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EPA

# Project Summary

# Post Construction Performance of Schreiber Counter-Current Aeration Facilities

As of the Fall of 1984, 22 Schreiber counter-current aeration* facilities were funded as innovative technology. The system employs air diffusers mounted at the bottom of a rotating bridge in a circular aeration tank. This aeration configuration is claimed to reduce energy costs by providing higher oxygen transfer efficiencies than alternative methods.

A total of 10 plants was contacted and both verbal and written information relevant to process performance, equipment reliability, and capital and O&M requirements were obtained. Furthermore, approximately 6 months of intensive plant monitoring were performed at Carlisle and Hampden, PA and Claiborne County and Loudon, TN. Blower power demand, blower run times, process loading information, and effluent quality data were collected to estimate aeration requirements and document process performance. Historical operating records were also utilized to estimate energy requirements over a longer time frame. The field studies summarized in this report were completed in 1985, but the report contents were substantially expanded in response to peer review comments. Final report revisions were completed in September 1987.

Based on an assumed oxygen requirement of 2.5 lb $O_2$/lb BOD applied, the estimated oxygen transfer varied from 1.42 lb $O_2$/HP·hr at Hampden to 4.12 lb $O_2$/HP·hr at Carlisle during the intensive observation period. Results from clean water testing performed by others are summarized in the report, and these efficiencies varied from 4.6 to 6.56 lb $O_2$/HP·hr. The reduced oxygen transfer efficiencies in wastewater may be presumed to represent both the influence of alpha and diffuser fouling.

Effluent at the Carlisle facility has normally had a $BOD_5$ less than 10 mg/L and SS less than 20 mg/L. Effluent quality at Hampden was normally even better. Loudon has experienced significant effluent solids problems and effluent solids frequently exceeded 30 mg/L. Schreiber was reported to provide excellent field service in response to maintenance problems.

*This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

## Introduction

The Clean Water Act of 1977 and the Municipal Wastewater Treatment Construction Grant Amendment of 1981 include provisions that encourage the use of innovative and alternative wastewater treatment technologies. The counter-current aeration system is a German technology that is proprietary to the Schreiber Corporation of Trussville, AL. As of the Fall of 1984, 44 wastewater

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

treatment plants were either operating or under construction in the United States. There were 22 counter-current aeration facilities funded as innovative technology projects. The basis for the innovative approval was energy savings in 20 cases, both cost and energy savings in 1 case, and cost savings alone in 1 case.

The specific objectives of this investigation were to gather information on Schreiber installations related to the following broad areas of interest:

- Process Performance,
- Equipment Reliability,
- Capital, Operating and Maintenance Costs, and
- Energy Efficiency.

## Schreiber Counter-Current Aeration System

The Schreiber counter-current aeration system consists mainly of air diffusers mounted at the bottom of a rotating bridge in a circular aeration tank (Figure 1). The diffuser density is varied with bridge position so that increasing amounts of air are supplied from the tank center to the tank periphery. The revolving bridge is centrally fixed in the aeration tank at a pivot point and is supported by a rubber-tire drive assembly on the top of the aeration tank wall. It travels at a velocity of roughly 2.8 to 3.5 ft/s at the tank periphery and completes one tank revolution about every 2 min in a typical design. Baffles are installed in the aeration tank to reduce the mixed liquor velocity. Although the process is called counter-current aeration by the manufacturer, both the bridge and liquid rotate in the same direction. For smaller installations, the secondary clarifier is normally incorporated into an unaerated circular center tank while for larger installations a separate secondary clarifier is utilized.

The Schreiber aeration configuration is claimed to reduce energy costs by providing a higher oxygen transfer efficiency (OTE) than alternative methods. Typically this aeration system has been installed in low load systems with a F/M ratio of $\pm$ 0.05 kg $BOD_5$/kg MLVSS/day and a hydraulic detention time of around 24 hr. Positive displacement blowers are recommended. Schreiber also offers a DO control system consisting of a DO probe, a receiver/transmitter, and a programmable controller. Under automated DO control, the number and sizes of blowers in operation are automatically varied in response to the DO level at a given point in the reactor at a defined time relative to the moving bridge. Brandol 60 fine bubble diffusers were installed on all systems evaluated in this study.

## Study Protocol

Initially, a list of 27 facilities was reviewed at a July 1984 meeting among U.S. EPA, Roy F. Weston, Inc., and Loren Nielson, President of Schreiber Corporation, to discuss candidate facilities to be evaluated. During this meeting some facilities were rejected because they were still under construction, were package-type plants, or were second-stage treatment applications. After this meeting there remained 10 candidate sites for detailed analysis, and preliminary information on process performance, costs, and equipment reliability was gathered from these sites. The following selection criteria were used to select five facilities for more detailed analysis:

- Operating experience of greater than one year,
- Absence of significant design or operating problems in other areas of the facility that would prevent or inhibit normal operation of the activated sludge process,
- A sufficient quantity and quality of historical influent and effluent data,
- Emphasis on selecting plants with automated blower control system furnished by Schreiber Corporation,
- Availability of run-time meters for aeration blowers, and
- Willingness to participate in the study.

Because of operating practices and maintenance problems observed at one of the five facilities during the initial site visits, extensive field studies were restricted to the installations shown in Table. 1.

Carlisle, Hampden, and Loudon utilized Schreiber equipment throughout and are totally new facilities. Claiborne County is an upgrade project utilizing Schreiber equipment (including counter-current aeration) in selected areas of the facility.

During the initial site visits, a variety of specific activities were performed which included:

- Power measurements taken for all operational aeration blowers and bridge drives,
- Air flow measurements taken for the air supply to the aeration basin (where appropriate),
- Calibration checks of the aeration basin mounted DO probe (where appropriate),
- Visual inspection of exposed air piping and seals for leakage,

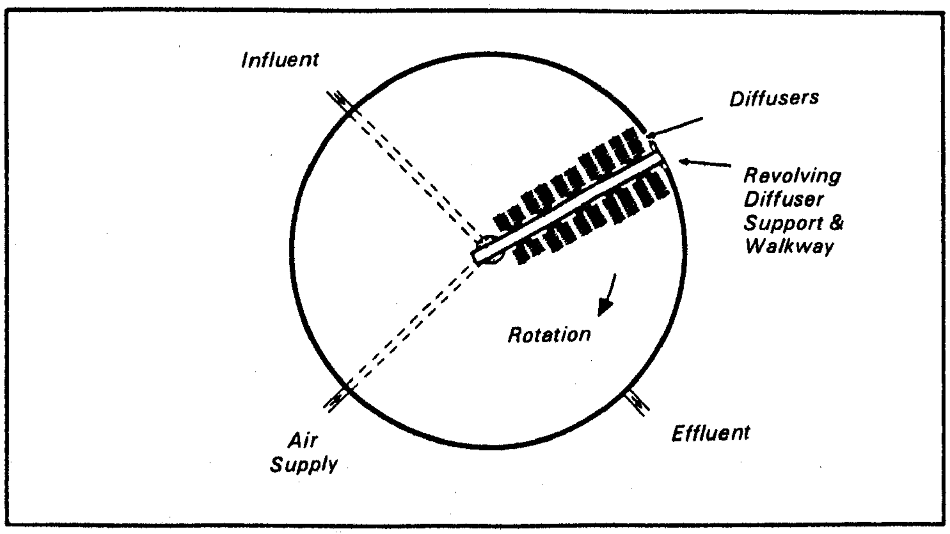


*Figure 1. Typical Schreiber aeration tank layout.*

*Table 1. Facilities Selected for Detailed Evaluation*

| Location | Design Flow, MGD | DO Control Strategy | Blower Sizes per Tank, HP |
|---|---|---|---|
| Carlisle, PA | 1.2 | Timer | 10,20 |
| Claiborne Co., TN | 0.65 | Automated | 15,15,15 |
| Hampden, PA | 2.5 | Automated | 15,30,60 |
| Loudon, TN | 7.0 | Automated | See Text |

- Review and discussion with plant personnel of laboratory analytical and sampling techniques,
- Review and summary of equipment maintenance histories,
- Collection of split samples of the plant influent and effluent for analysis by the plant and Weston laboratories, and
- Collection of historical plant operating data.

Following the initial site visits, additional influent and effluent samples were collected at each of the four plants and split for plant and Weston analysis. After approximately 6 months of intensive plant monitoring, final visits were made to each plant to remeasure power levels and review overall plant performance and operation.

## Oxygen Transfer Efficiencies and Aeration Requirements

The four systems intensively evaluated in this study were all operated at low F:M ratios. All of the systems were nitrifying and the split sample data indicate some denitrification was also occurring. Detailed estimates of oxygen requirements presented in the report show that, for a typical municipal wastewater, the total oxygen requirement in a nitrifying extended aeration system should not exceed 2.5 times the influent $BOD_5$ concentration and is probably closer to $2.1 \pm 0.1$ times the influent $BOD_5$ even with no credit for denitrification. For purposes of data analysis in this study, estimates of aeration efficiency were made using a factor of 2.5 lb of oxygen consumed per lb of $BOD_5$ applied. This method was chosen because in some cases this was the design basis utilized to size the aeration systems evaluated and it is an extremely conservative estimate of oxygen requirements.

A summary of the power requirements and aeration efficiency estimates is presented in Table 2. Results are presented both for the 6-month period of intensive observation and for the long-term historical data collected at the various plants. The Carlisle estimate during the intensive observation period includes a 2-month period when blowers were shut off for a total of 3 to 6 hr per day in an experimental operating procedure to promote denitrification. The normal operating efficiency is expected to be less than 4.12 lb of $O_2$/HP·hr. The Hampden estimate reflects higher average air flows per foot of diffuser (2.27 scfm/ft) than those at Carlisle (0.96 scfm/ft) and Claiborne County (0.85 scfm/ft) accounting for some of the difference in oxygen transfer efficiency among the plants.

The data for the intensive observation period at Loudon represent one aeration basin with excessive air flows per diffuser and use of a less efficient blower (cfm/KW) than the blowers originally installed by the Schreiber Corporation. The additional centrifugal blower increased the aeration capacity to 156% of that originally installed (6, 30-HP blowers) and was added because of a plant design evaluation and recommendation made by a consulting engineering firm other than the design engineer. These factors mean that the energy consumption and estimates of the lb $O_2$/HP·hr consumed during the period of intensive observation at Loudon do not represent values that would be associated with a typical Schreiber installation.

Oxygen transfer efficiencies from various clean water tests performed by others and estimates for wastewater from this study (excluding Loudon) and from other literature values are summarized in Figure 2. The clean water OTE's vary between 4.6 to 6.56 lb $O_2$/HP·hr where the power includes both the blowers and bridge drive. The reduced oxygen transfer efficiencies in wastewater may be presumed to represent both the influence of alpha and diffuser fouling. The relative influence of these two parameters cannot be ascertained from the data available. Diffusers removed from the Claiborne County installation and subjected to laboratory analysis were shown to have experienced increased head losses. The dynamic wet pressure averaged 30.5 in. of water at 1.5 scfm in comparison to 4.8 in. of water for a new diffuser at the same air flow.

The measured energy requirements for BOD removal during the period of intensive plant monitoring were 1.00, 1.11, and 2.86 kwh/kg BOD applied at Carlisle, Claiborne County, and Hampden, respectively, compared to manufacturer literature citations of 0.59 to 0.67 kwh/kg of BOD for a low load counter-current aeration process. These energy requirements are 159%, 176%, and 454% higher than the average value of 0.63 kwh/kg BOD specified in the manufacturer literature. The measurement for Loudon was 2.04 kwh/kg BOD applied, but the energy draw included the additional blower retrofitted to the original Schreiber design.

The four facilities had historical average BOD loadings of between 22% and 62% of design values. Ratios of the percentage of design BOD loading to the percentage of available aeration capacity were calculated to be 34:33, 56:57, 22:41, and 62:156 for Carlisle, Claiborne County, Hampden, and Loudon, respectively, during the intensive observation periods. These ratios suggest that, as the BOD loadings approach 100% of design, 100% of the available aeration capacity will be consumed (including reserve capacity intended for peaking conditions or loading increases). Schreiber and two other engineering firms responsible for

*Table 2. Power Consumption and Aeration Efficiency Estimates*

| Site | lb $BOD_5$ Applied per kwh | kwh per kg BOD Applied | lb Oxygen Transferred per HP·hr |
|---|---|---|---|
| Carlisle, PA | 2.21 (2.06)* | 1.00 (1.07) | 4.12 (3.84) |
| Claiborne, Co., TN | 1.99 (2.40) | 1.11 (0.92) | 3.71 (4.48) |
| Hampden, PA | 0.76 (0.95) | 2.86 (2.31) | 1.42 (1.77) |
| Loudon, TN | 1.07 (1.75) | 2.04 (1.26) | 2.00 (3.26) |

**Values in parenthesis are long-term historical averages.*

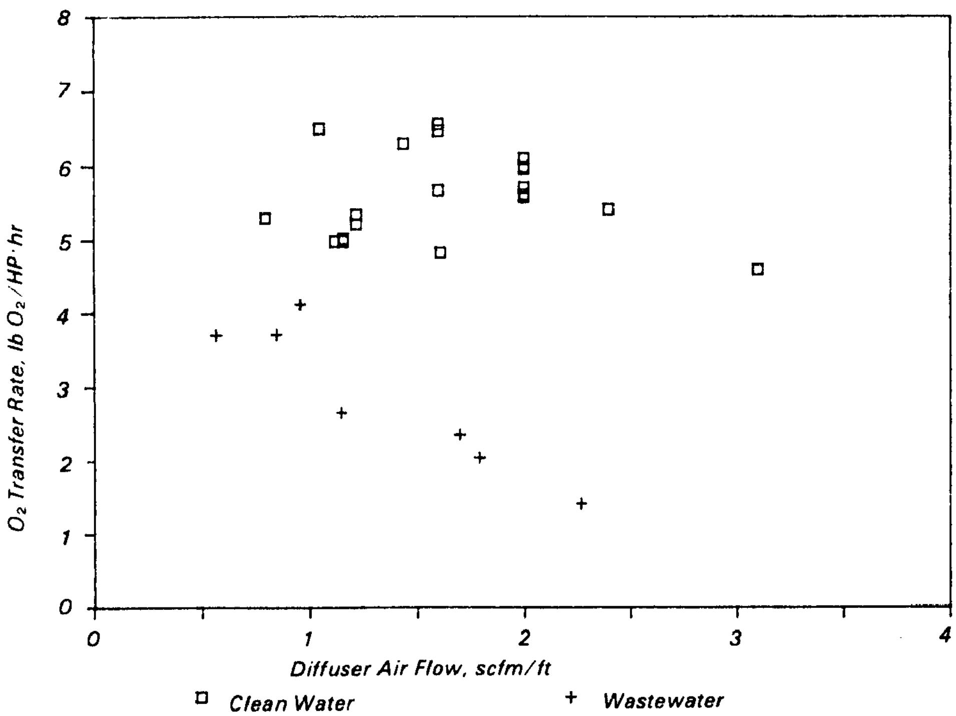


*Figure 2. Effect of diffuser air flow rate on oxygen transfer efficiencies in clean water and wastewater.*

the design of three of the four facilities have collected and interpreted data that, by their interpretation, do not agree with this suggestion. Their comments are appended to the final report.

## Effluent Quality

The effluent quality observations for the period of intensive plant monitoring are shown in Table 3.

Prior to the intensive observation period, the Claiborne County plant experienced operating problems when the DO control system fouled and inhibited the operation of the aeration blowers. Although effluent BOD concentrations were less than 30 mg/L during this period, effluent BOD values have generally been less than 10 mg/L since the DO control system has been calibrated. The intermittent sludge recycle strategy incorporated into the design of the facility results in rising sludge in the final clarifiers (due to denitrification) and subsequent solids loss to the effluent. The solids loss to the effluent is not considered to be related to the performance of the counter-current aeration system.

Loudon has experienced significant effluent solids problems. Severe solids loss was related to the overall poor treatment performance resulting from organic shock loads and leaking air mains. Since the air mains were repaired, severe solids losses have diminished, although it is still not unusual for the effluent solids concentrations to exceed 30 mg/L.

A review of the nitrogen data indicates that substantial ammonia and TKN conversion occurs at all plants and that typical effluent ammonia values are less than 5 mg/L. The Carlisle and Loudon effluent ammonia concentrations seem to be seasonally influenced (i.e., higher ammonia in the effluent during cold weather), while the Claiborne County and Hampden facilities consistently exhibited effluent ammonia values less than 1 mg/L.

## Maintenance Considerations

Maintenance data were gathered from the 10 candidate sites previously discussed. Also during the visits to the evaluation sites, maintenance information was gathered from maintenance logs and operating and maintenance personnel. Many of the maintenance items were non-reoccurring events that may have been related to the original installation or construction (i.e., electrical problems at Claiborne and air header leaks at Loudon).

Center seal leaks were the most prominent maintenance requirement occurring at 8 of the 10 facilities, with multiple occurrences at 4 of these 8 plants. The next most frequent maintenance problems were bridge drive gear box failures (4 of 10 plants) and blower control problems (4 of 10 plants).

Problems experienced with the DO control and center seal failures are considered to be relatively minor problems. Aeration blowers can be operated manually in the event of a control failure and center seal failures result in air leaks that can be readily detected and scheduled for replacement. Center seal replacement requires approximately 3 hr of down time and can usually be handled by one experienced person. DO control problems can usually be detected and corrected through a frequent calibration checking routine. Problems associated with the bridge drive are considered to be serious problems since air is only delivered to one segment of the aeration basin without the bridge in motion.

A consistent comment offered by the majority of operating and maintenance personnel was that the Schreiber Corporation was extremely responsive and provided superior service. It was often noted that a service representative was on site within 24 hr of a call. Also many of the center seal replacements and bridge drive repairs were performed by Schreiber at no expense to the owner.

## Costs

Capital costs per daily gallon of design capacity for a total Schreiber treatment system (excluding influent pumping

*Table 3. Effluent Quality Observations*

| | Effluent BOD | | | Effluent SS | | |
|---|---|---|---|---|---|---|
| | Observations | | | Observations | | |
| Site | Number | Number > 30 mg/L | Average | Number | Number > 30 mg/L | Average |
| Carlisle | 29 | 0 | 4.6 | 29 | 0 | 5.8 |
| Claiborne | 85 | 0 | 4.8 | 69 | 8 | 16.9 |
| Hampden | 63 | 0 | 1.6 | 62 | 0 | 1.0 |
| Loudon | 72 | 2 | 10.8 | 109 | 30 | 26.8 |

except for Mahanoy City) were $0.66/gal, $1.92/gal, $1.44/gal, and $2.93/gal for Loudon, Carlisle, Hampden, and Mahanoy City, respectively. Site specific considerations such as rock excavation and a SWIRL concentrator are included in the Mahanoy City costs. The capital cost for Loudon does not include plant retrofitting costs associated with installation of additional blower capacity and additional diffusers. Based on an assumed energy cost of 5 cents/kwh, the average aeration energy costs ranged from $27.78 per MG to $67.04 per MG (million gallons).

## Additional Conclusions

Results of a variety of studies summarized in the report show that the grid replacement of a number of fine pore and plastic tube systems will yield oxygen transfer efficiencies in tap water that are generally 2.5 to 3 times more efficient than coarse bubble diffusers. A clean water oxygen transfer efficiency of 6 to 8 lb $O_2$/HP·hr is easily attained for a variety of fine bubble aeration systems with grid diffuser placement. Values for clean water tests of the Schreiber counter-current system were previously mentioned in Figure 2.

In many conventional extended aeration systems with diffused air aeration, the amount of air supplied to maintain adequate mixing and solids suspension exceeds the requirements for satisfying the biomass oxygen demand. In the Schreiber system, mixing results from both the rotating bridge and the air cyclically supplied to all tanks sections. This approach makes it possible to design the air supply system to meet the requirements of the biomass rather than to design based on mixing considerations. Also, the wastewater DO near the leading edge of the rotating diffusers is low (normally $< 1.0$ mg/L) thereby maximizing the oxygen deficit and thus the driving force for oxygen transfer. Hence when it is desired to use fine bubble aeration in conjunction with an extended aeration system, the Schreiber counter-current aeration system is clearly a logical approach to accomplish this objective.

Examination of all information on process performance, equipment reliability, capital and O&M costs, and energy requirements gathered during the course of this investigation indicates that the Schreiber counter-current aeration process is a viable, competitive technology for municipal wastwater treatment.

The Schreiber Corporation did not concur with all conclusions in the report nor did the report authors and EPA Project Officer concur with all data interpretations offered by the Schreiber Corporation during the peer review process. Comments from Schreiber related to the final report are included in Appendix O to the report.

The full report was submitted in partial fulfillment of Contract No. 68-01-6737 by Roy F. Weston, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

*The Project Summary was prepared by staff of Roy F. Weston, Inc., West Chester, PA 19380.*

***James A. Heidman** is the EPA Project Officer (see below).*

*The complete report, entitled "Post Construction Performance of Schreiber Counter-Current Aeration Facilities," (Order No. PB 88-113 808/AS; Cost: $32.95, subject to change) will be available only from:*

*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*

*The EPA Project Officer can be contacted at:*

*Water Engineering Research Laboratory*
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