



Please read this manual attentively before installation

SONDAR

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About this Manual

This manual provides important information about the installation, wiring, operation, and control of ULM-200C. Please read this manual before installing or operating the product. In addition to operating the product, this manual is very important. Please keep it in a safe place for easy reference.

This manual is provided an electronic version only. The electric version is provided with the product package or it can be downloaded through our website (www.sondar.com).

Please note that the contents of this manual are subject to change without prior notice if the product is modified, upgraded or improved.

Although we have checked all contents of this manual but there would be the possibility to remain errors. Therefore the contents of this manual are regularly updated. We welcome all suggestions for improvement.

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Safety Guide Instruction

I. Safety Guide Instruction

1. Authorized Personnel

The installation and operation of the product must be carried out by licensed experts or qualified personnel. Please always wear protective equipment when operating the products.

2. Operation

Before operating the unit, please read this manual thoroughly. The manufacturer isn't responsible accidents caused by user's misuse or modification of the product without manufacture's permission. Conduct periodic inspection of the product.

3. Cautions

This manual provides all information you need to operate SL-100S, maintain and trouble shoot. Please follow the instructions. The manufacturer is not responsible in any way for the risk of an accident when user doesn't follow the instructions.

4. Product Inspection

When opening the product package box, look carefully to determine if the products or accessories have been damaged or contaminated. If the product has been damaged, it may not function properly.

5. Symbols



Caution:

If it is ignored, faults or malfunctions could be result.



Warning:

If it is ignored, injury to people and serious damage to the instrument could be result.



Electric Shock

If it is ignored, the product could be damaged by electric shock



Information:

It provides additional information.

Product Description

SL-100S | LXD-05,10,15

II. PRODUCT

SL-100S is an ultrasonic non-contacting level meter which will increase the effectiveness of your liquid management process. It is available to connect up to two sensors. Depending on the sensor, the measurement range is 5 meters, 10 meters or 15 meters. LXD-05 is 5 meter sensor. LXD-10 is 10 meter sensor and LXD-15 is 15 meter sensor for SL-100S. The sensor cable can be extended up to 360 meters. SL-100S's user friendly user interface offers the user easy installation and calibration. It is also simple and inexpensive to maintain. All functions are optimized which enables you to effectively monitor the liquid level and keep your facilities running safely and reliably.

Application:

LXD-Series sensors are suitable for liquids level monitoring in all industries, particularly in the water and wastewater industry.



- Compatible sensors only LXD-05, LXD-10, LXD-15.
- The sensors; XDS-800, XDS-1200, XDS-1500 are not compatible with the SL-100S controller.



- Depending on the sensor material, the application can be restricted. Before installing the sensor, please check the chemical compatibility chart.

1. Principle of operation

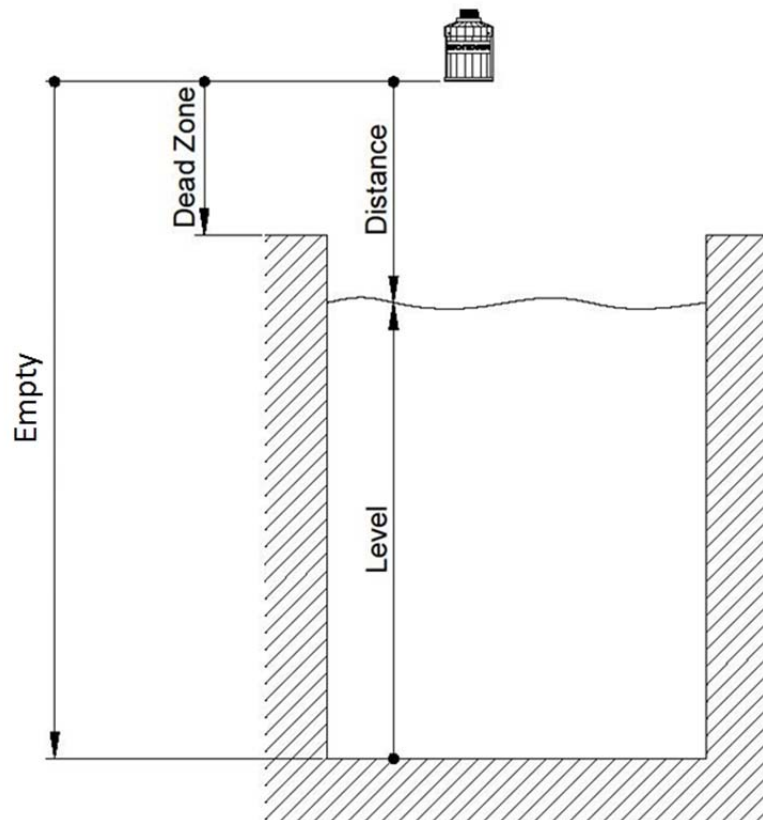
LXD-Series, the sensor transmits ultrasonic pulses to the measurement target. The pulses are reflected from the surface of the target and received back by the sensor. The running time is converted into the distance and it shows as level or volume on the display.

$$D=(C \cdot T) / 2$$

D: DISTANCE

C: SOUND VELOCITY

T: TIME OF FLIGHT



- Distance: from the sensor bottom to surface of the target
- Level: from the bottom of storage to surface of the target
- Empty: from the sensor bottom to the bottom of storage

2. Specification

| SL-100S (Controller) | |
|-------------------------|--|
| Measurement | Ultrasonic non-contacting |
| Accuracy | 0.2% of F.S |
| Resolution | 1mm |
| Damping Rate | 0.1m/min - 100m/min adjustable |
| Output Analog | Analog 4~ 20mA,max 750Ω isolated |
| | Relay 3 ea or 6 ea |
| | Digital RS232, RS485, Modbus |
| Display | Illuminated Graphic LCD |
| IP Rating | IP65 |
| Temperature | -20 ~ 60 (-4 ~ 140), 80% relative humidity |
| Material | Polycarbonate |
| Dimension | 166(W)× 250(H)×95(D) mm |
| Weight | ca. 2kg |
| Power Supply | <ul style="list-style-type: none"> • 100~ 230V AC± 15%, 50/60Hz, 29VA(12W) Fuse: 250V T1.0A • DC 9~ 30V, Max 8W |
| LXD-10, LXD-15 (Sensor) | |
| Range | 0.3~ 5m (0.98- 16.4ft), LXD-05 0.3~ 10m (0.98- 32.8ft), LXD-10 0.3~ 15m (0.98- 49.2ft), LXD-15 |
| Beam Angle | 10° at -3dB |
| Process Connection | 1" PF |
| Weight | 1.5kg - 2.0kg |
| Material | PP, PVDF |
| Temperature | -30 ~ 70 (-22 ~ 158), 80% relative humidity |
| | Temperature Compensation by a built-in temperature sensor |
| IP Rating | IP68 |
| Cable | 2 Core Shield (AWG18) |
| Cable Extension | up to 360m (1,181ft) |

External Temperature Sensor

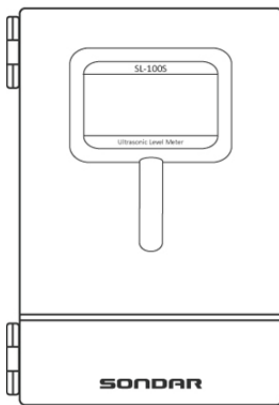
| | |
|--------------------|------------------------|
| Type | NTC, 10 k Ω |
| Temperature | -30 ~ 70 (-22 ~ 158) |
| Process Connection | 1/8" PT |
| IP Rating | IP68 |
| Cable | RG174 |

* The Specification is subject to change without prior notice.

3. Product Package

SL-100S is a controller measuring the level with the sensor, LXD-10 or LXD-15. SL-100S and sensors are packed respectively.

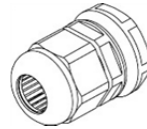
3.1 Controller Box Package



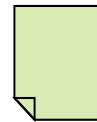
Controller



Manual CD



(PG13.5 1EA)
(PG11.0 2EA)



Test Report



USB Connector Cable (Option)



External Temperature Sensor

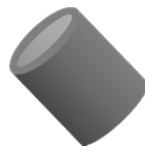


- The protection grade of SL-100S is IP65. It is valid before the cable gland whole is made. When the product is delivered to the customers, the cable gland wholes are made for user's convenience.

3.2 Sensor Box Package



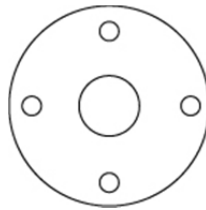
Sensor



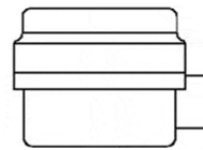
1" Adapter
(option)



Test Report



Flange(option)



Junction Box
(option)



Pipe (option)

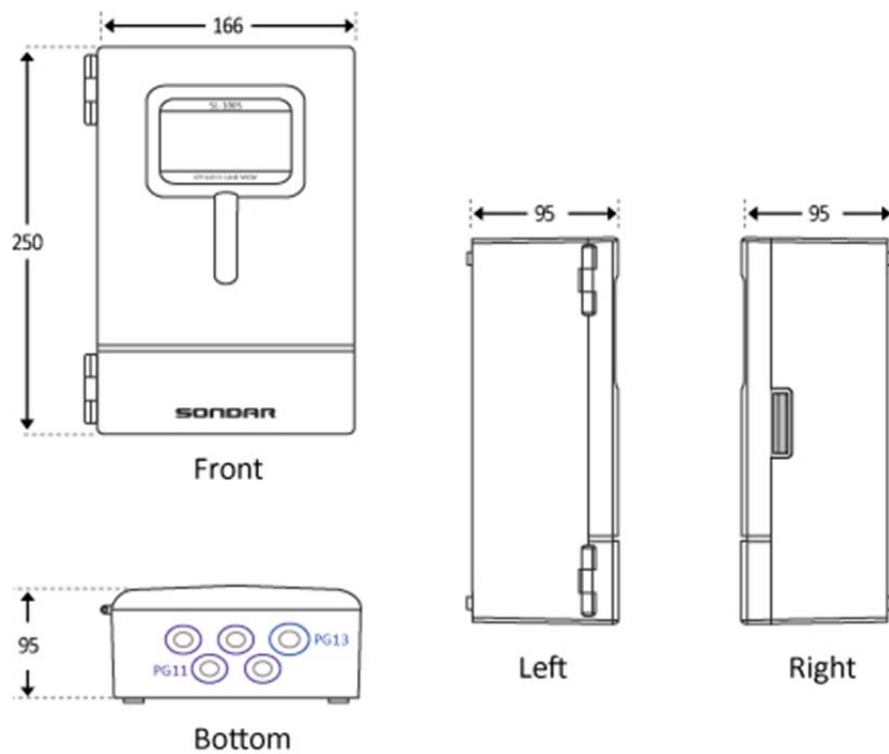


- The basic length of the sensor is 1 meter. The cable length is subject to change as an option if requested when ordering.

4. Dimension

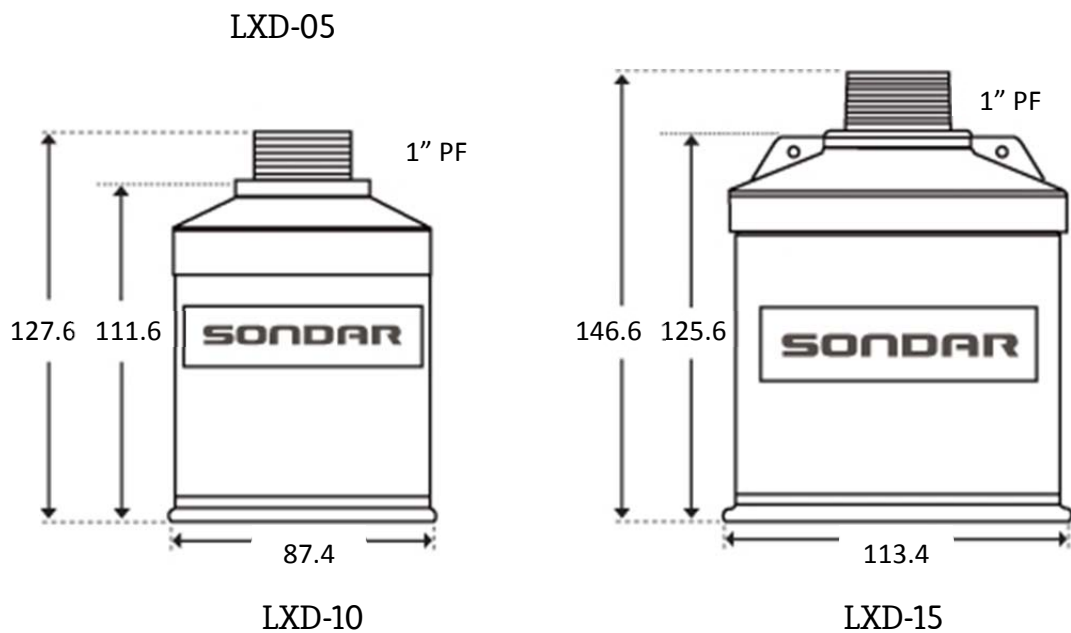
4.1 Controller

- 1) The enclosure material is polycarbonate and the protection grade is IP65.
- 2) Using the whole in the back of the controller it is mounted on the wall.



4.2 Sensor

LXD Sensor series are exclusive level sensors for SL-100S. According to the sensor range, it is 10meters and 15meters. The temperature is compensated by a built-in temperature sensor. The sensor materials are PP and PVDF. According to the application, the sensor housing material must be selected. Before mounting the sensor, check the chemical compatibility chart.



INSTALLATION

III. Installation

1. General Guide

Before mounting the product, read this manual and specification. It is installed in a place that is within the temperature range specified in this manual and that is suitable to the enclosure rating and materials. If the products are installed improperly, it may cause malfunction.

This is general guide for installing SONDAR products.

- ✓ Remove the obstacles in the space between the sensor and the measured target such as ladders, limit switches, heating spirals etc.
- ✓ When mounting the sensor, keep the distance to the vessel wall.
- ✓ The bottom of the sensor should be perpendicular to the surface of water.
- ✓ Do not set the maximum level into the Dead Zone range.
- ✓ Avoid the intense winds and excessive exposure to direct sunlight. The strong winds change the path of ultrasound and may cause a malfunction. If you need to install the unit in a spot exposed to direct sunlight, sun screen must be installed.
- ✓ Keep the distance from the place where are strong noise by high voltage, high current etc.
- ✓ Install the unit in the place vibration free.

2. Controller installation

2.1 Environment condition

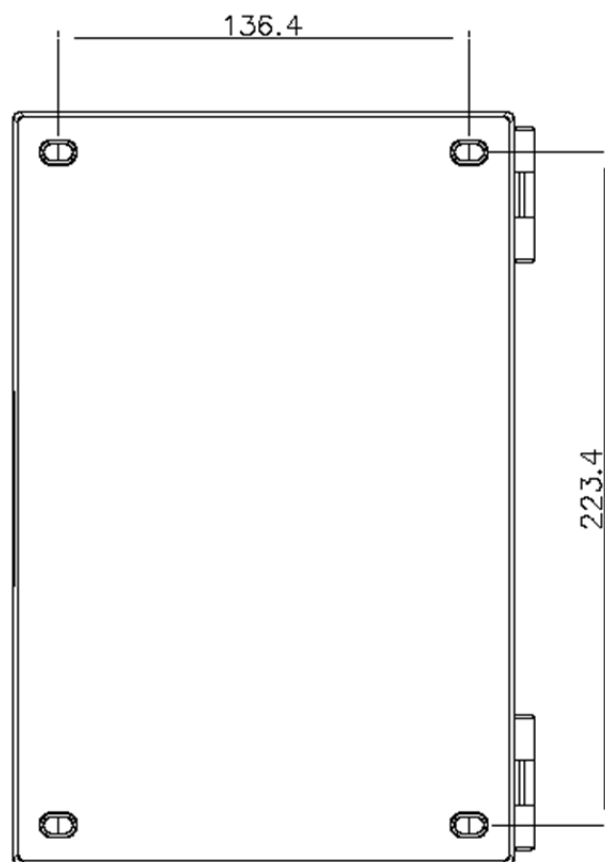
- ✓ In a place where ambient temperature is between -20 to +60 ° C (-4°F~ 140°F)
- ✓ In a place required minimum cable length.
- ✓ In a place where it can be operated conveniently
- ✓ In a place out of direct sunlight
- ✓ In a place free from vibration
- ✓ In a place that has sufficient space when its door is opened.



- Do not install near high voltage, current runs or variable frequency motors.

2.2 Installation

- ✓ Open the controller door and check the four screw holes.
- ✓ Mark and drill four holes in the mounting wall.
- ✓ Fasten the screw bolt by a screwdriver and mount the controller.
- ✓ Check the controller leveled off on the wall.
- ✓ Close the controller door.



3. Sensor Installation

3.1 Environment condition

- ✓ In a place where ambient temperature is between -30 to +70 ° C (-22°F~ 94°F)
- ✓ Suitable to the housing rating and materials for applications.
- ✓ In a place where is perpendicular to the measuring target surface

3.2 Dead Zone

Dead zone is the area which the ultrasonic sensor can't measure. The maximum level shouldn't be reached into the Dead Zone. The echo signal isn't calculated within Dead zone area. Thus the measurement value may not correct.

| Sensor Model | Dead zone |
|--------------|-----------------|
| LXD-05 | 0.3 m (11.81in) |
| LXD-10 | 0.3 m (11.81in) |
| LXD-15 | 0.3 m (11.81in) |

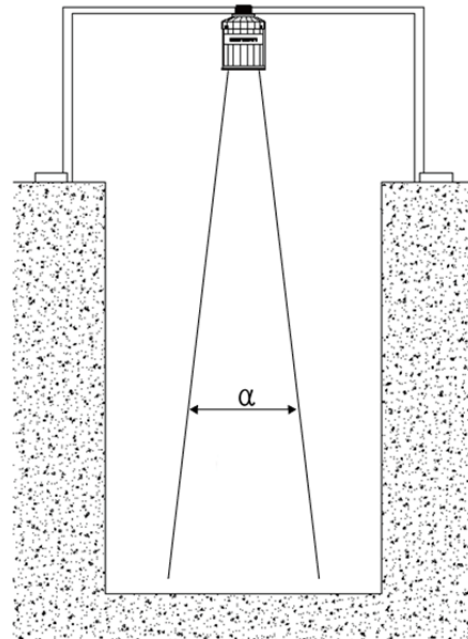


- The sensor cable should not be laid parallel to high voltage line and nearby frequency converters.

3.3 Beam Space

Make sure there is no interference on the emitted beam space area such as a limit switch, temperature sensors, and ladders. .

| Measurement distance | Beam Space(α) |
|----------------------|------------------------|
| 1m | 0.09m |
| 2m | 0.18m |
| 3m | 0.27m |
| 4m | 0.36m |
| 5m | 0.47m |
| 6m | 0.58m |
| 7m | 0.70m |
| 8m | 0.84m |
| 9m | 1.00m |
| 10m | 1.19m |
| 11m | 1.43m |
| 12m | 1.73m |
| 13m | 2.14m |
| 14m | 2.75m |
| 15m | 3.73m |



3.4 Installation

Vessel Installation

- ✓ Do not install the sensor in the middle of the tank. Keep the distance from the vessel wall over 300mm.
- ✓ There should be no interference on the emitted beam path.
- ✓ If there is vibration, it could result incorrect measurement value.
- ✓ Use a flexible conduit for protecting the sensor cable.
- ✓ When using the connection box, the thread size is 1 inch PF.

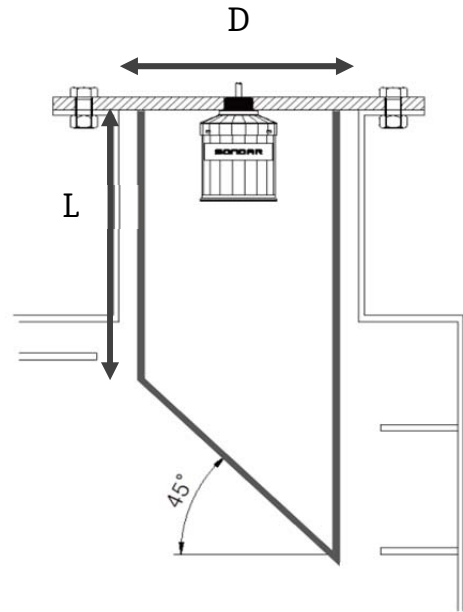
Nozzle Installation

When the maximum level is filled over dead zone in the tank, use the pipe nozzle.

The interior of the nozzle must be smooth and may not contain any edges or welded joints.

There should be no burr on the inside of the tank side nozzle end.

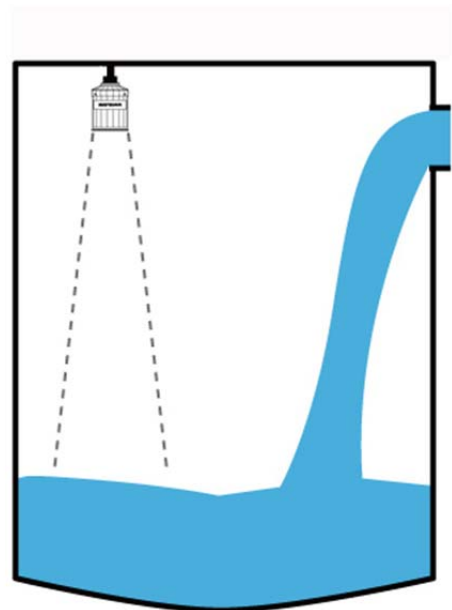
For making the pipe nozzle, specify the diameter and length as the table below.



| D[mm] | Length L [mm] | | |
|-------|---------------|--------|--------|
| | LXD-10 | LXD-10 | LXD-15 |
| 80 | < 180 | - | - |
| 100 | < 230 | < 230 | - |
| 150 | < 350 | < 350 | < 350 |
| 200 | < 470 | < 470 | < 470 |

Filling flow Outlet

Do not install the sensor in or above a filling flow outlet. Secure enough distance from the filling flow.



Foam

After filling, stirring and other process in the vessel, dense foams which considerable damp the emitted signals may form on the surface of the measuring target. It could be result measurement errors. Recommend to use a standpipe.

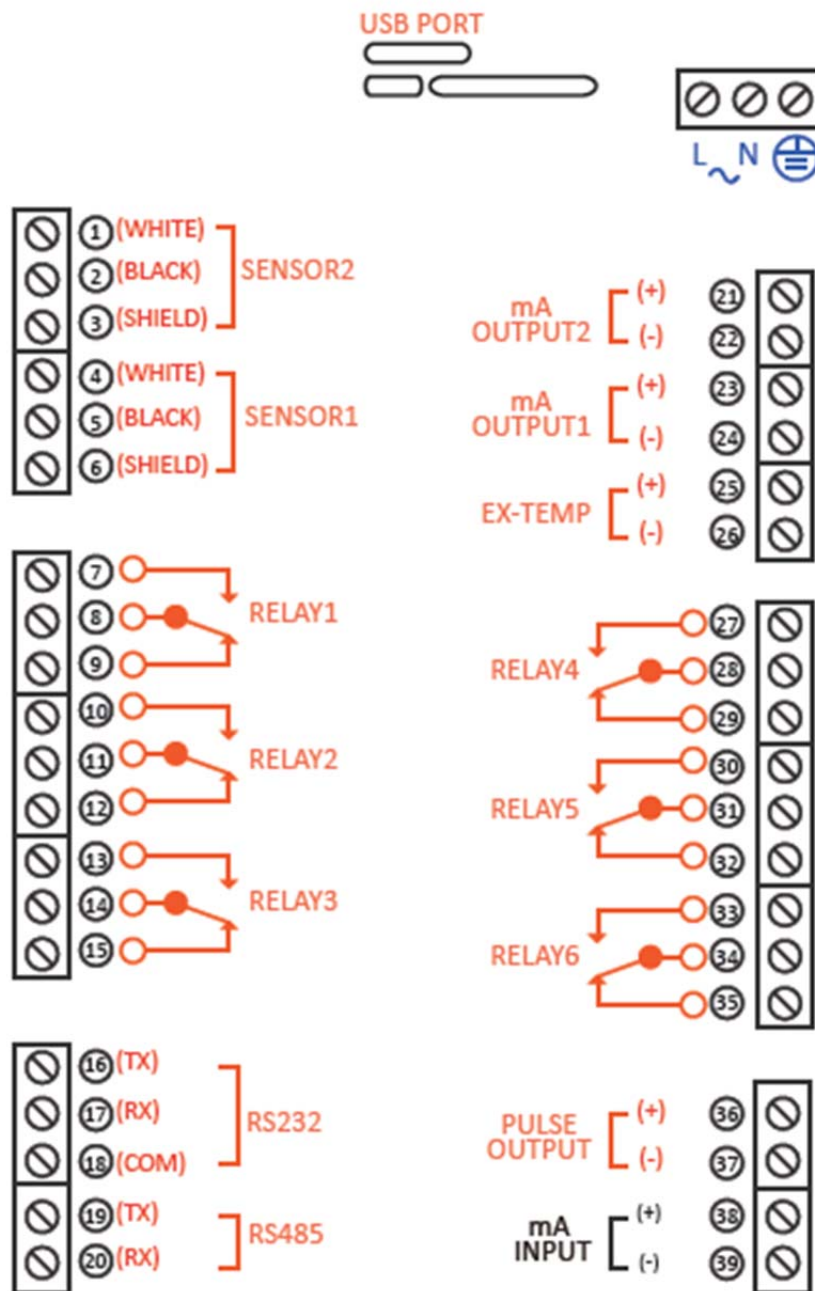
Wiring

IV. Wiring

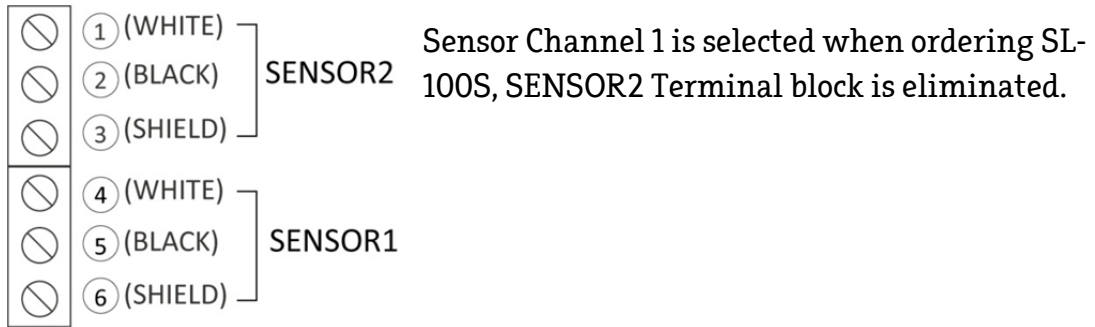
1. Wiring

CONTROL TERMINAL BOARD

There are 39 terminal blocks inside SL-100S. Make sure that all related equipment is connected with each correct terminal block.



TRASDUCER



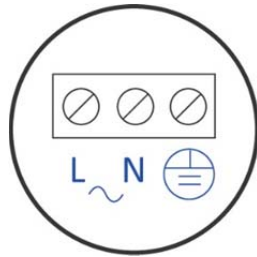
- Do not use coaxial cable.
- Do not use connect the shield and white transducer wires together



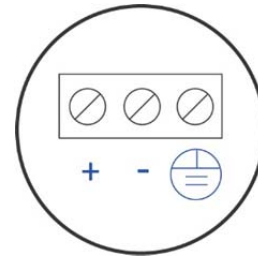
- Do not use old version sensors. Connect only the sensors stated in this manual.

Power

The standard power type is AC power. DC power can be selected as an option if requested when ordering. The thickness of the power cable should be more than 0.755SQmm.



AC Power Terminal



DC Power Terminal

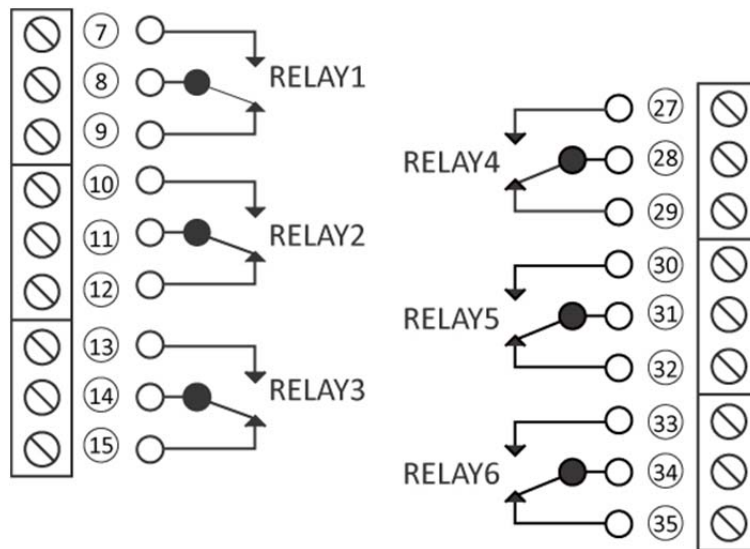


- When turning on the power of SL-100S for the first time, make sure any connected devices are disabled until all system functions are confirmed and to be operating properly.
- The system must be protected by a 10A fuse; otherwise it should be installed in a place where there is a circuit breaker or switch in the building. The switch must be easily accessible.

Relay

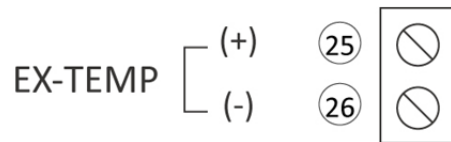
The Relay form is two Form C type. The relays can be wired either normally open or normally closed. The standard model has 3 relays. 3 relays more can be selected as an option if requested when ordering.

- ✓ Two Form C, NO or NC relays
- ✓ 4A at 250Vac



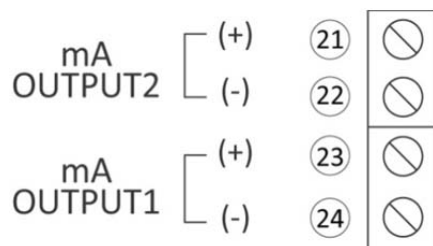
Temperature Sensor

The temperature information is a critical factor for measurement. LXD-05, LXD-10 and LXD-15 sensor has built-in temperature sensor inside the sensor to compensate. If the ambient temperature is changed rapidly, an external temperature sensor is recommendable.



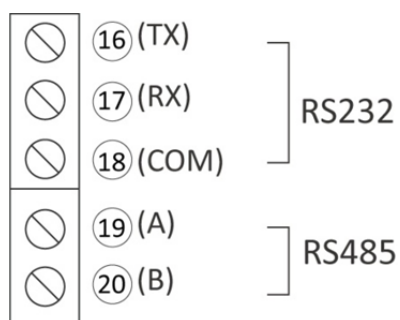
Analog output

mA OUTPUT1 is the analog output for SENSOR1. mA OUTPUT2 is the analog output for SENSOR2. Make sure that each output is wired to the correct terminal block.



Digital Communication

The standard communication type is RS232. RS485, Modbus can be selected as an option if requested when ordering.



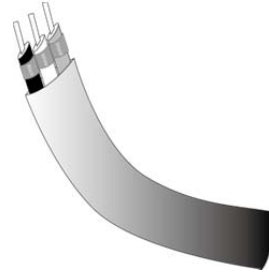
2. Sensor Cable

LXD transducer cable is a shielded two-wire cable. The standard cable length is 1meter (3.28ft). The cable can be extended by an option when placing the order. When the cable needs to extend with other cable, the cable has to be a shielded two-wire cable, same type.

Recommend to use a grounded conduit and a junction box for cable protection.



If the standard model is ordered, the end of cable is provided as the picture above.



If the cable is ordered more than 1meter, the end of cable is provided as the picture above.



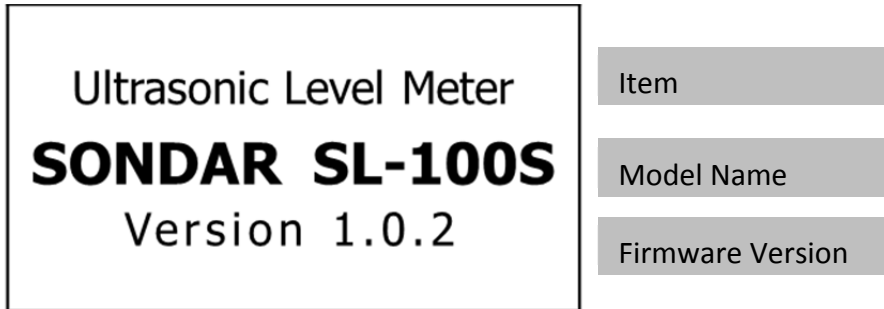
- Do not use a coaxial cable for extension with SL-100S. The extension cable must be used same specification as LXD Series sensor cable

Operation

V. Operation

1. Start-up Display

When SL-100S is powered on, the screen shows as bellow picture.

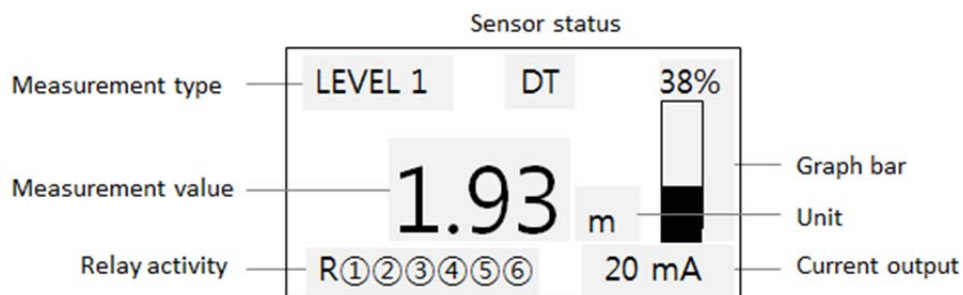


2. Display

2.1 Measuring Mode

There are 4 different display types in Measuring Mode. Switch through different display by using up and down buttons. When only SENSOR1 is wired, DISPLAY B and DISPLAY C aren't shown.

DISPLAY A



1) I

t shows the measurement type currently being measured and the sensor No. currently wired.

- LEVEL 1 : Level measured by SENSOR1
- LEVEL 2 : Level measured by SENSOR2
- DISTANCE 1 : Distance measured by SENSOR1
- DISTANCE 2 : Distance measured by SENSOR2
- SPACE 1 : Space measured by SENSOR1
- SPACE 2 : Space measured by SENSOR2
- VOLUME 1 : Volume measured by SENSOR1
- VOLUME 2 : Volume measured by SENSOR1

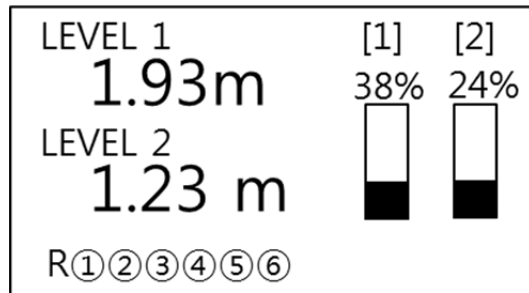
2) It shows the current measurement value

3) It shows the relay currently wired.

- 4) It shows a sensor condition.
 - DT: when it operates normally
 - D: when it receive the reflected signal
 - S1: when the measurement value is over than DAMPING SPEED
(The value is held)
 - S2: when it research the signal
 - LE: when it lost the signal
- 5) It shows the percentage of LEVEL/DISTANCE/SPACE/VOLUME currently being measured.
- 6) It shows the unit of measurement value.
- 7) It shows the current output value or ambient temperature.

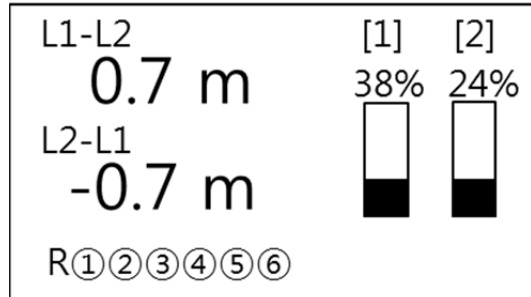
DISPALY B

All the factors displayed are the same as those shown DISPLAY A. DISPLAY B shows two sensors measurement at the same time. When only SENSOR1 is wired, DISPLAY B isn't shown.

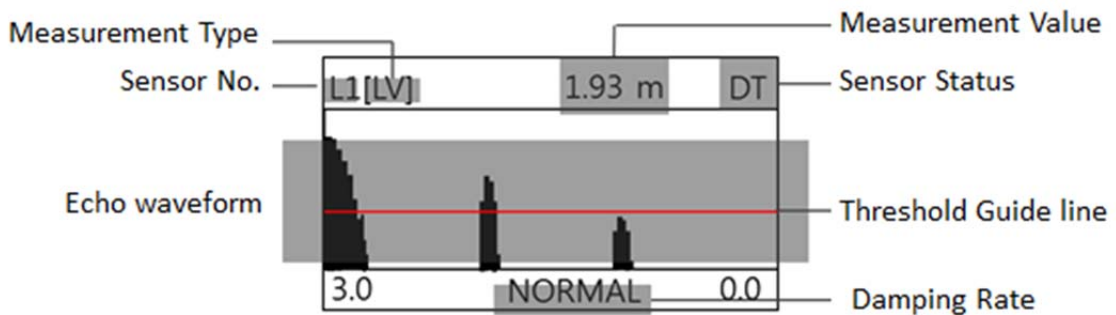


DISPLAY C

All the factors displayed are the same as those shown DISPLAY B. DISPLAY C shows the difference between LEVEL1 and LEVEL 2



Echo Trend DISPLAY



- 1) It shows the measurement type currently being measured.
 - [LV]: LEVEL
 - [DIST]: DISTANC
 - [VOL]: VOLUME
 - [SPACE]: SPACE
- 2) It shows the sensor no. currently activated.
 - L1: SENSOR 1
 - L2: SENSOR 2
- 3) It shows the echo waveform received by sensor.

- 4) It shows the measurement value currently measured.
- 5) It shows the sensor condition.
 - DT: when it operates normally
 - D: when it receive the reflected signal
 - S1: when the measurement value is over than DAMPING SPEED (The value is held)
 - S2: when it research the signal
 - LE: when it lost the signal
- 6) It shows the threshold guide line.
- 7) It shows the damping rate. The Setting Level is as below.
 - SLOW
 - NORMAL
 - FAST
 - VERY FAST

2.2 Operating Mode

Operating Mode is to be set the menus for measurement. Operating Mode can be switched by [MENU] button in measuring mode. It shows as the picture as below.

1. QUICK SETUP
2. LEVEL METER SETUP
3. LOGGING SETUP
4. SYSTEM SETUP
5. NAVIGATION

QUICK SETUP

This menu is the collection of often used menus.

LEVEL METER SETUP

This menu is for detail parameter setup of measurement.

LOGGING SETUP

This menu is for logging data management.

SYSTEM SETUP

This menu is for system setting

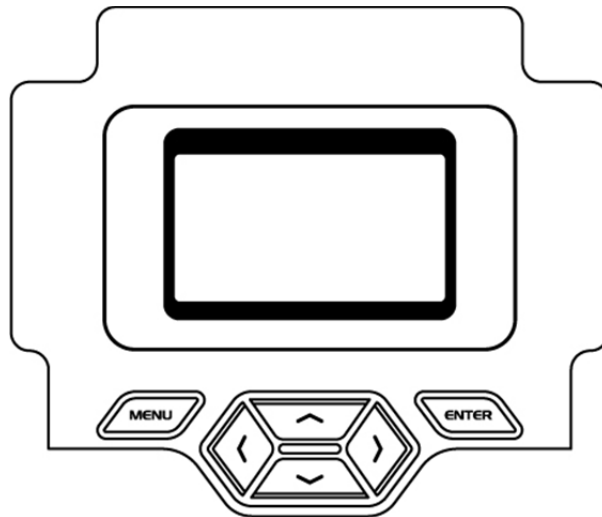
NAVIGATION

This menu allows for quick access to specific menus directly by entering the preset menu number. Refer to the menu list of SL-100S.

* The menu list is page95.

3. Buttons

SL-100S has 6 buttons to operate the system and to setup the menus.



- Measuring mode and Operating mode is switched by [MENU] button.



- Select a menu in Operating mode.
- Complete menu setting



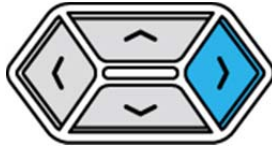
- Move up menus or change the parameters on each menu.



- Move down menus or change the parameters on each menu.



- Return to the previous category
- Move the cursor to the left when entering numbers.



- Return to the next category
- Move the cursor to the right when entering numbers.



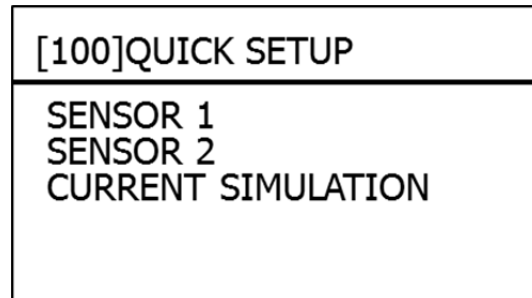
- If you press [ENTER] button, after changing the value in Program Mode, every time the user is asked whether the changed value is saved or not. If you select [YES] then the value is changed and Measuring Mode is switched. When you want to change several menus in same directory, press [ENTER] button after all parameters are changed.

Programming

VI. Programming

1. QUICK SETUP

QUICK SETUP is the menus frequently used. Parameters can be set conveniently in short time.



- The captured menu screen is based on the condition that the sensor channel 1 and the sensor channel 2 are both connected. If the sensor channel 1 is connected only, the screen might display differently.

- 1) SENSOR 1: The menus for SENSOR1 which is wired at SENSOR1 on the terminal block.
- 2) SENSOR 2: The menus for SENSOR2 which is wired at SENSOR2 on the terminal block.
- 3) CURRENT SIMULATION: This menu is that tests the current output of OUTPUT 1 and OUTPUT 2. According to the selection; 3.8mA / 4mA / 12mA / 20mA /22mA, the current output is transferred to the control system.

1.1 SENSOR 1

Set the detail menu of the sensor 1.

| [110]SENSOR 1 | |
|---------------|--------|
| UNIT | m |
| EMPTY | 10.00m |
| DEAD ZONE | 00.30m |
| 4mA OUT | 00.00m |
| 20mA OUT | 10.00m |

1) UNIT

This menu is to select the unit of the value being measured.

- Measuring range: mm, cm, m, yd, in, ft

| Units | |
|-------|--------|
| mm | 10000 |
| cm | 1000 |
| m | 10 |
| in | 393.70 |
| yd | 10.94 |
| Ft | 32.81 |

**Round off the numbers to two decimal places

2) EMPTY

This menu is for setting the distance between the bottom of the sensor and the bottom of the measured storage when there is empty. The input unit is changed depending on the measurements unit.

| Sensor | setting range | Default |
|--------|---------------|---------|
| LXD-05 | 0. 30~99.99m | 5.00m |
| LXD-10 | 0. 30~99.99m | 10.00m |
| LXD-15 | 0. 30~99.99m | 15.00m |



- The setting value of the bottom distance is mostly maximum measuring range of the sensor. However, the bottom distance could be set as 99.99m depending on the application conditions. The incorrect bottom distance value causes the incorrect measurement.

3) DEAD ZONE

This menu is for setting DEAD ZONE of a sensor. The ultrasonic sensor is both transmission and reception sensor. The sensor is not able to measure the distance between the surface of the sensor and the certain point. That distance is called DEAD ZONE.

| Sensor | Setting range | Default |
|--------|---------------|---------|
| LXD-05 | 0. 30~99.99m | 0.3m |
| LXD-10 | 0. 30~99.99m | 0.3m |
| LXD-15 | 0. 30~99.99m | 0.3m |

4) 4mA OUT

This is a mode for setting a distance that the current output is 4mA. This setting is normally set at the point that the water level is zero.

| Sensor | Setting range | Default |
|--------|---------------|---------|
| LXD-05 | -99.99~99.99m | 0.00m |
| LXD-10 | -99.99~99.99m | 0.00m |
| LXD-15 | -99.99~99.99m | 0.00m |

5) 20mA OUT

This is a mode for setting the distance that the current output is 20mA. This setting is normally set at the point that a water level is Maximum (100%).

| Sensor | Setting range | Default |
|--------|---------------|---------|
| LXD-05 | -99.99~99.99m | 5.00m |
| LXD-10 | -99.99~99.99m | 10.00m |
| LXD-15 | -99.99~99.99m | 15.00m |



A DEAD ZONE of 30cm should be excepted when setting 20mA OUT. If the level approaches in the DEAD ZONE, It might be displayed incorrect measurement value instead of the actual measurement level.

1.2 SENSOR 2

It is same as the settings menu of the sensor 1.

1.3 CURRENT SIMULATION

This function can simulate the cable connection status and the current output between the central control room and this device. When you move to the CURRENT SIMULATION menu, the measuring process is stopped and the current output becomes initialized to 0.

| [130]CURRENT SIMULATION | |
|-------------------------|---------|
| OUTPUT 1 | MEASURE |
| OUTPUT 2 | MEASURE |

1) OUTPUT 1

When you select a value of the Current Output 1 and 2, it is output by the value of the corresponding current.

- MEASURE
- 3.8mA
- 4mA
- 12mA
- 20mA
- 22mA

2) OUTPUT 2

Same as the OUTPUT 1

2. LEVEL METER SETUP

This menu is for setting the Level, Distance, Volume measuring, Relay, Current Output, and Communication of the sensor.

| |
|---|
| [200]LEVEL METER SETUP |
| LEVEL VOLUME RELAY CURRENT OUTPUT COMMUNICATION SETUP |

2.1 LEVEL

| |
|------------------------------|
| [210]LEVEL |
| SENSOR 1 SENSOR 2 UNIT |

SENSOR 1

| | |
|---------------|-----------|
| [211]SENSOR 1 | |
| USE | m |
| EMPTY | 10.00m |
| DEAD ZONE | 00.30m |
| TX POWER | 30 |
| RX GAIN | 200 |
| TYPE | LEVEL |
| THRESHOLD | 7 |
| TEMP TYPE | INSIDE |
| TEMP FIX | 25.00°C |
| TEMP | 25.00°C |
| DAMPING | NORMAL |
| SOUND SPEED | 0331.5m/s |
| SPEED FACTOR | 0.60m/ °C |
| LEVEL OFFSET | 0000.00m |

1) USE

This menu is for selecting the sensor use state. If you are using the sensor, please select ENABLE. If you are not using the sensor, please select DISABLE.

2) SENSOR TYPE

This is the menu for selecting the type of the sensor connected.

- LXD-05 5m sensor
- LXD-10 10m sensor
- LXD-15 15m sensor



- If the wrong sensor is selected, it causes incorrect measurement.

3) EMPTY

This menu is for setting the distance between the bottom of the sensor and the bottom of the measured storage when there is empty. The input unit is changed depending on the measurements unit.

| Sensor | Maximum range | Default |
|--------|---------------|---------|
| LXD-05 | 0.30~99.99m | 5.00m |
| LXD-10 | 0.30~99.99m | 10.00m |
| LXD-15 | 0.30~99.99m | 15.00m |



- The setting of the EMPTY is normally the maximum measuring range of the sensor. However, it could be set up to 99.99m according to the application conditions.

4) DEAD ZONE

This menu is for setting DEAD ZONE of a sensor. The ultrasonic sensor is both transmission and reception sensor. The sensor is not able to measure the distance between the surface of the sensor and the certain point. That distance is called DEAD ZONE.

| Sensor | Maximum range | Default |
|--------|---------------|---------|
| LXD-10 | 0.30~99.99m | 0.3m |
| LXD-15 | 0.30~99.99m | 0.3m |

5) TX POWER

This menu is for adjusting the strength of the transmission signal output from the ultrasonic sensor. By using the function that adjusts the intensity of the ultrasonic wave generated from the sensor, this product is applicable for the various environments.

[Default setting: 30, Maximum setting range: 1~ 100]

- 10: When ultrasonic output is weak.
- 30: The general case (Standard mode)
- 50: When ultrasonic output is strong.
- 70: When ultrasonic output is very strong.

6) RX GAIN

This menu is for adjusting the sensitivity of the signal received from the sensor. Attenuation of the ultrasonic signal is occurred depending on the install location, environment, and surface of measurement object. Please to correct this on the basis of the setting of the following criteria.

[Default setting: 85, Maximum setting range: 0~ 100]

- 30 or less: The Amplification degree is weakest. When the amplification degree of the received signal is about 20dB. (Short-range measurement of enclosed space or underground water pipe.)
- 50: When the amplification degree of the received signal is about 25dB. (Short-range measurement of enclosed space or underground water pipe.)
- 80: The general case. When the amplification degree of the received signal is about 30dB. (Standard mode),
- 90: When the amplification degree of the received signal is about 40dB. (Long-range measurement in open space)

- 95: When amplification degree of the received signal is about 50dB.
- (When the dust, powder, and solid there is a risk of diffuse reflection of the ultrasonic wave.)

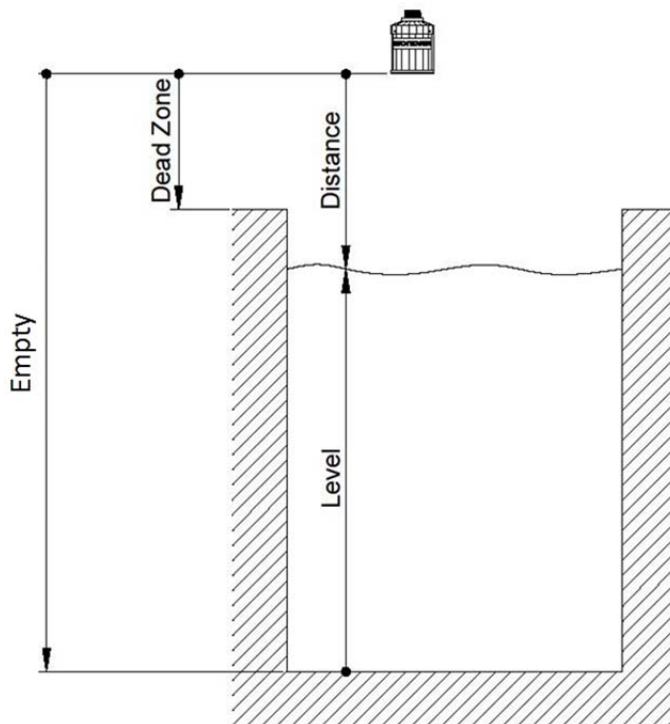


- The setting range is changed according to the sensor range.

7) TYPE

This menu is for selecting the type of the measured value to be displayed in the measurement mode.

- Distance : Display the distance to the measured object from the sensor bottom
- Level : Display the distance to the measurement point from the floor
- Space: Display the distance to the measured object, excluding the DEAD ZONE
- Volume: Display the capacity of the contents of the tank being measured(Volume)
- Differential: Display the difference between the measured value of the sensor channel 1 and the sensor channel 2.



8) N.THRESHOLD / F.THRESHOLD

This is the menu for setting the reference value used to detect the received signal reflected. To avoid false detection, please set THRESHOLD value high in the noisy environment and please set THRESHOLD value low when environmental noise is low.

- [Default setting: 3(0.5V), Maximum setting range: 1~10]

9) TEMP TYPE

This is the menu for selecting the type of the temperature value used in the ultrasonic distance measurement.

- INSIDE: Use the temperature sensor that is built inside the sensor for ultrasonic measuring.
- OUTSIDE: Use the value of the external temperature sensor for ultrasonic measuring. (optional)
- FIX: Set a fixed value without using a temperature sensor when the device is used in the places where the temperature is changed rapidly.



- When using the external temperature sensor for measurement, TEMP TYPE should be selected as OUTSIDE always. If it is set as OUTSIDE, but the external temperature sensor is not actually connected, it might be displayed incorrect measurement value instead of the actual measurement value.

10) TEMP FIX

This menu is for setting the value of the temperature manually when TEMP TYPE is FIX.

| Sensor | Celsius(°C) | Fahrenheit(°F) |
|--------|-------------|----------------|
| Range | 0~60 | 32~140 |

11) TEMP

This menu is for checking the temperature value measured currently.

12) DAMPING

This menu is for setting the speed of output change corresponding to the change in water level.

| Select Item | Slow | Normal | Fast | Very Fast |
|-------------|----------|--------|---------|-----------|
| Speed | 0.1m/min | 1m/min | 10m/min | 100m/min |

13) SOUND SPEED

This menu is for setting the sound speed value of the environment used. Please enter 331.5 in general. (in the air) If this product is operated in other gases, please enter the sound speed value of the corresponding gas when the temperature is 0 °C. (unit: m/sec)

| Name of gas | Sound speed (m/sec) |
|----------------|---------------------|
| Chlorine | 206 |
| Carbon dioxide | 259 |
| Argon | 308 |
| Oxygen | 316 |
| Air | 331.5 |
| Ammonia | 415 |
| Ethane | 430 |
| Neon | 435 |
| Helium | 965 |

14) SOUND SPEED FACTOR

This menu is for setting the sound speed change value due to temperature. Sound speed is changed depending on the temperature. In the air, please enter 0.60 (m / °C) in general. In the case of special circumstances, please enter the sound speed change value obtained by experiment to obtain an accurate measured value.

15) LEVEL OFFSET

This menu is to add and display a particular value (Offset) for the special environments on the display. The value of the water level is measured in the usual way, and it will display on the screen after being adjusted based on the specific value.

| Actual Value | OFFSET | Displayed Value |
|--------------|--------|-----------------|
| 15M | +10 | 25M |
| 15M | -10 | 5M |

SENSOR 2

Same as the setting menu of the sensor 1

| |
|--------------------------------------|
| [213]UNIT |
| UNIT m TEMP UNIT °C |

1) UNIT

This menu is for selecting the unit that displays the measured value.

- Available setting unit: mm, cm, m, in, yd, ft

2) TEMP UNIT

It is a menu for choosing the units that display the temperature value. You can choose between °C and °F.

2.2 VOLUME

VOLUME is the capacity of the contents of the tank that being measured currently. When measuring VOLUME, unit mm, cm, and m are converted to m^3 , and unit in, yd, ft are converted to gallon automatically.

| |
|--|
| [220]VOLUME |
| TYPE VARIABLE LEVEL TABLE VOLUME TABLE VOLUME SIMULATION |

1) Type

- TANK TYPE

This menu is for selecting the shape of the tank.

- VERTICAL CYLINDER
- HORIZONTAL CYLINDER
- SPHERE
- USER DEFINE

- HEAD TYPE

This menu is for selecting the HEAD TYPE of the tank.

- CONICAL HEAD
- ELLIPSOIDAL HEAD
- GUPPY HEAD
- SPHERICAL HEAD
- FLAT HEAD



- HORIZONTAL type is applied to the cylinder only, and not applied to other tank.

- **BOTTOM TYPE**

This menu is for selection the bottom type of the tank.

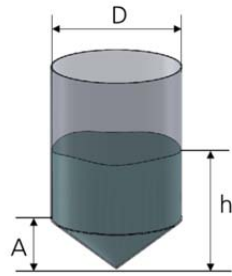
- CONICAL BOTTOM
- ELLIPSOIDAL BOTTOM
- SPHERICAL BOTTOM
- FLAT BOTTOM



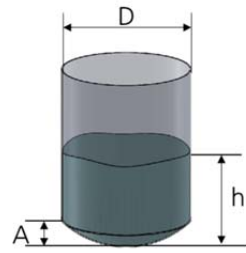
- **VERTICAL** This type is applied to the cylinder only, and not applies to other tank.

-

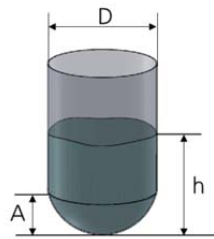
- VERTICAL CYLINDER TANK TYPE



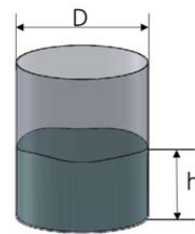
CONICAL BOTTOM TYPE



ELLIPSOIDAL BOTTOM TYPE



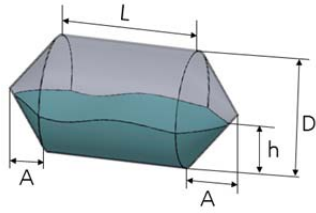
SPHERICAL BOTTOM TYPE



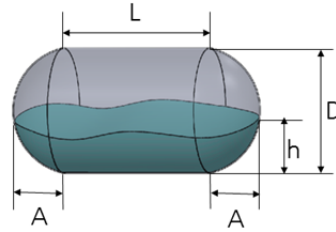
FLAT BOTTOM TYPE

- D: Diameter of the tank
- A: Distance of BOTTOM
- h: Measured level

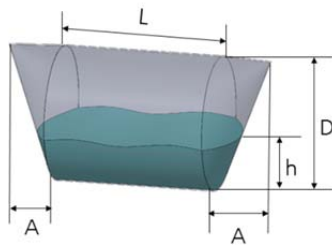
- HORIZONTAL CYLINDER TANK TYPE



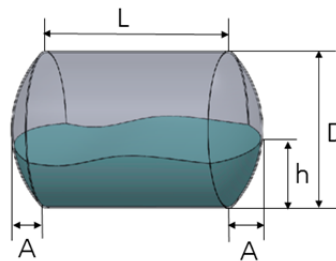
CONICAL HEAD TYPE



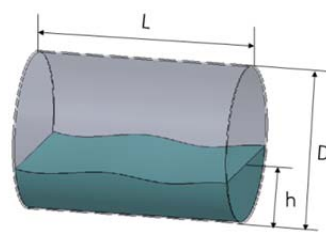
ELLIPSOIDAL HEAD TYPE



GUPPY HEAD TYPE



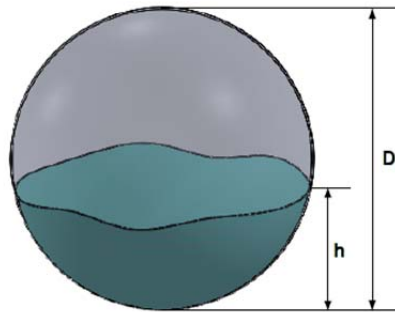
SPHERICAL HEAD TYPE



FLAT HEAD TYPE

- D: Diameter of the tank
- L: The length of the straight section
- A: Distance of HEAD
- h: Measured level

- SPHERE TANK TYPE



- D: Diameter of the tank
- h: Measured level

2) VARIABLE

| [222]VARIABLE | |
|---------------|---------|
| D | 05.00m |
| L | 10.00m |
| A | +00.50m |

- D
This is the menu to enter the diameter of the tank. If you use the SPHERE TANK, please enter $2r$ as value.
- L
This menu is to enter the length of the straight section of the HORIZONTAL CYLINDER.
- A
This menu is to enter the length of the HEAD and the BOTTOM of the VERTICAL CYLINDER and HORIZONTAL CYLINDER.

3) LEVEL/ VOLUME TABLE

This menu is used when setting the type of tank as USER DEFINE.

| [223]LEVEL TABLE | |
|------------------|--------|
| INDEX 1 | 00.00m |
| INDEX 2 | 00.00m |
| INDEX 3 | 00.00m |
| | ••• |
| INDEX 29 | 00.00m |
| INDEX 30 | 00.00m |

- INDEX

This menu is for setting the point of 30 places within the tank. LEVEL value and VOLUME value at each point is entered in the same INDEX and saved as TABLE.

4) VOLUME SIMULATION

| [225]VOLUME SIMULATION | |
|------------------------|----------------------|
| LEVEL | 00.00m |
| VOLUME | 0.00m ³ |
| MAX VOLUME | 196.35m ³ |
| RATIO | 0.0 |

- LEVEL

This menu is for setting the certain LEVEL value that is used to calculate VOLUME.

- VOLUME

This menu is for the output the VOLUME value that is calculated by the LEVEL value that was entered.

- MAX VOLUME

This menu is for the output the MAX VOLUME of the tank that set currently.

- RATIO

This menu is for the output the VOLUME and MAX VOLUME.

2.3 RELAY

| |
|--|
| [230]RELAY |
| RELAY 1 RELAY 2 RELAY 3 RELAY 4 RELAY 5 RELAY 6 RELAY SIMULATION |

| |
|---|
| [231]RELAY 1 |
| FUNCTION NONE OPERATE SENSOR 1 GROUP 1 ON POINT 00.00m OFF POINT 00.00m |

Relay 1-6

1) FUNCTION

This menu is for selecting RELAY use state.

- NONE: Not use this RELAY
- LIMIT: Operate each RELAY depending on the value of the ON / OFF.
- ALTERNATE: Operate RELAY in sequence on the basis of the measured value and the ON / OFF POINT value of the group that has been set.
Ex) If There are RELAY1 and RELAY 2 at the GROUP1, RELAY 1 is working to the first ON / OFF point and then RELAY 2 is working at the second ON / OFF point.
- ALARM: This menu is for generating alarm signals when errors that caused by error on the Fail Safe Time value occurs consistently.

2) OPERATE

It is a menu for selecting a sensor the corresponding relay is operating.

- Selection: SENSOR1/ SENSOR2

3) GROUP

This menu is for setting a group for ALTERNATE.

- Selection range: 1~3

4) ON POINT

This menu is for setting a point that RELAY is ON. If OFF POINT is less than ON POINT, RELAY become ON when the measured value is bigger than ON POINT. If OFF POINT is bigger than ON POINT, RELAY become ON when the measured value is less than ON POINT.

5) OFF POINT

This menu is for setting a point that RELAY is OFF.

If OFF POINT is less than ON POINT, RELAY become OFF when the measured value is less than OFF POINT. If OFF POINT is bigger than ON POINT, RELAY become ON when the measured value is bigger than OFF POINT.

RELAY SIMULATION

The ON / OFF test of RELAY is available.

| [237]RELAY SIMULATION | |
|-----------------------|-----|
| RELAY 1 | OFF |
| RELAY 2 | OFF |
| RELAY 3 | OFF |
| RELAY 4 | OFF |
| RELAY 5 | OFF |
| RELAY 6 | OFF |

2.4 CURRENT OUTPUT

This menu is for setting that is needed to convert the measured value to current output.

| |
|--|
| [240]CURRENT OUTPUT |
| CURRENT OUTPUT 1 CURRENT OUTPUT 2 CURRENT SIMULATION |

1) CURRENT OUTPUT 1

| |
|--|
| [241]CURRENT OUTPUT 1 |
| 4mA OUT 00.00m 20mA OUT 10.00m ERROR 22mA |

- 4mA
This menu is to enter the minimum level that the current output is 4mA.
- 20mA
This menu is to enter the maximum level that the current output is 20mA.
- ERROR
This menu is for setting the operation of the current output when an error occurs.
 - 3.8Ma
 - HOLD
 - 22mA

2) CURRENT OUTPUT 2

Same process as the CURRENT OUTPUT 1

3) CURRENT SIMULATION

This menu is that displays the output of CURRENT OUTPUT SENSOR1 and SENSOR2 as selected value.

- MEASURE
- 3.8mA
- 4mA
- 12mA
- 20mA
- 22mA

| [243]CURRENT SIMULATION | |
|-------------------------|---------|
| OUTPUT 1 | MEASURE |
| OUTPUT 2 | MEASURE |

2.5 COMMUNICATION SETUP

| |
|------------------------------|
| [250]COMMUNICATION SETUP |
| RS-232 SETUP RS-485 SETUP |

RS-232 SETUP

| |
|-------------------------------|
| [251]RS-232 SETUP |
| USE ENABLE |
| BAUDRATE 9600 |
| PARITY NONE |
| STOP BIT 1 |
| DATA BIT 8 |
| PROTOCOL ISTECH |

1) USE

This menu is for selecting the RS-232 use state.

- ENABLE / DISABLE

2) BAUDRATE

This menu is for selecting the transmission speed of RS-232.

- 4800 bps
- 9600 bps
- 14400 bps
- 19200 bps
- 38400 bps
- 57600 bps
- 115200 bps

3) PARITY

This menu is for selecting the Parity bit use state.

- None
- Odd
- Even

4) STOP BIT

This menu is for selecting the size of the STOP BIT of RS-232 data transmission.

- 1 bit (default)
- 2 bit

5) DATA BIT

This menu is for selecting the size of the transmission data of RS-232.

- 8 bit (default)
- 9 bit

6) PROTOCOL

This menu is for selecting the protocol of the measurement data that is output by RS-232.

- SONDAR
- BKCM
- Modbus – RTU
- Modbus–ASCII



- The protocol list can be different according to the communication option when you ordered.

RS-485 SETUP

| [252]RS-485 SETUP | |
|-------------------|--------|
| USE | ENABLE |
| BAUDRATE | 9600 |
| PARITY | NONE |
| STOP BIT | 1 |
| DATA BIT | 8 |
| PROTOCOL | ISTEC |



- The setting method is the same as the RS-232 SETUP on page 53. 6.3 LOGGING SETUP

3. LOGGING SETUP

This menu is for setting LOGGING PERIOD, LOGGING ERASE, USB LOGGING.

| |
|--|
| [300]LOGGING SETUP |
| LOGGING PERIOD LOGGING ERASE USB LOGGING |

3.1 LOGGING PERIOD

This menu is for setting the Logging period of measurement data.

| |
|------------------------|
| [310]LOGGING PERIOD |
| LOGGING PERIOD NONE |

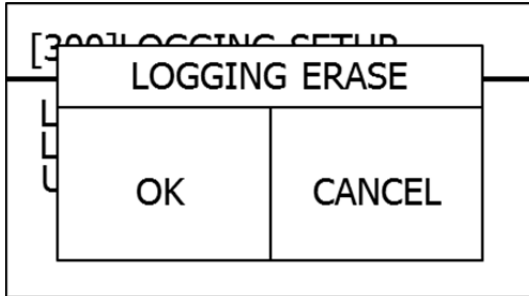
- NONE
- 10 SEC
- 1 MINUTE
- 5 MINUTE
- 10 MINUTE
- 15 MINUTE
- 30 MINUTE
- 60 MINUTE

Maximum storage period according to the data logging period (16,128 point)

| Data logging period | Maximum storage period |
|---------------------|------------------------|
| NONE | - |
| 10 SEC | 2 days |
| 1 MINUTE | 11 days |
| 5 MINUTE | 56 days |
| 10 MINUTE | 112 days |
| 15 MINUTE | 168 days |
| 30 MINUTE | 336 days |
| 60 MINUTE | 672 days |

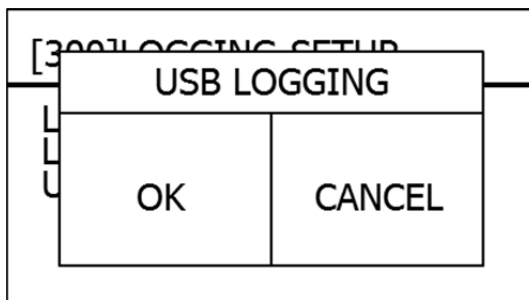
3.2 LOGGING ERASE

If you select LOGGING ERASE, Screen will be displayed as shown in [Figure 6-25] . By selecting OK, it initializes the saved logging.

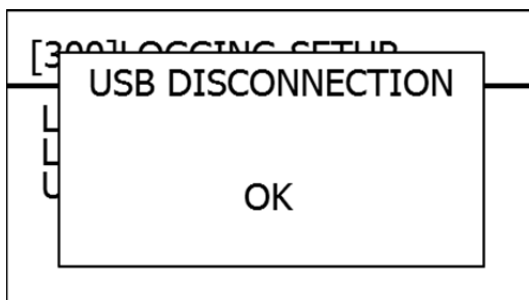


3.3 USB LOGGING

When USB is connected, screen will be displayed as shown in [Figure 6-26] . By selecting OK, it transfers logging data to USB as EXCEL file.



When USB is not connected, screen will be displayed as shown in the picture below. Please connect USB, and then click the OK button, the error pop-up will disappear.



4. SYSTEM SETUP

| |
|--|
| [400]SYSTEM SETUP |
| SYSTEM INFO SYSTEM ID SYSTEM TIME PASSWORD LANGUAGE FAIL SAFE TIME DISPLAY TYPE SETTING BACKUP RESET |

4.1 SYSTEM INFO

| |
|---|
| [410]SYSTEM INFO |
| VERSION 0.0.1 SYSTEM ID 0 UNIT METER |

This menu is for showing system information.

- 1) Version: Firmware version
- 2) SYSTEM ID: System ID for SONDAR protocol
- 3) UNIT: Measurement unit selected by a user

4.2 SYSTEM ID

| | |
|----------------|-----|
| [420]SYSTEM ID | |
| SYSTEM ID | 0 |
| MODBUS ID | 001 |
| 1) | |
| 2) | |

3)

1) SYSTEM ID

This menu is for setting the SYSTEM ID to be used for SONDAR Protocol.

- SYSTEM ID: 0 ~ 99
- MODBUS ID: 1~247

2) Modbus ID

This menu is for setting the Slave ID required when using Modbus Protocol.

4.3 SYSTEM TIME

This menu is for setting the system time. By using the Left / Right direction button, move the cursor to the year / month / day / hour / minute, change the setting using the Up / Down direction button.

- Setting range: JAN/01/2000 00:00 ~ DEC/31/2099 23:59

| |
|-------------------|
| [430]SYSTEM TIME |
| SYSTEM TIME |
| JAN/01/2013/05:54 |

4.4 PASSWORD

This menu is for setting a password by its user. No password is set at the factory. After you set a password, you must enter the password each time there is a menu change.

- Password setting range: 0000~9999

| |
|---------------|
| [440]PASSWORD |
| PASSWORD |
| 0000 |



- User can't configure the menus when user forgets the password. Please note password number and pay attention not to lose it.

4.5 LANGUAGE

| |
|---------------------|
| [450]LANGUAGE |
| LANGUAGE ENGLISH |

This is the menu for setting the system language. The current support language is English only.

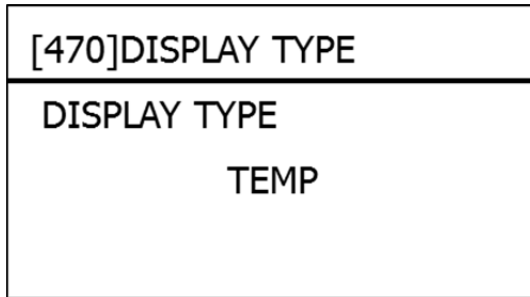
4.6 FAIL SAFE TIME

| |
|---------------------------|
| [460]FAIL SAFE TIME |
| FAIL SAFE TIME 300 sec |

This menu is for setting the time for then alarm when the device malfunctions or there is no receiving signal.

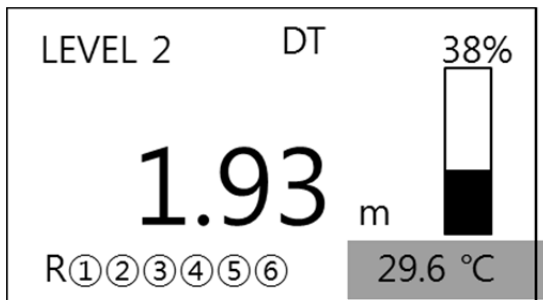
- [Default setting: 300sec, Setting range: 20 ~ 999sec]

4.7 DISPLAY TYPE



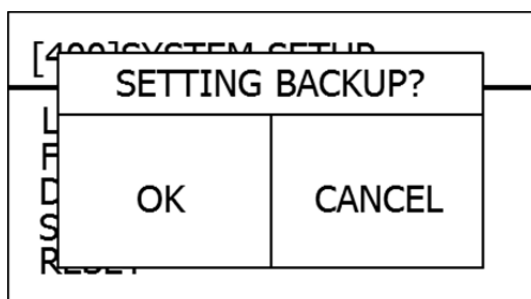
This menu is for selecting the display option in DISPLAY A. The ambient temperature or the current output can be displayed by user's selection.

- Setting range: TEMP or CURRENT



4.8 SETTING BACKUP

This menu is for saving the menu setting value by user. When user select menu, screen will be displayed as shown in picture below.



4.9 RESET

| |
|----------------------------|
| [490]RESET |
| MASTER RESET USER RESET |

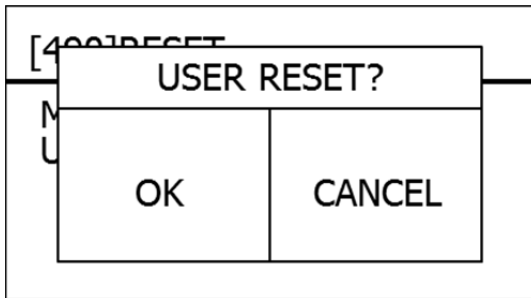
MASTER RESET

This menu is for resetting the device that is currently operating. If you select MASTER RESET function, the device will be initialized as default setting.

| |
|---------------|
| [490]RESET |
| MASTER RESET? |
| OK |
| CANCEL |

USER RESET

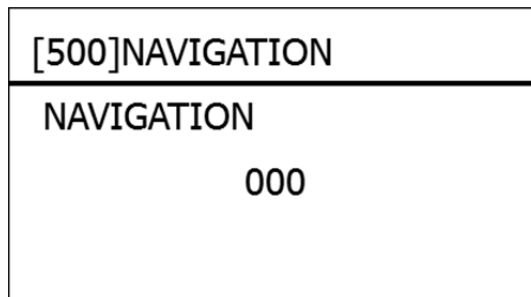
This menu is for resetting the device that is currently operating. If you select USER RESET, the device will be initialized as menu value that is stored at SETTING BACKUP.



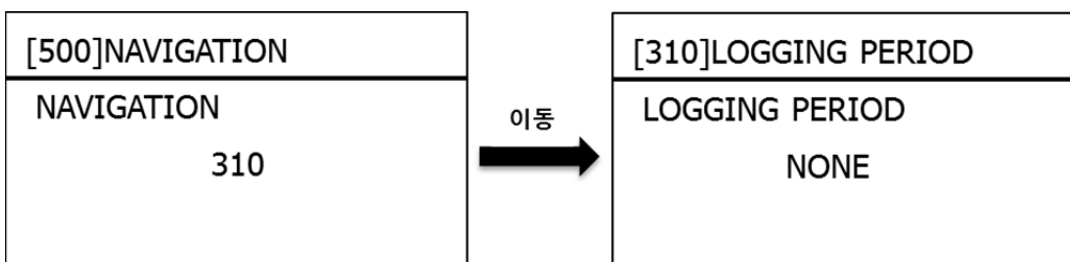
6.5 NAVIGATION

This menu allows for quick access to specific menus directly by entering the preset menu number. Refer to the menu list of SL-100S.

* The menu list is page95.



*Ex) If you want to move to the menu of LOGGING PERIOD, please enter menu number [310].
By entering menu number [310], you can access LOGGING PERIOD menu immediately..*



Maintenance

VII. Maintenance

Regular Inspection

- ✓ There are no contaminants on the surface of sensor.
- ✓ Current output is working in the normal range of 4-20mA.
- ✓ Value displayed at the screen is same as actual level value.
- ✓ Rating power supply is approved.

1. Battery

The battery which is equipped on the main board of SL-100S is CR-2032 from Maxwell Co. The normal product life is around 10 years but it is subject to change by the environment and operating condition. The life can be shortened. Before the battery is out, check it regularly and change it.



- If the battery is out, the time data cannot back-up.
- The battery brand and specification will be subject to change without prior notice.

2. SENSOR

- 1) Check the sensor cable regularly.
- 2) Check the sensor bottom if there is contaminant and clean the bottom of the sensor.

3. Warranty Period

Warranty period is 3 years for SL-100S but if the problem is caused by user's fault or misuse, the repair charge will be incurred.

4. Repair Service

When some problem is occurred in the product, the error code displays on the screen, it shows what the problem is. The error code information can be founded in this manual. Even though conduct every process by the trouble shootings in the manual, still the problem exists, contract an official distributor or SONDAR customer center.

When the product is sent for the repair, the repair request form has to be filled out and enclose it with the products.

Despite of being in warranty period, if the problem is caused by user's fault or misuse, the repair charge will be incurred.

Trouble shooting

VIII. Trouble shooting

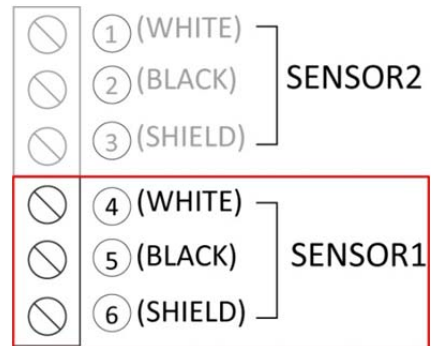
When some problem is occurred in SL-100S, the error code displays on the screen, it shows what the problem is. The error code information can be founded by scanning QR Code inside the controller door.

Error code list

| ERROR CODE | CAUSE |
|------------|--|
| E1101 | Not connected SENSOR1 |
| E2101 | Not connected SENSOR2 |
| E0101 | Not connected SENSOR1 and SENSOR2 |
| E1102 | Temperature error of SENSOR1 |
| E2102 | Temperature error of SENSOR2 |
| E0102 | Temperature error of SENSOR1 and SENSOR2 |
| E0401 | External Temperature sensor Error |
| E0210 | Flash memory error |
| E0202 | EEPROM error |
| E0203 | Real time clock error |
| E1204 | The received signal of SENSOR1 is abnormal |
| E2204 | The received signal of SENSOR2 is abnormal |
| E0204 | The received signal of SENSOR1 and SENSOR2 is abnormal |

E1101

This error appears when sensor1 is not connected to the terminal or if it is connected to the terminal incorrectly. Please proceed as follows to solve this problem.



When the sensor doesn't make sound radiation

(1) Please check that you can hear the sound emitted from the ultrasonic sensor. If you cannot hear the sound, please refer to (2). If you can hear the sound, please refer to (5).

(2) Please check the sensor cable (white, black) visually or by using Multi-meter if it is cut or shorted. If you find a problem, please repair or replace the cable. If the problem has not been solved yet, please refer to (3)



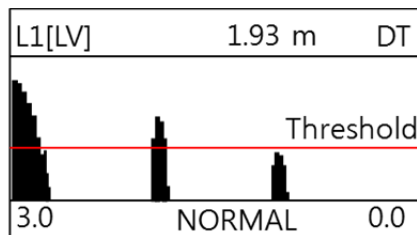
(3) Please check that the sensor cable (white, black) is properly connected on the terminal at the exact position. If it is not, please connect the sensor cable properly.

(4) If the problem has not been solved yet even though you have confirmed the process above (2) and (3), please contact our service center or your local dealer.



When the sensor makes sound radiation

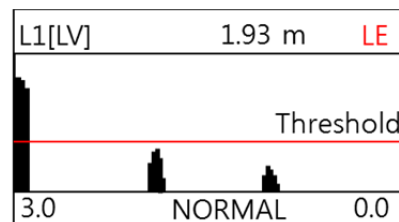
- (5) If you can hear the sound emitted from the ultrasonic sensor, please check the strength of the transmitted signal at the Echo Trend graph on the screen. You can suspect a faulty sensor if the transmitted signal is weak or received signal shows lower waveform than the Threshold value.



Transmitting Signal

Receiving Signal

Normal condition



Transmitting Signal

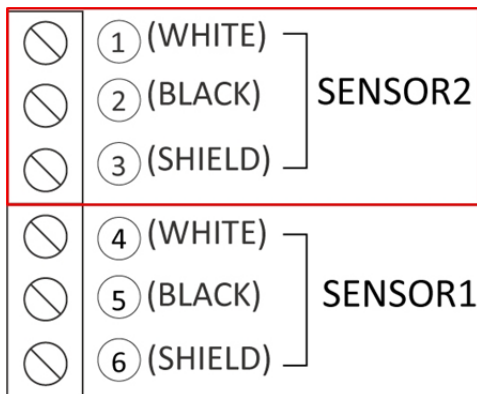
Receiving Signal

Abnormal condition

***** To see Echo Trend graph, press the [down] button on the Measuring Mode till the graph shows up on the screen.***

- (6) If there is a spare sensor, please replace it with other sensors and test again. If the changed sensor operates properly, the sensor is defective. If it doesn't operate normally even if the other sensor has been replaced, you should check the controller.
- (7) If you don't have a spare sensor, the faulty sensor needs repair or replacement. Please contact our service center or your local dealer.

E2101

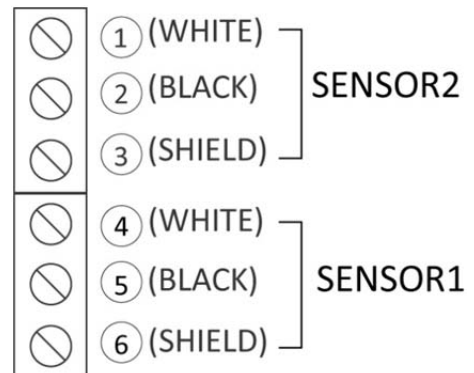


This error appears when sensor2 is not connected to the terminal or if it is connected to the terminal incorrectly. Please proceed as follows to solve this problem.

Processing method is the same as the E1101. (Please refer to Page _)

E0101

This error appears when sensor1 and sensor2 are not connected to the terminal or connected to the terminal incorrectly. Please proceed as follows to solve this problem.



Processing method is the same as the E1101. (Please refer to Page81)

E1102

This error appears when the built-in temperature sensor in sensor1 is not operating properly. The value of the temperature on the screen could be displayed abnormally. Please proceed as follows to solve this problem.

When the sensor doesn't make sound radiation

(1) Please check that you can hear the sound emitted from the ultrasonic sensor. If you cannot hear the sound, please refer to (2). If you can hear the sound, please refer to (5).

(2) Please check the sensor cable (white, black) visually or by using Multimeter if it is cut or shorted. If you find a problem, please repair or replace it. If the problem has not been solved yet, please refer to (3)



(3) Please check that the sensor cable (white, black) is properly connected on the terminal at the exact position. If it is not, please connect the sensor cable properly.



(4) If the problem has not been solved yet even though you have confirmed through the process (2) and (3), please contact our service center or your dealer.

When the sensor makes sound radiation

- (5) If you can hear the sound emitted from the ultrasonic sensor, please check the color of the sensor cable (black & shield) that connected to the terminal block. If it is not connected correctly, please re-assemble according to the color.
- (6) Please check that the ultrasonic sensor is not connected to the sensor terminal block or the bolt is not tightened. If reconnection is needed, please reconnect it.
- (7) If the problem has not been solved yet even though you have confirmed the process above (5) and (6) please check the resistance of cable (black & shield). At room temperature, it is normal if the resistance value is within about $9k\Omega \sim 15k\Omega$. If the resistance value is over this range, the built-in temperature sensor is defective. A faulty sensor needs repair or replacement. Please contact our service center or your local dealer.
- (8) If there is an external thermometer, you can use it instead of the built-in temperature sensor. When you change the temperature sensor, you have to change the menu option as well. The menu is as follows.

| [211]SENSOR 1 | |
|---------------|-----------|
| USE | m |
| EMPTY | 10.00m |
| DEAD ZONE | 00.30m |
| TX POWER | 30 |
| RX GAIN | 200 |
| TYPE | LEVEL |
| THRESHOLD | 7 |
| TEMP TYPE | INSIDE |
| TEMP FIX | 25.00°C |
| TEMP | 25.00°C |
| DAMPING | NORMAL |
| SOUND SPEED | 0331.5m/s |
| SPEED FACTOR | 0.60m/°C |
| LEVEL OFFSET | 0000.00m |

→ OUTSIDE

E2102

This error appears when the built-in temperature sensor in sensor2 is not operating properly. The value of the temperature on the screen could be displayed abnormally. Please proceed as follows to solve this problem.

Processing method is the same as the E1102. (Please refer to Page 83)

E0102

This error appears when the built-in temperature sensor in sensor1 and sensor2 are not operating properly. The value of the temperature on the screen could be displayed abnormally. Please proceed as follows to solve the problem.

Processing method is the same as the E1102. (Please refer to Page 83)

E0401

This error appears when an external thermometer that connected to the controller is not operating properly. Please proceed as follows to solve this problem.

When the temperature type is selected incorrectly in the menu

- (1) If you select “OUTSIDE” on the TEMP TYPE when setting the menu of the sensor, the value is measured based on the temperature value that measured by the external temperature sensor. Please check if you chose “OUTSIDE” instead of “INSIDE” on the TEMP TYPE menu even though an external temperature sensor is not connected.

| [211]SENSOR 1 | |
|---------------|-----------|
| USE | m |
| EMPTY | 10.00m |
| DEAD ZONE | 00.30m |
| TX POWER | 30 |
| RX GAIN | 200 |
| TYPE | LEVEL |
| THRESHOLD | 7 |
| TEMP TYPE | INSIDE |
| TEMP FIX | 25.00°C |
| TEMP | 25.00°C |
| DAMPING | NORMAL |
| SOUND SPEED | 0331.5m/s |
| SPEED FACTOR | 0.60m/ °C |
| LEVEL OFFSET | 0000.00m |

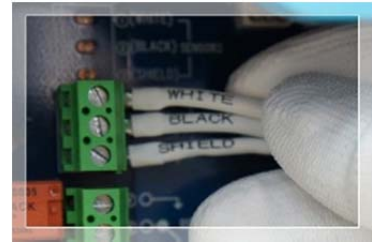
→ OUTSIDE

When the temperature sensor is connected incorrectly

- (2) Please check the sensor cable visually or by using Multimeter if it is cut or shorted. If you find a problem, please repair or replace it. If the problem has not been solved yet, please refer to (3)

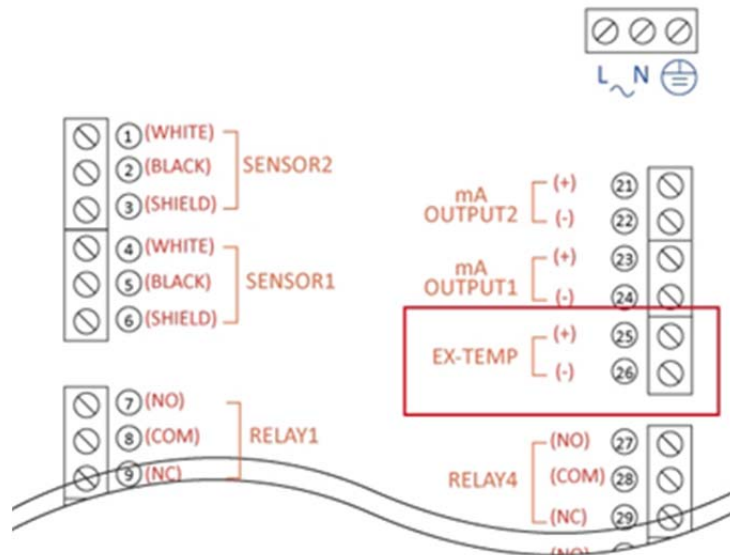


- (3) Please check that the sensor cable is properly connected on the terminal at the exact position. If you find a problem, please connect the sensor cable properly.



- (4) If the problem has not been solved yet even though you have confirmed the process above (2) and (3), please contact our service center or your local dealer.

SL-100S Terminal Block



E0201

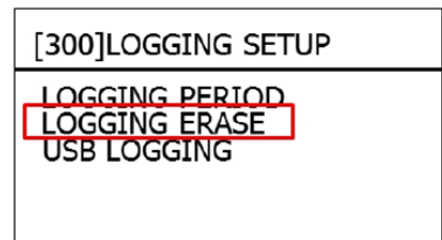
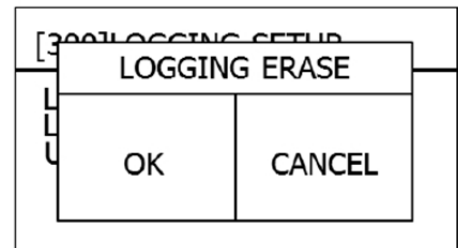
This error appears when the flash memory inside controller is not operating properly. Please proceed as follows to solve the problem.

Logging data Recovery

If the flash memory is defective, it is difficult to recover the stored data. For the recovery of the lost data, you will need to send the product to our service center for repair.

Memory Reset

- (1) Please try to reset the flash memory at the menu.
- (2) Please refer to the menu directory as follows. All data will be deleted and the memory will be rest.
- (3) If the problem continues, please contact our service center or your local dealer.



E0202

(1) This error appears when the EEPROM memory inside controller is not operating properly. Please proceed as follows to solve the problem.

(2) Please contact our service center immediately. Do not attempt to fix it yourself

(EEPROM memory stores the important information about the product and cannot be handled by non-experts. If you need specific inspection and repair, please contact our service center or your local dealer.)

E0203

This error appears when the REAL TIME CLOCK inside of the controller is not operating properly. Please proceed as follows to solve the problem.

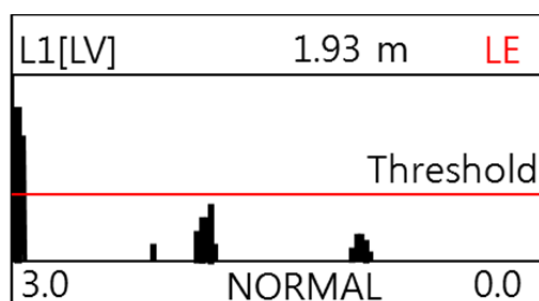
(1) Please contact our service center immediately. Do not attempt to fix it yourself

(2) REAL TIME CLOCK is sensitive and cannot be handled by non-experts. If you need specific inspection and repair, please contact our service center or your local dealer.

E1204

This error appears when the received signal from sensor1 is abnormal. “LE” will be flashing on the screen. Please proceed as follows to solve the problem.

- (1) Check the installation position of the sensor
- (2) Please check the strength of the received signal at the Echo Trend graph on the screen. If the received signal shows lower waveform than the default Threshold value, please check the installation location of the sensor.



Transmitting Signal

Receiving Signal

**** To see Echo Trend graph, press the [down] button on the Measuring Mode till the graph shows up on the screen.**

- (3) Please make sure that the sensor is installed perpendicularly to the object you're measuring. If it is not, please reinstall it correctly.
- (4) Check the contamination on the bottom of the sensor
- (5) Please check if there is a contaminant adhering to the radiating surface. If the radiating surface is contaminated, please wipe it with a soft cloth.



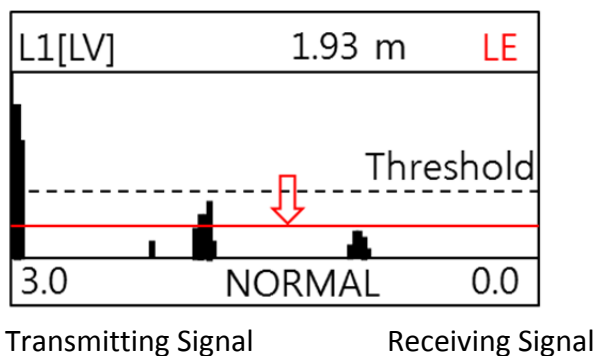
Adjust settings menu corresponding to the measurement object

- (6) Please check if the measurement object is the ultrasonic absorber (foam, sludge). If it is, the received signal is attenuated than normal condition. Please adjust TX POWER, RX GAIN, and Threshold value at menu [211] to set an appropriate status for your environment.

TX POWER: Please change the default value from 30 to 50 ~ 70

RX GAIN: Please change the default value from 85 to 90 ~ 95

- (7) If "LE" appears on the screen repeatedly and received value is lower than Threshold value, please change the default Threshold value from 4(0.8V) to 3(0.5V). if it is operating normally, "DT" will be displayed on the screen during normal operation.



**** To see Echo Trend graph, press the [down] button on the Measuring Mode till the graph shows up on the screen.**

- (8) Check the bottom distance setting
- (9) Please check that the value of the EMPTY has been set within the range.

| [211]SENSOR 1 | |
|---------------|-----------|
| USE | m |
| EMPTY | 10.00m |
| DEAD ZONE | 00.30m |
| TX POWER | 30 |
| RX GAIN | 200 |
| TYPE | LEVEL |
| THRESHOLD | 7 |
| TEMP TYPE | INSIDE |
| TEMP FIX | 25.00°C |
| TEMP | 25.00°C |
| DAMPING | NORMAL |
| SOUND SPEED | 0331.5m/s |
| SPEED FACTOR | 0.60m/ °C |
| LEVEL OFFSET | 0000.00m |

- (10) If the problem keeps occurring, please contact our service center or your local dealer.

E2204

This error appears when the signal from sensor2 is not received normally. “LE” will be flashing on the screen. Please proceed as follows to solve the problem.

Processing method is the same as the E1204. (Please refer to Page90.)

E0204

This error appears when the signals from sensor1 and sensor2 are abnormal. "LE" will be flashing on the screen. Please proceed as follows to solve the problem.

Processing method is the same as the E1204. (Please refer to Page 90)

APPENDIX A

SL-100S MENU LIST

APENDIX A. SL-100S MENU LIST

QUICK SETUP

| QUICK SETUP(100) | | | |
|--------------------------|-----------|--------------------------------------|---------|
| 1st MENU | 2nd MENU | Range | Default |
| SENSOR 1 (110) | UNIT | mm/ cm/ m/ in/ yd/ ft | m |
| | BOTTOM | 0.3 ~ 99.99m | 10m |
| | DEAD ZONE | 0.3 ~ 99.99m | 0.3m |
| | 4mA OUT | -99.99 ~ 99.99m | 0m |
| | 20mA OUT | -99.99 ~ 99.99m | 10m |
| SENSOR 2 (120) | UNIT | mm/ cm/ m/ in/ yd/ ft | m |
| | BOTTOM | 0.3 ~ 99.99m | 10m |
| | DEAD ZONE | 0.3 ~ 99.99m | 0.3m |
| | 4mA OUT | -99.99 ~ 99.99m | 0m |
| | 20mA OUT | -99.99 ~ 99.99m | 10m |
| CURRENT SIMULATION (130) | OUTPUT 1 | MEASURE/3.8mA/ 4mA/ 12mA/ 20mA/ 22mA | MEASURE |
| | OUTPUT 2 | MEASURE/3.8mA/ 4mA/ 12mA/ 20mA/ 22mA | MEASURE |

DETAIL MENU

| 1 st MENU | 2 nd MENU | 3rd MENU | 4th MENU | Input Range | Default |
|----------------------------|----------------------|--------------------|--------------|---|----------|
| LEVEL METER SETUP (200) | LEVEL (210) | SENSOR 1 (211) | USE | ENABLE/DISABLE | ENABLE |
| | | | SENSOR TYPE | LXD-10 / LXD-15 | LXD-10 |
| | | | BOTTOM | 0.3 ~ 99.99m | 10m |
| | | | DEAD ZONE | 0.3 ~ 99.99m | 0.3m |
| | | | TX POWER | 1~100 | 50 |
| | | | RX GAIN | 0~100 | 93 |
| | | | TYPE | DISTANCE/ LEVEL/ SPACE/ VOLUME | LEVEL |
| | | | N.THRES-HOLD | 1~10 | 4(0.8V) |
| | | | F.THRES-HOLD | 1~10 | 4(0.8V) |
| | | | TEMP TYPE | INSIDE/ OUTSIDE/ FIX | INSIDE |
| | | | TEMP FIX | 0~60℃ | 25℃ |
| | | | TEMP | 0~60℃ | |
| | | | DAMPING | SLOW/ NORMAL/ FAST/ VERY FAST | NORMAL |
| | | | SOUND SPEED | 1~9999 m/s | 331.5m/s |
| | | SOUND SPEED FACTOR | -2.0~2.0 m/℃ | 0.60m/℃ | |
| | | LEVEL OFFSET | -99m~999.9m | 0m | |
| | | SENSOR 2 (212) | USE | ENABLE/ DISABLE | DISABLE |
| | | | SENSOR TYPE | LXD-10 / LXD-15 | LXD-10 |
| | | | BOTTOM | 0.3 ~ 99.99m | 10m |
| | | | DEAD ZONE | 0.3 ~ 99.99m | 0.3m |
| | | | TX POWER | 1~100 | 30 |
| | | | RX GAIN | 0~100 | 85 |
| | | | TYPE | DISTANCE/ LEVEL/ SPACE/ VOLUME | LEVEL |
| | | | THRES-HOLD | 0.324 / 0.664 / 0.813 / 1.075 / 1.402 / 1.648 / 1.927 / 2.19 / 2.517 / 2.665 | 1.927V |

| 1st MENU | 2 nd MENU | 3rd MENU | 4th MENU | Input Range | Default |
|-------------------------|----------------------|--------------------|--------------------------------|---|-------------------|
| LEVEL METER SETUP (200) | LEVEL (210) | SENSOR 2 (212) | TEMP TYPE | INSIDE/ OUTSIDE/ FIX | INSIDE |
| | | | TEMP FIX | 0~60℃ | 25℃ |
| | | | TEMP | -30 ~80℃ | |
| | | | DAMPING | SLOW/ NORMAL/ FAST/ VERY FAST | NORMAL |
| | | | SOUND SPEED | 1~9999 m/s | 331.5m/s |
| | | | SOUND SPEED FACTOR | -2.0~2.0 m/℃ | 0.61m/℃ |
| | | | LEVEL OFFSET | -99m~999.9m | 0m |
| | UNIT (213) | UNIT | mm/ cm/ m/ in/ yd/ ft | meter | |
| | | TEMP UNIT | ℃ or °F | ℃ | |
| | VOLUME (220) | TYPE (221) | TANK TYPE | HORIZONTAL CYLINDER/ VERTICAL CYLINDER/ SPHERE/ USER DEFINE | VERTICAL CYLINDER |
| | | | HEAD TYPE | CONICAL HEAD/ ELLIPSOIDAL HEAD/ GUPPY HEAD/ SPHERICAL HEAD/ FLAT HEAD | FLAT HEAD |
| | | | BOTTOM TYPE | CONICAL BOTTOM/ ELLIPSOIDAL BOTTOM/ SPHERICAL BOTTOM/ FLAT BOTTOM | FLAT BOTTOM |
| | | VARIABLE (222) | D | 0~50M (Tank diameter) | 5M |
| | | | L | 0~15M (Tank width/height) | 10M |
| | | | A | Head/bottom width(-15M~15M) (+ : convex / - concave) | 0.5M |
| | | LEVEL TABLE (223) | INDEX1~30 | Measured level value by user's tank It has to be matched with the volume table below. | 0 |
| | | VOLUME TABLE (224) | INDEX1~30 | Measured volume value by user's tank. It has to be matched with the level table below. | 0 |
| | | SIMULATION (225) | LEVEL | Simulation level input | 0 |
| | | | VOLUME | Volume | 0 |
| | | | MAX VOLUME | Total volume value display by setting tank condition | 0 |
| RATIO | | | Ratio of Volume and max volume | 0 | |

| 1st MENU | 2 nd MENU | 3rd MENU | 4th MENU | Input Range | Default |
|-------------------------------|----------------------|-------------------------------|-----------|-------------------------------|----------|
| LEVEL METER SETUP (200) | RELAY (230) | RELAY 1 (231) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE |
| | | | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 |
| | | | GROUP | 1~3 | 1 |
| | | | ON POINT | 0~15.5m | 0 |
| | | | OFF POINT | 0~15.5m | 0 |
| | | RELAY 2 (232) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE |
| | | | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 |
| | | | GROUP | 1~3 | 1 |
| | | | ON POINT | -99.99 ~ 99.99m | 0 |
| | | | OFF POINT | -99.99 ~ 99.99m | 0 |
| | | RELAY 3 (233) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE |
| | | | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 |
| | | | GROUP | 1~3 | 1 |
| | | | ON POINT | -99.99 ~ 99.99m | 0 |
| | | | OFF POINT | -99.99 ~ 99.99m | 0 |
| | | RELAY 4 (234) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE |
| | | | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 |
| | | | GROUP | 1~3 | 1 |
| | | | ON POINT | -99.99 ~ 99.99m | 0 |
| | | | OFF POINT | -99.99 ~ 99.99m | 0 |
| | | RELAY 5 (235) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE |
| | | | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 |
| | | | GROUP | 1~3 | 1 |
| | | | ON POINT | -99.99 ~ 99.99m | 0 |
| OFF POINT | -99.99 ~ 99.99m | | 0 | | |
| RELAY 6 (236) | FUNCTION | NONE/ LIMIT/ ALTERNATE/ ALARM | NONE | | |
| | OPERATE | SENSOR 1 / SENSOR 2 | SENSOR 1 | | |
| | GROUP | 1~3 | 1 | | |
| | ON POINT | -99.99 ~ 99.99m | 0 | | |
| | OFF POINT | -99.99 ~ 99.99m | 0 | | |

| 1st MENU | 2 nd MENU | 3rd MENU | 4th MENU | Input Range | Default |
|-------------------------------|----------------------------|---------------------------------|--|--|-----------------|
| LEVEL METER SETUP (200) | RELAY (230) | RELAY SIMULATION (237) | RELAY 1 | ON/ OFF | OFF |
| | | | RELAY 2 | ON/ OFF | OFF |
| | | | RELAY 3 | ON/ OFF | OFF |
| | | | RELAY 4 | ON/ OFF | OFF |
| | | | RELAY 5 | ON/ OFF | OFF |
| | | | RELAY 6 | ON/ OFF | OFF |
| | CURRENT OUTPUT (240) | CURRENT OUTPUT 1 (241) | 4mA | -99.99 ~ 99.99m | 0m |
| | | | 20mA | -99.99 ~ 99.99m | 10m |
| | | | ERROR | HOLD/ 3.8mA/ 22mA | 22mA |
| | | CURRENT OUTPUT 2 (242) | 4mA | -99.99 ~ 99.99m | 0m |
| | | | 20mA | -99.99 ~ 99.99m | 10m |
| | | | ERROR | HOLD/ 3.8mA/ 22mA | 22mA |
| | | CURRENT SIMULATION (243) | OUTPUT 1 | MEASURE/ 3.8mA/ 4mA/ 12mA/ 20mA/ 22mA | MEASURE |
| | | | OUTPUT 2 | MEASURE/ 3.8mA/ 4mA/ 12mA/ 20mA/ 22mA | MEASURE |
| | | COMMUNICATION SETUP (250) | RS-232 SETUP (251) | USE | ENABLE/ DISABLE |
| | BAUDRATE | | | 4800, 9600, 14400, 19200, 38400, 57600, 115200 | 9600 |
| | PARITY | | | NONE/ ODD/ EVEN | NONE |
| | STOP BIT | | | 1 or 2 | 1 |
| | DATA BIT | | | 8 or 9 | 8 |
| | PROTOCOL | | | SONDAR/ BKCM/ Modbus-RTU/ Modbus-ASCII | SONDAR |
| | RS-485 SETUP (252) | | USE | ENABLE/ DISABLE | DISABLE |
| | | | BAUDRATE | 4800, 9600, 14400, 19200, 38400, 57600, 115200 | 9600 |
| | | | PARITY | NONE/ ODD/ EVEN | NONE |
| | | | STOP BIT | 1 or 2 | 1 |
| DATA BIT | | | 8 or 9 | 8 | |
| PROTOCOL | | | SONDAR/ BKCM/ Modbus-RTU/ Modbus-ASCII | SONDAR | |

| 1st MENU | 2 nd MENU | 3rd MENU | 4th MENU | Input Range | Default |
|------------------------|----------------------|----------------|----------|---|----------------|
| LOGGING SETUP (300) | LOGGING PERIOD (310) | LOGGING PERIOD | | NONE/ 10 SEC/ 1 MINUTE/ 5 MINUTE/ 10 MINUTE/ 15 MINUTE/ 30 MINUTE/ 60 MINUTE | NONE |
| | LOGGING ERASE (320) | | | | |
| | USB LOGGING (330) | | | | |
| SYSTEM SETUP (400) | SYSTEM INFO (410) | | | | |
| | SYSTEM ID (420) | SYSTEM ID | | 0~99 | 0 |
| | | MODBUS ID | | 1~247 | 1 |
| | SYSTEM TIME (430) | SYSTEM TIME | | 2000/00/00/ 00:00 ~ 2099/12/31 23:59 | 2013/1/1/00:00 |
| | PASSWORD (440) | PASSWORD | | 0~9999 | 0 |
| | LANGUAGE (450) | LANGUAGE | | ENGLISH | ENGLISH |
| | FAIL SAFE TIME (460) | | | 20~999 sec | 300 sec |
| | DISPLAY TYPE (470) | | | TEMP/ CURRENT | TEMP |
| | SETTING BACKUP (480) | | | | |
| RESET (490) | MASTER RESET (491) | | | | |
| | USER RESET (492) | | | | |
| NAVIGATION (500) | | | | | |

APPENDIX B

RS-232/RS-485 Protocol

APPENDIX B. RS-232/RS-485 Protocol

1. SONDAR PROTOCOL

| Data Field | DATA START | | | | | | System ID | | | YEAR | | | | | | MONTH | | | DAY | | | HOUR | | | MIN. | | |
|-------------|-----------------------|----|----|---------------------|----|---------------|----------------|----|----|---------------------|----|---------------|----------------|----|----|----------|----|-----------------------|-----|---------------|---------------|------|----|----|------|----|--|
| Byte Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | |
| Data | : | D | A | T | A | | 0 | 0 | | 2 | 0 | 1 | 3 | | 0 | 1 | | 0 | 1 | | 0 | 0 | | 0 | 0 | | |
| Data Field | SECOND | | | UNIT | | SENSOR1 Level | | | | | | SENSOR2 Level | | | | | | SENSOR1-SENSOR2 Level | | | | | | | | | |
| Byte Number | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | |
| Data | 0 | 0 | | M | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Data Field | SENSOR1-SENSOR2 Level | | | | | | SENSOR1 Volume | | | | | | SENSOR2 Volume | | | | | | | | | | | | | | |
| Byte Number | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | |
| Data | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Data Field | TEMP. UNIT | | | SENSOR1 TEMPERATURE | | | | | | SENSOR2 TEMPERATURE | | | | | | DATA END | | | | | | | | | | | |
| Byte Number | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | | | | | | |
| Data | | C | | +/- | 0 | 0 | 0 | 0 | . | 0 | | +/- | 0 | 0 | 0 | 0 | . | 0 | | Wn | Wr | | | | | | |

2. DATA FORMAT

- System ID: System ID
- YEAR/MONTH/DAY/HOUR/MINUTE/SECOND : DATA LOGGING TIME
- UNIT: MEASUREMENT UNIT

| UNIT | | | | | |
|------|----|---|----|----|----|
| mm | cm | m | ft | in | yd |

- SENSOR1 Level: Measurement value of SENSOR1.
- SENSOR2 Level: Measurement value of SENSOR2.
- SENSOR1-SENSOR2 Level: Differentiation subtracted SENSOR2 from SENSOR1
- SENSOR2-SENSOR1 Level: Differentiation subtracted SENSOR1 from SENSOR2.
- SENSOR1 Volume: Measurement value of SENSOR1 Volume.
- SENSOR2 Volume: Measurement value of SENSOR2 Volume.
- Temp. unit : the unit of temperature

| Temperature unit | |
|------------------|----|
| C | °C |
| F | °F |

- SENSOR1 Temperature: Temperature of SENSOR1
- SENSOR2 Temperature: Temperature of SENSOR1
- DATA END: The sign of DATA end. “\n\r(Line feed(0x12),carrage return(0x15))”

2. BKCM PROTOCOL

“This protocol is designed for a company. It isn’t printed in this manual.”

3. Modbus

SL-100S provides Modbus RTU and Modbus ASCII. It is Read Holding Registers only, Modbus ID is available between 1~ 247. Modbus ID setting menu locates as below.

- SYSTEM SETUP->SYSTEM ID->Modbus ID

| Type | Description | Start Register | | Register Offset | | Registers | Data Description |
|--------|--------------------------|----------------|---------|-----------------|---------|-----------|----------------------|
| | | Hex | Decimal | Hex | Decimal | | |
| ID | Product code | 8001 | 32769 | 8000 | 32768 | 1 | 0 = Level(SL-100S) |
| | | | | | | | 10 = Flow(SF-500S) |
| | | | | | | | 20 = Sludge(SL-300S) |
| Unit | Measurement Unit (Level) | 8002 | 32770 | 8001 | 32769 | 1 | 1 = Meter |
| | | | | | | | 2 = Millimeter |
| | | | | | | | 3 = Centimeter |
| | | | | | | | 4 = feet |
| | | | | | | | 5 = inch |
| | | | | | | | 6 = yard |
| | Temperature Unit | 8004 | 32772 | 8003 | 32771 | 1 | 0 = °C |
| 1 = °F | | | | | | | |

| Type | Description | Start Register | | Register Offset | | Registers | Data Description | |
|----------------------|----------------------|----------------|---------|-----------------|---------|-----------|----------------------|-------------|
| | | Hex | Decimal | Hex | Decimal | | | |
| Data | Distance1 | 8011 | 32785 | 8010 | 32784 | 2 | SENSOR1 Distance | float |
| | Level1 | 8013 | 32787 | 8012 | 32786 | 2 | SENSOR1 level | float |
| | Space1 | 8015 | 32789 | 8014 | 32788 | 2 | SENSOR1 space | float |
| | Volume1 | 8017 | 32791 | 8016 | 32790 | 2 | SENSOR1 volume | float |
| | Distance2 | 8019 | 32793 | 8018 | 32792 | 2 | SENSOR2 Distance | float |
| | Level2 | 801B | 32795 | 801A | 32794 | 2 | SENSOR2 level | float |
| Data | Space2 | 801D | 32797 | 801C | 32796 | 2 | SENSOR2 space | float |
| | Volume2 | 801F | 32799 | 801E | 32798 | 2 | SENSOR2 volume | float |
| | Temp 1(inside) | 802B | 32811 | 802A | 32810 | 2 | SENSOR1 temperature | float |
| | Temp 2(inside) | 802D | 32813 | 802C | 32812 | 2 | SENSOR2 temperature | float |
| | Temp (outside) | 802F | 32815 | 802E | 32814 | 2 | Outside temperature | float |
| Relay | Relay control status | 8031 | 32817 | 8030 | 32816 | 1 | Bit Mapped | |
| | | | | | | | 0bxxxx xxx0 / (0x00) | Relay 1 Off |
| | | | | | | | 0bxxxx xxx1 / (0x01) | Relay 1 On |
| | | | | | | | 0bxxxx xx0x / (0x00) | Relay 2 Off |
| | | | | | | | 0bxxxx xx1x / (0x02) | Relay 2 On |
| | | | | | | | 0bxxxx x0xx / (0x00) | Relay 3 Off |
| | | | | | | | 0bxxxx x1xx / (0x04) | Relay 3 On |
| | | | | | | | 0bxxxx 0xxx / (0x00) | Relay 4 Off |
| | | | | | | | 0bxxxx 1xxx / (0x08) | Relay 4 On |
| | | | | | | | 0bxxx0 xxxx / (0x00) | Relay 5 Off |
| | | | | | | | 0bxxx1 xxxx / (0x10) | Relay 5 On |
| | | | | | | | 0bxx0x xxxx / (0x00) | Relay 6 Off |
| 0bxx1x xxxx / (0x20) | Relay 6 On | | | | | | | |

Request PDU Example

- Product code Request

| Function Code | Data Request | |
|---------------|-----------------|----------|
| | Register Offset | Quantity |
| 0 X 03 | 0 X 8000 | 0 X 0001 |

- Distance, Level, Space, Volume Request

| Function Code | Data Request | |
|---------------|-----------------|----------|
| | Register Offset | Quantity |
| 0 X 03 | 0 X 8000 | 0 X 0002 |
| 0 X 03 | 0 X 8012 | 0 X 0002 |
| 0 X 03 | 0 X 8014 | 0 X 0002 |
| 0 X 03 | 0 X 8016 | 0 X 0002 |

Modbus Register Data type

- Data field: 4byte float type
- ID, UNIT, Relay field: Unsigned short(2byte) type

APPENDIX C

Volume Table

APPENDIX C. Volume Table

VERTICAL CYLINDER - CONICAL BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 0.13 | 0.03 | 0.01 | 1.18 | 0.29 | 0.07 | 3.27 | 0.82 | 0.20 | 6.41 | 1.60 | 0.40 | 10.60 | 2.65 | 0.66 |
| | 1.0 | 0.52 | 0.26 | 0.07 | 4.71 | 2.36 | 0.59 | 13.09 | 6.54 | 1.64 | 25.66 | 12.83 | 3.21 | 42.41 | 21.21 | 5.30 |
| | 1.5 | 0.92 | 0.65 | 0.22 | 8.25 | 5.89 | 1.99 | 22.91 | 16.36 | 5.52 | 44.90 | 32.07 | 10.82 | 74.22 | 53.01 | 17.89 |
| | 2.0 | 1.31 | 1.05 | 0.52 | 11.78 | 9.42 | 4.71 | 32.72 | 26.18 | 13.09 | 64.14 | 51.31 | 25.66 | 106.03 | 84.82 | 42.41 |
| | 2.5 | 1.70 | 1.44 | 0.92 | 15.32 | 12.96 | 8.25 | 42.54 | 36.00 | 22.91 | 83.38 | 70.55 | 44.90 | 137.84 | 116.63 | 74.22 |
| | 3.0 | 2.09 | 1.83 | 1.31 | 18.85 | 16.49 | 11.78 | 52.36 | 45.81 | 32.72 | 102.63 | 89.80 | 64.14 | 169.65 | 148.44 | 106.03 |
| | 3.5 | 2.49 | 2.23 | 1.70 | 22.38 | 20.03 | 15.32 | 62.18 | 55.63 | 42.54 | 121.87 | 109.04 | 83.38 | 201.45 | 180.25 | 137.84 |
| | 4.0 | 2.88 | 2.62 | 2.09 | 25.92 | 23.56 | 18.85 | 71.99 | 65.45 | 52.36 | 141.11 | 128.28 | 102.63 | 233.26 | 212.06 | 169.65 |
| | 4.5 | 3.27 | 3.01 | 2.49 | 29.45 | 27.10 | 22.38 | 81.81 | 75.27 | 62.18 | 160.35 | 147.52 | 121.87 | 265.07 | 243.87 | 201.45 |
| | 5.0 | 3.67 | 3.40 | 2.88 | 32.99 | 30.63 | 25.92 | 91.63 | 85.08 | 71.99 | 179.59 | 166.77 | 141.11 | 296.88 | 275.67 | 233.26 |
| | 5.5 | 4.06 | 3.80 | 3.27 | 36.52 | 34.16 | 29.45 | 101.45 | 94.90 | 81.81 | 198.84 | 186.01 | 160.35 | 328.69 | 307.48 | 265.07 |
| | 6.0 | 4.45 | 4.19 | 3.67 | 40.06 | 37.70 | 32.99 | 111.26 | 104.72 | 91.63 | 218.08 | 205.25 | 179.59 | 360.50 | 339.29 | 296.88 |
| | 6.5 | 4.84 | 4.58 | 4.06 | 43.59 | 41.23 | 36.52 | 121.08 | 114.54 | 101.45 | 237.32 | 224.49 | 198.84 | 392.31 | 371.10 | 328.69 |
| | 7.0 | 5.24 | 4.97 | 4.45 | 47.12 | 44.77 | 40.06 | 130.90 | 124.35 | 111.26 | 256.56 | 243.74 | 218.08 | 424.12 | 402.91 | 360.50 |
| | 7.5 | 5.63 | 5.37 | 4.84 | 50.66 | 48.30 | 43.59 | 140.72 | 134.17 | 121.08 | 275.81 | 262.98 | 237.32 | 455.92 | 434.72 | 392.31 |
| | 8.0 | 6.02 | 5.76 | 5.24 | 54.19 | 51.84 | 47.12 | 150.53 | 143.99 | 130.90 | 295.05 | 282.22 | 256.56 | 487.73 | 466.53 | 424.12 |
| | 8.5 | 6.41 | 6.15 | 5.63 | 57.73 | 55.37 | 50.66 | 160.35 | 153.81 | 140.72 | 314.29 | 301.46 | 275.81 | 519.54 | 498.34 | 455.92 |
| 9.0 | 6.81 | 6.54 | 6.02 | 61.26 | 58.90 | 54.19 | 170.17 | 163.62 | 150.53 | 333.53 | 320.70 | 295.05 | 551.35 | 530.14 | 487.73 | |
| 9.5 | 7.20 | 6.94 | 6.41 | 64.80 | 62.44 | 57.73 | 179.99 | 173.44 | 160.35 | 352.77 | 339.95 | 314.29 | 583.16 | 561.95 | 519.54 | |

| | | | | | | | | | | | | | | | | |
|--|------|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 10.0 | 7.59 | 7.33 | 6.81 | 68.33 | 65.97 | 61.26 | 189.80 | 183.26 | 170.17 | 372.02 | 359.19 | 333.53 | 614.97 | 593.76 | 551.35 |
| | 10.5 | 7.98 | 7.72 | 7.20 | 71.86 | 69.51 | 64.80 | 199.62 | 193.08 | 179.99 | 391.26 | 378.43 | 352.77 | 646.78 | 625.57 | 583.16 |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m3

VERTICAL CYLINDER - CONICAL BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|------|-------|-------|-------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 11.0 | 8.38 | 8.12 | 7.59 | 75.40 | 73.04 | 68.33 | 209.44 | 202.89 | 189.80 | 410.50 | 397.67 | 372.02 | 678.58 | 657.38 | 614.97 |
| | 11.5 | 8.77 | 8.51 | 7.98 | 78.93 | 76.58 | 71.86 | 219.26 | 212.71 | 199.62 | 429.74 | 416.92 | 391.26 | 710.39 | 689.19 | 646.78 |
| | 12.0 | 9.16 | 8.90 | 8.38 | 82.47 | 80.11 | 75.40 | 229.07 | 222.53 | 209.44 | 448.99 | 436.16 | 410.50 | 742.20 | 721.00 | 678.58 |
| | 12.5 | 9.56 | 9.29 | 8.77 | 86.00 | 83.64 | 78.93 | 238.89 | 232.35 | 219.26 | 468.23 | 455.40 | 429.74 | 774.01 | 752.80 | 710.39 |
| | 13.0 | 9.95 | 9.69 | 9.16 | 89.54 | 87.18 | 82.47 | 248.71 | 242.16 | 229.07 | 487.47 | 474.64 | 448.99 | 805.82 | 784.61 | 742.20 |
| | 13.5 | 10.34 | 10.08 | 9.56 | 93.07 | 90.71 | 86.00 | 258.53 | 251.98 | 238.89 | 506.71 | 493.88 | 468.23 | 837.63 | 816.42 | 774.01 |
| | 14.0 | 10.73 | 10.47 | 9.95 | 96.60 | 94.25 | 89.54 | 268.34 | 261.80 | 248.71 | 525.95 | 513.13 | 487.47 | 869.44 | 848.23 | 805.82 |
| | 14.5 | 11.13 | 10.86 | 10.34 | 100.14 | 97.78 | 93.07 | 278.16 | 271.62 | 258.53 | 545.20 | 532.37 | 506.71 | 901.24 | 880.04 | 837.63 |
| | 15.0 | 11.52 | 11.26 | 10.73 | 103.67 | 101.32 | 96.60 | 287.98 | 281.43 | 268.34 | 564.44 | 551.61 | 525.95 | 933.05 | 911.85 | 869.44 |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m³

VERTICAL CYLINDER - ELLIPSOIDAL BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 0.26 | 0.16 | 0.09 | 2.36 | 1.47 | 0.81 | 6.54 | 4.09 | 2.25 | 12.83 | 8.02 | 4.41 | 21.21 | 13.25 | 7.29 |
| | 1.0 | 0.65 | 0.52 | 0.33 | 5.89 | 4.71 | 2.95 | 16.36 | 13.09 | 8.18 | 32.07 | 25.66 | 16.04 | 53.01 | 42.41 | 26.51 |
| | 1.5 | 1.05 | 0.92 | 0.66 | 9.42 | 8.25 | 5.96 | 26.18 | 22.91 | 16.57 | 51.31 | 44.90 | 32.47 | 84.82 | 74.22 | 53.68 |
| | 2.0 | 1.44 | 1.31 | 1.05 | 12.96 | 11.78 | 9.42 | 36.00 | 32.72 | 26.18 | 70.55 | 64.14 | 51.31 | 116.63 | 106.03 | 84.82 |
| | 2.5 | 1.83 | 1.70 | 1.44 | 16.49 | 15.32 | 12.96 | 45.81 | 42.54 | 36.00 | 89.80 | 83.38 | 70.55 | 148.44 | 137.84 | 116.63 |
| | 3.0 | 2.23 | 2.09 | 1.83 | 20.03 | 18.85 | 16.49 | 55.63 | 52.36 | 45.81 | 109.04 | 102.63 | 89.80 | 180.25 | 169.65 | 148.44 |
| | 3.5 | 2.62 | 2.49 | 2.23 | 23.56 | 22.38 | 20.03 | 65.45 | 62.18 | 55.63 | 128.28 | 121.87 | 109.04 | 212.06 | 201.45 | 180.25 |
| | 4.0 | 3.01 | 2.88 | 2.62 | 27.10 | 25.92 | 23.56 | 75.27 | 71.99 | 65.45 | 147.52 | 141.11 | 128.28 | 243.87 | 233.26 | 212.06 |
| | 4.5 | 3.40 | 3.27 | 3.01 | 30.63 | 29.45 | 27.10 | 85.08 | 81.81 | 75.27 | 166.77 | 160.35 | 147.52 | 275.67 | 265.07 | 243.87 |
| | 5.0 | 3.80 | 3.67 | 3.40 | 34.16 | 32.99 | 30.63 | 94.90 | 91.63 | 85.08 | 186.01 | 179.59 | 166.77 | 307.48 | 296.88 | 275.67 |
| | 5.5 | 4.19 | 4.06 | 3.80 | 37.70 | 36.52 | 34.16 | 104.72 | 101.45 | 94.90 | 205.25 | 198.84 | 186.01 | 339.29 | 328.69 | 307.48 |
| | 6.0 | 4.58 | 4.45 | 4.19 | 41.23 | 40.06 | 37.70 | 114.54 | 111.26 | 104.72 | 224.49 | 218.08 | 205.25 | 371.10 | 360.50 | 339.29 |
| | 6.5 | 4.97 | 4.84 | 4.58 | 44.77 | 43.59 | 41.23 | 124.35 | 121.08 | 114.54 | 243.74 | 237.32 | 224.49 | 402.91 | 392.31 | 371.10 |
| | 7.0 | 5.37 | 5.24 | 4.97 | 48.30 | 47.12 | 44.77 | 134.17 | 130.90 | 124.35 | 262.98 | 256.56 | 243.74 | 434.72 | 424.12 | 402.91 |
| | 7.5 | 5.76 | 5.63 | 5.37 | 51.84 | 50.66 | 48.30 | 143.99 | 140.72 | 134.17 | 282.22 | 275.81 | 262.98 | 466.53 | 455.92 | 434.72 |
| | 8.0 | 6.15 | 6.02 | 5.76 | 55.37 | 54.19 | 51.84 | 153.81 | 150.53 | 143.99 | 301.46 | 295.05 | 282.22 | 498.34 | 487.73 | 466.53 |
| | 8.5 | 6.54 | 6.41 | 6.15 | 58.90 | 57.73 | 55.37 | 163.62 | 160.35 | 153.81 | 320.70 | 314.29 | 301.46 | 530.14 | 519.54 | 498.34 |
| 9.0 | 6.94 | 6.81 | 6.54 | 62.44 | 61.26 | 58.90 | 173.44 | 170.17 | 163.62 | 339.95 | 333.53 | 320.70 | 561.95 | 551.35 | 530.14 | |
| 9.5 | 7.33 | 7.20 | 6.94 | 65.97 | 64.80 | 62.44 | 183.26 | 179.99 | 173.44 | 359.19 | 352.77 | 339.95 | 593.76 | 583.16 | 561.95 | |
| 10.0 | 7.72 | 7.59 | 7.33 | 69.51 | 68.33 | 65.97 | 193.08 | 189.80 | 183.26 | 378.43 | 372.02 | 359.19 | 625.57 | 614.97 | 593.76 | |
| 10.5 | 8.12 | 7.98 | 7.72 | 73.04 | 71.86 | 69.51 | 202.89 | 199.62 | 193.08 | 397.67 | 391.26 | 378.43 | 657.38 | 646.78 | 625.57 | |
| 11.0 | 8.51 | 8.38 | 8.12 | 76.58 | 75.40 | 73.04 | 212.71 | 209.44 | 202.89 | 416.92 | 410.50 | 397.67 | 689.19 | 678.58 | 657.38 | |

| | | | | | | | | | | | | | | | | |
|--|------|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 11.5 | 8.90 | 8.77 | 8.51 | 80.11 | 78.93 | 76.58 | 222.53 | 219.26 | 212.71 | 436.16 | 429.74 | 416.92 | 721.00 | 710.39 | 689.19 |
| | 12.0 | 9.29 | 9.16 | 8.90 | 83.64 | 82.47 | 80.11 | 232.35 | 229.07 | 222.53 | 455.40 | 448.99 | 436.16 | 752.80 | 742.20 | 721.00 |
| | 12.5 | 9.69 | 9.56 | 9.29 | 87.18 | 86.00 | 83.64 | 242.16 | 238.89 | 232.35 | 474.64 | 468.23 | 455.40 | 784.61 | 774.01 | 752.80 |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m3

VERTICAL CYLINDER - ELLIPSOIDAL BOTTOM

| D[m] | | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 |
|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 |
| h[m] | 13.0 | 10.08 | 9.95 | 9.69 | 90.71 | 89.54 | 87.18 | 251.98 | 248.71 | 242.16 | 493.88 | 487.47 | 474.64 | 816.42 | 805.82 | 784.61 |
| | 13.5 | 10.47 | 10.34 | 10.08 | 94.25 | 93.07 | 90.71 | 261.80 | 258.53 | 251.98 | 513.13 | 506.71 | 493.88 | 848.23 | 837.63 | 816.42 |
| | 14.0 | 10.86 | 10.73 | 10.47 | 97.78 | 96.60 | 94.25 | 271.62 | 268.34 | 261.80 | 532.37 | 525.95 | 513.13 | 880.04 | 869.44 | 848.23 |
| | 14.5 | 11.26 | 11.13 | 10.86 | 101.32 | 100.14 | 97.78 | 281.43 | 278.16 | 271.62 | 551.61 | 545.20 | 532.37 | 911.85 | 901.24 | 880.04 |
| | 15.0 | 11.65 | 11.52 | 11.26 | 104.85 | 103.67 | 101.32 | 291.25 | 287.98 | 281.43 | 570.85 | 564.44 | 551.61 | 943.66 | 933.05 | 911.85 |

VERTICAL CYLINDER - SPHERICAL BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|-------------|------|------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 0.26 | 0.36 | 0.70 | 1.83 | 1.15 | 1.10 | 4.97 | 2.72 | 1.88 | 9.69 | 5.07 | 3.06 | 15.97 | 8.21 | 4.63 |
| | 1.0 | 0.65 | 0.92 | 2.29 | 5.37 | 4.06 | 3.86 | 14.79 | 10.34 | 7.00 | 28.93 | 19.77 | 11.72 | 47.78 | 32.33 | 18.00 |
| | 1.5 | 1.05 | 1.31 | 3.98 | 8.90 | 7.59 | 7.51 | 24.61 | 20.16 | 14.58 | 48.17 | 39.01 | 25.18 | 79.59 | 64.14 | 39.32 |
| | 2.0 | 1.44 | 1.70 | 4.97 | 12.44 | 11.13 | 11.26 | 34.43 | 29.98 | 23.82 | 67.41 | 58.25 | 42.67 | 111.40 | 95.95 | 67.81 |
| | 2.5 | 1.83 | 2.09 | 5.37 | 15.97 | 14.66 | 14.79 | 44.24 | 39.79 | 33.64 | 86.66 | 77.49 | 61.92 | 143.20 | 127.76 | 99.61 |
| | 3.0 | 2.23 | 2.49 | 5.76 | 19.50 | 18.20 | 18.33 | 54.06 | 49.61 | 43.46 | 105.90 | 96.73 | 81.16 | 175.01 | 159.57 | 131.42 |
| | 3.5 | 2.62 | 2.88 | 6.15 | 23.04 | 21.73 | 21.86 | 63.88 | 59.43 | 53.28 | 125.14 | 115.98 | 100.40 | 206.82 | 191.38 | 163.23 |
| | 4.0 | 3.01 | 3.27 | 6.54 | 26.57 | 25.26 | 25.39 | 73.70 | 69.25 | 63.09 | 144.38 | 135.22 | 119.64 | 238.63 | 223.18 | 195.04 |
| | 4.5 | 3.40 | 3.67 | 6.94 | 30.11 | 28.80 | 28.93 | 83.51 | 79.06 | 72.91 | 163.62 | 154.46 | 138.88 | 270.44 | 254.99 | 226.85 |
| | 5.0 | 3.80 | 4.06 | 7.33 | 33.64 | 32.33 | 32.46 | 93.33 | 88.88 | 82.73 | 182.87 | 173.70 | 158.13 | 302.25 | 286.80 | 258.66 |
| | 5.5 | 4.19 | 4.45 | 7.72 | 37.18 | 35.87 | 36.00 | 103.15 | 98.70 | 92.55 | 202.11 | 192.95 | 177.37 | 334.06 | 318.61 | 290.47 |
| | 6.0 | 4.58 | 4.84 | 8.12 | 40.71 | 39.40 | 39.53 | 112.97 | 108.52 | 102.36 | 221.35 | 212.19 | 196.61 | 365.86 | 350.42 | 322.28 |
| | 6.5 | 4.97 | 5.24 | 8.51 | 44.24 | 42.94 | 43.07 | 122.78 | 118.33 | 112.18 | 240.59 | 231.43 | 215.85 | 397.67 | 382.23 | 354.08 |
| | 7.0 | 5.37 | 5.63 | 8.90 | 47.78 | 46.47 | 46.60 | 132.60 | 128.15 | 122.00 | 259.84 | 250.67 | 235.10 | 429.48 | 414.04 | 385.89 |
| | 7.5 | 5.76 | 6.02 | 9.29 | 51.31 | 50.00 | 50.13 | 142.42 | 137.97 | 131.82 | 279.08 | 269.92 | 254.34 | 461.29 | 445.84 | 417.70 |
| | 8.0 | 6.15 | 6.41 | 9.69 | 54.85 | 53.54 | 53.67 | 152.24 | 147.79 | 141.63 | 298.32 | 289.16 | 273.58 | 493.10 | 477.65 | 449.51 |
| | 8.5 | 6.54 | 6.81 | 10.08 | 58.38 | 57.07 | 57.20 | 162.05 | 157.60 | 151.45 | 317.56 | 308.40 | 292.82 | 524.91 | 509.46 | 481.32 |
| | 9.0 | 6.94 | 7.20 | 10.47 | 61.92 | 60.61 | 60.74 | 171.87 | 167.42 | 161.27 | 336.80 | 327.64 | 312.06 | 556.72 | 541.27 | 513.13 |
| | 9.5 | 7.33 | 7.59 | 10.86 | 65.45 | 64.14 | 64.27 | 181.69 | 177.24 | 171.09 | 356.05 | 346.88 | 331.31 | 588.53 | 573.08 | 544.94 |
| | 10.0 | 7.72 | 7.98 | 11.26 | 68.98 | 67.68 | 67.81 | 191.51 | 187.06 | 180.90 | 375.29 | 366.13 | 350.55 | 620.33 | 604.89 | 576.74 |
| 10.5 | 8.12 | 8.38 | 11.65 | 72.52 | 71.21 | 71.34 | 201.32 | 196.87 | 190.72 | 394.53 | 385.37 | 369.79 | 652.14 | 636.70 | 608.55 | |
| 11.0 | 8.51 | 8.77 | 12.04 | 76.05 | 74.74 | 74.87 | 211.14 | 206.69 | 200.54 | 413.77 | 404.61 | 389.03 | 683.95 | 668.50 | 640.36 | |
| 11.5 | 8.90 | 9.16 | 12.44 | 79.59 | 78.28 | 78.41 | 220.96 | 216.51 | 210.36 | 433.02 | 423.85 | 408.28 | 715.76 | 700.31 | 672.17 | |
| 12.0 | 9.29 | 9.56 | 12.83 | 83.12 | 81.81 | 81.94 | 230.78 | 226.33 | 220.17 | 452.26 | 443.10 | 427.52 | 747.57 | 732.12 | 703.98 | |
| 12.5 | 9.69 | 9.95 | 13.22 | 86.66 | 85.35 | 85.48 | 240.59 | 236.14 | 229.99 | 471.50 | 462.34 | 446.76 | 779.38 | 763.93 | 735.79 | |

VERTICAL CYLINDER - SPHERICAL BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 13.0 | 10.08 | 10.34 | 13.61 | 90.19 | 88.88 | 89.01 | 250.41 | 245.96 | 239.81 | 490.74 | 481.58 | 466.00 | 811.19 | 795.74 | 767.60 |
| | 13.5 | 10.47 | 10.73 | 14.01 | 93.72 | 92.42 | 92.55 | 260.23 | 255.78 | 249.63 | 509.99 | 500.82 | 485.25 | 842.99 | 827.55 | 799.40 |
| | 14.0 | 10.86 | 11.13 | 14.40 | 97.26 | 95.95 | 96.08 | 270.05 | 265.60 | 259.44 | 529.23 | 520.06 | 504.49 | 874.80 | 859.36 | 831.21 |
| | 14.5 | 11.26 | 11.52 | 14.79 | 100.79 | 99.48 | 99.61 | 279.86 | 275.41 | 269.26 | 548.47 | 539.31 | 523.73 | 906.61 | 891.17 | 863.02 |
| | 15.0 | 11.65 | 11.91 | 15.18 | 104.33 | 103.02 | 103.15 | 289.68 | 285.23 | 279.08 | 567.71 | 558.55 | 542.97 | 938.42 | 922.97 | 894.83 |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m³

VERTICAL CYLINDER - FLAT BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| h[m] | 0.5 | 0.39 | 0.39 | 0.39 | 3.53 | 3.53 | 3.53 | 9.82 | 9.82 | 9.82 | 19.24 | 19.24 | 19.24 | 31.81 | 31.81 | 31.81 |
| | 1.0 | 0.79 | 0.79 | 0.79 | 7.07 | 7.07 | 7.07 | 19.63 | 19.63 | 19.63 | 38.48 | 38.48 | 38.48 | 63.62 | 63.62 | 63.62 |
| | 1.5 | 1.18 | 1.18 | 1.18 | 10.60 | 10.60 | 10.60 | 29.45 | 29.45 | 29.45 | 57.73 | 57.73 | 57.73 | 95.43 | 95.43 | 95.43 |
| | 2.0 | 1.57 | 1.57 | 1.57 | 14.14 | 14.14 | 14.14 | 39.27 | 39.27 | 39.27 | 76.97 | 76.97 | 76.97 | 127.23 | 127.23 | 127.23 |
| | 2.5 | 1.96 | 1.96 | 1.96 | 17.67 | 17.67 | 17.67 | 49.09 | 49.09 | 49.09 | 96.21 | 96.21 | 96.21 | 159.04 | 159.04 | 159.04 |
| | 3.0 | 2.36 | 2.36 | 2.36 | 21.21 | 21.21 | 21.21 | 58.90 | 58.90 | 58.90 | 115.45 | 115.45 | 115.45 | 190.85 | 190.85 | 190.85 |
| | 3.5 | 2.75 | 2.75 | 2.75 | 24.74 | 24.74 | 24.74 | 68.72 | 68.72 | 68.72 | 134.70 | 134.70 | 134.70 | 222.66 | 222.66 | 222.66 |
| | 4.0 | 3.14 | 3.14 | 3.14 | 28.27 | 28.27 | 28.27 | 78.54 | 78.54 | 78.54 | 153.94 | 153.94 | 153.94 | 254.47 | 254.47 | 254.47 |
| | 4.5 | 3.53 | 3.53 | 3.53 | 31.81 | 31.81 | 31.81 | 88.36 | 88.36 | 88.36 | 173.18 | 173.18 | 173.18 | 286.28 | 286.28 | 286.28 |
| | 5.0 | 3.93 | 3.93 | 3.93 | 35.34 | 35.34 | 35.34 | 98.17 | 98.17 | 98.17 | 192.42 | 192.42 | 192.42 | 318.09 | 318.09 | 318.09 |
| | 5.5 | 4.32 | 4.32 | 4.32 | 38.88 | 38.88 | 38.88 | 107.99 | 107.99 | 107.99 | 211.66 | 211.66 | 211.66 | 349.89 | 349.89 | 349.89 |
| | 6.0 | 4.71 | 4.71 | 4.71 | 42.41 | 42.41 | 42.41 | 117.81 | 117.81 | 117.81 | 230.91 | 230.91 | 230.91 | 381.70 | 381.70 | 381.70 |
| | 6.5 | 5.11 | 5.11 | 5.11 | 45.95 | 45.95 | 45.95 | 127.63 | 127.63 | 127.63 | 250.15 | 250.15 | 250.15 | 413.51 | 413.51 | 413.51 |
| | 7.0 | 5.50 | 5.50 | 5.50 | 49.48 | 49.48 | 49.48 | 137.44 | 137.44 | 137.44 | 269.39 | 269.39 | 269.39 | 445.32 | 445.32 | 445.32 |
| | 7.5 | 5.89 | 5.89 | 5.89 | 53.01 | 53.01 | 53.01 | 147.26 | 147.26 | 147.26 | 288.63 | 288.63 | 288.63 | 477.13 | 477.13 | 477.13 |
| | 8.0 | 6.28 | 6.28 | 6.28 | 56.55 | 56.55 | 56.55 | 157.08 | 157.08 | 157.08 | 307.88 | 307.88 | 307.88 | 508.94 | 508.94 | 508.94 |
| | 8.5 | 6.68 | 6.68 | 6.68 | 60.08 | 60.08 | 60.08 | 166.90 | 166.90 | 166.90 | 327.12 | 327.12 | 327.12 | 540.75 | 540.75 | 540.75 |
| | 9.0 | 7.07 | 7.07 | 7.07 | 63.62 | 63.62 | 63.62 | 176.71 | 176.71 | 176.71 | 346.36 | 346.36 | 346.36 | 572.56 | 572.56 | 572.56 |
| | 9.5 | 7.46 | 7.46 | 7.46 | 67.15 | 67.15 | 67.15 | 186.53 | 186.53 | 186.53 | 365.60 | 365.60 | 365.60 | 604.36 | 604.36 | 604.36 |
| | 10.0 | 7.85 | 7.85 | 7.85 | 70.69 | 70.69 | 70.69 | 196.35 | 196.35 | 196.35 | 384.85 | 384.85 | 384.85 | 636.17 | 636.17 | 636.17 |
| 10.5 | 8.25 | 8.25 | 8.25 | 74.22 | 74.22 | 74.22 | 206.17 | 206.17 | 206.17 | 404.09 | 404.09 | 404.09 | 667.98 | 667.98 | 667.98 | |
| 11.0 | 8.64 | 8.64 | 8.64 | 77.75 | 77.75 | 77.75 | 215.98 | 215.98 | 215.98 | 423.33 | 423.33 | 423.33 | 699.79 | 699.79 | 699.79 | |
| 11.5 | 9.03 | 9.03 | 9.03 | 81.29 | 81.29 | 81.29 | 225.80 | 225.80 | 225.80 | 442.57 | 442.57 | 442.57 | 731.60 | 731.60 | 731.60 | |
| 12.0 | 9.42 | 9.42 | 9.42 | 84.82 | 84.82 | 84.82 | 235.62 | 235.62 | 235.62 | 461.81 | 461.81 | 461.81 | 763.41 | 763.41 | 763.41 | |
| 12.5 | 9.82 | 9.82 | 9.82 | 88.36 | 88.36 | 88.36 | 245.44 | 245.44 | 245.44 | 481.06 | 481.06 | 481.06 | 795.22 | 795.22 | 795.22 | |
| 13.0 | 10.21 | 10.21 | 10.21 | 91.89 | 91.89 | 91.89 | 255.25 | 255.25 | 255.25 | 500.30 | 500.30 | 500.30 | 827.02 | 827.02 | 827.02 | |

VERTICAL CYLINDER - FLAT BOTTOM

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| h[m] | 13.5 | 10.60 | 10.60 | 10.60 | 95.43 | 95.43 | 95.43 | 265.07 | 265.07 | 265.07 | 519.54 | 519.54 | 519.54 | 858.83 | 858.83 | 858.83 |
| | 14.0 | 11.00 | 11.00 | 11.00 | 98.96 | 98.96 | 98.96 | 274.89 | 274.89 | 274.89 | 538.78 | 538.78 | 538.78 | 890.64 | 890.64 | 890.64 |
| | 14.5 | 11.39 | 11.39 | 11.39 | 102.49 | 102.49 | 102.49 | 284.71 | 284.71 | 284.71 | 558.03 | 558.03 | 558.03 | 922.45 | 922.45 | 922.45 |
| | 15.0 | 11.78 | 11.78 | 11.78 | 106.03 | 106.03 | 106.03 | 294.52 | 294.52 | 294.52 | 577.27 | 577.27 | 577.27 | 954.26 | 954.26 | 954.26 |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m³

HORIZONTAL CYLINDER - CONICAL HEAD

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|-----|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 2.09 | 2.23 | 2.49 | 3.97 | 4.07 | 4.27 | 5.19 | 5.27 | 5.43 | 6.17 | 6.24 | 6.38 | 7.01 | 7.07 | 7.20 |
| | 1.0 | 4.19 | 4.45 | 4.97 | 10.81 | 11.31 | 12.32 | 14.40 | 14.83 | 15.68 | 17.24 | 17.61 | 18.35 | 19.65 | 19.99 | 20.66 |
| | 1.5 | | | | 18.85 | 20.03 | 22.38 | 25.87 | 26.96 | 29.16 | 31.22 | 32.20 | 34.17 | 35.74 | 36.63 | 38.42 |
| | 2.0 | | | | 26.89 | 28.74 | 32.45 | 38.75 | 40.82 | 44.97 | 47.29 | 49.21 | 53.06 | 54.40 | 56.18 | 59.72 |
| | 2.5 | | | | 33.73 | 35.98 | 40.50 | 52.36 | 55.63 | 62.18 | 64.87 | 68.05 | 74.41 | 75.08 | 78.06 | 84.02 |
| | 3.0 | | | | 37.70 | 40.06 | 44.77 | 65.97 | 70.44 | 79.38 | 83.48 | 88.18 | 97.59 | 97.32 | 101.83 | 110.84 |
| | 3.5 | | | | | | | 78.85 | 84.30 | 95.20 | 102.63 | 109.04 | 121.87 | 120.74 | 127.07 | 139.72 |
| | 4.0 | | | | | | | 90.32 | 96.43 | 108.67 | 121.77 | 129.90 | 146.14 | 144.98 | 153.36 | 170.14 |
| | 4.5 | | | | | | | 99.53 | 106.00 | 118.93 | 140.38 | 150.03 | 169.33 | 169.65 | 180.25 | 201.45 |
| | 5.0 | | | | | | | 104.72 | 111.26 | 124.35 | 157.96 | 168.87 | 190.68 | 194.32 | 207.13 | 232.77 |
| | 5.5 | | | | | | | | | | 174.03 | 185.88 | 209.57 | 218.55 | 233.43 | 263.18 |
| | 6.0 | | | | | | | | | | 188.02 | 200.47 | 225.38 | 241.97 | 258.67 | 292.07 |
| | 6.5 | | | | | | | | | | 199.08 | 211.84 | 237.36 | 264.21 | 282.44 | 318.89 |
| | 7.0 | | | | | | | | | | 205.25 | 218.08 | 243.74 | 284.89 | 304.32 | 343.19 |
| | 7.5 | | | | | | | | | | | | | 303.55 | 323.86 | 364.49 |
| | 8.0 | | | | | | | | | | | | | 319.64 | 340.51 | 382.25 |
| 8.5 | | | | | | | | | | | | | 332.28 | 353.42 | 395.71 | |

- D: Tank diameter
- A: Bottom length
- h: Level height
- unit: m³

HORIZONTAL CYLINDER - ELLIPSOIDAL HEAD

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|-----|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 2.23 | 2.49 | 3.01 | 4.22 | 4.57 | 5.27 | 5.48 | 5.84 | 6.58 | 6.47 | 6.85 | 7.60 | 7.33 | 7.71 | 8.46 |
| | 1.0 | 4.45 | 4.97 | 6.02 | 11.53 | 12.76 | 15.20 | 15.34 | 16.70 | 19.42 | 18.28 | 19.70 | 22.55 | 20.77 | 22.23 | 25.14 |
| | 1.5 | | | | 20.03 | 22.38 | 27.10 | 27.60 | 30.43 | 36.08 | 33.26 | 36.29 | 42.35 | 37.99 | 41.13 | 47.41 |
| | 2.0 | | | | 28.52 | 32.01 | 38.99 | 41.28 | 45.89 | 55.10 | 50.45 | 55.54 | 65.71 | 57.99 | 63.34 | 74.04 |
| | 2.5 | | | | 35.83 | 40.20 | 48.92 | 55.63 | 62.18 | 75.27 | 69.17 | 76.65 | 91.61 | 80.10 | 88.10 | 104.10 |
| | 3.0 | | | | 40.06 | 44.77 | 54.19 | 69.99 | 78.47 | 95.43 | 88.87 | 98.97 | 119.16 | 103.81 | 114.81 | 136.80 |
| | 3.5 | | | | | | | 83.67 | 93.93 | 114.45 | 109.04 | 121.87 | 147.52 | 128.67 | 142.92 | 171.43 |
| | 4.0 | | | | | | | 95.93 | 107.65 | 131.11 | 129.21 | 144.77 | 175.89 | 154.28 | 171.96 | 207.33 |
| | 4.5 | | | | | | | 105.79 | 118.51 | 143.96 | 148.91 | 167.08 | 203.43 | 180.25 | 201.45 | 243.87 |
| | 5.0 | | | | | | | 111.26 | 124.35 | 150.53 | 167.63 | 188.20 | 229.34 | 206.22 | 230.95 | 280.40 |
| | 5.5 | | | | | | | | | | 184.82 | 207.44 | 252.70 | 231.83 | 259.99 | 316.30 |
| | 6.0 | | | | | | | | | | 199.80 | 224.03 | 272.50 | 256.69 | 288.10 | 350.94 |
| | 6.5 | | | | | | | | | | 211.60 | 236.89 | 287.45 | 280.40 | 314.81 | 383.63 |
| | 7.0 | | | | | | | | | | 218.08 | 243.74 | 295.05 | 302.51 | 339.57 | 413.69 |
| | 7.5 | | | | | | | | | | | | | 322.51 | 361.78 | 440.32 |
| | 8.0 | | | | | | | | | | | | | 339.72 | 380.68 | 462.59 |
| 8.5 | | | | | | | | | | | | | 353.17 | 395.20 | 479.27 | |
| 9.0 | | | | | | | | | | | | | 360.50 | 402.91 | 487.73 | |

HORIZONTAL CYLINDER - GUPPY HEAD

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|-----|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A[m] | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | 0.5 | 1.0 | 2.0 | |
| h[m] | 0.5 | 2.04 | 2.11 | 2.26 | 3.92 | 3.97 | 4.08 | 5.15 | 5.19 | 5.27 | 6.14 | 6.17 | 6.24 | 6.98 | 7.01 | 7.08 |
| | 1.0 | 4.19 | 4.45 | 4.97 | 10.58 | 10.85 | 11.39 | 14.20 | 14.42 | 14.86 | 17.05 | 17.24 | 17.63 | 19.49 | 19.66 | 20.00 |
| | 1.5 | | | | 18.35 | 19.03 | 20.38 | 25.35 | 25.94 | 27.10 | 30.74 | 31.26 | 32.28 | 35.31 | 35.77 | 36.69 |
| | 2.0 | | | | 26.28 | 27.53 | 30.03 | 37.81 | 38.95 | 41.22 | 46.38 | 47.40 | 49.43 | 53.56 | 54.48 | 56.32 |
| | 2.5 | | | | 33.36 | 35.25 | 39.04 | 50.97 | 52.85 | 56.62 | 63.41 | 65.13 | 68.56 | 73.67 | 75.24 | 78.39 |
| | 3.0 | | | | 37.70 | 40.06 | 44.77 | 64.30 | 67.09 | 72.68 | 81.38 | 84.00 | 89.22 | 95.23 | 97.65 | 102.48 |
| | 3.5 | | | | | | | 77.23 | 81.05 | 88.70 | 99.90 | 103.60 | 110.98 | 117.87 | 121.33 | 128.24 |
| | 4.0 | | | | | | | 89.10 | 94.00 | 103.80 | 118.59 | 123.53 | 133.40 | 141.28 | 145.97 | 155.35 |
| | 4.5 | | | | | | | 98.97 | 104.87 | 116.68 | 137.05 | 143.37 | 156.01 | 165.15 | 171.25 | 183.45 |
| | 5.0 | | | | | | | 104.72 | 111.26 | 124.35 | 154.85 | 162.65 | 178.24 | 189.18 | 196.86 | 212.23 |
| | 5.5 | | | | | | | | | | 171.50 | 180.81 | 199.42 | 213.08 | 222.48 | 241.30 |
| | 6.0 | | | | | | | | | | 186.33 | 197.10 | 218.64 | 236.52 | 247.77 | 270.26 |
| | 6.5 | | | | | | | | | | 198.37 | 210.42 | 234.52 | 259.15 | 272.31 | 298.64 |
| | 7.0 | | | | | | | | | | 205.25 | 218.08 | 243.74 | 280.56 | 295.67 | 325.89 |
| | 7.5 | | | | | | | | | | | | | 300.26 | 317.28 | 351.32 |
| | 8.0 | | | | | | | | | | | | | 317.57 | 336.37 | 373.97 |
| 8.5 | | | | | | | | | | | | | 331.44 | 351.75 | 392.37 | |
| 9.0 | | | | | | | | | | | | | 339.29 | 360.50 | 402.91 | |

HORIZONTAL CYLINDER - SPHERICAL HEAD

| D[m] | 1 | 1 | 1 | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 7 | 7 | 9 | 9 | 9 | |
|------|-----|------|------|------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|---------|---------|
| A[m] | 0.2 | 0.3 | 0.5 | 0.5 | 1.0 | 1.5 | 1.0 | 2.0 | 2.5 | 1.0 | 3.5 | 5.0 | 1.0 | 3.0 | 4.5 | |
| h[m] | 0.5 | 3.62 | 3.67 | 3.80 | 7.16 | 7.46 | 8.02 | 9.54 | 10.25 | 11.03 | 11.26 | 12.64 | 12.02 | 13.45 | 13.74 | 17.01 |
| | 1.0 | 7.23 | 7.33 | 7.59 | 19.43 | 20.55 | 22.23 | 26.83 | 29.63 | 31.97 | 31.81 | 37.42 | 35.18 | 38.03 | 39.54 | 51.45 |
| | 1.5 | | | | 33.64 | 35.87 | 38.88 | 48.55 | 54.40 | 58.73 | 58.06 | 70.27 | 65.74 | 69.72 | 73.52 | 98.30 |
| | 2.0 | | | | 47.86 | 51.18 | 55.53 | 72.97 | 82.49 | 89.05 | 88.42 | 109.06 | 101.77 | 106.86 | 114.03 | 155.10 |
| | 2.5 | | | | 60.12 | 64.28 | 69.74 | 98.70 | 112.18 | 121.08 | 121.70 | 152.09 | 141.73 | 148.35 | 159.89 | 220.00 |
| | 3.0 | | | | 67.28 | 71.73 | 77.75 | 124.42 | 141.87 | 153.12 | 156.86 | 197.89 | 184.25 | 193.33 | 210.07 | 291.45 |
| | 3.5 | | | | | | | 148.84 | 169.96 | 183.44 | 192.95 | 245.04 | 228.02 | 240.99 | 263.66 | 368.01 |
| | 4.0 | | | | | | | 170.56 | 194.74 | 210.20 | 229.03 | 292.20 | 271.80 | 290.65 | 319.77 | 448.34 |
| | 4.5 | | | | | | | 187.86 | 214.11 | 231.13 | 264.19 | 338.00 | 314.32 | 341.61 | 377.55 | 531.16 |
| | 5.0 | | | | | | | 197.40 | 224.36 | 242.16 | 297.47 | 381.03 | 354.28 | 393.22 | 436.16 | 615.23 |
| | 5.5 | | | | | | | | | | 327.83 | 419.82 | 390.31 | 444.83 | 494.77 | 699.29 |
| | 6.0 | | | | | | | | | | 354.08 | 452.67 | 420.87 | 495.80 | 552.55 | 782.12 |
| | 6.5 | | | | | | | | | | 374.63 | 477.45 | 444.03 | 545.45 | 608.66 | 862.45 |
| | 7.0 | | | | | | | | | | 385.89 | 490.09 | | 593.12 | 662.25 | 939.01 |
| | 7.5 | | | | | | | | | | | | | 638.09 | 712.43 | 1010.45 |
| | 8.0 | | | | | | | | | | | | | 679.59 | 758.28 | 1075.36 |
| | 8.5 | | | | | | | | | | | | | 716.73 | 798.80 | 1132.16 |
| 9.0 | | | | | | | | | | | | | 748.41 | 832.78 | 1179.01 | |
| 9.5 | | | | | | | | | | | | | 773.00 | 858.58 | 1213.45 | |
| 10.0 | | | | | | | | | | | | | 786.45 | 872.32 | 1230.46 | |

HORIZONTAL CYLINDER - FLAT HEAD

| D[m] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|
| h[m] | 0.5 | 0.39 | 0.61 | 0.77 | 0.91 | 1.02 | 1.13 | 1.22 | 1.31 | 1.39 | 1.47 | 1.54 | 1.61 | 1.68 | 1.74 | 1.81 |
| | 1.0 | 0.79 | 1.57 | 2.06 | 2.46 | 2.80 | 3.10 | 3.37 | 3.63 | 3.86 | 4.09 | 4.30 | 4.50 | 4.69 | 4.88 | 5.06 |
| | 1.5 | | 2.53 | 3.53 | 4.30 | 4.95 | 5.53 | 6.05 | 6.52 | 6.97 | 7.39 | 7.78 | 8.16 | 8.52 | 8.86 | 9.20 |
| | 2.0 | | 3.14 | 5.01 | 6.28 | 7.33 | 8.25 | 9.07 | 9.83 | 10.53 | 11.18 | 11.80 | 12.39 | 12.95 | 13.49 | 14.01 |
| | 2.5 | | | 6.29 | 8.26 | 9.82 | 11.15 | 12.34 | 13.42 | 14.42 | 15.35 | 16.24 | 17.07 | 17.87 | 18.63 | 19.36 |
| | 3.0 | | | 7.07 | 10.11 | 12.30 | 14.14 | 15.75 | 17.22 | 18.56 | 19.82 | 21.00 | 22.11 | 23.17 | 24.19 | 25.16 |
| | 3.5 | | | | 11.66 | 14.68 | 17.12 | 19.24 | 21.14 | 22.88 | 24.50 | 26.01 | 27.44 | 28.80 | 30.10 | 31.34 |
| | 4.0 | | | | 12.57 | 16.84 | 20.02 | 22.73 | 25.13 | 27.32 | 29.34 | 31.22 | 33.00 | 34.69 | 36.29 | 37.83 |
| | 4.5 | | | | | 18.61 | 22.75 | 26.15 | 29.12 | 31.81 | 34.28 | 36.58 | 38.74 | 40.78 | 42.73 | 44.59 |
| | 5.0 | | | | | 19.63 | 25.18 | 29.41 | 33.05 | 36.30 | 39.27 | 42.02 | 44.60 | 47.04 | 49.35 | 51.56 |
| | 5.5 | | | | | | 27.15 | 32.44 | 36.85 | 40.73 | 44.26 | 47.52 | 50.56 | 53.42 | 56.13 | 58.72 |
| | 6.0 | | | | | | 28.27 | 35.11 | 40.44 | 45.05 | 49.20 | 53.01 | 56.55 | 59.87 | 63.02 | 66.01 |
| | 6.5 | | | | | | | 37.26 | 43.74 | 49.20 | 54.04 | 58.46 | 62.54 | 66.37 | 69.97 | 73.40 |
| | 7.0 | | | | | | | 38.48 | 46.64 | 53.09 | 58.72 | 63.81 | 68.49 | 72.86 | 76.97 | 80.86 |
| | 7.5 | | | | | | | | 48.96 | 56.65 | 63.19 | 69.02 | 74.36 | 79.31 | 83.96 | 88.36 |
| | 8.0 | | | | | | | | 50.27 | 59.75 | 67.36 | 74.04 | 80.10 | 85.69 | 90.92 | 95.85 |
| | 8.5 | | | | | | | | | 62.23 | 71.15 | 78.80 | 85.66 | 91.95 | 97.81 | 103.31 |
| | 9.0 | | | | | | | | | 63.62 | 74.45 | 83.23 | 90.99 | 98.05 | 104.58 | 110.71 |
| | 9.5 | | | | | | | | | | 77.07 | 87.25 | 96.03 | 103.93 | 111.21 | 118.00 |
| | 10.0 | | | | | | | | | | 78.54 | 90.73 | 100.71 | 109.56 | 117.65 | 125.15 |
| 10.5 | | | | | | | | | | | 93.49 | 104.94 | 114.87 | 123.84 | 132.13 | |
| 11.0 | | | | | | | | | | | 95.03 | 108.60 | 119.78 | 129.75 | 138.88 | |
| 11.5 | | | | | | | | | | | | 111.48 | 124.21 | 135.31 | 145.38 | |
| 12.0 | | | | | | | | | | | | 113.10 | 128.04 | 140.45 | 151.55 | |
| 12.5 | | | | | | | | | | | | | 131.05 | 145.07 | 157.36 | |

HORIZONTAL CYLINDER - FLAT HEAD

| D[m] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|------|------|---|---|---|---|---|---|---|---|----|----|----|--------|--------|--------|
| h[m] | 13.0 | | | | | | | | | | | | 132.73 | 149.06 | 162.71 |
| | 13.5 | | | | | | | | | | | | | 152.19 | 167.52 |
| | 14.0 | | | | | | | | | | | | | 153.94 | 171.66 |
| | 14.5 | | | | | | | | | | | | | | 174.91 |
| | 15.0 | | | | | | | | | | | | | | 176.71 |

VERTICAL CYLINDER - SPHERICAL BOTTOM

| D[m] | | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 |
|------|-----|------|------|-------|-------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| h[m] | 0.5 | 0.26 | 1.05 | 1.83 | 2.62 | 3.40 | 4.19 | 4.97 | 5.76 | 6.54 | 7.33 | 8.12 | 8.90 | 9.69 | 10.47 | 11.65 |
| | 1.0 | | 3.67 | 6.81 | 9.95 | 13.09 | 16.23 | 19.37 | 22.51 | 25.66 | 28.80 | 31.94 | 35.08 | 38.22 | 41.36 | 46.08 |
| | 1.5 | | 7.07 | 14.14 | 21.21 | 28.27 | 35.34 | 42.41 | 49.48 | 56.55 | 63.62 | 70.69 | 77.75 | 84.82 | 91.89 | 102.49 |
| | 2.0 | | | 23.04 | 35.60 | 48.17 | 60.74 | 73.30 | 85.87 | 98.44 | 111.00 | 123.57 | 136.14 | 148.70 | 161.27 | 180.12 |
| | 2.5 | | | 32.72 | 52.36 | 71.99 | 91.63 | 111.26 | 130.90 | 150.53 | 170.17 | 189.80 | 209.44 | 229.07 | 248.71 | 278.16 |
| | 3.0 | | | | 70.69 | 98.96 | 127.23 | 155.51 | 183.78 | 212.06 | 240.33 | 268.61 | 296.88 | 325.15 | 353.43 | 395.84 |
| | 3.5 | | | | 89.80 | 128.28 | 166.77 | 205.25 | 243.74 | 282.22 | 320.70 | 359.19 | 397.67 | 436.16 | 474.64 | 532.37 |
| | 4.0 | | | | | 159.17 | 209.44 | 259.70 | 309.97 | 360.24 | 410.50 | 460.77 | 511.03 | 561.30 | 611.56 | 686.96 |
| | 4.5 | | | | | 190.85 | 254.47 | 318.09 | 381.70 | 445.32 | 508.94 | 572.56 | 636.17 | 699.79 | 763.41 | 858.83 |
| | 5.0 | | | | | | 301.07 | 379.61 | 458.15 | 536.69 | 615.23 | 693.77 | 772.31 | 850.85 | 929.39 | 1047.20 |
| | 5.5 | | | | | | 348.45 | 443.49 | 538.52 | 633.55 | 728.59 | 823.62 | 918.65 | 1013.69 | 1108.72 | 1251.27 |
| | 6.0 | | | | | | | 508.94 | 622.04 | 735.13 | 848.23 | 961.33 | 1074.42 | 1187.52 | 1300.62 | 1470.27 |
| | 6.5 | | | | | | | 575.17 | 707.91 | 840.64 | 973.37 | 1106.10 | 1238.83 | 1371.57 | 1504.30 | 1703.40 |
| | 7.0 | | | | | | | 795.35 | 949.28 | 1103.22 | 1257.16 | 1411.10 | 1565.04 | 1718.97 | 1949.88 | |
| | 7.5 | | | | | | | 883.57 | 1060.29 | 1237.00 | 1413.72 | 1590.43 | 1767.15 | 1943.86 | 2208.93 | |
| | 8.0 | | | | | | | | 1172.86 | 1373.92 | 1574.99 | 1776.05 | 1977.11 | 2178.17 | 2479.76 | |
| | 8.5 | | | | | | | | 1286.22 | 1513.20 | 1740.18 | 1967.16 | 2194.14 | 2421.12 | 2761.59 | |
| 9.0 | | | | | | | | | 1654.05 | 1908.52 | 2162.99 | 2417.46 | 2671.92 | 3053.63 | | |
| 9.5 | | | | | | | | | 1795.68 | 2079.21 | 2362.74 | 2646.27 | 2929.80 | 3355.09 | | |
| 10.0 | | | | | | | | | | 2251.47 | 2565.63 | 2879.79 | 3193.95 | 3665.19 | | |
| 10.5 | | | | | | | | | | 2424.52 | 2770.88 | 3117.25 | 3463.61 | 3983.15 | | |

VERTICAL CYLINDER - SPHERICAL BOTTOM

| D[m] | | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 |
|------|------|---|---|---|---|---|----|----|----|----|----|----|---------|---------|---------|---------|
| h[m] | 11.0 | | | | | | | | | | | | 2977.71 | 3357.84 | 3737.97 | 4308.17 |
| | 11.5 | | | | | | | | | | | | 3185.31 | 3600.79 | 4016.26 | 4639.48 |
| | 12.0 | | | | | | | | | | | | | 3845.31 | 4297.70 | 4976.28 |
| | 12.5 | | | | | | | | | | | | | 4090.62 | 4581.49 | 5317.80 |
| | 13.0 | | | | | | | | | | | | | | 4866.85 | 5663.24 |
| | 13.5 | | | | | | | | | | | | | | 5153.00 | 6011.83 |
| | 14.0 | | | | | | | | | | | | | | | 6362.77 |
| | 14.5 | | | | | | | | | | | | | | | 6715.29 |
| | 15.0 | | | | | | | | | | | | | | | 7068.58 |

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