# THE INS AND OUTS OF FAN TESTING IN THE REAL WORLD

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## ABSTRACT

Forced ventilation of collection systems is performed for any number of reasons, including eliminating nuisance odors at sensitive locations to protecting infrastructure from corrosion. Predicting the volume of air to ventilate to create a desired zone of influence is very difficult because the field of sewer ventilation is only beginning to be significantly researched and because of many unknown variables including pipe obstructions, sags, lack of record drawings, etc. For this reason, fan testing is often performed prior to design of a mechanical ventilation system to verify the expected effectiveness and design parameters of a proposed forced ventilation program.

As with any sampling or testing program, fan testing within collection systems often comes with unexpected challenges. Several models have been developed to predict air movement in sewer headspaces. Forced ventilation, however, most often becomes a favored solution in areas with constricted headspaces, irregular grades, or other features that can lower one's confidence level when using these models. The purpose of this paper is to explain the planning, execution, and results of fan testing, to discuss some "surprises" encountered in the field, and to offer suggestions for minimizing such surprises when planning a fan test.

Based on several fan tests recently performed in Texas, this paper will cover planning for fan tests, selection and positioning of air withdrawal points and instruments, a discussion of the field equipment and personnel efforts needed, setup and control of both large and small-scale tests, and execution of the tests. Both expected and unexpected results of fan tests will be presented and discussed, along with some "real world" challenges encountered in performing these tests.

## KEYWORDS

Collection System Fan Testing, Odor Control, Sewer Ventilation, Corrosion Abatement

## PLANNING FOR A FAN TEST

The purpose of fan testing is to evaluate the impact of venting a range of forced airflows on collection system headspace hydrogen sulfide levels and pressures. Planning for a fan test is the most crucial part to such a project. The collection system segment of interest will need to be evaluated using construction drawings, models, CCTV inspection data, and other information to determine the locations of any siphons, drop manholes, wetwells, or any other features that might affect the headspace air movement within the system. A siphon in the system creates a positive headspace pressure upstream of the siphon forcing foul air to disperse through the nearest manhole opening, meter station, or other relief point. The release of pressurized headspace air from the collection system can sometimes occur miles from the constriction point. Drop manholes can provide some aeration into the wastewater stream, which decreases the potential for anaerobic conditions necessary for hydrogen sulfide production. However, the mixing and turbulence in a drop manhole will allow the entrained gases to be released from the wastewater creating an odor source.

Once the background information of the collection system is evaluated, an air withdrawal location such as a manhole or lift station can be determined. This location will need to be considered for future design compatibility considering access to the site, power availability to the site, noise levels for neighboring entities, duct run costs, floodplain or other zoning restrictions, land availability, and water and drain line needs. The drain line can prove to be a major design factor as the condensate that may collect inside of the duct and the blowdown of an odor control system can reach very acidic conditions requiring a special sump or a low pH compatible drain such as a lined concrete manhole. After the air withdrawal location is determined, the upstream processes including any lift stations, chemical feeds, etc. need to be documented. Upstream operating elements can impact the air withdrawal location, such as lift stations potentially increasing air pressures and flows when pumps start and chemical feeds reducing odorous pollutants in the headspace.

When determining the air withdrawal location, it is also important to consider whether any traffic plans or special vehicle requirements will be necessary to access and/or operate at the site. The air being exhausted from the collection system will contain odorous and corrosive compounds which may require treatment prior to discharging dependent on the site. Figure 1 below shows an example of a fan test where treatment of the ventilated air was not necessary. A box was built to attach up to two fans with a blast gate used to control the airflow. Small generators were used to power these relatively small fans. Power availability at the withdrawal point is a critical consideration also. If no power is available, generators will be necessary; practical considerations for generators include assessing whether the site is secure and whether the generator can practically be left on site overnight. Personnel and vehicle access for delivering fuel to the generator need to be considered.

Figure 2 shows a trailer mounted carbon bed system. This system was required due to the sensitive area in which the testing was performed. The carbon bed system also had the fan mounted on the trailer. A generator was necessary to power the fan and expandable duct was used to connect the fan to the discharge manhole.

**Figure 1 – Atmospheric Discharge**

**Figure 2 – Treated Discharge**

Determining what type of instruments and materials, how many, and where to locate them will be one of the most important aspects of the planning phase. These locations vary from how far upstream or downstream a zone of influence is desired and the expected concentrations of odorous gases in the air. The locations are critical in ultimately producing meaningful test results. An equipment list such as tape, tarp, fan mounting systems, zip ties, hand sanitizer, bug spray, sun screen, water, jackets, hot-tip velocimeter, hydrogen sulfide meters, pressure differential meters, generator, generator fuel, hard hat, reflective vest, manhole pick, etc. will need to be made.

The OdaLog® hydrogen sulfide gas logger and the Acrulog™ pressure differential logger are the instruments typically used for the fan testing. Both instruments are data loggers and can be deployed for several days to weeks and some models allowing a month or more before their batteries deplete requiring replacement. The OdaLog® is used to measure hydrogen sulfide levels with different models to give a range from 10ppb up to 2000ppm detection ranges. The Acrulog™ measures the pressure differential between the collection system headspace and the atmospheric pressure and can detect from 0.001 inches of water column up to 2 inches of water column.

Placing instruments near the temporary fan and at or near desired zones of influence is critical. However, practical and safe access to the instruments for deployment, occasional checking and retrieval is critical as well and sometimes controls the decision process. With differential pressure loggers needing a tube extended to atmosphere, for instance, manholes located in roadways and areas subject to immersion can often be quickly ruled out.

The OdaLog® is shown in Figure 3 and the Acrulog™ is shown in Figure 4.

**Figure 3 – OdaLog®**


**Figure 4 – Acrulog™**

In some instances, it is recommended to collect samples for offsite analytical sampling to characterize other odorants in the foul air. Plan to collect two separate samples at various times during the day for better characterization of the foul air. Refer to these applicable laboratory test methods for supplies needed for such tests: ASTM D – 5504, Environmental Protection Agency (EPA) Method Total Organics (TO) 17, and Gas Chromatography for Amines.

Fan tests are typically a multi-day project. Allow enough days to gather the amount of data needed to determine the best suited design and enough time for each fan run to reach steady-state conditions. When developing the testing schedule, allow enough time to perform testing at all planned airflow rates and for baseline testing. Two hours for each testing phase, i.e. baseline and airflow rates, typically will provide enough time for the headspace pressure and airflow to equalize and gather necessary data. Upstream lift stations or odor control systems such as chemical feed systems should be noted and operated manually if necessary to capture the most representative data.

The beginning airflow rate to be tested can be estimated by calculating the volume of the headspace within the collection system then determining what the airflow equals to provide a target number of air changes per hour (ACH), typically ranging between three and six. This can be compared to the Pescod & Price(1) equation to better bracket baseline airflows. Once this is determined airflow rates can be increased incrementally for over the first day of testing. Testing airflows for subsequent testing days can be adjusted according to the data gathered through evaluation of the earlier testing results.

Hydrogen sulfide production is typically greatest in collection systems during dry weather events due to reduced amounts of dilution and lower rates of aeration provided by turbulent flows with added inflow and infiltration (I&I). Testing for the average daily flow or dry weather day will provide the most conservative data for full-scale system design. If wet weather events are likely, the testing should be postponed or extended, and results evaluated accordingly.

## EXECUTING A FAN TEST

During the execution phase, the equipment should be gathered and taken to the site. The different instruments should be deployed at their locations as previously determined and the air withdrawal system should be constructed/setup at the previously chosen site. It is important to begin logging data for at least two hours (longer times are preferable) prior to running the air withdrawal system to have a baseline data set for comparison. Each airflow tested should have an allotted amount of time necessary for the system to “equalize” at that airflow. This allotted time is recommended to be a minimum of two hours, but dependent on upstream processes and can vary. A full day for each air withdrawal rate is preferred if time and funds allow. Lessons learned through previous fan testing experiences include:

- Double check that the logging instrument is tied off to a tree, post, manhole insert, etc. prior to letting go of the rope or wire holding the instrument. Instruments don’t work as well when later found in a screenings dumpster!
- Double check that the instruments are turned on and logging. Check the instruments occasionally during the test period. When multiple instruments are deployed, it is common for one to stop logging for a number of reasons. If instruments are deployed in a manhole in a high traffic area or with a cover weighing hundreds of pounds, frequent checking can be time and labor intensive.
- Write down the instrument S/N and testing location prior to retrieving all the instruments,
- Be prepared for adverse weather (differential pressure loggers can become inoperable if tubes get filled with even small amounts of rain water)
- Determine where the nearest home improvement store is located prior to starting the testing. You’ll end up going there!

Hydrogen sulfide and pressure differential logging instruments should be installed in the headspace of the system. This means that the instruments will be installed in closed manhole lids to best represent the system. Manhole inserts and/or bars can be installed to provide hanging locations for the data loggers. A cable or rope can also be used to hang the instrument with the manhole lid closed on the rope and then tied off to a nearby structure. Caution should be taken to prevent the cable or rope from being sheared and the instrument being lost to the system.

The pressure differential logger consists of two hoses to measure the pressure differential between the headspace and the atmospheric pressure. One hose of the instrument will be located inside of the manhole with the opposing hose directed to the outside of the manhole. This requires a manhole with a hole in the lid. Any gaps resulting from installing the data logger should be blocked off or sealed to reduce air leakage. Figure 5 below shows the installation of a hydrogen sulfide logger and Figure 6 shows the atmospheric hose protruding through the manhole of a pressure differential logging instrument.

**Figure 5 – Deployed Hydrogen Sulfide Logger**

**Figure 6 – Deployed Pressure Differential Logger**

A hot-tipped velocimeter can be used to determine the velocity of the air at the discharge side of the fan. The volumetric flow rate would then be calculated by multiplying the velocity of the air by the cross-sectional area of the duct.

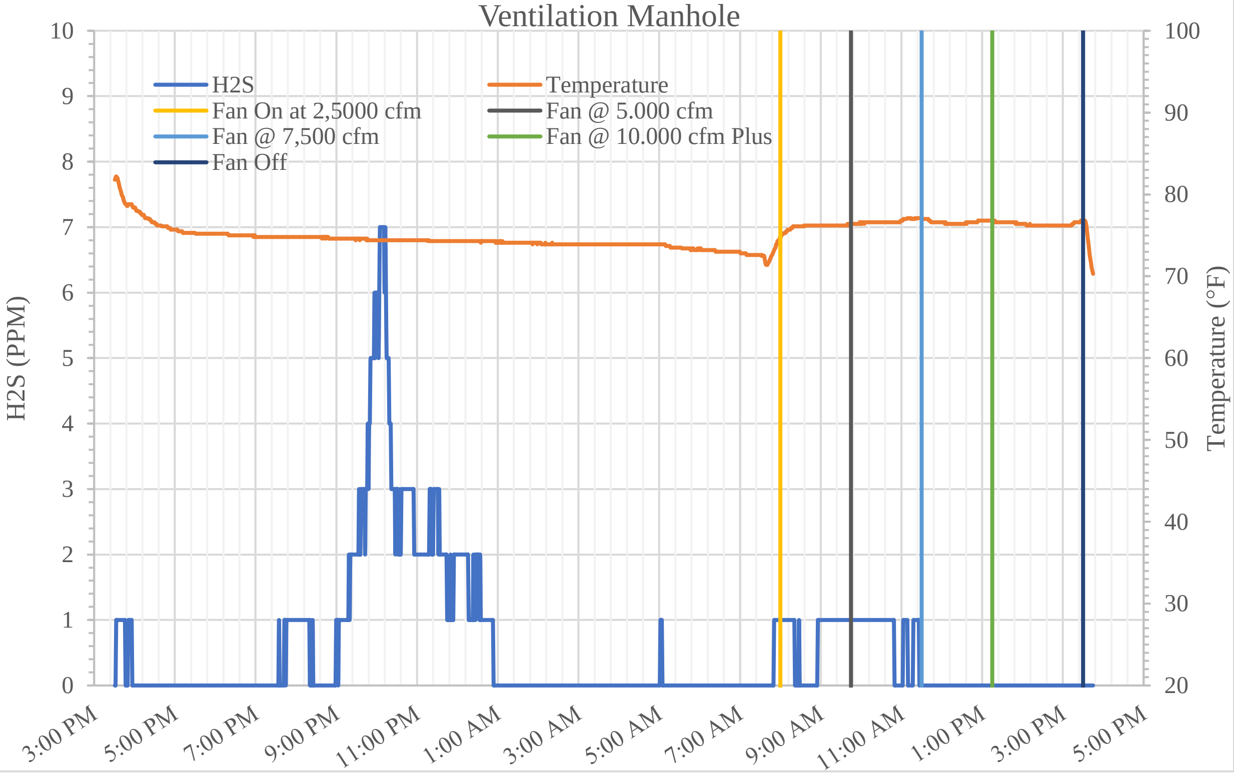
Odor characterization tests can be performed on air from the manhole or location chosen to ventilate the headspace to assist with the design of the full-scale odor control system. Odor characterization tests can consist of the following:

- Sulfur compounds – fill a one-liter Tedlar bag using a lung sampler for testing by ASTM D-5504,
- Volatile organic compounds – pass foul air through a thermal desorption tube for testing by Environmental Protection Agency (EPA) Method Total Organics (TO) 17,
- Amines – pass foul air through an adsorption tube for 100 minutes at an airflow of one liter per minute and sample using gas chromatography.

**RESULTS OF A FAN TEST**

The desired results of a fan test include corrosive and odorous chemical concentrations and pressure differentials at various testing locations. The treatment method will be determined by the chemical constituents of the headspace air and the required airflow. If the headspace air has a hydrogen sulfide level of 10 ppm or less, a carbon adsorber or biofilter system would be recommended. If the hydrogen sulfide concentration is higher, a biotrickling scrubber or chemical scrubber would be recommended. A carbon polisher system can be used after a chemical or biotrickling filter to remove malodorous organics from the ventilated air that was not removed by the scrubber system. Figure 7 is a sample graph of the hydrogen sulfide concentrations at the ventilation manhole. Obtaining the hydrogen sulfide concentrations at the manhole that will have the permanent installation will give us more accurate results and a better representation of what will be sent to the treatment unit.

**Figure 7** - Odalog Hydrogen Sulfide Data
Ventilation Manhole




The airflow to be pulled from the collection system will depend on the results of the pressure differential instruments and the desired zone of influence. A pressure differential of -0.05 inches of water column is the "rule-of-thumb" to determine how far of a zone of influence has been created at the tested airflow. This can vary depending on the extent of pressurization being experienced prior to ventilation. Figure 8 is a sample graph of differential pressures measured at a manhole of a known distance from the ventilation manhole.

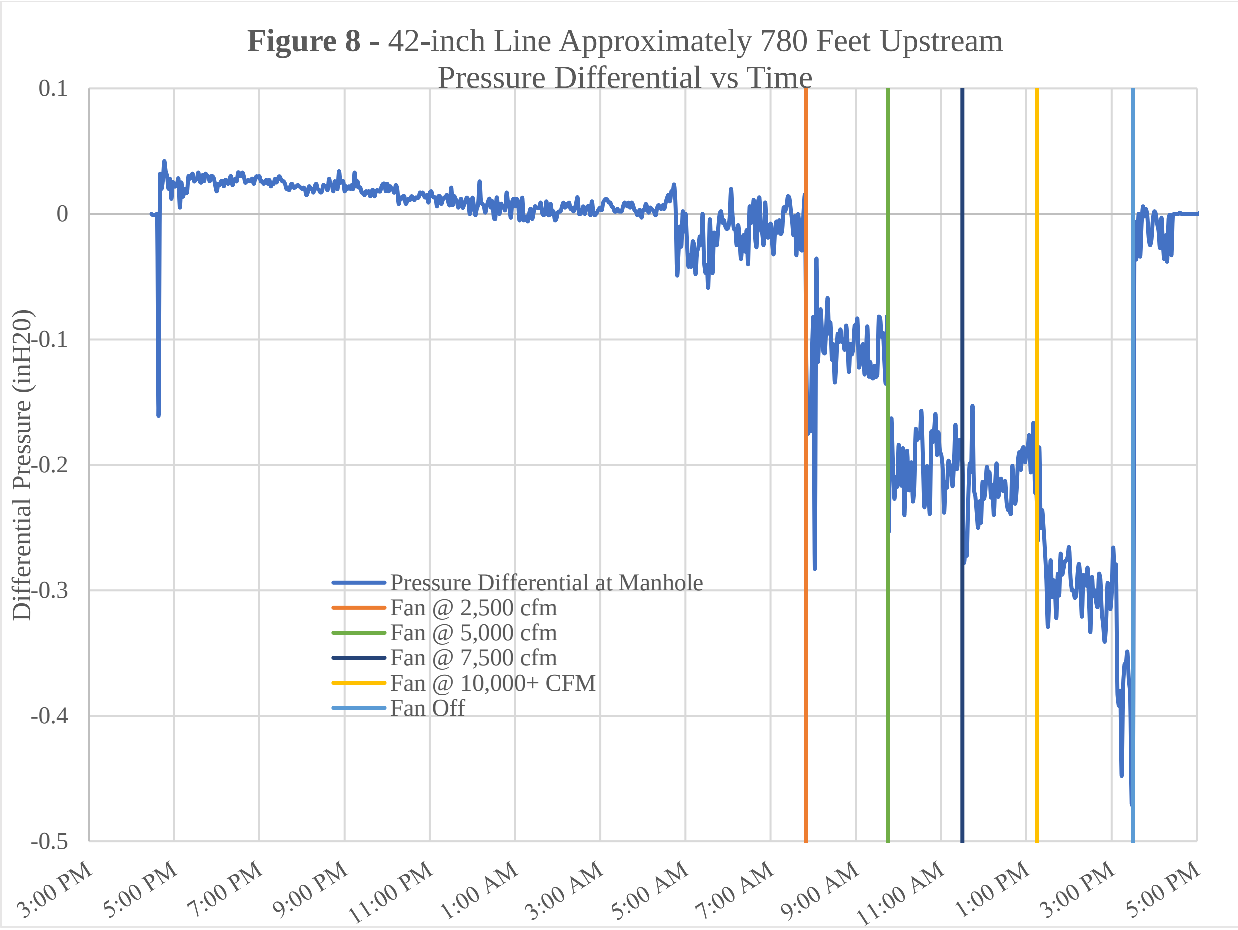



Table 1 summarizes the pressure differential data at manholes located approximately 300 feet upstream to 1,800 feet upstream of the ventilation manhole. The baseline testing reported an existing negative pressure. Based on information in the data, it is shown that the 5,000 cfm airflow rate provided an average of -0.05 inches of water at every testing location. This flow rate could then be used as the basis of design for the proposed treatment system.

**Table 1 – Airflow and Pressure Differential Data Summary**

| **Airflow (CFM)** | **Average Pressure Differentials (inches of water) at Manholes** | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| **2,500** | -0.08 | -0.10 | -0.14 | -0.09 | -0.11 | -0.04 |
| **5,000** | -0.14 | -0.14 | -0.15 | -0.16 | -0.20 | -0.06 |
| **7,500** | -0.15 | -0.13 | -0.22 | -0.20 | -0.22 | -0.07 |
| **10,000+** | -0.24 | -0.24 | -0.25 | -0.22 | -0.31 | -0.09 |
| **Approx. Distance from Air Withdrawal Manhole (LF)** | 310 | 445 | 460 | 430 | 780 | 1,800 |

Retrieve data from the loggers immediately after finishing the final fan airflow test. Evaluate collected data to determine what effect air withdrawal had on the collection system headspace.

Data from earlier days of testing can be used to decide if the next day's testing will utilize the same, higher or lower airflow rates and if moving any instrument locations would be beneficial.

Results from odor characterization testing provide information for non-hydrogen sulfide odors. Some of these odorous compounds and concentrations can be seen in Table 2. Dependent on the concentrations of these gases, a carbon polisher might be required, or a more selective media type can be specified.

**Table 2 – Odor Characterization Data**

| Compound | Result µg/m³ | MRL µg/m³ | Result ppbV | MRL ppbV |
|---|---|---|---|---|
| Hydrogen Sulfide | 1,600 | 9.5 | 1,100 | 6.8 |
| Carbonyl Sulfide | 66 | 17 | 27 | 6.8 |
| Methyl Mercaptan | 380 | 13 | 190 | 6.8 |
| Ethyl Mercaptan | ND | 17 | ND | 6.8 |
| Dimethyl Sulfide | 23 | 17 | 9.2 | 6.8 |

**MRL=** Method Reporting **Limit**

## CONCLUSION

Fan testing for a collection system is a good method for determining the airflows necessary to properly design a forced air odor control and corrosion abatement system. The mathematical modeling of such headspace conditions relies on assumptions such as empirical formulas, lack of sags or other headspace obstructions, minimal pull from connecting branches, etc. Modeling this type of system can become very complex, therefore, performing a fan test can often yield much more meaningful results than modeling. To perform a successful fan test, spend plenty of time in the planning phase to determine where, when, and how to perform the air withdrawal testing. The next crucial aspect is following the plan and executing the test in order to successfully obtain the results required for properly designing the forced air ventilation system.