PRODUCING EXCEPTIONAL QUALITY BIOSOLIDS THROUGH DIGESTION PASTEURIZATION AND REDIGESTION

Dennis A. Burke PE
Cyclus EnviroSystems
6007 Hill road NE
Olympia, WA 98516
dab@cyclus.com

ABSTRACT

The AGF process is the anaerobic activated sludge process using biogas flotation for liquid solids separation (Burke 1991, Burke 1992). The AGF pasteurization process (Burke 2000) includes the additional step of pasteurizing and re-digesting the thickened waste solids to convert an even greater portion of the biosolids to gas.

The AGF pasteurization process was installed at Southwest Suburban Sewer District's 3.0-mgd (1136 m^3/d) Salmon Creek plant in 1998. Installation of the process involved converting an unused 18-foot (5.5 m) diameter thickener to a gas flotation (AGF) unit and installing a 300-gallon (1.14 m^3) pasteurization tank. This paper presents the results of the AGF operation over the first 60 weeks of operation. This paper also presents the pasteurization pilot results using waste solids from the AGF float concentrate. Full-scale pasteurization results will be reported at the Biosolids 2001 Conference. Table 1 compares the solids handling process at Salmon Creek before and after AGF installation.

Table 1 – Results of AGF Process Installation

	Pre - AGF	Post - AGF	Change(%
Volatile Solids Destruction (%)	57	73	28
COD Conversion to Gas (%)	NA	70	
Belt Press Operation (days / week)	4	1	-75
Belt Press Volume (gallons / week)	106,500	40,300	-62
Solids Removed (cy / week)	44.5	32.9	-26
Digester Foaming (number / week)	1	None	∞

The process stabilized the digester and eliminated digester foaming. Volatile solids conversion to gas increased from 57 to 73% while the total solids removed from the plant decreased 26%. Operation of the belt press decreased from an average of 4 days per week to 1 day per week. The process increased digester capacity by a factor of 3 times its existing capacity (SRT/HRT = 3.04). The process also consumed less energy than that required to mix and heat an existing mesophilic digester.

A six month pilot investigation confirmed that concentrated float recycle could be pasteurized and redigested to achieve an additional 10 to 12% volatile solids destruction. The final biosolid product was relatively odorless, pathogen free, and fully stabilized.

KEY WORDS

Anaerobic digestion, pasteurization, gas flotation, AGF, anaerobic activated sludge, solids retention time, volatile solids destruction, class A biosolids

INTRODUCTION

Southwest Suburban Sewer District (SWSSD) operates two wastewater treatment plants in King County, Washington. Both the Miller Creek and Salmon Creek plants use a waste treatment process train consisting of primary sedimentation followed by RBC secondary treatment with gravity solids thickening, anaerobic digestion, digested solids holding (no heating or mixing), belt press dewatering, and disposal on crop land in Eastern Washington.

Although both plants are approximately the same size, the Miller Creek plant is far better equipped with more efficient sludge thickening facilities, larger digesters, and two belt presses. Over the years the Salmon Creek plant achieved an average 57% Volatile Solids destruction in spite of poor thickening and frequent foaming events. The operators were required to belt press solids eight hours a day, 4 to 5 days a week, with little relief over the holidays.

In addition to improving biosolids stabilization at Salmon Creek, SWSSD wanted to reduce biosolids disposal costs by producing Class A biosolids. Over the years the District invested heavily in composting facilities, refined the art of sewage sludge composting, and developed a high quality compost product and a substantial customer base. However, the District could not control odor problems at the compost facility without further investment in indoor, or in-vessel composting with treatment of all gasses generated. In addition the net cost of composting was about double the cost of disposing solids in Eastern Washington. As a result the District reduced their composting activities in 1996.

During this period SWSSD became aware of the AGF process. The AGF process had achieved an 80% COD reduction while digesting primary and waste activated sludge from the Olympia, WA (LOTT) treatment plant over a six month period in 1991(Burke 1992). Following the Olympia studies, King County installed an AGF pilot plant at their Renton treatment facility. The King County AGF pilot plant was operated parallel to a conventional digester for over a year (Burke, Butler et al. 1996). The AGF digester was operated at a 6, 10, and 18 day HRT while the conventional digester was operated at a 19-day HRT. The AGF process achieved a 64% VS reduction at a 6-day HRT, 69% VS reduction at a 10-day HRT, and a 72% VS reduction at an 18-day HRT. The parallel conventional digester achieved a 60% VS reduction at a 19-day HRT. The process tripled the capacity of the AGF digester since a SRT/HRT ratio of 3.3 was obtained. The solids produced were well stabilized with no significant odor.

SWSSD subsequently made its treatment facilities at the Miller Creek plant available for additional flotation separation and pasteurization studies while the AGF process was being demonstrated at King County's Renton wastewater treatment plant in 1995 and 1996. The early pasteurization laboratory studies at SWSSD showed that the primary digester's waste solids could be pasteurized and redigested to produce a well-stabilized relatively odorless Class A product (Burke and Yokers 1999). The process of pasteurizing the digested solids created a very odorous product that was rendered relatively odorless upon redigestion.

From 1996 through 1998 pilot plant demonstrations of the AGF process were performed at several potato processing (french-fry and flake) (Burke 1996) facilities in Idaho and at a dairy treating cow manure in Washington (Burke 2000). Those demonstrations showed extremely rapid conversion of soluble and particulate solids to gas while producing a relatively clear effluent from which struvite (Magnesium Ammonium Phosphate) was recovered.

Since the AGF process appeared to offer the potential to recover nutrients, stabilize the anaerobic digester, increase volatile solids destruction, and produce a Class A product, SWSSD authorized the construction of a full scale AGF pasteurization facility at the Salmon Creek Plant in 1998. The construction took place in three phases.

- Phase I – Install AGF process and operate process for one year while performing additional pasteurization and redigestion pilot studies using float solids.
- Phase II – Install and operate full-scale pasteurization facilities while performing nutrient recovery studies.
- Phase III – Install nutrient recovery facilities.

The full-scale pasteurization facilities were installed and placed in operation in 2000. This paper reports on the Phase I operation over a 13-month period. The phase II results of the full-scale pasteurization operation will be provided during the conference presentation and in subsequent papers.

THE AGF PROCESS

The AGF process is the anaerobic activated sludge process incorporating biomass flotation thickening and biomass recycle (Burke 1991) (Burke 1992). The pasteurization process (Burke 2000) adds another step. Periodically portions of the thickened solids are removed from the thickened recycle stream, pasteurized and re-digested in a second mesophilic digester (made available through the improved capacity of the primary AGF digester). The pasteurization tank is small since less than 25% of the total influent flow to the digester is processed through the tank. The pasteurization heat requirements are approximately equal to the heat required to maintain the 20-day HRT mesophilic digester at operating temperatures.

The pasteurization process destroys the anaerobic bacteria, and other pathogens that are maintained in the first anaerobic digester. The bacterial cells, which have undergone lysis, through pasteurization, can be subsequently re-digested and converted to gas in a second anaerobic digester. Previous laboratory tests showed that an additional 5% to 15%

more volatile solids are converted to gas in the second anaerobic digester. The process meets EPA's 503 requirements for producing Class A biosolids. With re-digestion the process is considered a batch "pasteurization / digestion process".

The AGF process uses "Anoxic Gas Flotation" to concentrate and separate anaerobic bacteria for recycle to the primary digester. Biogas is used for flotation separation. Gas flotation is advantageous since hydrophobic forces assist the separation of a wide variety of organic acids and other constituents, thus minimizing the need for large quantities of polymer (charge) for liquid / solids separation. The process is also tranquil and does not adversely affect the bacterial consortia. Very little energy is required to accomplish the separation when a multiphase flotation pump is used. The flotation process also scrubs the biogas by retaining CO_2 and H_2S in the effluent liquor. A relatively clean biogas can be produced, if desired for energy generation.

Pasteurized biosolids provide the heat required for the second mesophilic digester. No additional energy is required to maintain the digesters at mesophilic temperatures. Since only a small *volume* of biosolids must be pasteurized, the pasteurization tank size is less than 100 gallons per mgd (1/10,000 ratio) of treatment plant capacity.

THE AGF PROCESS AT SALMON CREEK

The AGF process was installed at the Salmon Creek plant by converting an old 18 foot (5.5 m) diameter thickener to a gas flotation separator and adding a 300-gallon (1.14 m^3) pasteurization tank and small steam boiler fueled by excess biogas.

Figure 1 – AGF Pasteurization at SWSSD

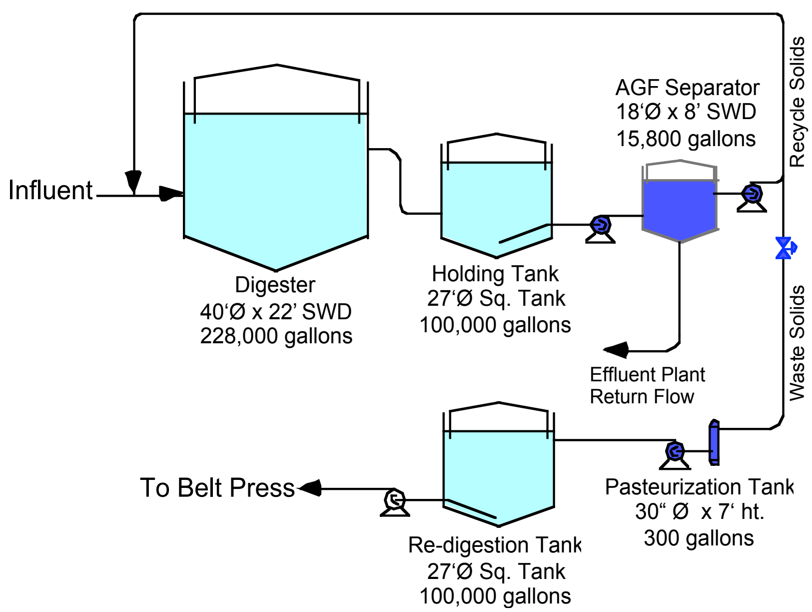


Figure 1 presents a schematic of the process installed at Salmon Creek. Photographs of the components can be viewed and downloaded at www.makingenergy.com.

The existing primary digester is heated and mixed. Biogas from the digester is used to heat the digester and treatment plant buildings. The two small holding tanks were not heated or mixed. The first holding tank isn't required for the process. The second holding tank was converted to the re-digestion digester by activating its gas mixing system. The pasteurized solids provide the necessary heat to the redigestion digester for mesophillic re-digestion.

SAMPLING AND ANALYSIS

To document the performance of the process all gas, solid, and liquid flow meters were calibrated. Calibration consisted of pumping to a tank truck and measuring the quantities delivered over time. The calibration resulted in lowering the previously reported influent pump rate by 11%. All gas volumes could not be accurately measured since the holding tanks operated on a different pressure system that could not be metered reliably.

Samples were collected from each process flow stream two to four times per week and analyzed for Total Solids and Volatile Solids. At least once a week the process streams were analyzed for COD, TKN, Total P, Soluble P, Ammonia, Sulfide, Calcium, Magnesium, and Alkalinity. Gas samples were analyzed for H_2S and CO_2. Once per quarter belt press cake solids were analyzed for a variety of heavy metals and conventional constituents. All analysis was performed using Standard Methods.

OPERATING RESULTS

The influent sludge flow to the primary digester averaged 15,540 gpd (58.8 m^3/d) during the 61-week operating period reported in this paper. The small flotation separator concentrated the solids sufficiently to achieve an average SRT/HRT ratio of 3.04. The capacity of the primary digester was thus increased by 3.04 times its capacity prior to installation of the AGF process. The average operating values are presented in Table 2.

Table 2 – Average Analytical Results –AGF Process

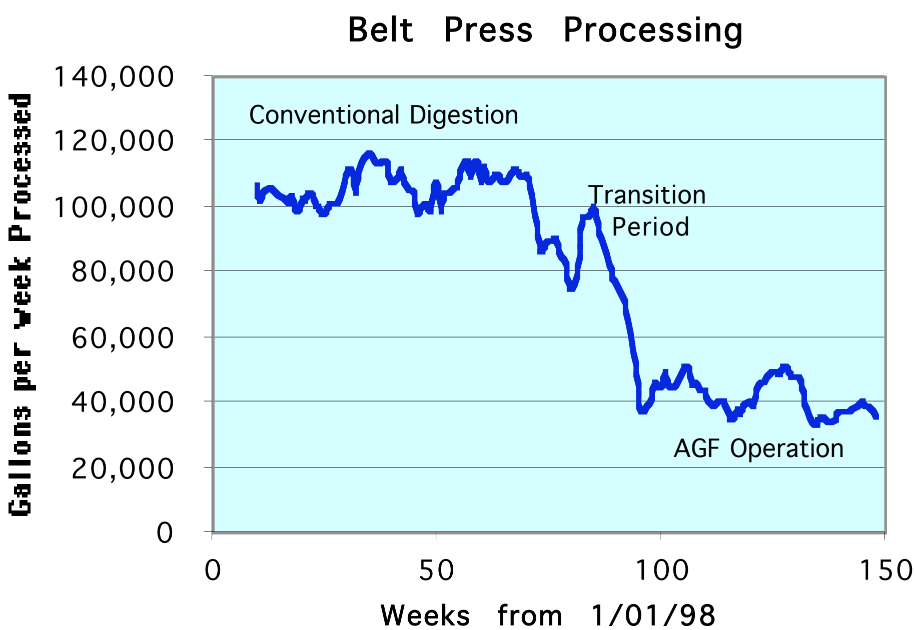
	Average of Weekly Values (Week 1 to 61)					
	Influent	Digester	Holding	Float	Redigestion	Effluent
Total Solids (%)	3.3	3.5	3.4	5.0	3.8	
VS / TS (%)	85.2	68.61	67.4	68.7	66.8	
Volatile Solids (%)	2.83	2.42	2.28	3.43	2.52	
COD (g/L)	39.04		36.05	57.95		0.90
COD / VS	1.38		1.58	1.69		
Total P (mg/L)	515		990	1611		126
Soluble P (mg/L)	145		499	817		85
TKN (mg/L)	2046		3122	4390		1369
Ammonia (mg/L)	274		931	1080		929
Sulfide (mg/L)	18.5		31.6	28		0.4
Alkalinity (mg/L)	2854		4711	4459		4282
pH	5.6		7.03	7.1		7.2

A mass balance established that the volatile solids destruction varied between 67% and 75% throughout the 60 weeks. The average VS destruction was 73%, closely approximating the results achieved during the King County pilot plant operation. COD reductions were 70%. Thirty seven percent of the influent total P was lost in the effluent. Most of the total P was concentrated in the waste solids. Fifty percent of the TKN was lost in the effluent, primarily as ammonia. Forty-four percent of the sulfide was lost, primarily as H_2S gas.

Float solids are more economical to waste than digester solids since the float solids are concentrated. In addition, float solids are charge neutralized and require very little additional polymer to dewater. As can be observed from Table 2 those solids also have a much higher concentration of nutrients than the raw waste.

The AGF process reduces the quantity of liquid that must be processed through a belt press or other dewatering device. Figure 2 presents the quantity of anaerobically digested biosolids that were dewatered each week. During the first 60 weeks, beginning in January 1998, the process was operated in the conventional mode. From week 61 to week 99 the AGF process was operating but had not achieved steady state operation. From week 99 to 150 the process was operated in a steady state AGF mode.

Figure 2, Weekly Belt Press Quantities from January 1998

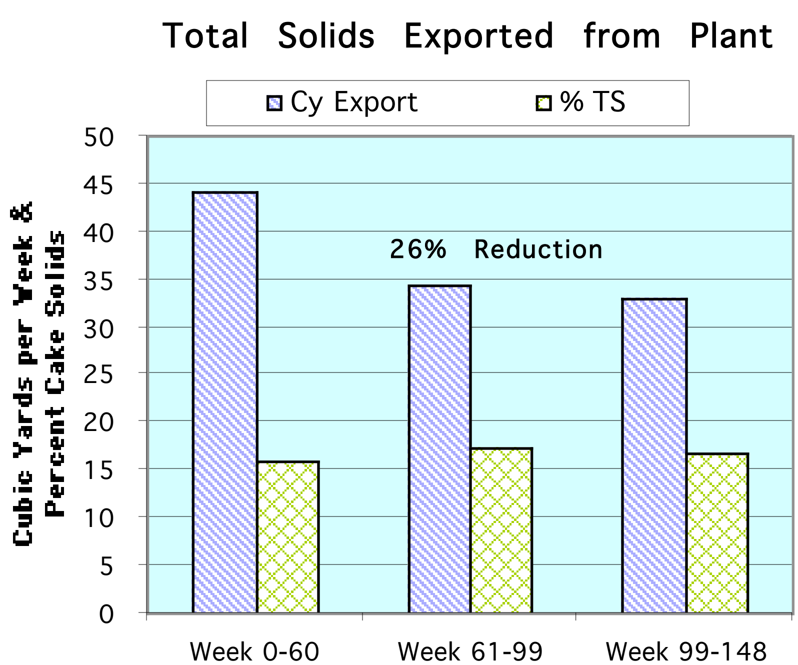


As can be observed from Figure 2 the quantity of liquid that was dewatered each week decreased from an average of 110,000 gallons (415.4 m^3) to 40,000 gallons (151.4 m^3). Belt press dewatering decreased from an average of 4 days per week to 1 day per week.

Increased volatile solids destruction was confirmed by the reduced quantity of cake solids removed from the Salmon Creek plant. Figure 3 presents the cubic yards of biosolids removed from the Salmon Creek plant since January 1998. During the conventional operating period, weeks 0-60, 44.5 cubic yards (34 m^3) of biosolids were removed each week. During the transition weeks 61 to 99, approximately 34 CY (26 m^3) were removed each week. Finally during the steady-state period from week 99 to 148, 32.9 CY (25.1 m^3) were removed each week. The total reduction in the volume of solids removed was approximately 26%.

Figure 3 also presents the dewatered solids content (%TS). The cake solids concentration increased from approximately 15% Total Solids to slightly over 16% during the 150-week analysis period. Consequently, a small percentage of the reduced quantity of solids removed can be attributed to increased cake total solids concentration. Nonetheless, the rather substantial decrease in solids removed must be attributed to the increased volatile solids destroyed.

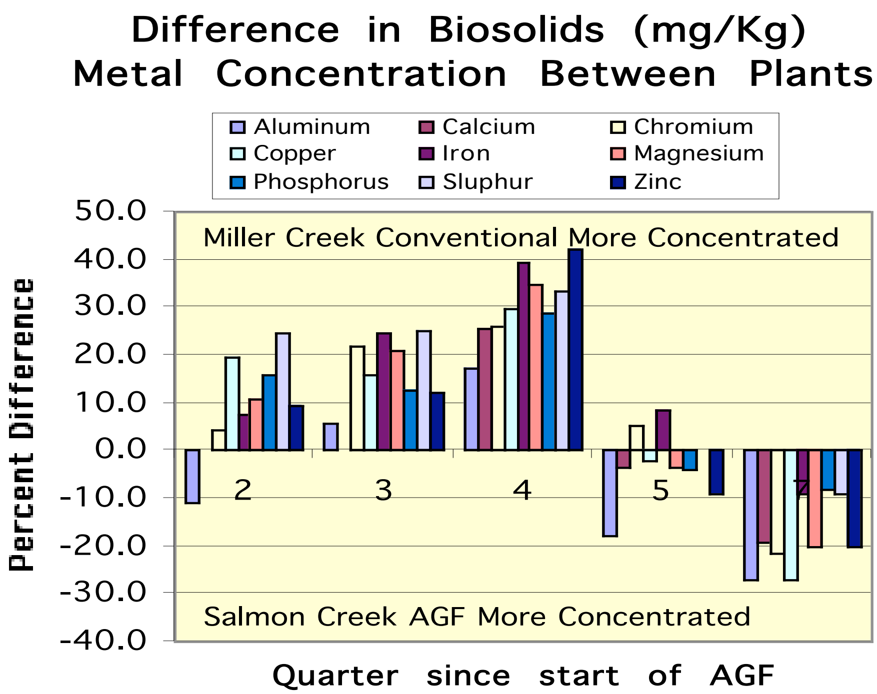
Figure 3 - Biosolids Removed and Cake Solids Concentration



The increased volatile solids destruction can also be observed when comparing the cake solids dry weight heavy metals concentration between the Miller Creek Plant and the Salmon Creek plant. Both plants treat comparable residential sewage. Historically, the Miller Creek plant has had a higher heavy metal concentration because of its larger digesters leading to larger solids retention times and higher volatile solids destruction. Figure 4 presents the change in the difference in heavy metal concentration between the two plants.

As can be observed, the heavy metal concentration was historically much higher at the Miller Creek plant (Quarters 1 through 4, 1998). Once the AGF process began operation the heavy metal concentration of the Salmon Creek solids became greater than the Miller Creek biosolids. The inverse was true of the soluble constituents such as potassium.

Figure 4 – Plant Differences in Heavy Metal Concentrations



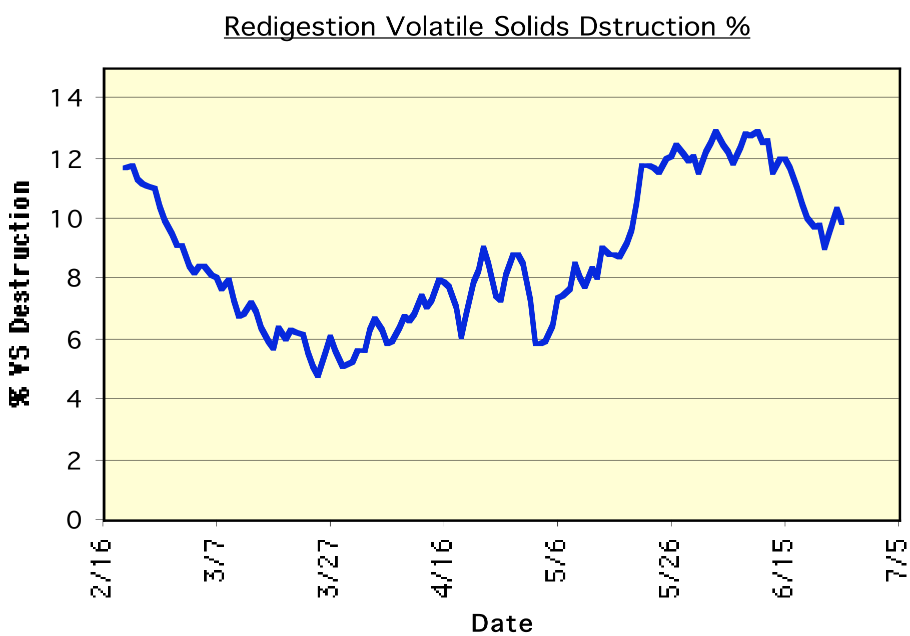
PASTEURIZATION FINDINGS

Operation of the AGF process over a prolonged period of time provided an accurate determination of the quantity of solids to be wasted each day. During steady state operation 5110 gallons (19.34 m^3) of digested solids or 3650 gallons (13.8 m^3) of concentrated float solids were wasted each day. Twenty-four one-hour batches of 150 gallons (0.57 m^3) each were sufficient to pasteurize the waste solids. Pasteurization is accomplished by adding small quantities of steam to each batch of waste solids to both dilute the solids (10 to 20%) and raise the temperature to 160°F. Prior to placing the full-scale pasteurization system on line SWSSD wanted to perform pilot pasteurization studies on the float. After observing thermophilically digested solids at another waste treatment plant they became concerned that the resulting product would be odorous. Consequently, a six-month pilot investigation was conducted to determine the composition and quality of the pasteurized and redigested float solids.

Over a six-month period daily-thickened float samples (0.5 L/d) were taken from the waste solids stream, diluted 50% and batch pasteurized for 30 minutes. The pasteurized solids were placed in a 26-Liter completely mixed anaerobic digester having an HRT of 20 days. The digester was initially seeded with digested sludge. After two months the samples were analyzed monthly to determine physical, chemical and biological quality. Gas quantity and quality were measured daily. The gas quantities were used to establish the volatile solids converted to gas. A ratio of 872 ml of gas to one gram of volatile solids destroyed was used.

Figure 5 presents the results of the pasteurization investigations. After an initial acclimation period the redigestion process converted between 10 and 12% of the influent volatile solids to gas. If the AGF process achieved 73% VS destruction an additional 10% VS reduction of the remaining solids would add 2.7% additional conversion to gas for an overall VS reduction of 75.7%.

Figure 5- Redigestion Volatile Solids Destruction Pilot Results



Only one sample showed any fecal coliform, and that sample had a value of 12 MPN per gram of total solids, well below the allowable 1000 MPN for class A biosolids. *Salmonella sp.* was not detected in any sample.

The pasteurized and redigested solids were relatively odorless. Gravity tests indicated that it had equal, if not better dewatering characteristics when compared to the AGF float solids.

CONCLUSION

The AGF process performed as the models derived from previous pilot scale work indicated. The redigestion of pasteurized float solids also confirmed previous investigations. This work has demonstrated that the process offers the following benefits to municipal waste treatment facilities.

It can be easily and economically added to existing facilities to:

a) Stabilize the anaerobic digestion process and eliminate foaming
b) Produce class A biosolids
c) Increase the capacity of existing anaerobic digesters by three times their existing capacity
d) Increase the volatile solids destruction to values approaching the theoretical maximum of 80%
e) Reduce the time required to dewater solids to at least one-third existing values
f) Produce an odorless fully stabilized product
g) Reduce the quantity of solids to be disposed by 25 to 30%
h) Use less power and heat than required to heat and mix a conventional digester to mesophilic temperatures.

REFERENCES

Burke, D. A. (1991). Anoxic Gas Flotation. Patent USA 5,015,384.

Burke, D. A. (1992). Anaerobic Digestion of Sewage Sludge Utilizing the AGF Process. The Future Direction of Municipal Sludge (Biosolids) Management: Where we are and Where we're Going, Portland, Oregon, Water Environment Federation.

Burke, D. A. (1992). Systeme De Fermentation Anaerobie. Canadian Intellectual Property Office.

Burke, D. A. (1996). High Rate Anaerobic Digestion of Food Processing Waste. Energy and the Environment, Northwest Food Processors Association, Portland Oregon.

Burke, D. A. (2000). Application of the AGF (Anoxic Gas Flotation) Process. The 4th International Conference: Flotation in Water and Waste Water Treatment, Helsinki Finland, Finnish Water and Waste Water Works Association.

Burke, D. A. (2000). Pasteurization Process. US 6113789A. United States**:** 8.

Burke, D. A., R. Butler, et al. (1996). Improved Anaerobic Digestion Utilizing Anoxic Gas Flotation. WEFTEC'96, Dallas Texas, Water Environment Federation.

Burke, D. A. and T. Yokers (1999). Class A Biosolids with the AGF Process. 66th Annual Pacific Northwest Pollution Control Association Conference, Double Tree Hotel Bellevue, Washington, Water Environment Federation.