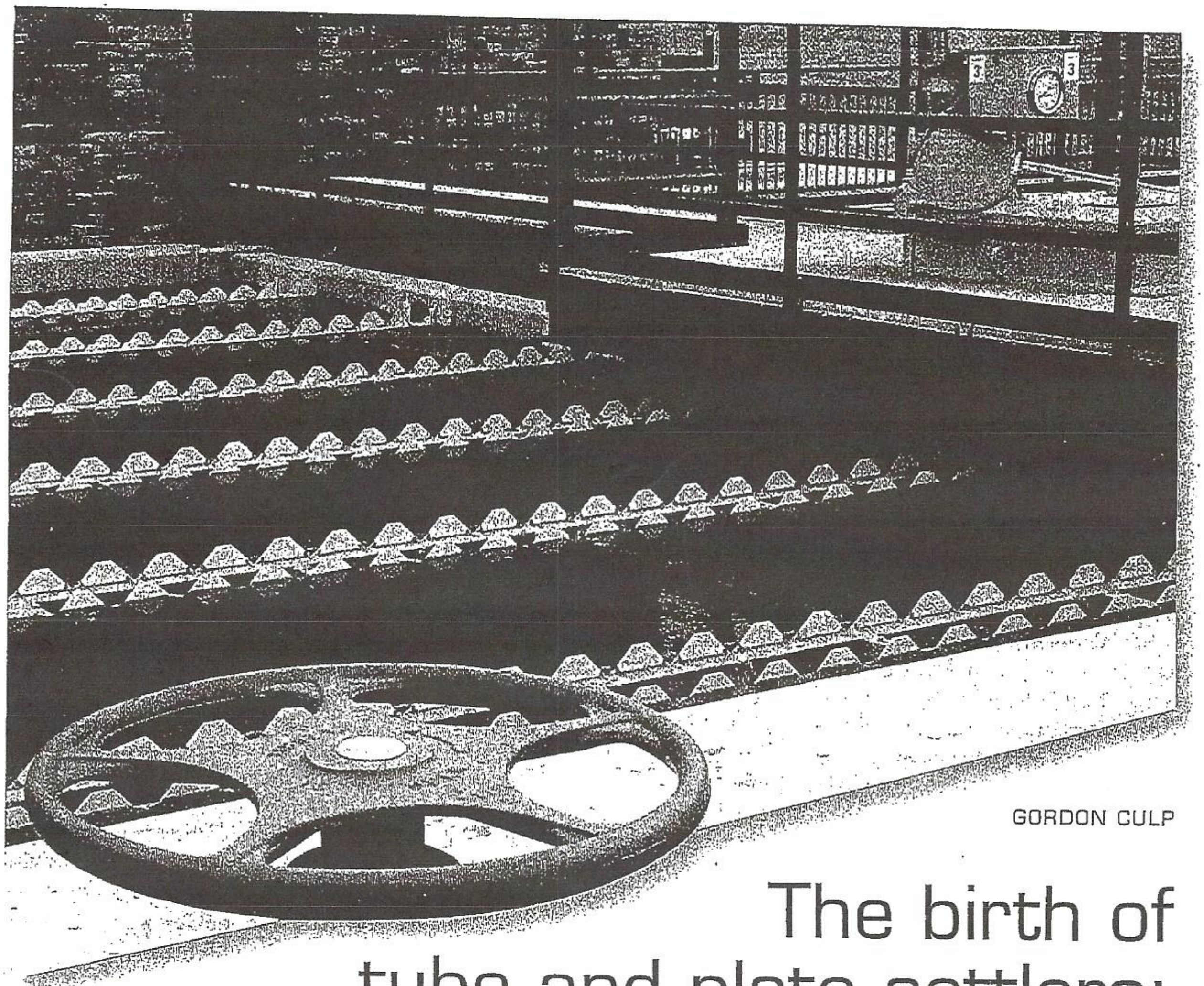

GORDON CULP

The birth of tube and plate settlers: Concept to reality, 1904–1965

HOW INGENUITY AND PERSEVERANCE IN DEVELOPING A WATER TREATMENT CONCEPT DESCRIBED IN 1904 BECAME AN "OVERNIGHT SUCCESS" 60 YEARS LATER.

We all marvel at useful products that come to be by happenstance: Post-it Notes were a result of a failed attempt by 3M to develop a new adhesive. This article describes how a water treatment concept first described in 1904—but never successfully applied—evolved into a real, now widely used technology in just a few months in 1965. The result has been millions of dollars saved in water treatment costs for many communities and industries. This article is not a technical treatise—that has been presented elsewhere (Hansen & Culp, 1967; Culp et al, 1968); instead, it describes a series of events that led to an unanticipated advancement in technology. It is an example of how following one thought can lead to a journey to an unanticipated destination.

INTRODUCING THE CONCEPT: 1904

Rivers and lakes that are used as a source of drinking water contain a range of impurities that must be removed to provide a safe water supply. Some of these impurities consist of particulate matter, some of which can be removed by settling, whereas some particles are so small that they must be removed by passing the water through a fine-grained sand or coal-sand filter. A step widely used to remove settleable material involves passing raw water, after adding chemical coagulants, through large, quiescent basins in which settleable material drops to the bottom of the basin and is removed by a mechanical scraper. Typically, the next treatment step involves passing the settled water through sand or coal-sand filters. The conventional settling basins are large, expensive concrete basins 10–15 ft deep where the water is retained for 2–4 hours.

In 1904, Alan Hazen published an article stating that an ideal concept would be to have a settling basin 1 in. deep rather than several feet deep (Hazen, 1904). Consider that a particle settling at a rate of 1 in. per minute requires 2 hours to settle through a depth of 10 ft but only 1 minute to settle 1 in.; as a result, the retention time, size, and cost of the settling step could be reduced dramatically if very shallow depths were used. Because of the vertical clearance required for the mechanical scrapers that remove settled material, the best that Hazen could suggest was placing one horizontal tray in a 10–15-ft-deep basin to double the capacity of the settling basin by cutting the settling depth in half to 5–7.5 ft. In 1946, Thomas Camp published an article suggesting that the benefits of shallow settling depths could be pushed even further by using depths as low as 6 in., but that was the minimum depth he believed was compatible with mechanical sludge scrapers (Camp, 1946).

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MOVING FROM CONCEPT TO REALITY: 1965

The concept of shallow-depth settling basins went nowhere, primarily because of concerns about the installation and maintenance of a large amount of mechanical equipment in such confined spaces and the issues associated with distributing flow to multiple layers within a basin. That is, it went nowhere until 1965, when a breakthrough was made by a small company, Neptune MicroFloc, in Corvallis, Ore.

Most of the staff members at Neptune MicroFloc were ex-employees of what was then a relatively small consulting engineering firm, CH2M (now CH2M HILL), which had about 300 (now about 28,000) staff members. CH2M developed several innovations related to pumping systems and high-rate water filtration that it perceived to be marketable but realized that other consultants were unlikely to specify products that would benefit a competing consultant. As a result, MicroFloc was spun off to develop and pursue marketing of innovative water treatment concepts. Some research-oriented staff members from CH2M went with MicroFloc. Soon thereafter, Neptune Meter Company purchased MicroFloc and it became Neptune MicroFloc.

MicroFloc was led by Archie Rice, who was in his 40s in 1965. He was a sanitary engineer who had joined CH2M in 1946, the year the firm was founded, as an equal partner with the founding four (Cornell, Howland, Hayes, and Merryfield). Rice left CH2M to manage MicroFloc. He was a bright, energetic, sometimes quite direct individual who kept the creative juices flowing at MicroFloc. He believed in research and recruited Walt Conley, who developed the high-rate water treatment filtration technology required to produce the large volume of high-quality water needed for the atomic bomb project at Hanford, Wash. At MicroFloc, Conley in turn brought in two engineers in their mid-20s to create a research department and technical support group. Those two engineers were Sig Hansen and me. Hansen was a recent graduate of Oregon State University. I had been working for CH2M at the South Tahoe (Nev.) Public Utility District advanced wastewater treatment plant on several research projects and starting up the plant.

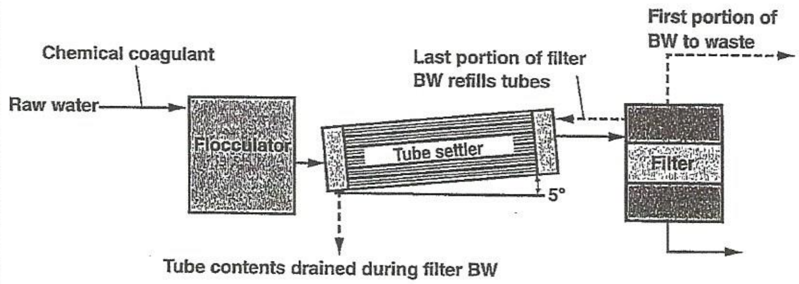
In 1965, Rice returned from a water treatment plant visit with an observation that he shared with Conley, Hansen, and me. Rice said the pipe feeding raw water to the treatment plant was acting as an effective settling device because it was filling up with sediment even though the detention time in the pipe was short. He said, "Why don't you guys take a look at what could be done by bundling a bunch of pipes together to create a settling basin and figure out a way to get the sludge out without mechanical equipment?" Conley turned Hansen and me loose to pursue the idea.

How to remove sludge. The first thing to address was getting the sludge out of a basin filled with pipes. Obviously, mechanical scrapers were not going to work and, if the sludge removal issue could not be solved, there was no need to go any further. We came up with the configuration shown in Figure 1 for a typical water treatment system in which the settling step is followed by a filtering step. Filters are cleaned periodically by backwashing them. Because the retention time in the settling basin would be reduced from 2–4 hours to about 5 minutes, the sludge could be removed simply by draining the settling basin during each filter backwash and routing the backwash wastewater through the settling basin to assist in flushing the solids that had accumulated in the pipes. Because the volume of water used in each backwash far exceeds the volume of a 5-minute detention settling basin, the last portion of the filter backwash water could be retained in the settling basin to avoid increasing the amount of water lost during filter backwashing. We could see no reason why the benefit of a shallow settling depth could not be enhanced by using small-diameter tubes rather than pipes.

Pilot-scale testing. The next step was to test the concept. Single tubes of various diameters and lengths were tested at different flow rates. The results were promising, and we were ready to move on to tests at a larger scale. Because we were operating in a small company with a limited budget for research, the goal was to expand the concept test quickly while minimizing time and expense. We had some pilot plant filters used for testing high-rate filter media design available. For a readily available, low-cost source of small-diameter tubes, we purchased plastic tubes used to separate golf clubs in a golf bag from the sporting goods department of the local drugstore.

For the first pilot-scale test, we assembled a pilot plant using our pilot filters, which were preceded in the treatment process by a small tank filled with the golf tubes that served as a settling basin. The tubes were inclined at 5° to assist in draining the sludge. The sediment in the raw water was removed effectively at detention times of about 5 minutes, sludge was readily drained from the tubes, and the filter performance was as good as or better than we would have expected downstream of a conventional settling basin. Work on the tube design was being done in parallel with these preliminary pilot tests. The golf tubes were replaced by a module of hexagonal tubes to complete the pilot tests.

FIGURE 1 Essentially horizontal tube settler



Source: Hansen & Culp, 1967

BW—backwash

Prototype-scale testing. Based on the promising pilot-scale test results, a prototype package treatment plant using the configuration shown in Figure 1 was designed and built with a capacity of 20 gpm. The prototype was mounted on a trailer and transported to several sites for testing; it performed well when treating a wide range of raw water quality (Hansen & Culp, 1967).

Package treatment plants hit the market. Using the information from the testing program, MicroFloc designed and, in 1967, began marketing package plants for water treatment and for tertiary wastewater treatment using the horizontal tube settlers. The package plants included Water Boy plants with capacities designed for small communities and resorts of 10–100 gpm and Aquarius plants with capacities up to 1,400 gpm per unit. There are now more than 400 Water Boy and 300 Aquarius units in service (WesTech, 2014). The birth of a practical method to apply the 60-year-old theory of shallow depth sedimentation had taken place!

Further evolution of the concept. Hansen and I proposed to Rice and Conley that, although tubes inclined at 5° were working well, we should look at other angles of inclination. We ran into some resistance because this seemed like an academic exercise to others, but regardless we were given the budget to run some tests. We expected we might make some design refinements but did not anticipate the major discovery we made: that when the tubes were inclined at 45–60°, the sludge moved down the inclined tubes and did not build up in them. Thus it was possible to create a continuously flowing tube settler that eliminated the need to drain or backflush the settler to remove sludge (Figure 2). The discovery of continuous sludge removal extended the application of shallow-depth

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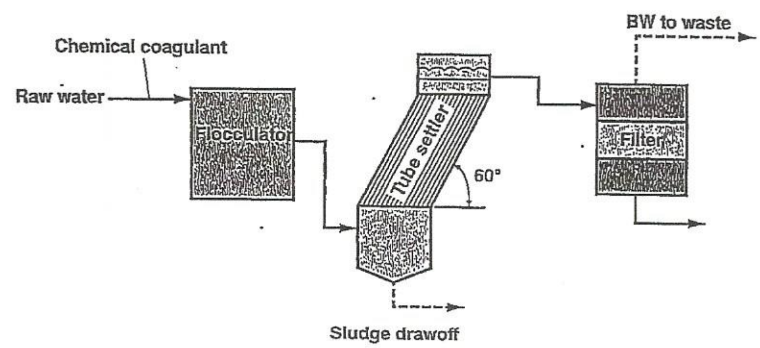
FIGURE 2 Steeply inclined tube settler



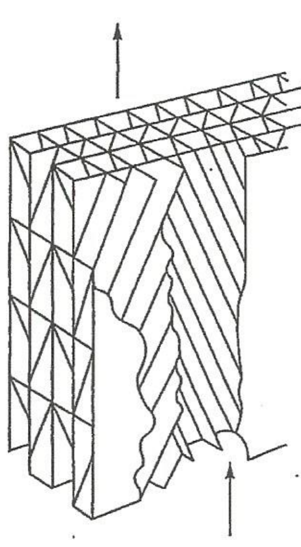
Source: Hansen & Culp, 1967

BW—backwash

sedimentation from relatively small package plants to plants with capacities of many million gallons of water per day.

MicroFloc developed a modular form of steeply inclined tubes (Figure 3). Extruded acrylonitrile butadiene styrene channels were installed at a 60° angle between thin sheets of polyvinyl chloride. Alternating the direction of inclination for each channel row forming the tube passageways caused the module to become a self-supporting beam that could easily be installed in a circular or rectangular basin (Figure 4). The size of a new settling basin could be substantially reduced by including the tube modules in the design, and the capacity of an existing basin could be increased by installing the tube modules.

FIGURE 3 Module of steeply inclined tubes



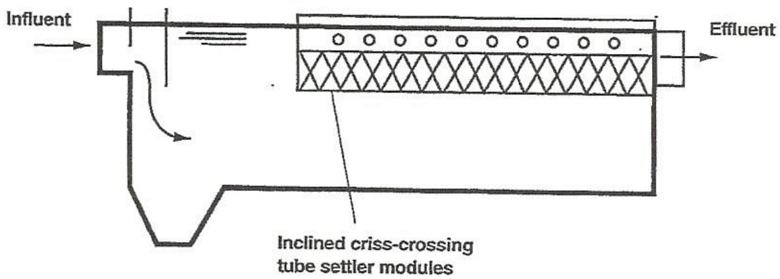
Source: Culp & Culp, 1974

First full-scale installation of steeply inclined tubes. The next step in developing the steeply inclined tube settler was a plant-scale application. The city of Newport, Ore., needed a water treatment plant expansion when the tube settler experiments were being completed. The city agreed to testing of the steeply inclined tube modules; this was carried out by first installing tubes in an isolated portion of the existing clarifier. On the basis of favorable test results, the expansion of the 1.5-mgd plant to 3 mgd was addressed by installing tube modules in the existing clarifier and converting the rapid sand filters to high-rate mixed-media filters. The permanent installation of tube modules in the existing clarifier began late in 1967. Tube modules were installed around the periphery of the existing circular clarifier to increase the clarifier capacity from 1.5 to 3 mgd. Even at twice the throughput, the clarifier modified with the tube settlers produced an effluent that contained no settleable solids, whereas samples collected from the original clarifier frequently did. Further confirming the effectiveness of the tube settlers, the length of filter runs increased from 26 to 60 hours after the clarifier modification (Culp et al, 1968). The promising potential of the inclined tube settlers had been realized in a full-scale application.

Sharing information with the industry. There was an internal debate within Neptune MicroFloc about how much of our developmental work should be shared and how much should be held close. Rice was concerned that sharing the information would be educating the competition. Hansen and I argued that widespread acceptance was going to depend on establishing a strong technical basis for the technology. We prevailed, and an article describing the developmental work was published in Journal AWWA (Hansen & Culp, 1967), with a follow-up article describing the results from several full-scale applications (Culp et al, 1968).

The self-cleaning tube concept was displayed at a national conference in New York City in 1968. We built a small Plexiglas tube-settling unit and used small plastic beads as the settleable solids to be removed in the tubes with a recirculating flow of water through the unit. The small recirculating pump was an operational headache, but we kept things running, and the unit provided a clear demonstration of the concept. When we went to dinner one evening during the conference, some competitors were sitting nearby and were mostly talking about our tube-settling display. Considering the hundreds of displays and presentations at the conference, hearing that conversation about our display made us feel that we were definitely onto something.

FIGURE 4 Tube module installation in a rectangular clarifier



Gaining industry acceptance. The technical work to develop the concept was one task, but gaining acceptance by regulatory agencies and design engineers was quite another. We spent a lot of time meeting with state regulatory agencies and consulting engineers to explain the tube-settling concept and to present data from operating installations. It was a challenge in a field as conservative as water and wastewater treatment to gain acceptance of such a radical departure from conventional design practices. Of the many meetings, a few are vivid memories. In one state health department, a red-faced regulator physically pushed me out the door yelling, "You people are always just trying to cheapen things up" after just 5 minutes of my presentation. Their state regulations defined sedimentation as having at least 2 hours of detention. It was a long time before that state was willing to approve any designs using tube settling.

On one of my trips, I had to opportunity to meet with Thomas Camp in his Boston, Mass., office. I had long respected and admired the work he had done during several decades in the water and wastewater treatment fields. He had published several articles on shallow-depth sedimentation, which we relied on in our early research. Sitting at his desk in his office, he politely listened to my presentation, leaned back in his chair, and said, "Sonny, it is never going to work," and that was the end of the meeting. The sense of disappointment I felt has been mitigated somewhat by the fact that it did work.

THE REALITY: 50 YEARS LATER

As experience was gained with our design, acceptance became more widespread. Competitors began to develop their own versions. Some varied the shape of the tubes (Permutit chevron shape); another (Graver) inclined the channels in the same direction. In 1971, Parkson introduced the Lamella separator, which used inclined plates spaced at 1.5 in. instead of inclined tubes. There have since been many variations of tube shapes and tube module designs, but all are based on the basic concepts we developed in 1965. Today, tube and plate settlers have become widely accepted and used around the world, with thousands of municipal and industrial installations. More than 50 suppliers of tube-settling systems are found on the Internet in India alone, which is a big change from that day 50 years ago when two young engineers walked out of a drugstore on a damp, cold winter day in Corvallis with armfuls of golf tubes.

ABOUT THE AUTHOR

Gordon Culp is the principal of Smith Culp Consulting, 653 Ravel Ct, Las Vegas, NV 89145 USA; gordon@smithculp.com. He has more than 52 years of consulting experience in water and wastewater treatment and cofounded Smith Culp Consulting in 1993. Before that, he was president of Culp Wesner Culp Consulting, which was acquired by HDR in 1986, where he served as national director of water and wastewater treatment. He is a Life Member of AWWA.

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REFERENCES

Camp, T.R., 1946. Sedimentation and the Design of Settling Tanks. *Transactions of American Society of Civil Engineers,* 111:895.

Culp, G.L and Culp, R.L., 1974. *New Concepts in Water Purification* [out of print]. Van Nostrand Reinhold, New York.

Culp, G.L; Hansen, S.P.; & Richardson, G.H., 1968. High Rate Sedimentation in Water Treatment Works. *Journal AWWA,* 60:681.

Hansen, S.P. & Culp, G.L., 1967. Applying Shallow Depth Sedimentation Theory. *Journal AWWA,* 59:1134.

Hazen, A., 1904. On Sedimentation. *Transactions of American Society of Civil Engineers,* 53:45.

WesTech, 2014. Aquarius and Water Boy Package Water Treatment Plants. www.westech-inc.com/public/uploads/global/2014/6/Brochure%20Aquarius%20Waterboy%20Brochure.pdf (accessed October 5, 2014).

AWWA RESOURCES

- Dissolved Air Flotation for Water Clarification. Edzwald, J.K. & Haarhoff, J., 2012. AWWA and McGraw Hill, Denver. Catalog No. 20748.
- WSO: Coagulation, Flocculation and Sedimentation. DVD. AWWA, Denver. Catalog No. 64388.

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