The Florida Keys Aqueduct Authority's Cross-Connection Control Program — 14 Years Later

Jolynn Cates

The Florida Keys Aqueduct Authority provides potable water to the residents of Monroe County through a 130-mile long transmission pipeline and 650 miles of distribution system piping. The FKAA's water treatment plant in south Dade County treats an average of 16.5 MGD. The FKAA cross-connection control program plays a major role in maintaining the FKAA water system integrity and thus is essential to a supply of safe potable water that meets all drinking water standards.

The cross-connection control program, adopted by the FKAA board in 1986, is a written plan required by Chapter 62-555 FAC for community water systems. The FKAA has the responsibility of eliminating cross connections by requiring the installation of an approved backflow prevention device or discontinuing water service until the contaminant is eliminated.

In 1993 the FKAA stepped up enforcement procedures as a result of non-compliance with installation and annual testing requirements of backflow prevention devices. Since the increased enforcement procedures, compliance rose from 89% to 97%.

In 1994 the FKAA program was challenged in an administrative hearing. The issue in the case was whether the control delegated to the FKAA was exceeded. The hearing officer ruled that the FKAA's program did in fact further the legislative goal of protecting the public water supply from the very real and significant danger that is posed by cross connections with non-potable water.

Although the FKAA program had been successful, in 1998 the FKAA recommended improvements to the program regarding the type of backflow prevention required, responsibility for installation of backflow prevention, and responsibility for annual testing and maintenance of backflow preventers. The purpose of the improvements was to provide better customer relations compliance and to promote protection of public health.

Type of Backflow Prevention

Initially, the authority concentrated inspections on customer accounts that posed a high degree of hazard to the water system, such as wells, cisterns, irrigation systems, marinas, and wastewater treatment plants that required the installation of an approved reduced pressure zone (RPZ) backflow preventer. The RPZ, installed aboveground after the meter, has within it two check valves and a differential relief valve, which, in the event of backflow (should the second check valve not close properly) allows water from the customer's side of the meter to discharge to the ground.

Emphasis is placed on the type of potential hazard identified at the premises to govern the type of backflow protection required at the service connection. If the potential hazard posed a threat to public health and the possibility of the hazard entering the potable water system is evident, an RPZ backflow preventer would be required to be installed at the meter.

According to the AWWA Manual M14 as cited in Rule 62-555.360 FAC, auxiliary water supply is defined as natural water derived from wells, springs, streams, rivers, lakes, harbors, bays and oceans that is not under the sanitary control of the water purveyor. Auxiliary water supplies are considered potential health hazards and require an approved backflow prevention assembly installed at the meter, even though there is no physical cross connections with the auxiliary water supply and the community water system. Also, the potential for cross connections with auxiliary water supplies is defined as the probability of piping being changed, equipment incorrectly being used, or negligence on the part of the customer resulting in a backflow condition. The existence of one or more of the following is considered a potential cross connection: bypass arrangements, jumper connections, removable sections, swivel or changeover assemblies, hoses and hose bibbs, or the presence of an abundance of piping that cannot be easily traced.

By strict definition of auxiliary water supplies, the FKAA would require every residence on waterfront property to install an approved backflow prevention assembly at the meter. Also, the existing program required customers with irrigation systems to install an RPZ.

Because the requirements would impose a significant economical impact on the community, which is surrounded by water and is aesthetically landscaped, the authority recommended that the program require customer accounts with auxiliary water sources that are completely separate from the potable water plumbing system and irrigation systems meeting plumbing code (isolation of irrigation system via approved pressure vacuum breaker, atmospheric vacuum breaker, etc.) to install combined double check valve/meter (DCM) assemblies. However, the DCM assembly is only available for 5/8-inch meters. Those customers who need a 1-inch or larger meter would require a separate meter and backflow prevention assembly installation.

Jolynn Cates, P.E., is with the Florida Keys Aqueduct Authority, Key West.

The authority recommended that the backflow prevention program continue to require customers who connect an auxiliary water source to the potable water plumbing system, and whose irrigation system does not meet plumbing code, to install an RPZ backflow preventer. Customers with no potential hazards identified would continue to have the dual check valve installed after a standard meter.

Responsibility for Installation

Upon discovery of a potential cross connection, the customer is required to install an approved backflow prevention assembly or eliminate the hazard within a specified time to avoid discontinuance of water service. The FKAA recommended that customers continue to be responsible for installation of the RPZ or 1-inch and larger double check valve (separate from meter), depending on type of potential hazard. However, the FKAA would install the DCM assembly and standard meter with dual check valve.

Responsibility for Testing and Maintenance

Originally, the FKAA recommended that it perform the annual testing and maintenance of all customer backflow prevention assemblies, excluding assemblies installed on firelines. That would eliminate "drive-by" (false) test reports, delinquent tests, and excessive repair time. But certified plumbers and backflow testers objected to authority personnel working on plumbing fixtures downstream of the meter, so the FKAA revised its recommendation to allow the customer to be responsible for having the downstream backflow preventer maintained and tested annually, while the FKAA would maintain and test annually the DCM assembly and also maintain the dual check valve device.

Other Issues and Concerns

To have a smooth transition during implementation of changes, several preliminary steps and issues needed to be addressed. Initially, the FKAA performed a survey to determine which customer accounts were waterfront facilities. If the waterfront facilities met the appropriate requirements, the FKAA would install the DCM assembly at no cost to existing customers. The retrofitting of the existing accounts would be performed in conjunction with the FKAA 10-year meter change-out program. For new customer accounts that are waterfront, the customer would be responsible for the cost of the initial installation of the DCM assembly. Those customers who qualify for the DCM assembly could keep the RPZ and continue maintaining and testing the RPZ annually, or the FKAA would replace the existing meter with a DCM assembly and maintain and test the DCM assembly at no cost.

Since the FKAA was absorbing the cost of the DCM and its annual testing for existing customers, it performed a preliminary cost analysis. The installation of DCM assemblies for waterfront facilities and replacement of RPZ with DCM assembly will cost approximately $240,000/year. This represents an increase of $140,000/year to the FKAA meter change-out program. The FKAA also considered the possibility of performing in-house or contracting out the maintenance and testing of the DCM assemblies. Cost information was obtained from different certified backflow testers who worked in Monroe County. The cost for testing backflow preventers without any repairs ranged from $25 to $75. Using an average cost of $35 to contract the maintenance and testing of DCM assemblies, a cost comparison of in-house versus contracted maintenance and annual testing of the DCM assemblies is as shown in the accompanying table.

Based on the cost analysis, the FKAA determined that the testing and maintenance of the DCM assemblies would be performed in-house and that the cost of the changes to the program would not have a significant impact on existing water rates.

To implement the program effectively, the FKAA hired a certified backflow tester whose job is to perform inspections to verify that customer's facilities/homes meet the criteria to qualify for the DCM assemblies, the initial and annual maintenance and testing of the DCM assemblies, and other related duties.

Another recommendation and addition to the backflow prevention program was the formation of the Cross-Connection Control Committee. The committee's purpose is to review and advise on matters such as hazard potential, compliance time frame, legal retaliation, and public education. In a concerted effort, this would help alleviate the FKAA as being perceived as "the enforcer" of backflow prevention policies.

The committee, composed of minimum of five members, includes a local plumber and a designee from the FKAA, the Monroe County Department of Health, the Monroe County Building and Plumbing Department, and the City Building and Plumbing Department. By engaging professionals from various fields related to water safety, the committee members would benefit from the expertise and knowledge shared concerning cross-connection hazards, health effects, and plumbing fixtures and uses.

Implementation

The accompanying flowchart shows the implementation process of the cross-connection control program. When the revised written plan for the program was completed, the FKAA issued a public notification to discuss and approve the changes at the monthly board meeting. The revisions were approved in November 1997 for implementation in January 1998.

The FKAA screens a customer account via customer service, new facility plan reviews, or initial inspection. When a customer signs up for water service and is required to install a backflow prevention assembly, customer service requires temporary service pending installation of backflow protection assembly for existing customer accounts. If the DCM assembly is required, customer service will have the maintenance department replace the existing meter with the DCM assembly. For new customer accounts, the FKAA engineering department performs the new facility plan reviews and determines what type of backflow protection assembly is required. If the FKAA requires the installation of the backflow protection assembly or DCM assembly, the installation of the backflow protection assembly must be installed prior to water service. The FKAA engineering department also performs initial inspection on existing facilities. These inspections are typically initiated by water quality complaints or observations by field personnel and local plumbers. If the FKAA determines that the customer must install backflow protection after the meter, it will be required within a specified time.

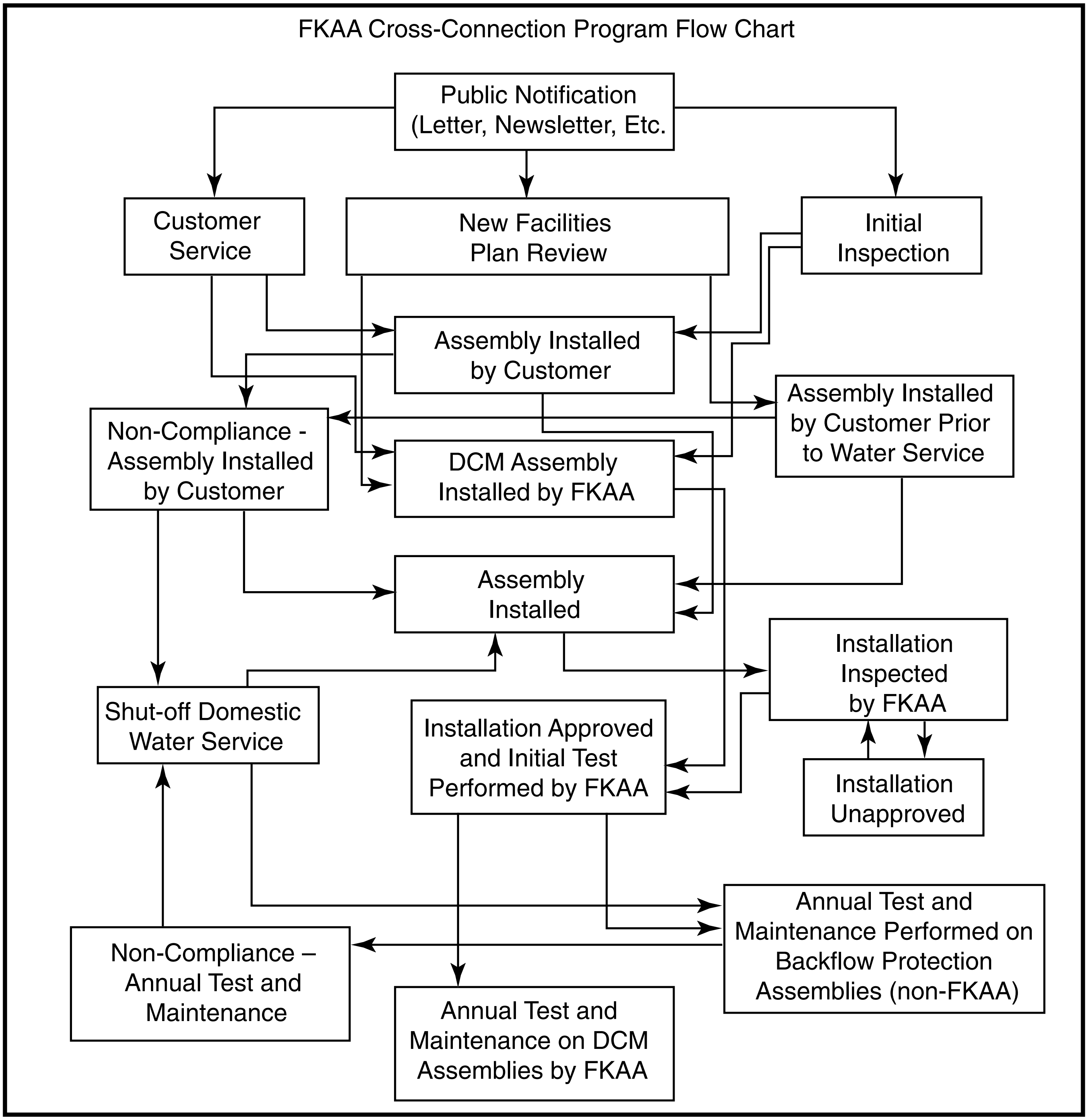
If the backflow protection assembly is not installed within the specified time, the FKAA discontinues water service until the backflow prevention assembly is installed after the meter. Upon installation, the FKAA performs an initial inspection and test to verify that the installation meets requirements and functions properly.

If a customer fails to test a backflow preventer within the specified time, the FKAA discontinues water service until receipt of a contract agreement between the customer and a certified backflow tester stating when the backflow preventer will be tested.

The FKAA maintains a computer database in which an inventory of installed backflow prevention assemblies is inputted. Currently, the inventory is composed of 2000 customer-owned backflow preventers and 3500 DCM assemblies. It contains information, such as size, type, serial number, and date installed and tested, on each backflow preventer and is linked to the customer account information, such as name, service and mailing address, and size of meter. The database is used to send annual letters reminding customers that the annual test of the

Summary	# of DCM assemblies to test, maintain, and repair by FKAA	# of FKAA employees	Cost per meter (In-house)	Cost per meter (Contracted)
1999	2,360	1	$20	$35
2000	4,720	1	$11	$35
2001	7,080	2	$15	$35
2002	9,440	2	$12	$35
2003	11,800	3	$14	$35
2004	14,160	3	$12	$35
2005	16,520	4	$13	$35
2006	18,880	4	$12	$35
2007	21,240	4	$11	$35
2008	23,600	5	$12	$35
Avg. Cost			$13	$35

Assumptions:
1. ten year meter change-out program
2. one-fourth of the customer accounts are waterfront
3. estimated 480 new customer accounts would require DCM assembly
4. FKAA cost to perform maintenance and annual testing would be the cost of employees, vehicles, equipment, etc.
5. each FKAA employee would annually test 5,280 backflow preventers.



backflow preventer installed after the meter is due, as well as to maintain record keeping and a history of each assembly.

Summary and Conclusions

The FKAA's overall objective of the recommended improvements to the cross-connection control program was to improve customer relations, compliance, and protection of public health. The following recommendations were approved and implemented:

The FKAA allows the installation of the DCM assembly in lieu of an RPZ backflow preventer if the customer has an auxiliary water source not connected to the potable water system, and irrigation systems that meet plumbing code. There is no charge for the DCM assembly for existing customers; new customers pay the cost for the initial installation. Customers are responsible for the installation of backflow preventers downstream of the standard meter.

The FKAA performs annual testing and maintenance of the DCM assemblies at no cost to customers. Customers are responsible for testing and maintenance of backflow preventers installed downstream of the standard meter.

Although the FKAA was absorbing the cost to install and test the DCM assemblies, it determined there would be no significant impact on consumer water rates. Those customer accounts who qualify for the DCM assembly would have the standard meter replaced with the DCM assembly during the FKAA's ten-year meter change-out program or sooner.

Those customers who qualify for the DCM assembly are no longer bothered with letters to install or test backflow preventers. The backflow preventer is tested annually in a more timely manner, and each customer has a form of backflow protection – reduced pressure zone or double check valve backflow assembly, DCM assembly, or dual check valve. ■

Upgrading a Wastewater Reclamation Facility

Paul A. Bizier

During the 1980s many cities in Florida built new treatment plants based on low-rate, oxidation ditch (and similar) technology. Although these plants have been stable and effective in meeting tightening effluent requirements, as their service populations have grown they have to be expanded. While simply building more low-rate facilities is certainly an option, it can be a very expensive option. Sometimes converting low-rate facilities to higher-rate processes and upgrading clarifiers can achieve equivalent results at a much lower cost. This article details such improvements at Lakeland's W. Carl Dicks Wastewater Reclamation Facility.

The increased rainfall of 1994 and 1995 led to a significant increase in flows to the W.C. Dicks Wastewater Reclamation Facility. In fact, the peak three-month average flow exceeded the 10.8 MGD permitted flow for the plant and was at a level which previous capacity analysis reports had predicted would not occur for over ten years. As a result, Lakeland authorized a re-rating evaluation to determine if the operation of the existing facilities could be optimized to increase its capacities. During the evaluation, it was found that increased organic loadings were resulting in overloading of the facility. Influent COD loadings had increased nearly 75% in two years, and influent BOD loadings had increased by 100% over the same period. A design analysis recommended the following improvements:

- Upgrading two existing 85-foot diameter primary clarifiers with energy dissipating inlets, flocculating feedwells, and spiral scrapers.
- Construction of an additional 85-foot diameter primary clarifier with precision bearing drive, energy dissipating inlets, flocculating feedwell, and spiral scrapers.
- Elimination of the existing trickling filters.
- Conversion of the existing Carrousel basins to fine bubble aeration and modified Ludzack-Ettinger operation, with multiple anoxic and aeration zones.
- Upgrading two existing 85-foot diameter secondary clarifiers and two existing 100-foot diameter secondary clarifiers with energy dissipating inlets, flocculating feedwells, current density baffles, and spiral scrapers.

All of the improvements to the clarifiers were made in accordance with recommendations published in several articles (see references).

As part of the above improvements, several other items were required. The new primary clarifier required a cover for odor control and connections to the existing odor control system. Three 450-HP centrifugal blowers were installed to provide over 16,000 SCFM of air for the new aeration system. The fine bubble diffusers in the modified ditches included both membrane diffusers (for the anoxic zones) and ceramic diffusers (for the aeration zones). An internal recycle of approximately four times the design flow is provided using a submersible propeller pump in each of the three basins. A new 1,250-kW emergency generator was also installed. These improvements increased the rated capacity of the treatment plant from 10.8 to 13.7 MGD.

Construction of the plant improvements began in February 1997 with demolition of the first trickling filter and construction of the new primary clarifier. Because of the necessity of maintaining plant operation, construction proceeded relatively slowly. Only one clarifier could be removed from service at a time, and similar constraints were imposed on the modifications to the aeration basin. In addition, the aeration blower structure had to be completed and made operational before any modifications could be made to the aeration basins. Because of such complex interweaving of operational requirements, construction required 23 months. Despite the relatively long construction time, the construction cost for all improvements was $3,850,000, or less than $1.35/gallon of additional capacity.

Given the importance of the clarifiers to proper operation, not only careful design, but also careful fabrication it is vital. Therefore, careful review and selection of acceptable manufacturers is vital. In addition, if the manufacturer's capabilities are not thoroughly understood, site visits by owner's and/or engineer's personnel should be considered.

The improvements, in addition to increasing treatment capacity, have improved system performance. Benefits have been seen both in plant operations and in the effluent quality.

Implementation of the Modified Ludzack-Ettinger process and the anoxic selector zones have significantly reduced problems with bulking sludge. As is typical for many oxidation ditch type systems, the original Carrousel system produced SVI's of 300 mL/g or greater. Lakeland had previously modified the flow scheme, essentially converting the trickling filters to anoxic selector zones, by recycling the RAS to the filters. While that reduced bulking, it also resulted in overloading of the trickling filters and a reduction of effluent quality. With the new anoxic selector zones, the SVI is routinely 120 mL/g or less, and often as low as 80 mL/g. The low SVI has reduced the sludge pumping rate and benefited effluent quality. The reduction in SVI also increases the effective capacity of the secondary clarifiers and the return sludge suspended solids (RSSS) concentration.

Paul A. Bizier, P.E., DEE, is director of environmental engineering for Chastain-Skillman, Inc., Lakeland.

Prior to the modifications to the clarifiers, the larger suction-type secondary clarifiers typically produced an RSSS concentration of approximately 6600 mg/L. After the removal of the suction system and replacement with spiral scrapers, the RSSS concentration increased to 9200 mg/L, and it has exceeded 10,000 mg/L. This nearly 50% increase, and a corresponding decrease in the required pumping rate, occurred even though the flat floors in these clarifiers are less than optimum for use with spiral scrapers.

After the improvements, and despite the higher flows, effluent BOD and TSS concentrations have remained essentially constant. During the years prior to 1993 and the increase in industrial loadings, influent CBOD loadings averaged 269 mg/L and the effluent CBOD concentrations averaged 2 mg/L. As the industrial load began to impact the facility, influent CBOD concentrations increased to 462 mg/L, while effluent CBOD concentration averaged 6 mg/L. Since startup of the complete modified system in January 1999, the influent CBOD concentrations have averaged 416 mg/L, while effluent CBOD concentrations average 4 mg/L. Despite the increases in both flow and loading, the system is demonstrating excellent removal of organic material.

The increased removal of organic material is due in part to improvements in the removal efficiency of the primary clarifiers. In 1993, prior to construction, the primary clarifiers were removing 23.7 % of the influent CBOD. In 1995 the reduction was 10.5%. Since the completion of construction, the CBOD removal has increased to 32%. It appears that the clarifiers have not yet been optimized fully, as there is data indicating that CBOD removal is heavily dependent on the total sludge residence time in the primary clarifiers. Currently, the sludge residence time in the primary clarifiers is approximately 73 hours, with a desired target value of 12-18 hours.

During the years prior to 1993 and the increase in industrial loadings, influent TSS loadings averaged 233 mg/L and the effluent TSS concentrations averaged 5 mg/L. The industrial load consisted primarily of soluble material, and so influent TSS concentrations did not increase as significantly as did CBOD and COD concentrations. During 1995 the influent TSS concentrations averaged 276 mg/L while effluent TSS concentration averaged 6 mg/L. Since startup of the complete modified system in January 1999, the influent TSS concentrations have averaged 320 mg/L, while effluent TSS concentrations average 5 mg/L. Again, the improved performance is partly attributable to greater removal efficiencies in the primary clarifiers. In 1993 the primary clarifiers were removing 39.8 to 51% of the influent TSS. Since the completion of construction, the TSS removal has increased to 61%.

The improvements in the secondary clarifiers have resulted in units that can handle 30% more flow without a deterioration in effluent quality. This is in line with previous research done on optimizing secondary clarifiers and indicates the significant improvement that can be made in clarifier performance, even in relatively shallow basins. The smaller secondary clarifiers at W.C. Dicks are only 10 feet deep, yet they function as well as the newer, deeper 100-foot diameter clarifiers in terms of TSS removal. Typical TSS concentrations for the smaller, shallower units are 5.8 mg/L, while the TSS concentration for the larger, deeper units average 5.2 mg/L.

There have also been improvements in nitrogen removal, with total nitrogen in the effluent dropping from 10.5 to 6.5 mg/L. Prior to the plant improvements, the plant was operating in an unstable area of nutrient removal. During a typical week, as the industrial loads produced overloading of the process, nitrification would be inhibited, and the plant would produce higher levels of effluent ammonia. This led to increases in chlorine demand. Since the completion of construction, effluent ammonia concentrations average 0.2 mg/L, while effluent nitrate concentrations average 3.7 mg/L. The improvements have also resulted in bio-P removal, especially during periods of high influent loading. This is an area which is being researched by the city, as bio-P removal was not a design goal for the facility.

With the completion of the improvements has also come a reduction in operating costs. Prior to the improvements, the existing aeration system required the continuous operation of six 100-hp mechanical aerators. Since the conversion, most plant loads are handled by a single 450-hp blower. The blowers also have automatic DO control and inlet throttling, with the blowers being sequenced and controlled by a small programmable logic controller. This ensures that adequate air is available at all times, while minimizing the total horsepower required during lower loading periods, and allows power usage to be reduced even further during off-peak periods.

In summary, conversion of the W. Carl Dicks Wastewater Reclamation Facility from a low-rate process to the higher rate Modified Ludzack-Ettinger process provided a significant upgrade to the facility. The modified facility is capable of treating 30% more flow, and 100% more organic loading, while at the same time reducing overall operating costs. These improvements were very cost effective at less than $1.50 per gallon of additional capacity, and construction was accomplished without disruption of the existing treatment process. The improvements in clarifier performance have been especially significant, with increases in the RSSS concentrations and maintenance or improvements in the effluent TSS concentrations. There have also been reductions in operational costs and an improvement in nutrient removal. These modifications demonstrate that upgrading the low-rate facilities to high-rate processes can often be a valuable alternative to simply building more low-rate systems.

References

1. Albertson, Orris E., "Clarifier Design," *Design and Retrofit of Wastewater Treatment Plants for Biological Removal*; ed. Clifford W. Randall, James L. Barnard, and H. David Stensel, Technomic Publishing, 185-254, 1992.

2. Albertson, Orris E., "Sludge Hopper Design for Activated Sludge Clarifiers," Proceedings of the 1994 National Conference on Environmental Engineering, Boulder, Colorado, July 11-13, 1994, American Society of Civil Engineers, 1994.

3. Albertson, Orris E., "Optimizing Primary Clarification and Thickening," *Water Environment and Technology*, December 1997. ■

Glossary of Common Terms Used in This Publication

ASR	aquifer storage and recovery
AWT	advanced water treatment
AWWT	advanced wastewater treatment
AWWA	American Water Works Association
BOD	5-day biochemical oxygen demand
BOD_x	BOD test based on other than 5 days
CBOD	5-day carbonaceous BOD
COD	chemical oxygen demand
cfm	cubic feet per minute
cfs	cubic feet per second
CWA	Clean Water Act
DEP	Florida Dept. of Environmental Protection
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAC	Florida Administrative Code
fps	feet per second
FSAWWA	Florida Section of AWWA
FWEA	Florida Water Environment Association
FWPCOA	Fla. Water & Pollution Control Operators Assoc.
GIS	Geographic Information System
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
hp	horsepower
I/I	Infiltration/Inflow
MGD	million gallons per day
mg/L	milligrams per liter
MLSS	mixed liquor suspended solids
MLTSS	mixed liquor total suspended solids
NPDES	Nat. Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
POTW	public-owned treatment works
ppm	parts per million
ppb	parts per billion
PSC	Public Service Commission
psi	pounds per square inch
PVC	polyvinyl chloride
RO	reverse osmosis
SCADA	supervisory control and data acquisition
SJRWMD	St. Johns River Water Mangement District
SFWMD	South Florida Water Management District
SRWMD	Suwannee River Water Management District
SSO	sanitary sewer overflow
SWFWMD	Southwest Florida Water Management District
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USGS	United States Geological Survey
WEF	Water Environment Federation
WRF	water reclamation facility
WTP	water treatment plant
WWTP	wastewater treatment plant

Reduction of Energy Consumption in Wastewater Sludge Treatment

Izrail S. Turovskiy

Anaerobic digestion, incineration, and composting of wastewater sludge, require expensive quantities of heat and electricity. Part of the cost can be offset by utilization of the organics in the sludge.

The two types of anaerobic digestion processes are mesophilic and thermophilic. Mesophilic processes occur in the temperature range of 32 to 35°C, while thermophilic processes require a temperature range of 50 to 55°C. Figure 1 shows the technological scheme of mesophilic and thermophilic anaerobic digestion.

Let's examine the amount of energy required for each process by assuming the following:

1. The quantity of gas obtained during digestion is approximately 1.0 m^3 for every 1.0 kg of disintegrated sludge organic.
2. The ratio of raw sludge from primary clarifiers to the thickened activated sludge from secondary clarifiers, as calculated by the mass of dry solids, is 1 to 1.
3. The solids content in the primary/secondary sludge mixture is 4%.
4. 70% of the 4% solids is organic, resulting in 2.8% organics as calculated by the mass of dry solids (70 % x 4%).
5. The disintegration of sludge organics for the mesophilic process is 40%, and for thermophilic process 45%.

One cubic meter of the primary/secondary sludge mixture contains 40 kg of dry solids (1.0 m^3 x 1000kg/m^3 x 4%), and therefore 28 kg (40 x 70%) organics. The quantity of gas obtained during the digestion of this cubic meter of sludge will be 28 x 40% = 11.2 m^3 for the mesophilic process and 28 x 45% = 12.6 m^3 for the thermophilic process.

The gas produced during digestion can be expected to be 60 to 70% methane, 16 to 34% carbon dioxide, and 0.4 to 6% nitrogen, hydrogen, and oxygen. The heat of combustion of the gas will average around 21 million joule/m^3 (Mjoule/m^3).

For digestion to occur, it is necessary to provide 1.1 x 5.67 x (33 – 16) = 106 Mjoule of heat per cubic meter of sludge for the mesophilic process, and 1.1 x 5.67 x (53 – 16) = 230 Mjoule per cubic meter of sludge for the thermophilic process, where 1.1 is a coefficient that takes into account heat loss, 5.67 is the quantity of heat in Mjoule required to heat 1.0 m^3 of sludge by steam per 1° C, 33 and 53 are the temperatures of mesophilic and thermophilic processes, respectively, in degrees Celsius, and 16 is the temperature in degrees Celsius of the original sludge mixture prior to digestion.

The heat released by the combustion of the gas obtained during the digestion of one cubic meter of sludge is as follows:

Mesophilic process: (11.2 x 21) - 106 = 129 Mjoule/m^3 sludge.
Thermophilic process: (12.6 x 21) - 230 = 35 Mjoule/m^3 sludge.

Izrail S. Turovskiy, D.Sc., currently a wastewater and sludge treatment consultant in Jacksonville, is the former head of the of the All-Union Research Institute of Water Supply, Sewage Systems and Hydrotechnical Structures in Moscow, Russia.

Where 11.2 and 12.6 = the quantity of gas in m^3 obtained from the digestion of 1.0 m^3 of sludge,
21 = heat of combustion of 1.0 m^3 gas in Mjoule/m^3, and
106 and 230 = energy required to heat 1.0 m^3 of sludge in Mjoule for the mesophilic and thermophilic processes, respectively.

Since the digestion of sludge organics creates gas, there is a corresponding decrease in the amount of sludge organics remaining following digestion. The 28 kg of sludge organics in digested sludge from the mesophilic process will decrease by 11.2 kg to 16.8 kg (28 minus 11.2). In the thermophilic process, the quantity of sludge organic will decrease by 12.6 kg to 15.4 kg (28 minus 12.6).

Incineration

Incineration dramatically reduces sludge volume. Prior to incineration, sludge must be dewatered and thermally dried, with drying being the most energy intensive step. Therefore, when considering the use of incineration, we must

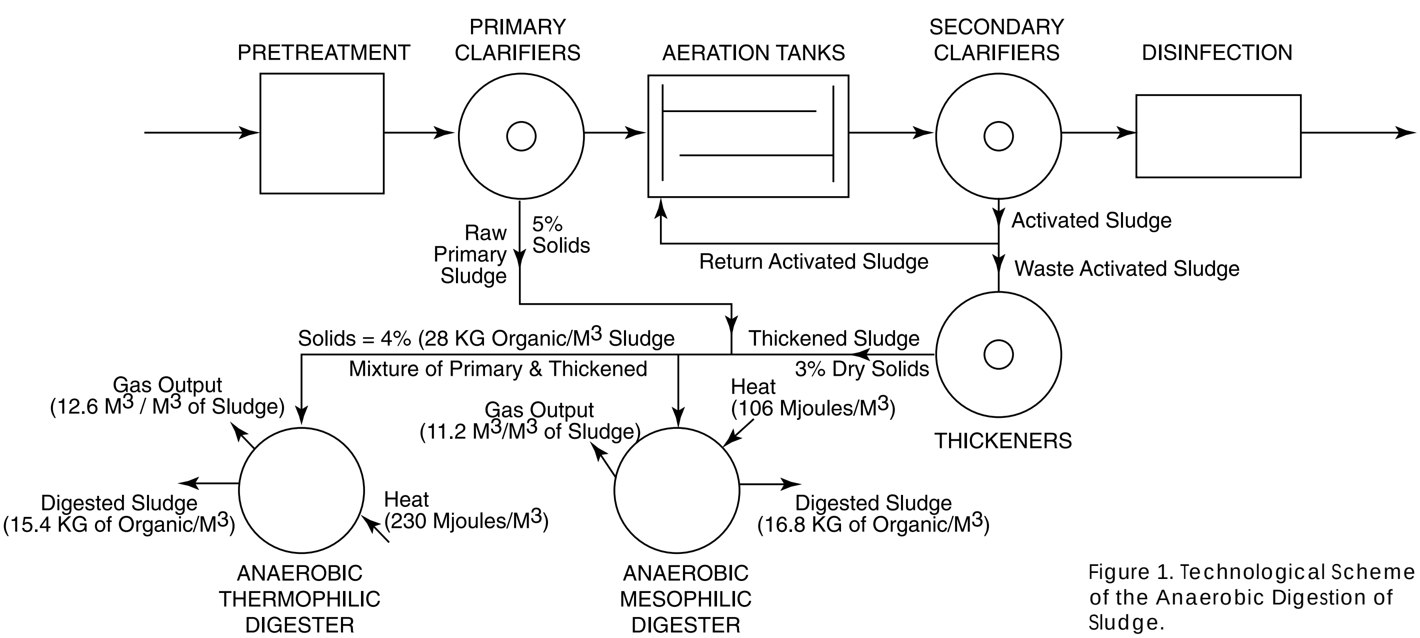


Figure 1. Technological Scheme of the Anaerobic Digestion of Sludge.

look for methods and techniques to reduce the amount of required energy and/or provide some if not all of the required energy from another sludge process.

Dewatering can be accomplished by any number of mechanical processes, including belt presses, filter presses, and centrifuges. The less moisture in mechanically dewatered sludge, the less the total consumption of energy (Figure 2). Therefore, it is most energy effective to remove as much moisture as possible prior to drying. The lower moisture content will reduce the energy requirements in the later steps of thermal drying and incineration.

Let's examine the technology of treatment of a mesophilic-digested primary/secondary sludge mixture using the thermal drying process. In dryers with opposite streams of air, approximately 3.4 to 3.9 Mjoule of heat and 0.02 to 0.06 kilowatt hours (kWh) of electricity are used for each 1.0 kg of evaporated moisture. Let's consider a wastewater treatment plant with a capacity of 100,000 m^3/day (26 MGD). The quantity of mesophilic digested primary/secondary sludge mixture with a solids content of 4% (96% moisture) would be about 800 m^3 per day. Let's further assume this 4% solid sludge was mechanically dewatered to a solids content of 18% to 24%, and we wish to compare the amount of energy required to dry sludge with 24 % solids versus one with 18% solids to a sludge with 60% solids.

The volume of dewatered sludge is calculated by the formula V2 = V1 (C1/C2), where V2 is the volume of dewatered sludge in m^3; V1 is the volume of sludge in m^3 prior to de-watering (800); C1 is the dry solids concentration prior to dewatering (4%), and C2 is the dry solids concentration following de-watering in percent.

For a sludge with a solids content of 24%, volume = 800 x (4/24) =133 m^3. The volume of the thermally dried sludge with solids content of 60% will be 800 x (4/60) = 53m^3. Thermal drying requires evaporation of 133 - 53 = 80 m^3 of moisture and energy of 80 m^3/day x 1,000 kg/m^3 x 3.9 Mjoule/kg = 312,000 Mjoule of heat and 80 m^3/day x 1,000 kg/m^3 x 0.03 kWh/kg = 2,400 kWh of electricity per day.

For the sludge with a solids content of 18%, the volume of dewatered sludge is 800 x (4/16) = 180 m^3. It is necessary to evaporate 180 minus 53 = 127 m^3 of moisture in process of thermal drying that requires 127 x 1,000 x 3.9 = 495,000 Mjoule of heat and 127 x 1,000 x 0.3 = 3,800 kWh of electricity. This is almost in 1.6 times more heat and electricity than required to dry the sludge that has 24% solids.

Utilization of the methane gas generated by the mesophilic digestion process will allow us to reduce the required quantity of heat for thermal drying by 129 Mjoule/m^3 x 800 m^3/day = 103,200 Mjoule/day.

The heat value of incinerated municipal wastewater sludge (Qb) normally ranges from 23.4 to 26.9 Mjoule/kg. This heat is obtained from the organics that are typically 65% to 72% of the sludge solids. The heat value is higher for raw sludge from the primary clarifiers and lower for the digested sludge and the activated sludge from secondary clarifiers. When 1.0 m^3 of a 1 to 1 primary/secondary sludge mixture with a Qb of 25.5 that contains 40 kg of dry solids or 28 kg of sludge organic is incinerated, approximately 28 kg x 25.5 Mjoule/kg = 714 Mjoule of heat may be required. When 1.0 m^3 of mesophilic digested sludge with a Qb of 23.5 is incinerated, 16.8 kg x 23.5 Mjoule/kg = 395 Mjoule of heat is obtained.

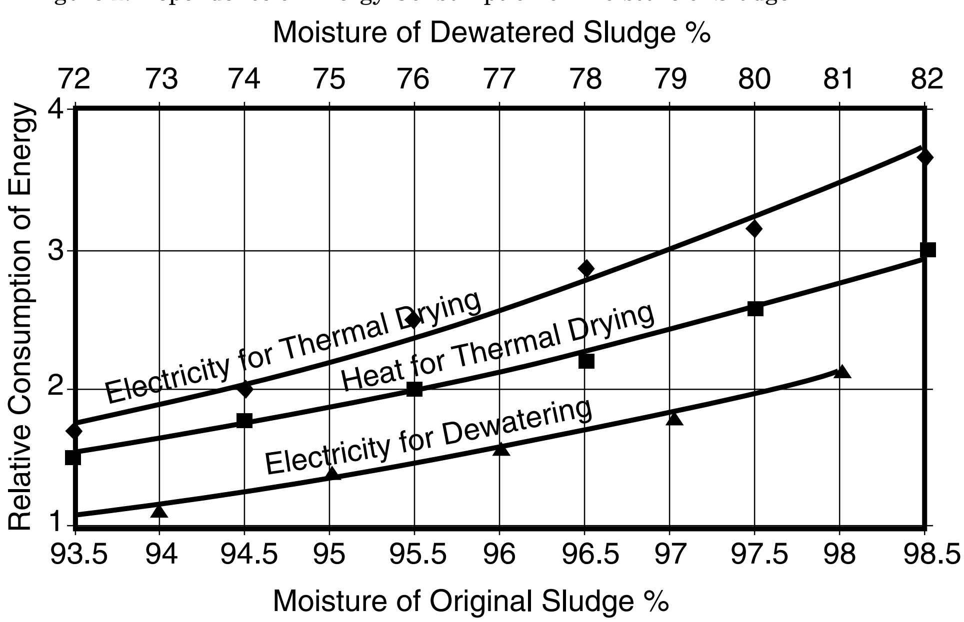
The total energy from anaerobically digested sludge includes the energy from the methane gas produced during digestion plus the energy obtained during incineration of the remaining sludge organics. For mesophilic digested sludge, the total energy obtained is 129 + 395 = 524 Mjoule, and for thermophilic digested sludge the amount of total energy is 35 + 361 = 396 Mjoule. It follows from these calculations that it is reasonable to incinerate the raw sludge because of its higher heat value.

Combining the thermal drying process with incineration of sludge may significantly reduce energy expenditures for thermal drying. As pointed out before, a significant quantity of heat may be obtained by incineration of the sludge. However, most of the heat is spent for moisture evaporation, heating of the blast air, and system losses. Therefore, incineration may cover only the part of heat that is necessary for thermal drying of sludge.

Incineration of a mechanically dewatered, thermally dried primary/secondary sludge mixture in an autothermicity process (conducting the process of thermal drying and incineration without additional consumption of fuel) may be achieved when the moisture of mechanically dewatered mixture is 64-66%. An increase in the moisture content of the dewatered sludge requires spending the appropriate quantity of energy for evaporation of moisture. An illustration of autothermicity incineration of sludge is shown in Figure 3.

It becomes reasonable to use incineration when toxic substances in the sludge prevents its use as fertilizer.

Figure 2. Dependence of Energy Consumption on Moisture of Sludge



Composting

In sludge composting a biothermal process takes place in which microorganisms reduce the sludge organics. This aerobic process is accompanied by a rise in temperature from 50 to 72° C and a decrease in the moisture content of the sludge.

The quantity of sludge organics reduced during composting averages 25%. The reduction of 1.0 kg of sludge organic creates an average 21 Mjoule/kg of heat. Taking in account heat losses and heating of compost material, it is necessary to spend approximately 4 Mjoule of heat for the evaporation of 1.0 kg of water. Thus, the reduction of 1.0 kg of sludge organic allows the removal from the sludge of 5.0 kg of water (21 Mjoule / 4 Mjoule per 1.0 kg of water).

Some moisture is removed from the

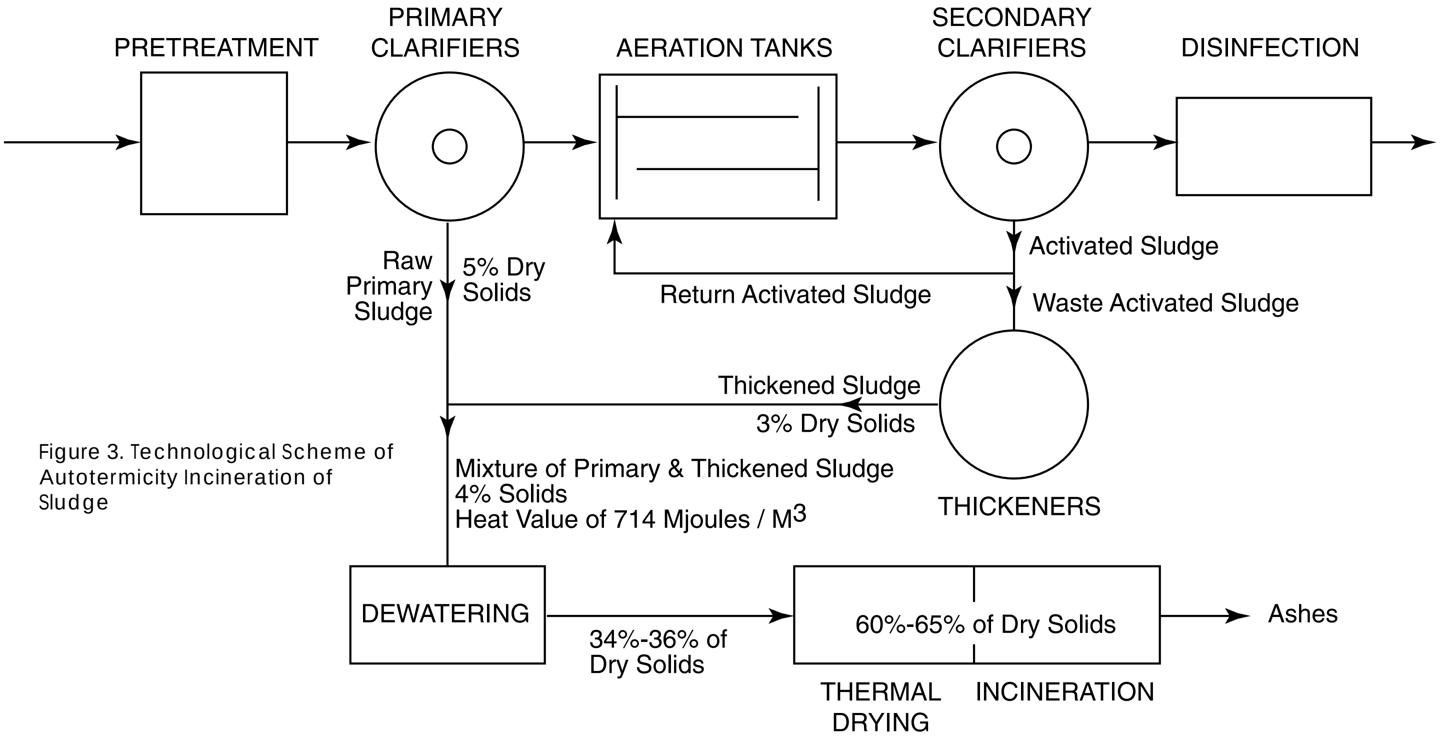


Figure 3. Technological Scheme of Autotermicity Incineration of Sludge

sludge by natural evaporation. The total quantity of removed moisture from the sludge depends on such factors as climate, season of the year, dimensions of piles, duration of composting, and periods of shoveling over. Removal of moisture from the sludge produces compost with moisture content of approximately 50%.

Utilization of sludge organics as a plant fertilizer may bring greater economical benefit than their use as a heat source. Selection of the method of sludge utilization should take into consideration sludge composition, a possible portion to be put into soil, and allocation of sludge on agriculture fields.

Conclusions

A calculation of expenses for heat and electricity for the complete cycle of treatment and utilization of sludge should take in account the quantity of energy that may be obtained from the sludge. Utilization of that energy can significantly reduce expenses for sludge treatment.

A comparison of sludge treatment processes shows that in terms of energy required, composting is the most economical method. It is reasonable to prepare the compost from dewatered raw sludge because it contains more organics than does an anaerobic digested primary/secondary sludge mixture. At the same time, the production schemes of sludge treatment should provide the possibility of the maximum reduction of moisture with the minimum expenditures.

We wish to express appreciation to Jeffrey D. Westbrook, P.E., Sverdrup Civil Inc., Jacksonville, for his assistance in editing this article — Editor.