FINAL REPORT

REDESIGN OF FDOT STATE MATERIALS OFFICE (SMO) TESTING STANDARDS

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the State of Florida Department of Transportation.

SI (MODERN METRIC) CONVERSION FACTORS (FROM FHWA)

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
FORCE and PRESSURE or STRESS				
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO ENGLISH UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.(Revised March 2003)

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16. Abstract

This study was conducted to reduce transcription errors and ensure Florida Department of Transportation (FDOT) testing integrity through laboratory automation. An in-depth literature review was conducted to determine how large federal and state agencies cope with transcription errors. Results appear to indicate that these laboratories do not rely on automation as a means to reduce these errors. In the medical field, systems have been established that have been shown to reduce transcription errors. Additionally, California has set up a system to automate laboratory testing at one of their facilities. The FDOT State Materials Office (SMO) was used as a representative example of a laboratory that may benefit from automated testing. An inventory of all existing mass balances and other equipment with automation potential was prepared and mapped on detailed engineering drawings. The inventory showed that a portion of equipment at the SMO is not compatible with automation. A budget was prepared to reflect upgrade requirements. A simplified control system for a computer to read information from mass balances was programmed using LabVIEW. This setup requires RS-232 to USB conversion. Results showed that automation at the SMO is feasible. Programming such a system may be complicated by command differences from scale to scale and by different Florida Method (FM) input requirements. Using this system at other FDOT facilities is feasible, but it will add another level of complexity. Using this system for private testing is also feasible, but it may require the setup of a server drive to accommodate these testers. Testing integrity was investigated, but sufficient data were unavailable to draw any strong conclusions. To compute meaningful statistics, test sources should be catalogued for the next year.

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EXECUTIVE SUMMARY

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CHAPTER 1
INTRODUCTION

1.1 Background Statement

Currently, the Florida Department of Transportation's (FDOT's) material testing standards are such that devices' digital readouts are recorded manually, computations are conducted, and results are manually transferred to a central database. Recently, FDOT inquired as to the feasibility of improving this method so that data could be sent from testing devices directly to the database. This improvement would serve two purposes: (1) it would minimize the potential for transcription and data entry errors; and (2) it would minimize potential for inadvertent bias or other forms of testing manipulation. The result would be a more accurate and secure process.

The goal of this project was to provide FDOT guidance in terms of transferring data from a test to their Laboratory Information Management System (LIMS) while eliminating transcription errors. To complete this objective, the following tasks were completed:

1.2 In-Depth Literature Review

FDOT indicated that they wished to consult testing standards from "top laboratories" where errors cannot be tolerated. Additionally, researchers investigated the benefits of implementing a system to eliminate handwriting and transcription errors. This topic has been covered extensively in the healthcare industry. Finally, the California's Geotechnical Laboratory Data Management System (GLDMS 2007) was used as a case-study of an engineering facility that has implemented automated testing plans . This literature review is discussed in detail in Chapter 2.

1.3 In-House Testing

FDOT's State Materials Office (SMO) was used as a representative example of a facility that could benefit from laboratory automation. As per discussions with the Project Manager, the facility's electronic balances were the focus of much of the work for this project because most tests conducted at the SMO require determining a sample's mass. The following is a brief outline the work that was conducted:

- An approximate schematic layout of each SMO laboratory was prepared. In each schematic, the appropriate mass balances were added.
- A representative list of common tests was prepared.
- The scope of this project indicates that investigators were not to set up the automation themselves. Rather, a selection of representative mass balances would be pseudo-automated in the sense that they would be programmed to feed data from the balance directly to a laptop. Programs associated with transferring these data were written, and a budget was prepared to illustrate the cost of setting up such a system at the SMO. Where equipment upgrades were necessary, recommendations were provided.
- Based upon test-type, and discussion with David Davis of FDOT, a system for transferring data from the electronic balances to the FDOT Laboratory Information Management System (LIMS) was developed. Recommendations are provided in terms of how to modify the representative program discussed above.

This work is discussed in detail in Chapter 3 and Chapter 4.

1.4 Private Testing

A representative list was developed to catalogue common private testing data obtained by FDOT – both in terms of test type and test quantity (per year). Recommendations were provided concerning:

- How to efficiently connect private tests directly with FDOT"s database so as to reduce transcribing errors and maximize security.
- How to efficiently assure accuracy and integrity of testing.
- How to standardize off-site testing from a computational standpoint in terms of connectivity, computer speed, and data transfer rate.

Work associated with offsite tests is discussed in detail in Chapter 5.

CHAPTER 2
BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

The literature review is split into three sections: (1) investigation of testing standards at other laboratories; (2) investigation of relevant research in the field of eliminating transcription errors; and (3) discussion of the California GLDMS.

2.2 Investigation of Testing Standards at Other Laboratories

The following is a discussion of procedures used at other top laboratories around the United States. The Federal Bureau of Investigation, a large police department (The Tampa Police Department, TPD), and the Food and Drug Administration (FDA) were used as representative examples.

2.2.1 Federal Bureau of Investigation

The Federal Bureau of Investigation (FBI) forensics laboratory utilizes "Quality Assurance Standards for Forensic DNA Testing Laboratories" guidelines during testing. According to the "Quality Assurance Standards for Forensic DNA Testing Laboratories", the purpose of these standards is to:

- Establish education and proficiency certification standards for employees.
- Establish a procedure for auditing.
- Establish a system whereby each lab and each test has a documented, well established procedure that can be easily accessed by employees.
- Maintain an equipment calibration schedule; and to set up a system whereby equipment calibration may be verified.

- Establish a system whereby administrators may review all forensics data and reports.

According to “The Federal Bureau of Investigation’s Implementation of the Laboratory Information Management System” (2006), the FBI has been attempting to transition toward a paperless recordkeeping system. However, currently, their procedures are such where QA/QC checks are procedurally based, and personal accountability is used to reduce errors. There is no semblance of automated data recording anywhere in the FBI procedures. Instead, data is hand-recorded and database entries are input manually.

2.2.2 Tampa Police Department

The Tampa Police Department (TPD) was consulted as a representative large police department to determine if its procedures matched FBI testing standards According to “Tampa Police Department Standard Operating Procedures” (2006), the TPD also uses a combination of handwritten and manually-written computer reports to catalog evidence. When evidence is collected, it is “tagged” and procedural paperwork is attached to it. An evidence technician inputs data into TPD’s computers manually to generate TPD’s evidence database, or TPD Records Management System (TPDRMS). Barcodes are also assigned to evidence (manually). While this does provide some degree of automation in terms of an investigator’s ability to automatically pull up information by scanning a bar code, one must keep in mind that the data pulled by scanning the barcode was manually generated.

2.2.3 Food and Drug Administration

The Food and Drug Administration (FDA) uses the "Investigations Operations Manual" as their primary guidance document on inspection policy and procedure for field investigators (FDA 2006). This document explicitly describes the procedure for manually recording data on detailed forms and entering it to a database. There are no indications that the FDA is conducting any automated data recording.

The FDA has a quality system employed, outlined in "Staff Manual Guides," which relies heavily on the training of personnel to improve and maintain quality assurance (2006). According to the "Staff Manual Guides", the FDA's procedure for QA/QC of purchased services and outsourced work includes verifying the accuracy of received products by testing the product for conformance to the FDA's standards.

2.3 Review of Other Relevant Literature

In addition to investigating current data collection practices from other agencies and departments, an in-depth literature review was conducted. The purposes of the literature review were to (1) attempt to quantify the possible extent of transcription errors; and (2) further investigate other methods of correcting these errors that have been cited in the literature. The following is a brief summary:

2.3.1 Extent of Transcription Errors

The first question to address through literature review was to quantify the extent to which FDOT has been experiencing errors due to transcription. While transcription does not appear to have been studied extensively in the context of data collection at laboratories, it has been studied in the context of the medical profession. Khushi et al.

(2012) studied a sample of 3,242 data forms with 81,714 entry fields; they found average error rates of 0.3% due to transcription. However, to reduce error, Kushni et al. only allowed data entry through the use of drop-down boxes rather than allowing users to freely type information.

Knudsen et al. (2007a) monitored 40 pharmacies dispensing an average of 900,000 prescriptions over 12 weeks to determine the extent of transcription errors. “Prescription corrections,” or incidents in which a mistake was made from an employee or consultant from outside the department, but was corrected by the department, had the highest error rate at 23.1 per 10,000 prescriptions. This yielded a 21.7 – 24.6 computed error rate per 10,000 cases at a 95% confidence interval. For errors that were classified as “near misses,” meaning the error was caught and corrected by an employee within the department before submission, the error rate was 2.4 per 10,000 cases. This results in computed error of 2.1 to 2.7 cases per 10,000 at a 95% confidence interval. The lowest error rate was for cases that resulted in actual dispensing of a medication. Error rate was 1.4 per 10,000 cases; or 1.2 – 1.6 out of 10,000 at a 95% confidence interval.

Errors that directly affected patients were selected by Knudsen et al. (2007b) for root cause analysis. Research concluded that these errors were made mostly during transcription through manual data entry. Handwritten prescriptions appeared to increase the risk of error because these handwritten prescriptions were often confusing, incomplete, or misread. To reduce error, researchers recommended that employees should be trained in safe prescription practices; that pharmacies should be frequently audited; and that handwritten prescriptions should be eliminated.

2.3.2 Interface between Analytical Instruments and LIMS

To connect analytical instruments and associated Scientific Data Management Systems (SDMS), a middle range interface was built by Zhu (2005). This system read data directly from instruments and sent these data directly to LIMS thereby eliminating manual data entry. The program was designed and implemented in a commercial analytical lab specializing in trace chemical measurement. The program developed has several advantages besides eliminating the time and error associated with manual data entry:

- By creating a generic middleware, instruments with similar data outputs could be manipulated without installing device drivers.
- Data was saved in a secure and neutral format (in XML) to allow for transfer and maintenance of results that were platform independent.
- The system allowed for approval of raw data before posting into LIMS.
- For security purposes, a secure login was created for different user-types, both administrators and normal users/lab employees. As an administrator, an employee could add, edit, and delete instruments that were assigned to specific projects as they were needed.
- A search form was also implemented to allow for querying of past submitted results based on project name, instrument name, sample id, and sample name.

There are a few disadvantages to the program developed:

- The main issue was that a new hand-coded transformation sheet would be needed for each type of file output. This would depend mainly on the type of instrument being examined. Similar instruments, such as those found in an analytical chemistry laboratory including chromatography machines, would use the same set of code since they produce similar data output.
- Writing transformation sheets to convert to XML would require the expertise of a computer programmer, and with the variety of instruments at the SMO, this would be a problem when trying to link all the equipment pieces directly to LIMS. Also, the need for direct data entry or qualitative entry was not addressed within the scope of Zhu study.

2.3.3 Data Collection Platforms

Scannable data forms ("bubble forms"), Web-based forms, and handheld computers were examined as methods for data collection in a research based facility or hospital. Each data entry method was evaluated based on: ease of use, experience/educational use of the designer, end-user training required, costs, flexibility, speed, accuracy/error rate, potential for data loss, need for technical support, and equipment/software requirements.

Scannable forms, which are often cited in earlier literature, are paper based documents that can be read by a computer scanner for data entry into a database (for example, a ScanTron). Used mostly for standardized testing, this method has many disadvantages because it would not really address the transcription error concern.

Web-based forms provide a more likely solution for the SMO. These forms are easy to use since most employees would have personal experience with Web platforms, therefore eliminating the need for any end-user training. Other advantages of a Web-based form discovered by Shapiro et al.(2004) include ease of modification; acceptation of a variety of inputs (numbers, words); immediate transfer of data into a database eliminating data entry and processing costs; reduction in data entry errors; and the reliability that they have shown as compared to paper based forms (Pettit 2002). Since the data is entered into a Web-based form, it is uploaded immediately to a server or database; it will not be lost because the forms due to form misplacement; and as data is uploaded in real time, the risk of losing data due to failure of equipment is reduced. Security could be addressed by either using encryption at the database level or requiring users to sign in to the system. Regular backup of data would be required in case of system failure.

Shapiro et al. (2004) also considered handheld computers (HC) as a separate data collection system. The researchers considered the HC as a portable device, such as a personal digital assistant (PDA), that would be physically linked to the database or synchronized after the data was collected in real time (similar to a Web-based form). Also required would be a data collection application, written in JAVA, C++, or Visual Basic, which would require the expertise of an IT employee. Training of employees in any new program written for data collection would also need to take place. Device battery life would need to be taken into consideration using such a system. However, with the advances in tablet, laptop, and associated rare earth metal (particularly lithium) based batteries, several hours of data collection could now be achieved using mobile platforms.

2.3.4 Central Hospital Database

Kline et al. (2004) developed both a system and a Web-based HTML form for hospital employees to centralize data, expedite data sharing, and reduce transcription errors. Data in this system was input in a Web-based e-form by a user; uploaded to central database protected by passwords, IP address authentication, and 128-bit encryption; and retrieved by authorized personnel with unique passwords. The form itself was programmed using hypertext markup language (HTML), active server pages (ASP) and standard query language (SQL), containing 70 different fields for users to input different patient related information through pull down menus, text and number/parametric entry. For user assistance, definitions for every field were provided through question mark links placed next to the fields.

As a quality assurance standard, fields that required numbers to fall within a predefined range were equipped to notify the user if data fell outside that preset range. If fields were left empty or an entry was made that was illogical (for example a combination of numbers and letters for a weight), an error message would be displayed, highlighting the mistake and directing the user to where the mistake was entered.

Users had two options for completing the patient's e-form: from a designated personal computer within the department where the form would be sent to the server upon clicking an update button; or from a pocket PC that could be synchronized via a user-prompted upload. A URL hyperlink was placed on the desktop of the desktop computers for ease of access. The user would click on the link, select his/her name, and a blank form would appear to be submitted. This form was marked with an electronic tag to indicate its author.

An issue with the placement of a URL hyperlink on the desktop was that it would sometimes be deleted by employees who weren't aware of what it was for. This was remedied by placing the link on the intranet homepage of the department.

Another option made available through the e-form was the ability to include "follow-up" information and revisions that might not have been known about at the time of the forms initial creation. Operating within the Health Insurance Portability and Accountability Act (HIPAA) regulations, patient data could only be accessed or downloaded with a password by pre-approved individuals on an IP address verified device.

When the e-form was reviewed for accuracy in the 8 parametric fields by two research observers, results showed that out of a total of 1022 patients with 8176 parametric fields only 0.6% were deemed unfit for statistical analysis or would be coded as missing upon review. For categorical data, no fields were missing or erroneous, resulting in an overall 98.8% of e-forms with 70 useable data fields

2.4 California Department of Transportation (GLDMS 2007)

In 2007, the California Department of Transportation (Caltrans) set up a testing system for geotechnical testing whereby data was input directly into a centralized database. The Caltrans facility, similar to the SMO, was such where a number of geotechnical tests were conducted. Each Caltrans testing station was equipped with a touch screen so that data could be manually entered. In the case of tests that cannot be automated such as Atterberg Limit tests and Moisture Content tests, manual data was input directly to the touch screens. The touch screens sent these data directly to a central database (web server) for data storage, retrieval, and analysis. The portion of the California system that is somewhat revolutionary is that during some tests (mass measurements for example), data was sent directly from the instrument (a balance for example) to the database. Administrative desktops were setup for analysis and report generation.

There are several advantages to this setup. First, handwritten transcription errors are largely reduced. This setup also eliminates paper, which allows investigators to more easily recall and cross-reference data. Because all data is now electronic, these administrative desktops could now also be automated – thereby allowing for the possibility of automatic report generation.

User-interface for the California system was controlled through Microsoft Internet Explorer (MSIE) 6.0. Therefore, there is no need for complicated software as a result of this system. Because the system is Web-based, users may be assigned different positions depending on their staff designation (for example administrator or laboratory technician). Edit restrictions may be setup so that only certain users have the ability to access certain options. Presumably, this "lockout" feature prevents someone with limited knowledge about a certain test or file-type from inadvertently changing something that he or she should not have touched.

There are some disadvantages to the Caltrans system. First, it should be emphasized that while some data entry is automated, most is still manually-generated. Secondly, from a procedural standpoint, the system was connected using hundreds of feet of Ethernet cable. From a hardware perspective, setting up such a system at FDOT's SMO would be time consuming and expensive.

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CHAPTER 3
AUTOMATION OF SMO MASS BALANCES REQUIREMENTS

3.1 Introduction

As discussed Section 1.3, this chapter provides a detailed discussion of work conducted to automate the SMO's mass balances.

3.2 SMO Mass Balance Inventory

The first step in programming the SMO balances to send data directly to the LIMS was to develop a comprehensive inventory of all mass balances. Investigators visited the bituminous (asphalt), chemical, corrosion, geotechnical, and physical laboratories, documented all balances, and double-checked results with existing inventories. A master list of all balances was compiled (Table 3-1 through Table 3-3). All balance locations were denoted on detailed engineering drawings to correspond with Table 3-1 through Table 3-3 (Figure 3-1 through figure 3-5). Additionally, a list of other devices with RS-232 output was compiled because these devices have the potential to be automated (Table 3-4).

3.3 FDOT Computing Architecture and Future LIMS

This project's PM indicated that FDOT's LIMS was to be redesigned. Therefore, results from this project would need to be compatible with the new LIMS. The first step in automating the SMO's mass balances then was to coordinate with David Davis, FDOT's Material Access and Certification (MAC) project manager of their Business Systems Support Office (BSSO).

Mr. Davis indicated that the new database is to accept data from approximately 700 laboratories. The testing standards that are to be designed as part of this project are to serve as a microcosm of what should ultimately exist in each laboratory in terms of taking raw data directly from measuring devices to the central database. The SMO is to be the first laboratory with such capabilities, but moving forward, all FDOT labs should have a link directly from their testing equipment to the database.

3.4 Automation Computing Architecture

The architecture presented in Figure 3-6 is recommended for automating mass balances at the SMO and at other FDOT facilities. As illustrated, each laboratory will contain several testing stations denoted as “Machine 1,” “Machine 2,” and “Machine 3.” Several laptops will be deployed to interface with each testing device. Devices should be hard-wired from “machine” to laptop via Universal Serial Bus (USB) connections.

3.4.1 Converting to USB

Because of the age of many of the SMO’s mass balances, conversion from RS-232-output to USB-output will often be necessary. Three cases must be considered:

1. For the case when a mass balance has a standard 9-pin RS-232 output, conversion to USB is the most simple. A Manhattan USB-to-RS-232 converter (Figure 3-7) and a DB-9 cable may be used to connect the mass balance to a laptop (Figure 3-8).

2. For the case when a mass balance has a different output (for example, sometimes 25 pin RS-232C outputs are provided), the output should be converted to a standard 9-pin output; and once again a Manhattan-style USB-to-RS-232 converter may be used to make the connection USB-compatible (Figure 3-9).

3. Several balances are not equipped with RS-232 output. Often, these incompatible balances are equipped with bayonet connections. Researchers are unaware of any method by which the bayonet plugs may be converted to USB. This situation will be discussed in more detail in Section 3.4.2.

While it would be possible to connect a DB-9 cable from the mass balances directly to some laptops, investigators strongly recommend against this approach. Newer laptops are rarely equipped with RS-232 input. It would be more expensive to add RS-232 inputs to laptops' motherboards (as opposed to purchasing stock laptops) than it would be to convert the mass balances' output.

3.4.2 Costs and Upgrade Requirements

The total cost associated with converting RS-232 outputs to USB was estimated. This computation was tabulated and categorized by SMO laboratory (Table 3-5). As shown, cost is expected to be approximately $1,000.

Cost associated with replacing incompatible balances (Case 3 above) was also investigated (Table 3-6). As shown, limited replacement of these instruments would be approximately $137,532. However, it may not be necessary to upgrade all balances listed in Table 3-5. The National Center for Asphalt Technology (NCAT) devices (the first 4 devices in Table 3-6) are used to measure percent moisture loss. They are also already equipped with paper output, thereby providing some level of protection against transcription errors. If FDOT chose not to upgrade these instruments, upgrade cost would be reduced to $116,976.

Please note that all upgrade computations assumed that latest model Mettler-Toledo XS devices would be used for replacement. These balances are Windows 8 compatible. If FDOT wanted to upgrade these instruments with new equipment, a minimum of three bids should be obtained.

Alternatively, a third option is available that may reduce cost. While balance manufacturers will try to sell as many new products as possible, there is a large market for used devices and older devices through third party dealers. It may be more cost effective to replace the incompatible devices with balances that, while not technically "Windows 8 compatible," are equipped with RS-232 output. By pursuing this option, the system discussed Chapter 4 would still be usable with these relatively newer devices. And, cost should be significantly reduced.

3.4.2 Microsoft Windows 8 Compatibility Issues

In an ideal world, Microsoft (MS) Windows plug-and-play technology would be used to distinguish one balance from another. The RS-232 converters discussed in Section 3.4.1 act as a "virtual serial port" whereby Windows "thinks" that an RS-232 port has been added to the computer. Thus, in theory, plug-and-play compatibility is possible. Unfortunately, again because of the balances' ages, several of these devices are not compatible with the current version of Windows (Windows 8, 64-bit was used for all testing associated with this project because it is the latest version). While it may be possible to program drivers for these balances, it probably would not be cost effective.

A work-around involves using National Instruments' Laboratory Visual Instrumentation Engineering Workbench (LabVIEW) to send traditional Telnet-style serial port commands to the balances. The user then specifies which mass balance he or she was using prior to the test so that the correct, preprogrammed Telnet-style commands would be sent to the device. This method will be discussed in more detail in Chapter 4.

Investigators spoke with the PM about the possibility of upgrading all the SMO's mass balances, but all parties agreed that this solution was cost-prohibitive. Investigators spoke with representatives from Mettler-Toledo about the possibility of the release of compatible drivers for older balances. Mettler-Toledo indicated that there were no plans for computer support for the older devices. Therefore, the LabVIEW work-around, combined with RS-232 method is recommended.

3.4.3 User Interface and Florida Method Test Types

User interface is another issue that must be addressed when discussing a new, automated system. Required data entry is often extensive and dependent upon test-type. Table 3-7 through Table 3-12 were developed to illustrate common test-types and associated Florida Methods (FMs) associated with the SMO laboratories. The “total number of samples” column (fifth column from the left) in each of these tables represents the total number of samples tested from January 1, 2011 through December 31, 2011.

As shown, only 8 of the 26 Florida Methods shown in Table 3-7 through Table 3-12 (approximately 31%) currently require direct sample mass inputs. Many of the other tests require a tester to measure sample mass at some point during testing. But, currently, this intermediate step is performed on a worksheet, computations are conducted, and only the final result (density for example) is input to the LIMS database. Further complicating matters, some tests (geotechnical plastic and liquid limit tests or physical percent elongation tests for example) require no mass measurements.

At minimum, the new automated system should have all computations from weight to another parameter automated, thereby eliminating the “worksheet step.” However, one must recognize that such a conversion will inherently require more user-input. For example, if density is to be measured, a user will be required to input volume. Furthermore, for each test, a user would be required to input the proper sample designation. Therefore, while automation may reduce some transcription errors, one cannot claim that all transcription errors have been entirely eliminated.

3.5 Menu of Options

As indicated in this project's first progress report, after discussion with Mr. Davis, investigators agreed that the scope of this project was to provide recommendations in getting information from the "Machines" shown in Figure 3-7 to a FDOT server via .txt file. The MAC server then would "ping" these .txt files continuously, determine if they changed, and develop a code for the information to be uploaded directly to the new LIMS. With this setup, there are two viable options that are discussed below:

3.5.1 Several User-Interfaces and FM Association

One solution is to program several user interfaces – one for each FM test-type. To start the test, the user would begin by running an automation program. Each automation program would be tailored to walk the user through its associated Florida Method. For example, if FM 1-T 180 (Modified Proctor Test) was to be conducted, the following represents an approximate algorithm (user-prompts are italicized).

1. *Enter sample designation and testing station*. *Enter '1' if this is the first day of testing or '2' if you measuring dry weight*. *Press OK when* ready. If the user entered '1,' the following algorithm would commence:

    - *Place the first moisture content container upon the balance. Press OK when ready*. The balance would record the weight of the moisture content container.

    - *Place your Proctor mold upon the balance*. The balance would record the weight of the compaction mold.

    - *Enter the volume of your mold, or press Enter to use the default value*. While the standard volume is 1/30 ft^3, the user would have the option of changing this.

- *Place a water container upon the scale. Press OK when ready*. The water vessel's weight would be recorded.
- *Add the appropriate amount of water to your water vessel. Press OK when ready*. The weight of the water and the water vessel would be recorded, and the weight of water would be computed.
- *Add the water to your mold and compact your soil*. *When finished, place your mold upon the scale and press OK*. The wet unit weight would be recorded.
- *Take a sample of your soil in the moisture content container, and place this sample upon the scale. When ready, press OK.* The weight of the moist sample would be recorded.
- *Enter '1' to run with another moisture content or '2' to end program*. If the user entered '1,' then steps 5 through 9 would be repeated.

2. If the user entered '2' (assuming after oven-drying for 24 hours), the following algorithm would commence:
    - *Based upon your sample designation, you will measure xx sample weights. Place the first moisture content container upon the balance*. *Press OK when ready*. The balance would record the mass the first dry sample.
    - *Place the second moisture content container upon the balance. Press OK when ready….*

Number (2) would repeat until all dry sample weights are properly recorded. Then, a computation would be conducted so that dry unit weight and optimum water content were computed. All data and computational results would be recorded via tabulated text file. The file would be saved to a local FDOT sever drive to be "pinged" by the new LIMS system. The "save file" would be preprogrammed into the control algorithm, and a different "save-file" would be associated with each FM-type.

3.5.2 Single User-Interface and FM Association

The second solution is to program one "master-interface program." This program would be similar to the system discussed in Section 3.5.2, except when the program was first “run,” the user would be asked to specify his or her test-type. This would associate itself with the appropriate FM, and the algorithm discussed in Section 3.5.1 would commence.

3.5.3 Recommendations for Program Structure

The new LIMS should be updated to seek appropriate data inputs associated with each FM. Both the methods described in Section 3.5.1 and Section 3.5.2 would be acceptable. The method described in Section 3.5.2 has the potential to suffer from bloat, in the sense that the program would by definition be larger than required for any one test. As a result, the interface program may run more slowly. But it would preclude the need for a user to search through several interface programs. In the short-run, programming the methods described in Section 3.5.1 would allow for slightly more simplified coding. If FDOT decided to employ the method discussed in Section 3.5.1, converting to a “master program” later is not believed to be significantly more work.

Table 3-1. Inventory of SMO balances corresponding to Figure 3-1 through figure 3-5 (balance nos. 1-31)

Assigned Number	Department	Location	NH Number	Make	Model
1	Bituminous	E122 Liquid Asphalt	581195	Mettler	AL 204
2	Bituminous	E122 Liquid Asphalt	580243	Mettler	PB 8001S
3	Bituminous	E122 Liquid Asphalt	580250	Ohaus	V1B 120
4	Bituminous	E122 Liquid Asphalt	581479	Mettler	AL 204
5	Bituminous	E123 Recycled Asphalt	565144	Mettler	PM 1200
6	Bituminous	E122 Liquid Asphalt	577823	Ohaus	VOK 210
7	Bituminous	E121 Mix Design	578787	Ohaus	VOK 210
8	Bituminous	E123 Recycled Asphalt	578788	Ohaus	VOK 210
9	Bituminous	E121 Mix Design	581159	Mettler	SB 16001
10	Bituminous	E121 Mix Design	576393	Mettler	PM11K
11	Bituminous	E121 Mix Design	580213	Ohaus	EOL 210
12	Bituminous	E121 Mix Design	577209	Ohaus	IP15 KS
13	Bituminous	E121 Mix Design	276714	Mettler	PM11K
14	Bituminous	E123 Recycled Asphalt	581569	Mettler	
15	Bituminous	E123 Recycled Asphalt	509202	Mettler	PE11
16	Bituminous	E121 Mix Design	576713	Mettler	PM11K
17	Bituminous	E121 Mix Design	576715	Mettler	PM11K
18	Bituminous	E121 Mix Design	577169	Mettler	PM 2000
19	Bituminous	E121 Mix Design	580655		
20	Bituminous	E121 Mix Design	581201	NCAT	10KG
21	Bituminous	E121 Mix Design	581084		
22	Bituminous		581516	Ohaus	EP2201
23	Bituminous		577211	Ohaus	IP15 KS
24	Bituminous		576201	Mettler	PM11K
25	Bituminous	E117 Bituminous Research	581176	Mettler	SB 16001
26	Bituminous	E117 Bituminous Research	581164	NCAT	10KG
27	Bituminous	E117 Bituminous Research	580262		
28	Bituminous	E117 Bituminous Research	281418	Ohaus	RD 15 LM
29	Bituminous	E117 Bituminous Research	577008	Mettler	PM 11K
30	Geotech	Soils Prep Room	565152	A&D	EP20K
31	Geotech	Soils Prep Room	none		

Table 3-2. Inventory of SMO balances corresponding to Figure 3-1 through figure 3-5 (balance nos. 32-61)

Assigned Number	Department	Location	NH Number	Make	Model
32	Geotech	Aggregate Lab	508650	Mettler	PE22
33	Geotech	Aggregate Lab	580656	Ohaus	Voyager VID 120
34	Geotech	Aggregate Lab	580375	A&D	HP 20K
35	Geotech	Aggregate Lab	580422	Ohaus	VIL 210
36	Geotech	Aggregate Lab	580240	A&D	HP30K
37	Geotech	Aggregate Lab	580423	Ohaus	VIL 210
38	Geotech	Foundation Prep Room	None		
39	Geotech	Soil Lab	576828	A&D	EP20K
40	Geotech	Soil Lab	510495		
41	Geotech	Foundations	577074	A&D	FP12K
42	Geotech	Foundations	none		
43	Geotech	Foundations	580660	A&D	GP20K
44	Geotech	Foundations	580661	A&D	GX6100
45	Chemistry	Micro Prep	577009	Sartorius	AC 210S
46	Chemistry		581570		
47	Chemistry		538261	American Scientific	SP18
48	Chemistry	Chem Lab D	580245	Scientech	SP1000
49	Chemistry		538260	Denver	Z660
50	Chemistry		577184	Ohaus	I10
51	Chemistry	Cut/Grind	508219	Mettler	AE163
52	Chemistry	Instrument Rm	581179	Mettler	XS 1003S
53	Chemistry	Instrument Rm	578370	Sartorius	BP 121S
54	Chemistry	Instrument Rm	577010	Sartorius	AC 210S
55	Physical	Cement Rm	565169	A&D	EP20KA
56	Physical	Cement Rm	576127	A&D	EP12KA
57	Physical	Curing	581137	Mettler	XP-504
58	Physical	Curing	581136	Mettler	XP-504
59	Physical	Curing	565193	A&D	EP20KA
60	Physical	Curing	538252	Sartorius	I31
61	Physical	Curing	580657	A&D	GP 40K

Table 3-3. Inventory of SMO balances corresponding to Figure 3-1 through figure 3-5 (balance nos. 62-69)

Assigned Number	Department	Location	NH Number	Make	Model
62	Physical	Research/Calibration D116	581144	Mettler	XP-504
63	Physical	Research/Calibration D117	580415	Mettler	AG 204
64	Physical	Research/Calibration D118	280416	Mettler	AG 204
65	Physical	Research/Calibration D119	581180	Mettler	XS 1003S
66	Corrosion	Electron Microscopy	581445	Sartorius	CP225D
67	Corrosion		577187	Sartorius	AC 210S
68	Corrosion		None	A&D	FG-150KX
69	Corrosion		None	Dever	APX6001

Table 3-4. SMO inventory with automation potential

Department	Type of Instrument	Make	Model
Bituminous	Bending Beam Rheometer	Cannon	
Bituminous	Bending Beam Rheometer	Cannon	
Bituminous	Direct Tension Test System	Instron	5525
Bituminous	Gyratory Compactor	Troxler	4140
Bituminous	Rotational Viscometer	Brookfield	DV-II+
Chemisty	Viscometer	Brookfield	KU-2
Chemisty	Rheometer	Brookfield	DV-III+
Chemisty	Expandable Ion Analyzer		EA 940
Corrosion	Data Acquisition / Data Logger Switch Unit	Agilent	34970A
Corrosion	Resistivity Meter	CNS Farnell	SR Meter
Corrosion	Multimeter	Fluke	187
Corrosion	Multimeter	Hewlett Packard	34401A
Corrosion	Ion Analyzer/pH meter	Orion	EA920
Corrosion	pH/mV/Temperatur Meter	Fisher Scientific	No. 50
Geotech	Virtual Chart Recorder	Omega	i.THX
Geotech	Load Cell	Dynacell	
Geotech	ServoHydraulic Press	Instron	8872
Geotech	Load Frame	Wykeham Farrance	5000 KG
Geotech	Load Frame	Humboldt	Tri-Scan 50
Geotech	Load Frame	United	STM 100KN
Geotech	Load Frame	ELE	Digital Tritest
Geotech	CBR/LBR Test Moniter	GPE	DMP-12A
Physical	Rockwell Hardness Tester	Instron	2000T
Physical	Compression Machine 500k	Test Mark	CM5000DB
Physical	Compression Machine 600k	Forney	F60CDFM/1
Physical	Compression Machine 60k	Forney	FX-300-AUTO-60
Physical	Micrometer	Mitutoyo	293-180
Physical	Universal Testing Machine 90k	Tinus Olsen	90-K218963
Physical	Digital Dial Indicator	Humboldt	BG 2600-16001
Physical	Digital Dial Indicator	Mitutoyo	C112E

Table 3-5. Cost estimate for converting SMO mass balances to USB output

Department	Cable	Quantity	Price per unit	Cost
Bituminous				
	DB9 Male to DB9 Female	13	6.99	90.87
	DB25 Male to DB9 Female	0	10.99	0
	RS-232 to USB	13	18.99	246.87
			Total	337.74
Geotech				
	DB9 Male to DB9 Female	3	6.99	20.97
	DB25 Male to DB9 Female	4	10.99	43.96
	RS-232 to USB	7	18.99	132.93
			Total	197.86
Chemical				
	DB9 Male to DB9 Female	1	6.99	6.99
	DB25 Male to DB9 Female	3	10.99	32.97
	RS-232 to USB	4	18.99	75.96
			Total	115.92
Physical				
	DB9 Male to DB9 Female	4	6.99	27.96
	DB25 Male to DB9 Female	2	10.99	21.98
	RS-232 to USB	6	18.99	113.94
			Total	163.88
Corrosion				
	DB9 Male to DB9 Female	0	6.99	0
	DB9 Female to DB9 Female	1	7.99	7.99
	DB25 Male to DB9 Female	2	10.99	21.98
	RS-232 to USB	3	18.99	56.97
			Total	86.94
			Total	902.34

- DB9 Male to DB9 Female –Price based on list price for 0.5 m Black Straight Through DB9 RS-232 Serial Cable - M/F from startech.com (variable discounted prices available on Amazon.com)
- DB9 Female to DB9 Female - Price based on list price for 10-ft DB9 RS-232 Serial Null Modem Cable F/F from startech.com (variable discounted prices available on Amazon.com)
- DB25 Male to DB9 Female - Price based on list price for 6-ft DB25 Male to DB9 Female Null Modem Cable from cablestogo.com
- RS-232 to USB - Price based on list price for Manhattan USB to Serial Converter Connects One Serial Device to A USB Port from amazon (variable discounted prices available on amazon)

Table 3-6. Mass balances without RS-232 output

Department	Make	Model	Capacity x Read	XS Model	2012 List
Bituminous	NCAT	10KG	10KG X 0.1G?	XS16001L	$5,139.00
Bituminous	NCAT	10KG	10KG X 0.1G?	XS16001L	$5,139.00
Bituminous	NCAT	10KG	10KG X 0.1G?	XS16001L	$5,139.00
Bituminous	NCAT	10KG	10KG X 0.1G?	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM 1200	1kg x 1mg	XS1003S	$4,682.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM11K	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Ohaus	IP15 KS	15kg x 0.1g	XS16001L	$5,139.00
Bituminous	Ohaus	IP15 KS	15kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PE11	11kg x 0.1g	XS16001L	$5,139.00
Bituminous	Mettler Toledo	PM 2000	2kg x 0.01g	XS2002S	$3,444.00
Chemistry	Ohaus	I10	200kg		
Chemistry	Mettler Toledo	AE163	160g x 0.01mg dual	XS205DU	$6,977.00
Corrosion	A&D	FG-150KX	150kg		
Geotech	A&D	FP12K	12kg x 0.1g	XS16001L	$5,139.00
Geotech	Mettler Toledo	PE22	22kg x 0.1g	XS32001L	$6,045.00
Geotech	A&D	HP30K	31kg x 0.1g	XS32001L	$6,045.00
Geotech	A&D	GP20K	21kg x 0.1g	XS32001L	$6,045.00
Physical	Mettler Toledo	AG 204	200g x 0.1mg	XS204	$5,601.00
Physical	Mettler Toledo	AG 205	200g x 0.1mg	XS205	$5,601.00
Physical	Sartorius	I31	32kg x 1g	XS32000L	$4,175.00
Physical	A&D	EP20KA	20kg x 0.1g	XS32001L	$6,045.00
Physical	A&D	GP 40K	41kg x 0.5g	XP64001L	$10,926.00
				XS TOTAL LIST	$137,532.00

Table 3-7. Common test-types associated with SMO Aggregate Laboratory

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Aggregate Lab	FM 1-T 011	FM1-T011D	Total Amount of Material Finer Than 0.075 mm (No. 200) Sieve in Aggregate	90	Percent Passing	%
	AASHTO T 27*	FM1T27SUPR20	Sieve Analysis of Fine and Coarse Aggregates	93	% Passing 3/8 in Sieve	pcpass
					% Retained 3/8 in Sieve	pcret
					Wt Retained 3/8 in Sieve	wtret
					% Passing No. 4 Sieve	pcpass
					% Retained No. 4 Sieve	pcret
					Wt Retained No. 4 Sieve	wtret
					% Passing No.100 Sieve	pcpass
					% Retained No.100 Sieve	pcret
					Wt Retained No.100 Sieve	wtret
					% Passing No.16 Sieve	pcpass
					% Retained No.16 Sieve	pcret
					Wt Retained No.16 Sieve	wtret
					% Passing No.30 Sieve	pcpass
					% Retained No.30 Sieve	pcret
					Wt Retained No.30 Sieve	wtret
					% Passing No.50 Sieve	pcpass
					% Retained No.50 Sieve	pcret
					Wt Retained No.50 Sieve	wtret
					% Passing No.8 Sieve	pcpass
					% Retained No.8 Sieve	pcret
					Wt Retained No.8 Sieve	wtret
	FSTM FM 1-T 085	FM1-T085DATA	Specific Gravity and Absorption of Coarse Aggregates	55	Absorbtion	ABS
					Apparent Specific Gravity	ASpGrav
					Bulk Specific Gravity	BSpGrav
					Bulk Specific Gravity SSD	BSpGravSSD
					Saturated Surface Dry	SSDGrav

* Test contains input in LIMS that is a weight

Table 3-8. Common test-types associated with SMO Bituminous Laboratory

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Bituminous Lab	FSTM FM5-559*	FM5-559GRAV	Testing of Ground Tire Rubber - Gravity	111	Specific Gravity	SPGR
					Mass of Original Sample	Wa
					Mass of Pyncnometer Filled with Rubber and Alcohol	Wb
					Mass of Pycnometer Filled with Alcohol	Wc
	FSTM FM5-559*	FM5-559METAL	Testing of Ground Tire Rubber - Metal	111	Metal Content of Sample	%
					Mass of Remaining Sample	Wr
					Mass of Original Sample	Ws
	FSTM FM5-559*	FM5-559MOIST	Testing of Ground Tire Rubber - Moisture	111	Total Moisture Content of Sample	%
					Mass of Dried Sample	D
					Mass of Original Sample	W
	N/A*	RO PG 76-22	Results Only, PG 76-22 Liquid Tests	224	Creep Stiffness @ -12C	M @ 60 Sec.
					Creep Stiffness S @ -12C	MPA@60 Sec.
					Flash Point, COC	Degrees F
					Orig. DSR, G*/sin d @ 76C	kPa
					PAV DSR @ 25C, G*sin d	kPa
					Phase Angle @ 76C	Degrees
					Rotational Visc. @ 135C	Pa-s
					RTF DSR @ 76C, G*/sin d	kPa
					RTFOT, Mass Change	Pct
					RTFOT, Mass Loss	Pct
					Smoke Point, COC	Degrees F
					Solubility	Pct
	FSTM FM 1-T 202, FM 1-T 049	RO T202_T49	Results Only, Pen. (T49) and Viscosity (T202)	2,197	Penetration	mm
					Viscosity	Poises

* Test contains input in LIMS that is a weight

Table 3-9. Common test-types associated with SMO Chemical Laboratory

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Chemical Lab	ASTM C114	C114-FA XRF	Fly Ash/XRF	1,461	Oxides of Si,Fe,Al	%
					Sulfur trioxide	%
	ASTM C114 ... 13.1*	C114-FALOI	Fly Ash Loss on Ignition	1,457	% Loss on Ingition	%LOI
					Final Weight	FinalWT
	ASTM C114 ... 11.1*	C114-FA%M	Fly Ash % Moisture	1,456	% Moisture	%
					Sample Weight	CruxSampWT
					Tare Weight	CruxTareWT
					Dry Weight	DryWT

* Test contains input in LIMS that is a weight

Table 3-10 Common test-types associated with SMO Geotechnical Laboratory

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Soils Lab	FM 5-515	FM5-515	Lime Rock Bearing (LBR) Test	23	@ Percent Moisture	%
					Limerock bearing ratio	LBR
					Maximum Density	lbs/ft3
					Percent Moisture	%
					Percent Pass #200 Sieve	%
					Percent Pass 3.5" Sieve	%
					Percent Pass No.4 Sieve	%
	FM 1-T 180	FM1-T180CQR	Modified Proctor (10 lbs hammer)	9	@ Percent Moisture	%
					Maximum Density	lbs/ft3
					Percent Pass 3.5" Sieve	%
					Percent Pass No200 Sieve	%
					Percent Pass No4 Sieve	%
	AASHTO T 90	FM1-T90	Determining the Plastic Limit & Index of Soil	6	Liquid Limit	%
					Plastic Limit	%
					Plasticity Index	%

* Test contains input in LIMS that is a weight

Table 3-11. Common test-types associated with SMO Physical Laboratory

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Physical Lab	ASTM 370*	A370REBARS	REBARS	1,155	Actual Weight	aw
					Bar Size	#
					Bend	Test OK
					Deformation	avg
					Elongation	percent
					Grade	#
					Heat Number	#
					Length	inches
					Percent of Nominal	percent
					Pin Diameter	size
					Sample Status	Pass Fail
					Tensile Strength	psi
					Theoretic Weight	tw
					Weight	gramwt
					Yield Point	psi
	ASTM C109	C109-%STD	Compressive Strength of Cement (% of Standard)	1,178	Compressive Strength % of Standard	%
					Compressive Strength % of Standard	AVGPSISam
					Compressive Strength % of Standard	AVGPSIStd
	ASTM C109	C109-%STD28F	Compressive Strength of FlyAsh (% of STD 28 Day)	1,380	Compressive Strength % of Standard	%
					Compressive Strength % of Standard	AVGPSISam
					Compressive Strength % of Standard	AVGPSIStd
	ASTM C430	C430FA	Fineness of Hydraulic Cement by the No.325 Sieve	1,415	Fineness	%
					Fineness	CF
					Fineness	R

Table 3-12 (a). List of common test-types associated with SMO Corrosion Laboratory (1 of 3)

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Corrosion Lab	FM 5-516	FM5-516	FM5-516 Det. Low-Levels of Chloride in Concrete & Raw Mat.	148	Avg	lbsyd3
					Chloride lb/yd^3	Avg
					Chloride lb/yd^3	Range
					Chloride lb/yd^3	SampleA
					Chloride lb/yd^3	SampleB
					Chloride lb/yd^3	SampleC
					Chloride lb/yd^3	UnitWeight
					Range	lbsyd3
					SampleA	lbsyd3
					SampleB	lbsyd3
					SampleC	lbsyd3
					UnitWeight	lbs
	FM 5-516	FM5-516SLICE	FM5-516 Concrete Chloride Profile	64	Slice 1 - Final	Final(in)
					Slice 1 - Initial	Initial(in)
					Slice 1	LB_YD^3
					Slice 1 Depth - Final	Final
					Slice 1 Depth - Initial	Initial
					Slice 1 Depth	LB_YD^3
					Slice 2	Final(in)
					Slice 2	Initial(in)
					Slice 2	LB_YD^3
					Slice 3	Final(in)
					Slice 3	Initial(in)
					Slice 3	LB_YD^3
					Slice 4	Final(in)
					Slice 4	Initial(in)
					Slice 4	LB_YD^3
					Slice 5	Final(in)
					Slice 5	Initial(in)
					Slice 5	LB_YD^3
					Slice 6	Final(in)
					Slice 6	Initial(in)

Table 3-12 (b). List of common test-types associated with SMO Corrosion Laboratory (2 of 3)

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Corrosion Lab	FM 5-516	FM5-516SLICE	FM5-516 Concrete Chloride Profile	64	Slice 6	LB_YD^3
					Slice 7 - Final	Final(in)
					Slice 7 - Initial	Initial(in)
					Slice 7	LB_YD^3
					Slice 8 - Final	Final(in)
					Slice 8 - Initial	Initial(in)
					Slice 8	LB_YD^3
					Slice 9 - Final	Final(in)
					Slice 9 - Initial	Initial(in)
					Slice 9	LB_YD^3
					Slice 10 - Final	Final(in)
					Slice 10 - Initial	Initial(in)
					Slice 10	LB_YD^3
					Slice 11 - Final	Final(in)
					Slice 11 - Initial	Initial(in)
					Slice 11	LB_YD^3
					Slice 12 - Final	Final(in)
					Slice 12 - Initial	Initial(in)
					Slice 12	LB_YD^3
					Slice 13 - Final	Final(in)
					Slice 13 - Initial	Initial(in)
					Slice 13	LB_YD^3
					Slice 14 - Final	Final(in)
					Slice 14 - Initial	Initial(in)
					Slice 14	LB_YD^3
					Slice 15 - Final	Final(in)
					Slice 15 - Initial	Initial(in)
					Slice 15	LB_YD^3
					Slice 16 - Final	Final(in)
					Slice 16 - Initial	Initial(in)
					Slice 16	LB_YD^3
					Slice Depth	in
					Slice Depth	LB_YD^3
					Slice Depth in inches	Final

Table 3-12 (c). List of common test-types associate with SMO Corrosion Laboratory (3 of 3)

Location of Testing	Test Method	Test Code	Test Description	Total # Samples	Input	Input Unit Name
Corrosion Lab	FM 5-516	FM5-516 SLICE	FM5-516 Concrete Chloride Profile	64	Slice Depth in inches	in
					Slice Depth in inches	Initial
					Slice Depth in inches	LB_YD^3
					Slice1	in
					Slice1	lbspercy
					Slice2	in
					Slice2	lbspercy
					Slice3	in
					Slice3	lbspercy
					Slice4	in
					Slice4	lbspercy
					Slice5	in
					Slice5	lbspercy
					Slice6	in
					Slice6	lbspercy
					Slice7	in
					Slice7	lbspercy
					Slice8	in
					Slice8	lbspercy
	FSTM FM 5-550	FM5-550	pH of Soil and Water	44	Sample pH	N/A
	FSTM FM 5-551	FM5-551	Resistivity of Soil and Water	44	Resistivity	OhmsCM
					Resistivity	OhmsM
	FSTM FM 5-552	FM5-552	Chloride in Soil and Water	44	Chloride	ppm
	FSTM FM5-553	FM5-553	Sulfate in Soil and Water	44	Sulfate	ppm

* Test contains input in LIMS that is a weight

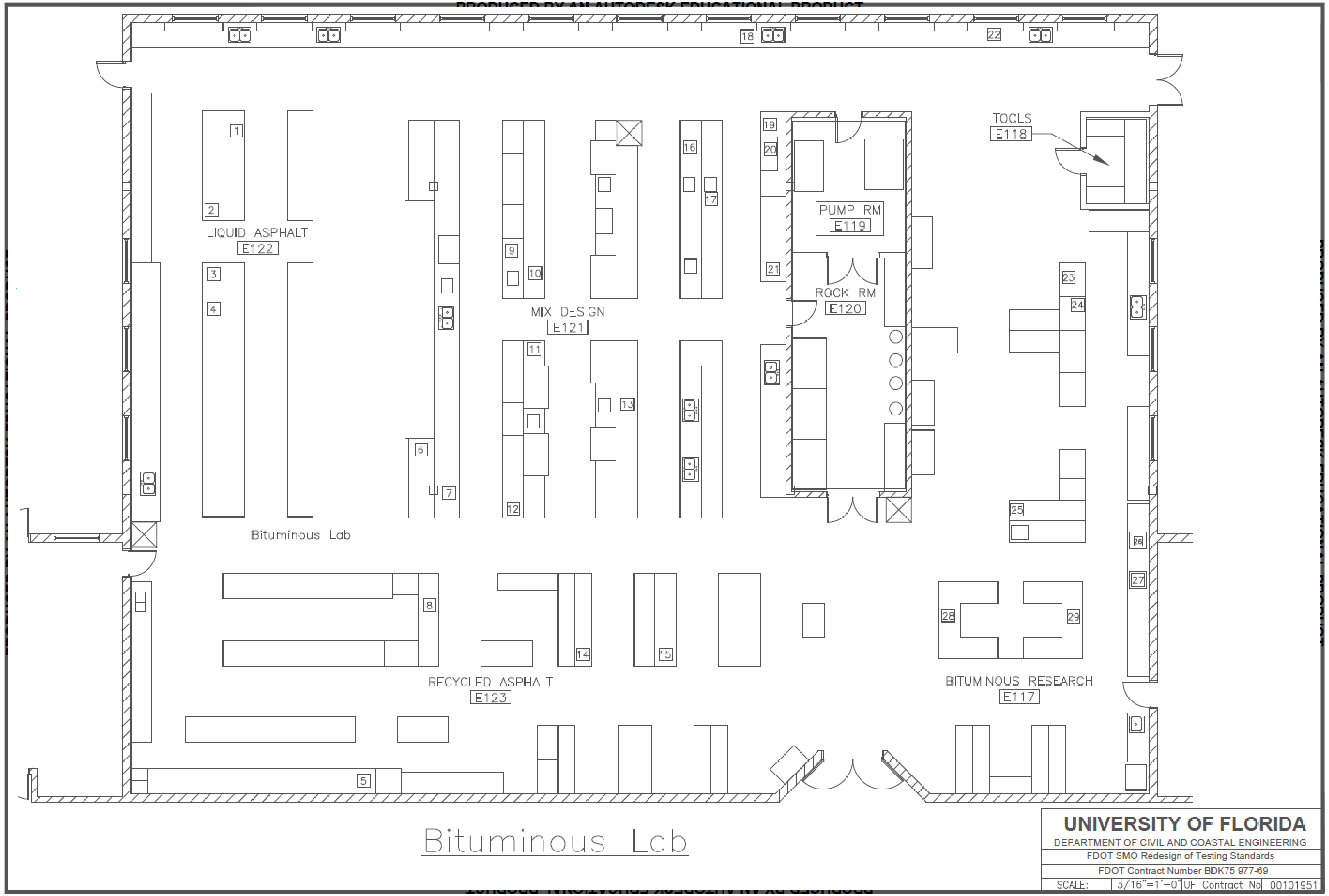


Figure 3-1. Mass balance locations in FDOT SMO Bituminous Laboratory

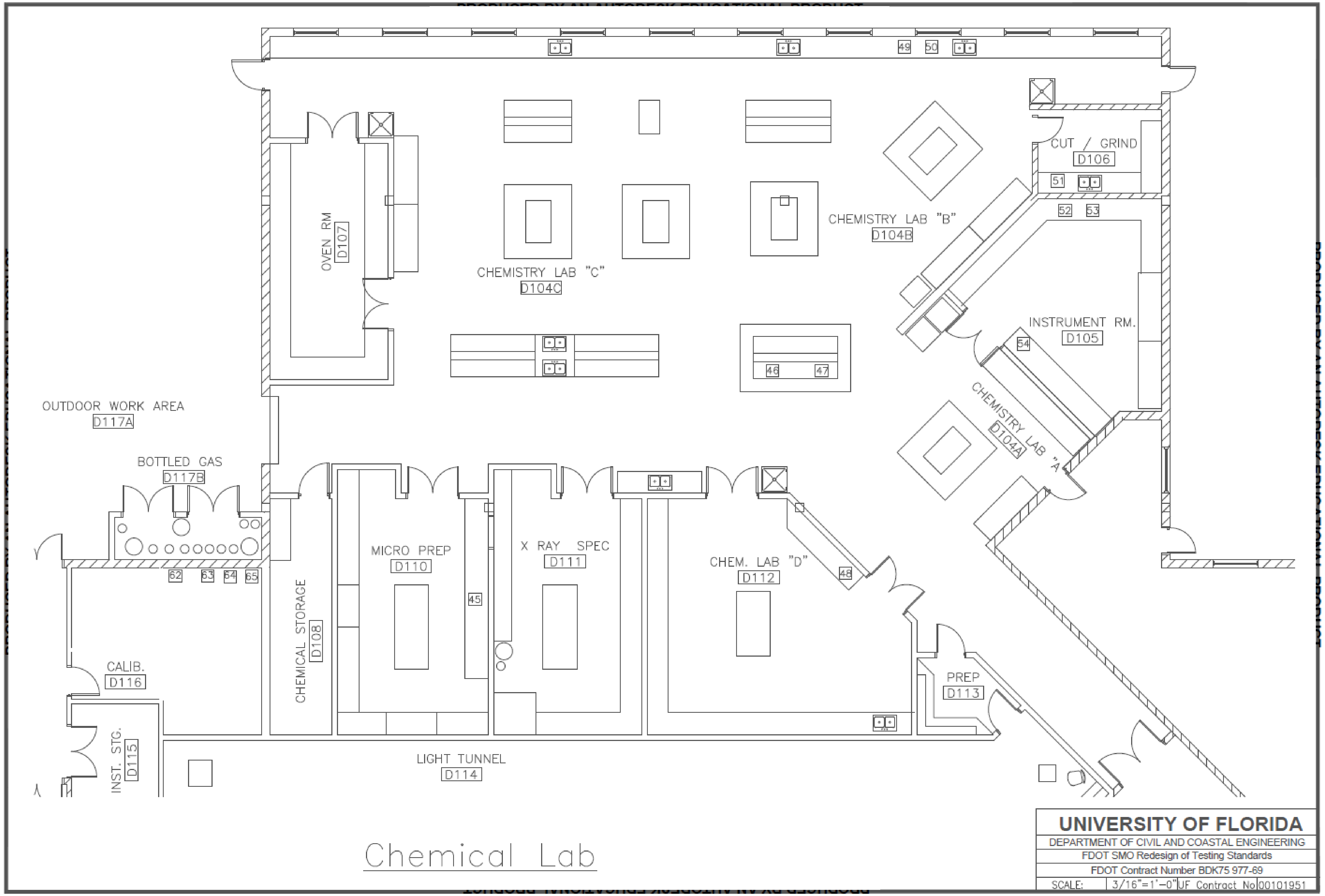


Figure 3-2. Mass balance locations in FDOT SMO Chemical Laboratory

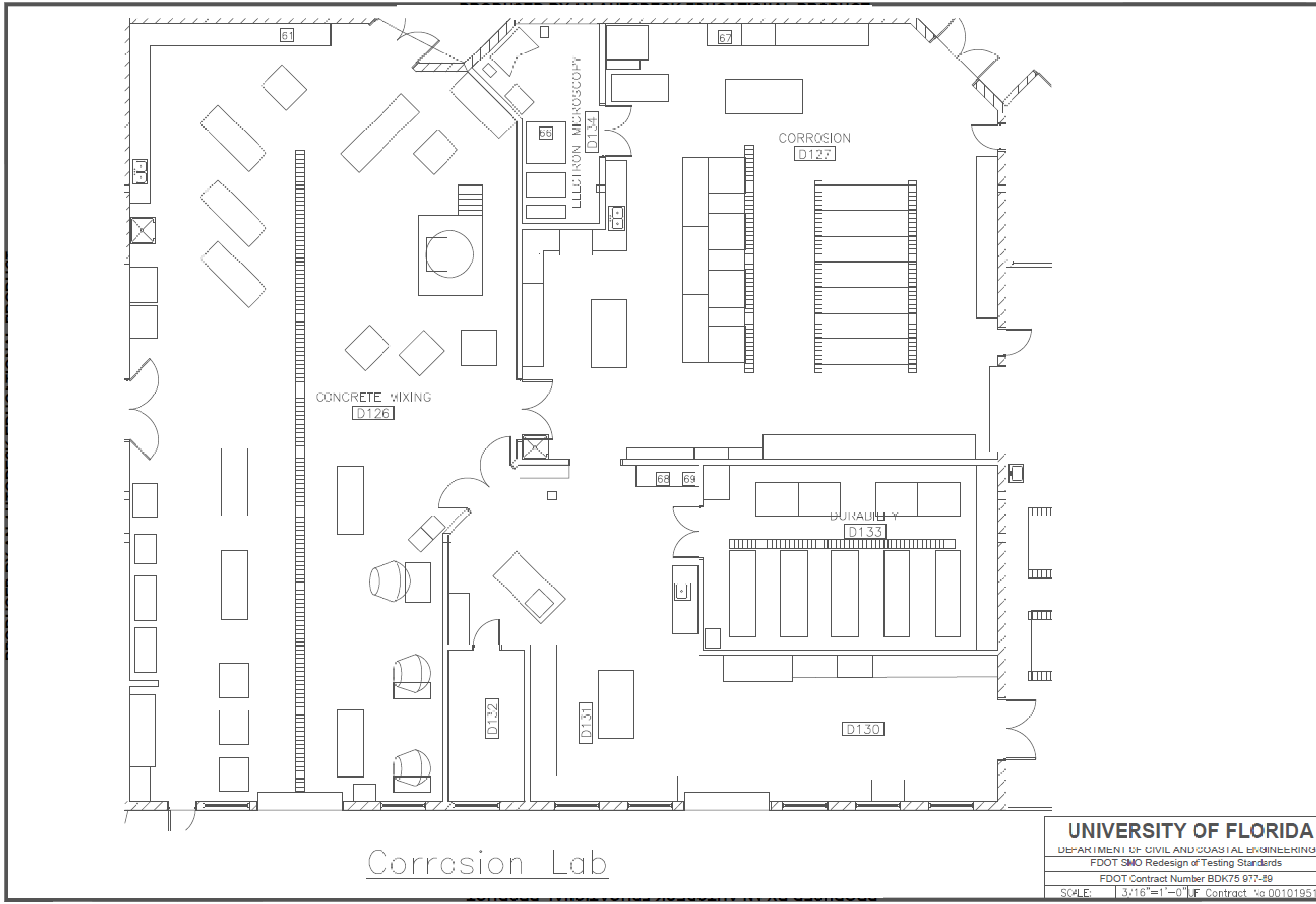


Figure 3-3. Mass balance locations in FDOT SMO Corrosion Laboratory

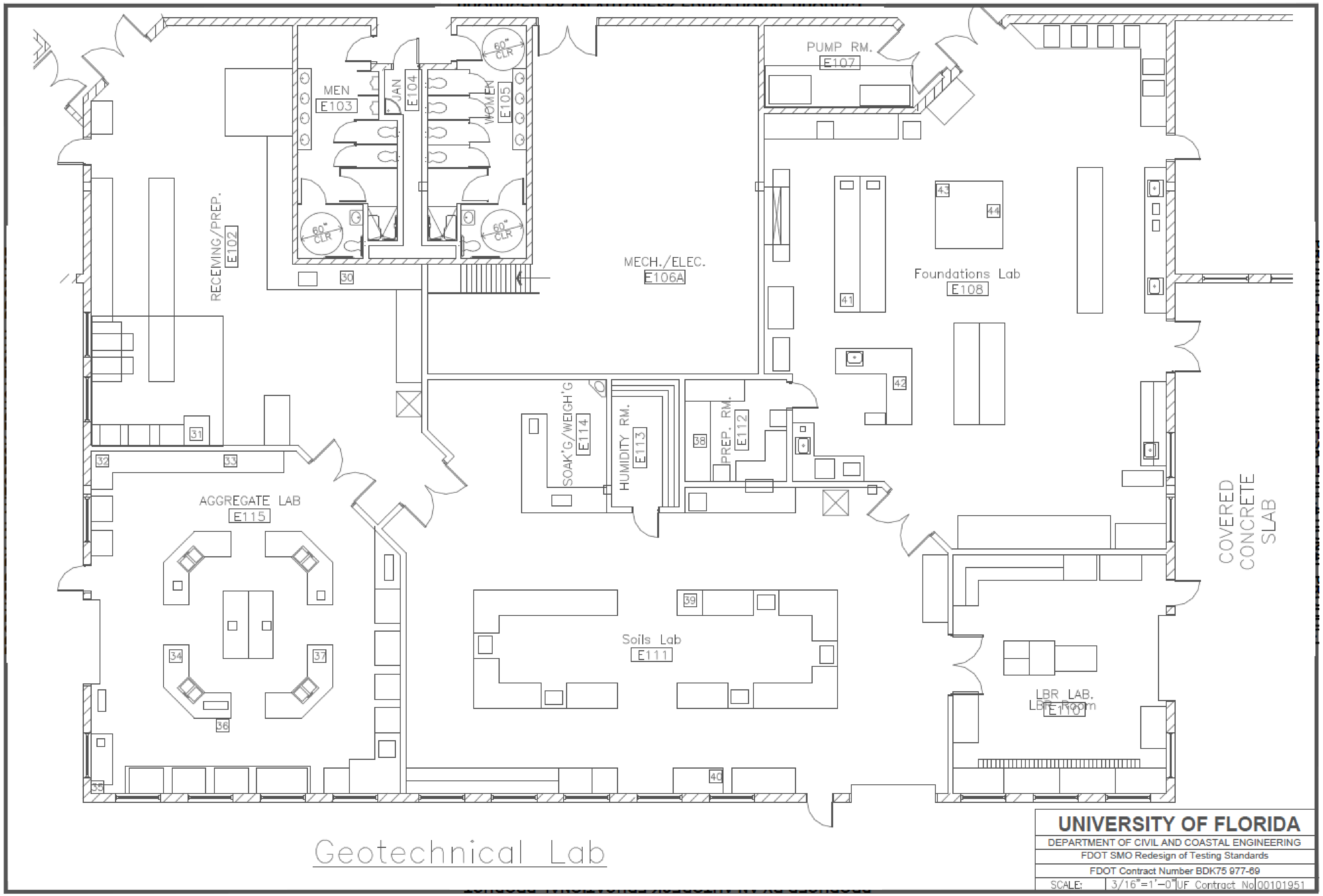


Figure 3-4. Mass balance locations in FDOT's Geotechnical Laboratory

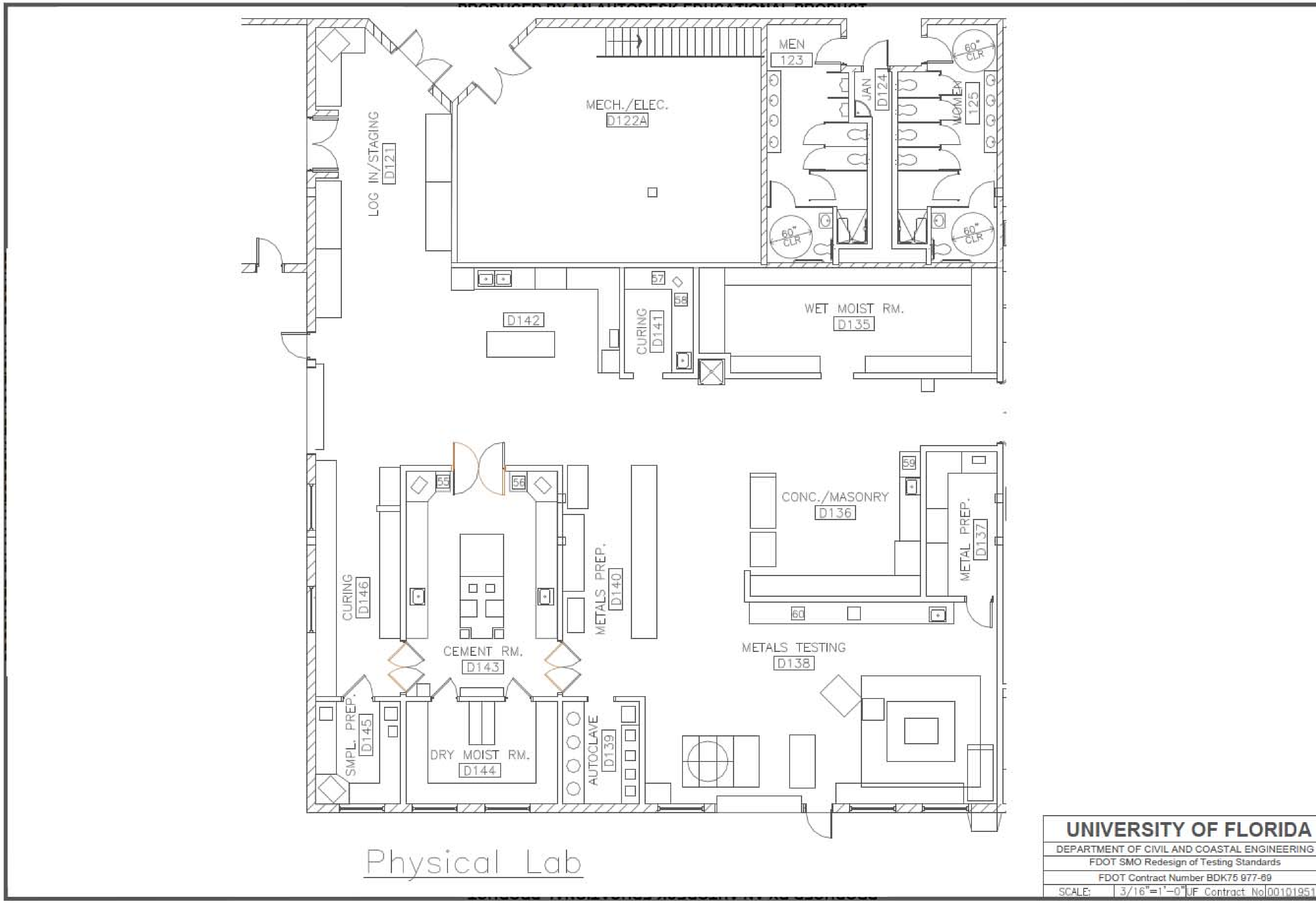


Figure 3-5. Mass balance locations in FDOT SMO Physical Laboratory

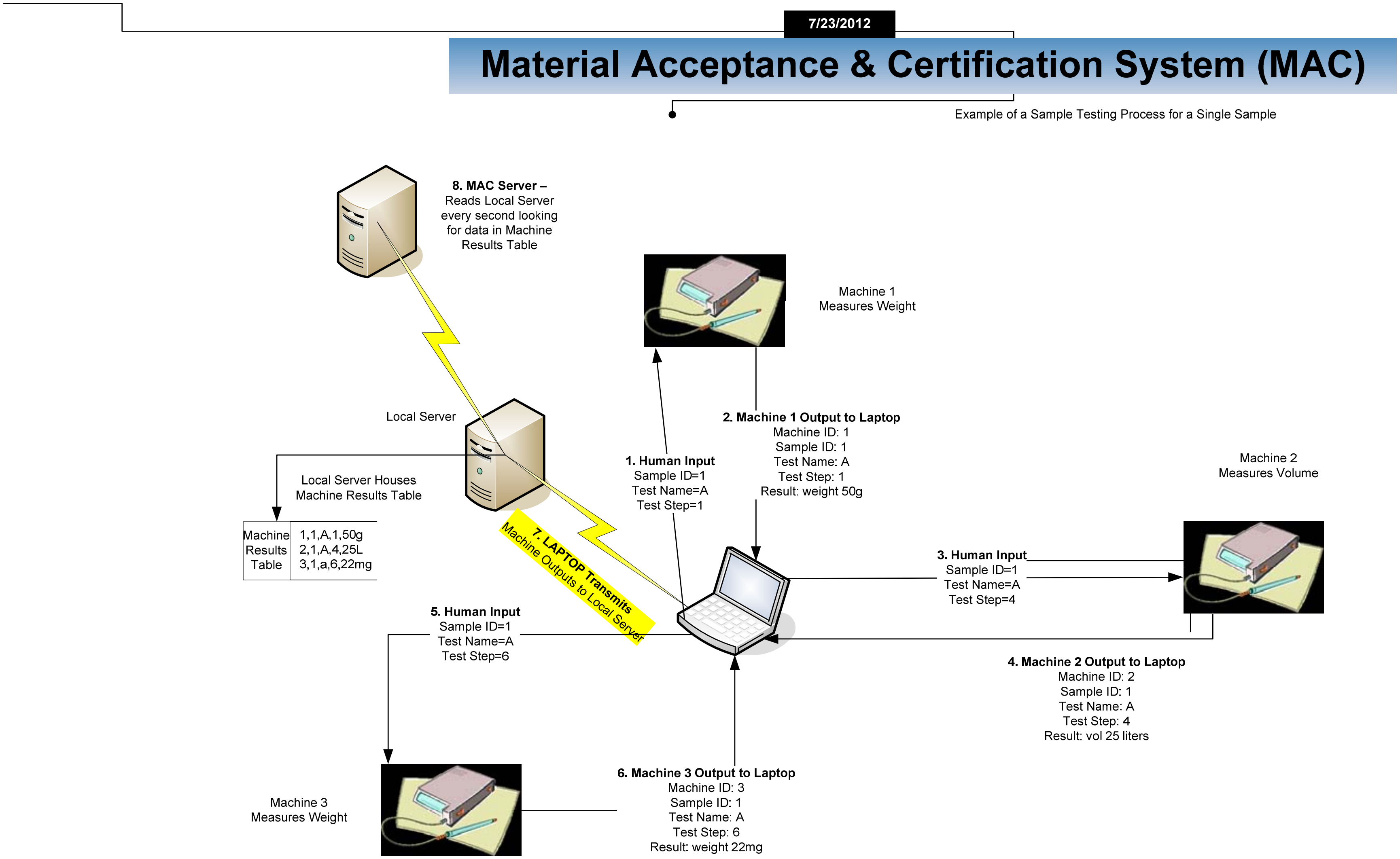


Figure 3-6. Overall architecture of new FDOT database system

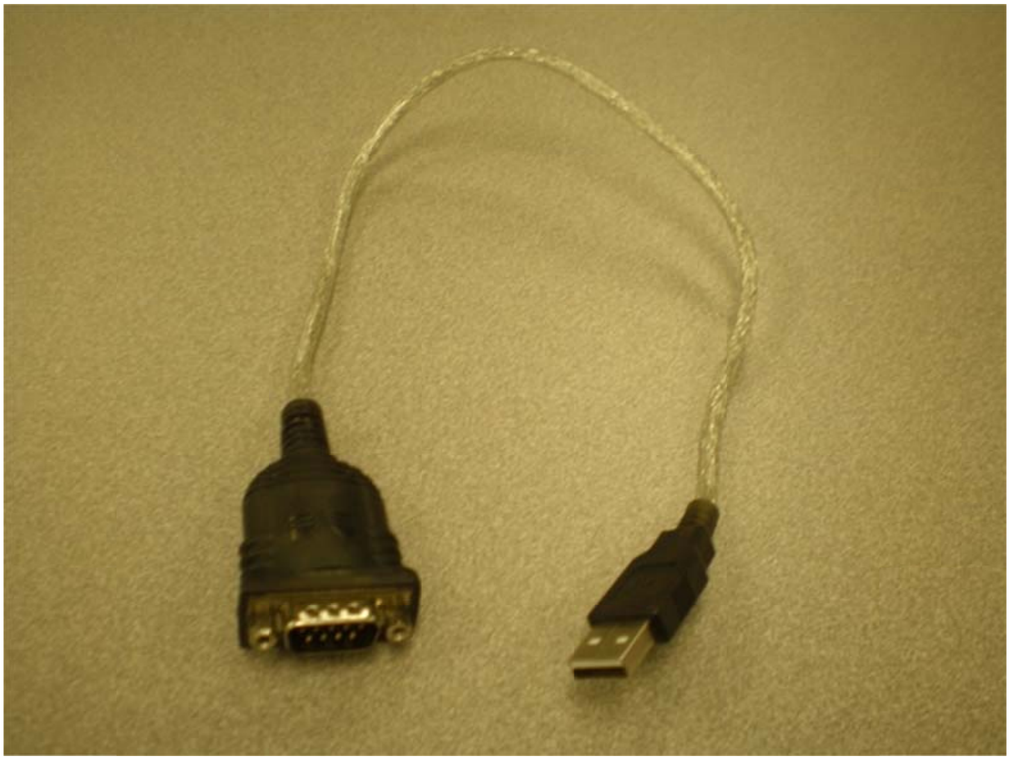


Figure 3-7. Photograph of Manhattan USB-RS-232 converter

Figure 3-8. Photograph of laptop, serial converter, and additional cable connected to digital scale.

Figure 3-9. Method for converting a 25-pin RS-232 output to USB

CHAPTER 4
REPRESENTATIVE AUTOMATION PROGRAM FOR THE SMO

4.1 Introduction

A representative automation program was developed to automate a selection of SMO mass balances. Because automating the SMO testing facility was specifically not in this project's scope, the level of complexity associated with this representative program was slightly reduced. A description of this preliminary program and requirements for advancing the program to the level of sophistication described in Chapter 3 is provided here.

4.2 Balance Variability and TeraTerm

As shown from Table 3-1 through Table 3-3, the SMO currently uses approximately eight mass balance manufacturers and several model-types from each manufacturer. As indicated in Chapter 3, the best method for communicating with these balances involves using Telnet-style commands through a serial port so that equipment upgrades may be avoided. While Telnet was discontinued with MS Windows when Windows Vista was released, open-source developers have released TeraTerm, which functions as an adequate replacement.

Investigators obtained user manuals from Mettler-Toledo and Ohaus to serve as representative examples of two common scale manufacturers used by the SMO. The user-manuals provide a list of Telnet commands that may be sent to the balances. However, there are subtle differences from model to model. For example, on one Ohaus model instrument, the command for a scale to output its serial number is 'PSN' while on another model the command to perform the same task was ‘SN.’ Similarly, for one Mettler-Toledo scale, the command to get a scale to output its serial number was ‘i5,’ while another Mettler-Toledo scale did not appear to recognize this command.

4.3 Program Development

Development of the automation control program consisted of scale manipulation with TeraTerm and LabVIEW. Discussion of each of these phases is discussed below.

4.3.1 TeraTerm

To set up a connection between a mass balance and TeraTerm, the following algorithm is required:

- Open TeraTerm
- Specify the following parameters through ‘Setup → Serial Port’ (Figure 4-1).
    - Baud rate
    - Parity
    - Stop bits
- Open a new connection. Go to ‘File → New Connection → Serial. Specify the correct communication port (COM). There should be only one COM option, although this subtle discussed will be discussed in greater depth in Section 4.4.1.1.

Required parameter specifications are available in each mass balance user manual. For the example shown in Figure 4-1 and Figure 4-2, the command to display the scale’s serial number is ‘i5’ for example while the scale’s help menu is displayed by pressing ‘i0.’ Please note that a serial port connection requires an ASCII-style carriage return after each command. Therefore, to send the command to a scale, the user must press ‘CTRL-Enter’ instead of simply ‘Enter.’

4.3.2 LabVIEW

During programing, investigators used TeraTerm to send basic commands to the scales to verify the commands' functionality. Once verified, a series of serial port commands was scripted using LabVIEW. Please note that the level of complexity discussed in Section 3.5.1 was not programmed. Rather, a simple 'sequence structure' was developed according to the following algorithm:

1. Ask the user to input the sample designation.
2. Ask the user to input his/her name.
3. Ask the user to designate scale manufacturer.
4. Read the balance's serial number.
5. Read the sample's mass.
6. Record sample mass, serial number, and a timestamp to a .txt file.

As described in Chapter 3, if one was to actually program a FM, a more complicated sequence structure would be developed. However, the structure of the simple algorithm described here can easily be modified to fit any of the FMs commonly tested at the SMO and other facilities.

This program was tested on two Ohaus-model and one Mettler-Toledo-model balances. Coincidently, subtle language differences described in Section 4.2 between scales of the same manufacturer were not an issue during these tests. However, because the subtle language differences are known to exist, the final version of the program should ask the user for "testing station" and not "scale manufacturer" in Step 3, above. This is a minor change that can easily be corrected when the final version of the program is written.

4.4 Automation Program Description

The program uses a serial of embedded case structures and sequence structures to coordinate sending serial port commands to the scales and reading their output. The following is a description of the program:

4.4.1 Front Panel Description

A modified version of this program's front panel is what will be seen by the user when its final version is complete. The current version is shown in Figure 4-3.

4.4.1.1 USB plug and communication port name

First, as in TeraTerm, the user must specify his or her communication port name on the front panel. The communication port name comes from installation of the USB to RS-232 converter. When its drivers are installed, and the converter is plugged into a laptop, the computer "thinks" that the USB plug has been transformed to a DB-9 connection. Each USB plug corresponds to a different communication port (or COM as shown). For the example programmed here, COM 3 was used. If the user were to plug the converter into a different USB port, a different communication port option would be available in the program's drop-down menu.

Plugging the converter into the incorrect USB port has the potential to cause serious issues for users who are unfamiliar with the LabVIEW requirement to specify the correct communication port. In the final version of the program, the communication port option should be hidden. To ensure that the correct communication port is always specified, future testers should be trained to always plug the balances' USB plugs into the same USB port. Additionally, a standardized "testing laptop" (any stock PC would suffice) should be specified so that there is no a question in terms of where to plug the USB cable.

If the USB cable is plugged into the wrong plug, the program will crash. To correct the issue, the USB cable must be plugged into the correct port, or the port's communication name must be changed. But, standardization would eliminate this potential error source.

4.4.1.2 Text-file location

The current version of the program allows the user to specify where he or she will save the program's output. This option is denoted “TEXT FILE LOCATION” in Fig. 4-3. In the final version of the program, the user should not have the option of switching file locations. Instead, the “TEXT FILE LOCATION” drop-down menu should be hidden. This will serve two purposes. First, it will help to ensure the integrity of each test. One could probably make the assumption that users are unfamiliar with LabVIEW and will be intimidated by its source code. Thus, it is unlikely that they would open the control program's source code to find where data are saved. If users are familiar with LabVIEW, integrity can be maintained by compiling the control program shown here to an .exe file. Thus, users would be precluded from changing the save file location.

Secondly, use of a static file location would ensure that the new LIMS system always “pings” the correct file. This is of vital importance to the system. If the output file location is continuously changing, it would be very difficult for programmers at the BSSO to account for this. In this version of the control program, the file location is specified to be somewhere on the PI's hard drive. However, in the program's final version, a server drive should be used. According to Mr. Davis, any laptop connected to the FDOT network can save to a server drive. If each output file is saved upon a server drive, the MAC will be able to talk to it.

With the structure described in Section 3.5, there is another subtle point about file save location that should be discussed. It is probably likely that at some point, two operators will be conducting the same FM at the same time. If they were both to write to the same output file at the same time, there is a small chance that data from one computer would contaminate data from another computer. The easiest way to guard against this would be for each laptop to have its own unique output file. But, this would require the MAC server to "talk" to more files. Conversely, if all tests from one FM wrote data to the same file, programming would be easier from a MAC-to-server standpoint. This detail is an area where future programmers and the BSSO must coordinate.

4.4.1.3 Running the program

Once all inputs have been properly specified, the user presses LabVIEW's "run" button, and the program begins. First the program asks the user to check a box to indicate the proper scale manufacturer (Figure 4-4). Then, the program asks the user to enter the sample designation and his or her name (Figure 4-5). After clicking "OK" in this dialogue window, the sample's weight, the scale's serial number, and a timestamp are displayed upon the front panel (Figure 4-6). Data are recorded via text file.

4.4.2 Source Code Description

Screenshots of the source code for this simplified program are shown from Figure 4-7 through Figure 4-10. As mentioned, the program is set up as a sequential, timed script whereby serial port commands are sent to a scale, the computer waits for a specified time period, reads the data, and moves on to the next task. The following is a description of the code:

4.4.2.1 Scale manufacturer stage

During the ‘scale manufacturer stage’ (Figure 4-11a), the user specifies which scale he or she is using. When the final version of the program is completed, this stage should be replaced with a ‘testing station’ list. This list acts as a ‘true-false test’ for the later stages of the program.

4.4.2.2 Sample designation stage

The ‘sample designation stage’ (Figure 4-11b)is similar to the ‘scale manufacturer stage’ in that a list was developed for user-specified inputs. This list may be replaced with appropriate inputs for any FM to be tested with the final program.

4.4.2.3 Serial number and data acquisition stages

After reading user-specified inputs, the sophisticated portion of the control program begins. First, as mentioned, LabVIEW assigns the correct serial port. Then, a series of embedded case and sequence structures were programmed to read/write data to and from the scales. The case structures check for the correct scale manufacturer (in the future this would be ‘test station), and assign the appropriate commands. In the final version of the control programs, it would be appropriate to make these station-specific preprogrammed commands unique subroutines, but the for the purpose of illustrating this simplified program’s functionality, they were left as scripts. The sequenced structures ensure that only one read/write serial port sequence is initiated at one time. This ensures that the program will run without an error each time the user presses the run button.

4.4.2.4 Serial port subroutine

As shown in Figure 4-12, a subroutine was written to read/write data to the scales' serial ports. This subroutine's source code is shown in Figure 4-13. It was programmed by modifying a preloaded NI LabVIEW example files that is available when the LabVIEW DAQmx module is installed. Its in-program comments should make its functionality relatively self-explanatory.

The serial port subroutine requires inputs of stop bits; baud rate; parity; and wait-time. These parameters are preprogrammed to match manufacturer specifications. The subroutine also requires the input of 'wait time' and 'write-data.' Write-data is simply the command that is to be written to the serial port. For the example shown in Figure 4-12, the command 'I5 \n' (\n represents a carriage return) was written to represent telling a Mettler-Toledo scale to output its serial number. As shown from Figure 4-7 through Figure 4-10, this command can be manipulated as desired.

Wait-time is determined through trial-and-error. It takes time for the scales to respond; for the scales to send their data to the computer; and for LabVIEW to interpret the data. Through trial-and-error with a Mettler-Toledo scale, an appropriate wait time was found to be approximately 500 ms (0.5 s) for a serial number read/write sequence. Similarly, as shown in Figure 4-8, the appropriate wait-time for a mass read/write sequence was found to be approximately 2000 ms (2.0 s).

4.4.2.5 Data manipulation

Figure 4-14 shows the next stage of the program. When data is sent from the scales to LabVIEW, it is often not in the correct format. Instead, extra spaces or quotation marks are also included. To guard against an improperly formatted data file, these spaces or quotation marks were removed by specifying an offset (the number '7' in Figure 4-14) and data string length (the number ‘9’ in Figure 4-14). Each character in a data string represents a data bit. The data offset command tells the computer to start reading at a certain position. The data length command tells the computer to read for a certain number of characters, thereby only saving the useful portion of the data.

Subtle command differences were discussed in Section 4.3.1 for different scales from the same manufacturer. Along with these command differences, often different scales from the same manufacturer have subtle data output differences. For example, for one Mettler-Toledo scale, the appropriate offset was 7 while for another Mettler-Toledo scale, the appropriate offset might be 10. Similarly, the appropriate data string length may vary based upon scale precision and balance units. This is another reason that in the final version of the program, station designation and not scale manufacturer should be specified.

4.4.2.6 Data/time stamp and concatenate string command

Figure 4-15 shows the date/time stamp commands and the concatenate string command. These commands are preprogrammed in LabVIEW. The concatenate string command creates one string from several strings. For the case shown in Figure 4-16, the ‘TAB’ command was used so that the output data file was properly delimited.

4.4.2.7 Writing data

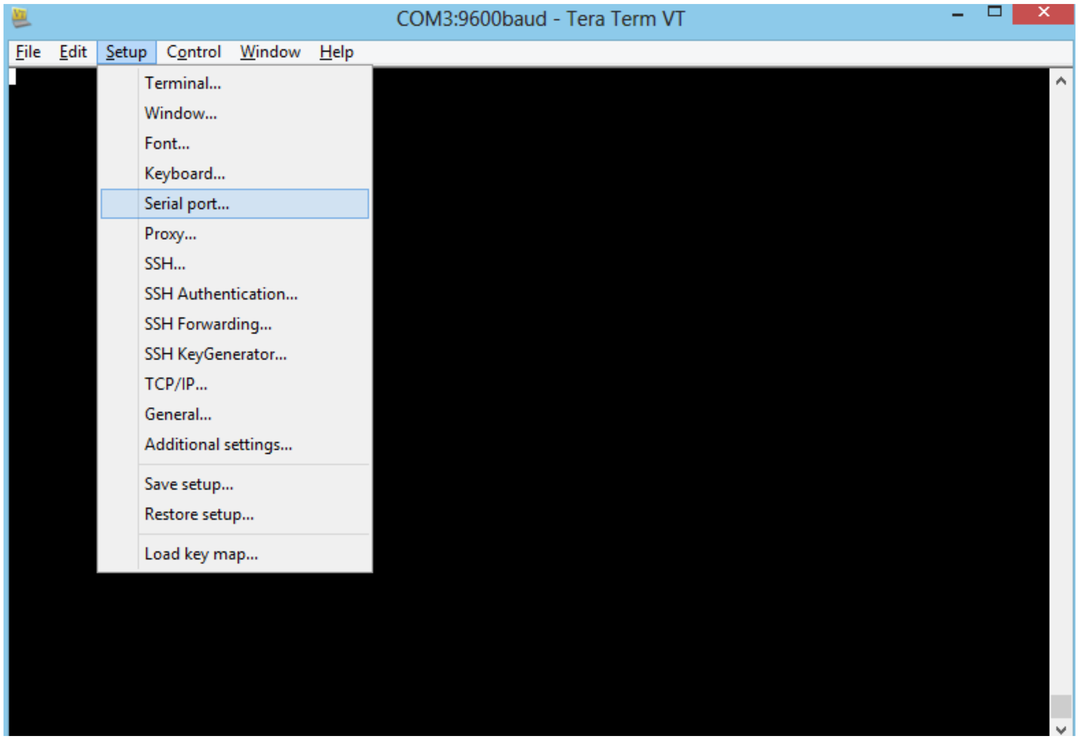
Figure 4-16 shows the data write sequence for the simplified program. As shown, a large concatenate string command is used to bring all the data together with appropriate TABS so that there is one line of data per test. The other commands in the window simply ensure that string data is written at the end of the data file. These commands tell LabVIEW to write data to a specified binary file, find the end of the file, and to close the file after each data run. Output data is recorded via .txt file spreadsheet as mentioned (Figure 4-17).

4.5 Discussion

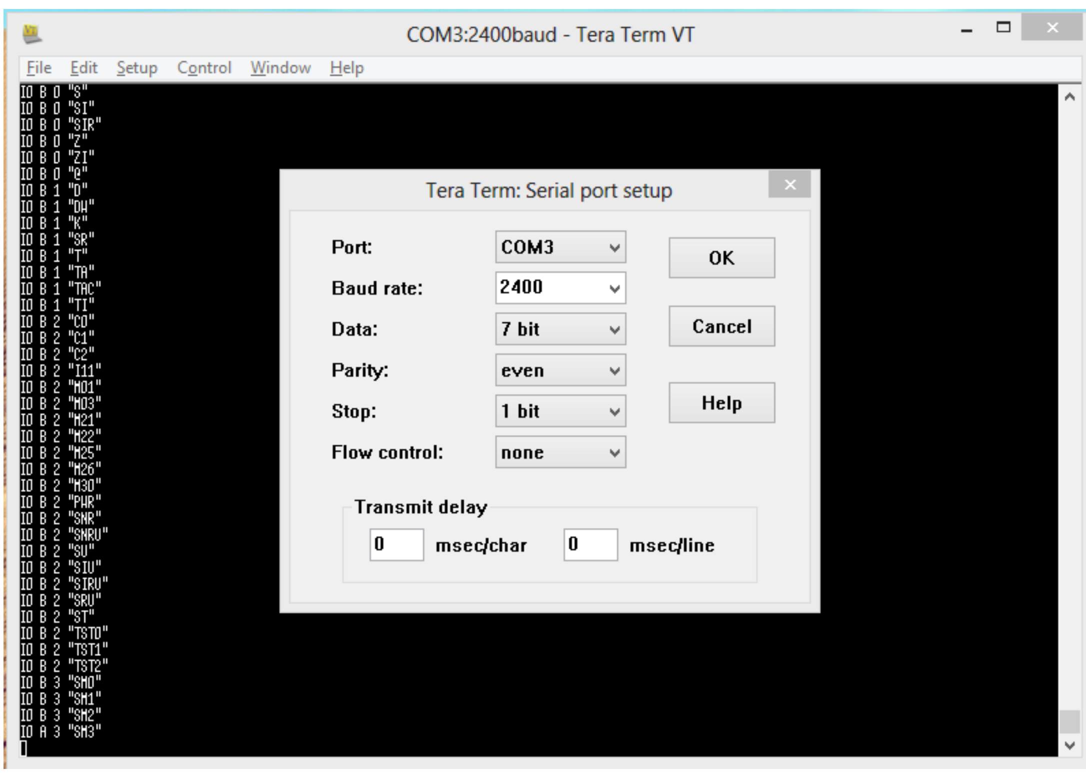
As mentioned several times throughout this chapter, this simplified program is meant to show that scale automation is possible. When the final control sequence is programmed, it will be much more sophisticated and contain many more embedded case/sequence structures.

It should be noted that the program structure discussed here inherently presumes static laboratory conditions. In other words, if a scale is swapped with another or if a balance is replaced, the method described here will not function as designed. This method hinges upon preprogramming a Telnet string of command, specific to each FM or test station.

When testing this sequence, the most common source of error occurred because users often forgot to ensure that the balances were powered ‘ON.’ It would be possible to eliminate this error source through the addition of another popup window.

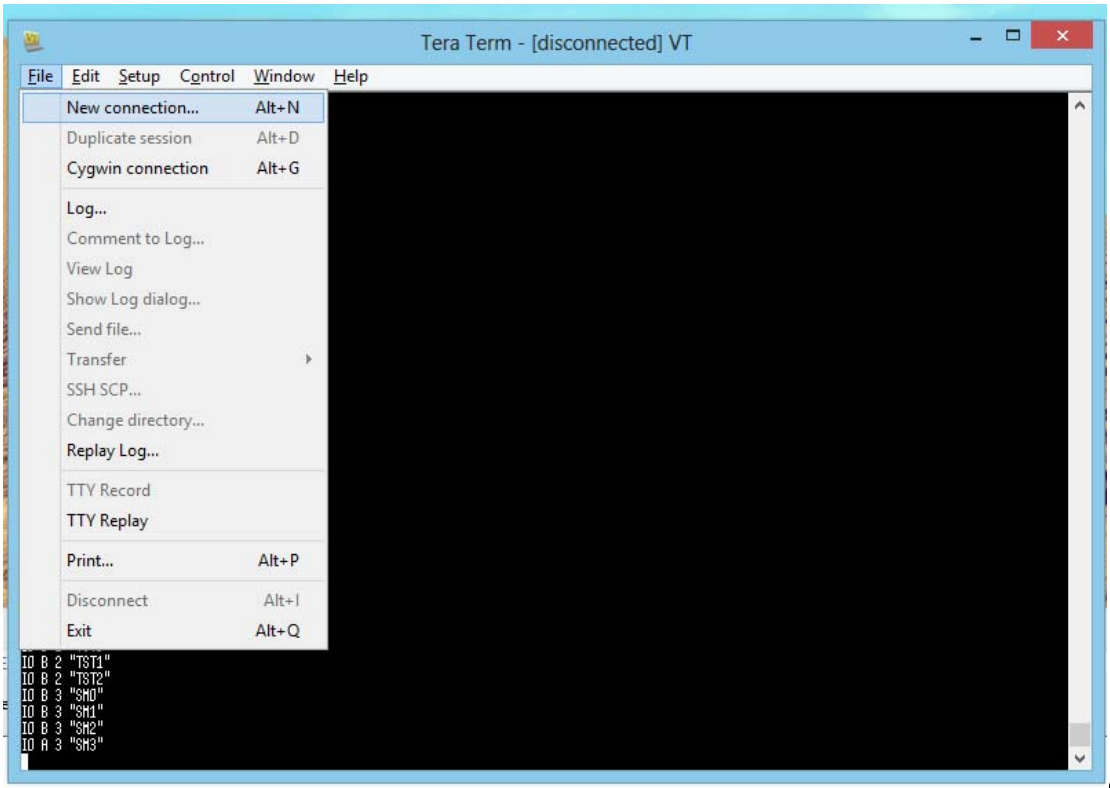


(a)

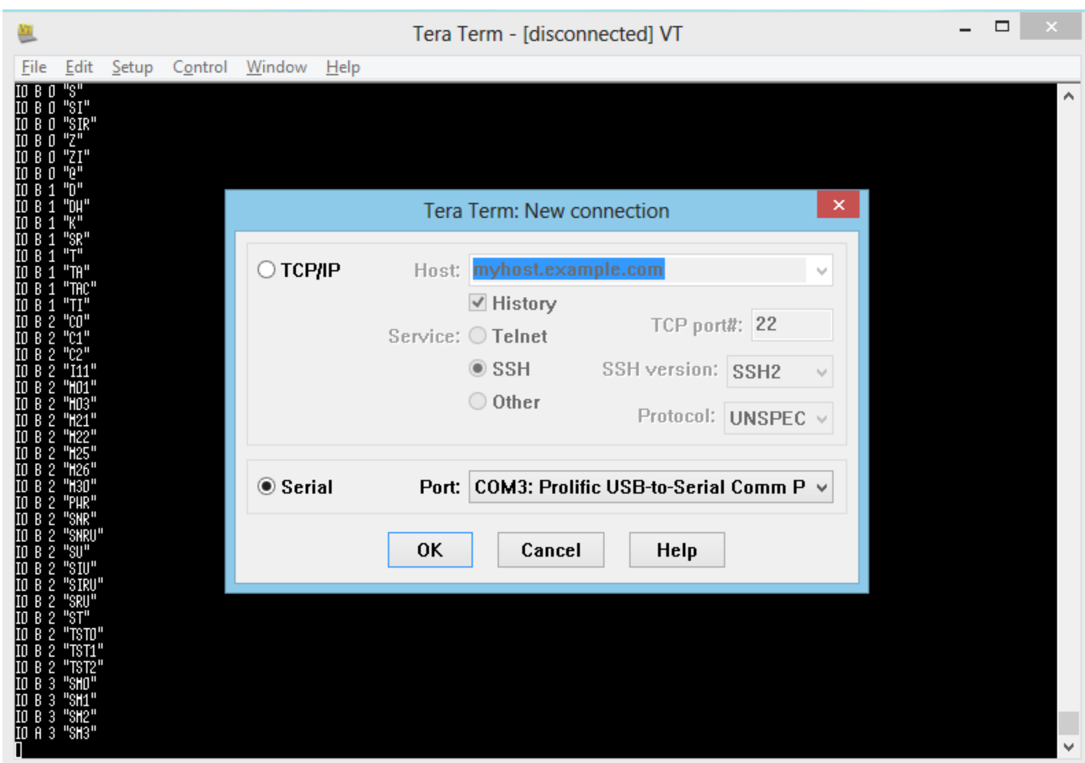


(b)

Figure 4-1. Correct TeraTerm setup for Mettler-Toledo model PL3002 showing (a) serial port menu location and (b) setup parameters.



(a)



(b)

Figure 4-2. Connection sequence through TeraTerm for Mettler-Toledo PL3002 showing (a) 'New Connection' location; and (b) COM3 selection

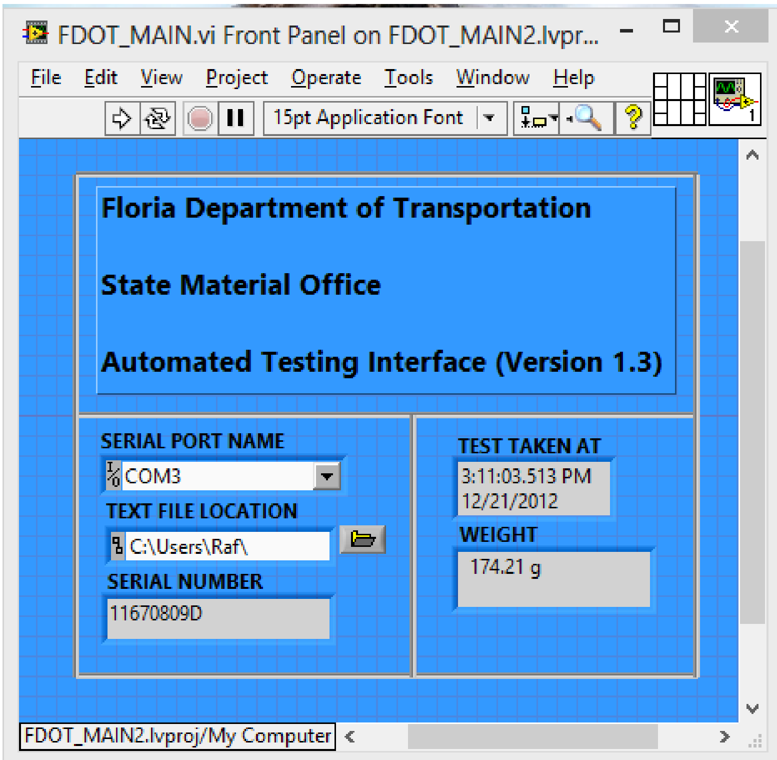


Figure 4-3. Front-panel of simplified automation program for SMO

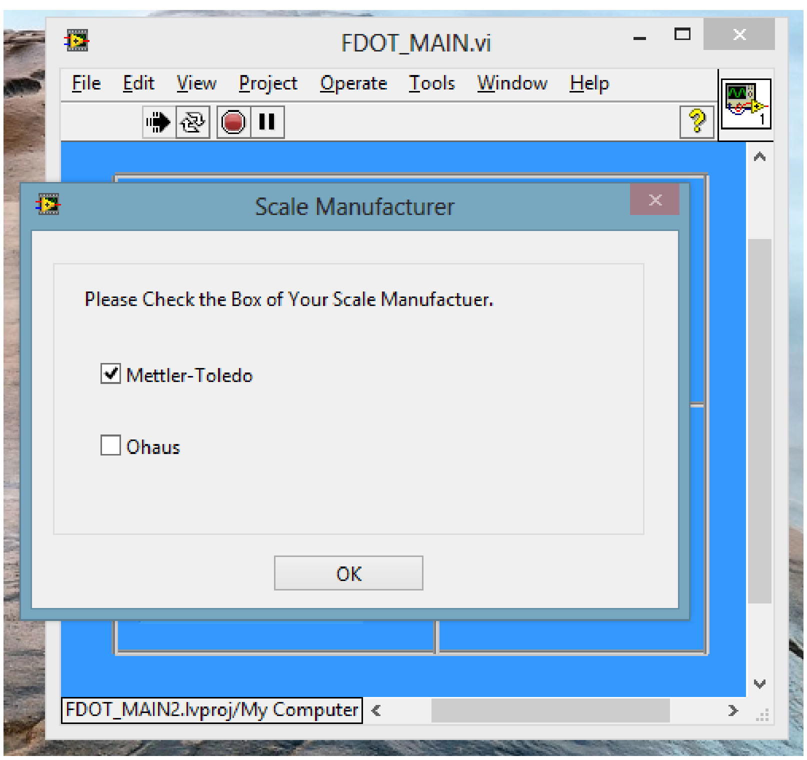


Figure 4-4. Scale manufacturer checkbox in simplified program. In the final version, this should be replaced with 'test-station designation.'

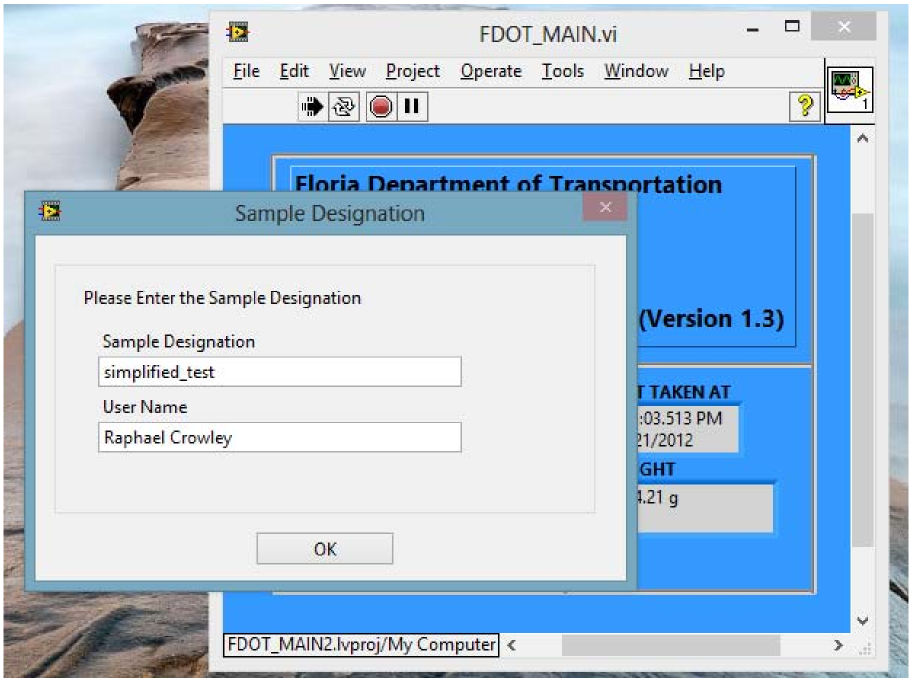


Figure 4-5. Sample designation and User Name popup in simplified program.

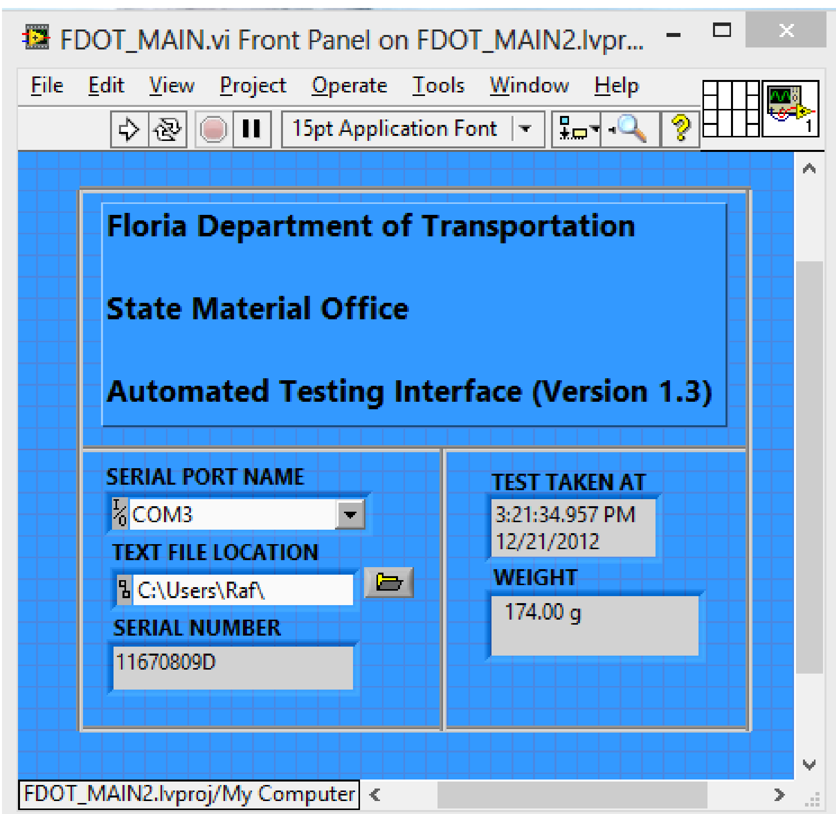


Figure 4-6. Front-panel after a data run. In this case, an iPhone 4s with Otterbox case was weighed.

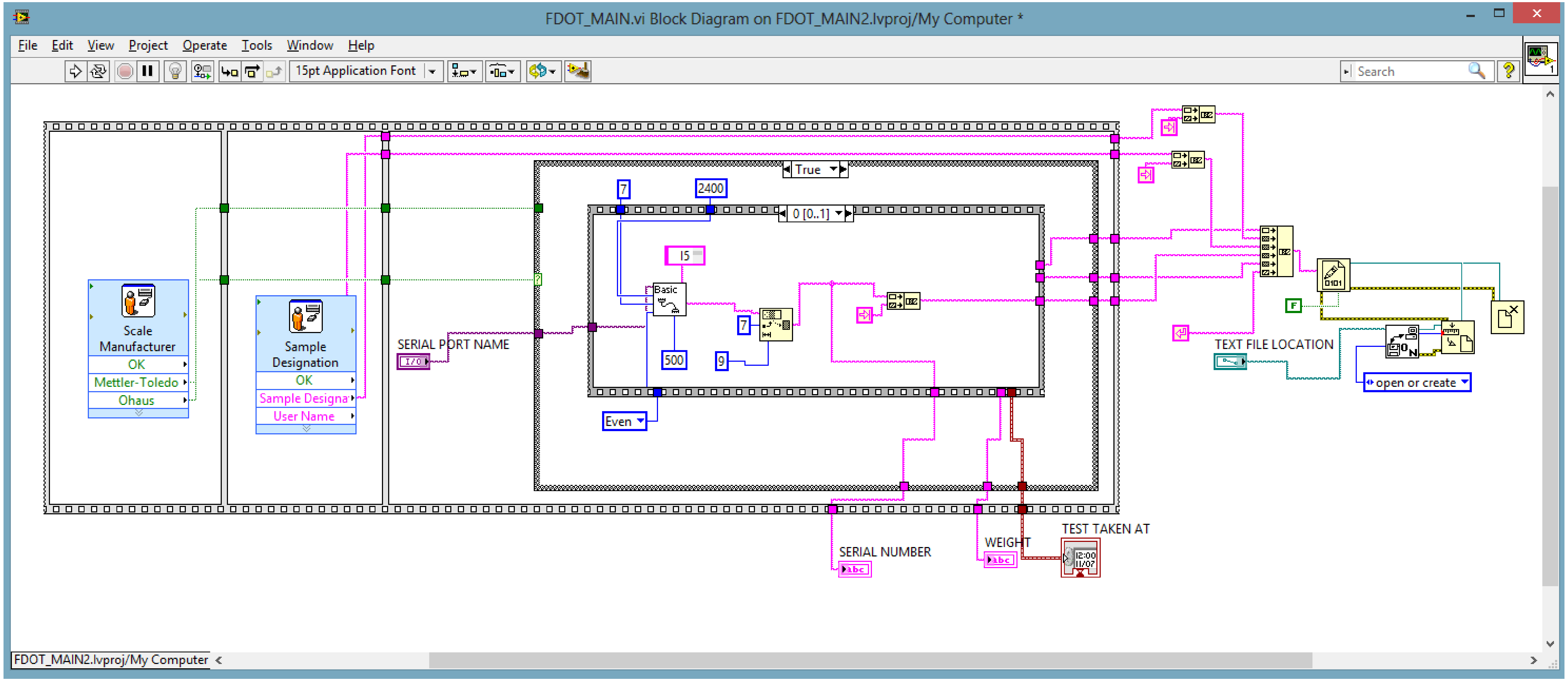


Figure 4-7. Screenshot of simplified program source code showing serial number stage for a Mettler-Toledo scale

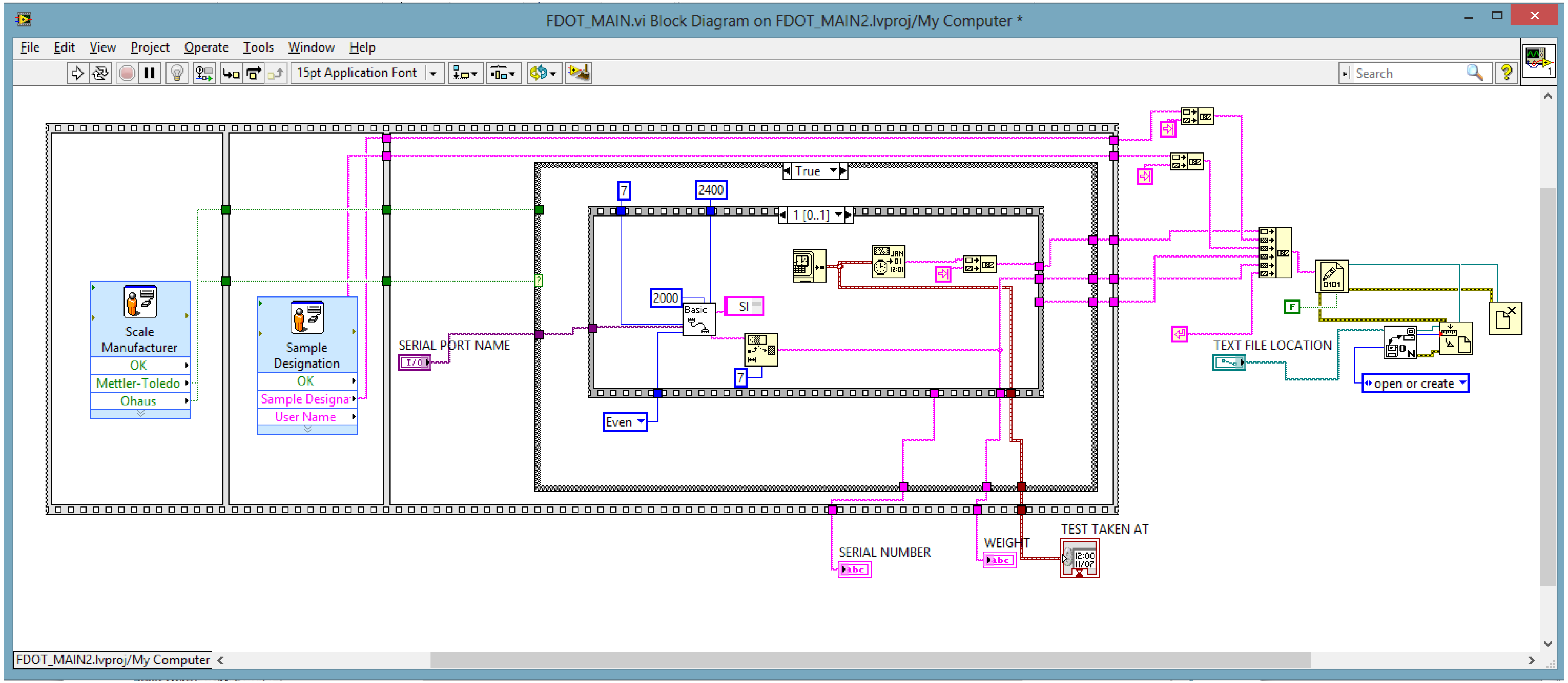


Figure 4-8. Screenshot of simplified program source code showing data acquisition stage for a Mettler-Toledo scale

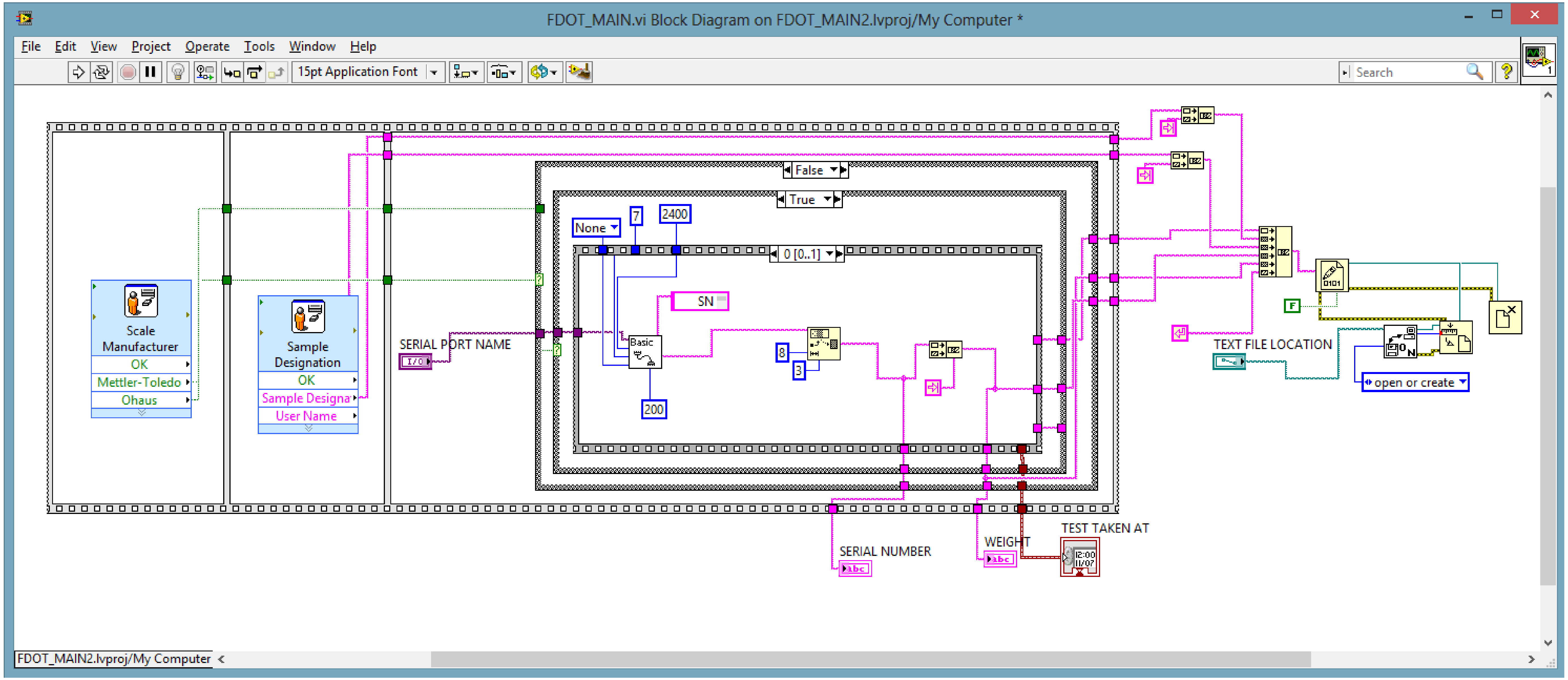


Figure 4-9. Screenshot of simplified program source code showing serial number stage for Ohaus scale

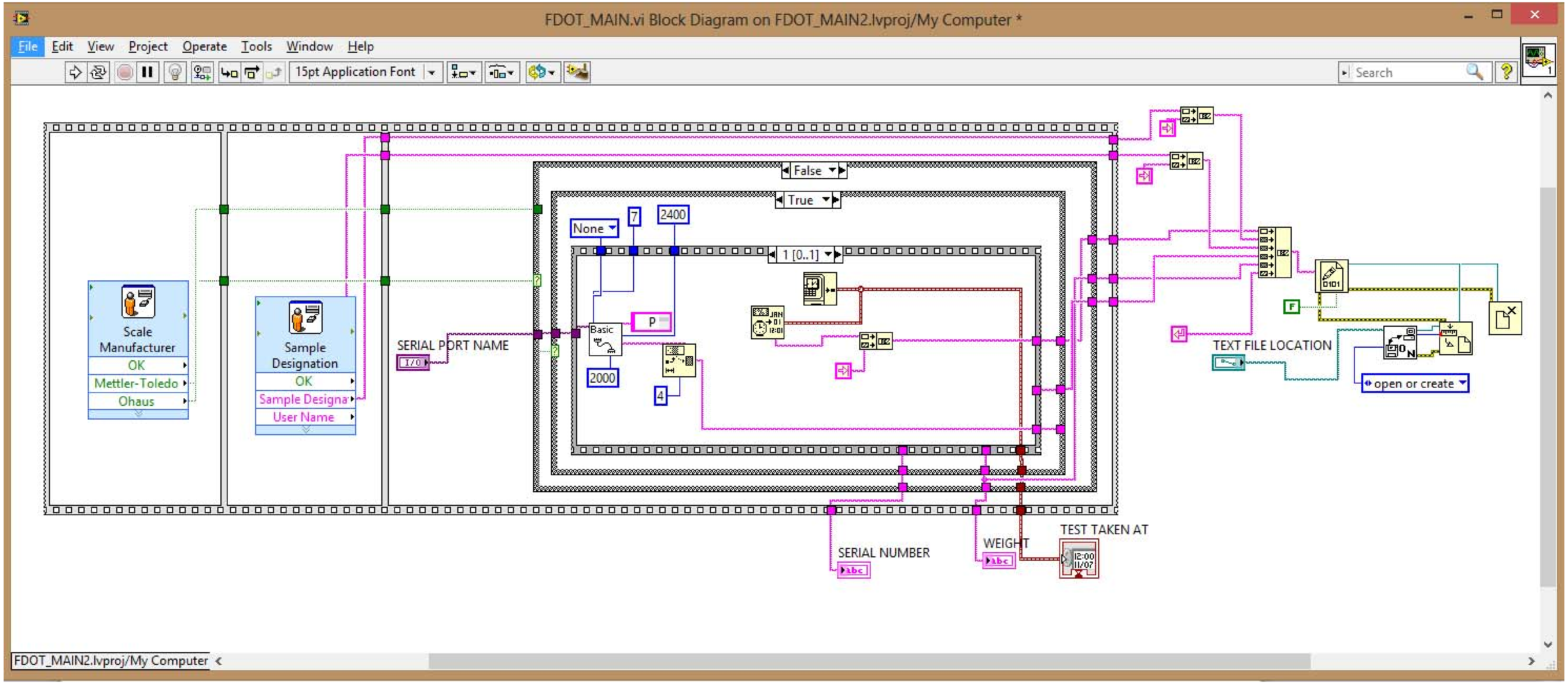


Figure 4-10. Screen shot of simplified program source code showing data acquisition stage for Ohaus scale

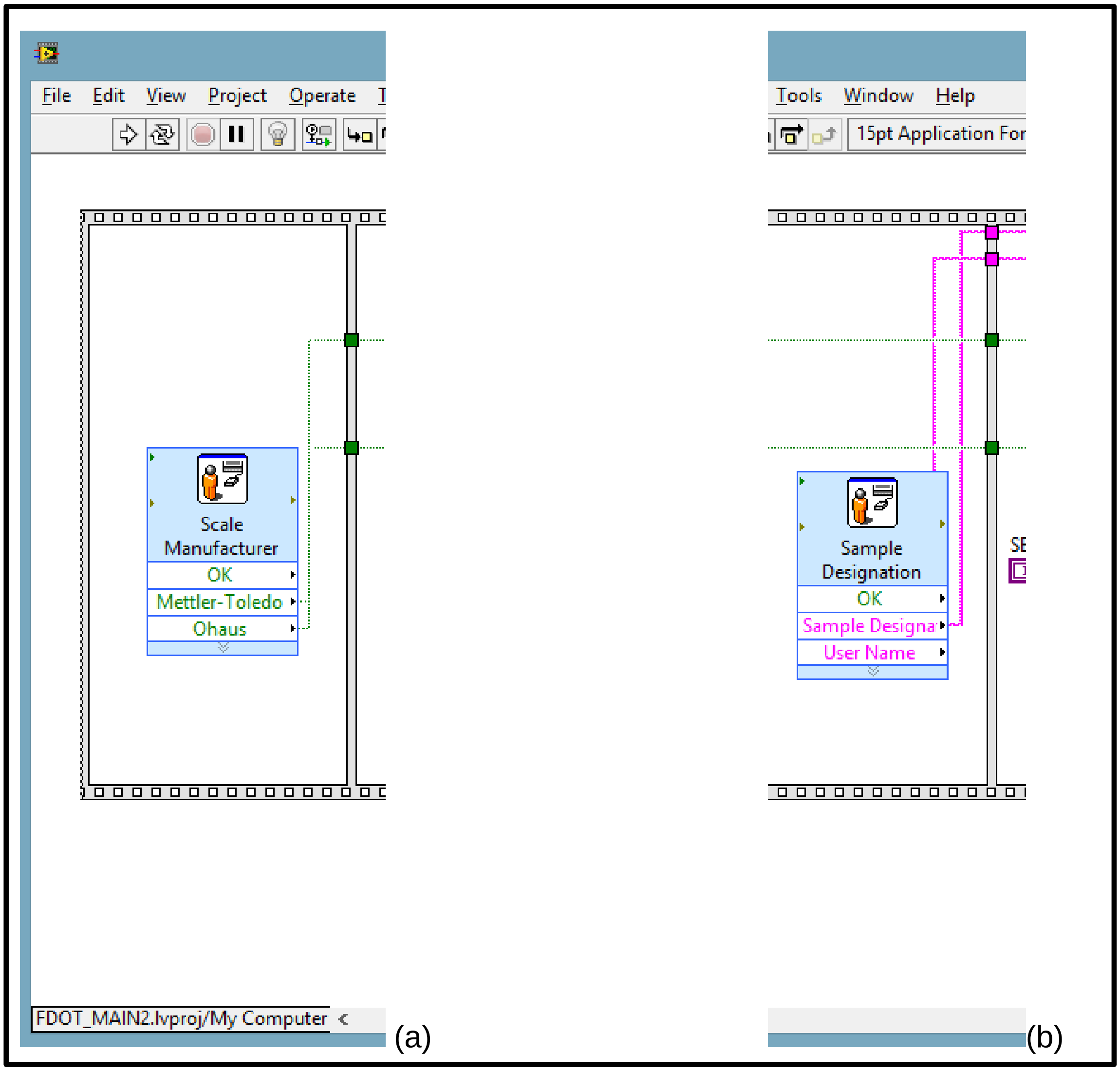


Figure 4-11. First two stages of simplified program. (a) shows sample manufacturer stage; (b) shows sample designation stage

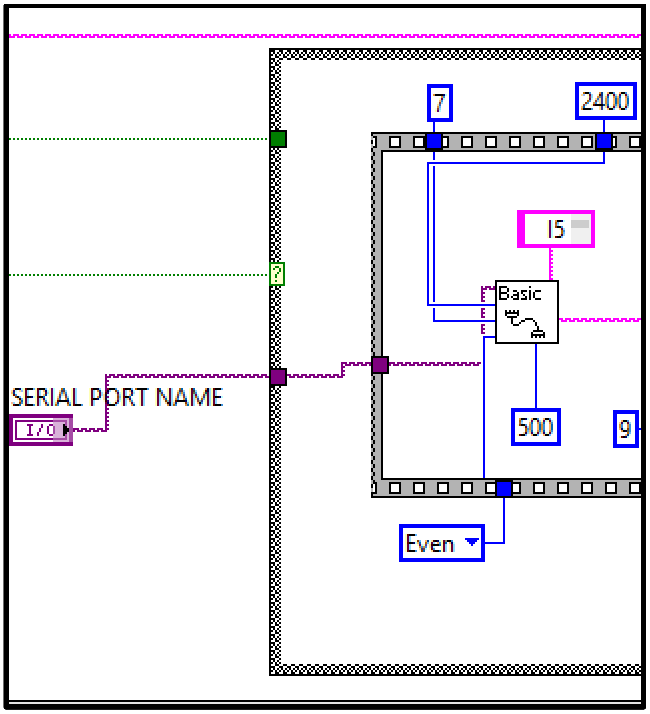


Figure 4-12. Read-write to serial port subroutine

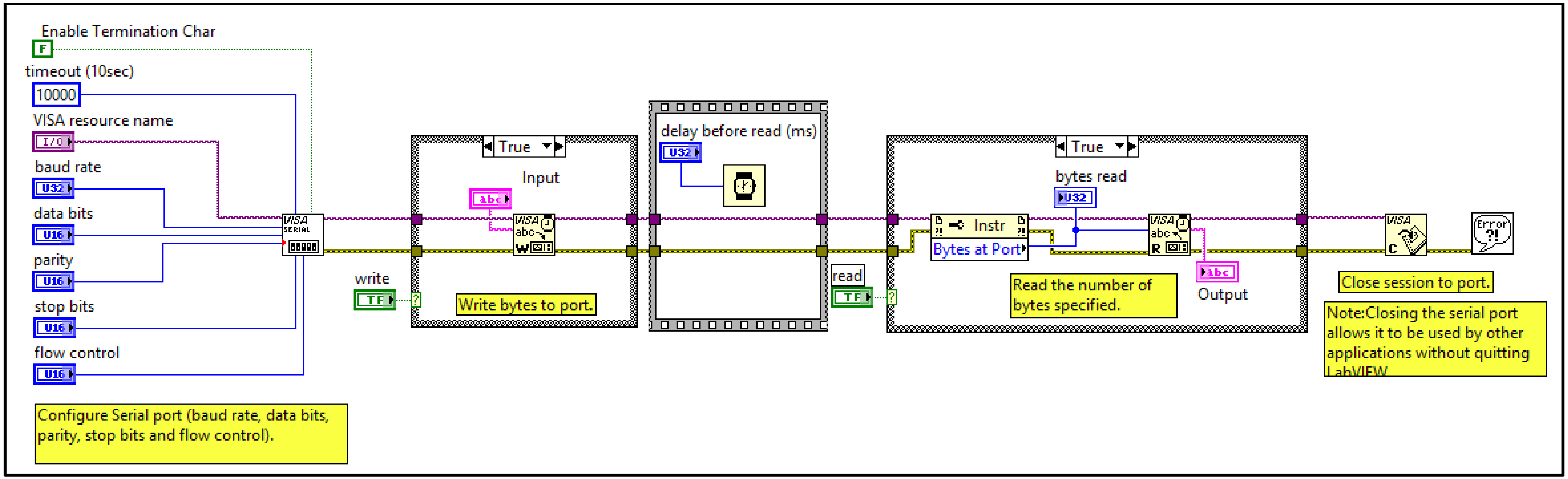


Figure 4-13. Source code for serial port read/write subroutine

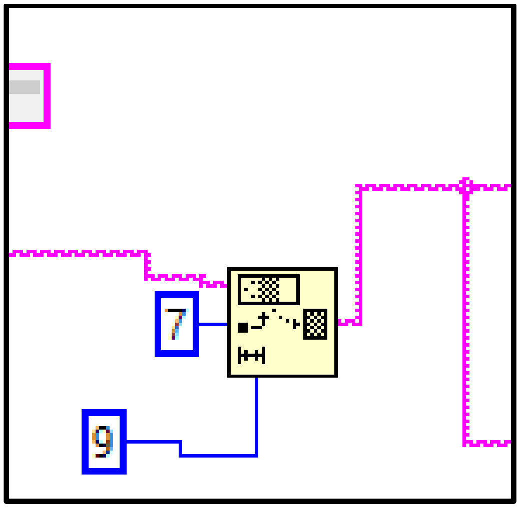


Figure 4-14. Data manipulation routine showing offsets and data length

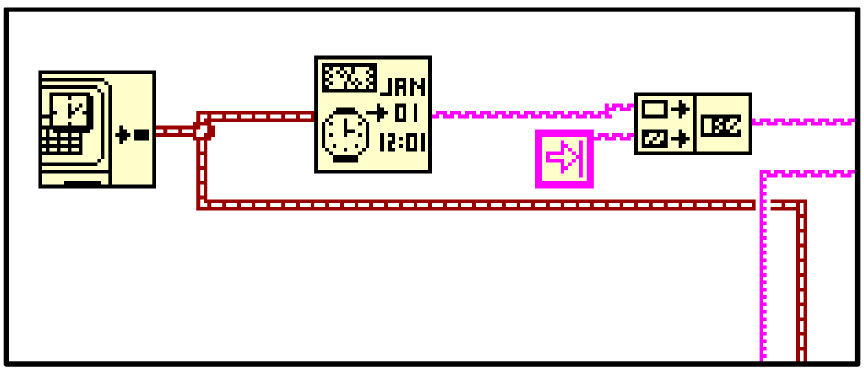


Figure 4-15. Data/time stamp commands and concatenate string commands

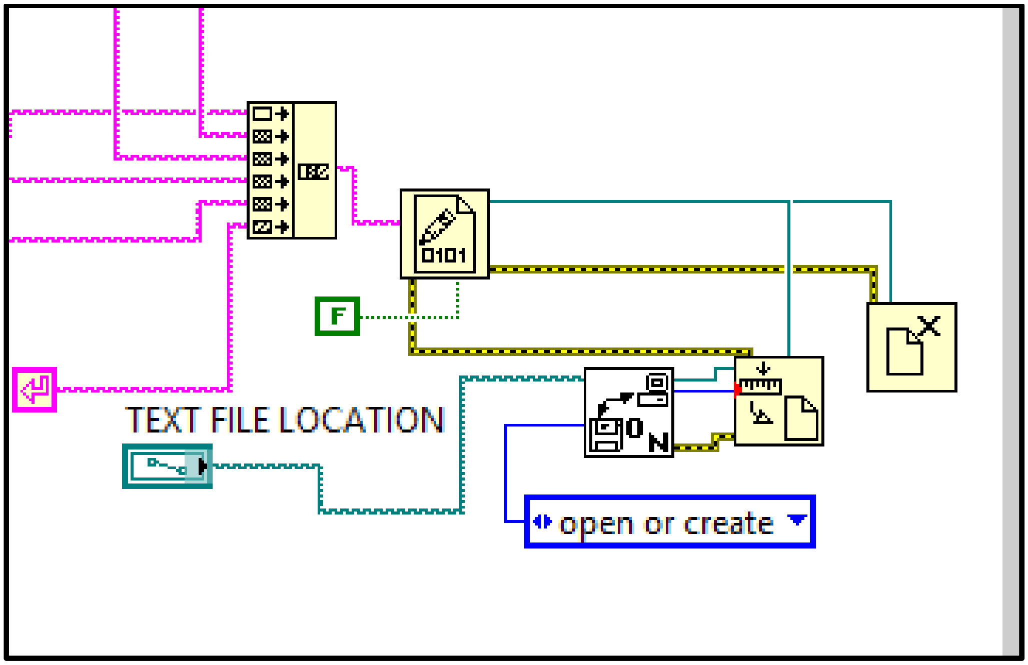


Figure 4-16. Data write sequence

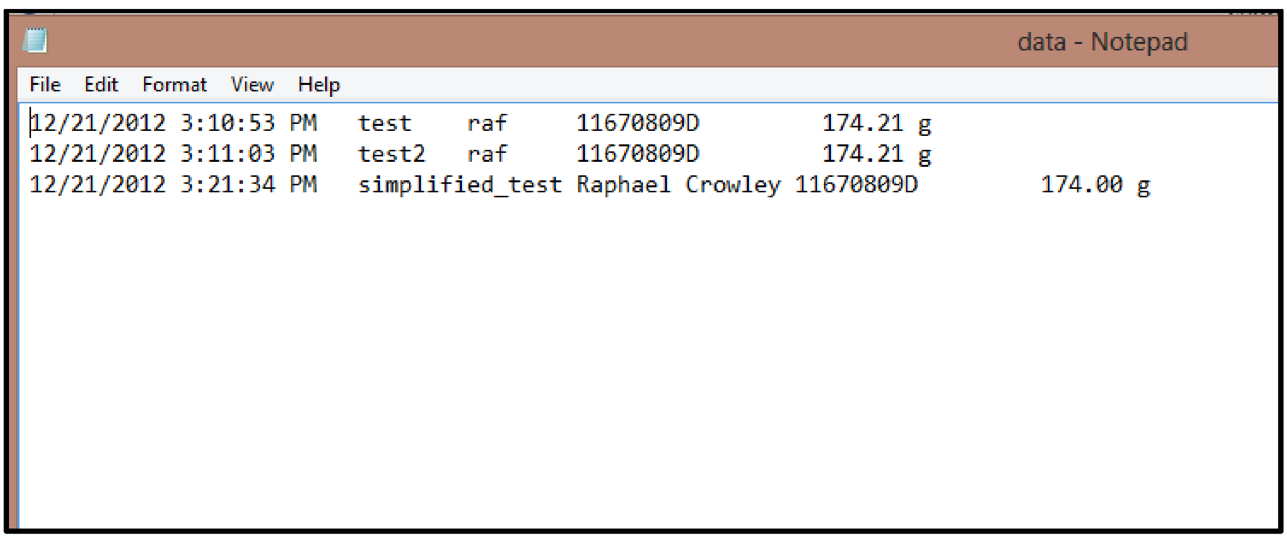


Figure 4-17. Example of output data

CHAPTER 5
TESTING OUTSIDE OF THE SMO

5.1 Introduction

As mentioned in the introduction, one of the other goals of this project was to find a system that would both improve test integrity and decrease transcription errors private, outside tests are conducted. Also as discussed in Chapter 3, the algorithms from this project are to be adopted by other FDOT testing facilities. The following is a discussion of work associated with outside testing:

5.2 Other FDOT Facilities

To reduce transcription errors FDOT facilities other than the SMO, the system described in this report would appear to be appropriate. However, implementing it on a statewide scale would require significant time because of programming requirements associated with designating a specific preloaded set of commands for each testing station/mass balance. Additionally, as discovered at the SMO, implementing this system in some outside laboratories may require equipment upgrades because this system presumes that all scales are at least equipped with an RS-232 connection. Before implementing such a system on a statewide scale, FDOT should develop and study an inventory to determine if the upgrade cost associated with older-model scales is balanced by the benefits of automation.

5.3 Outsourced Testing

Investigators were in contact with laboratory managers from the SMO throughout this project. Lists of outside tests associated with laboratory or LIMS access so investigators could look at data themselves were requested, but information and access were often unavailable. However, with the information that was available and the work presented in this report, investigators were able to come to some conclusions.

5.3.1 Transcription Errors

As indicated, one of FDOT"s priorities is to reduce transcription errors. The automation methods presented here should be possible outside of FDOT's network if contractors can be given limited access to the network. However, due to security concerns, this method is not recommended.

Alternatively, FDOT could set up a remote server drive specifically for outside testers. By setting up such an "outside-tester-only" (OTO) system, security within the current FDOT computing framework would be maintained. The OTO server would be "pinged" by the MAC server in the same manner described in Chapter 3. This OTO server would still require each private tester to input his or her username and password; but it would be separated from other FDOT servers so that security could be maintained. If FDOT required outside testers to use an automated system, computing, device, and network specifications would be required. These specifications should be as follows:

5.3.1.1 Device requirements

With the program framework described here, any scale with an RS-232 output could be made compatible. However, it would be inefficient for FDOT to program a specified user-interface for each prospective outside tester. Instead, FDOT should develop a list of scales and RS-232 to USB converters that they deem 'acceptable' for outside testing. The simplest method for this from a computing standpoint would be to choose a list of approximately 10 scales currently in use at the SMO and one converter. Release the finalized FM/testing station subroutines discussed in Chapter 3 as a stand-alone OTO program and provide it to private testers at no cost. The difference between the system described in Chapter 3 and Chapter 4 would be that outside testers would specify "scale model" instead of "testing station" in the program's first popup window. This way, FDOT would minimize future programming requirements.

5.3.1.2 Computing

To use the automation program described here, outside testers would be required to be equipped with an automated PC capable of running NI LabVIEW Runtime Engine 2012 or later. The LabVIEW runtime engine is required to run any .exe files built with LabVIEW. Therefore, as implied, the OTO release version of the automation program must be compiled to an .exe file. Within the install package for the control package, BSSO programmers should coordinate with future automation programmers so that both are ensured that data are properly written to the same server drive. According to NI, specific requirements for LabVIEW RunTime Engine include:

- A Pentium III/Celeron 866 MHz or equivalent processor
- 256 MB RAM
- 1024x768 screen resolution
- Windows 7/Vista, Windows XP, Windows Server 2003 R2 (32-bit), or Windows Server 2008 R2 (64-bit) operating system
- 353 MB free disk space

However, these are minimum requirements, and experience with LabVIEW has shown that using such slow processor speeds and RAM capacities significantly causes

LabVIEW programs to run sluggishly. FDOT may wish to stress that using computers associated with these speeds may cause frustration during testing, and FDOT may wish to encourage slightly enhanced computing standards.

Additionally, as of the date of this report, Windows 8 is not listed as a compatible operating system. However, as shown throughout this report, the system programmed here is known to be Windows 8 compatible with the 2011 version of LabVIEW.

5.3.1.3 Network Specifications

Network requirements should be specified after FDOT sets up an OTO server. At minimum, a direct service link (DSL) Internet connection would be required. From a connectivity standpoint, FDOT could specify a number of options. They could choose to use one laptop for a number of scales as recommended at the SMO, and the laptops would connect to the Internet through a router. However, as discussed in Chapter 4, the issue with using laptops and RS-232 converters is that a user could plug his or her USB cable into the wrong USB port. Therefore, it may be beneficial for FDOT to specify a list of laptops compatible with Section 5.3.1.2 and include instructions on which USB plug should be used.

Alternatively, outside testers could hard-wire a desktop computer to each mass balance and to the Internet. Such a setup would eliminate the USB plug issue, but it would require compiling the control programs for different computers based upon the computers' USB port configurations.

Finally, FDOT could specify either desktops or laptops, eliminate the RS-232 to USB conversion requirement, and instead require outside testers to obtain computers with serial ports. Since most computers with serial ports are only equipped with one port, it reduces the chance for a connectivity issue. This third method may be a viable option in the short-term, but in the long term, it is probably not feasible because the trend in computer manufacturing is to eliminate RS-232 inputs from the computers' motherboards.

5.3.2 Test Integrity

Unfortunately, a comprehensive list of all outside tests was unavailable as of the date of this report. However, based upon discussions with the PM, a study of some common FMs, and limited conversations with David Webb (SMO Bituminous Laboratory Manager), limited recommendations can be made.

In this project's original proposal, investigators speculated that it may be possible to record outside tests via webcam to ensure integrity. With the automation program described in this report, this option is certainly feasible from a programming standpoint. Without significantly more work, one could add a quick NI IMAQ programming sequence to the control program and send a video file of tests to FDOT (.avi format). However, from a feasibility standpoint, this option appears to be impractical for two reasons. First, it would be difficult to ensure proper webcam setup (focus, bitrate, etc.), and it would add another level of complexity to a system that is already significantly increasing its level of sophistication. Incremental changes to state testing requirements are probably more feasible. Secondly, such a setup would require testers at the SMO to view a certain number of tests. In a sense, this defeats the purpose of outsourcing testing.

A more feasible solution includes in-house verification. However, several FMs already require verification procedures. Once a comprehensive list of outside tests becomes available, it may be beneficial to crosscheck these tests with associated FMs to ensure that more verification is needed.

Mr. Webb did indicate that PSI, Inc. was often used to outsource mix design verification. He indicated that from September 2012 through December 2012, three of each of the following tests was performed per month by PSI:

- Asphalt correction factor
- Gradation
- Bulk specific gravity
- Maximum specific gravity
- Fine aggregate angularity
- Moisture susceptibility

Unfortunately, such a low sample-size over such a short time-domain makes it difficult to compute meaningful statistics for these tests. Over the next year, FDOT should catalog all outside tests so that meaningful verification statistics can be computed.

CHAPTER 6
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The following is a list of work conducted in this study, conclusions from the study, and recommendations:

- An in-depth literature review was conducted to determine other laboratories responses to transcription errors. Investigators found that a representative sample of some “top laboratories” do not have a method to guard against transcription errors.
- In the medical field, transcription errors have been studied. Systems designed to reduce these errors appear to be effective. Additionally, the California GLDMS was investigated. A modified version of the GLDMS should be appropriate for FDOT testing standards.
- An inventory was prepared of existing SMO equipment and inserted into detailed engineering drawings.
- Much current equipment at the SMO does not appear to be capable of automation. A budget was provided for upgrade requirements.
- For SMO equipment that is capable of automation must be converted to work with modern laptops. A budget for these conversions was presented.
- Automation of FDOT’s SMO and other laboratories is feasible, but it will require significant programming associated with each FM tested in these facilities.
- A simplified automation program was set up. This program was tested with four balances at the SMO and two balances at UF. Results appear to indicate that automation is feasible.
- Programming an automated system will be complicated because of equipment variability. Subtle command differences and subtle output differences were identified as two of the most likely sources of complication.
- Additionally, programming will be complicated by the number of FMs used by FDOT. Two options were discussed: (1) using a “master control program;” and (2) designing a different control program for each FM. Option (2) appears to be the most appropriate intermediate step, although both options are feasible.

- Programming with scales that are not “Windows compatible” means that any automation system must assume static equipment within each laboratory.

- Recommendations for offsite testing were provided for both other FDOT facilities and private laboratories. Other FDOT facilities should be compatible with the system discussed in this report, but this will add another layer of computing complexity. Outside testing facilities should be given specifications and an OTO server should be set up to accommodate them. A menu of these recommendations was provided.

- Testing integrity was investigated, but sufficient data were unavailable to draw any meaningful conclusions. Investigators recommend that FDOT begin cataloguing test sources over the next year so that statistics can be computed.

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