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Vapor Monitoring and Detection System Pilot-Scale Test Phase 1 Report (FY 2016)

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Abstract: The Vapor Monitoring and Detection System (VMDS) Phase 1 Pilot-Scale testing results covering installation and initial operation are presented in this report. The basic purpose of VMDS pilot-scale testing was to verify that the various components of the system as initially designed will operate in the tank farms. The Vapor Monitoring, Detection & Remediation (VMD&R) Project as a whole intends to use the information collected during the pilot-scale testing to provide a technical basis for the design and operation of a VMDS that can be tailored for use in any location on the Hanford Site. Pilot-scale testing of the VMDS to date has demonstrated the ability to detect chemical vapors, including Chemicals Of Potential Concern (COPC's) and leading indicators, in real time from both stationary and fugitive emission sources. Reliable operation across varying seasonal conditions will be a part of Phase 2 testing.

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EXECUTIVE SUMMARY

A vapor monitoring and detection system (VMDS) is being developed in response to the Tank Vapor Assessment Team (TVAT) recommendation to: "Accelerate implementation of tailored engineering technologies to detect and control vapor emissions and exposures experienced in the Hanford tank farms." A detailed review by the Chemical Vapors Solution Team (CVST) Technology Improvement sub-team identified enhancements for continuous, near real-time measurements of tank farm vapors, meteorological conditions, and the ability to visualize this information for response. A request for solutions submitted to industry, national laboratories, and academia culminated in a technology exchange to finalize applicable technologies for maturation. A rigorous Technology Maturation Plan (TMP)was developed, including component level testing, bench-scale testing, and pilot-scale testing/demonstration at 241-A Tank Farm (single-shell tanks) and 241-AP Tank Farm (double-shell tanks). The Phase 1 of 2 pilot-scale testing results are presented in this report.

The pilot-scale testing objectives can be organized into four main categories:

1. TMP requirements
2. Component level requirements and functionality (also part of the TMP)
3. Integrated component level requirements and functionality (also part of the TMP)
4. Initial data analysis as appropriate.

This first phase of pilot-scale testing (in fiscal year 2016) was focused on installation and initial operation of the VMDS. The components that have been tested include direct-reading instruments, spectroscopic instruments, autosamplers, local meteorological towers, SAFER® Systems LLC software, and tank farms communications systems as they apply to the VMDS. Initial testing has met many of the test requirements. The next phase of testing will evaluate the effects of seasonal variation and efficacy of the instrumentation during waste-disturbing activities.

In general, all of the instrumentation is functioning for its intended use. However, communication and software issues continue to challenge the integrated system. A summary of the testing results for equipment, communication, and software is provided below, followed by a recommendation for tank farm use based upon current results.

- **Meteorological Station**: The primary meteorological station, Coastal Environmental meteorological station, has met all five test requirements and one of the two objectives, operating continuously in the tank farms environment. The secondary (backup) Lufft meteorological station continues to be challenged with communication issues (faulty programming of the wireless radio) and has yet to meet any of the requirements or objectives.

- **Direct-Reading Equipment**: The direct-reading instruments (i.e., RAE MeshGuard®, AreaRAE®, MultiRAE® Pro, Gastronics Fixed Instrument Skid [FIS]) continue to function well for their intended use, but have experienced intermittent communication and software challenges. The N_2O sensor on the Gastronics FIS is undergoing temperature compensating re-engineering.

- **Spectroscopic Equipment**: The spectroscopic instrumentation (Ultraviolet Differential Optical Adsorption Spectrometer [UV-DOAS], Open Path Fourier Transform Infrared

Spectrometer [OP-FTIR], Ultraviolet Fourier Transform Infrared Spectrometer [UV-FTIR]) has been operating consistently throughout Phase 1 pilot-scale testing.

- **Optical Gas Imaging (OGI) Systems:** The fixed FLIR® OGI camera has not met test requirements due to challenges with software installation and instrument configuration issues. However, the portable FLIR OGI camera has been used in the field to evaluate passive breather filters and other plume sources indicating successful use of the gas imaging technology, meeting test requirements.
- **Autosamplers:** The autosamplers (stack, area and grab) were successfully field deployed and have met the bulk of test plan objectives and test requirements.
- **Personal Location Units:** The Blackline Loner® IS+ GPS units were tested to determine occupancy rate information. They have met all of the functional testing requirements.
- **Personal Badges:** Preliminary testing (calibration and connection to data downloading systems) of the ToxiRAE® Pro and the Ion Science Cub has indicated that these units will provide the information needed in Tank Farms for total volatile and semi-volatile organic compound (VOC) detection.
- **Communication:** Overall, communications to the Tank Farm Monitoring and Control System (TFMCS), OSIsoft Process Implementation (PI) Data Historian (OSI/PI), and the SAFER Systems Real-Time software are working satisfactorily and are ready – with minor exceptions noted in the equipment summaries – for continued operation of pilot-scale testing. However, unique configurations were necessary to ensure compatibility between communications infrastructure and some detectors, resulting in intermittent or no communications to the software services.
- **Data Display and Alarming Software:** The TFMCS human-machine interface has proven better than SAFER Real-Time or ProRAE® Guardian, primarily in the area of software/ human interface due to the use of site standard backgrounds, site-standard alarm color designators, and existing infrastructure compatibility. Similarly, OSI/PI, a standard Hanford Site product, has been used effectively as a simple graphing and analysis tool.
- **Modeling:** Initial system operation has shown the data acquisition module of SAFER Systems needs to allow better access to sensor groups and increase the quantity of sensors in a given group. Also, the testing results suggest that the software source area locator (SAL) and forward plume modeling modules require development to scale the system down to tank farm scale.

Based upon the Phase 1 test results, recommendations for path forward for each piece of equipment were determined and binned into levels of readiness. A summary is provided in Table ES-1.

The key parameters of the continued testing will be to determine the effect of seasonal variations and efficacy during waste-disturbing activities. The next phase will also continue to resolve the intermittent communication and infrastructure challenges. However, the central shift office will continue to respond to any direct-reading instrument alarms during the testing consistent with current protocols. In addition, engineering development activities for Level 1 and Level 2 components, defined in Section 7.0, will begin in parallel for future installation in other areas based upon prioritization.

Table ES-1. Summary Path Forward Recommendations.

Level	Criteria	Equipment	Recommendations
1	Ready for formalization of specification and functional requirements	Coastal Environmental meteorological station Blackline Loner IS+ GPS	Continue testing to determine seasonal variations and efficacy during waste-disturbing activities. Develop final engineering, procurement specifications, and functional requirements.
2	Requires minor modifications for acceptable use	Cerex UV-FTIR Cerex OP-FTIR Cerex UV-DOAS Autosamplers	Continue testing to determine seasonal variations and efficacy during waste-disturbing activities. Initiate development of engineering, procurement specifications, and functional requirements.
3	Requires more data to establish necessary final modifications	Gastronics FIS (N_2O sensor only) Portable FLIR OGI Lufft meteorological station	Continue testing to determine seasonal variations and efficacy during waste-disturbing activities. Resolve issues with the N_2O sensors on Gastronics FIS.
4	Extensive modifications necessary for use	Fixed FLIR OGI (software installation) SAFER Systems ToxiRAE AreaRAE (functionality) MeshGuard NH_3 monitor (communications)	Continue testing to determine seasonal variations and efficacy during waste-disturbing activities. Resolve communication challenges with AreaRAE. Fixed FLIR OGI requires software installation. Re-evaluate need for SAFER Systems given ease of TFMCS, OSI/PI use.
5	Low confidence that major modifications will meet program requirements	MultiRAE Pro SKC HAZ-SCANNER®	Continue testing to determine seasonal variations and efficacy during waste-disturbing activities. MultiRAE Pros continue to require premature sensor replacement. Continue to resolve communications challenges with RAE Systems units. The SKC HAZ-SCANNER has been completely re-engineered and has not functioned effectively as of yet.

While the basic purpose of VMDS pilot-scale testing is to verify that the various components of the system as initially designed will operate in the tank farms, the VMD&R Project as a whole intends to use the information collected during the pilot-scale testing to provide a technical basis for the design and operation of a VMDS that can be tailored for use in any location on the Hanford Site. Pilot-scale testing of the VMDS to date has demonstrated the ability to detect chemical vapors, including COPCs and leading indicators, in real time from both stationary and fugitive emission sources. Phase 2 of VMDS testing is expected to demonstrate reliable operations across varying seasonal conditions. Successful implementation of the VMDS will greatly enhance the ability to detect and respond to chemical vapor release events and over time potentially allow the capability to predict when and where such events are likely to occur.

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Abbreviations and Acronyms

ABB®	Asea Brown Boveri
AC	acceptance criteria
AI	autosampler instrumentation
CFD	computational fluid dynamics
CH_4	methane
CMS	Coastal Environmental Meteorological Station
CO	carbon monoxide
CO_2	carbon dioxide
CoC	concentration of concern
COPC	chemical of potential concern
COTS	commercial-off-the-shelf
CTO	Chief Technology Office
CVST	Chemical Vapor Solutions Team
DC	data collection
DCS	distributed control system
DRI	direct-reading instrument
DST	double-shell tank
EPA	U.S. Environmental Protection Agency
FAT	functional acceptance testing
FDS	fire dynamics simulator
FGS	Fire, Combustible Gas, and Toxic Gas System
FIS	fixed instrument skid
FWS	field work supervisor
GC-MS	gas chromatograph mass spectrometer
GHA	general hazards analysis
GPS	global positioning system
HLAN	Hanford Local Area Network
HMI	human-machine interface
HMS	Hanford (Site) Meteorological Station
IH	industrial hygiene
IHP	Industrial Hygiene Program
IHT	industrial hygiene technician
LDAR	leak detection and repair
LEL	lower explosive limit
LMS	Lufft Meteorological Station
NIST	National Institute of Standards and Technology
N_2O	nitrous oxide

NH_3	ammonia
NO_2	nitrogen dioxide.
O_2	oxygen
O_3	ozone
OEL	operational exposure limit
OGI	optical gas imaging
OP-FTIR	Open Path Fourier Transform Infrared Spectrometer
OSI/PI	OSIsoft PI Data Historian
PBF	passive breather filter
PCV	personal chemical vapor
PI	Process Implementation
PID	photoionization detector
PNNL	Pacific Northwest National Laboratory
PTR-MS	Proton Transfer Reaction Mass Spectrometer
QA	quality assurance
R&D	research and development
RAMI	reliability, availability, maintainability and inspectability
SAL	source area locator
SRNL	Savannah River National Laboratory
SST	single-shell tank
TDU	thermal desorption unit
TFLAN	Tank Farm Local Area Network
TFMCS	Tank Farm Monitoring and Control System
TFVMD	Tank Farm Vapor Monitoring and Detection System
TI	Technology Improvement (CVST sub-team)
TMP	Technology Maturation Plan
TOC	Tank Operations Contractor
TRL	Technology Readiness Level
TRM	test requirements matrix
TWINS	Tank Waste Information Network System
UV	ultraviolet
UV-DOAS	Ultraviolet Differential Optical Adsorption Spectrometer
UV-FTIR	Ultraviolet Fourier Transform Infrared Spectrometer
VMD&R	Vapor Monitoring, Detection, and Remediation (Project)
VMDS	Vapor Monitoring and Detection System
VMDS FRD	*Tank Farm Vapor Monitoring and Detection System (VMDS) Functional Requirements Document* (RPP-RPT-58714)
VMDS Test Plan	*241A Vapor Monitoring and Detection System Pilot-Scale Test Plan* (241A-TP-043)
VMDS TMP	*Technology Development Plan for the Tank Farm Vapors Monitoring and Detection System* (RPP-PLAN-59972)

VOC	volatile and semi-volatile organic compound
WRPS	Washington River Protection Solutions, LLC

Units

~	approximately
°F	degrees Fahrenheit
%	percent
$	dollar
μ	micron
°F	degrees Fahrenheit
ft	foot
GB	gigabyte
GHz	gigahertz
in.	inch
L	liter
m	meter
mi	mile
M	million
mph	miles per hour
ppm	parts per million

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1.0 INTRODUCTION

This report provides results of fiscal year (FY) 2016 Phase 1 pilot-scale testing of a Vapor Monitoring and Detection System (VMDS) in the Hanford Site tank farms. The Vapor Monitoring, Detection, and Remediation (VMD&R) Project effort is being conducted by Tank Operations Contractor (TOC) Washington River Protection Solutions, LLC (WRPS).

The results of Phase 1 Pilot-Scale testing are provided in Section 5.0, Pilot-Scale Testing Results. This section includes a short description of the overall objectives and testing. Results are summarized for each class of components, such as SAFER Systems software. Results and recommendations are provided for component readiness levels in Section 7.0, Conclusions and Recommendations. Recommendations for further testing are described in Section 7.0, Phase 2 Recommendations.

1.1 BACKGROUND

Volatile and semi-volatile organic compounds (VOC) continuously evolve from the Hanford Site waste storage single-shell tanks (SST) and double-shell tanks (DST) that are grouped into tank farms. Some of the VOCs are identical to the compounds that were originally transferred to tanks during large-scale Manhattan Project nuclear weapons production operations or from associated supporting operations. Other VOCs are evolved from the original waste in an ongoing cascade of interdependent chemical and radiolytic reactions (RPP-21854, *Occurrence and Chemistry of Organic Compounds in Hanford Site Waste Tanks*).

These VOCs have the potential to be released at concentrations that could potentially exceed established occupational exposure levels for workers who must enter the tank farms for operations, maintenance, and waste retrieval activities. Due to the concentrations of the COPCs in the tank headspace, any release within the tank farm has the possibility of affecting not only those workers who must enter the tanks farms, but also those outside of the vapor control zones (e.g. within the tank farm fence lines). The VMD&R Project is tasked with developing, evaluating, and implementing recommendations for use of Hanford Site vapor detection and monitoring technologies to improve information used to mitigate hazards to tank farm area workers. A major VMD&R Project objective is development of a VMDS to monitor and detect tank farm area vapors.

1.2 LOCATION OF TESTING

Pilot-scale testing is being performed in and around the 241-AP and 241-A Tank Farms and near the 242-A Evaporator in the Hanford Site 200 East Area. Testing of the VMDS in 241-AP Tank Farm provides for a broader area of detector coverage between the tank farms, and potential detection of DST emissions. Testing of the VMDS in neighboring 241-A Tank Farm provides for potential detection of SST emissions.

1.3 REPORT STRUCTURE

The remainder of this report is structured as follows:

- VMDS overview including testing approach and interface with overall project goals (Section 2.0)
- Brief overview of VMDS design (Section 3.0)
- Pilot-scale testing description including technical objectives and selected testing equipment (Section 4.0)
- Pilot-scale testing results collected to date and recommendations for future evaluations and testing (Section 5.0), including schedule for completion of pilot-scale testing (Section 5.12)
- Description of pilot-scale testing completion criteria (Section 6.0)
- Conclusions and recommendations (Section 7.0)
- References cited in the report (Section 8.0).

Supporting and supplemental information is provided in appendices:

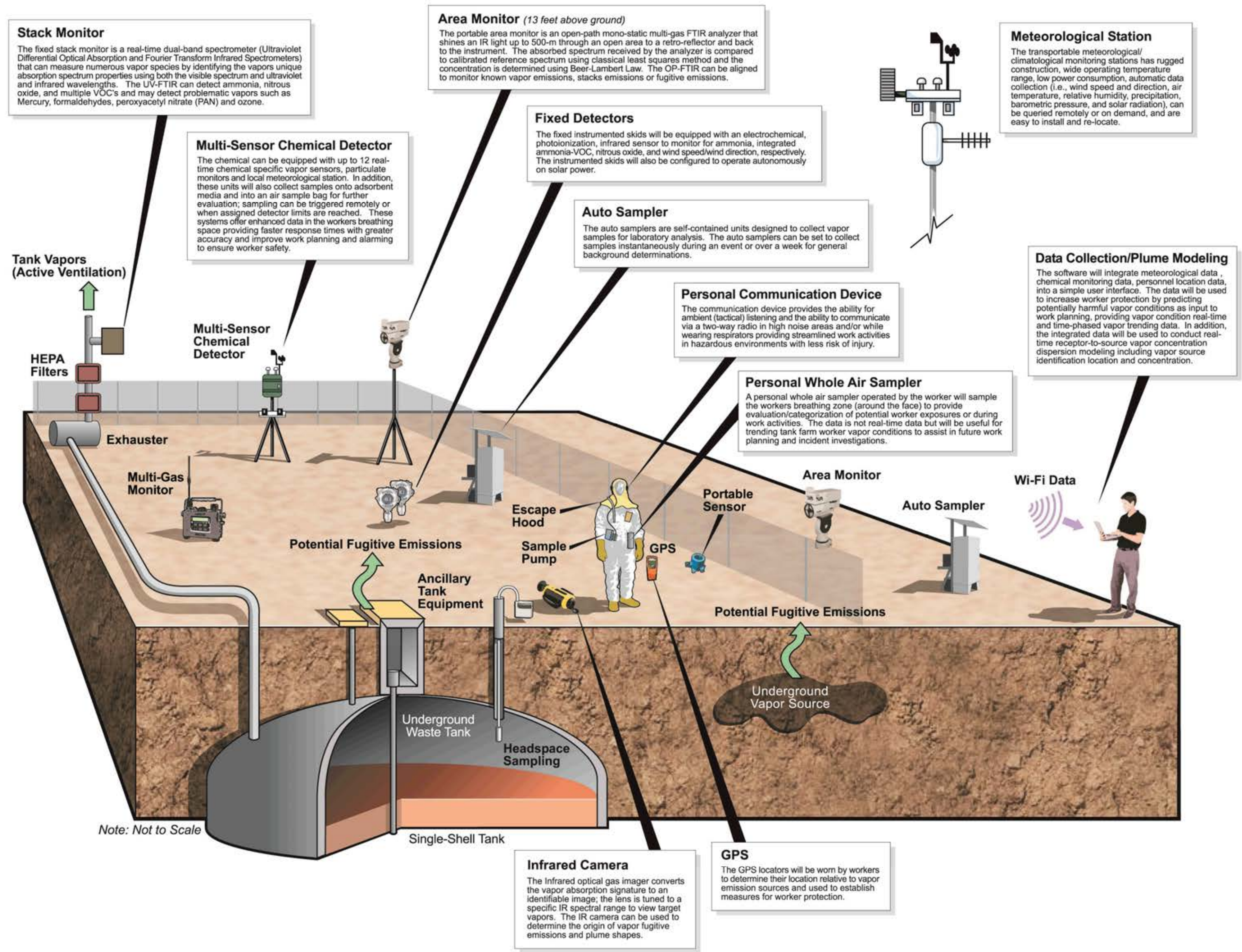
- Appendix A – List of Chemicals of Potential Concern
- Appendix B – Fact Sheets for VMDS Components
- Appendix C – Pilot-Scale Test Requirements Matrix
- Appendix D – VMDS Design Basis.

2.0 VAPOR MONITORING AND DETECTION SYSTEM OVERVIEW

A Hanford Site Industrial Hygiene Program (IHP) has been implemented to perform exposure assessment, sample and monitor the work environment, analyze environmental and exposure information, and establish control strategies to ensure worker protection. The IHP continues to perform extensive measurements to assess occupational exposure in the tank farms environment using an array of handheld and area chemical sensors, laboratory-analyzed air samples, and grab samples.

The VMDS has been designed to mitigate workers' risk of exposure to chemical vapors in the tank farms by detecting and presenting indications of chemical vapors in the work space. Secondary goals of the Technology Readiness Level (TRL) 6 pilot-scale VMDS testing. TRL 6, Technology Demonstration, is an engineering scale, similar validation in a relevant environment. This testing includes evaluating extending the use of some of the IHP tools; identifying chemical vapor detection and mitigation tools that are not currently in use; and developing those new tools for near real-time, location-specific detection that further mitigate risks to tank farms workers. The VMDS is depicted in Figure 2-1.

Figure 2-1. Artistic Depiction of the Vapor Monitoring and Detection System.



An extensive array of chemicals have been observed in the vapor phase both inside and outside of the Hanford Site waste tanks. The sheer number and characteristics of vapor species in the tank headspaces have posed difficult challenges for chemical vapor monitoring and detection. The Hanford Site, through the IHP, has used various commercial-off-the-shelf (COTS) sensors to detect certain chemical species that have been observed in worker breathing spaces at parts-per-million (ppm) concentrations (e.g., ammonia, nitrous oxide, VOCs) . However, many of the chemicals present in tank vapors include compounds (e.g., N-nitrosodimethylamine, furans, and aldehydes) that have very low occupational exposure limits (e.g. parts-per-billion [ppb]) and are thus more difficult to detect.

Gases and vapors in the SST and DST headspaces and exhaust stacks have been extensively characterized (RPP-21972, *Statistical Analysis of Tank Headspace Vapor Data*). The chemicals of potential concern (COPC) are the 59 organic and inorganic compounds listed in Appendix A. The original COPC list included 48 chemicals, and is detailed in RPP-22491, *Industrial Hygiene Chemical Vapor Technical Basis*. The IHP has updated this list to the current 59 based on evaluations of occupational exposure documents published by the Occupational Safety and Health Administration and professional IH societies.

The vapor sources within the tank farms have been classified as primary sources, secondary sources, and fugitive sources. Primary sources are designated tank headspace emission sources and include the exhausters and passive breather filters (PBF). Secondary sources are not easily designated or defined but are considered to originate from processes not connected to the tank headspaces and include vehicles, generators, evaporator emissions, regional pollution, and solvents used in Hanford Site work activities. Fugitive emissions originating from the tank headspaces are expected to be present within the tank farms but the emission point is not a primary source.

WRPS established a Chemical Vapor Solutions Team (CVST) to enhance capability to identify chemical vapor hazards in the tank farms. The CVST formed a Technology Improvement (TI) sub-team, made up of Chief Technology Office (CTO) management, crafts, engineers and chemists, to develop technology recommendations to improve understanding of tank vapor hazards and chemical vapor transport in the tank farms air space. A major outcome of the CVST TI team was to clearly articulate the need for a basic understanding of the tank farm vapor-related conditions that will allow for: (1) improved work planning; (2) selection of appropriate personal protective equipment; and (3) communication of tank farms working conditions, including the use of direct-reading instruments (DRI) that can be equipped with real-time alarms to warn workers when predetermined vapor concentration limits are reached or exceeded.

The CVST identified a number of technologies for potential use in detecting and monitoring vapors and recommended implementation of a phased testing approach to evaluate their use in the tank farms. The recommendation was accepted and the scope, budget, and schedule to execute the associated planned implementation activities are now established in the TOC baseline. Initial planning activities to implement the VMD&R Project VMDS scope of work included development of an execution plan RPP-PLAN-60656, *Execution Plan for the Hanford Tank Farm Vapor Monitoring, Detection and Remediation Project (OP 163)*, to define how the project will be structured and conducted and development of a technology maturation plan (TMP) RPP-PLAN-59972, *Technology Development Plan for the Tank Farm Vapors Monitoring* *and Detection System* (hereinafter the VMDS TMP), to outline the work activities needed to mature the proposed technologies.

2.1 TESTING APPROACH

DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, highly recommends technology readiness assessments and TMPs for smaller projects (total project cost less than $750M) and operational activities that involve the development and implementation of new technologies or technologies in new operational environments. The VMD&R Project technology demonstrations fall under that purview, which includes implementation of technologies up to defined Technology Readiness Levels (TRLs).

The VMDS TMP evaluated the design and divided the VMDS into 10 technology elements. From those, the critical technology elements were identified – the spectroscopy equipment and the data collection and management system. The TMP then outlines the steps necessary to mature the critical elements to readiness for final deployment in the tank farms. The VMDS TMP outlines a test program to mature the various technology elements comprising the VMDS to TRL 6, where the elements will be ready to perform activities to allow final deployment in the field. Once the final evaluations of the results from the testing are made, the decision of using the specified equipment will be made and all future tank farms VMDSs can be designed.

The first step in the maturation process was bench-scale testing performed at Pacific Northwest National Laboratory (PNNL). Bench-scale testing consisted of set up and operation of VMDS instruments and connection to SAFER Systems Real-Time software via a wireless network. It is important to note that the bench-scale wireless network was not indicative of the Hanford Site tank farms network. That testing (PNNL-25892, *Bench-Scale Testing of the Vapor Monitoring and Detection System*) demonstrated the viability of operation in an outdoor location on the Hanford Site. The bench-scale testing results were used to evaluate and determine the location, type, and number of monitors to be used in follow-on pilot-scale testing in the tank farms. The goal of bench-scale testing was to ensure the technologies used in the VMDS are at or above TRL 5.

After bench-scale testing, pilot-scale testing was initiated to demonstrate the recommended technologies in the tank farms environment at known and potential unidentified vapor source locations in the tank farms. The pilot-scale testing was implemented to prove the system can monitor and detect potentially hazardous conditions, the instruments are configured to detect released vapors, transmit the data to the data acquisition system, and provide real-time data on meteorological conditions within a specified area.

Testing of the pilot-scale VMDS is a major step toward satisfying the objectives of the VMD&R Project. Due to the complexity of this process, pilot-scale testing has been broken into two phases:

- **Phase 1 –** Set up, operational testing, and initial data collection from the VMDS
- **Phase 2 –** Full data collection, data evaluation, and recommendations for a final form of the VMDS.

This report provides the results of Phase 1 pilot-scale testing with recommendations on a path forward for both individual technology elements and the VMDS as a whole. Performance against Phase 1 testing criteria related to collecting data during waste-disturbing activities will be conducted during Phase 2.

An approved test plan and test procedure was required to initiate pilot-scale testing. Document 241A-TP-043, *241A Vapor Monitoring and Detection System Pilot-Scale Test Plan* (hereinafter the VMDS Test Plan), and its associated test procedure (241A-OAT-0048, *Vapor Monitoring and Detection System Pilot-Scale Test Procedure*) were approved by the WRPS Joint Test Working Group in accordance with TOC test procedure TFC-CHARTER-15, "Joint Test Group." Joint Test Working Group approval will be required to continue testing into FY 2017.

The technologies shown in Table 2- were selected for inclusion in pilot-scale testing.

Table 2-1. Technologies Chosen for Inclusion in Pilot-Scale Testing. (2 sheets)

Equipment	Manufacturer	QTY	Equipment Type	Analytes Detected
Primary meteorology instrumentation	Coastal Environmental Systems, Inc.	1	Meteorology station	WS, WD, T, P, RH, Rad, Rn at 10 m T at 2 m
Secondary meteorology instrumentation	Lufft USA, Inc.	1	Meteorology station	WS, WD, T, P, RH, Rn at 10 m
Fixed instrument skid	Gastronics, Inc.	25	Point chemical monitor	NH_3, N_2O, VOCs
MeshGuard NH_3	RAE Systems, Inc.	56	Point chemical monitor	NH_3
Area RAE	RAE Systems, Inc.	10	Point chemical monitor	NH_3, VOC, LEL, CO_2, O_2
ToxiRAE Pro	RAE Systems, Inc.	35	Point chemical monitor	VOCs
MultiRAE	RAE Systems, Inc.	3	Point chemical monitor	NH_3, VOC, LEL, CO_2, O_2
HAZ-SCANNER	SKC	2	Point chemical monitor	PM-10, PM-2.5, VOC, NO_2, O_3, SO_2, CH_4, NH_3, CO_2, WS, WD, T, RH
Cub	Ion Science Ltd.		Point chemical monitor	VOCs
UV-DOAS	Cerex Monitoring Solutions, LLC	1	Open path multiple chemical vapor monitor	Multiple COPCs
OP-FTIR	Cerex Monitoring Solutions, LLC	2	Open path multiple chemical vapor monitor	Multiple COPCs
UV-FTIR stack monitor	Cerex Monitoring Solutions, LLC	2	Extractive stack monitor	Multiple COPCs
Portable OGI camera GF-306	FLIR Systems, Inc.	1	Optical gas imager	NH_3
Portable OGI camera GF-346	FLIR Systems, Inc.	1	Optical gas imager	N_2O
Fixed OGI camera GF-306	FLIR Systems, Inc.	1	Optical gas imager	NH_3
Area/Stack sampler	GD Environmental Inc.	10	Transportable whole-air sampler	55 COPCs
Grab sampler	GD Environmental Inc.	6	Portable whole-air and TDU tube sampler	55 COPCs

Table 2-1. Technologies Chosen for Inclusion in Pilot-Scale Testing. (2 sheets)

Equipment	Manufacturer	QTY	Equipment Type	Analytes Detected
Loner IS+	Blackline	25	Personal global positioning system	N/A

CH_4	=	methane.
CO_2	=	carbon dioxide.
COPC	=	chemical of potential concern.
LEL	=	lower explosive limit.
N_2O	=	nitrous oxide.
NH_3	=	ammonia.
NO_2	=	nitrogen dioxide.
O_2	=	oxygen.
O_3	=	ozone.
OGI	=	optical gas imaging.
OP-FTIR	=	open path Fourier transform infrared spectrometer.
P	=	pressure.
PM-10	=	particulate matter D <10 μ.
PM2.5	=	particulate matter D <2.5 μ.
Rad	=	solar radiation.
RH	=	relative humidity.
Rn	=	precipitation.
SO_2	=	sulfur dioxide.
T	=	temperature.
TDU	=	thermal desorption unit.
UV-DOAS	=	ultraviolet differential optical adsorption spectrometer.
UV-FTIR	=	ultraviolet Fourier transform infrared spectrometer.
VOC	=	volatile and semi-volatile organic compound.
WD	=	wind direction.
WS	=	wind speed.

Selection of these technology elements represents the following:

- Those units purchased for bench-scale testing: OP-FTIR; fixed and portable FLIR OGI cameras; RAE Systems sensors (ToxiRAE Pro, MultiRAE, AreaRAE, MeshGuard); LMS; HAZ-SCANNER; Gastronics FIS.
- Additional units of the same equipment tested in the bench-scale testing were deployed as part of the Phase 1 pilot-scale testing to provide greater area coverage and for redundancy.
- New units that were not available for bench-scale testing: UV-DOAS, UV-FTIR stack monitor, Coastal Environmental meteorological station (CMS), Ion Science Cub VOC detector, and whole-air samplers (stack, area, grab, and personal).

Summary descriptions of the technologies and their capabilities and features are provided in Section 4 of the VMDS Test Plan. Appendix B of this report provides fact sheets with additional equipment information.

A summary of needs the CVST TI team identified for enhanced capabilities, along with the specific technologies to be evaluated in pilot-scale testing to provide the needed capability, is provided in Table 2-.

Table 2-2. Enhanced Capabilities and Recommended Technologies. (2 sheets)

Enhanced Capabilities	Recommended Technologies
Continuous, real-time chemical monitoring and reporting of chemical vapors extending over much of the occupied portions of tank farm work areas to: • Identify chemical vapor hazard concentrations	OP-FTIR UV-DOAS Gastronics FIS AreaRAE HAZ-SCANNER MeshGuard NH_3

Table 2-2. Enhanced Capabilities and Recommended Technologies. (2 sheets)

Enhanced Capabilities	Recommended Technologies
Continuous, real-time chemical monitoring of chemical vapors originating from known sources (exhausters and passive breather filters) to: • Identify chemical vapor hazard concentrations	UV-FTIR stack monitor MeshGuard NH_3
Personnel badges for continuous, real-time chemical monitoring of chemical vapors to: • Alert workers to the presence of chemical vapors • Record concentrations of VOCs in the plume • Record real-time vapor concentrations in worker air space	ToxiRAE Pro Cub
Integrate continuous, real-time meteorological monitoring with chemical monitoring equipment to: • Predict and estimate the transport of chemical vapors within or originating from tank farm operations	Coastal Environmental meteorological station Lufft meteorological station
Accurate work personnel location to: • Determine tank farm occupancy rates and heavy traffic areas	Loner IS+ GPS units
Develop methods to integrate: • Chemical monitor data • Meteorological data • Personnel location data • Real-time chemical vapor data	SAFER Systems Real-Time TFMCS OSIsoft PI Historian
Develop methods to: • Continuously collect whole-air and sorbent tube samples from primary sources (exhauster stacks) and tank farm areas	Primary sources: whole-air and sorbent tube sampling (area/stack samplers) Tank farm areas: whole-air and sorbent tube sampling (area/stack samplers, grab samplers)
Develop methods to: • Continuously collect or trigger collection of a whole-air sample and/or sorbent tubes in a tank farm work team	Continuous or triggered collection: whole-air and sorbent tube sampling (area/stack sampler; area around work team) Triggered collection: whole-air and sorbent tube sampling (grab sampler, can move with work team)
Develop methods to: • Identify fugitive emissions • Identify emerging plume release events	Fixed and portable FLIR cameras
Develop system design basis (e.g., ISA TR84.00.07) methods to: • Determine sensor locations • Determine alarm set points • Estimate risk reduction parameters	Kenexis expert consultation

ISA TR84.00.07, *Guidance on the Evaluation of Fire, Combustible Gas and Toxic Gas System Effectiveness.*

COPC = chemical of potential concern.
GPS = global positioning system.
NH_3 = ammonia.
OP-FTIR = open path Fourier transform infrared.
TFMCS = Tank Farm Monitoring and Control System.
UV-DOAS = ultraviolet differential optical adsorption spectrometer.
UV-FTIR = ultraviolet Fourier transform infrared.
VOC = volatile and semi-volatile organic compound.

The VMDS will remain in pilot-scale testing mode for at least six months (Phase 2) to verify adequate performance through changing environmental conditions (diurnal and seasonal), to allow adequate run time to fully assess equipment and system performance, and to provide information to establish a final system design for commissioning and turnover to Tank Farm Operations. The official beginning of pilot-scale testing was August 9, 2016; additional testing may be required to fully evaluate the VMDS operations during the summer months.

2.2 INTERFACE WITH OVERALL PROJECT GOALS

While the basic purpose of VMDS pilot-scale testing is to verify that the various components of the system as initially designed will operate in the tank farms, the VMD&R Project as a whole intends to use the information collected during the pilot-scale testing to provide a technical basis for the design and operation of a VMDS that can be tailored for use in any location on the Hanford Site. In addition, this information will be used to establish path forward for vapor remediation (abatement) activities.

To provide for a rigorous technical basis for the VMDS, a basic understanding of the conditions around the tank farms is necessary. This includes meteorological conditions, identification of locations of known and potential vapor sources, and the speciation/concentration determination of vapors. The pilot-scale testing was designed to provide much of this information and through the evaluation/analysis of the data to be collected, a firm technical basis can be developed. Necessary analysis will include the following:

- Corroboration of data between co-located equipment (e.g., DRIs, autosamplers)
- Plume modeling based on concentration and meteorological data
- Location of fugitive sources of vapors, including tank waste and external sources (source apportionment)
- Identification and determination of the utility of leading indicators as bounding markers of low concentrations species.
- Determination of any periodicity observed in vapor detection (e.g., diurnal, seasonal, work-source related).

It is anticipated that when enough pilot-scale testing data is collected and analyzed, a number of areas of information necessary for development of a final VMDS design will be available. These areas include, but are not limited to, the following:

- How well plume modeling works and what its utility will be for work planning and emergency response
- Utility of the system for source apportionment
- How the placement and frequency of sensors affects overall utility of the system
- How well instruments identify/quantify the COPCs and provide the level of certainty to ensure worker safety
- An acceptable level of false readings (both positive and negative) to provide confidence in the readings/alarms

- Ability of the system to identify unknowns and whether those unknowns can be addressed.

Not all of the information needs for engineering of the final VMDS and abatement technologies are addressed in pilot-scale testing. The VDM&R Project is pursuing other studies to provide other required vapor-related information. Other ongoing studies include the following:

- Development of a new IH plan for the tank farms; the COPC list was established to identify chemical compounds that are present in Hanford tank waste vapors at concentrations that may present a hazard to the work force. The COPC list is based on available toxicology information in conjunction with IH sampling of the atmosphere and tank headspaces. To be effective, the COPC list must be updated regularly. This work provides the technical basis and process to review available toxicology and tank farm IH sampling data to update the COPC list on an annual basis. In FY 2016, three new compounds were recommended for addition to the COPC list, five compounds were identified where inclusion in the list was based on analytical errors and 35 compounds were identified that need further consideration before making recommendations for inclusion in the list.
- Effect of aerosols on air quality; Savannah River National Laboratory (SRNL) conducted a study looking for the presence of sub-micron size aerosols in the vapor streams emitted from the tank 241-A-103 PBF and the 241-AP exhauster stack. Further samples were taken up and down wind from several tank farms in the 241-A Tank Farm complex and from the 241-C Tank Farm. This analysis did not find a significant difference in the quantity of aerosols present in the vapor source streams (tank 241-A-103 PBF and 241-AP stack) and the control samples taken up wind from the tank farms. Further, there was no significant difference in the aerosols present up and down wind from the tank farms. This test was done in the April-May timeframe during day shift with no waste-disturbing activities underway. SRNL recommended a more complete test be done over the course of a year with 24-hour sampling periods, samples taken from a much larger number of Hanford waste storage tanks, and to encompass all normal operating conditions.
- Use of a mobile laboratory (equipped with a proton transfer reaction mass spectrometer [PTR-MS] and other chemical sensors) for assessing plumes and as a corroboratory method for other sensors (e.g., the UV-FTIR stack monitor). The mobile laboratory was employed in eight, one-week campaigns to characterize vapor composition and concentrations across the Hanford Site. These measurement campaigns drew samples from the tank 241-A-103 PBF, the 241-AP stack, and a number of locations outside of the tank farms. While sampling outside of the tank farms, the mobile laboratory located between 3 and 20 plumes on a daily basis. These plumes were typically very short duration, lasting from a few seconds to a few minutes. With a few notable exceptions, chemical concentrations were well below 10% of the established occupational exposure limits (OELs). That being said, on several days furan concentrations peaked above the OEL and every day the average nitrosamine concentrations were above the OEL. It must be noted that the PTR-MS used in this study is only sensitive to the mass of a compound. It cannot differentiate between different compounds that have the same mass. It is possible, and in some cases likely, that interfering compounds artificially biased the

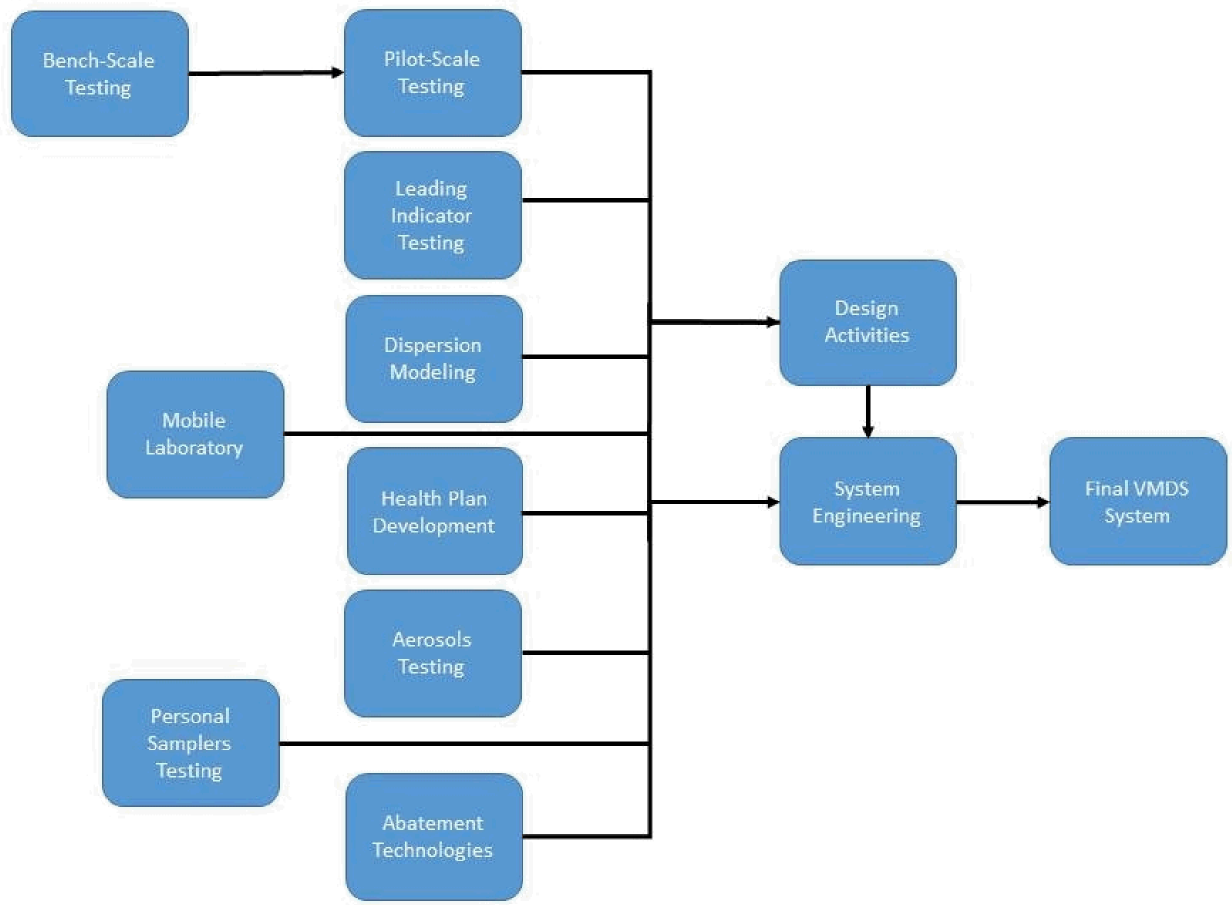
concentration measurements high. Analysis of data collected from the tank 241-A-103 PBF and the 241-AP stack is still in process.

- Use of personal samplers (e.g., mini summa cans) for accurate identification and quantification of vapors during work events
- Evaluation of potential vapor remediation (abatement) technologies; SRNL conducted a broad review of available vapor abatement technologies applicable to the Hanford Tank Farms. This review included a literature review, a request for information published in the FedBizOpps, a workshop, and visits to three of the four highest scoring vendors from the workshop. This study recommended further testing and down-selection of technologies before proceeding with pilot-scale testing in the tank farms.

Once this information is collected and evaluated, engineering of a final VMDS can proceed to provide a system that will be used to decrease worker exposures and guide efforts at abatement where feasible.

It is anticipated that engineering of a final VMDS will be performed in conjunction with private contractors (e.g., Kenexis Consulting Corporation) using ISA TR84.00.07, *Guidance on the Evaluation of Fire, Combustible Gas and Toxic Gas System Effectiveness*, methodology. The guidance relies on a thorough understanding of (1) the vapor concentration of chemical hazards, (2) the frequency of chemical vapor releases, (3) the frequency of employee occupancy inside the tank farms, and (4) the reliability, availability, maintainability, and inspectability (RAMI) of the system used to detect and monitor hazardous vapors. An overview of the major elements of the process can be seen in Figure 2-2.

Figure 2-2. Development of a Final Vapor Monitoring and Detection System.



VMDS = Vapor Monitoring and Detection System.

Continuation of pilot-scale testing into FY 2017 will include operation of the pilot-scale VMDS to collect data representative of a complete seasonal cycle and to complete design of the VMDS. At the end of FY 2017, the end state of the VMDS is expected to include a VMDS design that can be used to determine the mitigated and residual risks to tank farms workers from chemical vapor hazards. Figure 2-3 demonstrates the timeline of this process.

Figure 2-3. Pilot-Scale Testing Role in Overall VMD&R Project.

FY	=	fiscal year.	VMD&R	=	Vapor Monitoring, Detection, and Remediation.
FGS	=	Fire, Combustible Gas, and Toxic Gas System.	VMDS	=	Vapor Monitoring and Detection System.

Upon completion of pilot-scale testing (in FY 2017), additional information gathering will be performed to achieve the end-state goals of the VMD&R Project. Once adequate information is obtained for system design, final VMDS configurations can be established and the information necessary for turnover/commissioning to Tank Farms Operations can be provided for broad tank farms implementation.

3.0 VAPOR MONITORING AND DETECTION SYSTEM DESIGN

The VMDS will be designed to detect COPCs at a concentration of concern (CoC)[1] originating from identified vapor release sources in the tank farms. The intent of the system is to detect and indicate COPCs at their individual CoCs at the earliest stages of plume development. The system will not remove the chemical hazard, but only indicate the presence of the chemical vapor hazard and provide the information necessary to take appropriate actions to mitigate the risk to the workers from the hazard.

A significant outcome of the VMD&R Project is to develop a final VMDS that has a strong defensible technical basis. With this as a major goal, the development of the pilot-scale VMDS was influenced by multiple factors. These factors included; 1) consideration of the current IH Technical Basis (RPP-22491), 2) recent and past evaluations of commercially available detection equipment, 3) the results of the CVST TI team's efforts on benchmarking the industry, and 4) identifying technologies/equipment that could be used to detect currently accepted leading indicator species (NH_3, N_2O, and VOCs) and could also detect other hazardous compounds not readily identified by the monitoring equipment currently available onsite.

Using applicable WRPS procedures and the recommendations from the CVST-TI, the pilot-scale system was designed using past knowledge to locate those areas that have demonstrated a greater possibility of potential vapor release events. Areas of concern include PBFs, valve and pump pits, waste transfer lines, waste transfer tanks, waste receipt tanks, vessel vents, vacuum inlets, the exhauster train, and exhausters. In some cases, however, the equipment could not be located as designed due to tank farm configuration issues and the final location of the gas sensor was adapted to current plant layout. In addition, monitoring of personnel (sensor badges and GPS units) and boundaries will provide indication of gas plumes crossing those boundaries (e.g., tank farm fence line monitoring). The pilot-scale VMDS was deployed to provide information on the suitability of the various monitors tested, but also to provide data – along with the data from parallel activities such as the leading indicator study and a tank headspace sampling and analysis campaign – to strengthen the technical basis for the future design of the VMDS. The methodology that will be used in determining criteria for designing the final VMDS design is described in Appendix D.

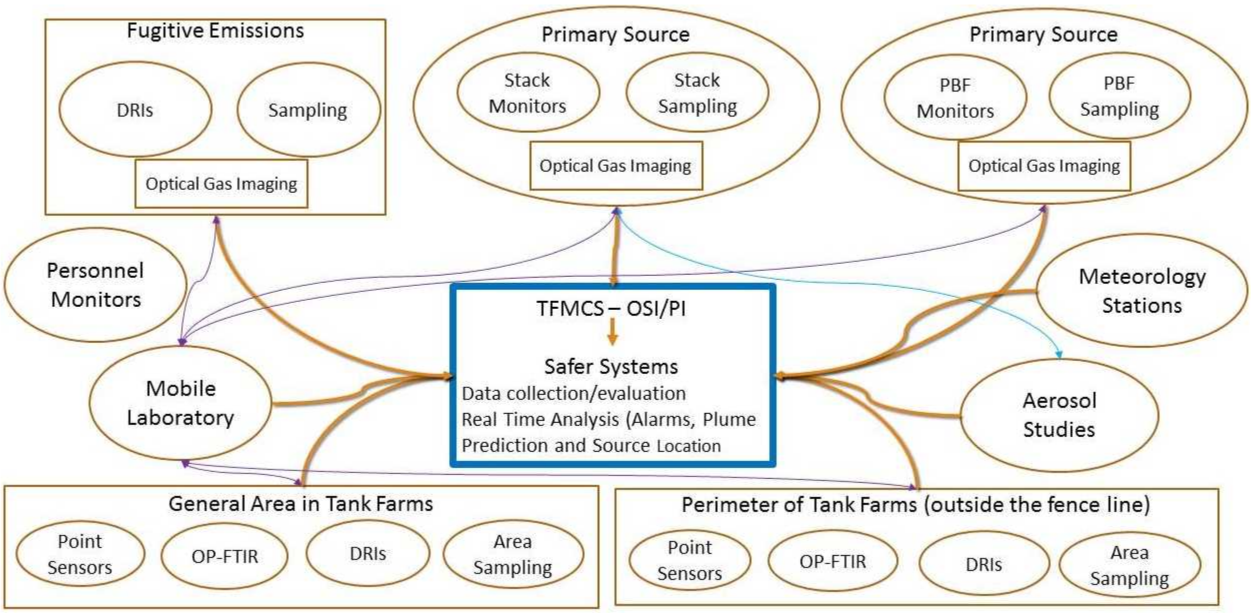
[1] 'Chemical of potential concern' (COPC) refers to the identity of the species of interest,'Concentration of concern' (CoC) refers to the amount or concentration of that species present in the airspace.

4.0 PILOT-SCALE TESTING

4.1 TECHNICAL OBJECTIVES

Pilot-scale testing technical objectives are derived from the VMDS TMP, RPP-22491, and ISA TR84.00.07. As stated previously, the purpose of pilot-scale testing is to determine; 1) how each instrument responds in the field, 2) how well each instrument can be utilized within the reporting system, and 3) how well the instruments complement each other in warning of a potential plume. Figure 4-1 shows the areas and the type of analyses that are being performed at each source predicted within the tank farms.

Figure 4-1. Pilot-Scale Testing Sampling Areas.



DRI	=	direct-reading instrument.	PBF	=	passive breather filter.
OP-FTIR	=	open path Fourier transform infrared spectrometer.	TFMCS	=	Tank Farms Monitoring and Control system.
OSI/PI	=	OSIsoft PI Historian.	VMDS	=	Vapor Monitoring and Detection System.

Table 4- includes a summary of the objectives as they relate to one or more of the following:

- VMDS TMP objectives for maturing the technology
- VMDS objectives for meeting VMDS performance goals
- FGS design objectives for acquiring data to develop a toxic gas safety system
- Equipment objectives for individual components
- Data collection/evaluation objectives for final use of the data.

Table 4- provides a reference to the VMDS Test Plan sections that addresses each objective. From these objectives, the detailed data collection requirements were captured in the VMDS Test Plan requirements, which are duplicated as the Test Requirements Matrix (TRM) in Appendix C of this report. The TRM specifies the information that needs to be collected for each system component to meet the testing objectives.

Table 4-1. Primary Pilot-Scale Testing Objectives. (3 sheets)

Objective	Objective Description	VMDS Test Plan Sections Addressing Objectives
VMDS TMP Objectives		
TMP-1	Determine bounds of function and performance of Real-Time software	5.1.3, 5.2.1, 5.2.10, 5.4, 7.0
TMP-2	Determine the end state requirements for the OP-FTIR, OGI, UV-FTIR stack monitor, and Real-Time software.	5.1.1, 5.1.2, 5.1.3, 5.2.1, 5.2.2, 5.2.3, 5.2.10, 5.3.1, 5.3.2, 5.4, 7.0
TMP-3	Determine bounds of function and performance of the UV-FTIR stack monitor	5.1.1, 5.1.3, 5.2.1, 5.2.10, 5.3.1, 5.4, 7.0
TMP-4	Determine the function and performance in the tank farm environment for the OP-FTIR, UV-DOAS, and UV-FTIR stack monitor	5.1.1, 5.1.2, 5.1.3, 5.2.1, 5.2.2, 5.2.3, 5.2.10, 5.3.1, 5.3.2, 5.4, 7.0
TMP-5	Develop a final technical report on technology in accordance with DOE-STD-1189	5.4, 7.0
VMDS Objectives		
VMDS-1	Demonstrate VMDS fulfills the requirements of VMDS FRD	5.1.3, 5.2.1, 5.4, 7.0
VMDS-2	Operate Real-Time software to demonstrate the system can process data collected from the field	5.1.3, 5.2.1, 5.4, 7.0
VMDS-3	Operate Real-Time software to demonstrate the VMDS (simulated) central control room strategy	5.2.1, 5.4, 7.0
FGS Design Objectives		
FGS-1	Determine release frequency at primary sources	5.2.1, 5.2.4, 5.2.5, 5.2.6, 5.2.8, 5.3.1, 5.3.2, 5.4, 7.0
FGS-2	Verify magnitude of COPC concentration at primary sources	5.2.1, 5.2.4, 5.2.5, 5.2.6, 5.2.8, 5.3.1, 5.3.2, 5.4, 7.0
FGS-3	Opportunistically determine release frequency from fugitive sources	5.2.3, 5.4, 7.0
FGS-4	Opportunistically determine magnitude of COPC concentration from fugitive sources	5.2.3, 5.4, 7.0
FGS-5	Verify tank farm occupancy rates	5.2.5, 5.4, 7.0
Equipment Objectives		
Optical Gas Imaging		
OGI-1	Demonstrate operational requirements of VMDS FRD	5.1.3, 5.2.1, 5.4, 7.0
OGI-2	Test efficacy of OGI in tank farms environment	5.1.3, 5.2.1, 5.2.10, 5.3.2, 5.4, 7.0
Direct-Reading Instruments [a]		
DRI-1	Demonstrate operational requirements of VMDS FRD	5.1.3, 5.2.1, 5.4, 7.0
DRI-2	Test efficacy of DRI in tank farms environment	5.1.3, 5.2.1, 5.2.3, 5.2.5, 5.2.6, 5.2.7, 5.2.10, 5.3.2

Table 4-1. Primary Pilot-Scale Testing Objectives. (3 sheets)

Objective	Objective Description	VMDS Test Plan Sections Addressing Objectives
Spectroscopy Instruments [b]		
SI-1	Demonstrate operational requirements of VMDS FRD	5.1.3, 5.2.1, 5.4, 7.0
SI-2	Test efficacy of open path spectroscopy instruments in tank farms environment	5.1.3, 5.2.1, 5.2.3, 5.2.5, 5.2.6, 5.3.2
SI-3	Test efficacy of stack spectroscopy instruments in tank farms environment	5.1.3, 5.2.1, 5.2.10, 5.3.1, 5.4, 7.0
SI-4	Recommend end state requirements for spectroscopy instruments	7.0
Personal Chemical Vapor Badges		
PCV-1	Demonstrate operational requirements of VMDS FRD	5.1.1, 5.1.3, 5.2.3, 5.2.4, 5.2.8, 5.4, 7.0
PCV-2	Test efficacy of personal chemical vapor badges for use in tank farms environment	5.1.3, 5.2.3, 5.4, 7.0
Meteorological Instruments		
MI-1	Demonstrate operational requirements of VMDS FRD	5.1.3, 5.2.1, 5.4, 7.0
MI-2	Test efficacy of meteorological station in tank farms environment	5.2.1, 5.4, 7.0
Personal Location Instruments		
PL-1	Demonstrate operational requirements of VMDS FRD	5.1.3, 5.2.3, 5.2.4, 5.2.8, 5.4, 7.0
PL-2	Test efficacy for use in tank farms environment	5.2.1, 5.4, 7.0
Autosampler Instruments		
AI-1	Demonstrate operational requirements of VMDS FRD	5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.8, 5.2.10
AI-2	Test efficacy of area sampler in tank farms environment	5.2, 5.4, 7.0
AI-3	Test efficacy of grab sampler in tank farms environment	5.2, 5.4, 7.0
Data Collection/Evaluation Objectives		
DC-1	Monitor select chemical vapors in real-time	5.2.1, 5.2.10, 5.4, 7.0
DC-2	Quantify select chemical vapors in and around the tank farms	5.2, 5.3
DC-3	Verify and correlate select chemical vapors monitored by real-time instrumentation to sample chemical vapors	7.0
DC-4	Examine transport of chemical vapors from source to workers	7.0

[a] DRIs include: AreaRAE, Gastronics FIS, HAZ-SCANNER, MultiRAE, and MeshGuard NH_3.

[b] SIs include: UV-DOAS, OP-FTIR, UV-FTIR stack monitor.

241A-TP-043, *241A Vapor Monitoring and Detection System Pilot-Scale Test Plan.*

DOE-STD-1189, *Integration of Safety into the Design Process.*

RPP-RPT-58714, *Tank Farm Vapor Monitoring and Detection System (VMDS) Functional Requirements Document.*

RPP-PLAN-59972, *Technology Development Plan for the Tank Farm Vapors Monitoring and Detection System.*

Table 4-1. Primary Pilot-Scale Testing Objectives. (3 sheets)

Objective	Objective Description	VMDS Test Plan Sections Addressing Objectives

AI	=	autosampler instrumentation.	PCV	=	personal chemical vapor.
COPC	=	chemical of particular concern.	PL	=	personal location instrument.
DC	=	data collection/evaluation.	SI	=	spectroscopy instrument.
DRI	=	direct-reading instrument.	Test Plan	=	241A-TP-043.
FGS	=	Fire, Combustible Gas, And Toxic Gas System.	UV-DOAS	=	ultraviolet differential optical adsorption spectrometer.
			UV-FTIR	=	ultraviolet Fourier transform infrared spectrometer.
MI	=	meteorological instrument.	VMDS FRD	=	RPP-RPT-58714.
OGI	=	optical gas imaging.	VMDS TMP	=	RPP-PLAN-59972.
OP-FTIR	=	open path Fourier transform infrared spectrometer.	VMDS	=	Vapor Monitoring and Detection System.

4.2 TESTING EQUIPMENT

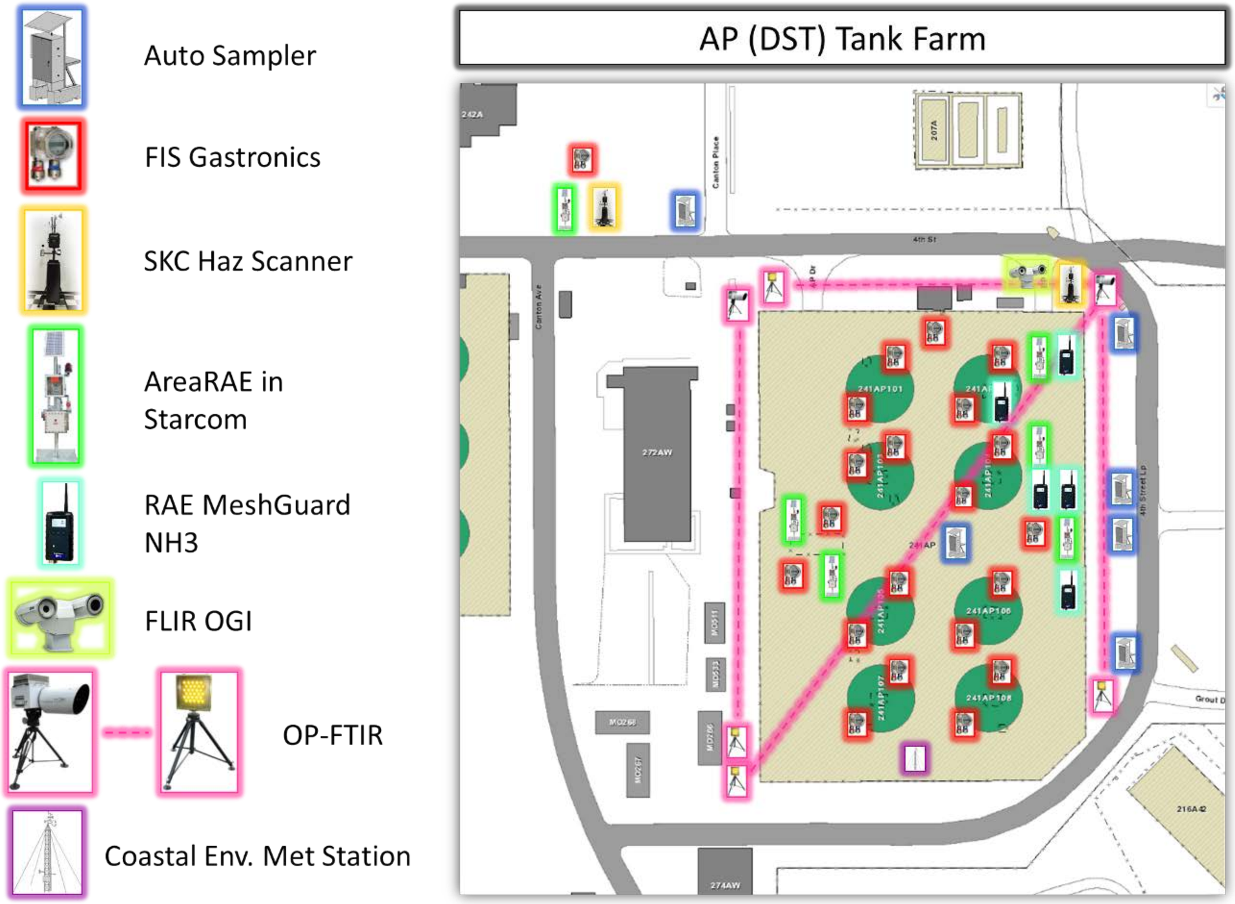
Figure 4-2 and Figure 4-3 show the final locations of pilot-scale testing equipment in and near the 241-A and 241-AP Tank Farms. These locations were selected to evaluate system designs representative of SST and DST farm configurations.

SST farms (e.g., 241-A Tank Farm) have passive ventilation (i.e., PBFs) with tank emissions generally controlled by environmental factors (e.g., temperature, wind velocity, barometric pressure) that disperse the chemical vapors into the tank farm area at ground level. DST farms (e.g., 241-AP Tank Farm) have a common, interconnected ventilation train and are actively ventilated through a forced-air exhauster to disperse the vapors into ambient air well above and away from the workers. The pilot-scale testing tank farms have high occupancy rates (241-AP Tank Farm) or are adjacent to areas with high occupancy rates (241-A Tank Farm). Detectors are also placed near the parking lot of the 242-A Evaporator which is located between 241-A and 241-AP Tank Farms. The 242-A Evaporator parking lot has a history of reported chemical vapor odors and a high occupancy rate; placement of chemical detectors in this area also allows for a broader area of detector coverage between the tank farms.

The information collected during testing will allow for evaluation of the pilot-scale VMDS against the VMDS TMP using actual SST and DST farm emission scenarios. The data will be used to develop and verify the technical basis for a final VMDS design for the 241-A and 241-AP Tank Farms. Also, a process will be refined from the TRL 6 pilot-scale activities for design of the future VMDS for other tank farms.

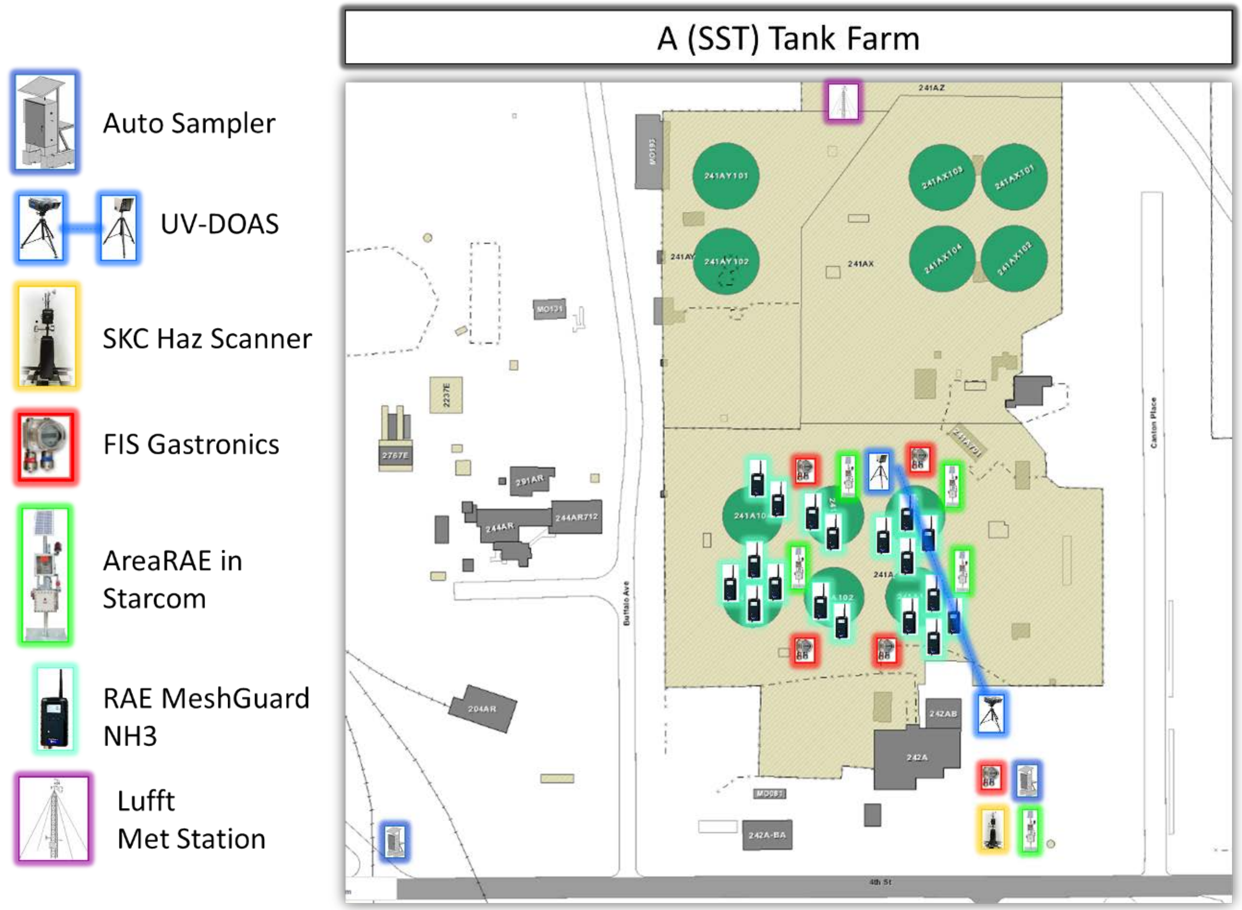
To represent VMDS design, the sensors and samplers are placed in locations to include comprehensive coverage close to primary vapor sources, in the general area where the workers will be present, and along the fence lines to provide perimeter detection of chemical vapors. Other detectors were placed throughout the tank farms to detect fugitive emissions. Detectors were placed in areas outside the tank farm boundaries to establish a baseline and also to detect non-tank-farm vapor sources.

Figure 4-2. 241-AP Tank Farm Instrument Location Diagram.



DST	=	double-shell tank	OGI	=	optical gas imaging
FIS	=	fixed instrument skid	OP-FTIR	=	open path Fourier transform infrared spectrometer
NH_3	=	ammonia.			

Figure 4-3. 241-A Tank Farm Instrument Location Diagram.



FIS = fixed instrument skid.
NH3 = ammonia.
OGI = optical gas imaging.
SST = single-shell tank.
UV-DOAS = ultraviolet differential optical adsorption spectrometer.

Brief descriptions of the equipment to be evaluated are provided in the following sections. Most of the pilot-scale VMDS equipment is COTS and is considered mature for detecting well-defined toxic gas hazards. Fact sheets for each element are provided in Appendix B.

4.2.1 Electronic Monitoring, Control, and Data Logging

The pilot-scale VMDS uses the current tank farms control systems infrastructure for many of the instruments and software. The pilot-scale VMDS is generally composed of wireless transmitting detectors and wireless receivers. New hardware and software is being tested for interfacing wireless systems with the existing OSIsoft PI Historian (OSI/PI), Tank Farm Local Area Network (TFLAN), and TFMCS. OSI/PI is a secure database capable of storing and managing large amounts of data; it is currently used to store operating data for the TFMCS. New wireless receivers will be incorporated into the existing TFLAN for communication of data from devices in the tank farms to the TFMCS. The existing TFMCS will be updated to include the new device inputs and outputs required by the pilot-scale VMDS.

Monitoring of the real-time data will be performed on a SAFER Systems human-machine interface (HMI) and TFMCS HMI located in a VMDS control room outside of the tank farms (Connex trailer on the northwest corner of 241-AP Tank Farm). Data will also be available on OSI/PI and SAFER Systems software in room C-213 of Building 2750 in the 200 East Area. Both the SAFER Systems software and the TFMCS have the capabilities to display data that is continuously updated in real time. The data can be displayed as discrete variables with alarm information and as trending data as a time series plot. During regular workdays, the data is monitored by VMDS staff that includes WRPS and PNNL engineers, scientists, and analysts. Additionally, the Shift Operations Engineer console in Building 274AW at 200 East Area has access to the VMDS HMI screens in TFMCS to monitor for high levels of COPCs during off hours (i.e., nights and weekends).

4.2.2 Personal Direct-Reading Instruments

Personal DRIs are worn by staff as they perform their tank farms duties. These units are useful for detection of vapors in the wearer's work location. Personal chemical badges are intended to provide real-time monitoring for the presence of chemical vapors in the worker's immediate location. Many versions of these badges are present in the marketplace. The RAE Systems ToxiRAE Pro and the Ion Science Cub were chosen for demonstration in the pilot-scale VMDS. The personal DRIs during testing will only be used by Construction and IH staff directly supporting pilot-scale testing.

4.2.3 Fixed Direct-Reading Instruments

Fixed DRIs are detectors equipped with single or multiple chemical sensors mounted on skids or support bases for stability, yet allow the sensors to be relocated with common forklift trucks. Several variants of these instruments include the Gastronics fixed instrumented skid (FIS), RAE Systems AreaRAE and MeshGuard NH_3, and SKC HAZ-SCANNER. These detectors are customized to detect specific chemical vapors and their uses are varied accordingly to meet specific test objectives.

4.2.4 Spectrometry Instruments

State-of-the-art multi-gas detection spectroscopy instruments are used to identify and quantify organic vapors that could be present in the tank farms. While the instruments are capable of identifying over 500 separate compounds, at this time, they are capable of detecting only a subset of the 59 Hanford tank farms COPCs. In the future, more of the 59 COPCs may be able to be added to the unit's library of compounds that can be detected. The spectrometry class of instruments include the dual-band UV-DOAS/FTIR stack monitor (UV-FTIR), the open path Fourier transform infrared spectrometer (OP-FTIR), the open path ultraviolet differential absorption spectrometer (UV-DOAS), and OGI infrared cameras.

4.2.5 Weather Station/Meteorological Data Collection

The primary meteorological station, CMS, is a customizable, fixed-mount weather station configured with sensors to determine temperature, barometric pressure, relative humidity, precipitation, wind speed, wind direction, and shortwave solar radiation levels. Temperature, humidity, and barometric pressure are determined using standard components. The wind speed and direction are determined using a two-dimensional ultrasonic sensor equipped with a heater for winter conditions. A pyrometer will be implemented to determine the incoming shortwave radiation levels. Data from the sensors will be wirelessly communicated to the TFMCS. The components will be mounted on a 30-ft tower.

The secondary meteorological station, Lufft meteorological station (LMS), is a single-sensor assembly that measures the same variables as the CMS except precipitation. It also is not equipped with the heating function to keep the system clear of ice. This system will also be mounted on a 30-ft tower.

4.2.6 Personnel Location Instruments

The personnel location monitor is a personnel safety device used to track the location of personnel in the work area through GPS. A Blackline Loner IS+ GPS was deployed for pilot-scale testing data collection to obtain occupancy rates within various areas of the tank farms.

4.2.7 Corroboratory Laboratory Testing

Corroboratory testing consists of sample collection using U.S. Environmental Protection Agency (EPA) approved methods for sorbent tubes and summa canisters. The sorbent tubes chosen for this work are used routinely by the IHP and include Carbotrap® 300/PE/G tubes, Thermosorb-N (TDX) tubes, and SKC-226-119 tubes. Tube selection was predicated on getting the most toxic species captured for laboratory analysis (e.g., furans, nitrosamines, and approximately 55 of the 59 Hanford Site COPCs). After the samples are collected, they are analyzed using standard laboratory methods. The sampling equipment consists of two types of autosamplers; 1) the area/stack autosampler primarily for integrated air samples, and 2) the grab autosampler primarily for triggered grab samples. The methods for sample collection and analysis are described in RPP-RPT-59474, *Air Sampling Execution Plan Supporting the Hanford Site Tank Farms Vapor Project Pilot-Scale Testing and Demonstrations*.

5.0 PILOT-SCALE TESTING RESULTS

Pilot-scale VMDS testing can be differentiated into two major areas. The first area is set-up, configuration, and operational testing of the various VMDS components, which comprises the bulk of the work performed in FY 2016 (Phase 1 testing). The second area, which will be the follow-on work for FY 2017 (Phase 2 testing), is collecting data (including RAMI data for operability testing and analytical data from the instruments to verify the utility of the various components) and providing information on tank farms conditions for future VMDS designs at other tank farms. Due to the complexity of the VMDS and the relatively short timeframe available to perform the testing, each component comprising the VMDS was set up independently. The communications and SAFER Systems software were set up in parallel to tie the individual components together to form an integrated system. This strategy allowed for the less complex components to come online first and provide for follow-on data collection. A drawback of this strategy was the inability to complete the first objective – set up and shakedown testing – for the overarching communications and software systems. Each component of the VMDS was assigned to a test engineer and a team of construction and engineering staff to complete the set up and initiate testing of those components.

This section is comprised of a short description of the status of the overall objectives and the testing as described in the TRM, followed by a summary of the results of each class of components, namely the SAFER Systems software, the CMS and LMS, the sensors, the spectroscopic equipment, and the laboratory sampling equipment. The test procedures completed through September 17, 2016 with all of the operational data from pilot-scale testing are available in project files. Communications/network issues are discussed in Section 5.1.

Table 5- shows the current state of the pilot-scale testing objectives and the location of the TRM requirements that were used to assess the status. Because pilot-scale testing is not yet complete, only a subset of the objectives and requirements for the test have been completed to date.

Table 5-1. Summary Results of Pilot-Scale Testing Objectives. (6 sheets)

Objective	Objective Description	Status Based on FY 2016 Testing	Test Plan/TRM/FR Items Addressing Objectives
VMDS TMP Objectives			
TMP-1	Determine bounds of function and performance of the SAFER Systems Real-Time software	The Real-Time software has been up and running for over 40 days, but many instruments are not yet performing consistently and there have been no vapor release events to exercise the system. A full data set (FY 2017 testing) is required to make this determination.	TRM requirements 17.2, 17.5, 17.10, 17.13, 17.16, and 17.17
TMP-2	Determine the end state requirements for OP-FTIR, OGI, UV-FTIR stack monitor, and Real-Time software	Data have been collected from all instruments, but no vapor release events have occurred in tank farms as yet and RAMI data is required to develop the final specifications. A full data set (FY 2017 testing) is required to make this determination.	TRM requirements 6.14, 7.9, 9.9, 17.5,17.6,17.8,17.17, 17.17.1, 17.18, and 17.21

Table 5-1. Summary Results of Pilot-Scale Testing Objectives. (6 sheets)

Objective	Objective Description	Status Based on FY 2016 Testing	Test Plan/TRM/FR Items Addressing Objectives
TMP-3	Determine bounds of function and performance of the UV-FTIR stack monitor	The stack monitor has been operating successfully for over 30 days, but there have not yet been any waste-disturbing activities to determine the effect on stack release. A full data set (FY 2017 testing) is required to make this determination.	TRM requirements 7.5, 7.6, 7.7, and 7.8
TMP-4	Determine the function and performance in the tank farms environment for the OP-FTIR, UV-DOAS, and UV-FTIR stack monitor	Most of the information has been collected, but seasonal meteorological changes and waste-disturbing activities need to be observed. A full data set (FY 2017 testing) is required to make a final determination.	TRM requirements 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13, 7.5, 7.6, 7.7, 7.8, 8.6, 8.7, 8.8, 8.9, 8.10, and 8.11
TMP-5	Develop a final technical report on technology in accordance with DOE-STD-1189	A full data set (FY 2017 testing) is required to make this determination. In addition, the collection of information from parallel studies (e.g., leading indicators) is required to complete the final technical report.	All TRM requirements
VMDS Objectives			
VMDS-1	Demonstrate the VMDS fulfills the requirements of the VMDS FRD	All of the FRs have been met with the exception of: GPS (6.6.3, 6.6.4); Data Analysis (6.9.1, 6.9.5, 6.9.6, 6.9.7, 6.9.8); and Directing Personnel Actions (6.11.1, 6.11.2, 6.11.3).	All TRM requirements
VMDS-2	Operate SAFER Systems Real-Time to demonstrate the system can process data collected from the field	Objective met.	TRM requirements 17.2, 17.3, 17.4, 17.5, 17.6, 17.7, 17.8, 17.9, 17.10, and 17.11
VMDS-3	Operate SAFER Systems Real-Time to demonstrate the VMDS (simulated) central control room strategy	Testing to be completed in FY 2017.	All TRM requirements
FGS Design Objectives			
FGS-1	Determine release frequency at primary sources	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	N/A
FGS-2	Verify magnitude of COPC concentration at primary sources	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	N/A
FGS-3	Opportunistically determine release frequency from fugitive sources	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	N/A

Table 5-1. Summary Results of Pilot-Scale Testing Objectives. (6 sheets)

Objective	Objective Description	Status Based on FY 2016 Testing	Test Plan/TRM/FR Items Addressing Objectives
FGS-4	Opportunistically determine magnitude of COPC concentration from fugitive sources	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	N/A
FGS-5	Verify tank farm occupancy rates	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	N/A
Equipment Objectives			
Optical Gas Imaging			
OGI-1	Demonstrate operational requirements as described in the VMDS FRD	Since the OGI detectors do not report to the data collection and management system, there were no defined FRs for the OGI unit's general requirements (e.g., maintainability, reliability, availability).	N/A
OGI-2	Test efficacy of OGI in the tank farms environment	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 9.1 – 9.10 and 19.1 – 19.6
Direct-Reading Instruments [a]			
DRI-1	Demonstrate operational requirements as described in the VMDS FRD	The FRs for this objective include that the VMDS be capable of receiving data from these instruments and meet general requirements listed in the equipment specifications. All of the DRIs except for the HAZ-SCANNER have met these requirements.	TRM requirements 1.2, 1.3, 1.4, 1.10, 2.2, 2.4, 4.2, 4.4, 4.10, 4.11, 5.2, 5.3.1, 5.4, 5.11, 12.2, 12.4, 12.5, and 12.13
DRI-2	Test efficacy of DRIs in the tank farms environment	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 1.1 – 1.10, 2.1 – 2.10, 4.1 – 4.11, 5.1 – 5.11, and 12.1 – 12.13
Spectroscopy Instruments [b]			
SI-1	Demonstrate operational requirements as described in the VMDS FRD	All of the FRs have been met for the spectroscopy instrumentations.	TRM requirements 6.2, 6.8, 6.9, 7.2, 7.5, 7.7, 7.8, 8.2, and 8.5
SI-2	Test efficacy of open path spectroscopy instruments in the tank farms environment	Much of the data is collected, but no vapor events have occurred in tank farms as yet and RAMI data is required to develop the final specifications. A full data set (FY 2017 testing) is required to make this determination.	TRM requirements 6.1 – 6.10 and 8.1 – 8.13
SI-3	Test efficacy of stack spectroscopy instruments in the tank farms environment	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	TRM Requirements 7.1 – 7.10

Table 5-1. Summary Results of Pilot-Scale Testing Objectives. (6 sheets)

Objective	Objective Description	Status Based on FY 2016 Testing	Test Plan/TRM/FR Items Addressing Objectives
SI-4	Recommend end state requirements for spectroscopy instruments	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 6.1 – 6.10, 7.1 – 7.10, and 8.1 – 8.13
Personal Chemical Vapor Badges			
PCV-1	Demonstrate operational requirements as described in the VMDS FRD	Preliminary testing has been completed, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 3.2, 3.3, 3.9, 3.12, 18. 3, and 18.5
PCV-2	Test efficacy of personal chemical vapor badges for use in the tank farms environment	Preliminary testing has been completed, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 3.1 – 3.12 and 18.1 – 18.9
Meteorological Instrumentation			
MI-1	Demonstrate operational requirements as described in the VMDS FRD	Objective met with 49 days of continuous operation by the CMS but not completed for LMS.	FRs 6.5.1 – 6.5.12 TRM requirements 10.2, 10.3, 10.4, 11. 2, 11.3, and 11.4
MI-2	Test efficacy of meteorological station in the tank farms environment	Objective met for the CMS but not the LMS.	TRM requirements 10.1 – 10.5 and 11.1 – 11.6
Personal Location Instruments			
PL-1	Demonstrate operational requirements as described in the VMDS FRD	Objective met.	FRs 6.6.1 – 6.6.5, 6.7.3, and 6.8.3
PL-2	Test efficacy for use in the tank farms environment	Objective met.	TRM requirements 13.1 – 13.6
Autosampler Instruments			
AI-1	Demonstrate operational requirements as described in the VMDS FRD	Since the autosamplers do not report to the data collection and management system, there were no defined functional requirements for the sampling unit's general requirements (e.g., maintainability, reliability, availability).	N/A
AI-2	Test efficacy of area sampler in the tank farms environment	Objective met for area and stack samplers.	TRM requirements 15.1 – 15.8
AI-3	Test efficacy of grab sampler in the tank farms environment	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	TRM requirements 14.1 – 14.8
Data Collection /Evaluation Objectives			

Table 5-1. Summary Results of Pilot-Scale Testing Objectives. (6 sheets)

Objective	Objective Description	Status Based on FY 2016 Testing	Test Plan/TRM/FR Items Addressing Objectives
DC-1	Monitor select chemical vapors in real-time	Daily and weekly reports are being developed, but a full data set with seasonal variations (FY 2017 testing) is required to make this determination.	All TRM requirements
DC-2	Quantify select chemical vapors in and around the tank farms	Initial testing has shown few detectable quantities in covered areas, but the seasonal and operational changes (e.g., waste-disturbing activities) need to be observed to get a more complete picture. A full data set (FY 2017 testing) is required to make this determination.	All TRM requirements
DC-3	Verify and correlate select chemical vapors monitored by real-time instruments to sample chemical vapors	Some data has been collected, but a full data set (FY 2017 testing) is required to make this determination.	All TRM requirements
DC-4	Examine transport of chemical vapors from source to workers	Modeling of transport has not yet been satisfactory. Collection of additional data (FY 2017 testing) and use of other dispersion models will be necessary to make this determination.	All TRM requirements

[a] DRIs include: AreaRAE, Gastronics FIS, HAZ-SCANNER, MultiRAE, and MeshGuard NH_3.

[b] SIs include: UV-DOAS, OP-FTIR, UV-FTIR stack monitor.

241A-TP-043, *241A Vapor Monitoring and Detection System Pilot-Scale Test Plan.*

DOE-STD-1189, *Integration of Safety into the Design Process.*

RPP-RPT-58714, *Tank Farm Vapor Monitoring and Detection System (VMDS) Functional Requirements Document.*

AI = autosampler instrumentation
CMS = Coastal Environmental meteorological station
COPC = chemical of potential concern
DC = data collection/evaluation
DRI = direct-reading instrument
FGS = Fire, Combustible Gas, And Toxic Gas System
GPS = global positioning system
LMS = Lufft meteorological station
MI = meteorological instrument
N/A = not applicable
OGI = optical gas imaging
OP-FTIR = open path Fourier transform infrared spectrometer
PCV = personal chemical vapor
PL = personal location instrument
SI = spectroscopy instrument
Test Plan = 241A-TP-043
TRM = test requirements matrix
UV-DOAS = ultraviolet differential optical adsorption spectrometer
UV-FTIR = ultraviolet Fourier transform infrared spectrometer
VMDS FRD = RPP-RPT-58714
VMDS = Vapor Monitoring and Detection System

As can be seen in Table 4-, the VMDS TMP objectives (TMP-1 through TMP-5) require a complete data set spanning all of the seasonal variations observed at tank farms in order to evaluate the TRL, and this data will not be available until completion of Phase 2 testing in FY 2017. The same is true for the data collection and evaluation to be used in the VMDS design basis determination (FGS and DC objectives). The remaining objectives are tied to the operation and functioning of the equipment and therefore within the range of information collected and evaluated to date.

In addition to the objectives specified in the test plan, the VMDS must meet the functional requirements outlined in RPP-RPT-58714, *Tank Farm Vapor Monitoring and Detection System (VMDS) Functional Requirements Document* (hereinafter the VMDS FRD). Table 5- provides a list of the functional requirements, status of the completion of the requirements, and the TRM item that addresses the requirement. Information for Table blank spaces will be provided with the completion of Phase 2 Pilot-Scale testing.

Table 5-2. Functional Requirements Crosswalk with Test Requirements Matrix. (4 sheets)

FR #	Description	Has FR Been Met?	TRM Item Addressing FR
Functional Requirements for Detecting Chemical Vapors			
6.4.1	The system shall be capable of receiving chemical concentration data from OP-FTIR sensors.	Yes	17.1
6.4.2	The system shall be capable of receiving chemical concentration data from UV-FTIR sensors.	Yes	17.1
6.4.3	The system shall be capable of receiving chemical concentration data from fixed sensors.	Yes	17.1
6.4.4	The system shall be capable of receiving data from IR gas detection sensors.	Yes	17.1
6.4.5	The system shall be capable of receiving data from photoionization detector point sensors.	Yes	17.1
6.4.6	The system shall be capable of receiving data from electrochemical point sensors.	Yes	17.1
6.4.7	The system shall be capable of receiving chemical concentration data from portable sensors.	Yes	17.1
6.4.8	The system shall be capable of receiving data from personnel location monitors.	Yes	17.1
Functional Requirements for Monitoring Meteorological Data			
6.5.1	The system shall monitor meteorological data.	Yes	10.2, 10.3
6.5.2	The system shall measure horizontal wind direction.	Yes	10.2, 10.3
6.5.3	The system shall measure horizontal wind speed.	Yes	10.2, 10.3
6.5.4	The system shall measure vertical wind direction.	Yes	10.2, 10.3
6.5.5	The system shall measure vertical wind speed.	Yes	10.2, 10.3
6.5.6	The system shall measure the atmospheric boundary layer.	Yes	10.2, 10.3
6.5.7	The system shall measure atmospheric pressure.	Yes	10.2, 10.3
6.5.8	The system shall measure relative humidity.	Yes	10.2, 10.3
6.5.9	The system shall measure temperature.	Yes	10.2, 10.3
6.5.10	The system shall measure precipitation.	Yes	10.2, 10.3
6.5.11	The system shall measure short wave radiation.	Yes	10.2, 10.3

Table 5-2. Functional Requirements Crosswalk with Test Requirements Matrix. (4 sheets)

FR #	Description	Has FR Been Met?	TRM Item Addressing FR
6.5.12	The system shall monitor meteorological data.	Yes	10.2, 10.3
Functional Requirements for Reading Personnel Location Monitors			
6.6.1	The system shall be capable of receiving indications from personnel location monitors.	yes	13.2, 13.3, 13.4
6.6.2	The personnel location monitor shall be capable of identifying the location of the wearer using GPS sensors.	Yes	13.2, 13.3, 13.4
6.6.3	The personnel location monitor shall be capable of alerting the wearer of an event.		
6.6.4	The personnel location monitor shall be capable of a manual actuation alert/alarm.		
6.6.5	The personnel location monitor shall be capable of detecting a man-down event.		13.5
Functional Requirements for Data Availability			
6.7.1	Sensor and Analytical Device data shall be made available on the TFLAN.	Yes	
6.7.2	Meteorological data shall be made available on the TFLAN.	Yes	
6.7.3	Personnel Location Monitor data shall be made available on the HLAN.	Yes	
Functional Requirements for Data Sharing			
6.8.1	The TFMCS shall share chemical sensor and meteorological sensor data with OSI/PI Historian.	Yes	17.19
6.8.2	The OSI/PI Historian shall share data with SAFER Systems software.	Yes	17.20
6.8.3	Personnel location monitor data shall be shared with the SAFER Systems software.	Yes	17.10
Functional Requirements for Data Analysis Software Components			
6.9.1	The SAFER Systems software shall perform receptor data analysis, modeling, and plume source prediction.		
6.9.2	The SAFER Systems software shall display data on a satellite based map of the tank farm.	Yes	17.9
6.9.3	The SAFER Systems software shall display on the map the sensor readings and meteorological data values involved in the vapor event.		17.8, 17.9
6.9.4	The SAFER Systems software shall display on the map the personnel location monitor data.	Yes	17.10
6.9.5	The SAFER Systems software shall analyze and display the predicted receptors of the vapor event.		17.17.1

Table 5-2. Functional Requirements Crosswalk with Test Requirements Matrix. (4 sheets)

FR #	Description	Has FR Been Met?	TRM Item Addressing FR
6.9.6	The SAFER Systems software shall analyze and display the predicted source of the vapor event.		
6.9.7	The SAFER Systems software shall be capable of providing a report of the data and analysis of the vapor event.		17.16, 17.17
6.9.8	The SAFER Systems software shall produce tabular charts of the sensor and meteorological data.	Yes	17.3
6.9.9	The SAFER Systems software shall display real time trends of the sensor and meteorological data.		
6.9.10	The SAFER Systems software shall be capable of utilizing archived data from past events to display the predicted plume source and receptors.	Yes	17.13
Functional Requirements for Indicating and Alerting			
6.10.1	The TFMCS shall be capable of indicating and/or alerting if a potential vapor event is occurring based on limits being exceeded by the chemical and analytical sensors.		17.17.1
6.10.2	The SAFER Systems software shall indicate sensor and analytical device concentration readings and meteorological data in engineering units.	Yes	17.14
6.10.3	The SAFER Systems software shall provide alarms/alerts based on sensor and analytical device concentration readings.		17.4
Function Requirements for Directing Personnel Actions			
6.11.1	The TFMCS shall direct the initial response to a potential vapor event based on an alarm response procedure.		
6.11.2	The SAFER Systems software shall direct locations for the potential vapor event based on the software graphical interface.		
6.11.3	An abnormal operating procedure shall direct personnel actions based on an analysis of the SAFER Systems software data.		
User Requirements			
6.12.1	The system shall have general users.	Yes	17.15
6.12.2	The general users shall have access to sensor, meteorological, and personnel indicator data.	Yes	
6.12.3	General users shall receive alerts from the system to indicate a potential event has occurred.		
6.12.4	General users shall have access to initiate the data analysis and run plume modeling scenarios.	Yes	

Table 5-2. Functional Requirements Crosswalk with Test Requirements Matrix. (4 sheets)

FR #	Description	Has FR Been Met?	TRM Item Addressing FR
6.12.5	General users shall have access to the results of the data analysis and plume modeling.	Yes	
6.12.6	General users shall not have access to network and communication configuration parameters.	Yes	
6.12.7	The system shall have administrator users.	Yes	
6.12.8	Administrative users shall have access to all sensor, network, communication, and device configuration parameters.	Yes	

FR = functional requirement.
IR = infrared.
TRM = test requirements matrix.
OP-FTIR = open path Fourier transform infrared spectrometer.
UV-FTIR = ultraviolet Fourier transform infrared spectrometer.
GPS = global positioning system.
TFMCS = Tank Farm Monitoring and Control System.
HLAN = Hanford Local Area Network.
TFLAN = Tank Farms Local Area Network.

Table 5- shows a summary how many of each type of equipment performed the required functions as described in the VMDS Test Plan TRM. The final TRM containing all of the information collected during testing can be seen in Appendix C.

Table 5-3. Number of Units of Each Type of Equipment Performed during Pilot-Scale Testing.

Test Item	Calibration - Shakedown	Data Collected in TFMSC-OSI/PI	RAMI Results	Test Plan Section Containing Results
HAZ-SCANNER	1 of 2	None	None	4.6
AreaRAE	8 of 8	4 of 8 ~15 days	4 of 8 ~15 days	4.6
ToxiRAE Pro	32 of 35	None	None	4.11
MultiRAE	4 of 10	None	None	4.6
MeshGuard NH_3	23 of 26	23 of 26 ~15 days	23 of 26 ~15 days	4.6
OP-FTIR	2 of 2	2 of 2 ~30 days	2 of 2 ~30 days	4.7
UV-FTIR stack monitor	1 of 1	1 of 1 ~25 days	1 of 1 ~25 days	4.7
UV-DOAS	1 of 1	1 of 1 ~25 days	1 of 1 ~25 days	4.7
Fixed OGI	1 of 1	None	None	4.8
Primary meteorological station	1 of 1	1 of 1 35 days	1 of 1 35 days	4.5

Table 5-3. Number of Units of Each Type of Equipment Performed during Pilot-Scale Testing.

Test Item	Calibration - Shakedown	Data Collected in TFMSC-OSI/PI	RAMI Results	Test Plan Section Containing Results
Secondary meteorological station	1 of 1	None	None	4.5
Gastronics FIS	25 of 25	21 of 25 NH_3, VOC 4 of 25 N_2O	21 of 25 ~ 20 days	4.6
Personal GPS locators	5 of 50	N/A	5 of 50 5 days	4.9
Grab air samplers	6 of 6	N/A	6 of 6 10 days	4.10
Area/Stack air samplers	10of 10	N/A	10 of 10 35 days	4.10
SAFER Systems software	1 of 1	N/A	1 of 1 35 days	4.4
Ion Science Cub	2 of 10	None	None	4.11
Portable FLIR OGI	1 of 1	1 of 1 3 days	1 of 1 3 days	4.8

241A-TP-043, *241A Vapor Monitoring and Detection System Pilot-Scale Test Plan.*

FIS = fixed instrument skid.
N/A = not applicable.
GPS = global positioning system.
OGI = optical gas imaging.
OP-FTIR = open path Fourier transform infrared spectrometer.
OSI/PI = OSIsoft PI Historian.
RAMI = reliability, availability, maintainability and inspectability.
Test Plan = 241A-TP-043.
TFMCS = Tank Farms Monitoring and Control System.
UV-DOAS = ultraviolet differential optical adsorption spectrometer.
UV-FTIR = ultraviolet Fourier transform infrared spectrometer.
VOC = volatile and semi-volatile organic compound.

As per the VMDS TMP, there are only four elements of the VMDS that are considered to be critical technologies, but the interaction of each separate element is critical to the overall performance of the system. To address the system, each test item is being evaluated on an individual basis with the overall operation and interaction of the system being evaluated with communications and the data collection, management, and modeling software system. The following sections are devoted to describing the performance of each tested item and include an overall evaluation of how well the item operates with recommendations on the utility of the item for use in a final VMDS and testing required, if any, to mature the item for use in a final VMDS.

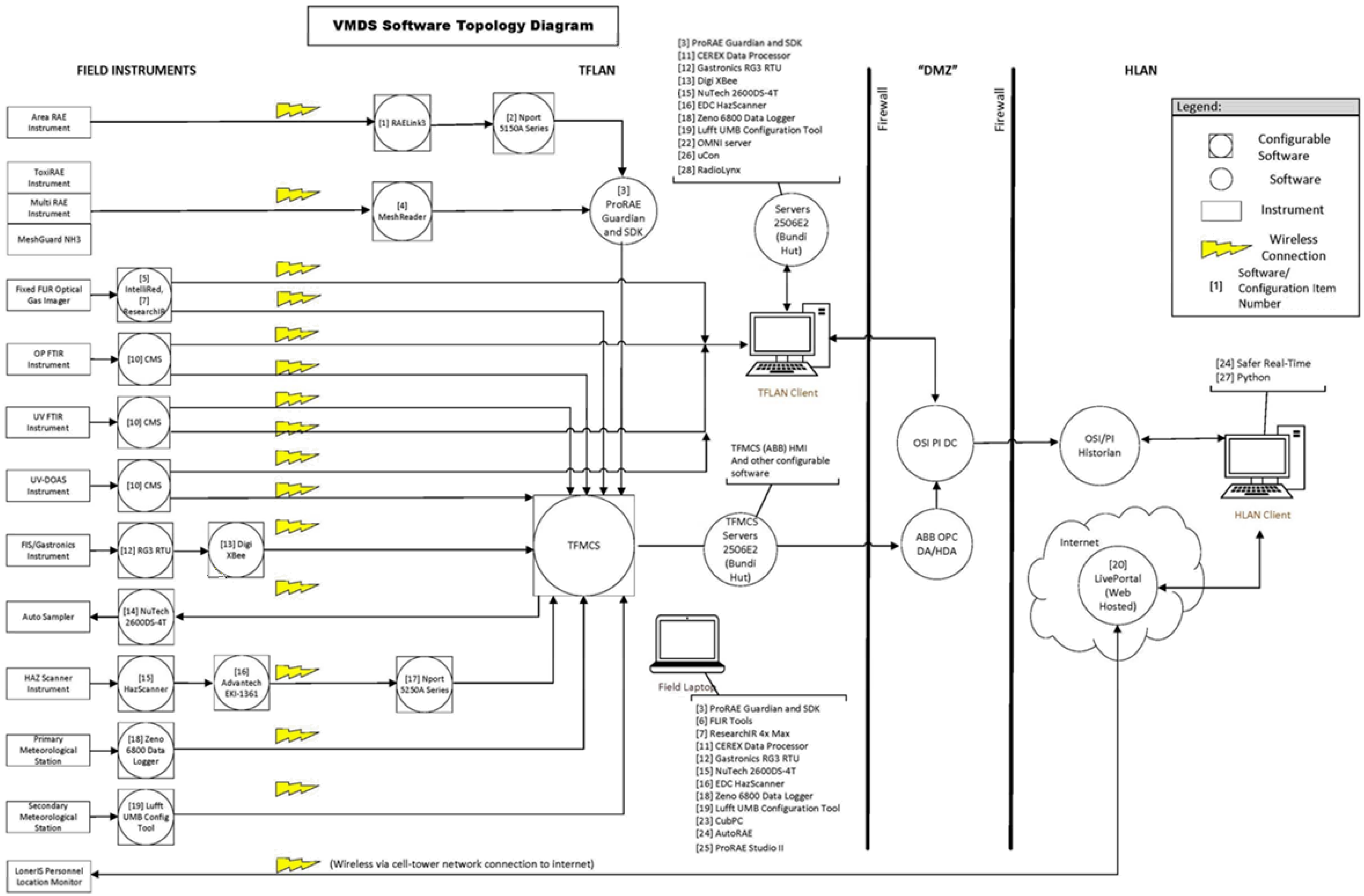
5.1 SUMMARY OF COMMUNICATIONS INFRASTRUCTURE

The key to successful operation and utilization of the VMDS is the communication of data from the field deployed instrumentation to the data collection, management and modeling system (TFMCS, OSI/PI, and SAFER Systems software). The TFLAN system available in the 241-A and 241-AP Tank Farms is quite extensive. The large number of individual pieces of equipment in the VMDS requires the use of wireless communication to minimize invasive installation activities (trenching for communications and power) that prolong the project. Bench-scale testing could not replicate all aspects of the tank farms. There were several first-time equipment uses during pilot-scale testing, including the following:

- One of the first uses of the Site-wide wireless access points and infrastructure to connect field sensors to control system equipment
- First significant use of solar and battery power to keep field sensors operational
- First significant field deployment of spectroscopy instrumentation
- First use of Modbus and Serial interfaces for the Site-wide TFMCS
- First use of Omni server third-party software to connect RAE Systems and ABB software
- First use of SAFER Systems software for plume location and prediction modeling
- First use of cloud data incorporated into Tank Farms Operations (Blackline Loner IS+ GPS).

Figure 5-1 shows the architecture of the system currently being used by the VMDS. The analytical devices and meteorological stations are equipped with site standard Wi-Fi radios to communicate over the existing 2.4/5.0 GHz Wi-Fi wireless infrastructure. The wireless access points and controller have been configured by Lockheed Martin Information Technology to direct the sensor data to the TFMCS over the TFLAN. Instruments from RAE Systems utilize their own proprietary access points to provide data to the ProRAE Guardian software. The RAE Systems software provides reading to the TFMCS through a custom-developed third-party software product.

Figure 5-1. Vapor Monitoring and Detection System Topology Diagram.



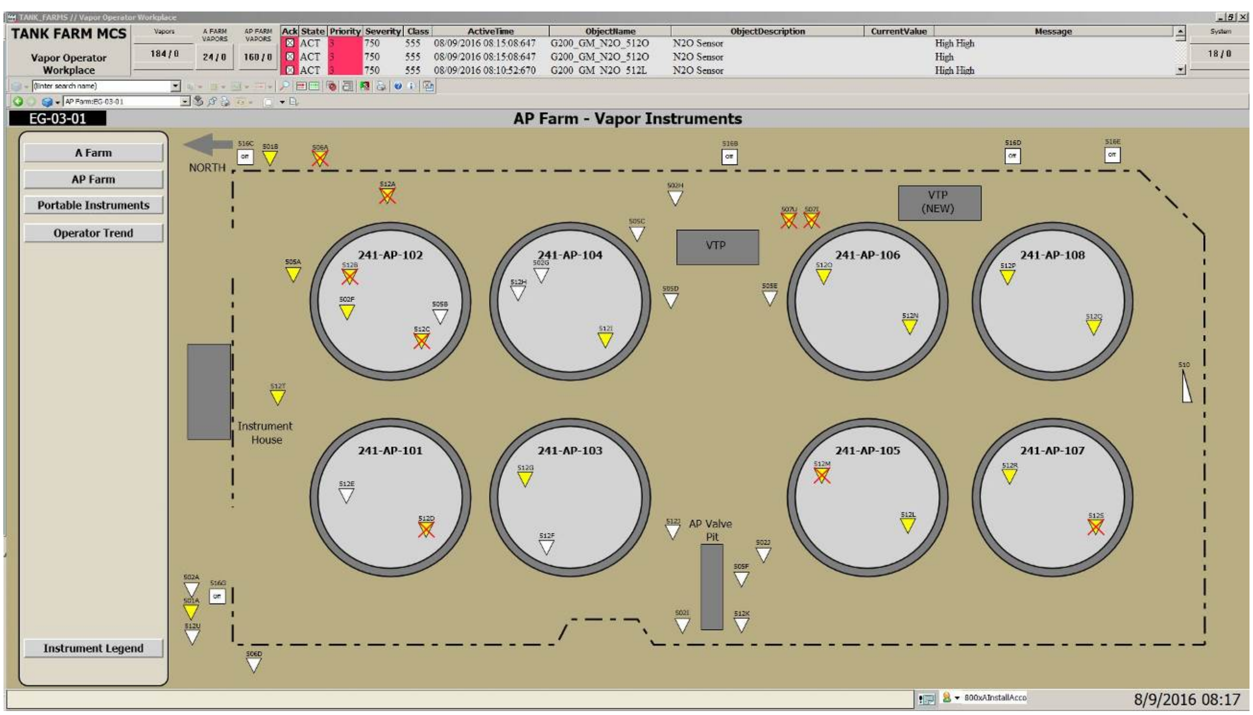
Given the significant number of first-time approaches for the pilot-scale VMDS, it was not unexpected to have technical challenges associated with implementing each type of equipment and connecting it to both the wireless infrastructure and TFMCS. It is also not expected that each type of equipment would have recommendations for changes before being deployed to other SST and DST farms. Each piece of equipment provided is own challenges to effective communications. Communication challenges are delineated within the write ups for each piece of equipment.

Overall, the communications to TFMCS, OSI/PI, and SAFER Systems software are working satisfactorily. With minor exceptions noted in the equipment summaries, they are ready for continued operation of pilot-scale testing.

5.2 SUMMARY OF DATA DISPLAY AND ALARMING SOFTWARE

The TFMCS provides a centralized location for Tank Farms Operations to view and trend vapor data from all types of instruments installed for the pilot-scale VMDS. The system utilizes architecture from Asea Brown Boveri (ABB) as specified in TFC-PLN-118, “Strategic Plan for Hanford Waste Feed Delivery and Treatment Process Control Systems.” Figure 5-2 shows the TFMCS vapors workplace, which was developed for the VMDS and is independent of other TFMCS applications and tank farms monitoring.

Figure 5-2. TFMCS 241-AP Tank Farm Display.



The TFMCS HMI was programmed consistently with other TFMCS graphics, providing a significant human factors improvement over the SAFER Systems interface. The operator workplace is set up so alarms from vapor equipment are segregated and can be monitored separate from other TFMCS alarms.

Custom interface drivers were needed to be developed in ABB software for each type of instrument. Now that they are written, they can be re-used for other tank farms. The TFMCS uses its Historian module to communicate sensor readings over to the OSI/PI data collector on the business network (Hanford Local Area Network [HLAN]). Adding the vapor equipment caused the ABB Historian data collector nodes to reach maximum capacity, which resulted in some data not being available to OSI/PI and SAFER Systems software. Troubleshooting determined the need to update the ABB data collector nodes to a 64-bit operating system so it could take advantage of the 16 GB of memory installed on the server.

Overall, the TFMCS graphics and alarming have worked as designed and provide a consistent user interface with other tank farms systems. Custom drivers developed for each type of instrument have worked well, with exception of the interface to RAE Systems as discussed in Section 5.6.

5.3 SUMMARY OF BUSINESS HISTORIAN ANALYSIS TOOL

OSI/PI is a COTS software package purchased by WRPS that provides a single data repository responsible for storing all sensor data regardless of source. OSI/PI provides a near real-time Web-based display and desktop client user interface, available on HLAN as PI Coresight, for retrieving, displaying, trending, and analyzing data. Data sources which provide input to OSI/PI are independent of the PI system and may exists on networks independent of HLAN. The current defined data sources are TFMCS, Tank Monitor and Control System (TMACS), 242-A Evaporator, Effluent Treatment Facility, liquid observation well, Hanford Site Meteorological Station (HMS), automated bar coding of all samples at Hanford (ABCASH), HOBO®, and eSOMS®. While the data sources, including TFMCS, may retain some data for short term trending and troubleshooting purposes, OSI/PI is known as the Site Data Historian and ultimately will contain several decades' worth of data from these multiple data sources.

For the VMDS, TFMCS will maintain short-term trends of vapor sensor readings, but will feed the readings into OSI/PI utilizing a previously developed TFMCS/PI interface. Once in OSI/PI, these readings will be available to HLAN users via the PI Coresight interface and are also available as a data source for the SAFER Real-Time software. Because SAFER is not directly retrieving data from TFMCS, this eliminates the risk of SAFER causing performance issues with the Site-wide control system. The primary advantage to PI Coresight is the ability to easily graph multiple vapor sensor readings and the ability to add readings that originate outside of TFMCS.

5.4 SUMMARY OF MODELING SYSTEM SOFTWARE

During evaluation of technologies by the CVST TI team, the requirements identified for the data modeling system software were quite extensive and included the ability to identify and quantify toxic gas releases, alarm and notify operations, and model plumes and releases to determine both the path of the release and the location of the source. SAFER Systems had commercially available software, SAFER Real-Time, that claimed to have these attributes and had been used at oil refineries and chemical plants.

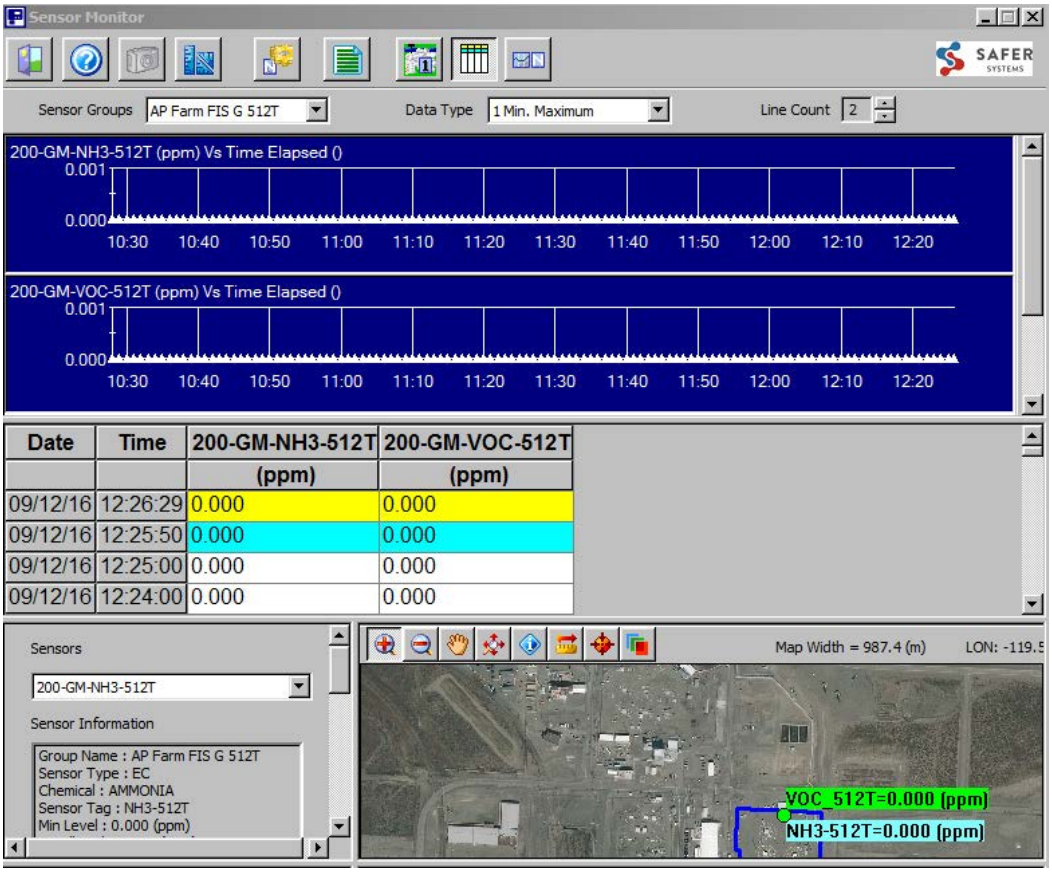
SAFER Real-Time uses real-time data to monitor, measure, and visualize the effects of an unplanned vapor release event and allows facility operators to initiate planned mitigating actions to reduce potential consequences. It provides analysis tools to help determine concentrations at any point, dosage, and building infiltration. When the event is over, be it a simulation or actual event, critical event information that has been saved can be replayed for post-event analysis, regulatory purposes, or legal purposes.

All parts of SAFER Real-Time have been exercised in pilot-scale testing including; 1) the sensor display and reporting, 2) alarming functions, 3) source area locations, and 4) forward plume modeling. During this part of the testing, all of the test requirements (see Section 17.0 in Table C-1 of Appendix C) have been met with the exception of Item 17.14. Item 17.14 requires a real-time vapor release event at the tank farms large enough to exercise more than one or two sensors, and none that meet this criterion have as yet been observed by the system since the bulk of the sensors came online. The probability of a vapor release event is expected to be higher during waste-disturbing activities. The next phase of testing will evaluate the effectiveness of instrumentation during waste disturbing activities. Because of the overarching nature of the software, SAFER Real-Time is a basic component of the primary TMP and VMDS objectives. While Objectives VMDS-1 and VMDS-2 have been met, the remaining objectives (Objectives TMP-1 through TMP-5 and Objective VMDS-3) require a complete data set including data collected during routine waste storage operations and data collected during waste-disturbing activities in the tank farms. The following subsections provide the objective evidence to present how the SAFER Real-Time software has performed during Phase 1 testing.

5.4.1 Sensor Display and Reporting

The Sensor Monitor and Met Monitor applications in Real-Time record and display real-time sensor data for both chemical and meteorological instruments, respectively, and can be used to generate reports of archived data. During initial pilot-scale testing, sensor data were displayed, archived, and reported to meet test criteria (Appendix C, Table C-1, Items 17.1, 17.3, 17.8, and 17.14) (Figure 5-3). The monitoring applications allow the user to select the sensor group of interest for display and reporting. Map functions in SAFER Real-Time show the locations of sensors and allow the user to zoom, pan, and measure distances between points of interest.

Figure 5-3. Example Display Showing Real-Time Sensor Concentrations and Mapped Locations.



Meteorological data were displayed during testing to visualize current conditions (Figure 5-4) and to report archived data using the Met Monitor application (Appendix C, Table C-1, Item 17.8). The Met Analysis application provides a tool to visualize recent or past wind directions at the test location (Figure 5-5). The example wind rose shows the predominant wind conditions for the selected time period as a percentage of the day that winds blew from the indicated directions.

Figure 5-4. Example Showing Real-Time Displays of Meteorological Sensors.

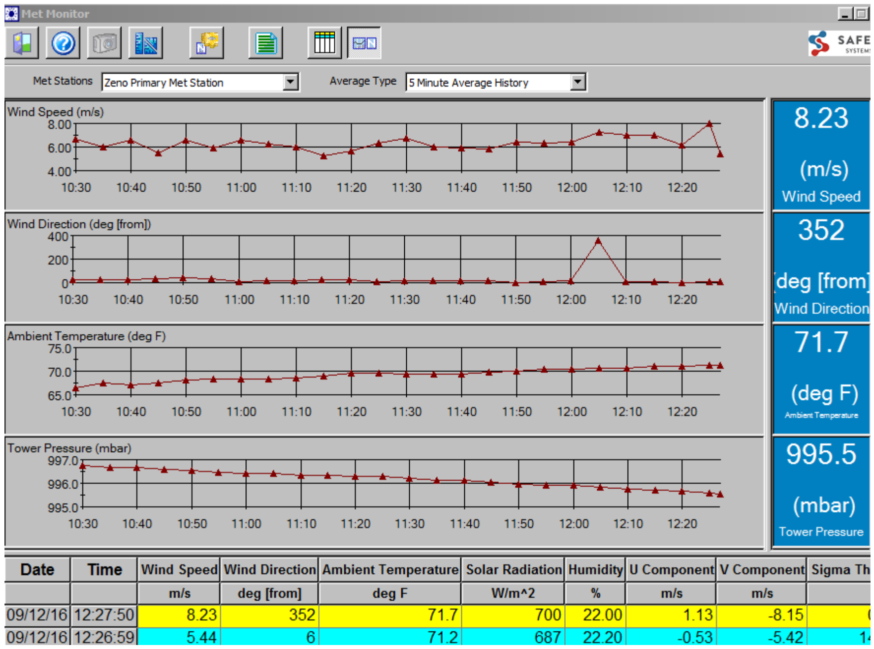
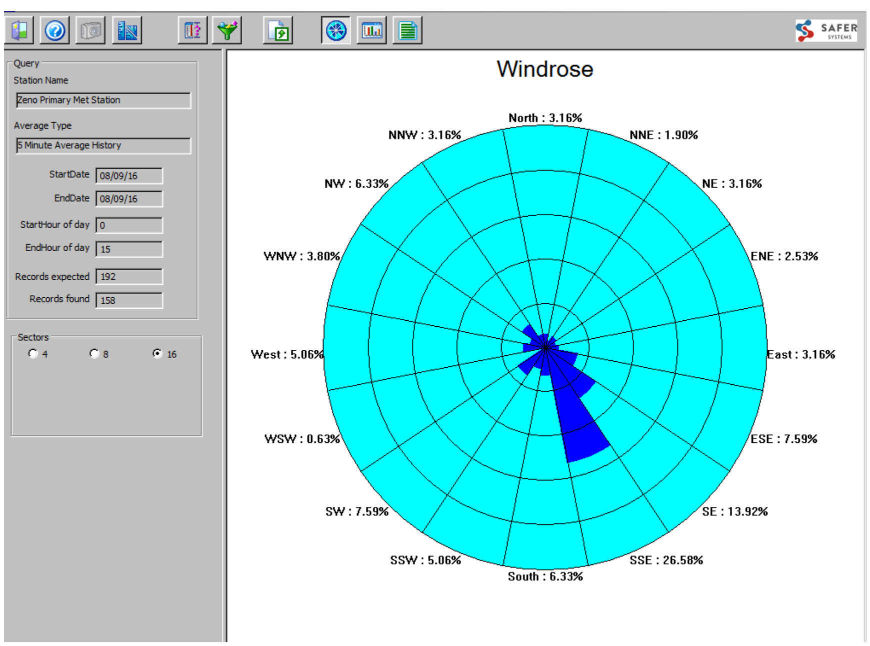


Figure 5-5. Example of Wind Rose Generated During Testing on August 9, 2016.



5.4.2 Alarms and Bump Tests

Two types of alarms were set in SAFER Systems Real-Time for selected chemicals during configuration; 1) a low alarm to alert at 10% of the OEL value and 2) a high alarm to alert at 50% of OEL value. As needed, the alarm set points can be easily changed, disabled, or enabled by the system administrator. Bump tests (calibration verification tests) of instruments with gas standards online during pilot-scale testing were successfully displayed by SAFER Systems (Figure 5-6). The elevated values generated both audible and visual alarms on the SAFER Systems HMI, indicating that the sensor alarms functioned as configured and were activated within an acceptable timeframe (Appendix C, Table C-1, Items 17.2, 17.3, and 17.4). Alarm reports (see Table 5-) can be generated as needed for selected instruments.

Figure 5-6. Example of Bump Test Recorded by Sensor Monitor in SAFER Real-Time.

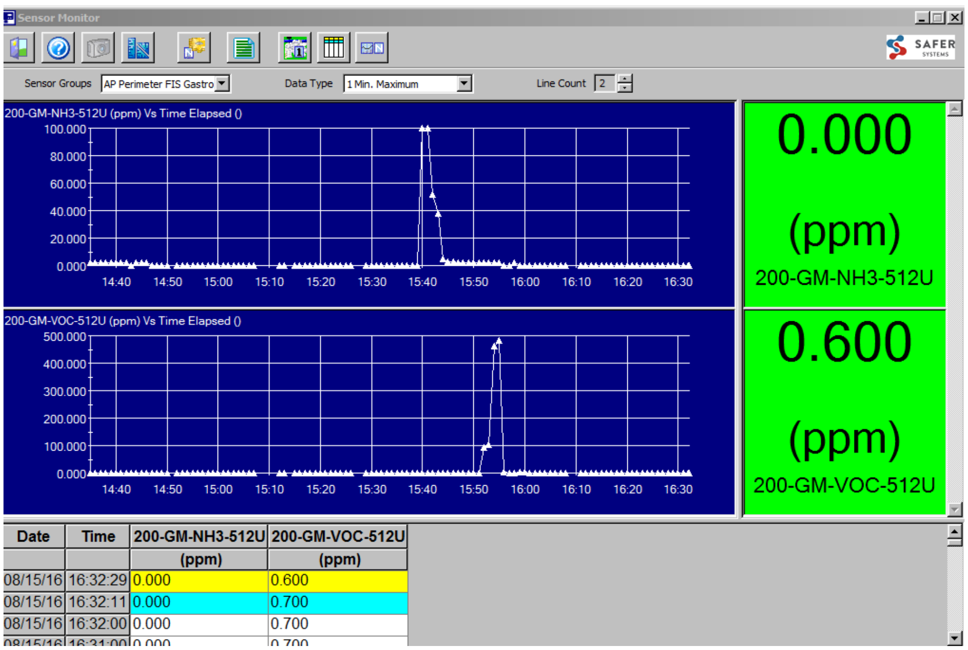


Table 5-4. Example of Alarm Report Generated from SAFER Real-Time.

Sensor Monitor - Alarm Report: AP Farm FIS G 512A: 200-GM-NH3-512A					
Date	**Time**	**Lon:**	**Lat:**	**(ppm)**	**Status**
9/12/2016	8:59:00	-119.514023	46.551494	79	Hi Alarm
9/12/2016	9:00:00	-119.514023	46.551494	79	Hi Alarm
9/12/2016	9:10:00	-119.514023	46.551494	9	Lo Alarm

5.4.3 Source Area Location

SAFER Real-Time Emergency Response modules include a SAL module that computes an estimate of the release location from the meteorological data and sensor data using their Advanced Back Calculation® model. The model can be operated when chemical vapors are detected on two or more sensors. Data from the wind sensor(s) are used to determine an upwind segment where a potential source could be located for each active (detecting) sensor. Then, the forward trajectory plume model is used to iteratively compare sensor detection values against modeled plume concentrations for a range of release rates and potential source locations. The best fit with the sensor data is selected as the most likely source location.

Initial tests of the SAL module predicted contaminant release locations outside the tank farms. The SAL module was run twice in an iterative fashion using pilot-scale testing data from two Gastronics FIS VOC sensors detecting measureable concentrations at the 241-AP Tank Farm for a 2-hour period between 2:45 and 4:45 AM on September 7, 2016. It first predicted that the source of the contaminant was 120 m upwind of the sensors (Figure 5-7 a), and the second run predicted the location to be 60 m upwind from the sensors detecting the VOCs (Figure 5-7 b). Both of these locations lie outside the tank farm in the upwind direction which, at the time, was just southeast of the 241-AP Tank Farm. One dataset has been evaluated to date,[2] which is not considered adequate to fully evaluate the SAL module. This application should be tested further with different sets of meteorological and chemical sensor inputs during the remainder of pilot-scale testing.

5.4.4 Forward Plume Model

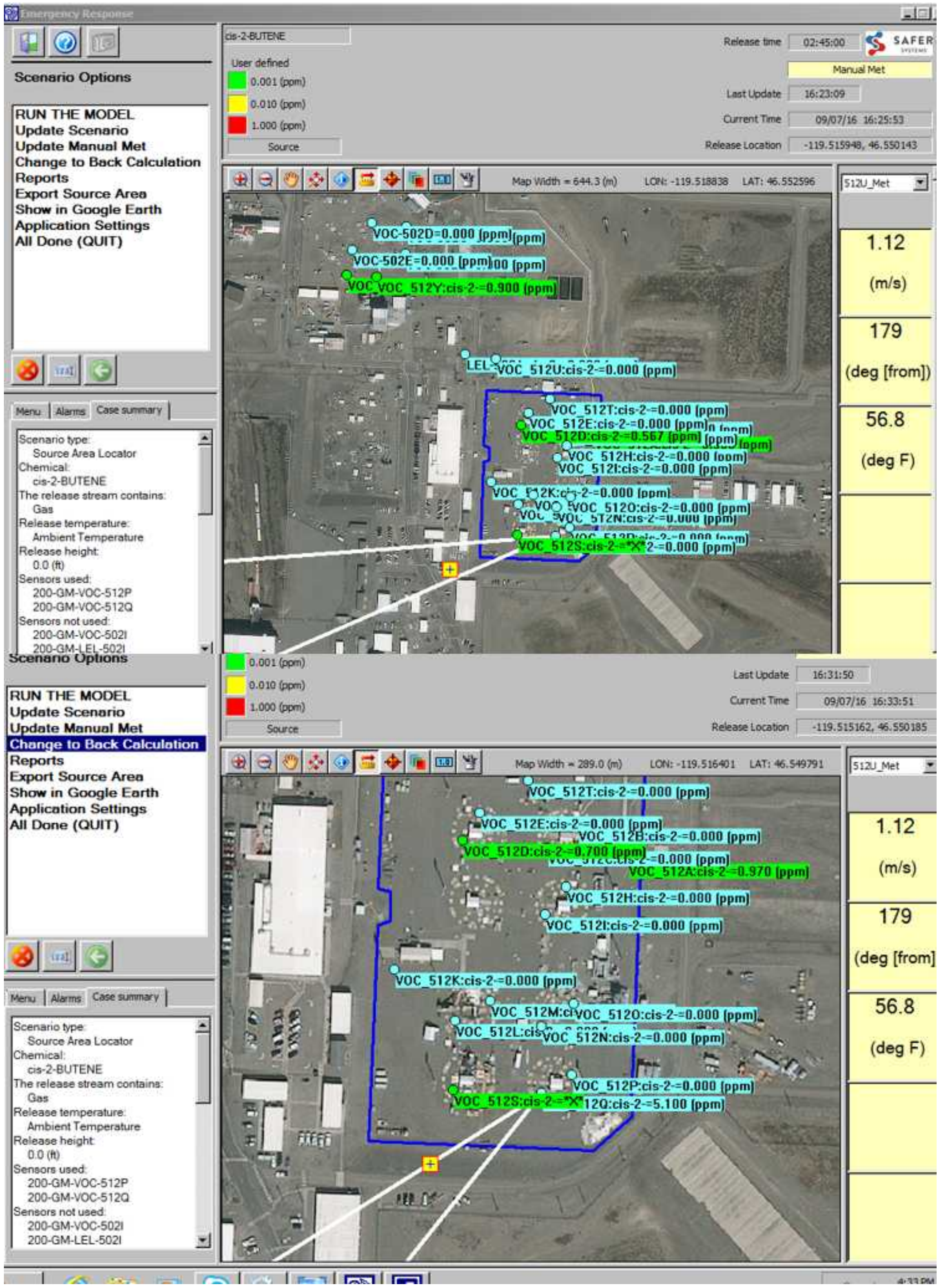
SAFER Real-Time estimates vapor plume travel in the downwind direction using those sensors measuring concentrations that are at least 10% of a user-specified isopleth value. An example plume trajectory was modeled using the same pilot-scale testing data set described for running the SAL using the SAL-predicted release location shown in Figure 5-7. Figure 5-8 shows the mapped plume generated by the model (Appendix C, Table C-1, Item 17.7). The vapor plumes modeled in Real-Time show contaminant dispersion in the downwind direction for a 2-hour period for either an instantaneous or continuous release of the selected chemical. The resulting plume maps allow users to visualize the potentially affected area. The example in Figure 5-8 shows that the predicted plume shows estimated concentrations above values measured by the sensors in 241-AP Tank Farm.

[2] It is interesting to note that that the VOC detected in this event was also identified by its chemical species cis 2-Butene. 2-Butene is not one of the 59 tank farm COPs. It was detected a less than 1 ppm in both 241-A and 241-AP Tank Farms and has an ACGIH OEL of 250 ppm.

Figure 5-7. Examples of Predicted Release Location Using the SAFER Real-Time Source Area Locator Module.

a)

b)

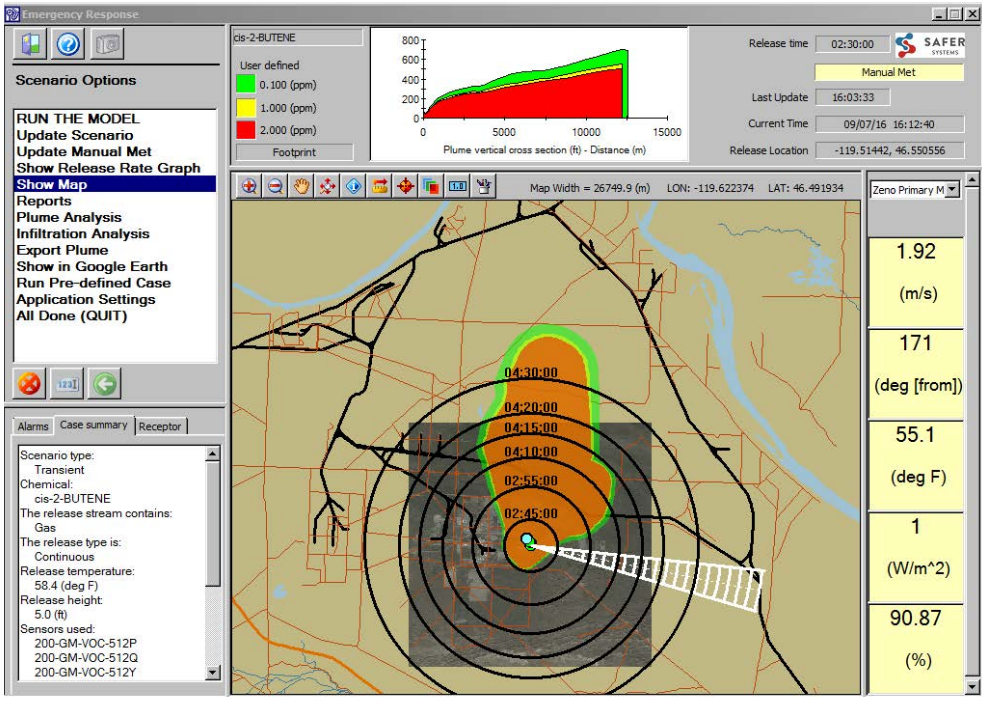


$\boxed{+}$ = release location.

a—first model run.

b—second model run.

Figure 5-8. Example Vapor Plume Generated for VOCs (Isobutylene) Detected at 241-AP Tank Farm on September 7, 2016.



Results of TRL 5 bench-scale testing suggest that the forward plume model overestimates the chemical release rate and thus the calculated plume concentrations are over-estimated. For the pilot-scale test case, it is evident that plume concentration is over-estimated because other sensors in the 241-A and 241-AP Tank Farms did not indicate the presence of a plume as indicated on the SAFER Systems software. Only one case of multiple sensors detecting chemical vapor emissions has been observed at this point in pilot-scale testing. For this reason, the SAL and forward plume model could only be exercised one time. The project recommends that further evaluation of the different modules in Real-Time be conducted in FY 2017. The evaluation requires that two or more sensors detect a plume to exercise the SAFER Systems predictive modules. Therefore, more time will have to be spent waiting for this condition to manifest or a man-made plume must be released in the tank farms under controlled conditions. To ensure these modules are exercised, a gas release must be conducted that is representative of a tank farm emission scenario.

5.4.5 Overall Assessment

The combined results from TRL 5 bench-scale testing and TRL 6 pilot-scale testing suggest that SAFER Systems software still requires development to be successfully deployed in the tank farms and used as a chemical vapor operational aid. In general, the user interface is constructed nicely, but work must be done on the data acquisition system to allow better access to sensor groups and increase the quantity of sensors in a given group. Also, testing results suggest that the SAL and forward plume modeling modules require development to scale the system to the tank farms scale. The system was developed to characterize the plumes from large continuous releases (e.g., ruptured pipe or tank car) and the release rate of the chemical vapors in the tank farms is orders-of-magnitude smaller. The following activities should be conducted to; 1) determine the feasibility of modifying the software to tank farms conditions and 2) implement modifications to the software to fit tank farms conditions if it is deemed feasible. Specifically, the following tasks should be considered:

- A numerical study should be conducted to determine the effective bounds of operation for the SAFER Systems software. The variables that define the model operation should be identified, and then studies should be conducted exercising the software to the limits of those variables to define effective applicability of model to the tank farms environment. At the end of this study, the software vendor will be consulted to determine potential improvements to the software. WRPS will then make a decision on whether to proceed forward with implementation of the software modifications.
- The vendor should develop and implement the software modifications once an approved implementation plan and verification and validation test plan are developed. The software will then be tested using the numerical analysis techniques developed in the previous step to ensure the modifications were successful.
- WRPS and the vendor will then conduct a release of a benign compound that is readily detectable by the VMDS sensors at various concentrations in the tank farms to exercise the implemented software modifications.

The following are other modifications/improvements to the SAFER Systems software that are desired to better optimize its functionality for monitoring and collecting data:

- The current sensor group is limited to 64 sensors. This should be expanded so that all the sensors in a single tank farm can be added to a group. Improve the software so that if one sensor from a group goes offline, all the other sensors in that group do not go offline.
- Improve the process for updating the Chemical Library module. There have been several instances to date where changes to the Chemical Library were needed. Information was sent to the vendor and the average turnaround time for modifications was six weeks. WRPS will work with the vendor to understand why the process takes this amount of time and determine if it can be shortened or if WRPS can receive training on how to do this in-house.
- Improve the software so that if one sensor from a group goes offline, all the other sensors do not go offline.
- Improve the error logging to aid in troubleshooting. Logging should include when and what sensors or services go offline with a notification function.
- Determine from the vendor if the program can be changed to allow configuration without taking the program offline (stopping the service). Taking the program offline makes data and modeling unavailable to operators and engineers.
- Add a feature to allow reports to be exported to Microsoft® Excel®.
- Allow multiple sensor/time selection for analysis and reporting purposes.
- The ability to display data from Blackline Loner IS+ GPS sensors was added to the map but the longitude and latitude does not show up in the sensor parameters like it does for

other sensors that supply longitude and latitude. This should be added for the Loner IS+ GPS units.

- If proceeding past pilot-scale testing, purchase more licenses for: one maintained production server license, 10 client licenses, one test server license, and one development server license to meet WRPS software development standards.

The overall recommendation is to continue to exercise SAFER Systems software (during Phase 2 testing) to evaluate system performance and work with the vendor to implement recommendations identified in this report that will improve pilot-scale performance. In particular, the SAFER Systems software should be exercised during a bolus vapor release event (high concentration, low volume) to determine if the source locator model is accurate. In addition, the vendor has added several new modules to the SAFER Systems software, including stack sampling data and stack plume downwash modeling. These modules should be added to the WRPS SAFER Systems software version and testing should be conducted to evaluate them.

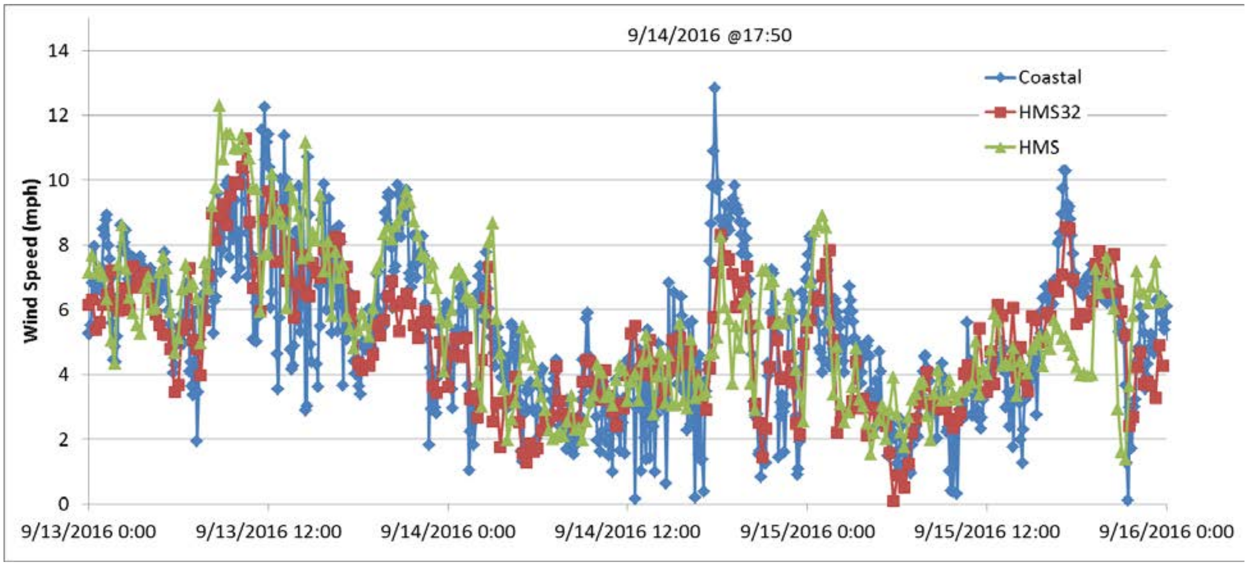
5.5 SUMMARY OF METEOROLOGICAL EQUIPMENT OUTCOMES

Two meteorological towers were installed at the tank farms as part of pilot-scale testing, the CMS at 241-AP Tank Farm, and the LMS outside 241-A Tank Farm on the west fence line. The CMS has been up and operating and sending data regularly to the SAFER Real-Time software for 49 days. With this performance, it has met all five of the test requirements (Appendix C, Table C-1, Items 10.1 through 10.5) and one of the two objectives. Test Objective MI-1 (demonstrate operational requirements as described in the VMDS TRD) has been met for requirements that are tied to its operation. Meeting Objective MI-2 (test efficacy of meteorological station in a tank farms environment) requires continuous operation for the duration of pilot-scale testing, collecting data throughout the necessary operational activities at the tank farms (e.g., waste-disturbing activities). The LMS system has experienced communications issues and some mechanical issues. It has not met any of the test requirements to date. However, it is important to note that the LMS system is a backup to the CMS when it is sent for calibration. The LMS is not required to be operational as long as the CMS is meeting requirements.

The data from the CMS was compared against data from the main HMS located about 4.3 mi west of 241-AP Tank Farm and from a station in the 200 East Area (HMS 32) located about 0.8 mi southwest of 241-AP Tank Farm. Data from those stations was not incorporated into the pilot-scale VMDS because; 1) previous experiences have demonstrated that the HMSs may not represent the conditions in the tank farms at the micro-meteorological scale and 2) the reporting interval of the HMSs is 15 minutes and the VMDS requirements demand a data reporting interval in tens of seconds.

Figure 5-9 shows the comparison of the CMS data with two HMS reporting sites. The range of wind speeds reported from the CMS appears to be slightly greater than speeds recorded at HMS 32. This difference is probably a result of both smaller averaging intervals, and the fact that the CMS site uses a sonic anemometer to measure wind speeds, which has a faster response time than the cup and vane sensor at the HMS 32 station.

Figure 5-9. Comparison of CMS Data with HMS Data from Two HMS Sites.



The cup sensors have inertia effects that dampen their response to wind changes compared to the sonic anemometer. The sampling frequency of the CMS data system interrogating the sonic anemometer can also affect the variability and this is apparent in reported 5-min averages. At 17:50 on September 14, 2016, a significant difference in wind speed between the stations is apparent with the CMS showing wind speeds 2 to 5 mph higher than the HMS. Even when wind direction is constant there can be significant differences in wind speed reported by the different stations. At 17:10 on September 15, 2016, the CMS system in 241-AP Tank Farm and HMS 32 both report wind speeds 4 to 5 mph higher than the HMS, while wind direction shows little change, likely due to the closer proximity of HMS32 to the 241-AP Tank Farm. These types of differences are critical to correctly interpreting how a plume is moving and dispersing within a tank farm.

It is anticipated that when the communications issues are resolved, the LMS will provide results similar to the CMS. The project therefore recommends additional testing to further evaluate CMS performance in a wintertime environment the most critical aspects being rain and freezing rain, which is consistent with the Hanford Site environment through the projected duration of pilot-scale testing. In addition, it is recommended that the LMS will be brought online and tested as a backup to the CMS system; reliable meteorological data are essential for successful operation of the VMDS.

5.6 SUMMARY OF DIRECT-READING INSTRUMENT OUTCOMES

DRIs are an integral part of the ability of the VMDS to provide real-time vapor concentration data for general tank farm and near tank farm work areas. The pilot-scale testing includes activities to judiciously locate and operate an array of various DRIs to detect specific tank farms vapors. The testing includes evaluation of each type of DRI detection capabilities and to determine their viability to operate in tank farm conditions and within the constraints of the tank farms operating infrastructure. Establishing a design basis (see discussion in Section 3.0), inherently involves providing those features that allow mitigating risk of worker exposure to potentially harmful vapors. A key element of a viable design is to identify vapor hazardous release points/areas and to then strategically place those sensors to detect hazardous vapor concentrations and communicate the concentration information such that actions can be taken by the workers to minimize exposures. The type of DRIs selected and deployed as part of pilot-scale test are listed in Table 5-. In addition, Table 5- includes the general location and number of units. In 241-AP Tank Farm, the DRIs are placed around potential vapor release points and in general areas to detect plumes generated within the farm (from 241-AP tanks) or that pass over the farm (e.g., from the nearby 242-A Evaporator).

Table 5-5. General Locations of Direct-Reading Instruments in Pilot-Scale Testing.

Unit	# in 241-AP Tank Farm	# in 241-A Tank Farm	# in General Areas
Gastronics FIS	20	4	1
MeshGuard	1	17	5
AreaRAE	4	0	2
MultiRAE	3	0	0
HAZ-SCANNER	0	0	2

In 241-A Tank Farm, the DRIs are placed to detect releases from 241-A Tank Farm tank PBFs. Communication of the data to a central point of command is important for overall VMDS success (minimize worker exposures) and each of the units presented in Figure 4-3 has successfully reported vapor concentration data to the tank farms communications/network (TFMCS and OSI/PI) and the VMDS SAFER Real-Time software. The following are detected:

- Gastronics FISs detect NH_3, total VOCs, and N_2O with limited meteorological data
- MeshGuards detect NH_3 only
- AreaRAEs detect VOCs, NH_3, CO, LEL, and O_2
- MultiRAEs detect VOCs, NH_3, CO, LEL, and O_2
- HAZ-SCANNERs detect a number of chemicals with limited meteorological data.

For added information on these DRIs and specifically their detection capabilities, see the fact sheets provided in Appendix B.

The location of the DRIs in and around the 241-A and 241-AP Tank Farms is presented in Figure 4-2 and Figure 4-3. Table 5- provides a listing of each of the pilot-sale DRIs, the number of units that have communicated data to the Hanford Site communications network infrastructure, and their general locations.

The general workflow included in the test plan/procedures relative to each instrument include the following:

- Installation of the equipment
- Initial calibration
- Loop testing (expose unit to calibration gases) to confirm data communication
- Bump testing (expose to gas and note response)
- Alarm testing (to pre-set limits for each vapor detected)

- Confirmation of analyte data collection
- Notation of plume generation event(s) and perform associated opportunistic testing
- Collection of operations data for RAMI determinations
- Evaluation of overall ability of system(s) to meet overall test objectives, test requirements, and overall system viability to provide required design input data
- Continuous evaluation of component and overall system performance.

Once the equipment was installed, configured, and subsequently connected to the data collection and management system, the planned equipment testing was initiated. All of the available equipment has been deployed except for three MeshGuard units (due to limitations in the wireless network), one of the HAZ-SCANNER units (due to a failed radio unit), and six of the MultiRAE units (due to failure of individual detectors within the units). Figure 5-10 shows an example of a filled in data sheet from the test procedure (dated September 17, 2016) providing the evidentiary documentation of the equipment installation and configuration for the Gastronics FIS. The remainder of this section describes the functional performance of the units, and based on that performance any additional short-term work that needs to be performed to complete pilot-scale objectives and requirements during Phase 2 testing. To the extent possible, an overall assessment of system performance and path forward recommendations is discussed based on testing results to date (e.g., RAMI data needs, equipment replacement/improvement needs, new infrastructure modifications/requirements).

Figure 5-10. Example Equipment Status Sheet from the Pilot-Scale Test Procedure.

VAPOR MONITORING AND DETECTION SYSTEM PILOT SCALE TEST PROCEDURE	Document:	241A-OAT-0048, Rev. 0
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Table 6-1: Equipment Status **Cont.**

Equipment type and EIN	A: Physically Positioned	B: Configuration Complete	C: Calibrated or Tested	D: Removed from Service
Gastronics FIS 200-GM-AE-512D	8-23-16 TJT	8-23-16 TJT	8-23-16 TJT	
Gastronics FIS 200-GM-AE-512E	8-17-16 TJT	8-17-16 TJT	8-17-16 TJT	
Gastronics FIS 200-GM-AE-512F	8-23-16 TJT	8-23-16 TJT	9-1-16 TJT	
Gastronics FIS 200-GM-AE-512G	8-23-16 TJT	8-23-16 TJT		
Gastronics FIS 200-GM-AE-512H	8-24-16 TJT	8-24-16 TJT	8-24-16 TJT	
Gastronics FIS 200-GM-AE-512I	8-24-16 TJT	8-24-16 TJT	8-24-16 TJT	
Gastronics FIS 200-GM-AE-512J	8-23-16 TJT	8-23-16 TJT	8-23-16 TJT	
Gastronics FIS 200-GM-AE-512K	8-25-16 TJT	8-25-16 TJT	8-25-16 TJT	
Gastronics FIS 200-GM-AE-512L	8-23-16 TJT	8-23-16 TJT	9-1-16 TJT	
Gastronics FIS 200-GM-AE-512M	8-31-16 TJT	8-31-16 TJT	9-1-16 TJT	
Gastronics FIS 200-GM-AE-512N	8-23-16 TJT	8-23-16 TJT	8-23-16 TJT	
Gastronics FIS 200-GM-AE-512O	8-31-16 TJT	8-31-16 TJT	8-31-16 TJT	
Gastronics FIS 200-GM-AE-512P	8-31-16 TJT	8-31-16 TJT	8-31-16 TJT	
Gastronics FIS 200-GM-AE-512Q	8-31-16 TJT	8-31-16 TJT	9-1-16 TJT	
Gastronics FIS 200-GM-AE-512R	8-23-16 TJT	8-23-16 TJT		

From p. 39 of 241A-OAT-0048, 2016, *Vapor Monitoring and Detection System Pilot-Scale Test Procedure.*

5.6.1 Direct-Reading Instrument Communications

Communication with the central data collection systems (TFMCS, OSI/Pi and Safer Real-Time) is fundamental to collecting near real-time vapor concentration data, which is the main function of the DRIs. All of the DRI units except for one of the HAZ-SCANNERs have been shown to communicate through the existing wireless architecture of the TFMCS and have provided data to OSI/PI and SAFER Real-Time at some point during testing. Table 5- lists the amount of time each type of instrument was communicating with the data collection system over the last two weeks of testing. During that two-week span, 13 Gastronics FIS, 15 MeshGuard, 4 AreaRAE, and 1 MultiRAE units communicated with the system every day.

Table 5-6. Online Communication of Deployed DRI Units with the VMDS Data Collection System.

Unit	>90% Online	>65%	<65%
Gastronics FIS	15	4	6
MeshGuard	23	0	0
AreaRAE	4	2	0
MultiRAE	3	0	0
HAZ-SCANNER	0	1	1

Communication up time was evaluated and at this time 90% is expected to provide adequate coverage. A FGS design is currently ongoing and this metric will be included in the future design. In general, the majority of the units communicated with the TFMCS and therefore the SAFER Real-Time system at greater than 65% of the time. It appears that ProRAE Guardian does not have an automatic reboot after power outages so the RAE units can potentially be offline for an entire weekend. In addition, there are a couple of specific issues that need to be addressed during the remaining pilot-scale testing (in FY 2017). These are discussed for each of the DRIs in the following sections.

5.6.1.1 Gastronics FIS

For the FIS units, there is an ongoing issue where for short periods of time the units drop out of communication (minutes) several times per day which results in data loss. Also, a significant amount of effort was spent configuring the software/hardware with the tank farms wireless network infrastructure (TFMCS, OSI/PI) and then with the VMDS SAFER system. Configuring the system included resolution of Hanford Site infrastructure issues and problems with the vendor supplied antenna; the unit's low-gain Omni-directional antenna was placed within a grounded frame of the unit. It is expected that this minor modification can be made to the radios and/or antennas (in the first quarter of FY 2017) to provide a successful configuration and allow operation of the 10 remaining units that have communications issues (15 of 25 are operating successfully). Once communications issues are resolved, it is recommended that these units continue testing long enough to prove performance in inclement weather (meet RAMI-related requirements) and to resolve N_2O sensor issues.

5.6.1.2 RAE Systems Instruments

All of the RAE Systems DRIs (MeshGuard, AreaRAE, and MultiRAE), communicate together over a number of frequencies using proprietary protocols that have not yet successfully been configured to the Hanford Site communications/network infrastructure utilizing a Wi-Fi based system.[3] The RAE Systems instruments are not configured to provide data directly to the VMDS data collection and management system and they must go through the ProRAE Guardian server. The information coming from the ProRAE Guardian server requires additional interpretation before it can be sent to TFMCS. Because the output of ProRAE Guardian is in a format not natively supported by ABB, third-party software had to be purchased and configured to perform the data translation. At the beginning of pilot-scale testing, the communication between ProRAE Guardian and TFMCS was not robust and the ProRAE Guardian had to be frequently re-started. This resulted in the loss of data from all RAE sensor types (AreaRAE, MultiRAE, and MeshGuard). Interfacing three software products and providing life cycle support can be complicated and expensive and has proven to fail often, resulting in the loss of data. An alternative to the current architecture of the RAE system is going to be necessary for them to provide the reliability necessary for the VMDS.

5.6.1.3 HAZ-SCANNER

Upon installation for pilot-scale testing, a connector on the unit to the radio failed on one of the two units. In order to repair the unit, the warranty would have to be voided. As a result, only one of the units was available for pilot-scale testing.

During pilot-scale testing, a significant amount of effort was expended to make the Advantech radio (standard equipment on the units) communicate with the serial device server which is required to allow the unit communicate with the control system. Eventually, an Advantech serial device server had to be purchased in order to be compatible with the Advantech radio. Even then, significant help from the radio vendor was required to make the unit communicate with the Hanford Site control system.

5.6.2 Calibration, Bump Testing, and Loop Testing

The calibration, bump testing, and loop testing of the VMDS DRI units was performed in the field per test procedure 241A-OAT-0048. Table 5- shows the calibration testing (initial, bump, and loop) results for the DRIs. Only the sensors for the leading indicator species (VOC, NH_3, and N_2O) are reported here. The HAZ-SCANNER, Gastronics FIS, AreaRAE, and MultiRAE units have other sensors that have not been tested to the extent of the leading indicator sensors.

Table 5-7. Calibration, Loop Testing, and Bump Testing for Direct-Reading Instruments.

Units	# Successfully Calibrated	# Successfully Bump Tested	# Successfully Loop Tested
HAZ-SCANNER – 2 units			
VOC	0	0	0

[3] For this discussion the ToxiRAE units, while reporting to the data collection and management system, are considered personal monitors and not DRIs since they do not have fixed locations.

NH_3	0	0	0
Gastronics FIS – 25 units			
VOC	24	21	21
NH_3	24	21	21
N_2O	25	21	21
AreaRAE – 10 units			
VOC	4	4	4
NH_3	4	4	4
MeshGuard – 24 units			
NH_3	21	21	21
MultiRAE Pro – 3 units			
VOC	3	3	3
NH_3	0	0	0

FIS = =fixed instrument skid.

Figure 5-11 shows an example of bump test data collected for a DRI during testing. This example is for a Gastronics FIS unit; however, these data sheets have been generated for all other units bump tested. The bump and loop tests were generally performed simultaneously by being in contact with the SAFER Real-Time operator while performing the bump test to verify that the reading on the instrument screen was identical to the value on the SAFER display.

Figure 5-11. Example Bump Test Calibration from the Pilot-Scale Testing Procedure.

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Attachment 5 Data Sheet 2
FIFTH WEEK BUMP TEST RESULTS

EIN	200-GM-AE-512N		Serial Number	F15	
Sensor	**Test Gas Concentration**	**Gas Lot Number**	**Sensor Reading**	**Safer Reading**	**TFMCS Reading**
NH_3-High	100 PPM	FAQ-13-100-2	88 ppm	88	88
NH_3-Med	50 PPM	FAQ-13-50-11	40 ppm	40	40
N_2O-High	1000 PPM	FAQ-M21-3	1000 ppm	999	1000
N_2O-Med	500 PPM	FAQ-M21-500-2	500 ppm	500	500
VOC-High	50 PPM	FAQ-248-50-2	46.7 ppm	46.6	46.7
VOC-Med	10 PPM	FAQ-248-10-7	10.3 ppm	10.2	10.3
Zero Air (NH_3)	20.9% O_2	EAQ-1-15	0	0	0
Zero Air (N_2O)	20.9% O_2	EAQ-1-15	0	0	0
Zero Air (VOC)	20.9% O_2	EAQ-1-15	0	0	0

This instrument was tested using gases that are traceable to N.I.S.T standards.

Bump Test Date		8-23-16	Test Location*	241-AP
Recorded By	Name Print	SA STROPE	Name Sign	[signature]
Reviewed By	Name Print	Todd Thiesen	Name Print	Todd T[signature]

* Bench or Field

From p. 419 of 241A-TP-043 R00, 2016, *241A Vapor Monitoring and Detection System Pilot-Scale Test Plan.*

5.6.2.1 Test Results

To summarize DRI test results to date, this section compares the collected and documented test results and data to the test objectives and requirements. As with most of the instrumentation, the DRI testing will provide input to the overarching objectives (TMP-1, TMP-5, VMDS-1, VMDS-2, DC-1, DC-2, DC-3 and DC-4); however, the test objectives directly related to the DRIs are DRI-1 (demonstrate operational requirements as described in the VMDS FRD) and DRI-2 (test efficacy of DRI in the tank farms environment).

Most of the requirements, including the completion of the calibrations, bump testing, and loop testing of a significant subset of each type of the DRIs (with the exception of the HAZ-SCANNER) are complete or close to completion with respect to test objectives DRI-1 and DRI-2. However, until the final communications and operations issues are addressed, the project cannot declare these objectives have been satisfied. Some required testing, during phase II, still needs to be completed including opportunistic data collection from vapor release events and determining fugitive emissions from sources in and outside of the tank farms.

The test requirements matrix in Appendix C provides a list of the specific tests, the acceptance criteria, and the bases to claim that the criteria are met. Table 5- through Table 5- show an abbreviated version of the TRM and provides a quick view of how far pilot-scale testing has progressed with respect to the DRIs.

Table 5-8. Fixed Instrument Skid Test Results.

Requirements	Test	Performed	Requirement Met
12.1	Calibration	Yes (all NH_3 and VOC, only 3 N_2O)	Yes (no for N_2O)
12.2	Shakedown	Yes	Yes
12.3	Alarm	No	Not yet
12.4	Loop	Yes (all NH_3 and VOC, no N_2O)	Yes (no for N_2O)
12.5	Continuous data collection	Yes (all NH_3 and VOC, no N_2O)	Yes (no for N_2O)
12.6	Bump	Yes (all NH_3 and VOC, no N_2O)	Yes (no for N_2O)
12.7	Plume detection	Insufficient plumes for testing	Not yet
12.8	Fugitive emissions	No opportunity	Not yet
12.9	Fugitive emissions from IH rounds	No opportunity	Not yet
12.10	RAMI data	Very limited	No
12.11	3D anemometer	Yes	Yes
12.12	2D anemometer	Yes	Yes
12.13	Communications disconnect	Yes	Yes

Table 5-9. AreaRAE Test Results.

Requirements	Test	Performed	Requirement Met
2.1	Calibration	Yes (all NH_3 and VOC)	Yes
2.2	Shakedown	Yes (all NH_3 and VOC)	Yes
2.3	Alarm	No	Not yet
2.4	Loop	Yes (all NH_3 and VOC)	Yes
2.5	Continuous data collection	Yes (all NH_3 and VOC)	Yes
2.6	Bump	Yes (all NH_3 and VOC)	Yes
2.7	Plume detection	Insufficient plumes for testing	Not yet
2.8	Fugitive emissions	No opportunity	Not yet
2.9	Fugitive emissions from IH rounds	No opportunity	Not yet
2.10	RAMI data	Very limited	No

Table 5-10. MeshGuard Test Results.

Requirements	Test	Performed	Requirement Met
5.1	Calibration	Yes	Yes
5.2	Shakedown	Yes	Yes
5.3	Alarm	No	Not yet
5.3.1	Loop	Yes	Yes
5.4	Continuous data collection	Yes	Yes
5.5	Bump	Yes	Yes
5.6	Plume detection	Insufficient plumes for testing	Not yet
5.7	Fugitive emissions	No opportunity	Not yet
5.8	Fugitive emissions from IH rounds	No opportunity	Not yet
5.9	RAMI data	Very limited	Yes
5.11	Communications disconnect	Yes	Yes

Table 5-11. MultiRAE Pro Test Results.

Requirements	Test	Performed	Requirement Met
4.1	Calibration	Yes	Yes
4.2	Shakedown	Yes	Not yet
4.3	Alarm	No	Not yet
4.4	Loop	Yes	Yes
4.5	Continuous data collection	Yes	Yes
4.6	Bump	Yes	Yes
4.7	Plume detection	Insufficient plumes for testing	Not yet
4.8	Fugitive emissions	No opportunity	Not yet
4.9	Fugitive emissions from IH rounds	No opportunity	Not yet
4.10	RAMI data	Very limited	No
4.11	Communications disconnect	Yes	Yes

Table 5-12. HAZ-SCANNER Test Results.

Requirements	Test	Performed	Requirement Met
1.1	Calibration	1 unit only	No
1.2	Shakedown	1 unit only	No
1.3	Loop	No	No
1.4	Continuous data collection	No	No
1.5	Bump	No	No
1.6	Plume detection	Insufficient plumes for testing	Not yet
1.7	Fugitive emissions	No opportunity	Not yet
1.8,	Fugitive emissions from IH rounds	No opportunity	Not yet
1.9	RAMI data	Very limited	No
1.10	Communications disconnect	Yes	Yes

During the test, three events were detected by two different sensors. Since these were small and did not exercise a significant number of sensors, the team assessed that the intent of the TRM item was not fully satisfied. Each one of the DRIs have issues that still need to be addressed. In Section 7.0, the issues associated with each DRI and the resolution path forward and general recommendations are discussed in the context of continued testing. From a practical standpoint, the project feels that those DRIs that are up and operating should continue to operate in Phase 2 testing (into FY 2017). The following section provides the specific issues associated with each of the DRIs.

5.6.2.2 Special Considerations

The following is a list of the special considerations that will need to be evaluated to determine whether or not the various instrument should be used for the remainder of pilot-scale testing and/or for future VMDSs.

- The N_2O sensors on the Gastronics FIS failed to operate during testing; the vendor has provided a potential fix (temperature compensation). The other two sensors (NH_3 and VOCs) are operating well and proving data at many locations throughout both tank farms.
- All Gastronics FIS units periodically drop connectivity (for <5 minute intervals). This will continue to be explored.
- Communications for all of the RAE Systems equipment (AreaRAE, MeshGuard, and MultiRAE) require a complex and cumbersome system to communicate data to the TFMCS. This could be a fatal flaw and needs additional evaluation. The vendor is introducing a new model of the AreaRAE with a new radio that may solve the problem; the project will follow these developments.
- Other than the communications issues, the AreaRAE and MeshGuard units are performing well and could be suitable for inclusion in the final VMDS.

- In addition to the communications issues, the MultiRAE units have a problem with failure of individual sensors and require constant maintenance. The WRPS IH group has observed similar issues. IH is required to maintain the units (replace sensors) every time they are used. One of the requirements for DRIs is that they can be deployed within the tank farms with minimal maintenance, so a required daily or weekly maintenance routine will not meet the needs of the VMDS. Because of these issues, project staff are recommending that these units not be brought forth to Phase 2 testing or any future consideration.
- The HAZ-SCANNER units required extensive structural modification, had a number of issues regarding digital communications and power to resolve (as of September 17, 2016, these systems had not yet been set up to communicate with TFMCS, OSI/PI, nor SAFER Real-Time). That said, the highly modified unit may be able to provide information on the utility of the sensors and may be worth keeping in the VMDS through Phase 2 testing, depending on resource availability.

5.7 SUMMARY OF SPECTROSCOPIC EQUIPMENT OUTCOMES

Four spectroscopic instruments were installed in the tank farms as a part of VMDS pilot-scale testing. The UV-FTIR unit is connected to the 241-AP Tank Farm exhauster stack to monitor the emissions while the other three instruments are open path units set up on the periphery of the 241-A and 241-AP Tank Farms to look for vapors in general areas (e.g., along fence lines and across the tank farms). A brief description of the instruments and their capabilities is provided in in Appendix B. The four units consist of one 241-AP Tank Farm stack monitor (UV-FTIR), two OP-FTIR units (along 241-AP Tank Farm fence lines and diagonally across the general tank farm area), and one UV-DOAS (detection target is across 241-A Tank Farm PBFs). The four instruments have been operating continuously since initial set up and have provided information to the VMDS SAFER Real-Time software.

During the project technology maturation evaluation, this equipment was determined to be a critical technology element requiring careful evaluation during testing to achieve the desired TRL by the end of testing. This necessitated that many of the objectives of the testing, listed in Table 4-, be tied to testing and outcomes of the spectroscopy equipment. The objectives tied to the spectroscopy equipment are TMP-2, TMP-3, TMP-4, TMP-5, SI-1, SI-2, SI-3, SI-4, DC-2, DC-3, and DC-4. None of these objectives have as yet been completely satisfied. Both RAMI and analytical data need to be collected throughout a complete seasonal cycle and during waste-disturbing activities to satisfy all of the test objectives requirements.

5.7.1 Communications

Early issues related to communications of the spectroscopy equipment were due to the tank farms wireless architecture. After the early communication drops were corrected, the communications have been consistent and steady. To ensure only minor problems are encountered in future tank farm VMDS, local infrastructure needs to be in place.

5.7.2 Calibration and Bump Testing

None of these instruments have been calibrated or bump tested during pilot-scale testing; however, all of the spectroscopy equipment is calibrated at the factory prior to shipping. During bench-scale testing, calibrated gasses were passed though the path of the OP-FTIR and the results were as expected. It should be noted that due to the large number of chemicals detected and the nature of instrument response, single point calibrations are performed on this type of equipment.

5.7.3 Test Results

Once the equipment was set up, there was very little interaction required with the instrumentation. Of the test requirements in the TRM (see Appendix C, Table C-1), they all met the requirements for which they were tested: unit set up (Items 6.2, 7.2, and 8.2); five days continuous operations (Items 6.5, 7.5, and 8.5); and monitoring gases over specified locations in the tank farms (Items 6.8, 6.9, 7.7, 7.8, 8.7, and 8.9). Figure 5-12 is an example data sheet showing the functioning of the equipment. Completing the remaining requirements will be part of FY 2017 pilot-scale testing. The only issue that complicated the operation of the UV-FTIR was condensation in the manifold leading from the stack to the instrument. This was fixed by removing a radiation particulate filter from the UV-FTIR. This is not expected to cause any potential radiation contamination issue since the sampling point is downstream of the high-efficiency particulate air filters and no contamination is expected during routine operations. One maintenance issue with the OP-FTIR was the failure of the power supply. This caused a week of down time and the reliability of the component will need to be evaluated during Phase 2 testing.

5.7.4 Overall Assessment

All of the spectroscopy units functioned well in the conditions tested (temperature range of 50 to 110 °F and winds up to 30 mph). The UV-FTIR is contained in a housing that shields it from the weather, so the impact of inclement weather should not affect the operations of the stack monitor though it should be verified via extended testing. However, the open path instruments have the potential to be affected by any number of Hanford Site conditions. The reflectors could be susceptible to high winds (although it is documented that they have been deployed in similar desert settings), fog, freezing rain, and snow, to name a few. Hanford winter conditions could not only affect the physical parts of the system, but during some of those times (e.g., fog or dust storm) the signal could be affected, potentially masking the results.

The main issue with this instrumentation is the complicated nature of the data collection and evaluation. While the instruments provide chemical compound identification and quantification, the project is relying heavily on the vendor for assistance at this time. Initial data collected appeared to have issues identified by WRPS and PNNL staff that require the vendor to change some settings and work with the spectral libraries – which is currently outside of the expertise of Hanford Site staff. In addition, in order to identify unknowns the individual spectra (several spectra are collected per minute of operation) will need to be exported and de-convoluted by expert personnel.

Figure 5-12. Data Sheet 3 Showing Operation of the Spectroscopic Equipment.

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Attachment 33 Data Sheet 3 Routine Review of Spectrographic Data

Initial: CDC	Date: 8/11/16	Data Review Period	Start Date: 8/10/16 Time: 0600	End Date: 8/11/16 Time: 0600	Page 1 of 1

EIN Status Line	Data recorded (✓)		Data Gaps? (✓)		Anomalous Data? (✓)		COPC''s Detected?		Test Deficiency Report	
	YES	NO	YES	NO	YES	NO	How Many	No (✓)	Number	NA (✓)
200-GM-AE-506A OBS	~~✓~~ CDC									
200-GM-AE-506B	✓			✓	✓ see comment			N/A		
200-GM-AE-507A SB	✓		✓ see comment			✓	~~12~~ 13 CDC			
200-GM-AE-508A	✓			✓		✓		✓		

COMMENTS:

For 200-GM-AE-506B - gaps were determined using two species - NH3 and Butanal - there were none observed a general peak between 24:00 and 0600 - an undefined hydrocarbon - also observed 8/8/16

For 200-GM-AE-507 - Instrument went online @ 0823 so there is no data prior to this.

For 200-GM-AE-508 - gaps were determined using NH3, Acetaldehyde, Mercury, O-Xylene, and benzene

~~twelve~~ thirteen CDC COPCs were detected including ammonia ~~and~~ mercury, butadiene, butanol, butanal, ethylamine, acetaldehyde, methanol, methyl vinyl Ketone, nitrous oxide, NDMA, propionitrile, and tributyl-phosphate.

~~RECORD COPY~~

From p. 700 of the Test Procedure, dated 9-17-16.

Once enough data is collected and corroborated by laboratory data, the spectral de-convolution routine can be modified to ensure the data received from the spectroscopy instruments accurately represent the conditions in the path. It is recommended that during Phase 2 the role that the vendor is currently providing be shifted to selected WRPS technical staff with expertise in interpreting IR spectra.

5.8 SUMMARY OF OPTICAL GAS IMAGING CAMERA OUTCOMES

Three units were acquired for the VMD&R Project, two FLIR OGI portable (handheld) infrared camera (GF-306 & GF-346) and the other a fixed unit (GF-306pt) using essentially the same camera secured to a base that can scan a defined area. The cameras are tuned to a narrow window of infrared wavelengths that includes the target gas or vapor. The target vapor within the tank farms is anhydrous ammonia (GF-306). Ammonia and nitrous oxide are also the assumed leading indicators for other gasses.[4] The OGI cameras may also indicate the presence of other gasses (e.g., refrigerants for GF-306). Ideally this visualization tool could be used to identify sources of the target vapor and identify if the source gases are present in work areas in and around the tank farms. The OGI camera is reported to be progressing to become the ‘go-to’ tool for fugitive emissions indication in industry and the EPA recommends OGI as a tool for leak detection and repair (LDAR) programs. See the fact sheets in Appendix B.

The G-306pt (fixed) FLIR camera and did faintly see ammonia emissions from AP tank Farm exhauster stack. However, the image quality was adversely affected by the distance. The pan/ tilt mechanism has worked as expected. The IntelliRed™ video analytics program provided by the vendor works well. It is anticipated that the unit will operate as well as the portable unit because the internal workings of the two cameras are identical. The test objectives that relate to the OGI cameras are Objective OGI-1 (demonstrate operational requirements as described in VMDS FRD) and Objective OGI-2 (test efficacy of OGI in the tank farms environment). While both objectives have been met by the portable unit, the project cannot claim success until the fixed camera is operational and taking data.

It should be noted that while the OGI camera can detect vapors that absorb in the infrared window, it also measures temperature difference. The speciation of the gas is not definitive, but will provide indication of vapor emissions. The vendor is scheduled to come to the site in the first quarter of FY 2017 to assist in tuning the camera and providing technical assistance/training to help discern the data generated.

The TRM items (see Section 19.0 in Table C-1 of Appendix C) that have been met are as follows:

- Item 19.1, shakedown testing
- Item 19.2, data collection
- Item 19.3, opportunistic exhauster plume monitoring
- Item 19.4, opportunistic PBF plume detection.

[4] Ammonia was selected as the target vapor to be detected by the OGI camera and a leading indicator based on historical data indicating that ammonia is nearly always present in tank vapors and other COPCs are often present co-mingled with ammonia but at lower concentrations.

The two TRM items not yet tested for are Item 19.5 (opportunistically monitor transfer/valve pit fugitive emissions) and Item 19.6 (opportunistically monitor dead end fugitive emissions). Opportunities for these items have not yet arisen.

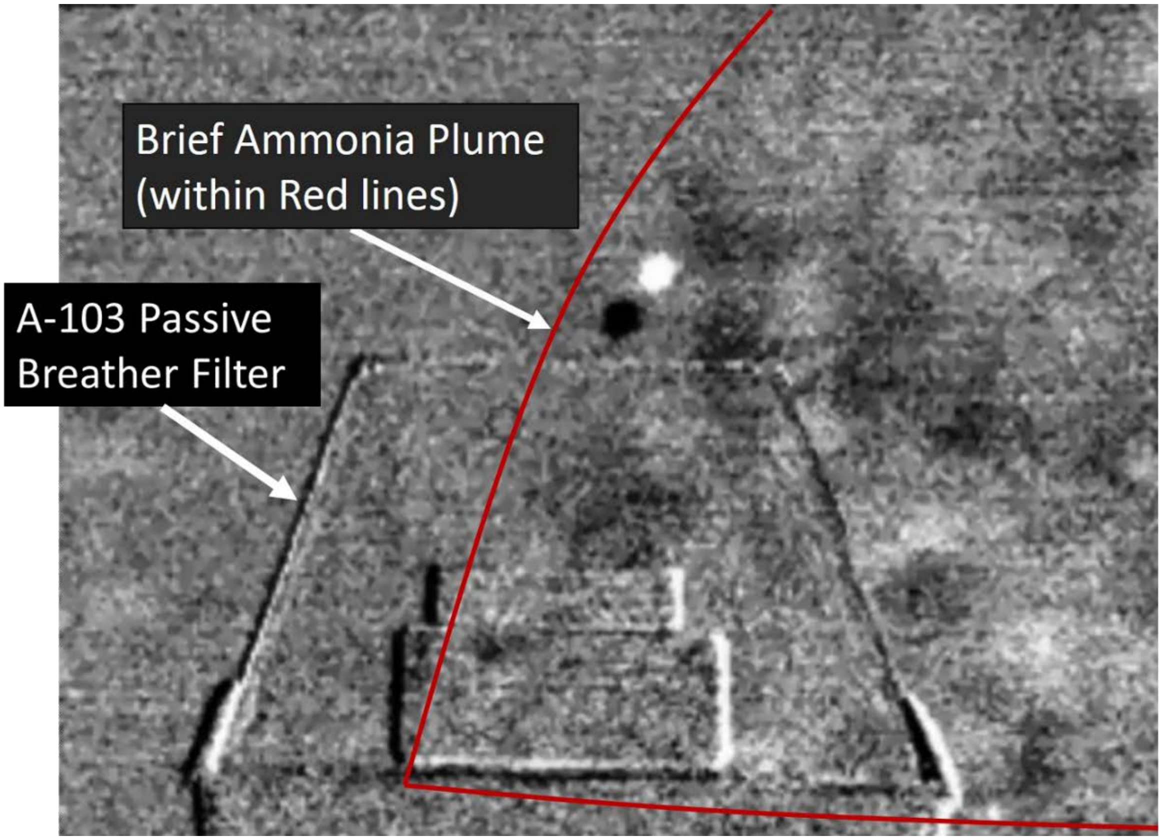
Figure 5-13 shows a still picture of the tank 241-A-103 PBF taken at approximately 12:49 on September 21, 2016. However, evaluation of the OGI at low concentrations is required in the next few months. In addition to the view of ammonia leaving the PBF, the following items were also captured by the OGI portable camera:

- Viewed ammonia plume coming out of the 241-AP stack
- Recorded footage of ammonia plume leaving the 241-AP stack
- Recorded footage of ammonia plume leaving the 241-AP stack at 15 m
- Recorded footage of ammonia plume leaving the 241-AP stack at 40 m
- Recorded footage of ammonia plume leaving the 241-AP stack at 100 m
- Recorded obstructions that may influence imaging capability
- Observed ammonia leaving the tank 241-A-103 PBF (image poor, but emission positively identified).

The use of the OGI camera in the tank farms as a method to detect vapor emissions shows promise, but a process needs to be developed to use the OGI for LDAR. The use of OGI has been incorporated into LDAR programs as defined by the EPA. Similar processes are found in the EPA LDAR programs and should be adopted by WRPS as they relate to the use of OGI.

The remaining activities in pilot-scale testing will attempt to prove that the OGI can be used for locating fugitive emissions and to ensure vapor containment methods are sound. The project recommends that these activities be conducted in FY 2017.

Figure 5-13. Still Picture of Tank 241-A-103 Passive Breather Filter.

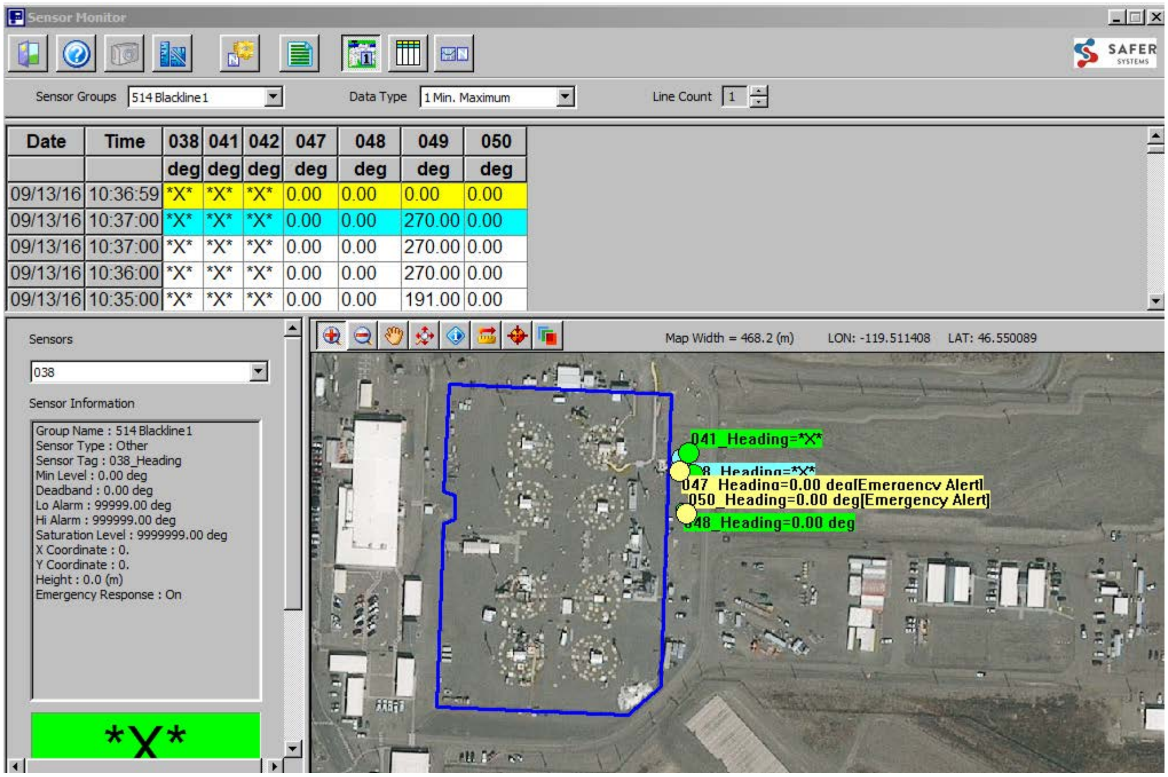


Note: Light and dark areas to the right of the red line are the plume of ammonia coming out of the tank 241-A-103 passive breather filter on September 21, 2016 at 12:49 p.m. Corroboratory analysis inside of the filter hood using a MultiRAE analyzer showed ammonia at 13 ppm.

5.9 SUMMARY OF PERSONAL LOCATION UNIT OUTCOMES

There have been 50 Blackline Loner IS+ GPS units acquired for the VMDS, and 4 of those were tested as part of the pilot-scale testing. The Loner IS+ is a small (2.48 × 4.21 × 1.1 in.) personal GPS alarm unit designed to be worn on-person. The unit is equipped with several safety features that include fall detection technology, emergency latch, silent emergency, worker motion monitoring, and worker check-in. The unit sends and receives data to and from cloud servers at Blackline. For a more complete description of the instrument, see Appendix B. The units were assigned to four tank farms workers during routine operations and their locations were tracked on the SAFER Real-Time display (see Figure 5-14).

Figure 5-14. SAFER Real-Time Display Screenshot.



Note: Image showing location of personnel wearing Loner IS+ GPS units with two indicating emergency alert (TRM Item 13.2) as part of the test.

The Loner IS+ units have met all of the test requirements (Items 13.1 through 13.6) and both of the test objectives, Objective PL-1 (meet requirements from the VMDS FRD) and Objective PL-2 (test efficacy for use in tank farms). Figure 5-15 shows the evidence of the testing as recorded in the pilot-scale test procedure (24A-OAT-0048).

The units are suitable for field use. The Loner IS+ units satisfactorily reported the location of units when deployed into the tank farms. The units will be effective tools to track and analyze worker movement patterns in the tank farms. The units will provide data to calculate occupancy rates in the tank farms when deployed with workers. It is recommended that activities to field deploy these units more globally in the tank farms be considered and implemented.

Figure 5-15. Example of Test Procedure Verification.

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NOTE: The following steps can be performed by one person simulating a group, or the units can be assigned to different individuals in an actual group.

NOTE: The audible alarms on the Personal Location Devices are disabled during testing.

TJT 9/13/16 **A17.5.2.** **CARRY** the Personal Location Devices into a tank farm THEN **PLACE** the device on the ground or on a flat surface for 20 minutes.

[Test Criteria]

A17.5.2.1. **VERIFY** the unit visually alarms and the alarm event was recorded. TRM 13.5 ✓

Todd Thiesen (print) [signature] (sign) 9-14-16 (date)

Test Director

TJT 9/14/16 **A17.5.3.** WHEN in the field, TURN off the personal location device.

[Test Criteria]

A17.5.3.1. **VERIFY** TFMCS and Safer System HMI indicate the instrument is disconnected from the VMDS. TRM 13.6 ✓

Todd Thiesen (print) [signature] (sign) 9-14-16 (date)

Test Director

Note. Sample is from test procedure p. 538 showing verification of two test requirements for the global positioning system units (Item 13.5, man down alarm testing, and Item 13.6, disconnection from the Vapor Monitoring and Detection System).

5.10 SUMMARY OF AUTOSAMPLER OUTCOMES

A final check on all of the information coming into the data collection and management system is the corroboratory laboratory analysis. The standard procedure has been to engage IH technicians to collect sorbent tube samples that are then sent to the laboratory for analysis. This is a time-consuming and expensive process and the need for an autosampler was apparent. The following criteria were devised by the VMD&R Project for autosamplers:

1. Autonomous and unattended sequential sampling
2. Multiple sorbent media types
3. Sorbent media in nonstandard format (i.e., not typical Perkin Elmer size and shape)
4. Both sorbent media and whole-air sampling canisters (i.e., summa format)
5. Both long-term integrated samples and short-term grab samples
6. Remotely triggered sampling
7. Operating in outdoor, all-weather environments
8. Considerations for nuclear environments and radioactive contamination.

While a number of vendors had autosamplers, none met more than five of the criteria. The project identified an equipment manufacturer that had instruments and technology that could be combined to meet the first five criteria. That manufacturer teamed with a local fabricator with experience fielding instruments in the Hanford Site tank farms environment, and that resulted in complete sampling systems that could meet all eight criteria. However, while these new sampling systems contained proven technologies the combined system was untested.

Two devices were developed to satisfy the need for; 1) a unit that could collect numerous one day long samples for a week at a time – designated an area/stack autosampler and 2) a unit that could be co-located with a sensor to collect a sample during a vapor release event – designated a grab autosampler. An area/stack autosampler collects a set of integrated samples (i.e., samples that are taken over a period of time, and thus the results reflect time-averaged concentration values) continuously and autonomously over a selected duration (e.g., one week or one day). See the Appendix B area/stack autosampler fact sheet for more information.

A grab autosampler collects air from a single sampling event (typically a short event of 20 to 120 min), as compared to the larger area/stack autosampler that is designed to collect an integrated sample (typically long continuous runs of one to seven days). Once triggered to obtain a sample, the units autonomously collect a whole-air sample in a single 6 L canister (summa can) and sorbent media samples in tubes and cartridges. See the Appendix B grab autosampler fact sheet for more information.

As with all of the instruments, the autosamplers are involved with the VMDS-related test objectives and the data collection objectives, but the directly relatable test objectives are as follows:

- Objective AI-1, demonstrate operational requirements of the VMDS FRD
- Objective AI-2, test efficacy of area sampler in tank farms environment
- Objective AI-3, test efficacy of grab sampler in tank farms environment.

To date, all of these objectives have been completely satisfied per the specific test requirements and implementation of the required test procedures. However, both RAMI and analytical data need to be collect throughout a complete seasonal cycle, during vapor release events, and during waste-disturbing activities to satisfy all of the test objectives requirements for the overarching objective (e.g., VMDS and data collection objectives).

5.10.1 Communications

All autosamplers within range of the TFMCS wireless network communicated with the TFMCS, OSI/PI, and SAFER Systems software as expected. The background sampler was the only unit that did not communicate with the TFMC wireless network. It was located almost 1 mi from nearest Wi-Fi access point. At this distance, it was never expected to communicate with the network.

5.10.2 Test Results

Overall, the autosamplers have met all expectations. Based on over 3,000 hours of continuous operation and over 30 sample media change outs, all seven area/stack autosamplers are fully functional and operated as designed. The area/stack autosamplers were the first instruments brought online during the VMDS pilot-scale testing, and ran unattended for the entire test. The autosamplers performed without system failures or major upsets, and collected over 400 samples. The grab autosamplers have not yet operated as long, but due to the similarity in design and components, there is no reason to believe that they will perform any differently. During the testing, both types of autosamplers met all but one of the items from the TRM (see Appendix C):

- Items 14.1 and 15.1, bench shakedown testing
- Items 14.2 and 15.2, field shakedown testing
- Items 14.3 and 15.3, loop test
- Items 14.4 and 15.4, continuous data collection
- Items 14.6 and 15.6, transport samples through radiological boundaries
- Items 14.7 and 15.7, whole-air sampling
- Items 14.8 and 15.8, sorbent tube sampling.

The only TRM items not satisfied involve alarm testing (Items 14.5, 15.5, and 16.5) and could not be completed because the software in the instrument required modification. The modification should be completed within six weeks. This testing will be performed during Phase 2 pilot-scale testing.

To date, many sorbent tube and summa canister samples have been collected. Because there were no vapor release events detected near any of the autosamplers, it is assumed that the results will be a good representation of the background levels present in the airspace in and around the tank farms. When this data is obtained, it will provide a good picture of the ambient conditions over several summer months of testing. When the continued data for the remainder of the test is collected, a complete picture of the tank farm vapors environment will emerge.

5.10.3 Overall Assessment

All of the autosamplers have so far functioned well under Hanford Site summer weather conditions (temperature range of 50 to 99 °F and winds up to 30 mph). Further operation to collect RAMI data is still a high priority. Added information on performance of valves, flow controllers, and overall durability under adverse weather conditions still needs to be collected.

In order to fully exercise the autosamplers and determine their utility, the samplers need to be operated when vapor release events occur, as is anticipated when waste-disturbing activities and an evaporator campaign occur. Because the functions of these units are relatively simple, it is anticipated that these units will be useful throughout the Hanford Site to collect background information to better evaluate the IH technical basis.

5.11 SUMMARY OF PERSONAL BADGE OUTCOMES

The personal chemical vapor badge monitors that were a part of pilot-scale testing were the ToxiRAE Pro and the Ion Science Cub. Both of these units monitor for VOCs near the personal breathing space of the wearer. A necessary requirement of the design of a safety/warning system is that its location be known and fixed, traits that are not inherent to normal operation of these units. Understanding the vapor conditions in a worker's personal breathing space has many advantages including providing immediate feedback to the workers in the field. These units are part of a 'defense-in-depth' warning system that provide supplementary information relative to the VMDS.

The testing of the ToxiRAE systems has been delayed due to issues with communications and availability of technical resources. Initial shakedown testing of 9 of the 11 available units (the remaining two malfunctioned and are being returned to the manufacturer) has been performed, including bump and loop tests but additional testing is required before these units can be fully evaluated. However, their capabilities are needed and it is recommended that testing of these units continue in Phase 2. The testing of the Ion Science Cubs has also been delayed; however, testing of these units by Vapor Program IH staff outside of the pilot-scale testing has shown promising results. These badges will provide personal exposure data and will require development of a process and features for protecting any personally identifiable medical information. This issue will need to be addressed prior to broader testing of these units.

5.11.1 Communications

An issue with the ToxiRAE Pro, as is the case with all of the RAE Systems units, is the communications with the VMDS. While this is an issue with the future use of data, it is expected that a resolution can be provided in the next couple of months. The personal badges will be used in conjunction with the VMDS Phase 2 testing. In contrast, the alternative personal badge is the Ion Science Cub, which does not have a wireless data transmittal feature and must be placed into a docking mechanism at the end of a shift to download data.

5.11.2 Calibration, Bump Testing, and Loop Testing

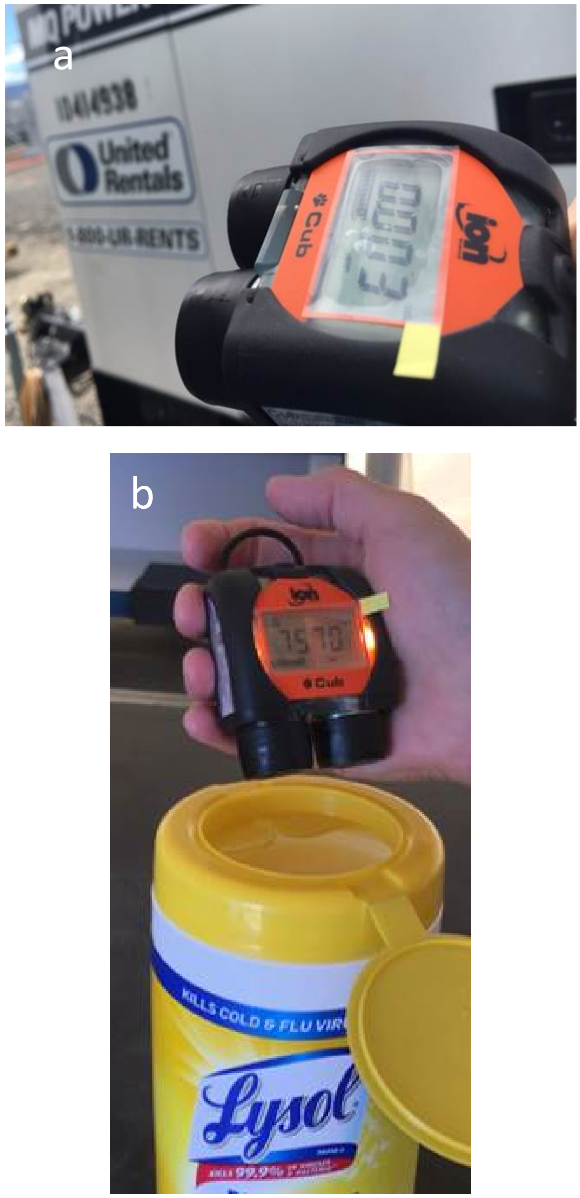
The calibration, bump testing, and loop testing of the personal chemical vapor badges has not been performed in conjunction with pilot-scale testing; however, they have been exercised to the procedural requirements informally and have performed well. Following the processes described in Attachment A5 of the VMDS Test Procedure (241A-OAT-0048), 9 of 11 ToxiRAE units have completed bump and loop testing and two of the Ion Science Cub units have successfully passed calibration testing.

5.11.3 Test Results

The testing of both ToxiRAE Pro and Ion Science Cub are integral to fulfilling test objectives PCV-1 (demonstrate operational requirements as described in VMDS FRD) and PCV-2 (test efficacy of personal chemical vapor badges for use in the tank farms environment). While the testing to date has not been officially performed as part of VMDS pilot-scale testing, they have provided very promising results. Figure 5-16 shows the Ion Science Cub taking readings next to an operating diesel-fired generator and a box of cleaning wipes. Both units have been unofficially bump and loop tested and met the required criteria from the VMDS Test Plan.

Both units are battery powered and have lasted for an 8-hr shift, but additional testing for RAMI and data collection features is necessary. Both of these units appear to operate as expected and we recommend they be included in Phase 2 testing to collect the necessary RAMI data.

Figure 5-16. Ion Science Cub Readings.



a. Showing a 3 ppb VOC reading next to an operating diesel generator.
b. Showing 75.5 ppb above a box of cleaning wipes.

5.12 DATA EVALUATION

With initiation of pilot-scale testing on August 9, 2016, data evaluation began to determine the functionality of the equipment that was part of the VMDS. Initially, this information was primarily used to direct project staff to problem areas that needed to be addressed to make the system operational. As testing progressed, analytical data was received that could be used in evaluating conditions at the tank farms. The Phase 2 testing will provide the operational data that will help determine which of the instruments will meet the reliability needs of the project in order to be considered for permanent placement in the tank farms vapor monitoring system.

With the successful operation of many of the sensors, analytical data will be used to help map conditions at the tank farms. It is the intent of the VM&DR Project to use the data collected during pilot-scale testing in conjunction with other studies (see Figure 2-2) to help map the vapors environment around the tank farms based on source location, meteorological data, concentration information and occupancy rates. It is hoped that this mapping can be used in a predictive manner to help reduce exposure by influencing work schedules and work locations.

The following subsections describe the process currently used to evaluate and report the data, and provide an outline for how data analysis will be performed in the future.

5.12.1 Current Data Evaluation Process

5.12.1.1 Daily Instrument Status Form

The test plan requires instrument data to be reviewed daily to evaluate the performance of each instrument set. The review performs two functions. The first and primary purpose of the daily logs is to status the equipment – especially during the early stages of pilot-scale testing. The status informs the software and instrument technicians of issues with each instrument. Second, it enables the review team to get familiar with the instruments regarding accuracy, precision, uptime, mean-time to repair, and required calibration frequency (drift). Information is captured by filling out a form from the test plan. Specific categories on the form are as follows:

- Data recorded
  - Is information making its way to OSI/PI?
  - If the instrument is up for even a short period of time it is considered to have been up?
- Data gaps
  - If any instrument is down >15 min during the day it is flagged as having a data gap.
  - Gap durations are not distinguished (i.e., whether the instrument was down for 15 min or 1000 min at one time it is still counted as one gap).
- Anomalous data
  - Non-standard instrument readings – defined as above background for COPCs.
  - Background, or typical non-zero concentrations, are not considered anomalous.
  - Instrument calibrations and bump tests are not considered anomalous.
- Comments
  - Capture any observations seen as important to pass on to the test director and team.
  - Specific information on any of the previous status information may be expounded upon (i.e., information on anomalous data such as start and end time and maximum value is recorded).
  - Known instrument or mapping issues.

The review of the data typically involves performing three steps. First, data for the instrument set is retrieved via OSI/PI as a trend. If data is observed in the trend, the data is extracted into an Excel file. Note that the increment used by OSI/PI during export is based on the amount of data retrieved – for one day's worth of data OSI/PI exports data at 1-min intervals (i.e., 1440 rows of data per day). The Excel file is then used to check for data gaps and get an indication of possible anomalous data. If anomalous data is viewed either in the initial trend chart (containing data for all instruments of that type) or the review of the exported data – then the trend for specific instruments is reviewed in OSI/PI. Review down to the instrument level enables the team to determine maximum values and durations of the anomaly. After the form is filled out, that information is used to develop review notes.

5.12.1.2 Daily Review Notes

Daily review notes are developed to quickly status each instrument set. The notes are developed following the review of each set of instruments for pilot-scale testing. Information presented targets end users of the information and does not focus on instrument software or hardware issues; however, these are captured on a high-level basis by stating the number of instruments reporting (in service). Specific information reported is as follows:

- Unless anomalous data is observed, information is presented on an instrument type basis (e.g., all AreaRAEs at a time).
- Number of instruments reporting to OSI/PI.
- Key chemical constituents are given status at all times.
  - Ammonia (NH_3)
    a. If present indicates probable vapor emissions from tank waste source.
    b. Status on every tool set that analyses for it.
- Other COPCs or monitored chemical constituents are given status when observed above background levels.
  - Figures of anomalous or informative trends are provided to quickly convey the observations.
- Specific items that the analysis team feels need to be addressed.

5.12.1.3 Weekly Summary Reports

Figure 5-17 provides a sample weekly summary report for DRIs for September 7 to September 14, 2016. Weekly reports will be made available to the general public on the Hanford Tank Vapors Website (http://hanfordvapors.com)/

Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Direct Reading Instrumentation Weekly Summary

9/7/16 6:00 – 9/14/16 6:00

Sampling Location –A & AP-Tank Farms (see maps below)

- RAE Meshguard (ammonia (NH_3))
- ToxiRAE (volitial organic carbon (VOC))
- AreaRAE (5 Total Operable Units)
- FIS – Gastronics (NH_3, 4 in A Tank Farm, 20 in AP Tank Farm, one located in the uncontrol area between the two tank farms)
- HazScanner (2 Total Operable Units)

Instrument Type	Tank Farm Tag prefix	Sensor Target Analyte	Instruments in A Tank Farm	Instrument in AP Tank Farm	242A Evaporator (between the two Tank Farms)
Haz-Scanner	200-GM-x-501y	VOC, CO, CO_2, SO_2, NO_2, H_2S, CH_4, NH_3, PM 2.5, and PM 10			
AreaRAE	200-GM-x-502y	VOC, CO, O_2, NH_3, and LEL			
ToxiRAE	200-GM-x-503y	VOC			
MultiRAE	200-GM-x-504y	VOC, CO, O_2, NH_3, and LEL			
RAE MeshGuard	200-GM-x-505y	NH_3			
FIS-Gastronics	200-GM-x-512y	NH_3, VOC, N_2O	Five	Twenty	One
Notes and Abbreviations:	Tank Farm Tag Prefix: x represents chemical compound reported for that instrument (e.g., CO, NH_3, VOC, etc.) and y represents the specific instrument; for example 200-GM-NH3-512A represents the ammonia sensor from Gastronics instrument 512A. NH_3 = ammonia CO = carbon monoxide CO_2 = carbon dioxide LEL = lower explosive limit NO = nitric oxide N_2O = nitrous oxide NO_2 = nitrogen dioxide PM 2.5 / PM 10 = particle monitors for >2.5µm and >10µm particles respectively H_2S = hydrogen sulfide SO_2 = sulfur dioxide VOC = volatile organic carbons				

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Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Weekly Summary Analysis: The following information is for the time period from September 7th at 6:00 AM through September 14th at 6:00 AM.

On September 7th, communication issues were resolved on the AreaRAEs and data was successfully transmitted to the database. Throughout most of the week carbon monoxide (CO) was reported in a recurring pattern, starting about 11:00 and subsiding at about 20:00, see Figure *1* below. Values reported were low, maximum of about 10 ppm; carbon monoxide is not on the Hanford Tank Farm chemical vapors of potential concern (COPC) list and values reported were significantly below the OSHA PEL[1].

Communication issues were also resolved by September 7th on the Mesh Guards, and no ammonia was measured from 15 operable units.

The FIS-Gastronics are instrumentation for ammonia, total volatile organic carbon (VOCs) and nitrous oxide (N_2O). All nitrous oxide (N_2O) sensors had been removed for temperature compensation work, but five were installed, four reporting, during this period. The Gastronics did not report ammonia during the week and except for early morning, prior to 8:30, on the 7th, total VOCs were below 1 ppm. Early morning on the 7th instrument 512Q reported VOCs up to about 5.5ppm. A total VOC limit of 2 ppm currently is employed by the Industrial Hygiene Program Technical Basis[2].

September 7th – 14th 2016 By Instrument:

HazScanner – No data was reported to OSI PI from 501A or 501B during this time period.

AreaRAE – Fixed instruments located in and around tank farms. See tables and figures below for weekly status and reporting information.

Table 1) AreaRAE Operational Status

Instrument	Sensor %Down				
	CO	LEL	NH3	O2	VOC
502A	100	12.4	12.4	12.4	100
502F	28.4	28.4	28.4	28.4	28.4
502G	30.8	30.8	30.8	30.2	30.8
502H	30.2	30.2	30.2	29.6	30.2
502I	30.2	30.2	30.2	30.2	30.2
502J	100	100	100	100	100

Notes:
1. % down is based on hourly interval data as exported from OSI PI[3]
2. Tags for B, C, D, and E were linked to tools F, G, H, and I respectively so it appears that they were reporting when they were not; their downtime was 100%.

[1] Add link to https://www.osha.gov/OshDoc/data_General_Facts/carbonmonoxide-factsheet.pdf
[2] Add link to IH Technical Basis Document.
Note: Information correlates with daily reports which report for the time frame of 6AM the previous day to 6AM of the report date.
[3] OSI PI is a data visualization software package from OSIsoft.

Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Table 2) AreaRAE Comments

Compound (units)	Comment	OEL	Action Level	Detection Range
CO (ppm)	Maximum value of 10ppm reported; see Figure 1.	50	25	1 – 500
LEL (%)	Constant at 0%.	N/A		0 – 100
NH_3 (ppm)	Below detection limit.	25	12.5	1 – 50
Oxygen (%)	For time period outside instrument calibration, minimum value reported on any of the four operating sensors (F, G, H, and I) was 20.9%, maximum value was 22.0%.		<19.5	1 - 30
VOC (ppm)	Below detection limit.			1 - 200

Figure 1: AreaRAE Carbon Monoxide Monitor Data.

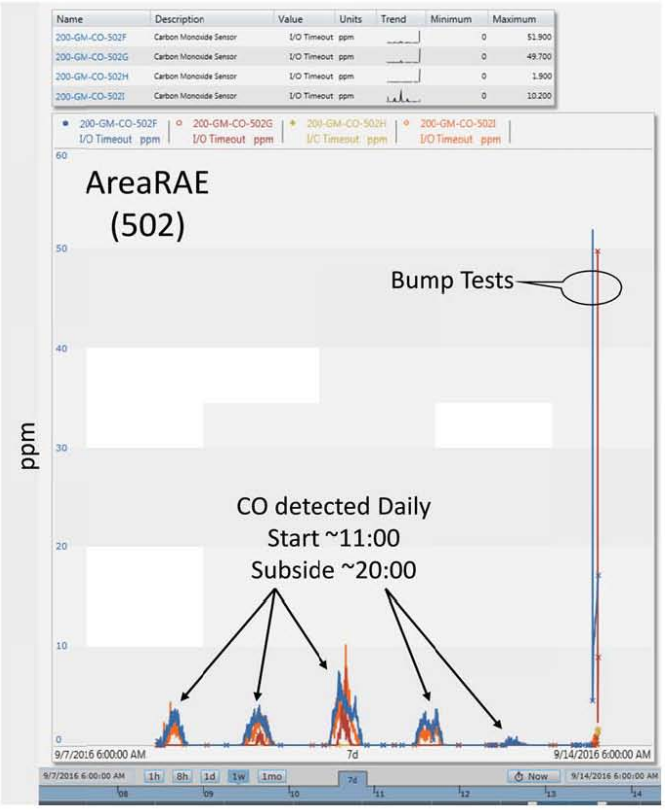

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Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

ToxiRAE – Instruments are personnel monitors and are not continuously utilized during daytime; they were not deployed for most of the time period under evaluation. Data recorded for only a short period of time for VOCs on a couple of instruments. See tables and figures for this week's uptime and reporting.

Table 3) ToxiRAE downtime by instrument sensor.

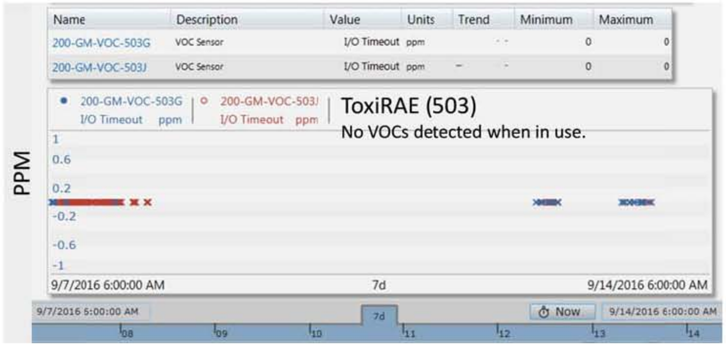
Instrument	VOC Sensor %Down	Instrument	VOC Sensor %Down
503A	100	503G	92.9
503B	100	503H	100
503C	100	503I	100
503D	100	503J	91.1
503E	100	503K	100
503F	100		

Notes: 1. % down is based on hourly interval data as exported from OSI PI[4]

Table 4) RAE Comments

Compound (units)	Comment	OEL	Action Level	Detection Range
CO (ppm)	Maximum value of 10ppm reported; see Figure 1.	50	25	1 – 500
LEL (%)	Constant at 0%.	N/A		0 – 100
NH_3 (ppm)	Below detection limit.	25	12.5	1 – 50
Oxygen (%)	For time period outside instrument calibration, minimum value reported on any of the four operating sensors (F, G, H, and I) was 20.9%, maximum value was 22.0%.		<19.5	1 - 30
VOC (ppm)	Below detection limit.			1 - 200

Figure 2) OSI PI graph for ToxiRAE reporting; VOCs.



[4] OSI PI is a data visualization software package from OSIsoft.

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Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

MultiRAE – Instruments are personnel monitors and are not continuously utilized during daytime; they were not deployed for most of the time period under evaluation. Issues with LEL sensors: 1) 504B reported consistent 45% values and not believed, 2) 504C indicated 20.9% - most likely a mislabeled oxygen sensor. See the figure below.

Table 5) MultiRAE downtime instrument sensor (note these are personal monitors)

Instrument	Sensor %Down				
	CO	LEL	NH3	O2	VOC
504A	100	100	100	100	100
504B	100	100	100	100	100
504C	100	99.4	99.4	99.4	99.4

Notes: a) % down is based on hourly interval data as exported from OSI PI[5]

Table 6) MultiRAE Comments

Compound (units)	Comment	OEL	Action Level	Detection Range
CO (ppm)	Instruments not reporting.	50	25	0 – 500
LEL (%)	None detected for the period of time in use by instrument 504C (a).	N/A		0 – 100
NH_3 (ppm)	None detected for the period of time in use by instrument 504C.	25	12.5	1 – 500
Oxygen (%)	20.9% for the period of time in use by instrument 504C (a).		<19.5	1 – 30
VOC (ppm)	None detected for the period of time in use by instrument 504C.			0.1 – 5000

Notes: a) The tag for oxygen is assumed to be crossed with the tag for LEL.

Mesh Guards – Ammonia detection.

Table 7) MeshGuard RAE downtime.

Instrument	NH3	Instrument	NH3	Instrument	NH3	Instrument	NH3
505A	8.9	505G	100	505M	8.9	505S	12.4
505B	100	505H	100	505N	11.2	505T	14.2
505C	100	505I	100	505O	11.8	505U	100
505D	12.4	505J	16	505P	16.6	505V	13.6
505E	100	505K	100	505Q	11.2	505W	100
505F	11.2	505L	8.9	505R	24.3	505X	8.9

Notes: 1. % down is based on hourly interval data as exported from OSI PI.

[5] OSI PI is a data visualization software package from OSIsoft.

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Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Table 8) RAE MeshGuard Comments.

Compound (units)	Comment	OEL	Action Level	Detection Range
NH_3 (ppm)	Below detection limit for the period of time in use by instrument 504C.	25	12.5	1 – 50

Notes: a) The tag for oxygen is assumed to be crossed with the tag for LEL.

Figure 3) RAE MeshGuard report; no ammonia detected during normal operations.

RAE MeshGaurd (505) (from 6:00 9/7/16 through 6:00 9/14/16)

Bump/Calibration Test

Name	Description	Value	Units	Trend	Minimum	Maximum
200-GM-NH3-505A	Ammonia Sensor	I/O Timeout	ppm		0	0
200-GM-NH3-505D	Ammonia Sensor	I/O Timeout	ppm		0	44.000
200-GM-NH3-505F	Ammonia Sensor	I/O Timeout	ppm		0	46.000
200-GM-NH3-505J	Ammonia Sensor	I/O Timeout	ppm		0	40.000
200-GM-NH3-505L	Ammonia Sensor	I/O Timeout	ppm		0	0
200-GM-NH3-505M	Ammonia Sensor	I/O Timeout	ppm		0	0
200-GM-NH3-505N	Ammonia Sensor	I/O Timeout	ppm		0	33.000
200-GM-NH3-505O	Ammonia Sensor	I/O Timeout	ppm		0	44.000
200-GM-NH3-505P	Ammonia Sensor	I/O Timeout	ppm		0	44.000
200-GM-NH3-505Q	Ammonia Sensor	I/O Timeout	ppm		0	41.000
200-GM-NH3-505R	Ammonia Sensor	I/O Timeout	ppm		0	0
200-GM-NH3-505S	Ammonia Sensor	I/O Timeout	ppm		0	37.000
200-GM-NH3-505T	Ammonia Sensor	I/O Timeout	ppm		0	33.000
200-GM-NH3-505V	Ammonia Sensor	I/O Timeout	ppm		0	35.000
200-GM-NH3-505X	Ammonia Sensor	I/O Timeout	ppm		0	0

9/7 6:00am – 9/14 6:00am

FIS-Gastronics – Monitor for ammonia, volatile organic carbon, and nitrous oxide. Earlier all Nitrous oxide sensors were removed for temperature compensation, at the time of reporting only five were installed.

Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Table 9) Gastronics Downtime by instrument sensor.

Instrument	NH3	VOC	N2O	Instrument	NH3	VOC	N2O
512A	5.9	4.7	18.3	512N	4.1	4.1	N/A
512B	5.3	4.7	22.5	512O	5.9	5.3	N/A
512C	3	1.2	17.2	512P	2.4	2.4	N/A
512D	61.5	60.9	76.3	512Q	6.5	6.5	N/A
512E	2.4	2.4	N/A	512R	100	100	N/A
512F	100	100	N/A	512S	48.5	47.3	N/A
512G	100	100	N/A	512T	3	3.6	N/A
512H	3	2.4	N/A	512U	5.9	5.9	5.9
512I	4.7	5.3	N/A	512V	100	100	N/A
512J	100	100	N/A	512W	74.6	74.6	N/A
512K	8.3	9.5	N/A	512X	94.1	94.7	N/A
512L	4.7	4.7	N/A	512Y	3.6	3.6	N/A
512M	2.4	3	N/A				

Notes: a) % down is based on hourly interval data as exported from OSI PI.

Table 10) Gastronics comments.

Compound (units)	Comment	OEL	Action Level	Detection Range
NH_3 (ppm)	Below detection limit.	25	12.5	1 – 500
VOC (ppm)	Reported on some instruments at values less than 1 ppm.			0 – 1000
N2O (ppm)	Below detection limit after calibrations.			0 – 1000

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Figure 5-17. Sample Weekly Summary Report: Direct-Reading Instruments. (8 sheets)

Figure 4) Gastronics report.

	NH3			VOC			N2O		
	Trend	Min	Max	Trend	Min	Max	Trend	Min	Max
-512A		0	79.000		0.700	141.400		0	1,008
-512B		0	0		0	0		Sensor Broke	1,100
-512C		0	100.000		0	50.200		0	1,023
-512D		-3.000	100.000		0.400	500.300		0	838.000
-512E		0	48.000		0	7.600		[-11059]	[-11059]
-512H		0	47.000		0	9.000		[-11059]	[-11059]
-512I		0	45.000		0	7.500		[-11059]	[-11059]
-512K		0	44.000		0	8.900		[-11059]	[-11059]
-512L		0	48.000		0	0.700		[-11059]	[-11059]
-512M		0	41.000		0	8.400		[-11059]	[-11059]
-512N		0	43.000		0	1.800		[-11059]	[-11059]
-512O		0	39.000		0	5.400		[-11059]	[-11059]
-512P		0	41.000		0	2.700		[-11059]	[-11059]
-512Q		0	42.000		0	9.700		[-11059]	[-11059]
-512S		0	0		0.200	1.400		[-11059]	[-11059]
-512T		0	0		0	0		[-11059]	[-11059]
-512U		0	39.000		0	9.200		0	1,100
-512W		0	0		0	0		[-11059]	[-11059]
-512X		0	0		0.700	1.000		[illegible]	[illegible]1059]
-512Y		0	0		0.700	7.100		[-11059]	[-11059]

1) All Min and Max values are in ppm.
2) VOC values highlighted with red are 10x actual values (instruments used during Bench Scale Testing and instrument scale was changed to increase reporting sensitivity).

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5.12.2 Future Data Evaluation

This report focuses of data analysis to support instrumentation and data processing system development – to aid in getting all instruments online, reporting, and calibrated. Once the systems are reliably reporting, the data analysis team will need to perform deeper reviews of the data to look for trends, triggers, and sources to support the final pilot-scale testing report. The VMDS Test Plan specifically calls out the following data analysis objectives:

- Determine which sensors meet the needs of VMDS and the utility/overlap of the functions of the sensors.
- Determine correlations between instruments and with the laboratory data. These correlations to the laboratory data should provide estimates of where threshold values for any alarms should be set for each instrument.
- Determine if the SAFER Systems software provides reasonable determination of plume location/severity.
- Determine correlation between events (e.g., releases of gases from the waste/increased pressures inside the tanks, sampling operations, retrieval activities, and changes in atmospheric temperature, wind events such as dust devils or wind shear, and tank /atmospheric temperature change) and plumes/release events/fugitive emission detections.
- Determine empirically if the leading indicators are reliable for estimating toxicity of plumes.
- For spectroscopy instruments, determine the ability of the instrument/spectra to identify ‘unknown’ compounds
- Evaluate all chemicals identified during testing and sampling for toxic exposure risk.
- Identify potential fugitive emissions sources and release points.
- Develop/evaluate models to provide predictive capabilities for tank farms vapor plumes.

The VMDS Test Plan further breaks down what will be performed with the data by defining the sub-objectives outlined in Table 5-.

A Data Quality Objectives process review will be performed during the instrument evaluation period of the test to evaluate the objectives in the initial release of the test plan to ensure they are still applicable and include all data analysis goals. The primary goal of this review will be to ensure that any new data analysis needs are captured and accounted for during testing, analysis, and reporting of the pilot-scale testing.

Table 5-13. Data Collection and Evaluation Sub-Objectives.

DC-1: Monitor select chemical vapors in real-time	
DC-1 sub-objectives	Quantify select chemical vapors present at primary sources in real-time
	Quantify select chemical vapors present inside the tank farms in real-time
	Quantify select chemical vapors present outside the tank farms in real-time
	Quantify select chemical vapors present at the tank farm worker in real-time
	Quantify select chemical vapors present at select heating, ventilation, and air-conditioning inlets in real-time
DC-2: Quantify select chemical vapors in and around the tank farms in real-time	
DC-2 sub-objectives	Quantify high level constituents (e.g., NH_3, N_2O, VOCs) at primary sources during normal and non-standard conditions
	Quantify low level constituents (COPCs) at primary sources during normal and nonstandard conditions
	Quantify high level constituents (NH_3, N_2O, VOCs) in general tank farm areas during normal and non-standard conditions
	Quantify low level constituents (COPCs) in general tank farm areas during normal and non-standard conditions
	Determine efficacy of instrumentation (mainly spectroscopy instrumentation) in identifying fugitive emissions locations
DC-3: Verify and correlate select chemical vapors monitored by real-time instrumentation to sample chemical vapors	
DC-3 sub-objectives	Determine if high-level species correlate to low-level species
DC-4: Examine transport of chemical vapors from source to workers	
DC-4 sub-objectives	Examine chemical vapor sources as they relate to worker location
	Examine chemical vapor plumes as they relate to worker location
	Examine meteorological conditions as they relate to chemical vapor plumes

From Table 7.2 of the Pilot Scale Test Plan.

6.0 PILOT-SCALE TESTING COMPLETION CRITERIA

The maturation of the technology elements within the VMDS is a main objective of pilot-scale testing, as stated in Section 3.0. The items needed to meet the testing objectives are enumerated in the TRM in Appendix C. Of those test requirements yet to be completed, the majority require conditions in the tank farms that have not yet been observed during this phase of testing:

- A vapor plume large enough with a high enough concentration of at least one COPC (detectable by DRIs)
- Seasonal changes in weather
- Release of vapor from a source other than the primary sources.

The most likely scenario for the generation of a vapor plume is the performance of waste-disturbing activities (e.g., a tank transfer). During pilot-scale testing to date, the tank farms have been in quiescent conditions due to situations outside of the project's control. Therefore, functioning of the VMDS in an off-normal situation could not be tested. It would be ideal to have multiple conditions with vapor plumes generated, but if the concentrations of at least one COPC detectable by DRIs can be observed.

The collection of RAMI data to evaluate the functioning of the individual instruments requires that the system undergo testing during all of the extremes in weather it is likely to see. The testing started on August 9, 2016, and proceeded through the remainder of the summer, seeing temperatures as high as 99 °F and wind gusts over 30 mph. For completeness, it may be desirable to go through another summer cycle to see temperatures over 100 °F and higher wind speed. The information that we do not have is the cold temperatures and precipitation (including snow, freezing rain, and fog), common for the Hanford Site in winter. To test in these conditions, we believe that testing should run through the end of April 2017.

The final condition that the VMDS needs to be exposed to is releases from sources not considered primary sources in the tank farms (e.g., sources other than the 241-AP stacks and 241-A PBFs). A desired function of the VMDS is to locate these secondary and tertiary sources. Since AOP-15 events (i.e. responses to reported odors or unexpected changes in vapor conditions) have occurred in all seasons, the project believes that testing should be continued through the full range of seasonal conditions to detect and monitor potential releases from these sources.

Once the VMDS has operated in these conditions, there will be sufficient information to make final determinations regarding the functionality of the equipment. The collection of analytical data should provide the information necessary to finalize the design plus begin the overall mapping effort of the vapor environment of the tank farms.

7.0 CONCLUSIONS AND RECOMMENDATIONS

According to the technology maturation process adopted and utilized by the VMD&R Project, pilot-scale testing of the VMDS was initiated to evaluate and mature the various technology elements making up the VMDS and to test how those subsystem components operated as an overall integrated system. It was anticipated that the testing and test results evaluations would lead to recommendations to proceed with a number of the technology elements and that there may also be some that are not recommended for future use. The deployed pilot-scale testing elements that are recommended for either future testing and/or to proceed with engineering and programmatic activities for general tank farm use will likely continue to be operated through FY 2017 (Phase 2). Those with issues that do not allow a recommended path forward may continue to be tested or may be removed from the testing scope before or after the phased VMDS testing is completed. The information collected in this test – both analytical data and RAMI data on the technology elements – is to be used to develop the technical basis for a final design for the current 241-A and 241-AP Tank Farm VMDS and to establish a general design and suitable approach to implement the design for future tank farm deployments.

For each VMDS test element, the VMDS Integrated Project Team considered the test data/results and the relevant test objectives, functional design requirements, test requirements, and test experience to establish the path forward recommendations. Evaluation criteria were established and used as a tool in establishing the specific recommendations. The Phase 1 test results evaluation criteria took into account the status of the system relative to satisfying the test requirements and overall test objectives and the team assigned rankings to assist in developing the final recommendations.

The outcomes of the testing of the various components varied widely. Some of the instruments were basically plug and play, so that after connection to TFLAN, they were providing data to the system on a consistent basis. Other instruments required varying degrees of modification that precluded initiation of testing to either late in the Phase 1 test duration or not all. Given the significant number of firsts for the VMDS pilot-scale testing, it was not unexpected to have technical challenges for each type of equipment both from a functional performance perspective as well as the ability for each to communicate data/information such that it could meet the overall test objectives (i.e., connecting to both the wireless infrastructure and Site monitoring and control system). It is also not unexpected that each type of equipment would require some degree of modifications/changes prior to being able to develop recommendations to proceed.

A tabular representation of the Phase 1 test results is contained in Appendix C of this report. The bulk of the test requirements that have not been satisfied relate to the collection of RAMI data and the exercising of the system during waste-disturbing vapor release events (i.e., waste transfer and/or 242-A Evaporator run). Assuming that vapor release events occur during the remainder of the phased VMDS pilot-scale testing (Phase 2 operation in FY 2017), it is expected that the bulk (if not all) of the TRM items can be satisfied.

An important part of the Phase 1 pilot-scale testing was to determine if the components could/should be transitioned from a testing regime to performing engineering and programmatic activities necessary to either make permanent the systems deployed in the 241-A and 241-AP Tank Farms and/or to proceed with deployment to other tank farms. In order to make this determination, the testing staff – cognizant engineers and scientific staff from WRPS, ABB, and PNNL – developed an evaluation process including rankings to help in understanding near-term and long-term path forward options for each test element. The ranking system includes five levels of readiness to proceed based on Phase 1 pilot-scale testing results. Each rank includes two distinct evaluation components; 1) how each element satisfied the relevant test requirements and general operations experience and 2) how it interacted with the communications/network infrastructure. The ranking system used by the team to establish the path forward recommendations was as follows:

- **Level 1** – The instrument is ready to be deployed as is. Specifications and functional requirements can be formalized and preliminary engineering/programmatic activities can be initiated.
- **Level 2** – The equipment is acceptable for use, but requires minor modification or additional engineering to operate successfully in the field. The field units can be used as modified but this will be formally confirmed in the FY 2017 time-frame. It may be the case that more testing is required before preliminary engineering begins but development of specifications can be initiated.
- **Level 3** – The equipment appears to operate as intended, but there is some uncertainty as to the final configuration/design and whether the equipment will meet requirements and/or operate as needed. May meet some of our needs but not all. The equipment needs more extensive modification and/or testing – some of which still need to be defined prior to providing a firm recommendation to proceed. Further test data is likely necessary to establish the final specifications and/or design. Recommend continued testing and evaluation. Speculative items will be determined by the end of FY 2017 pilot-scale testing to allow for a final path forward recommendation.
- **Level 4** – Only 50% confidence the equipment will meet requirements and/or operate as needed. Extensive testing and engineering will be required to establish a form that can be successful and meet project needs. Specification development should not be initiated until the later stages or after completion of Phase 2 testing.
- **Level 5** – Less than 30% confidence that the equipment will meet requirements and/or meet project/program needs. Do not recommend continuing with this equipment relative to tank farm use. Either continue testing (no impact and/or resources, or serves an identified test need) or discontinue use.

Each VMDS component was evaluated during a meeting that included the cognizant engineers, other technical staff, and project /program managers. The rankings and associated recommendations are as follows:

- Level 1
  - CMS
  - Blackline Loner IS+ GPS

  General Recommendations; 1) continue testing and 2) initiate development of engineering/procurement specifications, functional requirements and preliminary engineering/programmatic activities.
- Level 2
  - Cerex UV-FTIR stack monitor

- Cerex Air Sentry OP-FTIR
- Cerex open path UV-DOAS
- Area autosamplers
- Network Wi-Fi wireless infrastructure.

General Recommendations; 1) continue testing deployed units to obtain necessary RAMI data information, 2) finalize functional requirements and 3) initiate final technical/procurement specifications.

- Level 3
  - Gastronics FIS (Level 4 for the N_2O sensor)
  - LMS (not required to be developed for field use, backup unit)
  - Portable FLIR OGI camera.

  General Recommendations; 1) continue testing deployed units to obtain sufficient data to establish a path forward recommendation and 2) continue to resolve N_2O sensor issues.

- Level 4
  - SAFER Real-Time
  - AreaRAE
  - ToxiRAE
  - RAE MeshGuard NH_3 detector.
- General Recommendations; Continue testing system as-is and develop path forward actions with the vendor to resolve identified issues; if issues can be resolved in next couple of months then implement changes and continue testing of the deployed system. Note: additional testing of the SAFER Real-Time plume modeling features will likely be required but is not yet included in the current test plan scope. In parallel with implementation of this recommendation, evaluate alternative vapor dispersion models (real-time or next best) and include models that have been recently identified and implement if viable.
- Level 5
  - HAZ-SCANNER
  - MultiRAE Pro.

  General Recommendation: Continue testing during Phase 2 (minimal impact).

- Not Ranked
  - Ion Science Cub
  - Fixed FLIR OGI (concept tested via testing of portable FLIR but no testing of unique features; continuous scan and wireless communication of data).

Below are the individual assessments of each system/piece of equipment that makes up the pilot-scale VMDS. The items will be discussed in order of their ranking level, with the most promising technologies discussed first.

7.1 LEVEL 1 EQUIPMENT

7.1.1 The Coastal Environmental Meteorological Station

The CMS was set up in the tank farms with no major issues. The units have operated as planned for the duration of the test. The communications with TFMCS and OSI/PI are well established and the units rank as a Level 1 relative to this attribute as well as from a functional performance perspective. It is recommended that the units remain operational and be used during Phase 2 testing to support the evaluation of the other equipment and overall VMDS. Two potential improvements to the system have been identified, but they are only for convenience and the systems can be used as received/deployed. The two subject modifications include a modified tower design that precludes use of a crane for installation. A new design is proposed that would require only two workers and hand tools to install. The second modification is to allow easier-to-read field data displays.

7.1.2 Blackline Loner IS+ GPS

The units (50) were procured off-the-shelf and have met all requirements during testing. The only drawback is that they do not report through the TFMCS and OSI/PI and are currently only report directly to the SAFER Real-Time data monitoring and collection system. We recommend a parallel evaluation be performed to provide an alternate method for data collection and tracking in the event that the SAFER Real-Time software is not utilized. In addition, we recommend abstaining from future purchases of these GPS units until the evaluation and associated tank farms communications/network changes are implemented and these changes are tested to allow the units to report data directly to the TFMCS.

7.2 LEVEL 2 EQUIPMENT

7.2.1 Cerex UV-FTIR Stack Monitor

The stack monitor evaluated in this test is similar to a unit already in operation at the 242-A Evaporator. The UV-DOAS portion of the unit is similar (same manufacturer and the same components) to the UV-DOAS stack monitor already in operation at the 242-A Evaporator. The system has inherent calibration, with initial functional acceptance testing (FAT) providing the necessary calibration verification using NH_3 and CH_4. The main concern is that two subsystem components have failed, namely an air compressor and the radio for wireless communications. These issues have been subsequently resolved. However, this is a strong indication that we need further RAMI data prior to providing a final recommendation for specification development and/or preliminary engineering for future siting of the equipment. Based on results to date, it is expected that the equipment will meet project/program objectives/requirements and that the unit should continue into Phase 2 testing. It is important to note that the unit's ability to communicate with the tank farms network has been as planned (met all expectations) and that the unit is considered Level 1 relative to meeting communications requirements.

7.2.2 Cerex Air Sentry OP-FTIR

The system includes an inherent calibration feature with initial calibration with NH_3 and CH_4 performed during the FAT. This feature precludes calibration of the unit as a test requirement; formal operation will include vendor services to calibrate the unit, as required. The instrument has been deployed in pilot-scale testing as a 'fence line' monitor and operated as expected but has yet to be tested in inclement weather (e.g., freezing rain potentially coating the reflectors, fog interfering with the light beam). During testing, the power supply on one of the units failed and was replaced. During Phase 2 testing, the reliability of this component still needs to be evaluated. Because of these uncertainties, it is recommended that additional testing is necessary to provide RAMI-related data. However, it is also recommended that specification development and preliminary engineering be initiated including work for future siting of the equipment. We recommend that the OP-FTIR continue in Phase 2 testing. It is important to note that the unit's ability to communicate with the tank farms network has been as planned (met all expectations) and that the unit is considered Level 1 relative to meeting communication requirements.

7.2.3 Cerex Open Path UV-DOAS

Same discussion as for the OP-FTIR. The system includes an inherent calibration feature with initial calibration with NH_3 and CH_4 performed during the FAT. This feature precludes calibration of the unit as a test requirement; formal operation will include vendor services to calibrate the unit, as required. The instrument has been deployed in pilot-scale testing as a 'fence line' monitor and operated as expected but has yet to be tested in inclement weather (e.g., freezing rain potentially coating the reflectors, fog interfering with the light beam) and therefore it is recommended that additional testing is necessary to provide RAMI-related data. However, it is also recommended that specification development and preliminary engineering be initiated including work for future siting of the equipment. We recommend that the OP-FTIR continue in Phase 2 pilot-scale testing. It is important to note that the unit's ability to communicate with the tank farms network has been as planned (met all expectations) and that the unit is considered Level 1 relative to meeting communication requirements.

7.2.4 Autosamplers

The autosamplers have operated for a significant portion of Phase 1 pilot-scale testing. These units satisfied all tests with respect to the TRM and have provided over 400 samples. Issues with sample collection and analysis still need to be resolved prior to final specification development and purchasing. In addition, there is some minor work required to develop software to allow for automatic triggering of the grab samplers when a DRI alarms, but this is a TOC function and is not expected to be difficult or costly. It is recommended that testing continue with these units to support the corroboratory sample analysis for the other equipment in Phase 2 pilot-scale testing and to gather RAMI-related data. Also, engineering and programmatic activities should be initiated to procure and deploy these units in other tank farms as required.

7.2.5 Network Wi-Fi Wireless Infrastructure

The network infrastructure has redundant wireless access points in 241-A and 241-AP Tank Farms that improve the ability of sensors to be monitored. Network infrastructure is monitored 24/7 by the Site-wide network monitoring contractor, Mission Support Alliance, so disruptions can be communicated to Tank Farm Operations in a quick manner. In addition, the Site contractors have tools to analyze wireless network performance. The VMDS was one of the first to take advantage of the Wi-Fi network infrastructure, which brought to light several hardware and performance issues. Initial issues were worked through, but continued monitoring and tuning of the system will be required as sensors are added to the Wi-Fi network, as there is a limit on the number of clients which can connect without performance issues. Wireless communication was used for the pilot-scale testing because cost and schedule did not allow for hardwired communication. For the final system, hardwiring will be the preferred communications method and wireless will only be used where hardwiring is not practical.

Because of early performance issues, the spectroscopy instruments were moved to a temporary wireless network utilizing Hanford Site standard radio equipment. However, the testing schedule prohibited these instruments from being brought back to the Site network infrastructure. FY 2017 testing should continue to utilize the site network infrastructure and work with Mission Support Alliance to improve system performance and determine the maximum number of sensors that can be on the system. The spectroscopy instruments should be moved off the temporary infrastructure over to the Site wireless access points and system performance should be monitored when this occurs.

7.3 LEVEL 3 EQUIPMENT

7.3.1 Gastronics Fixed Instrument Skid

The Gastronics FIS is a multisensory skid that has had mixed results in the testing so far. Seventeen of 25 units were installed in the field and were successfully calibrated, bump tested, loop tested, and communicated with the SAFER Real-Time software. Each unit has three sensors: NH_3, VOC, and N_2O. The performance of each sensor is independent of the other sensors therefore relative performance was also different and each of the three sensor types were evaluated separately.

The NH_3 sensors all performed well including calibration, bump, and loop testing, but the amount of testing is not adequate to recommend them for future use at this time (primary reason for Level 3 designation). The VOC sensor also performed well in the calibration, bump, and loop testing, but three of the sensors failed during the test. It is recommended that the unit's NH_3 and VOC sensors continue to obtain data to provide the basis for a path forward recommendation. The overall recommendation for continuing with the unit as currently designed and configured will likely hinge on the performance of the N_2O sensor.

Initially the N_2O sensors would not hold calibration and readings were suspect. It was later determined in discussion with the vendor that the instruments were configured at the factory for constant temperature indoor use. Several of the units were then reconfigured to account for temperature variations and seemed to perform better; however, not enough data has been collected with the new configuration to make a firm judgment on whether the problem has been satisfactorily resolved. In addition, there are also some minor issues related to communication with the data collection systems (TFMCS, OSI/PI, SAFER). There are several potential paths forward for this equipment; 1) continue using the instruments as is and ignore/disable the N_2O sensor if the temperature compensation does not work, 2) remove/replace the N_2O sensor with a better N_2O sensor, and 3) separate the NH_3 and VOC sensors from the FIS and use them separately. It is recommended that the project continue collecting data through the end of Phase 2 to better understand the issues and the most viable path forward.

Several of the Gastronics units have not been able to communicate with the Site-wide Wi-Fi infrastructure. This is primarily caused by a vendor supplied low powered radio and low gain omni-directional antenna which was placed within a grounded frame of the unit. To date, communication between all Gastronics units have had short periods of dropout (minutes) several times per day which cause data loss and an indication of poor quality on the control system. The cause of this is yet to be determined. The Gastronics vendor has also acknowledged a condition where a unit goes into a non-responsive state until power is cycled and this has been experienced several times.

7.3.2 Lufft Meteorological Station

The setup of communications for the LMS has been problematic, but because of the simplicity of the instrument, the project has high confidence the instrument will operate satisfactorily. The LMS will be used as the only met station when the CMS is sent for calibration (6- to 8-week turn around). The LMS will be kept in a standby mode in if the CMS requires calibration, fails or underperforms. In that that event, the LMS will be brought online – which is anticipated to be less costly and less time consuming than purchasing a new CMS system.

7.3.3 Portable FLIR Optical Gas Imaging Camera

The portable OGI camera had been used to collect video of emissions emanating from the 241-AP exhauster stack starting at the top of the stack and continuing on to record the ammonia 100 m from the stack (downwind). In addition, an emission plume at much lower concentrations (~13 ppm) was recorded at the tank 241-A-103 PBF. This unit is used extensively in industry to locate plumes (EPA recommended method) and we recommend that we use this unit as is and complete the TRM required testing in Phase 2. It is also recommended that the project evaluate a viable/reasonable path forward test approach to determine the unit's capability to detect NH_3 at potential tank farm levels (0 to 100 ppm). About 100 ppm was seen in the 241-AP stack during pilot-scale testing using the high sensitivity mode; the unit performed well during the bench-scale testing; however, the NH_3 concentrations were very high (1000 ppm or greater) and were detected using standard mode.

7.4 LEVEL 4 EQUIPMENT

7.4.1 SAFER Real-Time

The SAFER Real-Time software performs well in its function as a data collection program. The system's displays do a good job of showing the results from the instruments in an easy to understand graphical representation and the system has a good subroutine for alerting when instrument alarms are triggered. The software also performs a data management function. The software can receive a limited number of data sets however those data sets can be quite large. A problem identified during testing is that if any one of the sensors in a data set is not functioning properly, then none of the data is recorded or displayed. The final two SAFER functions are modeling components – forward modeling (where is the plume going) and backward modeling (where the plume came from). The SAFER Real-Time modeling was exercised using several actual and simulated plumes and the system has yet to make a reasonable prediction of either the forward or backward plumes. It is expected that with a concerted effort, the vendor could identify and resolve these issues; however, vendor support is dubious based on recent discussions. There has not as yet been a high-level gas release (>50% of the OEL) of any species within the tank farms. The TFMCS and OSI/PI can perform many of the data collection and management functions as well as alarm notification functions. We recommend that, since the capability has been developed and the operation of the SAFER Real-Time software is fully staffed, the project continue to operate the software through Phase 2 testing to allow the vendor time to modify the software. In conjunction, we recommend the project work on a parallel path to develop alternative models that can meet the project's dispersion modeling needs or to determine the most viable path forward.

7.4.2 RAE MeshGuard NH_3 Detector

The RAE MeshGuard are working as prescribed by the vendor. The units have met the calibration and set up requirements set forth in the test plan/procedure. With respect to the instrument operation, we regard them as a Level 2. However, a significant issue is that the RAE communications system is inherently very cumbersome and has been evaluated at Level 4. All of the RAE equipment communicates with ProRAE Guardian, which then goes through a Modbus followed by an interpreter and then to TFMCS and OSI/PI. This complexity leads to units dropping out of communications periodically resulting in an operational availability factor of 80%. In addition, the battery life may not be optimal, with some units (those farthest away from the ProRAE Guardian) needing battery change-outs monthly. The fact that these units are small and inexpensive would allow for greater coverage that could compensate for the down time and battery life issues. It is recommended that a value engineering study be performed to compare the use of the MeshGuard with other more expensive NH_3 monitors (e.g., Gastronics FIS) with respect to the coverage and down time.

7.4.3 AreaRAE

The AreaRAE units are already used by TOC IH groups and are working as expected with respect to setup, calibration, and bump testing. It appears that there may be an issue with drift and calibration frequency, but an evaluation cannot be made until more RAMI data is collected. Until these issues are resolved the equipment ranks as a Level 3. As stated in the MeshGuard discussion, there is a serious issue with the cumbersome communications system that has been ranked as a Level 4. All of the RAE equipment communicates with ProRAE Guardian, which then goes through a mod bus followed by an interpreter and then to TFMCS and OSI/PI. For the AreaRAEs, the vendor is introducing a model using TCP communications which may solve these issues; therefore, it is recommended that the vendor provide a near term onsite demonstration of this newer model to determine if the communications issues can be resolved. We recommend that the units remain in the testing for Phase 2 to collect the data to further understand the issues and to assist in issue resolution.

7.4.4 ToxiRAE

The ToxiRAE units are designed as chemical badges meant to be worn by employees during operations in the tank farms. While the ToxiRAE units met the initial testing requirements (calibration and connection with TFMCS and OSI/PI), they were not tested further due to resource constraints (discipline mix of VMD&R Project staff was not adequate to oversee the testing). It is recommended that the units continue to be tested to allow for a final recommendation. Additional data from the bench-scale tests and non-Hanford industry experience was also considered in ranking these units, however communications issues caused them to be ranked at Level 4. It is important to note that there are alternatives in the market place for VOC badges and this equipment is therefore not one of the high-priority VMDS technologies. We recommend that the deployed units be part of Phase 2 to the end of Phase 2 pilot-scale testing.

7.5 LEVEL 5 EQUIPMENT

7.5.1 HAZ-SCANNER

Upon receipt of the HAZ-SCANNER units to support bench-scale testing, it was clear that the units were not robust enough to meet requirements for tank farm use. Extensive modifications to the structure of the system, the power supply (solar panels), the communications systems, and active air sampling system were required. These modifications were performed by the project to allow testing of the varied sensors but this was time consuming and left little time for testing to be performed. A great deal of testing is still required and it is uncertain if the vendor is capable of making a unit that meets project needs. This unit performs the same function as the Gastronics FIS units and can readily be replaced by them so they are not critical to the VMDS operations. We recommend the units continue to be tested in Phase 2 testing to capture the sensor performance attributes which may be used either as stand-alone sensors or in other multiple sensor units (e.g., the Gastronics FIS). However, unless there is an unexpected benefit observed from its performance, continuing to develop this system for future use in not recommended.

7.5.2 MultiRAE Pro

The three MultiRAE Pro units met the initial set up and calibration requirements; however, during operation, all of the NH_3 sensors failed and needed to be replaced. In addition several of the CO sensors failed. The communications endemic to the RAE systems is also an issue with these units. The Hanford Site IHP uses MultiRAE Pro instruments and indicates that sensor failure is a continuing issue – they have numerous replacements on hand because they need to replace sensors on a regular basis. This unit has redundant capabilities with other instruments in the VMDS and therefore it is not a critical component. However, unless there is an unexpected benefit observed from its performance, due to the significant effort and manpower necessary to keep these units operational, it is recommended that the project immediately discontinue their use.

7.6 NOT RANKED

7.6.1 Ion Science Cub

The Ion Science Cub has been tested and has met expected calibrations and connectivity requirements set forth by the vendor (it is not made to connect wirelessly and has an auto-calibration feature). The Cub units would be used in the same capacity as the ToxiRAE units. The Cub units show promise and it is recommended that they progress to field deployment on a broader basis than the pilot-scale test platform as a personal VOC badge. We recommend that testing of this unit continue through Phase 2.

7.6.2 Fixed FLIR Optical Gas Imaging Camera

Vendor support is required for instrument setup and the vendor was not available to travel to the site during Phase 1 testing. The instrument is installed and has power, but the software must be installed and configured before the unit is fully operational. These issues have precluded any testing of the system. However, since the portable OGI camera, which has the same internal functioning camera is operating well, we recommend that the installation continue and the unit undergo testing in Phase 2. Comments relative to the portable FLIR above are also relevant to the fixed unit.

7.7 PHASE 2 RECOMMENDATIONS

In addition to evaluating the suitability of each of the components that make up the VMDS, the pilot-scale testing team devised a number of recommendations for more general testing that needs to be completed in Phase 2. Testing shall include work to make all VMDS components operational and generating data to allow for a more technically defensible set of recommendations for moving forward with final design and activities required for deployment in other tank farms. These more general recommendations are as follows:

- Continue Phase 2 testing until a reasonable amount of data for RAMI determination can be collected – estimated to be between 3 and 6 months.
- When waste-disturbing activities are planned, make sure all pertinent instrumentation is in place to record any release events – for example, a PTR-MS, OP-FTIR, autosamplers (both grab and area), DRIs in strategic locations based on daily weather conditions (all data to date have been collected under quiescent conditions).
- Devise a test to exercise the full system, including modeling efforts (a planned release of a detectable gas in quantities that will provide responses from a large fraction of instruments).
- Perform Phase 2 testing long enough to collect the data necessary for design inputs to the final VMDS design (e.g., occupancy rates, location of fugitive emissions sources, determination of the efficacy of leading indicators, selecting new species as leading indicators, identification of potential new COPCs) – anticipate a minimum of 4 months of testing.
- Perform extensive data evaluation on pilot-scale data plus data from other studies that can provide a better picture of the tank farms environment.
- Evaluate modifications required within the tank farms infrastructure to help determine the timelines required to set up a new VMDS.
- Evaluate potential abatement technologies and locations if detection does not provide the safety margin required for working in tank farms without supplied air.

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APPENDIX A

LIST OF CHEMICALS OF POTENTIAL CONCERN

Table A-1. Chemicals of Potential Concern. (2 sheets)

Chemical Groups	Vapor Compound	Hanford 59-COPC Number	OEL[1] (ppm)	10% of OEL (ppm)	CAS Number[2]
Other	Ammonia	1	25	2.5	7664-41-7
	Nitrous Oxide	2	50	5	10024-97-2
	Mercury	3	0.003	0.000	7439-97-6
Hydrocarbons	1,3-Butadiene	4	1	0.1	106-99-0
	Benzene	5	0.5	0.05	71-43-2
	Biphenyl	6	0.2	0.02	92-52-4
Alcohols	1-Butanol	7	20	2	71-36-3
	Methanol	8	200	20	67-56-1
Ketones	2-Hexanone	9	5	0.5	591-78-6
	3-Methyl-3-butene-2-one	10	0.02	0.002	814-78-8
	4-Methyl-2-hexanone	11	0.5	0.05	105-42-0
	6-Methyl-2-heptanone	12	8	0.8	928-68-7
	3-Buten-2-one	13	0.2	0.02	78-94-4
Aldehydes	Formaldehyde	14	0.3	0.03	50-00-0
	Acetaldehyde	15	25	2.5	75-07-0
	Butanal	16	25	2.5	123-72-8
	2-Methyl-2-butenal	17	0.03	0.003	1115-11-3
	2-Ethyl-hex-2-enal	18	0.1	0.01	645-62-5
Furans and Substituted Furans	Furan	19	0.001	0.0001	110-00-9
	2,3-Dihydrofuran	20	0.001	0.0001	1191-99-7
	2,5-Dihydrofuran	21	0.001	0.0001	1708-29-8
	2-Methylfuran	22	0.001	0.0001	534-22-5
	2,5-Dimethylfuran	23	0.001	0.0001	625-86-5
	2-Ethyl-5-methylfuran	24	0.001	0.0001	1703-52-2
	4-(1-Methylpropyl)-2,3-dihydrofuran	25	0.001	0.0001	34379-54-9
	3-(1,1-Dimethylethyl)-2,3-dihydrofuran	26	0.001	0.0001	34314-82-4
	2-Pentylfuran	27	0.001	0.0001	3777-69-3
	2-Heptylfuran	28	0.001	0.0001	3777-71-7
	2-Propylfuran	29	0.001	0.0001	4229-91-8
	2-Octylfuran	30	0.001	0.0001	4179-38-8
	2-(3-Oxo-3-phenylprop-1-enyl)furan	31	0.001	0.0001	717-21-5
	2-(2-Methyl-6-oxoheptyl)furan	32	0.001	0.0001	51595-87-0
Phthalates	Diethyl Phthalate	33	0.550	0.055	84-66-2
Nitriles	Acetonitrile	34	20	2	75-05-8
	Propanenitrile	35	6	0.6	107-12-0
	Butanenitrile	36	8	0.8	109-74-0
	Pentanenitrile	37	6	0.6	110-59-8
	Hexanenitrile	38	6	0.6	628-73-9

Table A-1. Chemicals of Potential Concern. (2 sheets)

Chemical Groups	Vapor Compound	Hanford 59-COPC Number	OEL[1] (ppm)	10% of OEL (ppm)	CAS Number[2]
Nitriles (Cont.)	Heptanenitrile	39	6	0.6	629-08-3
	2-Methylene butanenitrile	40	0.3	0.03	1647-11-6
	2,4-Pentadienenitrile	41	0.3	0.03	1615-70-9
Amines	Ethylamine	42	5	0.5	75-04-7
Nitrosamines	N-Nitrosodimethylamine	43	0.003	0.0003	62-75-9
	N-Nitrosodiethylamine	44	0.001	0.0001	55-18-5
	N-Nitrosomethylethylamine	45	0.003	0.0003	10595-95-6
	N-Nitrosomorpholine	46	0.006	0.0006	59-89-2
Organophospates & Organophonates	Tributylphosphate	47	0.2	0.02	126-73-8
	Dibutylbutylphosphonate	48	0.007	0.0007	78-46-6
Halogenated Hydrocarbons	Chlorinated Biphenyls	49	0.001	0.000	varies
	2-Fluoropropene	50	0.1	0.01	1184-60-7
Pyridines	Pyridine	51	1	0.1	110-86-1
	2, 4-Dimethylpyridine	52	0.5	0.05	108-47-4
Organonitrites	Methyl nitrite	53	0.1	0.01	624-91-9
	Butyl nitrite	54	0.1	0.01	544-16-1
Organonitrates	Butyl nitrate	55	2.5	0.25	928-45-0
	1,4-Butanediol, dinitrate	56	0.05	0.005	3457-91-8
	2-Nitro-2-methylpropane	57	0.3	0.03	594-70-7
	1,2,3-Propanetriol, 1,3-dinitrate	58	0.05	0.005	623-87-0
Isocyanates	Methyl Isocyanate	59	0.02	0.002	624-83-9

[1] Eight-hour time weighted occupational exposure limit.
[2] Chemical Abstract Services chemical identification number.

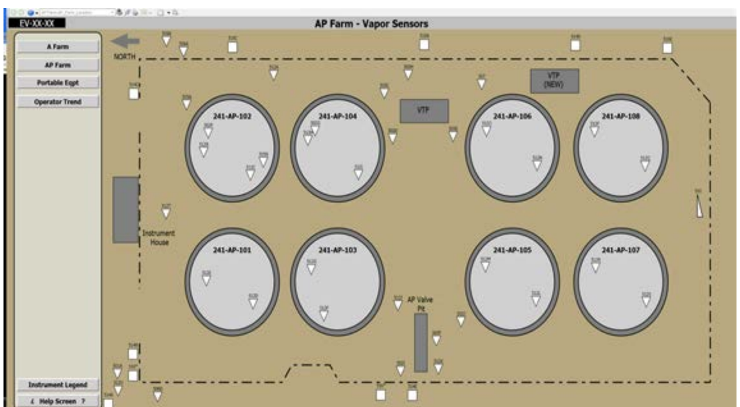
APPENDIX B

FACT SHEETS FOR VAPOR MONITORING AND DETECTION SYSTEM COMPONENTS

washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**Tank Farms Software**	**Version 1.0 2016/7/21 RBC**

General Description: The Tank Farm Monitoring and Control System (TFMCS) is the Hanford Site Tank Operations Contractor's distributed control system for the Hanford Site tank farms. The TFMCS provides monitoring and control of exhauster and waste transfer operations. The OSIsoft PI Historian is used as a repository of data produced by tank farm plant systems and selected data is available for viewing via OSI/PI Coresight.

Hanford Tank Farms Application: Instrument data associated with Vapor Monitoring and Detection System pilot-scale testing will be available to TFMCS and OSI/PI Historian to provide real-time monitoring and trending capability for all vapor concentration and meteorological readings. The TFMCS will provide Engineering, Operations, and Industrial Hygiene personnel with a dedicated workspace to supervise the pilot-scale testing and to respond to vapor instrument events when they occur. Selected sensors will have alarm capabilities to alert personnel when vapor thresholds have been reached, which will allow personnel to take actions and alert others. Sensor trends will be available on OSI/PI Historian to analyze the behavior of detected chemical vapors. The pilot-scale screens for each tank farm, with test equipment, will be available. When vapor thresholds are exceeded, icons on the graphic will change color to indicate the event. By clicking on the icon, a secondary graphic provides real time sensor values and trending capabilities.



TFMCS Sample Screen

OSIsoft PI Coresight Sample Screen

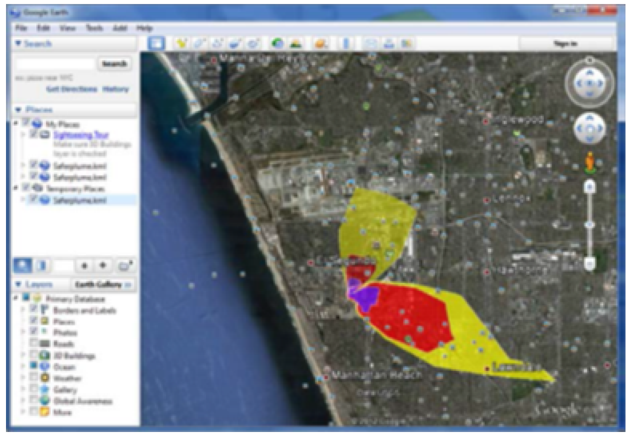
Capabilities/Features:

- Real-time monitoring, control, and data management
- Centralized control rooms and workstations

washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	**SAFER Real-Time**	**Version 1.0 2016/8/8 RBC**

General Description: SAFER® Real-Time®, by SAFER Systems LLC, is a fixed facility emergency management software solution that uses real-time data to monitor, measure, and visualize the effects of an unplanned vapor release event and allows facility operators to initiate planned mitigating action to reduce potential consequences. The Real-Time system collects vapor concentration data from facility sensors along with meteorological data to model the dispersion characteristics of released vapor plumes. The system can also be used to develop potential vapor release scenarios to aid in development of response actions, training, and to assist in establishing mitigation actions prior to an actual release.

Actual release data from a leak at an industrial location monitored by SAFER System software.



Hanford Tank Farms Application: The Real-Time system will be installed and operated from locations established near the Hanford Site tank farms and from remote client locations. As part of Vapor Monitoring and Detection System pilot-scale testing, various sensors (i.e., open path Fourier transform infrared spectrometers, ultraviolet differential optical absorption spectrometers, and direct-reading instruments) and meteorological stations will be located in and around the 241-AP and 241-A Tank Farms. All real-time data is received and stored directly in the tank farms OSIsoft PI Historian database and then as input to the Real-System. The system will collect the vapor related data and provide an initial indication of chemical vapor releases that are trending to or are higher than pre-determined limits. The dispersion modeling capability will then be used to predict vapor plume configurations and concentrations in near real-time event conditions.

Capabilities and Features:

- Quick response mode
- Data acquisition configuration
- Meteorological conditions monitoring and analysis
- Sensor data monitoring and analysis
- Emergency response
- Geographical visualization (vapor plume characteristics and concentration profiles)
- Building infiltration
- Post-event analysis/documentation

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washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	**Primary Meteorological Station**	**Version 1.0 2016/7/21 RBC**

General Description: The primary meteorological station, by Coastal Environmental Systems, Inc., is an array of instruments including an anemometer, rain gauge, two temperature and humidity sensors, a solar radiation sensor, and a barometer feeding into a data-logger that then can transmit the data wirelessly. The system is mounted on a 10-m tower that is permanently affixed to a concrete base.

Hanford Tank Farms Application: The primary meteorological station will be deployed as part of Vapor Monitoring and Detection System pilot-scale testing. The unit will be placed in the south end of 241-AP Tank Farm for accurate weather readings. This data will be transmitted to the Tank Farm Monitoring and Control System to correlate instrument readings with real-time weather data.

Capabilities/Features:

- Anemometer
- Rain gauge
- Temperature and humidity sensors
- Data logger
- Wi-Fi radio
- Back up battery supply
- Barometer
- Solar radiation sensor
- Permanent supplied power

washington river protection solutions

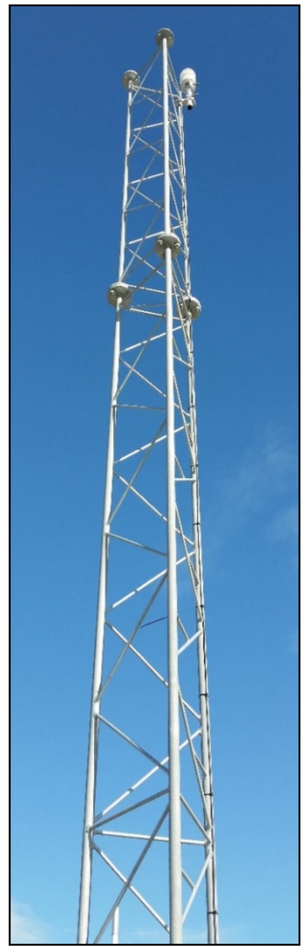
One-Page Fact Sheet

Tank Farm Vapors Control Team

Secondary Meteorological Station

Version 1.0 2016/7/21 RBC

General Description: The secondary meteorological station, by Lufft, is a solar-powered weather station with multiple integrated sensors that measures solar radiation, wind direction, wind speed, air temperature, relative humidity, and air pressure that can then be transmitted wirelessly. The system is mounted on a 10-m tower that is permanently affixed to a concrete base.



Hanford Tank Farm Application: The station will be deployed as part of Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The unit will be placed northwest of the 241-AY/AZ Tank Farms complex for accurate weather readings. This data will be transmitted to the Tank Farm Monitoring and Control System to correlate instrument readings with real-time weather data.

Capabilities/Features:

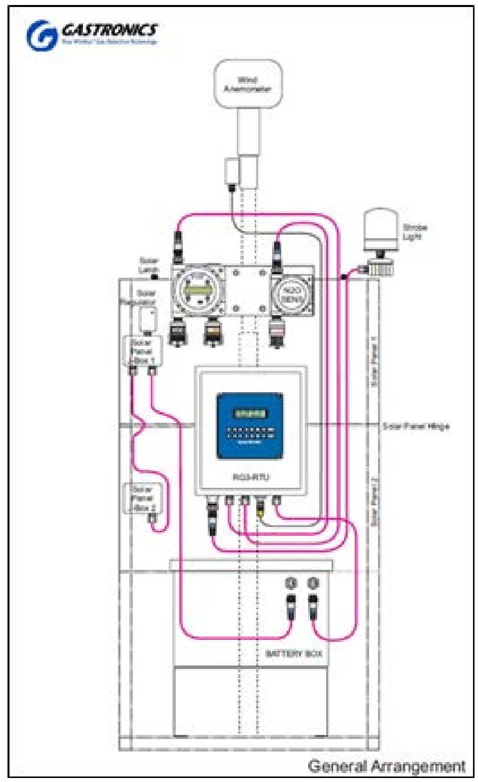
- Single integrated instrument
- Solar powered
- Solar radiation sensor
- Wind direction
- Wind speed
- Air temperature
- Relative humidity
- Air pressure

WS510-UMB		
WS310-UMB without wind sensor		
Technical data	Dimensions	Ø approx. 150 mm, height 392 mm
	Weight	Approx. 1.5 kg
Temperature	Principle	NTC
	Measuring range	–40 to 80 °C
	Accuracy	± 0.2 °C (–20 °C to 50 °C), otherwise ±0.5 °C (>–30 °C)
Relative humidity	Principle	Capacitive
	Measuring range	0 to 100% RH
	Accuracy	±2% RH
Radiation	Spectral range (50% points)	285 to 2,800 nm
	Measuring range	4000 W/m²
Air pressure	Principle	MEMS capacitive
	Measuring range	300 to 1200 hPa
	Accuracy	±0.5hPa (0 to 40°C)
Wind direction	Principle	Ultrasonic
	Measuring range	0 to 359.9 °
	Accuracy	<3° RMSE >1.0 m/s
Wind speed	Principle	Ultrasonic
	Measuring range	0 to 75 m/s
	Accuracy	±0.3 m/s or 3% (0 to 35 m/s) RMS of reading, whichever is greater ±5% (>35 m/s) RMS

RPP-RPT-59729, Rev. 0

washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**Gastronics Fixed Instrument Skid**	**Version 1.0 2016/7/21 RBC**

General Description: The Gastronics fixed instrument skid is a direct-reading, transportable integrated set of gas sensors and meteorological instruments that provides real-time gas measurement for ammonia (NH_3), total volatile organic compounds (VOC), nitrous oxide (N_2O), and directional wind data. The system is specifically designed for long-term outside use and includes optional alarm signals, solar/battery power, and wireless data transmission.



Hanford Tank Farms Application: The fixed instrument skid was built specifically for the Hanford Site tank farms environment and will be deployed as part of Vapor Monitoring and Detection System pilot-scale testing. Twenty-five units will be placed in and around potential vapor release points in the 241-AP and 241-A Tank Farms to provide indication of chemical vapors. The wind information measured by the units will be used to understand dispersion of chemical vapors and improve the accuracy of dispersion models. This data, along with other direct-reading instrument data, will be transmitted to the Tank Farm Monitoring and Control System.

Capabilities/Features:

- Solar power/battery system
- Real-time data transmission via 2.4 GHz Wi-Fi
- Three chemical sensors:
  - VOC via 10.6 eV photoionization detection (5 ppb to 50 ppm)
  - NH_3 via electrical conductivity sensor (1 to 100 ppm)
  - N_2O via electrical conductivity sensor (1 to 1000 ppm)
- 3-dimension anemometer (6 units) and 2-dimension anemometer (19 units)

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One-Page Fact Sheet

Tank Farm Vapors Control Team

RAE MeshGuard

Version 1.0 2016/7/21 RBC

General Description: The MeshGuard®, by RAE Systems, Inc., is a direct-reading instrument that provides real-time measurements of ammonia (NH_3) and optional alarm signals when exposure exceeds preset limits. The portable gas monitor contains a sensor that monitors ammonia in hazardous environments.

Hanford Tank Farm Application: The MeshGuard will be used to provide continuous chemical vapor monitoring with wireless real-time data availability to support Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

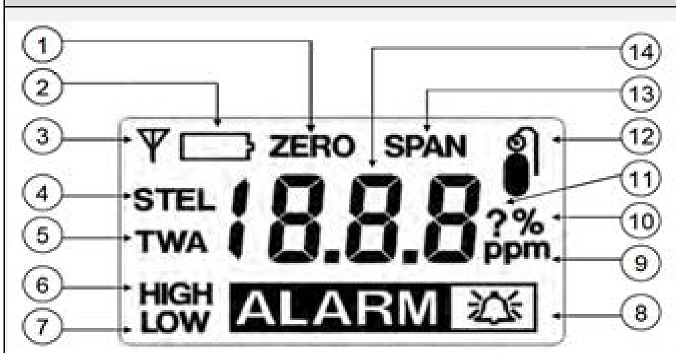
Capabilities/Features:

- Direct-reading for NH_3
- Portable, battery powered, wireless, inexpensive device
- Parts per million volatile organic compound measurement
- Real-time chemical monitoring and data transmission
- Maintainable with replaceable sensors, pump, and battery
- Fully automatic bump testing and calibration
- IEEE 802.15.4 mesh network functionality with 64-bit encryption
- Robust wireless mesh network with auto network forming and configuration
- Operating distance up to 300 m, line of sight

Instrument Diagram

1 LED alarm
2 LCD
3 Buzzer alarm
4 Sensor gas inlet
5 Battery cover (on bottom)
6 Y/+, MODE, and N/- keys
7 Antenna
Not visible: Optional magnetic mount on rear

Display Overview



1*	Zero calibration
2	Low battery indicator
3	Wireless communication (if on, the monitor is in STD; if blinking, the monitor is RTR)
4*	Short term exposure limit (STEL)
5*	Time weighted average (TWA)
6, 8*	High alarm
7, 8*	Low alarm
9*	Gas concentration unit, ppm
10*	Gas concentration unit, %
11	Save setting
12,13*	Span calibration
14	Reading value

Note: Concentration unit is shown as either ppm (9) or % (10).

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washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**AreaRAE**	**Version 1.0 2016/7/21 RBC**

General Description: The AreaRAE®, by RAE Systems, Inc., is a direct-reading instrument that provides real-time vapor measurements and optional alarm signals when concentrations exceed preset limits. This portable multi-gas monitor contains up to five sensors that monitor toxic gases, oxygen, and combustible gases in hazardous environments.

Hanford Tank Farm Application: AreaRAEs are currently used extensively in the Hanford Site tank farms as the primary hazardous vapor monitors. A number of these units (10) will be installed for Vapor Monitoring and Detection System pilot-scale testing in a solar-powered enclosure and will evaluate unit operations as fixed monitor versus portable monitor. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities and Features:
- Solar/battery powered
- Real-time data transmission by wireless communications
- Maintainable w/ replaceable sensors, pump, and battery
- Five chemical sensors
  1. Volatile organic compounds via 10.6 eV photoionization detection (1 to 200 ppm)
  2. Carbon monoxide via electrical conductivity sensor (1 to 500 ppm)
  3. Oxygen via electrical conductivity sensor (1 to 30%)
  4. Ammonia via electrical conductivity sensor (1 to 50 ppm)
  5. Lower explosive limit via catalytic bead sensor (0 to 100%)

Weatherproof Enclosure with Solar Panel and Sun Shield

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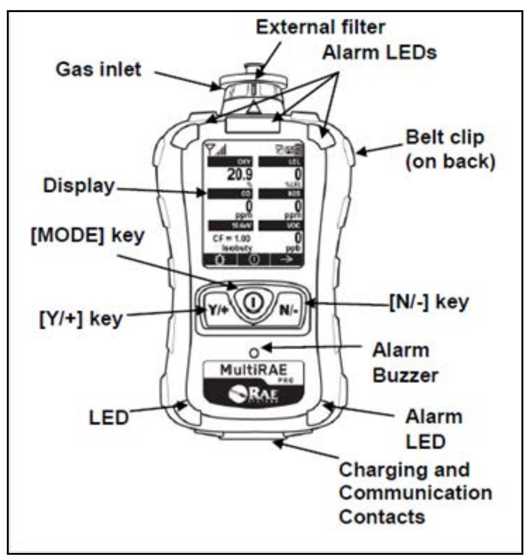
washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	MultiRAE Pro	Version 1.0 2016/7/21 RBC

General Description: The MultiRAE® Pro, by RAE Systems, Inc., is a direct-reading instrument that provides real-time measurements and optional alarm signals when exposure exceeds preset limits. The portable multi-gas monitor contains up to five sensors that monitor toxic gases, oxygen, and combustible gases in hazardous environments.

Hanford Tank Farm Application: The MultiRAE Pro is currently used at the Hanford Site to provide continuous chemical vapor monitoring to work teams. It will be used to support Vapor Monitoring and Detection System pilot-scale testing, but with addition of wireless real-time data availability. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities/Features:

- Portable, battery powered, wireless
- Real-time data transmission
- Maintainable with replaceable sensors, pump, and battery
- Lightweight with belt/lanyard attachment
- Five chemical sensors
    6. Volatile organic compounds via 10.6 eV photoionization detection (1 to 200 ppm)
    7. Carbon monoxide via electrical conductivity sensor (1 to 500 ppm)
    8. Oxygen via electrical conductivity sensor (1 to 30%)
    9. Ammonia via electrical conductivity sensor (1 to 50 ppm)
    10. Lower explosive limit via catalytic bead sensor (0 to 100%)



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washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**HAZ-SCANNER**	**Version 1.0 2016/7/21 RBC**

General Description: The HAZ-SCANNER™ environmental perimeter air station (EPAS) wireless is an ambient air quality monitor capable of measuring and documenting gases and vapors with up to 11 electrochemical sensors including nitrogen dioxide; sulfur dioxide; ozone; carbon dioxide; particulates; volatile organic compounds (VOC); meteorological data (e.g., rain, solar irradiance, wind direction and speed); and more. The HAZS-SCANNER EPAS is designed for exposure and is constructed of weatherproof components and electronics enclosures.

Hanford Tank Farms Application: The Washington River Protection Solutions, LLC (WRPS) EPAS support structure has been fortified to Hanford tank farm environment specifications. The WRPS HAZ-SCANNER monitor contains eight sensors that monitor VOCs, SO_2, CH_4, CO_2, NO_2, H_2S, CO, NH_3 and contains a suite of meteorological instruments. The EPAS provides direct-readings in real-time with data logging capabilities.

Capabilities/Features:
- Solar/Battery powered
- 2.4 GHz Wi-Fi communication
- Meteorological data
  - Wind speed and direction
  - Relative humidity
  - Temperature
- Chemical sensors
  - VOCs (5 to 50,000 ppb)
  - CO (20 to 10,000 ppb)
  - CO_2 (50 to 5,000 ppm)
  - SO_2 (20 to 5,000 ppb)
  - NO_2 (20 to 5,000 ppb)
  - H_2S (50 to 2,000 ppb)
  - CH_4 (50 to 25,000 ppm)
  - NH_3 (0 to 100 ppm)
  - PM 2.5
  - PM 10

™ HAZ-SCANNER is a trademark of SKC.

washington river protection solutions

One-Page Fact Sheet

Tank Farm Vapors Control Team

Stack Analyzer

Version 1.0 2016/7/21 RBC

General Description: The stack analyzer is made up of an ultraviolet (UV) differential optical absorption spectrometer (DOAS) and a Fourier transform infrared (FTIR) spectrometer in a single fixed continuous stack emissions monitor. The system provides real-time multi-gas measurement of gases using both UV and infrared radiation providing the capability to monitor many different chemical vapors common to the tank farms.

Hanford Tank Farms Application: The UV-DOAS/ FTIR dual channel system will be utilized in Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The system will be used to detect chemical vapor emissions from the operating 241-AP Tank Farm exhaust stack. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities/Features:

- Fixed line-powered, wireless data transmission (Wi-Fi enabled) and integrated networking
- Real-time analytics with dedicated PC, user interface, and data storage, automated reporting
- Temperature controlled gas inlet/outlet lines, customizable alarms, NEMA 4 enclosure
- Interferometer and cryo-cooled single element detector with 2 to 14 μ range, one wavenumber resolution, actual measured resolution of less than 0.5 wavenumber, all ZnSe optics (non-hygroscopic) (FTIR) advanced ultra-low noise, miniature spectrometer with thermoelectrically-cooled solid state detector array, deep UV capability beginning at 200 nm (UV)

Key Chemicals Detected	
FTIR Spectrometer	**UV Spectrometer**
Nitrous Oxide	Nitric Oxide
Ammonia	Sulfur Dioxide
Methane	P-Xylene
1,3-Butadiene	M-Xylene
Benzene	O-Xylene
1-Butanol	Oxygen
Methanol	Ozone
2-Hexanone	Benzene
3-Buten-2-one	Toluene
Formaldehyde	Ethylbenzene
Acetaldehyde	Acetaldehyde
Butanal	Formaldehyde
Furan	Ammonia
Acetonitrile	1-2-4 Trimethylbenzene
Propanenitrile	1-3-5 Trimethylbenzene
Ethylamine	Styrene
N-Nitrosodimethylamine	1,3 Butadiene
N-Nitrosomorpholine	
Tributyl phosphate	
Pyridine	
Methyl Nitrite	
Butyl Nitrite	
Methyl Isocyanate	
N-Nitrosodiethylamine	

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washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	Open Path FTIR	Version 1.0 2016/8/8

General Description: The open path (OP) Fourier transform infrared (FTIR) spectrometer system provides real-time multi-gas measurement (qualification and quantification) of gases. The OP-FTIR operation is based on Beer-Lambert's absorption law that relates the relationship between the quantity of light absorbed and the number of molecules in the light path. The produced absorption spectra are compared to a library of chemicals allowing for monitoring of multiple (300+) chemicals in near real-time. There are only two consumable items: the infrared source and the MCT (mercury-cadmium-telluride) detector with stirling engine compressor. The integrated solid state air conditioner increases longevity of electronics. Gold-coated optical surfaces are bound with chromium and coated with magnesium fluoride (MgF_2) to improve corrosion resistance. Inherent calibration eliminates the need for time consuming and expensive routine calibration. Quality assurance audits require only small quantities of primary standard gas.

Key Compounds Detected
FTIR Spectrometer
Nitrous Oxide
Ammonia
Methane
1,3-Butadiene
Benzene
1-Butanol
Methanol
2-Hexanone
3-Buten-2-one
Formaldehyde
Acetaldehyde
Butanal
Furan
Acetonitrile
Propanenitrile
Ethylamine
N-Nitrosodimethylamine
N-Nitrosomorpholine
Tributylphosphate
Pyridine
Methyl Nitrite
Butyl Nitrite
Methyl Isocyanate
N-Nitrosodiethylamine

Hanford Tank Farms Application: The OP-FTIR system is utilized in Hanford Site Vapor Monitoring and Detection System pilot-scale testing. There are two OP-FTIR spectrometers: one fixed path monitor and one multi-path monitor (autonomous scanning). This system is used to detect chemical vapor emissions from the operating 241-AP Tank Farm with emphasis on tank farm boundaries (fence line detection). The data will be available via wireless communications to the tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities/Features:

- Fixed line-powered, wireless data transmission (Wi-Fi enabled) and integrated networking
- Analog/serial outputs, internal controller for data logging
- Real-time analytics with dedicated computer, user interface, and data storage, automated reporting
- Interferometer and cryo-cooled single element detector with 2 to 14 µ range and resolution of <0.5 wavenumber

Fixed Path OP-FTIR

Multi Path OP-FTIR

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Tank Farm Vapors Control Team	**UV-DOAS Spectrometer**	**Version 1.0 2016/8/8**

Key Compounds Detected
UV-DOAS Spectrometer
Nitric Oxide
Sulfur Dioxide
P-Xylene
M-Xylene
O-Xylene
Oxygen
Ozone
Benzene
Toluene
Ethylbenzene
Acetaldehyde
Formaldehyde
Ammonia
1-2-4 Trimethylbenzene
1-3-5 Trimethylbenzene
Styrene
1,3 Butadiene

General Description: The ultraviolet (UV) differential optical absorption spectrometer (DOAS) is a fixed continuous emissions monitor. It provides real-time multi-gas measurement (qualification and quantification). The UV-DOAS is based on Beer-Lambert's absorption law that relates the relationship between the quantity of light absorbed and the number of molecules in the light path. A high-intensity light source (i.e., high-pressure xenon lamp) produces the UV wavelengths through the gas field and the system analytics determine the losses from molecular absorption using advanced computer calculations. The produced absorption spectra are compared to a library of chemicals to determine the vapor stream constituents. UV spectral system allows monitoring of multiple (300+) compounds in near real-time.

Hanford Tank Farms Application: The UV-DOAS system will be utilized in Hanford Site Vapor Monitoring and Detection System pilot-scale testing. It will be used to detect chemical vapor emissions from the operating 241-A Tank Farm fixed open path monitoring. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities/Features:

- Fixed line-powered, wireless data transmission (Wi-Fi enabled) and integrated networking
- Analog/serial outputs, internal controller for data logging
- Real-time analytics with dedicated computer, user interface, data storage, and automated reporting
- Advanced ultra-low noise, miniature spectrometer with a thermoelectrically-cooled solid state detector array, deep UV capability beginning at 200 nm (UV) (FTIR)

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Tank Farm Vapors Control Team

Portable FLIR

Version 1.0 2016/8/8 RBC

General Description: The portable FLIR® Systems, Inc. camera is an optical gas imaging instrument that visualizes and pinpoints gas or vapor emissions from a distance by utilizing the physics of fugitive gas leaks. The camera provides remote indication of visible and invisible chemical gases and vapors that are present. The camera can scan areas of interest that are difficult to reach with conventional methods. The FLIR model G306pt is a hand held portable camera with optional tripod and user software.

Hanford Tank Farms Application: The portable FLIR is one of the optical instruments providing monitoring of general area, fugitive emissions and targeted vapor detection for Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The camera allows the user to carry it to any location within the tank farms to monitor different areas and specific locations to characterize vapor plumes from known or unknown (fugitive) release points. While the camera cannot identify specific chemicals, it can see the presence of a wide range of chemicals when they differ in temperature from the background temperature of the image.

Capabilities/Features:

- Infrared image, visual image, and high sensitivity modes
- GPS location data automatically added to every image
- Real-time data transmission via Wi-Fi wireless communications
- 2 independent video streaming channels MPEG4 using WLAN (via Wi-Fi)
- Robust weatherproof case
- Non-radiometric infrared video recording MPEG4
- Visual video recording MPEG4
- Optical zoom 36×
-

Chemicals Detected
Portable FLIR
Acetyl Chloride
Acetic Acid
Allyl Bromide
Allyl Chloride
Allyl Fluoride
Ammonia (NH_3)
Benzene
Bromomethane
Chlorine Dioxide
Ethanol
Ethyl benzene
Ethyl Cyanoacrylate
Ethylene
Furan
Hexane
Hydrazine
Hexane
Methylsilane
Isoprene
Methyl Ethyl Ketone
Methyl Vinyl Ketone
Propenal
Propene
R 134a
Sulfur Hexafluoride (SF_6)
Tetrahydrofuran
Trichloroethylene
Uranyl Fluoride
Vinyl Chloride
Vinyl Cyanide
Vinyl Ether

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washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	**Fixed FLIR**	**Version 1.0 2016/6/30 SDW**

General Description: The fixed FLIR® Systems, Inc. camera is an optical gas imaging instrument that visualizes and pinpoints gas or vapor emissions from a distance. The system detects infrared energy (heat) and converts it into an electronic signal which is then processed to produce a thermal image on the unit's onboard video monitor. The camera provides remote indication that chemical gases/vapors (visible or invisible) are present based on the difference in temperature of the gas from the background temperature. It can continuously scan areas of interest that are difficult to reach with conventional methods. Movement of the unit is automated and allows vapor monitoring by continuously scanning areas. It also allows programing of up to 128 preset positions-of-interest, or suspect sources locations.

Chemicals Detected
Fixed FLIR
Sulfur Hexafluoride (SF6)
Acetyl Chloride
Acetic Acid
Allyl Bromide
Allyl Chloride
Allyl Fluoride
Ammonia (NH3)
Benzene,
Bromomethane
Chlorine Dioxide
Ethanol
Ethyl benzene
Ethyl Cyanoacrylate
Ethylene
Furan
Hexane
Hydrazine
Hexane
Methylsilane
Isoprene
Methyl Ethyl Ketone
Methyl Vinyl Ketone
Propenal
Propene
R 134a
Tetrahydrofuran
Trichloroethylene
Uranyl Fluoride
Vinyl Chloride
Vinyl Cyanide
Vinyl Ether

Hanford Tank Farms Application: The ability of the fixed FLIR camera to detect and indicate the presence of chemical vapors in the Hanford Site tank farms will be evaluated as part of Vapor Monitoring and Detection System pilot-scale testing. The units will be used to detect emissions from primary sources (exhausters and passive breather filters) and fugitive sources if present. If the fixed FLIR camera indicates vapors are present, other pilot-scale vapor monitors with the capability to detect speciation and concentrations will be used to confirm the camera results. The fixed FLIR camera will be collocated with one of the pilot-scale open path Fourier transform infrared units in a tower that will allow unobstructed scanning of the 241-AP Tank Farm.

Capabilities/Features:

- Fixed, line powered, real-time indication devices
- Infrared image, visual image, and high sensitivity modes
- Real-time data transmission via Wi-Fi wireless communications
- Robust weatherproof enclosure and rotating camera housing
- Mounted on a precision pan/tilt mechanism
- Optical zoom 36× continuous

Fixed FLIR Camera

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washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**Loner Personal GPS**	**Version 1.0 2016/7/21 RBC**

General Description: The Loner® personal global positioning system (GPS), by Blackline Corp., is a lightweight battery operated unit with multiple capabilities to include wireless communication, fall detection, silent emergency alert, and worker motion monitoring.

Hanford Tank Farms Application: The Loner GPS units will be evaluated/tested as part of Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The personal units will be used to provide real-time location and activity data on workers while in the tank farms. This information can then be used to focus future detection technologies based on the traffic data. The Loner GPS can also be used to signal an emergency either locally and remotely through manual initiation by the wearer or automatically through the worker motion monitor and fall detection.

Capabilities/Features

- GPS radio: 20-channel, antenna accuracy 5 m, indoor positioning, beacon resolution 5 m, real-time location turnaround time 20 seconds
- True fall detection, tri-axis accelerometer, tri-axis gyrometer, plus software processing
- Rechargeable Li-ion battery 1500 mAH, battery life 25 hours continuous at 20 °C (68 °F)
- Indicator: acoustic buzzer, LED and vibration motor, buzzer sound pressure level 90 db at 10 cm
- Radio, antenna, communication

® Loner is a registered trademark of Blackline Safety Corp.

washington river protection solutions	**One-Page Fact Sheet**	
Tank Farm Vapors Control Team	**Area/Stack Autosampler and Canister Cases**	**Version 2.0 2016/7/21 RBC**

General Description: The area/stack autosampler is designed to perform integrated continuous air sampling.

Sampler protected by weatherproof enclosure containing controller, interface (laptop), and sorbent tubes.

Hanford Tank Farms Application: In support of Hanford Site Vapor Monitoring and Detection System pilot-scale testing, seven units will be located around 241-AP and 241-A Tank Farms, including one sampling directly from the AP exhauster and one from the tank 241-A-103 passive breather filter.

Capabilities/Features:

- System provides capability for analysis of 55 of the 59 Hanford Site constituents of potential concern (all that are detectable using gas chromatography–mass spectrometry analysis)
- Continuous whole-air and sorbent media sampling
- Can be remotely triggered to facilitate "quick" sample collection
- Sorbent media sample collection
  - Collects 3 different sets of sorbent media simultaneously (1 set = sample, duplicate, and blank)
- Whole-air sample collection
  - 8 air sampling canisters (7 samples and 1 duplicate)
- Canister cases stored in 2 cases to facilitate easy handling of the sampling canisters (4 canisters per case; 2 cases)
- Accepts varied sorbent media including Carbotrap® 300, Carbotrap 150, SKC 226-118 (XAD®-2), Thermosorb-N (TDX), SKC 226-119 (XAD-2) and SKC 226-119-7 (XAD-2)
- Powered by 115 VAC, via standard 20-amp cord

5 Ports for Sorbent Tubes or Cartridges

Ports can be used to support two parallel tubes each (sample and duplicate).

8 Summa Cans in 2 Carrying Cases

Rugged canister cases are loaded in the laboratory and sent into the field as single unit.

UL 508A/NEMA 4 Enclosure

Shelves in back for canister cases; includes sun shield, air conditioning and heater.

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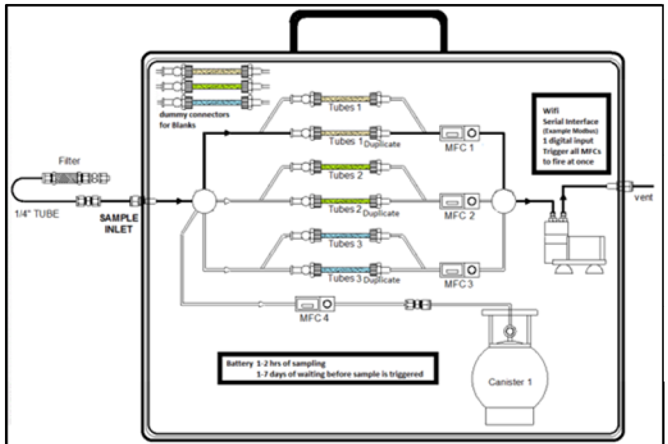
® XAD is a registered trademark of The Dow Chemical Company.

washington river protection solutions	One-Page Fact Sheet	
Tank Farm Vapors Control Team	Grab Autosampler	Version 2.0 2016/7/21 RBC

General Description: The grab autosampler is designed to perform targeted single-event whole-air and sorbent media grab sampling. This sampler can be automatically triggered by another direct-reading instrument (DRI) vapor monitoring instrument or can be triggered locally or remotely by an operator when there is an indication that chemicals of potential concern (COPC) may exist in that area.



Case with sorbent tubes (colored in picture) and air sampling canisters

Hanford Tank Farms Application: The grab autosampler units will be carried into tank farm areas to support general work activities to provide the capability to quickly collect a whole air sample and sorbent media sample in the event that a work team senses the presence of chemical vapors. The units will be associated to selected Vapor Monitoring and Detection System pilot-scale testing DRIs. The grab sampler is activated by workers or DRIs if there are indications of a vapor releases.

Capabilities/Features:

- Provides sample media that allow analysis for 55 of the 59 Hanford Site COPCs (all that are detectable using gas chromatography mass spectrometry analysis)
- Sorbent media sample collection
  - Collects two different sets of sorbent media simultaneously (1 set = sample, duplicate, and blank)
- Whole-air sample collection
  - 1 air sampling canister
- Single-triggered sampling event that all media is filled simultaneously
- Accepts varied sorbent media including: Carbotrap® 300, Carbotrap 150, SKC 226-118 (XAD®-2), Thermosorb-N (TDX), SKC 226-119 (XAD-2) and SKC 226-119-7 (XAD-2)
- Self-contained, battery-operated system in a transportable, weatherproof/rugged case
- Includes standard Hanford Site Industrial Hygiene/Health Physics Technician inlet filter for internal contamination control

Weatherproof case includes controller, interface (laptop), canister, and sorbent tubes.

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Tank Farm Vapors Control Team	**Ion Science Cub**	**Version 1.0 2016/7/21 RBC**

General Description: The Cub, by Ion Science, is a direct-reading instrument that provides real-time volatile organic compound (VOC) measurements, is wearable (badge), and includes optional alarm signals when exposure exceeds preset limits.

Hanford Tank Farms Application: The Cub units will be evaluated as part of Hanford Site Vapor Monitoring and Detection System pilot-scale testing. The units will be used to provide real-time, on-the-person indication of tank farm chemical vapors. The units will also be compared to other selected wearable direct-reading photoionization detectors. The Cub data will not be available to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, or SAFER® Real-Time®) in real time, but will be available to the software once the data is stored for evaluation. The recorded data may be considered as part of a broader Vapor Monitoring, Detection, and Remediation Project evaluation.

Capabilities/Features:

- Parts per billion VOC measurement; 10.6 eV
- Range: 0.1 to 5000 ppm and 0.001 ppb to 5000 ppm
- Accuracy: +/-5% display reading + one digit
- Battery life up to 16 hours with 4-hour charge time
- 2-point calibration via docking station
- Wall charging
- Alarm: LED, audio (86 dB at 300 mm), vibrate
- Belt attachment
- Weighs 3.91 oz.
- Measures 2.4 × 2.6 × 2.3 in.

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Tank Farm Vapors Control Team	ToxiRAE Pro	Version 1.0 2016/7/21 RBC

General Description: The ToxiRAE® Pro, by RAE Systems, Inc., is a direct-reading instrument that provides real-time measurements of volatile organic compounds (VOC) and optional alarm signals when concentrations exceed preset limits. The portable gas monitor contains a sensor that monitors VOCs in hazardous environments.

Hanford Tank Farms Application: The ToxiRAE Pro is currently used at the Hanford Site to provide continuous chemical vapor monitoring to work teams. It will be used to support Vapor Monitoring and Detection System pilot-scale testing in the same capacity, but with addition of wireless real-time data availability. The data will be available via wireless communications to tank farms software (Tank Farm Monitoring and Control System, OSIsoft PI Historian, and SAFER® Real-Time®).

Capabilities/Features:

- Direct-reading instrument for VOCs 10.6 eV photoionization detection
- Portable, battery powered, wireless, inexpensive device
- Parts per billion VOC measurement
- Real-time chemical monitoring and data transmission
- Maintainable with replaceable sensors, pump, and battery
- Fully automatic bump testing and calibration
- IEEE 802.15.4 mesh network functionality with 64-bit encryption
- Robust wireless mesh network with auto network forming and configuration
- Operating distance up to 300-m, line of sight

Lightweight for carrying on belt or lanyard.

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® Real-Time is a registered trademark of SAFER Systems LLC.

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One-Page Fact Sheet

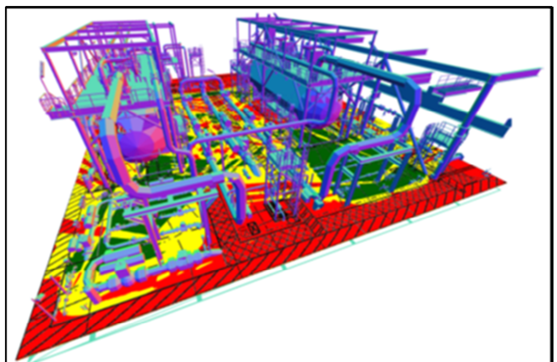
Tank Farm Vapors Control Team	**Kenexis**	Version 1.0 2016/7/21 RBC

General Description: Kenexis Consulting Corp. provides safety-based design analysis and performance-based evaluation of chemical vapor hazards to commercial industry standards (i.e., IEC 61511 / ISA 84 and ISA TR84.00.07) to determine the optimum placement and specification of chemical sensing technologies. Evaluation includes development of a design philosophy to define system performance targets and consideration of the degree of hazards, hazard location, frequency of release, and occupancy rates. These factors form a design basis, that when evaluated for risk (quantitative risk analysis) using risk and dispersion modeling, allows for mapping of vapor sensors to mitigate risk.

Hanford Tank Farms Application: Kenexis will provide a toxic gas monitoring system design philosophy, design basis, chemical vapor hazard risk analysis, and system design for the Hanford Site tank farms and associated facilities. The design basis will provide for sensor location and required performance characteristics necessary to mitigate risks in the tank farms. This effort will be used to refine and confirm the pilot-scale Vapor Monitoring and Detection System sensor configuration and to establish the basis for future tank farms vapor monitoring.

Capabilities/Features:

- Fire, Combustible Gas, and Toxic Gas System design philosophy report:
  - Encompass all tank farms
  - Criteria for chemical vapor hazard identification
  - Criteria for risk categorization (risk guidelines)
  - Criteria for chemical vapor detection performance targets
  - Criteria for selecting detector technology
  - Alarming philosophy
  - Manual activation philosophy
  - Detector voting philosophy
  - Criteria for set-point selection



3D Monitoring of Hazard Monitoring Coverage

- Tank-Farm-Specific Fire, Combustible Gas, and Toxic Gas System design basis document:
  - List of 241-A and 241-AP Tank Farm chemical vapor sources (i.e., exhausters, passive breather filters, transfer pumps, valve pits)
  - Define variables for source terms (e.g., emission rate, equipment failure rate, height, size)
- Design analysis and quantitative risk analysis:
  - Performance based safety analysis
  - Compare to commercial standards
  - Map of unmitigated and mitigated risk from chemical vapors in tank farms
  - Map of sensor locations and sensor coverage

APPENDIX C

PILOT-SCALE TEST REQUIREMENTS MATRIX

A2.0 ATTACHMENT 2 - *TEST REQUIREMENTS MATRIX*

Position		Date
Reviewed By:		
Design Authority	Darrel Heimberger	6/30/16
Project Engineer	Jacob McCoskey	6/30/16
Approved By:		
Engineering Manager	Tom Sackett	6/30/16

241A Vapor Monitoring and Detection System Pilot-Scale Test Plan

241A-TP-043 R00

ATTACHMENT 2, Test Requirements Matrix

Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
1.0 SKC HazScanner (GS)						
1.1	*1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Instrument Calibration	Test Proc.	Expose instrument sensors to a standard gas.	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
1.2	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
1.3	*1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Loop Test	CAT	Expose instrument sensors to a standard gas.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
1.4	*1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Continuous Data Collection	Test Proc.	Normal Operation,	DC: A minimum 5 days of data is collected	Test Plan Section 5.2.1
1.5	*1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Bump Tests	Test Proc.	Expose instrument sensors to a standard gas.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
1.6	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.5, 5.3.2
1.7	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Opportunistic Fugitive Emission Detection	Test Proc.	Normal Operations	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
1.8	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Opportunistic Fugitive Emission Detection when discovered by IH rounds	Test Proc.	Locate instrument near suspected fugitive emissions	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
1.9	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
1.10	1 instrument from 200-GM-AE-501A 200-GM-AE-501B	Offline Testing	CAT	Turn Instrument Off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3

241A Vapor Monitoring and Detection System Pilot-Scale Test Plan

241A-TP-043 R00

ATTACHMENT 2, Test Requirements Matrix

Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
2.0 AREARAE (GS)						
2.1	*1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument Calibrates DC: One calibration data set collected.	Test Plan Section 5.1.1
2.2	1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
2.3	*1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Alarm Testing	CAT	Expose instrument sensors to a gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
2.4	*1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Loop Test	CAT	Expose instrument sensors to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
2.5	*1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected.	Test Plan Section 5.2.1
2.6	*1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Bump Test	Test Proc.	Expose instrument sensors to a gas standard.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
2.7	1 instruments from 200-GM-AE-502A through 200-GM-AE-502J	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.5, 5.3.2
2.8	1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Opportunistic Fugitive Emission Detection	Test Proc.	Normal Operations	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
2.9	1 instrument from 200-GM-AE-502A through 200-GM-AE-502J	Opportunistic Fugitive Emission Detection when discovered by IH rounds	Test Proc.	Locate instrument near suspected fugitive emissions	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
2.10	1 instruments from 200-GM-AE-502A through 200-GM-AE-502J	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10

241A Vapor Monitoring and Detection System Pilot-Scale Test Plan

241A-TP-043 R00

ATTACHMENT 2, Test Requirements Matrix

Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
3.0 ToxiRAE (GS)						
3.1	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument Calibrates DC: One calibration data set collected.	Test Plan Section 5.1.1
3.2	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Instrument Calibration with Auto Calibrators	Test Proc.	Calibrate instruments with Auto Calibrators	TC: Instrument is auto calibrated	Test Plan Section 5.1.1
3.3	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
3.4	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
3.5	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
3.6	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected	Test Plan Section 5.2.1
3.7	*1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Bump Test	Test Proc.	Expose instrument to gas standards per Attachment 3.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
3.8	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.5, 5.3.2
3.9	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Transport badges through radiological boundaries	Test Proc.	Demonstrate routine to transport badges through radiological boundaries, for data collection and calibration	TC: 1 instrument will be transported through radiological boundary, used in the Tank Farms, and then returned to the auto calibration docking station	Test Plan Section 5.2.8
3.10	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10

241A Vapor Monitoring and Detection System Pilot-Scale Test Plan

241A-TP-043 R00

ATTACHMENT 2, Test Requirements Matrix

Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
3.11	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	HVAC Monitoring	Test Proc.	Continuous monitoring of HVAC inlets when HVAC inlet is in the plume collocated with ammonia sensor	DC: Collect a minimum of 1 day of data from each of 2 instruments	Test Plan Section 5.2.7
3.12	1 instruments from 200-GM-AE-503A through 200-GM-AE-503J	Offline Testing	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
4.0 MultiRAE (GS)						
4.1	1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
4.2	1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
4.3	1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
4.4	*1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
4.5	*1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected	Test Plan Section 5.2.1
4.6	*1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Bump Test	Test Proc.	Expose instrument to gas standards.	TC: Instrument shows response to introduced gas. DC: A minimum of 1 bump test is performed.	Test Plan Section 5.2.2
4.7	1 instrument from 200-GM-AE-504A through 200-GM-AE-504C	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present.	Test Plan Section 5.2.5, 5.3.2
4.8	1 instrument from 200-GM-AE-504A through 200-GM-AE-504C	Opportunistic Fugitive Emission Detection	Test Proc.	Normal Operations	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
4.9	1 instrument from 200-GM-AE-504A through 200-GM-AE-504C	Opportunistic Fugitive Emission Detection when discovered by IH rounds	Test Proc.	Locate instrument near suspected fugitive emissions	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
4.10	1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
4.11	1 instruments from 200-GM-AE-504A through 200-GM-AE-504C	Offline Testing	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
5.0 RAE Mesh NH3 (GS)						
5.1	*1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
5.2	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
5.3	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response	Test Plan Section 5.1.3
5.3.1	*1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
5.4	*1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected	Test Plan Section 5.2.1
5.5	*1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Bump Test	Test Proc.	Expose instrument to gas standards	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
5.6	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.5, 5.3.2
5.7	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Opportunistic Fugitive Emission Detection	Test Proc.	Normal Operations	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
5.8	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Opportunistic Fugitive Emission Detection when discovered by IH rounds	Test Proc	Locate instrument near suspected fugitive emissions	TC: Instrument sensors detect fugitive emissions DC: Collect at least 1 response to fugitive emission	Test Plan Section 5.2.3
5.9	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Data to determine RAMI	Test Proc	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
5.10	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	HVAC Monitoring	Test Proc.	Continuous monitoring of HVAC inlets when HVAC inlet is in the plume collocated with PID sensor	DC: Collect a minimum of 1 day of data from 1 instrument.	Test Plan Section 5.2.7
5.11	1 instruments from 200-GM-AE-505A through 200-GM-AE-505Y	Offline Testing	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
6.0 OP-FTIR (GS)						
6.1	*1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
6.2	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
6.3	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
6.4	*1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
6.5	*1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected.	Test Plan Section 5.2.1
6.6	*1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Bump Test	Test Proc.	Expose instrument to gas standards	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
6.7	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	A TF Fence Line Gas Monitoring	Test Proc.	Monitor gasses at the A TF fence line (Buffalo Rd.)	DC: Collect at least 1 day of data from the A TF fence line (Buffalo Rd.)	Test Plan Section 5.2.1
6.8	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	AP TF Fence Line Gas Monitoring	Test Proc.	Monitor gasses at the AP TF fence line	DC: Collect at least 1 day of data from the AP TF fence line	Test Plan Section 5.2.1
6.9	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	AP TF Fence Line Gas Monitoring using Servo Mount	Test Proc.	Monitor gasses at the AP TF fence line using Servo Mount	TC: Instrument should target and collect data from multiple retro-reflectors. DC: Collect at least 1 day of data from the AP TF fence line using servo mount	Test Plan Section 5.2.1
6.10	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	A TF Area Gas Monitoring	Test Proc.	Monitor gasses in the A TF Area	DC: Collect at least 1 day of data from the A TF Area	Test Plan Section 5.2.1
6.11	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	AP TF Area Gas Monitoring	Test Proc.	Monitor gasses in the AP TF Area	DC: Collect at least 1 day of data from the AP TF Area	Test Plan Section 5.2.1
6.12	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Evaporator Gas Monitoring	Test Proc.	Monitor gasses at the intersection of 4th and Canton Ave preferably during an Evaporator Campaign.	DC: Collect at least 1 day of data	Test Plan Section 5.2.6
6.13	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	PBF Gas Monitoring	Test Proc.	Monitor gasses originating from the PBFs	DC: Collect at least 1 day of data	Test Plan Section 5.3.2
6.14	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities.	Test Plan Section 5.2.10
6.15	1 instruments from 200-GM-AE-506A 200-GM-AE-506B	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
7.0 UV-FTIR Stack Monitor (GS)						
7.1	200-GM-AE-507A	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
7.2	200-GM-AE-507A	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
7.3	200-GM-AE-507A	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
7.4	200-GM-AE-507A	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
7.5	200-GM-AE-507A	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected.	Test Plan Section 5.2.1
7.6	200-GM-AE-507A	Bump Test	Test Proc.	Expose instrument to gas standards.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
7.7	200-GM-AE-507A	Existing exhauster gas monitoring	Test Proc.	Monitor gasses of existing exhauster	DC: Collect a minimum of 1 day of data	Test Plan Section 5.2.1
7.8	200-GM-AE-507A	New exhauster gas monitoring	Test Proc.	Monitor gasses of new exhauster	DC: Collect a minimum of 1 day of data	Test Plan Section 5.2.1
7.9	200-GM-AE-507A	Data to determine RAMI	Test Proc	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
7.10	200-GM-AE-507A	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
8.0 UV-DOAS (GS)						
8.1	200-GM-AE-508A	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
8.2	200-GM-AE-508A	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
8.3	200-GM-AE-508A	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
8.4	200-GM-AE-508A	Loop Test	CAT	Expose instrument to a gas standard.	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
8.5	200-GM-AE-508A	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected.	Test Plan Section 5.2.1
8.6	200-GM-AE-508A	Bump Test	Test Proc.	Expose instrument to gas standards per Attachment 3.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
8.7	200-GM-AE-508A	A TF Fence Line Gas Monitoring	Test Proc.	Monitor gasses at the A TF fence line (Buffalo Rd.)	DC: Collect at least 1 day of data from the A TF fence line (Buffalo Rd.)	Test Plan Section 5.2.1
8.8	200-GM-AE-508A	AP TF Fence Line Gas Monitoring	Test Proc.	Monitor gasses at the AP TF fence line	DC: Collect at least 1 day of data from the AP TF fence line	Test Plan Section 5.2.1
8.9	200-GM-AE-508A	A TF Area Gas Monitoring	Test Proc.	Monitor gasses in the A TF Area	DC: Collect at least 1 day of data from the A TF Area	Test Plan Section 5.2.1
8.10	200-GM-AE-508A	AP TF Area Gas Monitoring	Test Proc.	Monitor gasses in the AP TF Area	DC: Collect at least 1 day of data from the AP TF Area	Test Plan Section 5.2.1
8.11	200-GM-AE-508A	Opportunistic PBF Gas Monitoring	Test Proc.	Monitor gasses originating from the PBFs if opportune.	DC: Collect at least 1 day of data	Test Plan Section 5.2.5, 5.3.1
8.12	200-GM-AE-508A	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
8.13	200-GM-AE-508A	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
9.0 Fixed OGI (GS)						
9.1	200-GM-AE-509A	Shakedown Testing	CAT	Unit positioned in the field.	TC: Instrument powers up. TC: Instrument is communicating with network	Test Plan Section 5.1.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
9.2	200-GM-AE-509A	OGI Loop Test	CAT	Unit positioned in the field.	TC: Camera and software have communication link as indicated by OGI software TC: OGI camera produces image as indicated by OGI software TC: Visual camera produces image as indicated by OGI software TC: Camera position can be controlled by joystick	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
9.3	200-GM-AE-509A	Alarm Testing	CAT	Expose instrument to detectable gas	TC: Alarm indicated on OGI software TC: Alarm indicated on TFMCS DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
9.4	200-GM-AE-509A	Continuous Data Collection	Test Proc.	Normal Operation	DC: Video of alarm condition is recorded DC: Alarms are recorded in OSI/PI	Test Plan Section 5.2.1
9.5	200-GM-AE-509A	Exhauster Plume Monitoring	Test Proc.	Monitor plume originating from TF forced air exhauster	TC: The instrument will show a plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the exhauster plume if plume is visible to instrument.	Test Plan Section 5.2.1, 5.3.1, 5.3.2
9.6	200-GM-AE-509A	Opportunistic PBF Plume Monitoring	Test Proc.	Monitor plume originating from TF PBF if opportune.	TC: The instrument will show a plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the PBF plume if plume is visible to instrument.	Test Plan Section 5.2.1, 5.3.2
9.7	200-GM-AE-509A	Opportunistically monitor transfer/valve pit fugitive emissions	Test Proc.	Monitor transfer pit fugitive emissions	TC: The instrument will show a fugitive emission plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the plume if plume is visible to instrument.	Test Plan Section 5.2.3
9.8	200-GM-AE-509A	Opportunistically monitor dead end fugitive emissions	Test Proc.	Monitor fugitive emissions from a dead end infrastructure that is connected to the head space of a TF tank	TC: The instrument will show a fugitive emission plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the plume if plume is visible to instrument.	Test Plan Section 5.2.3
9.9	200-GM-AE-509A	Data to determine RAMI	Test Proc.	Continuous Data Collection	TC: Conduct 1 set of maintenance activities.	Test Plan Section 5.2.10

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
9.10	200-GM-AE-509A	Communications disconnect from VMDS	CAT	Turn instrument off	TC: Fixed OGI HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
10.0 Primary Meteorological Station (GS)						
10.1	200-GM-AE-510A	Shakedown Testing	CAT	Unit positioned in Field	TC: Front panel indications indicate power applied.	Test Plan Section 5.1.3
10.2	200-GM-AE-510A	Loop Testing	CAT	Sensors are exposed to sunny day with winds Rain bucket is slowly filled with water	TC: TFMCS and Safer System will indicate horizontal wind velocity and direction. TC: TFMCS will indicate vertical wind velocity and direction. TC: TFMCS and Safer System will indicate atmospheric pressure. TC: TFMCS and Safer System will indicate relative humidity. TC: TFMCS and Safer System will indicate 2 meter and 10 meter temperature. TC: TFMCS will indicate short wave radiation. TC: TFMCS and Safer System will indicate rainfall.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.2, 6.5.2, 6.5.3, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.5.8
10.3	200-GM-AE-510A	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of meteorological data will be recorded	Test Plan Section 5.2.1 RPP-RPT-58714, 6.5.1
10.4	200-GM-AE-510A	Fair Weather Data Collection during the Summer	OAT	Operate the system during fair weather during the summer	DC: Collect a minimum of 1 day of meteorological data	
10.5	200-GM-AE-510A	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
11.0 Secondary Meteorological Station (GS)						
11.1	200-GM-AE-511A	Shakedown Testing	CAT	Unit positioned in Field	TC: Front panel indications indicate power applied	Test Plan Section 5.1.3
11.2	200-GM-AE-511A	Loop Testing	CAT	Sensors are exposed to sunny day with winds Rain bucket is slowly filled with water	TC:TFMCS and Safer System will indicate horizontal wind velocity and direction. TC: TFMCS will indicate vertical wind velocity and direction. TC: TFMCS and Safer System will indicate atmospheric pressure. TC: TFMCS and Safer System will indicate relative humidity. TC: TFMCS and Safer System will indicate temperature. TC: TFMCS will indicate short wave radiation. TC: TFMCS and Safer System will indicate rainfall.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.2, 6.5.2, 6.5.3, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.5.8
11.3	200-GM-AE-511A	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of meteorological data will be recorded	Test Plan Section 5.2.1 RPP-RPT-58714, 6.5.1

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11.4	200-GM-AE-511A	Fair Weather Data Collection during the Summer	Test Proc.	Operate the system during fair weather during the summer	DC: Collect a minimum of 10 days of meteorological data	Test Plan Section 5.2.1
11.5	Deleted	Deleted	Deleted	Deleted	Deleted	Deleted
11.6	200-GM-AE-511A	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
12.0 Gastronics Fixed Instrumentation Skid (GS)						
12.1	*1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
12.2	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Shakedown Testing	CAT	Unit positioned in the field.	TC: Reading is within range and consistent with expected results TC: Instrument is communicating with network	Test Plan Section 5.1.3
12.3	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Alarm Testing	CAT	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response.	Test Plan Section 5.1.3
12.4	*1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Loop Test	CAT	Expose instrument to a gas standard. per Attachment 3	TC: The difference of data recorded in OSI/PI and the calibration certificate for the standard gas is within manufacturer's specification. TC: The TFMCS and Safer System HMI display the sensor concentration within ± 10% of the concentration reported on the instrument screen.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.7.1
12.5	*1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected	Test Plan Section 5.2.1
12.6	*1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Bump Test	Test Proc.	Expose instrument to gas standards per Attachment 3.	TC: Instrument shows response to introduced gas. DC: A minimum of 1 bump test is to be collected.	Test Plan Section 5.2.2
12.7	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.5, 5.3.2
12.8	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Opportunistic Fugitive Emission Detection	Test Proc.	Normal Operations	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3
12.9	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Opportunistic Fugitive Emission Detection when discovered by IH rounds	Test Proc.	Locate instrument near suspected fugitive emissions	DC: Collect at least 1 response to fugitive emission if fugitive emission is present	Test Plan Section 5.2.3

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12.10	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10
12.11	3D Anemometer equipped FIS from 200-GM-AE-512A through 200-GM-AE-512Y	3D Anemometer Operation	Test Proc.	Continuous Data Collection during off normal operation	DC: Collect a minimum of 1 day of data	Test Plan Section 5.2.1
12.12	2D Anemometer equipped FIS from 200-GM-AE-512A through 200-GM-AE-512Y	2D Anemometer Operation	Test Proc.	Continuous Data Collection during off normal operation	DC: Collect a minimum of 1 day of data	Test Plan Section 5.2.1
12.13	1 instruments from 200-GM-AE-512A through 200-GM-AE-512Y	Communications disconnect from VMDS	CAT	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3
13.0 Personal GPS Locator (GS)						
13.1	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Unit in Field	Test Proc.	Turn unit on	TC: Unit lights indicate that unit is powered	Test Plan Section 5.1.3
13.2	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Latch Pull Alert	Test Proc.	Pull latch on unit	TC: Unit will alarm and send indication to GPS software DC: Alarm Indication and unit location recorded.	Test Plan Section 5.1.3 RPP-RPT-58714, 6.6.1, 6.6.3, 6.6.4
13.3	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Loop Test	Test Proc.	Unit turned on and acquired GPS signal as indicated by steady green flash on unit	TC: Unit position is indicated on GPS software TC: Unit position is indicated on SAFER System Software	Test Plan Section 5.1.3 RPP-RPT-58714, 6.10.2, 6.7.3, 6.8.3
13.4	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Continuous Data Collection	Test Proc.	Unit turned on and acquired GPS signal as indicated by steady green flash on unit	TC: When the unit is powered on and has establish GPS communications, position data is recorded. A total of 1 day of data was recorded.	Test Plan Section 5.2.1 RPP-RPT-58714, 6.6.2
13.5	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Man Down Alert	Test Proc.	Drop the unit on the ground	TC: The unit will alarm to indicate man down alert. DC: Alarm event is recorded	Test Plan Section 5.2.8 RPP-RPT-58714, 6.6.5
13.6	1 instruments from 200-GM-AE-514A through 200-GM-AE-514XX	Communications disconnect from VMDS	Test Proc.	Turn instrument off	TC: TFMCS and Safer System HMI indicate instrument is disconnected from the VMDS.	Test Plan Section 5.1.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
14.0 Grab Air Sampler (GS)						
14.1	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Bench Shakedown Testing	CAT	Unit powered and operating	TC: Verify with flow M&TE that sorbent tube flow is within 5% of specified range TC: Verify with flow M&TE the whole air sample flow is within 5% of specified range	Test Plan Section 5.1.1
14.2	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Field Shakedown Testing	CAT	Unit positioned in the field and powered.	TC: Instrument is communicating with network	Test Plan Section 5.1.3
14.3	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Loop Test	CAT	Normal Operation	TC: Sample collection is initiated from HMI	Test Plan Section 5.1.3
14.4	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 1 day of "Sampler deployed" data points are stored DC: A minimum of 1 manually triggered alarm events DC: a minimum of 1 automatically triggered alarm events	Test Plan Section 5.2.1
14.5	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Automatic Alarm Testing	Test Proc.	Expose related DRI sensor to high concentration of gas to evoke high alarm	TC: Sampler captures sample. DC: 1 Alarm event is recorded.	Test Plan Section 5.1.3
14.6	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Transport Grab Sampler through radiological boundaries	Test Proc.	Transport Grab Sampler through radiological boundaries	TC: Release from radiological control a minimum of 1 Grab Sampler from a CA.	Test Plan Section 5.2.1
14.7	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Whole Air Sampling	Test Proc.	Collect Whole Air Samples	TC: A minimum of 1 whole air sample will be collected from at least one sampler	Test Plan Section 5.2.1
14.8	1 instruments from 200-GM-AE-515A through 200-GM-AE-515F	Sorbent tube Sampling	Test Proc.	Collect Sorbent tube samples	TC: A minimum of 1 sets of tubes will be collected from at least one sampler	Test Plan Section 5.2.1
15.0 Area Air Sampler (GS)						
15.1	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Bench Shakedown Testing	CAT	Unit powered and operating	TC: Verify with flow M&TE that sorbent tube flow is within 5% of specified range TC: Verify with flow M&TE the whole air sample flow is within 5% of specified range	Test Plan Section 5.1.1
15.2	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Field Shakedown Testing	CAT	Unit positioned in the field and powered.	TC: Instrument is communicating with network	Test Plan Section 5.1.3

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15.3	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Loop Test	CAT	Normal Operation	TC: Sample collection is initiated from HMI	Test Plan Section 5.1.3
15.4	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 1 day of "Sampler deployed" data points are stored DC: A minimum of 1 manually triggered alarm events logged DC: a minimum of 1 automatically triggered alarm events logged	Test Plan Section 5.2.1
15.5	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Automatic Alarm Testing	Test Proc.	Expose related DRI sensor to high concentration of gas to evoke high alarm	TC: Sampler captures sample. DC: 1 Alarm event is recorded	Test Plan Section 5.1.3
15.6	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Transit Summa cases through radiological boundary	Test Proc.	Transport whole air sample cases through radiological boundaries	TC: Release from radiological control a minimum of 1 transit case with whole air samples from a CA.	Test Plan Section 5.2.1
15.7	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Whole Air Sampling	Test Proc.	Collect Whole Air Samples	TC: A minimum of 1 whole air sample will be collected from at least one sampler	Test Plan Section 5.2.1
15.8	1 instruments from 200-GM-AE-516A through 200-GM-AE-516H	Sorbent tube Sampling	Test Proc.	Collect Sorbent tube samples	TC: A minimum of 1 set of tubes will be collected from at least one sampler	Test Plan Section 5.2.1
16.0 Stack Air Sampler (GS)						
16.0	1 instruments from 200-GM-AE-517A and 200-GM-AE-517B	Bench Shakedown Testing	CAT	Unit powered and operating	TC: Verify with flow M&TE that sorbent tube flow is within 5% of specified range TC: Verify with flow M&TE the whole air sample flow is within 5% of specified range	Test Plan Section 5.1.1
16.1	1 instruments from 200-GM-AE-517A and 200-GM-AE-517B	Field Shakedown Testing	CAT	Unit positioned in the field and powered.	TC: Instrument is communicating with network	Test Plan Section 5.1.3
16.2	1 instruments from 200-GM-AE-517A and 200-GM-AE-517B	Loop Test	CAT	Normal Operation	TC: Sample collection is initiated from HMI	Test Plan Section 5.1.3

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Item #	SSC to be Tested (SS or GS)	Tests to be Performed Basis for Test	Type of Test	Condition/Sequence	Acceptance Criteria (AC), or Test Criteria (TC), or Data Collection (DC)	Basis for AC, TC, or DC
16.3	1 instruments from 200-GM-AE-517A and 200-GM-AE-517B	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 1 day of "Sampler deployed" data points are stored in OSI/PI DC: A minimum of 1 manually triggered alarm events logged DC: a minimum of 1 automatically triggered alarm events logged	Test Plan Section 5.2.1
16.4	1 instruments from 200-GM-AE-517A and 200-GM-AE-517B	Automatic Alarm Testing	Test Proc.	Expose related DRI sensor to high concentration of gas to evoke high alarm	TC: Sampler captures sample. DC: 1 Alarm event is recorded.	Test Plan Section 5.1.3
16.5	A minimum of 1 summa cases from the instruments 200-GM-AE-517A or 200-GM-AE-517B	Transit Summa cases through radiological boundary	Test Proc.	Transport whole air sample cases through radiological boundaries	TC: Release a minimum of 1 transit cases with whole air samples from radiological control.	Test Plan Section 5.2.1
16.6	1 instruments from 200-GM-AE-517A or 200-GM-AE-517B	Whole Air Sampling	Test Proc.	Collect Whole Air Samples	TC: A minimum of 1 whole air sample will be collected from at least one sampler	Test Plan Section 5.2.1
16.7	1 instruments from 200-GM-AE-517A or 200-GM-AE-517B	Sorbent tube Sampling	Test Proc.	Collect Sorbent tube samples	TC: A minimum of 1 sets of tubes will be collected from at least one sampler	Test Plan Section 5.2.1
17.0 Software (GS)						
17.1	Safer System Realtime	Software Set-Up	Test Proc.	Normal Operation	TC: Show that available instruments and available sensors are present in the software displays.	RPP-RPT-58714, 6.4.1, 6.4.2, 6.4.3, 6.4.7, 6.4.8
17.2	Safer System Realtime	Time Plot	Test Proc.	Bump test 1 instrument.	TC: 1 time plot demonstrated variability when the related instrument was bump tested. TC: The bump test response was indicated on the software within 30 seconds of initiated test.	RPP-RPT-58714, 6.9.9
17.3	Safer System Realtime	Tabular Charts	Test Proc.	Receive data from 1instrument.	TC: The software will generate tabular charts of data received from 1 instrument	RPP-RPT-58714, 6.9.8
17.4	Safer System Realtime	Software Alarms	Test Proc.	Bump test 1 instrument.	TC: 1 alarm activated when the related instrument was bump tested and the reported concentration was above the alarm set point. TC: Alarm was activated within 30 seconds of bump test of instrument.	RPP-RPT-58714, 6.10.3

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17.5	Safer System Realtime	Source Plume	Test Proc.	Initiate a source plume on the software of a point that has a known concentration.	TC: A plume from a known source should be displayed on the software screen showing the horizontal distribution of the plume. TC: A vertical distribution of the plume will be displayed on vertical distribution graph.	RPP-RPT-58714, 6.9.12
17.6	Safer System Realtime	Source Area Locator (SAL)	Test Proc.	Using sensor responses from adjacent and available sensors, initiate the Source Area Locator function to estimate the sources.	TC: The software should display a source upwind from the sensors.	RPP-RPT-58714, 6.9.1 & 6.9.6
17.7	Safer System Realtime	Receptor to Source Plume	Test Proc.	Using source determined from Item # 17.6, demonstrate a plume.	TC: The software should display a plume downwind of the calculated source.	RPP-RPT-58714, 6.9.1
17.8	Safer System Realtime	Meteorological Values	Test Proc.	Turn to weather inputs page	TC: The software should display reasonable weather results.	RPP-RPT-58714, 6.9.3
17.9	Safer System Realtime	Map	Test Proc.	Turn to map page	TC: The software should display data on satellite based map	RPP-RPT-58714, 6.9.2
17.10	Safer System Realtime	Personal Locations	Test Proc.	Three personal GPS location devices activated in Tank Farms	TC: Personal Location Device should be displayed on map	RPP-RPT-58714, 6.9.4
17.11	Safer System Realtime	Receptor Identification	Test Proc.	Initiate receptor identification tool when source is located	TC: Software will display affected receptors	RPP-RPT-58714, 6.9.5
17.12	Safer System Realtime	Data Report	Test Proc.	Initiate a data report of an event from software	TC: Software will provide data and analysis report of vapor event	RPP-RPT-58714, 6.9.7
17.13	Safer System Realtime	Archived Event	Test Proc.	Generate event from archived data	TC: Software will generate plume from archived data	RPP-RPT-58714, 6.9.10
17.14	Safer System Realtime	Engineering Units	Test Proc.	Normal Operations	TC: Concentration readings and meteorological data displayed in engineering units	RPP-RPT-58714, 6.10.2
17.15	Safer System Realtime	Users	Test Proc.	Normal Operation	TC: Can assign General Users to operate software	RPP-RPT-58714, 6.12.1
17.16	Safer System Realtime	Puff Observation	Test Proc.	Operate SAL and plume model for transient detection of chemical vapors	TC: The software should show a puff of gas in the plume DC: The generated data should be recorded	Test Plan Section 5.2.1
17.17	Safer System Realtime	Exhauster Plume Observation	Test Proc.	Operate the plume model using the exhauster plume data	TC: The software should produce a plume consistent with meteorological conditions DC: The generated plume should be recorded	Test Plan Section 5.2.1
17.17.1	TFMCS	Vapor event	Test Proc.	Instrument Alarm	TC: TFMCS indicates alarming condition	RPP-RPT-58714, 6.10.1
17.18	TFMCS	Display Reading	Test Proc.	Normal Operations	TC: TFMCS HMI indicates sensor concentration	RPP-RPT-58714, 6.10.1

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17.19	OSI/PI	Continuous Data	Test Proc.	Normal Operations	TC: OSI/PI receives data from TFMCS	RPP-RPT-58714, 6.8.1
17.20	OSI/PI	Continuous Data	Test Proc.	Normal Operations	TC: OSI/PI sends data to Safer System RealTime	RPP-RPT-58714, 6.8.2
17.21	OSI/PI	Continuous Data	Test Proc.	Normal Operations	TC: OSI/PI saves at least 30 days of data from all **sensors connected to VMDS**	Test Plan Section 5.2.1
Ion Science CUB (GS)						
18.1	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Instrument Calibration	Test Proc.	Expose instrument to one or more gas standards per Attachment 3	TC: Instrument calibrates. DC: One calibration data set collected.	Test Plan Section 5.1.1
18.2	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Instrument Calibration with Auto Calibrators	Test Proc.	Calibrate instruments with Auto Calibrators	TC: 1 Instrument is auto calibrated	Test Plan Section 5.1.3
18.3	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Shakedown Testing	Test Proc.	Unit positioned in the field.	TC: Reading is within range and consistent with **expected results**	Test Plan Section 5.1.3
18.4	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Alarm Testing	Test Proc.	Expose instrument to gas standard	TC: Alarm shall activate when exposed to vapor concentration greater than the alarm set point. DC: Collect 1 example of the instrument response	Test Plan Section 5.1.3
18.5	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Continuous Data Collection	Test Proc.	Normal Operation	DC: A minimum of 5 days of data is collected	Test Plan Section 5.2.1
18.6	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Bump Test	Test Proc.	Expose instrument to gas standards per Attachment 3.	TC: Instrument shows response to introduced gas. DC: A minimum of one bump test data to be collected.	Test Plan Section 5.2.2
18.7	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Tank Farm Plume Detection	Test Proc.	Expose instrument to Tank Farm Vapors from a known source	DC: Collect at least ½ shift downwind of plume if a plume is present	Test Plan Section 5.2.1
18.8	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Transport badges through radiological boundaries	Test Proc.	Demonstrate routine to transport badges through radiological boundaries, for data collection and calibration	TC: 1 instrument will be transported through radiological boundary, used in the Tank Farms, and then returned to the auto calibration docking station	Test Plan Section 5.2.8
18.9	1 instruments from 200-GM-AE-518 A to 200-GM-AE-518J	Data to determine RAMI	Test Proc.	Continuous Data Collection	DC: Collect data up to end of test (August 10th, 2016) TC: Conduct 1 set of maintenance activities	Test Plan Section 5.2.10

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Portable FLIR OGI (GS)						
19.1	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Shakedown Testing	Test Proc.	Unit positioned in the field.	TC: Instrument powers up. TC: Instrument cools for operation	Test Plan Section 5.1.3
19.2	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Data Collection	Test Proc.	Normal Operation	DC: Record video	Test Plan Section 5.2.1
19.3	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Opportunistic Exhauster Plume Monitoring	Test Proc.	Monitor plume originating from TF forced air exhauster	TC: The instrument will show a plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the exhauster plume if plume is visible to instrument.	Test Plan Section 5.2.1, 5.3.1
19.4	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Opportunistic PBF Plume Detection	Test Proc.	Put instrument downwind of PBF Plume if opportune.	TC: The instrument will show a plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the PBF plume if plume is visible to instrument.	Test Plan Section 5.2.1, 5.3.2
19.5	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Opportunistically monitor transfer/valve pit fugitive emissions	Test Proc.	Monitor transfer pit fugitive emissions	TC: The instrument will show a fugitive emission plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the plume if plume is visible to instrument.	Test Plan Section 5.2.1
19.6	1 instruments from 200-GM-AE-509B or 200-GM-AE-509C	Opportunistically monitor dead end fugitive emissions	Test Proc.	Monitor fugitive emissions from a dead end infrastructure that is connected to the head space of a TF tank	TC: The instrument will show a fugitive emission plume in the viewfinder or on the portable computer if plume is visible to instrument. DC: Record the plume if plume is visible to instrument.	Test Plan Section 5.2.1
VMDS Receptacles (GS)						
20.1	Receptacle: RCPT-1 in Enclosure MO193-GM-ENCL-001	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.2	Receptacle: RCPT-1 in Enclosure AP271-GM-ENCL-001	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.3	Receptacle: POR545-GM-RCPT-101 on Portable Power Supply POR545-GM-EES-001	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1

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20.4	Receptacle: POR545-GM-RCPT-102 on Portable Power Supply POR545-GM-EES-001	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.5	OP-FTIR Receptacle: AP02D EDS RCPT 311	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.6	OP-FTIR Receptacle: AP07A EDS RCPT 306	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.7	OP-FTIR Receptacle: APVP EDS RCPT 306	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1
20.8	OP-FTIR Receptacle: AP08A EDS RCPT 306	Check voltage is within operating range	CAT	Check the receptacle voltage with calibrated MTE	AC: The receptacle will have a voltage of 120 volts +/- 5% (114-126 Volts).	RPP-SPEC-60323, Section, 26.05.19, Paragraph D.7 and ANSI C84.1

Where only one of a group of instruments is required to be tested, tests marked with an "" should all be performed on the same unit.

APPENDIX D

VAPOR MONITORING AND DETECTION SYSTEM DESIGN BASIS

TABLE OF CONTENTS

LIST OF TERMS

AV	active venting
CAV	continuous active venting
CFD	Computational Fluid Dynamics
CoC	concentration of concern
COPC	chemical of potential concern
CPV	continuous passive venting
DCS	Distributed Control System
DRI	direct-reading instrument
DST	double-shell tank
DST	double-shell tank
ES	emission scenario
FDS	Fire Dynamics Simulator
FGS	Fire, Combustible Gas, and Toxic Gas System
FIS	fixed instrument skid
FY	fiscal year
GRE	gas release event
HEPA	high-efficiency particulate air
ILDH	immediately dangerous to life and health
LES	Large Eddy Simulator
LI	leading indicator
NIST	National Institute of Standards and Technology
NIST	National Institute of Standards and Technology
OEL	operational exposure limit
OP-FTIR	open path Fourier transform infrared spectrometer
PNNL	Pacific Northwest National Laboratory
PV	passive venting
QRA	Quantitative Risk Analysis
SST	single-shell tank
TAV	temporary active venting
TOC	Tank Operations Contractor
TWINS	Tank Waste Information Network System
UP	unsealed penetration
UV-DOAS	ultraviolet differential optical adsorption spectrometer
UV-FTIR	ultraviolet Fourier transform infrared spectrometer
VMD&R	Vapor Monitoring, Detection, and Remediation (Project)
VMDS	Vapor Monitoring and Detection System
VOC	volatile and semi-volatile organic compound

WRPS	Washington River Protection Solutions, LLC

D1.0 INTRODUCTION

The Vapor Monitoring and Detection System (VMDS) will be designed to detect chemicals of potential concern (COPC) at a concentration of concern (CoC) originating from identified vapor release sources in the tank farms. The intent of the system is to detect and indicate COPCs at CoCs at the earliest stages of plume development. The system will not remove the chemical hazard, but only indicate the presence of the chemical vapor hazard and provide the information necessary to take appropriate actions to mitigate the risk to the workers from the hazard.

This appendix outlines the methodology that will be used in determining criteria for designing VMDSs throughout the Hanford Site.

D2.0 FUTURE VMDS DESIGN

The Vapor Monitoring, Detection, and Remediation (VMD&R) Project has contracted with Kenexis, an industry leader in gas detection design, to assist Washington River Protection Solutions, LLC (WRPS) in the development of a design basis for the final VMDS. The vendor will utilize their expertise to evaluate the tank farms hazards and vapor-related tank farms conditions in conjunction with the pilot-scale VMDS and accompanying results to recommend a final VMDS design. To this end, WRPS supplied the vendor with a set of guidelines for performing this work. The guidelines essentially directed that the system should be designed to the following:

1. Reliably detect and warn tank farm workers of chemical vapors emissions from specified sources.
2. Minimize the risk from these chemical vapors to tolerable levels. Risk, in this context, is defined as the frequency and severity of the exposure from acute tank farm chemical vapors.
3. Locate detectors in and around the tank farms to mitigate vapor-related risk by providing an indication of chemical vapors.
4. Follow guidelines in ANSI/ISA 84.00.01-2004 and system lifecycle guidelines in ISA TR-84.00.07 for performance-based VMDS design, which should include the following:
    a. Identify sources of concern
    b. Identify design-basis emission scenarios
    c. Analyze consequences of emission with gas dispersion model
    d. Analyze frequency / likelihood of emissions
    e. Perform unmitigated exposure assessment
    f. Identify target performance requirements
    g. Develop an initial detector layout
    h. Analyze detector coverage and VMDS availability
    i. Perform mitigated exposure assessment.

Starting with these guidelines, the vendor was requested to produce a number of deliverables to provide a design methodology for the Hanford Site tank farms (the design philosophy), evaluate the risks inherent at the Hanford tank farms, and develop a coverage mapping outline that includes expected placement of sensors to meet the guidelines consistent with overall VMD&R Project objectives and requirements. The deliverables include the following:

- Pilot-scale VMDS evaluation
- VMDS design philosophy document
- VMDS basis of design document
- Quantitative risk analysis (QRA) and coverage mapping report
- VMDS performance specification package.

The contents of each of these deliverables is described in the following sections. Results are not included in this report but will be made available in early fiscal year (FY) 2017 subsequent to adequate review and approval of the subject deliverables.

D.3 PILOT-SCALE VDSM EVALUATION

For pilot-scale testing, several pieces of equipment are being demonstrated and include the following items:

- AreaRAE*
- RAE MeshGuard NH_3*
- MultiRAE Pro
- ToxiRAE
- HAZ-SCANNER*
- Gastronics fixed instrument skid FIS*
- Autosampler
- Grab sampler
- Ultraviolet differential optical adsorption spectrometer (UV-DOAS)*
- Open path Fourier transform infrared spectrometer (OP-FTIR)*
- Ultraviolet Fourier transform infrared spectrometer (UV-FTIR) stack analyzer*
- Personal sampler
- Ion Science Cub
- Meteorological station.

Typically, equipment included in Fire, Combustible Gas, and Toxic Gas System (FGS) design are fixed, have known detection capabilities, and provide real time information. These generally include fixed direct-reading instrument (DRI) and fixed open path sensors. The equipment that will be included in the final VMDS design is indicated in the above list by an asterisk. The other equipment is not considered to be a part of the formal VMDS design, mainly because if equipment is mobile (e.g., personal badges and the MultiRAE Pro), it by definition cannot be counted on to be in a specified location for detection/warning purposes. In addition, equipment that does not provide real time information, such as whole air and/or sorbent tube samples (e.g., autosamplers, grab samplers, and personal samplers) are not included in the design. Both of these types of devices are added to the system as a ‘defense in depth’ by providing corroboration of the results of the system design or because they provide coverage and direct indication/warning to the workers in the field.

*Fixed sensors that will be used as part of the VMDS.

The vendor was tasked with the comparison of the pilot-scale VMDS design with a typical FGS design. Using the known conditions of the tank farms (e.g., source locations, estimate release rates, estimate occupancy rates), their objective is to determine the degree of needed sensor coverage and overall adequacy of the deployed pilot-scale system. Preliminary results indicate the current system should be greater than 75% effective as a FGS warning system. The main deficiency identified was the coverage of sensors at some of the sources, so in order to improve the 241-A and 241-AP Tank Farms VMDS design will require the addition of some sensors. Additional data from the pilot-scale testing (Phase 2) plus other related information may help to improve the number, but the vendor description of the weaknesses in the system will help the project fill in data/information gaps; the design is an iterative process with the gathering of field data and confirmation of enabling assumptions..

D4.0 VMDS DESIGN PHILOSOPHY DOCUMENT

The VMDS design philosophy document will detail the standards and processes used to develop the other documents included in the design process. This document will define the scope of the design activities and the applicable standards to include, but not be limited to, the following standards:

- 10 CFR 851, “Worker Health and Safety Program”
- ANSI/ISA 84.00.01-2004, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector (IEC 61511-1 Mod)*, International Society of Automation, 2004
- ISA-TR84.00.07, *Guidelines for the Evaluation of Effectiveness of Fire, Combustible Gas, and Toxic Gas Systems*, International Society of Automation, 2010
- DOE-STD-1027, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23*, Nuclear Safety Analysis Reports, U.S. Department of Energy, December 1997
- DOE-STD-3009, “Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses,” U.S. Department of Energy July 1994.

In general, the document will provide the overarching assumptions for what constitutes a chemical vapor emission release that must be addressed in the VMDS design process. Key items to be included in the approach are: (1) explanation of the VMDS design lifecycle, (2) assumptions pertaining to the tolerable chemical vapor concentrations, (3) assumptions of possible emission scenarios and (4) a description of the Quantitative Risk Analysis (QRA) process and how it will be applied.

The document will outline what COPCs will be included in the design and, more importantly, what leading indicators for the other hard to detect COPCs will be included in the design. The document will outline what COPC concentrations are tolerable in the work environment.

The document will also define basic system requirements that should be considered, such as recommend equipment.

D5.0 QUANTITATIVE RISK ANALYSIS AND COVERAGE MAPPING REPORT

A QRA will be performed for each emission scenario to determine what the unmitigated risk (when no chemical vapor detectors are present) inside and outside the tank farms is and what the risk would be. While a VMDS does nothing to mitigate the release and therefore eliminate or reduce exposure, it will warn the employee of a release allowing the employee to take action to mitigate the exposure. A QRA will then be conducted using the chemical detector arrangement of the VMDS pilot-scale testing equipment with the goal of 90% or greater effectiveness (i.e., ability to detect the species of interest). If necessary, a third QRA will be conducted if pilot-scale testing requires design alteration to improve VMDS effectiveness to mitigate the possible chemical vapor hazard. A design alteration may be required if sensor placement or numbers are not adequate or optimal.

The Basis of Design will result in a determination of the average frequency rate and spatial distribution of the chemical vapor plumes that the system can detect at or above set concentration targets. For this project, the target is to mitigate an exposure to COPC concentration of 10% of the operational exposure limit (OEL) to no more than once per year.

The overall design process will then be evaluated (WRPS and vendor staff) to determine effectiveness considering the unique and novel tank farm vapor conditions and system configurations and operation.

D5.1 OCCUPANCY RATES

Occupancy rates of the tank farm areas are essential to conducting a QRA and determining the optimal location of chemical vapor detectors in the tank farms. For example, if a farm has no occupancy, then no sensors are required whereas a farm that is always occupied would require many sensors to ensure the VMDS will effectively notify worker of a chemical vapor hazard. Adequate occupancy documentation for inside and near each tank farm where vapor releases are anticipated to occur is not available at this time. For the initial QRA, the occupancy rate will be considered to be 100% as this is the most conservative approach.

D5.2 QRA OF UNMITIGATED RISK OF CHEMICAL VAPOR EXPOSURES

A QRA will be conducted for each tank farm the outcome of which will include a contour map of risk from the chemical vapor sources in each tank farm. The contour map illustrates the risk in terms of the frequency per year of exposure to a COPC at a concentration of 10% of the OEL or greater. The focus of this effort will be to identify areas where the exposure frequencies could exceed one event per year.

D5.3 QRA OF MITIGATED RISK OF CHEMICAL VAPOR EXPOSURES (PILOT SCALE DEMONSTRATION)

Another QRA will then be conducted using the pilot-scale design. The pilot-scale design includes 241-A and 241-AP Tank Farms and to a limited extent the surrounding areas. The contour map will be generated in terms of frequency per year of exposure to any COPC concentration at 10% of the OEL or greater. The goal is greater than 90% effectiveness to mitigate the risk of the possible exposure. If this target is not met, then either the chemical detectors will be moved or added to achieve this target.

D5.4 QRA OF MITIGATED RISK OF CHEMICAL VAPOR EXPOSURES (90+ % VMDS EFFECTIVENESS)

A final QRA will be conducted with chemical detectors of the pilot-scale design relocated or additional chemical detectors added to the design to achieve greater than 90% VMDS effectiveness at detecting a chemical vapor release and alerting personnel of the location and extent of the hazard.

D5.5 COVERAGE MAPPING

The result of the QRA process will be a map showing optimal sensor location/s to provide chemical sensor coverage that is greater than 90% effective at mitigating the risk of a chemical vapor exposure to no more than one exposure per year to a COPC at a concentration of 10% or more of the OEL for that COPC. Chemical sensor coverage assumes that a point sensor provides a spherical coverage geometry of 5 m in diameter and a path detector provides a cylindrical coverage geometry equal to the distance between the sensors and 5 m in diameter. These assumptions are based on actual plant experience to estimate the amount of coverage a particular sensor will provide.

D6.0 VMDS BASIS OF DESIGN DOCUMENT

The driver for the QRA for each tank farm is a fully developed emission scenario that forms the Basis of Design. A Basis of Design document will be created for each tank farm. The most important part of the design process is to accurately describe the sources of the chemical vapors and the mechanisms of chemical vapor transport. The Basis of Design will estimate the source release mechanism and then estimate the downwind concentration of chemical vapors in a vapor release plume.

The document will identify the emission scenarios, the COPCs, and their respective CoCs for the respective tank farm. It also assumes a release mechanism for each emission scenario and uses the developed release mechanisms to predict the impact (frequency and concentration) of the plumes from the emission scenarios inside the tank farm and outside the tank farms in order to classify the severity of the plume.

D6.1 EMISSION SCENARIOS

A draft design philosophy document has been developed by Kenexis with WRPS input. At this time five emission scenarios (ES) have been identified. The ESs include both passive and active sources and sources that are a result of routine and non-routine operations. In general, a subset of these ESs will be included in the Basis of Design document, depending on the tank farm. The ESs are as follows:

- **ES1, Continuous Active Venting (CAV):** Normal exhauster operation as well as high turndown.

- **ES2, Continuous Passive Venting (CPV).** Emission from vent for tanks without permanent exhausters, and other tanks for periods of time when exhausters are unavailable due to maintenance.
- **ES3, Passive Ventilation (PV).** Emissions from unsealed tank penetrations:
  - Valve and pump pits with drains and other connections to tanks including instrument enclosures
  - Risers that extend above ground level.
- **ES4, Temporary Active Venting (TAV).** Portable exhausters used to actively vent tanks that do not have permanent exhausters.
- **ES5, Venting Due to Shutdown of Exhausters.** Waste-disturbing operations in progress and unplanned shutdown of exhauster occurs, resulting in temporary but significant passive venting.

Other ESs, such as highly transient and/or randomly occurring emissions, will likely not be included in the design of the VMDS as these types of ESs are not generally predictive in nature.

The emission scenarios were developed by identifying three general process for emission of chemical vapors and identifying several operating modes of the tank farms. In general, sources for the design of VMDS are predictive in nature and are listed below.

- AV source – Active venting (CAV and TAV) through exhauster stacks
- PV source – Passive venting (CPV) through tank conservation breather filter vents
- UP source –Unsealed penetrations to tank vapor space (e.g., valve pits, pump pits).

The following operating modes were also identified in the pilot-scale VMDS and were used to develop the above ESs:

1. Emissions during normal/quiescent tank operations. Steady diffusion and convection to the surface and released into the headspace by evaporation or off-gassing. See *Overview of Hanford Site High-Level Waste Tank Gas and Vapor Dynamics*, Section 4.
2. Episodic emissions when trapped gases in stratified waste layers equilibrate (gas release events [GRE], or 'burping').
3. Episodic emissions during waste-disturbing activities.
4. Valve and pump pits when access covers are removed for extended maintenance.

Occupancy patterns may vary depending on the operating mode. The operating modes should be identified in the Basis of Design for each tank farm.

D6.2 EMISSION MECHANISM DEVELOPMENT

In general there are two types of tank farms on the Hanford Site, double-shell tank (DST) farms and single-shell tank (SST) farms. Transport mechanisms will be developed for each tank farm, but the mechanism development will have two general variants for each type of tank farm.

D6.2.1 Double-Shell Tank Farms

The DST farms can be generally characterized as a set of underground tanks interconnected by exhauster trains to a common forced air exhauster (actively ventilated). Each tank is kept at vacuum (slight negative pressure relative to atmosphere) and has a vacuum inlet or air in-leakage pathways (e.g., risers, pits) to let air into the primary tank. The tanks can also be interconnected by transfer pipe lines and valve/transfer pits.

The following mechanisms of release will likely be considered in the design basis:

- **ES1, Continuous Active Venting (CAV)**. Normal exhauster operation as well as high turndown.
- **ES3, Passive Ventilation (PV).** Emissions from unsealed tank penetrations:
  - Valve and pump pits drain connections to tanks
  - Risers that extend above ground level.
- **ES5, Venting Due to Shutdown of Exhausters.** Waste-disturbing operations in progress and unplanned shutdown of exhauster occurs, resulting in temporary but significant passive venting.

D6.2.2 Single-Shell Tank Farms

SST farms can be generally characterized as a set of underground tanks interconnected by ventilation trains and transfer piping, but passively ventilated using natural mechanisms. The tanks generally are configured with a passive breather filter that exhausts vapors during the daytime hours due to three effects: (1) buoyancy-driven effects, (2) barometric-driven effects, and (3) chimney ventilation effects.

The following mechanisms of release will likely be considered in the basis of design:

- **ES2, Continuous Passive Venting (CPV).** Emission from vent for with tanks without permanent exhausters, and other tanks for periods of time when exhausters are unavailable due to maintenance.
- **ES3, Passive Ventilation (PV).** Emissions from unsealed tank penetrations:
  - Valve and pump pits with drains or other connections to tanks
  - Risers that extend above ground level.
- **ES4, Temporary Active Venting (TAV).** Portable exhausters used to actively vent tanks that do not have permanent exhausters.
- **ES5, Venting Due to Shutdown of Exhausters.** Waste-disturbing operations in progress and unplanned shutdown of exhauster occurs, resulting in temporary but significant passive venting.

D6.3 RELEASE MECHANISM DEVELOPMENT

Release mechanisms will be developed for each emission scenario as it applies to the tank farm and the unique configuration of each tank farm. Essentially, the release mechanism will model the transport of chemical vapors from the headspace of the tank to identified openings where the chemical vapors can reach the environment and a worker exposure could occur. The transport of the chemical vapors from the headspace to the receptor will be modeled by solving the Navier-Stokes fluid dynamics equations. The Computational Fluid Dynamics (CFD) model that will be used to solve the equations is Fire Dynamics Simulator (FDS) developed by the National Institute of Standards and Technology (NIST). Turbulence in the FDS is modeled using a Large Eddy Simulator (LES). In terms of application of CFD to the problem of atmospheric dispersion, this tool allows transient conditions to be accurately modeled, including short-term emission effects and other transient phenomena such as accumulation and dissipation of turbulent kinetic energy in the wind field.

ES1 and ES4 dispersion mechanisms both involve discharging diluted headspace gasses into the atmosphere through an exhaust stack and will be modeled similarly. The models will incorporate standard CFD techniques to simulate gaseous dispersion from forced air exhausters. The driving force is the blowers on the exhausters and associated dimensions of the exhauster, all of which are known parameters.

ES2 and ES5 describe passive venting from a riser equipped with a high-efficiency particulate air (HEPA) filter. ES2 is a normal operation for the SSTs and the ES5 is the off-normal condition for a DST when the exhausters are shut down. The driving force for passive breathing is associated with barometric pressure (including diurnal and seasonal variations), buoyancy-driven stack-effect, and wind-driven stack-effect. The differential gradients for each force results in a net driving pressure.

ES3 is the scenario that describes the transport of chemical vapors from open valve pits, transfer pits, and other open infrastructure (e.g., open risers) that are connected to the tank head space. The mechanisms for this release scenario will be similar to ES2 and ES5. The large difference is the periodicity of when the infrastructure is open (e.g., removal of valve and transfer pit covers), general dimensions of the open infrastructure and the lack of a HEPA filter.

GREs will also be included in the chemical vapor release scenarios. These models will be developed from past data and information developed by previous TOCs. The general release mechanism and release frequency of the GRE have been developed to mitigate hydrogen hazards.

D6.4 LEADING INDICATORS

It is not possible to monitor for all COPCs using real time sensors. Commercially available real time sensors generally detect compounds that have immediately dangerous to life and health (ILDH) values that are possible in industrial situations. A few of these compounds are a part of the Hanford COPC list and they will be at higher level in tank vapors. The level of indication needed for other compounds is so low that you cannot measure it in real time. For this reason, leading indicators (LI) are used as a surrogates for the other species that cannot be detected in a real time mode. In order for LIs to be effective, they must be in high enough concentrations to be detected, and the concentration of the LI must be such that if it is detected, the concentration of the other species is below a the concentration of concern. LIs must be chosen such that if they are below a certain threshold limit, there is great confidence that all of the other compounds are below the action levels. For the purposes of the pilot-scale VMDS design, LIs were used as means to predict the presence and relative concentration of other COPCs in a chemical vapor plume. These leading indicators are characterized by relatively high concentrations and low detection thresholds. During a vapor emission event the leading indicator COPCs are expected to be more readily detected than other chemicals that constitute the emission. Ongoing activities (LI study) will refine these assumptions in the future. Also, set-point calculations will be conducted after additional data is collected to refine the action level for the LIs.

The current LIs included in the pilot-scale VMDS design are as follows:

- Ammonia
- Nitrous oxide
- Volatile and semi-volatile organic compounds (VOC).

D6.5 DATA SOURCES

The source data for the tank head spaces were taken from the Tank Waste Information Network System (TWINS) and the results of the FY 2016 Headspace Sampling Project. The data was analyzed using the above scenarios using two data groups: (1) using maxima COPC concentrations from the data as conservative bounding conditions and (2) as an alternative analysis, using the average COPC concentrations. The first data case bounds the dispersion of COPCs to a worst case scenario, such as a GRE, where the chemical vapor concentration in the worker breathing area will likely be the highest. Case 2 is intended to represent normal operating conditions.

Meteorological data from the Hanford Weather Station instrument tower from 1983 to 2002 were used to determine stability parameters and wind speed distribution. The data were used to characterize the range of conditions and define four subsets that will be used in the modeling.

Reports developed by the Tank Operations Contractor (TOC) and Pacific Northwest National Laboratory (PNNL) were also used as supplemental information to characterize the emission mechanisms from both SSTs and DSTs. These reports were also used to describe the mechanism for GRE. Tank farm configuration will be taken from current drawings and verified through physical inspection.

D7.0 VMDS PERFORMANCE SPECIFICATION PACKAGE

Finally, the project will deliver a VMDS performance specification package, which will detail the system and equipment requirements and specifications. The package will include locations, numbers, and types of chemical vapor sensors. It will also include the specifications for system components (e.g., logic drivers, detectors).

The infrastructure for an FGS, such as the VMDS, is typically built to be independent of the plant Distributed Control System (DCS). By designing the system to be independent of the DCS, the calculated risk that the system mitigates can be more readily determined. For the case of the DCS for the tank farms, the plant DCS performance is well understood and some credit for this may be able to be applied in the VMDS design calculations. The VMDS pilot-scale testing will include an evaluation to determine if the plant DCS is an adequate platform to attain VMDS performance targets.

In general, the VMDS shall be constructed to have the following components:

1. Detectors and interfacing equipment
2. Control unit

3. Interconnecting wiring/cabling
4. Visible and audible alarms
5. Communications interface to the Tank Farms Monitoring and Control System (TFMCS) (the DCS)
6. Power supply.

D7.1 CHEMICAL DETECTORS

The specifications for the chemical detectors will be generally targeted to measure LI compounds at or below the design target of 10% of the OEL. The sensors will generally have the capability to alarm at a low alarm (10% of the OEL) and a high alarm (50% of the OEL). The chemical detectors will also generally be configured to provide local audible and/or visible indication of an alarming state. The chemical sensors should also be capable of transmitting an alarm state.

D7.2 VMDS AVAILABILITY

The delivered specification will also state a system availability or in other words, the integrated time the VMDS is available to provide indication of chemical vapors above targets. The parameters included in this calculation typically include down time due to system faults, such as communication outages and faulty detectors. Typically, an availability of 90% or greater is a requirement of the system.

D8.0 REFERENCES

10 CFR 851, “Worker Health and Safety Program,” *Code of Federal Regulations*, as amended.

ANSI/ISA 84.00.01, 2004, *Functional Safety: Safety Instrumented Systems for the Process Industry Sector (IEC 61511-1 Mod),* Instrumentation Systems, and Automation Society, Research Triangle Park, North Carolina.

ISA TR84.00.007, 2010, *Guidance on the Evaluation of Fire, Combustible Gas and Toxic Gas System Effectiveness,* Instrumentation Systems, and Automation Society, Research Triangle Park, North Carolina.

DOE-STD-1027, 1997, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

DOE-STD-3009, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, U.S. Department of Energy, Washington, D.C.