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CALIBRATION OPTIMIZATION OF STRAPPING TABLE DATA IN HORIZONTAL FUEL STORAGE TANKS USING 3D LASER SCANNING

Ahmed Jasim Mohammed ALISHAQEE

Master's Thesis

Supervisor

Asst. Prof. Dr. Merve Bulut YILGÖR

Istanbul, 2023

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The thesis titled CALIBRATION OPTIMIZATION OF STRAPPING TABLE DATA IN HORIZONTAL FUEL STORAGE TANKS USING 3D LASER SCANNING prepared and presented by Ahmed Jasim Mohammed ALISHAQEE was accepted as a Master of Science in Electrical and Computer Engineering.

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Asst. Prof. Dr. Merve Bulut YILGOR

the Supervisor

Thesis Defense Jury Members:

Asst. Prof. Dr. Merve Bulut YILGÖR	Department of Basic Sciences, Altınbaş University	__________________
Asst. Prof. Dr. Selin Selen Özbek ŞİMŞEK	Department of Basic Sciences and Mathematics, Altınbaş University	__________________
Assoc. Prof. Dr. Elif Segah ÖZTAŞ	Department of Basic Sciences, Altınbaş University	__________________

I hereby declare that this thesis meets all format and submission requirements of a Master;s Thesis.

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Ahmed Jasim Mohammed ALISHAQEE

Signature

DEDICATION

To my family, whose unwavering support and love have been the driving force behind my academic journey. Your encouragement, understanding, and sacrifices have shaped me into the person I am today. This thesis is dedicated to you.

To my supervisor, for your guidance, expertise, and belief in my abilities. Your mentorship has been invaluable, and I am grateful for the opportunities you provided me to grow as a researcher.

To my friends, for the laughter, camaraderie, and moments of respite during this challenging endeavor. Your presence has brought joy and balance to my life, reminding me of the importance of connection and shared experiences.

May this work contribute to the advancement of knowledge, spark further inquiry, and inspire future generations of researchers and scholars.

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ABSTRACT

CALIBRATION OPTIMIZATION OF STRAPPING TABLE DATA IN HORIZONTAL FUEL STORAGE TANKS USING 3D LASER SCANNING

ALISHAQEE, Ahmed Jasim Mohammed
M.Sc., Electrical and Computer Engineering, Altınbaş University,
Supervisor: Asst. Prof. Dr. Merve Bulut YILGÖR
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In wet stock management we do need to know how much fuel we have in the storage tanks (inventory), to get good reconciliation reports i.e. (volume of fuel dispensed from the pumps vs volume decreased in the fuel tank), the difference called variance, the smallest variance, the best reconciliation, the best tank strapping, or calibration. So, we have to get good strapping table T.C.T. (Tank Calibration Table, that profile the fuel height against the volume of each height) from here we can list the well-known Calibration methods:

a. Meter drop\dispense Method, using master Flow meter Certificated & calibrated [1].
b. Manual strapping Method [2].
c. EODR Method, Electro-Optical-Distance-Ranging [3].
d. 3D Laser Scanning Method [4].

3D Laser Scanning for Horizontal Fuel Tanks is a unique technology which there is no laboratory or accredited body to apply through any standard. Because there is no standard to fit this method, Therefore, we cannot deploy any known standard. As a definition “International standards are the set of rules and regulations where we can evaluate ability and accuracy of given technology/product”.

In this scope we can go with 5th method we can call it hybrid method [5] witch we can use the accuracy of the ATG (Automatic Tank Gauge) only for height measurement and get the volume from 1st method to optimize and proving the accuracy of the 3rd and 4th methods.

As we do so, we can make sure that the 3rd & 4th methods (specially 4th) is very close to any calibration methods that have a standard.

The question is if we use the Meter drop\dispense Method for optimizing, why we don't use it for everyday calibration? and why do we aim to use laser calibration?

The answer is the Meter/Prover calibration in the 1st method need hard work and time consuming also consist of uncertainty error% due to the equipment used in this method like Master flow meter or Prover CAN which both need to recalibrate from time to time (normally every six months), however the 3D Laser method will take up to 30 minutes to profile the internal volume body of the tank with no hard work, but the issue is with the International Organization for Standardization ISO, since this technology does not fit into any standard, they stated that ISO 12917-3 must be created for this new technology as "Calibration of horizontal cylindrical tanks with Laser method; a method for the calibration of horizontal cylindrical tanks…", ISO and API (American Petroleum Institute) are responsible for the most important standards within automatic tank gauging, but they don't have their own testing institute.

Fortunately, a national organization that perform testing such International Organization of Legal Metrology (OIML), In this organization a number of test procedures are defined, and there is a special procedure defined for tank gauging equipment called OIML R 71 Edition 2008 (E) and_OIML R 85-1/2, Eventually to prove compliance to a standard we need a standard from ISO&API and using the Recommendation by OIML for testing procedures while applying any method described in the standard, however OIML does not have the authority to impose solutions on its members, but its recommendations are often used as part of domestic laws.

However, if we reached to a point that we can use the 3D Laser Scanning Method with Manual strapping method to optimize/compare the calibration in aboveground storage tanks and same 3D Laser Scanning Method with Meter drop\dispense Method to optimize/compare the calibration in underground storage tanks, in this point we can use the 3D Laser Scanning Method as a proved technology for calibration even if there is no standards.

Keywords: Fuel Tank Calibration, Storage Fuel Tank Calibration, ISO, API, OIML.

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ABBREVIATIONS

API	:	American Petroleum Institute
ATG	:	Automatic Tank Gauge
EODR	:	Electro-Optical Distance Ranging
ISO	:	International Organization For Standardization
MPMS	:	Manual Of Petroleum Measurement Standards
OIML	:	International Organization Of Legal Metrology
TCT	:	Tank Calibration Table
UST	:	Underground Storage Tank
AST	:	Aboveground Storage Tank
FIR	:	Finite Impulse Response
ADC	:	Analog To Digital Converter
AOI	:	Angle Of Incidence
DSP	:	Digital Signal Processor
FPGA	:	Field Programmable Gate Arrays Integrated Circuits

1. INTRODUCTION

Why do we need to measure quantities and volumes, basically any field that dealing with fluids (liquid, gas) we may need to know the amount of the substance enclosed in specific container so we can deal with the physical or chemical properties, reactions, mass transfer, heat transfer, and a lot of operations and characterization of that matter [6].

However, there are a lot of non-scientific needs that require a measurement of the volume, mass and gas amount to verify and make sure how much I should pay for the seller for example in business transaction, in general, if we want to buy 1 liter of milk, usually we ask for unit price. That is the amount of money we should pay to get 1 liter of milk in exchange, but the question is how we know and make sure we get what we pay for it.

Normally, we do some measurement by volume or weight, in the milk scenario we have a reference container previously measured and calibrated to represent the 1 liter that we were buying, so if the buyer and the seller agreed to rely on that trusted container, all the parties will be happy, the seller will get his money and the buyer will get his 1 liter of milk that he paid for with satisfaction.

As this agreement has been solved depends on the trusted container (a 1-liter bottle), obviously there is no issue in this case, but sometimes trust is not enough! And 1 liter may does not make difference if there are some milliliters missing or extra of the standard 1-liter volume.

At this point the major challenge in the wet stock management is who and how can tell that the 1-liter container is holding the actual volume to be trusted and it is in the accepted accuracy range, repeatability, resolution, uncertainty and turn down ration, these concepts can give us straight advantage to take the dissension to accept the measurement or not, especially if we are talking about thousands or millions of liters has been sold or bought. Therefore, to address the assessment of measurement operation we have to use gauging topic that will consolidate the procedure and the way to measure and quantifying the exact of the amount of the fluid in the containers (Storage Tanks) in the range of the accuracy that required depending on the tank design and orientation [7].

1.1 THESIS OUTLINE

This work will be goes in to three main sections, the first one will describe the concepts of the tank gauging and calibration techniques, the second will talk about laser point cloud and the ability to deploy this technique in different types of tanks, and the third is about the accuracy and the relationship between the output data that may correlate showing us the regression due to different reasons.

These three concepts may help us to use different technology that available and/or suitable when applying metrology terms and standards on specific case to achieve the requirement measurements and accuracy.

1.2 GAUGING

Gauging is the measurements of liquid in storage tanks to specify the volume or mass of the product in the tanks. The oil and gas industry normally uses static volumetric evaluations of the tank content. This involves level, temperature, and pressure measurements. There are many ways to get the measurements of the liquid level and other data of the liquid. Measuring methods depends on tank type, liquids in the tank and how we are using the tank [1].

The accuracy of a tank gauging system is very important when measuring the tank content at any given period. Tank gauging systems are used in large storage tanks in refineries and depots, pipelines, airports filling stations, and storage terminals. Storage tanks normally come in four standard designs; Cylindrical fixed roof, cylindrical floating roof and pressurized of either spherical or horizontal cylinder [5].

Tank gauging systems typically consist of sensors, instruments, and software that work together to provide real-time data about the contents of a tank, providing inventory control, preventing overfills or shortages, optimizing logistics and supply chain management, and ensuring compliance with regulations and safety standards. It provides accurate and reliable information for decision-making, maintenance planning, and overall operational efficiency.

1.3 THE PURPOSE OF TANK GAUGING

The data comes from tank gauging systems that can be used for very useful operations; however, it can be recorded for a long time as a reference to be obtained later for statistics or reporting. The most common reports are:

a. Inventory control and volumetric analysis.
b. Custody transfer @ 15 °C.
c. Loss control and mass balance
d. Business inventory reconciliation BIR
e. Overfill prevention.
f. Leak detection

As we using all the tank gauge operation we do need to get accurate data from the system, however that data not only required to be used only with tank gauge system, because that data meant to be obtain even manually, because knowing the storage tank dimension and calibration table are the tank itself characteristics that define how much fuel in the tank at each level, so the most important data that we can represent the tank is the TCT which means Tank Calibration Table or Strapping Table [8].

1.4 CALIBRATION

In the terminology of calibration of a tank, regarding to OIML R 71: 11 July 2007, we can use one of the following methods:

a. Geometric measurements (like optical, strapping).
b. Volumetric measurements.
c. A combination of the two above.
d. Other accepted methods.

The choice of the method or of the procedure is imposed by the nominal capacity of the tank and the shape, the position, the conditions of use, etc.

For the calibration of any storage tank, one of the ISO calibration methods shall be adopted to generate the calibration table according to applicable ISO standards:

a. ISO 4512:2000
b. ISO 4269:2001

c. ISO series 7507

d. ISO 12917-2:2002

In case these standards cannot be applied, the metrological authority(W&M) decides on the method which is acceptable.

1.5 STRAPPING TABLE

We will refer to strapping table as TCT, as we can obtain the table by multiple means by following the available & approved standards, we still sometimes cannot use that methods on certain tank due to their size or orientation because some of the standard are old and not updated or new technology are invented can be used in this method but not approved in the particular standard that we need to use as a reference for this processes.

The issue of standards has been explained in the abstract so we will mention it slightly with the main problem only.

The ISO 12917-3 [3] is not available right now, so we have to depend on testing and comparing the results with the data from other standards related to our scenario. If we reached the point that the resulting data that matches the original data coms from dependable method according to the right standard, we can rely on that method according standard from ISO & API and using the Recommendation by OIML for testing procedures.

There are several technologies out there in the market adopted this technology; but using it! must follow the local W&M authority, and that what we did with W&M in testing procedure while calibrating the aboveground storage tank AST that belongs to the Iraqi Ministry of Oil, in the Oil Product Distribution Company OPDC, with assist and blessing of the weight & Measurement authority.

1.6 THE PROCEDURE OF CALIBRATION

Preparing the TCT according to a standard method, in this scope an accurate flow meter well calibrated as master flow meter will be used, then filling a batches of certain volume like 200 liter per run, at the end of each filling run we measure the fuel level height to get the volume against the height, that is the TCT.

Maintaining the temperature while the filling is very important to avoid the contraction or expansion in the fuel, so we make sure that we have the same volume measured from the flow meter that entered the tank.

After reaching 270 run (filling batches) we end up with 54000 liter that represents the label volume of the tank, however we have to leave some empty volume for safety proposes and to keep space to the vapors for condensate and prevent it from escape from the tank manhole.

It is good to mention that this method need a lot of effort, man work, cleaning the slugs from the bottom of the tank if any, and we have to use the same fuel that using in this tank if we avoid using water that will make the job more safe but needs more extra work like eliminate any trace of the water after finishing the calibration and we have to use special flow meter that can deal with water with accepted accuracy [9].

1.7 METER DROP/DISPENSE METHOD - ISO 4269:2001

The table below is made by the joint procedure with the W&M team in the OPDC depot that running as in-hose solution equipped with Tank Gauge System but not calibrated, using this method will give us a good understanding of what is the tank profile based on some measurements, so we decided to choose this site as a sample under the W&M authority.

For calibration purposes, the liquid used can be water or a suitable petroleum product with low volatility and viscosity. When calibration involves wide temperature variations, water is recommended due to its low coefficient of cubic expansion.

Table 1.1: Tank Profile (TCT), Volume and Fuel Level Representation.

Meter Calibration									
Meter Level	V	Meter Level	V	Meter Level	V	Meter Level	V	Meter Level	V
25	200	466	6400	752	12600	1009	18800	1248	25000
49	400	478	6600	759	12800	1016	19000	1256	25200
71	600	490	6800	768	13000	1024	19200	1264	25400
95	800	500	7000	775	13200	1033	19400	1273	25600
115	1000	509	7200	783	13400	1041	19600	1280	25800
131	1200	518	7400	791	13600	1050	19800	1287	26000
153	1400	529	7600	800	13800	1057	20000	1295	26200
171	1600	538	7800	809	14000	1065	20200	1303	26400
185	1800	548	8000	818	14200	1072	20400	1310	26600
201	2000	556	8200	827	14400	1080	20600	1317	26800
214	2200	564	8400	836	14600	1086	20800	1325	27000
230	2400	572	8600	845	14800	1093	21000	1335	27200
241	2600	581	8800	855	15000	1102	21200	1344	27400
253	2800	590	9000	862	15200	1110	21400	1352	27600
265	3000	599	9200	870	15400	1117	21600	1360	27800
275	3200	608	9400	879	15600	1126	21800	1367	28000
288	3400	619	9600	887	15800	1131	22000	1376	28200
303	3600	629	9800	895	16000	1139	22200	1382	28400
315	3800	640	10000	904	16200	1149	22400	1389	28600
327	4000	648	10200	914	16400	1156	22600	1394	28800
339	4200	657	10400	922	16600	1164	22800	1400	29000
350	4400	666	10600	930	16800	1171	23000	1410	29200
361	4600	674	10800	938	17000	1179	23200	1419	29400
373	4800	682	11000	945	17200	1187	23400	1426	29600
388	5000	691	11200	953	17400	1194	23600	1433	29800
398	5200	701	11400	961	17600	1200	23800	1439	30000
410	5400	711	11600	969	17800	1208	24000	1447	30200
422	5600	721	11800	976	18000	1218	24200	1456	30400
433	5800	730	12000	985	18200	1226	24400	1464	30600
445	6000	736	12200	994	18400	1233	24600	1473	30800
	6200	744	12400	1000	18600	1241	24800	1480	31000

Table 1.1: Tank Profile (TCT), Volume and Fuel Level Representation 'Table Continued'.

Meter Level	V	Meter Level	V	Meter Level	V	Meter Level	V
1487	31200	1727	37400	1980	43600	2262	49800
1495	31400	1735	37600	1989	43800	2272	50000
1504	31600	1745	37800	1997	44000	2279	50200
1510	31800	1754	38000	2007	44200	2287	50400
1515	32000	1764	38200	2016	44400	2295	50600
1521	32200	1772	38400	2024	44600	2307	50800
1529	32400	1780	38600	2030	44800	2317	51000
1537	32600	1789	38800	2038	45000	2329	51200
1546	32800	1796	39000	2045	45200	2339	51400
1552	33000	1805	39200	2056	45400	2350	51600
1560	33200	1814	39400	2066	45600	2360	51800
1567	33400	1822	39600	2075	45800	2372	52000
1577	33600	1829	39800	2083	46000	2387	52200
1586	33800	1835	40000	2094	46200	2400	52400
1592	34000	1845	40200	2104	46400	2411	52600
1600	34200	1851	40400	2113	46600	2424	52800
1609	34400	1859	40600	2121	46800	2435	53000
1617	34600	1866	40800	2130	47000	2445	53200
1625	34800	1872	41000	2141	47200	2455	53400
1631	35000	1880	41200	2150	47400	2469	53600
1640	35200	1888	41400	2159	47600	2487	53800
1650	35400	1894	41600	2167	47800	2495	54000
1658	35600	1904	41800	2176	48000		
1666	35800	1910	42000	2188	48200		
1674	36000	1917	42200	2199	48400		
1681	36200	1927	42400	2209	48600		
1689	36400	1937	42600	2219	48800		
1697	36600	1944	42800	2228	49000		
1705	36800	1951	43000	2236	49200		
1711	37000	1960	43200	2246	49400		
1720	37200	1971	43400	2255	49600		

At this point we can draw a graphical representation curve (Tank Profile) for the TCT between the fuel level and the volume of the fuel at each height.

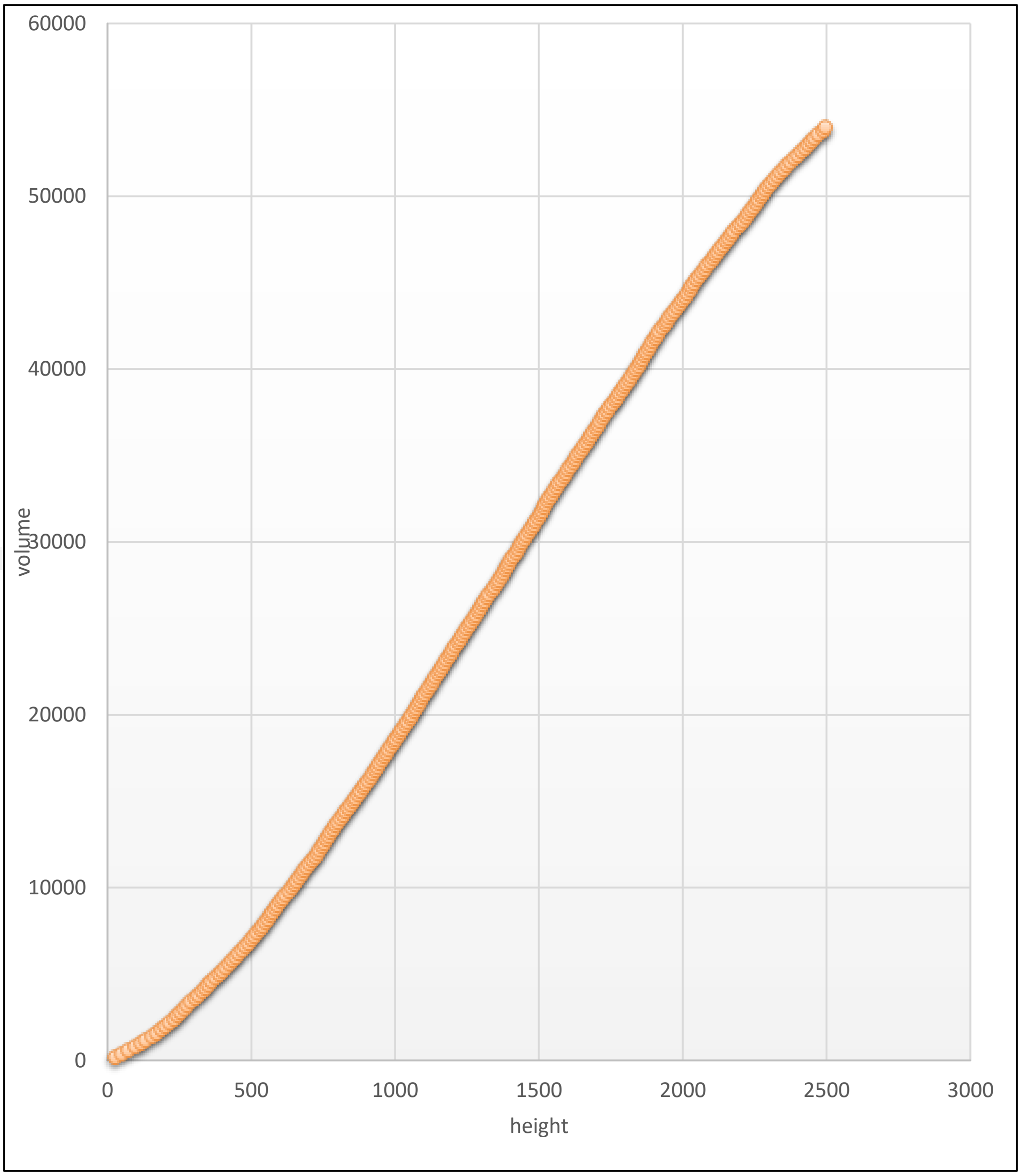

Chart 1.1: Graphical Representation for the TCT

1.8 OPTIMIZATION (LASER CALIBRATION)

Optimization involves maximizing the effectiveness, efficiency, or functionality of a process by identifying the most optimal solution or approach to a problem within a given set of constraints that should be used in terms of international standards and objectives expected.

Accurate measurements: more accurate measurement points are taken, giving us more accurate results.

Safe Procedure: tanks are measured automatically with no human interacting or exposing to the fuel vapors or fumes directly.

Minimize down-time: the tank can be calibrated in minutes, so we can achieve multiple tanks per day.

Minimize human Errors: measurements are recorded electronically eliminating transcription errors.

However, there are three methods can be using digital equipment like laser:

a. There are standards for the statice laser ranging called EODR (Electro-Optical Distance Ranging) that follows the ISO 7507 chapter 4&5 to calibrate large scale engineering metrology to measure vertical, spherical storage tanks (internal & External).
b. The Optical Reference line and circumference called Strapping methods (ISO 7507 chapter 1&2) uses the traditional measurement for vertical, spherical, and horizontal storage tanks.
c. A 3D laser scanner is available but not approved, and there is no standard, as mentioned before, for small horizontal tanks.

2. 3D LASER POINT CLOUD

A laser 3D point cloud refers to a collection of three-dimensional coordinates captured by a laser scanning system. It is commonly used in various fields such as surveying, mapping, engineering, architecture, and computer vision. The process involves emitting laser pulses and measuring the time it takes for the light to bounce back from objects in the environment. By calculating the distance and angles from the scanner to the objects, a 3D representation of the scanned area can be generated [10].

Laser Scanning: A laser scanning device, such as a LiDAR (Light Detection and Ranging) system, is used to emit laser pulses towards the target area. These pulses hit the surfaces of objects and bounce back to the scanner.

The scanner measures the time it takes for the laser pulses to return. By knowing the speed of light, it calculates the distance between the scanner and the objects. This process is known as time-of-flight measurement.

The scanner also records the angles at which the laser pulses were emitted and the angles at which they were reflected back. This information is crucial for determining the position and orientation of objects in 3D space.

2.1 POINT CLOUD GENERATION

As the laser scanner collects data, it generates a point cloud by combining the measured distances and angles. Each point in the point cloud represents a specific location in 3D space and is defined by its XYZ coordinates (x, y, and z).

Once the point cloud is obtained, it may undergo post-processing steps to remove noise, filter out unwanted points, and enhance the overall quality. Various algorithms and software tools are available for this purpose.

The resulting laser 3D point cloud can be used for a wide range of applications, including creating accurate 3D models, conducting measurements, performing structural analysis, virtual reality simulations, object recognition, and more.

Laser 3D point clouds have become an invaluable tool for capturing detailed spatial information of real-world objects and environments, enabling precise measurements, analysis, and visualization in various industries.

When conducting a 3D laser scan, the laser scanner captures a vast number of data points from the surfaces within the scanned area. They are recorded along the x, y, and z coordinates, forming a point cloud that represents a detailed and comprehensive depiction of the scanned site.

The scanners are commonly used to acquire point cloud data. It is crucial, especially for construction projects or storage tanks, to use high-end survey-grade laser scanners and equipment. To obtain a complete view of the target area, scans need to be taken from multiple locations, a process handled by trained technicians who ensure accurate data collection and efficient scanning methods.

After the internal/external surface of the tank has been laser scanned, we will take the raw scan data and transform it into a usable point cloud for modeling and measurements a high-quality drawing, and accurate models can be generated. The point cloud provides detailed data of the high accuracy 3D tank profile that can be built later.

The point cloud can be imported into software for visualization purposes or to manage the geometrical process to produce the strapping table i.e., level vs volume with considering the tilt of the tank. The data appears as a pixelated, digital representation of the scanned site. Individual points can be selected to obtain dimensions of objects or to measure the scale of the room. Point cloud data can be manipulated, modified, and parsed to meet specific user requirements.

2.2 SEGMENTATION OF POINT CLOUDS

Generating 3D models of measured objects is currently relevant subjects. Point cloud segmentation involves categorizing the points in a point cloud into distinct regions with similar characteristics. Points within the same region share common properties. The most commonly used segmentations group points together based on fitting onto a plane, cylinder, or other geometric primitive. This segmentation process is akin to identifying simple shapes within a point cloud. However, due to factors such as excessive redundancy, uneven sampling density, and the absence of an explicit structure in point cloud data, segmentation can be quite challenging. In many instances, the point cloud may have missing parts caused by covers or hidden sections of the scanned object [11].

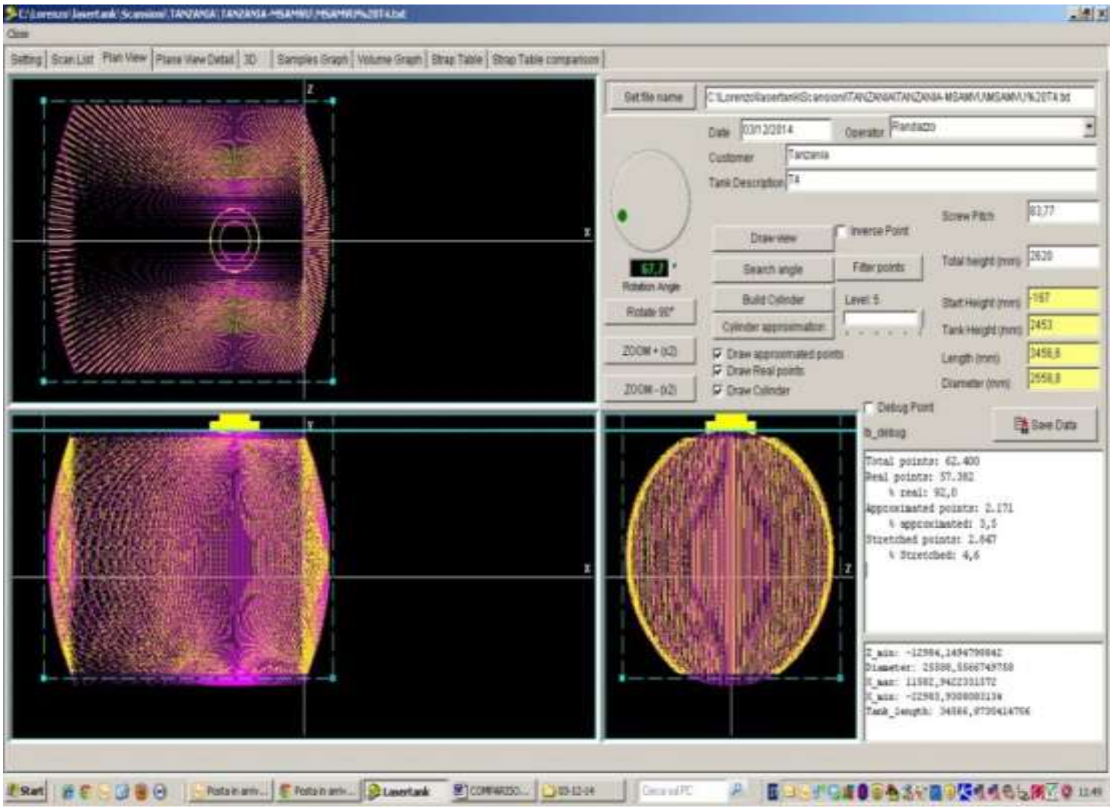

Figure 2.1: Laser Tank Application.

To create advanced deliverables, the point cloud data is imported into CAD/BIM (Computer-Aided Design/Building Information Modeling) software such as Autodesk. Skilled CAD technicians transform the point clouds into 3D solids and surfaces, a process that requires time and expertise. Custom deliverables, including 2D drawings and 3D models, can be generated at various levels of detail.

2.3 COMPARING THE RESULTS

Previously in the Chart 1.1 that describes the tank profile when it can be used to verify every level in the tank getting the volume at given height (level), so far this chart it is not optimized and if any error in meter reading occurred it will be in that TCT of that tank, it will keep producing errors in calculating the volume in the ATG or even in the dip-stick in manual measuring. In the past correction was only by re-calibrating the entire tank from the beginning, but now with the laser scanning equipment can be done in very short time regarding to the manual method, getting the point cloud data in to any software that can produce strapping table like AutoCAD [11] to generate the volume with respect to level TCT, then it can be compare between the two series of data obtained manually from the meter drop (meter calibration) and the 3D laser scanning and the point cloud strapping table (laser calibration), just for initial comparison, in the table below, the volume between the steps are constant for both methods i.e. 200 liters added each time level has been obtained , in the other hand we can see a difference or variances(VAR) in the level reading between laser level and meter level which is normal due to the uncertainty [9] [12] factor and the data collected from different methods as in the.

Table 2.1: Comparison Between Meter TCT and Laser TCT.

8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75
9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75
9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95
19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

Laser Calibration		Meter Calibration			Laser Calibratio		Meter Calibration		
Volume	Laser Level	Meter Level	Volume	VAR	Volume	Laser Level	Meter Level	Volume	VAR
200	46.09	25	200	21.09	27200	1331.09	1335	27200	-3.91
400	73.17	49	400	24.17	27400	1338.65	1344	27400	-5.35
600	95.9	71	600	24.9	27600	1346.2	1352	27600	-5.8
800	116.24	95	800	21.24	27800	1353.75	1360	27800	-6.25
1000	134.94	115	1000	19.94	28000	1361.3	1367	28000	-5.7
1200	152.46	131	1200	21.46	28200	1368.86	1376	28200	-7.14
1400	169.06	153	1400	16.06	28400	1376.41	1382	28400	-5.59
1600	184.92	171	1600	13.92	28600	1383.96	1389	28600	-5.04
1800	200.14	185	1800	15.14	28800	1391.51	1394	28800	-2.49
2000	214.82	201	2000	13.82	29000	1399.06	1400	29000	-0.94
2200	229.05	214	2200	15.05	29200	1406.61	1410	29200	-3.39
2400	242.87	230	2400	12.87	29400	1414.16	1419	29400	-4.84
2600	256.35	241	2600	15.35	29600	1421.72	1426	29600	-4.28
2800	269.5	253	2800	16.5	29800	1429.27	1433	29800	-3.73
3000	282.37	265	3000	17.37	30000	1436.83	1439	30000	-2.17
3200	294.96	275	3200	19.96	30200	1444.39	1447	30200	-2.61
3400	307.31	288	3400	19.31	30400	1451.95	1456	30400	-4.05
3600	319.44	303	3600	16.44	30600	1459.51	1464	30600	-4.49
3800	331.36	315	3800	16.36	30800	1467.08	1473	30800	-5.92
4000	343.1	327	4000	16.1	31000	1474.65	1480	31000	-5.35
4200	354.67	339	4200	15.67	31200	1482.22	1487	31200	-4.78
4400	366.07	350	4400	16.07	31400	1489.79	1495	31400	-5.21
4600	377.32	361	4600	16.32	31600	1497.37	1504	31600	-6.63
4800	388.42	373	4800	15.42	31800	1504.95	1510	31800	-5.05
5000	399.39	388	5000	11.39	32000	1512.54	1515	32000	-2.46
5200	410.23	398	5200	12.23	32200	1520.13	1521	32200	-0.87
5400	420.94	410	5400	10.94	32400	1527.73	1529	32400	-1.27
5600	431.53	422	5600	9.53	32600	1535.33	1537	32600	-1.67
5800	442.02	433	5800	9.02	32800	1542.93	1546	32800	-3.07
6000	452.4	445	6000	7.4	33000	1550.54	1552	33000	-1.46
6200	462.68	455	6200	7.68	33200	1558.16	1560	33200	-1.84
6400	472.87	466	6400	6.87	33400	1565.78	1567	33400	-1.22
6600	482.97	478	6600	4.97	33600	1573.41	1577	33600	-3.59
6800	492.99	490	6800	2.99	33800	1581.04	1586	33800	-4.96
7000	502.92	500	7000	2.92	34000	1588.68	1592	34000	-3.32
7200	512.78	509	7200	3.78	34200	1596.33	1600	34200	-3.67
7400	522.56	518	7400	4.56	34400	1603.98	1609	34400	-5.02
7600	532.27	529	7600	3.27	34600	1611.65	1617	34600	-5.35
7800	541.91	538	7800	3.91	34800	1619.32	1625	34800	-5.68
8000	551.49	548	8000	3.49	35000	1627	1631	35000	-4
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05
14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95
19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 2.1: Comparison Between Meter TCT and Laser TCT ‘Table Continued’.

Laser Calibration		Meter Calibration			Laser Calibratio		Meter Calibration		
Volume	Laser Level	Meter Level	Volume	VAR	Volume	Laser Level	Meter Level	Volume	VAR
200	46.09	25	200	21.09	27200	1331.09	1335	27200	-3.91
400	73.17	49	400	24.17	27400	1338.65	1344	27400	-5.35
600	95.9	71	600	24.9	27600	1346.2	1352	27600	-5.8
800	116.24	95	800	21.24	27800	1353.75	1360	27800	-6.25
1000	134.94	115	1000	19.94	28000	1361.3	1367	28000	-5.7
1200	152.46	131	1200	21.46	28200	1368.86	1376	28200	-7.14
1400	169.06	153	1400	16.06	28400	1376.41	1382	28400	-5.59
1600	184.92	171	1600	13.92	28600	1383.96	1389	28600	-5.04
1800	200.14	185	1800	15.14	28800	1391.51	1394	28800	-2.49
2000	214.82	201	2000	13.82	29000	1399.06	1400	29000	-0.94
2200	229.05	214	2200	15.05	29200	1406.61	1410	29200	-3.39
2400	242.87	230	2400	12.87	29400	1414.16	1419	29400	-4.84
2600	256.35	241	2600	15.35	29600	1421.72	1426	29600	-4.28
2800	269.5	253	2800	16.5	29800	1429.27	1433	29800	-3.73
3000	282.37	265	3000	17.37	30000	1436.83	1439	30000	-2.17
3200	294.96	275	3200	19.96	30200	1444.39	1447	30200	-2.61
3400	307.31	288	3400	19.31	30400	1451.95	1456	30400	-4.05
3600	319.44	303	3600	16.44	30600	1459.51	1464	30600	-4.49
3800	331.36	315	3800	16.36	30800	1467.08	1473	30800	-5.92
4000	343.1	327	4000	16.1	31000	1474.65	1480	31000	-5.35
4200	354.67	339	4200	15.67	31200	1482.22	1487	31200	-4.78
4400	366.07	350	4400	16.07	31400	1489.79	1495	31400	-5.21
4600	377.32	361	4600	16.32	31600	1497.37	1504	31600	-6.63
4800	388.42	373	4800	15.42	31800	1504.95	1510	31800	-5.05
5000	399.39	388	5000	11.39	32000	1512.54	1515	32000	-2.46
5200	410.23	398	5200	12.23	32200	1520.13	1521	32200	-0.87
5400	420.94	410	5400	10.94	32400	1527.73	1529	32400	-1.27
5600	431.53	422	5600	9.53	32600	1535.33	1537	32600	-1.67
5800	442.02	433	5800	9.02	32800	1542.93	1546	32800	-3.07
6000	452.4	445	6000	7.4	33000	1550.54	1552	33000	-1.46
6200	462.68	455	6200	7.68	33200	1558.16	1560	33200	-1.84
6400	472.87	466	6400	6.87	33400	1565.78	1567	33400	-1.22
6600	482.97	478	6600	4.97	33600	1573.41	1577	33600	-3.59
6800	492.99	490	6800	2.99	33800	1581.04	1586	33800	-4.96
7000	502.92	500	7000	2.92	34000	1588.68	1592	34000	-3.32
7200	512.78	509	7200	3.78	34200	1596.33	1600	34200	-3.67
7400	522.56	518	7400	4.56	34400	1603.98	1609	34400	-5.02
7600	532.27	529	7600	3.27	34600	1611.65	1617	34600	-5.35
7800	541.91	538	7800	3.91	34800	1619.32	1625	34800	-5.68
8000	551.49	548	8000	3.49	35000	1627	1631	35000	-4
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75

Table 2.1: Comparison Between Meter TCT and Laser TCT ‘Table Continued’.

9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05
14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

Laser Calibration		Meter Calibration			Laser Calibratio		Meter Calibration		
Volume	Laser Level	Meter Level	Volume	VAR	Volume	Laser Level	Meter Level	Volume	VAR
200	46.09	25	200	21.09	27200	1331.09	1335	27200	-3.91
400	73.17	49	400	24.17	27400	1338.65	1344	27400	-5.35
600	95.9	71	600	24.9	27600	1346.2	1352	27600	-5.8
800	116.24	95	800	21.24	27800	1353.75	1360	27800	-6.25
1000	134.94	115	1000	19.94	28000	1361.3	1367	28000	-5.7
1200	152.46	131	1200	21.46	28200	1368.86	1376	28200	-7.14
1400	169.06	153	1400	16.06	28400	1376.41	1382	28400	-5.59
1600	184.92	171	1600	13.92	28600	1383.96	1389	28600	-5.04
1800	200.14	185	1800	15.14	28800	1391.51	1394	28800	-2.49
2000	214.82	201	2000	13.82	29000	1399.06	1400	29000	-0.94
2200	229.05	214	2200	15.05	29200	1406.61	1410	29200	-3.39
2400	242.87	230	2400	12.87	29400	1414.16	1419	29400	-4.84
2600	256.35	241	2600	15.35	29600	1421.72	1426	29600	-4.28
2800	269.5	253	2800	16.5	29800	1429.27	1433	29800	-3.73
3000	282.37	265	3000	17.37	30000	1436.83	1439	30000	-2.17
3200	294.96	275	3200	19.96	30200	1444.39	1447	30200	-2.61
3400	307.31	288	3400	19.31	30400	1451.95	1456	30400	-4.05
3600	319.44	303	3600	16.44	30600	1459.51	1464	30600	-4.49
3800	331.36	315	3800	16.36	30800	1467.08	1473	30800	-5.92
4000	343.1	327	4000	16.1	31000	1474.65	1480	31000	-5.35
4200	354.67	339	4200	15.67	31200	1482.22	1487	31200	-4.78
4400	366.07	350	4400	16.07	31400	1489.79	1495	31400	-5.21
4600	377.32	361	4600	16.32	31600	1497.37	1504	31600	-6.63
4800	388.42	373	4800	15.42	31800	1504.95	1510	31800	-5.05
5000	399.39	388	5000	11.39	32000	1512.54	1515	32000	-2.46
5200	410.23	398	5200	12.23	32200	1520.13	1521	32200	-0.87
5400	420.94	410	5400	10.94	32400	1527.73	1529	32400	-1.27
5600	431.53	422	5600	9.53	32600	1535.33	1537	32600	-1.67
5800	442.02	433	5800	9.02	32800	1542.93	1546	32800	-3.07
6000	452.4	445	6000	7.4	33000	1550.54	1552	33000	-1.46
6200	462.68	455	6200	7.68	33200	1558.16	1560	33200	-1.84
6400	472.87	466	6400	6.87	33400	1565.78	1567	33400	-1.22
6600	482.97	478	6600	4.97	33600	1573.41	1577	33600	-3.59
6800	492.99	490	6800	2.99	33800	1581.04	1586	33800	-4.96
7000	502.92	500	7000	2.92	34000	1588.68	1592	34000	-3.32
7200	512.78	509	7200	3.78	34200	1596.33	1600	34200	-3.67
7400	522.56	518	7400	4.56	34400	1603.98	1609	34400	-5.02
7600	532.27	529	7600	3.27	34600	1611.65	1617	34600	-5.35
7800	541.91	538	7800	3.91	34800	1619.32	1625	34800	-5.68
8000	551.49	548	8000	3.49	35000	1627	1631	35000	-4
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75

Table 2.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05
14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95

Table 2.1: Comparison Between Meter TCT and Laser TCT ‘Table Continued’.

19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54

Furthermore, to visualize the comparison between the two method and observe the tight relation between them before going to advance mathematical techniques to determine the correlation and linear regression between the two methods, the Chart 2.1: Laser VS Meter

Calibration is very good way to profound and get clear picture whether if any deformation in the tank wall is existed, as in Figure 2.2

This initial perspective can help to evaluate the condition of the tank and making the decision of re-calibrating it, or in case the site showing a big variance in sales regarding with stock left in the tank at the end of the day.

Figure 2.2: The Tank #1 is Showing Differences in Calibration Table About ±3%.

Inspecting the two curves in Chart 2.1, it showing the blue one (laser level) is more smother than the red curve (meter level), that because the meter calibration method is a non-continues procedure, while it takes long time to complete, different temperature, flow meter and human errors, in the other hand, the 3D laser calibration takes short time and less errors In terms of accuracy and efficiency, 3D laser scanning generally provides more precise results compared to manual tank calibration. Laser scanning eliminates many potential sources of error associated with manual measurements and calculations. It can capture the tank's shape and volume with high accuracy and can also provide additional information about the tank's condition, such as surface irregularities or deformations, 3D laser scanning can be a quicker and more efficient method since it automates the data capture process, reducing the need for extensive manual labor. It also allows for digital storage and analysis of the captured data, making it easier to revisit and compare measurements over time, also is often considered a superior method for tank calibration due to its higher accuracy, efficiency, and the additional benefits it offers in terms of data analysis and documentation.

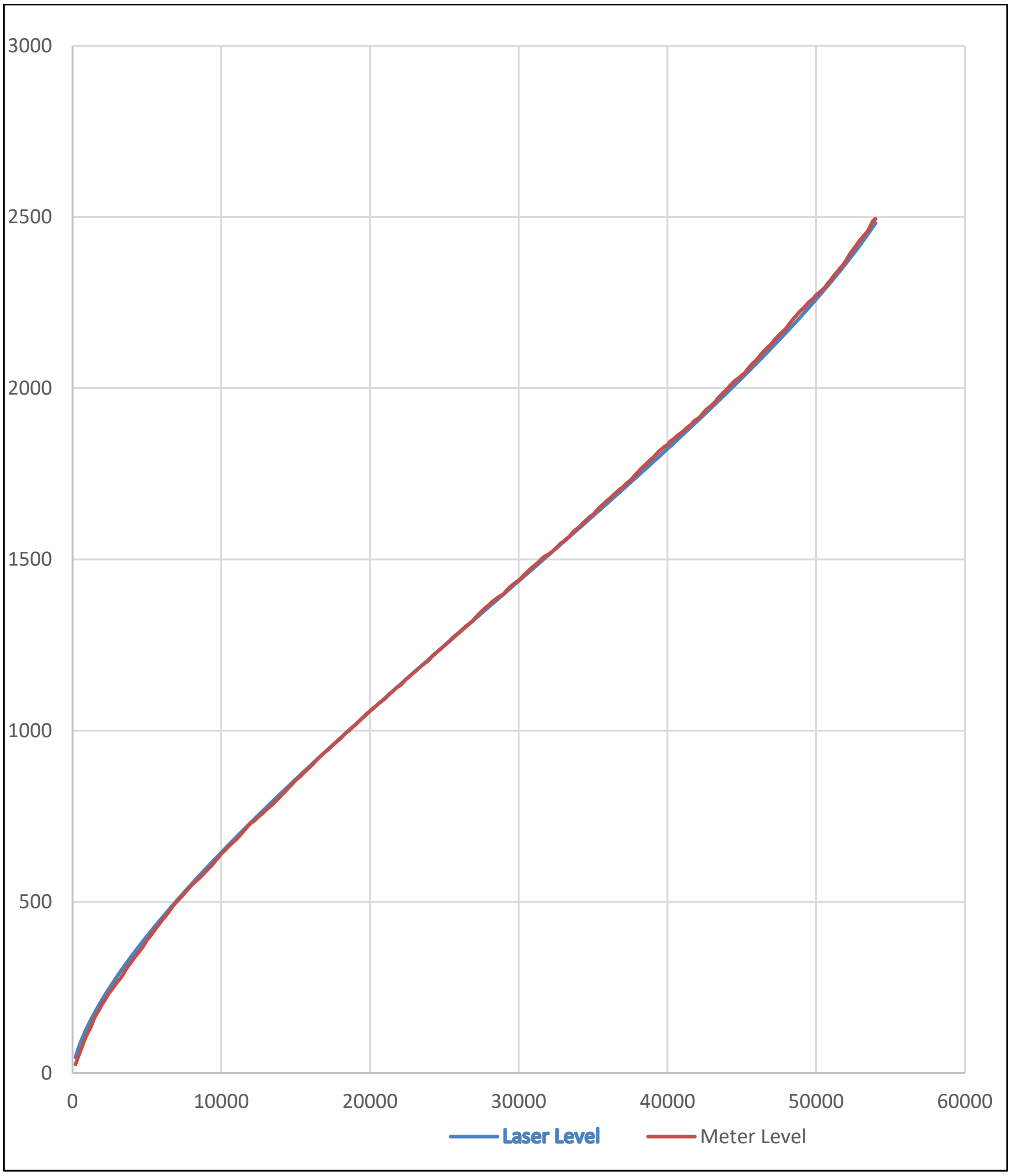

Chart 2.1: Laser VS Meter Calibration.

2.4 ANGLE OF INCIDENCE

Schulz (2008) examines the influence of surface reflectivity and AOI on distance measurements. The study also considers the effects of various types of object surfaces and instrumental errors. Findings from Schulz (2008) indicate that wood and Styrofoam exhibit apparent surface penetrations of approximately 5mm and 15mm, respectively, suggesting that the measured point may not correspond precisely to the true surface of the object [13], from this study we have to put some limitation on 3D laser scanning in tank calibration, due to the roughness of the internal tank surface witch affect the laser accuracy, we end up with the idea to clean the internal surface as much as we can to reach the desire accuracy, this can be by steaming the tank or even jet sanding it if we noticed a rust surface or dirty.

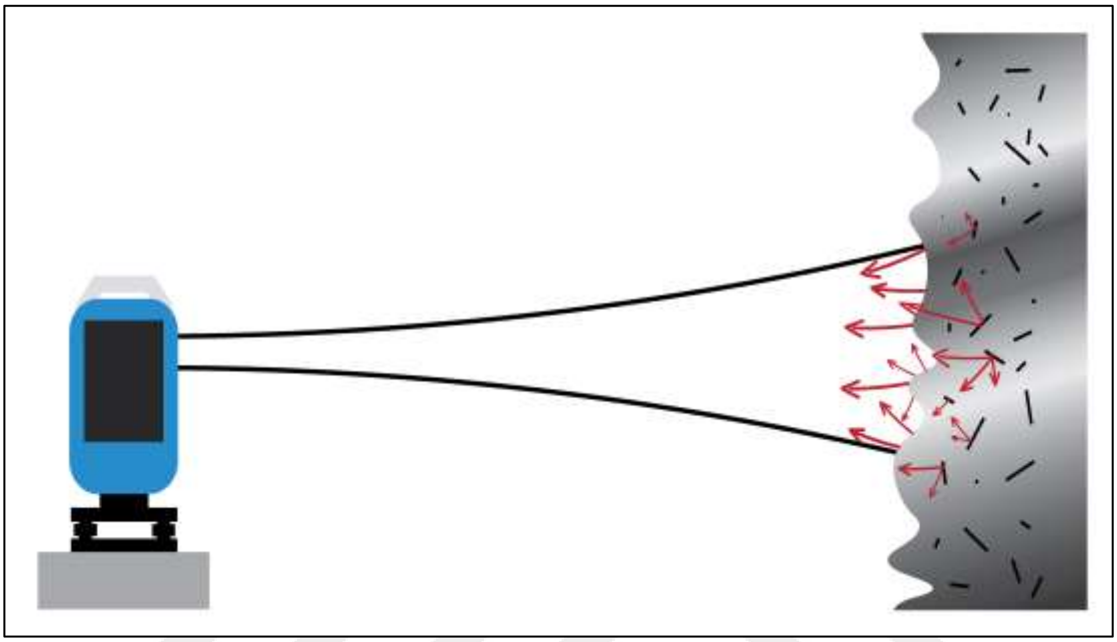

Figure 2.3: The Laser Scanning Employs the Emission of A Gaussian Laser Beam to Measure on A Surface With Irregularities, Resulting in Various Delays Observed Within the Scanning Area.

2.5 RECOMPENCE THE MISSING PARTS FROM THE 3D LASER SCANNING POIT CLOUD

When working with 3D laser scanning point clouds, it is common to encounter missing parts or incomplete data due to various reasons such as occlusions or limitations in the scanning process. By additional Scanning we can capture the missing areas from different positions. By combining multiple scans, we can obtain a more complete tank profile. If the additional scans are not feasible, we can use photogrammetry techniques. Take photographs of the missing areas from different viewpoints and use photogrammetry software to generate a 3D model that can be merged with the existing point cloud. However, the missing parts are relatively small or simple in shape, we can manually model or reconstruct those parts using 3D modeling software. This approach requires expertise in 3D modeling but can be effective for filling in small gaps or details. Interpolation calculation of the missing areas that surrounded by scanned data to use interpolation algorithms to estimate the shape and appearance of the missing parts based on the neighboring points. Various interpolation methods, such as nearest-neighbor, Delaunay triangulation, or moving least squares, can be employed to fill in the gaps [14].

In another hand, If we have access to complementary data sources, such as traditional measurements or CAD models, we can integrate that information with the point cloud data to compensate for the missing parts. Align the additional data with the point cloud using registration techniques to create a more complete representation.

Each approach has its advantages and limitations, and the choice depends on the specific situation, available resources, and desired level of accuracy. It's important to assess the requirements of our project and we may choose the most appropriate method for compensating the missing parts in the 3D laser scanning point cloud if required.

2.6 UTILIZING RANSAC FOR AUTOMATED PLANE SEGMENTATION

RANSAC is an iterative technique for estimating a mathematical model from a data set that includes outliers, is employed for automated plane segmentation, the RANSAC algorithm detects outliers within the data set and calculates the desired model using outlier-free data [11]. Consequently, the RANSAC approach extracts shapes from the point data and constructs corresponding primitive shapes, employing the concept of minimal sets. A minimal set represents the minimum number of data samples necessary to uniquely define a model. The resulting potential shapes are evaluated against all the data points to identify the points that are well approximated by the primitive shape. Following a specified number of iterations, the shape that best approximates the largest number of points is extracted, and the algorithm proceeds with the remaining data. This method can be applied in some cases when deadwood [3].

In order to use RANSAC, an important procedure should be followed:

a. Data Sampling: Random subsets of measurements are selected from the dataset, including both the tank dimensions (such as height and radius) and the corresponding volume measurements.
b. Model Fitting: A model (such as a mathematical equation) is fitted to each subset of data. In tank calibration, this model represents the relationship between the tank's physical dimensions and its corresponding volume. [15]
c. Inlier Selection: The algorithm assesses the degree to which each measurement in the dataset fits the fitted model. Measurements that closely align with the model are considered inliers, while those deviating significantly from the model are considered outliers. [14]
d. Consensus Set: A consensus set is formed by collecting the inliers from multiple model fittings. This set represents the measurements that agree with the estimated model.
e. Model Refinement: Using the consensus set, the model parameters are refined or optimized to provide a more accurate representation of the tank's characteristics.
f. Calibration Results: The final calibrated parameters, such as tank capacity or volume calculation formulas, are derived from the refined model. [10]

By applying the RANSAC algorithm, the calibration process becomes more robust and resistant to outliers or erroneous measurements. It helps to ensure accurate calibration results by filtering out unreliable data points and focusing on the measurements that consistently align with the estimated model.

3. ACCURACY AND OTHER PARAMETERS

The most crucial issue is the accuracy of the measurement, and what is the need to reach the optimum accuracy, basically the most accurate, the most precise to get results in calculations for daily bases with dealing with weights and measurements legislations.

However, accuracy is not the only constraints that can be depended on, there are other concepts that regulates the measurements and address some boundaries to the data that obtained from the tests as follows:

a. Accuracy: The value of which the result gotten from a measurement, calculation, or specification meets the correct value or a standard.
b. Uncertainty: The lack of certainty, a state of limited knowledge where it is impossible to exactly describe the existing state, a future outcome, or more than one possible outcome [16].
c. Repeatability (Repetitive Accuracy): Refers to the number of readings, measurements that point to the correct value or a standard.
d. Resolution: Resolution is the ability of the measurement system to detect and faithfully indicate small changes in the characteristic of the measurement result [17].

These are the most important factors that can determine if the device can give us precise data for specific reading or measurement. However, device accuracy refers to the degree to which a device's measurements or outputs match the true or expected values. It is a measure of how reliable and trustworthy the device is in providing accurate information. The accuracy of a device depends on several factors, including its design, manufacturing process, calibration, and the conditions under which it is used. Some devices are designed to be highly accurate and precise, while others may have a greater margin of error. The accuracy of a device is typically measured and reported as a percentage or a fraction of the true or expected value, for example, a device with an accuracy of ±0.3% means that its measurements can be off by no more than 0.3% of the true value. Here we can address the range of operating Values, like the operating pressure, temperature, flowrate…etc. Normally the best accuracy can be applied at this range of value but not in full scale making the device can give a good accuracy, but the result will be not accurate as the values in the selected range given of accuracy. It is important to consider the accuracy of a device when selecting and using it for a particular application. In some cases, a high degree of accuracy may be essential, while in others, a lower degree of accuracy may be acceptable. It is also important to regularly calibrate and maintain devices to ensure their accuracy over time.

Uncertainty and resolution are two important concepts in measurement that are often confused with each other, but they have distinct meanings.

According to the existing standards (ISO 4269 2001, EU:ISO 12917-1 2017), the standard uncertainty of the fuel tanks calibration using liquid fill method must be less or equal to ±0:3%.

Uncertainty refers to the degree of doubt or lack of knowledge about the true value of a measurement. It is a measure of the range of values within which the true value of a measurement is likely to lie. Uncertainty can arise from a variety of factors, such as the limitations of the measurement device, the variability of the measurement process, or the accuracy of the reference standard used to calibrate the device.

Resolution, on the other hand, refers to the smallest increment of a measurement that can be detected or displayed by a measuring device. It is a measure of the level of detail that a device can detect in a measurement. For example, a device with a resolution of 0.2 mm can detect changes in length as small as 0.2 mm.

In other words, uncertainty is related to the accuracy of a measurement, while resolution is related to the precision of a measurement. A device with high resolution may not necessarily have high accuracy, and a device with low resolution may still be highly accurate.

Both uncertainty and resolution are important considerations when selecting and using a measuring device. A device with high uncertainty or low resolution may not be suitable for certain applications where a high degree of accuracy or precision is required.

1.3 STEPS TO ACHIEVE GOOD OPTIMIZATION

3D laser scanning can be a very effective tool for detecting blind spots in underground storage tanks (USTs) calibration.

Here are some ways to enhance the effectiveness of 3D laser scanning for this purpose:

a. Optimize the scanning parameters: The scanning parameters should be optimized based on the specific requirements of the UST calibration. This includes the resolution, accuracy, and scan density. The scanning should be performed at a suitable height, speed and angle.
b. Multiple scans: To ensure full coverage of the UST, multiple scans should be taken from different angles and positions. This can help to identify blind spots and ensure that all areas are covered.
c. Advanced software: Advanced software can be used to process and analyze the 3D laser scans. This can include automatic registration of multiple scans, point cloud classification, and feature extraction. Such software can help to identify blind spots more effectively.
d. Include manual inspection: While 3D laser scanning is a very effective tool, it should not be used in isolation. A manual inspection should also be carried out to verify the results and identify any areas that may have been missing.
e. Regular inspection and maintenance: Regular inspection and maintenance of the USTs can help to prevent blind spots from developing in the first place. This includes regular cleaning and maintenance of the tanks, and inspection of the pipelines and fittings.

Overall, 3D laser scanning can be a very effective tool for detecting blind spots in USTs calibration, but it should be used in conjunction with other methods and approaches to ensure maximum effectiveness.

3.2 FIR FILTERING

FIR filtering is a type of digital signal processing technique used to filter a signal. FIR stands for "finite impulse response". In FIR filtering, the filter output is a weighted sum of past and present input samples. The weights are called coefficients, and they are finite in number because the impulse response of the filter is of finite duration.

The FIR filter operates by convolving the input signal with the filter coefficients. This convolution operation effectively smooths out the input signal, removing any high-frequency noise or other unwanted components. The output of the filter is a delayed version of the input signal, with the delay determined by the number of filter taps (i.e., the number of coefficients).

FIR filters have several advantages over other types of filters, including linear phase response (which means that all frequency components of the input signal are shifted in time by the same amount) and stability (which means that the filter output will not become unstable or oscillate in response to certain input signals). FIR filters are commonly used in a variety of applications, including audio processing, image processing, and signal analysis.

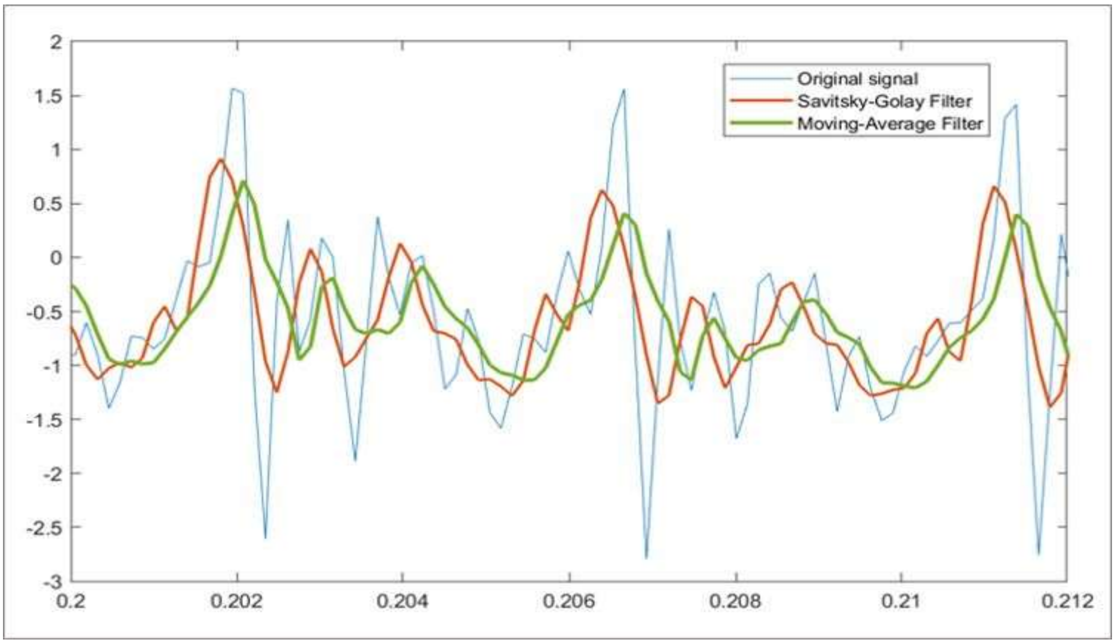

Figure 3.1: The Original Signal Has Been Smoothed Using Savitzky-Golay Filter and Moving-Average Filter.

3.3 LOW-PASS FILTER

There are various types of low-pass filters, including passive filters (such as RC filters) and active filters (such as operational amplifier-based filters). The choice of filter type depends on factors like the required frequency response, desired attenuation characteristics, and the specific application. Moving average filters and Savitzky-Golay filters are commonly employed to enhance signals by reducing noise, generating a smoothing effect, averaging data, and constructing decimators and interpolators. These low-pass filters facilitate the production of gradual output changes, enabling the visualization of trends and enhancing the signal-to-noise ratio while minimizing signal degradation.

3.3.1 Moving-Average Filter

Filters are data processing techniques that can smooth out high-frequency fluctuations in data or remove periodic trends of a specific frequency from data In MATLAB simulator, The filter function is one way to implement a moving-average filter, which is a common data smoothing technique.

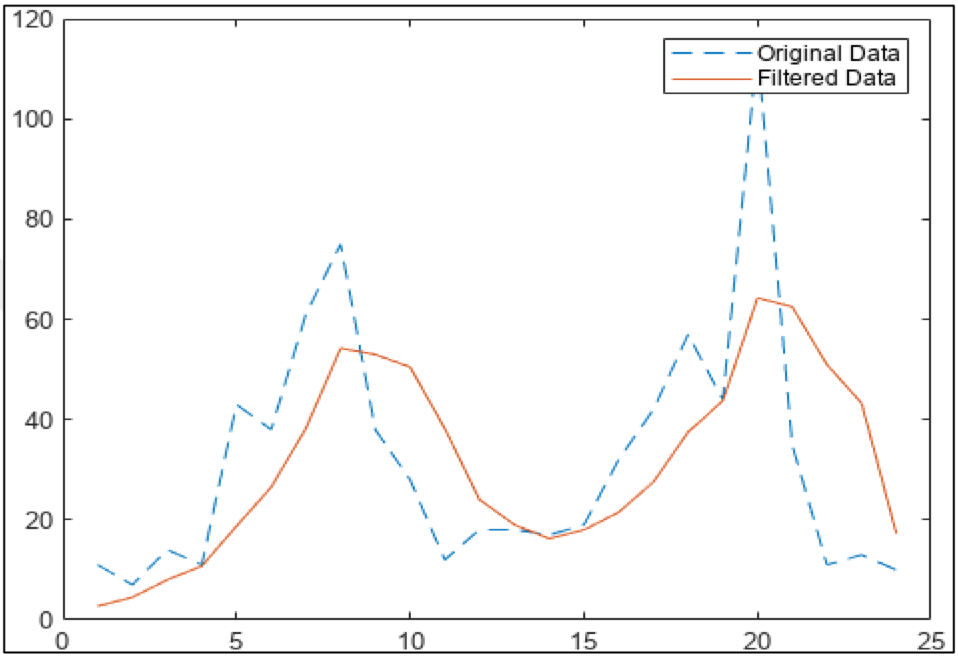

Figure 3.2: Moving-Average Filter.

3.3.2 Savitzky-Golay Filters

The fundamental concept underlying Savitzky-Golay filters involves approximating the local behavior of a signal by fitting a polynomial within a moving window of data points. This polynomial fitting procedure aids in retaining crucial signal characteristics while diminishing noise and undesirable fluctuations. The filter employs the least squares method to calculate weighted polynomial coefficients, optimizing the fit to the data within the window.

Savitzky-Golay filters come with various advantages, they can smooth the signals while preserving essential features like sharp edges or peaks. Also, they can handle unevenly spaced or irregularly sampled data. Furthermore, the filter coefficients can be precomputed and stored, enabling efficient real-time filtering.

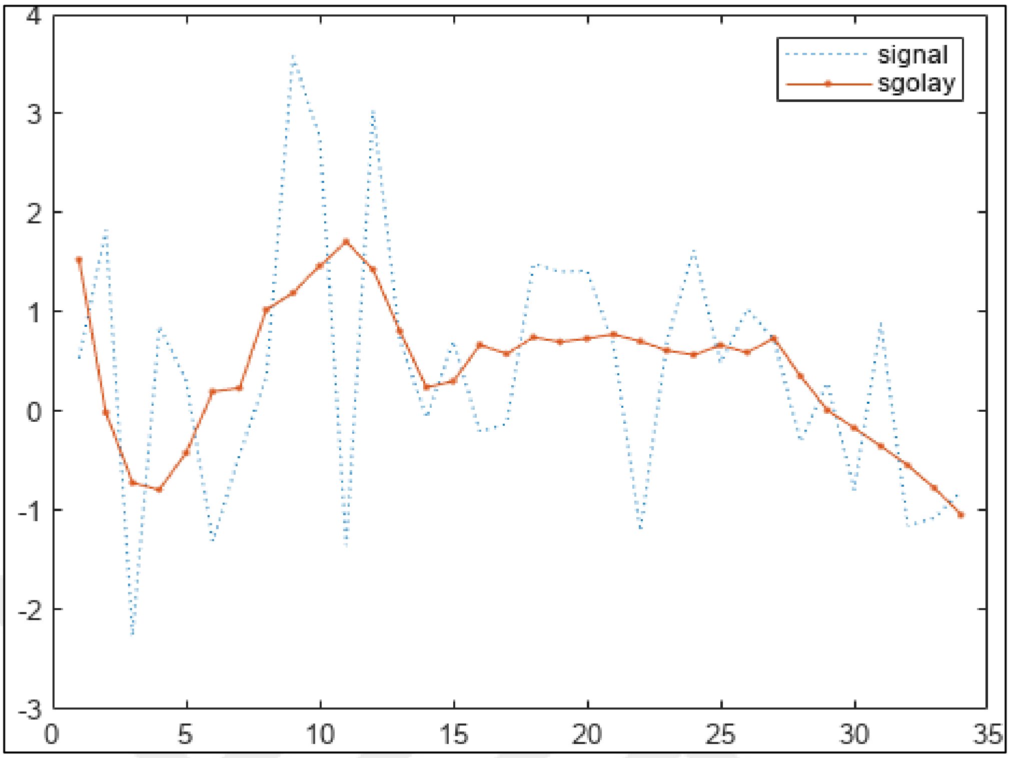

Figure 3.3: Savitzky-Golay Filters.

FIR filtering is a popular choice in digital signal processing for several reasons:

a. Linear phase response: FIR filters have a linear phase response, meaning that all frequency components of the input signal are delayed by the same amount. This makes them useful in applications where preserving the relative timing of different frequency components is important.

b. Flexibility: FIR filters can be designed to have a wide range of frequency response characteristics, including low-pass, high-pass, band-pass, and notch filters. This makes them highly versatile and adaptable to a variety of applications.

c. Stability: FIR filters are inherently stable, meaning that the filter output will not become unstable or oscillate in response to certain input signals. This makes them a reliable choice for many applications.

d. Implementation efficiency: FIR filters can be efficiently implemented using a variety of hardware and software techniques, including DSP chips, FPGA, and general-purpose processors. This makes them widely applicable and accessible.

e. Design control: FIR filters offer a high level of design control, allowing engineers to precisely tailor the filter characteristics to meet specific application requirements.

f. FIR filtering is a powerful and flexible technique that is well-suited for many applications in digital signal processing.

For example, we can simulate FIR filtering to eliminate abnormal readings from a laser distance meter and keep only the readings with a resolution of 1.0 mm using python,

This code applies a 5-tap FIR filter with coefficients [1/9, 2/9, 3/9, 2/9, 1/9] to a list of distance readings. The filter is used to eliminate abnormal readings and smooth out the signal. The resulting filtered signal is then rounded to the nearest 1.0 mm and printed to the console.

```
import numpy as np

import scipy.signal as signal

# Define the filter coefficients

b = np.array([1, 2, 3, 2, 1])/9

# Define the input signal (distance readings)

distance_readings = [10.5, 11.2, 9.8, 100.3, 10.1, 11.4, 10.7, 9.9, 9.5, 9.6]

# Apply the filter to the distance readings

filtered_readings = signal.lfilter(b, 1, distance_readings)

# Round the filtered readings to the nearest 1.0 mm

rounded_readings = np.round(filtered_readings)

# Print the filtered readings with 1.0 mm resolution

print(rounded_readings)
```

FIR filter circuit board would depend on the specific requirements of the application. However, a basic FIR filter circuit board might include the following components:

a. Analog-to-digital converter (ADC): Converts the analog distance readings from the laser distance meter into digital signals that can be processed by the filter.

b. Microcontroller: Runs the filter algorithm and controls the other components on the circuit board.
c. Filter coefficients: These can be stored on a lookup table or hardcoded into the microcontroller.
d. Digital signal processor (DSP): Performs the FIR filtering on the digital signals from the ADC.
e. Digital-to-analog converter (DAC): Converts the filtered digital signals back into analog signals that can be output to a display or other device.

Going back to Fig-1, we can see the slight regression between two curves that represents the data that obtained from the two methods that we used, meter drop and EODR using laser measurements and geometrical calculations, but we still have errors in both methods, and we will keep getting these errors no matter what we tried to do all the steps in the previous paragraphs.

To reduce such errors, we assume a surface, and measure the distance between the one point on it along to the reference point as in Figure 3-1.

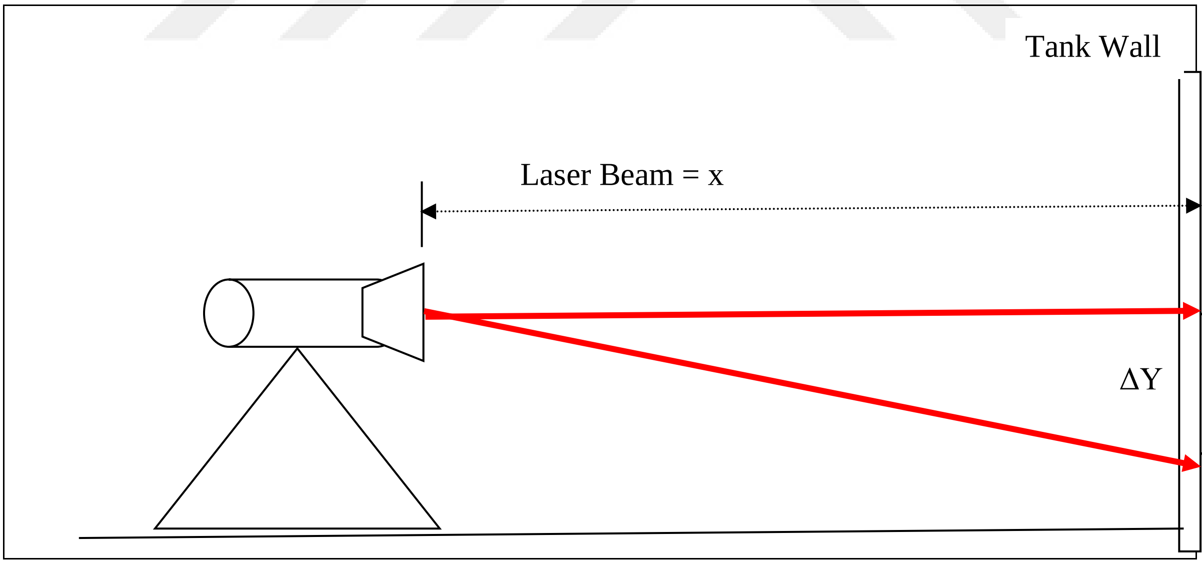

Figure 3.4: Measurements and Geometrical Calculations.

The length x represents the distance from the reference point (laser) to the point at the tank's wall, that mean we have actual distance, but unfortunately this measurement can be affected with several obstacles we may facing during the measuring process, like internal surface roughness and deadwood…etc., also we can get noise while measuring that leads to errors can be x ±c in this case we can use finite impulse response FIR filtering (M. Knyva, 3D Laser Scanning Pointcloud Processing Uncertainty Estimation for Fuel Tank Volume Calibration) that eliminates the noise (impulse) if it was beyond the accepted limits, in this case ± 0.3% standard uncertainty of the fuel tanks calibration [10].

If we calculate the strapping table of a perfect tank, we can get the theoretical dimension which does not match the real tank because of the uniform shape and constant diameter along the tank length and other theoretical parameter, but we can follow the pattern of the perfect tank wall that can help to adjust the deformation while scanning only if ΔY is small (like 1 cm), we have to find a relation between the tank theoretical internal surface and the collected data of the scanner output [13].

Before the relation we may ask about why ΔY shall be small like 1 cm, in real life we cannot get perfect geometrical shape, however the cylinder of the tank and its both end cap can be deformed and it may have some bending, more bending means more volume error, in this case, some range of error can be acceptable, this concept lead to use correlation.

3.4 CORRELATION COEFFICIENT

Correlation refers to the statistical relationship between two or more variables. It measures the extent to which the values of one variable are associated with the values of another variable. In other words, correlation tells us whether two variables are related and if so, the strength and direction of their relationship.

Correlation is typically measured using a correlation coefficient, which is a numerical value that ranges between -1 and 1. A positive correlation coefficient indicates a positive association between the variables, meaning that as one variable increases, the other variable tends to increase as well. A negative correlation coefficient indicates a negative association between the variables, meaning that as one variable increases, the other variable tends to decrease.

A correlation coefficient of 0 indicates no correlation between the variables, meaning that there is no association between the values of the two variables. A correlation coefficient of 1 or -1 indicates a perfect correlation between the variables, meaning that the values of one variable can be perfectly predicted by the values of the other variable.

Correlation is an important concept in many fields, including statistics, economics, psychology, and social sciences. It can be used to identify patterns in data, to make predictions, and to inform decision-making. However, it's important to remember that correlation does not necessarily imply causation, and other factors may be at play in the relationship between the variables.

Collecting data: First, we need to gather the data that we want to correlate. We have to Make sure that the data are numerical and has a sufficient sample size.

Calculate the correlation: Once we have the values, we can calculate the correlation between them using a statistical method such as Pearson's correlation coefficient or Spearman's rank correlation coefficient. These methods will give us a numerical value between -1 and 1, which indicates the strength and direction of the correlation.

3.5 PEARSON'S CORRELATION COEFFICIENT

To deploy the Pearson's correlation coefficient on our data collected from the meter and laser data from Table-2, an online correlation coefficient calculator will be used:

R Calculation

$r = \sum((X - My)(Y - Mx)) / \sqrt{((SSx)(SSy))}$

X: X Values (Laser Level)

Y: Y Values (Meter Level)

Mx: Mean of X Values

My: Mean of Y Values

X - Mx & Y - My: Deviation scores

(X - Mx)2 & (Y - My)2: Deviation Squared

(X - Mx)(Y - My): Product of Deviation Scores

X Values

$\sum = 355829.94$

Mean = 1317.889

$\sum(X - Mx)2 = SSx = 111183234.768$

Y Values

$\sum = 356271$

Mean = 1319.522

$\sum(Y - My)2 = SSy = 114145147.367$

X and Y Combined

N = 270

$\sum(X - Mx)(Y - My) = 112653039.208$

$r = 112653039.208 / \sqrt{((111183234.768)(114145147.367))} = 1$

The value of R is 1.

This is a strong positive correlation, which means that high X (Laser Level) variable scores go with high Y (Meter Level) variable scores (and vice versa).

3.6 POLYNOMIAL REGRESSION

Polynomial regression is a type of regression analysis in which the relationship between the independent variable(s) and the dependent variable is modeled as an nth-degree polynomial. It extends the concept of linear regression by allowing for curved relationships between the variables, in our case we can assume that the height of the fuel in the tank is independent and the volume that come out as a result of the increasing of that height (fuel level) which is X.

In polynomial regression, the equation takes the form:

$y = b_0 + b_1 x + b_2 x^2 + ... + b_n x^n$

where: y is the dependent variable being predicted, fuel volume at corresponding level, x is the independent variable, level of fuel, $b_{0,}$ $b_{1,}$ b_2..., b_n are the coefficients to be estimated, n is the degree of the polynomial, determining the number of terms in the equation.

In polynomial regression, the selection of the polynomial degree and the assessment of the model's goodness of fit rely on subjective judgments made by the user. It is widely recognized that attempting to extract more correlation from the data than what is genuinely supported may lead to an unpredictable function that, while fitting the data points, meanders aimlessly between them. Thus, simply having a good correlation coefficient close to 1.0 is insufficient to guarantee a well-behaved or meaningful function. Determining the appropriateness of the results is more a matter of personal judgment rather than purely mathematical criteria.

Achieving a "perfect" fit, where all data points are matched exactly, is sometimes feasible by setting the polynomial degree equal to the number of data pairs minus one. However, depending on the characteristics of the dataset, this approach can also produce the problematic outcome, where the function freely wanders between data points in order to precisely match the data.

To conduct polynomial regression, the following steps are typically followed:

a. Data Collection: Gather a dataset that includes values for both the dependent variable and the independent variable.
b. Degree Selection: Determine the appropriate degree for the polynomial regression. This choice depends on the complexity of the relationship between the variables and can be determined through experimentation or domain knowledge.
c. Predictor Creation: Create additional predictor variables by raising the independent variable to the corresponding power for each degree from 2 to n. For instance, if the degree is 3, generate additional predictors such as x^2 and x^3.
d. Model Fitting: Employ the dataset and the additional predictor variables to fit the polynomial regression model. This process involves estimating the coefficients (b0, b1, b2, ..., bn) that best align with the data. Various techniques, such as least squares estimation, can be utilized to estimate the coefficients.
e. Model Evaluation: Evaluate the goodness of fit of the polynomial regression model by analyzing residuals, calculating the coefficient of determination (R-squared), and considering other evaluation metrics. It is crucial to validate the model's performance on new, unseen data to ensure its ability to generalize.

Polynomial regression offers more flexibility in modeling the relationships between variables compared to linear regression. Nevertheless, it is important to exercise caution regarding overfitting the model to the data, particularly with high-degree polynomials, as it may result in poor generalization to new data.

3.7 POLYNOMIAL REGRESSION CALCULATOR

Table 3.1: Comparison Between Meter TCT and Laser TCT.

8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75
9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05
14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74

Table 3.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5
18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95
19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 3.1: Comparison Between Meter TCT and Laser TCT ‘Table Continued’.

Laser Calibration		Meter Calibration			Laser Calibratio		Meter Calibration		
Volume	Laser Level	Meter Level	Volume	VAR	Volume	Laser Level	Meter Level	Volu me	VAR
200	46.09	25	200	21.09	27200	1331.09	1335	27200	-3.91
400	73.17	49	400	24.17	27400	1338.65	1344	27400	-5.35
600	95.9	71	600	24.9	27600	1346.2	1352	27600	-5.8
800	116.24	95	800	21.24	27800	1353.75	1360	27800	-6.25
1000	134.94	115	1000	19.94	28000	1361.3	1367	28000	-5.7
1200	152.46	131	1200	21.46	28200	1368.86	1376	28200	-7.14
1400	169.06	153	1400	16.06	28400	1376.41	1382	28400	-5.59
1600	184.92	171	1600	13.92	28600	1383.96	1389	28600	-5.04
1800	200.14	185	1800	15.14	28800	1391.51	1394	28800	-2.49
2000	214.82	201	2000	13.82	29000	1399.06	1400	29000	-0.94
2200	229.05	214	2200	15.05	29200	1406.61	1410	29200	-3.39
2400	242.87	230	2400	12.87	29400	1414.16	1419	29400	-4.84
2600	256.35	241	2600	15.35	29600	1421.72	1426	29600	-4.28
2800	269.5	253	2800	16.5	29800	1429.27	1433	29800	-3.73
3000	282.37	265	3000	17.37	30000	1436.83	1439	30000	-2.17
3200	294.96	275	3200	19.96	30200	1444.39	1447	30200	-2.61
3400	307.31	288	3400	19.31	30400	1451.95	1456	30400	-4.05
3600	319.44	303	3600	16.44	30600	1459.51	1464	30600	-4.49
3800	331.36	315	3800	16.36	30800	1467.08	1473	30800	-5.92
4000	343.1	327	4000	16.1	31000	1474.65	1480	31000	-5.35
4200	354.67	339	4200	15.67	31200	1482.22	1487	31200	-4.78
4400	366.07	350	4400	16.07	31400	1489.79	1495	31400	-5.21
4600	377.32	361	4600	16.32	31600	1497.37	1504	31600	-6.63
4800	388.42	373	4800	15.42	31800	1504.95	1510	31800	-5.05
5000	399.39	388	5000	11.39	32000	1512.54	1515	32000	-2.46
5200	410.23	398	5200	12.23	32200	1520.13	1521	32200	-0.87
5400	420.94	410	5400	10.94	32400	1527.73	1529	32400	-1.27
5600	431.53	422	5600	9.53	32600	1535.33	1537	32600	-1.67
5800	442.02	433	5800	9.02	32800	1542.93	1546	32800	-3.07
6000	452.4	445	6000	7.4	33000	1550.54	1552	33000	-1.46
6200	462.68	455	6200	7.68	33200	1558.16	1560	33200	-1.84
6400	472.87	466	6400	6.87	33400	1565.78	1567	33400	-1.22
6600	482.97	478	6600	4.97	33600	1573.41	1577	33600	-3.59
6800	492.99	490	6800	2.99	33800	1581.04	1586	33800	-4.96
7000	502.92	500	7000	2.92	34000	1588.68	1592	34000	-3.32
7200	512.78	509	7200	3.78	34200	1596.33	1600	34200	-3.67
7400	522.56	518	7400	4.56	34400	1603.98	1609	34400	-5.02
7600	532.27	529	7600	3.27	34600	1611.65	1617	34600	-5.35
7800	541.91	538	7800	3.91	34800	1619.32	1625	34800	-5.68
8000	551.49	548	8000	3.49	35000	1627	1631	35000	-4
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2

Table 3.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
9200	607.61	599	9200	8.61	36200	1673.25	1681	36200	-7.75
9400	616.77	608	9400	8.77	36400	1681	1689	36400	-8
9600	625.88	619	9600	6.88	36600	1688.75	1697	36600	-8.25
9800	634.94	629	9800	5.94	36800	1696.51	1705	36800	-8.49
10000	643.95	640	10000	3.95	37000	1704.29	1711	37000	-6.71
10200	652.92	648	10200	4.92	37200	1712.08	1720	37200	-7.92
10400	661.84	657	10400	4.84	37400	1719.88	1727	37400	-7.12
10600	670.72	666	10600	4.72	37600	1727.69	1735	37600	-7.31
10800	679.56	674	10800	5.56	37800	1735.51	1745	37800	-9.49
11000	688.36	682	11000	6.36	38000	1743.35	1754	38000	-10.65
11200	697.12	691	11200	6.12	38200	1751.2	1764	38200	-12.8
11400	705.85	701	11400	4.85	38400	1759.06	1772	38400	-12.94
11600	714.53	711	11600	3.53	38600	1766.94	1780	38600	-13.06
11800	723.19	721	11800	2.19	38800	1774.83	1789	38800	-14.17
12000	731.8	730	12000	1.8	39000	1782.74	1796	39000	-13.26
12200	740.39	736	12200	4.39	39200	1790.66	1805	39200	-14.34
12400	748.94	744	12400	4.94	39400	1798.6	1814	39400	-15.4
12600	757.46	752	12600	5.46	39600	1806.55	1822	39600	-15.45
12800	765.95	759	12800	6.95	39800	1814.52	1829	39800	-14.48
13000	774.41	768	13000	6.41	40000	1822.51	1835	40000	-12.49
13200	782.84	775	13200	7.84	40200	1830.52	1845	40200	-14.48
13400	791.24	783	13400	8.24	40400	1838.54	1851	40400	-12.46
13600	799.61	791	13600	8.61	40600	1846.58	1859	40600	-12.42
13800	807.95	800	13800	7.95	40800	1854.65	1866	40800	-11.35
14000	816.26	809	14000	7.26	41000	1862.73	1872	41000	-9.27
14200	824.55	818	14200	6.55	41200	1870.83	1880	41200	-9.17
14400	832.81	827	14400	5.81	41400	1878.95	1888	41400	-9.05
14600	841.05	836	14600	5.05	41600	1887.09	1894	41600	-6.91
14800	849.27	845	14800	4.27	41800	1895.26	1904	41800	-8.74
15000	857.46	855	15000	2.46	42000	1903.44	1910	42000	-6.56
15200	865.62	862	15200	3.62	42200	1911.65	1917	42200	-5.35
15400	873.77	870	15400	3.77	42400	1919.89	1927	42400	-7.11
15600	881.9	879	15600	2.9	42600	1928.15	1937	42600	-8.85
15800	890	887	15800	3	42800	1936.43	1944	42800	-7.57
16000	898.08	895	16000	3.08	43000	1944.74	1951	43000	-6.26
16200	906.15	904	16200	2.15	43200	1953.08	1960	43200	-6.92
16400	914.19	914	16400	0.19	43400	1961.44	1971	43400	-9.56
16600	922.22	922	16600	0.22	43600	1969.84	1980	43600	-10.16
16800	930.23	930	16800	0.23	43800	1978.26	1989	43800	-10.74
17000	938.22	938	17000	0.22	44000	1986.72	1997	44000	-10.28
17200	946.19	945	17200	1.19	44200	1995.2	2007	44200	-11.8
17400	954.15	953	17400	1.15	44400	2003.72	2016	44400	-12.28
17600	962.09	961	17600	1.09	44600	2012.26	2024	44600	-11.74
17800	970.02	969	17800	1.02	44800	2020.84	2030	44800	-9.16
18000	977.93	976	18000	1.93	45000	2029.46	2038	45000	-8.54
18200	985.82	985	18200	0.82	45200	2038.1	2045	45200	-6.9
18400	993.7	994	18400	-0.3	45400	2046.78	2056	45400	-9.22
18600	1001.57	1000	18600	1.57	45600	2055.5	2066	45600	-10.5

Table 3.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

18800	1009.42	1009	18800	0.42	45800	2064.26	2075	45800	-10.74
19000	1017.26	1016	19000	1.26	46000	2073.05	2083	46000	-9.95
19200	1025.08	1024	19200	1.08	46200	2081.88	2094	46200	-12.12
19400	1032.9	1033	19400	-0.1	46400	2090.76	2104	46400	-13.24
19600	1040.7	1041	19600	-0.3	46600	2099.68	2113	46600	-13.32
19800	1048.49	1050	19800	-1.51	46800	2108.64	2121	46800	-12.36
20000	1056.26	1057	20000	-0.74	47000	2117.64	2130	47000	-12.36
20200	1064.03	1065	20200	-0.97	47200	2126.69	2141	47200	-14.31
20400	1071.79	1072	20400	-0.21	47400	2135.79	2150	47400	-14.21
20600	1079.53	1080	20600	-0.47	47600	2144.95	2159	47600	-14.05
20800	1087.26	1086	20800	1.26	47800	2154.15	2167	47800	-12.85
21000	1094.99	1093	21000	1.99	48000	2163.4	2176	48000	-12.6
21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21400	1110.41	1110	21400	0.41	48400	2182.09	2199	48400	-16.91
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Table 3.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

21200	1102.7	1102	21200	0.7	48200	2172.72	2188	48200	-15.28
21600	1118.11	1117	21600	1.11	48600	2191.52	2209	48600	-17.48
21800	1125.79	1126	21800	-0.21	48800	2201.01	2219	48800	-17.99
22000	1133.47	1131	22000	2.47	49000	2210.58	2228	49000	-17.42
22200	1141.15	1139	22200	2.15	49200	2220.21	2236	49200	-15.79
22400	1148.81	1149	22400	-0.19	49400	2229.91	2246	49400	-16.09
22600	1156.47	1156	22600	0.47	49600	2239.68	2255	49600	-15.32
22800	1164.12	1164	22800	0.12	49800	2249.52	2262	49800	-12.48
23000	1171.76	1171	23000	0.76	50000	2259.44	2272	50000	-12.56
23200	1179.39	1179	23200	0.39	50200	2269.45	2279	50200	-9.55
23400	1187.02	1187	23400	0.02	50400	2279.53	2287	50400	-7.47
23600	1194.64	1194	23600	0.64	50600	2289.71	2295	50600	-5.29
23800	1202.26	1200	23800	2.26	50800	2299.98	2307	50800	-7.02
1200	152.46	131	1200	21.46	28200	1368.86	1376	28200	-7.14
1400	169.06	153	1400	16.06	28400	1376.41	1382	28400	-5.59
1600	184.92	171	1600	13.92	28600	1383.96	1389	28600	-5.04
1800	200.14	185	1800	15.14	28800	1391.51	1394	28800	-2.49
2000	214.82	201	2000	13.82	29000	1399.06	1400	29000	-0.94
2200	229.05	214	2200	15.05	29200	1406.61	1410	29200	-3.39
2400	242.87	230	2400	12.87	29400	1414.16	1419	29400	-4.84
2600	256.35	241	2600	15.35	29600	1421.72	1426	29600	-4.28
2800	269.5	253	2800	16.5	29800	1429.27	1433	29800	-3.73
3000	282.37	265	3000	17.37	30000	1436.83	1439	30000	-2.17
3200	294.96	275	3200	19.96	30200	1444.39	1447	30200	-2.61
3400	307.31	288	3400	19.31	30400	1451.95	1456	30400	-4.05
3600	319.44	303	3600	16.44	30600	1459.51	1464	30600	-4.49
3800	331.36	315	3800	16.36	30800	1467.08	1473	30800	-5.92
4000	343.1	327	4000	16.1	31000	1474.65	1480	31000	-5.35
4200	354.67	339	4200	15.67	31200	1482.22	1487	31200	-4.78
4400	366.07	350	4400	16.07	31400	1489.79	1495	31400	-5.21
4600	377.32	361	4600	16.32	31600	1497.37	1504	31600	-6.63
4800	388.42	373	4800	15.42	31800	1504.95	1510	31800	-5.05
5000	399.39	388	5000	11.39	32000	1512.54	1515	32000	-2.46
5200	410.23	398	5200	12.23	32200	1520.13	1521	32200	-0.87
5400	420.94	410	5400	10.94	32400	1527.73	1529	32400	-1.27
5600	431.53	422	5600	9.53	32600	1535.33	1537	32600	-1.67
5800	442.02	433	5800	9.02	32800	1542.93	1546	32800	-3.07
6000	452.4	445	6000	7.4	33000	1550.54	1552	33000	-1.46
6200	462.68	455	6200	7.68	33200	1558.16	1560	33200	-1.84
6400	472.87	466	6400	6.87	33400	1565.78	1567	33400	-1.22
6600	482.97	478	6600	4.97	33600	1573.41	1577	33600	-3.59
6800	492.99	490	6800	2.99	33800	1581.04	1586	33800	-4.96
7000	502.92	500	7000	2.92	34000	1588.68	1592	34000	-3.32
7200	512.78	509	7200	3.78	34200	1596.33	1600	34200	-3.67
7400	522.56	518	7400	4.56	34400	1603.98	1609	34400	-5.02
7600	532.27	529	7600	3.27	34600	1611.65	1617	34600	-5.35
7800	541.91	538	7800	3.91	34800	1619.32	1625	34800	-5.68

Table 3.1: Comparison Between Meter TCT and Laser TCT 'Table Continued'.

8000	551.49	548	8000	3.49	35000	1627	1631	35000	-4
8200	560.99	556	8200	4.99	35200	1634.68	1640	35200	-5.32
8400	570.43	564	8400	6.43	35400	1642.38	1650	35400	-7.62
8600	579.81	572	8600	7.81	35600	1650.08	1658	35600	-7.92
8800	589.13	581	8800	8.13	35800	1657.8	1666	35800	-8.2
9000	598.4	590	9000	8.4	36000	1665.52	1674	36000	-8.48
24000	1209.87	1208	24000	1.87	51000	2310.34	2317	51000	-6.66
24200	1217.48	1218	24200	-0.52	51200	2320.81	2329	51200	-8.19
24400	1225.08	1226	24400	-0.92	51400	2331.39	2339	51400	-7.61
24600	1232.68	1233	24600	-0.32	51600	2342.08	2350	51600	-7.92
24800	1240.27	1241	24800	-0.73	51800	2352.9	2360	51800	-7.1
25000	1247.85	1248	25000	-0.15	52000	2363.84	2372	52000	-8.16
25200	1255.44	1256	25200	-0.56	52200	2374.93	2387	52200	-12.07
25400	1263.02	1264	25400	-0.98	52400	2386.15	2400	52400	-13.85
25600	1270.59	1273	25600	-2.41	52600	2397.53	2411	52600	-13.47
25800	1278.16	1280	25800	-1.84	52800	2409.07	2424	52800	-14.93
26000	1285.73	1287	26000	-1.27	53000	2420.78	2435	53000	-14.22
26200	1293.3	1295	26200	-1.7	53200	2432.67	2445	53200	-12.33
26400	1300.86	1303	26400	-2.14	53400	2444.77	2455	53400	-10.23
26600	1308.42	1310	26600	-1.58	53600	2457.08	2469	53600	-11.92
26800	1315.98	1317	26800	-1.02	53800	2469.63	2487	53800	-17.37
27000	1323.54	1325	27000	-1.46	54000	2482.46	2495	54000	-12.54
average VAR = the average variance between levels in both methods 1.63 mm									

Using online Regression calculator, normally the best analysis can come out with result as in the chart below, as tight correlation as 1, and small errors can approach 0.999.

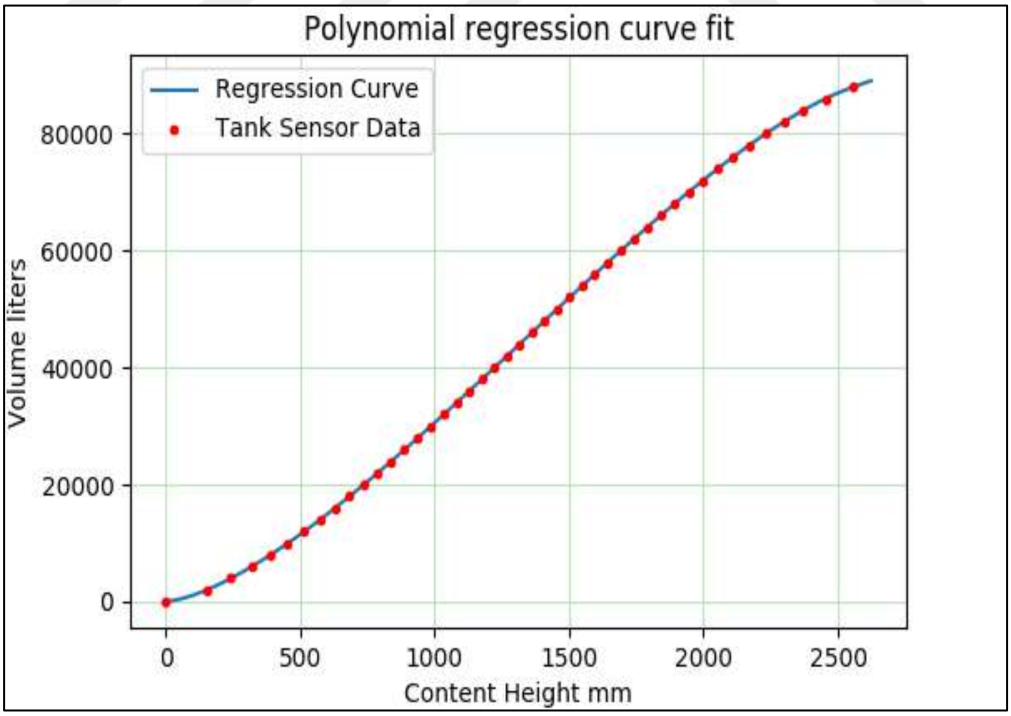

Chart 3.1: Polynomial Regression Curve Fit.

3.7.1 Laser Calibration Regression Coefficient

By using the online calculator and 8th polynomial degree with 2 decimal points as in the below polynomial model: $y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 x^4 + \beta_5 x^5 + \beta_6 x^6 + \beta_7 x^7 + \beta_8 x^8$

Regression Polynomials:

VOLUME = 0.00 x^8 + 0.00 x^7 + 0.00 x^6 + 0.00 x^5 + 0.00 x^4 + 0.00 x^3 + 0.03 x^2 + 4.77 x – 88

=0.03 x2 + 4.77 x – 88

R-squared: r_2=1

Adjusted R-squared: r_{2adj}=1

Adjusted R-squared: r_{2adj}=1

Residual Standard Error: 1.58 on 261 degrees of freedom

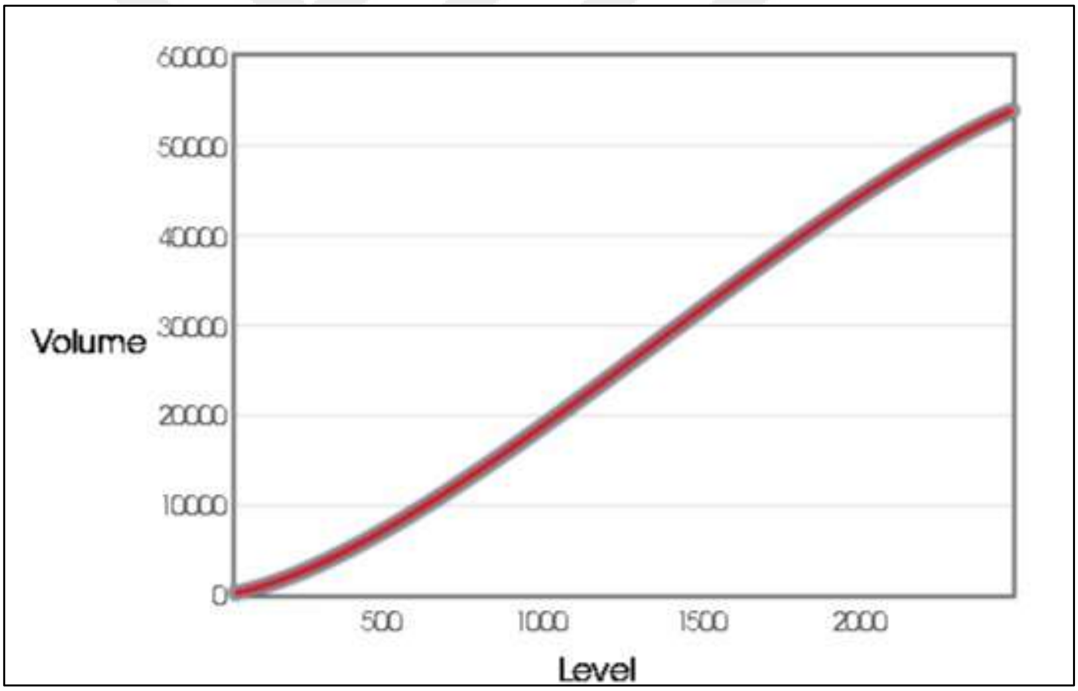

Chart 3.2: Laser Calibration Regression.

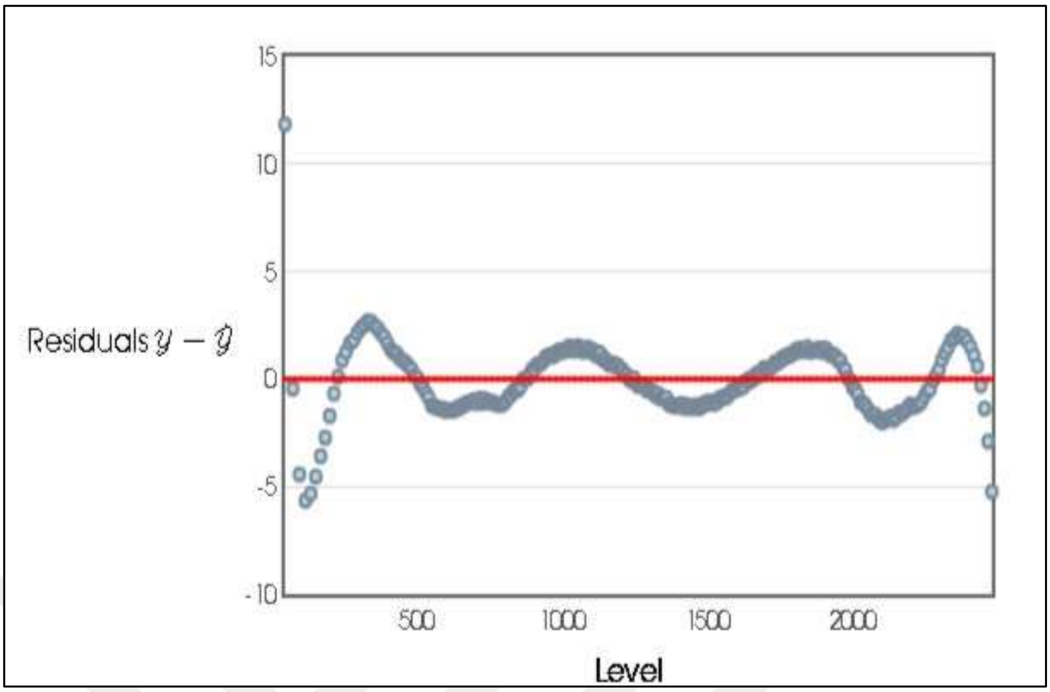

Chart 3.3: Laser Calibration Residual Plot.

3.7.2 Meter Calibration Regression Coefficient

For the same calculation and table, but now we use Meter calibration, and the analysis was like:

R-squared: $r_2=1$

Adjusted R-squared: $r_{2adj}=1$

Residual Standard Error: 58.14 on 261 degrees of freedom

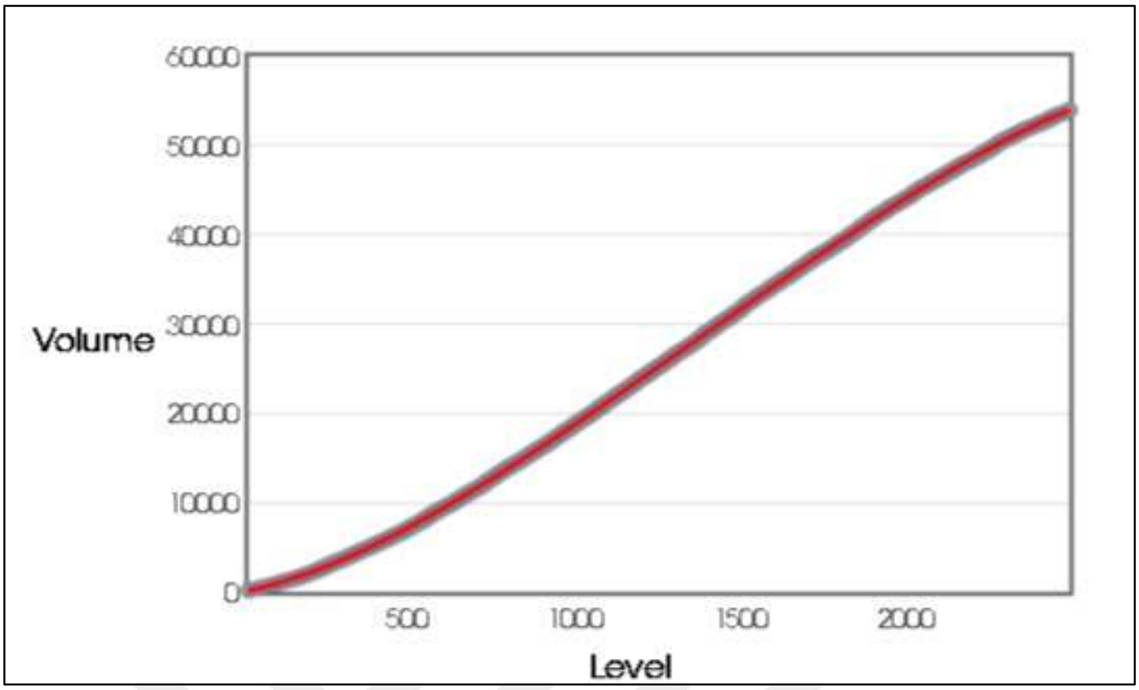

Chart 3.4: Meter Calibration Regression.

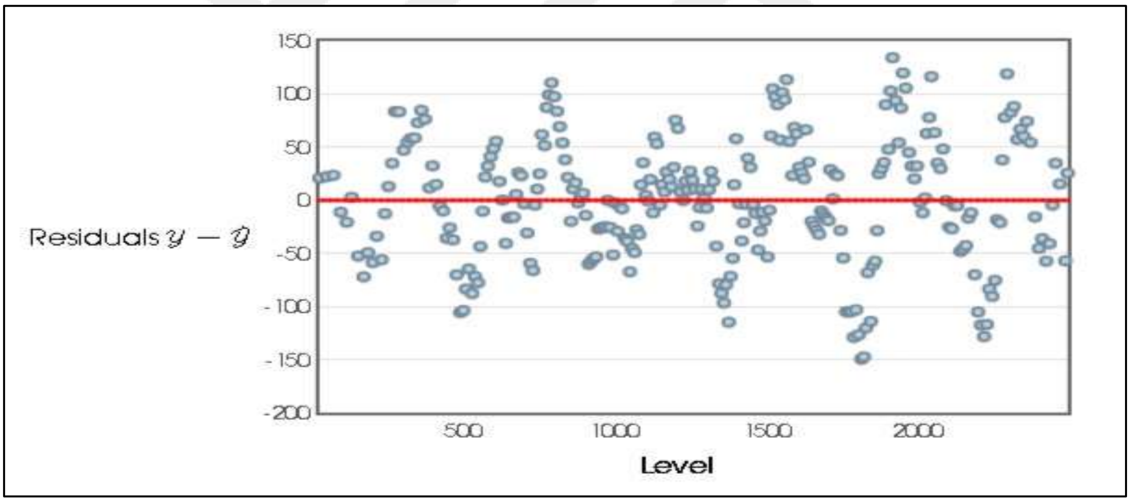

Chart 3.5: Meter Calibration Residual Plot.

To compare the difference between the result we have to understand the concept of the Residual Standard Error, The Residual Standard Error (RSE) is a measure of the average distance between the observed values and the predicted values obtained from a regression model. It is used as an estimate of the variability of the residuals, which are the differences between the observed values and the predicted values.

The RSE is calculated by taking the square root of the mean squared error (MSE), which is the average of the squared residuals.

The RSE provides an estimate of the standard deviation of the residuals. It is commonly used to assess the overall goodness of fit of a regression model. A smaller RSE indicates a better fit of the model to the data, as it indicates that the predicted values are closer to the observed values on average.

It's important to note that the RSE is sensitive to the scale of the dependent variable. Therefore, it is not suitable for comparing the goodness of fit across different models with different scales of the dependent variable. In such cases, it is often more appropriate to use metrics such as the coefficient of determination (R-squared) or adjusted R-squared.

4. CONCLUSION

So, as a conclusion we can depend on the data of the calibration that profile the tank strapping table for more accurate and precision representation of level against volume, because we got 1.58 RSE for laser calibration versus 58.14 for meter calibration in the same condition in the range of acceptance of Uncertainty of 0.3%. Utilizing a 3D laser scanner for calibrating storage tanks offers several significant advantages. The technology provides a highly accurate and comprehensive representation of the tank's geometry and dimensions. By capturing a vast number of data points, including intricate details of the tank's structure, the 3D laser scanner ensures precise measurements.

The point cloud generated from the laser scanning process allows for thorough analysis and modeling of the storage tank. It provides a detailed digital representation of the tank, enabling engineers and technicians to assess its condition, identify potential issues, and optimize its performance.

Moreover, the point cloud data obtained from the 3D laser scanner can be seamlessly integrated into CAD/BIM software for further analysis, design, and construction purposes. This integration facilitates the creation of accurate 3D models, as-built documentation, and customized deliverables.

By using a 3D laser scanner, the calibration process becomes more efficient and reliable. The scanner's ability to capture complex geometries, irregular shapes, and unique features of the tank ensures a more precise calibration procedure. The detailed point cloud data aids in identifying any discrepancies or deviations in the tank's volume or shape, allowing for adjustments and calibration to be performed with greater accuracy.

Overall, the utilization of 3D laser scanners in calibrating storage tanks offers enhanced precision, improved efficiency, and a comprehensive understanding of the tank's characteristics. It enables better decision-making, reduces uncertainties, and contributes to the optimization of tank operations and operation.

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