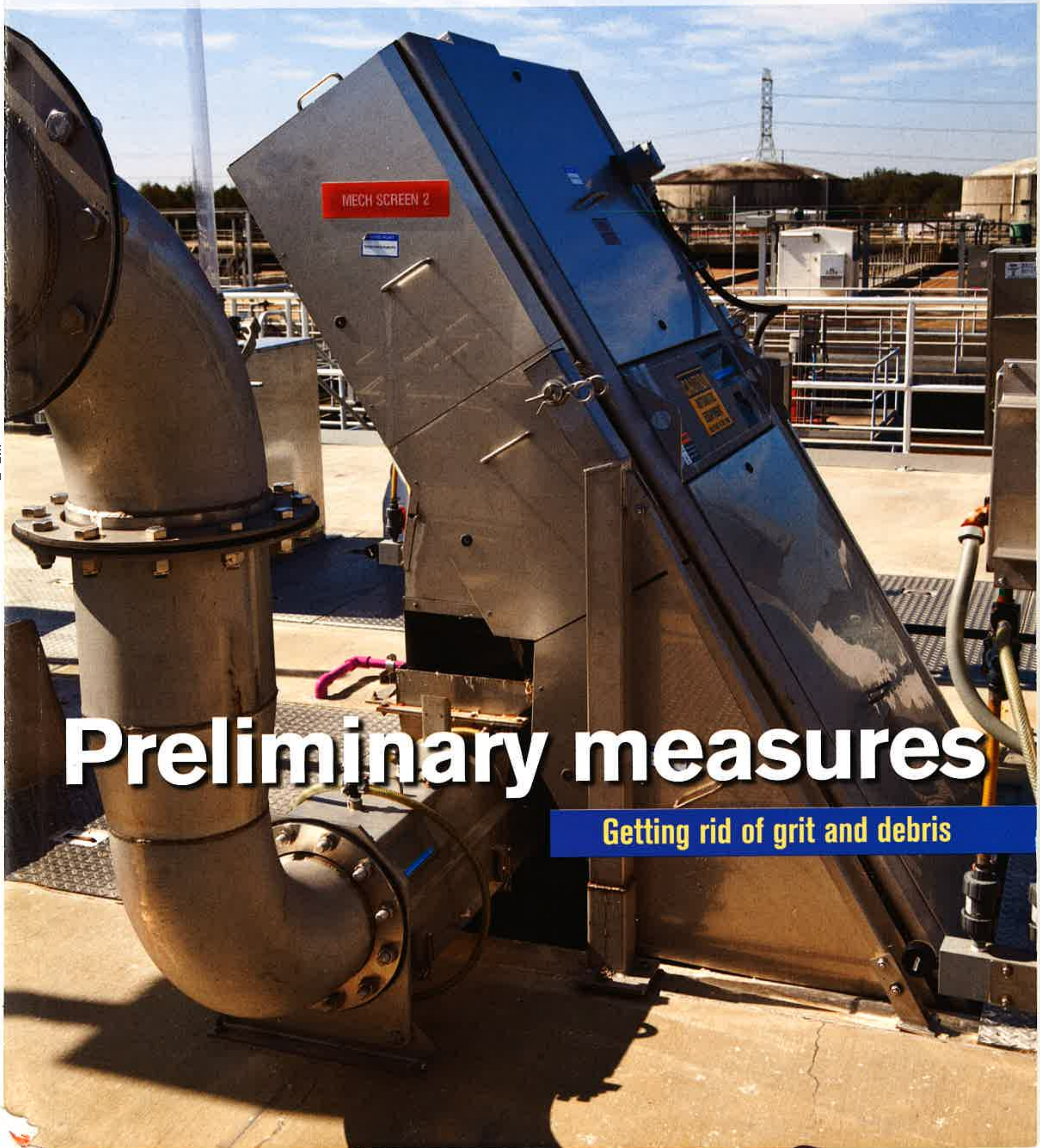
VOLUME 25 | NUMBER 10
WE&T
OCTOBER 2013

WE&T

water environment and technology

October 2013



Preliminary measures

Getting rid of grit and debris

COVER
Proper preliminary treatment can yield big results for little particles. (See pp. 34 and 40). Paul Cockrell

Water Environment & Technology is the magazine of the Water Environment Federation and the official publication of WEFTEC

WE&T
VOLUME 25, NUMBER 10
OCTOBER 2013

Features

(of) Look for this symbol identifying Operations forum content

The Gulf Pond Pump Station in Milford, Conn., discharges into two force mains. Before upgrades and fixes, these force mains were the source of high levels of hydrogen sulfide, which led to odor and corrosion problems throughout the downstream system. Charlie Smith/AECOM

Milford fights odor and corrosion

Use of pure oxygen improves sewer system safety and operation

Kenneth A. Bradstreet, Charles N. Smith, Robert P.G. Bowker, and Inken N. Mello

Milford, Conn., has an extensive sewer system that includes two water resource recovery facilities, 42 pumping stations, and an extensive system of sanitary sewers. In recent years, the system has been plagued with odor complaints and has undergone severe corrosion problems caused by hydrogen sulfide.

Odor and corrosion issues were most evident in the East/West Interceptor and at the West Avenue Pump Station. All of the manholes on the East/West Interceptor had deteriorated badly. The city started a program of manhole rehabilitation using various types of manhole liners. It was then learned that the 900-mm (36-in.) ductile-iron sewer had developed perforations along the spring line of the pipe. At that point, the city opened a sewer contract to completely replace the interceptor, which then was slightly more than 20 years old.

Corrosion damage in the West Avenue Pump Station wet well also was severe. Concrete in the channels carrying flow into the wet well was crumbling, and reinforcing steel was exposed in many areas. All of the electrical conduit and fixtures and all of the heating, ventilation, and air-conditioning ductwork in the lower level of the wet well were damaged beyond repair and no longer functional.

The effects of the hydrogen sulfide at the Housatonic Wastewater Plant were not as severe as at the West Avenue Pump Station but still were noticeable, exhibiting metal corrosion and persistent odors.

The investigation into the odor and corrosion issues began in 1998, before the full extent of the damage to the sewer system was known. Three major pumping stations were suspected of being the source of the hydrogen sulfide: the Gulf Pond Pump Station, the Rock Street Pump Station, and the East Broadway Pump Station. Measurements of hydrogen sulfide in the atmosphere of key manholes downstream from these three discharges were taken during sampling periods in August 1998 and 2001.

The Gulf Pond Pump Station in Milford, Conn., discharges into two force mains. Before upgrades and fixes, these force mains were the source of high levels of hydrogen sulfide, which led to odor and corrosion problems throughout the downstream system. Charlie Smith/AECOM

Milford fights odor and corrosion

Use of pure oxygen improves sewer system safety and operation

Kenneth A. Bradstreet, Charles N. Smith, Robert P.G. Bowker, and Inken N. Mello

Milford, Conn., has an extensive sewer system that includes two water resource recovery facilities, 42 pumping stations, and an extensive system of sanitary sewers. In recent years, the system has been plagued with odor complaints and has undergone severe corrosion problems caused by hydrogen sulfide.

Odor and corrosion issues were most evident in the East/West Interceptor and at the West Avenue Pump Station. All of the manholes on the East/West Interceptor had deteriorated badly. The city started a program of manhole rehabilitation using various types of manhole liners. It was then learned that the 900-mm (36-in.) ductile-iron sewer had developed perforations along the spring line of the pipe. At that point, the city opened a sewer contract to completely replace the interceptor, which then was slightly more than 20 years old.

Corrosion damage in the West Avenue Pump Station wet well also was severe. Concrete in the channels carrying flow into the wet well was crumbling, and reinforcing steel was exposed in many areas. All of the electrical conduit and fixtures and all of the heating, ventilation, and air-conditioning ductwork in the lower level of the wet well were damaged beyond repair and no longer functional.

The effects of the hydrogen sulfide at the Housatonic Wastewater Plant were not as severe as at the West Avenue Pump Station but still were noticeable, exhibiting metal corrosion and persistent odors.

The investigation into the odor and corrosion issues began in 1998, before the full extent of the damage to the sewer system was known. Three major pumping stations were suspected of being the source of the hydrogen sulfide: the Gulf Pond Pump Station, the Rock Street Pump Station, and the East Broadway Pump Station. Measurements of hydrogen sulfide in the atmosphere of key manholes downstream from these three discharges were taken during sampling periods in August 1998 and 2001.

Based on these results, a decision was made to replace the existing East Broadway station with a new one at a new location, reducing the force-main length to approximately one-half its original length, with the goal to significantly reduce sulfide levels. Hydrogen sulfide levels downstream of the Rock Street station were relatively low, so the city chose to re-examine issues at this location at a later date.

The main cause of odor and corrosion in the collection system was identified to be the dual force mains carrying wastewater from the Gulf Pond Pump Station to the East/West Interceptor and, eventually, to the West Avenue Pump Station.

Gulf Pond Pump Station

The Gulf Pond Pump Station is the second-largest pump station in Milford, with an average flow of 11,400 m^3/d (3 mgd) and a capacity of 60,600 m^3/d (16 mgd). It services the eastern portion of Milford, pumping the collected wastewater through 4 km (2.5 mi) of dual 500-mm (20-in.) and 600-mm (24-in.) force mains to the East/West Interceptor Sewer, which discharges to the West Avenue Pump Station. While either force main alone has sufficient capacity to carry the average flow, both are required to carry peak flows.

Prior to the pump-station upgrade, the force mains were controlled by labor-intensive manual gate valves located in the pump station.

Sulfide generation in dual force mains

Both force mains are required to carry peak pump-station flows, so both would have to be open if there were a chance of a significant rain event. However, keeping both force mains open during the hot and dry summer months resulted in very long hydraulic retention times and, ultimately, high sulfide generation rates. City crews made an effort to close off one of the force mains during the hottest, driest periods of the year using the manual gate valves, but this was a hit-or-miss solution to the problem. In addition, opening and closing these valves was a labor-intensive operation, which could not be expected to be performed with any frequency.

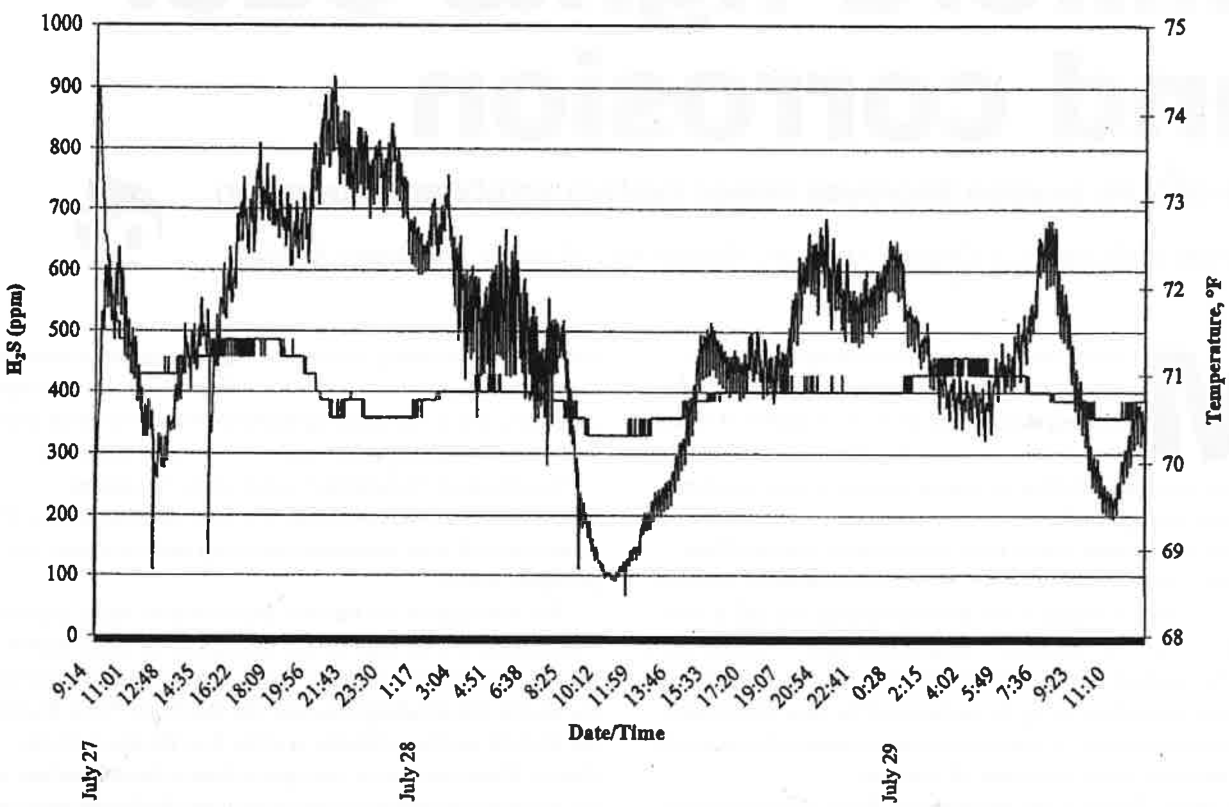
As a result, wastewater often remained in the parallel force mains for several hours, and hydrogen sulfide concentrations at the discharge of the Gulf Pond Force Main were extremely high, with spikes up to 900 ppm (Figure 1, below).

Samples taken in July 2004 were analyzed for sulfides, sulfates, pH, oxidation–reduction potential, temperature, and oxygen uptake rate. The table (p. 65) shows a tabulation of average liquid-stream sampling data taken from the Gulf Pond station wet well and force main discharge. The negative oxidation–reduction potential and the increased oxygen uptake rate are indications that the wastewater is in an anaerobic state.

Hydrogen sulfide control methodologies

There are two general ways to approach control of sulfides in sewers. The first is to prevent their formation by providing sufficient oxygen to the wastewater to keep it fresh. The second is to use chemical addition to oxidize the sulfide after it has formed. The second approach had been used at various locations in the Milford system with limited success. Commonly used chemicals include potassium permanganate, sodium hypochlorite, iron salts, and

Figure 1. Gulf Pond force-main discharge (before modifications and oxygenation system) July 27–29, 2004



Average values of liquid-stream sampling data, Gulf Pond Pump Station and discharge (before modifications and oxygenation system)

Parameter	Wet well	Force-main discharge
Sulfide (mg/L)	0.0	2.9
Sulfate (mg/L)	160.0	164.0
pH	6.72	6.66
Oxidation–reduction potential (mv)	19.0	–109.2
Temperature (°C)	20.2	20.1
Oxygen uptake rate (mg/L•h)	10.0	13.0

hydrogen peroxide. Milford used both potassium permanganate and sodium hypochlorite.

Activated carbon canister systems also were deployed at key locations in Milford to absorb hydrogen sulfide; however, the large quantities of hydrogen sulfide generated rendered these systems useless within a relatively brief period.

Oxygen may be added to wastewater simply by injecting air into the system, usually at a point some distance downstream from the pump station. However, as pure oxygen contains five times more oxygen than air, it is possible to maintain a much higher dissolved-oxygen concentration in the force main by introducing pure oxygen.

Another approach to preventing the formation of sulfides is the addition of a commercial form of nitrate to satisfy the oxygen demand of the wastewater.

A research report, *Odor Control Study and Engineering Report for the East Shore Water Pollution Abatement Facility*, prepared for the City of New Haven, Conn., by Samuel S. Cha and Robert P.G. Bowker in 1995, determined that pure oxygen had the lowest cost per pound of hydrogen sulfide removed, while sodium hypochlorite was approximately 10 times more expensive, and potassium permanganate was 18 times more expensive. A recent comparison of various commercial processes using nitrate to control hydrogen sulfide indicates operating costs seven to 10 times greater than the cost of pure oxygen.

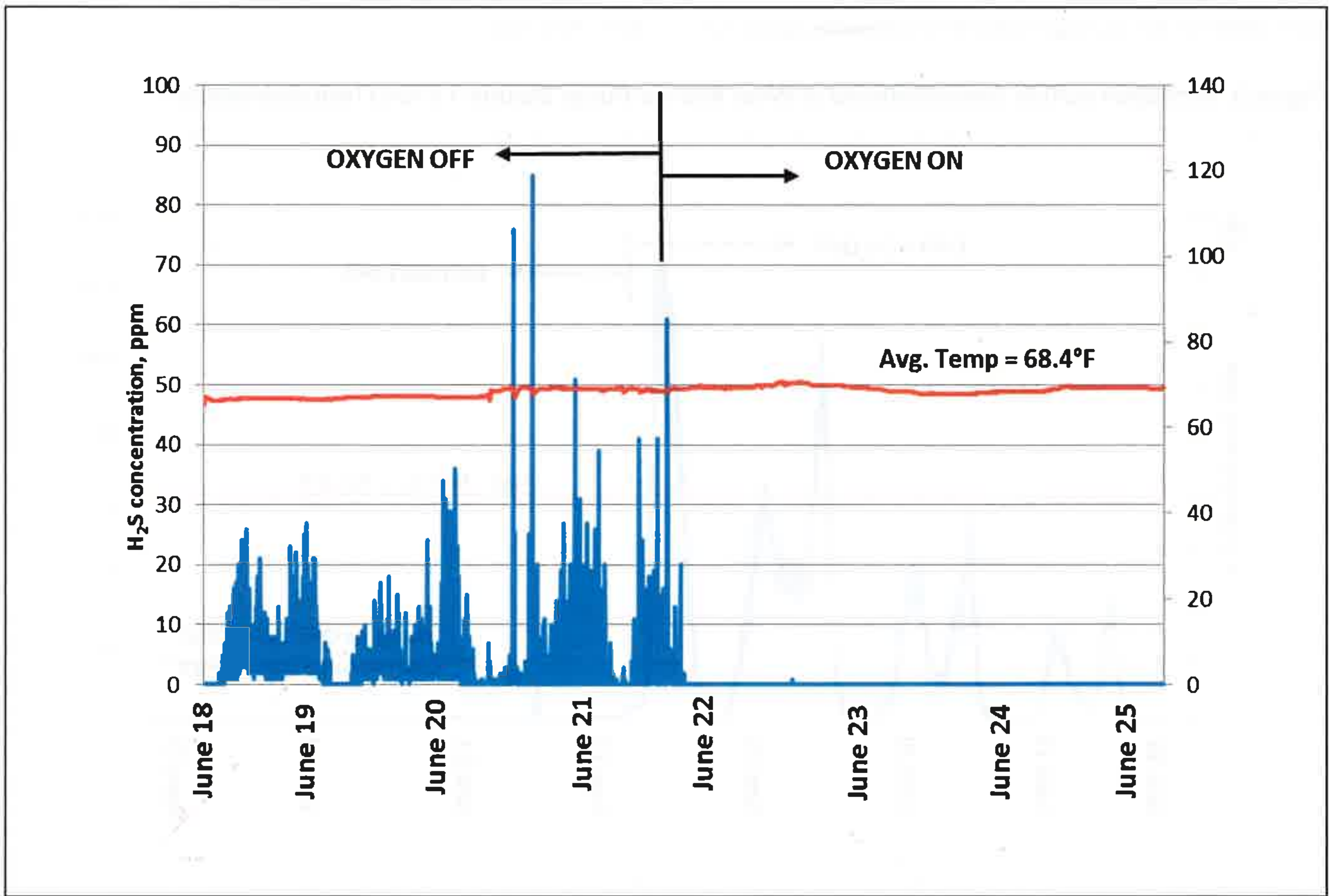
A pure-oxygen injection system was chosen for installation at the Gulf Pond Pump Station because of its relatively low operating cost, proven effectiveness, and simplicity.

Two-pronged approach to odor and corrosion control

Milford used a two-pronged approach to eliminate the generation of hydrogen sulfide. The first part consisted of installing motorized valves and magnetic flowmeters on each force main leaving the Gulf Pond Pump Station to optimize force-main use, depending on flow.

The second part consisted of introducing a sidestream flow saturated with pure oxygen to satisfy oxygen demand in the force main. The combination of efforts has been successful in eliminating

Figure 2. Hydrogen sulfide concentrations at Gulf Pond force-main discharge



odors in the downstream sewer system and has eliminated hydrogen sulfide in the West Avenue Pump Station wet well.

Pump-station modifications. The Gulf Pond Pump Station recently was upgraded to increase capacity, improve reliability, and reduce or eliminate the generation of hydrogen sulfide in its dual force mains.

It was possible to increase capacity by simply replacing the impellers with larger-diameter impellers. The original motors were sufficiently large to accommodate the change.

The original relay-based pump control system was replaced with a programmable-logic controller-based system, which enables considerably more flexibility in programming. The programmable logic controller now controls use of the force mains based on actual force-main flow. Piping changes included adding a magnetic flowmeter and motorized isolation valves at each force main.

At low flows of zero to 7600 m^3/d (zero to 2 mgd), the valve to the 600-mm (24-in.) force main is closed, and only the 500-mm (20-in.) force main is used, reducing hydraulic retention time to its minimum. At normal flows of 7600 to 18,900 m^3/d (2 to 5 mgd), the force mains are programmed to alternate every 2 hours to prevent wastewater in the inactive force main from becoming septic. During high-flow periods of 18,900 to 26,500 m^3/d (5 to 7 mgd), the 600-mm (24-in.) force main is used, and for the occasional rain event and flows higher than 26,500 m^3/d (7 mgd), both force mains will be opened.

By matching force-main use to pump-station flow, detention time in the force mains is reduced. While this does not completely eliminate the generation of hydrogen sulfide, it does reduce it, and it reduces the amount of oxygen needed.

Pure-oxygen system. The oxygen system selected for the Gulf Pond Pump Station in Milford is simple in theory; in eliminating hydrogen sulfide at the discharge of the force main, a sidestream wastewater flow is taken from the discharge header of the wastewater pumps and saturated with pure oxygen before being reintroduced to the force main.

Adding dissolved oxygen to the force main helps maintain aerobic conditions under which sulfide formation is prevented. Using a sidestream system prevents entrainment of oxygen bubbles into the force main and the potential of airlocking pipe or pumps. Milford chose liquid oxygen as an oxygen source, but, alternatively, gaseous oxygen could have been generated on demand.

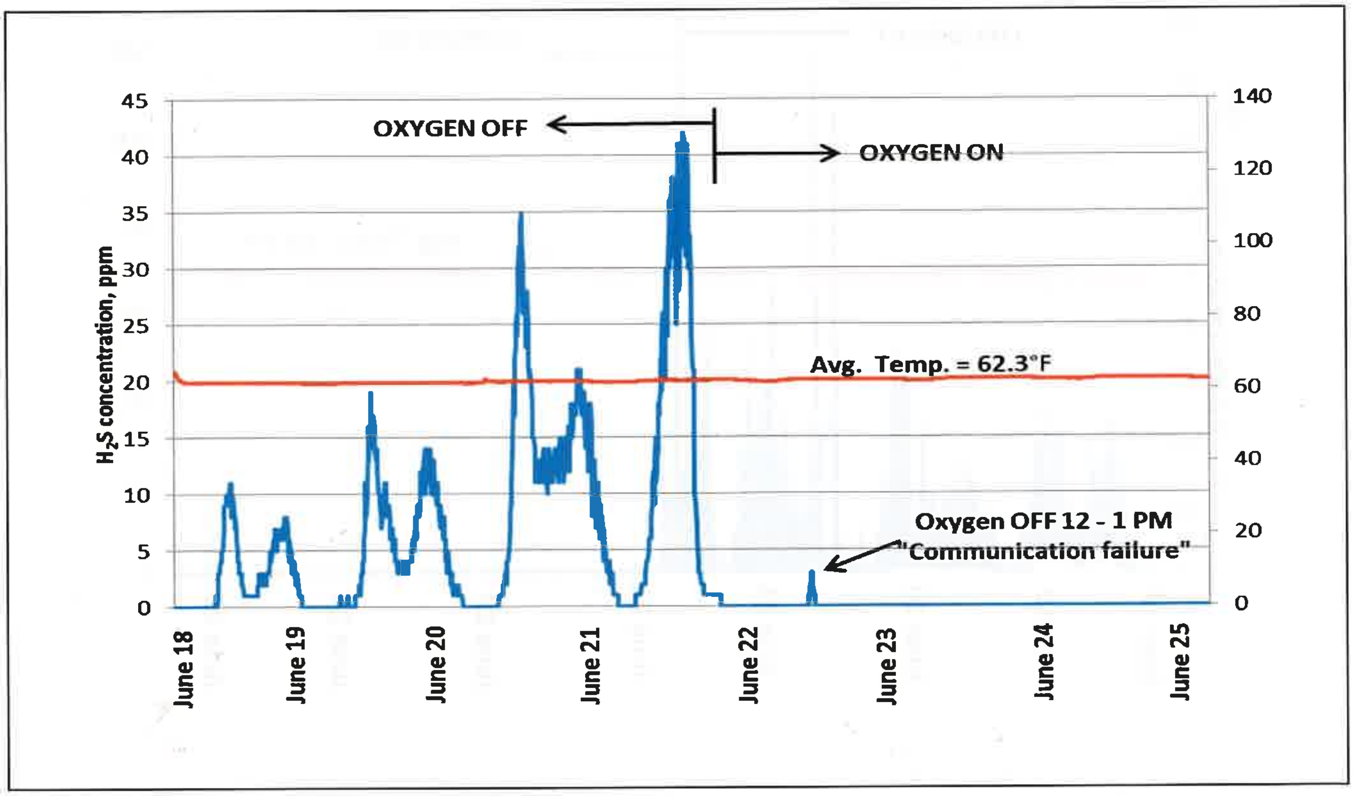
At the heart of the system used to dissolve the oxygen in Milford is the Speece Cone, which disperses the oxygen into the wastewater and dissolves oxygen at an average 95% transfer efficiency. Testing during system startup indicated 95% to 98% oxygen-transfer efficiency. The system employs no moving parts other than the sidestream pump, and all openings are a minimum of 100 mm (4 in.) in diameter, enabling them to pass wastewater and minimize maintenance requirements.

The oxygen system is sized to provide sufficient dissolved oxygen to satisfy the oxygen uptake of the wastewater in the force main during its travel from the pump station to the point of discharge.

The basic concept of the oxygen system for the Gulf Pond Pump Station is that it is only required when flows are at or below average – this corresponds to when detention time in the force main is approaching 2 hours or more. An estimated value, based on experience, of 18,900 m^3/d (5 mgd) was chosen as the break point – the oxygen system turns off for flows greater than this value. This value is operator-adjustable in the oxygen-system control panel; however, this value has proven to be acceptable in practice.

The sizing of the cone and the magnitude of the sidestream flow were determined by the system supplier based on the concentration of oxygen required in the force main and the pressure in the system. The oxygen system was designed to deliver 450 kg/d (1000 lb/d) to the 600-mm (24-in.) force main and 295 kg/d (650 lb/d) to the 500-mm (20-in.) force main.

Figure 3. Hydrogen sulfide concentrations at West Avenue Pump Station 1.6 km (1 mi) downstream



In addition to altering and automating the flow controls at the Gulf Pond Pump Station, Milford also added a sidestream treatment process to add pure oxygen to wastewater flowing through the force mains. This automated system helps ensure that the conditions inside the lines do not become septic. Charlie Smith/AECOM

Performance testing

Milford conducted performance testing of the oxygen system in June 2012. During the week of sampling, typical wastewater flows were between 14,400 and 16,700 m³/d (3.8 and 4.4 mgd), which is higher than what would be expected under dry, summer conditions. As a result, wastewater sulfide concentrations and headspace hydrogen sulfide levels were lower than under peak summer conditions.

Hydrogen sulfide was monitored continuously in the headspace of a sewer manhole just downstream from the discharge of the Gulf Pond force mains (Figure 2, p. 65) and in the headspace of a sewer manhole 1.6 km (1 mi) downstream in the East/West Interceptor, just upstream of the West Avenue Pump Station (Figure 3, p. 66).

Both figures demonstrate that when oxygen was added to the force main at the Gulf Pond Pump Station, sulfide generation in the force main was eliminated. At the discharge prior to oxygenation, hydrogen sulfide peaks of about 90 ppm were recorded, with an average concentration of 3.8 ppm. At the West Avenue manhole, peaks were more than 40 ppm, with an average of 7.3 ppm. As shown in Figure 3, a small peak of hydrogen sulfide was noted on June 22 after the oxygenation system had been operating. This was due to a brief outage of the system caused by a "communication failure." Oxygen flow was re-established within an hour of the shutdown, and the hydrogen sulfide concentrations returned to zero.

The oxygenation system has proven to be highly effective in preventing generation of hydrogen sulfide in the Gulf Pond force main. At the design oxygen dosage of 450 kg/d (1000 lb/d) at a flow rate of approximately 15,100 m³/d (4 mgd), the dissolved-oxygen concentration at the end of the force main increased by an average of 7 mg/L higher than background levels. With the oxygenation system operating, no sulfide was detected in the force-main discharge, and hydrogen sulfide levels in the headspaces of two downstream manholes were reduced to zero.

A success for the community and city workers

Prior to installation of the oxygen system at the Gulf Pond Pump Station, the odors along the downstream sewer route were pervasive. Odors were noticeable to people driving on the nearby interstate highway and limited outdoor activities in the senior condominium complex adjacent to the West Avenue Pump Station.

When the oxygen system was turned on for the first time in April 2012, the change was immediate. An area known for its sickening odor now had clean air, with no hint of hydrogen sulfide. The West Avenue Pump Station wet well, previously a dangerous work environment, now had zero levels of hydrogen sulfide. Work recently has been completed to repair the damage done to the concrete structure in the West Avenue Pump Station. The East/West Interceptor was replaced after it was severely corroded. Using the oxygen system will prevent new damage to the refurbished infrastructure, as well as to downstream treatment facilities.

The City of Milford has found that operation of the system is cost-effective – totaling about $60 per day at its maximum oxygen usage. Minimal maintenance of the system is required. The city expects to fine-tune operations as it gains experience – perhaps varying the oxygen feed rates on a seasonal basis.

Kenneth A. Bradstreet *is project manager in the Rocky Hill, Conn., office, and* ***Charles N. Smith*** *is senior program director in the Chelmsford, Mass., office of AECOM (Los Angeles).* ***Robert P.G. Bowker*** *is president of Bowker and Associates (Portland, Maine).* ***Inken N. Mello*** *is sales and marketing director at ECO Oxygen Technologies (Indianapolis).*

The basics of hydrogen sulfide odor and corrosion

Hydrogen sulfide is formed by the anaerobic action of bacteria found in the submerged slime layer of sewer pipes in the absence of dissolved oxygen. This occurs in force mains or in slow-moving, flat sewer lines where the wastewater undergoes long detention times. As the dissolved oxygen is depleted, the bacteria will use any nitrates in the wastewater for metabolism, and after the nitrates are depleted, they will reduce sulfates to sulfides.

The sulfide ions then combine with hydrogen ions in the wastewater to form hydrogen sulfide in the form of dissolved gas. Hydrogen sulfide gas is released into the sewer atmosphere at any point of turbulence, such as may be found at the discharge of a force main.

Once released, the hydrogen sulfide gas combines with moisture and air on the nonsubmerged surfaces of the pipe, where it is oxidized to sulfuric acid. The sulfuric acid attacks metal and concrete and can cause severe damage to the sewer pipes, manholes, and downstream pump stations. Hydrogen sulfide is extremely odorous, as well as toxic in relatively low concentrations.