Once I was blind, but now I can see

A reliable and accurate solids meter is the trusted set of eyes in optimal sludge treatment

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Operating a sludge or biosolids process without knowing the percentage of solids in influent and effluent is like driving a car blindfolded. These data are critical especially for sludge, as the associated costs for treatment and disposal are as much as 50% of the entire cost of operating a water resource and recovery facility (WRRF).

The need to reduce costs led the Passaic Valley Sewerage Commission (PVSC; Newark, N.J.) to explore total solids measurement methods and yield timelier results for its centrifuge thickeners. Solids concentration in its facility's centrifuge-thickened sludge was difficult to determine. Operators had to perform manual solids analyses every 4 hours to adjust centrifuge discharge solids. In addition, the analytical methods – involving a lab centrifuge for determining percent solids by volume and a microwave oven or heat lamp to dry a manually prepared sludge sample – produced good results but did not provide real-time feedback and were time-consuming. In addition, even with manual sample analysis, changes in centrifuge feed solids between tests periodically would result in overthickening and clogging.

After conducting an investigation, PVSC found that entrained air bubbles were interfering with accurate measurements. It replaced its existing meters with a new meter using a patented

◀ **A centrifuge operator manually measures percent solids in grab samples. Manual measurement was necessary since the existing solids meter was unable to provide accurate results.** PVSC

microwave time-of-flight measurement technology. The meter uses a continuous modulating microwave signal that measures percent solids and internally compensates for sludge conductivity. With continuous measurements, the centrifuges are able to thicken sludge to the optimal percent solids for better sludge treatment, reduced operating costs, and minimal operator involvement.

Varied feed concentration

PVSC operates a 14.5-m^3 (330-mgd) WRRF in northern New Jersey. The facility serves a connected population of 1.3 million in 48 towns and cities and operates one of the largest out-of-district liquid waste acceptance programs in the nation. Each day, an average of 3.4 ML/d (900,000 gal) of liquid sludge is delivered to the facility by truck and barge. The sludge mix – consisting of primary, waste-activated, anaerobically digested, and water-treatment sludges – constantly changes in amount and source.

Processing starts with screening, degritting, and gravity thickening for PVSC's primary, waste-activated, and truck-delivered sludges. Gravity-thickened sludge, which varies monthly from a minimum of 1.6% solids in the summer to 5.8% in the winter, is pumped to three, small, mixed wet wells feeding four thickening centrifuges, which process 4500 L/min (1200 gal/min). Digested sludges averaging 1.6% solids and water treatment sludges averaging 4.5% also are fed to the centrifuge wet wells. The various sludges, mixing ratios, and seasonal fluctuations result in centrifuge feed concentration of between 1.8% and 4.8%.

Sludge treatment

PVSC uses a wet-air oxidation sludge treatment system for volatile solids reduction and sludge conditioning for dewatering. The process consists of 12 process trains each rated at 980 L/min (260 gal/min). The process is both capital- and energy-intensive. However, once the capital cost is amortized, the process is cost-effective for PVSC to operate as it is suitable for a wide range of sludges, reduces volatile solids by 50%, and produces a relatively small amount of dry cake (55% solids) without chemical addition.

Each treatment unit uses a fixed amount of energy to heat each gallon of sludge independent of the feed sludge solids concentration. A thicker liquid sludge decreases the total sludge flow to the sludge treatment process. With a lower sludge volume, the number of treatment units needed decreases, minimizing total energy use.

The units also have a mechanical limitation that limits the maximum feed concentration to 6.0%. The "sweet spot" for operation is a feed concentration close to but not exceeding 6.0% solids. But because of the facility's problem in accurately measuring percent solids, operators have adjusted the percent solids setpoint lower than 6% to prevent clogging or mechanical damage. The larger than necessary factor of safety results in a substantial increase in sludge feed and therefore an increase in energy consumption.

Table. Comparison of lab data and percent solids meter readings

Sludge feed to centrifuge (percent solids)		Centrifuge discharge, no back-pressure (percent solids)		Centrifuge discharge with back-pressure (percent solids)	
Lab	**Meter**	**Lab**	**Meter**	**Lab**	**Meter**
2.5	2.5	5.4	5.05	5.1	5.4
3.1	3.2	5.3	5.03	5.3	5.7
1.1	1	5.1	5.06	5.5	5.8
2.45	2.5	5.1	5.06	5.5	5.9
2.54	2.6	5.4	4.2	5.3	5.3
2.2	2.1	5.3	5.97	5	5.1
2.2	2.2	5.3	5.99	4.3	4.6
2.5	2.6	5.3	6.04	4.8	5.2
1.78	1.8	5.3	5.26	3.9	4.4
2.2	2.1	5.4	5.35	4.9	4.9
2	2	5.4	5.22	4.9	5.4
2.6	2.5	5.4	5	5.3	5.5
2.6	2.5	5.6	5.56	2.1	2.6
2.2	2.2	4.5	6.52	2.1	2.2
2.9	2.9	5.2	6.02		
2.1	2.3	5.1	5.53		
2.1	2.2	5.1	6.04		
		4.9	6.04		
		4.9	6.39		
R^2	**0.97**	**0.34**		**0.98**	

The PVSC water resource recovery facility uses four thickening centrifuges that play a critical role in its solids treatment train. PVSC

Accurate solids measurement difficult

Pond depth, bowl speed, scroll conveyor speed, and polymer dose are used in centrifuges to control the solids content of the final product. The thickening centrifuges at PVSC use a patented device to control solids thickness by varying pond depth in real time (see Figure 1, p. 47). The centrifuges can provide excellent automatic control of discharge solids, but only when used with an accurate percent solids measurement for a feedback control signal.

In actual operation, however, the device was unable to provide automatic control – the percent solids in discharge had to be entered manually. The solids meter originally supplied with the centrifuge relied on back-scatter light technology that was unable to adjust to the different colors, particle sizes, air bubbles, and changing sludge characteristics. In spite of efforts by the centrifuge manufacturer to rectify the problem, including the trial use of another meter that could not perform satisfactorily with PVSC's high-conductivity sludge, reliable solids measurement was unattainable.

It was theorized (and later proven) that air entrainment in the discharge was the cause of the meter failures. Thickened sludge from the rotating centrifuge bowl is thrown outward radially and hits the centrifuge casing at high speed, resulting in great turbulence and entrained air. Installations with large wet wells have enough detention time to allow entrained air to exit the sludge. In PVSC's case, the centrifuges discharge directly into pipelines that lead to the next processing step. In spite of a stilling area in the centrifuge discharge line, small bubbles formed in the liquid sludge.

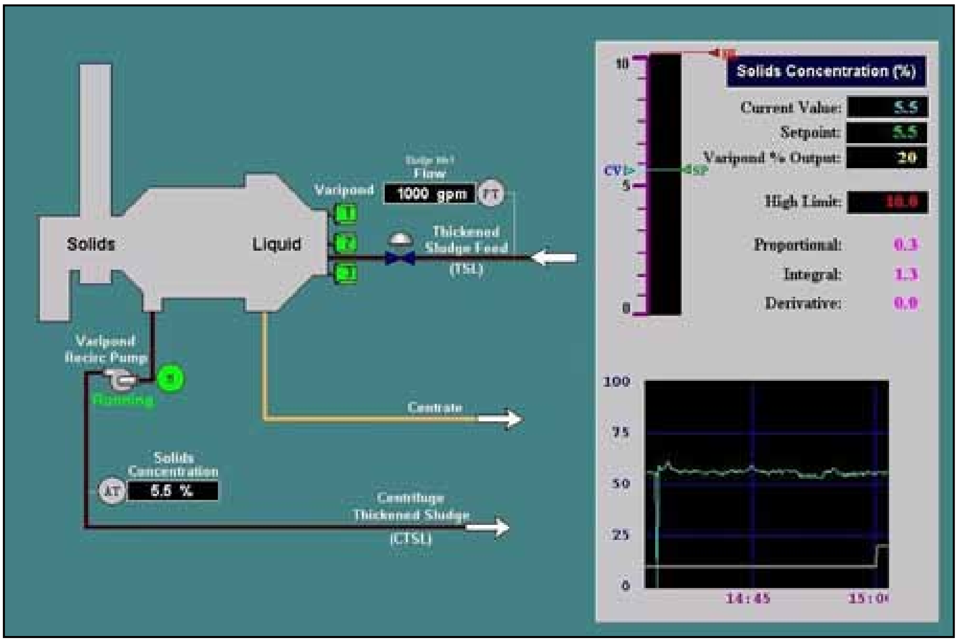
Solids measurement for process control

PVSC was introduced to a new solids meter that is based on a patented microwave time-of-flight measurement system at a Water Environment Federation Residuals and Biosolids conference. The meter uses a continuous modulating microwave signal that measures percent solids and internally compensates for sludge conductivity.

The meter confirmed the root cause of the problem as volatile entrained air bubbles trapped in the sludge. To correct the problem, the pressure in the meter sample line was increased to 1.5 bar (22.5 $lb/in.^2$) to collapse the air bubbles back into the solution.

A full-scale test program of the new meter, left, was conducted on one centrifuge. PVSC

Figure 1. A screenshot from the SCADA system showing the centrifuge control system



Grab sample analysis confirmed the meter results (see the table, p. 45). On centrifuge feed sludge without entrained air bubbles, the correlation between lab-analyzed grab samples and the meter output was near perfect, with an R^2 of 0.97. However, when reading the centrifuge discharge with entrained air, the correlation was poor at 0.34. After back-pressure was applied to the metered flow, the correlation between the lab results and the meter was similar to the feed sludge at 0.98.

Next, a full-scale test program of the meter was conducted on one centrifuge. PVSC staff, with the assistance from the centrifuge manufacturer, implemented a control algorithm to vary the meter position in response to solids meter readings. The system was able to operate the thickening centrifuge automatically. A comparison of discharge total solids from the centrifuge during automatic and manual modes is shown in Figure 2 (right).

As a result of the test program's success, new solids meters were installed on all four thickening centrifuges to measure solids in the sludge feed and discharge. The meter has no moving parts and therefore maintenance requirements are minimal.

Cost and energy savings

Solids concentration is a critical measurement for process control and for reducing operating costs. And the on-line solids meter yielding instantaneous solids measurements improves operation even further. Automatic adjustments to changing feed solids will reduce sludge volume discharged from the centrifuges by an average of 9%. The reduction in flow to wet-air oxidation treatment will save PVSC $1.2 million per year in both energy and chemical costs.

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Figure 2. Comparison of discharge total solids from the centrifuge during automatic and manual modes