1350

Research Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

M•DOT

DEVELOPMENT OF A MOBILE SYSTEM FOR MEASURING TRAFFIC SIGN RETROREFLECTIVITY

R. E. Nordlund
D. C. Long

Research and Technology Section
Materials and Technology Division
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Computer Programs:	Mike Conner
Van Standards:	Bill Andrews

ACTION PLAN

1. Engineering Operations Committee

   A. Approve Report

2. Materials & Technology Division

   A. Distribute Report

   B. Begin Using to Determine Sign Replacement Schedules

   C. Investigate Use for Approval of Replacement Signs

   D. Investigate Ways to Improve Data Processing Efficiency

EXECUTIVE SUMMARY

The Michigan Department of Transportation's Research Laboratory has developed a system for Mobile Evaluation of Traffic Signs (METS) capable of measuring traffic sign retroreflectivity at highway speeds. Potential uses include evaluating experimental signs, monitoring state-wide reflectivity levels, and accepting new signs.

Mounted on the van roof is a laser range finder, a strobe light, a black and white video camera, and a color aiming camera. As the van travels at speeds up to 90 kilometers per hour, the system operator uses the color camera to track the target sign with the roof-mounted equipment. At the appropriate distance, the laser range finder triggers the strobe unit and data acquisition camera simultaneously. The black and white image is digitized and stored as a computer file. Retroreflectivity data, sign location, sheeting type, legend, etc are combined in a computer database for future reference.

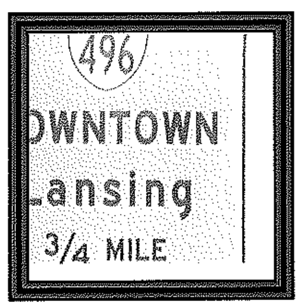
METS can acquire retroreflectivity readings from hundreds of signs a day, however, processing and evaluating the data takes much longer. METS van results compare well with manual ART 920L retroreflectivity measurements. Some examples of METS images showing different retroreflectivity levels are shown below.

Diamond Grade

Guide Sign

1000 cd/fc/ft^2

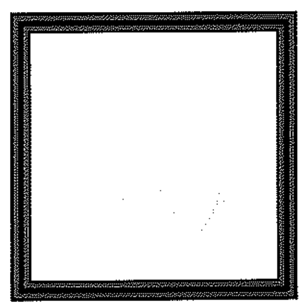
High Intensity



Guide Sign

300 cd/fc/ft^2

Engineer Grade



Exit Sign

80 cd/fc/ft^2

Negative images shown for detail. Actual computer images are larger.

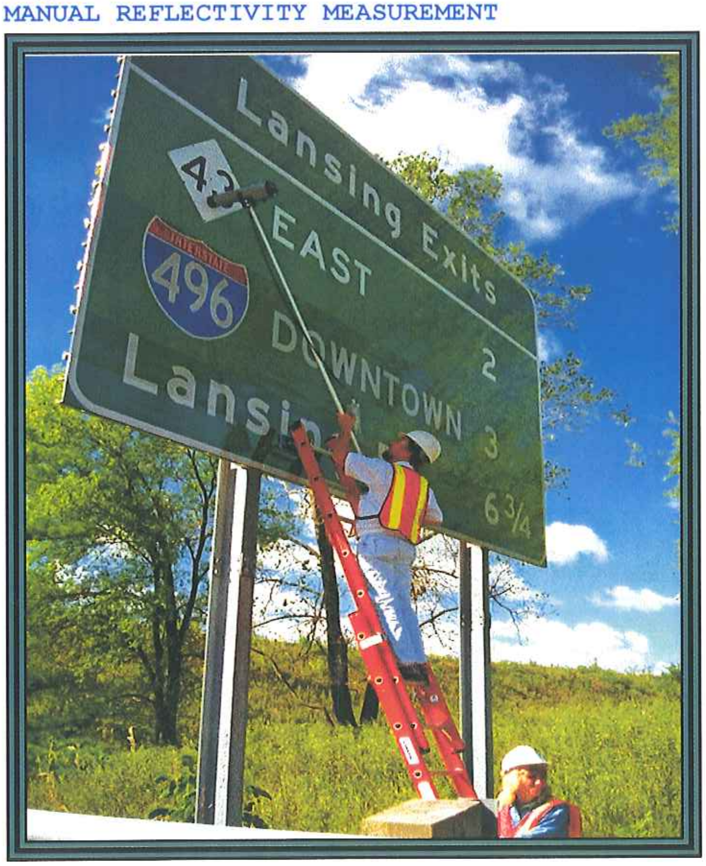
BACKGROUND INFORMATION

The Problem

Traffic signs use reflective sheeting to provide a safe nighttime environment, especially for motorists in an unfamiliar area. The useful reflectivity life of individual traffic signs varies, depending on weather effects, sheeting type, and other factors. Some signs may be reflective for more than 15 years, while others may not last nearly as long. Therefore, it is necessary to periodically evaluate the reflectivity of traffic signs to validate traffic sign replacement schedules.

In addition, FHWA is formulating new regulations to establish minimum retroreflectivity levels for traffic signs. It may become necessary to measure the retroreflectivity of each sign on the highway system. Previously, this required manual measurements(Figure 1) or subjective nighttime observation. Both methods are labor intensive and require trained personnel. An automated system is essential before any regulations could be fully implemented.

Figure 1
MANUAL REFLECTIVITY MEASUREMENT



Purpose

The purpose of this research project is to develop an operational mobile system for high-speed measurement of traffic sign retroreflectivity. Once operational, METS would be used to (1) evaluate field performance of new types of reflective sheeting, (2) evaluate performance of selected existing traffic signs, and (3) evaluate sign sheeting problems throughout the state.

History

Under NCHRP Project No. 5-10, Ektron Corporation developed a prototype system for FHWA to measure the average retroreflectivity of a sign legend and background. The system used an electronically-shuttered video camera to acquire sign images illuminated by a xenon flash. A laser range finder measured the distance to the sign. These components were mounted on top of a van in a weather-tight enclosure. The operator aimed the system from inside the van using by means of a mechanical arm. A personal computer synchronized the camera, flash, and range finder as the vehicle approached the sign. Computer processing of the video image calculated the average reflectivity of the sign background and legend.

Early in 1992, MDOT Research Laboratory personnel had the opportunity to test the FHWA prototype vehicle. Our preliminary findings were that the system was capable of indicating which signs were good, bad, or marginal. Our testing also indicated that further work was required to develop a functional system[1]. This would include system calibration, evaluating accuracy and precision, and developing a data handling system.

In June of 1992, FHWA approved the research project "Experimental Use of Mobile System for Measurement of Sign Retroreflectivity" under HRP Part II. The initial budget of $166,773 was later increased by $30,000 to upgrade computer and other electronic equipment.

Research Objectives

The objectives for this project were:

1) Design and construct an operational vehicle to accurately measure the retroreflectivity of traffic signs at highway speeds.

2) Debug the equipment and operational aspects of the vehicle. Identify needed improvements to expand the vehicle capabilities beyond the basic prototype van.

3) Calibrate the system for various types and colors of retroreflective materials. Evaluate the system's accuracy and precision for calibration and traffic sign reflectivity.

4) Develop a practical data and image handling system. METS acquires a large amount of data and requires an automated computerized data system for efficient operation.

5) Document the system operation and issue a final report.

METS EQUIPMENT

Overview

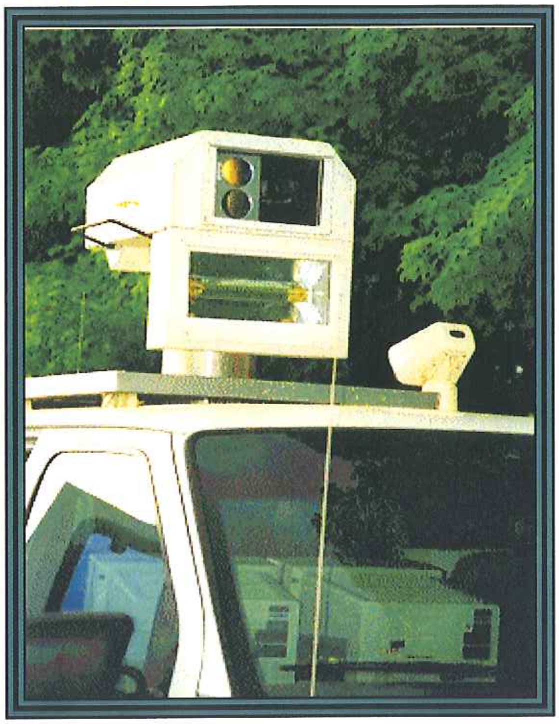
Figure 2 shows a picture of the MDOT METS van, a Ford Club Wagon. We patterned the MDOT van after the FHWA prototype vehicle. The details of their system have been previously reported.[2] We made some initial modifications, but used most of the same electronic,

Figure 2
MDOT METS VAN

photographic and computer systems. The strobe is the same model as used in the FHWA van. The range finder is a newer, more accurate version of the one used in the FHWA van. We added a color aiming camera, a new laser range finder, and updated the computer.

MDOT completed the design and construction of METS in June of 1994. Equipment modifications and replacement of faulty parts were completed in August of 1994. The first routine METS run occurred in October 1994 when 1000 signs were measured in two days. The calibration was limited, and data manipulation was cumbersome, but METS was operational. The remaining research time has been spent validating the calibration, accuracy, precision, and improving data processing.

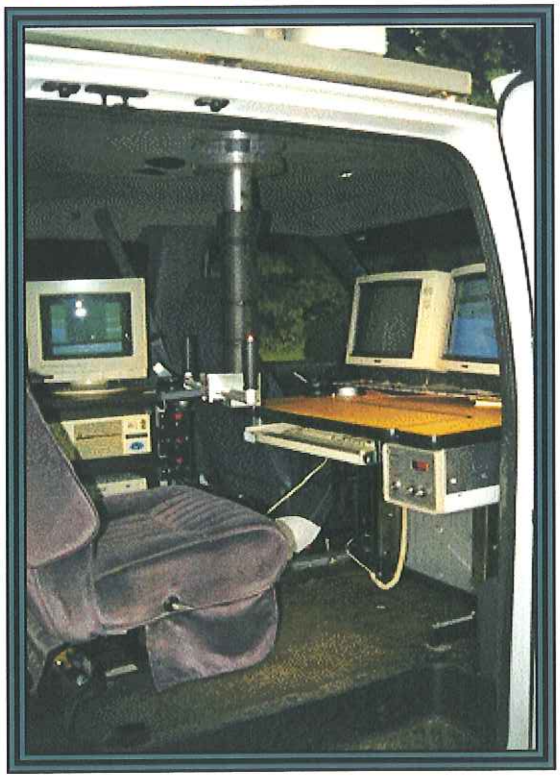
Figure 3
ROOF MOUNT UNIT



Exterior Equipment

The roof-mounted unit contains the laser range finder, black and white data acquisition camera, color aiming camera, and xenon strobe (Figure 3). The shutter speeds of both cameras can be controlled from inside the van. Changing the shutter speed on the data acquisition camera compensates for the different brightness levels of Diamond Grade and high intensity sheeting. Changing the shutter speed on the color aiming camera accommodates the differences from cloudy to sunny days. (The color aiming camera has been changed from a manual to an automatic exposure system). The roof-mounted enclosure is weather tight with a temperature controlled ventilation fan. Two warning strobes are mounted on the rear of the van.

Figure 4
METS INTERIOR



Interior Systems

The van interior was extensively modified to accommodate computer and other electronic equipment (Figure 4). The van seats four people; the driver, operator, and two observers.

One monitor displays the output from the overhead color aiming camera. A box marked on the monitor denotes the focal point for the range finder and data acquisition camera. The operator aims the system by placing the box on the target sign. A second monitor displays the black and white image obtained by the data acquisition camera when the strobe illuminates the sign.

The power for the computer, strobe, and monitors is supplied by an inverter which converts the 12 volt DC supplied by the vehicle to 120 volts AC. The inverter is connected to deep-cycle 12 volt batteries.

Computers & Software

Two separate computer systems are used to acquire, process, and store images and readings. A 486/33, running a modified version of the FHWA program, operates the system and collects raw data in the van. Another computer, located in the Research Laboratory, is used to process and store image information in a data base[3] on read-write optical disks. Removable Bernulli disks are used to transfer data from the van computer to the laboratory computer.

METS OPERATION

Introduction

The METS software combines sign inventory, reflectivity values, and three images from each sign into a common database. Appendix A contains a detailed description of the METS operation. During data acquisition, METS captures two images: a raw data file containing a continuous tone black and white image (Figure 5), and a separate color image file (Figure 7). Using the relative brightness levels of the legend and background, the raw data file is processed into a black and white only image (Figure 6). The thin white line or box represents the area that was used to calculate the retroreflectivity values. The color image provides a wide view of the sign for reference, but is not used in calculating retroreflectivity values.

Figure 5
RAW DATA IMAGE

Figure 6
BLACK/WHITE ONLY IMAGE

Figure 7
AIMING CAMERA IMAGE

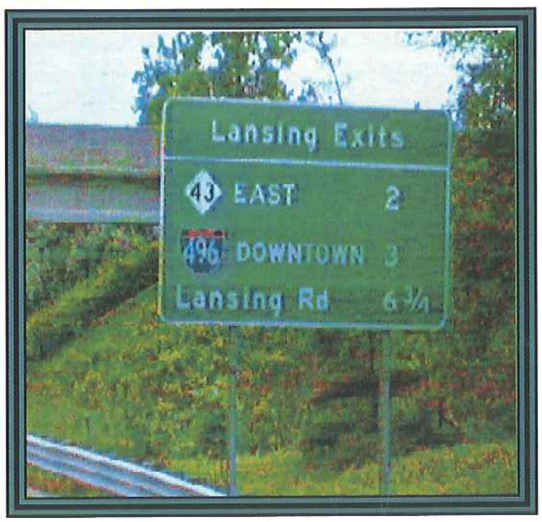


Image Processing

During computer processing of the raw data image, each dot or pixel is rated on a grey scale from 0 to 255, with black 0 and white 255. The gray scale values for each pixel are plotted on a histogram. Figure 8 is a histogram of a new high intensity guide sign. The first peak at 20 represents the pixels from the green background, while the second peak at 110 represents the pixels from the brighter white legend. Figure 9 is a histogram from a yellow and white 3M Diamond Grade prismatic standard panel. The peak at 130 represents the yellow sheeting and the peak at 215 is from the white sheeting.

The higher the retroreflectivity, the higher the grey scale value. The correlation between average grey scale value and the final retroreflectivity is the calibration factor. A broad histogram peak indicates more grey scale (brightness) variation in the prismatic sheeting compared to high intensity sheeting.

The computer determines a background/legend separation number (entropy grey level) from 0 and 255, between the two histogram peaks. A second image is generated where pixels brighter than the entropy grey level are processed as white, and pixels darker than the grey level are processed as black. The resultant image is black (0) or white (255) only. This image is reviewed to ensure the proper legend and background areas are processed.

Figure 8
HIGH INTENSITY HISTOGRAM

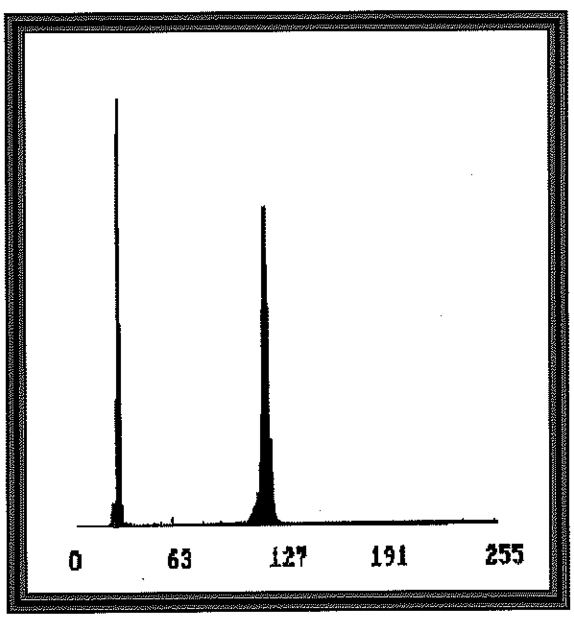
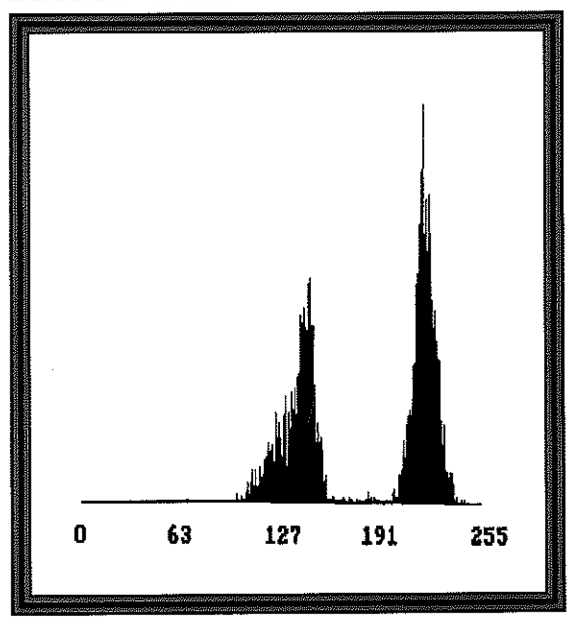


Figure 9
DIAMOND GRADE HISTOGRAM



The figures below, of a composite sign, illustrate the need for manually evaluating the raw data file before processing. Figure 10 shows the raw data file with the brighter high intensity 65 overlay against the dimmer engineer grade background. METS software translates this sign into a three level histogram (black, engineer white and high intensity white). Since the software can only process two levels, it forces all pixels to either white or black. Figure 11 is the B/W only image where the lower reflective engineer grade is processed to black. Figure 12 is the B/W only image where the engineer grade is processed to white. If the reflectivity was calculated on the full image in figure 10, the result yields an incorrect 140 cd/fc/ft^2. However, the program is capable of analyzing individual portions of the signs so that the high intensity and engineer grade section can be analyzed individually. This gives the correct values of 78 for the engineer grade sheeting and 307 for the high intensity.

Figure 10
RAW DATA IMAGE
HIGH INTENSITY ON
ENGINEER GRADE

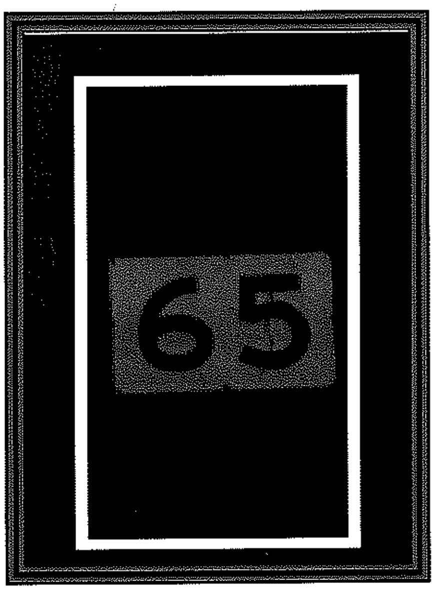


Figure 11
B/W ONLY
ENGINEER AS BLACK

Figure 12
B/W ONLY
ENGINEER AS WHITE

SYSTEM VALIDATION

Calibration

We constructed 600 mm X 600 mm aluminum panels with various colors and types of reflective sheeting. The retroreflectivity values for these 'standards' were determined in our photometric range and tested with a portable ART 920 retroreflectometer.

Our initial calibrations were performed by placing standard sheeting panels 61 m in front of the van. An appropriate offset was used to simulate the normal laboratory testing geometry. The original FHWA computer program had a calibration routine, but we found more variation in the calibration process than with the actual data acquisition process. This could be due to the small size of the standard panels compared to a normal traffic sign.

We tested the white high intensity sheeting many times to calculate an average bias (intercept) and scale factor (slope). We tested green high intensity, plus white and green engineering grade sheeting to validate the lower range of reflectivity values. This process was more difficult than anticipated due to calibration variations, and not having color correction factors for green sheeting. We also made several changes to the shutter speed and aperture setting to find acceptable working ranges. We have successfully tested signs with reflectivity values from 1200 cd/fc/ft^2 to less than 10. Follow up visual inspections and ART readings have shown good agreement.

We speculated that calibration variability could be improved with larger standards and fixed mounting. As part of another research project, we constructed a roadside guide sign with several types of sheeting (Figure 1). The top line of the sign had diamond grade legend on high intensity background. The second line had Stimsonite on Stimsonite sheeting. The third line had high intensity on high intensity sheeting. The bottom line had high intensity on engineer grade sheeting.

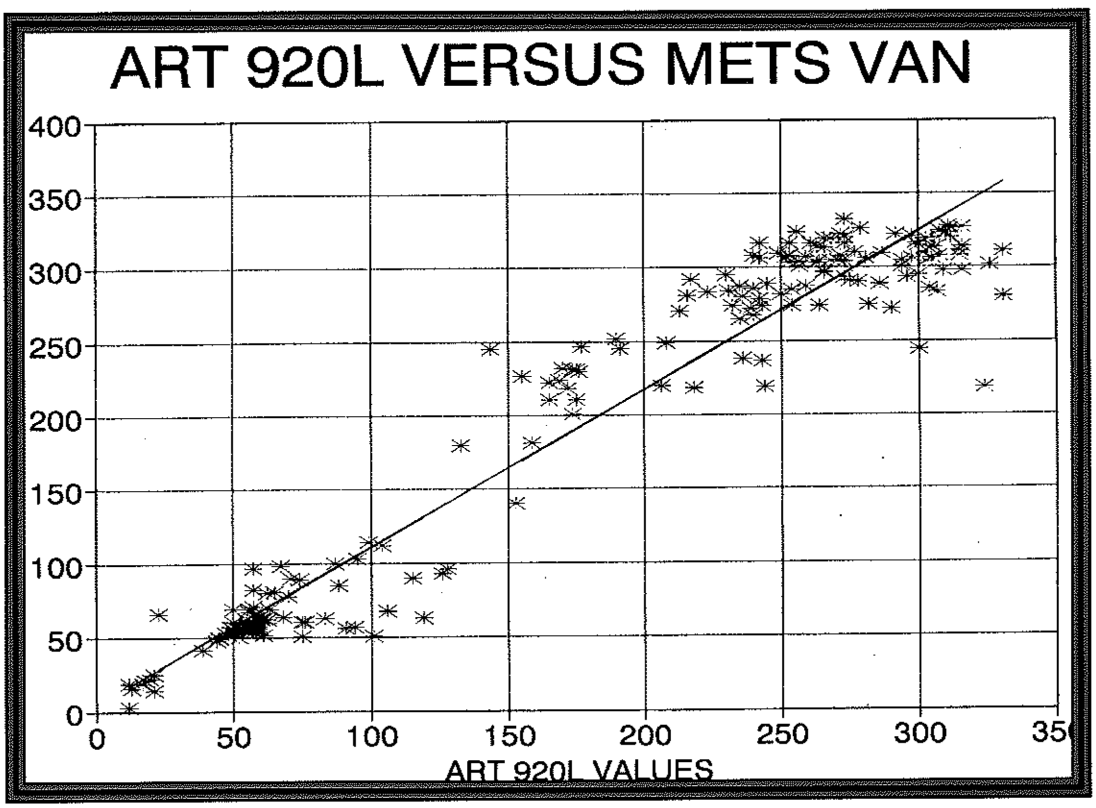
The retroreflectivity values for the various sheeting were determined using an ART 920. We then tested each line of the special sign with the METS van. Based on this data, we increased the previous calibration factor by approximately 10 percent.

Calibration	Individual Averages	Average
METS - Older Calibration	271, 277, 264, 267,255	267
METS - Revise Calibration	320, 285, 299, 297, 303, 294, 316	302
Manual ART 920L	312, 299, 308, 311, 305	307

Accuracy

During the summer of 1994, MDOT participated in the FHWA Field Evaluation of Minimum Retroreflectivity Guidelines for Traffic Signs. As part of this study, we analyzed 342 field traffic signs, installed from 1981 to 1993, with an ART 920L and METS. Figure 13 is a plot of the 180 individual data comparison points for ART and METS measurements for white and green signs, engineer grade and high intensity sheeting. Regression analysis resulted in an R Squared value of 0.943, an intercept of 5.8 and an X Coefficient of 0.884. This confirms a good correlation between the ART 920L and METS, but also indicates that METS was generating results approximately 12 percent lower, on the average, than the ART 920L.
METS calibration during 1994 was based on the 600 mm X 600 mm standard panels. Since then the calibration factor has been

Figure 13
ART 920L vs METS



increased by 10 percent based on the multi-sheeted roadside sign testing. Based on the previous data, we are satisfied with the accuracy of METS data. Accuracy validation will continue and be expanded into additional sheeting types and colors.

Precision

Summaries of METS measurements made during 1995 and 1996 on white and green high intensity sheeting are contained in Appendix B. Across the top of the table is the date of the METS evaluation, and along the left is the sign identification code. The average reading, standard deviation, and percent relative standard deviation are listed on the right. The average relative standard deviation for the white high intensity measurements in 1995 and 1996 was 4.3 and 3.9 percent, respectively (Tables 1,2).

The average relative standard deviation for green high intensity sheeting in 1995 and 1996 was 5.5 and 4.9 percent respectively (Tables 3 and 4). Retroreflectivity levels decreased overall in 1996 compared to 1995 which may be due to sheeting degradation, dirt on the signs, or a change in METS calibration. We suspect environmental effects and will continue to monitor the readings.

Lane Location

Most METS readings have been taken from the right lane. To evaluate the effects of lane location, we tested 10 signs from directly underneath to as far as three lanes left of the sign. Results are listed below in cd/fc/ft^2. There appears to be no significant difference for high intensity sheeting. There was a difference for the Stimsonite prismatic sheeting for each lane change.

LANE LOCATION RESULTS

Glass Bead Sheeting

		White Legends				Green Backgrounds			
SIGNS	CODE	O LFT	1 LFT	2 LFT	3 LFT	O LFT	1 LFT	2 LFT	3 LFT
I96 W	3	276	256	264	276	63	66	64	67
	4	275	260	271	285	55	51	54	59
	5	270 257	275	269		62 57	66	64	
	6	259	253		263	63	61		63
	7					77	71	71	75
I96 E	17		243	226	262 245 256		67	56	63 66 68
	19		256	240	260 255		16	13	14 15
	23	275 266	268	266 276		65 61	59	58 60	

Prismatic Sheeting

SIGNS	CODE	O LFT	1 LFT	2 LFT	3 LFT	O LFT	1 LFT	2 LFT	3 LFT
I96 W	9	725	684	526		78	67	56	
I96 E	22	661	612	503		75	65	56	
	22			484 491				58	

USING METS

Once the data have been acquired, evaluated, and processed, they are compiled into a computer database containing retroreflectivity values, the sign message, location, sheeting, etc. It also contains the images from the color aiming camera, the 256 grey scale raw data file image, and the B/W only image. The information in the database can be summarized or browsed in various formats and configurations.

Figure 14 is a sample report combining the color picture from the aiming camera, the B/W only picture plus the location and reflectivity data.

Figure 14
Individual Sign Report

EXIT 65B
14 MILE RD
WEST =>

SIGN #: I75 /N/ 65:30.00:1 Section: 63174 Mileage: 64.980
Location: _ Mali: .000
WHITE III Legend on GREEN III Background
Installed: Sign Facing:

Date	Calib	Grey	Raw Bkgd	BACKGRD	LEGEND	Raw Legend		BW#	
95-10-25	3.40	32	24	66	266	97		5	METS # 12341
14:12	ColorX .80		CorrX .00	53	266		9/9/9		64.980

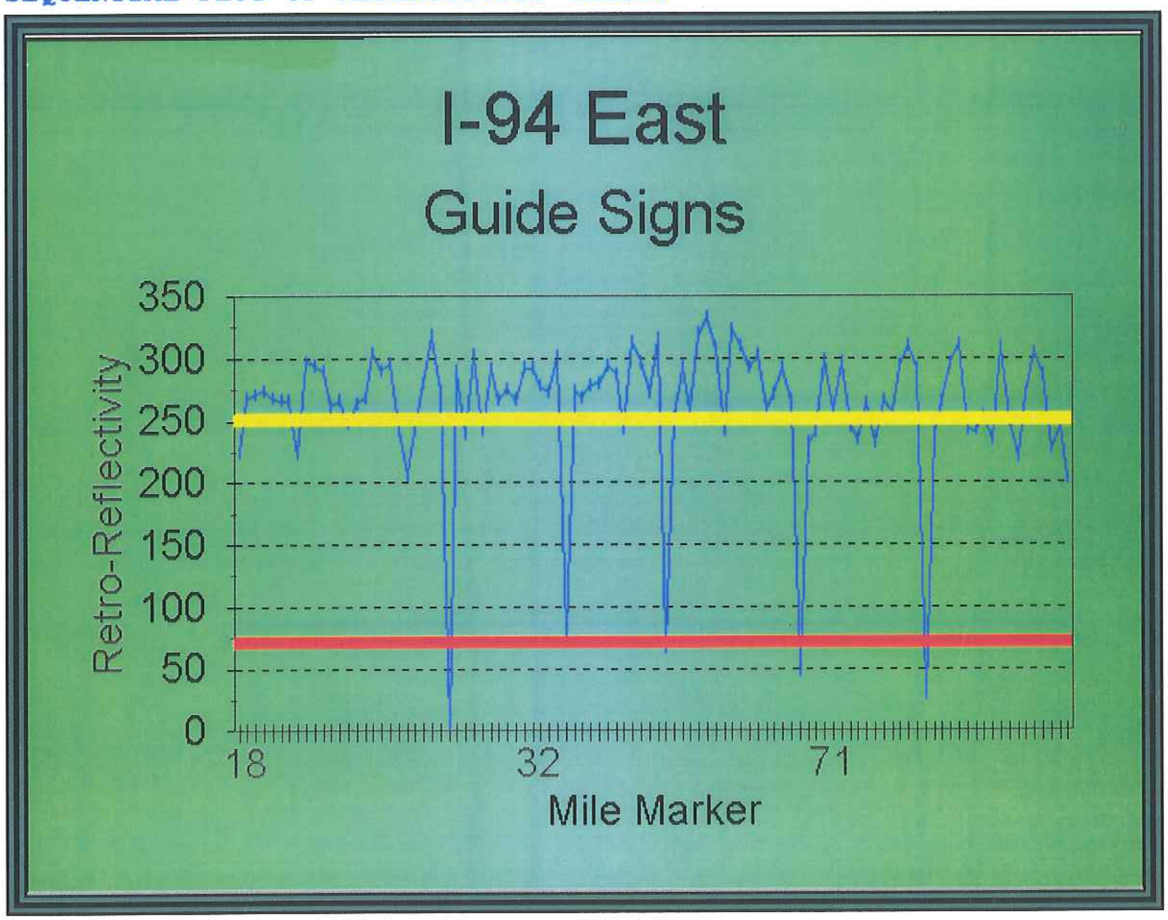
Information in the main database can also be accessed by other commercially available software to prepare thumbnail image summaries of the raw data files (Figure 15) and other reports.

Figure 15
THUMBNAIL IMAGE SUMMARY

Retroreflectivity data were exported from the main database into a spreadsheet program to plot retroreflectivity values for signs in the same order that they appear along the roadway (Figure 16). The yellow line on the graph is at 250 cd/fc/ft^2. This represents the minimum specification limit for new white high intensity sheeting. Our experience indicates that new white high intensity sheeting normally runs from 280 to 310.

The five low values indicate white signs with engineer grade sheeting. Michigan now specifies that all new permanent traffic signs be high intensity sheeting. However, as the graph shows, some old engineer grade signs still exist on state roads. New engineer grade white sheeting runs in the 90 to 110 range. The red line on the graph at 75 indicates old engineer grade signs. The first low peak represents a mile marker sign, which is non-reflective, and essentially useless at night.

Figure 16
SEQUENTIAL PLOT OF REFLECTIVITY VALUES



Another potential use of METS data is documenting surface defects on signs. Delaminating and other problems are sometimes visible on METS images (Figs. 17 and 18). This capability could be useful in accepting newly fabricated signs that were damaged during installation.

Figure 17
DELAMINATION

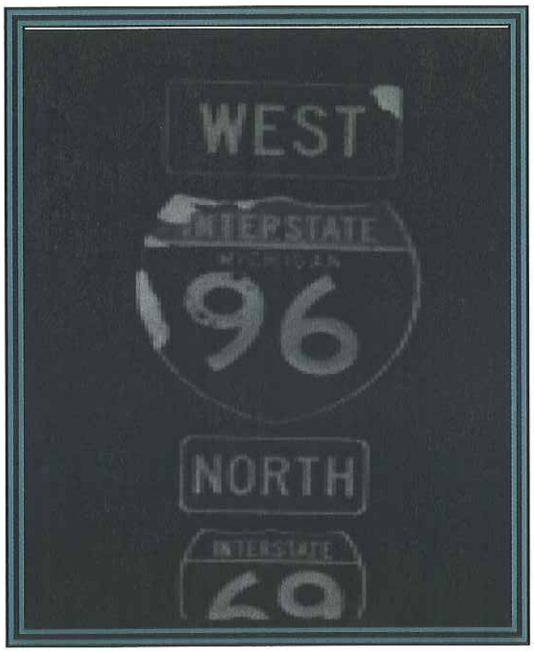
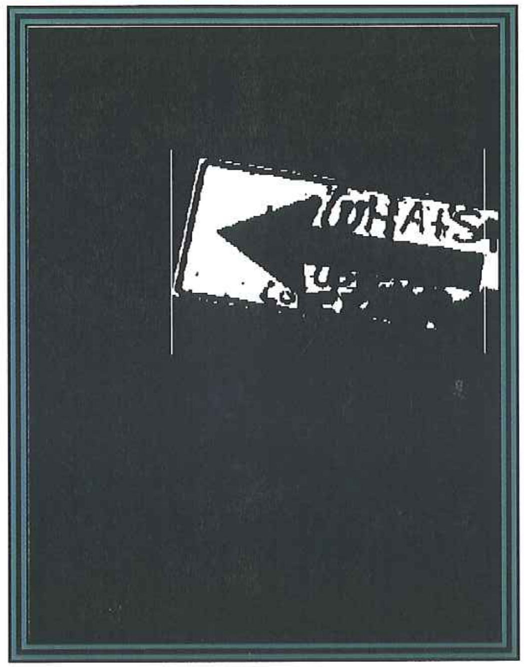


Figure 18
GRAFFITI DAMAGE



SUMMARY

The Research Laboratory has developed an operational system capable of measuring traffic sign retroreflectivity at highway speeds during day light hours. METS retroreflectivity results correspond favorably with manual procedures. The pictures produced by METS can also document surface defects.

During the last several years of METS development, we have traveled many miles and 'shot' about ten thousand traffic signs. Having personally looked at every one of these images, I have concluded that Michigan has very reflective traffic signs. While writing this report, I have included some of the unusual data to show the capabilities of the system.

The next challenge is to determine how best to use METS for the benefit of the department and motoring public. We will continue to use this vehicle to evaluate experimental signs and assist field staff with problem resolution. We will investigate using the vehicle for acceptance of new traffic signs, and we will continue to improve the efficiency of the data processing.

RECOMMENDATIONS

The Materials & Technology Division should continue to develop and expand the use of the METS van. This should include:

A.) Calibrate the system for additional sheeting types and colors;

B.) Implement ways to improve data processing efficiency;

C.) Investigate the addition of a G.P.S. system;

D.) Continue to evaluate experimental traffic signs;

E.) Share this state-of-the-art research knowledge and data with other interested agencies;

F.) Investigate possible METS use for approval of replacement traffic signs;

G.) Encourage other Divisions to investigate ways to use METS data for evaluation of existing State traffic signs, and

H.) Investigate ways to incorporate METS data into the state-wide sign inventory system.

REFERENCES

1.) Nordlund, R.E., *Field Evaluation of Minimum Retroreflectivity Guidelines for Traffic Signs,* Michigan Department of Transportation Report.

2.) Lumia, J.J., A Mobile System for Measuring Retroreflectivity of Traffic Signs, Ektron Applied Imaging, Inc. NCHRP Project No. 5-10.

3.) Advanced DB Master, Macon Systems, Inc. P.O. Box 1388, Colorado Springs, CO 80901, (719) 520-1555.

APPENDIX A

METS PROCEDURE

The State of Michigan owns an estimated 500,000 signs. Tracking the individual signs, legends, locations, age, etc. is a monumental task. The current sign inventory system is not conducive to easy field tracking and identification of the signs at highway speeds, and it is not capable of storing images. Therefore, we developed another data- base for METS data. We indexed the signs by roadway route marker, direction and either mile marker or mileage from the last state crossroad. We then included a sign number and mileage point. For example, a freeway sign with a code of "I96/W/90.4 @ 90.210" would identify the fourth sign record on westbound I-96 past mile marker 90. The mileage at that sign would be 90.210. For non-freeway signs, a sign code of "M25/W/US27 #119 @ 12.345" would indicate the 119th sign record on M-25, westbound, 12.345 miles west of the US-27 intersection.

During a METS run, we use a laptop computer to track the signs being evaluated. If previous sign inventory data exist, the laptop computer displays a list of the anticipated or previously METS tested signs. If sign inventory data are not available, the laptop is used to start a list of signs for each METS test. This list is later used as the core for compiling all the various pieces of information gathered by the system.

Each time METS 'shoots' a sign, it stores the raw data image in a file named 'F#######.pic'. The number sign (#) indicates a numeric value that is incremented for each new sign file. The computer also records the mileage from the METS van and stores it in a text file with the same number as the raw data file. We also record the same file number on laptop computer. Watching the laptop computer for sign inventory data, aiming the METS system and assuring that all numbering systems match, sometimes makes the operator's job very demanding. In many cases, the METS van is a three-person operation. The van driver has the easier job of assuring accurate mileage readings and driving safely. The driver can also assist the operator in visually locating the next target sign.

After a METS run, the raw data files, mileage text files, and laptop data are all transferred into the laboratory computer. The sequential file number is key to getting all the data back together. The new laptop records are imported into the main laboratory data base along with the mileage records. The raw data files are then processed.

The laboratory computer is equipped with the same frame grabber board as the METS computer. During processing, the raw data file image is displayed on the second laboratory computer monitor. The processor selects the area of the sign to be processed. The software has an automatic processing function, but this seldom selects a proper area. The processor must review the histogram, entropy gray level, the black/white only image, and final reflectivity results. It is extremely helpful to have another computer display the data base files so that notes, comments or problems can be entered during processing.

The retroreflectivity values calculated during processing are stored in another text file which can be imported into the METS data base. The next step is to process the three image files for attachment to each sign record. METS generates a vast amount of data and processing takes more time than acquiring the data.

APPENDIX B

Table 1
1995 METS REPEAT DATA
WHITE HIGH INTENSITY SHEETING

SIGN CODE	1995 7/10	7/12	7/18	7/31	8/30	9/27	9/27	9/28	10/19	10/25	AVG	STD DEV	%RSD
I96/E/90.4	295												
I96/E/91.15.3	299				297	303	294	316	320		305	9.8	3.2%
I96/E/91.18								255	277		266	11.0	4.1%
I96/E/91.23													
I96/E/92.2	231	214			202	225	229	238	226		224	11.1	5.0%
I96/E/92.4	301	295			298			321			304	10.2	3.4%
I96/E/92.6	214	207			189	216		232	220		213	13.1	6.2%
I96/E/92.17	272					280	260	324	287		285	21.6	7.6%
I96/E/92.19	228	214			210						217	7.7	3.6%
I96/E/93.19	294		281		286	296	310	305			295	10.0	3.4%
I96/E/93.20	295								288		292	3.5	1.2%
I96/E/93.21	304												
I96/E/93.22	273		211		255			285	269		259	25.7	9.9%
I96/E/93.25	314	298						314	287		303	11.4	3.8%
I96/E/93.27						302							
I96/E/93.28	335	327			289			332	316		320	16.7	5.2%
I96/E/94.2	299	320			286	324	310	340	329		315	17.1	5.4%
I96/E/94.23	320	296			304	300	305	328	327	284	308	14.6	4.8%
I96/E/95.2						278		299			289	10.5	3.6%
I96/E/95.6	316		297		306	325	308	339	333		318	14.2	4.5%
I96/E/95.7	290	306			280	314	303	307	312		302	11.4	3.8%
I96/E/96.24	308		296		283	307	327	326	329		311	16.2	5.2%
I96/E/96.25	304					315					310	5.5	1.8%
I96/E/96.26	321		293		326		345		333	292	318	19.7	6.2%
I96/E/96.27	272	277	289			287	280	305	304		288	11.9	4.1%
I96/E/97.20	266							284	284		278	8.5	3.1%
I96/E/97.23								261	286		274	12.5	4.6%
I96/E/97.25	327		305					349	332		328	15.7	4.8%
I96/E/97.28	311		262			282	286	328	308		296	21.8	7.4%
I96/E/97.29													
I96/E/97.30	265							282			274	8.5	3.1%
I96/W/90.3						292		304	288		295	6.8	2.3%
I96/W/90.4		274		286	284	277	301	321	314		294	17.0	5.8%
I96/W/90.5				273		254	267	277	266		267	7.8	2.9%
I96/W/90.6					285			289	286		287	1.7	0.6%
I96/W/90.7	328					305		313	298		311	11.2	3.6%
I96/W/90.8													
I96/W/90.9	317	315		311		276					305	16.7	5.5%
I96/W/91.3		291		311							301	10.0	3.3%
I96/W/91.4	275	290		270	261	262	281	311	283		279	15.3	5.5%
I96/W/91.5		250											
I96/W/91.6		293							324		309	15.5	5.0%
I96/W/92.1				274									
I96/W/92.2	280	295				282	283	301	299		290	8.6	3.0%
I96/W/92.4					278	301		324	290		298	16.9	5.7%
I96/W/93.22								291					
I96/W/93.29													
I96/W/93.31				323				324			324	0.5	0.2%
I96/W/93.32	295			296	296	267		314	308	233	287	25.9	9.0%
I96/W/94.14		253	267		260	272	265	274	259		264	6.9	2.6%
I96/W/94.15	305	289		325	292	302	310	311	307	287	303	11.5	3.8%
I96/W/95.14	326			338		305	314	328	334	281	318	18.4	5.8%
I96/W/95.15				328	320			355	332		334	13.0	3.9%
I96/W/95.16	323			314		295		325	306	300	311	11.2	3.6%
I96/W/96.3	302	303		302		292	304	309	307	264	298	13.6	4.6%
I96/W/96.4		307				322		328	325		321	8.1	2.5%
I96/W/96.6	298	296		300		274		321	288	282	294	14.0	4.7%
Average	294.4	282	278	304	277	288	294	307	300	278			
Count	35	22	9	14	22	31	20	41	38	8	293	12.6	4.3%

Table 2
1996 METS REPEAT DATA
WHITE HIGH INTENSITY SHEETING

SIGN CODE	1996 1/17	5/13	5/13	5/13	5/13	6/13	6/13	7/11			1996 AVG	STD DEV	%RSD
I96/E/90.4													
I96/E/91.15.3	240	290	294	286		292	285				289	3.4	1.2%
I96/E/91.18													
I96/E/91.23													
I96/E/92.2	208	204				218					211	7.0	3.3%
I96/E/92.4		254											
I96/E/92.6	209	191	219			199					203	11.8	5.8%
I96/E/92.17		248	255			260					254	4.9	1.9%
I96/E/92.19						242		278			260	18.0	6.9%
I96/E/93.19		249	278	275	270	255	284	285			271	12.9	4.8%
I96/E/93.20													
I96/E/93.21													
I96/E/93.22													
I96/E/93.25													
I96/E/93.27													
I96/E/93.28		270				286					278	8.0	2.9%
I96/E/94.2		255				243	248				249	4.9	2.0%
I96/E/94.23		270	296	280	292	306	299				291	12.1	4.2%
I96/E/95.2		276				286	259				274	11.1	4.1%
I96/E/95.6		284	292	304	300	308	287				296	8.8	3.0%
I96/E/95.7	243	260	286	271	287	277	270				275	9.4	3.4%
I96/E/96.24	204	276	292	281		280	286				283	5.5	1.9%
I96/E/96.25		296	305	292	303	304					300	5.1	1.7%
I96/E/96.26													
I96/E/96.27	214	245	268	252	269	276					262	11.6	4.4%
I96/E/97.20	218	243											
I96/E/97.23	231	262				295	280				279	13.5	4.8%
I96/E/97.25	275	281	295					295			290	6.6	2.3%
I96/E/97.28	239	274	270	295		281					280	9.5	3.4%
I96/E/97.29						294							
I96/E/97.30													
I96/W/90.3		268	254			272	282	307			277	17.7	6.4%
I96/W/90.4		265	248	267		280	282	276			270	11.5	4.3%
I96/W/90.5		240	239			257		263			250	10.5	4.2%
I96/W/90.6						287		298					
I96/W/90.7		273											
I96/W/90.8													
I96/W/90.9		286				294					290	4.0	1.4%
I96/W/91.3													
I96/W/91.4	233	241	253	284		253	263	290			264	17.5	6.6%
I96/W/91.5													
I96/W/91.6		324						258					
I96/W/92.1													
I96/W/92.2		246	260	249		247	263	267			255	8.3	3.3%
I96/W/92.4		265	263					285			271	9.9	3.7%
I96/W/93.22													
I96/W/93.29													
I96/W/93.31		297											
I96/W/93.32	293	278	279	265		272	279	285			276	6.3	2.3%
I96/W/94.14	278	246	266	266		261	258				259	7.4	2.8%
I96/W/94.15	307	275	278	288		292	276	320			288	15.6	5.4%
I96/W/95.14	315	270	309	317		323	317	325			310	18.7	6.0%
I96/W/95.15	320	286	309	311		321		330			311	14.8	4.7%
I96/W/95.16	321	269	287	294		298	294	306			291	11.5	3.9%
I96/W/96.3	299	267	284	282		283		309			285	13.5	4.7%
I96/W/96.4	298	280				281	282	300			286	8.3	2.9%
I96/W/96.6	279	264	249			295	289	288			277	17.6	6.3%
Average	261	265	274	282	287	277	279						
Count	20	38	26	19	6	34	20			Ave	274	10.5	3.9%

Table 3
1995 METS REPEAT DATA
GREEN HIGH INTENSITY SHEETING

GREEN TYPE III
BW SETTING #5

	7/10	7/12	7/18	7/31	8/30	9/27	9/27	9/28	10/19	10/25	AVG	STD DEV	%RSD
I96/E/90.4													
I96/E/91.15.3	60				59	59	58	60	65		60	2.3	3.8%
I96/E/91.18								47	54		51	3.5	6.9%
I96/E/91.23	60		60		61	67	70	66	65		64	3.6	5.6%
I96/E/92.2													
I96/E/92.4	62	59			60			62			61	1.3	2.1%
I96/E/92.6													
I96/E/92.17	54					54	54	59	57		56	2.1	3.7%
I96/E/92.19	40	37			38						38	1.2	3.3%
I96/E/93.19													
I96/E/93.20	55								53		54	1.0	1.9%
I96/E/93.21	56												
I96/E/93.22	50		42		45			55	53		49	4.9	9.9%
I96/E/93.25													
I96/E/93.27													
I96/E/93.28													
I96/E/94.2	48	54			46	56	52	54	51		52	3.3	6.4%
I96/E/94.23	61	53			51	54	54	58	57	51	55	3.3	6.0%
I96/E/95.2						52		60			56	4.0	7.1%
I96/E/95.6													
I96/E/95.7	51	58			49	58	54	55	58		55	3.4	6.2%
I96/E/96.24		58	50		51	55	58	56	58		55	3.1	5.7%
I96/E/96.25		52			51	55					53	1.7	3.2%
I96/E/96.26		43	52			59		60	59	51	54	6.1	11.2%
I96/E/96.27			58			59	54	61	57		58	2.3	4.0%
I96/E/97.20													
I96/E/97.23													
I96/E/97.25													
I96/E/97.28		50	44			48	49	56	53		50	3.8	7.6%
I96/E/97.29													
I96/E/97.30													
I96/W/90.3						52		50	47		50	2.1	4.1%
I96/W/90.4		47		46	50	52	53	58	58		52	4.4	8.5%
I96/W/90.5				49		46	47	50	47		48	1.5	3.1%
I96/W/90.6					49			50	48		49	0.8	1.7%
I96/W/90.7													
I96/W/90.8	64				61						63	1.5	2.4%
I96/W/90.9	54			50		53					52	1.7	3.2%
I96/W/91.3		53		60							57	3.5	6.2%
I96/W/91.4	54			46	49	46	47	54	49		49	3.2	6.5%
I96/W/91.5		41											
I96/W/91.6		42							50		46	4.0	8.7%
I96/W/92.1													
I96/W/92.2	54					51	53	56	56		54	1.9	3.5%
I96/W/92.4													
I96/W/93.22								57					
I96/W/93.29	55					63		64	67		62	4.4	7.1%
I96/W/93.31													
I96/W/93.32	58			56	61	58		62	62	44	57	5.8	10.2%
I96/W/94.14													
I96/W/94.15	54	51		59	57	54	56	57	54	54	55	2.2	4.1%
I96/W/95.14	56			52		60	50	52	57	44	53	4.9	9.2%
I96/W/95.15													
I96/W/95.16	63			58		57		58	56	54	58	2.7	4.8%
I96/W/96.3	58	56		56		54	57	54	59	53	56	2.0	3.5%
I96/W/96.4		54				55		58	54		55	1.6	3.0%
I96/W/96.6	61	54		58		54		62	51	56	57	3.7	6.5%
0													
0													
0													
0													
0													
0													
	55.82	50.7	51	53.6	52.4	55	54.1	56.9	55.5	50.9	--------	--------	----------
	22	17	6	11	16	26	16	29	28	8	54	2.9	5.5%

Table 4
1996 METS REPEAT DATA
GREEN HIGH INTENSITY SHEETING

	1/17	5/13	5/13	5/13	5/13	6/13	6/13						
I96/E/90.4													
I96/E/91.15.3	48	61	61	61		62	57						
I96/E/91.18													
I96/E/91.23	56	63	60			62					62	1.2	2.0%
I96/E/92.2													
I96/E/92.4		50											
I96/E/92.6													
I96/E/92.17		50	52			54					52	1.6	3.1%
I96/E/92.19						45							
I96/E/93.19													
I96/E/93.20													
I96/E/93.21													
I96/E/93.22													
I96/E/93.25													
I96/E/93.27													
I96/E/93.28													
I96/E/94.2		44				39	42						
I96/E/94.23		50	54	52	58	55	54				54	2.5	4.6%
I96/E/95.2		54				54	50						
I96/E/95.6													
I96/E/95.7	43	47	54	48	57	52	48				51	3.7	7.2%
I96/E/96.24	38	55	58	56		53	57				56	1.7	3.1%
I96/E/96.25		54	58	53	56	58					56	2.0	3.7%
I96/E/96.26													
I96/E/96.27	41	49	57	50	54	57					53	3.4	6.3%
I96/E/97.20													
I96/E/97.23													
I96/E/97.25													
I96/E/97.28	43	47	46	50		49					48	1.6	3.3%
I96/E/97.29						54							
I96/E/97.30													
I96/W/90.3		50	42			49	47				47	3.1	6.6%
I96/W/90.4		47	48	51		53	50				50	2.1	4.3%
I96/W/90.5		49	41			48					46	3.6	7.7%
I96/W/90.6						48							
I96/W/90.7													
I96/W/90.8													
I96/W/90.9		53				51							
I96/W/91.3													
I96/W/91.4	44	43	46	53		47	51				48	3.6	7.5%
I96/W/91.5													
I96/W/91.6		46											
I96/W/92.1													
I96/W/92.2		43	48	46		44	51				46	2.9	6.2%
I96/W/92.4													
I96/W/93.22													
I96/W/93.29	70	68	62			65	69				66	2.7	4.1%
I96/W/93.31													
I96/W/93.32	55	53	54	52		52	54				53	0.9	1.7%
I96/W/94.14													
I96/W/94.15	58	57	54	58		55	51				55	2.4	4.5%
I96/W/95.14	50	44	54	55		57	56				53	4.7	8.8%
I96/W/95.15													
I96/W/95.16	58	52	56	58		60	60				57	3.0	5.2%
I96/W/96.3	54	56	57	58		56					57	0.8	1.5%
I96/W/96.4	50	50				50	51						
I96/W/96.6	50	52	51			58	60				55	3.8	6.9%
0													
0													
0													
0													
0													
0													
	50.5	51.4	53	53.4	56.3	53.1	53.4				--------	--------	---------
	15	27	21	15	4	28	17				53	2.6	4.9%