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" Automated Mass Calibration and Measurement Control Program " *

By: John P. Clark and Joel Jones

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

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INTRODUCTION

Mass and weight standards calibration costs have been reduced by 50% and the measurement quality improved at the Department of Energy's Savannah River Site's (SRS) Savannah River Standard's Laboratory (SRSL). This was accomplished by automating calibration procedures, upgrading equipment, obtaining National Institute of Standards and Technology (NIST) Office of Weights & Measures training and integrating measurement controls in the calibration program for the site's 5000 weights or sets. All of the balances have been replaced with electronic mass comparators. SRS has developed a Mass Automation Program that has been integrated into its mass calibration process. This paper discusses the past, present, and future of the SRSL mass calibration process with emphasis on the new *Mass Automation Program*.

Figure 1. Mass Lab 1997 after First Automation

PAST

Prior to the 1990's mass calibrations were performed with mechanical and hybrid mechanical/electronic weighing systems. All measurements were manually recorded on work sheets and calculated back at the desk. In the 1990's many of the mechanical balances such as the Volland Jupiter™ 5,000 were replaced with Mettler balances that could be interfaced to a computer through a manual Black Box™ serial switch. Excel™ spreadsheet templates were developed to guide the technicians through the calibration procedure. Mettler Balance Link ™ software was used to import the data through the Black Box interface into the spreadsheet. The spreadsheet performed standards and uncertainty lookup and all calculations. Figure 1 shows the first automated system. The first program was limited to 3 electronic balances that weighed mass standards from 1-mg to 2-kg.

The spreadsheet programs were based on NBS HB 145 procedures; SOP 4 & 6 “Recommended Standard Operations Procedure for Weighing by Double (SOP 4) or Single (SOP 6) substitution Using a Single – Mechanical Balance, Full Electronic Balance, or a Balance with Digital indications and Build-in-Weights”[i].

The laboratory had one Class-S set of mass standards that was used for all calibrations. Many of the weights saw double duty as sensitivity weights in the double substitution mass calibrations. The SRSL’s quality assurance programs were limited to periodic performance testing for the DOE’s primary standards laboratory. The system was not user friendly and required frequent technical support. When support was unavailable, data entry had to be done manually. The system required manual input of the environmental conditions at time of calibration for air buoyancy corrections. Calibration of all masses above 2 kg also had to be manually entered into the computer. The average time spent in calibration, records and logistics averaged an hour per weight.

Training of laboratory personnel at the NIST Office of Weights and Measures (OWM) metrology classes provided valuable information concerning current technology, good laboratory practices, procedures and the fundamentals of good technique in calibrating mass standards.

This training helped identify several opportunities for improvement. These included buying 1 piece OIML E2 weights for use as the primary standards. Implementation of a process measurement assurance program that uses independent 1 piece mass standards having European traceable calibrations for check standards that are calibrated routinely to monitor the quality of the mass calibration procedures.

PRESENT

System Overview

The new *Mass Automation Program* is a custom application written by SRS using National Instruments LabVIEW, which is a graphical programming language for building instrumentation systems. The program runs on a Dell PC running Microsoft Windows 98.   A Microsoft Access database has been developed to store information on metrologist, standards, balances, and to store all calibration data. A wireless keyboard is used to operate the program so that the metrologist does not have to move back and forth from the balance to the PC while performing a calibration. Large fonts are used so that the program screens and prompts can be read from any balance in the mass lab. Figure 2 above shows the current laboratory configuration with the new automation system in the mass laboratory.

Figure 2. Current Configuration

The new mass program communicates with several balances, a Vaisala Barometric Pressure Gauge, and a Vaisala Temperature and Relative Humidity Gauge through RS232 serial communications ports and a Black Box smart switch. Figure 3 shows a block diagram of the new mass lab set-up.

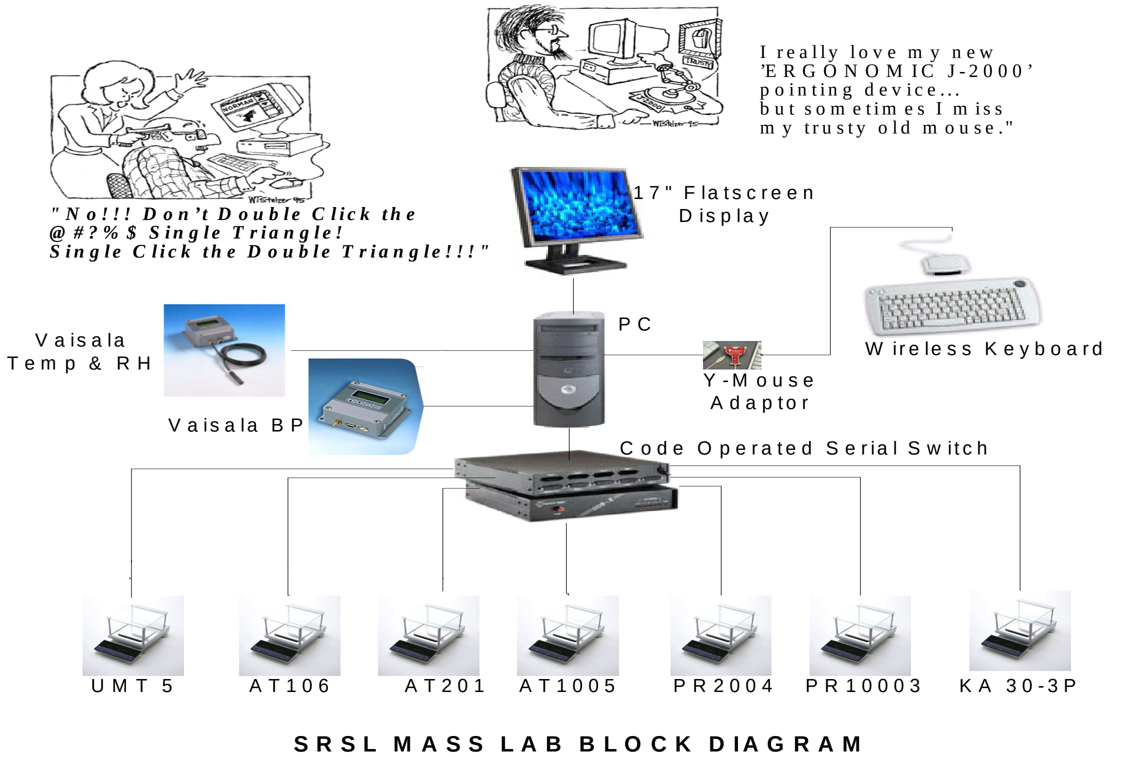

Figure 3. Block Diagram for New Set-up

Mass Automation Program Main Screen

When the *Wt Cal* program icon is selected the *Mass Automation Program* main screen is displayed (See Figure 4 below).

The data fields are initialized with the last weight set to be calibrated. The user has the option to continue working with the current set, select a previous set, or enter in information for a new set. The user can also choose to do a new calibration on a previously calibrated set. If this option is chosen the program automatically fills in all of the appropriate information into the data fields. The user simply verifies the information and begins the calibration. This feature has greatly reduced the time required to perform subsequent calibrations on sets already in the database.

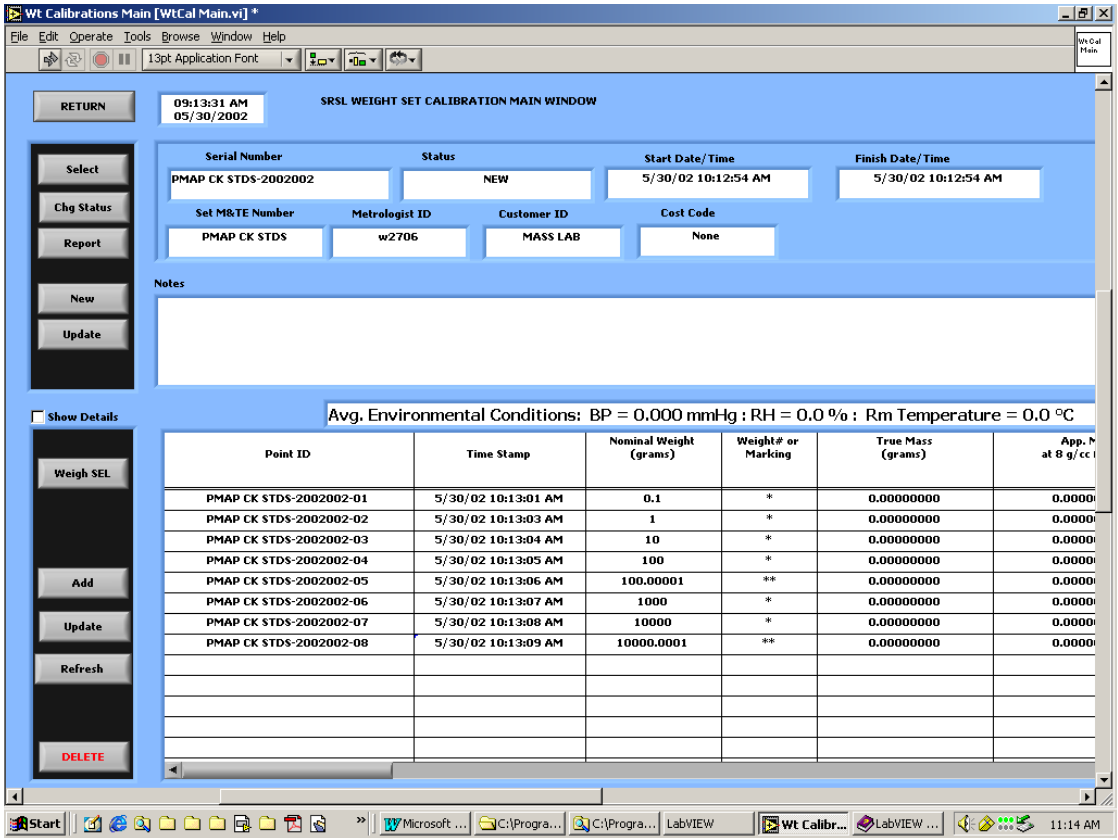

Figure 4. Weight Set Calibration Main Screen

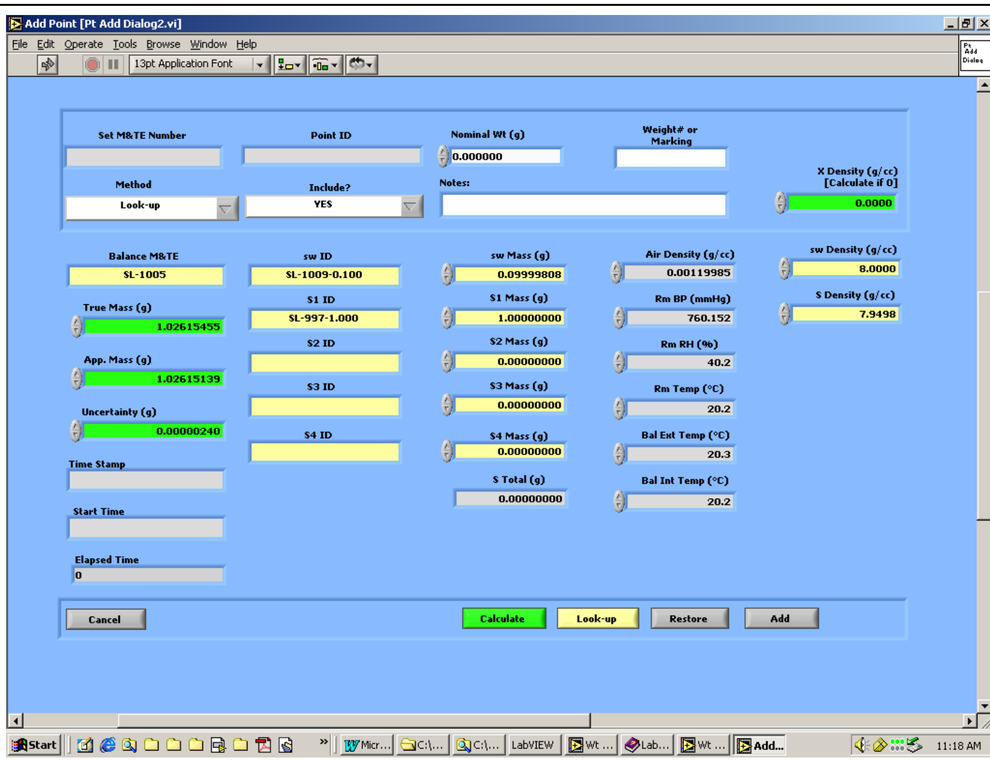

Figure 5. Add Point Screen

The program allows the user to enter in a variable number of weights for each set. When the user chooses to *add* a new weight to a set, the Add Point screen is displayed (See Figure 5).

Add Point Screen

The user enters the weight information on the Add Point Screen. He/she enters the nominal weight in grams of the new weight. The program uses the nominal weight to select the method, balance, sensitivity weight and standards to use for the calibration. The user can also override any of the automatic choices made by the program. The current methods available are Single Substitution, Double Substitution, and Comparison. Up to four standards can be stacked to perform calibration of a weight. After the weight information is entered the user returns to the main screen.

On the Weight Set Calibration Main Screen, the user can chose to calibrate that weight or the user can enter the information for another weight in the set. When the user is ready to calibrate a weight, he/she selects the weight(s) to be calibrated and the program guides him/her through the weighing process.

Weighing Screens

After the user selects the weights to be weighed and selects the measure option a series of screens guides him/her through the calibration of the weight based on the method selected for each weight. If the *Show Details* option is selected the Weigh X Using *method name* screen is displayed (See Figure 6 below).

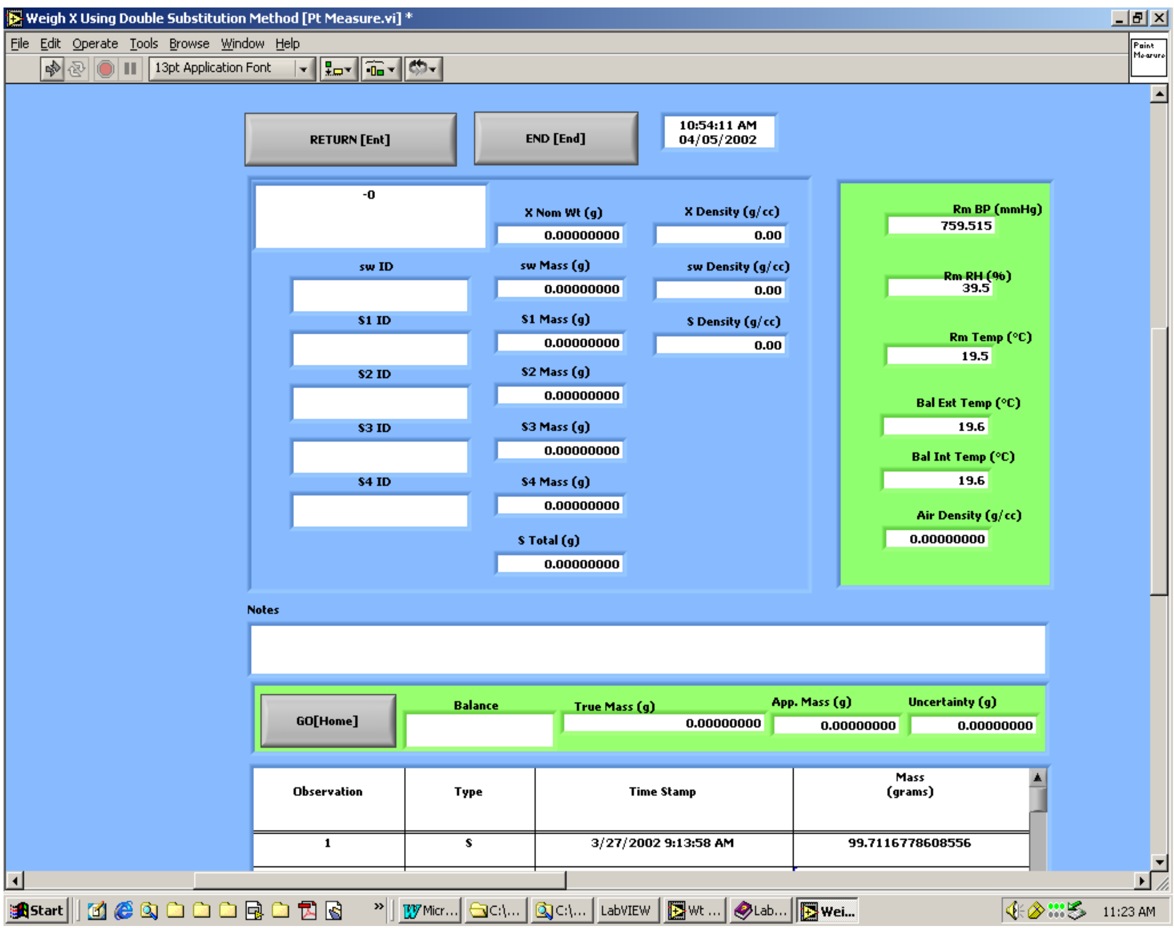

Figure 6. Weigh X Using Double Substitution Method Screen

The user can review the weight information prior to weighing. When he/she is ready, the ***GO*** button is selected and the weighing process begins. The program automatically switches the Black Box™ switch to the correct balance and displays instructions to the user (See Figure 7).

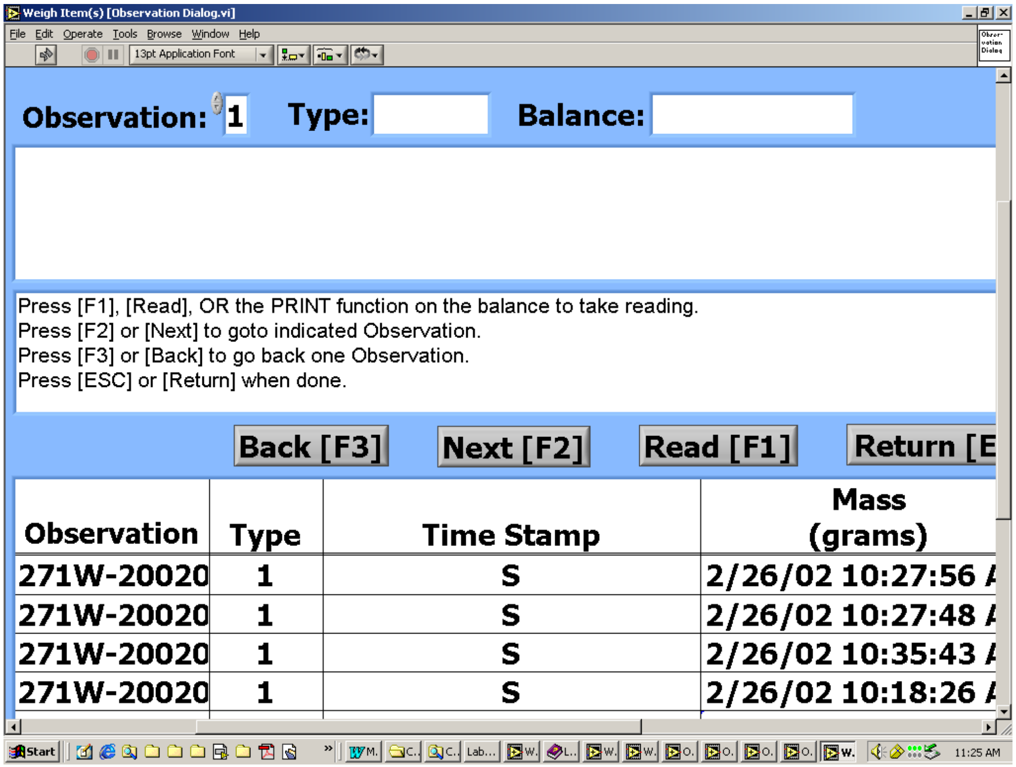

Figure 7. Weigh Items Screen

Environmental conditions are automatically monitored and logged. The user presses a button on the electronic mass comparator to send the measurement for the current observation to the program where it is read, displayed, and logged. The program makes real-time checks on things such as the addition and removal of the sensitivity weight. The program warns the user if it thinks a mistake has been made. This allows the user to immediately correct the condition, eliminating the need to recalibrate the weight, as is the case when the mistake is found in the review process. Once the user is finished calibrating the current weight, he/she can continue with the rest of the weights in the set edit the current weight or continue with the rest of the weights in the set.

Reports

Once the entire set has been calibrated, the user selects the ***Report*** option on the main screen to generate a Microsoft Word calibration report. The report is reviewed by a trained metrologist/statistician who checks the measurement and uncertainty data prior to acceptance of the calibration.

Database

A Microsoft Access database was created for storing and retrieving weight set calibration records. This allows the program to default much of the required information for a given weight set once the set has been calibrated the first time. This saves a significant amount of time for subsequent calibrations. The database also facilitates historical viewing and analysis. This capability is an integral part of the Process Measurement Assurance Program in the SRSL.

PMAP

The SRSL is developing a comprehensive Process Measurement Assurance Program (PMAP) for mass calibrations. Personnel have obtained excellent training from the Office of Weights and Measures of the National Institute of Standards and Technology. The training covered procedures for calibrating mass standards and covered all of the parameters that affect the quality of measurements. Annual retraining is offered through regional meetings of state and industrial metrology laboratories. Round robins are conducted under the supervision of the OWM, which provide proficiency testing that provides objective evidence of measurement capability. These tests have identified areas for corrective action.

The procurement of new one-piece mass standards has permitted determination of their actual density that reduces the associated uncertainty of their calibrations. Additional one-piece sensitivity weights and check standards were purchased for calibrations and measurement control. Most of the new mass comparators are capable of measuring to one more significant decimal place than their predecessors could measure. The new balances all have bi-directional communication capabilities that have been utilized in the automation program.

Currently the automation program assists with measurement quality assurance by greatly improving the efficiency of collecting balance uncertainties via the use of check standards. This makes it possible to obtain the data used for uncertainty calculations on a more frequent basis.

The automation program has a ***Show History*** feature that displays the history and statistical data on all Weight Set Calibrations performed. Figure 8 below shows the Show History Main Screen with the Select Weight tab selected.

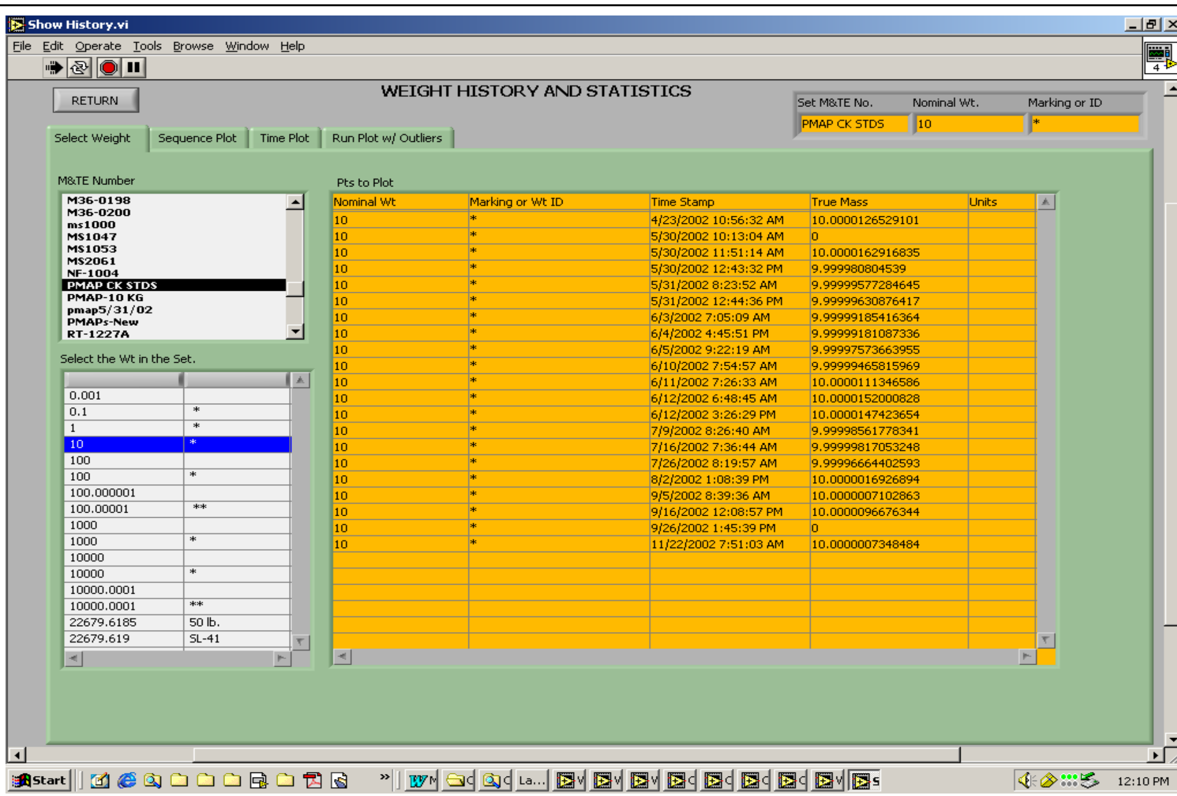

Figure 8. Show History Select Weight Option

Figure 9 below shows the Show History Main Screen with the Run Plot w/ Outliers tab selected.

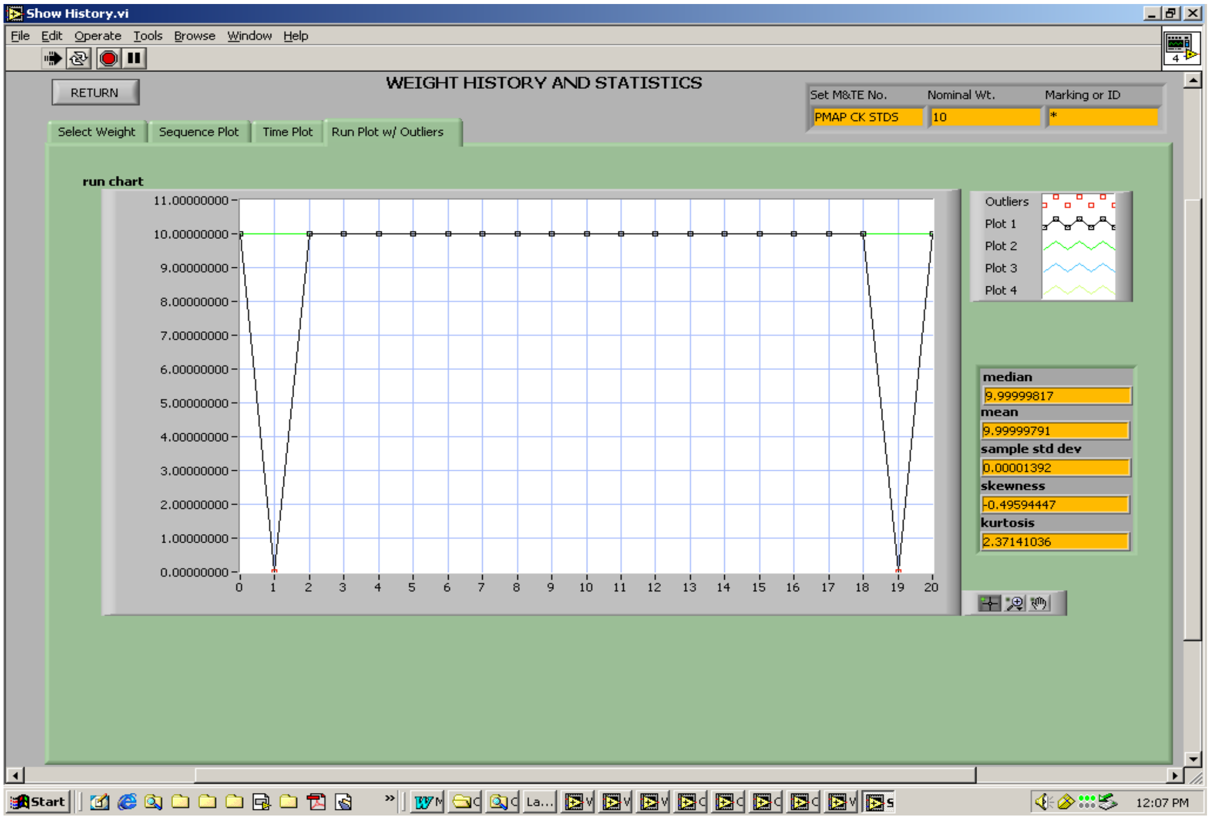

Figure 9. Show History Run Plot w/ Outliers Option

FUTURE

In the future, the Mass Automation Program will be expanded to include more real time error checking such as that used for the Sensitivity Weight. The ability to use both metric and Avoirdupois units will be added. The ability to select the set of standards to be used will be added. Additional report capabilities will be added for printing detailed calibration reports in accordance with customer requirements. PMAP reports will be added. Programmatic testing of the deviation from nominal value will facilitate determination of the tolerance class the weight meets will be added. The program will have a lockout feature that will not allow weight calibrations until PMAP standards have been run in-accordance with an established schedule. Uncertainty estimates will be automatically updated and reported as new PMAP data is obtained. Environmental alarms for out of tolerance environmental conditions will be added to stop calibration activities when procedural limits are exceeded.

Ultimately all analysis will be done real time to determine the acceptance of a weight calibration based on the tolerance level and uncertainties, eliminating the need for post analysis by a trained statistician. The immediate feedback will also allow the calibrator to check for and correct mistakes before reports are generated and reviews are performed.

CONCLUSION

This latest effort is one of the many improvements made to the Mass Calibration Laboratory over the past five years. Through training, quality procedures, state-of-the-art equipment and computer automation the

SRSL Mass Lab is providing its 100 plus customer's with calibrations having lower uncertainties at a lower cost with a shorter turnaround time. A major heating and ventilation renovation project will significantly reduce the temperature and humidity variations that are currently being experienced with a 20-year-old system. In-line HEPA filters will reduce the dust levels in the laboratory. These improvements will have a ripple affect in providing customers with accurate calibrations and good uncertainty estimates. Electronic records of past calibrations will facilitate analysis of the weight changes due to wear or contamination. Continual monitoring of performance and customer requirements will allow the SRS to plan what additional improvements will be needed to continue meeting today's high calibration standards and the emerging standards of tomorrow.

* The information contained in this paper was developed during work under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

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[i] Taylor, John K. and Oppermann, Henry V. NBS Handbook 145, Handbook for the Quality Assurance Metrological Measurements, National Bureau of Standards, Gaithersburg, MD, published 1986.