STRAIN GAGE DATA COLLECTION FOR DETERMINING EFFECTIVE STRESS AND CYCLES FOR INSPECTION INTERVALS ON BRIDGES

Methods & Procedures
September 1998

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TECHNICAL REPORT DOCUMENTATION PAGE

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7. AUTHOR(S) Rudy L. Brockelsby, Sr. Michael E. Sawyer		8. PERFORMING ORGANIZATION REPORT 10. WORK UNIT NO.
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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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List Of Figures

Introduction

The 21X Data logger was presented to Research, Development and Technology Transfer (RD&TT) of the Oklahoma Department of Transportation (ODOT) in hopes of determining why readings could not be ascertained from the unit or through the supplied software program.

Procedure

The equipment hardware was examined and evaluated for any necessary repair (ie: broken wires, secure connectors, etc.).
First was to set up a test model for initial checking of the Hardware and software.
Second was to perform sample field tests at a useful site.
Third was to perform field tests under normal conditions.
Analysis of the software would be ongoing.

Materials

The model consists of:
Eight strain gages epoxied to an eighteen inch piece of one inch spring steel. The spring steel was placed into cutouts made in the sides of a wooden box. To keep the steel centered, a stop was placed to cover the opening on the outside of the slots. This allowed for the spring steel to act as if it had expansion units at each end. (Figure 1)
Uniform repeatability of the test was another concern. To control the maximum travel while bending the steel, a stop bolt was mounted to wood placed across the center of the box. The gap was set to three-eighths inch clearance. (Figure 2)
Wiring was attached from the strain gages to the junction box which was attached to the Data logger (Figure 3). A laptop was then connected to the Data logger.

Testing

Office Procedures

The Data logger was given settings through the setup function. Warmup was performed. The trucktest procedure was used. On screen graphic monitoring of the compressions was done while recording strain data in the trucktest mode. With each compression of the spring steel, each strain gage registered accordingly with it's distance from the center of the bar. The highest readings came from strain gages closest to the center. Negative readings were also noted from strain gages mounted on the bottom side of the steel.

Next, the Data logger was initialized in a deadload condition for thirty seconds. The rainprint test was begun. Visual monitoring was also conducted. There was very little difference between the trucktest and the rainflow test results. This was apparently due to little or no internal or adjacent stresses affecting the spring steel.

Several of these tests were ran in the office which verified confidence to collect uniform repeatable data. However, when significant numbers of final data was collected in the Data logger and the download to the laptop was tried, the program crashed into a none stop loop. The data could be downloaded through the Telcom program in PC208, but the data could not be retrieved to the frame program for calculations. Further investigation of the frame program would be conducted and an alternate method for calculations would be programmed.

Field Procedures

A field test site was selected by Brian Windsor , Bridge Division, ODOT, who also chose the strain gage locations on the bridge beams. The site that was chosen to provide usable meaningful data. The soldering, placing, wiring and connections in the field were done by Michael Sawyer, Bryan Hurst and Robert Kennada of RD&TT. When installation had been completed, the system was checked and found to be functioning satisfactorily. Initialization was planned for 3:00 am. This was considered to be the best time of day for the least amount of traffic on the I-40 Cross-Town bridge. A thirty second initialization with no traffic was completed. The Data logger was monitored to ensure that all eight gages were responding and the rainflow test was started.

The following day the collection process (download) was started, but the software malfunctioned. The data had to be retrieved manually. The Data logger final storage was cleared and left running for a seven day collection of data.

At the end of the seven day test period, utilization of the software program was used to retrieve the data, again failing. The raw data had to be retrieved manually.

<u>Office (Software) Procedures</u>

Three of the problems that were faced in debugging were the EOF(), the Error Loop that could only be stopped by shutting down the laptop, and the inability to read raw data more than once in a twenty-four hour period.

1. First the OSU program was broke down. The use of a database (Paradox) was programmed and used so that files could be processed more than once during testing and debugging.
While processing various sizes of raw data files, it was found that some files had a blank line at the beginning and others did not.
The OSU program took into account the fact that raw data files had one blank line, but did not allow for some data files that did not. This problem was inapparent at first, however when the data file is expected to have one line blank at the beginning followed by intervals of a set number of channels and if all that the file has is the intervals of a set number of channels then the program can not complete it's loop, having reached the end of the file before reading all of the data. This problem was alleviated by having the program check the first data line of the raw data, if the first line was empty then ignore it, otherwise use it.

2. In order to read a raw data file more than once, other than by directly accessing the 21X, the incorporation of a storage module (SM-192) was utilized. The SM-192 uses a PC208 program called SMCOM.COM instead of the PC208 program TELCOM.COM that the OSU program utilized. Also noted, due to the SM-192 having greater capacity to hold more records of raw data

and an internal battery that is independent of the 21X, larger files were inadvertently collected. The 21X could also remain in the field while that data was processed in the office.

3. Correction of Item 1 and the addition of Item 2 created and helped explain the problem of working with files greater than 17K in size (ie: Data could be collected at shorter intervals providing for greater amounts of raw data per day). The new problem was that the program would run out of memory before completing it's calculations.
This was a significant problem, as it was thought that the OSU program was designed to download data every twenty-four hours due to a time limit to properly calculate data. This was later found to be untrue. The real problem laid within the limitations of the DOS environment of 64K RAM. It was found that with eight channels using twenty bins to record data, that a maximum twenty intervals of raw data could be collected at a time (this would equal one hundred sixty lines of raw data). If the size of the raw file was one interval (eight lines or channels) greater, there would be insufficient memory to perform the calculations before storing the processed data to file.

4. Several needs were found which will be incorporated into the OSU program (Appendix D).

A) Raw data file check

B) Ability to read stored files

C) Collect data from SM-192

D) Allow for normal data download more than once from the 21X

E) Allow for use of a SM192 Storage Module

F) Read all raw data, instead of automatically ignoring the first interval

G) Auto detect and limit the maximum intervals of data to fit within the memory constraint

H) Allow for switching to different files and directories so as not to overwrite any previously downloaded files.

I) Allow, as in 4.H, to use different initializations and variable files unique to various locations.

J) Use an open channel in a second table for display of battery voltage

Performance Evaluation & Observations

Three areas of error and/or limitations were observed: 1. User Error, 2. Software Constraints, and 3. Mechanical Error.

1. User Error

A) Warmup to equalize gages
(This Stabilizes Current Flow)

B) Initialization Must Be Done Under Deadload Conditions
(Failure to do this will result in Zero Readings of Raw Data)

C) Initialization Must Be At Least 30 Seconds
(Failure to do this will result in Incorrect Readings from Offset of Raw Data)

D) Allowing Data Collection to Exceed 160 Lines of Final Raw Storage
(ie: Interval = 6 hrs, Channels = 8 Gages, Maximum Collection = 20 Intervals
20 x 8 / 6 = 30 Total Collections of Final Data, 30 / 24 hrs = 1.25 days)

E) Must Reinitialize If Connections Have To Be Cleaned, Replaced or Reconnected
(This Can Possibly Change The Initialization Offsets)

F) Monitoring of Channels Should Be Done When System is First Started
(This Will Ensure That All Channels Are Working And Recording Data)

2. Software Limitations/Constraints

A) 64K Limitation of DOS Based Program

B) Allows For One Download of Raw Data Within a 24 Hour Period

C) Limited Capacity For Final Storage of Data

D) Unable To Reread Files Previously Downloaded To Disk

E) Always Ignores First Interval Of Data Collection

F) Uses Only One Station (OSU.STN) and Variable Set (VARS.SET)

G) Must Be Ran From The C:\

2. Software Limitations/Constraints (Cont'd)

H) Dimensioned Variables For Maximum of 20 Intervals
(More Will Crash The Program)

I) Set For A Maximum of 50 Bins

3. Hardware Error

A) Vibrations Can Loosen Wiring Connections

B) Light, Unseen Rust Can Cause Erratic or No Readings From Gage

C) Battery Life Is Limited
(If the Batteries Fail, Any Stored Data Is Lost)

Conclusions and Recommendations

1. Proper Procedure

A) Ensure Proper Connections Have Been Made

B) Use Fresh Batteries and/or Check For Minimum Voltage

C) Warmup to equalize gages

D) Initialization Must Be Done Under Deadload Conditions For 30 Seconds

E) Calculate Data Collection Download Time/Dates To Not Exceed 20 Interval Limit

F) Monitor Channels When System is First Started

2. Software/Hardware

A) Develop Software Program to Work Beyond the 64K Limitation of the DOS Based Program

B) Force Downloads of Raw Data Regardless of Time Period

C) Use of Storage Modules
- I) For Greater Capacity To Store Final Data
- ii) Eliminates The Need To Download Data In The Field
- iii) Has An Internal Battery (Is Not Dependant On The 21X)
- iv) Will Retain Data Long Term Without Loss

D) Allow User to Accept or Ignore First Interval Of Data Collection

E) Allow For Other Stations and Variable Sets By Project or Location

F) Use of Solar Panels and Ni-Cads For Unattended Log-Term Data Collection Without Power Interruption

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Farrel J. Zwerneman, P.G. Poynter, M.D. Abbas, A. Rauf, and J. Yang. "Fatigue Assessment of Bridge Members Based on In-Service Stresses, Interim Report No.1: Field Tests, Analysis, and Laboratory Tests" Report No.FHWA\OK-95(07), August 1996.

Farrel J. Zwerneman, John W. Kelly, Orin A. Johnson. "Fatigue Assessment of Bridge Members Based on In-Service Stresses, Interim Report No.2: Data Acquisition System For Strain Measurements" Report No.FHWA\OK-97(05), June 1997.

Farrel J. Zwerneman. "Fatigue Assessment of Bridge Members Based on In-Service Stresses, Final Report:Executive Summary" Report No.FHWA\OK-97(06), June 1997.

Downing, S.D., and D.F. Socie. "Simple Rainflow Counting Algorithms" International Journal of Fatigue, Jan. 1982

CAMPBELL SCIENTIFIC, INC. "21X Micrologger Operator's Manual, Revision:3/96"

Appendix A

Office Model, Gage Locations and Field Site

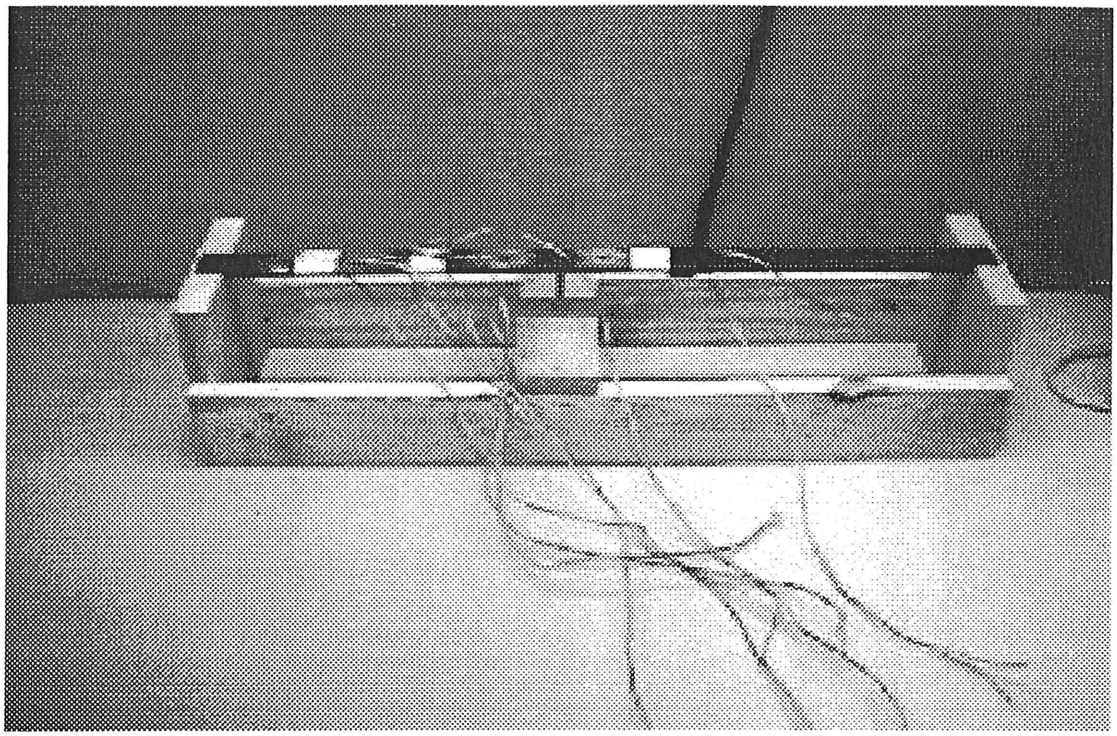

Figure 1 Test Model

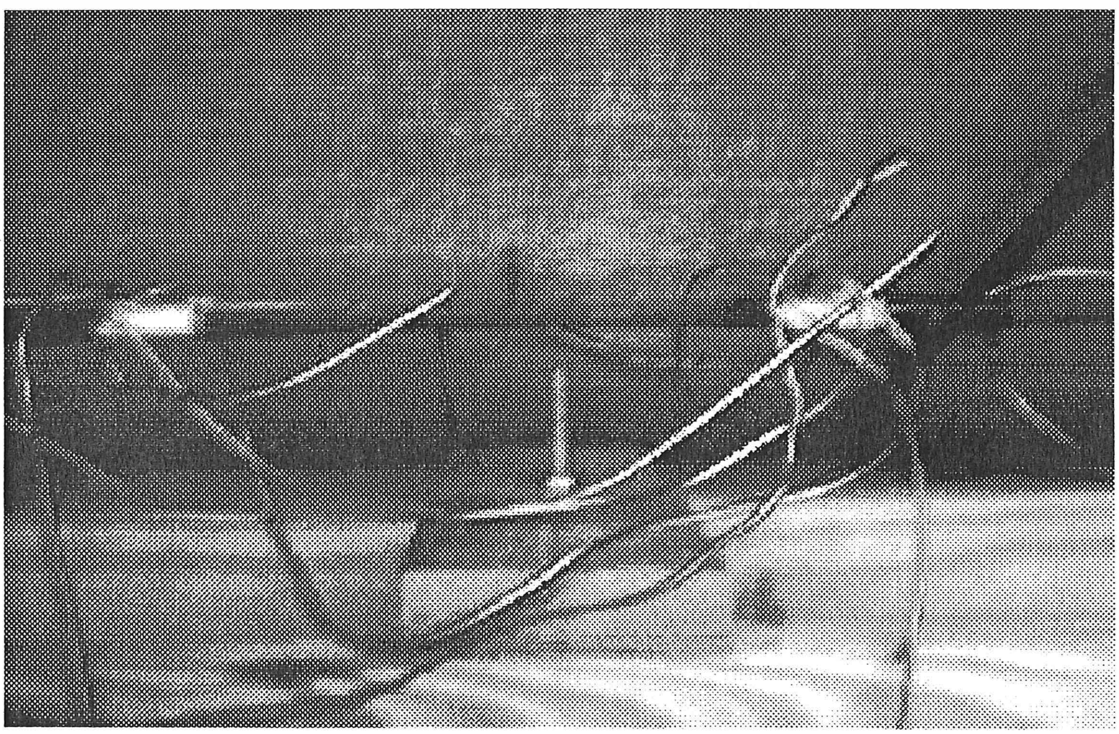

Figure 2 Bolt Detail

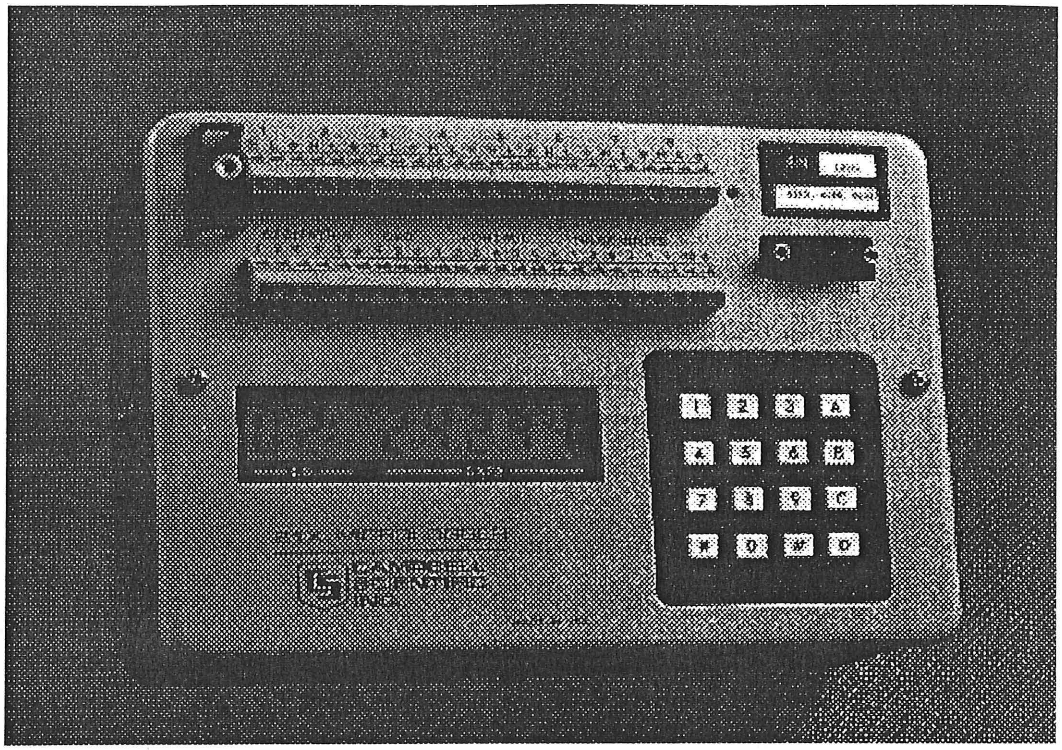

Figure 3 21X Data logger

Figure 4 Bridge Location

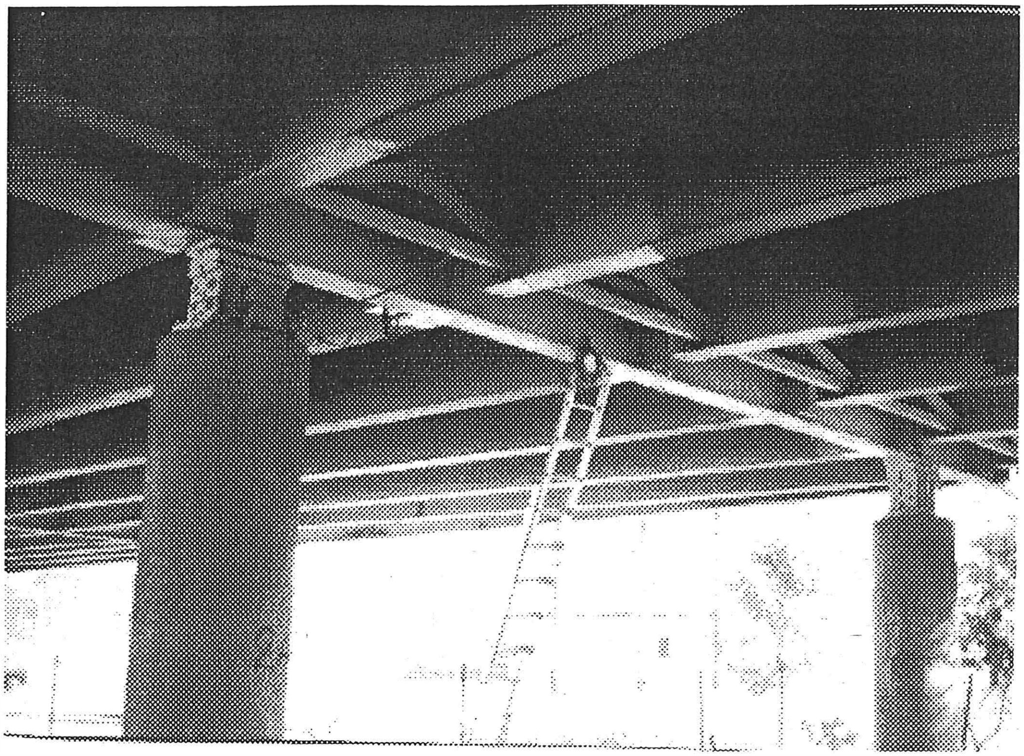

Figure 5 Junction Box Wiring

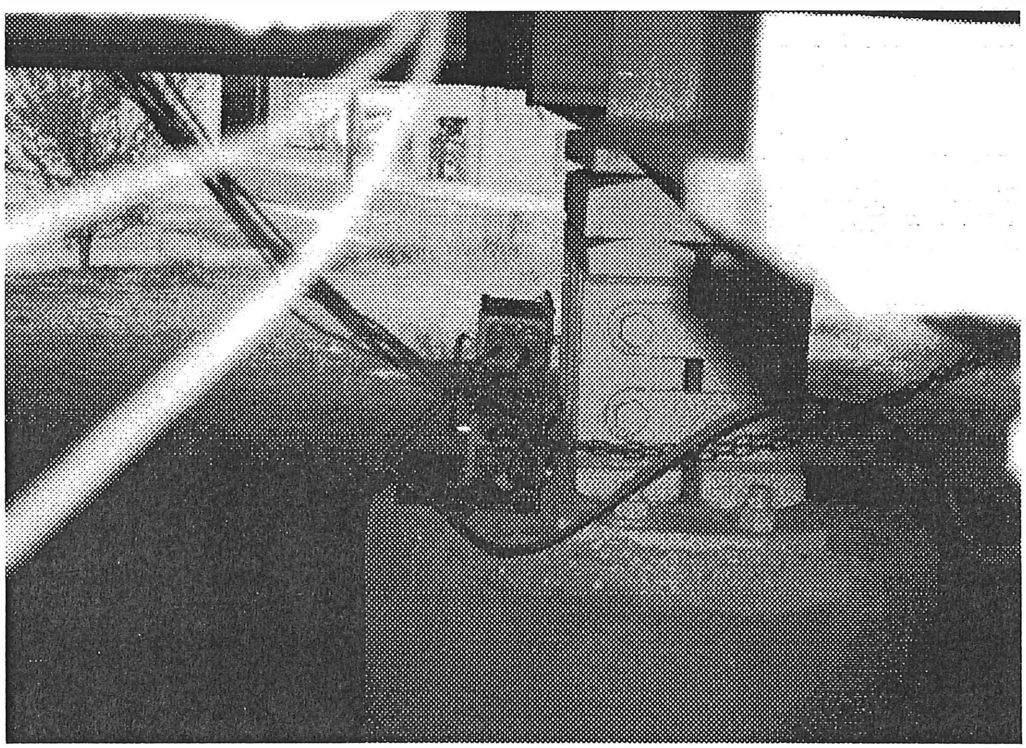

Figure 6 Junction Box

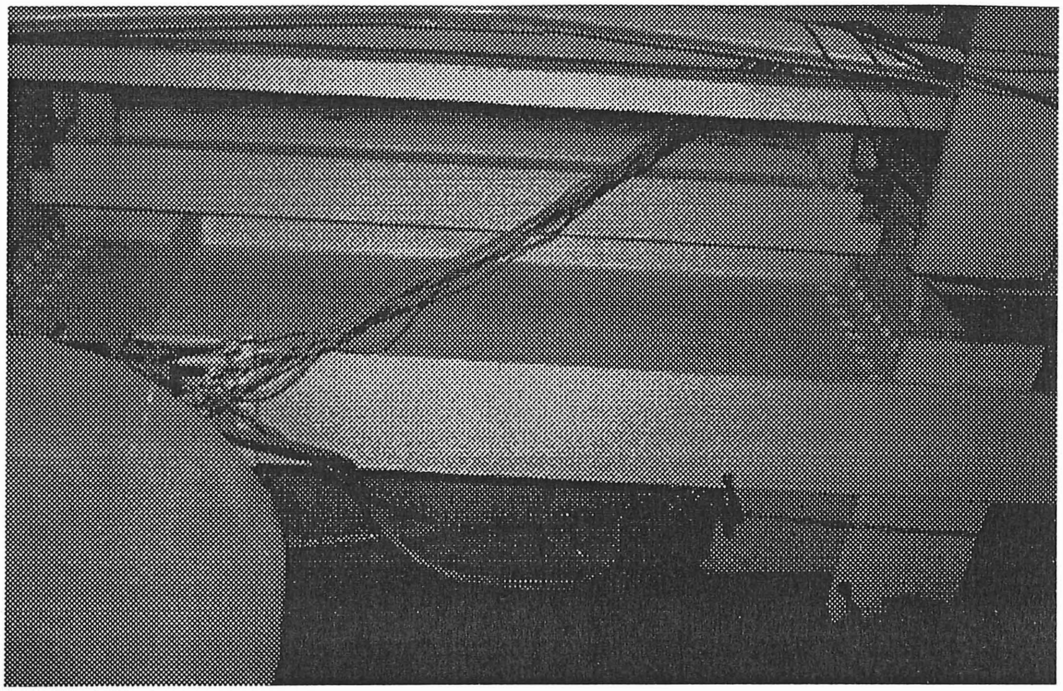

Figure 7 Junction Box/Datalogger Connection

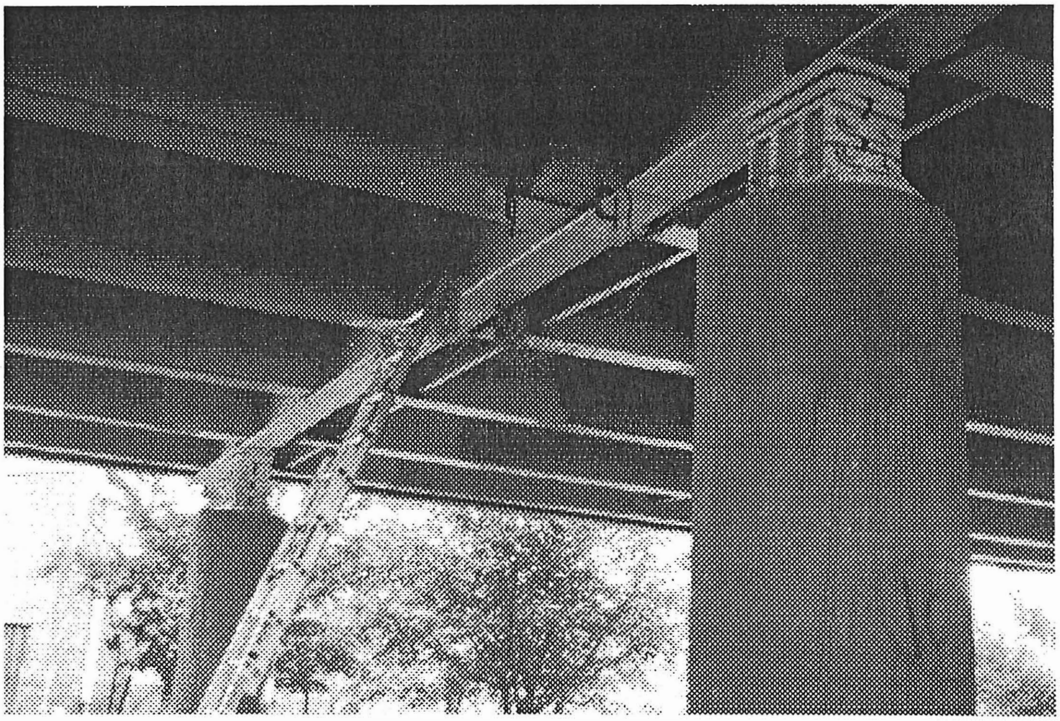

Figure 8 Datalogger Location

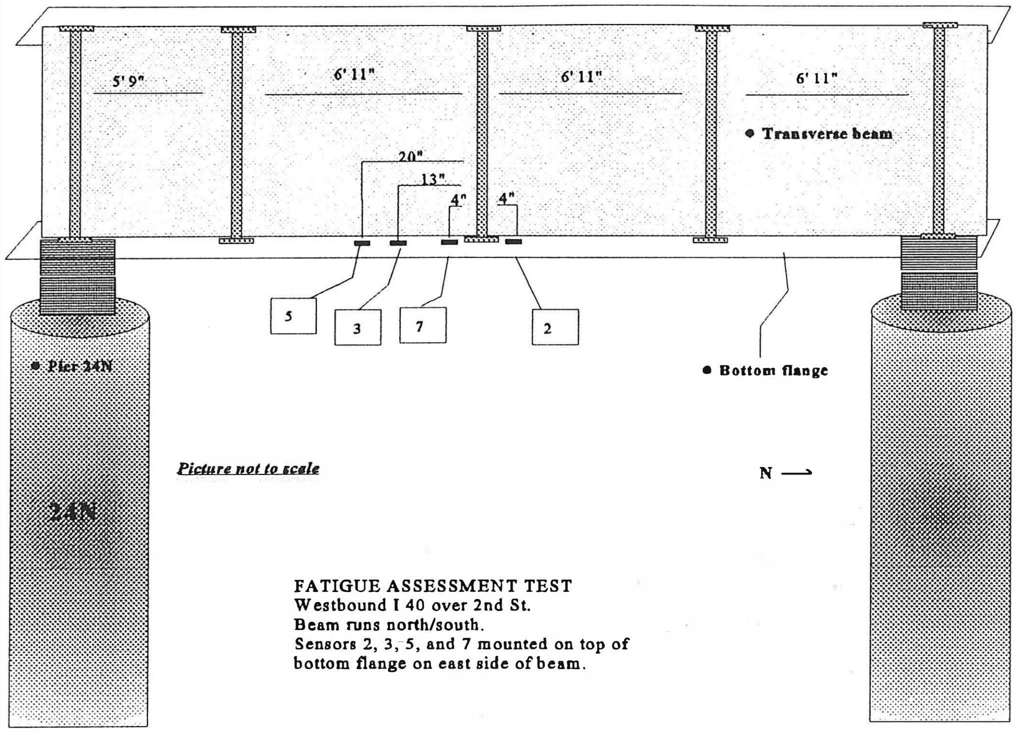

Figure 9 Gage Location Diagram (West View)

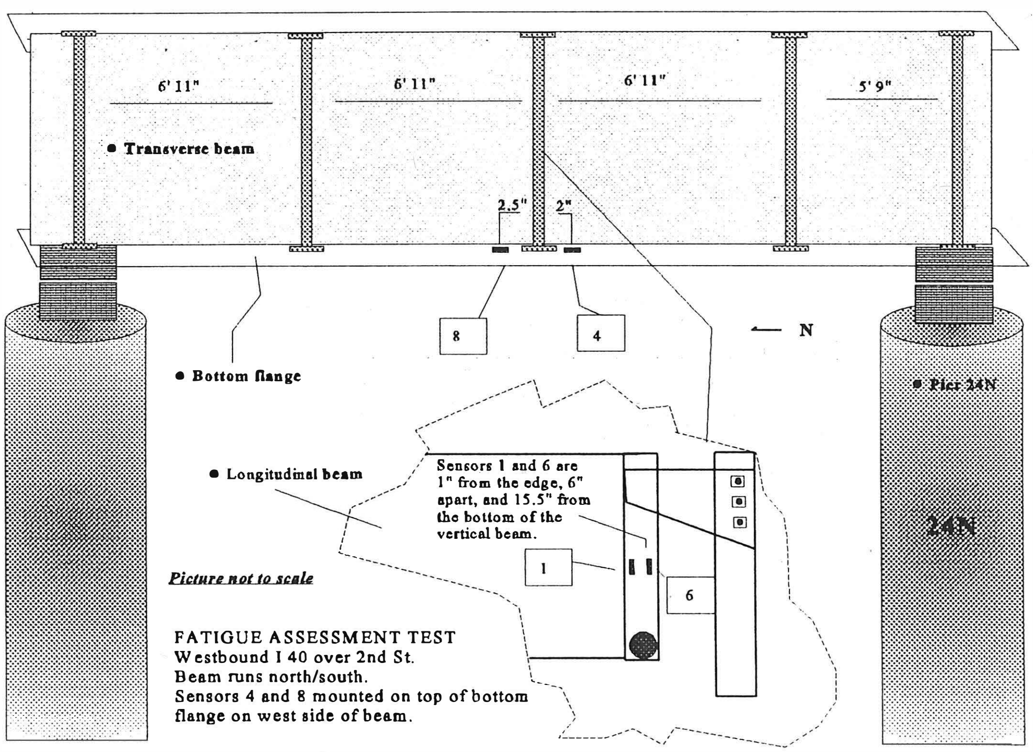

Figure 10 Gage Location Diagram (East View)

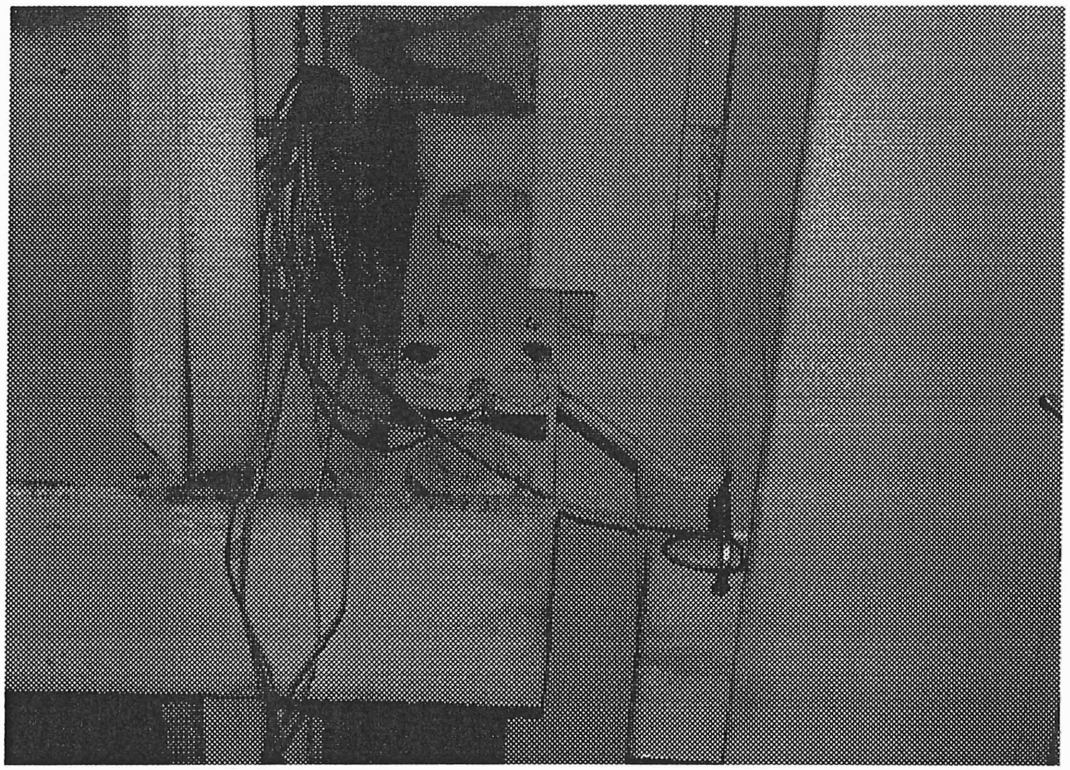

Figure 11 Gages 1 and 6 on Expansion Unit

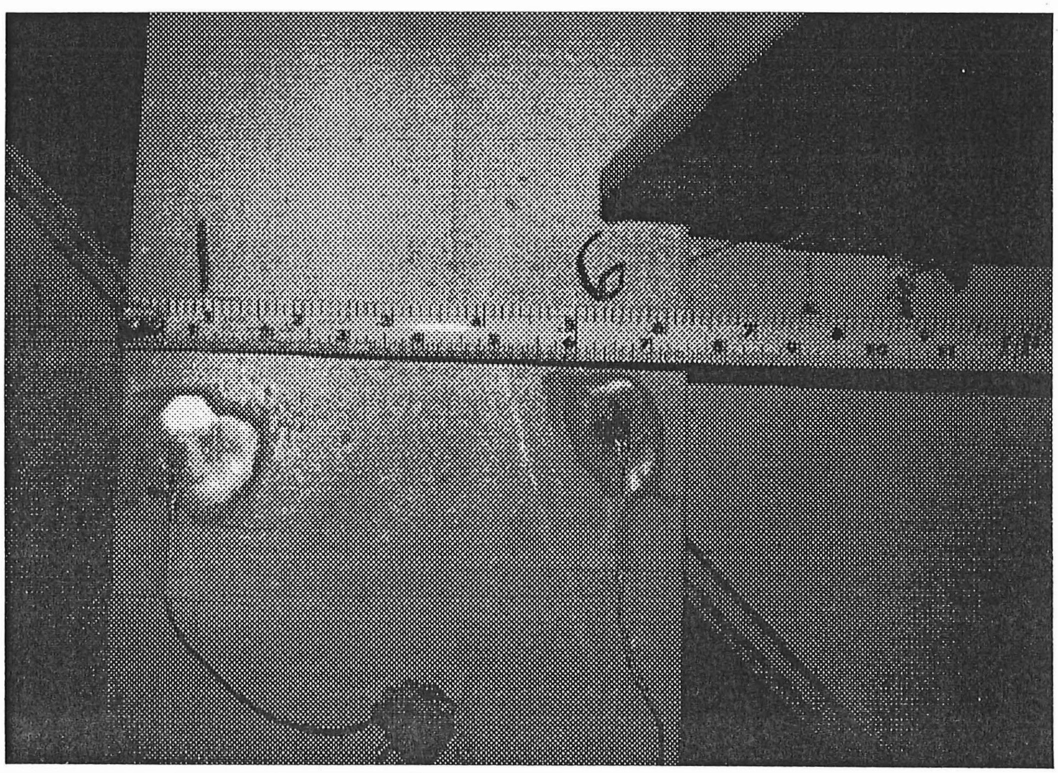

Figure 12 Close-up Gages 1 and 6

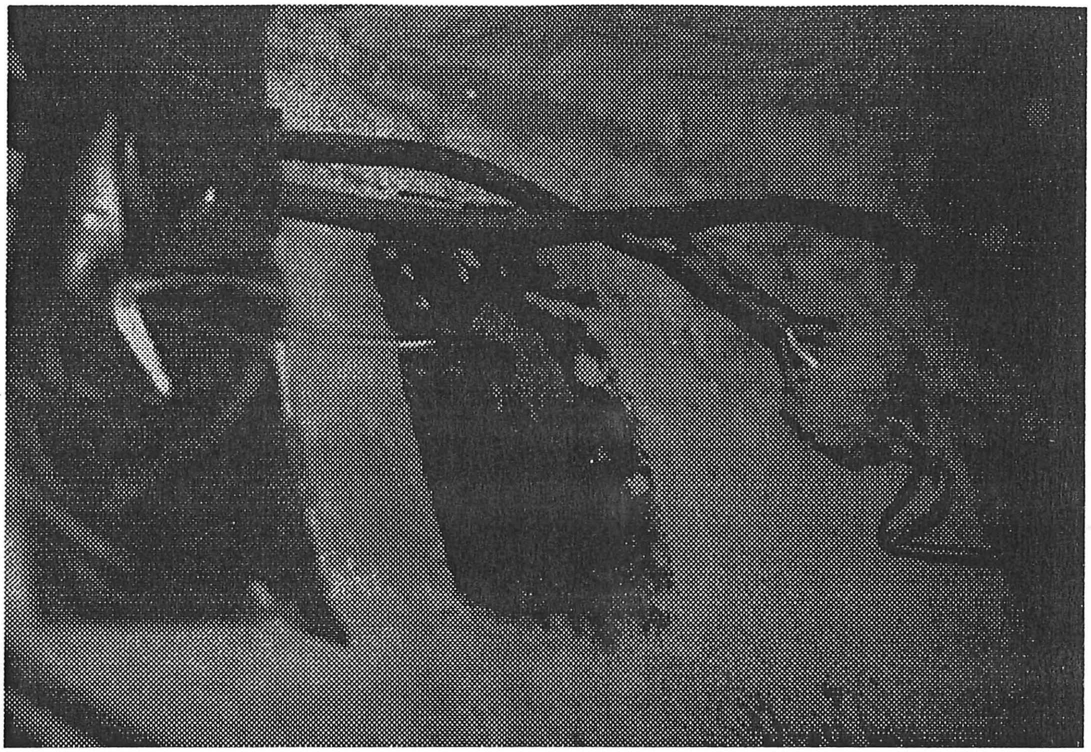

Figure 13 Close-up Gage 5

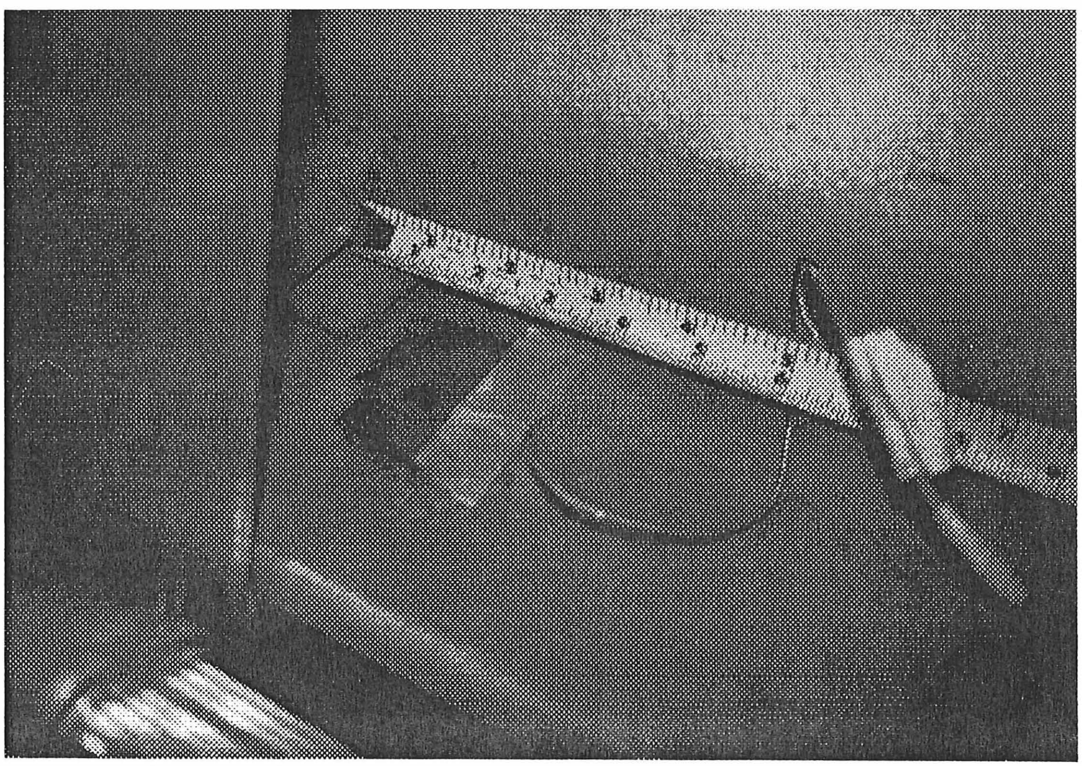

Figure 14 Close-up Gage 8

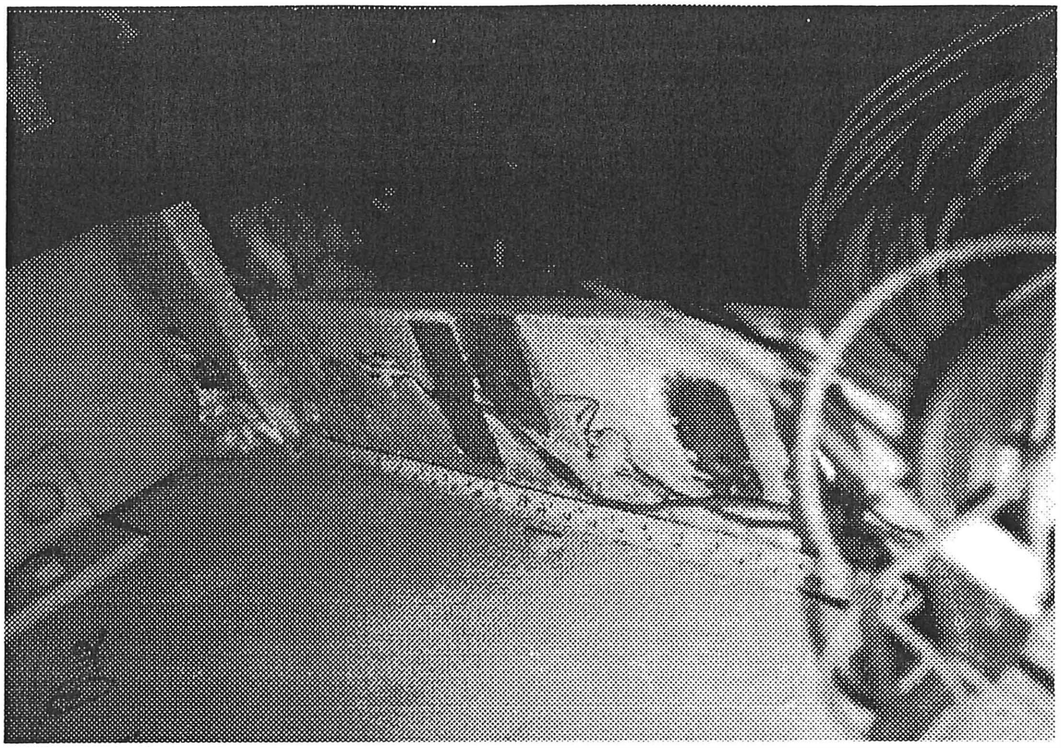

Figure 15 Close-up Gages 3, 5, and 7

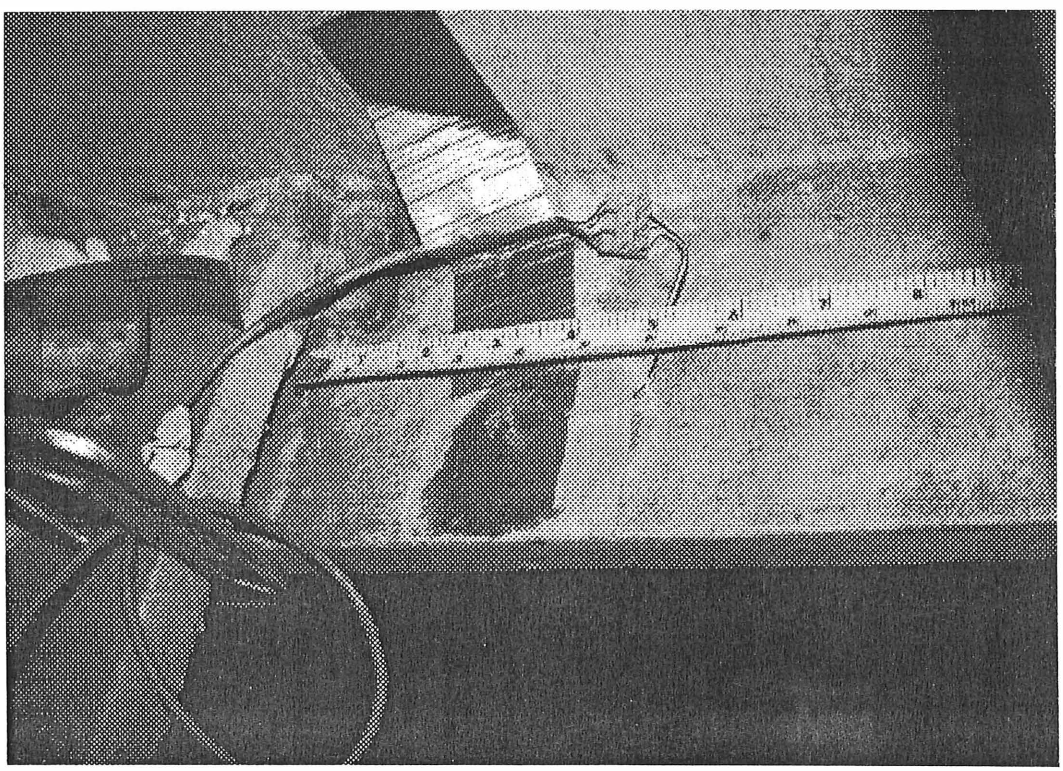

Figure 16 Close-up Gage 4

Appendix B

Raw Data Example

Raw Data File (Ran For 36 Hours)
Chnl,Day,Hr,Sec,Bin 1-20,Upper Bin 1-20

109,237,1800,.5,791,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,237,1800,.5,65,80,29,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,237,1800,.6,33,68,24,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,237,1800,.6,244,85,32,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,237,1800,.6,46,72,16,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,237,1800,.7,581,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,237,1800,.7,266,92,28,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,237,1800,.8,79,83,21,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,237,2400,.5,1573,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,237,2400,.5,3366,277,81,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,237,2400,.6,3227,278,81,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,237,2400,.6,3477,260,105,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,237,2400,.6,3210,267,62,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,237,2400,.7,1484,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,237,2400,.7,3328,255,99,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,237,2400,.8,3411,269,85,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,238,600,.5,1199,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,238,600,.5,1978,220,88,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,238,600,.5,1865,217,88,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,238,600,.6,2000,216,93,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,238,600,.6,1793,217,59,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,238,600,.7,1232,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,238,600,.7,1907,214,84,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,238,600,.8,1990,238,76,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,238,1200,.5,3063,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,238,1200,.5,3741,317,119,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,238,1200,.6,3660,306,119,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,238,1200,.6,3827,310,113,4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,238,1200,.7,3721,304,73,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,238,1200,.7,2482,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,238,1200,.7,3870,310,109,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,238,1200,.8,3681,335,104,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,238,1800,.5,2367,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,238,1800,.5,61,234,108,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,238,1800,.6,24,177,104,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,238,1800,.6,120,263,116,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,238,1800,.7,45,209,67,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,238,1800,.7,1834,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,238,1800,.8,186,277,112,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,238,1800,.8,59,231,107,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

109,238,2400,.5,1416,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,238,2400,.5,2678,201,72,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,238,2400,.6,2477,198,74,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,238,2400,.6,3007,209,74,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,238,2400,.7,2442,227,37,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,238,2400,.7,1296,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,238,2400,.7,2918,214,74,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,238,2400,.8,2672,210,71,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,239,600,.5,1345,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,239,600,.5,2038,213,82,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,239,600,.6,1950,215,78,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,239,600,.6,2129,218,77,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,239,600,.7,1856,216,54,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,239,600,.7,1322,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,239,600,.7,1981,225,79,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,239,600,.8,2033,231,79,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
109,239,1200,.5,3104,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
112,239,1200,.5,3567,281,93,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
115,239,1200,.6,3409,281,87,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
118,239,1200,.6,3616,293,90,3,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
121,239,1200,.6,3461,273,58,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
124,239,1200,.7,2385,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
127,239,1200,.7,3823,272,94,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
130,239,1200,.8,3442,298,86,2,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0→

Appendix C

Partial Listing of the Calculated Data

Example of the data in the processed DAT file which shows total cycles.
(Note: The data is processed for each channel.)

Beginning Day 239
Channel 8
No. of Points 20
1.5 17288
2.5 1812
3.5 608
4.5 8
5.5 1
6.5 0
7.5 0
8.5 0
9.5 0
10.5 0
11.5 0
12.5 0
13.5 0
14.5 0
15.5 0
16.5 0
17.5 0
18.5 0
19.5 0
20.5 0

Example of the data in the processed TAB file with a summary at the end.
(Note: The data is processed for each channel and interval.)

Date = 239
Time = 1200:.8
Interval = 7
Channel = 8

BIN NUMBER	STRESS COUNTS	RANGE	PERCENT	DAMAGE FACTOR
1	3442	0.50	0.90	0.11
2	298	1.50	0.08	0.26
3	86	2.50	0.02	0.35
4	2	3.50	0.00	0.02
5	1	4.50	0.00	0.02
6	0	5.50	0.00	0.00
7	0	6.50	0.00	0.00
8	0	7.50	0.00	0.00
9	0	8.50	0.00	0.00
10	0	9.50	0.00	0.00
11	0	10.50	0.00	0.00
12	0	11.50	0.00	0.00
13	0	12.50	0.00	0.00
14	0	13.50	0.00	0.00
15	0	14.50	0.00	0.00
16	0	15.50	0.00	0.00
17	0	16.50	0.00	0.00
18	0	17.50	0.00	0.00
19	0	18.50	0.00	0.00
20	0	19.50	0.00	0.00

Cycles per Hour (CPH) = 638.1666666666666
Effective Stress Range = .9174244109211155

Summary
Chart Presents The Effective Stress Rate and No. of Cycles In The Form:

(SREff, No. Cycles)

Int	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6	Ch 7	Ch 8
1	0.5,1573	0.9,3724	0.9,3587	0.9,3843	0.9,3540	0.5,1484	0.9,3682	0.9,3766
2	0.5,1199	1.0,2286	1.0,2170	1.0,2310	1.0,2069	0.5,1232	1.0,2205	1.0,2307
3	0.5,3064	0.9,4180	0.9,4087	0.9,4254	0.9,4098	0.5,2482	0.9,4290	0.9,4120
4	0.5,2367	1.8, 403	1.9, 306	1.8, 502	1.8, 321	0.5,1834	1.7, 576	1.8, 398
5	0.5,1416	0.9,2952	0.9,2751	0.9,3291	0.9,2707	0.5,1296	0.9,3207	0.9,2954
6	0.5,1345	1.0,2333	1.0,2244	1.0,2425	0.9,2126	0.5,1322	1.0,2287	1.0,2343
7	0.5,3104	0.9,3942	0.9,3779	0.9,4003	0.8,3792	0.5,2385	0.9,4190	0.9,3829

Appendix D

Refinements to the Existing Program

A) Raw Data File Check - Inserted IF statement to check for a blank line in ReadRain

```
IF Dummy$ <> "" THEN
  CLOSE #1
  OPEN Title$ FOR INPUT AS #1 '*** THIS IS THE USER NAME DATA FILE THAT
DATA IS READ FROM ***
END IF
```

B) Ability to Read Stored Files - Added Option K, Added a READFILE sub-program which is basically the same as ReadRain

Added To Beginning of Program

```
DECLARE SUB ReadFile (MainTitle$, Runner1$, Runner2$, Ch%, HighLim!, LowLim!,
RnTime#, FirstCollect$, Factor#(), AmpBins%)
```

Added To The Menu

```
  '*****************************************************************
  '*     OPTION K ASKS FOR THE NAME OF THE DAT FILE TO READ FROM *
  '*     THEN READS THE RAW DATA, PERFORMS CALCULATIONS AND      *
  '*     WRITES TO THE FINAL OUTPUT TAB AND DAT FILES             *
  '*****************************************************************
  ELSEIF q$ = "K" THEN
    FirstCollect$ = "Y"
    CALL ReadFile(MainTitle$, Runner1$, Runner2$, Ch%, HighLim!, LowLim!, RnTime#,
FirstCollect$, Factor#(), AmpBins%)
    CLS
    LOCATE 10, 15: PRINT "Your Data Files Are Titled:"
    LOCATE 12, 20: PRINT Runner1$
    LOCATE 13, 20: PRINT Runner2$
    LOCATE 15, 10: PRINT "Please Make Note Of These Assigenements!"
    LOCATE 16, 10: PRINT "(Press ESC To Continue)"
    DO WHILE q$ <> CHR$(27)
      q$ = INPUT$(1)
    LOOP
    END
```

Added Sub-Program

```
SUB ReadFile (MainTitle$, Runner1$, Runner2$, Ch%, HighLim!, LowLim!, RnTime#,
FirstCollect$, Factor#(), AmpBins%)
DIM Sum%(20, 8), DamSum#(20, 8), CPH#(20, 8), SREff#(20, 8), SumPnt%(8, 50),
TotalSREff#(8), TotalCycles%(8), Pnt%(8, 50)
Intrvl% = 0
```

```
TotalSREff#(J) = 0
TotalCycles%(J) = 0
Runner1$ = MainTitle$ + CHR$(65) + "1.TAB"
Runner2$ = MainTitle$ + CHR$(65) + "1.DAT"
INPUT "Name of File to Process: "; FileName$
Title$ = FileName$ + ".DAT"
```

C) Collect Data from SM-192 - Added a Routine to utilize SMCOM.COM, Option J

```
  ELSEIF q$ = "J" THEN
'*************************************************************
'*    OPTION J COLLECTS THE DATA FROM THE STORAGE MODULE      *
'*    AND PLACES THE DATA INTO A DAT FILE W/O MODIFICATIONS   *
'*************************************************************
    Title$ = MainTitle$
    OPEN "TESTER.BAT" FOR OUTPUT AS #1
    PRINT #1, "SMCOM 1 A " + Title$ + " C Q"
    CLOSE #1
    CLS
    END
```

D) Allow for Normal Data Download More than Once from the 21X - Changed the Sub-Program Collect By Adding Trigger /G

```
PRINT #1, "TELCOM OSU/C/G/F " + Title$
```

E) Allow for Use of a Sm192 Storage Module - Added to Sub-Program RainPrint

```
Count = Count + 1
PRINT #1, Count; ":P96" '*** SENDS OUTPUT TO SM-192 FINAL STORAGE, IF
PRESENT ***
PRINT #1, "1:30"
PRINT #1,
```

F) Read All Raw Data, Instead of Automatically Ignoring the First Interval - Added Question to the user

```
IF FirstCollect$ = "Y" THEN
  INPUT "Do You Want To Calculate All Intervals ? "; DoWe$
  IF DoWe$ <> "Y" THEN
  FOR I = 1 TO Ch%
    INPUT #1, DUMB% '*** READS 1ST SPOT OF DATA LINE AND ASSIGNS IT VAR.
NAME DUMB% ***
    INPUT #1, Day$ '*** READS 2ND SPOT OF DATA LINE AND ASSIGNS IT VAR.
NAME DAY$ ***
    INPUT #1, HourMin$ '*** READS 3RD SPOT OF DATA LINE AND ASSIGNS IT VAR.
HOURMIN$ ***
    INPUT #1, Secs$ '*** READS 4TH SPOT OF DATA LINE AND ASSIGNS IT VAR.
SECS$ ***
    FOR J = 1 TO 2 '*** BECAUSE THE MEAN AVG. IS TWO FROM THE RAINFLOW
PROGRAM THERE ARE ***
              '*** TWO SETS OF DATA FOR EACH CHANNEL ON A DATA LINE AND
THIS MAKES ***
              '*** SURE ALL THE NUMBERS OR COUNTS ARE READ. ***
      FOR K = 1 TO AmpBins% '*** THE DATA IS BROKEN UP INTO BINWIDTHS AND
THE TOTAL # OF BINS
                '*** IS EQUAL TO THE AMPBINS% VARIABLE. ***
        INPUT #1, DUMB% '*** READS THE REMAINING SPOTS ON THE DATA LINE
***
        NEXT K
      NEXT J
    NEXT I
  FirstCollect$ = "N"
  END IF
```

The Following are planned enhancements:
G) Auto detect and limit the maximum intervals of data to fit within the memory constraint
H) Allow for switching to different files and directories so as not to overwrite any previously downloaded files.
I) Allow, as in 4.H, to use different initializations and variable files unique to various locations.