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# Development and Testing of a Hydrogen Sulfide Detection System for Use in Swine Housing

## **Abstract**

Transient hazards to human and animal health can occur in swine barns due to sudden bursts of high concentration hydrogen sulfide (H<sub>2</sub>S) gas released when manure slurry is agitated during removal from sub-floor pits. Studies have shown that H<sub>2</sub>S levels can go from harmless to deadly in a matter of minutes during pit agitation (Patni and Clarke, 2003). From 1983 to 1990, H<sub>2</sub>S poisoning was responsible for the death of 24 swine workers in the Midwest alone and at least 15 more deaths since 1994 (Walinga, 2004). Swine slurry removal workers and producers report swine deaths every year from slurry agitation in sub-floor storage, or pits. Hence, a system that can reliably and promptly report H<sub>2</sub>S concentrations in swine housing without direct exposure of the operator(s) to the potentially hazardous environment is of socioeconomic importance to the swine producers. This paper describes the development and testing of a wireless, portable H<sub>2</sub>S detection system, followed by the use of the system under field conditions by slurry removal workers to monitor H<sub>2</sub>S levels during slurry agitation and removal in deep-pit swine housing systems in Iowa. The system developed in this study has a component cost of \$2,735 and is based on a Pemtech PT-295 electrochemical H<sub>2</sub>S sensor and a Phoenix Contact Wireless Transmitter / Receiver set. The portable H<sub>2</sub>S detection system has the following operational characteristics: a) 90% (t<sub>90</sub>) response to 10 - 500 ppm H<sub>2</sub>S within one minute, b) ± 5 % full scale accuracy, and c) < 2 hr warm-up time for operation.

## **Keywords**

Hydrogen sulfide poisoning, H<sub>2</sub>S detection, swine manure agitation, worker and swine health

## **Disciplines**

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## **Development and Testing of a Hydrogen Sulfide Detection System for Use in Swine Housing**

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**Abstract.** *Transient hazards to human and animal health can occur in swine barns due to sudden bursts of high concentration hydrogen sulfide ( $H_2S$ ) gas released when manure slurry is agitated during removal from sub-floor pits. Studies have shown that  $H_2S$  levels can go from harmless to deadly in a matter of minutes during pit agitation (Patni and Clarke, 2003). From 1983 to 1990,  $H_2S$  poisoning was responsible for the death of 24 swine workers in the Midwest alone and at least 15 more deaths since 1994 (Walinga, 2004). Swine slurry removal workers and producers report swine deaths every year from slurry agitation in sub-floor storage, or pits. Hence, a system that can reliably*

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**Keywords.** Hydrogen sulfide poisoning, H<sub>2</sub>S detection, swine manure agitation, worker and swine health

## Introduction

Unpredictable hazardous conditions can occur in swine barns due to sudden bursts of high concentration hydrogen sulfide ( $H_2S$ ) gas when manure slurry is agitated. Generally, the only time slurry is agitated is during removal. It is the burst characteristic of  $H_2S$  gas releases that make it dangerous, and studies have shown that  $H_2S$  levels can go from harmless to dangerous in a matter of minutes during agitation of manure in sub-floor pits (Patni and Clarke, 2003, Ni, et al., 2000).

Hydrogen sulfide poisoning was responsible for the death of 24 swine workers in the Midwest from 1983 to 1990, and at least 15 more deaths since 1994 (Wallinga, 2004). Dangerous concentration levels for humans vary but one source sets the levels at 500 ppm for unconsciousness and 600 ppm for immediate death (Wallinga, 2004). Other sources set the level for immediate death as high as 1000 ppm and the level set by OSHA for immediate danger is 100 ppm. Levels in swine confinements with sub-floor pits during agitation have been recorded as high as 1300 ppm (Patni and Clarke, 2003).

Puck Custom Enterprises (PCE) is a custom manure removal and application business. In the past, an average of 20-30 hogs/year succumbed to  $H_2S$  poisoning associated with slurry agitation. The worst event occurred in January of 2006 when 300 market-size hogs died from  $H_2S$  poisoning (Puck, 2006). In all cases, preventive measures were taken to avoid the loss of animal life. Ventilation was increased and no personnel were allowed in the swine housing facility during manure pump-out, yet these losses still occur. In the case where 300 hogs were lost, the same preventative measures were taken as the previous 5 years at that site (when no hogs died). This speaks of the unpredictability of the burst characteristics of  $H_2S$  concentrations during slurry removal. Because a typical deep-pit swine facility manure pump-out may take eight hours or more it is not feasible to operate the ventilation system at a maximum level during the duration of the manure removal. Doing so could result in stressfully low temperatures inside the swine barn during cool weather, potentially leading to animal health problems.

The literature indicates there has been very little investigation into  $H_2S$  detection systems adapted for swine confinement use. A study by Robert et al. (2001) showed that added ventilation can effectively clear  $H_2S$  from a swine house and that there is a need for  $H_2S$  gas detection systems adapted for swine house use. Research has shown that swine can recover from exposure to potentially fatal concentrations of  $H_2S$  gas (O'Donahue, 1961). This supports the hypothesis that if ventilation can be adjusted in response to  $H_2S$  burst, swine loss can be avoided. Although it is never recommended a person enter a swine house during slurry agitation, use of a system to detect hazardous conditions in a swine house combined with effective ventilation or agitation techniques to prevent hazardous conditions could increase human safety in the event of inadvertent entry.

The goal of this project was to eliminate or significantly reduce the risk of human and animal fatalities due to  $H_2S$  poisoning during manure agitation and pump-out events by monitoring  $H_2S$  bursts and adjusting ventilation accordingly in swine production systems. This paper describes the development and testing of a portable wireless  $H_2S$  detection system for use in swine production systems during manure agitation and removal from under-floor swine manure slurry storage pits. Data collected with the system under field conditions also add to the knowledge base concerning the development of hazardous conditions due to  $H_2S$  generation during agitation and subsequent removal of swine manure slurry from under-floor pits.

# Materials and Methods

## Lab Testing

Hydrogen sulfide sensors are commercially available and are prevalent in the petroleum industry. Several low-cost to moderately priced H<sub>2</sub>S sensors developed for industrial use were tested in a lab setting. Sensors that performed adequately during lab testing were developed into a portable H<sub>2</sub>S detection system and tested against a pulsed fluorescence H<sub>2</sub>S analyzer (Model 45C Thermo Scientific, Franklin, MA) in swine housing during slurry agitation and removal. Following lab testing and controlled field testing the system shown to provide the best performance was used by a custom manure application business at a variety (> 20) of swine production systems. During field testing and use, the system was evaluated using the following criteria: Accuracy, Response Time, Durability and Cost.

Six H<sub>2</sub>S sensors were selected for testing in the project. The sensors were tested for accuracy and response time in the Iowa State University Agricultural and Biosystems Engineering Department Air Emissions laboratories. Table 1 shows the six sensors chosen for lab testing. Sensors were chosen based on availability, range, and customer service technical support. Sensor features are reflected in their respective price as three had displays and linear outputs while three only had a voltage output that required calibration with known H<sub>2</sub>S concentration calibration gases. While 100 ppm H<sub>2</sub>S is considered lethal, a 500 ppm range was designed to capture the higher H<sub>2</sub>S burst concentration data that have been shown to exist in swine housing during slurry agitation (Patni and Clarke, 2003). Sensors from Synkera and Transducer Technologies were tested as per advice from the respective manufactures to 500 ppm despite their claimed 100 ppm range. Technicians from Synkera and Transducer Technologies advised the project team on the experimental re-calibration of their sensors to accommodate the higher range.

Sensors were evaluated based on the following criteria.

- Sensor must respond to 90% ( $t_{90}$ ) of test concentrations of 10, 20, 45, 100, 200 ppm and 500 ppm within one minute. Research from Patni and Clarke (2003) shows that dangerous H<sub>2</sub>S concentrations can be reached within minutes during sub-floor slurry agitation. The sensor must react to rapid burst releases to allow the swine worker to adjust ventilation in time to disperse the burst.
- Sensor must be accurate within  $\pm 5\%$  of full scale during triplicate lab testing.
- Sensor must meet above criteria within a 2-hour warm-up period, as per request by a commercial slurry application business.
- If sensors perform similarly, the less expensive one will be developed into a detection system prototype.

To evaluate the sensors, cylinders of 100, 200, and 500 ppm hydrogen sulfide gas were used for lab testing. A digital dilutor coupled with a zero air generator (zero air generator produces clean, dry air free of SO<sub>2</sub>, NO, NO<sub>2</sub>, O<sub>3</sub>, H<sub>2</sub>S, herein referred to as zero air) was used to dilute 500 ppm gas to 10, 20, and 45 ppm concentrations. The test circuit consisted of Teflon® tubing and Teflon® coated electric solenoids. A switch controlled the solenoids to switch between two concentrations of calibration gas or zero air and the calibration gas. An in-line humidifier was installed as recommended by sensor manufacturers for prolonged testing utilizing compressed air. A Dew Prime II monitor was connected in the circuit to measure the dew-point temperature of the gas which in turn was used to determine the relative humidity (RH). A thermocouple was located in the gas stream just prior to the sensor. The temperature was maintained at 22°C and the RH was approximately 45% during testing. The temperature, sensor, and Dew Prime II output were recorded using a Campbell Scientific CR10X data logger (Campbell Scientific Inc.,

Logan, UT). Sensors were initially calibrated according to manufacturer supplied specifications. Figure 1 shows the test circuit schematics.

Table 1. Sensors acquired for initial lab testing.

Sensor	Range	Price*	Type	Description
Pemtech PT-295	0-500 ppm	\$865.00	Electrochemical	Sensor with digital display, linear 4-20 mA output, adjustable alarm contacts
Detcon TP-254C	0-500 ppm	\$895.00	Mixed metal oxide	Sensor with digital display, linear 4-20 mA output, adjustable alarm contacts
Draeger Polytron II	0-500 ppm	\$1970.00	Electrochemical	Sensor with digital display, linear 4-20 mA output
Synkera	0-100 ppm	\$210.00	Metal oxide	Sensor and evaluation circuit with 0-5 VDC output
Transducer Tech T-series	0-100 ppm	\$240.00	Electrochemical	Sensor and evaluation circuit with 0-5 VDC output
Transducer Tech R-series	0-100 ppm	\$210.00	Electrochemical	Sensor and evaluation circuit with 0-5 VDC output

\* Prices reflect cost in April, 2008

During testing the sensors were challenged with six different concentrations (10, 20, 45, 100, 200, and 500 ppm). The circuit was flushed with zero air prior to each test. The sensors were challenged with calibration gas until output had stabilized or three minutes had passed. When sensor output was stable, or three minutes had passed, zero air was applied until the sensor returned to its baseline output or 10 minutes had passed. Figures 1.1 and 1.2 show the schematic for these tests. Two background tests were also performed. Following the same procedure as the concentration tests, the sensor was placed in a background of 10 ppm H<sub>2</sub>S and introduced to a burst of 200 ppm. Additionally, the sensor was given a background of 200 ppm and introduced to a burst of 500 ppm H<sub>2</sub>S. Figures 1.3 and 1.4 show the test circuits for the background tests. All tests were done in triplicate. Research has shown that H<sub>2</sub>S burst releases can reach dangerous concentrations in a few minutes and reoccur within 10 minutes (Patni and Clarke, 2003). For this reason these time constraints were applied to lab testing.

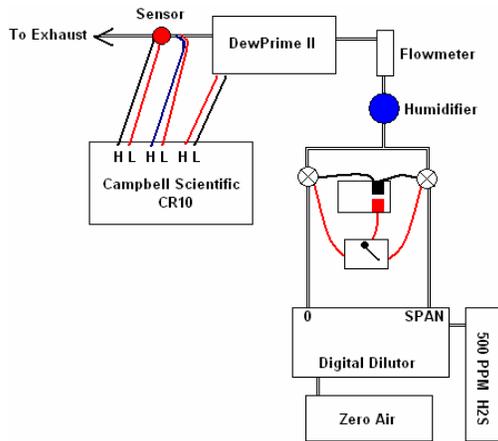


Figure 1.1. The lab test circuit for 10, 20, and 45 ppm H<sub>2</sub>S concentration tests.

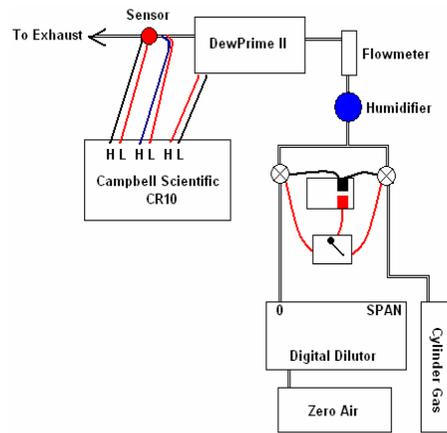


Figure 1.2. The lab test circuit for 100, 200, and 500 ppm H<sub>2</sub>S concentration tests.

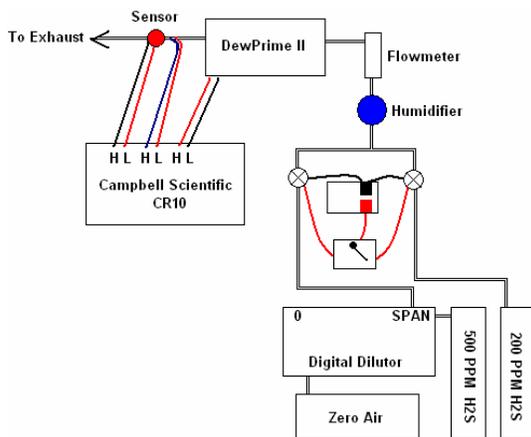


Figure 1.3. Lab test circuit for 10 PPM background, followed by 200 PPM burst.

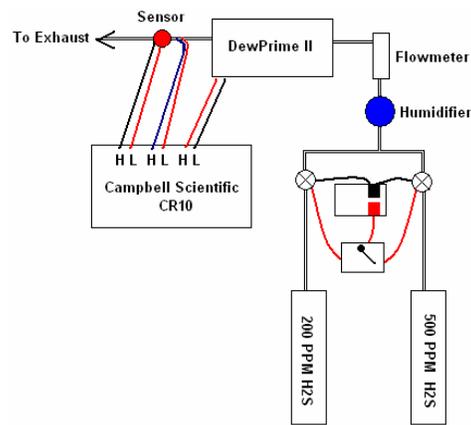


Figure 1.4. Lab test circuit for 200 PPM background, followed by 500 PPM burst.

Figure 1. Lab test circuits used to evaluate sensors for response time and accuracy.

### Lab Test Results

Lab testing was used to evaluate and choose sensors to be developed into mobile H<sub>2</sub>S detection systems and tested in swine housing. Table 2 gives the sensor performance during lab testing with respect to the lab testing criteria previously mentioned. While both the Pemtech PT-295 and the Draeger Polytron 2 passed all the evaluation criteria, the Pemtech was chosen for development based on its lower purchase cost. Although the Transducer Tech R series only had a 0-300 ppm range, it was exposed to 500 ppm during testing and still passed the evaluation criteria at the concentrations in its range. For this reason, as well as its purchase price, it was also chosen for development as a low cost alternative to the Pemtech.

Figure 2 shows the response time of the Pemtech PT-295 at 100, 200, and 500 ppm, and Figure 3 shows the Transducer Technologies R series' response time at 10, 20 and 45 ppm. The Pemtech had a digital display and a 4-20mA signal output while the Transducer Technologies sensor only provided a voltage output.

Table 2. Sensor type and performance during lab testing.

Sensor	Price	Type	Results
Pemtech PT-295	\$865	Electrochemical	Passed all criteria
Detcon TP-254C	\$895	Mixed metal oxide	Failed warm-up time criteria
Draeger Polytron II	\$1970	Electrochemical	Passed all criteria
Synkera*	\$210	Metal oxide	Failed accuracy at high concentration
Transducer Tech T-series*	\$240	Electrochemical	Failed accuracy at high concentration
Transducer Tech R-series*	\$210	Electrochemical	Passed all criteria (with 300 ppm max)

\* Sensors were designed for 0-100ppm range. At the manufacturer's request they were tested with the calibration altered to allow for a higher range. Two of the three failed at the higher concentrations.

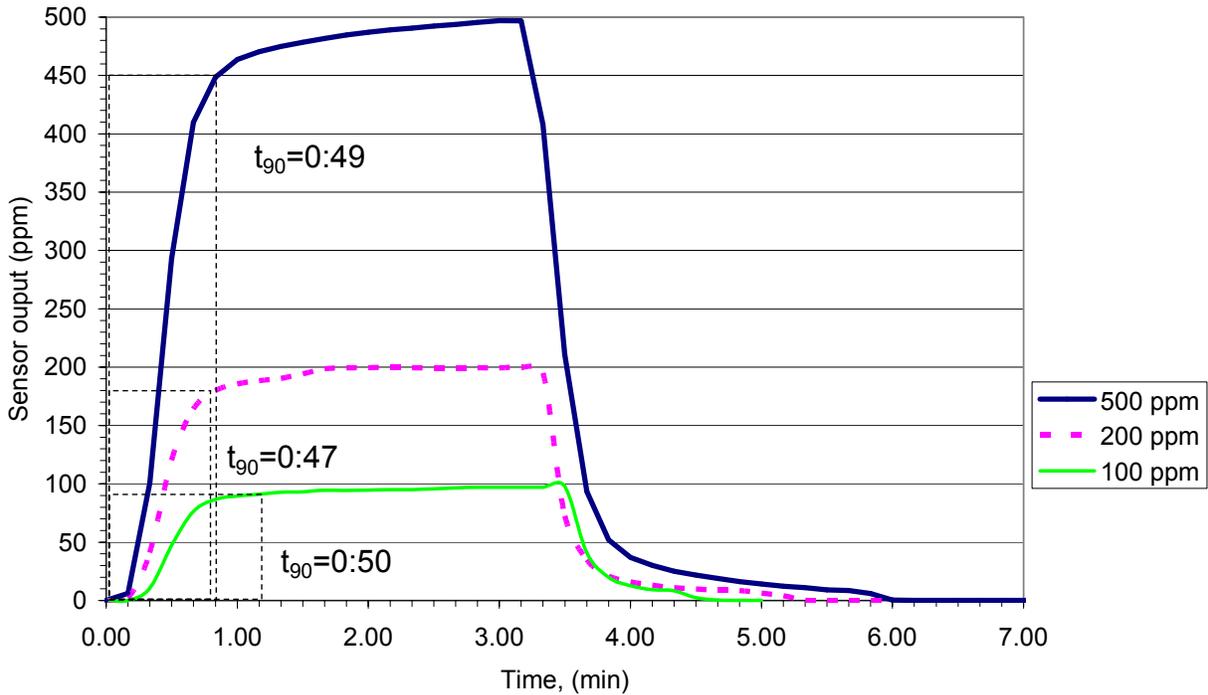


Figure 2. Pemtech PT-295 response time at 100, 200, and 500 ppm H<sub>2</sub>S.  $t_{90}$  represents the amount of time the sensor takes to reach 90% of the actual concentration.

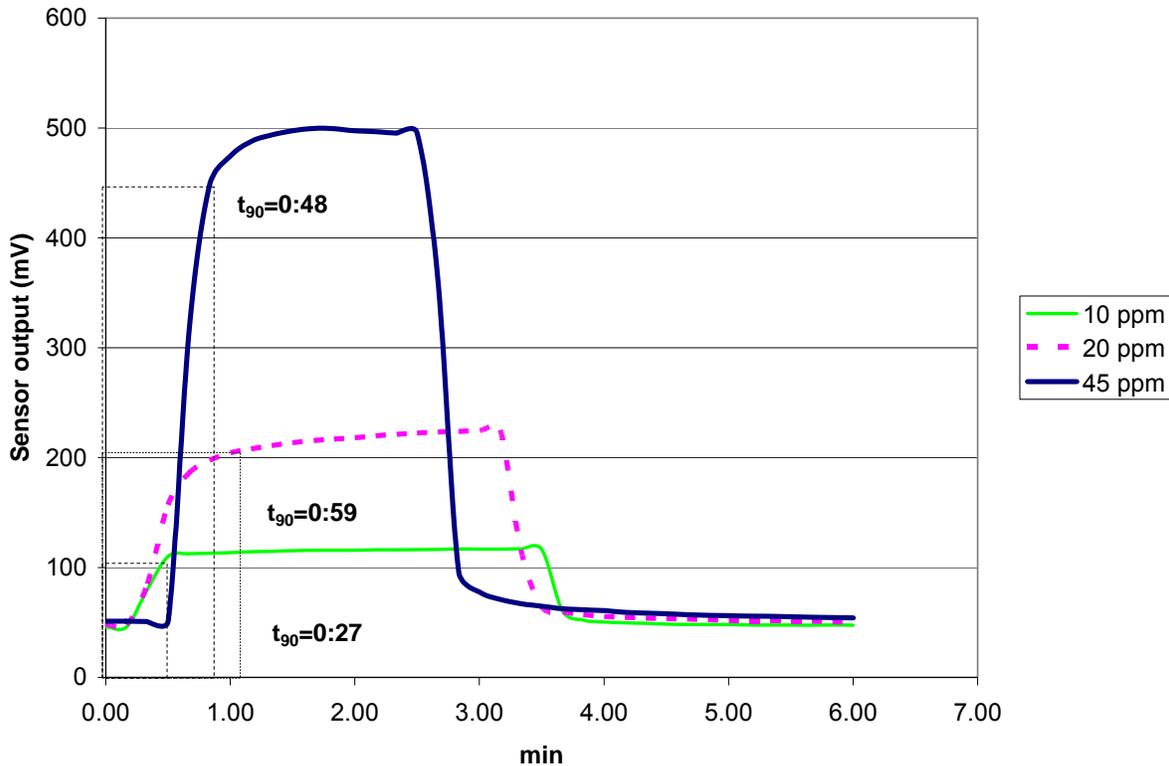


Figure 3. Transducer Technologies R-series response time at 10, 20, and 45 ppm H<sub>2</sub>S. t<sub>90</sub> represents the amount of time the sensor takes to reach 90% of the actual concentration.

## Detection System Development

Two portable detection system prototypes were developed to be tested in swine houses during slurry agitation.

### *Pemtech PT-295 based H<sub>2</sub>S detection system development*

The Pemtech PT-295 sensor was used to develop a wireless H<sub>2</sub>S detection system. It was coupled with a wireless data transfer transmitter (Phoenix Contacts, RAD-ISM-900-UD) and 7.5 amp-hour battery to provide a 14 hour operation time. The components were enclosed (except for the sensor head) in a 30x30x15 cm (12"x12"x6") NEMA-4 electrical enclosure to protect them from the dust and moisture in swine housing. The wireless receiver was connected to an LCD digital display and a 5 amp-hour battery to provide a 9 hour operation time. These were mounted in a 15x15x10 cm (6"x6"x4") NEMA-4 electrical enclosure. Based on input from the commercial slurry application business, the smaller battery was chosen to allow for a smaller overall "hand-held" receiver design. This was desired over the 14 hour operation time capable with a larger battery. Both the sensor/transmitter unit and the receiver unit used 24 Vdc voltage regulators to convert battery voltage for use by components. The sensor/transmitter unit also used a 5 Vdc regulator to support a simple logic circuit using the sensor's user-set alarm contacts. A voltage meter was mounted on both units to display battery voltage as well as external charging posts to allow the battery to be charged without removing the enclosure back plate. Figure 4 shows the sensor/transmitter and receiver units.

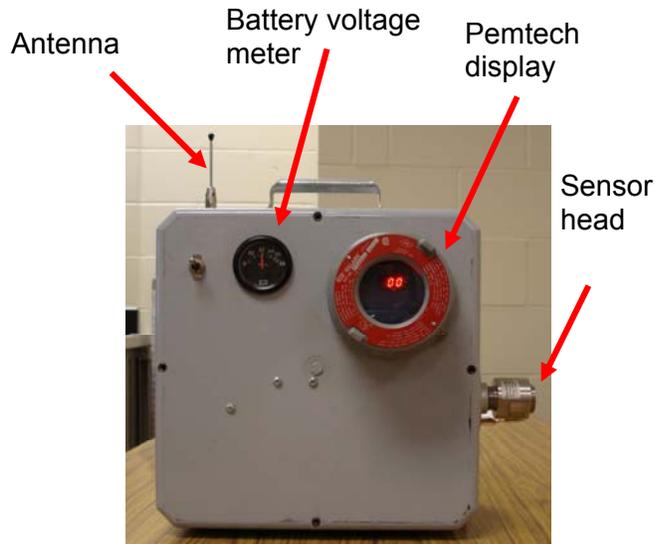


Figure 4.1. Sensor/transmitter unit.

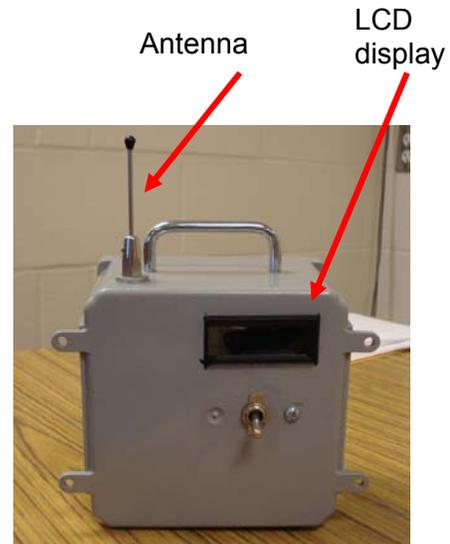


Figure 4.2. Receiver unit.

Figure 4. Pemtech PT-295 based wireless H<sub>2</sub>S detection system transmitter and receiver units.

A simple logic circuit was developed to activate an audible and visual alarm on the receiver unit. The Pemtech had contacts that would close at a user-set H<sub>2</sub>S concentration. A 5 Vdc was supplied to the contacts. When the concentration was met, the contacts would close, sending the 5 Vdc signal to the digital input on the wireless transmitter. The normally open digital output contacts would then be closed on the receiver allowing a supplied 12 Vdc to activate the audible and visual alarm. The RF signal contacts on the receiver were also used as a safety mechanism. When the receiver had an adequate signal from the transmitter the normally open RF signal contacts would close allowing the supplied 24 Vdc to activate the LCD digital display. By doing this, the LCD display would only turn on when an adequate signal was being transmitted so a false reading would never be seen on the receiver. The Pemtech PT-295 based detection system schematic can be seen in figure A-1 in the appendix. This system cost \$2735 in materials; a breakdown of these costs can be seen in table A-1 in the appendix.

### ***Transducer Technologies R-series H<sub>2</sub>S detection system development***

A detection system based on the Transducer Technologies R-series sensor was developed as a less expensive alternative to the Pemtech based system. Instead of a wireless data transfer system the sensor was remote located via a cable. In place of an LCD digital display a series of LED's were calibrated to illuminate at user set voltages that corresponded to sensor output voltages for known H<sub>2</sub>S concentrations obtained from lab testing. Utilizing comparator circuits, the LED's illuminated when the sensor output matched the user-set voltage (via potentiometers). This schematic can be seen in figure A-2 in the appendix.

This system consisted of the base unit and the remote sensor seen in figure 6. The base unit contained the comparator circuit, the LED "light bar", a battery voltage meter, external charging posts and a 7.5 amp-hour battery that provided a 44 hour operating time. These components were housed in a 20.3x20.3x10 cm (8"x8"x4") electrical enclosure that provided protection from moisture. The sensor was mounted in an electrical enclosure with a 5 Vdc regulator to convert battery voltage for use by the sensor. This system cost \$430 in materials; a breakdown of these costs can be seen in table A-2 of the appendix.

Battery voltage meter      LED "light bar"      Sensor cable connection



Figure 6.1. System base unit.

Sensor head



Figure 6.2. System sensor

Figure 6. Transducer Technologies R-series based H<sub>2</sub>S detection system sensor and base unit connected via a cable.

This system was designed to be deployed under the slatted floor in the airspace above the slurry. The sensor was mounted on an extendable aluminum pole and inserted through the pump-out opening on the building exterior. The sensor was connected to the base unit outside the building via a signal cable as seen in figure 7.

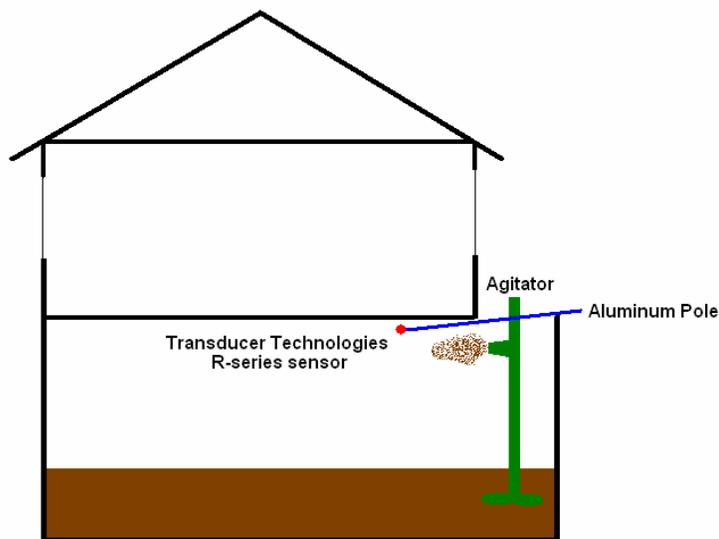


Figure 7. Transducer Technologies R-series based H<sub>2</sub>S detection system deployed under the slatted floor via an aluminum pole.

## Field Testing

The detection systems were tested in swine houses with sub-floor slurry storage against a calibrated H<sub>2</sub>S lab analyzer (Model 45C, TEI) during multiple slurry agitation events. Figure 8 shows the mobile lab and agitator pump used during field testing.



Figure 8. Field testing at an empty swine finishing confinement.

### ***Transducer Technologies R-series based H<sub>2</sub>S detection system***

The Transducer Technologies R-series sensor failed to operate correctly during field testing. The reason for failure was unknown but could be contributed to rough handling or the experimental re-calibration allowing a higher range. The pole mounted sensor method also proved unacceptable. The angle at which the pole is inserted into the pump out, coupled with the pole deflection placed the sensor too close to the slurry surface. During agitation the sensor could be submerged or be sprayed by the turbulent slurry surface. For these reasons, no performance data could be collected on this system.

### ***Pemtech PT-295 based H<sub>2</sub>S detection system***

The Pemtech PT-295 based H<sub>2</sub>S detection system was tested in swine housing during 13 slurry agitation events and 2 slurry agitation/removal events. The sensor/transmitter unit was placed in the empty swine confinement (figure 9) before slurry agitation was initiated. The receiver was outside of the swine house in a mobile lab with the TEI H<sub>2</sub>S analyzer. Teflon® tubing was routed from the TEI into the swine house to continuously sample the swine confinement air for H<sub>2</sub>S concentration. The Pemtech (via the wireless receiver) and the TEI output were recorded using a Campbell Scientific CR10X data logger. Initially the sensor/transmitter unit and the Teflon® tubing inlet were co-located (location one, figure 9) to compare the detection system output with that of the TEI. After validating the Pemtech based system's performance (with respect to that of the TEI), it was moved to various locations (different from the TEI tube inlet) in the swine house to collect H<sub>2</sub>S burst characteristics data during subsequent tests. Sampling locations in figure 9 are denoted by the numbered X's. For the majority of field testing, the TEI's Teflon® tubing inlet was left stationary at location one. However, for a few tests, the tubing inlet was placed 51cm (20") below the slatted floor at location one to collect pit airspace H<sub>2</sub>S concentration data. The Pemtech and the TEI provided H<sub>2</sub>S output continuously every 10 sec.

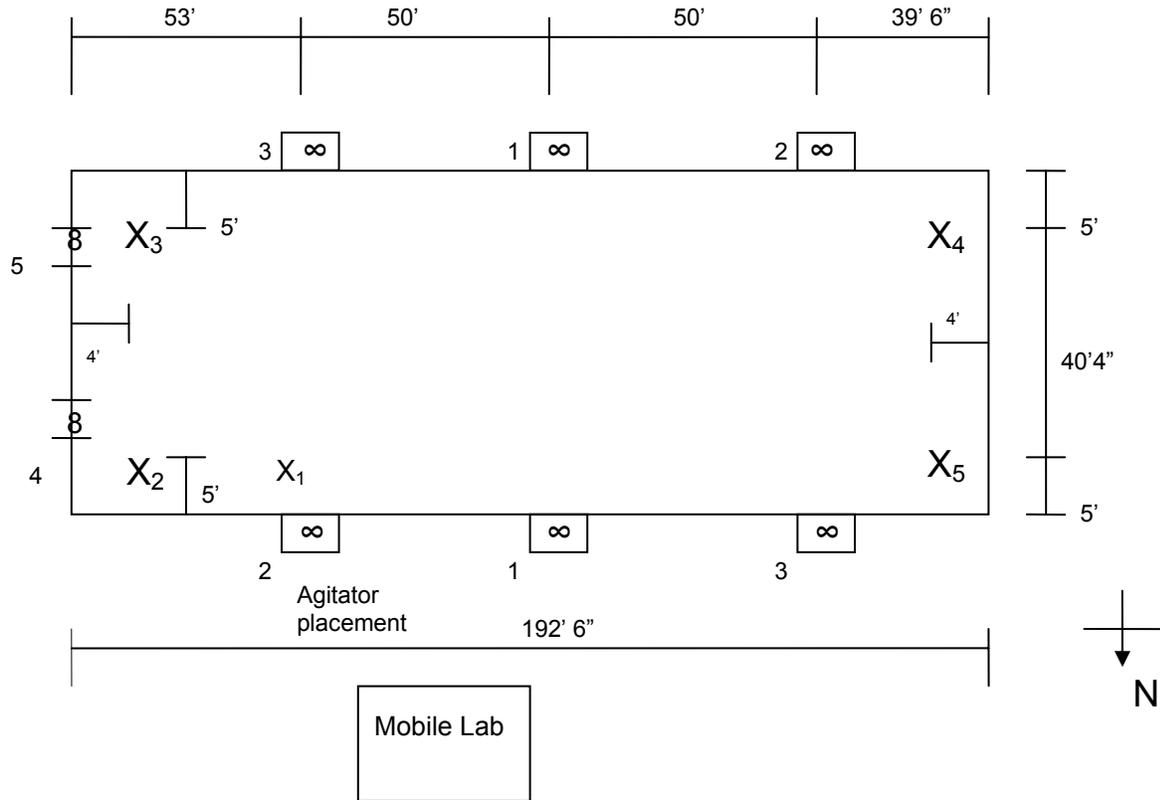


Figure 9. Swine confinement used for field testing layout and sensor location.

The numbers next to the fans in figure 9 represent each fan's ventilation stage. The ventilation rate for each stage is found in table 3. Only one fan for stage 2 was available due to the agitator located in one stage 2 pump out. During field testing, the effect of added ventilation on H<sub>2</sub>S dispersion was monitored. In doing so, the detection system's intended purpose of aiding ventilation management was evaluated and valuable H<sub>2</sub>S burst characteristic data was collected.

Table 3. Ventilation stage data for swine confinement used during field testing.

Ventilation Stage	Ventilation Rate (ft <sup>3</sup> /min)	Ventilation Rate (air changes/hr)
1	12,000	8.15
2	18,000	12.2
3	30,000	20.3
4	36,000	24.5
5	42,000	28.5

In addition to adjusting ventilation during field testing, the effects of surface and sub-surface agitation on H<sub>2</sub>S burst release was monitored.

## Field Test Results

The Pemtech based H<sub>2</sub>S detection system performed well during all tests. During three tests where the detection system and the TEI were at the same location (location one, figure 9), its output was within 5% of the TEI's output during periods of steady (or constant increasing or decreasing) H<sub>2</sub>S concentrations. Due to the difference in response time of the TEI and the detection system, it was impossible to compare the two outputs during periods of rapidly fluctuating H<sub>2</sub>S concentration. However, the results seen below show the similarity of the TEI's and Pemtech based detection system's outputs during periods of rapid concentration fluctuation.

Figure 10 shows the performance of the H<sub>2</sub>S detection system against the TEI during this test. The sensor/transmitter unit and TEI tubing inlet were co-located at location 1 (for all locations refer to figure 9). Ventilation was added (represented by stage lines) to monitor its effect on H<sub>2</sub>S dispersion.

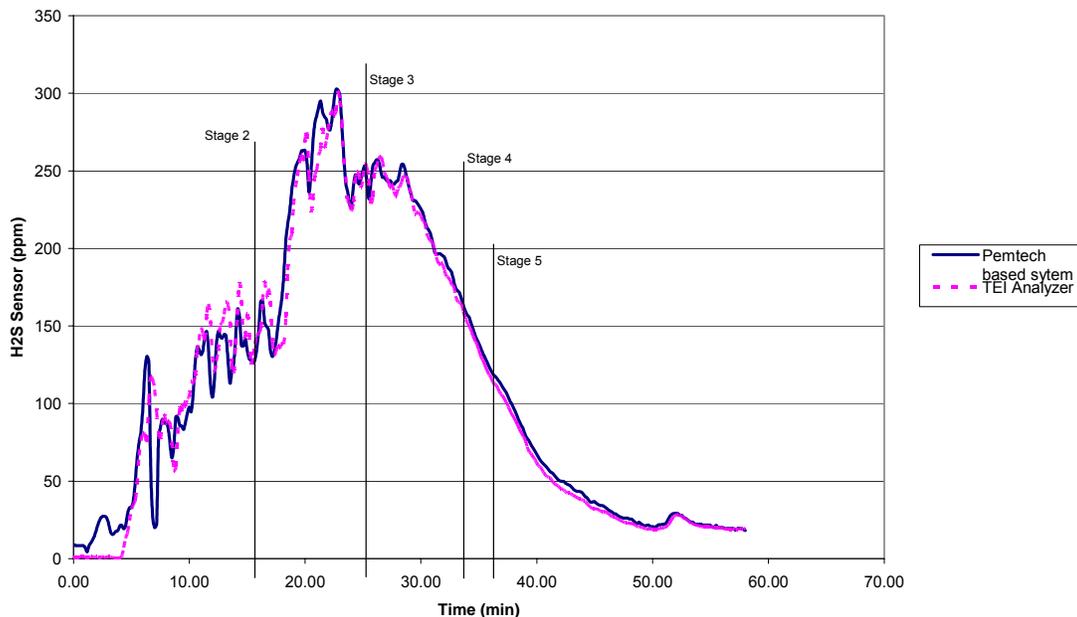


Figure 10. Performance of the wireless H<sub>2</sub>S detection system vs. the TEI analyzer at location 1 in swine confinement. Agitation and stage 1 ventilation were initiated at t = 0. Measurements were taken at 10-s intervals (Test 4).

This and similar tests confirm that ventilation can be used to disperse H<sub>2</sub>S bursts during slurry agitation. It also confirms that the Pemtech based detection system can be used to warn of dangerous H<sub>2</sub>S levels in order to adjust ventilation accordingly.

After the detection system was validated during three tests against the TEI, the TEI inlet tube was placed 51 cm (20") below the slatted floor at location 1. Interior stirring or mixing fans were activated to monitor their effect on H<sub>2</sub>S concentration. Figure 11 shows the results of this test. The stirring fans equalized the H<sub>2</sub>S concentration above and below the slatted floor during this and a second, similar test. This suggests the H<sub>2</sub>S concentration elsewhere in the confinement was similar to the below floor concentration prior to stirring fans being turned on. This could

mean dangerous levels are present away from the detection point. For this reason, stirring fans can be used to achieve a representative sample when using a single point detection system.

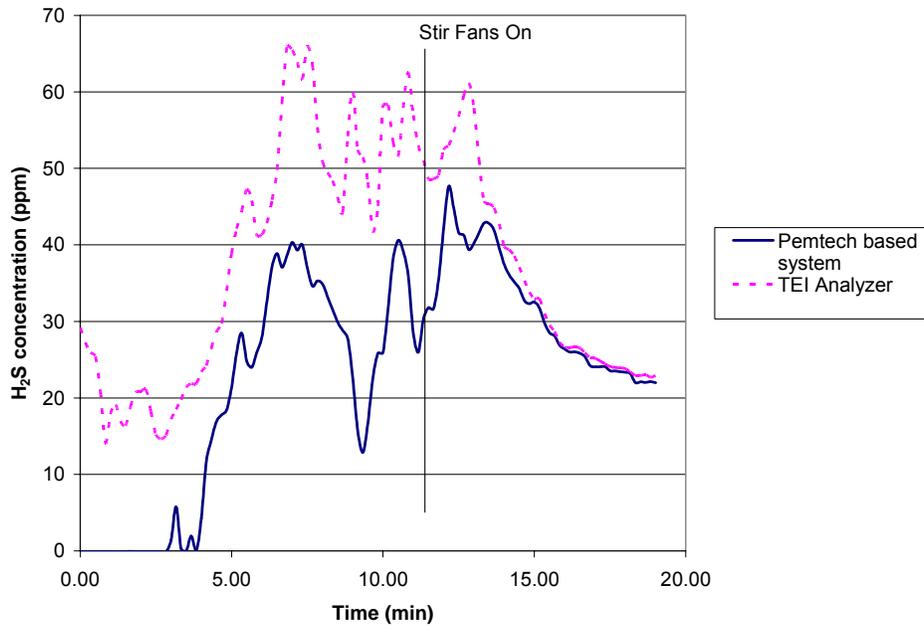


Figure 11. Profiles of H<sub>2</sub>S concentration above and below the slatted floor during slurry agitation. Sensor/transmitter unit was placed at location one, whereas TEI tube inlet was 51 cm (20") below the slatted floor at location 1. Above surface agitation initiated at t=0. (Test 7)

During the test shown in figure 12, below surface agitation was used reducing the H<sub>2</sub>S burst release concentration. While the TEI recorded H<sub>2</sub>S below the slatted floor, the detection system did not detect a measurable amount above the slats. These results suggest sub-surface agitation should be used whenever possible to minimize H<sub>2</sub>S burst releases.

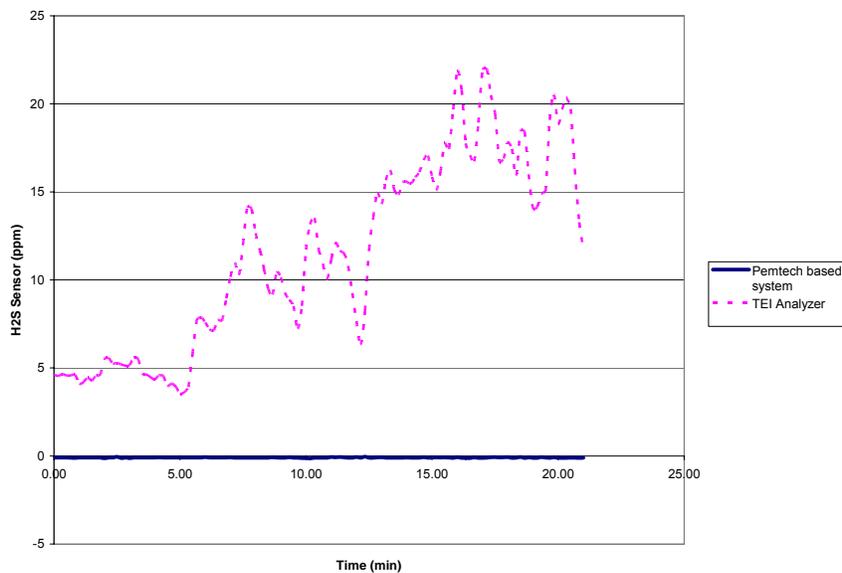


Figure 12. H<sub>2</sub>S concentration during sub-surface slurry agitation. Sensor/Transmitter unit at location 1, TEI tube inlet 51 cm (20") below slatted floor at location 1. Agitation initiated at t = 0.

Figure 13 shows the results of a test during above surface agitation with the TEI tube inlet at location 1 and the sensor/transmitter unit at location 2.

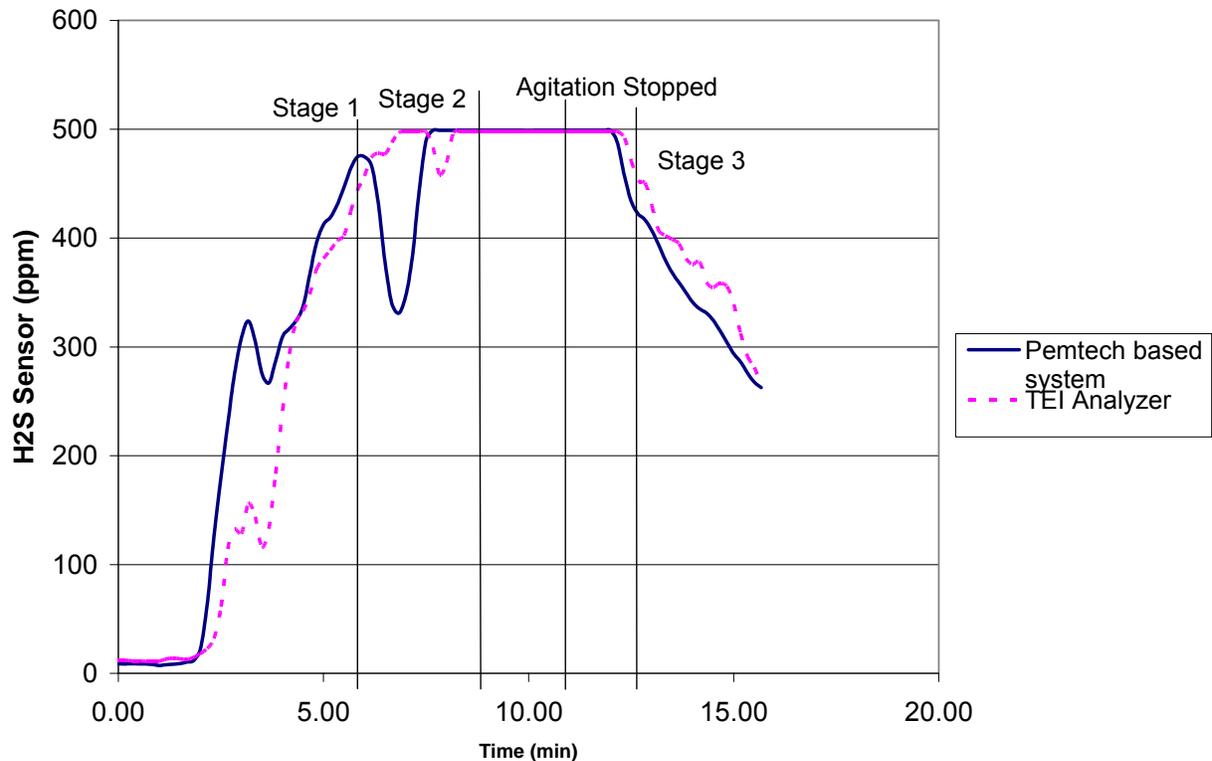


Figure 13. H<sub>2</sub>S concentration during above-surface slurry agitation. Sensor/Transmitter unit at location 2, TEI tube inlet at location 1. Agitation initiated at = 0. (Test 10)

The results seen in figure 13 show how quick and intense an H<sub>2</sub>S burst can be. This supports existing research on the dangers of H<sub>2</sub>S burst releases. The instruments outputs were maximized at 500 ppm. The actual concentration could have been higher. This test (and others not shown here) also confirms that the H<sub>2</sub>S concentration can vary at different locations in a swine confinement. The spatial variations could result in H<sub>2</sub>S burst being missed by the single-point detection system. Research is thus needed on a multi-point detection system to adequately monitor in-house H<sub>2</sub>S concentrations and gain more knowledge about the characteristics of H<sub>2</sub>S burst released during slurry agitation. Such a system could be incorporated with a swine house's ventilation system to control H<sub>2</sub>S concentrations and ultimately reduce the risk of animal and human fatality due to H<sub>2</sub>S poisoning.

At the time of this paper submission the Pemtech H<sub>2</sub>S detection system is undergoing daily use and testing in the field by a commercial custom slurry removal and application business. Upon return it will be lab tested for accuracy and sensor drift.

## Conclusions

A portable, wireless H<sub>2</sub>S detection system based on currently available sensors and wireless technology has been successfully developed. The system has a component cost of \$2,735 and is based on a Pemtech PT-295 electrochemical H<sub>2</sub>S sensor and a Phoenix Contact Wireless Transmitter / Receiver set. This system meets all of the H<sub>2</sub>S monitoring system selection criteria

specified by the project team. It features the following operational characteristics: a) 90% ( $t_{90}$ ) response to 10, 20, 45, 100, 200 ppm and 500 ppm H<sub>2</sub>S within one minute, b)  $\pm$  5% full scale accuracy, and c) < 2 hr warm-up time for operation.

The system was used to characterize H<sub>2</sub>S concentrations and manage ventilation to disperse H<sub>2</sub>S bursts during slurry agitation and removal from swine houses with sub-floor slurry storage. Using results from field testing, the following recommendations are suggested in regards to minimizing in-barn H<sub>2</sub>S concentrations and exposure risks:

- 1) Never enter a swine confinement during slurry agitation. OSHA's limit for immediate threat to life is 100 ppm (OSHA, 2000). The field tests show concentrations can greatly exceed that level quickly during slurry agitation.
- 2) Activate stirring fans, if available, to equalize H<sub>2</sub>S concentration in the confinement. This will give a more representative reading when using a single-point detection system like the one developed for this research.
- 3) Use sub-surface agitation when possible. The tests show that this greatly reduces H<sub>2</sub>S burst release.
- 4) Ventilate the confinement to provide around 35 air changes per hour (ACH). Although 20 ACH generally leads to a good dissipation of H<sub>2</sub>S, more intense bursts like those seen in some of our field tests will require greater ventilation to dissipate.
- 5) Considerable spatial variations in H<sub>2</sub>S concentration can exist in the swine confinement, which necessitates development and use of a multi-point detection system to adequately monitor in-house H<sub>2</sub>S concentrations during slurry agitation.

### **Acknowledgements**

This project was funded by the National Pork Board. Field testing assistance was provided by Puck Custom Enterprises, a commercial slurry application business in western Iowa that currently applies over 100 million gallons per year for over 100 producers. Field testing was done at sites managed by Audubon Manning Vet Clinic and Josh Linde, a private swine producer.

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## Appendix or Nomenclature

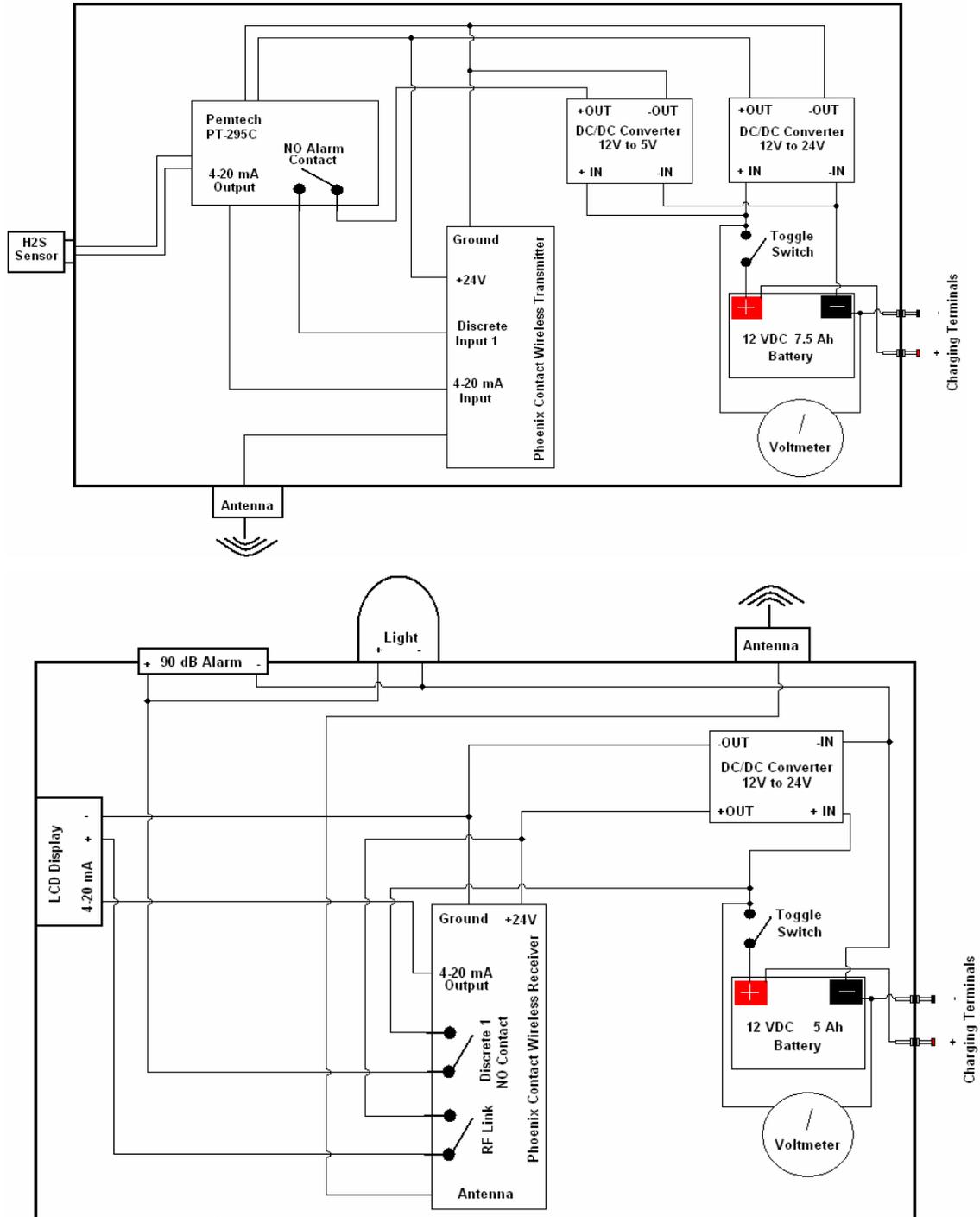


Figure A-1. Penttech PT-295 based wireless H<sub>2</sub>S detection system transmitter (top) and receiver (bottom) schematic.

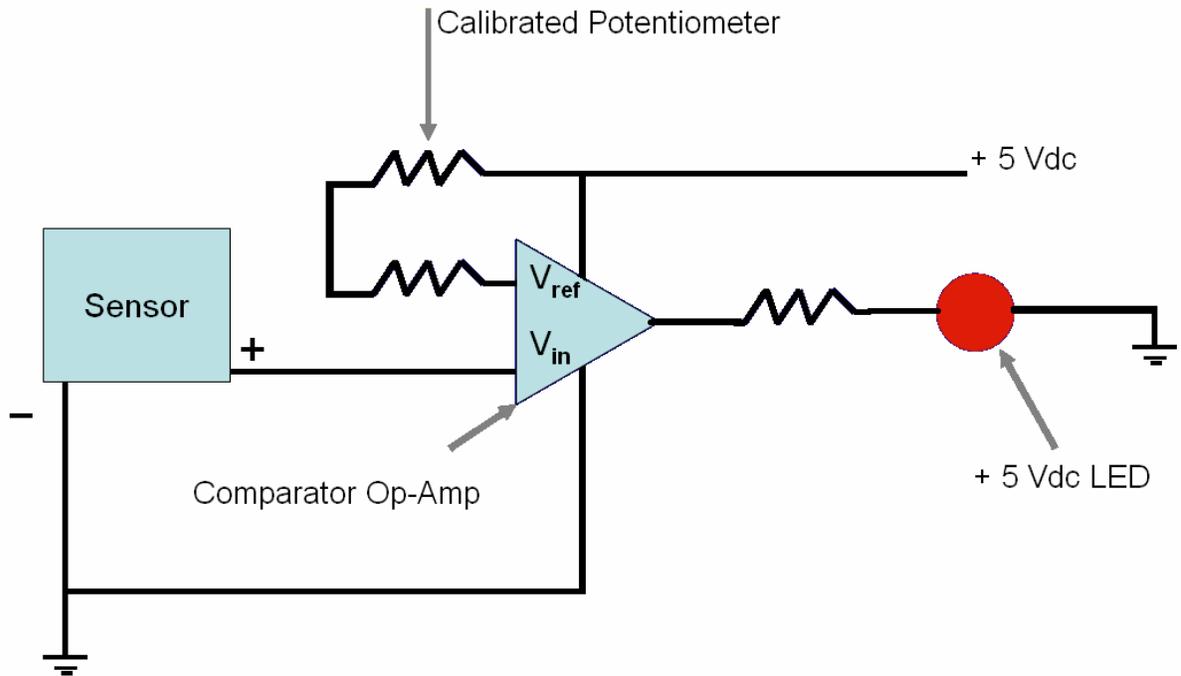


Figure A-2. Transducer Tech R-Series based H<sub>2</sub>S detection system calibrated LED "light bar" schematic. This circuit is for 1 LED; it is duplicated for additional LED's.

Table A-1. Cost of materials to construct Pemtech Pt-295 based H<sub>2</sub>S detection system.

<b>Pemtech Pt-295 based H<sub>2</sub>S detection system costs</b>	
Pemtech PT-295	\$865
Phoenix Contact Wireless Transmitter/Receiver Set	\$1400
Materials for transmitter unit	
12 Vdc / 5 Vdc Converter	\$5
12 Vdc / 24 Vdc Converter	\$90
Battery	\$40
Enclosure	\$45
Voltmeter	\$13
Hardware and wire	\$15
Materials for receiver unit	
12 Vdc / 24 Vdc Converter	\$90
Battery	\$35
Enclosure	\$23
Voltmeter	\$13
LCD Display	\$82
Pulsing Piezo Buzzer and Light	\$6
Hardware and wire	\$13
<b>TOTAL</b>	<b>\$2735</b>

Table A-2. Cost of materials to construct Transducer Tech R-Series based H<sub>2</sub>S detection system.

<b>Transducer Tech R-Series based H<sub>2</sub>S detection system costs</b>	
Transducer Tech R-Series	\$210
Telescoping Pole 24'	\$60
Materials	
12 Vdc / 5 Vdc Converter	\$5
Two-Pair Shielded Signal Wire	\$40
Battery	\$40
Enclosure	\$22
Voltmeter	\$13
Hardware, wire, electrical components	\$40
<b>TOTAL</b>	<b>\$430</b>

