MEASUREMENT METHODS FOR LIQUID STORAGE TANKS
Class # 2290

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Introduction

This paper will provide, in general terms, an overview of the different technologies available to measure Net Standard Volumes in storage tanks. The Net Standard Volume (NSV) is used as the primary unit of measurement for custody transfer and/or Inventory Control. The Net Standard Volume (NSV) documents the agreement between the representatives of the interested parties (custody transfer) of the measured quantities and qualities of the transferred liquid.

Definition

Net Standard Volume (NSV) is the equivalent volume of a liquid at its base conditions that does not include non merchantable items such as sediment and water.

Net Standard Volume (NSV) can be determined by establishing the following known values:

Determine **Total Observed Volume (TOV)** by measuring the liquid height of the tank. The Total Observed Volume is made up of all liquids contained in the storage tank including the water. Total Observed Volume is derived by referencing the liquid height of the tank to a calculated volume from the tank capacity table (Strap Table). See Figure 1 and 2.

Determine **Water Volume** by measuring the water level of the tank via the tank capacity table (Strap Table). See Figure 1 and 2.

Determine **Gross Observed Volume (GOV)** by taking the **Total Observed Volume (TOV)** minus the Water Volume. See Figure 1 and 2.

(GOV) = (TOV) – Water Volume

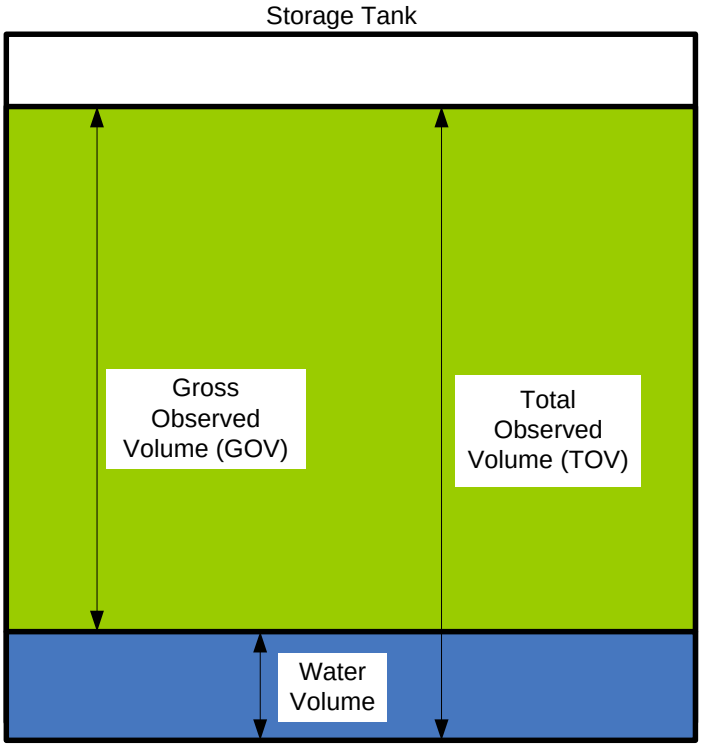


Figure - 1

Determine the **Observed Temperature** of the product by establishing an average temperature of the liquid. See Figure 2.

Determine the **Observed Density** of the product by using a calibrated Densitometer. See Figure 2.

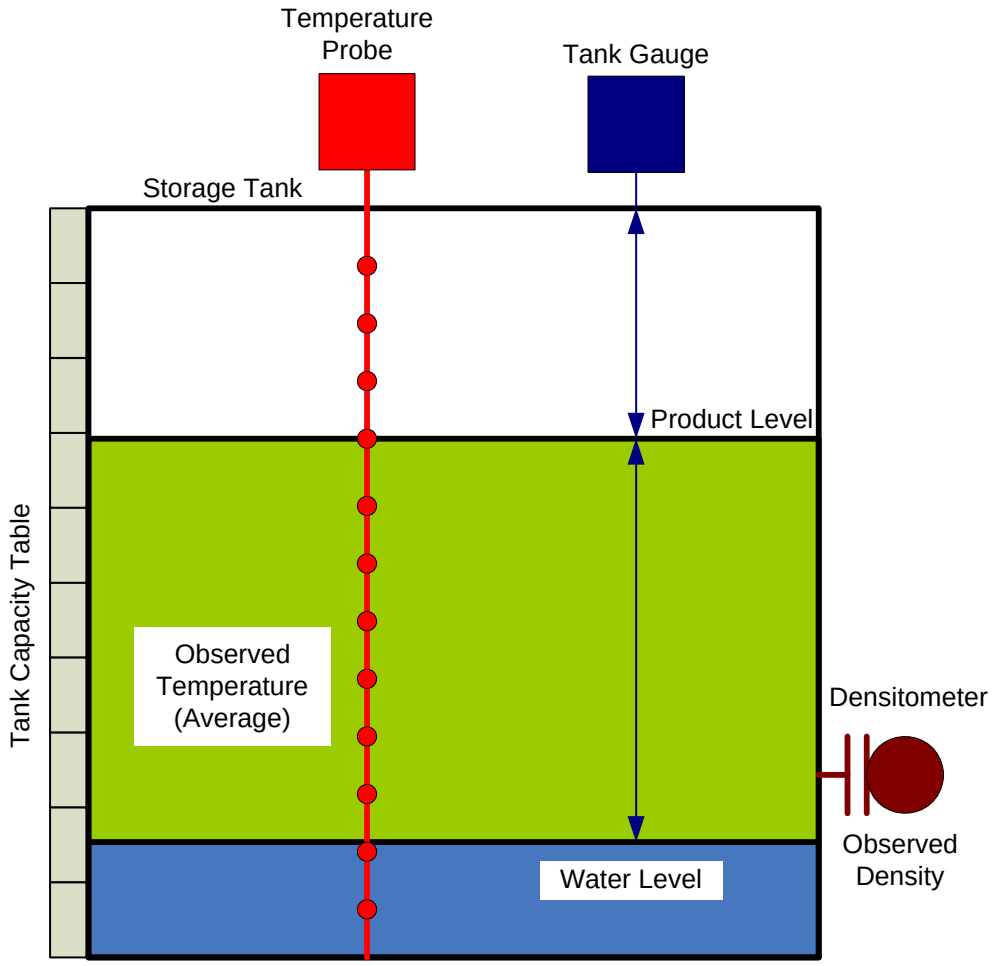


Figure - 2

Determine the **Volume Correction Factor (VCF)** based on the **Observed Temperature** and **Observed Density** of the liquid in reference to the required API/ASTM Petroleum Measurement Table Volume II (ex. API/ASTM Table 5B/6B – Generalized Products Correction of Observed API Gravity to API Gravity at 60ºF).

Net Standard Volume (NSV) = [Gross Observed Volume (GOV)] X [Volume Correction Factor (VCF)]

Key Elements

In order for you to achieve an accurate Net Standard Volume (NSV), there are four key elements of field data that need to be obtained: (See Figure 2)

1. **Product Level** – derived from a manual tape gauge or an automatic tank gauge. See Figure 2.
2. **Water Level** – derived from a manual tape gauge with use of water paste or an automatic tank gauge with the capability of measuring the interface between product and water.
3. **Observed Temperature** – derived from a single spot element or and average temperature derived from a multi-spot element temperature probe. See Figure 2.
4. **Product Density** – derived from a manual sample or a device mounted on a tank to measure the mass of the product. See Figure 2.

Based on this information, Net Standard Volume (NSV) is only as accurate as the methods used in obtaining these key elements.

There are two methods used to determine these values for calculating Net Standard Volume (NSV):

1. Manually measuring these values and entering them into a program that will calculate a Net Standard Volume (NSV).
2. Install devices that will automatically measure these values and transmit the values to a computer based tank inventory management system that will compute Net Standard Volume (NSV) in real-time.

Product Level

An accurate product level defines the amount of liquid present in the storage tank. Along with a complete and accurate tank capacity table, product level provides the basis to obtaining an accurate Net Standard Volume (NSV). It is very important to establish accuracy along with reliability and repeatability.

The Tank Capacity Table is a document or a chart that defines the overall capacity, in volume, of the storage tank. The Tank Capacity Table provides a volume at a specific level point in the storage tank. This document is normally provided by the tank manufacturer and is considered to be a legal document when used in a custody transfer application. Therefore it is very important to keep this document current and accurate. If there are any structural changes made to the tank that may have an adverse affect on the volume of the tank, it is very important to have a company come out and verify the accuracy of the tank capacity table. It is also recommended that every 10 years you should have your storage tank, tank capacity table checked and verified for accuracy. Your storage tank is considered to be a calibrated instrument, and it should be considered as such in the scheme of your maintenance programs.

There are two primary methods of providing an accurate Product Level:

1. **Manual Gauging** - the values that are obtained from this device are written down and Net Standard Volume (NSV) is manually calculated.
2. **Automatic Tank Gauging - t**he values that are obtained from this device are normally connected to a tank gauging inventory management system and Net Standard Volume (NSV) is automatically calculated.

Manual Gauging

Manual gauging is a method that is most commonly used to obtain the product level in a storage tank.

Figure – 3

In order to obtain an accurate, reliable, and repeatable product level via manual gauging, it is highly recommended to follow the guidelines and procedures outlined in API's *"Manual of Petroleum Measurement Standards Chapter 3 - Tank Gauging Section 1A - Standard Practice for the Manual*

Gauging of Petroleum and Petroleum Products". This document will provide you good basis for developing your program for manual tank gauging. In most cases, this document is used as the procedure for manual gauging in a custody transfer application.

In order to conduct manual gauging of a tank, you must be equipped with the proper equipment. It is highly recommended to use a manual gauge tape that has been calibrated and certified to a NIST traceable standard. The manual gauge tapes should be kept in good physical condition to where the numbers are legible on the tape and the tape does not include kinks. See Figure 4.

Figure – 4

Prior to performing a manual gauge, an operator or a gauger must take all safety and precautionary measures to assure personal safety and avoid any possible incidents. See Figure 3. In some operations, because of the tank contents, safety programs and/or local or federal EPA programs, do not allow personnel on top of a storage tank and open the tank contents to atmosphere. In cases such as this, it is highly recommended to implement a manual-closed tank gauge system along with a gauging station. See Figure 5. These devices are equipped with technology that allows you to determine the water level in the storage tank.

Manual-Closed Tank Gauge

Gauging Station

Figure – 5

Water Level

Water Level is a function of level determination in a storage tank. With a manual tape gauge, you would apply water paste to the bob, to determine the water cut in the storage tank. You would lower the bob with water paste into the tank and the water paste will react to the water and the water paste will change its state of color (Red). This change is color of the water will illustrate the level of water in the storage

tank. Once you have determined the water level in the tank, you would look at the tank capacity table to determine the water volume.

Although manual gauging is the most commonly used method, it is not the most accurate, reliable, or repeatable method of obtaining an accurate product level. A manual gauge is left up to the individual to perform and document an accurate, consistent, and repeatable manual gauge even when faced with harsh physical and environmental conditions. In addition, it puts personnel in a high risk situation that presents the possibility of an un-safe act or condition. Where there are locations that present these conditions, it is highly recommended to implement an automatic tank gauging system.

Automatic Tank Gauging

An automatic tank gauge is a device that is installed on a storage tank that continuously measures the liquid height in a storage tank which is then considered to be Product Level. For Net Standard Volume (NSV) calculations, automatic tank gauges will provide the most accurate, reliable, and repeatable product level measurement.

To setup automatic tank gauges for your facility, follow the recommended API Standard, *Manual of Petroleum Measurement Standards Chapter 3 - Tank Gauging Section 1B - Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging*

There are three different types of automatic tank gauges:

1. Mechanical Automatic Tank Gauges
2. Electro-Mechanical Automatic Tank Gauges
3. Electronic Automatic Tank Gauges

Automatic tank gauges have incorporated a local read out where personnel can view the measured value at tank side, or the measured value is transmitted to a tank inventory management system where it is displayed at a remote location. This allows the operator or gauger to obtain an accurate product level without having to climb the tank and open the tank contents to atmosphere.

Mechanical Automatic Tank Gauges

Mechanical Automatic Tank Gauges are devices that provide a product level measurement with use of mechanical devices assembled to measure the liquid level in of a storage tank. These devices do not include any electronic devices that require an electrical current. The local readout on these devices is made of a mechanical register. These devices are commonly known as Float and Tape devices. See Figure 6.

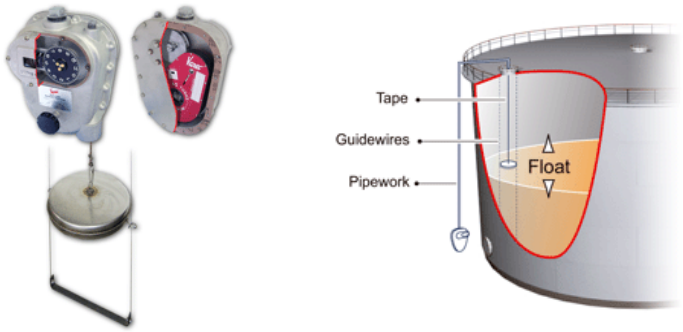


Figure – 6

Mechanical automatic tank gauges are more accurate, reliable, and repeatable than manual tank gauges. But with a high number of moving parts, these devices require constant attention for parts replacement and frequent re-calibration. As long as these devices are well maintained and are a part of a frequent maintenance program, they will provide an accurate, reliable, and repeatable product level measurement for calculating an accurate Net Standard Volume (NSV).

Water Level

Water Level is a function of level determination in a storage tank. The float and tape device has no way of determining the amount of water in a storage tank, With a manual tape gauge, you would apply water paste to the bob, to determine the water cut in the storage tank. You would lower the bob with water paste into the tank and the water paste will react to the water and the water paste will change its state of color (Red). This change is color of the water will illustrate the level of water in the storage tank. Once you have determined the water level in the tank, you would look at the tank capacity table to determine the water volume.

An additional problem with mechanical automatic tank gauging was the human interface. It was still left up to the operator/gauger to go out to the tank side and properly document the product level being displayed on the local mechanical register. At times this would present opportunities to document wrong product level measurements because of the numbers not being legible or personnel not properly trained to read the correct values. For what ever reason it would be, this was becoming an increasing problem so the mechanical automatic tank gauge could then be equipped with a transmitter to transmit the product level measurement to a remote location where it could be displayed in a more legible, user-friendly digital format, such as FEET-INCHES-SIXTEENTHS (ex. 10’ 08” 09). In addition, the transmitted value could be displayed on a tank gauging system that would automatically document the contents without having human interaction. This then provided the basis to developing the Electro-Mechanical Tank Gauge and implements some additional functionality, such as Water Level, that is used in calculating a Net Standard Volume (NSV).

Electro-Mechanical Tank Gauges

The electro-mechanical tank gauges are devices that derived from the float and tape technology. These devices were developed on the basis of the float and tape technology, with the implementation of electronics. This device is known as a Servo Tank Gauge. See Figure 7.

Figure - 7

The Servo Tank Gauge is a hybrid device that was specifically designed and built to provide Net Standard Volume (NSV). The Servo Tank Gauge, as a stand-alone device, can provide Product Level used to determine Total Observed Volume, Water Level to determine Gross Observed Volume, and Product Density used to determine a real-time Net Standard Volume. In addition, the Servo Tank Gauge implemented a series of gauge commands that can be initiated from remote locations obtain this data and test the device for accuracy, repeatability, and reliability. With all this functionality, the Servo Tank Gauge is an ideal device for providing an accurate, repeatable, and reliable Net Standard Volume (NSV).

The Radar Tank Gauge

The Radar Tank Gauge is a non-contact device that accurately measures the product level. See Figure 8. The Radar Tank Gauge is the most accurate level measurement device in the industry today. With its capability of delivering product level measurements in the accuracy range of less than a millimeter and a fraction of an inch, makes this device the ideal device for providing the most accurate calculation of Net Standard Volume (NSV).

Figure - 8

The Radar Tank Gauge being the most accurate device for determining product level, it needs to be installed with instruments that deliver the same quality of measurement for water level, temperature, and density.

Water Level

Determining the amount of water in a storage tank is a function of a level measurement. The Radar Tank Gauge does not have the capability of measuring water level, therefore you are required to use a separate level measuring device called a Water Level Sensor. See Figure 9.

The Water Level Sensor must be installed in a separate tank connection. If you install this device in the same tank connection as the Radar Tank Gauge, you will have an adverse affect on the accuracy of the Radar Tank Gauge. See Figure 9.

The accuracy of the Water Level Sensor is very important in obtaining an accurate Net Standard Volume (NSV). These Water Level Sensors will normally provide a water level measurement within 2mm of accuracy. Once the Water Level Sensor provides the water level measurement, you reference the water level measurement to the Tank Capacity Table to obtain Water Volume.

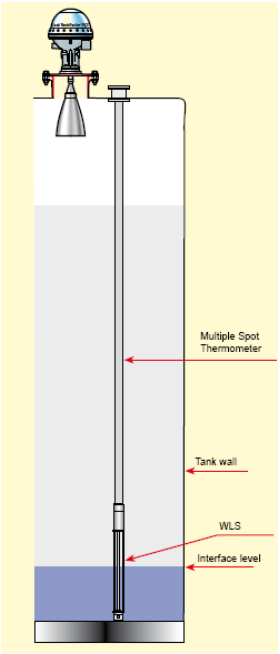


Figure - 9

Observed Temperature

Now that we have determined the important volumes (TOV and GOV) by measuring the product level and the water level, it is now very important to measure the temperature of the product. The measurement of temperature is critical in determining the true volume of the stored liquid. Temperature has the most significant effect on the accurate determination of Net Standard Volume (NSV). An error in the temperature measurement will result in either an over-or understatement of the volume in the storage tank, regardless of the accuracy obtained by the tank gauge. For best results, devices used for temperature measurement should have an accuracy of 0.5ºC (0.25ºF).

There are three methods of obtaining Observed Temperature in a storage tank:

1. **Portable Electronic Thermometers** – provides a manual method of obtaining product temperature measurement. These devices can provide spot temperatures are multiple points in the storage tank. See Figure 10. The values that are obtained from this device are written down and Net Standard Volume (NSV) is manually calculated.
2. **Spot Temperature Probe** – provides a continuous single spot temperature measurement of the liquid in the storage tank. See Figure 11. The values that are obtained from this device are normally connected to a tank gauging inventory management system and Net Standard Volume (NSV) is automatically calculated.
3. **Multiple Spot Element Probe** – provides multiple-spot temperature measurements throughout the entire measuring range of the storage tank. These devices are custom made to the measuring range of the tank. See Figure 12. The values that are obtained from this device are normally connected to a tank gauging inventory management system and Net Standard Volume (NSV) is automatically calculated.

Figure - 10

Figure - 11

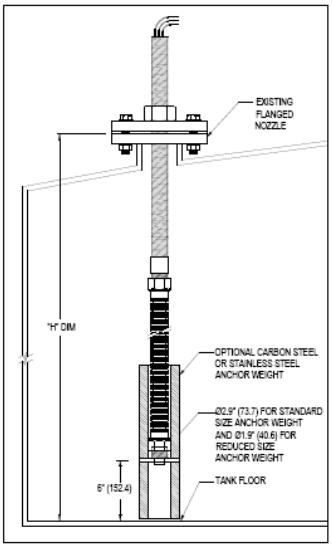


Figure – 12

Portable Electronic Thermometers

These devices are considered to be the most commonly used method of measuring product temperature, it is not the most accurate, reliable, or repeatable method. A manual temperature gauge is left up to the individual to perform and document an accurate, consistent, and repeatable measurement even when faced with harsh physical and environmental conditions. In addition, it puts personnel in a high risk situation that presents the possibility of an un-safe act or condition. Where there are locations that present these conditions, it is highly recommended to implement an automatic tank temperature gauging system.

Spot Temperature Probes

These devices are installed at the bottom of the tank, normally 3 feet above the tank bottom. These devices continuously measure the temperature of the liquid in the storage tank, but it only measures the temperature at a single point in the storage tank. This device does not take the product stratification into consideration when providing the product temperature measurement.

Automatic Tank Thermometer (Multi-Spot Temperature Probes)

These devices are installed vertically in the storage tank. They attach at the top of the tank and extend to the bottom of the tank. There are up to 16 spot elements evenly spaced through the measuring range of the storage tank. These devices will measure the temperature at each element and a transmitter will average each temperature point and provide an overall average temperature measurement of the liquid. The overall average of the product temperature takes the temperature stratification into account and provides a more accurate product temperature measurement to use in determining a more accurate Net Standard Volume (NSV).

Observed Density

Observed Density is the relationship of "mass per unit volume" of a liquid. Observed Density is measured in units of API Gravity. Thus, API gravity is thus a measure of the relative density of petroleum liquid and the density of water. API Gravity is used to compare the relative densities of petroleum liquids. Observed Density is one of the key elements is determining the Net Standard Volume (NSV). If this measurement is not done correctly, the Net Standard Volume (NSV) will not be determined properly.

There are 2 methods of determining Observed Density:

1. **Hydrometer** – This is determined by obtaining a sample of the product and testing it with a Hydrometer to determine the API gravity.
2. **Pressure Transmitter** – this is determined by installing a pressure transmitter to continuously measure the mass of the liquid in the storage tank.

Hydrometer

There are 2 types of Hydrometers that are used to measure the Observed Density of the liquid:

1. Glass Graduated Hydrometer with a Hydrometer jar. See Figure 13.
2. Digital Hand Held Hydrometer or a Digital Bench Type Hydrometer. See Figure 14

Both of these methods will accurately measure the density of the liquid and provide an Observed Density, but it is left up to discretion of the individual to view and document the measurement correctly. In situations of this nature, the Digital Hydrometers are of recommended use.

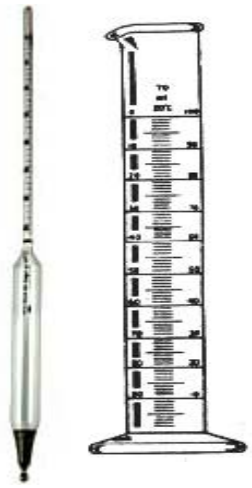


Figure – 13

Figure - 14

Pressure Transmitter

A pressure transmitter can be installed at the bottom of the tank to measure the static pressure of the liquid in the storage tank. See Figure 15. This static pressure measurement is transmitted to a hybrid processor that will convert this measurement to an Observed Density. The hybrid processor calculates the Observed Density based on the Product Temperature.

The pressure transmitter must be selected with a reference accuracy of +/- 0.02% URL and a total performance accuracy of +/- 0.05% URL at a temperature range of -40 to 185ºF (-40 to 85ºC). The pressure transmitter should also be selected for a pressure range of 0 to 150 PSI. It is recommended that analog devices are not used for this application; it is recommended that a digital transmitter, such as a HART device is used for this application. As long as the transmitter is calibrated to correctly and is subsequently verified for accuracy, this is the most accurate method of determining Observed Density.

The pressure transmitter and the hybrid processor is normally connected to a tank inventory management system that will store this data and calculate a Net Standard Volume (NSV) in real-time. The Hybrid Processor can be a stand-alone device that is remotely controlled or it can be part of an automatic tank gauge that has the capability of performing this calculation. These systems are known as Hybrid Tank Measurement Systems (HTMS).

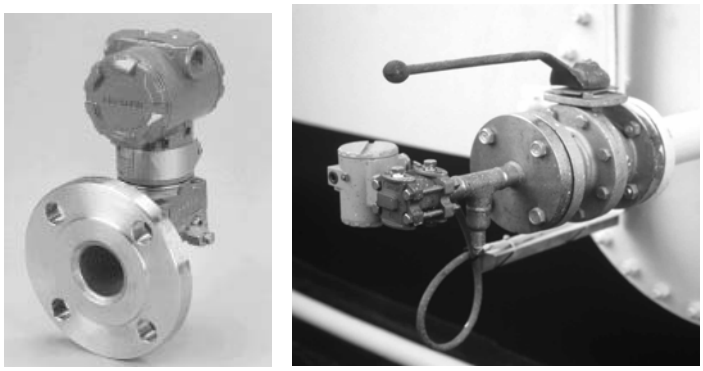


Figure - 15

Hybrid Tank Measurement Systems

A Hybrid Tank Measurement System (HTMS) consists of four major components:

1. Automatic Tank Gauge that provides accurate level
2. Automatic Tank Thermometer that provides accurate temperature
3. Pressure Sensor that provides accurate pressure
4. Hybrid Processor that provides an accurate determination of pressure to density

These four components are described in this document as the most accurate methods of calculating a Net Standard Volume (NSV). This method of measurement is considered to be the most accurate of all technologies of providing Net Standard Volume (NSV)

In order for your to implement a Hybrid Tank Measurement System the American Petroleum Institute provides a document; *API MPMS Chapter 3 – Tank Gauging SECTION 6 -- MEASUREMENT OF LIQUID YDROCARBONS BY HYBRID TANK MEASUREMENT SYSTEMS,* that give guidance in implementing a Hybrid Tank Measurement System.

A Hybrid Tank Measurement System is normally connected to a Tank Inventory Management System. See Figure 16. The Hybrid Tank Measurement System will transmit its data to the tank inventory management system and this system will store this data and will provide the final Net Standard Volume (NSV) in real-time.

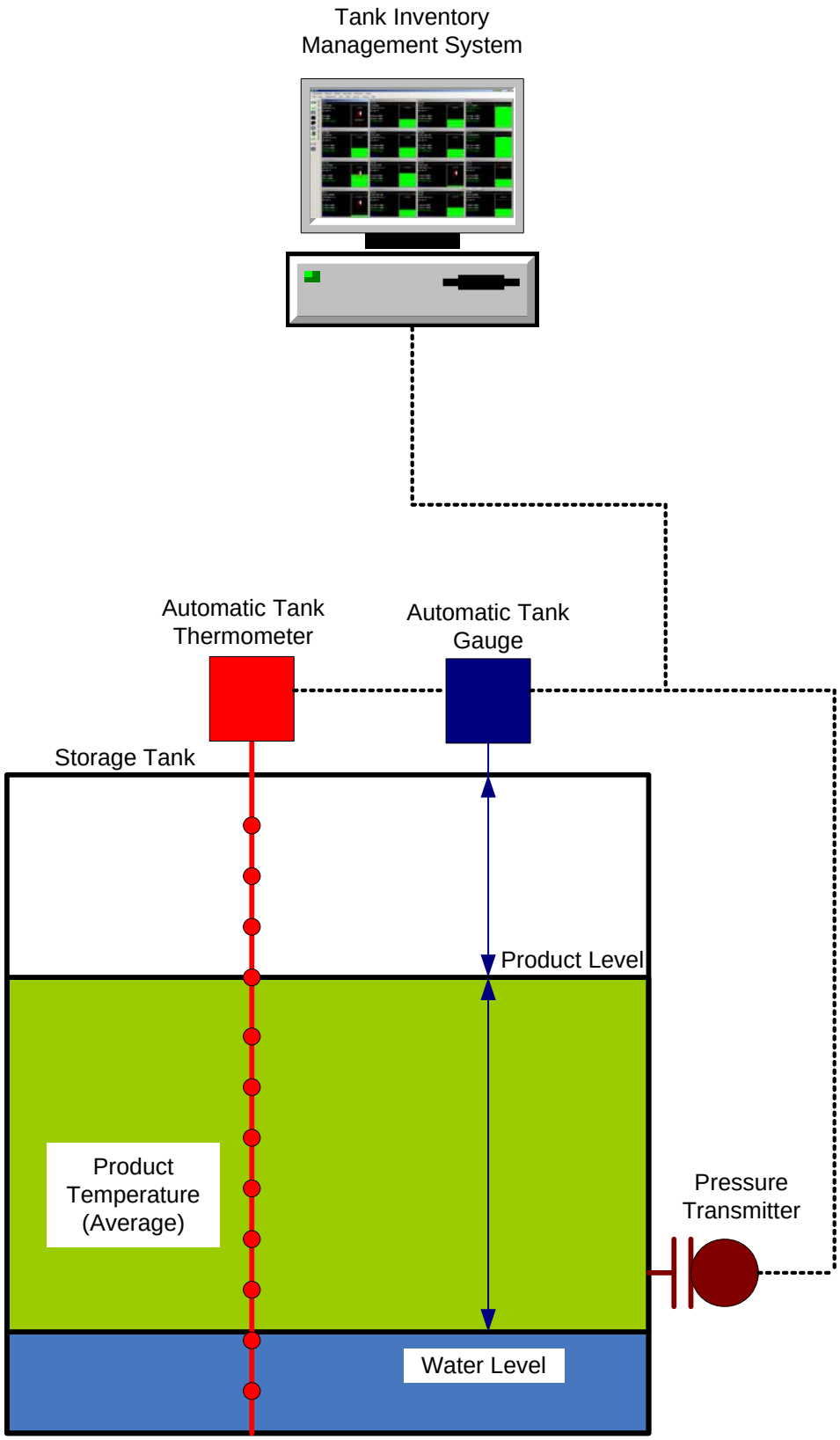
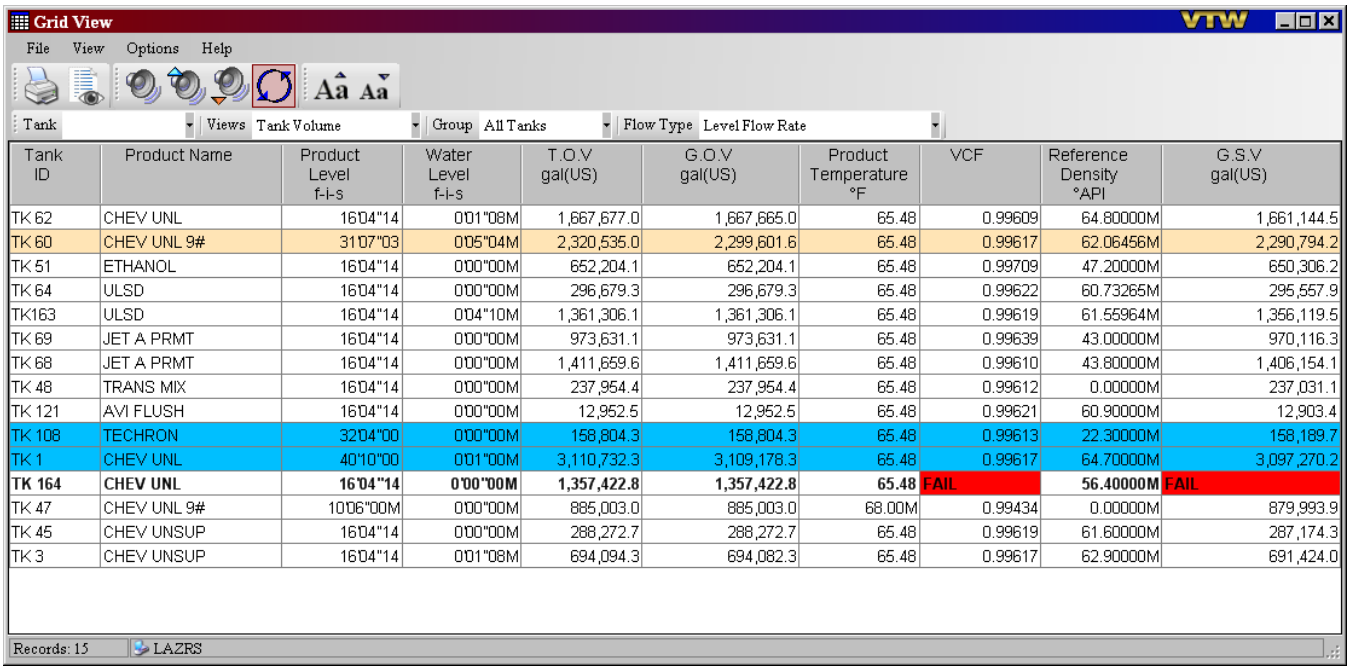

Tank Inventory
Management System
Automatic Tank
Thermometer
Automatic Tank
Gauge
Storage Tank
Product Level
Product
Temperature
(Average)
Pressure
Transmitter
Water Level

Figure - 16

Conclusion

In conclusion, Net Standard Volume (NSV) is a complex calculation that relies on 4 key elements of data. This data can be provided via manual methods or automatic methods. The manual methods have been the most commonly used but the automatic methods are on the rise. End users are seeing the value in having the accuracy of these systems provide this critical data (NSV). These systems provide more than just Net Standard Volume (NSV); these systems are being used to provide data for Loss/Gain Analysis, Production Reports, Stock Balancing, and Environmental Reporting.

At the current price of fuel, it is very easy to see the value in these systems. As companies invest in these systems the payback is quick and definite.



Grid View

File View Options Help

Tank | Views: Tank Volume | Group: All Tanks | Flow Type: Level Flow Rate

Tank ID	Product Name	Product Level f-i-s	Water Level f-i-s	T.O.V gal(US)	G.O.V gal(US)	Product Temperature °F	VCF	Reference Density °API	G.S.V gal(US)
TK 62	CHEV UNL	16'04"14	0'01"08M	1,667,677.0	1,667,665.0	65.48	0.99609	64.80000M	1,661,144.5
TK 60	CHEV UNL 9#	31'07"03	0'05"04M	2,320,535.0	2,299,601.6	65.48	0.99617	62.06456M	2,290,794.2
TK 51	ETHANOL	16'04"14	0'00"00M	652,204.1	652,204.1	65.48	0.99709	47.20000M	650,306.2
TK 64	ULSD	16'04"14	0'00"00M	296,679.3	296,679.3	65.48	0.99622	60.73265M	295,557.9
TK163	ULSD	16'04"14	0'04"10M	1,361,306.1	1,361,306.1	65.48	0.99619	61.55964M	1,356,119.5
TK 69	JET A PRMT	16'04"14	0'00"00M	973,631.1	973,631.1	65.48	0.99639	43.00000M	970,116.3
TK 68	JET A PRMT	16'04"14	0'00"00M	1,411,659.6	1,411,659.6	65.48	0.99610	43.80000M	1,406,154.1
TK 48	TRANS MIX	16'04"14	0'00"00M	237,954.4	237,954.4	65.48	0.99612	0.00000M	237,031.1
TK 121	AVI FLUSH	16'04"14	0'00"00M	12,952.5	12,952.5	65.48	0.99621	60.90000M	12,903.4
TK 108	TECHRON	32'04"00	0'00"00M	158,804.3	158,804.3	65.48	0.99613	22.30000M	158,189.7
TK 1	CHEV UNL	40'10"00	0'01"00M	3,110,732.3	3,109,178.3	65.48	0.99617	64.70000M	3,097,270.2
TK 164	**CHEV UNL**	**16'04"14**	**0'00"00M**	**1,357,422.8**	**1,357,422.8**	**65.48**	**FAIL**	**56.40000M**	**FAIL**
TK 47	CHEV UNL 9#	10'06"00M	0'00"00M	885,003.0	885,003.0	68.00M	0.99434	0.00000M	879,993.9
TK 45	CHEV UNSUP	16'04"14	0'00"00M	288,272.7	288,272.7	65.48	0.99619	61.60000M	287,174.3
TK 3	CHEV UNSUP	16'04"14	0'01"08M	694,094.3	694,082.3	65.48	0.99617	62.90000M	691,424.0

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