



Process Monitoring: Chemical and Mechanical Parameters

To achieve process control for Process E-6, you must monitor and control the key process parameters. Measuring the key parameters and plotting the results on control charts enables you to detect changes or “out-of-control” conditions before they affect customer film or control strips. When you detect a change, investigate the cause and correct it, if necessary. With process control, you will be able to identify and fix the cause of the problem instead of just compensating for the effect of it.

As you monitor and control the key parameters—specific gravity, replenishment rates, time, temperature, recirculation, agitation, and the concentrations of certain chemical components—you will continue to use control strips to *confirm* that your process is in control. For more information on using control strips, see *Process Monitoring: Sensitometric Parameters*, Section 5.

Process monitoring is a critical step toward achieving optimum control of Process E-6 and maintaining the process at an optimum level.

Now you are ready to follow these steps:

1. Eliminate or minimize all sources of oxidation
2. Eliminate or minimize evaporation
3. Begin process monitoring

4. Stabilize your process
5. Adjust your process to aim
6. Optimize your process
7. Maintain your process at an optimum level

Explanations and procedures for steps 1 through 3 are given in this section; explanations and procedures for steps 4 through 6 are given in Section 6; and maintenance procedures are given in Section 16.

Eliminate or Minimize All Sources of Oxidation

Oxidation of chemicals in solutions can occur by aerial oxidation and by oxidation within solutions.

Whenever a solution is in contact with air, **aerial oxidation** can occur. Solutions are subject to aerial oxidation during processing hours **and** during non-processing hours if they are kept in tanks without floating lids.

Oxidation within solutions occurs when air or oxygen is mixed into the solution. This can be caused by a bad recirculation pump (with a leak that allows air to enter the line), a faulty filter housing, a low solution level that permits air to be sucked into the recirculation system, or poor mixing procedures, such as over-mixing and mixing too vigorously.

To eliminate or minimize all sources of oxidation, follow these steps:

1. Use floating lids on all rack-and-tank machine tanks—except the bleach and fixer—when the process is not in operation, as well as on all replenisher tanks. If you cannot use floating lids, you must find another method of minimizing oxidation.
2. Eliminate, or minimize, solution-to-air contact during idle periods or periods of low utilization. Use floating lids on rack-and-tank machine tanks to cover the solutions whenever the machine is up to temperature but is not processing film.
3. Routinely check recirculation pumps, filter housings, and lines for leaks. Make sure that the solution levels are adequate to prevent air from entering the recirculation system.
4. Follow proper mixing procedures. Do not overmix solutions or mix them so vigorously that foaming or vortexing occurs.



Eliminate or Minimize Evaporation

The rate of evaporation of a solution depends on the surface-to-volume ratio, agitation and turbulence, the temperature of the solution, the relative humidity in the processing area, and the rate of air flow immediately above the surface of the solution.

The **surface-to-volume ratio** is the ratio of the surface area of the solution in a processing tank to the volume of the tank. A 10-gallon tank that exposes 1 square foot of solution surface has a surface-to-volume ratio of 1 square foot to 10 gallons, or 0.1 sq ft/gal. A tray with a 1-gallon capacity and a surface area of 1 square foot has a ratio of 1 sq ft/gal. The rate of evaporation of the solution in the tray will be much greater than that of the solution in the tank, because the tray has a greater surface-to-volume ratio.

Although a lab may have very little control over the surface-to-volume ratio of machine tanks, it can control **agitation** and **turbulence**. Excessive agitation or turbulence causes ripples, waves, and bubbles that increase the rate of evaporation by increasing the effective surface area of the solution. You can't eliminate all agitation and turbulence because they are essential to process performance. You must establish an acceptable balance between the agitation and turbulence required for quality processing and the rate of evaporation.

To avoid unnecessary evaporation, turn off the agitation system of the first developer and the color developer whenever you are not

processing film. Use humidified nitrogen for agitation in the first developer and color developer to minimize evaporation.

The evaporation rate also depends on the **temperature** of the solution. As temperature increases, the rate of evaporation increases. Process E-6 requires a high temperature (100.4°F [38°C]); you cannot lower solution temperatures to reduce evaporation. However, if you maintain tight control of solution temperature, the effect of temperature on evaporation will remain constant.

The last factors that affect the rate of evaporation are the **relative humidity** in the processing area and the **rate of air flow** immediately above the solution. As humidity increases, evaporation decreases. Maintaining a constant level of humidity is important in avoiding fluctuations that affect the rate of evaporation. Fluctuating rates of evaporation cause fluctuations in solution concentrations, which may result in poor process quality.

To eliminate or minimize evaporation, follow these guidelines:

1. Avoid excessive agitation and turbulence; turn off agitation systems when you are not processing film.
2. Use humidified nitrogen for agitation in the first developer and color developer.
3. Avoid low or variable humidity in the processing area.
4. Avoid excessive air flow or exhaust over the processing tanks.

Monitor the concentration of your first developer, reversal bath, and color developer frequently by making specific-gravity measurements and plotting your variations from aim on control charts. If your specific-gravity measurements are still high after you have followed the steps described earlier, and the problem is not caused by replenisher mixing errors, compensate for the remaining evaporation by following the procedure given in Appendix 4A, "Compensating for Evaporation."

Once you have corrected oxidation and evaporation problems, you can begin to monitor the key process parameters.

PROCESS MONITORING

The following pages describe the key process parameters, outline procedures for measuring the parameters, explain how to plot variations from aim, and direct you to the appropriate sections for instructions on taking corrective action.

The key parameters described are

- Specific gravity
- Replenishment rates
- Time
- Temperature
- Recirculation
- Agitation
- Concentrations of key chemical components

Note: Use measuring instruments that are sufficiently accurate to measure and control the key parameters to the specifications.

Specific Gravity

Specific gravity is the ratio of the mass of a liquid to the mass of an equal volume of water at a specific temperature. For example:

$$\text{Specific gravity of Liquid A} = \frac{\text{mass of Liquid A}}{\text{mass of water (equal volume)}} \text{ at a specific temperature}$$

Specific-gravity measurements indicate the overall concentration of processing solutions, and can help you detect replenisher mixing errors, improper concentrate-to-water ratios in blender or in-line dilution systems, or evaporation problems. Measure the specific gravity of each replenisher mix before using the replenisher.

Specific-gravity measurements *do not* indicate incorrect replenishment rates. For Process E-6 solutions, the concentration of the replenishers is approximately equal to the concentration of the seasoned tank solutions. Therefore, under- or over-replenishment will *not* significantly change the specific-gravity measurements, but will affect the concentrations of certain chemical components.

Make specific-gravity measurements with a set of standard hydrometers or the KODAK Process Hydrometer Syphon Set (see page 4-5).

Using Standard Hydrometers to Measure Specific Gravity: A standard hydrometer is a tapered air-filled glass tube with a stem at the top and a weight at the bottom. Measurements in increments of 0.001 are marked on the stem. To measure the specific gravity of Process E-6 solutions, you will need the standard hydrometers listed in the table below.

Note: You should *not* need all 6 standard hydrometers listed in the table for any one type of machine running Process E-6.

| Process E-6 Solution | Range of Standard Hydrometer | ASTM No. |
|--|--|------------------------------|
| First developer and replenisher | 1.050 to 1.100 | 126H |
| Reversal bath and replenisher Color developer and replenisher Pre-bleach and replenisher | 1.000 to 1.050 | 125H |
| Bleach* and replenisher | 1.100 to 1.150 1.150 to 1.200 1.200 to 1.250 1.250 to 1.300 | 127H 128H 129H 130H |
| Fixer* and replenisher | 1.000 to 1.050 1.050 to 1.100 | 125H 126H |

*More than one hydrometer is listed for bleach and fixer because the acceptable ranges of the specific-gravity measurements for these solutions are large.

To use a standard hydrometer, you must extract tank solution and place it in a graduated cylinder (or similar vessel), and insert the hydrometer into the cylinder.

Equipment Needed

1. Standard hydrometers (see the table on page 4-3)
2. 250 mL graduated cylinder or similar vessel
3. Tray
4. Thermometer
5. Sampling bulb (battery type or equivalent)

Measuring Specific Gravity

1. Fill the dry, clean 250 mL graduated cylinder to within 1 inch (2.5 cm) of the top with the solution you are measuring.
2. Adjust the solution to the proper temperature (see the specifications given in the sections on the individual solutions). *Proper solution temperature is very important.*
3. Place the cylinder in a sink or tray to catch overflow.
4. Choose the correct hydrometer to match the approximate specific gravity of the solution. (See the hydrometer ranges listed in the table on page 4-3.)
5. Be sure that the hydrometer is clean and dry. Carefully lower the hydrometer into the solution. Let it bob up and down slightly. When it stops, read the number at the top of the MENISCUS; see Figure 1.
6. After making the measurement, discard the sample. To avoid contaminating solutions, **do not** return the sample to the tank.
7. Rinse the hydrometer and graduated cylinder thoroughly with water.

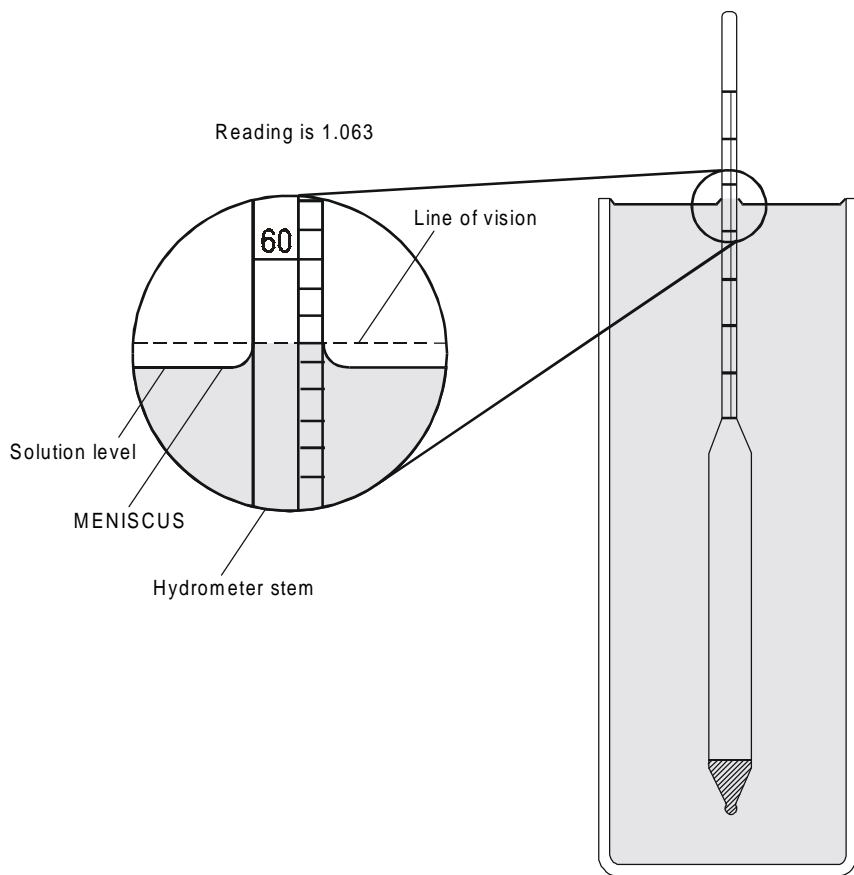


Figure 1

Note: Never take specific-gravity readings of solutions in the tanks. If you use the wrong hydrometer, it can sink to the bottom of the tank and break, or bob on the surface, where the stem may hit the edge of the tank and break. Label hydrometer boxes to avoid confusion.

Do not use tape labels on the hydrometers.

Using the KODAK Process Hydrometer Syphon Set to Measure Specific Gravity: The KODAK Process Hydrometer Syphon Set consists of a glass tube with a three-hole plug and a rubber suction bulb installed on the upper end, a hydrometer that fits inside the glass tube, and a three-hole plug and a rubber nozzle with a clamp for the lower end of the glass tube. Use this hydrometer set to extract solutions directly from your processing tanks to measure the specific gravity of the solutions at 100.4°F (38°C).

Assembling the Syphon Set

1. Insert the **HYDROMETER—stem first**—into the **GLASS TUBE** through the lower end; see Figure 2.
2. Insert the three-hole plug into the lower end of the glass tube.
3. Wet the rubber **NOZZLE** and the bottom of the glass tube with tap water, and fit the nozzle over the end of the tube. Handle the nozzle carefully; it contains a glass joint.

Measuring Specific Gravity

1. Before you make the first measurement, open the **CLAMP** and draw warm water into the tube by squeezing the **SUCTION BULB** and releasing it. Then squeeze the bulb again to expel the water.

Note: Do not use cold water; the hydrometer could crack when you later draw warm solution into the tube.

2. Squeeze the suction bulb **before** immersing the nozzle into the tank solution.
3. Immerse the nozzle into the solution at least 1 inch (2.5 cm) below the surface. To draw the solution into the glass tube, gradually release your grip on the suction bulb.

Important: Perform this operation slowly to avoid drawing air into the tube and to prevent solution foaming, which can affect your reading. Your measurements may be high if you draw air into the tube.

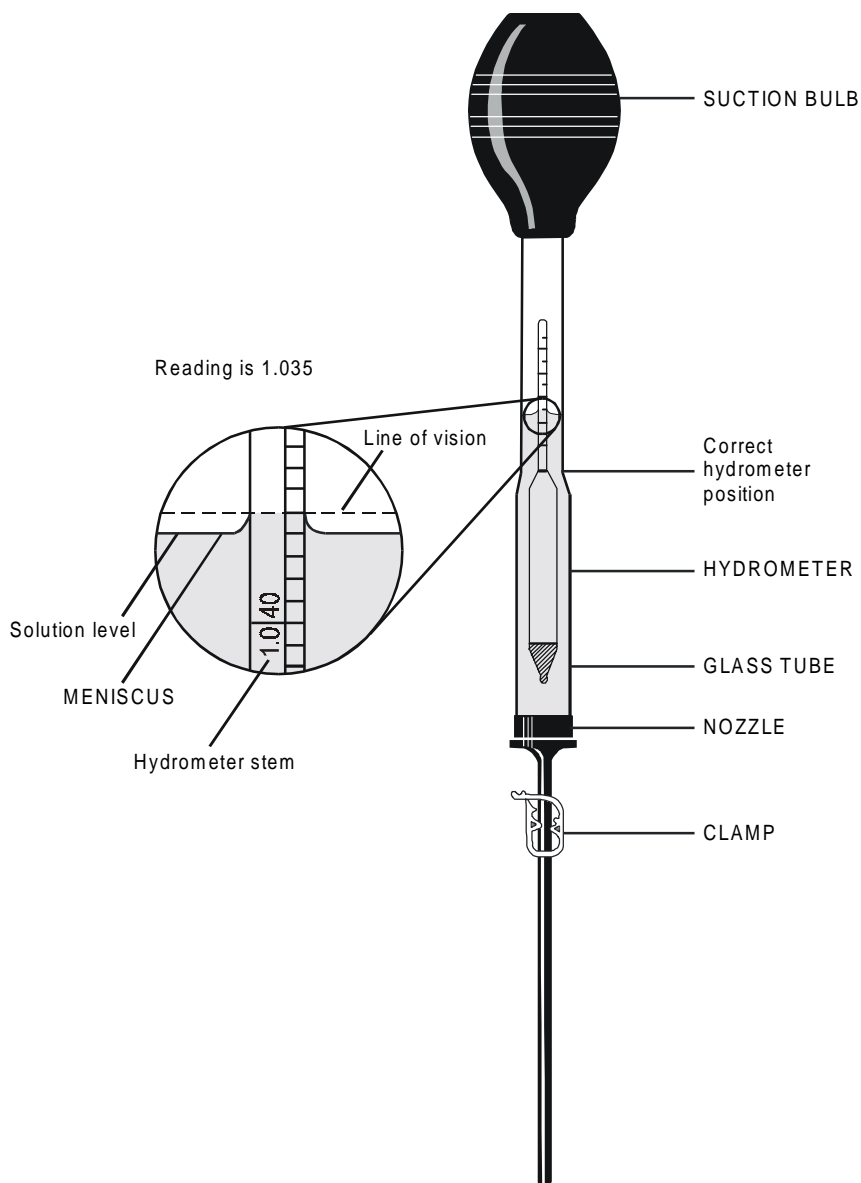


Figure 2

As soon as the bottom of the hydrometer stem reaches the narrow section of the glass tube (see Figure 2), close the clamp on the nozzle so that the solution remains in the tube. Release your grip on the suction bulb. The amount of solution that you draw into the tube will depend on the specific gravity of the solution, so the solution level in the tube will be different for different solutions.

4. Hold the syphon set vertically. Gently shake or tap the glass tube to make sure that the hydrometer floats freely and to dislodge air bubbles. The hydrometer should not touch the sides of the tube.

Note: If you cannot dislodge air bubbles from the hydrometer, discard the sample and draw another one.

5. To make the measurement, hold the set so that the solution is at eye level. Read the number on the hydrometer at the top of the MENISCUS; see the enlarged portion of Figure 2.
6. To discard the sample from the tube, open the clamp and squeeze the bulb to expel the solution. To avoid contaminating solutions, do not return the sample to the tank.
7. Rinse the set thoroughly by drawing warm water into the tube and expelling it. Do this 3 times. To avoid breaking the glass tube and the hydrometer, store the set in its original box or another safe place.

Note: A crossover procedure for hydrometers is given in Appendix 4B.

Plotting Specific-Gravity Measurements:

After you measure the concentration of your tank solutions, calculate and plot your variations from aim on the appropriate plotting form; see “Using Forms Y-34, Y-35, and Y-36” on page 4-13 for more information. Check the plots of specific-gravity measurements for outliers, shifts, trends, and cycling to determine the state of control. If you detect an out-of-control condition, refer to the diagnostic charts in the sections on the individual solutions.

Replenishment Rates

The correct chemical composition of tank solutions is critical to optimum performance of Process E-6. For optimum quality in the many films for Process E-6, the chemical composition of tank solutions must be “on aim” and remain stable.

Many chemical reactions occur during processing. These reactions affect the concentration of key chemical components in the tank solutions. When you replenish Process E-6 solutions properly, you maintain optimum levels of chemicals in the process. Replenishers for Process E-6 contain a higher concentration of the chemicals that are consumed or oxidized during processing than a seasoned tank solution. The higher

concentration of these chemicals in replenisher solutions restores the proper chemical concentration of tank solutions. Replenisher solutions also dilute some developer by-products (e.g., bromide and iodide) and other reaction by-products.

When properly operated and monitored, replenishment systems will maintain the chemical composition of tank solutions at their optimum (aim) level.

Note: Replenishment rates for Process E-6 are based on average film exposure and a typical mix of low- and high-speed films. If you process a non-typical film mix (e.g., all low-speed films) or films with unusual exposure levels (e.g., a majority of high- or low-key scenes per roll or batch), you may have to adjust your replenishment rates or replenisher concentration (or both) to maintain proper tank concentrations. The composition of the tank solution is critical; you must carefully monitor replenishment rates, as well as replenisher concentration, to maintain the composition of the tank solution.

Calculating Replenishment Rates:

To calculate the replenishment rate for each solution, you must determine the amount of replenisher used **and** the amount of film processed. For pre-mixed solutions, you can use the formula:

$$\text{Replenish-ment rate} = \frac{\text{amount of replenisher used (mL)}}{\text{amount of film processed (sq ft)}}$$

For in-line dilution and blender systems, you can use a similar formula, but you base the calculation on each flexible container of concentrate (see page 4-8).

For Pre-Mixed Solutions: We recommend that you calculate and plot replenishment-rate data as often as possible—at least once a week. Calculate replenishment rates by following these steps or by using Worksheet 1.

(A sample replenishment-rate calculation on Worksheet 1 is shown on page 4-7. A copy of Worksheet 1 is included in Section 17.)

1. Record the volume of replenisher in the replenisher tank at the beginning of the day or shift.
Note: Throughout the day or shift, record the amount of film processed (in square feet). The table on Worksheet 1 lists equivalents in square feet for different film formats.
2. At the end of the shift, record the volume of replenisher in the replenisher tank.
3. Determine the amount of replenisher used by subtracting the volume you recorded in step 2 from the volume you recorded in step 1.
4. Record the volume used for pump calibrations and waste.
5. Subtract the amount of replenisher used for pump calibrations (waste) from the volume you calculated in step 3 to determine the amount of replenisher used to process film.
6. Calculate the amount of film processed (in square feet). If you push process film, see note on Worksheet 1 example.
7. Divide the amount of replenisher used (step 5) by the amount of film processed (step 6) to determine the replenishment rate. Round the result, if necessary.

Example:

$$\text{Replenishment rate} = \frac{19,000 \text{ mL}}{93.38 \text{ sq ft}} = \frac{203.47 \text{ mL/sq ft}}{203 \text{ mL/sq ft mL}}$$

8. Calculate and plot your variation from aim on the appropriate plotting form; see “Using Forms Y-34, Y-35, and Y-36” on page 4-13 for more information. Check the plots of replenishment rates for outliers, shifts, trends, and cycling to determine the state of control. If you detect an out-of-control condition, refer to the diagnostic charts in the sections on the individual solutions.

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WORKSHEET 1

EXAMPLE

**CALCULATION OF REPLENISHMENT RATES
 FOR PRE-MIXED SOLUTIONS**

To calculate the replenishment rate of each solution, determine the amount of replenisher used **and** the amount of film processed. Use the formula:

$$\text{Replenishment rate} = \frac{\text{amount of replenisher used (mL)}}{\text{amount of film processed (sq ft)}}$$

| | |
|--|---------------------------|
| 1. Volume of replenisher at start-up: | <u>46,000</u> mL |
| 2. Volume of replenisher at shutdown: | <u>26,000</u> mL |
| 3. Volume of replenisher used (1 – 2): | <u>20,000</u> mL |
| 4. Volume used for pump calibrations/waste: | <u>1,000</u> mL |
| 5. Volume of replenisher used to process film (3 – 4): | <u>19,000</u> mL |
| 6. Total film processed*: | <u>93.38</u> mL |
| 7. Replenishment rate (5 ÷ 6): | <u>203.47 or</u> mL/sq ft |
| | <i>203 mL/sq ft</i> |

* If you push process film, the film area for pushed film must be increased by the same percentage as the increase in replenisher rate.
 Example: If 1.1 square feet of film is processed at push one and the push one replenishment rate is 1.5x normal, the 1.1 sq ft of film should be accounted for as 1.65 sq ft (1.5 x 1.1=1.65)

Example:

$$\text{Replenishment rate} = \frac{19,000 \text{ mL}}{93.38 \text{ sq ft}} = 203.47 \text{ mL/sq ft}$$

(rounded to 203 mL/sq ft)

STANDARD REPLENISHMENT RATES

| Solution | STANDARD REPLENISHMENT RATES (mL/sq ft) |
|-----------------|---|
| First developer | 200 |
| Reversal bath | 100 |
| Color developer | 200 |
| Pre-bleach | 100 |
| Bleach | Depends on machine type |
| Fixer | 100 |
| Final rinse | 100 |

**EQUIVALENTS IN SQUARE FEET
 FOR FILM FORMATS**

| Film Size | Area Per Sheet or Roll (Square Feet) |
|-------------------|--------------------------------------|
| 4 x 5-in sheets | 0.134 |
| 5 x 7-in sheets | 0.238 |
| 8 x 10-in sheets | 0.549 |
| 11 x 14-in sheets | 1.064 |
| 135-24 | 0.395 |
| 135-36 | 0.556 |
| 120 | 0.550 |
| 220 | 1.090 |

For In-Line Dilution and Blender Systems: We recommend that you base replenishment-rate calculations on each flexible container of concentrate used. (It is difficult to measure use of partial amounts of concentrate from a flexible container, so the rates are calculated from the *total volume* of the flexible container.) You must keep a careful record of all pump calibrations and any concentrate that is wasted (i.e., concentrate that is not added to the tank). Calculate replenishment rates by following these steps or by using Worksheet 2. (A sample replenishment-rate calculation on Worksheet 2 is shown on page 4-9. A copy of Worksheet 2 is included in Section 17.)

1. When you install a new flexible container, begin recording the amount of film you process (in square feet). The table on Worksheet 2 lists equivalents in square feet for different film formats.
2. Keep a record of the **concentrate** that you remove from the flexible container for all pump calibrations/waste.
3. When the flexible container is empty, determine the amount of concentrate removed for pump calibrations/waste by totaling the amounts recorded in step 2.
4. Subtract the total amount of concentrate used for pump calibrations/waste from the original volume of concentrate in the flexible container (the volume marked on the flexible-container carton) to calculate the amount of **concentrate** used.
5. Calculate the amount of film processed (in square feet).

6. Divide the amount of **concentrate** used (step 4) by the amount of film processed (step 5). Round your result, if necessary

Example:

$$\frac{\text{Amount of Concentrate Used}}{\text{Amount of Film Processed*}} = \frac{18,670 \text{ mL}}{461 \text{ sq ft}} = 40.49 \text{ mL/sq ft, rounded to } 40 \text{ mL/sq ft}$$

* If you push process film, the film area for pushed film must be increased by the same percentage as the increase in replenisher rate. Example: If 1.1 square feet of film is processed at push one and the push one replenishment rate is 1.5x normal, the 1.1 sq ft of film should be accounted for as 1.65 sq ft (1.5 x 1.1=1.65)

7. To determine the replenishment rate, add the amount of water used per square foot of film (use the amount from the table below) to the amount of concentrate used per square foot of film.

| Replenisher Solution | Volume of Water Used* per Square Foot of Film Processed (mL/sq ft) |
|----------------------|--|
| First developer | 160 |
| Reversal bath | 95 |
| Color developer | 120 |
| Pre-bleach | 90 |
| Bleach | 0 |
| Fixer | 90 |
| Final rinse | 99 |

*Based on pump calibrations that indicate the proper ratio of water to concentrate. If you are compensating for evaporation, use the modified value for your water pump.

Example:

$$40 \text{ mL/sq ft of concentrate} + 160 \text{ mL/sq ft of water} = 200 \text{ mL/sq ft}$$

8. Calculate and plot your variation from aim on the appropriate plotting form; see “Using Forms Y-34, Y-35, and Y-36” on page 4-13 for more information. Check the plots of replenishment rates for outliers, shifts, trends, and cycling to determine the state of control. If you detect an out-of-control condition, refer to the diagnostic charts in the sections on the individual solutions.

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WORKSHEET 2

EXAMPLE

**CALCULATION OF REPLENISHMENT RATES FOR
 IN-LINE DILUTION/BLENDER SYSTEMS**

Calculate replenishment rates based on the **total volume** of each flexible container of concentrate used. Keep a careful record of pump calibrations and any concentrate that is wasted (i.e., concentrate that is not added to the tank).

Solution: *First Dev* Batch No.: _____

- Record the amount of film processed daily.
- Record the amount of concentrate removed from the container for daily pump calibrations/waste.

| Date | ① Film Processed (sq ft) | ② Amount of Concentrate Used for Pump Calibrations/Waste (mL) | Comments |
|------|-----------------------------|--|-------------------------|
| 5/14 | 50 | 82 | |
| 5/15 | 49 | 83 | |
| 5/16 | 61 | 81 | |
| 5/17 | 63 | 78 | |
| 5/19 | 34 | 75 | <i>Adjusted pump</i> |
| 5/20 | 63 | 80 | |
| 5/21 | 60 | 74 | <i>Adjusted pump</i> |
| 5/22 | 60 | 85 | <i>End of container</i> |
| | | | |
| | | | |
| | | | |

- Total the amounts of concentrate recorded in step 2. _____ *638* _____ mL
- Subtract the total amount of concentrate used for pump calibrations/waste (step 3) from the original volume of concentrate in the container.

$$19,000 - \underline{\quad 638 \quad} \text{ mL} = \underline{\quad 18,362 \quad} \text{ mL}$$
- Total the amounts of film recorded in step 1. _____ *440* _____ sq ft
- Divide the amount of concentrate used to process film (step 4) by the amount of film processed (step 5). _____ *41.7* _____ mL/sq ft
- To determine the replenishment rate, add the amount of water used per square foot of film (use the amount from the table on the reverse side) to the amount of concentrate used (step 6).

$$\underline{\quad 160 \quad} \text{ mL/sq ft} + \underline{\quad 41.7 \quad} \text{ mL/sq ft} = \underline{\quad 201.7 \text{ or } 202 \text{ mL/sq ft} \quad}$$

Time

Reactions in the first developer are the most sensitive to time variations. Changes in the first-developer time have significant photographic effects, e.g., a change of only 3 seconds can result in a density difference of about 0.01 at a density of 1.00. Reactions in the other solutions go to completion; they are less sensitive to time variations, particularly longer times.

Important: You must measure the first-developer time **daily**. Measure the times of all other solutions once a month.

Use a stopwatch to measure the time that the film is in a solution from the time the film enters the solution to the time it enters the next solution (or wash).

Note: The optimum time for a solution will vary from processor to processor due to differences in machine design, agitation, temperature, and crossover times. Once you determine the optimum time for each solution in a machine, you should maintain these times to ± 3 seconds.

Calculate and plot your variation from aim on the appropriate form; see "Using Forms Y-34, Y-35, and Y-36" on page 4-13 for more information. Check the plots for outliers, shifts, trends, and cycling to determine the state of control. If you detect an out-of-control condition, refer to the diagnostic charts in the sections on the individual solutions.

Temperature

The temperature of a solution controls the *rate* of the chemical reactions. Make sure that your recirculation system is functioning properly. The most critical temperature in Process E-6 is the first-developer temperature. A temperature change of $\pm 0.2^{\circ}\text{F}$ ($\pm 0.1^{\circ}\text{C}$) can result in a

density difference of about 0.01 at a density of 1.00.

Important: You must control the first-developer temperature to within $\pm 0.2^{\circ}\text{F}$ ($\pm 0.1^{\circ}\text{C}$) to control density within ± 0.01 .

The temperature of the color developer is also important. A temperature change of $\pm 0.5^{\circ}\text{F}$ ($\pm 0.3^{\circ}\text{C}$) in the color developer can result in color and density shifts. Control the temperature of the color developer to within $\pm 0.5^{\circ}\text{F}$ ($\pm 0.3^{\circ}\text{C}$) for optimum process performance.

You must maintain the temperature of a solution *uniformly* throughout the process tank; the temperature of a solution must *not* fluctuate when you add replenisher. (If the tank temperature decreases during replenishment, you should preheat your replenisher solution.)

Properly designed and maintained recirculation systems help you maintain a uniform tank temperature. To check that your recirculation system is working properly and that it is keeping the tank temperature uniform, periodically measure the temperature of the solutions at different locations in the process tanks.

Important: When you monitor and plot the temperature of the first developer and color developer, make sure that you make the measurement at the same location in each tank for consistency.

Measure the temperature of the developers **daily**. Calculate and plot your variation from aim on the appropriate plotting form; see "Using Forms Y-34, Y-35, and Y-36" on page 4-13 for more information. Check the plots for outliers, shifts, trends, and cycling to determine the state of control. If you detect an out-of-control condition, refer to the diagnostic charts in the sections on the individual solutions.

Recirculation

Proper recirculation is important to maintain a uniform tank temperature and to provide uniform chemical distribution. Poor recirculation can cause temperature variations in a tank that result in nonuniform development or inconsistent development within a rack or across a tank.

Recirculation and agitation do not provide the same function. Agitation helps remove the by-products of chemical reactions so that fresh chemicals can act on the film. Poor recirculation can cause poor agitation, but good recirculation does not guarantee good agitation.

Inspect the recirculation systems of the first-developer, color-developer, bleach, and fixer tanks daily. Keep a record of all checks on the systems. Note any changes and take corrective action, if necessary.

Agitation

Agitation helps remove the by-products of the chemical reactions so that fresh chemicals can act on the film. Proper agitation is critical for process control and uniformity of the final images; it is especially important in the first developer, first wash, and color developer. Poor or insufficient agitation may result in nonuniformity and streaking.

Different types of machines use different methods of agitation. In roller-transport processors, the rollers provide the agitation; you cannot adjust the agitation of these processors.

The bleach requires aeration to maintain activity. If the action of the rollers does not provide enough aeration in the bleach tank, you may also have to use air agitation.

In rack-and-tank machines, nitrogen and air provide the agitation. To minimize evaporation, use humidified nitrogen for agitation in the first developer and color developer. Agitation should begin as you lower the film into the tank. Any delay in the initial burst—particularly in the color developer—can result in streaking. The timing of the bursts of nitrogen and air is very important to prevent streaking (especially when you process sheet film). A burst should begin every 10 seconds and last for 2 seconds (a cycle consists of a 2-second burst followed by an 8-second rest). Agitation must be the same at the bottom and the top of the tank. Be sure that the burst pattern is even across the tank, with fine bubbles (pea-sized or smaller), and that it is vigorous enough to raise the solution level $\frac{5}{8}$ inch (16 mm).

Note: Agitation in some solutions may cause foaming. If foaming is excessive, determine the causes of it and correct them. High agitation, loose connections on recirculation pumps, and low solution levels that permit air to be sucked into the solution can cause excessive foam.

You can use KODAK Defoamer, Process E-6, to control foaming in the first-developer, color-developer, and bleach tanks; **do not** use defoamer in the final-rinse tank (it can leave oily deposits on the film). Apply a thin layer of defoamer to the inside of the process tank above the solution level—**do not** add defoamer directly to the tank solution.

For most continuous processors, turbulator bars provide agitation. Turbulator bars are spray bars that force fresh chemicals onto the film.

You can check the operation of turbulator bars by installing pressure gauges on incoming chemical lines. When the small holes in the turbulator bars begin to plug, the pressure will increase. When you detect a 5-pound increase in pressure, clean the turbulator bars.

Visually inspect the agitation in the first-developer, color-developer, bleach, fixer, and wash tanks **daily**. Keep a record of all checks on the agitation system. Plot measurable data (e.g., timing of burst, length of burst, solution rise, etc), note any changes, and take corrective action, if necessary

Concentrations of Key Chemical Components

The procedures that have been available to professional labs for monitoring the chemical composition of solutions are specific-gravity measurements, replenishment-rate calculations, and replenisher-pump calibrations. These procedures provide only indirect measurements of overall solution concentration or specific chemical concentrations, and do not enable labs to measure individual chemical parameters. Now, the KODAK Q-LAB Chemical Test Kit, Process E-6, provides an easy method of measuring the bromide concentration in the first developer, the reversal-agent concentration in the reversal bath, and the sulfite concentration in the color developer. These parameters are important indicators of correct process operation. The Q-LAB Chemical Test Kit is composed of 3 kits: KODAK Bromide Test Kit, Process E-6; KODAK Reversal Agent Test Kit, Process E-6; and KODAK Sulfite Test Kit, Process E-6.

Bromide Concentration: Use the Bromide Test Kit to detect changes in the concentration of bromide in the first developer *before* they affect the film you process. For example, as bromide concentration increases, developer activity decreases, and film densities increase. As bromide concentration decreases, developer activity increases, and film densities decrease. Bromide concentration is affected primarily by replenishment rate. Instructions for using this kit and diagnostics are given in *First Developer*, Section 7.

Reversal-Agent Concentration: Use the Reversal Agent Test Kit to detect changes in the concentration of reversal agent in the reversal bath *before* they affect the film you process. For example, when the reversal-agent concentration is high, the process will drift blue; when the concentration is low, the process will drift yellow. When the reversal-agent concentration is *extremely low*, the color balance of upper-scale densities and D-max will drift green. Instructions for using this kit and diagnostics are given in *Reversal Bath*, Section 9.

Sulfite Concentration: Use the Sulfite Test Kit to detect changes in the concentration of sulfite in the color developer *before* they affect the film you process. For example, as sulfite concentration increases, film contrast will be lower, especially in the high densities. As sulfite concentration decreases, film contrast will be higher, especially in high-density areas. Instructions for using this kit and diagnostics are given in *Color Developer*, Section 10.

FREQUENCY OF MEASUREMENTS

The frequency of measuring the process parameters depends on the state of control of your process. As you begin process monitoring, for example, you must measure the parameters frequently—more frequently than typical process fluctuations occur. After your process is in control and adjusted to aim, you can measure the parameters less frequently.

When you begin process monitoring, we recommend that you make at least 1 measurement of all key parameters **every 8-hour day or shift**. For machines that operate more than 12 hours a day, we recommend that you measure all key parameters every 8 to 10 hours. The more measurements you make, the more data you will have to help you make process-control decisions. See “Stabilizing Your Process” in Section 6.

After your process has stabilized and you have adjusted it to aim, you can decrease the frequency of measurement according to the state of control of your process and the number of tank solution turnovers (processor utilization). However, if the variability of your data increases (or plots approach the tolerance limits), you should make measurements more frequently—at least once a day. This will help you detect out-of-control conditions quickly. If the variability of your data is small and your plots are well within the tolerance limits, you can reduce the frequency of measurements.

When your process is in control—on aim with minimum variability—base your frequency of measurements on the number and frequency of tank turnovers for the first developer. A tank turnover is the point at which the volume of replenisher used is equal to the original volume of solution in the process tank at start-up. To determine the number of tank turnovers, use the formula:

$$\text{Number of tank turnovers} = \frac{\text{volume of first developer replenisher used}}{\text{volume of the first-developer tank}} \text{ per week}$$

Example:

$$\text{Number of tank turnovers} = \frac{80 \text{ L}}{100 \text{ L}} = 0.8 \text{ turnovers per week}$$

After you determine the number of first-developer tank turnovers per week, determine the frequency of measurements from the following table.

| First-Developer Tank Turnovers Per Week | Minimum Frequency of Measurements* |
|---|------------------------------------|
| Fewer than ½ | Once per day |
| ½ to 2 | Once every 3 days |
| More than 2 | Once per day |

*After your process is stable and in control.

If your processor has fewer than ½ turnover per week, its utilization is relatively low. Measure the key parameters at least **every day** to ensure that oxidation and evaporation do not adversely affect process control, and that your replenisher concentration and replenishment rate are sufficient to maintain proper solution concentrations.

One-half to 2 turnovers per week is considered average utilization. After your process is stable, you can reduce the frequency of measurements to once every 3 days. This rate is adequate to detect problems caused by oxidation, evaporation, and improper replenishment.

If your processor has more than 2 turnovers per week, its utilization is relatively high. Measure the key parameters at least **every day** to ensure that you detect changes before they affect the film you process. With high utilization, you run a high risk of not detecting problems soon enough unless you measure the parameters at least once a day. We recommend that you measure the parameters more frequently than once a day.

Note: It is important to make measurements more frequently than typical when process fluctuations occur. The frequencies recommended earlier are starting points. Base measurement frequency on the performance record of each machine.

PLOTTING CHEMICAL AND MECHANICAL PARAMETERS

KODAK Publications No. Y-34, Y-35, and Y-36 provide a convenient means of tracking the key process parameters. Use Form Y-34, KODAK First Developer Plotting Form for Process E-6, to track tank temperature, specific gravity, time, replenishment rate, and bromide concentration for your first developer. Use Form Y-35, KODAK Reversal Bath Plotting Form for Process E-6, to track specific gravity, replenishment rate, and reversal-agent concentration for your reversal bath. Use Form Y-36, KODAK Color Developer Plotting Form for Process E-6, to track tank temperature, specific gravity, replenishment rate, and sulfite concentration for your color developer.

These forms include color zones that enable you to determine the control status of your process quickly and easily. The following colors are used:

- White**—indicates that your process is in excellent control in relation to professional standards
- Yellow**—indicates that your process is in marginal control in relation to professional standards
- Orange**—indicates that your process is out of control in relation to professional standards

Aims for Chemical and Mechanical Parameters

We recommend that you control your process to the aims provided in the sections on the individual solutions. However, we recognize that professional labs may have to adjust the aims of some parameters to obtain optimum image quality; the sections on the individual solutions give an acceptable range

for these parameters. (For more information on acceptable ranges, see *Process Specifications*, Section 2.)

After you make chemical and mechanical measurements for your first developer, reversal bath, and color developer, plot the variations from aim on Forms Y-34, Y-35, and Y-36.

Using Forms Y-34, Y-35, and Y-36

Use a separate set of forms for each processor.

1. Record the name (or identity code) of the processor in the blank labeled “Machine”. On each form.
2. Record the aim value for each parameter in the appropriate blank on each form.
3. Make the required chemical and mechanical measurements.

To calculate and plot your variations from aim, follow these steps:

1. Subtract the aim values from the measurements to calculate the differences.
 Example of determining the difference between a measurement and your aim value:

| | |
|-----------------------------|-----------|
| First-developer temperature | 100.6°F |
| Aim value | – 100.4°F |
| Difference | + 0.2°F |

2. Plot the differences on the appropriate form for each parameter. Plot differences that are **larger** than the corresponding aim values (+ values) above the aim line, and those that are **smaller** than the aim values (– values) below the line. If all of your data plots within the scales on Forms Y-34, Y-35, and Y-36, proceed to “Stabilizing Your Process” in Section 6.

If the difference from aim for any parameter exceeds the scale on the form when you begin process monitoring, take another measurement.

Example:

| | |
|---|-----------|
| Color-developer temperature (first measurement) | 99.2°F |
| Aim value | – 100.4°F |
| Difference | – 1.2°F* |

*Difference exceeds the scale of Form Y-36; in this case you would take another measurement.

If your second measurement matches your first measurement closely, calculate the average of the 2 measurements, and use this value as a temporary aim. In the example above, the second measurement was 99.4°F, so the operator calculated the temporary aim as 99.3°F.

Unless you can determine and fix the causes of an out-of-control condition, do not make any adjustments to your process at this point.

If your second measurement is closer to aim (e.g., the difference from aim does not exceed the scale on the plotting form), plot the difference from aim and then proceed to “Stabilizing Your Process” in Section 6.

SAFE HANDLING OF PHOTOGRAPHIC CHEMICALS

- Handle photographic chemicals and processing solutions with care. See *Safe Handling of Photographic Chemicals*, KODAK Publication No. J-98A. For more information about potential health hazards and safe handling of specific Kodak chemicals, see the package label and the Material Safety Data Sheet (MSDS) for the chemicals.
- Packages of Kodak photographic chemicals have precautionary labels when necessary. Always read the labels and follow the instructions carefully. Also read the Material Safety Data Sheets (MSDSs) for the chemicals for precautionary information.*
- Keep the darkroom, processing area, and mixing room clean. Clean up spilled chemicals promptly.
- Use personal protective equipment, such as a waterproof apron and impervious gloves made of a material such as Neoprene or nitrile, when you handle solutions. Always wear goggles or safety glasses when you mix solutions from concentrates.
- Avoid contact of any chemicals with your skin; some photographic solutions, particularly developers, can cause skin irritation and an allergic skin reaction. In case of accidental chemical contact, wash your skin with running tap water and a non-alkaline (slightly acid) hand cleaner. If symptoms persist, get medical attention.
- Keep chemical solutions out of your mouth. Never start a siphoning action with your mouth. Do not eat or drink in a room where chemicals are mixed or used.
- Maintain proper ventilation in the mixing room and processing area.
- Store chemicals and processing solutions safely. Keep them out of the reach of children.
- Dispose of solutions safely. See *Dealing with Hazardous Waste and Processing Effluents at Photographic Processing Facilities*, KODAK Publication No. J-411.

* In the USA, you can obtain MSDSs for Kodak via the internet. You can download them from the Kodak web site: www.kodak.com/go/MSDS. Outside of the USA, contact Kodak in your country. Please supply the catalog (CAT) numbers for the chemicals when you request MSDSs.

APPENDIX 4A

COMPENSATING FOR EVAPORATION

When water evaporates from processing solutions, the chemical components remain, and the solution becomes overconcentrated. After you have followed the steps to minimize the causes of evaporation (see page 4-2), high specific-gravity measurements may indicate that evaporation is still occurring. To compensate for any remaining

evaporation that occurs during operating hours, follow the procedure given below. The procedure helps you to determine how much water is lost during daily operation and how to adjust your replenisher and replenishment rate to compensate. It requires you to make specific-gravity measurements at start-up and shutdown to determine the amount of water lost to evaporation; it does not interfere with your normal operations.

Note: Once you have compensated for evaporation that occurs during operating hours, you can easily compensate for overnight evaporation by adding water to “top off” your tank solutions.

Calculate the average amount of film (square feet or square metres) that you process per day. Then follow these steps to compensate for evaporation that occurs during operating hours.

| Step | Why? | Example |
|--|---|--|
| 1. Measure the specific gravity of your tank solution at start-up. Then operate your machine as you normally do. | 1. Establishes the concentration of the solution at the start of the day. | 1. 1.063 |
| 2. Measure the specific gravity of your tank solution at shutdown. | 2. Establishes the concentration of the solution at the end of the day. | 2. 1.065 |
| 3. Subtract the start-up specific gravity from the shutdown specific gravity. | 3. Determines the change in solution concentration. | 3. $1.065 - 1.063 = 0.002$ |
| 4. Subtract the specific gravity of water (1.000) from the start-up specific gravity (step 1). | 4. Determines the chemical component of the solution specific gravity. | 4. $1.063 - 1.000 = 0.063$ |
| 5. Divide the change in specific gravity from step 3 by the chemical component of the solution specific gravity from step 4. | 5. Determines the percent change in solution concentration. | 5. $0.002 \div 0.063 = 0.032$ (or 3.2 percent) |
| 6. Multiply the change in solution concentration (step 5) by the volume of your tank. | 6. Determines the total amount of water lost due to evaporation. | 6. $0.032 \times 100 \text{ L} = 3.2 \text{ L}$ or 3200 mL |

(Continued on next page)

| Step | Why? | Example |
|---|---|---|
| <p>7. Divide the amount of water lost to evaporation (step 6) by the average amount of film processed to calculate the water addition.</p> <p>Note: The water addition is based on each square foot (or square metre) of film processed because you replenish the solution for each square foot (or square metre) of film you process.</p> | <p>7. Determines the water loss in the same units as your replenishment rate (e.g., mL/ft² or mL/m²).</p> | <p>7. $3200 \text{ mL} \div 100 \text{ ft}^2 = 29 \text{ mL/ft}^2$ $(3200 \text{ mL} \div 10.2 \text{ m}^2 = 314 \text{ mL/m}^2)$</p> |
| <p>8. Adjust the amount of water in the replenisher by using the water addition you calculated in step 7.</p> <p>For in-line dilution/blender systems, increase the output of the water pump by the water addition from step 7.</p> | <p>8. Compensates for the evaporation that occurs during operating hours.</p> | <p>Current output of the water pump + 29 mL/ft² $(314 \text{ mL/m}^2 = \text{New water output per replenishment cycle})$</p> |
| <p>Your total replenishment rate will increase by the additional volume of water per square foot (or square metre).</p> | | <p>$200 \text{ mL/ft}^2 + 29 \text{ mL/ft}^2 = 229 \text{ mL/ft}^2$ $(2153 \text{ mL/m}^2 + 314 \text{ mL/m}^2 = 2467 \text{ mL/m}^2)$</p> |
| <p>For pre-mixed solutions, first divide the volume of replenisher you mix by your aim replenishment rate.</p> | <p>Determines the amount of film you can process with that volume of replenisher.</p> | <p>$95 \text{ L (or 95,000 mL)} \div 200 \text{ mL/ft}^2 = 475 \text{ ft}^2$ $(95,000 \text{ mL} \div 2153 \text{ mL/m}^2 = 44 \text{ m}^2)$</p> |
| <p>Then multiply the amount of film by the water addition from Step 7.</p> | <p>Determines how much extra water to add to each replenisher mix.</p> | <p>$475 \text{ ft}^2 \times 29 \text{ mL/ft}^2 = 13,775 \text{ mL or 13.8 L}$ $(44 \text{ m}^2 \times 314 \text{ mL/m}^2 = 13,816 \text{ mL or 13.8 L})$</p> |
| <p>Increase your total replenishment rate by the additional volume of water per square foot or square metre.</p> | <p>Provides the same amount of chemical components (per replenishment cycle) that your system provided before you adjusted the replenisher to compensate for evaporation.</p> | <p>$200 \text{ mL/ft}^2 + 29 \text{ mL/ft}^2 = 229 \text{ mL/ft}^2$ $(2153 \text{ mL/m}^2 + 314 \text{ mL/m}^2 = 2467 \text{ mL/m}^2)$</p> |

APPENDIX 4B

HYDROMETER CROSSOVER PROCEDURE

Like other measuring instruments, hydrometers have an inherent variability. Although the variability from hydrometer to hydrometer is usually small, you should run a crossover test when you use a “new” hydrometer. To run a crossover test, follow these steps:

1. Make specific-gravity measurements of at least 4 different samples of the same tank solution with both the “old” and the “new” hydrometer.
2. Determine the average measurement for each hydrometer by adding the measurements and dividing the result by the number of readings.
3. To calculate the difference between the hydrometers, subtract the smaller average from the larger average.

If the difference between the average readings for the hydrometers is greater than 0.002, contact your Technical Sales Representative (TSR) to help you determine which hydrometer is correct. If the difference is less than or equal to 0.002, start using the “new” hydrometer.

Note: Sample calculations are given at the right.

Example 1

| Measurement | Reading with “Old” Hydrometer | Reading with “New” Hydrometer |
|-------------|----------------------------------|----------------------------------|
| 1 | 1.063 | 1.062 |
| 2 | 1.062 | 1.062 |
| 3 | 1.063 | 1.063 |
| 4 | 1.062 | 1.063 |
| 5 | 1.064 | 1.064 |
| Total | 5.314 | 5.314 |

$$\text{Average Reading—“old” hydrometer} = \frac{5.314}{5} = 1.0628$$

$$\text{Average Reading—“new” hydrometer} = \frac{5.314}{5} = 1.0628$$

Difference = 1.0628 – 1.0628 = 0; use the “new” hydrometer.

Example 2

| Measurement | Reading with “Old” Hydrometer | Reading with “New” Hydrometer |
|-------------|----------------------------------|----------------------------------|
| 1 | 1.063 | 1.066 |
| 2 | 1.062 | 1.065 |
| 3 | 1.061 | 1.064 |
| 4 | 1.062 | 1.066 |
| 5 | 1.064 | 1.066 |
| Total | 5.312 | 5.327 |

$$\text{Average Reading—“old” hydrometer} = \frac{5.312}{5} = 1.0624$$

$$\text{Average Reading—“new” hydrometer} = \frac{5.327}{5} = 1.0654$$

Difference = 1.0654 – 1.0624 = 0.003 > 0.002; contact your TSR to determine which hydrometer is correct.