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ROLLER BEARING TEMPERATURE MEASUREMENTS ON DOUBLE-STACK CONTAINER CARS

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EXECUTIVE SUMMARY

This report describes the test methods, operations, and results obtained from monitoring roller bearing temperatures on double-stack container cars and conventional cars in revenue service train operations. The purpose of the testing was to determine whether roller bearings on double-stack cars operate at substantially higher temperatures than bearings on other cars, as many hotbox detector readings have appeared to indicate. However, the hotbox detector indications were not regarded as definitive because the detectors are designed and calibrated to detect extreme temperatures indicating imminent bearing failure; they are not normally used to measure the relatively small temperature differences of interest in this study.

It is thought that significantly higher operating temperatures might contribute to the extensive grease "weepage" or "leakage" which has been observed from roller bearings on the double-stack cars and to a lesser extent on conventional cars. A method which allows practical, economical monitoring of several bearings in a revenue service consist was designed to conclusively compare operating temperatures of both double-stack and conventional car bearings operating under identical conditions in the same consist.

This report describes both a prototype test run made between Las Vegas, Nevada, and Los Angeles, California, and a full comparison test in which both double-stack and conventional car bearings were monitored between Atlanta, Georgia, and New Orleans, Louisiana. The prototype test measured only bearing temperatures on double-stack cars to validate the test equipment and procedures.

In both tests, wayside hotbox detector readings were obtained for comparison with the onboard data. The wayside detector readings, after "calibration" using the onboard data for specific bearings, provided a method for determining the temperatures of a much larger population of bearings than could be measured with the limited amount of onboard equipment.

The prototype test run demonstrated that onboard temperature measurements could be practically obtained, and could be correlated with wayside hotbox detector readings. The full comparison test demonstrated conclusively that the double-stack roller bearings were operating at higher temperatures than conventional bearings in the same train, at levels typically 16° to 26° F warmer.

The recorded double-stack bearing temperatures were not outside the range regarded as normal for railroad roller bearing operations, and were not sufficiently high to cause hotbox detector alarms or to indicate imminent bearing problems. Some or all of the observed temperature difference may be due to heavier axle loadings routinely applied on the double-stack cars as a result of the planned loading strategies employed particularly with these cars.

Although the higher temperatures on the double-stack cars are not outside of the normal range for such bearings, they are consistently higher than for other roller bearings in similar service. This difference in behavior may account for the difference in observed grease "leakage" or "weepage" observed more commonly on the double-stack fleets.

INTRODUCTION

The first major operation of double-stack container cars was initiated by the American President Lines (APL) in 1984. The cars were operated in unit train consists between Kearney, New Jersey, and west coast points. The cars received extremely high utilization in comparison with conventional intermodal equipment, being operated up to 15,000 miles per month. The double-stack trains were noted for sustained high-speed operation with few enroute stops in an entire transcontinental trip.

Each double-stack car consists of five "platforms" and six truck assemblies. The end platforms are supported on one conventionally-applied 35 ton capacity truck, plus a second 50 ton capacity truck shared with the adjacent platform via an articulation assembly. The central three platforms are all supported on articulated joints on 50 ton capacity trucks. The truck assemblies, including bolsters, side frames, roller bearings, axles, and wheels are identical to equipment in service under conventional cars.

Shortly after the double-stack cars were introduced, railroad and Federal Railroad Administration (FRA) inspectors noticed that the roller bearings frequently appeared to be leaking (or "purging" or "weeping") grease. This was evidenced by accumulations of solid grease on the outside of the bearing housing and spots or lumps of grease thrown onto the truck springs and car bodies. These observations raised concern that the bearings might eventually lose all available lubrication, resulting in bearing thermal failure, burnoff, and derailment.

The concern led to the removal of several wheelsets for teardown and evaluation of the leakage problem. No apparent defects were noted in the removed bearings or wheelset components. A program of visually monitoring the bearings at terminals was undertaken to determine the time history of the leakage phenomenon, to identify bearings which might be low on lubricant as a result of sustained leakage, and to determine whether any bearing failures resulted from the problem.

No pattern was immediately evident in the leakage behavior. Some observed bearings never leaked. Other bearings leaked once, and then not again for several months. Some individual bearings were observed to leak as many as six times within a one year period. Possible contributing factors such as load weight and center-of-gravity on particular trips were checked for correlation with observed leakage on those trips; no correlations were found.

Ultimately, the monitoring program demonstrated that the bearings successfully completed the entire normal wheelset life, controlled by wheel wear, despite the continuing occasional leakage from some bearings. However, grease quantities less than 50% of the initial charge were observed in several bearings when examinations were conducted during routine wheel renewals. Although no bearing was detected to have failed thermally as a result of inadequate lubrication, the leakage phenomenon remained a matter of concern.

Potential causes for the observed leakage were sought. Some of the grease from removed wheelsets had a thinner consistency than expected. The same grease observed with thin consistency in double-stack service operated successfully with no apparent problems in conventional service. Differences in operating conditions were sought which might account for grease deterioration in the double-stack bearings.

One difference which was noted was hotbox detector signatures. Double-stack bearings commonly gave higher readings on the hotbox detectors, appearing to indicate higher operating temperatures. These indications were not regarded as definitive because the detectors read out only temperature differences from ambient and are designed and calibrated to detect extreme temperatures indicating imminent bearing failure; they are not normally used to measure the smaller temperature differences of interest here. Factors such as relative infrared emissivity of the bearing enclosures and an ambient temperature reference taken from the car body of each car, influence the hotbox detector reading for each bearing.

The test program described in this report was undertaken to determine the actual operating temperatures of double-stack bearings and to compare them with conventional bearing operating temperatures. This information will be made available to the parties assessing lubrication specifications and formulation, both to diagnose the observed leakage problem on the double-stack fleet and for reference for future decisions on railroad roller bearing lubrication.

This report describes both a prototype test run made between Las Vegas, Nevada, and Los Angeles, California, and a comparison test in which both double-stack and conventional car bearings were monitored between Atlanta, Georgia, and New Orleans, Louisiana. The prototype test measured only bearing temperatures on double-stack cars to validate the test equipment and procedures.

In both tests, wayside hotbox detector readings were obtained for comparison with the onboard data. The wayside detector readings, after "calibration" using the onboard data for specific bearings, provided a method for determining the temperatures of a much larger population of bearings than could be measured with the limited amount of onboard equipment.

PROTOTYPE TEST OBJECTIVES

The three major objectives of this test were to:

1. validate the feasibility of the proposed instrumentation methods, including readily mounted and removed thermocouples, Hall-effect portable speed/distance sensors, and Rustrak Ranger data loggers;

2. validate the feasibility of using the onboard measurements to "calibrate" wayside detector readings to allow more accurate determination of conditions on all bearings in the consist; and

3. obtain baseline temperature data for double-stack bearings in revenue service under a range of loading conditions.

PROTOTYPE TEST OPERATIONS

The revenue service prototype testing was conducted between Las Vegas, Nevada, and Los Angeles, California, February 1 through 4, 1988, with the support and assistance of American President Intermodal (API), and the Union Pacific Railroad (UP). API is the car owner and contracts for the train operation; UP is the operating rail carrier under contract to API.

The persons involved in planning and executing the prototype test included:

R. Nance - Director, Opns. Planning and Administration, API
P. Baumhefner, Manager, Line Operations, API
R. Cartwright - Director, Research, UP
D. Jellie - Supervisor Field Engineering, BRENCO, Inc.
S. Williams - Senior Railroad Application Specialist, Timken Co.
T. Moser - Staff Engineer, ENSCO, Inc.
R. McCown - Consultant, ENSCO, Inc.

R. Cartwright, D. Jellie, T. Moser and R. McCown conducted the instrumentation operations and observed the data collection on all or part of the field data collection operations.

The participants selected API double-stack car APLX 4558 for testing because it was known to have original wheelsets, had not undergone significant equipment retrofits since entering service, and was known to have been inspected for grease leakage during the extensive leakage monitoring effort conducted earlier. As of November, 1987, Car 4558 had been inspected specifically for bearing grease leakage on 11 occasions. No leakage was noted from any bearing.

Car 4558 was available for testing after undergoing repairs at Salt Lake City. API arranged to load the car with empty containers, providing conditions representative of the lightest loading under which these cars normally operate. API and UP arranged to have the car available at Las Vegas for instrumentation, and to operate the test car in regular double-stack unit trains operating between Las Vegas and Los Angeles.

The planned test schedule was as follows:

Feb. 1	Instrument Car at Las Vegas
Feb. 1	Depart in Train APLA
Feb. 2	Arrive at Los Angeles; check data; unload car
Feb. 3	Fully load car; depart Los Angeles in Train LAAPZ
Feb. 4	Arrive Las Vegas; remove equipment; end test.

The test was completed as scheduled. The only major exception was that the test data collection was ended and the instrumentation removed at Cima, 80 miles prior to Las Vegas, when train operational problems unrelated to the testing caused the return trip time to become much longer than anticipated, exceeding the data collection interval programmed into the data logger.

PROTOTYPE TEST INSTRUMENTATION

The test instrumentation consisted of manual and automatic data collection equipment. The manual equipment included an Omega handheld digital thermometer reading a Type K thermocouple. This was used to monitor ambient temperature conditions by extending the thermocouple assembly outside the locomotive window. Train speed was monitored by observing a locomotive speedometer; milepost locations and other operating conditions were visually observed and logged by the test crew.

The automated recording device was a Rustrak Ranger data logger manufactured by Gulton Industries and augmented with three thermocouple and one pulse counter signal conditioning modules. The data logger and signal processing modules were mounted in a weatherproof box approximately 12" x 8" x 6" overall bolted to the test car. The unit was battery-powered and entirely self-contained for this test.

The Rustrak unit records up to four channels of data in solid-state random access memory (RAM). It contains an internal clock and is programmable for intervals of recording up to 30 days. Recorded data is downloaded to an IBM-compatible personal computer (PC). Rustrak provides a proprietary software program named PRONTO which can be used to graph, analyze, and translate the data using the PC.

The Rustrak data logger employs sophisticated algorithms to determine when data should be recorded. This is done to optimize the use of the limited amount of internal memory available in the data logger. The data logger and PRONTO software operate to interpolate and reconstruct the original data flow.

The sophisticated nature of the data logger/software combination makes detailed prediction of operating performance difficult for a situation with unknown rates of change in the measured parameters. The prototype test operations were conducted to validate the operation of the data logger and software under actual field conditions, prior to conducting the comparison test operations with larger numbers of data loggers and sensors.

The sensors recorded by the Rustrak included three Type K thermocouples and a speed/distance sensor. For the westbound trip on the prototype test, two of the thermocouples were located at the top of the cup of the L-10 roller bearing on APLX 4558; the third was at the bottom of the cup.

The L-10 bearing was an AAR 1A no-field-lube 6 1/2 x 12 size F roller bearing, manufactured in 1985. It was selected for testing because the L-10/R-10 wheelset was original equipment on Car 4558, had undergone over 200,000 miles of revenue service, and had been observed during the detailed monitoring of the APL fleet for grease leakage from bearings. As noted above, Car 4558 had been inspected specifically for grease leakage on 11 occasions and no leakage was reported.

The L-10/R-10 wheelset was also inspected in detail at Las Vegas and no anomalies such as tread spalling or unusual wheel wear were noted. The wheelset and bearings were regarded as representative examples of the hardware which operates in the double-stack fleet.

The two L-10 top-of-cup thermocouples were co-located on the westbound trip to test the variability of the measurement system. The top-of-cup position was chosen because prior testing has shown that maximum cup temperatures occur at the load zone of the bearing, due to roller contact at that location which both creates heat and transmits internal heat through conduction. The bottom-of-cup location was selected because this area is read by the wayside hotbox detectors.

On the eastbound return trip, one of the two L-10 top-of-cup thermocouples was relocated to the top-of-cup position on the L-9 bearing. The L-9 bearing was an AAR Type 5A, no-field-lube, 6 1/2 x 12, size F roller bearing, manufactured in 1987 and mounted by the UP wheelshop at Pocatello, ID. The L-9/R-9 wheelset had been installed at Salt Lake City just prior to this test. The total accumulated mileage on the wheelset was therefore only about 800 miles when testing of it began at Los Angeles. The test run was its first operation under full loading conditions.

Considerable pre-test effort was expended to design suitable mounting arrangements for the thermocouples. Close contact with the bearing cup was necessary, but attachment to the cup was not possible because the cup rotates, or "creeps", during normal operation. This motion is beneficial in that it prevents concentration of all fatigue loads in a single area of the circumference of the cup. The amount of rotation or creepage of the cup is not constant, but apparently depends on operating conditions. Accordingly, the use of wires fixed to the cup might result in twisting and severing of the wires.

A thermocouple mounting method was designed which uses spring tension to maintain contact between the thermocouples and the bearing cup, as shown in Figure 1. The thermocouples were soldered to steel banding strap material. The steel strap was passed over the top of the bearing cup, using the normal relief groove in the bearing adapter for a passageway. A similar assembly was passed beneath the bearing cup.

A formed bracket was inserted through an existing hole in the truck side frame and bolted into place. This provided an anchor point well below the bottom of the cup on the shorter side of the truck pedestal. The frame key provided a similar mounting point on the long side of the truck pedestal.

The banding straps carrying the thermocouples were drilled and small coil springs attached, so that each thermocouple assembly could be stretched taut between the installed bracket and the frame key, using either plastic ties or eyebolts for attachment. This method of thermocouple mounting allows rapid installation or removal at any location and on virtually any truck, without requiring any disruption to the normal car configuration.

The speed sensor was based on a Hall-effect transducer element which provides an electronic pulse whenever it senses a rapid change in magnetic fields. As shown in Figure 1, a collar was constructed which could be bolted onto the rotating end cap of the bearing. The collar was fitted with six small permanent magnets. The Hall-effect sensor was mounted on a small bracket and clamped onto a protruding lug on the roller bearing adapter, and leads routed to the Rustrak data logger.

The pulse count recorded by the data logger would be directly proportional to speed, and could be converted to actual speed values by multiplying by a factor to account for wheel diameter. The arrangement of the speed sensor was also designed for ready installation and removal at any location, without disruption to the existing car components.

PROTOTYPE TEST RESULTS

Westbound Test Run; Onboard Data

Figure 2 is a graph showing the measured temperatures and speeds for the westbound trips on Train APLA6X. In general, excellent temperature measurements were obtained on the westbound trip with the car loaded only with empty containers. The two L-10 top-of-cup thermocouples produced virtually identical results, with typical differences in readings of only 1 to 2° F between the two thermocouples.

The data logger system worked well, providing a typical range of 5°F between reported maximum and minimum values for each top-of-cup channel for each interval used by the data logger algorithm to record the data segments. In some cases, the algorithm allowed a difference of up to 32°F between the within-interval maximum and minimum on the westbound run.

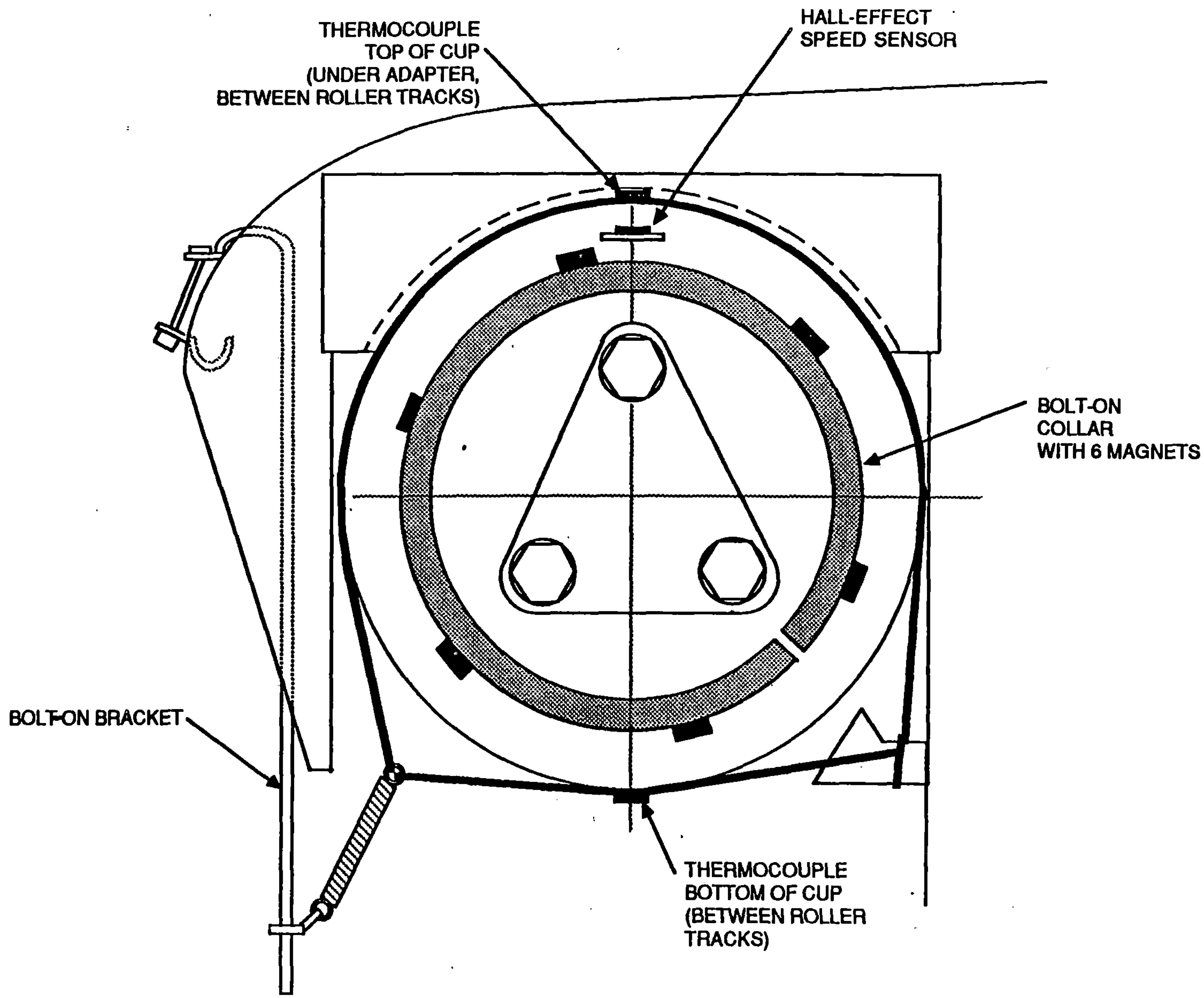


FIGURE 1 TEMPERATURE AND SPEED SENSING INSTRUMENTATION

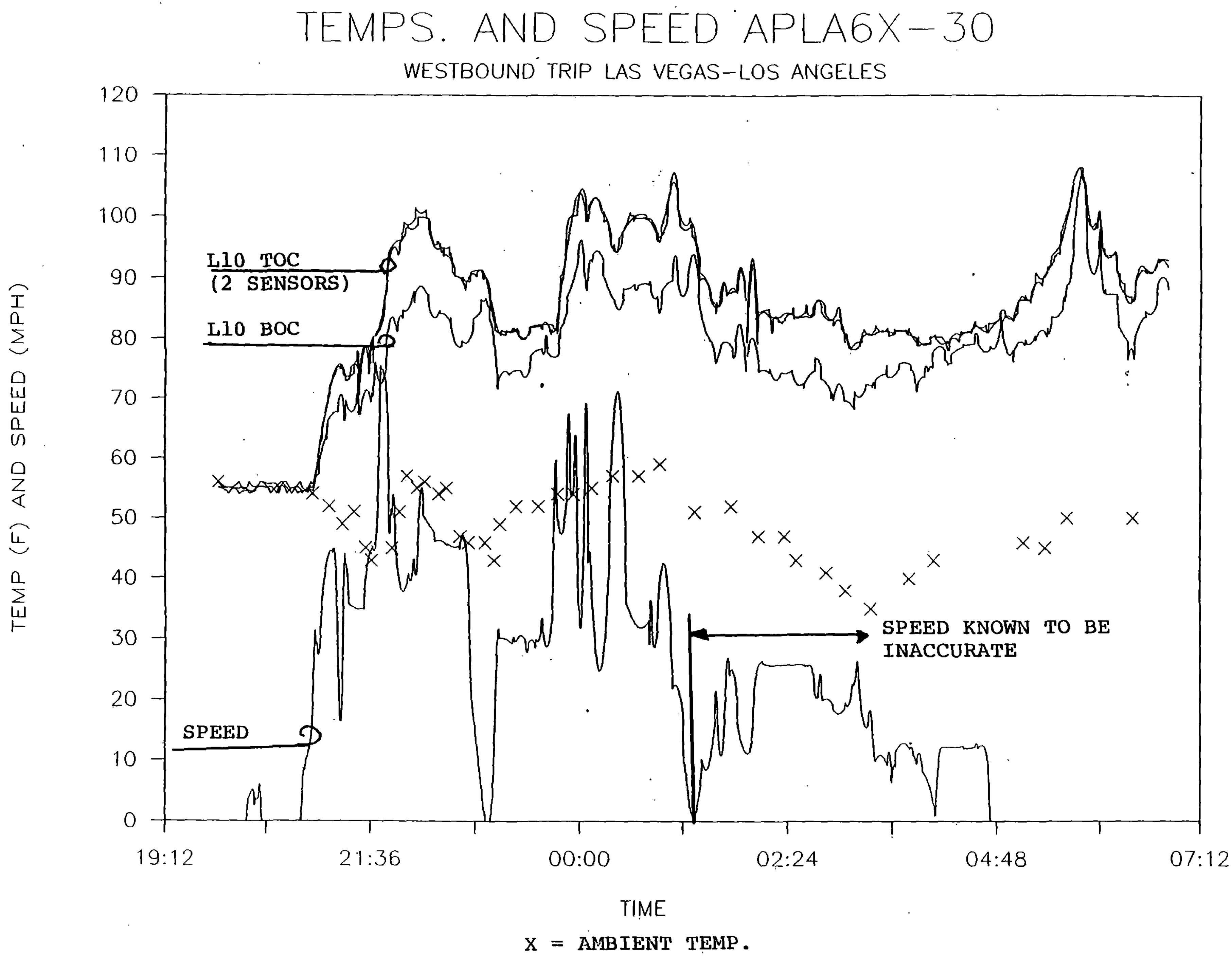


Fig 2. Temps. and Speed APLA6X

In one case, an extreme variation was reported for two twenty-second intervals, which appears to have been electronic interference since anomalous values appeared concurrently in all three temperature channels. (The anomalous points are deleted from Figure 2.)

The top-of-cup temperatures rose to a maximum of 108^{o} F after sustained high speed running, at an ambient temperature of about 50^{o} F. A clear relationship between bearing temperatures and operating speeds is shown in the data. The bottom-of-cup temperatures ran up to 15^{o}F cooler, particularly during high speed running. The top- and bottom-of-cup temperatures equalized rapidly, at about midpoint between recent running temperatures, when stops or very low speed running occurred.

An attempt to convert the recorded pulse data to actual speed was made by multiplying the pulse count by a factor of 1.07. This factor was calculated based on a wheel diameter of 36 inches, six magnets passing the sensor per revolution, and a recorded count in pulses per second (Hertz). As shown in Figure 3, this calculation did not yield reasonable speeds when compared with known speeds and distances from the manual log.

Subsequent laboratory tests indicated that positioning of the permanent magnets and the Hall-effect sensor is more sensitive than anticipated. Apparently, not all of the six magnets were routinely triggering the sensor. This may have been due to normal lateral shifting of the axle in response to track loading.

However, a clear relationship between the measured pulse counts and the known speeds were observed in the data. A regression was conducted as shown on Figure 4. Although a very low correlation is evidenced, the relatively fast variation in actual speed versus time must be acknowledged. The double-stack trains are operated with ample motive power, and can accelerate or decelerate more than 50 mph in less than two minutes. Routine variation in recording manual log entries for both times (recorded based on analog watch and only to nearest minute) and mileposts can therefore introduce significant errors in correlated measured times and speeds.

The regression indicated that a multiplier of approximately 4 was needed to correct the calculated speed to more closely represent actual speed. By trial and error, a factor of 3.48 was adopted. This factor proved to correct the calculated speed value to actual speed. The accuracy of the correction was confirmed by integrating the final speed values calculated from the pulse count over the entire trip. For the first segment of the eastbound trip, the integrated speed values closely reproduce the known trip events, as shown on Figure 5. Figure 6 shows that a similar technique was successful in calculating reasonable speeds and therefore distances for the return trip.

However, Figure 5 also shows a large variation from actual speed beginning shortly after the midpoint of the trip, and increasing in magnitude until the Hall-effect sensor ultimately failed. We have no explanation for the sensor apparent degradation or ultimate failure, but we note that the degradation began at the time a very light rain began. The rain became progressively heavier as the trip proceeded. The leads to the Hall-effect sensor were directly soldered and were open; the moisture provided by the rain may have contributed to the degradation in sensitivity and ultimate failure of the sensor.

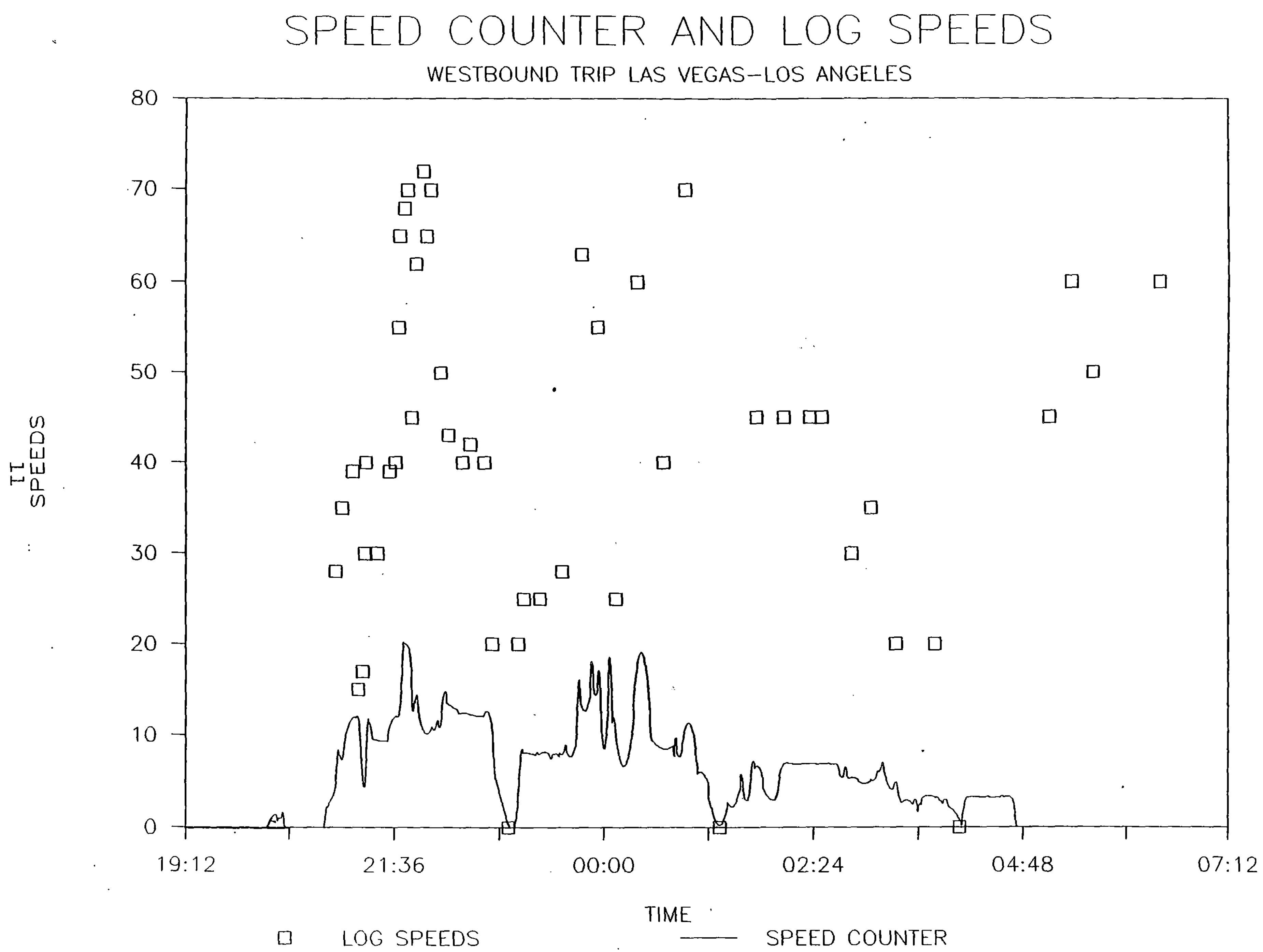


Fig 3. Speed Counter and Log Speeds

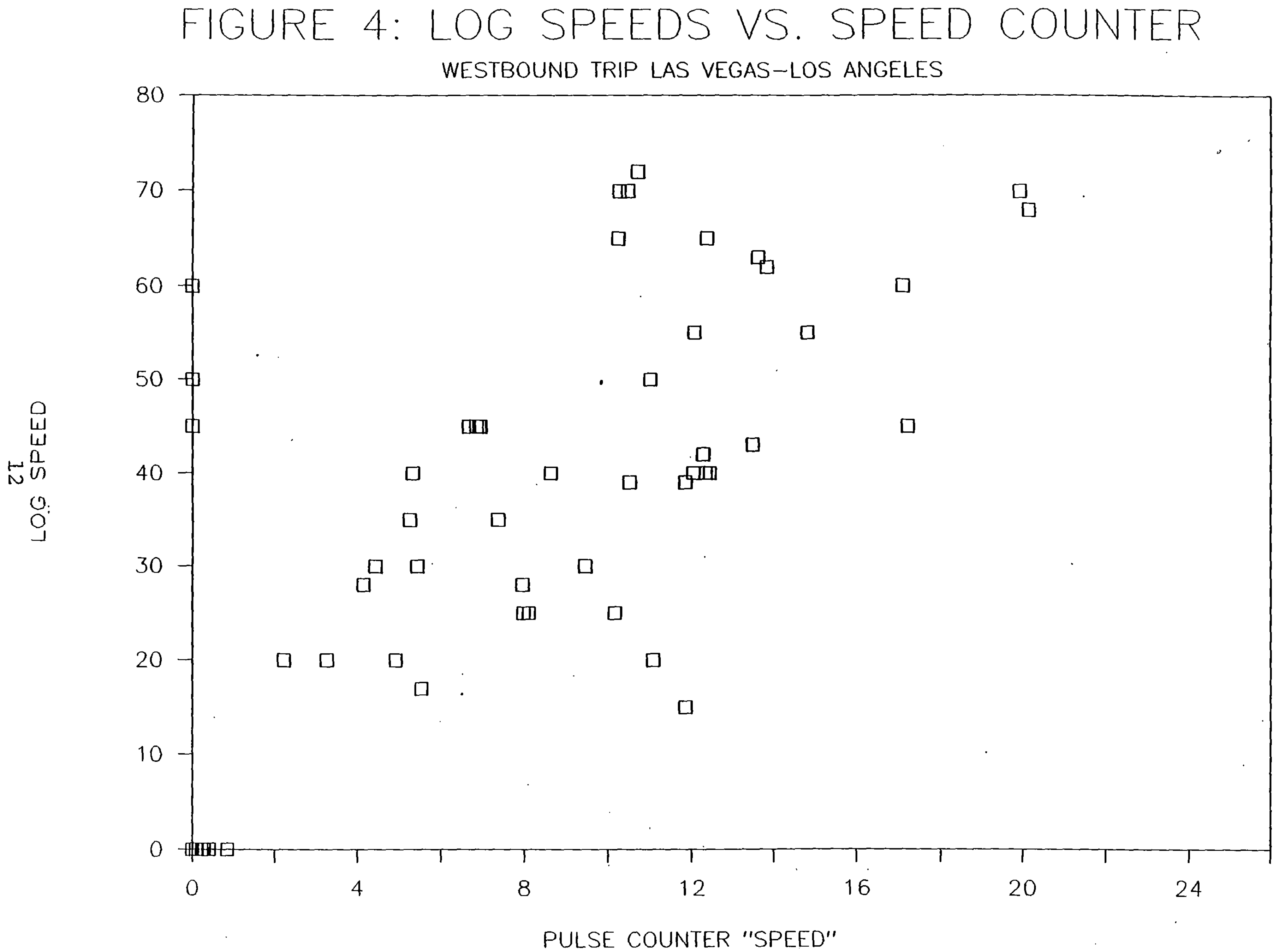


Fig 4. Log Speeds vs Speed Counter

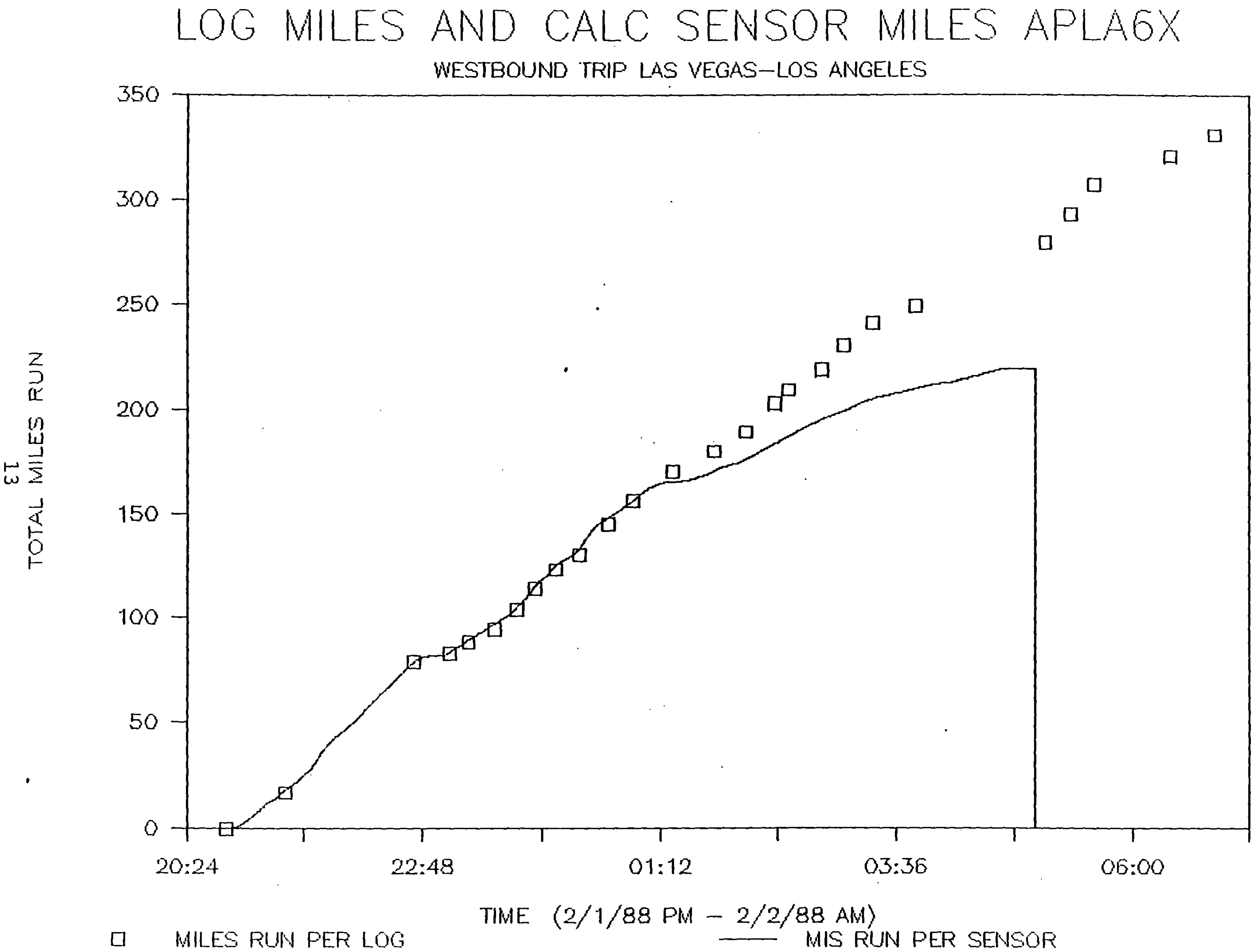


Fig 5. Log Miles and Calculated Sensor Miles

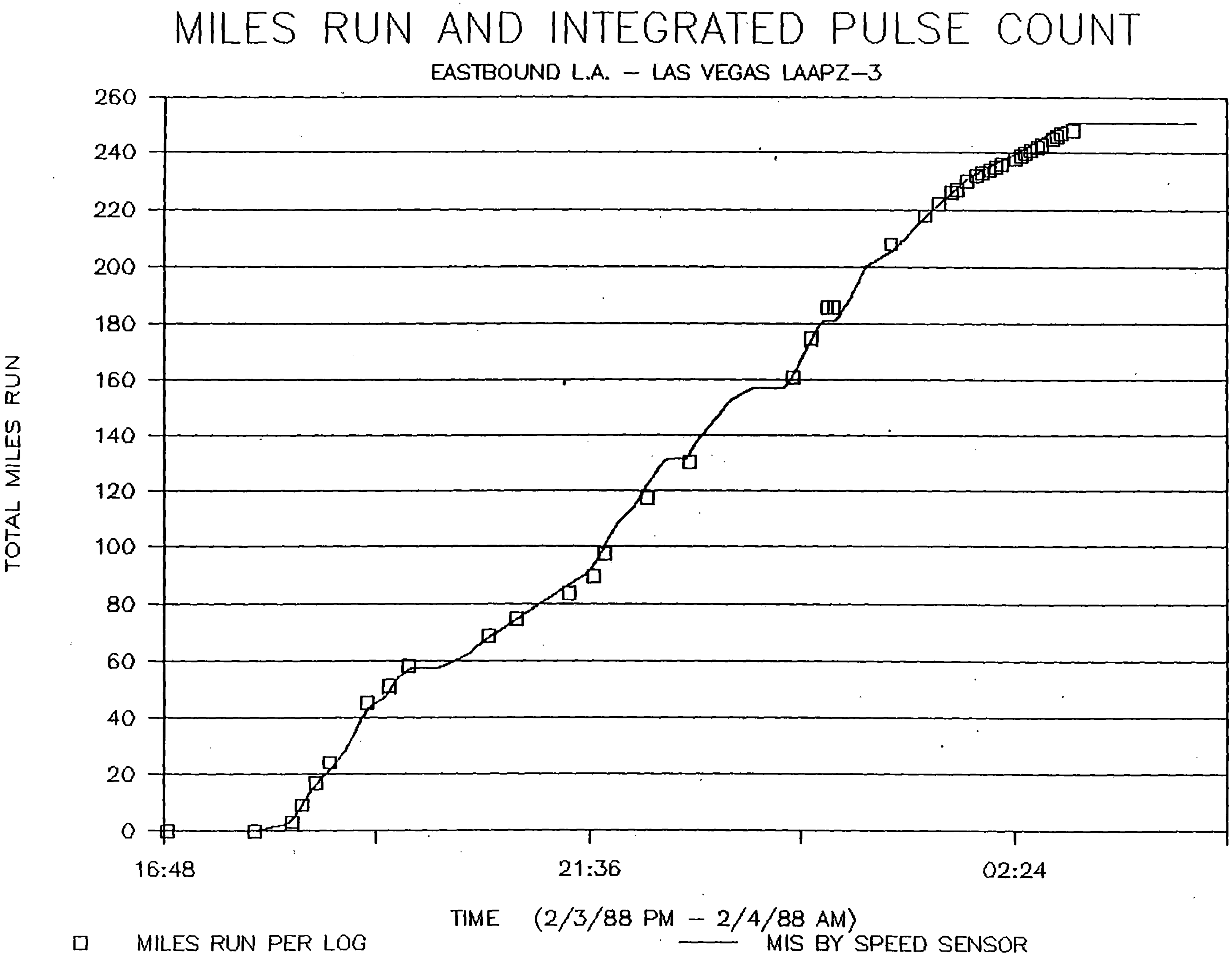


Fig 6. Miles Run and Integrated Pulse Count (Eastbound)

Eastbound Test Run; Onboard Data

Figure 7 is a graph of the temperature and adjusted speed data for the eastbound trip on Train LAAPZ, with the test car fully loaded with heavy containers. On this run, severe spiking was recorded in the temperature data on all channels, with spikes usually occurring simultaneously in all of the channels. In some cases, the data logger recorded maximum and minimum temperature values which differed over several hundred degrees Fahrenheit, and such variations occur within seconds of more nominal data.

Electromagnetic interference is suspected as the source of these spikes (severely anomalous values are deleted from Figure 7.) Such interference would not distort the speed recording significantly, since pulse-type interference would increment the pulse counter by only a small fraction of normal values. The interference may have entered the data acquisition system through relatively long (six to eight feet) and unshielded thermocouple leads.

The most likely source of such interference was thought to be the diesel-electric locomotives. The instrumented truck was only fifty feet behind the trailing locomotive unit on the eastbound trip, and was under one end of the first platform behind the locomotives. On the westbound trip, the instrumented truck was four platforms away from the locomotives.

The terrain for the test was extremely rugged, requiring almost continuous full-throttle or full dynamic braking operation of the locomotives. These operations generate direct currents in excess of 1,000 amps at each traction motor. However, examination of the data shows no clear relationship between operating conditions and the occurrence of spiking.

Another potential source of electromagnetic interference is the train radio system. The locomotives are equipped with 75 watt transmitters operating between 160 and 162 Megahertz. Interference from train radio communications to data recording systems has been observed in other tests. Again, close proximity to the transmitter would increase the likelihood of interference to the data recording system. In addition, the use of helper locomotives for the entire eastbound trip and the operating problems experienced caused extensive use of the radios, which was not required on the westbound trip.

After removal of the data suspect due to spiking, considerable useful information remains from the eastbound trip. The loaded car generated maximum L-10 top-of-cup temperatures of about 120^{o}F, under similar operating conditions and ambient temperatures to those which generated only 105^{o}F under the lightly loaded car.

The newly-installed L-9 bearing reached a maximum top-of-cup temperature over 140^{o}F, and consistently ran warmer than the L-10 except when low speeds or stops allowed equalization to occur. The L-10 bottom-of-cup temperatures behaved similarly to on the westbound run, but differences of over 30^{o} F were noted between top-of-cup and bottom-of-cup temperatures.

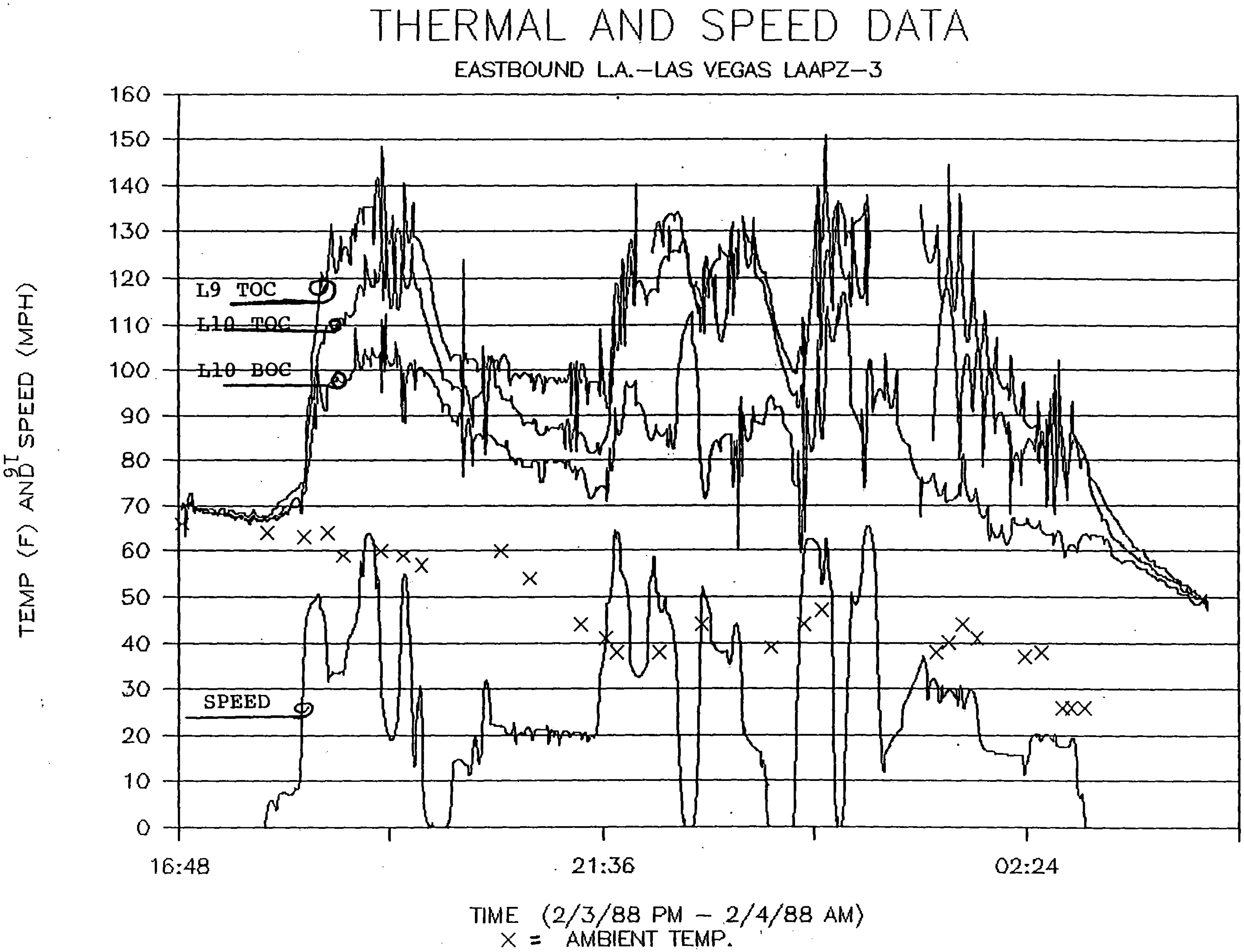


Fig 7. Thermal and Speed Data LAAPZ-3

Comparison With Wayside Detector Data (Both Runs)

The Union Pacific Railroad provided thirteen wayside hotbox detector charts for inspections of the test trains during the test runs. The data from the detector paper tapes and the corresponding data from the test logs and instrumentation is summarized in Table 1.

The nine cases for which both test measurements and wayside readings are available are graphed in Figure 8, which shows a general relationship between the readings and the measured values. It must be noted that the readings obtained were for an entirely nominal train, and variations of the magnitude shown are insignificant for the normal use of the detectors. In the one case where onboard and wayside data are available for both the L-9 and L-10 bearings, the onboard and wayside readings are both identical.

The hotbox detectors are designed and maintained to detect severely overheated components. For that purpose, precise measurements (i.e. to within a few degrees Fahrenheit) at nominal operating temperatures are not required. The results of this comparison re-emphasize that hotbox detector readings alone can not be interpreted as accurate representations of actual bearing temperatures.

However, the possibility still exists that individual detectors, "calibrated" more precisely with the use of onboard measurements and under the relatively fixed ambient conditions which occur during the passage of a single train might be used to compare results along the length of that train. This is the approach which was used for the comparison test described in the following sections of this report.

PROTOTYPE TEST CONCLUSIONS

1. The method for mounting top-of-cup and bottom-of-cup thermocouples is suitable for monitoring bearing temperatures during revenue service runs.

2. The speed/distance sensor system is suitable for revenue service use, provided that measures are taken to insure that all magnets trigger the Hall-effect sensor.

3. The Rustrak Ranger data logger is suitable for revenue service use, provided that the source of spiking in the sensor channels can be controlled or eliminated.

4. The data collected provides a useful baseline for normal operation of roller bearings under double-stack cars. A heavily loaded car caused the bearings to operate at significantly higher temperature than when the car is lightly loaded. This result is to be expected both on theoretical grounds and based on results of prior studies of bearing temperatures by the railroads and by bearing manufacturers.

TABLE 1

HOTBOX READINGS AND MEASURED TEMPERATURES (APLA6X AND LAAPZ3-3)

ITEM #	HOTBOX DETECTOR LOCATION	HB DETR MP	TRN. DIR.	AMB. TEMP	DETR MM L10	BOTM CUP L10	L10 BOTM - AMB	TOP CUP L10	TOP CUP L9	DETR MM L9
1	ARDEN	324.2	W	50	3.0	67	17	74	NI	4.0
2	ROACH	292.7	W	47	4.0	83	36	95	NI	4.0
3	MOORE	273.7	W	55	6.7	84	29	95	NI	6.7
4	KELSO	233.4	W	53	4.2	77	24	82	NI	5.0
5	BALCH	209.2	W	55	6.7	93	38	103	NI	6.6
6	HARVARD	175.3	W	55	5.0	89	34	99	NI	5.1
7	HARVARD	175.3	E	47	5.0	89	42	108	-	4.8
8	BALCH	209.2	E	40	6.2	93	53	-	-	6.2
9	KELSO	233.4	E	41	3.5	71	30	105	105	3.5
10	CIMA	255.9	E	*	2.0	*	*	*	*	2.5
11	MOORE	273.7	E	*	5.0	*	*	*	*	4.8
12	ROACH	292.7	E	*	6.7	*	*	*	*	5.5
13	ARDEN	324.2	E	*	5.0	*	*	*	*	5.0

NI = NOT INSTRUMENTED ON WESTBOUND TRIP
- = DATA NOT USABLE
* = DATA COLLECTION ENDED AT CIMA; TRIP EXCEEDED SET TIME INTERVAL

[redacted]

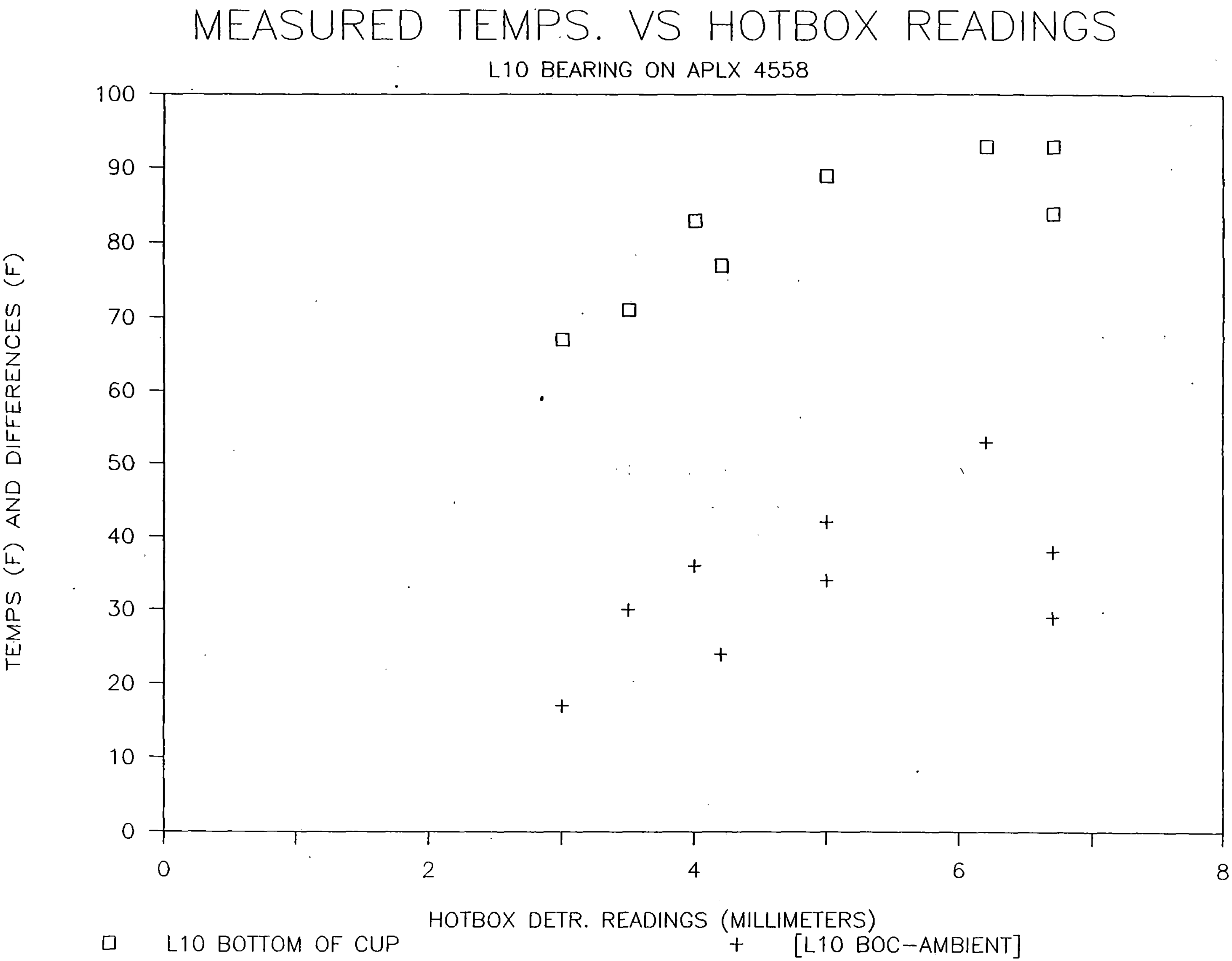


Fig 8. Detector Readings vs Measured Temp

5. Comparison between onboard measurements and wayside hotbox detector readings showed general, but not precise, consistency. Only limited data was available from the prototype test to compare more than one bearing over a given detector on a given trip.

COMPARISON TEST OBJECTIVES

The objectives of the comparison test were to:

(1) Obtain comparable temperature measurements for both double-stack and conventional car bearings to determine if the double-stack bearings run at consistently higher temperatures, and

(2) Obtain representative temperature histories for both types of bearings as a matter of general interest to the railroad industry community.

COMPARISON TEST OPERATIONS

The comparison test was conducted between Atlanta, Georgia, and New Orleans, Louisiana, May 24 through 26, 1988, with the support and assistance of American President Intermodal and the Norfolk Southern Corporation (NS). In this service API contracts for Norfolk-Southern to haul API-owned cars in regular NS trains.

NS Train 219 was selected because it is one of the revenue service consists which routinely includes both double-stack and conventional intermodal cars. Such a consist was sought to obtain measurements most representative of normal service and to obtain maximum comparability between double-stack and conventional car bearings.

The persons involved in planning and conducting the test included:

R. Nance - Director, Opns. Planning and Administration, API
J. Bevins - Southern Region Manager, Mechanical Dept., NS
G. Hamilton - Equipment Maintenance Engineer, NS
J. Corea - Master Mechanic, NS
J. Ricks - General Car Foreman, NS
P. Jenkins - Car Foreman, NS
S. Keegan - Mechanical Engineer, NS
T. Moser - Staff Engineer, ENSCO, Inc.
R. McCown - Consultant, ENSCO, Inc.

The test plan called for selecting and instrumenting a single double-stack car and a single intermodal ("TTX") flatcar at the Norfolk Southern Inman Yard in Atlanta. Revenue cars with regular loads were to be selected to minimize interference to the high-priority intermodal operation. Instrumentation was completed on May 25, 1988, for departure from Atlanta in Train 219 late that evening. The test consist arrived at New Orleans on the afternoon of May 26.

Double-stack car APLX 2049 was selected for testing because it had been observed during the earlier visual monitoring of grease leakage and was available for service at Inman Yard. API personnel at Inman Yard selected container loads to assure that APLX 2049 was loaded as nearly to weight capacity as possible. Two additional double-stack cars, fully loaded with containers, operated ahead of the APLX 2049 in the test consist. This helped to assure that the operating conditions remained representative of those that would apply in double-stack unit consists.

Intermodal flatcar TTWX 972980 was selected because it was loaded with two trailers bound for New Orleans. Although the trailers, and hence the car, did not appear to be heavily loaded, it was one of the few cars available in time to accomplish the instrumentation. In most cases, cars for Train 219 are loaded at Atlanta within a few hours of the train's departure, and waiting for a heavily loaded trailer flatcar would not have allowed sufficient time to apply the instrumentation to the car. Descriptions of the test bearings on both cars are included in Appendix A.

The three double-stack cars were directly behind the locomotives leaving Atlanta; the TTX flatcar was the 34th car in the train. The consist of Train 219 is routinely switched at Birmingham, Alabama, and at Meridian, Mississippi, with cars set off and picked up at both points. During the test, the train length and weight was reduced after both stops. At Birmingham, the test TTX flatcar was removed from a group of cars being set out, and cut in as the first car in the train directly ahead of the three double-stack cars.

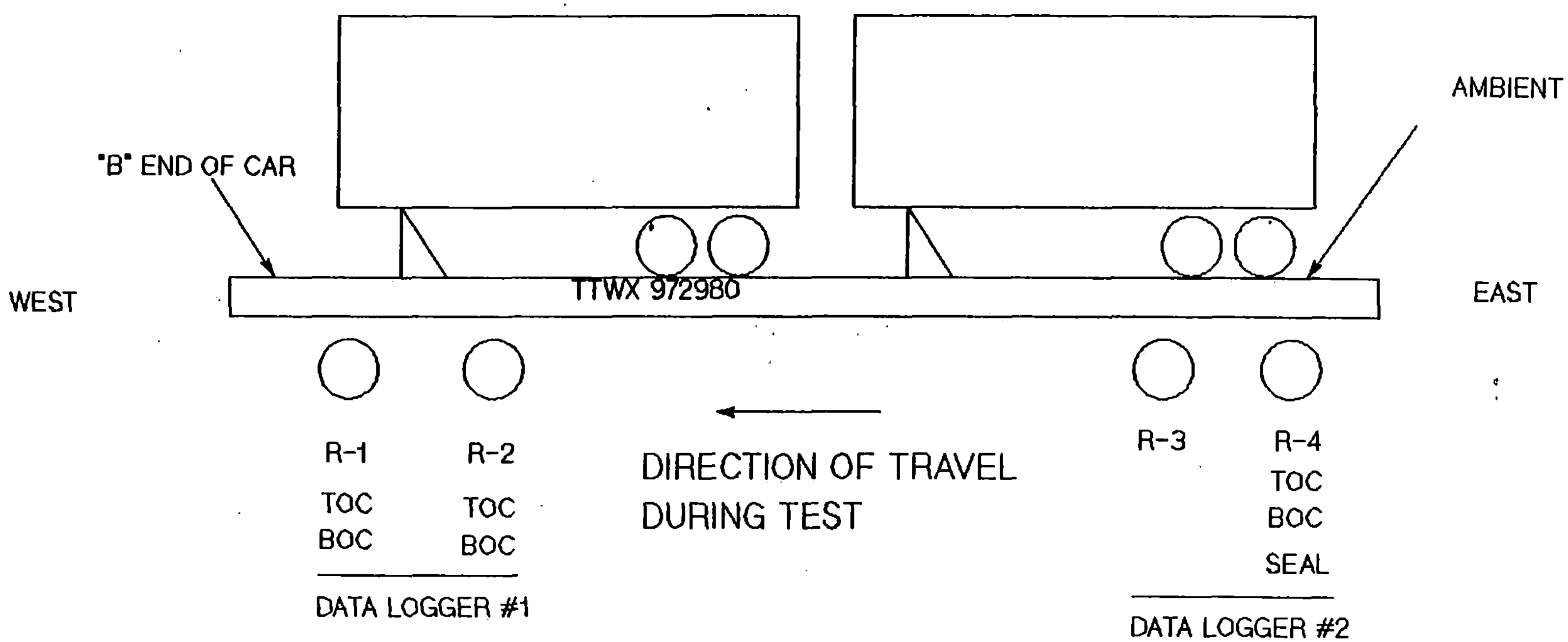
The Southern Railway route operated by Train 219 is characterized by frequent changes in authorized speeds due to curves and restrictions for towns. The maximum authorized speed for intermodal trains such as Train 219 is 60 mph, but the number of speed restrictions allowed little sustained 60 mph running. The manual logs kept of the train operation showed virtually continuous rapid cycling between high throttle settings and high amounts of dynamic braking. As a result, it is likely that the bearings did not reach their absolute maximum operating temperatures, which might be expected to occur after sustained high speed running.

COMPARISON TEST INSTRUMENTATION

The same instrumentation approach which had been proven during the prototype test was again used. The instrumentation used for the comparison test is diagrammed in Figures 9 and 10. For the comparison test, four Rustrak Ranger data loggers were used; two on each instrumented car. This provided a total of sixteen channels of data. Shielded thermocouple leads were used to attempt to reduce electromagnetic interference in the data.

[redacted]

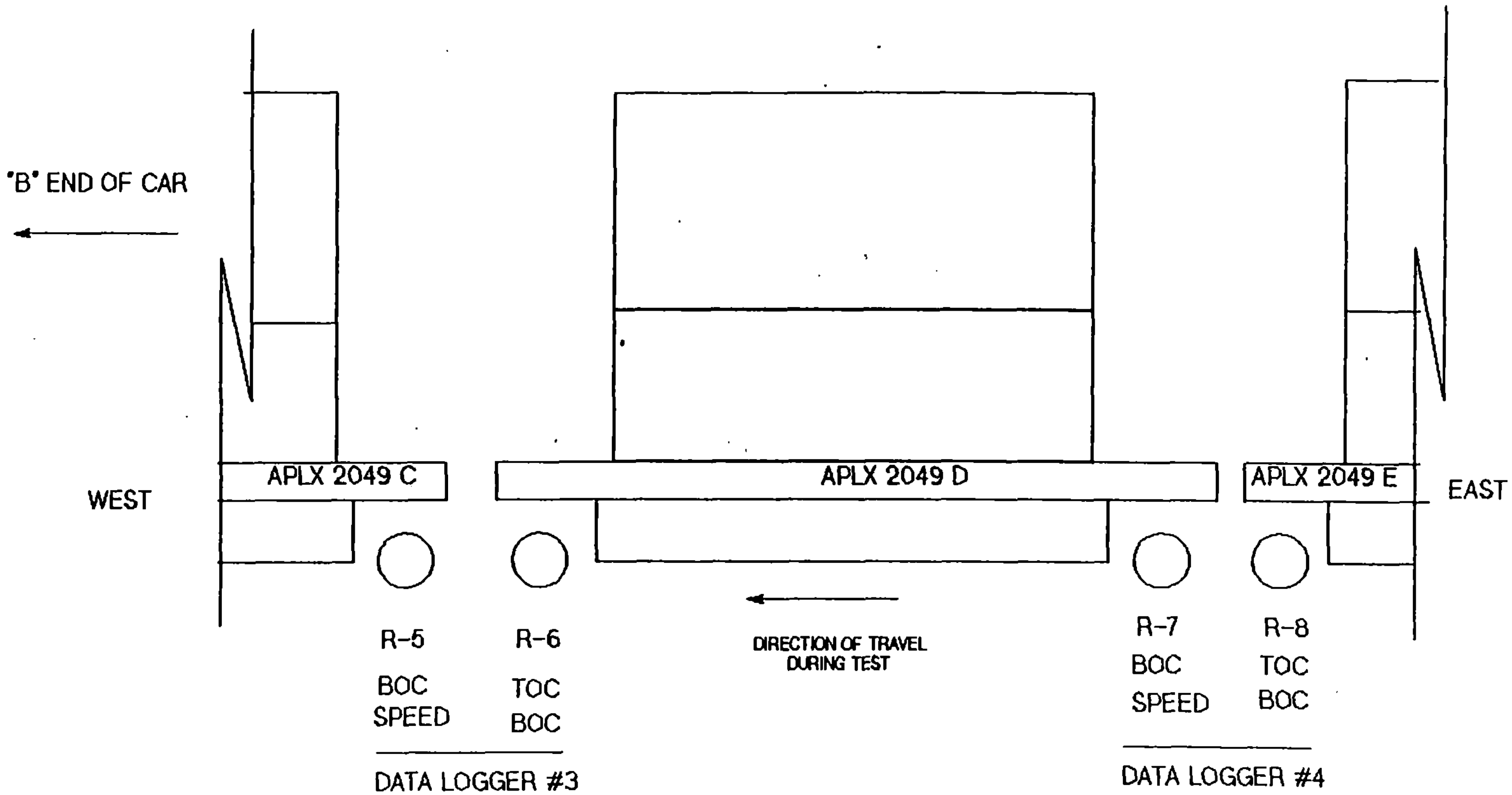
FIGURE 9: INSTRUMENTATION ON FLATCAR TTWX 972980



LEGEND:

TOC = TOP-OF-CUP THERMOCOUPLE ON BEARING
BOC = BOTTOM-OF-CUP THERMOCOUPLE ON BEARING
SEAL = THERMOCOUPLE GLUED TO SEAL ENCLOSURE

FIGURE 10: INSTRUMENTATION ON DOUBLE-STACK CAR APLX 2049



LEGEND:

TOC = TOP-OF-CUP THERMOCOUPLE ON BEARING
BOC = BOTTOM-OF-CUP THERMOCOUPLE ON BEARING

Two Hall-effect speed sensors and magnet collars were used to provide redundant speed channels. The Hall-effect transducers were upgraded after the prototype test to include a wider field of view for magnet detection, and sealed transducers to avoid any moisture problems. Both speed sensors were located on the double-stack car because the available magnet collars fit only Size F (sized for 100 ton cars) bearing end caps, and the bearings on almost all intermodal flat cars are the smaller Size E (sized for 70 ton cars).

One thermocouple was placed on the deck of the TTX car to provide an ambient temperature reference. Twelve additional thermocouples were applied at both the top-of-cup and bottom-of-cup locations on bearings on both cars, as shown in Figures 9 and 10. The remaining channel was used to record a thermocouple glued to the seal enclosure of one of the bearings on TTX car.

COMPARISON TEST RESULTS

Onboard Data

The operating speeds for the test consist are shown in Figure 11. Despite improvements made in the Hall-effect sensors, the recorded pulse counts did not provide a correct speed indication. As with the prototype test, the manual logs of speed and distance were used to generate a correction factor. Applying the correction generated the speed signal shown, which was proved to be accurate by integrating it and producing a time/distance history for the test run which matched the manual logs as shown in Figure 12. The ambient temperature history as recorded on the deck of the TTX flatcar is shown in Figure 13.

The recorded bearing operating temperatures and the corresponding differences above ambient temperature are shown in Figures 14 to 39. The data shown in these graphs was downloaded from the four Rustrak Ranger data loggers at New Orleans. It was smoothed to a five minute average for clarity in plotting the figures.

Excellent data quality was obtained for the thermocouples on the TTX flatcar bearings. As shown in the figures, maximum observed temperatures on the TTX car bearings approached 160^{O}F, which represented about 80^{O}F above ambient temperature. Typical temperatures for the warmest TTX bearing were in the 120 to 140^{O}F range on the warmest bearing. The R-4 TTX bearing barely exceeded 100^{O}F at its warmest point during the test. Very little difference was measured between the top-of-cup and bottom-of-cup thermocouples on the TTX bearings. This is consistent with operation of a lightly loaded car, as was observed on the lightly loaded portion of the prototype test.

The double-stack car bearings operated considerably warmer than the TTX car bearings, with operating temperatures over 190^{O}F observed on two bearings, representing 130^{O}F above ambient temperature. Differences of over 30^{O}F were observed between top- and bottom-of-cup readings.

Fig. 11: Consist Operating Speed

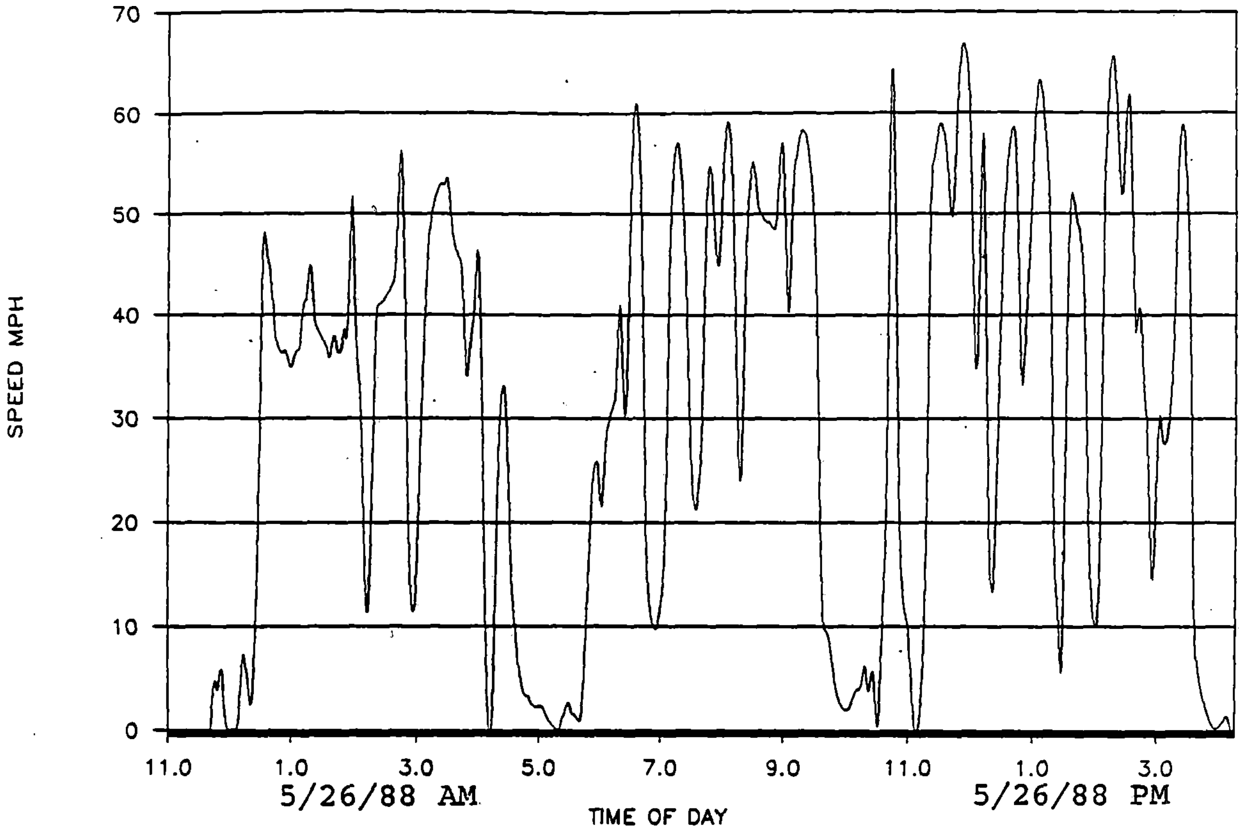


Fig. 12: Time - Distance History

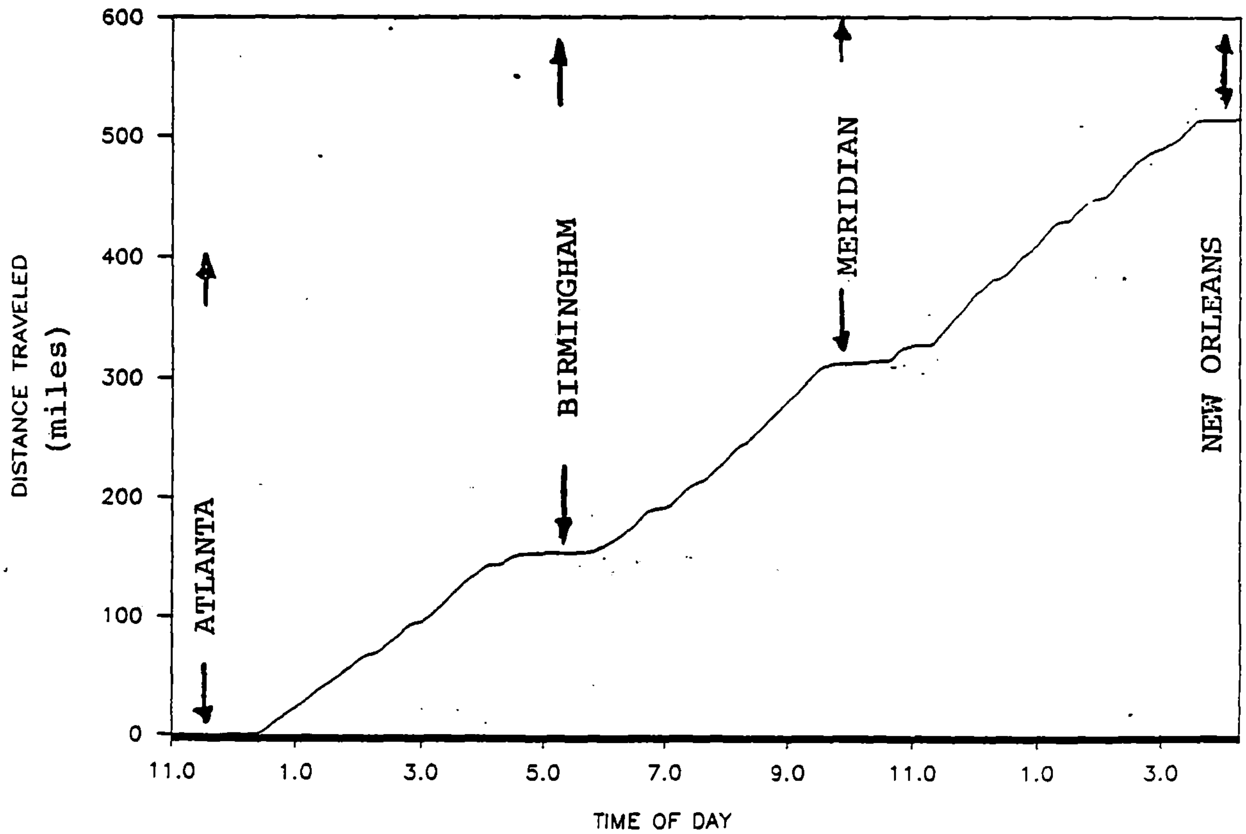


Fig. 13: Ambient Temperature at TTX Car Deck

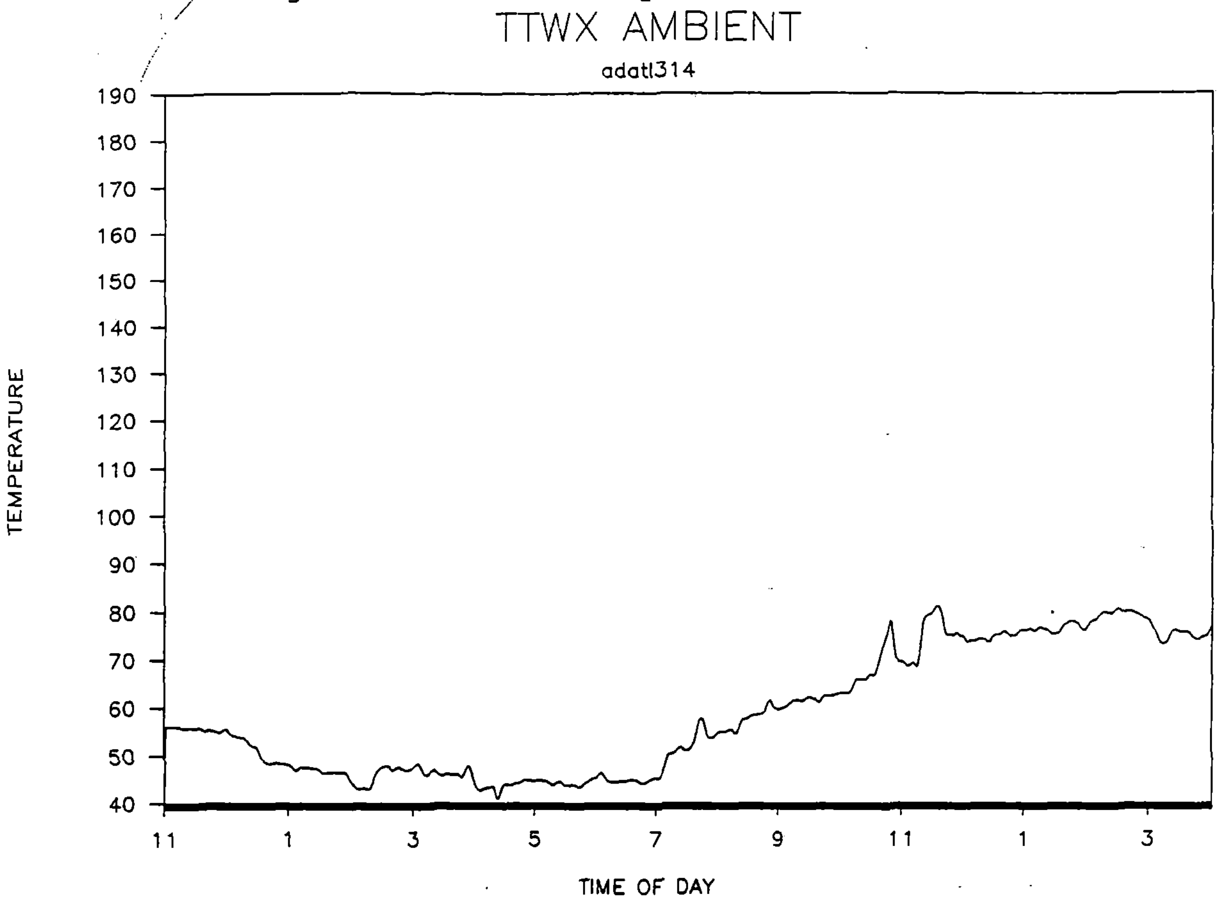


Fig. 15: TTWX BOTTOM R-1

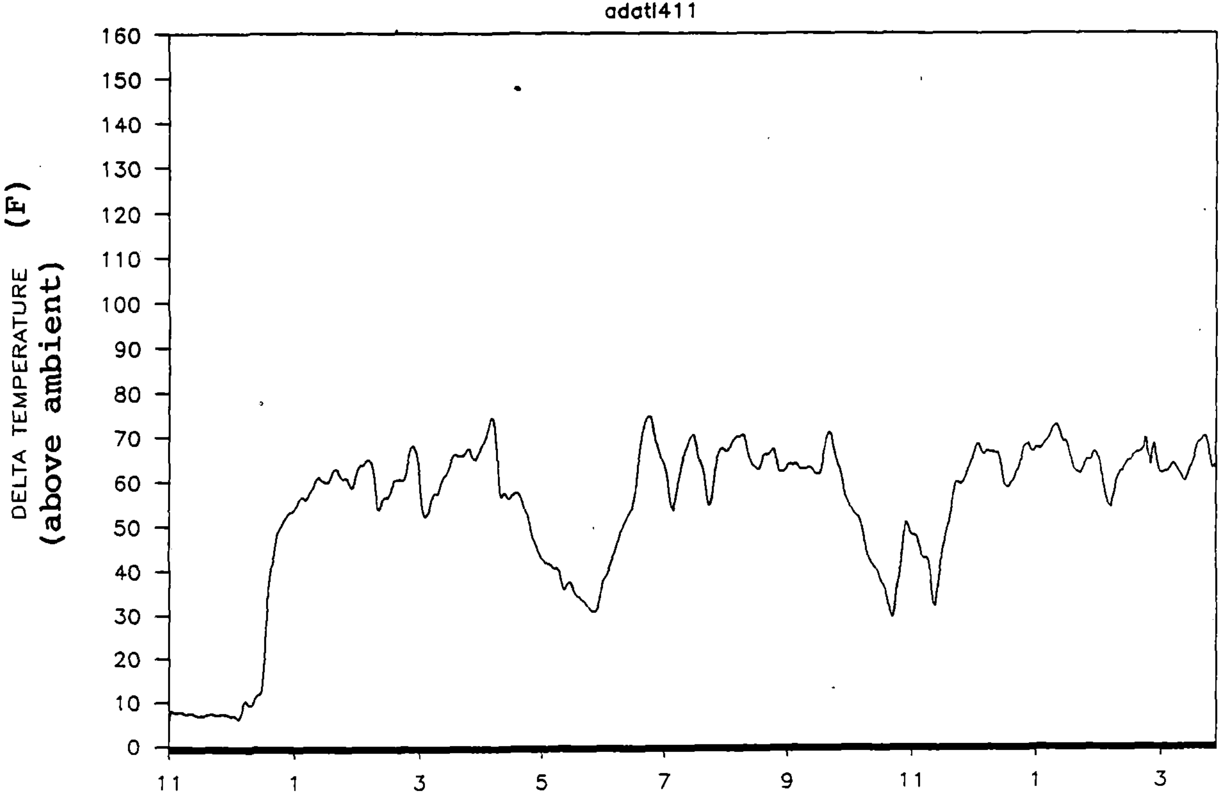


Fig. 14: TTWX BOTTOM R-1

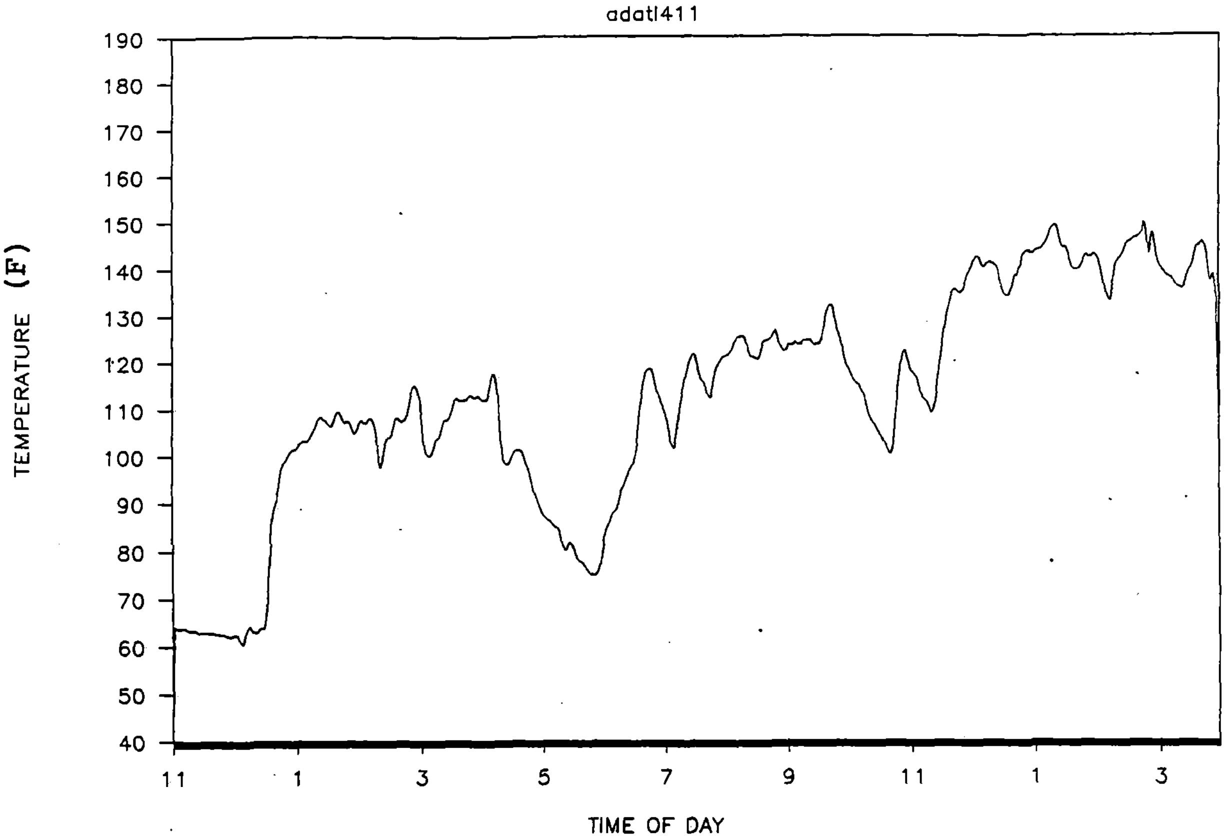


Fig. 17: TTWX TOP R-1

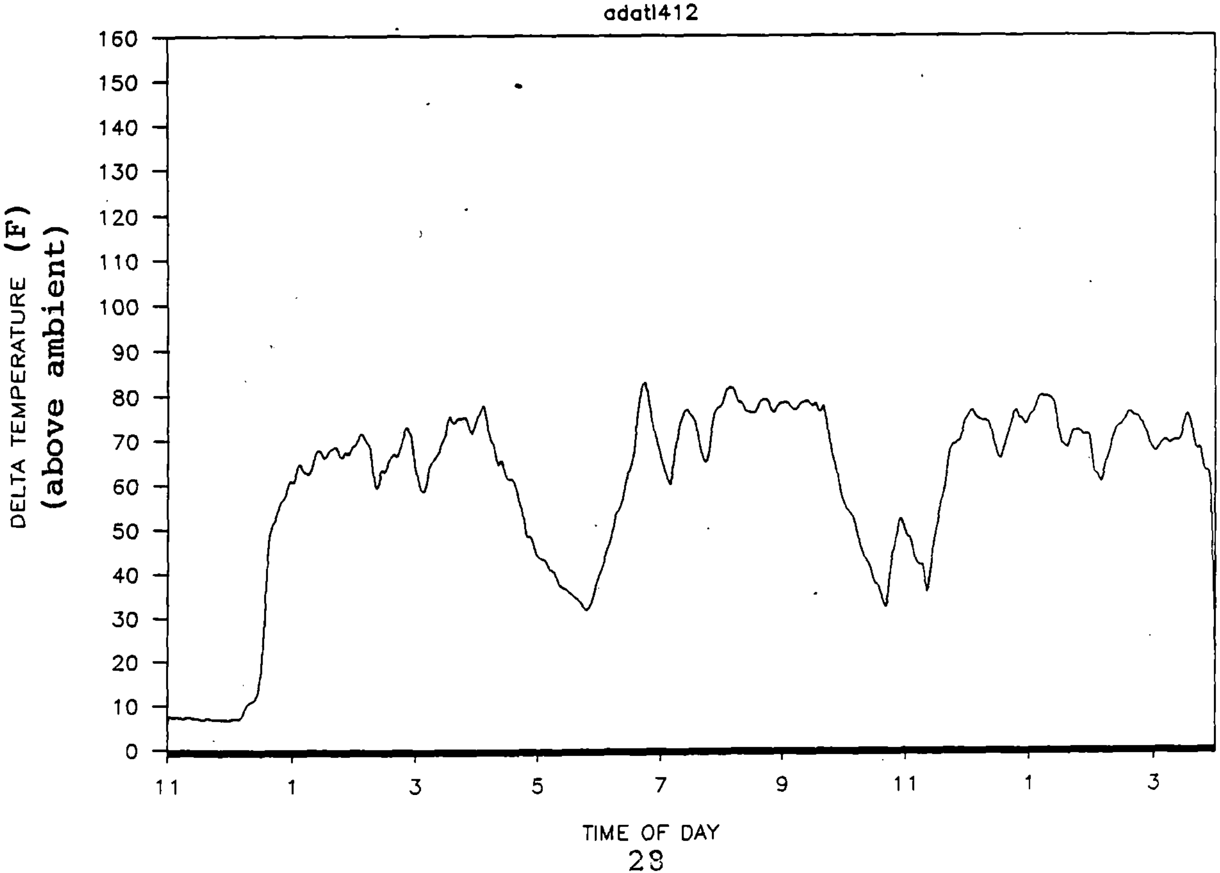


Fig. 16: TTWX TOP R-1

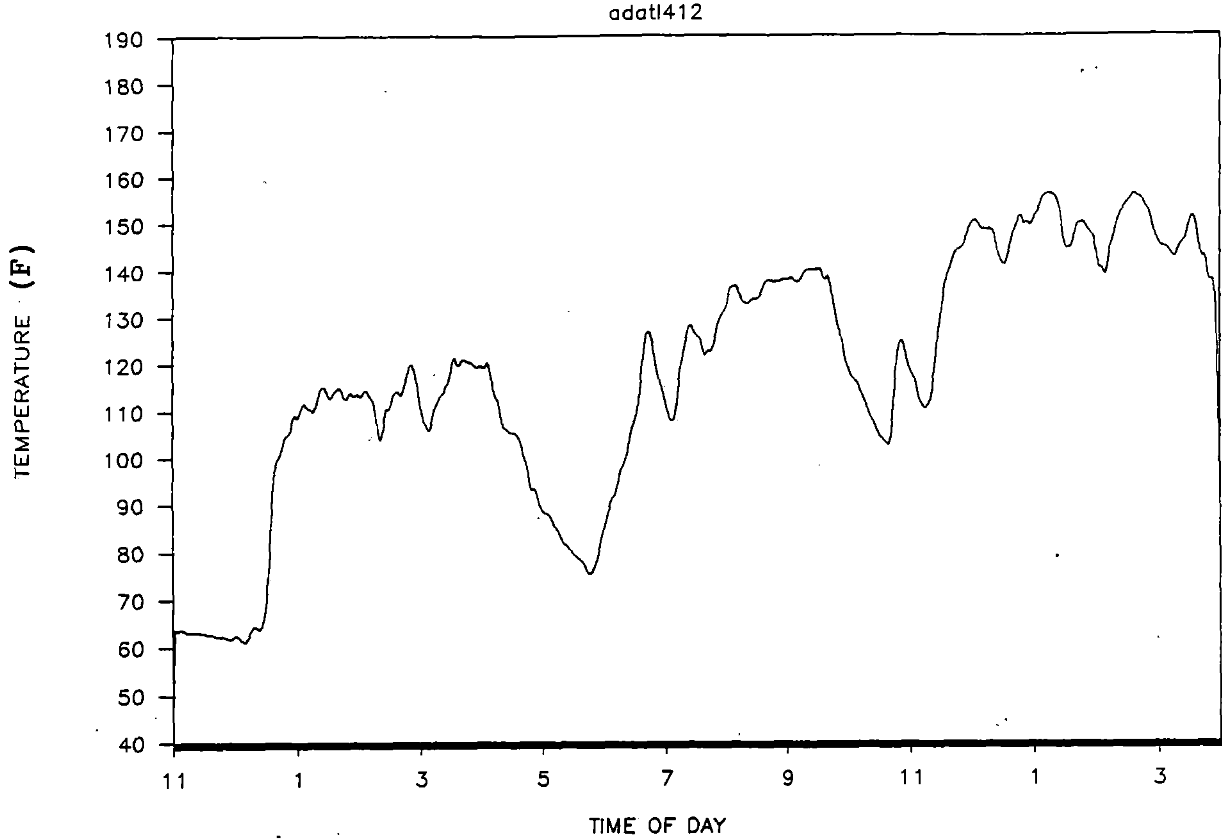


Fig. 19:

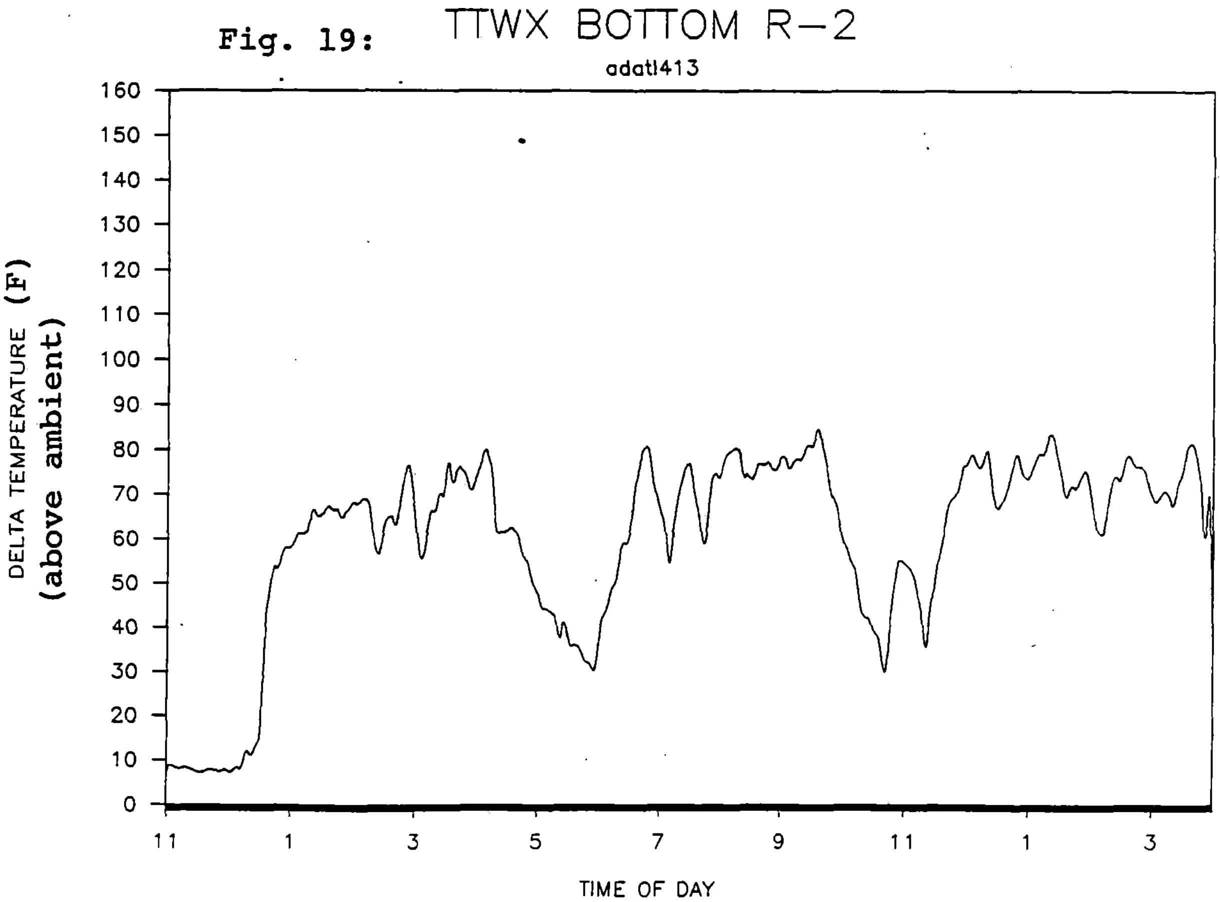

TTWX BOTTOM R-2
adatl413
DELTA TEMPERATURE (F)
(above ambient)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
11
1
3
5
7
9
11
1
3
TIME OF DAY

Fig. 18: TTWX BOTTOM R–2

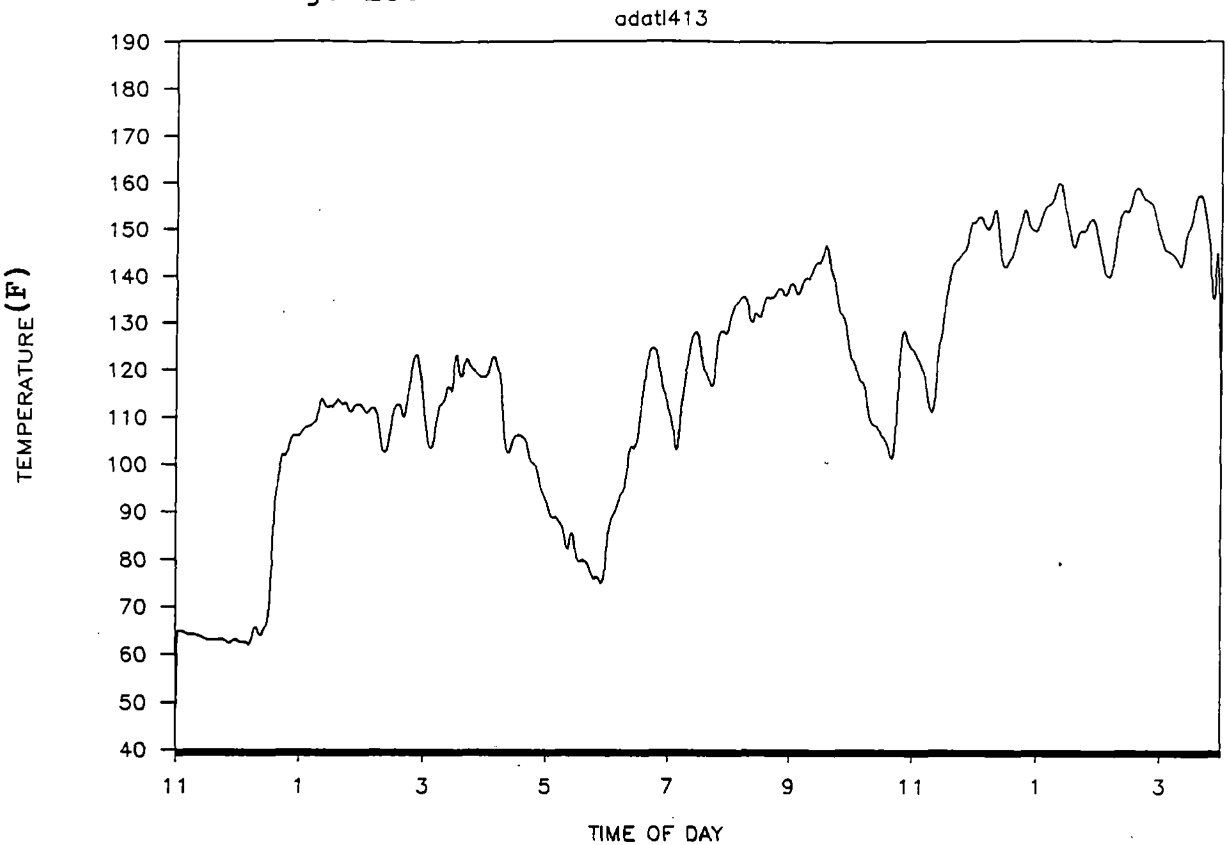


Fig. 21: TTWX TOP R-2

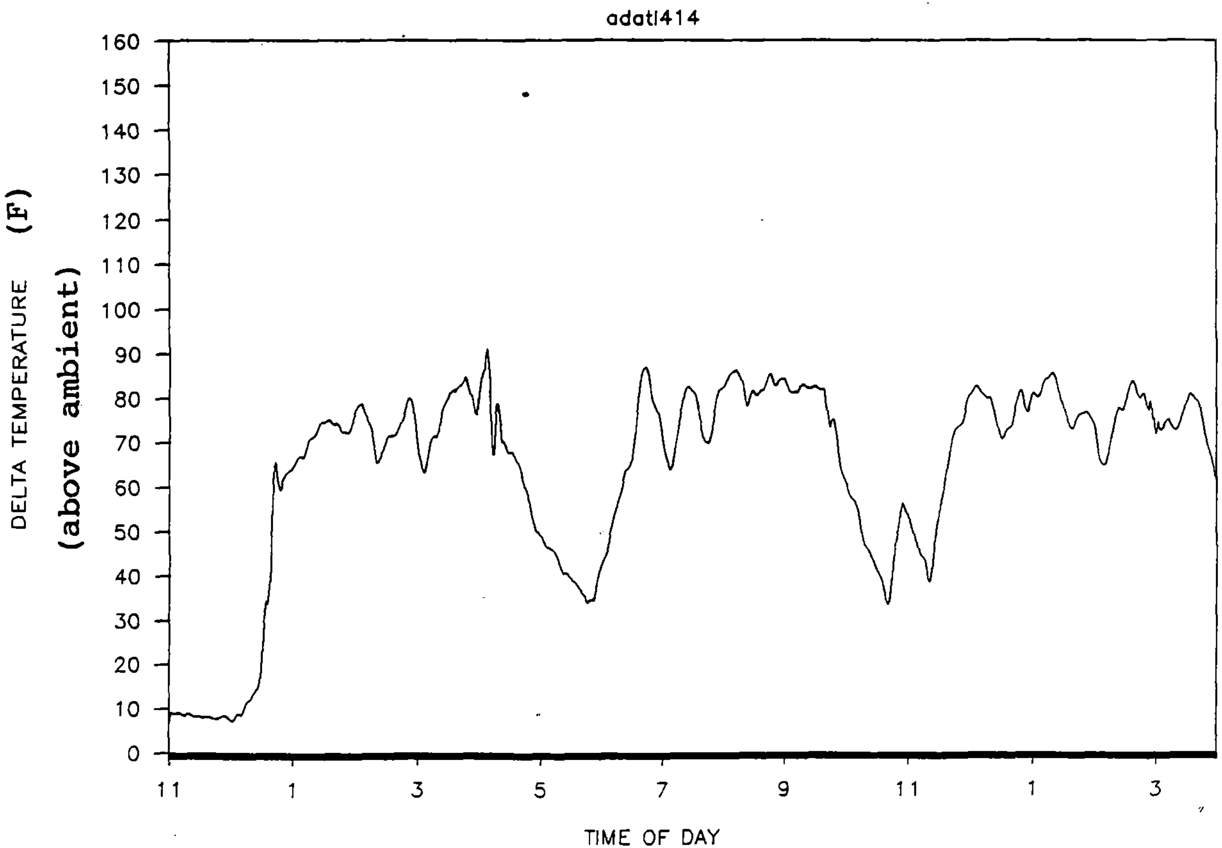


Fig. 20: TTWX TOP R-2

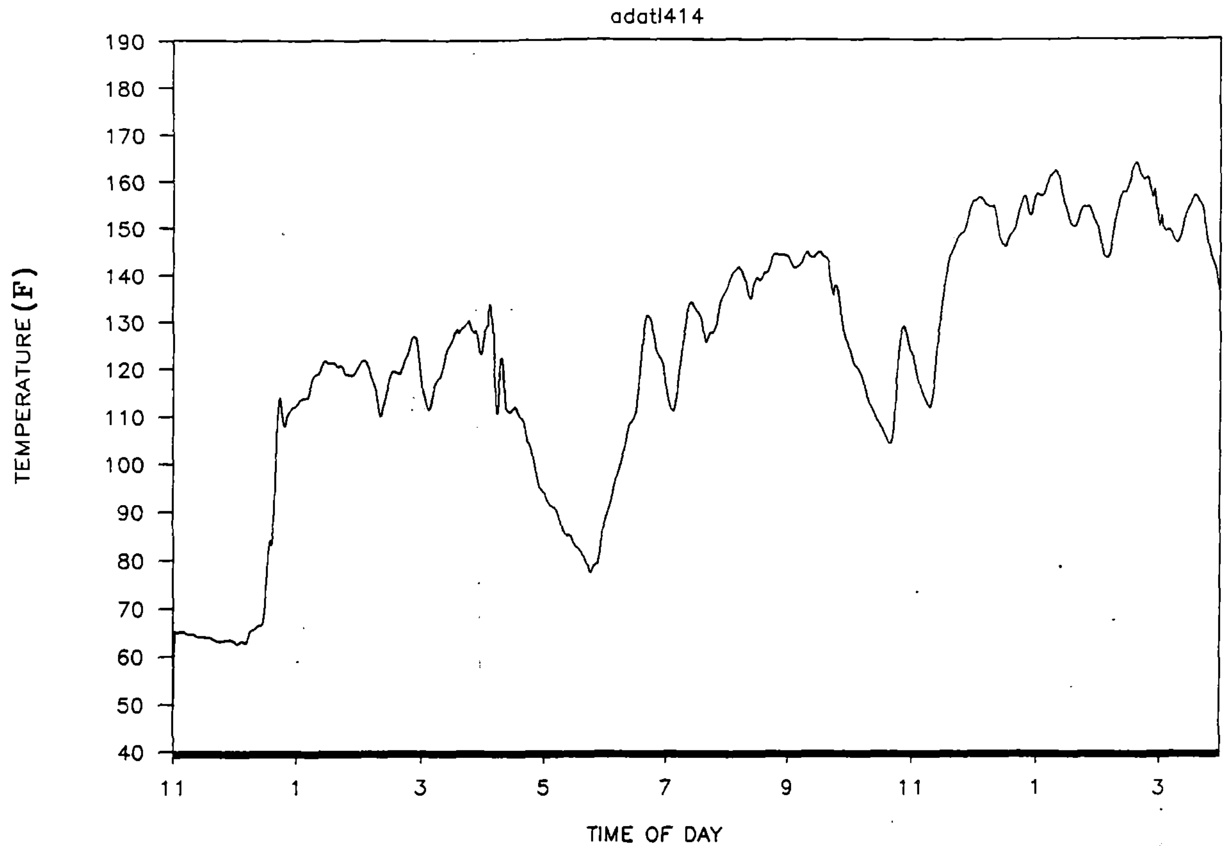


Fig. 23: TTWX BOTTOM R-4

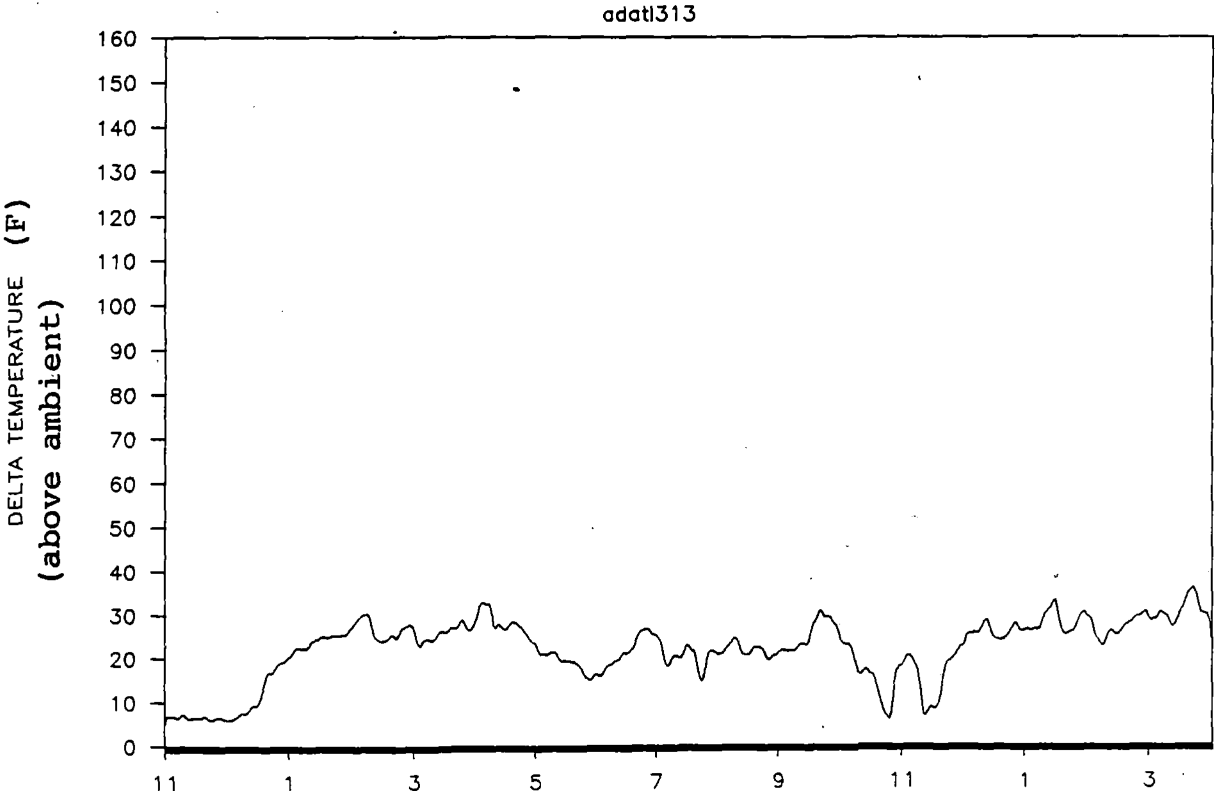


Fig. 22: TTWX BOTTOM R-4

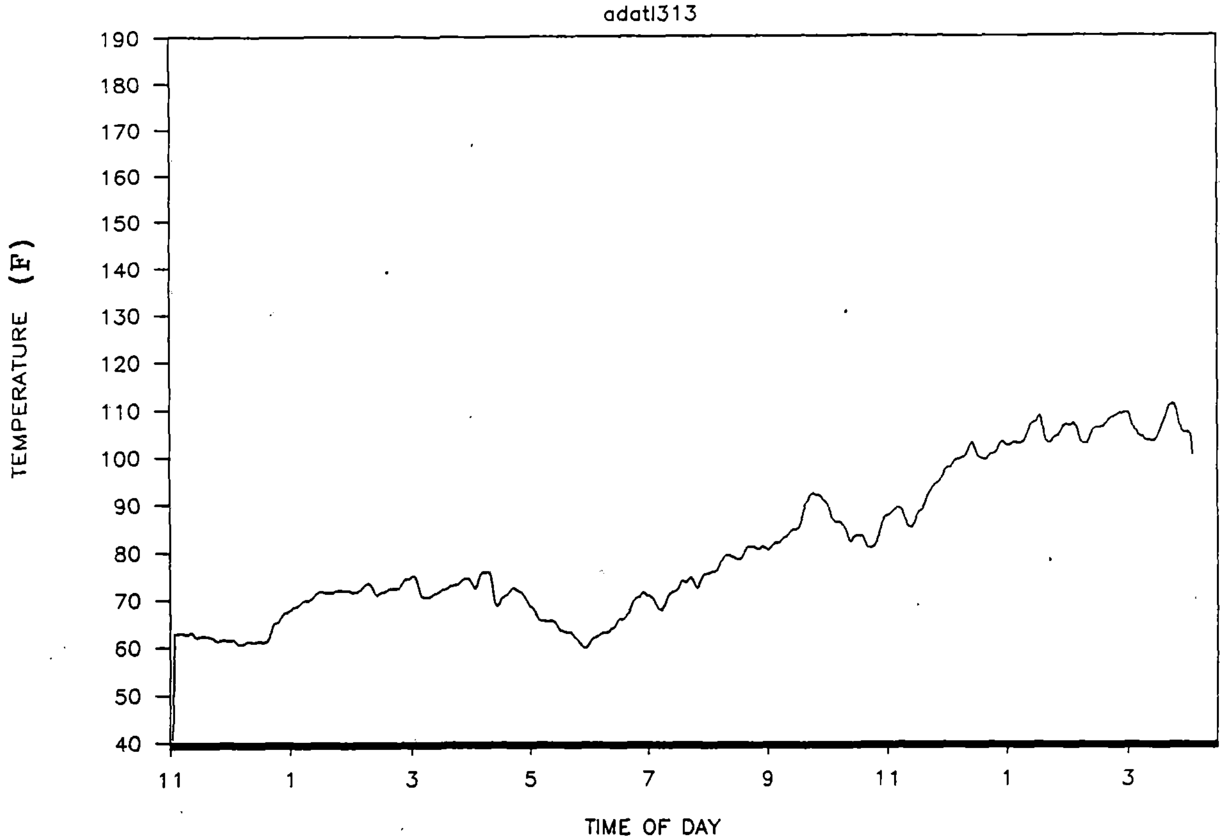


Fig. 25: TTWX TOP R-4

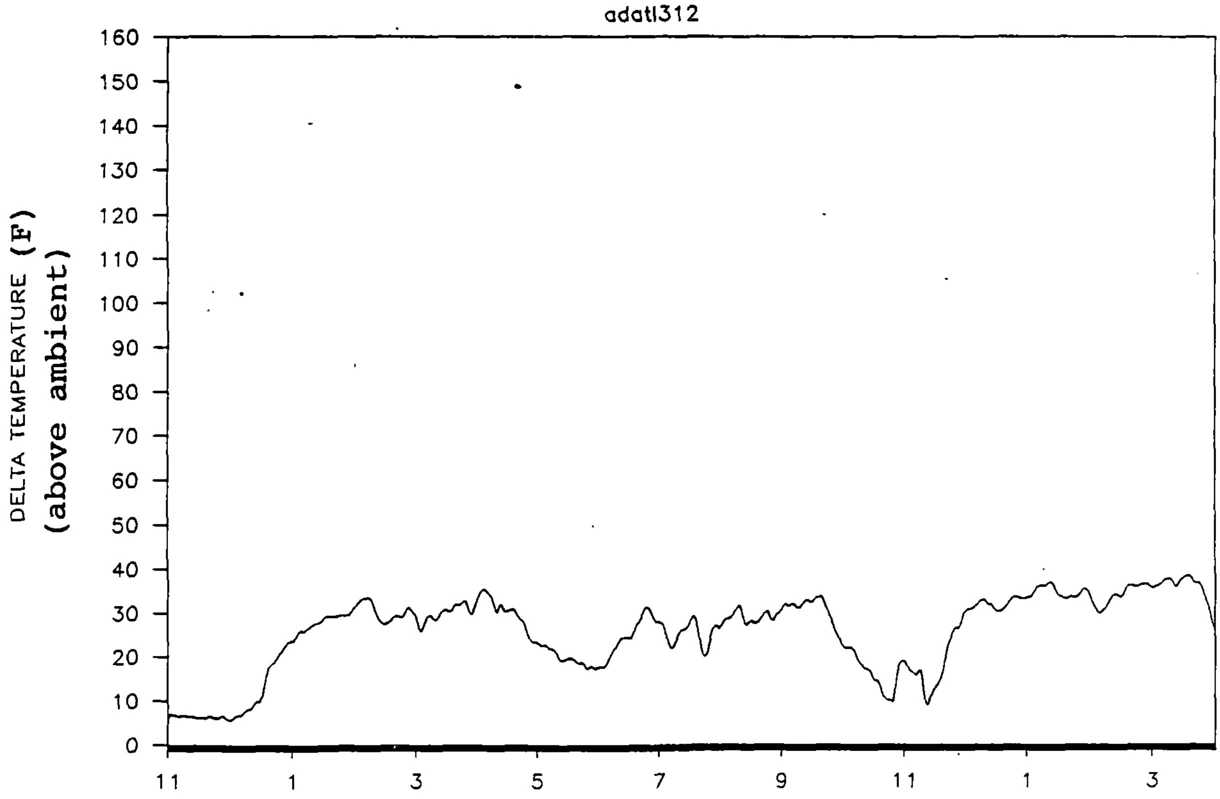


Fig. 24: TTWX TOP R-4

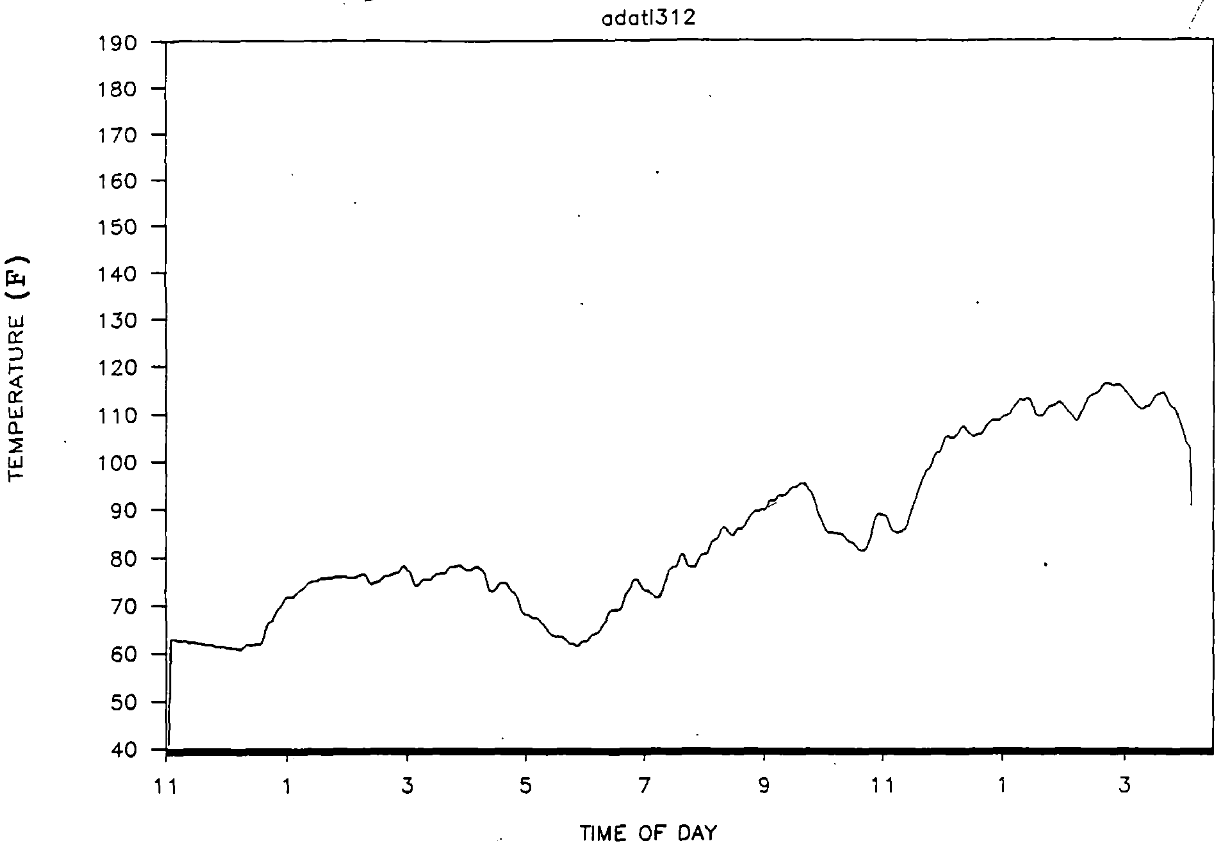


Fig. 27: TTWX SEAL ENCLOSURE R-4

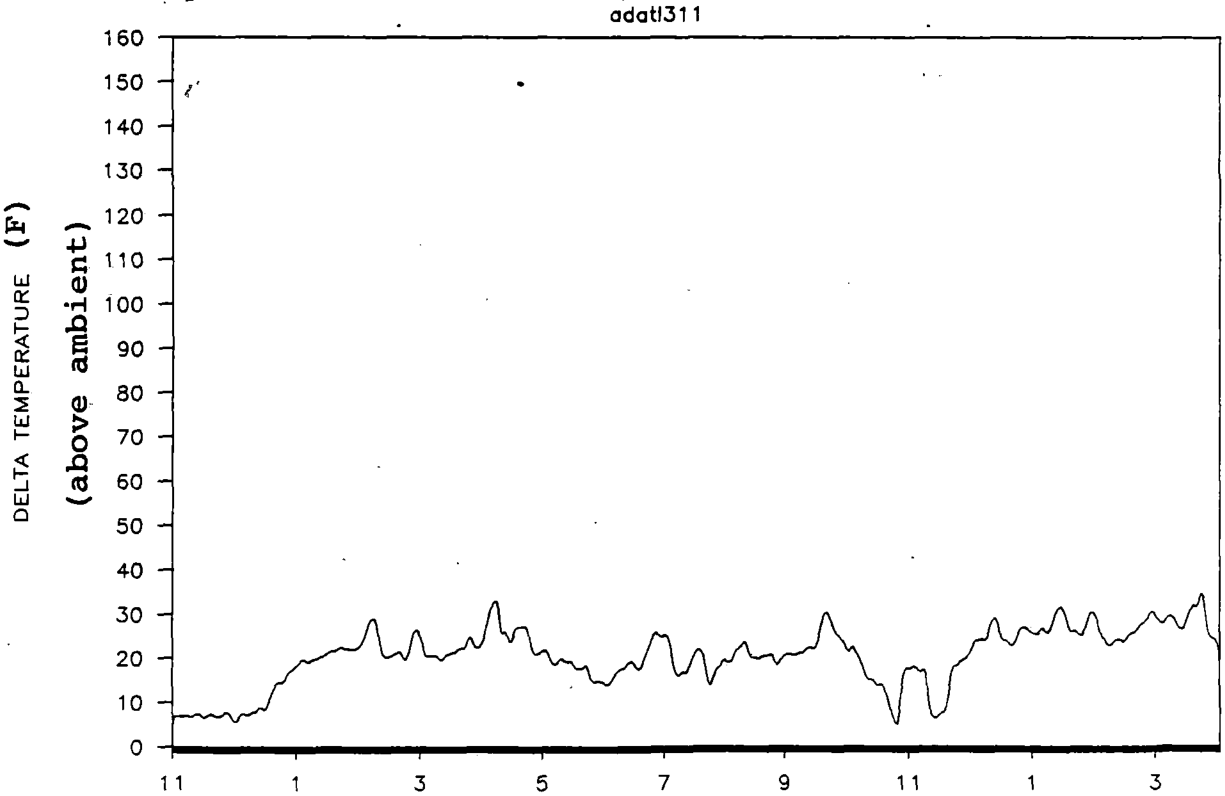


Fig. 26: TTWX SEAL ENCLOSURE R-4

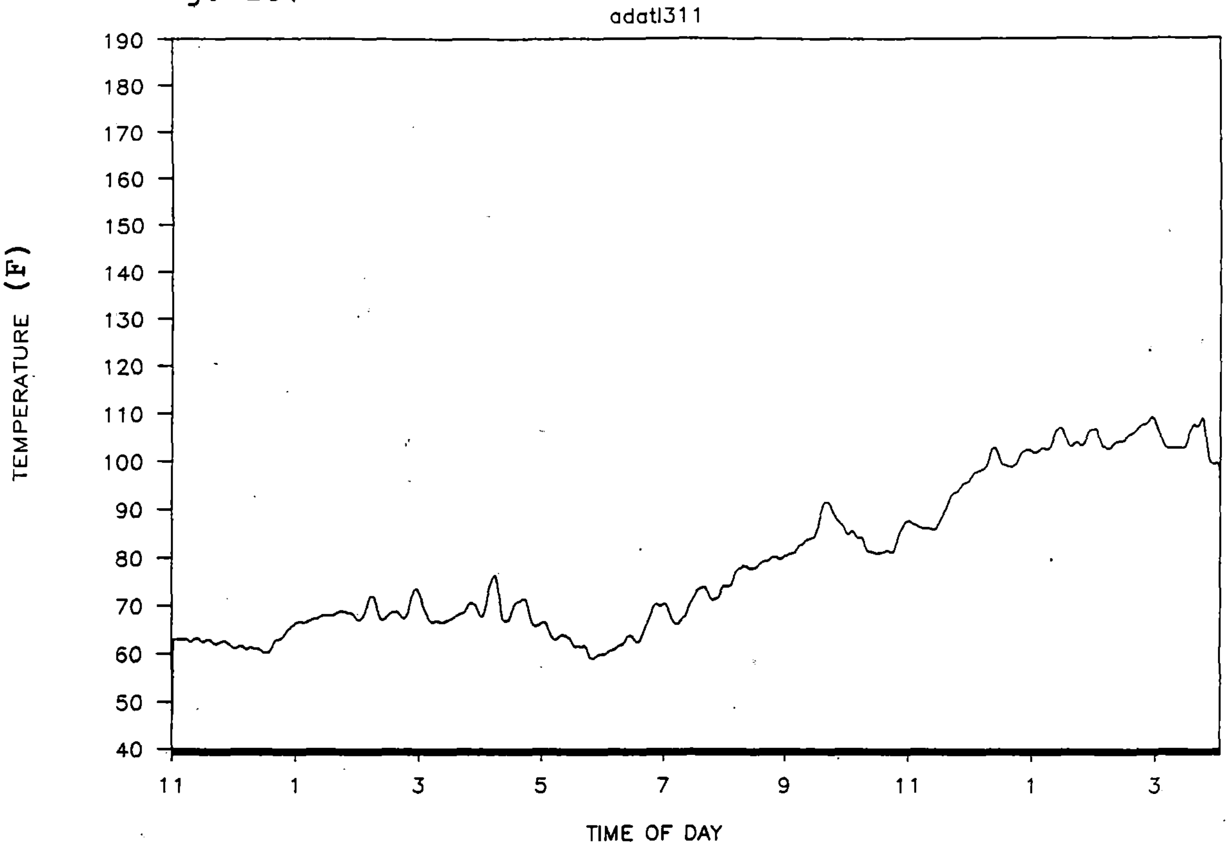
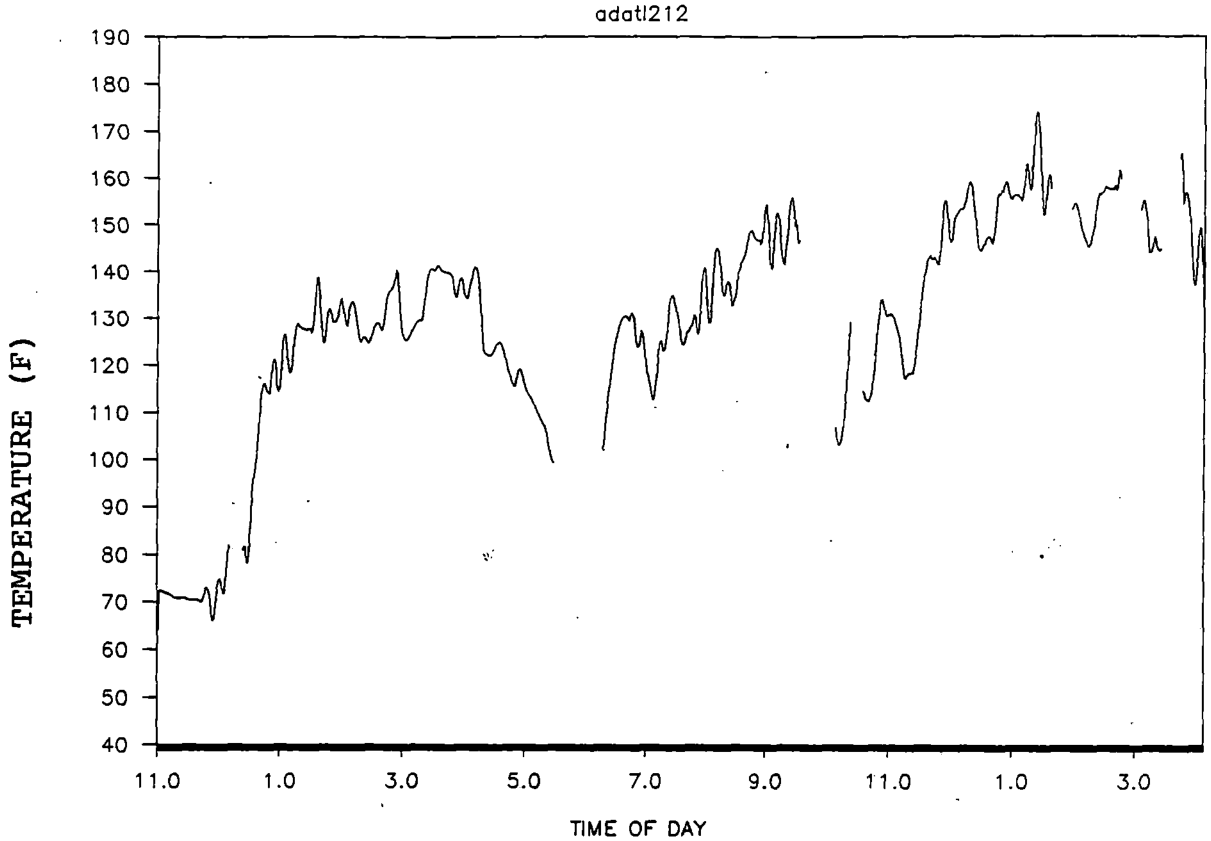


Fig. 28: APLX 2049 R-5 BOTTOM



NOTE: Anomalous Values Deleted

Fig. 29: APLX 2049 R-5 BOTTOM

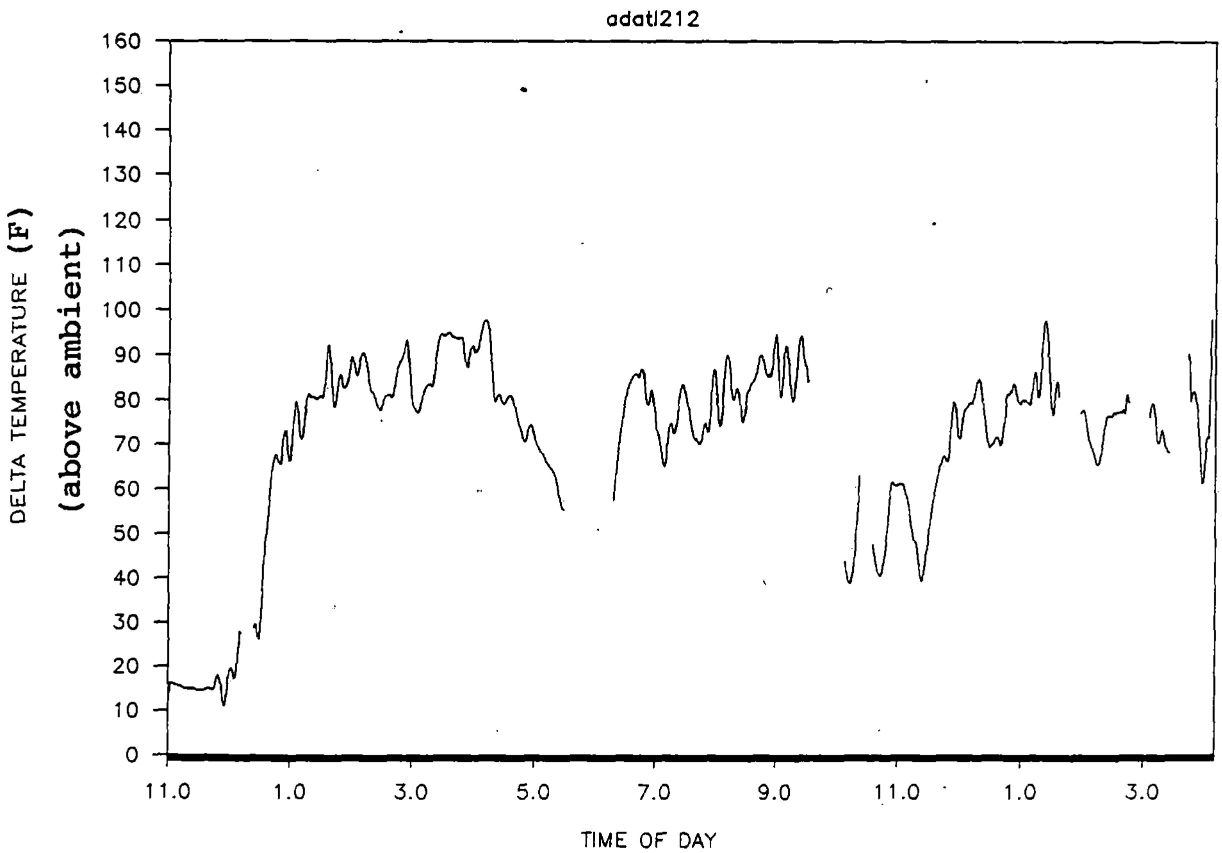


Fig. 31: APLX 2049 R-6 BOTTOM

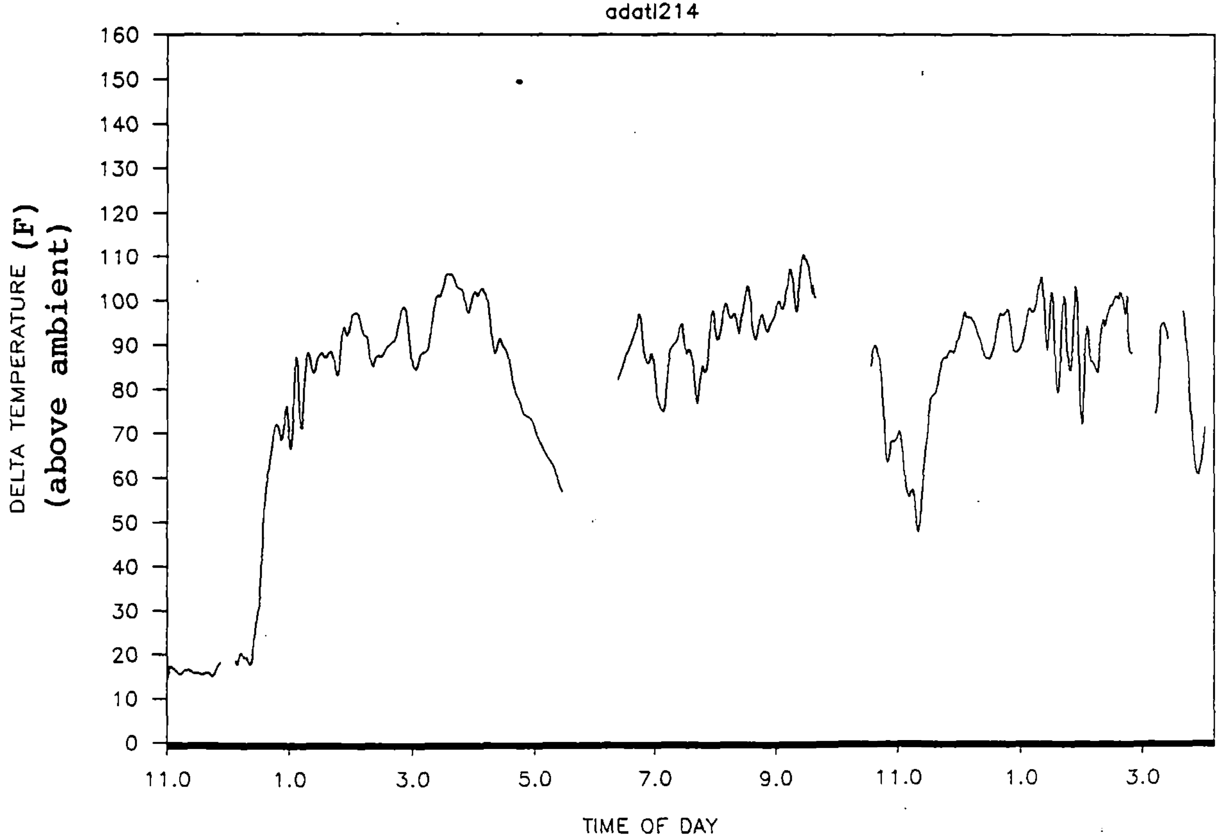
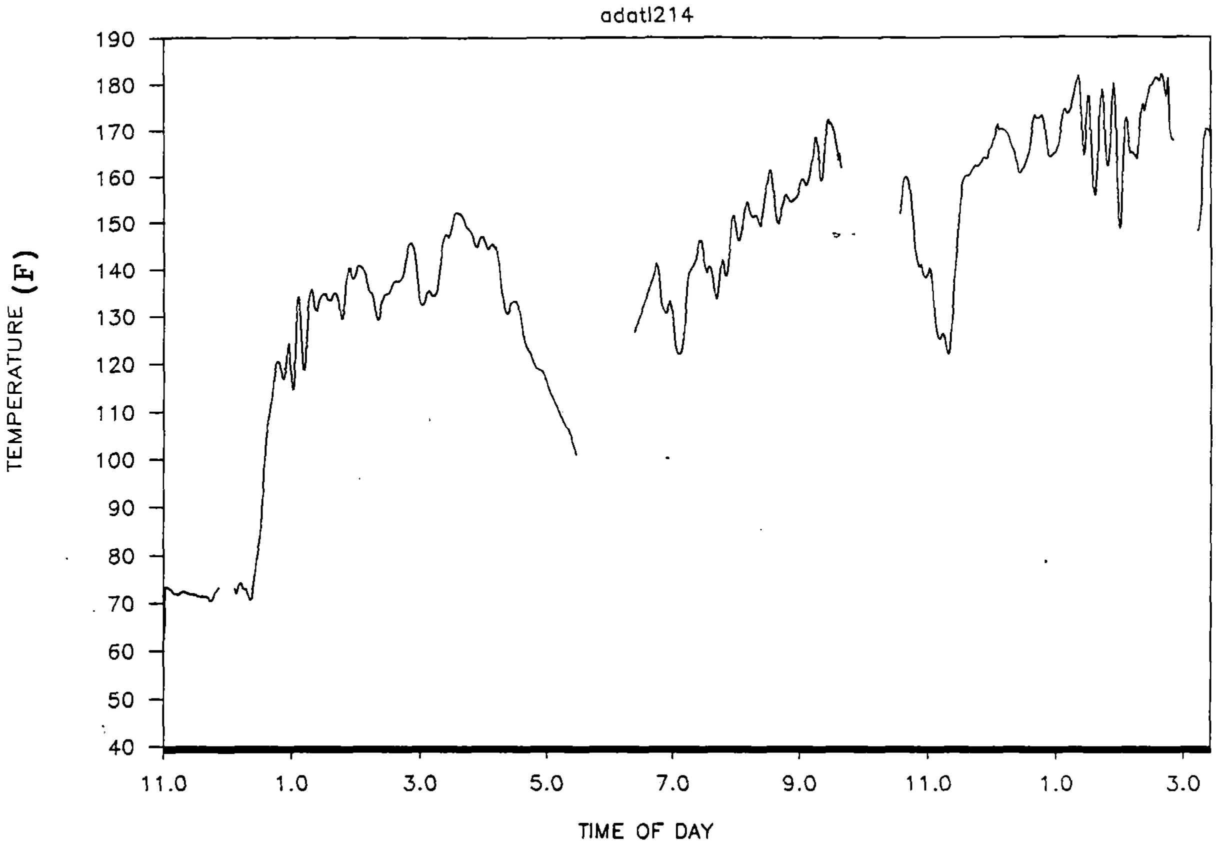
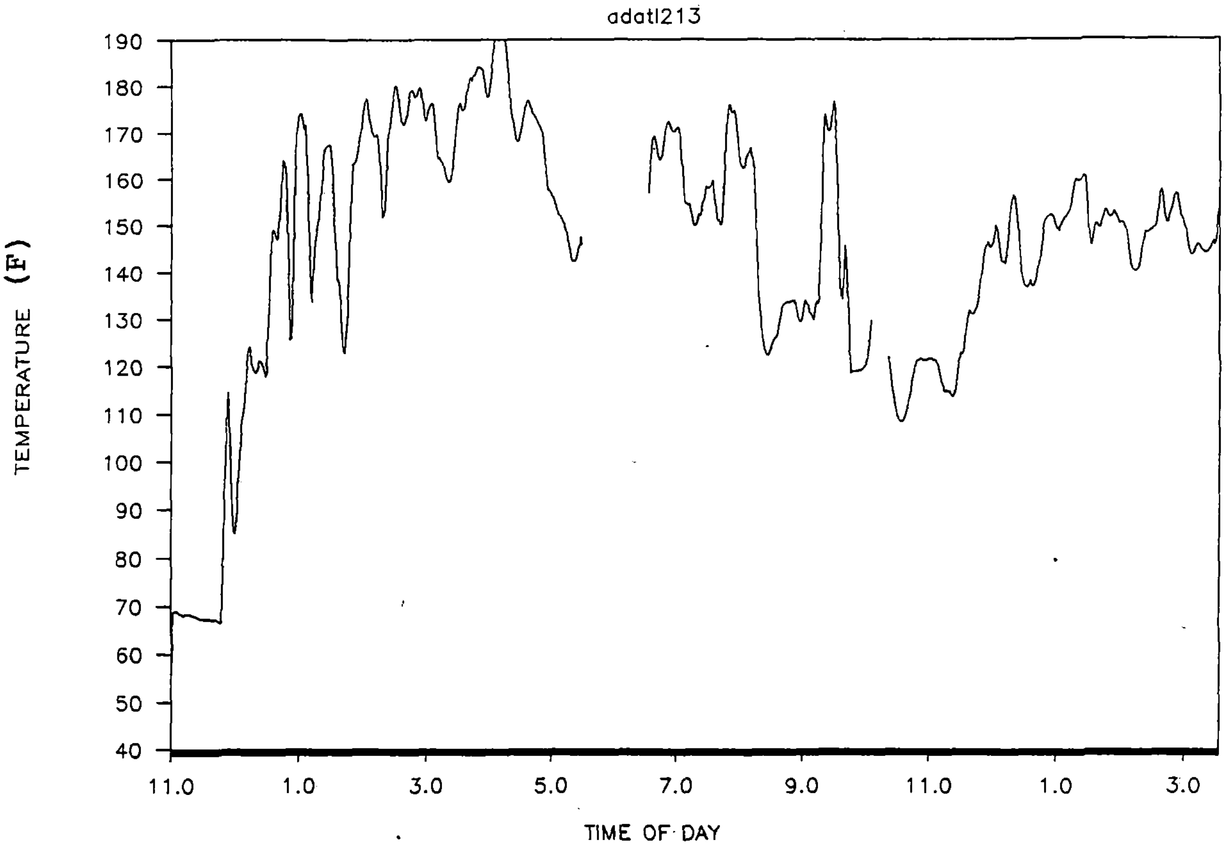


Fig. 30: APLX 2049 R-6 BOTTOM



NOTE: Anomalous Values Deleted

Fig. 32: APLX 2049 R-6 TOP



NOTE: Anomalous Values Deleted

Fig. 33: APLX 2049 R-6 TOP

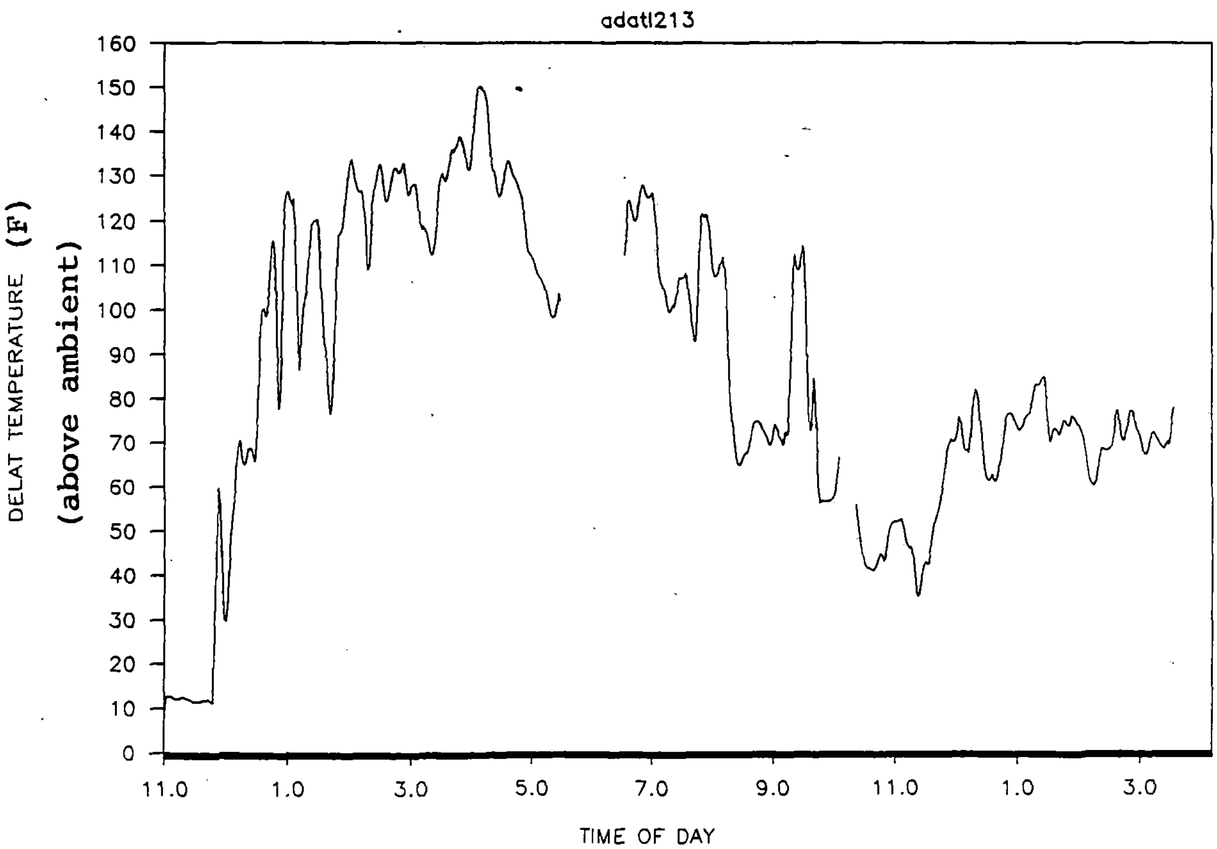
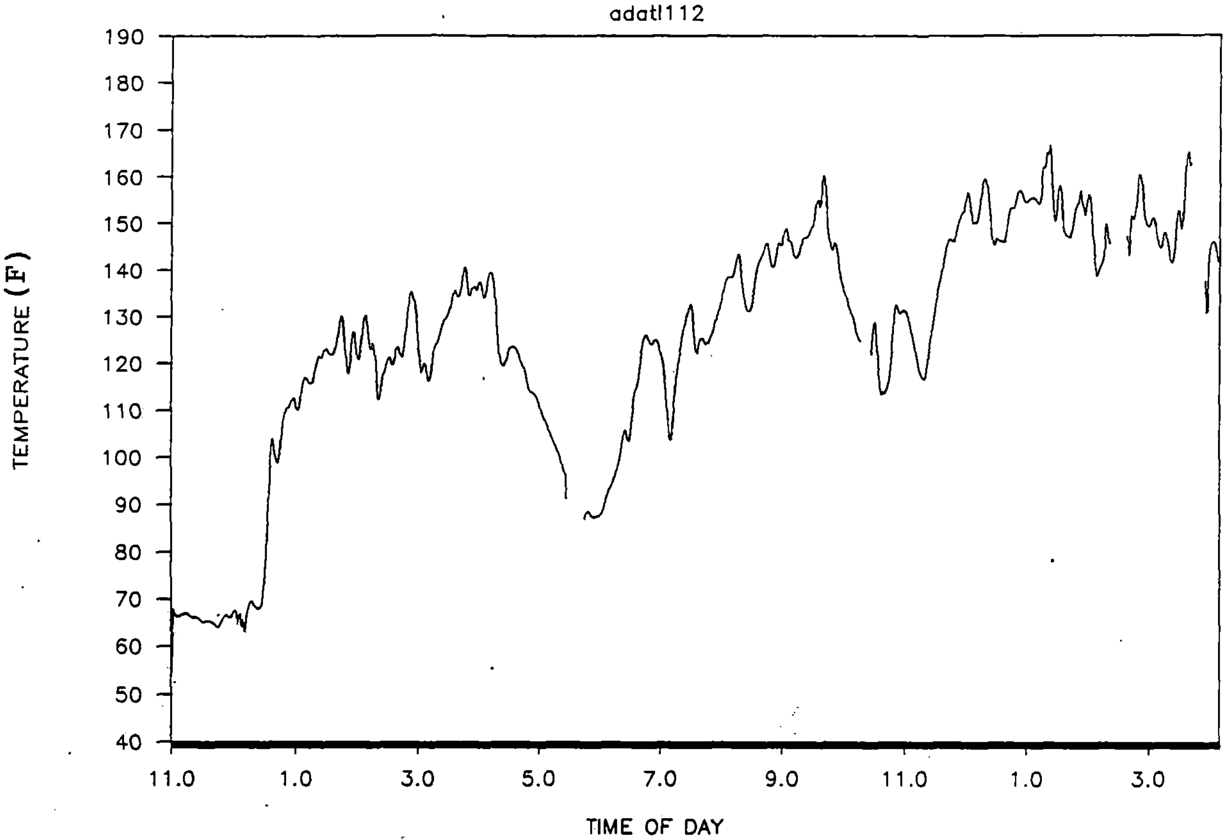


Fig. 34: APLX 2049 R–7 BOTTOM



NOTE: Anomalous Values Deleted

Fig. 35: APLX 2049 R–7 BOTTOM

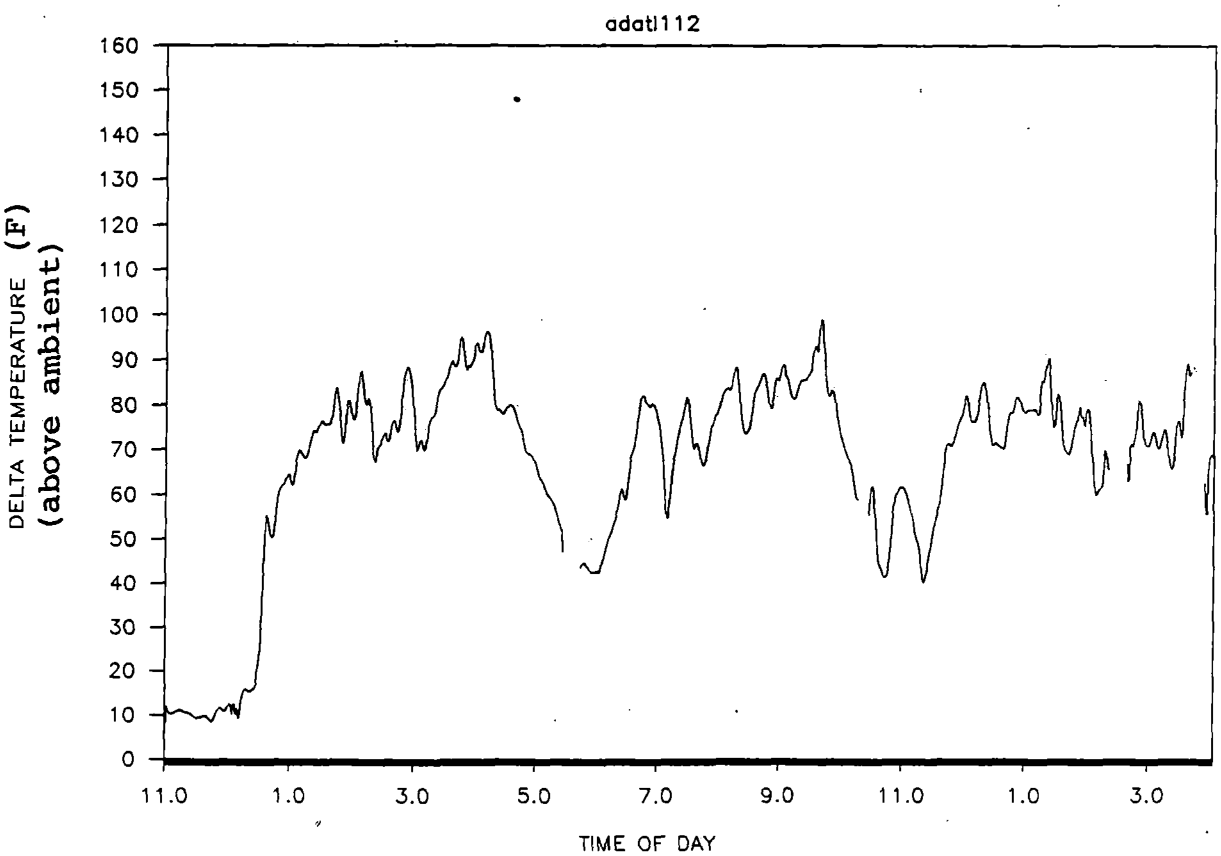
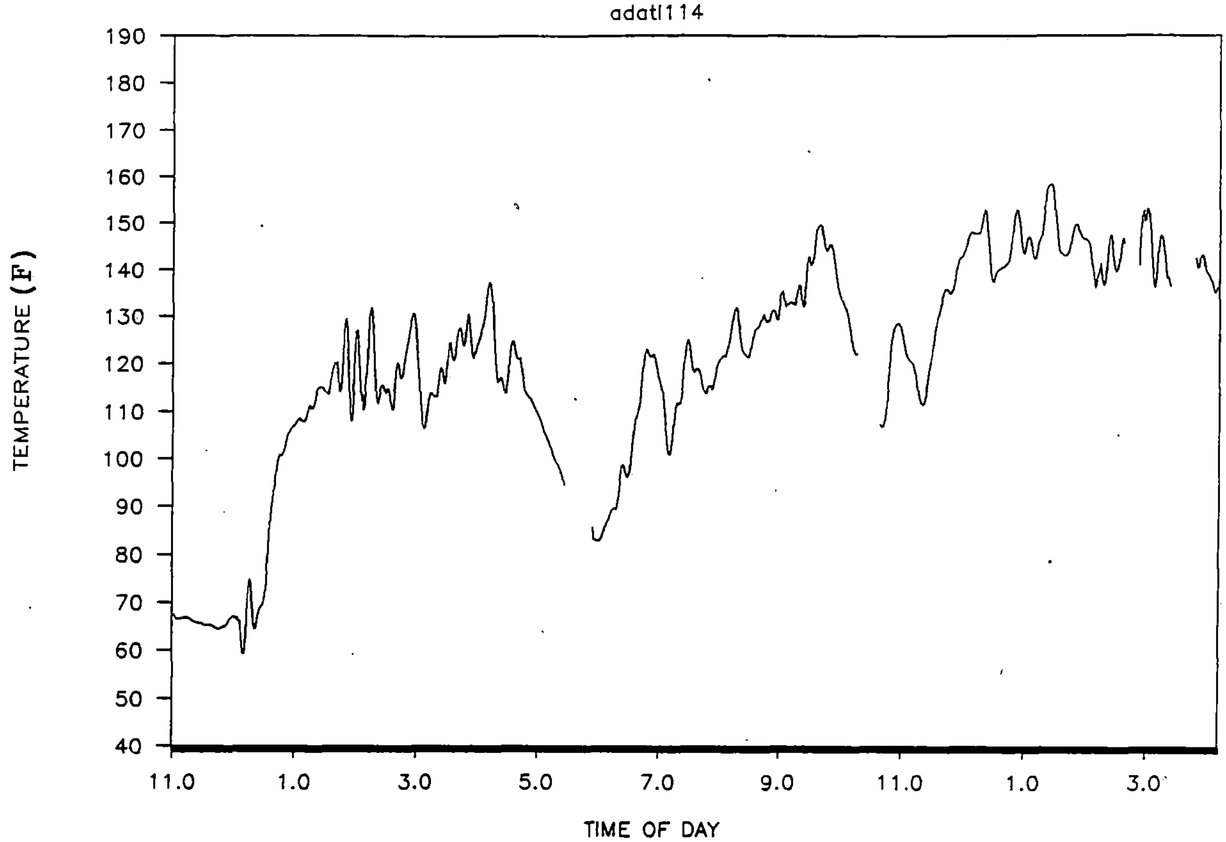


Fig. 36: APLX 2049 R-8 BOTTOM



NOTE: Anomalous Values Deleted

Fig. 37: APLX 2049 R-8 BOTTOM

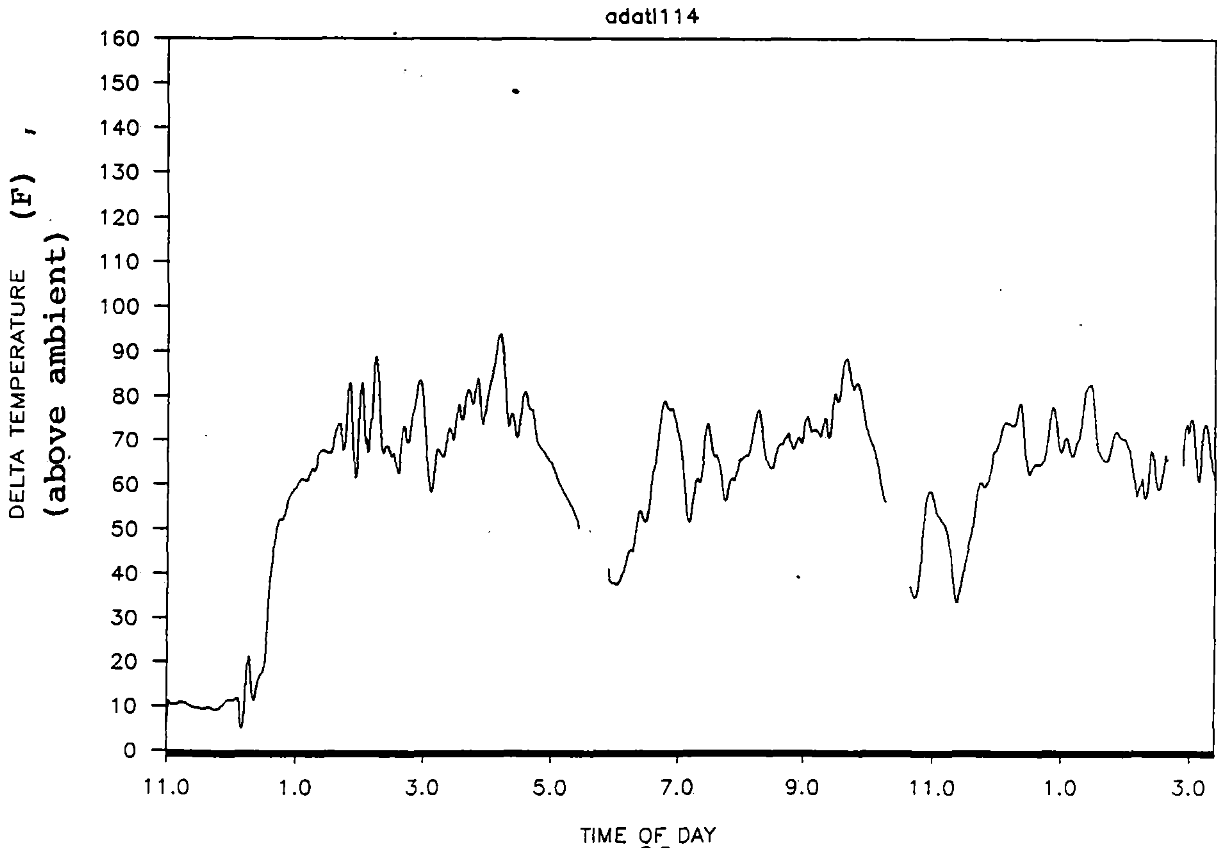
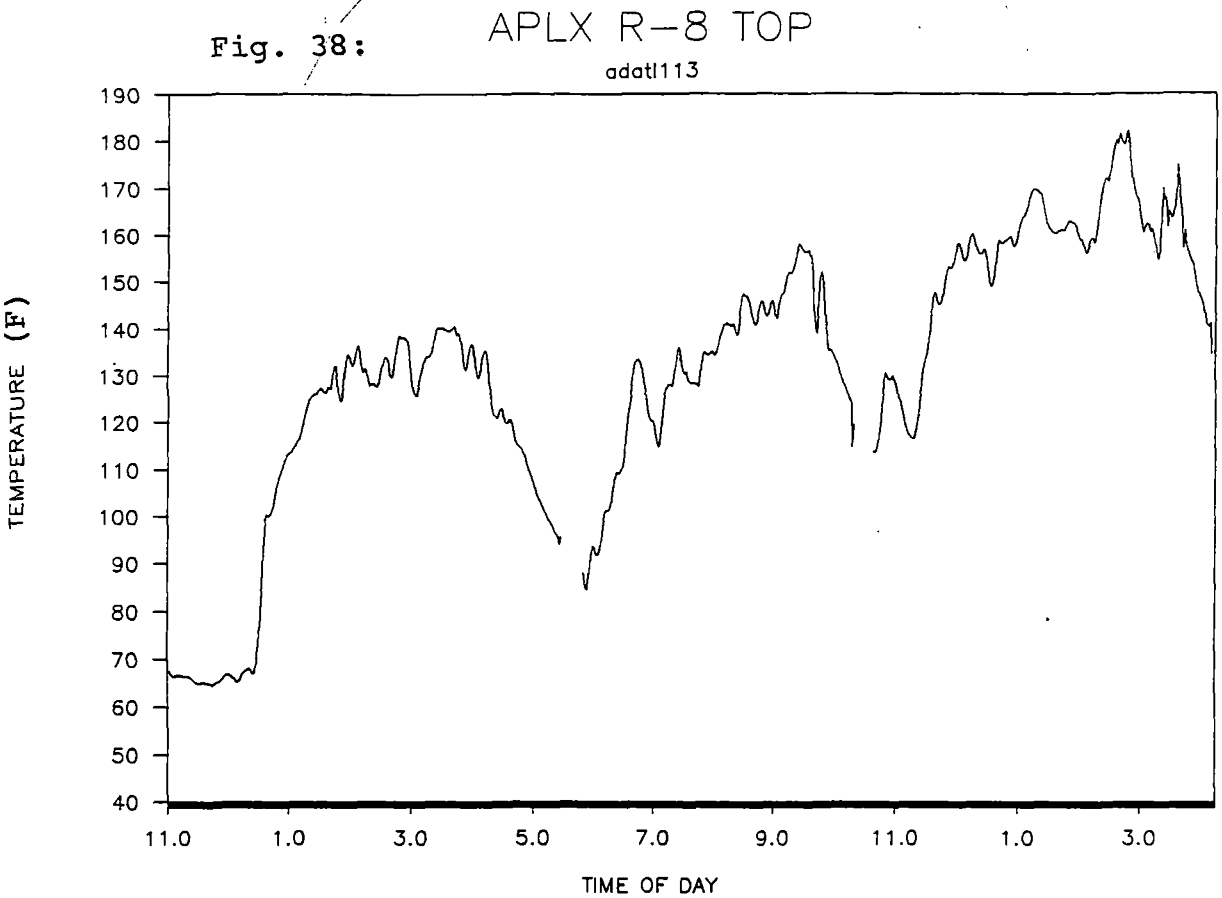
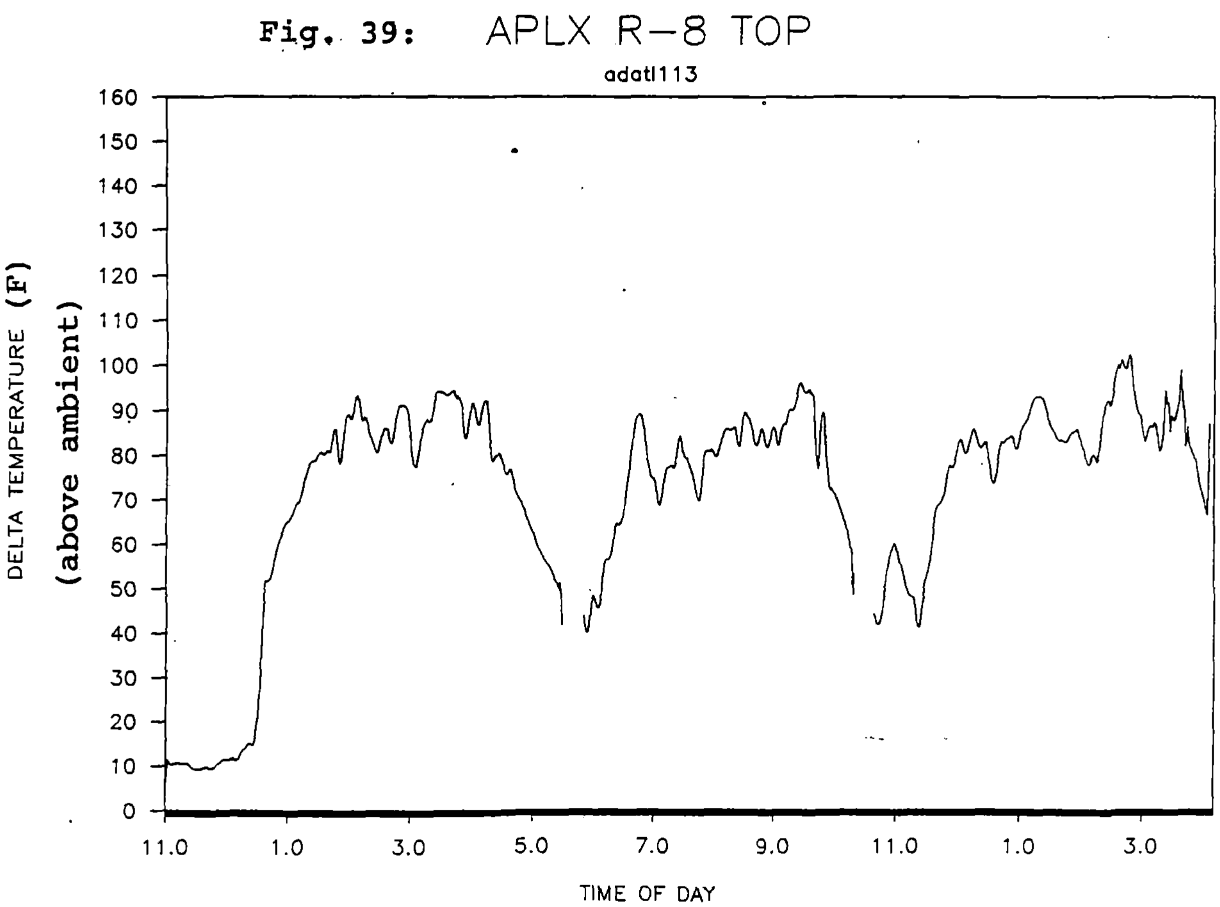


Fig. 38:



NOTE: Anomalous Values Deleted

Fig. 39:



Electronic noise was again encountered on the double-stack bearing recorders, as it had been on the prototype test. Obviously anomalous values have been removed from the figures. We are unable to explain the source of the noise on only the double-stack recorders; the TTX flatcar was in closer proximity to the locomotives over two thirds of the test run and suffered no interference. The interference particularly occurred during stops.

Wayside Hotbox Detector Data

Norfolk Southern provided the paper stripchart recording of the output of each of the twelve hotbox detectors on the test run. A sample hotbox detector output chart is Figure 40. The known locations of the test bearings within the test consist were used to read the corresponding hotbox detector value for each test bearing, in millimeters (mm) of height of the trace on the stripchart.

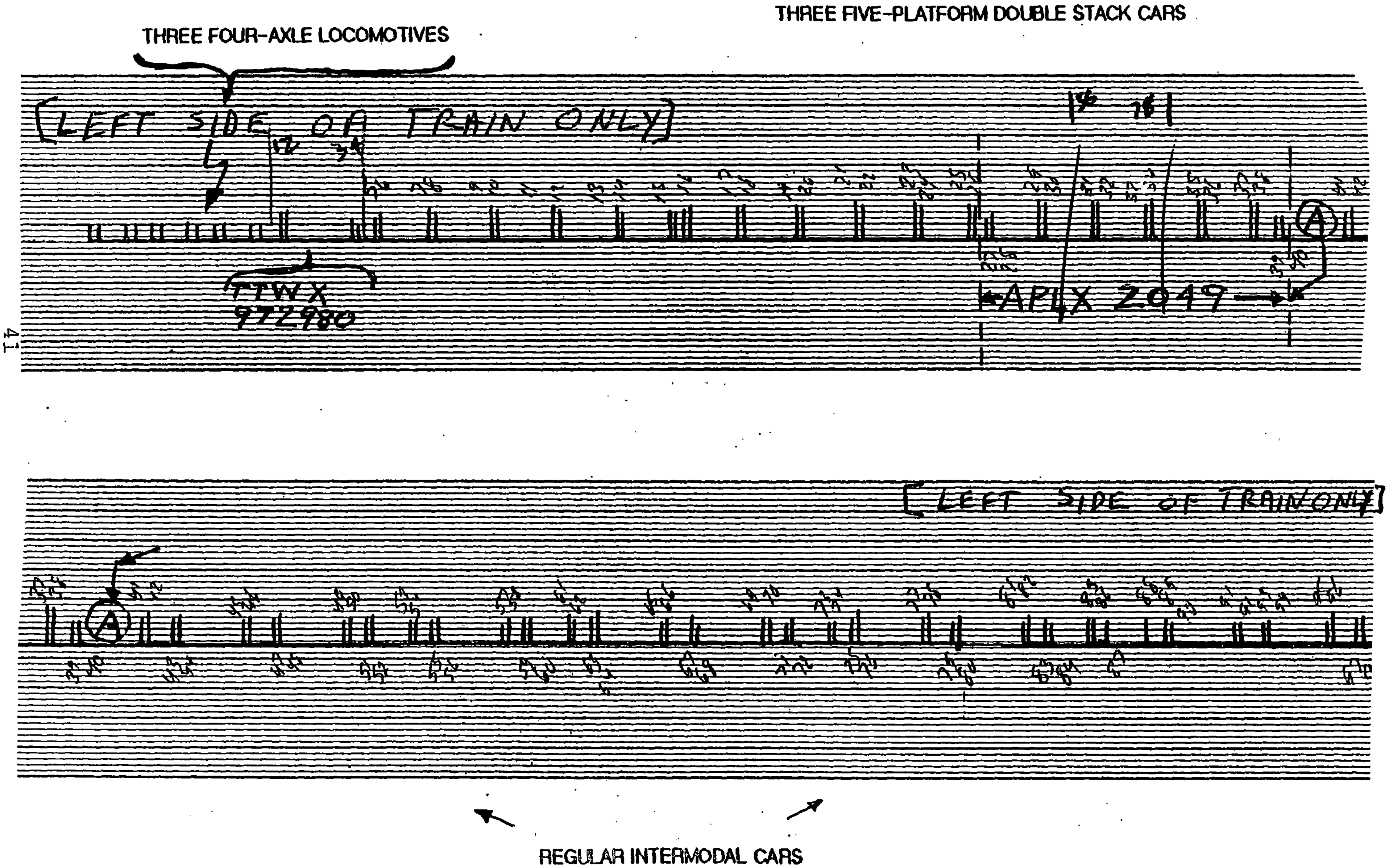
The seven bottom-of-cup readings for bearings on both the TTX and double-stack car were adjusted to above-ambient readings by subtracting the onboard ambient recorded value. This was done to match the hotbox readings, which are reported as the difference between the observed bearing temperature and ambient. The manual test logs were used to determine the time at which the train passed each detector. The time/temperature histories for each bearing were then used to specify the bottom-of-cup temperature record onboard the consist at the time the bearing was being surveyed by each wayside detector.

The detector readings for each test bearing are shown in Table 2. The onboard and wayside values were graphed and correlated for each detector. Sample graphs are shown in Figures 41 to 43. The NS Southern Railway detectors are calibrated so that a bearing at 175^{o}F above ambient should generate a 25mm stripchart spike; a rate of 7^{o}F per stripchart millimeter. The correlation coefficients determined from the onboard versus wayside ranged from 6.4^{o}F to 14.8^{o}F per millimeter.

The difference for some detectors from the expected 7^{o}F rate is probably due to our inability to select the exact time in the onboard data at which the wayside detector was passed. As noted above, the test run territory involves continuous acceleration and braking cycles, leading to bearing temperature changes which can occur relatively rapidly. However, changes in bearing temperatures tend to occur along the consist simultaneously; all bearings become warmer as the speed increases, and cool when the speed decreases. This means that the onboard/wayside correlation coefficients can be appropriately used to determine temperatures of bearings in the test consist, other than the test bearings, despite the possibility that the timing of the correlation was not exact.

[redacted]

FIGURE 40: SAMPLE HOTBOX DETECTOR OUTPUT TAPE
DETECTOR AT RICHBURG, MISSISSIPPI
TEST TRAIN 219 MAY 26, 1988



[redacted]

TABLE 2
HOTBOX DETECTOR READINGS FOR TEST BEARINGS

DETECTOR LOCATION		TTX BEARINGS				APLX BEARINGS			
		L1	L2	L3	L4	L5	L6	L7	L8
WINSTON	1	5	5.5	4	3.25	7.25	6.75	6.5	7.25
MORGAN	2	7.75	8.75	6.25	5.25	10.5	9	10	11
TALLAPOOSA	3	7	8	5	3.25	7.5*	8.5*	8.5*	8.5*
DEARMANVILLE	4	5.25	7.25	4.25	2.75	8.25*	8.25*	11.5*	10.5*
LINCOLN	5	5.75	6.75	4	3.25	9.75	11	9.75	11.25
COOKSPRINGS	6	8	9	6.25	4.25	13	13.5	13	14.75
KIMBRELL	7	6.5	7	4.75	3.25	8.25	8.75	8	9.75
TUSCALOOSA	8	6	7	4.25	3.25	7.5	8	8	8.5
MOUNDVILLE	9	5.25	6.25	4	3.25	7.25	8	7.25	8
BOLLIGEE	10	5.5	6.25	3.75	2.75	7.5	9	8	9
LIVINGSTON	11	6.25	8	4	3	9.25	10.75	10	10.5
CUBA	12	7	8	5	3.5	10	10.5	10	11.25
PACHUTA	13	4.5	6	3.5	3.25	7.25	7.75	7.25	7.75
SANDERSVILLE	14	4.5	5	3.5	3	7	7.5	6.5	7
ELLISVILLE	15	6	7.5	4.5	3	9	9	8.25	9.5
RICHBURG	16	5	5.75	4	3	6.5	6.5	5.5	6.75
POPLARVILLE	17	5.75	6	4.25	3.25	7	7.5	7	7.75
PICAYNE	18	6.25	7	5	4.25	9	7.5	6	9.25*
SLIDELL	19	5.25	5.75	4	3	7.25	7	7	7.75

Fig. 41: HOT BOX DETECTOR # 5 (Lincoln, AL)

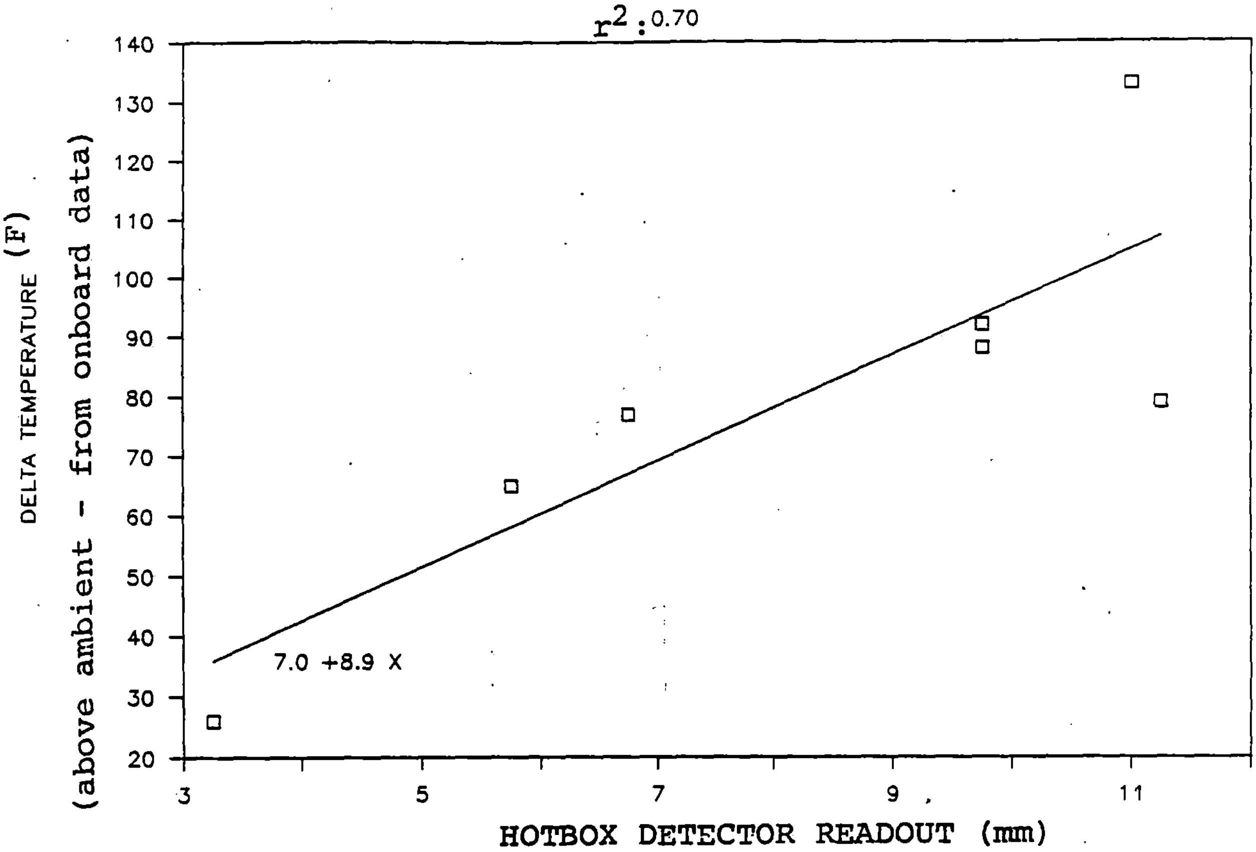


Fig. 42: HOT BOX DETECTOR # 12 (Cuba, MS.)

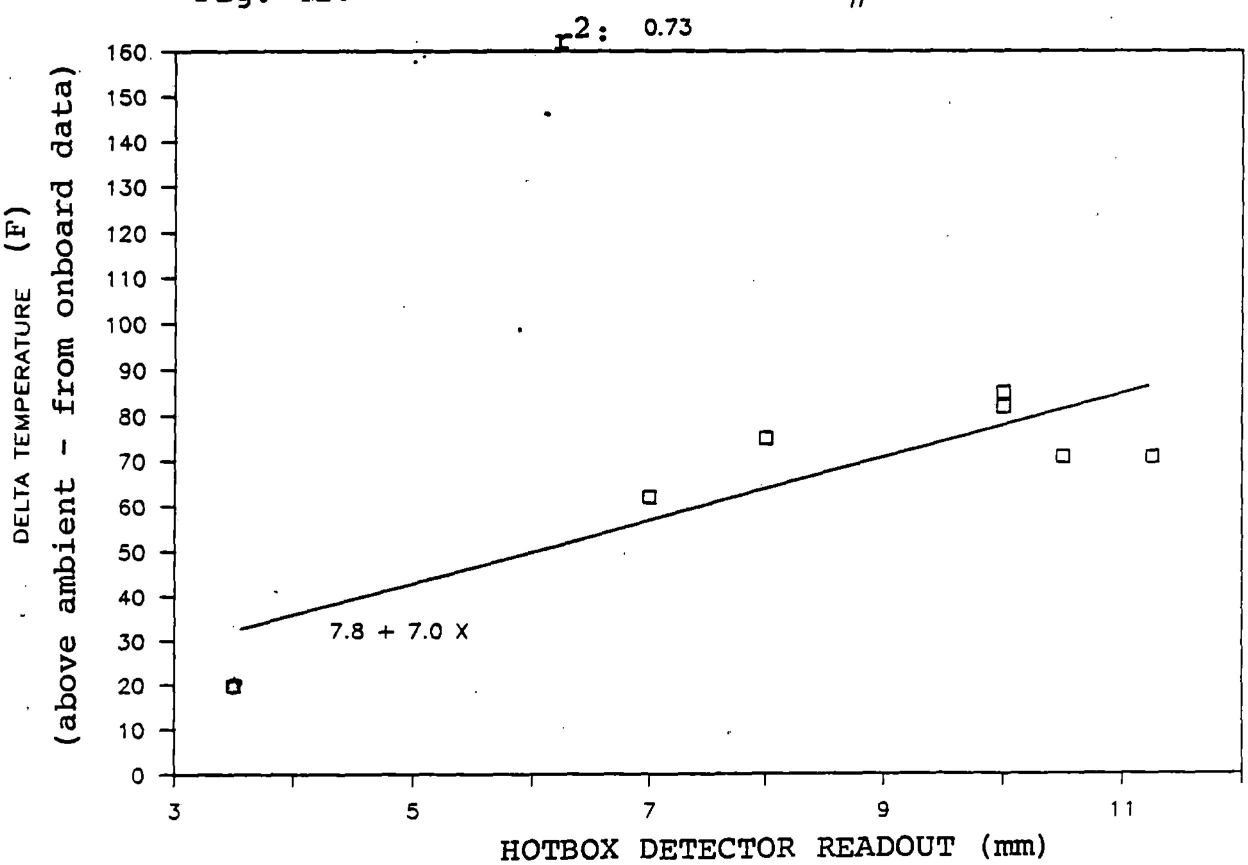
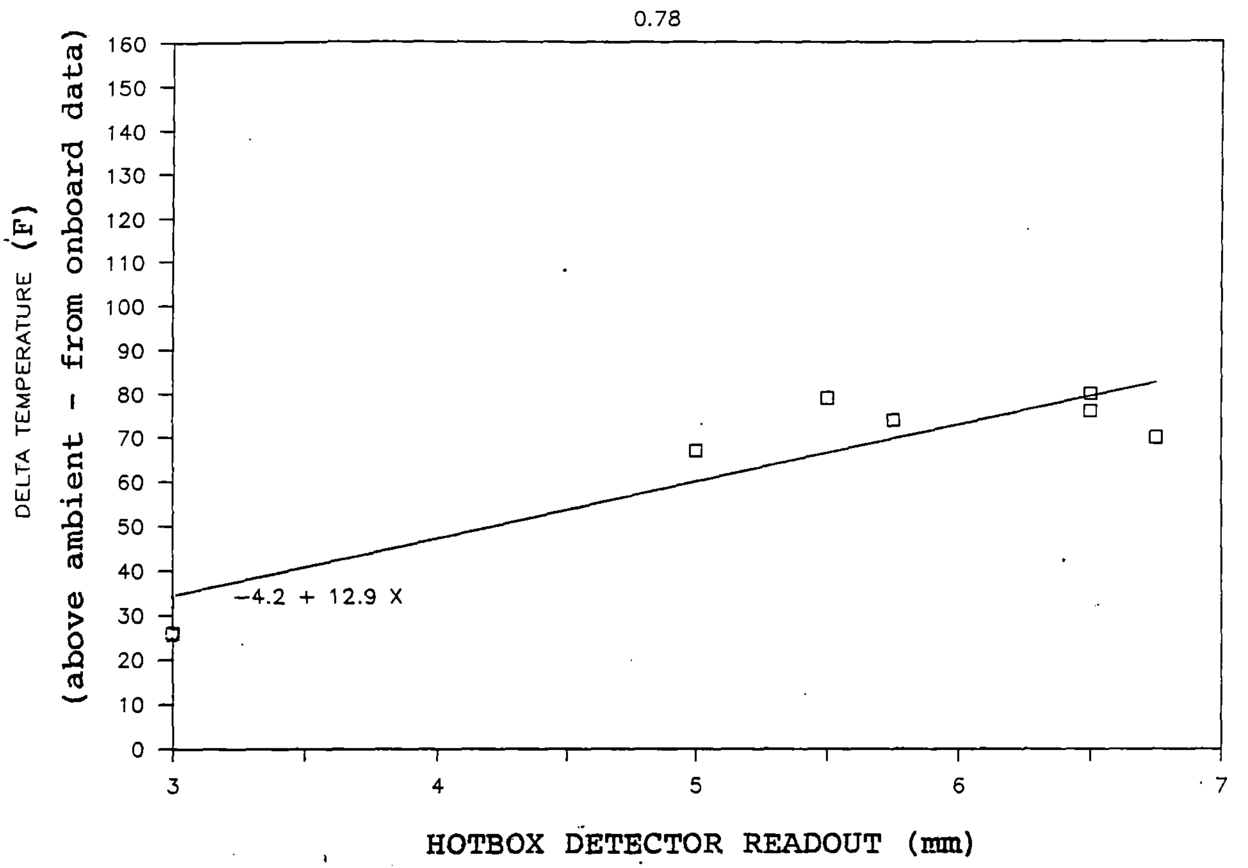


Fig. 43: HOT BOX DETECTOR # 16 (Richburg, MS.)



The detectors at Lincoln, Alabama, and Cuba and Richburg, Mississippi, were selected to generate representative information about other bearings on the test consist. These three detectors provide one in each major segment of the test run; provide maximum valid onboard readings after deletion of electronic interference, and provided the strongest correlation of wayside and onboard readings.

The hotbox stripchart tapes were read and recorded for the left side of the entire test consist. Onboard readings had been limited to bearings on the left side of cars in the test consist to maximize the number of test bearings seen by the sensors on the left rail of each detector location. The equations determined for each detector from the onboard/wayside correlations were applied to the detector readings for left side of the entire test consist to generate estimated bottom-of-cup temperatures.

The results of the estimates for each detector are shown in Tables 3 to 5. At the detector at Lincoln, the operating temperature of the 36 double-stack bearings in the consist averaged 133.4^{O}F. The 194 conventional car bearings averaged 107.1^{O}F, a difference of 26^{O}F. The average difference dropped to about 15^{O}F at the second and third detectors.

The double-stack bearing average was 145^{O}F at the bottom-of-cup position as the ambient temperature rose toward the end of the test run. Adding the measured 20 to 30^{O}F differential between the top and bottom-of-cup positions indicates average top-of-cup operating temperatures of 175^{O}F for the double-stack bearings on this test run. Since ambient temperatures on the test run were only about 80^{O}F, routine higher ambient temperatures exceeding 100^{O}F and higher sustained operating speeds can be expected to raise this temperature beyond 200^{O}F.

The observations are consistent with prior information from hotbox detectors on both NS and other railroads. The double-stack bearings routinely operate at higher temperatures than conventional car bearings in intermodal service.

CONCLUSIONS

1. The testing reported herein confirmed that roller bearings operating on double-stack container cars operate at higher temperatures than bearings on conventional cars operating in the same consist.

2. Average differences of up to 26^{O}F between all double-stack and all conventional car bearings were calculated on one side of the test consist by making use of both onboard and wayside hotbox detector readings.

3. The bearings observed in the test are routinely operated at both higher ambients and higher sustained speeds than were observed in these test runs. Greater differences between the temperatures may occur under more severe operating conditions. Hotbox detector readings could be used to evaluate this question.

4. Although the double-stack bearings operate at higher temperatures than other bearings, this condition has not been shown to cause bearing failures in service. The temperature difference may contribute to grease leakage. The quantitative information provided by this testing will be made available to persons formulating greases for application in railroad roller bearings.

APPENDIX A
DESCRIPTION OF TEST CARS AND BEARINGS

TTWX 972980 Intermodal Flatcar

Builder's Date: 3-73
Light Weight: 71,100 lbs. Capacity: 148,000 lbs. Load Limit: 148,900 lbs.
Loaded Weight per Train 219 Consist: 52 tons (104,000 lbs.)
(Car not weighed; weights from waybill only and may not be actual weight.)
Test Bearing R-1: Timken AAR 1A, Class E, Locking Plate ID "CSX"
Test Bearing R-2: Timken AAR 1A, Class E, Locking Plate ID "ARX"
Bearing R-3: BRENCO AAR 5A (newly installed wheelset, not instrumented)
Test Bearing R-4: BRENCO AAR 5A, Class E, Locking Plate ID "BN"

APLX 2049 Double-Stack Container Car

Builder's Date: 4-84
Following weights are for each of 5 platforms:
Light Weight: 31,200 lbs. Capacity: 102,000 lbs Load Limit: 131,500 lbs.
Loaded Weight per Train 219 Consist (all 5 platforms): 364 tons (728,000 lbs)
(Car not weighed; weights from waybill only and may not be actual weight.)
Test Bearing R-5: Timken AAR 1A, Class F, Locking Plate ID "QSX-K"
Test Bearing R-6: Timken AAR 1A, Class F, Locking Plate ID "QSX-K"
Test Bearing R-7: Timken AAR 1A, Class F, Locking Plate ID "QSX-K"
Test Bearing R-8: Timken AAR 1A, Class F, Locking Plate ID "QSX-K"

#

Roller Bearing Temperature Measurements on Double-Stack Container Cars,1988, Ensco, Inc., RJ McCown, TE Moser, 03-Rail Vehicles & Components