ManningUX-1100

Portable Ultrasonic Measuring System
ManningUX-1100

Portable Ultrasonic Measuring System

Part No. 717721

March 1992
Warranty and Disclaimer

For warranty information, refer to the Limited Warranty Statement shipped with your invoice or call TN Technologies.

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## Contents

**Chapter 1: Introduction** .........................................................1-1  
- General Description ......................................................... 1-1  
- Pulsed Ultrasound Theory .................................................. 1-3  
  - Application ................................................................. 1-3  
- UL-1100 Chart Plate .......................................................... 1-5  
- UF-1100 Chart Plate ........................................................... 1-7  
- UD-1100 Chart Plate ........................................................... 1-9  

**Chapter 2: Calibration** .........................................................2-1  
- Shop Calibration ...................................................................... 2-2  
- Field Calibration ..................................................................... 2-4  
- Calibration to a Different Transducer ..................................... 2-5  
- Calibration With a Calibrator Box ......................................... 2-5  
- UF Totalizer (UD Option) ....................................................... 2-5  
- Sample Rate Settings ............................................................ 2-8  

**Chapter 3: Installation and Operation** .................................3-1  
- General Guidelines .................................................................. 3-1  
- Transducer .............................................................................. 3-1  
- Sites ....................................................................................... 3-3  
- Transducer Mounting .............................................................. 3-6  
  - Transducer Mounting Bracket ............................................ 3-6  
  - Transducer Flume Mounting Assembly ................................ 3-6  
- Recorder Installation .............................................................. 3-8  
- Charts .................................................................................... 3-9  
- Operation ............................................................................... 3-10  
  - Data Logger Set-up ............................................................. 3-11  
  - Interpreting Raw Data (UD-1100) ....................................... 3-13  

**Chapter 4: Maintenance and Troubleshooting** .......................4-1  
- Maintenance .......................................................................... 4-1  
- Battery Care and Use .............................................................. 4-1  
- Troubleshooting ..................................................................... 4-3  
  - Power .................................................................................. 4-3  
  - Echoes/Meter ................................................................... 4-3  
  - Multi-curve (Level/Flow) ..................................................... 4-5  
- Outputs .................................................................................. 4-5
Appendix A: Flow Measurements .............................................A-1
  Open Channel Flow ..................................................A-1
  Weirs .................................................................A-2
     V-Notch Weir ....................................................A-2
     Rectangular Weir ...............................................A-3
     Cipolletti Weir ..................................................A-3
  Flumes ...............................................................A-4
     Parshall Flume ...................................................A-4
     Palmer-Bowlus Flumes .........................................A-4
     Venturi Flumes ..................................................A-5
  Uniform Flow Sections (Round Pipe) ..............................A-5

Appendix B: Flow Calculations and Tables ..............................B-1
  Application of the Manning Formula ...............................B-1
  Maximum Flows for Parshall Flumes ...............................B-3
  Maximum Flow for Palmer-Bowlus Flumes .........................B-4
  Maximum Flows for Circular Pipe .................................B-5

Appendix C: Specifications ..............................................C-1
Chapter 1: Introduction

General Description

The TN/Manning UX-1100 is a non-contact system for precise measurements of liquids in open channels. The basis for measurement is an ultrasonic wave formed by a high voltage pulse to a piezoelectric crystal. The UX measures the time between the initial pulse and echoes returned from the liquid surface and converts the echoes into level or flow data.

There are three versions of the TN/Manning UX-1100 Portable Ultrasonic Measuring System. Each UX-1100 permanently records flow or level data on a circular chart which coordinates data with the time and date.

UL-1100 Level Recorder Measures and records level.

UF-1100 Flow Recorder Measures and records flow or level. A digital, non-resettable totalizer calculates volume. The UF-1100 can also drive a flow proportional sampler.

UD-1100 Data Logger Stores either level or flow data on an Eprom for later uploading to a computer. It records up to 16,384 discrete flow or level readings. The UD with Totalizer can also drive a flow-proportional sampler.

All units consist of two major components: A transducer and a recorder.

Transducer

The ultrasonic transducer functions as a transceiver in that it both transmits an ultrasonic pulse and receives the return echo. It has a sealed-in air temperature sensor.

Recorder

The recorder contains the power system, internal PC boards, an easy-to-use chart plate control, and connectors for the transducer and battery recharging. Recorders are housed in impact resistant, watertight ABS plastic cases with anti-skid feet and transparent plexiglass covers.

The power system consists of a sealed, lead acid 12VDC battery. Battery life is dependent upon continuous use, mode of operations, and temperature.
The circular recording chart is held on the chart plate. The chart becomes a permanent record. Chart speed can be set for 24-hour or seven-day operation. For the UL-1100, the penned line represents level as a percent of maximum level. For the UF-1100, the level data are converted into flow data and the penned line represents flow as a percent of maximum flow. In addition to recording flow or level data on the circular chart, the UD-1100 data are stored sequentially on a solid state memory chip, an Eprom.

The UF-1100 recorder houses a totalizer and the chart plate displays the total flow on a digital counter. The recorder also houses the sampler trigger mechanisms, sample rate setting options, and has an additional connector for a sampler for flow proportional sampling.

The sample rate settings for the UD are internal — the chart plate must be raised to change settings.

Detailed illustrations and descriptions of the chart plates begin on page 1-4.
Pulsed Ultrasound Theory

Ultrasound is exactly like audible sound but frequencies are above the hearing range. Sound wave frequencies are measured in “hertz” or “Hz.”

Sound waves are not affected by gravity and travel in straight lines until contacting a reflective (or absorptive) surface which bounces, or echoes, the wave back. If sound waves hit a surface dead-on, the waves will echo straight back, similar to a rubber ball dropped onto concrete bouncing straight up. If waves hit an irregular surface, the echo will not return straight back, just like a ball bounces whichever way off of cobblestones. Unlike a bouncing ball, sound waves can also scatter when they hit a rough surface. (Waves do not echo from absorptive surfaces.)

The speed of sound varies with temperature, slowing when temperature decreases.

Application

The UX-1100 Ultrasonic System transducer sends a 40 kHz ultrasonic wave, measures the time from the first echo returned to a cut-off time and uses the data to calculate levels.

Your UX can be calibrated to reflect this time measurement in inches and feet, or centimeters and meters. If the distance being measured changes 1 foot, the time change is approximately 2 milliseconds (ms).

To compensate for waves widening with distance, the UX automatically increases sensitivity through Time Compensated Gain (TCG).

Signal velocity varies with temperature changes (1% change in velocity with each 10°F variation). The transducer measures temperature variations and the electronics compensate from 40°F to 140°F (-40°C to 60°C). The received signal and air temperature DC level signals are carried to the receiver by a coaxial cable.
## UL-1100 Chart Plate

1. **MODE**
   - 3-position switch labeled CALIBRATE-OFF-OPERATE

2. **SPAN**
   - 10-turn knob with outer locking ring for setting maximum height

3. **RANGE**
   - 10-turn knob with outer locking ring for setting the zero point

4. **OVER UNDER**
   - LEDs (2) SPAN and RANGE setting indicators

5. **ECHO STRENGTH - BATTERY CHARGE**
   - Spring-loaded switch: permanent position of echo strength; temporary toggle to battery charge

5A
   - Meter indicates echo strength or battery condition as a percent of full charge
**UF-1100 Chart Plate**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 1 | MODE | 3 position switch  
CALIBRATE-OFF-OPERATE |
| 2 | SPAN | 10-turn knob with outer locking ring for setting maximum height |
| 3 | RANGE | 10-turn knob with outer locking ring for setting the zero point |
| 4 | OVER UNDER | LEDs (2) SPAN and RANGE setting indicators |
| 5 | ECHO STRENGTH - BATTERY CHARGE | Spring-loaded switch: permanent position of echo strength; temporary toggle to battery charge |
| 5A | | Meter indicates echo strength or battery condition as a percent of full charge |
| 6 | TOTAL FLOW X 100 | Non-resettable counter continuously updates and displays total flow |
| 7 | SAMPLE RATE | 10-position thumbwheel and 3-position switch for setting sample rates |
| 8 | MAXIMUM FLOW INPUT | Three single-digit thumbwheels for setting 100% flow rate in units per minute |
| 8A | PRIMARY DEVICE SELECT | 15-position thumbwheel for selecting level-to-flow conversion (primary devices — flumes, weirs, etc.) |
## UD-1100 Chart Plate

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MODE</td>
</tr>
<tr>
<td>2</td>
<td>SPAN</td>
</tr>
<tr>
<td>3</td>
<td>RANGE</td>
</tr>
<tr>
<td>4</td>
<td>OVER UNDER</td>
</tr>
<tr>
<td>5</td>
<td>ECHO STRENGTH - BATTERY CHARGE</td>
</tr>
<tr>
<td>5A</td>
<td></td>
</tr>
<tr>
<td>8A</td>
<td>PRIMARY DEVICE SELECT</td>
</tr>
<tr>
<td>9</td>
<td>LEDs</td>
</tr>
<tr>
<td>10</td>
<td>ADDR/DATA</td>
</tr>
<tr>
<td>11</td>
<td>LOAD/RUN</td>
</tr>
<tr>
<td>12</td>
<td>MEASUREMENT INTERVAL</td>
</tr>
<tr>
<td>13</td>
<td>HEADER FIELD</td>
</tr>
<tr>
<td>14</td>
<td>ADDR RESET</td>
</tr>
<tr>
<td>15</td>
<td>MEMORY FULL</td>
</tr>
<tr>
<td>16</td>
<td>ADDR STEP</td>
</tr>
<tr>
<td>17</td>
<td>HEADER FIELD</td>
</tr>
<tr>
<td>18</td>
<td>ENTER</td>
</tr>
<tr>
<td>19</td>
<td>SOLID STATE MEMORY</td>
</tr>
</tbody>
</table>
Chapter 2: Calibration

Calibrating your UX-1100 for your specific application is critical in order to acquire accurate data. Before starting you should be familiar with these terms. They will be used often in the directions.

Note: All directions are given in inches and feet. If your application is in centimeters or meters use a dead zone of 55.9 cm.

Zero point
0% flow or level
The point at which there is no flow or level. It is the bottom of a channel or tank except in some cases where flumes or weirs are used. (Bottom of span.)

Maximum height
100% flow or level
The highest flow or level expected. (Top of span.)

Dead zone
22 inches
Distance in front of the transducer where no meaningful measurements can be taken. The receiver is "blanked" for a distance (creating a dead zone) to exclude the ringing from the transducer's powerful pulse from the valid echoes.

Range
Not more than 21.8 feet
Distance from the transducer face to zero point. RANGE is the knob used to set the zero point.

Span
At least 4 inches; not more than 20 feet
Distance from the zero point to the maximum height. All useful measurements are taken in the span. SPAN is the knob used to set the maximum height.

Before you can calibrate your UX, you need to know precisely where and how it will be installed. The installation determines the zero point and the maximum height. Read Chapter 3: Installation and Operation for further information.

There are two ways to calibrate your instrument: in the shop or in the field. There are four basic steps: battery installation, transducer set-up, calibrating the zero point and calibrating the maximum height.
Shop Calibration

Battery Installation

Note: All instruments are shipped with the battery and transducer.

1. MODE must be OFF before transporting or connecting the transducer.

2. The transducer must be at air temperature. (It generally will be if it has been at the location where it will be used.) If it isn't, let it adjust to the shop temperature for an hour.

3. Raise the cover, then the chart plate. Connect the internal battery to the interconnect board and screw on tightly.

4. Close and lock the chart plate.

UD-1100 Note: Do not install the Eprom until the unit is calibrated and ready for installation.

Transducer Set-up

1. Remove the dust cap from the transducer and connect the transducer cable to TRANSDUCER on the side of the recorder (it's the only place it will fit).

   Note: Never operate the instrument without the transducer connected. It can damage PC board components.

2. Set up a target — any smooth, flat hard surface will work.

3. Determine your maximum height (remember, it cannot be in the dead zone). In some applications maximum height is straight forward: level in a tank, or flow through a half-round pipe. For flumes or weirs, refer to the flow table or formula in Appendix A.

4. Mount your transducer and set it up so the face is the exact distance it should be from your target. The transducer face must be parallel to the target. You are now ready to begin calibrating.
Calibrating the Zero point

UF Note: When measuring small distances (less than 12 inches) with weak or varying echoes, it may appear that the distance is constantly changing. This will cause a ragged line on the chart but will average out in the totalizer.

1. Set PRIMARY DEVICE SELECT. See the chart plate list in Appendix C: Specifications.

Note: The zero point in a Palmer Bowls is not the distance to the bottom of the flume, but rather the distance to the standing water upstream of the step (the hump in the bottom of the flume) when the flow stops. Use the highest listing in the flow table for your flume (Appendix B).

2. Turn MODE to CALIBRATE. Let the instrument stabilize a few minutes.

3. Place a circular chart on the chart hub (you don't need a pen at this point).

4. Unlock the RANGE and SPAN outer locking rings by turning them counter-clockwise.

5. Turn RANGE and SPAN knobs fully counter-clockwise. Then turn SPAN 1 1/2 turns clockwise.

6. Turn RANGE the direction you want the pen arm to rotate until the UNDER light goes out as the pen arm comes up off of zero point (the outer edge of the circular chart). Then turn slowly back until the pen is at 0%. The exact zero point is where the range light comes on steadily. To insure that RANGE is not turned too far, the adjustment can be set to where the light blinks. (This will cause a small false totalization since counts would eventually accumulate during zero point and you would show 1/2% flow or less when in fact there wasn't any flow.)

7. Observe the echo strength on the ECHO METER. It usually wavers over a 20% range. If it bounces more, either the target is moving (ripples, waves, or turbulent air between the transducer and surface) or objects are too near and are obstructing the sound path. If it shows below 10%, call TN Service.

8. Verify or fine-tune the zero point. Lock it in by turning the outer RANGE ring clockwise to LOCK.
Calibrating the Maximum height

Note: Overall system accuracy improves with higher percent flow and full flumes at maximum height. A system that normally reads 3% to 9% (so that winter storms won't go over 100%) will not be as reliable as a system that normally reads 90% to 95%.

1. Move either the transducer or the target so distance between them simulates the distance where the maximum height would occur (keep the 22 inch dead zone clear). As you decrease the distance, the pen arm should move left smoothly and peg-out above 100%. It won’t get that far if SPAN has already been turned clockwise too far.

For round pipe applications, simulate a full pipe. This will yield a reading of 93% when calibrated. Over range will peg-out to the left from 93%, not from 100%.

2. Turn SPAN the direction you want the pen arm to rotate until the span light goes out or blinks. Then turn SPAN back for maximum height (100%—93% with a round pipe curve). The OVER light may flash occasionally as the pen arm jumps above 100% on the chart.

3. Verify calibration by moving the target (or transducer) between settings. Fine tune as necessary, then lock the SPAN knob.

Calibration is complete at this point if the transducer can be installed in the field to the identical distances.

Field Calibration

Field calibration is not recommended for new applications or for inexperienced users. Field calibration is, however, recommended for experienced users who are replacing or installing a unit into a familiar site. Battery installation and transducer set-up are the same as for shop calibration.

Calibrating the zero point

If possible, stop the flow then proceed as in shop calibration. If the flow cannot be stopped, try to calibrate using a known low flow. This must be repeated until it no longer needs adjustment.

Alternatively, it may be easier to move the transducer to an area beside the flow. After installing the transducer, verify a known flow.
Calibrating the maximum height

It is often difficult to control flow through a channel during field calibration. If possible, run maximum height flow and proceed as in shop calibration. At less than maximum flow, select option zero (linear) on the PRIMARY DE- VICE SELECT thumbwheel (the multi-curve switch). Use a dip stick to gauge the level. The actual level divided by maximum height is the percent level. For example, if a dip stick shows 4 inches and the maximum is 10 inches,

\[ \frac{4}{10} = .4 \text{ or } 40\%. \]

Calibrate to percent of calculated maximum. Return multi-curve switch to proper setting for conversion to flow measurement.

Alternatively, use a target to simulate maximum height. The target should have a water surface if accuracy is critical. (The water need only be deep enough to cover the whole target and you can improvise a container — bucket, cake pan, heavy-duty aluminum foil with the edges folded up.) Shims can be measured for placement under the target to produce known flow heights. This target should be the full width of narrow flumes.

If the instrument does not “behave” at this point, it probably heard something closer than your maximum height. Make sure there is a clear beam area — no interference from weirs, flumes, walls, etc. If there is, you may need a collimating tube (see page 3-2). Continued trouble could mean there is something acoustically odd about the application or the transducer is ringing excessively.

Calibration to a Different Transducer

If you swap transducers and accuracy is critical, you will have to (at least) fine-adjust the zero point. Transducers differ from one another effectively by as much as 1- 1/2 inch, especially between older and newer units.

Calibration With a Calibrator Box

A calibrator box can be used in place of a transducer and movable target. First, connect the box to recorder. Then, calibrate as normal, using the cal box to simulate zero point and maximum height. Final adjustment using the transducer over a known flow is necessary for maximum accuracy.

UF Totalizer (UD Option)

Note: The totalizer can calculate virtually any flow for any unit of measure. These instructions use gallons per minute — the most commonly used unit. If your application differs, substitute your units and proceed exactly the same way.

The totalizer counts 1 for each 100 gallons — up to what you enter as MAXIMUM FLOW INPUT. If you enter 4 0 0 as the maximum flow, it will count 4 during every minute there is maximum flow. However, if you tell it
4000 and your maximum flow is actually 800 gallons per minute it will still count 4 when there is maximum flow—completely ignoring the final 400 gallons. (Most applications are for between 100 and 999 gallons per minute, which is why there are three thumbwheels.)

When flow is below maximum height, it counts the actual flow. If you've entered 400 and the flow is at 50%, you will get 2 counts per minute (it will take 2 minutes to get four counts).

To find your flow, use the flow table in Appendix B, a formula for your application, or previous data from your site. For high and low flows, read the average flow directions first.

- Low flow is less than 100 gallons per minute
- Average flow is between 100 and 999 gallons per minute
- High flow is for more than 1000 gallons per minute.

**Average flow**

1. Set the three MAXIMUM FLOW INPUT thumbwheels to your maximum flow.

2. Take a reading of the totalizer and write it on the chart. (The totalizer is not resettable so you have to track the numbers.)

3. At the end you your time period (usually every 24 hours), take another reading. Subtract the first day from the second day.

4. Multiply by 100. (X 100 below the counter is to remind you.) This is your gallons of flow for that period of time.

**High flow**

When the maximum flow is 1000 gallons per minute or more, obviously the numbers won't fit on the three MAXIMUM FLOW INPUT thumbwheels. This means you have to drop digits off the flow and multiply by more than X 100.

**Example #1**

<table>
<thead>
<tr>
<th>your flow</th>
<th>MAXIMUM FLOW INPUT</th>
<th>drop</th>
<th>multiply counter by</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>[4] [0] [0]</td>
<td>0</td>
<td>1000</td>
</tr>
</tbody>
</table>

**TOTAL FLOW**

X 100

As you can see, you have to add a 0 to the X 100 “reminder” for every digit you drop from your maximum flow.
Reading the totalizer is the same for as for average flow (steps 2 and 3).

**Example #2**

<table>
<thead>
<tr>
<th>your flow</th>
<th>MAXIMUM FLOW INPUT</th>
<th>drop</th>
<th>multiply counter by</th>
</tr>
</thead>
<tbody>
<tr>
<td>56,000</td>
<td>1 5 6 0 0</td>
<td>0 0</td>
<td>10,000</td>
</tr>
</tbody>
</table>

**Example #3 — Rounding** Round up your flow input. If you drop off digits other than zeros and do not round up, you are rounding down by default. Remember that the counter stops at the value you enter. Giving it a little extra leeway on the upside is preferable to having it cut off before counting all of the maximum flow.

<table>
<thead>
<tr>
<th>your flow</th>
<th>MAXIMUM FLOW INPUT</th>
<th>drop</th>
<th>multiply counter by</th>
</tr>
</thead>
<tbody>
<tr>
<td>67,950</td>
<td>6 1 8 0 0</td>
<td>0 0</td>
<td>10,000</td>
</tr>
</tbody>
</table>

**Low flow**

Rarely will an application have maximum flow below 100 gallons per minute. *(Actual flow may often fall below 100 gallons per minute, but you don't need to set anything special for that condition.)*

**Example #4 — Low flow**

<table>
<thead>
<tr>
<th>your flow</th>
<th>drop</th>
<th>multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>nothing</td>
<td>100</td>
</tr>
</tbody>
</table>

**TOTAL FLOW**

X 100
Sample Rate Settings

Note: The sample rate can be set for virtually any unit of measure. These instructions are for gallons — the most commonly used unit. If your application differs, carefully read Sampling Units at the end of this section, substitute your unit and proceed exactly the same way.

The sample rate can be set at any rate from 100 to 90,000 gallons. With the UF, each sample taken is noted by a check mark on the circular chart.

Note: You must set MAXIMUM FLOW INPUT before setting the sample rate.

1. Plug the connector cable into the sampler and the UX outlets.

2. Turn the SAMPLE RATE thumbwheel and the multiplier switch to the sample rate you want. Examples:

   \[
   \text{SAMPLE RATE} \quad \begin{array}{c}
   8 \\
   \times 10,000 \\
   \times 100
   \end{array} \quad \text{sample every 8000 gallons}
   \]

   \[
   \text{SAMPLE RATE} \quad \begin{array}{c}
   4 \\
   \times 10,000 \\
   \times 100
   \end{array} \quad \text{sample every 40,000 gallons}
   \]

3. When sample rate is set, turn MODE to OFF for 10 seconds and then to CALIBRATE or OPERATE to load the settings.

Note: If the unit is not turned to OFF and then to CALIBRATE or OPERATE, the next sample will occur at the previous switch setting. The new switch setting will be used for the second sample and all samples thereafter.

Confirming the Sample Rate

Note: Directions are for confirming the sample rate over a 24-hour period. Make the necessary adjustments for any other testing period.

This example assuming these settings:

\[
\text{SAMPLE RATE} \quad \begin{array}{c}
8 \\
\times 10,000 \\
\times 100
\end{array} \quad \text{MAXIMUM FLOW INPUT} \quad \begin{array}{c}
5 \\
\times 10 \\
\times 100
\end{array}
\]

1. Compute your daily volume. You see that 36 samples have been taken. Multiply the samples by the SAMPLE RATE setting.

   \[36 \times 8000 = 288,000\]

2. This will correspond to the counter. Subtract the second day totalizer count from the first day. Multiply the difference by 100. (The X 100 under the TOTAL FLOW will remind you. Remember, if your volume
is more than 1000 gallons a minute, your multiplier will depend upon how many zeros you dropped when setting the flow. See page 2-6.)

Note: If these numbers don't match, call TN for assistance.

3. Figure what the maximum volume would have been. For example, if MAXIMUM FLOW INPUT setting was 500 the maximum count possible was 7200 (remember the X 100).

\[ 500 \times 60 \text{ (minutes)} \times 24 \text{ (hours)} = 720,000 \]

4. To get the flow rate, divided the actual count by the maximum count

\[ 288,000 \div 720,000 = .4 \text{ or } 40\% \text{ average flow for the day.} \]

Determine if this flow is typical for your operation. Was it low, say 20% of maximum? Was it high — 85%? Reset the sample rate if necessary.

**Sampling Conditions**
The Totalizer will track flow output to ±0.5 percent. However, accurate sampling depends upon many other factors.

**MAXIMUM FLOW INPUT**
If set too low, you will not get samples when the actual flow is greater than the flow that is set.

**Transducer**
If the transducer is not installed correctly (see Chapter 3: Installation), you will not get accurate counting nor accurate sampling.

**Lost echo**
(transducer related) Sampling will continue at rate of last valid reading.

**Sampling Units**
The sampler mechanism is triggered by the counter. (Our instructions base sampling on actual volume because for most applications it is essentially the same and makes set-up easier.) If your application uses a different unit:

With sample settings of 1 and X 100 a sample will be taken each time the totalizer counts (one count per 100 gallons of flow)
- 2 is every other time; 3 is every third time, etc.

With the toggle raised to X 1000, the rate is less by a factor of 10
- settings of 5 and X 1000 would be one sample per 50 counts (5,000 units of flow).

X 10,000 slows the rate by another factor of 10
- 9 and X 10,000 would be one sample per 900 counts (90,000 units of flow).
Chapter 3: Installation and Operation

If a tree falls in the forest and there is no one there to hear it, does it make a sound?

This ancient question of metaphysics has real meaning when calibrating and installing your transducer. It must be both calibrated accurately and aligned correctly or it will not "hear" the sound.

General Guidelines

There are many possible UX installations. By following the general guidelines, you can devise an optimal installation for your application.

Transducer

The transducer must be perpendicular to the surface of the liquid or it will not receive the echoes.

Keep the path clear between the transducer and the level being measured. Grating, plumbing, even a nearby wall or ladder can interfere if too close. Allow room for a 7 degree cone of sound (3 1/2 degrees on either side of a theoretical line) to reach the flow target. In narrow flumes it is important to center the transducer to avoid interference.
For flumes less than 8 inches wide at the sound beam it may be necessary to use a collimating tube (P/N 886163) to prevent echoes from being received from the edges of the flume.

Avoid windy, gusty location if you can. Where wind is inevitable, the collimating tube will keep the echoes focused.

Avoid installation where the transducer will be exposed to direct sunlight. Air temperature compensation is provided by a sensing element in the transducer and the heat from direct sunlight will throw this compensation off. Also, direct sunlight will reduce the life expectancy of the transducer.

Mount the transducer as close as possible to the liquid level, but not into the 22 inch dead zone.
Where the maximum level is within the dead zone, you will need to “make” a dead zone by installing the transducer parallel to the flow or liquid surface with a 45 degree reflective surface.

Sites

With flumes, the transducer should be mounted between the arrows on flumes, or further upstream. On 6 inch or 4 inch Palmer Bowlus flumes, you will get better accuracy by placing the transducer at least a full channel diameter upstream from the bottom of the step.

For weirs, the transducer must be upstream of the crest by a distance of at least 4 times the distance between the zero point and the maximum height (four times full span).

For pipe and tank applications, there aren't many options. Basically center the transducer, using a collimating tube if necessary.
For manholes, there are many possibilities. We have illustrated several. These two use the transducer mounting bracket (see page 3-6). Both are good installations when the manhole is easy to get into. These both keep the transducer steady even if there is heavy road traffic above.

(After you install the transducer, secure the cable to the top of the ladder or tape it to a wall so that it is easy to reach after you install the recorder.)
If the manhole is straight and narrow, you can wedge in a 2 x 4 and mount the transducer to that. (Wedging a long board is easier than cutting one to an exact size and mounting it.) Secure the transducer to the board.

For these methods it is critically important that the transducer mount follow the general guidelines and is calibrated accurately for its actual mounting.
Transducer Mounting

Transducer Mounting Bracket

The transducer mounting bracket holds the transducer steady and makes it easy to install the transducer perpendicular to the water.

1. Secure the bracket to the mounting surface with 4 bolts. (Type of bolts depends on type of mounting surface, i.e. wood, metal, concrete, etc.) Use a level to align horizontal and vertical axes.

   Note: Bracket must be installed so that the face of the transducer will be over the center of the channel.

2. Route the transducer coaxial cable through the threaded hole in the adjusting plate of the bracket.

3. Screw the transducer into the threaded adjusting plate. Hand tighten firmly.

4. Route the cable back along the bracket and tie down with clamp at the center of the bracket.

5. Connect the loose end of the cable to the TRANSUCER connection on the case of the instrument.

Transducer Flume Mounting Assembly

The flume mounting assembly is designed for use with Palmer-Bowlus and Parshall flumes. (Illustrated opposite.)
Recorder Installation

Before installing the ultrasonic recorder in a field operation, you must:

1. Fully charge the battery. (See Chapter 4: Maintenance and Troubleshooting for detailed battery information.)

2. Calibrate the instrument.

3. Wind the clock (the key is in the accessory kit). Do not over wind — stop when you feel it getting tighter.

4. Adjust the chart drive for 24-hour or 7-day operation.

5. Install a new chart (see opposite page).

Recorder Bracket

The recorder bracket should be used with manhole installations and any other application where it logically fits. It is not necessary with indoor pipes and tanks when you can set the recorder on the floor or a bench.

Install the transducer before installing the recorder bracket — when the recorder bracket is in place, you cannot get down the manhole.

The three legs should be about 4 inches below the manhole cover ledge. Tighten the three T-screw tips firmly into sides of the manhole. Connect the transducer coaxial cable to the recorder. Leave some slack in the cable.

**Note:** Never let the transducer hang by the BNC connection. Secure it to the bracket with a tie strip.

Check that it is solidly installed by pressing — cautiously at first — with one hand on the flat plate area of the bracket.

**Note** Bracket should be installed so that recorder will be level within 3/4 inch across its length.
Charts

There are two charts, a 24-hour and a seven day. Both record the time-specific levels or flows as a percent of maximum. Chart rotation is counterclockwise.

Circles represent percent increments of the readings — 20, 40, 60, and 80 percent are labelled. The inner-most circle is the maximum (100%) and the outer circle is the zero point (0%).

Hours are printed along the outer circle in both clock time (A.M./P.M.) and in military time (1-24). On seven day chart, days are divided into eight 3-hour units.

The shaded area extends from 6 P.M. to 6 A.M. —roughly the hours without sunshine— making seven shaded areas on the seven-day chart and half the chart shaded on the 24-hour chart.

Each chart must be labelled before use. Although the information is also on the recorder, the data must be written on chart because the chart becomes the permanent record.

1. Month, day, and year. There is no specific line, but there is room in the middle.

2. Maximum Height (100% level) on the MAX. LEVEL line.

For the UF and UD also record —

3. Maximum flow on the MAX. FLOW line. To determine maximum flow, see Appendix B, another reference source you may have, or call TN Service for assistance.

For the UF also record —

4. Beginning totalizer count on the BEGIN line.

5. Likewise, note the end totalizer count when you replace the used chart.
Operation

After you have calibrated and installed the system, it is ready for operation.

Note: You must first label your chart (see previous page).

1. Raise the U-shaped clamp on the chart hub.
2. Rotate the chart so the pen rests at the right time and day.
3. Lock in chart by folding down the U-shaped clamp. Secure the clamp by pushing toward the hub.
4. Remove the protective cap from the pen.
5. For ULs and UF s, turn MODE to OPERATE. (UDs will be in operation upon completion of set up. See next page.)
6. For UF-1100s, record the TOTAL FLOW counter reading on the BEGIN line on the chart. (Likewise, record the end reading.)
7. Close cover and fasten latches. Secure dust caps on unused connectors.

Note: Leaving the cover open or connectors uncovered can cause permanent damage to the instrument.

If applicable —

8. Fasten bungee strap to secure recorder in place.
9. Place cover on manhole.
Data Logger Set-up

Note: You must calibrate your UD before programming your Eprom chip.

The UD-1100 data logger is designed for user flexibility. It has 16k memory and can be expanded to 32k. The first 8 bytes are reserved for information essential to your application. To program:

1. Turn MODE to CALIBRATE, the display toggle to ADDR, and LOAD/RUN to LOAD (all switches up).

2. Insert the Eprom chip into the socket.

3. Press ADDR RESET. The MON LED (right most) will light up.

4. To program month, turn the two HEADER FIELD thumbwheels to the current month — January is 1, December is 12, etc. Press ENTER.

   Note: Make sure the thumbwheels are correct and correspond to the LED before pressing ENTER. You cannot erase an Eprom chip when it is in the UD socket.

5. The second-from-the-right LED will light up. Set and enter the date the same as you did month.

6. The third LED indicates HOUR. Time is set military style, noon is 12, midnight is 24.

7. The fourth LED is MIN.

8. The fifth LED is site location. (If you do not have a site number, enter 00.)

9. The sixth LED is INTERVAL. Use the MEASUREMENT INTERVAL thumbwheel (not HEADER FIELD). This corresponds to specific time intervals set up to take measurements.

   1  15.0 minutes
   2  7.5 minutes
   3  3.8 minutes
   4  1.9 minutes
   0  49 minutes
10. The seventh and eighth LEDs, labeled XX and YY can be programmed with any information you need, such as additional site specifications or operator information. (If you don't have any additional information, enter 00.)

To start recording data:

1. Turn MODE to OPERATE.

   Note: Do not leave MODE at OFF for more than 5 seconds or you will lose all the data you just programmed.

2. Switch LOAD/RUN to RUN. This starts the interval clock, hence the measurements. The UD-1100 is now in service.

   Note: You must turn MODE to OPERATE before switching to RUN - otherwise the addresses will advance rapidly (several per second) and no data will be entered into the memory. You will have a large gap of "no data" when the memory is read.

The Eprom may be removed during operation for on site verification using the optional Eprom carrying case. Take care that:

1. The UD-1100 is on (operate mode).

2. No LEDs are lit when removing or installing the Eprom.

3. If you have to switch to CALIBRATE (to check or adjust zero point or maximum height), first switch to LOAD to prevent address run-away. The instrument should never be in, or be put in, RUN if it is not in OPERATE - "it can't RUN if it's not in OPERATION".

   Note: It is recommended that Eproms be stored and transported in a static-free environment such as the optional Eprom carrying case. The solid state memory includes a carrier/connector system, keyed for correct insertion. Static discharges can cause permanent damage to the memory chip.
Interpreting Raw Data (UD-1100)

The UD-1100 writes the level/flow data sequentially in an 8-bit parallel format. The data consist of one bit for error conditions and 7 bits of level/flow. It is easiest to read the data by using a PC and purchased software such as Calcuflow. If you are using TN/Manning Calcuflow, it will need the first eight bytes of memory to contain the suggested format information.

Data can also be interpreted using an Eprom reader or in the field as acquired.

Data are displayed in 8 bit, binary form in the DATA display (ADDR/DATA switch down). Each light has a numeric value increasing from 2 to 128.

| 128 | 64 | 32 | 16 | 8 | 4 | 2 |

Note: When only the first bit is on and the other seven are off it indicates the echo is over the maximum. When all lights are off it indicates the echo is at or under the zero point.

To interpret data:

Example #1

| 64 | 16 | 4 |

1. Add the values of all the lights that are on.
   64 + 16 + 4 = 84

2. Divide the total by 255.
   84 / 255 = .33 or 33% percent flow

Example #2

| 128 | 32 | 4 |

128 + 32 + 4 = 164

164 / 255 = .64 or 64% percent flow
Chapter 4: Maintenance and Troubleshooting

Maintenance

All units have undergone stringent quality assurance inspection and tests to ensure long, trouble-free operation. No scheduled maintenance is required.

We, however, recommend you regularly clean the connectors, especially the transducer. Every six months check the calibration and change the corrosion protection package (change this more often in very humid applications).

We also recommend you return your UX to our Service Department every two years for a calibration check. This ensures the calibration will be accurate even when installed in harsh conditions.

Caution: To prevent permanent damage to the unit:

- Keep the instrument sealed air tight.
- Keep dust caps on unused external connectors.
- Never apply oil or other lubricants.

Battery Care and Use

All units have a 12-volt, 5 ampere hour sealed, lead acid battery. The battery can be used and charged in any position.

Battery life depends upon MODE setting. In CALIBRATE, the battery will last 10 to 16 hours. In OFF, the battery will last several months (depending upon temperature). In OPERATE, battery life is 14 days or more at 25°C with an internal battery. Do not run the battery down completely — you’ll reduce its life span.
Battery Charging

WARNING: Never charge the battery in a sealed container.

If the charger were to malfunction and begin charging at higher than the normal rate, hydrogen and oxygen gas could be vented from the battery cells. This could create an explosive condition if sparks are introduced.

The unit can be charged and operated continuously only in OPERATE. The charger connection is labeled on one end of the unit.

Use charger P/N 889131 (110V) or 889132 (240V) available from TN Technologies. These are specifically designed for the sealed lead acid battery supplied. Do not use automotive trickle or fast chargers since battery damage can result.

Using an External Battery

Note: If an external battery is used, disconnect the internal battery. You can also remove the internal battery.

An external battery must be 12 to 14 VDC wired with 14 to 18 gauge wire. Observe correct polarity. Reverse polarity will blow the 2 amp fuse (F1) located on the interconnect PC board.

Battery Charge Indicator

Battery condition may be monitored by using the meter and adjacent toggle switch. With the unit in CALIBRATE or OPERATE, push the switch toward BATTERY CHARGE. The battery should be recharged when it indicates 20%.

Temperature vs Battery

High temperatures cause the battery to self discharge, reducing its storage or "shelf" life. For example, at 0°C the battery will lose 50% of full charge in 450 days; at 25°C the same loss occurs in 75 days; at 50°C the 50% loss of its charge occurs in 12 days.

Low temperatures reduce the chemical activity rate necessary for energy production. For example, in CALIBRATE the unit will run twice as long at 40°C than at minus 40°C. In OPERATE however, battery drain is much less and self discharge (3:1 ratio) is the main cause of reduced operating life.
Troubleshooting

Troubleshooting instructions follow a logical sequence of events leading to the cause of a malfunction. When a problem occurs, look for the obvious possibilities first. Is the power supply connected? Is a switch in the wrong position? Is a fuse blown? Are connections loose or wires broken? Review the malfunction, review normal operation, and check one possibility at a time starting with the easiest to verify. If you can’t easily resolve the problem, contact the TN Service Department at 1-800-736-0801 or 512-388-9326.

Note: Attempting repairs without authorization can void your warranty. Call TN Service for help.

Power

No power

Probable Causes | Remedy
---|---
1 Defective PC board | Contact factory for assistance
2 Polarity reversed (battery) | Reconnect wiring to correct polarity
3 Fuse F1 blown (interconnect board) | Replace fuse F1 (2 amp)
4 Low battery | Charge or replace
5 DC power not applied to correct terminals | Reconnect DC wires
6 Wrong size DC wires | Install 14 to 18 gauge wire

Echoes/Meter

Weak or lost echo

1 Transducer not connected to unit or open/short transducer cable | Connect cable to unit, or Close open circuit, or Open short in cable
2 Transducer incorrectly aligned with target | Align transducer
3 Low Battery | Charge or replace battery
4 Extreme roughness or foam on surface of target.
   Move transducer to target with smooth surface, or
   Install baffles to eliminate turbulence or foam

5 Unit under range
   Calibrate zero point

6 Over range, over span or both.
   Calibrate zero point, maximum height, or both

**Meter erratic although target level changes are smooth**

1 UF—Sampler event check marks on chart
   Check sample rate setting
   (If you want frequent sampling, you will have many check marks.)

2 Defective multi-curve
   Replace

**Echo meter bouncing**

1 Target moving (ripples, waves or severe air turbulence between transducer and surface)
   Install baffles to quiet surface and reduce air turbulence

**Erratic Chart Readings**

1 Transducer alignment
   Check placement and stability

2 Ambient noise from traffic
   Install collimating tube

3 Obstruction in sound beam path
   Reinstall transducer and/or install collimating tube

4 Small diameter flume
   Install collimating tube
Multi-curve (Level/Flow)

Discrepancy between level to flow data

1 Incorrect curve for type of channel
   Select correct curve

2 Defective multi-curve PC board/IC chip
   Replace

3 Incorrect channel shape (flume)
   Select channel shape to match curve or select correct curve

Outputs

Counter not operating or counting incorrectly

1 Incorrect max flow input setting
   Reset

2 Digit wheel(s) sticking
   Contact factory, or
   Replace counter

Sampler does not take samples

1 Fuse F1 blown.
   Replace fuse F1 (1/2 amp) on totalizer board

2 Sampler not connected at terminals
   Connect

3 Sampler inoperative
   Verify sampler operation
   Check with factory for assistance

Samples taken at wrong flow increments

1 Sample switch incorrectly set
   Reset
Power Supply Distribution

Note: Schematic on page 4-8.

To reduce power consumption most of the circuitry is turned off between measurements. In OPERATE power distribution is:

For 315 ms the power supply charges storage capacitors.

For the next 45 ms the circuitry in (D), (E), (F), (G), (H), (J), and (K) measure the distance and convert it to level or flow.

For the next 1.3 seconds the servo system activates the pen to record data on the circular chart, and the memory control board writes data.

Next the system shuts down for 1.5 minutes (1.9 to 49 minutes in the UD) and power is only supplied to the master clock (B) for initiation of the next measurement cycle.

Circuit Functions

Note: Servo on page 4-9, multi-curve on 4-10, interconnect on 4-11.

Three printed circuit boards are common to all UXs; the power board, the servo board, and the interconnect board. A fourth board provides circuitry for the totalizer, and a fifth for memory control.

A the interconnect board connects the power and servo boards electrically. It also handles primary (battery) power distribution, the MODE switch, and a battery charge indication chip.

B is an oscillator, a counter, and several gates. It is continuously powered by the battery and controls the timing and sequencing of the other circuitry (on servo board).

C is an inverter power supply which provides regulated +15 volts, M+, to the measurement circuitry and high voltage AC to D and 40VAC for the Vpp memory programming voltage (on power board).

D has a voltage doubler, rectifier, and zener to provide high voltage to the pulse transformer (on power board).

E amplifies and detects the 40 KHz echo and includes a Time Compensated Gain (TCG) network to give greater gain to more distant, weaker echoes (on power board).

F measures the resistance of a thermistor in the transducer, providing a temperature compensating signal to G.

G converts the time for echo return into a series of digital pulses representing level. An adjustable span oscillator generates 256 pulses in the time between when an echo is received from the maximum height (close) and when one is received from the zero point (far). An adjustable range
“one-shot” gates off the pulses from the span oscillator, at the time when you would receive an echo from the 0% distance. The gate is opened when the first echo is detected; thus, if it is detected from the maximum height, 256 counts will be gated before the range one-shot closes the gate. If the echo comes from the zero point, it will try to open the gate at the same time as the range one-shot is closing the gate, and 0 counts will be gated (on power board).

H clocks the measurement circuitry, including a 3.1 ms delay to prevent detection of transducer ringing (on power board).

I counts the pulses representing level into an 8-bit counter and over range. Under range is the absence of any count (on servo board).

J an 8-bit look-up table (Multicurve) provides level-to-flow conversion in the UF-1100 and UD-1100. In the UL-1100 the address and data are the same (on multicurve board which plugs into the servo board).

K drives indicators for over range, under range, and echo strength (on servo board).

L latches (holds) data received from J for the time the servo system is on. J2 provides this data to the totalizer (UF-1100, UD-1100) or the Eprom. An R-2R network converts the digital information into an analog signal for M (on servo board).

M consists of a servo drive amplifier and a gating circuit to turn the servo on and off (on servo board).
Totalizer

Latches U4 and U5 hold data for the binary comparator. The data are compared with the count in a binary counter, U9. U10, pin 11, gates the oscillator into the BCD rate multipliers, U12, U13, and U14; thus the number of pulses gated through U10 pin 11 is proportional to the flow data at J1.

The rate multipliers are controlled by S3, S4, and S5 to permit adjusting the totalizer to the actual flow rate of the channel being measured. The output of the rate multipliers is divided by 2 (U11) to smooth the rate at which the counter updates. U10 has a one-shot to drive the totalizer counter.

For flow proportional sampling, S2 selects one of three inputs from the totalizer drive: X100, X1000, or X10,000. The selected input drives a BCD down counter which is settable via S1 for a sample rate of X1 through X9. A one-shot, U1, drives sampler relay K1.

[Diagram of the totalizer system]
Memory Control

The memory control board is the “data logger” of the UD. The memory control provides:

1. A solid state memory device known as an Eprom (erasable, programmable read only). The memory provides nonvolatile storage of 16,384 8-bit “words” of data. Data are stored permanently (100 years) or until erased by exposure to ultraviolet light.

2. The high accuracy recording clock interval function for incremental time keeping. This clock “wakes up” the level meter at the selected measurement interval.

3. A means of manually entering user data via two thumbwheel switches.

4. The control logic functions necessary for disabling front panel controls (enter, address step, address reset) when the unit is in the run mode to ensure against inadvertent resetting of address counter, or accidental entering of data.

5. A toggle display. One acts as a header data prompter (date, time, etc.). The other allows observation of the data (in binary form) being written into the Eprom.

6. Power supply circuitry for Eprom programming.
Eproms

Each Eprom stores 16,384 8-bit items of data. Therefore, the measurement interval setting determines how many days worth of data an Eprom can hold. However, because the Eprom stores data sequentially, it must be changed anytime the power is interrupted, including when the battery is changed. (Also see Data Logger Set-up pages 2-12/11.)

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Erasing Memory

Erasure begins when Eproms are exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å); sunlight and certain types of fluorescent lamps have wavelengths in the 3000-4000 Å range. Constant exposure to room level fluorescent lighting could erase the typical Eprom in approximately 3 years, but it would only take about 1 week for direct sunlight to erase it. If your Eproms will be exposed to these types of lighting conditions for extended periods of time, place opaque labels over the windows to prevent unintentional erasure.

Note: The clear cover of the UD-1100 is opaque to UV light. When the cover is in place, the memory is sufficiently protected from UV light.

To erase an Eprom, expose it to shortwave ultraviolet light which has a wavelength of 2537 Angstroms (Å). Put the chip within 1 inch of the lamp tubes. The integrated dose (i.e. UV intensity x exposure time) for erasure should be a minimum of 15-w-sec/cm². The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with 12000 uW/cm² power rating. Exposure for 45 minutes to one hour is recommended to ensure complete erasure.

Note: Insufficient erasure can produce a seemingly blank memory; then data can “fade back” within a day or so.

Chips can be reused approximately 100 times. Typical signs of over-age are: memory fade-back, inability to erase, and inability to store data.
## Parts List

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<th>Item No.</th>
<th>Part Number</th>
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*Includes*

|          | 756612      | 24-hour charts (50 pkg)            | 1    |          |
| *        | 756613      | 7-day chart (50 pkg)               | 1    |          |
| *        | 579443      | Key Clock                          | 1    |          |
| *        | 783027      | Ze rust corrosion protector        | 1    |          |
| *        | 568086      | Hex Wrench                         | 1    |          |
| *        | 783028      | Desiccant                          | 1    |          |
| *        | 710041      | Instructions of desiccant          | 1    |          |

*Item not illustrated*
Appendix A: Flow Measurements

Open Channel Flow

The essential characteristic of open channel flow is that the pressure is constant (usually atmospheric) along the conduit. Flow is determined by the balance of gravity and friction. By measuring the flow height, the gravitational energy available can be measured and, if the energy/flow rate characteristics of the channel are known, the flow rate can be determined.

There are two common methods for measuring flow rate.

1. A control section (weir, flume) in which the effects of changes in flow upstream and downstream does not affect the measurements. A control section has a definite flow depth-discharge relationship which is independent of channel roughness and other uncontrolled factors. The weir or flume configuration determines accuracy. Accuracy is not affected by varying conditions in the channel.

2. Flow measurement in uniform flow sections such as pipes and troughs require gravity and friction resistance forces to be in balance uniformly along the length of the channel. The section must be straight, with slope, roughness, size, and shape uniform over the length of the section.

Flow can be measured at any accessible point, eliminating the need for special construction of a control section. Measurement accuracies of uniform flow sections tend to be less accurate than with control sections because of variations of the channel below or above the metering point. Under normal conditions, however, reasonable accuracies should be achieved.
Weirs

The weir is essentially a shaped dam creating a small, still pond upstream with minimal velocity of approach.

V-Notch Weir

![Diagram of V-Notch Weir]

Flow rate $Q = K_3H^{5/2}$

The V-notch weir is used for measuring low flows (less than 500 gallons/minute) because there is sufficient head to measure even at minimal flow rates. The flow rate $Q$ is a $5/2$ power function of height. The selection of various notch angles is made by considering the maximum flow rate and the maximum desired (or available) head. Some practical considerations in siting and constructing a V-notch weir in a stream are:

- The depth of the channel below the V should be two times the maximum height of the flow anticipated. This assures that the velocity of approach is minimal.

- The weir edge should be knife-edge sharp and beveled to provide a clean discharge (debris and other suspended solids tend to collect in the bottom of a V-notch weir causing inaccuracies).

- The measuring instrument should be positioned upstream four times ($H$) the maximum flow height.

- Consideration should be given to the increase in head caused by the insertion of a weir in the channel. This type of control section causes the highest head loss, and the effect of this damming of the stream should be considered on the backing up of the water in the upstream channel.

- The downstream discharge section should not be allowed to back up to a level greater than 2 inches below the bottom of the weir.

- The approach section should be straight for a distance of $20H$ upstream from the weir.
Rectangular Weir

Flow rate $Q = K_1(L-0.2H) \frac{H^{3/2}}{2}$

The rectangular weir should be used when heavy flow levels are anticipated. It is difficult to measure low flow conditions with a rectangular weir as accurately as with a V-notch weir due to the small heads at low flows, also, this shape is not as good as the Cipolletti weir because the flow is contracted on the side as it goes over the weir. This narrows the width of the weir and limits the range of accuracy.

Cipolletti Weir

Flow rate $Q = K_2LH \frac{3}{2}$

This trapezoidal configuration of the rectangular weir has sloping sides which compensates for the contraction allowing less complex calculation of flow rate $Q$. $Q$ varies as the 3/2 power of height (H).
Flumes

Flumes are specially shaped channel constrictions which have a converging section, and a throat section, and a diverging section. The velocity of the water is increased and subsequently decreased with the consequent drop in water level. Thus a flume is the open channel equivalent of the Venturi tube restriction in a closed pipe.

Because a flume is a smooth section with high flow rates, it is self-cleaning (without sediment build-up) and results in a very small head loss and fewer problems of water backing upstream.

A critical condition of flow measurement with flumes is that the downstream water level is low enough. If the downstream level builds up (submergence) the flow rate is reduced causing the depth-flow rate relationship to be in error.

Parshall Flume

The Parshall Flume is characterized by a dip in the floor of the throat section. The Parshall Flume has application in large flow installations such as the influent to a sewer treatment plant.

Palmer-Bowlus Flumes

This flume shape is characterized by a raised floor and trapezoidal side walls in the throat section and can be installed in the existing circular pipe section without special construction. Versions of this design can be mounted in the downstream pipe section of a manhole, allowing the upstream head to be measured in the manhole itself. It does not follow the same H 3/2 curve as other flumes.
Venturi Flumes

The Venturi Flume is easily installed in an existing rectangular channel. The flume is characterized by a flat bottom but has a shaped, restricted throat section. A straight section upstream is required to provide accurate flow readings. It is critical that the throat section is flat and level and that no downstream submergence occurs.

Uniform Flow Sections (Round Pipe)

Flow measuring method in sewer systems is to measure the height of flow in gravity pipe systems using the Manning equation (see Appendix B). It is used in flow measurements because it is the most practical and useful formula for measuring open channel round pipe flow. It is often impractical, if not impossible, to construct some of the more sophisticated primary devices (flumes and weirs) to do more accurate metering.
Appendix B: Flow Calculations and Tables

Application of the Manning Formula

Robert Manning, an Irish engineer, first presented his formula for flow measurements in the late 1800s. In 1936, the 3rd World Power Conference recommended a modified version for international use. The Manning equation remains the most practical and useful formula for measuring open channel round pipe flow.

Even the equations for flumes and weirs (which do not depend on the surface condition of the conduit) have severe limitations if the following assumptions are not met:

1. Smooth straight, non-turbulent upstream flow (usually for a distance of 10 times maximum head) and,

2. No downstream backup or submerged flow.

In practice one of the greatest variables in the equation is the Manning roughness coefficient \( n \). For simplicity in concrete pipe the constant value is:

\[
 n = 0.013
\]

In actuality this "constant" can vary over \( \pm 10\% \) of the total range of the full pipe height. Other \( n \) constants are used for other pipe materials.

Another major factor in measurement accuracy is the downstream condition of the pipe. If it is blocked by roots or sand build-up, there tends to be some back-up of flow, giving extraneous results. This of course is true for flumes and weirs too.

Also, the slope is sometimes difficult to measure accurately in real life. However, since this is a square root function, slight errors are not critical.
A major misapplication of the Manning equation is in manholes where either:

1. The channel in the middle does not approximate the shape of a round pipe.

2. There is an abrupt change such as the inlet pipe coming in at a different height than the exit pipe.

3. Two or more streams enter, or

4. The flow is not straight—entering at a different angle than exiting.

Despite these limitations, the Manning equation gives extremely useful information, thus explaining its use over all the years. In many cases such as the infiltration/inflow analysis, approximate or relative flow data are more than sufficient.

The height data using an instrument such as Manning’s are the most reliable data input in the measurement.

The tables are based on an $n = 0.013$; to convert to other $n$ values, multiply the flow $Q$ by $0.013/n$. For example:

For: $n = 0.010$ multiply $Q$ by 1.3  
$n = 0.011$ multiply $Q$ by 1.18  
$n = 0.015$ multiply $Q$ by 0.86

To convert million gallons per day flow to other flow rates:

<table>
<thead>
<tr>
<th>To convert flow in</th>
<th>Multiply flow (in mgd) by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>million imperial gallons per day</td>
<td>0.8333</td>
</tr>
<tr>
<td>million cubic feet per day</td>
<td>0.1337</td>
</tr>
<tr>
<td>million cubic meters per day</td>
<td>$3.7 \times 10^3$</td>
</tr>
<tr>
<td>U.S. gallons per minute</td>
<td>694.4</td>
</tr>
<tr>
<td>imperial gallons per minute</td>
<td>578.7</td>
</tr>
<tr>
<td>liters per minute</td>
<td>2628.0</td>
</tr>
<tr>
<td>cubic feet per second</td>
<td>1.548</td>
</tr>
</tbody>
</table>

Also, note that the maximum flow rate in round pipe occurs at .938 of the pipe diameter and not at the full height.
### Maximum Flows for Parshall Flumes

<table>
<thead>
<tr>
<th>Flume Model No.</th>
<th>Throat Width (Inches)</th>
<th>Maximum Free Flow Discharge (MGD)</th>
<th>Maximum Head (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF-1</td>
<td>1</td>
<td>.123</td>
<td>8.3</td>
</tr>
<tr>
<td>PF-2</td>
<td>2</td>
<td>.280</td>
<td>9.0</td>
</tr>
<tr>
<td>PF-3</td>
<td>3</td>
<td>1.20</td>
<td>18.0</td>
</tr>
<tr>
<td>PF-6</td>
<td>6</td>
<td>2.50</td>
<td>18.0</td>
</tr>
<tr>
<td>PF-9</td>
<td>9</td>
<td>5.70</td>
<td>24.0</td>
</tr>
<tr>
<td>PF-12</td>
<td>12</td>
<td>10.40</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-18</td>
<td>18</td>
<td>15.90</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-24</td>
<td>24</td>
<td>21.40</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-30</td>
<td>30</td>
<td>27.10</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-36</td>
<td>36</td>
<td>32.60</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-48</td>
<td>48</td>
<td>43.90</td>
<td>30.0</td>
</tr>
<tr>
<td>PF-60</td>
<td>60</td>
<td>55.30</td>
<td>30.0</td>
</tr>
</tbody>
</table>
## Maximum Flow for Palmer-Bowlius Flumes

<table>
<thead>
<tr>
<th>Manning Flume Model No.</th>
<th>Permanent (MGD)</th>
<th>Invert Exit (MGD)</th>
<th>Quick Insert (MGD)</th>
<th>Head at Max Discharge (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBF-4</td>
<td>.074</td>
<td>.074</td>
<td>.074</td>
<td>2.9</td>
</tr>
<tr>
<td>PBF-6</td>
<td>.240</td>
<td>.230</td>
<td>.240</td>
<td>4.7</td>
</tr>
<tr>
<td>PBF-8</td>
<td>.494</td>
<td>.480</td>
<td>.494</td>
<td>6.3</td>
</tr>
<tr>
<td>PBF-10</td>
<td>.850</td>
<td>.830</td>
<td>.850</td>
<td>7.85</td>
</tr>
<tr>
<td>PBF-12</td>
<td>1.330</td>
<td>1.310</td>
<td></td>
<td>9.4</td>
</tr>
<tr>
<td>PBF-15</td>
<td>2.375</td>
<td>2.340</td>
<td></td>
<td>11.8</td>
</tr>
<tr>
<td>PBF-18</td>
<td>3.765</td>
<td>3.710</td>
<td></td>
<td>14.2</td>
</tr>
<tr>
<td>PBF-21</td>
<td>5.490</td>
<td>5.430</td>
<td></td>
<td>16.5</td>
</tr>
<tr>
<td>PBF-24</td>
<td>7.650</td>
<td>7.540</td>
<td></td>
<td>18.8</td>
</tr>
<tr>
<td>PBF-27</td>
<td>10.300</td>
<td>10.160</td>
<td></td>
<td>21.2</td>
</tr>
<tr>
<td>PBF-30</td>
<td>13.470</td>
<td>13.390</td>
<td></td>
<td>23.6</td>
</tr>
<tr>
<td>PBF-36</td>
<td>21.120</td>
<td>20.900</td>
<td></td>
<td>28.4</td>
</tr>
<tr>
<td>PBF-42</td>
<td>30.860</td>
<td>30.500</td>
<td></td>
<td>33.0</td>
</tr>
<tr>
<td>PBF-48</td>
<td>43.490</td>
<td>43.060</td>
<td></td>
<td>37.6</td>
</tr>
<tr>
<td>PBF-54</td>
<td>57.190</td>
<td>57.100</td>
<td></td>
<td>42.4</td>
</tr>
<tr>
<td>PBF-60</td>
<td>75.130</td>
<td>74.580</td>
<td></td>
<td>47.2</td>
</tr>
</tbody>
</table>
# Appendix C: Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure</td>
<td>ABS plastic case with plexiglass DR transparent, hinged cover, stainless steel hinges and latches.</td>
</tr>
<tr>
<td>Power</td>
<td>Internal 12VDC, sealed lead acid battery</td>
</tr>
<tr>
<td>Weight</td>
<td>16 lbs. (recorder)</td>
</tr>
<tr>
<td>Connections (Case external)</td>
<td>Battery charger</td>
</tr>
<tr>
<td></td>
<td>Sampler (UF-1100) (UD-1100 W/Totalizer)</td>
</tr>
<tr>
<td></td>
<td>Transducer cable</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>32°F to 122°F (0°C to 50°C) ambient.</td>
</tr>
<tr>
<td>Operation</td>
<td>-40°F to 140°F (-40°C to 60°C) wo/ battery</td>
</tr>
<tr>
<td>Storage</td>
<td>0°F to 86°F (-18°C to 30°C) w/ battery</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±1% full scale</td>
</tr>
<tr>
<td></td>
<td>±1 1/2% full scale for the chart</td>
</tr>
<tr>
<td>Range</td>
<td>Dead zone to 21.8 feet (664 cm)</td>
</tr>
<tr>
<td>Span</td>
<td>4 inches to 20 feet (10.16 cm to 609 cm)</td>
</tr>
<tr>
<td>Dead Zone</td>
<td>22 inches (55.9 cm) from face of transducer</td>
</tr>
<tr>
<td>Primary Device Select</td>
<td>15 positions for selecting look-up table for level-to-flow conversion:</td>
</tr>
<tr>
<td></td>
<td>0 - Linear</td>
</tr>
<tr>
<td></td>
<td>1 - Round pipe</td>
</tr>
<tr>
<td></td>
<td>2 - Half round pipe</td>
</tr>
<tr>
<td></td>
<td>3 - Palmer Bowls</td>
</tr>
<tr>
<td></td>
<td>4 - Parshall</td>
</tr>
<tr>
<td></td>
<td>5 - Contracted rect. weir 1.5/.667</td>
</tr>
<tr>
<td></td>
<td>6 - V-notch weir</td>
</tr>
<tr>
<td></td>
<td>7 - Rectangular channel</td>
</tr>
<tr>
<td></td>
<td>8 - Leopold lagco</td>
</tr>
<tr>
<td></td>
<td>9 - Cipoletti</td>
</tr>
<tr>
<td></td>
<td>10 - Suppressed Rect. Weir</td>
</tr>
<tr>
<td></td>
<td>11 - Reverse linear</td>
</tr>
<tr>
<td></td>
<td>12 - Reserved for test</td>
</tr>
<tr>
<td></td>
<td>13 - Custom</td>
</tr>
<tr>
<td></td>
<td>14 - Custom</td>
</tr>
<tr>
<td></td>
<td>15 - Custom</td>
</tr>
</tbody>
</table>
Time Interval Between Measurement in minutes
  UL & UF  .2, .4, .8, 1.5, 3, 6, 12, 24, 49
  UD  1.9, 3.7, 7.5, 15, 49

Totalizer (UF)  6 digit X100 indicates total flow

Maximum Flow Input (UF, UD)
  Three digit switch - 000-999
  Accuracy  0.25% of flow conversion

Totalizing Conditions (UF, UD)
  In range, In span  Flow dependent
  Out of range  Span
  Over Range  Counts at maximum rate as if 100% flow
  Under Range  No count
  Lost echo  Totalizer continues to count at rate of last valid reading

Data Format (UD)  8-bit parallel word — 7-bit data with LSB used as error (over range/lost echo) bit.

Memory  16384 x 8 bit UV Eprom

Transducer Specifications

Temperature Range  -40°F to 140°F (-40°C to 60°C), operation and storage

Frequency  40 kHz, single element

Cable  Coaxial — 25 feet (7.6 m) standard

Air Temperature Compensation  Sensing element potted with transducer. Temperature DC level returned to electronic package through coaxial cable with 40 kHz echo pulses.

Weight (w/ 25' cable)  2.2 lbs.
Index

A
accuracy C-1
addr/data 1-9, 3-13
air temperature compensation C-2

B
Battery
battery charge 1-5, 1-7, 1-9
care and use 4-1
charger 4-2
external 4-2
installation 2-2
life 4-1
meter 4-2
power board 4-6
power consumption 4-6
temperature 4-2

C
cable 1-3, C-2
Calcuflow 3-13
Calibration 2-1
different transducer 2-5
field 2-4
maximum height 2-4
shop 2-2
with a Cal-100 2-5
zero point 2-3
Chart
24-hour 3-9
seven day 3-9
Chart Plates
UD-1100 1-9
UF-1100 1-7
UL-1100 1-5
Circuits 4-6
clock 4-7
interconnect board 4-6
memory control 4-14
power board 4-6
power supply 4-6
servo board 4-6
totolizer 4-12
clock, circuit 4-7
clock, UD (circuit) 4-14
coaxial cable 1-3

D
Data
chart 3-9
conversion B-2
discrepancies 4-5
gaps 3-12
interpreting (UD) 3-13
recording 3-12
storage 4-15
Data Logger set-up 3-11
dead zone 2-1

E
echo strength 1-5, 1-7, 1-9
circuit 4-7
Eprom 1-1, 3-11, 4-15
capacity 4-15
erasing 4-15
in operate 3-13
installation 2-2
memory control 4-14
programming 3-11
storage, transport 3-12

F
Flow A-1
angled B-2
back-up or blocked B-1
circular pipe B-5
conversions B-2
Manning equation measurement B-1
measurement A-1
open channel A-1
Palmer-Bowltus B-4
Parshall Flumes B-3
round pipe A-5
rounding maximum flow 2-7
weirs A-2
Flumes A-4
flow A-4
mounting assembly 3-6
Palmer-Bowltus A-4
Parshall A-4
Venturi A-5

I
Installation
guidelines 3-1
recorder 3-8
recorder bracket 3-8
transducer 3-2
transducer - 45 degrees 3-3
L
LED 1-5, 1-7, 1-9
  circuit 4-7
  data 3-13
  in calibrate mode 3-11
load/run 1-9

M
maintenance 4-1
Manning equation B-1
maximum flow input 1-7, 2-6
maximum height 2-1
measurement 1-9
memory. See Eprom
mode 1-5, 1-7, 1-9
mounting assembly, flume 3-6
mounting bracket 3-6

P
power. See Battery
power supply (troubleshooting) 4-3
primary device select 1-7, 1-9, C-1
programming (Eprom) 3-11

R
range 1-5, 1-7, 1-9, 2-1
Recorder 1-1
  bracket 3-8
  installation 3-8

S
sample rate, setting 2-8
Sampler 1-1, 2-8
  errors 4-5
  misfunctions 4-5
set-up, transducer 2-2
signal velocity 1-3
Sites
  manholes 3-4
  narrow 3-2
  pipe and tank 3-3
  sunlight 3-2
  windy, gusty 3-2
slope, errors B-2
software, Calculflow 3-13
sound path 3-1
span 1-5, 1-7, 1-9, 2-1
specifications C-1

T
Temperature 1-3
  range
    operation C-1
    storage C-1
  temperature compensation 3-2, 4-6, C-2
Thumbwheels
  sample rate 1-7, 2-8
Time
  echo return (circuit) 4-6
  measurement interval 3-11, C-2
  military 3-11
Time Compensated Gain 1-3, 4-6
total flow 1-7
Totalizer 1-1, 2-5
  circuit 4-7, 4-12
  misfunctions 4-5
totalizing conditions C-2
Transducer 1-1
  flume mounting assembly 3-6
  frequency C-2
  mounting bracket 3-6
  set-up 2-2
troubleshooting 4-3

U
UD-1100 Data Logger 1-1
UF Totalizer 2-5
UF-1100 1-1
UL-1100 1-1
ultrasound 1-3

W
Weirs A-2
  Cipollettii A-3
  rectangular A-3
  trapezoidal A-3
  V-notch A-2

Z
zero point 2-1