Application Note: Using the Turner Designs Model 10-AU Fluorometer to Perform Flow Measurements in Sanitary Sewers by Dye Dilution

Instrument set-up: Model 10-AU Digital Fluorometer equipped with the 13 mm x 100 mm cuvette holder; and a 10-056/10-056R (546 nm) Excitation Filter, a 10-052/10-052R (>570 nm) Emission Filter, 10-053/10-053R (>535 nm) Reference Filter, and 10-046 Clear Quartz Lamp, installed.

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SUMMARY OF THE METHOD

Flow in sanitary sewers may be measured to an accuracy of ± 1% using fluorescent dye dilution techniques.

This procedural guide includes step-by-step instructions for using the Turner Designs Model 10-AU Digital Fluorometer for measuring flow in sanitary sewers.

Since there is no need to crawl a manhole, the procedure can be done by one person. Samples may be measured on the spot, or if preferred, may be taken to the office or a lab and measured at your convenience.

Detailed discussion of principles, equipment, sample collection, preparation of standards, and flow rate calculations can be found in the Turner Designs monograph, "Fluorometric Facts: Flow Measurements in Sanitary Sewers by Dye Dilution" (referred to hereafter as "Sanitary Sewers").

The procedure requires:

1. Setting the basic operating level of your fluorometer (this only needs to be done once, prior to running samples for the FIRST time).
2. Obtaining Standards & Blank
3. Measurements:
   a. Recovery ratio test
   b. Reading samples
4. Flow rate calculation.

SETTING THE BASIC OPERATING LEVEL

The basic operating level of your fluorometer is set on screen 3.2 using the Sensitivity Adjustment Knob.

```
Fluorescence readout: XXXX.XXX
PM signal output: XXXX.XXX

Cal std val: XXX.XX Blank:  XX.XXX
FS: XX% of XXXX.XXX (PPB) at HIGH
Span level%: 48
<ENT> to next screen                #3.2
```

Diagnostic Screen #3.2

Your user's manual contains detailed instructions for setting the basic operating level (Appendix 5B of the Model 10-AU-000 Laboratory Fluorometer User's Manual and Appendix 6B of the Model 10-AU-005 Field Fluorometer User's Manual).

Once the basic operating level (sensitivity) is set, you should not have to adjust it unless you want to drastically increase or decrease sensitivity.

Through experience, we have found the following operating level to be appropriate for flow measurements in sanitary sewers.

The maximum concentration you will wish to read is 500 ppb (0.5 ppm). This is the upper limit of the linear range for rhodamine WT. While this limit is actually dependent on the path length of the cuvette, this is a safe figure for even the largest cuvette.

Prepare a dilution of 100 ppb of Rhodamine WT. This standard does not have to be very accurately prepared. It will not be used to standardize the instrument during calibration. Its purpose is to adjust the instrument to optimum operating level -- which is quite broad. To prepare the 100 ppb dilution:

1. Dilute 1 ml of the pure tracer (20% aqueous solution) to 1000 ml.

2. Then 1 ml of this initial dilution to 100 ml.

3. Finally, 1 ml of the second dilution to 100 ml.

Take care not to spill any liquids inside the fluorometer's sample chamber. If you do have a spill, turn off the fluorometer immediately and consult the Sample System appendix of your user's manual. Wipe up splashes on the instrument's exterior promptly.

Procedure:

1. Turn on the fluorometer and allow to warm up for 10 minutes.

2. On the keypad, access screen 2.0, Calibration. Press <6> once and then <9> five times to reset calibration defaults.

3. From screen 2.0, press <4>, then <2> to access screen 2.42. Set the concentration range to HIGH.

4. Access screen 3.2, Diagnostic.

5. Loosen (do not remove) the Sensitivity Knob Lock (hex screw to the left of the keypad; see Figure 1 in the user's manual) with the 5/32" Allen wrench (behind, lower right of the keypad).

6. Fill a clean 13 mm test tube with the 100 ppb dilution. Dry the outside of the tube with a lab wipe and insert it in the opening to the sample compartment. Replace the light cap.

7. On screen 3.2, look at the third line from the bottom: FS: XX% of XXX (ppb) at HIGH. Turn the Sensitivity Knob (large screw to the lower right of the keypad) slowly, pausing between adjustments for the reading to stabilize, until the FS % reads approximately:

   FS: 20% of 900.000 at HIGH

   Turning the Sensitivity Knob clockwise increases the FS %; turning it counter-clockwise decreases FS %.

8. When an FS % of about 20 is reached, use the Allen wrench to tighten the Sensitivity Knob Lock. (IMPORTANT!)

9. Remove the 100 ppb dilution from the fluorometer and set aside.

10. Proceed to the next section.

OBTAINING STANDARDS AND BLANK

Standards are required to calibrate the fluorometer precisely in terms of the dye that you injected.

For detailed instructions for sample collection and preparation, preparation of your Sewage Blank and preparation of your Sewage and Recovery Standards consult the "Preparation of Standards" section of the "Sanitary Sewers" monograph.

Definitions:

Recovery Standard: A dilution of the dye--exact same dilution as the sewage standard--being injected made with deionized water (distilled water). The purpose of the "recovery standard" is to see whether the reading of a given concentration of dye is the same in clean water and sewage -- in other words, whether the dye is all "recovered" in sewage.

Sewage Standard: A known dilution of the dye being injected mixed with sewage collected just prior to the start of dye injection.

Sewage Blank: Sewage collected just prior to the start of dye injection. This will represent the amount of fluorescent materials occurring naturally in the system, expressed as a concentration of the fluorescent material being measured.

To perform your recovery ratio test and run your samples, you will need:

1. One cuvette filled with a blank of distilled water.
2. Two cuvettes filled with Recovery Standard.
3. Two cuvettes filled with Sewage Standard.
4. One cuvette filled with Sewage Blank.

   If you are studying Blank variability, you may have a number of cuvettes filled with Sewage Blank. Refer to the "Dye Injection - Dye Concentration" section of the "Sanitary Sewers" monograph.

5. Your various samples, each in its own cuvette.

MEASUREMENTS

We are looking for the ratio of the Sewage Standard to samples (i.e., the readings of samples relative to the Sewage Standard). Thus, we will set the Model 10-AU to subtract the Sewage Blank, but will not use a known concentration of the Sewage Standard, only a known dilution.

Readings will be taken from the HOME screen or Screen 3.2 (see explanation, below):

```
CONC: MED (MAN)                    XXX (PPB)
Time Const: 2 (SEC)

0            499                          999

<?> for help                 4:42:05 PM 1/25/93
```

HOME Screen

If you prefer to see more digits than are shown on the HOME screen (XXXX.XXX), you MAY record your readings from the Diagnostic screen 3.2. The reading from the top line of this screen is what is sent to the HOME screen, rounded off to three digits. To avoid inconsistency, record readings from the HOME screen or screen 3.2, but not both.

The Model 10-AU has two features of special interest for this method:

1. The Discrete Sample Averaging capability, where the instrument averages a reading over a preset period, allowing you to read samples after they have been in the instrument for the same time. This minimizes errors due to temperature changes and removes the guesswork from reading the digital display. Defaults for this feature on the Model 10-AU are 15 seconds pre-delay for the signal to stabilize, and an averaging period of 10 seconds. (To change these periods, access screen 1.63. See the appendix on Operational Parameters, screen 1.63, of your user's manual.) To use Discrete Sample Averaging, after putting in a sample, **from the HOME screen**, press <*> and the instrument will countdown a delay period, average the reading, and then display "DONE" in the upper right hand corner of the screen. The averaged reading will be displayed for 10 seconds so you can write it down.

2. Auto-ranging. In AUTO, the fluorometer will automatically select the range with the best resolution for the sample being read. You will, however, have to wait for the instrument to change ranges, as well as for the reading to

stabilize. The instrument will change ranges whenever the light cap is removed. (To set to auto-ranging, access screen 2.43 and set to AUTO.)

For these reasons, we recommend that you read samples in the manual mode (MAN, set on screen 2.43).

The best resolution is obtained by reading samples on the lowest range possible. In most however, even if you read all of your samples on the HIGH range you will obtain adequate results, as the 10-AU has been designed with good range-to-range correlation.

Recovery Ratio

Before proceeding, if you have not already done so before using the instrument for the FIRST time, set the basic operating level of your fluorometer as described in the previous section.

Recovery Ratio tests are important in predicting the precision of your flow measurements and guiding you in improving this precision.

1. Turn on the fluorometer and allow it to warm up for 10 minutes.

2. From the Main Menu, press <2> to access screen 2.0, Calibration.

3. Set the concentration range control to MAN. From screen 2.0, press <4> to bring up screen 2.4, then <3> to bring up screen 2.43 (set conc. range control), and press <ENT> to toggle.

4. Set the concentration range to MED. From screen 2.4, press <2> to bring up screen 2.42 (change concentration range), and press <ENT> to toggle. Return to screen 2.0.

5. To run the Distilled Water Blank, press <1> to access screen 2.1. Make sure #2 on screen 2.1 reads YES. Then, from screen 2.1, press <1> to call up screen 2.11.

```
Use UP or DOWN arrow to set Blank %
to less than 200%!
                    Blank%:

TC: 8 (SEC)   Range: MED          Span: 48%
Press <0> after reading is stable!   #2.11
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Screen 2.11

If you wish to abort the blank run and revert to the former calibration settings, press <ESC> before pressing <0>. This will retain the current settings for Span and blank.

Fill a clean 13 mm test tube with a blank of distilled water. Put the blank into in the sample chamber and replace the light cap. After the Blank % reading is stable ("TC" on screen 2.11 cycles from 1 to 8 sec) and assuming the Blank % is less than 200%, press <0>. When "FINISHED" appears, press <HOME>.

For this procedure, do not adjust the Span% by pressing the UP or DOWN arrows. Span% should remain at the default of 48.

Remove the Distilled Water Blank.

6. Set the concentration range to HIGH. From screen 2.4, press <2> to bring up screen 2.42 (change concentration range), and press <ENT> to toggle. Go to the HOME screen (or screen 3.2).

7. Insert a cuvette containing your Recovery Standard. Record the reading from the HOME screen (or screen 3.2).

   This reading is not an actual concentration. Since you have not calibrated with a standard of known concentration, what you are reading is relative concentration. You only need to know relative concentration for this method.

8. Insert a cuvette containing your Sewage Standard. Record the reading from the HOME screen (or screen 3.2).

9. Insert the cuvette containing your Sewage Blank. Record the reading from the HOME screen (or screen 3.2). For better resolution, read on the MED range.

10. Subtract reading 9 from reading 8. This net reading is the reading due to the dye present in the sewage.

11. Divide the net reading from step 10 by the reading from step 7 to get the Recovery Ratio. To see what the ratio means, refer to "Recovery Ratio Test" in the "Sanitary Sewers" monograph.

12. Proceed to the next section.

Reading Samples

Remember, we are looking for the ratio of the Sewage Standard to samples (i.e., the readings of samples relative to the standard). It is presumed that you have just run the Recovery Ratio described above.

Continuing from the Recovery Ratio section:

1. Insert the cuvette containing your Sewage Blank. (For better resolution, read on the MED range--access screen 2.42 to change ranges.) Record the reading from the HOME screen (or screen 3.2).

   If you prefer, you may run this as your actual blank, in place of distilled water. However, it is useful to know how large the Sewage Blank is. If it is small compared to the standard and samples, then you are more confident of the relative accuracy of the test. If a small blank varies by a few percent, it is negligible. If a large one varies the same percentage, the error in the answer will be proportionately larger.

   Therefore, we recommend that you leave the Distilled Water Blank set to zero. This way you definitely have a record of the magnitude of the Sewage Blank; repeats will always have positive values; and you may average 3 or more cuvettes of Sewage Blank for greater accuracy. You will always work with the net reading: sample (or standard) minus the Sewage Blank.

2. Set to the HIGH range on screen 2.42. Insert the cuvette containing your Sewage Standard into the instrument. Record the reading from the HOME screen (or screen 3.2).

   As with the Sewage Blank, you may want to read and average 3 or more cuvettes containing the Sewage Standard.

3. One by one, insert the cuvettes containing your samples and record the readings from the HOME screen (or screen 3.2).

   For better resolution, read your sample on the lowest range in which you can obtain an on-scale reading. In the MAN mode, access screen 2.42 to change ranges. (In AUTO, the instrument will find the best range.)

   If you see OVER on the LOW or MED range, access screen 2.42 and change to a higher range.

   If any sample reads "OVER" on the HIGH range, you must dilute the sample. Refer to the "High Concentration Measurements" section of the "Sanitary Sewers" monograph.

4. When all samples have been read, and you are finished for the day, turn off the fluorometer.

   NOTE: If you are going to be reading samples off-and-on over the course of a few days, leave the fluorometer on; it won't hurt it.

FLOW RATE CALCULATION

The mathematical equation normally used to calculate flow is:

1. $Q = q\ C/c$

   Where:

   Q is the flow being measured
   q is the dye injection rate
   C is the concentration of the injected dye
   c is the concentration of dye measured downstream of injection

Since fluorescence is normally proportional to concentration, a more practical form of this equation is:

2. $Q = q \times Rst\ D/r$

   Where:

   Q is the flow being measured
   q is the dye injection rate
   Rst is the reading obtained on your standard
   r is the reading obtained on your sample
   D is the dilution ratio, used to prepare the standard

We will use equation 2.

Sample Readings (r). Sample readings are net readings, IF sewage blank was set to zero. If the distilled water blank was set to zero, then subtract the sewage blank reading from all readings, including the **standard (Rst)**, to obtain the actual net reading.

Injection Rate (q). The Injection Rate is normally determined by finding the time it takes to fill a volumetric flask, See DYE INJECTION -- Calibrating the Injector in the "Sanitary Sewers" monograph.

Since volumetric flasks are calibrated in milliliters and elapsed time is most easily measured in seconds, we must make a conversion.

Two handy numbers are:

milliliters x .0002642 = U.S. gallons
milliliters x .00003532 = cubic feet

As an example, let's presume that when you tested your dye injector, you found that it took 158 seconds to fill a 100 ml volumetric flask.

This means that the flow rate was 100 divided by 158, or 0.631 milliliters per second, or 37.85 milliliters per minute.

If you wish your final answer to be in mgd, then the rate of dye introduced must also be in mgd.

To convert milliliters per minute to gallons per minute, multiply 37.85 by .0002642, yielding .01 gallons per minute, or 0.00001440 mgd.

If you wish your final answer to be in cubic feet per second, then convert milliliters per second (0.631) to cubic feet per second by multiplying 0.631 by .00003532, yielding .00002287 cubic feet per second.

Standard Dilution Ratio (D). You have already selected a Standard Dilution Ratio. See PREPARATION OF STANDARDS in the "Sanitary Sewers" monograph.

In the example given, it was 100,000 (two 100-fold and one 10-fold: 100 x 100 x 10 = 100,000).

Example:

We wish to calculate the flow in mgd.

q = 00.0000144 mgd (Injection Rate)
Rst = 95.4 (Dye Reading)
r = 24.8 (Dye Reading)
D = 100,000 (Standard Dilution Ratio)
Q = 0.0000144 x 95.4 x 100,000/25.8 = 5.32 mgd, or more reasonably stated, 5.3 mgd.

Of course, if you are measuring several flows from one injection, the obvious thing to do is calculate q Rst D, as r is the only variable, from sample to sample.