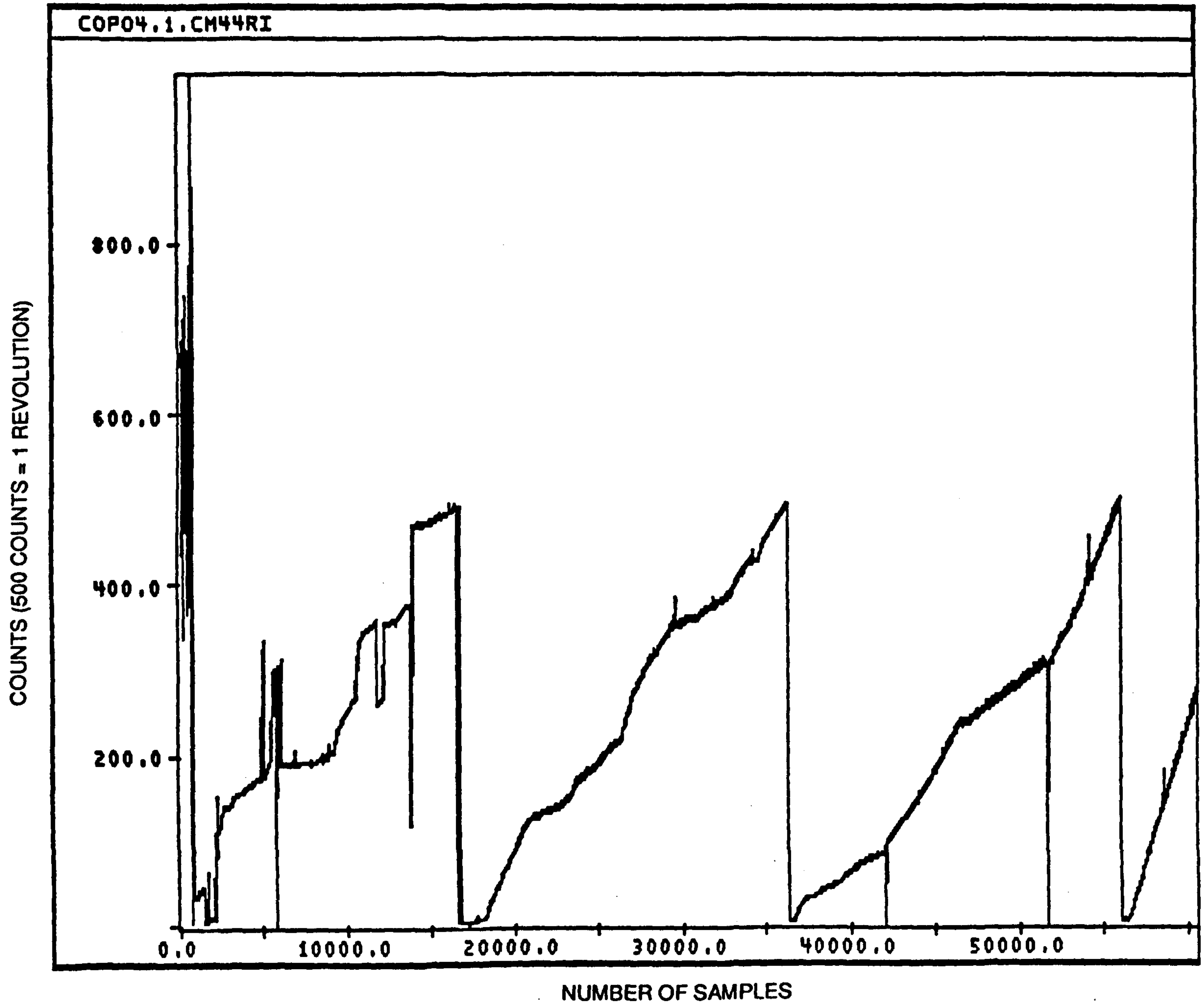


BEARING RACE ROTATION ANGLE

CAR 4 AXLE 4 REFERENCE



BEARING RACE ROTATION ANGLE
CAR 4 AXLE 4 RIGHT INSIDE



BEARING RACE ROTATION ANGLE
CAR 4 AXLE 4 RIGHT OUTSIDE