Wastewater Treatment Plant Operator Training
Instructor Guide

Module 26:
Advanced Flowmeters

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group

A Note to the Instructor

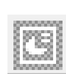
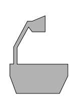
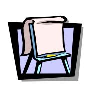
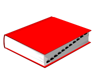
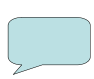
Dear Instructor:

The primary purpose of this course, *Advanced Flowmeters* is to move beyond the basic topics taught in the "Introduction to Flowmeters" course. This course covers more advanced flowmetering topics, including those topics and concepts needed for the operation of large wastewater treatment facilities. This module has been designed to be completed in approximately 3 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by DEP.

Delivery methods to be used for this course include:
- Lecture
- Class activities and calculations
- Group Discussions

To present this module, you will need the following materials:
- One workbook per participant
- Extra pencils
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Flip Chart
- Markers

Icons to become familiar with include:

Participant Workbook		Instructor Guide	
	Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.	
	Case Study	Ans:	Answer to exercise, case study, discussion, question, etc.
	Discussion Question		PowerPoint Slide
	Calculation(s)		Overhead
	Quiz		Flip Chart
	Key Definition(s)		Suggested "Script"
	Key Point(s)		

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.

PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	Press
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

Display Slide 1—Module 26: Advanced Flowmeters.

Welcome participants to Module 26 – Advanced Flowmeters.

This advanced course builds on the basic flowmeter concepts covered in the "Introduction to Flowmeters" course. This course moves beyond the topics needed to understand flowmetering in collection systems and small wastewater treatment plants (WWTP) to cover the concepts needed for more complex flowmetering applications and larger facilities.

We will only deal with flowmeters related to wastewater. You may have flowmeters at your facility for air flow and for potable water usage. Although these are important, we need to limit our scope in this course.

Introduce yourself.

Provide a brief overview of the module.

This module contains 5 units. On page i, you will see the topical outline for Unit 1 – Introduction and Unit 2 – Flowmeter Technologies.

Briefly review the outline.

If you turn the page, you will see the topical outline for Unit 3 – Calibration.

Continue to briefly review outline.

If you turn the page once more, you will see the topical outline for Unit 4 – Maintenance and Unit 5 – Problems/Troubleshooting.

Continue to briefly review outline.

Now let's begin the course with an introduction to flowmeters.

UNIT 1: 35 minutes

Display Slide 2—Unit 1: Introduction.

At the end of this unit, you should be able to:

- Explain why flow is measured.
- List two types of data output.
- Calculate flow when given area and velocity.

INTRODUCTION: 5 minutes

Stress that this is an advanced course. It is similar in layout to the Introduction to Flowmeters course, but it contains more advanced topics. Indicate that they may not realize the full potential of this course if they did not take the "Introduction to Flowmeters" course and/or if they are not very familiar with flowmetering.

Definitions

Note to Instructor: This material is in the "Introduction to Flowmeters" course. Cover it quickly.

Mention that these definitions were covered in the Introduction course but they are key concepts that need to be gone over here as well.

Let's move on to discuss why flowmeters are used.

WHY USE FLOWMETERS: 10 minutes

There are two fundamental aspects of flowmetering: regulatory requirements and practical requirements. It is common for the practical requirements to supersede the minimum regulatory requirements, and you may need to do more to adequately control your system.

Regulatory Requirements

Section 64.8 of the Domestic Wastewater Facilities Manual-10/97

Review the material in the workbook. Include the information below in your discussion of each bullet.

- Devices should be installed in all plants to indicate flow rates of raw wastewater or primary...

  Knowledge of the wastewater and sludge flow through the plant is important in order to adjust the equipment for optimization of treatment efficiency. We will not worry about airflow in this course because it is dependent on air density, temperature, elevation, and humidity. In addition, the density of water at the temperatures we deal with does not vary enough to affect the measurements of our flowmeters.

- Section 64.8 discusses raw wastewater and not WWTP effluent…

  If flowmeters were 100% accurate, the values would be the same, except when there is heavy rainfall, a lot of liquid sludge (biosolids) removed from the WWTP, or severe drought conditions that caused massive evaporation. (If there was heavy rainfall, the flows would be so high it would not matter.)

- Plants designed for flows of 100,000 gallons per day (gpd) or more should totalize and record flow.

  If you only have an instantaneous flow value, you will not know what is happening throughout the day.

  Discussion Question
  How many of you know your minimum flow through the wastewater treatment plant (WWTP) or pumping station? What is the maximum flow rate? This can be critical if you are sizing equipment to handle the flows or need to consider bypassing a unit. You do not want to store wastewater in a collection system except under dire and unusual conditions.

National Pollutant Discharge Elimination System (NPDES) Permit

Review the material in the workbook. Include the following information.

- Part A of most NPDES Permits contains the following verbiage under "Composite Sample"….

  This means the flow must be determined in some way so that the volume of sample is representative of the flow through the WWTP. If you do not have a flowmeter, how do you comply with this portion of your NPDES Permit?

  - Using a discreet sampler with a strip chart…

    The flow chart is read for each hour. Based on the flow, a sample bottle is shaken and then a portion measured out and placed into a larger composite sample. This is done for each bottle during the 24 hour day. As an example, if the flow is 0.40 mgd rate, a portion of 200 ml may be composited into the main composite sample jug.

Display Slide 3—Discreet Sampler Multi Bottle Holder.

In the picture of the discreet sampler multi bottle holder, call the students attention to the pull out holder showing the individual bottles. This allows for discrete sample collection.

PADEP Chapter 94 Requirements

A full copy of Chapter 94 is attached as Appendix A. We are only going to review specific requirements.

Review the material in the workbook. Include the information below in your discussion of each item.

- Section 94.12. Annual report.

  The report shall include the following:

  (5) A discussion of sewer system monitoring, maintenance, repair and rehabilitation….

  Monitoring of a system could include a program that evaluates drainage areas in a collection system as part of a program to determine base flow and the flow attributed to Infiltration/Inflow (I/I). This portion of a program may involve the use of portable v-notch weirs, which we will discuss later.

  (7) A discussion of the condition of sewage pumping stations….

  Ideally, all pumping stations would have flowmeters either on the influent flow or on the force main. This would allow for a comparison between designed capacity of the station and the volume pumped each day. As defined, the discussion must identify present and projected 2 year maximum flows. However, there are several devices on the market which utilize the run time for each pump in conjunction with a field test known as a pumping station wet well draw down test to allow for calculation of flows conveyed by the pumping station. You **must** know what the station is conveying during **maximum** conditions in order to state that it can handle additional flow.

  Note to Instructor: If a participant tells you they only use “average monthly” flows, this may be an indication that he or she does **not** have a full understanding of the pumping station.

- Section 94.13. Measuring, indicating, and recording devices.

  Flow measuring, indicating, and recording equipment shall be calibrated **annually**.

  In the Chapter 94 requirements, PADEP has highlighted and underlined this task because it is critical to understanding what is occurring through a system. Flowmetering equipment that is working but providing inaccurate readings will cause an operator to make faulty decisions. If you suspect inaccurate readings, consider putting a monitoring process in place so that a solution can be developed and implemented.

Capacity, Management, Operation, and Maintenance (CMOM) Analysis

Chapter 94 is Pennsylvania's version of requirements for sewage collection systems and wastewater treatment plants. CMOM is a federal program that was released during 2000 and ensures more uniformity throughout the United States. We are mentioning this because it has requirements that reinforce the necessity of knowing your collection system. The main function of a collection system is to convey wastewater; therefore, you must know what the flow is throughout the day in order to honestly say you can handle more flow.

Review the material in the workbook. Include the information below in your discussion of each item.

4. A System Evaluation and Capacity Assurance Plan

   – Development of management performance objectives and goals of the collection system.

     This could be as simple as prevent backups, have no overflows, repair lines with defects, and replace lines when conditions are beyond repair.

   – Clarification of management and performance objectives, developing and evaluating…

     This could be to address customer complaints in a certain area because sewer flows are sluggish due to surcharging of the main sewer line.

   – Implementation of measures.

     This could be to flush lines, televise lines, and determine flow rates during wet weather.

Indicate that the Water Environment Federation CMOM Summary has been included in the workbook as Appendix B.

Discussion Question

- How many of you are comfortable that you know the true wastewater flow through your system?
- Assuming that potable water bills with an extra amount added for I/I may not accurately reflect true wastewater flows, how many of your plants capture or measure the annual average, maximum month, peak day, and maximum instantaneous rates?
- What are the advantages for knowing the annual average, maximum month, peak day, and maximum instantaneous rate?

  Ans: Annual average: May be useful for determining a municipalities budget, may also be useful for billing purposes.

  Maximum month: Requirement of Chapter 94 for WWTP loading. Useful for inventory management, such as chemical for a feed system.

  Peak day: Requirement of Chapter 94 for pumping stations. Useful to know if equipment needs serviced—can remaining equipment handle the peak day?

  Maximum instantaneous rate: If wastewater will not be stored, this indicates the minimum-sized pump required; otherwise, flooding or surcharging will occur.

Potential Requirements

Review the material in the workbook. Include the following information in your discussion.

- If a municipality has problems such as sanitary sewer overflows (SSO)…

  A CAP is generally incurred after other efforts to correct flow problems in a sewer system have failed and DEP is issuing more detailed requirements against a borough/township/authority on how it must develop a plan to identify and correct known problems.

Process Control

Review the material in the workbook. Include the information below in your discussion of each bullet.

- The ability to adjust process equipment or ensure that adequate pumping capacity is available.
  - To use an analogy, "How far can you drive without knowing how much fuel is in the tank?"
- The ability to control downstream chemical feed systems.
  - A chemical feed system may be something at a WWTP such as a disinfection system. A chemical feed system may also be an odor control system at a pumping station.
- The ability to determine when you are reaching the capacity of a system…
  - If you do not know what the average and maximum flows are—how can you be sure that when you take a pump out of service, you will not create backups?

Billing

Review the material in the workbook. Include the information below in your discussion of each item.

- Potable water use is normally measured and billed—wastewater (WW) flows are...
  - People are accustomed to a potable water bill. It would be impractical for individual homeowners to have wastewater flowmeters.
- Use of potable water flows does not account for I/I.
  - Many communities try to say that because they have a specific number of customers and the average daily water flow is a calculated number of gallons, the same water is discharged to the sewer system. They feel that if 65 gallons of water is used by a person during a day, then the person discharges 65 gallons per day to the sewer system. However, Act 57 of 2003, a recent Act in PA that defines allowable volume, stipulates that potable water tapping fees are to be based on 65 gallons per day per capita (gpdc) and wastewater is 90 gpdc. This difference illustrates that developers in PA realize there is a difference between potable water used and wastewater discharged into a sewer system.
- A wastewater flowmeter makes sense for larger communities that discharge to other municipalities.

  Instructor Note: In case anyone does not know what an orange-burg pipe is, here is a description: One of the unique types of pipe that began to evolve in the 1890s was one whose wall was made of cellulose (wood) fibres, impregnated with coal-tar pitch. The first known use of "fibre" pipe was for water transmission—a 1.5-mile pipeline in the Boston area, which stayed in service for 60+ years (1865-1927). Production of fibre conduit started in 1893 by the Fibre Conduit Company of Orangeburg, New York. In the late 1940s, a heavier walled version of the fibre conduit was developed and sold as "Orange-burg Pipe"—in sizes ranging from 3" to 8" I.D.—for sewer and drain applications. (This type of pipe was also manufactured by other companies, including Bermico, American, and J - M Fibre Conduit.)
- Billing should be related to flows, not an outdated "number of fixtures."
  - Fixture counts are probably one of the worst methods to estimate flow because it does nothing to encourage water conservation. Several communities which have used this system have found that homeowners may leave a fixture running in the winter to keep their pipes from freezing. Since they are not billed for the water used (or wastewater discharged), many are not concerned about the volume of wastewater generated.

Intermunicipal Connections

Review the material in the workbook and make the following point about the bullet listed below:

- Different usage and I/I components.

As more regionalization of WWTP occurs, more municipalities that may not have their own WWTP will discharge to another community's WWTP.

Example

Some township/borough/authorities may base the billings on flow or an estimated equivalent dwelling unit (EDU).

Compare two municipalities that convey flow to a WWTP. Township A makes a statement that based upon their records there are 1,500 EDUs connected to the system with an EDU contributing an assumed 250 gpd. The other community, Borough B, also has 1,500 EDUs but has a flowmeter at the connection point to the WWTP so they know their actual flow, which was 375,000 gpd. The total flow to the WWTP averaged 1,000,000 gpd.

If both communities are billed for service based on the number of EDUs, their bills would be the same. However, if the bills are pro-rated, Township A should pay more because they are generating more flow and should pay more for service.

As more communities realize the differences between sewer line requirements, more communities are constructing metering facilities at all major connection points.

We will now discuss how flow metering can detect problems in a collection system.

Example from Two Municipal Connections

Display Slide 4—Tight Borough.

Review the chart of Tight Borough.

Exercise/Activity

1. What is the normal flow for midday, which is about half way between each date stamp?

Ans: About 1600 to 1200 gpm.

2. There were 2 rain events when the intensity went above 0.06 inch. What was the affect to the flows?

Ans: Very little impact. Flowmetering indicates that I/I is not much of a problem.

Display Slide 5—Leaky Township.

Review the chart of Leaky Township.

Exercise/Activity

1. What is the normal flow for midday (look at the first two days)?

Ans: About 200 to 500 gpm.

2. What happens during rain events?

Ans: For the time period between the first Tuesday and Wednesday, the two events caused the peak flow to go up almost twice the normal range. Additionally, the flow took a long time to decrease which illustrates that the water continued to get into the system. A second rainfall event caused the flow to quadruple. In our previous discussion about how one municipality may use EDUs to report possible flows, the above data showing impact from a rainstorm would be missed.

I/I is a very bad problem in this system and must be corrected.

Now that we have talked about why flowmeters are used, let's discuss some devices used to determine flows and the utilization of the resulting information. A flow can be determined for one point in time, totaled for a given period, or averaged over a given time period.

DATA OUTPUT: 5 minutes

We will begin this section on data output by first looking at instantaneous flowmeters.

Instantaneous Flowmeters

Display Slide 6—Instantaneous Flowmeters.

Review the material in the workbook. Include the information below in your discussion.

- Can be used for control of flow-paced equipment…

  A flow-paced signal controller for a chorine feed system may use the current flow through the WWTP to initially pace the amount of chlorine feed. Allowing the wastewater flow rate to control a chemical feed system is called flow-paced controlling.

The next data output method we will look at is continuous recording.

Continuous Recording

Review the material in the workbook.

Display Slide 7—Continuous Recording.

Review the two examples of continuous recordings.

- Strip charts are easy to read once they are unrolled. However, their size limits the identification of problems unless they are reviewed daily.
- Circular charts are easy to read at a glance. Can be difficult to use for in-depth analysis.

Now let's discuss Supervisory Control and Data Acquisition.

Supervisory Control and Data Acquisition (SCADA)

As the name implies, a SCADA system is doing more than just recording data. SCADA systems monitor data and control various pieces of equipment. For example, a SCADA system may have logarithms that send a control signal to another piece of equipment as flow increases. As an example, if raw wastewater flow increases, a downstream return activated sludge (RAS) pump speed may be increased. Such interconnection typically requires some computer or PLC (programmable logic controller). Such SCADA systems may have a computer monitor that will allow an individual to toggle through screens and view the real-time operation of the system along with past trends.

Review the material in the workbook and include the following for the last bullet:

- ▶ It can be used for off-site control.

  SCADA has the capability to allow for off site control of process equipment through a remote access system, such as a secured internet site. The tracking of changes and flows is a typically tracked parameter of SCADA.

- ▶ SCADA normally uses instantaneous flows to control other process equipment in a real-time mode.

  Some SCADA systems may take an average of several instant readings.

Now let's discuss Variable Rate Data Storage.

Variable Rate Data Storage

Display Slide 8—Variable Rate Data Storage.

Review the material in the workbook.

To understand flowmeters, you must also have a basic understanding of flow hydraulics.

FLOW HYDRAULICS: 15 minutes

Types of Conditions

Review the material in the workbook. Include the information below in your discussion of each item.

- Closed Pipes (flowing full)

  You must be very careful when determining which equation to use on a sewer running full. If you have any surcharging of a manhole, it puts the sewer line under pressure and the Manning equation will not be valid.

One of the most basic equations used in wastewater treatment determines the flow in a conduit. The conduit can be either a round pipe, such as a force main, or an irregular shaped channel. Let's review the equation and do some calculations.

$$Q = AV$$

Display Slide 9—Q = AV.

Review the material in the workbook. Include the information below in your discussion of the following item.

- All units in the equation must be the same.

  As an example, you can not multiply a velocity that is in feets per second (fps) by an area calculated in square inches. You must convert the area into square feet. The final result will be in cubic feet per second.

Review the example by writing it on a flip chart or whiteboard. For the second half of the example, indicate that the number of gallons in a cubic foot is 7.48 gallons.

Calculation

For each calculation, ask a volunteer to share his or her answer. Record the correct calculation and answer on a flip chart or whiteboard.

1. If you have an 8 inch diameter pipe and the velocity is 2.5 fps, what is the flow rate? (Hint: $A = \pi r^2$)

Ans: 8 inch diameter pipe equals a radius of 0.33 feet.

Therefore, area = $\pi(0.33 \text{ ft})^2$.

Which calculates to 0.34 sq. ft.

If the velocity is 2.5 fps and the area is 0.34 sq. ft, the resultant flow is 0.85 cubic feet per second (cfs).

0.85 cfs X 7.48 gals/cu. ft X 60 seconds/minute = a flow of about 384 gpm.

Instructor Note: This illustrates how you can determine flow through a line without directly having a flowmeter.

Class Expansion of Problem (use if there is time available)

If the pipe is the force main from a pumping station and is 1,000 feet long, how long would it take 1 gallon of wastewater to travel through the force main if the flowrate is 384 gpm?

Ans: Since the flow rate has been determined based on an 8 inch diameter pipe and a velocity of 2.5 fps, divide the 1,000 feet by 2.5 fps and it would take 400 seconds. This could be confirmed by adding a dye directly to the pump suction, through a pressure gauge fitting, and timing it until it appears at the downstream manhole.

This might help you decide if an odor control chemical has sufficient time to react with the wastewater as it travels through the pipe at the calculated flow rate.

2. Given a flow rate of 0.87 cfs conveyed in a 12 inch diameter sewer line, what would be the velocity? (Hint: $A = \pi r^2$). If this is a sewer line, would settling of solids be a concern?

Ans: Remember to keep units the same, therefore, convert 12 inches to feet.
12 inches/12 inches = 1 ft

The radius is equal to half the diameter.
1 ft/2 = 0.5 ft

Determine the area.
Area = $(3.14)\ (0.5\ \text{ft})^2 = 0.78$ sq ft

Now determine the velocity.
V = Q/A = 0.87 cfs/ 0.78 sq ft = 1.11 fps

Typically, a sewer line should not have a velocity of less than approximately 2 fps. Therefore, solids may settle out unless flows increase. Settling of solids would be a concern.

This illustrates how knowing a flow rate can help you determine if other operational problems could exist.

If you want to calculate the flow in a channel, you will probably use prepared tables to determine the velocity. To understand when tables can be used and when they cannot, let's briefly discuss the Manning Equation.

Manning Equation

Display Slide 10—Manning Equation.

Review the material in the workbook. Include the following when discussing hydraulic radius:

- Hydraulic radius is not your typical radius. Hydraulic radius is the section of the channel or pipe that is wet. The perimeter and wetted perimeter are *only the same when a pipe is full*.

Please turn the page and you will see an illustration of the wetted perimeter of a pipe.

Display Slide 11—Wetted perimeter in a pipe.

The diagram on the page in your workbook is an illustration of the wetted perimeter of a pipe. The area is shown in the lower portion of the pipe as “A” and the wetted perimeter is shown as “WP.” It is important to note that the wetted perimeter is only that portion of the pipe in contact with water.

Please turn back to the formula. As can be seen, this is a complicated formula so we will break it down into its basic components.

Let’s start with the easiest to understand. If the slope is steeper, the velocity will be greater in the channel or open pipe.

The Manning n-factor comes from a table, so all you need to do is pick out the right conditions. As the surface becomes more irregular, the factor increases. Look at Table 6.1 in Appendix C. Find and compare the values of a paved invert (which is 0.019) with that of a masonry rubble channel (which is 0.025). The “n” is higher for the masonry rubble channel because the surface is rougher.

Calculation

For each calculation, ask a volunteer to share his or her answer. Record the correct calculation and answer on a flip chart or whiteboard.

1. Find the hydraulic radius of a 12 inch diameter pipe, if the depth is 9 inches. Use the “Wetted perimeter in a pipe” figure in this unit and Table 6.2 in Appendix C.

Note to Instructor: It is good practice to develop a technique that will minimize the potential for error. Because most tables reference diameters in feet, we will convert inches to feet in the following calculation.

Ans: All units MUST be the same.
Depth of flow is 9 inches. Convert 9 inches to feet.
9 inches/12 inches = 0.75 foot

Diameter of pipe is 12 inches. Convert 12 inches to feet.
12 inches/12 inches = 1 foot

d/D = 0.75 /1 = 0.75, refer to Table 6.2 which shows that the wetted perimeter factor is 0.3017 times the diameter of 1 foot.

2. What is the velocity if the wetted perimeter is 0.3017 ft, the slope is 0.007, and the pipe is a 12 inch diameter sanitary sewer line with a normal amount of internal slime, showing a Manning factor of 0.013?

Ans: $V = \dfrac{1.486\ R^{2/3}\ S^{1/2}}{n}$

$$V = \frac{(1.486)\ (0.3017\text{ft}^{2/3})\ (0.007^{1/2})}{0.013}$$

$$V = \frac{(1.486)\ (0.44987\text{ ft})\ (0.08367)}{0.013}$$

$$V = \frac{0.0559}{0.013}$$

Therefore the velocity is 4.3 feet per second (fps).

3. Determine the volume conveyed by the typical sewer line depicted in Problem 2 by using Q=AV and ISCO Table 6.2 in Appendix C.

Ans: Since we know the velocity is 4.3 fps and we can find the area by using Table 6.2, we can use the Q = AV formula to determine the volume conveyed by this typical sewer line.

Table 6.2 shows the area factor for a 0.75 depth of flow pipe is 0.6318. Multiply the area factor by the diameter $^{(\text{squared})}$.
$A = (0.6318)\ (1\text{ ft})^2 = 0.6318$ square feet.

Multiplying the area of 0.6318 sq ft by the velocity of 4.3 fps yields a volume of 2.12 cubic feet per second.

This is the end of Unit 1. Are there any questions before we move on?

Respond accordingly.

Now that we covered the legal and practical requirements for flowmetering in Unit 1, let's discuss the technologies used to gather flowmetering information in Unit 2.

References need not be mentioned.

UNIT 2: 60 minutes

Display Slide 12—Unit 2: Flowmeter Technologies.

At the end of this unit, you should be able to:

- Identify two open channel flowmeter components.
- List three primary open channel hydraulic control elements.
- Name four types of open channel measuring devices.
- List three types of closed pipe flowmeters.
- Describe three installation considerations for closed pipe meters.

We will begin this section with a discussion of flowmeter technologies in an open channel.

OPEN CHANNEL: 45 minutes

Review the material in the workbook.

Accuracy

Review the material in the workbook.

Review the material in the workbook.

Primary Hydraulic Control Element

Review the material in the workbook. Include the following information in your discussion.

- ▶ Maintenance requirements of a PCHE can be important in the selection of a PHCE…

  Instructor Note: Make sure students understand this means the PHCE and **not** the measuring device. You will almost always have to provide a regular service to the measuring device.

Although beyond the scope of the course, the following is an overview of the Reynolds number in case participants ask for additional information:

- The Reynolds number is a calculation that allows an individual to determine the type of flow:
  - Laminar if Re < 2300. A slow moving body of water such as a large river. Also, the flow in a slow moving section of a WWTP such as the chlorine contact tank.
  - Transient if 2300 < Re < 4000.
  - Turbulent if Re > 4000. A fast section of water, such as rapids. Also the end of a pumping station force main if the flow drops out of the pipe and into an open channel.
- The calculation of the Reynolds number is a dimensionless number. This means it has no units of measurement, such as ft, square feet, etc. Calculating a Reynolds number is a complicated procedure that is best left to a consultant engineer.

Nozzles are used at locations where solids may be a concern. Another alternative, which will be covered later, is a flume.

Nozzles

Review the material in the workbook.

Kennison

Review the material in the workbook.

Parabolic

Review the material in the workbook.

Display Slide 13—Parabolic nozzle.

In the picture of the Parabolic nozzle, point out to the participants that there is a free fall out of the nozzle. Also point out the design—as the flow increases, the area which allows the flow to pass also increases, which provides a wide range of flow capability. However, a parabolic nozzle tends to be a little less accurate than a Kennison nozzle. At the very top of the picture, the ultrasonic sensor is visible above the open portion of the nozzle.

Exercise/Activity

Compare the maximum flow capacity of a 10 inch Kennison versus a 10 inch Parabolic Nozzle. Look at Appendix C - ISCO Tables 3-8 and 3-9.

Ans A Kennison nozzle has a maximum capacity of 0.80 mgd and a parabolic nozzle has a 1.2 mgd capacity.

Now that we have discussed nozzles, let's turn our attention to a discussion of weirs.

Weir

Review the material in the workbook.

Sharp-Crested

Display Slide 14—Sharp-Crested Weir

Review the material in the workbook. Include the following information:

- Sharp-crested is important. A thick board or piece of rusted steel is **not** acceptable…

  Instructor Note: Mention that the weir is thin and sharp crested. K= 1/8 inch and if not, there is a minimum of 45 degree angle away from it.

V-Notch Weir

Review the material in the workbook. Include the following information:

- Maintenance of the V-notch to prevent clogging becomes more critical. A wider V-notch does not give good accuracy at low flows, but it does not clog as easily.

☑ Exercise/Activity

A well-operated WWTP has an effluent flow that ranges from 10 gpm to 1,500 gpm. We do not anticipate an unacceptable amount of solids because the weir will be installed as a WWTP effluent flowmeter. What are the possible weir options? Use Appendix C - ISCO Table 5-3A.

Ans

1. If you look at the table you will notice that only V-notch weirs are within this range. (This illustrates how concentrating the flow through a narrow opening, such as a V-notch, provides proper hydraulic conditions.)
2. Within the V-notch ranges, at the lower flow rate of 10 gpm, there are only three possibilities of either a 22 ½, 30, or 45 degree notch weir.
3. At the upper range of 1,500 gpm, the only one which fails to comply with a maximum of 1,500 gpm is the 22 ½ degree V-notch.
4. Therefore, using the V-notch with the widest opening, to reduce potential problems when algae builds up in the notch, our choice would be the 45 degree.

Rectangular Weir

Display Slide 15—Rectangular Sharp-Crested Weirs

Review the material in the workbook. Include the following information:

- The first diagrams on this page show cross sections of Rectangular Sharp-Crested Weirs. The picture on the left is with end contractions and the picture on the right is without end contractions.
- The bottom diagram shows the head measurement point on a sharp-crested weir.
  - It is common for people to attempt to measure depth over the weir. This is not correct and will not yield a proper flow value.
- If the channel walls are clean and smooth during initial construction and calibration and then become pitted and covered with algae, the accuracy may degrade.

Exercise/Activity

If we have a 2 ft rectangular weir without end contractions and the depth is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 11-3. Using Table 5-3, what is the flow range for this PHCE?

Ans 566.6 gpm, 0.8159 mgd.
Approximately 400 gpm for a lower limit and approximately 4,000 gpm for an upper range.

Cipolletti Weir

Display Slide 16—Trapezoidal (Cipolletti) Sharp-Crested Weir

Review the material in the workbook.

Exercise/Activity

If we have a 2 ft Cipolletti weir and the depth of flow is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 12-3.

Ans Based on ISCO Table 12-3, the flow is 573 gpm.

Now that we have discussed nozzles and weirs, let's take a look at flumes.

Flume

Review the material in the workbook.

Parshall Flume

Display Slide 17—Parshall Flume

In addition to the diagrams of Parshall Flumes in the workbook, have the participants take a look at ISCO Table 4.1A in Appendix C. Note the numerous dimensions of a Parshall flume and point out that it is a carefully constructed device. Note that the table also shows the minimum length necessary for a flume.

Also have participants review Table 4.2A in Appendix C. This table shows the flow ranges of Parshall flumes.

Review the material in the workbook. Include the following information about the diagrams:

- Converging sections are sections “M” and “B” (elevation view). Note level floor in area “B” (elevation view).
- Throat is labeled as “T” in the figure (elevation view) and “W” (plan view) indicates the width or size of the flume. Note the drop in channel floor.
- Diverging section is section “G” (elevation view) and is sloped uphill but at a lower elevation.

Display Slide 18—Parshall Flumes

Continue to review the information in the workbook. Include the following information:

- Metering manholes can be used with either Parshall, Trapezoidal, or Palmer-Bowlus flumes.

☑ Exercise/Activity

1. For a 12 inch Parshall Flume, where is the measuring point in relationship to the start of the throat? The throat is the size of the flume and is where the sides are parallel. Use Appendix C - ISCO Table 4.1A and the Parshall flume diagrams on the previous pages.

Ans From ISCO Table 4.1A, column 2/3A, the answer is 3 feet.

☑ Exercise/Activity

2. If we have a 6 inch flume and the depth of flow is measured to be 0.42 feet at the head, what is the flow rate in gallons per minute (gpm)? In million gallons per day (mgd)? Use Appendix C - ISCO Table 13-4.

Ans ISCO Table 13-4 shows the flows are 235 gpm or 0.3380 mgd.

Palmer-Bowlus Flume

Display Slide 19—Palmer-Bowlus Flumes

Review the material in the workbook.

Note that the diagram in the workbook illustrates the many modifications of the Palmer-Bowlus flume.

Discussion Question

Look at Appendix C - ISCO Table 14-3 for an 8 inch Palmer-Bowlus Flume and see that at a depth of 0.09 ft at the head, the minimum recorded flow is 13.7 gpm or 0.0198 mgd. If attempting to measure flow in a small residential development, what problems will occur? (Consider an average flow per household of 225 gpd in a development of 75 homes.)

Ans The minimum capability of the Palmer-Bowlus will miss the lower flows. (The table does not start until you are almost at 14 gpm which is 19,800 gpd.)

More information: A typical home, based on Act 57, will discharge 90 gallons per day per person. If a home has an average occupancy of 2.5 people, the flow per household would average 225 gpd. If we look at a small development of 75 homes, this would equal about 16,875 gpd. This is below the usable portion of a Palmer-Bowlus flume. The point is to have the students realize there are limitations with some metering systems and they must verify that the selected device is okay. If you have them compare the range of a trapezoidal flume (ISCO Table 17-2), note that it can accurately measure the flows in this development.

Leopold-Lagco Flume

Review the material in the workbook.

Trapezoidal Flume

Display Slide 20—Trapezoidal Flume

Review the material in the workbook.

Discussion Question

Look at Appendix C - ISCO Tables 14-3 and 17-2. Compare an 8 inch Palmer-Bowlus with a depth of 0.10 feet to an extra large 60 degree V Trapezoidal Flume. What is the advantage of the Trapezoidal flume vs. a Palmer-Bowlus flume?

Ans Table 17-2 from ISCO shows that the flow is 1.6 gpm, which is almost 1/10 of the minimum flow which can be recorded in a Palmer-Bowlus flume.

HS, H, and HI Flumes

Display Slide 21—Typical H-Flume Application

Review the material in the workbook. The picture of the “Typical H-Flume Application” shows the flume being used to check surface water runoff.

Exercise/Activity

Select a flume that could be used for flows ranging from about 1 gpm up to 900 gpm. The type of material in the flow is normal fecal matter and paper most commonly present in domestic wastewater. Use Appendix C - ISCO Table 5-4.

Ans Look at various flow rates shown on ISCO Table 5-4. There are several H-type flumes and an extra large 60 degree trapezoidal flume that will work. Because we are not sure of the amount of solids that could clog the flume or settle out, we may want to consider the trapezoidal flume.

We have discussed how we control the hydraulic conditions, such as depth, in the channel. Now we need to discuss methods of determining the level in the channel.

Measuring Devices

Review the material in the workbook.

Depth

In open channels, measuring devices can be used to measure depth or velocity. Let's first discuss devices that are designed to measure depth.

Bubbler System

Review the information in the workbook. When reviewing back pressure, include the following information:

- As depth increases, it becomes more difficult to push a small bubble out the end of a submerged pipe. Compare blowing bubbles out of a garden hose if the end is in 1 foot of water versus the end being in 12 feet of water at the bottom of a pool.
- Only a small volume of air is required. Some less expensive systems actually use a small aquarium pump.

Ultrasonic

Display Slide 22—Ultrasonic Sensor, Mounting Bracket, and Stilling Well

Review the material in the workbook. Include the following information:

- Although the sensor never touches the water, it is exposed to vapors. This might be a concern if the vapors are corrosive or might create a lot of humidity which can create a “fog” at the sensor.
- The signal may be false if there is a layer of foam on the water or if there is high humidity in the air.
- It is common to hear a pinging sound when the unit is operating.

Continue to review the material in the workbook. Include the following information in your discussion.

- To keep the sensor operating properly if high humidity is a problem…

  As an example, if you are metering flow from an industry where the wastewater has an elevated temperature.

Instructor Note: The reflector plate can also be mounted up in the manhole, as illustrated in the "Introduction to Flowmeters" module.

Submerged Pressure Transducer

Review the material in the workbook. Include the following information:

- Used with some portable flowmeters.

Float

Display Slide 23—Stilling Well

Review the material in the workbook. Include the following:

- In the stilling well picture located in the workbook, the nozzle is on the left and it is connected to the stilling well through a 1 inch diameter line.

Portable Meter

Review the material in the workbook. Include the following information:

- The selection of portable meters should be coordinated with your consultant engineer and meter manufacturer so that you select the proper sized meter.
- Depending on the amount of time the flow may be measured, it may be advantageous to retrofit a manhole into a metering manhole instead of using a portable meter. The metering manhole may also be better if the data collected is critical.

Velocity

In addition to measuring depth, some measuring devices are used to measure flow velocity in an open channel.

Doppler

Review the material in the workbook.

Area Velocity

Review the material in the workbook. Include the following information:

- You must know the size of the pipe when selecting an area-velocity meter because the size of the pipe is programmed into the meter when it is set up for measuring.

Instructor Note: The area velocity meter in the picture is equipped with multiple sensors. The center one is the area-velocity meter. The other sensors, such as the ultrasonic on the left, can be used in the same manhole to monitor other influent lines coming into the manhole.

Now that we have covered flowmeter technologies in an open channel, let's discuss the technologies as they apply to closed pipes.

CLOSED PIPE: <u>15 minutes</u>

Flow Measuring Components

Review the material in the workbook.

Let's discuss the measuring devices in more detail.

Measuring Devices

Ultrasonic

Review the material in the workbook. Include the information below in your discussion of the following bullet.

- Requires a clamp-on mount.

Several meters have a temporary mounting system which may allow for an initial test of meter location.

Display Slide 24—Ultrasonic strap on meter

In the picture of the ultrasonic strap on meter, point out to the participants that there are stainless steel band clamps holding the unit in place on the pipe.

Doppler

Review the material in the workbook. Include the following information:

- Some adjustment to the frequency may be needed for temperature variations.
- An example of the Doppler effect is the sound of a siren as an emergency vehicle comes toward you versus the sound of the siren once the emergency vehicle has passed. The lower tone of the siren once the vehicle has passed comes from the compression and expansion of sound waves as the vehicle is moving. The Doppler effect can be used to measure velocity.
- The velocity can be about 2-3 ft/sec for solids, but if a fluid has only air bubbles, the velocity must be increased up to about 6 ft/sec. As velocity increases, the accuracy may increase, up to a point.

Transit-Time

Review the material in the workbook. Include the following information:

- Several terms used by some manufacturers for their transit-time meters include:
  - time-of-travel
  - transit

Magnetic

Review the material in the workbook. Include the following information:

- A limited number of magnetic meters claim a turn down ratio of 100:1.
- The disadvantages of earlier designs were high power consumption and the need to obtain a full pipe with no flow to initially set the meter to zero.

Display Slide 25—Magnetic meter

In the picture of the magnetic meter, point out to the participants that there is unobstructed flow before and after the meter. The meter is located in a straight section of pipe and is easily accessible.

Venturi

Review the material in the workbook.

Display Slide 26—Set of Four Venturi Flowmeters

Note to Instructor: The Venturi flowmeters in the picture are from a sludge incinerator. They were used because of the very large volumes of water being sent to the exhaust gas scrubber system.

Although beyond the scope of the course, the following is an overview of the Bernoulli effect in case participants ask for additional information:

- Daniel Bernoulli developed the equation used most frequently in engineering hydraulics in 1738. This equation relates the **pressure**, **velocity**, and **height** in the steady motion of an ideal fluid.
- First, the velocity must be derivable from a velocity potential. Second, external forces must be conservative—that is, derivable from a potential. Third, the density must either be constant or a function of the pressure alone.

$$P + \frac{1}{2}\rho V^2 + \rho g h = \text{constant}$$

P is the pressure, **ρ** is the density,
V is the velocity, **h** is the elevation,
g is the gravitational acceleration

Pitot

Review the material in the workbook.

Propeller

Review the material in the workbook.

Now that we have discussed the types of closed pipe meters, let's take a look at flowmeter installation considerations for closed pipes.

Installation Considerations

Vertical Orientation

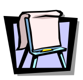
Review the material in the workbook.

Horizontal Orientation

Review the material in the workbook.

Separation Distances

Review the material in the workbook.



Ask participants to complete the calculation. Ask participants for their answers. Review the calculation on a flipchart or whiteboard.

Calculation

If we have a pipe of 5 inch diameter, using the separation distance guidelines, what is the absolute minimum distance of straight pipe that is needed (excluding the width of the meter)?

Ans 10 D = (10) (5 inches) = 50 inches upstream

5 D = (5) (5 inches) = 25 inches downstream

50 + 25 = 75 inches. We will need at least a 75 inch section of straight unobstructed pipe, excluding the width of the meter.

- ▶ Note to the class that the most common metering problem is inadequate separation distance. Inadequate flow through a meter may account for 50% of improper installations.

Pipe Material

Metal

Review the material in the workbook, include the following information:

- A coal based lining product would not be acceptable because it is non-uniform.
- The use of stainless steel is becoming more common because of low maintenance, both internal and external. However, this type of pipe must be coordinated with the meter vendor. As an example, a stainless steel pipe should **not** be used with an aggregate material or other irregularly lined pipe.

PVC

Review the material in the workbook.

Now that we have reviewed the various types of flowmeters for open channels and closed pipes, let's discuss the calibration of flowmeters in the next unit.

References need not be mentioned.

UNIT 3: 45 minutes

Display Slide 27—Unit 3: Calibration.

At the end of this unit, you should be able to:

- List three site conditions that can affect the calibration of a flowmeter on open channels or closed pipes.
- Describe how to identify the correct location for a sensor.
- Outline three calibration techniques.
- Explain how a sensor is verified.
- Calculate known volumes for comparison to meter readings.

INTRODUCTION: 5 minutes

Review the material in the workbook. Include the following information:

- Inaccurate billings—A flowmeter that is inaccurate can negatively impact the financials of a facility. For example, if a facility is providing services to another community but using a flowmeter that is out of calibration, it is possible that billings may be inaccurate. As a result, the facility may not be billing enough to cover its costs.

▶ For open channels, the depth of flow at the correct location on a primary hydraulic control…

This will normally be the preferred technique for verification of flow through an element with a reading on a meter. If this needs conducted on a regular basis, consider installation of a staff gauge.

The site condition is an important factor in the calibration of a flowmeter. Let's discuss the site conditions in an open channel and a closed pipe.

SITE CONDITIONS: 5 minutes

Open Channel

Review the material in the workbook. Include the following examples:

- Clean the area before calibration.

  As an example, the sides of a rectangular weir that does not have end contractions uses the channel wall as part of the hydraulic conditions. Before calibrating the meter, the wall should be cleaned of debris, such as algae. For a flowmeter located in a flowmetering manhole, there should not be a lot of fats/oils/greases (FOG) accumulated in the pipe or flume.

Closed Pipe

Review the material in the workbook. Include the following information:

- To send the meter to the factory for calibration, it is important to have a spool piece or properly designed meter bypass piping to replace or bypass the section of pipeline normally occupied by the meter.
- It is suggested that partial pipe flows be avoided unless it is coordinated carefully with a consultant and the meter manufacturer.
- Any non-uniform transitions can lead to inaccuracy. For example, if there is a small lip at the junction between the upstream pipe and the meter flange, inaccuracy may result.
- Remember that once the pump is turned on, the wastewater or sludge is being accelerated from zero up to some normal flow rate of several feet per second. Reaching normal flow for calibration purposes may take a few seconds or minutes.
  - In addition, if you would watch the incoming electrical surge through a pump motor, you would see it go from a very high point at the initial start of the pump to a lower value after the fluid is moving.

LOCATION OF SENSOR: <u>5 minutes</u>

To calibrate a flowmeter, it is important to have the sensor in the correct location.

Open Pipe or Channel

Review the material in the workbook. Include the following information.

- The mounting bracket must be secure.

    Do not mount it on a wooden 2 x 4 which will warp or defect depending on moisture. Do not duct tape the sensor into place.

Exercise/Activity

Using Appendix C Table 4-1a, find the sensor location for the following Parshall Flumes:

1 foot wide = Ans: 2/3 Ha is 9 17/32 inches

2 foot wide = Ans: 2/3 Ha is 10 7/8 inches

Closed Pipe

Review the material in the workbook. Include the following information.

- Some closed pipe sensors must be oriented in the proper direction.

    There may be a small tab or other indicator that specifies which side is pointed up, when installed in a horizontal pipe.

Now that we have discussed the location of the sensors, let's go over how we can perform some field testing to determine if a flowmeter is accurate.

CALIBRATION OPTIONS: 10 minutes

Open Channels

Review the material in the workbook. Include the information below in your discussion.

- Vary the flow through the flowmeter and measure with a device that is more accurate...

  For example, you cannot calibrate a meter rated at 1% to 3% accuracy with a device that is only accurate to within 10%.

Closed Pipes

Review the material in the workbook. Remind the participants that the pipe is the primary hydraulic control element and include the information below in your discussion.

- If you know the range of the flowmeter and then measure the velocity at the...

  For example, the flow range is 0-1,000 gpm and the meter operates with a 4 - 20 milliamp output. At zero flow, the output signal should be 4 milliamps and at 1,000 gpm the output should be 20 milliamps. If we measure the flow and it is 500 gpm, the calculations show this should be 12 milliamps.

  This is when the calibration method becomes important.

  Instructor Note: This may involve a one point or five point calibration of the meter which will be covered later in the course.

Measured Volume

Pumping Station Wet Well Drawdown Test

Review the material in the workbook.

Use of Pump Station Monitor

Review the material in the workbook.

Calculated Volume

Use of an Elapsed Time Meter and Calibrated Pump Curve to Check Flow

Review the material in the workbook. Include the following information:

- An hour meter normally does not provide enough accuracy to allow for the calculation of the flow conveyed. For example, if you know that a pump conveys 600 gpm and the pump operates for 215 minutes, a total volume of 129,000 gallons is conveyed. However, if an hour meter is used, it would show about 3 or 4 hours, which creates a range of 108,000 gallons to 144,000 gallons.
- Mention that this is the only way you can properly determine when two pumps are operating at the same time. The capacity of two pumps is **rarely** a simple addition of each individual pump. As an example, if pump No 1 discharges 100 gpm and Pump No. 2 discharges 110 gpm; it is very unlikely that when both pumps are operating at the same time, the total capacity is 210 gpm. This is evident by **properly** conducting a pumping station wet well draw down test just mentioned.

Calculation

Determine if a flowmeter needs calibration based upon comparing the flowmeter totalizer reading with calculations from the elapsed time meters for a pump station and a calibrated flow curve.

- The pumping station has two pumps. Refer to the pump performance curve from Gorman-Rupp on model S8A in Appendix E. Each pump was tested to provide 1,800 gallons per minute at a total dynamic head of 116 feet.
- The elapsed time meter for pump No 1 is 135 minutes, pump No. 2 is 140 minutes, and the simultaneous elapsed time meter had no run time.
- The discharge pressure on the pumps is normally 50 psi.
- Compare this with the flowmeter reading of 49,500 gallons per day.
- The flowmeter was calibrated by a new company who was not sure if there is a multiplier factor for the meter.

Ans: Pump No. 1 running for 135 minutes at 1,800 gpm conveys 243,000 gallons for the day.

Pump No. 2 running for 140 minutes at 1,800 gpm conveys 252,000 gallons for the day.

Pumps Nos. 1 and 2 do not run at the same time, therefore, there are no flow components for simultaneous operation of the pumps.

The total volume conveyed is 243,000 gallons plus 252,000 gallons for a total of 495,000 gallons for the day.

The flowmeter reading shows 49,500 gallons per day but the calculated flow is 495,000 gallons per day. The flowmeter is 1/10 of the calculated flow. It appears that when the flowmeter was calibrated, a factor of 10 was inadvertently missed.

Air Lift

Review the material in the workbook. Include the following information.

- There are locations where flowmetering is not possible.

  However, other methods can be used to develop an understanding of flowrates, as presented in the “Introduction to Flowmetering” module with the bucket and stopwatch technique.

- You cannot insert a flowmeter into the air lift line because it would obstruct flow…

  It is extremely uncommon to try and attach a flume at the discharge end due to the numerous operational problems it would create. Therefore, use of reference information to generate an approximate flow rate is required.

- The thickness or density of the liquid being conveyed has a noticeable influence on the flow rate.

  As the density increases, the ability to convey it is decreased.

1. Determine air flow to the air lift. Use of Figure F.1 in Appendix F enables…

   If the system is already installed, you may want to assume it was designed properly by a qualified engineer and not worry about air pressure or volume. However, you must realize there are minimum requirements.

Display Slide 28—Various Elementary Low Lift Types of Air Lifts.

3. Determine how high the RAS flow is lifted from the water surface…

   Some locations may have a valve on the discharge side of the RAS pipe, this is normally left fully open. That valve may be used to backflush the air lift line with air if any clogs occur.

5. Observe the pressure gauge reading to verify it is above minimum pressure.

   If the air pressure can not be determined at the actual air lift and must be determined from another location, such as the blower inside a building, it is necessary to determine the loss through the piping by use of Figure F.4 in Appendix F.

Continue to review the material in the workbook. Include the following information.

8. Follow the horizontal line across to the Y axis and read the flow rate…

    There are similar curves for air lifts up to 30 inches in diameter, however, air lifts of this size are rare and not discussed in this level of flowmetering.

Notes:

Review the material in the workbook. Include the following information.

- There are points on the airlift curves where the flow rate drops off after a peak rate is provided.

  Increasing the percent submergence does not generate any extra flow rate.

- As the length of air pipe increases, the pressure and volume of air available for operation of the air lift is adversely affected.

  For simplicity of this example, that loss is not calculated. If necessary, Figure F.4 of Appendix F should be used for this determination.

Display Slide 29—Picture of Air Lift.

Example

Review the example in the workbook.

Instructor Note: This would indicate that the RAS rate is 80 gpm which equals (0.125 mgd rate). If all three air lifts are operating the same, the total RAS rate is 0.375 mgd. Therefore the RAS rate is 50 % of the raw flow into the WWTP.

Now that we have discussed various calibration options, let's talk about sensor and transmitter verification.

SENSOR AND TRANSMITTER VERIFICATION: 5 minutes

Review the material in the workbook.

4-20 Milliamp Signal

Review the material in the workbook.

In addition to checking the sensor to verify that it is generating the proper signal, the following equations can be used to check the reading of a flowmeter.

ACCURACY LIMITS: 15 minutes

Weirs

Display Slide 30—Rate of Flow Equations for V-Notch Weirs.

Review the material in the workbook. Note that the equations are for reference and are available from such books as “Instrument Engineers Handbook” third Edition, Process Measurement and Analysis.

Flumes

Display Slide 31—Rate of Flow Equations for Single Point Measurement of a Parshall Flume.

Review the material in the workbook.

Exercise/Activity

1. A 9 inch Parshall Flume on the raw wastewater line was checked by WWTP staff and the depths in inches are shown below, along with the depth converted to feet. Should an instrumentation person be contacted to inspect the flume? Refer to Appendix C - ISCO Table 13-5.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
1.2	0.10	10
3	0.25	165
4.5	0.38	310
6	0.50	477
7.5	0.62	663

Ans Although the meter shows a noticeable deviation from the table at the lowest flow, the other readings match the table. Since 4 of the 5 readings match the table, it is probable that the first reading was not done properly.

Note: ISCO Table 13-5 starts at 0.10 feet, so the first reading is at the lowest end of the table. This is not desirable and could have caused some of the meter inaccuracy.

2. A 2 foot Cippoletti Weir is used at the effluent end of a WWTP. What is your opinion of the meter readings? Use Appendix C - ISCO Table 12–3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	270
2.52	0.210	291
2.76	0.230	333
3.00	0.250	378
3.60	0.300	497
4.32	0.360	653
5.00	0.417	795

Ans The depth was measured very precisely based upon three significant figures. This allows for the correct calculation of three significant figures and the meter readings are acceptable.

3. There is a two foot wide board that an operator installed trying to fabricate a rectangular weir without end contractions. The operator measured directly above the weir with the following results. Was it measured properly and what are the flows? If measured properly, Appendix C - ISCO Table 11-3 can be used.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
0.5	0.04	
1.0	0.08	
1.5	0.12	
2.0	0.17	

Ans The readings are not valid because the flows were measured directly above the weir which is incorrect. Additionally, the board does not produce a sharp crested weir. Otherwise, you could use ISCO Table 11-3 if a sharp-crested weir was installed.

4. There is a sharp-crested 2 foot long rectangular weir without end contractions at a WWTP. Having taken this course, the operator measured at the proper location upstream of the weir. What are the flows? Use Appendix C - ISCO Table 11-3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	*267*
2.52	0.210	*288*
2.76	0.230	*330*
3.00	0.250	*374*
3.60	0.300	*491*
4.32	0.360	*646*
4.92	0.410	*785*

Ans The readings are valid because the flows were determined at the proper location. You could use ISCO Table 11-3. Correct readings are inserted in the table above.

5. Determine the amount of error an incorrect depth reading of ½ inch creates in a 120 degree V-notch weir if the perceived depth was 7 inches versus 7.5 inches. Determine its impact for a typical day at that rate. Use Appendix C, table 9-6.

Ans: At a depth of 7 inches (0.583 feet), the flow would be 498 gpm or a daily flow of 0.72 mgd but at 7.5 inches (0.625 feet), the closest value in the table is 0.62 feet and the flow at this depth is 588 gpm or a daily flow of 0.85 mgd.

The error of the average flow rate is 588 – 498 = 90 gpm.

If the flow rate stayed constant throughout the day, the error would be approximately 0.13 million gallons per day in error.

For a flowmeter to work properly, it must not only be calibrated, but it must also be maintained. The next unit of our course covers flowmeter maintenance. The maintenance of a flowmeter is minimal but critical. Sometimes, the only required maintenance is to calibrate the meter once a year to ensure that cobwebs or other debris have not obstructed the sensor.

References need not be mentioned.

UNIT 4: 15 minutes

Display Slide 32—Unit 4: Maintenance.

At the end of this unit, you should be able to:

- Name three considerations for sensor maintenance.
- Identify the advantages of using surge protection.
- Explain how the data acquisition interval affects the ability to monitor flow variations.
- Explain the importance of data backup.
- List four maintenance procedures for portable flowmeters.

SENSOR MAINTENANCE: 2 minutes

A sensor is often exposed to liquid or vapors and may develop a coating. This can adversely affect the performance of the flowmeter. There are several steps that can be taken to properly maintain a sensor.

Review the information in the workbook. Include the following information when discussing sensor obstructions:

- Clearing cobwebs from an ultrasonic sensor may be required if the ultrasonic unit has a cone surrounding the ultrasonic transducer/receiving unit.

In addition to maintaining the sensors, it is important to protect the unit from power surges.

SURGE PROTECTION: 2 minutes

Review the material in the workbook. When reviewing TVSS systems, include the following information:

- As an example, the sacrificial component in a TVSS system may cost $450 but it may protect the $15,000 control panel.

Now let's review a few maintenance issues regarding site conditions that can affect the performance of a flowmeter.

SITE CONDITIONS: <u>3 minutes</u>

Review the material in the workbook. Include the following information.

- Solids deposition

  Example: The stilling well for nozzles that use floats to determine flow levels, such as a Kennison nozzle, may require a flush at least every two weeks.

- Extreme site conditions

  Extreme site conditions may include sources of high heat such as welding on the pipeline. Remove the flowmeter if necessary to avoid damage.

Continue to review the material in the workbook. Include the information below.

- Primary hydraulic control element—is it level?
  - It is critical that the weir or flume be level and perpendicular to the flow.

    For example, if staff is cleaning algae from a trough area, they may step on the weir, causing it to no longer be level. Use a carpenter's level to check the weir and adjust it if necessary.

Discussion Question

What is your most difficult maintenance problem?

Instructor Note: See if anyone in the class has suggestions for making identified maintenance problems easier to perform.

Batteries are used with many types of flowmeters. Portable flowmeters are almost always dependent on batteries for power. A few permanent flowmeters have an internal battery. Let's take a look at some suggestions for maintaining battery performance.

BATTERIES: 2 minutes

Review the information in the workbook. Include the following information:

- When using a portable flowmeter, check the voltage after usage.
  - A portable flowmeter may be used for several days or a week. Long periods of operation, such as a month, are generally avoided unless extended life batteries are being used.

Review the two photos in the workbook. The purpose of the two photos is to illustrate the value of a good digital meter.

Data downloading and backup are critical to gathering and storing useful information. Let's discuss some data downloading and backup issues.

DATA DOWNLOADING AND BACKUP: 2 minutes

Review the material in the workbook. Include the information below.

▶ Data acquisition and downloading of data.

- Data backup is critical to ensure that data is not lost if the primary storage device fails.

  Backup of data can be thought of as having spare parts for your information system. You have a spare tire for your vehicle in case a tire goes flat or fails. Having a good set of backup data gives you a "spare tire" for your data systems.

▶ Data downloading interval.

- If the data is critical and may easily become compromised, it may be worthwhile to...

  As an example, download frequently if the flowmeter is in a vulnerable location or has previously had problems with data storage.

▶ Data backup.

- It is better to store data in more than one location and on more than one media…

  Two commonly used media are CDs and flash drives.

Portable flowmeters require special maintenance and care. Here are a few portable flowmeter considerations.

PORTABLE FLOWMETERS: <u>2 minutes</u>

Review the material in the workbook.

Portable samplers are often used with portable flowmeters. Let's discuss portable samplers.

SAMPLER INTERFACE: <u>2 minutes</u>

Review the material in the workbook.

Discussion Questions

1. Ask the class to discuss how often internal containers are cleaned.

Ans: Clean after each usage.

2. Ask the class to discuss how often the sampler tubing might be replaced.

Ans: Routine sampling—replace tubing annually.
If sampling highly contaminated liquid or if analytical results are critical, replace after each usage.

Now that we have reviewed various maintenance issues, in the next unit we'll take a look at some problems that may occur when using flowmeters.

References need not be mentioned.

UNIT 5: 20 minutes

Display Slide 33—Unit 5 – Problems/Troubleshooting

At the end of this unit, you should be able to:

- Identify two considerations when selecting a flowmeter.
- Discuss how backwater can affect a flume or weir.
- Define subcritical and supercritical flow.
- Name two ways a sensor becomes fouled.
- List three post-installation problems inside the pipe that create meter inaccuracies.
- Identify the problems caused by placing the signal cable adjacent to a power cable.
- Explain the proper use of a scatter diagram.

IMPROPER CONDITIONS: 5 MINUTES

Improper Initial Flow Estimates and Applications

Improper Initial Flow Estimates

Review the material in the workbook. Include the following information:

- Although the meter was never sized properly, do not jump to the conclusion that the meter is wrong without exploring all options. First, check all recommended maintenance procedures and calibration techniques, as stipulated by the manufacturer.
- The wider the range that a flowmeter can detect, the more inaccurate the meter may be. As a result, it is best to match the range of the meter to the estimated flow range as much as possible.
- There are circumstances where you cannot measure the estimated minimum, average, and maximum flow rates. In those cases, a meter that only measures the two most important readings must be selected.
- V-notch weirs are usually easy to replace. For example, if a 22.5 degree v-notch weir cannot handle the maximum flows, it may be possible to replace it with a 30 or 45 degree v-notch weir.

☑ Exercise/Activity

The average flow through a facility was estimated to be 200 gpm, based on water records. A 120 degree V-notch weir was installed. The staff reported a lack of flow detection sensitivity. The staff needed to interface a chemical feed disinfection system with the flowmeter and were able to determine that the minimum flow might be about 20 gpm and the maximum flow might be about 450 gpm. The metering point is the effluent from the WWTP, with suspended solids always below 30 mg/L, which allows the use of a V-notch weir. Use Appendix C - ISCO Tables 9-3, 9-5, and 9-6 to select a better V-notch weir.

Ans Either the 45 degree or 60 degree V-notch weir would work but the 45 degree V-notch is almost at its maximum range and would be operating at 1 foot of depth.

The 60 degree V-notch weir would only be operating at 0.87 feet (10 inches), which is better.

Select and use the 60 degree V-notch weir.

Emphasize that the 120 degree was too coarse of a measuring device.

Improper Application

Review the material in the workbook. Include the following information:

- The depth may only vary 1 inch from no flow up to the maximum peak design rate for the disinfection system.

Backwater

Review the material in the workbook.

Display Slide 34—Beginning Stages of a Submerged Condition.

Display Slide 35—Submerged Flume.

Supercritical/Subcritical

Display Slide 36—Illustration of Super Critical/Transition/Subcritical Flow

Review the material in the workbook. Include the following information.

- There are very specific calculations for determining if a fluid is a supercritical or subcritical flow. However, these calculations are beyond the scope of this course.

POST INSTALLATION PROBLEMS: 5 minutes

Sensor Fouling

When evaluating the operation of a flowmeter in an open channel, sensor fouling is probably one of the easiest items to check. In a closed pipe, sensors may be more difficult to inspect. However, it is important that sensors be checked on a regular basis to ensure the proper operation of the flowmeter.

Display Slide 37—Fouled Sensor

Review the material in the workbook. Include the following information.

- If using a V-notch weir, remember to clean the V-notch on a regular basis…

  This can be done after you get the fecal coliform or chlorine residual samples at a WWTP.

Discussion Question

How often do you flush closed pipes at your plant?

How often do you need to clean the V-notch weirs at your plant?

There are several problems that can result from the power source. Let's take a look at a few of those issues.

Power Source

Review the material in the workbook.

Discussion Question

Name some portable units at your plant and tell us how often you replace the batteries.

Once in awhile, the security of a flowmeter becomes an issue.

Security

Review the material in the workbook.

Discussion Question

What types of security issues have you experienced with flowmeters? What steps were required to solve the issue?

Let's discuss other common problems that can develop after a flowmeter has been installed.

Other Common Problems

Review the material in the workbook. Include the information below along with the material in the workbook.

- Encrustation in a pipe.
  - If encrustation develops inside a pipe, the encrustation should be removed...

    The manufacturer should be contacted if chemicals will be used, since some chemicals can harm the sensor element.

Continue to review the material in the workbook. Include the following information.

- Temperature fluctuations.
  - If temperature changes are frequent or extreme, it may adversely affect accuracy.

    For example, if the pipe line is not designed for high temperatures but steam or hot water is sent through the line, the meter may be adversely affected.

Display Slide 38—Evidence of Surcharging by Debris on Top of the Nozzle.

Display Slide 39—Possible Improper Isolation Distance.

Exercise/Activity

Display Slide 40—What is Wrong?

What is wrong with this picture?

Ans: Incorrect location of sensor in the flume.

Remind the participants that the measuring location on a parshall flume is before the actual throat.

Portable flowmeters and insertable v-notch weirs can be useful tools for identifying problems. Let's review their usage.

USE OF PORTABLE FLOWMETERS AND INSERTABLE V-NOTCH WEIRS: 2 MINUTES

Review the material in the workbook.

Discussion Question

How have you used portable flowmeters or insertable v-notch weirs to resolve problems at your facilities?

There are certain conditions that can cause false signals. These are covered in the next section.

PREVENTING THE INTRODUCTION OF FALSE SIGNALS: 2 MINUTES

Review the material in the workbook. Include the following information.

- As an example, do not install a meter directly below a high voltage transformer.

  Think of how your car radio is affected when you drive under a high power line. Even though you are several hundred feet from the voltage, the signal is still affected. In the same manner, if there is a signal wire close to a high voltage power source, it can influence the meter.

Discussion Question

Have you discovered problems at your plants with meters giving false signals? How was the problem resolved?

SCATTER DIAGRAMS: 6 MINUTES

A scatter diagram or graph is a technique used in quality assurance in many areas. Obviously, we will talk about it in determining the accuracy of a flowmeter but there are other areas. We could plot the amount of wastewater received at a WWTP and the amount of dry tons of sludge or biosolids produced. A WWTP that is three times the size of a smaller WWTP and both are using the same type of treatment should produce a proportionally larger amount of sludge. If a WWTP has eight times a larger flow, the sludge production would be eight times more. Plotting this on a graph or diagram would allow you to visually see if the flows are proportional. For water flowmetering, we will go through an example comparing the depth of flow in the flowmeter with the signal generated by the meter and recorded on a paper chart.

Review the material in the workbook. Include the following example when introducing the scatter diagram:

- Example of two variables: The correlation between the flow in a channel and the depth of flow. Specifically, if the flow in a channel increases, how does this affect the depth of flow?

Continue to review the material in the workbook. Include the information below along with the material in the workbook.

▶ How to create and interpret a scatter diagram.

- Creating a scatter diagram can be easily done with a simple spreadsheet in Lotus or Excel.

  Use the X-Y graph feature for the scatter diagram.

- Step 1. Collect at least 40 paired data points. "Paired" data points are measures of both...

  You can use fewer than 40 data points, but you may not get enough data to create meaningful results.

- Step 3. Determine the lowest and highest value of each variable and mark the...

  Interpretation can be limited by the scale used. If the scale is too small and the points are compressed, then a pattern of correlation may not be visually apparent.

Scatter Diagram Interpretation

Review the material in the workbook.

Discussion Question

Ask the class how they would interpret the graphs.

Continue to review the material in the workbook.

This ends our course on flowmeters. In summary:

- Flowmetering has made drastic improvements since the development of computer logic programs.
- Calibration is a part of normal maintenance.
- Flowmetering may not always be "required per permit," but it still provides a better, more stable wastewater treatment plant.
- All flowmeters have an acceptable percentage of error.
- Various factors determine which flowmeter may be the best selection. It is common to have several possibilities.
- Hydraulics must be considered. If in doubt about the meter application, contact your consultant engineer or a qualified instrumentation company.
- Be careful when making new piping connections near flowmeters to avoid creating post-installation problems.

▶ Ask the class if they have any additional questions.

▶ Thank them for participating in the course.

▶ Remind them that the appendices contain information that can be used for future reference.

References need not be mentioned.