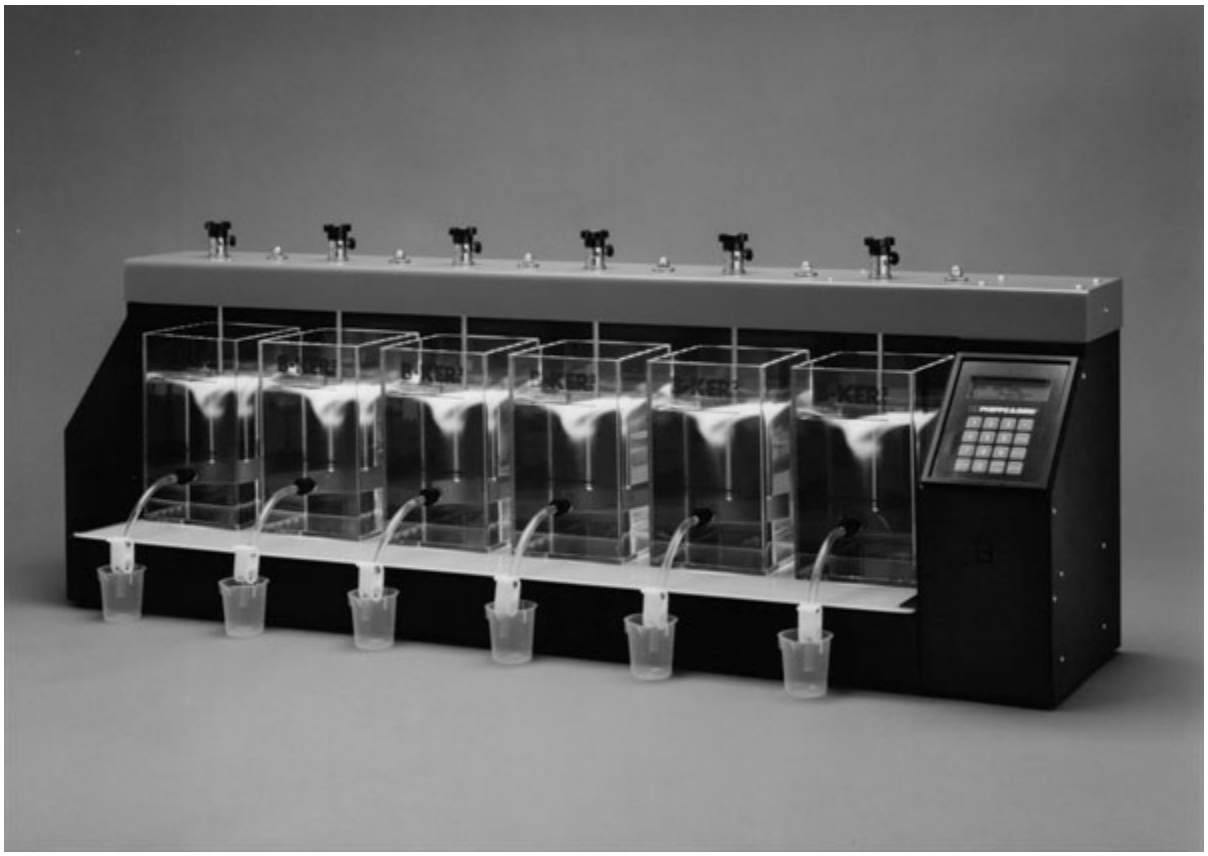
Coagulation/Flocculation Workshop

Course # 3103



Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

Updated June 2021

Coagulation/Flocculation Workshop

Course #3103

March 1 - 3, 2021

Instructor: Amanda Carter

Tuesday

8:30	Pre-test
8:45	Water Treatment Processes
11:45	Lunch
1:00	Jar Testing Math

Wednesday

8:30	Jar Testing Math cont'd
9:30	Plant Example
11:45	Lunch
1:00	Laboratory

Thursday

8:30	Laboratory
9:45	Exam Review
11:15	Lunch
12:30	Course Review and Exam

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3103 Coagulation Flocculation Workshop

Section 1

Water Treatment Processes

Water Treatment Processes

3103 Coagulation/Flocculation Workshop

Updated June 2021

OBJECTIVES

- Particulate Matter in Water
- Coagulation
- Coagulants
- Flocculation
- Sedimentation
- Filtration

PARTICULATE MATTER IN WATER

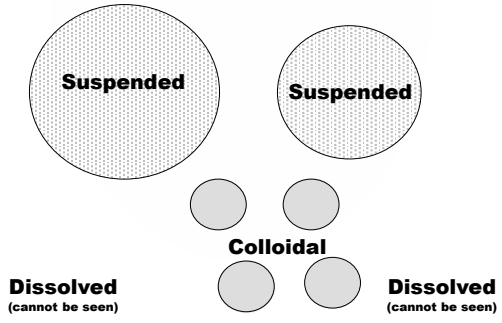
PARTICULATE MATTER IN WATER

- Results from land erosion, dissolved minerals, decay of plant material, industrial discharges, animal wastes, etc.
- Settleable Solids
  - Larger sized particles that can be removed from water by slowing down the flow
  - Will settle unaided to the bottom of a sedimentation basin within 4 hours
- Nonsettleable solids
  - Smaller sized particles, such as bacteria and fine clays and silts, that do not readily settle out and treatment is required to form larger particles that are settleable

NONSETTLEABLE SOLIDS

- Resist settling due to
  - Particle size
    - Suspended solids
    - Colloidal solids
    - Dissolved solids
  - Natural forces between particles
    - Zeta potential
    - van der Waals force
  - Particle shape
    - Smooth round particulates will settle faster than rough

NONSETTLEABLE SOLIDS



Particle Diameter, mm	Representative Particle	Time Required to Settle 1 foot
10	Gravel	0.3 sec
1	Coarse sand	3 sec
0.1	Fine sand	38 sec
0.01	Silt	33 min
0.001	Bacteria	55 hours
0.0001	Color	230 days
0.00001	Colloidal particles	6.3 yrs
0.000001	Colloidal Particles	63 year min

SUSPENDED SOLIDS

A solid organic or inorganic particle that is held in suspension by the action of flowing water

SUSPENDED SOLIDS COMMON IN SURFACE WATERS

- Clay
- Sand
- Silt
- Bacteria
- Algae and other microorganisms

EFFECTS SUSPENDED SOLIDS IN SURFACE WATERS

- Turbidity
- Suspended solids
- Taste and odors
- Corrosion

COLLOIDAL SOLID

Finely divided solid that will not settle out of water for very long periods of time unless the coagulation-flocculation process is used

COLLOIDAL SOLIDS COMMON IN SURFACE WATERS

Water color	Aquatic humic substances	Decomposition by-products (organic)
Industrial wastes	Silica	Calcium carbonate

EFFECTS OF COLLOIDAL SOLIDS IN SURFACE WATERS

- Turbidity
- Deposition
- Taste and odors
- Increase coagulant usage and residuals
- Disinfection by-products (THM's)

DISSOLVED SOLIDS

Any material that is dissolved in water and can be recovered by evaporating the water after filtering out the suspended material

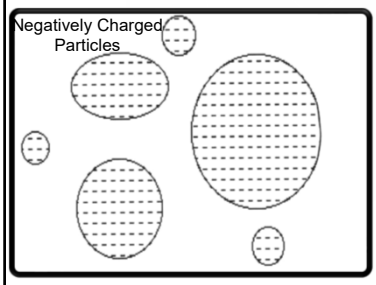
DISSOLVED SOLIDS COMMON IN SURFACE AND GROUND WATERS

- Water hardness (Ca & Mg)
- Iron & Manganese
- Heavy Metals
- Nitrates & Nitrites
- Salts (Cl^-, SO_4^{2-}, SO_3^{2-})
- Fluoride & Silica compounds

EFFECTS OF DISSOLVED SOLIDS IN SURFACE AND GROUND WATERS

- Scaling and deposits
- Tastes and odors
- Toxic effects
- Corrosion
- Staining

COLLOIDAL AND SUSPENDED PARTICLES



These particles have a surface charge which is responsible for their “stability” to remain separate and suspended in the water

NONSETTLEABLE SOLIDS

- Natural forces between particles
  - Zeta potential
    - Natural repelling force between any two particles of like charge
    - Particles in water tend to carry a negative electrical charge
  - van der Waals force
    - Attraction that exists between all particles and tends to pull any two particles together
- As long as the zeta potential is stronger than the van der Waals force, the particles will stay in suspension

COAGULATION

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WATER TREATMENT PROCESS

- Primary objective of water treatment process is to destabilize and condition particulate matter chemically and physically to encourage settling
  - Particle destabilization is accomplished through coagulant addition
- Coagulation can be viewed as a two-step process
  - The addition of coagulant to destabilize particles and react with NOM (natural organic matter)
  - The physical collision among particles to precipitate or adsorb NOM for later clarification and filtration (flocculation)

COAGULATION

- The water treatment process that causes very small suspended particles to attract to one another and form larger particles (floc)
  - Floc – clumps of bacteria and particles or coagulants and impurities that have come together and formed a cluster
- Accomplished by addition of chemical (coagulant) that neutralizes the electrostatic charges on the particles that cause them to repel each other
- Neutralizes or reduces the zeta potential of the nonsettleable solids allowing the van der Waals force of attraction to begin pulling the particles together
  - Forms small, weak groups of *microfloc*

COAGULATION

- Major purposes:
  - To destabilize solid particles
  - To remove organic color and precursors for DBPs
  - To enhance flocculation using chemical coagulants
  - To improve filtration
  - To pretreat water prior to contact with GAC
- Control of microbes such as Giardia, Cryptosporidium, viruses and DBPs makes understanding and optimizing coagulation vital

COAGULANTS

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COAGULANTS

- Primary coagulants neutralize (destabilize) the electrical charge of particles, which causes them to begin to clump together
- Metallic Salts
  - Enough chemical must be added to exceed the solubility limit of the metal hydroxide, resulting in precipitation (aka floc formation)
  - Common additives:
    - Aluminum, Al^{+3}
    - Iron, Fe^{+3}

COMMON PRIMARY COAGULANTS

- Aluminum
  - Coagulation optimal pH = 5.8 - 8.5
  - Color removal optimal pH = 5 - 6
  - Forms
    - Aluminum sulfate
    - Liquid alum

ALUMINUM SULFATE
$Al_2(SO_4)_3 \cdot 14H_2O$

- Positively charged Al^{3+} ion neutralizes negatively charged particles of color and turbidity
  - Occurs within 1-2 seconds after chemical added to water which is why rapid, thorough mixing is critical
- Microfloc still has positive charge and will continue to neutralize negatively charged particles until they become neutral themselves
  - Referred to as charge neutralization
- Works best in pH range of 5.8-8.5
  - Outside this range, incomplete floc formation or floc may dissolve back into water

ALUMINUM SULFATE
$Al_2(SO_4)_3 \cdot 14H_2O$

- Reacts with alkalinity in water to form jellylike floc particles of aluminum hydroxide $Al(OH)_3$
  - 1 mg/L alum will consume 0.5 mg/L alkalinity as $CaCO_3$
  - 1 mg/L alum will produce 0.26 mg/L sludge

$$\underset{\text{alum}}{Al_2(SO_4)_3} + \underset{\substack{\text{natural}\\\text{bicarbonate}\\\text{alkalinity}}}{3Ca(HCO_3)_2} \rightarrow \underset{\substack{\text{aluminum}\\\text{hydroxide floc}}}{2Al(OH)_3\downarrow} + \underset{\substack{\text{calcium}\\\text{sulfate}}}{3CaSO_4\downarrow} + \underset{\substack{\text{carbon}\\\text{dioxide}}}{6CO_2}$$

↓ Indicates precipitation occurring

ALUMINUM CHLOROHYDRATE (ACH)
$Al_2Cl(OH)_5$

- Contains more reactive aluminum so can be used in lower dosages
- Produces more sludge than alum pound for pound
  - Since lower feed rate is required, less sludge is produced
- Less alkalinity consumption means more pH control
- 1 mg/L ACH consumes 0.18 mg/L alkalinity
- 1 mg/L ACH produces 0.35 mg/L sludge

COMMON PRIMARY COAGULANTS

- Iron Salts
  - Operate over wider pH range
  - Cheaper
  - Forms heavier floc
  - Corrosive and staining
  - Requires special storage and handling facilities
  - Consumes alkalinity
  - Forms
    - Ferric sulfate $Fe_2(SO_4)_3$
    - Ferrous sulfate $Fe_2(SO_4)_3 \cdot 7H_2O$
    - Ferric chloride $FeCl_3$

COMMON PRIMARY COAGULANTS

Common Name	Chemical Formula	Comments
Aluminum sulfate	$Al_2(SO_4)_3 \cdot 14(H_2O)$	Most common coagulant in US; often used with cationic polymers
Aluminum chlorohydrate	$Al_2Cl(OH)_5$	May help to produce less sludge and less corrosivity
Ferric chloride	$FeCl_3$	May be more effective than alum in some applications
Ferric sulfate	$Fe_2(SO_4)_3$	Often used with lime softening
Ferrous sulfate	$Fe_2(SO_4)_3 \cdot 7H_2O$	Less pH dependent than alum
Aluminum polymers	---	Includes polyaluminum chlorides (PAC) and polyaluminum sulfates
Cationic polymers	---	Synthetic polyelectrolytes; large molcules
Sodium aluminate	$Na_2Al_2O_4$	Used with alum to improve coagulation
Sodium silicate	$Na_2O \cdot (SiO_2)_x$	Ingredient of activated silica coagulant aids

COAGULANT AIDS

- Coagulant aids add density to slow-settling flocs and add toughness to resist breaking up
- Added during coagulation to achieve:
  - Improved coagulation
  - Stronger, more settleable floc
  - Overcome effects of temperature drops
  - Reduce amount of coagulant needed
  - Reduce the amount of sludge produced
- Because alum sludge is difficult to dewater and dispose of, reduction in sludge is often the prime consideration in decision to use coagulant aid

COAGULANT AIDS

- Also known as flocculation aid, flocculant, sedimentation aid, filter aid, etc.
- General types
  - Polyelectrolytes
  - Activated silica
  - Weighting agents (turbidity addition)
  - Alkalinity addition
  - pH adjustment
  - Oxidation chemicals

COAGULANT AIDS

- Polyelectrolytes (aka polymers)
  - Have extremely large molecules, that when dissolved in water, produce highly charged ions
  - Relatively low dosages when compared to primary coagulants
  - Three basic classifications
    - Cationic – produce positively charged ions
    - Anionic – dissolve to produce negatively charged ions
    - Nonionic – release both positively and negatively charged ions

COAGULANT AIDS

- Cationic Polyelectrolyte
  - Produce positively (+) charged ions when dissolved in water
  - Can be used as primary coagulant or coagulant aid
    - Most effective when used with a primary coagulant such as alum or ferric sulfate
  - Advantages
    - Amount of coagulant can be reduced
    - Floc settles better
    - Less sensitivity to pH
    - Flocculation of living organisms (bacteria and algae) is improved

COAGULANT AIDS

- Anionic Polyelectrolyte
  - Produce negatively (-) charged ions when dissolved in water
  - Advantages
    - Increased floc size
    - Improved settling
    - Stronger floc
    - Not affected by pH, alkalinity, hardness or turbidity
- Nonionic Polyelectrolytes
  - Balanced or neutral charge
  - Produce both positive and negatively charged ions
  - Larger doses required, but less expensive

COAGULANT AIDS

- Activated Silica
  - Increase coagulation rate, decrease coagulant dosage, widen acceptable pH range
  - Produced on site by reacting sodium silicate (Na_2SiO_3) with an acid (typically HCl)
    - Silica is “activated” to form gel
  - Should never be added directly with alum (either before or after) to prevent reaction between the two chemicals

COAGULANT AIDS

- Activated Silica
  - Advantages
    - Stronger floc
    - Larger and denser floc (faster settling)
    - Improved color removal and floc formation at low temperatures
  - Disadvantages
    - Precise control required during activation process to prevent solution turning to a gel
    - Proper dosage is critical as too much can reduce coagulation and clog filters

COAGULANT AIDS

- Weighting Agents
  - Material added to provide additional particles for good floc formation in waters with
    - High color content
    - Low turbidity
    - Low mineral content (low TDS)
  - Materials used
    - Bentonite clay (most common)
    - Powdered limestone
    - Powdered silica
    - Recycled sludge or backwash water

COAGULANT AIDS

- Alkalinity Adjustment
  - Lime, caustic soda, or soda ash may be necessary if raw water alkalinity is not sufficient to provide good hydroxide floc production
  - May be required if high coagulant doses are required
  - Should have 10 mg/L $CaCO_3$ alkalinity to prevent residual coagulant reacting with chemicals later and forming an undesirable “refloc” condition

COAGULANT AIDS

- pH Adjustment
  - All primary coagulants have an optimum pH range
  - Outside this range, hydroxide flocs can become soluble again (dissolve) allowing previously coagulated solids to pass through the filter media
  - Increase pH by adding lime, sodium hydroxide, or soda ash
  - Decrease pH by adding an acid such as sulfuric acid

COAGULANT AIDS

- Oxidation chemicals
  - Chemicals such as chlorine, ozone, potassium permanganate added to oxidize dissolved organics that make color difficult to remove
  - Add before primary coagulant to oxidize from soluble (dissolved) form to the insoluble (precipitated) form

MIXING FACILITIES

INITIAL MIXING

- The point at which the primary coagulant is added to the water
  - Hydrolysis takes place almost instantaneously
- Completely disperses primary coagulant into raw water flow stream fast and uniformly
- Also known as
  - Rapid mixing
  - Flash mixing

RAPID-MIX FACILITIES

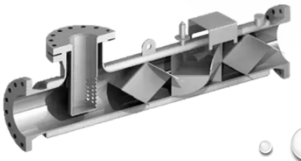
- Rapid agitation and mixing is essential once coagulation chemicals have been added to the water
  - Reaction time (hydrolysis) 2-3 seconds
  - Too long a detention time will be more detrimental to process than too short
- Common facilities for flash mixing
  - Mechanical mixers
  - Static or hydraulic mixers
  - Pumps and conduits
  - Baffled chambers

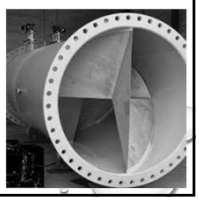
RAPID-MIX FACILITIES

- Mechanical Mixers
  - Use propeller, impeller, or turbine mixer in a small tank
  - Very short detention times
    - Less than 30 seconds
  - In-line mixers
    - Good instantaneous flow with little short circuiting
    - Must be located near the flocculation chamber to prevent settling within pipeline
  - Pipe grids
    - Grid systems of perforated pipes disperse coagulant into water
    - Susceptible to disruption from flow changes

RAPID-MIX FACILITIES

- Static Mixers
  - Produce turbulence and mixing using fixed sloping vanes within the mixer
  - Headloss is significant
  - Mixing energy directly related to flow rate, so way to adjust





RAPID-MIX FACILITIES

- Pumps and Conduits
  - Chemicals added to the suction side of a low lift pump use the turbulence in the pump as a mixing mechanism
  - Pump must be able to provide enough speed to create sufficient turbulence for mixing
- Baffled Chambers
  - Provide turbulence to water flowing over and under baffles
  - Turbulence is determined by flow rate and cannot be controlled

FLOCCULATION

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FLOCCULATION

- Gentle mixing process to increase the size of particles resulting in the formation of floc
- Floc - grouping of solid particles with a wooly appearance
- Floc strength - resistance to fragmentation by shear forces induced by hydraulic velocity gradients
  - Size and strength of floc determines efficiency of solids removal process

FLOCCULATION

- The process, following coagulation, that uses gentle stirring to transform small floc particles together so that they will form larger clumps of floc
- Rate of aggregation (floc growth) determined by the rate at which particles collide
  - Aggregates (floc particles) will become more fragile as particles grow in size, therefore mixing intensity must not be so high as to cause floc to break or shear
- Baffles can be installed to decrease short-circuiting

FLOCCULATION

- Most flocculation basins designed for tapered flocculation
  - Velocity gradient should decrease as the water passes through the basin to promote development of readily settable floc
- Flocculator tip speed should be 0.9-1.3 ft/sec
  - May need to increase in cold water or with heavy floc formation caused by increased turbidity

FLOCCULATION

- Flow through velocity should be 0.5-1.5 ft/min
- Minimum detention time 30 minutes with 45 minutes recommended
- Excessive flocculation time can lead to
  - Breakage of fragile flocs
  - Excessive coagulant usage
  - Settled floc in flocculation basins
    - Increased maintenance and cleaning
    - Short-circuiting

VELOCITY GRADIENT FLOCCULATION

- Gentle stirring promotes flocculation for particles that have been destabilized, during coagulation, and started to aggregate
  - Stirring motion and relative particles collisions are induced in the water by velocity gradient
- Constant velocity gradient (uniform shear field)
- Variable velocity gradient (nonuniform shear field)
- Taper flocculation

SEDIMENTATION/ CLARIFICATION

PARTICLE SEPARATION

SEDIMENTATION

- Also called clarification
- Process of holding water in low flow conditions to allow suspended particles that are heavier than water to settle out by gravity
- Settling velocity affected by
  - Particle size, shape, density
  - Water viscosity
- Flow through basin should be uniform
- Minimum detention time
  - Conventional sedimentation - 4 hours
  - Sedimentation using high-rate settlers – 1 hour

SEDIMENTATION BASIN ZONES

- Inlet zone - evenly distributes water through tank and slows to a uniform flow
- Settling zone - water flows slowly through the tank and flocculated particles settle out
- Sludge zone - bottom of the tank where settled material accumulates
- Outlet zone - water flows over weirs or launders into a channel for leaving the tank

SEDIMENTATION

- Contributing factors non-ideal settling conditions
  - Nonspherical particles have a higher drag coefficient leading to decreased settling velocity
  - Poor flow distribution and collection, wind, rising bubbles, and density differences (temperature or solids concentration)
  - Presence & concentration of other particles in water
    - Settling becomes hindered as free area between particles is reduced leading to a decreased settling velocity
  - Inefficient coagulation/flocculation
  - Sludge removal frequency

SURFACE LOADING RATE (SLR)

- Also called surface overflow rate (SOR)
- Most important parameter of sedimentation
- Measured in gpd/ft^2
- Directly related to settling velocity (cm/min) or the rate at which the particles settle
  - ↑ of SLR means ↓ sedimentation efficiency
  - Imagine throwing dirt vs a rock into a flowing stream
- A sedimentation basin will remove all particles that exceed the critical velocity for a given overflow rate
  - Very important part of jar test to ensure proper sampling time

FILTRATION

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FILTRATION

- The removal of suspended matter by passing water though a porous medium
  - Sand, anthracite coal, granular activated carbon (GAC), garnet sand, or some combination of those
- Utilizes physical and chemical adsorption on the filter surface, straining, sedimentation, interception, diffusion, and inertial compaction to remove particles from water
- Conventional filtration includes sedimentation
- Direct filtration omits the sedimentation step

Section 2

Jar Testing

JAR TESTING

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OBJECTIVES

- General Information
- Preparing for a Jar Test
- Reagent Preparation
- Conducting the Jar Test
  - Coagulation Jar Test
  - Lime/Soda Ash Jar Test
  - Powdered Activated Carbon Jar Test

GENERAL THEORY

- Involves duplicating, sequentially in a single vessel, conventional treatment steps that occur simultaneously at different locations in the plant
- Jar testing is used to
  - Evaluate effects of changes in chemical dosages and points of application
  - Choosing alternative coagulants
  - Adding polymeric coagulant aids
  - Implementing alternative peroxidation strategies
  - Varying mixing intensities and times
  - Changing water overflow rates on particle removal

JAR TESTING

- Can be used for screening new coagulants, coupon testing for corrosion control, biological spiking experiments
- Requires working knowledge of stock solutions and how to prepare them
- Shows nature and extent of the chemical treatment that will optimize the quality of water that leaves the plant
- Many chemicals can be evaluated using jar testing
  - Coagulants
  - Coagulant aids
  - Alkaline compounds
  - Softening chemicals
  - Powdered activated carbon

VELOCITY GRADIENT

- Measure of the intensity of the mixing
  - Higher number indicates more intense mixing
- Expressed as G with units of sec^{-1}
- Calculated using energy dissipation rate in fluid or using calibration curves
- Mixing intensities during jar tests should correspond to those in the treatment plant

PREPARING FOR A JAR TEST

DEFINING STUDY GOALS

- Goal that include evaluation of the effects of process changes on treated water quality
  - Changes in chemical doses
    - e.g. Optimizing coagulation
  - Alternative chemical choices
    - e.g. Coagulants, pH control, preoxidants, etc.
  - Additional chemical doses
    - e.g. Organic polymers
  - Physical modifications
    - e.g. Varying mixing intensities and points of chemical application

DEFINING STUDY GOALS

- Water quality parameters often used to assess treatment performance
  - Velocity gradient
    - Can be found in facility design documents or operations and maintenance manual
    - OR learn how to calculate in this class
  - Detention times
    - Theoretical or actual time for water to flow through a basin
  - Sedimentation basin overflow rate (SLR)
    - Determines length of time that water is allowed to settle in jar before sampling

DEFINING STUDY GOALS

- Water quality parameters often used to assess treatment performance continued…
  - Chemicals and points of application
    - Must know:
      - Chemical formula
      - Specific gravity
      - % weight
      - Liquid chemical viscosity
      - Solubility
  - Current treatment performance data
    - Shows how well jar testing conditions/procedures simulate conditions in full-scale facility

TYPES OF JARS

- 1-Liter Circular
  - First used
  - Least expensive
- 2-Liter Circular
- 2-Liter Square

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1-LITER CIRCULAR JARS

- Disadvantages:
  - Holds very little water
    - Minor errors in chemical doses result in large error in actual doses
  - Water rotates with paddles
    - Reduces the amount of actual mixing
  - Limited amount of water for analysis
  - Does not provide a good sampling point

In general, 1-L jars are not acceptable

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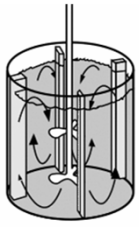
2-LITER CIRCULAR JARS

- Provides enough sample
- Stators inserted may help with mixing
  - May interfere with dosing and sampling
- Sample siphon can be added, but with some difficulty
- Disadvantage:
  - Water still rotates with the stirrer unless stators are used



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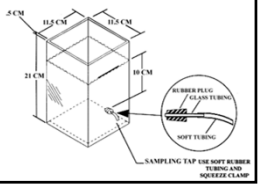
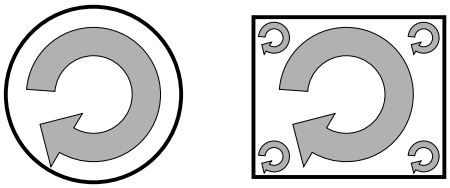
2-LITER SQUARE BEAKER

- Advantages:
  - Square configuration reduces rotation of water
  - Thicker wall and lower heat conductivity of plexiglass reduces water temp change during test
  - Jars are less fragile and can be repaired
  - Sampling port can easily be installed



ROUND VS. SQUARE MIXING



Use the same shape as your flash mix

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STIRRERS

- Two basic types
  - Gear-driven
    - Best
  - Magnetic-driven
    - Easier to add chemicals
    - Doesn't turn smoothly at slow speeds

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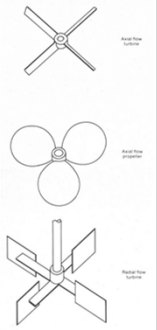
IMPELLERS

- Types
  - Paddle
  - Turbine
  - Marine
  - Axial flow
- Need the one that best simulates full scale



IMPELLERS

- Magnetic stirrers are only available with paddles
  - Corresponds to paddle, walking-beam, flat-blade turbine type mixing devices
- Top mounted stirrers with flat paddles are best
  - Shaft and impeller can be changed

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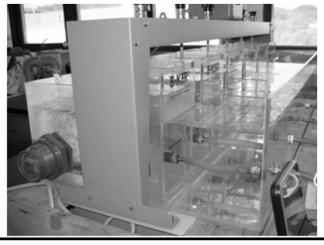
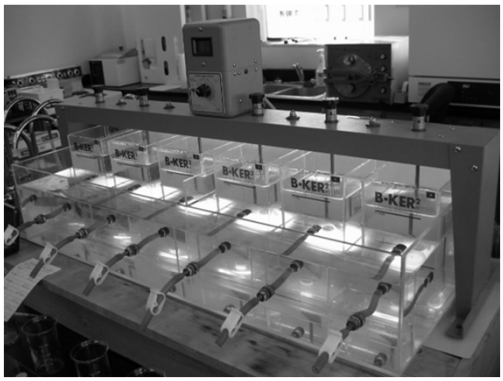
WATER BATH

- Jars set in a rectangular tank with raw water circulating around them
- This is only necessary for cold water





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WATER BATH

- Determination for use of water bath:
  - Take a raw sample
    - Run jar test immediately
  - Take another sample
    - Let warm 5-10 degrees
    - Run same test and take note in difference

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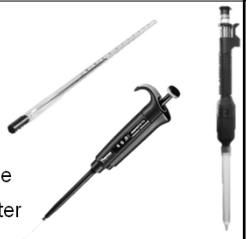
GENERAL JAR TEST INFORMATION

- Apparatus
  - Stirring machine with 3-6 paddles with variable speeds
  - Square 2-L jars with sampling ports
  - Sample collection container
  - Thermometer
  - Balance
  - 1-L volumetric flasks
  - Pipettes/syringes
  - Analytical equipment
    - Varies depending on the parameters you are trying to evaluate

ANALYTICAL EQUIPMENT



- Turbidimeter
- pH meter
- Thermometer
- Pipets
- Analytical balance
- Spectrophotometer

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REAGENT PREPARATION

SOLUTION PREPARATION – INORGANIC COAGULANTS

- Includes aluminum sulfate, ferric chloride, ferric sulfate, polyaluminum chloride (PAC)
- Should be prepared daily using concentrated coagulant from plant supply
- Procedure
  - Weigh 10 g of coagulant
    - If using liquid, tare out balance with empty syringe then weigh 10 g of liquid
  - Dissolve in 500 mL of DI water and dilute to 1L

1 mL solution = 5 mg/L in 2L of water sample

**Be sure to account for percent active ingredient (*aka % purity*)

SOLUTION PREPARATION

- Process will vary depending on chemical
  - Liquid polymer stock solution
    - Prepare a 1.0% weight to volume solution
    - Prepare a 0.1% working solution
  - Emulsion polymer stock solution
    - Prepare a 1% weight to volume stock solution
    - Prepare a 0.05% working solution
  - Solid polymer stock solution
    - Prepare a 0.5% weight to volume stock solution
    - Prepare a 0.01% working solution
  - Lime or soda ash solutions

SOLUTION PREPARATION – LIQUID POLYMER STOCK SOLUTION

Prepare A 1.0% Weight To Volume Solution

1. Put 500-mL of DI water into a 1-L beaker
   - Using pipet/syringe, remove 5 mL of water
2. Weigh pipet/syringe on balance and record
3. Shake “neat” polymer until mixed
   - Fill pipet/syringe with 5 grams of polymer, weigh, record
4. With blender, mix water in beaker
   - Place syringe tip below water near the center and slowly empty
5. Continue to mix for 30-60 seconds, then let age for 15 min
6. Prepare every 48 hrs

SOLUTION PREPARATION – LIQUID POLYMER STOCK SOLUTION

Prepare 0.1% working solution

1. Place 180-mL DI water in beaker
   - Fill 20-mL pipet with 1.0% stock polymer solution (we just made)
2. With blender, mix water in beaker
   - Place syringe tip below water near the center and slowly empty
3. Prepare daily within 2 hours of use
4. Each 1-mL of working solution ≈ 0.5 mg/L in a 2-L sample

SOLUTION PREPARATION – EMULSION POLYMER STOCK SOLUTION

Prepare a 1.0% weight to volume solution

- Follow same steps as for liquid polymer

Prepare a 0.05% working solution

1. Place 190-mL DI water in beaker
   - Fill 10-mL pipet with 1.0% stock polymer solution (we just made)
2. With blender, mix water in beaker
   - Place syringe tip below water near the center and slowly empty
3. Prepare daily within 2 hours of use
4. Each 1-mL of working solution ≈ 0.25 mg/L in a 2-L sample

SOLUTION PREPARATION – SOLID POLYMER STOCK SOLUTION

Prepare 0.5% weight to volume stock solution

1. Place 500-mL of DI water in 1-L beaker
2. Weight out 2.5 grams of polymer
3. Using a blender, mix the water in the beaker
   - Slowly add solid polymer in middle of beaker
   - Pause to let solution mix after each incremental addition
4. Continue to mix 60-90 seconds or until solution appears homogenous (consistent)
5. Prepare every 48 hours

SOLUTION PREPARATION – SOLID POLYMER STOCK SOLUTION

Prepare 0.5% weight to volume stock solution

1. Place 196-mL DI water in beaker
   - Fill 4-mL pipet with 0.5% stock polymer solution
2. With blender, mix water in beaker
   - Place syringe tip below water near the center and slowly empty
3. Prepare daily within 2 hours of use
4. Each 1-mL of working solution ≈ 0.05 mg/L in a 2-L sample

SOLUTION PREPARATION – LIME OR SODA ASH

1. Boil DI water for 15 minutes to expel CO_2
   - Cool to room temperature shortly before use
2. Weigh 10 grams of solid material and suspend in 1-L boiled DI water
   - Mix immediately before each use
3. Each 1-mL ≈ 5 mg/L in 2-L sample
4. Prepare daily

MAKING STOCK SOLUTIONS

- Effectiveness of dry and liquid coagulants varies with dilution
- Highly diluted stock solutions may degrade over time
- New stock solutions must be made up every day
- Polymeric inorganic coagulants such as PAC can degrade very quickly and should not be diluted
- To test dry metal salts (e.g., alum and ferric), stock solutions should be made up
- Dilution of liquid coagulants is usually not required if necessary volume can be added to test jars with micropipette
  - If micropipette not available, recommend dilution ratio of 1:100

STOCK SOLUTIONS PREPARATION - DRY COAGULANT

- Dry Alum
  - Dissolve 10-g alum in DI water and dilute to 1-L
  - Creates stock solution: 10,000 mg/L or 0.17% Al_2O_3 by weight
    - 1-mL added to 2-L jar ≈ 5 mg/L as alum or 17 µM as Al
- Dry Ferric Chloride (anhydrous, $FeCl_3$)
  - Dissolve 2.93-g in DI water and dilute to 1-L
  - Creates stock solution: 1,000 mg/L or 0.1% Fe by weight
    - 1-mL added to 2-L jar ≈ 0.5 mg/L or 9 µM as Fe
- Dry Ferric Sulfate (anhydrous)
  - Dissolve 3.57-g in DI water and dilute to 1-L
  - Creates stock solution: 1,000 mg/L or 0.1% Fe by weight
    - 1-mL added to 2-L jar ≈ 0.5 mg/L or 9 µM as

STOCK SOLUTIONS PREPARATION - LIQUID COAGULANT

- Microliters (µL) to add to 2-L solution can be calculated using coagulant concentration (%) and the specific gravity
- Alum

$$\text{volume, µL} = \frac{(\text{dose, µM})(5.10)(\text{jar vol, L})}{(\%Al_2O_3)(\text{sp. gr})} \times \text{dilution factor}$$

- Iron

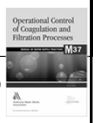
$$\text{volume, µL} = \frac{(\text{dose, µM})(5.59)(\text{jar vol, L})}{(\%Fe)(\text{sp. gr})} \times \text{dilution factor}$$

STOCK SOLUTIONS PREPARATION – COAGULANT AIDS

1. Add 200-500 mL of DI water to volumetric flask
2. After thorough mixing, weigh out 0.2-g of polymer
3. Rinse all the polymer into volumetric flask
4. Fill to 1,000-mL mark
5. Cap and shake for 1 minute
6. Makes stock solution of 200 mg/L or 0.2 mg/mL
   - 1-mL added to 2-L jar ≈ 0.1 mg/L
7. Make daily to avoid degradation

Polymer content of the liquid must be known to make accurate comparison to dry polymer which is typically 100%.

STOCK SOLUTIONS PREPARATION – POTASSIUM PERMANGANATE



1. Dissolve 1 gram of $KMnO_4$ in DI water and dilute to
2. Makes stock solution of 1,000 mg/L or 1 mg/mL
   - 1-mL of stock solution ≈ 0.5 mg/L in 2-L sample

STOCK SOLUTIONS PREPARATION – pH CONTROL

- Use of caustic is more convenient for jar testing than lime
  - Lime is dosed in a suspension that requires continuous stirring
  - Difference in effectiveness is typically negligible
  - Once dose is determined, use the following conversion factors to adjust the values

1 mg/L CaO = 1 mg/L $CaCO_3$ x 0.56

1 mg/L $Ca(OH)_2$ = 1 mg/L $CaCO_3$ x 0.74

1 mg/L Na_2CO_3 = 1 mg/L $CaCO_3$ x 1.06

1 mg/L NaOH = 1 mg/L $CaCO_3$ x 0.80

STOCK SOLUTIONS PREPARATION – SODIUM HYDROXIDE

- 0.1 N NaOH is generally sufficient
- Regent grade NaOH is usually supplied in pellet form

Prepare 0.1N solution

1. Add 200-500 mL of DI water to 1-L flask
   - Add magnetic stir bar and put on stir plate
2. Weigh out 4 grams of NaOH pellets
3. Pour pellets into 1-L flask and mix at medium speed until pellets dissolve
4. Remove stir bar; fill flask to 1-L mark with DI water
5. Cap and shake for 1 minute
6. Makes stock solution of 4,000 mg/L or 4 mg/mL as 100% NaOH
   - 1-mL of stock solution ≈ 2.0 mg/L in 2-L sample

POWDERED ACTIVATED CARBON DOSING SOLUTION

- Dry PAC

1. Weigh 10 grams PAC on balance
   - Dissolve in 1-L of DI water
   - Mix thoroughly before each use
2. 1-mL of dosing solution ≈ 5.0 mg/L in 2-L sample

- PAC in slurry form

1. Measure 10 mL well-mixed carbon slurry and place in small pre-weighed container
2. Allow to sit in drying oven (100°C) overnight; cool in desiccator; weigh

Dry carbon weight (mg) ÷ 0.01 = slurry concentration (mg/L)

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CONDUCTING THE JAR TEST

COAGULATION JAR TEST

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COAGULATION JAR TEST

- Uses jar test in an attempt to imitate the mixing, flocculation and settling conditions in the full-scale treatment plant
  - When fine tuned and implemented, plant will produce better quality water
- Select a series of doses
  - First jar represents undertreatment
  - Last jar represents overtreatment
- Can be used to compare various types of coagulants and coagulant aids
- *Best test to optimize your coagulation/flocculation process*

CONDUCTING THE JAR TEST

- Preparation tasks completed
- Study goals defined
- Testing parameters determined
- Operator should ensure all chemicals properly labeled and mixed
- Jars and paddles cleaned by wiping with wet cloth and rinsing with tap water

CONDUCTING THE JAR TEST

1. Determine quality of raw water
   - Often treatment performance data is expressed in terms of percentage removal
2. Input chemical names and concentrations to be added into data sheet/bench sheet
3. Input *G* values for rapid mix and flocculation stages
   - Convert these to appropriate rpms in the jar test
4. Input detention times for rapid mix and flocculation stages
5. Input coagulant doses
   - Useful to select doses increments of 10 mg/L
   - Use smaller increments for fine-tuning optimum dosage

CONDUCTING THE JAR TEST

6. Proceed with all other chemicals in a similar manner
7. Determine critical settling velocity based on SOR or SLR
8. Fill jars with sample water
9. Lower impellers/paddles so they are about 1/3 from the bottom
10. Begin flash mix period based on determined values
    - Dispense chemicals to jars as rapidly as possible
    - Dispense chemicals in the same order as in full-scale plant
11. After rapid mix, decrease mixing speed for flocculation step
    - Typical to measure coagulation pH at this point

CONDUCTING THE JAR TEST

12. After flocculation, stop mixer and remove paddles from jars
    - Collect samples at to previously calculated times to simulate full scale sedimentation basin
13. Collect sample
    - First portion of sample taken from fixed port should be discarded
    - When using syringe, samples should be taken from the same dept as the fixed port
14. Conduct laboratory analysis on collected samples being sure to observe holding times
15. Input laboratory results into data sheet

PROCEDURE

1. Clean jars with detergent and scrub brush. Rinse with tap water
2. Clean paddles with damp cloth
3. Collect water to be treated and run test promptly
4. Mix sample thoroughly and fill jars half full
   - Remix the sample water
   - In reverse order, fill jars to fill line
5. Place paddles in jars and tighten thumb screws
6. Add clay suspension to each jar, if applicable

PROCEDURE

7. Fill plastic syringes with correct amounts of chemical solution to be added to each jar
   - Fill one syringe for each chemical for each jar
8. Begin rapid mixing
9. Inject chemicals into jars below the surface of the water near the paddles
   - Inject all the jars at the same time
   - Add chemicals in the order they would be added in the plant
10. Lower paddles speed to simulate flocculation mixing process
11. Observe each jar for the appearance of microfloc (“pinpoint” floc); note time and order

PROCEDURE

12. At end of flocculation period, stop stirring machine, remove paddles, and allow floc to settle
13. Observe floc as it settles
    - Hazy sample = poor coagulation
    - Clear sample = acceptable coagulation
14. Collect samples at 5, 10, 15, and 30 min or as desired
    - If using jar with sampling port, flush 20 mL to waste
      - Do not clamp tube between flush and sample collection
      - Make sure tube is 100% open
    - If using jar without a sampling port, carefully obtain sample with 100-mL pipet
    - Collect necessary amount of sample in sample cup

I do not agree with this. Sampling time should be based of SOR and settling velocity.

PROCEDURE

15. Analyze samples for any parameters of interest using appropriate testing methods
    - pH
    - Turbidity
    - TOC
    - Etcetera

LIME OR SODA ASH SOFTENING JAR TEST

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PROCEDURE

1. Determine hardness, phenolphthalein and total alkalinity, calcium, and free carbon dioxide
2. Calculate dosages of lime and/or soda ash needed
3. Follow steps 1-5 of Coagulation Jar Test (clean equipment and collect sample)
4. Fill plastic syringes with correct amounts of lime or soda ash (prepared previously) to be added to each jar
    - Fill one syringe for each jar
5. Begin mixing at 30 rpm or speed that replicates the plant
6. Inject chemicals into jars below the surface of the water near the paddles
    - Inject all the jars at the same time

PROCEDURE

7. Continue mixing for same time period as in the plant
8. Stop stirring machine and allow sample to settle until supernatant liquid is fairly clear
9. Collect samples between 10 - 15 minutes
    - If using jar with sampling port, flush 20 mL to waste
      - Do not clamp tube between flush and sample collection
      - Make sure tube is 100% open
    - If using jar without a sampling port, carefully obtain sample with 100-mL pipet
10. Warm sample to 25°C

PROCEDURE

11. Filter samples through filter paper to remove any solid precipitate
12. Run analysis on sample water
    - Hardness
    - Phenolphthalein alkalinity
    - Total alkalinity
    - pH

POWDERED ACTIVATED CARBON JAR TEST

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PROCEDURE

1. Clean and scrub jar test equipment and sample containers with non-odorous detergent
   - Rinse thoroughly with odor free water
2. Follow steps 3-5 of Coagulation Jar Test (sample collection)
3. Begin mixing at 30 rpm or speed that replicates the plant
4. Fill plastic syringes with correct amounts of lime or soda ash (prepared previously) to be added to each jar
   - Fill one syringe for each jar
   - Fill syringes for any other chemicals that are to be added during jar test e.g. coagulant

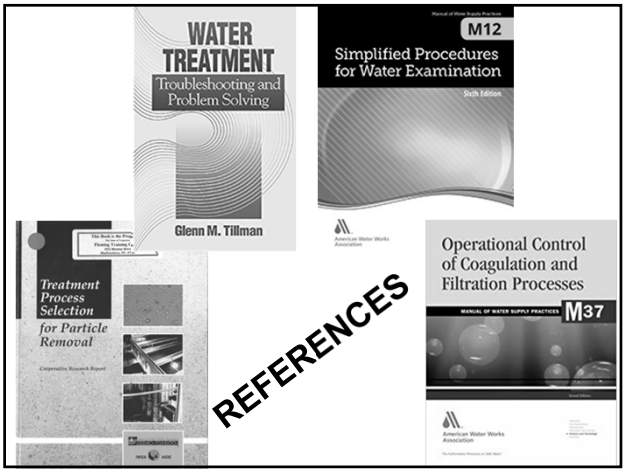
PROCEDURE

5. Inject dosing solution into jars below water surface near paddle
   - Add chemicals in the same order they would be added in the plant
6. Continue mixing for the same period as in the plant
7. Stop stirring machine; allow to settle for 15 minutes or desired time period
8. Collect samples between 10 - 15 minutes
   - If using jar with sampling port, flush 20 mL to waste
     - Do not clamp tube between flush and sample collection
     - Make sure tube is 100% open
   - If using jar without a sampling port, carefully obtain sample with 100-mL pipet

PROCEDURE

9. Filter portion of sample through glass fiber filter (pre-washed with odor free water) to remove carbon from sample
10. Determine TON (threshold odor number) of each sample jar and blank

REFERENCES



Section 3

Math

Jar Testing

1

Practical Uses
Velocity Gradient
Laboratory Testing Techniques
Filterability Index
Demonstration

Objectives

2

- Velocity Gradient
  - Mechanical Mixers
  - Hydraulic mixers
  - Variable Speed Drives
- Jar Test Correction
- Surface Overflow Rate
- Settling Time
- Sampling Time

Key Parameters

3

- Velocity gradient in the flash mix
- Effective retention time in the flash mix
- Velocity gradient in the flocculator
- Effective retention time in the flocculator
- Surface overflow rate on the sedimentation basin

Practical Uses for Jar Tests

4

- Determine coagulant and flocculant dosages
- Determine mixing times
- Chemical addition sequence
- Mixing energies
- Dosages of taste and odor control chemicals
- Dosages of oxidant chemicals

Determine Dose

5

- Bracket expected “best” dosage
  - If 15 mg/L alum is expected to be best, test 5, 10, 15, 20, 25 and 30 mg/L
- Change only one variable (i.e. pH adjustment chemical dose) during each test run
  - Perform multiple runs if multiple variable changes are necessary
- https://www.youtube.com/watch?v=6cl0E0JIVTk
  - Basketball analogy (start at 4:50)

Rules to Remember

6

- Keep equipment clean
  - Rinse jars and paddles with DI water
- Use fresh chemicals
- Add chemicals in correct order
- Pre-measure chemicals

Rules to Remember

7

- Use 2 liters of water per jar
- Drain 20 mL of sample water out of sample line before taking sample
- Check pH at flash mix and jar to compare
- Light heats up water – leave off

Velocity Gradient, G, sec^{-1}

8

- The power input per unit volume of water
  - How much horsepower the mixing device is supplying to the water to mix the coagulant into the water

  OR
  - How much horsepower is being supplied to increase floc formation in the flocculators

Velocity Gradient, G, sec^{-1}

9

- The concept of velocity gradient is one of the most important ideas to be understood when conducting jar tests
- The intensity of mixing is generally measured by the velocity gradient
  - A higher number indicates more intense mixing
- Mixing intensities, or velocity gradients, during jar tests should correspond to those in the treatment plant
- G should decrease as water goes through the treatment process
- Units = ft/sec/ft or sec^{-1}

How to Find Velocity Gradient

10

- Consultant or plant engineer
- Manufacturer of unit
- Bid specs, drawings or O&M manual
- Calculations taught in this workshop
- Educated guess/trial and error

Sedimentation

11

- Sedimentation basins remove particles by gravity
- The surface loading rate or overflow rate is the most important parameter for sedimentation
- Surface loading corresponds to velocity

Settling Velocity

13

- To calculate the settling velocity or the rate at which the particles settle, the following conversion factors can be used

Plant Flow Rate / Surface Area	Multiply By	Settling Velocity
MGD/ft^2	2,829.56	cm/min
$gal/min/ft^2$	4.0746	cm/min

Settling Velocity cont.

14

- A sedimentation tank with a surface overflow rate of 1440 gpd/ft^2 removes particles that settle faster than 4 cm/min.
- Particles that settle slower would not be removed

Surface Overflow Rate, gpd/ft^2	Settling Velocity, cm/min
180	0.5
360	1.0
720	2.0
1440	4.0
3600	10.0

SLR to Settling Velocity

15

- A sedimentation tank will remove all particles that exceed the critical velocity for a given overflow rate
- Therefore, the surface loading rate corresponds to the settling velocity and must match that of the process
  - Think of dropping a large rock vs a handful of grit in a flowing stream
  - The same applies in the sedimentation basin

Settling Velocities

16

- General design of alum and ferric sedimentation basins:
  - SOR rates of 400-1000 gpd/ft^2
  - Settling velocities of 1-3 cm/min
- Samples should be taken from 2-10 min in jar tests
  - Allowing the water to settle for 30-60 minutes and then taking a sample for turbidity has no relationship to the full-scale system
  - This sample should not be used for collecting useful jar test information

Settling Velocities cont.

17

- Jar tests can be used to determine what percent of the turbidity has a certain settling velocity
- Basin efficiencies can be estimated for a given overflow rate with this info

18

Ready for Some Math???

How to Find Velocity Gradient

19

- Formula

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

- V = tank volume, ft^3
- P = horsepower minus 10%
- μ = viscosity, (lbs)(sec)/ft^2
- 550 converts HP to work (ft-lb/sec)

Horsepower

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

20

- P = horsepower (motor and gear unit)
- Take about 10% off for wear and tear
  - e.g. 100 hp, use 90 hp
- Get this from your motor nameplate or paperwork

Viscosity

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

21

- μ = viscosity of water in force (lb)(sec)/ft^2
- See full chart in Coag/Floc Formula Book provided

Temperature ° C	μ, (lbs)(sec)/ft^2	Temperature ° F
14	0.000024529	57.2
16	0.000023293	60.8
18	0.000022139	64.4
20	0.000021061	68.0
22	0.000020061	71.6
24	0.000019128	75.2

Volume

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

22

- V = volume of the flash mix basin in ft^3
- Square basin, ft^3 = (length, ft)(width, ft)(depth, ft)
- Round basin, ft^3 = (0.785)(Diameter, ft)^2(depth, ft)

Example 1

23

- Motor HP = 6 hp
- Water Temp = 18°C
- Flash mix = 10 ft x 10 ft x 12 ft deep
- Based on the information provided, what is the calculated velocity gradient, G (sec^{-1})?

Example 1

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

24

Given:

- Motor HP = 6
- Water Temp = 18°C
- Flash mix = 10 ft x 10 ft x 12 ft deep

- P = (6 hp)(0.90) = 5.4 hp
- μ = 0.000022139 (from chart)
- V = (10ft)(10ft)(12ft) = 1200 ft^3

Example 1 Cont'd

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

25

$$G = \sqrt{\frac{(550)(5.4\ \text{hp})}{(0.000022139)(1200\ \text{ft}^3)}}$$

$$G = \sqrt{\frac{2970}{0.0265668}}$$

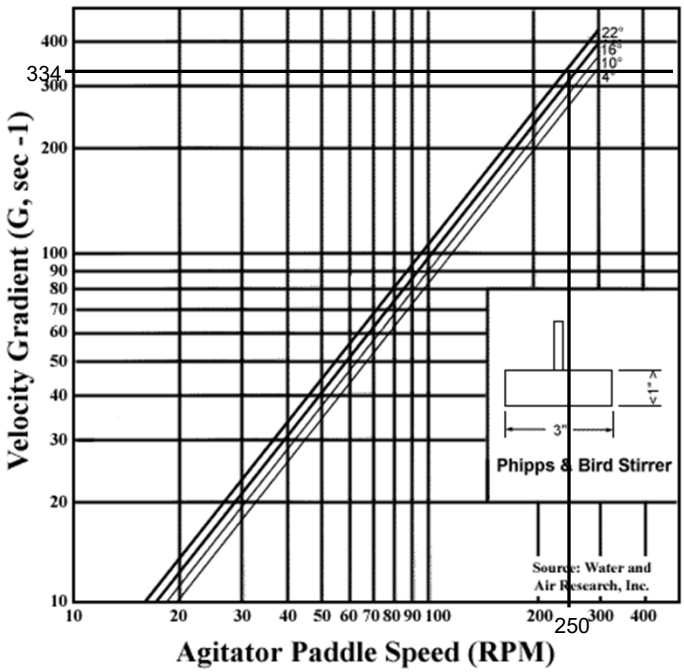
$$G = \sqrt{111{,}793.6673}$$

$$G = 334\ \text{sec}^{-1}$$

Example 1 – Step Two

26

- What do we do with G now that we have found it?
- Velocity gradient can be correlated to paddle speed in the jar test machine
  - Use the Phipps and Bird chart provided in the Coag/Floc Formula Book



Water Temp = 18° C

Your Turn - #1

28

- HP = 3
- Temperature = 16° C
- Volume of flash mix = 8ft x 8ft x 10ft

- What is the velocity gradient (sec^{-1}) and what should be the setting for the jar test paddles (rpm)?

Your Turn - #1

29

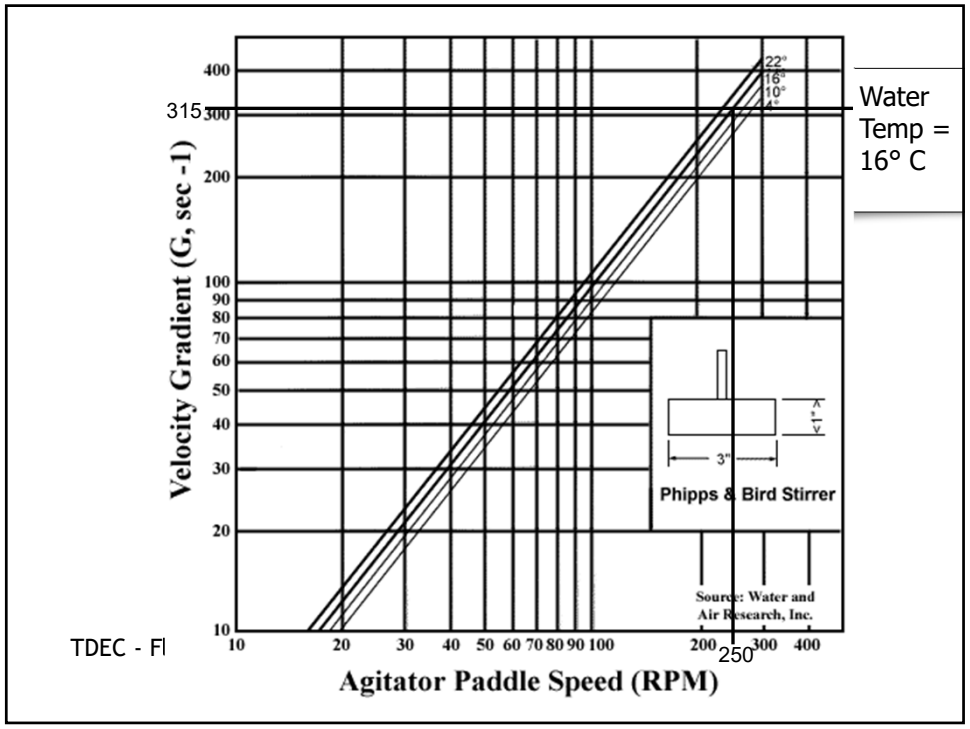
Motor HP = 3
Water Temp = 16° C
Flash mix = 8ft x 8ft x 10 ft deep

- P =
- μ =
- V =

Your Turn - #1

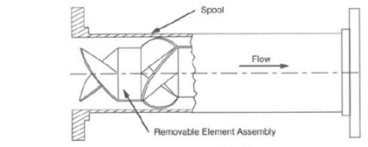
$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

30



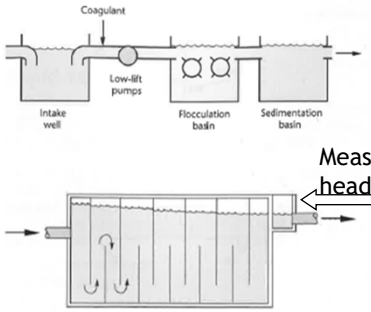
Hydraulic Jumps, Weirs and Baffles

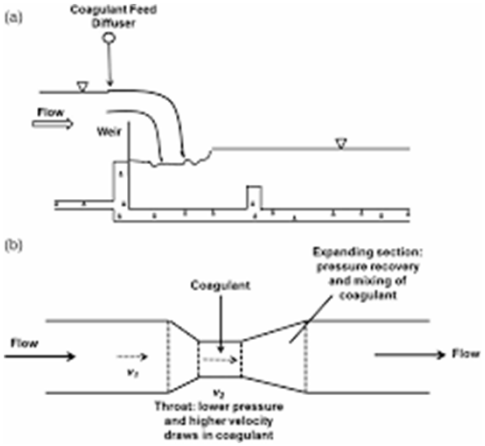
32



Source: Water Quality and Treatment. 5th ed. *(1999).*

FIGURE 4–11 Section view of a static mixer





Hydraulic Jumps, Weirs and Baffles

33

- Formula

$$G = \sqrt{\frac{(62.4)(H)}{(\mu)(T)}}$$

- H= head loss, ft
- μ = viscosity, (lbs)(sec)/ft^2
- T = detention time, sec

Example 2

$$G = \sqrt{\frac{(62.4)(H)}{(\mu)(T)}}$$

34

- Temperature = 20°C
  - μ = 0.000021061
- Weir is 2 feet high
- Detention time = 55 seconds

- What is the velocity gradient (sec^{-1}) and what should be the setting for the jar test paddles (rpm)?

Example 2

$$G = \sqrt{\frac{(62.4)(H)}{(\mu)(T)}}$$

35

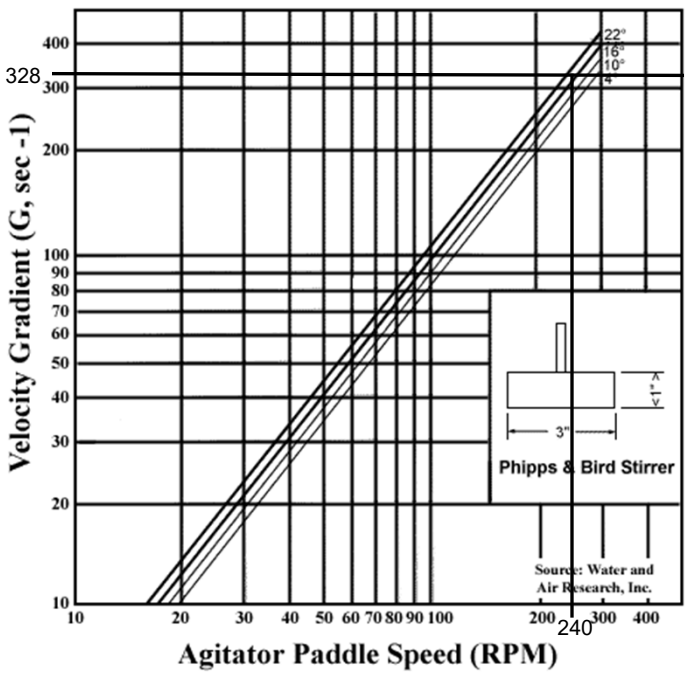
$$G = \sqrt{\frac{(62.4)(2\ ft)}{(0.000021061)(55\ sec)}}$$

$$G = \sqrt{\frac{124.8}{0.001158355}}$$

$$G = \sqrt{107{,}738.9919}$$

$$G = 328.2\ sec^{-1}$$

Temperature = 20°C
μ = 0.000021061
Weir is 2 feet high
Detention time = 55 seconds



Water Temp = 20° C

Your Turn #2

37

- Temperature = 18° C
- Weir is 2 feet high
- Detention time = 51 minutes**

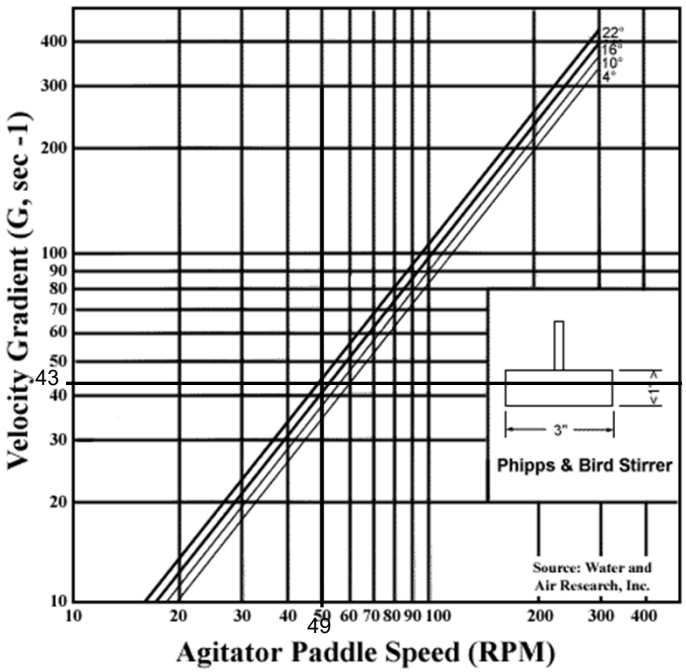
- What is the velocity gradient (sec^{-1}) in the basin, and what should be the setting for the jar test paddles (rpm)?

**Pay attention to your units

Your Turn #2

38

Temperature = 18° C
Weir is 2 feet high
DT= 51 min = 3060 sec



Water Temp = 18° C

Variable Speed Mixers

40

$$\frac{G_1}{G_2} = \left(\frac{N_1}{N_2}\right)^{3/2}$$

- Rearrange to solve for G_2

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

- $G_1 = G_{max}$
- G_2 = Velocity Gradient
- $N_1 = RPM_{max}$
- N_2 = RPM's

Example 3 – Variable Speed Mixers

41

- A facility has a variable speed drive in the rapid mix. Based on the water parameters provided, determine the velocity gradient if the drive is operating at setting 4.

- Water Temp = 16°C
- Flash mix = 12 ft x 12 ft x 10 ft
- 3 HP motor
- Max RPM's = 2.5

- Variable Drive
  - 10 = 2.5 rpm
  - 9 = 2.25 rpm
  - 8 = 2.0 rpm
  - 7 = 1.75 rpm
  - 6 = 1.5 rpm
  - 5 = 1.25 rpm
  - 4 = 1.0 rpm = N_2
  - 3 = 0.75 rpm
  - 2 = 0.5 rpm
  - 1 = 0.25 rpm

Example 3 – Variable Speed Mixers

42

First, we have to find the maximum velocity gradient that the mixer can accomplish.

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

Water Temp = 16°C
Flash mix = 12 ft x 12 ft x 10 ft
3 HP motor
Max RPM's = 2.5

- P = (3 hp)(0.90) = 2.7 hp
- μ = 0.000023293 (from chart)
- V = (12 ft)(12 ft)(10 ft) = 1440 ft^3

Example 3 – Variable Speed Mixers

43

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

P = (3 hp)(0.90) = 2.7 hp
μ = 0.000023293 (from chart)
V = (12ft)(12ft)(10ft) = 1440 ft^3

$$G = \sqrt{\frac{(550)(2.7)}{(0.000023293)(1440\ ft^3)}}$$

$$G = \sqrt{\frac{1485}{0.03354192}}$$

$$G = \sqrt{44272.95754}$$

This is the maximum (G_1) velocity gradient that can be obtained by the variable speed drive on setting 10.

$$G = 210.4\ sec^{-1}$$

Example 3 – Variable Speed Mixers 44

$G_1 = G_{max}$
G_2 = Velocity Gradient
$N_1 = RPM_{max}$
N_2 = RPM's

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

$$G_2 = \frac{210.4\ \text{sec}^{-1}}{\left(\frac{2.5}{1.0}\right)^{3/2}}$$

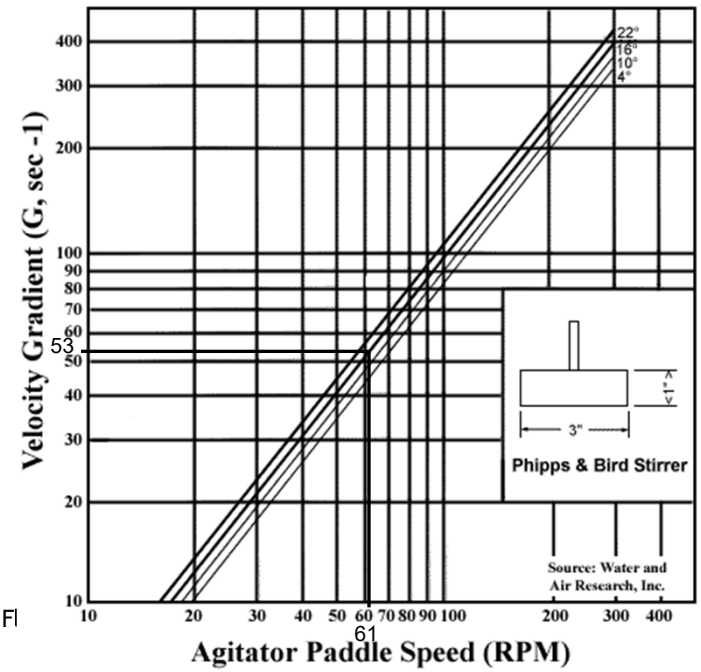
$G_1 = 210.4\ \text{sec}^{-1}$
$N_1 = 2.5$ rpm (at setting 10)
$N_2 = 1.0$ rpm (at setting 4)

$$G_2 = \frac{210}{3.952847075}$$

$$G_2 = 53\text{sec}^{-1}$$

This is the actual (G_2) velocity gradient obtained by the variable speed drive on setting 4.

- Variable Drive
  - 10 = 2.5 rpm
  - 9 = 2.25 rpm
  - 8 = 2.0 rpm
  - 7 = 1.75 rpm
  - 6 = 1.5 rpm
  - 5 = 1.25 rpm
  - 4 = 1.0 rpm
  - 3 = 0.75 rpm
  - 2 = 0.5 rpm
  - 1 = 0.25 rpm



Water Temp = 16° C

Example 3 – Your Turn

46

- A facility has a variable speed drive in the rapid mix. Based on the water parameters provided, determine the velocity gradient if the drive is operating at setting 4.
- Using 2.5 for N_1 and 210 for G_1, solve for G_2 at all other RPM's

Variable Drive Settings

- 10 = 2.5 rpm
- 9 = 2.25 rpm
- 8 = 2.0 rpm
- 7 = 1.75 rpm
- 6 = 1.5 rpm
- 5 = 1.25 rpm
- 4 = 1.0 rpm
- 3 = 0.75 rpm
- 2 = 0.5 rpm
- 1 = 0.25 rpm

Example 3 – Your Turn

47

Setting	Flocculator RPM	G_2	Jar Test RPM
10	2.5		
9	2.25		
8	2.0		
7	1.75		
6	1.5		
5	1.25		
4	1.0		
3	0.75		
2	0.5		
1	0.25		

Calculating Stirring Times

48

$$^{**}\text{Detention time, min} = \frac{\text{tank vol, gal}}{\text{flow rate, gpm}}$$

**make sure the units you are using match the part of the process you are looking at

i.e. rapid mix → seconds
flocculation → minutes
sedimentation → hours

$$\text{Stirring time, min} = \frac{(\text{plant capacity, gpm})(\text{DT, min})}{\text{actual flow rate, gpm}}$$

Jar Test Correction

49

- What if your jar test machine won't give you a high enough G (velocity gradient)?
  - You must mix longer to compensate for the decreased velocity gradient

$$(G_1)(T_1) = (G_2)(T_2)$$

- Rearrange to solve for T_1

$$T_1 \equiv \frac{(G_2)(T_2)}{G_1}$$

- $T_1 = T_{max}$ = time to use in jar test, sec
- $G_1 = G_{max}$= maximum G for jar test machine, sec^{-1}
- T_2 = actual process detention time, sec
- G_2 = calculated velocity gradient, sec^{-1}

Example 4

50

- According to our calculations, the rapid mix has a velocity gradient of 1000 sec^{-1}. If the water temperature is 22°C and the rapid mix detention time is 15 seconds. Our Phipps & Bird jar testing machine will only go up to 105 rpm's, which is equivalent to ≈ 100 sec^{-1}. Determine the amount of time required to mix the sample in the lab to accurately mimic the plant.

Example 4 Cont'd

Velocity Gradient = 1000 sec^{-1}
Time = 15 sec
Temp = 22°C

51

$$T_1 \equiv \frac{(G_2)(T_2)}{G_1}$$

$$T_1 \equiv \frac{(1000\ \text{sec}^{-1})(15\ \text{sec})}{100\ \text{sec}^{-1}}$$

$$T_1 = 150\ \text{sec@105 rpm}$$

$T_1 = T_{max}$ = time to use in jar test, sec
$G_1 = G_{max}$= maximum G for jar test machine, sec^{-1}
T_2 = actual process detention time, sec
G_2 = calculated velocity gradient, sec^{-1}

Sedimentation

52

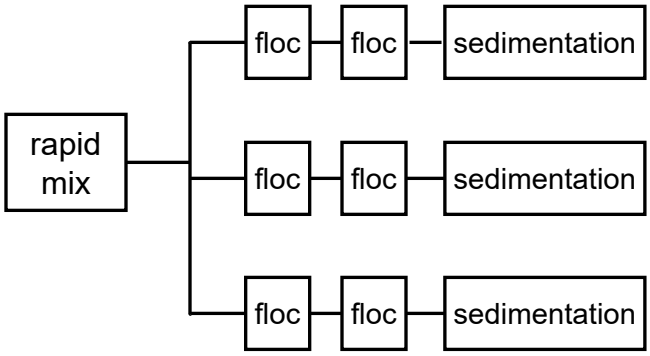
- Does surface loading rate influence sedimentation?
  - Yes – this is one of the most important factors
  - Also knows as Surface Overflow Rate

$$\text{SOR, gpd/ft}^2 = \frac{\text{basin flow rate, gpd}}{\text{basin surface area, ft}^2}$$

Example 5

53

- A water plant has four sedimentation basins. It treats 6 MGD. The flow is split equally between all four basins. The basins are 30 feet long and 20 feet wide. What is the surface overflow rate for each basin in gpd/ft^2?



Example 5 Cont'd

54

$$\text{gpd/basin} = \frac{6{,}000{,}000 \text{ gpd}}{4 \text{ basins}}$$

$$\text{gpd/basin} = 1{,}500{,}000 \text{ gpd/basin}$$

$$\text{SOR} = \frac{1{,}500{,}000 \text{ gpd}}{(30 \text{ ft})(20 \text{ ft})}$$

$$\text{SOR} = \frac{1{,}500{,}000 \text{ gpd}}{600 \text{ ft}^2}$$

This will allow us to determine the settling velocity and jar test sampling time.

$$\text{SOR} = 2{,}500 \ {}^{\text{gpd}}/_{\text{ft}^2}$$

Converting SOR to Setting Velocity

55

$$\text{Settling velocity, cm/min} = \frac{(\text{SOR, gpd/ft}^2)(3785 \text{ cm}^3/\text{gal})}{(1440 \text{ min/day})(929 \text{ cm}^2/\text{ft}^2)}$$

1 cm^3 = 1 mL
3785 mL = 1 gal
Therefore, 3785 cm^3 also = 1 gal

Example 5 Cont'd

56

As determined previously, the surface overflow rate for a basin is 2,500 gpd/ft^2. What is the settling velocity in cm/min for the basin?

$$\text{Settling velocity, cm/min} = \frac{(\text{SOR, gpd/ft}^2)(3785\ \text{cm}^3/\text{gal})}{(1440\ \text{min/day})(929\ \text{cm}^2/\text{ft}^2)}$$

$$\text{cm/min} = \frac{(2500\ \text{gpd/ft}^2)(3785\ \text{cm}^3/\text{gal})}{(1440\ \text{min/day})(929\ \text{cm}^2/\text{ft}^2)}$$

$$\text{cm/min} = \frac{9{,}462{,}500}{1{,}337{,}760}$$

$$\text{cm/min} = 7.07\ \text{cm/min}$$

Example 5 Cont'd

57

Determine jar test sampling time based on settling velocity of 7.07 cm/min.

Settling Velocity, cm/min	Sampling Time, min
0.5	20
1.0	10
2.0	5
4.0	2.5
10.0	1

Chart based on a sample depth in the jar of 10 cm.

Example 5 Cont'd

58

- We determined the settling velocity is 7.07 cm/min. This number cannot be found on the chart so we will have to calculate the sampling time

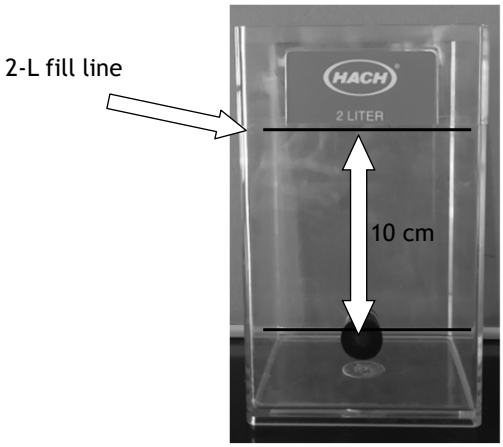
$$sampling\ time, \min = \frac{10\ cm}{settling\ velocity, cm/min}$$

$$sampling\ time, \min = \frac{10\ cm}{7.07\ \ cm/min}$$

$$sampling\ time, \min = 1.4 \text{ minutes}$$

Jar Test "Floc Beaker"

59



Determining Dosage

60

- Need to choose 6 dosages for the jar test
- Feed chemicals in the jar test in µL (microliters)

$$\mu L = \frac{(\text{dose, mg/L})(\text{sample volume, L})}{\text{chemical specific gravity}}$$

Example 6

61

- A water treatment plant is currently feeding 17 mg/L of coagulant to treat their raw water. The coagulant in use has a specific gravity of 1.333. Determine the microliters of coagulant necessary for the jar test.

$$\mu L = \frac{(\text{dose, mg/L})(\text{sample volume, L})}{\text{chemical specific gravity}}$$

$$\mu L = \frac{(17\ \text{mg/L})(2\ \text{L})}{1.333}$$

$$\mu L \approx 25\ \mu L$$

Example 6 Cont'd

62

- Now, choose 5 other doses to feed while keeping the plant dose, 17 mg/L, in the middle as a control

$$\mu L = \frac{(\text{dose, mg/L})(\text{sample volume, L})}{\text{chemical specific gravity}}$$

Jar #	Dosage (mg/L)	≈ Jar test dose (µL)
1	7	
2	12	
3	17	
4	22	
5	27	
6	32	

Coagulation/Flocculation Workshop
Warm-up Math

Volume

1. A flash mix chamber is 4 feet wide by 5 feet long and contains water to a depth of 3 feet. What is the volume in gallons of water in the flash mix chamber?

2. A flocculation basin is 50 feet long by 20 feet wide and contains water to a depth of 8 feet. What is the volume in gallons of the water in the basin?

3. A flocculation basin is 40 feet long by 16 feet wide and contains water to a depth of 8 feet. How many gallons of water are in the basin?

4. A flash mix chamber is 5 feet square and contains water to a depth of 42 inches. What is the volume in gallons of water in the flash mixing chamber?

5. A flocculation basin is 25 feet wide by 40 feet long and contains water to a depth of 9 feet 2 inches. What is the volume in gallons of water in the flocculation basin?

Detention Time

6. The flow to a flocculation basin is 3,625,000 gal/day. If the basin is 60 feet long by 25 feet wide and contains water to a depth of 9 feet, what is the detention time (in minutes) of the flocculation basin?

7. A flocculation basin is 50 feet long by 20 feet wide and has a water level of 8 feet. What is the detention time (in minutes) in the basin if the flow to the basin is 2.8 MGD?

8. A flash mix chamber is 6 feet long, 5 feet wide and 5 feet deep. It receives a flow of 9 MGD. What is the detention time (in seconds) in the chamber?

9. A flocculation basin is 50 feet long by 20 feet wide and has a water depth of 10 feet. If the flow to the basin is 2,250,000 gal/day, what is the detention time in minutes?

10. A flash mix chamber is 4 feet square and has a water depth of 42 inches. If the flash mix chamber receives a flow of 3.25 MGD, what is the detention time in seconds?

Dry Feeder Settings

11. The desired dry alum dosage, as determined by the jar test, is 10 mg/L. Determine the lb/day setting on a dry alum feeder if the flow is 3,450,000 gal/day.

12. Jar tests indicate that the best polymer dose for a water sample is 12 mg/L. If the flow to be treated is 1,660,000 gal/day, what should the dry chemical lb/day feed setting be?

13. Determine the desired lb/day setting on a dry alum feeder if jar tests indicate an optimum dose of 12 mg/L and the flow to be treated is 2.66 MGD.

14. The desired dry alum dose is 9 mg/L, as determined by a jar test. If the flow to be treated is 940,000 gal/day, how many lb/day dry alum will be required?

15. A flow of 4.10 MGD is to be treated with a dry polymer. If the desired dose is 13 mg/L, what should the dry chemical feeder in lb/day setting be?

16. Calculate the actual chemical feed rate in pounds per day if a container is placed under a chemical feeder and 2.3 pounds are collected during a 30-minute period.

17. During a 24-hour period, a flow of 1,920,000 gal/day is treated. If 42 pounds of polymer were used for coagulation during that 24-hour period, what is the polymer dosage in mg/L?

Liquid Feeder Settings

18. Jar tests indicate that the best alum dose for a unit process is 7 mg/L. The flow to be treated is 1.66 MGD. Determine the gal/day setting for the alum solution feeder if the liquid alum contains 5.24 pounds of alum per gallon of solution.

19. The flow to a plant of 3.43 MGD. Jar testing indicates that the optimum alum dose is 12 mg/L. What should the gal/day setting be for the solution feeder if the alum solution is a 55% solution and has a density of 11.12 lb/gal.

20. Jar tests indicate that the best alum dose for a unit process is 10 mg/L. The flow to be treated is 4.13 MGD. Determine the gal/day setting for the alum solution feeder if the liquid alum contains 5.40 pounds of alum per gallon of solution.

21. Jar tests indicate the best liquid alum dose for a unit process is 11 mg/L. The flow to be treated is 880,000 gal/day. Determine the gal/day setting for the liquid alum chemical feeder if the liquid alum is a 55% solution.

22. A flow of 1,850,000 gal/day is to be treated with alum. Jar tests indicate that the optimum alum dose is 15 mg/L. If the liquid alum contains 640 mg alum per milliliter solution, what should be the gallons per day setting for the alum solution feeder?

23. The desired solution feed rate was calculated to be 40 gal/day. What is this feed rate expressed at milliliters per minute (mL/min)?

24. The desired solution feed rate was calculated to be 34.2 gal/day. What is this feed rate expressed at milliliters per minute (mL/min)?

25. The optimum polymer dose has been determined to be 10 mg/L. The flow to be treated is 2,880,000 gal/day. If the solution to be used contains 55% active polymer, what should the solution chemical feeder setting be in milliliters per minute (mL/min)?

26. The optimum polymer dose for a 2,820,000 gal/day flow has been determined to be 6 mg/L. If the polymer solution contains 55% active polymer, what should the solution chemical feeder setting in milliliters per minute be? Assuming the polymer solution weighs 8.34 lbs/gal.

27. Jar tests indicate that the best alum dose for a unit process is 16 mg/L. The liquid alum contains 5.40 pounds alum per gallon of solution. What should the setting be on the solution chemical feeder in milliliters per minute (mL/min) when the flow to be treated is 3.45 MGD?

Chemical Usage

28. Based on the amount of chemical used each day, what was the average chemical use in pound/day for the following week: Monday, 81 pounds; Tuesday, 73 pounds; Wednesday, 74 pounds; Thursday 66 pounds; Friday 79 pounds; Saturday 80 pounds and Sunday, 82 pounds.

29. The average chemical use at the plant is 90 lbs/day. If the chemical inventory in stock is 2200 pounds, how many days supply is this?

30. The chemical inventory in stock is 889 pounds. If the average chemical use at the plant is 58 pounds per day, how many days supply is this?

31. The average gallons of polymer solution used each day at a treatment plant are 88 gal/day. A chemical feed tank has a diameter of 3 feet and contains solution to a depth of 3 feet 4 inches. How many days supply is in the solution tank?

32. Jar tests indicate that the optimum polymer dose for a unit process is 2.8 mg/L. If the flow to be treated is 18 MGD, how many pounds of dry polymer will be required for a 30-day period?

Coagulation/Flocculation Workshop
Jar Testing Math

Velocity Gradient

33. What is your velocity gradient (sec^{-1}) for a flash mix that is 6 feet square by 8 feet deep. You have a 5 hp motor and the water temperature is 20°C.

34. What is your velocity gradient (sec^{-1}) for a flash mix that is 10 feet by 10 feet and 12 feet deep. You have a 8 hp motor and the water temperature is 22°C.

35. Your flocculators are 20 feet square by 16 feet deep. You have a variable speed drive that has 3 hp and the maximum RPM's equals 2.5 and you have the variable speed set on 6. The water temperature is 18°C. Find your velocity gradient (sec^{-1}) for the current setting.

Variable Drive Settings

- 10 = 2.5 rpm
- 9 = 2.25 rpm
- 8 = 2.0 rpm
- 7 = 1.75 rpm
- 6 = 1.5 rpm
- 5 = 1.25 rpm
- 4 = 1.0 rpm
- 3 = 0.75 rpm
- 2 = 0.5 rpm
- 1 = 0.25 rpm

36. Your second set of flocculators is 20 feet square by 16 feet deep. You have a variable speed drive that has 3 hp and the maximum RPM's equals 2.5 and you have the variable speed set on 3. The water temperature is 18°C. Using the chart in the previous question, find your velocity gradient (sec^{-1}).

37. Your old jar test machine will only go up to 125 rpm's, which is equivalent to about 140 sec^{-1}. Your water temperature is 22°C. You wanted to achieve a mixing velocity of 600 sec^{-1} for 16 seconds. How many seconds must the sample mix to make up for the slow mixing?

38. Your old jar test machine will only go up to 80 rpm's, which is equivalent to about 75 sec^{-1}. Your water temperature is 16°C. You wanted to achieve a mixing velocity of 153 sec^{-1} for 13 seconds. How many seconds must you mix the samples during the jar test to make up for the slower mixing speed?

Surface Overflow Rate

39. A rectangular sedimentation basin is 60 feet long and 25 feet wide. When the flow is 510 gal/min, what is the surface overflow rate in gal/day/ft^2?

40. A circular clarifier has a diameter of 70 feet. If the flow to the clarifier is 1610 gal/min, what is the surface overflow rate in gal/day/ft^2?

41. A rectangular sedimentation basin receives a flow of 540,000 gal/day. If the basin is 50 feet long and 20 feet wide, what is the surface overflow rate in gal/day/ft^2?

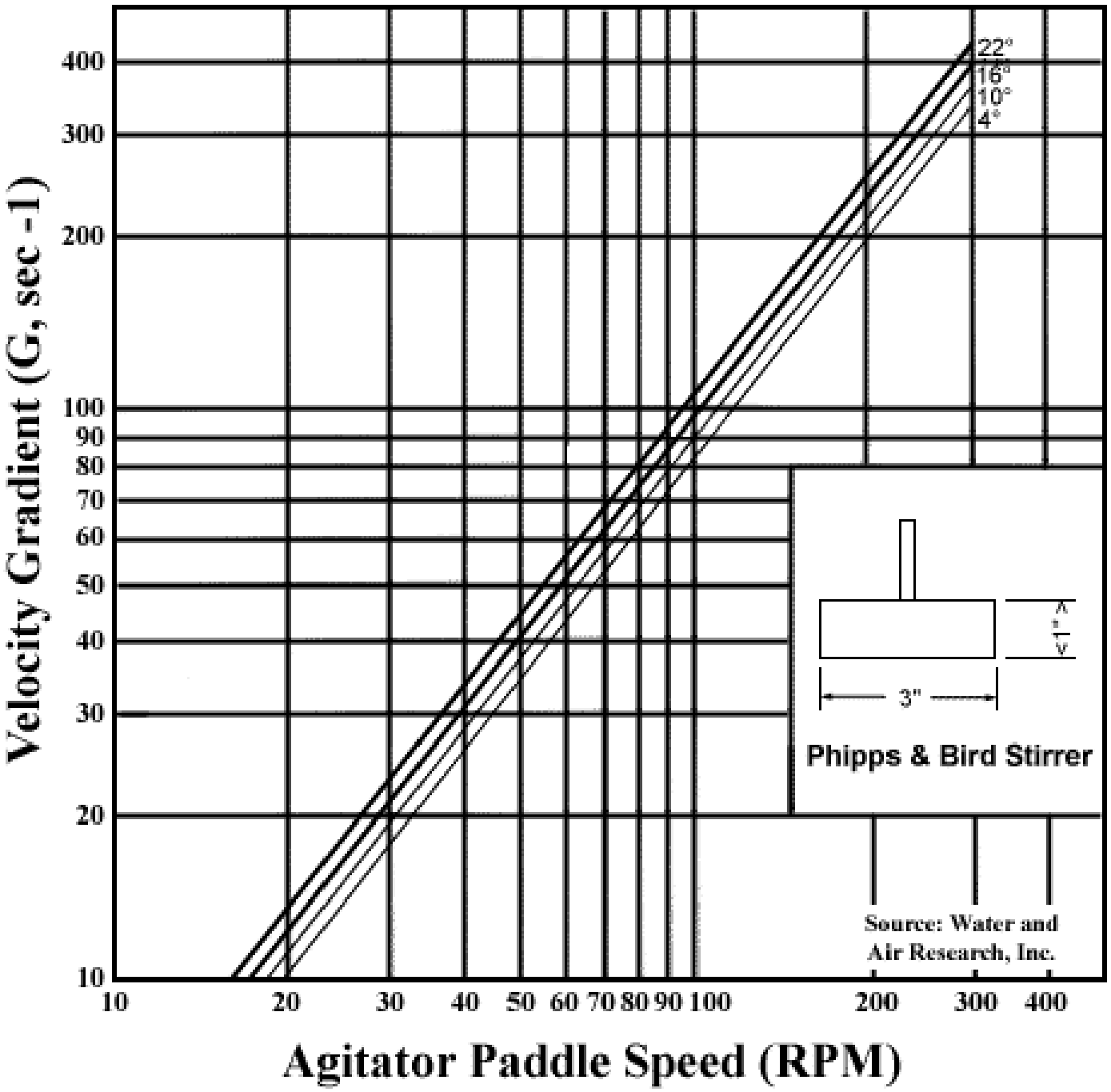
42. The surface overflow rate for a basin is 2,300 gal/day/ft^2. What is the settling velocity in cm/min?

43. The surface overflow rate for a basin is 1,500 gal/day/ft^2. What is the settling velocity in cm/min?

Answers:

1. 448.8 gal
2. 59,840 gal
3. 38,298 gal
4. 654.5 gal
5. 68,567 gal
6. 40 min
7. 30.8 min
8. 10.8 sec
9. 48 min
10. 11.1 sec
11. 288 lbs/day
12. 166 lbs/day
13. 266 lbs/day
14. 70.6 lbs/day
15. 445 lbs/day
16. 110.4 lbs/day
17. 2.6 mg/L
18. 18.5 gpd
19. 56.13 gpd
20. 63.8 gpd
21. 17.6 gpd
22. 43.3 gpd
23. 105 mL/min
24. 89.9 mL/min
25. 137.6 mL/min
26. 80.9 mL/min
27. 224 mL/min
28. 76.4 lbs/day
29. 24.4 days
30. 15.3 days
31. 2 days
32. 12,610 lbs
33. 638 sec^{-1}
34. 406 sec^{-1}
35. 47 sec^{-1}
36. 17 sec^{-1}
37. 69 sec
38. 27 sec
39. 489.6 gpd/ft^2
40. 602.7 gpd/ft^2
41. 540 gpd/ft^2
42. 6.5 cm/min
43. 4.2 cm/mi

μ, Density of Water		
Temperature ° C	μ, (lbs)(sec)/ft2	Temperature ° F
2	0.000033613	35.6
4	0.000032731	39.2
6	0.000030747	42.8
8	0.000028964	46.4
10	0.000027846	50
12	0.000024879	53.6
14	0.000024529	57.2
16	0.000023293	60.8
18	0.000022139	64.4
20	0.000021061	68
22	0.000020061	71.6
24	0.000019128	75.2
26	0.000018261	78.8
28	0.000017461	82.4
30	0.000016712	86


Velocity Gradient (G, sec -1)
400
300
200
100
90
80
70
60
50
40
30
20
10
22°
16°
10°
4°
3"
1"
Phipps & Bird Stirrer
Source: Water and Air Research, Inc.
10 20 30 40 50 60 70 80 90 100 200 300 400
Agitator Paddle Speed (RPM)

Volume

① $Vol = (4\,ft)(5\,ft)(3\,ft)(7.48\,gal/ft^3) = 448.8\,gal$

② $Vol = (50\,ft)(20\,ft)(8\,ft)(7.48\,gal/ft^3) = 59,840\,gal$

③ $Vol = (40\,ft)(16\,ft)(8\,ft)(7.48\,gal/ft^3) = 38,297.6\,gal$

④ $d = 42\,in \div 12\,in/ft = 3.5\,ft$
$Vol = (5\,ft)(5\,ft)(3.5\,ft)(7.48\,gal/ft^3) = 654.5\,gal$

⑤ $d = 2\,in/12\,in/ft = 0.1667\,ft + 9\,ft = 9.167\,ft$
$Vol = (25\,ft)(40\,ft)(9.1667\,ft)(7.48\,gal/ft^3) = 68,566.9\,gal$

Detention Time

⑥ $$DT = \frac{(60\,ft)(25\,ft)(9\,ft)(7.48\,gal/ft^3)}{3,625,000\,gal/day} = 0.0278\,day$$
$DT_{min} = (0.0278\,day)(24\,hr/day)(60\,min/hr) = 40.1\,min$

⑦ $$DT = \frac{(50\,ft)(20\,ft)(8\,ft)(7.48\,gal/ft^3)}{2,800,000\,gal/day} = 0.0214\,day$$
$DT_{min} = (0.0214\,day)(24\,hr/day)(60\,min/hr) = 30.8\,min$

⑧ $$DT = \frac{(6\,ft)(5\,ft)(5\,ft)(7.48\,gal/ft^3)}{9,000,000\,gpd} = 0.0001247\,day$$
$$DT_{sec} = \left(\frac{0.0001247\,day}{}\right)\left(\frac{24\,hr}{1\,day}\right)\left(\frac{60\,min}{1\,hr}\right)\left(\frac{60\,sec}{1\,min}\right) = 10.8\,sec$$

(9) $DT = \frac{(50ft)(20ft)(10ft)(7.48 gal/ft^3)}{2,250,000 gal/day} = 0.0332 day$

$DT_{min} = \left(\frac{0.0332 day}{}\right)\left(\frac{24 hr}{1 day}\right)\left(\frac{60 min}{1 day}\right) = 47.872 min$

(10) $d = 42 in / 12 in/ft = 3.5 ft$

$flow = \left(\frac{3.25 MG}{day}\right)\left(\frac{1,000,000 gal}{1 MG}\right)\left(\frac{1 day}{1440 min}\right)\left(\frac{1 min}{60 sec}\right) = 37.6 gal/sec$

$DT_{sec} = \frac{(4ft)(4ft)(3.5ft)(7.48 gal/ft^3)}{37.6 gps} = 11.1 sec$

Dry Feeder Settings

(11) $lb/day = (dose)(flow)(8.34)$
$= (10 mg/L)(3.45 MGD)(8.34 lb/gal)$
$= 287.7 lb/day$

(12) $lb/day = (12 mg/L)(1.66 MGD)(8.34 lb/gal)$
$= 166.13 lb/day$

(13) $lb/day = (12 mg/L)(2.66 MGD)(8.34 lb/gal)$
$= 266.21 lb/day$

(14) $lb/day = (9 mg/L)(0.94 MGD)(8.34 lb/gal)$
$= 70.56 lb/day$

(15) $lb/day = (13 mg/L)(4.10 MGD)(8.34 lb/gal)$
$= 444.52 lb/day$

(16) $\left(\frac{2.3\ lb}{30\ min}\right)\left(\frac{60\ min}{1\ hr}\right)\left(\frac{24\ hr}{1\ day}\right) = \frac{(2.3)(60)(24)}{(30)(1)(1)} = 110.4\ \frac{lb}{day}$

(17) $42\ ^{lb}/_{day} = (x\ ^{mg}/_{L})(1.92\ MGD)(8.34\ ^{lb}/_{gal})$

$\frac{42}{16.0128} = \frac{(x)(16.0128)}{16.0128}$

$2.62\ ^{mg}/_{L} = x$

Liquid Feeder Settings

(18) $^{lb}/_{day} = (7\ ^{mg}/_{L})(1.66\ MGD)(8.34\ ^{lb}/_{gal}) = 96.9108\ ^{lb}/_{day}$

$gal/day = \left(\frac{96.9108\ lb}{day}\right)\left(\frac{1\ gal}{5.24\ lb}\right) = 18.49\ gal/day$

(19) $^{lb}/_{day} = (12\ ^{mg}/_{L})(3.43\ MGD)(8.34) = 343.2744\ ^{lb}/_{day}$

$gal/day = \left(\frac{343.2744\ lb}{day}\right)\left(\frac{1\ gal}{11.12\ lb}\right) = 30.87\ gal/day$

(20) $^{lb}/_{day} = \frac{(12\ ^{mg}/_{L})(3.43\ MGD)(8.34)}{0.55} = 624.1353\ ^{lb}/_{day}$

$gal/day = \left(\frac{624.1353\ lb}{day}\right)\left(\frac{1\ gal}{11.12\ lb}\right) = 56.13\ gal/day$

(20) $^{lb}/_{day} = (10\ ^{mg}/_{L})(4.13\ MGD)(8.34) = 344.442\ ^{lb}/_{day}$

$gal/day = \left(\frac{344.442\ lb}{day}\right)\left(\frac{1\ gal}{5.40\ lb}\right) = 63.79\ gal/day$

(21) $lb/day = \frac{(11\ mg/L)(0.88\ MGD)(8.34)}{0.55} = 146.784\ lb/day$

$gal/day = \left(\frac{146.784\ lb}{day}\right)\left(\frac{1\ gal}{8.34\ lb}\right) = 17.6\ gal/day$

(22) $lb/day = (15\ mg/L)(1.85\ MGD)(8.34) = 231.435\ lb/day$

$lb/gal = \left(\frac{640\ mg}{mL}\right)\left(\frac{1000\ mL}{1\ L}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1\ g}{1000\ mg}\right)\left(\frac{1\ lb}{454\ g}\right) =$

$gal/day = \left(\frac{231.435\ lb}{day}\right)\left(\frac{1\ gal}{5.33\ lb}\right) = 43.42\ gal/day \quad = 5.33\ lb/gal$

(23) $mL/min = \left(\frac{40\ gal}{1\ day}\right)\left(\frac{1\ day}{24\ hr}\right)\left(\frac{1\ hr}{60\ min}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1000\ mL}{1\ L}\right)$

$= 105.14\ mL/min$

(24) $mL/min = \left(\frac{34.2\ gal}{day}\right)\left(\frac{1\ day}{24\ hr}\right)\left(\frac{1\ hr}{60\ min}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1000\ mL}{1\ L}\right)$

$= 89.89\ mL/min$

(25) $lb/day = \frac{(10\ mg/L)(2.88\ MGD)(8.34)}{0.55} = 436.7127\ lb/day$

$mL/min = \left(\frac{436.7127\ lb}{day}\right)\left(\frac{1\ day}{1440\ min}\right)\left(\frac{1\ gal}{8.34\ lb}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1000\ mL}{1\ L}\right)$

$= 137.164\ mL/min$

(26) $lb/day = \frac{(16\ mg/L)(2.82\ MGD)(8.34)}{0.55} = 256.5687\ lb/day$

$mL/min = \left(\frac{256.5687\ lb}{day}\right)\left(\frac{1\ day}{1440\ min}\right)\left(\frac{1\ gal}{8.34\ lb}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1000\ mL}{1\ L}\right)$

$= 80.86\ mL/min$

(27) $lb/day = (116\ mg/L)(3.45\ MGD)(8.34) = 460.368\ lb/day$

$$mL/min = \left(\frac{460.368\ lb}{day}\right)\left(\frac{1\ day}{1440\ min}\right)\left(\frac{1\ gal}{5.40\ lb}\right)\left(\frac{3.785\ L}{1\ gal}\right)\left(\frac{1000\ mL}{1\ L}\right)$$

$$= 224.09\ mL/min$$

Chemical Usage

(28) $$avg = \frac{81\ lb + 73\ lb + 74\ lb + 66\ lb + 79\ lb + 80\ lb + 82\ lb}{7\ days}$$

$$= 76.4\ lb/day$$

(29) $$day = \left(\frac{2200\ lb}{1}\right)\left(\frac{day}{90\ lb}\right) = 24.4\ days$$

(30) $$days = \left(\frac{889\ lb}{1}\right)\left(\frac{day}{58\ lb}\right) = 15.3\ days$$

(31) $vol = (0.785)(3\ ft)(3\ ft)(3.3333\ ft)(7.48\ gal/ft^3)$

$$= 176.14\ gal$$

$$days = \left(\frac{176.14\ gal}{88\ gal}\right)\left(\frac{day}{88\ gal}\right) = 2.0\ days$$

(32) $lb/day = (2.8\ mg/L)(18\ MGD)(8.34) = 420.336\ lb/day$

$$lbs = \left(\frac{420.336\ lb}{day}\right)\left(\frac{30\ days}{1}\right) = 12610.08\ lb$$

Jar Testing

(33) $P = (5\ hp)(0.90) = 4.5\ hp$

$\mu = 0.000021061$

$vol = (6ft)(6ft)(8ft) = 288\ ft^3$

$$G = \sqrt{\frac{(550)(4.5\ hp)}{(0.000021061)(288\ ft^3)}} = \sqrt{\frac{2475}{0.0060065}}$$

$$= \sqrt{408040.9287} = 638.78\ sec^{-1}$$

(34) $P = (8\ hp)(0.90) = 7.2\ hp$

$\mu = 0.000020061$

$vol = (10ft)(10ft)(12ft) = 1200\ ft^3$

$$G = \sqrt{\frac{(550)(7.2\ hp)}{(0.000020061)(1200\ ft^3)}} = \sqrt{\frac{3960}{0.02407}}$$

$$= \sqrt{164498.2802} = 405.58\ sec^{-1}$$

(35) $P = (3\ hp)(0.90) = 2.7\ hp$

$\mu = 0.000022139$

$vol = (20ft)(20ft)(16ft) = 6400\ ft^3$

$$G_{max} = \sqrt{\frac{(550)(2.7\ hp)}{(0.000022139)(6400\ ft^3)}} = 102.375\ sec^{-1}$$

$$G_2 = \frac{G_{max}}{\left(\frac{N_1}{N_2}\right)^{3/2}} = \frac{102.375}{\left(\frac{2.5}{1.5}\right)^{3/2}} = \frac{102.375}{2.1516} = 47.58\ sec^{-1}$$

(36) $G_{max} = 102.375\ sec^{-1}$

$$G_2 = \frac{102.375\ sec^{-1}}{\left(\frac{2.5}{0.75}\right)^{3/2}} = \frac{102.375}{6.0858} = 16.82\ sec^{-1}$$

(37) $$T_1 = \frac{(600\ sec^{-1})(16\ sec)}{140\ sec^{-1}} = 68.57\ sec$$

(38) $$T_1 = \frac{(153\ sec^{-1})(13\ sec)}{75\ sec^{-1}} = 26.52\ sec$$

Surface Overflow Rate

(39) $$gal/day = \left(\frac{510\ gal}{min}\right)\left(\frac{60\ min}{1\ hr}\right)\left(\frac{24\ hr}{1\ day}\right) = 734400\ gal/day$$

$$SOR = \frac{734,400\ gpd}{(60ft)(25ft)} = 489.6\ gpd/ft^2$$

(40) $$gal/day = (1610\ \tfrac{gal}{min})(60\ \tfrac{min}{hr})(24\ \tfrac{hr}{day}) = 2318400\ gal/day$$

$$SOR = \frac{2318400\ gpd}{(0.785)(70ft)(70ft)} = 602.73\ gpd/ft^2$$

(41) $$SOR = \frac{540,000\ gpd}{(50ft)(20ft)} = 540\ gpd/ft^2$$

(42) $$cm/min = \frac{(2300\ gpd/ft^2)(3785\ cm^3/gal)}{(1440\ min/day)(929\ cm^3/ft^3)} = 6.51\ cm/min$$

(43) $cm/min = \frac{(1500\ gpd/ft^2)(3785\ cm^3/gal)}{(1440\ min/day)(929\ cm^2/ft^2)} = 4.24\ cm/min$

Section 4

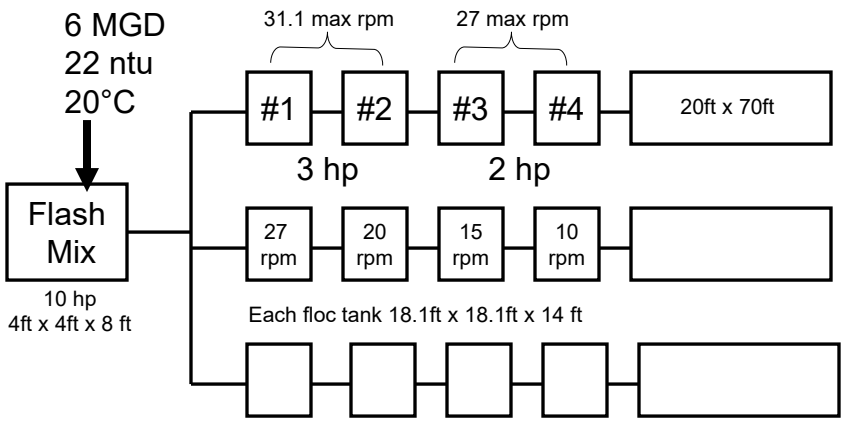
Plant Examples

Plant Examples

1

Plant Example

Jar Tester maxes out at 400 sec^{-1}



2

Plant Example

- We need to replicate in the lab how our plant performs
  - Velocity gradients (RPMs in lab)
  - Detention times (stir times)
  - Surface overflow rate
    - Settling velocity
  - Sampling time

3

Step 1 – Flash Mix

- Find G (velocity gradient) of flash mix basin
- Find Detention time for Flash Mix in seconds
- Determine stir time
  - May have to increase time to make up for lack of G in lab

4

Flash Mix

- Find G (velocity gradient) of flash mix basin

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

$$\text{flash mix vol, ft}^3 = (4\text{ ft})(4\text{ ft})(8\text{ ft}) = 128\text{ft}^3$$

$$P = (10\text{ hp})(0.90) = 9\text{ hp}$$

$$G_1 = \sqrt{\frac{(550)(9\text{ hp})}{(0.000021061)(128\text{ ft}^3)}} = 1355\text{sec}^{-1}$$

5

Flash Mix

- Find Detention time (seconds)

$$DT = \frac{\text{volume, gal}}{\text{flow}}$$

Flash mix vol, gal $= (128\text{ft}^3)(7.48\ \text{gal/ft}^3)$
Flash mix vol, gal $= 957.44$ gal

$$DT = \frac{957.44\text{ gal}}{6{,}000{,}000\text{ gpd}}$$

$$DT = 0.00016\text{ days}$$

$$DT, \text{sec} = \left(\frac{0.00016\ \cancel{\text{days}}}{}\right)\left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hr}}}\right)\left(\frac{60\text{ sec}}{1\ \cancel{\text{min}}}\right)$$

$$DT, \text{sec} = 13.8\text{ sec}$$

6

Flash Mix

G_1 = 1355 sec^{-1}
Jar Test Max = 400 sec^{-1}

- Determine jar test stir time
  - Jar test cannot achieve plant velocity gradient. We must stir for longer to make up for the lack of speed.

$$T_1 = \frac{(G_2)(T_2)}{G_1}$$

$$T_1 = \frac{(1355\ \text{sec}^{-1})(13.8\ \text{sec})}{400\ \text{sec}^{-1}}$$

$$T_1 = 46.7\ \text{sec}$$

46.7 sec @ 300 rpm

7

Step 2 - Flocculators

- Find G_2 (actual) for Flocculator #1
- Plug velocity gradient into Phipps & Bird chart to determine paddle RPMs on jar tester
- Repeat for any additional flocculators
- ** Be sure to note any changes in dimensions, RPMs and HP

8

Flocculator #1

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

- Determine G_{max} (G_1)

$$\text{floc tank vol, ft}^3 = (18.1\text{ ft})(18.1\text{ ft})(14\text{ ft})$$
$$\text{floc tank vol} = 4586.54\text{ ft}^3$$

$$P = (3)(0.9) = 2.7\text{ hp}$$

$$G_1 = \sqrt{\frac{(550)(2.7\text{ hp})}{(0.000021061)(4586.54\text{ ft}^3)}}$$

$$G_1 = 124\text{ sec}^{-1}$$

9

Flocculator #1

- Determine actual G for variable speed drive setting

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

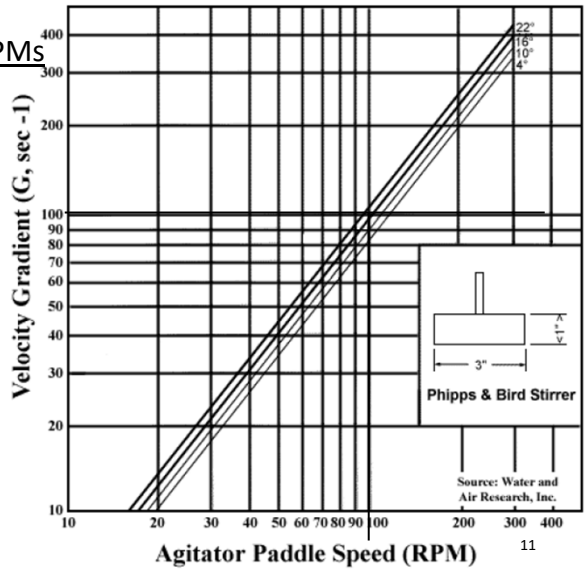
$$G_2 = \frac{124}{\left(\frac{31.1}{27}\right)^{3/2}}$$

$$G_2 = 100.3\text{ sec}^{-1}$$

10

Flocculator #1

- Determine jar test RPMs
  - ≈100 sec^{-1}
  - 20°C
- Set jar test @ 98 RPMs



11

Flocculator #1

- Determine jar test Stir Time

$$DT = \frac{\text{volume, gal}}{\text{flow}}$$

$$\text{volume, gal} = (4586.54\ \text{ft}^3)(7.48\ \text{gal/ft}^3)$$

$$\text{volume, gal} = 34307.3192\ \text{gal}$$

$$\text{flow} = \frac{6{,}000{,}000\ \text{gpd}}{3\ \text{basins}}$$

$$\text{flow} = 2{,}000{,}000\ \text{gpd}$$

$$DT = \frac{(34307.3192\ \text{gal})}{2{,}000{,}000\ \text{gpd}} = 0.0172\ \text{days}$$

$$DT, \text{min} = \left(\frac{0.0172\ \cancel{\text{days}}}{}\right)\left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \text{min}}{1\ \cancel{\text{hr}}}\right)$$

$$DT, \text{min} = 24.7\ \text{min} \approx 25\ \text{min}$$

12

Flocculator #2

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

- Determine G_{max} (G_1) (same as flocculator #1)

$$\text{floc tank vol, ft}^3 = (18.1\text{ ft})(18.1\text{ ft})(14\text{ ft})$$
$$\text{floc tank vol} = 4586.54\text{ ft}^3$$

$$P = (3)(0.9) = 2.7\text{ hp}$$

$$G_1 = \sqrt{\frac{(550)(2.7\text{ hp})}{(0.000021061)(4586.54\text{ ft}^3)}}$$

$$G_1 = 124\text{ sec}^{-1}$$

13

Flocculator #2

- Determine actual G for variable speed drive setting
  - This will be different than Floc #1 due to using tapered flocculation

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

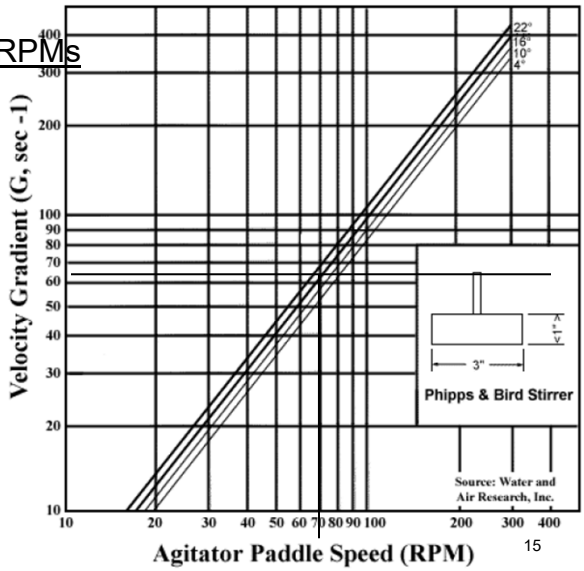
$$G_2 = \frac{124}{\left(\frac{31.1}{20}\right)^{3/2}}$$

$$G_2 = 63.9\text{ sec}^{-1}$$

14

Flocculator #2

- Determine jar test RPMs
  - ≈ 64 sec^{-1}
  - 20°C
- Set jar test @ 69 RPMs



15

Flocculator #2

- Determine jar test Stir Time (same as flocculator #1)

$$\mathrm{DT} = \frac{\text{volume, gal}}{\text{flow}}$$

$$\text{volume, gal} = (4586.54\ \text{ft}^3)(7.48\ \text{gal/ft}^3)$$

$$\text{volume, gal} = 34307.3192\ \text{gal}$$

$$\text{flow} = \frac{6{,}000{,}000\ \text{gpd}}{3\ \text{basins}}$$

$$\text{flow} = 2{,}000{,}000\ \text{gpd}$$

$$\mathrm{DT} = \frac{(34307.3192\ \text{gal})}{2{,}000{,}000\ \text{gpd}} = 0.0172\ \text{days}$$

$$\mathrm{DT, min} = \left(\frac{0.0172\ \cancel{\text{days}}}{}\right)\left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \text{min}}{1\ \cancel{\text{hr}}}\right)$$

$$\mathrm{DT, min} = 24.7\ \text{min} \approx 25\ \text{min}$$

16

Flocculator #3

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

- Determine G_{max} (G_1)

$$\text{floc tank vol, ft}^3 = (18.1\text{ ft})(18.1\text{ ft})(14\text{ ft})$$
$$\text{floc tank vol} = 4586.54\text{ ft}^3$$

$$P = (2)(0.9) = 1.8\text{ hp}$$

$$G_1 = \sqrt{\frac{(550)(1.8\text{ hp})}{(0.000021061)(4586.54\text{ ft}^3)}}$$

$$G_1 = 101\text{ sec}^{-1}$$

17

Flocculator #3

- Determine actual G for variable speed drive setting

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

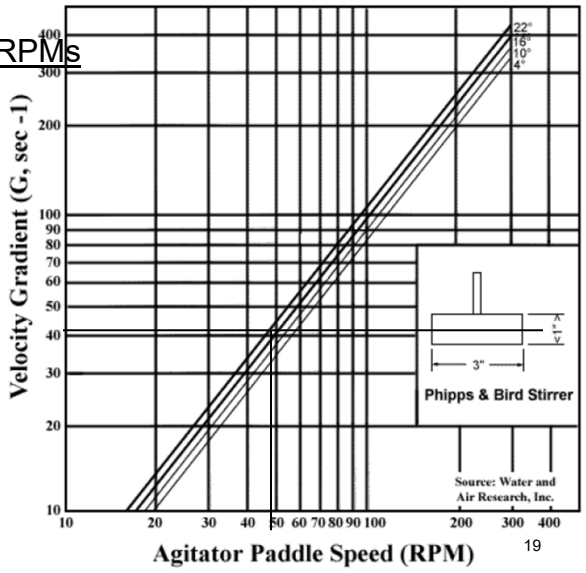
$$G_2 = \frac{101}{\left(\frac{27}{15}\right)^{3/2}}$$

$$G_2 = 41.8\text{ sec}^{-1}$$

18

Flocculator #3

- Determine jar test RPMs
  - ≈ 42 sec^{-1}
  - 20°C
- Set jar test @ 48 RPMs



19

Flocculator #3

- Determine jar test Stir Time (same as flocculator #1)

$$\mathrm{DT} = \frac{\text{volume, gal}}{\text{flow}}$$

$$\text{volume, gal} = (4586.54\ \text{ft}^3)(7.48\ \text{gal/ft}^3)$$

$$\text{volume, gal} = 34307.3192\ \text{gal}$$

$$\text{flow} = \frac{6{,}000{,}000\ \text{gpd}}{3\ \text{basins}}$$

$$\text{flow} = 2{,}000{,}000\ \text{gpd}$$

$$\mathrm{DT} = \frac{(34307.3192\ \text{gal})}{2{,}000{,}000\ \text{gpd}} = 0.0172\ \text{days}$$

$$\mathrm{DT, min} = \left(\frac{0.0172\ \cancel{\text{days}}}{}\right)\left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \text{min}}{1\ \cancel{\text{hr}}}\right)$$

$$\mathrm{DT, min} = 24.7\ \text{min} \approx 25\ \text{min}$$

20

Flocculator #4

$$G = \sqrt{\frac{(550)(P)}{(\mu)(V)}}$$

- Determine G_{max} (G_1) (same as flocculator #3)

$$\text{floc tank vol, ft}^3 = (18.1\text{ ft})(18.1\text{ ft})(14\text{ ft})$$
$$\text{floc tank vol} = 4586.54\text{ ft}^3$$

$$P = (2)(0.9) = 1.8\text{ hp}$$

$$G_1 = \sqrt{\frac{(550)(1.8\text{ hp})}{(0.000021061)(4586.54\text{ ft}^3)}}$$

$$G_1 = 101\text{ sec}^{-1}$$

21

Flocculator #4

- Determine actual G for variable speed drive setting

$$G_2 = \frac{G_1}{\left(\frac{N_1}{N_2}\right)^{3/2}}$$

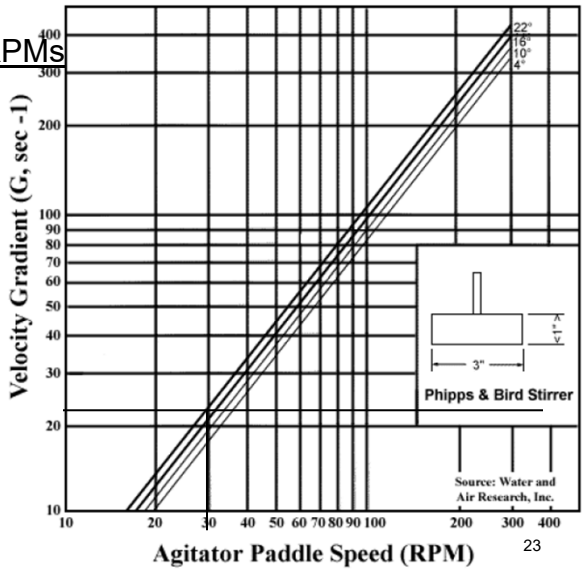
$$G_2 = \frac{101}{\left(\frac{27}{10}\right)^{3/2}}$$

$$G_2 = 22.8\text{ sec}^{-1}$$

22

Flocculator #4

- Determine jar test RPMs
  - ≈ 23 sec^{-1}
  - 20°C
- Set jar test @ 30 RPMs



23

Flocculator #4

- Determine jar test Stir Time (same as flocculator #1)

$$\mathrm{DT} = \frac{\text{volume, gal}}{\text{flow}}$$

$$\text{volume, gal} = (4586.54\ \text{ft}^3)(7.48\ \text{gal/ft}^3)$$

$$\text{volume, gal} = 34307.3192\ \text{gal}$$

$$\text{flow} = \frac{6{,}000{,}000\ \text{gpd}}{3\ \text{basins}}$$

$$\text{flow} = 2{,}000{,}000\ \text{gpd}$$

$$\mathrm{DT} = \frac{(34307.3192\ \text{gal})}{2{,}000{,}000\ \text{gpd}} = 0.0172\ \text{days}$$

$$\mathrm{DT, min} = \left(\frac{0.0172\ \cancel{\text{days}}}{}\right)\left(\frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \text{min}}{1\ \cancel{\text{hr}}}\right)$$

$$\mathrm{DT, min} = 24.7\ \text{min} \approx 25\ \text{min}$$

24

Jar Test Sequence

- Flash 46.7 sec @ 300 rpm
- Then 25 min @ 98 rpm
- Then 25 min @ 69 rpm
- Then 25 min @ 49 rpm
- Then 25 min @ 30 rpm

25

Step 3 – Sedimentation

- Find Surface Overflow Rate (gpd/ft^2) for sedimentation basin
- Find settling velocity (cm/min)
- Find sampling time (min) for sedimentation basin

26

Surface Overflow Rate

$$\text{SOR, gpd/ft}^2 = \frac{\text{flow, gpd}}{\text{area, ft}^2}$$

$$\text{volume} = \frac{6{,}000{,}000 \text{ gpd}}{3 \text{ basins}}$$

$$\text{volume} = 2{,}000{,}000 \text{ gpd}$$

$$\text{SOR, gpd/ft}^2 = \frac{2{,}000{,}000 \text{ gpd}}{(20 \text{ ft})(70\text{ft})}$$

$$\text{SOR} = 1428.6 \text{ gpd/ft}^2$$

27

Settling Velocity

$$\text{Settling velocity, cm/min} = \frac{(\text{SOR, gpd/ft}^2)(3785 \text{ cm}^3/\text{gal})}{(1440 \text{ min/day})(929 \text{ cm}^2/\text{ft}^2)}$$

$$\text{cm/min} = \frac{(1428.6 \text{ gpd/ft}^2)(3785 \text{ cm}^3/\text{gal})}{(1440 \text{ min/day})(929 \text{ cm}^2/\text{ft}^2)}$$

$$\text{cm/min} = \frac{5{,}407{,}251}{1{,}337{,}760}$$

$$\text{cm/min} = 4.04 \text{ cm/min}$$

28

Sampling Time

$$\text{Settling Velocity, cm/ min} = 4 \text{ cm/min}$$

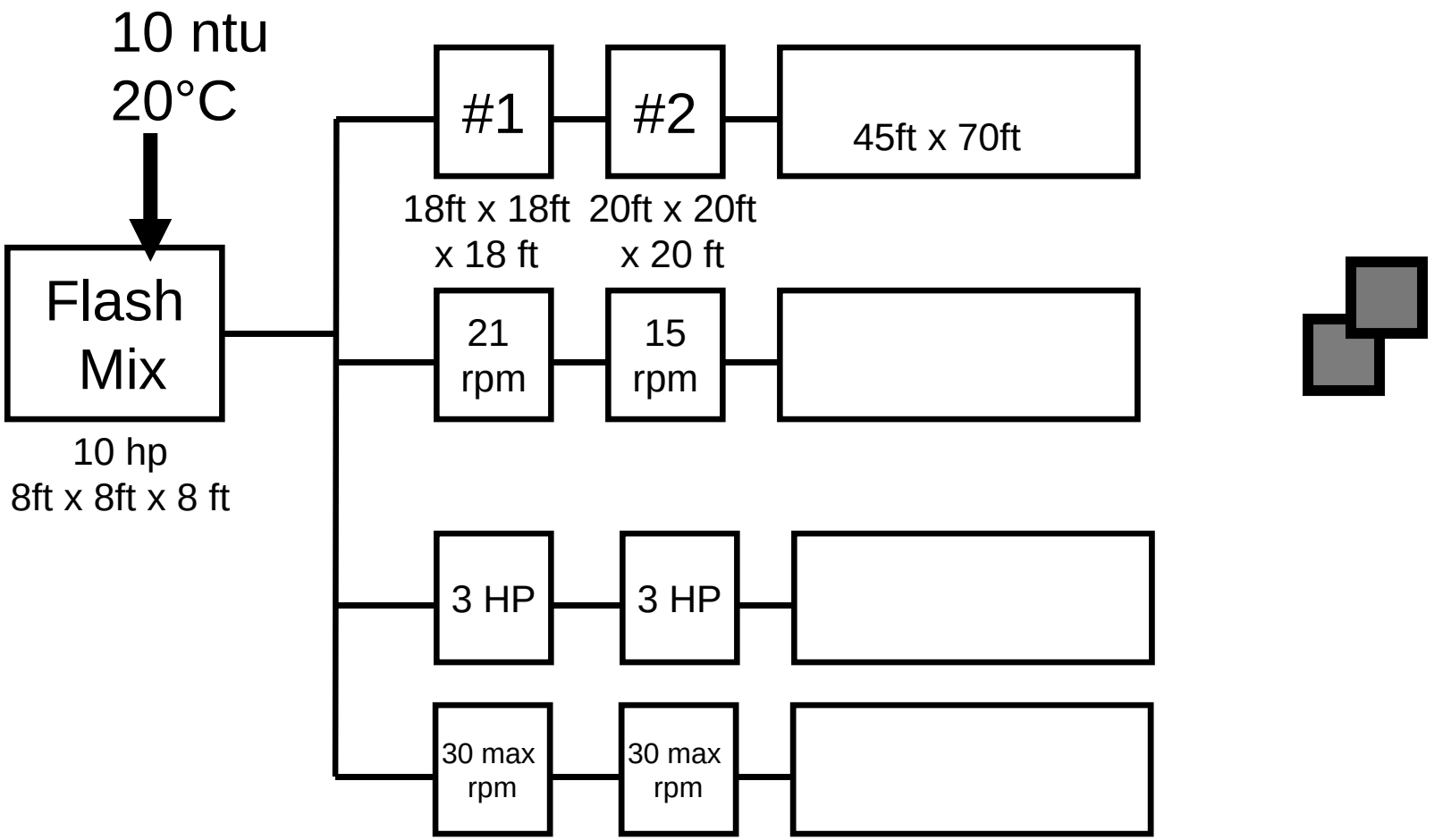
Settling Velocity, cm/min	Sampling Time, min
0.5	20
1.0	10
2.0	5
4.0	2.5
10.0	1

Sample at 2.5 min and 10 min

29

Plant Example

8 MGD
10 ntu
20°C



Coagulation/Flocculation Workshop
Plant Example #2
(to run in lab)

Flash Mix

Velocity Gradient (current/actual) = _____

Detention time, sec = _____

Jar test max RPM = _____

Jar Test Detention Time, sec = _____

Flocculator #1

Velocity Gradient (current/actual) = _____

Jar Test rpm = _____

Detention Time, min = _____

Flocculator #2

Velocity Gradient (current/actual) = _____

Jar Test rpm = _____

Detention Time, min = _____

Sedimentation

Surface Overflow Rate, gpd/ft^2 = _____

Settling Velocity, cm/min = _____

Sampling Time, min = _____

Section 5

Jar Test Lab

Coagulation/Flocculation Workshop
Conducting a Jar Test Study

Before starting:

- Define study goals
- Define testing parameters
- Have testing and analytical equipment ready
  - Working and clean
- Prepare reagent solutions
  - Properly labeled and mixed
- Data sheet available
  - Should be a good guide for conducting

Step 1. Find the specs for **full-scale plant**, including:

- Flash (rapid) mix
  - Dimensions (length x width x depth)
  - Type of mixing mechanism
    - mechanical, baffle, static mixer, etc.
  - Horsepower of mechanical mixer OR Hydraulic drop
  - Detention time (seconds)
  - Mixing Intensity (sec^{-1})
    - Velocity Gradient
- Flocculation basins
  - # of trains of basins
  - # of basins in series
  - For each basin in the series:
    - Dimensions (length x width x depth)
    - Type of mixing mechanism (mechanical, baffle, static mixer, etc.)
    - Horsepower of mechanical mixer OR Hydraulic drop
    - Detention time (in minutes)
    - Mixing Intensity (sec^{-1})
    - Velocity Gradient

- Sedimentation basins
    - Dimensions (length x width x depth)
    - Surface Overflow Rate (gpd/ft^2)
    - Settling Velocity (cm/min)
    - Sampling Time (min)
- All chemicals fed as part of treatment process
    - Chemical name
    - Chemical dosage
    - Chemical specific gravity
    - % concentration
    - Order of application

Step 2. Prepare jar test solutions. See handout "How To Make Dosing Solutions For Jar Tests"

- Sodium permanganate
- GPAC (inorganic coagulant)
- Clarifloc (coagulant aid)
- Lime (calcium hydroxide)

Step 3. Determine dosages for each chemical in each jar. Fill in datasheet (bench sheet).

- First jar should represent underdosing. Last jar should represent overdosing. Control jar (represents actual plant) should be in the middle.
- **Remember to only change one parameter at a time. All others remain constant.
    - This would be the time to decide what your Jar Test Study goals are. Based on that, you can choose which process parameter to alter. Examples of goals:
        - Organics removal
        - Removal of turbidity
        - pH adjustment
        - Hardness removal
        - Alkalinity additions

Step 4. Set up jar test machine and fill in datasheet.

- Rinse jars and paddles with DI water.
- Fill all jars with tap water. Lower paddles being sure to tighten the set screw.
- Turn jar test machine to maximum setting. Record RPMs on datasheet.
    - Determine Jar Test Time Correction. Record on datasheet.
- Complete remainder of datasheet to reflect entire process, including
    - Flocculation RPMs
    - Flocculation detention times
    - Sampling time

Step 5. Collect sample and run preliminary lab tests.

- Make sure sample is representative of the water in the plant. Compare pH in flash mix to pH of sample water.
- Be sure to collect enough sample to completely fill at least six 2-liter jars.
- Run all necessary lab tests on sample (mix sample well before each sub-sample collection).
    - pH
        - Calibrate probe; verify with 7.
    - Temperature
        - Can be read when measuring pH.
    - TOC
        - Instructor will run this for the class.
    - Turbidity
        - Calibrate turbidimeter if needed; otherwise, verify.
    - Alkalinity
        - Run Total Alkalinity using pH method.

Step 6. Run jar test. Use the datasheet as road map.

Step 7. Collect a sample from each jar. After filtering samples through a 45 µm filter, perform the same tests on the treated samples as was performed on the untreated water.

- Be sure to flush approximately 20 mL through the sample line before collecting sample to be tested.
- Compare before results and after results.
    - Determine % removal.
- Compare control to other jars.

Step 8. Record conclusions.

Jar Test Bench Sheet

Date:		
Time:		Concentration (mg/L)
Coagulant:		
Oxidant:		
Polymer:		

Source Water				
pH	Turbidity (ntu)	Alkalinity (mg/L)	Hardness (mg/L)	TOC (mg/L)

Jar Number		1	2	3	4	5	6
Rapid Mix	G (s^{-1})						
	rpm						
	Duration (s)						
Flocculator #1	G (s^{-1})						
	rpm						
	Duration (s)						
Flocculator #2	G (s^{-1})						
	rpm						
	Duration (s)						
Coagulant Dose (mg/L)							
Volume of Coagulant Added (mL)							
Polymer Dose							
Volume of Polymer Added (mL)							
Lime Dose (mg/L)							
Volume of Lime solution added (mL)							
Oxidant Dose (mg/L)							
Volume of Oxidant Added (mL)							
Settling Velocity (cm/min)	Depth of Sampling (cm)	Time of Settling (min)					
	10 cm						

Coagulation pH							
Record final jar test numbers here	pH						
	Turbidity						
	TOC						
	Alkalinity						
	Hardness						

pH

DOC316.53.01245

USEPA Electrode Method

Method 8156

pH electrode

Scope and application: For drinking water[1], wastewater[2] and process water.

[1] Based on Standard Method 4500-H+B, ASTM Method D1293-95 and USEPA Method 150.1
[2] Based on Standard Method 4500-H+B, ASTM Method D1293-84(90)/(A or B) and USEPA Method 150.1

Test preparation

Instrument specific information

This procedure is applicable to the meters and probes that are shown in Table 1. Procedures for other meters and probes can be different.

Table 1 Instrument-specific information

Meter	Probe
HQ1100 and HQ11d portable one input, pH/ORP HQ4100, HQ2100 and HQ30d portable one input, multi-parameter HQ4200, HQ2200 and HQ40d portable two input, multi-parameter HQ4300 portable three input, multi-parameter HQ411d benchtop one input, pH/mV HQ430d benchtop one input, multi-parameter HQ440d benchtop two input, multi-parameter	Intellical PHC101, PHC201, PHC281 or PHC301 pH
Sension+ MM156 portable pH/EC/DO	Sension+ 5049 multi-parameter
Sension+ pH1 portable pH Sension+ MM110 portable pH/ORP Sension+ MM150 portable pH/ORP/EC	Sension+ 5050T, 5051T or 5052T combination pH Sension+ 5045, 5048 or 5059 multi-parameter
Sension+ pH3 lab pH Sension+ pH31 GLP lab pH Sension+ MM340 lab two input, pH/mV/ISE Sension+ MM374 lab two input, pH/mV/EC/ISE Sension+ MM378 lab two input, pH/ISE/EC/DO	Sension+ 5010T, 5011T, 5014T or 5021T combination pH

Before starting

Refer to the meter documentation for meter settings and operation. Refer to probe documentation for probe preparation, maintenance and storage information.
Prepare the probe before initial use. Refer to probe documentation.
When an Intellical probe is connected to an HQ meter or an HQd meter, the meter automatically identifies the measurement parameter and is prepared for use.
Condition the electrode for the best response time. To condition the electrode, soak the electrode for several minutes in a solution that has almost the same pH and ionic strength as the sample.
Calibrate the probe before initial use. Refer to Calibration procedure on page 3.
For rugged electrodes, it may be necessary to remove the shroud before measurement and calibration.
Air bubbles under the sensor tip can cause slow response or measurement errors. To remove the bubbles, carefully shake the probe.
To save data automatically, set the measurement mode to Press to Read or Interval. When the measurement mode is Continuous, select Store to save data manually.

Rinse the electrode between measurements to prevent contamination.
Keep the electrode in a pH storage solution when not in use. Refer to the probe documentation.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Refer to the Safety Data Sheets for disposal information for unused reagents. Refer to the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.
This procedure is specified for the HQ meters and HQd meters. The Sension+ meters can be used, but the menus and navigation will be different.

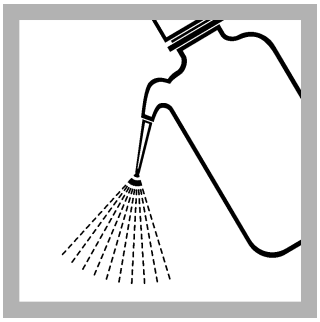
Items to collect

Description	Quantity
Beaker or sample containers	3
Wash bottle with deionized water	1
pH buffers (4.0, 7.0, 10.0)	3

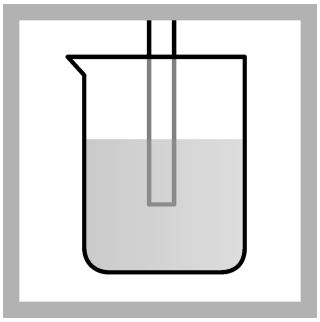
Sample collection

- Analyze the samples immediately. The samples cannot be preserved for later analysis.
- Collect samples in clean glass or plastic bottles.

Test procedure

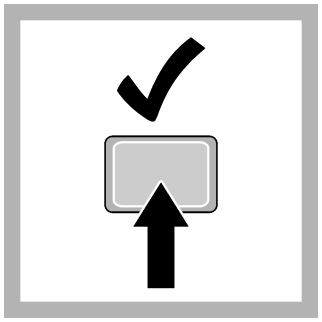


1. Rinse the probe with deionized water. Dry the probe with a lint-free cloth.

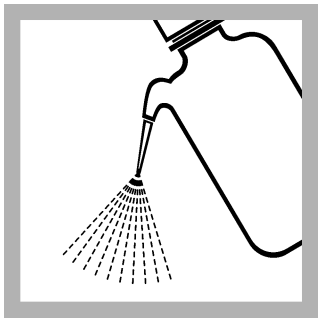


2. Laboratory test: Put the probe in a beaker that contains the solution. Do not let the probe touch the stir bar, bottom or sides of the container. Remove the air bubbles from under the probe tip. Stir the sample at a slow to moderate rate.
Field test: Put the probe in the sample. Move the probe up and down to remove bubbles from the electrode.

Make sure to put the temperature sensor fully in the sample.

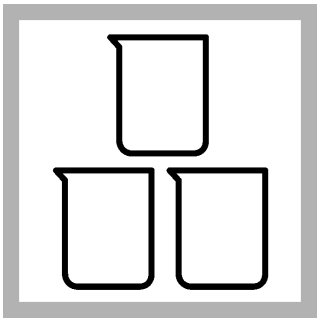


3. Push **Read**. A progress bar is shown. When the measurement is stable, the lock icon is shown.



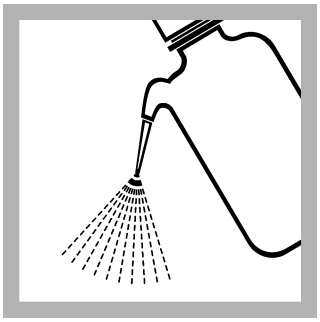
4. Rinse the probe with deionized water. Dry the probe with a lint-free cloth.

Calibration procedure

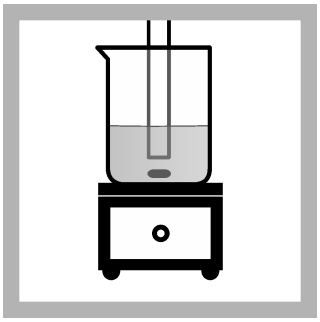


1. Prepare two or three fresh buffer solutions in separate beakers. If two buffers are used, use a 7.0 and a 4.0 or a 7.0 and a 10.0 pH buffer solution.

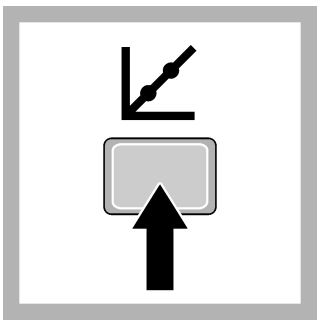
2. Add a stir bar and put the beaker on a magnetic stirrer. Stir at a moderate rate.



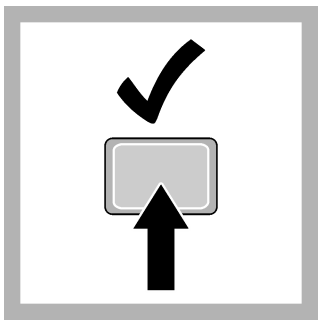
3. Rinse the probe with deionized water. Dry the probe with a lint-free cloth.



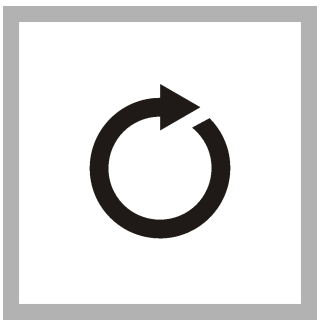
4. Put the probe in the solution. Do not let the probe touch the stir bar, bottom or sides of the container. Remove the air bubbles from under the probe tip.



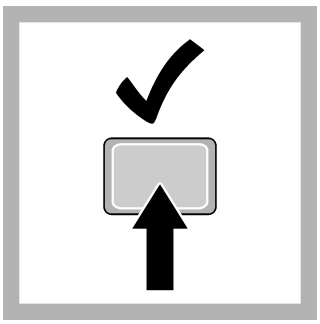
5. Push **Calibrate**. The standard solution value is shown.



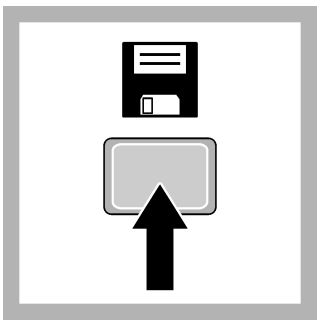
6. Push **Read**. A progress bar is shown. When the measurement is stable, the lock icon is shown.



7. Measure the remaining buffer solutions.



8. Push **Done**. A calibration summary is shown when the minimum number of calibration standards are measured.



9. Push **Store** to accept the calibration.

Low ionic strength or high-purity water measurements

NOTICE

Do not keep the probe in LIS samples for a long period of time because this can decrease the probe life. Put the probe in electrode storage solution or 3 M KCl when LIS measurements are complete.

Low ionic strength (LIS) solutions have very low buffering capacity and absorb carbon dioxide from the air. When a sample absorbs carbon dioxide from the atmosphere, carbonic acid forms. Carbonic acid decreases the sample pH, which causes inaccurate

readings. One solution to this problem is to measure the sample in a low volume, airtight sample chamber such as a low ionic strength chamber.

Use refillable or platinum series electrodes for measurement of pH in LIS or high purity waters.

Before an LIS sample is measured, condition the probe as follows:

1. Soak the probe in a solution equivalent to the sample in ionic strength and pH for 10 to 15 minutes.
2. Rinse the probe with deionized water.
3. Dry the probe with a soft paper towel.

Between measurements, keep the probe in the sample or a neutral LIS solution (e.g., tap water) for a maximum of 2 hours.

Interferences

The sodium error is low but increases at pH values that are higher than pH 11. The acid error is negligible. Refer to the electrode or the meter documentation.

Accuracy check

Slope test

The electrode operation is satisfactory when the calibration slope is within the specified range (typically –58 mV (±3) at 25 °C).

Calibration accuracy

Measure the pH of a fresh buffer solution. A calibration is satisfactory when the measured pH value agrees with the known pH value of the buffer solution.

Clean the probe

Clean the probe when:

- Drifting/inaccurate readings occur as a result of contamination on the sensing element or incorrect storage conditions.
- Slow response time occurs as a result of contamination on the sensing element.
- The slope is out of range as a result of contamination on the sensing element.

For general contamination, complete the steps that follow.

1. Rinse the probe with deionized water. Blot dry with a lint-free cloth.
2. Soak the glass bulb for 12 to 16 hours in Hach Electrode Cleaning Solution.
3. Rinse or soak the probe for 1 minute in deionized water.
4. Soak the probe in pH 4 buffer for up to 20 minutes, then rinse with deionized water.
5. Blot dry with a lint-free cloth.
6. If harsh contaminants are attached to the probe, polish the probe tip with a soft cloth or cotton swab to remove the contaminants.
7. Soak for up to 20 minutes in pH 4 buffer, then rinse with deionized water.

Method performance

The accuracy of the measurements is dependent on many factors that are related with the overall system, which includes the meter, the probe and calibration solutions. Refer to the meter or probe documentation for more information.

Summary of method

A combination pH electrode develops a potential at the glass/liquid interface. At a constant temperature, this potential varies linearly with the pH of the solution.

The pH is the hydrogen ion activity in a solution and is defined as $-\log_{10}a(H^+)$, where $a(H^+)$ is the activity of the hydrogen ion. The sample pH can change when carbon dioxide is absorbed from the atmosphere. In water that has a high conductivity, the buffer capacity is typically high and the pH does not change much.

Consumables and replacement items

HQ meters, HQd meters and probes

Description	Unit	Item no.
HQ1110 portable one input, pH/ORP meter	each	LEV015.53.1110A
HQ2100 portable one input, multi-parameter meter	each	LEV015.53.2100A
HQ2200 portable two input, multi-parameter meter	each	LEV015.53.2200A
HQ4100 portable one input, multi-parameter meter	each	LEV015.53.4100A
HQ4200 portable two input, multi-parameter meter	each	LEV015.53.4200A
HQ4300 portable three input, multi-parameter meter	each	LEV015.53.4300A
HQ411d benchtop one input, pH/mV meter	each	HQ411D
HQ430d benchtop one input, multi-parameter meter	each	HQ430D
HQ440d benchtop two input, multi-parameter meter	each	HQ440D
Intellical pH gel probe, standard with 1 m cable	each	PHC10101
Intellical pH gel probe, standard with 3 m cable	each	PHC10103
Intellical pH gel probe, rugged with 5 m cable	each	PHC10105
Intellical pH gel probe, rugged with 10 m cable	each	PHC10110
Intellical pH gel probe, rugged with 15 m cable	each	PHC10115
Intellical pH gel probe, rugged with 30 m cable	each	PHC10130
Intellical pH gel probe, standard with 1 m cable	each	PHC20101
Intellical pH gel probe, standard with 3 m cable	each	PHC20103
Intellical pH gel probe, ultra with 1 m cable	each	PHC28101
Intellical pH gel probe, ultra with 3 m cable	each	PHC28103
Intellical pH liquid probe, standard with 1 m cable	each	PHC30101
Intellical pH liquid probe, standard with 3 m cable	each	PHC30103

Sension+ meters and probes

Description	Unit	Item no.
Sension+ pH3 lab pH meter	each	LPV2010T.97.002
Sension+ pH31 GLP lab pH meter	each	LPV2110T.97.002
Sension+ MM340 lab two input, pH/mV/ISE meter	each	LPV2200.97.0002
Sension+ MM374 lab two input, pH/mV/EC/ISE meter	each	LPV4110.97.0002
Sension+ MM378 lab two input, pH/ISE/EC/DO meter	each	LPV4130.97.0002
Sension+ 5010T combination pH probe	each	LZW5010T.97.002
Sension+ 5011T combination pH probe	each	LZW5011T.97.002
Sension+ 5014T combination pH probe	each	LZW5014T.97.002
Sension+ 5021T combination pH probe	each	LZW5021T.97.002
Sension+ 5050T combination pH probe	each	LZW5050T.97.002
Sension+ 5051T combination pH probe	each	LZW5051T.97.002
Sension+ 5052T combination pH probe	each	LZW5052T.97.002
Sension+ 5045 multi-parameter probe	each	LZW5045.97.0002

Sension+ meters and probes (continued)

Description	Unit	Item no.
Sension+ 5048 multi-parameter probe	each	LZW5048.97.0002
Sension+ 5049 multi-parameter probe	each	LZW5049.97.0002
Sension+ 5059 multi-parameter probe	each	LZW5059.97.0002

Recommended standards

Description	Unit	Item no.
pH 4.01 buffer solution, Singlet one-use packets, 20 mL each	20/pkg	2770020
pH 7.00 buffer solution, Singlet one-use packets, 20 mL each	20/pkg	2770120
pH 10.01 buffer solution, Singlet one-use packets, 20 mL each	20/pkg	2770220
pH 4.01 and pH 7.00 buffer solution kit, Singlet one-use packets, 20 mL each	2 x 10/pkg	2769920
pH 7.00 and 10.01 buffer solution kit, Singlet one-use packets, 20 mL each	2 x 10/pkg	2769820
pH color-coded buffer solution kit (NIST), 500 mL, includes:	1	2947600
pH 4.01 ± 0.02 pH buffer (NIST)	500 mL	2283449
pH 7.00 ± 0.02 pH buffer (NIST)	500 mL	2283549
pH 10.01 ± 0.02 pH buffer (NIST)	500 mL	2283649
Powder pillows:		
pH 4.01 ± 0.02 pH buffer powder pillow (NIST)	50/pkg	2226966
pH 7.00 ± 0.02 pH buffer powder pillow (NIST)	50/pkg	2227066
pH 10.01 ± 0.02 pH buffer powder pillow (NIST)	50/pkg	2227166
Radiometer Analytical (IUPAC Series certified pH standards):		
pH 1.679 ± 0.010 at 25 °C (77 °F)	500 mL	S11M001
pH 4.005 ± 0.010 at 25 °C (77 °F)	500 mL	S11M002
pH 6.865 ± 0.010 at 25 °C (77 °F)	500 mL	S11M003
pH 7.000 ± 0.010 at 25 °C (77 °F)	500 mL	S11M004
pH 9.180 ± 0.010 at 25 °C (77 °F)	500 mL	S11M006
pH 10.012 ± 0.010 at 25 °C (77 °F)	500 mL	S11M007
pH 12.45 ± 0.05 at 25 °C (77 °F)	500 mL	S11M008
pH buffer 1.09, technical	500 mL	S11M009
pH buffer 4.65, technical	500 mL	S11M010
pH buffer 9.23, technical	500 mL	S11M011

Accessories

Description	Unit	Item no.
Beaker, polypropylene, 50 mL, low form	each	108041
Beaker, polypropylene, 100-mL	each	108042
Bottle, wash, 500 mL	each	62011
Stir bar, magnetic, 2.2 x 0.5 cm (7/8 x 3/16 in.)	each	4531500
Stirrer, electromagnetic, 120 VAC, with electrode stand	each	4530001
Stirrer, electromagnetic, 230 VAC, with electrode stand	each	4530002

Accessories (continued)

Description	Unit	Item no.
Sample bottle with screw-top cap, polypropylene, 500-mL	each	2758101
Water, deionized	4 L	27256

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Telephone: (970) 669-3050
FAX: (970) 669-2932

02/2021, Edition 9

Alkalinity, Total

DOC316.53.01257

Colorimetric Method **Method 10239**

25 to 400 mg/L $CaCO_3$ **TNTplus™870**

Scope and application: For drinking water, wastewater and boiler water.

Test preparation

Instrument-specific information

Table 1 shows all of the instruments that have the program for this test. The table also shows the adapter and light shield requirements for the applicable instruments that can use TNTplus vials.

To use the table, select an instrument, then read across to find the applicable information for this test.

Table 1 Instrument-specific information for TNTplus vials

Instrument	Adapters	Light shield
DR 6000, DR 5000	—	—
DR 3900	—	LZV849
DR 3800, DR 2800	—	LZV646
DR 1900	9609900 or 9609800 (A)	—

Before starting

DR 3900, DR 3800, DR 2800: Install the light shield in Cell Compartment #2 before this test is started.
Review the safety information and the expiration date on the package.
The recommended temperature for samples and reagents is 15–25 °C (59–77 °F).
The recommended temperature for reagent storage is 15–25 °C (59–77 °F).
DR 1900: Go to All Programs>LCK or TNTplus Methods>Options to select the TNTplus number for the test. Other instruments automatically select the method from the barcode on the vial.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Refer to the Safety Data Sheets for disposal information for unused reagents. Refer to the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

Items to collect

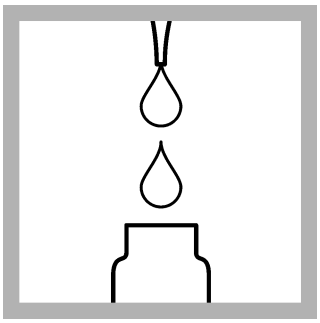
Description	Quantity
Total Alkalinity TNT870 Reagent Set	1
Pipet, adjustable volume, 1.0–5.0 mL	1
Pipet, adjustable volume, 0.2–1.0 mL	1
Pipet tips	1

Refer to Consumables and replacement items on page 3 for order information.

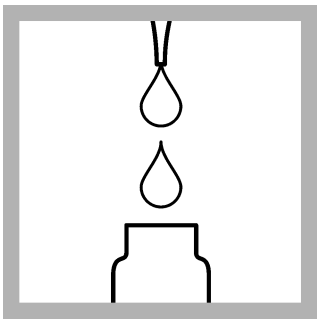
Sample collection

- Collect samples in clean glass or plastic bottles with tight-fitting caps. Completely fill the bottle and immediately tighten the cap.
- Prevent agitation of the sample or exposure to air.
- Analyze the samples as soon as possible for best results.
- If immediate analysis is not possible, keep the samples at or below 6 °C (43 °F) for a maximum of 24 hours.
- Let the sample temperature increase to room temperature before analysis.

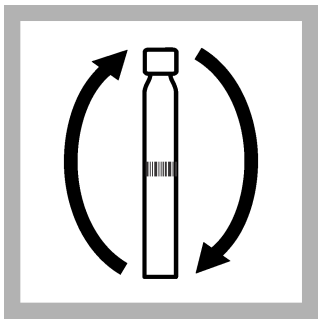
Test procedure



1. Use a pipet to add 2.0 mL of Solution A to the test vial.

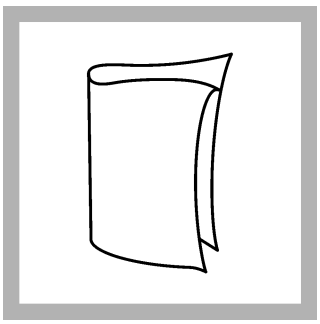


2. Use a pipet to add 0.5 mL of sample to the test vial.

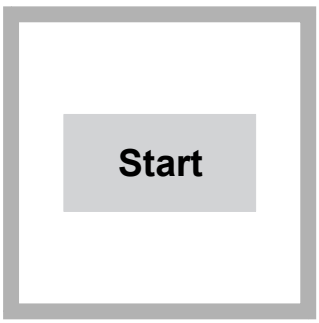


3. Tighten the cap on the vial and invert until completely mixed. Make sure that the contents are well mixed.

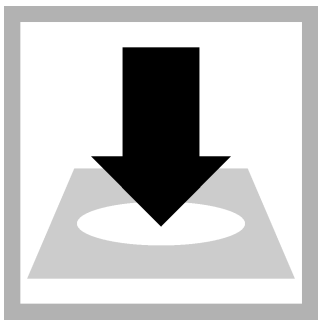
4. Start the reaction time of 5 minutes.



5. When the timer expires, clean the vial.



6. DR 1900 only: Select program 870. Refer to Before starting on page 1.



7. Insert the vial into the cell holder. DR 1900 only: Push **READ**.
Results show in mg/L $CaCO_3$.

Interferences

If the samples contain particles, use a 0.45 µm filter to remove the particles.

Accuracy check

Standard solution method

Use the standard solution method to validate the test procedure, the reagents and the instrument.

Items to collect:

- 25,000-mg/L $CaCO_3$ Alkalinity Voluette® Ampule Standard Solution
- Ampule breaker
- 100-mL volumetric flask, Class A
- Pipet, adjustable volume, 1–5 mL with pipet tips
- Deionized water

1. Prepare a 250-mg/L $CaCO_3$ standard solution as follows:
   a. Use a pipet to add 1.0 mL of the standard solution into the volumetric flask.
   b. Dilute to the mark with deionized water. Mix well. Prepare this solution daily.
2. Use the test procedure to measure the concentration of the prepared standard solution.
3. Compare the expected result to the actual result.

   Note: *The factory calibration can be adjusted slightly with the standard adjust option so that the instrument shows the expected value of the standard solution. The adjusted calibration is then used for all test results. This adjustment can increase the test accuracy when there are slight variations in the reagents or instruments.*

Summary of Method

Carbonates and other buffers react with the reagent in the vial to change the pH. The pH has an effect on the color of the indicator, which is measured photometrically. The measurement wavelength is 615 nm.

Consumables and replacement items

Required reagents

Description	Quantity/Test	Unit	Item no.
Total Alkalinity TNT870 Reagent Set	1	25/pkg	TNT870

Required apparatus

Description	Quantity/test	Unit	Item no.
Pipet, adjustable volume, 1.0–5.0 mL	1	each	BBP065
Pipet tips, for 1.0–5.0 mL pipet	1	75/pkg	BBP068
Pipet, adjustable volume, 0.2–1.0 mL	1	each	BBP078
Pipet tips, for 0.2–1.0 mL pipet	2	100/pkg	BBP079
Light shield, DR 3900	1	each	LZV849
Light shield, DR 3800, DR 2800, DR 2700	1	each	LZV646

Recommended standards

Description	Unit	Item no.
Alkalinity Voluette® Ampule Standard Solution, 25,000-mg/L $CaCO_3$, 10-mL	16/pkg	1427810

Optional reagents and apparatus

Description	Unit	Item no.
Ampule Breaker, 10-mL Voluette® Ampules	each	2196800
Filter membrane, 0.45-micron, 25-mm	100/pkg	2514101
Filter holder, 25-mm, for Luer-type syringe	each	246800
Flask, volumetric, Class A, 100-mL glass	each	1457442
Sampling bottle with cap, low density polyethylene, 500-mL	12/pkg	2087079
Syringe, 10-cc, Luer-Lock tip	each	2202400
Water, deionized	4 L	27256

FOR TECHNICAL ASSISTANCE, PRICE INFORMATION AND ORDERING:
In the U.S.A. – **Call toll-free 800-227-4224**
Outside the U.S.A. – **Contact the HACH office or distributor serving you.**
On the Worldwide Web – **www.hach.com**; E-mail – **techhelp@hach.com**

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WORLD HEADQUARTERS
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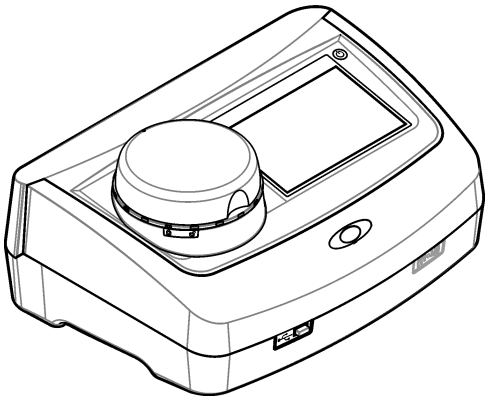
FAX: (970) 669-2932

02/2014, Edition 2

DOC022.97.80488

TU5200

07/2019, Edition 5



Basic User Manual
Manuel d'utilisation de base
Manual básico del usuario
Manual Básico do Usuário
基本用户手册
基本取扱説明書
기본 사용 설명서
คู่มือผู้ใช้เบื้องต้น

Table of Contents

Section 1 Table of contents

Section 2 Additional information

An expanded user manual is available on the manufacturer's website. Videos on how to install, operate and do maintenance and troubleshooting on the TU5200 turbidimeter are available on the *TU5 Series Turbidimeters* playlist at http://www.youtube.com/user/hachcompany.

Section 3 Specifications

Specifications are subject to change without notice.

Specification	Details
Measurement method	Nephelometry with the scattered light collected at a 90° angle to the incident light and 360° around the sample vial.
Primary compliance method	EPA approved Hach Method 10258[1]
Dimensions (W x D x H)	41 x 28 x 12.5 cm (16 x 11 x 7.7 in.)
Weight	2.37 kg (5.23 lb)
Enclosure	IP20
Protection class	Instrument: III; Power supply: I
Pollution degree	2
Installation category	II
Power requirements	Instrument: 15 VDC, 2 A; Power supply: 100 to 240 VAC, 50/60 Hz
Operating temperature	10 to 40 °C (50 to 104 °F)
Storage temperature	–30 to 60 °C (–22 to 140 °F)
Humidity	5 to 95% relative humidity, non-condensing
Display	17.8 mm (7 in.) color touch screen
Laser	**Class 2 laser product:** Contains a non user-serviceable class 2 laser.
Optical light source	650 nm, maximum 0.43 mW
Measurement units	NTU, FNU, TE/F, FTU, EBC, mg/L, mNTU[2] or mFNU
Range	0 to 700 NTU, FNU, TE/F, FTU; 0 to 100 mg/L; 0 to 175 EBC
Accuracy	± 2% of reading plus 0.01 NTU from 0 to 40 NTU ± 10% of reading from 40 to 700 NTU based on Formazin primary standard at 25 °C (77 °F)
Linearity	Better than 1% for 0 to 40 NTU on Formazin at 25 °C (77 °F)

1 http://www.hach.com

2 1 mNTU = 0.001 NTU

Specification	Details
Precision	< 40 NTU: 0.002 NTU or 1% (the larger value); > 40 NTU: 3.5% based on Formazin primary standard at 25 °C (77 °F)
Stray light	< 0.01 NTU
Calibration options	**StablCal®:** 1-point calibration (20 NTU) for 0 to 40 NTU measurement range; 2-point calibration (20 and 600 NTU) for 0 to 700 NTU (full) measurement range **Formazin:** 2-point calibration (20 NTU and dilution water) for 0 to 40 NTU measurement range; 3-point calibration (20 NTU, 600 NTU and dilution water) for 0 to 700 NTU (full) measurement range **Degrees:** 3-point calibration (20 and 100 mg/L and dilution water) for 0 to 100 mg/L (full) measurement range **SDVB:** 3-point calibration (20 NTU, 600 NTU and dilution water) for 0 to 700 NTU (full) measurement range **Custom:** 2- to 6-point custom calibration for a measurement range of 0 NTU to the highest calibration point.
Verification options	Glass verification rod (secondary turbidity standard) < 0.1 NTU, StablCal or Formazin (0.1 to 40 NTU)
Verification (RFID or Link2SC®)	Process and laboratory measurements are compared with RFID or Link2SC for verification of the measurement value.
Certifications	CE compliant; US FDA accession number: 1420493-xxx. This product complies with IEC/EN 60825-1 and to 21 CFR 1040.10 in accordance with Laser Notice No. 50. Australian RCM.
Warranty	1 year (EU: 2 years)

Section 4 General information

In no event will the manufacturer be liable for direct, indirect, special, incidental or consequential damages resulting from any defect or omission in this manual. The manufacturer reserves the right to make changes in this manual and the products it describes at any time, without notice or obligation. Revised editions are found on the manufacturer's website.

4.1 Safety information

NOTICE

The manufacturer is not responsible for any damages due to misapplication or misuse of this product including, without limitation, direct, incidental and consequential damages, and disclaims such damages to the full extent permitted under applicable law. The user is solely responsible to identify critical application risks and install appropriate mechanisms to protect processes during a possible equipment malfunction.

Please read this entire manual before unpacking, setting up or operating this equipment. Pay attention to all danger and caution statements. Failure to do so could result in serious injury to the operator or damage to the equipment.

Make sure that the protection provided by this equipment is not impaired. Do not use or install this equipment in any manner other than that specified in this manual.

4.1.1 Use of hazard information

⚠ DANGER

Indicates a potentially or imminently hazardous situation which, if not avoided, will result in death or serious injury.

⚠ WARNING

Indicates a potentially or imminently hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION
Indicates a potentially hazardous situation that may result in minor or moderate injury.

NOTICE
Indicates a situation which, if not avoided, may cause damage to the instrument. Information that requires special emphasis.

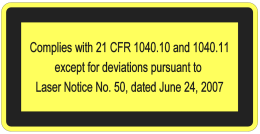
4.1.2 Precautionary labels

Read all labels and tags attached to the instrument. Personal injury or damage to the instrument could occur if not observed. A symbol on the instrument is referenced in the manual with a precautionary statement.

	Electrical equipment marked with this symbol may not be disposed of in European domestic or public disposal systems. Return old or end-of-life equipment to the manufacturer for disposal at no charge to the user.
	This symbol, if noted on the instrument, references the instruction manual for operation and/or safety information.
	This symbol indicates the need for protective eye wear.
	This symbol indicates a laser device is used in the equipment.
	This symbol identifies a risk of chemical harm and indicates that only individuals qualified and trained to work with chemicals should handle chemicals or perform maintenance on chemical delivery systems associated with the equipment.
	This symbol indicates radio waves.

4.1.3 Class 2 laser product

⚠ DANGER	
	Personal injury hazard. Never remove covers from the instrument. This is a laser-based instrument and the user risks injury if exposed to the laser.

	Class 2 laser product, IEC60825-1:2014, 650 nm, maximum 0.43 mW Location: Rear of the instrument.
	Conforms to U.S. regulations 21 CFR 1040.10 and 1040.11 in accordance with Laser Notice No. 50. Location: Rear of the instrument.
	Caution—Class 2 laser radiation when the lid is open. Do not look into the laser beam. Location: Top of the vial compartment.

This instrument is a Class 2 Laser product. There is only visible laser radiation when the instrument is defective and when the instrument lid is open. This product complies with EN 61010-1, "Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use" and with IEC/EN 60825-1, "Safety of Laser Products" and with 21 CFR 1040.10 in accordance with Laser Notice No. 50. Refer to the labels on the instrument that supply laser information.

4.1.4 RFID module

Instruments with the optional RFID module receive and transmit information and data. The RFID module operates with a frequency of 13.56 MHz.

RFID technology is a radio application. Radio applications are subject to national conditions of authorization. The use of instruments with the optional RFID module is currently permitted in the regions that follow:

EU (European Union) countries, EFTA (European Free Trade Association) countries, Turkey, Serbia, Macedonia, Australia, Canada, US, Chile, Ecuador, Venezuela, Mexico, Brazil, South Africa, India, Singapore, Argentina, Columbia, Peru and Panama

The use of instruments with the optional RFID module outside of the above-mentioned regions can violate national laws. The manufacturer reserves the right also to get authorization in other countries. In case of doubt, contact the manufacturer.

4.1.4.1 Safety information for RFID modules

⚠ WARNING

Multiple hazards. Do not disassemble the instrument for maintenance. If the internal components must be cleaned or repaired, contact the manufacturer.

⚠ WARNING

Electromagnetic radiation hazard. Do not use the instrument in dangerous environments.

NOTICE

This instrument is sensitive to electromagnetic and electromechanical interference. These interferences can have an effect on the analysis performance of this instrument. Do not put this instrument near equipment that can cause interference.

Obey the safety information that follows to operate the instrument in accordance with local, regional and national requirements.

- Do not operate the instrument in hospitals and equivalent establishments or near medical equipment, such as pace makers or hearing aids.
- Do not operate the instrument near highly flammable substances, such as fuels, highly flammable chemicals and explosives.
- Do not operate the instrument near combustible gases, vapors or dust.
- Keep the instrument away from strong vibration or shock.
- The instrument can cause interference in immediate proximity to televisions, radios and computers.
- The warranty does not cover improper use or wear.

4.1.4.2 FCC conformance for RFID

This instrument may contain a registered radio frequency identification device (RFID). Refer to Table 1 for the Federal Communications Commission (FCC) registration information.

Table 1 Registration information

Parameter	Value
FCC identification number (FCC ID)	YUH-QR15HL
IC	9278A-QR15HL
Frequency	13.56 MHz

4.1.5 Certification

⚠ CAUTION

This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.

Canadian Radio Interference-Causing Equipment Regulation, IECS-003, Class A:

Supporting test records reside with the manufacturer.

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de classe A répond à toutes les exigences de la réglementation canadienne sur les équipements provoquant des interférences.

FCC Part 15, Class "A" Limits

Supporting test records reside with the manufacturer. The device complies with Part 15 of the FCC Rules. Operation is subject to the following conditions:

1. The equipment may not cause harmful interference.
2. The equipment must accept any interference received, including interference that may cause undesired operation.

Changes or modifications to this equipment not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at their expense. The following techniques can be used to reduce interference problems:

1. Disconnect the equipment from its power source to verify that it is or is not the source of the interference.
2. If the equipment is connected to the same outlet as the device experiencing interference, connect the equipment to a different outlet.
3. Move the equipment away from the device receiving the interference.
4. Reposition the receiving antenna for the device receiving the interference.
5. Try combinations of the above.

4.2 Product overview

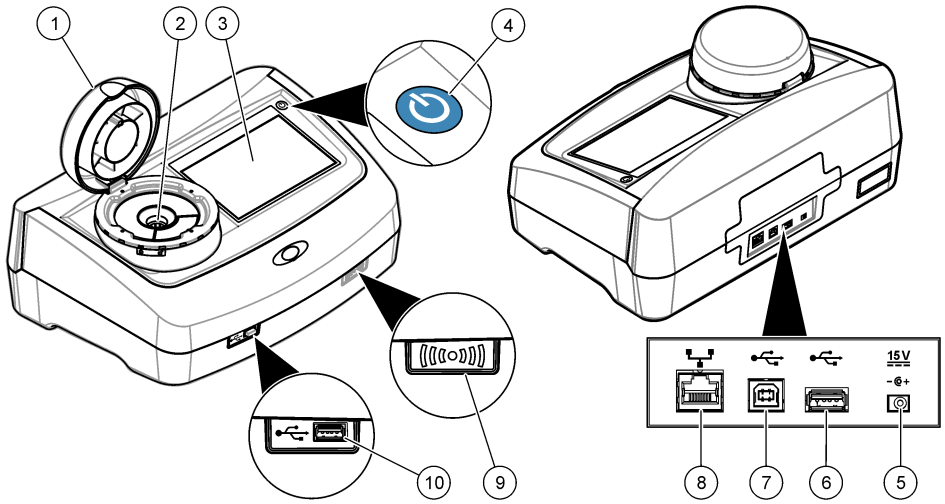
The TU5200 turbidimeter measures low turbidity mostly in finished drinking water applications. This laboratory instrument is factory calibrated and measures scattered light at an angle of 90° in a 360° radius around the axis of the incident light beam. Use the touch screen to operate the instrument. Refer to Figure 1.

An optional RFID module is available. Figure 1 shows the RFID module. The RFID module lets process and laboratory turbidity measurements be easily compared.

Videos on how to install, operate and do maintenance and troubleshooting on the TU5200 turbidimeter are available on the *TU5 Series Turbidimeters* playlist at http://www.youtube.com/user/hachcompany.

For the accessories, refer to the expanded user manual on the manufacturer's website.

Figure 1 Product overview

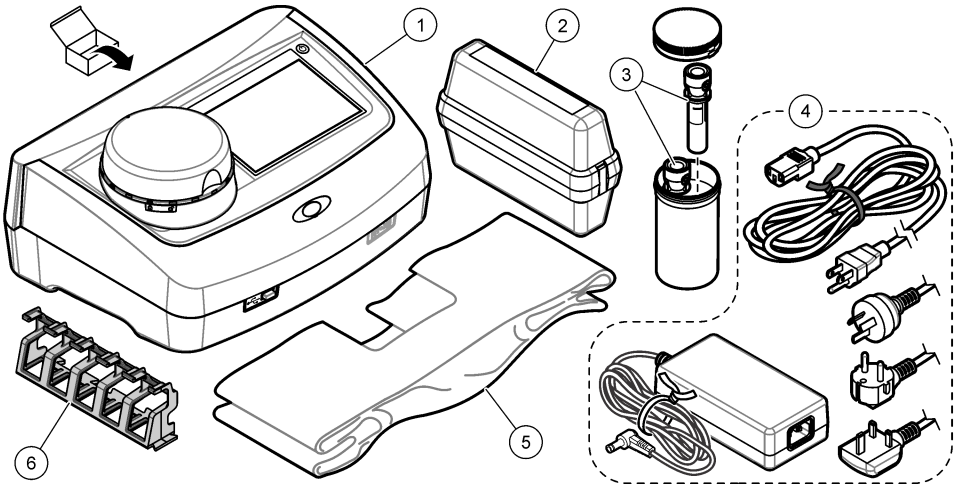


1 Lid	**6** USB port type A
2 Vial compartment	**7** USB port type B
3 Display	**8** Ethernet port for LAN connection
4 Power button	**9** RFID module indicator (optional)
5 Power supply connection	**10** USB port type A

4.3 Product components

Make sure that all components have been received. Refer to Figure 2. If any items are missing or damaged, contact the manufacturer or a sales representative immediately.

Figure 2 Product components



1 TU5200	**4** Power supply
2 StablCal kit, sealed vials with RFID (10, 20 and 600 NTU)	**5** Dust cover
3 Sample vials	**6** Vial stand

Section 5 Installation

⚠ CAUTION

Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

This instrument is rated for an altitude of 3100 m (10,710 ft) maximum. Use of this instrument at an altitude higher than 3100 m can slightly increase the potential for the electrical insulation to break down, which can result in an electric shock hazard. The manufacturer recommends that users with concerns contact technical support.

5.1 Installation guidelines

Install the instrument:

- On a level surface
- In a clean, dry, well ventilated, temperature controlled location
- In a location with minimum vibrations that has no direct exposure to sunlight
- In a location where there is sufficient clearance around it to make connections and to do maintenance tasks
- In a location where the power button and power cord are visible and easily accessible

5.2 Connect to external devices (optional)

NOTICE

Network and access point security is the responsibility of the customer that uses the wireless instrument. The manufacturer will not be liable for any damages, inclusive however not limited to indirect, special, consequential or incidental damages, that have been caused by a gap in, or breach of network security.

The instrument has three USB 1.1 ports and one Ethernet port. Refer to Figure 1 on page 8.

USB type A port—Connect to a printer, barcode handset scanner, USB flash drive, keyboard[3] or SIP 10 module.

USB type B port—Connect to a PC.

Ethernet port—Connect to a LAN with a shielded cable (e.g., STP, FTP, S/FTP). The maximum length of the shielded cable is 20 m (65.6 ft). To set up a LAN connection at the instrument, refer to the expanded user manual on the manufacturer's website .

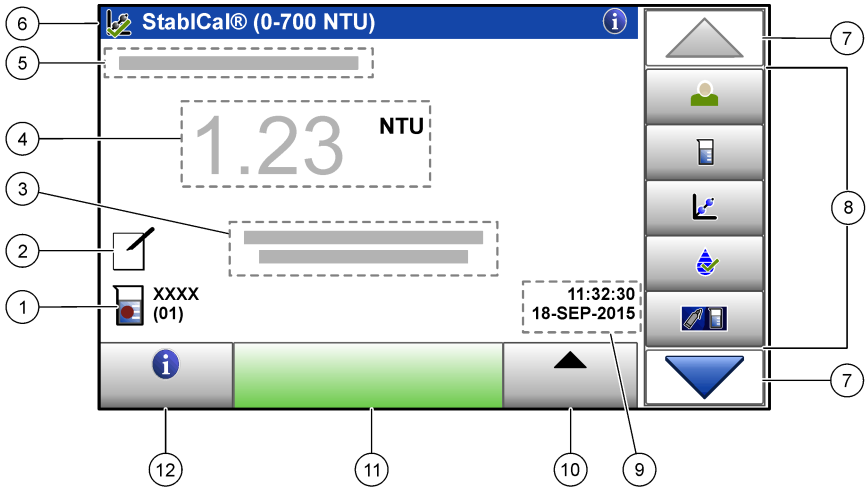
Note: *USB cables must not be longer than 3 m (9.8 ft).*

Section 6 User interface and navigation

The instrument display is a touch screen. Only use a clean, dry finger tip to navigate the functions of the touch screen. Do not use writing tips of pens or pencils or other sharp objects to make selections on the screen or damage to the screen will occur.

Refer to Figure 3 for an overview of the home screen.

Figure 3 Display overview



1 Sample ID and measurement number[4]	**7** UP/DOWN navigation arrows
2 User comments	**8** Sidebar menu (refer to Table 2)
3 Instructions	**9** Time and date
4 Turbidity value, unit and reading mode	**10** Options button
5 Warning or error message	**11** Read button
6 Calibration status icon and calibration curve	**12** Information (help) button

[3] As an alternative to the touchscreen, use a keyboard to enter text into text boxes on the display (e.g., passwords and sample IDs).

[4] The measurement number increases by one each time a measurement is completed.

Table 2 Sidebar menu icons

Icon	Description
 Login	Logs in or logs out an operator. To log in, select an operator ID and then push **Login**. To log out, push **Logout**. ***Note:*** *When an operator is logged in, the Login icon changes to the icon selected for the operator ID (e.g., fish, butterfly or soccer ball) and the text "Login" changes to the operator ID.*
 Sample ID	Selects the sample ID.
 Calibration	Starts a calibration.
 Verification	Starts a verification.
 Link2SC	Compares process and laboratory measurements.
 Data Log	Shows the reading log, calibration log, verification log and compare log. Refer to Show the recorded data on page 18.
 Setup	Configures the instrument settings. Refer to Configure the instrument settings on page 12.
 Diagnostics	Shows the firmware information, instrument backup, instrument updates, signaling information and factory service data.
 Timer	Sets a timer.
	Goes to the manufacturer's website for the latest software versions and user manual when the instrument has a LAN connection.
 Documents	Shows the user manual and video(s) for the instrument.

Section 7 Startup

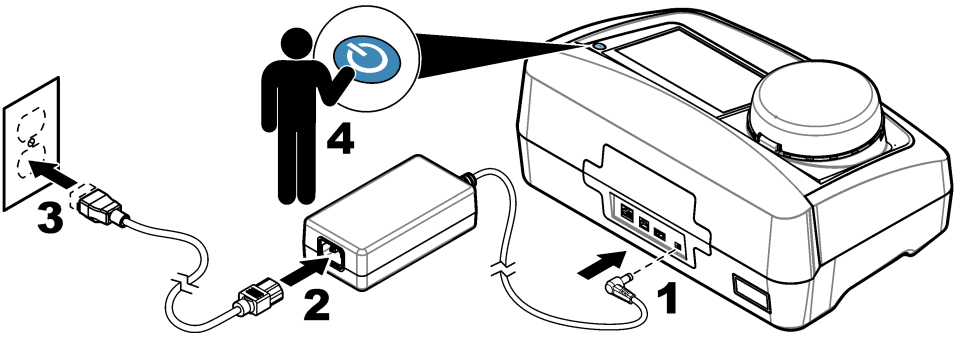
⚠ CAUTION	
	Personal injury hazard. Never remove covers from the instrument. This is a laser-based instrument and the user risks injury if exposed to the laser.

⚠ CAUTION

Personal injury hazard. Do not look into the vial compartment when the instrument is connected to power.

Refer to the illustrated steps that follow to connect power to the instrument and start the instrument. When the language menu shows, select the language and then push **OK**. The self-check will start.

Note: *To change the language after the initial startup, refer to* Change the language *on page 13.*



Section 8 Operation

8.1 Configuration

8.1.1 Configure the instrument settings

1. Push ▼ two times, then push **Setup**.
2. Select an option.

Option	Description
Location	Sets the location name of the instrument. The location is saved with measurements to the data log.
Date & Time	Sets the date format, the time format and the date and time. Enter the current date and time. **Date Format**—Sets the date format. Options: dd-mmm-yyyy (default), yyyy-mm-dd, dd-mm-yyyy or mm-dd-yyyy. **Time Format**—Sets the time format. Options: 12 or 24 hours (default).
Security	Enables or disables password protection for the settings and tasks in the security list. **Security Password**—Sets or changes the security (administrator) password (10 characters maximum). Passwords are case sensitive. **Security List**—Sets the security level for each setting and task in the security list. • **Off**—All operators can change the setting and or do the task. • **One key**—Only operators with a one-key or two-key security level can change the setting or do the task. Refer to Add operator IDs on page 13. • **Two keys**—Only operators with a two-key security level can change the setting or do the task. ***Note:*** *The Security setting is not set to on until Close is pushed.*
Sound Settings	Enables or disables the sound settings for individual events. Sets the sound volume for each event (1 to 10). To enable or disable all of the sound settings, select All and then push **Setup**.

Option	Description
Network & Peripherals	Shows the connection status of the devices that are directly connected to the instrument and connected to the instrument by LAN (local area network). • Printer—Local printer or network printer • Network—LAN connection • Controller—sc controller(s) • PC • USB Memory—USB flash drive • Keyboard
Power Management	Sets when the instrument is automatically set to sleep mode or off after a period of no activity. **Sleep Timer**—Sets when the instrument is set to sleep mode. Options: OFF, 30 minutes, 1 (default), 2 or 12 hours. **Power-Off Timer**—Sets when the instrument is set to off. Options: OFF, 2, 6, 12 (default) or 24 hours.

8.1.1.1 Change the language

NOTICE

Wait a minimum of 20 seconds after the power is set to off before the power is set to on again or damage to the instrument can occur.

To change the language after the initial startup, do the steps that follow.

1. Set the instrument to off.
2. Set the instrument to on.
3. During startup, touch the display until the language menu shows (approximately 45 seconds).
4. When the language menu shows, select the language and then push **OK**.

8.1.2 Add operator IDs

Add a unique operator ID for each person who will measure samples (30 maximum). Select an icon, operator password and security level for each operator ID.

1. Push **Login**.
2. Push **Options**>**New**.
3. Enter a new operator ID (10 characters maximum), then push **OK**.
4. Push the **LEFT** and **RIGHT** arrows to select the icon for the operator ID (e.g., fish, butterfly or soccer ball).
5. Push **Operator Password**, then enter a password for the operator ID.

   Note: *Passwords are case sensitive.*
6. Push **Security Level**, then select the security level for the operator ID.

   - **Off**—The operator cannot change the settings or do the tasks in the Security settings that have a security level of one key or two keys.
   - **One key**—The operator can change all the settings and do all the tasks in the Security settings that have a security level of off or one key.
   - **Two keys**—The operator can change all the settings and do all the tasks in the Security settings.

   Note: *Before a security level can be selected, the Security setting must be set to on. Refer to* Configure the instrument settings *on page 12.*
7. Push **OK**>**Close**.
8. To edit an operator ID, select the operator ID and then push **Options**>**Edit**.
9. To delete an operator ID, select the operator ID and then push **Options**>**Delete**>**OK**.

8.1.2.1 Configure an operator RFID tag (optional)

To use an operator RFID tag to log in to the instrument, save the applicable operator ID to an operator RFID tag as follows:

1. Push **Login**.
2. Select the operator ID, then push **Options**>**Initialize RFID Tag**.
3. Enter the password for the operator ID as necessary.
4. Complete the steps that show on the display.
5. Push **OK** to replace the operator ID on the RFID tag with a new operator ID if applicable.
6. Push **Close**.
7. Put the operator RFID tag in front of the RFID module to log in.

8.1.3 Add sample IDs

Add a unique sample ID for each sample (100 maximum). The sample ID identifies the sample location or other sample specific information.

As an alternative, import sample IDs from a spreadsheet file to the instrument. Refer to the expanded user manual on the manufacturer's website to import sample IDs.

Note: *When a sample bottle with a sample RFID sticker is put in front of the RFID module, the sample ID is automatically added to the instrument and selected on the instrument.*

1. Push **Sample ID**.
2. Push **Options**>**New**.
3. Enter a new sample ID (20 characters maximum).
4. If the sample bottle has a barcode that identifies the sample ID, read the barcode with a barcode handset scanner that is connected to the instrument. The barcode is added to the sample ID.
5. Push **OK**.
6. Select an option.

Option	Description
Add Date/Time	Adds the data and time that the sample was collected to the sample ID (optional). The date and time entered for each sample ID show on the Sample ID menu.
Add Number	Adds a measurement number to the sample ID (optional). Select the first number used for the measurement number (0 to 999). The measurement number shows in parenthesis after the sample ID on the home screen. Refer to Figure 3 on page 10.
Add Color	Adds a colored circle to the sample ID icon (optional). The sample ID icon shows before the sample ID on the home screen. Refer to Figure 3 on page 10.

7. Push **OK**>**Close**.
8. To edit a sample ID, select the sample ID and then push **Options**>**Edit**>**OK**.
9. To delete a sample ID, select the sample ID and then push **Options**>**Delete**>**OK**.

8.1.4 Configure the measurement settings

Select the reading mode, measurement units, data log settings, resolution and more.

1. At the main reading screen, push **Options**>**Reading Setup**.
2. Select an option.

Option	Description
Reading	Sets the reading mode to single, continuous or minimum mode. Default: Single. **Single**—The measurement stops when the reading is stable. **Continuous**—The measurement continues until the user pushes **Done**. **Minimum Mode**—Set to on when a process and laboratory measurement are compared and the process measurement is a lower NTU range. Removes the effect of non-representative particles in the grab sample. **Signal Avg**—The turbidity reading that shows on the display is an average of the values measured during the time interval selected. Options: For single measurement mode, 5 to 15 seconds. For continuous measurement mode, 5 to 90 seconds.
Unit	Selects the measurement units that show on the display and that are recorded to the data log. Options: NTU, FNU, TE/F, FTU, EBC, mNTU or mFNU. Default: NTU).
Data Log Setup	Sets the data log settings. **Auto Store**—Measurement data is automatically recorded in the reading log. Default: On. When not selected, push **Options**>**Store** to record the current measurement to the reading log as necessary. **Send Data Format**—Sets the output format of measurement data that is sent to external devices (CSV or XML). Default: XML. **Print Format**—Sets the output format of measurement data that is sent to a printer (Quick Print or Detailed Print (GLP)). **Comments**—Lets users add comments to log entries. **Auto Send**—Measurement data is automatically sent to all of the devices (e.g., printer, USB flash drive and FTP server) that are connected to the instrument after each measurement.
Resolution	Selects the number of decimal places that show on the display. Options: 0.001 (default) or 0.0001.
Bubble Reject	Sets the bubble reject to on (default) or off. When set to on, high turbidity readings caused by bubbles in the sample are not shown or saved to the data log.
Close lid to start reading	Enables or disables the instrument to start a measurement automatically when the lid is closed. Default: On. A measurement is only done when there is a sample vial in the instrument.

8.1.5 Set the acceptance range

Before process and laboratory measurements are compared on the instrument, set the acceptance range for the compare results. The acceptance range is the maximum difference permitted between the process and laboratory measurements.

1. Push **LINK2SC**.
2. Push **Options**>**Compare Setup**.
3. Push **Acceptance Range**>**Unit**.
4. Select an option.

Option	Description
%	Sets the acceptance range to a percentage (1 to 99%).
NTU	Sets the acceptance range to NTU units (0.015 to 100.00 NTU).

5. Push **Value**, then enter the acceptance range.

8.2 Measurement

8.2.1 Sample collection

- Collect samples in clean glass or plastic bottles with tight-fitting caps.
- Rinse the container a minimum of three times with the sample.

- When collecting a sample from a water tap in a distribution system or treatment plant, turn the water on for at least five minutes, then collect the sample. Do not adjust the flow because this can add particles.
- When collecting a sample from a body of water (e.g., a stream or storage tank), collect at least one liter (1 quart) and fully mix before taking an aliquot for measurement. If the quality of the sample source is not constant, collect samples at many locations at different depths as necessary. Then, mix the samples together to prepare one sample for measurement.
- Fill the container. Let the container overflow with the sample and then immediately put the cap on the sample container so that there is no headspace (air) above the sample.
- Write the sample information on the container.
- Start analysis as soon as possible to prevent temperature changes, bacteria growth and settling.

8.2.2 Prevent vial contamination

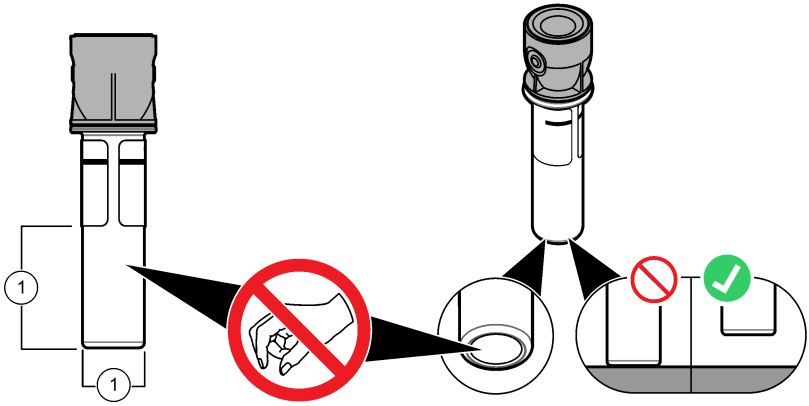
NOTICE

Do not to touch or scratch the glass of the sample vial. Contamination or scratches on the glass can cause measurement errors.

The glass must stay clean and have no scratches. Use a no-lint cloth to remove dirt, fingerprints or particles from the glass. Replace the sample vial when the glass has scratches.

Refer to Figure 4 to identify where not to touch the sample vial. Always keep the sample vials in the vial stand to prevent contamination on the bottom of the vial.

Figure 4 Sample vial overview



1 Measurement surface—Do not touch.

8.2.3 Prepare a sample vial

⚠ CAUTION

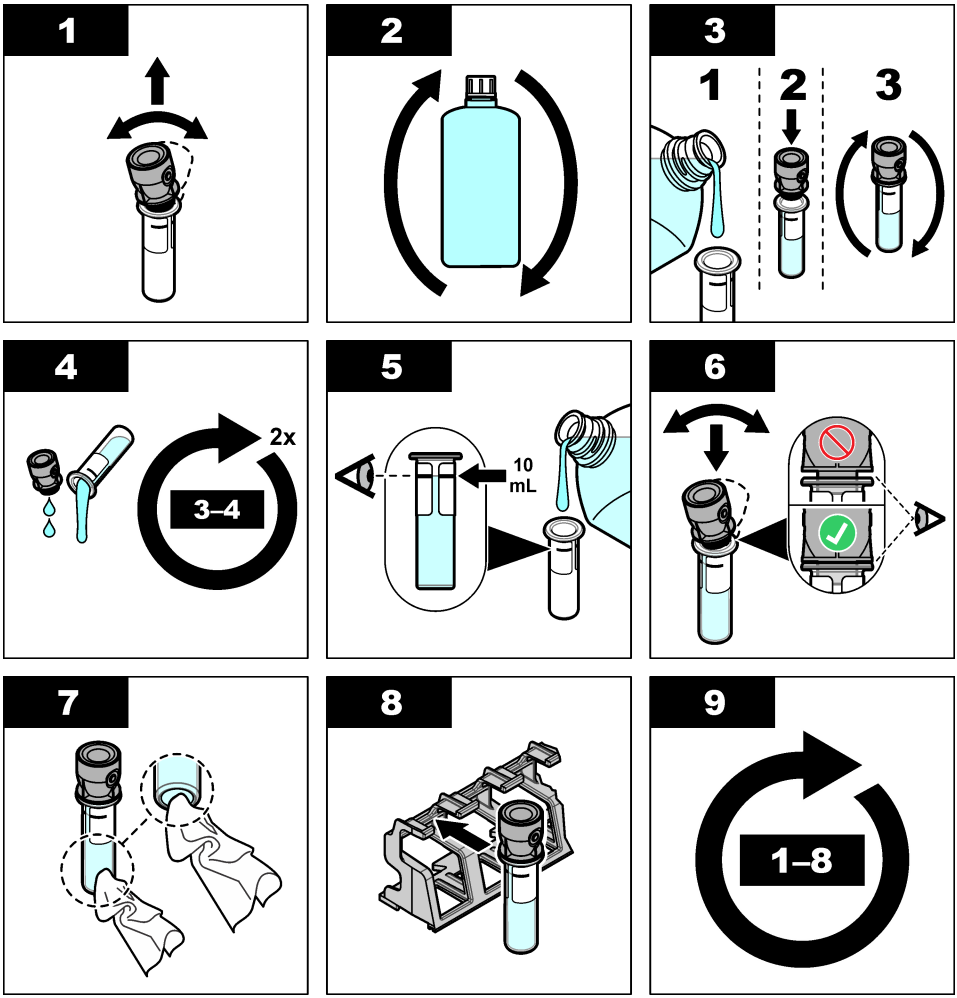
Chemical exposure hazard. Dispose of chemicals and wastes in accordance with local, regional and national regulations.

NOTICE

Always put a cap on the sample vial to prevent spills in the vial compartment.

Refer to the illustrated steps that follow to prepare a sample vial for measurement. Measure the sample immediately.

Note: *If there is contamination in the sample vial after it is rinsed with the sample, clean the sample vial. Refer to* Clean a sample vial *on page 21.*



8.2.4 Put the vial in the instrument

⚠ CAUTION

Personal injury hazard. Never remove covers from the instrument. This is a laser-based instrument and the user risks injury if exposed to the laser.

⚠ CAUTION

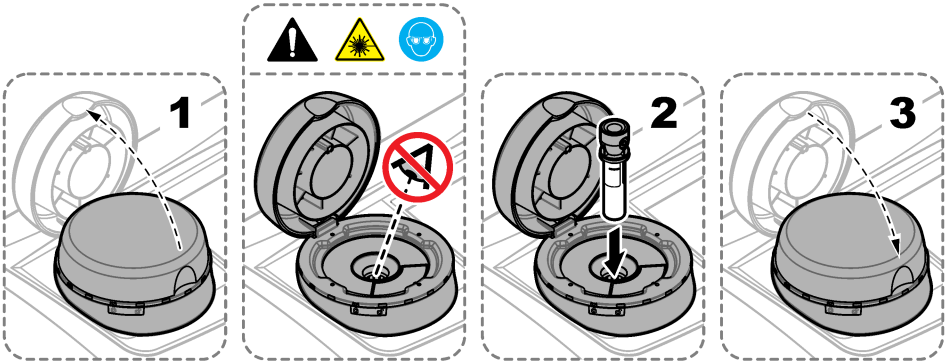
Personal injury hazard. Do not look into the vial compartment when the instrument is connected to power.

NOTICE

Keep the lid closed to keep contamination out of the vial compartment.

1. Log in to the instrument as follows:
   - Put an operator RFID tag in front of the RFID module or
   - Push **Login**. Select the applicable operator ID, then push **Select**.
2. Select the sample ID as follows:
   - Put the sample RFID sticker on the sample bottle in front of the RFID module or
   - Push **Sample ID**. Select the applicable sample ID, then push **Select**.

   Note: *To add sample IDs to the instrument, refer to* Add sample IDs *on page 14*.
3. Clean the sample vial with a no-lint cloth to remove contamination.
4. Dry the external surfaces of the vial with a no-lint cloth. Make sure to dry the bottom of the vial.
5. Put the sample vial in the vial compartment. Refer to the illustrated steps that follow.



8.2.5 Measure the sample

1. Push **Read** if a measurement does not start automatically when the lid is closed.
2. When the measurement is complete, push **Options**>**Store** to record the measurement to the reading log as necessary.

   Note: *If the Auto Save setting is set to on, "Data Stored" shows on the display and the measurement is automatically recorded to the reading log.*
3. To show the recorded measurements, push **Options**>**Reading Log**. Refer to Show the recorded data on page 18 for more options.
4. To send the measurement data to external devices that are connected to the instrument, push **Options**>**Send Data**. Refer to Show the recorded data on page 18 for more options.

   Note: *If the Auto Send settings is set to on, the measurement data is automatically sent to the external device(s) that is connected to the instrument.*

8.2.6 Compare process and laboratory measurements

Refer to the expanded user manual on www.hach.com to compare process and laboratory measurements.

8.3 Show the recorded data

All the recorded data is kept in the data log. The data log is divided into four logs:

- **Reading log**—Shows the recorded measurements.
- **Calibration log**—Shows the calibration history.
- **Verification log**—Shows the verification history.
- **Compare log**—Shows the recorded comparisons of process and laboratory measurements.

1. Push **Data Log** and select the applicable log to show.
2. To show the details of a log entry, select the log entry and then push **View Details**.

   Note: *To add a comment to the log entry, push the comments icon.*
3. To only show the log entries recorded during a time interval or with a specific operator ID or sample ID, do the steps that follow.

   a. Push **Filter**, then select On.

   b. Select an option.

Option	Description
Time Interval	Selects the time interval.
Operator ID	Selects the operator ID.
Sample ID	Selects the sample ID. This option only shows when Reading Log or Compare Log is selected.

4. To send log data to a device (e.g., printer or USB flash drive), delete a log entry or show a compare log or reading log entries in a graph, do the steps that follow.

   a. Push **Options**.

   b. Select an option.

Option	Description
Delete	Removes one of the items that follow. • The selected log entry • The log entries for a time interval • The log entries with a specific operator ID • The log entries with a specific sample ID[5] • All the entries in the selected log
Send Data	Sends one of the items that follow to all the devices that are directly connected to the instrument (e.g., printer or USB flash drive) and connected to the instrument by LAN (network printer or FTP server). • The selected log entry • The log entries for a time interval • The log entries with a specific operator ID • The log entries with a specific sample ID[5] • All the entries in the selected log
View Graph	Shows the reading log entries that have the same sample ID in a graph. This option only shows when Compare Log or Reading Log is selected. To add the log entries for another sample ID to the graph, push **Options**>**Add Data**. Select a sample ID to add to the graph. To show the details of a data point, touch a data point on the display or push the **LEFT** and **RIGHT** arrows to select a data point. **Data points**—Selects the symbol used for the data points. **Control Limit**—Sets the minimum value and maximum value of the readings that show on the graph.

[5] This option only shows when Reading Log or Compare Log is selected.

Section 9 Calibration

⚠ WARNING

Chemical exposure hazard. Obey laboratory safety procedures and wear all of the personal protective equipment appropriate to the chemicals that are handled. Refer to the current safety data sheets (MSDS/SDS) for safety protocols.

When the instrument is used for US EPA regulatory reporting, calibrations must be done according to US EPA guidance documents and methodologies. Contact local regulating authorities for additional compliance regulations.

The instrument is factory calibrated and the laser light source is stable. The manufacturer recommends that a calibration verification be done periodically to make sure that the system operates as intended. The manufacturer recommends calibration after repairs or comprehensive maintenance work.

Refer to the expanded user manual on the manufacturer's website to calibrate the instrument and do a calibration verification.

Section 10 Maintenance

⚠ CAUTION

Multiple hazards. Only qualified personnel must conduct the tasks described in this section of the document.

⚠ CAUTION

Chemical exposure hazard. Obey laboratory safety procedures and wear all of the personal protective equipment appropriate to the chemicals that are handled. Refer to the current safety data sheets (MSDS/SDS) for safety protocols.

⚠ CAUTION

Personal injury hazard. Never remove covers from the instrument. This is a laser-based instrument and the user risks injury if exposed to the laser.

NOTICE

Do not disassemble the instrument for maintenance. If the internal components must be cleaned or repaired, contact the manufacturer.

10.1 Clean spills

⚠ CAUTION

Chemical exposure hazard. Dispose of chemicals and wastes in accordance with local, regional and national regulations.

1. Obey all facility safety protocols for spill control.
2. Discard the waste according to applicable regulations.

10.2 Clean the instrument

Clean the exterior of the instrument with a moist cloth, and then wipe the instrument dry.

10.3 Clean a sample vial

⚠ CAUTION

Chemical exposure hazard. Obey laboratory safety procedures and wear all of the personal protective equipment appropriate to the chemicals that are handled. Refer to the current safety data sheets (MSDS/SDS) for safety protocols.

Clean the sample vial when there is contamination in the sample vial after the sample vial is rinsed.

Items to collect:

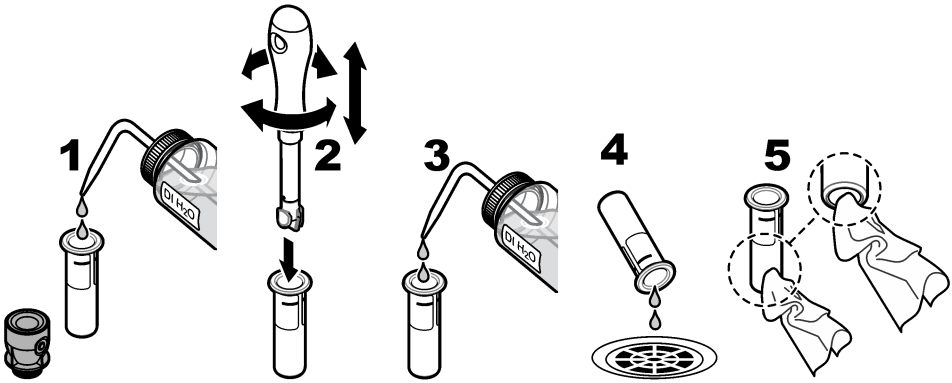
- Hydrochloric acid (concentration 10%)
- Laboratory cleaning detergent for glass (concentration 0.1%)
- Distilled or deonized water
- Dilution water
- Vial wiper (optional)
- No-lint cloth

1. Put the exterior and interior surfaces of the sample vial and the cap in 10% hydrochloric acid for 15 minutes.
2. Clean the exterior and interior surfaces of the sample vial and the cap with laboratory cleaning detergent for glass (concentration 0.1%).
3. Fully rinse the sample vial three times with distilled or deionized water.

   Note: *If the sample vial is used to measure low range turbidity samples or dilution water, rinse with dilution water (not distilled or deionized water).*
4. For the best results, clean the sample vial with the optional vial wiper. Then fully rinse the sample vial again. Refer to Figure 5.
5. Dry the external surfaces of the sample cell with a soft, no-lint cloth. Do not let the sample vial air dry.
6. For storage, fill the sample vial with distilled or demineralized water.

   Note: *If the sample vial is used to measure low range turbidity samples or dilution water, fill the sample vial with dilution water (not distilled or deionized water).*
7. Immediately put the cap on the sample vial to keep the interior of the sample vial wet.

Figure 5 Clean the vial with the vial wiper (optional)



10.4 Clean the vial compartment

Clean the vial compartment only when the compartment has contamination. Make sure that the tool to clean the vial compartment has a soft surface and does not damage the instrument. Table 3 shows the options on how to clean the vial compartment.

Table 3 Cleaning options

Contaminant	Options
Dust	Vial compartment wiper, micro fiber cloth, lint-free cloth
Liquid, oil	Cloth, water and cleaning agent

Section 11 Troubleshooting

Refer to the expanded user manual on www.hach.com for troubleshooting information.

Organic Carbon, Total

DOC316.53.01334

USEPA[1] Direct Method — Method 10267

1.5 to 30.0 mg/L C (LR) — TNTplus 810

Scope and application: For wastewater, drinking water, surface water and process water analyses.

[1] Hach Method 10267 is USEPA approved for the determination of total organic carbon (TOC) in drinking water, Federal Register Volume 81, Number 138 (Tuesday, July 19, 2016).

Test preparation

Before starting

DR 3900, DR 3800, DR 2800: Install the light shield in Cell Compartment #2 before this test is started.
Review the safety information and the expiration date on the package.
Use the DRB reactor with 13-mm wells for the digestion. If the reactor has 16-mm wells, insert adapter sleeves into the wells.
Make sure to digest the samples at 100 °C. Higher temperatures may cause the vials to break apart.
Be careful with the vials after the digestion. Pressure increases in the vials during the digestion and can cause the vials to break apart.
Use only the TOC-X5 shaker to remove total inorganic carbon (TIC) from the sample.
Carbon dioxide from the air can contaminate the sample. Do not open the indicator vial before the shaker operation is complete. Immediately install the double cap on the indicator vial after the cap is removed, then immediately install the other side of the double cap on the sample vial.
The formation of crystals in the sample vial does not affect the result.
The recommended temperature for reagent storage is 2–8 °C (35–46 °F).
The recommended sample pH is 3–10.
If the sample contains particles, dilute the sample. Use the diluted sample in the test procedure. Multiply the test result by the dilution factor.
After both vials are attached to the double cap, keep the vial assembly together. Put the vial assembly in the plastic packaging after the analysis.
DR 1900: Go to All Programs>LCK or TNTplus Methods>Options to select the TNTplus number for the test. Other instruments automatically select the method from the barcode on the vial.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used. Use the recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Refer to the Safety Data Sheets for disposal information for unused reagents. Refer to the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

Items to collect

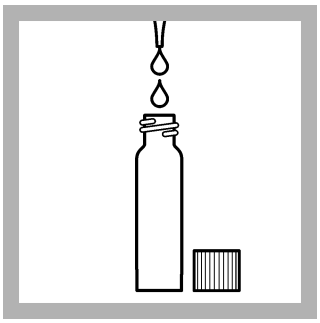
Description	Quantity
Total Organic Carbon, LR TNTplus 810 Reagent Set	1
DRB200 reactor with 13-mm wells	1
TOC-X5 shaker	1
Pipet, adjustable volume, 1.0–5.0 mL	1
Pipet tips, for 1.0–5.0 mL pipet	1
Test tube rack	1

Refer to Consumables and replacement items on page 4 for order information.

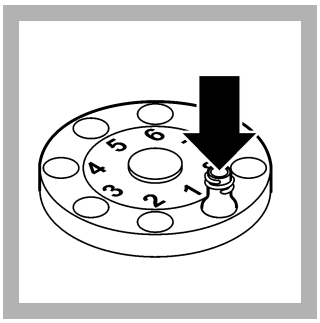
Sample collection

- Collect samples in clean glass bottles.
- Homogenize samples that contain solids to get a representative sample.
- Rinse the sample bottle several times with the sample to be collected.
- Fill the bottle completely full, then tighten the cap on the bottle.
- Analyze the samples as soon as possible for best results.
- Acid preservation is not recommended.

Test procedure

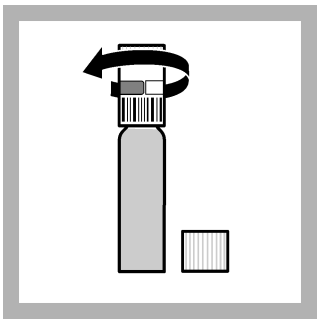


1. Remove the cap from a clear vial. Use a pipet to add 2 mL of sample to the vial.

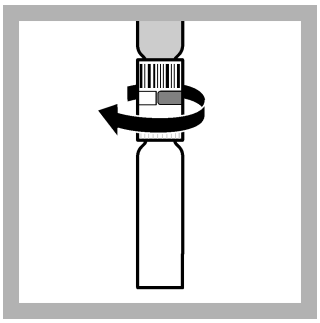


2. Insert the uncapped sample vial into the TOC-X5 shaker. Make sure that the vial is pushed all the way down into the shaker. Move the fan over the vial.

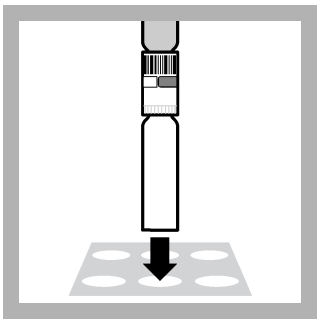
3. Push the on/off switch to start the shaker. Operate the shaker for 5 minutes.



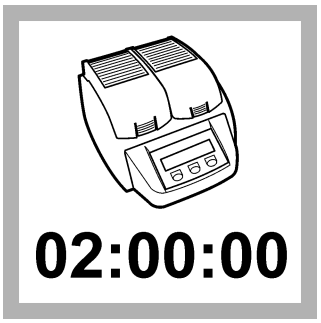
4. When the shake time is complete, remove the cap from a blue indicator vial. Immediately install and tighten a double cap on the indicator vial with the barcode label toward the vial.



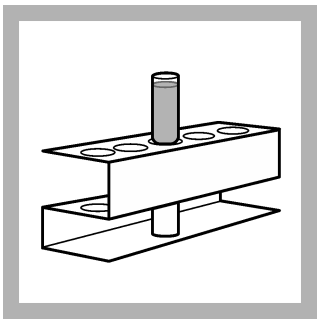
5. Immediately invert the indicator vial, then install and tighten the other side of the double cap on the sample vial. Hold the vial assembly vertically.



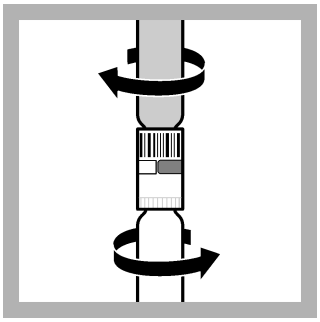
6. Insert the vial assembly into the DRB reactor (indicator vial on top).



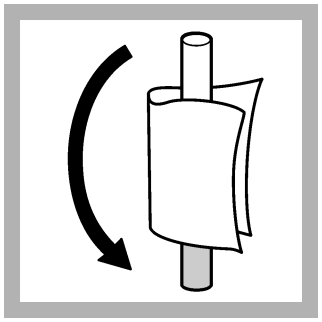
7. Increase the vial assembly temperature for 2 hours at 100 °C.



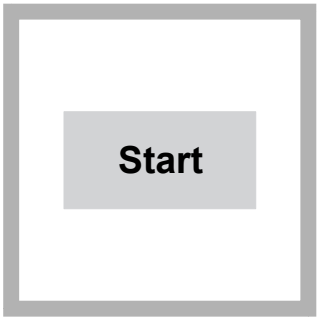
8. Let the vial assembly cool completely to room temperature. Make sure that the vials cool completely. Warm vials will give high results.



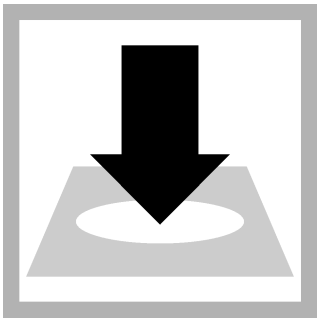
9. Tighten the double cap on both vials.



10. Invert the vial assembly so the indicator vial is on the bottom. Clean the indicator vial.



11. DR 1900 only: Select program 810. Refer to Before starting on page 1.



12. Insert the vial into the cell holder. DR 1900 only: Push **READ**.
Results show in mg/L C.

Interferences

The table that follows shows the substances that were tested for interference and did not interfere up to the levels shown.

Interfering substance	Interference level
Ammonium	200 mg/L
Calcium	2000 mg/L as $CaCO_3$
Chloride	1000 mg/L
Magnesium	2000 mg/L as $CaCO_3$
TIC	250 mg/L

Accuracy check

Standard solution method

Use the standard solution method to validate the test procedure, the reagents and the instrument.

Items to collect:

- 1000-mg/L C TOC Standard Solution
- 500-mL volumetric flask, Class A
- 200-mL volumetric flask, Class A
- 50-mL volumetric pipet, Class A and pipet filler safety bulb
- 20-mL volumetric pipet, Class A and pipet filler safety bulb
- Organic-free water

1. Prepare a 100-mg/L C stock solution as follows:
   a. Use a pipet to add 20 mL of a 1000-mg/L C standard solution into a 200-mL volumetric flask.
   b. Dilute to the mark with organic-free water. Mix well.
2. Prepare a 10-mg/L C standard solution as follows:
   a. Use a pipet to add 50 mL of a 100-mg/L C stock solution into a 500-mL volumetric flask.
   b. Dilute to the mark with organic-free water. Mix well. Prepare this solution daily.
3. Use the test procedure to measure the concentration of the prepared standard solution.
4. Compare the expected result to the actual result.

   Note: *The factory calibration can be adjusted slightly with the standard adjust option so that the instrument shows the expected value of the standard solution. The adjusted calibration is then*

used for all test results. This adjustment can increase the test accuracy when there are small variations in the reagents or instruments.

Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users can get different results under different test conditions.

Program	Standard	Precision (95% confidence interval)	Sensitivity Concentration change per 0.010 Abs change
TNTplus 810	10 mg/L C	9.72–10.28 mg/L C	0.4 mg/L C

Summary of method

The total inorganic carbon (TIC) in the sample is first removed during the shaker operation. The sample is then digested to oxidize the total organic carbon (TOC) in the sample to carbon dioxide (CO_2). The CO_2 from the digested sample goes through the membrane in the double cap to the indicator vial and causes the indicator solution to change color. The color of the indicator solution is measured by the spectrophotometer. The measurement wavelength is 435 nm.

Consumables and replacement items

Description	Quantity/test	Unit	Item no.
Total Organic Carbon Reagent Set, LR, TNTplus	1	25/pkg	TNT810

Required apparatus

Description	Quantity/test	Unit	Item no.
DRB 200 Reactor, 115 VAC option, 9 x 13 mm + 2 x 20 mm, 1 block	1	each	DRB200-01
DRB 200 Reactor, 230 VAC option, 9 x 13 mm + 2 x 20 mm, 1 block	1	each	DRB200-05
Pipet, adjustable volume, 1.0–5.0 mL	1	each	BBP065
Pipet tips, for 1.0–5.0 mL pipet	1	75/pkg	BBP068
Test tube rack	1	each	1864100
TOC-X5 shaker	1	each	LQV148.99.00002
Wipes, disposable	1	280/pkg	2097000

Recommended standards

Description	Unit	Item no.
TOC Standard Solution Ampule (KHP Standard, 1000-mg/L C)	5/pkg	2791505

Optional reagents and apparatus

Description	Unit	Item no.
Reactor adapter sleeves, 16 mm to 13 mm diameter, for TNTplus vials	5/pkg	2895805
Ampule Breaker, 2-mL PourRite® Ampules	each	2484600
Flask, volumetric, Class A, 500 mL, glass	each	1457449
Flask, volumetric, Class A, 200 mL	each	1457445
Pipet, volumetric, Class A, 50 mL	each	1451541
Pipet, volumetric Class A, 20 mL	each	1451520
Pipet filler, safety bulb	each	1465100

Optional reagents and apparatus (continued)

Description	Unit	Item no.
Potassium Acid Phthalate (KHP), ACS	500 g	31534
Water, organic-free	500 mL	2641549

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04/2017, Edition 4