



**To:** Steve Teel, Department of Ecology

**From:** Tasya Gray, Taylor Way and Alexander Avenue Fill Area (TWAFA) Agreed Order Potentially Liable Parties Group Project Coordinator

**Cc:** Scott Hooton, Port of Tacoma, TWAFA Enforcement Order Project Coordinator

**Date:** July 2, 2021

**Subject: TWAFA Data Gap Investigation Progress Summary and Soil Vapor Intrusion Status and Recommendations**

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This memorandum has been prepared to address comments received from the Washington State Department of Ecology (Ecology) on May 5, 2021 (Ecology, 2021) regarding the Aboveground Site Conditions Memorandum (DOF, 2021a) and Existing Groundwater Monitoring Network Evaluation and Recommendations Memorandum (DOF, 2021b).

This memo includes information provided to satisfy the requirements set forth under section 6.0 of the Final Data Gaps Work Plan (DGWP) (DOF, 2020) regarding current vapor intrusion status and recommendations for each parcel included in the TWAFA Site. Evaluation of vapor intrusion potential is necessary to understand potential impacts to current and future uses of each parcel across the TWAFA site. The information will, along with other data collected under the DGWP, inform the feasibility study and remedy planning.

DOF signed an access agreement for the former CleanCare parcel on June 25, 2021 and anticipates receiving a fully executed access agreement from Pierce County soon. DOF will then schedule field work on the former CleanCare parcel specified under the DGWP.

**1205 Alexander Avenue/1300 Taylor Way (Hylebos Marsh) Property**

The Ecology comment letter (2021) requested additional information regarding the debris observed eroding from the bank, adjacent to the Burlington Environmental property. Figure 1 provides the location of the observed debris. The debris consisted of shredded rubber, foam, wire, and metal. We understand that the Port of Tacoma also provided Ecology additional photos of this area via email in June 2021.

Assessment of vapor intrusion on this property is not proposed or recommended as part of data gaps investigation.

**Burlington Environmental Property**

The Ecology comment letter (2021) requested that groundwater monitoring well CTMW-11R would be replaced. DOF will evaluate locations near the current tank farm that are feasible for installation of replacement well and provide a location recommendation to Ecology prior to installation. This well will be installed concurrent to other TWAFA well installation work to be conducted under the DGWP.

The potential for vapor intrusion exists on the Burlington Environmental Property and assessment will be necessary for some of the structures on the property. As noted in the Ecology comment letter (2021), the numerous open-air buildings with open sides and the laboratory/office buildings with passively ventilated crawl spaces are likely to have an incomplete pathway for vapor intrusion and therefore additional assessment of these structures is not warranted at this time. The following sections address comments from Ecology for specific structures on site related to potential vapor intrusion.

#### Lab Pack Building

A vapor mitigation system (VMS) was installed as part of construction of the Lab Pack building in 2016 and commissioned on May 5, 2017, as documented in the Vapor Mitigation System Operation and Maintenance (O&M) Manual (AMECFW, 2018). The O&M Manual is provided as Attachment A to this memorandum. The VMS was designed in collaboration with Ecology and consists of two major components. The first is a passive impermeable 40-mil high density polyethylene liner located below the building slab and grade beams and the second is an active venting system. Crushed rock and conveyance piping are located below the HDPE liner to intercept vapors from the subsurface and VMS blower actively removes vapors and vents them to the atmosphere via a vent stack. Sub-slab monitoring locations were installed in the floors of each of the enclosed rooms in the Lab Pack building and correspond to individual vent lines located in the crushed rock. Each enclosed space within the building contains a methane sensor, and a differential pressure gauge is installed to measure vacuum induced on the subsurface due to the blower (AMECFW, 2018).

Routine monitoring of the VMS includes monthly visual inspections of the system, including readings of the sensors and gauges. Semi-annual inspections include vacuum measurements from the sub-slab monitoring points and measurements from the individual vapor lines for methane, VOCs and vacuum. Annual monitoring includes all semi-annual tasks and a calibration check for the methane sensors in each enclosed room of the Lab Pack building.

Due to the operation and routine maintenance of the VMS, the vapor pathway is likely to be incomplete for vapor intrusion and therefore additional assessment of the structure is not warranted at this time.

#### Stabilization Building

The Ecology comment letter (2021) discussion of the potential for vapor intrusion in the stabilization building made it clear that additional information regarding the use and operation of the structure should be provided to Ecology as part of the data gaps investigation work. The building is used for stabilization of hazardous wastes, specifically cyanide and metals wastes with less than 500 parts per million VOCs. The stabilization process uses lime kiln dust (LKD) to entrap the wastes in a pozzolan-concrete matrix. Mixing is accomplished via a tracked-excavator manually mixing the waste with the LKD.

The building is open to ambient air conditions through five large passive louvers (three slotted vents located on the east and two on the west side of the structure), as shown in the structure as-built drawings provided in Attachment B. The louvers allow passive ventilation when the building is not in use (unoccupied) and influent ventilation air during blower operations. The structure is not cooled during warmer weather months or heated during cooler weather

months. The entire structure is constructed on a gravel pad which brings the east side of the structure up to level grade with the facility operational area and a gravel slope on the west side of the structure leads down to the truck drive between the facility entrance and the north trailer parking lot. The gravel on the west side of the structure provides a preferential pathway for release of sub-slab pressure and vapors.

Operation of the blower is part of the ventilation system to control particulate air emissions during hazardous waste treatment/stabilization. The blower flow rate of 20,000 cubic feet per minute (CFM) is designed to properly ventilate and collect airborne dust during the mixing process and passive ventilation is sized such that a vacuum is not induced within the building.

Further, soil vapor samples collected approximately 100 feet north of the stabilization building in preparation for construction of the Lab Pack building exhibited a maximum concentration of benzene of 310 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ), the only compound detected above soil gas screening levels at the time of sampling (AMECFW, 2016). If an influent flow rate of 10 CFM is theoretically assumed (conservative to reflect infiltrating through a micro-silica concrete building slab), mixing due to the introduction of 20,000 CFM of ambient air would result in a concentration of  $0.155 \mu\text{g}/\text{m}^3$  benzene, well below the Method C Indoor Air Cancer Cleanup Level of  $3.21 \mu\text{g}/\text{m}^3$ . To observe a concentration of  $3.21 \mu\text{g}/\text{m}^3$ , the rate of soil vapor entering the building would need to be 207 CFM.

Similarly, if we assume the same theoretical influent rate of 10 CFM for methane at 75% of the lower explosive limit (the highest concentration detected in preparation for construction of the nearby Lab Pack building) and an introduction of 20,000 CFM of ambient air, the resulting methane would be 0.0375% of the lower explosive limit. This condition would not present a hazardous atmosphere within the stabilization building.

Based on construction of the building (including a direct route for sub-slab vapors to vent to ambient air), operation of the building, and the theoretical dilution of previous concentrations observed on site, the vapor pathway is likely to be incomplete for vapor intrusion and therefore additional assessment of the structure is not warranted at this time.

#### Parcel A

To address Ecology concerns regarding the risk of vapor intrusion to future buildings on Parcel A and areas of historical observation of LNAPL in the subsurface, DOF proposes to collect a soil vapor sample following collection of soil samples at location TWA-SB5, as discussed in the DGWP (DOF, 2020). The soil sample is planned to be collected from 5-feet below ground surface (bgs), the same depth as the Ecology requested soil vapor depth.

In other areas where LNAPL has historically been observed on the BE property, structures have been assessed with regards to vapor intrusion potential (modular buildings) or are currently paved and used for parking. If use were to change, additional assessment may be warranted. Location TWA-SB5 is a conservatively-placed location based on the presence of the cap in this area.

#### **Sample Location Install**

Construction of the soil vapor sampling point will be in accordance with procedures set forth in Appendix M of the DGWP (DOF, 2020). The soil vapor sampling point will be constructed using a

6-inch stainless-steel screen, connected to Teflon tubing that is installed up to the surface to allow for sampling. Filter pack sand will be placed from approximately 3 inches below to 3 inches above the 6-inch stainless steel screen for a total of 1 foot of sand pack. Hydrated bentonite chips will be placed above the sand pack interval to seal the soil vapor sampling point up to the surface. The vapor sampling point will be completed with a flush mount well monument and the locations will be installed at least one day prior to sampling to allow the bentonite chips to become fully hydrated and form a seal between the screen interval and the ground surface. Upon completion of installation, drill rods will be decontaminated using Alconox and deionized water, in accordance with industry standards.

Following installation of the sample location, a GPS unit will be used to record the location and documented with photos.

### **Sample Collection**

Prior to sample collection, a shroud will be placed over the sampling point, a single-use laboratory provided soil gas manifold will be connected to the: vapor sampling location, Summa® canister, and the purge line; helium gas will then be applied to the shroud as a leak detection indicator. A rotary vane pump or equivalent will be connected to the purge line and operated for 5 minutes to remove any stagnant soil vapor and confirm the sample tubing is leak free. An MGD 2002 Helium Leak Detector instrument or equivalent will be used monitor effluent of the purge line for helium.

Following purging and confirmation of sealed connection and tubing, sample collection will occur using a 1L Summa® canister equipped with a laboratory certified 200 mL per minute regulator prepared by the analytical laboratory. Sampling completion will occur when the pressure reaches -5 inches of mercury, at which time, the valve will be closed tightly, the manifold will be disconnected from canister and the threaded cap will be replaced. The manifold will be removed from the sample location and the sample location will be secured at the completion of sampling.

Sample collection on Parcel A will coincide with vapor sampling on the CleanCare Property.

### **Sample Analysis**

A chain of custody (COC) form will be completed that records the sample name, date, time, canister serial number, regulator serial number, starting pressure, and final pressure. Summa® canisters will be repackaged in shipping containers they were received in, with the COC accompanying them, and shipped, within 12 hours of sample collection, to the laboratory for analysis under COC as specified in the Quality Assurance Project Plan (QAPP) provided in Appendix L of the DGWP (DOF, 2020).

Samples will be analyzed under a standard turnaround time (TAT) of 10-15 days for the VOCs and Air-Phase Hydrocarbons (APH) listed in Table 1 of Appendix M of the DGWP (DOF, 2020) via EPA Method TO-15 and the Massachusetts DEP APH Test Method WSC-CAM-IX, respectively. Methane will be analyzed in the field during sampling by a Landtec GEM 2000 Landfill Gas Monitor. Differential pressure will be measured at the sample location if methane concentrations are above 5% as per ASTM E2993-16. Washington screening levels for sub-slab



soil vapor will be shared with the laboratory to establish minimum reporting goals that at least achieve these levels.

#### Transportation Office and Shop

Vapor intrusion assessment for the offices within the transportation building is proposed consistent with the tiered approach provided in the Ecology *Guidance for Evaluating Soil Vapor Intrusion in Washington State* (Ecology, 2018). Current site conditions warrant a Tier I assessment under the guidance because we have soil and/or groundwater contamination above screening levels within 100 feet of the structure.

The building consists of shop bays and an office space. We propose to collect two sub-slab soil gas samples from within the office area to assess if sub-slab soil gas concentrations could lead to unacceptable indoor air concentrations. A sample would be collected during a period of heating (winter) and cooling (summer). If either of the soil gas concentrations exceed sub-slab soil gas screening levels, Tier II assessment of indoor air, including an ambient air sample, will be collected to assess indoor air and the potential need for mitigation. The procedure for assessment of sub-slab soil gas sampling is provided below.

#### **Sample Location Install**

A single sample location, located central to the office space, will be installed using the VaporPin® system. VaporPins® are constructed of a single piece of metal, installable by hand tools, and use a silicon sleeve to form an air-tight seal between the VaporPins® and the side of the borehole, eliminating the need for grout or other adhesives. Installation of VaporPin® sampling locations will require boring through the concrete foundation slabs with a roto-hammer and installing a VaporPin® per manufacturer specifications. The standard operating procedure for installation and extraction of the VaporPin® is provided in Attachment C. Hand measurements will be collected to properly document the sample location inside the building and will also be documented with photos.

#### **Sample Collection**

Prior to sample collection, a shroud will be placed over the sampling point, a single-use laboratory provided soil gas manifold will be connected to the: vapor sampling location, Summa® canister, and the purge line; helium gas will then be applied to the shroud as a leak detection indicator. A rotary vane pump or equivalent will be connected to the purge line and operated for 5 minutes to remove any stagnant soil vapor and confirm the sample tubing is leak free. An MGD 2002 Helium Leak Detector instrument or equivalent will be used monitor effluent of the purge line for helium.

Following purging and confirmation of sealed connection and tubing, sample collection will occur using a 1L Summa® canister equipped with a laboratory certified 200 mL per minute regulator prepared by the analytical laboratory. Sampling completion will occur when the pressure reaches -5 inches of mercury, at which time, the valve will be closed tightly, the manifold will be disconnected from canister and the threaded cap will be replaced. The manifold will be removed from the sample location and the sample location will be secured at the completion of sampling with a stainless steel security cap.

Sample collection within the transportation building will occur in July or August 2021 to assess sub-slab soil gas during operation of the cooling system and January or February 2022 to assess sub-slab soil gas during operation of the heating system.

### **Sample Analysis**

A chain of custody (COC) form will be completed that records the sample name, date, time, canister serial number, regulator serial number, starting pressure, and final pressure. Summa<sup>®</sup> canisters will be repackaged in shipping containers they were received in, with the COC accompanying them, and shipped, within 12 hours of sample collection, to the laboratory for analysis under COC as specified in the QAPP provided in Appendix L of the DGWP (DOF, 2020).

Samples will be analyzed under a standard turnaround time (TAT) of 10-15 days for the VOCs and Air-Phase Hydrocarbons (APH) listed in Table 1 of Appendix M of the DGWP (DOF, 2020) via EPA Method TO-15 and the Massachusetts DEP APH Test Method WSC-CAM-IX, respectively. Methane will be analyzed in the field during sampling by a Landtec GEM 2000 Landfill Gas Monitor. Differential pressure will be measured at the sample location if methane concentrations are above 5% as per ASTM E2993-16. Washington screening levels for sub-slab soil vapor will be shared with the laboratory to establish minimum reporting goals that at least achieve these levels.

### **Former Potter Property**

The Port of Tacoma proposes to conduct sub-slab soil vapor sampling inside the buildings present at the Potter Property using methods consistent with those proposed for the Burlington Environmental parcels and has prepared the Sampling and Analysis Plan provided as Attachment D to address Ecology's comments related to the need for vapor intrusion assessment on the former Potter Property parcel. The Port of Tacoma proposes to collect one sub-slab vapor sample inside each of the two Quonset huts and timber shell structure.

Monitoring well MW-1 was inspected on June 25, 2021 and was determined to be in acceptable condition for groundwater monitoring. This well was previously covered by debris during the January 14, 2021, inspection of the Potter Property.

### **Former CleanCare Property**

Soil vapor sampling for the property will be completed per the DGWP (DOF, 2020) to provide data that will allow for further evaluation if soil gas is a potential hazard to indoor air for future site use. This work is currently being scheduled and coordinated with Pierce County.

Additional discussion related to site inspection in areas previously inaccessible due to brush will be provided under separate cover once a site visit is scheduled and inspections have been completed. This work will be performed concurrent to vapor sampling.

### **1514 Taylor Way Property**

The Port of Tacoma has worked with Ecology to address vapor intrusion potential for this parcel as part of completion of interim measures conducted under a separate Agreed Order specific to that property. Assessment of vapor intrusion on this property is not proposed or recommended as part of data gaps investigation.

## **References**

Washington State Department of Ecology (Ecology), 2018. *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*. April.

AMEC Foster Wheeler Environment & Infrastructure, Inc. (AMECFW), 2018. *Vapor Mitigation System Operation and Maintenance Manual*. May.

AMECFW, 2016. *Revised Soil Vapor Sampling Memorandum*. Stericycle Tacoma Facility, Tacoma, Washington, July.

Dalton, Olmsted, & Fuglevand, Inc. (DOF), 2020. *Final Data Gaps Work Plan*. July.

Dalton, Olmsted, & Fuglevand, Inc. (DOF), 2021. *Aboveground Site Conditions Memorandum*. March 5.

Washington State Department of Ecology (Ecology), 2021. *Re: Comments on the Aboveground Site Conditions Memorandum and Existing Groundwater Monitoring Network Evaluation and Recommendations Memorandum*. May 5.

## **Figures and Attachments**

Figure 1 – 1205 Alexander Avenue & 1300 Taylor Way Property Debris Location

Attachment A – Vapor Mitigation System Operation and Maintenance Manual

Attachment B – Stabilization Building As-Built Drawings

Attachment C – Standard operating procedure for installation and extraction of the VaporPin®

Attachment D – Port of Tacoma Former Potter Property Sampling and Analysis Plan

# Figures

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PLOT TIME: 6/24/2021 3:36 PM MOD TIME: 6/24/2021 3:35 PM USER: Kelley Begley DWG: P:\TWAFA\A\CAD\Figures\2021-06\2021-06 TWAFA Abovegrd Site Cond Fig 1.dwg

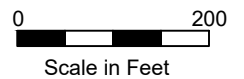


### Legend

- ◆ Wells to be installed
- ◆ Groundwater Well/Piezometer
- ◆ Abandoned Groundwater Well/Piezometer

- TWAFA Project Boundary
- Parcel Boundary
- Site Boundary
- x Fence

Source: Aerial Photography-Google Earth Pro, 08/14/2020.



Note:  
Pondered water locations approximated at the time of inspection (01/14/2021).

**TWAFA Site  
Tacoma, Washington  
Aboveground Site Conditions Memorandum**

**1205 Alexander Ave &  
1300 Taylor Way Property**



**FIGURE  
1**

06/24/2021

# **Attachment A**

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## **Vapor Mitigation System Operation and Maintenance Manual**





# **VAPOR MITIGATION SYSTEM OPERATIONS AND MAINTENANCE MANUAL**

Stericycle

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Prepared for:

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May 2018

Project No. 0-100-48005-0.00003

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March 26, 2018  
Project No. 0-100-48005-0.00003



Mr. John Carpenter  
Stericycle Tacoma  
1701 Alexander Drive  
Tacoma, Washington 98421

**Subject: Operations and Maintenance Manual  
Vapor Mitigation System  
1701 Alexander Drive  
Tacoma, Washington 98421**

Dear Mr. Carpenter:

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), presents the Operations and Maintenance (O&M) Manual for the vapor mitigation system (VMS) at the Stericycle site located at 1701 Alexander Drive in Tacoma, Washington. This O&M Manual provides guidance and instructions for operation and maintenance of the VMS for the new receiving structure.

This O&M Manual includes manual and component information of all major system equipment, updated system schematics, and annotated photographs showing locations of equipment and system control screens.

We appreciate the opportunity to provide our services for your project. If you have any questions or request further information, please feel free to contact us at (503) 639-3400.

Sincerely,

**Amec Foster Wheeler  
Environment & Infrastructure, Inc.**

A handwritten signature in black ink that reads "Crystal Thimsen".

Crystal Thimsen  
Project Manager

A handwritten signature in black ink that reads "Paul Stull III".

Paul Stull III, PE  
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EXPIRES June 2019

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Appendix B	Raven Industries – Absolute Barrier HDPE Liner Documents / Installer Certification
Appendix C	Liner Installation Field Description and Photo Log
Appendix D	System Commissioning Photo Log
Appendix E	Vapor Mitigation System – Pressure Transmitter Documents
Appendix F	Vapor Mitigation System – Blower Documents
Appendix G	Vapor Mitigation System – Methane Sensor Documents
Appendix H	Control Panel Specification
Appendix I	Direct Electrical Contractors – Control Panel Book
Appendix J	Commissioning Field Report

# VAPOR MITIGATION SYSTEM OPERATIONS AND MAINTENANCE MANUAL

Stericycle Site  
1701 Alexander Drive  
Tacoma, Washington

## 1.0 INTRODUCTION

This Operations and Maintenance (O&M) Manual was prepared by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) to provide guidance for the operation and maintenance of the vapor mitigation system (VMS) at the Stericycle receiving building (Site) located at 1701 Alexander Drive in Tacoma, Washington (see Sheet ENV-0 in Appendix A). The system was installed to prevent the buildup of volatile organic compounds (VOCs) and methane gases below the Site by removing vapors gases from the new building sub-slab area through collection lines and a regenerative blower. This O&M Manual provides a detailed description of the VMS and provides instructions and information on how to operate the system and conduct routine maintenance. The manual includes figures, photographs, equipment manuals, and control specifications to assist in ongoing operation, maintenance, and troubleshooting of the system.

## 2.0 BACKGROUND

The Site receiving building was built on a former landfill site with significant detections of methane gas in the subsurface at concentrations of up to 75 percent (%) of the lower explosive limit (LEL). Other VOCs, including benzene, were detected in the subsurface at concentrations above screening levels (Amec Foster Wheeler, 2016). To mitigate the buildup of methane gas below the new receiving building, a VMS was designed and installed under the concrete slab. A high-density polyethylene (HDPE) liner was also installed just below the concrete foundation to provide a barrier to gas transmission into the overlying enclosed portions of the building.

The VMS liner was smoke tested in three sections during three separate visits to the Site. The liner passed all three of the smoke tests, with no visible signs of punctures or defective welds. The above ground portion of the system was installed in April 2017, after the structure was nearing completion. Final system commissioning and testing was conducted in May 2017, after electrical and control work was completed. The system passed final electrical inspection and commissioning tests and went online on May 5, 2017.

### **3.0 SYSTEM DESCRIPTION**

The VMS is comprised of two major components. The first is the passive impermeable liner located below the building slab and grade beams described in Section 3.1. The second is the active venting system described in Section 3.2. These two components work in concert to provide a barrier to intrusion of methane and other volatile organic compounds (VOCs) into the enclosed spaces of the building. The recovered gases are directed through the active system and vented out into the atmosphere via the discharge vent stack on the top of the building. Refer to the “as-built” drawings in Appendix A for the details and layout of the installed VMS. The system was installed to address the concentrations of methane and other VOCs that were detected during soil vapor sampling conducted prior to the construction of the building. The sensors in each of the enclosed spaces measure sub slab methane concentrations as a percentage of the LEL, as described in Section 3.2. This system was designed and installed in accordance with ASTM E2435-05, E1643-11, and E1745-11, as applicable. The design of the VMS was approved by the Washington Department of Ecology (Ecology) and conforms with the required specifications and requirements and successfully demonstrated proper operation during commissioning activities.

#### **3.1 PASSIVE HDPE LINER**

The passive impermeable liner is a Raven Industries Absolute Barrier HDPE geomembrane liner that is 40 millimeters in thickness (model X40BAL). The liner was installed by Northwest Linings and heat fusion welded together in accordance with the manufacturer’s requirements. The liner system was installed with a geotextile (Agru America Agrutex 321 geotextile) layer below the liner to protect it from the crushed rock venting layer below it (See Env-1 A, B, C, and D sections in Appendix A). The geotextile was installed above and below the venting layer (layer of clean crushed rock compacted in a 3-inch vertical layer – venting piping is installed in this layer) to keep the venting materials segregated from native and other subgrade materials not suitable for venting. The liner was installed as a continuous barrier below the entire enclosed spaces of the building to provide an impermeable barrier above the venting later where soil gases are recovered and discharged out the system stack (on top of building). Without the liner, the soil gases would transition up through the building floors and potentially collect in the rooms. Refer to Appendix B for repair protocols if the liner is damaged during any future floor or utility work. If the liner is not disturbed, it should perform as detailed in the manufacturers literature (see Appendix B).

In order to confirm the proper installation of the liner and to look for potential damage to the liner during installation, three smoke tests were conducted using the VMS piping system during installation to test three different areas of the liner. All three tests passed without signs of any significant leaks or damage to the liner. Refer to Appendix B for the specifications sheet for the

HDPE liner and underlying geotextile. The installer's certification of acceptance of the soil subgrade layer and the geosynthetic liner is also provided in Appendix B. Appendix C provides a description of the field observations and a photo log of the liner installation and smoke tests.

As part of the liner installation work, sub-slab monitoring points were installed in the floors of each of the enclosed rooms. A monitoring point was installed for each venting line (associated with each air pocket zone – See ENV-1 in Appendix A). The tops of the monitoring points were installed flush with the floor with a threaded port (see ENV-5 – B for installation details of the monitoring points).

### **3.2 ACTIVE VMS COMPONENTS**

The active venting system was installed throughout the subslab zone under the enclosed portions of the building in rooms “A” to “E” (see Sheet ENV-1 in Appendix A). The active part of the system consists of the following parts:

1. Vent Piping – The piping uses horizontal screened Schedule 40 polyvinyl chloride (PVC) lines to recover vapors and gases below the slab and direct them out to the atmosphere at a vent stack above the roof of the building (Appendix D – Photo 3). The above grade piping is all Schedule 40 galvanized steel piping (Appendix D – Photos 4 and 14).
2. VMS Blower – A regenerative blower (Ametek Rotron model EN404AR72ML – 1.0HP, 208-230/460, 3PH, XP-rated motor) was installed in the mechanical room with the venting manifold to provide vacuum to actively recover the sub-slab vapors and direct them out of the vent stack. Refer to Appendix D – Photos 4 and 13 for photographs of the blower.
3. VMS Control Panel – The VMS system is controlled and monitored by a single control panel with a programmable logic control (PLC) system and human-machine interface (HMI) touchscreen interface. The control panel monitors the methane sensors and pressure transmitters and controls the operation of the blower. Refer to Appendix D – Photos 4 and 5.
4. Methane Sensors – The system has six methane sensors for each of the enclosed spaces (rooms “A” through “E”). The sensors are RKI M2A methane specific transmitters (part # - 65-2649RK-CH4). They have a 0-100% LEL range, 4-20mA output, and operate on 10-30VDC power. Refer to Appendix D – Photos 6 through 10 for the locations of the methane sensors and associated alarm lights in rooms “A” to “D”. No picture is shown of the methane sensor and light in Room “E” – which is also the location of VMS Control Panel.
5. VMS Pressure Transmitter – The VMS blower induces a vacuum on the sub-slab piping side of the system and the level of the vacuum is monitored by a Dwyer model 616W-C-LCD differential pressure transmitter. The operating range is 0 to 100 inches water column.



The output is 4-20mA and operates on 10-35VDC power. See Appendix D – Photo 5 for the VMS Vacuum Transmitter.

6. VMS Vacuum Gauge – A Dwyer mechanical vacuum gauge model SGX-D7722N (0-100 inches WC, 1/4-inch brass male pipe thread [MPT] end) is located just to the right of the VMS Control Panel (see Appendix D, Photo 5). This provides a mechanical backup to the electronic VMS Vacuum Transmitter.
7. Sampling Ports – Each VML line has an isolation valve and sampling port and the whole VMS has a sampling port (see Appendix D – Photo 14). Air samples can be collected during system operation if the line is isolated from the rest of the system using the proper valve and an air sample collected from the hose barb end of the port (after sample port valve is opened then closed after sampling).

The following appendices contain the specifications and manuals for the VMS Pressure Transmitter (Appendix D), VMS Blower (Appendix E), and VMS Methane sensors (Appendix F). The following section provides some additional details for the VMS Control Panel.

### 3.2.1 VMS Control Panel

The VMS Control Panel includes the following main components on the inside and the outside of the control panel box:

- **Front of Main Control Panel.** The following components are located on the front (exterior) of the main control panel (see Appendix D – Photo 5):
  - **Main Power Switch / Disconnect Handle.** The main power switch / disconnect handle (total power supply to the entire system) is the red handle in the upper right corner on the front of the panel. The disconnect switch must be turned to the OFF position before the panel can be opened. Turning the main disconnect switch to OFF shuts off power to the entire system.
  - **Touchscreen Interface.** The HMI is a color touchscreen located in the upper center on the front of panel. All programming and controls are run through this interface.
  - **Universal Alarm Light.** If a system alarm is active, the red light (on the top center of the VMS Control Panel) will flash. The universal alarm light will stay ON (flashing) until the alarm is cleared and the system is reset (pressing universal virtual alarm reset button on the touchscreen).
  - **Universal Virtual Alarm Reset Button.** The universal virtual alarm reset button is the red virtual button located on the lower right side of the Touchscreen Interface – Main Screen. Once an alarm condition has been cleared, the operator can press this button to clear the alarm signal to the PLC.

- **Interior of VMS Control Panel.** The interior of the control panel contains much of the system electrical equipment, including the following major components (see Appendix D – Photos 20 to 22 for interior pictures of the control panel):
  - **Programmable Logic Controller.** The PLC controls the entire system operations based on the system programming, setpoints, and telemetry. The PLC is located in the upper left corner of the control panel (Appendix D – Photos 20 and 21).
  - **VMS Blower Motor Starter.** The blower motor starter is located in the lower right corner of the control panel (Appendix D – Photo 20).
  - **DC Transformer.** The AC to DC power transformer is the white and green module located in the lower center of the control panel. This provides all of the DC power to the methane sensors and pressure transmitter.

## 4.0 SYSTEM OPERATION

This section provides details on proper operation of the VMS, including procedures for turning the equipment on and off, scheduling ON and OFF cycles, equipment rotation schedule, and how to operate the VMS Control Panel using the HMI touchscreen interface.

**IMPORTANT:** If the system is making atypical loud noises or grinding sounds or if a fire is present or nearby, immediately turn the Main Power switch on the front of the VMS Control Panel to the OFF position (see Appendix D – Photo 5) – located on the right side of the VMS Control Panel. Turning this switch to off will shut down the system completely (blower and sensors all shut down and are de-energized). To reactivate the VMS, turn the Main Power switch to the ON position.

It is important to wear the proper personal protective equipment (PPE) when operating the VMS. Level D PPE is recommended including hard hat, safety glasses, boots, gloves, and hearing protection. Outside the compound room is a cabinet on the far wall with additional hearing and hand protection. Due to the sound level, it is very important to wear significant hearing protection (ear muffs and ear plugs together are recommended). Leather gloves should be worn when touching the galvanized steel pipes, which may become hot. Otherwise nitrile gloves are sufficient.

### 4.1 VMS SYSTEM ACTIVATION

The VMS system electrical components only include one regenerative blower, six methane sensors, one pressure transmitter, seven alarm lights, and the control panel. These steps should be followed to activate the VMS system. These steps assume that the system is shut down completely upon arrival and that electrical power is ON to the system at the load center (located in

room “E” with the VMS Control Panel). If lights and control power are not on, check the load center to see if the breakers have been turned off. If they are off, flip them to the ON position only if you know which ones are for the system and it is safe to energize the system. To shut down the blower and VMS system go to Step 7.

**Step 1.** Check that gate valves on all six VML lines on manifold (See Appendix D – Photo 14) are fully open (turned all the way counter-clockwise). Close the VMS Blower By-Pass Valve (turned all the way clockwise) and open the VMS Blower Effluent Isolation and Influent Isolation valves (Appendix D – Photo 4). Open the VMS System Auxiliary Port/Valve (Appendix D – Photo 5). Turn the VMS Control Panel power switch / main disconnect to the vertical (ON) position (see Appendix D – Photo 5).

**Step 2.** Turn the VMS Control Panel power switch / main disconnect to the vertical (ON) position (see Appendix D – Photo 5).

**Step 3.** The touchscreen interface screen should light up, the program will boot up, and the main screen should come up (see Appendix D – Photo 15). The VMS Blower picture is on the far left with a label above it showing the current mode of the blower (Appendix D – Photo 15 shows it in AUTO mode). The operating mode is indicated above the blower picture and should be RED and show OFF. The reading for the pressure transmitter (this is labeled as “vacuum” on the Main Screen) should be zero or near zero when the blower is OFF. If the mode is BLUE and reads ON or AUTO, then the blower should be running. If the blower is in Alarm mode (mode is flashing red), then confirm the blower is in OFF mode (see Step 7) and hit the universal alarm reset button (see Appendix D – Photo 15) to clear the alarm.

**NOTE:** If system is ON at arrival and blowers are OFF, then skip to Step 7 and restart these steps.

**IMPORTANT:** If the power does not come ON to the touchscreen interface, then check that the load center breakers are ON for the system.

**Step 4.** Check the pressure transmitter and vacuum gauge (Appendix D – Photo 5) to see that they are reading zero or nearly zero. If these gauges read zero or near zero, then continue with next step. If they do not, attempt to zero the gauge and check to make sure connections are clear and sealed. Make sure that the tubing to the transmitter is on the low-pressure (right) side, the tubing valve is open (parallel with tubing), and the tubing is clear of water and debris. If one of these gauges does not zero, then log the reading, note that a replacement gauge may be necessary, and continue to next step.

**Step 5.** Tap the “Blower HOA Screen” button on the left bottom of the main screen (see Appendix D – Photo 15) and the VMS Blower Mode screen will come up (see Appendix D – Photo 16). The screen will show the virtual blower mode switch (virtual HAND-OFF-AUTO switch). The white line on the virtual switch will point to the current mode (it should be in OFF mode). To switch the mode to AUTO (recommended operating mode), tap the virtual switch to toggle the mode between OFF, AUTO, and HAND until you get to AUTO mode. The blower should activate at this time. If the blower does not activate, perform the following system checks:

1. Check the universal alarm light (red light on top of the control panel—see Appendix D – Photo 5). If the light is on or blinking, then press the universal alarm reset virtual button located on the far right of the VMS Main Screen (press the Main Screen button on the Blower Mode screen to return to the Main Screen). This should clear the alarm, turn off the universal alarm light, and start the blower.
2. Check the Cycle 1 ON time below the blower virtual HOA button (Appendix D – Photo 16). If that time is set to 000 (zero minutes) and the Cycle 2 OFF time is greater than 000 (zero), then the system is in the OFF cycle (see Section 4.3 for blower cycling programming) and will not come ON until the Cycle 1 OFF period has ended. If this is the case, then toggle the blower mode to OFF and reprogram the blower cycles. Refer to Section 4.3 to reprogram the cycle durations so that the blower activates in AUTO mode immediately on selecting the AUTO mode.
3. If the pressure transmitter reading is elevated above the high set point (above 30 inches WC), there might be a valve or valves closed or partially closed, or some other obstruction may be blocking the air flow in the system. Check the valves, equipment, and lines for obstructions, constrictions, or excessive water. If none is found, recheck gauge and sensor for erroneous readings with vacuum gauge. If an obstruction or restriction is found and cleared, then return to Step 5 and toggle blower mode switch to AUTO mode.
4. If none of the preceding checks resolve the issue, contact a licensed electrician familiar with these types of systems to check the system for a wiring, control, or motor failure. If discovered, have the electrician fix the problem with the proper equipment.

**Step 6.** Once blower is operating in AUTO mode, press the main screen button (see Appendix D – Photo 16) to return to the main screen and check the vacuum and methane telemetry (see Appendix D – Photo 15). The vacuum level should be between 2 and 4 inches WC if all the VML lines are open and the auxiliary valve is open. If the level is higher than 20 inches WC, then continue checking the lines and valves. If the vacuum level on the Main Screen is below 10 inches WC, then close the auxiliary valve all the way and read the new vacuum level. If it is still below 20 inches WC then let the system run normally. The expected vacuum level for all VML lines open is approximately 4 to 10 inches WC.

**IMPORTANT:** If the unit makes a grinding or oscillating sound that is not typical, then immediately go to Blower Mode by pressing the Blower HOA Screen virtual button (Appendix D – Photos 15 and 16) and toggle the blower mode to OFF. Have the blower checked for bearing, motor, or compressor failure.

**Step 7. SHUT DOWN BLOWER:** To shut down the blower, tap the Blower HOA Screen virtual button on the main screen (see Appendix D – Photo 15). The Blower Mode screen will come up (see Appendix D – Photo 16). Tap the virtual blower HOA switch to toggle it between modes until the white vertical line points up to the OFF position. The blower should shut down after that. If the blower does not shut down, turn the system main switch / local disconnect switch blower to the OFF position on the front of the VMS Control Panel (see Appendix D – Photo 5) and have a licensed electrician or panel fabricator check the system and PLC programming.

## 4.2 SETPOINTS PROGRAMMING

The VMS control logic is controlled by setpoints (programmed valves). Some of these setpoints are programmed into the code. Other set points can be adjusted from the touchscreen interface to activate an alarm condition and determine the length of time (duration) that an alarm condition will constantly exist before the alarm is activated and shuts down the system. Refer to the Control Panel Specifications in Appendix G for a detailed description of the VMS sensor controls, alarm types, and system responses to these alarms.

The following four VMS setpoints can be easily adjusted through the touchscreen interface on the main control panel (Appendix D – Photo 15) by touching the Set Points Screen virtual button on the main screen, which opens the VMS Setpoints screen (Appendix D – Photo 18):

1. **VMS High Vacuum** - This vacuum level (in inches WC) will shut down the blower if a high vacuum level (from the differential pressure transmitter) is observed for a constant period greater than the Methane Alarm Activation Period (seconds – this time setting is used for the vacuum and methane sensors). This level should typically be 30.0 inches WC. This level can be adjusted down to test the system or provide a lower high-vacuum level.
2. **VMS Low Vacuum** - This vacuum level (in inches WC) will cause the control panel alarm light to flash to notify the operator if the vacuum level is too low during periods of blower operation indicating that there may be a problem with the blower. The alarm condition must be on for a constant period greater than the Methane Alarm Activation Period (seconds – this time setting is used for the vacuum and methane sensors). This level should typically be 0 to 2.0 inches WC. This level can be adjusted down to test the system or provide a lower or higher low vacuum level.

3. **Methane Alarm Activation** - This is the high level of any methane sensor in the system. If the methane alarm activation level (in LEL from 0 to 100%) is exceeded for a period longer than the Methane Alarm Activation Period, then the alarm condition will activate and the blower will come on if it is in AUTO mode (even if it's in an OFF cycle). This level should typically be 10% LEL. This level can be adjusted down to test the system or provide a lower LEL level. The default level was selected to be a safe level that would not typically be activated by potential site materials or equipment (forklift, etc.).
4. **Methane Alarm Activation Period** - This setpoint adjusts the period of continuous amount of time to be exceeded before the alarm condition is activated resulting from an exceedance of the high level set point for any of the methane sensors or the differential pressure transmitter (vacuum level). This period is set in seconds from 000 to 999. The recommended period is between 5 and 20 seconds (the default level is 5 seconds) to reduce the potential for an extended high vacuum or high methane level period that would damage the system or be a hazard to the operators. This alarm period reduces the potential for “false” alarms if telemetry signals bounce or momentarily spike due to electrical “noise.”

The value of the current setpoint is shown on the virtual button to the right of the setpoint label. All four are in white boxes. To adjust the set points, use the following steps:

**Procedure for Changing Set Points:**

**Step 1.** Press the setpoints button on the main screen (Appendix D – Photo 15) to go to the setpoints screen (Appendix D – Photo 18).

**Step 2.** Select the setpoint that you wish to adjust, and press the virtual button (the virtual button with the current setpoint value located to the right of the setpoint label; Appendix D – Photo 18).

**Step 3.** A keypad screen should come up over the setpoints screen (Appendix D – Photo 19). Enter the value you want using the keypad, and press the virtual “Enter” button. The keypad screen should disappear and return to the setpoints screen. Confirm that the new value is the one you entered. If not, repeat Steps 2 and 3.

If you make an error, press the “Clr” (clear) button to clear the value and start over to enter the new value on the keypad.

If you want to back out of the keypad without making any changes, press the “Esc” (escape) button, and the keypad screen will disappear and return you to the setpoints screen.

**Step 4.** Press the main screen button to return to the main screen.



Setpoints can be adjusted at any time to modify the system parameters or to test the alarm logic of the system. The operator should be careful to return to the proper setpoint values to the system after any testing values have been entered. The operator should also log any new setpoint numbers on the field report form during the visit to document any setpoints changes.

### 4.3 CYCLE PROGRAMMING FOR BLOWER

The VMS Blower can be programmed to run either continuously or on an ON/OFF cycle during a standard 24-hour cycle period.

#### **Continuous Blower Operation Programming**

To program the VMS Blower to run continuously, follow these steps.

**Step 1.** Press the Blower HOA Screen button in the lower left of the main screen (Appendix D – Photo 15). This should take you to the Blower Mode screen with the cycle programming buttons below the virtual HOA switch (Appendix D – Photo 16).

**Step 2.** The cycle programming buttons are below the HOA switch on the Blower Mode screen (Appendix D – Photo 16). There are four buttons labeled (from top to bottom) Cycle 1 ON, Cycle 1 OFF, Cycle 2 ON, and Cycle 2 OFF. These buttons show the number of minutes the respective cycle will run (for example, using settings shown on Appendix D – Photo 16, Cycle 1 ON will run for 100 minutes).

**Step 3.** Press the Cycle 1 ON button. This will bring up a keypad screen as shown on Appendix D – Photo 17. Enter the value of 100 minutes and press the virtual “Enter” button. This should make the keypad screen disappear and return you to the cycle programming screen. Confirm that the new value is the one you entered. If not, repeat Step 3.

If you make an error, press the “Clr” (clear) button to clear the value and start over to enter the new value on the keypad.

If you want to back out of the keypad without making any changes, press the “Esc” (escape) button, and the keypad screen will disappear and return you to the cycle programming screen.

**Step 4.** Repeat Step 3 for the blower, but select the Cycle 1 OFF button, program it for 0 minutes (this will cause the PLC to skip the Cycle 1 OFF duration), and press the “Enter” button. Repeat this setting for the Cycle 2 ON and Cycle 2 OFF buttons (programming them with 0-minute duration to cause PLC to skip these cycles).

The PLC will now run the blower continuously as it loops through the two ON/OFF cycles.

### **ON/OFF Cycle Operation Programming**

To program the VMS Blower to cycle during the day once or twice, follow these steps:

For this procedure, we are going to simulate the blower running from 7 AM to 7 PM with the programming starting at 4 PM. To do this we will program the cycles using the following values:

- Cycle 1 ON = 180 minutes (3 hours—this will run the blower from 4 PM to 7 PM);
- Cycle 1 OFF = 720 minutes (12 hours—this will keep the blower off from 7 PM until 7 AM the next day);
- Cycle 2 ON = 540 minutes (9 hours—this will keep the blower on from 7 AM to 4 PM the next day);
- Cycle 2 OFF = 000 minutes (since the Cycle 2 ON duration ended at 4 PM—the desired start time—the Cycle 2 OFF duration needs to be zero so the unit stays ON and into the following Cycle 1 ON duration).

**IMPORTANT:** The operator needs to consider the start time of the cycles, since the cycles will run for the minutes programmed in sequence until all four durations are done. The operator needs to make sure that the sum of the minutes for the four cycles equals 1440 minutes (1 day of minutes). If the four cycles do not sum to 1440, the cycles will not run consistently from day to day.

**Step 1.** Press the Blower HOA Screen button in the lower left of the main screen (Appendix D – Photo 15). This should open the Blower Mode Screen which has the blower cycle programming buttons (Appendix D – Photo 16).

**Step 2.** The cycle programming buttons are below the HOA switch on the Blower Mode screen (Appendix D – Photo 16). There are four buttons labeled (from top to bottom) Cycle 1 ON, Cycle 1 OFF, Cycle 2 ON, and Cycle 2 OFF. These buttons show the number of minutes the respective cycle will run.

**Step 3.** Press the Cycle 1 ON button. This will bring up a keypad screen as shown on Appendix D – Photo 17. Enter the value of 180 minutes and press the virtual “Enter” button. This should make the keypad screen disappear and return you to the cycle programming screen. Confirm that the new value is the one you entered. If not, repeat Step 3.

If you make an error, press the “Clr” (clear) button to clear the value and start over to enter the new value on the keypad.

If you want to back out of the keypad without making any changes, press the “Esc” (escape) button, and the keypad screen will disappear and return you to the cycle programming screen.

**Step 4.** Repeat Step 3, but select the Cycle 1 OFF button, program it for 720 minutes, then press “Enter.” This will cause the keypad to disappear and the cycle programming screen to come back. Confirm that the Cycle 1 OFF value is now 720 minutes.

**Step 5.** Repeat Step 3, but select the Cycle 2 ON button, program it for 540 minutes, then press “Enter.” This will cause the keypad to disappear and the cycle programming screen to come back. Confirm that the Cycle 2 ON value is now 540 minutes.

**Step 6.** Repeat Step 3, but select the Cycle 2 OFF button, program it for 000 minutes, then press “Enter.” This will cause the keypad to disappear and the cycle programming screen to come back. Confirm that the Cycle 2 OFF value is now 000 minutes.

**Step 7.** Once all of the cycle durations have been properly set, wait until the designated start time (4 PM) and then hit the “Auto Start” button (green) just to the right of the HOA virtual switch on the Blower Mode screen. This will activate the cycle programming. The current mode of the cycle programming is shown on the extreme left of the Main Screen (Appendix D – Photo 15). When the cycles are running the blower picture will be green (“ON”). If you press the red “Auto Stop” button while the system is ON, then the cycling will stop and the current mode will show “OFF.”

**Step 8.** Once the cycles have been programmed and are running, press the “Main Screen” button at the bottom of the screen to return to the main screen. At the main screen confirm that the blower is running, and log the new program cycle times and durations on the field report form.

The programmed cycle can be overridden by re-programming the cycle durations or by toggling the HOA virtual switch to the “HAND” mode in the Blower Mode Screen to put the blower in manual override “ON”. The blower can be shut off at any time by toggling the virtual HOA switch to the “OFF” position. The cycles will continue to go until the Auto Stop button is pressed.

#### **4.4 DATE AND TIME PROGRAMMING**

The current date and time of the VMS Control Panel is displayed in the lower right corner of the main screen (Appendix D – Photo 15). The date is shown in MM/DD/YY format, and the time is shown in military (24-hour) format. If the date and time need to be adjusted, follow these steps.

## **Date and Time Programming**

**Step 1.** Press the Set Points Screen button on the main screen (Appendix D – Photo 15). The Set Points screen will open (Appendix D – Photo 18).

**Step 2.** The date is shown on three buttons for year, month, and day, while the time is shown on three buttons for hour, minute, and second (Appendix D – Photo 18) on the right side of the screen. Press the button for the date or time unit to be adjusted.

**Step 3.** A keypad screen should open over the date/time screen (Appendix D – Photo 19). Enter the value you want using the keypad, and press the virtual “Enter” button. This should make the keypad screen disappear and return you to the date/time screen. Confirm that the new value is the one you entered. If not, repeat Steps 2 and 3.

If you make an error, press the “Clr” (clear) button to clear the value and start over to enter the new value on the keypad.

If you want to back out of the keypad without making any changes, press the “Esc” (escape) button and the keypad screen will disappear and return you to the date/time screen.

**Step 4.** Press the Main Screen button to return to the main screen.

The new values for the date or time should be visible on the main screen. If the values are not correct, wait about 30 seconds to see if they are updated. If they do not update, go back to the date/time screen and repeat steps 1 to 4.

## **4.5 ALARM CONDITIONS**

The system has two primary alarm conditions – High Methane Level or High Vacuum Level. These two situations should be addressed in the following manner:

1. **High Methane Level** – All of the methane sensors in the system are independent from each other and each has an associated red flashing light. The default High Methane Level is 10% LEL for methane. This could be caused by methane gas entering the enclosed space from below, materials in the room off-gassing methane (or other volatile compounds), or use of equipment that exhausts volatile gases. If the methane sensor activates and the light flashes, the room should be evacuated and electrical and other combustion sources removed/de-energized to avoid an explosion. Doors on both ends of the room should be opened (if possible) to allow for ventilation of the space to help reduce the level of volatile gases. Once this has happened, a trained person should monitor the space with an

appropriate methane or volatile organic carbon analyzer to determine if the condition still exists. It can be possible for the methane sensors to produce false positive readings if they go out of calibration or are nearing the end of their life expectancy.

2. **High Vacuum Level** – This alarm will shut down the VMS Blower to avoid damage to the blower. Extended operation at high vacuum will stress the motor and compressor head. If you have a high vacuum level alarm, make sure that the blower is off. If it does not shut off, turn the main switch / local disconnect to the OFF position. Have a licensed electrician check the system and blower for potential problems. If the blower is faulty, have it replaced with the same make and model. During the blower down time, close the Blower Influent and Effluent valves and open the Blower By-Pass valve to allow for passive venting of sub-slab gases. Once the blower has been fixed or replaced, close the Blower By-Pass valve and open the Blower Influent and Effluent valves before turning on the blower (follow the blower activation procedures in Section 4.1).

## 5.0 SYSTEM MAINTENANCE

The VMS is designed to be automated and operate with very little operator oversight. The telemetry and alarm system can be accessed through the control panel touchscreen. This document contains several manufacturer's manuals (located in respective appendices) for major system equipment. The operational and maintenance information in those manuals should take precedence over the summary presented here. If maintenance issues arise, the manufacturer's manuals should be reviewed along with the respective section in this document. This section includes site-specific maintenance issues and schedules. Operation and maintenance of the VMS should be conducted by facility personnel trained to oversee and maintain the system. Amec Foster Wheeler (503-639-3400) and Direct Electrical Contractors (503-756-3457) can provide additional technical support for system layout, controls, and operation. The facility operator should complete a field log describing VMS inspections, repairs, and routine maintenance and keep these logs in a log book on the site.

In general, a visual inspection of main system components should be conducted during routine monthly site visits. Every two years, the panel fabricator should be subcontracted to perform a biannual control inspection (see Section 5.3).

The maintenance section has been separated into three areas: 1) the VMS Active Components, 2) the VMS Passive Liner, and 3) VMS Control System.

## **5.1 VMS ACTIVE COMPONENTS**

Routine system maintenance requirements and schedules address the following main system components. Monthly inspection visits will primarily consist of visual inspections of the system and readings of the sensors and gauges. Quarterly visits include additional equipment checks per the operation and maintenance schedule summary sheet. Some equipment is checked on an annual basis and all electrical and control systems should be checked by the panel fabricator bi-annually (see Section 5.3 for more details of the VMS Controls System bi-annual system check).

### **5.1.1 VMS Blower**

The VMS includes a 1.0HP (explosion proof rated motor) regenerative blower built by Ametek Rotron. This blower has an expected life span of approximately 5 to 7 years, with some units lasting longer under ideal conditions. These units are typically very reliable and require little maintenance as long as particles and moisture are kept out of the units and the units do not sit idle for more than a month at a time. The blower should be visually inspected for signs of damage or discoloration (suggesting high heat conditions), and any issues observed should be documented. If a blower is making grinding or oscillating noises, the blower should be shut down immediately and checked by a competent blower repairman to determine the failure and remedy the blower and put it back into service.

The vacuum level for each line and the total system should be checked during blower operation every six months. The vacuum levels at the respective sub-slab monitoring points (monitoring points associated with the local VML line) should be checked with a differential pressure gauge connected to the threaded monitoring point to confirm that each zone still has adequate vacuum to recover soil gases. The six vapor lines and total system effluent should also be checked during the electronic six month inspections for concentrations of VOCs with a PID and methane concentrations with a multi-gas meter.

### **5.1.2 Methane Sensors/Transmitters**

The VMS has six identical methane sensors/transmitters that are located in each of the enclosed spaces (with one being in the corner room of room “A” – See Appendix A – As-built Plans for locations of each). Each sensor is electrically connected to the VMS Control Panel via conduit sealed for XP rating. The sensors require very little maintenance. It is important to keep them clean and free of liquids or dust. If dust or liquids do impact the unit, they should be carefully cleaned and retested with known concentrations of methane gas to confirm proper operation in accordance with the manufacturer’s requirements. The sensors are rated for a continuous operation of approximately 5 years. Therefore, the sensors should be replaced with the same model or equivalent units in May of the following years: 2022, 2027, 2032, 2037, 2042, 2047, etc. The



sensors should be checked at least once a year with a known concentration of methane and checked against a multi-gas meter with a methane specific sensor. If the unit is not reading properly, it should be calibrated in accordance with manufacturer's requirements (see Appendix F for methane sensor documentation). These sensors should also be checked during the electronic biannual inspection.

### 5.1.3 Vacuum Gauge

It is expected that the mechanical vacuum gauge will periodically fail and require replacement. The mechanical gauge can be checked monthly by briefly shutting down the blower and seeing if the units go to zero (or near zero) inches WC vacuum. If the mechanical gauge does not go to zero, attempt to zero or unstick the dial hand with the blower(s) off after removing the plastic cover. Then retest the gauge with the blower(s) on and off. If this process does not remedy the mechanical gauge, replace the gauge. It is recommended to purchase replacement vacuum gauges in groups of at least three or four so replacements are available on site.

### 5.1.4 VMS Pressure Transmitter

The life expectancy of the VMS (differential) pressure transmitter (electronic vacuum gauge with the LCD display) should be a few years under normal range vacuum operating conditions. The vacuum gauge hose has a valve on it below the vacuum gauge (Appendix D – Photo 14). Make sure that this valve is open (parallel to hose) during all testing. The transmitter should be checked monthly when the vacuum gauge is being checked using the same procedure. If the transmitter fails the test, check that the hose is connected to the low-pressure connection and that it is not blocked or full of water or debris. If the line has water or debris in it, cut out the line and replace it with a new line. If the mechanical vacuum gauge is reading properly but the transmitter is not and the line is clear and connected to the proper side, then the transmitter may require replacement. The transmitter should also be electrically checked during the biannual controls inspection. Refer to Appendix D for the pressure transmitter documents.

### 5.1.5 System Pipes, Fittings, and Valves

A visual inspection of the accessible VMS piping, fittings, and valves should be made during each monthly visit in accordance with the following list.

- **Pipes.** Visually check all of the pipes for signs of cracking, leaking, warping, discoloration, or bending. Mark the pipe where any of these signs are observed and take a picture to document the current condition. If damage is significant, repairs to the piping should be implemented as soon as possible by replacing the damaged section and providing the proper support.

- **Fittings.** The fittings include the turns, unions, couplers, and other PVC or steel fittings. These components should be visually inspected for leaks or damage. If a leak is present, either tighten the fitting or replace it, as necessary. If a fitting is damaged, it should be replaced with an equivalent fitting. All damage and leaks should be documented in the field report form.
- **Valves.** The system valves include the individual VML line gate valves, blower isolation valves, blower by-pass valve, pressure transmitter valve, and auxiliary port valve (Appendix D – Photo 4). During the monthly visits, each gate and ball valve should be opened and closed to check that the valve is not frozen in the current state. All of the gate and ball valves should be in the open position, with the exception of the Blower By-Pass Valve and the Auxiliary Port Valve.

**IMPORTANT:** Remember to ALWAYS turn the blower mode to OFF position and local disconnects to OFF position when implementing any repairs to the VMS equipment. Once repairs are completed, return the mode button and local disconnect to their normally operating positions.

## 5.2 VMS PASSIVE LINER

The VMS passive HDPE liner is located entirely below the building slab and is not accessible. This liner does not require any maintenance or inspections due to its design and inaccessibility. The material has a rated life expectancy greater than 50 years if not exposed to sunlight or incompatible concentrated chemicals. If sub-slab utility or repair work is being conducted that required the HDPE liner to be cut or partially removed, the damaged section should be repaired in accordance with the manufacturer's requirements (see Appendix B). This will require an extended area around the planned opening to be opened to allow for adequate access to the surrounding HDPE liner for fusion welding a patch into place. A smoke test using the existing VMS recovery lines (VML) and manifold (injection of smoke into the Auxiliary Port and through the proper VML line to the repair area). Once the patch has been properly welded into place and successfully smoke tested, the overlying concrete floor patch can be installed. If new utility or equipment penetrations are installed through the VMS Passive Liner, then proper HDPE "boots" or other custom sealing devices will need to be installed or a change in the liner design will be needed. Any changes like these will also need to be smoke tested to ensure a proper seal to the liner prior to floor patch installation.

## 5.3 VMS CONTROL SYSTEM

The system controls and panel do not require routine maintenance, but component failure can occur after prolonged periods of use (typically a few years, unless components are subjected to

temperature extremes, inclement weather, or excessive on/off cycles). The panel fabricator is Direct Electrical Contractors (DEC - Terry DeVries) and can be contacted at 503-756-3467 for technical support and to conduct repairs. DEC prepared a VMS Control Panel Book (Appendix H) with the control logic diagrams, functional specifications, equipment documentation, and a CD copy of the PLC program.

The following maintenance activities should be conducted for the controls system.

- **Monthly Visual Inspection.** A visual inspection of the control panels should be conducted during the monthly site visits to see if any damage has been done to any panel, conduit, sensor, or switches/lights. Confirm that the touchscreen is working and the set points are working properly. Any damage should be recorded in the field report and the panel fabricator notified to implement the repairs.
- **Biannual Control Inspection.** The panel fabricator should be subcontracted to inspect the system, check the PLC programming, and test the unit for proper operation at least once every two years (**odd years**) of operation between April and June. If PLC programming updates or fixes are required, the fabricator should implement those at the Site during the visit, if possible. All maintenance items identified by the fabricator should be listed on the field report and an estimate for these items submitted to the project manager. These maintenance items should be completed in a timely manner to ensure continued proper operation of the system. These repairs could include replacement of PLC components, motor starter, breakers, and other electrical equipment that failed or showed indications of pending failure.

## 6.0 SUPPORT CONTACTS

The following contacts can be contacted to provide technical support for the system if the respective components or systems appear to be malfunctioning or have failed:

### **System Design and Layout**

Amec Foster Wheeler

Paul Stull, PE (Design Engineer) – 503-639-3400 or [paul.stull@amecfw.com](mailto:paul.stull@amecfw.com)

### **VMS Blower**

AOP Technologies

Cliff Best (Technical Support) – 503-257-9848 Ext 1421 or [cliffb@aoptec.com](mailto:cliffb@aoptec.com)

### **VMS Passive HDPE Liner**

NW Linings and Geotextile Products (Installer for Raven Industries material)

253-872-0244 or [info@northwestlinings.com](mailto:info@northwestlinings.com)

### **Controls, Sensors, Programming, and Telemetry**

Direct Electrical Contractors

Terry DeVries (Panel Fabricator and Electrician) – 503-756-3457 or [twdelectric@gmail.com](mailto:twdelectric@gmail.com)

## **7.0 VMS COMMISSIONING**

The system installation work was completed in early May 2017. The VMS commissioning work was conducted on May 5, 2017, to test the functionality of the system and identify and discrepancies in the work or make edits to the PLC programming. The work was conducted by the VMS design engineer (Amec Foster Wheeler – Paul Stull) and the control panel fabricator / electrician (DEC – Terry DeVries). The following tests were conducted during the commissioning work at the Site and the results were collected and documented (see Appendix I for the Commissioning Field Report):

1. Methane Sensor Test – A canister of known concentration of methane (50% LEL) was used to simulate elevated methane concentrations at each of the methane sensors. Methane readings were collected at the VMS Control Panel (VMS CP), on the local sensor display (Sensor), and from a multi-gas meter with a methane specific sensor (MG Meter). Each sensor was tested and the readings on all three sensors/outputs read with 2% LEL of each other which is within tolerance. Each of the respective methane sensor alarm lights and sensor labels on the VMS Control Panel Main Screen flashed when the methane level exceeded the Methane High LEL Level set point (10% LEL) and stopped flashing when the levels declined below the high-level set point and the alarm reset button on the control panel main screen was pressed. Based on this test, the methane sensors and associated PLC programming and interface components were APPROVED.
2. Blower Test – The VMS Blower and associated high and low vacuum set point control logic programming was tested for vacuum response at varying vacuum levels by closing all of the VML valves and varying the opening of the auxiliary port valve (“bleed valve”). The vacuum level was monitored with the pressure transmitter, vacuum gauge, and VMS Control Panel touchscreen reading. As the test began, it was observed that the vacuum gauge was not operating properly since it was not the proper gauge. No values from the vacuum gauge were recorded for the commissioning. The test was started with the auxiliary port valve in the fully open position. The low and high vacuum set points were set at 2 and 30 inches of WC, respectively. Initially the system showed no vacuum, which was below the low vacuum set point. The system alarm activated at all times below the 2-inch WC level. As the

auxiliary port valve was progressively closed (2/3 open, 1/2 open, 1/3 open, 1/4 open, 1/5 open, and fully closed), the vacuum level increased from 0 at fully open to 46.9 inches WC (sensor reading – VMC Control Panel read 47.8 inches WC) and fully closed. The VMS Control Panel alarm was activated when the vacuum level exceeded 30 inches WC at the VMC Control Panel when the auxiliary port valve was closed to about 1/4 open (reading was 33.5 inches WC). Both the low and high vacuum alarms worked properly and cleared properly when the alarm condition was cleared.

3. Manifold Line Test – A test of each individual VML line was conducted to see what the relative vacuum levels and local methane levels (methane recovered near the respective VML lines) would be for each individual line. The test was conducted by first fully opening the auxiliary port valve and closing all of the VML valves. Next, VML-1 was opened and the auxiliary port valve was closed. The vacuum and methane LEL readings were taken after both levels stabilized. Once they had stabilized and been recorded, the auxiliary port valve was opened and VML-1 valve was closed. This process was repeated for each of the VML lines. At the end of the test, all of the VML lines were opened and a total system vacuum and methane LEL level were recorded. The vacuum levels in each line (vacuum being pulled ONLY from that line) varied from 15.4 (VML-3) to 30.4 (VML-4) inches of WC. All of these vacuum levels were within normal blower operating tolerances and within expected levels. The respective methane levels in the lines varied from 0.8% (VML-3) to 2.8% (VML-5) LEL. The total system vacuum was 4.5 inches WC (at the sensor – the touchscreen reported a vacuum of 4.2 inches WC) and 1.4% LEL of methane from the multi-gas meter. Due to the prior system tests, these methane levels are within the expected ranges and should be indicative of operating conditions at the Site.
4. During the manifold test, the respective sub-slab monitoring points were connected to Dwyer magnahelic differential pressure gauges to confirm vacuum influence at points on the edges of the air pocket for each VML line. The vacuum influence observed at the monitoring points ranged from 0.11 to 0.22 inches of WC, thus confirming adequate vacuum coverage in these zones. No monitoring points were installed outside the vapor barrier area.
5. General Equipment Inspection – A general visual and manual inspection of the accessible piping and system equipment was conducted during the commissioning work. No visual or apparent mechanical issues were identified other than the vacuum gauge issue identified during the Blower Test. All valves appear to be in good order and no leaks in the piping were observed.

At the conclusion of the commissioning work, it was determined that the system was working properly and the sensors were within calibration tolerances. The only outstanding issue was the vacuum gauge (wrong gauge installed). We have been notified by the owner that the proper gauge

has been installed after the commissioning work and is working properly. Based upon these results, Amec Foster Wheeler APPROVED the VMS for operation.

## **8.0 CONCLUSION**

Amec Foster Wheeler has prepared this Operation and Maintenance Manual to provide the system operator a guide for operating and maintaining the VMS equipment and to document the commissioning work. The operator should review the document, conduct the recommended equipment rotations and maintenance schedule, and familiarize themselves with the recommended maintenance, setpoints, operational configuration, and manufacturers' requirements/information. Please contact Amec Foster Wheeler or the panel fabricator if you have any questions or require additional system technical support.

## **LIMITATIONS**

This operation and maintenance manual was prepared exclusively for Stericycle Inc by Amec Foster Wheeler Environment & Infrastructure, Inc. The quality of information contained herein is consistent with the level of effort involved in Amec Foster Wheeler services and is based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this manual. This operation and maintenance manual is intended to provide direction for the operation and maintenance of the VMS at the Site and is subject to the terms and conditions of its contract with Amec Foster Wheeler. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

The information contained herein is relevant to the dates of the Amec Foster Wheeler Site work and the manufacturer's documentation. In the event that changes in the nature, usage, or layout of the system or property are made, the information contained in this report may not be valid. If additional information becomes available, it should be provided to Amec Foster Wheeler so the original conclusions and recommendations can be modified as necessary.

## **REFERENCES**

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), 2016, Revised Soil Vapor Sampling Memorandum, Stericycle Tacoma Facility, Tacoma, Washington, July.



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**APPENDIX A**

Vapor Mitigation System – As-Built Drawings



# STERICYCLE

## VAPOR MITIGATION SYSTEM

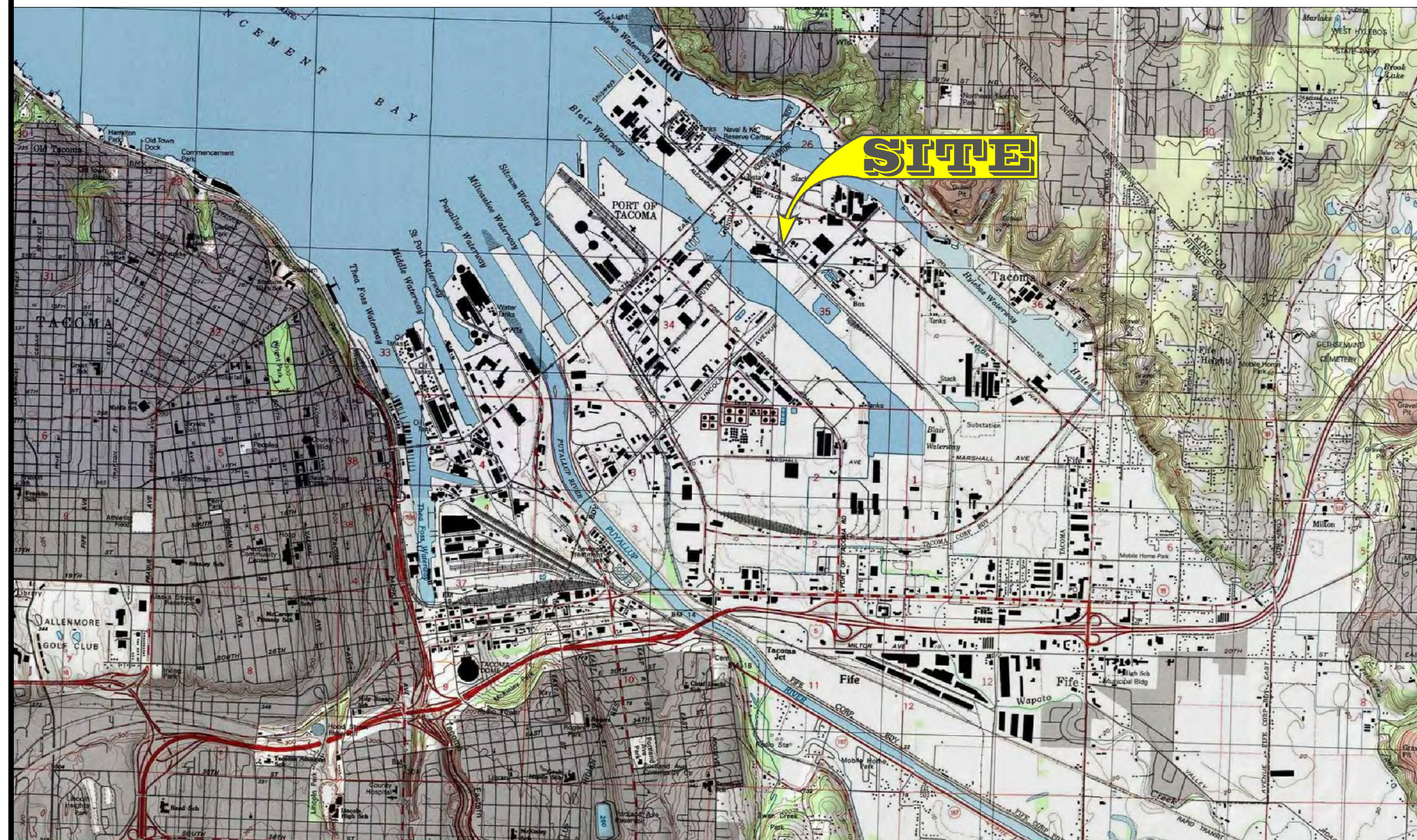
### 1701 ALEXANDER AVE E, TACOMA WA 98421



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Environment &  
Infrastructure, Inc.  
7376 S.W. Durham Road  
Portland, OR 97224

TITLE SHEET

#### VICINITY MAP



#### AERIAL PHOTO

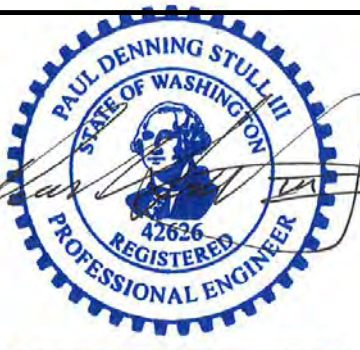


#### INDEX OF DRAWINGS

SHEET NUMBER	DESCRIPTION
ENV-0	TITLE SHEET
ENV-1	VAPOR MITIGATION SYSTEM PIPING LAYOUT
ENV-2	VAPOR MITIGATION SYSTEM TYPICAL SECTIONS
ENV-3	VAPOR MITIGATION SYSTEM VAPOR BARRIER LINER DETAILS
ENV-4	VAPOR MITIGATION SYSTEM VAPOR BARRIER LINER DETAILS
ENV-5	VAPOR MITIGATION SYSTEM EXTERIOR EXHAUST PIPING

#### MATERIALS SCHEDULE

- ① 3/4" - 1-1/2" CLEAN CRUSHED ROCK
- ② COMPACTED FILL
- ③ STRUCTURAL SUBGRADE PER ORIGINAL DESIGN
- ④ RAVEN INDUSTRIES ABSOLUTE BARRIER X40BAL GEOLINER (40-MIL HPDE LINER)
- ⑤ AGRU AMERICA AGRUTEX 321 GEOFABRIC
- ⑥ CONCRETE
- ⑦ PEA GRAVEL
- ⑧ CONTROLLED DENSITY FILL (CDF)



EXPIRES June 2019

REV	DATE	MONTH	YEAR	DESCRIPTION
A	17	05	2017	AS-BUILTS
B	12	03	2018	AS-BUILTS-REV B

STERICYCLE  
VAPOR MITIGATION SYSTEM

DATE MARCH 2018

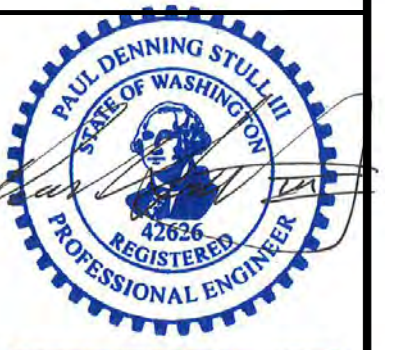
PROJECT NO. 0100480050.00003

SHEET ENV-0

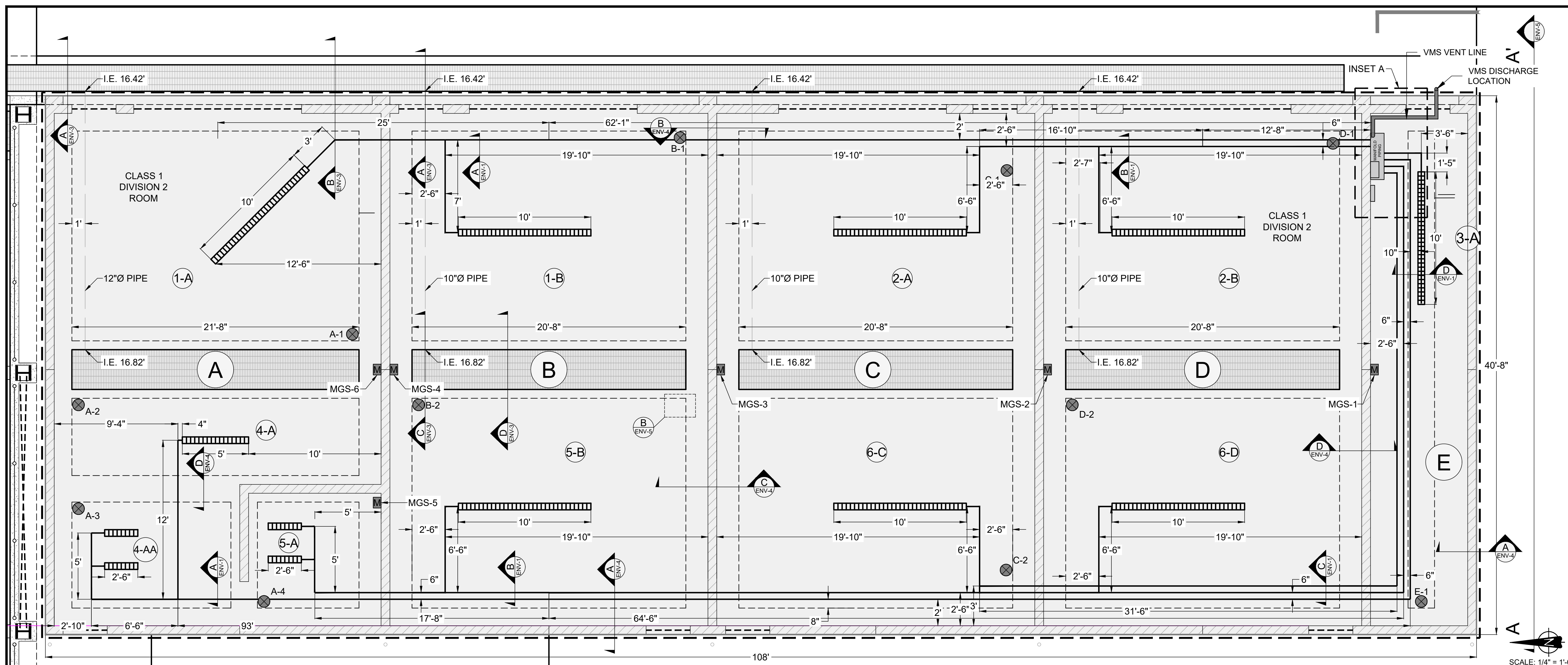
SHEET 1 of 6



VAPOR MITIGATION SYSTEM PIPING LAYOUT



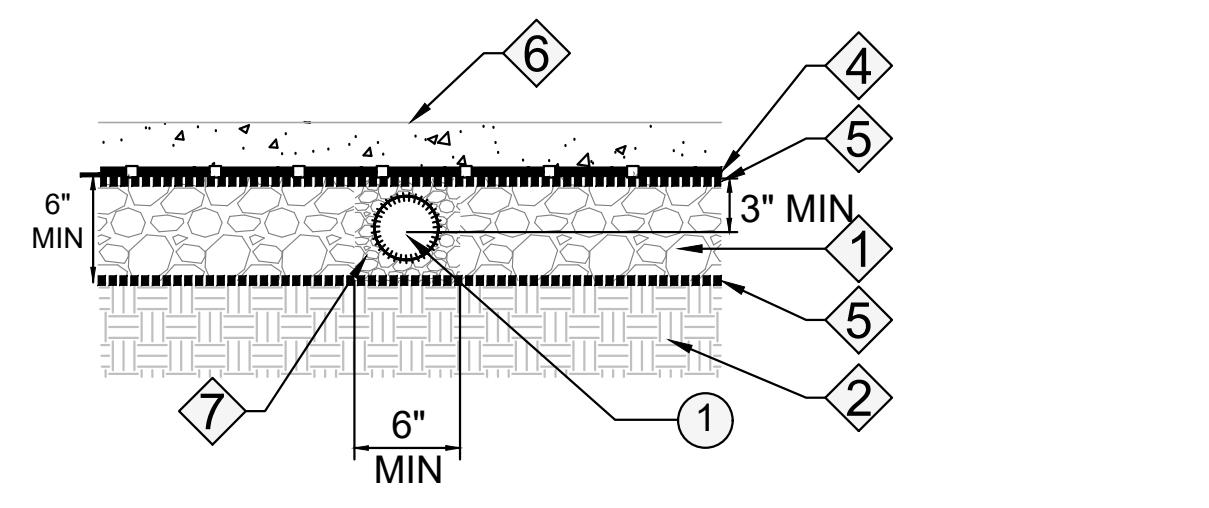
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B	12	03	2018	AS-BUILTS-REV B



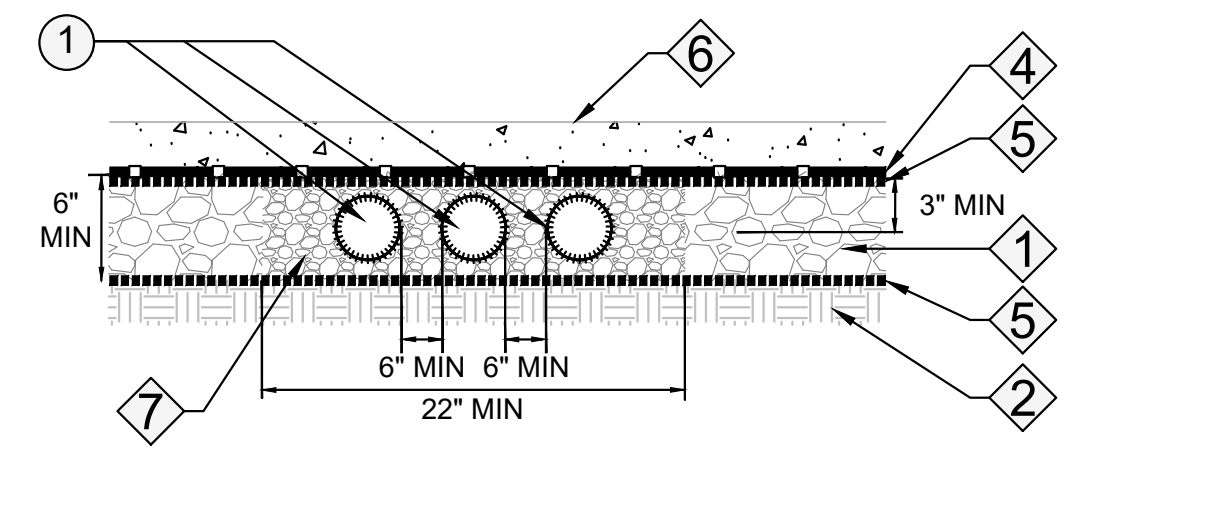
SCALE: 1/4" = 1'-0"  
(WHEN PLOTTED AT FULL SCALE (34"x22"))

**LEGEND**

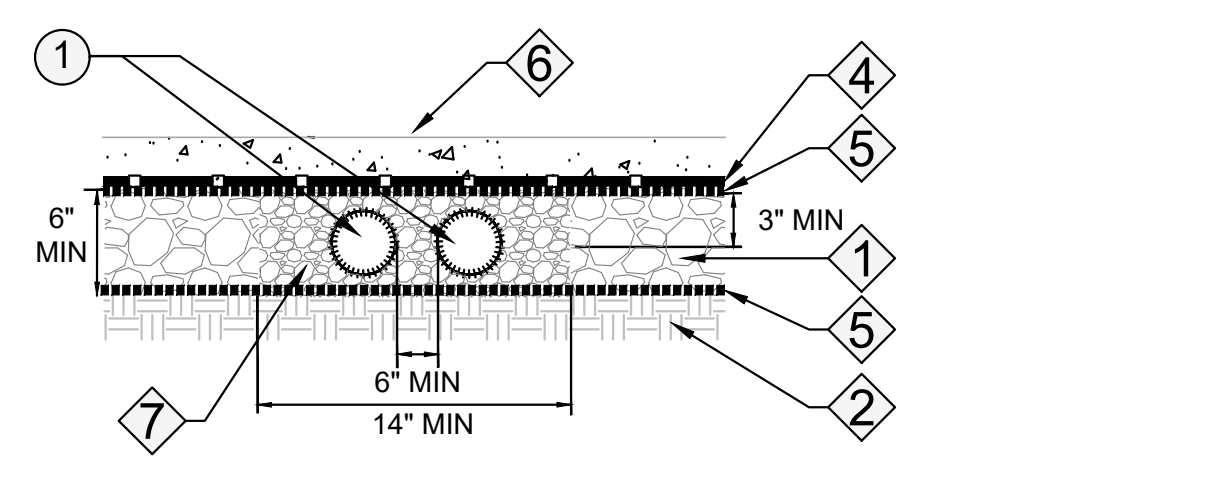
- 2" SCH. 40 PVC PIPE
- 2" SCH. 40 PVC 0.02" SLOTTED PIPE SCREEN WITH END CAP
- EXTENT OF VAPOR BARRIER LINER COVERAGE (SEE ENV-3 AND ENV-4 FOR CONSTRUCTION DETAILS)
- VMS RADIUS OF INFLUENCE (ROI)
- VAPOR MITIGATION ZONE
- METHANE GAS SENSOR
- VMS MONITORING PORT



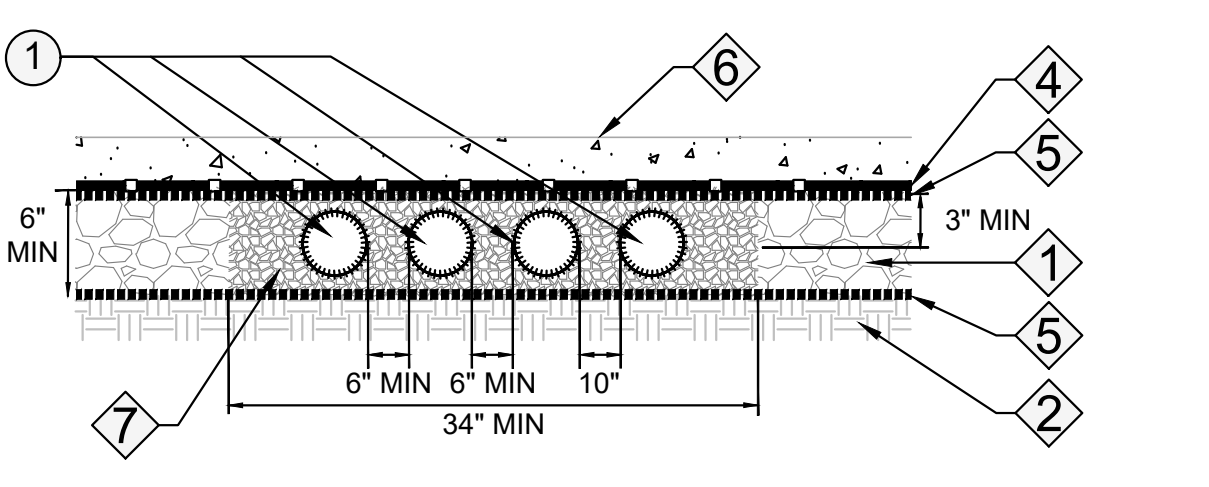
TYPICAL SINGLE 2" PIPE SECTION  
NTS



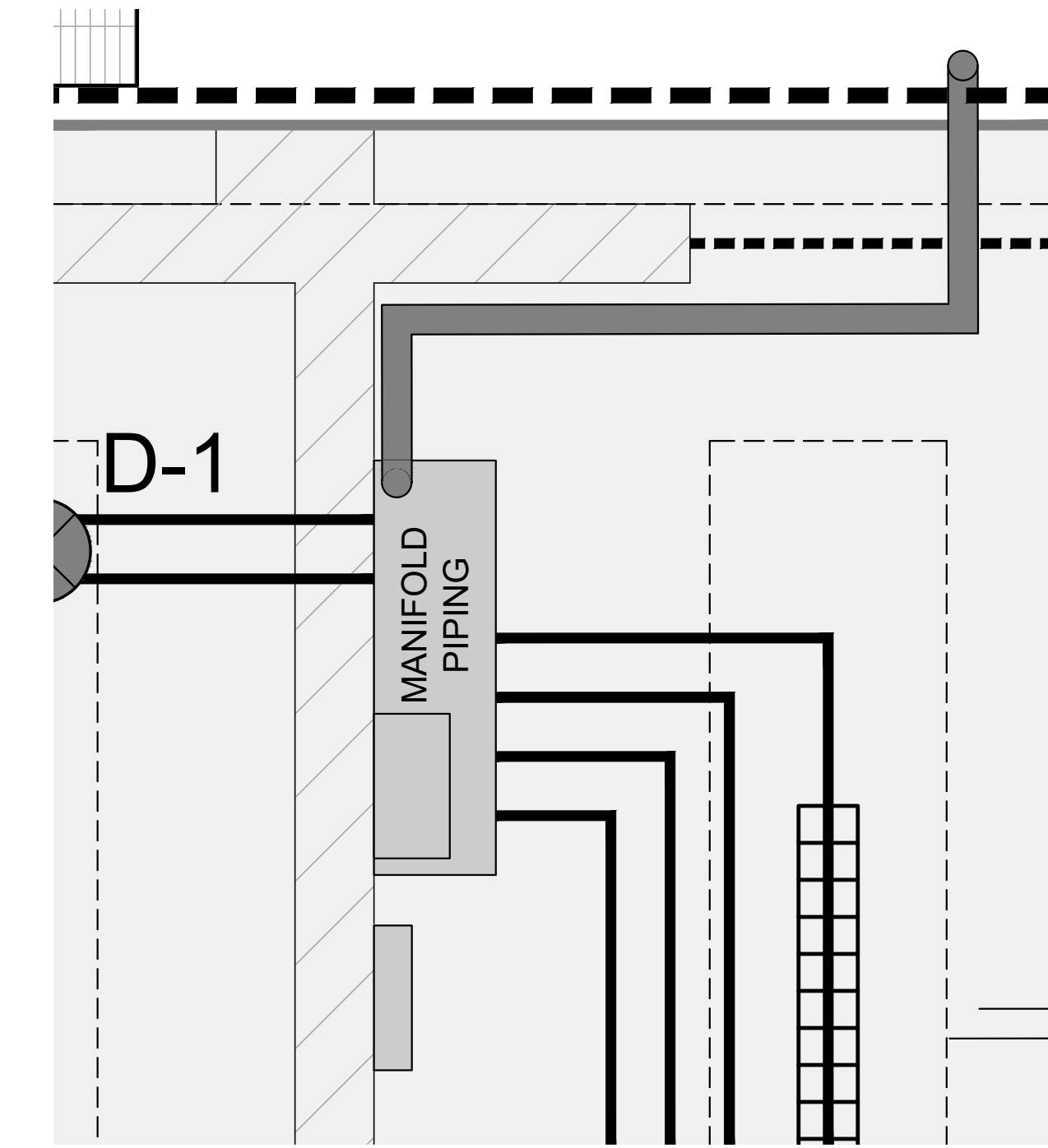
TYPICAL TRIPLE 2" PIPE SECTION  
NTS



TYPICAL DOUBLE 2" PIPE SECTION  
NTS



TYPICAL QUAD 2" PIPE SECTION  
NTS



INSET A

STERICYCLE  
VAPOR MITIGATION SYSTEM

DATE	MARCH 2018
PROJECT NO.	0100480050.00003
SHEET	ENV-1



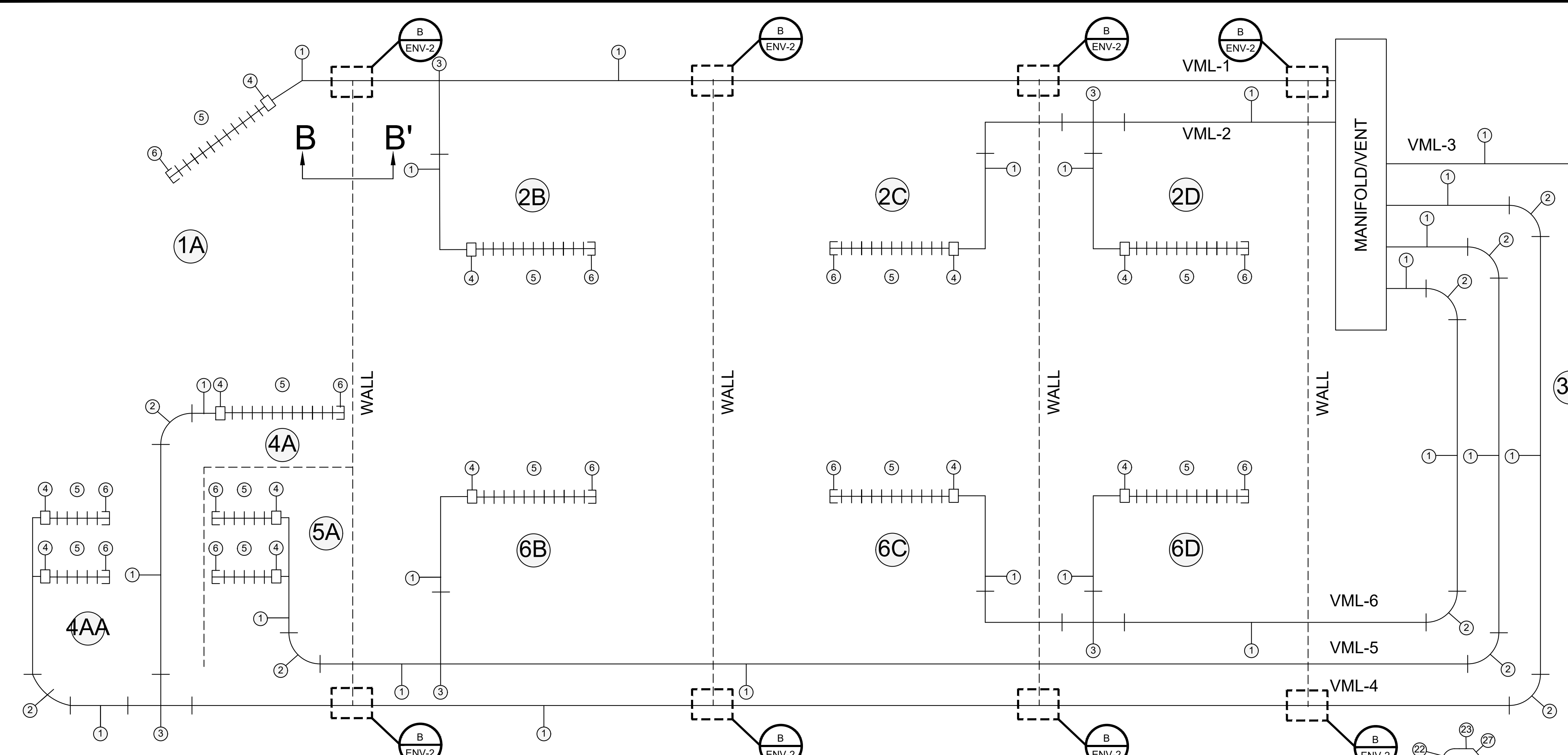
REV	DATE	MONTH/YEAR	DESCRIPTION	ENG.	INSTR.	CHK.	APP.
A	17	05	2017				
B	12	03	2018				

PIPING SCHEDULE

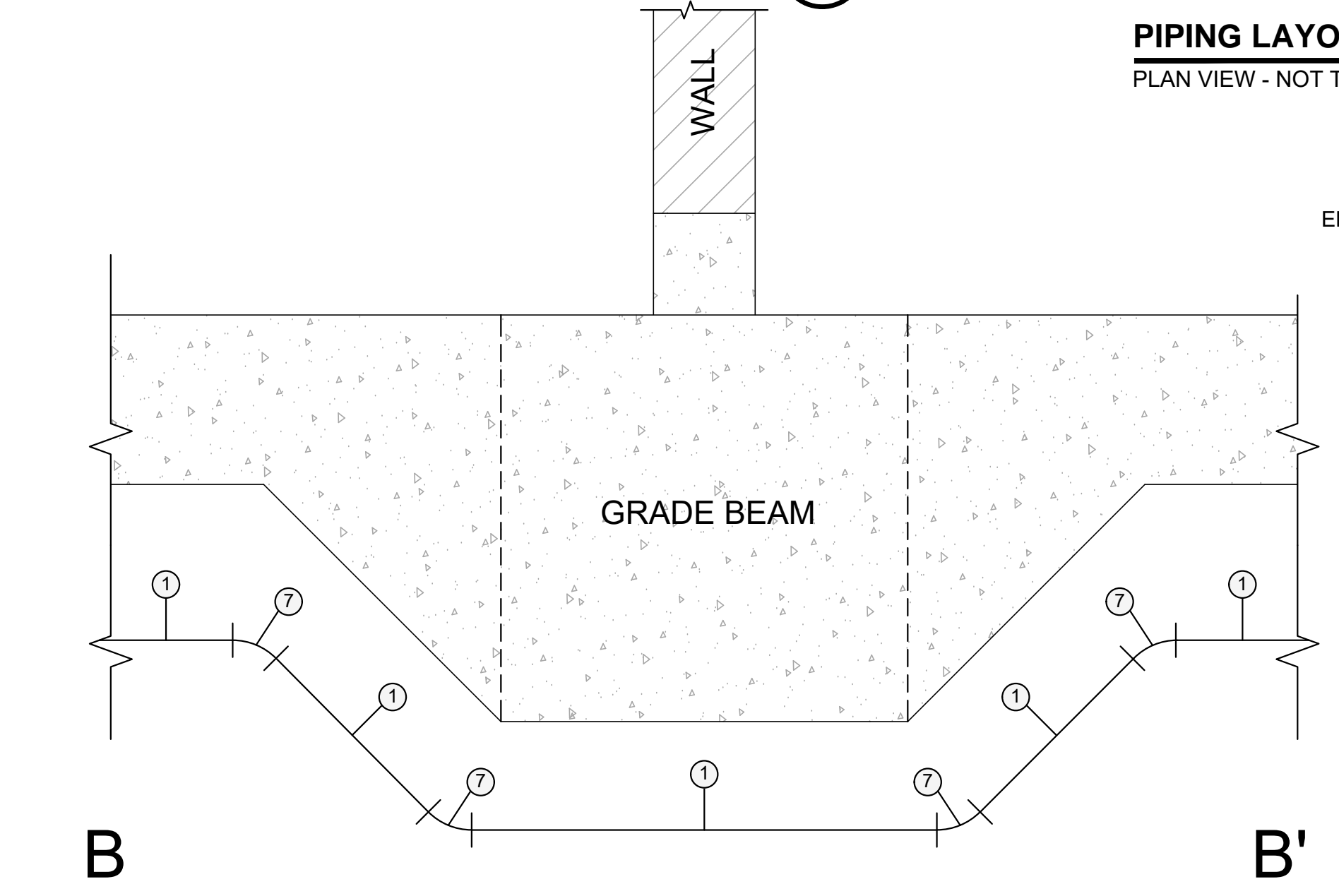
- 1 = 2" Sch 40 PVC Pipe
- 2 = 2" Sch 40 Sweep 90 Elbow
- 3 = 2" Sch 40 Tee (SSS)
- 4 = 2" Sch 40 Coupler (SS)
- 5 = 2" Sch 40 Screen Section (20 slot well screen)
- 6 = 2" Sch 40 Cap (S)
- 7 = 2" Sch 40 45 Elbow
- 8 = 2" Sch 40 Female Adapter (S x FPT)
- 9 = 2" GS Pipe (MPT x MPT ends)
- 10 = 2" Brass Gate valve
- 11 = 2" GS Coupler (FPT x FPT)
- 12 = 2" GS Tee (All FPT)
- 13 = 2" x 3" GS Reducer Bushing (FPT x MPT)
- 14 = 3" GS Pipe (MPT ends)
- 15 = 2" GS Close Nipple
- 16 = 1/4" Brass Sample Port (MPT x Ball Valve x Hose Barb with 2" GS Tee with Reducers from 2" to 1/4") (VMS Manifold Sampling Ports can be used for Measuring Air Flow Velocity and Vacuum Levels)
- 17 = 3" GS Couplers
- 18 = 2" GS 90 Elbow (FPT)
- 19 = 2" PVC Swing Check Valve
- 20 = 2" GS Plug (MPT)
- 21 = 2" GS 6" Nipples (MPT x MPT)
- 22 = 3" GS 90° Elbow
- 23 = 3" GS Close Nipple
- 24 = Rotron EN404AR72ML (208-230/460 VAC 3PH, 60Hz, 1.0 HP)
- 25 = 1 1/2" x 2" GS Bell Reducer (FPT x FPT)
- 26 = 1 1/2" GS Close Nipple (MPT ends)
- 27 = 3" GS 45° Elbow
- 28 = 2" GS Union (FPT)
- 29 = 1/4" Electronic Vacuum Transducer (MPT with 2" to 1/4" Reducer Bushing)
- 30 = 1/4" Mechanical Vacuum Gauge (Dwyer Model SGX-D7522N 0-60" WC Vacuum, Brass 1/4" (MPT with 2" to 1/4" Reducer Bushing)
- 31 = 2" GS Pipe Sized for Blower Separation (MPT ends)
- 32 = 1-1/2" GS 45° Elbow (FPT ends)

ABBREVIATIONS

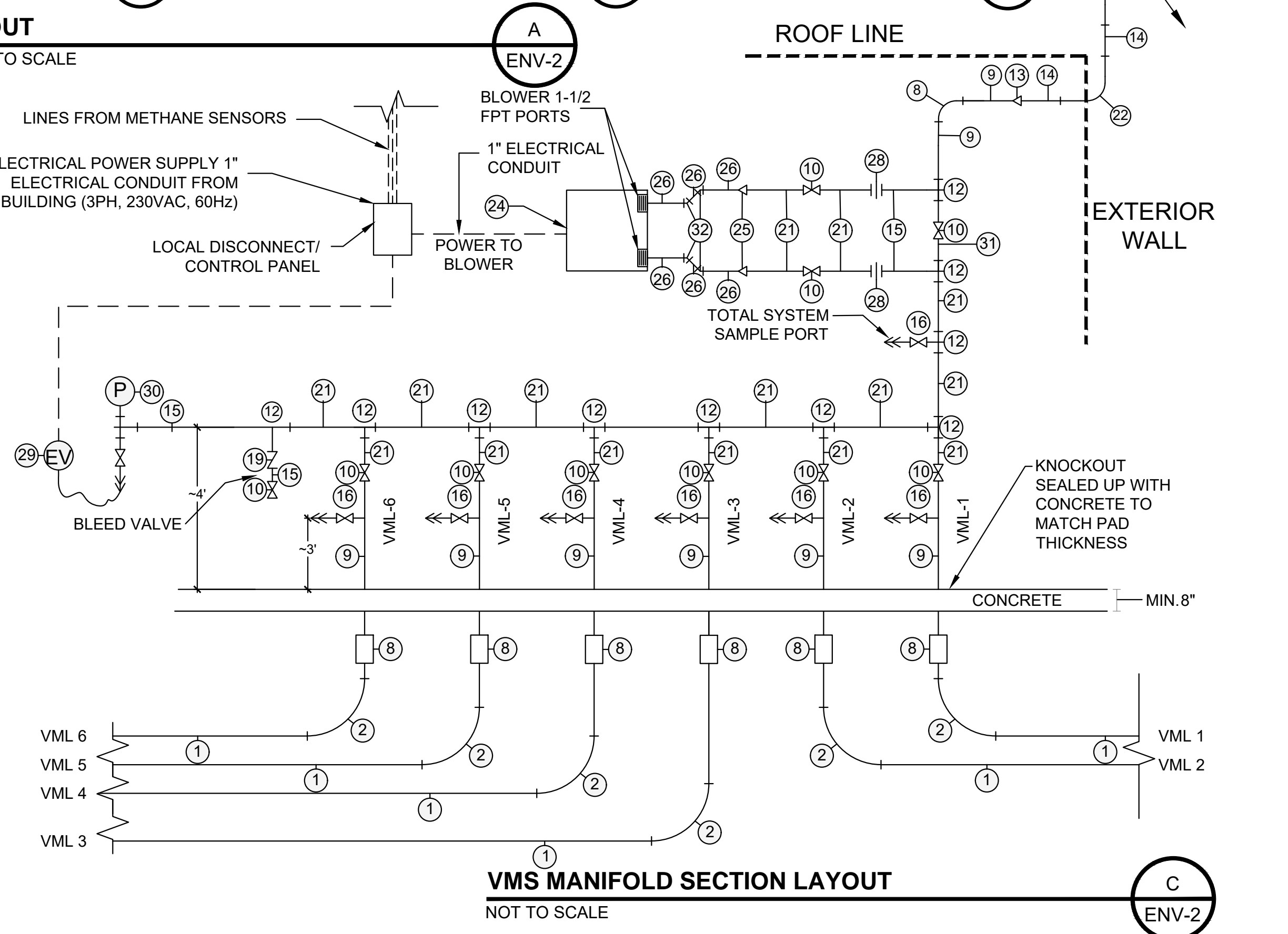
- VML = Vapor Mitigation Line
- VMS = Vapor Mitigation System
- S = Socket
- FPT = Female Iron Pipe Thread
- MPT = Male Iron Pipe Thread
- GS = Galvanized Steel
- EV = Electronic Vacuum Transducer
- P = Pressure/Vacuum Mechanical Gauge



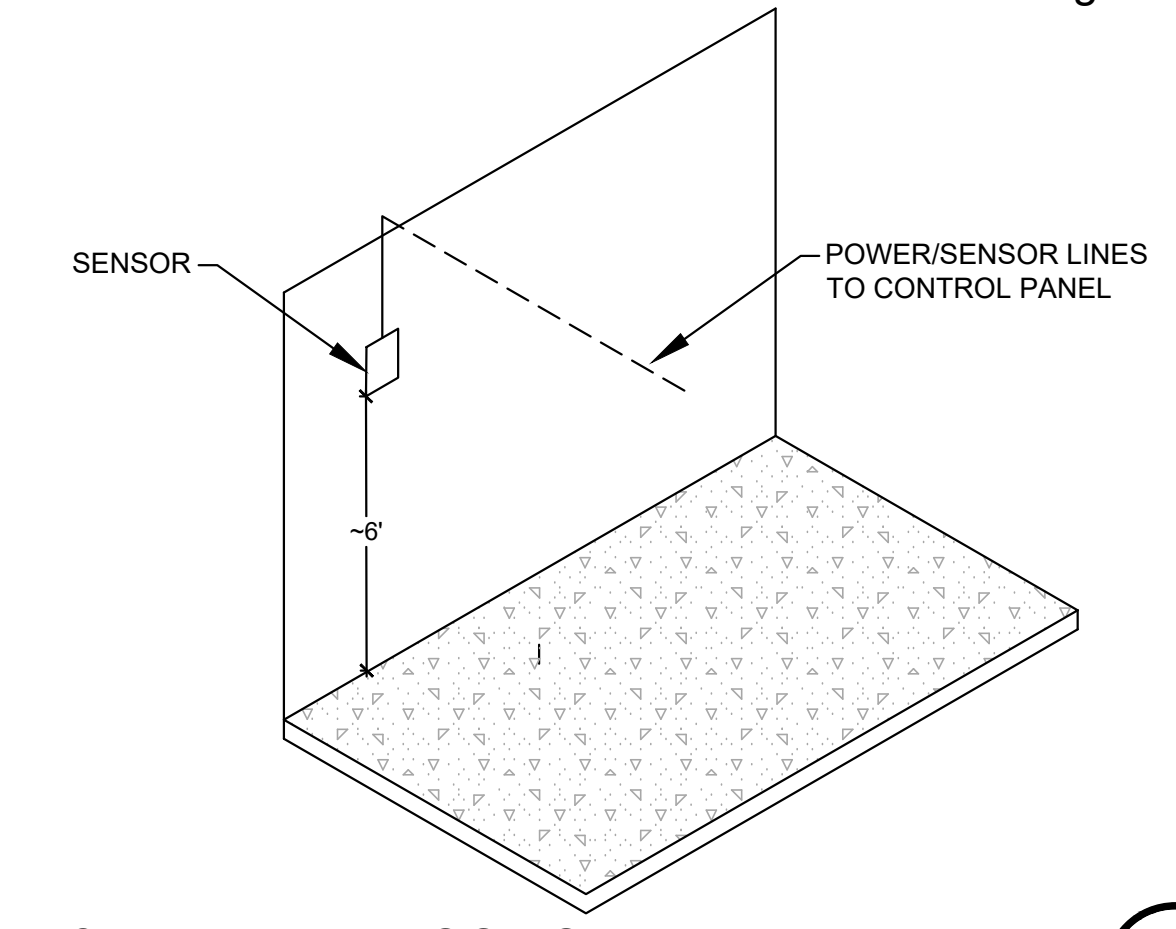
**PIPING LAYOUT**  
PLAN VIEW - NOT TO SCALE



**PIPING LAYOUT UNDER INTERIOR GRADE BEAMS/DRAIN LINES**  
SIDE VIEW - NOT TO SCALE



**VMS MANIFOLD SECTION LAYOUT**  
NOT TO SCALE



**TYPICAL METHANE GAS SENSOR**  
NTS

STERICYCLE  
VAPOR MITIGATION SYSTEM



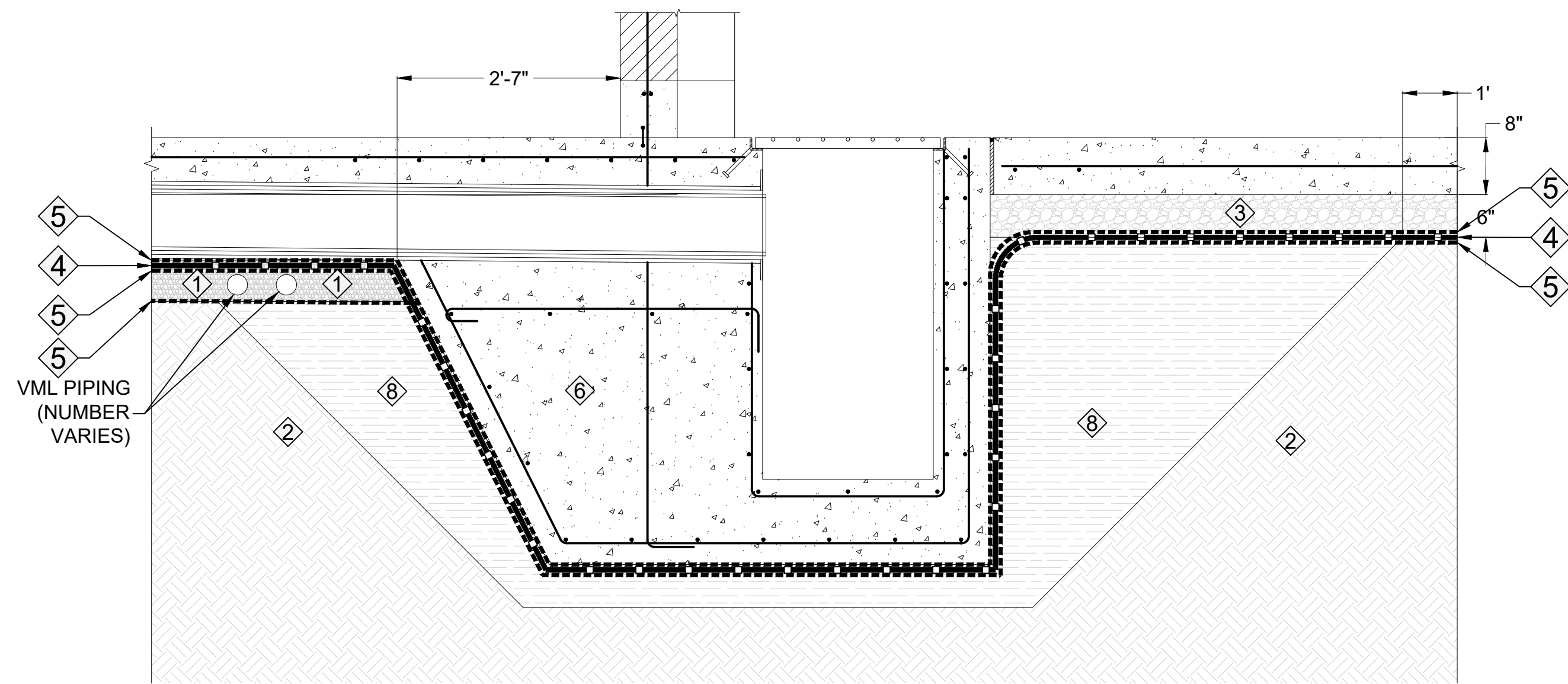


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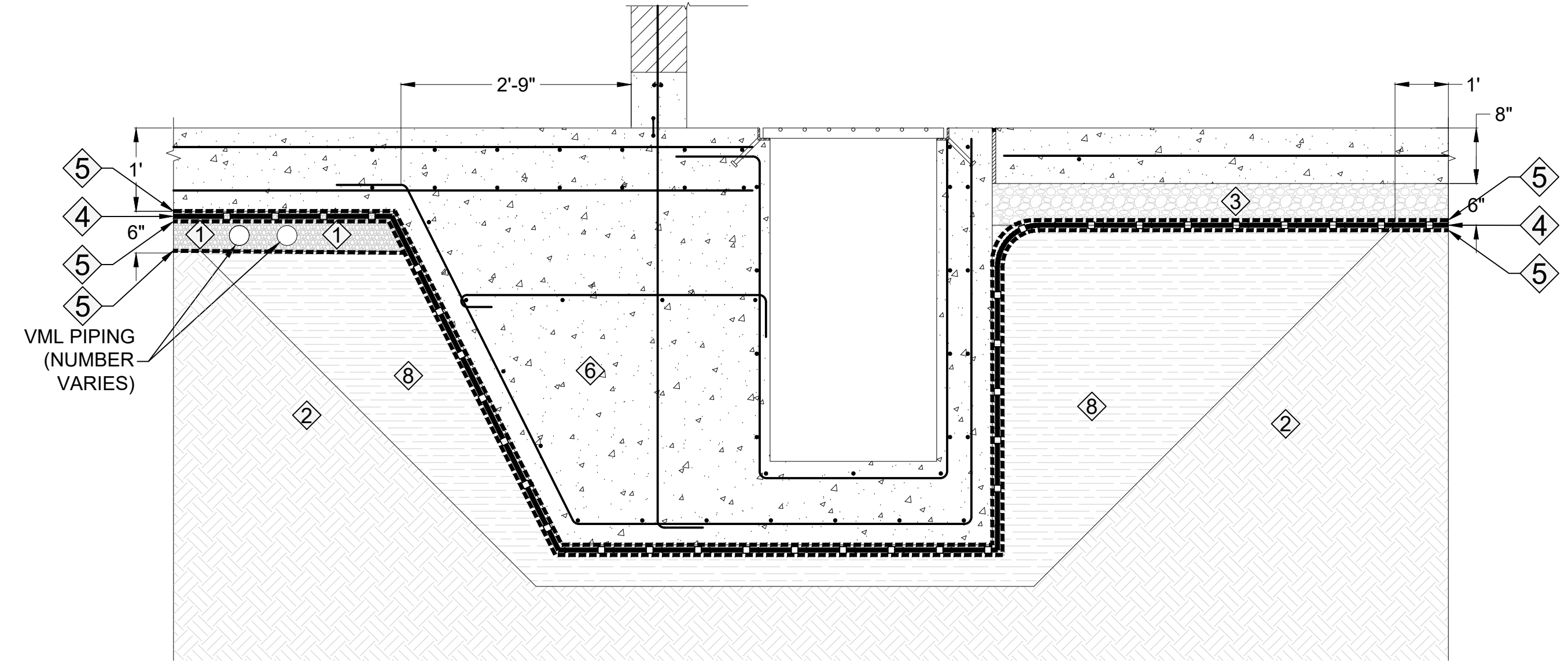
VAPOR  
MITIGATION  
SYSTEM VAPOR  
BARRIER LINER  
DETAILS



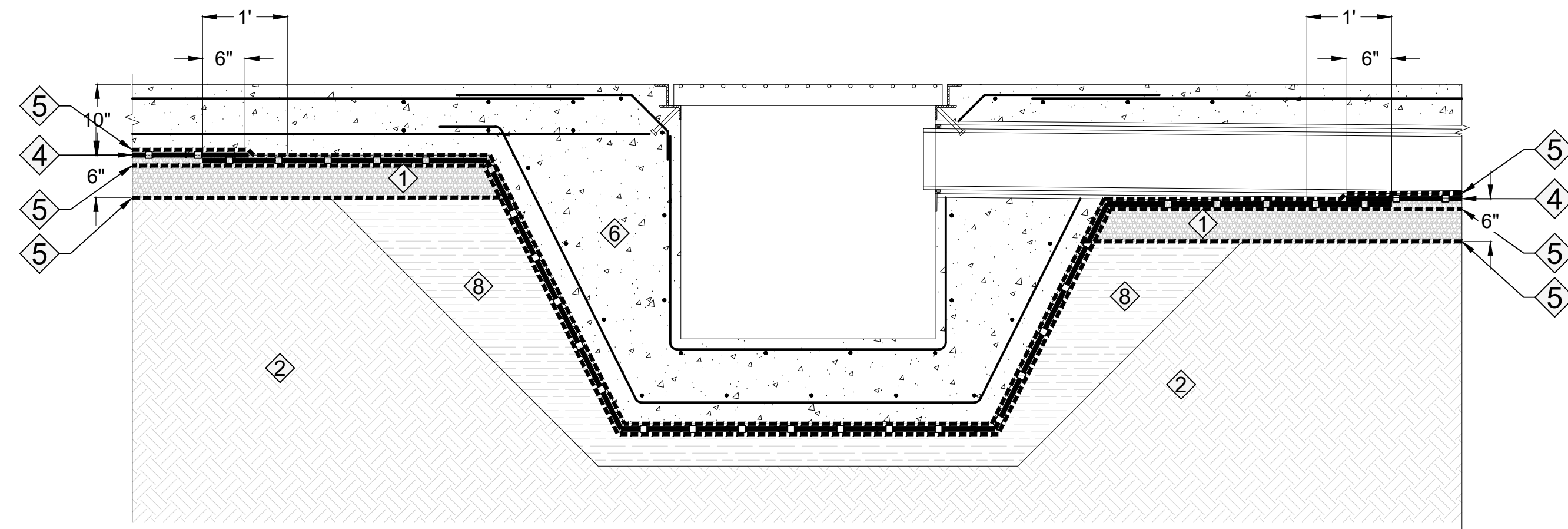
EXPIRES June 2019



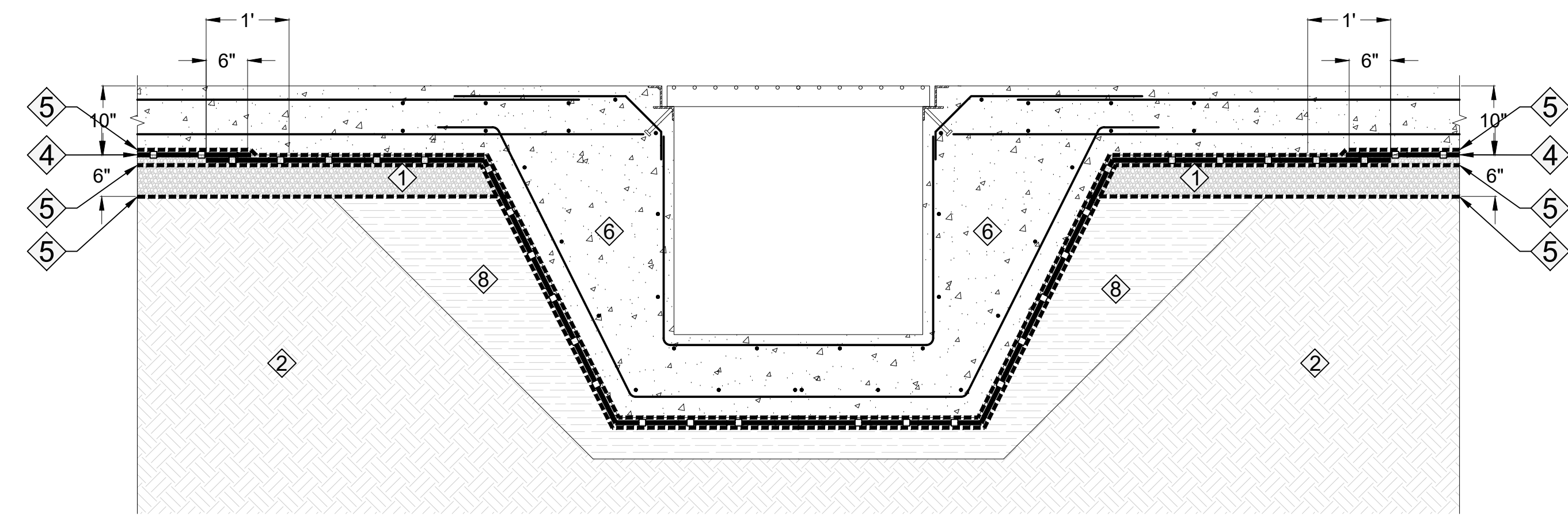
**CONCRETE TRENCH DRAIN AT LAB PACK** A  
NTS ENV-3



**CONCRETE TRENCH DRAIN AT LAB PACK WITHOUT OVERFLOW LINE** B  
NTS ENV-3



**TRENCH AT LAB PACK** C  
NTS ENV-3



**TRENCH AT LAB PACK WITHOUT OVERFLOW LINE** D  
NTS ENV-3

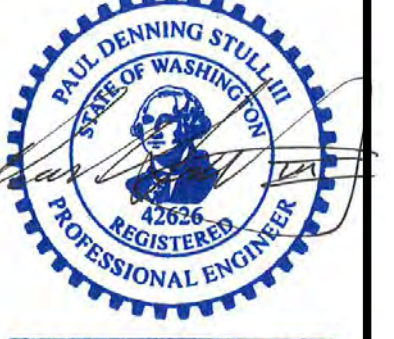
REV	DATE	MONTH	YEAR	DESCRIPTION
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B	12	03	2018	AS-BUILTS-REV B

STERICYCLE  
VAPOR MITIGATION SYSTEM

DATE MARCH 2018  
PROJECT NO. 0100480050.00003  
SHEET ENV-3  
SHEET 4 of 6



VAPOR MITIGATION SYSTEM VAPOR BARRIER LINER DETAILS

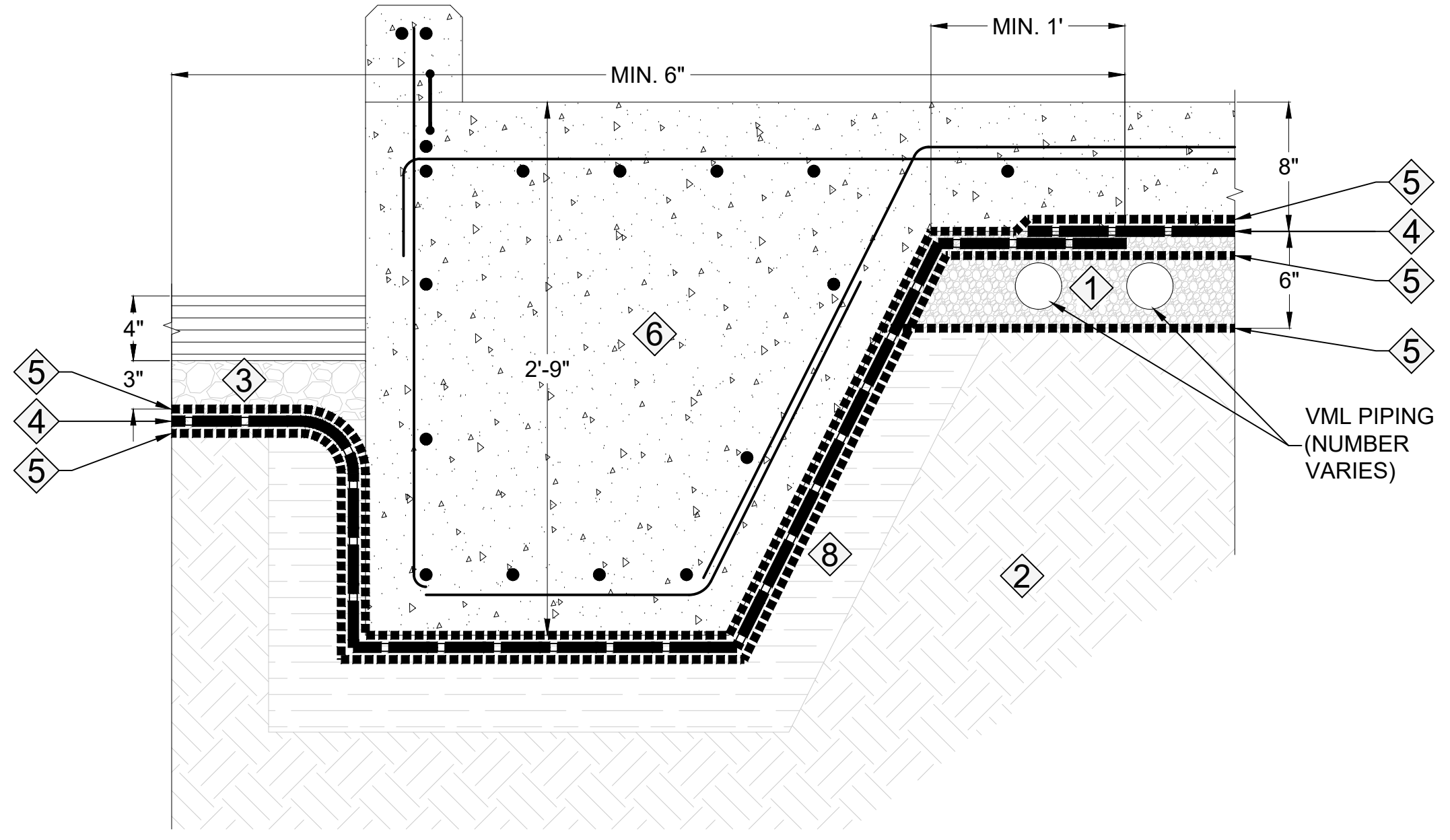


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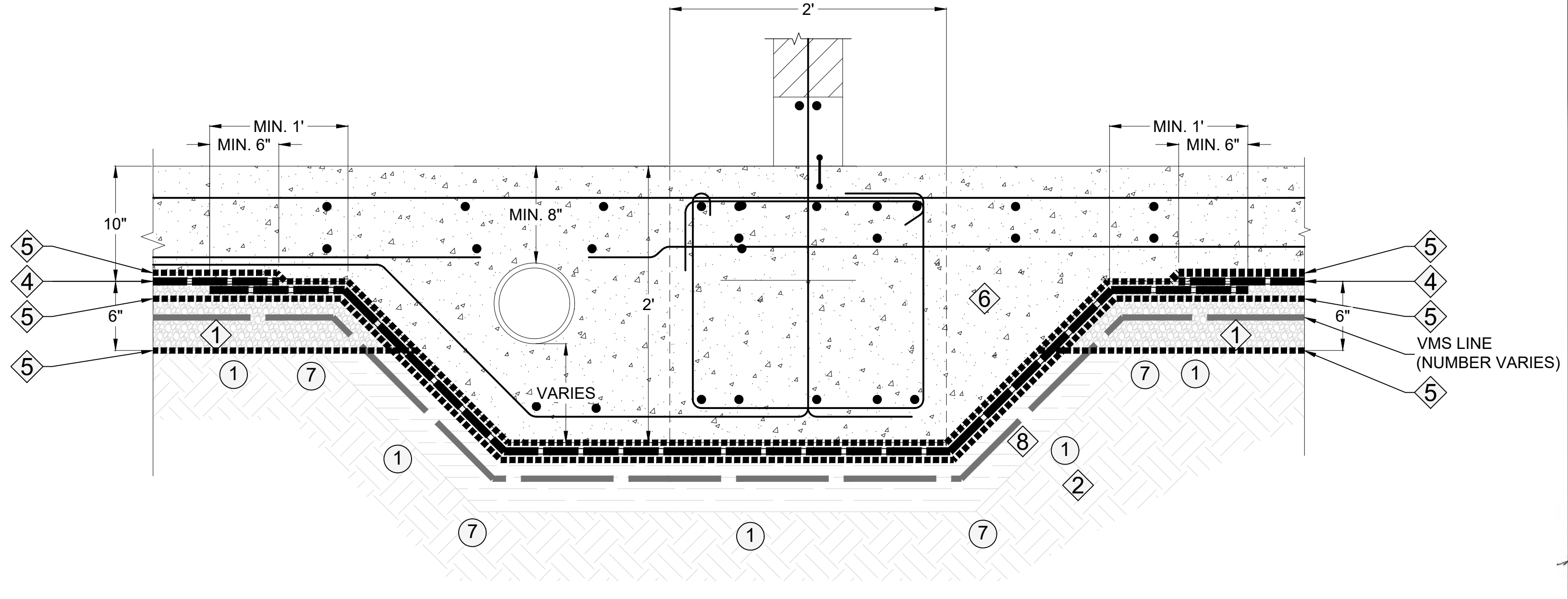
STERICYCLE VAPOR MITIGATION SYSTEM

DATE	MARCH 2018
PROJECT NO.	0100480050.00003
SHEET	ENV-4
	SHEET 5 of 6



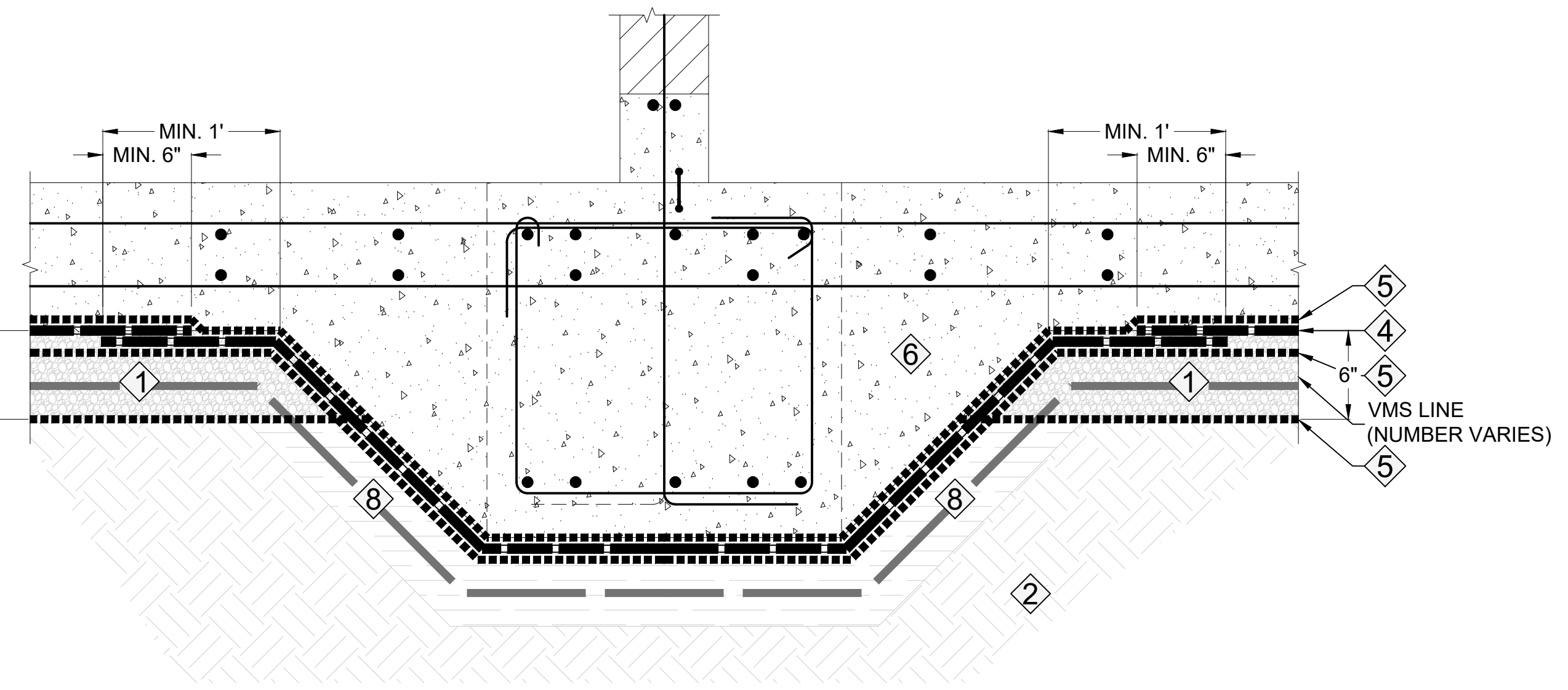
**EXTERIOR CONCRETE GRADE BEAM**  
NTS

A  
ENV-4



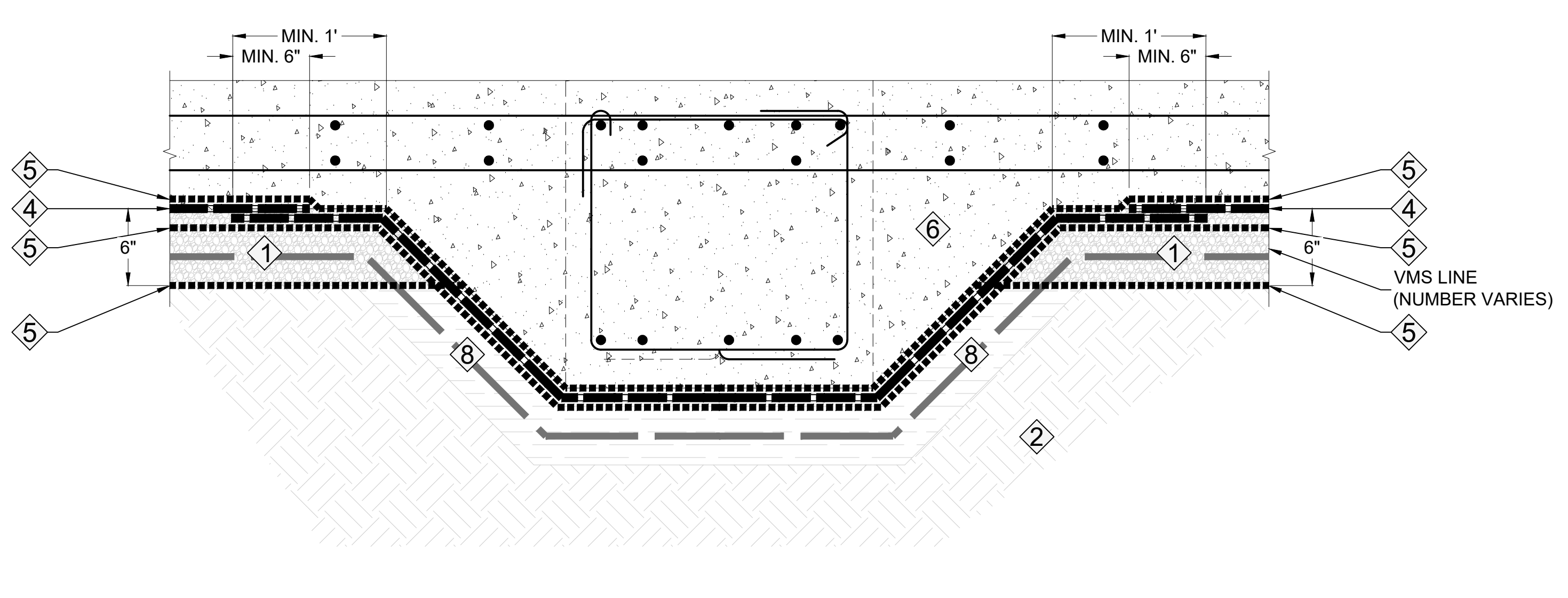
**INTERIOR CONCRETE GRADE BEAM**  
NTS

B  
ENV-4



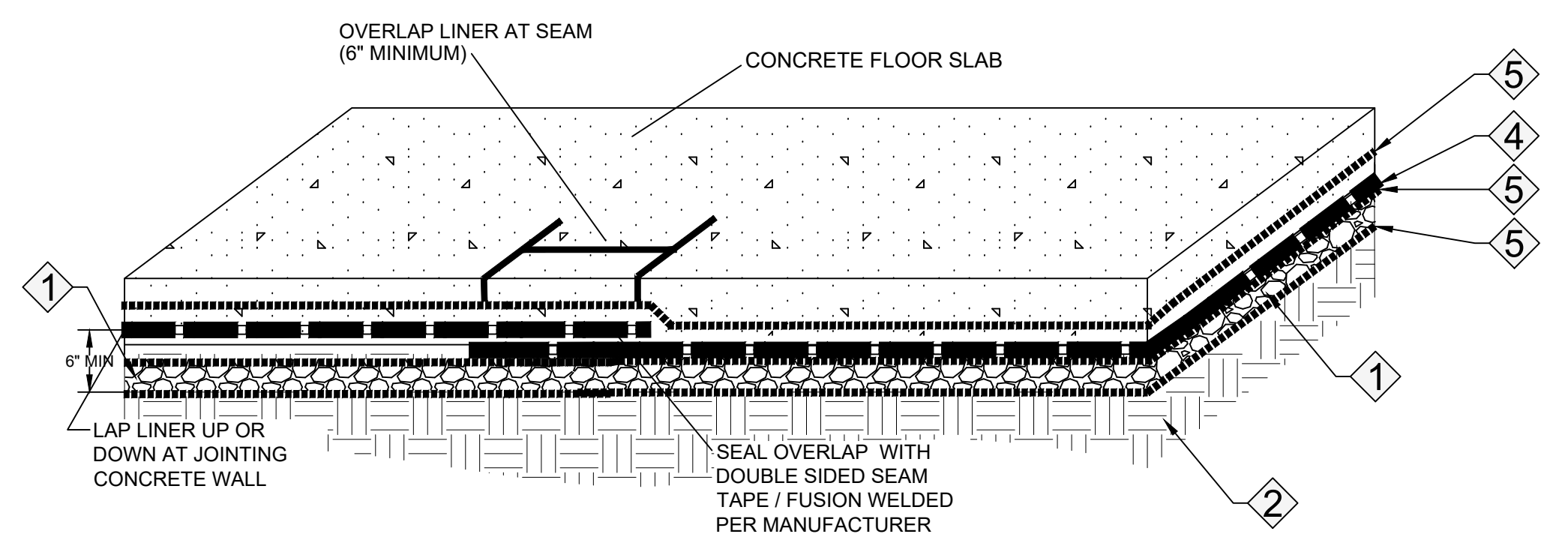
**INTERIOR CONCRETE GRADE BEAM**  
NTS

C  
ENV-4



**INTERIOR CONCRETE GRADE BEAM**  
NTS

D  
ENV-4



**VAPOR BARRIER BELOW SLAB**  
NTS

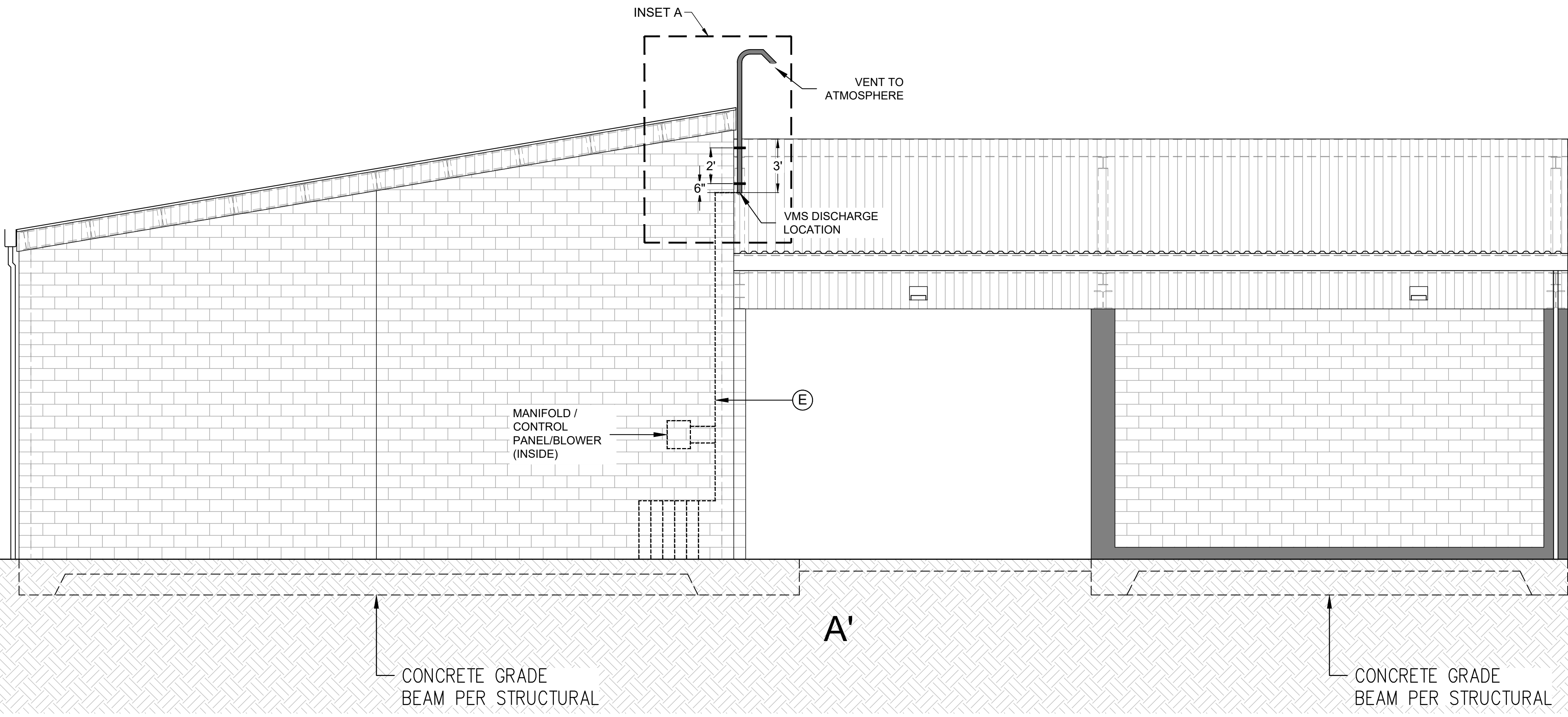
E  
ENV-4

DRAWING IN EXCELLENCE

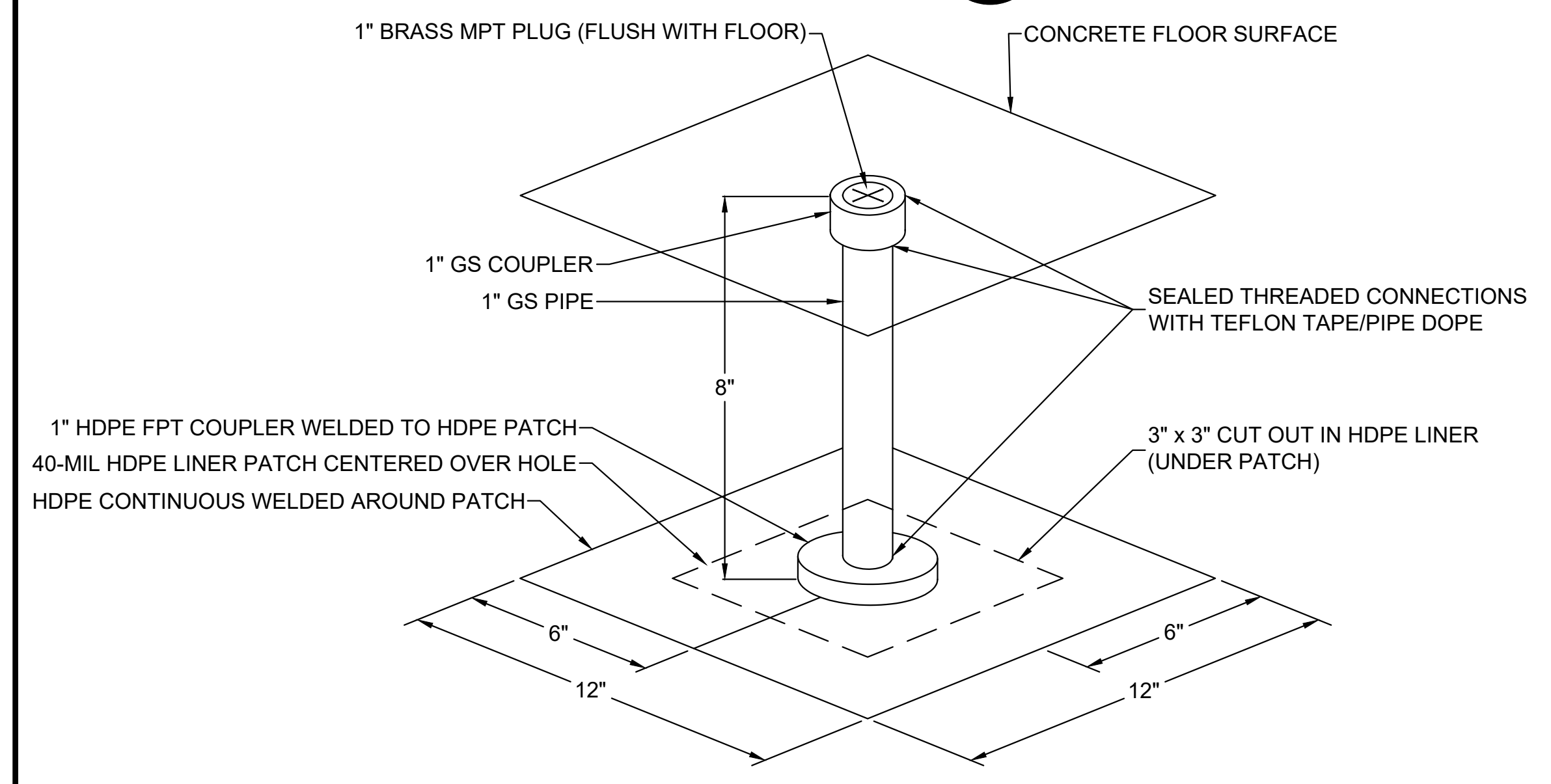
NOTE: THESE DRAWINGS ARE THE PROPERTY OF AMEC FOSTER WHEELER ENVIRONMENT AND INFRASTRUCTURE, INC. AND ARE NOT TO BE REPRODUCED IN ANY MANNER WITHOUT THE EXPRESS WRITTEN CONSENT OF AMEC FOSTER WHEELER ENVIRONMENT AND INFRASTRUCTURE, INC. AND ITS CLIENT.



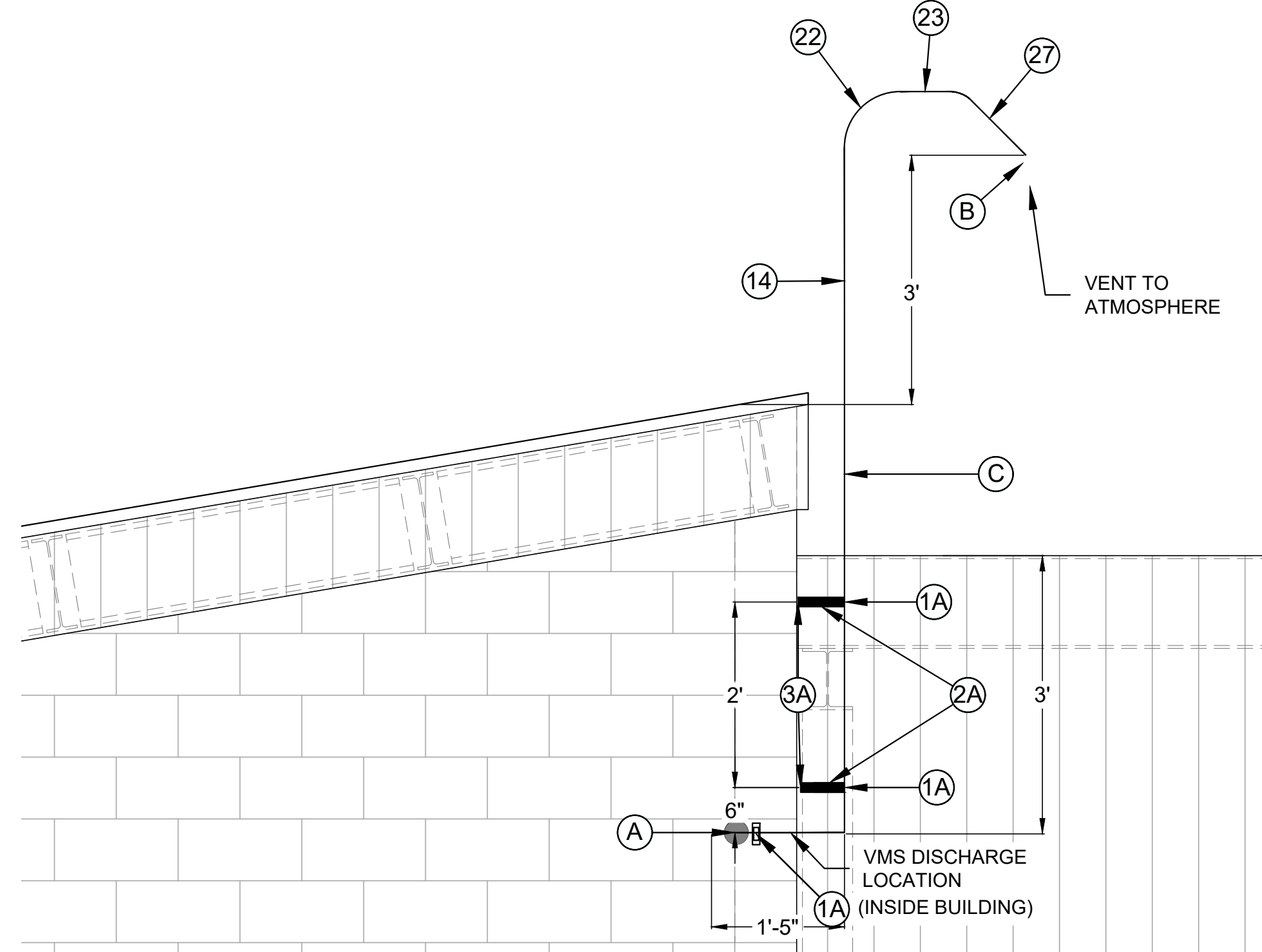
REV	DATE	MONTH/YEAR	DESCRIPTION	ENG.	PR.
A	17	05	2017		
B	12	03	2018		



**EXTERIOR VIEW OF VMS DISCHARGE VENT**  
NTS



**GAS SAMPLING/MONITORING PORT (TYPICAL)**  
NTS



**NOTES**

- (A) 3" GS PIPE PENETRATED OUTER WALL AND WAS SEALED WITH NON-SHRINKING GROUT.
- (B) DISCHARGE POINT IS SOUTH DESPITE AS SHOWN
- (C) VENT EXHAUST OPENING IS A MINIMUM OF 15-FT LATERALLY FROM ALL HVAC INTAKES AND ANY ELECTRICAL SYSTEMS.
- (D) VERTICAL LINE PLACED ALONGSIDE EDGE OF ROOF.
- (E) PLACARDS INSTALLED EVERY 5' ON PIPE WITH PLACARD @ 3" X 4" WIDE WITH 3/8" HIGH BLACK LETTERS

**CAUTION**  
METHANE GAS IN PIPE  
NO SMOKING  
OR ELECTRICAL  
EQUIPMENT WITHIN 10'  
**PIPE PLACARD**

**MATERIALS SCHEDULE**

- (1A) STANDARD C-CHANNEL STRUT (ZINC PLATED)
- (2A) 3" ZINC PLATED PIPE CLAMP
- (3A) STRUCT FIXED TO WALL WITH CONCRETE ANCHOR BOLTS/EPOXY OR OTHER APPROVED ANCHOR BOLT DEVICE.

**STERICYCLE  
VAPOR MITIGATION SYSTEM**



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## **APPENDIX B**

Raven Industries – Absolute Barrier HDPE Liner Documents / Installer Certification

# ABSOLUTE BARRIER® X40 & X60

HIGH PERFORMANCE HDPE/EVOH GEOMEMBRANE GAS BARRIER

RAVEN

## PRODUCT DESCRIPTION

Absolute Barrier® X-Series X40BAL and X60BAL are a seven layer co-extruded geomembranes consisting of a durable high-density polyethylene (HDPE) with an inner core of highly effective EVOH barrier resin, designed specifically as a barrier against odors, methane, radon, and VOCs. High strength HDPE provides excellent chemical resistance and durability. The combination of these highly effective resins provides unequalled barrier performance in demanding buried applications.

## PRODUCT USE

Absolute Barrier® X-Series X40BAL and X60BAL are designed to stop gas vapor migration on Brownfield sites, in residential and commercial buildings, along with geomembrane containment covers and systems for effective odor control. When installed under concrete slabs as a gas barrier, a passive system is recommended to include a ventilated system with sump(s) that could be converted to an active control system with properly designed ventilation fans.

Absolute Barrier® performs extremely well preventing the degradation of EPS geofoam by protecting it from harsh VOCs including direct gasoline or diesel fuel contact.

Absolute Barrier® X-Series X40BAL and X60BAL are effective in buried landfill cap applications and are 50 to 400 times less permeable to VOCs than standard 80 mil HDPE geomembranes. Leachate contaminants and landfill odors/gases in municipal and hazardous waste landfills can migrate through standard HDPE contributing to both atmospheric and groundwater contaminations. Both X40BAL and X60BAL provide an effective barrier against a wide range of VOCs including benzene, toluene, ethylbenzene, o-xylene and many others.

## SIZE & PACKAGING

Absolute Barrier® is available in 16' wide layflat rolls in various lengths. All panels are tightly rolled onto a heavy-duty core for ease of handling and time saving installation. Absolute Barrier® geomembranes are produced in the color black as standard and can be manufactured in other custom colors with minimum quantity order requirements.



Landfill Rainshed Cover

## PRODUCT

## PART #

ABSOLUTE BARRIER® ..... X40BAL

ABSOLUTE BARRIER® ..... X60BAL

## APPLICATIONS

Odor Control Barrier	Underslab Radon Barrier
EPS Geofoam Protection	Underslab Methane Barrier
Buried Landfill Cap	Underslab Vapor Barrier
Temporary Landfill Gas Cover	Remediation Cover / Liner
Floating Gas Cover	Leachate Collection Ponds
Underslab VOC Barrier	

**Absolute Barrier®**  
THE ULTIMATE IN GAS CONTAINMENT

# ABSOLUTE BARRIER® X40 & X60

HIGH PERFORMANCE HDPE/EVOH GEOMEMBRANE GAS BARRIER

## PRO-FORMA DATA SHEET - TYPICAL VALUES

PROPERTIES	TEST METHOD	ABSOLUTE BARRIER® X40BAL		ABSOLUTE BARRIER® X60BAL	
		IMPERIAL	METRIC	IMPERIAL	METRIC
WEIGHT		198 lbs/msf	967 g/m <sup>2</sup>	296 lbs/msf	1445 g/m <sup>2</sup>
THICKNESS	ASTM D5199	40 mils	1.0 mm	60 mils	1.5 mm
DENSITY	ASTM D792 or ASTM D1505	0.94 g/cm <sup>3</sup> (minimum)		0.94 g/cm <sup>3</sup> (minimum)	
<sup>3</sup> TENSILE STRENGTH	ASTM D638/D6693 1. Tensile Strength at Break 2. % Elongation at Break	109 lbf/in. 411 %	19.1 N/mm 411 %	166.5 lbf/in. 404 %	29.2 N/mm 404 %
OXIDATIVE INDUCTION TIME (OIT)	ASTM D3895 Method A	> 100 min.		> 100 min.	
HIGH PRESSURE OIT (HPOIT)	ASTM D5885	> 400 min.		> 400 min.	
PUNCTURE RESISTANCE	ASTM D4833	91 lbf	405 N	141 lbf	627 N
<sup>3</sup> TEAR RESISTANCE	ASTM D1004	32 lbf	142 N	49 lbf	218 N
STRESS CRACK RESISTANCE	ASTM D5397	>1800 hrs		>1800 hrs	
LOW TEMP, IMPACT FAILURE TEMP	ASTM D746 Method B	Pass, 5 min @ -40°F		Pass, 5 min @ -40°F	
BENZENE PERMEANCE	See Note <sup>6</sup>	8.79E <sup>-11</sup> m/s		5.86E <sup>-11</sup> m/s	
TOLUENE PERMEANCE	See Note <sup>6</sup>	1.23E <sup>-10</sup> m/s		8.17E <sup>-11</sup> m/s	
ETHYLBENZENE PERMEANCE	See Note <sup>6</sup>	9.63E <sup>-11</sup> m/s		6.42E <sup>-11</sup> m/s	
M & P-XYLENES PERMEANCE	See Note <sup>6</sup>	9.09E <sup>-11</sup> m/s		6.06E <sup>-11</sup> m/s	
O-XYLENE PERMEANCE	See Note <sup>6</sup>	8.60E <sup>-11</sup> m/s		5.73E <sup>-11</sup> m/s	
METHANE PERMEANCE	ASTM D1434	< 3.70E <sup>-13</sup> m/s		< 2.46E <sup>-13</sup> m/s	
CARBON BLACK DISPERSION	ASTM D5596	Pass - See Note <sup>7</sup>		Pass - See Note <sup>7</sup>	
CARBON BLACK %	ASTM D1603 or D4218	> 2.0 %		> 2.0 %	
PERMS	ASTM E96 - Method A 73° F, 50% RH	< 0.0052 grains/(ft <sup>2</sup> -hr-in-Hg)	< 0.0034 g/(24hr-m <sup>2</sup> -mm Hg)	< 0.0042 grains/(ft <sup>2</sup> -hr-in-Hg)	< 0.0028 g/(24hr-m <sup>2</sup> -mm Hg)
MAXIMUM USE TEMPERATURE		180° F	82° C	180° F	82° C
FACTORY SEAM REQUIREMENTS					
BONDED SEAM STRENGTH	ASTM D6392 Mod. <sup>5</sup>	120 lbf/in.	534 N/cm	190 lbf/in.	845 N/cm
SEAM PEEL ADHESION	ASTM D6392 Mod. <sup>5</sup>	80 lbf/in.	356 N/cm	130 lbf/in.	578 N/cm

<sup>3</sup> Tests are an average of machine and transverse directions.

<sup>5</sup> Raven Industries performs seam testing at 20" per minute.

<sup>6</sup> Aqueous Phase Film Permeance.

Permeation of Volatile Organic Compounds through EVOH Thin Film Membranes and Coextruded LLDPE/EVOH/LLDPE Geomembranes, McWatters and Rowe, Journal of Geotechnical and Geoenvironmental Engineering © ASCE/September 2015. (Permeation is the Permeation Coefficient adjusted to actual film thickness)

<sup>7</sup> Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3

PRO-FORMA SHEET CONTENTS: The data listed in the Pro-Forma data sheet is representative of initial production runs. These values may be revised at anytime without notice as additional test data becomes available.

**Absolute Barrier**  
THE ULTIMATE IN GAS CONTAINMENT

Absolute Barrier® X-Series X40BAL and X60BAL are a seven layer co-extruded geomembranes consisting of a durable high-density polyethylene (HDPE) with an inner core of highly effective EVOH barrier resin, designed specifically as a barrier against odors, methane, radon, and VOCs. High strength HDPE provides excellent chemical resistance and durability. The combination of these highly effective resins provides unequalled barrier performance in demanding buried applications.



Scan QR Code to download technical data sheets.

Note: To the best of our knowledge, unless otherwise stated, these are typical property values and are intended as guides only, not as specification limits. Chemical resistance, odor transmission, longevity as well as other performance criteria is not implied or given and actual testing must be performed for applicability in specific applications and/or conditions. RAVEN INDUSTRIES MAKES NO WARRANTIES AS TO THE FITNESS FOR A SPECIFIC USE OR MERCHANTABILITY OF PRODUCTS REFERRED TO, no guarantee of satisfactory results from reliance upon contained information or recommendations and disclaims all liability for resulting loss or damage. Limited Warranty available at [www.ravenefd.com](http://www.ravenefd.com)

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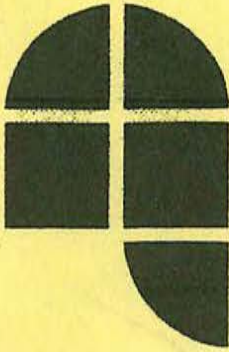
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**NORTHWEST LININGS &  
GEOTEXTILE PRODUCTS, Inc.**

*"Helping to Protect the Environment"*

21000 77th Avenue South

Kent, WA 98032

(253) 872-0244 • (800) 729-6954

FAX: (253) 872-0245

www.northwestlinings.com

**CERTIFICATE OF ACCEPTANCE OF SOIL SUB GRADE SURFACE**

PROJECT: STERICYCLE  
LINER TYPE/QTY: 4" HDPE  
OWNER: \_\_\_\_\_  
LOCATION: FIND UP

I, the undersigned, a duly appointed representative of Northwest Linings & Geotextile Products, Inc. have visually observed the soil sub grade surface described below, and found it to be an acceptable surface on which to install geomembrane.

Northwest Linings & Geotextile Products, Inc. accepts no responsibility for the composition or character of the soil, nor any underlying conditions present at the sight, including, but not limited to, those arising out of improper compaction, use of improper soil materials, or the presence of underlying harmful objects of any kind. This acceptance is based solely upon a visual inspection of the completed sub grade preparation.

This acceptance is based upon the present condition of the sub grade preparation and Northwest Linings & Geotextile Products, Inc. accepts no responsibility for restoration of the sub grade preparation, upon physical harm or change, including, but not limited to, that caused by man, animal, or machinery. Neither does Northwest Linings & Geotextile Products, Inc. accept responsibility for restoration of the sub grade preparation upon the occurrence of any Act of God, including but not limited to, rain, wind, hail, snow, flood, or earthquake.

Area Being Accepted: ENTIRE AREA

**NORTHWEST LININGS REPRESENTATIVE:**

Date: 9/26/10  
Signature: \_\_\_\_\_  
Name/Title: MICHAEL VAUGHN / SUPERVISOR

**OWNERS REPRESENTATIVE:**

Date: 9/26/10  
Company: CHRYSLER MOUNTAIN  
Signature: \_\_\_\_\_  
Name/Title: Sup /



# Geosynthetic Installation Certificate of Acceptance

Project Name: STOKELY Date: 10-3/16

Project Location: FOUR CORNERS

Type of Project: PAVEMENT

## Geosynthetic Products Installed By Northwest Linings Personnel

Geomembranes:  HDPE  LLDPE  PVC  Polypropylene  Other \_\_\_\_\_

Thickness:  20 Mil  30 Mil  36 Mil  40 Mil  45 Mil  60 Mil  80 Mil

Surface:  Smooth  Textured  Reinforced  Non-Reinforced

Geotextiles:  Non-Woven  Woven Type: 330#

Geocomposite Product: \_\_\_\_\_

GCL Product: \_\_\_\_\_

## Owners Project Information:

Owner Representative: \_\_\_\_\_

General Contractor: \_\_\_\_\_

Contractors Representative: \_\_\_\_\_

Project Authorized Representative: \_\_\_\_\_

I, the undersigned a duly authorized representative of: NORTH WEST LININGS

do hereby takeover and accept the work described above from the date hereof, subject to the exceptions below, and confirm that the installation of the subject geosynthetic products has been completed in accordance with the specifications and the terms and conditions and conditions of the contract. There is no apparent damage to the installed geosynthetic products, nor is there any interference within or without the surrounding works.

Exceptions: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Project Authorized Representative: JOHN MILLER Title: Sup

[Signature] Signature: \_\_\_\_\_ Date: 10/3/16

Northwest Linings Representative: ANTONIO VARGAS Title: Supervisor

[Signature] Signature: \_\_\_\_\_ Date: 10-3-2016



# INSTALLATION GUIDELINES

## Raven Advanced Technology Geomembranes

### 1.0 INTRODUCTION

The Engineered Films division of Raven Industries has developed and continues to develop, several advanced technology geomembranes. These reinforced and unreinforced, smooth and textured/structured geomembranes are made by round-die blown-film and flat cast extrusion techniques with up to 7 co-extruded layers to provide sheet materials with a wide range of properties and performance characteristics.

While this Manual has been prepared primarily to help geomembrane installers to achieve durable liner installations, it will also be useful for CQA personnel, project engineers, and regulators, who all need to be working in an integrated manner to achieve maximum geomembrane performance and durability.

### 2.0 SCOPE

The scope of the Manual includes guidance and integrated protocols to ensure that Raven's products delivered to the construction site meet Raven and project specifications through to final installed liner testing to assure the integrity of the complete lining system (not just the welds), before it is handed over to the owner or project engineer.

There are three primary objectives:

1. To provide an easy-to-follow protocol for the proper installation and record-keeping of each Raven geomembrane product
2. To provide a vehicle that integrates Raven's specifications and QC/QA program with typical geomembrane Project Specifications such that there are no confusing conflicting overlaps or any gaps through which installation details might fall
3. To ensure that, if any nonconformance is found during installation or subsequent service, the records of personnel, materials, equipment, and installation activities are sufficient to enable a rapid definition of the full extent of the nonconformance and to facilitate its resolution

The Manual therefore includes guidance through all required installation activities and the provision of logs and data sheets to ensure that all necessary steps have been taken. For instance, it requires that all non-conformances and all non-passing test results be recorded, not just passing ones. Such comprehensive data are invaluable in pursuing the reason for and extent of, any performance problems at any stage of installation or service.

The Manual has been prepared as a single document with appropriate section introductions applicable to all products followed, where necessary, by sub-sections specific to each type of product.



### 3.0 GEOMEMBRANE PRODUCTS

There are four basic classes of geomembrane covered by the Manual:

1. Unreinforced (Absolute Barrier® / HydraFlex™ / Rufco® / VaporBlock® Plus™ Series)
2. Reinforced with a 7x7 yarns per inch polyester (PET) scrim (Dura♦Skrim® K-series)
3. Reinforced with a diagonal pattern scrim (Dura♦Skrim® R-series)
4. Reinforced with a tri-axial pattern scrim (Dura♦Skrim® J-series)

The more common geomembrane designations within each of these classes are listed below. Technical data sheets for individual products are attached as Appendix A.

#### **Absolute Barrier® / HydraFlex™ / Rufco® VaporBlock® Plus™ products (unreinforced)**

- Absolute Barrier® EB25BS, Y30BAC/Y40BAC, X40BAL/X60BAL
- HydraFlex™ H20/H30/H40, HP20/HP30/HP40, HU20/HU30/HU40
- Rufco® C25BT1/C30BT1/C36DT1, E15DBS/E30BS, PP30/PP40
- VaporBlock® Plus™ VBP20

#### **DURA♦SKRIM® products (reinforced)**

##### **K-Series (7 x 7 reinforcement)**

- Dura♦Skrim® K30B, K36B, K45B, K36BT1, K40BT2, K45BT2, KQ36B, KQ45B

##### **R-Series (diagonal reinforcement)**

- Dura♦Skrim® R8/12/20/24

##### **J-Series (tri-axial reinforcement)**

- Dura♦Skrim® J25DT1/J30DT1, J30B/J36B

Additional products may be assigned to these different classes as they are developed, particularly in the J-Series.

### 4.0 NOMENCLATURE

The legend that more specifically identifies each product is listed below:

The first two available digits of each number equate to the nominal thickness in mil (0.001 in.). HydraFlex® H20B and HP20B are 20 mil thick as an example.

B black, W white, D gray, W/B white one side black the other side, T textured, S enhanced grip surface.

## 5.0 TEST METHODS

There are two types of tests; 1) **Index** tests such as thickness, density, tensile strength, tear, and puncture resistance measurements that are used primarily for basic specification and QC/QA testing, and 2) **Performance** tests such as UV resistance, thermal aging, direct shear, and VOC diffusion rates that provide information on the performance of the geomembrane. Performance tests facilitate the selection of an appropriate geomembrane, but are used sparingly for conformance testing due to time constraints.

Test methods directly and indirectly referenced in this Manual are listed in Appendix B.

Where possible, internationally recognized standard test methods (ASTM, GRI) are used. Custom tests developed by Raven for the more unique products are described in detail at the appropriate location.

Test methods must be strictly followed. Any deviations should be explained in detail.

Failing test results should be provided.

## 6.0 ACCEPTANCE OF MANUAL

Prior to the start of each project the Installer will designate one person as its on-site CQC representative (QCR). The QCR will be responsible for all installation QC activities including the preparation of a comprehensive final report.

Prior to the start of each project copies of this Manual will be presented by the Installer's designated QCR to the General Contractor (GC), CQA firm, and Project Engineer (PE) for their review and confirmation that they understand, agree with, and will comply with all its requirements. They will return a signed copy of the Compliance Memorandum of Understanding (MOU) in Appendix C together with details of any conflicting, omitted, and unclear items.

The QCR will be responsible for seeing that all queries and comments are adequately addressed as will be confirmed on the MOU.

The intent of this action is to remove conflicts in, and gaps between, other project documents so that installation may continue without undue interruption.

## 7.0 PANEL LAYOUT DIAGRAM

As soon as the Installer has generated a proposed panel layout diagram it shall be submitted to the PE for approval.

In general the number of field seams will be minimized, particularly in corners. Seam orientation will typically be up and down slopes. Special considerations should be addressed by the Project Engineer (PE).

There shall be no floor seam parallel to the toe of slope closer than 5 ft. to the toe of any slope.

Seams at sumps will be minimized or avoided if at all possible. This may require the cooperation of the PE.

It must be recognized by all project parties that the panel layout diagram is a general outline and not a firm commitment, since modifications may be required to suit final grades, distances, and related structures.

## **8.0 MATERIAL DELIVERIES AND INVENTORY**

A record (Appendix D) shall be maintained of all material delivered to site. This record shall be compared to Raven's resin, geomembrane manufacturing, and panel fabrication QA/QC certificates, and shipping manifests. These records will be maintained by the Installer's QCR in a construction record file.

Each roll/panel will be labeled on the end(s) to show:

- Product type
- Roll/panel number
- Date manufactured
- Width
- Length
- Weight

The Installer shall confirm that:

- All geomembrane for a project is made from the same resin type
- Welding rods are made from the same resin class as the geomembrane
- Manufacturing QC (MQC) and fabrication QC (FQC) certificates cover every roll or fabricated panel received.

## **9.0 MATERIAL CONFORMANCE TESTING**

Conformance testing is not an opportunity to reproduce the MQC testing program. Rather it is intended to double check some key properties of the material. Typically, conformance testing will not be done by the installer but by the PE or CQA firm. However, if not done by others, it is good practice for the installer to do a few spot tests.

When possible, and certainly for overseas projects, conformance testing shall be done before the material leaves Raven's plant.

Conformance tests should be performed every 100,000 ft. of material.

When roll and panel numbers are assigned for each project and are received by the installer relevant ones shall be identified by the installer (or the CQA firm) for conformance testing. Selection of rolls/panels to test will be a function of the sequencing of resin lot and roll numbers. Thus, if there is an orphan (out of sequence) resin lot or roll number it should be tested. If roll numbers are sequential but two resin lots are used, a roll from each resin lot should be tested, etc.

Full roll width samples about 18 in. wide can be cut freehand (with intentional curves, and appropriate match marks) by Raven’s MQC/FQC personnel. After test specimens have been removed from the sample the sample remnant will be sent to the installer.

When passing conformance test results are received, the installer (or CQA firm) will approve material shipping to the site. When received on site the QCR will match the cut edges and match marks of the sample and the tested roll to confirm that the correct roll has been tested.

If any nonconformance is found, the next numbered rolls on each side will be tested, and so on until the range of nonconformance is identified. All nonconforming rolls will be clearly marked and set aside and not used. They will be replaced by Raven.

Suggested conformance tests for the different geomembranes are shown in Table 1

Table 1 Conformance tests

Parameter	Test Method	Unreinforced	Reinforced
Thickness	D5199/5994	x	x
Density	D1505/792	x	
Tensile Break Tension	D6693	x	
Tensile Break Elongation	D6693	x	
Tensile Scrim Break	D7003		x
Tensile Scrim Elongation	D7003		x
Tensile Polymer Break	D7003		x
Tensile Polymer Elongation	D7003		x
Ply Adhesion	D6636		x
Tear Resistance	D1004	x	
Tongue Tear	D5884		x
Puncture Resistance	D4833	x	x

## 10.0 MATERIAL STORAGE AND HANDLING

Rolls and fabricated panels (accordion-folded in one direction, rolled in the other direction) will be unloaded from trucks in such a way that no damage occurs to the geomembrane.

Fabricated panels accordion folded in both directions will not be used.

Rolls will be moved using sufficiently long stingers, spreader bars, or other equipment using at least two slings. Rolls will be lifted vertically off, and not dragged along, the truck bed.

Fabricated panels on pallets will be moved by forklifts.

The folds of fabricated panels that are visible shall be examined for damage, particularly at kinks in the folds.

All material will be stored on smooth clean dry level surfaces such that it will not be damaged, become dirty, or get wet internally.

Rolls shall be stored no more than three high and with sufficient space between ends such that access is available to read identification labels

Depending on the size of project, material shall be stored in a safe central location then staged at appropriate intermediate locations for deployment.

Fabricated panels will ultimately be placed in the correct location and in the correct orientation for deployment as shown on the protective packaging or in contained deployment instructions.

## **11.0 SUBGRADE PREPARATION**

The function of the geomembrane is to act solely as a barrier and not to be a load-bearing member of the lining system. The subgrade is the structural member of the lining system so should not be the cause of stress in the geomembrane. It should not be susceptible to differential settlement.

Specification and preparation of the subgrade are the responsibility of the geotechnical engineer (PE) and should not be assumed by the installer.

The installer should confirm that the subgrade is smooth, firm, and unyielding.

There should be no step elevation changes exceeding 1 in. and no desiccation cracks exceeding 0.25 in. in width.

There should be no rocks, roots, or any other protruding objects in the 2 in. surface layer. If there is any potential for vegetation growth a suitable sterilant shall be applied to the surface layer by the GC before final compaction. Such sterilant shall not be chemically incompatible with the geomembrane material.

However, unreinforced LLDPE and PP geomembranes may be placed on rounded gravel up to 0.5 in. in diameter.

The Installer will approve the subgrade and sign the form in Appendix E. The form will also be signed by the PE or CQA superintendent. Only as much subgrade that can be covered in one day should be approved.



It is the GC's responsibility to maintain the subgrade to the requirements of the installer.

There shall be no standing water on the subgrade when liner is placed.

## **12.0 MATERIAL DEPLOYMENT**

Rolls and panels shall be deployed in such a way that they are not damaged. Deployment shall not be done in strong or gusty winds or during precipitation events and lightning storms.

Rolls shall be suspended from a spreader bar and material pulled off the roll. Alternatively the end of the roll shall be fixed and the roll unrolled manually.

Rolls shall not be allowed to unroll freely down slopes. They shall be kept under control at all times.

Vehicles shall not be used to carry and unroll the geomembrane as the vehicle traverses the subgrade unless the vehicle leaves no tire or track impressions in the subgrade. Any damaging rocks or roots, etc. seen in the subgrade during deployment shall be removed and not covered.

Final adjustments to the location of the panel can best be done by lifting and flapping the liner so it "floats" on air. In gusty conditions the panel shall be kept close to the ground.

In gusty conditions that might unexpectedly lift the liner no one shall walk on the liner until it has been effectively ballasted. Many injuries have been caused by uplifted and blowing liner.

Panels shall be overlapped no less than 4 in. for extrusion welding, and no less than 6 in. for fusion welding. These overlaps will ensure sufficient material for seam peel testing.

If friction between the panel and substrate is too high to float and adjust the liner it may be necessary to deploy a slip sheet of geotextile below the liner to facilitate minor positional adjustments.

Large prefabricated panels shall be unrolled and unfolded as indicated in the deployment instructions included with the panel. Unfolding shall be done with a man every 15 to 30 ft. depending on the size/weight of the panel.

During deployment, folds and kinks in folds shall be carefully examined for thinning and cracking damage particularly at low temperatures.

Deployment will generally commence on side slopes and proceed down-gradient with the up-gradient sheet on the floor overlapping the down-gradient sheet for easy shedding of water. There should be no horizontal seams on slopes. All seams should be oriented up and down slopes.

Panels will be clearly numbered in the sequence in which they are placed.

Only as much material as can be seamed that day shall be placed.

### **13.0 BALLASTING AGAINST WIND UPLIFT**

Unwelded edges shall be ballasted with sandbags or other non-damaging items (tires, rolls, etc.) in such a way as to protect the liner from uplift due to reasonably expected winds prior to the resumption of work. This may require an end-to-end row of sandbags along the leading edge.

On slopes, such as landfill closures, the liner may be ballasted with sandbags approximately every 10 ft. across the slope and every 5 ft. up and down the slope. On steep slopes sandbags may be held in place by ropes anchored at the top of the slope. The PE should approve the spacing used.

The PE will determine whether sand bags can be allowed to “leak” their contents and whether they can be allowed to stay in place at the conclusion of the project. Preferably, to facilitate subsequent testing, they should be removed.

Sandbags may be used to hold the liner in place at the toes of slopes and in corners but they shall not be used as ballast to force the liner into corners. Remember the geomembrane should function as a barrier only and not be a load-bearing member of the lining system.

If not shown in project drawings, a method of supporting the geomembrane in 90 degree corners will be discussed with, and decided by, the PE (see Appendix F).

Panels shall be overlapped between 4 and 6 in. or to the appropriate edge markings, for extrusion and fusion welding, respectively.

### **14.0 ANCHOR TRENCH**

Liner shall be placed down the front wall and across the bottom of anchor trenches. The geomembrane will not be folded in the anchor trench.

The front edge of the anchor trench will be rounded, with no sharp stones that might damage the liner. There shall be no loose stones/rocks in the anchor trench and no standing water. The GC shall be responsible for maintaining the anchor trenches in good condition for the installer.

It is frequently suggested that the liner in the trench not be covered until it has gone through one cold (overnight) cycle that will allow it to contract without major stress. However this will require the liner to remain unballasted, with the potential that unexpected winds will blow it away. Appropriate care should be taken.

The anchor trench shall be filled with soil that does not damage the liner and that will not damage the liner when compacted. The soil shall be compacted sufficiently to preclude standing water in the trench. If there are holes in the liner on the front face of the anchor trench,

and the soil is not compacted such as to preclude standing water, water might seep through the holes and erode the slopes.

The anchor trench is a critical part of the design and must not be modified by the installer in any way. In addition to conventional rectangular trenches the use of V trenches is increasing. Flat run-outs with ballast soil on top of the liner are occasionally used.

If no anchor trench design is available, and slope gradients and lengths are not excessive, a trench 2 ft. deep, 1 to 2 ft. wide, and 2 to 3 ft. back from the slope crest is a good place to start. However, the PE should approve the proposed anchor trench design.

## 15.0 COMPENSATION WRINKLES

Material shall not be allowed to bridge corners and the toes of slopes – it shall be fully supported by the subgrade at the time of covering. Depending on the geomembrane temperature during installation and the temperature at which it will be covered it may be necessary to build in some slackness between fixed points to allow for thermal contraction. This applies only if the expected temperature at covering is lower than the temperature during installation.

When the liner is to be left exposed sufficient compensation shall be installed between any two fixed points to prevent contraction stresses at the lowest service temperatures.

Appendix G provides more detailed guidance.

The amount of slackness required between any two fixed points is the difference in **liner temperatures** at installation (higher) and covering (lower) multiplied by the distance between fixed points multiplied by the coefficient of linear thermal expansion (CTE) of the material (Appendix G).

When the geomembrane temperature at covering will be higher than the temperature at installation the liner should be installed flat without any compensation.

Note that the only temperature of importance is the **geomembrane temperature**. Ambient temperature is not important. White surfaces will be at lower temperatures than black surfaces in the sun. When it is cloudy, both will effectively be at the same temperature.

## 16.0 GENERAL REQUIREMENTS

There shall be no smoking on the liner. Soft sole shoes shall be worn. Only hook blade knives with automatic blade retraction will be used on the liner. Equipment such as generators are not allowed on the liner without a protective cushion. Fuel containers will only be allowed on the liner if they have leak-tight secondary containment.

ATVs may be used on large sites provided tire ground pressures are less than 8 psi. They must not be started or stopped suddenly and wheels must not be turned when stationary. They must not be operated when wrinkles are large enough to be folded over.

Deployment shall not be done in strong winds, precipitation, lightning, or when there is standing water on the subgrade.

The QCR shall constantly monitor the weather forecasts.

## **17.0 WELDING/JOINING**

### **17.1 GENERAL**

Welding should be done as uniformly and consistently as possible. The objective is to melt the two surfaces and to allow them to cool and solidify as one integral body.

When the weld is sectioned there should not be a well-defined interface, nor should there be any particulates or voids along the weld line. There should be no crimps due to overheating. The adjacent geomembrane should not be overheated and oxidized such that it becomes brittle.

In cases where thinner geomembranes ( $\leq 20$  mil) are used as temporary covers or as rain covers it may be sufficient to sew them together, tape them, or even to simply overlap them and ballast them. See sandbag ballasting requirements in Section 13.

Acceptable field welding methods are thermal fusion and extrusion. The thermal energy for fusion welding can be provided by hot wedges, hot air, or a combination. Any other method (laser, ultrasonic, etc.) must be approved by Raven and the PE.

Chemical bonding is not acceptable.

Extrusion welding rod should be made from the same resin class as the bonding surface of the geomembrane surfaces being extruded too.

### **17.2 TRIAL WELDING**

Trial welding is essential to confirm that welding machines are fully functional. Production welding shall not be started until trial welding has been successfully completed. Trial welding will be done at the start of every 4 hr. (approx.) shift, after the machine has been turned off and restarted, and when the geomembrane changes temperature by more than 25°C.

Trial welds, at least 4 ft. long, shall be made on scraps of the same material as will be installed.

Welds will be made with sheet in the same orientation (flat floor, slope, wall etc.) and on the same substrate as the planned production welds. Trial welding conditions shall not be optimized.

For unreinforced material three peel specimens shall be cut from the last two thirds of the weld and tested in peel mode according to the parameters in (Table 2) for peel separation, peel elongation, and locus of break (Appendix H) as also listed in Table 2. Results, both passing and failing, will be reported on the Trial Seaming log in Appendix I.

For reinforced materials five specimens shall be tested in peel mode according to the parameters in Table 2. The minimum geomembrane tab elongation of 50% allows for scrim break but the polymer layers must not break.

Table 2. Trial seam peel test parameters

Parameter	Unreinforced	K-series	R-series	J-series
Width specimen (in.)	1	1	1	2
Number of specimens	3	5	5	5
Grip/Specimen distance (in.)	1	1	1	1
Crosshead speed (in./min)	2	2	2	2
Break locus	Refer to Appendix H	Refer to Appendix H	Refer to Appendix H	Refer to Appendix H
Elongation (% min)	100	50	50	50
Separation (%)	25	0	0	0

Specimens shall be prepared from the different materials as described in Sections 18.2.1 to 18.2.4.

All specimens must pass before production welding commences.

If three trial weld attempts fail, the equipment shall be put aside and repaired. When used again, two passing trial welds shall be made before that equipment can be used for production welding.

The cross sections of welds shall be examined for symmetry, lack of crimping (overheating), and the presence of voids and foreign particulates. If voids and particulates are present the weld will be rejected, even if the weld passes a peel test. Such flaws may be the cause of weld failures in service, particularly in exposed liners.

When geomembrane temperatures during welding are below 40°F or above 100°F 5 peel specimens will be tested for unreinforced material seams. All must pass.

When sewn seams are acceptable, and only in the thinner ( $\leq 20$  mil) reinforced materials, a portable 2 thread, single needle sewing machine (Union Special 2200 CLASS, or similar) shall be used to make a “J” seam with F or FF polyester thread with 3 stitches/in.

When taping is acceptable Raven tape shall be used.

### 17.3 FIELD WELDING

Three types of weld geometry are acceptable:

1. Double track fusion welding for long straight seams with free flaps on each side of the weld for peel and shear testing.
2. Single track fusion welding (typically more than 1 in. wide) for long straight seams with no external flap, but with a flap on the underside.
3. Extrusion welding for detail work such as pipe boots and patches with a flap on the underside.

Sheet overlaps should be sufficient to facilitate seam peel testing, typically 4 in. for extrusion seams and 6 in. for fusion seams.

For double track fusion welds the outer flap shall be wide enough to facilitate peel testing.

Welding shall not be done in strong winds, during precipitation, and during lightning storms, nor where there is standing water on the subgrade.

The surfaces to be bonded shall be dry and clean for fusion welding. Dry with a clean cloth, or carefully with a hot air gun. Clean with a cloth or carefully with isopropyl alcohol and water.

For extrusion welding materials >45 mil in thickness surfaces will be ground or abraded carefully so as not to remove more than 10% of geomembrane thickness. For material thicknesses of 45 mil and below grinding is not necessary, but thorough cleaning is required.

For extrusion welds on unreinforced materials 40 mil and more in thickness the top corner of the top sheet shall be beveled to about 45 degrees for a depth of at least 50% of the thickness to help ensure contact of the weld bead with the complete edge of the sheet.

Under no circumstances will reinforcement yarns be exposed during grinding/abrasion, and all abrasion debris must be removed.

Welding shall be done within 30 minutes of surface preparation.

All preparatory abrasion marks shall be covered by the extruded weld bead.

Special attention will be required in blowing dust, on GCL substrates, and on moist subgrades, to avoid weld contamination. A plywood sheet placed under the edges to be welded might help in this regard, but be sure not to damage the subgrade or underside of the liner with sharp edges and splinters.

Welding shall continue to the edge of the liner in the anchor trench.

Fishmouths in reinforced materials shall be cut along the peak, overlapped, laid flat, and extrusion welded along the full length. A minimum 6 in. diameter patch will be placed over the end of the cut. For unreinforced materials the overlap shall be extrusion welded where it exceeds 1 in. A keyhole shall be made at the end of the cut and the remainder of the overlap patched. The keyhole will minimize the potential for further propagation of the cut.

When a conductive ground wire/tape is placed in extrusion welds for spark testing it shall be positioned and retained just under the edge of the upper sheet. When DC spark testing is required one end of the wire shall be grounded under the liner prior to closure seaming.

If there is a tendency for a wedge welder to dig into a soft subgrade (the subgrade should not be soft) and seize up, a strip of plywood can be moved under the overlapped liner to provide support for the welding machine. However, care must be taken that the board does not scoop up subgrade soil and contaminate the weld.

If a weld burn-through does occur any large blobs of material shall be ground down before patching. There should be no point stresses on the underside of the patch.

Weld seams on slopes going upslope

At the end of every weld write on the liner:

- Initials of operator
- Number of welding machine
- Machine speed, temperature, pressure settings
- Date
- Time started

## **18.0 SEAM TESTING**

Two types of tests will be performed on the field seams – nondestructive and destructive. All seams shall be 100% tested nondestructively. Destructive tests will be performed at a defined frequency.

### **18.1 NONDESTRUCTIVE TESTING**

Four test methods are available:

- center air channel pressure testing for double track fusion seams
- vacuum box testing for single track fusion and extrusion seams
- spark testing for detail extrusion seams that cannot otherwise be tested
- air lance testing for single track fusion seams.

#### **18.1.1 AIR CHANNEL TESTING**

The test procedure is defined in ASTM D5820 and summarized below:

- Clamp or otherwise seal both ends of the seam to be tested – distance not to exceed 450 ft.
- Insert pressure feed needle into the air channel at one end and pressurize according to Table 3.

- Allow conditions to stabilize for 2 minutes.
- Note starting pressure.
- Note pressure after 5 minutes.
- Ensure pressure loss does not exceed that allowed in Table 3.
- If pressure cannot be generated or if pressure loss is excessive walk the length of the seam listening for the whistling noise at a leak. If a leak is found repair and re-test.
- If pressure loss is acceptable release seal at far end of seam and confirm loss of pressure.
- If pressure is not lost locate blockage in the channel and test the untested section.
- Repair needle hole with one extrusion bead.
- Write on the liner the tester's initials, date, start time/pressure, finish time/pressure, pressure drop, pass/fail.

Table 3. Air pressure test parameters for double track fusion welds

Thickness (mil)	Pressure (psi)	Time (min)	Loss (psi)
20-45	24	5	4
40-100	30	5	2

### 18.1.2 VACUUM BOX TESTING

Vacuum box testing is performed on extrusion welds and single track fusion welds with no free flap, i.e. bonded to the outer edge. It is not normally performed on double track fusion welds, but if it is required the edge flap must be carefully cut off back to the edge of the outer weld track. A hook blade knife shall be used. Under no circumstances will the flap be torn off.

The test procedure is defined in ASTM D5641 and is summarized below:

- Apply soapy solution to seam area to be tested.
- Place vacuum box with clean viewing glass along seam.
- Ensure sealing foam around bottom of box is well seated and provides a good seal.
- It may be necessary to “work” the box into place and to use some wet rags to get a good seal.
- Reduce pressure difference in the box to about 4 psi.
- Monitor the seam for soap bubbles for at least 5 seconds.
- Mark any locations where bubbles indicate leaks for repairs.
- If no bubbles occur after 5 seconds relieve vacuum and move to next seam section.
- Overlap sections tested by about 3 in. and re-test.
- Write on the liner the tester's initials, date, time tested, test pressure, and “VB pass/fail”.

With thinner products it may be beneficial to install a rigid mesh over the bottom of the box to prevent the liner being sucked into the box. Avoid rough edges that might damage the liner.

### 18.1.3 SPARK TESTING



Spark testing is usually done at locations, such as pipe boots, where vacuum box testing cannot be done. There are two methods of spark testing – AC and DC. The DC method is recommended for its higher sensitivity. Both methods require a conductive wire/strip behind the extrusion weld. This wire/strip does not need to be grounded for AC testing. It is grounded for DC testing.

Very high voltages are used. Due care must be taken and warning signs placed.

The liner must be dry when being tested.

The test procedure is defined in ASTM D6365 and summarized below:

- Ensure the liner is dry.
- Place warning signs at edge of work area.
- Connect the negative of the power supply to a grounding rod.
- Connect the positive of the power supply to the survey probe, preferably a brass wire brush that exceeds the width of the weld bead.
- Determine the length of leak that needs to be detected, usually the distance from the edge of the weld bead to the conductive wire in the weld.
- Set the voltage to the required value as determined in Table 4.
- Check that a leak will be indicated on a test weld with a fabricated leak of the required length.
- Check that the liner adjacent to the weld will not be damaged at this voltage setting. Too high a voltage could punch a hole in the liner.
- At the established voltage pass the brass brush steadily along, and in contact with the weld bead.
- Look for sparks and listen for discharges.
- Mark hole locations for repair.
- Switch off power supply when not testing.
- Do not step off liner or contact ground while the voltage is switched on.

Table 4. Spark test voltage for various distances

Distance (in.)	Distance (mm)	Voltage (kV)
0.250	6	20
0.375	10	25
0.500	13	28
0.625	16	31
0.750	19	35

AC equipment often has a single point wand as the survey probe. In this case pass the probe along each edge of the weld bead and along the center of the bead. Note that if the voltage is set to discharge through a 0.5 in. long leak from edge of bead to conductive wire, a leak will not be indicated if the single point probe is passed along the center of the bead. This would require a voltage setting to discharge over about 1 in.

#### **18.1.4 AIR LANCE TESTING**

Air lance testing is typically used on flexible sheet less than 50 mil (1 mm) in thickness when there is no flap on the edge of the weld.

Refer to ASTM D4437 section 4.2 for the test procedure.

Air at a pressure of 50 psi is passed through a 0.188 in. diameter nozzle directed perpendicularly to the edge of the seam from a distance of no more than 2 in.

The air jet must be maintained on the edge of the weld and not above it.

A flapping sound indicates an area of inadequate bonding.

A whistling sound indicates a leak passageway through the weld.

Mark, repair, and re-test these locations.

#### **18.2 DESTRUCTIVE TESTING**

Conventional seam destructive testing (on HDPE geomembrane seams) typically requires the periodic removal of seam samples, from which ten specimens are typically die-stamped, five for testing in shear mode (sheet to sheet) and five in peel mode. However, the testing protocol on Raven (non-HDPE) geomembrane seams, has been updated to better assess the associated bond strengths.

Note that for HDPE geomembrane seams, both peel and shear strengths are a function of geomembrane thickness when what we are trying to assess is independent of geomembrane thickness. We are not measuring seam strength. In fact, if bond efficiency exceeds only about 20%, shear strength tests are only measuring geomembrane tab strengths.

All required information is obtained from a peel test:

- Bond efficiency is adequate, which is challenged more in a peel test than in a shear test.
- Bond strength is adequate, shown by no peel separation.
- Ductility showing that the adjacent geomembrane has not been embrittled during welding.
- That break occurs outside the weld.

Remove samples from field seams at an average frequency of every 500 ft. for each welding machine/operator combination. Unless there is a reason to suspect the quality of seams on the floor of a pond liner, remove samples from the upper levels of the slopes.

If independent CQA is being performed the CQA monitor will identify the locations for destructive testing.

Prior to cutting the full test sample remove one specimen from the proposed testing location and test as described below. If this specimen meets the criteria in Table 5 cut a full size sample for testing. However, if this specimen fails to meet the criteria in Table 5, cut two additional strip

specimens for testing from 10 ft. each side of the failed specimen. Continue outwards until two good specimens define the limits of the seam nonconformance. Test two full size samples at these locations.

Table 5. Field peel test parameters

	<b>Unreinforced</b>	<b>K-Series</b>	<b>R-Series</b>	<b>J-Series</b>
Width specimen (in.)	1	1	1	2
Number of specimens	5	5	5	5
Grip/Specimen distance (in.)	1	1	1	1
Crosshead speed (in./min.)	2	2	2	2
Break locus (ppi)	Refer to Appendix H	Refer to Appendix H	Refer to Appendix H	Refer to Appendix H
Elongation (% min.)	100	50	50	50
Separation (%)	25	0	0	0

If either of these full samples fails continue sampling in the direction of nonconformance until a passing test is obtained. Repair the seam between the two passing samples.

### **18.2.1 UNREINFORCED MATERIALS**

#### **18.2.1.1 ABSOLUTE BARRIER® / HYDRAFLEX™ / RUFECO® / VAPORBLOCK® PLUS™ SERIES**

Unreinforced material seam samples will be 3 ft. long and minimum 12 in. wide with the seam centered lengthwise.

One half of the sample will be used for CQC testing and the other half will be made available to the PE or CQA firm for CQA testing.

Five 1 in. wide specimens will be cut from across the seam (with seam centered and at 90 degrees to the length) for peel testing. Shear testing will not be required.

Peel testing on extrusion welds will be performed according to ASTM D6392 at a crosshead displacement rate of 2 in./min. and with each grip 1 in. from the edge of the weld. I.E. a gage length of 1 in., since only one of the geomembrane tabs will elongate and break. Therefore the grip on the top sheet will be 1 in. from the edge of the extrusion weld bead on the top sheet (about 1.5 in. from the center of the weld bead), and the grip on the bottom sheet will be 1 in. from the center of the weld bead.

Both sides of the fusion welds will also be tested with 1 in. gage lengths. Fusion welds will require an outer flap at least 1.5 in. wide.

Peel testing may be stopped when one of the geomembrane gage length elongations exceeds 1 in. (100%).

Acceptance criteria are (see Table 5):

- Zero peel separation.
- Break in the geomembrane outside the weld.
- Elongation of geomembrane tab >100%.

When the specimens are cut their cross sections shall be examined for porosity and contaminants in the weld bead and on the weld interface. If such features are present the seam shall be rejected.

All five specimens shall meet these specifications for the sample to be accepted.

Test results shall be recorded on the form in Appendix J.

Tested specimens shall be retained until completion of the project.

Note that all geomembranes incorporating a layer of EVOH will peel on the EVOH interface. This cannot be avoided.

## **18.2.2 REINFORCED MATERIAL**

### **18.2.2.1 DURA♦SKRIM® K-SERIES (7 x 7 reinforcement)**

7 x 7 reinforced material seam samples will be 3 ft. long and minimum 12 in. wide with the seam centered lengthwise.

One half of the sample will be used for CQC testing and the other half will be made available to the Owner's Project engineer for CQA testing.

Five 1 in. wide specimens will be stamped from the sample and tested only in peel mode. Every attempt must be made not to cut the reinforcing yarns that are parallel to the length of the specimen.

Grips will be positioned 1 in. from the nearer edge of the seam. Crosshead displacement rate will be 2 ipm. Both sides of the fusion seams will be tested.

Results must meet the following criteria (see Table 5):

- Zero peel separation.
- Break in the geomembrane outside the weld.
- Elongation of geomembrane tab >100% without polymer break.

All five specimens must meet these criteria for the sample to be accepted.

### **18.2.2.2 DURA♦SKRIM® R-SERIES (diagonal reinforcement)**

For diagonally reinforced materials, samples will be 3 ft. long and 12 in. wide with the seam centered lengthwise.

One half of the sample will be used for CQC testing and the other half will be made available to the Owner's Project Engineer for CQA testing.

Five 1 in. wide specimens will be stamped from the sample and subjected to peel testing. Specimens will be cut normal to the direction of the weld with the reinforcing yarns at about 45 degrees to the axis of the specimen. Any machine/roll direction specimens shall avoid the roll direction yarns that occur every 3 in.

Grips shall be positioned 1 in. from the edges of the seam and crosshead displacement rate will be 2 ipm. Both sides of the fusion seams will be tested.

Test results shall meet the values in Table 5. All 5 specimens shall meet these specifications for the sample to pass.

### **18.2.2.3 DURA♦SKRIM® J -SERIES (tri-axial reinforcement)**

The seam samples for tri-axially reinforced products will be 3 ft. long and minimum 12 in. wide with the seam centered lengthwise.

One half of the sample will be used for CQC testing and the other half will be made available to the PE or CQA firm for CQA testing.

Five 2 in. wide specimens will be stamped from the seam for peel testing using 2 in. wide grips.

Transverse specimens will include 8 diagonal reinforcing yarns. If machine direction specimens are tested they shall incorporate three longitudinal yarns.

Both sides of the fusion welds shall be tested.

Shear testing will not be performed at a crosshead displacement rate of 2 ipm.

All 5 specimens shall meet the requirements of Table 5 for the sample to be accepted.

### **18.3 SEAM SAMPLE FAILURES**

If any sample fails seam testing two new samples shall be taken about 10 ft. each side of the failing sample, and so on until two passing samples define the limits of the non-conforming seam.

The seam shall be repaired between the two passing samples.

### **19.0 FLAWS AND REPAIRS**

All non-penetrating linear flaws less than 0.125 in. wide may be repaired with no more than one extrusion bead of the same base polymer as the geomembrane.

Penetrating holes less than 0.125 in. in diameter that do not expose scrim yarns may also be repaired with no more than one bead application.

Holes that expose scrim yarns and those that are more than 0.125 in. in diameter shall be patched with the same geomembrane with patch yarns oriented in the same direction as in the

geomembrane. The patch shall extend at least 3 in. from the edge of the nearest damage if the damaged area is less than 1 in. in diameter. When damage exceeds 1 in. in diameter the patch shall extend at least 6 in. from the nearest damage.

Under no circumstances will parallel and overlapping beads be used to fill in a flawed area or a gap.

All corners on patches shall be rounded.

All patch extrusion welds shall be vacuum box tested and hot air patches can be either air lanced or vacuum tested and the results recorded.

All patches shall be numbered and their sizes and locations recorded.

A single extrusion bead may be used to repair the edge of a fusion weld but only after the free flap has been carefully cut back to the edge of the weld using a hook blade knife. The free flap shall not be torn off.

For geomembranes that have an encapsulated edge, all cut edges of reinforced materials that expose scrim shall be covered with a single extruded bead to prevent access of liquids into the scrim yarns.

## **20.0 APPURTENANCES**

This section covers connections of the geomembrane to concrete structures (ramps, walls, sumps, etc.) and to pipe penetrations. Such connection details are primarily the responsibility of the design engineer but they are often left to the discretion of the installer.

Where possible liner/structure connections should be above liquid levels and pipe penetrations should be avoided wherever possible.

Basic guidance for appurtenance connection design is provided in ASTM D6497. Some of these designs are attached as Appendix K.

### **20.1 BATTEN STRIPS**

Stainless steel batten strips are often used to seal geomembrane to concrete pads and walls. Such batten strips shall be no less than 1.375 in. wide and 0.25 in. thick. Fastening bolts will be no less than 0.375 in. in diameter with bolts spaced no more than 12 in. on centers. These details are strictly the responsibility of, and should be approved by, the PE.

Concrete surfaces shall be smooth and not friable.

Neoprene gaskets (or another material that is compatible with the contained liquid) shall be placed between geomembrane and concrete and between batten and geomembrane.



Bolt shafts shall be smooth (not threaded) between the surface of the concrete and the center of the batten strip. Holes a little less than the diameter of the bolt shall be stamped, not drilled or punctured in the gasket strips.

Nuts shall be tightened such that the compressive deformation of the gasket does not exceed its elastic limit. It is not necessary to fully tighten the nuts. The batten strip should remain straight and not be bowed between bolts. Thus the gaskets remain uniformly compressed between bolts.

Butt joints in batten strips should have no more than a 0.10 in. gap with the nearest fasteners no more than 2 in. from the joint. Joints in gaskets shall not be coincident with batten strip joints. Joints in gaskets shall be scarfed (angled) and glued.

Geomembrane welds, particularly extrusion welds should not pass under the batten strips. To avoid this, a wide strip of liner the shape of the batten seal can be cut and secured by the batten strip. The geomembrane can then be welded to this strip.

When the batten strip has been tightened an encapsulating bead of caulking (GE RTV 103, or equivalent) shall be placed along the edge of the geomembrane between the batten strip and the concrete.

Before leaving the site all batten strips should be revisited to ensure there are no loose nuts.

## **20.2 CAST-IN LOCK STRIP**

Instead of a batten strip, a rigid extruded plastic profile (lock strip) can be cast-into the concrete when it is poured to which the geomembrane can be welded, if both are the same polymer, e.g. PP and LLDPE.

The strip must be well embedded in the concrete so there is no air trapped under it and so the surface of the strip is level with the surface of the concrete. The strip and the concrete will be a significant heat sink during welding so must be preheated with hot air in order that surface melting will occur when the extruded weld bead is applied.

There is no standard ASTM or GRI procedure to test such a weld. It is suggested that a trial weld bead about 6 in. long be bonded to the top of a short spare piece of lock-strip then run onto an incompatible substrate that prevents bonding to the strip. The unbonded tab can then be pulled in peeling mode using a set of liner clamps to see if the bead can be peeled off the strip.

Butt joints in the strip shall contain no gap. Any gaps that do occur shall beveled on each side and fillet welded. Before welding all loose material shall be blown out of the joint. The proud surface of the weld bead shall be ground to be level with the surface of the strip.

Corners shall be mitered and any gaps shall be filled by fillet welding as above.

The concrete surface under the liner shall be smooth and any corners shall be rounded to a radius of no less than 0.75 in.

Soil surfaces at the edges of the concrete shall be well compacted to be level with the surface of the concrete to minimize differential settlement.

A protective strip of nonwoven geotextile should be placed between geomembrane and concrete and adjacent soil. This strip may be adhered to the concrete but shall not extend beyond the edge of the geomembrane when welding is performed. The geotextile shall not extend into the weld.

### **20.3 PIPE PENETRATIONS**

Pipe penetration boots may be fabricated in the field or prefabricated in a controlled plant environment. Before any boot is finally installed it should be checked for leakage by a water ponding test or a water pressure hose test.

The boot should be fabricated such that, when installed, it is fully supported by the pipe and the surrounding subgrade, particularly in the low angle between the underside of the pipe and the subgrade.

The number of welds made to fabricate a boot should be minimized. There shall be no more than two extrusion welds in any one location, except where they cross or meet for continuity. Weld beads shall not be placed side by side.

For as-installed nondestructive testing, a ground wire could be installed in each extrusion weld to facilitate spark testing (see section 18.1.3 above). In this case the wire(s) should be well-grounded under the boot.

The skirt of the boot shall be welded to the liner first.

At the pipe clamp end, prior to placement of the boot, any free weld flap on the underside of the geomembrane shall be carefully cut back to the edge of the weld using a hook-blade knife.

Weld beads at the pipe sealing end shall be ground flat to a thickness no less than twice the thickness of the geomembrane. Squeeze-out beads along the edge of the primary bead shall be removed by careful grinding that does not contact and damage the surface of the liner.

A gasket or chemically resistant sealant shall be placed between the end of the boot and the pipe. A strip or two of sacrificial geomembrane shall be placed between geomembrane and fastening clamps.

Clamps shall be tightened at the end of a low temperature period when thermal contraction has allowed the boot to contract along the pipe towards the slope.

Before leaving the site, pipe boot clamps shall be revisited to ensure they are still tight.

*Underwater seals are frequent locations of leaks so it is most important that they be properly installed and checked.*

*Every effort shall be made to avoid underwater seals.*

## 20.4 VENTS

Vents at the crests of slopes are extremely important for the release of trapped air, air pushed up under the liner as groundwater rises, naturally generated gas (Radon), and methane generated by leaking waste water.

Simple vents can be constructed by cutting a 1 in. diameter hole in the liner just below the crest of the slope (but above the maximum water line) and covering with a patch about 12 in. square welded on the top and both vertical sides. The bottom unwelded edge should be flat so that rodents cannot get into the hole and under the liner.

Vents will typically be no more than 100 ft. apart.

The PE is responsible for designing a gas venting and leak drainage system under the liner that will ensure that any gas can reach the vents. This will typically require a sloping floor with a leakage collection and removal sump at the low end. Floor gradients typically exceed 1.5%.

A nonwoven geotextile that may act to cushion the geotextile from the subgrade will usually not serve double duty as gas vent and leak drainage system. At a minimum a network of drainage geocomposite strips leading to each vent should be installed. A blanket geocomposite is better.

Any Leakage Detection System (LDS) proposed by the installer must be approved by the PE.

## 21.0 GEOELECTRIC LINER INTEGRITY SURVEYS (LIS)

These surveys are often called “leak location surveys” but for CQC/CQA purposes it is preferred they be called “liner integrity surveys” (LIS). They cover the complete surface of the liner. They can be performed on soil-covered, water-covered, and exposed liners.

Relevant ASTM standards are D6747 (guide to test methods), D7002 (exposed liner), D7007 (water and soil-covered liners), and D7240 (conductive liner).

Statistics have proven that no matter how well the liner has been installed, and no matter how effective the CQA, there are invariably a few leaks in the liner that are not detected. Therefore, an LIS is a valued final phase of CQC and CQA. For the installer it is a final check (proof) of liner integrity before handing over the liner to another party that might subsequently damage it.

An effective LIS requires the following conditions:

1. A conductive medium on top of the geomembrane
2. A conductive medium through the holes being sought
3. A conductive medium immediately under the geomembrane
4. No, or little, contact between the media above and below the liner other than through the holes being sought

A direct current potential is applied across the geomembrane from a current injector electrode in the soil/water above the liner to a current return electrode in contact with the conductive layer

under the liner. Because the geomembrane is an electrical insulator current only flows through the holes (leaks) we are trying to find. A dipole (two electrode) survey probe is passed through the water or over the surface of the soil to measure potential gradients, which have a unique pattern at a leak. Small leaks (~50 mil) can be pinpointed.

For exposed liners a positively charged stream or puddle of water is moved over the surface of the liner. When this water penetrates a hole and contacts the negatively charged subgrade current flows through the water stream/puddle and is recorded.

It is therefore difficult to perform an effective survey on a single soil-covered liner if the cover soil is in contact with the subgrade soil around the edge of the liner – Condition 4 above is not met. It is also difficult with a double liner where there is only a geonet or geocomposite (both non-conductive) between the two liners – Condition 3 is not met.

Approximately 2 acres can be surveyed in one day.

Additional LIS-specific information or training should be sought if such surveys are desired or are a regulated requirement.

## **22.0 FINAL LINER INSPECTION**

On the completion of geomembrane installation representatives of all parties concerned, shall perform a thorough walkover of the complete liner surface checking for any remaining flaws that need repairing prior to the installer handing over the geomembrane to the next contractor for further work e.g. covering with soil.

At the conclusion of the walkover the Final Liner Visual Inspection document in Appendix M will be signed by all parties acknowledging the repairs and adjustments that are needed. The installer will make required repairs and adjustments.

Another visual examination of the repairs and modifications will then be made by the installer and the Project Engineer/CQA Firm to confirm the adequacy of those repairs and modifications as indicated by additional signatures on the Final Visual Inspection form.

## **23.0 RECORD DRAWINGS**

Detailed record drawings shall be made of all liner installations. A record drawing is the single most important document for the installer, the CQA firm, and the project owner should performance problems occur during service.

The drawings shall show:

- Panel numbers, usually in order of installation
- Roll number from which each panel was removed

- Locations of field seams
- Orientation of factory seams in prefabricated panels
- Whether material is smooth, textured/structured, reinforced/unreinforced, or otherwise surface treated
- Destructive seam sample numbers and locations
- Repair numbers, types (bead, patch, cap strip, etc.), and locations
- Toe of slope locations
- Crest of slope locations
- Gas vent locations
- Sump locations
- Pipe penetration locations

## **24.0 PROJECT DOCUMENTATION**

A full set of records will be accumulated for each project. Suggested forms/logs are attached in Appendix L. Records may include:

- Raven geomembrane manufacturing QC certificates
- Raven panel fabrication QC certificates
- Raven bills of lading for shipping
- Compliance Memorandum of Understanding
- Material inventory
- Conformance testing
- Subgrade acceptance
- Material deployment
- Trial seaming
- Production seaming
- Repairs
- Seam nondestructive testing
- Seam destructive testing
- Liner integrity survey details when applicable
- Problems/Resolutions
- Daily work report including sketch of panels installed
- Weekly work summary

These records will allow full traceability of materials, personnel, and equipment to determine the full extent of a concern should a problem occur in service.

## **25.0 CLOSURE**

These geomembrane installation guidelines do not take precedence over Project Specifications.

However, if a potential conflict with the Project Specifications is noted the Installer's QC designate should discuss the matter with the CQA Superintendent and/or the Project Engineer. If, in the opinion of the Installer, a satisfactory conclusion is not reached, as will be recorded in the Problem/Solution log, the Installer will contact Raven for further technical and procedural advice:

Raven Contact: Gary Kolbasuk

Email Address: [geo@ravenind.com](mailto:geo@ravenind.com)

Office Phone: 16-800-635-3456

Date: 6-01-2016

If this date is more than six months ago please contact Raven for possible updated contact details.

*The information contained in this document is to be used as a guide only.*

**RAVEN INDUSTRIES MAKES NO WARRANTIES OR GUARANTEES OF SATISFACTORY RESULTS FROM RELIANCE UPON CONTAINED INFORMATION OR RECOMMENDATIONS AND DISCLAIMS ALL LIABILITY FOR RESULTING LOSS OR DAMAGE.**

*Weather conditions, experience of installation crew, and ground and/or pile surface conditions will affect installation procedures and methods.*





# **INSTALLATION GUIDELINES**

## Raven Advanced Technology Geomembranes

### APPENDIX

## APPENDIX A

### Technical Data Sheets

A1 Absolute Barrier® / HydraFlex™ / Rufco® / VaporBlock® Plus™ Series  
(unreinforced)

A2 Dura♦Skrim® K-Series (7 x 7 reinforced)

A3 Dura♦Skrim® R-Series (diagonally reinforced)

A4 Dura♦Skrim® J-Series (triaxially reinforced)

APPENDIX B  
Test Methods

## **ASTM**

D638, Standard Test Method for Tensile Properties of Plastics

D751, Standard Test Methods for Coated Fabrics

D746, Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

D792, Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting

D1203, Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods

D1204, Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature

D1434, Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting

D1505, Standard Test Method of Density of Plastics by the Density-Gradient Technique

D1603, Standard Test Method for Carbon Black in Olefin Plastics

D1709, Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method

D1746, Test Method for Transparency of Plastic Sheeting

D2136, Test Method for Coated Fabrics – Low-Temperature Bend Test

D3895, Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

D4218, Test Method for Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

D4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles

D4545, Standard Practice for Determining the Integrity of Factory Seams Used in Joining Manufactured Flexible Sheet Geomembranes

D4833, Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

D5199-01(2006) Standard Test Method for Measuring the Nominal Thickness of Geosynthetics

D5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles

D5397(A)-07 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

D5617, Standard Test Method for Multi-Axial Tension Test for Geosynthetics.

D5641-94 (2006) Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber ,

D5721-08 Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.

D5820-95 (2006) Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.

D5884-04a (2010) Standard Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes .

D5885-06 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.

D6241-04 (2009) Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.

D6365-99 (2006) Standard Practice for the Nondestructive Testing of Geomembrane Seams Using the Spark Test.

D6392-08 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

D6636-01 (2006) Standard Test Method for Determination of Ply Adhesion Strength of Reinforced Geomembranes.

D6693-04 (2010) Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.

D6747-04 Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes.

D7002-10 Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System.

D7003-03 Standard Test Method for Strip Tensile Properties of Reinforced Geomembranes.

D7004-03 (2008) Standard Test Method for Grab Tensile Properties of Reinforced Geomembranes.

D7007-09 Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials.

D7240-06 Standard Practice for Leak Location Using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test).

D7466-10 Standard Test Method for Measuring the Asperity Height of Textured Geomembrane.

E96, Test Method for Water Vapor Transmission of Materials

E154, Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover

## **GRI**

GRI GM17, Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density of Polyethylene (LLDPE) Smooth and Textured Geomembranes

GRI GM18, Test Methods, Test Properties and Testing Frequencies for Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes

GRI GM19, Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

GRI GM22, Test Methods, Required Properties and Testing Frequencies for Scrim Reinforced Polyethylene Geomembranes Used in Exposed Temporary Applications

APPENDIX C  
Compliance Memorandum of Understanding





*LINER INSTALLATION QUALITY PROGRAM:*  
**COMPLIANCE MEMORANDUM OF UNDERSTANDING**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Having read and understood the Raven Geomembrane Installation Manual, I confirm that I am in agreement with, and will comply with, all the protocols and requirements of the Manual. Exceptions are noted below:

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

Resolutions to be above exceptions, as follows, are acceptable.

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

APPENDIX D  
Material Inventory and Conformance Test Log



APPENDIX E  
Subgrade Acceptance Record



LINER INSTALLATION QUALITY PROGRAM:  
**SUBGRADE ACCEPTANCE**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Date: \_\_\_\_\_

Area Prepared: \_\_\_\_\_

Location: \_\_\_\_\_

Dimensions: \_\_\_\_\_

Features: \_\_\_\_\_

I have examined the above area of subgrade and deem it acceptable for the deployment of \_\_\_\_\_ (material) geomembrane.

Installer: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

CQA: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

PE: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

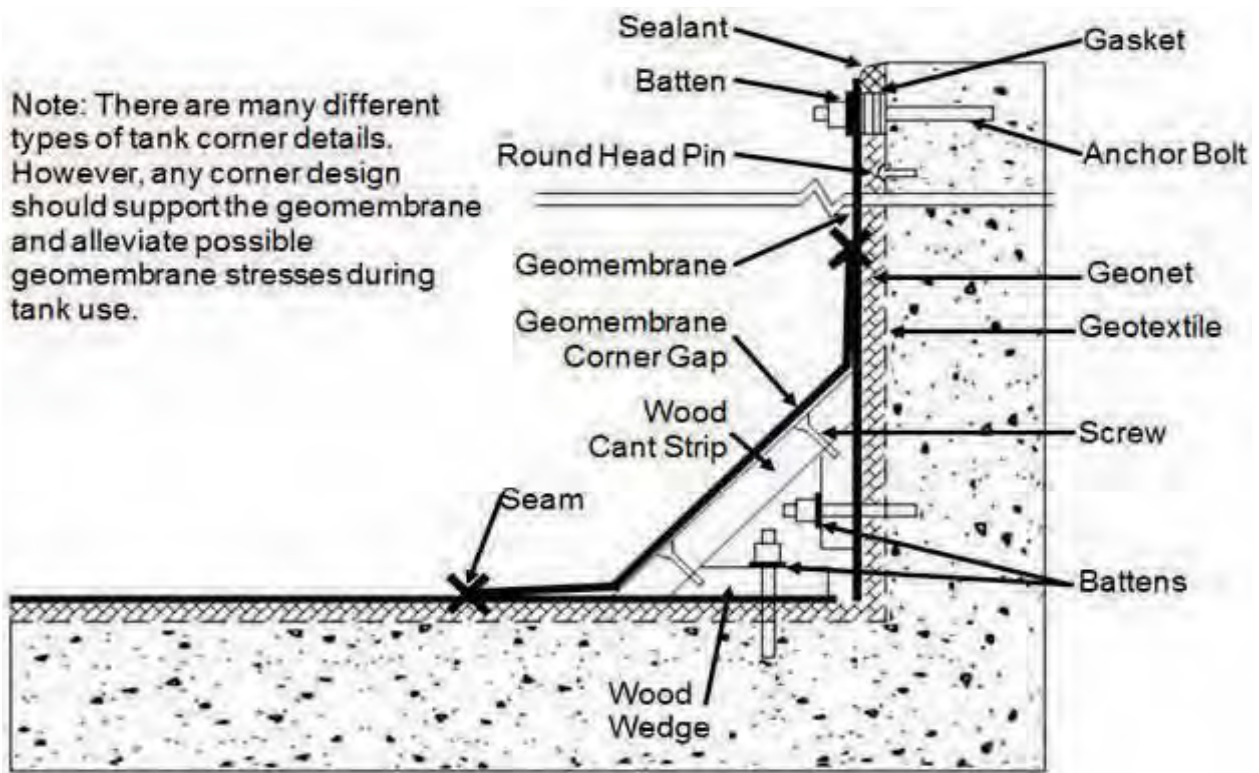
Date: \_\_\_\_\_

Installer's acceptance requires the following actions: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

APPENDIX F  
Proposed Corner Treatment

Note: There are many different types of tank corner details. However, any corner design should support the geomembrane and alleviate possible geomembrane stresses during tank use.





APPENDIX G  
Compensation Determination



LINER INSTALLATION QUALITY PROGRAM:  
**COMPENSATION DETERMINATION**

The amount of compensation required during installation to ensure the liner is not unduly stressed at lower covering and service temperatures is a function of the material’s coefficient of linear thermal expansion (contraction)(CTE), the drop in material temperature (Tinstall – Tcover)( dT), and the distance between any two fixed points (L). Note that it is only the geomembrane temperature that is of any significance. Ambient temperature and the temperature 6 inches above the geomembrane are of no significance at all, except that when it is cloudy and there is no sun on the liner the geomembrane temperature is the same as the ambient temperature. White sheet will probably be ~20°C higher than black sheet in the sun, but the same in the shade.

The amount of compensation required between any two fixed points (e.g. anchor trench, pipe penetration, batten strip fastening) is:

$$CTE \times dT \times L$$

CTE values for the different geomembrane materials between -30°C and +30°C are:

PP unreinforced	6 x 10 <sup>-5</sup> . C-1
LLDPE unreinforced	1.6 x 10 <sup>-4</sup> . C-1
Reinforced	zero

Therefore, a PP liner that is installed at 70°C and that will be covered at 5°C (dT = 65°) will require the following compensation between 2 pipe penetrations 100 ft apart:

$$(6 \times 10^{-5}) \times 65 \times 100 = 0.39 \text{ ft}$$

Reinforced materials need essentially no compensation.

If covering and exposed service temperatures will be higher than installation temperatures no compensation is needed.

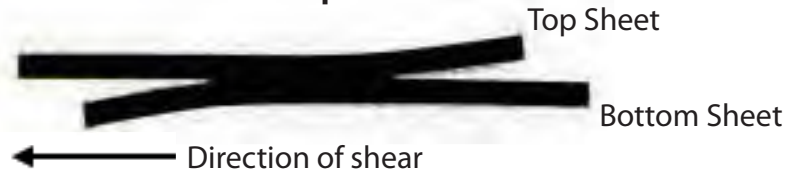
Strictly, the requirements for compensation are the responsibility of the PE for it is he/she that knows the expected service conditions of the liner. However, such requirements are often left to the discretion of the installer. If this is the case, and the installer makes the compensation calculations, it would be prudent to have them approved by the PE.

Project:	_____	Material:	_____
CTE:	_____	Installation Temperature:	_____
Expected Covering Temp.:	_____	Compensation per 100ft:	_____

APPENDIX H  
Locus of Seam Test Breaks

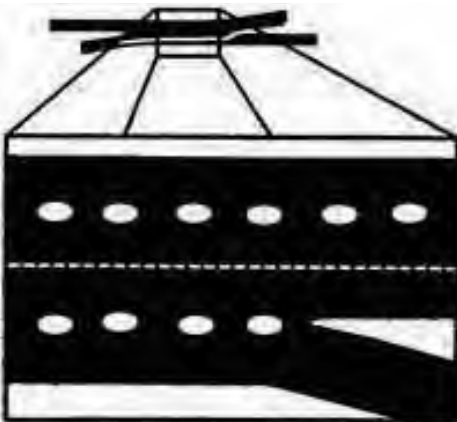
Locus of Seam Test Breaks

**Schematic of Untested Specimen**

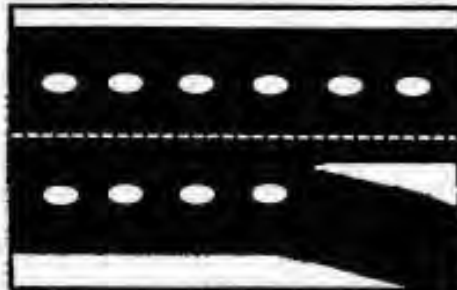


Types of Breaks	Break Code	Description
	AD	Adhesion failure
	BRK	Break in sheeting Break can be in either top or bottom sheet.
	SE1	Break in outer edge of seam Break can be in either top or bottom sheet.
	SE2	Break at inner edge of seam through both sheets.
	AD-BRK	Break in seam after some adhesion failure. Break can be in either top or bottom sheet.

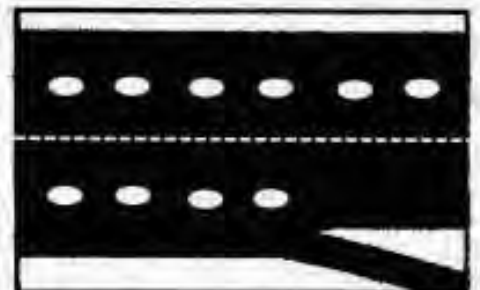
SIP (see below)



**SIPR** Separation in plane of reinforcement. Can occur in either top or bottom sheet.



**SIPR** Separation in plane of coating on inner side of reinforcement. Can occur in either top or bottom sheet.

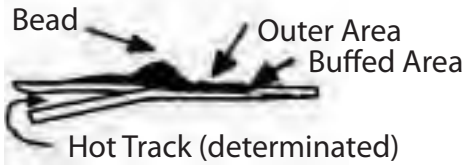


**SIPR** Separation in plane of coating on inner side of reinforcement. Can occur in either top or bottom sheet.

	SIPR-BRK SIPCI-BRK SIPCO-BRK	Break after some separation in plane. See above for types of in-plane separation.
--	------------------------------------	--

**Figure 4:** Break Codes for dual hot wedge and hot air seams of reinforced geomembranes tested for seam strength in shear and peel modes.

**Schematic of  
Untested Specimen**



	Location of Break Code	Description
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.
	AD2	Failure in adhesion.
	AD-WLD	Break through the fillet.
	SE1	Break at seam edge in the bottom sheet (applicable to shear only)
	SE2	Break at the seam edge in the top sheet (applicable to peel only)
	SE3	Break at the seam edge in the bottom sheet (applicable to peel only)
	BRK1	Break in the bottom sheet. A "B" in parentheses following the code means the specimen broke in the buffed area.
	BRK2	Break in the top sheet. A "B" in parentheses following the code means the specimen broke in the buffed area
	AD-BRK	Break in the bottom sheeting after some adhesion failure between the fillet and the bottom sheet.
	HT	Break at the edge of the hot tack for specimens, which could not be delaminated in the hot tack.
	SIPR, SIPIC, SIPOC	Separation in plane of the sheet. See Figure 4.

**Figure 5:** Break Codes for fillet extrusion weld seams in reinforced geomembranes tested for seam strength in peel and shear modes.

APPENDIX I  
Trial Seaming Log

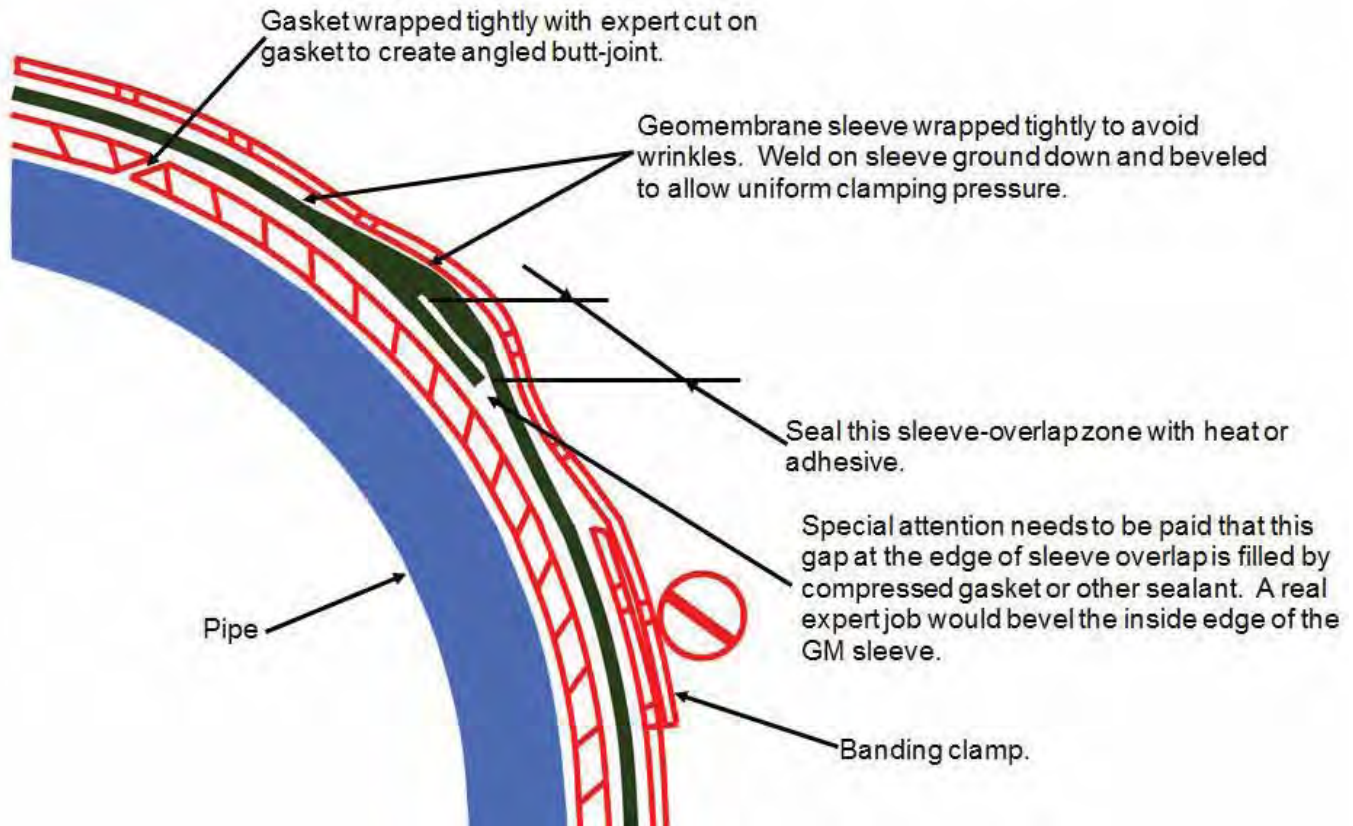




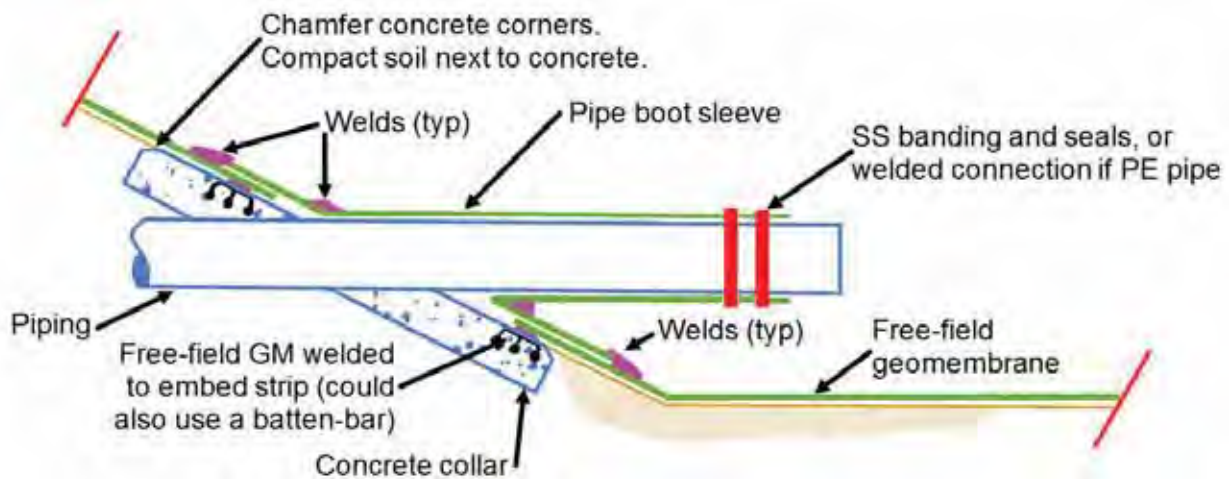
APPENDIX J  
Production Seaming Log



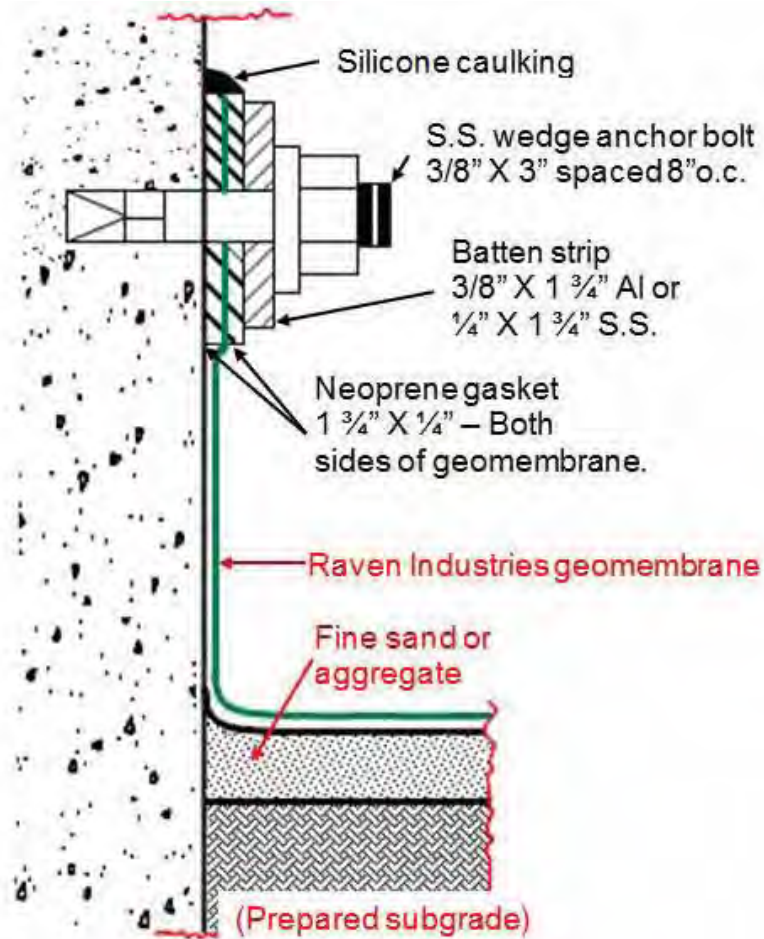
APPENDIX K  
Appurtenances



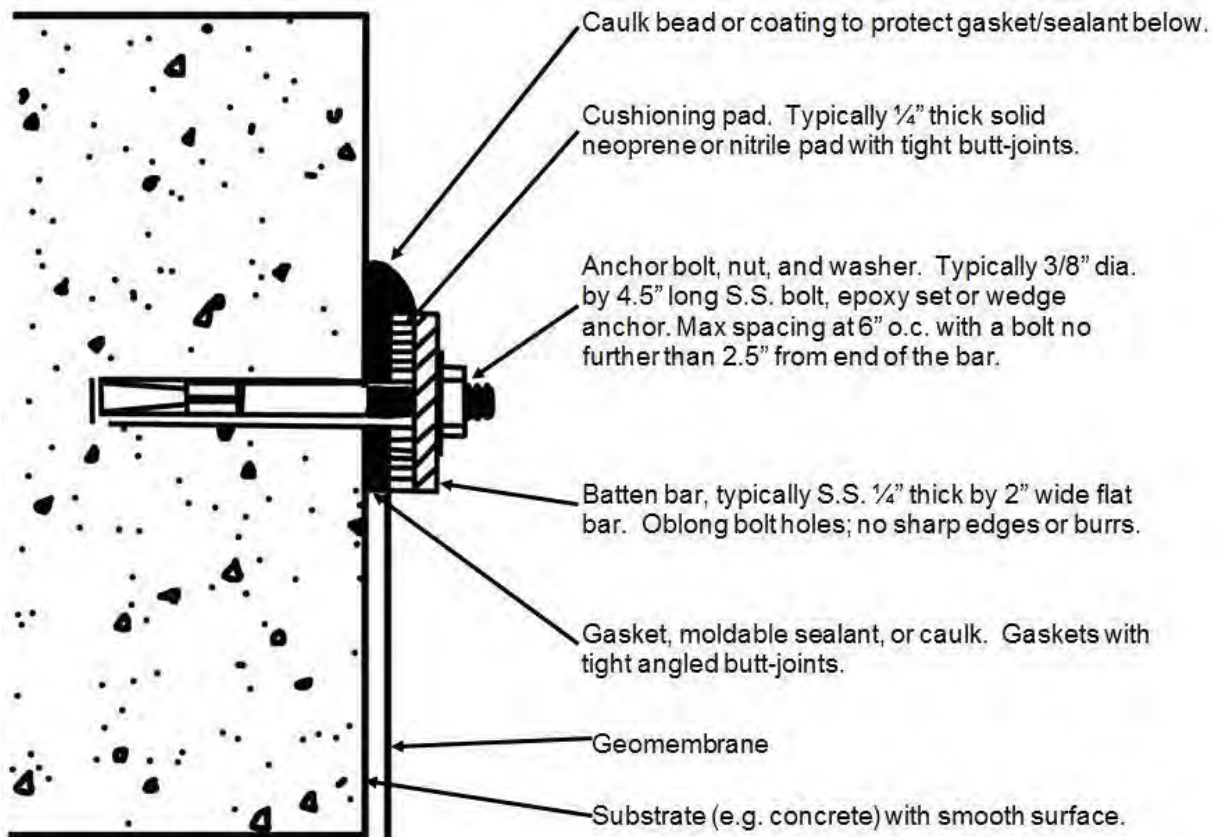
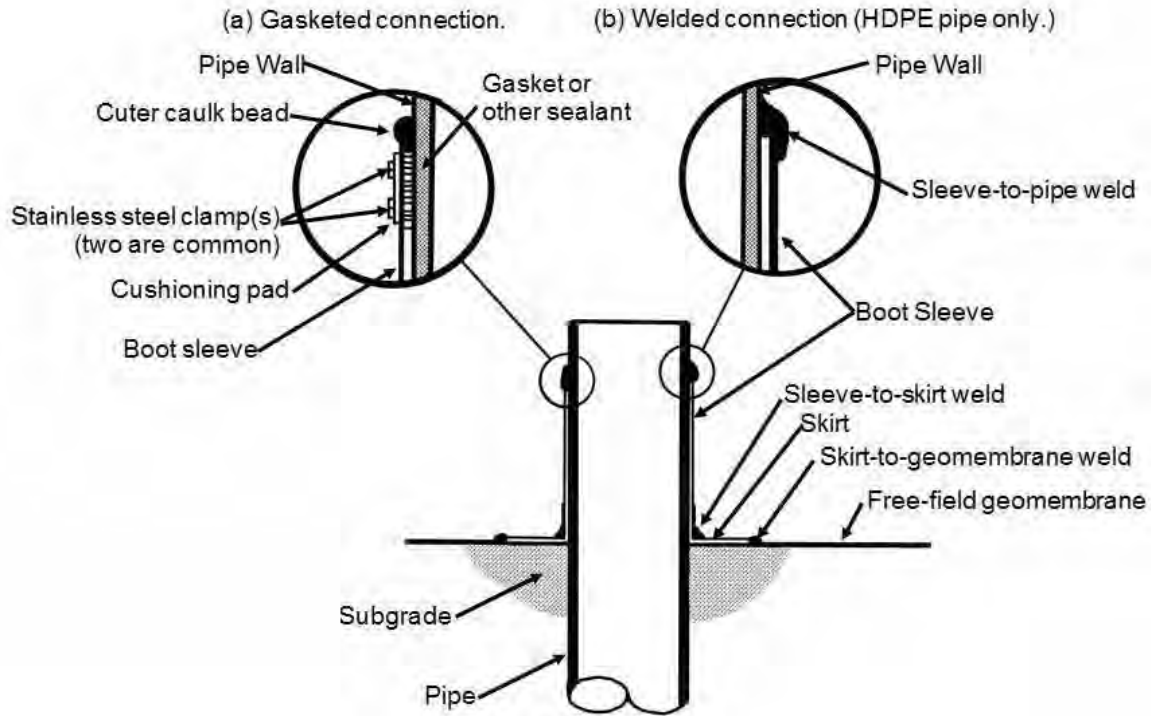
R.Thiel/G. DeJarnett Acknowledgement



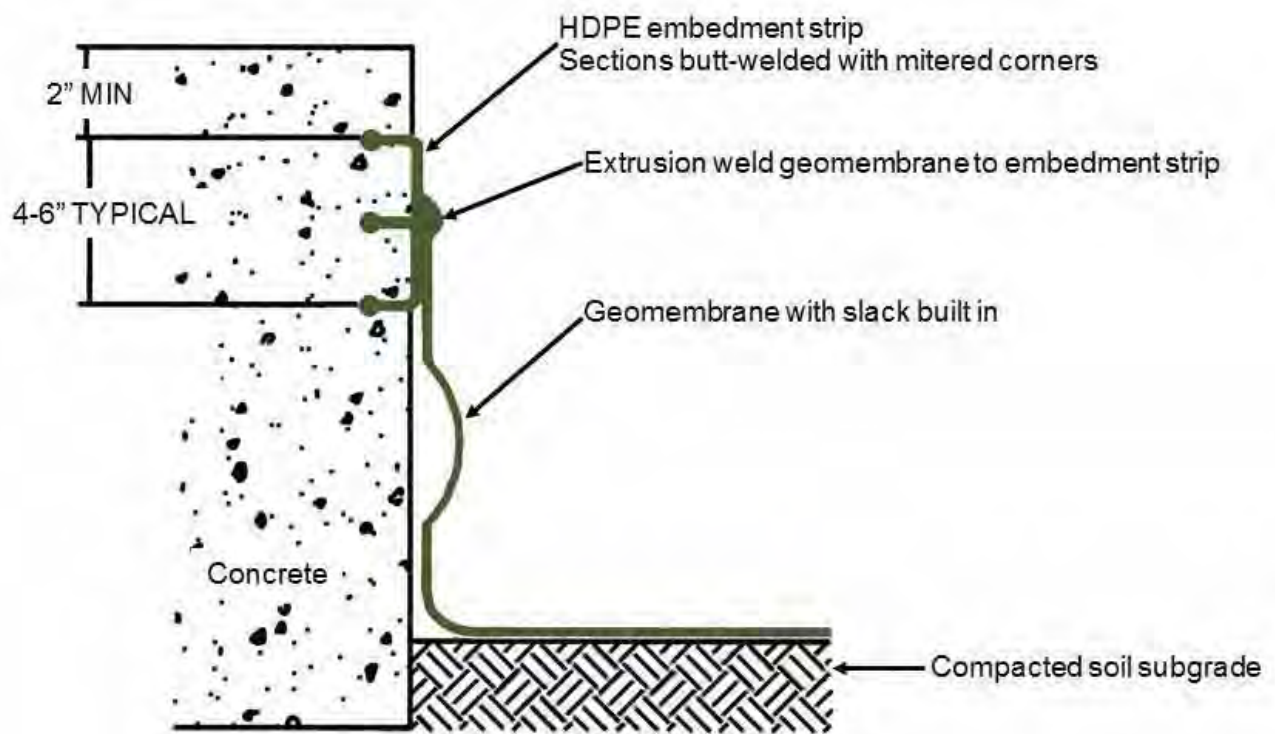
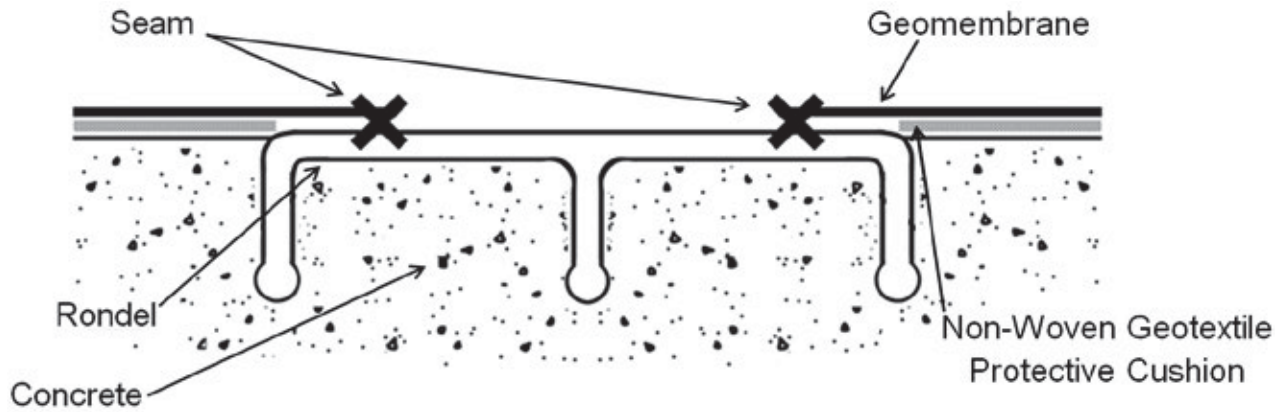
R.Thiel/G. DeJarnett Acknowledgement



**VERTICAL  
CONCRETE  
ATTACHMENT**









APPENDIX L  
Project Certificates, Records, and Logs



*LINER INSTALLATION QUALITY PROGRAM:*  
**COMPLIANCE MEMORANDUM OF UNDERSTANDING**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Having read and understood the Raven Geomembrane Installation Manual I confirm that I am in agreement with, and will comply with, all the protocols and requirements of the Manual. Exceptions are noted below:

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

Resolutions to be above exceptions, as follows, are acceptable.

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			



LINER INSTALLATION QUALITY PROGRAM:  
**CONFORMANCE SAMPLING/TESTING LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_ Material: \_\_\_\_\_

Project: \_\_\_\_\_ Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Item	Test Method	Sample Number	Sample Number	Sample Number	Sample Number	Sample Number	Sample Number
Date							
Roll/Panel Number							
Pre/Post Shipping							
Lab Used							
Date Results Received							
Thickness	D5199						
Density	D1505						
Tensile Scrim Break	D7003						
Tensile Scrim Strain	D7003						
Tensile Polymer Break	D7003						
Tensile Polymer Strain	D7003						
Tear Resistance	D1004						
Tongue Tear	D5884						
Ply Adhesion	D6636						
Puncture Resistance	D4833						
Grab Strength	D7004						
Grab Elongation	D7004						
Sample/Roll Match							
QCR Init.							
Re-Test							
P/F							
QCR Init.							



LINER INSTALLATION QUALITY PROGRAM:  
**SUBGRADE ACCEPTANCE**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Date: \_\_\_\_\_

Area Prepared: \_\_\_\_\_

Location: \_\_\_\_\_

Dimensions: \_\_\_\_\_

Features: \_\_\_\_\_

I have examined the above area of subgrade and deem it acceptable for the deployment of \_\_\_\_\_ (material) geomembrane.

Installer: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

CQA: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

PE: \_\_\_\_\_

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

Installer's acceptance requires the following actions: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_





LINER INSTALLATION QUALITY PROGRAM:  
**DAILY DEPLOYED AREA DETAILS - SCHEMATIC**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Weather: \_\_\_\_\_ a.m. \_\_\_\_\_ p.m. Date: \_\_\_\_\_

Area Installed: \_\_\_\_\_

Location: \_\_\_\_\_

Dimensions: \_\_\_\_\_

Features: \_\_\_\_\_

Diagram:



**TRIAL SEAM LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_  
 Geomembrane: \_\_\_\_\_

Date	Time	Liner Temp	Tech I.D.	Equip I.D.	Temp Set	Speed Set	1			2			3			4			5			P/F	QCR I.D.				
							P	E	L	P	E	L	P	E	L	P	E	L	P	E	L						

P - Peel      E - Elongation      L - Locus

LINER INSTALLATION QUALITY PROGRAM:  
**PRODUCTION SEAMING LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Manufacturer: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Seam No.	Location	SEAMING							CHECKLIST				
		Seaming Direction	Date	Start Time	Liner Temp	Tech I.D.	Equip I.D.	Trail Seam No.	DT	NDT	DT P/F	NDT P/F	QCR Inits



LINER INSTALLATION QUALITY PROGRAM:  
**AIR PRESSURE TESTING LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Seam No.	Location/Segment	Date	Tech I.D.	Start Time	Start Pressure	Stop Time	Stop Pressure	Pressure Change	Pass/Fail	Holes Sealed	Retest Date	QCR I.D.

## LINER INSTALLATION QUALITY PROGRAM: VACUUM BOX TESTING LOG

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Repair No.	Date	Item Tested*	Panel No.	Seam No.	Location/Segment	Tech I.D.	P/F	Date Retested	P/F	CQA I.D.

\*Item Tested:    B - Bead                  P - Patch                  C - Cap                  S - Seam                  RS - Reconstructed Seam                  CS - Capped Seam



LINER INSTALLATION QUALITY PROGRAM:  
**SPARK TEST LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_ Material: \_\_\_\_\_

Project: \_\_\_\_\_ Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Date	Item Tested*	Location	Operator Inits.	Voltage (kV)	AC/DC	Brush Probe	Point Probe	QCR I.D.	P/F	Repair Number	Retest P/F	QCR I.D.

\*P - Repair Patch    B - Boot    C - Corner



LINER INSTALLATION QUALITY PROGRAM:  
**AIR LANCE TEST LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_ Material: \_\_\_\_\_  
 Project: \_\_\_\_\_ Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Seam Number	Date	Length	Operator Inits.	Disbonds	Leaks	P/F	QCR I.D.	Repair Number	Retest	P/F	QCR I.D.



*LINER INSTALLATION QUALITY PROGRAM:*  
**FIELD SEAM PEEL TEST LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_

Material: \_\_\_\_\_ Project: \_\_\_\_\_

Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Sample Number	Test Date	Seam Number	Location	Equip I.D.	1			2			3			4			5			Field P/F	Lab P/F	QCR I.D.
					P	E	L	P	E	L	P	E	L	P	E	L	P	E	L			





LINER INSTALLATION QUALITY PROGRAM:  
**REPAIR LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
Material: \_\_\_\_\_ Installer: \_\_\_\_\_  
Manufacturer: \_\_\_\_\_ I-CORP Project #: \_\_\_\_\_

REPAIR INFORMATION										NONDESTRUCTIVE TESTING					
Repair No.	Date	Tech I.D.	Equip I.D.	Repair Type**	Location	Panel/ Seam	Length (ft)	Width (ft)	Area (ft <sup>2</sup> )	QCR I.D.	Test Date	Tech I.D.	Test Type	P/F	QCR Inits.

\*Repair Type:      B - Bead      P - Patch      C - Cap  
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**LINER INSTALLATION QUALITY PROGRAM:  
GEOELECTRIC INTEGRITY SURVEY**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_ Material: \_\_\_\_\_  
 Project: \_\_\_\_\_ Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Date	Area Surveyed	Method*	Operator Inits.	Applied Voltage	Calibration**	# of Leaks Found	Repairs Done	Retest LIS/VB	P/F	QCR I.D.

\*S - Soil Covered  
 \*\*H6 - Actual Hole 6 mm

W - Water Covered  
 A1 - Artificial 1.3 mm

EL - Water Lance  
 A6 - Artificial 6 mm

EP - Water Puddle



LINER INSTALLATION QUALITY PROGRAM:  
**FINAL VISUAL INSPECTION**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_  
 Geomembrane: \_\_\_\_\_

On \_\_\_\_\_ (date) we visually examined the full surface of the \_\_\_\_\_ (material) liner in the following area: \_\_\_\_\_

We deem it be acceptable with the following exceptions:

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

Repairs and modifications were made by Installer and re-exminded on \_\_\_\_\_ (date) and found to be acceptable.

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			



LINER INSTALLATION QUALITY PROGRAM:  
**PROBLEM/SOLUTION LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
Material: \_\_\_\_\_ Project: \_\_\_\_\_  
Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Date Problem Occurred:
Problem:
Location:
Probable Cause:
Actions:
Proposed Remediation:
Date Solution Implemented:

QCR Initials: \_\_\_\_\_



LINER INSTALLATION QUALITY PROGRAM:

**DAILY SUMMARY REPORT**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
Material: \_\_\_\_\_ Project: \_\_\_\_\_  
Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_  
Weather: \_\_\_\_\_ a.m. \_\_\_\_\_ p.m. Date: \_\_\_\_\_

Summary of Events

Distribution: \_\_\_\_\_ Signature: \_\_\_\_\_  
Name: \_\_\_\_\_



LINER INSTALLATION QUALITY PROGRAM:

**WEEKLY SUMMARY REPORT**

Week Ending: \_\_\_\_\_ Project Number: \_\_\_\_\_

Client: \_\_\_\_\_ Project: \_\_\_\_\_

Material: \_\_\_\_\_ Site Manager: \_\_\_\_\_

Thickness \_\_\_\_\_

Summary of Events

Distribution: \_\_\_\_\_ Signature: \_\_\_\_\_

Name: \_\_\_\_\_

**PERSONNEL LOG**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
Material: \_\_\_\_\_ Project: \_\_\_\_\_  
Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_  
From: \_\_\_\_\_ To: \_\_\_\_\_ Week No: \_\_\_\_\_

Name	Position	Company**	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

\*\*Installer, GC, CQA, PE, Owner



APPENDIX M  
Final Visual Inspection



*LINER INSTALLATION QUALITY PROGRAM:*  
**FINAL VISUAL INSPECTION**

Client: \_\_\_\_\_ Project Number: \_\_\_\_\_  
 Material: \_\_\_\_\_ Project: \_\_\_\_\_  
 Thickness: \_\_\_\_\_ Site Manager: \_\_\_\_\_  
 Geomembrane: \_\_\_\_\_

On \_\_\_\_\_ (date) we visually examined the full surface of the \_\_\_\_\_ (material) liner in the following area: \_\_\_\_\_

We deem it be acceptable with the following exceptions:

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

Repairs and modifications were made by Installer and re-exmined on \_\_\_\_\_ (date) and found to be acceptable.

- 1: \_\_\_\_\_
- 2: \_\_\_\_\_
- 3: \_\_\_\_\_

Title	Signature	Name	Date
Project Engineer			
General Contractor			
CQA Firm			

However, if a potential conflict with the Project Specifications is noted the Installer's QC designate should discuss the matter with the CQA Superintendent and/or the Project Engineer. If, in the opinion of the Installer, a satisfactory conclusion is not reached, as will be recorded in the Problem/Solution log, the Installer will contact Raven for further technical and procedural advice:

Raven Contact: Gary Kolbasuk

Email Address: [geo@ravenind.com](mailto:geo@ravenind.com)

Office Phone: 1-800-635-3456

Date: 6-01-2016

If this date is more than six months ago please contact Raven for possible updated contact details.

*The information contained in this document is to be used as a guide only.*

**RAVEN INDUSTRIES MAKES NO WARRANTIES OR GUARANTEES OF SATISFACTORY RESULTS FROM RELIANCE UPON CONTAINED INFORMATION OR RECOMMENDATIONS AND DISCLAIMS ALL LIABILITY FOR RESULTING LOSS OR DAMAGE.**

*Weather conditions, experience of installation crew, and ground and/or pile surface conditions will affect installation procedures and methods.*



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**APPENDIX C**

Liner Installation Field Description and Photo Log



Subject: **Stericycle Tacoma Liner Installation Report**  
Stericycle Vapor Mitigation System Project  
Tacoma, Washington

## **VAPOR MITIGATION SYSTEM INSTALLATION**

This section describes Amec Foster Wheeler's oversight of the installation of a vapor mitigation system at the Stericycle facility located at 1701 Alexander Avenue East, Tacoma, WA 98421. A photo log is provided in Appendix C1.

Several changes were made to the layout of the system piping (see figure 1). Cells 4-AA and 5-A were not large enough to fit a continuous 5' screen so the screen was installed in two, 2.5' sections in each cell. The screens in cells 1-B, 5-B, 2-C, 6-C, 2-D, and 6-D were installed in a north-south orientation at the center of each cell. The screen in cell 1-A was installed at an angle in order to fit the full 10' screen. All joints were inspected for proper gluing and were satisfactory.

Next, the crew poured a pea gravel controlled density fill material (CDF) around each cell. After allowing the CDF to set, each cell was backfilled with gravel.

Northwest Linings installed 2 layers of 16 ounce geotextile fabric on top of the backfill and CDF within the footprint of the entire building. An extra amount of geofabric was nailed to temporary forms surrounding the perimeter of the building to be placed with a minimum of 6 inches of overlap beneath the future walls of the building. This overlap will be installed at a later date as construction of the exterior walls progresses.

Next, they installed a 40 mil HDPE liner within the footprint of the entire building. The liner was installed as several overlapping pieces welded together to create a single, continuous liner per product specifications. Monitoring points were installed onto the liner to allow for sampling below the liner in each of the cells. The monitoring points in cells 5-A, 1-B, and 2-D were moved and installed on different corners of each cell.

Finally, a single layer of 16 ounce geofabric was placed on top of the liner in order to provide added liner protection during rebar installation. A smoke test conducted by Amec Foster Wheeler staff on October 5, 2016 revealed no liner leaks within the building footprint. Additionally, smoke was detected at all of the monitoring points after opening the seal which indicates complete vapor mitigation throughout the building.

## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 1 Overview of project site and initial pipe layout



Photograph 2 Overview of project site and manifold



## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 3 Pipe layout



Photograph 4 Pipe layout



## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 5 Pipe crossing at future grade beam location



Photograph 6 Piping layout

## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 7 Project overview after CDF cells have been poured



Photograph 8 Final pipe layout in Cell 3-E



## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 9 Final pipe layout in Cell 5-A



Photograph 10 Final pipe layout in Cell 4-AA

## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 11 Gravel backfill



Photograph 12 Gravel backfill and bottom layer of geofabric



## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 13 Bottom layer of geofabric



Photograph 14 Liner welds

## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 15 Liner boot welds



Photograph 16 Liner installation on East wall



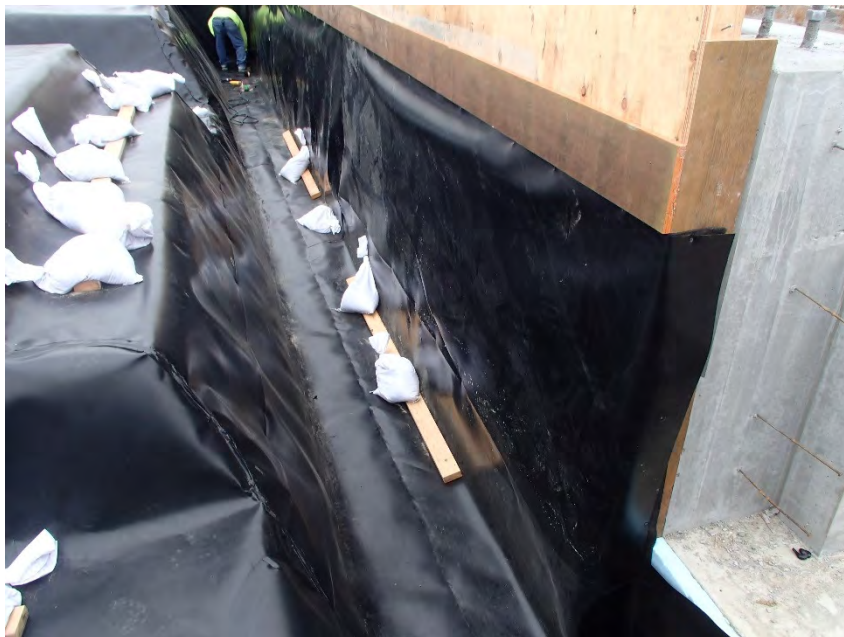
## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 17 Site overview of liner installation



Photograph 18 Liner installation on North wall

## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 19 Top layer of geofabric



Photograph 20 Monitoring point



## APPENDIX C

### PHOTO LOG

#### Stericycle Vapor Mitigation System Tacoma, Washington



Photograph 21 Manifold top geofabric layer



Photograph 22 Smoke testing liner



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**APPENDIX D**

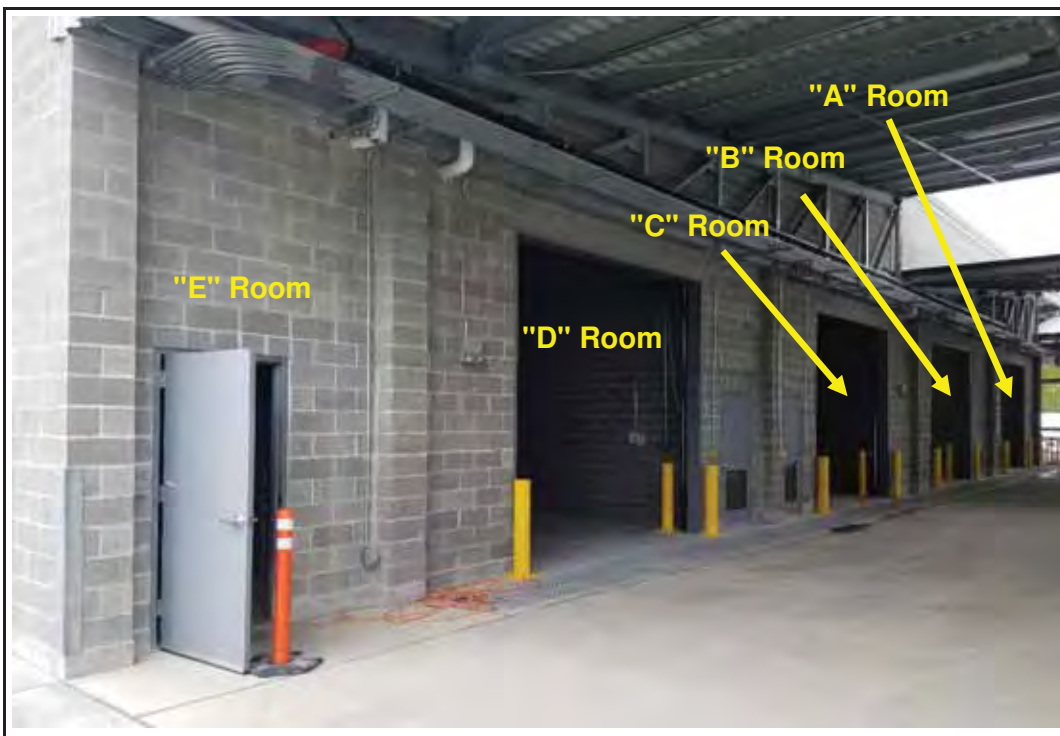
System Commissioning Photo Log

# Photograph Log

Site Name:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	1 of 11



**Photo 1:** View of the eastern side of the new receiving building.



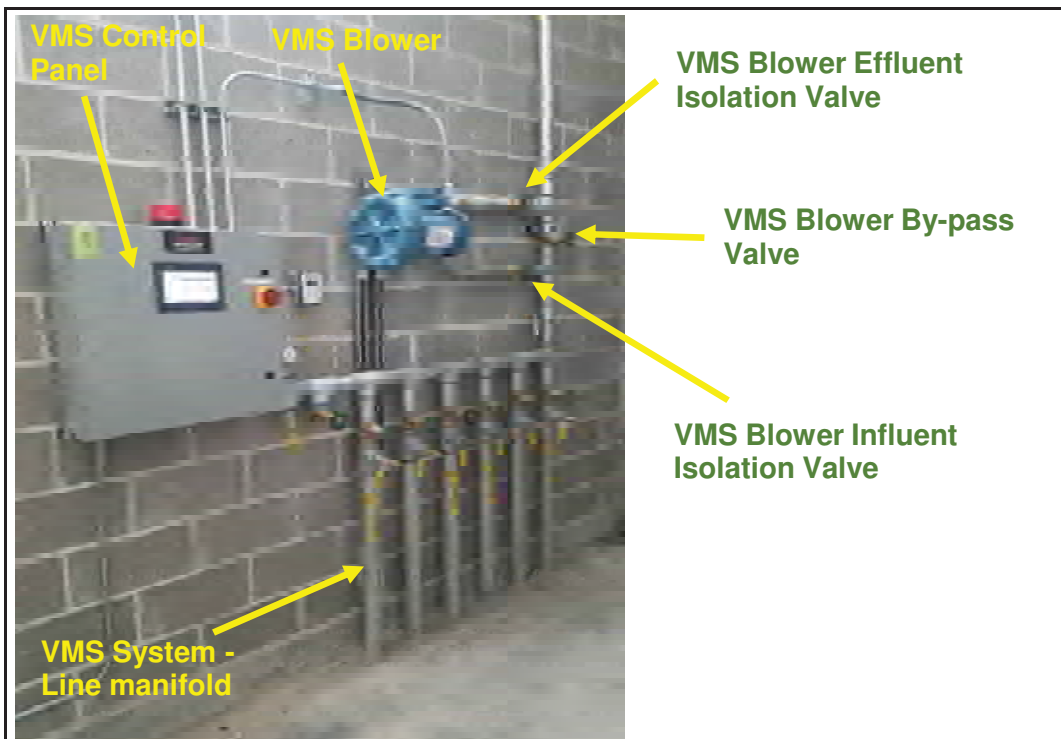
**Photo 2:** View of the eastern side of the enclosed rooms in the receiving building. Notes the door in the foreground goes to the mechanical room with the VMS equipment.

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	2 of 11



**Photo 3:** View of the south side of the receiving building showing the vent stack in the center of the picture at the roof line. Mechanical room is on south side of building.



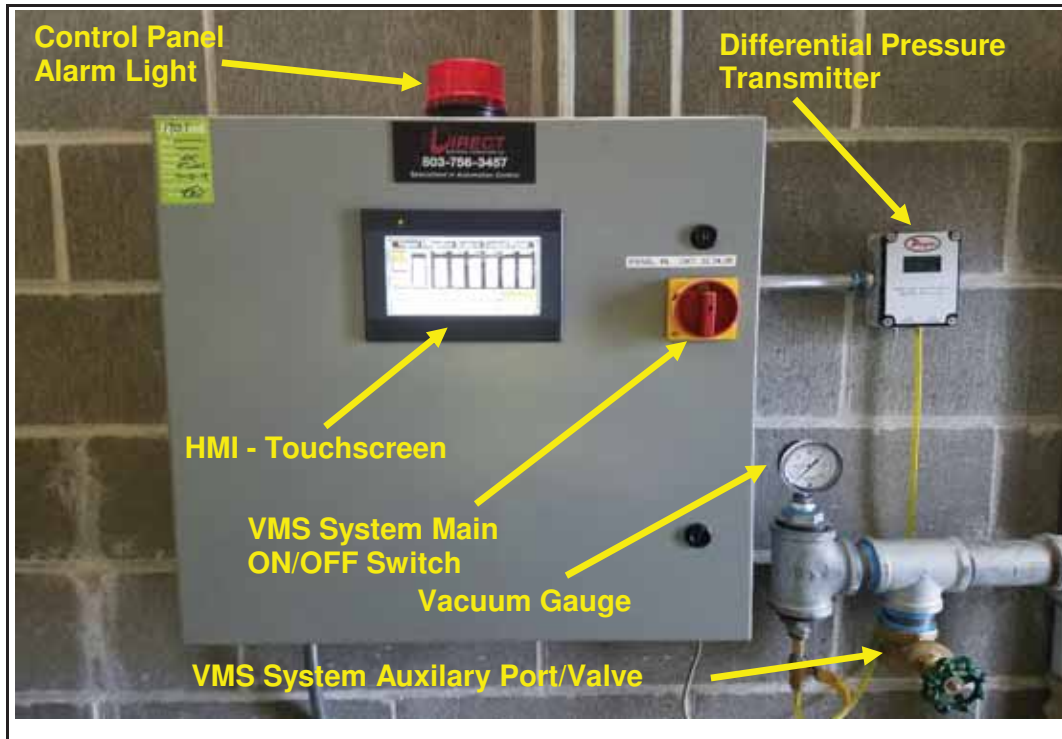
**Photo 4:** View of the VMS equipment - control panel, blower (blue), piping manifold and sampling ports/valves, pressure transmitter, and vacuum gauge. This is "E" room on plans



# Photograph Log

Well ID: Stericycle - Tacoma  
Site Address: 1701 Alexander Drive  
Tacoma, Washington

Date: 5-May-2017  
Time: 10:00 to 14:00  
Page: 3 of 11



**Photo 5:** View of VMS Control Panel, alarm light (red on top of control panel), pressure transmitter (right of control panel) and vacuum gauge. On/Off switch is red/yellow.



**Photo 6:** View of room "D" (from plans) looking to the west. Note the methane sensor and associated alarm light on the north wall (right side).

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	4 of 11



**Photo 7:** View of room "C" (from plans) looking to the west. Note the methane sensor and associated alarm light on the north wall (right side).



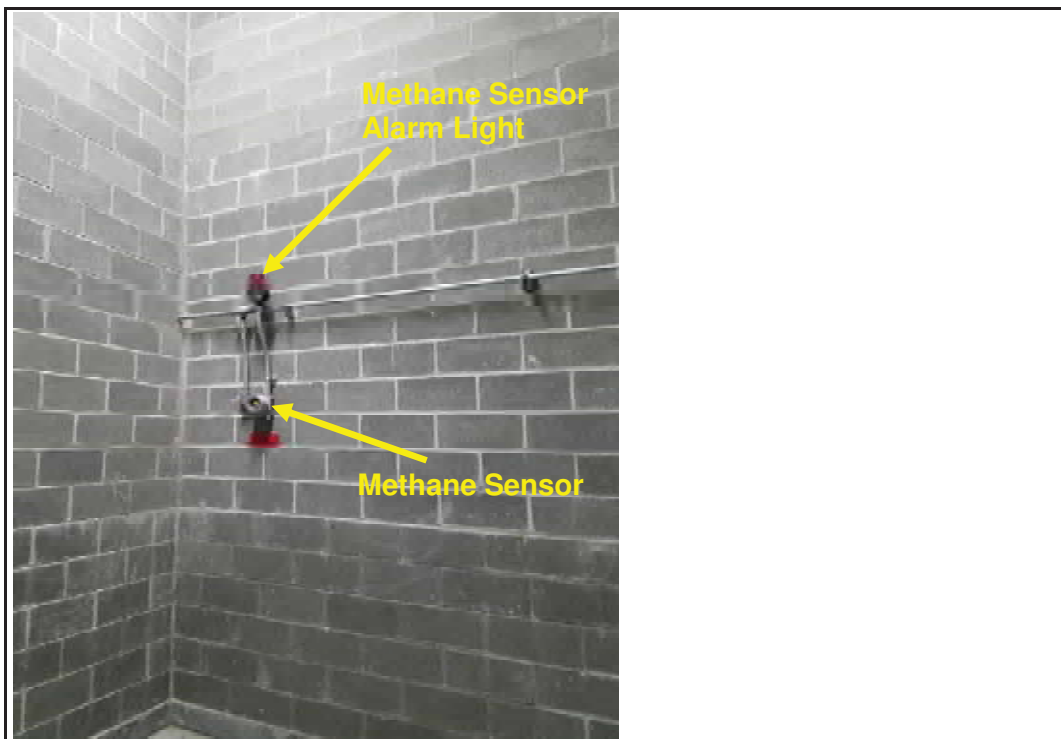
**Photo 8:** View of room "B" (from plans) looking to the west. Note the methane sensor and associated alarm light on the north wall (right side).

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	5 of 11



**Photo 9:** View of room "A" (from plans) looking to the west. Note the methane sensor and associated alarm light on the south wall (left side). Note A-sub room in corner.



**Photo 10:** View of room "A-sub" (from plans) looking to the south. Note the methane sensor and associated alarm light on the south wall (left center of picture).



# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	6 of 11



**Photo 11:** View of a methane sensor (left side) reading in percent (%) lower explosive limit (LEL). View of methane sensor alarm light (right side).



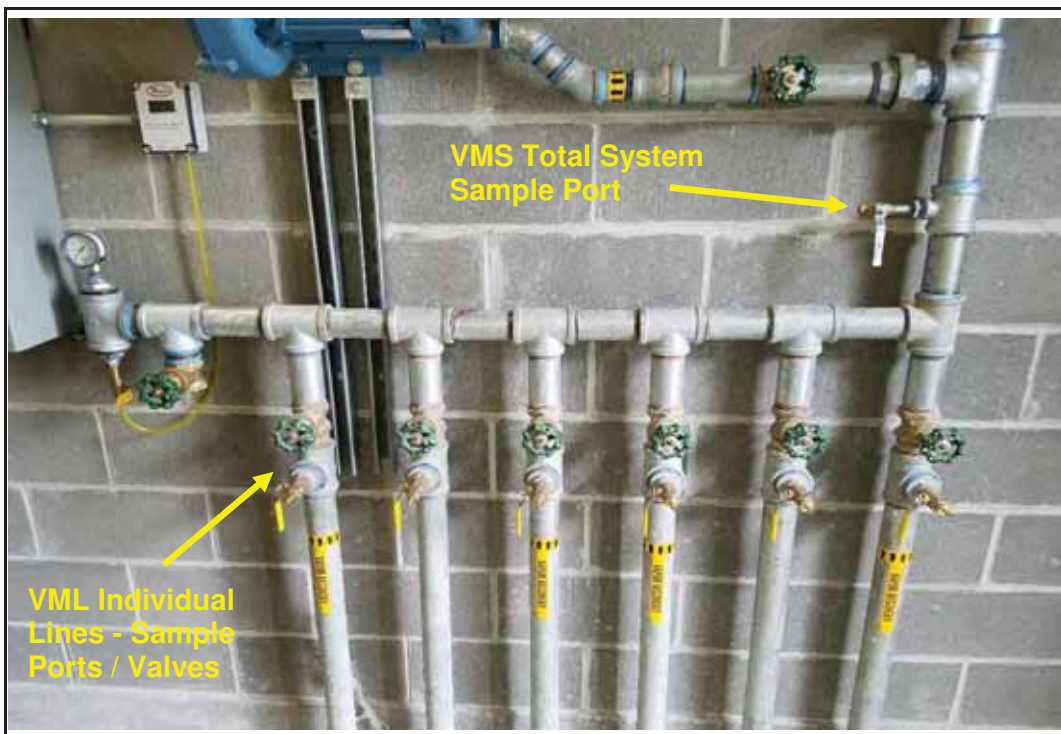
**Photo 12:** View of Dwyer differential pressure transmitter and screen. Transmitter reads in inches water column vacuum.

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	7 of 11



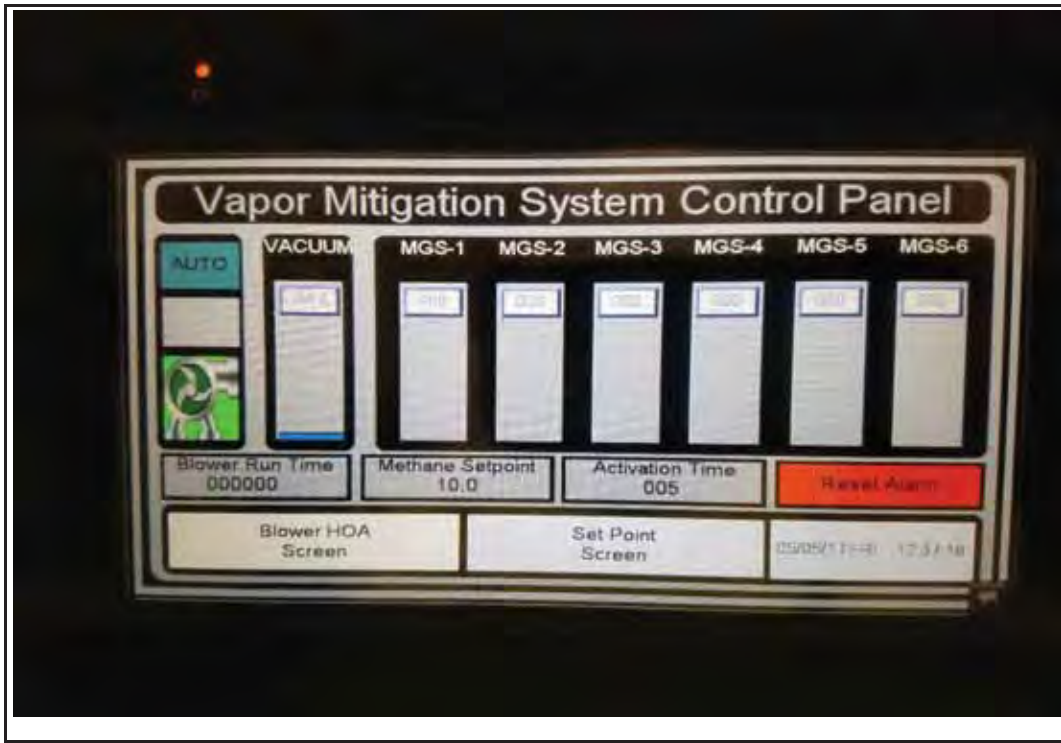
**Photo 13:** View of the Ametek Rotron EN404AR72ML regenerative blower that induces the vacuum and air flow from the sub-slab recover pipes.



**Photo 14:** View of the VMS piping manifold (VML-1 to VML-6 from right to left). Note the sampling ports for each line and total system sampling port (upper right).

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	8 of 11



**Photo 15:** View of the VMC Control Panel - Main Screen. Note the virtual buttons to navigate to the Blower HOA (lower left) and Set Point (lower center) screens.

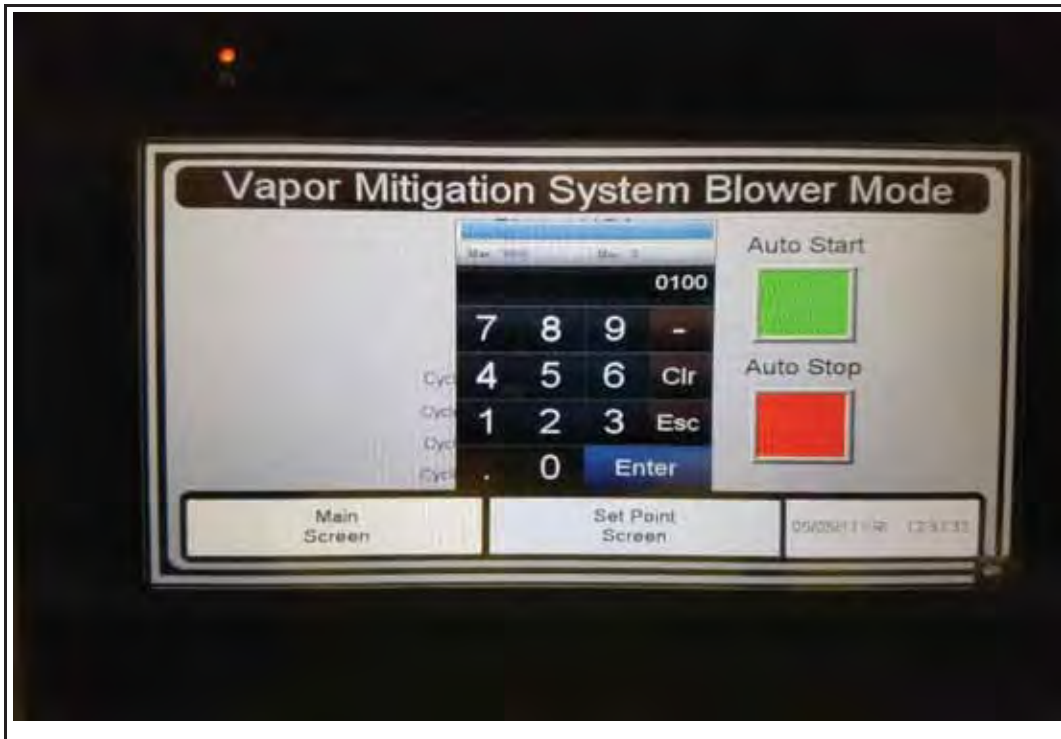


**Photo 16:** View of the VMS Control Panel - Blower HOA (Mode) Screen. Note the virtual HOA switch (center) and ON/OFF cycle buttons (below switch) and Auto Stop/Start buttons.



# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	9 of 11



**Photo 17:** View of the VMS Control Panel - Blower HOA (Mode) screen with numeric touchpad activated to program in duration of an ON or OFF cycle and "Enter" button.



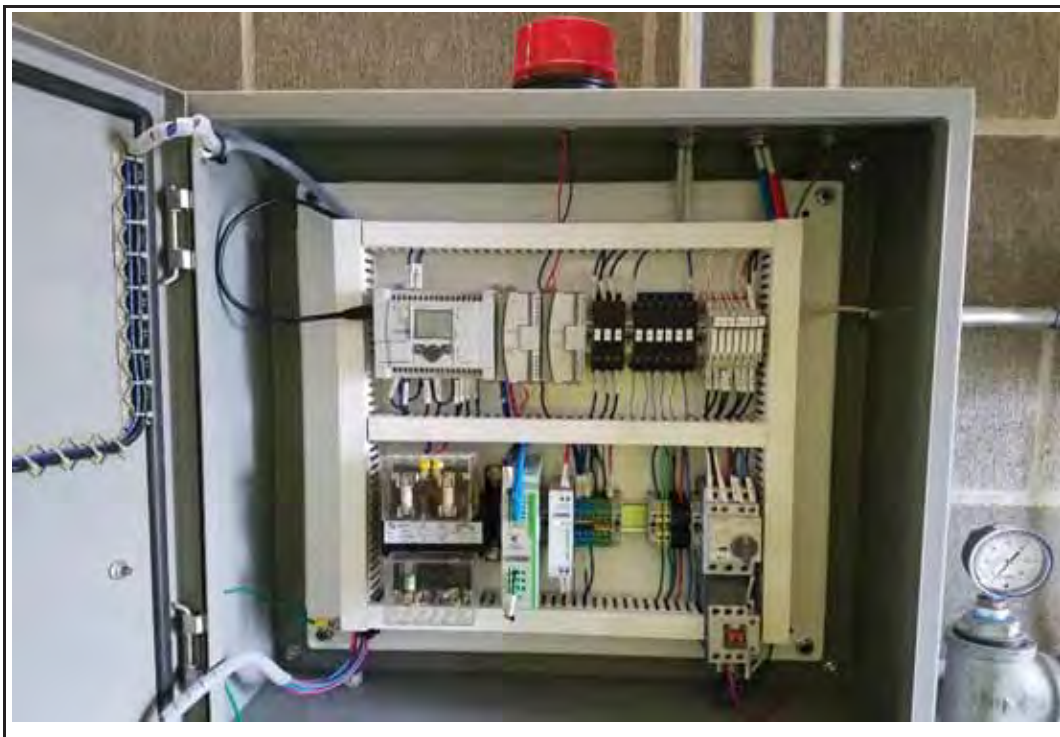
**Photo 18:** View of the VMS Control Panel - System Setpoints screen. Note the blue control set point buttons, red counter reset buttons, and date/time buttons.

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	10 of 11



**Photo 19:** View of the VMS Control Panel - System Setpoints screen with the numeric touchpad active to help program in set point values or date/time values.



**Photo 20:** View of the interior of the VMS Control Panel. Note the motor starter (lower right), PLC unit (upper left), fuse bank (upper right), and red alarm light (on top of control panel).

# Photograph Log

Well ID:	Stericycle - Tacoma	Date:	5-May-2017
Site Address:	1701 Alexander Drive Tacoma, Washington	Time:	10:00 to 14:00
		Page:	11 of 11



**Photo 21:** View of the VMS Control Panel Allen Bradley PLC unit (located in upper left of the control panel interior).



**Photo 22:** View of the back of the human-machine interface (touchscreen) on the back of the door panel inside the VMS Control Panel.



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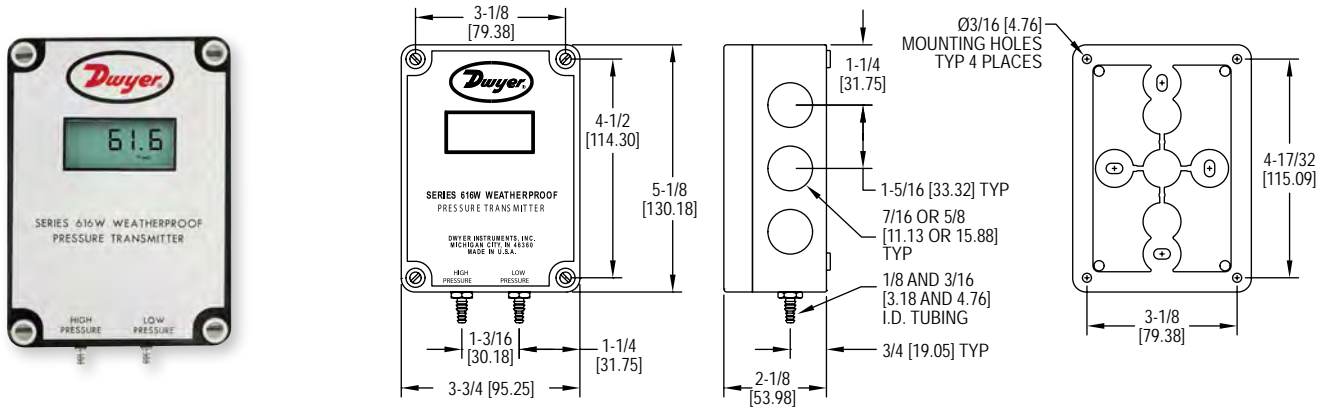
**APPENDIX E**

Vapor Mitigation System – Pressure Transmitter Documents



# Series 616W Differential Pressure Transmitter

## Specifications - Installation and Operating Instructions



The **SERIES 616W** Differential Pressure Transmitter senses the pressure of air and non-combustible, compatible gases and sends a standard 4 to 20 mA or selectable 0 to 5/0 to 10 VDC output signal. All models, including those featuring an LCD, are factory calibrated to specific ranges. Positive, negative, and differential pressures can be measured within a full scale accuracy of  $\pm 0.25\%$ . This weatherproof unit is enclosed in a polycarbonate case, rated IP66/NEMA 4X. The span and zero controls are for use when checking calibration, and are not intended for re-ranging.

### SPECIFICATIONS

**Service:** Air and non-combustible, compatible gases.  
**Wetted Materials:** Consult factory.  
**Accuracy:** 0.25% FS @ 77°F (25°C), display accuracy  $\pm 0.5\%$ .  
**Thermal Effect:**  $\pm 0.02\%$  FS/°F ( $\pm 0.036\%$  FS/°C).  
**Stability:**  $\pm 1\%$  FS/yr.  
**Temperature Limits:** 14 to 185°F (-10 to 85°C).  
**Pressure Limits:** See chart.  
**Power Requirements:** 10 to 35 VDC (2-wire), 17 to 36 VDC, or isolated 21.6 to 33 VAC (3-wire).  
**Output Signal:** 4 to 20 mA (2-wire), 0 to 5 VDC, or 0 to 10 VDC (3-wire)  
**Zero and Span Adjustments:** Push buttons.  
**Loop Resistance:** Current Output: 0 to 1250  $\Omega$  (max); Voltage Output: Load resistance 1 k $\Omega$  (min).  
**Current Consumption:** 40 mA max.  
**Electrical Connections:** 3-wire removable European style terminal block for 16 to 26 AWG.  
**Process Connections:** Barbed, dual size to fit 1/8" and 3/16" (3.12 and 4.76 mm) I.D. rubber or vinyl tubing.  
**Enclosure Rating:** NEMA 4X (IP66).  
**Mounting Orientation:** Any orientation.  
**Weight:** Without LCD: 8.8 oz (249 g); With LCD: 9.6 oz (272 g).  
**Agency Approvals:** CE.

Series 616W Transmitter Models & Ranges

MODEL CHART			
Model	Range	Max. Pressure	Digital Display
616W-2	0 to 6 in w.c.	10 psig	—
616W-3	0 to 10 in w.c.	10 psig	—
616W-4	0 to 20 in w.c.	20 psig	—
616W-5	0 to 40 in w.c.	20 psig	—
616W-6	0 to 100 in w.c.	15 psig	—
616W-7	0 to 200 in w.c.	45 psig	—
616W-2-LCD	0 to 6 in w.c.	10 psig	0 to 6.00
616W-3-LCD	0 to 10 in w.c.	10 psig	0 to 10.00
616W-4-LCD	0 to 20 in w.c.	20 psig	0 to 20.0
616W-5-LCD	0 to 40 in w.c.	20 psig	0 to 40.0
616W-6-LCD	0 to 100 in w.c.	15 psig	0 to 100.0
616W-7-LCD	0 to 200 in w.c.	45 psig	0 to 200.0
616W-6B-LCD	3-0-3 in w.c.	10 psig	-3.00-0-3.00
616W-10B-LCD	5-0-5 in w.c.	10 psig	-5.00-0-5.00
616W-20B-LCD	10-0-10 in w.c.	10 psig	-10.00-0-10.00
616W-2M-LCD	0 to 1.5 kPa	68.9 kPa	0 to 1.50
616W-3M-LCD	0 to 2.5 kPa	68.9 kPa	0 to 2.50
616W-4M-LCD	0 to 5 kPa	137.8 kPa	0 to 5.00
616W-5M-LCD	0 to 10 kPa	137.8 kPa	0 to 10.0

Table 1



**INSTALLATION**

**1. Location:** Select a clean, dry mounting location free from excess vibration where the temperature will remain between 14 to 185°F (-10 to 85°C). Distance from the receiver is limited only by total loop resistance. See Electrical Connections below. The tubing supplying pressure to the instrument can be practically any length required, but long lengths will increase response time slightly.

**2. Position:** A vertical position, with the pressure connection pointing down, is recommended. That is the position in which all standard models are spanned and zeroed at the factory. They can be used at other angles, but final spanning and zeroing must be done while the transmitter is in that alternate position.

**3. Pressure Connections:** Two integral barbed tubing connections are provided. They are dual-sized to fit both 1/8" and 3/16" (3.12 and 4.76 mm) I.D. tubing. Be sure the pressure rating of the tubing exceeds that of the operating range. On ranges over 20 psi, we recommend use of a suitable hose clamp to assure the integrity of the connection.

**ELECTRICAL CONNECTIONS**

**CAUTION** Do not exceed specified supply voltage ratings. Permanent damage not covered by warranty will result. This unit is not designed for 120 or 240 VAC line operation.

Electrical connections are made to the terminal block located on the inside of the transmitter. Determine which of the following circuit drawings best applies to your application and wire accordingly.

**Electrical Connection**

The Series 616W simultaneously transmits a 2-wire 4 to 20 mA current output and a 3-wire 0 to 5 V / 0 to 10 V voltage output via a removable European-style three conductor terminal block. The transmitter can be wired in one of the following three ways to utilize the current and/or voltage output.

**Power Supply**

Refer to Table 2 for the required supply rating.

MODEL CHART	
Output Type	Power Supply Rating
2-wire current	10 to 35 VDC (40 mA min)
3-wire current	17 to 36 VDC or 21.6 to 33 VAC (40 mA min)
Simultaneous current and voltage	17 to 35 VDC (40 mA min)

**Table 2**

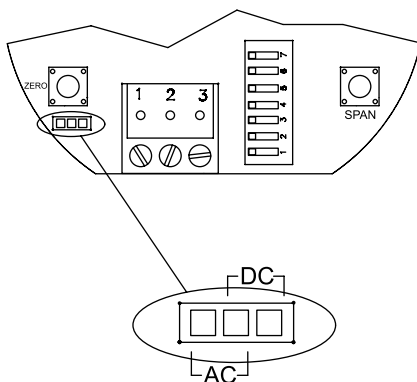
Choose a power supply with a voltage and current rating sufficient to meet the power specifications under all operating conditions. If the supply is unregulated, make sure that the output voltage remains within the required voltage range under all power line conditions. Ripple on the supply should not exceed 100 mV.

**AC/DC Jumper Selection**

**NOTICE** The jumper is factory set to AC. If DC power is applied while the jumper is set to AC, no damage will occur. However, the accuracy of the unit may be temporarily affected.

**CAUTION** Powering the unit with AC power while the jumper is set to DC may permanently damage the transmitter.

Refer to Figure 1 for the location of the AC/DC jumper. Place the shorting jumper across either the two pins marked AC or the two pins marked DC.

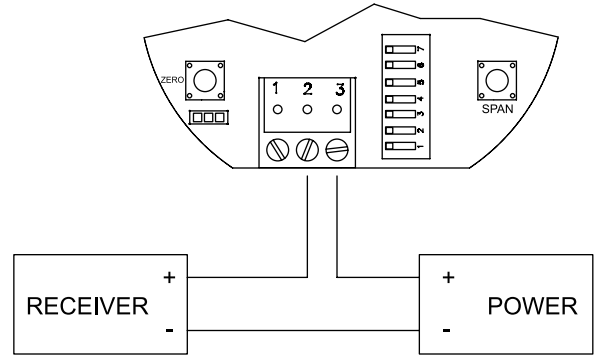


**Figure 1: AC/DC Jumper**

**2-Wire 4 to 20 mA Current Operation**

**CAUTION** Do not exceed specified supply voltage ratings. Permanent damage not covered by warranty will result. Simultaneous outputs are not designed for AC voltage operation.

The connections to the transmitter are made through terminals 2 and 3 on the terminal block as shown in Figure 2. The terminal block is removable and each of the terminals are labeled underneath the terminal block on the circuit board. Polarity is indicated by terminals 2 (+IOUT) and 3 (-IOUT). The AC/DC selection jumper should be set for DC operation.



**Figure 2: Current Output Wiring**

The range of appropriate receiver load resistances (RL) for power supply voltage available is given by the formula listed below. Shielded 2-wire cable is recommended for control loop wiring. Ground the shield at the power supply end.

**NOTICE** The receiver may be connected to either the negative or positive side of the loop, whichever is most convenient. Should the polarity of the transmitter or receiver be inadvertently reversed, the loop will not function properly, but no damage will be done to the transmitter.

$$R_L = \frac{V_{PS} - 10.0}{20 \text{ mA DC}}$$

The maximum length of connecting wire between the transmitter and the receiver is a function of wire size and receiver resistance. That portion of the total current loop resistance represented by the resistance of the connecting wires themselves should not exceed 10% of the receiver resistance. For extremely long runs (over 1,000 ft/305 m), it is desirable to select receivers with lower resistances in order to keep the size and cost of the connecting leads as low as possible. In installations where the connecting run is no more than 100 ft (30.5 m), connecting lead wire as small as No. 22 ga. can be used.



### 3-Wire 0 to 10 V and 0 to 5 V Voltage Operation

**CAUTION** Do not exceed specified supply voltage ratings. Permanent damage not covered by warranty will result.

The connections to the transmitter are made to Terminals 1, 2, and 3 on the terminal block as shown in Figure 3. The terminal block is removable and each of the terminals are labeled underneath the terminal block on the circuit board. Polarity is indicated by 1, 2, and 3. When connecting using a DC power source, make sure the AC/DC selection jumper is set for DC. If the polarity of the transmitter is inadvertently reversed, the unit will not function properly, but no damage will be done to the transmitter. When connecting to an AC power source, make sure the AC/DC selection jumper is set for AC. Either lead of the supply power may be connected to terminals 1 and 2 without affecting the operation of the transmitter or causing damage to the transmitter.

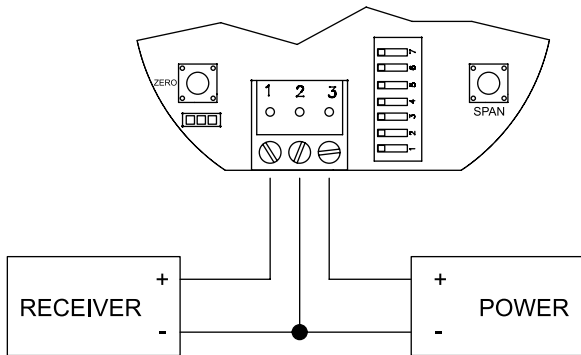


Figure 3: Voltage Output Wiring

The minimum receiver load is 1 kΩ. The resistance due to the wire should be low compared to the receiver load resistance. While the voltage at the terminal block remains unchanged with a 10 mA current flow, resistive losses in the wiring do cause errors in the voltage delivered to the receiver. For a 1% accuracy gauge, the resistance of the wires should be less than 0.1% of the value of the receiver load resistance. This will keep the error caused by the current flow below 0.1%.

### Simultaneous Current and Voltage Operation

**CAUTION** Do not exceed specified supply voltage ratings. Permanent damage not covered by warranty will result. Simultaneous outputs are not designed for AC voltage operation.

The connections to the transmitter are made to Terminals 1, 2, and 3 on the terminal block as shown in Figure 4. The terminal block is removable and each of the terminals are labeled underneath the terminal block on the circuit board. Polarity is indicated by terminals 1, 2, and 3. The AC/DC selection jumper should be set for DC operation. The voltage output and the power supply must have separate wire leads that are only joined at terminal 2 of the transmitter. Additional error may occur for the voltage output if a single wire is used or if the wires are joined at the power supply or receiver.

NOTE- POWER AND VOLTAGE RECEIVER "-" MUST BE SEPERATE WIRES AND BOTH WIRED TO

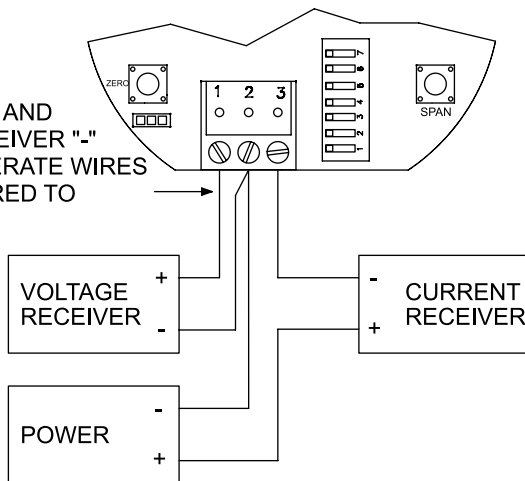


Figure 4: Simultaneous Current and Voltage Output Wiring

For the current output, the maximum allowable loop resistance (wiring + receiver resistance) is dependent on the power supply. The maximum loop voltage drop must not reduce the transmitter voltage below 17 V. The maximum loop resistance can be calculated using the following equation:

$$R_{MAX} = \frac{V_{PS} - 17.0}{20 \text{ mA DC}}$$

(where  $V_{PS}$  is the power supply voltage)

The equation uses 17.0 instead of 10.0 used in the current only equation. This represents the minimum voltage supply which is higher on the simultaneous output configuration due to the requirements of the voltage outputs.

Shielded 4-wire cable is recommended for control loop wiring. Ground the shield at the power supply end only. Should the polarity of the transmitter or receiver be inadvertently reversed, the unit will not function properly, but no damage will be done to the transmitter.

For voltage outputs, the minimum receiver load is 1 kΩ. The resistance due to the wire should be low compared to the receiver load resistance. While the voltage at the terminal block remains unchanged with a 10 mA current flow, resistive losses in the wiring do cause errors in the voltage delivered to the receiver. For a 1% accuracy gauge, the resistance of the wires should be less than 0.1% of the value of the receiver load resistance. This will keep the error caused by the current flow below 0.1%.

### CALIBRATION

**NOTICE** There is a 5 second delay from the time the zero or span calibration button is released until the time that the change in the calibration takes place. This delay is used to prevent stress related offsets on the lower range.

#### Zero Calibration

The zero calibration can be set by applying zero pressure to both the pressure ports and pressing the zero button for 3 seconds. If either the remote or local LCD is present, the display will read ZERo and then sequence back to the home display.

#### Span Calibration

The span calibration can be adjusted only after setting the zero adjustment. It must be completed within 5 minutes of the last zero calibration. The span calibration button will be ignored until the zero calibration is completed. Apply pressure to the ports of the transmitter that are associated with the maximum output of the transmitter (20 mA, 5 V, or 10 V, depending on the output being used). Press and hold the span button for 3 seconds. If either the remote or local LCD are present, the display will read SPAN and then sequence back to the home display. If the span calibration is attempted before adjusting the zero calibration, the FAiL error message will flash on the display. On bi-directional models, separate spans can be performed on the positive and negative sides of the range.

### ZERO DEADBAND

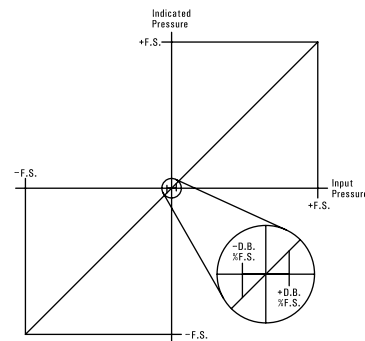


Figure 5

### MAINTENANCE/REPAIR

Upon final installation of the Series 616W Differential Pressure Transmitter, no routine maintenance is required. The Series 616W is not field serviceable and is not possible to repair the unit. Field repair should not be attempted and may void warranty.

### WARRANTY/RETURN

Refer to "Terms and Conditions of Sale" in our catalog and on our website. Contact customer service to receive a Return Goods Authorization number before shipping the product back for repair. Be sure to include a brief description of the problem plus any additional application notes.



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## **APPENDIX F**

Vapor Mitigation System – Blower Documents

PROJECT NAME		Stericycle - Tacoma Site Vapor Mitigation System		PROJECT NO.	
SUBJECT		Air Recovery Rate / Blower Sizing Calculations		PAGE 1 OF	
CALCULATED BY		PDS		DATE 7/15/16	
DATE		7/11/2016		CHECKED BY DS	
DESCRIPTION					
Assume: - Subgrade thickness (d) = 9 inches (0.75-foot)					
- Subgrade porosity (p) = 0.4 (greater than effective porosity)					
- Vent 20 pore spaces / day					
DESIGN					
Determine: 1) Calculate pore space under enclosed area in subgrade					
		Total Volume = L x H x D $Vol_{Tot} = (106\text{-ft})(43\text{-ft})(0.75\text{-ft})$ $Vol_{Tot} = \underline{\underline{3,418.5\text{ ft}^3}}$			
2) Calculate Pore Space: $Vol_{ps} = (p)(V_{Tot}) = (0.4)(3,418.5\text{ ft}^3) = \underline{\underline{1,367.4\text{ ft}^3}}$					
3) Calculate 20 Pore Space / Day $Vol_{20ps} = (V_{ps})(20) = (1,367.4\text{ ft}^3)(20)$ $Vol_{20ps} = \underline{\underline{27,348\text{ ft}^3}}$					
4) Calculate Flow Rate to Achieve 20 Pore Spaces / Day $Q_{20ps} = (Vol_{20ps}) / 1\text{day} = (27,348\text{ ft}^3) / [1\text{day} (1440\text{ min}/1\text{day})]$ $Q_{20ps} = \underline{\underline{18.99\text{ cfm}}}$					
5) Assume need to provide up to 50% of total air flow as bleed air ; $Q_{Total} = \frac{Q_{20ps}}{50\%} = \frac{18.99\text{ cfm}}{0.5} = 37.98 \approx \underline{\underline{38\text{ cfm}}}$					
NOTES					
Blower selection:					
A) Assume 5" WC losses in lines @ 38 cfm in 2" lines.					
B) Use oilless regenerative blower					
C) Select Rotron EN404AR72ML blower (1HP, 208-230/460VAC, 3PH, XP motor) or equivalent. Produces 40 cfm @ 47" WC vacuum.					



1.0 HP Sealed Regenerative w/Explosion-Proof Motor

**FEATURES**

- Manufactured in the USA - ISO 9001 and NAFTA compliant
- Maximum flow: 100 SCFM
- Maximum pressure: 52 IWG
- Maximum vacuum: 48 IWG
- Standard motor: 1.0 HP, explosion-proof
- Cast aluminum blower housing, impeller, cover & manifold; cast iron flanges (threaded); teflon® lip seal
- UL & CSA approved motor with permanently sealed ball bearings for explosive gas atmospheres Class I Group D minimum
- Sealed blower assembly
- Quiet operation within OSHA standards

**MOTOR OPTIONS**

- International voltage & frequency (Hz)
- Chemical duty, high efficiency, inverter duty or industry-specific designs
- Various horsepower for application-specific needs

**BLOWER OPTIONS**

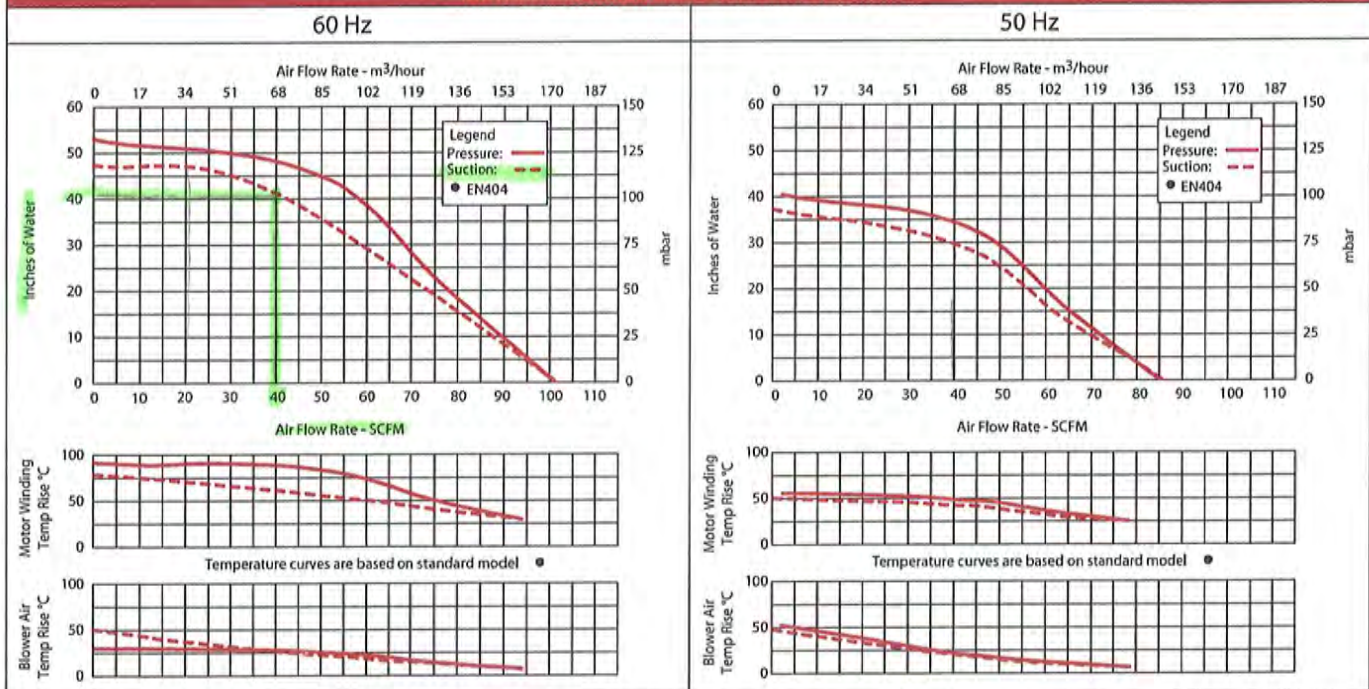
- Corrosion resistant surface treatments & sealing options
- Remote drive (motorless) models
- Slip-on or face flanges for application-specific needs

**ACCESSORIES**

- Flowmeters reading in SCFM
- Filters & moisture separators
- Pressure gauges, vacuum gauges, & relief valves
- Switches - air flow, pressure, vacuum, or temperature
- External mufflers for additional silencing
- Air knives (used on blow-off applications)
- Variable frequency drive package



Blower Performance at Standard Conditions



This document is for informational purposes only and should not be considered as a binding description of the products or their performance in all applications. The performance data on this page depicts typical performance under controlled laboratory conditions. AMETEK is not responsible for blowers driven beyond factory specified speed, temperature, pressure, flow or without proper alignment. Actual performance will vary depending on the operating environment and application. AMETEK products are not designed for and should not be used in medical life support applications. AMETEK reserves the right to revise its products without notification. The above characteristics represent standard products. For product designed to meet specific applications, contact AMETEK Technical & Industrial Products Sales department.

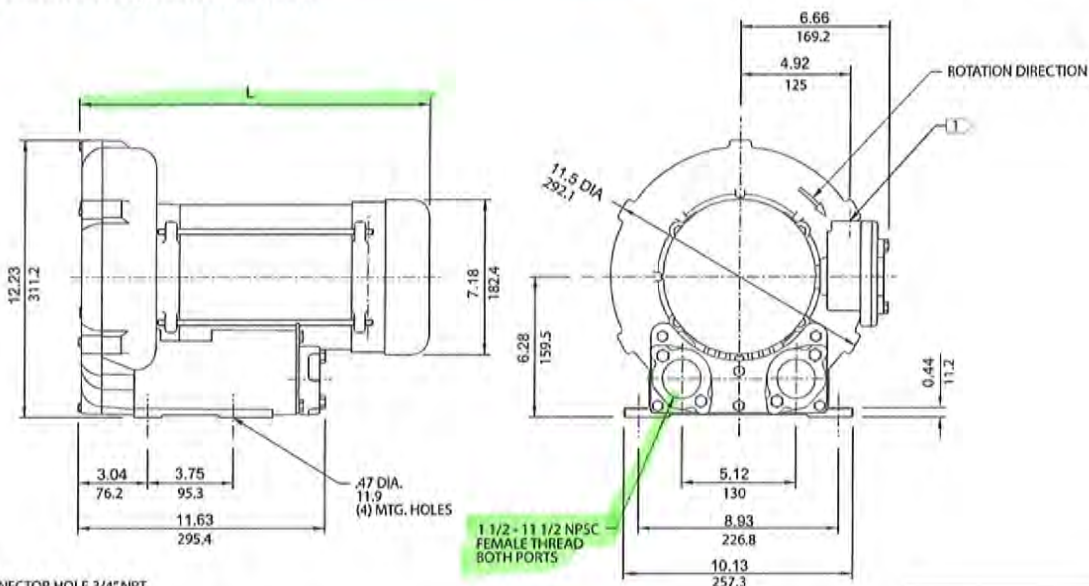


Environmental / Chemical Processing Blowers

EN 404 & CP 404

1.0 HP Sealed Regenerative w/Explosion-Proof Motor

# ROTRON®



IN  
MM

NOTES

1. TERMINAL BOX CONNECTOR HOLE 3/4" NPT.
2. DRAWING NOT TO SCALE, CONTACT FACTORY FOR SCALE CAD DRAWING.
3. CONTACT FACTORY FOR BLOWER MODEL LENGTHS NOT SHOWN.

MODEL	L (IN/MM)
EN404AR58ML	16.41/416.8
EN404AR72ML	15.50/393.7

*This Model*  
↓

Specification	Units	Part/Model Number			
		EN404AR58ML 038173	EN404AR72ML 038174	CP404FQ58MLR 080075	CP404FQ72MLR 038958
Motor Enclosure - Shaft Mt.	-	1.0	1.0	1.0	1.0
Horsepower	-	Explosion-proof-CS	Explosion-proof-CS	Chem XP-SS	Chem XP-SS
Phase - Frequency	-	Single-60 hz	Three-60 hz	Single-60 hz	Three-60 hz
Voltage	AC	115/230	208-230/460	115/230	208-230/460
Motor Nameplate Amps	Amps (A)	11.4/5.69	3.2/1.6	11.4/5.69	3.2/1.6
Max. Blower Amps	Amps (A)	14.4/7.2	3.6/1.8	14.4/7.2	3.6/1.8
Inrush Amps	Amps (A)	72/36	20.2/10.1	72/36	20.2/10.1
Service Factor	-	0/00	00/00	0/00	00/00
Starter Size	-	1.0	1.0	1.0	1.0
Thermal Protection	-	Class B - Pilot Duty	Class B - Pilot Duty	Class B - Pilot Duty	Class B - Pilot Duty
XP Motor Class - Group	-	I-D, II-F&G	I-D, II-F&G	I-D, II-F&G	I-D, II-F&G
Shipping Weight	Lbs Kg	81 36.7	64 29	81 36.7	64 29

**Voltage** - ROTRON motors are designed to handle a broad range of world voltages and power supply variations. Our dual voltage 3 phase motors are factory tested and certified to operate on both: **208-230/415-460 VAC-3 ph-60 Hz** and **190-208/380-415 VAC-3 ph-50 Hz**. Our dual voltage 1 phase motors are factory tested and certified to operate on both: **104-115/208-230 VAC-1 ph-60 Hz** and **100-110/200-220 VAC-1 ph-50 Hz**. All voltages above can handle a ±10% voltage fluctuation. Special wound motors can be ordered for voltages outside our certified range.

**Operating Temperatures** - Maximum operating temperature: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F rated motors or 120°C for Class B rated motors. Blower outlet air temperature should not exceed 140°C (air temperature rise plus inlet temperature). Performance curve maximum pressure and suction points are based on a 40°C inlet and ambient temperature. Consult factory for inlet or ambient temperatures above 40°C.

**Maximum Blower Amps** - Corresponds to the performance point at which the motor or blower temperature rise with a 40°C inlet and/or ambient temperature reaches the maximum operating temperature.

**XP Motor Class - Group** - See Explosive Atmosphere Classification Chart in Section I

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# SERVICE AND PARTS MANUAL FOR BLOWER MODEL

## EN101 – EN404



AMETEK Dynamic Fluid Solutions  
100 East Erie St., Kent, Ohio 44240  
Telephone: 330-673-3452 Fax: 330-677-3306  
email: [dfs.information@ametek.com](mailto:dfs.information@ametek.com)  
internet: [www.ametekdfs.com](http://www.ametekdfs.com)

**Your Choice. Our Commitment.™**

# WARRANTY, INSTALLATION, MAINTENANCE AND TROUBLESHOOTING INSTRUCTIONS



AMETEK Dynamic Fluid Solutions  
100 East Erie St., Kent, Ohio 44240  
Telephone: 330-673-3452 Fax: 330-677-3306  
email: [dfs.information@ametek.com](mailto:dfs.information@ametek.com)  
internet: [www.ametekdfs.com](http://www.ametekdfs.com)

1. AMETEK Rotron DR, EN and HiE regenerative direct drive blowers are guaranteed for one full year from the date of installation (limited to 18 months from the date of shipment) to the original purchaser only. Should the blower fail we will evaluate the failure. If failure is determined to be workmanship or material defect related, we will at our option repair or replace the blower.
2. AMETEK Rotron Minispiral, Revaflow, Multiflow, Nautilair, remote drive blowers, moisture separators, packaged units, CP blowers, Nasty Gas™ models and special built (EO) products are guaranteed for one full year from date of shipment for workmanship and material defect to the original purchaser only. Should the blower fail, If failure is determined to be workmanship or material defect related, we will at our option repair or replace the blower.
3. **Parts Policy** - AMETEK Rotron spare parts and accessories are guaranteed for three months from date of shipment for workmanship and material defect to the original purchaser only. If failure is determined to be workmanship or material defect related we will at our option repair or replace the part.

**Corrective Action** - A written report will be provided indicating reason(s) for failure, with suggestions for corrective action. Subsequent customer failures due to abuse, misuse, misapplication or repeat offense will not be covered. AMETEK Rotron will then notify you of your options. Any failed unit that is tampered with by attempting repair or diagnosis will void the warranty, unless authorized by the factory.

**Terms and Conditions** - Our warranty covers repairs or replacement of regenerative blowers only, and will not cover labor for installation, outbound and inbound shipping costs, accessories or other items not considered integral blower parts. Charges may be incurred on products returned for reasons other than failures covered by their appropriate warranty. Out-of-warranty product and in warranty product returned for failures determined to be caused by abuse, misuse, or repeat offense will be subject to an evaluation charge. Maximum liability will in no case exceed the value of the product purchased. Damage resulting from mishandling during shipment is not covered by this warranty. It is the responsibility of the purchaser to file claims with the carrier. Other terms and conditions of sale are stated on the back of the order acknowledgement.

## Installation Instructions for SL, DR, EN, CP, and HiE Series Blowers

1. **Bolt It Down** - Any blower must be secured against movement prior to starting or testing to prevent injury or damage. The blower does not vibrate much more than a standard electric motor.
2. **Filtration** - All blowers should be filtered prior to starting. Care must be taken so that no foreign material enters the blower. If foreign material does enter the blower, it could cause internal damage or may exit at extremely high velocity.

Should excessive amounts of material pass through the blower, it is suggested that the cover(s) and impeller(s) be removed periodically and cleaned to avoid impeller imbalance. Impeller

imbalance greatly speeds bearing wear, thus reducing blower life. Disassembling the blower will void warranty, so contact the factory for cleaning authorization.

- Support the Piping** - The blower flanges and nozzles are designed as connection points only and are not designed to be support members.

Caution: Plastic piping should not be used on blowers larger than 1 HP that are operating near their maximum pressure or suction point. Blower housing and nearby piping temperatures can exceed 200°F. Access by personnel to the blower or nearby piping should be limited, guarded, or marked, to prevent danger of burns.

- Wiring** - Blowlers must be wired and protected/fused in accordance with local and national electrical codes. All blowlers must be grounded to prevent electrical shock. Slo-Blo or time delay fuses should be used to bypass the first second of start-up amperage.
- Pressure/Suction Maximums** - The maximum pressure and/or suction listed on the model label should not be exceeded. This can be monitored by means of a pressure or suction gage (available from Rotron), installed in the piping at the blower outlet or inlet. Also, if problems do arise, the Rotron Field representative will need to know the operating pressure/suction to properly diagnose the problem.
- Excess Air** - Bleed excess air off. DO NOT throttle to reduce flow. When bleeding off excess air, the blower draws less power and runs cooler.

**Note:** Remote Drive (Motorless) Blowlers - Properly designed and installed guards should be used on all belts, pulleys, couplings, etc. Observe maximum remote drive speed allowable. Due to the range of uses, drive guards are the responsibility of the customer or user. Belts should be tensioned using belt gauge.

Maintenance Procedure

**When properly piped, filtered, and applied, little or no routine maintenance is required. Keep the filter clean. Also, all standard models in the DR, EN, CP, and HiE series have sealed bearings that require no maintenance. Bearing should be changed after 15,000 to 20,000 hours, on average. Replacement bearing information is specified on the chart below.**

Bearing Part Number	Size	Seal Material	Grease	Heat Stabilized
510217 510218 510219	205 206 207	Polyacrylic	Nye Rheotemp 500 30% +/- 5% Fill	Yes – 325 F
510449 516440 516648	203 202 307	Buna N	Exxon Polyrex Grease	NO
516840 516841 516842 516843 516844 516845 516846 516847	206 207 208 210 309 310 311 313	Buna N	Exxon Polyrex Grease	NO

## Troubleshooting

		POSSIBLE CAUSE	OUT OF WARRANTY REMEDY ***
IMPELLER DOES NOT TURN	Humming Sound	<ol style="list-style-type: none"> <li>* One phase of power line not connected</li> <li>* One phase of stator winding open</li> <li>Bearings defective</li> <li>Impeller jammed by foreign material</li> <li>Impeller jammed against housing or cover</li> <li>** Capacitor open</li> </ol>	<ol style="list-style-type: none"> <li>Connect</li> <li>Rewind or buy new motor</li> <li>Change bearings</li> <li>Clean and add filter</li> <li>Adjust</li> <li>Change capacitor</li> </ol>
	No Sound	<ol style="list-style-type: none"> <li>* Two phases of power line not connected</li> <li>* Two phases of stator winding open</li> </ol>	<ol style="list-style-type: none"> <li>Connect</li> <li>Rewind or buy new motor</li> </ol>
IMPELLER TURNS	Blown Fuse	<ol style="list-style-type: none"> <li>Insufficient fuse capacity</li> <li>Short circuit</li> </ol>	<ol style="list-style-type: none"> <li>Use time delay fuse of proper rating</li> <li>Repair</li> </ol>
	Motor Overheated Or Protector Trips	<ol style="list-style-type: none"> <li>High or low voltage</li> <li>* Operating in single phase condition</li> <li>Bearings defective</li> <li>Impeller rubbing against housing or cover</li> <li>Impeller or air passage clogged by foreign material</li> <li>Unit operating beyond performance range</li> <li>Capacitor shorted</li> <li>* One phase of stator winding short circuited</li> </ol>	<ol style="list-style-type: none"> <li>Check input voltage</li> <li>Check connections</li> <li>Check bearings</li> <li>Adjust</li> <li>Clean and add filter</li> <li>Reduce system pressure/vacuum</li> <li>Change capacitor</li> <li>Rewind or buy new motor</li> </ol>
	Abnormal Sound	<ol style="list-style-type: none"> <li>Impeller rubbing against housing or cover</li> <li>Impeller or air passages clogged by foreign material</li> <li>Bearings defective</li> </ol>	<ol style="list-style-type: none"> <li>Adjust</li> <li>Clean and add filter</li> <li>Change bearings</li> </ol>
	Performance Below Standard	<ol style="list-style-type: none"> <li>Leak in piping</li> <li>Piping and air passages clogged</li> <li>Impeller rotation reversed</li> <li>Leak in blower</li> <li>Low voltage</li> </ol>	<ol style="list-style-type: none"> <li>Tighten</li> <li>Clean</li> <li>Check wiring</li> <li>Tighten cover, flange</li> <li>Check input voltage</li> </ol>
<p>* 3 phase units            ** 1 phase units            *** Disassembly and repair of new blowers or motors will void the Rotron warranty. Factory should be contacted prior to any attempt to field repair an in-warranty unit.</p>			

### **Blower Disassembly:**

**WARNING:** Attempting to repair or diagnose a blower may void Rotron's warranty. It may also be difficult to successfully disassemble and reassemble the unit.

- 1) Disconnect the power leads. **CAUTION:** Be sure the power is disconnected before doing any work whatsoever on the unit.
- 2) Remove or separate piping and/or mufflers and filters from the unit.
- 3) Remove the cover bolts and then the cover. **NOTE:** Some units are equipped with seals. It is mandatory that these seals be replaced once the unit has been opened.
- 4) Remove the impeller bolt and washers and then remove the impeller. **NOTE:** Never pry on the edges of the impeller. Use a puller as necessary.
- 5) Carefully note the number and location of the shims. Remove and set them aside. **NOTE:** If the disassembly was for inspection and cleaning the unit may now be reassembled by reversing the above steps. If motor servicing or replacement and/or impeller replacement is required the same shims may not be used. It will be necessary to re-shim the impeller according to the procedure explained under assembly.

- 6) Remove the housing bolts and remove the motor assembly (arbor/housing on remote drive models).
- 7) Arbor disassembly (Applicable on remote drive models only):
  - a) Slide the bearing retraining sleeve off the shaft at the blower end.
  - b) Remove the four (4) screws and the bearing retaining plate from the blower end.
  - c) Lift the shaft assembly far enough out of the arbor to allow removal of the blower end snap ring.
  - d) Remove the shaft assembly from the arbor.
  - e) If necessary, remove the shaft dust seal from the pulley end of the arbor.

*Muffler Material Replacement:*

- 1) Remove the manifold cover bolts and them manifold cover.
- 2) The muffler material can now be removed and replaced if necessary. On blowers with fiberglass acoustical wrap the tubular retaining screens with the fiberglass matting before sliding the muffler pads over the screens.
- 3) Reassemble by reversing the procedure.

**NOTE: On DR068 models with tubular mufflers it is necessary to remove the cover and impeller accessing the muffler material from the housing cavity.**

*Blower Reassembly:*

- 1) Place the assembled motor (assembled arbor assembly for remote drive models) against the rear of the housing and fasten with the bolts and washer.
- 2) To ensure the impeller is centered within the housing cavity re-shim the impeller according to the procedure outlined below.
- 3) If blower had a seal replace the seal with a new one.
- 4) Place the impeller onto the shaft making sure the shaft key is in place and fasten with the bolt, washer and spacer as applicable. Torque the impeller bolt per the table below. Once fastened carefully rotate the impeller to be sure it turns freely.
- 5) Replace the cover and fasten with bolts.
- 6) Reconnect the power leads to the motor per the motor nameplate.

Bolt Size	Torque Pound-Force-Foot
<b>1/4-20</b>	<b>6.25 +/- 0.25</b>
<b>5/16-18</b>	<b>11.5 +/- 0.25</b>
<b>3/8-16</b>	<b>20.0 +/- 0.5</b>
<b>1/2-13</b>	<b>49.0 +/- 1</b>
<b>5/8 -11</b>	<b>90.0 +/- 2</b>



*Impeller Shimming Procedure:*

WARNING: This unit may be difficult to shim. Extreme care may be exercised.

Tools Needed: Machinist's Parallel Bar  
Vernier Caliper with depth measuring capability  
Feeler gauges or depth gauge

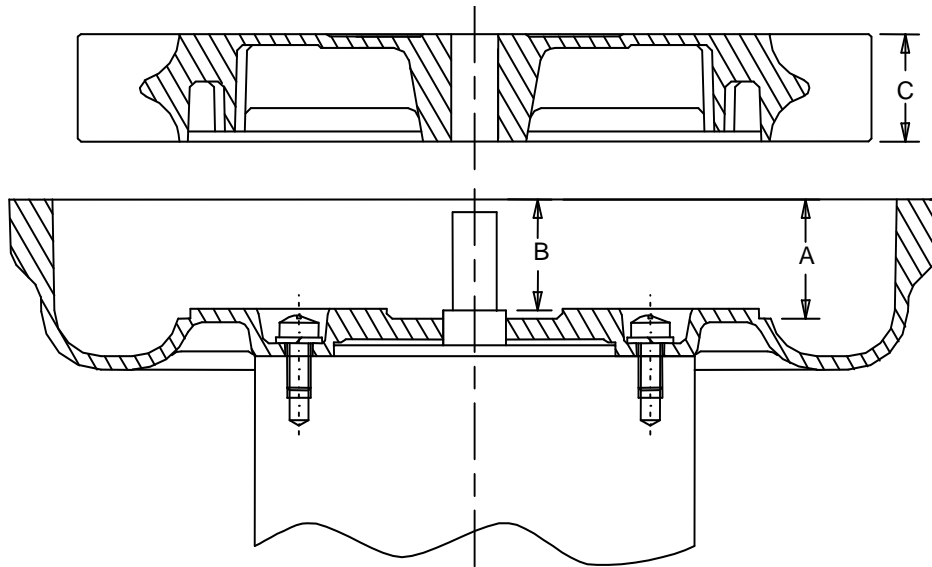
Measure the Following:

- Distance from the flange face to the housing (A)
- Distance from the flange face to the motor shaft shoulder (B)
- Impeller Thickness (C)

Measurements (A) and (B) are made by laying the parallel bar across the housing flange face and measuring to the proper points. Each measurement should be made at three points, and the average of the readings should be used.

$$\text{Shim Thickness} = B - (A+C)/2$$

After the impeller installation (step #4 above) the impeller/cover clearance can be checked with feeler gauges, laying the parallel bar across the housing flange face. This clearance should nominally be  $(A-C)/2$ .



# AMETEK Dynamic Fluid Solutions .

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internet: [www.ametekdfs.com](http://www.ametekdfs.com)

## EXPLOSION-PROOF BLOWERS



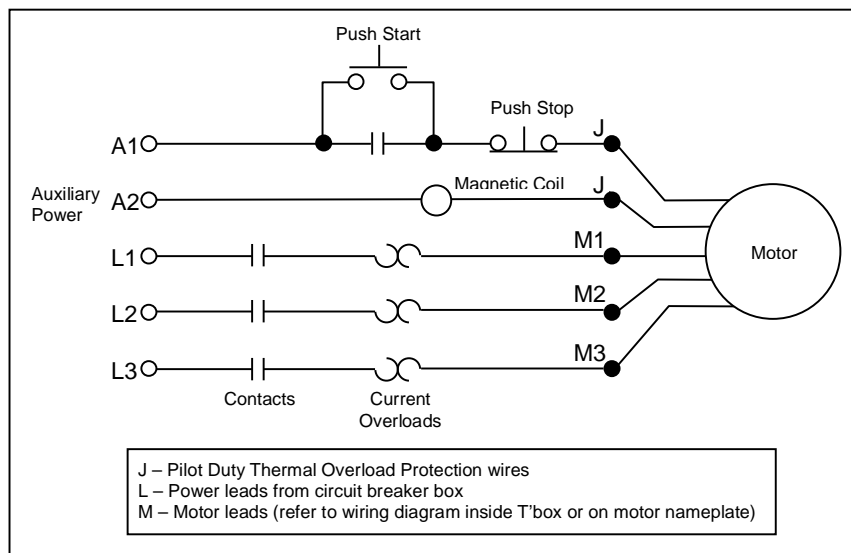
**IMPORTANT:** Read before wiring this Explosion-proof Blower

This AMETEK Rotron Explosion-proof Regenerative Blower may be equipped with Pilot Duty Thermal Overload (PDTO) or Automatic Thermal Overload (ATO) protection. When properly wired to a motor starter, this protection limits the motor winding temperature rise per the National Electric Code (NEC) article 500. Failure to properly wire this blower is an NEC violation and could cause an explosion. AMETEK Rotron assumes no responsibilities for damages incurred by negligent use of this product, and will not warranty a blower on which the PDTO is not properly connected. Some blowers 1 HP and under do not require PDTO and have built in ATO. Consult the factory if verification of wiring connections is required.

In all cases, follow the motor controller manufacturer's instructions. The following schematic is for conceptual understanding only, and may not apply to all motor/controller combinations.

The manufacturer's wiring diagram found on the motor takes precedent over reference diagrams supplied by AMETEK Rotron Technical Motor Division.

### Schematic



The schematic is shown for a three phase motor. For a single phase motor disregard L3 and M3. Pushing the START button completes the auxiliary control circuit, allowing current to flow through the magnetic coil. The contacts are magnetically closed, starting the motor and latching the auxiliary circuit. The motor will continue to run until the STOP push button is depressed, the motor reaches the overload temperature, or the current sensing overloads trip out.

If you have any questions, contact AMETEK Rotron at 914-246-3401 for the location of your area representative.

## **POLICY REGARDING INSTALLATION OF AMETEK ROTRON REGENERATIVE BLOWERS IN HAZARDOUS LOCATIONS**

AMETEK Rotron will not knowingly specify, design or build any regenerative blower for installation in a hazardous, explosive location without the proper NEMA motor enclosure. AMETEK Rotron does not recognize sealed blowers as a substitute for explosion-proof motors. Sealed units with standard TEFC motors should never be utilized where local, state, and/or federal codes specify the use of explosion-proof equipment.

AMETEK Rotron has a complete line of regenerative blowers with explosion-proof motors. Division 1 & 2, Class I, Group D; Class II, Groups F & G requirements are met with these standard explosion-proof blowers.

AMETEK Rotron will not knowingly specify, design or build any regenerative blower for installation in a hazardous, corrosive environment without the proper surface treatment and sealing options.

AMETEK Rotron has a complete line of Chemical Processing and Nasty Gas™ regenerative blowers with Chem-Tough™, stainless steel parts, and seals.

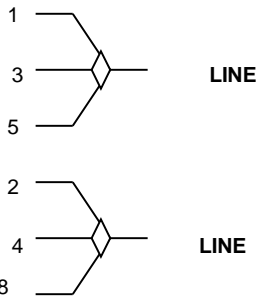
AMETEK Rotron offers general application guidance; however, suitability of the particular blower selection is ultimately the responsibility of the purchaser, not the manufacturer of the blower.

FS2 Rev. B 3/10/98

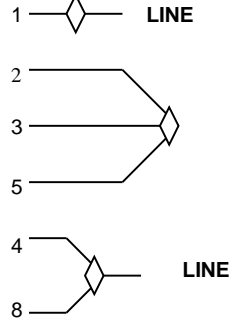
# WIRING DIAGRAMS, XP MOTORS

## H. 1Ø, 6 WIRE

**115 VAC**



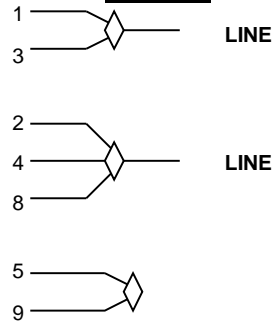
**230 VAC**



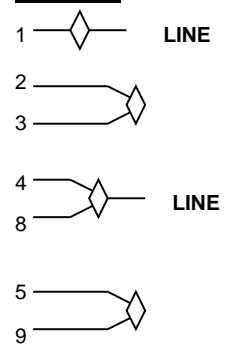
INTERCHANGE LEADWIRES 5 & 8 to REVERSE ROTATION

## I. 1Ø, 7 WIRE

**115 VAC**



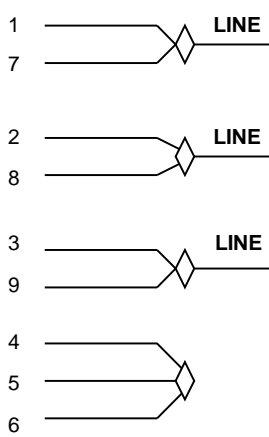
**230 VAC**



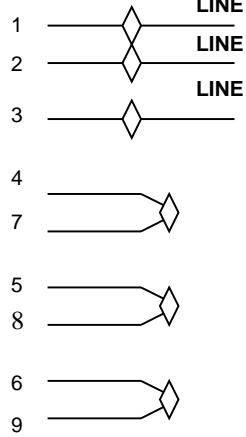
INTERCHANGE LEADWIRES 5 & 8 to REVERSE ROTATION

## K. 3Ø, 9 WIRE

**230 VAC**

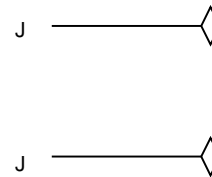


**460 VAC**



INTERCHANGE ANY TWO LEAD LINES TO REVERSE ROTATION

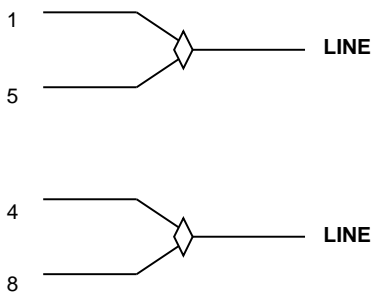
## L. PILOT DUTY THERMAL OVERLOADS



HOOK J LEADS TO CONTROL CIRCUITRY

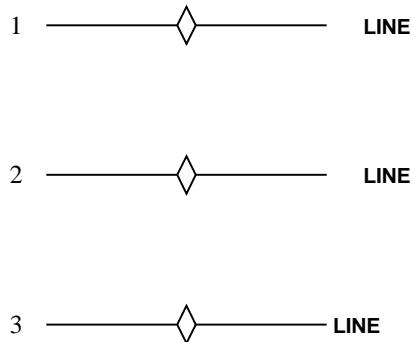
## M. 1Ø 230 VAC

SINGLE VOLTAGE



INTERCHANGE LEADWIRES 5 & 8 TO REVERSE ROTATION

## N. 3Ø 575 VAC

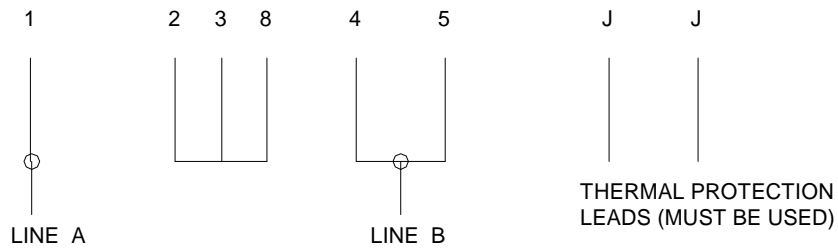


INTERCHANGE ANY TWO LEAD LINES TO REVERSE ROTATION

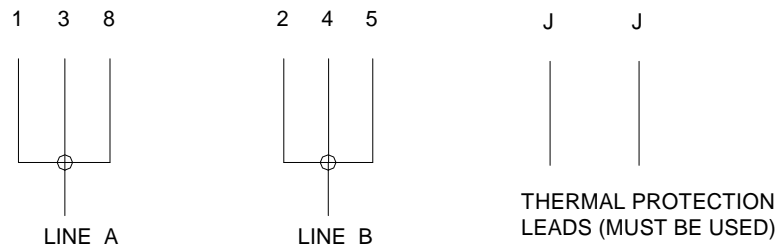
# EN404AR58ML

## 080487

230 VAC (HIGH VOLTAGE)



115 VAC (LOW VOLTAGE)



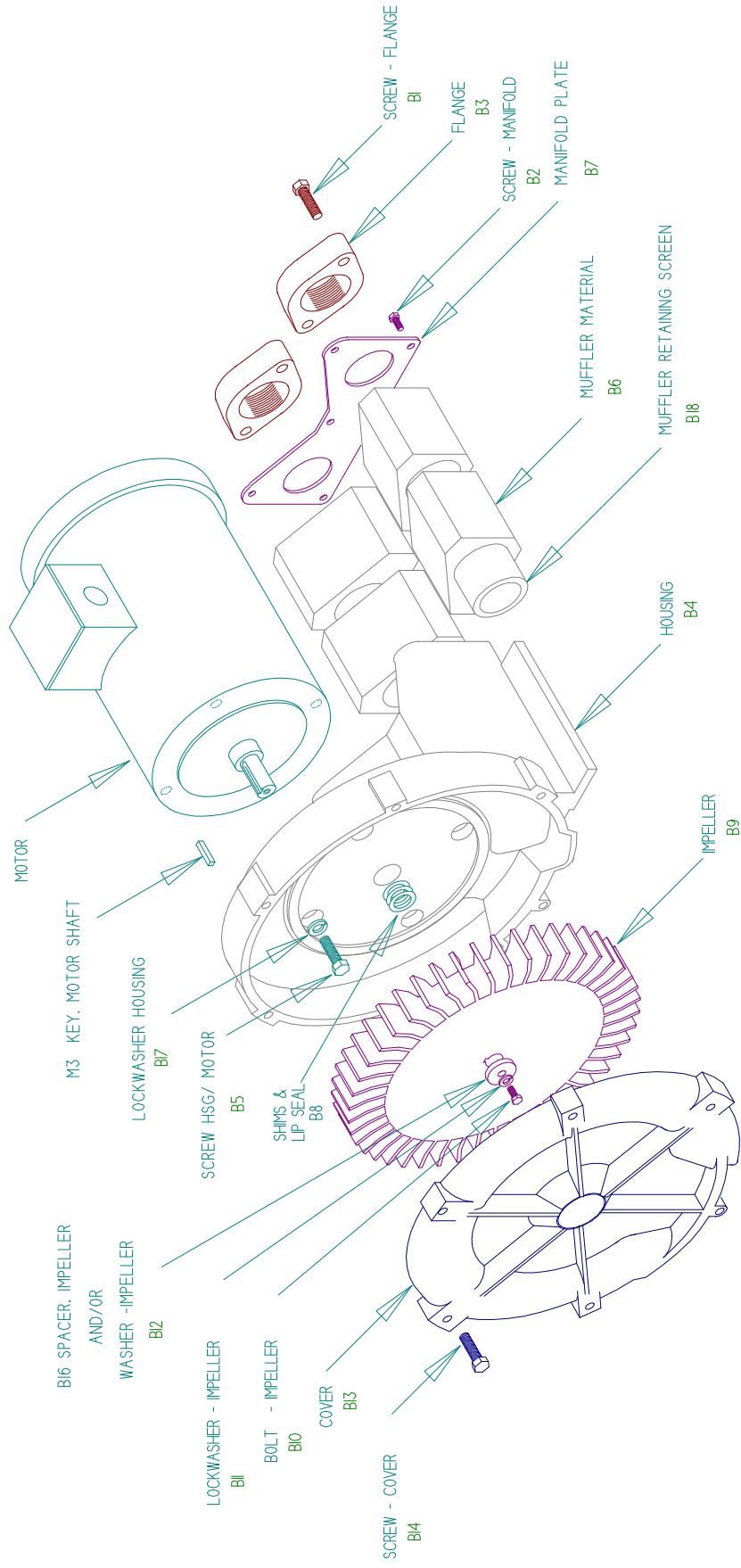
NOTE: TO REVERSE ROTATION, SWITCH LEADS 5,8

COLORS:

1 BLUE, 2 WHITE, 3 ORANGE, 4 YELLOW, 5 BLACK, 8 RED, J BROWN



# ASSEMBLY DIAGRAM EN101 – EN404



**EN 101/202/303/353/404**

**Service and Parts Manual**

Model:

Part No.:

**Parts Breakdown**

EN101

038019

038171

EN202

038022

038021

**OBSOLETE**

EN303

038172

038026

**OBSOLETE**

EN353

038031

038033

**OBSOLETE**

EN404

038173

038174

Item No.	Qty.	Req'd	Description	511501	511501	511501	515582	510629
M3	1		Key Motor Shaft	511501	511501	511501	515582	510629
B1	4		Screw, Flange	120262	120214	120162	120162	120162
B2	6		Screw, Manifold	155423	155423	155496	155496	155308
B3	2		Flange	510480	510480	510493	510493	510962
B4	1		Housing	550679	523410	523412	523416	517009
B5	4		Screw, Hsg /Motor	121925	120235	121925	120235	155128
B6	4		Muffler Material	510544	510485	510488	516384	517015
B7	1		Manifold Plate	528760	528761	551211	523415	528790
B8	*		Shim .002"	510494	510494	510494	510494	510356
	*		Shim .005"	510495	510495	510495	510495	510357
	*		Shim .010"	510496	510496	510496	510496	510358
	*		Shim .020"	155411	155411	155411	155411	510359
	*		Shim .030"	155412	155412	155412	155412	Not Used
B9	1		Impeller	550410	510345	510339	516318	516987
B10	1		Bolt, Impeller	120118	120118	120118	120325	120214
B11	1		Lockwasher, Impeller	120203	120203	120203	120203	120203
B12	1		Washer, Impeller	Not Used	Not Used	Not Used	Not Used	Not Used
B13	1		Cover	550685	517802	510337	516329	516990
B14	6		Screw, Cover	155514	120232	155514 (5 pcs)	155129	155129
B16	1		Spacer, Impeller Bolt	510355	510355	510355	510355	510355
B17			Lockwasher, Housing	Not Used	Not Used	Not Used	Not Used	Not Used
B18	1		Screen, Muffler Retaining, Right (**)	Not Used	Not Used	Not Used	Not Used	510444
	1		Screen, Muffler Retaining, Left (**)	Not Used	Not Used	Not Used	Not Used	510444
B19			Bolt, Muffler Hsg/Hsg	Not Used	Not Used	Not Used	Not Used	Not Used
B20			Muffler Housing	Not Used	Not Used	Not Used	Not Used	Not Used
			Bolt, Motor/Muffler	Not Used	Not Used	Not Used	Not Used	Not Used
			Lockwasher, Motor/Muffler	Not Used	Not Used	Not Used	Not Used	Not Used
			Washer, Motor/Muffler	Not Used	Not Used	Not Used	Not Used	Not Used
			Spacer, Motor/Muffler	Not Used	Not Used	Not Used	Not Used	Not Used
	1		Lip Seal	515969	515969	515969	515969	516587

d \*\*Viewed looking at inlet/outlet ports

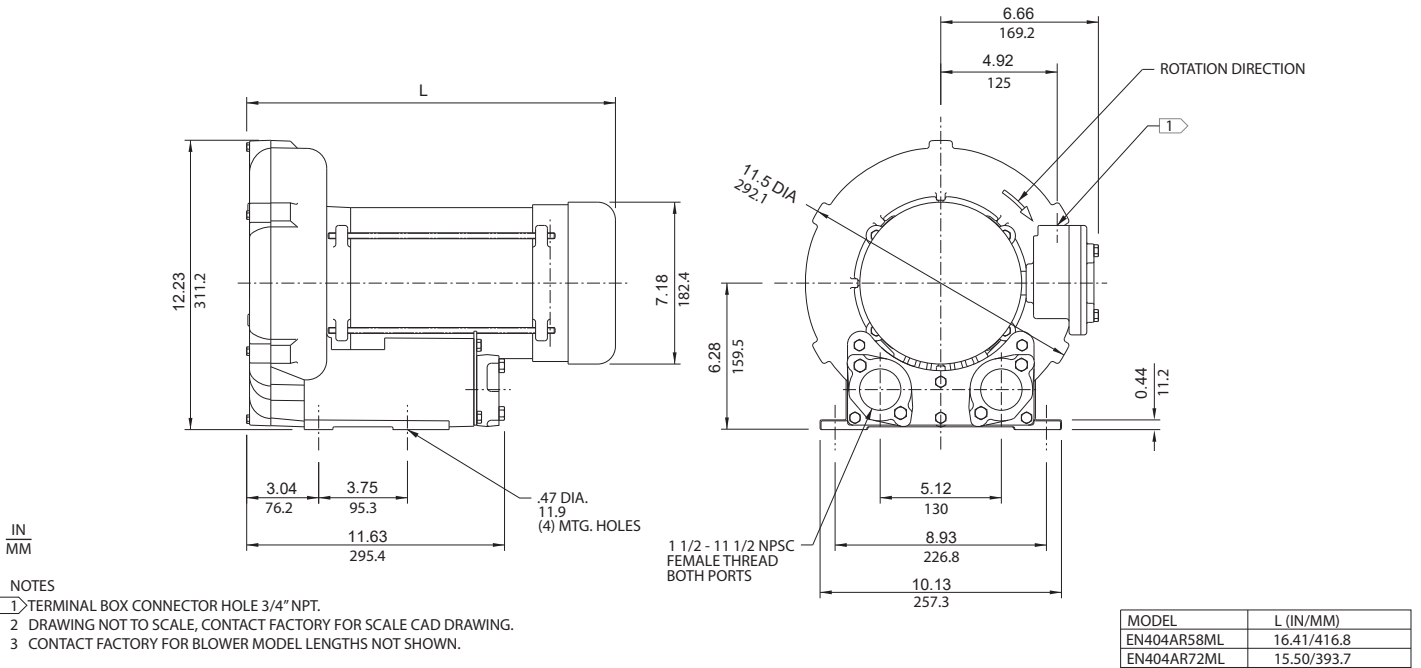
Model	Part No.	Motor	Specific Parts	Wiring Diagram	Bearing, Rear (M1)	Bearing, Impeller End (M2)
EN101AG91L	038019	515635		K	510449	510449
EN101AG58L	038171	552722		H		
EN202AA58L	038022	515628		H	510449	510449
EN202AA91L	038021	515634		K		
EN303AG58L	038172	552722		H	510449	510449
EN303AG91L	038026	515635		K		
EN353BT72L	038031	515631		K	510449	510449
EN353BT58L	038033	515630		H		
EN404AR58ML	038173	551182		See Motor	510449	510217
EN404AR72ML	038174	510442		K + L		

# Environmental / Chemical Processing Blowers

## EN 404 & CP 404

1.0 HP Sealed Regenerative w/Explosion-Proof Motor

# ROTRON®



Specification	Units	Part/Model Number			
		EN404AR58ML 038173	EN404AR72ML 038174	CP404FQ58MLR 080075	CP404FQ72MLR 038958
Motor Enclosure - Shaft Mt.	-	Explosion-proof-CS	Explosion-proof-CS	CHEM XP-SS	CHEM XP-SS
Horsepower	-	1.0	1.0	1.0	1.0
Phase - Frequency Voltage	-	Single-60 hz	Three-60 hz	Single-60 hz	Three-60 hz
Motor Nameplate Amps	AC	115/230	208-230/460	115/230	208-230/460
Max. Blower Amps	Amps (A)	11.4/5.69	3.2/1.6	11.4/5.69	3.2/1.6
Locked Rotor Amps	Amps (A)	14.4/7.2	3.6/1.8	14.4/7.2	3.6/1.8
Service Factor	Amps (A)	72/36	20.2/10.1	72/36	20.2/10.1
Starter Size	-	0/00	00/00	0/00	00/00
Thermal Protection	-	1.0	1.0	1.0	1.0
XP Motor Class - Group	-	Class B - Pilot Duty I-D, II-F&G	Class B - Pilot Duty I-D, II-F&G	Class B - Pilot Duty I-D, II-F&G	Class B - Pilot Duty I-D, II-F&G
Shipping Weight	Lbs Kg	81 36.7	64 29	81 36.7	64 29

**Voltage** - ROTRON motors are designed to handle a broad range of world voltages and power supply variations. Our dual voltage 3 phase motors are factory tested and certified to operate on both: **208-230/415-460 VAC-3 ph-60 Hz** and **190-208/380-415 VAC-3 ph-50 Hz**. Our dual voltage 1 phase motors are factory tested and certified to operate on both: **104-115/208-230 VAC-1 ph-60 Hz** and **100-110/200-220 VAC-1 ph-50 Hz**. All voltages above can handle a ±10% voltage fluctuation. Special wound motors can be ordered for voltages outside our certified range.

**Operating Temperatures** - Maximum operating temperature: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F rated motors or 120°C for Class B rated motors. Blower outlet air temperature should not exceed 140°C (air temperature rise plus inlet temperature). Performance curve maximum pressure and suction points are based on a 40°C inlet and ambient temperature. Consult factory for inlet or ambient temperatures above 40°C.

**Maximum Blower Amps** - Corresponds to the performance point at which the motor or blower temperature rise with a 40°C inlet and/or ambient temperature reaches the maximum operating temperature.

**XP Motor Class - Group** - See Explosive Atmosphere Classification Chart in Section I

This document is for informational purposes only and should not be considered as a binding description of the products or their performance in all applications. The performance data on this page depicts typical performance under controlled laboratory conditions. AMETEK is not responsible for blowers driven beyond factory specified speed, temperature, pressure, flow or without proper alignment. Actual performance will vary depending on the operating environment and application. AMETEK products are not designed for and should not be used in medical life support applications. AMETEK reserves the right to revise its products without notification. The above characteristics represent standard products. For product designed to meet specific applications, contact AMETEK Technical & Industrial Products Sales department.

## EN 404 & CP 404

1.0 HP Sealed Regenerative w/Explosion-Proof Motor \*ATEX model certified

### FEATURES

- Manufactured in the USA - ISO 9001 and NAFTA compliant
- Maximum flow: 100 SCFM
- Maximum pressure: 52 IWG
- Maximum vacuum: 48 IWG
- Standard motor: 1.0 HP, explosion-proof
- Cast aluminum blower housing, impeller, cover & manifold; cast iron flanges (threaded); teflon® lip seal
- UL & CSA approved motor with permanently sealed ball bearings for explosive gas atmospheres Class I Group D minimum
- Sealed blower assembly
- Quiet operation within OSHA standards

### MOTOR OPTIONS

- International voltage & frequency (Hz)
- Chemical duty, high efficiency, inverter duty or industry-specific designs
- Various horsepower for application-specific needs

### BLOWER OPTIONS

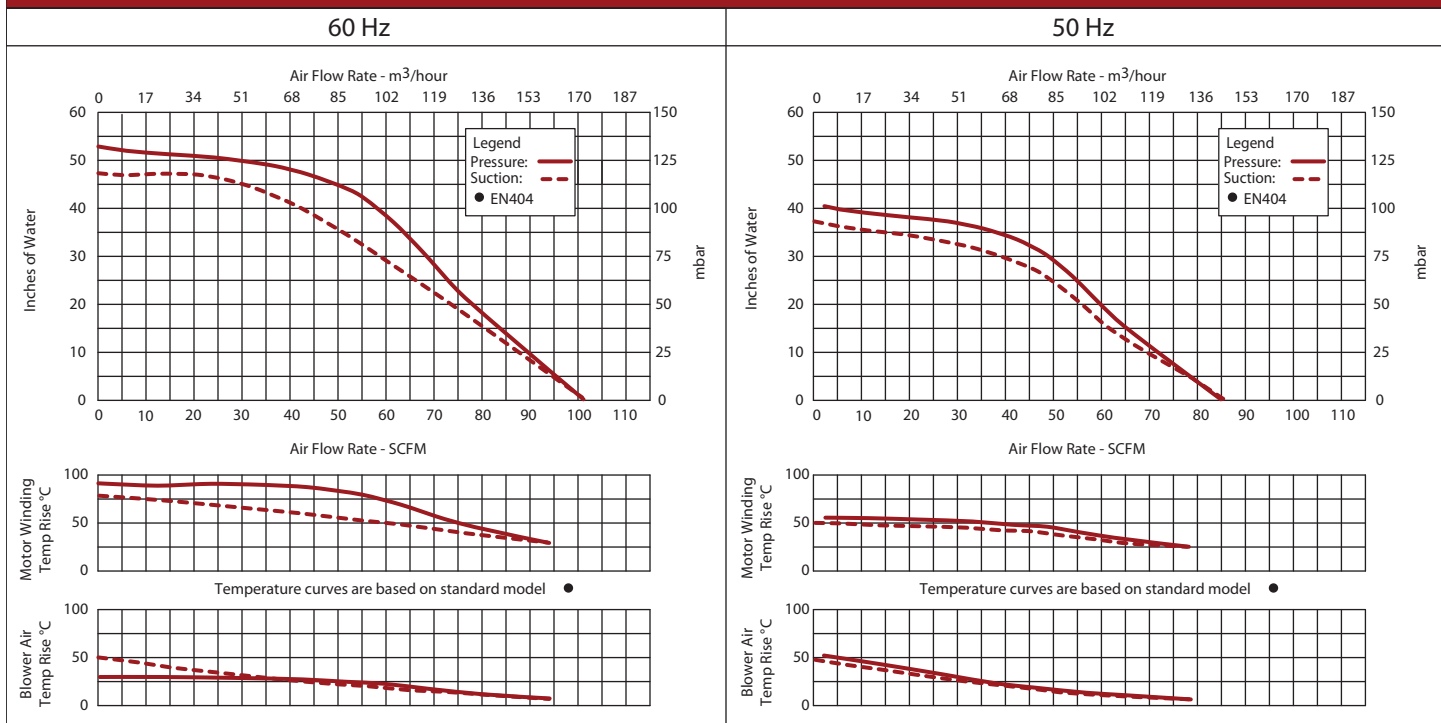
- Corrosion resistant surface treatments & sealing options
- Remote drive (motorless) models
- Slip-on or face flanges for application-specific needs

### ACCESSORIES

- Flowmeters reading in SCFM
- Filters & moisture separators
- Pressure gauges, vacuum gauges, & relief valves
- Switches - air flow, pressure, vacuum, or temperature
- External mufflers for additional silencing
- Air knives (used on blow-off applications)
- Variable frequency drive package



### Blower Performance at Standard Conditions



This document is for informational purposes only and should not be considered as a binding description of the products or their performance in all applications. The performance data on this page depicts typical performance under controlled laboratory conditions. AMETEK is not responsible for blowers driven beyond factory specified speed, temperature, pressure, flow or without proper alignment. Actual performance will vary depending on the operating environment and application. AMETEK products are not designed for and should not be used in medical life support applications. AMETEK reserves the right to revise its products without notification. The above characteristics represent standard products. For product designed to meet specific applications, contact AMETEK Technical & Industrial Products Sales department.



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**APPENDIX G**

Vapor Mitigation System – Methane Sensor Documents



# M2A STAND ALONE TRANSMITTER



- Operates with or without a controller
- Direct digital readout with OLED cold temperature display
- Available gases include
  - LEL, O<sub>2</sub>, H<sub>2</sub>S, CO, CO<sub>2</sub>, and 100% Vol CH<sub>4</sub>
  - Toxic gases include NH<sub>3</sub>, SO<sub>2</sub>, HCN, and more
- Infrared sensor for combustibles and CO<sub>2</sub>
- 4-20 mA & digital Modbus outputs standard
- 2 fully programmable alarm relays & fail relay
- Non-intrusive calibration via magnetic wand
- Explosion proof construction
- Patented water repellent sensor cover
- User friendly setup, push buttons & OLED menus
- Long-life sensors (2 + years typical)

The RKI M2A™ is a state-of-the-art transmitter that can operate as an independent, stand-alone monitor or as part of an integrated system. The M2A connects with an analog or digital signal to virtually any controller, PLC, or DCS. Setup procedures are simplified with user friendly push buttons and OLED menus. It utilizes a magnetic wand technique for performing non-intrusive calibration. The M2A provides an automatic zero drift correction feature, which results in more stable readings and reduces the need for adjustments due to sensor aging.

The housing of the M2A does not need to be opened for zeroing or calibration, making it unnecessary to declassify the area for routine maintenance. It is designed so that a complete field calibration can be performed by one person. Sensor construction is rated Class I, Div. 1 Groups B, C, D for flammables, CO, H<sub>2</sub>S, O<sub>2</sub>, and CO<sub>2</sub>, and Class I, Div. 2 for all other toxics.


The transmitter provides a 4-20 mA output in addition to a Modbus digital output. It also has two levels of alarms with relays, plus a fail alarm with relay. A digital display of the gas concentration, as well as alarm and status lights, can be viewed through the front window.

The toxic sensors are electrochemical type plug-in sensors, which provide high specificity, fast response, and long life. The plug-in design allows quick replacement in the field with no tools required. Toxic sensors are designed for use in Class I, Div. 2 hazardous locations. Sensors available for NH<sub>3</sub>, SO<sub>2</sub>, PH<sub>3</sub>, AsH<sub>3</sub>, and HCN.


The M2A represents the latest leading edge technology in sensor / transmitters today.

World Leader In Gas Detection & Sensor Technology


# Explosion Proof

	LEL General Purpose	LEL H2 Specific	O2 Oxygen	H2S Hydrogen Sulfide	CO Carbon Monoxide	CH4 Methane	HC Hydrocarbons	CO2 Carbon Dioxide
 Part#	65-2640RK 65-2640RK-05	65-2641RK 65-2641RK-05	65-2643RK-05	65-2645RK-05	65-2646RK-05	65-2649RK-CH4 65-2658RK-CH4	65-2649RK-HC	65-2660RK-02 65-2660RK-03 65-2660RK-05 65-2660RK-10
<b>Sensors</b>	Catalytic		Galvanic cell	Electrochemical		Infrared		
<b>Measuring Ranges</b>	0 - 100 % LEL		0 - 25.0% Vol.	0 - 100 ppm	0 - 300 ppm	0 - 100% LEL 0 - 100% Vol.	0 - 100% LEL	-02 0 - 5000 ppm -03 0 - 5% Vol. -05 0 - 50% Vol. -10 0 - 100% Vol.
<b>Resolution</b>	1% LEL		0.1% Vol.	1 ppm		1% LEL / 1% Vol.		20 ppm / 0.1% Vol. / 1% Vol.
<b>Lower Detectable Limit (LDL)</b>	2% of full scale		0.1% Vol.	2% of full scale				
<b>Max Current Draw (24VDC)</b>	160 mA with alarm 1 and alarm 2 active and all relays energized		125 mA with alarm 1 and alarm 2 active and all relays energized					
<b>Response Time (T-90)</b>	35 Seconds or less					30 Seconds or less		
<b>Life Expectancy</b>	2 to 3 years with normal service	3 to 5 years with normal service	2 to 3 years with normal service			5 years plus with normal service		
<b>Accuracy (which ever is greater)</b>	± 5% of reading or ± 2 % LEL		± 0.5% Vol. O2	± 5% of reading or ± 2 ppm H2S	± 5% of reading or ± 5 ppm CO	± 5% of reading or ± 2 % of full scale		
<b>Weather Resistant</b>	Patented water repellent sensor coating							
<b>Alarms</b>								
<b>Alarm Settings</b>	Two fully programmable alarm set points, increasing / decreasing, latching / self-resetting, on delays, off delays, normally energized or de-energized							
<b>Alarm Indication</b>	Visual LEDs. Alarm 1, Amber; Alarm 2, Red; Fail, Red							
<b>Relays</b>	5 amp form 'C' contacts for alarm 1, alarm 2, and fail							
<b>Physical</b>								
<b>Dimensions</b>	Height: 8.5" (215 mm), Width: 5.2" (132 mm), Depth: 4.5" (114 mm)							
<b>Display</b>	Alphanumeric OLED display. 8 characters per line; 2 lines for gas concentration readout, plus user-friendly calibration and setup							
<b>Enclosure</b>	Explosion proof for Class I, Div 1, Groups B, C, D.							
<b>Enclosure Rating</b>	NEMA 4X, explosion proof, watertight, cast aluminum with o-ring seal and epoxy powder coating							
<b>Controls</b>	Magnet used for calibration functions. Calibrates without opening the housing. Internal push-button controls also available for calibration and setup							
<b>Operating Environment</b>								
<b>Operating Temperature</b>	-40°F to 167°F -40°C to 75°C	-4°F to 113°F -20°C to 45°C	-40°F to 104°F -40°C to 40°C	23°F to 104°F -5°C to 40°C	-40°F to 122°F -40°C to 50°C			
<b>Relative Humidity</b>	5 - 95% RH non-condensing							
<b>Location</b>	Indoor or outdoor. Explosion proof for Class I, Div. 1, Groups B, C, D.							
<b>Operating Voltage</b>	10 VDC - 30 VDC							
<b>Outputs</b>								
<b>Analog</b>	Linear 4-20 mA signal, into 1000 ohms impedance max (24DC), 0 - 500 ohms max (12VDC) corresponding to 0 - full scale							
<b>Digital</b>	Modbus RTU output standard, fully configurable, 2-wire RS-485, 1200 to 19.2k baud							
<b>Approvals</b>	65-2640RK UL	65-2641RK UL	c CSA US			c UL US		
	65-2640RK-05 c CSA US	65-2641RK-05 c CSA US						
<b>Controllers</b>	Compatible with all RKI Beacon controllers, as well as most DCS / PLC systems: Beacon 110, Beacon 200, Beacon 410, Beacon 800							
<b>Warranty</b>	One year material and workmanship							

# Non Explosion Proof

	O2 Oxygen	H2S Hydrogen Sulfide	CO Carbon Monoxide	Toxics See Chart Below	CO2 Carbon Dioxide
 Part#	65-2666RK *65-2644RK	65-2662RK	65-2663RK	See Chart Below	65-2661RK-02 65-2661RK-03 65-2661RK-05 65-2661RK-10
<b>Sensors</b>	Galvanic cell	Electrochemical			Infrared
<b>Measuring Ranges</b>	0-25% Vol.	0-100 ppm	0-300 ppm	See Chart Below	-02 0 - 5000 ppm -03 0 - 5% Vol. -05 0 - 50% Vol. -10 0 - 100% Vol.
<b>Resolution</b>	0.1% Vol.	1 ppm		See Chart Below	20 ppm / 0.1% Vol. / 1% Vol.
<b>Lower Detectable Limit (LDL)</b>	0.1% Vol.	2% of full scale			
<b>Response Time (T-90)</b>	35 Seconds or less			60 Seconds or less	30 Seconds or less
<b>Max Current Draw (24VDC)</b>	125 mA with alarm 1 and alarm 2 active and all relays energized				
<b>Life Expectancy</b>	2 to 3 years with normal service				5 years plus
<b>Accuracy</b> (which ever is greater)	± 0.5% Vol. O2	± 5% of reading or ± 2 ppm H2S	± 5% of reading or ± 5 ppm CO	± 10% of reading or ± 5% of full scale	± 5% of reading or ± 2% of full scale
<b>Alarms</b>					
<b>Alarm Settings</b>	Two fully programmable alarm set points, increasing / decreasing, latching / self-resetting, on delays, off delays, normally energized or de-energized,				
<b>Alarm Indication</b>	Visual LEDs. Alarm 1=Amber; Alarm 2=Red; Fail=Red				
<b>Relays</b>	5 Amp form 'C' contacts for alarm 1, alarm 2, and fail				
<b>Physical</b>					
<b>Dimensions</b>	Height: 8.5" (215 mm), Width: 5.2" (132 mm), Depth: 4.5" (114 mm)				
<b>Display</b>	Alphanumeric OLED display. 8 characters per line; 2 lines for gas concentration readout, plus user-friendly calibration and setup				
<b>Sensor Rating</b>	Non explosion proof construction, designed for Class I, Div. 2, Groups B, C, D (no certification)				
<b>Housing J-Box</b>	NEMA 4X, explosion proof, watertight, cast aluminum with o-ring seal and epoxy powder coating				
<b>Controls</b>	Magnet used for calibration functions. Calibrates without opening the housing. Internal push-button controls also available for calibration and setup				
<b>Sensor</b>	Aluminum / Plastic (non explosion proof)				
<b>Operating Environment</b>					
<b>Operating Temperature</b>	-4°F to 113°F -20°C to 45°C	-40°F to 104°F -40°C to 40°C	23°F to 104°F -5°C to 40°C	14°F to 104°F -10°C to 40°C	-40°F to 122°F -40°C to 50°C
<b>Relative Humidity</b>	5 - 95% RH non-condensing				
<b>Location</b>	Indoor or outdoor				
<b>Operating Voltage</b>	10 VDC - 30 VDC				
<b>Outputs</b>					
<b>Analog</b>	Linear 4-20 mA signal, into 1000 ohms impedance max (24DC), 0 - 500 ohms max (12VDC) corresponding to 0 - full scale				
<b>Digital</b>	Modbus RTU output standard, fully configurable, 2-wire RS-485, 1200 to 19.2k baud				
<b>Controllers</b>	Compatible with all RKI Beacon controllers, as well as most DCS / PLC systems: Beacon 110, Beacon 200, Beacon 410, Beacon 800				
<b>Warranty</b>	One year materials and workmanship				

\* Partial pressure sensor for helium applications. Consult factory for details.

	M2A Toxic Transmitter Sensor Ordering Information			
	Part Number With J-Box	Gas	Range	Resolution
	65-2648RK-AsH3	Arsine (AsH3)	0 - 1.5 ppm	0.01 ppm
	65-2648RK-NH3	Ammonia (NH3)	0 - 75.0 ppm	0.1 ppm
	65-2648RK-PH3	Phosphine (PH3)	0 - 1.00 ppm	0.01 ppm
	65-2648RK-HCN	Hydrogen Cyanide (HCN)	0 - 15.0 ppm	0.1 ppm
	65-2648RK-SO2	Sulfur Dioxide (SO2)	0 - 6.00 ppm	0.01 ppm

# AVAILABLE ACCESSORIES



AC power supply



Remote horns & lights



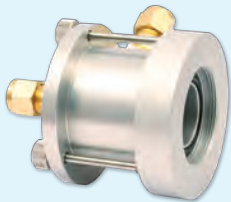
Air aspirator adaptors / panels



Calibration adaptors



Splash guards



Flow through adaptors



Dataloggers



Calibration kits

## Direct Interface with Beacon 110 / 200 / 410 / 800 Controllers

M2A Wiring Matrix				
	Number of Wires to Controller	Maximum Distance to Controller		
		18 AWG wire	16 AWG wire	14 AWG wire
M2A Transmitter	3	2500 ft.	5,000 ft.	8,000 ft.



Made in the USA

Authorized Distributor:





**INSTRUMENTS**

# **M2A Transmitter Operator's Manual**

**Part Number: 71-0305RK**

**Revision: C**

**Released: 9/8/15**

## **WARNING**

Read and understand this instruction manual before operating instrument. Improper use of the gas monitor could result in bodily harm or death.

Periodic calibration and maintenance of the gas monitor is essential for proper operation and correct readings. Please calibrate and maintain this instrument regularly! Frequency of calibration depends upon the type of use you have and the sensor types. Typical calibration frequencies for most applications are between 3 and 6 months, but can be required more often or less often based on your usage.



---

## Product Warranty

RKI Instruments, Inc. warrants gas alarm equipment sold by us to be free from defects in materials, workmanship, and performance for a period of one year from date of shipment from RKI Instruments, Inc. Any parts found defective within that period will be repaired or replaced, at our option, free of charge. This warranty does not apply to those items which by their nature are subject to deterioration or consumption in normal service, and which must be cleaned, repaired, or replaced on a routine basis. Examples of such items are:

- a) Absorbent cartridges
- b) Pump diaphragms and valves
- c) Fuses
- d) Batteries
- e) Filter elements

Warranty is voided by abuse including mechanical damage, alteration, rough handling, or repair procedures not in accordance with the operator's manual. This warranty indicates the full extent of our liability, and we are not responsible for removal or replacement costs, local repair costs, transportation costs, or contingent expenses incurred without our prior approval.

*THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY AND ALL OTHER WARRANTIES AND REPRESENTATIONS, EXPRESSED OR IMPLIED, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF RKI INSTRUMENTS, INC. INCLUDING BUT NOT LIMITED TO, THE WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL RKI INSTRUMENTS, INC. BE LIABLE FOR INDIRECT, INCIDENTAL, OR CONSEQUENTIAL LOSS OR DAMAGE OF ANY KIND CONNECTED WITH THE USE OF ITS PRODUCTS OR FAILURE OF ITS PRODUCTS TO FUNCTION OR OPERATE PROPERLY.*

This warranty covers instruments and parts sold to users by authorized distributors, dealers, and representatives as appointed by RKI Instruments, Inc.

We do not assume indemnification for any accident or damage caused by the operation of this gas monitor, and our warranty is limited to the replacement of parts or our complete goods.

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(Appendix C available from RKI Instruments, Inc. Not included in manual as normally provided with M2A detector head.)	

# Chapter 1: Introduction

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## Overview

This chapter briefly describes the M2A Transmitter. This chapter also describes the *M2A Transmitter Operator's Manual* (this document). Table 1 at the end of this chapter lists the specifications for the M2A.

---

## About the M2A Transmitter

The M2A transmitter is a fixed mount, continuous-monitoring detector head. All user adjustable parameters may be accessed using push button switches. In addition, calibration may be performed non-intrusively by use of a magnetic wand accessory which activates magnetic switches through a window at the front face of the detector head.

The M2A displays the current gas reading on an OLED display which is visible through the window in the cover (front face) and provides a 4 - 20 mA signal which indicates the target gas reading for use by a gas monitoring controller, recording device, or programmable controller. The M2A also provides an RS-485 Modbus output. Three sets of relay contacts, two controlled by the gas alarms and one by the fail alarm, rated at 115 VAC 5 amps are available for controlling devices such as lights or horns or for controlling higher rated relays.

Four operating modes allow you to display and change setup and calibration settings and change the gas type. They are Calibration Mode, Configuration Mode, Gas Type Mode, and Modbus Mode.

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## About this Manual

The *M2A Transmitter Operator's Manual* uses the following conventions for notes, cautions, and warnings.

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**NOTE:** Describes additional or critical information.

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**CAUTION:** Describes potential damage to equipment.

---

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**WARNING:** Describes potential danger that can result in injury or death.

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## Specifications

Table 1 lists specifications for the M2A.

**Table 1: M2A Specifications**

Target Gas/Detection Range	<p><b><u>Combustible Gas/Carbon Dioxide (CO<sub>2</sub>)</u></b></p> <ul style="list-style-type: none"> <li>Catalytic LEL: 0 - 100% LEL, 1% LEL increments (CH<sub>4</sub> calibration unless otherwise specified. H<sub>2</sub> specific detector available)</li> <li>IR (infrared) CH<sub>4</sub> LEL: 0 - 100% LEL, 1% LEL increments</li> <li>IR HC LEL: 0 - 100% LEL, 1% LEL increments (propane calibration)</li> <li>IR CH<sub>4</sub> Volume: 0 - 100 % volume, 1% increments</li> <li>IR CO<sub>2</sub> ppm: 0 - 5,000 ppm, 20 ppm increments</li> <li>IR CO<sub>2</sub> Volume: 0 - 5.00 % volume, 0.01% increments</li> <li>IR CO<sub>2</sub> Volume: 0 - 50.0 % volume, 0.1% increments</li> <li>IR CO<sub>2</sub> Volume: 0 - 100 % volume, 1% increments</li> </ul> <p><b><u>Oxygen</u></b></p> <ul style="list-style-type: none"> <li>Oxygen (O<sub>2</sub>): 0 - 25.0 % volume, 0.1% increments</li> </ul> <p><b><u>CO/H<sub>2</sub>S</u></b></p> <ul style="list-style-type: none"> <li>Carbon Monoxide (CO): 0 - 300 ppm, 1 ppm increments</li> <li>Carbon Monoxide (CO): 0 - 200 ppm, 1 ppm increments</li> <li>Carbon Monoxide (CO): 0 - 100 ppm, 1 ppm increments</li> <li>Hydrogen Sulfide (H<sub>2</sub>S): 0 - 100 ppm, 1 ppm increments</li> </ul> <p><b><u>ESM-01 Toxic</u></b></p> <ul style="list-style-type: none"> <li>Ammonia (NH<sub>3</sub>): 0 - 75.0 ppm, 0.1 ppm increments</li> <li>Arsine (AsH<sub>3</sub>): 0 - 1.50 ppm, 0.01 ppm increments</li> <li>Chlorine (Cl<sub>2</sub>): 0 - 3.00 ppm, 0.01 ppm increments</li> <li>Chlorine (Cl<sub>2</sub>): 0 - 10.0 ppm, 0.1 ppm increments</li> <li>Hydrogen Cyanide (HCN): 0 - 15.0 ppm, 0.1 ppm increments</li> <li>Phosphine (PH<sub>3</sub>): 0 - 1.00 ppm, 0.01 ppm increments</li> <li>Sulphur Dioxide (SO<sub>2</sub>): 0 - 6.00 ppm, 0.01 ppm increments</li> </ul>
Alarm Settings (Alarm 1/Alarm 2)	<p><b>Combustible Gas (%LEL):</b> 10 %LEL/50 %LEL  <b>Combustible Gas (%Volume):</b> 100 %/100 %  <b>CO<sub>2</sub> 0 - 5,000 ppm:</b> 2,500 ppm/5,000 ppm  <b>CO<sub>2</sub> 0 - 5.00%:</b> 0.50 %/3.00 %  <b>CO<sub>2</sub> 0 - 50.0%:</b> 50.0%/50.0%  <b>CO<sub>2</sub> 0 - 100%:</b> 100%/100%  <b>Oxygen:</b> 19.5%(decreasing)/23.5%(increasing)  <b>Carbon Monoxide (all ranges):</b> 25 ppm/50 ppm  <b>Hydrogen Sulfide:</b> 10 ppm/50 ppm  <b>Ammonia:</b> 12 ppm/25 ppm  <b>Arsine:</b> 0.20 ppm/0.50ppm  <b>Chlorine (0 - 3.00 ppm):</b> 0.50 ppm/1.50 ppm  <b>Chlorine (0 - 10.0 ppm):</b> 1.0 ppm/3.0 ppm  <b>Hydrogen Cyanide:</b> 5.0 ppm/10.0 ppm  <b>Phosphine:</b> 0.10 ppm/0.30 ppm  <b>Sulphur Dioxide:</b> 1.00 ppm/2.00 ppm</p>
Construction (housing)	Explosion-proof Junction Box, NEMA 4X
Area Classification	Explosion-proof for Class I, Groups B, C, and D (Combustible, CO <sub>2</sub> , CSA Type CO and H <sub>2</sub> S, and CSA Type oxygen)

**Table 1: M2A Specifications**

Sampling Method	Diffusion		
Input Power	10 - 30 VDC		
Controls	<ul style="list-style-type: none"> <li>• Three push button switches</li> <li>• Three magnetic switches for non-intrusive calibration</li> </ul>		
Weight	4.5 lbs.		
Signal Output	<ul style="list-style-type: none"> <li>• 4 to 20 mA with impedance maximums listed below <ul style="list-style-type: none"> <li>-12 VDC input: 500 ohms impedance max</li> <li>-24 VDC input: 1000 ohms impedance max</li> </ul> </li> <li>• RS-485 Modbus</li> </ul>		
		<b>Explosion Proof</b>	<b>Non-Explosion Proof</b>
Operating Temperature	<b>LEL</b>	-40°C to 75°C	N/A
	<b>Oxygen</b>	-20°C to 45°C	-20°C to 50°C
	<b>H<sub>2</sub>S</b>	-40°C to 40°C	-40°C to 50°C
	<b>CO</b>	-5°C to 40°C	-20°C to 50°C
	<b>Toxic (ESM-01)</b>	N/A	-10°C to 40°C
	<b>Infrared LEL</b>	-20°C to 50°C	-40°C to 50°C
	<b>Infrared CO<sub>2</sub></b>	-20°C to 50°C	-40°C to 50°C
Accuracy	<p><u>Catalytic Combustible Gas:</u> ± 5% of reading or ± 2% LEL (whichever is greater)</p> <p><u>IR Combustible Gas/IR CO<sub>2</sub>:</u> ± 5% of reading or ± 2% of full scale (whichever is greater)</p> <p><u>Oxygen:</u> ± 0.5% O<sub>2</sub></p> <p><u>Hydrogen Sulfide:</u> ± 5% of reading or ± 2 ppm H<sub>2</sub>S (whichever is greater)</p> <p><u>Carbon Monoxide:</u> ± 5% of reading or ± 5 ppm CO (whichever is greater)</p> <p><u>ESM-01 Toxic Sensors:</u> ± 10% of reading or ± 5% of full scale (whichever is greater)</p>		
<p>* These are the RKI factory settings. You can change the alarm settings in Configuration Mode. See “Viewing &amp; Changing M2A Parameters” on page 31.</p>			

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**WARNING:** *When using the M2A, you must follow the instructions and warnings in this manual to assure proper and safe operation of the M2A and to minimize the risk of personal injury. Be sure to maintain and periodically calibrate the M2A as described in this manual.*

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# Chapter 2: Description

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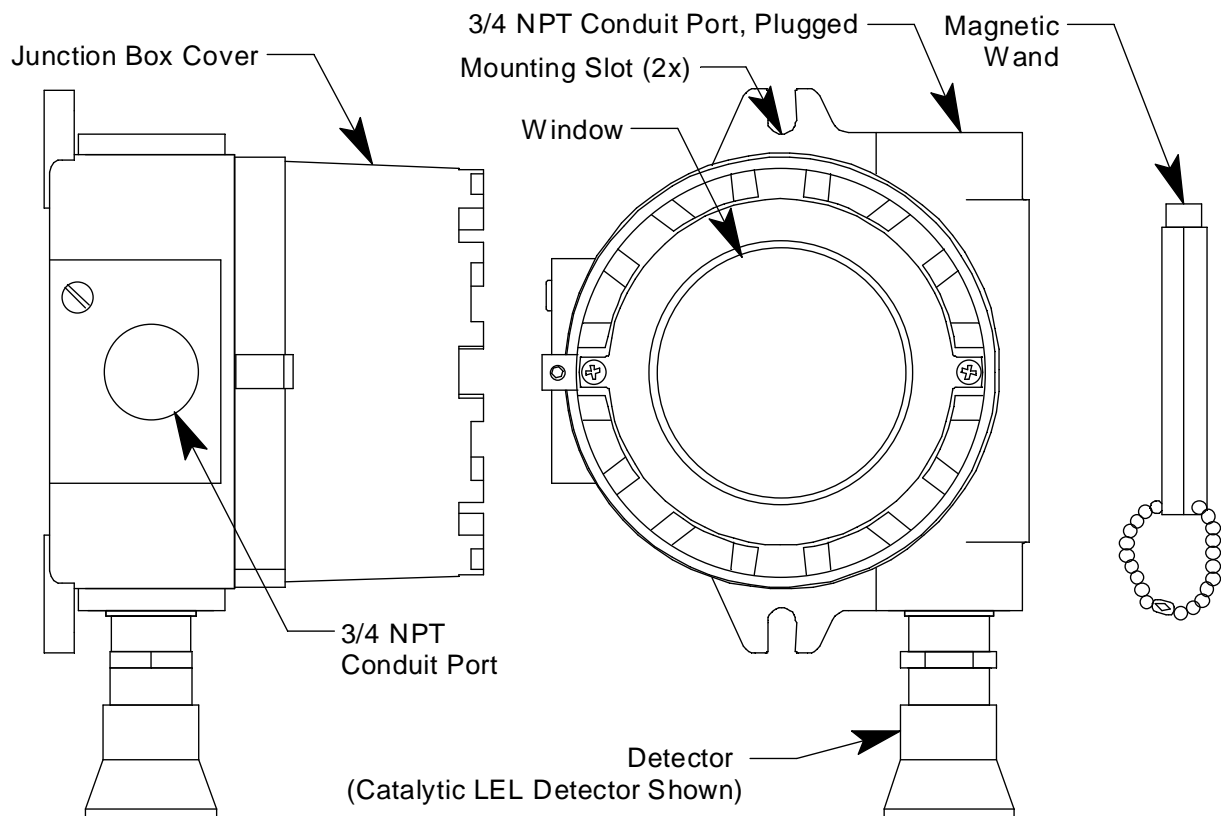
## Overview

This chapter describes external and internal components of the M2A Transmitter.

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## External Description

This section describes the junction box and all external components of the M2A transmitter.



**Figure 1: M2A External Components**

### Junction Box

The M2A's cast aluminum junction box is dust and weather resistant. The junction box also protects the M2A and all connections made to it. Use the three 3/4 in. conduit ports to mount the detector to the junction box (factory installed in the bottom port) and connect wiring from an external device (left port). The top port is shipped with a factory installed and sealed conduit plug to avoid leaks into the junction box. If necessary, the conduit plug can be removed and the top port can be used for wiring.

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**WARNING:** *If the top conduit port is used for wiring, be sure to seal the threads to ensure water does not enter the junction box. See “Wiring the M2A Transmitter” on page 18 for complete wiring instructions.*

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Use the junction box's two mounting holes to mount the M2A to a vertical surface at the monitoring site. The window in the cover on the front of the junction box allows you to view the OLED display and use the magnetic wand to actuate the magnetic control switches so you can perform non-intrusive calibration. Removing the cover allows you to access the interior of the junction box.

## Magnetic Wand

The magnetic wand is a short plastic rod with a magnet in one end. It is used to actuate the magnetic control switches on the control PCB while the junction box cover is still installed so that non-intrusive calibration can be performed.

## Gas Detector

The gas detector senses the target gas and is mounted in a 3/4" conduit port on the right bottom side of the M2A. A variety of detectors may be used with the M2A. Table 2 below lists the detectors that can be used with the M2A.

**Table 2: M2A Detectors**

Target Gas, Range	Detector(s) Used
Combustible Gas, 0 - 100% LEL	<ul style="list-style-type: none"> <li>61-0140RK (Catalytic UL version)</li> <li>61-0140RK-05 (Catalytic CSA version)</li> </ul>
Hydrogen, 0 - 100% LEL	<ul style="list-style-type: none"> <li>NC-6205-01 (Catalytic UL version, hydrogen specific)</li> <li>NC-6205-05 (Catalytic CSA version, hydrogen specific)</li> </ul>
CH <sub>4</sub> , 0 - 100% LEL	<ul style="list-style-type: none"> <li>61-0190RK-CH4 (IR UL)</li> </ul>
HC, 0 - 100% LEL (cal. to propane)	<ul style="list-style-type: none"> <li>61-0190RK-HC (IR UL)</li> </ul>
CH <sub>4</sub> , 0 - 100% volume	<ul style="list-style-type: none"> <li>61-0192RK-CH4 (IR UL)</li> </ul>
CO <sub>2</sub> , 0 - 5,000 ppm	<ul style="list-style-type: none"> <li>61-0191RK-02 (IR UL)</li> <li>61-0198RK-02 (IR)</li> </ul>
CO <sub>2</sub> , 0 - 5%	<ul style="list-style-type: none"> <li>61-0191RK-03 (IR UL)</li> <li>61-0198RK-03 (IR)</li> </ul>
CO <sub>2</sub> , 0 - 50%	<ul style="list-style-type: none"> <li>61-0191RK-05 (IR UL)</li> <li>61-0198RK-05 (IR)</li> </ul>
CO <sub>2</sub> , 0 - 100%	<ul style="list-style-type: none"> <li>61-0191RK-10 (IR UL)</li> <li>61-0198RK-10 (IR)</li> </ul>
Oxygen, 0 - 25%	<ul style="list-style-type: none"> <li>65-2494RK (capillary)</li> <li>65-2510RK (partial pressure)</li> <li>65-2511RK (capillary)</li> <li>65-2514RK (capillary, CSA)</li> </ul>
CO, 0 - 300 ppm	<ul style="list-style-type: none"> <li>65-2438 (CSA)</li> <li>65-2496RK</li> </ul>
CO, 0 - 200 ppm	<ul style="list-style-type: none"> <li>65-2438-01</li> </ul>
CO, 0 - 100 ppm	<ul style="list-style-type: none"> <li>65-2438-01</li> </ul>
H <sub>2</sub> S, 0 - 100 ppm	<ul style="list-style-type: none"> <li>65-2428 (CSA)</li> <li>65-2495RK</li> </ul>

**Table 2: M2A Detectors**

Target Gas, Range	Detector(s) Used
NH <sub>3</sub> , 0 - 75 ppm	• 65-2300RK-NH3
AsH <sub>3</sub> , 0 - 1.5 ppm	• 65-2300RK-ASH3
Cl <sub>2</sub> , 0 - 3 ppm	• 65-2300RK-CL2
Cl <sub>2</sub> , 0 - 10 ppm	• 65-2300RK-CL-10
PH <sub>3</sub> , 0 - 1 ppm	• 65-2300RK-PH3
SO <sub>2</sub> , 0 - 6 ppm	• 65-2300RK-SO2

**Catalytic LEL Detectors**

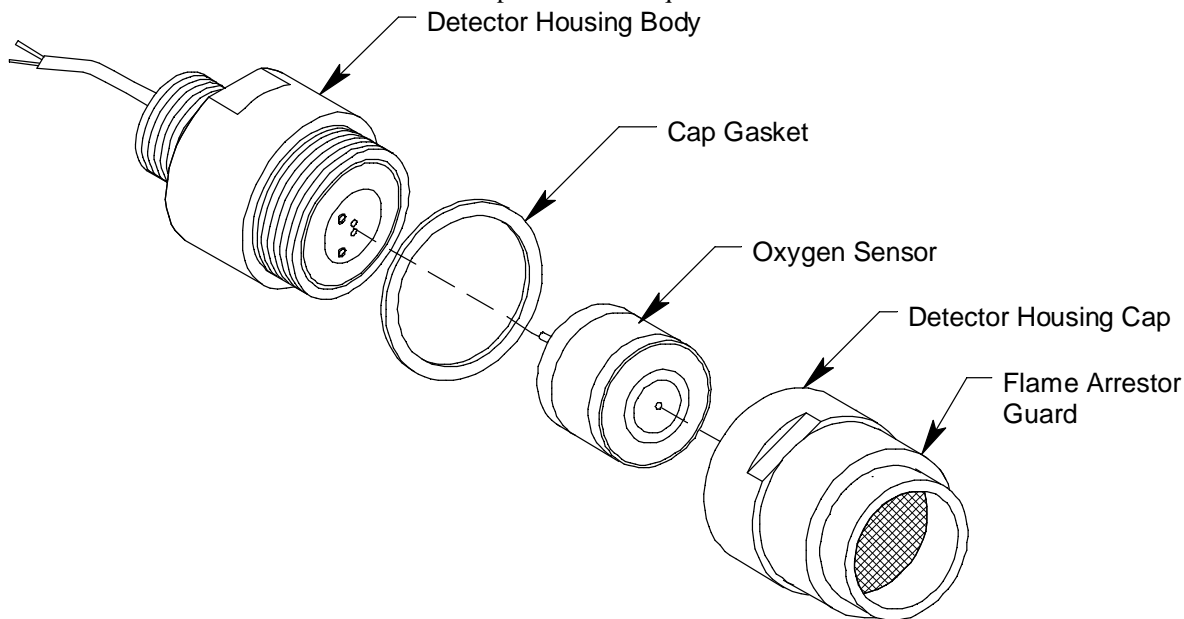
The catalytic LEL detectors have a 1/2" NPT thread and require a 3/4"NPT x 1/2"NPT reducer to install in the detector port. The rest of the detectors have a 3/4" NPT mounting thread and are installed directly in the detector port.

**IR Detectors**

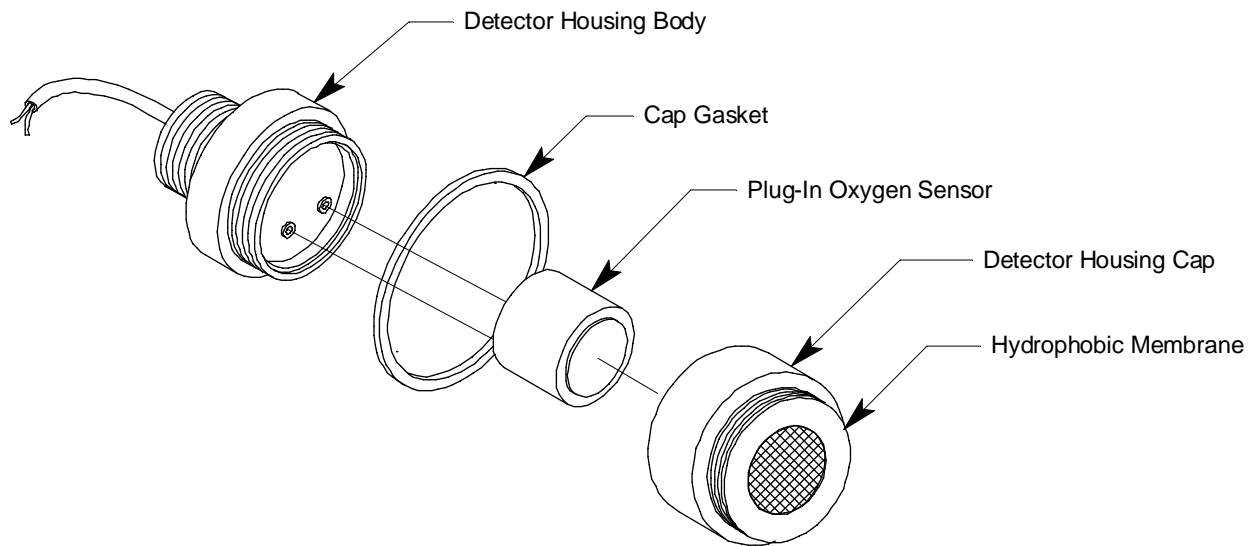
The IR combustible detectors are generally used instead of the catalytic combustible detectors in applications where there may be catalyst poisons such as silicone present or where oxygen is not present in the monitoring environment.

**Oxygen Detectors**

There are four types of oxygen detectors available, a non-explosion proof partial pressure type, a non-explosion proof capillary type, a non-explosion proof capillary type with a replaceable sensor, and an explosion proof (CSA) capillary type with a replaceable sensor. The capillary type's output is less susceptible to variations in atmospheric pressure than the partial pressure type. The CSA type oxygen detector (65-2514RK) and one of the non-explosion proof capillary type detectors (65-2494RK) have a replaceable plug-in sensor inside the detector housing while the entire oxygen detector must be removed if replacement is required for the other two.

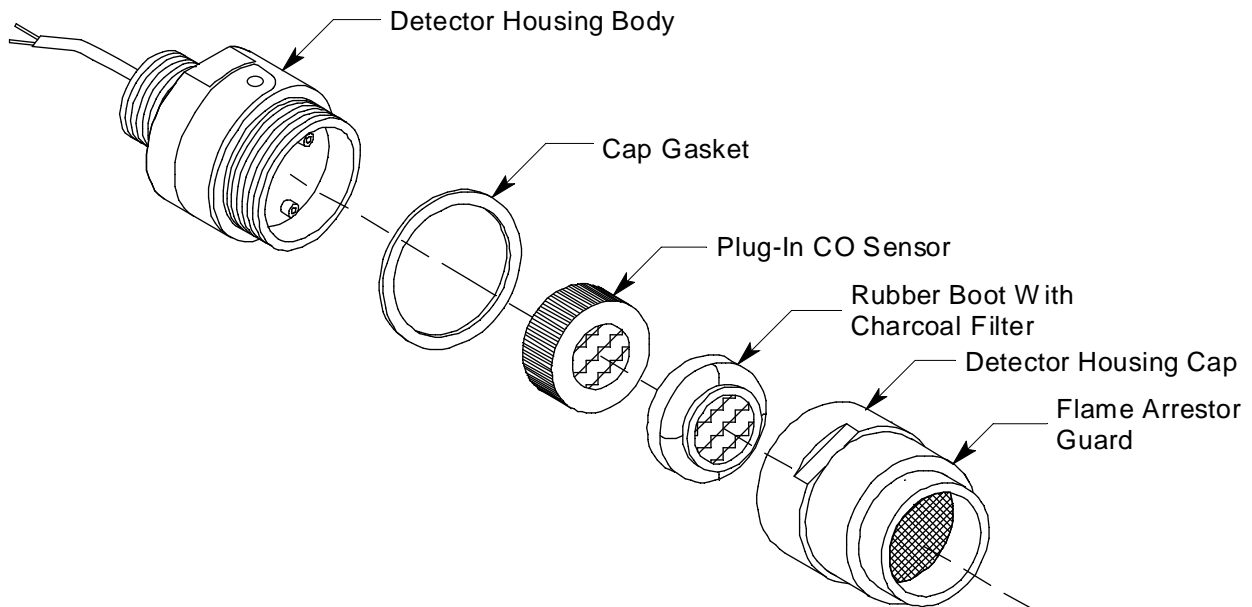


**Figure 2: 65-2514RK Oxygen Detector, CSA**

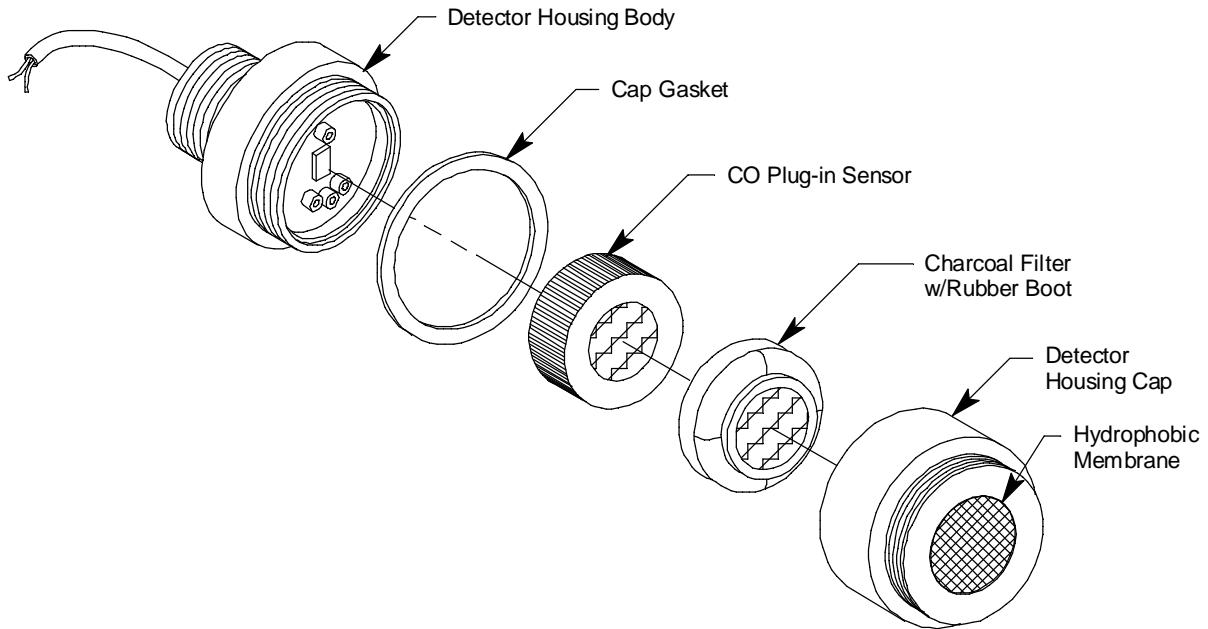


**Figure 3: 65-2494RK Oxygen Detector, Non-Explosion Proof, Capillary Type  
CO and H<sub>2</sub>S Detectors**

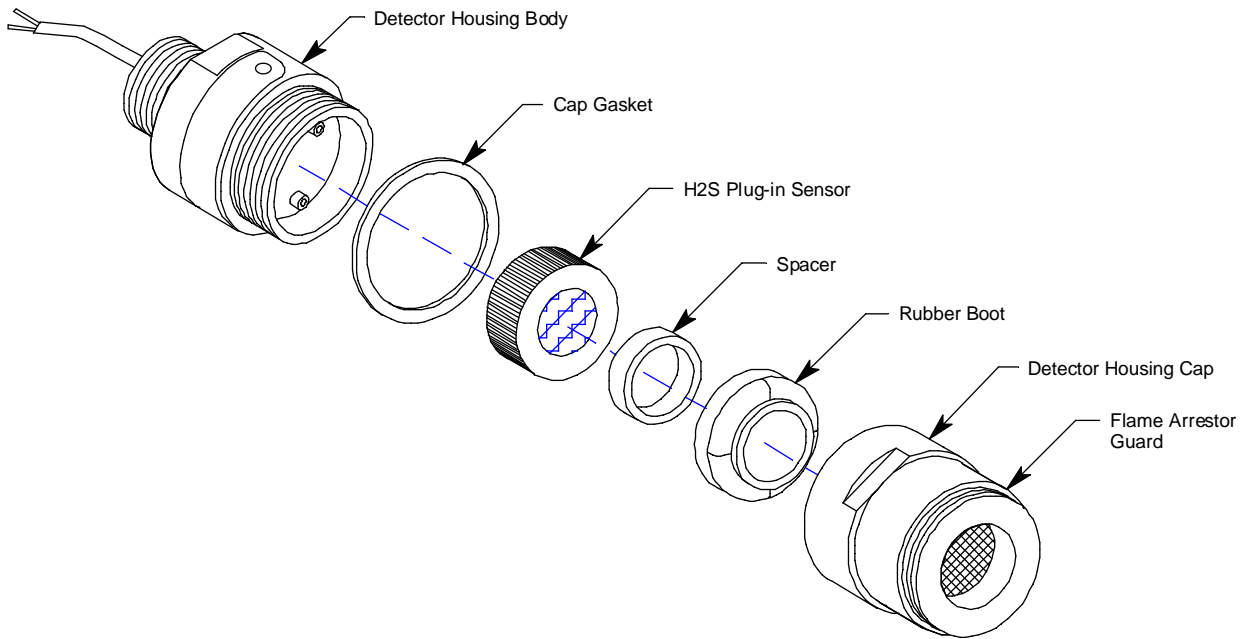
Both types of CO and H<sub>2</sub>S detectors have replaceable plug-in sensors inside the detector housing. The CO detector includes a charcoal filter disk which is held onto the sensor with a rubber retaining boot. The charcoal filter disk scrubs out interfering gases to which the CO sensor responds such as H<sub>2</sub>S and certain hydrocarbons. The 65-2428 explosion-proof H<sub>2</sub>S detector includes a rubber boot and a spacer which help ensure that the sensor remains plugged into the detector housing body. The 65-2495RK non-explosion-proof H<sub>2</sub>S detector includes an adhesive backed gasket inside the detector housing cap which helps ensure that the sensor remains plugged into the detector housing body.



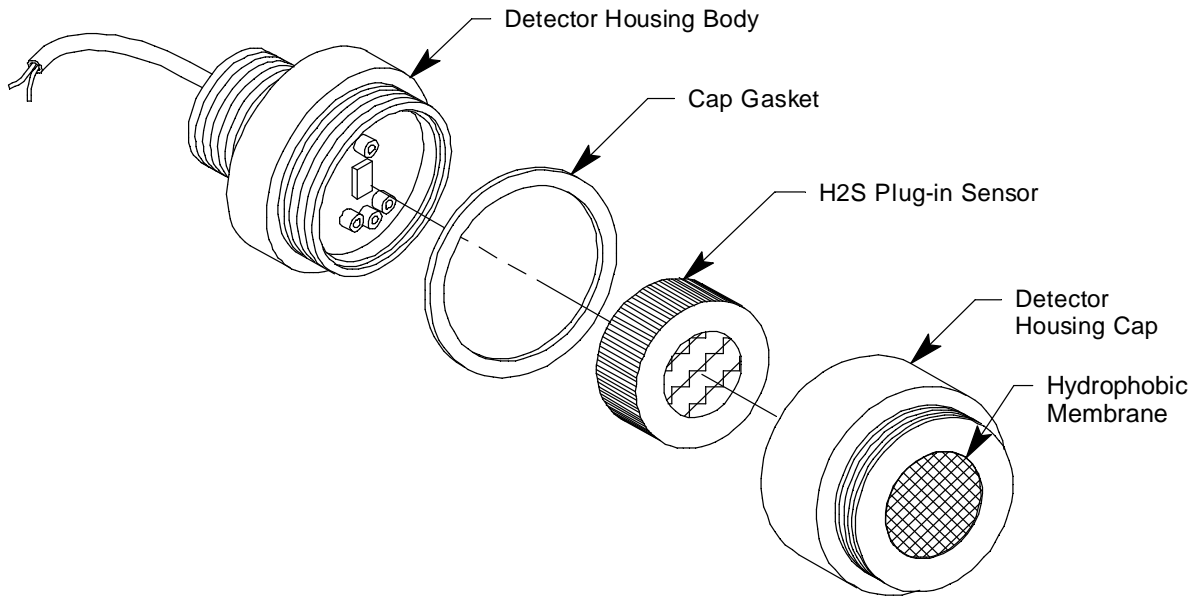
**Figure 4: 65-2438 and 65-2438-01 CO Detector, CSA**



**Figure 5: 65-2496RK CO Detector Non-Explosion Proof**



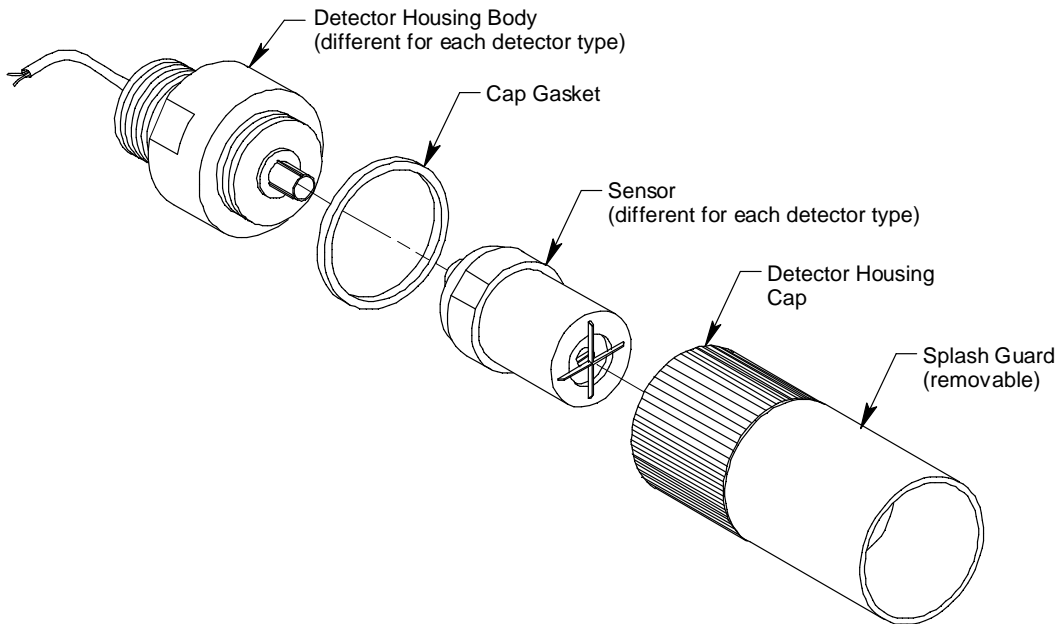
**Figure 6: 65-2428 H<sub>2</sub>S Detector, CSA**



**Figure 7: 65-2495RK H<sub>2</sub>S Detector Non-Explosion Proof**

***ESM-01 Detectors***

The construction of the various ESM-01 detectors is similar. Each of the ESM-01 detectors has a different replaceable plug-in sensor that protrudes through the detector housing cap. Although ESM-01 detectors look the same except for the plug-in detector, the detector housing which includes the detector socket and conditioning circuitry is specific to a sensor type. For example, a detector housing from a Cl<sub>2</sub> detector cannot be used with an NH<sub>3</sub> detector. One of the two detector wires is color coded for each specific detector type. The ESM-01 detectors include a removable splashguard that screws onto the detector housing cap. When it is necessary to apply gas to an ESM-01 detector, remove the splashguard to allow access to the sensor that protrudes through the detector housing cap. You can then push the appropriate ESM-01 calibration cup onto the sensor.



**Figure 8: ESM-01 Type Detector**



## Internal Description

This section describes the internal components of the M2A. The internal components of the M2A include the terminal PCB which provides for all the wiring connections to the M2A and the control PCB which displays the gas reading and has the control buttons.

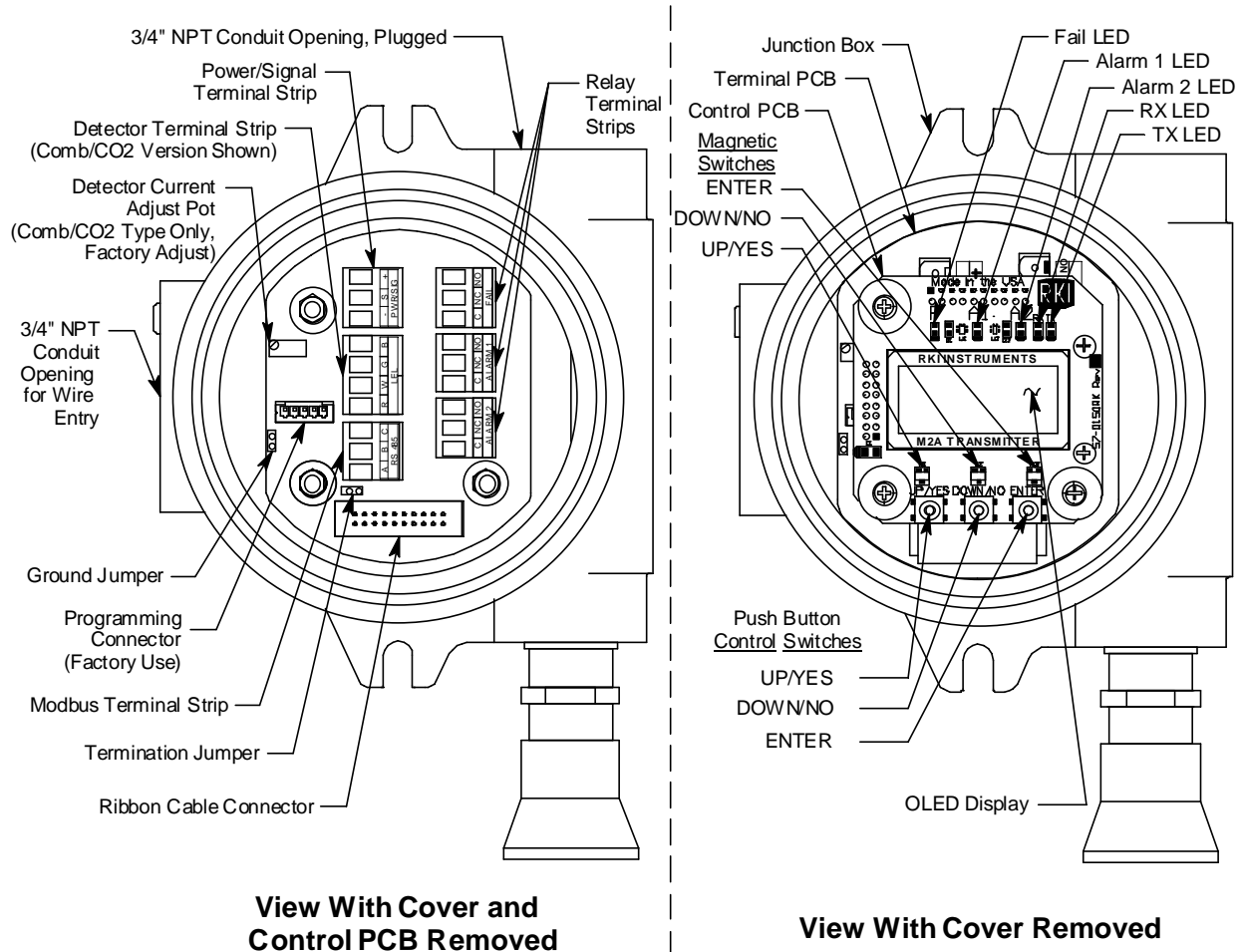


Figure 9: M2A Internal Components

### Terminal PCB

The terminal PCB is encapsulated in epoxy for protection against moisture and physical damage. It is mounted into the rear of the junction box with three standoffs and rests on a thin layer of foam. A banana jack is screwed into each of the standoffs and used for mounting the control PCB. The terminal PCB converts the electrical output from the detector to a signal which can be displayed by the OLED display, a 4 - 20 mA signal (that is proportional to the detection range), and an RS-485 Modbus output signal. The 4 - 20 mA signal may be used by a recording device, gas monitor controller, or programmable controller. The Modbus output may be used to connect the M2A to a Modbus network. The terminal PCB also controls three relays, one fail and two gas alarm relays.

Two columns of plug-in style terminal strips are used to make all wiring connections to the M2A. The column on the left consists of the power/signal, detector, and Modbus terminal strips. The column on the right consists of the relay terminal strips. A 20 position connector at the bottom of the terminal PCB is used to connect the terminal PCB to the control PCB with a ribbon cable. A 5 position connector on the left side of the terminal PCB is used by factory or field service personnel

to program the M2A. On the combustible and CO<sub>2</sub> versions of the M2A, a factory adjust pot just above the programming connector is used to set the detector current.

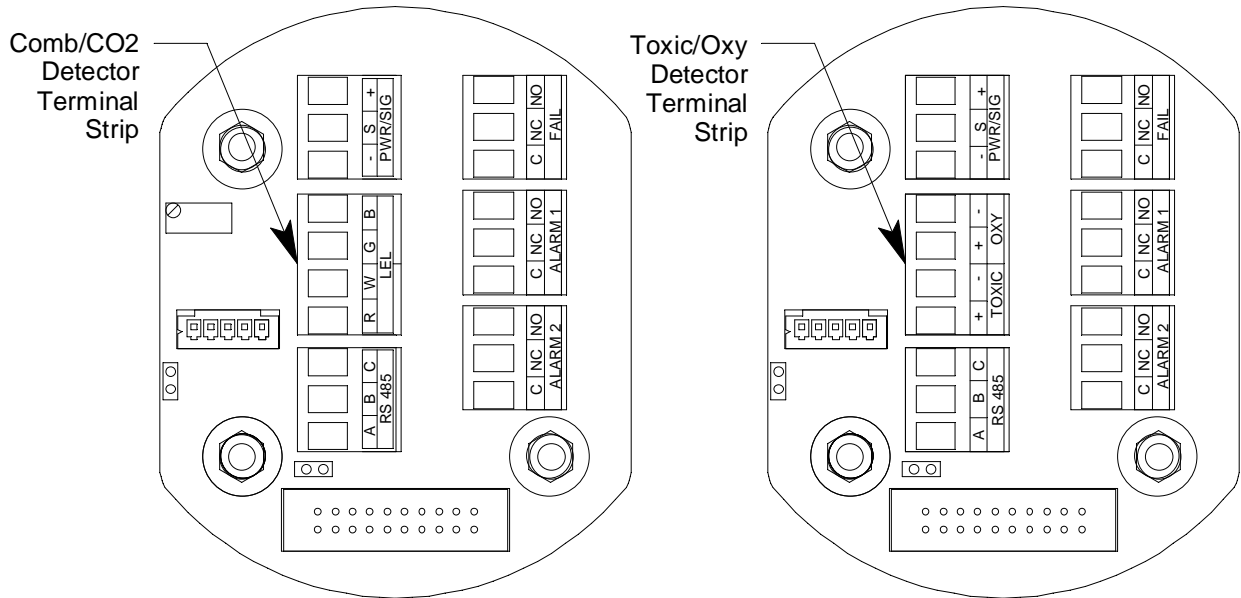
**Power/Signal Terminal Strip**

The power/signal terminal strip is a three position plug-in style terminal strip located at the top of the left terminal column. It is used to connect 24 VDC power to the M2A and to connect the 4 - 20 mA output signal to a device.

The signal output, the S terminal, does not have to be connected for the M2A to function. The S terminal is used if you want to connect the 4 - 20 mA output signal to another device such as a gas monitoring controller, chart recorder, or programmable controller (PLC).

**Detector Terminal Strip**

The detector terminal strip is a four position plug-in style terminal strip and is the middle terminal strip in the left terminal column. For a combustible or CO<sub>2</sub> M2A, all four terminals are used to connect the detector to the M2A. For a toxic or oxygen M2A, only two of the terminals are used for connecting a detector: two terminals are dedicated for connecting a toxic detector and two are dedicated for connecting an oxygen detector (only one detector can be installed).



**Figure 10: Detector Terminal Strip**

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**NOTE:** The detector is factory-wired to the M2A. See “Wiring the M2A Transmitter” on page 18 for all wiring procedures related to M2A.

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**Modbus Terminal Strip**

The Modbus terminal strip is a three position plug-in style terminal strip and is the bottom terminal strip in the left terminal column. It allows connection of the M2A into a Modbus network.

### **Relay Terminal Strips**

The right column of terminal strips consists of, from top to bottom, the fail, alarm 1, and alarm 2 relay terminal strips. They are three-position plug-in style terminal strips. The relay terminal strips are used to connect devices such as lights and horns that are controlled by the relay contacts. The relay contacts are rated at 115 VAC, 5 amps. The relay contacts may also be used to control higher rated relays.

### **Termination Jumper**

A two pin header with a termination jumper installed is located below the Modbus terminal strip. Leave this jumper installed unless directed to remove it for a Modbus installation. See “Chapter 8: RS-485 Modbus Output” on page 51 for a description of using the M2A in a Modbus system.

### **Ground Jumper**

A two pin header with a jumper installed is located along the left side of the terminal PCB. Leave this jumper installed unless directed to remove it for a Modbus installation. See “Chapter 8: RS-485 Modbus Output” on page 51 for a description of using the M2A in a Modbus system.

### **Control PCB**

The OLED display and control switches are located on the control PCB. It is installed on top of the terminal PCB by lining up its three spacing standoffs with the banana jacks in the terminal PCB mounting standoffs and pushing it onto the banana jacks. The jacks retain the control PCB.

#### **OLED Display**

The OLED display is located at the top of the control PCB. It indicates the current gas reading and displays messages and parameters in the M2A’s programs.

#### **Control Buttons**

The M2A includes three push button switches that allow you to enter the M2A’s operating modes, navigate through the modes, update settings, and save changes to the settings. The push button switches are located along the bottom edge of the control PCB (see Figure 9). The UP/YES button is on the left, the DOWN/NO button is in the middle, and the ENTER button is on the right.

**Table 3: M2A Control Button Functions**

<b>Switch</b>	<b>Function</b>
UP (YES)	<ul style="list-style-type: none"><li>• Saves settings</li><li>• Changes the displayed setting</li><li>• Enters the Calibration Program</li><li>• Enters Gas Type Mode (press with DOWN/NO button)</li><li>• Enters Configuration Mode (press with ENTER button)</li></ul>
DOWN (NO)	<ul style="list-style-type: none"><li>• Cancels setting changes</li><li>• Changes the displayed setting</li><li>• Enters Gas Type Mode (press with UP/YES button)</li><li>• Enters Modbus Mode (press with ENTER button)</li><li>• Displays the Information Screen</li></ul>
ENTER	<ul style="list-style-type: none"><li>• Initiates operations</li><li>• Enters Configuration Mode (press with UP/YES button)</li><li>• Enters Modbus Mode (press with DOWN/NO button)</li><li>• Functions as an alarm reset switch</li></ul>

Just above each push button switch is a magnetic switch with the same function as the push button

switch below it. The magnetic switches are for use in non-intrusive calibration. They are actuated by bringing the magnetic wand close enough to them to actuate them. Although the magnetic switches have the same functions as the push button switches, it is not practical to use them for operations other than calibration because it is not possible to actuate two magnetic switches at once with only one magnetic wand. Since displaying the Information Screen only requires the use of one switch, the wand may be used to show the Information Screen (see “Information Screen” on page 26).

### **Status LEDs**

The M2A includes five status LEDs that are located above the display (see Figure 9).

- Fail LED

The fail LED turns on when the M2A is experiencing a fail condition. A fail condition can be caused by a detector failure or low detector signal.

- Alarm 1 LED

The alarm 1 LED is on when the M2A is experiencing an alarm 1 condition.

- Alarm 2 LED

The alarm 2 LED is on when the M2A is experiencing an alarm 2 condition.

- RX & TX LED's

These LED's indicate data being received (RX) and transmitted (TX) when the M2A's Modbus output is operating.

# Chapter 3: Installation & Startup

## Overview

This chapter describes procedures to mount the M2A Transmitter in the monitoring environment and wire it to input power and devices.

## Mounting the M2A Transmitter

1. Select a mounting site that is representative of the monitoring environment. Consider the following when you select the mounting site.
  - Select a site where the M2A is not likely to be bumped or disturbed. Make sure there is sufficient room to perform start-up, maintenance, and calibration procedures.
  - Select a site where the target gas is likely to be found first. For lighter gases, mount the detector near the ceiling; for heavier gases, mount the detector near the floor.
2. At the monitoring site, use #10 screws through the junction box's two mounting holes to secure the junction box to a vertical surface. Figure 11 - Figure 16 show the outline and mounting dimensions for each version of the M2A. Mount the M2A with the detector facing down as shown in the following figures.

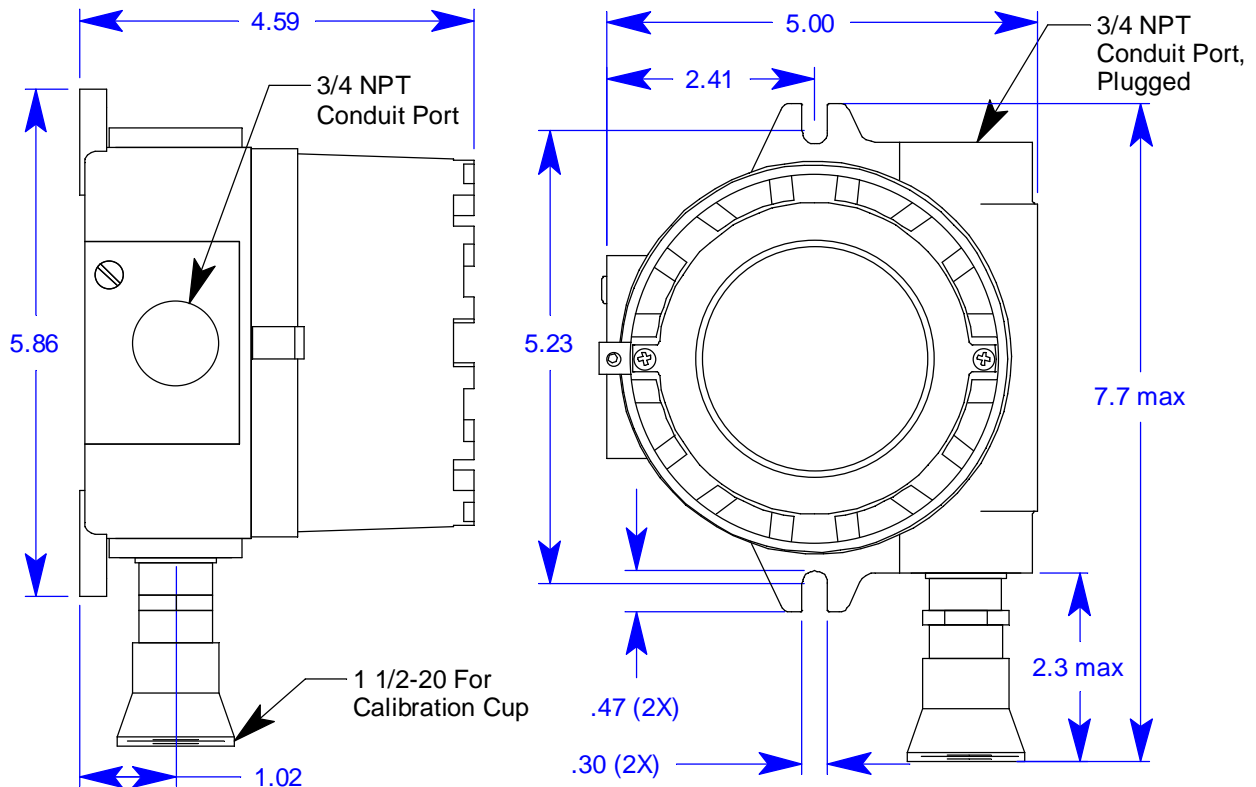


Figure 11: Outline & Mounting Dimensions, Catalytic LEL

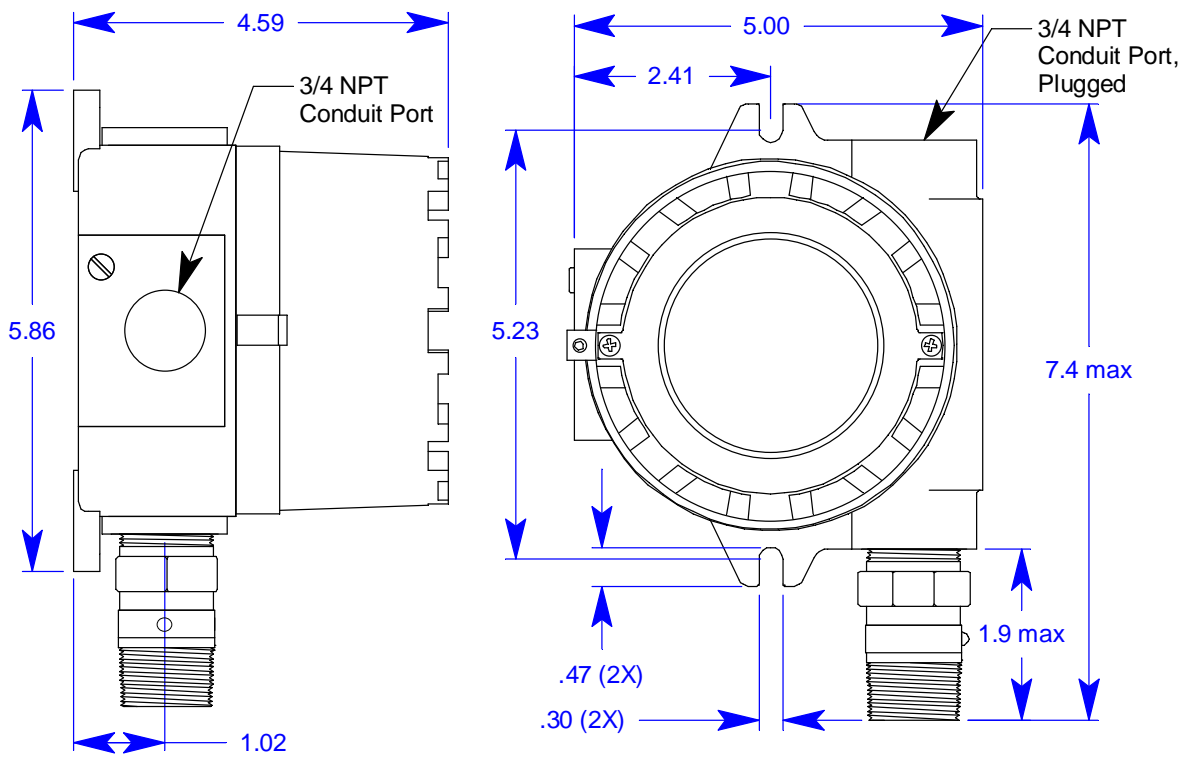


Figure 12: Outline & Mounting Dimensions, IR Combustible & CO<sub>2</sub>

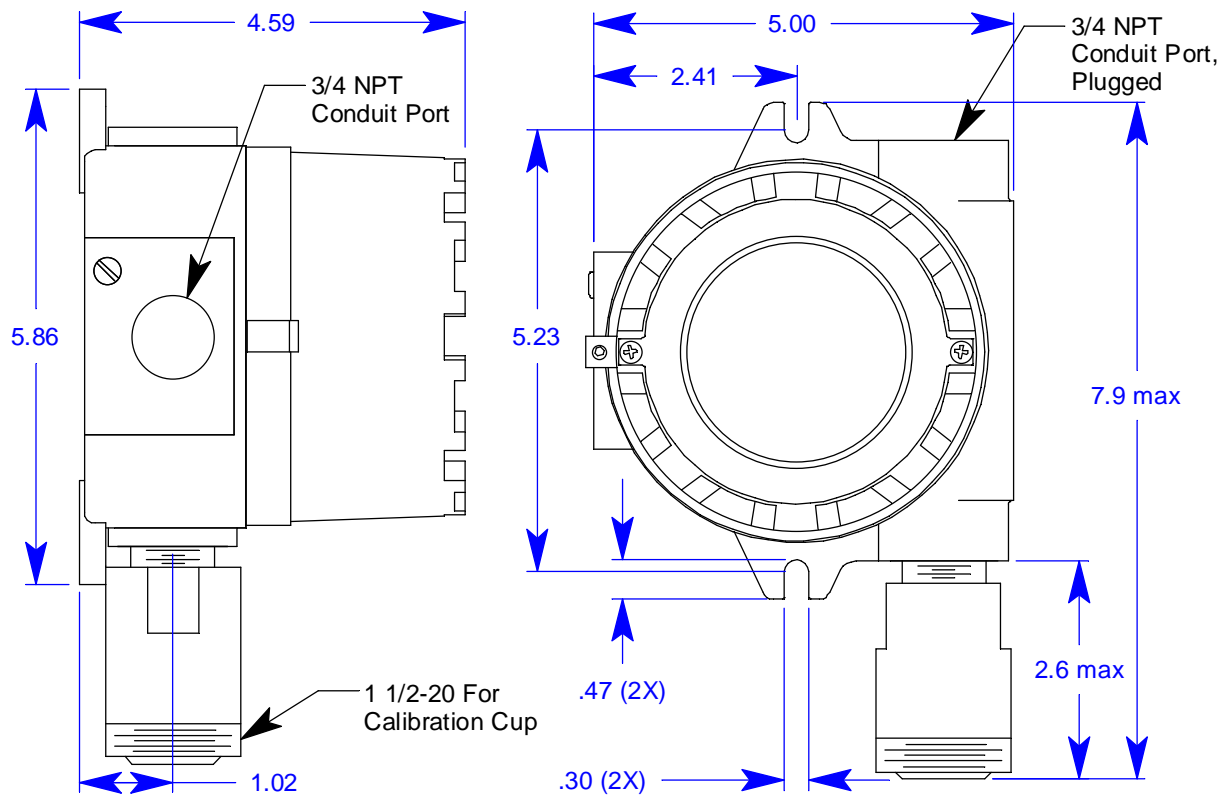
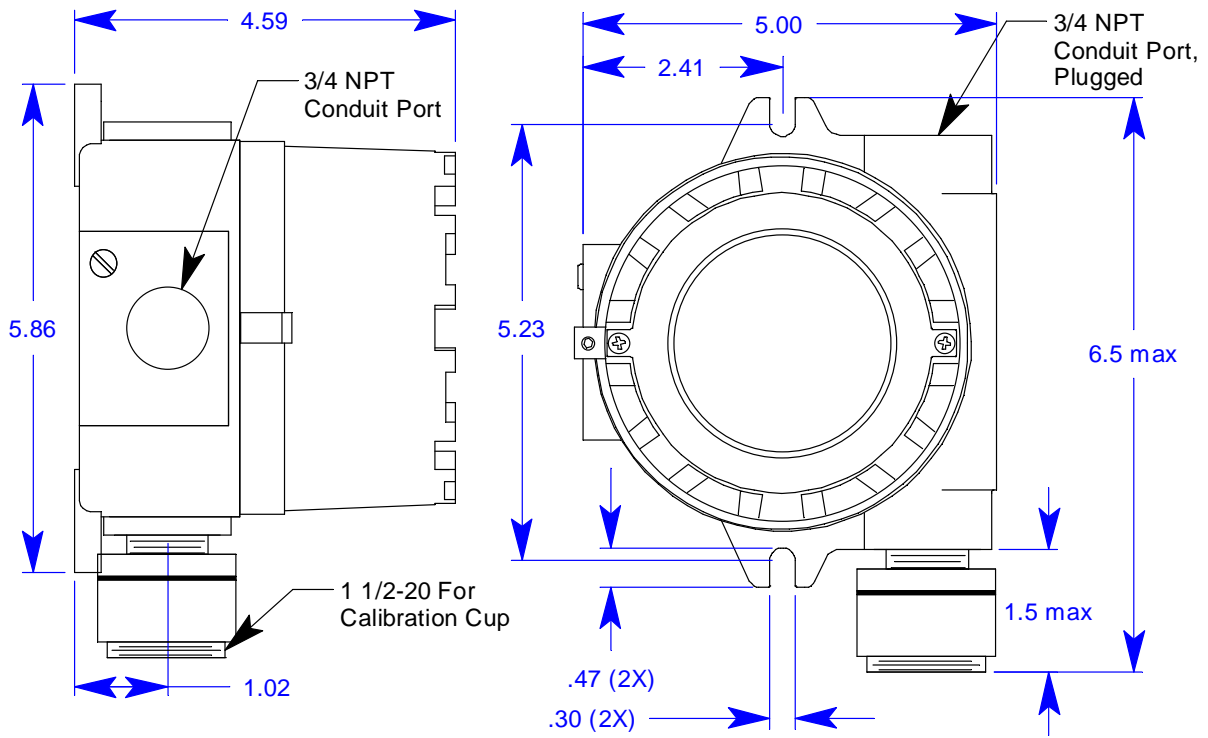
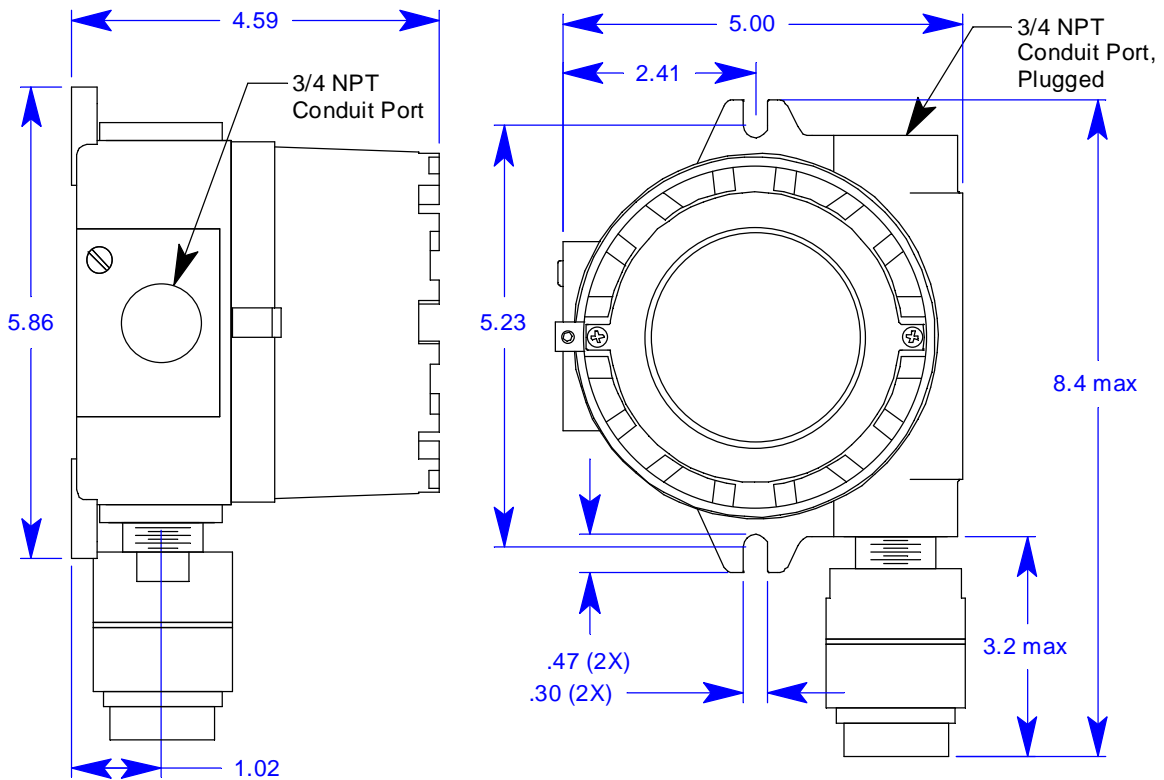


Figure 13: Outline & Mounting Dimensions, Oxygen, Partial Pressure Type

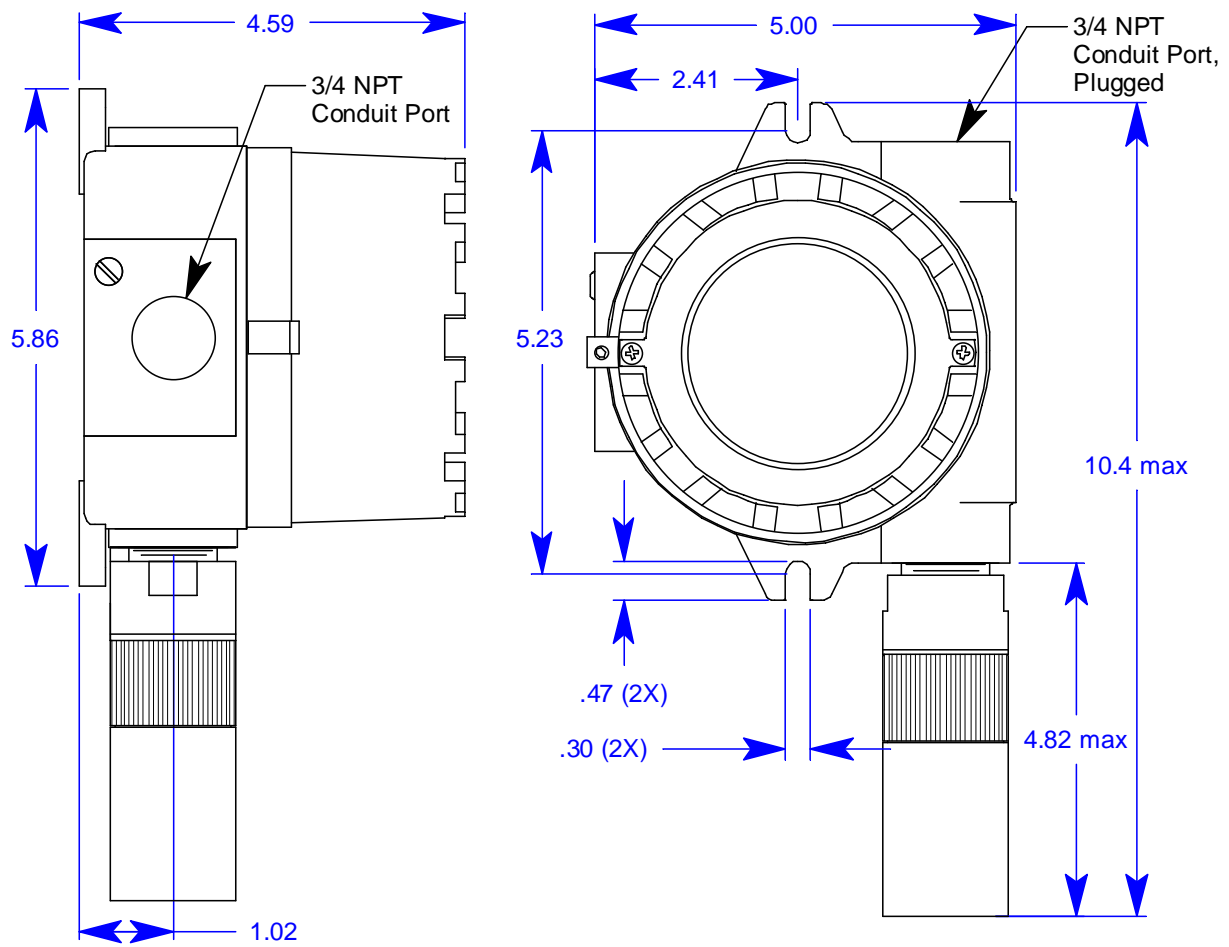




**Figure 14: Outline & Mounting Dimensions, Replaceable Sensor, Non Explosion Proof, H<sub>2</sub>S, CO, and Oxygen**



**Figure 15: Outline & Mounting Dimensions, CSA Type H<sub>2</sub>S, CO, and Oxygen**



**Figure 16: Outline & Mounting Dimensions, ESM-01 Toxic**

## Wiring the M2A Transmitter

**WARNING:** Always verify that the power source is OFF before making any wiring connections.

1. Remove the junction box cover.
2. Grasp the control PCB by its edges.
3. Gently pull until the control PCB is pulled away from the banana jacks. Take care not to pull too hard and damage the cable which connects the control and terminal PCBs.
4. Let the control PCB hang by the cable. The terminal strips are now visible on the terminal PCB. The control PCB may be left hanging while wiring is done. If desired, the control PCB may be disconnected from the cable and set aside while wiring.
5. The detector leads are factory wired. Verify that the detector leads are wired to the detector terminal strip as shown in the applicable figure below:
  - Catalytic LEL/Combustible IR/CO<sub>2</sub> Detectors

The wiring for these types of detectors is the same. Red wire to terminal labeled LEL R, white wire to terminal labeled LEL W, green wire to terminal labeled LEL G, black wire to terminal labeled LEL B.

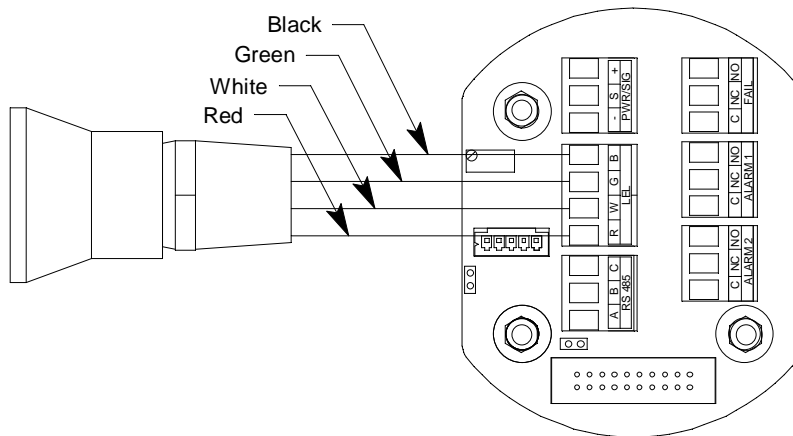


Figure 17: Catalytic LEL Detector Wiring

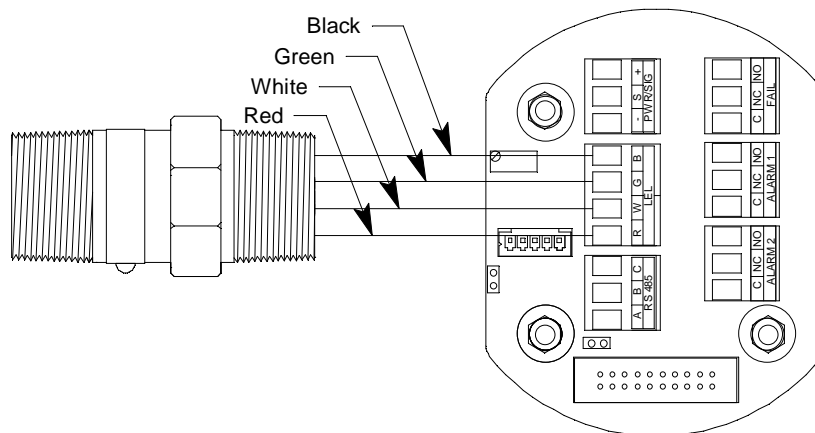
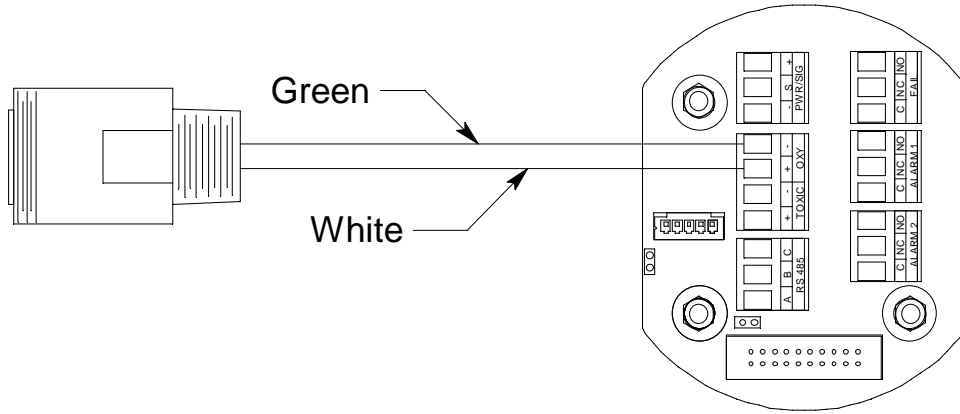


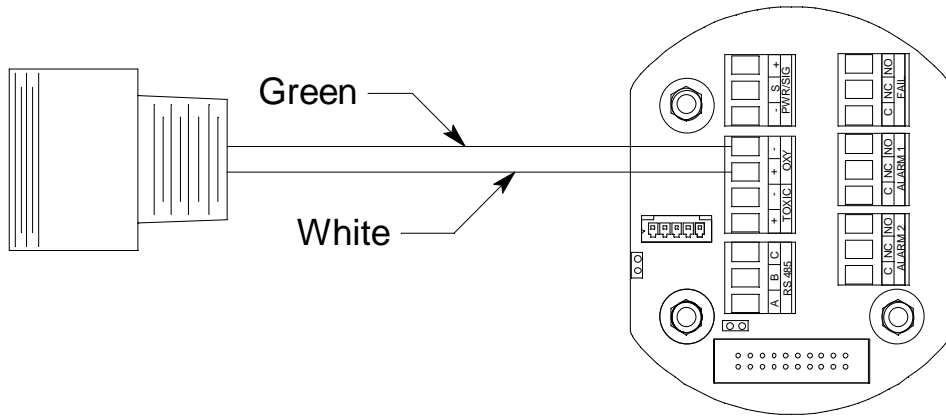
Figure 18: Combustible IR/CO<sub>2</sub> Detector Wiring

- Oxygen Detector, Partial Pressure, Capillary Type, and CSA Capillary Type

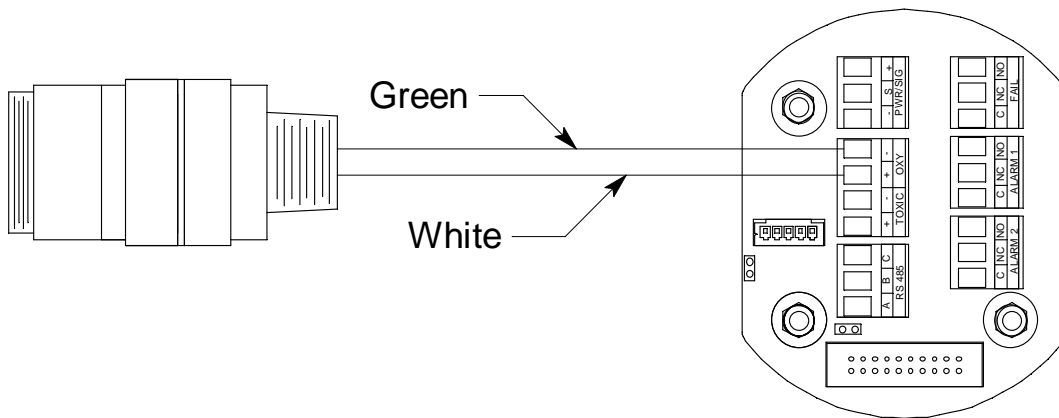
The wiring for all the oxygen detectors is the same. White wire to terminal labeled OXY +, green wire to terminal labeled OXY -.



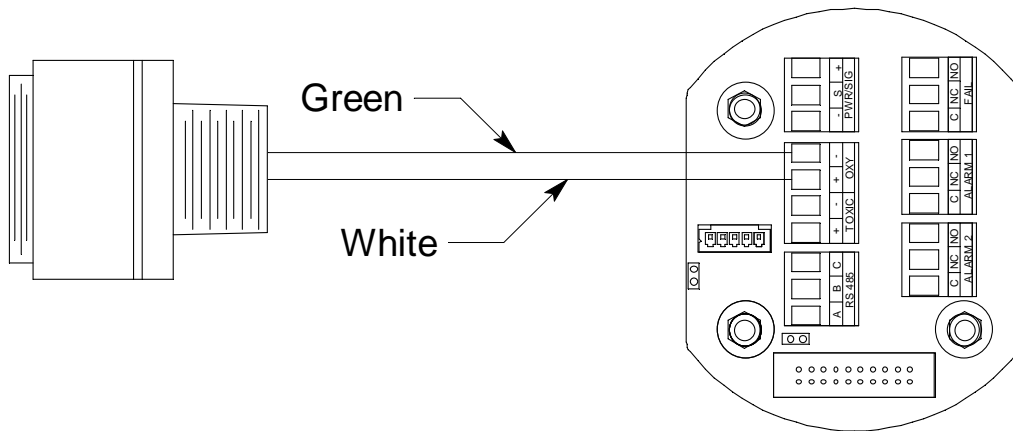
**Figure 19: Partial Pressure Oxygen Detector Wiring**



**Figure 20: Capillary Oxygen Detector Wiring**



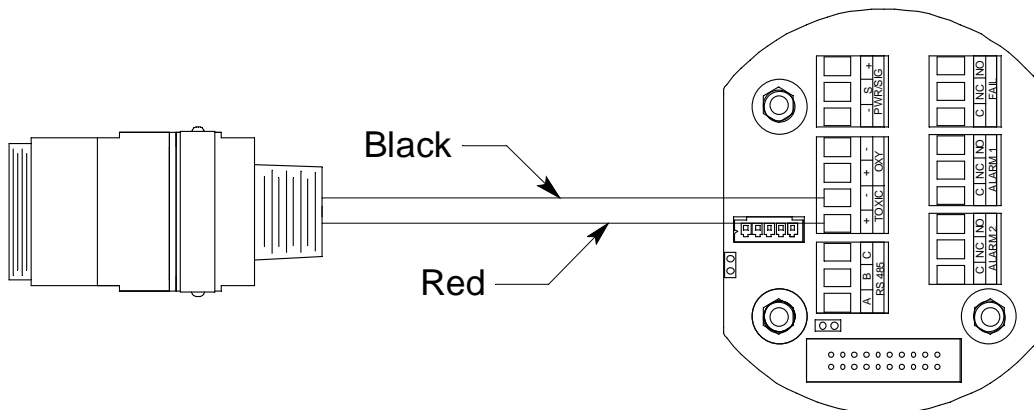
**Figure 21: CSA Capillary Type Oxygen Detector Wiring**



**Figure 22: Capillary Type Replaceable Sensor Oxygen Detector Wiring**

- CSA type CO or H<sub>2</sub>S gas detector.

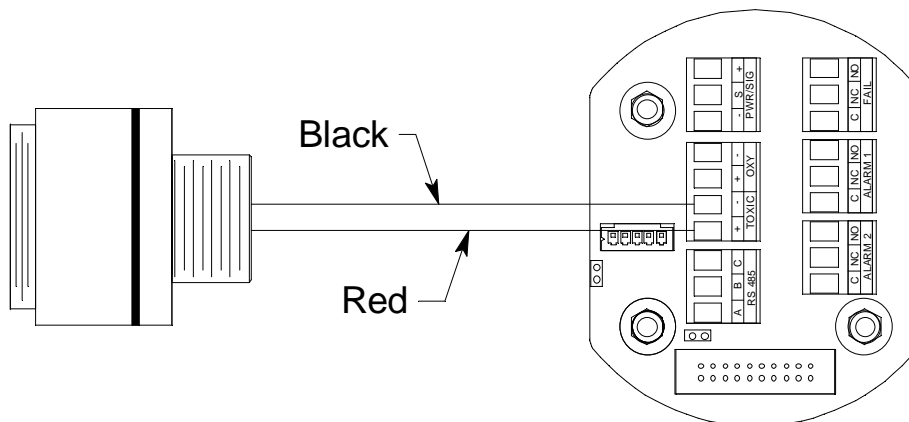
Red wire to terminal labeled TOXIC +, black wire to terminal labeled TOXIC -.



**Figure 23: H<sub>2</sub>S/CO Detector Wiring, CSA**

- Non Explosion Proof CO or H<sub>2</sub>S gas detector

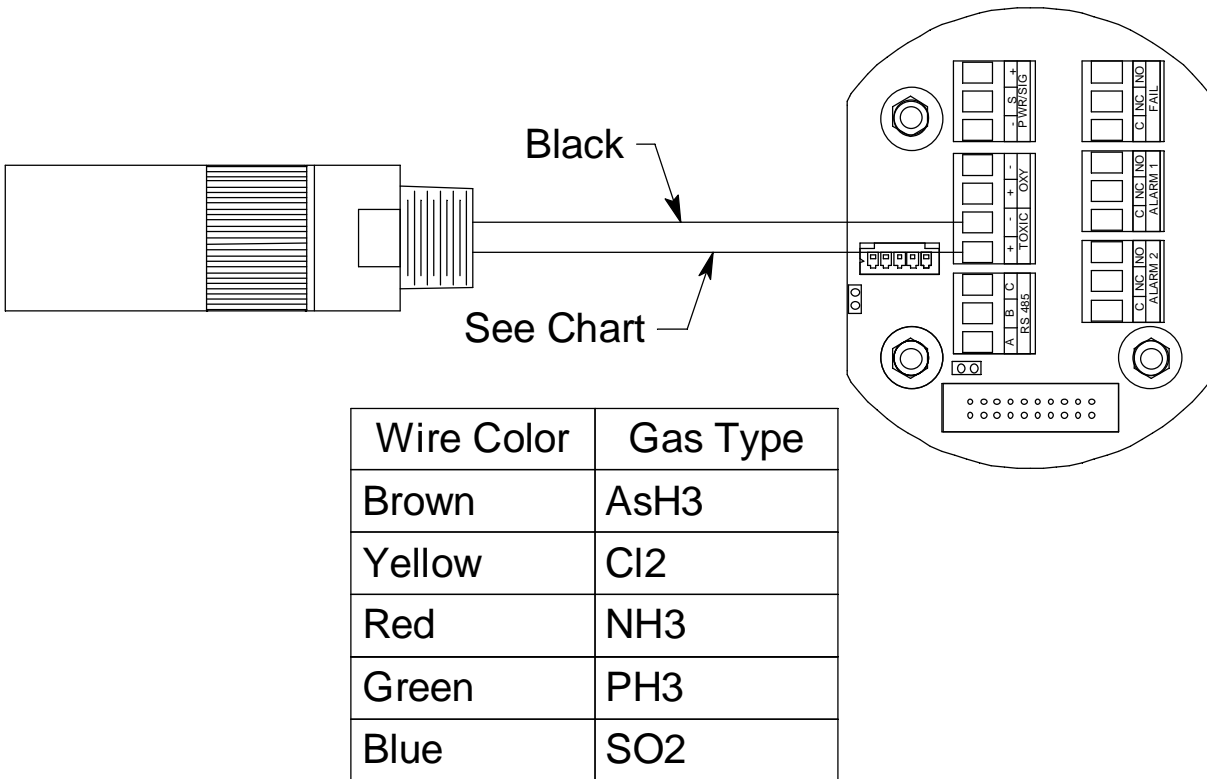
Red wire to terminal labeled TOXIC +, black wire to terminal labeled TOXIC -.



**Figure 24: H<sub>2</sub>S/CO Detector Wiring**

- ESM-01 Toxic Detectors

The ESM-01 toxic detectors have one black wire and one color coded wire. Connect the color coded wire (see chart below) to the terminal labeled TOXIC + and the black wire to the terminal labeled TOXIC -.



**Figure 25: ESM-01 Toxic Detector Wiring**

6. To gain access to a plug-in terminal strip for wiring, pull it out of its socket by grasping the wall between two terminal positions with needle nose pliers and pulling. Be careful not to exert too much force on the wall to avoid damage to the terminal strip. The detector terminal strip and the alarm 1 relay terminal strip may be removed by grasping them with your fingers if the adjacent terminal strips have been removed.

---

**WARNING:** *If the M2A is installed in a hazardous location, use appropriately rated conduit, conduit fittings, and appropriate construction technique that complies with the local electrical code.*  
*In addition, use appropriately rated conduit, conduit fittings, and appropriate construction technique to maintain the NEMA 4X environmental rating of the junction box and avoid water entering the junction box at the conduit ports.*

---

7. Guide multi conductor shielded cable or cables or wires in conduit through the conduit port on the left side of the junction box.

---

**WARNING:** *If the top conduit port is used for wiring, be sure to seal the threads to ensure water does not enter the junction box. A conduit seal, which is normally required to maintain the junction box's hazardous location rating, will also help to prevent water from entering through the top port.*

---



The number of cables or wires needed will depend on whether the M2A is wired to a gas monitoring controller or just to power, whether any relays are used, and whether the Modbus output is used.

---

**NOTE:** If the M2A is being wired to a PLC or DCS device, see “Appendix B: PLC and DCS Device Wiring” on page 66, then continue with step 8.

---

Use the following recommendations to determine how to wire the M2A:

- If Modbus connections will not be used and only the PWR/SIG connections will be used, use a two or three conductor shielded cable or two or three wires in conduit for connections to the power/signal terminal strip depending on whether or not the signal (S) terminal is used. The S terminal has a 4 - 20 mA output, but if you do not need to monitor this signal and do not connect to the S terminal to access this signal, the M2A will still function completely.

**Table 4: Wire Size for PWR/SIG Connections**

<b>Max Distance to Controller w/18 Gauge Wire</b>	<b>Max Distance to Controller w/ 16 Gauge Wire</b>	<b>Max Distance to Controller w/14 Gauge Wire</b>
2,500 ft.	5,000 ft.	8,000 ft.

- If the PWR/SIG connections and one or more relays are used, route the connections to the M2A in conduit. Use shielded cable in the conduit for the PWR/SIG connections and unshielded cable or individual wires for the relay connections. Make sure any wire or cable used for relay wiring is appropriately rated for the power that it will carry.

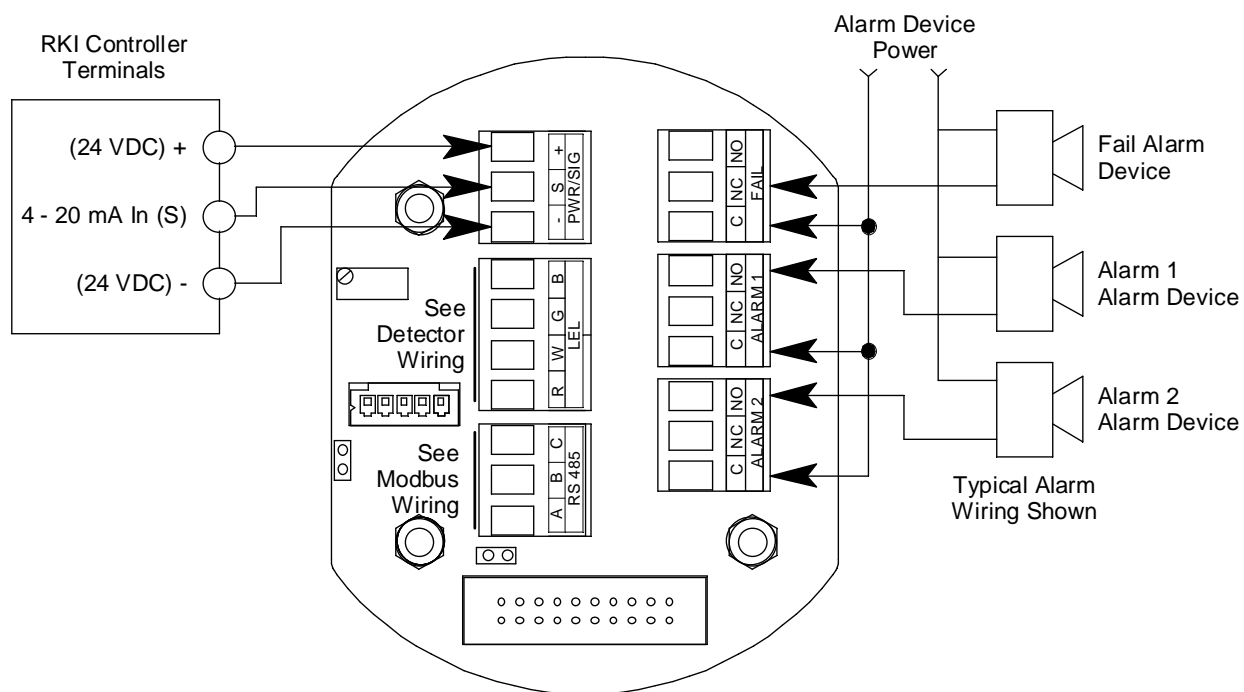
---

**NOTE:** If shielded cable is used for the PWR/SIG connections, leave the cable shield’s drain wire insulated and disconnected at the M2A. You will connect the opposite end of the cable’s drain wire at the controller or device.

---

- If the M2A will be wired into a Modbus network, see “Chapter 8: RS-485 Modbus Output” on page 51.

See Figure 26 below for field wiring connections to the M2A.



**Figure 26: Wiring the M2A to a Controller and Alarm Devices**

8. Re-install the control PCB (and ribbon cable if necessary). Be sure the ribbon cable is routed down below the control PCB so it will not be damaged by the cover when it is screwed back on.
9. Secure the junction box cover to the junction box.
10. Make controller, device, and relay connections as appropriate. If shielded cable is used for the PWR/SIG connections, connect the cable shield's drain wire to an available chassis ground at the gas monitoring controller, recording device, or programmable controller.

## Start Up

### Introducing Incoming Power

1. Complete the installation procedures described earlier in this manual.
2. Verify that all wiring connections are correct and secure.
3. Turn on the incoming power.
4. If necessary, turn on the controller or other monitoring device that is connected to the M2A.
5. The OLED display will indicate the firmware version when the M2A is first powered up and will then count down a one minute warm-up period before normal operation begins. During normal operation, the display will indicate the target gas and current gas reading. Verify that the display is indicating the target gas and current gas reading after the warm-up period is complete and normal operation begins.

METHANE  
0 %LEL

---

**NOTE:** Allow the M2A's detector to warm up for 15 minutes before you continue with the next section, "Adjusting the Fresh Air Reading."

---

## Adjusting the Fresh Air Reading

When the M2A is shipped from RKI Instruments, Inc., it is factory calibrated. If a full calibration is desired at startup, see "Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions" on page 42 or "Calibration, Oxygen Version" on page 45.

Verify that the M2A is in a fresh air environment (environment known to be free of the target gas and combustible or toxic gas vapors and of normal oxygen content, 20.9%).

---

**CAUTION:** *If you suspect the presence of combustible gas, CO<sub>2</sub>, toxic gas, or that the oxygen content is not normal in the monitoring environment, use the calibration kit and the zero air calibration cylinder to introduce "fresh air" to the detector and verify an accurate fresh air setting. See the "Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions" on page 42 or "Calibration, Oxygen Version" on page 45 for instructions on how to use a zero air cylinder when performing a fresh air adjustment.*

---

## Non-Intrusive Fresh Air Signal Adjustment

If the M2A is installed in a classified area and non-intrusive zero adjustment is required, follow the instructions below, **but do not remove the junction box cover**. Use the magnetic wand accessory to actuate the magnetic switches instead of pushing the control switch buttons. To actuate a magnetic switch and perform the same operation as pressing a control switch button, touch the magnet in the end of the magnetic wand to the M2A's glass cover directly over the magnetic switch you wish to actuate. Touching the glass and removing the wand is the same as pressing and releasing a button. Touching the glass and keeping the wand in place is the same as pressing and holding a button.

---

**WARNING:** *The M2A is not an active gas monitoring device during the fresh air adjustment procedure. The 4-20 mA output signal will "freeze" at 3.5 mA for a toxic, combustible gas, or CO<sub>2</sub> M2A, or at 17.4 mA for an oxygen M2A, and all relays will remain in their non-alarm state while the M2A is in Calibration Mode. The output signal will not indicate current readings and the relays will not resume operating normally until the M2A is in normal operation again.*

---

**NOTE:** While in the calibration program, if there is no switch activity for the calibration time-out period the unit will return to normal operation. The factory set time-out is 15 minutes. If you want a different time-out period, see "Viewing & Changing M2A Parameters" on page 31 for instructions to change the calibration time-out.

---

## Combustible Gas, CO<sub>2</sub>, and Toxic Versions, Adjusting the Fresh Air Reading

1. While in normal operation, press and hold the UP/YES button for 5 seconds to enter Calibration Mode. Release the button when the following screen appears.

Calib?  
YES/NO

2. Press and release the UP/YES button to continue. The display will indicate the target gas and **CAL Mode** for a few seconds before showing **FreshAir Adjust?**.
3. Press and release the UP/YES button. **ENTER** will alternate with **FreshAir** on the top display line and the current gas reading will be on the bottom display line.
4. Press and release the ENTER button. The M2A will perform a zero operation and the display will indicate **SPAN w/Cal Gas?**.
5. Press and release the DOWN/NO button. The display will indicate **Leaving CAL Mode** and the M2A will return to normal operation.

### ***Oxygen Version, Adjusting the Fresh Air Reading***

1. While in normal operation, press and hold the UP/YES button for 5 seconds to enter Calibration Mode. Release the button when the following screen appears.

Calib? YES/NO
------------------

2. Press and release the UP/YES button to continue. The display will indicate **OXYGEN CAL Mode** for a few seconds before showing **FreshAir Adjust?**.
3. Press and release the UP/YES button. **ENTER** will alternate with **FreshAir** on the top display line and the current oxygen reading will be on the bottom display line.
4. Press and release the ENTER button. The M2A will perform a span operation and then the display will indicate **ZERO w/Cal Gas?**.
5. Press and release the DOWN/NO button. The display will indicate **Leaving CAL Mode** and the M2A will return to normal operation.

# Chapter 4: Operation

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## Overview

This chapter describes the M2A in normal operation. This chapter also describes the M2A in alarm 1, alarm 2, and fail conditions and suggests responses to these conditions.

---

## Normal Operation

Normal operation is defined as follows:

- The start-up procedure is complete.
- The M2A is not indicating an alarm 1, alarm 2, or fail condition.
- The M2A is not in Calibration, Configuration, or Gas Type modes.

During normal operation, the M2A simultaneously displays the current gas reading, unit of measure, and target gas. The example below illustrates a typical combustible gas M2A.

METHANE 0 %LEL
-------------------

---

## Information Screen

The Information Screen displays the M2A's operating voltage and firmware and hardware information. To display the Information Screen, do the following:

1. Press and hold the DOWN/NO button for 3 seconds. The Information Screen will appear.

24.2V v6.0L 2A
-------------------

2. Continue holding the DOWN/NO button to keep the Information Screen on the display. The top line indicates the operating voltage that is connected to the M2A. The second line indicates the firmware that is running, version 6.0 in this example, and the M2A's hardware version, version 2A in this example. This information may be useful if you need to contact the factory with questions about the M2A.
3. Release the DOWN/NO button when you are done viewing the Information Screen. The display will return to the normal operation screen within a couple of seconds.

---

## 4 - 20 mA Signal Output Operation

The output at the S terminal of the power/signal terminal strip is a 4 - 20 mA signal that corresponds to the detection range of the M2A. During normal operation, this signal tracks the gas concentration on the OLED display.

There are several circumstances where the signal output will not track the display reading but will behave as follows:

- When the M2A is in its warm-up period, the signal output will be fixed at 3.5 mA (zero) for all gas types except oxygen. For oxygen types, the output will be fixed at 17.4 mA (20.9% oxygen) while the M2A is in warm-up.
- When the M2A's gas type is changed, the M2A will enter Configuration Mode for you to verify the parameter settings. When you exit Configuration Mode, the display will indicate **NEEDS CALIBRATION** and will continue to indicate this until Calibration Mode is entered and a calibration is performed. In this situation, the signal output will be fixed at 3.5 mA for LEL and toxic versions and 17.4 mA for oxygen versions from the time Gas Type Mode is entered until the M2A is calibrated and returns to normal operation.
- If you enter Calibration Mode, Configuration Mode, Gas Type Mode, or Modbus Mode, the signal output will be fixed at 3.5 mA for combustible gas, CO<sub>2</sub>, and toxic versions and 17.4 mA for oxygen versions until the M2A returns to normal operation.
- If the M2A's input power decreases below 9.5 volts so that the M2A is in a low power alarm, the signal output is fixed below 2.4 mA until the low power alarm is cleared.
- If the M2 goes into a fail condition, after a 30 second delay, the signal output is fixed below 2.4 mA until the fail alarm is cleared. During the 30 second delay, the signal output follows the detector output. In the case of a downscale reading, the display and the signal output continue to track the reading down to -99% of full scale (1.15 mA).



## Alarm Indications

**NOTE:** The M2A includes alarm on and alarm off delay settings for alarm 1 and alarm 2. The alarm indications described in this section operate according to the factory set alarm settings. See Table 6 on page 32 for all the factory settings.

**Table 5: Visual and Audible Alarm Indications**

Condition	Cause	Visual Indication(s)
Alarm 1 <sup>1</sup>	Increasing (decreasing for O <sub>2</sub> ) gas reading at or above the alarm 1 setpoint	<ul style="list-style-type: none"> <li>A1 LED is on</li> <li>Gas reading alternates with <b>ALARM-1</b> message</li> </ul>
Alarm 2 <sup>1</sup>	Increasing gas reading at or above the alarm 2 setpoint	<ul style="list-style-type: none"> <li>A2 LED is on</li> <li>Gas reading alternates with <b>ALARM-2</b> message</li> </ul>
Fail	<ul style="list-style-type: none"> <li>Disconnected or misconnected detector wiring</li> <li>Display reading at -10% of full scale or lower</li> <li>Defective components</li> </ul>	<ul style="list-style-type: none"> <li>F LED is on</li> <li><b>FAIL</b> message replaces gas reading</li> </ul> <p><i>NOTE: There is a 30 second delay on the fail condition.</i></p>
Low Power	DC power source less than 9.5 volts.	<ul style="list-style-type: none"> <li>F LED is on</li> <li><b>LowPower</b> message and actual voltage of incoming DC power</li> </ul>
<p>* <i><sup>1</sup>If the M2A is in both an alarm 1 and an alarm 2 condition, both alarm LEDs are on and the display alternates between the gas reading and the ALMS 1&amp;2 message.</i></p>		

**NOTE:** You can select normally energized (N. EN) or normally de-energized (N. DE-EN) alarm 1 and alarm 2 relay settings in Configuration Mode. The following sections describe the standard factory setting for these relays which is N. DE-EN.

The fail relay is factory set as N. EN and is not user-adjustable.

### Alarm 1 Condition

#### **Alarm 1 Condition Indications**

When the gas reading reaches the alarm 1 setpoint, the M2A senses an alarm 1 condition. The M2A alerts you to an alarm 1 condition as follows:

- The A1 LED turns on.
- The gas reading alternates with the **ALARM-1** message.
- The alarm 1 relay energizes.

#### **Responding to an Alarm 1 Condition**

- Follow your established procedure for a low level combustible or toxic gas condition or a decreasing oxygen concentration condition.
- After the gas reading falls below (above for oxygen) the alarm 1 setpoint, press the ENTER button to reset the alarm 1 circuit. Resetting the alarm 1 circuit turns off the A1 LED, resets the

OLED display, and de-energizes the alarm 1 relay.

---

**NOTE:** If the ENTER button is pressed while the M2A is in an alarm 1 condition, the A1 LED will flash but all other indications will remain unchanged.

You cannot de-energize the alarm 1 relay until the gas reading falls below (above for oxygen) the alarm 1 setpoint.

---

## Alarm 2 Condition

### *Alarm 2 Condition Indications*

When the gas reading reaches the alarm 2 setpoint, the M2A senses an alarm 2 condition. The M2A alerts you to an alarm 2 condition as follows:

- The A2 LED turns on.
- The gas reading alternates with the **ALARM-2** message.
- The alarm 2 relay energizes.

---

**NOTE:** If the M2A is in both an alarm 1 and alarm 2 condition, both the A1 and A2 LEDs will be on, the gas reading will alternate with the **ALMS 1&2** message, and both alarm relays will energize.

---

### *Responding to an Alarm 2 Condition*

1. Follow your established procedure for a high level combustible or toxic gas condition or an increasing oxygen concentration condition.
2. After the gas reading falls below the alarm 2 setpoint, press the ENTER button to reset the alarm circuit. Resetting the alarm circuit turns off the A2 light, resets the OLED display, and de-energizes the alarm 2 relay.

---

**NOTE:** If the ENTER button is pressed while the M2A is in an alarm 2 condition, the A2 LED will flash but all other indications will remain unchanged.

You cannot de-energize the alarm 2 relay until the gas reading falls below the alarm 2 setpoint.

---

## Fail Condition

### *Fail Condition Indications*

The M2A indicates a fail condition for any of the following:

- The detector wiring is disconnected or incorrectly connected.
- The display reading is -10% of full scale or lower.

When the M2A senses a fail condition, it alerts you as follows:

- The F LED turns on.
- The gas reading is replaced by the **FAIL** message.
- The fail relay de-energizes.

---

**NOTE:** The fail alarm has a 30 second delay.

---

### ***Responding to a Fail Condition***

1. Verify that the detector wiring is correctly and securely connected.
2. If the M2A has a replaceable plug-in sensor, verify that the replaceable plug-in sensor in the detector housing is properly installed.

## **Low Power Alarm**

### ***Low Power Alarm Indications***

The M2A senses a low power condition when the DC power source is 9.5 volts or less.

---

***WARNING:***     *While in a low power condition, the M2A is not an active gas monitor.*

---

When the M2A senses a low power condition, it alerts you as follows:

- The F LED turns on.
- The message **LowPower** is indicated on the top line of the OLED display and the input voltage is displayed on the bottom line of the OLED display.
- The fail relay de-energizes.

---

***NOTE:***     The low power alarm cannot be cleared using the ENTER button.

---

When the voltage increases to 10.0 volts, the low power alarm is cleared and the M2A will begin its warm-up sequence.

### ***Responding to a Low Power Condition***

1. Determine and correct the cause of the low power condition.
2. When the input power increases above 10.0 volts, the M2A will begin its warm-up sequence.
3. Verify that the M2A enters normal operation after its warm-up sequence. If necessary, perform a fresh air adjustment. See “Adjusting the Fresh Air Reading” on page 24.

# Chapter 5: Configuration Mode

---

## Overview

This chapter describes how to view and change M2A parameters using Configuration Mode. It is accessed using the program buttons.

Configuration Mode includes a 5-minute time-out feature. If you do not press a control button for 5 minutes, the M2A automatically returns to normal operation.

---

**NOTE:** If the M2A returns to normal operation because of a time-out, it enters a warm-up period just as it does when it is first turned on.

If you are installing a new M2A, it has been setup at the factory. Use Configuration Mode only if you want to change the M2A's setup. If you want to change the detector type see "Chapter 6: Gas Type Mode" on page 34.

---

---

## Viewing & Changing M2A Parameters

1. While in normal operation, simultaneously press and hold the UP/YES and ENTER buttons for 5 seconds to enter Configuration Mode. Release the buttons when the following screen appears.

Enter  
Config?

2. If you want to exit Configuration Mode, press and release the DOWN/NO button and the M2A will return to normal operation.

If you want to continue in Configuration Mode, press and release the UP/YES button. The target gas and the full scale will be displayed for a few seconds before the first adjustable parameter, the alarm 1 setpoint, is displayed.

3. If you want to change the currently displayed parameter, use the UP/YES and DOWN/NO buttons to adjust it to the desired setting, then press ENTER to continue to the next parameter.

If the currently displayed parameter is OK, press the ENTER button to proceed to the next parameter.

Table 6 lists the M2A parameters you can set. Table 6 also lists the factory set value for each parameter.

**Table 6: Configuration Parameters**

<b>Parameter (Factory Set Value)</b>	<b>Description</b>
ALARM-1 (level) (See “M2A Specifications” on page 2)	The gas reading at which the M2A initiates an alarm 1 condition.
ALARM-1 (activation) (Decrease for oxygen M2A, Increase for all other types)	Indicates if the alarm 1 circuit is activated by gas readings increasing ( <b>Increase</b> ) or decreasing ( <b>Decrease</b> ) to the ALARM-1 Level.
ALARM-1 (relay action) (N. DE-EN)	If set as <b>N. DE-EN</b> , the alarm 1 relay is de-energized in normal operation and energizes when an alarm 1 condition is initiated. If set as <b>N. EN</b> , the alarm 1 relay is energized in normal operation and de-energizes when an alarm 1 condition is initiated.
ALARM-1 (relay reset) (LATCH)	If set as <b>LATCH</b> , you must press the ENTER button to reset the alarm 1 circuit after the alarm 1 condition passes. If set as <b>SELF-RST</b> , the M2A automatically resets the alarm 1 circuit after the alarm 1 condition passes.
A1 OnDy (alarm 1 on delay) (1 secs)	The amount of time the M2A delays activation of the alarm 1 circuit once an alarm 1 condition is initiated. It can be set in 1 second increments from 0 - 60 seconds, in 1 minute increments from 1 - 15 minutes, and in 15 minute increments from 15 - 60 minutes.
A1 OffDy (alarm 1 off delay) (0 sec.)	The amount of time the M2A delays turning off the alarm 1 circuit once an alarm 1 condition passes. This parameter appears only if the alarm 1 relay reset setting is set to <b>SELF-RST</b> . It can be set in 1 second increments from 0 - 60 seconds, in 1 minute increments from 1 - 15 minutes, and in 15 minute increments from 15 - 60 minutes.
ALARM-2 (level) (See “M2A Specifications” on page 2)	The gas reading at which the M2A initiates an alarm 2 condition.
ALARM-2 (activation) (Increase for all types)	Indicates if the alarm 2 circuit is activated by gas readings increasing ( <b>Increase</b> ) or decreasing ( <b>Decrease</b> ) to the ALARM-1 Level.
ALARM-2 (relay action) (N. DE-EN)	If set as <b>N. DE-EN</b> , the alarm 2 relay is de-energized in normal operation and energizes when an alarm 2 condition is initiated. If set as <b>N. EN</b> , the alarm 2 relay is energized in normal operation and de-energizes when an alarm 2 condition is initiated.
ALARM-2 (relay reset) (LATCH)	If set as <b>LATCH</b> , you must press the ENTER button to reset the alarm 2 circuit after the alarm 2 condition passes. If set as <b>SELF-RST</b> , the M2A automatically resets the alarm 2 circuit after the alarm 2 condition passes.
A2 OnDy (alarm 2 on delay) (1 secs)	The amount of time the M2A delays activation of the alarm 2 circuit once an alarm 2 condition is initiated. It can be set in 1 second increments from 0 - 60 seconds, in 1 minute increments from 1 - 15 minutes, and in 15 minute increments from 15 - 60 minutes.
A2 OffDy (alarm 2 off delay) (0 sec.)	The amount of time the M2A delays turning off the alarm 2 circuit once an alarm 2 condition passes. This parameter appears only if the alarm 2 relay reset setting is set to <b>SELF-RST</b> . It can be set in 1 second increments from 0 - 60 seconds, in 1 minute increments from 1 - 15 minutes, and in 15 minute increments from 15 - 60 minutes.

**Table 6: Configuration Parameters (Continued)**

<b>Parameter (Factory Set Value)</b>	<b>Description</b>
ZeroSupp (0.0% of the <b>detection range</b> in terms of the detection units for carbon dioxide channel types, 0.5% <b>oxygen</b> for oxygen types, 2% of the <b>detection range</b> in terms of the detection units for all other types)	The zero suppression feature helps prevent “jumpy” readings near the fresh air reading. For example, if the zero suppression setting for a combustible LEL detector is <b>2.0% LEL</b> , the M2A will display a reading of 0% LEL for gas readings from -2% LEL to 2% LEL. It is settable from 0 to 6% of the detection range.
FILTER (5 secs)	The filter feature helps “smooth out” jumpy or noisy signals from the detector. You can set the filter from 0 seconds to 60 seconds in 5 seconds increments. The displayed gas reading is the average reading over the previous time period defined by the filter setting. So if the filter is set to 5 seconds, the displayed gas reading is the average over the past 5 seconds.
CAL Time (15 mins)	The calibration time-out sets the amount of time after the last button push while in Calibration Mode that the M2A will wait before returning to normal operation. If the calibration time-out is set to <b>15 mins</b> , then M2A will return to normal operation automatically 15 minutes after the last button push.
Auto Zero (Disabled for carbon dioxide channels; Enabled for all other channel types)	If set to <b>Enabled</b> , the M2A’s firmware will monitor the zero (fresh air) reading and make automatic zero adjustments under precisely specified conditions if it determines that a reading change is due to normal sensor drift. If set to <b>Disabled</b> , the Auto Zero function is turned off.

4. When you have scrolled through all the adjustable parameters, **SAVE IT? YES/NO** appears on the display.
5. If you do not wish to save the adjustments and want to exit Configuration Mode, press and release the DOWN/NO button. The **DO OVER? YES/NO** message will display. Press and release the DOWN/NO button. The **ABORT? YES/NO** message will display. Press the UP/YES button to return to normal operation.

If you wish to change some of the adjustments made, press and release the DOWN/NO button. The **DO OVER? YES/NO** message will display. Press and release the UP/YES button. The **Re-do Config** message will display and the M2A will return to the first adjustable parameter. Go back to step 3 and continue.

If you wish to save the adjustments made, press and release the UP/YES button. **Config Saved** is indicated on the display for a few seconds and the M2A returns to normal operation.



# Chapter 6: Gas Type Mode

---

## Overview

This chapter describes how to use Gas Type Mode to select the M2A's gas type. The gas type determines the target gas and detection range. The combustible gas/CO<sub>2</sub> and toxic/oxygen M2As have a different terminal PCB and run on different firmware. Your M2A will only have gas type choices available that it can support.

Gas Type Mode includes a 5-minute time-out feature. If you do not press a button for 5 minutes, the M2A automatically returns to normal operation.

---

**NOTE:** If the M2A enters normal operation because of a program time-out, it enters a warm-up period just as it does when it is first turned on.

---

---

## Selecting the Gas Type

1. While in normal operation or during the warm-up sequence, press and hold the UP/YES and DOWN/NO buttons for five seconds. Release them when the following screen appears.

Select  
GasType?

2. If you want to exit Gas Type Mode, press and release the DOWN/NO button. The display will indicate **NO CHANGE** and the M2A will return to normal operation.

If you want to continue in Gas Type Mode, press and release the UP/YES button. The top display line will indicate **GasType?** and the bottom display line will indicate the target gas choice.

3. Use the UP/YES or DOWN/NO button to scroll through the choices of target gas. Table 7 and Table 8 below list the choices of target gas for the M2A.

**Table 7: Combustible Gas/CO<sub>2</sub> Gas Types**

Gas Type Choices	Detection Range
HC	0 - 100% LEL
iBUTANE	0 - 100% LEL
PROPANE	0 - 100% LEL
HEXANE	0 - 100% LEL
HYDROGEN	0 - 100% LEL
METHANE	0 - 100% Volume
METHANE	0 - 100% LEL
CO2	0 - 5,000 ppm

**Table 7: Combustible Gas/CO<sub>2</sub> Gas Types**

<b>Gas Type Choices</b>	<b>Detection Range</b>
CO <sub>2</sub>	0 - 2,000 ppm
CO <sub>2</sub>	0 - 100% volume
CO <sub>2</sub>	0 - 50.0% volume
CO <sub>2</sub>	0 - 5.00% volume
NH <sub>3</sub>	0 - 5.00% volume
NH <sub>3</sub>	0 - 2.00% volume

**Table 8: Toxic/Oxygen Gas Types**

<b>Gas Type Choices</b>	<b>Detection Range</b>
H <sub>2</sub> S	0 - 100 ppm
CO	0 - 300 ppm
CO	0 - 200 ppm
CO	0 - 100 ppm
OXYGEN	0 - 25.0% volume
SiH <sub>4</sub>	0 - 15.0 ppm
PH <sub>3</sub>	0 - 1.00 ppm
O <sub>3</sub>	0 - 1.00 ppm
NO	0 - 100 ppm
HF	0 - 9.00 ppm
HCN	0 - 15.0 ppm
HCL	0 - 15.0 ppm
GEH <sub>4</sub>	0 - 1.50 ppm
F <sub>2</sub>	0 - 3.00 ppm
CLO <sub>2</sub>	0 - 1.00 ppm
B <sub>2</sub> H <sub>6</sub>	0 - 5.00 ppm
ASH <sub>3</sub>	0 - 1.50 ppm
SO <sub>2</sub>	0 - 6.00 ppm
NH <sub>3</sub>	0 - 75.0 ppm
CL <sub>2</sub>	0 - 3.00 ppm
CL <sub>2</sub>	0 - 10.0 ppm

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**NOTE:** Consult factory for availability of detectors for toxic M2A types not listed in “M2A Specifications” on page 2.

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4. When the desired target gas is on the display, press and release the ENTER button. The display will ask **SAVE IT? YES/NO**.
5. To discard the gas type change, press and release the DOWN/NO button. The display will ask **DO OVER? YES/NO**. Press the DOWN/NO button. The display will ask **ABORT? YES/NO**. Press the UP/YES button. The M2A will return to normal operation without changing the gas type.  
  
To save the gas type, press and release the UP/YES button. The display will indicate **Gas Type Updated**, the display will indicate the target gas and the detection range for a few seconds, and then the M2A will enter Configuration Mode automatically so that the parameter settings in Configuration Mode can be verified or changed.
6. While in Configuration Mode press and release the ENTER button to accept the displayed parameter setting and move to the next one. Use the UP/YES and DOWN/NO buttons to adjust a setting. See “Chapter 5: Configuration Mode” on page 31 for a complete description of Configuration Mode.
7. When you have reviewed and accepted the last item in Configuration Mode by pressing the ENTER button, display will ask **SAVE IT? YES/NO**.
8. To save the configuration settings, press and release the UP/YES button. The display will indicate **Config Saved** and the M2A will begin its warm-up sequence.  
  
To discard the settings and review them again, press the DOWN/NO button. The display will ask **DO OVER? YES/NO**. Press the UP/YES button and the display will indicate **Re-do Config**, then display the target gas and the detection range for a few seconds before returning to Configuration Mode. Repeat steps 6 - 8 until the settings are as desired.
9. After the M2A completes its warm-up sequence, the display will indicate **CAL NEEDED**. Since the gas type has been changed, a successful calibration must be performed before the M2A can enter normal operation.
10. Press and release the UP/YES button to enter Calibration Mode. Normally, you must hold the UP/YES button for 5 seconds to enter Calibration Mode, but since a calibration is required, only a momentary push is needed to enter Calibration Mode after changing the gas type.
11. See “Calibration, Combustible Gas, CO2, and Toxic Versions” on page 42 or “Calibration, Oxygen Version” on page 45 for calibration instructions.

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**NOTE:** When calibrating an M2A after changing the gas type, the M2A will not ask if you want to calibrate, or whether you want to perform a fresh air adjustment, span adjustment or zero adjustment. Since a complete calibration is required, the calibration sequence will proceed without asking if you want to perform certain operations.

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# Chapter 7: Maintenance

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## Overview

This chapter describes procedures for performing preventive maintenance, troubleshooting, calibrating the M2A, and replacing field replaceable parts. It includes separate procedures for calibrating the combustible gas/CO<sub>2</sub>/toxic and oxygen versions of the M2A.

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## Preventive Maintenance

This section describes a recommended preventive maintenance schedule to ensure the optimum performance of the M2A. It includes daily, monthly, quarterly, and biannual procedures.

### Daily

Verify a display reading of zero (20.9% for an oxygen M2A). Investigate significant changes in the reading.

### Monthly

This procedure describes a test to verify that the M2A responds properly to the target gas.

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**NOTE:** Performing a response test on the M2A may cause alarms. If you do not want external alarms to actuate, disable any external alarms during the response test to avoid unwanted external alarm indications.

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**NOTE:** The following procedure assumes the use of a calibration kit which includes a calibration gas cylinder, a fixed flow regulator with an on/off knob, a calibration cup for the detector, and a short piece of sample tubing to connect the regulator to the calibration cup.

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1. Disable all external alarms if external alarm indications are not desired during the response test.
  2. Connect the calibration kit sample tubing to the calibration cup hose barb.
  3. Screw the calibration cup onto the detector.
- 

**NOTE:** For an ESM-01 detector, you must unscrew the removable splashguard from the detector housing cap so you can push the appropriate calibration cup onto the ESM-01 sensor. Make sure to use the correct calibration cup for the sensor being used. There is a Cl<sub>2</sub> type calibration cup for a Cl<sub>2</sub> sensor, an NH<sub>3</sub> type calibration cup for an NH<sub>3</sub> sensor, and a general type (usually labeled SO<sub>2</sub>) calibration cup for all other ESM-01 sensors.

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4. Connect the fixed flow regulator to the calibration cup using the sample tubing.

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**NOTE:** When applying gas to an NH<sub>3</sub> ESM-01, the 0.25 LPM flowrate regulator must be used. All other M2As require a 0.5 LPM flowrate regulator.

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5. Screw the calibration gas cylinder into (onto for an H<sub>2</sub>S cylinder) the fixed flow regulator.
6. Turn the regulator knob counterclockwise to open the regulator.
7. Allow calibration gas to flow for one minute.
8. Verify that the display reading is within  $\pm 20\%$  of the gas concentration.

---

**NOTE:** If the reading is not within  $\pm 20\%$  of the gas concentration, calibrate the M2A as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42 or “Calibration, Oxygen Version” on page 45.

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9. Turn the regulator knob clockwise to close the regulator.
10. Unscrew the calibration gas cylinder from the fixed flow regulator and unscrew the calibration cup from the detector.  
For an ESM-01 detector, pull the calibration cup off the ESM-01 sensor and screw the splashguard back onto the detector housing cap.
11. If external alarms have been disabled, enable them when the display returns to a normal fresh air reading.
12. Store the components of the calibration kit in a safe place.

### **Quarterly**

Calibrate M2As that do not have an IR detector as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42 or “Calibration, Oxygen Version” on page 45. See “Calibration Frequency” on page 41 for a discussion of calibration frequency guidelines.

### **Biannually**

Calibrate M2As that have an IR detector as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42. See “Calibration Frequency” on page 41 for a discussion of calibration frequency guidelines.

## Troubleshooting

The troubleshooting guide describes symptoms, probable causes, and recommended action for problems you may encounter with the M2A.

**NOTE:** This troubleshooting guide describes M2A problems only. If the M2A is connected to a controller, see the controller operator’s manual for problems you may encounter with the controller.

**Table 9: Troubleshooting the Combustible Gas Detector**

Condition	Symptom(s)	Probable Causes	Recommended Action
No Power	The display backlight is off and the display screen is blank.	<ul style="list-style-type: none"> <li>The power wiring is disconnected or misconnected.</li> <li>The display cable is disconnected or misconnected.</li> </ul>	<ol style="list-style-type: none"> <li>Verify that the wiring to the power source or controller is correct and secure.</li> <li>Verify that the ribbon cable connecting the terminal PCB to the control PCB is securely installed. This ribbon cable plugs into a connector on the top edge of the control PCB and on the bottom of the terminal PCB.</li> <li>If the power difficulties continue, contact RKI for further instruction.</li> </ol>
Frequent or Suspect Alarms	The M2A alerts you to frequent or suspect alarms while the fresh air readings remain on zero (20.9 for oxygen).	<ul style="list-style-type: none"> <li>The M2A is experiencing false readings due to RFI or EMI.</li> <li>The detector wiring is disconnected, misconnected, or intermittent.</li> </ul>	<ol style="list-style-type: none"> <li>Verify that the M2A wiring is properly shielded. See “Wiring the M2A Transmitter” on page 18.</li> <li>Verify that the detector wiring is correct and secure.</li> <li>Increase the alarm on delay setting in Configuration Mode.</li> <li>If the frequent or suspect alarm difficulties continue, contact RKI for further instruction.</li> </ol>
Flickering Display	The display reading flickers often.	<ul style="list-style-type: none"> <li>The M2A is experiencing false readings due to RFI or EMI.</li> <li>The noise filter setting is too low.</li> <li>The zero suppression setting is too low.</li> <li>The display screen is malfunctioning.</li> </ul>	<ol style="list-style-type: none"> <li>Verify that the M2A wiring is properly shielded. See “Wiring the M2A Transmitter” on page 18.</li> <li>Verify that the detector wiring is correct and secure.</li> <li>Increase the filter setting in Configuration Mode.</li> <li>Increase the zero suppression setting in Configuration Mode.</li> <li>If the display difficulties continue, contact RKI for further instruction.</li> </ol>



**Table 9: Troubleshooting the Combustible Gas Detector (Continued)**

Condition	Symptom(s)	Probable Causes	Recommended Action
Fail Condition	<ul style="list-style-type: none"> <li>• M2A indicates a fail condition.</li> <li>• Controller indicates a fail condition</li> </ul>	<ul style="list-style-type: none"> <li>• The detector wiring to the terminal PCB is disconnected or misconnected.</li> <li>• The wiring from the M2A to the controller is disconnected or misconnected.</li> <li>• The detector fresh air signal is low enough to cause a fail condition.</li> <li>• The detector is malfunctioning.</li> <li>• The terminal or display PCB is malfunctioning.</li> </ul>	<ol style="list-style-type: none"> <li>1. Verify that the detector wiring is correct and secure.</li> <li>2. Verify that the wiring between the M2A and the controller is correct and secure.</li> <li>3. Calibrate the M2A.</li> <li>4. If the fail condition continues, replace the detector.</li> <li>5. If the fail condition continues, contact RKI for further instruction.</li> </ol>
Slow or No Response/ Difficult or Unable to Calibrate	<ul style="list-style-type: none"> <li>• M2A responds slowly or does not respond to response test.</li> <li>• Unable to successfully set the fresh air or span (zero for oxygen) reading during calibration.</li> <li>• M2A requires frequent calibration.</li> </ul> <p><i>Note: See "Calibration Frequency" on page 41 for calibration frequency guidelines.</i></p>	<ul style="list-style-type: none"> <li>• The calibration cylinder is low, out-dated, or defective.</li> <li>• The detector is malfunctioning.</li> <li>• The terminal PCB is malfunctioning.</li> </ul>	<ol style="list-style-type: none"> <li>1. Verify that the calibration cylinder contains an adequate supply of a fresh test sample.</li> <li>2. If the calibration/response difficulties continue, replace the detector.</li> <li>3. If the calibration/response difficulties continue, contact RKI for further instruction.</li> </ol>

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## Calibration Frequency

Some M2As have IR (infrared) type detectors, such as an M2A for CO<sub>2</sub> or an LEL M2A with an IR detector. Most of the M2As do not have an IR detector. For example, an H<sub>2</sub>S M2A has an electrochemical detector and some of the combustible M2As use catalytic detectors. The M2As that use IR detectors typically need less frequent calibration as is discussed below. See Table 1, “M2A Specifications,” on page 2 to see which M2As are IR versions.

Although there is no particular calibration frequency that is correct for all applications, a calibration frequency of every 3 to 6 months for M2As that do not have an IR detector and every 6 to 12 months for M2As that have an IR detector is adequate for most M2A applications. Unless experience in a particular application dictates otherwise, RKI Instruments, Inc. recommends a calibration frequency of every 3 months for M2As that do not have an IR detector and every 6 months for M2As that have an IR detector.

If an application is not very demanding, for example detection in a clean, temperature controlled environment where the toxic or combustible target gas is not normally present, and calibration adjustments are minimal at calibration, then a calibration frequency of every 6 months for a non-IR M2A or 12 months for an IR M2A is adequate.

If an application is very demanding, for example if a combustible or toxic gas is present often and in significant concentrations or the environment is not well controlled, then more frequent calibration than every 3 months for a non-IR M2A or every 6 months for an IR M2A may be necessary. For combustible gas detection with an M2A that uses a catalytic detector, if potential catalyst poisons are known or likely to be present, more frequent calibration than every 3 months will be necessary.

---

## Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions

This section describes how to calibrate the combustible gas, CO<sub>2</sub>, and toxic gas versions of the M2A. It includes procedures to prepare for calibration, enter Calibration Mode, adjust the fresh air (zero) setting, adjust the span setting, and return to normal operation. See the next section, “Calibration, Oxygen Version” for instructions to calibrate an oxygen M2A.

---

**WARNING:** *The M2A is not an active gas monitoring device during the calibration procedure. The 4-20 mA output signal will “freeze” at 3.5 mA and all relays will remain in their non-alarm state while the M2A is in Calibration Mode. The output signal will not indicate current readings and the relays will not resume operating normally until the M2A is in normal operation again.*

---

### Preparing for Calibration

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**NOTE:** The following procedure assumes the use of a calibration kit which includes a calibration gas cylinder, a zero air cylinder, a fixed flow regulator with an on/off knob, a calibration cup for the appropriate sensor, and a short piece of sample tubing to connect the regulator to the calibration cup.

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**NOTE:** While in the calibration program, if there is no switch activity for the calibration time-out period the unit will return to normal operation. See “Viewing & Changing M2A Parameters” on page 31 for instructions to set the calibration time-out.

---

---

**NOTE:** The following procedure assumes that the target gas is present in a high enough concentration to affect the fresh air (zero) reading. If a fresh air environment can be verified, applying zero air to the detector is not necessary when setting the zero (span for oxygen) reading.

---

1. Connect the calibration kit sample tubing to the calibration cup hose barb.
  2. Screw the calibration cup onto the detector.
- 

**NOTE:** For an ESM-01 detector, you must unscrew the removable splashguard from the detector housing cap so you can push the appropriate calibration cup onto the ESM-01 sensor. Make sure to use the correct calibration cup for the sensor being used. There is a Cl<sub>2</sub> type calibration cup for a Cl<sub>2</sub> sensor, an NH<sub>3</sub> type calibration cup for an NH<sub>3</sub> sensor, and a general type (usually labeled SO<sub>2</sub>) calibration cup for all other ESM-01 sensors.

---

3. Connect the fixed flow regulator to the calibration cup using the sample tubing.
- 

**NOTE:** When calibrating an NH<sub>3</sub> ESM-01, the 0.25 LPM flowrate regulator must be used. All other M2As require a 0.5 LPM flowrate regulator.

---

## Non-Intrusive Calibration

If the M2A is installed in a classified area and non-intrusive calibration is required, follow the instructions below, but do not remove the junction box cover. Use the magnetic wand accessory to actuate the magnetic switches instead of pushing the control switch buttons. To actuate a magnetic switch and perform the same operation as pressing a control switch button, touch the magnet in the end of the magnetic wand to the M2A's glass cover directly above the magnetic switch you wish to actuate. Touching the glass and removing the wand is the same as pressing and releasing a button. Touching the glass and keeping the wand in place is the same as pressing and holding a button.

## Calibration Gas Response Memory Feature

The M2A has the capability to “remember” the detector’s response to the calibration gas after the gas is removed from the detector during the fresh air and span adjustment procedure. This feature enables one person to perform a calibration if the detector is mounted remotely from the M2A. When zero air is applied to the M2A during a fresh air adjustment, the M2A will freeze the display reading at the lowest response and the M2A will continue to display this reading and retain it in its memory until the fresh air adjustment procedure is completed. When calibration gas is applied to the M2A during a span adjustment, the M2A will freeze the display reading at the highest response to the calibration gas. The calibration gas can then be removed and the M2A will continue to display this reading and retain it in its memory until the span adjustment procedure is completed.

## Adjusting the Fresh Air Reading

1. While in normal operation, press and hold the UP/YES button for 5 seconds to enter Calibration Mode. Release the button when the following screen appears.

Calib? YES/NO
------------------

2. If you want to continue with calibration, press and release the UP/YES button. The display will indicate the target gas and **CAL Mode** for a few seconds before showing **FreshAir Adjust?**.

If you want to exit Calibration Mode, press and release the DOWN/NO button. The M2A will indicate **Leaving CAL Mode** and the M2A will return to normal operation.

3. To continue with adjusting the fresh air reading, press and release the UP/YES button. **ENTER** will alternate with **FreshAir** on the top display line and the current gas reading will be on the bottom display line.

To skip adjusting the fresh air reading, press and release the DOWN/NO button. The display will indicate **SPAN w/Cal Gas?**. Skip to the next section, “Adjusting the Span Setting”.

4. Screw the zero air cylinder into the fixed flow regulator.
5. Turn the regulator knob counterclockwise to open the regulator.
6. Allow zero air to flow for two minutes. If there was gas present causing a reading on the M2A, the reading should decrease and stabilize after two minutes.
7. Turn the regulator knob clockwise to close the regulator.
8. Unscrew the zero air cylinder from the fixed flow regulator leaving the calibration cup on the detector. The M2A will continue to display the minimum gas response on the display and retain the response level in its memory.
9. Press and release the ENTER button. The M2A will perform a fresh air adjustment and the display will indicate **SPAN w/Cal Gas?**.

---

**NOTE:** If the fresh air adjustment fails, see “Troubleshooting” on page 39 for recommended actions.

---

## Adjusting the Span Setting

1. If you want to continue with adjusting the span setting, press and release the UP/YES button. **APPLY** will alternate with **SPAN Gas** on the top display line and the current gas reading will be on the bottom display line.

If you want to skip adjusting the span reading, press and release the DOWN/NO button. The display will indicate **Leaving Cal Mode** and the M2A will return to normal operation.

2. Screw the calibration gas cylinder into (onto for an H<sub>2</sub>S cylinder) the fixed flow regulator.
3. Turn the regulator knob counterclockwise to open the regulator.
4. Allow calibration gas to flow for two minutes. The gas reading should be stable after two minutes.
5. Turn the regulator knob clockwise to close it.
6. Unscrew the calibration gas cylinder from the fixed flow regulator and unscrew the calibration cup from the detector. For an ESM-01 detector, pull the calibration cup off of the ESM-01 sensor and screw the splashguard back onto the detector housing cap. The M2A will continue to display the maximum gas response on the display and retain the response level in its memory.
7. Adjust the gas reading up or down to match the calibration gas cylinder concentration by using the UP/YES and DOWN/NO buttons, then press and release the ENTER button.
8. The M2A will perform a span operation. The display will indicate **SPAN Gas PASS** for a few seconds, then indicate **SPAN Gas SAVED** before indicating **Leaving CAL Mode** for a few seconds.

---

**NOTE:** If the span adjustment fails, see “Troubleshooting” on page 39 for recommended actions.

---

9. The display will now alternate between the normal operation screen and the message **REMOVE CAL GAS** for 1 minute. If the calibration gas has not been removed from the detector, remove it now to avoid unwanted alarms.

During this 1 minute period, the signal output will remain fixed at 3.5 mA and the relays will remain in their non-alarm state to avoid unwanted alarms while the calibration gas clears from the detector. At the end of the 1 minute period, the **REMOVE CAL GAS** message will stop appearing and the M2A will return to normal operation.

10. Store the components of the calibration kit in a safe place.

---

## Calibration, Oxygen Version

This section describes how to calibrate the oxygen version of the M2A. It includes procedures to prepare for calibration, enter Calibration Mode, set the fresh air (span) reading, set the zero reading, and return to normal operation.

---

**WARNING:** *The M2A is not an active gas monitoring device during the calibration procedure. The 4-20 mA output signal will “freeze” at 17.4 mA and all relays will remain in their non-alarm state while the M2A is in Calibration Mode. The output signal will not indicate current readings and the relays will not resume operating normally until the M2A is in normal operation again.*

---

### Preparing for Calibration

---

**NOTE:** The following procedure assumes the use of a calibration kit which includes a zero air (20.9% oxygen) calibration cylinder to set the fresh air reading, a 100% nitrogen (0% oxygen) calibration gas cylinder to set the zero reading, a fixed flow regulator with an on/off knob, a calibration cup, and a short piece of sample tubing to connect the regulator to the calibration cup. A cylinder with up to an 18% oxygen concentration may be used instead of a 100% nitrogen cylinder to set the zero reading.

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---

**NOTE:** While in calibration mode, if there is no switch activity for the calibration time-out period the unit will return to normal operation. See “Viewing & Changing M2A Parameters” on page 31 for instructions to set the calibration time-out.

---

---

**NOTE:** The following procedure assumes that the oxygen concentration in the calibration area is not normal, 20.9%, but is oxygen deficient. If a fresh air environment can be verified, applying zero air to the detector is not necessary when adjusting the fresh air (span) setting.

---

1. Connect the calibration kit sample tubing to the calibration cup hose barb.
2. Screw the calibration cup onto the detector.
3. Connect the fixed flow regulator to the calibration cup using the sample tubing.

### Non-Intrusive Calibration

If the M2A is installed in a classified area and non-intrusive calibration is required, follow the instructions below, but do not remove the junction box cover. Use the magnetic wand accessory to actuate the magnetic switches instead of pushing the control switch buttons. To actuate a magnetic switch and perform the same operation as pressing a control switch button, touch the magnet in the end of the magnetic wand to the M2A’s glass cover directly above the magnetic switch you wish to actuate. Touching the glass and removing the wand is the same as pressing and releasing a button. Touching the glass and keeping the wand in place is the same as pressing and holding a button.

### Calibration Gas Response Memory Feature

The M2A has the capability to “remember” the detector’s response to the calibration gas after the gas is removed from the detector during the fresh air or zero adjustment procedure. This feature enables one person to perform a calibration if the detector is mounted remotely from the M2A. When zero air is applied to the M2A during a fresh air adjustment, the M2A will freeze the display

reading at the highest response and the M2A will continue to display this reading and retain it in its memory until the fresh air adjustment procedure is completed. When calibration gas is applied to the M2A during a zero adjustment, the M2A will freeze the display reading at the lowest response to the calibration gas. The calibration gas can then be removed and the M2A will continue to display this reading and retain it in its memory until the zero adjustment procedure is completed.

## Adjusting the Fresh Air Setting

1. While in normal operation, press and hold the UP/YES button for 5 seconds to enter Calibration Mode. Release the button when the following screen appears.

Calib? YES/NO
------------------

2. If you want to continue with calibration, press and release the UP/YES button to continue. The display will indicate **OXYGEN CAL Mode** for a few seconds before showing **FreshAir Adjust?**.

If you want to exit Calibration Mode, press and release the DOWN/NO button. The M2A will indicate **Leaving CAL Mode** and the M2A will return to normal operation.

3. To continue with adjusting the fresh air (span) reading, press and release the UP/YES button. **ENTER** will alternate with **FreshAir** on the top display line and the current oxygen reading will be on the bottom display line.

To skip adjusting the fresh air reading, press and release the DOWN/NO button. The display will indicate **ZERO w/Cal Gas?**. Skip to the next section, "Adjusting the Zero Setting".

4. Screw the zero air cylinder into the fixed flow regulator.
5. Turn the regulator knob counterclockwise to open the regulator.
6. Allow zero air to flow for 2 minutes. If the oxygen concentration in the area is less than 20.9, the reading should stabilize after 2 minutes.
7. Turn the regulator knob clockwise to close the regulator.
8. Unscrew the zero air cylinder from the fixed flow regulator leaving the calibration cup on the detector. The M2A will continue to display the maximum gas response on the display and retain the response level in its memory.
9. Press and release the ENTER button. The M2A will perform a fresh air adjustment and the display will indicate **ZERO w/Cal Gas?**.

---

**NOTE:** If the fresh air adjustment fails, see "Troubleshooting" on page 39 for recommended actions.

---

## Adjusting the Zero Setting

1. If you want to continue with adjusting the zero setting, press and release the UP/YES button. **APPLY** will alternate with **ZERO Gas** on the top display line and the current oxygen reading will be on the bottom display line.

If you want to skip adjusting the zero reading, press and release the DOWN/NO button. The display will indicate **Leaving Cal Mode** and the M2A will return to normal operation.

2. Screw the 100% nitrogen gas cylinder into the fixed flow regulator.
3. Turn the regulator knob counterclockwise to open the regulator.
4. Allow gas to flow for 2 minutes. The gas reading should be stable after 2 minutes.



5. Turn the regulator knob clockwise to close the regulator.
6. Unscrew the nitrogen cylinder from the fixed flow regulator and unscrew the calibration cup from the detector. The M2A will continue to display the minimum gas response on the display and retain the response level in its memory.
7. Adjust the oxygen reading up or down to match the 100% nitrogen cylinder oxygen concentration of 0 by using the UP/YES and DOWN/NO buttons.

---

**NOTE:** If a cylinder other than a 100% nitrogen (0% oxygen) cylinder is used to set the zero reading, such as a cylinder with 12% oxygen, set the zero reading to match the cylinder's oxygen concentration.

---

8. Press and release the ENTER button. The M2A will perform a zero operation. The display will indicate **ZERO Gas PASS** for a few seconds, then indicate **ZERO Gas SAVED** before indicating **Leaving CAL Mode** for a few seconds.

---

**NOTE:** If the zero adjustment fails, see "Troubleshooting" on page 39 for recommended actions.

---

9. The display will now alternate between the normal operation screen and the message **REMOVE CAL GAS** for 1 minute. If the calibration gas has not been removed from the detector remove it now to avoid unwanted alarms.

During this 1 minute period, the signal output will remain fixed at 17.4 mA and the relays will remain in their non-alarm state to avoid unwanted alarms while the calibration gas clears from the detector. At the end of the 1 minute period, the **REMOVE CAL GAS** message will stop appearing and the M2A will return to normal operation.

10. Store the components of the calibration kit in a safe place.

---

## Replacing Components of the M2A

### Replacing the Gas Detector

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**NOTE:** For M2A versions that do not have a replaceable plug-in sensor, or if you determine that it is necessary to replace the entire detector, use the procedure in this section to change the entire detector. For M2A versions that include a replaceable plug-in sensor, see the appropriate instructions in the sections that follow this one to replace the plug-in sensor.

---

1. Turn off or disconnect power to the M2A.
2. Remove the junction box cover.
3. Grasp the control PCB by its edges.
4. Gently pull until the control PCB is pulled away from the banana jacks. Take care not to pull too hard and damage the cable which connects the control and terminal PCBs.
5. Let the control PCB hang by the cable. The terminal strips are now visible on the terminal PCB. The control PCB may be left hanging while wiring is done. If desired, the control PCB may be disconnected from the cable and set aside while wiring.
6. Remove the detector terminal strip from its socket.
7. Disconnect the detector leads from the detector terminal strip. Note the position of the color-

coded leads as you remove them.

8. Unscrew the detector from the junction box.
9. Guide the replacement detector leads through the bottom conduit port of the junction box, then screw the mounting threads of the detector into the conduit port.
10. Connect the detector leads to the detector terminal strip as follows:
  - Catalytic Combustible Gas Detector, IR Combustible Gas Detector, and IR CO<sub>2</sub> Detector  
Red wire to terminal labeled LEL RED, white to terminal labeled LEL WHT, green wire to terminal labeled LEL GRN, black wire to terminal labeled LEL BLK.
  - CO or H<sub>2</sub>S gas detector.  
Red wire to terminal labeled TOXIC +, black wire to terminal labeled TOXIC -.
  - ESM-01 Gas Detector  
Color coded wire to terminal labeled TOXIC +, black wire to terminal labeled TOXIC -. See Figure 25, “ESM-01 Toxic Detector Wiring” on page 21 for the wire color coding.
  - Oxygen gas detector.  
Green wire to terminal labeled OXY +, white wire to terminal labeled OXY -.
11. Re-install the detector terminal strip into its socket.
12. Re-install the control PCB (and ribbon cable if necessary). Be sure the ribbon cable is routed down below the control PCB so it will not be damaged by the cover when it is screwed back on.
13. Secure the junction box cover to the junction box.
14. Turn on or reconnect power to the M2A.

---

**NOTE:** Allow the replacement detector to warm up for 15 minutes before you continue with the next step.

---

15. Calibrate the replacement detector as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42 or “Calibration, Oxygen Version” on page 45.

### Replacing the CO or H<sub>2</sub>S Plug-in Sensor

---

**NOTE:** This procedure is applicable for both the CSA type, explosion proof CO and H<sub>2</sub>S detectors and the non-explosion proof CO and H<sub>2</sub>S detectors.

---

1. Turn off or disconnect power to the M2A.
2. Unscrew the detector cap from the housing body. Make sure not to lose the cap gasket. See Figure 4 - Figure 7 for illustrations of the CO or H<sub>2</sub>S detectors.
3. Unplug and remove the sensor.
4. If you are replacing a CO sensor, remove the rubber boot and charcoal filter from the old sensor.

---

**NOTE:** RKI instruments recommends replacing the charcoal disk filter whenever a CO sensor is replaced.

---

If you are replacing the 65-2428 explosion-proof H<sub>2</sub>S detector’s sensor, remove the rubber

boot and spacer from the old sensor.

5. If you are replacing a CO sensor, install the rubber boot and charcoal filter onto the new sensor's face.

If you are replacing the 65-2428 explosion-proof H<sub>2</sub>S detector's sensor, install the rubber boot and spacer on the new sensor's face.

6. Carefully match the replacement sensor's male pins with the 4-socket pattern in the top section and plug it in.
7. Make sure the cap gasket is in place and screw the detector cap back onto the housing body.
8. Turn on or reconnect power to the M2A.

---

**CAUTION:** *Allow the replacement sensor to warm up for 15 minutes before you continue with the next step.*

---

9. Calibrate the detector as described in "Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions" on page 42.

### Replacing the CO Sensor Charcoal Filter

The charcoal filter is used to scrub out interfering gases from the environment being monitored, such as H<sub>2</sub>S and certain hydrocarbons. If you are experiencing unexplained upscale readings on a CO M2A, the charcoal filter may be saturated and no longer scrubbing out interfering gases and it may be necessary to change the charcoal filter.

1. Turn off or disconnect power to the M2A.
2. Unscrew the detector housing cap from the housing body. Make sure not to lose the cap gasket. See Figure 4 for an illustration of the CO detector.
3. Remove the rubber retaining boot with the charcoal filter disk from the sensor.
4. Replace the charcoal filter disk in the rubber retaining boot and install the boot onto the sensor.
5. Make sure that the cap gasket is in place and screw the detector cap back onto the housing body.
6. Turn on or reconnect power to the M2A.

### Replacing an Oxygen Plug-in Sensor

---

**NOTE:** This procedure is applicable for both the CSA type, explosion proof oxygen detector (65-2514RK) and non-explosion proof, replaceable sensor oxygen detector (65-2494RK).

---

1. Turn off or disconnect power to the M2A.
2. Unscrew the detector cap from the detector housing body. Take care not to lose the cap gasket. See Figure 2 or Figure 3 for an illustration of the oxygen detector.
3. Unplug and remove the sensor.
4. Carefully match the replacement sensor's male pins with the 2-socket pattern in the top section and plug it in.
5. Make sure the cap gasket is in place and screw the detector cap back on to the detector housing.
6. Turn on or reconnect power to the M2A.

---

**NOTE:** Allow the replacement sensor to warm up for 15 minutes before you continue with the next step.

---

7. Calibrate the detector as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42.

### **Replacing an ESM-01 Plug-in Sensor**

1. Turn off or disconnect power to the M2A.
2. Unscrew the detector cap from the detector housing body. Take care not to lose the cap gasket. If the splashguard begins to unscrew from the detector cap, make sure to remove the detector cap also. See Figure 8 for an illustration of the ESM-01 detector.
3. Unplug and remove the sensor.
4. Carefully match the replacement sensor’s plug with the socket in the housing body and plug it in.

---

**WARNING:** *The ESM-01 detectors cannot be changed from one type to another. Replace the plug-in sensor only with the same type of ESM-01 sensor.*

---

5. Make sure the cap gasket is in place and screw the detector cap back onto the housing body. If the splash guard was unscrewed from the detector cap, screw it back onto the detector cap.
6. Turn on or reconnect power to the M2A.

---

**NOTE:** Allow the replacement sensor to warm up for 15 minutes before you continue with the next step.

---

7. Calibrate the detector as described in “Calibration, Combustible Gas, CO<sub>2</sub>, and Toxic Versions” on page 42

# Chapter 8: RS-485 Modbus Output

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## Overview

This chapter describes the M2A's RS-485 Modbus output and how to configure the M2A to make use of it. It also discusses how to wire the M2A into a Modbus system.

The M2A provides an RS-485 serial communications interface. It is a Modbus Slave Device, supporting 2-wire RS-485 Modbus RTU serial communications.

---

## Wiring the M2A in a Modbus System

The M2A is a 2-wire Modbus RTU device. When wiring the M2A into a Modbus system, adhere to standard Modbus wiring practices per the Modbus Over Serial Line Specification and Implementation Guide V1.0 or later. This document can be found online at [www.modbus.org/specs.php](http://www.modbus.org/specs.php).

The Modbus protocol supports a maximum of 247 unique slave addresses (1-247). The M2A's line driver provides for up to 128 M2As to be connected together without the need for a repeater. Figure 29 & Figure 30 below illustrate typical M2A wiring configurations. If more than 128 M2As need to be connected together, RS-485 repeater(s) should be used such that no more than 128 M2As reside on any given network segment.

---

**CAUTION:** *The network segment can only support 128 units if RKI M2As are being used. The use of any other instruments will lower the number of units that may reside on any given network segment.*

---

The MODBUS terminal strip is located on the terminal PCB (see Figure 9). The following signals are available at the Modbus terminal strip:

**Table 10: Modbus Terminal Strip Signals**

Modbus Terminal Label (RS-485 Name)	Modbus Signal Name
A	D0
B	D1
C	Common

### Ground Jumper

The M2A includes a 2-pin ground header (see Figure 9) that is used when the M2A is used in a Modbus system. Every M2A is supplied with a ground jumper (a jumper block) installed onto this header. If the M2A isn't wired into a Modbus system or if it is wired into one as shown in Figure 28, the ground jumper should be installed. If the M2A is wired in a Modbus system as shown in Figure 27, the ground jumper should be removed.

## Recommended Modbus Wiring

The recommended Modbus wiring for the M2A is illustrated in Figure 27 below. In this configuration, 5 wires are used for wiring the M2A into a Modbus system. Figure 27 also illustrates typical alarm device wiring. The ground jumper must be removed in this wiring configuration.

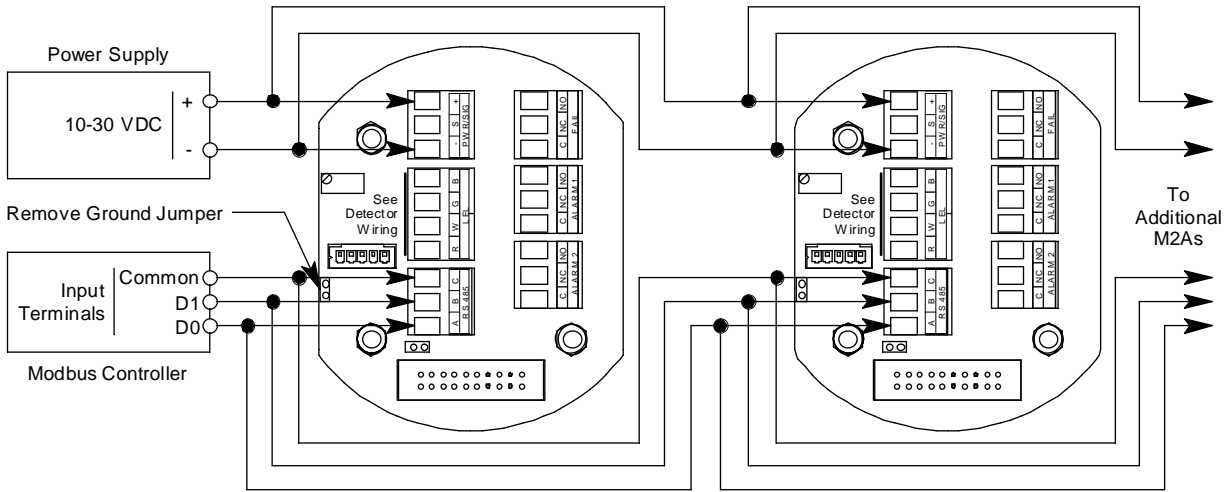


Figure 27: Recommended Modbus Wiring

### Adding an M2A to an Existing M2 Modbus Installation with Recommended Wiring

An M2A can be wired into an existing M2 Modbus system. The shape of the terminal PCB will be different but the wiring connections are identical and the ground jumper on the M2A must still be removed.

### Alternate Modbus Wiring For Existing Installations

Although the wiring shown in Figure 27 is recommended, it is possible to wire the M2A into a Modbus system with only 4 wires in situations where a pre-existing system is being replaced and wiring is already in place. This should only be done if wiring for a system that is being replaced is already installed and it is not practical to run another wire. See Figure 28 below for this wiring configuration. In this configuration, the wire between the “C” terminal on the M2A and the Common terminal on the Modbus controller is omitted. Instead, the Common terminal on the Modbus controller is connected to the “-” of the 24 VDC power supply. The ground jumper must be installed in this wiring configuration.

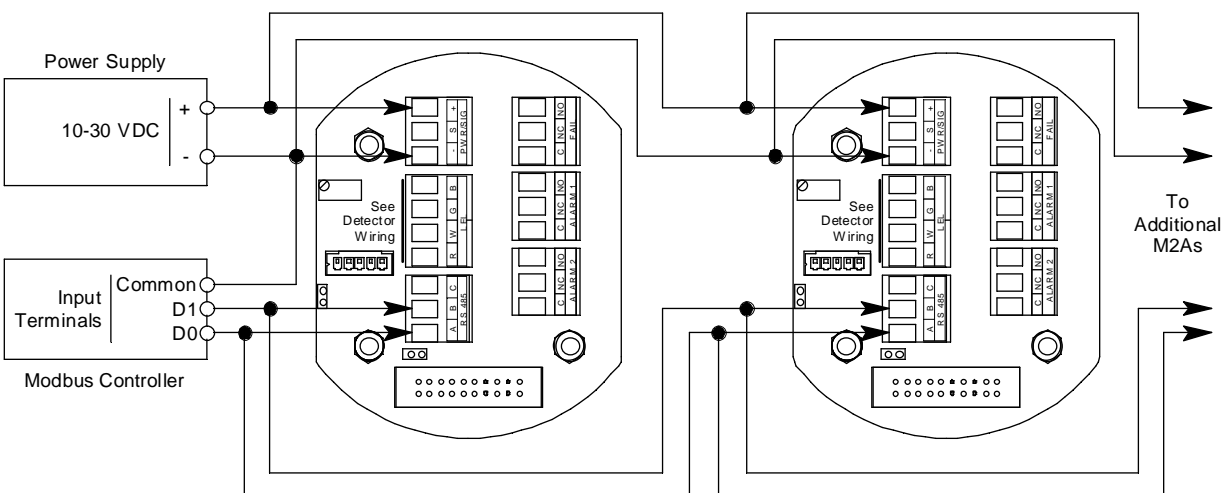


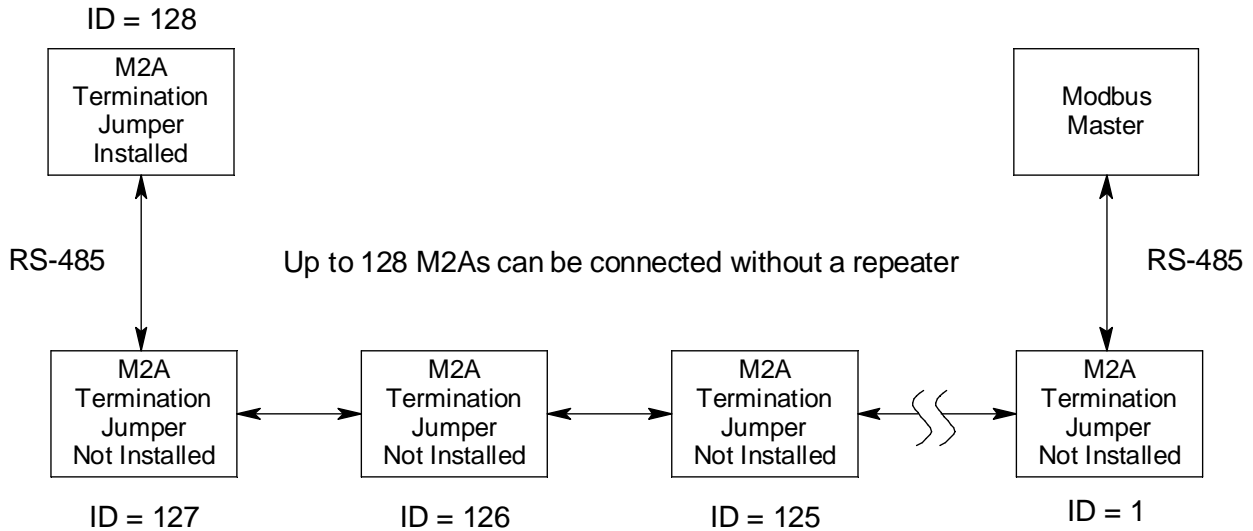
Figure 28: Alternate Modbus Wiring

### ***Adding an M2A to an Existing M2 Modbus Installation with Alternate Wiring***

An M2A can be wired into an existing M2 Modbus system. The shape of the terminal PCB will be different but the wiring connections are identical and the ground jumper on the M2A must still remain installed.

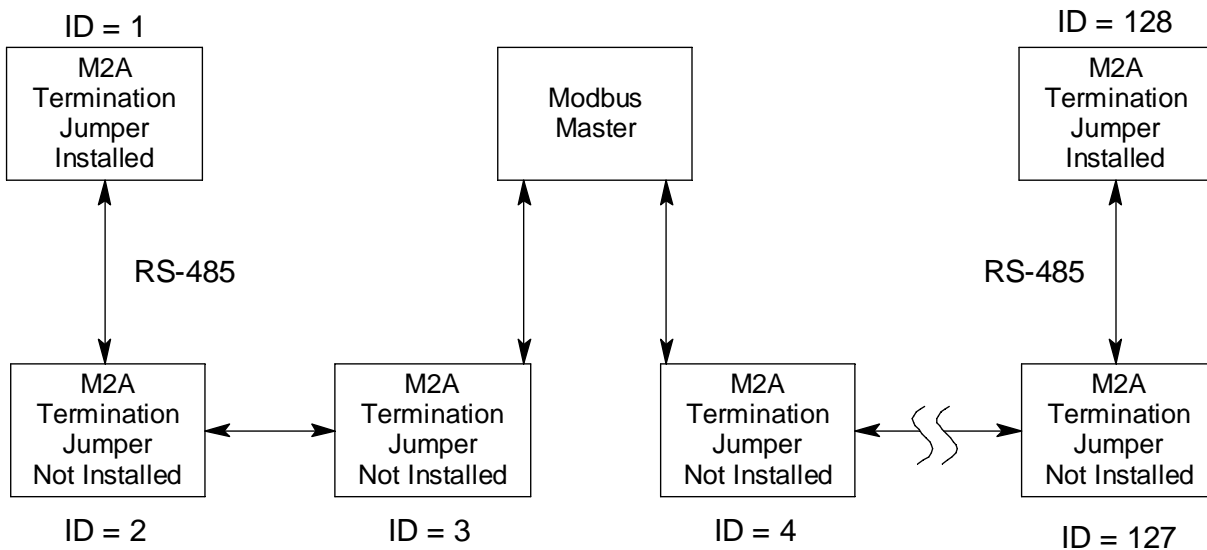
### **Termination Jumper**

The M2A includes a 2-pin termination header (see Figure 9) that is used when the M2A is used in a Modbus system. Every M2A is supplied with a termination jumper (a jumper block) installed onto this header. If the M2A is not used in a Modbus system, this jumper has no function. When the M2A is installed in a Modbus system, this jumper must be installed in an M2A that is at the end of a Modbus line. Any M2A in a Modbus system that is not at the end of a line must have the termination jumper removed (see Figure 29 & Figure 30 below).



**Figure 29: Multiple M2As in a Daisy Chain Configuration**





Up to 128 M2As can be connected without a repeater

**Figure 30: Multiple M2As in a Two Branch Configuration**

---

## Using the M2A in a 4-wire Modbus System

Although the M2A is a 2-wire Modbus RTU device, it can be used with a 4-wire Modbus controller if the system wiring is modified as follows:

- Connect the controller's TxD0 and RxD0 wires together and use this connection as the 2-wire Modbus D0 signal.
- Connect the controller's TxD1 and RxD1 wires together and use this connection as the 2-wire Modbus D1 signal.
- Connect these D0 and D1 signals and the common wire from the controller to the 2-wire Modbus Network of M2As.

---

## Modbus Mode

Modbus Mode allows you to configure various parameters relating to the Modbus setup of the M2A. Modbus Mode includes a 5-minute time-out feature. If you do not press a control button for 5 minutes, the M2A automatically returns to normal operation.

---

**NOTE:** If the M2A returns to normal operation because of a time-out, it enters a warm-up period just as it does when it is first turned on.

---

1. While in normal operation, simultaneously press and hold the DOWN/NO and ENTER buttons

for 5 seconds to enter Modbus Mode. Release the buttons when the following screen appears.

Set Up  
Modbus?

2. To exit Modbus Mode, press and release the DOWN/NO button. The M2A will return to normal operation.

To continue in Modbus Mode, press and release the UP/YES button. The current ENABLED/DISABLED setting will appear.

3. If you want to change the currently displayed parameter, use the UP/YES and DOWN/NO buttons to adjust it to the desired setting, then press ENTER to continue to the next parameter.

If the currently displayed parameter setting is OK, press the ENTER button to proceed to the next parameter.

Table 11 lists the M2A Modbus Mode parameters you can set. Table 11 also lists the factory set value for each parameter.

**Table 11: Configuration Parameters**

<b>Modbus Mode Parameter</b>	<b>Available Settings &amp; Description</b>
Enabled/Disabled	Can be set to ENABLED or DISABLED (factory setting). Enables or disables the Modbus output.
Slave ID	The Slave ID can be set to values from 1 (factory setting) to 247.  The M2A will only receive messages from the Master which are addressed to this Slave ID (except for broadcast messages which are received by all slaves).
Baud Rate	Can be set to 1200, 2400, 4800, 9600 (factory setting), 14440, & 19200.
Parity	EVEN (factory setting), ODD, NONE
Response Delay	The response delay can be set from 0 (factory setting) to 20 mS.  This is an optional additional delay inserted by the M2A prior to returning a response message to the Master. It may be helpful in some installations where the Master's preparedness to receive responses might be delayed.

4. When you have scrolled through all the adjustable parameters, **SAVE IT? YES/NO** appears on the display.
5. If you do not wish to save the adjustments, press and release the DOWN/NO button. The **DO OVER? YES/NO** message will display. Press and release the DOWN/NO button. The **ABORT? YES/NO** message will display. Press the UP/YES button to return to normal operation.

If you wish to change some of the adjustments made, press and release the DOWN/NO button. The **DO OVER? YES/NO** message will display. Press and release the UP/YES button. The **Re-do MB Setup** message will display and the M2A will return to the first adjustable parameter. Go back to step 3 and continue.

If you want to save the adjustments made, press and release the UP/YES button. **Modbus Saved** is indicated on the display for a few seconds and the M2A returns to normal operation.

---

**NOTE:** All M2As on a Modbus network must be configured with the same baud rate and parity, and each M2A must have a unique slave ID. For an M2A to participate on a network, the ENABLED/DISABLED setting must be set to ENABLE.

---

## Supported Modbus Functions

The M2A supports Function Code 03: Read Holding Registers and Function Code 16: Write Registers.

### Function Code 03: Read Holding Registers

There are a total of 40 registers available to be read via this Function Code.

#### Registers 1 - 2

The format (bit & field assignments) for registers 1 - 2 is shown below in Table 12 - Table 13.

**Table 12: Register 1, Numerical Reading with Sign & Decimal Point Bit & Field Assignments**

Bit(s)	Value & Field
[15]	<u>Sign of Reading</u> 0 = Positive 1 = Negative
[14:13]	<u>Format of Reading</u> 0 = XXX (no decimal point) 1 = XX.X 2 = X.XX 3 = .XXX
[12:0]	Numerical value of display reading (8000 max)

**Table 13: Register 2, Operating State, Alarms & Relays Bit & Field Assignments**

Bit(s)	Value
[15:12]	<u>Operating State</u> 0 = Undefined 1 = Initialization 2 = Normal 3 = Warm-up 4 = Fail 5 = Calibration 6 = Post-Calibration 7 = Low Power 8 = Setup
[11]	<u>Gas Type Change</u> 0=Not Changed 1=Changed
[10]	<u>Configuration Change</u> 0=Not Changed 1=Changed
[9]	<u>Calibration Activity Flag</u> 0=No Calibration Activity 1=Calibration Activity Has Occurred
[8]	<u>Fail Status</u> 0 = Fail Not Asserted 1 = Fail Asserted

**Table 13: Register 2, Operating State, Alarms & Relays Bit & Field Assignments (Continued)**

<b>Bit(s)</b>	<b>Value</b>
[7:6]	<u>Alarm 2 Status</u> 0 = No Alarm 1 = Unacknowledged Alarm 2 = Acknowledged Alarm 3 = Unused Code
[5:4]	<u>Alarm 1 Status</u> 0 = No Alarm 1 = Unacknowledged Alarm 2 = Acknowledged Alarm 3 = Unused Code
[3]	<u>Overscale Status</u> 0 = Not Overscale 1 = Overscale
[2]	<u>Fail Relay Status</u> 0 = Not Energized 1 = Energized
[1]	<u>Alarm 2 Relay Status</u> 0 = Not Energized 1 = Energized
[0]	<u>Alarm 1 Relay Status</u> 0 = Not Energized 1 = Energized

**Register 3**

Register 3 is the supply voltage (0.1 volt per count).

**Registers 4 - 11**

The 16 bytes in these registers contain the same ASCII text information that is displayed on the M2A's OLED (not NULL Terminated).

**Register 12**

Register 12 is the range (full scale readout).

**Register 13**

Register 13 is the alarm 1 set point.

The decimal point location is the same as specified in Register 1.

**Register 14**

Register 14 is the alarm 2 set point.

The decimal point location is the same as specified in Register 1.

**Registers 15 - 19**

Registers 15 - 19 are the Gas Name ASCII String (NULL Terminated).

**Registers 20 - 22**

Registers 20 - 22 are the Gas Units String (NULL Terminated).

**Register 23**

Register 23 is the alarm 1 trigger.

0=Decreasing

1=Increasing

**Register 24**

Register 24 is the alarm 1 normal relay state.

0=Normally De-Energized

1=Normally Energized

**Register 25**

Register 25 is the alarm 1 relay reset.

0=Latching

1=Self-Resetting

**Register 26**

Register 26 is the alarm 1 ON delay.

Integer values are in seconds.

**Register 27**

Register 27 is the alarm 1 OFF delay.

Integer values are in seconds.

**Register 28**

Register 28 is the alarm 2 trigger.

0=Decreasing

1=Increasing

**Register 29**

Register 29 is the alarm 2 normal relay state.

0=Normally De-Energized

1=Normally Energized

**Register 30**

Register 30 is the alarm 2 relay reset.

0=Latching

1=Self-Resetting

**Register 31**

Register 31 is the alarm 2 ON delay.

Integer values are in seconds.

**Register 32**

Register 32 is the alarm 2 OFF delay.

Integer values are in seconds.

**Register 33**

Register 33 is zero suppression.

Toxics and LEL: 0%-6% of full scale

Oxygen: 0%-0.7% Oxygen

The decimal point location is the same as specified in Register 1.

### **Register 34**

Register 34 is noise filter.  
Integer values in seconds.  
0-60 in 5 second increments.

### **Register 35**

Register 35 is calibration timeout in minutes (5, 10, 15, 20, 25, or 30).

### **Register 36**

Register 36 is calibration month (upper byte) and day (lower byte).  
This is zero based (e.g. January=0 and the 1st=0).

### **Register 37**

Register 37 is the calibration year.

### **Register 38**

Register 38 is the calibration outcome.  
Upper=Gas Operation  
Lower=Air Operation

Calibration Outcome Codes:

- 1=Sensor Missing
- 2=Sensor Too Weak
- 3=Signal Too Strong
- 4=Not Enough Span
- 5=Negative Reading
- 6=Span Gas Value Is Not OK
- 7=Calculated Zero Is Too Low
- 8=Calculated Zero Is Too High
- 9=Zero Failure
- 10=Span Failure
- 11=Calibration Is Overscale
- 12=LEL Sensor Offset Is Too High
- 13=LEL Null Operation Failed
- 14=Operation Not Performed

### **Register 39**

Register 39 is the auto-zero disable.  
0=AutoZero Enabled  
1=AutoZero Disabled

### **Register 40**

Register 40 is the remote configuration register access level  
0=None  
1=Alarm Reset



## Function Code 16: Write Registers

There are 21 registers in Function Code 16 that can be used to write to the M2A. This manual only describes Register 16 because it can be used to reset an alarm condition. For a complete description of Function Code 16, request Appendix C from RKI Instruments, Inc.

### Register 16

Register 16 performs the same function as the ENTER button on the M2A. It is useful for remotely silencing alarms. With the M2A in an alarm condition, bit [0] can be used to silence it.

**Table 14: Register 16, Button Function**

**NOTE:** Register 40 in Function Code 03, the remote configuration register, must be set to 1 in order for Register 16 to work.

Bit	Value & Field
[0]	ENTER (used for "Alarm Reset") 0=Not Pressed 1=Pressed

## Parts List

Table 15 lists replacement parts and accessories for the M2A Transmitter.

**Table 15: Parts List**

Part Number	Description
06-1248RK	Calibration kit sample tubing (3/16 in. x 5/16 in.; specify length when ordering)
07-0033RK	Cap gasket, for CSA type CO and H <sub>2</sub> S detector
07-0125RK	Cap gasket, for ESM-01 detector
07-0203RK	Rubber retaining boot for charcoal filter and for 65-2428 H <sub>2</sub> S detector
14-2101RK	Spacer for 65-2428 H <sub>2</sub> S detector
18-0431RK-01	Junction box
33-7101RK	Charcoal filter disk
45-6132RK	Termination and group jumper
61-0140RK	LEL detector, catalytic type, UL version
61-0140RK-05	LEL detector, catalytic type, CSA version
61-0190RK-CH <sub>4</sub>	CH <sub>4</sub> LEL detector, IR type
61-0190RK-HC	HC LEL detector, IR type, propane calibration
61-0191RK-02	CO <sub>2</sub> detector, IR type, 0 - 5,000 ppm
61-0191RK-03	CO <sub>2</sub> detector, IR type, 0 - 5% volume
61-0191RK-05	CO <sub>2</sub> detector, IR type, 0 - 50.0% volume

**Table 15: Parts List**

<b>Part Number</b>	<b>Description</b>
61-0191RK-10	CO <sub>2</sub> detector, IR type, 0 - 100% volume
61-0192RK-CH4	CH <sub>4</sub> detector, IR type, 0 - 100% volume
61-0198RK-02	CO <sub>2</sub> detector, IR type, replaceable sensor, 0 - 5000 ppm
61-0198RK-03	CO <sub>2</sub> detector, IR type, replaceable sensor, 0 - 5% volume
61-0198RK-05	CO <sub>2</sub> detector, IR type, replaceable sensor, 0 - 50.0% volume
61-0198RK-10	CO <sub>2</sub> detector, IR type, replaceable sensor, 0 - 100% volume
65-1025RK	Plug-in oxygen sensor, for 65-2514RK
65-2300RK-ASH3	ESM-01 detector, 0 - 1.50 ppm arsine
65-2300RK-CL-10	ESM-01 detector, 0 - 10.0 ppm chlorine
65-2300RK-CL2	ESM-01 detector, 0 - 3.00 ppm chlorine
65-2300RK-NH3	ESM-01 detector, 0 - 75.0 ppm ammonia
65-2300RK-PH3	ESM-01 detector 0 - 1.00 ppm phosphine
65-2300RK-SO2	ESM-01 detector, 0 - 6.00 ppm sulphur dioxide
65-2428	H <sub>2</sub> S detector assembly, CSA version
65-2438	CO detector assembly, 0 - 300 ppm, CSA version
65-2438-01	CO detector assembly, 0 - 100 ppm and 0 - 200 ppm, CSA version
65-2494RK	Oxygen detector assembly, non-explosion proof, replaceable sensor
65-2495RK	H <sub>2</sub> S detector assembly, 0 - 100 ppm, non-explosion proof, replaceable sensor
65-2496RK	CO detector assembly, 0 - 300 ppm, non-explosion proof, replaceable sensor
65-2510RK	Oxygen detector, partial pressure type
65-2511RK	Oxygen detector, capillary type
65-2514RK	Oxygen detector, CSA version, capillary type
71-0305RK	<i>M2A Transmitter Operator's Manual (this document)</i>
81-0002RK-01	Calibration cylinder, 50% LEL hydrogen in air, 34 liter steel
81-0002RK-03	Calibration cylinder, 50% LEL hydrogen in air, 103 liter steel
81-0004RK-01	Calibration cylinder, 50% LEL propane in air, 34 liter steel
81-0004RK-03	Calibration cylinder, 50% LEL propane in air, 103 liter steel
81-0007RK-01	Calibration cylinder, 15% LEL hexane in air, 34 liter steel
81-0012RK-01	Calibration cylinder, 50% LEL methane in air, 34 liter steel
81-0012RK-03	Calibration cylinder, 50% LEL methane in air, 103 liter steel
81-0013RK-01	Calibration cylinder, 50% volume methane in nitrogen, 34 liter steel

**Table 15: Parts List**

<b>Part Number</b>	<b>Description</b>
81-0013RK-05	Calibration cylinder, 50% volume methane in nitrogen, 58 liter steel
81-0064RK-01	Calibration cylinder, CO, 50 ppm in air, 34 liter steel
81-0064RK-03	Calibration cylinder, CO, 50 ppm in air, 103 liter steel
81-0070RK-01	Calibration cylinder, CO <sub>2</sub> , 2,000 ppm in nitrogen, 34 liter steel
81-0070RK-03	Calibration cylinder, CO <sub>2</sub> , 2,000 ppm in nitrogen, 103 liter steel
81-0072RK-01	Calibration cylinder, CO <sub>2</sub> , 2.5% in nitrogen, 34 liter steel
81-0072RK-03	Calibration cylinder, CO <sub>2</sub> , 2.5% in nitrogen, 103 liter steel
81-0073RK-01	Calibration cylinder, CO <sub>2</sub> , 15% in nitrogen, 34 liter steel
81-0073RK-03	Calibration cylinder, CO <sub>2</sub> , 15% in nitrogen, 103 liter steel
81-0076RK-01	Zero air calibration cylinder, 34 liter steel
81-0076RK-03	Zero air calibration cylinder, 103 liter steel
81-0078RK-01	Calibration cylinder, 100% nitrogen, 34 liter steel (used for setting oxygen zero)
81-0078RK-03	Calibration cylinder, 100% nitrogen, 103 liter steel (used for setting oxygen zero)
81-0151RK-02	Calibration cylinder, H <sub>2</sub> S, 25 ppm in nitrogen, 58 liter aluminum
81-0151RK-04	Calibration cylinder, H <sub>2</sub> S, 25 ppm in nitrogen, 34 liter aluminum
81-0170RK-02	Calibration cylinder, 5 ppm SO <sub>2</sub> in nitrogen, 58 liter
81-0170RK-04	Calibration cylinder, 5 ppm SO <sub>2</sub> in nitrogen, 34 liter
81-0175RK-02	Calibration cylinder, 10 ppm NH <sub>3</sub> in nitrogen, 58 liter
81-0175RK-04	Calibration cylinder, 10 ppm NH <sub>3</sub> in nitrogen, 34 liter
81-0185RK-02	Calibration cylinder, 0.5 ppm PH <sub>3</sub> in nitrogen, 58 liter
81-0185RK-04	Calibration cylinder, 0.5 ppm PH <sub>3</sub> in nitrogen, 34 liter
81-0190RK-02	Calibration cylinder, 5 ppm Cl <sub>2</sub> in nitrogen, 58 liter
81-0190RK-04	Calibration cylinder, 5 ppm Cl <sub>2</sub> in nitrogen, 34 liter
81-0192RK-02	Calibration cylinder, 2 ppm Cl <sub>2</sub> in nitrogen, 58 liter
81-0192RK-04	Calibration cylinder, 2 ppm Cl <sub>2</sub> in nitrogen, 34 liter
81-1050RK	Regulator, with gauge and knob, 0.5 liter/minute continuous flow, for combustible gas, nitrogen, zero air, and CO cylinders.
81-1051RK	Regulator, with gauge and knob, 0.5 liter/minute continuous flow, for H <sub>2</sub> S cylinder
81-1051RK-25	Regulator, fixed flow, w/gauge & knob, 0.25 LPM, for 34 liter aluminum/58 liter/103 liter cylinder ( <b>Used to calibrate NH<sub>3</sub> ESM-01 M2A only</b> )
81-1103RK	Calibration cup, for 3/4" NPT IR detectors, combustible gas and CO <sub>2</sub>

**Table 15: Parts List**

<b>Part Number</b>	<b>Description</b>
81-1117RK	Calibration cup, for catalytic LEL, CO, H <sub>2</sub> S, and oxygen detectors
81-1138RK	Calibration cup, general (SO <sub>2</sub> ), for ESM-01, use 0.5 LPM flow
81-1138RK-CL2	Calibration cup, for ESM-01 Cl <sub>2</sub> , use 0.5 LPM flow
81-1138RK-NH <sub>3</sub>	Calibration cup, for ESM-01 NH <sub>3</sub> , use 0.25 LPM flow
81-1190RK	Splashguard, for ESM-01 detector cap
ES-1531-CO	CO sensor, plug-in
ES-1537-H <sub>2</sub> S	H <sub>2</sub> S sensor, plug-in
ESM-015-NO	ESM-01 plug-in sensor, 0 - 100 ppm nitric oxide
ESM-01DH-ASH <sub>3</sub>	ESM-01 plug-in sensor, 0 - 1.50 ppm arsine
ESM-01DH-D-SO <sub>2</sub>	ESM-01 plug-in sensor, 0 - 6.00 ppm sulphur dioxide, diffusion type only
ESM-0DH-PH <sub>3</sub>	ESM-01 plug-in sensor, 0 - 1.00 ppm phosphine
ESM-01R-D-NH <sub>3</sub>	ESM-01 plug-in sensor, 0 - 75.0 ppm ammonia, diffusion type only
ESM-K01-D-CL <sub>2</sub>	ESM-01 plug-in sensor, 0 - 3.00 ppm chlorine, diffusion type only
ESM-K01D-CL <sub>2</sub> -10	ESM-01 plug-in sensor, 0 - 10.0 ppm chlorine, diffusion type only
NC-6205-01	Hydrogen specific LEL detector, catalytic type, UL version
NC-6205-05	Hydrogen specific LEL detector, catalytic type, CSA version

## Appendix A: Control Button Quick Reference Guide

The M2A's control buttons allow access to operational modes, resetting of alarms, and display of the Information Screen. Table 16 shows which button combinations perform these functions and which parameters are available for adjustment while in the operational modes. While in these modes, display prompts showing a “?” require you to respond by pressing either the UP/YES (for yes) or DOWN/NO (for no) button. To change parameter settings, use the UP/YES and DOWN/NO buttons to get the desired setting, then press and release the ENTER button to accept the setting.

**Table 16: Control Button Quick Reference Chart**

<b>Mode Entered or Function Performed</b>	<b>Button Combination</b>	<b>Adjustable or Viewable Parameters</b>
Alarm Reset	Press and Release ENTER	n/a
Show Information Screen	Press and Hold DOWN/NO	<ul style="list-style-type: none"> <li>• Input Voltage</li> <li>• M2A Version/Revision Information</li> </ul>
Calibration Mode	Press and Hold UP/YES for 5 seconds	<ul style="list-style-type: none"> <li>• Fresh Air Adjust</li> <li>• Span (or Zero for Oxygen) Adjust with Calibration Gas</li> </ul>
Configuration Mode	Press and Hold UP/YES & ENTER for 5 seconds	<ul style="list-style-type: none"> <li>• Alarm Levels</li> <li>• Increasing or Decreasing Alarms</li> <li>• Normally Energized or Normally De-energized Relays</li> <li>• Latching or Self-resetting Alarms</li> <li>• Alarm On Delay</li> <li>• Alarm Off Delay (if self-resetting)</li> <li>• Zero Suppression</li> <li>• Noise Filter</li> <li>• Calibration Time-out Period</li> </ul>
Gas Type Mode	Press and Hold UP/YES and DOWN/NO for 5 seconds	Gas Type
Modbus Mode	Press and Hold DOWN/NO and ENTER for 5 seconds	<ul style="list-style-type: none"> <li>• Enable or Disable Modbus</li> <li>• Slave ID</li> <li>• Baud Rate</li> <li>• Parity</li> <li>• Response Delay</li> </ul>

# Appendix B: PLC and DCS Device Wiring

The M2A can be wired to a PLC or DCS device if desired.

1. Guide multi conductor shielded cable or cables or wires in conduit through the top conduit port of the junction box. The number of cables or wires needed will depend on whether any relays are used and whether the Modbus output is used. Use the following recommendations to determine how to wire the M2A:
  - If Modbus connections will not be used and only the PWR/SIG terminal strip connections will be used, use four conductor shielded cable or four wires in conduit for connections to the power/signal terminal strip.

**Table 17: Wire Size for PWR/SIG Connections**

Max Distance to Controller w/18 Gauge Wire	Max Distance to Controller w/16 Gauge Wire	Max Distance to Controller w/14 Gauge Wire
2,500 ft.	5,000 ft.	8,000 ft.

- If the PWR/SIG terminal strip connections and one or more relays are used, route the connections to the M2A in conduit. Use shielded cable in the conduit for the PWR/SIG connections and unshielded cable or individual wires for the relay connections. Make sure any wire or cable used for relay wiring is appropriately rated for the power that it will carry.

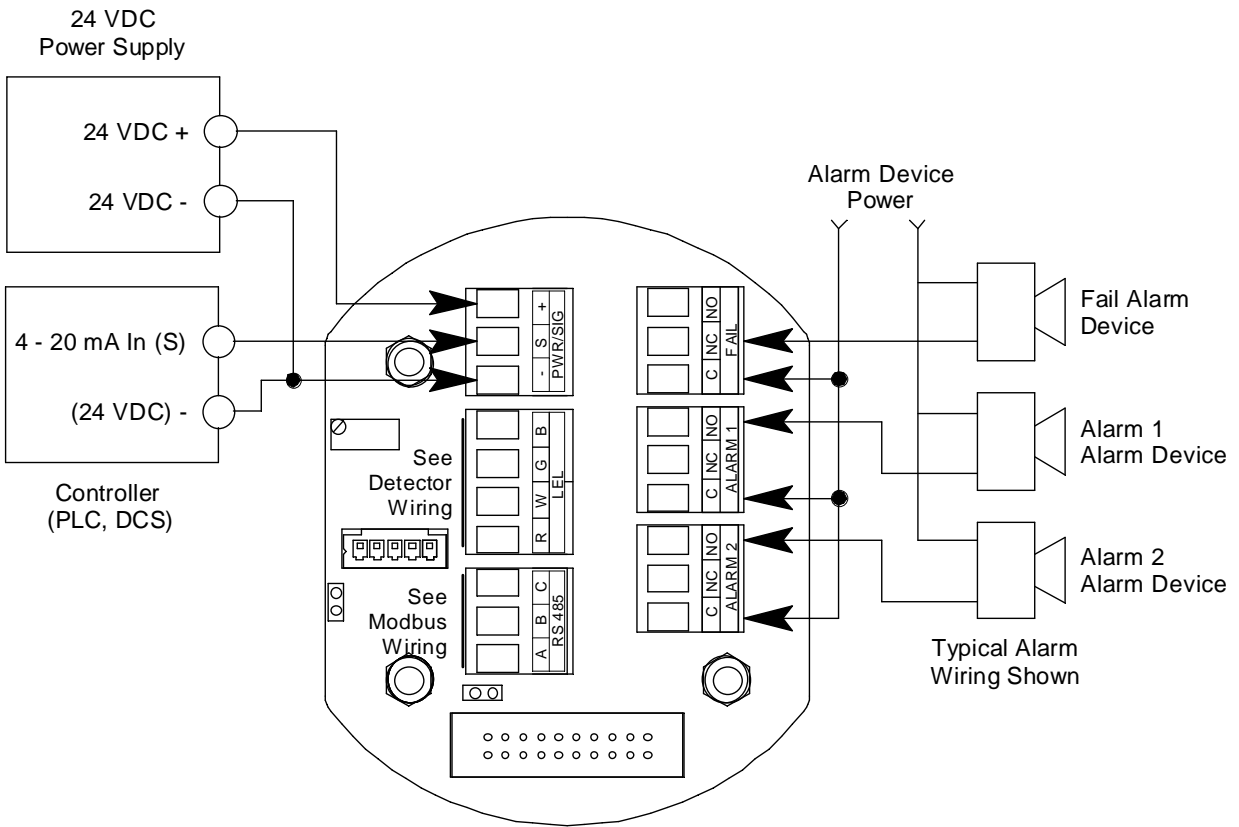
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**NOTE:** If shielded cable is used for the PWR/SIG connections, leave the cable shield's drain wire insulated and disconnected at the M2A. You will connect the opposite end of the cable's drain wire at the controller or device.

---

- If the M2A will be wired into a Modbus network, see "Chapter 8: RS-485 Modbus Output" on page 51.

See Figure 31 below for field wiring connections to the M2A.



**Figure 31: PLC and DCS Device Wiring**



# Appendix C: Function Code 16 Registers

The M2A supports Function Code 16 that allows writing to the M2A. There are 21 registers in this Function Code.

## Register 1

Register 1 is the alarm 1 set point.  
Value must be an integer. Any decimals are omitted.

## Register 2

Register 2 is the alarm 1 trigger.  
0=Decreasing  
1=Increasing

## Register 3

Register 3 is the alarm 1 relay state.  
0=Normally De-Energized  
1=Normally Energized

## Register 4

Register 4 is the alarm 1 relay reset.  
0=Latching  
1=Self-Resetting

## Register 5

Register 5 is the alarm 1 ON delay.  
Integer value is in seconds.

## Register 6

Register 6 is the alarm 1 OFF delay.  
Integer value is in seconds.

## Register 7

Register 7 is the alarm 2 set point.  
Value must be an integer. Any decimals are omitted.  
The decimal point location is the same as specified in Register 1 of Function Code 03.

## Register 8

Register 8 is the alarm 2 trigger.  
0=Decreasing  
1=Increasing

## Register 9

Register 9 is the alarm 2 relay state.  
0=Normally De-Energized  
1=Normally Energized

## Register 10

Register 10 is the alarm 2 relay reset.

0=Latching

1=Self-Resetting

## Register 11

Register 11 is the alarm 2 ON delay.

Integer value is in seconds.

## Register 12

Register 12 is the alarm 2 OFF delay.

Integer value is in seconds.

## Register 13

Register 13 is the zero suppression.

Toxics and LEL: 0%-6% Full Scale

Oxygen: 0%-0.7% Oxygen

Value must be an integer. Any decimals are omitted.

## Register 14

Register 14 is the noise filter.

Integer value is in seconds (0-60 in 5 second increments).

## Register 15

Register 15 is the calibration timeout.

Value is in minutes (5, 10, 15, 20, 25, or 30).

## Register 16

Register 16 is explained in “Supported Modbus Functions” in the M2A manual.

## Register 17

Register 17 is the calibration month (MSB) and day (LSB).

This is zero-based (e.g. January=0 and the 1st=0).

## Register 18

Register 18 is the calibration year.

## Register 19

Register 19 is for clearing change flags. When parameters are changed at the M2A, a flag is raised at the controller. This register can be used to clear those flags.

**Table 18: Register 19, Clear Change Flags**

Bit(s)	Value & Field
[15:2]	Unused
[1]	Write “1” to this bit to clear “Gas Type Changed” flag
[0]	Write “1” to this bit to clear “Configuration Changed” flag

## **Register 20**

Register 20 is the AutoZero Disable.

0=AutoZero Enabled

1=AutoZero Disabled

## **Register 21**

Register 21 is the Remote Configuration Register.

0=No Remote Configuration

1=Reset Alarm



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## **APPENDIX H**

### Control Panel Specification

## SECTION 26 00 00

### BASIC ELECTRICAL

#### PART I - GENERAL

##### 1.1 DESCRIPTION

This section covers furnishing and installation of items required for the basic electrical connections for the vapor mitigation system (VMS) project.

##### 1.2 APPLICABLE PUBLICATIONS

Publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1. National Electrical Code (NEC), latest edition.
2. National Fire Protection Association (NFPA).
3. National Electrical Manufacturers Association (NEMA).
4. National Electrical Contractors Association (NECA).
5. American National Standards Institute (ANSI).
6. Institute of Electrical and Electronics Engineers (IEEE).
7. Underwriters Laboratories (UL).

#### PART II - PRODUCTS

##### 2.1 RACEWAYS

- A. Conduit and conduit fittings, which will be encased in concrete and buried in earth, shall be not smaller than 1-inch, unless otherwise specified in the plans; conduit embedded in slabs shall have an inside diameter not smaller than 1-inch. Exposed (aboveground and inside the enclosure) conduit runs shall be rigid galvanized steel. Conduit shall accommodate the respective wire and permit either the insertion or removal of wire without injurious abrasion. Conduit shall be manufactured under the supervision of the Underwriters' Laboratories factory inspection label service, and each finished length shall bear the official UL label (at time of acquisition from vendor). For this project, it is recommended that no electrical conduit be buried, unless absolutely necessary and they Class 1 Division 1 requirements would be in force.
- B. Rigid Galvanized Steel Conduit (RSC): Rigid galvanized steel conduit shall be carbon steel, hot-dip galvanized, threaded and shall conform to ANSI C80.1, FS WW-C-581E and UL-6.
- C. Liquid Tight Flexible Conduit (LFC): Flexible steel conduit shall be full weight interlocking steel, liquid-tight, and shall conform to the requirements of FS WW-C-566C and UL 360. Conduit shall consist of a flexible galvanized steel core having an extruded neoprene jacketing. Conduits 1-1/4 inches and smaller in diameter shall contain copper bonding conductor spiral-wound between the convolutions. Conduit compound shall be lead free, conductive and anti-seize type.
- D. Polyvinyl Chloride Conduit (PVC): PVC conduit shall be Carlon PV-Duit, Type 40, 90 degree C or approved substitute conforming to UL 651. Conduit shall conform to NEMA and NEC standards. The same manufacturer shall produce conduit, fittings and cement. Material must have a tensile strength of 7000 psi at 73.4 degrees F., flexural strength of 11,000 psi and compressive strength of 8600 psi.

## 2.3 EMPTY CONDUIT SYSTEMS

Empty conduit systems shall consist of, conduits, junction boxes, pull boxes, plates, identification tags, fittings, support devices, and other associated equipment. Empty conduits shall be furnished with a nylon or polypropylene pull rope having a minimum tensile strength of 500 pounds. Empty conduit systems shall be demonstrated to be free from debris prior to final acceptance of the work.

## 2.4 IDENTIFICATION

- A. Underground Utilities Markers:
  - 1. Allen Systems, Inc., inert polyethylene plastic ribbon, 6 inches wide by 4.0 mil thick or equivalent, as approved by the Owner.
  - 2. Color code as recommended by American Public Works Association (APWA). Safety red for electric power distribution. Safety alert orange for telephone, signal, data and cable television.
  - 3. Imprint over entire length of ribbon in permanent black letters, the system description, selected from manufacturer's standard legend, which most accurately identifies the subgrade system.
  - 4. Install continuous tape, 6 to 8 inches below finish sub-base, for each exterior underground raceway.
  - 5. Where multiple small lines are buried in a common trench and do not exceed an overall width of 16 inches, install a single marker, over 16 inch width of lines, install multiple tapes not over 10 inches apart (edge to edge) over the entire group of lines.
  - 6. No underground utilities are planned for this project.

## PART III - EXECUTION

### 3.1 GENERAL INSTALLATION REQUIREMENTS

- A. All items shall be installed rigid and secure, plumb and level, and aligned with related and adjoining work.
- B. Anchor bolts and anchorage items shall be furnished as required. Embedded items shall be checked for correctness of location and detail before concrete is placed. All conduit and fixtures shall be anchored to the walls, sides, ceiling, floor, and interior/exterior of the building using proper methods rated for prolonged exterior use in hot and cold weather climate and direct sunlight.
- C. Electrical connections between the electrical components shall be installed in an organized fashion in accordance with all applicable electrical codes and manufacturer requirements/recommendations.
- D. VMS Blower – The VMS blower shall be installed and wired for 230VAC - 3-PH power. The blower shall be an Amatek Rotron model EN404AR72ML (1.0HP, 208-230/460VAC, 3-PH, 60Hz XP-rated motor) regenerative blower. The VMS Control Panel shall contain all equipment and wiring to operate the blower. All necessary conduit and wires shall also be installed to the VMS Control Panel and between the VMS Control Panel and all of the VMS equipment. The blower shall be mounted to the wall using two parallel c-channel struts to allow for easy installation/replacement. The power supply lines to the VMS Blower shall not penetrate the building VMS liner but can penetrate the adjacent walls above the floor.

- E. Methane Gas Sensors – The interior VMS shall include six continuous methane gas monitoring sensors installed at locations throughout the enclosed interior rooms (over the liner) of the building (see ENV 1.0 for locations of the sensors and D/ENV 2.0 for installation configuration). All six sensors shall be RKI M2A Methane specific transmitters (part #65-2649RK-CH4, 0-100% LEL range, 4-20mA output, 10-30VDC). All units shall be installed per manufacturer’s specifications and power and output signal run back to the VMS Control Panel.
- F. VMS Vacuum Transducer – The VMS will be continuously monitored by a Dwyer model SGX-D7522N vacuum transducer (0-60” water column {WC} range, ¼” MPT port, 4-20mA output). A high and low set point for the VMS will be set in the set points screen using telemetry from this transducer.
- G. VMS Blower Run-time Meter – The PLC timer shall log a cumulative run-time meter (in XXX,XXX.X hours) that shows the amount of time the blower has been running. The meter pauses when the system blower is in OFF mode, or in OFF cycle, or thermals are trips or another alarm condition that shuts down the blower. The counter can be reset in the set-points screen when a new blower is installed.
- H. The VMS Control Panel shall include the following components and operate in the following manner:
1. Power distribution for the VMS using 230VAC, 3PH, 60Hz power shall contain a local through panel disconnect switch on the exterior of the VMS Control Panel box.
  2. Properly sized motor starter and thermal protection, per applicable electrical codes, for the VMS blower motor.
  3. A touchscreen HMI (human machine interface) screen shall be installed on the front of the VMS Control Panel. There will be the following three screens:
    - a. Main Screen
    - b. Blower Control Screen
    - c. Set Points Screen
  4. Main Screen – The following information shall be displayed on the Main Screen
    - a. Title of System – “Vapor Mitigation System Control Panel”
    - b. Current time and date
    - c. VMS Blower Mode – This should show if the blower is in “Hand”, “Off”, or “Auto”
    - d. VMS Blower Status – This should show if the blower is “OFF”, “ALARM” (flashing), or “ON”
    - e. VMS Vacuum – Show “VMS Vacuum Level = XX.X inches WC” (current vacuum level of the system to one decimal place.
    - f. Methane Gas Sensors MGS-1 to MGS-6 in units of % LEL (should read 0 to 100 % LEL in accordance with the 4-20mA signals)
    - g. Alarm Activation Methane Level – “Alarm Activation Methane Level = XX.X% of LEL”. The respective Methane Gas Sensor IDs and levels should flash when they reach or exceed this level for more than 5 consecutive seconds.
    - h. Alarm Activation Methane Exceedance Period – “Alarm Activation Methane Exceedance Period = XXX seconds”
    - i. VMS Blower Run-time – There shall be “VMS Blower Run-time = XXX,XXX.X hours”
    - j. Buttons to get to the Blower Control Screen and Set Point Screen.
  5. Blower Control Screen – The following should be visible on the Blower Control Screen:
    - a. VMS Blower Mode – A “Hand/Off/Auto” button should be next to blower label and pressing it rotates its selected mode.
  6. Set Points Screen – The following should be visible on the Set Point Screen
    - a. Alarm Activation Methane Level – XX.X% The operator should be allowed to set a level between 0.0% to 100.0% (one decimal place). Level should flash



- on Set Point Screen and Main Screen if it exceeds 15.0% LEL
- b. Alarm Activation Exceedance Period – This is the period of time that the Alarm Activation Methane Level or either of the VMS Vacuum levels has to continuously exceeded before the system goes into Alarm mode. This period is set between 1 and 999 seconds. If the Alarm Activation does not exceed the level for the entire period (for each respective sensor), then the period is reset to 0 until the next time the level is exceeded on any sensor.
  - c. Blower Cycle – Have ON and OFF cycle times in hours per day and Cycle Start time in 24-HR mode
  - d. Unit will have two ON periods and two OFF periods per 24-HR continuous period (in series – ON/OFF/ON/OFF). A ON or OFF time period can be set between 0 and 1000 minutes.
  - e. VMS Vacuum High and Low Levels – The operator should be able to set high and low set point levels for the VMS in XX.X inches WC.
  - f. Set Time and Date – operator should be able to set time and date.
  - g. VMS Blower Run-Time Counter Reset – Allow the counter to be reset after confirming that they want to do it. Counter will reset back to 000,000.0 hours.
  - h. Buttons to get to the Main Screen or Blower Control Screen
7. One universal Alarm Reset button (labeled “Alarm Reset”) placed on the outside of the VMS Control Panel that should clear alarm and blower shutdown (if it is in the OFF cycle) as long as the alarm condition(s) has been cleared.
  8. The VMS Control Panel should have a digital timer unit that can maintain the date and time for the VMS Control Panel and have a standard battery backup to preserve the time function even when power to the blower is cut (power failure to system or building). The digital time unit should automatically adjust for Pacific Standard Time (PST) and Pacific Daylight Savings Time (PDT).
  9. Motor Thermal Failure Alarm – While the system is in AUTO mode the VMS Blower should shut down if the blower motor thermal protection is tripped. The system should not reactivate until the Alarm Reset button is pushed and the thermal issue has been resolved. The status should flash “ALARM” until it is cleared. The methane sensors shall continue to operate and can also go into Alarm Mode if they have an exceedance.
  10. VMS High Vacuum Level Alarm – If the system reaches or exceeds the high vacuum level set point for a continuous period longer than the Alarm Activation Exceedance Period, the system will go into Alarm mode with the VMS Blower shutting down. When in Alarm mode the blower status will flash “ALARM” until the alarm condition is cleared and the alarm reset button is pressed.
  11. VMS Low Vacuum Level Alarm – If the system drops below or reaches the low vacuum level set point for a continuous period longer than the Alarm Activation Exceedance Period **while the VMS Blower is in AUTO mode and during an ON cycle** the VMS Blower shall continue to run (unless it is off due to a power outage or blower failure) and the status line shall flash “Alarm” and the system will go into Alarm mode. The system will remain in Alarm mode until the alarm condition is cleared and the alarm reset button is pressed.
  12. High Methane Gas Concentration Alarm – If ANY of the methane gas sensors exceed the Alarm Activation Methane Level Set Point level for more than the Alarm Activation Exceedance Period time then the blower shall be activated if it is not already on. The VMS shall go into “ALARM” mode until the alarm is cleared and the reset button is pressed. While in “ALARM” mode the normal AUTO cycles will continue to count time and when the alarm condition is cleared the blower will go back into Auto mode (unless the blower is switched to OFF or HAND) and pick up into the cycle where it would normally be operating (ON or OFF cycle).
  13. ALARM Mode Strobe – A bright (no less than 1,000 lumens) red LED flashing (strobe at about 3 flashes per second) light will need to be installed in the building where it will be seen by personnel/management **and it will flash whenever any alarm condition is active**. The light will flash until the alarm reset button has been pressed and the alarm cleared. A label below this light shall have the following text – “Vapor Mitigation System Methane Alarm – Vacate rooms and

- Check O&M Manual before re-entry”.
14. The VMS Control Panel shall be fabricated and installed by a licensed electrician with experience building vapor mitigation system control panels. All necessary parts, equipment, and supplies shall be supplied by the fabricator to produce a UL listed VMS Control Panel. Contact Amec Foster Wheeler at 503-639-3400 x4044 if you require a reference for a control panel vendor.
  15. The VMS Control Panel shall be installed in the same room as the VMS piping manifold and blower.
  16. All electrical connections in and out of the VMS Control Panel shall be Class 1 – Division 1 and appropriately sealed, as required by site conditions. The control panel shall be at least NEMA4 rated and installed in accordance with manufacturer specifications.
  17. VMS Control Panel should auto restart after a “brown out/black out” and have adequate battery backups to preserve both time, programming, and place in blower cycle.
  18. Six sets of fuse replacements of each type of fuse must be provided with the VMS Control Panel.
  19. Panel fabricator shall provide a three copies of the VMS Control Panel manual with copies of all manufacturer equipment manuals/info, electrical ladder logic, program and CD copy of current program.
  20. Panel fabricator shall be required to provide technician and equipment to test system during commissioning activities and be able to make PLC program adjustments as requested by Engineer during commissioning.

- I. Contractor shall work with the licensed electrical subcontractor and the Owner to ensure that the electrical utilities and systems are installed properly.

END OF SECTION



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**APPENDIX I**

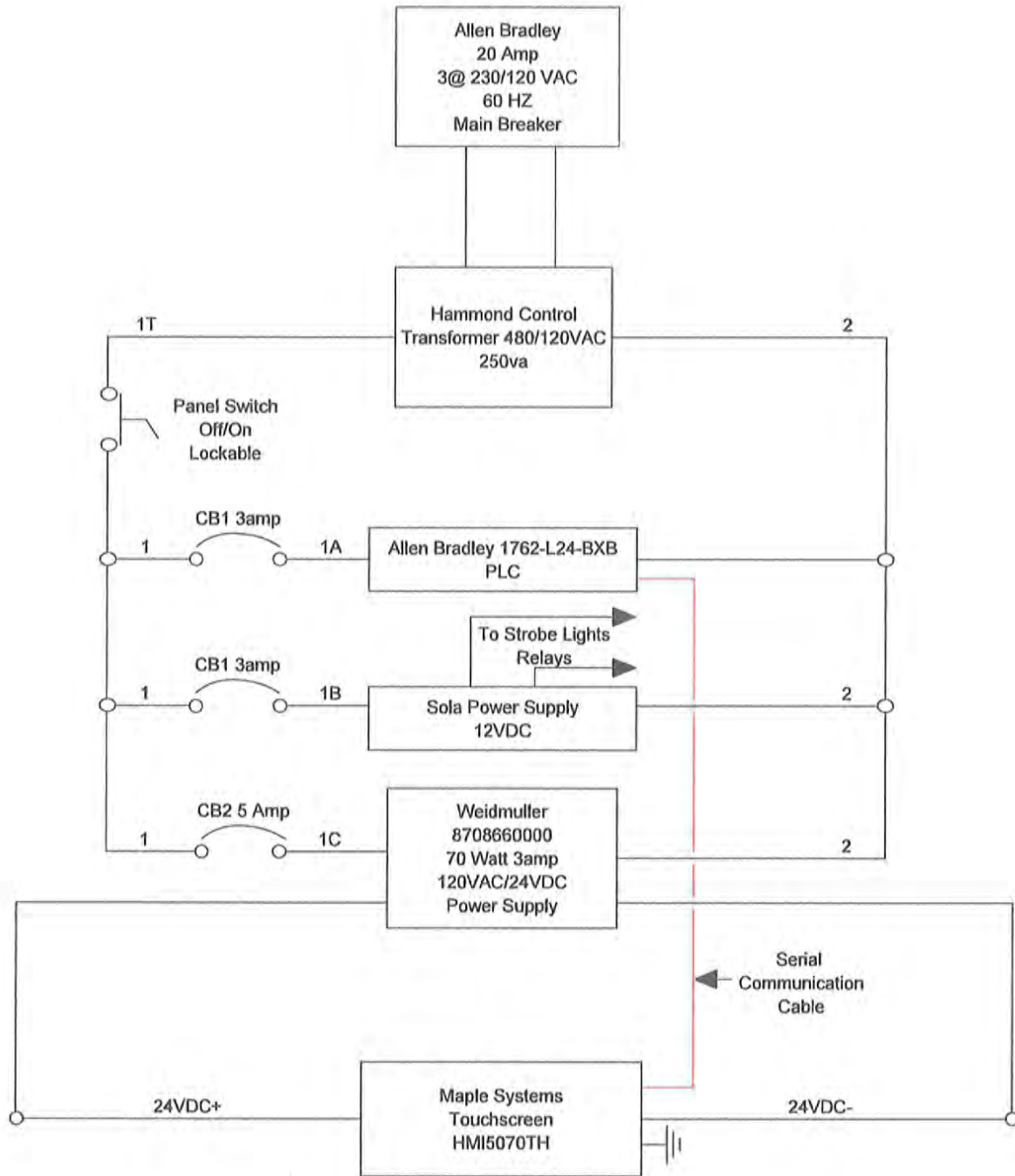
Direct Electrical Contractors – Control Panel Book





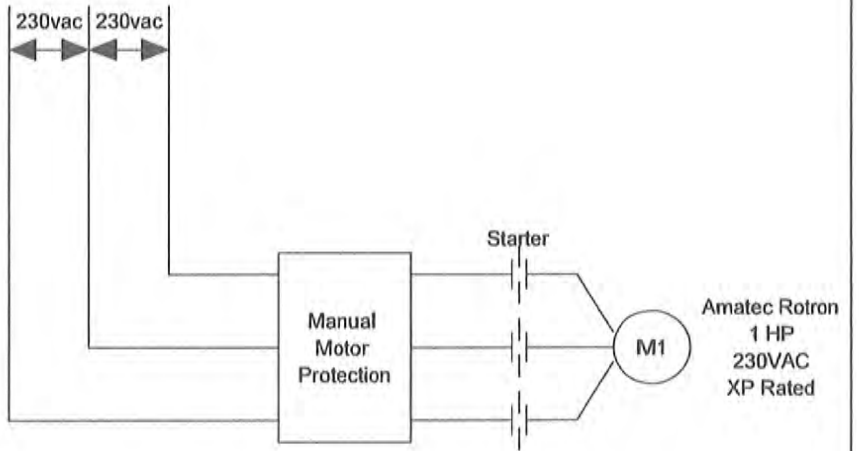
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Vapor Mitigation System  
Control Panel Description and Specifications**





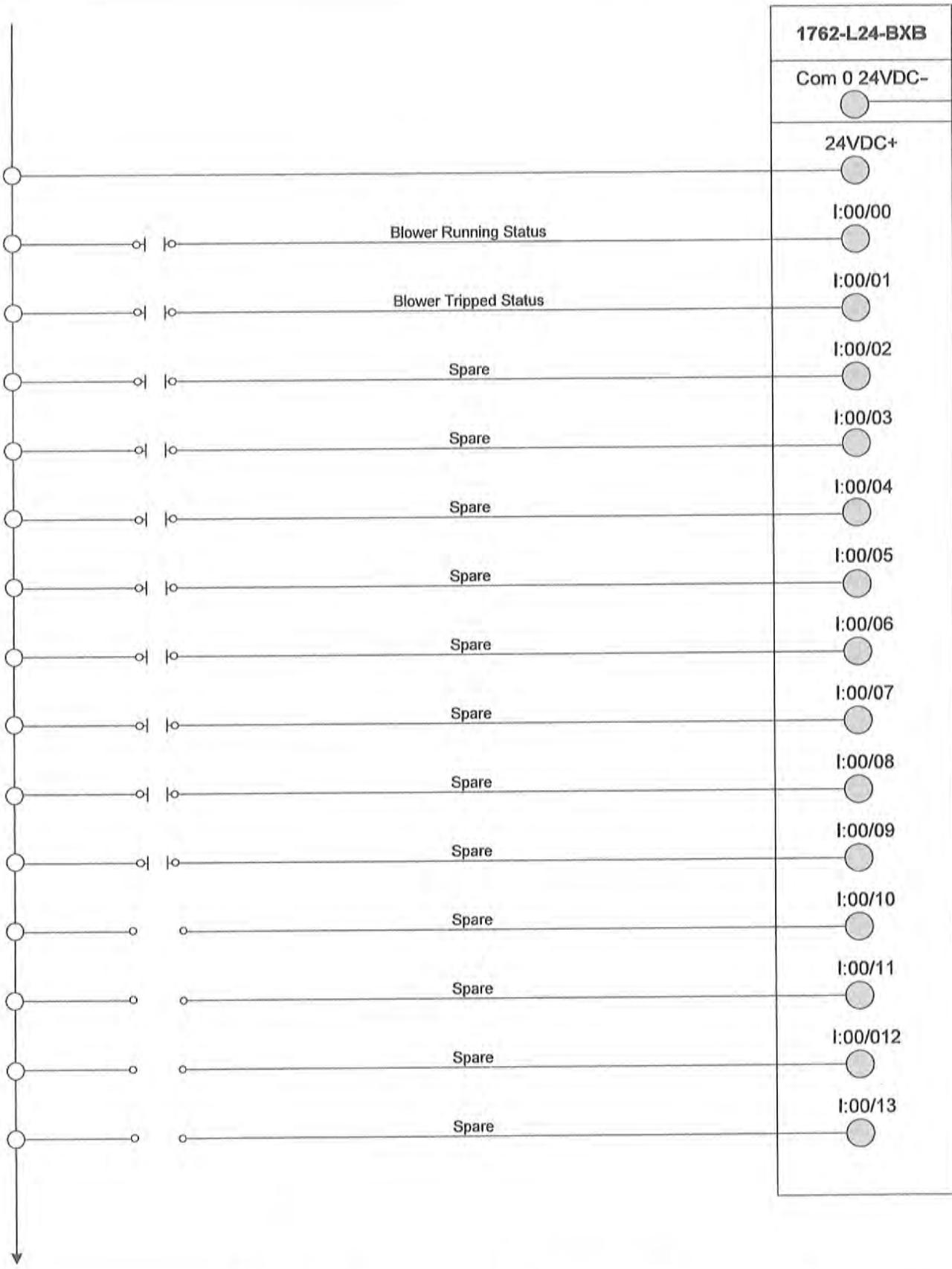
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Oregon City, OR 97045  
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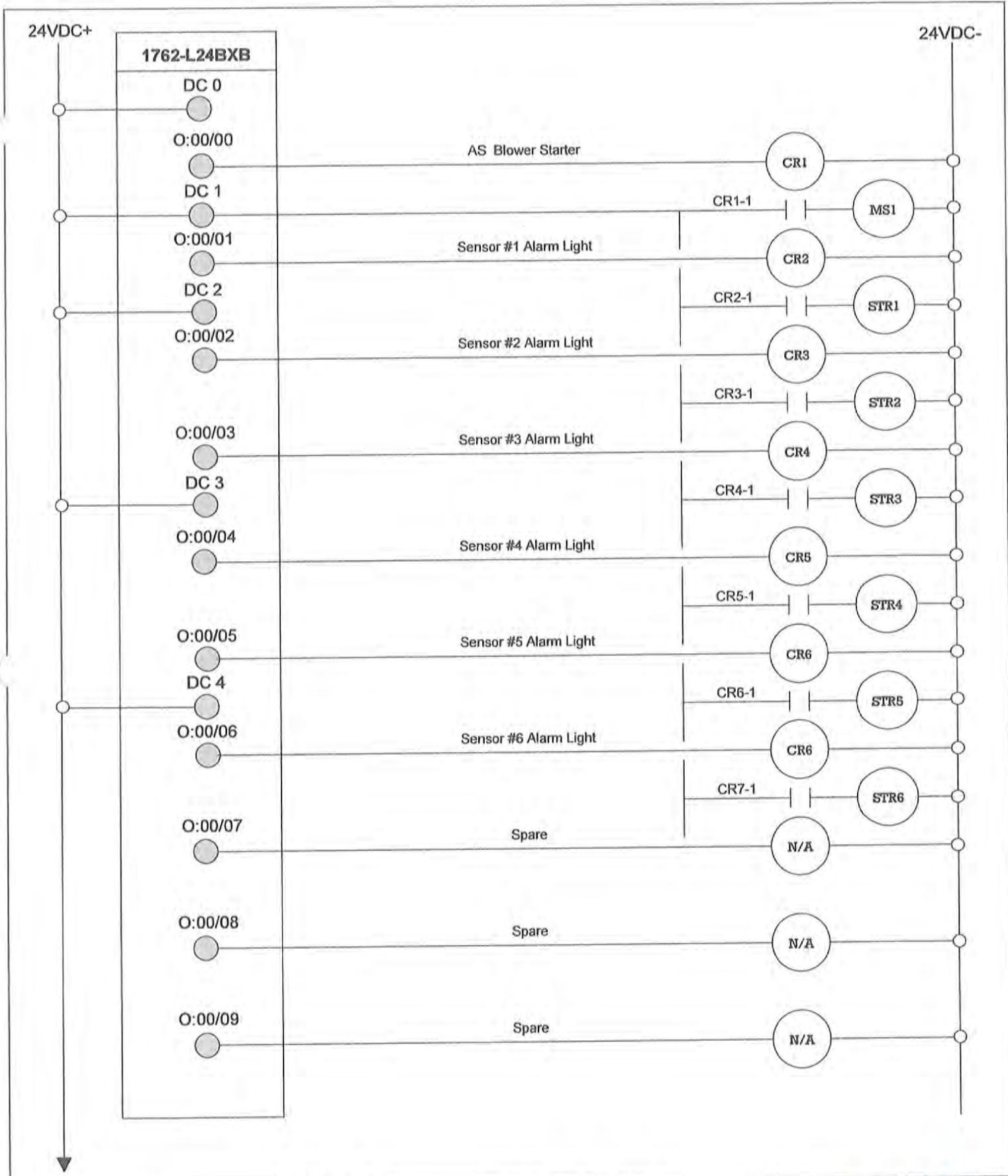




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			Motor Control	

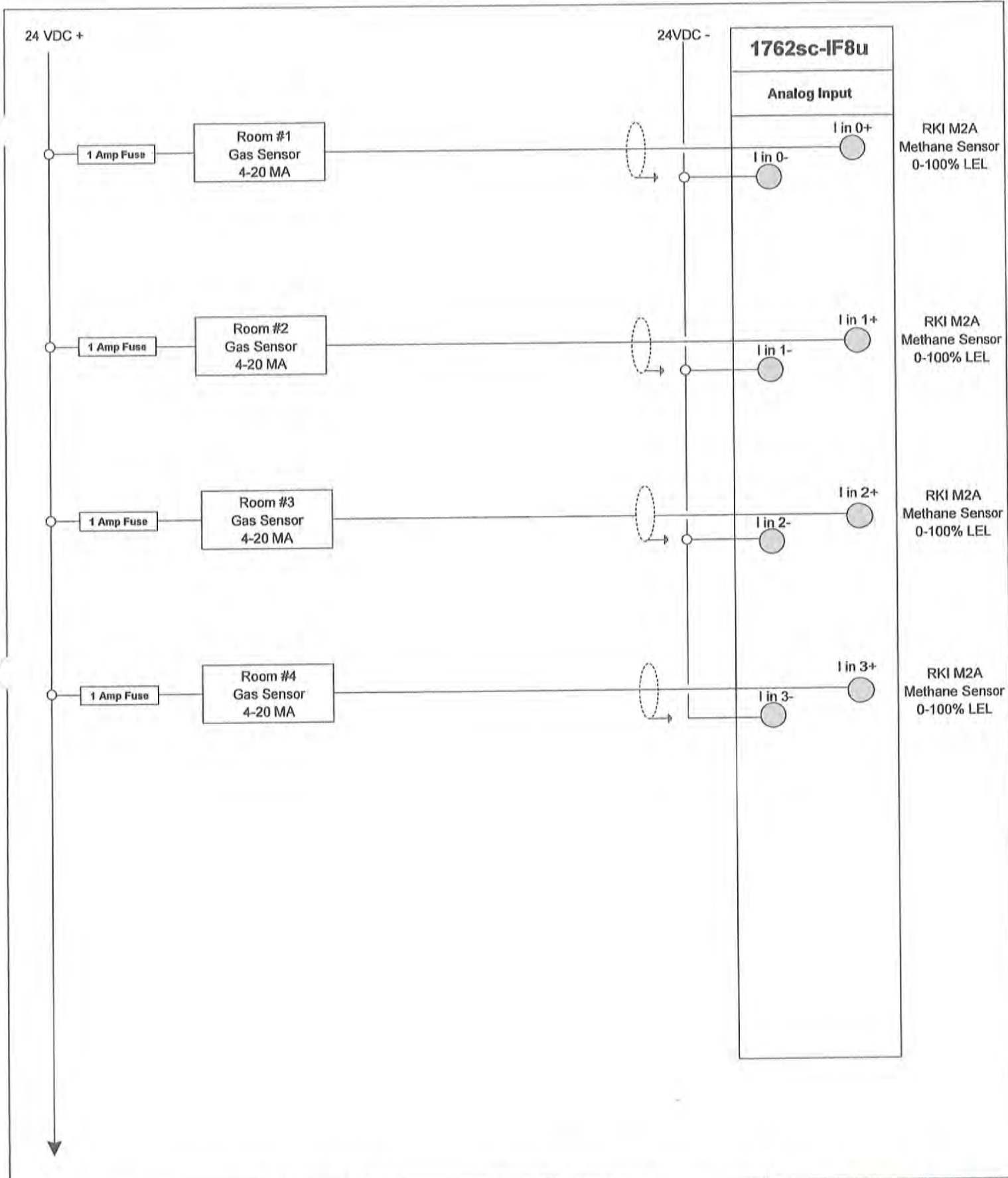


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	11/3/2016	1			Drawn By: TWD	Sheet #3
	DESCRIPTION			PLC Main Module Inputs		





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	11/3/2016	1			Date: 11/3/2016    Drawing # 1004
	<b>DESCRIPTION</b>			Drawn By: TWD	SHEET #4
	PLC Inputs Main Module Outputs				



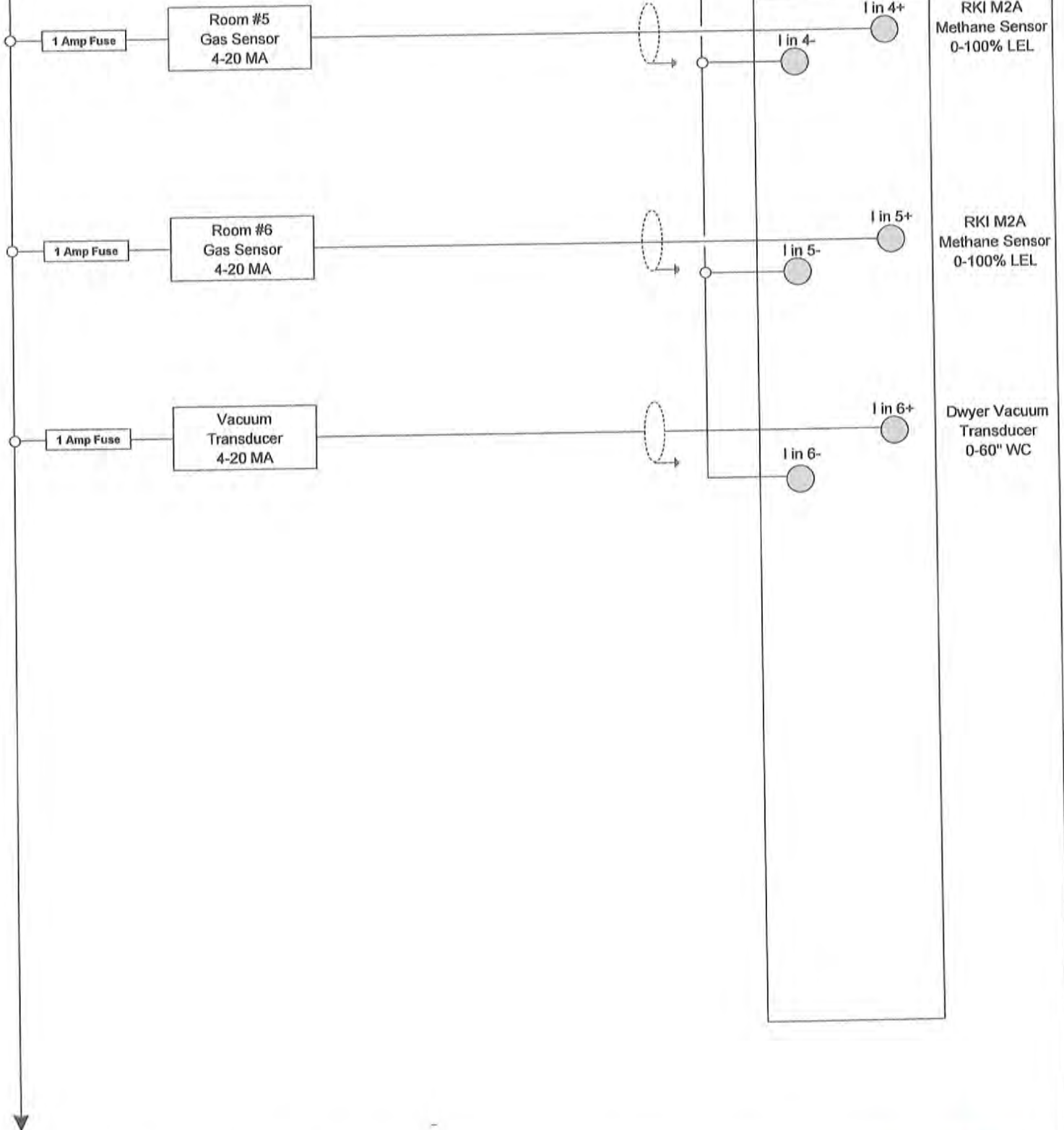
	<b>DATE</b>	<b>REV</b>	Stericycle Monitoring System		Date: 11/3/2016	Drawing # 1105
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	Four Chanel Analog Configuration					



24 VDC +

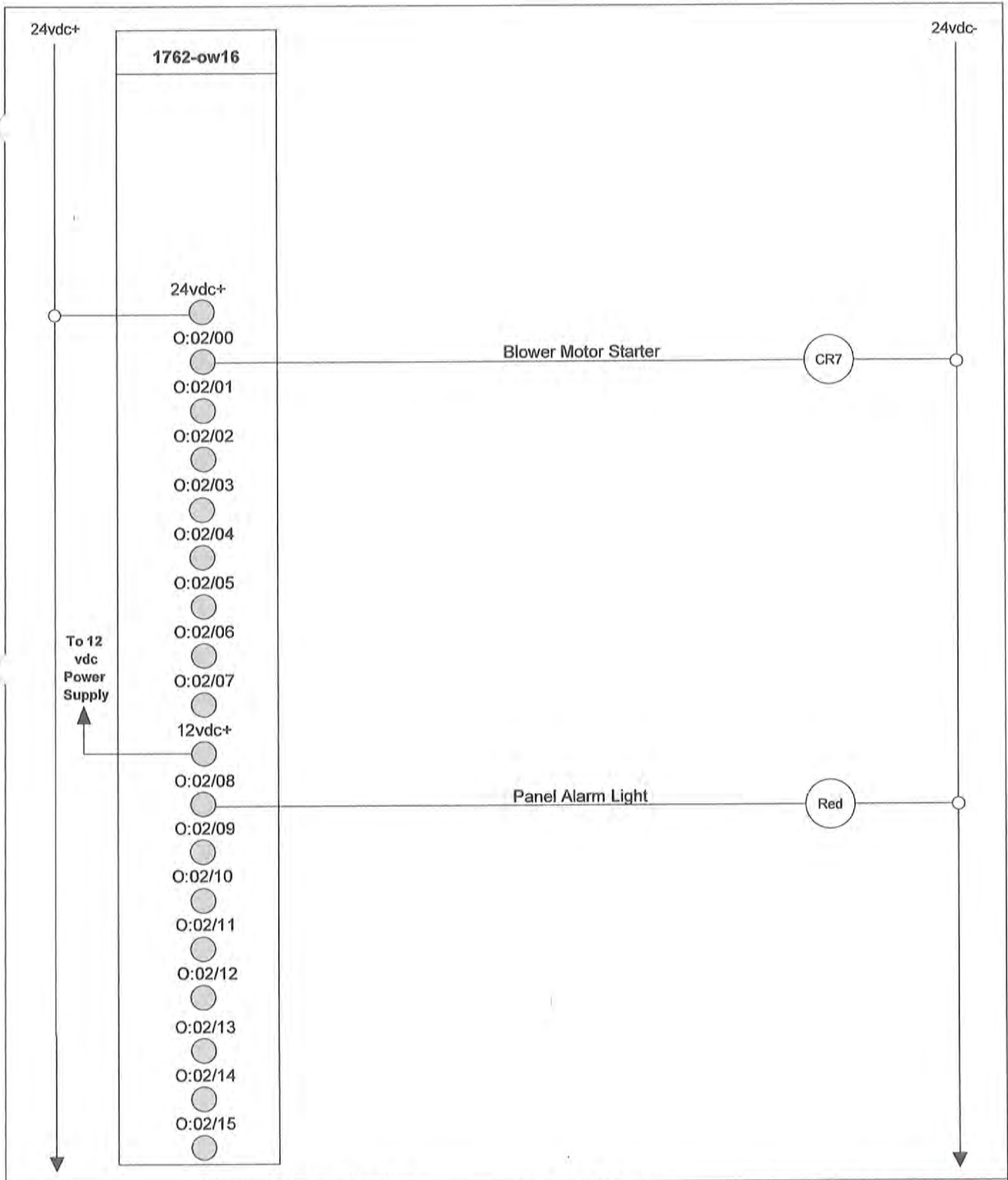
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1762sc-IF8u

Analog Input



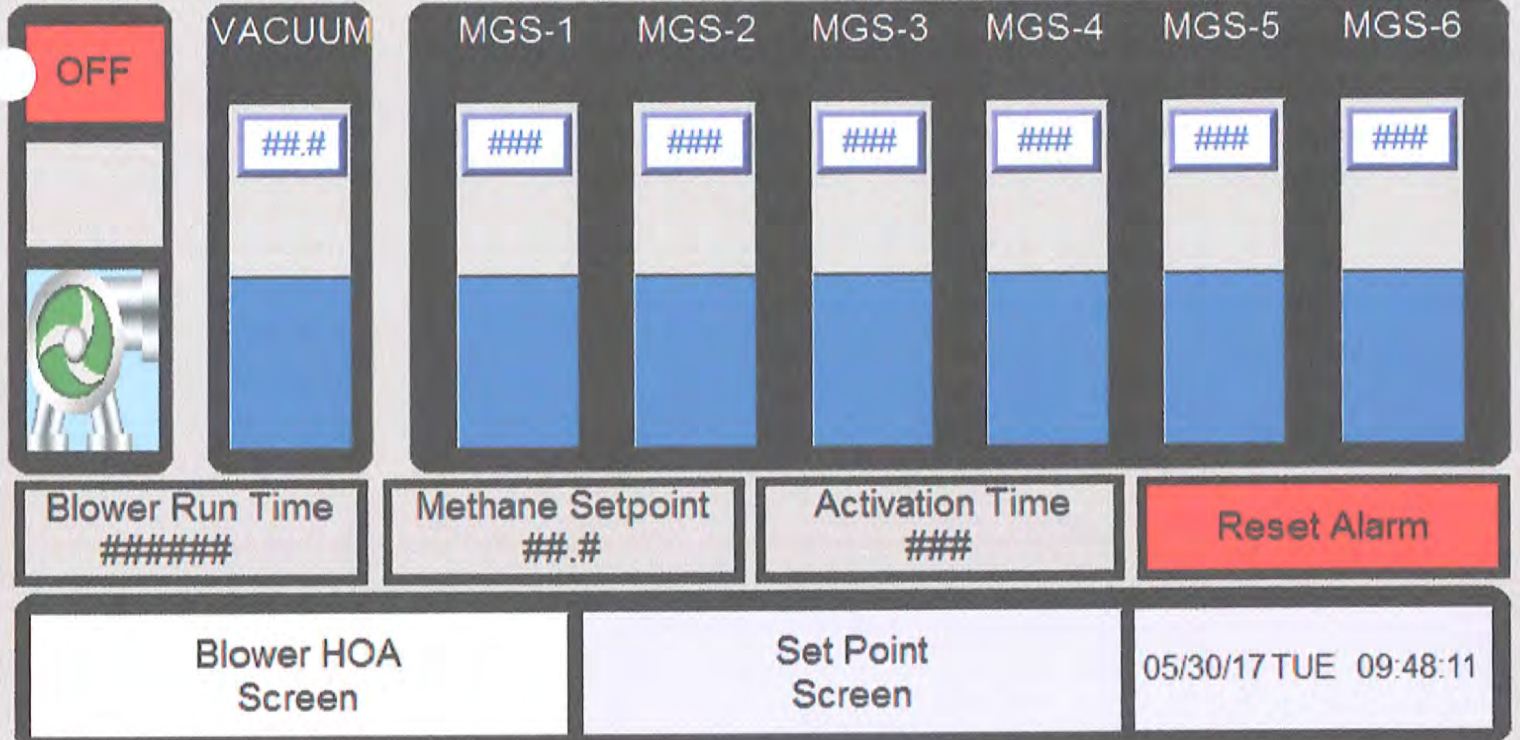
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	11/03/2016	1		
				Drawing # 1107
			<b>DESCRIPTION</b>	Drawn By: TWD
		Micrologix relay output module	Sheet 7	



# Vapor Mitigation System Control Panel



## MAIN SCREEN

The main screen is used to display the following:

- Title of System - "Vapor Mitigation System Control Panel"
- Current time and date
- VMS Blower mode - "hand", "off" or "auto"
- VMS Blower status - "off", "alarm" (flashing) or "on"
- VMS Vacuum - "VMS Vacuum Level = XX.X inches WC" (current vacuum level of the system to one decimal place.
- Methane Gas Sensors MGS-1 to MBS-6 in units of %LEL (should read 0 to 100% LEL in accordance with the 4-20mA signals)
- Alarm Activation Methane Exceedance Period = "XXX seconds"
- VMS Blower run time = XXX,XXX.X
- Buttons to get to the Blower Control Screen and Set Point Screen

# Vapor Mitigation System Blower Mode

## Blower HOA



## Auto Start



## Auto Stop



Cycle 1 ON

Cycle 1 OFF

Cycle 2 ON

Cycle 2 OFF

Main  
Screen

Set Point  
Screen

05/30/17 TUE 09:48:12

## BLOWER CONTROL SCREEN

The blower control screen is used to display the following:

- VMS Blower Mode - A “Hand/Off/Auto” button should be next to blower label and pressing it rotates its selected mode.
- Access to Main Screen and Set Point Screen



# Vapor Mitigation System Setpoints

Methane Alarm Activation Setpoint (% LEL)	##.#	VMS High Vacuum Setpoint (in. WC)	##.#	Year	####	Month	##	Day	##
Methane Alarm Activation Period (Seconds)	###	VMS Low Vacuum Setpoint (in. WC)	##.#	Hour	##	Minute	##	Second	##
Reset Counter		Confirm Reset		Run Time Counter (Hours)					
				#####					
Main Screen			Blower HOA Screen			05/30/17 TUE 09:48:11			

## SET POINTS SCREEN

The Set Points Screen is used to display the following:

- Methane level - The operator should be allowed to set a level between 0.0% to 100.0% (one decimal place) XX.X% . Level should flash on Set Point Screen and Main Screen if it exceeds 15.0% LEL
- Alarm Activation Exceedance Period - This is the period of time the Alarm Activation Methane Level or VMS Vacuum levels have to exceed before the system goes into Alarm mode. This period is set between 1 and 999 seconds.
- Blower Cycle - "ON" and "OFF" cycle times in hours per day, and Cycle Start time in 24-hour mode.
- Unit will have two "ON" periods and two "OFF" periods per 24-hour continuous period (in series - ON/OFF/ON/OFF.) ON or OFF time periods can be set between 0 and 1000 minutes.
- VMS Vacuum High and Low Levels - The operator can set high and low set point levels for the VMS in XX.X inches WC.
- Set Time and Date
- VMS Blower Run Time Counter Reset - Allows the counter to be reset after confirming this action. Counter will reset back to 000,000.0 hours.
- Access to Main Screen and Blower Control Screen



Catalogs > Automation Systems Catalog > Programmable Controllers > MicroLogix 1200 System > MicroLogix 1200 Controllers

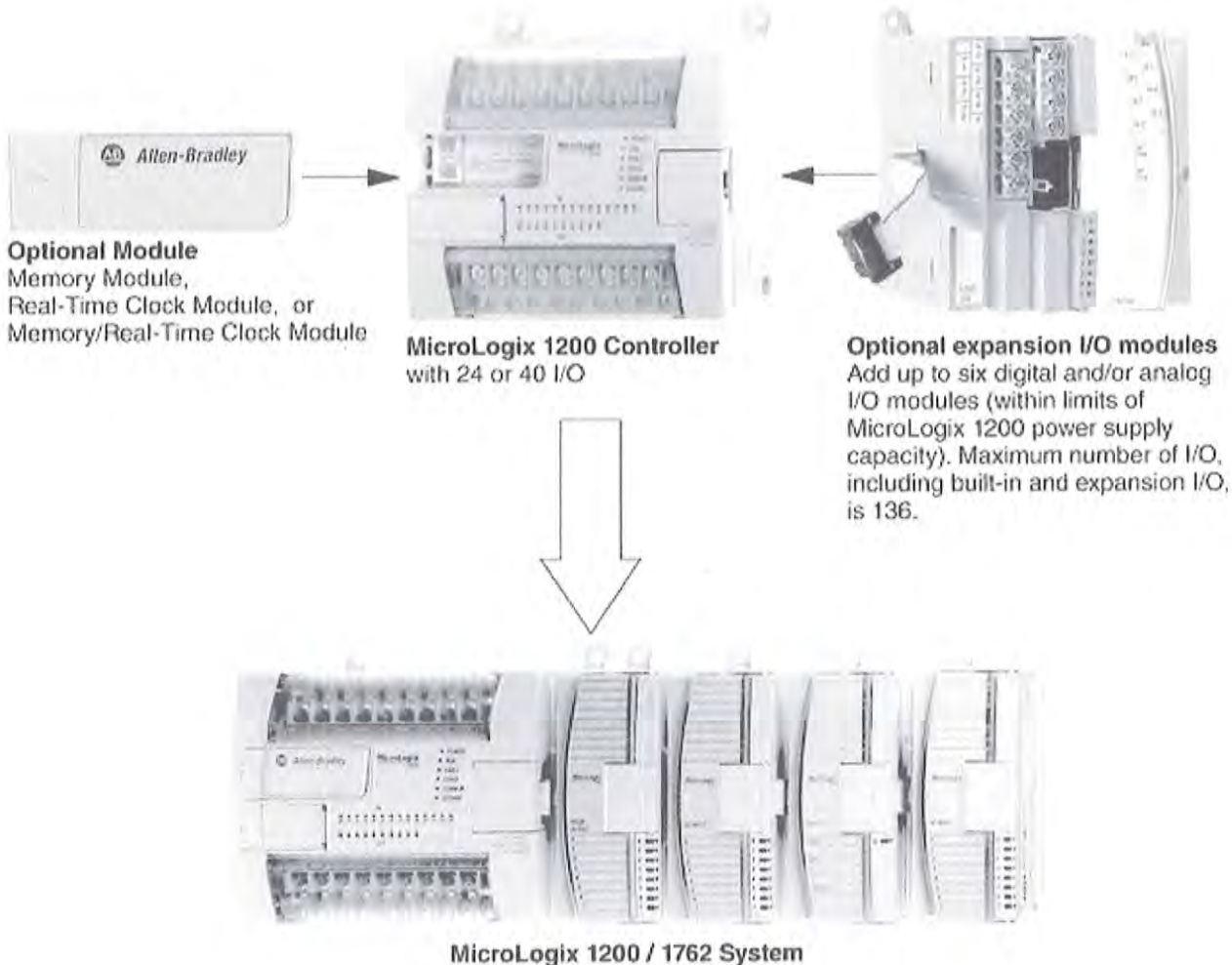
# MicroLogix 1200 Controllers

Introduction Product Design Communication Typical Configurations Specifications

Product Overview

## System Overview

The MicroLogix 1200/1762 system provides functionality between the MicroLogix 1000/1761 and MicroLogix 1500/1764 systems, using the proven MicroLogix and SLC family architecture. The 6K-word memory provides for a maximum program of 4K words and maximum data of 2K words with 100% data retention. An optional memory module provides program and data backup with program upload and download capability. The optional real-time clock enables time scheduling of control activities. The flash upgradeable operating system lets you upgrade system software without replacing hardware.



## Benefits

- *Small Footprint*—The MicroLogix 1200 controller is designed to optimize panel space. Integrated packages just 90mm (3.54 in) high (110mm high including mounting tabs) and 110 or 160mm (4.33 or 6.30 in) wide include processor, embedded inputs and outputs, and power supply. Expansion I/O modules add only 40mm (1.57 in) each in width.
- *Flexibility*—A range of I/O and communication options let you configure a MicroLogix 1200 controller for a variety of applications:
  - 24 or 40 built-in I/O. The inputs are either 24V DC (sink or source) or 120V AC. Outputs are relay contact or FET.
  - Add up to 96 I/O in up to 6 digital and/or analog I/O modules (within the limits of power supply capacity, for a total of 136 I/O maximum).
- *Wide range of communication options:*
  - DF1 full- or half-duplex, DF1 Radio Modem, Modbus RTU slave and RTU master. Communication interface modules support DH-485, DeviceNet, and EtherNet/IP.
  - MicroLogix 1200R controllers also provide a Programming / HMI port with fixed communication parameters to provide an additional means to communicate to the controller.
- *High Functionality*—The MicroLogix 1200 / 1762 system provides powerful features that let you tackle tough applications:
  - 20k-Hz high-speed counter.
  - 20k-Hz PTO (Pulse Train Output) or PWM (Pulse Width Modulation).
  - 6K-word non-volatile memory (4K-word maximum program, 2K-word maximum data).
  - 4 interrupt inputs.
  - 4 latching inputs.
  - 2 built-in trim potentiometers.
  - optional memory, real-time clock, or memory/real-time clock module.
  - powerful instruction set with support for PID and ASCII.
  - uses RSLogix 500 programming software.
  - field-upgradeable flash operating system.
- *Low Price*—This compact but powerful control solution will fit well within your budget.

## 1756sc-IF8u Eight Channel Universal Input Module Voltage, Current, Resistance, RTDs and Thermocouple Allen-Bradley 1756 ControlLogix™ PLC



- Eight channels of voltage, current, resistance, RTD or thermocouple, input provide a flexible solution to analog monitoring applications.
- Features 1000 Vdc channel-to-backplane isolation; 1000 Vdc channel-to-chassis ground isolation; 12.5 Vdc channel-to-channel isolation.
- Easily configured using existing programming software.
- Provides several input noise filters that are selectable on a channel by channel basis to customize your installation for maximum speed with minimum noise.
- Enhanced features include 16-21 bit resolution, digital filtering, user scaling, time stamping and alarms.

### Reduced System Costs

Unsurpassed flexibility is provided with the broad variety of input signals that can be applied. For systems requiring a variety of analog input types, the 1756sc-IF8u can help you save money on I/O racks, power supplies and enclosures.

### Get State-of-the-Art Features

The 1756sc-IF8u applies the producer/consumer networking model. The I/O module produces information only when needed rather than waiting for the controller to poll for data. Communication is more efficient, the potential burden on the controller lessened, and integration with other products is improved. Productivity improves from the system's greater ease of maintenance, increased speed and efficiency of communication, as well as from software integration that provides a single view of the system that's easily understood. Removal-and-insertion-of modules under power (RIUP) enables easier, faster and more efficient maintenance with little interference to the application process.

**Module-level fault detection** (self-diagnosing)

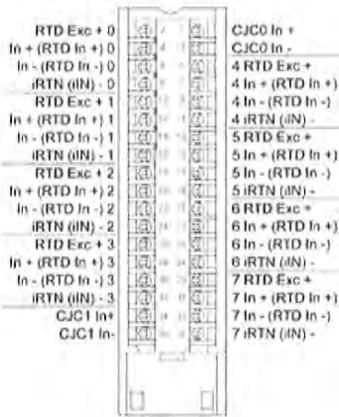
**Selectable time-stamping** of control data

**Flash memory** allows upgrades to the module to be performed by the user



# 1756sc-IF8u Eight Channel Universal Input Module Voltage, Current, Resistance, RTDs and Thermocouple Allen-Bradley 1756 ControlLogix™ PLC

1756sc-IF8u Wiring



Note: RTBs are not included with the module.  
Order Allen-Bradley Part Numbers:  
1756-TBCH - 36 position screw terminals  
1756-TBS6H - 36 position press terminals

Prewire Cable:  
Specify Spectrum Controls Part Number:  
1492-ACABLE-xx0sc xx=length in meters  
Use Allen Bradley IFM P/N -  
1492-IFM-40F Series A

Specifications	
<b>Inputs per Module</b>	8 (eight)
<b>Module Location</b>	1756 I/O chassis—1 slot
<b>Input Types</b> Thermocouple RTD Resistance Current Voltage	B, C, E, J, K, N, R, S, T PT 385/3916, N 618/672, NI 518, CU 426 250, 500, 1000, 2000, 3000, 4000 ohms 0-20 mA, 4-20 mA ±50mV, ±150mV, 0-5V, 1-5V, 0-10V, ±10V
<b>Advanced Features</b>	5 filter frequencies (individually selectable by channel); full auto-calibration; on-board error checking; open circuit detection for most input types, short circuit for RTDs
<b>Accuracy</b>	Better than 0.1% of Range @ 0° to 25°C
<b>Resolution</b>	16-21 Bits (filter frequency dependent)
<b>Update Times*</b>	With eight channels enabled: 0.99 sec @ 10 Hz                      0.19 sec @ 50/60 Hz 0.13 sec @ 100 Hz                    0.07 sec @ 250 Hz 0.04 sec @ 1000 Hz * = RTD/TC update times may be longer. Update times do not include autocalibration time.
<b>Data Formats</b>	Floating Point IEEE 32 bit
<b>Electrical Isolation</b>	±12.5 Vdc channel-to-channel for all but RTDs 1000 Vdc field-wiring-to-backplane 1000 Vdc field-wiring-to-chassis-ground
<b>Input Impedance</b>	>1 Mohm Thermocouple, Voltage, RTD <250 ohm, Current
<b>Input Overvoltage Protection</b>	14.5 Vdc continuous 250W pulsed for 1 msec.
<b>Input Overcurrent Protection</b>	28mA continuous 40mA, 1msec pulsed, 10% duty cycle max
<b>Common Mode Rejection</b>	96 dB @ 50/60 Hz
<b>Normal Mode Rejection</b>	64.5 dB @ 50/60 Hz
<b>Backplane Current Required</b>	75 mA @ 24 V max 230 mA @ 5 V max
<b>Thermal Dissipation</b>	3.00 Watts maximum
<b>Environmental Conditions</b> Operational Temperature Storage Temperature Relative Humidity	0° to 60°C (32° to 140°F) -40° to 85°C (-40° to 185°F) 5 to 95% (non-condensing)
<b>Certifications</b>	UL/CUL (Class I, Div 2, Groups ABCD) and CE
<b>Recommended Cable</b>	For TC inputs: Shielded, twisted-pair TC extension wire For mV, V or mA inputs: Belden 8761 or equivalent For RTD inputs: Shielded Belden #9501, #9533 or #83503



**Corporate Headquarters**  
Spectrum Controls, Inc.  
P.O. Box 5533 • Bellevue, WA 98006 USA  
Tel 425-746-9481 • Fax 425-641-9473  
Email spectrum@spectrumcontrols.com  
www.spectrumcontrols.com





## 7" Light Grey Industrial HMI



- 800 x 480 Pixel Resolution
- Ethernet
- 2 Serial Ports
- Class I, Division 2 Certified

System	CPU	32-bit RISC Cortex-A8, 600 MHz
	Memory (RAM)	128 MB
	Memory (Flash)	128 MB
	RTC	Built-in
I/O Ports	Serial	1 x DE9P COM1: RS-232 1 x DE9S COM1: RS-485 2 or 4 wire, COM3: RS-485 2 wire
	Ethernet	1 x 10/100 Base-T
	CANbus	N/A
	USB Host	1 x USB 2.0
	USB Client	N/A
	Audio	N/A
	Video	N/A
	Wi-Fi	N/A
	HDMI	N/A
	SD Card Slot	N/A
	Display	Display Type
Size (W x H)		6.11 x 3.42 inches [154 x 87 mm]
Resolution (pixels)		800 x 480
Luminance (cd/m <sup>2</sup> )		350
Contrast Ratio		500:1
Max. Colors		16 M
Backlight Lifetime (hours)		30,000+
Touch Screen	Type	4-wire resistive touch
	Active Area Accuracy	Length (X) ± 2%, width (Y) ± 2%
Electrical	Input Voltage	24 ± 20% VDC
	Input Current	350 mA @ 24 VDC
	Power Isolation	N/A
	Isolation Resistance	Exceed 50 MΩ at 500 VDC
Mechanical	Enclosure	Plastic, light grey
	PCB Coating	Yes
	Dimensions (W x H x D)	7.89 x 5.76 x 1.34 inches [200 x 146 x 34 mm]
	Weight	1.32 lbs. [0.6 kg]
	Mounting	Panel mounting
Environmental	Operating Temperature	32° ~ 122° F (0° ~ 50° C)
	Storage Temperature	-4° ~ 140° F (-20° ~ 60° C)
	Relative Humidity	10% ~ 90% (non-condensing)
	Vibration Endurance	10 to 25 Hz (X, Y, Z direction, 2 G, 30 minutes)
	Ratings	IP65 compliant front panel, NEMA 4X indoor use only
	Certifications	cULus, CE, RoHS
Software	EZwarePlus (v4.00.01 or later)	
Notes		





We, Maple Systems Inc., hereby declare that the following standard models have been tested by Underwriters Laboratories and are in accordance and compliance with those UL standards (United States and Canada) as noted below.

*Please Note: The official UL certification can be found by entering the UL File Number into the UL Online Certifications Directory Search Engine (accessed via the Underwriters Laboratories website).*

UL File Number: E196787, E344564  
Type Of Product: LCD Touch Screen Programmable Logic Controllers  
Product: Communication Display for Human Machine Interface (HMI)  
Certification: Class I, Division 2, Groups A, B, C and D  
Trade Name: Graphic HMI  
Model Number: HMI5070L, HMI5070LB

[CLICK HERE TO VIEW ONLINE UL CERTIFICATION DOCUMENT  
\(UNITED STATES\)](#)

[CLICK HERE TO VIEW ONLINE UL CERTIFICATION DOCUMENT  
FOR CLASS I, DIVISON 2 \(UNITED STATES\)](#)

[CLICK HERE TO VIEW ONLINE UL CERTIFICATION DOCUMENT  
\(CANADA\)](#)

[CLICK HERE TO VIEW ONLINE UL CERTIFICATION DOCUMENT  
FOR CLASS I, DIVISON 2 \(CANADA\)](#)



Maple Systems Inc.  
808 134th St. SW, Suite 120  
Everett, WA 98204  
phone: (425) 745-3229 web: [www.maplesystems.com](http://www.maplesystems.com)

# Warranty Information

Direct Electrical Contractors, LLC guarantees the components used in all control panels are free of defective workmanship for a period of (1) one year from the date of installation.

This warranty does NOT cover equipment which has been damaged due to misuse, abuse, or accidents such as:

- use of incorrect line voltages
- negligence
- improper storage
- improper handling or improper installation
- use of incorrect fuses
- improper or insufficient ventilation
- failure to follow the operating instructions provided by Direct Electrical Contractors, LLC
- improper or unauthorized repair
- fire, flood, vandalism, insect/rodent/animal damage, "acts of God," and/or other contingencies

Failure to comply with the manufacturers specifications during operation may result in component failure and void this warranty.

In the event of defective workmanship, Direct Electrical Contractors, LLC (Direct) must be notified in writing within one (1) week of discovery. If Direct finds that the component is faulty separate from misuse, neglect, improper handling and/or improper installation, operation, maintenance, repair, alteration, or modification, or unusual deterioration, this warranty will be satisfied and the faulty component(s) will be replaced free of charge less shipping. Direct is not responsible for costs incurred to secure a qualified electrician to install defective component(s).

Send Correspondence to:  
Direct Electrical Contractors, LLC  
PO Box 1654  
Oregon City, OR 97045





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**APPENDIX J**

Commissioning Field Report

## SYSTEM COMMISSIONING FIELD REPORT

**SITE:** Stericycle - Tacoma  
**ADDRESS:** 1701 Alexander Drive, Tacoma WA  
**DATE:** 05-MAY-2017  
**PERSONNEL:** Paul Stull (Amec Foster Wheeler)  
 Terry DeVries (Direct Electrical Contractors)



### Methane Sensor Test

Sensor ID	Time	All units (% LEL)			Alarm Response			
		Sensor	MG Meter	VMS CP	Lights On	Lights Off	VMS CP Flash	Approved
MGS-1	9:55	21	20	21	YES / NO	YES / NO	YES / NO	YES / NO
MGS-2	10:00	19	21	20	YES / NO	YES / NO	YES / NO	YES / NO
MGS-3	10:07	23	25	24	YES / NO	YES / NO	YES / NO	YES / NO
MGS-4	10:13	24	26	24	YES / NO	YES / NO	YES / NO	YES / NO
MGS-5	10:24	22	20	21	YES / NO	YES / NO	YES / NO	YES / NO
MGS-6	10:18	21	22	21	YES / NO	YES / NO	YES / NO	YES / NO

**Notes:** 1) Sensor = each respective RKI M2A Methane Sensor. 2) MG meter = multi-gas meter field instrument (we used the Rae Systems Multi-gas meter). 3) VMS CP = vapor mitigation system control panel output touchscreen. 4) Test conducted with 50% methane gas from 2-liter cylinder.

### Blower Test

Blower Info - Rotron Regenerative Blower Model EN404AR72ML - 1.0HP, 208-230/460VAC, 3-PH, 60Hz XP motor

Time:	Vacuum Level (units = inches WC)				Vacuum Alarm Response	
	V-Gauge	P Sensor	VMS CP	Bleed Valve Position	Low Vac (2" WC)	High Vac (30" WC)
10:40	0	0.0	0.0	Full Open	OK - Alarm responded	OK - No Alarm
10:56	0	0.0	0.0	Full Open	OK - Alarm responded	OK - No Alarm
10:59	N/A	12.0	11.5	2/3 Open	OK - No Alarm	OK - No Alarm
11:03	N/A	22.1	22.5	1/2 Open	OK - No Alarm	OK - No Alarm
11:05	N/A	30.5	29.0	1/3 Open	OK - No Alarm	OK - No Alarm
11:07	N/A	34.0	33.5	1/4 Open	OK - No Alarm	OK - Alarm responded
11:10	N/A	37.5	36.8	1/5 Open	OK - No Alarm	OK - Alarm responded
11:14	N/A	46.9	47.8	Fully Closed	OK - No Alarm	OK - Alarm responded

**Notes:** 1) Alarms responded properly to alarm high and low set points. Pressure transducer (P Sensor) and VMS control panel (VMS CP) readings were within acceptable tolerances.

### Manifold Line Test

Line ID	Vacuum Level (Inches WC)							MG Meter Level (% LEL)
	V-Gauge	P Sensor	VMS CP	MP ID	MP Level	MP ID	MP Level	
VML-1	N/A	26.7	27.2	A-1	0.15	B-1	0.12	1.2
VML-2	N/A	17.5	17.2	C-1	0.18	D-1	0.19	1.6
VML-3	N/A	15.4	15.7	E-1	0.11			0.8
VML-4	N/A	30.4	30.1	A-2	0.14	A-3	0.21	2.1
VML-5	N/A	22.8	23.2	A-4	0.22	B-2	0.12	2.8
VML-6	N/A	16.7	16.6	C-2	0.13	D-2	0.14	1.5
All together	N/A	4.5	4.2					1.4

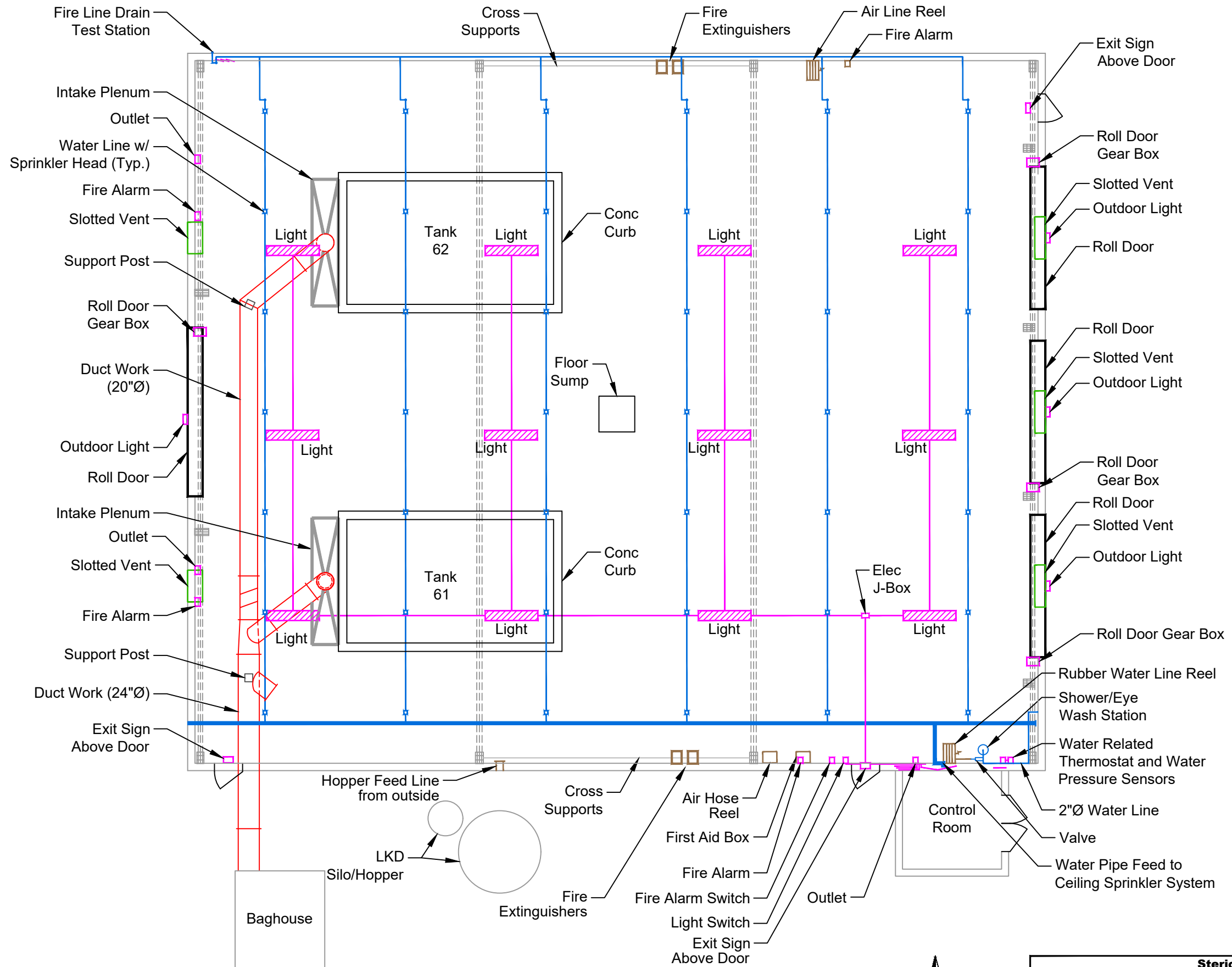
**Notes:** 1) MP ID = Sub-slab monitoring point identification number  
 2) MP Level = vacuum level in inches WC at respective MP  
 3) MG Meter Level = taken at manifold sampling port  
 4) Shaded boxes indicate not applicable or no secondary MP for that line  
 5) Vacuum levels taken at MP with Dwyer magnahelic gauge (0-1 inch WC range)

# **Attachment B**

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## **Stabilization Building As-Built Drawings**

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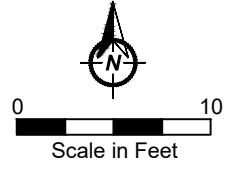


**LEGEND**

- Electrical
- Water
- ✓ Door

- NOTES**
1. Locations plus or minus 6 inches.
  2. Locations should be verified in field prior to construction.
  3. Piping and electrical conduit not to scale.

**PLAN VIEW**



**Stericycle  
Tacoma, Washington**

---

**Stabilization Building  
Plan View**

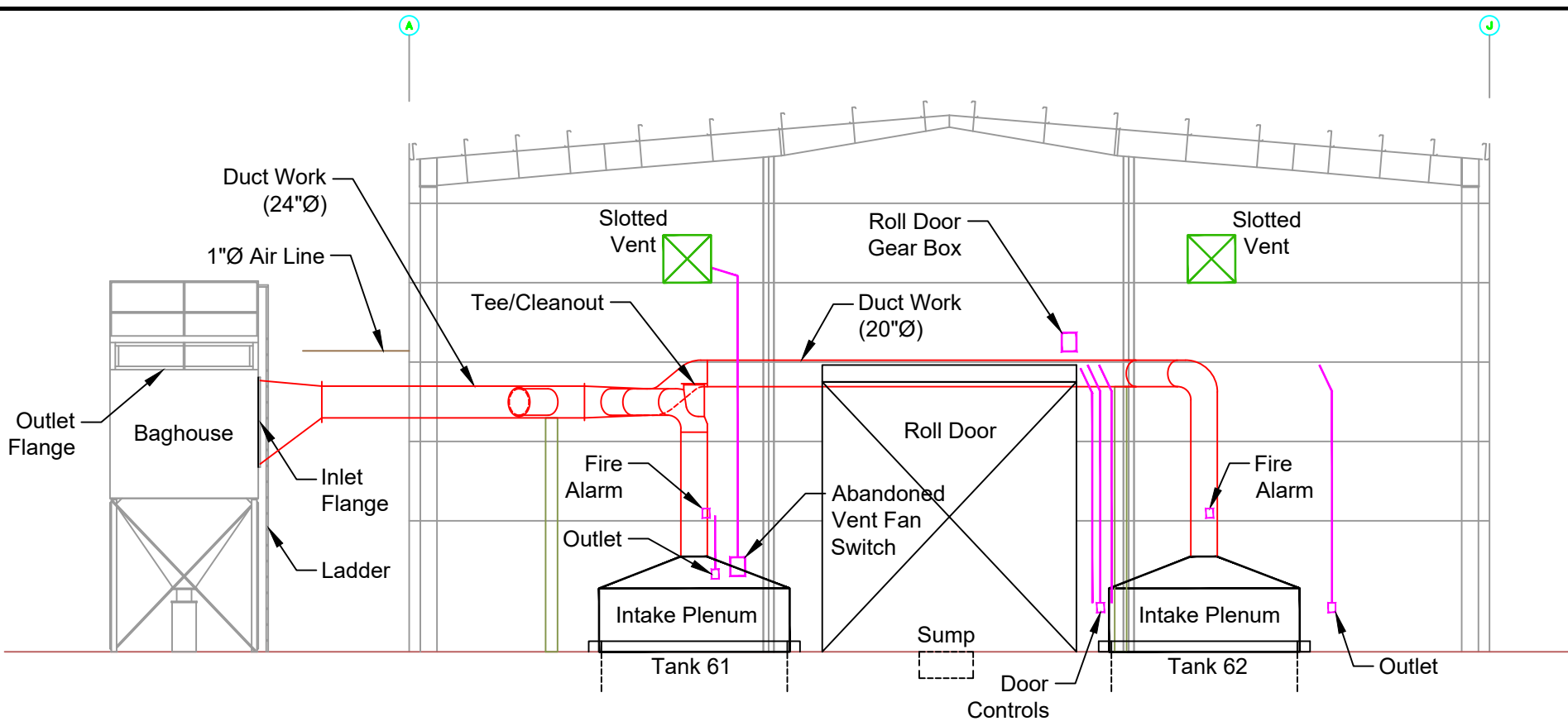
**DOF**

DALTON  
OLMSTED  
FUGLEVAND

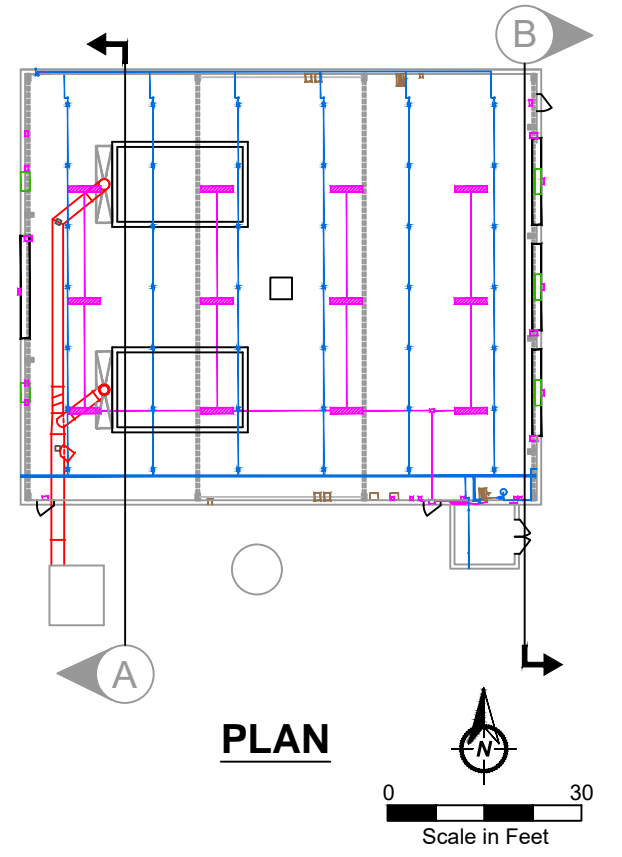
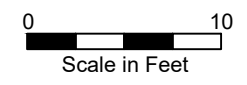
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FIGURE  
1

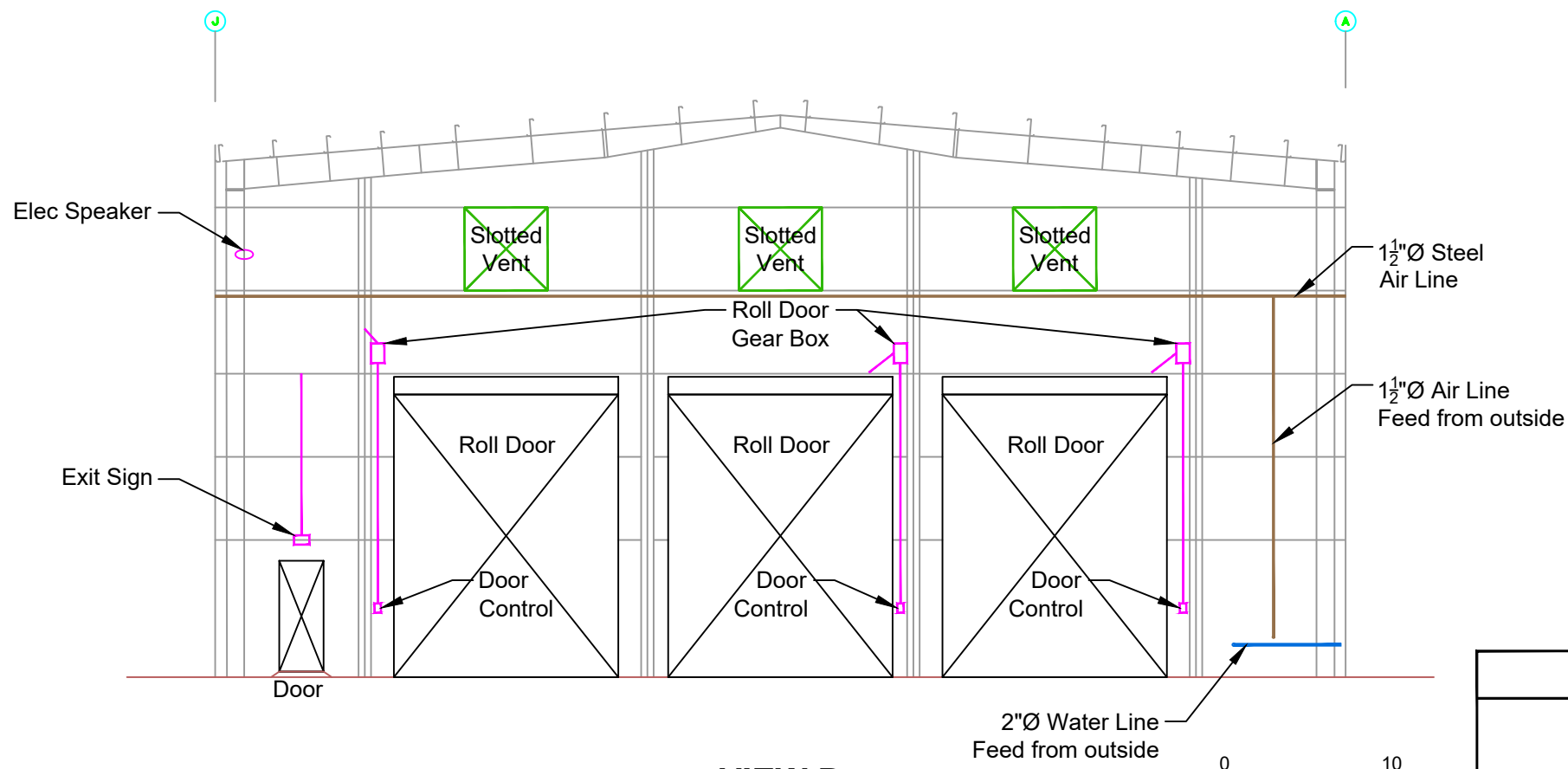
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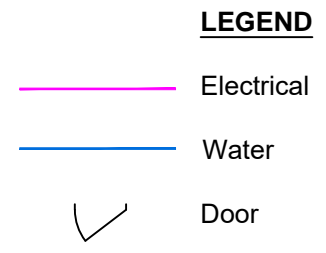
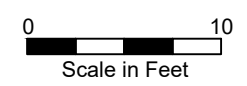
**VIEW A**  
Interior West Wall



**PLAN**



**VIEW B**  
Interior East Wall

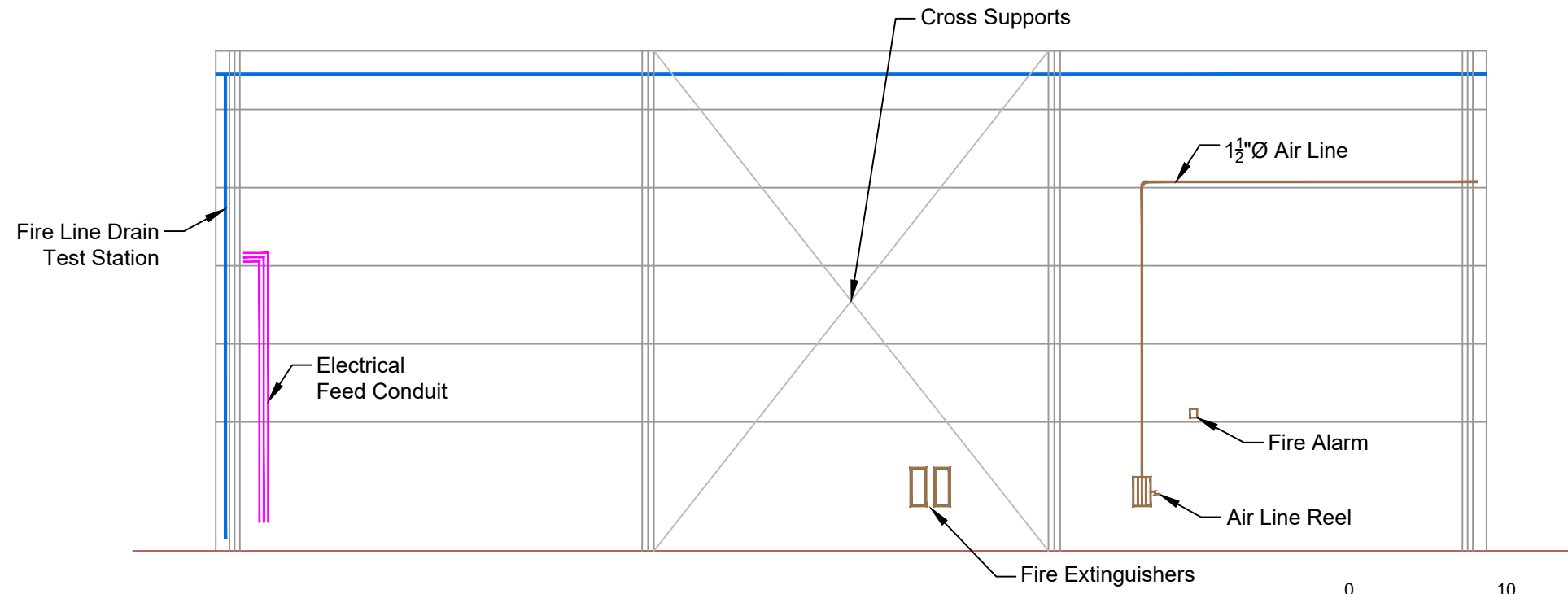


- NOTES**
1. Locations plus or minus 6 inches.
  2. Locations should be verified in field prior to construction.
  3. Piping and electrical conduit not to scale.

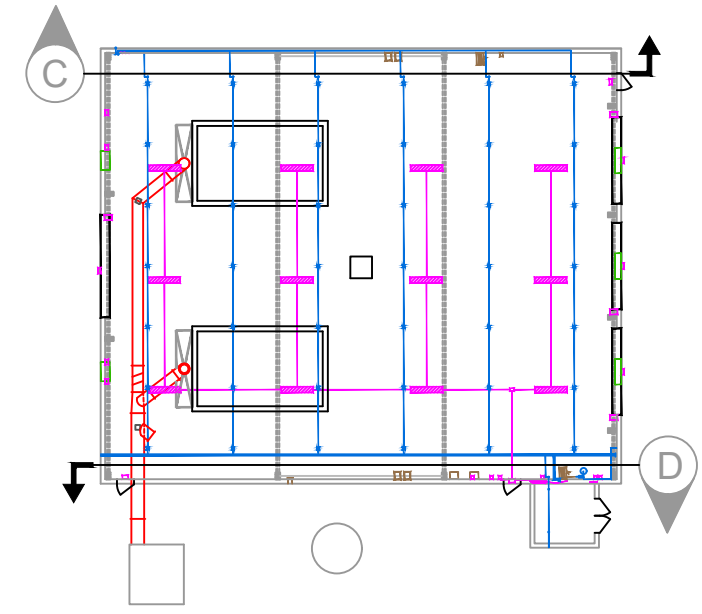
<b>Stericycle</b> Tacoma, Washington	
<b>Stabilization Building</b> Inside Wall Views	
<b>FIGURE</b> 2	



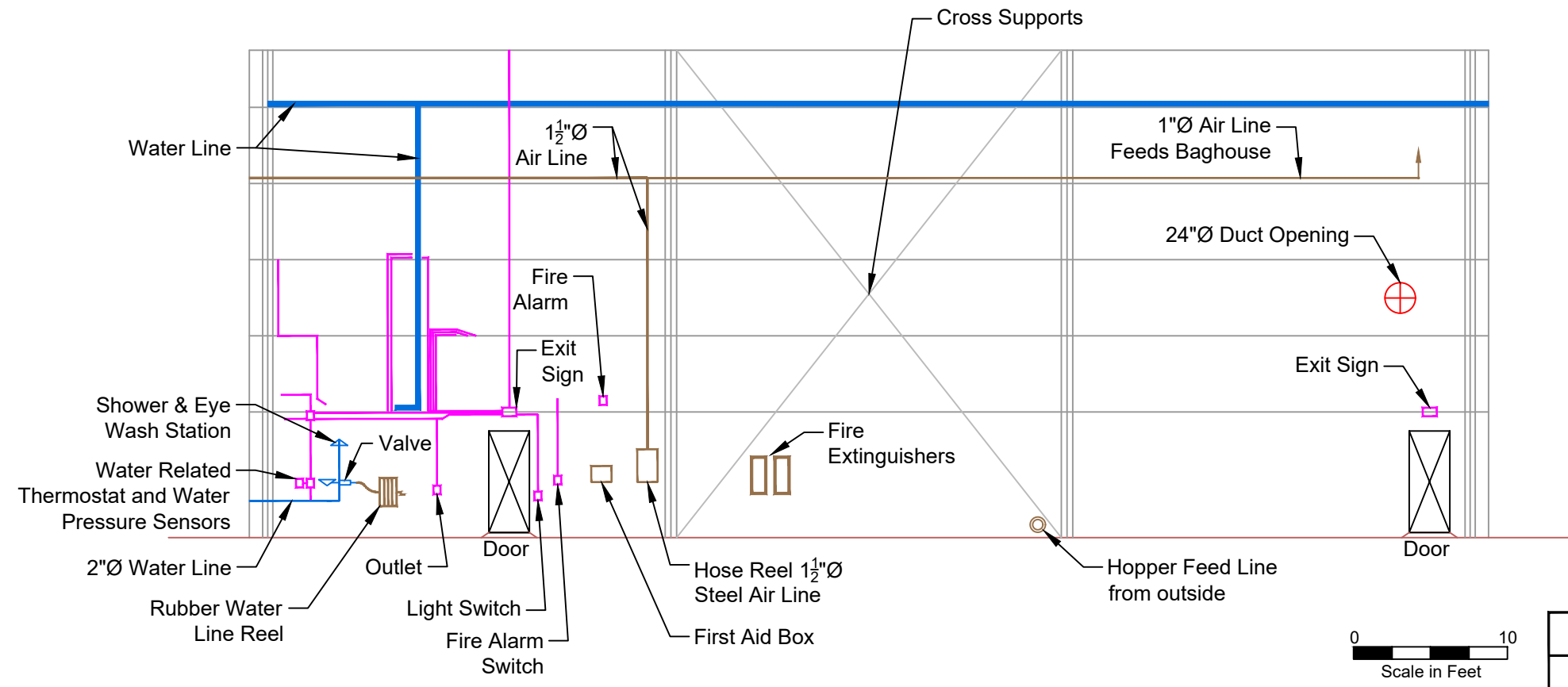
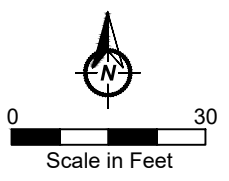
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**VIEW C**  
Interior North Wall



**PLAN**



**VIEW D**  
Interior South Wall

**LEGEND**

- Electrical
- Water
- ✓ Door

**NOTES**

1. Locations plus or minus 6 inches.
2. Locations should be verified in field prior to construction.
3. Piping and electrical conduit not to scale.

<b>Stericycle</b> Tacoma, Washington	<b>DOF</b> DALTON OLMSTED FUGLEVAND
<b>Stabilization Building</b> Inside Wall Views	
<b>FIGURE</b> 3	

# **Attachment C**

---

## **Vapor Pin<sup>®</sup> Standard Operating Procedure**





## Standard Operating Procedure Installation and Extraction of the Vapor Pin®

Updated September 9, 2016

### Scope:

This standard operating procedure describes the installation and extraction of the VAPOR PIN® for use in sub-slab soil-gas sampling.

### Purpose:

The purpose of this procedure is to assure good quality control in field operations and uniformity between field personnel in the use of the VAPOR PIN® for the collection of sub-slab soil-gas samples or pressure readings.

### Equipment Needed:

- Assembled VAPOR PIN® [VAPOR PIN® and silicone sleeve(Figure 1)]; Because of sharp edges, gloves are recommended for sleeve installation;
- Hammer drill;
- 5/8-inch (16mm) diameter hammer bit (hole must be 5/8-inch (16mm) diameter to ensure seal. It is recommended that you use the drill guide). (Hilti™ TE-YX 5/8" x 22" (400 mm) #00206514 or equivalent);
- 1½-inch (38mm) diameter hammer bit (Hilti™ TE-YX 1½" x 23" #00293032 or equivalent) for flush mount applications;
- ¾-inch (19mm) diameter bottle brush;
- Wet/Dry vacuum with HEPA filter (optional);
- VAPOR PIN® installation/extraction tool;
- Dead blow hammer;
- VAPOR PIN® flush mount cover, if desired;
- VAPOR PIN® drilling guide, if desired;

- VAPOR PIN® protective cap; and
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel for repairing the hole following the extraction of the VAPOR PIN®.



Figure 1. Assembled VAPOR PIN®

### Installation Procedure:

- 1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.
- 2) Set up wet/dry vacuum to collect drill cuttings.
- 3) If a flush mount installation is required, drill a 1½-inch (38mm) diameter hole at least 1¾-inches (45mm) into the slab. Use of a VAPOR PIN® drilling guide is recommended.
- 4) Drill a 5/8-inch (16mm) diameter hole through the slab and approximately 1-inch (25mm) into the underlying soil to form a void. Hole must be 5/8-inch (16mm) in diameter to ensure seal. It is recommended that you use the drill guide.

VAPOR PIN® protected under US Patent # 8,220,347 B2, US 9,291,531 B2 and other patents pending

- 5) Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.
- 6) Place the lower end of VAPOR PIN® assembly into the drilled hole. Place the small hole located in the handle of the installation/extraction tool over the vapor pin to protect the barb fitting, and tap the vapor pin into place using a dead blow hammer (Figure 2). Make sure the installation/extraction tool is aligned parallel to the vapor pin to avoid damaging the barb fitting.



Figure 2. Installing the VAPOR PIN®

During installation, the silicone sleeve will form a slight bulge between the slab and the VAPOR PIN® shoulder. Place the protective cap on VAPOR PIN® to prevent vapor loss prior to sampling (Figure 3).



Figure 3. Installed VAPOR PIN®

- 7) For flush mount installations, cover the vapor pin with a flush mount cover, using either the plastic cover or the optional stainless-steel Secure Cover (Figure 4).



Figure 4. Secure Cover Installed

- 8) Allow 20 minutes or more (consult applicable guidance for your situation) for the sub-slab soil-gas conditions to re-equilibrate prior to sampling.
- 9) Remove protective cap and connect sample tubing to the barb fitting of the VAPOR PIN®. This connection can be made using a short piece of Tygon™ tubing to join the VAPOR PIN® with the Nylaflo tubing (Figure 5). Put the

Nylaflow tubing as close to the VAPOR PIN® as possible to minimize contact between soil gas and Tygon™ tubing.



Figure 5. VAPOR PIN® sample connection

10) Conduct leak tests in accordance with applicable guidance. If the method of leak testing is not specified, an alternative can be the use of a water dam and vacuum pump, as described in SOP Leak Testing the VAPOR PIN® via Mechanical Means (Figure 6). For flush-mount installations, distilled water can be poured directly into the 1 1/2 inch (38mm) hole.



Figure 6. Water dam used for leak detection

11) Collect sub-slab soil gas sample or pressure reading. When finished, replace the protective cap and flush mount cover

until the next event. If the sampling is complete, extract the VAPOR PIN®.

#### Extraction Procedure:

- 1) Remove the protective cap, and thread the installation/extraction tool onto the barrel of the VAPOR PIN® (Figure 7). Turn the tool clockwise continuously, don't stop turning, the VAPOR PIN® will feed into the bottom of the installation/extraction tool and will extract from the hole like a wine cork, DO NOT PULL.
- 2) Fill the void with hydraulic cement and smooth with a trowel or putty knife.



Figure 7. Removing the VAPOR PIN®

- Prior to reuse, remove the silicone sleeve and protective cap and discard. Decontaminate the VAPOR PIN® in a hot water and Alconox® wash, then heat in an oven to a temperature of 265° F (130° C) for 15 to 30 minutes. For both steps, STAINLESS – ½ hour, BRASS 8 minutes
- 3) Replacement parts and supplies are available online.

# **Attachment D**

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## **Port of Tacoma Former Potter Property Sampling and Analysis Plan**

# ECOLOGY REVIEW DRAFT VAPOR SAMPLING AND ANALYSIS PLAN

---

1801 E. ALEXANDER AVENUE  
TAYLOR WAY AND ALEXANDER AVENUE FILL AREA

AGREED ORDER DE 14260  
FACILITY/SITE NO. 1403183  
CLEANUP SITE ID NO. 4692



*Prepared for*  
**PORT OF TACOMA**  
*June 30, 2021*  
*Project No. 0615.20.02*

*Prepared by*  
*Maul Foster & Alongi, Inc.*  
*2815 2nd Avenue, Suite 540, Seattle, WA 98121*

ECOLOGY REVIEW DRAFT  
VAPOR SAMPLING AND ANALYSIS PLAN  
1801 E. ALEXANDER AVENUE  
TAYLOR WAY AND ALEXANDER AVENUE FILL AREA

AGREED ORDER DE 14260  
FACILITY/SITE NO. 1403183  
CLEANUP SITE ID NO. 4692

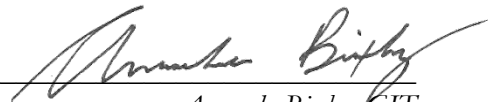
*The material and data in this plan were prepared  
under the supervision and direction of the undersigned.*

MAUL FOSTER & ALONGI, INC.



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*Yen-Vy Van, LHG  
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# TABLES AND ILLUSTRATIONS

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FOLLOWING PLAN:

## TABLES

- 4-1 QC SAMPLE SUMMARY
- 4-2 CONTAINERS, PRESERVATION, AND HOLDING TIMES

## FIGURES

- 1-1 PROPERTY LOCATION
- 1-2 PROPERTY FEATURES AND PROPOSED SAMPLING LOCATIONS

## ACRONYMS AND ABBREVIATIONS

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bgs	below ground surface
BE	Burlington Environmental
COC	chain-of-custody
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FSDS	field sampling data sheet
HVAC	heating, ventilation, and air-conditioning
LCS	laboratory control sample
LNAPL	light non-aqueous phase liquid
MFA	Maul Foster & Alongi, Inc.
ml/min	milliliter per minute
Order	Agreed Order DE 14260/Enforcement Order Number DE 19410
the Port	Port of Tacoma
the Property	1801 E Alexander Avenue, Tacoma, Washington
PRT	post-run tubing
QA	quality assurance
QC	quality control
SAP	sampling and analysis plan
SOP	standard operating procedure
TWAAFA	Taylor Way and Alexander Avenue Fill Area
VI	vapor intrusion
VOC	volatile organic compound

# 1 INTRODUCTION

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Maul Foster & Alongi, Inc. (MFA) has prepared this vapor sampling and analysis plan (SAP), consistent with the requirements of Washington Administrative Code 173-340-820, for the Port of Tacoma (the Port) to guide sample collection during the vapor intrusion (VI) assessment at a property, located at 1801 E Alexander Avenue in Tacoma, Washington (the Property) (see Figures 1-1 and 1-2). The Property is part of the Taylor Way and Alexander Avenue Fill Area (Agreed Order DE 14260; Enforcement Order 19410; Facility/Site No. 1403183; Cleanup Site Id No. 4692), an approximately 1.7-acre area currently used for shipping container and vehicle maintenance operations by a Port tenant (Handan Containers).

Dalton, Olmsted & Fuglevand prepared the Aboveground Site Conditions and Existing Groundwater Monitoring Network Evaluation and Recommendations Memorandum (Memo) as required under the Washington State Department of Ecology's (Ecology) Agreed Order DE 14260/Enforcement Order Number DE 19410 (Order). Ecology did not agree that the vapor intrusion pathway at the Property can be assumed to be incomplete based on the condition of the buildings and the observations during the inspection (Ecology, 2021). Due to the historical presence of light non-aqueous phase liquid (LNAPL) in soil and/or groundwater, Ecology requested a soil vapor sampling and analysis plan for various Taylor Way and Alexander Avenue Fill Area (TWAAFA) locations, including the Property. This vapor sampling and analysis plan was prepared to address the directive (Ecology 2021) for the Property only.

## 1.1 Background

The Property (Pierce County parcel number 0321352063) was predominantly wetlands/marshland until 1958, when the first two buildings were constructed in the northern portion of the parcel. An additional building was constructed in 1972. The exact dates of filling and grading at the Property are unknown. Previous subsurface investigations indicate presence of automobile fluff and lime wastes. In the 1960s, Educators Furniture and Supply and/or Educators Manufacturing Company operated at the Property. Since the 1970s, various light manufacturing and truck trailer and container repair businesses have also operated at the Property (Ecology, 2020).

Releases from unlined waste-oil storage and -treatment ponds from what is now the adjacent Burlington Environmental (BE) Tacoma property (which comprises the following Pierce County Parcel Numbers 0321352043, 0321352044, 0321352053, 0321352062, 0321263003, and 0321263024) extended onto the Property. In November 2000, BE Tacoma constructed a 104-foot-long trench on the parcel to remove LNAPL, originating from the historical waste-oil pond on the adjacent BE Tacoma property (Ecology, 2020). According to Ecology, the Property subsurface conditions (soil and/or groundwater) are known to be impacted by metals, petroleum fuels mixtures, volatile organic compounds (VOCs), and semi-volatile organic compounds (Ecology, 2020). The Port purchased the Property in 2008. BE Tacoma has continued to monitor groundwater impacts at the Property since that time as a condition of its Dangerous Waste permit.

This sampling and analysis plan describes the Port's proposed approach to conduct an air quality assessment within the building below the floors slabs at the Property for petroleum hydrocarbons related to the releases from BE Tacoma's former waste oil pond.

## 2 SCOPE OF WORK

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### 2.1 Site Reconnaissance

MFA had conducted a site reconnaissance at the Property on June 25, 2021 to survey the Property's buildings, including the two Quonset huts and the shop building's interior floor structure including identifying suitable sample locations. The following tasks were completed:

- Provided information to the building owner about the scope of the vapor assessment and required sampling conditions. All windows and doors should be closed for at least 12 hours before and during the sub-slab vapor sampling, per Ecology's direction (Ecology, 2021).
- Evaluated preferential pathways that could contribute to VI inside the buildings, such as foundation cracks, sumps, and utility penetrations.
- Characterized the buildings' heating, ventilation, and air-conditioning (HVAC) ventilation systems, as applicable, including how, when, and where they operate, and identify which portions of the buildings are intermittently or continually open to outside air.
- Conducted site reconnaissance and interview the building owner to identify potential indoor sources of VOC vapors.
- Evaluated the type of floor beneath the Property, i.e., under the two Quonset huts and the shop building and confirmed the presence of concrete floor slabs at the buildings on the Property.
- Identified representative sub-slab vapor sampling locations.

### 2.2 Pre-sampling Site Preparation

MFA will conduct an additional site visit before vapor sampling to complete the following site preparation tasks:

- Conduct public and private utility-locating services and review available site plans to check for underground utilities or obstructions before installing sub-slab vapor pins (see Standard Operating Procedure [SOP] 18 in Appendix A).
- Install temporary sub-slab vapor pins in the buildings.
- Install a data-logging manometer to measure the pressure differential between at least one sub-slab vapor pin and indoor air in an occupied portion of the buildings. Pressure

differential data will be collected for at least 24 hours to determine if the pressure differential favors migration from the sub-slab to the indoor air. The measurements will be completed at least 72 hours before sub-slab vapor sampling.

- Conduct site reconnaissance and interview the building owner to identify and coordinate the removal of potential indoor sources of VOC vapors immediately prior to sampling.

## 2.3 Vapor Sampling

The proposed vapor sampling will include collecting samples of sub-slab vapor. Proposed sample locations will be based on the findings from the site reconnaissance and information and/or feedback from the Port and Ecology. The work will be implemented after Ecology concurs with sample locations. Sampling locations will be presented in a table summarizing the sampling and analysis results.

The sampling scope will be developed in general accordance with guidance published by Ecology (Ecology, 2018), including Implementation Memorandum No. 22 (Ecology, 2019). Sampling locations will be selected based on the following criteria:

- Sub-slab vapor samples will be collected in areas with previously identified LNAPL contamination.

Indoor and ambient air samples will be collected only if the chemicals of interests exhibited in the sub-slab vapor samples exceed the MTCA Method C industrial screening levels.

# 3 FIELD METHODS

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## 3.1 Sub-slab Vapor Sampling

MFA will collect sub-slab vapor samples from the space immediately beneath the building slabs (see SOP 16 in Appendix A). The samples will be collected in 1-liter, stainless steel canisters (Summa© canisters) with 5-minute flow regulators at a flow rate of 200 milliliter per minute (ml/min). Helium contained in a small tent-like structure that is set up around the sampling apparatus and sampling location will serve as a leak-check compound (see SOP 16 in Appendix A). Temporary sub-slab sampling points will not be installed in areas where the slab appears to be in contact with groundwater. If groundwater is encountered in any of the sub-slab vapor pins, the sample location will be abandoned.

MFA will record field data before and after the sampling, including the sampling start and stop times, the initial and final canister vacuum readings, and observations of conditions that may influence sampling results (e.g., significant industrial activities or chemical odors) (see FSDSs in Appendix B).

## 3.2 Sample Nomenclature

Vapor samples will be labeled with an abbreviation to indicate the sample matrix and the location identification number. The following matrix abbreviations will be used:

- SB = sub-slab vapor

# 4 ANALYTICAL METHODS

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## 4.1 Laboratory Test Methods and Reporting Limits

Petroleum hydrocarbons and VOCs were identified as chemicals of interest for the Property. In accordance with the quality assurance (QA) and quality control (QC) requirements set forth in this SAP, Friedman & Bruya, Inc., an accredited laboratory, will perform the following analyses:

- Air-phase hydrocarbons by Massachusetts APH Method
- VOCs by Toxics Organics-15 Method

Analytical methods and performance criteria will follow the previously Ecology approved Vapor SAP for the TWAAFA site (Dalton, Olmsted & Fuglevand, 2020).

## 4.2 Laboratory Operations

In the laboratory, QC samples may include laboratory control samples (LCSs), surrogate spike samples, and method blanks, as well as other QC samples and procedures as required by the individual methods (see Table 4-1).

### 4.2.1 Sample Handling

Sub-slab vapor samples will be collected in stainless steel Summa canisters which do not require special preservation or temperature storage. All vapor samples will be delivered to the lab via courier or dropped off by MFA field staff in person. Sample custody will be tracked from point of origin through analysis and disposal, using a chain-of-custody (COC) form, which will be filled out with standard sample and analytical information. Sample container and holding information is provided in Table 4-2.

## 4.3 Instrumentation

### 4.3.1 Field Instrumentation

Field instruments, including a manometer and a helium-leak detector, will be used during the VI assessment. Field instrument calibration and preventive maintenance will follow the manufacturers' guidelines, and deviations from the established guidelines will be documented.

## 4.3.2 Laboratory Instrumentation

Laboratory instrument calibration procedures, frequency of calibration, and preparation of calibration standards will be according to the method requirements.

### 4.3.2.1 Laboratory Calibration and Preventive Maintenance

Preventive maintenance of laboratory equipment will be the responsibility of the laboratory personnel and analysts. This maintenance includes routine care and cleaning of instruments and inspection and monitoring of laboratory equipment used in analyses. The preventive-maintenance approach for specific equipment should follow the manufacturers' specifications, good laboratory practices, and industry standard techniques.

Precision and accuracy data will be examined for trends and excursions beyond control limits to determine evidence of instrument malfunction. Maintenance should be performed when an instrument begins to change, as indicated by the degradation of peak resolution, shift in calibration curves, decrease in sensitivity, or failure to meet any of the QC criteria.

## 4.4 Laboratory Quality Assurance/Quality Control Samples

The laboratory QC samples will be used to assess the accuracy and precision of the laboratory analysis. Each category of laboratory QA/QC will be performed by the laboratory as required by method-specific guidelines. The acceptance criteria presented in the guidelines will be adhered to, and samples that do not meet the criteria will be reanalyzed or qualified, as appropriate.

### 4.4.1 Calibration Verification

Instruments will initially be calibrated at the start of the project or sample run, as required, and when any ongoing calibration does not meet control criteria. The number of points used in the initial calibration is defined in the analytical method. Calibration will be continued as specified in the analytical method to track instrument performance. If a continuing calibration does not meet control limits, analysis of project samples will be suspended until the source of the control failure is either eliminated or reduced to within control specifications.

### 4.4.2 Method Blanks

Method blanks are prepared using purified air and are processed with the same methodology (e.g., extraction, digestion) as the associated investigative samples. Method blanks are used to document contamination resulting from the laboratory's analytical process. A method blank shall be prepared and analyzed for every analytical batch. The method blank results are used to verify that reagents and preparation do not impart unacceptable bias to the investigative sample results. The presence of analytes in the method blank sample will be evaluated against method-specific thresholds. If analytes are present in the method blank above the method-specific threshold, corrective action will be taken to eliminate the source of contamination before proceeding with analysis. Investigative samples of an



analytical batch associated with method blank results outside acceptance limits will be qualified, as appropriate, by the data validation contractor.

### 4.4.3 Laboratory Control Samples

LCSs are prepared by spiking purified air with the analytes of interest or a certified reference material that has been prepared and analyzed. The result for percent recovery of the LCS is a data quality indicator of the accuracy of the analytical method and laboratory performance.

### 4.4.4 Field QC

MFA staff will perform field QC checks, including a shut-in test and helium shroud for sub-slab vapor sampling and a water dam test for sub-slab vapor sampling to ensure a good seal on the vapor pin. QC procedures are described in SOP 16 in Appendix A.

## 4.5 Data Reduction, Validation, and Reporting

The analytical laboratory will submit analytical data packages that include laboratory QA/QC results to permit independent and conclusive determination of data quality. MFA will determine the data quality, using the data evaluation procedures described in this section. The results of the MFA evaluation will be used to determine if the project data quality objectives have been met.

### 4.5.1 Field Data Reduction

Daily internal QC checks will be performed for field activities. Checks will consist of reviewing field notes and field activity memoranda to confirm that the specified measurements, calibrations, and procedures are being followed. The need for corrective action will be assessed on an ongoing basis, in consultation with the project manager.

### 4.5.2 Laboratory Evaluation

Initial data reduction, evaluation, and reporting at the analytical laboratory will be carried out consistent with the laboratory's internal QA manual (FBI, 2019). Additional laboratory data qualifiers may be defined and reported to further explain the laboratory's QC concerns about a particular sample result. These additional data qualifiers will be defined in the laboratory's case narrative reports.

### 4.5.3 Data Deliverables

Laboratory data deliverables are listed below. Electronic deliverables will contain the same data that are presented in the hard-copy report.

- Transmittal cover letter
- Case narrative
- Analytical results

- COC
- Surrogate recoveries
- Method blank results
- LCS results

## 4.5.4 MFA Evaluation

### 4.5.4.1 Data QA/QC Review

MFA will evaluate the laboratory data for precision, completeness, accuracy, and compliance with the analytical method. MFA will review data according to applicable sections of U.S. Environmental Protection Agency (EPA) organics and inorganics procedures (EPA, 2017), as well as appropriate laboratory method-specific guidelines.

Data qualifiers, as defined by EPA, are used to classify sample data according to their conformance to QC requirements. Common qualifiers are listed below:

- J—Estimate, qualitatively correct but quantitatively suspect.
- R—Reject, data not suitable for any purpose.
- U—Not detected at a specified reporting limit.

Poor surrogate recovery, blank contamination, or calibration problems, among other things, can require qualification of the sample data. The reasons for qualification will be stated in the data evaluation report. QC criteria not defined in the guidelines for evaluating analytical data are adopted, where appropriate, from the analytical method. The results of the data evaluation review will be summarized for each data package. Data qualifiers will be assigned to sample results based on EPA guidelines, as applicable.

### 4.5.4.2 Data Management and Reduction

MFA uses a database (i.e., EQuIS™) to manage laboratory data. The laboratory will provide the analytical results in electronic, EQuIS-compatible format. Following data evaluation, data qualifiers will be entered into the database.

Data may be reduced to summarize particular data sets and to aid interpretation of results. Statistical analyses may also be applied to results. Data reduction QC checks will be performed on hand-entered data, calculations, and data graphically displayed. Data may be further reduced and managed using one or more of the following computer software applications:

- Microsoft® Excel (spreadsheet)
- EQuIS (database)
- AutoCAD® and/or ArcGIS (graphics)
- EPA ProUCL (statistical software)

## 5 REPORTING

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After the data are received, MFA will generate for the Port a data report summarizing and screening the data against the applicable criteria. All validated data will be uploaded to Ecology's environmental information management system within 30 days of receipt of data and no later than 120 days from the date of sampling, in accordance with the Order.

## LIMITATIONS

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The services undertaken in completing this plan were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This plan is solely for the use and information of our client unless otherwise noted. Any reliance on this plan by a third party is at such party's sole risk.

Opinions and recommendations contained in this plan apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this plan.

## REFERENCES

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Dalton, Olmsted & Fuglevand. 2020. Final Data Gaps Work Plan. Taylor Way and Alexander Avenue Fill Area Site, Tacoma, Washington. Prepared for General Metals Glenn Springs Holdings, Port of Tacoma, Clean Earth (formerly Stericycle Environmental Solutions). July.

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Ecology. 2020. Enforcement Order No. DE 19410: In the matter of remedial action by: the Port of Tacoma at the Taylor Way and Alexander Avenue Fill Area (TWAAFA) Site to Eric Johnson, Port of Tacoma. December 4.

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FBI. 2019. Quality assurance manual. Rev. 17. Friedman & Bruya, Inc., Seattle, Washington. November 6.

# TABLES



**Table 4-1  
QC Sample Summary  
Port of Tacoma  
1801 E Alexander Avenue  
Tacoma, Washington**



QC Check Sample	Frequency
Surrogate Spiking	Added to all project and QC samples (for organic analyses only)
Method Blanks	Each analytical batch of samples of every 20 (or fewer) samples received
Laboratory Control Sample	Each analytical batch of samples of every 20 (or fewer) samples received
NOTE: QC = quality control.	



**Table 4-2**  
**Containers, Preservation, and Holding Times**  
**Port of Tacoma**  
**1801 E Alexander Avenue**  
**Tacoma, Washington**



Method	Analysis	Field Container Preservative	Holding Time (Days)	Sample Container
MA DEP-APH	APH	None	30	1-L Summa Canister <sup>(a)</sup>
ASTM D1946	Helium	None	30	1-L Summa Canister <sup>(a)</sup>
TO-15	VOCs	None	30	1-L Summa Canister <sup>(a)</sup>
<p>NOTES:</p> <p>APH = air-phase hydrocarbons.</p> <p>ASTM = ASTM International.</p> <p>L = liter.</p> <p>MA DEP = Massachusetts Department of Environmental Quality.</p> <p>TO = toxic organics.</p> <p>VOC = volatile organic compound.</p> <p><sup>(a)</sup>Subslab vapor samples will be collected in 1-L Summa canisters.</p>				

# FIGURES





Property

Source:  
 U.S. Geological Survey (2021) 7.5-minute topographic  
 quadrangle: Tacoma, Washington.  
 Township 21 North, Range 3 East, Section 35.  
 Tax parcel obtained from Pierce County assessor.

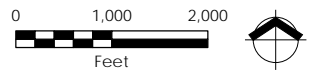
Legend

 Property Parcel

**Figure 1-1**  
**Property Location**  
 Port of Tacoma  
 1801 E Alexander Avenue  
 Tacoma, Washington

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Path: X:\0615\_20\02\Projects\Fig\_PropertyFeatures.mxd  
Print Date: 6/28/2021  
Reviewed By: syran  
Produced By: abibby  
Project: 0615\_20.02

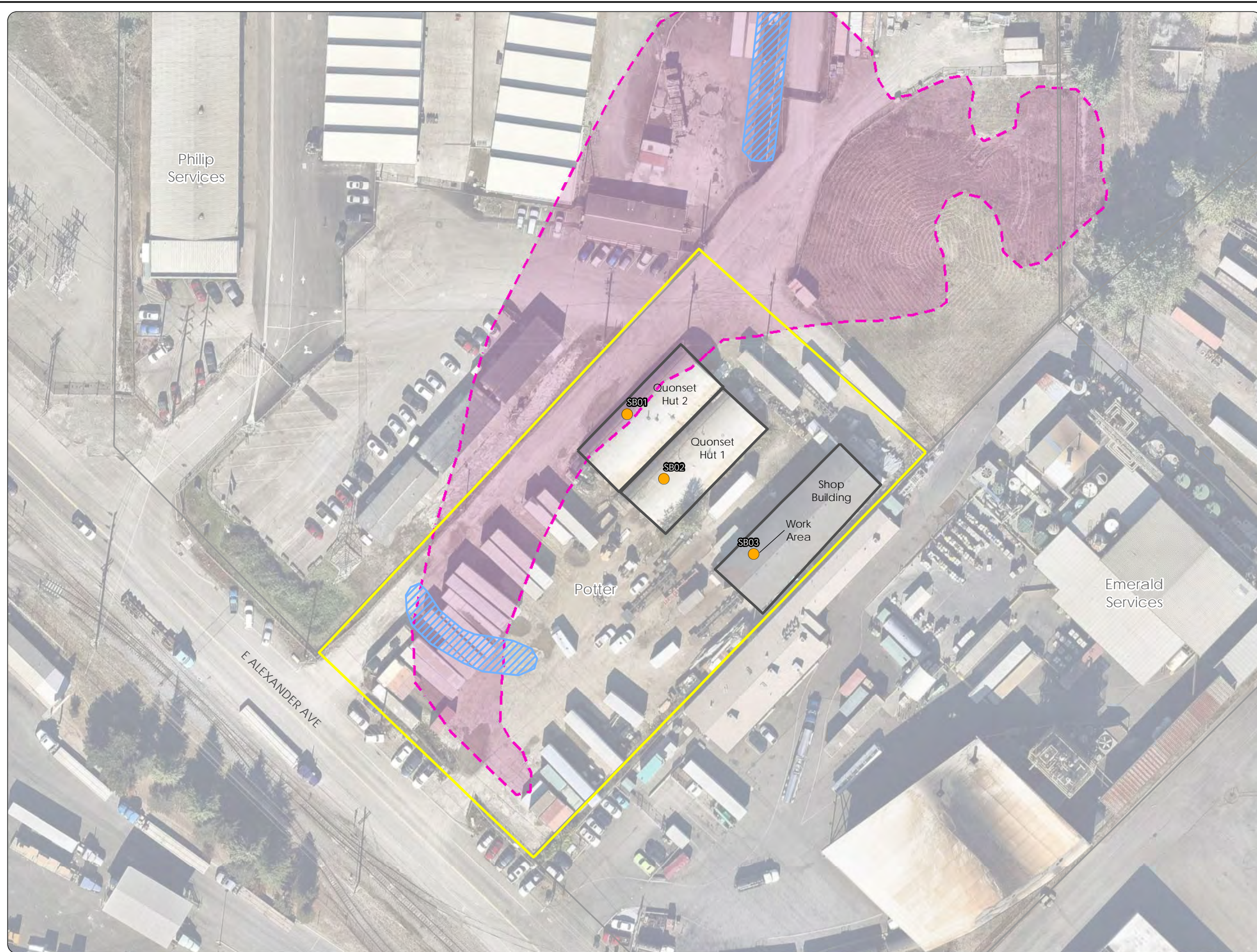
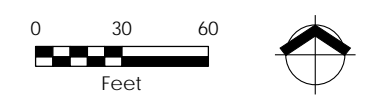


Figure 1-2  
Property Features and  
Proposed Vapor Samples  
Port of Tacoma  
1801 E Alexander Avenue  
Tacoma, Washington

Legend

- Proposed Sub-Slab Sample
- Historical Extent of Light Non-Aqueous Phase Liquid (DOF, 2020)
- ▨ Historical Light Non-Aqueous Phase Liquid Trench (PSC, 2007)
- ▭ Building
- ▭ Property Parcel (Floyd Snider, 2006)
- ▭ Tax Parcel (Floyd Snider, 2006)

NOTE:  
All features are approximate.  
DOF = Dalton Olmsted & Fuglevand.  
PSC = Philip Services Corporation.



Source:  
Aerial photograph obtained from ArcGIS Online.  
Tax parcels obtained from Port of Tacoma.



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# APPENDIX A

## STANDARD OPERATING PROCEDURES





## STANDARD OPERATING PROCEDURE

### Soil Vapor Sampling

SOP Number: 16  
Date: 3/9/2021  
Revision Number: 0.1

#### SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the methods for collecting soil vapor samples from temporary or permanent equipment installed in unsaturated subsurface soil. Sample collection may require drilling through concrete or asphalt to gain access to subsurface soils.

#### EQUIPMENT AND MATERIALS REQUIRED

The following materials are necessary for this procedure:

- Personal protective equipment
- Tubing and wrenches
- Laboratory-supplied sample canister, manifolds, and flow controllers
- Leak-detection equipment (helium tank, two-stage regulator, and gas-flow-control valve; and helium leak detector)
- Peristaltic pump
- Laboratory chain-of-custody form
- Soil vapor field sampling data sheet and field notebook

#### METHODOLOGY

When the project-specific sampling and analysis plan (SAP) provides additional or different requirements for vapor sampling, it takes precedence over this SOP. In the absence of a SAP, the procedures in this SOP shall be used.

Complete the attached questionnaire before beginning vapor sampling activities. The intent of this questionnaire is to document potential sources of vapors that could require the collection of vapor samples that are not representative of vapors present in subsurface soil.

#### General Sampling Procedure:

##### Sample collection from a temporary or permanent boring

- Installation of the sample point may be completed by a drilling subcontractor. See SOPs 7 for push-probe drilling procedures, if applicable.
- Vapor point construction details, including screen length and depth placement, annular material, and seal specifications, may be project-specific and should be described in the project SAP.
- Clear the ground surface of brush, root mat, grass, leaves, and other debris.
- Remove soil to the target depth, verify that the sample depth is correct, and record the depth in the field notebook and the boring log (see SOP 2).
- Assemble and attach the sampling equipment as described below. Before sampling, temporary sampling points must equilibrate for at least 30 minutes. Permanent points should equilibrate for at least 48 hours.

### **Sample collection from a subslab sample point**

Subslab soil-gas sampling points consist of a Cox-Colvin & Associates, Inc. (Cox-Colvin) Vapor Pin™ system. The procedures developed by Cox-Colvin for installing and removing the Vapor Pin system, including the secure cover, are attached.

### **Assembly and attachment of sampling equipment**

- Connect the sampling equipment as shown in the attached figure such that the equipment can be purged, leak tested, shut-in tested, and sampled in the field.
- The vapor pin installed in an asphalt or cement slab will be connected to the ¼ turn ball valve (Valve #1—sampling valve) using Tygon® tubing. The sampling valve is connected to a vacuum gauge, which is attached to the flow controller.
- At the flow controller, a tee connection will be fitted to the canister and to a second ¼ turn ball valve (Valve #2—purge valve) used to isolate the purging equipment during actual sampling.
- The canister has a built-in valve that allows isolation of the canister during purging and leak-checking activities. On the other side of the purge valve (#2), a vacuum pump will be connected in order to induce vacuum for purging and shut-in testing.

### **Leak detection**

- Helium will be contained around the sampling apparatus and sampling pin to serve as a leak-check compound. Helium will be released into a small structure (shroud) that is placed over the sampling pin and sampling train.
- With the canister valve closed, a sample of the soil gas collected during purging (described below) will be contained in a Tedlar® bag.
- A field helium detector will be used to sample the air purged through the sampling train to verify the presence or absence of helium. A helium concentration greater than 10 percent of the concentration in the containment structure indicates that a leak is occurring.
- If a leak is detected, the sampling and purging train fittings will be tightened and the leak check will be repeated.
- The absence of helium during the purging process verifies the integrity of the sampling system before the sample is collected.
- The canister will also be analyzed for helium by the analytical laboratory as a quality assurance measure.

### **Sampling**

- After the sampling train is purged and no leaks are detected in the sampling train, close the valve leading to the vacuum pump (Valve #2—purge valve), open the valve leading to the sampling pin (Valve #1—sample valve), and then open the valve on the canister to collect the sample over the duration of time required.
- Record field data during the sampling on the soil vapor field sampling datasheet, including the sampling start and stop times, the initial and final canister vacuum readings, and weather conditions.
- The sample will be rejected if the initial canister pressure is not at least -25 inch of mercury or if the final canister pressure is greater than -0.1 inch of mercury. The final canister pressure is recommended at or near -5 inch of mercury.



### **Data Recording**

In a field log notebook and soil vapor field sampling data sheet, record the following:

- Project name, sample date, sampling location, canister serial number, initial vacuum reading, final pressure reading, and sampling time.
- Weather conditions during sampling (temperature, barometric pressure, humidity, sunny/cloud cover, wind).
- Date and amount of most recent prior rainfall.

### **Abandonment of Sampling Points**

- Temporary Borings: Abandon each borehole in accordance with local and state regulations/procedures. The abandonment procedure typically consists of filling the boring with granular bentonite and hydrating the bentonite with water. Match the surface completion to the surrounding materials.
- Subslab Vapor Pin: The subslab vapor pin will be properly decommissioned consistent with the attached Cox-Colvin procedure. The slab borehole will be filled with grout and/or concrete.

## QUESTIONNAIRE

Preparer's Name: \_\_\_\_\_

Date/Time Prepared: \_\_\_\_\_

Preparer's Affiliation: \_\_\_\_\_

### 1. OCCUPANT:

Last Name: \_\_\_\_\_ First Name: \_\_\_\_\_

Building / Suite: \_\_\_\_\_

Number of occupants/persons at this location: \_\_\_\_\_

### 2. FACTORS THAT MAY INFLUENCE INDOOR AIR QUALITY

- a. Are petroleum-powered machines or vehicles stored in the building or attached garage?** (e.g., lawnmower, ATV, car) Y / N  
Please specify \_\_\_\_\_
- b. Has the building ever had a fire?** Y / N  
When? \_\_\_\_\_
- c. Is a kerosene or unvented gas space heater present?** Y / N  
Where and type? \_\_\_\_\_
- d. Is there a workshop or hobby/craft area?** Y / N  
Where and type? \_\_\_\_\_
- e. Is there smoking in the building?** Y / N  
Frequency? \_\_\_\_\_
- f. Have cleaning products been used recently?** Y / N  
When and type? \_\_\_\_\_
- g. Have cosmetic products been used recently?** Y / N  
When and type? \_\_\_\_\_
- h. Has painting/staining been done in the last 6 months?** Where and when? Y / N  
\_\_\_\_\_
- i. Is there new carpet, drapes, or other textiles?** Y / N  
Where and when? \_\_\_\_\_
- j. Have air fresheners been used recently?** Y / N  
When and type? \_\_\_\_\_
- k. Is there a kitchen exhaust fan?** Y / N  
If yes, where vented? \_\_\_\_\_

## QUESTIONNAIRE

**l. Is there a bathroom exhaust fan?** Y / N

If yes, where vented? \_\_\_\_\_

**m. Is there a clothes dryer?** Y / N

If yes, is it vented outside? Y / N

**n. Has there been a pesticide application?** Y / N

When and type? \_\_\_\_\_

**o. Are there odors in the building?** Y / N

If yes, please describe: \_\_\_\_\_

**p. Do any of the building occupants use solvents or volatile chemicals at work?** (e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide applicator, cosmetologist, carpet installer) Y / N

If yes, what types of solvents are used? \_\_\_\_\_

If yes, are the occupants' clothes washed at work? Y / N

### 3. PRODUCT INVENTORY FORM

List specific products in the building that may contain petroleum hydrocarbons. Please note that MFA will visit the site to help complete the product inventory.

Location	Product Description	Size (units)	Condition*

\*Describe the condition of the product containers as unopened, used, or deteriorated.

## Scope:

This standard operating procedure describes the installation and extraction of the Vapor Pin™<sup>1</sup> for use in sub-slab soil-gas sampling.

## Purpose:

The purpose of this procedure is to assure good quality control in field operations and uniformity between field personnel in the use of the Vapor Pin™ for the collection of sub-slab soil-gas samples.

## Equipment Needed:

- Assembled Vapor Pin™ [Vapor Pin™ and silicone sleeve (Figure 1)];
- Hammer drill;
- 5/8-inch diameter hammer bit (Hilti™ TE-YX 5/8" x 22" #00206514 or equivalent);
- 1½-inch diameter hammer bit (Hilti™ TE-YX 1½" x 23" #00293032 or equivalent) for flush mount applications;
- ¾-inch diameter bottle brush;
- Wet/dry vacuum with HEPA filter (optional);
- Vapor Pin™ installation/extraction tool;
- Dead blow hammer;
- Vapor Pin™ flush mount cover, as necessary;
- Vapor Pin™ protective cap; and
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel.



**Figure 1.** Assembled Vapor Pin™.

## Installation Procedure:

- 1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.
- 2) Set up wet/dry vacuum to collect drill cuttings.
- 3) If a flush mount installation is required, drill a 1½-inch diameter hole at least 1¾-inches into the slab.
- 4) Drill a 5/8-inch diameter hole through the slab and approximately 1-inch into the underlying soil to form a void.
- 5) Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.
- 6) Place the lower end of Vapor Pin™ assembly into the drilled hole. Place the small hole located in the handle of the extraction/installation tool over the Vapor Pin™ to protect the barb fitting and cap, and tap the Vapor Pin™ into place using a

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<sup>1</sup>Cox-Colvin & Associates, Inc., designed and developed the Vapor Pin™; a patent is pending.

dead blow hammer (Figure 2). Make sure the extraction/installation tool is aligned parallel to the Vapor Pin™ to avoid damaging the barb fitting.



**Figure 2.** Installing the Vapor Pin™.

For flush mount installations, unscrew the threaded coupling from the installation/extraction handle and use the hole in the end of the tool to assist with the installation (Figure 3).



**Figure 3.** Flush-mount installation.

During installation, the silicone sleeve will form a slight bulge between the slab and the Vapor Pin™ shoulder. Place the protective cap on Vapor Pin™ to prevent vapor loss prior to sampling (Figure 4).



**Figure 4.** Installed Vapor Pin™.

- 7) For flush mount installations, cover the Vapor Pin™ with a flush mount cover.
- 8) Allow 20 minutes or more (consult applicable guidance for your situation) for the sub-slab soil-gas conditions to equilibrate prior to sampling.
- 9) Remove protective cap and connect sample tubing to the barb fitting of the Vapor Pin™ (Figure 5).



**Figure 5.** Vapor Pin™ sample connection.

- 10) Conduct leak tests [(e.g., real-time monitoring of oxygen levels on extracted sub-slab soil gas, or placement of a water

dam around the Vapor Pin™) Figure 6]. Consult your local guidance for possible tests.



**Figure 6.** Water dam used for leak detection.

11) Collect sub-slab soil gas sample. When finished sampling, replace the protective cap and flush mount cover until the next sampling event. If the sampling is complete, extract the Vapor Pin™.

Extraction Procedure:

1) Remove the protective cap, and thread the installation/extraction tool onto the barrel of the Vapor Pin™ (Figure 7). Continue



**Figure 7.** Removing the Vapor Pin™.

turning the tool to assist in extraction, then pull the Vapor Pin™ from the hole (Figure 8).



**Figure 8.** Extracted Vapor Pin™.

2) Fill the void with hydraulic cement and smooth with the trowel or putty knife.  
3) Prior to reuse, remove the silicone sleeve and discard. Decontaminate the Vapor Pin™ in a hot water and Alconox® wash, then heat in an oven to a temperature of 130° C.

The Vapor Pin™ is designed to be used repeatedly; however, replacement parts and supplies will be required periodically. These parts are available on-line at [www.CoxColvin.com](http://www.CoxColvin.com).

Replacement Parts:

Vapor Pin™ Kit Case - VPC001  
Vapor Pins™ - VPIN0522  
Silicone Sleeves - VPTS077  
Installation/Extraction Tool - VPIC023  
Protective Caps - VPPC010  
Flush Mount Covers - VPFM050  
Water Dam - VPWD004  
Brush - VPB026



Scope:

This standard operating procedure (SOP) describes the methodology to use the Vapor Pin™ Drilling Guide and Secure Cover to install and secure a Vapor Pin™ in a flush mount configuration.

Purpose:

The purpose of this SOP is to detail the methodology for installing a Vapor Pin™ and Secure Cover in a flush mount configuration. The flush mount configuration reduces the risk of damage to the Vapor Pin™ by foot and vehicular traffic, keeps dust and debris from falling into the flush mount hole, and reduces the opportunity for tampering. This SOP is an optional process performed in conjunction with the SOP entitled “Installation and Extraction of the Vapor Pin™”. However, portions of this SOP should be performed prior to installing the Vapor Pin™.

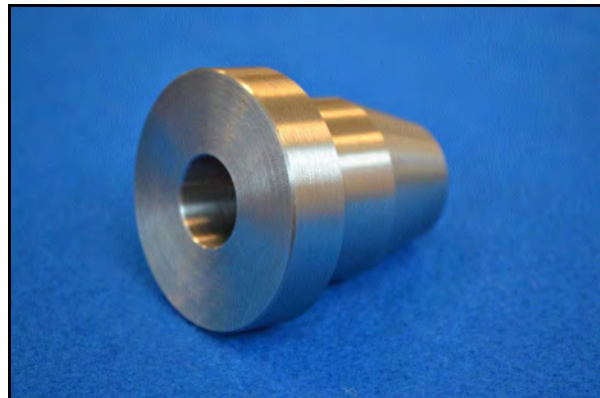
Equipment Needed:

- Vapor Pin™ Secure Cover (Figure 1);
- Vapor Pin™ Drilling Guide (Figure 2);
- Hammer drill;
- 1½-inch diameter hammer bit (Hilti™ TE-YX 1½” x 23” #00293032 or equivalent);
- 5/8-inch diameter hammer bit (Hilti™ TE-YX 5/8” x 22” #00226514 or equivalent);
- assembled Vapor Pin™;
- #14 spanner wrench;
- Wet/Dry vacuum with HEPA filter (optional); and

- personal protective equipment (PPE).



**Figure 1.** Vapor Pin™ Secure Cover.



**Figure 2.** Vapor Pin™ Drilling Guide.

Installation Procedure:

- 1) Check for buried obstacles (pipes, electrical lines, etc.) prior to proceeding.
- 2) Set up wet/dry vacuum to collect drill cuttings.
- 3) While wearing PPE, drill a 1½-inch diameter hole into the concrete slab to a



depth of approximately 1 3/4 inches. Pre-marking the desired depth on the drill bit with tape will assist in this process.

- 4) Remove cuttings from the hole and place the Drilling Guide in the hole with the conical end down (Figure 3). The hole is sufficiently deep if the flange of the Drilling Guide lies flush with the surface of the slab. Deepen the hole as necessary, but avoid drilling more than 2 inches into the slab, as the threads on the Secure Cover may not engage properly with the threads on the Vapor Pin™.



**Figure 3.** Installing the Drilling Guide.

- 5) When the 1½-inch diameter hole is drilled to the proper depth, replace the drill bit with a 5/8-inch diameter bit, insert the bit through the Drilling Guide (Figure 4), and drill through the slab. The Drilling Guide will help to center the hole for the Vapor Pin™, and keep the hole perpendicular to the slab.
- 6) Remove the bit and drilling guide, clean the hole, and install the Vapor Pin™ in accordance with the SOP “Installation and Extraction of the Vapor Pin™”.



**Figure 4.** Using the Drilling Guide.

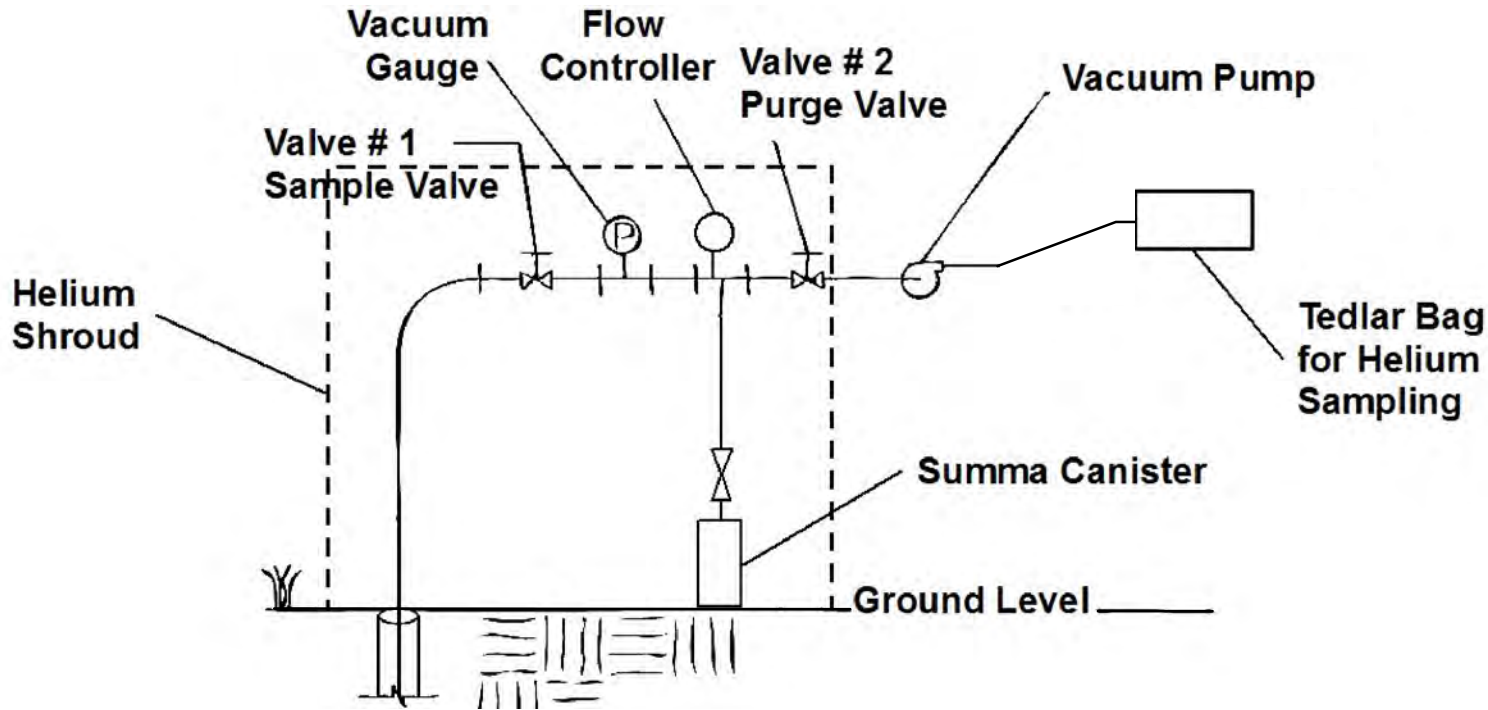
- 7) Screw the Secure Cover onto the Vapor Pin™ and tighten using a #14 spanner wrench by rotating it clockwise (Figure 5). Rotate the cover counter clockwise to remove it for subsequent access.



**Figure 5.** Tightening the Secured Cover.

Limitations:

On slabs less than 3 inches thick, it may be difficult to obtain a good seal in a flush mount configuration with the Vapor Pin™.



### Figure Sub-Slab Soil Gas Sampler System

Former Office Building  
Port of Astoria  
Astoria, Oregon

Source: CH2MHill, Corvallis Applied Sciences  
Laboratory



MAUL FOSTER ALONGI  
p. 971 544 2139 | www.maulfooster.com

This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.



## STANDARD OPERATING PROCEDURE

### Underground Utility Locates

SOP Number: 18  
Date: 3/9/2021  
Revision Number: 0.1

#### SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the practices for locating underground utilities. Refer to the MFA health and safety plan (HASP), if available, for additional information regarding communication procedures to be followed when an inadvertent utility strike occurs, as well as regarding methods for mitigating hazards during a utility strike.

#### EQUIPMENT AND MATERIALS REQUIRED

The following materials are necessary for this procedure:

- Personal protective equipment (as specified in the HASP)
- Marking materials (e.g., marking paint, stakes, flags)
- Field documentation materials

#### METHODOLOGY

When the project-specific sampling and analysis plan (SAP) specifies additional or different requirements for underground utility locates, it takes precedence over this SOP. In the absence of a SAP, the procedures in this SOP shall be used.

#### Before Conducting Utility Locates:

- Ensure that the locate will be conducted reasonably soon before the excavation work begins, e.g., within 48 hours. There may be project-specific conditions, e.g., weather and/or ground features that could cause markings to fade, which would require scheduling of the excavation work sooner than 48 hours after the locate.
- Clearly define the boundary of the work and the locations of all proposed excavations. Prepare a map of the project area showing the excavation locations.
- Interview site managers/property owners and obtain plans or drawings, if available, showing on-site utilities.
- For project work that will not take place in the public right-of-way, ensure that the public rights-of-way nearest to the project are identified and communicated during the one-call notification.
- Identify the township and range of the project area. This information can be easily attained by a quick email to MFA's GIS Exchange.
- If feasible, conduct a site visit to identify site conditions that could cause fading or disruption of marking paint. Such conditions could include gravel or ground sensitive to erosion and high traffic.
- Check the weather forecast to assess the potential for snow or rain to make marking utilities difficult or cause the markings to fade.

#### One-Call Utility Notification:

- If possible, initiate the one-call utility notification at least one week before the proposed work begins.
- Include a map or GPS coordinates when submitting the notification.
- Before conducting any excavation activities, confirm with each public utility that the utility locate has been completed.

- On remote or complicated sites, consider meeting public locators on site.
- Document the one-call ticket number and results in the project files.
- Provide the one-call ticket number to subcontractors who will be doing the excavations.

### **Private Utility Locate:**

- Conduct the private utility locate only after confirmation that the public utility locate has been completed and all public utilities have been marked and the results reviewed by MFA staff who will be overseeing the excavations.
- Meet the private locator on site and participate in the entire private utility locate. Be engaged in the process, ask questions, and take time to walk the site thoroughly with the locator.
- Bring a copy of the one-call utility ticket and results of the one-call utility locator to check against the utility markings on the ground.
- If possible, have a site/property representative knowledgeable of on-site utilities participate in the private utility locate.
- If paint alone may not suffice to ensure clear marking of utilities, add vertical markers such as stakes or flags.
- Visually assess the area of the proposed excavation(s) to identify features potentially indicative of buried utilities. Have the private utility locator examine each feature identified below to assess the presence of buried utilities.
  - Examine adjacent public rights-of-way where public utilities have been marked for evidence of utilities that may extend onto the project site.
  - Identify nearby light poles, telephone poles, electrical utility poles, or other overhead utility poles with wires or conductors that run from the overhead utility, down the pole, and into the ground.
  - Identify the location of gas meters, water meters, or other aboveground junction boxes for evidence of utilities extending from these features into the ground.
  - Examine asphalt and concrete ground surfaces for discontinuities in the surface indicative of utility installations. Discontinuities may include recent patches of asphalt or concrete inlaid within older concrete or asphalt surfaces.
  - Identify manholes and catch basins indicative of buried storm or sanitary sewer pipes. Open manholes to examine the orientation of associated pipes to assess whether the utilities may be present near proposed excavations.
  - Identify tank ports and vent pipes.
  - Identify irrigation systems and associated features such as valve boxes and controllers.
  - Identify any other signs indicating the presence of buried utilities.
  - Be wary of utility marks that suddenly begin or dead end.

**Preparing to Perform Subsurface Activities after a Locate:**

- Ensure that the markings are still visible when the work begins.
- Adjust locations, as needed, to avoid identified utilities, or use alternative methods such as nonmechanical excavation means (i.e., manual excavation or air-knifing) to a minimum depth of 5 feet.

**Table  
 APWA UNIFORM COLOR CODE**

	WHITE—Proposed Excavation
	PINK—Temporary Survey Markings
	RED—Electric Power Lines, Cables, Conduit and Lighting Cables
	YELLOW—Gas, Oil, Steam, Petroleum or Gaseous Materials
	ORANGE—Communication, Alarm or Signal Lines, Cables or Conduit
	BLUE—Potable Water
	PURPLE—Reclaimed Water, Irrigation and Slurry Lines
	GREEN—Sewers and Drain Lines
Source: Uniform Color Codes, ANSI Standard Z535.1. American Public Works Association. Revised 1999.	

# APPENDIX B

## FIELD SAMPLING DATA SHEETS



Sampler(s):

**Subslab and Soil Vapor Sampling Data Sheet**  
**Potter Property**  
**Port of Tacoma**  
**Tacoma, Washington**



Sample ID	Date	Shut-in Test Pass/Fail	Summa Canister ID	Manifold ID	Canister Type/Rate	Purge				Helium		Sample			
						Begin Time	End Time	Volume (L)	Helium (ppm)	Indoor Ambient Air (ppm)	Under Shroud (%) (ideal = 40)	Begin Time	End Time	Initial Vacuum (Hg)	Final Vacuum (Hg)
Example	4/6/2021	Pass	3671	225	1 L Summa	13:46	13:51	1	50	0	43.9	13:55	14:00	-30	-5
Example	4/6/2021	Pass	3347	204	1 L Summa	13:05	13:10	1	175	0	58	13:13	13:19	-29	-5

NOTES:  
 1% = 10,000 ppm.  
 To avoid data rejection during validation, the amount of helium in the sample must be less than 5% of the helium concentration under the shroud. For example, if there is 50% helium in the shroud, your sample may contain up to 2.5%, (25,000 ppm) helium.  
 "Hg = inches of mercury.  
 ID = identification.  
 L = liter.  
 ppm = parts per million.



Sampler(s):

**Subslab and Soil Vapor Sampling Data Sheet**  
**Potter Property**  
**Port of Tacoma**  
**Tacoma, Washington**



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