

## Operating Instructions

# Tankvision

## Tank Scanner NXA820, Data Concentrator NXA821, Host Link NXA822

### System Description





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## 1 Target audience for this manual

This manual is giving detailed information on the system capabilities and architecture. It supports project and sales engineers in designing the system architecture during acquisition and execution phase. Furthermore during operation time of the system all servicing personnel in need of detailed knowledge about the system capabilities.

## 2 Version history

Document version	Valid for SW version	Changes to the previous version
BA00426G/00/EN/01.12	01.02.02-00xxx/01.04.00	Initial version

## 3 Application

### 3.1 Inventory control

By using Tankvision to monitor the tank level and stored volume of valuable liquids remotely, owners or operators of tank farms or terminals for petroleum products and chemicals (liquids) can visualize the volumes or mass of the stored medium in real time. The data can be used to plan the inventory and distribution. The data can also be used to manage tank farm operations like pumping or transferring products.













Tankvision has its unique concept using network technology. Without using proprietary software, the users can visualize and manage their valuable liquids stored in the tanks by a web browser. Tankvision is a flexible and cost effective solution due to its scalable architecture. The application coverage goes from small depots with only a few tanks up to refineries.

### 3.2 Application areas

- Tank farms in refineries
- Ship loading terminals
- Marketing and distribution terminals
- Pipeline terminals
- Logistic terminals for tanks storing products like crude oils, refined white and black products, chemicals, LPGs, fuels, biofuels, alcohols

## 4 Explanation of signs and abbreviations

In order to highlight safety-relevant or alternative operating procedures in the manual, the following conventions have been used, each indicated by a corresponding symbol in the margin.

Safety conventions	
	<b>Warning!</b> A warning highlights actions or procedures which, if not performed correctly, will lead to personal injury, a safety hazard or destruction of the device.
	<b>Caution!</b> Caution highlights actions or procedures which, if not performed correctly, may lead to personal injury or incorrect functioning of the device.
	<b>Note!</b> A note highlights actions or procedures which, if not performed correctly, may indirectly affect operation or may lead to a device response which is not planned.
Explosion protection	
	<b>Device certified for use in explosion hazardous area</b> If the device has this symbol embossed on its name plate it can be installed in an explosion hazardous area.
	<b>Explosion hazardous area</b> Symbol used in drawings to indicate explosion hazardous areas. Devices located in and wiring entering areas with the designation "explosion hazardous areas" must conform with the stated type of protection.
	<b>Safe area (non-explosion hazardous area)</b> Symbol used in drawings to indicate, if necessary, non-explosion hazardous areas. Devices located in safe areas still require a certificate if their outputs run into explosion hazardous areas.
Electrical symbols	
	<b>Direct voltage</b> A terminal to which or from which a direct current or voltage may be applied or supplied.
	<b>Alternating voltage</b> A terminal to which or from which an alternating (sine-wave) current or voltage may be applied or supplied.
	<b>Grounded terminal</b> A grounded terminal, which as far as the operator is concerned, is already grounded by means of an earth grounding system.
	<b>Protective grounding (earth) terminal</b> A terminal which must be connected to earth ground prior to making any other connection to the equipment.
	<b>Equipotential connection (earth bonding)</b> A connection made to the plant grounding system which may be of type e.g. neutral star or equipotential line according to national or company practice.
	<b>Temperature resistance of the connection cables</b> States, that the connection cables must be resistant to a temperature of at least 85 °C (185 °F).

## 5 Identifying the components

### 5.1 Nameplate

Made in Germany  
D-79689 Maulburg

**Endress+Hauser**

**Tankvision**

Order Code:

Ser.-No.:

100 (Auto-MDIX)  
 MAC:

100 (Auto-MDIX)  
 MAC:

**CE**

250002393-

L00-NXA82xxx-18-00-00-yy-001

- 1 Order code according to the product structure
- 2 Serial number
- 3 Supply voltage
- 4 Type of fieldbus communication (only for Tank Scanner NXA820)
- 5 Degree of protection
- 6 Admissible ambient temperature
- 7 MAC address of the System LAN port
- 8 MAC address of the Sync Link LAN port
- 9 Technical data of the Service LAN port

## 5.2 Tank Scanner NXA820

- The Tank Scanner NXA820 connects multiple tank gauges: from up to 15 tanks via one field-loop. The Tank Scanner NXA820 supports different field protocols (Modbus EIA485, Sakura V1, Whessoe WM550).
- The measured values are transmitted by the network and visualized on HTML pages.
- The Tank Scanner NXA820 can be used stand-alone for small tank farms, but also be integrated into a large system for use in refineries.
- The Tank Scanner NXA820 is equipped with a full set of tank inventory calculations. The calculations are based on various international standards such as API, ASTM, IP and many others. Measured values are used to calculate volume and mass.

### 5.2.1 Ordering information

Detailed ordering information is available from the following sources:

- In the Product Configuration on the Endress+Hauser website: [www.endress.com](http://www.endress.com) ?Select country ?Instruments ?Select device ?Product page function: Configure this product
- From your Endress+Hauser Sales Center: [www.endress.com/worldwide](http://www.endress.com/worldwide)



Note!

Product Configurator - the tool for individual product configuration

- Up-to-the-minute configuration data
- Depending on the device: Direct input of measuring point-specific information such as measuring range or operating language
- Automatic verification of exclusion criteria
- Automatic creation of the order code and its breakdown in PDF or Excel output format
- Ability to order directly in the Endress+Hauser Online Shop

### 5.2.2 Product picture



100-NXA8xxxx-10-08-06-xx-002

## 5.3 Data Concentrator NXA821

- The NXA821 Tankvision Data Concentrator is the enhanced solution for large tank farms and refineries. The Data Concentrator is required if:
  - The plant contains more than one field loop (each of which has its own Tank Scanner NXA820) and tanks of more than one Tank Scanner NXA820 are to be grouped
- The Data Concentrator collects the data of several Tank Scanner units and enables reconciliation and totalization of the tank data of many or all tanks in structured groups.
- Alarms and events from all connected Tank Scanners NXA820 can be shown in a common screen. Any tank of the system can be assigned to any tank group, regardless of the Tank Scanner it is linked to. This ensures the highest possible flexibility for the plant or tank farm.
- An alarm pop-up shows alarms of all connected Tank Scanners NXA820 even if the web browser is closed.
- Direct serial printer connection for report printing (W+M certified acc. PTB)
- 90 tanks (more on request) can be allocated to each Data Concentrator NXA821. Each of these tanks must have been allocated to a Tank Scanner NXA820 beforehand.
- Tanks from up to 6 different Tank Scanners NXA820 (more on request) can be integrated in this way.

### 5.3.1 Ordering information

Detailed ordering information is available from the following sources:

- In the Product Configuration on the Endress+Hauser website: [www.endress.com](http://www.endress.com) ?Select country ?Instruments ?Select device ?Product page function: Configure this product
- From your Endress+Hauser Sales Center: [www.endress.com/worldwide](http://www.endress.com/worldwide)



Note!

Product Configurator - the tool for individual product configuration

- Up-to-the-minute configuration data
- Depending on the device: Direct input of measuring point-specific information such as measuring range or operating language
- Automatic verification of exclusion criteria
- Automatic creation of the order code and its breakdown in PDF or Excel output format
- Ability to order directly in the Endress+Hauser Online Shop

### 5.3.2 Product picture



L00-NXA8xxxx-10-08-06-xx-003



## 5.4 Host Link NXA822

- The Host Link NXA822 collects data from all Tank Scanners NXA820 on a network and transfers them to the host system.
- The MODBUS option supports serial EIA-232(RS) and EIA-485(RS) or MODBUS TCP/IP. The NXA822 is configured as a MODBUS slave. Supported functions are:
  - Coil Status (#01)
  - Holding Registers (#03)
  - Input Registers (#04)
  - Write Modbus Values (#06)
- The MODBUS register map is described via XML files and can easily be adapted to individual MODBUS master requirements.
- Gauge commands for Servo Gauges
- 90 tanks (more on request) can be allocated to each Host Link NXA822. Each of these tanks must have been allocated to a Tank Scanner NXA820 beforehand.
- Tanks from up to 6 different Tank Scanners NXA820 (more on request) can be integrated in this way.
- Per system 2 NXA822 units can be installed.

### 5.4.1 Ordering information

Detailed ordering information is available from the following sources:

- In the Product Configuration on the Endress+Hauser website: [www.endress.com](http://www.endress.com) ?Select country ?Instruments ?Select device ?Product page function: Configure this product
- From your Endress+Hauser Sales Center: [www.endress.com/worldwide](http://www.endress.com/worldwide)



Note!

Product Configurator - the tool for individual product configuration

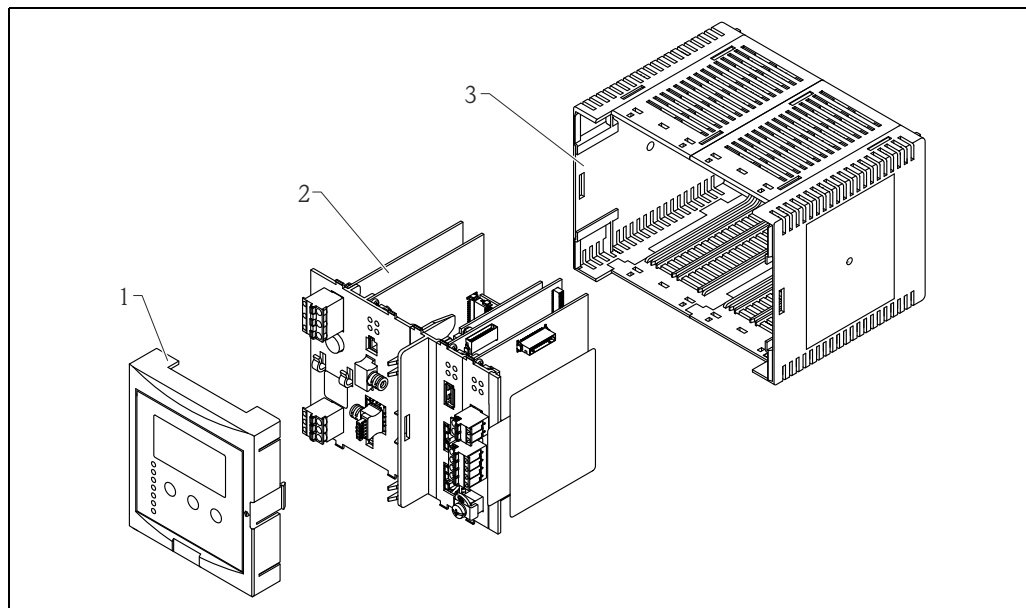
- Up-to-the-minute configuration data
- Depending on the device: Direct input of measuring point-specific information such as measuring range or operating language
- Automatic verification of exclusion criteria
- Automatic creation of the order code and its breakdown in PDF or Excel output format
- Ability to order directly in the Endress+Hauser Online Shop

### 5.4.2 Product picture



L00-NXA8xxxx-10-08-06-xx-004

## 5.5 Explosion picture



- 1 Cover plate
- 2 Inner electronics
- 3 Housing

L00-NXA82xxx-16-00-00-xx-071

## 5.6 Tankvision OPC Server

- The OPC Server is a Windows program installed on a PC connecting to NXA820 and allows access to measured and calculated tank parameters.
- The OPC Server connects to OPC clients on the same PC or other PCs via LAN.
- The OPC Server supports browsing tanks and tank parameters on NXA820.
- The OPC Server is included in each NXA820 and can be uploaded to the PC.
- The OPC Server is based on OPC DA V2.05a

## 5.7 Tankvision Printer Agent

- The Printer Agent is a Windows program installed on a PC, connecting to NXA820/NXA821.
- The program is running in the background and enables (scheduled) printing reports on connected printers.
- Up to 3 printers (directly connected to the PC or network printers) can be assigned to the Printer Agent.
- If a printout can not be performed, a record is kept within the Printer Agent.
- The printer agent software is included in each NXA820 and can be uploaded to the PC.

## 5.8 Tankvision Alarm Agent

- The Alarm Pop-Up-Agent is a Windows program installed on a PC, connecting to NXA820/ NXA821.
- The program is running in the background and scans for alarms generated in NXA820/NXA821.
- If an alarm is present, a pop-up window opens displaying the alarm.
- The alarm can be acknowledged within this window.
- The window can only be closed if no alarm is active.
- The Alarm Agent can be uploaded from NXA820/821 to the PC.

Date	Status	FGTagName	Element	Sub Type	Object	Value	Units	Event ID
06/25/2007 03:31:55 PM	Active	REV5-MODBUS	Product Level	HA	MODBUS_1	+17.500	m	60
06/25/2007 03:34:38 PM	Inactive	REV5-MODBUS	Product Level	LL	MODBUS_1	+0.500	m	63
06/25/2007 03:34:08 PM	Inactive	REV5-MODBUS	Product Level	LA	MODBUS_1	+1.000	m	62
06/25/2007 03:33:25 PM	Inactive	REV5-MODBUS	Product Level	HH	MODBUS_1	+18.100	m	61

Tank Name	MODBUS_1	
Alarm Id	60	
Alarm Type	HA	
Alarm Status	Active	
Parameter	Product Level	
Value	+17.500	
Timestamp	06/25/2007 03:31:55 PM	
Mute	Summary	ACK

100-NXA82xxx-20-00-00-en-005

## 6 PC recommendations

### 6.1 PC connection for viewing data

Tankvision Tank Scanner NXA820, Tankvision Data Concentrator NXA821 and Tankvision Host Link NXA822 are providing a web server to view and enter data or perform configurations. Viewing the pages requires a web browser and JAVA runtime installed on a PC.

PC and the Tankvision components must be connected within the same Local Area Network (LAN) consisting out of Ethernet lines, switches and/or routers.



Note!

HUBs shall not be used. In secured systems e.g. for W&M purposes, routers cannot be used. If company policies allow a remote connection into the LAN also enables a remote connection to Tankvision components.

#### 6.1.1 Recommendations PC configuration

With all on the market available web browser entering the Tankvision web server is possible. Nevertheless the pages are optimized for Microsoft Internet Explorer (supported version IE7, IE8 and IE9).

For a proper operation JAVA runtime need to be installed on the PC. As recommendation the version 6 update 31 should be used for best performance.

The user interface pages are optimized for a screen resolution of 1280x1024 (or higher).

### 6.2 Recommendations when using OPC Server, Printer Agent or Alarm Agent

- Windows XP 32 Bit Service Pack 3, Windows7 32 Bit or Windows7 64 Bit
- Java 6 or higher

### 6.3 Alternations from the recommendations

Alternations to the recommendations in the previous chapters might have influences on the proper behavior of the system especially when communication ports are used by other programs (e.g. other OPC servers). In case of uncertainty consult Endress+Hauser.

## 7 Connections to gauges and host systems

### 7.1 Field instruments and slave devices



Note!

Please take care that the signal and power cables always are separated to prevent noise and electrical interference between them.

#### 7.1.1 Communication variants

Field instruments or other slave devices are connected to the Tankvision Tank Scanner NXA820. The unit is available in 3 communication versions.

##### ■ Modbus RTU RS485

According to "Modbus over serial line specification and implementation guide V1.02" published by the Modbus-IDA organization ([www.modbus.org](http://www.modbus.org)) and based upon the EIA/TIA-485-A physical layer specification.

Characteristic impedance	135 to 165 $\Omega$ at measuring frequency of 3 to 20 MHz
Cable capacitance	$\leq 30$ pF/m
Core cross-section	$\geq 0.34$ mm <sup>2</sup> (AWG 22) multi-strand cable is preferred
Cable type	Single twisted pair + third conductor (for common) or Dual twisted pair (common uses second pair with wire joined together)
Cable resistance	$\leq 110$ $\Omega$ /km
Signal damping	Max. 9 dB over the entire length of the cable cross-section
Shielding	Copper braided shielding or combined foil and braided shielding

##### ■ Sakura V1

V1 fieldbus is a voltage mode digital communication using up to  $\pm 30$  VDC.

Cable capacitance	$\leq 50$ nF/m
Core cross-section	$\geq 0.9$ mm <sup>2</sup> (AWG 17) multi-strand cable is preferred
Cable type	Twisted pair
Cable resistance	$\leq 30$ $\Omega$ /km
Shielding	Copper braided shielding or combined foil and braided shielding
Insulation	$\geq 60$ V <sub>DC</sub>

##### ■ Whessoe WM550

The WM550 communication protocol works using a current loop principle.

##### Connection

Please take into consideration that the principle of current loop connection works as follows: The Tankvision (master) (-) signal point connects to slave 1 (+) signal point. Slave 1 (-) signal point connects to slave 2 (+) signal point until (the last) slave N (-) signal point connects back to the Tankvision (master) (+) signal point closing the current loop.

##### Cable specification

Please ensure to follow the following recommendations for field installation of the Tankvision with the WM550 protocol variant.

- Cable with twisted and non-shielded pairs
- Cable with at least 0.5 mm<sup>2</sup> (AWG 20) section
- Maximum total cable resistance: 250  $\Omega$
- Cable with low capacitance

	Cross section (mm <sup>2</sup> (AWG))	Resistance (Ω/km)	Capacitance (nF/km)
Cable 1	0.5 (20)	39.2	60
Cable 2	0.75 (18)	24.6	65
Cable 3	1.3 (16)	14.2	75

### 7.1.2 Field devices

The following list gives an overview on possible field instruments which can be connected directly or via system components. Nevertheless the connection possibilities are not limited to these devices.

#### ■ Proservo NMS5/7

The Proservo NMS5/7 intelligent tank gauges are designed for high accuracy liquid level measurement in storage and process applications. Tank mounted intelligence makes the Proservo NMS5 ideal for single or multi-task installation, converting a wide of measurement functions including beside others:

- Liquid level
- Interface level
- Spot density
- Density profile

Proservo NMS5/7 is beside others available with Modbus RTU RS485, Sakura V1, Whessoe WM550 output. For more information see TI00452G/08/EN.

#### ■ Tank Side Monitor NRF590

The Tank Side Monitor NRF590 is a sensor integration and monitoring unit for bulk storage tank gauging applications. It can be used with Micropilot radar or Proservo level gauges and can be combined with other HART compatible devices.

Connects up to 6 HART devices via intrinsic safe 2 wire, for example Prothermo for average temperature measurement and Cerabar/Deltabar for HTMS density applications. Various industry standard communication protocols, including

- Sakura V1
- EIA-485 Modbus
- Whessoe WM550

For more information see TI00402F/00/EN.

#### ■ Micropilot S FMR53x/FMR540

The Micropilot S is used for highly accurate level measurement in storage tanks and can be applied in custody transfer applications. It meets the relevant requirements according to OIML R85 and API 3.1B.

The Micropilot S is communicating via the industry standard protocol HART (Standard 5) and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor. For more information see TI00344F/00/EN and TI00412F/00/EN.

#### ■ Prothermo NMT539

The Prothermo NMT539 is based on API (American Petroleum Institute) Manual of Petroleum Measurement Standard, Chapter 7, and enables high accuracy temperature measurement. At the same time, it is an intelligent average temperature sensor for tank gauging with an optional WB capacitance sensor at the bottom of the temperature probe. For average temperature measurement, it consists of precision multi-spot Pt100 elements. The NMT539 is a highly capable solution that provides both constant average temperature data and water interface data via local HART<sup>®</sup> communication. For accurate inventory measurement, it is best suited connected to Endress+Hauser's Proservo NMS5/NMS7 or Tank Side Monitor NRF590 with level tank gauge (e.g. Micropilot). For more information see TI00042G/08/EN.

#### ■ Prothermo NMT532

The Prothermo NMT532 consists of an intelligent local HART<sup>®</sup> signal converter and average temperature sensor. For average temperature measurement, it consists of precision multi-spot Pt100 (max. 6) elements which have fixed interval (2 m (6.6 ft) or 3 m (9.8 ft)). The NMT532 is a highly capable solution for a variety of tank gauging applications and provides constant average temperature data via local HART<sup>®</sup> communication. For accurate inventory measurement, it is best suited connected to Tank Side Monitor NRF590 with level tank gauge (e.g. Micropilot) or NMS5 Proservo. For more information see TI00049G/08/EN.

- Micropilot M FMR2xx

The Micropilot M is used for continuous, non-contact level measurement of liquids, pastes, slurries and solids. The measurement is not affected by changing media, temperature changes.

- The FMR230 is especially suited for measurement in buffer and process tanks.
- The FMR231 has its strengths wherever high chemical compatibility is required.
- The FMR240 with the small 40 mm (1½") horn antenna is ideally suited for small vessels. Additionally, it provides an accuracy of ±3 mm (0.12 in).
- The FMR244 combines the advantages of the horn antenna with high chemical resistance. The 80 mm (3") horn antenna is used additionally in solids.
- The FMR245 - highly resistance up to 200 °C (392 °F) and easy to clean.

The Micropilot M is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or an HART to Modbus converter e.g. by Moore Industries. For more information see TI000345F/00/EN.

- Levelflex M FMP4x

Level Measurement - Continuous level measurement of powdery to granular bulk solids e.g. plastic granulate and liquids.

- Measurement independent of density or bulk weight, conductivity, dielectric constant, temperature and dust e.g. during pneumatic filling.
- Measurement is also possible in the event of foam or if the surface is very turbulent.

Interface measurement

Continuous measurement of interfaces between two liquids with very different dielectric constants, such as in the case of oil and water for example.

The Levelflex M is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or an HART to Modbus converter e.g. by Moore Industries. For more information see TI00358F/00/EN.

- Levelflex FMP5x

- FMP51

Premium device for level and interface measurement in liquids.

- FMP52

Premium device with coated probe for the use in aggressive liquids. Material of wetted parts FDA listed and USP Class VI compliant.

- FMP54

Premium device for high-temperature and high-pressure applications, mainly in liquids.

Levelflex is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or an HART to Modbus converter e.g. by Moore Industries. For more information see TI01001F/00/EN.

- Cerabar M

The Cerabar M pressure transmitter is used for the following measuring tasks:

- Absolute pressure and gauge pressure in gases, steams or liquids in all areas of process engineering and process measurement technology.
- High reference accuracy: up to ±0.15%, as PLATINUM version: ±0.075%

Cerabar M is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or Proservo.

For more information see TI000436P/00/EN.

- Cerabar S

The Cerabar S pressure transmitter is used for the following measuring tasks:

- Absolute pressure and gauge pressure in gases, steams or liquids in all areas of process engineering and process measurement technology.
- High reference accuracy: up to ±0.075%, as PLATINUM version: ±0.05%

Cerabar S is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or Proservo.

For more information see TI000383P/00/EN.

■ Deltabar M

The Deltabar M differential pressure transmitter is used for the following measuring tasks:

- Flow measurement (volume or mass flow) in conjunction with primary elements in gases, vapors and liquids
- Level, volume or mass measurement in liquids
- Differential pressure monitoring, e.g. of filters and pumps
- High reference accuracy: up to  $\pm 0.1\%$ , as PLATINUM version:  $\pm 0.075\%$

Deltabar M is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or Proservo.

For more information see TI000434P/00/EN.

■ Deltabar S

The Deltabar S differential pressure transmitter is used for the following measuring tasks:

- Flow measurement (volume or mass flow) in conjunction with primary devices in gases, vapors and liquids
- Level, volume or mass measurement in liquids
- Differential pressure monitoring, e.g. of filters and pumps
- High reference accuracy: up to  $\pm 0.075\%$ , as PLATINUM version:  $\pm 0.05\%$

Deltabar S is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or an HART to Modbus converter e.g. by Moore Industries. For more information see TI000382P/00/EN.

■ Liquicap M

The Liquicap M FMI5x compact transmitter is used for the continuous level measurement of liquids.

- Suitable for interface measurement

Liquicap M is communicating via the industry standard protocol HART and can be connected to the Tankvision Tank Scanner via the Tank Side Monitor or an HART to Modbus converter e.g. by Moore Industries. For more information see TI00401F/00/EN.

■ Whessoe ITGs

■ Sakura Endress Float&Tape Transmitter TMD

■ Sakura Endress TGM5000

■ Sakura Endress TGM4000

■ Modbus slave devices

As Modbus is an open protocol there are various system components available which can be connected to Tankvision Tank Scanner. To do so the so called gauge definition file and the Modbus map file need to be adapted to the needs. This is a standard procedure and described in BA00339G/00/EN. Examples for such devices are HART to Modbus converters, PLCs or other protocol converters e.g. Gauge Emulator by MHT.



Note!

Remote service access via the Endress+Hauser device configuration tool FieldCare is supported for the following device combination:

- Tankvision Tank Scanner with Modbus or Sakura V1 communication
- Tank Side Monitor Modbus or Sakura V1 communication and SW version 02.04.00 or later
- HART devices connected to Tank Side Monitor intrinsic safe HART bus and supporting FDT/DTM or
- Tankvision Tank Scanner with Modbus or Sakura V1 communication
- Proservo NMS5/7 (Modbus or Sakura V1 communication) with
  - TCB-6 version 4.27E
  - Graphical display operation module
  - Modbus communication module COM-5, version 2.0 or
  - V1 communication module COM-1 (SRAM-mounted), version 5.01
  - HART devices connected to Proservo cannot be reached by FieldCare



## **7.2 Host Systems communication**

To transfer and receive data to/from host system the communication variants OPC DA (version 2.05A) and Modbus RS232, Modbus RS485 and Modbus TCP are available.

### **7.2.1 OPC DA server**

See "Tankvision OPC Server", →  10.

For available parameters see A.1 Parameter list.

### **7.2.2 Modbus slave via Host Link NXA822**

See "Host Link NXA822", →  9.

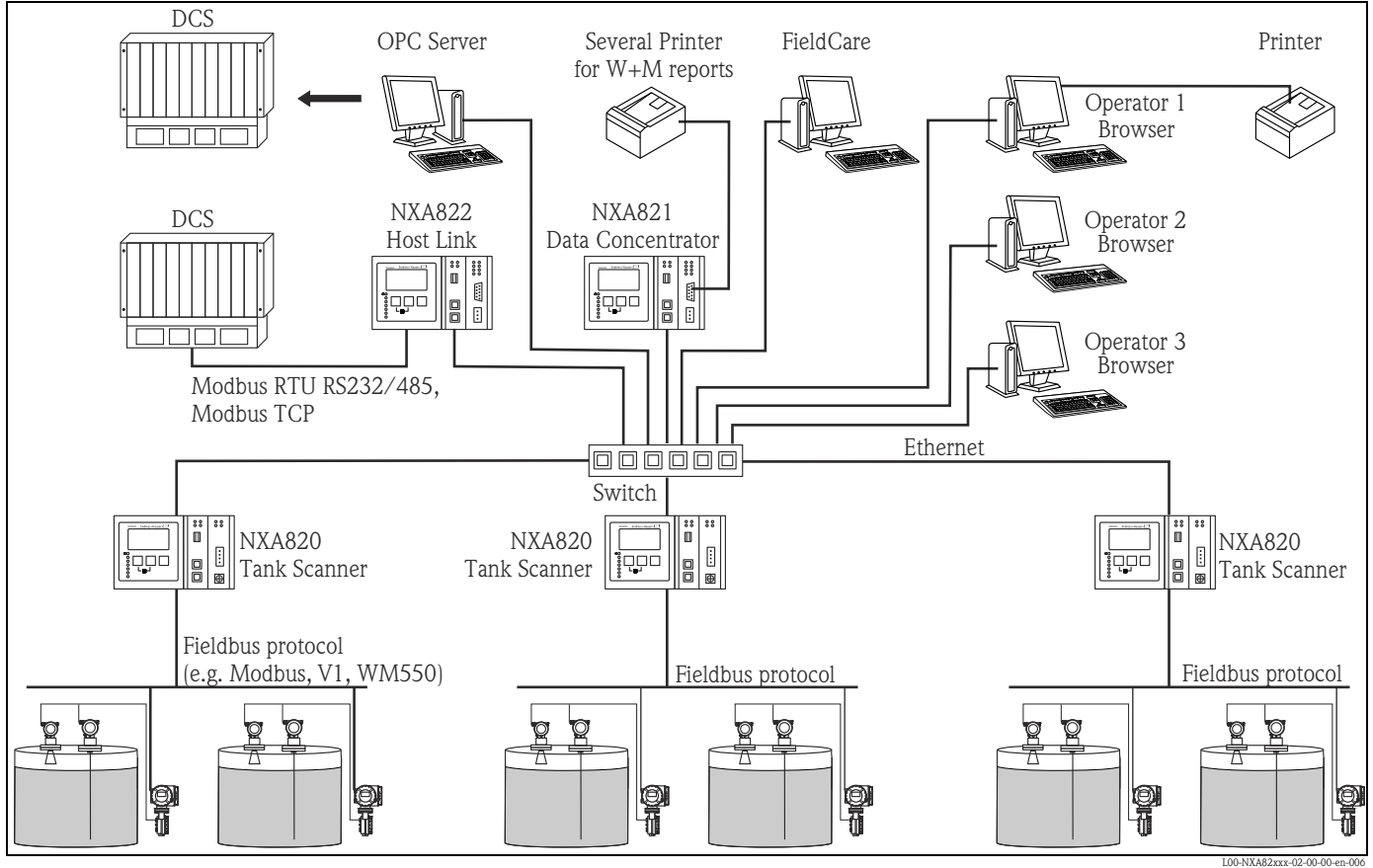
For available parameters see A.1 Parameter list.

### **7.2.3 Connection to Tankvision Professional**

To connect to Tankvision Professional a dedicated communication is available. In this case measured data are transferred as the calculations are performed in Tankvision Professional.

# 8 Examples

## 8.1 System architecture



## 8.2 Screen examples in Browser

The screenshot shows the 'People for Process Automation' software interface. The main window displays a table titled 'Customized Groups - All' with the following columns: Tank Name (N/A), Product (N/A), Product Level (N/A), Product Temperature (N/A), Observed Density (N/A), Pressure (N/A), TOV (N/A), and Vapour Pressure (N/A). The table lists data for 15 tanks, with Tank-10 Ammonia being the only one with a product. The interface includes a sidebar with navigation options like 'Offsite', 'Tanks(15)', 'Products(4)', and 'Customized Groups(1)'. At the bottom, there is an 'Alarm & Event' section with a table for event logs.

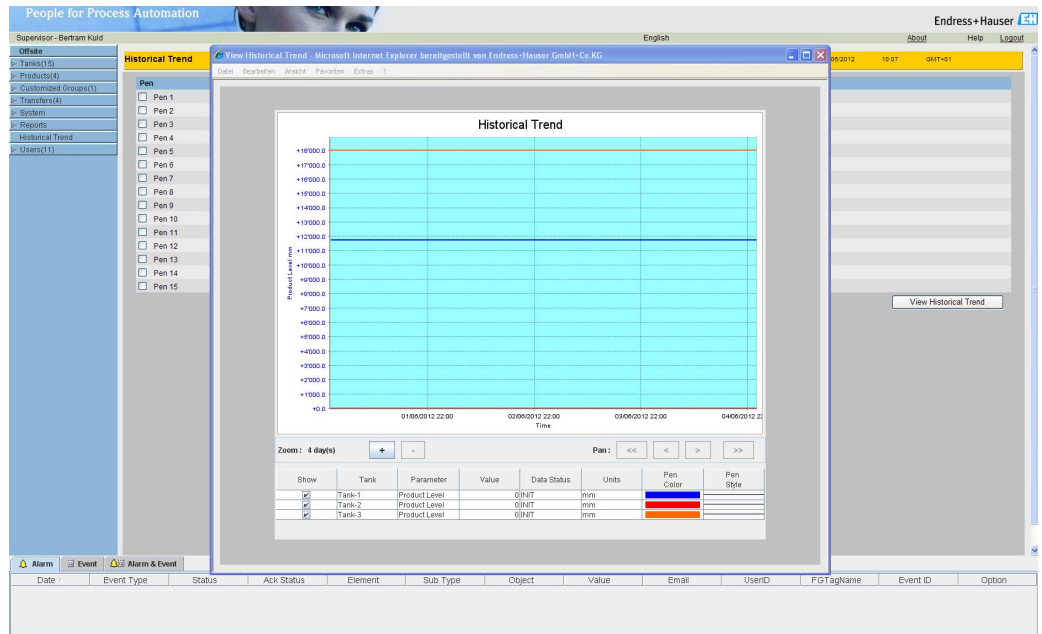
Tank Name (N/A)	Product (N/A)	Product Level (N/A)	Product Temperature (N/A)	Observed Density (N/A)	Pressure (N/A)	TOV (N/A)	Vapour Pressure (N/A)
Tank-1	Petrol	+11752	+18.6	+0.0	+0.01	+10363.423	+7.01
Tank-10 Ammonia	No Product	+16751	+18.6	+0.0	+0.00	+1575.100	+0.00
Tank-11	No Product	+14250	+18.6	+0.0	+0.00	+1425.000	+0.00
Tank-12	No Product	+14755	+18.6	+0.0	+0.00	+1475.500	+0.00
Tank-13	No Product	+14245	+18.6	+0.0	+0.00	+1424.500	+0.00
Tank-14	No Product	+15961	+18.6	+0.0	+0.00	+1596.100	+0.00
Tank-15	No Product	+16798	+18.6	+0.0	+0.00	+1679.800	+0.00
Tank-2	No Product	+18	+18.6	+0.0	+0.00	+1.800	+0.00
Tank-3	No Product	+18000	+18.6	+0.0	+0.00	+1800.000	+0.00
Tank-4	No Product	+14753	+18.6	+0.0	+0.00	+1475.300	+0.00
Tank-5	No Product	+11054	+18.6	+0.0	+0.00	+1105.400	+0.00
Tank-6	No Product	+4033	+18.6	+0.0	+0.00	+403.300	+0.00
Tank-7	No Product	+3215	+18.6	+0.0	+0.00	+321.500	+0.00
Tank-8	No Product	+12099	+18.6	+0.0	+0.00	+1209.900	+0.00
Tank-9	No Product	+5340	+18.6	+0.0	+0.00	+534.000	+0.00

Tank tabular view

The screenshot shows the 'People for Process Automation' software interface with a detailed view for 'Tank-1 - Petrol'. The main window displays various data points for the tank, including 'Measured Values', 'Calculated Values', and 'Configuration Data'. A 'Tank Display and Alarm Set Point' section includes a 3D diagram of the tank with level indicators (HH, HA, LA, LL). The interface includes a sidebar with navigation options like 'Offsite', 'Tanks(15)', 'Products(4)', and 'Customized Groups(1)'. At the bottom, there is an 'Alarm & Event' section with a table for event logs.

Item	Value	Unit
Product Level	INIT	+11752 mm
Secondary Level	INIT	21650012 11:38
Product Temperature	INIT	+18.6 °C
Water Level	INIT	+0 mm
GP Register 01	INIT	+0 No Unit
GP Register 02	INIT	+0 No Unit
Total Observed Volume	INIT	+107363.423 m³
Gross Observed Volume	INIT	+107363.423 m³
Free Water Volume	OK	+0.000 m³

Tank details



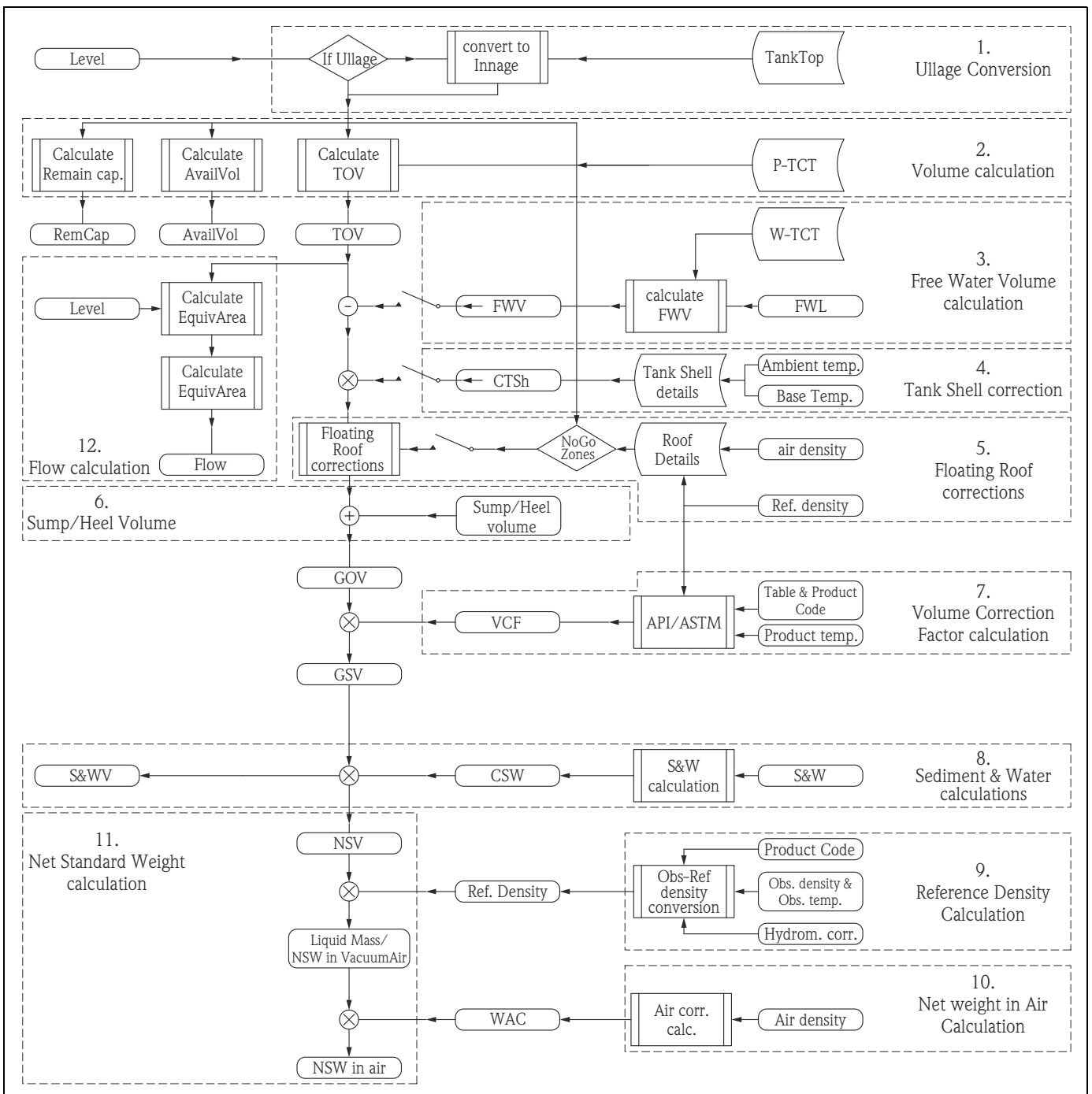
Trend view

## 9 Calculations

Tankvision Tank Scanner can perform various kinds of calculations which are described in the following chapters. The inventory calculations allow the conversion from measured data like level and temperature to standard data (e.g. Net standard volume or mass). There are various standards for these calculations available differing in the sequence of the calculation or the way compensation factors are determined (from tables or formula). Today calculations from API (see Text → 22) and GB/T (see Text → 22) are implemented in Tankvision Tank Scanner.

### 9.1 API Flow Charts

The chart shows the sequence calculations are done according to the API. The different steps are explained in the following chapters.



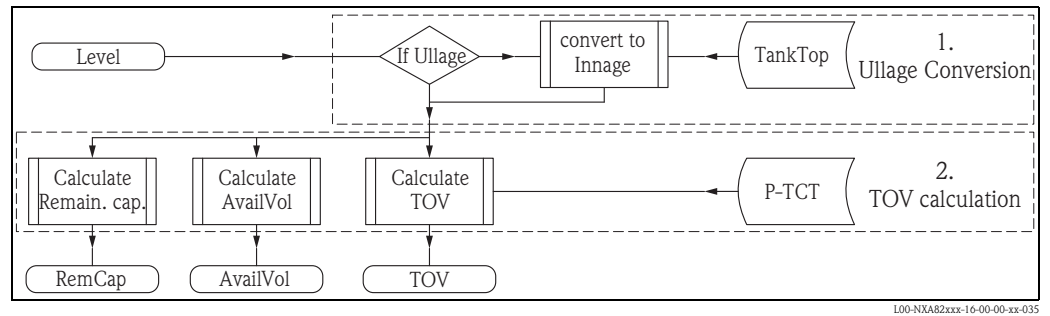
**API (American Petroleum Institute)**

The American Petroleum Institute, commonly referred to as API, is the largest U.S trade association for the oil and natural gas industry. It claims to represent about 400 corporations involved in production, refinement, distribution and many other aspects of the petroleum industry. The association's chief functions on behalf of the industry include advocacy and negotiation with governmental, legal and regulatory agencies; research into economic, toxicological and environmental effects; establishment and certification of industry standards; and education outreach. API both funds and conducts research related to many aspects of the petroleum industry.

**GB (Chinese national standards)**

GB standards are the Chinese national standards issued by the Standardization Administration of China (SAC), the Chinese National Committee of the ISO and IEC. GB stand for Guobiao, Chinese for national standard. Mandatory standards are prefixed "GB". Recommended standards are prefixed "GB/T". A standard number follows "GB" or "GB/T".

### 9.1.1 Total Observed Volume - TOV



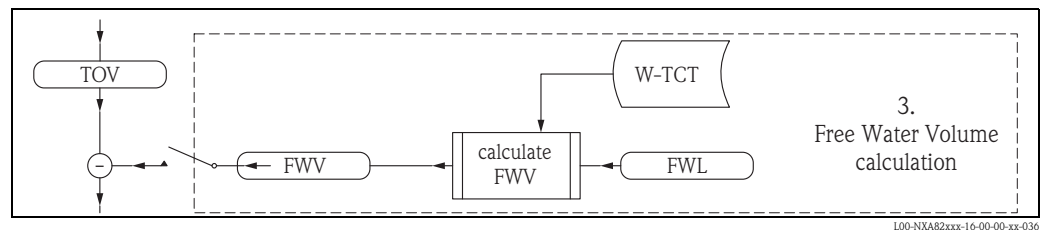
The Total Observed Volume (TOV) is determined with the level information and the Tank Capacity Table (TCT). The TOV is the volume observed at the present (temperature) conditions. The TCT is a tank specific table created by calibration holding the level to volume transfer information. To differentiate the TCT for the Product and for the Water the TCT gets marked with a P (P-TCT).

The level information needed for this step is in innage which is the normal way the level is transferred from the gauge. In case the gauge inputs ullage to the system a calculation into innage is necessary beforehand (Ullage subtracted from Mounting position).

Two more information can be derived from TCT and level:

- Remaining Capacity (RemCap) shows how much more product could be pumped into the tank safely.
- Available Volume (AvailVol) indicates how much product can be pumped out of the tank to the lowest (defined) possible point e.g. the tank outlet.

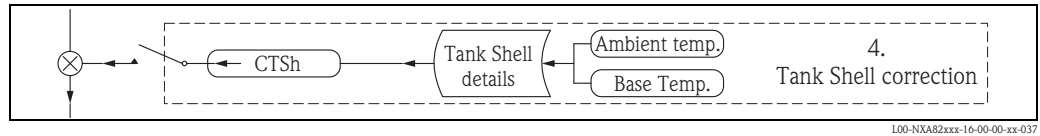
### 9.1.2 Free Water Volume - FWV



In some cases the tank can also contain water. It can derive from the delivered crude oil, the processing or by tank breathing. The (innage) water level information together with a Water Tank Capacity Table (W-TCT) result in the Free Water Volume. It is subtracted from the TOV.

### 9.1.3 Tank Shell Correction - CTSh

- The Tank Shell expands and contracts with temperature changes (compared to TCT calibration temperature)
- Some countries require CTSh (Correction for Tank Shell temperature effects)
- For heated products the CTSh can be in excess of 0.3% TOV

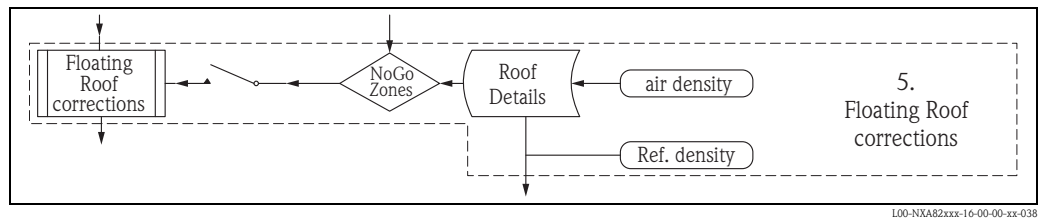


Note!

For more details see → 45, Chapter "CTSh".

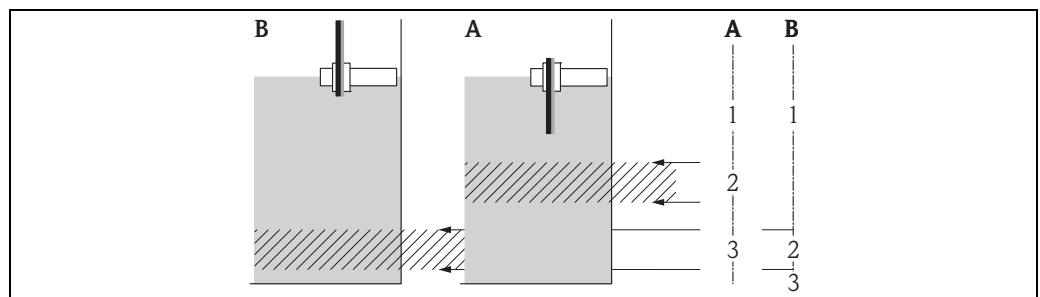
The Tank Shell Correction is a factor which is multiplied with the TOV reduced by the FWV.

### 9.1.4 Floating Roof Correction - FRC

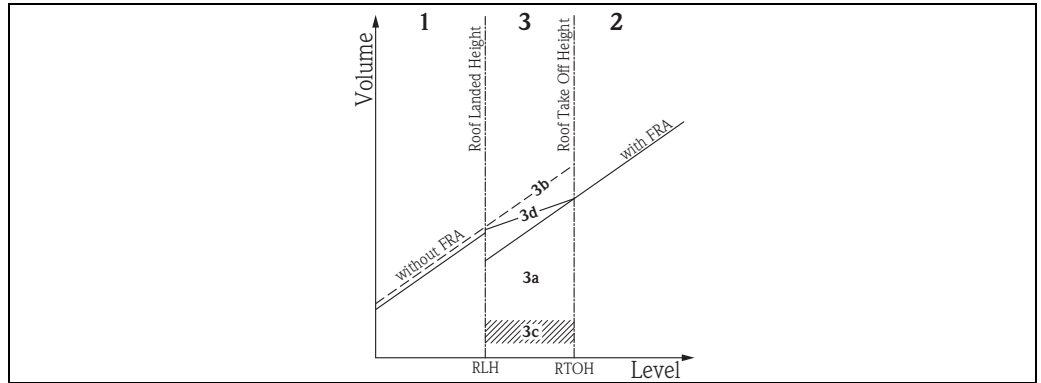


A tank can often have a floating roof. A floating roof is called so because it floats on the product stored in the tank. The roof moves up or down along with product level. Since the roof is floating on the tank, it displaces some amount of product depending on the weight of the roof and the density of the product. This displacement in product level results in a different apparent level, introducing an error into the volume calculations. The product volume therefore needs to be corrected.

A floating roof often has supporting legs. The roof can be rested on these legs when the level is too low or the tank is empty. This allows maintenance staff to enter below the roof for carrying on tank maintenance. Based on the product level, the floating roof can be landed on the legs or floating on the product. However, in a certain range of product level, the floating roof can be partially landed. This zone is called "critical zone". In the Tankvision system there can be two critical zones related to the position of the floating roof legs.







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Inside critical zone:

- 3a Apply full FRA
- 3b Do not Apply FRA
- 3c Do not calculate FRA
- 3d Use partial FRA (interpolate)

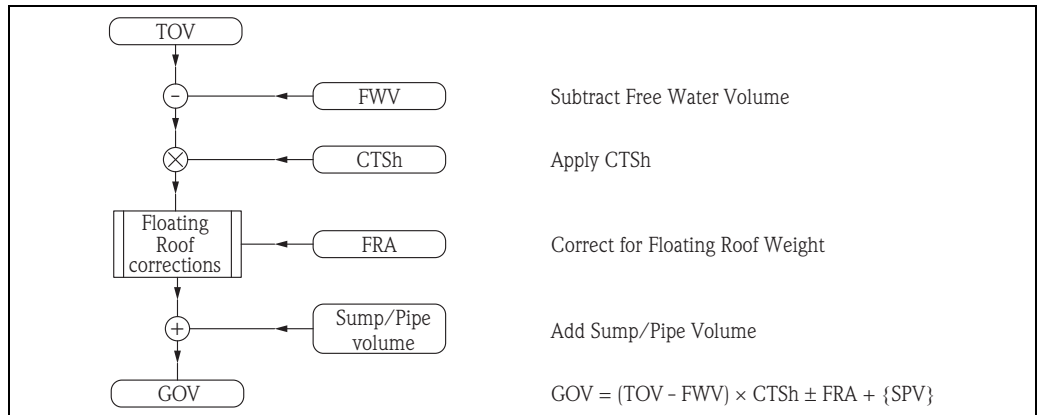


Note!  
Floating roofs can already be considered in the TCT.

### 9.1.5 Sump/Heel/Pipe volume

Volume of the Sump and Pipes are added.

### 9.1.6 Gross Observed Volume - GOV



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### 9.1.7 Volume Correction Factor - VCF

The VCF corrects for the temperature expansion of the liquid. Especially hydrocarbons have a large expansion factor. The most common VCF corrections were developed by American Society for Testing and Materials (ASTM), USA and Institute of Petroleum, UK and updated regularly. There are more authorities issuing VCF corrections. Most of them are derived from the ASTM/IP tables.

#### VCF Implementation

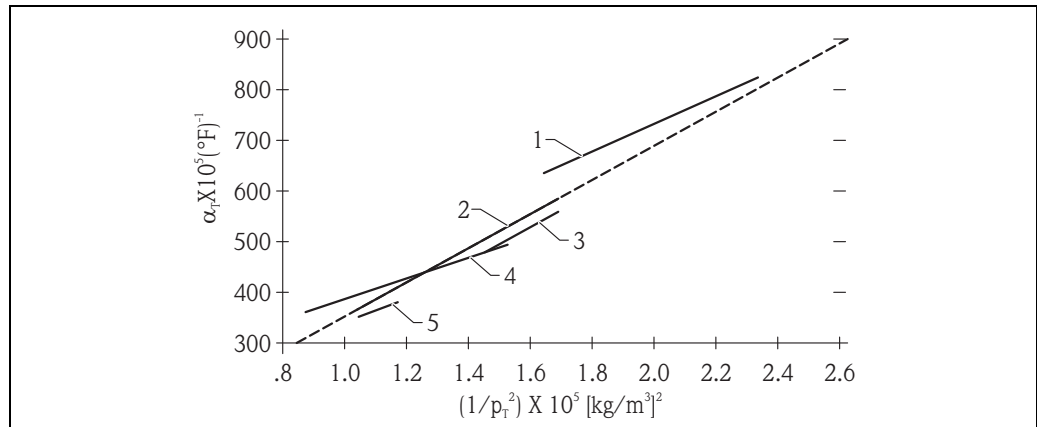
- Calculations are based on "representative samples" ("generalized products")

$$VCF = e^{-\alpha_{60}\Delta t(1.0+0.8\alpha_{60}\Delta t)}$$

- The "Tables" are based on specific calculation procedures

$$\alpha_{60} = \frac{K_0 + K_1 p + K_2 p^2}{p^2} = \frac{K_0}{p^2} + \frac{K_1}{p} + K_2$$

- Calculation is complex and rounding and truncating unique. There are many small but significant differences - exact requirements and needs depend on application, country and company.



- 1 Gasolines
- 2 Crudes
- 3 Jets
- 4 Fuel oils
- 5 Lube oils

#### VCF Tables

- The formulas are too complex for direct use - hence the "Tables" were printed
- There are specific tables for:
  - Products (crudes, refined products, lube oils, alcohols, palm oil, chemicals, etc.)
  - Different measurement units (kg/m<sup>3</sup> vs. °API, °C vs. °F, etc.)
  - Different "Reference" or standard temperature (60 °F, vs. 15 °C, 25 °C or 30 °C)
  - Each table has range limits
  - Tables for VCF and for density correction are available

**Most known VCF "Tables"**

The Tables are normally grouped in pairs:

- Tables 5 and 6 - ODC resp. VCF °API at 60 °F
- Tables 53 and 54 - ODC resp. VCF kg/m<sup>3</sup> at 15 °C
- Tables 24 and 25 - ODC resp. VCF RD 60/60 °F at 60 °F
- Tables 50 and 60 - ODC resp. VCF kg/m<sup>3</sup> at 20 °C

Most tables have so called Product Codes:

- A = for generalized crude's
- B = for refined products
- C = for chemicals
- D = for lube oils
- E = liquefied gases

For chemicals normally a "polynomial equation" is used.

**Typical table example: 54B (1980)**

The range of application:

Density, kg/m <sup>3</sup>	Temperature, °C
653.0 to 778.5	-18.0 to 90.0
779.0 to 824.0	-18.0 to 125.0
824.5 to 1075.0	-18.0 to 150.0

$$VCF = \text{EXP} [-\alpha_{15}\Delta t(1.0+0.8\alpha_{15}\Delta t)]$$

where:  $\Delta t = \text{DEGC} - 15.0$

$$\alpha_{15} = \frac{K_0}{p_{15}^2} + \frac{K_1}{p_{15}}$$

$$K_0 = 346.4228$$

$$K_1 = 0.4388$$

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**Special corrections**

*VCF Chemical 1*

$$VCF = \{D_{\text{Ref}} - A \times 10E3 \times (T_{\text{Obs}} - T_{\text{Ref}}) - B \times 10E3 \times (T_{\text{Obs}} - T_{\text{Ref}})^2 - C \times 10E3 \times (T_{\text{Obs}} - T_{\text{Ref}})^3 - D \times 10E3 \times (T_{\text{Obs}} - T_{\text{Ref}})^4 - E \times 10E3 \times (T_{\text{Obs}} - T_{\text{Ref}})^5\} / D_{\text{Ref}}$$

100-NXA82xxx-16-00-00-xx-049

with:

- $D_{\text{Ref}}$  = Reference density
- $T_{\text{Obs}}$  = Actual or observed temperature
- $T_{\text{Ref}}$  = Reference Temperature
- A-E = Configurable coefficients

*TCF Method*

$$TCF = K_0 + K_1 \times \Delta t + K_2 \times \Delta t^2 + K_3 \times \Delta t^3 + K_4 \times \Delta t^4$$

$$\Delta t = t - T_{\text{Ref}}$$

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with:

- $K_0, K_1, K_2, K_3, K_4$  = Customer coefficients
- $t$  = Actual product temperature
- $T_{\text{Ref}}$  = Reference Temperature

For the VCF we can write:

$$TCF = 1 - TCF \times (T_{\text{Obs}} - T_{\text{Ref}})$$

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Note!

With the TCF method the  $p_{\text{Ref}}$  can be calculated with  $p_{\text{Obs}} / VCF$  (when manual  $p_{\text{Obs}}$  is provided) and an actual  $p_{\text{Obs}}$  can be calculated with  $p_{\text{Ref}} \times VCF$ , when  $p_{\text{Ref}}$  is known and no actual  $p_{\text{Obs}}$  is available.

*Palm oil*

$$D_{Obs} = K_0 + K_1 \times T_{Obs} + K_2 \times (T_{Obs})^2 + K_3 \times (T_{Obs})^3 + K_4 \times (T_{Obs})^4$$

$$D_{ref} = K_0 + K_1 \times T_{ref} + K_2 \times (T_{ref})^2 + K_3 \times (T_{ref})^3 + K_4 \times (T_{ref})^4$$

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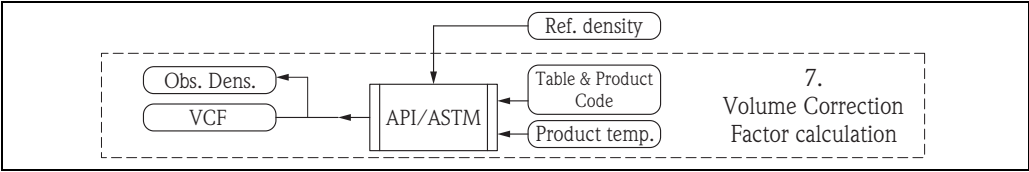
For the VCF we can easily derive:  $VCF = D_{Obs} / D_{ref}$

$$VCF = \frac{K_0 + K_1 \times T_{Obs} + K_2 \times (T_{Obs})^2 + K_3 \times (T_{Obs})^3 + K_4 \times (T_{Obs})^4}{K_0 + K_1 \times T_{ref} + K_2 \times (T_{ref})^2 + K_3 \times (T_{ref})^3 + K_4 \times (T_{ref})^4}$$

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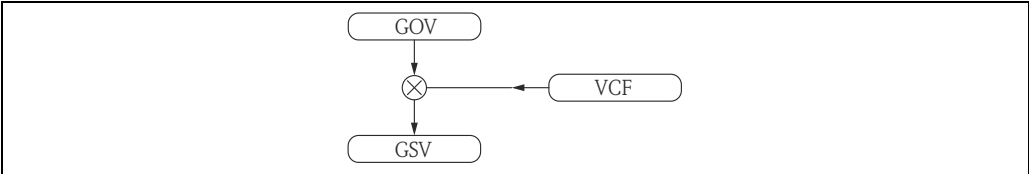
**VCF Calculation**

- The API/ASTM Tables are a "primary" need for any Tank Inventory system



The correct table for the product must be chosen. Together with the Product temperature and reference density the VCF can be calculated. In addition to the VCF the observed density can be calculated.

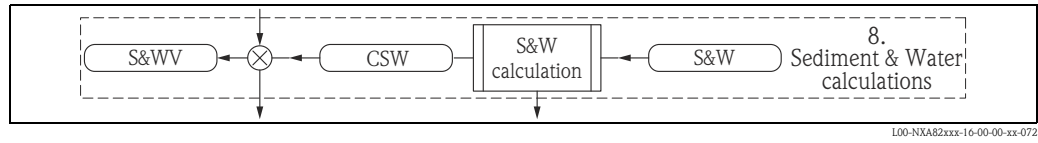
**9.1.8 Gross Standard Volume - GSV**



100-NXA82xxx-16-00-00-xx-048

The Gross Standard Volume is calculated by applying the VCF to the GOV.

### 9.1.9 Sediment & Water - S&W



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- Some products have entrained (suspended) sediment and water (S&W)
  - i.e. crude's
- S&W is determined from sample by laboratory method ("Karl-Fisher"-method). The Sediment and Water percentage (S&W%) determined with the sample is transferred in the Sediment and Water Fraction (SWF). A correction factor for the product is determined.

As second result the Sediment and Water Volume can be calculated.

#### Sediment & Water calculation methods

There are 6 methods to calculate S&W

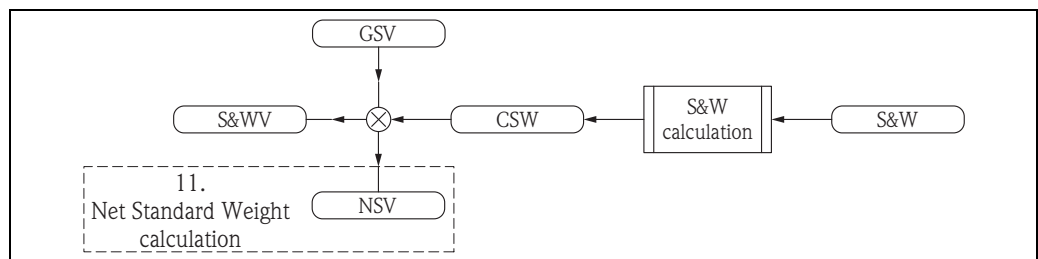
1.  $SWV = 0$
2.  $SWV = TOV \times SWF$
3.  $SWV = (TOV - FWV) \times SWF$
4.  $SWV = \{(TOV - FWV) \times CTSh\} \times SWF$
5.  $SWV = GOV \times SWF$
6.  $SWV = GSV \times SWF$  ("standard" or "default" method)

Where the sediment and water fraction (SWF) is:

$$SWF = 1 - (100 - S\&W\%) / 100 = S\&W\% / 100$$

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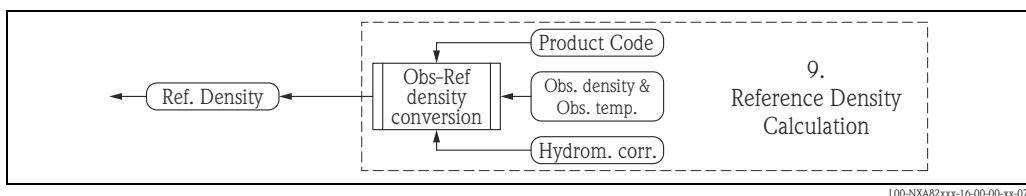
### 9.1.10 Net Standard Volume - NSV



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Subtracting the SWV from the GSV result in Net Standard Volume.

### 9.1.11 Density calculations



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We have to distinguish between: observed and reference density

- Observed density is the density of the product at actual (observed) temperature
- Reference density is the density the product would have if we heat/cool it until the reference temperature (usually 15 °C/60 °F)
- Reference density is used to calculate VCF, FR and mass
- If you know the RefDens you can easily get the ObsDens  
ObsDens = RefDens x VCF
- If you know the ObsDens you need (API/ATSM) tables and the sample temperature to get the RDC (reference density correction factor).
- You can also correct for the thermal expansion of the hydrometer glass (HYC)  
RefDens = RDC x ObsDens x HYC

#### Hydrometer Correction - HYC

$$HYC = 1.0 - A_{HYC} \times (t - T_{Cal}) - B_{HYC} \times (t - T_{Cal})^2$$

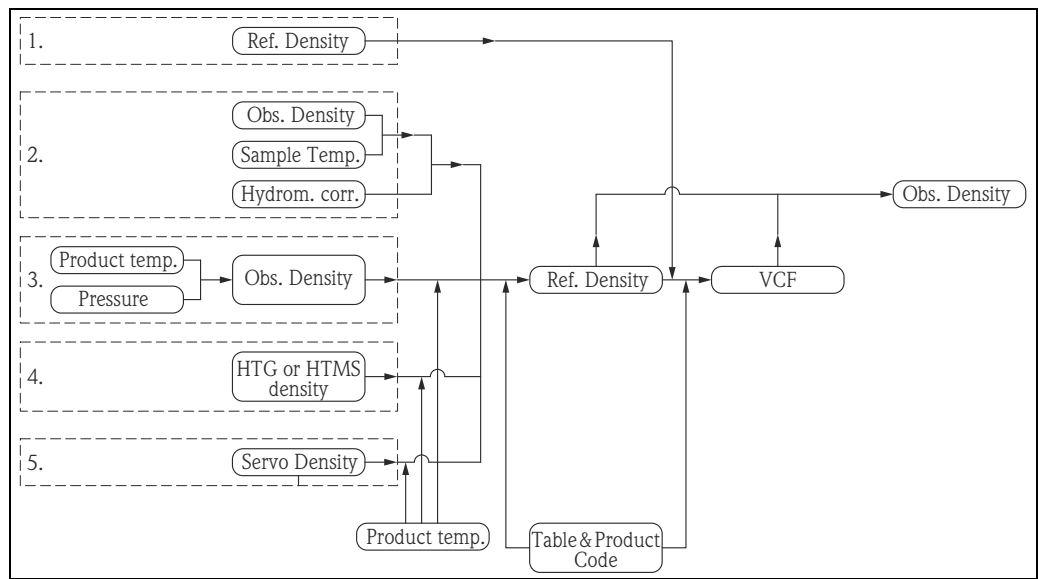
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with:

- HYC = Hydrometer correction
- $A_{HYC}$ ,  $B_{HYC}$  = Thermal expansion coeff. for glass
- $t$  = Temperature of sample
- $T_{Cal}$  = Calibration temperature of glass hydrometer

$T_{Cal}$	$A_{HYC}$	$B_{HYC}$
15 °C	0.000 0230 0	0.000 000 020
60 °F	0.000 0127 8	0.000 000 062

### Density handling in NXA820



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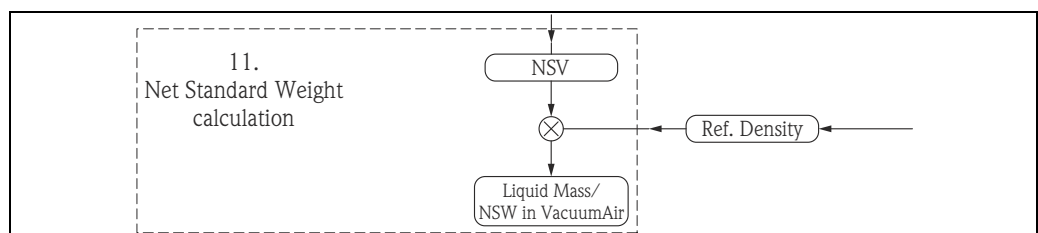
NXA820 offers various possibilities to enter and further process density information:

1. Manual entry of Reference density (from laboratory)
2. Manual entry of Observed density with the according sample temperature (from laboratory) is required corrected for the hydrometer. With the above information and the according Product information and ASTM/IP table (for density correction) the reference density can be calculated.
3. Product pressure, temperature, density table (PTD table): look up table for observed density with the use of measured product temperature and pressure. With the from the table derived Observed density, the product temperature and the according Product information and ASTM/IP table (for density correction) the reference density can be calculated.
4. Density from HTG or HTMS calculation (→ 40). With the from the calculations derived Observed density, the product temperature and the according Product information and ASTM/IP table (for density correction) the reference density can be calculated.
5. Density measured by Servo gauge. With the by the servo gauge measured Observed density, the product temperature and the according Product information and ASTM/IP table (for density correction) the reference density can be calculated.

Having the reference density and the according Product information and ASTM/IP table (for volume correction) the VCF can be determined.

Observed density can be calculated by multiplying reference density with VCF.

### 9.1.12 Mass/Net Weight in Vacuum

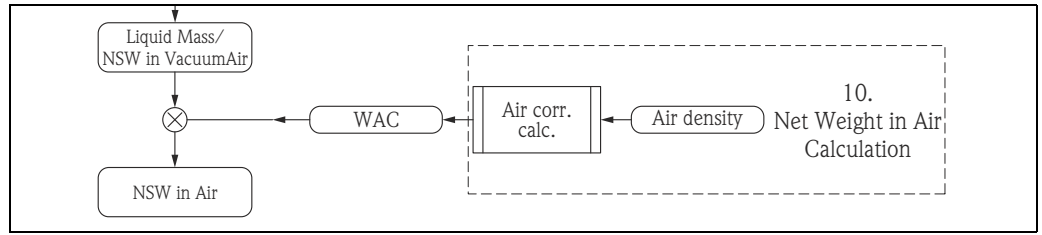


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- Mass in temperature and product property independent
- Mass is needed for "Loss Reconciliation" required for every refinery and terminal
- Mass is calculated out of NSV and the reference density (or GOV and observed density)



### 9.1.13 Net Weight in Air - NWA



L00-NXA82xxx-16-00-00-xx-075

- The flotation of a body is based on the principle discovered by Archimedes on century 3 BC  
"Every submerged body in a liquid experience a vertical upper force that is equal to the weight of the liquid displaced"
- Considering the liquid displaced is air
- The flotation is related to the liquid density where the body is floating because:  
Weight = Vol x Dens.

Calculation formula:

$$WAC = \frac{1 - \left(\frac{Dens_{Air}}{Dens_{Ref}}\right)}{1 - \left(\frac{Dens_{Vap}}{Dens_{Brass}}\right)}$$

$$NWA = WAC \times Mass$$

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*Dens<sub>Air</sub>* Air density  
*Dens<sub>Ref</sub>* Product reference density  
*Dens<sub>Vap</sub>* Vapor density  
*Dens<sub>Brass</sub>* Brass density used to calibrate the weight scale

#### Net weight in Air methods

WAC Methods	Calculated	AirDen	VapDen	BrassDen
Weight in vacuum	No	0	0	0
OIML R85	Yes	1.2	1.2	8000
Table 56	Yes	1.22	1.22	8100
Table 57 (short tons)	Yes≈	1.2194	1.2194	8393.437
Table 57 (long tons)	Yes	1.224	1.224	8135.8
Simplified	Yes	1.1	0	1
Custom	Yes	1.225	1.225	8553

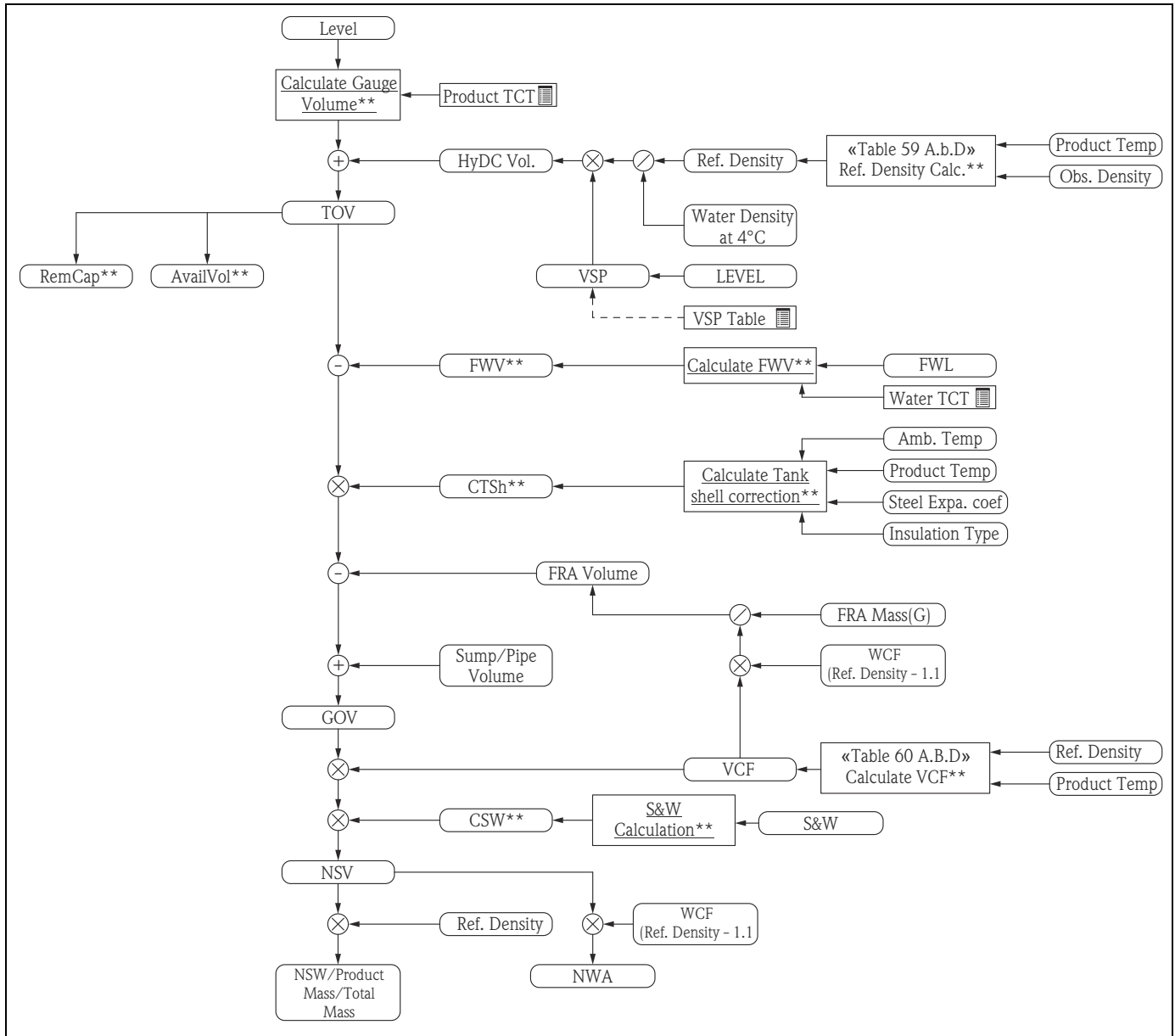


Note!  
The Net Standard Weight in Air is in some countries called Mass.

## 9.2 GBT calculation flow chart

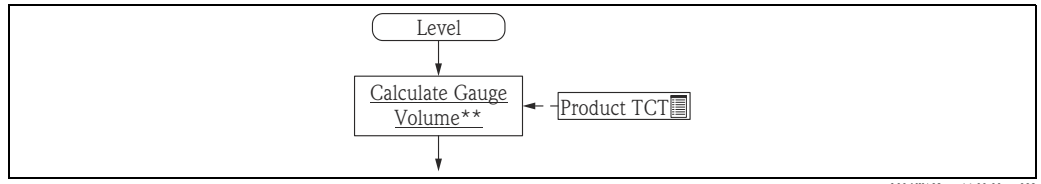
The GBT standard is the standard for China.

Main difference is the hydrostatic deformation of the tank not being part of the product TCT but in a separate table. The VCF and density calculations are based on the same ASTM/IP tables like the API calculations.



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### 9.2.1 Calculated Gauge Volume



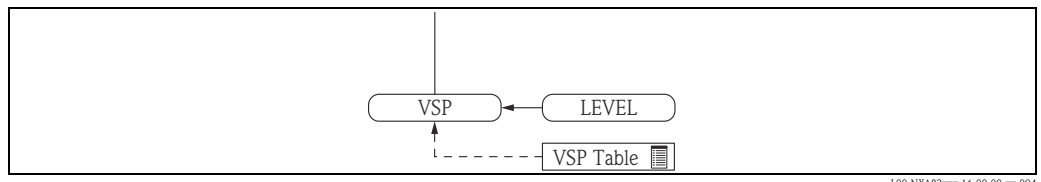
L00-NXA82xxx-16-00-00-xx-093

The Calculated Gauge Volume is determined with the level information and the Tank Capacity Table (TCT). The Calculated Gauge Volume is the volume observed at the present (temperature) conditions without considering the hydrostatic deformation of the tank.

The TCT is a tank specific table created by calibration holding the level to volume transfer information. To differentiate the TCT for the Product and for the Water the TCT gets marked with a P (P-TCT).

The level information needed for this step is in innage which is the normal way the level is transferred from the gauge. In case the gauge inputs ullage to the system a calculation into innage is necessary beforehand (Ullage subtracted from Mounting position).

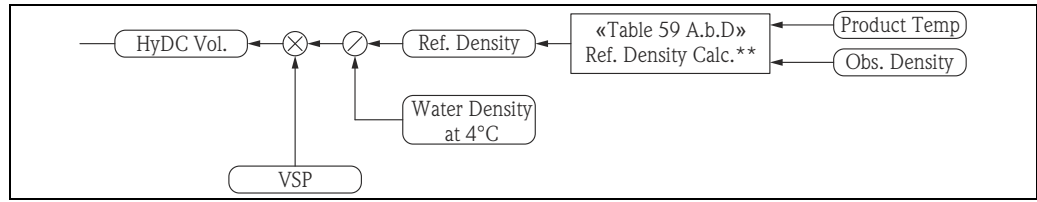
### 9.2.2 Static Pressure Correction Volume - VSP



L00-NXA82xxx-16-00-00-xx-094

The VSP is determined with the level information and the static pressure correction table (VSP-table). The VSP is the volume the tank expands at the actual level if it would be filled with water (wet calibration).

### 9.2.3 Hydrostatic Deformation Correction Volume - HyDC Vol



L00-NXA82xxx-16-00-00-xx-095

The Hydrostatic Deformation Correction Volume is the real from the product fill level created hydrostatic volume.

It is calculated by correcting the VSP with the ratio of the density of the product versus the water density.

$$HyDC = [Vsp \times \rho_r]$$

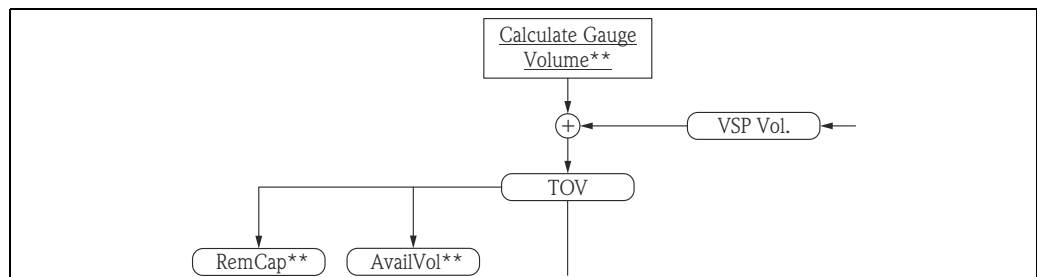
$$\rho_r = [\rho_{20} / \rho_{w4}]$$

$\rho_{20}$  Reference Density at 20 °C (68 °F)

$\rho_{w4}$  Water Density at 4 °C (39 °F)

The reference density of the Product can be calculated (if not known) with the Observed Density, the Product/Sample Temperature and the Reference Density Table for the Product.

### 9.2.4 Total Observed Volume - TOV



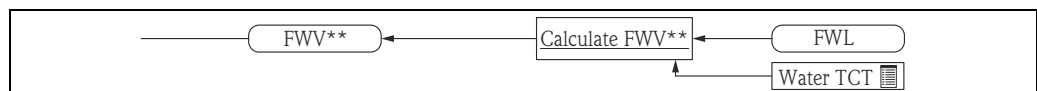
L00-NXA82xxx-16-00-00-xx-097

The Total Observed Volume is calculated from the Calculated Gauge Volume and the Hydrostatic Deformation Correction Volume.

Two more information can be derived from TCT and level:

- Remaining Capacity (RemCap) shows how much more product could be pumped into the tank safely
- Available Volume (AvailVol) indicates how much product could be pumped out of the tank to the lowest (defined) possible point e.g. the tank outlet.

### 9.2.5 Free Water Volume - FWV

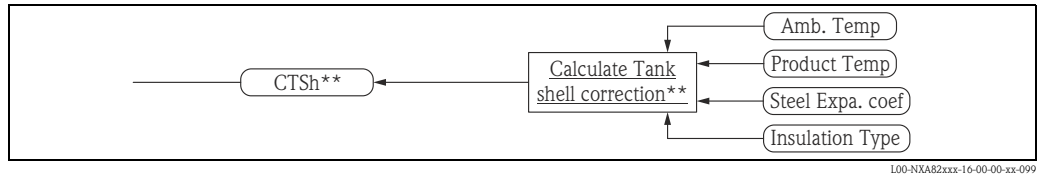


L00-NXA82xxx-16-00-00-xx-098

In some cases the tank can also contain water. It can derive from the delivered crude oil, the processing or by tank breating.

The (innage) water level information together with a Water Tank Capacity Table (W-TCT) result in the Free Water Volume. It is subtracted from the TOV.

### 9.2.6 Correction for the thermal Expansion of the tank shell - CTSh



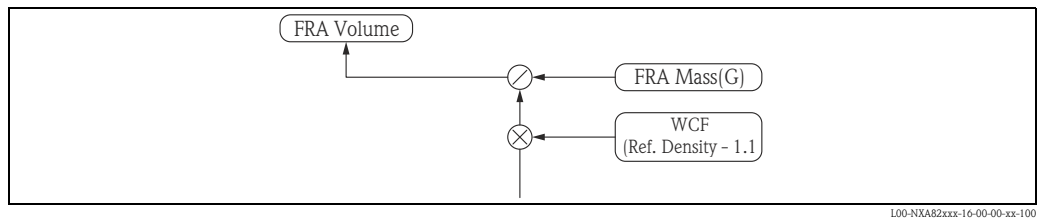
- The Tank Shell expands and contracts with temperature changes (compared to TCT calibration temperature)
- Some countries require CTSh (Correction for Tank Shell temperature effects)



Note!

For more details see → 45, Chapter "CTSh".

### 9.2.7 Floating roof adjustment - FRA



Note!

Additional displacement due to the air is considered, see Net Weight in Air calculation.

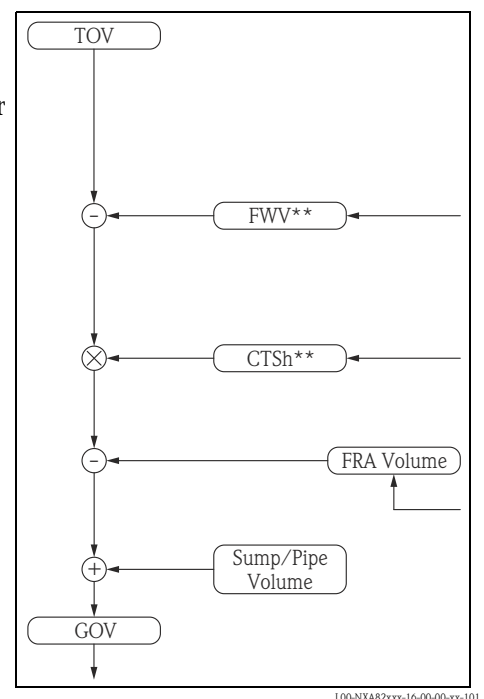
### 9.2.8 Sump/pipe volume

The Volume of the sump and pipes is added.

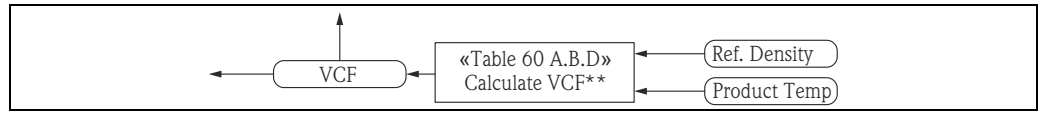
### 9.2.9 Gross Observed Volume - GOV

GOV is calculated like follows:

- Starting from the TOV
- Subtract FWV
- Multiply by the thermal expansion correction factor
- Subtract the floating roof adjustment volume and
- Add the Sump/pipe volume

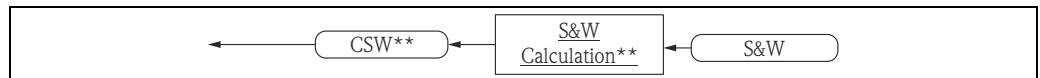


### 9.2.10 Volume Correction Factor - VCF



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### 9.2.11 Sediment and Water



L00-NXA82xxx-16-00-00-xx-103

- Some products have entrained (suspended) sediment and water (S&W)
  - i.e. crude's
- S&W is determined from sample by laboratory method ("Karl-Fisher"-method). The Sediment and Water percentage (S&W%) determined with the sample is transferred in the Sediment and Water Fraction (SWF). A correction factor for the product is determined.

As second result the Sediment and Water Volume can be calculated.

#### Sediment & Water calculation methods

There are 6 methods to calculate S&W

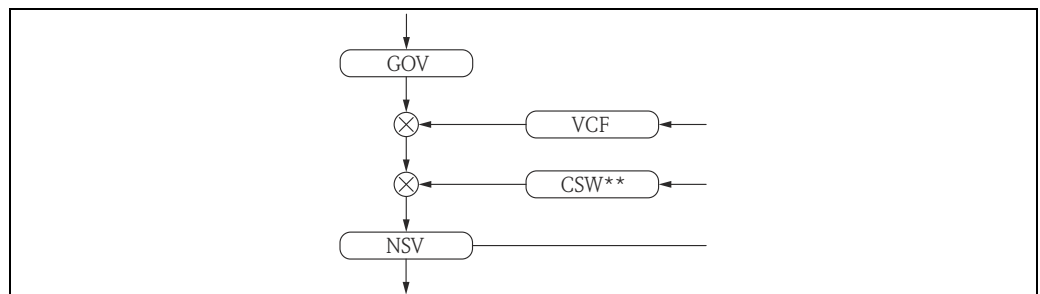
1. SWV = 0
2. SWV = TOV x SWF
3. SWV = (TOV - FWV) x SWF
4. SWV = ((TOV - FWV) x CTSh) x SWF
5. SWV = GOV x SWF
6. SWV = GSV x SWF ("standard" or "default" method)

Where the sediment and water fraction (SWF) is:

$$SWF = 1 - (100 - S\&W\%) / 100 = S\&W\% / 100$$

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### 9.2.12 Net Standard Volume - NSV

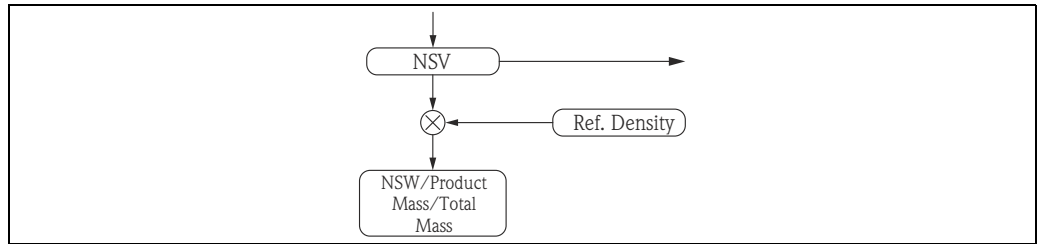


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Net Standard Volume is calculated like follows:

- Starting from GOV
- Multiply by the Volume Correction Factor and
- Multiply by the S&W correction factor

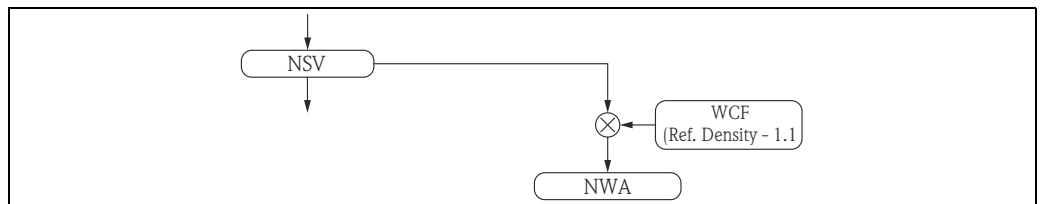
### 9.2.13 Net Standard Weight - NSW / Product Mass



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Mass is calculated by multiplying NSW with the Reference density.

### 9.2.14 Net Standard Weight in air - NWA



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The Net Standard Weight in Air is calculated by multiplying the NSW with the Reference Density reduced by the influence of the Air buoyancy (Reference density - 1.1).

## 9.3 Mass Measurement

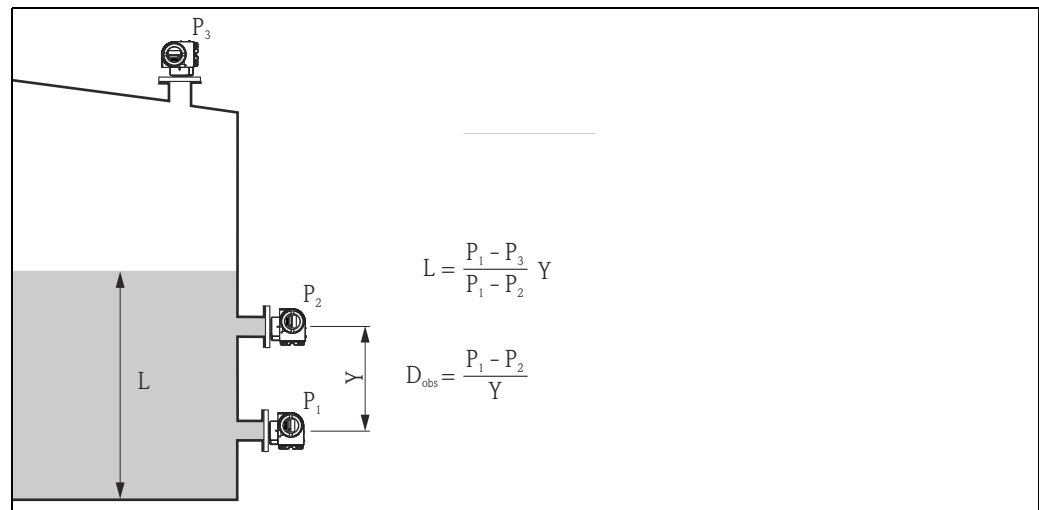
Today, most hydrocarbons in the western world are bought and sold using volume measurement. However, in many eastern countries and in some specialised industries, product are sold based on mass due to traditions in particular markets, so mass calculation can be important in those areas of trade. Mass-based measurement offers other advantages, since mass is independent of product temperature and other parameters.

For custody transfer, high accuracy tank gauging is required, and mass-based calculation is often used.

### 9.3.1 Hydrostatic Tank Gauging

The advantage of HTG is that it provides direct mass measurement with only pressure transmitters to measure hydrostatic pressure in determining density via a fixed distance and vapour pressure. Therefore, it is a low-cost solution for mass measurement. However, there are substantial disadvantages:

- Level and volume measurements are less accurate, especially when density stratification occurs.
- Density is only measured at the between the two pressure sensors.
- Difficult to verify, commission and calibrate



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Note!

The middle or  $P_2$  transmitter is unique to Hydrostatic Tank Gauging.

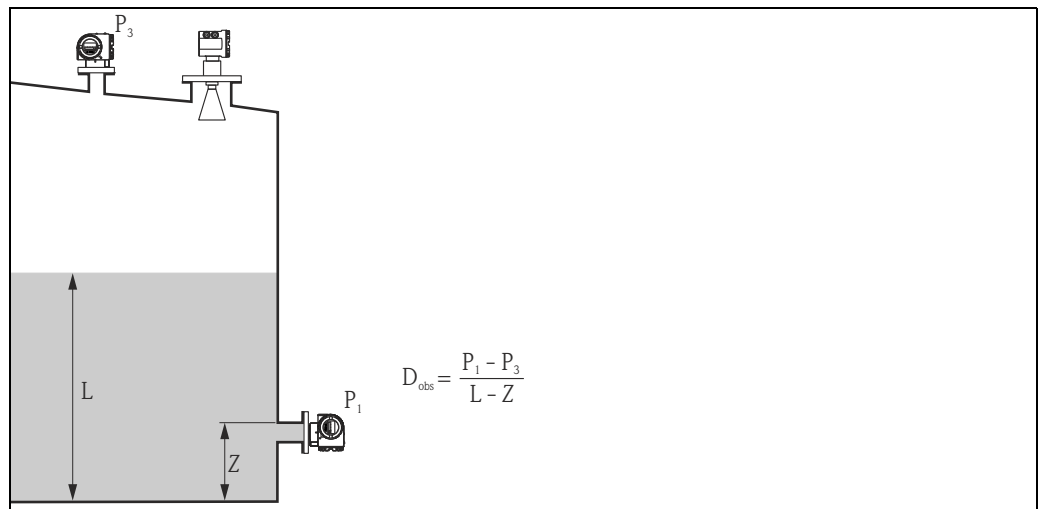


### 9.3.2 Hybrid Tank Measurement Systems

A Hybrid Tank Management System (HTMS) is a combination of conventional level gauging, enhanced with one or two pressure transmitters for continuous measurement of the actual observed density in a bulk liquid storage tank. Or otherwise stated, it is a combination of level and hydrostatic pressure measurement. Pressure measurement, combined with level, provides true average density measurement over the entire product level height. Normally, the vapor (top) pressure is identified as  $P_3$  and the hydrostatic (bottom) pressure is identified as  $P_1$ .

Advantage of HTMS

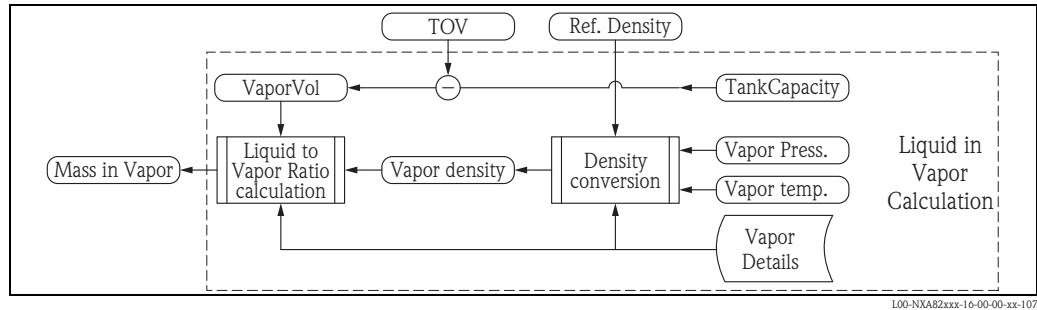
- Accurate level measurement
- Continuous density measurement
- Excellent mass and volume measurements



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## 9.4 Calculations for liquefied gases

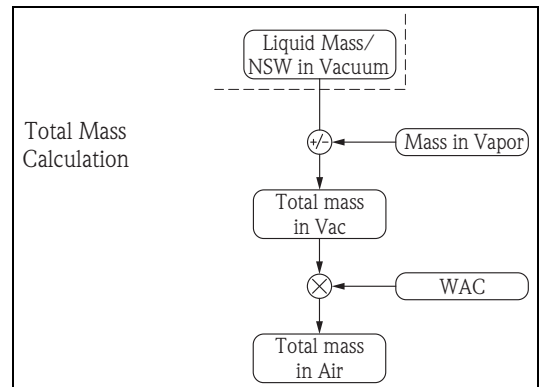
The mayor difference in the calculation for liquefied gases compared to liquids is that the gas phase must be considered. Therefore a calculation for the mass of the product in the gas phase must be applied.



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### 9.4.1 Total Mass

Total Mass = Liquid Mass + Vapor Mass



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### 9.4.2 MBR method

- The method is based on a specific done by "Moore, Barrett & Redwood" in November 1985. The calculation procedure was specified for "Whessoe Systems and Controls Ltd.".
- MBR specify not just the gas calculation, it define a whole process to calculate VCF and RDC.
- This method is only for LPG's intended but it might also give acceptable results for other Chemical gasses - as long as the density and temperature are within the specified range.
- Density Input Range: 470 to 610 kg/m<sup>3</sup>.
- Temperature Inpute Range: -85 to 65 °C (-121 to 149 °F).
- It is not possible to use the M, B & R method for other Reference Temperatures than 15 °C.

Method is based on 10 steps:

1. Measure and input the data
2. VCF Calculation
3. Observed Density calculation
4. Calculate GSV
5. Calculate Liquid Mass
6. Calculate Vapor Volume
7. Calculate Vapor Density
8. Calculate Vapor Mass
9. Calculate Total Mass
10. Calculate Total Weight

**MBR - Data to be measured (1)**

For the LPG application the following data should be real-time measured on the tank(s):

- Product level
- Product Temperature (spot or average)
- Vapor Temperature (spot or average)
- Vapor space pressure - also called "Vapor pressure"

*Input data*

- The liquid density at 15 °C (59 °F) has to be input by the operator. This density can either be obtained from a pressurized hydrometer and corrected via an appropriate table or should be established on basis of chemical analysis.
- The method as implemented in Tankvision also allows the operator to enter Observed or Actual density as a manual value. Tankvision will then calculate the corresponding Reference Density.

**MBR - VCF Calculation (2)**

The following formula shows the calculation method.

$$\begin{aligned}
 X &= (\text{DENL15} - 500) / 25 \\
 Y1 &= 0.296 - 0.2395 * X + 0.2449167 * X * X - 0.105 * X * X * X + 0.01658334 * X * X * X * X \\
 Y2 &= 368.8 + 4.924927 * X + 13.66258 * X * X - 6.375 * X * X * X + 1.087503 * X * X * X * X \\
 TR &= 298.2 / Y2 \\
 TT &= (1 - TR)^{(1/3)} \\
 VO &= 1 - 1.52816 * TT / 1.43907 * TT * TT - 0.81446 * TT * TT * TT / 0.190454 * TT * TT * TT * TT \\
 VD &= (-0.296123 + 0.386914 * TR - 0.0427258 * TR * TR - 0.0480645 * TR * TR * TR) / (TR - 1.00001) \\
 V1 &= VO * (1 - Y1 * YD) \\
 TR &= (TL + 273.2) / Y2 \\
 TT &= (1 - TR)^{(1/3)} \\
 VO &= 1 - 1.52816 * TT / 1.43907 * TT * TT - 0.81446 * TT * TT * TT / 0.190454 * TT * TT * TT * TT \\
 VD &= (-0.296123 + 0.386914 * TR - 0.0427258 * TR * TR - 0.0480645 * TR * TR * TR) / (TR - 1.00001) \\
 V2 &= VO * (1 - Y1 * VD) \\
 VCF &= V1 / V2
 \end{aligned}$$

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**MBR - Observed density (3)**

The observed density is calculated using the reference density and the VCF:

- Observed density = Density at 15 °C (59 °F) x VCF



Note!

The above equation can not be used to calculate the density under reference conditions (i.e. 15 °C (59 °F)).

**MBR - Calculate GSV (4)**

The gross standard volume is calculated using the Total observed volume and the VCF

- G.S.V = T.O.V x VCF

**MBR - Calculate Liquid Mass (5)**

The liquid mass is calculated out of the gross standard volume and the reference density:

- Liquid Mass = G.S.V. x Density at 15 °C (59 °F)

**MBR - Calculate Vapor Volume (6)**

The vapor volume is obtained using the total tank volume and the liquid total observed volume:

- Vapor volume = Total Tank Volume - TOV

**MBR - Calculate Vapor Density (7)**

There are some steps to be followed to get the vapor density

- Molecular weight (MW)

$$X = (D.Ref - 500 / 33.3333)$$

$$MW = 43 + 4.4 \times X + 1.35 \times X^2 - 0.15 \times X^3$$

- Critical temperature and pressure

$$TC = 364 + 13.33 \times X + 8.5 \times X^2 - 1.833 \times X^3$$

$$PC = 43 - 2.283 \times X + 0.05 \times X^2 - 0.0667 \times X^3$$

- Reduced temperature and pressure

$$TR = (TV + 273.2) / TC$$

$$PR = (VP + 1.103) / PC$$

- Compressibility

$$W = 0.214 - 0.034333 \times X + 0.005 \times X^2 - 0.0001667 \times X^3$$

Locate smallest root of:

$$Z^3 - Z^2 + Z \times (A - b - B^2) - A \times B$$

With:

$$A = 0.42747 \times L^2 \times PR/TR^2$$

$$B = 0.08664 \times PR/TR$$

$$L = 1 + (0.48 + 1.574 \times W - 0.176 \times W^2) \times (1 - \text{SQRT}(TR))$$

Compressibility Z should be in the range of 0.2 to 1 for typical LPG applications.

- Vapor density

$$\text{VapDen} = (MW \times (VP + 1.013)) / (0.08314 \times (TV + 273.2) \times Z)$$

 Note!

The Vapor density is calculated in [kg/m<sup>3</sup>]

**MBR - Calculate Vapor Mass (8)**

- The vapor mass (VM) can now be calculated:

$$MV = \text{Vapor Space} \times \text{VapDens}$$

- Calculate Total Mass:

$$\text{Total Mass} = \text{Liquid Mass} + \text{Vapor Mass}$$

- Equivalent Vapor Liquid Volume

$$\text{EVLV} = \text{Vapor Mass} / \text{Liq. Ref. Density}$$

## 9.5 CTSh

### 9.5.1 What is CTSh

CTSh stands for "**C**orrection for **T**emperature of the **T**ank **S**hell". CTSh is about correcting for when the temperature of the tank shell is different than the calibration temperature of the tank.

This temperature influence affects the calculated Inventory via (1) the gauge reading, and (2) via a change in the capacity of the tank as the tank diameter has changed under the temperature effect.

Temperature difference	Volume change	Temperature difference	Volume change
1.0 °C (34 °F)	0.002%	50.0 °C (122 °F)	0.110%
5.0 °C (41 °F)	0.011%	60.0 °C (140 °F)	0.132%
10.0 °C (50 °F)	0.022%	70.0 °C (158 °F)	0.154%
20.0 °C (68 °F)	0.044%	80.0 °C (176 °F)	0.176%
30.0 °C (86 °F)	0.066%	90.0 °C (194 °F)	0.198%
40.0 °C (104 °F)	0.088%	100.0 °C (212 °F)	0.220%

Temperature Effect on Tank Volume for a given height of liquid (based tec for steel:  $22 \times 10^{-6} / ^\circ\text{C}$ )

#### Temperature effect on gauge reading

The temperature effect via the Gauge Reference Height (GRH) affect the level reading and depends on:

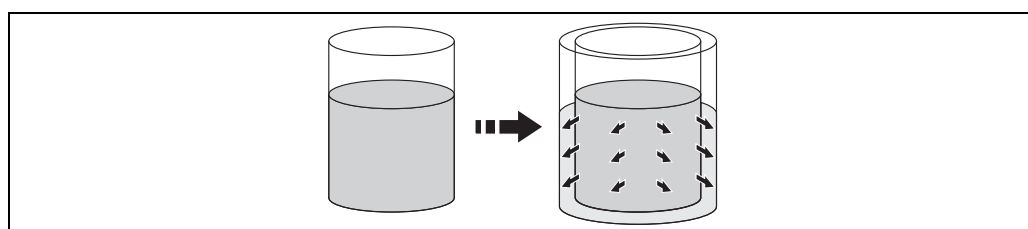
- The actual product level in relation to the Gauge Reference Height (GRH),
- The gauge type, for example radar and servo are differently affected,
- The thermal expansion coefficient of the tank steel,
- and the actual tank shell temperature in relation to the tanks shell calibration temperature.

The temperature correction for the Gauge Level reading should be corrected in the Level gauge and NOT corrected in the Tank Inventory System.

Reason is that it makes more sense to this correction in the gauge itself:

- Level reading in Gauge ans System should be identical with the same correction applied.
- The required correction depends on the gauge type. A servo, needs for example a different correction as the temperature effects on the measuring wire in the tank partly compensates the temperature effects of the tank shell. For a Radar this is not the case.
- Why burden the Tank Inventory system with correction which are gauge specific.

#### Temperature effect on tank capacity



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The temperature effects also the tank capacity via the tank shell diameter. With the changed diameter, the surface area is changed, and as result the tank can contain more or less liquid product depending on wheter the tank shell temperature is higher or respectively lower than the tank shell calibration temperature.

While the Level gauge is affected by two influences, one related to the thermal effects on the "wet" part of the tank shell, and one for the "dry" part of the tank shell, the tank capacity is only affected by the "wet" part of the tank shell.

Hence we also only have to establish the temperature of the "wet" part, i.e. the part in direct contact with the liquid product.

### Wet tank shell temperature

It is unpractical to measure the tank shell temperature for each and individual tank. Hence one common "estimate" method is used for all tanks. This method is based on the ambient temperature (Tamb) and the actual liquid product temperature. For most tanks the following expression is specified in the standards:

$$T_{\text{shell}} = 7/8 * T_{\text{product}} + 1/8 * T_{\text{ambient}}$$

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Unfortunately there are also tanks which behave differently. This can be tanks with a real thermal insulation, but they can also be buried. Hence we had re-write the above equation so we could use a "insulation factor"  $I_f$ .

$$T_{\text{shell}} = I_f * T_{\text{product}} + (1 - I_f) * T_{\text{ambient}}$$

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Where:

- $T_{\text{shell}}$  = Temperature of "wet" tank shell
- $T_{\text{product}}$  = Temperature of liquid product in tank
- $T_{\text{ambient}}$  = Ambient temperature
- $I_f$  = Insulation Factor

Now we can use the  $I_f$  and use one common equation. Selecting the Insulation factor is simple:

- $I_f = 1.0$  for all tanks where the tank is somehow insulated, and
- $I_f = 7/8$  for all other tanks

Of course you can modify this setting in the configuration of Tankvision.



Note!

- In Appendix B you can find a table with some examples as illustration.
- How to obtain the ambient temperature is discussed further on.

### Thermal expansion

With the Shell temperature we can now calculated the expansion of the tank capacity. This factor is indicated with the name CTSh. Late we will see how it applied to the calculated volume. The CTSh equation depends on the tank type.

#### Vertical cylindrical tanks

The equation for vertical cylindrical tanks for the volumetric CTSh is relative easy:

$$CTSh = 1 + 2 * \alpha * \delta T + \alpha^2 * \delta T^2$$

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Where:

- $\alpha$  = Linear thermal expansion coefficient of tank shell material
- $\delta T$  = Tank Shell Temperature - Tank Calibration temperature

The complexity starts with inconsistencies between the CTSh calculation as specified in various International standards.

In IP PMP No. 11 (paragraph C.2, page 20) the above equation (1) is simplified to:

$$CTSh = 1 + 2 * \alpha * \delta T$$

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In order to be able to combine both equations, we have rewritten the equations to:

$$CTSh = 1 + 2 * \alpha_1 * \delta T + \alpha_s * \delta T^2$$

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Where:

- $\alpha_1$  = Linear thermal expansion coefficient
- $\alpha_s$  = Area or surface thermal expansion coefficient
- $\delta T = T_{\text{shell}} - T_{\text{calib}}$

#### *Spherical tanks*

Temperature correction for Spherical Tanks is calculated using the following equation:

$$CTSh = 1 + \alpha_1 * \delta T * f'$$

100-NXA82xxx-16-00-00-xx-008

Where:

- $f'$  = non-dimension factor representing change in partial volume, corresponding with  $h/2$

The factor  $f'$  can be calculated with:

$$f' = (h^2 * r) / (h^2 * r - (h^3 / 3))$$

100-NXA82xxx-16-00-00-xx-009

Where:

- $h$  = liquid depth
- $r$  = vessel radius



Note!

- This calculation is conform to IP PMP No. 11
- Refer to Appendix A3 for values of  $f'$

#### *Horizontal cylindrical tanks (bullets)*

Temperature correction for Horizontal Cylindrical Tanks is calculated using the following equation:

$$CTSh = 1 + \alpha_1 * \delta T * f''$$

100-NXA82xxx-16-00-00-xx-010

Where:

- $f''$  = non-dimension factor representing change in partial volume, corresponding with  $h/r2$

The factor  $f''$  can be calculated with:

$$F'' = 1 + \{2 * (\theta - \sin \theta) / (\theta - \sin \theta * \cos \theta)\}$$

100-NXA82xxx-16-00-00-xx-011

Where:

- $h$  = liquid depth
- $r$  = vessel radius
- $\theta$  = angle subtended by liquid surface at the centre of the circular cross-section



Note!

Refer to Appendix A3 for values of  $f''$ .

*Thermal expansion coefficient(s)*

In the previous equations we have used two thermal expansion coefficients:

- $\alpha_1$  = Linear thermal expansion coefficient
- $\alpha_s$  = Area or surface thermal expansion coefficient

The first one represents the linear thermal expansion of the material of which the tank shell is made. The second factor represents the squared or area thermal expansion coefficient.

It is of paramount importance that the factor used is in the correct engineering units, i.e. as fraction per °C or fraction per °F.

The method for this calculation depends on what equation is to be emulated:

- In case of equation CTSh (3) =  $1 + 2 * \alpha * \delta T + \alpha^2 * \delta T^2$   
 In this case " $\alpha_s$ " can be derived from " $\alpha_1$ " by squaring, i.e. " $a_{tec}$ " = " $1_{tec}$ "
- In case of equation CTSh (4) =  $1 + 2 * \alpha * \delta T$   
 In this case " $\alpha_s$ " should be set to zero.
- For spherical and horizontal cylindrical tanks " $\alpha_s$ " should be set to zero.

Please also make sure that the exponent value is considered when entering the value in Tankvision. For example if " $\alpha_1$ " is set to be equal to " $1.6 \cdot 10^{-5}$ ", while as engineering units shown is " $10EE-7/^\circ\text{C}$ ", the " $\alpha_1$ " value to be entered is "160".



## 9.5.2 Measurement of ambient temperature

The CTSh should be calculated automatically, which is only possible if we also have the actual ambient temperature measured automatically.

Tankvision is capable of integration of this temperature from field equipment. It can redistribute this information over the whole or part of the Tank Farm. This makes it possible to use one ambient temperature sensor and use the measure temperature for one or more tanks within the same Tankvision system.

### Automatic measurement of ambient temperature on site

Exact recommendations on the location, installation and accuracy of the Ambient Temperature sensor are vague. The sensor should be located in the outside environment, be protected from direct sun shine, rain and wind, and preferable be approximately 1 meter (3 ft) from any building or large object.

An external Ambient Temperature sensor can be connected via:

- NRF590 – for example by adding an extra HART converter with temperature sensor, or by using the optional RTD input
- Proservo NMS53x – as above

Other methods may also possible be possible, depending on installed equipment and used field protocol. Please consult Endress+Hauser.

Later we will also see that there is a special setting in Tankvision where we can disable fail propagation if the ambient temperature doesn't work. After all it would be pretty horrific if the calculated inventory data of all tanks is suddenly useless, just because one sensor fails.

### Manual entry of ambient temperature

It is also possible to enter the ambient Temperature manual.

This could be used, for either verifying the CTSh calculations, or in the unlikely case the ambient temperature is in fail.

## 9.6 Alcohol calculations

### 9.6.1 The OIML R22

The OIML R22, as issued in 1975 deals with the calculations for the basic data "relating to the density and to the alcoholic strengths by mass and by volume of mixtures of water and ethanol". As per OILM R22 standards the range is -20 to +40 °C (-4 to +104 °F) and defines the following:

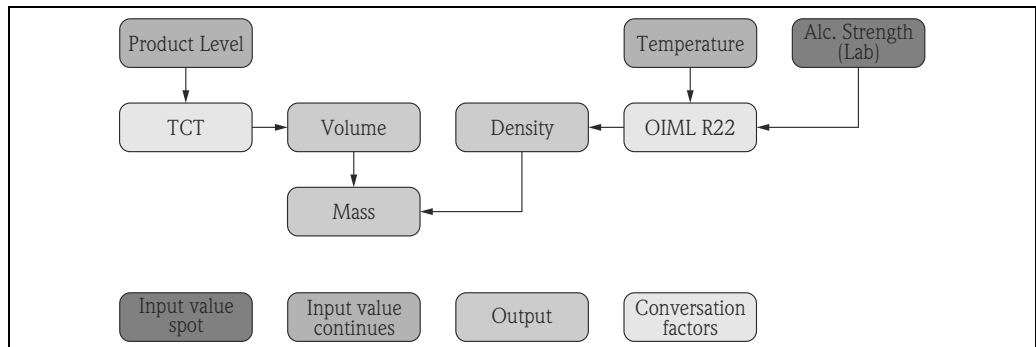
- Table 1:  
Gives the Observe density as a function of the temperature and the alcohol strength by mass
- Table 2:  
Gives the Observe density as a function of the temperature and the alcohol strength by volume
- Table 3A and 3B:  
Gives the standard (reference) density at 20 °C (68 °F) (Table 3A) and the alcoholic strength by volume (Table 3B) as a function of the alcoholic strength by mass
- Table 4A and 4B:  
Gives the standard density at 20 °C (68 °F) (Table 4A) and the alcoholic strength by mass (Table 4B) as a function of the alcohol strength by volume
- Table 5A and 5B:  
Gives the acloholic strength by mass (Table 5A) and the alcoholic strength by volume (Table 5B) as a function of the observe density at 20 °C (68 °F)
- Table 6:  
Gives the alcoholic strength by mass as a function of the observe density and temperature
- Table 7:  
Gives the alcoholic strength by volume as a function of the observe density and temperature
- Table 8A and 8B:

Gives the alcoholic strength by mass (Table 8A) and the alcoholic strength by volume (Table 8B) as a function of the observe density (density is read from alcoholmeter of soda lime glass at 20 °C (68 °F)) and temperature. Density at a given temperature is calculated by the given formula.

- Table 9A and 9B:  
Gives the alcoholic strength by mass (Table 9A) and the alcoholic strength by volume (Table 9B) as a function of the observe density (taken from hydrometer) and temperature
- Table 10A and 10B  
Gives the alcoholic strength by mass (Table 10A) and the alcoholic strength by volume (Table 10B) as a function of the observe density (taken from a instrument made of borosilicate glass) and temperature
- Table 11A and 11B  
Calculates volume using alcohol strength by mass (Table 11A) or alcohol strength by volume (Table 11B)
- Table 12A and 12B:  
Calculates volume using alcohol strength by mass (Table 12A) or alcohol strength by volume (Table 12B)



Note!  
Currently Table 1-5 are implemented in Tankvision NXA820



## 9.7 Annex A.1

ID	PARAMETER	OPC	ID	PARAMETER	OPC
622	P_LEVEL	Level (default)	1634	TEMP_1	SPOT_TEMP_1 (dynamic)
623	S_LEVEL	SecondaryLevel (dynamic)	1635	TEMP_2	SPOT_TEMP_2 (dynamic)
624	W_LEVEL	WaterLevel (default)	1636	TEMP_3	SPOT_TEMP_3 (dynamic)
625	P_TEMP	Temperature (default)	1637	TEMP_4	SPOT_TEMP_4 (dynamic)
626	V_TEMP	VaporTemperature (default)	1638	TEMP_5	SPOT_TEMP_5 (dynamic)
660	A_TEMP	AmbientTemperature (default)	1639	TEMP_6	SPOT_TEMP_6 (dynamic)
627	V_PRESS	VaporPressure (default)	1640	TEMP_7	SPOT_TEMP_7 (dynamic)
628	P_OBS_D	CALC_OBSERVED_DENSITY (default)	1641	TEMP_8	SPOT_TEMP_8 (dynamic)
661	P_REF_D	CALC_REF_DENSITY (default)	1642	TEMP_9	SPOT_TEMP_9 (dynamic)
690	P_PRESS_A	-	1643	TEMP_10	SPOT_TEMP_10 (dynamic)
691	P_PRESS_G	-	1644	TEMP_11	SPOT_TEMP_11 (dynamic)
692	P_PRESS	-	1645	TEMP_12	SPOT_TEMP_12 (dynamic)
693	V_PRESS_A	-	1646	TEMP_13	SPOT_TEMP_13 (dynamic)
694	V_PRESS_G	-	1647	TEMP_14	SPOT_TEMP_14 (dynamic)
717	TOT_OBS_VOL	TOT_OBSERVED_VOLUME (default)	1648	TEMP_15	SPOT_TEMP_15 (dynamic)
718	REM_CAP_TANK	REM_CAPACITY_TANK (default)	1649	TEMP_16	SPOT_TEMP_16 (dynamic)
719	AVAIL_VOL	AVAIL_VOLUME (default)	2101	ALCOHOL_BY_MASS	AlcoholByMass (default)
720	SED_W_VOL	SED_WATER_VOL (default)	2102	ALCOHOL_BY_VOLUME	AlcoholByVolume (default)
721	P_LVLCHNG_RATE	PROD_LVLCHANGE_RATE (default)	1551	SAMPLE_TEMPORAURE	SampleTemperature (default)
722	TOTOBS_FLW_RATE	TOTOBSERVED_FLOT_RATE (default)	2601	GP01	GP01 (dynamic)
723	NETSTD_FLW_RATE	NETSTD_FLOW_RATE (default)	2602	GP02	GP02 (dynamic)
724	TOTMASS_FLW_RATE	TOTMASS_FLOW_RATE (default)	2603	GP03	GP03 (dynamic)
725	FREE_W_VOL	FREE_WATER_VOL (default)	2604	GP04	GP04 (dynamic)
726	GROSSS_OBS_VOL	GROSS_OBS_VOLUME (default)	2605	GP05	GP05 (dynamic)
752	TOT_STD_VOL	TOTAL_STD_VOLUME (default)	2606	GP06	GP06 (dynamic)

ID	PARAMETER	OPC	ID	PARAMETER	OPC
754	VCF	VCF (default)	2607	GP07	GP07 (dynamic)
756	MASS_VAPR	MASS_VAPOUR (default)	2608	GP08	GP08 (dynamic)
760	NET_WGHT_AIR	NET_WEIGHT_AIR (default)	2609	GP09	GP09 (dynamic)
761	NET_STD_WGHT	NET_STD_WEIGHT (default)	2610	GP10	GP10 (dynamic)
762	R_ROOF_ADJUS	FLOAT_ROOF_ADJUS (default)	2611	GP11	GP11 (dynamic)
763	F_ROOF_POS	FLOAT_ROOF_POS (default)	2612	GP12	GP12 (dynamic)
774	TNK_SHELL_CORR	TANK_SHELL_CORREC (default)	2613	GP13	GP13 (dynamic)
727	GROSS_STD_VOL	GROSS_STD_VOLUME (default)	2614	GP14	GP14 (dynamic)
728	NET_STD_VOL	NET_STD_VOL (default)	2615	GP15	GP15 (dynamic)
729	P_MASS	PRODUCT_MASS	2616	GP16	GP16 (dynamic)
730	TOT_MASS	TOTAL_MASS (default)	2650	PROTOCOL_ALARM_1	-
1592	VAPOR_ROOM_VOL	-	2651	PROTOCOL_ALARM_2	-
			2652	PROTOCOL_ALARM_3	-
			2653	PROTOCOL_ALARM_4	-
			2654	PERCENTAGE_LEVEL	-

dynamic = exported via OPC only when scanned via field scan or set to manual value

## 9.8 Annex A.2

Insulation factors for various tank geometries

	Fixed Roof Tank	Insulated Tank	Tank with Still. Well (SW)	Tank with Internal FR & SW	External Floating Roof Tank with SW	Floating or No Roof - Direct measurement
d = dry w = wet v = vapor p = product a = ambient						
TS =	$\frac{7}{8} * T_p + \frac{1}{8} * T_a$	$T_p$	$T_p$	$T_p$	$T_p$	$\frac{7}{8} * T_p + \frac{1}{8} * T_a$
Recommended Insulation Factor (IFw)	$IFw = \frac{7}{8} (.825)$	$IFw = 1.0$	$IFw = 1.0$	$IFw = 1.0$	$IFw = 1.0$	$IFw = \frac{7}{8}$

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## 9.9 Annex A.3

Correction factors for CTSh (spheres ( $F'$ ) and horizontal cylindrical tanks ( $F''$ ))

$h/2r$	Spherical $f'$	Horiztl. Cylinder $f''$	$h/2r$	Spherical $f'$	Horiztl. Cylinder $f''$
0.00			0.40	1.364	1.664
0.01	1.007	1.503	0.41	1.376	1.670
0.02	1.014	1.506	0.42	1.389	1.676
0.03	1.020	1.509	0.43	1.402	1.682
0.04	1.027	1.512	0.44	1.415	1.688
0.05	1.034	1.516	0.45	1.429	1.694
0.06	1.042	1.519	0.46	1.442	1.700
0.07	1.049	1.522	0.47	1.446	1.707
0.08	1.056	1.525	0.48	1.471	1.713
0.09	1.064	1.529	0.49	1.485	1.720
0.10	1.071	1.532	0.50	1.500	1.727
0.11	1.079	1.536	0.51	1.515	1.734
0.12	1.087	1.539	0.52	1.531	1.741
0.13	1.095	1.543	0.53	1.546	1.748
0.14	1.103	1.546	0.54	1.563	1.756
0.15	1.111	1.550	0.55	1.579	1.764
0.16	1.119	1.554	0.56	1.569	1.772
0.17	1.128	1.557	0.57	1.613	1.780
0.18	1.136	1.561	0.58	1.630	1.788
0.19	1.145	1.565	0.59	1.648	1.796
0.20	1.154	1.569	0.60	1.667	1.805
0.21	1.163	1.573	0.61	1.685	1.814
0.22	1.172	1.577	0.62	1.705	1.823
0.23	1.181	1.581	0.63	1.724	1.833
0.24	1.190	1.586	0.64	1.744	1.843
0.25	1.200	1.590	0.65	1.765	1.853
0.26	1.210	1.594	0.66	1.786	1.863
0.27	1.220	1.599	0.67	1.807	1.874
0.28	1.230	1.603	0.68	1.829	1.885
0.29	1.240	1.608	0.69	1.852	1.896
0.30	1.250	1.613	0.70	1.875	1.907
0.31	1.261	1.617	0.71	1.899	1.920
0.32	1.271	1.622	0.72	1.923	1.932
0.33	1.282	1.627	0.73	1.948	1.945
0.34	1.293	1.632	0.74	1.974	1.958
0.35	1.304	1.637	0.75	2.000	1.972
0.36	1.316	1.642	0.76	2.027	1.986
0.37	1.327	1.648	0.77	2.055	2.001
0.38	1.339	1.653	0.78	2.083	2.017
0.39	1.351	1.658	0.79	2.113	2.033

## 9.10 Annex A.4

Example CTSh calculations

Tank Type	Vertical Cylindrical	Vertical Cylindrical	Vertical Cylindrical	Spherical	Vertical Cylindrical
Vessel Radius	n.a.	n.a.	n.a.	17.253	n.a.
Product Level	n.a.	n.a.	n.a.	4.6	n.a.
$\alpha l$ (apha)	$6.2 \times 10^{-6}$	$6.2 \times 10^{-6}$	0.000011	$110 \times 10^{-7}$	$6.2 \times 10^{-6}$
$\alpha s$	4.01E-09	0	0	n.a.	4.01E-09
Tcal	60 °F	60 °F	15 °C	20 °C	60 °F
Tprod	300 °F	300 °F	-43 °C	23.5 °C	88.3 °F
Tamb	70 °F	70 °F		n.a.	74.5 °F
Ifs	0.875	0.875	1	1	0.875
CTSh	1.00279801	1.0026195	0.998724	1.000047	1.00032

## 9.11 Documentation

Document	Instrument	Description
TI00419G/00/EN	Tankvision	Inventory Management System wch completely integrated software for operation via standard web browser
TI00452G/08/EN	Proservo NMS5	Intelligent tank gauge with high accuracy performance Liquid level, I/F, Density & Density Profile
TI00402F/00/EN	Tank Side Monitor NRF590	Field device for tank sensor operation and monitoring and for integration into inventory control system
TI00344F/00/EN	Micropilot S FMR53x	Continuous level transmitter for continuous and non-contact precision level measurement. For custody transfer and inventory control applications with NMI- and PTB-approvals
TI00412F/00/EN	Micropilot S FMR540	Continuous level transmitter for continuous and non-contact precision level measurement. For custody transfer and inventory control applications with NMI and PTB approvals
TI00042G/08/EN	Prothermo NMT539	Intrinsically safe multi-signal converter with precision average temperature and water bottom sensor for inventory control and custody transfer applications
TI00049G/08/EN	Prothermo NMT532	Intrinsically safe multi-signal converter with precision average temperature sensor for inventory control
TI00345F/00/EN	Micropilot M FMR23x, FMR24x	Continuous and non-contact level measurement. Cost-effective 4 to 20 mA 2-wire technology. Suitable for hazardous locations.
TI00358F/00/EN	Levelflex M FMP40	Continuous Level Transmitter for: - Level Measurement in Bulk Solids and Liquids - Interface Measurement in Liquids
TI01001F/00/EN	Levelflex FMP51, FMP52, FMP54	Level and interface measurement in liquids
TI00436P/00/EN	Cerabar M PMC51, PMP51, PMP55	Pressure transmitter with ceramic and metal sensors; With analog electronics or communication via HART, PROFIBUS PA or FOUNDATION Fieldbus
TI00383P/00/EN	Cerabar S PMC71, PMP71, PMP75	Pressure transmitter with ceramic and metal sensors Overload-resistant and function-monitored; Communication via HART, PROFIBUS PA or FOUNDATION Fieldbus
TI00434P/00/EN	Deltabar M PMD55	Differential presure transmitter with metal sensor Communication via HART, PROFIBUS PA or FOUNDATION Fieldbus

Document	Instrument	Description
TI00382P/00/EN	Deltabar S PMD70/75, FMD76/77/78	Differential pressure transmitter with ceramic and silicon sensors; Overload-resistant and function monitored; Communication via HART, PROFIBUS PA or FOUNDATION Fieldbus
TI00401F/00/EN	Liquicap M FMI51, FMI52	For continuous measurement in liquids

Document	Instrument	Description
BA00340F/00/EN	Tankvision	Tank Scanner NXA820, Data Concentrator NXA821, Host Link NXA822
BA00339G/00/EN	Tankvision	Tank Scanner NXA820, Data Concentrator NXA821, Host Link NXA822









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