Portable Bench Tester for
Piezo Weigh-In-Motion Equipment
Final Report

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Introduction

Statement of the Problem

State governments conduct traffic monitoring for many reasons, and Weigh-in-Motion (WIM) is an effective tool used to collect traffic and truck weight data. WIM equipment provides highway managers and planners with traffic volume and classification data by time of day and day of week and with loadings that heavy vehicles place on pavements and bridges. Planners can use the data to reduce queues, congestion, and lane changes as well as increase vehicle throughput. Motor vehicle enforcement officers use heavy truck axle load data to plan enforcement activities, and can reduce the number of violators missed because of facility closing. The data collected may also be used for legislative and regulatory issues.

Ohio Department of Transportation (ODOT) utilizes Automated Traffic Recorders (ATR) and piezo WIM devices to collect highway traffic vehicle count, class, and weight data, which is used to support funding proposals and highway maintenance decisions. The Federal Highway Administration (FHWA) requires each state to test their highway traffic data collection equipment (Ref: 23 CFR Parts 500.203 & 500.204) on a regular basis. Further, the regulation states that only equipment passing the test procedures may be used for the collection of data for projects funded by FHWA. Federal regulations also call for specific consideration of freight in the development of the ODOT plans and programs as a condition of federal funding.

The ODOT piezo WIM equipment must be tested for initial working operation and to insure continued correct operation. At this time, the only available method to verify the vehicle classification parameters of the piezo WIM equipment is field-testing. Field-testing requires either duplicate WIM equipment and sensor installations or a single sensor installation site coupled with manual counts to provide the basis for evaluation of the device under test. Both the duplicate equipment and the manual counting methods are expensive, time intensive, and expose the field personnel to roadway hazards. Manual counting may also introduce human error, and provides no basis of

evaluation for the weighing accuracy of the device under test.

ODOT tests their traffic recorders and classifiers with an automated bench-top tester, the ATSI ATRT-1700. This automated tester saves costs and eliminates the roadway hazards to the field personnel. However, the ATRT-1700 lacks the capability for testing piezo WIM equipment.

Research Approach

The piezo WIM installation consists of two major components: 1) the in-pavement sensors and field wiring, and 2) the WIM signal receiver and data processing device (hereinafter: WIM equipment or WIM device). The in-pavement sensors are not serviceable. They are either functional, marginal, or failed. Marginal and failed sensors are simply replaced. Due to the installation process and other variables, the signal characteristics obtained from the sensors lie within a range. The WIM device processes the signals and makes allowances for the variances in signal characteristics to give a repeatable computed weight estimate for each vehicle that crosses the sensor array.

Of these two major components, only the WIM device can be readily exchanged or adjusted to improve the recording performance at a given WIM site. Developing a WIM Tester that evaluates the WIM device performance is the focus of this project. The WIM Tester is designed to duplicate the signal sent from the sensor to the WIM device in a highly repeatable fashion. The signal can be manually manipulated by the user to reproduce a normal signal sequence or an unusual signal sequence to evaluate the WIM device response. This testing capability will allow the user to compare the responses of several different WIM devices to identify failed units or compare the relative performance of various makes or models of WIM equipment. This capability is new to the industry and should lead to a new level of reliability in WIM data for the user.

The key development is to accurately and repeatably reproduce the desired WIM

piezo output signal. The first task is to carefully characterize the signal, then design circuitry that will mirror the signal in an adjustable and repeatable fashion. Once these objectives have been achieved, the hardware is built around the new circuitry, and the PC application is developed to allow the user a productive method of utilizing the system and the results of the testing effort.

Research Objectives

The objectives of this project, as stated in the proposal, are to develop a bench-top WIM Tester, similar to the ATSI model ATRT-1700, that tests the counting, classification, and weighing capability and accuracy of piezo WIM devices. The tester setup method will provide flexibility and ease of use through a program which operates on a modern Microsoft Windows XP®-based PC.

The WIM Tester shall simulate up to eight lanes of simulated sensor outputs (piezo-loop-piezo). The output signals produced should allow testing of different classification schemes on piezo WIM equipment. The tester will adjust the width (time on) and the amplitude (height) of all pulses, depending on the user choice of vehicle type, axle weights, and speed. All timings and output waveforms will be accurately simulated by the tester outputs.

The tester will allow an attached piezo WIM device to receive axle waveform signals and generate an appropriate report. Signals from the tester should be able to duplicate the ranges experienced from in-road piezo sensors, by setting or adjusting the sensor output levels as the base to scale all signals appropriately. This allows for the differences in installations, and variations in piezo sensors.

The tester output impedance matches the range encompassing the typical output impedance normally associated with a 250' lead-in, 11' long piezo sensor. The goal is to

have the tester mimic the in-road characteristics of a Measurement Specialties Inc., Brass Linguini piezo sensor.

The WIM Tester shall produce waveforms that result in vehicle signatures for each of the Federal Highway Administration's 13 different vehicle classifications (Scheme F) as input by the user. The piezo WIM device should be able to determine the classification of each vehicle based on the spacing between each output waveform.

The sequence of pulses shall be automatically generated by the tester after user setup via the PC software. The tester PC software will produce a weight report at the conclusion of the test session. The report from the WIM Tester will allow the user to compare the data from the tester to the data from the piezo WIM device.

The tester will also allow user diagnostics to determine if a WIM device is recognizing and classifying a particular vehicle as expected. The user can actuate each output of the WIM Tester one at a time, to verify the operation and sensitivity of each individual WIM device input.

General Description of Research

ATSI measured the piezo signal generated at multiple ODOT WIM installations in order to properly understand the nature of the signal and how the WIM device would interpret the signal. ATSI used this knowledge to design, test, and manufacture the Bench Tester for Piezo WIM equipment as described herein.

The design emphasis is on creating a flexible testing environment and a highly repeatable signal output to meet current and future testing needs. The PC software allows the user to set up a test regimen that can includes from one to many vehicle types. The vehicle types can be picked from a pre-set library of FHWA Scheme F vehicles, or custom-designed by the user, or both. The test duration can be set up for a

few seconds to a few days. The vehicle signatures sent out to the WIM device are tracked in speed bins, to ease the comparison of test reports between the WIM Tester and the WIM device under test.

The WIM Tester was delivered to ODOT as a finished system, ready for use.

Results: Findings of the Research Effort

ATSI reviewed the available collection of data on the impedance of typical piezo sensors. ATSI also verified the impedance on a limited sample of piezo strips in the lab, and took some field samples. Table 1 (next page) is a sample of the data collected in the lab from an 11 foot Brass Linguini piezo sensor provided by ODOT. (A copy of all recorded data is available on the ATSI ftp site: ftp://atsi-tester.com/pub/wimt/.)

The data was collected using a GenRad 1689 Precision RLC Digibridge; the voltages and frequencies shown are closest to those used in the field. The relatively high Q (and low dissipation factor [D]) are partially due to the large physical size of the piezo strip, especially when compared to discrete surface mount devices.

 The engineers developed test output circuits to match the piezo impedance. Data collected   with a Tektronix TX1 Multimeter, showed typical capacitance between 12 and 15 nF. The field data was collected at ODOT WIM sites in Jackson, Marietta, and Norton, Ohio. The output circuit was developed to mimic an 11 foot BL piezo with a 250' cable length. Table 2 shows the results of the above impedance tests on the output circuit of the prototype WIM Tester.

Table 1: Lab Impedance Tests on BL CLS1 sensor serial # JBL35677

Sensor Length = 11'		Cable Length = 150'		Sensor Type = BL CLS1		C = 10.97 nF	DF = 0.0109
Voltage	Frequency	Cp	Rp	Cs	Rs	D	Q
0.250	60 Hz	10.541 nF	?	10.611 nF	0.0562 KΩ	0.0083	241.00
	120 Hz	10.575 nF	?	10.576 nF	0.6588 KΩ	0.0058	180.60
	1 kHz	10.489 nF	1883 KΩ	10.490 nF	0.1205 KΩ	0.0079	125.90
0.500	60 Hz	10.605 nF	?	10.604 nF	1.315 KΩ	0.0049	198.10
	120 Hz	10.576 nF	?	10.577 nF	0.6984 KΩ	0.0056	179.70
	1 kHz	10.489 nF	1918 KΩ	10.490 nF	0.1204 KΩ	0.0079	126.00
0.750	60 Hz	10.595 nF	?	10.601 nF	1.239 KΩ	0.0053	190.00
	120 Hz	10.574 nF	?	10.575 nF	0.7004 KΩ	0.0056	180.20
	1 kHz	10.488 nF	1902 KΩ	10.488 nF	0.1207 KΩ	0.0080	125.70
1.000	60 Hz	10.603 nF	?	10.604 nF	1.249 KΩ	0.0050	191.80
	120 Hz	10.577 nF	?	10.578 nF	0.6957 KΩ	0.0056	180.00
	1 kHz	10.493 nF	1905 KΩ	10.491 nF	0.1200 KΩ	0.0079	126.40
1.275	60 Hz	10.607 nF	?	10.604 nF	1.282 KΩ	0.0051	195.30
	120 Hz	10.577 nF	?	10.577 nF	0.6984 KΩ	0.0056	179.50
	1 kHz	10.492 nF	1902 KΩ	10.490 nF	0.1206 KΩ	0.0079	126.00

Table 1

Abbreviations for Table 1 and Table 2:

Cp = equivalent parallel capacitance of the piezo sensor

Rp = equivalent parallel resistance of the piezo sensor

Cs = equivalent series capacitance of the piezo sensor

Cs = equivalent series resistance of the piezo sensor

D = dissipation factor of the piezo sensor (see Appendix A)

Q = quality factor of the piezo sensor (see Appendix A)

V = Volts: Unit measure of voltage

F = Farad: Unit measure of capacitance

Hz = Hertz: Unit measure of frequency

Ω(omega) = Ohm: Unit measure of resistance

Small circuits were prototyped to test the output signal characteristics of the WIM

unit(s) provided by ODOT. Figures 1 and 2 show actual data collected.

Table 2: Lab Impedance Tests on WIMT-7000 Output Circuit

| Sensor Length = 11'	Cable Length = 250'			Sensor Type = WIMT		C = 15.0 nF	DF = 0.0100
Voltage	Frequency	Cp	Rp	Cs	Rs	D	Q
0.250	60 Hz	15.063 nF	?	15.082 nF	1.995 KΩ	0.0104	96.12
	120 Hz	14.845 nF	8334 KΩ	14.828 nF	0.945 KΩ	0.0105	95.50
	1 kHz	14.709 nF	550 KΩ	14.735 nF	0.2137 KΩ	0.0199	50.70
0.500	60 Hz	15.245 nF	?	15.265 nF	0.3507 KΩ	0.0166	60.87
	120 Hz	14.992 nF	7279 KΩ	15.004 nF	1.080 KΩ	0.0123	81.60
	1 kHz	14.940 nF	487.6 KΩ	14.960 nF	0.2370 KΩ	0.0223	44.91
0.750	60 Hz	15.398 nF	?	15.393 nF	2.573 KΩ	0.0153	67.01
	120 Hz	15.243 nF	6042 KΩ	15.246 nF	1.253 KΩ	0.0144	69.50
	1 kHz	15.179 nF	426.5 KΩ	15.198 nF	0.2576 KΩ	0.0245	40.71
1.000	60 Hz	15.585 nF	?	15.592 nF	2.576 KΩ	0.0151	67.50
	120 Hz	15.418 nF	5357 KΩ	15.407 nF	1.362 KΩ	0.0158	63.52
	1 kHz	15.330 nF	398.7 KΩ	15.346 nF	0.2702 KΩ	0.0260	38.48
1.275	60 Hz	15.677 nF	?	15.684 nF	2.775 KΩ	0.0164	61.55
	120 Hz	15.527 nF	5005 KΩ	15.520 nF	1.449 KΩ	0.0168	59.28
	1 kHz	15.458 nF	377.5 KΩ	15.475 nF	0.2805 KΩ	0.0272	36.72

Table 2

Piezo Output from Class 9 Vehicle
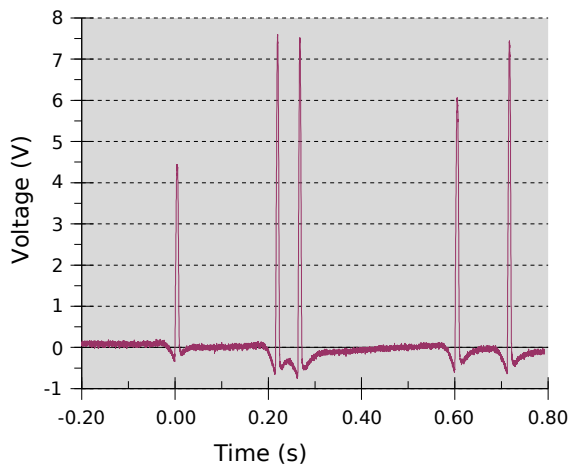
Figure 1: Vehicle 0, Jackson WIM Site
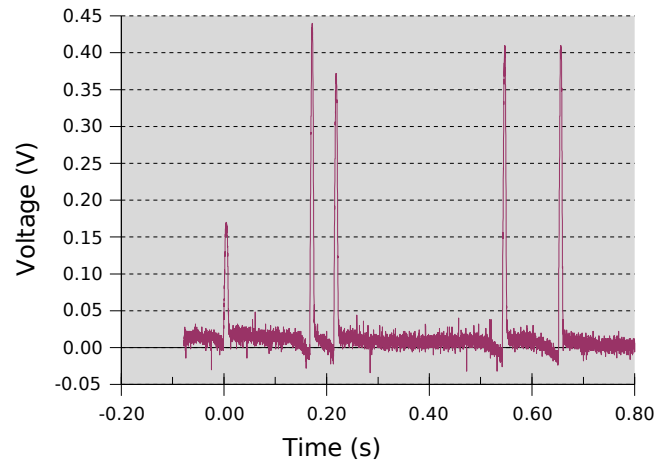

Piezo Output with ADR load from Class 9 Vehicle

Figure 2: Vehicle 6, Jackson WIM Site

The circuits tested different combinations of chips to find the closest representation of a piezo output. The output circuit was tested with a PEEK ADR for a load. The corresponding simulated data can be seen in Figures 3 and 4. The simulated data was generated by the prototype WIM Tester. The output was loaded by the oscilloscope

collecting data and by a Peek ADR WIM device where indicated. The relatively high output impedance of the piezo and the relatively low input impedance of the ADR account for the differences in the signal amplitude. These figures should help show the importance of matching the output impedances of the WIM Tester with those found in a typical piezo. Even allowing for a ten percent difference in front axle weight, the ADR loaded piezo exhibits an output signal with 25 times attenuation. The piezos tested showed varying signal attenuation between 7 and 26 times. This is attributed to the impedances of each piezo and the individual inputs of the different ADRs. The final output circuit mimics the impedances of a typical piezo and exhibits similar signal attenuation when connected to the load of a WIM device input. This can be seen in Figures 3 and 4.

The circuit largely consists of a micro-controller, digital to analog converter (DAC) digital potentiometer and assorted analog components. The system uses the DAC to construct the basic output signal. The digital potentiometer adjusts gain, and allows each channel to be individually adjusted. The analog circuitry allows the voltages to be within the desired range, and more importantly, attempted to duplicate the output impedance of the piezo.
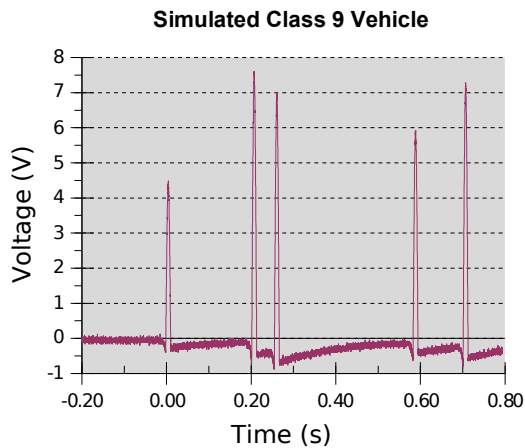
Simulated Class 9 Vehicle

Simulated Class 9 Vehicle with ADR Load

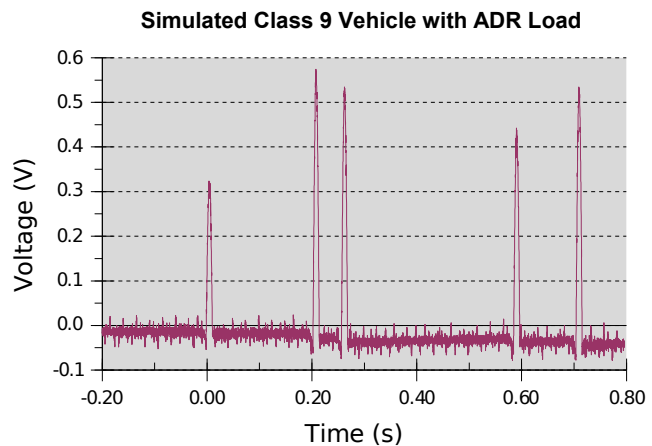*Figure 3: Vehicle 1, WIMT-7000 Simulation*

Figure 4: Vehicle 3, WIMT-7000 Simulation

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Once a satisfactory output circuit was found, the work expanded to develop the rest of the hardware design. The loop outputs were designed and added to the circuit. The communications and other necessary components were then added. All the sub circuits were independently constructed and tested. The loop simulation circuit was tested and showed improved Q over previous ATSI designs.

ATSI and ODOT discussed requirements and recommendations for the interface of the specific hardware design. The tester circuit schematic was entered using Cadence software, finishing the initial WIM Tester hardware design. The circuit was checked using the built-in electrical tests. All parts were 'placed' on the PCB then routing the traces was accomplished so the prototype printed circuit board (PCB) could be manufactured. A PCB was manufactured and assembled with the specified components. The prototype was used for firmware development as well as testing the complete integrated hardware design.

The WIM Tester firmware was developed to test the hardware on the PCB. The simulated loop and piezo outputs were tested to ensure quality of signals. The amplitude, pulse width and shape of the waveforms was measured and analyzed. The inductance changes of the loop outputs were measured and verified. This data was provided to ODOT for consideration. The outputs were then connected to a WIM vehicle classifier to test for compatibility and viability. Modifications were made to the prototype. Minor adjustments were made to components and component values and incorporated into the second version of the PCB. Firmware and hardware adjustments were made until a feasible solution was found.

A complete hardware unit was constructed. The enclosure was chosen and the panel layout designed. The enclosure was designed for easy bench top access. The unit includes power supplies and all other necessary electrical hardware. The WIM Tester

interfaces with WIM vehicle classifiers via removable Phoenix Contact style and D-sub connectors on the face of the unit. The connectors attach to cabling provided by the specific WIM device manufacturer. Additional connectors were provided to accommodate further ODOT testing requirements.

A final PCB was manufactured to include all necessary changes made to the original prototype. The circuit was tested to ensure proper working functionality. The second prototype PCB was completed, manufactured, stuffed and tested. Minor adjustments were made to component values. The boards were integrated into the enclosure, and wired for use.

ATSI developed software with ODOT review and feedback. The interface software was tested to ensure Microsoft Windows XP® compatibility, as well as upload and download of information to the tester. Total system testing was accomplished and demonstrated with the piezo WIM device supplied by ODOT at the onset of the project.

A complete WIM Tester unit was delivered to ODOT along with a full day of training.

Conclusions and Recommendations

ATSI has delivered a working bench WIM Tester and interface software capable of simulating up to eight lanes of piezo WIM (piezo-loop-piezo). The final product is known as the WIMT-7000. The tester is a tool that simulates traffic moving across WIM piezo and loop inputs. It should be used to assess the accuracy and reliability of WIM equipment. The tester can be used in various sensor layouts with up to 16 piezo and 8 loop inputs.

The WIM Tester will answer questions about the accuracy and effectiveness of current WIM data collection. This allows much more speed and flexibility in testing. Almost any imaginable vehicle can be easily simulated and repeated over multiple

channels (lanes) with little effort from the user. This work can be done while safe from all roadway hazards.

Implementation Plan

ODOT Technical Services personnel can utilize the delivered WIM Tester to verify WIM device performance and compare performance between various WIM devices. An Operating Manual is provided in Appendix B of this report to help the users become familiar with the WIM Tester.

ODOT can verify that new equipment is working properly before being used in the field. This will reduce erroneous data collection and stop faulty equipment from not collecting any data. ODOT can bench test piezo WIM devices before returning them to the manufacturer for repairs. When repaired units are later returned, the WIM Tester can verify repairs were correctly carried out. ODOT will also be able to verify the accuracy of their piezo WIM equipment in a more timely, automated fashion.

The various classification schemes can be tested without having to subject field crews to roadway hazards. ODOT can better define requirements for WIM piezos and data collection equipment. These requirements will help field technicians create acceptable values for testing existing piezos.

ODOT can verify that various WIM devices obtain the same weight results. This will help ODOT by enabling them to know that all of the WIM devices produce a result within a given tolerance. It will also enable ODOT to use different WIM device vendors and know what variables that the new equipment will introduce.

Appendix A: References and Definitions

General Reference:

Preserving Highway Infrastructure Using Weigh-In-Motion (WIM)   November 1998

> Dr. A.T. Bergan, Professor Emeritus, College of Engineering, University of Saskatchewan
>
> Norm Lindgren, Utah Department of Transportation Motor Carrier Division (Retired 1998)
>
> Dr. Curtis Berthelot, College of Engineering, University of Saskatchewan
>
> Bob Woytowich, Director, CVO Market Development, International Road Dynamics Inc.

Definitions:

Quality Factor Q: "Q is a dimensionless ratio. In essence, Quality Factor is a measure of the energy storage property of a circuit in relation to its energy dissipation property. A definition based on this concept is

> Q = 6.283(max energy stored/energy dissipated per cycle)"

From: *Circuits, Devices, and Systems Third Edition*, 1976 J. Wiley & Sons

> Dr. Ralph J. Smith, Professor of Electrical Engineering, Stanford University

Dissipation Factor D (or DF): "DF is defined as Rc/Xc, the ratio of the R in the capacitor (Rc) to the reactance of the capacitor (Xc). The higher the Rc, the higher the DF and the "poorer" the capacitor. So far so good. The reactance (Xc) is a function of frequency. Xc=1/(2*pi*f*C). So, as the frequency goes up, Xc goes down. Now look back at the formula for DF. DF is an inverse function of Xc. As Xc goes down, DF goes up, and vice-versa. So DF varies proportionately with frequency."

From: *Capacitor Testing, Safe Discharging and Other Related Information (www)*

> Author: Samuel M. Goldwasser, contributed by Michael Caplan (cy173@FreeNet.Carleton.CA)

Appendix B: Operating Manual

Introduction

This manual is written to give a new user of the WIM Tester (as delivered to ODOT) a basic familiarity with the system.

This manual does not cover the operation of the user's WIM device. The manual assumes the user is proficient at the setup and operation of the WIM device under test. The new user should read the development project report prior to reading this manual: *Portable Bench Tester for Piezo Weigh-In-Motion Equipment, Final Report,* August 2005, Ohio Department of Transportation. The Final Report explains what is tested and how it is tested, and contains important information for the user.

Operation of the WIM Tester requires the use of a Microsoft Windows XP-based Personal Computer (PC) with one RS232 9-pin serial port and a CDROM drive (for software installation). This manual does not cover the operation of a Microsoft Windows XP-based PC. The user is should contact their System Administrator to learn the use of the PC and installation of software.

The WIM Tester consists of the tester hardware (shown above) interface cables to

connect the hardware to the WIM device and PC, and a CDROM with the PC application software.

Getting Started

Find a suitable working location for the WIM Tester, the WIM device to be tested, and with access to a Windows XP computer. Connect the WIM Tester to 115 VAC power via the IEC cord connector and cord, and to the Windows XP computer via 9-pin serial data cable and 9-pin front panel connector. Using the proper cables, connect the WIM Tester to the WIM device and make sure the WIM device has a power source and is turned on.

One of the first steps is to install the application software onto a suitable Microsoft Windows XP-based personal computer. The installation is just like any other Windows software installation, and is mostly automatic.

Maintenance and Support

The WIM Tester does not require any maintenance. If problems are encountered, and the user checks the WIM Device under test, the host PC, the interface cables, and suspects the WIM Tester is causing problems, first try checking the fuse on the front panel. If the fuse has failed, replace it with a new 2 Amp 3AG fuse and try the tester again. Further telephone technical support can be obtained from ATSI:

Athens Technical Specialists, Inc. (ATSI)

8157 US Route 50

Athens, OH 45701

(740) 592-2874

email: service@atsi-tester.com

Setup and Operation

After installation of the software, click on the icon for the WIM Tester software which is displayed on the Windows Desktop. This will start the software and display the first window, as shown below.

Aside from the obvious entries, the sensor array information must be know and match up with the settings programmed into the WIM device. After establishing these settings, click on the tabs across the top of the window to move to the next window. The "Test" window actually starts the test session, and is the last window the user

should use, after verifying all the other setup parameters are correct.

The "Vehicle Select" window is shown below. This is where the user selects which vehicles are going to be simulated during the test session.
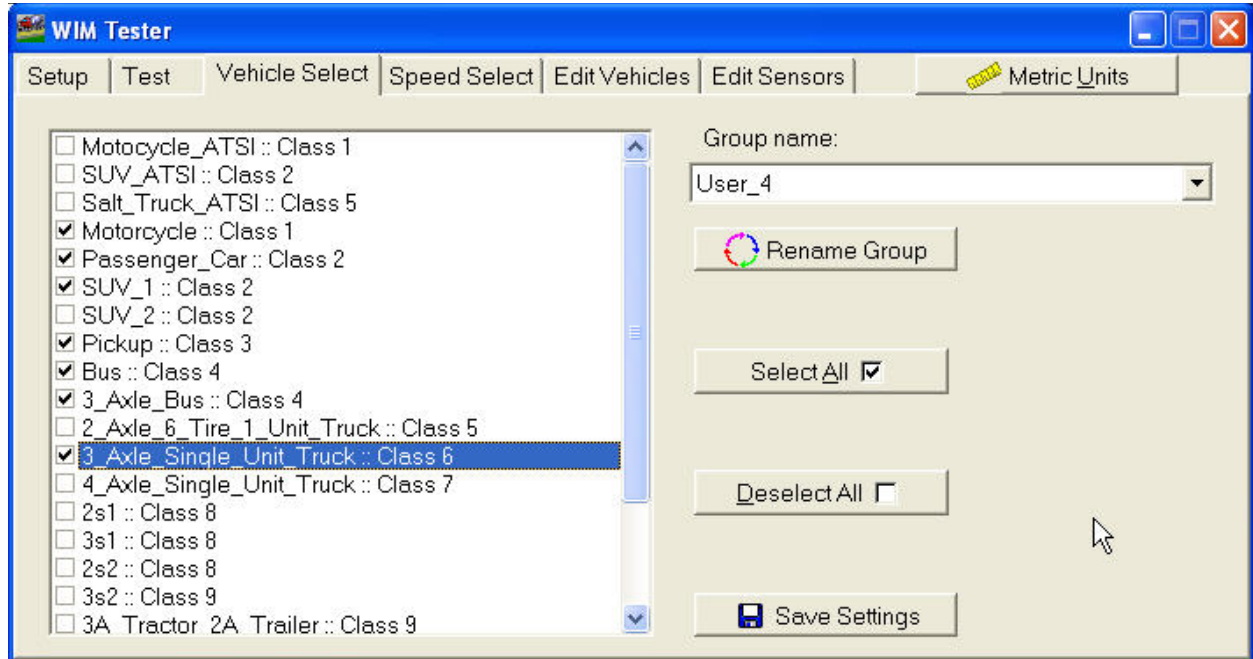
Vehicle Select Window:
Drop down fields
- Group Name – There are 31 available groups. The group name can be modified from the default "User_1,2,3,etc." by clicking the "Rename User Group" button.

Buttons
- Rename Group – Opens a window with a field for typing the new name. Has an "OK" and a "Cancel" button on the window.
- Select All – Will check mark all boxes for the available vehicles shown on the left.
- De-Select All
- Save Settings – A window appears asking "Do you want to save the selected vehicles as the vehicle group indicated?" If Yes, the group is auto-saved to the appropriate folder. If No, the window closes to allow user to re-name the group.

Check Boxes
- One for each available vehicle. (These vehicles are created under the Edit Vehicles tab)

The list shows all the vehicles available for the session, and the selected vehicles are checked in the selection box as shown. A user-selected group can be saved in one of 30 Groups on the right side of this window. If a "standard" test pattern is desired, a group (or groups) should be created with the standard selection of vehicles. The user can create new vehicle descriptions to be added to the list on the left by opening the "Edit

Vehicles" window, shown below.
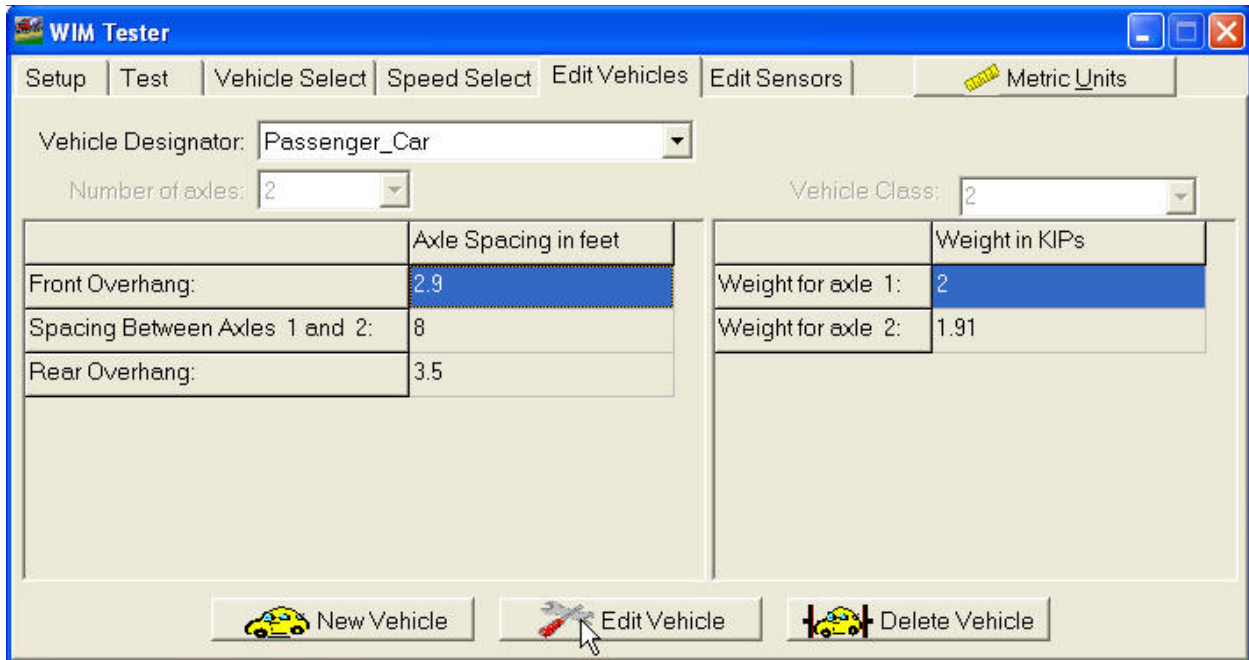
Edit Vehicles Window:
Drop down fields
- Vehicle Designator – All vehicles available under the "Vehicle Select" tab.
- Number of Axles – Number and drop down arrow are grayed out. The number will change to match the vehicle being selected from the Vehicle Designator drop down list.
- Vehicle Class – Same as Number of Axles drop down.

Buttons
- New Vehicle- Allows user to create new vehicle from a blank form
- Edit Vehicle – Allows user to change the Number of Axles and the Vehicle Class drop down fields. It will also allow the user to change the Axle Spacing and Weight
- Delete Vehicle – This button changes to "Discard Entry" when in edit vehicle mode.

The WIM Tester software comes with a series of pre-defined vehicles, which should

be reviewed by the user for appropriate settings. Clicking the "Edit Vehicle" button

allows the user to change the settings, shown below.

Editing is similar to editing in any Windows application. After editing a vehicle,

there will be a popup dialog box asking you to confirm or discard the changes to the

vehicle signature. This window is only needed if revisions to the vehicles or new

vehicles are needed for a specific test session. This window can be skipped if the

standard vehicles will suffice.
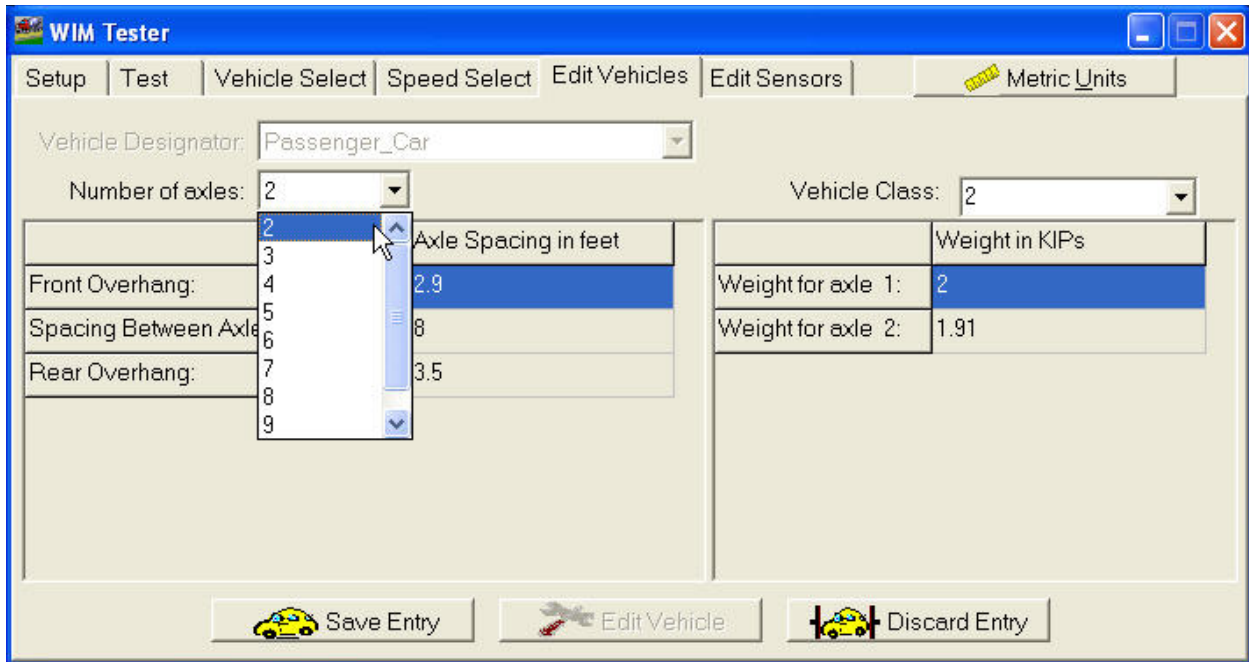
All the other adjustments are made by using the Tab key to move the cursor from one field to the next and typing in new values for overhang and spacing between axles, etc. After making the changes needed, click the Save button.

The "Metric Units" button at the top right of the main window automatically changes every unit in the system to metric without changing any settings. 3.28 feet becomes 1 Meter, 2.2 KIPS becomes 1000 KG, etc. The units change, but the values remain the same.

The next logical step is to confirm the speed bins for reporting the census of vehicle signatures generated by the WIM Tester. The user should know how the speed bins and other setup parameters in the WIM device have been set, so to make sure these settings are matched up. This matching of the setup is very important to allow the test reports from each unit to be compared following the test session. Open the "Speed Select" window to adjust the speed bin settings, as shown below.
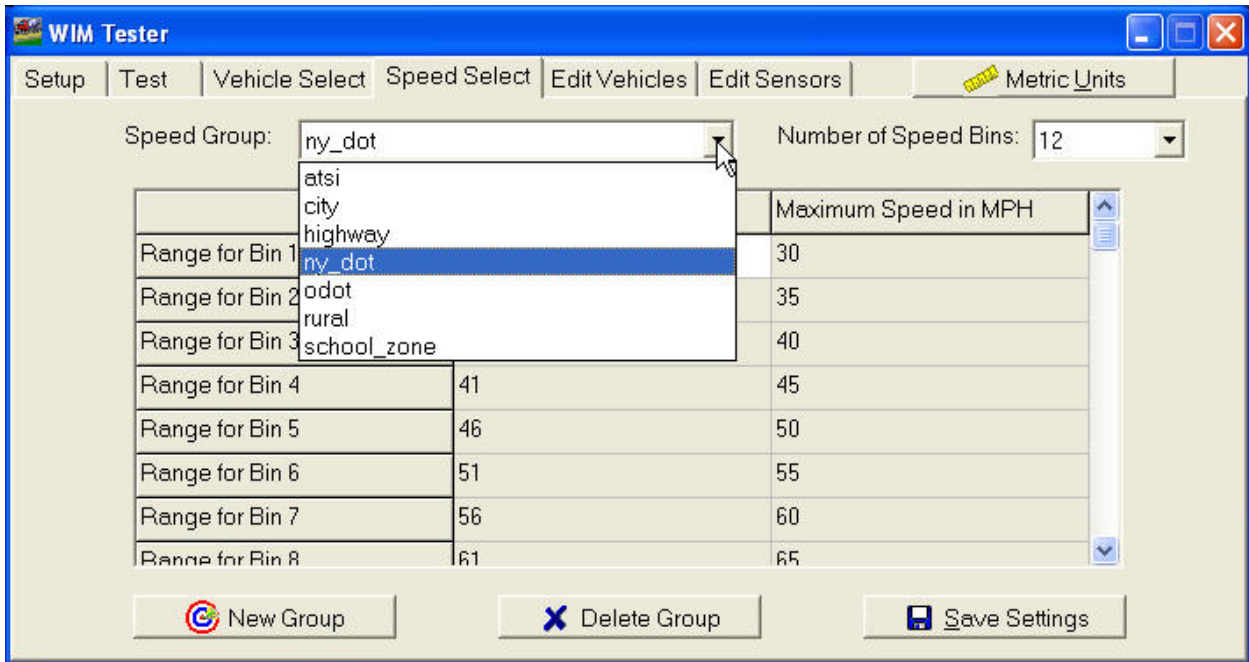
Speed Select Window:

- Drop down fields
- Speed Group - All available groups are selectable.
- Number of Speed Bins – From 1 to 16 bins are selectable.

User Input Fields

- Maximum Speed in MPH – One field for each bin (can be changed to Metric by clicking the "Metric Units" button)
- Minimum Speed in MPH – One field for each bin

Buttons

- New Group: Allows user to establish a new group starting from the displayed group settings. Use Tab key to edit.
- Delete Group: Erases the currently selected group
- Save Settings: Allows user to save edits

Several pre-established speed bin groups are already in the WIM Tester software, and they can be modified by the user and saved under a new name to suit the need at hand. Once this is done, you need to adjust the sensor output levels to simulate a new or weakened sensor array. Remember, the objective is to test the performance of the WIM recording device, so it makes sense to try it out under less-than-perfect conditions.

The WIM Tester allows total control over the signal strengths for each channel of output. Open the "Edit Sensors" window to make the adjustments as shown below.
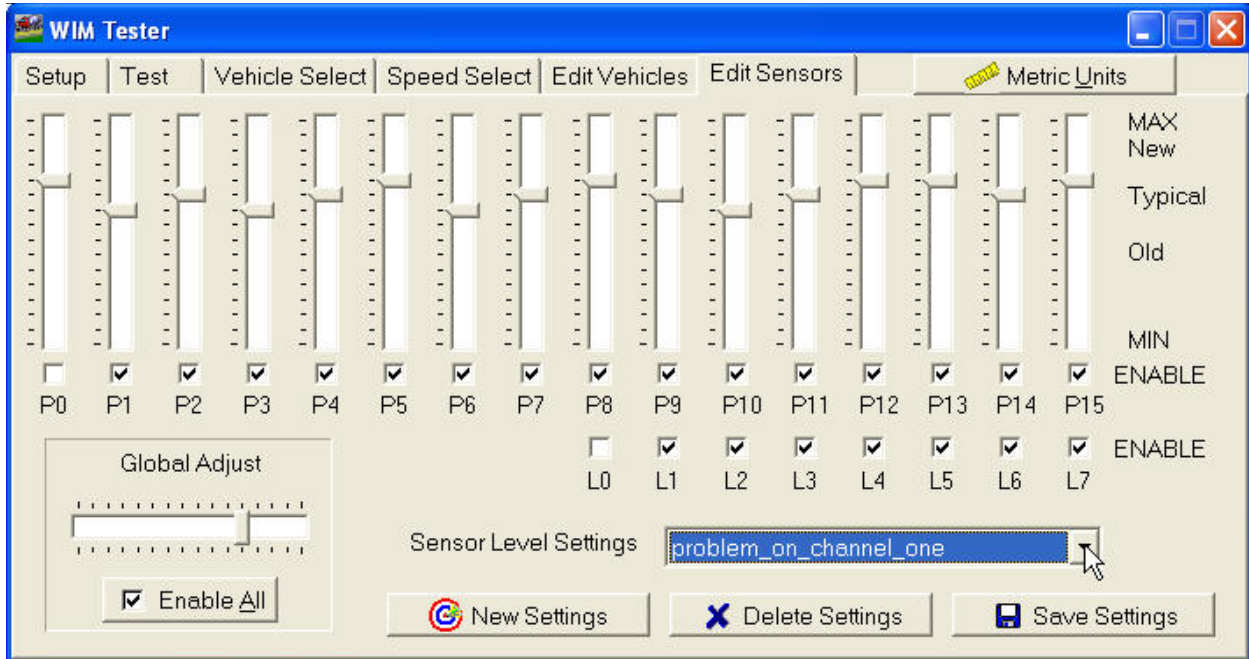
Edit Sensors Window:

Drop down fields
- Sensor Level Settings — All available sensor settings are listed

Buttons
- Enable All - Will check mark all boxes.
- New Settings — Allows the creation of a new group of settings
- Delete Settings — Deletes a group of settings
- Save Settings — Saves the group that is created

Check Boxes
- 16 Piezo check boxes.(Labeled "P0" to "P15")
- 8 Inductive Loop check boxes. (Labeled "L0" to "L7")

Slide Bars
- One for each piezo. There are 16 levels for each, broken down into 4 categories: "New", "Typical", "Old" and "MIN".
- Global Adjust — Moves all of the slide bars for the piezos in unison. When this slide bar is clicked, all of the piezo slide bars will move to whatever level the Global Adjust slide bar is on currently.

   As with all other setting windows, this window allows the user to save special settings as a named group for recall and later use. The group shown above simulates a failed piezo sensor and a failed loop sensor in the first array, by simply turning the outputs off in this window. This simulates a broken lead-in wire, but you could simulate a weak output by sliding down the signal strength, like using an equalizer on a

stereo receiver.

The sensor setting shown below simulates a new 4-lane site with one very weak piezo strip in array number 2. This was achieved by selecting a new 4-lane sensor group, and then turning down the signal strength on only one sensor. Whatever is shown on this window when the test session begins is what the WIM Tester will use to create signatures for the WIM device.
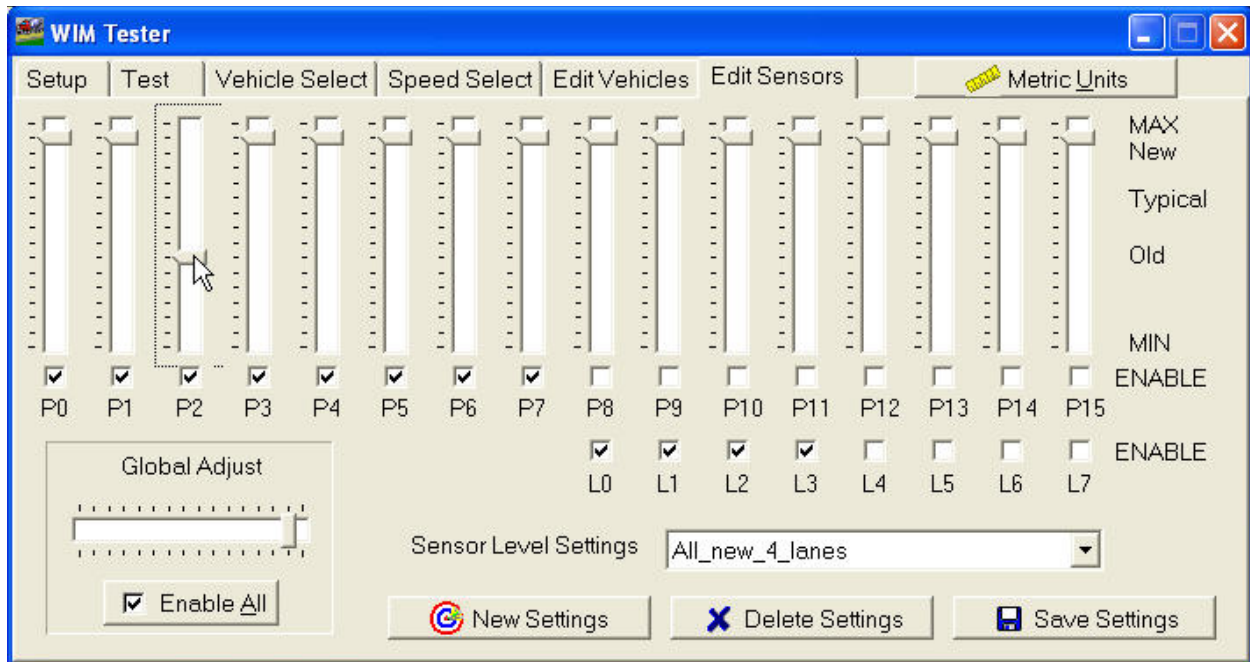
Once the settings are established for the test session, and checked against the settings in the WIM device to be tested, make sure the WIM Tester and WIM device are on and ready to record, and the interface cables are in place. The user should now select the "Test" window as shown on the next page. This window allows the user to verify all the selected variable groups that will be used for the test session, determine the length of the test session, and start the session. The Minimum Interval establishes the minimum amount of time between vehicle signatures being generated by the WIM Tester. From this window the user can change the Speed or Vehicle Group being used for the test. The Sensor Setting Group can also be changed. To run the calibration

routine on the WIM device, the user can run a small sample of vehicle signatures into the WIM device by clicking the Calibrate button.
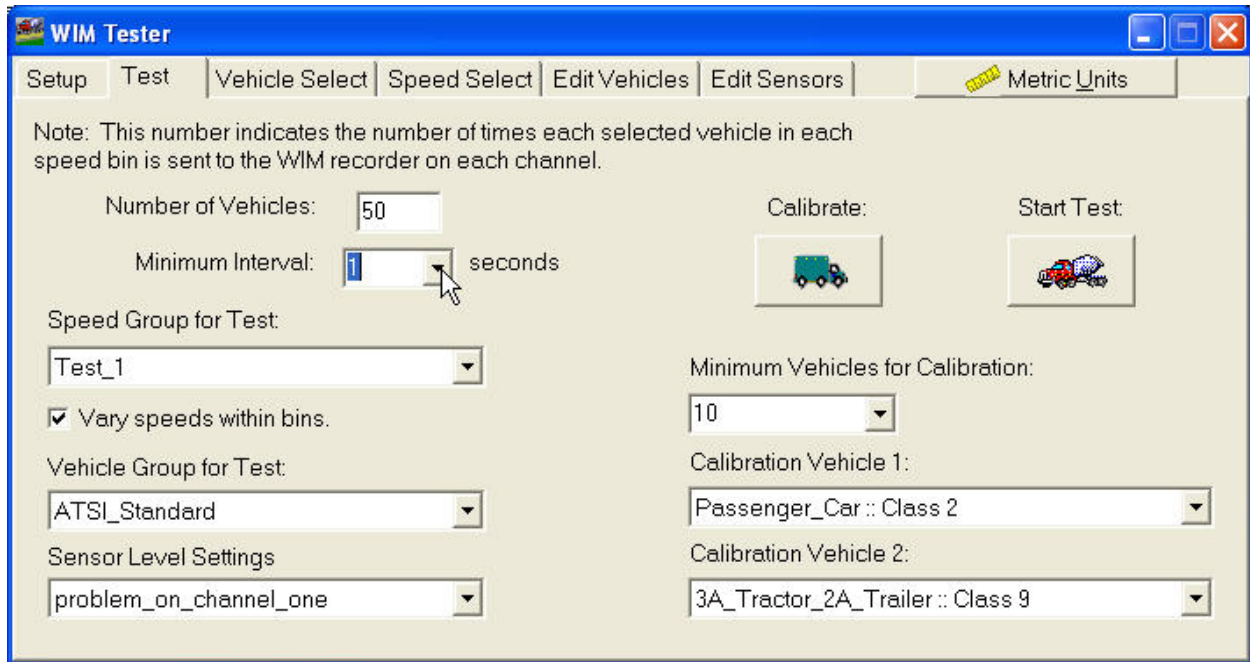
Test Window:

Drop down fields
- Minimum Interval – From 0 to 9 seconds are selectable.
- Speed Group for Test – All available groups are selectable. (Groups are created under the Speed Select tab)
- Vehicle group for Test - All available groups are selectable. (Groups are created under the Vehicle Select Tab. There are a total of 31 groups possible)
- Sensor Level Settings – All available settings are selectable. (settings are created under the Edit Sensors tab)
- Minimum Vehicles for Calibration- 10 to 100 vehicles are available in multiples of 10. the user can also input an amount.
- Calibration Vehicle 1, Calibration Vehicle 2 – All available vehicles listed under the Vehicle Select tab are selectable.

Buttons
- Calibrate – Starts the calibration process
- Start Test – Opens the Test window. (this looks like the ATRT Test window) The buttons include: "Minimize" (will minimize all WIMT windows), "Auto Start" (starts test at the time shown to left. If the time has already past, user will be asked if the test should start now), "Start Now" and "Abort". The bottom half of the window shows the data for the current vehicle being sent. At the completion of the test, the WIMT and WIM reports need to be saved. The user must compare the WIMT report of what was sent, to the WIM report of what was recorded.

Check Boxes
- Vary Speed Within Bins – Check this box to get various speeds within the range of each speed bin

To start the Test session, the user clicks the Start Test button. The test session will send the Number of Vehicles shown on the left side (adjustable by the user) times the

number of vehicles in the selected Vehicle Group, times the number of Speed bins in the Speed Group, times the number of sensor arrays defined in the Sensor Level Settings Group.

Example:

- 4 Vehicles are used

- 2 Speed Bins are used

- 4 Sensor arrays are used

- Number of Vehicles = 20

- Minimum Interval = 1 second

Result: 160 vehicle signatures will be sent across each of 4 arrays for a total of 640 vehicles for the test session. A test session like this should last around 960 seconds, or 16 minutes, if the vehicles are being simulated at highway speeds.

The checkbox labeled "Vary Speed Within Bins" will cause the vehicle speeds to change slightly with the range of each speed bin. If this is not checked, all vehicles will be generated at the median speed of each speed bin. That is, if Speed Bin 1 is from10 to 30 mph, all the vehicle signatures will be set for 20 mph (median speed) for Speed Bin 1.

After the test is completed, a window will appear that prompts the user to select the report format for the results of the test session. The user should try the different report formats and use the one that best meets their needs.