U.S. Department of Transportation

Federal Railroad Administration

INTERIM REPORT: INFLUENCE OF CONTACT PATCH RESISTANCE ON LOSS OF SHUNT

Office of Research and Development
Washington D.C. 20590

Howard G. Moody
Richard P. Reiff
Scott E. Gage

Association of American Railroads
Transportation Test Center
Pueblo, Co 81001

DOT/FRA/ORD-

August 1993
Final Report

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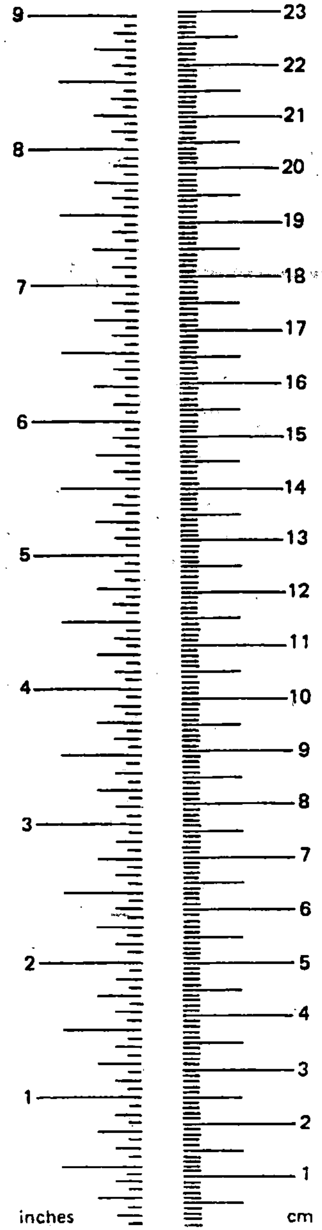
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

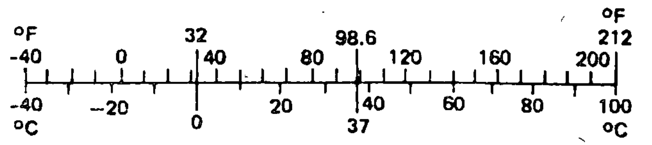
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.50	centimeters	cm
ft	feet	30.00	centimeters	cm
yd	yards	0.90	meters	m
mi	miles	1.60	kilometers	km
	AREA			
in^2	square inches	6.50	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.80	square meters	m^2
mi^2	square miles	2.60	square kilometers	km^2
	acres	0.40	hectares	ha
	MASS (weight)			
oz	ounces	28.00	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.90	tonnes	t
	VOLUME			
tsp	teaspoons	5.00	milliliters	ml
Tbsp	tablespoons	15.00	milliliters	ml
fl oz	fluid ounces	30.00	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.80	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in. = 2.54 cm (exactly)



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.40	inches	in
m	meters	3.30	feet	ft
m	meters	1.10	yards	yd
km	kilometers	0.60	miles	mi
	AREA			
cm^2	square centim.	0.16	square inches	in^2
m^2	square meters	1.20	square yards	yd^2
km^2	square kilom.	0.40	square miles	mi^2
ha	hectares (10,000 m^2)	2.50	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.10	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36.00	cubic feet	ft^3
m^3	cubic meters	1.30	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32	Fahrenheit temperature	°F



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16. Abstract

The railroad signal community and the grade crossing equipment suppliers have reported an increase in the occurrence of loss of shunt on railroad grade crossing island circuits, as confirmed through an October 1990 Association of American Railroads' (AAR) survey of railroad signal officers.

Loss of shunt is described as a brief deactivation of flashers or gate arms while passing trains are still occupying highway grade crossings. Grade crossing island circuits are short (110'-120') track circuits that span the highway crossing. They keep the flashers on and/or hold the gates down at grade crossings, while any railroad car in a train is in the island circuit. Once the last car of a train leaves the circuit, the island relay becomes activated allowing the flashers to go off and the gates to return to their upright position thereby permitting highway traffic to cross.

A temporary loss of shunt (which may cause a deactivation) in grade cross warning devices, while the train spans the crossing, may create a question of reliability in the minds of individuals dependent on them. For this reason, the railroad signal community has asked the AAR Research and Test Department, in cooperation with the Federal Railroad Administration (FRA), to study the loss of shunt problem.

This report describes work results and recommends future direction for FRA funded efforts. It also describes AAR/Committee funded efforts.

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EXECUTIVE SUMMARY

The railroad signal community and the grade crossing equipment suppliers have reported an increase in the occurrence of loss of shunt on railroad grade crossing island circuits, as confirmed through an October 1990 Association of American Railroads' (AAR) survey of railroad signal officers.

For the purposes of this report, loss of shunt is described as a brief deactivation of flashers or gate arms while passing trains are still occupying highway grade crossings.

Grade crossing island circuits are short (110'-120') track circuits that span the highway crossing. They keep the flashers on and/or hold the gates down at grade crossings, while any railroad car in a train is in the island circuit. Once the last car of a train leaves the circuit, the island relay becomes activated allowing the flashers to go off and the gates to return to their upright position thereby permitting highway traffic to cross.

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The objectives of the study were to identify the causes of loss of shunt in island circuits, and to identify and evaluate potential ways to reduce or eliminate the incidents of loss of shunt. Due to task order limitations during this study, only those island circuits that are audio frequency circuits were evaluated.

Six field sites were initially selected by the members of the signal Task Force for automated monitoring and detailed investigation. These six original sites were supplemented later to include multiple tracks, when double track was present. These sites were selected by railroad members of the Task Force, based on input from eye witness reports as crossings having experience "gate bob" or "gate lift" during train passage. Sites were inspected to ensure crossing detection equipment was operational and in proper calibration before studies continued. Later, two sites were equipped with "auxiliary circuits." These are conventional island track circuits, but do not activate/deactivate island circuit, gates, or flashers. Their operation, voltage, and island relay drive operation are monitored in the same fashion as others.

The following observations can be made from data collected to date.

- It appears that the nature of the loss of shunt phenomenon is universal, and similar data has been observed and collected at all sites.
- Although some sites show more occurrences than others, the basic level of occurrence is low (i.e. low risk, 0.3 %, of gate bob while a train is present) except under certain trains. To date since the monitoring of the island drive relay, there have been numerous events causing deactivation when empty or light cars are present; however, the overall occurrence rate is extremely low. It must be emphasized that an "island drive relay lift" does not always result in gate lift or stoppage of the flashing lights.
- The cause of the loss of shunt may be from semi-conductor films on both the wheel and rail. These films may be thicker in some locations than others, and may be exacerbated by variations in wheel/rail profile. There is also some speculation that rolling contact does not remove or break through (perforate) these films as sliding contact appears to do.
- Lubrication need not be present for loss of shunt to occur. In fact, none of the field sites are heavily lubricated. Although lubrication was not present at these sites, there is no evidence that in specific locations; that is, crossings not part of this monitoring program, lubrication may have an effect. In fact, films were observed on top of the rail at most sites. These films did not indicate lubrication as measured by the tribometer, however, could be wiped off the rail.

The evidence collected to date is not sufficient to conclude any particular remedy that may be optimum or applicable at all locations. Some possible solutions include but are not limited to the following:

- Developing an expert system with the capability of looking at the loss of shunt pattern including the pattern of the last car leaving the circuit instead of simply relying on the receiver voltage level. This pattern recognition is suggested by the nature of the repeated on-off characteristics during loss of shunt. The present measurement at 50 Hz might be increased to 1000 Hz or so to look at the instantaneous response at the contact patches under a train at speed to better evaluate the needs of an expert system.
- Grind different rail patterns to alter contact patch location and size, thus reducing the contact patch size and improving electrical conductivity.
- Evaluate frequency of occurrence statistics for a specific site to determine if an engineered solution is necessary.
- Evaluate all parameters at each site including traffic characteristics, traffic patterns, and track characteristics to determine if an engineered solution is possible based on these characteristics.
- Evaluate the films at those sites, including the electrical and physical properties to determine if an engineered solution is possible.
- Determine the influence of differences that may exist in the traffic mix, and in the design and set up of the track circuit. The results of this evaluation may focus on a few specific issues such as minimum shunt resistance or wheel/rail patterns that can mitigate the loss of shunt utilizing various rail profiles.
- Develop site specific engineered solutions. The conditions at each site may vary enough to require engineered solutions. These solutions could include accommodating higher shunt resistance to perforate the films, balanced against ballast resistance.

Even though this study was limited to island circuits, there is a potential of future applicability to other types of track circuits. Track circuits operate on the principle of short circuiting (shunting) a low voltage signal, preventing that signal from reaching a control relay or microprocessor. This circuit is placed along each running rail over controlled limits. Each rail car axle passing over a track circuit limit applies a low impedance path from rail to rail which provides that shunt.

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1.0 INTRODUCTION

The railroad signal community and the grade crossing equipment suppliers have reported an increase in the occurrence of loss of shunt on railroad grade crossing island circuits, as confirmed through an October 1990 Association of American Railroads' (AAR) survey of railroad signal officers.

Loss of shunt is described as a brief deactivation of flashers or gate arms while passing trains are still occupying highway grade crossings.

Grade crossing island circuits are short (110'-120') overlay track circuits that span the highway crossing. They keep the flashers on and/or hold the gates down at grade crossings, while any railroad car in a train is in the island circuit. Once the last car of a train leaves the circuit, the island relay becomes deactivated allowing the flashers to go off and the gates to return to their upright position thereby permitting highway traffic to cross.

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Various reports from North American, European, and Japanese railroads have identified the principal cause of loss of shunt as "semi-conductor oxide film," composed of rust, black iron oxide (magnetite) or other foreign particles from brake shoes. Films composed of leaves, and lading materials also have caused loss of shunt, usually on rare site specific instances. Lubrication films have been suspect, although data collected by this task order to date indicates no direct evidence for lubrication causing loss of shunt.

The evidence from several reports is sufficient to conclude that thin films on both the wheel and rail can be considered a major cause leading to loss of shunt.[1,2,4] Another possible contributor to loss of shunt is the axle-wheel resistance which generally is low, on the order of 1-4 milliohms. A single axle, by itself usually is considered to have "negligible" effect in the ability to obtain or maintain shunt.

Shunt resistance also depends on the wheel/rail contact resistance. The thin films are created from mild wheel/rail wear and oxidation of the wheel/rail steel or from materials deposited on the wheel tread from composition brake shoes. The "oxide" film estimated thickness is from 400 to over 1000 angstroms.

A report published on the results of laboratory experiments in Japan on the effects of thin films on wheels has concluded: "a smooth surface and resin (sic) brake shoes influence malfunctions of train shunting circuits, and that contact resistance has the characteristic of semi-conductor film resistance."[1]

A report on a track shunting problem with a track circuit concluded that the probable cause of the loss of shunt was a thin film of magnetite (Fe_3O_4), black iron oxide.[2] Magnetite is formed from the rolling/sliding contact of wheels on rail.[3] Loss of shunt occurred in this case when a short train of cars and locomotives ran on a different contact patch than other trains. This was most likely due to a different wheel profile.

As stated in the 1992 C&S Division, AAR, Committee Reports and Technical Papers: "Given that even a modest amount of rust (sic) can cause a track circuit to fail in an unsafe manner, it was surprising that a literature search uncovered very little basic research in to the physical nature of rust (sic) and shunting performance. An oxide layer can form on rails which exhibits resistive characteristics of a semi-conductive nature. This means that the rail/wheel interface must be treated as a non-linear resistive element when determining whether a track circuit will work under conditions where an oxide layer has formed."[4]

With films of a characteristic "semi-conductor" nature, once a threshold voltage is achieved, usually .4 to .6 volts, the film is "perforated" and current flows more freely. Once this occurs, the current required to maintain the circuit drops to a low value which lasts until the current is shut off, goes to zero, or the contact patch changes from car movement. For a moving train on an alternate current track circuit, this amounts to having to constantly perforate the film. The total voltage required could reach 1.2 volts for perforation of the films on both rails.[4]

Other factors such as wheel/rail contact pressure have an effect on the film characteristics changing the perforation voltage. This factor has caused North American railroads not to rely on the shunting track circuits to protect light axle high rail vehicles, generally used by track crews. Instead, they usually are protected by work permits.

Thus, films of undetermined nature are high on the "suspect list" for causes of loss of shunt. Solutions to problems of loss of shunt have varied from periodic rail grinding, and "shunt assisters," to axle counting systems. Rail grinding is thought to temporarily remove the thin film creating better contact across the railhead or in some cases creating a running surface contact patch that results in higher pressures, thus also improving shunt. The value of rail grinding and the length of time between grinding periods has not been established. Shunt assisters have varied from copper brushes positioned near the wheel tread to provide lower resistance between axles on a truck to constantly perforate the films. Some European operators have utilized a system of counting axles in to and out of signal blocks as a back up for track shunting.

In some instances, additional power can be provided through another battery to overcome the limiting resistance, also referred to as a "whetting" circuit. Some improvement in performance can be gained from adjusting the track circuit for improved shunting sensitivity to take advantage of higher ballast resistance from a well maintained ballast cross section. This latter remedy can cause the gates and flashers to activate when moisture or contaminates reduce ballast resistance, even without a train present.

2.0 OBJECTIVES

The objectives of the study were to identify the causes of loss of shunt in island circuits, and to identify and evaluate ways to reduce or eliminate the incidents of loss of shunt. Due to task order limitations during this study, only those island circuits that are audio frequency circuits were evaluated.

3.0 MILESTONES

In a September 1990 letter from the Norfolk Southern Railway to Hugh Henry, AAR Executive Director Communications & Signal (C&S), Norfolk requested the AAR Research and Test Department to conduct tests at the Transportation Test Center (TTC), Pueblo, Colorado, "to determine the effect of grease on the wheels and rail, (and) wheel and rail grinding profile has on the ability to detect and maintain a reliable wheel rail shunt." The reference to grease or wheel/rail lubrication was made because of the belief at that time, that lubrication was a leading cause of shunt loss. There was visual evidence of lubrication on the railhead in several cases of shunt loss.

The same concern about lubrication causing loss of shunt was reiterated in the initial meeting of the AAR C&S Task Force on Track Circuit Parameters (loss of shunt) in October 1990 and in responses to a concurrent survey about the same by various railroad C&S officers. Several recommendations for conducting tests at TTC on the effects of several parameters were made in the survey responses. These parameters included rail lubrication, car axle weight, island circuit design, rail grinding, rust, and wheel profile. The results of the survey did point out the lack of technical evidence and consensus on what was causing the loss of shunt.

On November 8, 1990, the Operations General Committee of the AAR requested that the AAR Research and Test Department conduct a test and evaluation project determining the causes of loss of shunt on track circuits. On December 5, 1990, a proposed plan of action was presented to the AAR Research Committee to conduct an evaluation of the loss of shunt. The proposed approach consisted of field evaluations to determine the conditions leading to loss of shunt, a laboratory test to identify the film materials, and a full scale test at the TTC to sort out the influence of the variables and to evaluate circuit design solutions.

Since there was no funding for this project within the 1991 AAR Research and Test budget, an effort to enlist FRA financial assistance was initiated. The FRA had funding appropriated for grade crossing research programs and had shown considerable interest in this issue. On August 2, 1991, the FRA by letter agreed to support a joint FRA/AAR project on "loss of shunt." This project was to begin once the procurement request was approved.

In mid-August the FRA provided a written draft of a scope of proposed work based on committee recommendations. The FRA had indicated that they wished to contract with the AAR TTC to take advantage of the existing process through the FRA-AAR contract for "Care, Custody, and Control of TTC."

The Task Force on Track Circuit Parameters met at TTC on September 24, 1991, to detail the course of action for the initial phase in the loss of shunt project. The results of that meeting were as follows:

1. To conduct a baseline testing program at the TTC on the Transit Test Track (TTT) and the Railroad Test Track (RTT) on island circuits furnished by the suppliers.

2. The TTC was to investigate the purchase of six strip chart recorders for revenue service tests and determine the costs of doing the testing. These recorders were to measure, at 50 Hz sample rate, the voltage at the receiver. That measurement was to be used as the indicator of loss of shunt. Any voltage received is not being shunted through the axle.

The Task Force put a strong emphasis on a long (six month) revenue service data collection effort. The existing data on loss of shunt was incomplete and lacked the quality, precision, and consistency needed to analyze the problem. There was an insufficient technical record of loss of shunt events. The data collection was to be in concert with "baseline" tests at TTC, but was to precede any other proposed testing, including film analysis.

The AAR was to support the testing within budget until the FRA funding became available. The TTC staff determined that the use of strip chart recorders had very limited capability and was likely to add a considerable amount of extra expense to the program for hardware and data analysis. An effort was initiated in early October to design and build remote site computer monitors at a lower cost for the hardware and a fixed cost for the software development.

This approach allowed the AAR to provide for long-term monitoring capability and more importantly to analyze the data utilizing automated computer techniques, significantly reducing costs. This approach also considerably improved the quality of the data. A contract was written between AAR and Salient Systems to design, build and install two PC based recording systems, the first of which would be installed in March 1992.

In its January 1992 meeting, the Task Force on Track Circuit Parameters recommended the number of recording devices be increased to nine. This was based on the number of field sites where loss of shunt had been reported. Table 1 lists these sites. Subsequent modifications, increased test sites and the need for a spare recorder has brought the number of recorders to 10.

On March 13, 1992, the AAR and FRA signed a task order to "Investigate the Influences of Contact Patch Resistance on Loss of Shunt." This task order reflected all of the changes to the test program requested by the Subcommittee in its September and January meetings. The changes included an increased revenue service monitoring program. The AAR (including the industry and suppliers) and FRA agreed to a 50-50 split on expenses. The AAR expenses included all software and hardware for the measurement program. The suppliers furnished island circuits, technical support and hardware to interface the measurement system to the recording equipment. The railroads supplied technical support, system maintenance and the test sites. The FRA task order period of performance ran to December 31, 1992, and subsequently extended to May 1993.

4.0 PROCEDURES

4.1 SITE SELECTION

Six field sites were initially selected by the members of the signal Task Force for automated monitoring and detailed investigation. These six original sites were supplemented later to include multiple tracks, when double track was present, as shown in Table 1. These sites were selected by railroad members of the Task Force, based on input from eye witness reports as crossings having experience "gate bob" or "gate lift" during train passage. Sites were inspected to ensure crossing detection equipment was operational and in proper calibration before studies continued. Later, two sites were equipped with "auxiliary circuits." These are conventional island track circuits, but do not activate/deactivate island circuit, gates, or flashers. Their operation, voltage, and island relay drive operation are monitored in the same fashion as others.

Table 1. Loss of Shunt Data Collection Sites

DOT NUMBER	LOCATION	SITE CODE	RR	DIRECTION	INSTALL DATE
717-823C	Selma St.	A	NS	Northbound	Mar. '92
	Buford, GA	B	NS	Southbound	May '92
471-1877X	King Road	C	NS	Bidirectional	May '92
	Harbor Creek, PA	S	NS	Auxiliary	Nov. '92
524-021S	King Road	D	CR	Westbound	May '92
	Harbor Creek, PA	E	CR	Eastbound	May '92
(CANADA)	Brook Road	F	CN	Westbound	July '92
N/A	Cobourg, Ontario	Q	CN	Eastbound	Jan. '93
83-297L	West Crossing Sterling, NE	G	BN	Bidirectional	July '92
83-299A	East Crossing	H	BN	Bidirectional	July '92
	Sterling, NE	R	BN	Auxiliary	Dec. '92
813-799E	Lawrence, KS	I	UP	Westbound	July '92
	MP 42.24	J	UP	Eastbound	July '92
813-781F	Midland, KS	K	UP	Westbound	July '92
	MP 43.4	L	UP	Eastbound	July '92
N/A	Pueblo, CO	M	TTC	Bidirectional	Mar. '93
N/A	Pueblo, CO	N	TTC	Bidirectional	Mar. '93
N/A	Pueblo, CO	O	TTC	Bidirectional	May '93
N/A	Pueblo, CO	P	TTC	Bidirectional	On hold
N/A	Gothenburg, NE	T	UP	Auxiliary	Jan. '93
		U	UP	Auxiliary	Jan. '93

*** TTC site M installed to establish baseline data. Other TTC sites will be installed prior to conducting controlled tests.**

4.2 DATA COLLECTION SYSTEM

The field site data collection system consists of a computer, software, an island drive repeater relay and an isolation box. The island drive repeater relays were supplied by the AAR while the computer and software were purchased by the AAR through Salient Systems, Inc. The buffer circuits in the isolation boxes were provided by the suppliers of grade crossing protection units for their respective systems.

When the presence of a train is detected by the motion sensor, the data collection system is turned on. The receiver detector voltage is sampled at 50 hertz producing a time history of each train passing over the island circuit. Each train is assigned a severity ranking determined by the peak voltage reading while the train is on the island circuit. This severity rating is a first cut for selecting data to be retained for future studies. The status of the island relay drive is also monitored making it possible to determine the position of the train if the peak voltage surpasses the "pickup" threshold and a possible island relay drive activation occurs. When data storage capacity is full (about 500 trains), trains with lower severities are automatically overwritten when a train with a higher severity is detected.

Data from train passes, with a high severity ranking, is downloaded and memory cleared, by modem, by TTC personnel on a weekly basis. The number of train passes from each site is noted before being cleared. This will allow AAR to do an analysis of the probability of occurrence for each site.

4.3 FIELD DATA

Beginning in March 1992, with the Buford, Georgia, test site on the Norfolk Southern Railroad, data recording equipment was installed at all the railroad sites listed in Table 1. Some of these sites are the second track at a single location, which share the recorder with the first or primary track.

Identical field data was collected at all sites. This usually was collected during the time of the island monitoring system installations. The Buford test sites are listed as site A and B in Table 1. Figure 1 shows the layout and measurement locations of the Buford site. The main track is site A, track 1. Site B, track 2, is the secondary main, a 10 mile passing siding. This is a typical layout for the other sites as well. All but three of the field sites are double track. Measurements of track conditions including rail profiles and lubrication effectiveness were taken. Track data collected at Buford showed a different rail profile through the crossing on track 1 (site A), than what was found where no rail grinding was done within the island limits. Also, tribometer measurements indicated that both tracks were poorly lubricated even though wayside lubricators were located within two miles.

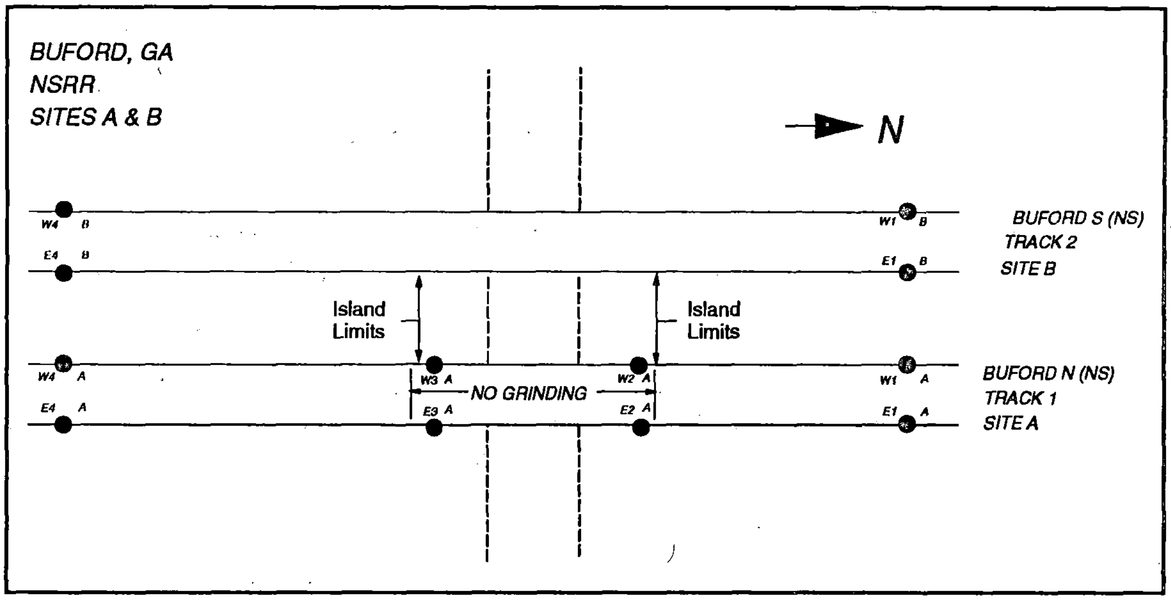

Figure 1. Sites A & B -- Buford, GA

Sample tribometer data (rail friction) for each site is summarized in Table 2. For reference, dry rail is considered to have friction values of $>= 0.45\mu$, while lubricated rail is generally $<= 0.25\mu$. As can be seen, top of rail and gage corner values generally were dry, or in some cases mildly contaminated. Note that lubrication monitoring is being accomplished on tangent track, thus gage face contact with the flange is not common; therefore, coefficient of friction data is shown only for top of rail and gage corner.

Table 2. Summary of Average Friction Data (in μ)

CODE	SITE	TOP OF RAIL	GAGE CORNER
A	Buford, GA	0.50	0.38
B	Buford, GA	0.48	0.42
C	Harbor Creek, PA	0.39	0.23
D	Harbor Creek, PA	0.46	0.33
E	Harbor Creek, PA	0.41	0.32
F	Cobourg, Ontario	0.46	0.35
G	Sterling, NE	0.47	0.35
H	Sterling, NE	0.48	0.35
I	Lawrence, KS	0.45	0.37
J	Lawrence, KS	0.48	0.32
K	Midland, KS	0.44	0.38
L	Midland, KS	0.50	0.34
M	Pueblo, CO	0.50	0.40

4.4 SAMPLE DATA

Sample island circuit data plots from site B taken in May and June 1992, show the characteristics of "perfect" shunt (Figure 2) and a loss of shunt (Figure 3). These plots are measurements of voltage, scaled to represent fully energized at the top of the plot to a near perfect shunt, which is the bottom line of Figure 2. The data was recorded at 50 Hz.

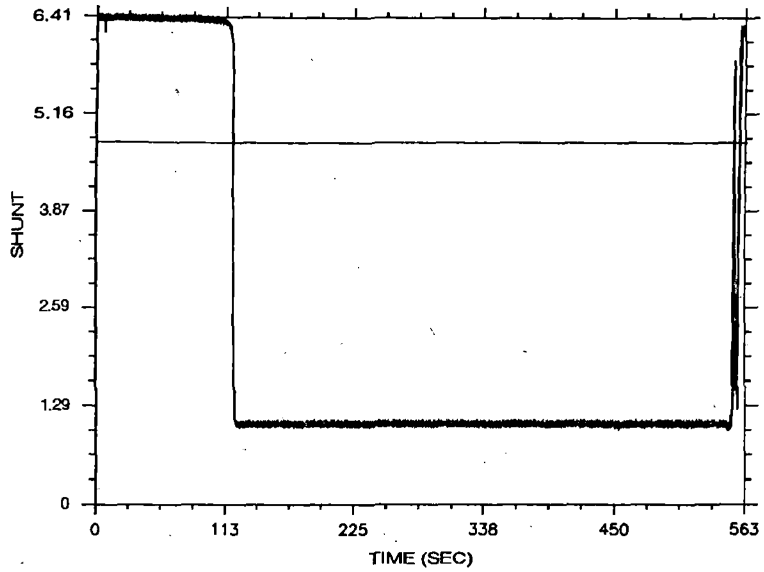

Figure 2. Time History of Perfect Shunt

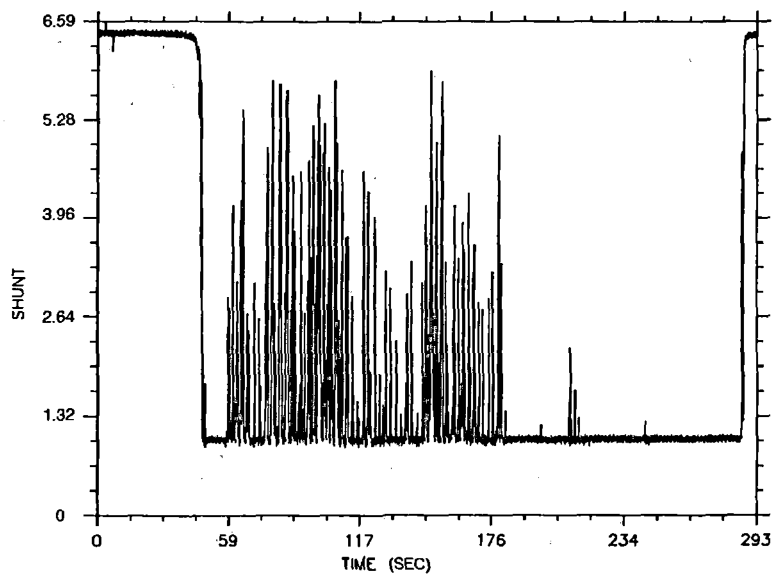

Figure 3. Time History of Train with Shunt Loss

Loss of shunt creates a pattern that has the appearance of an on-off switch. This characteristic was later confirmed at other sites (refer to Appendix A for examples from all sites). If the likely cause of the loss of shunt is the presence of semiconductor films on the contact patch, then the on-off characteristic is either when perforation of the film leaves and returns, or movement of the contact patch into and out of areas of film build up. Noticeably absent at each site was lubrication on the rail surface.

On request from the task force in September 1992, the island circuits were calibrated to record the threshold level of voltage where deactivation and reactivation occurred and to monitor the island relay drive to determine if deactivation had occurred. The threshold is generally about 2/3 of the full voltage on the scale. As shown, for example, in Figure 2, the threshold is 5.03 volts direct current. These modifications; that is, the addition of island drive monitoring relays, have been completed and are in place at all the test sites. The task force also requested the AAR to coordinate the installation of auxiliary circuits at Sterling, Nebraska, and Harbor Creek, Pennsylvania.

Figure 4 shows the island relay drive being activated due to a loss of shunt situation at site G. As can be seen, once the voltage rises above the threshold, the reaction of the island relay drive is almost instantaneous. It should be noted that, due to other safeguards (built in control circuit time delays) and the mechanical aspects of crossing protection, an island drive indication does not always equate to gate bob or lift.

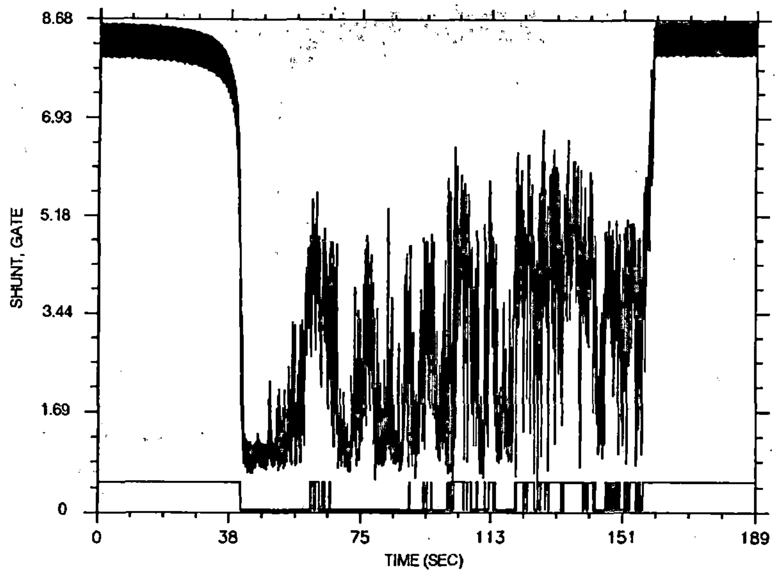

Figure 4. Time History with Island Relay Drive Activation

4.5 AUXILIARY CIRCUITS

The auxiliary circuits were to be installed in series close to the existing island circuits, at sites H and C (auxiliary circuits coded R & S, respectively) as shown in Table 1. These new installations allowed comparison of the performance of the same consist over two island circuits of the same track located near each other. The intent was to identify situations where loss of shunt was either a "track" or "consist" dependent phenomenon. This process was also done using the pair of locations H-G on the Burlington Northern Railroad at Sterling and on the UP (double track) site I-K on the westbound and J-L on the eastbound tracks. These site pairs, although on the same tracks, are approximately 1 1/4 miles apart in each case.

Analysis of the "single train" data from Lawrence and Midland, Kansas, are shown in Figures 5 a, b, and c. The patterns are similar, but not exact. There appears to be some justification for concluding that some car axles or patterns are repetitious, but there is also significant evidence of site differences. This would tend to reinforce the argument that the films are on both wheel and rail surfaces, but differ at various times and locations along a route.

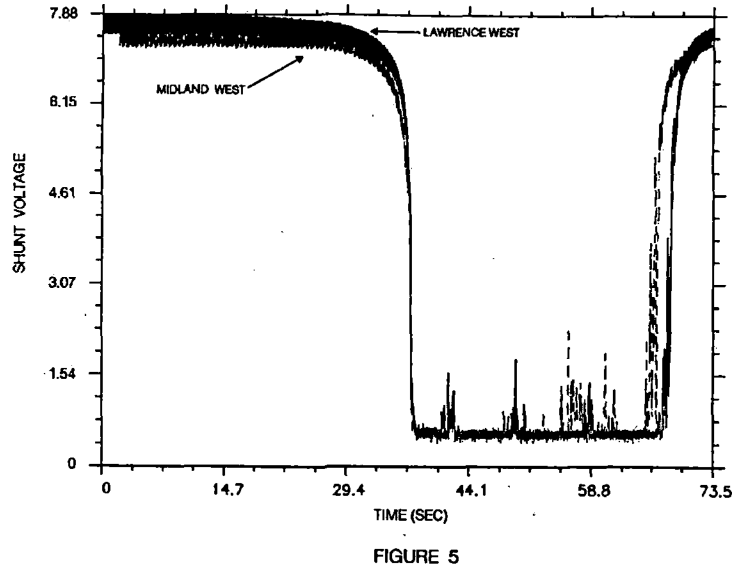

Figure 5(a). Overlay of Single Train Data from Lawrence and Midland, Kansas

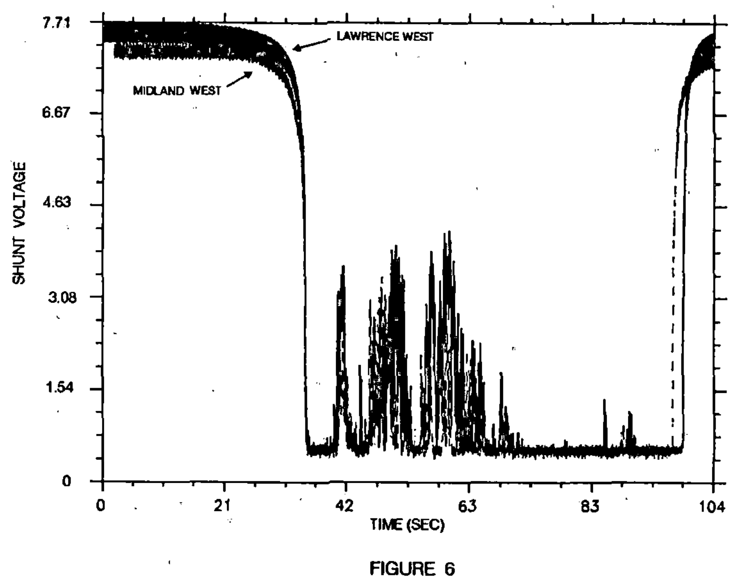

Figure 5(b). Overlay of Single Train Data from Lawrence and Midland, Kansas

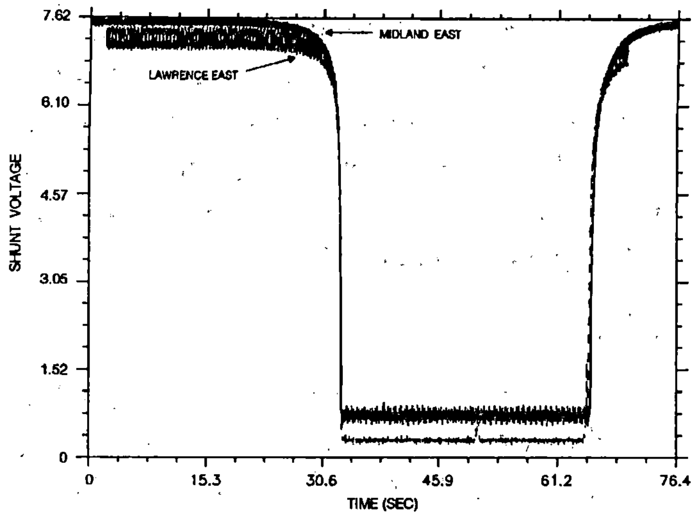

FIGURE 7

Figure 5(c). Overlay of Single Train Data from Lawrence and Midland, Kansas

4.6 GOTHENBURG SITE

In December 1992, the Task Force recommended expansion of field testing to include a Union Pacific engineering test site near Gothenburg, Nebraska. This site is co-located with video cameras, AEI readers and a wheel impact load detector. With an auxiliary track circuit installed as an overlay on each track, a simulated grade crossing was created. Cars exhibiting a loss of shunt can be identified, traced and visually inspected. The car axle weight and car type can be correlated with the loss of shunt. It is generally accepted that the loss of shunt is inversely proportional to axle load, although there is no calculated relationship. These sites are coded as T and U. To date insufficient data has been collected at the Gothenburg sites to identify specific cars causing problems.

In addition, the Task Force agreed to recommend a data analysis program conducted by TTC staff to determine the probability of an event occurring versus the number of train passes. The "events" were the loss of shunt exceeding a threshold where the island drive relay would pick up. This analysis began January 1, 1993.

The changes requested by the task force are reflected in the new TTC Test Implementation Plan (Appendix B), which includes the Gothenburg Test. These changes impacted the original task order eliminating support for testing at TTC. The FRA has indicated a willingness to consider initiating another task order to cover further testing, including the TTC tests planned originally. This test plan (included in Appendix B) is designed to continue the evaluation already started.

4.7 LEVEL OF OCCURRENCE

Even though the revenue service sites were chosen by the railroads because of their history of poor shunting performance, the overall level of occurance at these sites is low. As of May 1, 1993, data on over 10,000 trains has been collected with only 46 trains exhibiting loss of shunt severe enough to activate the island drive relay, an occurance level of less than 0.46 percent

5.0 OBSERVATIONS

A number of observations can be made from data collected to date.

- It appears that the nature of the loss of shunt phenomenon is universal, and similar data has been observed and collected at all sites.
- Although some sites show more occurrences than others, the basic level of occurrence is low (i.e. low risk of gate bob while a train is present) except under certain trains. To date since the monitoring of the island relay drive, there have been numerous events causing island drive activation when empty or light cars are present; however, the overall occurrence rate is low. It must be emphasized that an island relay drive activation does not always result in gate lift or stoppage of the flashing lights.
- The cause of the loss of shunt may be from semi-conductor films on both the wheel and rail. These films may be thicker in some locations than others, and may be exacerbated by variations in wheel/rail profile. There is also some speculation that rolling contact does not remove or break through (perforate) these films as sliding contact appears to do.

- Lubrication need not be present for loss of shunt to occur. In fact, none of the field sites are heavily lubricated. Even though lubrication was not present at these sites, it may have an effect if monitored on other field sites. In fact, films were observed on top of the rail at most sites. These films did not indicate lubrication as measured by the tribometer, however, they could be wiped off the rail.

5.1 POSSIBLE SOLUTIONS

The evidence collected to date is not sufficient to conclude any particular remedy that may be optimum or applicable at all locations. Some possible solutions include but are not limited to the following:

- Developing an expert system with the capability of looking at the loss of shunt pattern including the pattern of the last car leaving the circuit instead of simply the receiver voltage level. This pattern recognition is suggested by the nature of the repeated on-off characteristics during loss of shunt. The present measurement at 50 Hz might be increased to 1000 Hz or so to look at the instantaneous response at the contact patches under a train at speed in order to better evaluate the needs of an expert system.

- Grind different rail patterns to alter contact patch location and size, thus reducing the contact patch size and improving electrical conductivity.

- Evaluate probability of occurrence statistics for a possible trouble site to determine if an engineered solution is necessary.

- Evaluate all parameters at each site including traffic characteristics, traffic patterns and track characteristics to determine if an engineered solution is possible.

- Evaluate the films at those sites, including the electrical and physical properties to determine if an engineered solution is possible.

- Determine what differences if any exist in the traffic mix and in the design and set up of the track circuit. The results of this evaluation may focus on a few specific issues such as minimum shunt resistance or wheel/rail patterns that can mitigate the loss of shunt utilizing various rail profiles.
- Develop site specific engineered solutions. The conditions at each site may vary enough allowing engineered solutions. These solutions could include accommodating higher shunt voltages to perforate the films, balanced against better ballast resistance.

Even though this study was limited as stated, there is a potential of future applicability to other types of track circuits, such as block signals. Track circuits operate on the principle of short circuiting (shunting) a low voltage signal, preventing that signal from reaching a control relay or receiver. This circuit is placed along each running rail over controlled limits. Each rail car axle passing over a track circuit limit applies a low impedance path from rail to rail which provides that shunt.

5.2 ONGOING AND FUTURE INVESTIGATIONS

One of the original test objectives, as stated in the Test Implementation Plan dated February 19, 1992, was to "determine if these loss of shunt occurrences can be related to a limited set of specific track, mechanical, or other conditions, and document the conditions leading to loss of shunt." To accomplish this objective (and to determine if these are reasonable solutions to the loss of shunt, first at grade crossing island circuits, but in time with block signals and detector circuits), the following steps were recommended by the Steering Committee. This becomes the future task order test plan which is based upon a statement of work from committee input.

5.2.1 Field Sites

Continue the revenue service measurement program into the summer of 1993 and develop comprehensive probability of occurrence statistics (TTC).

Using data from the field sites, with the appropriate indications of island relay performance, compute the probability of occurrence of loss of shunt at each site. The loss of shunt is defined as sufficient voltage leakage to allow the island relay to pick up. The probability of occurrence could be computed in two ways: occurrences per train above the threshold, or the number of occurrences of island relay pick up per train. To determine seasonal and environmental effects, data is sorted by site, season (i.e. summer-winter) and any major change in variables, such as circuit design, and rail grinding. This will require the continuation of monitoring in the fields until summer 1993. Consideration should be given moving to new test sites where there is no observance of provlems and to a site where lubrication is abundant.

These data bases, although similar, describe different situations. The severity ratings are based on observed voltage leakages (loss of shunt), while the island relay pickups occur only in cases of severe loss of shunt. Data has indicated that island relays do not always pick up, even in cases of relatively poor shunt, thus a history of "zero" island pickup does not necessarily indicate no shunting problems.

5.2.2 Film Electrical Characteristics

Electrical (in situ) and physical (laboratory) properties of the wheel/rail films need to be characterized and correlated with loss of shunt.

Develop devices to measure the impedance characteristics of wheel and rail films dynamically. The rail device can use the current AAR tribometer as a base design. A modified tribometer could dynamically measure the rail film impedance, instead of lubrication effectiveness, at the wheel/rail contact patch.

AAR will request the design and fabrication of a wheel semi-conductor film impedance instrument. This instrument design would rely on the success of the rail impedance device. One design already proposed would rely on a stationary fixture placed against the tread of a rotating freight car wheel (jacked under the bearings on a RIP track) to determine individual axle shunting capability.

Contract with a laboratory to evaluate the physical properties of the thin films on selected samples of wheel and rails. Samples for the film characterization will cover the transverse and longitudinal planes of the railhead and the wheel tread. The film characterizations will at a minimum cover:

- General appearance
- Electrical properties
- Composition
- Location and extent
- Thickness

The output of this effort would provide input into the engineering model, and identify the nature and extent of the films which are causing the loss of shunt. This output could be used in field evaluations to determine optimum contact patch requirements and grinding intervals (if grinding helps at all), and to put an upper limit on the resistivity expected from the films for track circuit design. Additionally, data will be used to determine if rail/wheel conditions at the TTC are representative of field sites.

5.2.3 Engineering Model (AAR Effort)

The development of an engineering model to understand the electrical path from rail to rail is proposed. This work element will take the basic proposed model, use the data on the film properties from the field measurements, and construct a suitable engineering model. This will allow sensitivity studies to be run at varying input voltages, wheel/rail loads and film properties.

The output of the model thus developed would be verified from field data, obtained from the revenue service tests and at TTC. The model will be used to determine expected results from other sites with given film characteristics, traffic and circuit design, This would reduce the cost to any railroad to troubleshoot loss of shunt and allow for engineered solutions. The coupling of the model with the film measurement tools will provide a powerful tool to diagnose loss of shunt. The model output will provide the exact requirements for any expert system development.

The implementation of these three items should occur in parallel with the continuation of data collection in revenue service and at TTC.

5.2.4 TTC Testing

TTC's track circuit and instrumentation will be used to identify the shunting characteristics of certain types of equipment that exhibit loss of shunt tendencies. The test bed at TTC will serve as a means to verify (confirm) any changes to circuit design, maintenance practices, or other parameters before full scale implementation. The use of the TTC test facility will allow testing not suitable for revenue service; for example, varying block signal characteristics to determine how they affect island circuit performance.

5.3 PROGRAM MANAGEMENT/BUDGET

The current program management of the Loss of Shunt Project is twofold. Program guidance is provided by the Track Circuit Parameters Task Force, which reports to the AAR C & S Division Committee D, on Highway Grade Crossings. Members are from the railroads, FRA, AAR, and the suppliers. The Task Force meets three or four times a year to review project progress, and to provide technical guidance and test support. A major output of this committee includes review and continuous update of the technical direction of the test plan.

The project management is provided through the Manager of Train Control Technology of the Associations of American Railroads. Day to day conduct of the testing program is performed by the Section Manager of Civil Engineering at the TTC. This is also the project manager for the FRA contract on "Investigate the Influences of Contact Patch Resistance on the Loss of Shunt."

The original task order budget was based on the estimates provided by the TTC, and reflected the original Test Plan as developed to address the FRA statement of work. During several meeting with the signal task force, review of ongoing data indicated changes in project direction would be necessary, as follows:

- Additional auxiliary circuits
- Addition of island relay drive indication

- Exchange of TTC testing (from 1992) with double track site at Gothenburg
- Extension of field site monitoring period to capture winter to summer climate change effect on Loss of Shunt

Each change was documented and approved by FRA after submitting a revised test plan; however, actual expenditures differ from original budget estimate/expenditure predictions. Figure 8 summarizes expenditures for this task order through March 1993.

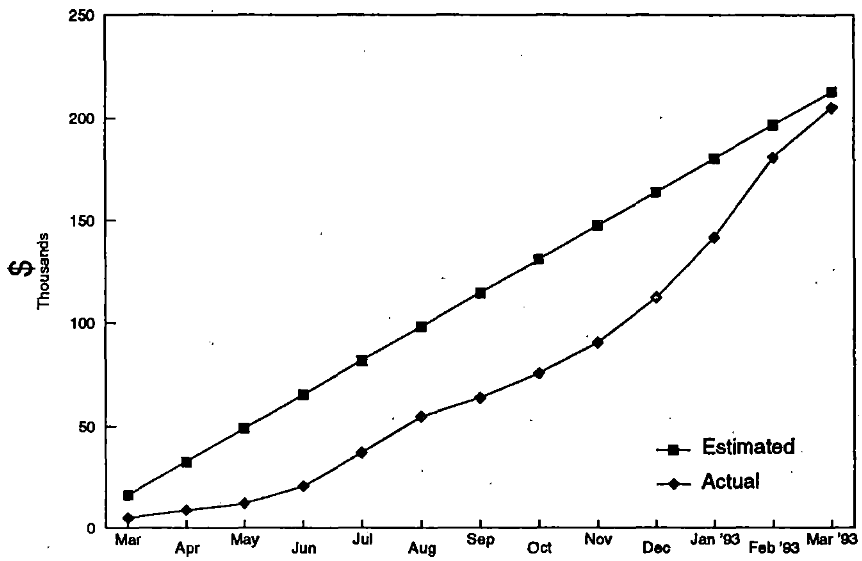

Figure 6. Task Order Expenditures

There is also an AAR contract with the Salient Systems of Dublin, Ohio, to build and maintain the recording equipment. The AAR also supports the acquisition and use of computers at TTC to analyze data and to maintain a data base.

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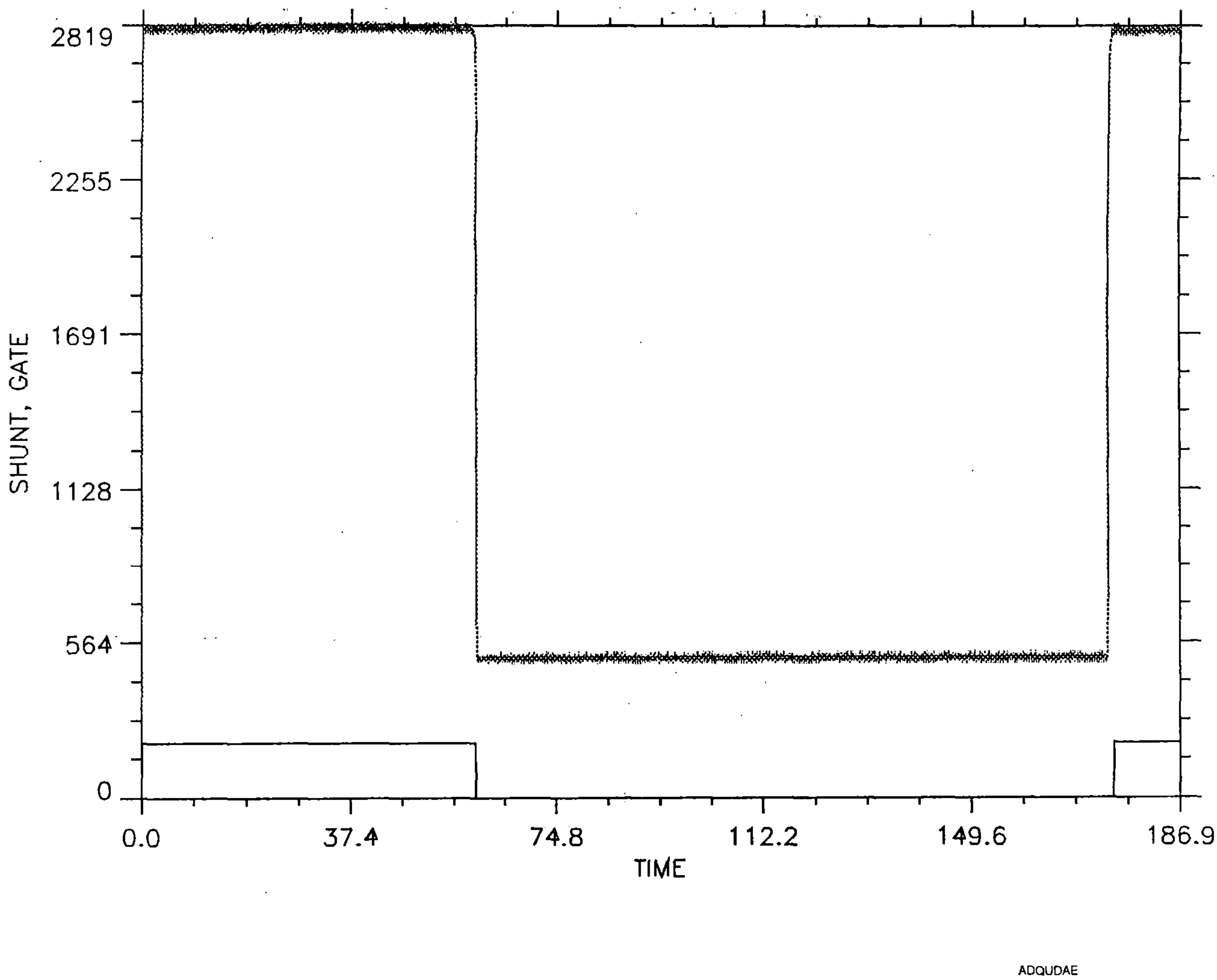
2. Scott, C.N. Letter Report: "Track Shunting Problem" F.H. McIntyre, Norfolk Southern Corporation, January 1989.

3. Bolten, P.J., Clayton, P. and McEwen, I.J. "Wear of Rail and Tyre Steels under Rolling/Sliding Conditions," *ASLE Transaction*, Vol. 25 pp 17-24.

4. Association of Amerian Railroads. The Rail Wheel Interface, Appendix H - 1992, Committee Reports and Technical Papers, AAR C&S Division, Washington D.C., October 1992.

APPENDIX A

Data Plots



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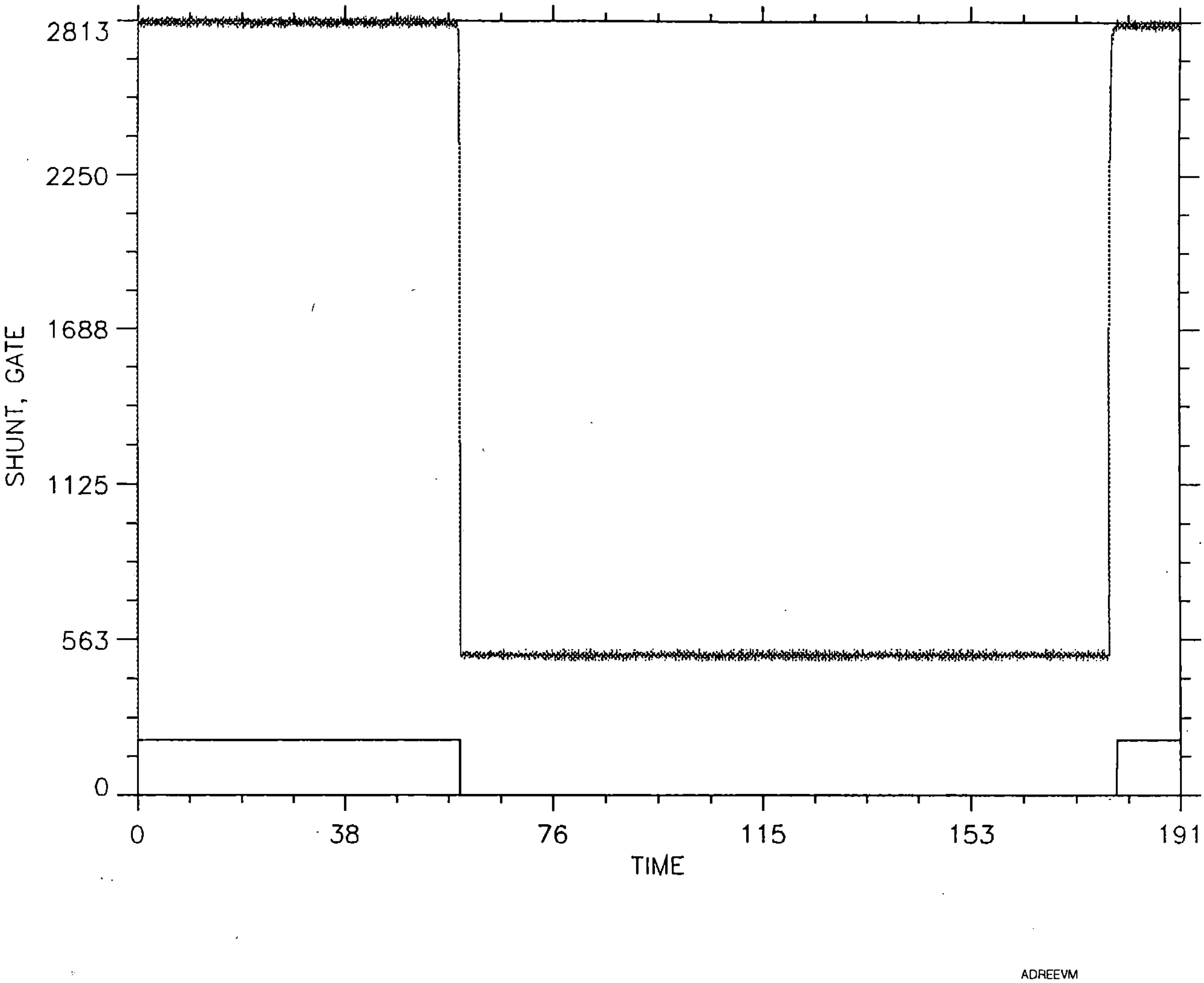

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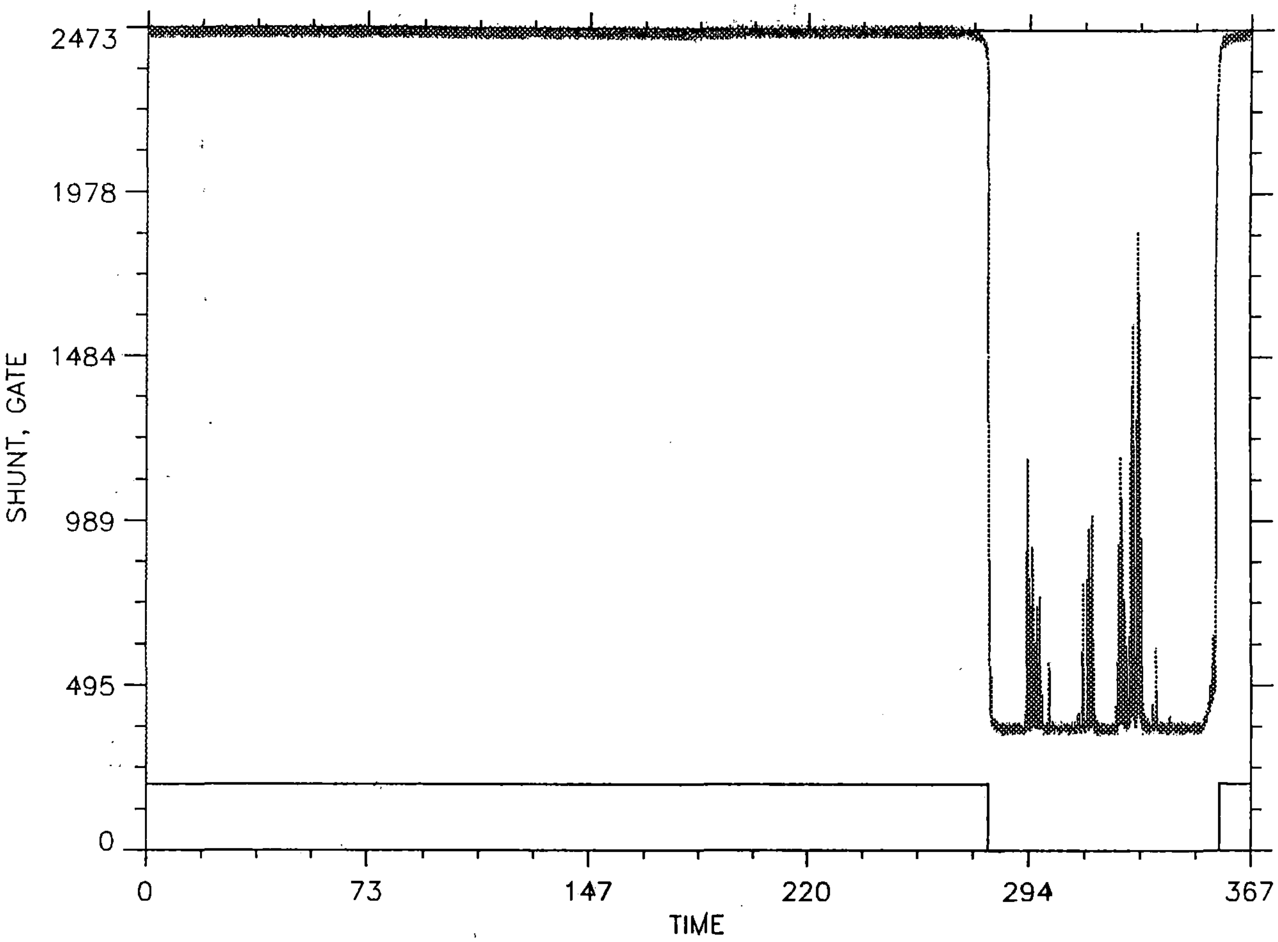

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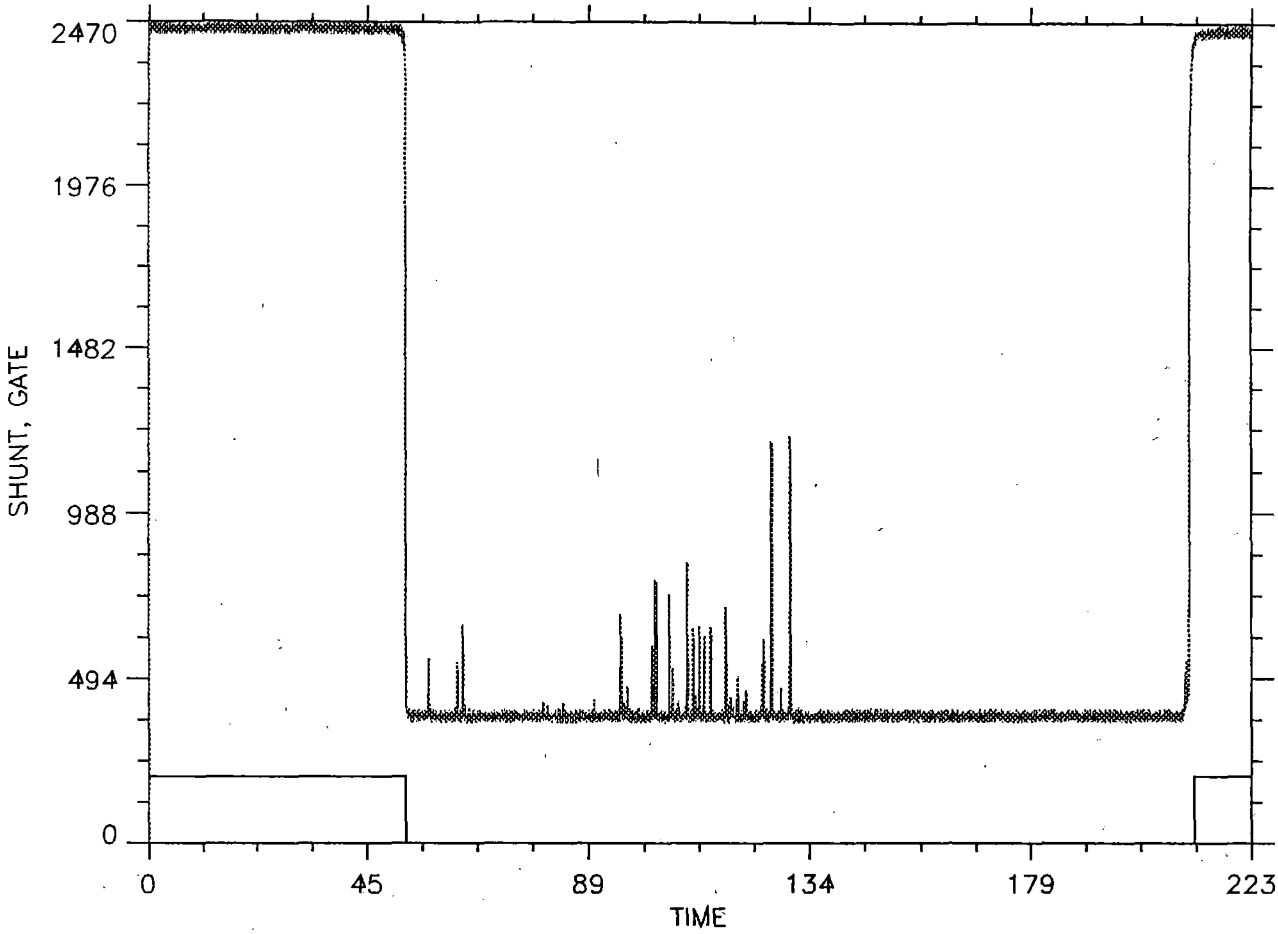

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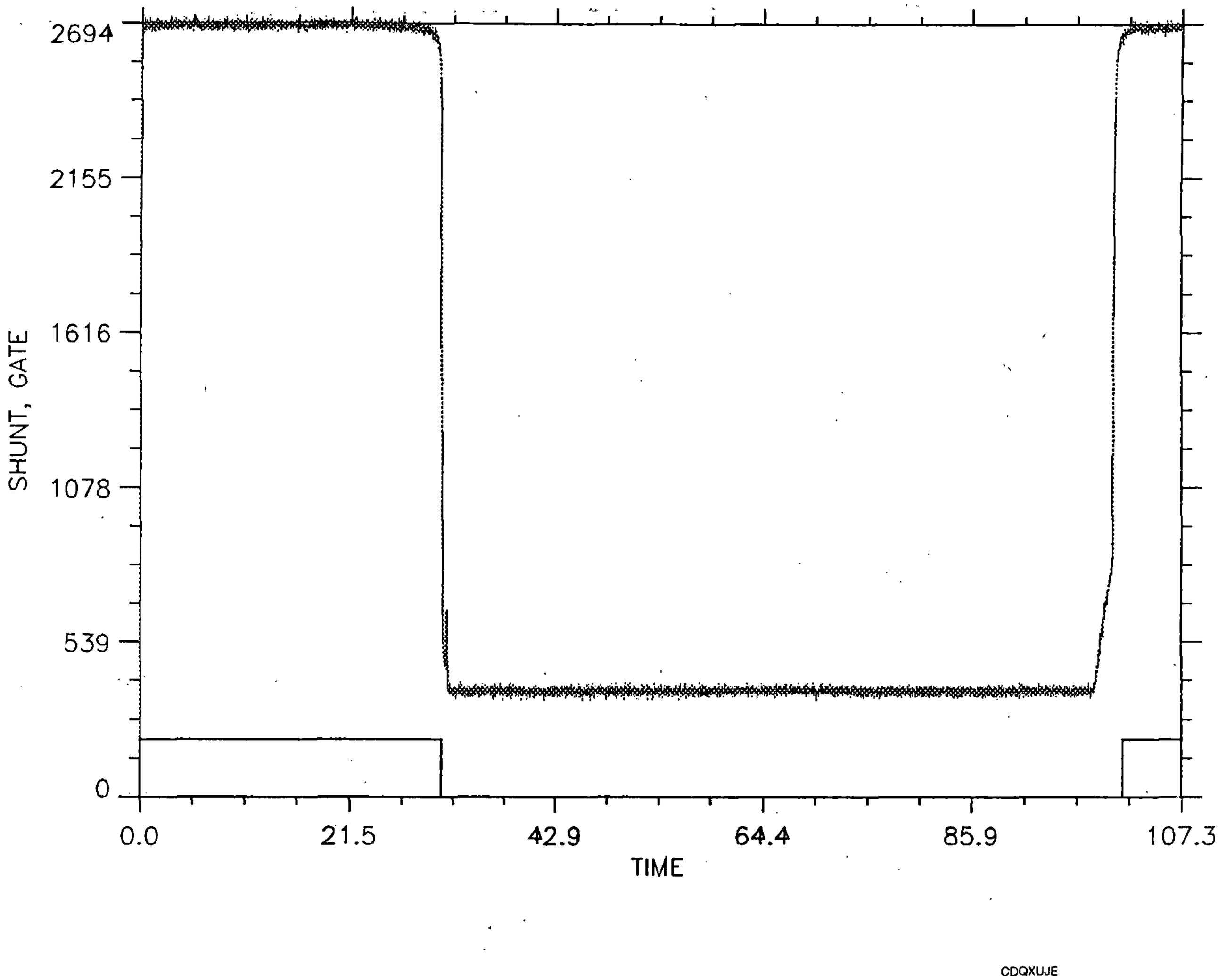

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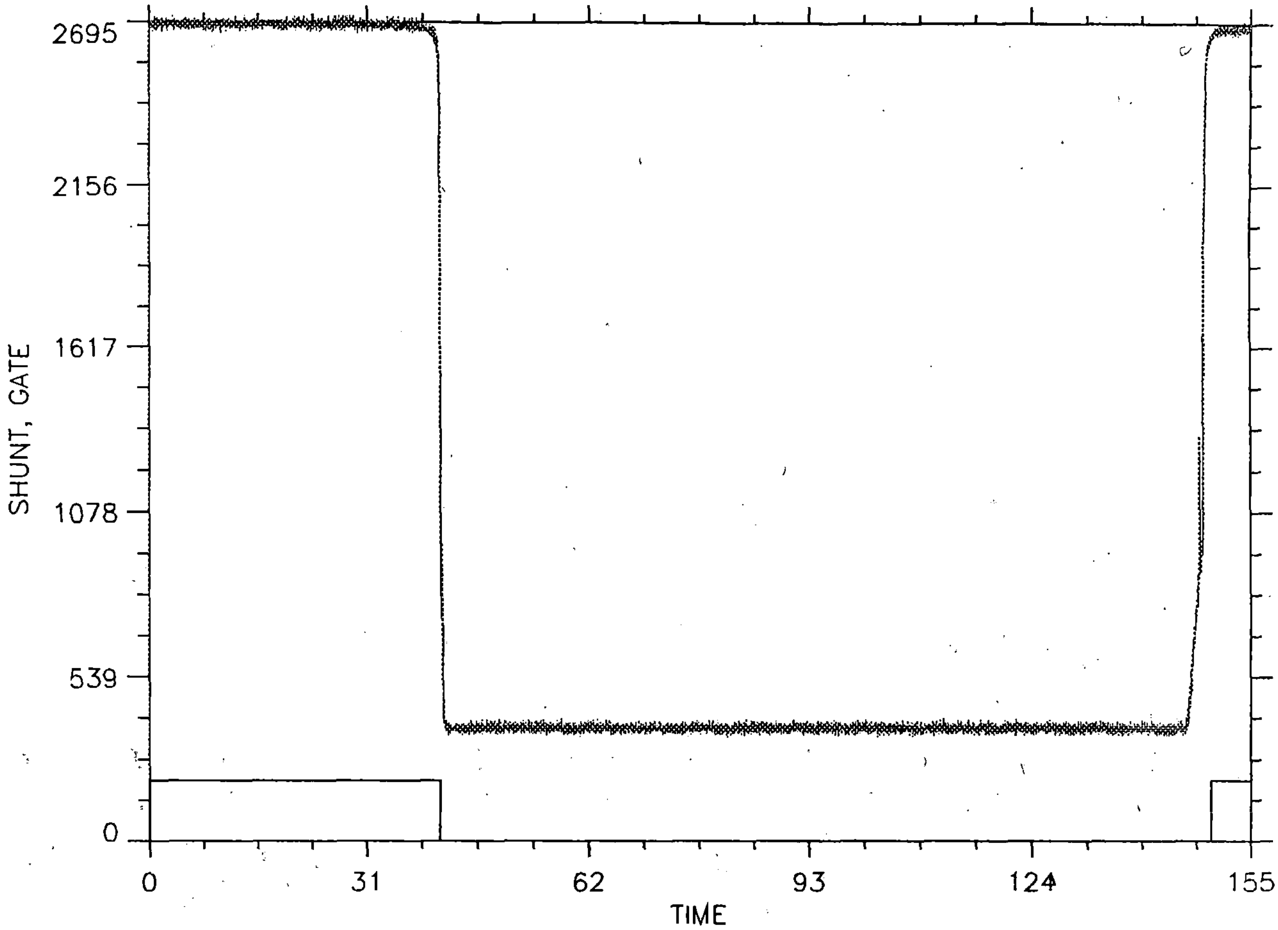

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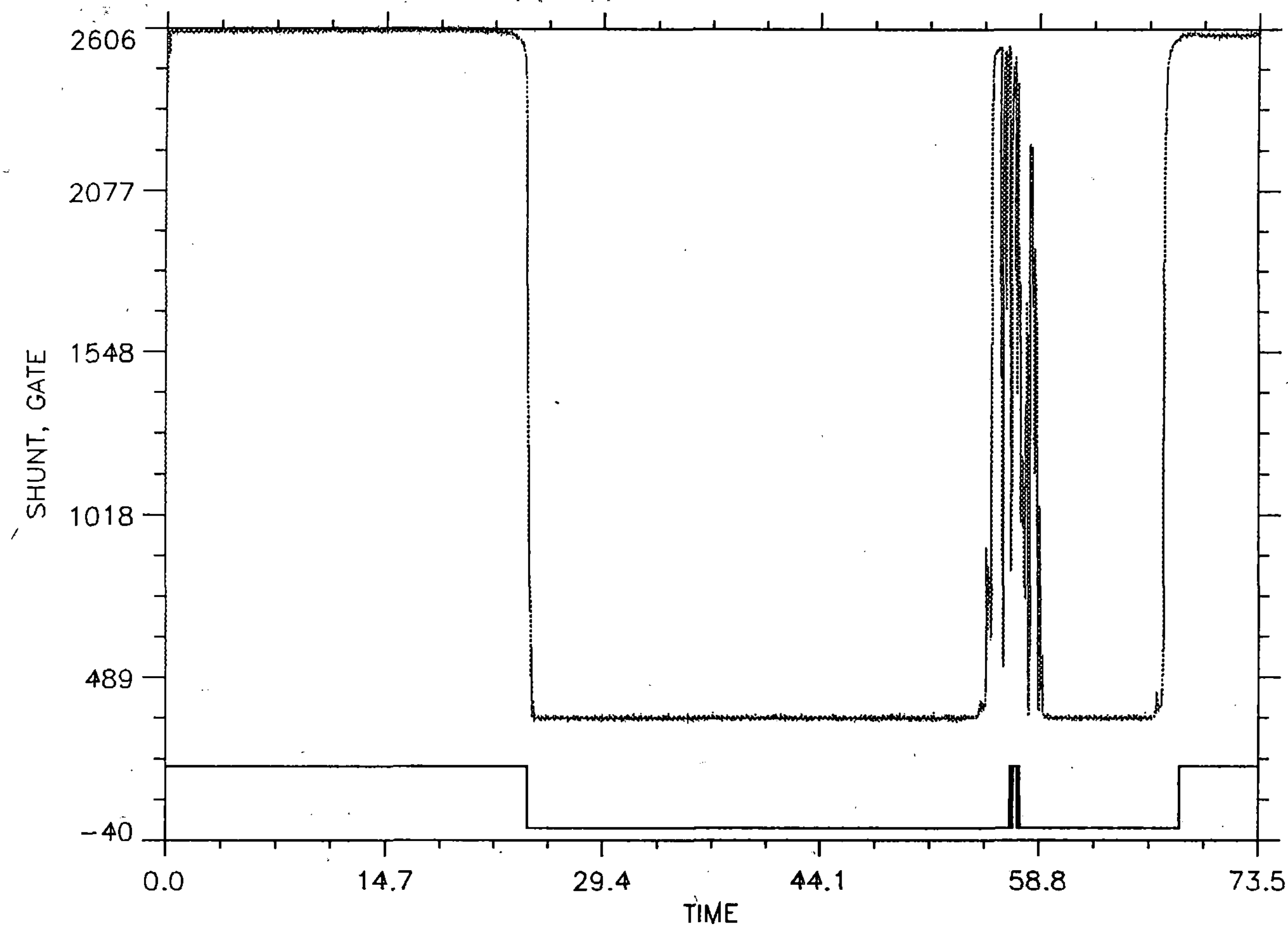

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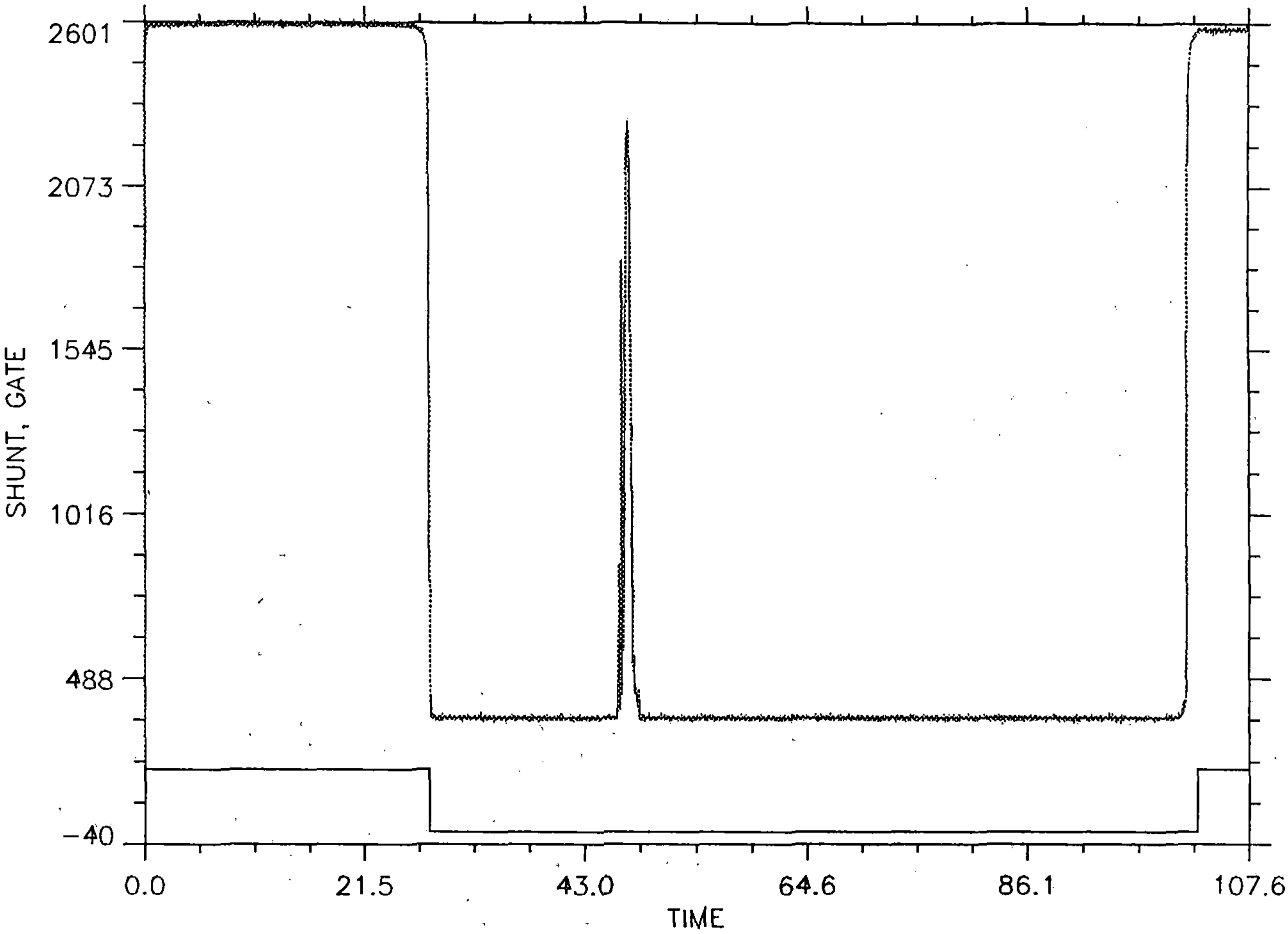

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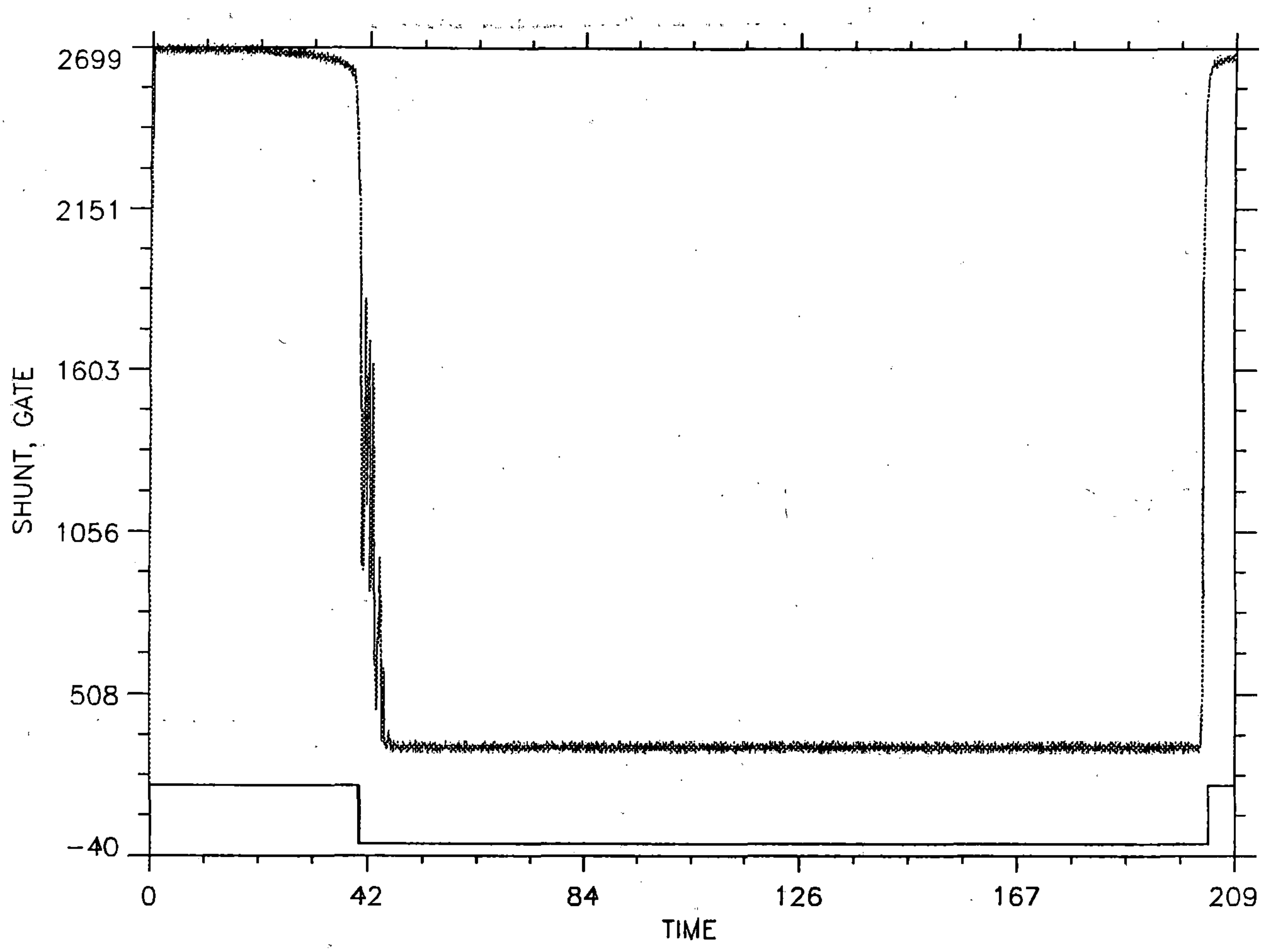

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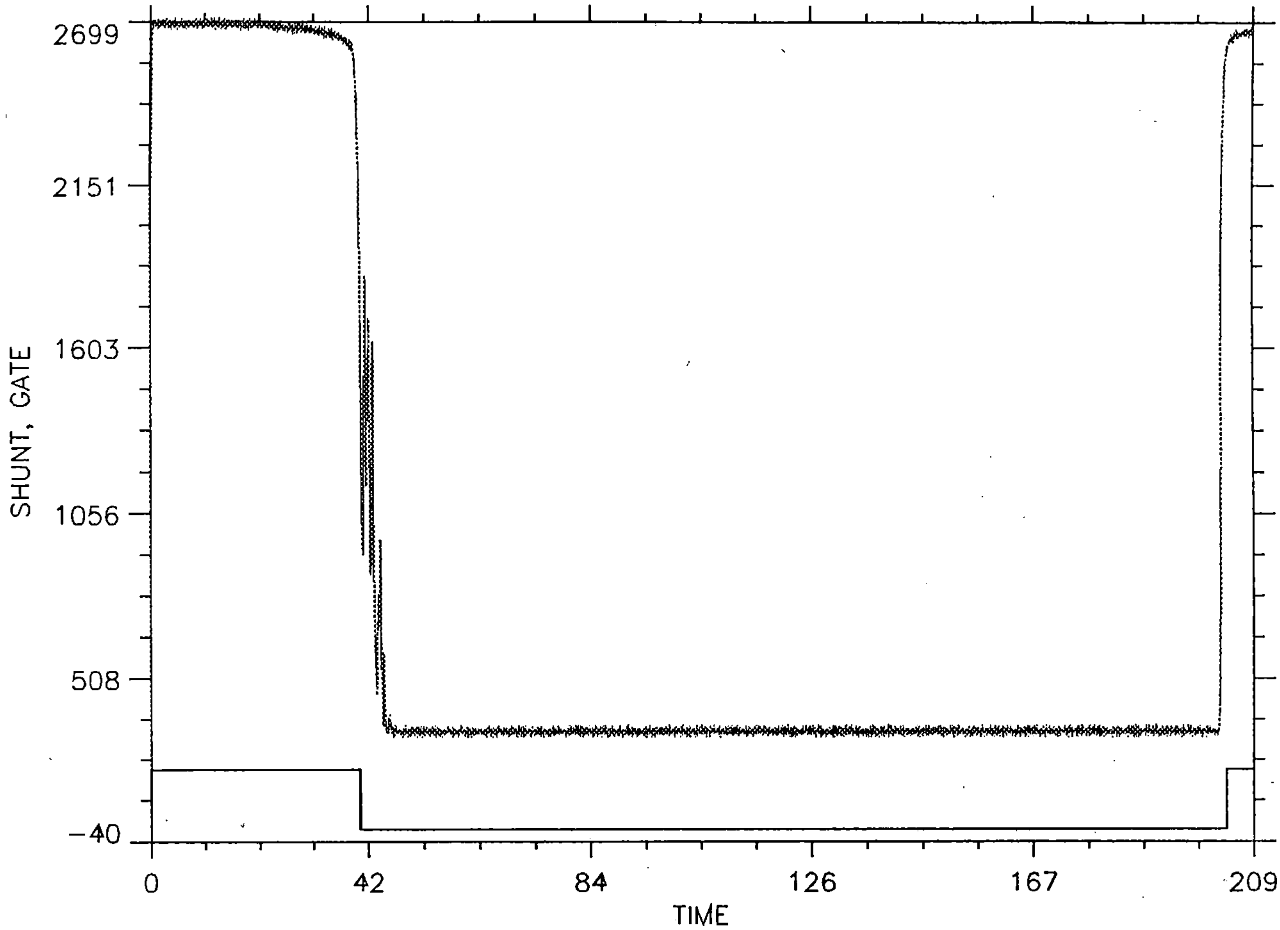

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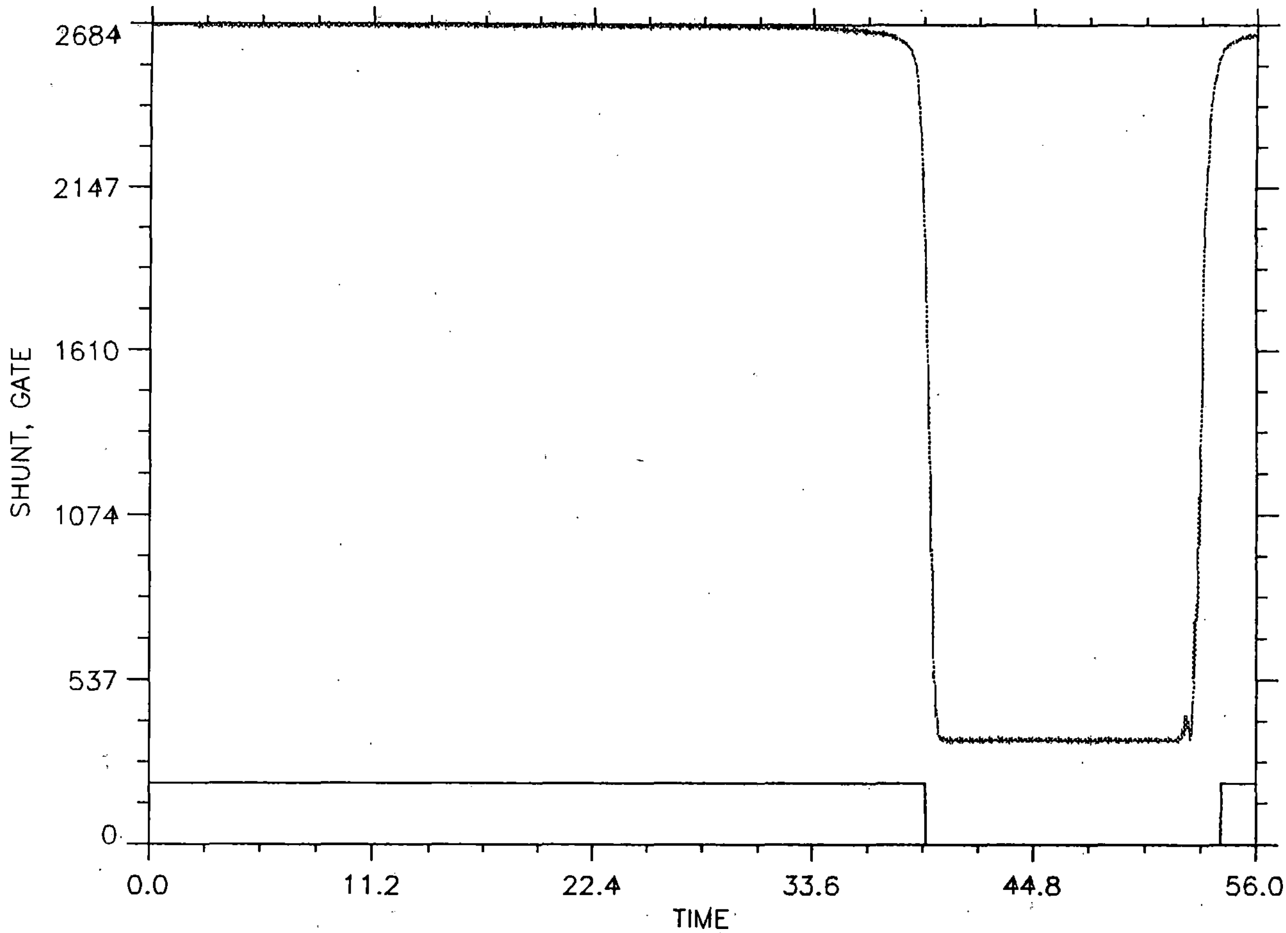

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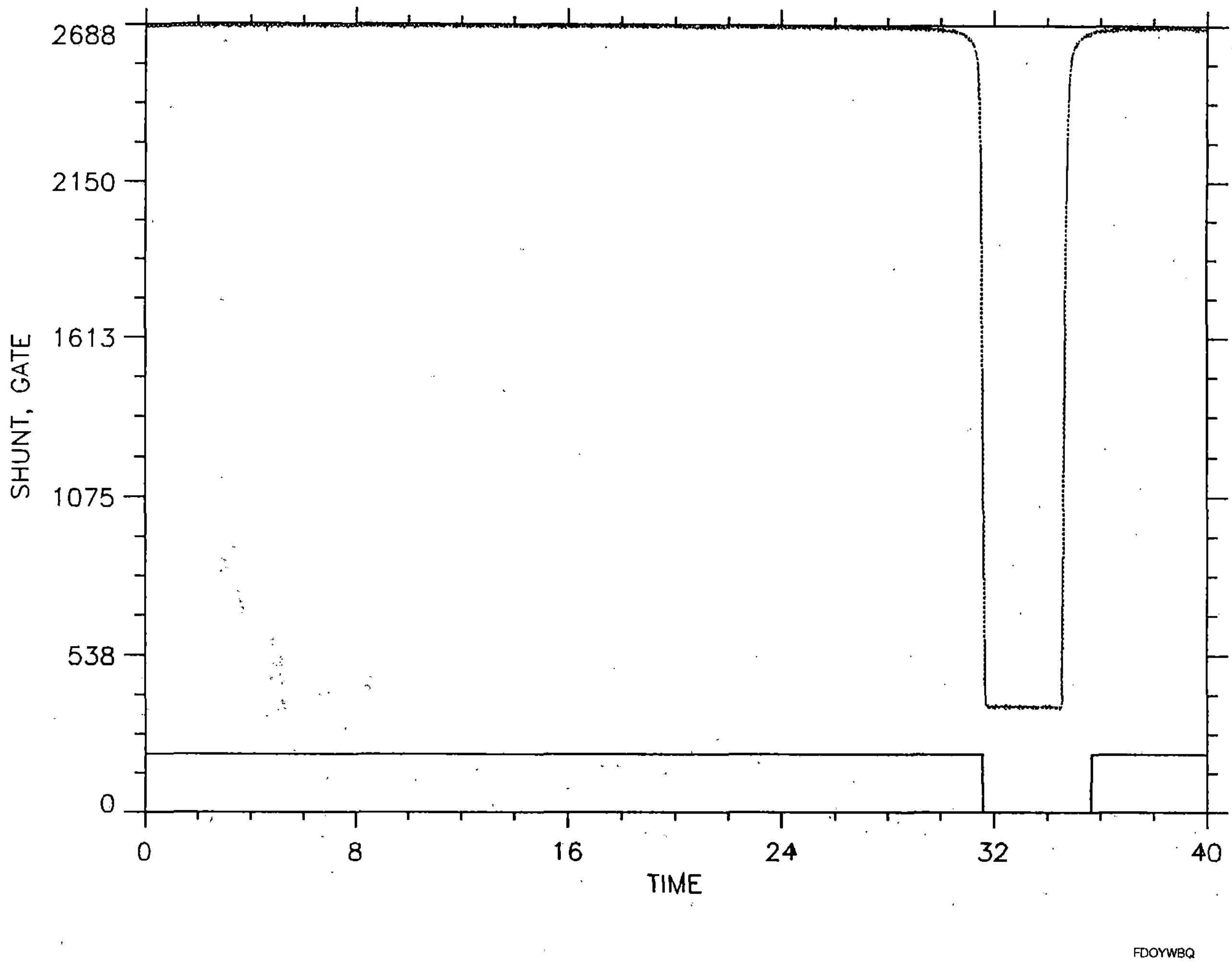

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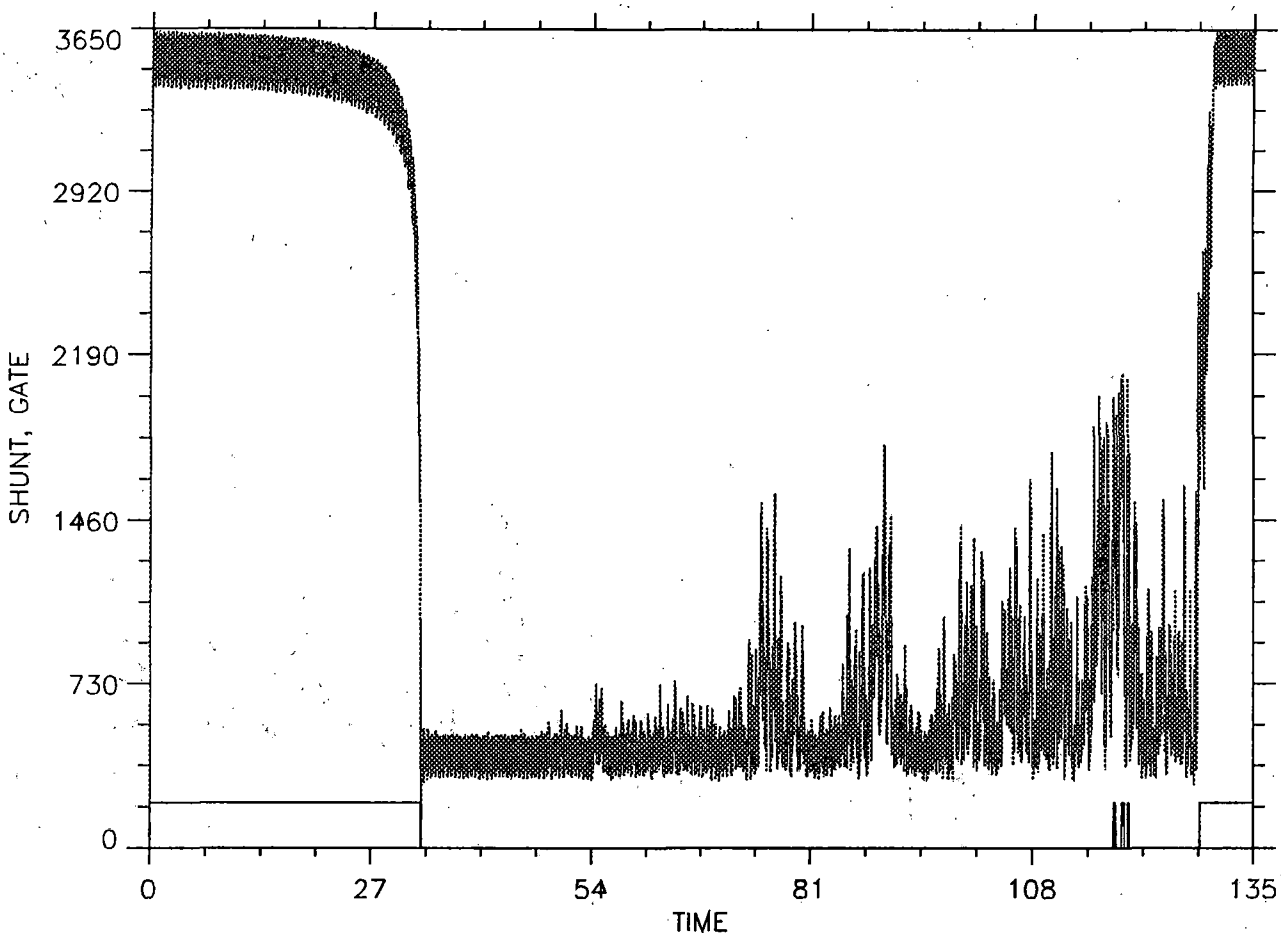

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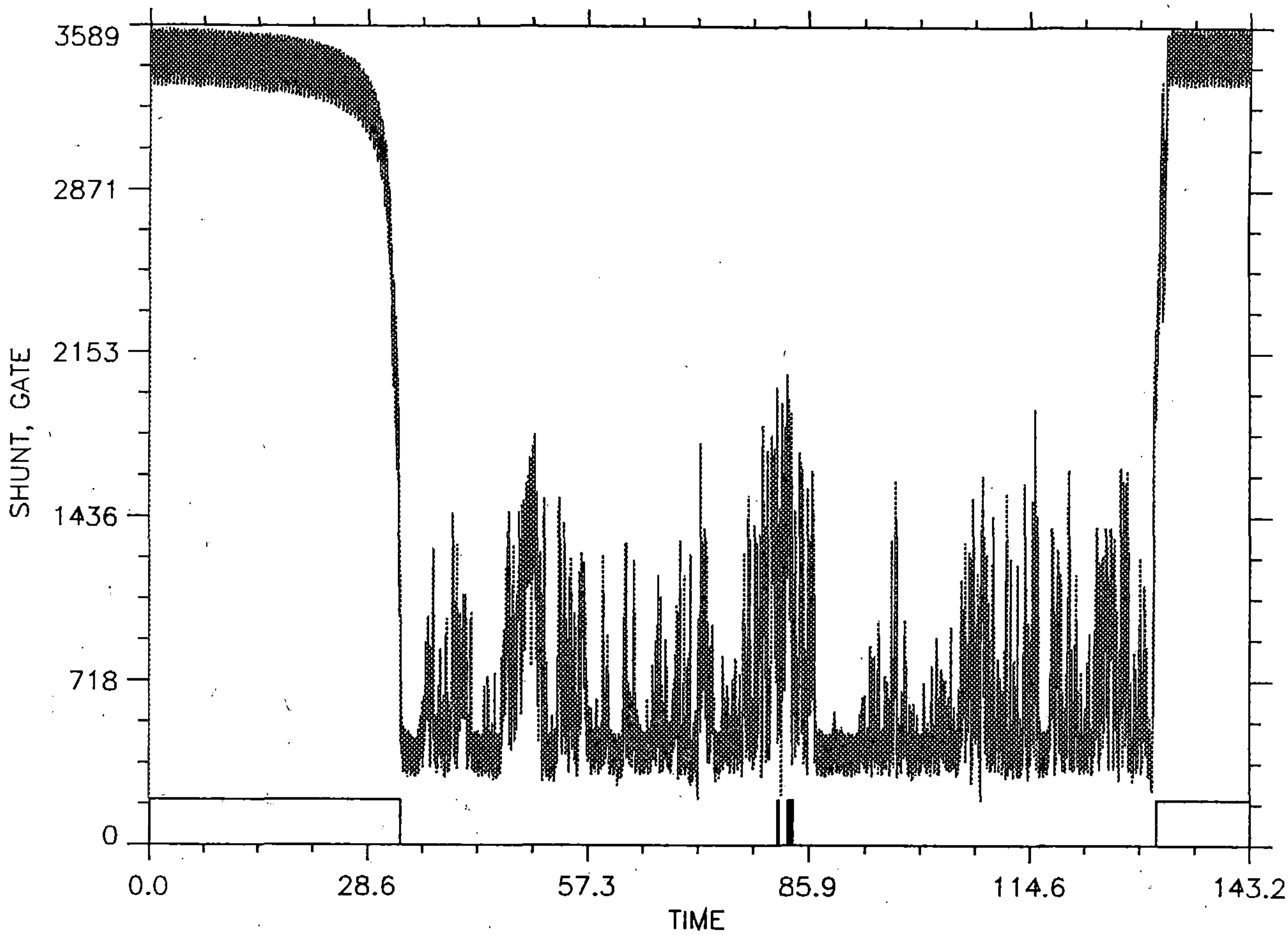

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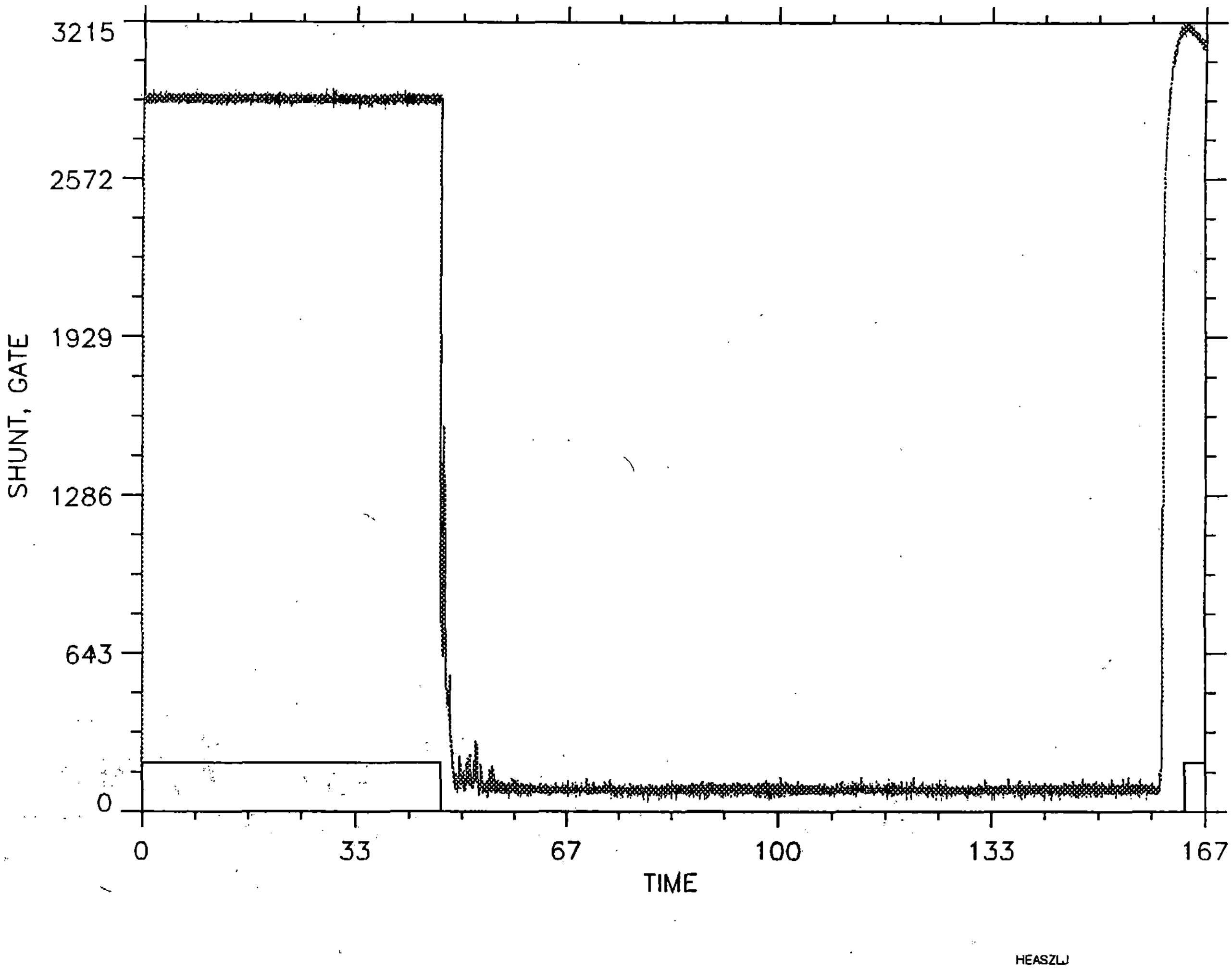

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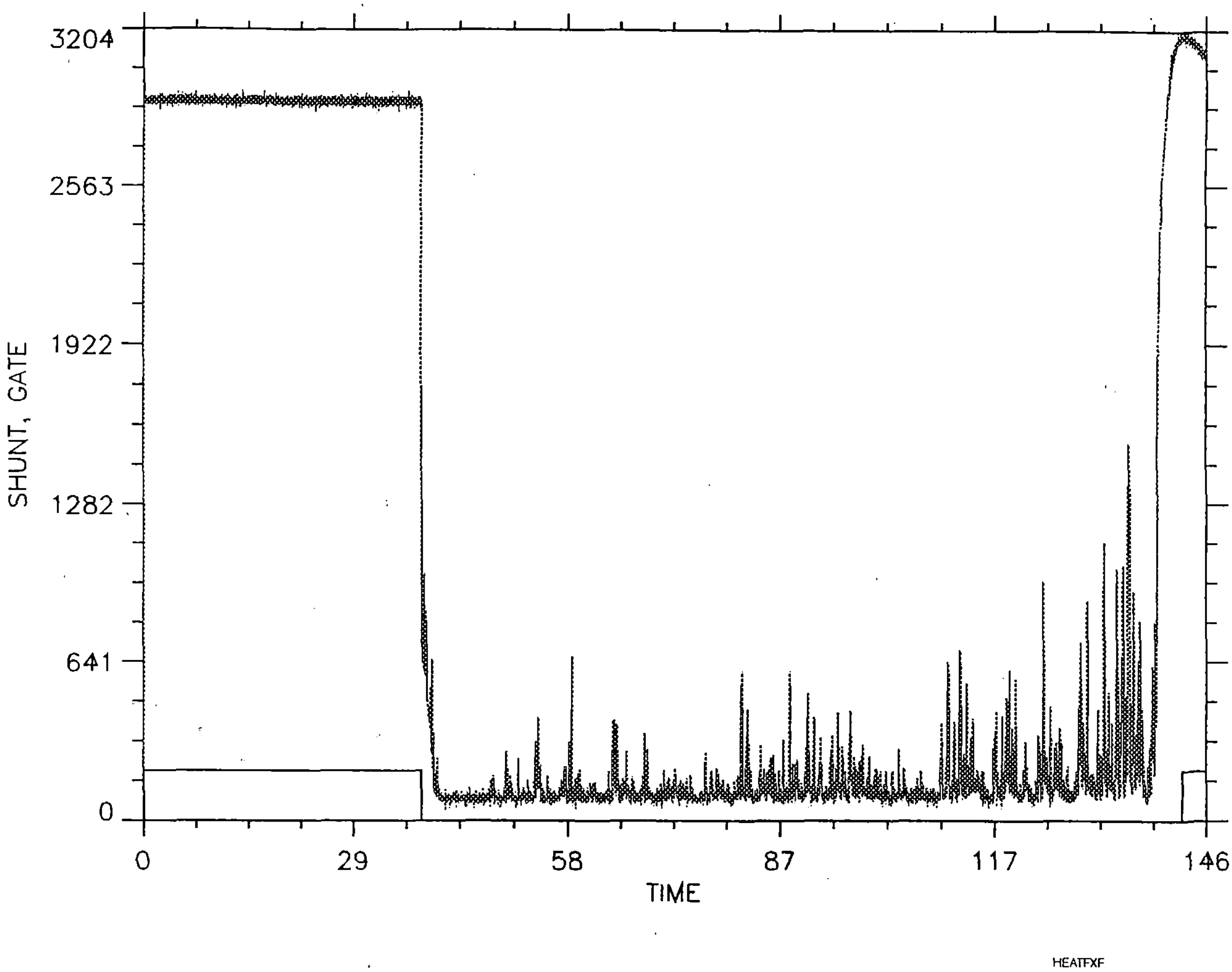

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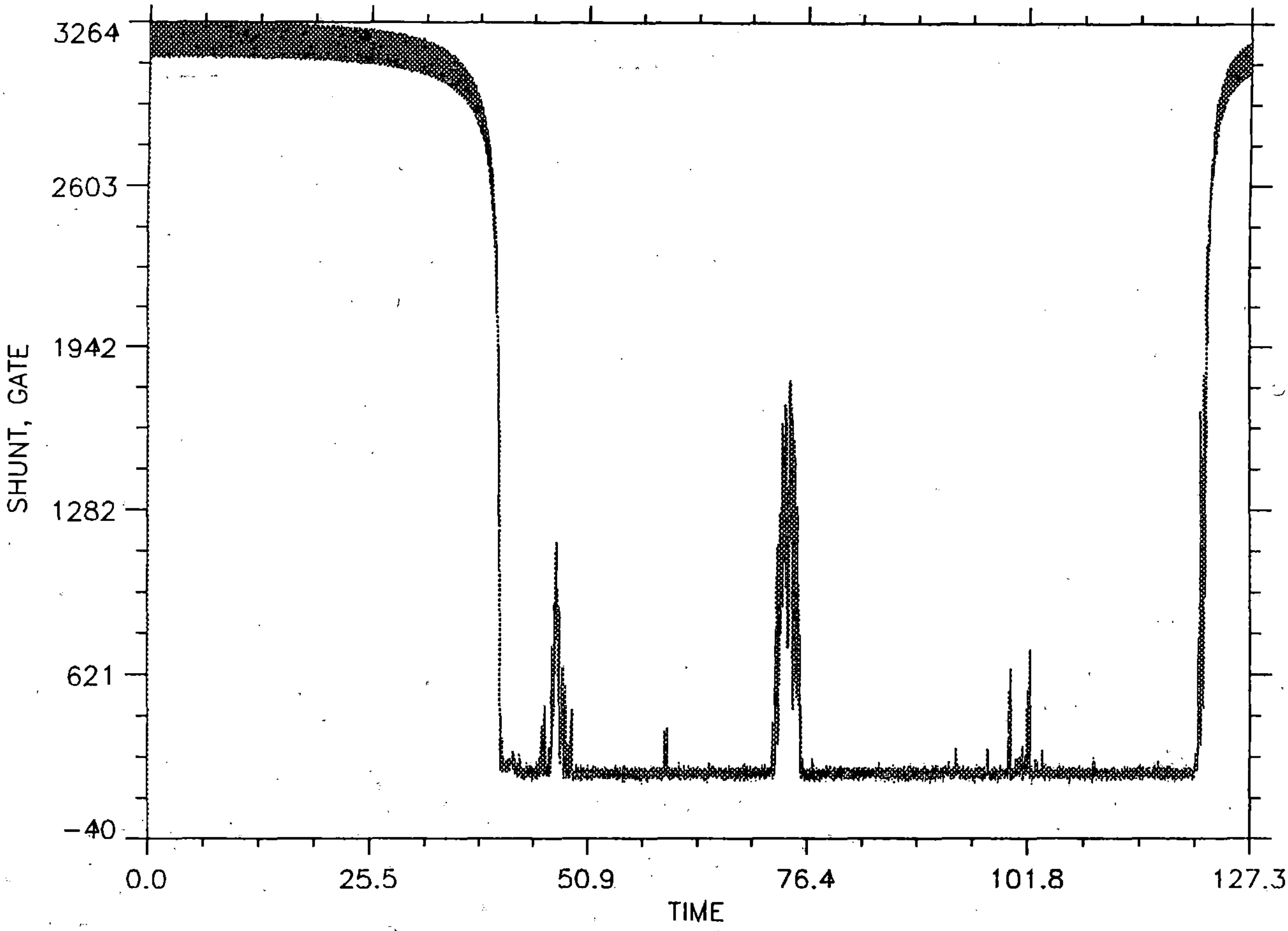

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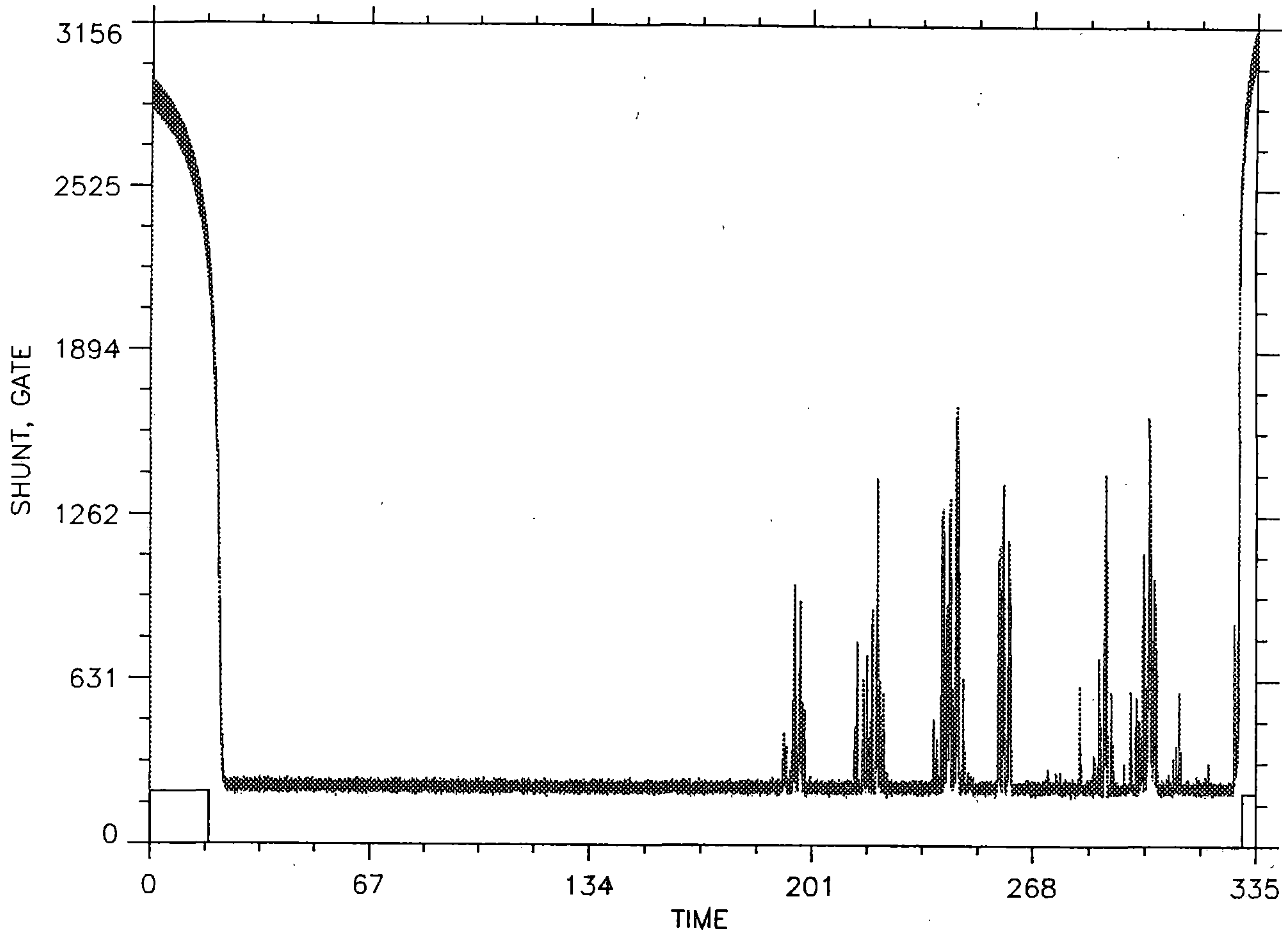

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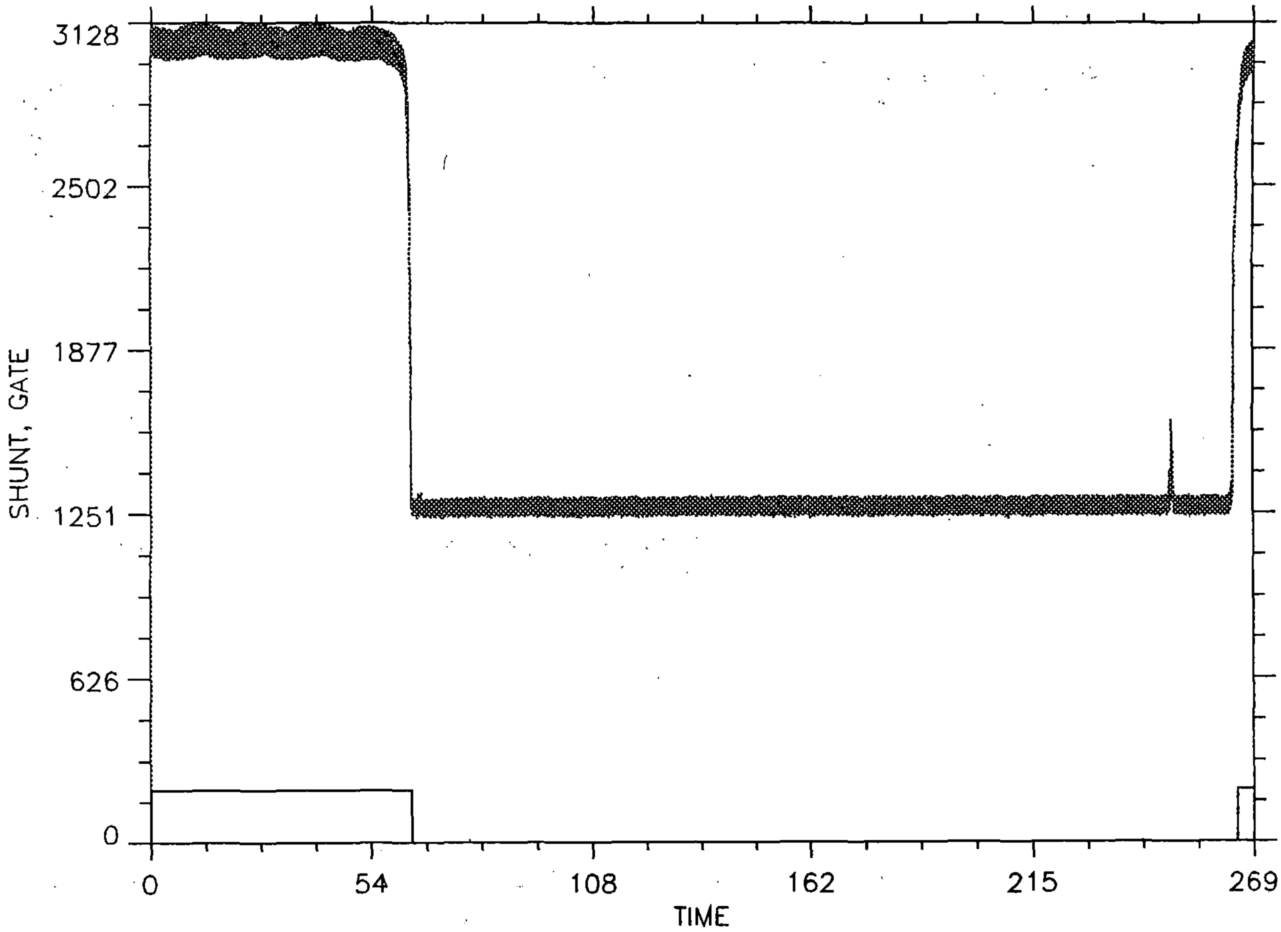

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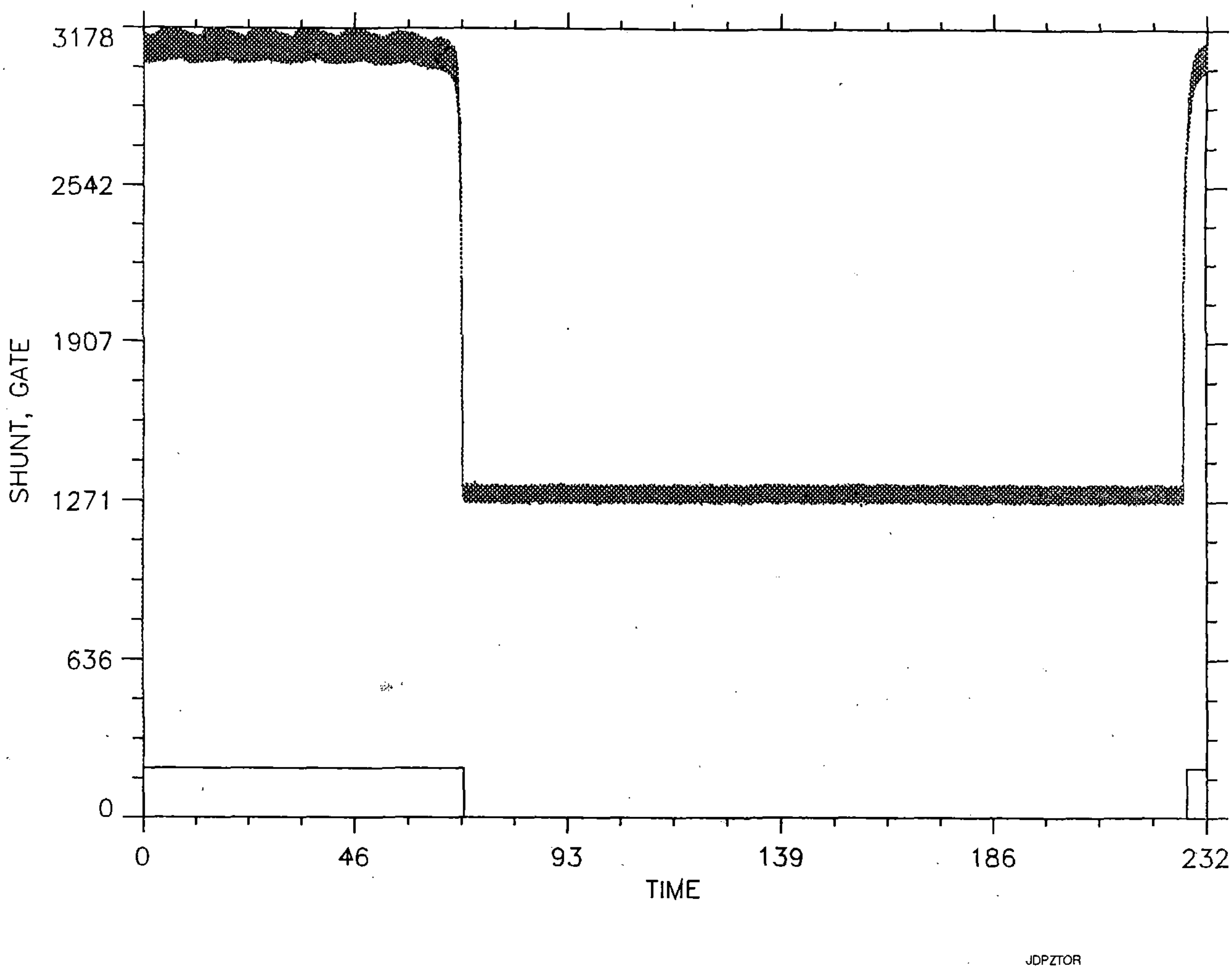

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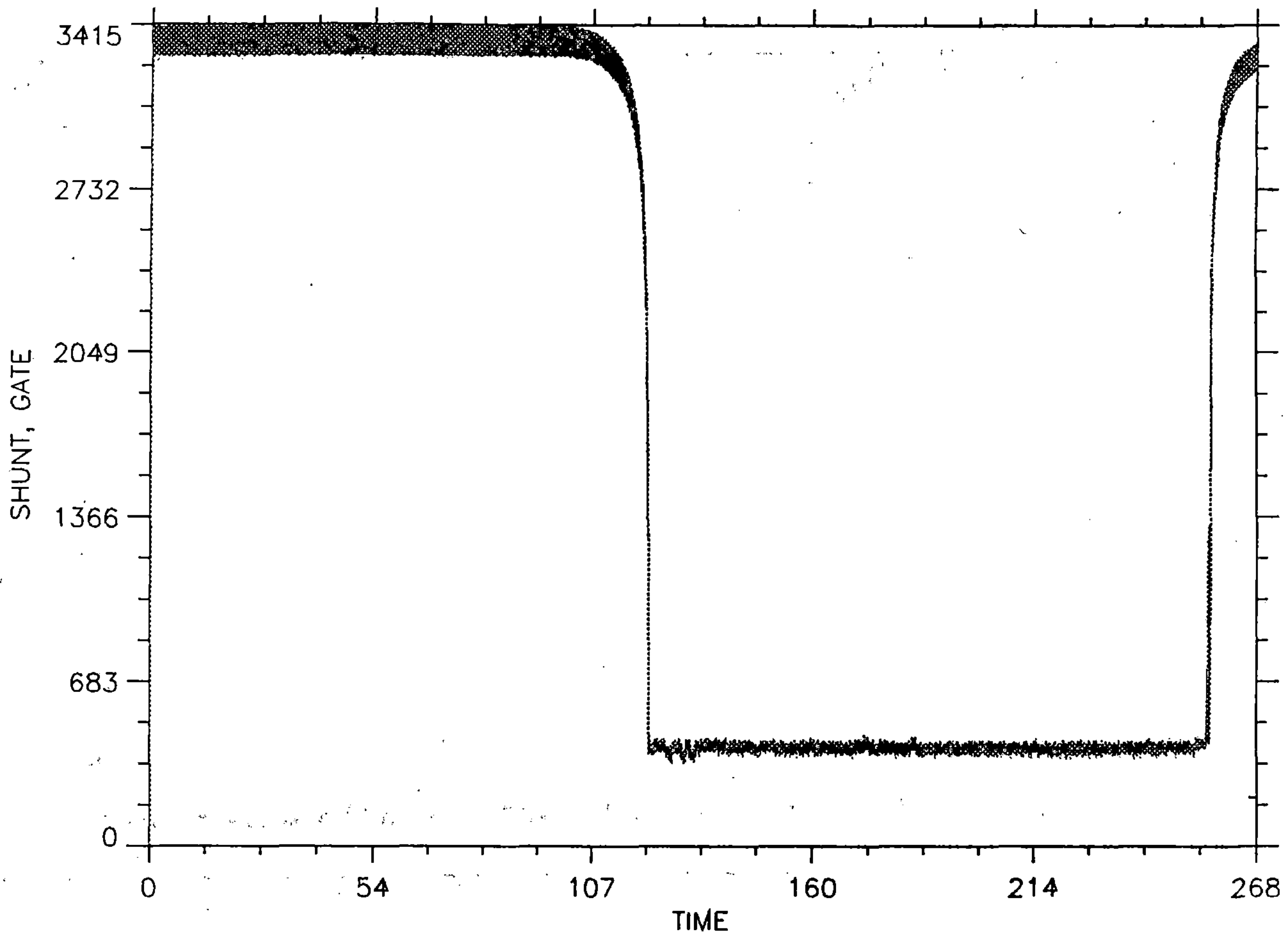

SITE K · JUNE 29, 1993

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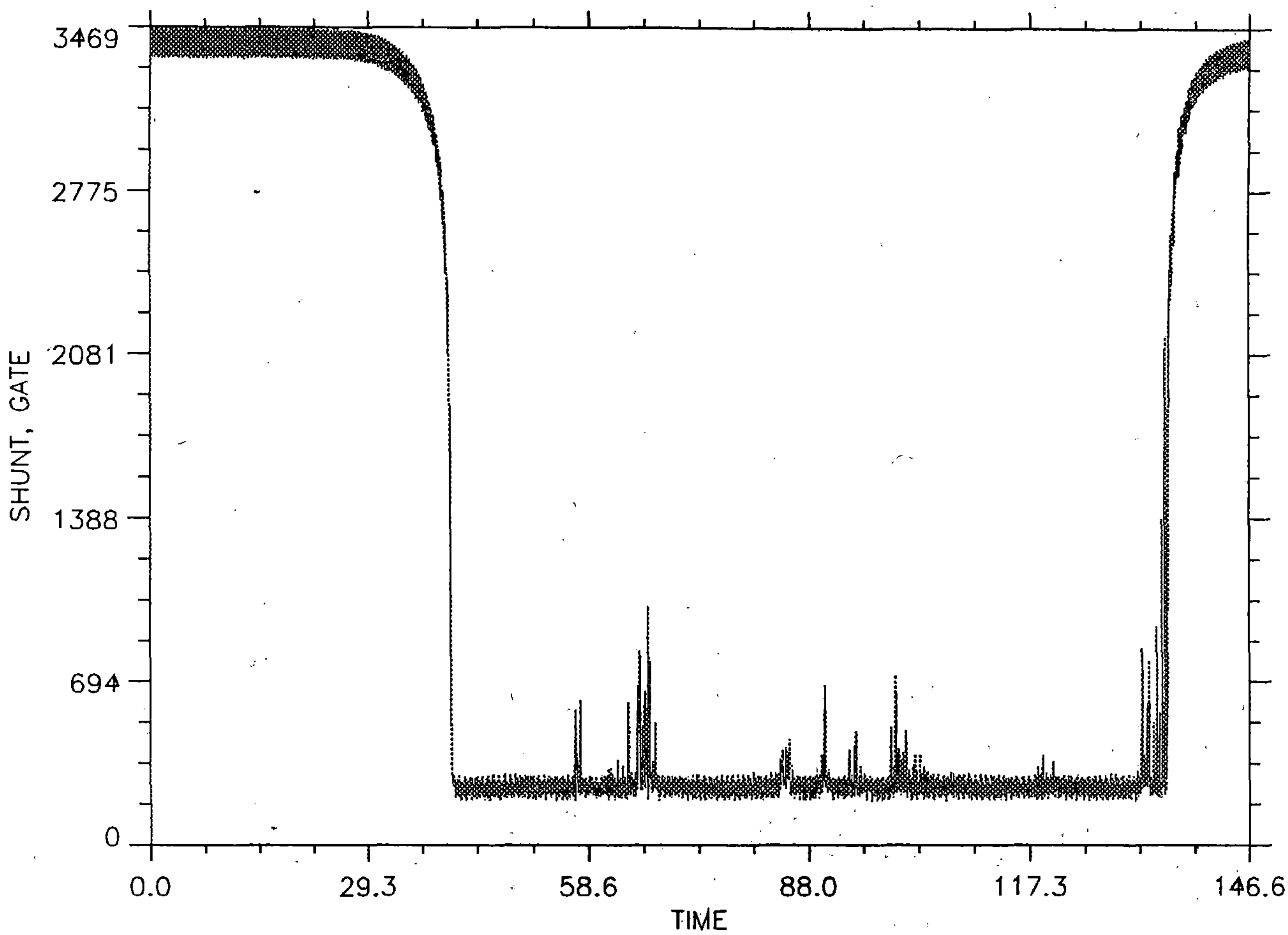
* Island relay drive in use by railroad. Not applicable.



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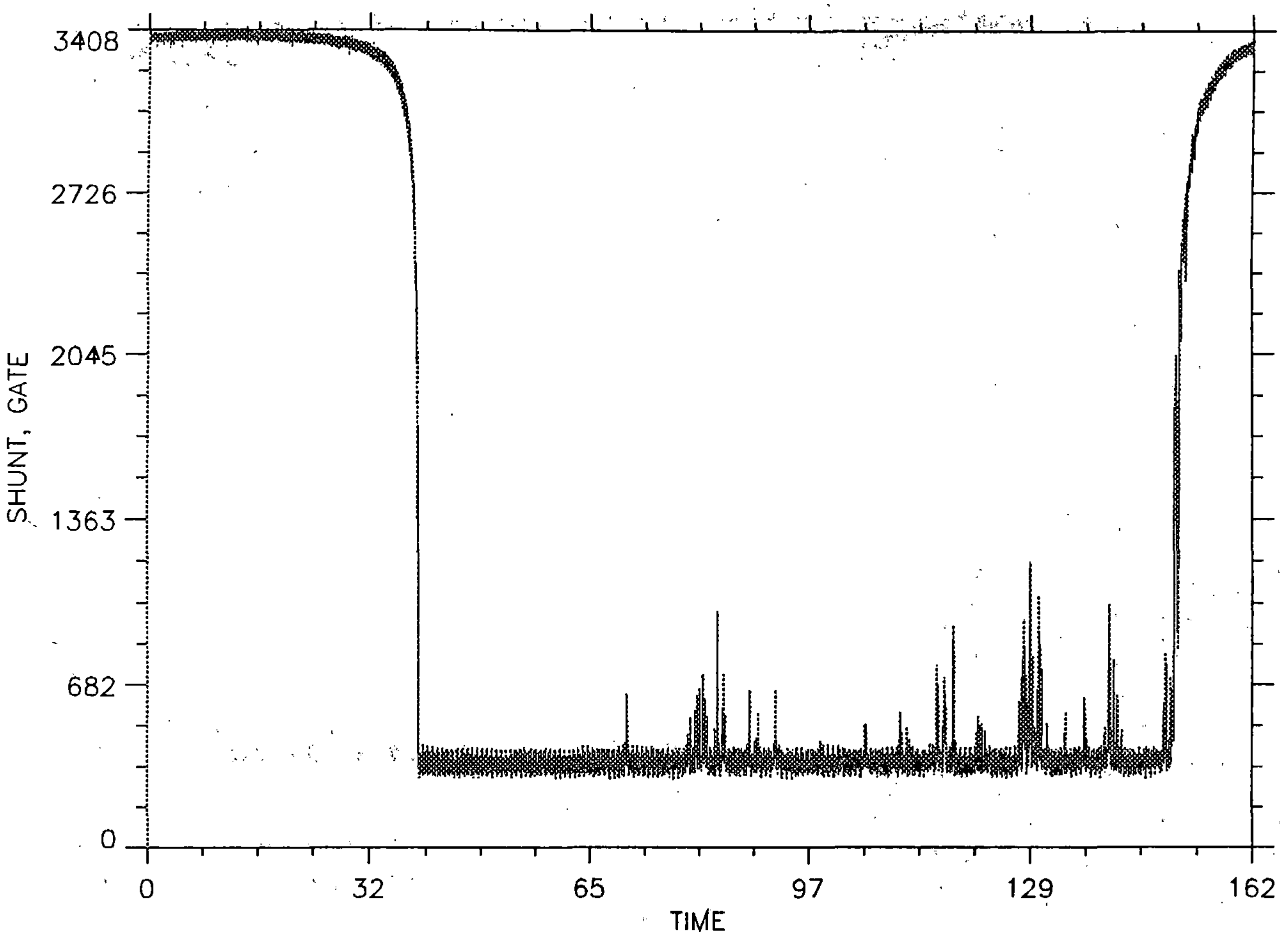

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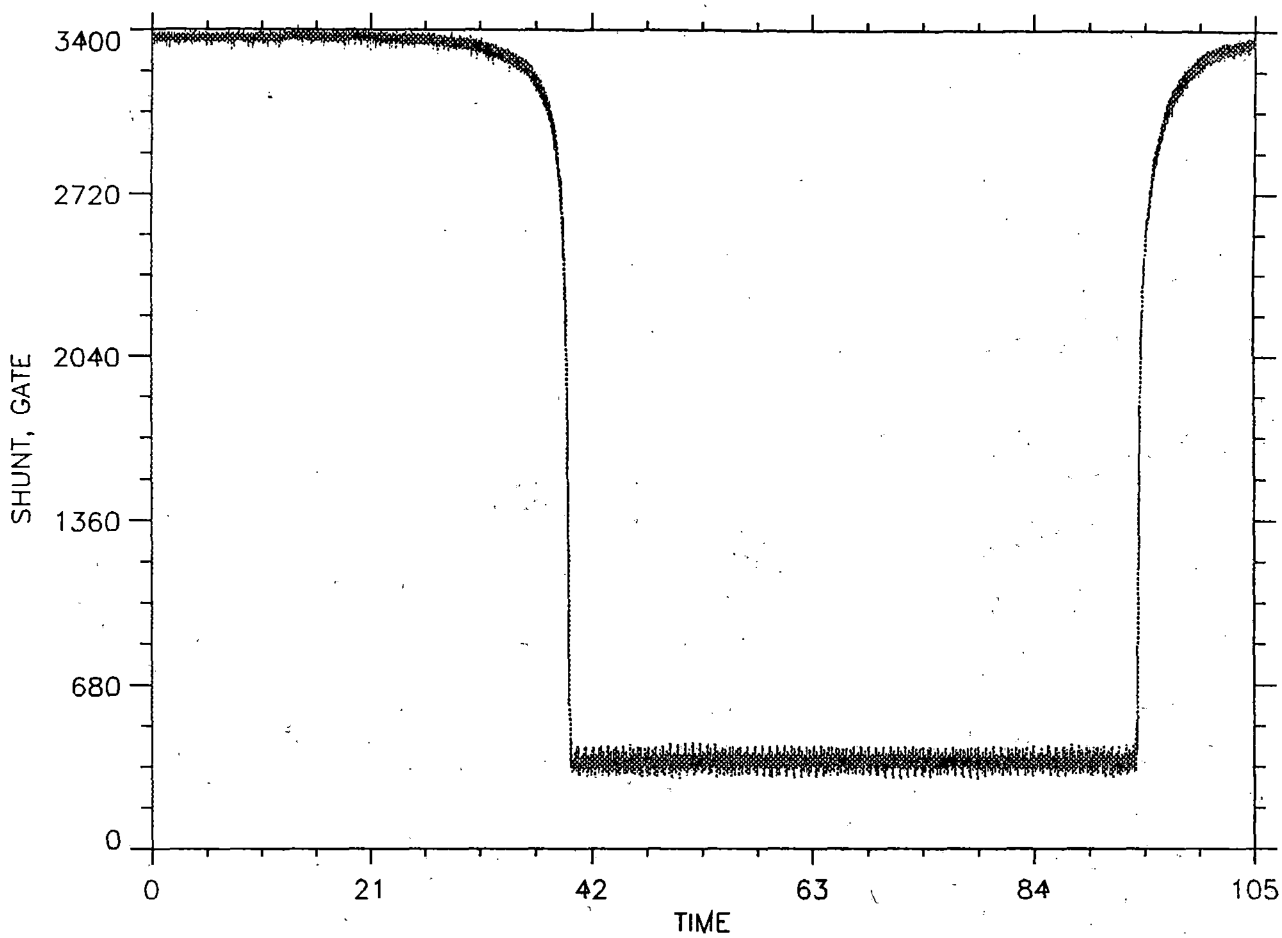

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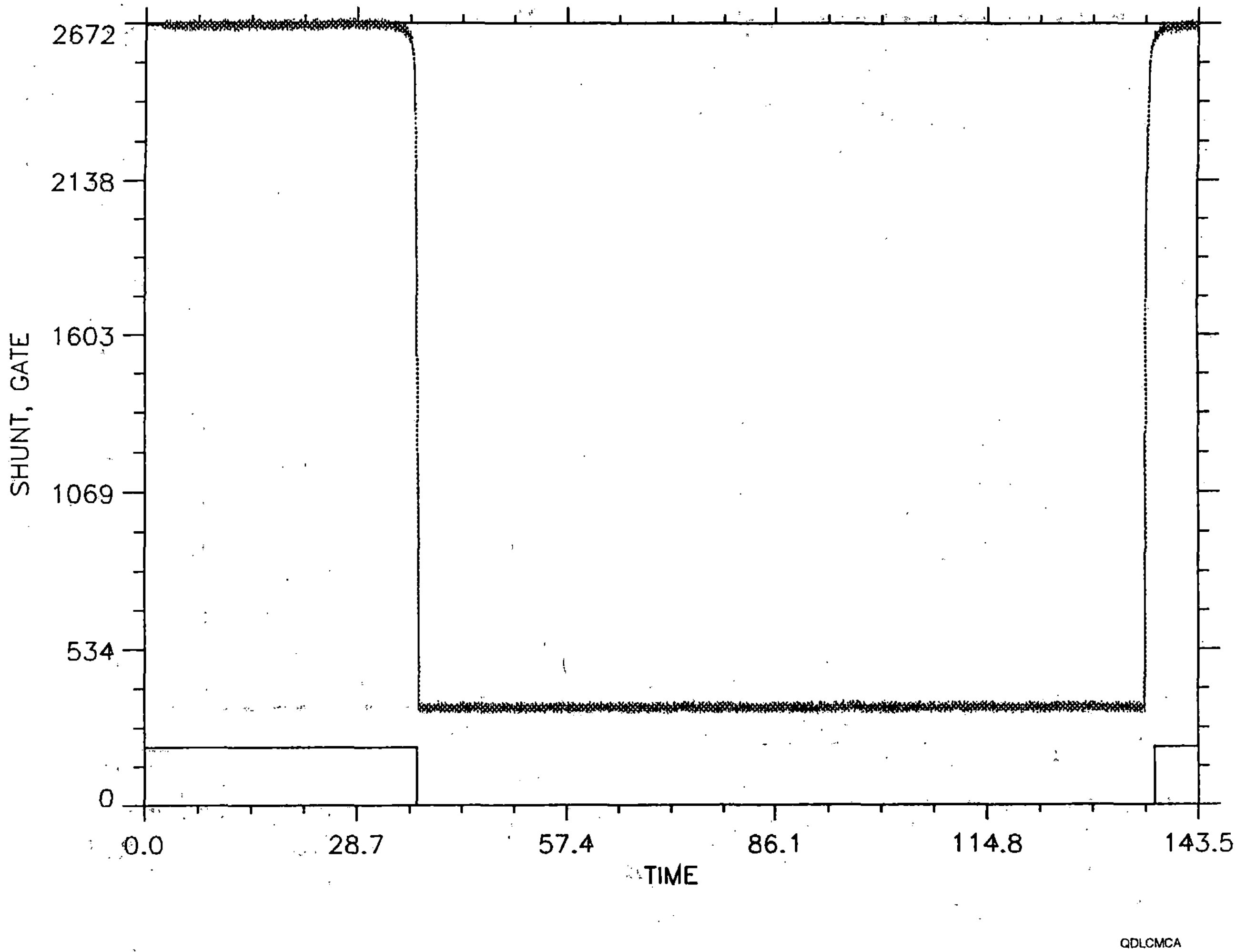

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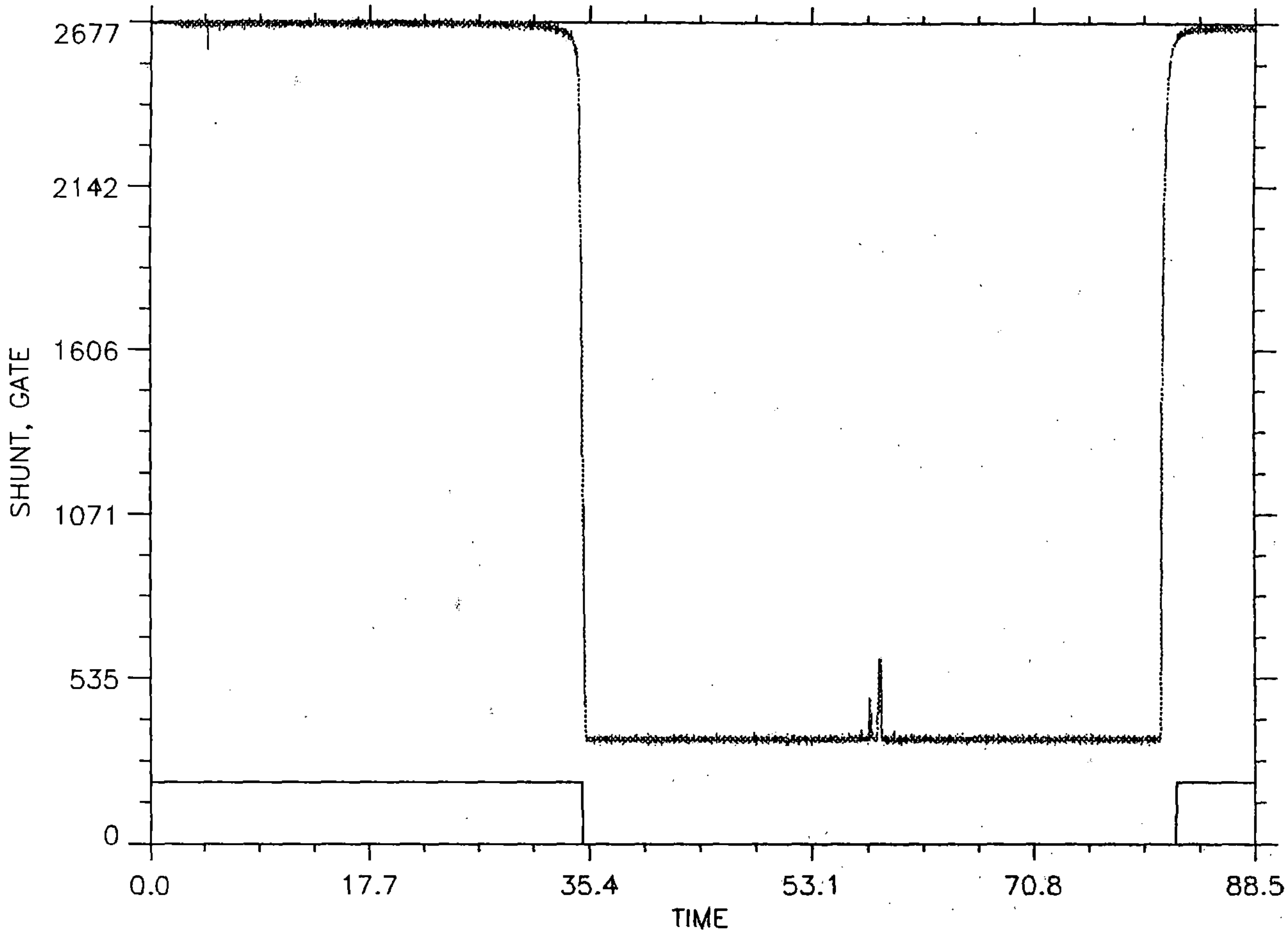

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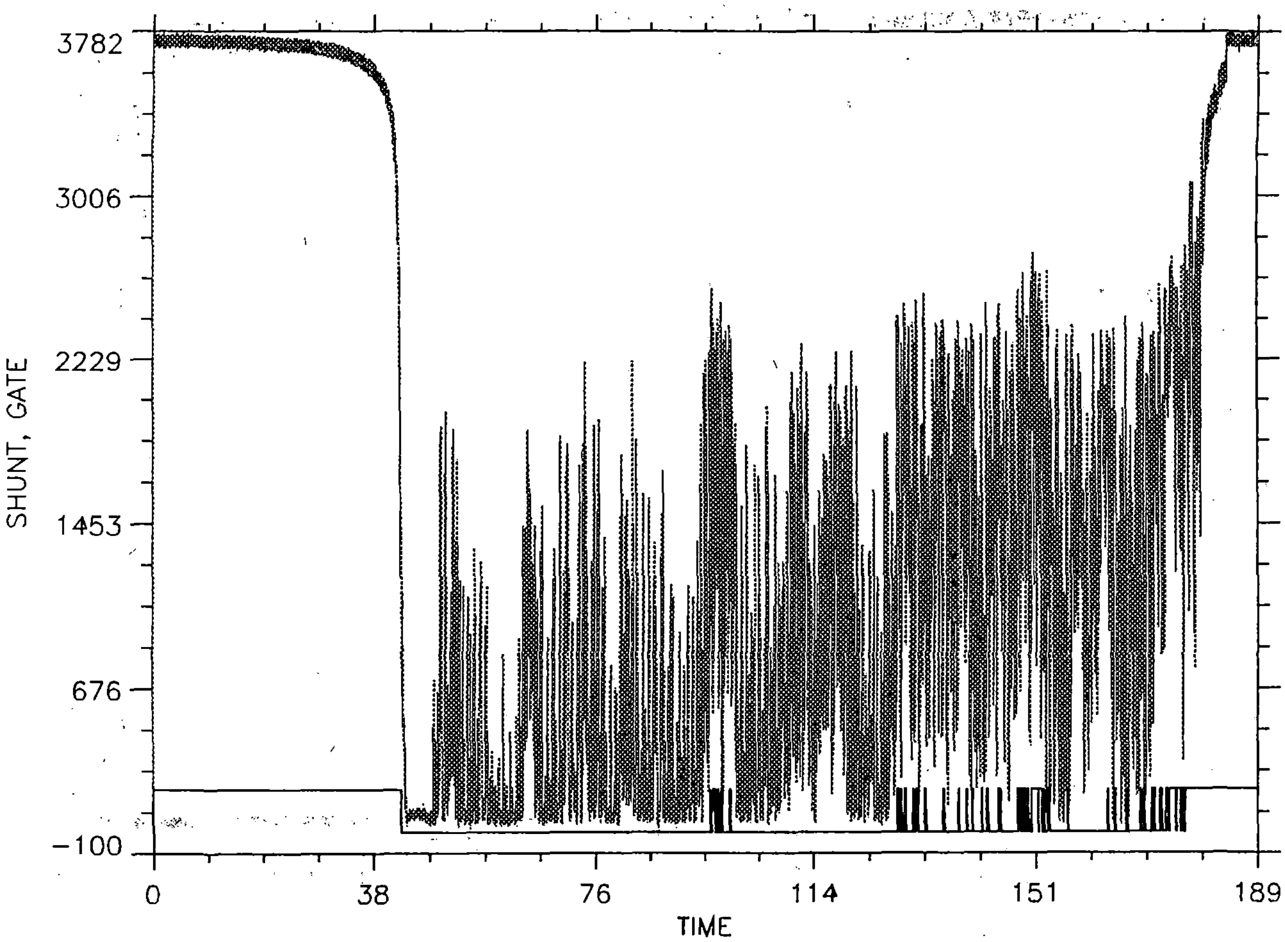

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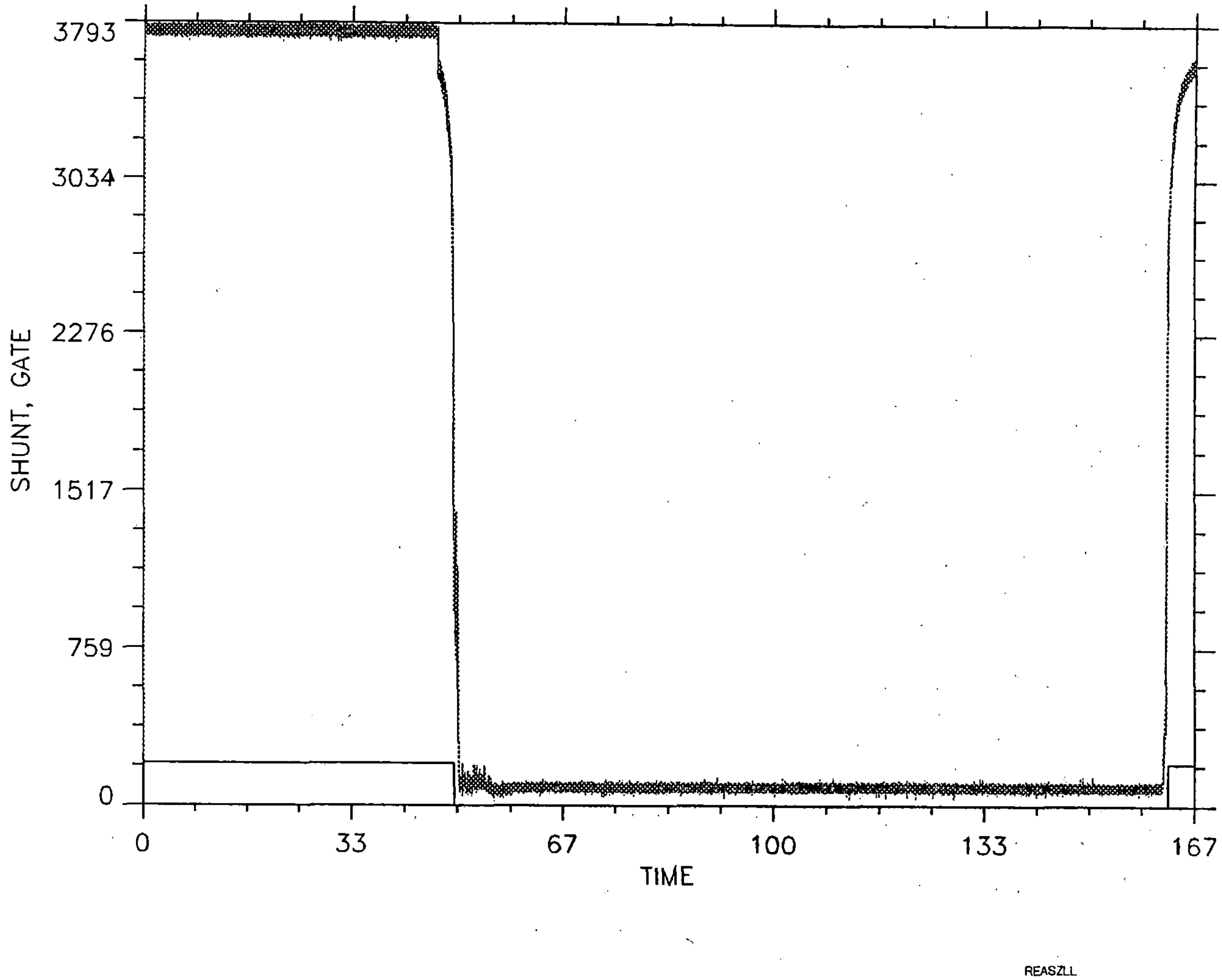

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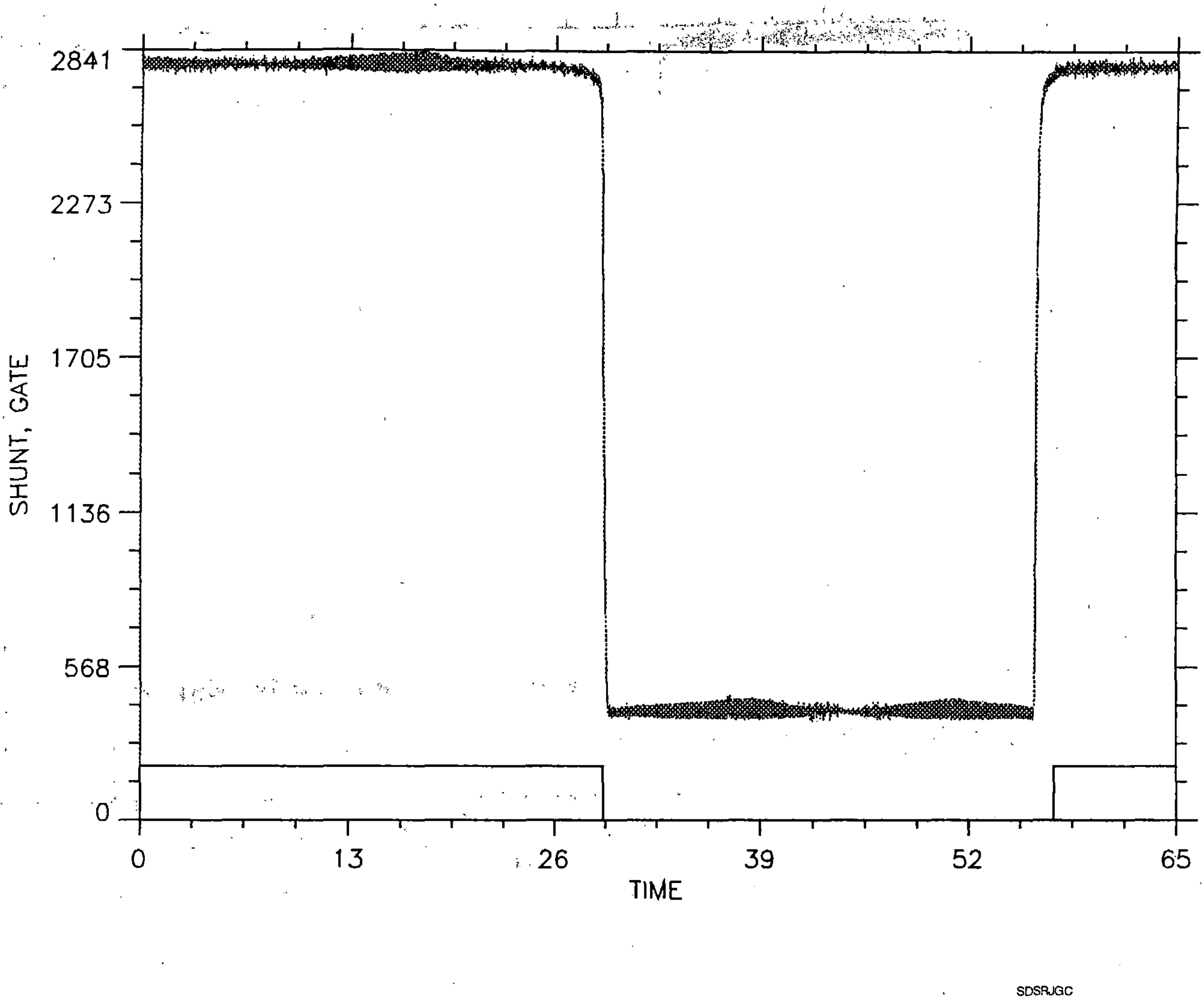

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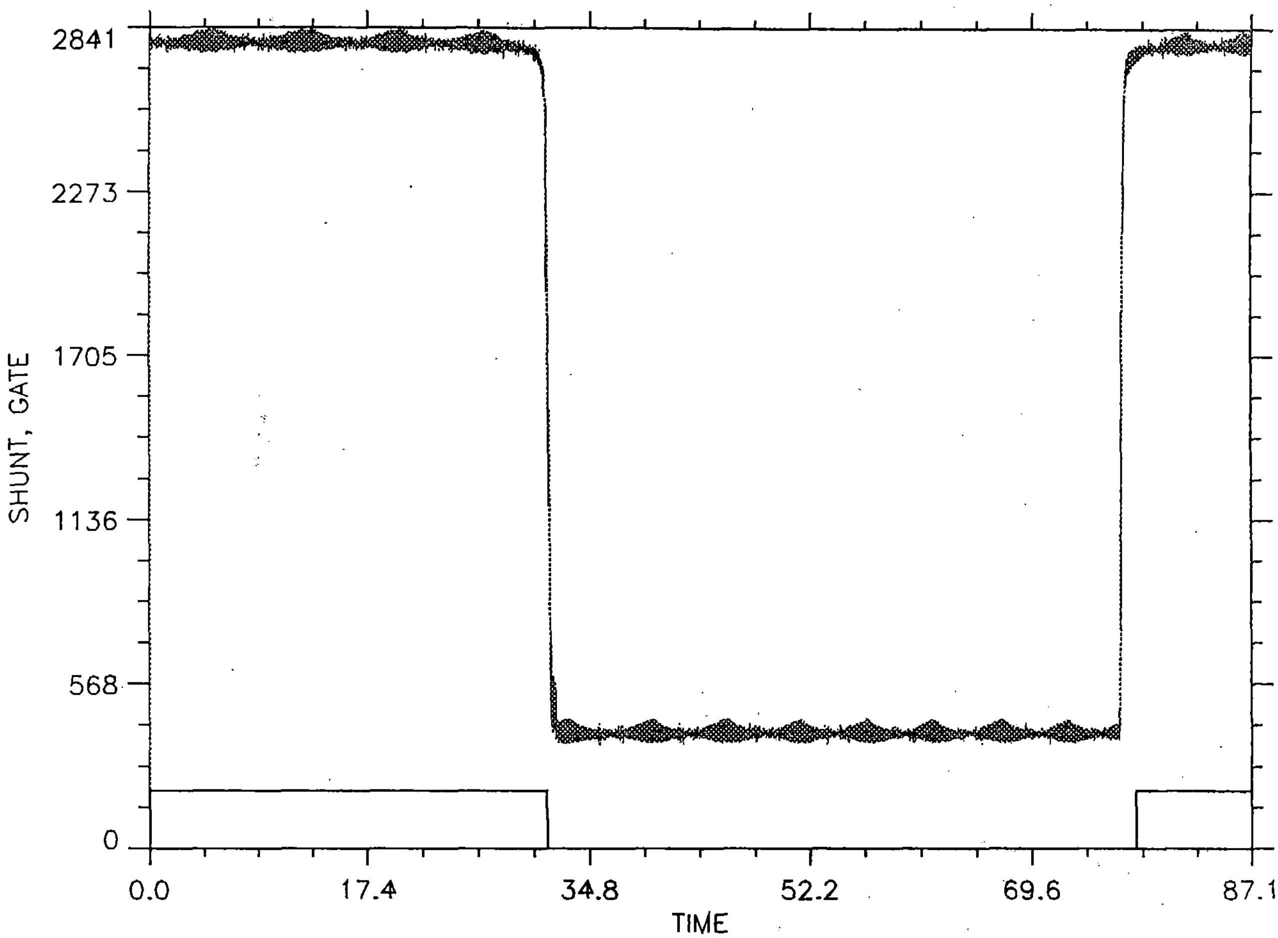

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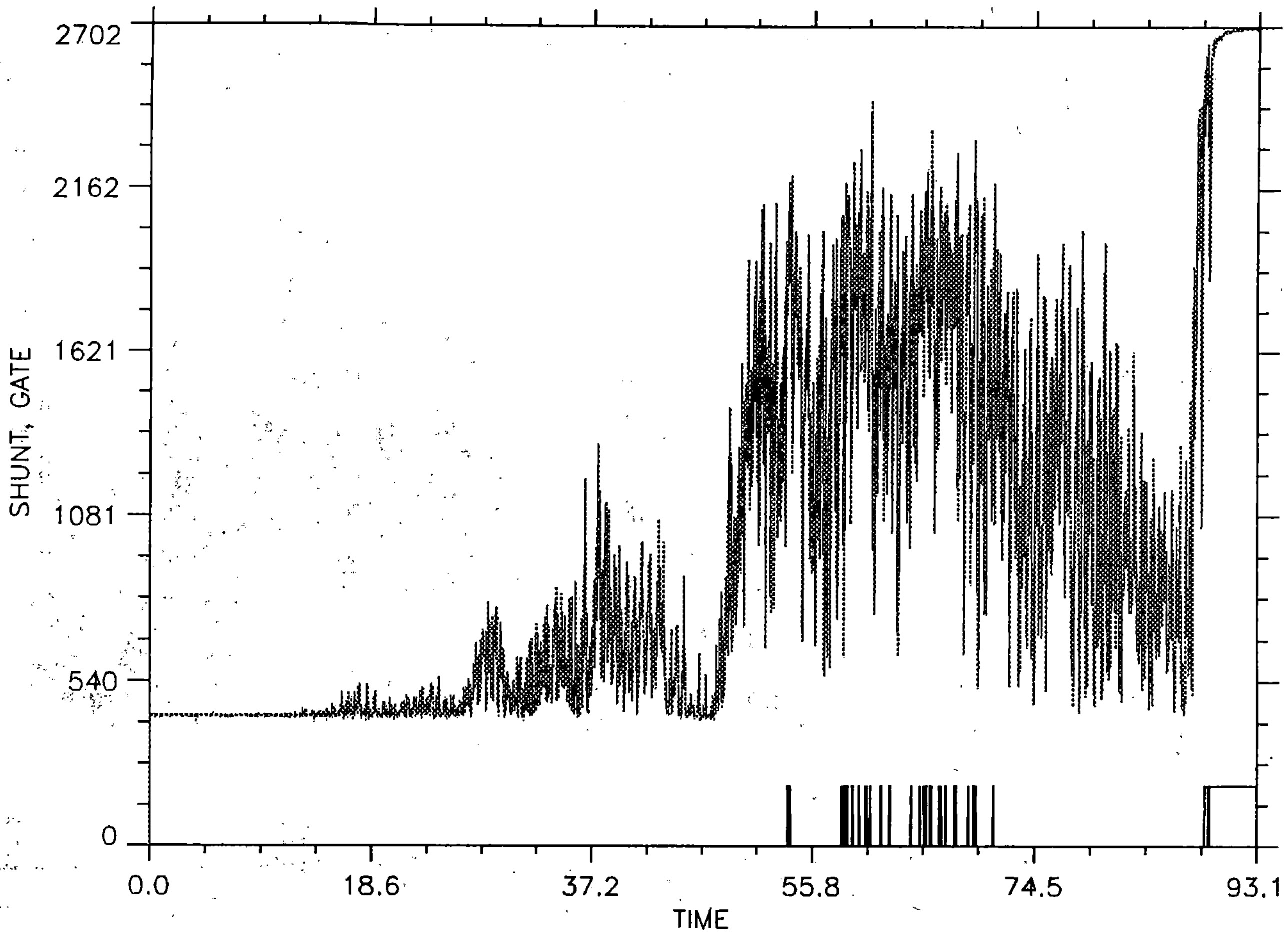

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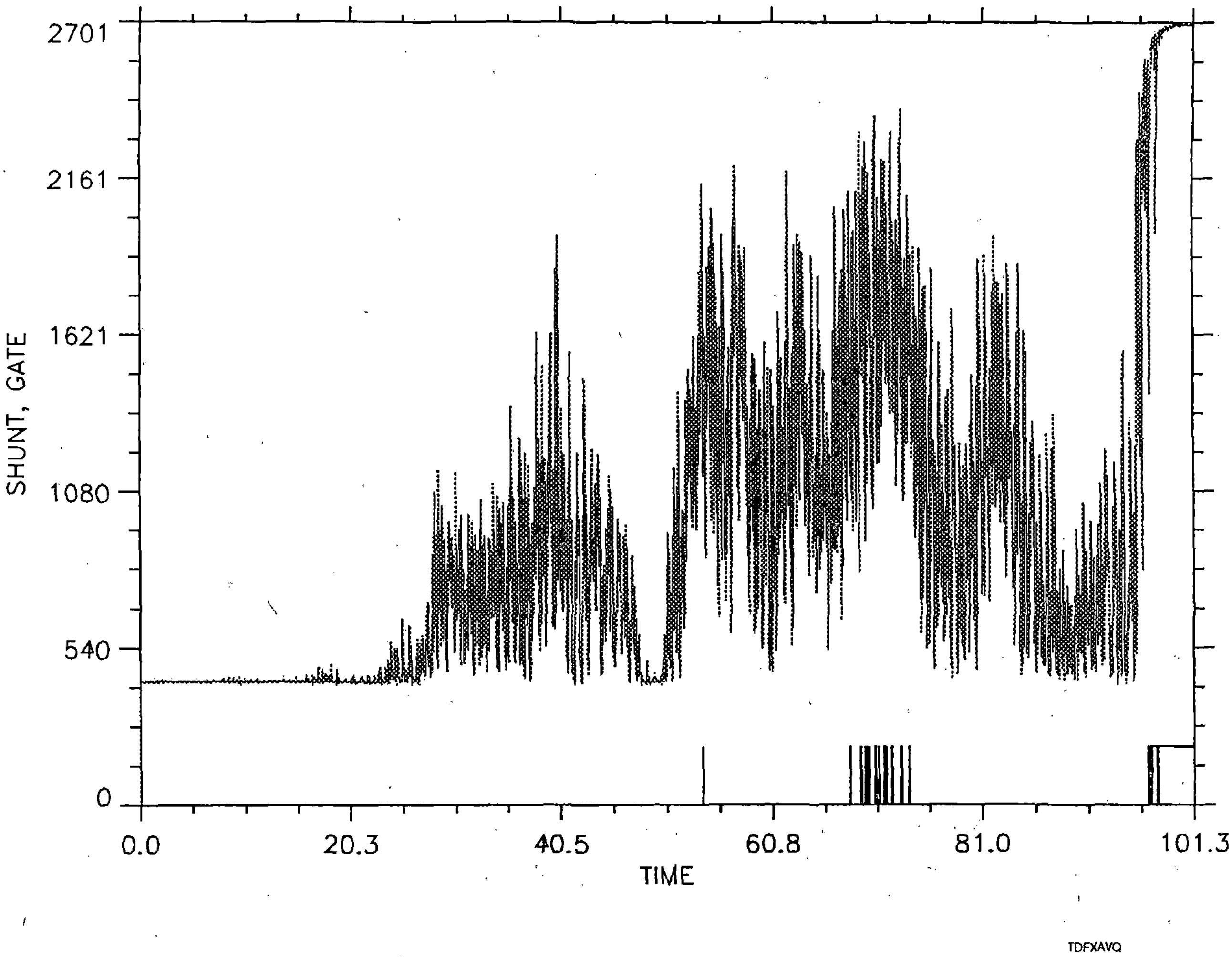

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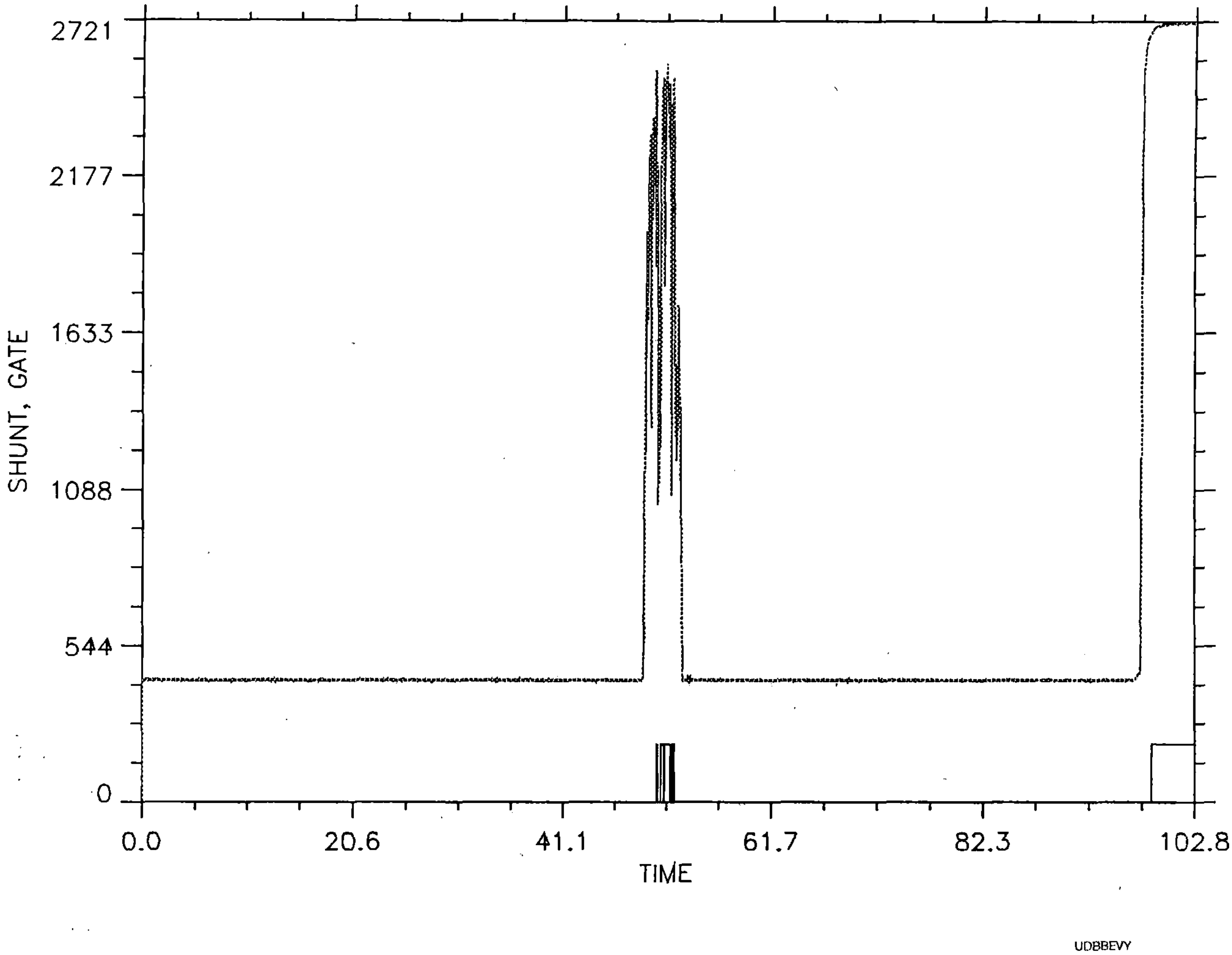

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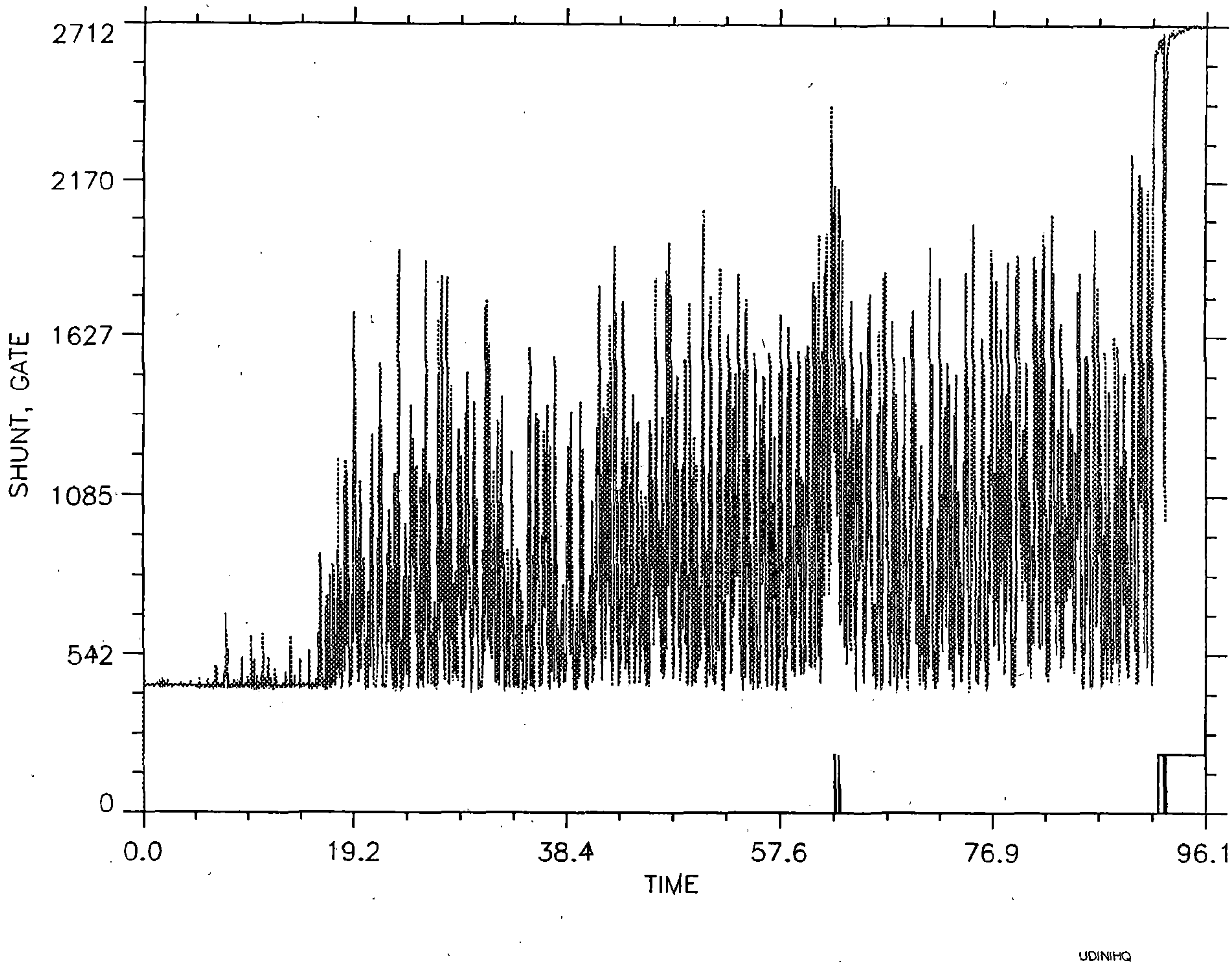

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APPENDIX B

Test Implementation Plan

Test Implementation Plan

Investigation of Influence of Contact Patch Resistance on Loss of Shunt

May 15, 1993

WORK TO BE PERFORMED UNDER FUTURE TASK ORDER APPEARS IN ITALICS TYPE

PREVIEW

The initial investigation into the loss of shunt (LOS) problem began in February 1992 under T.O. #46. The findings while the test program was on-going prompted many revisions and changes in scope to the test implementation plan (TIP) and the FRA's statement of work (SOW). Due to these changes in scope, FRA decided to close T.O. #46 after the initial investigation and continue the LOS program, with a new scope, under T.O. #XX.

Since the objectives of the LOS investigation have not changed, the TIP for T.O. #46 was revised and modified to address the SOW for T.O. #XX. Therefore, much of the data collection and analysis in this TIP were covered under T.O. #46. Work that will be performed under T.O. #XX appears in itilics type in this TIP.

1.0 INTRODUCTION

Safety and reliability of grade crossing warning devices are a major concern of the railroad industry. The primary activation of a crossing warning device is through vehicle wheel sets which apply a shunt between the two rails along a designated section of railroad track. This shunting action causes track circuit voltage to short-circuit and prevents power from reaching control relays. The contacts of these relays control crossing gates, signals, and island circuits at railroad crossings.

It has been suggested that a loss of shunt may be occurring in revenue service at certain locations, causing premature release of crossing protection devices. This loss of shunt could be due to a number of individual parameters, or a combination of several conditions, such as:

a. films, contaminants and/or oxides on the rail and/or wheel surfaces,
b. light axle loads,
c. changes in contact patch due to grinding or different wheel profiles, and/or
d. losses from hunting or irregular wheel/rail surface.

Presently the exact combination of the above conditions that could lead to loss of shunt is not fully known, nor is it certain that these are the only items that adversely influence shunt. As part of this program, the items influencing shunt will be documented, including identification of parameters that can reduce shunting reliability.

2.0 TEST OBJECTIVES

Program objectives fall into several categories, of which some are dependent on the results of others. Specific objectives are to determine loss of shunt parameters and possible mitigations procedures. Details of these objectives include:

a. determine the number of "loss of shunt" or "near loss of shunt" occurrences at a selected number of field locations,
b. determine if these loss of shunt occurrences can be related to a limited set of specific track, mechanical or other conditions, and document the conditions leading to loss of shunt,
c. determine shunt characteristics of an island crossing circuit installed at a location that can be closely monitored and altered if desired, specifically a circuit to be installed at the Transportation Test Center (TTC), Pueblo, Colorado,
d. evaluate data collected at field locations where loss of shunt has occurred. Where possible, replicate specific parameters causing or leading up to a loss of shunt at the TTC, then determine what mitigation techniques could be transferred into field use.

3.0 PROCEDURES

3.1 TEST APPROACH

Shunt history will be monitored at a number of locations, both at revenue service sites and at the TTC. The history of shunt voltage loss will be used to flag the presence of conditions that require additional evaluation. This evaluation will identify a limited set of parameters that lead to loss of shunt.

3.1.1 Revenue Service Sites

Eight revenue service sites, which have exhibited loss of shunt histories, have been selected for monitoring. These sites include a range of track and train conditions and offer a variety of track circuit designs. The revenue service sites have been agreed upon by the participating railroads, suppliers, AAR, and the FRA. The sites selected are:

LOCATION	RAILROAD
Harbor Creek, PA - King Road, MP 77.56	CR & NS
Sterling, NE (East) MP 27.05	BN
Sterling, NE (West) MP 27.71	BN
Buford, GA, Selma Street	NS
Lawrence, KS, MP 42.24	UP
Midland, KS, MP 43.4	UP
Cobourg, Ontario, (Canada), Brook Road	CN
Gothenburg, NE	UP

A test site will be also installed at Gothenburg Nebraska, on the UP, to take advantage of existing lateral and vertical load and car identification systems.

Where possible, the host railroad will provide a commercial phone line to allow modem transfer of data from the remote site to the TTC data collection base. Adequate 110 volt alternating current (VAC) power for operation of the remote site computer will also be provided.

Table 1.

Location Codes for
Loss of Shunt
Data Collection Sites

CODE	SITE	RAILROAD	LOCATION	DIRECTION	INSTALLED
A	Buford, GA	NS	Selma St.	North	03/17/92
B	Buford, GA	NS	Selma St.	South	05/05/92
C	Harbor Creek, PA	NS	King Rd. MP 77.56	------ ------	05/15/92
D	Harbor Creek, PA	CR	King Rd.	West	05/16/92
E	Harbor Creek, PA	CR	King Rd.	East	05/16/92
F	Cobourg, Ontario (Canada)	CN	Brook Rd.	West	07/17/92
G	Sterling, NE	BN	MP 27.71	West	07/07/92
H	Sterling, NE	BN	MP 27.05	East	07/07/92
I	Lawrence, KS	UP	MP 42.24	West	07/17/92
J	Lawrence, KS	UP	MP 42.24	East	07/17/92
K	Midland, KS	UP	MP 43.4	West	07/17/92
L	Midland, KS	UP	MP 43.4	East	07/17/92
M	Pueblo, CO	TTC	RTT-125'	------	* Oct '92
N	Pueblo, CO	TTC	TTT-125'	------	* On hold
O	Pueblo, CO	TTC	RTT-6'	------	* On hold
P	Pueblo, CO	TTC	TTT-6'	------	* On hold
Q	Cobourg, Ontario (Canada)	CN	Brook Rd.	East	Jan '93
R	Sterling, NE	BN	MP 27.71	Auxiliary	Dec '92
S	Harbor Creek, PA	NS	MP 77.56	Auxiliary	Nov '92
T	Gothenburg, NE	UP		Auxiliary	Jan '93
U	Gothenburg, NE	UP		Auxiliary	Jan '93

*** TTC site M installed to establish baseline data. Other TTC sites will be installed prior to conducting controlled tests.**

3.1.2 TTC Test Site

Typical track circuits will be installed on the Railroad Test Track (RTT) and the Transit Test Track (TTT) at the TTC. Two circuits are to be provided for TTC use through the supply industry with the following characteristics:

1. One 5.0 kHz circuit to represent a typical island circuit 120 feet long.
2. One 25 kHz circuit 6 feet long that will allow the identification of specific wheels that may be exhibiting loss of shunt.

Both circuits will include an "approach" type control circuit to activate the data collection system when a train approaches the data collection site. It will also be necessary to manually switch the data collection system to the appropriate track (RTT or TTT) that a train is operating over. These tracks are parallel, approximately on 30-foot centers at this location.

Each TTC site is constructed using standard wood ties and welded rail. Figure 1 indicates the approximate location where the track circuits will be installed at the TTC. Existing wayside hot box shanties will be used to house track circuit equipment, power supplies, and provide a phone line for modem transmittal of data to the TTC collection location.

3.2 PRIMARY TEST VARIABLES

3.2.1 Dependent Variables

Shunt voltage will be the primary dependent variable measured at each site. This is the voltage that is received at the circuit detector relay.

3.2.2 Independent Variables

Initially, no changes to track or rail conditions will be made, other that full documentation of existing parameters thought to influence shunt reliability. These parameters may be controlled or altered at a later date during the period where mitigation techniques are to be evaluated.

Major independent variables include:

1. Rail Lubrication
2. Rail Profile
3. Track Gage
4. Wheel Profile
5. Ballast Resistance
6. Circuit Design
7. Rail Surface Conditions

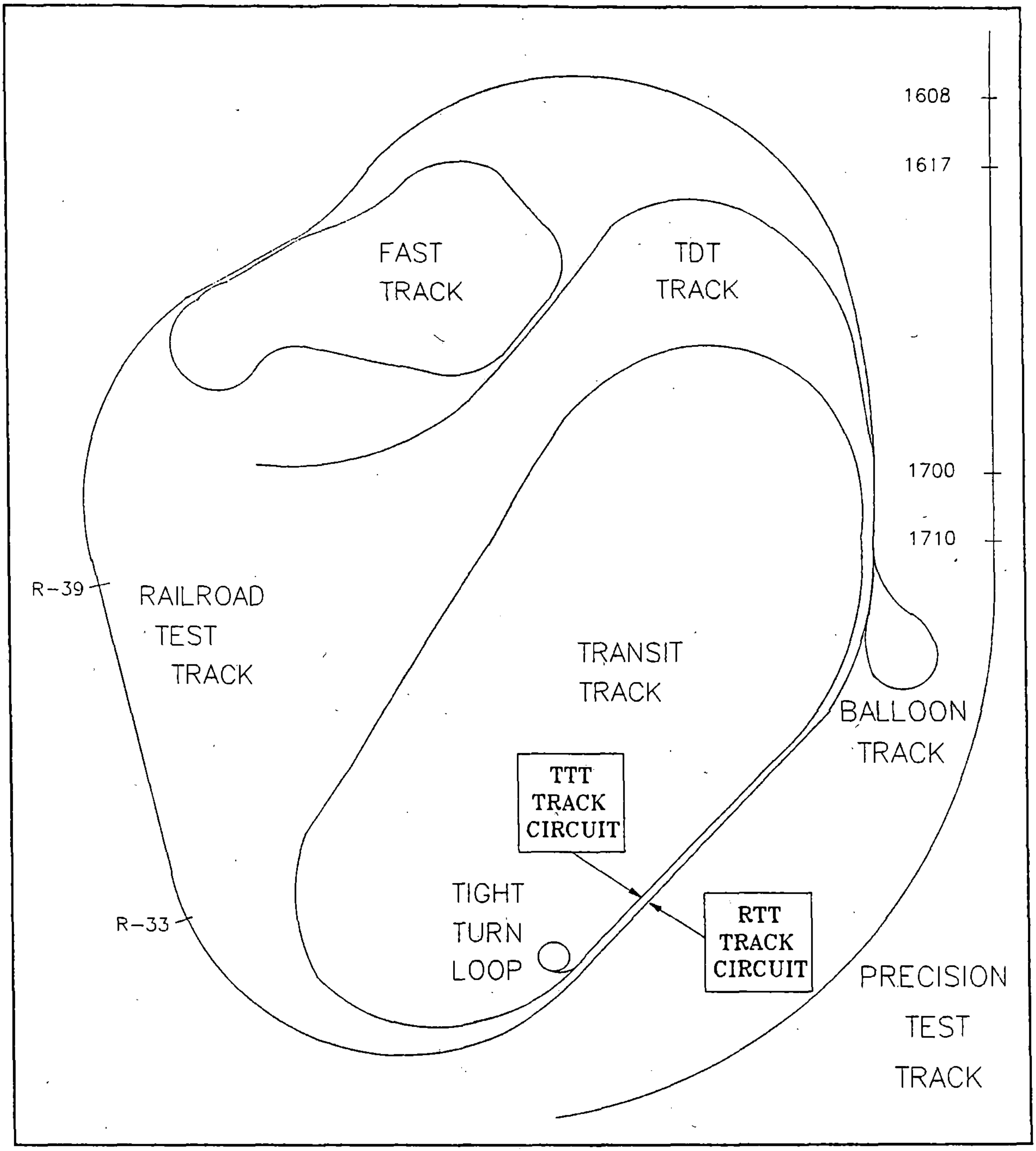

Figure 1. Proposed Location of Track Circuits at the TTC

3.3 TEST LIMITATIONS

Data for revenue service loss of shunt will be based on conditions present during the data collection period at these nine specific sites. The parameters leading to loss of shunt (if any) observed at these sites may not encompass all possibilities.

During TTC testing, track conditions may be altered to more accurately simulate field conditions based on data collected from the revenue service sites. Climatic conditions at the TTC may prevent a full range of loss of shunt variables to be simulated.

3.4 EXPECTED RESULTS

Test results are expected to document conditions in the field that can lead to a reduction of loss of track shunt. These conditions will be characterized, and, where possible, mitigation techniques proposed. By the appropriate implementation of these mitigation techniques, the potential of loss of shunt will be reduced or eliminated at areas similar to the field sites being investigated.

4.0 MEASUREMENTS

4.1 MEASUREMENT SUMMARY

All sites (TTC and revenue) will be equipped with a data collection system to monitor shunt relay receiver voltage, and each site will be fully documented as to track, rail and other conditions that may influence shunt reliability. These data collection systems, modems, and other hardware associated with the installation will be supplied by the AAR for use during this program.

4.1.1 Track Circuit Receiver Voltage

At each of the revenue field locations and the TTC site, the manufacturer of the track circuit will assist in locating the contacts to permit the measurement of receiver relay voltage using a shunt monitoring recorder supplied by the AAR. The recorder setup will be observed by an AAR-TTC technician, along with the appropriate railroad representative. This initial measurement period will be conducted for up to 14 months.

Data collection will be automatic, with transmittal to the TTC for logging purposes accomplished by a computer driven modem, or if no phone line exists, a visit by the railroad representative on a periodic basis (to be determined) will be required to download data onto disks for subsequent transmittal to the TTC. Documentation for computer operation will be provided by the AAR.

4.1.2 Monitoring of Physical Conditions

At each field location and the TTC sites, the TTC engineer will collect and store the following information during the time period that the remote monitoring system is being installed. The purpose of this requirement is to document track conditions in place during the initial phase to this test:

a. coefficient of friction (measure of lubrication) using a tribometer,
b. grinding data,
c. rail cross section profiles,
d. general site description and supporting photographs, and
e. as an option, x:y coordinate profiles utilizing the British Rail profilometer measuring system may be requested at a later date. This will be performed if results from the analysis of monitored data indicates that a site requires more detailed data.

4.1.3 Calibrate Revenue Site Pickup Voltages

A TTC engineer will coordinate and participate in the calibration of all field sites to determine threshold voltages and other field electrical conditions.

4.1.4 Changes During Field Monitoring Period

At the field locations, once the recorder is set up by a joint AAR/TTC railroad/supplier visit, the railroad personnel will be responsible for the day to day operation of the recorder and data collection. Should any track work take place, the TTC engineer must be notified and may need to revisit the site to perform additional measurements.

If field conditions change during the test period, they should be noted by the on-site railroad representative, and the changes forwarded to the TTC data monitor. Such changes include, but are not limited to: rail change out, lubrication, train speeds, rail grinding, and adjustments to shunt activation circuit/voltages. A decision as to the requirement for additional site documentation will be made after a thorough review of the change and of the data being monitored at that site. Data monitoring will require the examination of shunt data obtained from modem or mailed in data. The site data log form will include areas to note time spent on the project, changes to track conditions, and documentation of data collected or computer manipulation. A form will be developed by the AAR for this purpose.

4.1.5 Train Traffic

At the revenue field sites, maximum shunt voltage during the "activation period" of the island circuit from all passing train traffic will be collected and stored for subsequent analysis. At the TTC sites, which will include the passage of electrically driven trains, only data from diesel hauled equipment will be included in the data base.

4.1.6 Auxiliary Island Circuits

Auxiliary island circuits will be installed at the Erie (NS) and Sterling (BN) sites immediately adjacent to existing island circuits (See Table 1. for site designations). The purpose of these auxiliary circuits is to compare time histories of a single train pass on two adjacent track circuits with different frequencies. This comparison may give evidence of "train signatures" and/or differences in island circuit frequencies.

4.1.7 Wheel/Wheel Axle Resistance Measurements

A four wire measurement technique will developed to measure the impedance of individual axles. Trouble shooting and initial data collection will be conducted at the TTC. Once system integrity has been verified, testing at one or two AAR member railroad car shops will be proposed to obtain a broad background for the data base. See Figure 3 for measurement schedule.

4.1.8 Rail and Wheel Film Resistance Measurements

A measurement device will be developed to measure the resistance of films on both wheels and rails. A TTC representative will visit sites having a good shunting history and sites exhibiting LOS to determine parametric differences. If the differences are significant, further measurements may be required. See Figure 3 for measurement schedule.

4.1.9 Rail and Wheel Chemical Film Analysis

AAR will provide the funds for a chemical analysis on rail and wheel films. The initial analysis will be a rail film analysis. One or two member railroads will be asked to provide rail from in or near grade crossings exhibiting LOS. Future analysis will be performed for wheel films. The results of these analysis will help to determine the type of testing to be performed at the TTC. See Figure 3 for measurement schedule.

5.0 GOTHENBURG, NE TEST

5.1 BACKGROUND

Present testing of the causes of loss of shunt at road crossings indicates the evidence of "train signatures". By overlaying time history traces of island circuit voltages, it is clear that individual trains follow the same pattern of shunt loss across different islands. The next step in the Loss of Shunt (LOS) investigation is to identify the individual cars within trains that are exhibiting various levels of shunting ability, something that is very difficult at present test sites. By utilizing some of the data being collected by the Union Pacific Railroad at Gothenburg, NE, car identification, as well as other information on those cars, could be obtained. See Figure 3 for test schedule.

5.2 OBJECTIVE

The objectives of the Gothenburg test is to determine the shunting characteristics of loaded and unloaded cars, as well as different car types and determine if a pattern exists for different ladings and/or car types, thus allowing individual cars with limited shunting ability to be identified.

5.3 IMPLEMENTATION

Installation of two parallel island circuits, supplied by Safetran, at or near the site of the car identification system.

Set up of a data collection system, triggered by car identification system. Salient Systems will perform the set up and required changes to interface the car identification and LOS systems.

An initial two week monitoring period will begin as soon as the data collection system is installed to check system and data reliability. If the site does not exhibit LOS characteristics, the island length may need to be manipulated until the desired LOS levels are obtained. Once this condition is established, information on certain trains will begin to be requested.

Once a baseline is established, it may be requested that the orientation of the islands is changed from parallel (one on each track) to series (both islands on same track 50 feet apart), or island length may be adjusted as stated above.

5.4 DELIVERABLES

Identification of car types and characteristics of individual cars with limited shunting ability. Based on these results, further testing may be required at the Gothenburg site or at the TTC.

5.5 RAILROAD REQUIREMENTS

1. *Installation of two 125' island circuits.*
2. *Representative at site during installation of data collection equipment and calibration of island circuit.*
3. *Space in a bungalow with telephone line for data collection and track circuit equipment.*
4. *Cooperation in obtaining required data on trains or cars exhibiting various levels of shunt loss.*
5. *Manipulation of island lengths and/or changes in orientation from series to parallel.*
6. *Inspection of certain cars exhibiting LOS.*

6.0 DATA REDUCTION AND ANALYSIS

Data from the monitoring sites will consist of two data bases, with limited on site data reduction and handling.

6.1 ON SITE DATA STORAGE FORMAT

The on site data monitoring computer will collect and store data with a minimum amount of analysis as follows.

a. a time history of receiver voltage for the entire passage of a train, identified by a date stamp,

b. a tabular listing of train passage date/time, and

c. a value for the highest voltage occurrence during the period of track shunt of that train pass.

d. status of the island drive relay

6.2 ON-SITE DATA HANDLING AND STORAGE

Based on the date stamp and maximum voltage for each time history, the on-site computer will:

a. store the date/time and peak voltage and for every train during the entire data collection period. Once the updated software is available, island drive relay status will also be included.

b. rank the peak voltage for each train, and because of the 40 megabyte memory available, will eliminate unwanted time histories as the memory is filled. In order to limit the amount of data collected for analysis only the time histories for up to 100 trains will be stored. Once the memory has been filled, only the time histories of the top 100 trains (based on maximum observed loss of shunt voltage) will be retained.

6.3 DATA HANDLING AT THE TTC

The date/time peak voltage data collected at the eight sites will be collated by the TTC. This will be accomplished weekly by modem to ensure data collection systems are performing properly. Where phone lines are not supplied, the railroad representative will be required to make an on-site inspection, along with operating the computer and downloading the appropriate data onto floppy disks, and forwarding these disks to the TTC for subsequent collating into the data base.

Part of the instruction effort will be to teach each railroad representative the appropriate operating commands to manipulate the on-site computer and download data to floppy disks. This will be accomplished during the orientation session at the Conrail Signal School, and/or at the field site during installation of the equipment.

Statistical sorting will be performed, and will include tabulated and historical results of the receiver voltage measurements, wheel counts, and other data collected at each site. Statistical analysis will consist of histories of various voltage levels by date range and site to identify sites requiring more detailed analysis in the future. *This data will also be used to perform an occurrence analysis of various levels of shunt loss for each site.* Follow on analysis of statistical and historical data will be performed by the AAR.

6.4 TTC DATA ANALYSIS

TTC will include the following in the analysis:

1. *Compare two adjacent sites (I/K, J/L, G/H/R, C/S) on the same track for a 24-48 hour period. Obtain train consist data for each passing train from railroad representatives. Correlate, using various severity ratings, with stated train consist, car weights and other known variables.*

2. *Revise performance tables to include known indications of when island relay becomes energized while a train is on the island. This will be done by monitoring the island relay drive at each site.*
3. *As stated above in Section 5.0 Gothenburg, NE Test.*
4. *Perform occurrence and risk analysis for each individual field site.*
5. *Analyze results of wheel/wheel axle resistance, wheel and rail film resistance, and chemical film analysis.*

7.0 TEST IMPLEMENTATION REQUIREMENTS

7.1 TRAINING REQUIREMENTS

A one day training session will be conducted at the Conrail Signal School (Columbus, OH) to orient all potential railroad and TTC personnel as to the hookup, operation, and data transmittal requirements of the remote site data collection system.

7.2 HARDWARE REQUIREMENTS

The AAR will supply all hardware and software for this test program. Donations by the signal supply industry will provide the needed track circuits for installation at the TTC.

7.3 INSTALLATION REQUIREMENTS

After the instruction program at the Conrail school, actual installation of data collection equipment at the eight sites will be scheduled individually with each railroad.

7.4 ANALYSIS REQUIREMENTS

AAR will fund TTC to develop post-processing software to provide an occurrence severity index and probability index.

8.0 TEST DURATION AND SEQUENCE

Field site data collection will begin immediately after installation of the respective sites. *Data collection will continue through June 1993 to collect data in cold weather.* An initial data review will be conducted 2 to 4 weeks after the installation of the first sites to insure that the proper data is being saved. *A full review will be conducted after completion of cold weather data collection.*

The period of performance for T.O. #46 is from March 1992 through June 1993. Testing from July '93 thru September '94 will be conducted under T.O. XX. Field testing is expected to begin in March 1992. Figures 2 & 3 show approximate time lines of the various activities for this test program.

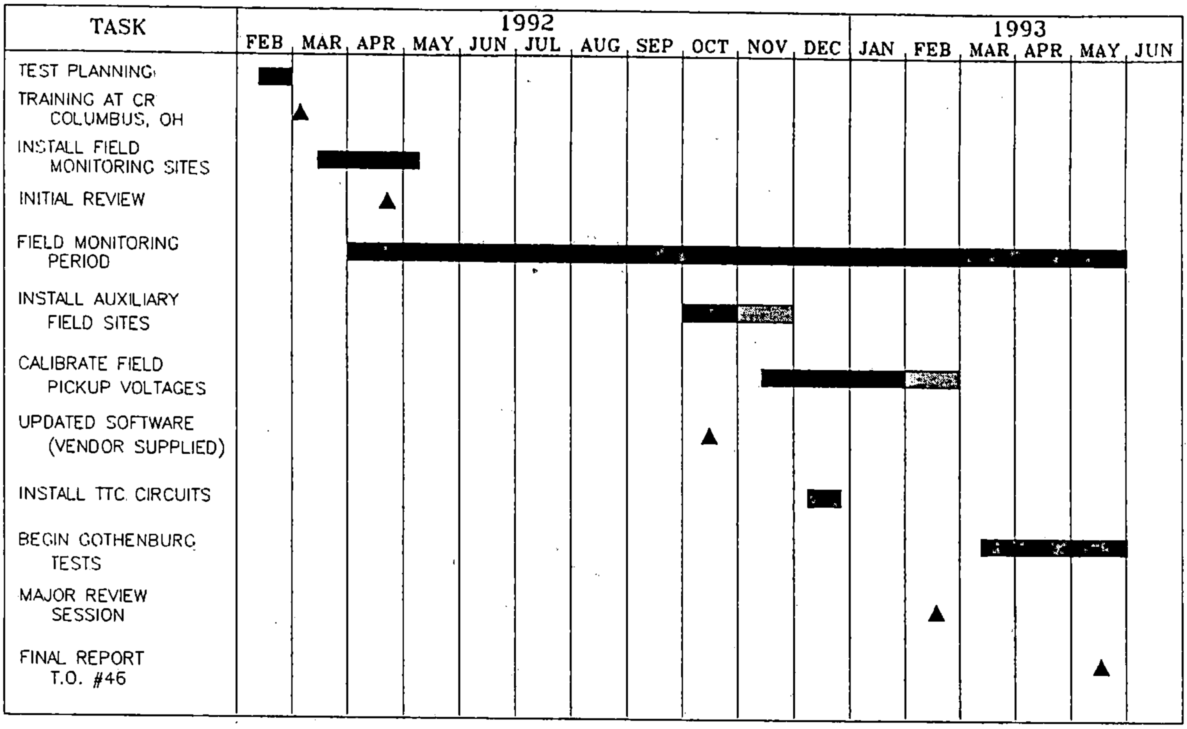

Figure 2. T.O. #46 - Test Schedule

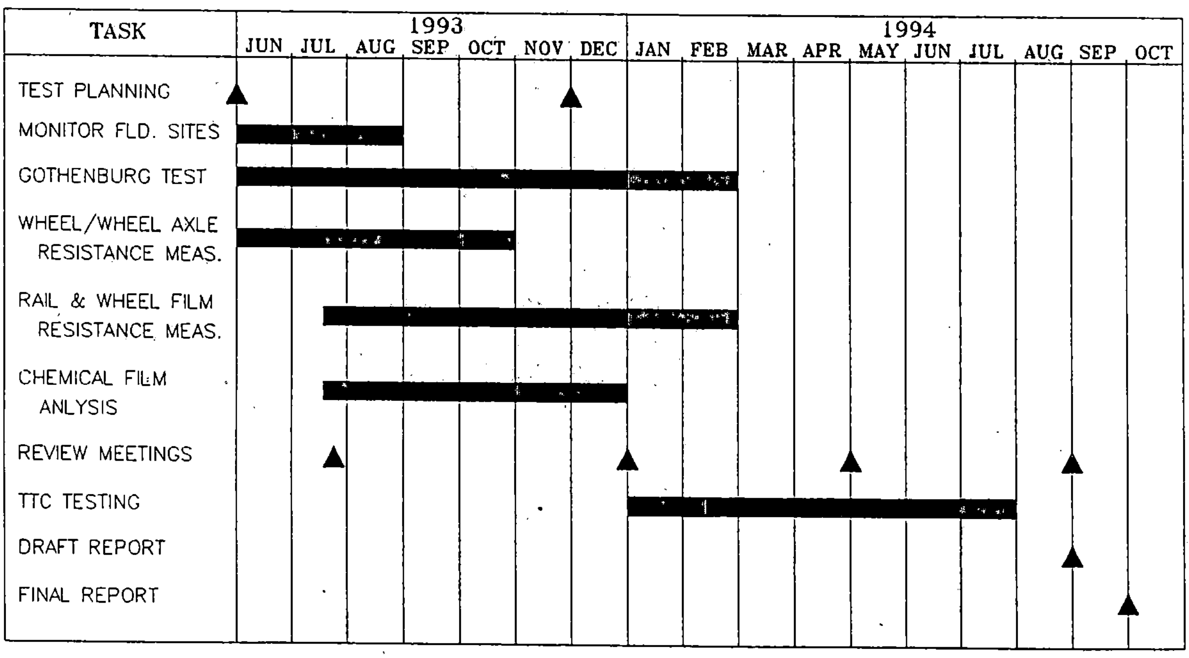

Figure 3. T.O. XX - Test Schedule

9.0 DATA REVIEW SESSIONS

9.1 TWO TO FOUR WEEK DATA REVIEW

To ensure that the appropriate data is being stored (the 100 time histories displaying peak voltage) based on date/time peaks, a detailed review of field data from at least the first two sites will be conducted 2 to 4 weeks after installation. This will include a review of time history data plots.

Should review of the data at this date indicate that a more appropriate time history selection process be required, the necessary re-programming of remote site data collection systems will be undertaken. If review of the data indicates that the correct data base is being archived, then a 8 to 10 month data collection period will be authorized.

During this period the railroad representative at each site must inspect and report on any site conditions that may change the shunt environment. Reported information will be used to help explain changes in shunt voltages observed from data summaries collected in the field.

9.2 END OF COLD WEATHER DATA REVIEW

After collecting data from all sites for approximately 12-14 months, a major data review session will be scheduled. At this time, data collected at the TTC test site will be analyzed and compared to the revenue service site data. Selected time history traces from revenue service sites will also be evaluated to determine which location(s) may require a detailed inspection. This will identify parameters for additional evaluation to determine specific conditions, such as lubrication, rail film characteristics, profile shape, and, if needed, specific train wheel conditions, car types or other items that could influence shunt reliability.

Part of this review will be to determine what adjustments should be made to the TTC track circuits and/or trackage to better reflect revenue service site conditions. Mitigation techniques to eliminate loss of shunt will be proposed and results fully documented.

9.3 GOTHENBURG TEST REVIEW

After collecting and collating associated train data from the Gothenburg test site, a review session may be required to determine which variables and/or equipment will be tested at the TTC.

9.4 COMMITTEE REVIEW MEETINGS

Periodic committee meetings to review data and determine certain testing parameters will be scheduled when deemed necessary by the committee, AAR, or FRA.

10.0 TTC TESTING

If required, a dedicated consist will be operated specifically for this program, with a train consist to be specified based on evaluation of field service trains or equipment that has exhibited loss of shunt. This consist can only be defined in detail after the equipment that is causing the shunt problem is identified at the eight test sites. It should be noted that until this decision can be made as to the type of equipment to test, all traffic over the TTC sites will be "passive"; that is, made up of equipment being tested by other TTC programs. See Figure 3 for TTC test schedule.

10.1 TTC BRAKING TESTS

Following the completion of the rail/wheel film analysis, a matrix of brake shoe types currently being used in revenue service will be developed by the AAR. The brake shoes that have similar compounds to those found in the rail/wheel film will be tested to determine the contribution of brake shoe films on LOS. A detailed test plan for the braking test will be developed prior to testing.

10.2 TTC EQUIPMENT TESTS

After collecting data from the Gothenburg site, including train videos, and identifying certain types of equipment that may aggravate LOS (i.e. aluminum coal hoppers, articulated cars, etc...), TTC will attempt to acquire a number of these type of equipment for testing at the TTC. The measurements to determine car characteristics will include wheel/wheel axle resitance, wheel/rail profiles (contact patch), wheel/rail film resistance, axle weight, and track tests. A detailed test plan will be developed prior to testing.

10.3 TTC MITIGATION TESTS

Any mitigation techniques developed from the LOS investigation may require testing at the TTC for safety and/or effectiveness before being applied to revenue service sites. A detailed test plan will be developed prior to testing.

11.0 REPORTING

11.1 MONTHLY STATUS REPORT

A monthly status report will be written to the FRA.

11.2 T.O. #46 FINAL REPORT

All of the data from the revenue service sites and the TTC test site will be combined in a final report for T.O. #46, documenting the site conditions, the data collected and analyzed, observations of loss of shunt, and mitigation techniques investigated, if any. Other supporting work performed by the railroads and suppliers will also be included. This report will not necessarily draw any conclusions about LOS.

The draft final report will be presented 30 days following completion of the analysis of the track circuit receiver voltages. All parties participating in this program (railroads, AAR, suppliers and the FRA) will have 30 days to review the draft and provide comments. The final report will be submitted 30 days after review comments are received.

11.3 T.O. #XX FINAL REPORT

A final report for T.O. #XX will be submitted to FRA by September 30, 1994. This report will encompass all work performed under T.O. #XX and include much of the work performed under T.O. #46.

12.0 RESPONSIBILITIES

12.1 AAR

AAR funding will supply all equipment for data collection, transmittal, storage and analysis. In addition, AAR will provide software upgrades and changes as deemed appropriate after the scheduled data review sessions.

AAR employees under FRA funding will oversee each field installation, and install the two track circuits at the TTC. AAR will perform the site inspection during installation of equipment at each of the revenue service sites.

Data storage, collating, basic statistical sorting, analysis, and presentation will be conducted at the TTC by AAR.

12.2 FRA

The FRA will supply funding for labor and travel to install data collection systems at the eight field sites. FRA will also fund labor to conduct periodic data retrieval and sorting functions at the TTC, and prepare the necessary data plots for review sessions.

12.3 SUPPLY INDUSTRY

The supply industry will provide two track circuits to be installed at the TTC, and will oversee the installation at a mutually agreed time. Representatives of the supply industry will also oversee the installation of remote data collection systems at each of the eight field sites.

12.4 AAR MEMBER RAILROADS

The member railroads will provide necessary personnel and travel to the Conrail signal school, and a field representative at each of the eight sites to oversee the installation and provide periodic field inspection. Each site is to be equipped with 110 VAC power and if possible a phone line for data transmission. If no phone line is provided, the railroad representative will be required to download data on a period basis and send floppy disks to the TTC.

If specific types of equipment are determined to contribute to the problem of shunt loss, the railroad industry may be asked to provide this type of equipment on a short-term basis for testing at the TTC.

13.0 SAFETY

During each railroad visit, the host railroad will provide necessary flagging and other protection during installation and check out of the shunt detector. The shunt detector circuits will be installed in a fail-safe manner so as to not interfere with the normal operation of crossing gates, flashers, or other warning devices.

During the TTC site installation, a TTC railroad safety review session will be required by all off-site visitors who are expected to be working on or near TTC trackage. No occupancy of tracks will be allowed without the permission of a TTC person in charge of the test.

14.0 COSTS

A cost estimate for the period of June '93 thru September '94 is attached detailing labor, materials, and travel to support the FRA portion of this project.