OPTIMIZING CLARIFIER DESIGN and PERFORMANCE

Prepared for:
The Water Environment Federation
Industrial Wastes Technical Conference
St. Louis, MO
May 2000

By: John K. Esler, P.E.[1]
ESLERCPE @ AOL.COM

INTRODUCTION:

Perhaps the most important thing to remember, when evaluating any wastewater treatment facility …. whether small, medium or large ….. is that it's performance is impacted by a combination of factors. These factors have been categorized by Bob Hegg in his EPA manual "Retrofitting POTW's" into the areas of operations, maintenance, design and administration. So, when evaluating and looking for opportunities to improve clarifier performance, please remember to investigate each of these functional areas for factors that may be limiting its performance.

How can you tell what's right for your clarifier? The answer is that often you can't tell without trying it out first at your plant. We've seen too many theories presented …. and nifty modifications proposed ….. that simply don't work in many wastewater plants. There are often small differences …. and sometimes major differences ….. between clarifiers that appear to look alike. This is a lesson that we must remember. Because of these differences, we have to learn to apply some caution when dealing with clarifiers; we have to try to find out first what makes your particular clarifier "tick". This is the real challenge in the evaluation process.

The following outline is a summary of ideas that are intended to help you avoid some of the problems that have been identified in clarifiers, and to point you in the right direction for change. Most of what I've written comes from our field experience, but some is from the shared experience of others. I think you'll be able to find something useful here that will make your life at the plant a bit easier.

I. REMEMBER THAT THE CLARIFIER IS A PART OF A SYSTEM

A. Preliminary Treatment: effects rag, grit and grease removal.
B. Equalization: what every operator dreams of; sized for production excesses and storm water.
C. Raw Sewage Pumping: should always be variable speed.
D. Cooling systems are major contributors, esp. for paper industry

1. President, CPE Services, Inc., Albany, NY

E. Aeration Units
1. Mechanical aerators:
   - May have an adverse impact on floc formation …. but it can be remedied.
   - Effect on heat transfer? Definitely, esp. in northern climates.
   - Effect on Nocardia scum production? You bet!!!
2. High-purity oxygen systems can increase a temperature problem.
3. Take advantage of the benefits of step aeration and contact stabilization for storing solids during high flow events.

F. Flow Distribution to clarifiers dramatically affects performance !!
1. Plan for future expansion ..... without compromising the present.
2. Lack of hydraulic balance often leads to poor distribution.
3. Design to avoid the "operational imbalance" caused by taking a clarifier out of service.
4. Automated flow-balancing systems work best when paced by open-channel effluent flow meters.
5. An upflow, overflow distribution box <u>of adequate size</u> ….. with adjustable overflow weirs ….. works best.
6. **<u>Always</u>** provide a flow measurement device for **<u>each</u>** clarifier!

G. Stormwater and Stormwater Storage Flows
1. Provide for bypass or storage to protect the biological process.
2. If no bypass ??
   a) Go to step-feed or contact stabilization mode.
   b) Reduce aeration (i.e. mixing) to retain solids in aeration.
   d) Force excess flow to one basin..... to save the solids in the other basins.
   e) Be wary of the temperature effects of the colder stormwater on the biological system and its settling characteristics.

H. Return Sludge Flows
1. Provide lots of pump capacity as well as good turn-down capability.
2. <u>Avoid</u> using a RAS pump header that serves multiple clarifiers.
3. Always provide <u>separate</u> RAS pumps for each clarifier ...... with individual flow meters …. that work!

II. IS SHAPE A FACTOR IN PERFORMANCE ?

A. "Yes" and "No"; rectangular and circular clarifiers each have their advantages and disadvantages due to their shapes.

B. **However**….. the **best**-**performing** clarifier….. as <u>tested</u> by the ASCE-CRTC protocol, and <u>proven</u> by time!….. is <u>rectangular</u> ….. 150' long by 20' wide ….. and only 9.5' deep! ….. and with **co**-current sludge removal! (L.A. County San. Dist. – San Jose Creek)

C. The **poorest** shape is the "squircle" (square) ….. followed closely by the "double squircle" …. and, yes, the "triple squircle"!

III. IS DEPTH A FACTOR ?

In unmodified clarifiers, additional depth has a beneficial effect, primarily for additional sludge storage. It may also be effective in reducing the solids loss from the upwelling current at the wall ...... but is it really cost-effective ?

Remember, the **best** clarifier (see II B) has only a **9.5-foot SWD**! So don't be fooled by rating curves that try to relate performance directly to depth.

IV. INTERNAL DETAILS HAVE A GREAT EFFECT ON PERFORMANCE

A. Influent flow balance: must provide a means to measure flow !

B. Inlet Design:
1. Avoid jetting.
2. Provide for flocculation: see L.A. City/County design for rectangular clarifiers; consider energy-dissipating centerwell for circulars **(** see new L.A. City-Hyperion plant design**.)**
3. Distribute flow horizontally ? Yes; see L.A. City/County design.
4. Distribute flow vertically ?
   - Yes ….. esp. in primaries or following fixed-film reactors.
   - Avoid blowing out the blanket with some nozzle-type inlets.
   - Be wary of the "waterfall" effect from straight influent weirs in rectangular clarifiers.

C. Sludge Withdrawal Mechanisms in Circular Clarifiers:
1. RAS draft tubes should be aligned horizontally, not vertically.
2. Manifold-type suction mechanisms have rotating seal concerns.
3. Slow collectors down?? Definitely should in squircles.
4. Speed them up?? Perhaps, esp. for heavier paper mill waste, or to avoid denitrification.
5. Avoid (like the plague!) collector arms with pantographic corner sweeps ...... as in squircles.

D. Hydraulic Sludge Withdrawal (RAS) Tube Flow Control:
1. Submerged gates/slots are difficult to control individually.
2. Telescopic valves <u>theoretically</u> provide better control, but they are difficult to adjust ….. and usually collect rags. Avoid them.
3. Use "twist-turn" type for easier control and maintenance.
4. Avoid plugging problems by reducing number of tubes in service.

E. Plow-Type Sludge Scrapers:
1. Standard plows are OK (may be even better than suction-type?).
2. Consider adding extra depth to scraper collectors (it's cheaper!).
3. Then, <u>maybe</u>, consider increased tip speed ….. to15 fpm +/-.
4. Spiral scrapers? A very expensive retrofit ….. not a "silver bullet"!
5. Spiral scrapers didn't improve treatment at Passaic Valley …. but did cost a lot of money!!!

F. Circular Centerwells:

1. Problems with scum? Design relief for it; use a skimmer blade, or, extend ducking scum trough into the centerwell.
2. Optimum depth? approx. ½ SWD; avoid DEEP centerwells.
3. Optimum diameter? 0.2 D+/-; avoid <u>LARGE</u> centerwells.
4. Designing to enhance flocculation? consider a dual (energy-dissipating) centerwell. (much better - the new "L.A.-Hyperion inlet")
5. Avoid using a return shelf ("lip") on the bottom of the centerwell.
6. Provide flocculators? They are effective in some chemical plants, esp. when using polymers; generally not useful in POTW's.

G. Scum Collection w/ Circular Clarifiers:

1. Dual skimmers are handy !! Avoid a perpendicular alignment.
2. Use large scum hoppers and drain pipes (8" min.).
3. Multiple scum hoppers are another (but more expensive) option.
4. Provide underwater flushing system for hoppers (Hinsdale, IL)
5. **Best idea:** Install "<u>scum squeegees</u> ", a simple, low-cost retro-fit !!!
6. Plan for getting lots of scum ...... like when there's Nocardia !!
6. Always provide for safe access to scum hoppers (Elizabeth, NJ).
7. Ducking skimmers? NG! Cost lots of $$$ …. return lots of water …. and preclude having the <u>useful option</u> of providing an algae sweep mechanism.
8. Full-radius scum beach? <u>Maybe</u> OK on smaller clarifiers.

H. Rectangular Sludge Collection (w/ scrapers):

1. MUST provide for scum removal !!!
2. How fast ? Normal rate is 2 fpm; 4+ fpm OK, esp. to avoid denite.
3. How slow ? 1 fpm OK w/ fixed film; maybe OK w/A.S. too.
4. What kind of chain? Non-metallic is easiest; and long-lasting!!
5. Traveling Bridges?
   a) They really complicate the collection process, <u>and</u>
   b) force the currents and flow to launders at the far end, <u>and</u>
   c) are difficult to correct for short-circuiting conditions, <u>and</u>
   d) can be maintenance night-mares! 'Nuff said??

I. Inlets for Rectangular Clarifiers:

1. L.A. City/County design is best ….. w/ baffled inlet pipes/diffusers.
2. Submerged gates w/ head differential OK, but plan for lots of scum removal from the distribution channel.
3. Deep inlet baffles are NG; they increase the density current effect.
4. Overflow weir inlet increases the density current and nocardia foam generation; plugs too easily.

J. Location of RAS Hoppers in Rectangular Clarifiers:

1. At inlet end is the standard condition. It's OK, but be prepared for dealing with the density current.
2. At middle (Gould type II) is best in long (200'+/-) clarifiers; will have density currents in first half …. and <u>variable</u> currents in second half!
3. At effluent end ?? This works great at all L.A. County plants!

V. WEIR PLACEMENT IS CRITICAL!!

A. In Rectangular Clarifiers (w/o baffles):

1. Worst Conditions:
   - a) at or near the end wall
   - b) close together
   - c) with launders deeper than necessary.
   - d) with short (finger) weirs perpendicular to end wall.
   - e) with submerged pipe launders.
2. Better Conditions:
   - a) covering at least 20% of surface.
3. Best Conditions:
   - a) covering at least 30% of surface.
   - b) having the ability to measure the flow.
   - c) w/ adjustable weirs that are able to be taken out of service.
   - d) no deeper than necessary !!
   - e) parallel to the flow (see L.A. County/City)

B. In Circular Clarifiers (w/o baffles):

1. Worst Conditions:
   - a) with a single perimeter weir that’s flush w/ face of wall, or even cantilevered inward.
   - b) an inboard launder that's deeper than necessary.
   - c) an inboard launder that’s too close to the wall.
   - d) a single perimeter weir with a close inboard launder.
   - e) some peripheral feed (downward flow) w/ peripheral weirs.
2. Better Conditions:
   - a) an inboard launder ...... but, not too deep!
   - b) spiral flow (peripheral feed) w/ central launders.
   - c) “Rim-Flo” peripheral feed (downward flow) w/ peripheral weirs.
   - d) a good flocculating centerwell w/ inboard launder.
3. Best Conditions:
   - a) a good flocculating centerwell w/ dual launders.
   - b) the new “L.A.” flocculating/ energy-dissipating inlet

VI. THE EFFECT OF MAINTENANCE ON PERFORMANCE

- Periodic Maintenance: dewater and inspect at least once/yr.
- Torque Overload Protection should be checked frequently.
- Rotating bottom seals (on suction manifolds) are difficult to check; should dewater in order to inspect properly.
- RAS well center column seal needs periodic replacement.
- Weir leveling is very important.
- Algae growth can actually shut off flow over portions of the weir. Plan for periodic cleaning ….. or else!

- For effective algae control …. consider that:

1. hypochlorite solution piping under water near the weir can work.
2. automatic brushing systems are slick!(AKA the "algae sweep")

For safety's sake, provide …..

1. safety screens/bars at the outlet of the effluent launders.
2. safe access to the launders and the scum hopper.
3. for easy access for maintenance of gear drives.

VII. THE EFFECT OF OPERATIONS ON PERFORMANCE

A. Sludge Blanket Level Control: a critical activity.
- Keep blankets low as best way to accommodate high flows.
- Increase the blanket monitoring activity during high flows
- Manual core samplers are reliable; keep them clean.
- Some automatic blanket detectors are reliable.
- Hand-held electronic blanket detectors are very useful; they provide for uniform measurements by staff, esp. w/ typically poor lighting conditions at the clarifiers.

B. SVI Control:
- It's the most important operational activity.
- Every operator should know how to identify and control filaments (or have access to someone who does!).
- Plants should have a good phase-contrast microscope.

C. MLSS Control:
- It's your call on the proper concentration; i.e. use whatever works best for your process and your sludge dewatering.
- Generally, a lower MLSS is better.(i.e. lower solids loading)

D. Nutrient Control: be aware of N and P requirements.

E. Be <u>diligent</u> about scum removal, esp. for controlling odors and to reduce freezing problems.

F. Flow Balancing:
- <u>Must</u> measure and control flow to (or from) each clarifier; that means ….. install flow measurement weirs, etc.
- <u>Must</u> measure and control RAS flow from each clarifier

G. RAS Control:
- RAS rate can effect hydraulic performance, esp. in circular clarifiers.
- RAS rate effects treatment time in aeration reactors.
- RAS tube selection: control tubes/take tubes out of service to optimize RAS concentration and blanket control.
- "Solids Flux / State Point" concept: may be useful in predicting the typical clarifier blanket failure.
- Remember the basics of “pounds out" (as RAS) must balance the "pounds in" (as MLSS).

- The diurnal fluctuation of blanket levels yields a helpful diurnal change in the RAS concentrations.

H. Effluent TSS monitoring
- Monitor the ETSS periodically from <u>each individual clarifier</u> for better process control.
- Compare clarifier ETSS with settleometer supernate TSS for better clarifier process control.
- Use DSS and FSS tests for diagnostic observations.
- Occasionally, check the diurnal ETSS pattern.
- Use a low-level TSS meter or turbidimeter for on-line control.

VIII. USE OF POLYMERS (primarily for industrial plants)

A. Consider CEPT (chemically enhanced primary treatment) to reduce biological loadings on secondary systems.
B. Consider polymer use to enhance flocculation for improving settling rate/reducing sludge blanket thickness/reducing ETSS.
C. Consider its use for control of certain types of filaments.
D. May be a cost-effective temporary solution (esp. during wet weather events), and even a cost-effective <u>long-term</u> solution (i.e. instead of adding more clarifiers).
E. Laboratory jar testing should mimic the actual plant conditions with respect to mixing time and mixing intensity.
F. Always use the "stirred" settlometer test for determining SSV's for SVI when using polymers.
G. Provide for multiple feed points/effective initial mixing/distribution.
H. Be wary of the effect of a more compact blanket on collector torque.

IX. STEPS IN ANALYZING CLARIFIER PERFORMANCE

First ………..

A. Determine the flow distribution to each individual clarifier.

B. Determine the individual clarifier return sludge flows; confirm flow meter accuracy.
C. Monitor the biological or chemical treatment performance with respect to flocculation (use microscope; jar tests; settleometer)
D. Determine individual clarifier ETSS performance at various overflow rates and blanket conditions.
E. Monitor changes in blanket profiles at selected locations; monitor the diurnal blanket changes.

F. Monitor effluent turbidity.

G. Look for diurnal ETSS variations (esp. the time of the peak ETSS).

H. Optimize the activated sludge quality for your plant conditions.

Then ……..

Determine the Actual Clarifier Hydraulic Characteristics.

1. Determine the actual detention times.
2. Determine overall flow patterns for different conditions.
3. Look for reverse currents; unusual currents.
4. Examine the currents at different depths and locations.
5. Determine the effects of the individual launders and weirs.
5. Determine the location and intensity of short-circuiting currents.
6. Look for temperature effects, esp. following fixed-film reactors or with warm industrial wastes (and esp. in primary clarifiers).
7. Determine the impact of higher and lower RAS rates.

X. IMPROVING INTERNAL CLARIFIER HYDRAULICS

A. This is …. by far …. the most cost-effective means of improving clarifier performance and increasing plant capacity!!

B. Refer to the work of Bob Crosby in circular clarifiers:

1. the Crosby sloped-peripheral baffle (@ Stamford, CT, it improved average ETSS by > 30%); does not reduce short-circuiting and does increase bottom currents; must have at least 45^{o} slope.
2. the Crosby mid-radius/cylindrical baffle: CPE projects @ Franklin, (NH), improved ETSS by >35%); worked well at Atlanta (GA), etc.; does reduce short-circuiting and provide for additional flocculation.
3 "Distributive Centerwell" (@ Stamford, CT and at an industrial site), didn't reduce short-circuiting; didn't improve ETSS. Don't repeat it!

C. A combination of Crosby peripheral baffle and Crosby mid-radius baffle ..... may be more effective than either one individual baffle. See CPE projects @ Augusta (ME) ….. a 1997 EPA award-winner; and New Haven (CT))

D. The peripheral horizontal shelf baffles may not improve performance enough (Atlantic City, Orlando, Hyperion - L.A.); and they always, always collect solids on the surface!

E. Use interior baffles in rectangular clarifiers (Esler-Miller baffles)

1. The right baffle will improve most clarifiers
2. Beware! The wrong baffle(s) can make them worse !
3. Two baffles are better than one.
4. Three baffles can be better than two (Branford, CT).
5. Four baffles are even better. (Waterford, NY)
5. Avoid horizontal end-wall baffles.

F. Focus on improving the center feedwell to give better flow distribution and minimize currents, esp. with scraper-type clarifiers; see the new L.A.-Hyperion flocculating EDI inlet.

X. SOME INNOVATIONS (Some are good ...... but some are not so good !!)

A. Stacked rectangular units in parallel:

1. This is a difficult clarifier to maintain and operate: consider especially the confined space entry requirements …. and monitoring the blanket in the bottom unit!
2. They will have the same (poor) hydraulic characteristics as most counter-current sludge withdrawal rectangular clarifiers.
3. Haven't worked well at the Boston project (MWRA-Deer Island)
4. Worked better at Mammaroneck, NY.

B. Stacked rectangular units in series (experiment in Sweden):
This experiment failed due to the overload of the bottom unit.

C. Multiple compartments in series in rectangular clarifiers:

1. This system is used in Japan's best-performing clarifiers!
2. Can be an excellent retro-fit for existing clarifiers.

D. End-around / Folded-flow / "Boomerang" configurations:
Worked well at Toronto and at NYC's Hunt's Point plant.

E. Lamella / tubes / trays are not recommended for biological systems.

F. DEEEEEP clarifiers: Are they really worth the extra $$$$$?

I. "Standard " dual centerwells / energy-dissipating inlets: this EDI should enhance flocculation (somewhat), but it is certainly <u>not</u> the "cure-all" that it is claimed to be! i.e. The clarifier will still have <u>strong</u> density currents (Orlando; Cedar Rapids), maybe even <u>worse</u> currents (Atlantic City). This standard type of EDI can even cause premature **clarifier failure**!!!! (see L.A.-Hyperion project).

CLOSING THOUGHTS:

- Use a "holistic" Comprehensive Process Evaluation approach to evaluating and improving clarifier performance. i.e. Identify all the performance-limiting factors in the Design / Operation / Maintenance / and Management of the biological system as well as in the clarifier system. There are usually several of these factors present that are limiting the clarifier's performance. Your challenge is to find them and optimize them!

- Making your existing clarifiers (with a 20% to 30% hydraulic efficiency) more efficient is much more cost-effective than adding more of the same inefficient clarifiers! Always start by considering that your existing clarifiers are units with a money-saving potential !!

- If you haven't already read it, do read (and re-read) the US-EPA Technology Transfer release on "Hydraulic Considerations That Effect Secondary Clarifier Performance" (1980), by Bob Crosby and Jon Bender. It has a lot of good observations for both operations people and design engineers.

- Don't forget your primary clarifiers! These units are also effected by many of the same conditions that cause problems in secondary clarifiers. Remember ….. this is where you can remove BOD most economically ….. and where you often have real opportunities to capture more materials for recycle and re-use. Improvements in primary clarifier performance will pay multiple dividends!!

- Wherever possible, provide for equalization of influent flows and sidestream loadings!

Remember ….. There are a lot of good ideas ….. here and elsewhere ….. for your clarifiers. However, you'll never know if they're right for you unless you try them! Just go for it!!!

Note: This outline is presented with gratitude for and in appreciation for the good work begun in the 1970's and 1980's by the late Bob Crosby. His insight and ingenuity and principles have always been an inspiration for our work.