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Vapor Recovery by Electrothermal Swing Adsorption

ESTCP Project WP-200521

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14. ABSTRACT

VaPRRS™ is a new type of regenerative filter adsorption system which uses a high-performance activated carbon fiber cloth (ACFC) contained within a vessel. Applying an electrical current regenerates the fabric by rapidly heating it, which efficiently desorbs the contaminant(s) with minimal heating of the vessel. The adsorbate is released and condensed onto the inner surface of the vessel and is collected as a liquid. After cooling, the filter is capable of reuse. A major advantage of this technology over conventional systems is that the entire adsorption, desorption, and recovery process occurs in the same vessel. This technology was demonstrated at Hill Air Force Base, Utah, in a portable emissions treatment cart used for painting the wheel wells of C-130 aircraft. The prototype cart met the 98% efficiency performance objective, but failed to meet five of the other seven performance objectives, mainly because the regeneration/solvent recovery cycle failed to operate properly. No solvent was recovered, probably because of improper valve sequencing or leaks. A rough cost analysis showed a potential 6.2 year investment payback.

15. SUBJECT TERMS
ESTCP; Hill AFB, Utah; Vapor Phase Removal and Recovery System (VaPRRS); air pollution; pollution control; hazardous air pollutants (HAPs); volatile organic compounds (VOCs); paint solvents; adsorption; activated carbon fiber cloth

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LIST OF ACRONYMS AND SYMBOLS

ACFC	Activated Carbon Fiber Cloth
AFB	Air Force Base
AFRL	Air Force Research Laboratory
CERL	Construction Engineering Research Laboratory
cfm	cubic foot per minute
DLSME	Defense Land Systems and Miscellaneous Equipment
DoD	Department of Defense
ECAM	environmental cost analysis methodology
ERDC	Engineer Research and Development Center
ESA	electrothermal swing adsorption
FID	flame-ionization detector
GAC	granular activated carbon
GC-FID	gas chromatography and flame-ionization detector
HAP	hazardous air pollutant
HEPA	high-efficiency particulate air
MEK	methyl ethyl ketone
MIBK	methyl isobutyl ketone
MPK	methyl propyl ketone
MSDS	material safety data sheet
NA	not available
NDCEE	National Defense Center for Environmental Excellence
NESHAP	National Emissions Standards for Hazardous Air Pollutants
OO-ALC	Ogden Air Logistics Center
PCE	perchloroethylene
PID	photo-ionization detector
ppmv	parts per million on a volume basis
RH	relative humidity
RMS	root mean square
TCE	trichloroethylene
TRC	Technical Repair Center
UI	University of Illinois
USEPA	United States Environmental Protection Agency
VaPRRS™	Vapor Phase Removal and Recovery System
VOC	volatile organic compound

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EXECUTIVE SUMMARY

The development of new vapor recovery technologies can allow for continued use of higher-performance chemicals, reuse of those chemicals, and lower overall emissions of Hazardous Air Pollutants/Volatile Organic Compounds (HAPs/VOCs). Vapor Phase Removal and Recovery System (VaPRRS™) was developed cooperatively by the University of Illinois, ERDC-CERL, and Air Force Research Laboratory (AFRL) as an economical adsorption technology to control emissions from Department of Defense (DoD) HAP/VOC emissions sources such as painting operations. VaPRRS is a new type of regenerative filter system which works by using a high-performance activated carbon fiber cloth (ACFC) contained within a vessel. Applying an electrical current regenerates the ACFC by rapidly heating it, and this initial action causes efficient desorption of the contaminant with only minimal heating of the vessel. The adsorbate is released and condensed onto the inner surface of the vessel where it is collected as a liquid. After cooling, the filter is capable of reuse. A major advantage of VaPRRS technology over conventional systems is that the entire adsorption, desorption, and recovery process occurs inside the same vessel. This advantage ultimately reduces the size, complexity, and cost of the system.

During a prior pilot field study at a paint booth at Fort Hood, TX, the VaPRRS system achieved greater than 99% control efficiency. The technical objective for ESTCP Project WP-0521 was to demonstrate that the VaPRRS technology can efficiently and economically control VOCs from a dedicated DoD waste stream. The chosen demonstration site was Hill Air Force Base (AFB), where the VaPRRS technology was implemented within a compact and portable emission treatment cart. The demonstration was designed to remove VOCs from gas streams generated while painting C-130 aircraft wheel wells. The portable paint cart encloses the painting operation so that evacuation of the hangar is not necessary during painting; thus, control efficiency is important. The existing system's cart contains granular activated carbon (GAC) beds. When the bed becomes saturated, it is sent offsite for disposal or regeneration, and a new bed is installed. VaPRRS will allow for regeneration of the adsorbent and recovery of the adsorbate. This demonstration replaces the GAC beds with a VaPRRS unit in a new treatment cart prototype.

The design of the VaPRRS demonstration prototype proved to be a large challenge that became marred with contracting issues, filter performance problems, scale-up issues, and a competing spinoff technology project competing for resources. The first filter design was a pleated filter that performed unsatisfactory. This led to in-house development by Dr. Sullivan of filters utilizing skeletal structures. The final design resulted in cylindrical-shaped filters that were organized in arrays to be inserted into a modified version of the current emission treatment cart at Hill AFB. The prototype VaPRRS loaded treatment cart was built by Global Finishing Systems, Inc. (www.globalfinishing.com), makers of the existing treatment cart. The VaPRRS treatment cart was tested during two troubleshooting efforts at Global Finishing's facility in Osseo, WI.

Performance testing of the VaPRRS treatment cart occurred October 31– November 2, 2011 at Hill AFB. Treatment of VOCs being emitted from wheel-well coating was performed by coating

one C-130 aircraft during the testing period. Approximately 5.8 gal of solvents were used. Other than the regeneration phase, the new system operated similarly to the paint booth emission control cart that exists at Hill AFB, so the testing did not impact the base's ongoing operations.

Data from the first two days of testing showed the control efficiency during adsorption was 81.1%–84.6%. That efficiency was lower than the expected value of 98%, so the cart was modified to reduce leaks that were allowing some of the incoming coating-laden air to bypass the ACFC filters. Tests from the third day showed that the repairs were successful with an average control efficiency of 98% achieved. The ACFC did not reach breakthrough after adsorbing VOCs and water during the complete coating of the wheel wells for the C-130 aircraft.

Desorption of the cart was conducted after the wheel-well coating activity was complete on the C-130. It was evident during desorption that there was a problem because high VOC concentrations were detected near the inlet of the cart where they were not expected. There was no liquid in the liquid recovery vessel after regeneration of the primary or secondary filters. This finding suggests there were leaks or open valves that allowed the regeneration gas to escape through the adsorption inlet into the hanger. The liquid recovery efficiency was 0%, and this leak or valve sequence problem needs to be addressed before the ACFC cart can function properly.

The treatment cart with VaPRRS loaded did not pass all of the primary performance criteria because the regeneration cycle did not function properly. As stated, after sealing leaks in the initial tests, the average control efficiency was 98.0%, which meets the 98% control efficiency requirement. The cart was considered to be fully functional for each adsorption test during the field campaign, resulting in a reliability of 100% that exceeds the 90% reliability requirement. There was 0% hazardous waste recovery, while 95% recovery was required. It was inconclusive whether the cart passed the ease-of-use criterion because the regeneration process did not function properly. The cart performed similarly to the pilot-scale unit during adsorption but did not function properly during regeneration, so the scale-up criterion was not met. The cart performed consistently for adsorption during the field campaign for the different wheel wells, coatings, and ambient weather conditions. The system required minimal operator training and did not require additional training after the first use. However, the system did not successfully operate during desorption to recover solvent, so it was inconclusive whether operators could successfully maintain the system during regeneration. The cart was not successfully utilized at Hill AFB due to the regeneration issue and thus failed the versatility criterion.

Due to the unsatisfactory performance of the VaPRRS treatment cart during the field test, a complete cost assessment was not conducted. However, a capital cost estimation suggests that the VaPRRS cart would cost 120% more than the current treatment cart ($143,000 versus $65,000). The difference in operating costs indicates that payback would occur in 6.2 years with a $48,000 savings over the 10-year life expectancy.

With the current regeneration malfunction, the cart is not recommended for further implementations. However, it is believed the problems are related to construction issues with the prototype and not with the VaPRRS technology; thus a subsequent evaluation would be more successful if the current prototype is refurbished.

1. INTRODUCTION

1.1 BACKGROUND

New, efficient, and practical vapor recovery technologies are needed to conserve our natural resources, reduce our dependence on petrochemicals, and minimize pollution of our environment. The cost of complying with volatile organic compound (VOC) emission regulations is more than a billion dollars per year; thus, VOCs should be recovered for cost savings and also reused whenever it is economically feasible. The development of new technologies can allow for the continued use of higher-performance chemicals, re-use of those chemicals at the source, and lower overall emissions of Hazardous Air Pollutants/Volatile Organic Compounds (HAPs/VOCs) to the environment. Concerns over ozone-depleting chemicals and greenhouse gas emissions have provided additional incentives to examine how new technologies can be used to capture and recover these gases. It is also beneficial for these devices to capture and recover the HAPs/VOCs instead of converting them into greenhouse gases (e.g., CO_2) or acids (e.g., HCl), as occurs during oxidative techniques.

The most energy-efficient way to capture low concentrations of volatile organics is by adsorption. Unfortunately, the regeneration of adsorbents and the recovery of the captured contaminants are often economically or practically unfeasible with current technologies, such as granular activated carbon (GAC) with steam regeneration, particularly for small-scale systems. A compact, simple, energy efficient, and readily scalable technology for the capture and recovery of volatile organics is needed. The subject technology is named Vapor Phase Removal and Recovery System (VaPRRS™) and was developed cooperatively between the University of Illinois (UI), U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL), and Air Force Research Laboratory (AFRL). The original driver that led to the development of VaPRRS was a desire for a technology that could control organic vapor emissions from Department of Defense (DoD) painting operations.

This technology addresses all Army, Air Force, Navy and DoD requirements for the control/recycle of VOC emissions. DoD operates numerous activities that generate VOC emissions. Some examples of VOC-emitting operations include painting, paint stripping, adhesive application, specialty coating application, solvent cleaning, degreasing, wastewater remediation, soil remediation, and refueling. The potential VOCs of concern from these operations are aromatic hydrocarbons (toluene, styrene, xylene); ketones: methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), methyl propyl ketone (MPK); chlorinated solvents: trichloroethylene (TCE) and perchloroethylene (PCE); and other toxic organic vapors. The number of air pollution rules that regulate these activities is increasing, and the rules are generally becoming more stringent. The potential Defense Land Systems and Miscellaneous Equipment (DLSME) National Emissions Standards for Hazardous Air Pollutants (NESHAPs) could cover painting-type VOC emission sources for ground-based materiel at DoD facilities specifically. The US Army alone has 26 major Hazardous Air Pollutant (HAP) sites that that are currently subject to regulation by NESHAPs. At a minimum, all of these installations conduct some type of painting or coating operation; aircraft and ships are already covered under the

Aerospace and Shipbuilding NESHAPs. When control technologies are employed at DoD painting sites, they are typically destructive combustion technologies such as thermal oxidizers, regenerative thermal oxidizers, recuperative oxidizers and catalytic recuperative oxidizers, or adsorption technologies such as GAC and zeolite systems.

A successful demonstration of the VaPRRS technology will benefit DoD by providing a new, versatile, and cost-effective way of controlling emissions, recovering solvents, and eliminating hazardous waste. Operational cost savings, hazardous waste reductions, recovery of reusable materials, and reduced liability will result in increased resources being available to benefit the warfighter. These benefits would only increase as environmental regulations become more stringent in the future.

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this effort was to demonstrate that the VaPRRS technology can be efficiently and economically operated at a DoD site to control HAPs/VOCs from a dedicated waste stream. The chosen application was the portable paint booth system located at Hill Air Force Base (AFB) for coating the wheel wells of the C-130 aircraft. This system is a multiple VOC system that operates inside a hangar so that very high capture efficiency was required. This is a full-scale operational paint booth system that will be used with VaPRRS beyond the testing phase, if the demonstration is successful. The testing phase of this demonstration showed whether the system can control more than 98% of the VOC emissions, and whether it can operate more cost effectively than the GAC bed system than is currently being used.

1.3 REGULATORY DRIVERS

The Clean Air Act Amendments, specifically Titles I and III, regulate VOC emissions. In Title III, there are several existing NESHAPs that regulate industrial sources such as the Aerospace, Shipbuilding, Miscellaneous Parts, and the proposed DLSME NESHAPs. Many DoD sites also must follow state regulations, which may be stricter than the federal rules.

2. DEMONSTRATION TECHNOLOGY

2.1 TECHNOLOGY DESCRIPTION

VaPRRS is a new type of regenerative filter system which uses a high-performance activated carbon fiber cloth (ACFC) contained within a vessel. Applying an electrical current regenerates the fabric and this action causes rapid heating of the fabric, which then efficiently desorbs the contaminant with minimal heating of the vessel. The adsorbate is released and condensed onto the inner surface of the vessel and is collected as a liquid. After cooling, the filter is capable of reuse. This Electrothermal Swing Adsorption (ESA) technology is the subject of US Patent 6,364,936 [1]. The following is a brief description of VaPRRS that was submitted for publication in the *Federal Register* as part of the Notice of Availability for the patent:

> An adsorption/desorption unit containing one or more activated carbon cloth elements used to separate gases from air streams, typically organic. The elements conduct electricity so that they can be heated to permit selective adsorption and subsequent desorption to regenerate the elements and recover the sorbate. The elements are housed by an enclosure that is designed to direct the incoming gas/air stream through the elements and out the enclosure, direct a carrier gas to pass through the elements in the opposite direction for desorption, and to collect a liquid condensate during desorption as the gas may condense on the colder enclosure walls. Although not limited to this application, this patent was developed as a method to selectively adsorb, desorb and recover organic emissions from industrial processes.

Additional information, including a video of this technology in operation, can be viewed on two websites [2, 3]. A schematic of the technology is provided in Figure 1.

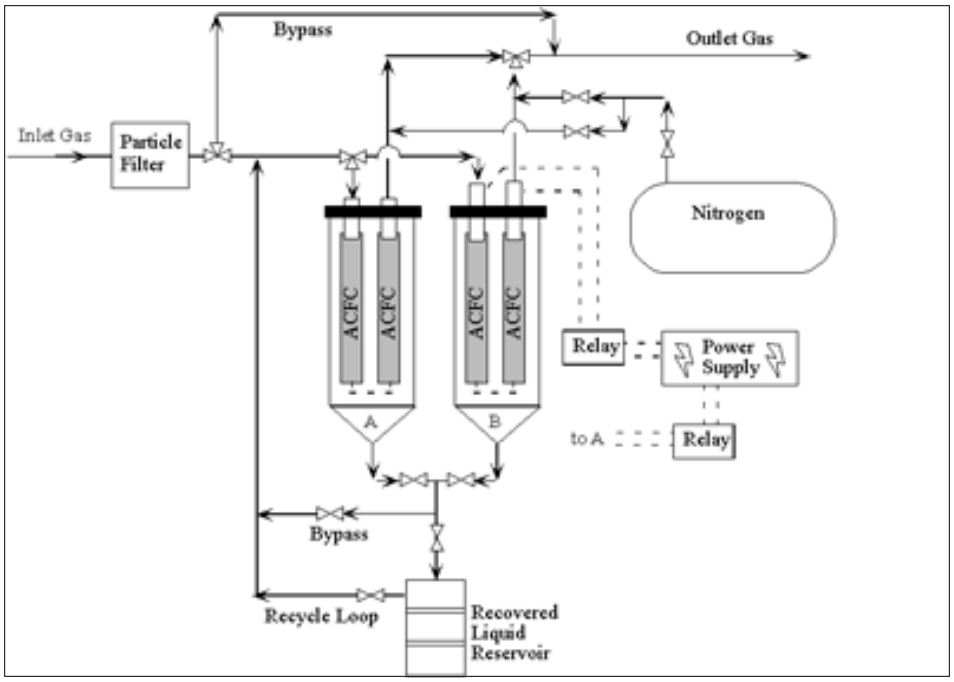

Figure 1. Schematic of VaPRRS.

VaPRRS is able to readily capture and recover vapors from air streams with a wide range of properties. However, the current version of the system is limited to capturing and recovering vapors as liquids for compounds with boiling points > 45°C, concentrations of vapors > tens of parts per million on a volume basis (ppmv), and dry bulb temperatures that are more than 20°C lower than the boiling point of the vapor that is to be captured and recovered from the gas stream. Relative humidity (RH) of the inlet gas stream can be as high as 90% because the RH of the gas stream can be readily reduced to 40% by heating of the gas stream by approximately 15°C. The primary design criteria for the demonstration will be the volumetric flow rate of the incoming gas stream, the concentration of VOCs in that stream, and the expected daily usage of the system.

VaPRRS has been under development by UI researchers since 1992. Development started with basic bench-scale experimental and modeling studies to evaluate the effectiveness of ACFC to capture organic vapors from dry and humid air streams [4]. These adsorption studies led to further successful studies that characterized how ACFC captured and recovered organic vapors while using electrothermal regeneration [5]. However, that bench-scale system was too complicated and expensive for practical applications. Further research by the inventors resulted in a much simpler, more effective, and less expensive bench-scale vapor capture and recovery system that was then patented with the cooperation of UI and DoD, due to its unique and low-cost properties compared to commercially available vapor control technologies [6]. The bench-scale system was then scaled up to a pilot-scale system and tested in a UI laboratory [7] and in the field at a paint spray booth at Fort Hood [8, 9].

2.2 TECHNOLOGY DEVELOPMENT

A three-month field campaign at Fort Hood was very successful in evaluating VaPRRS when it was connected to the exhaust duct of a paint spray booth [10, 11, 12]. Representative concentration profiles of vapor emissions from the full-scale paint booth going into the inlet and out of the ESA system are presented in Figure 2. The volumetric flow rate of this pilot-scale ESA system is approximately 80 cu ft per min. There was a wide range of vapor concentrations with the organic vapor consisting of about eight different compounds. Material balances for the entire campaign resulted in > 99% removal efficiencies for the organic vapors.

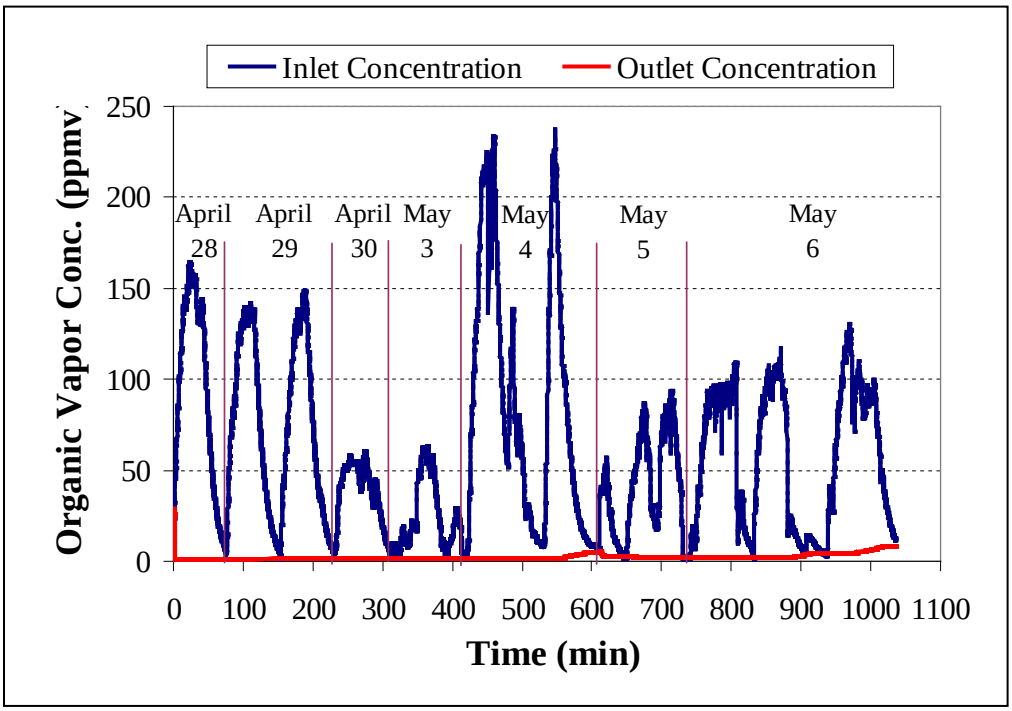

Figure 2. Inlet and outlet vapor concentrations of ESA system for the capture of vapor emissions from the Fort Hood painting facility on April 28 – May 6 (overall mean inlet concentration = 60.1 ppmv as MEK, standard deviation = 50.8).

The electrical energy applied to regenerate the ACFC cartridges at Fort Hood was 4.9 x 103 kJ when the average inlet vapor concentration was 60 ppmv as MEK. The total electrical energy used during desorption cycling increased to 39 x 103 kJ—including the energy consumed by the compressor, system utilities, and electrothermal regeneration of the ACFC. Hence, the energy required to regenerate the ACFC cartridges is 12.5% of the total energy requirements to operate the entire ESA system (Figure 3). Most of the energy (58%) is used by the compressor to generate compressed air to make the nitrogen on site. The balance of the energy (29.5%) is consumed by utilities in the enclosure such as the remote computer, air conditioning or heating system, lights, induced draft blower, and system control panel. The full-scale system tested at Hill AFB did not require a nitrogen generator because there is a readily available supply of nitrogen on site. This availability should result in a significant reduction in energy requirements (and cost) to operate the system since it eliminated the need for a nitrogen generator and the energy to operate it.

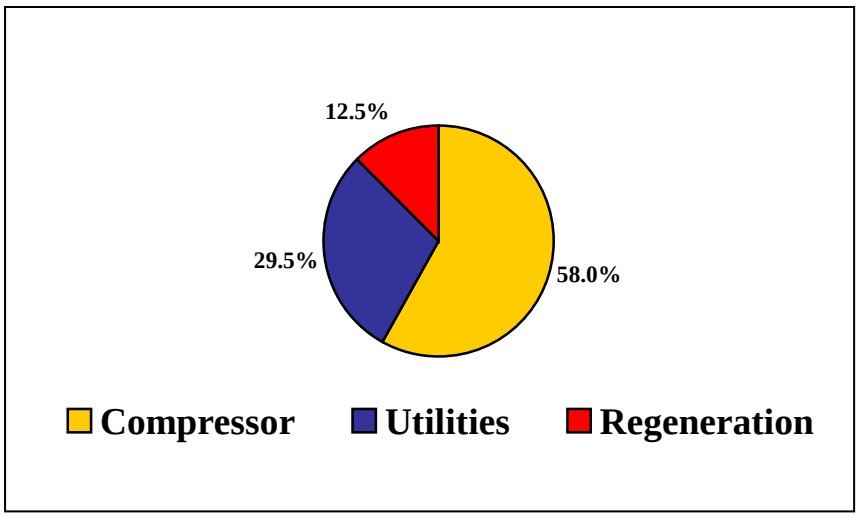

Figure 3. Electrical energy consumption during regeneration of the ACFC cartridges during pilot test.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

A major advantage of this technology over conventional systems (typically GAC adsorption systems) is that the entire adsorption, desorption, and recovery process occurs in the same vessel. This consolidation ultimately reduces the size and cost of the system; other advantages include possible selective sorption in multi-component streams and the recovery of a potentially reusable product. Conventional carbon systems use steam for the carbon regeneration, which adds water to the desorbate and creates another separation step to recover a reusable product. In addition, the risk of causing fires when using VaPRRS technology is dramatically reduced when compared to the use of GACs. This reduction is due to the lack of impurities and the woven structure of the carbon fiber which has a small diameter of 12 μm that allows for rapid heat and mass transfer. At Hill AFB, the technology was directly compared to a GAC system in which the carbon was not regenerated on site, but rather was shipped off site as waste for subsequent regeneration or disposal.

3. PERFORMANCE OBJECTIVES

Table 1 provides a summary of the performance criteria set forth in the project's Demonstration Plan. A discussion of each criterion follows.

Table 1. Performance Objectives.

Performance Criteria	Expected Performance Metric	Performance Confirmation Method	Actual Performance
Primary Quantitative Criteria			
Control Efficiency	*Greater than 98% VOC control efficiency.*	*Onsite VOC measurements and mass balance analysis.*	98.0% Pass
Reliability	*Greater than 90% uptime.*	*Record keeping.*	100% Pass
Hazardous Materials	*Greater than 98% control efficiency for each component. Mass balance closure within 20%.*	*Quantification of recovered liquid VOC, quantification of VOC emitted, speciation of components and mass balance analysis*	0% Fail
Primary Qualitative Criteria			
Ease of Use	*Minimal operator training and attention during use. Does not exceed current requirements for GAC system.*	*Operating experience*	Inconclusive
Scale-Up Constraints	*Similar performance and functionality compared to pilot unit in operation.*	*Operating experience*	Fail
Secondary Qualitative Criteria			
Factors Affecting Performance	*Performance not to be hindered by unexpected issues such as changes in production schedule or high relative humidity of gas stream.*	*Operating experience and testing data analysis*	Pass
Maintenance	*Minimal operator training and attention during use. Does not exceed current requirements for GAC system.*	*Operator experience and record keeping. Visual inspection of system.*	Inconclusive
Versatility	*Successful application at this site.*	*Overall evaluation of other criteria*	Fail

Control Efficiency. The control efficiency is the percent mass of VOCs controlled by the adsorption phase during painting operations. This quantitative parameter tells how well the new technology actually controls painting VOCs (100% would imply all VOCs are controlled). It is determined by continuously measuring the concentration of VOCs entering the control and the concentration of VOCs exiting the cart during an adsorption event. Integrating these data with respect to time will give the total mass of VOCs entering and exiting the cart during the painting event. Subtracting the total mass of VOCs exiting the cart from total mass of VOCs entering the cart gives the total mass of VOCs controlled. Dividing the total mass of VOCs controlled by the total mass of VOCs entering the cart and multiplying by 100 gives the percent control efficiency. Although the Aerospace NESHAP only mandates 81% control efficiency, the pilot testing of this device showed control efficiencies greater than 99%. Therefore, it is a reasonable expectation that a full-scale system of this technology will meet the arbitrary goal of 98%. Results of the demonstration testing showed that the technology met the 98% goal.

Reliability. The reliability of the technology is determined by recording the amount of downtime the system experiences due to breakdown or improper function and comparing that to the amount of time it is functioning properly. Percent uptime is determined by subtracting the amount of downtime from the total amount of uptime, dividing by the total amount of uptime, and multiplying by 100. The VaPRRS cart was tested at Hill AFB for one C-150 aircraft over a period of four days. During that period, it was operational 100% of the time, so technically it met the objective. It was determined during the test that the technology needs to be modified before it can be put into service. Therefore, a more meaningful evaluation cannot be performed until the modifications take place and the VaPRRS cart is put into service for a considerable period of time.

Hazardous Materials. It is important that the VaPRRS cart is able to recover the VOCs that are controlled during the regeneration or desorption phase of operation. Otherwise the VOCs can reenter the hangar and cause a subsequent hazardous situation. To determine whether the cart is performing this task, a mass balance approach is applied where the mass of VOCs recovered is gravimetrically weighed, and this weight is compared to the amount of VOCs controlled, as determined when calculating the control efficiency. A mass balance error of 20% can be expected from the measurements and calculations. Unfortunately, during the demonstration test no VOC condensate was recovered, indicating that the system failed the hazardous materials objective. It is suspected that either the device's dampers are not leakproof or there was improper sequencing of the valves that resulted in release of the captured VOCs during desorption.

Ease of Use. The parameter called "ease of use" can be initially evaluated based on the system operation and similarity to the existing control booth. A more thorough evaluation could take place after the system has been in service. The adsorption phase operates in a completely similar manner to the existing cart so that no additional training is needed and no complications are present. The desorption phase requires attention to a nitrogen supply, condensate disposal (small amount of liquid with similar disposal as waste solvents), and basic knowledge of the operation. The push button controls are simple and easy to learn. Nitrogen handling is probably the only significant issue. The existing system involves the periodic disposal (hazardous materials) and replenishment of the carbon beds. It may be questionable whether it "exceeds" the current

system, but it is at least comparable. Insufficient observations were made during the limited testing period to properly evaluate this criterion.

Scale-Up Constraints. A considerable issue with this demonstration has been the scaling up of the technology from 80 cubic feet per minute air flow rate to about 1000 cubic feet per minute. Difficulties in filter design and system design integration into a different geometry have contributed too many time delays with this project. The criterion for a successful scale-up is that the technology performs and operated in a similar manner experienced during bench or pilot testing. With the system failing to collect the desorbed VOCs as condensate, this parameter was not met. In all other aspects it functioned and operated comparably to the successful pilot-scale system.

Factors Affecting Performance. Factors affecting performance are unexpected changes in operation that could affect the performance of the VaPRRS cart, such as high humidity or a production schedule change. During the limited test period, the cart operated consistently under all conditions and production tasks.

Maintenance. The maintenance criterion mainly relates to the extra care that an operator will have to apply to the cart during the desorption phase by switching it to desorption mode and maintaining solvent recovery. The test did not yield any recovered solvent, so this factor cannot be fully evaluated and is inconclusive.

Versatility. The final criterion, versatility, refers to whether this application of the VaPRRS technology was successful. Considering the unsuccessful regeneration phase, this criterion was not met.

NOTE: All three of the qualitative secondary parameters (performance, maintenance and versatility) should be more properly evaluated, when and if the VaPRRS cart is modified and put into service.

4. SITE/PLATFORM DESCRIPTION

4.1 TEST PLATFORMS/FACILITIES

When this project was initially funded, a survey of potential industrial applications at Hill AFB was performed to determine the likelihood of success while remaining within budgetary constraints. The top three applications evaluated at Hill AFB were: a groundwater remediation site where TCE is the contaminant, vapor degreasing with N-propyl bromide, and a portable paint booth for applying paint/primer solvents to C-130 aircraft wheel wells. The groundwater remediation site was the original application in this project's proposal. However, it was later revealed that site would be operational for only a limited time, making a long-term demonstration unfeasible. There was also no scale-up potential for that application. The vapor degreaser application would have provided a substantial payback opportunity; however, it would have involved extensive ventilation modifications unrelated to the VaPRRS technology. The portable paint booth became the chosen site for several reasons: it offered a scale-up opportunity to a full-scale system for the limited project budget, it was a long-term application, the ventilation system was already in place, and there is good transfer potential to other painting operations at other installations. The only disadvantage to this application's selection is that the waste stream is multi-component, and resale or reuse of the recovered solvents may be limited.

Hill AFB is host to the Ogden Air Logistics Center (OO-ALC) which provides depot-level maintenance for F-22, F-16, A-10, and C-130 aircraft and the Minuteman II inter-continental ballistic missile (ICBM). OO-ALC also is also the Air Force Technical Repair Center (TRC) for landing gear. OO-ALC is one of only three major ALCs in the Air Force. Hill AFB employs approximately 23,000 military, civilian, and contractor personnel; it is located in Layton, Utah, between Ogden and Salt Lake City.

4.2 PRESENT OPERATIONS

The particular application for this demonstration is the paint booth for the C-130 transport vehicle. This vehicle is maintained in a large hangar where multiple activities may be occurring simultaneously. The portable paint booth was designed to enclose the painting process so that evacuation of the hangar is not necessary during painting. The booth used for the rear wheel wells is shown in Figure 4.

The existing portable treatment cart contains a bed of GAC to adsorb the VOCs from the paint booth exhaust. The ventilated air first passes through fabric filters (to collect particulate material), then goes through the GAC bed, and finally goes back into the booth. When the GAC bed becomes saturated, it is sent offsite for disposal or regeneration, and a new GAC bed is installed in the booth exhaust. The costs for disposing and replacing the GAC bed are the primary operating costs of the existing system. The housing cart for the treatment portion of the booth is shown in Figure 5 and Figure 6. This demonstration replaced the GAC bed (Figure 7) with a VaPRRS unit that was positioned inside a cart similar to that shown in Figure 5 and Figure 6.

Figure 4. Portable paint booth for the rear wheel wells of the C-130 aircraft.

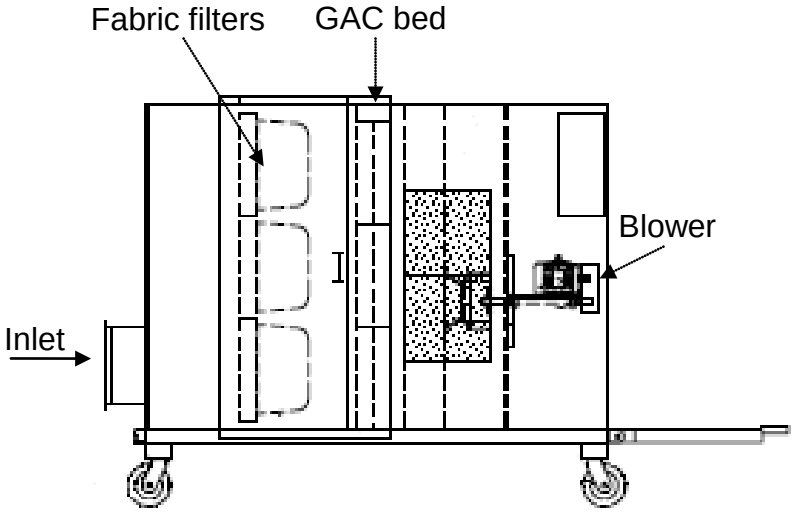

Figure 5. As-built drawing for the existing portable paint booth treatment cart.

Figure 6. Existing portable paint booth treatment cart with door open to access fabric filters and GAC bed.

Figure 7. Non-regenerable GAC filter from existing portable paint booth treatment cart.

A pre-demonstration site visit was conducted in June 2006. Measurements were performed of the VOC concentrations and exhaust flow rate during operations of the paint booth. The operation was also observed to understand how it is used and any limitations that must be considered when installing the new technology.

Findings from the site visit include:

1. A rough measurement of the volumetric flow rate was 840 cubic feet per minute.
2. Paint process involves sealer, primer, and topcoat.
3. Inlet concentration ranges between 3 to 400 ppmv during spray application, with an average concentration of about 100 ppmv.
4. Each C-130 requires a partial painting of the nose well and full painting of the two rear wheel wells.
5. The duration of application of each component in each well ranges from 20–50 min.
6. The painting of one C-130 aircraft takes three days—one day for the sealer and primer and one day for each of the two layers of topcoat.

4.3 SITE-RELATED PERMITS AND REGULATIONS

A notice to the Utah Department of Environmental Quality was required for the VaPRRS cart to be used at Hill AFB. This requirement for notice of use is identical to that for the existing cart. Approximately one month lead time was necessary to allow for this action before the demonstration testing could occur.

5. TEST DESIGN

5.1 SYSTEM DESIGN

This section provides the detailed description of the system design. This description includes scale-up, filter design, overall system design, and troubleshooting. This project saw many schedule delays, often excessive, due to contracting issues, a competing demonstration project, the scaled-up filter design, and system design changes. As a result, the progression through several filter designs and two troubleshooting tests are presented.

5.1.1 Filter Design

The original experimental prototypes of this system used annular filters of activated carbon fiber cloth. That design showed difficulty in handling high volumetric flow rates during the pilot studies. Therefore, Hunter Manufacturing Company (Hunter) was originally contracted to design and build new activated carbon fiber cloth filters (as well as construct the entire system) that would improve the pressure drop and eliminate the problems related to filter collapse with higher flow rates that was of concern in the pilot scale system.

5.1.1.1 Pleated Filter Design

The result of the Hunter effort was a more conventional flat pleated design as shown in Figure 8. The supporting features and enclosure were constructed of non-conductive Torlon. The actual prototype that was constructed by Hunter is shown in Figure 9. As evident by the saggy activated carbon cloth in Figure 9, it was difficult to construct the filter with the fabric taut. In addition, it was costly to build, primarily due to the Torlon. Pressure gradient simulations showed that the filter design would provide minimal and even pressure drop at higher flow rates, as seen in Figure 10. Despite this, the experimental results were not satisfactory, yielding a poorly-shaped breakthrough curve.

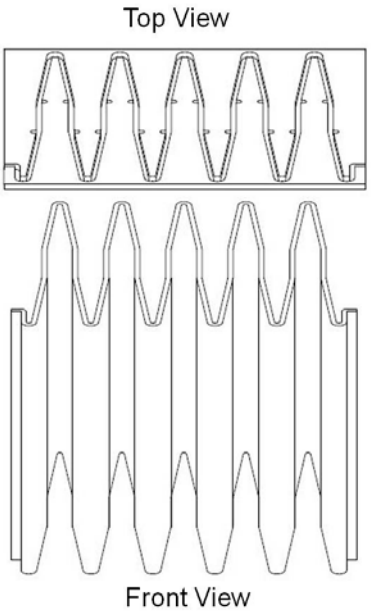

Figure 8. Pleated filter design drawing, top view and front view (angled downward).

Figure 9. Pleated filter prototype.

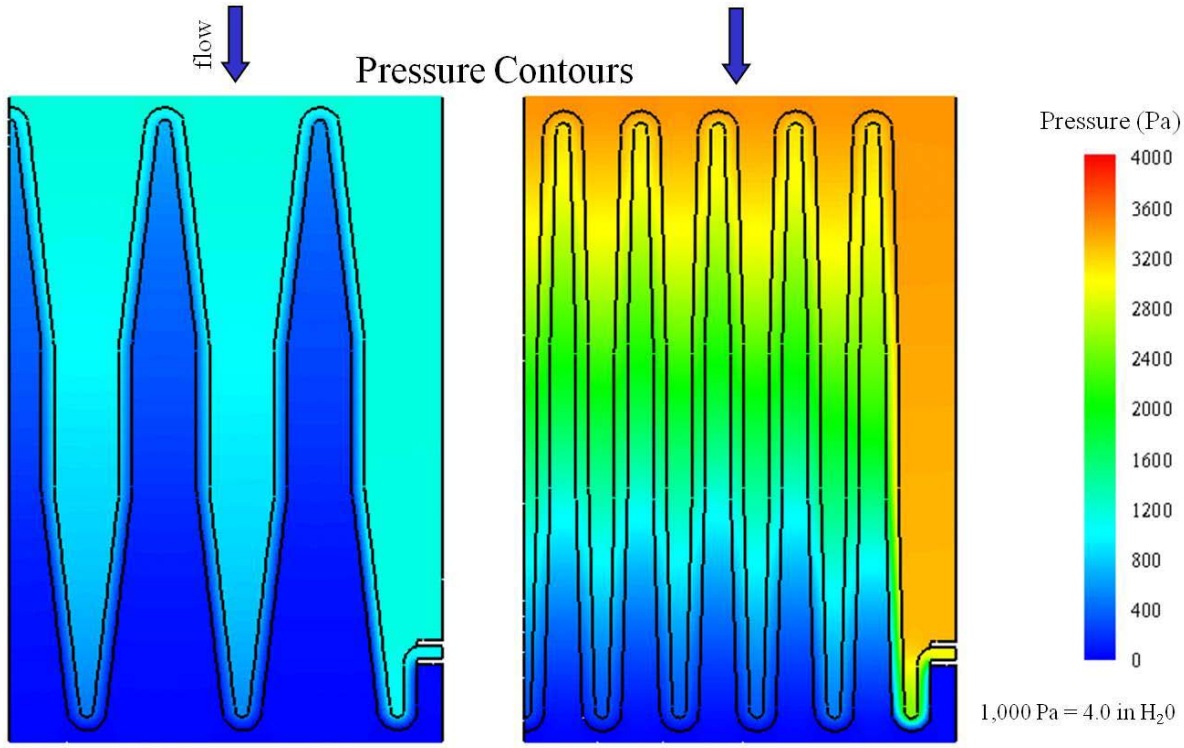

Figure 10. Pressure contour simulation through pleated filters.

5.1.1.2 Oblong Filter Design

Due to the poor results of the pleated filter design effort, Dr. Sullivan (AFRL) developed a new design that was similar to a bag-type filter, but with an inexpensive skeletal structure inside as shown by the concept drawing in Figure 11. A key ingredient of this design is the use of mica board as the material for constructing the skeletal structure and the bulkhead to hold the filters in position. Mica board was chosen because of its insulating properties, its ability to withstand higher temperatures, and its low cost. A bench-scale apparatus with two small filters was set up for testing this design (Figure 12). Experimental results were promising. Figure 13 shows the breakthrough curves for the oblong filters in comparison with the pleated filter in a normalized manner. The oblong filters provided a better-shaped curve with minimal initial leakage and a steeper gradient.

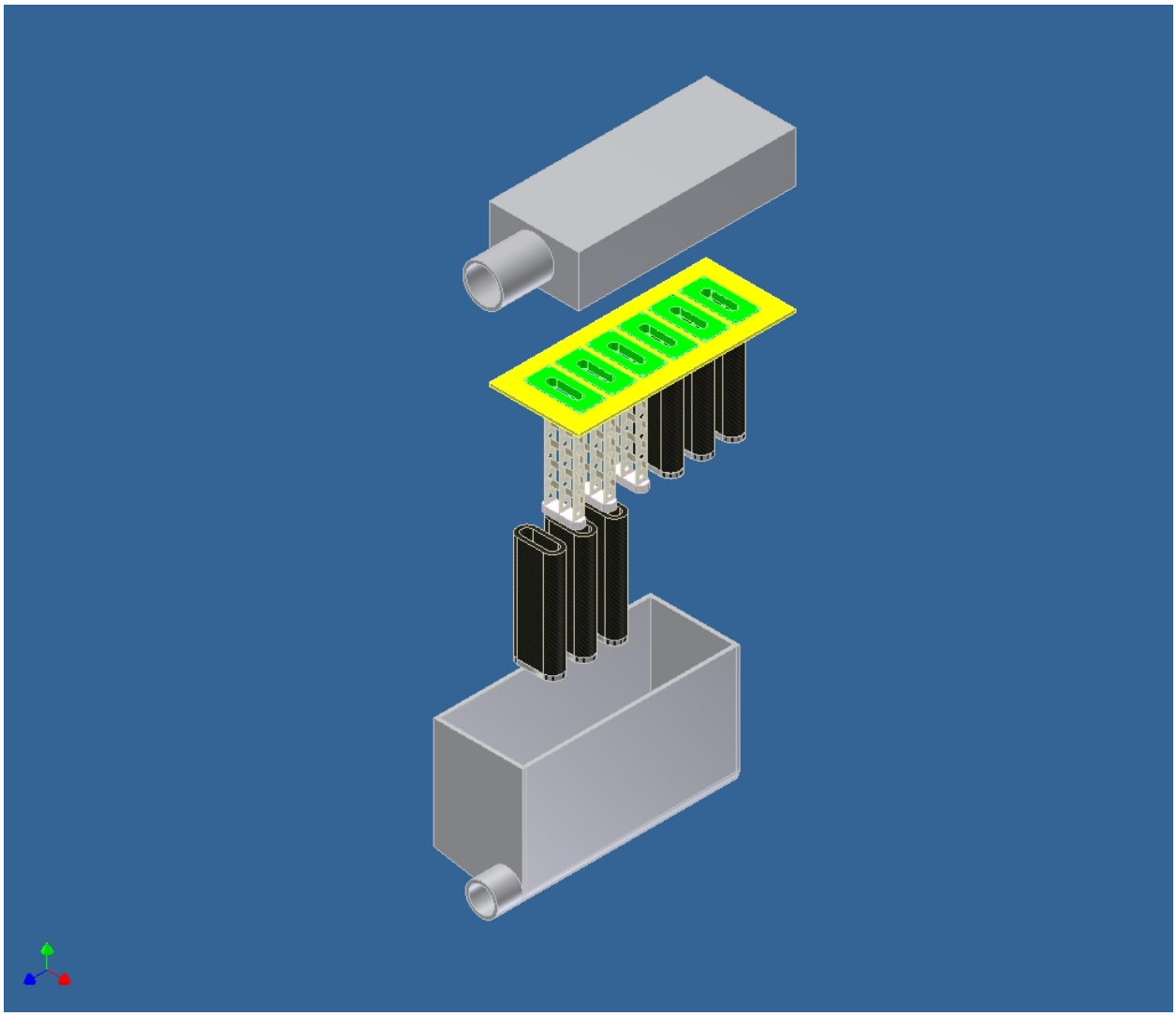

Figure 11.Oblong filter design concept.

Figure 12. Bench-scale apparatus used to conduct breakthrough tests with oblong filters.

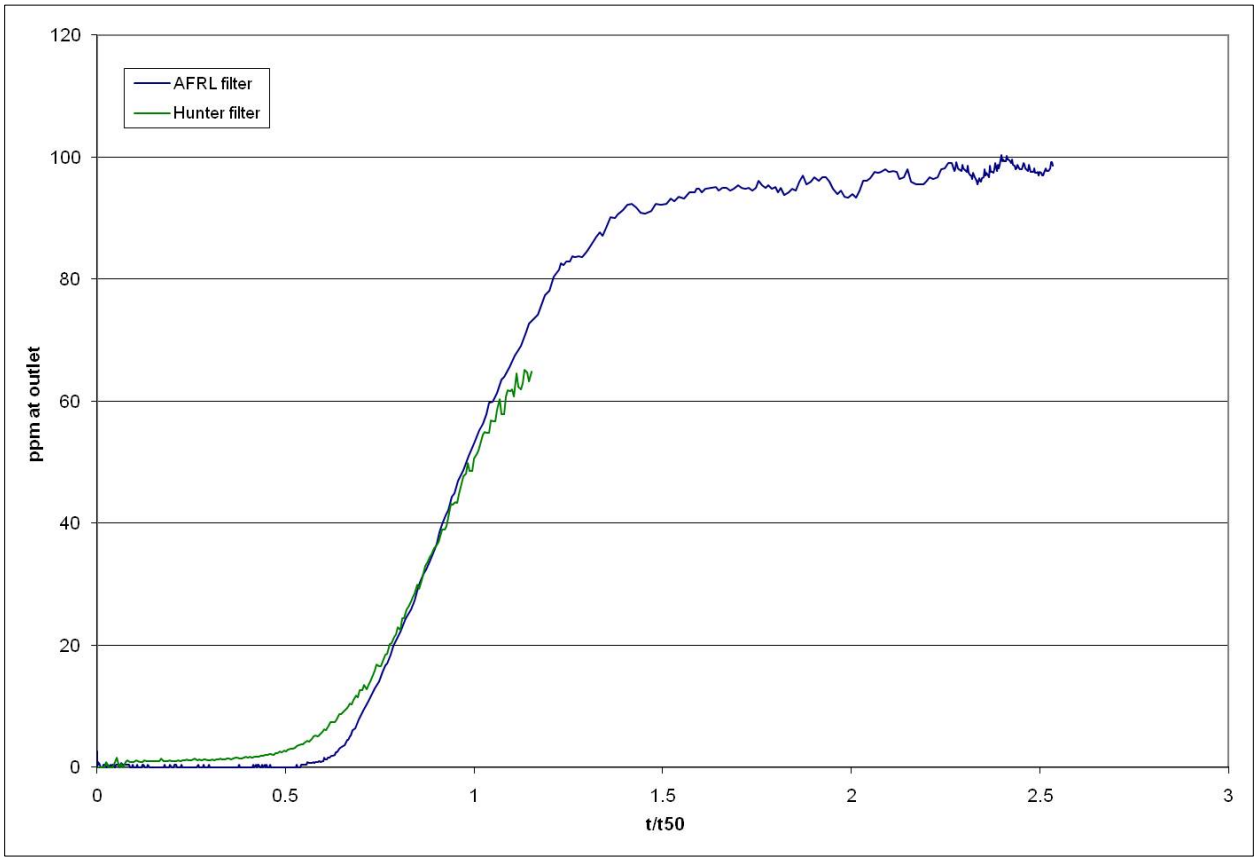

Figure 13. Normalized breakthrough curves comparing oblong filter and pleated filter results (t/t50 = duration of the breakthrough test divided by the time to reach 50% breakthrough).

The oblong filter design was applied to the production of full-scale filters for the Steady-State Tracking (SST) desorption system, which is a related spinoff technology that was the subject of another demonstration project managed by the National Defense Center for Environmental Excellence (NDCEE). AFRL built the filters for the SST system with the exception of the support pieces, which were fabricated by an offsite contractor. The unfortunate result of this sister demonstration was the delay and usage of this project's in-kind resources. The benefit was the realization that with the filter collapse problem of the pilot-scale filters solved by the skeletal structure design, a cylindrical design that would be easier to build could be utilized with better packing in a compact system such as the treatment cart application. Figure 14, Figure 15, and Figure 16 show the structure, filters, and bulkhead built for the SST system.

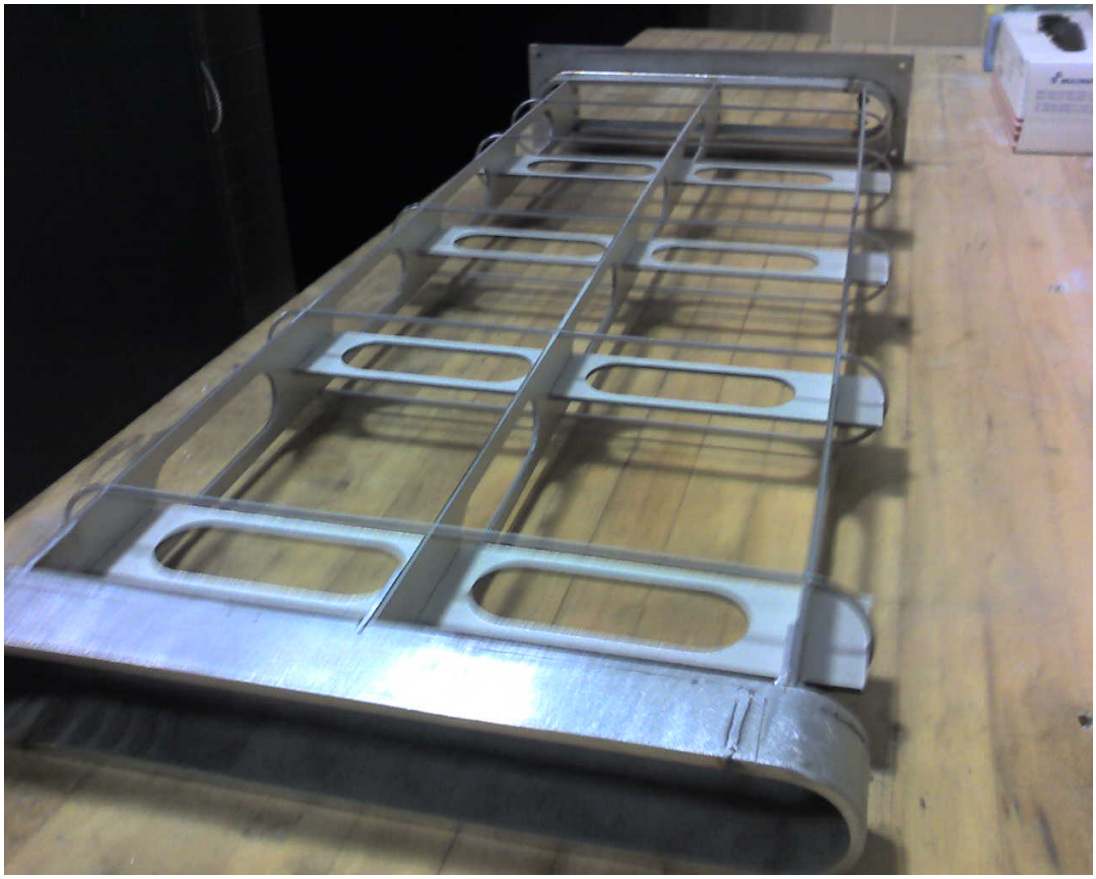

Figure 14. Skeletal structure for one oblong filter for the SST system.

Figure 15. Array of oblong filters built for SST system.

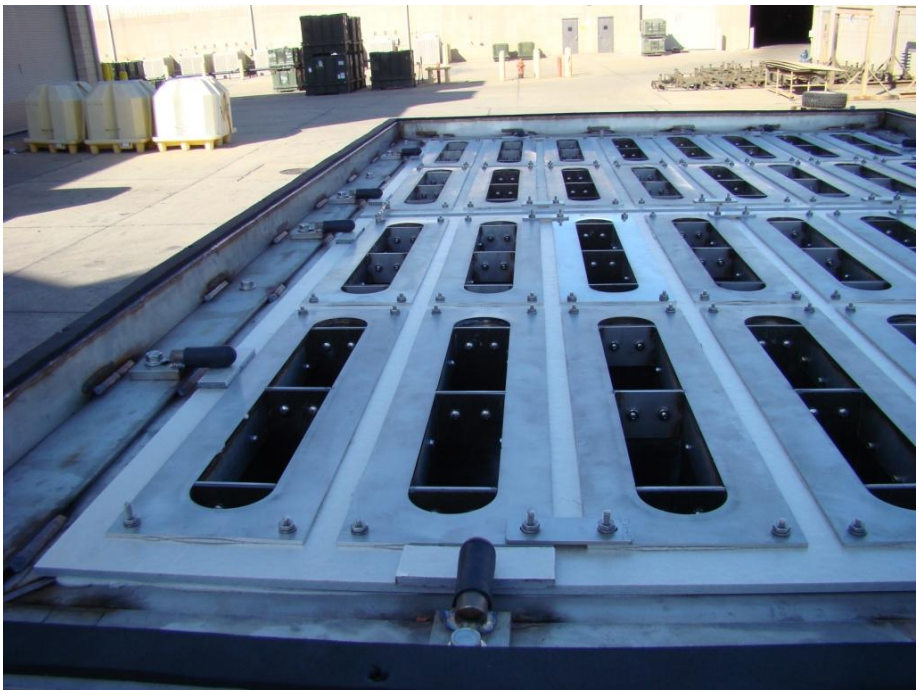

Figure 16. Top view of bulkhead pieces for oblong filters placed in SST system.

5.1.1.3 Cylindrical Filter Design

Dr. Sullivan modified the oblong filter design into a more easily built cylindrical concept. A similar skeletal structure was used, but used just two support pieces and support rings. The two support pieces of the structure are machine-cut mica boards that are interlocked perpendicular to each other to form a firm inside support. Mica board was also used to build the bulkheads that support the filter arrays. The other pieces of the array are stainless steel, such as the end caps of the filters, the support rings, and the connectors so that electrical current can flow from one filter to the next. This more simple design allowed the complete fabrication to be done by AFRL in-house. Figure 17 provides a drawing of selected portions of the bulkhead and filter cartridge array for the cylindrical design.

Figure 17. Concept drawing of select portions of the bulkhead and filter array.

During the building of the filters, the ACFC was wrapped by hand to a predetermined number of layers around the skeletal structures. It was then bound to that structure using circular stainless steel clamps. The ACFC was made by American Kynol, Inc. (Pleasantville, NY; www.kynol.com) and is referred to as ACC-5092-15. It is a novoloid-based activated carbon fabric with an approximate density of 290 kg/m^3 and a thickness of 0.6 mm. The total mass of cloth used on the primary filters is 21 kg with 20 layers of cloth on 24 filters (0.875 kg per filter), while 4.65 kg are used on the 28 smaller secondary filters also with 20 layers (0.166 kg per filter). The filters and bulkheads were shipped to Global Finishing Systems, Inc. (Global Finishing) for final assembly into the treatment cart. Some modifications were completed at Global Finishing, such as the fiber cloth trimming and steel connector fabrication. Figure 18 and

Figure 19 show a primary filter array and the complete set of secondary filters (two arrays) after final assembly at Global Finishing.

Figure 18. Bottoms of twelve primary bulkhead filters with connectors.

Figure 19. Secondary filter arrays.

The electrical resistances across each filter were tested at Global Finishing. Initially, the filters showed high and inconsistent resistances, which were easily corrected by tightening the clamps at both ends of each filter. Consistent resistance values are important for determining the power requirements for desorption and to provide uniform heating.

5.1.2 VaPRRS Loaded Treatment Cart Design

Design drawings for the treatment cart used in this demonstration are shown in Figure 20–Figure 22. The cart is fabricated from 12-gage galvanized and stainless steel. These diagrams show most of the physical components of the system, except the control system, electrical components, and plumbing. The control system is located on the access door at the rear of the cart. This cart has a higher back end than the original treatment cart, to accommodate the VaPRRS components. This cart was designed and manufactured by Global Finishing.

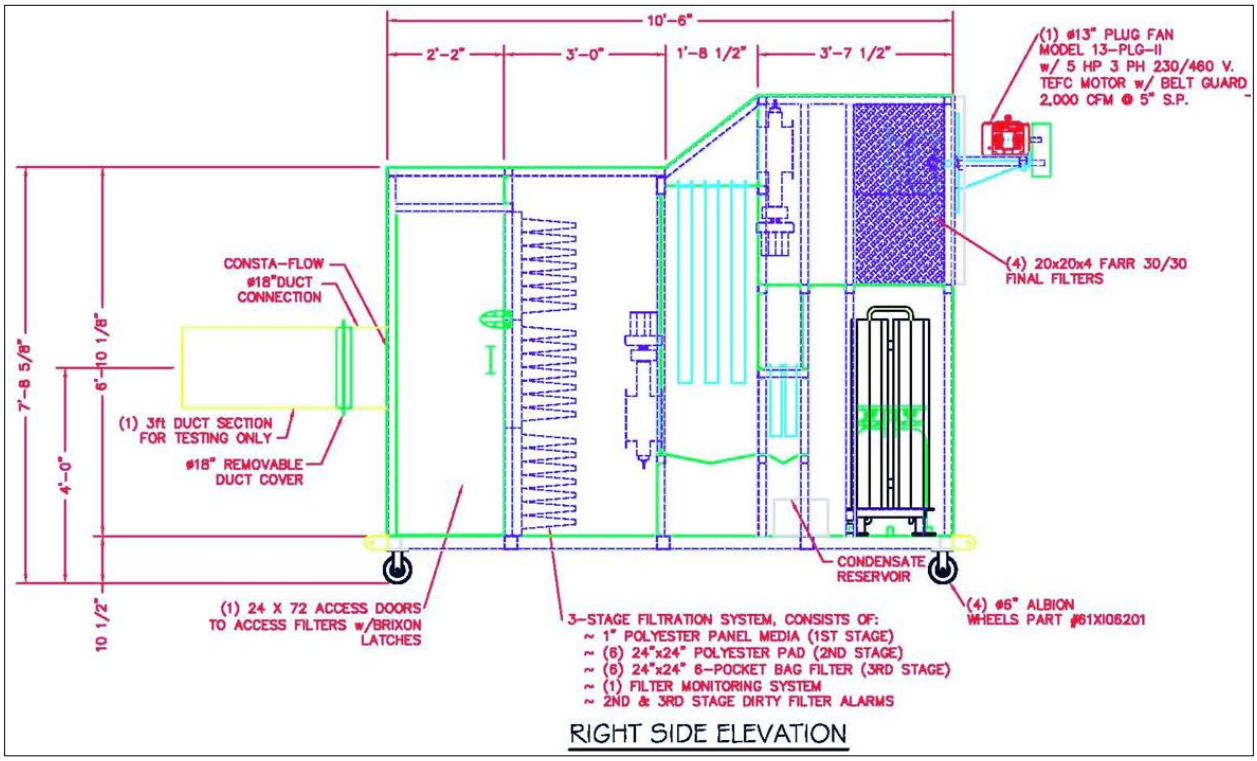

Figure 20. Design drawing of treatment cart, right-side elevation.

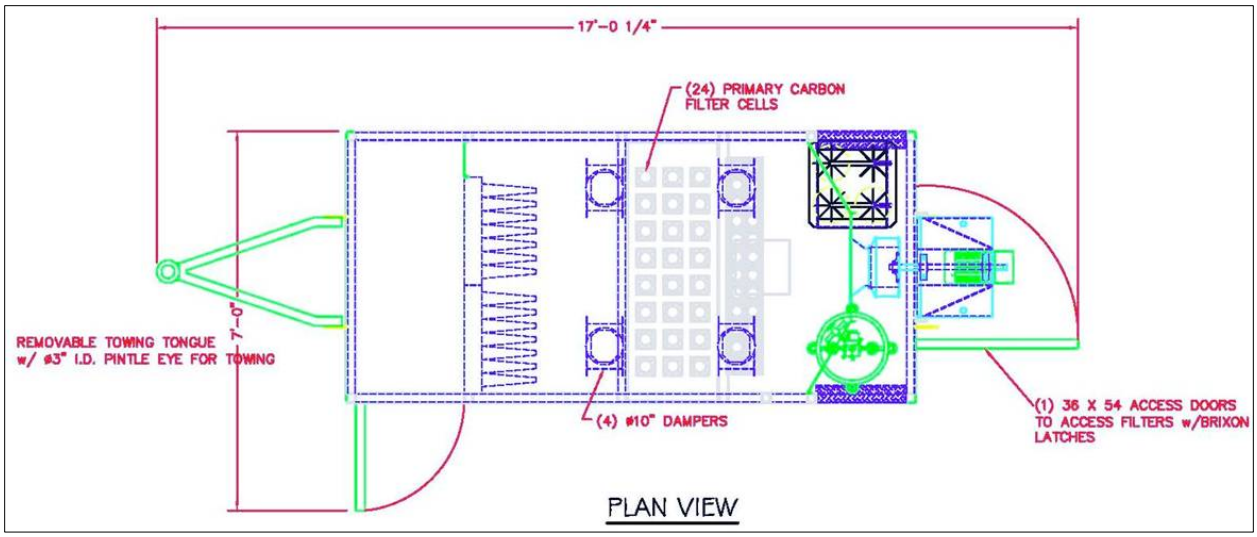

Figure 21. Design drawing of treatment cart, top view.

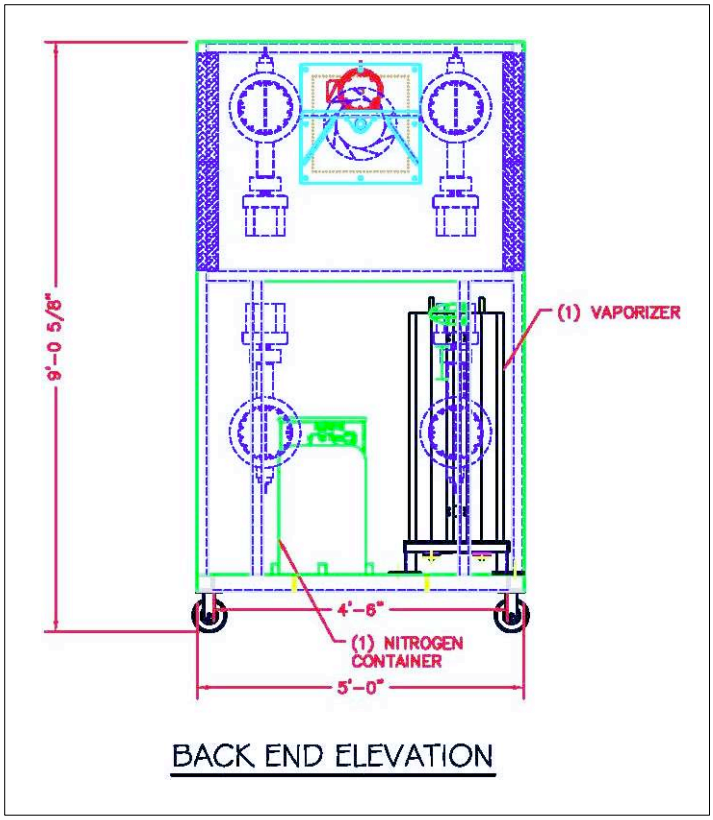

Figure 22. Design drawing of treatment cart, back-end elevation.

The basic flow path during the adsorption phase is as follows: contaminated air is drawn in through the horizontal duct located by the blower mounted on the back of the cart, the air passes through the particulate filters, through the entry dampers into the primary filter chamber, out the

top of the filters and through the exit dampers, through the blower and out the final filters on the upper back sides of the cart. The organic vapors are adsorbed as they pass through the activated carbon fiber filters. During desorption, both sets of dampers are closed and nitrogen flows into the primary filter chamber from top to bottom (opposite flow from adsorption phase) to pass through the secondary filter chamber before exiting the system. Electrical current is passed through the primary filters to facilitate desorption, the expelled vapors condense on the walls of the vessel and flow out the drain to a condensate reservoir, and uncondensed vapors are adsorbed by the secondary filters as the nitrogen passes through to exhaust. Regeneration of the secondary filters occurs in a similar fashion except the uncondensed vapors exiting the secondary filter chamber are adsorbed by the primary filters as the nitrogen passes through and exits through the open exit damper.

Figure 23 and Figure 24 show the exterior shell of the treatment cart prior to the complete installation of all the interior components (note that the Dewar in Figure 23 is not located in its final position). Figure 25 shows the interior rear of the cart with the nitrogen delivery system Cryo-Cyl Dewar (center), evaporator (right), and condensate reservoir (bottom left box). The rear walls of the primary filter chamber (top) and secondary filter chambers (bottom) are visible at the back of Figure 25. Also visible are the data acquisition box (upper left side) and electrical conduits extending from the control panel (in access door) to the cart. In this figure, the nitrogen flow meter (small green circle at bottom center, in pipe to right of Dewar) is not positioned correctly and has since been relocated to the pipe between the evaporator and the filter chambers. One secondary filter array is shown placed inside the secondary filter chamber in Figure 26. Figure 27 shows the control valves in the primary filter chamber.

Figure 23. Exterior shell of treatment cart, showing rear and left sides.

Figure 24. Exterior of treatment cart, showing front and right sides with rear access door open.

Figure 25. Interior rear of treatment cart.

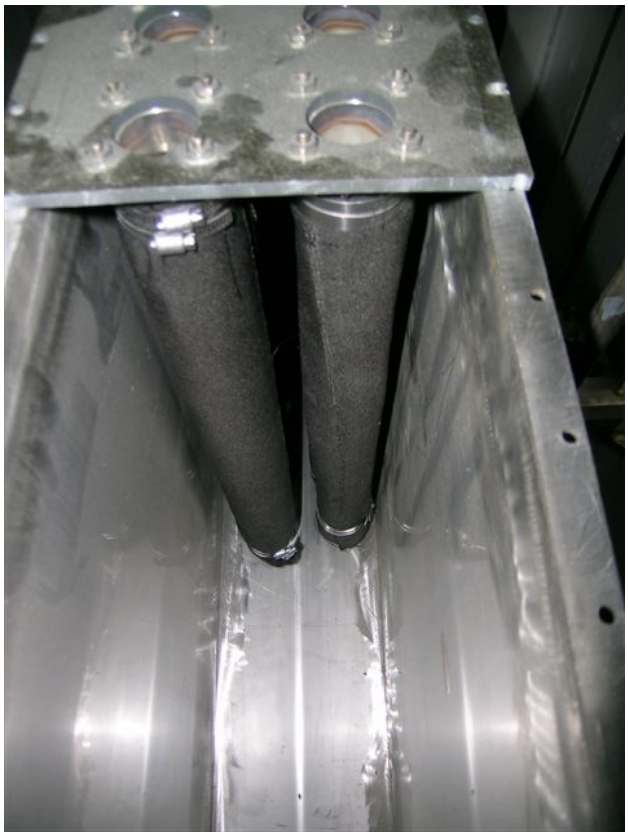

Figure 26. One ACFC filter array in secondary chamber.

Figure 27. Control valves into primary chamber.

The bulk of the electrical components are located inside the access door (Figure 28). Figure 29 shows the oxygen sensor and display that are located on the left exterior side of the cart. (Note that the oxygen sensor is not shown in Figure 23, because that picture was taken before the sensor was installed.) The main controls and readout are located on the outside panel of the rear access door (Figure 30). The data acquisition access box that is shown in Figure 31 is located on in interior wall of the cart's rear compartment.

Figure 28. Electrical components inside access door with front panel open.

Figure 29. Oxygen sensor and display.

Figure 30. Main controls and readout on front of access door.

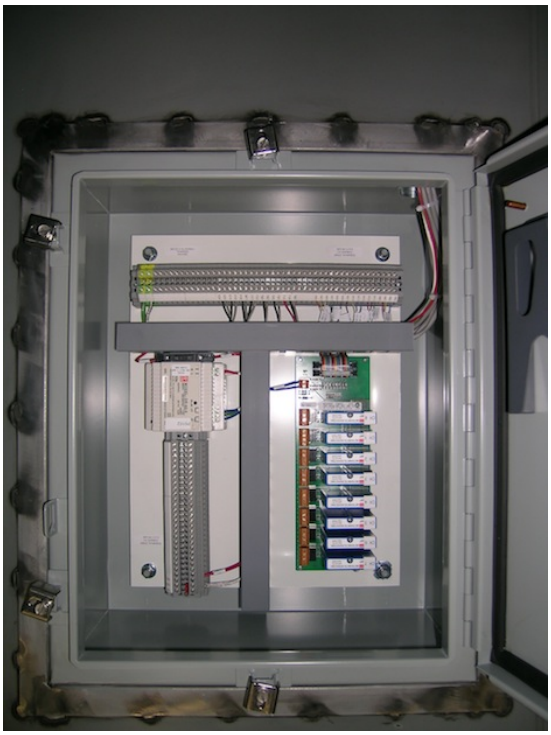

Figure 31. Open data acquisition box.

The Installation, Operation, and Maintenance Manual developed by Global Finishing for the VaPRRS treatment cart is presented in Appendix B. It contains detailed electrical diagrams, a parts list, a logic diagram, and descriptions of the sequences of operation.

5.2 TROUBLESHOOTING

Water adsorption and regeneration tests were performed at Global Finishing's facilities to evaluate the performance of the ACFC cart during adsorption and regeneration cycles and to determine and fix any potential problems. There were two sets of troubleshooting tests that took place during June 16–17, 2011 and September 1–October 7, 2011. The symbols used in the plots describing the results below are defined as follows:

Electrical Current:	I1 - leg 1
	I2 - leg 2
	I3 - leg 3
Electrical Power:	P1 - leg 1
	P2 - leg 2
	P3 - leg 3
Relative Humidity:	RHi - inlet gas stream
	RHo - outlet gas stream
Thermocouples:	T11 - #1 primary vessel
	T21 - #2 primary vessel
	Tw1 - wall of primary vessel
	T_GFS - Global Finishing thermocouple

	T12 - #1 secondary vessel
	T22 - #2 secondary vessel
	Tw2 - wall of secondary vessel
Voltage:	V1 - leg 1
	V2 - leg 2
	V3 - leg 3

5.2.1 First Set of Troubleshooting Tests

The results shown below were obtained by UI researchers during the first troubleshooting series conducted June 16–17, 2011.

- Day 1 (June 16, 2011)

The first water adsorption cycle was performed by passing ambient air with relative humidity (RH) values between 64%–73% through the ACFC for approximately 160 min. The air flow rate was 730 cu ft per minute (cfm), as measured at the inlet duct of the cart with an anemometer. Outlet RH varied between 51%–64% (Figure 32, top). The plot of cumulative adsorbed water as a function of time indicates a maximum of 0.52 kg of adsorbed water at 89 min, which then decreased to 0.34 kg of adsorbed water (Figure 32, bottom). Desorption of water is unlikely to occur at these conditions, so this decrease in adsorbed water may be due to an error in RH readings due to water condensation on the sensors.

The primary vessel was electrothermally heated to a set-point temperature of 150 ^{o}C to remove adsorbed water from the ACFC (Figure 33). First, N_2 was passed through the cart to purge the ACFC vessel of O_2. Then, O_2 was reduced to less than 5% in less than 4 min. Electrothermal heating was then performed (Figure 33), and the following problems occurred: (a) heating was slow and only reached 105° C before a fault was tripped and ended the heating cycle, and (b) measurements of the O_2 concentration in the vessel increased rapidly at approximately 11 min due to condensation in the sampling line that prevented N_2 gas from the vessel from reaching the O_2 sensor. A liquid collection vessel was added to the O_2 sampling line to prevent future condensation from affecting the O_2 sensor readings. This vessel needs to be periodically drained in the field.

The primary vessel was regenerated a second time with the above-mentioned changes (Figure 34). ACFC now heated to 150 ^{o}C within 5 min, and O_2 measurements were maintained at less than 5%. However, no additional adsorption occurred before this run, so the ACFC had limited initially adsorbed water during this test. Thus, it was uncertain whether the improved performance was due to the system modifications or the lack of initially adsorbed water.

The secondary vessel was regenerated next by heating the ACFC to 180 ^{o}C within 1.7 min (Figure 35). The O_2 sensor functioned properly during this regeneration.

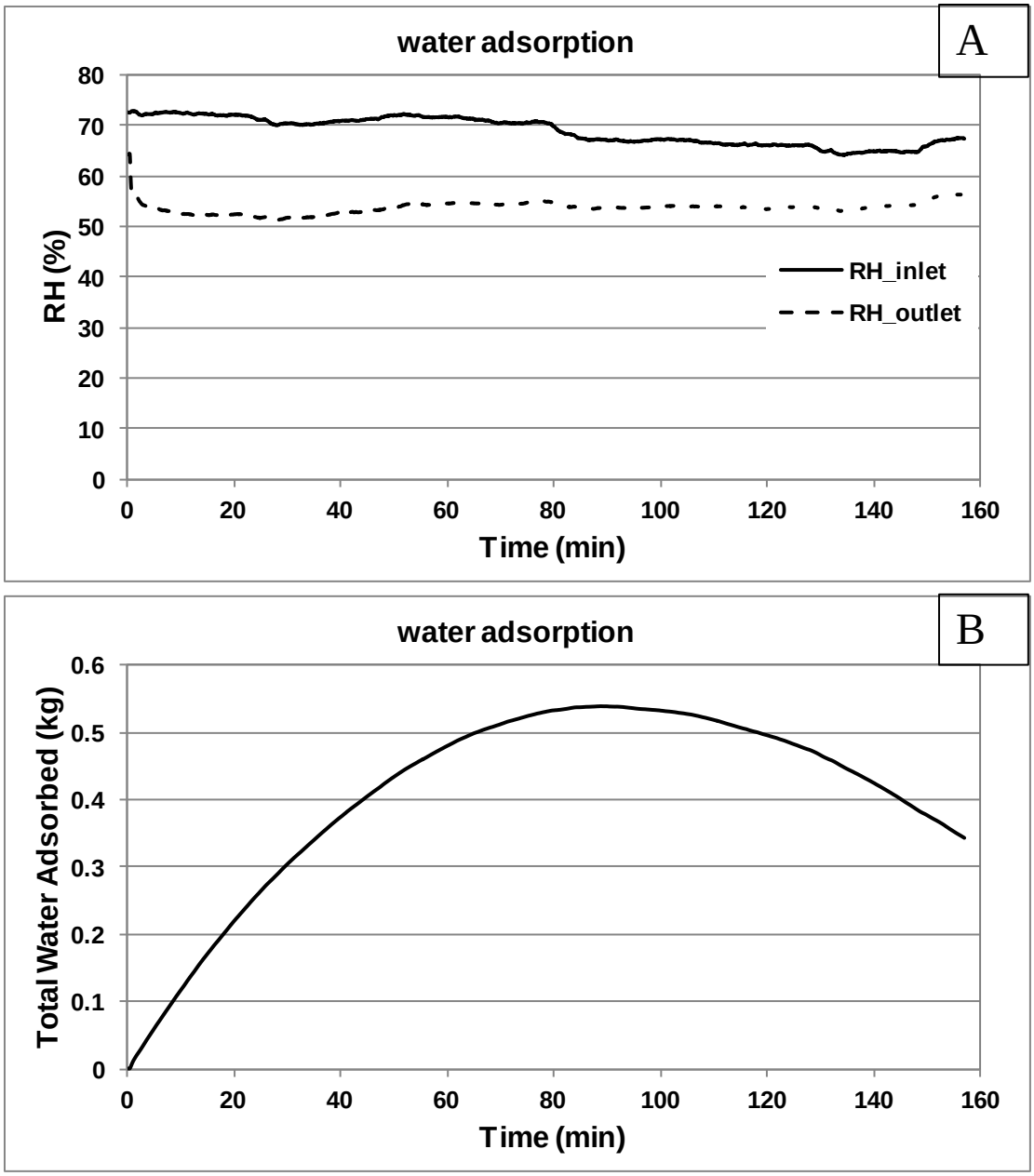

Figure 32. Water adsorption at ambient temperature with an air flow rate of 730 cfm.

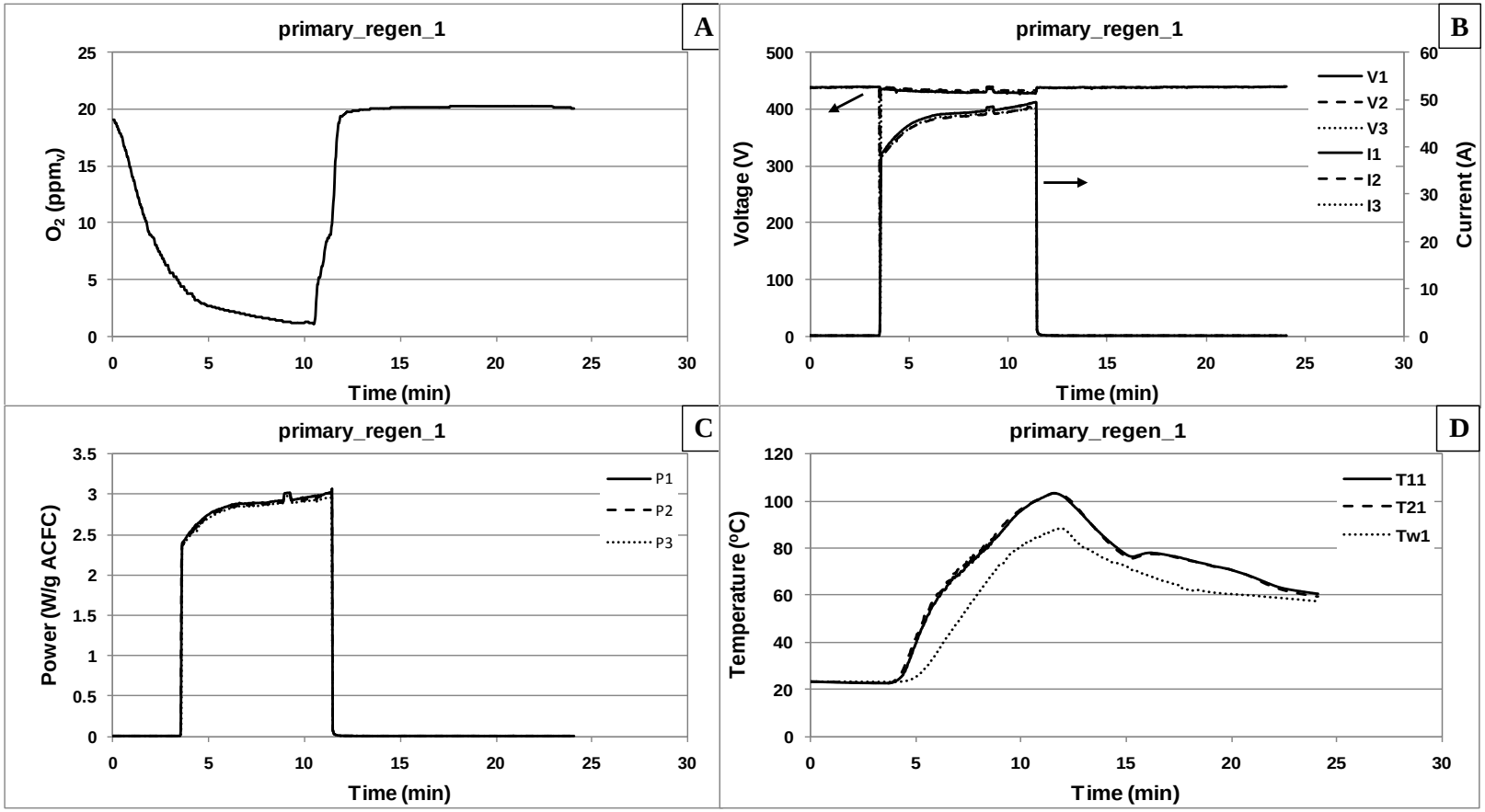

Figure 33. First attempt to regenerate the primary vessel (O_2 sensor failure at ~11 min).

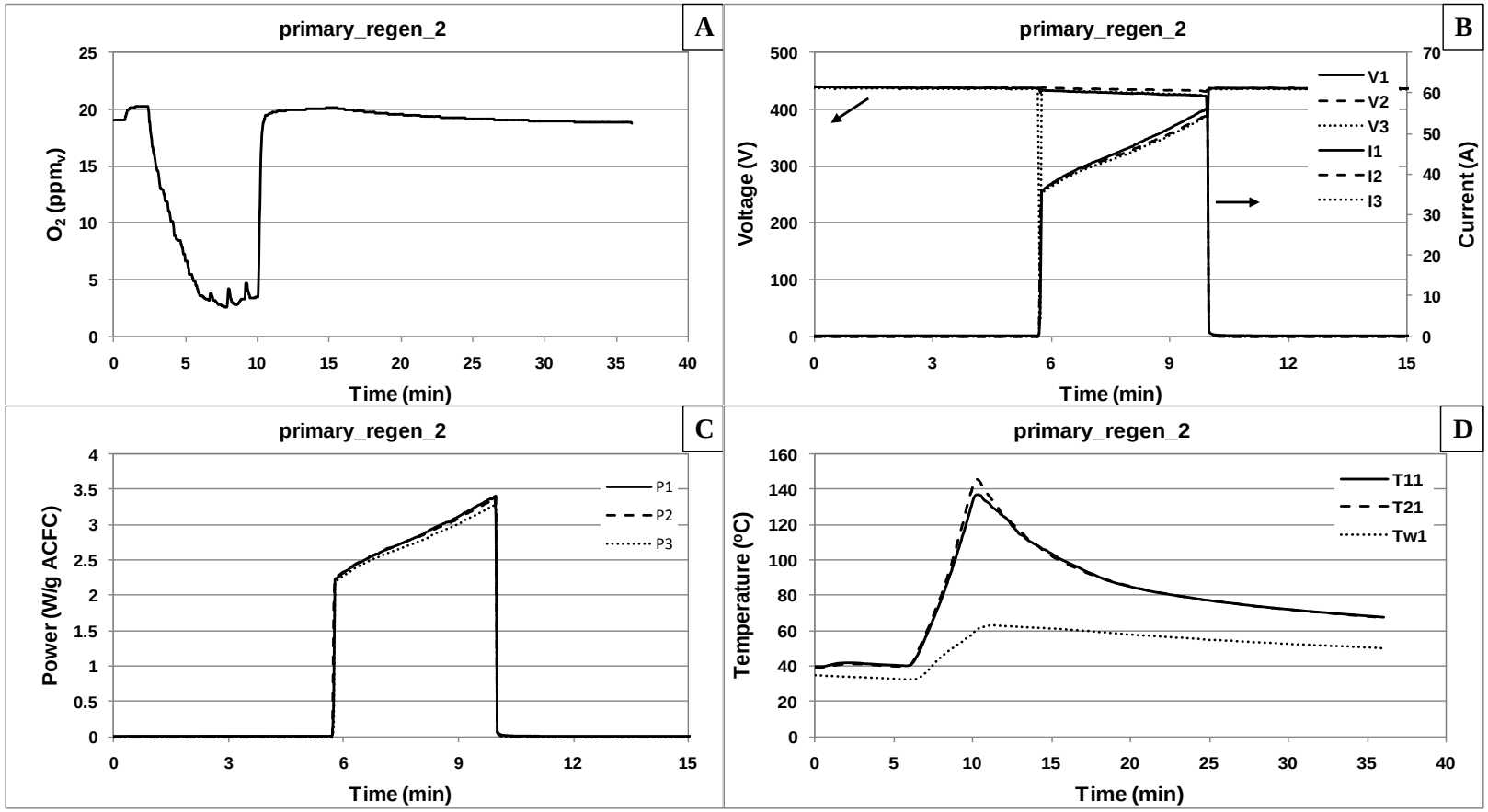

Figure 34. Second regeneration of the primary vessel (successful test but without previous water adsorption).

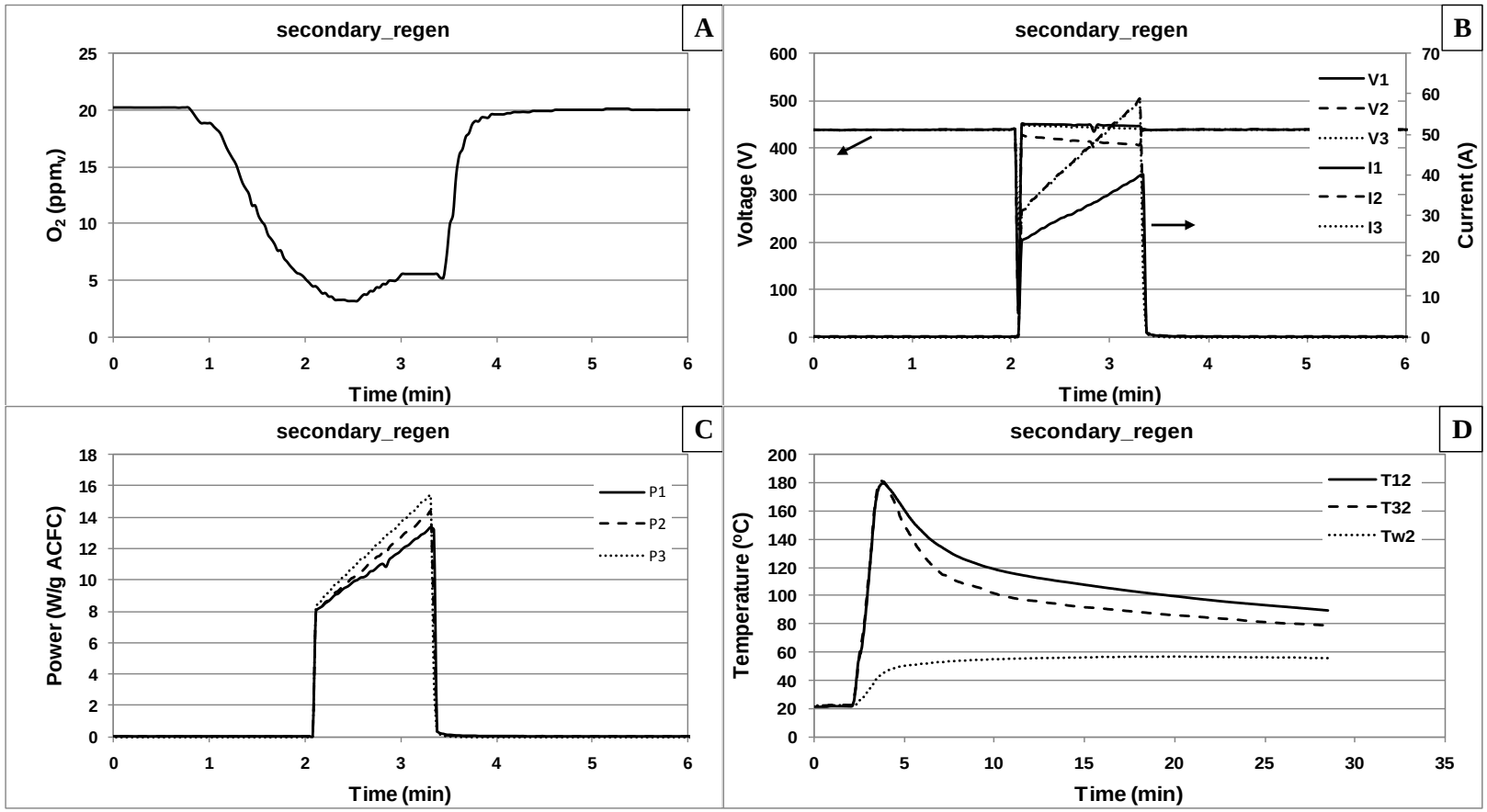

Figure 35. Regeneration of the secondary vessel.

- Day 2 (June 17, 2011)

A water adsorption cycle was performed by passing ambient air with RH ranging from 69%–72% through the ACFC for approximately 95 min. The air flow rate was 600 cfm for the first 68 minutes and then was adjusted to 1,088 cfm for the remaining 27 minutes. The outlet RH varied from 50%–57% (Figure 36-A). The cumulative adsorbed water is provided in Figure 36-B and indicates that a total of 0.53 kg of water was adsorbed.

After water adsorption, a regeneration of the primary vessel was attempted (Figure 37), but the electrical current exceeded 50 A and damaged the power cord that was only rated for 30 A.
A new power cord rated at 100 A was installed, and the primary vessel was heated a second time (Figure 38). Heating ended when the ACFC reached 150 ^{o}C in approximately 6 min. There was 1.45 L of water recovered in the liquid recovery vessel. No additional water adsorption occurred between the first and second primary vessel regenerations. The secondary vessel was then regenerated to 160 ^{o}C within 1.6 min (Figure 39).

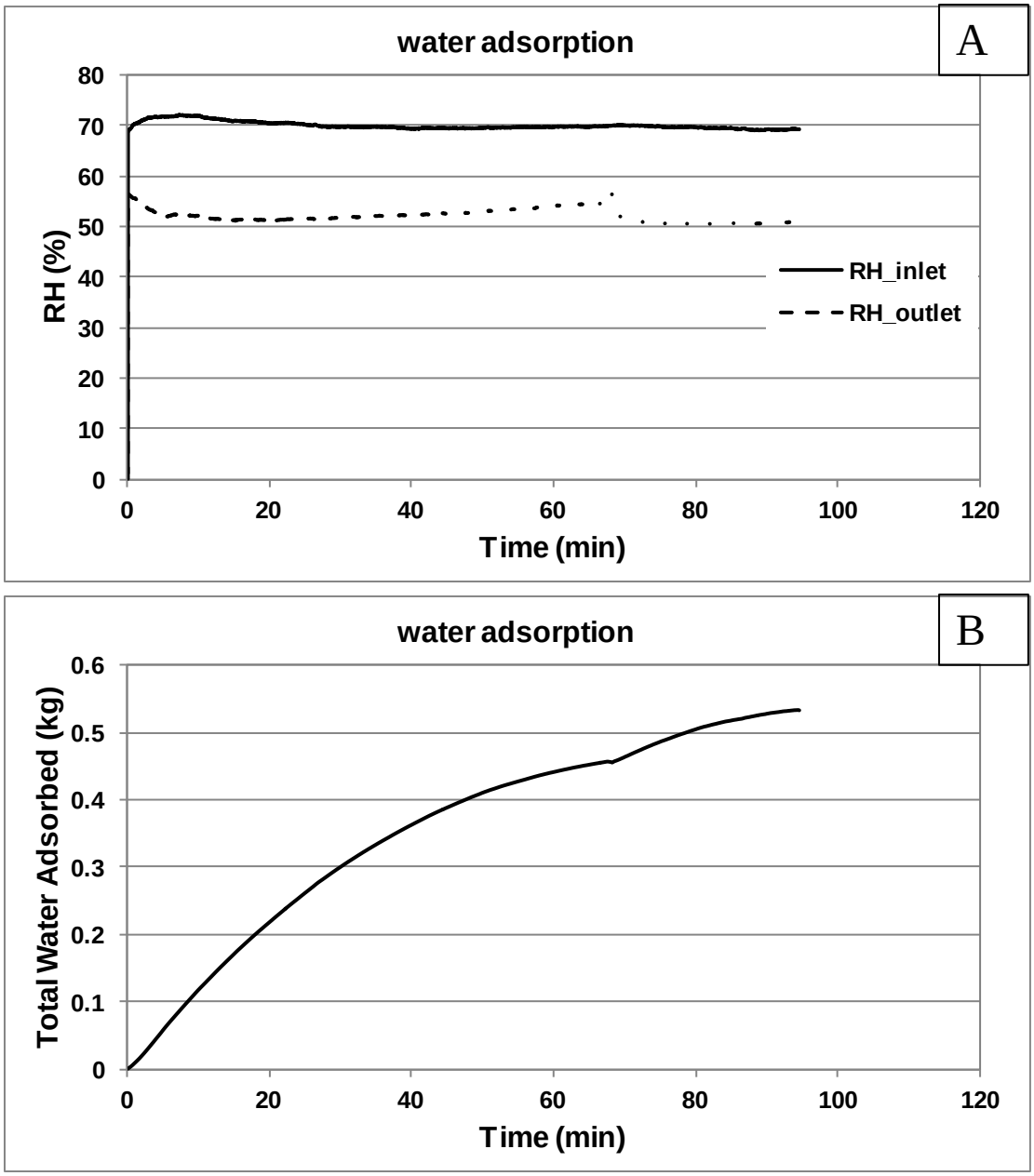

Figure 36. Water adsorption at ambient temperature with air flow rates of 600 cfm (first 68 min) and 1,088 cfm (last 27 min).

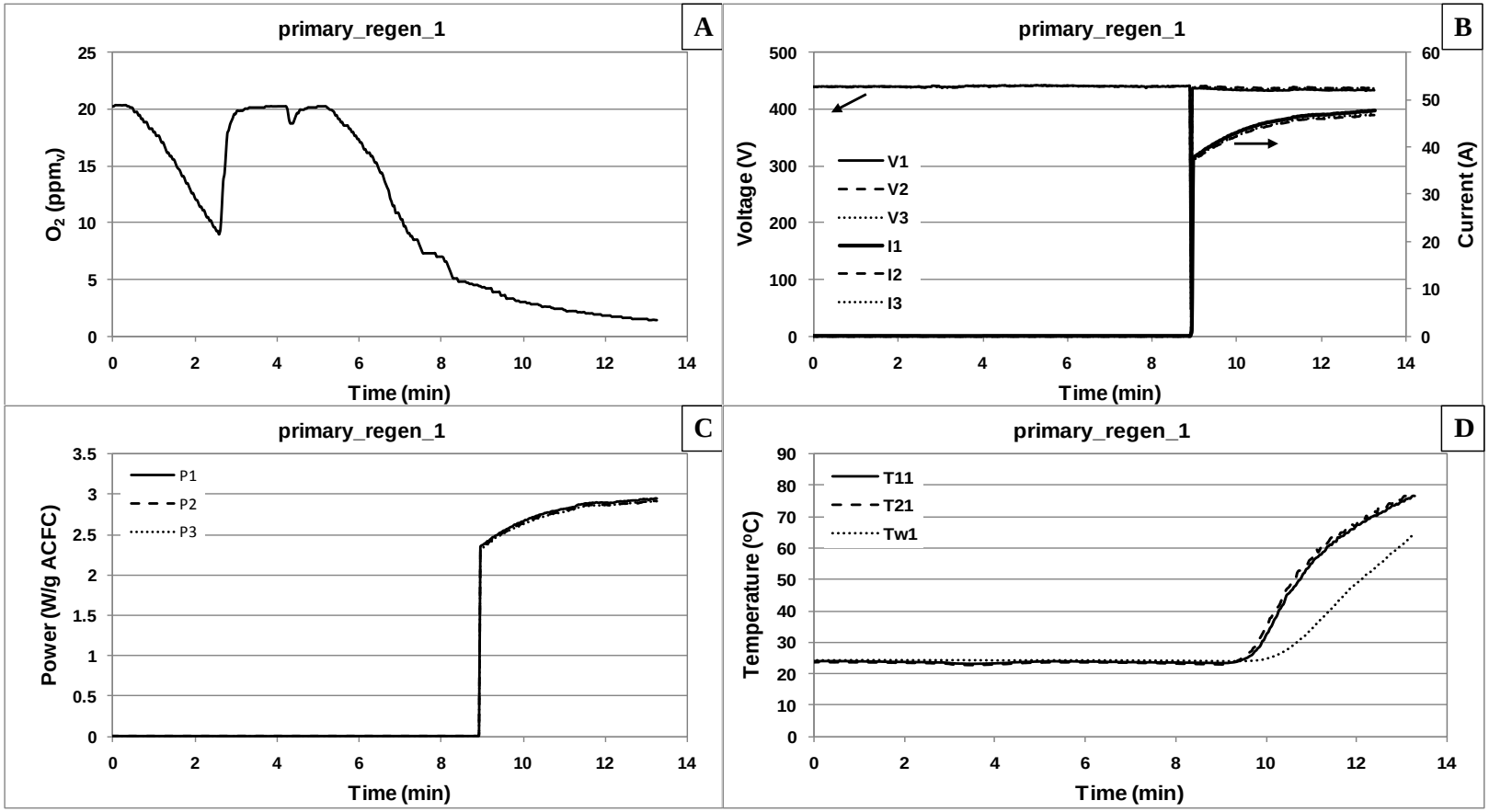

Figure 37. First regeneration of the primary vessel (power cord failure).

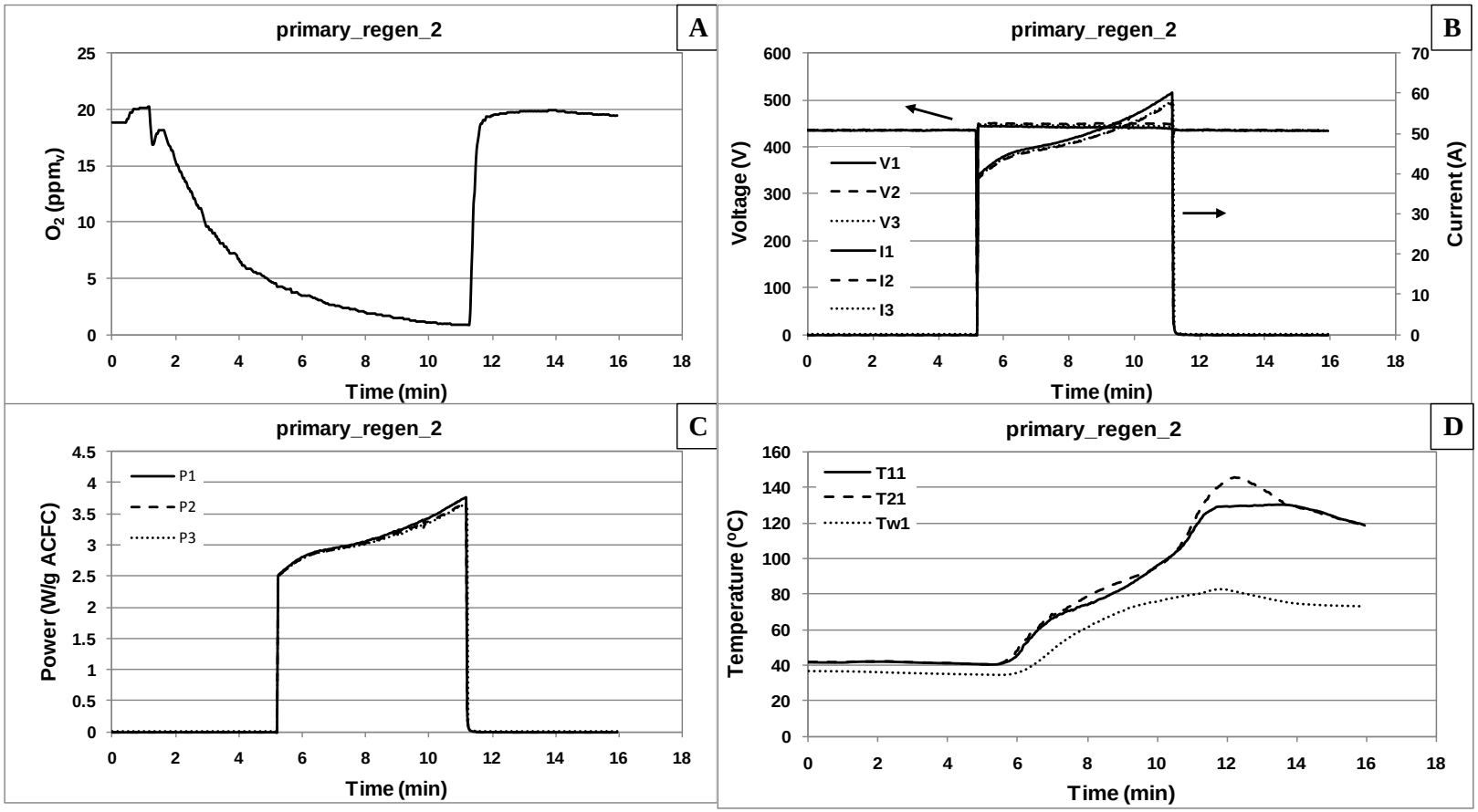

Figure 38. . Second regeneration of the primary vessel (did not include a water adsorption cycle after the previous heating).

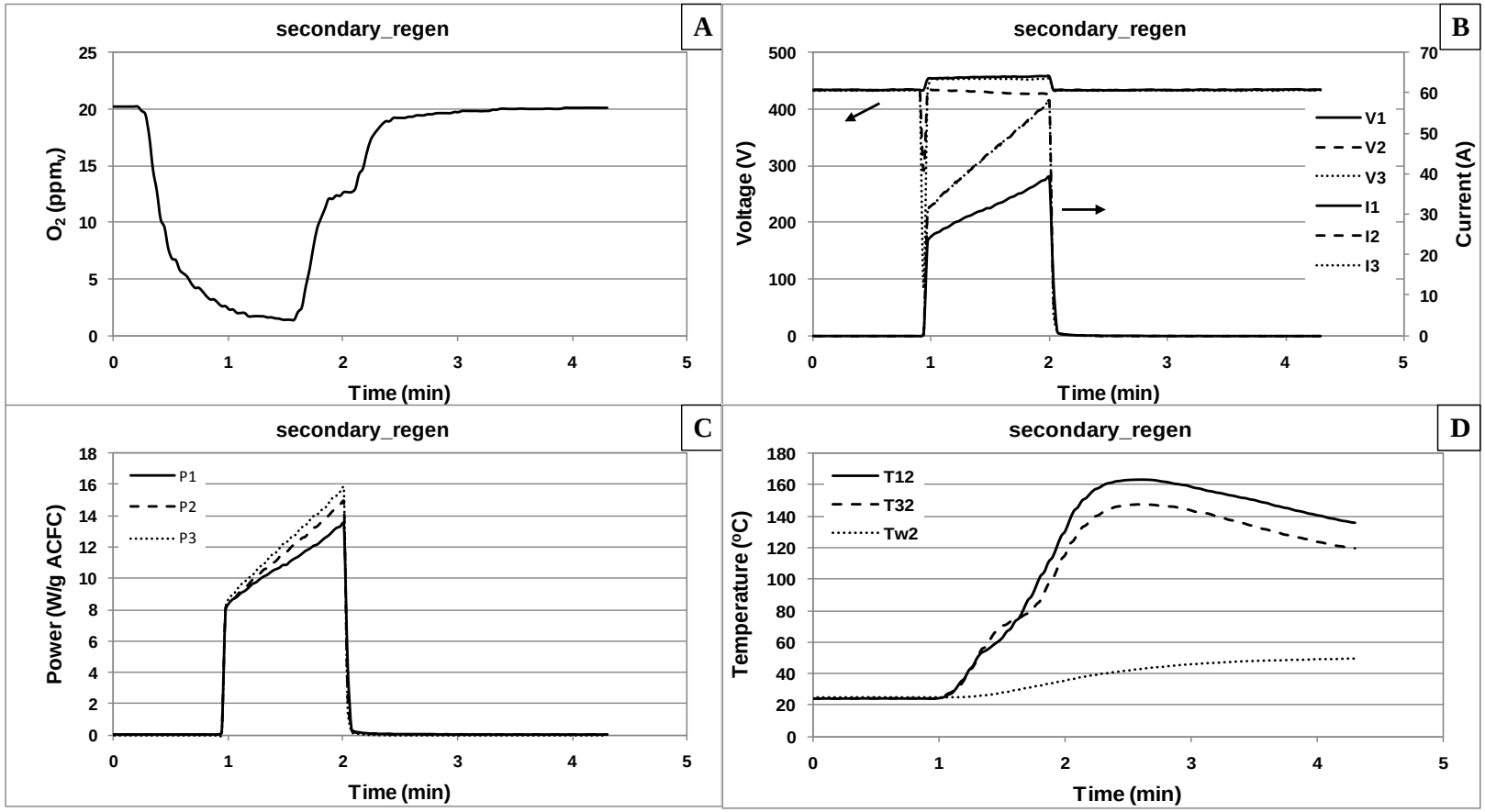

Figure 39. Regeneration of the secondary vessel.

5.2.2 Second Set of Troubleshooting Tests

Five troubleshooting tests were conducted by Global Finishing from September 1–October 7, 2011, and the results were analyzed by UI researchers. Results for the fifth test are believed to be representative and are provided in Figure 40–Figure 43.

Each vessel was electrothermally heated to a set-point of 150 ^{o}C. However, the primary vessel was only able to reach 140 ^{o}C and the secondary vessel was able to reach 100 ^{o}C and 125 ^{o}C in two consecutive heating cycles before a 50 A current limit was reached that ended the regeneration cycle. Because VOC adsorption is expected to decrease the electrical resistance of the ACFC and the same voltage is used at Hill AFB, it was expected that the ACFC would be able to be heated to 150 ^{o}C before reaching the current limit. Additionally, the current limit was increased to 60 A for the tests at Hill AFB.

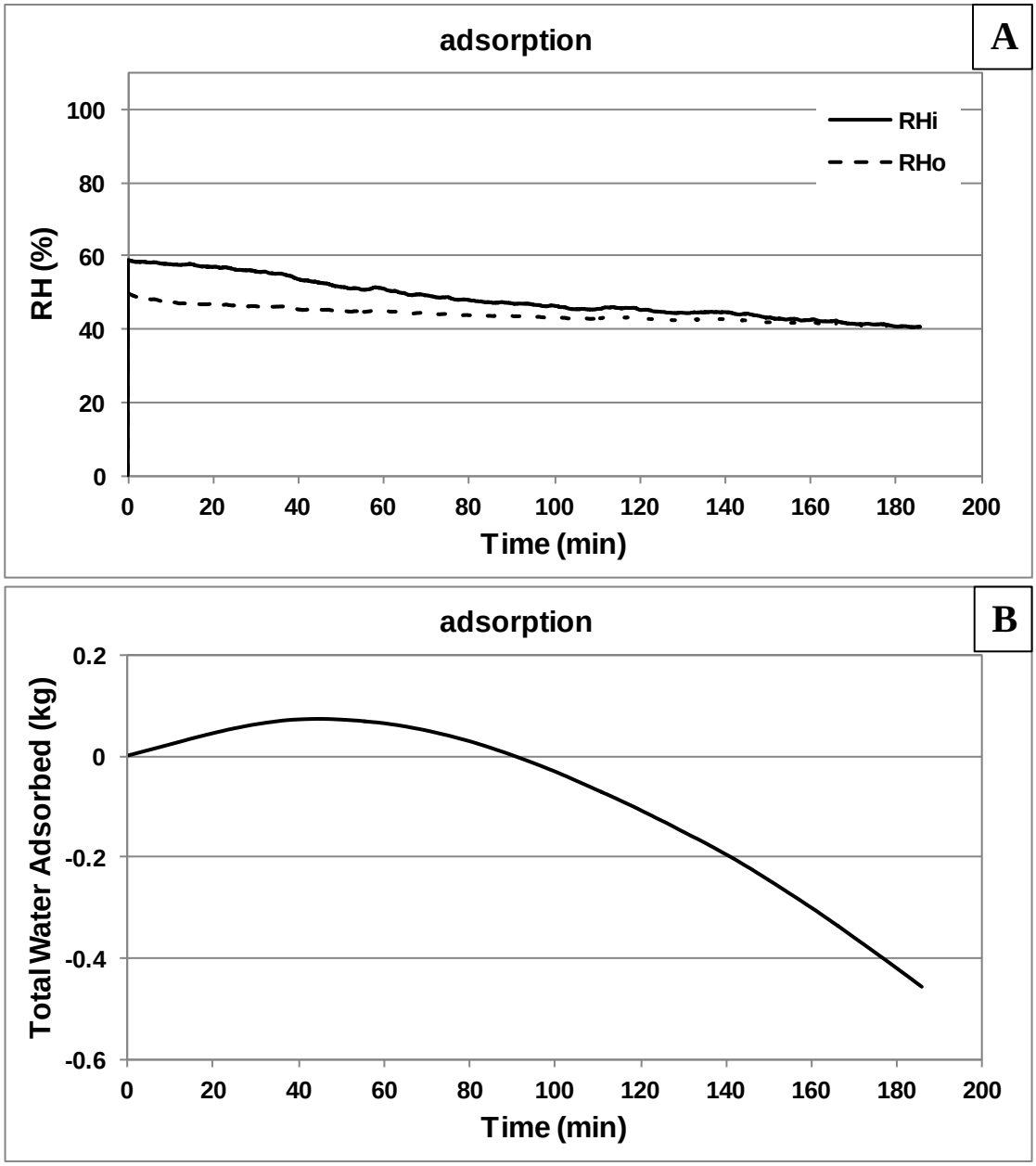

Figure 40. Water adsorption at ambient temperature with an air flow rate of 433 cfm.

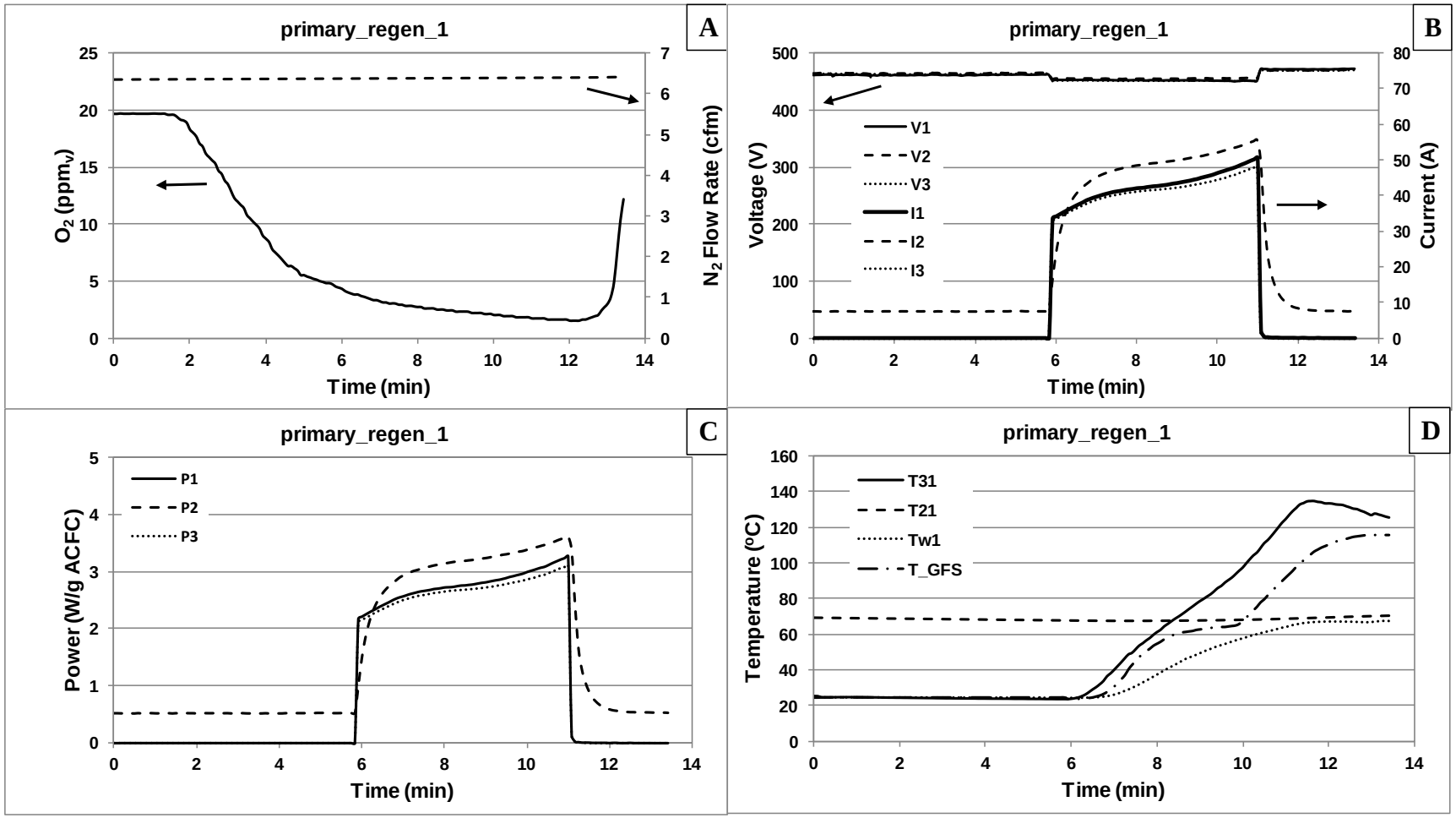

Figure 41. Regeneration of the primary vessel.

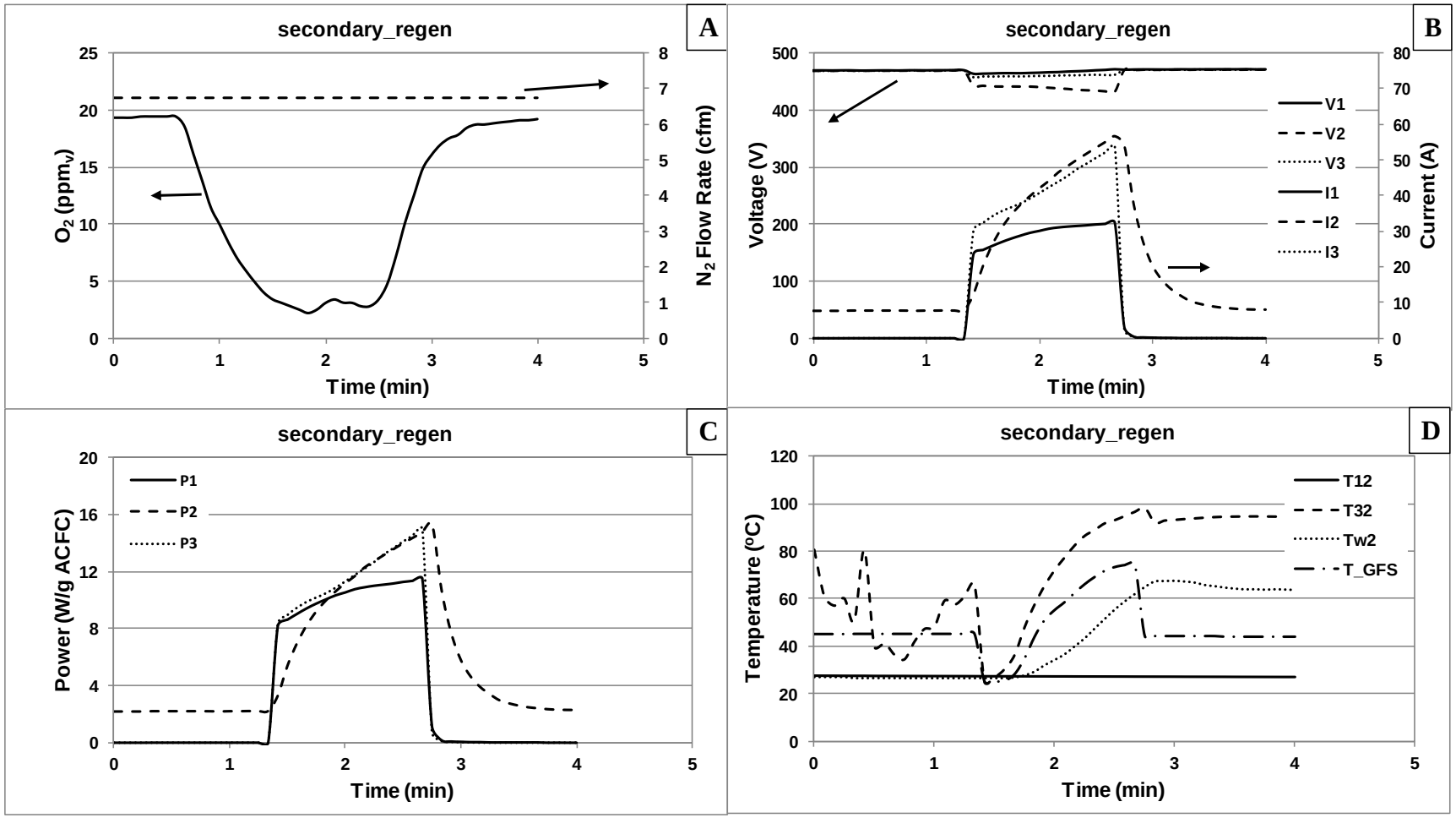

Figure 42. Regeneration of the secondary vessel.

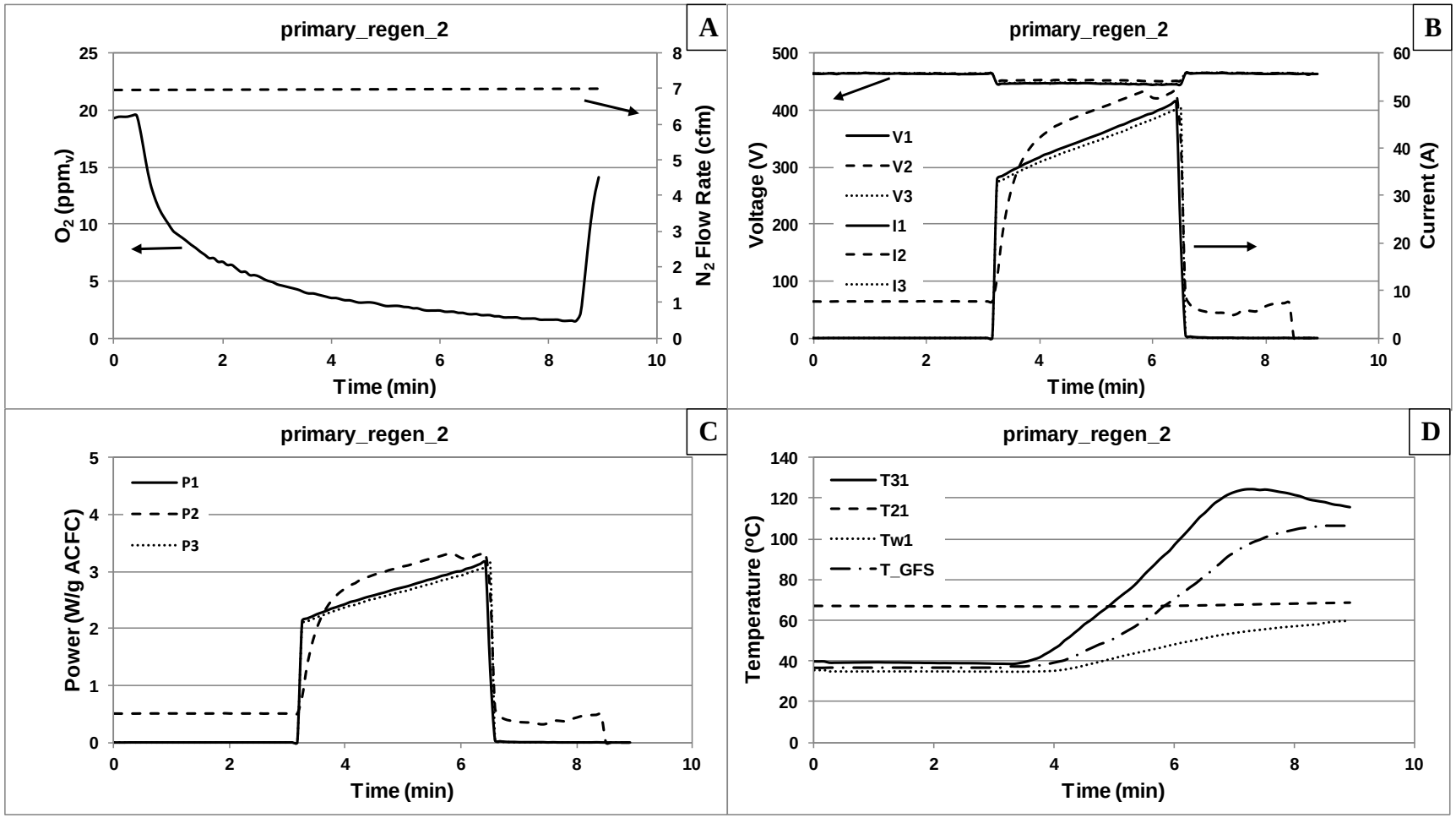

Figure 43. Regeneration of the primary vessel, second run.

5.3 TESTING AND EVALUATION

5.3.1 Demonstration Setup and Startup

The VaPRRS loaded treatment cart built by Global Finishing was shipped to Hill AFB for testing. Global Finishing and UI personnel collaborated to prepare the cart for testing at Hill AFB. Pictures of the testing setup are presented in Figure 44–Figure 46.

Preparation at Hill AFB included access to a 480 VAC power supply and a convenient location to park the cart for regeneration during non-use. Liquid nitrogen (N_2) was made available for regeneration cycles of the cart through Hill AFB.

A safety briefing was held before any personnel commenced fieldwork and covered safety information relevant to this demonstration. The Health and Safety Plan presented in the project the project's Demonstration Plan was available to all demonstration participants.

5.3.2 Period of Operation

The cart was tested twice at Global Finishing, with UI personnel present for troubleshooting purposes, before the cart was shipped to Hill AFB. Performance testing occurred over three days, from October 31–November 2, 2011 at Hill AFB.

Figure 44. VaPRRS cart (right forefront) and C-130 aircraft (background).

Figure 45. VaPRRS cart (left) connected to nose wheel-well booth (center) with existing treatment cart on standby (right).

Figure 46. Left wheel-well booth up against C-130 and connected to flexible ducting.

5.3.3 Amount/Treatment Rate of Treated Material

Treatment of VOCs emitted from wheel-well coating was performed during the coating of one aircraft during the demonstration period. Approximately 5.8 gal of solvents were used for this aircraft.

5.3.4 Operating Parameters for the Technology

Parameters that were monitored during the three-day test operation of the VaPRRS unit at Hill AFB included: volumetric flow rate of treated gas stream; temperature of ACFC inlet and outlet gas temperatures; inlet and outlet RH, pressure drop across the HEPA filters, ACFC filters, and blower; and the inlet and outlet VOC concentrations. During regeneration, N_2 flow rate, oxygen (O_2) content in the vessel, ACFC and wall temperature, electrical current and voltage were also monitored. The system was designed to process one day of painting (either sealer and primer or a layer of topcoat) on the three wheel wells of a C-130 aircraft before requiring a regeneration cycle of the adsorbent. Other than the regeneration phase, the system operates similar to the paint booth emission control cart that exists at Hill AFB.

5.3.5 Experimental Design

The existing painting operations were kept the same for this demonstration. The new system was integrated into the portable paint booth and used as required during operation. One experimental test case was completed (i.e., one aircraft). Personnel from the UI conducted the measurements of the system during the three day testing duration.

During each test, the control efficiency was determined by comparing measurements of VOC concentration in the gas stream entering and exiting the VaPRRS system on an average basis:

$$\eta_c = \frac{\overline{C}_{in} - \overline{C}_{out}}{\overline{C}_{in}} \times 100$$

Where:

η_c = control efficiency

$\overline{C}_{in}$ = time weighted average inlet concentration

$\overline{C}_{out}$ = time weighted average outlet concentration

There were multiple organic compounds in this waste stream. Grab samples were also taken at the inlet and outlet to verify the continuously measured results and to determine the individual gas stream constituents. These samples were analyzed at UI laboratories. No condensate was recovered so analysis of liquid chemical composition was not performed. Visual inspection of the carbon filters was performed to check for damage or physical alteration.

5.3.5.1 Product Testing

The painted product was not altered by the presence of the VaPRRS™ technology. There was no need to test the product.

5.3.5.2 Demobilization

The VaPRRS treatment cart remains at Hill AFB for future modifications by Global Finishing due to unsuccessful operation of the regeneration cycles.

5.3.5.3 Health and Safety Plan

See Appendix B of the Demonstration Plan for the Health and Safety Plan.

5.3.6 Analytical/Testing Methods

Properties of VaPRRS technology that were measured when VaPRRS was operating during an adsorption cycle were: (1) volumetric flow rate of treated gas stream with an anemometer, (2) temperature of ACFC with Type K thermocouples, (3) pressure drop across the HEPA filters, ACFC filters, and blower with a pressure transducer, (4) the inlet and outlet RH and temperatures with RH meters, and (5) the inlet and outlet VOC concentrations with photo-ionization detectors (PIDs). Velocity was measured at 1, 3, 5, 7, and 9 in. from the top of the 18 in. diameter duct and was then normalized based on the area of the corresponding cross sections compared to the entire area of the duct. For example, the cross section corresponding to the measurement that was 1 in. from the top included the area of a 7 in. radius circle subtracted from a 9 in. radius circle.

Properties of VaPRRS technology that were measured when VaPRRS was operating during a regeneration cycle, along with type of measurement were: (1) inlet N_2 gas flow rate with mass flow controller, (2) inlet gas temperature and adsorbent temperature with Type K thermocouples, (3) ambient pressure and RH from a meteorological station at Hill AFB, (4) outlet VOC concentration for the secondary adsorption vessel with a PID, (5) liquid mass recovered with a gravimetric balance (none recovered), (6) liquid volume recovered with a graduated cylinder (none recovered), (7) root-mean-square (RMS) voltage applied to the adsorbent with a voltmeter, (8) RMS current passing through the adsorbent with an ammeter, and (9) O_2 concentration in the vessel with an O_2 analyzer.

The mass and composition of the coatings consumed during each test was also documented based on specifications located on the containers of the solvents and coatings. N_2 consumption was not measured due to issues with the corresponding output signal from the cart. Measurements for mass of liquid recovered, volume of liquid recovered, and complete material balances for the adsorption and regeneration cycles are not available because no liquid was recovered. Penetration of the organic vapor from the primary adsorption vessel during the adsorption cycle and penetration of the organic vapor from the secondary adsorption vessel during regeneration of the primary adsorption vessel and energy requirements to regenerate the adsorbent were recorded. Mass of organic vapor remaining in the adsorbent after regeneration

was not determined due to issues with regeneration that are discussed in subsection 6.2.3 in Section 6 of this report.

The compositions of the coatings were determined by investigating the Material Safety Data Sheets (MSDS) and through comparison with existing test databases held by AFRL. Analyses of grab samples of the inlet and outlet gas flow with gas chromatography and flame-ionization detectors (GC-FIDs) were also used for comparison to the expected composition. A predominant solvent found in these coatings (methyl ethyl ketone, MEK), was used as the reference solvent for the PID measurements. This gave a more accurate representation of the actual VOC concentration than using a common reference chemical such as propane.

5.3.6.1 Analytical/Testing Laboratory

Testing was conducted by UI at Hill AFB, and subsequent analysis of the grab samples was performed at UI.

6. PERFORMANCE ASSESSMENT

6.1 LABORATORY TEST RESULTS

This section provides GC-FID data from grab samples obtained during operation of the VaPRRS unit at Hill AFB. Table 2 includes grab samples 1–8 that were obtained during adsorption as described in Table 3, and grab sample 9 that was obtained during regeneration of the ACFC. An example of the chromatograph for grab sample 1 is provided in Figure 47. Chromatograph peaks were used to identify the species from the grab samples. The main species from the chromatographs, as described in Table 2, were MEK, n-butyl alcohol, and xylene for the primer; toluene and MEK for the sealer; butyl acetate and ethyl acetate for the top coat; and MEK, toluene, and butyl acetate for the sample obtained during regeneration. These species matched the species from the MSDSs for each coating. There was also one species that was detected for the top coat and regeneration sample that was not found on the MSDS. Based on analysis of the chromatographs, this species may be one of the following compounds or a compound with similar properties such as: 2-pentanol, 3-pentanol, 3-pentanone, acetal (acetaldehyde diethyl acetal), bromodichloromethane, propyl acetate, dibromomethane, ethyl propionate, 1,4-dioxane, or 2,3-pentanedione.

Table 2. Grab sample results.

Grab sample number	Date	Test number[1]	Coating (type)	Wheel well location	Sample location	Species from chromatographs
1	10/31/2011	1	Primer	Nose	Inlet	MEK, n-Butyl Alcohol, Xylene
2	10/31/2011	1	Primer	Nose	Outlet	MEK, n-Butyl Alcohol, Xylene
3	10/31/2011	2	Sealer	Left main	Inlet	Toluene, MEK
4	10/31/2011	2	Sealer	Left main	Outlet	Toluene, MEK
5	11/1/2011	4	Top coat	Right main	Inlet	Butyl acetate, Ethyl acetate
6	11/1/2011	4	Top coat	Right main	Outlet	Butyl acetate, Ethyl acetate
7	11/2/2011	7	Top coat	Nose	Inlet	Butyl acetate, Ethyl acetate
8	11/2/2011	7	Top coat	Nose	Outlet	Butyl acetate, Ethyl acetate
9	11/2/2011	NA[2]	NA	NA	Outlet	MEK, Toluene, Butyl acetate

[1]Field tests are described in detail in section 6.2.

[2] NA= not available. Grab sample 9 was obtained at the outlet of the ACFC vessel during regeneration.

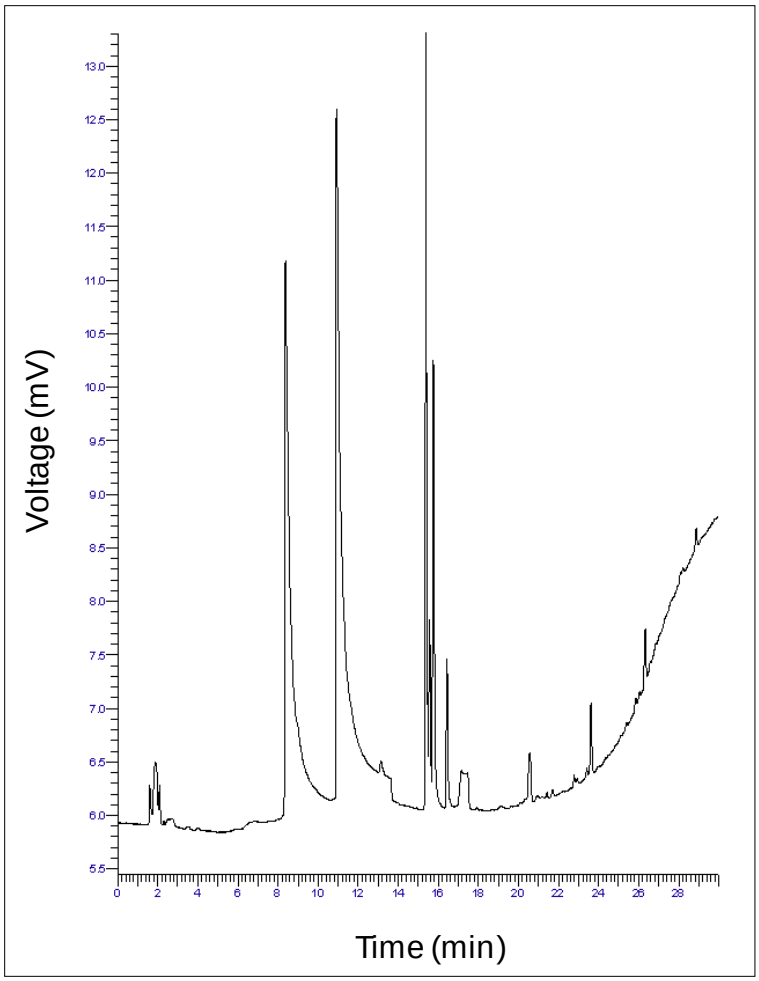

Figure 47. Chromatograph of grab sample obtained during coating test 1.

6.2 FIELD TEST RESULTS

This section provides results from test operation of the VaPRRS unit at Hill AFB. Tests were performed by UI researchers from October 31–November 2, 2011, and were later analyzed at UI. The symbols used in the plots were defined in section 5.2 (page 31). In addition, VOCi is the concentration of VOC in the inlet gas stream, and VOCo is the concentration of VOC in the outlet gas stream

The nose, right main, and left main wheel wells of a C-130 aircraft were coated on three consecutive days for a complete coating operation, and exhaust from the coating booth was sent to the ACFC cart. The inlet gas stream had a concentration of 150-1000 ppmv during operation, while the output concentration was less than 10 ppmv. A summary of the tests is provided in Table 3, and the tests are described in more detail in the subsections below.

6.2.1 Day 1 (31 October 2011)

Primer was applied to the nose wheel well, and then the sealer was applied to the left and right main well wheels. The primer was a high-solids epoxy primer with a 1:1 mixture of catalyst/activator (PPG Aerospace DRC-DeSoto, CA7233B) and base (PPG Aerospace, DRC-DeSoto, CA7233). The sealer was made by combining a 100:6.67 mixture (by volume) of base (PPG Aerospace, PRC-DeSoto, PR1432-G) and activator/accelerator (PR-1432-GP). This mixture was then mixed with 24 oz of a 1:1 mixture of MEK and toluene to make a total of 1.5 gal.

The first test at Hill AFB involved adsorption of the gas stream produced from coating the nose wheel well. During this initial test, the data acquisition system was not functioning properly. This issue was resolved after the first test, and real-time data are available for all subsequent tests. Figure 48 and Figure 49 include VOC and water adsorption for the left and right main well wheels, respectively.

6.2.2 Day 2 (1 November 2011)

Top coat was applied to the right main, left main, and nose wheel wells. The top coat was a 1:1 mixture (by volume) of a base (Deft polyurethane, component A, pigmented polyester resin, MIL-PRF-85285D, type 1, class H (MIL-PRF-85285C), color 16473, gray);, and a top coat activator: (Deft polyurethane, component B, aliphatic isocyanate resin, MIL-PRF-85285D, type 1, class H (MIL-PRF-85285C), color 16473, gray). Figure 50, Figure 51, and Figure 52 include VOC and water adsorption for the right main, left main, and nose well wheels, respectively.

6.2.3 Day 3 (2 November 2011)

Data from day 1 and 2 were analyzed, and the ACFC control efficiency was 81.1%–84.6% which is lower than expected value of 98%, so the cart was modified to reduce leaks that allowed the incoming coating-laden air to bypass the ACFC filters. A sealer was added along the connection between the top plate that supports the ACFC and the top of the vessel walls that supports the top plate. Top coat was then applied to the nose, left main, and right main wheel wells. The adsorption control efficiency improved from 81.1%–84.6% on days 1 and 2 to ≥ 97.9% by volume on day 3 after adding the sealer. Figure 53, Figure 54, and Figure 55 include VOC and water adsorption for the nose, left main, and right main well wheels, respectively. The ACFC did not reach breakthrough after adsorbing VOCs from the coatings and water from the ambient air over the complete coating of the wheel wells for the C-130 aircraft (tests 1–9). More tests are required to determine the number of C-130 aircrafts that can be coated before cart regeneration is necessary.

After the wheel well coatings were complete, the ACFC was regenerated. First, the filters in the primary vessel were electrothermally heated to 150 ^{o}C (Figure 56). Then the primary filters were heated a second time followed by the filters in the secondary vessel (Figure 57 and Figure 58, respectively). While first heating the primary filters, there was a strong VOC odor near the cart and the inlet PID concentration reached the maximum value even though the regeneration gas flow should not have traveled to the location where the inlet PID was sampling. Additionally,

there was no liquid in the liquid recovery vessel after regeneration of the primary or secondary filters. This suggests there were leaks or open valves that allowed the regeneration gas to escape through the adsorption inlet into the ambient air force hanger air. The liquid recovery efficiency was ~0%, and this leak or valve sequence problem needs to be addressed for the ACFC cart to be functional.

The energy required to heat the primary vessel to 150 ^{o}C was 813 J/g ACFC and 380 J/g ACFC for the first and second heating cycles, respectively. The first primary regeneration required heating for 4.2 min to achieve the set point temperature, while the second primary regeneration required only 1.8 min. This increase in energy and heating time is likely due to the water and VOCs that were adsorbed. None of the thermocouples in the secondary vessel were functioning during regeneration, so the regeneration was ended once the electrical current level reached the 60 A limit. The secondary vessel contained 4.65 kg ACFC compared to the 21 kg of ACFC in the primary vessel. Thus, the 60 A limit likely allows the ACFC in the secondary vessel to heat to higher temperatures than the primary vessel (~150 ^{o}C). Thus, the energy required to heat the secondary vessel to 60 A (1176 J/g ACFC) over the short 1.5 min heating cycle was larger than the values for the primary regeneration. The maximum power applied during the first primary, second primary, and secondary regeneration cycles was 4.0, 3.8, and 16.1 W/g ACFC, respectively. Similarly, the maximum power value for the secondary vessel was larger than the primary vessel, because a smaller mass of ACFC was heated to the same current limit. For comparison, the typical values of voltage, current, and power applied for tested bench-scale and pilot-scale units are 70 and 180 V, 25 and 50 A, 4.5 and 7 W/g ACFC, respectively.

A grab sample of the inlet and outlet air was taken during tests 1, 2, 4, and 7, as described in Table 2 and Table 3, and an additional grab sample was taken from the outlet during the first regeneration of the primary filters. Grab samples were analyzed at UI (Section 6.1)

Table 3. Summary of tests performed at Hill AFB.

Date	Test number	Paint type	Paint volume (gal)	Wheel well location	Ambient temperature (^oC)	Ambient RH (%)	Test duration (min)	Flow rate (cfm)	HEPA filter pressure drop (in. H_2O)	ACFC pressure drop (in. H_2O)	Blower pressure drop (in. H_2O)	Bag sample number	VOC capture efficiency (%)
10/31/2011	1	Primer	0.28	Nose	39-43	52-60	20	345	NA	NA	NA	1, 2	NA
10/31/2011	2	Sealer	0.75	Left main	39-41	56-62	41	345	0.4	3.4	3.7	3, 4	84.3
10/31/2011	3	Sealer	0.75	Right main	39-41	60-60	53	345	NA	3.8	NA	NA	82.9
11/1/2011	4	Top coat	0.75	Right main	45-46	81-87	37	768	0.7	4.8	5.5	5, 6	81.1
11/1/2011	5	Top coat	0.75	Left main	45-45	87-93	35	685	0.6	4.3	4.8	NA	84.6
11/1/2011	6	Top coat	0.50	Nose	43-45	81-89	29	685	0.7	4.4	4.8	NA	84.5
11/2/2011	7	Top coat	0.5	Nose	30-30	75-80	22	637	0.6	4.6	5.0	7, 8	98.2
11/2/2011	8	Top coat	0.75	Left main	28-30	69-74	22	637	0.6	4.6	5.0	NA	97.9
11/2/2011	9	Top coat	0.75	Right main	27-28	74-80	31	637	0.6	5.0	5.0	NA	97.8

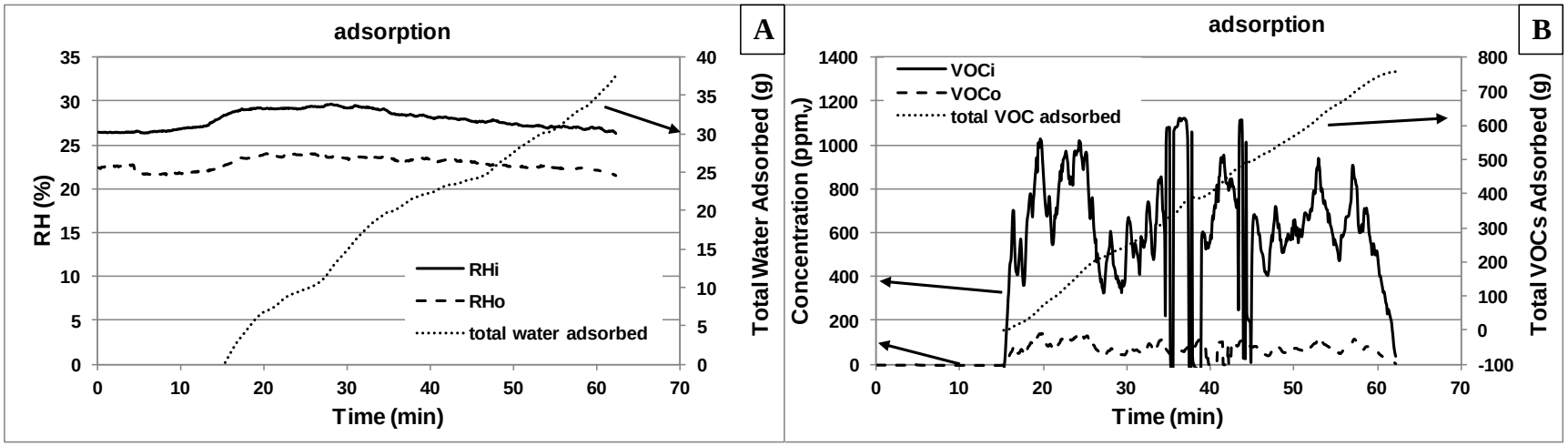

Figure 48. VOC and Water adsorption (test 2) during left main wheel well painting with an air flow rate of 345 cfm.

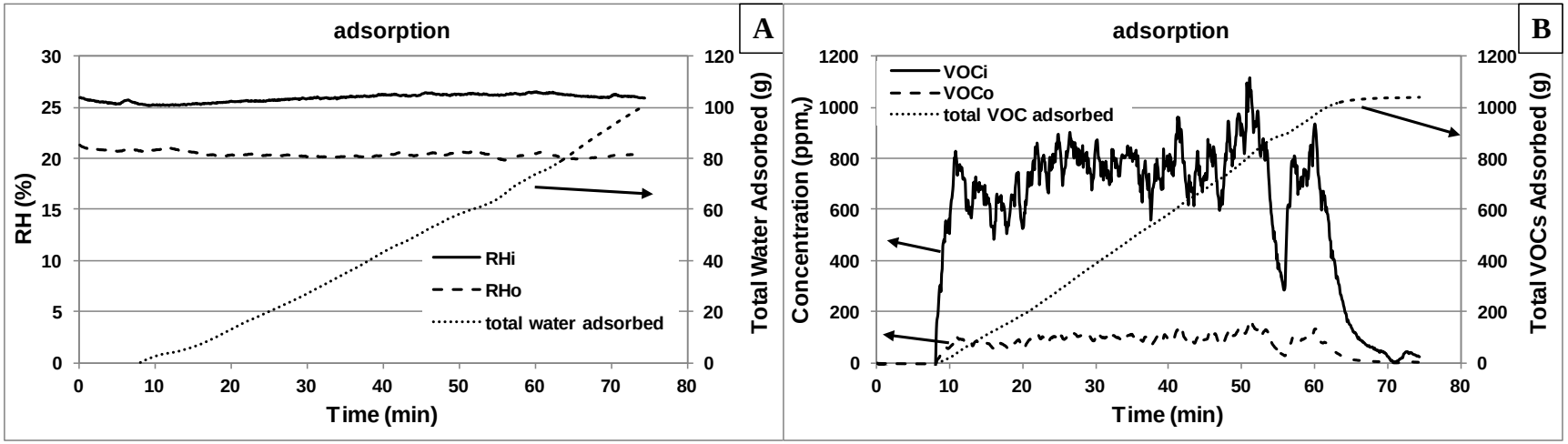

Figure 49. VOC and Water adsorption (test 3) during right main wheel well painting with an air flow rate of 345 cfm.

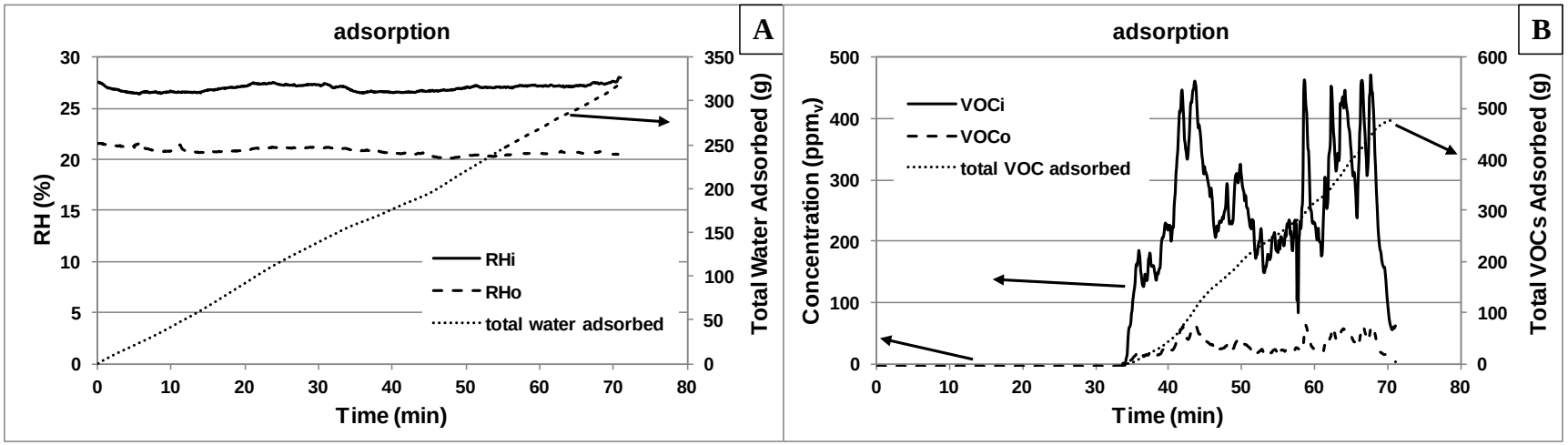

Figure 50. VOC and Water adsorption (test 4) during right main wheel well painting with an air flow rate of 768 cfm.

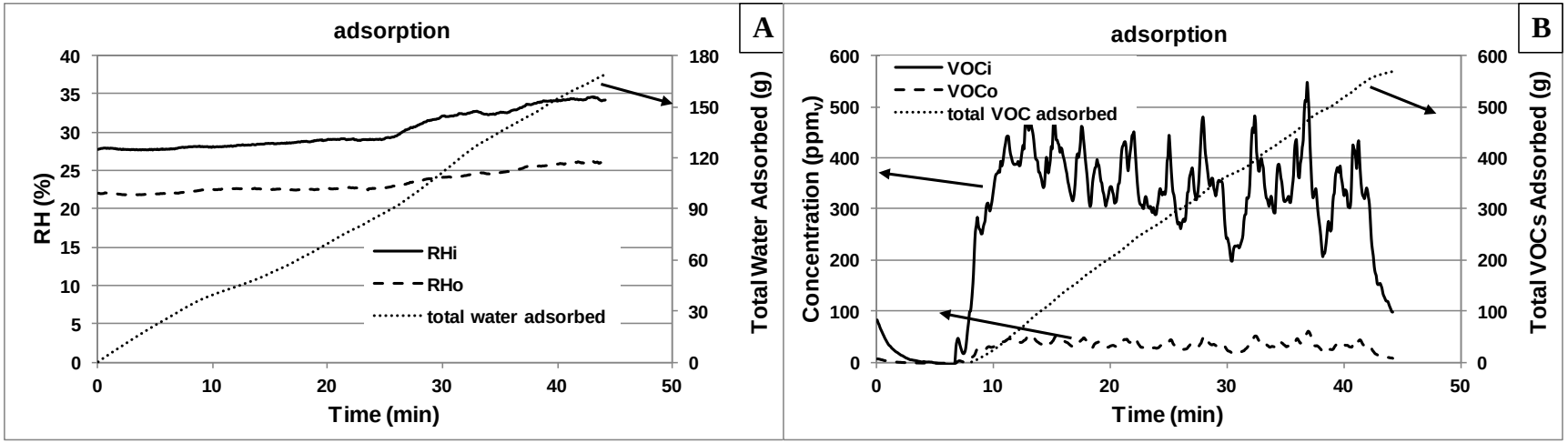

Figure 51. VOC and Water adsorption (test 5) during left main wheel well painting with an air flow rate of 685 cfm.

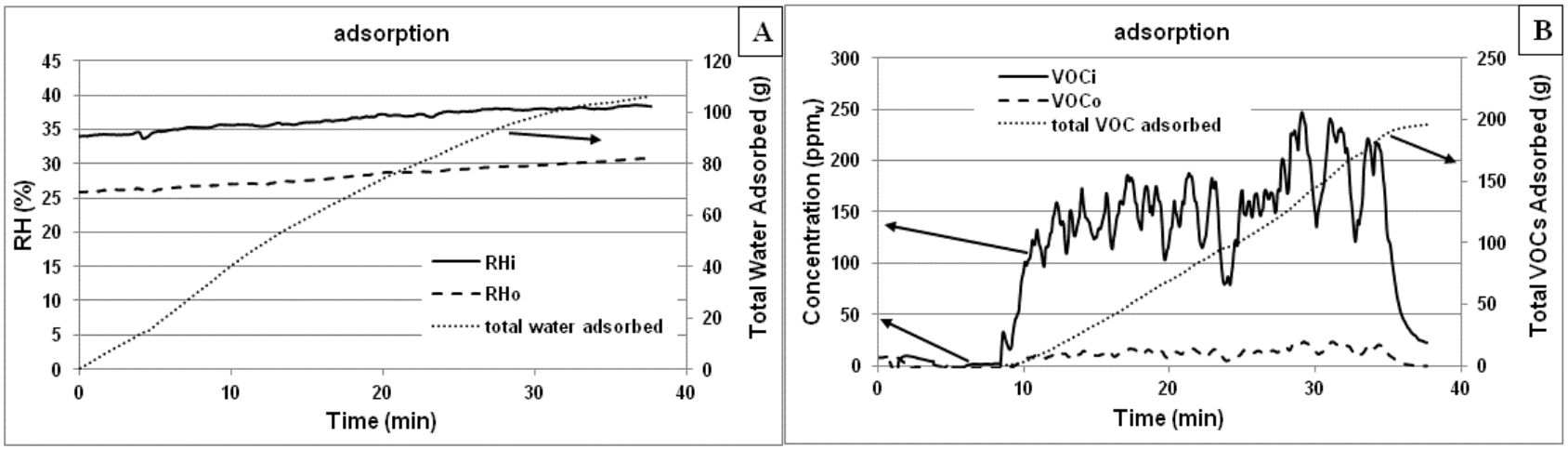

Figure 52. VOC and Water adsorption (test 6) during nose wheel well painting with an air flow rate of 685 cfm.

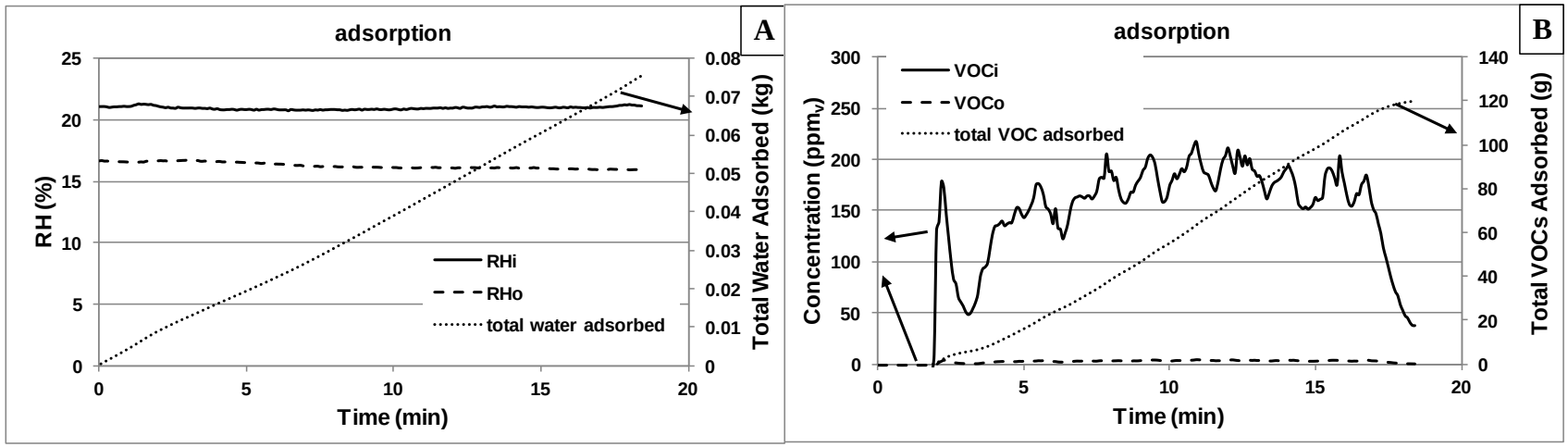

Figure 53. VOC and Water adsorption (test 7) during nose wheel well painting with an air flow rate of 637 cfm.

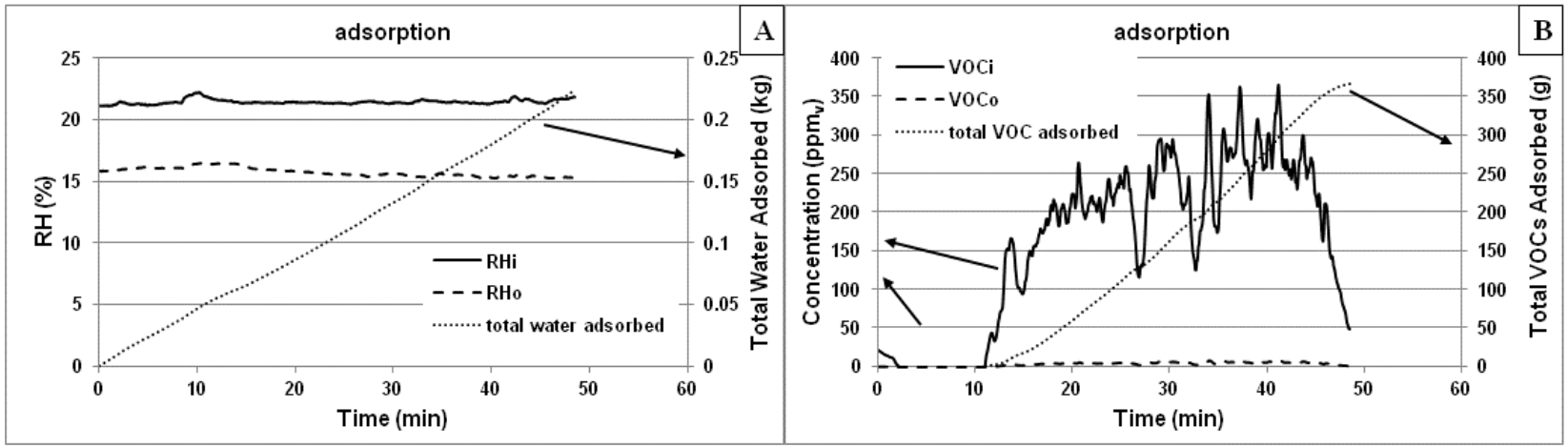

Figure 54. VOC and Water adsorption (test 8) during left main wheel well painting with an air flow rate of 637 cfm.

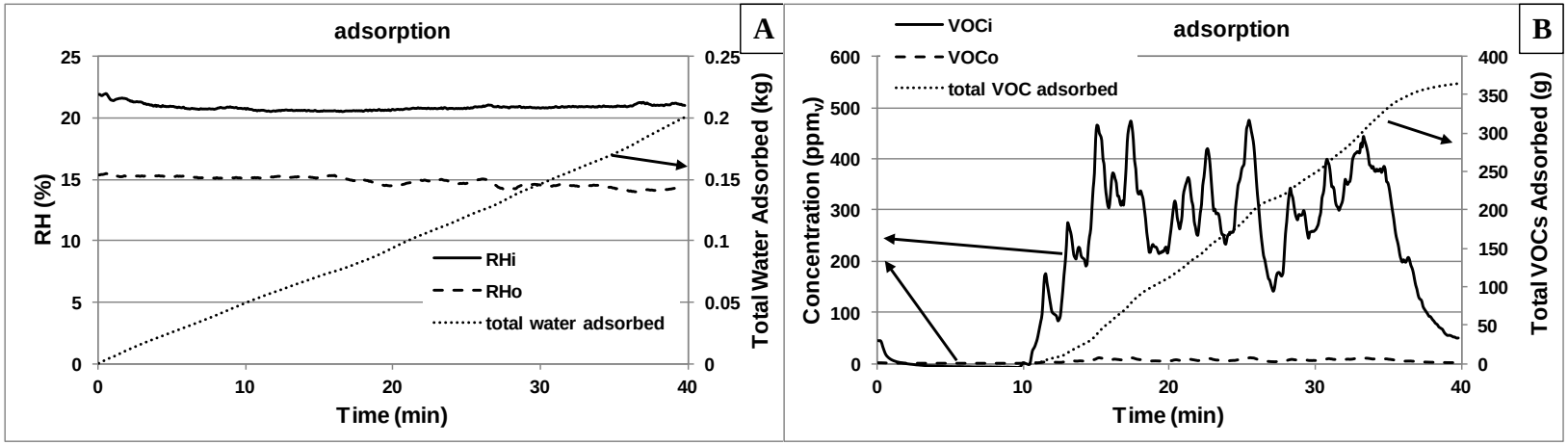

Figure 55. VOC and Water adsorption (test 9) during right main wheel well painting with an air flow rate of 637 cfm.

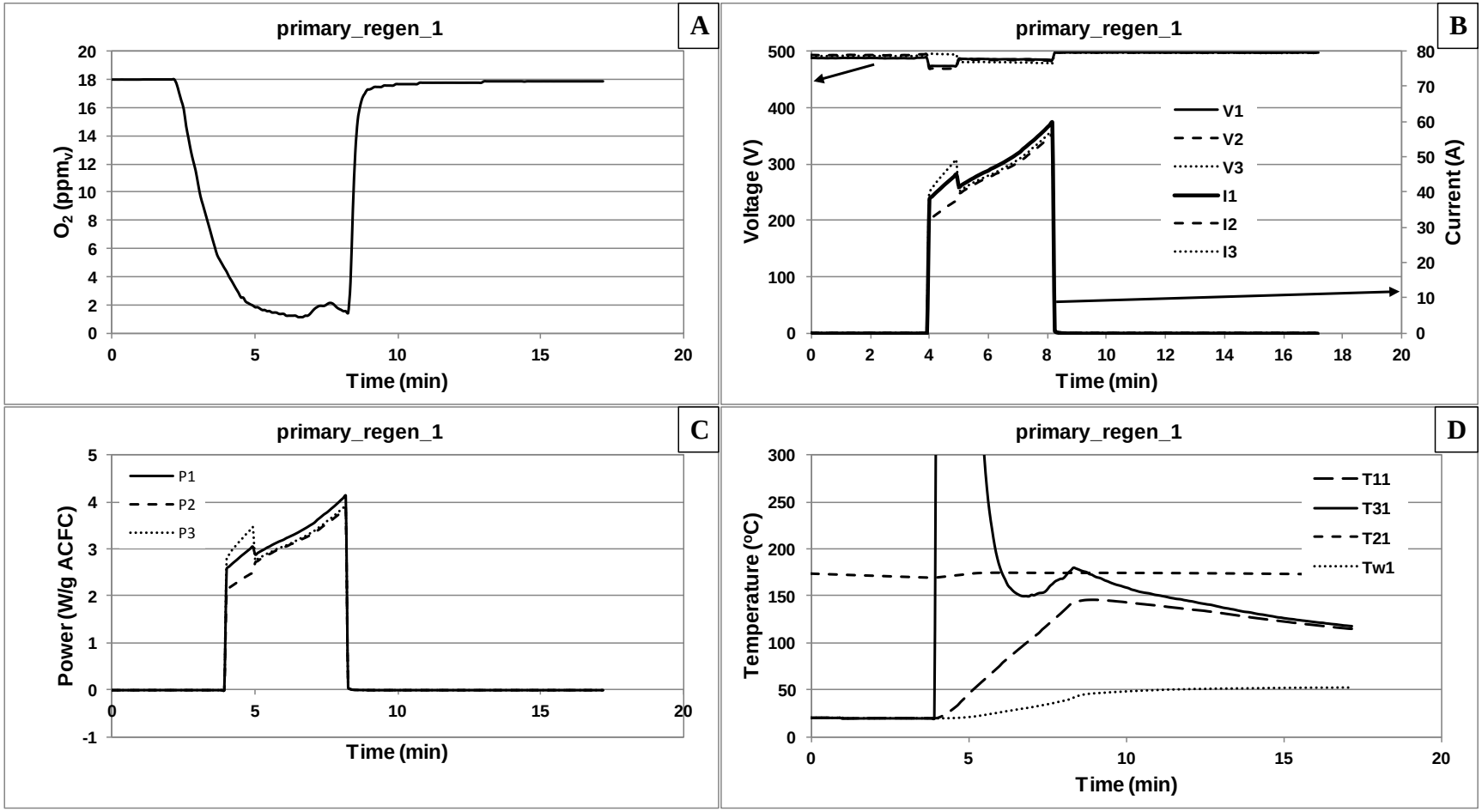

Figure 56. First regeneration of the primary vessel.

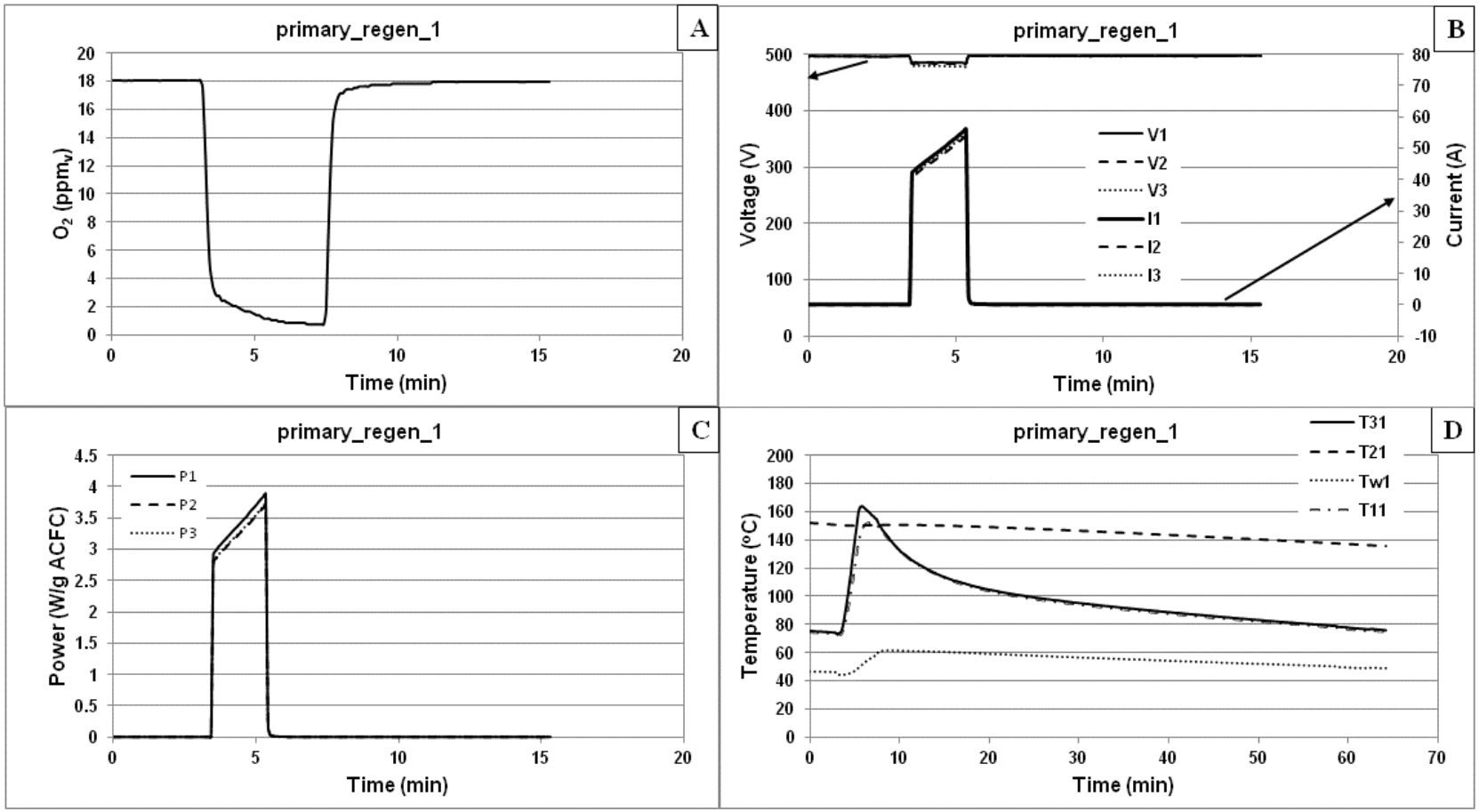

Figure 57. Second regeneration of the primary vessel.

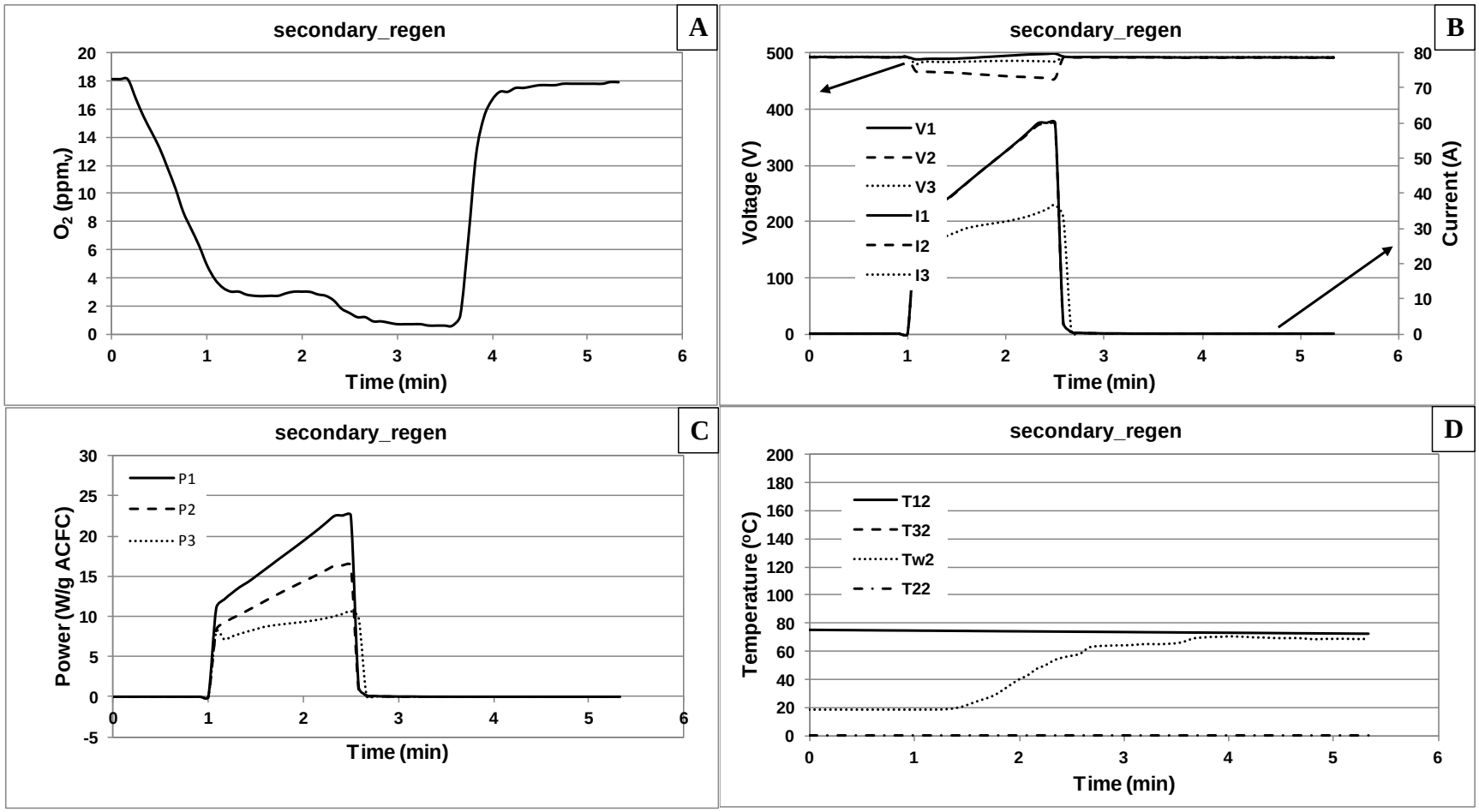

Figure 58. Regeneration of the secondary vessel.

6.3 PERFORMANCE CRITERIA

Performance criteria for evaluation of the VaPRRS technology are described in Table 4-1 of Section 4.1 of the Demonstration Plan and Table 1 in Section 3 of this report. These criteria include: (1) primary criteria of control efficiency, reliability, hazardous materials, ease of use, and scale-up constraints, and (2) secondary criteria of factors affecting technical performance, maintenance, and versatility.

Table 4 includes evaluation of the performance criteria from field results at Hill AFB (identical to Table 1 in Section 3, except with the addition of a "results" column). The VaPRRS technology did not pass all of the primary performance criteria because the regeneration cycle did not function properly and 0% of the captured VOCs were recovered as a liquid. Each performance criterion is addressed below:

- *Control efficiency:* The control efficiency passed the performance criteria after sealing leaks that were apparent during the initial adsorption experiments. During the three tests that occurred after sealing the leaks, the average control efficiency was 98.0%, which meets the 98% control efficiency requirement.

- *Reliability:* Although the data acquisition system was not functioning properly for the first adsorption test, the cart was still utilized to adsorb the VOC-laden gas stream and likely performed similarly to the performances during tests 2 and 3. Thus, the cart was considered to be fully functional for each adsorption test during the field campaign, resulting in a reliability of 100% that exceeds the 90% reliability requirement.

- *Hazardous material:* During regeneration, there was a distinct VOC odor, and the PID at the inlet of the adsorption vessel reached the maximum measurable concentration value. However, no gas flow should have been able to reach the inlet PID during regeneration. Thus, it is expected that this regeneration problem was a result of either leaks in the cart or incorrect programming of the valve sequencing during the regeneration cycle. This issue prevented the cart from passing multiple performance criteria and resulted in 0% hazardous waste recovery, while 95% recovery was required.

- *Ease of use:* The on-site operators had no problems operating the cart during the adsorption phase after an approximate five minute explanation given by Global Finishing representatives. The ease of use for regeneration could not be evaluated because the process did not function properly. Therefore, the result for this criterion is inconclusive.

- *Scale-up constraints:* The cart performed similarly to the pilot-scale unit during adsorption but did not function properly during regeneration, so this criterion was not met.

- *Factors affecting performance:* The cart performed consistently for adsorption during the field campaign for the different wheel wells, coatings, and ambient weather conditions. The system passed this criterion.

- *Maintenance:* The system required minimal operator training and did not require additional training after the first use. However, the system did not successfully operate

during desorption and recover solvent, so it was inconclusive whether operators could successfully maintain the system during regeneration.

- *Versatility:* The cart was not successful utilized at Hill AFB due to the regeneration issue and thus failed the versatility criterion.

Table 4. Performance evaluation.

Performance Criteria	Expected Performance Metric	Performance Confirmation Method	Actual Performance
Primary Quantitative Criteria			
Control Efficiency	*Greater than 98% VOC control efficiency.*	*Onsite VOC measurements and mass balance analysis.*	98.0% Pass
Reliability	*Greater than 90% uptime.*	*Record keeping.*	100% Pass
Hazardous Materials	*Greater than 98% control efficiency for each component. Mass balance closure within 20%.*	*Quantification of recovered liquid VOC, quantification of VOC emitted, speciation of components and mass balance analysis*	0% Fail
Primary Qualitative Criteria			
Ease of Use	*Minimal operator training and attention during use. Does not exceed current requirements for GAC system.*	*Operating experience*	Inconclusive
Scale-Up Constraints	*Similar performance and functionality compared to pilot unit in operation.*	*Operating experience*	Fail
Secondary Qualitative Criteria			
Factors Affecting Performance	*Performance not to be hindered by unexpected issues such as changes in production schedule or high relative humidity of gas stream.*	*Operating experience and testing data analysis*	Pass
Maintenance	*Minimal operator training and attention during use. Does not exceed current requirements for GAC system.*	*Operator experience and record keeping. Visual inspection of system.*	Inconclusive
Versatility	*Successful application at this site.*	*Overall evaluation of other criteria*	Fail

7. COST ASSESSMENT

Due to the unsatisfactory performance of the VaPRRS treatment cart during the field test, a meaningful cost assessment is not possible or warranted. Much of the data that were to be used for this assessment were not collected. However, the cost elements and model that would have been used are presented below along with some cost information.

7.1 COST MODEL

An analysis similar to the level-two Environmental Cost Analysis Methodology (ECAM) [13] would be conducted to compare the existing technology (disposable carbon beds) to the VaPRRS implementation at Hill AFB. A level-three analysis would not be performed because it is not expected that the new technology would bring about a significant non-environmental cost impact, such as a change in the production capacity. Table 5 shows the type of cost data to be used to determine the total costs of the existing system and new technology. This table has been modified from this project's Demonstration Plan to reflect a better representation of the costs involved. The capital costs of the existing system would be included in this analysis because a decision to utilize the new technology would be made at the time of adding a new portable paint booth system, not as a replacement. To assist in applying this information to other sources, a final cost basis would be determined in terms of dollars per unit mass of organic solvent captured. Figure 59 and Figure 60 show treatment flow schematics of the two treatment cart processes.

Table 5. Data for technology cost assessment.

Direct Environmental Activity Process Costs				**Indirect Environmental Activity Costs**	
Startup		**Operation & Maintenance**			
Activity	$	Activity	$	Activity	$
Equipment purchase		Utilities (energy usage)		Test/analyze waste streams	
Equipment design		Hazardous waste disposal fees (spent GAC, condensate)		Waste transportation (on and off-site)	
Site preparation		Materials, consumables and supplies (Nitrogen supply, new GAC, prefilters)		Envr. Mgmt. Plan development & maintenance *	
Installation		Equipment maintenance		Reporting requirements*	
Training of operators		Labor to manage hazardous waste		Document maintenance*	
Permitting *		Labor to operate equipment			

*Likely to be similar cost for both existing and new technologies

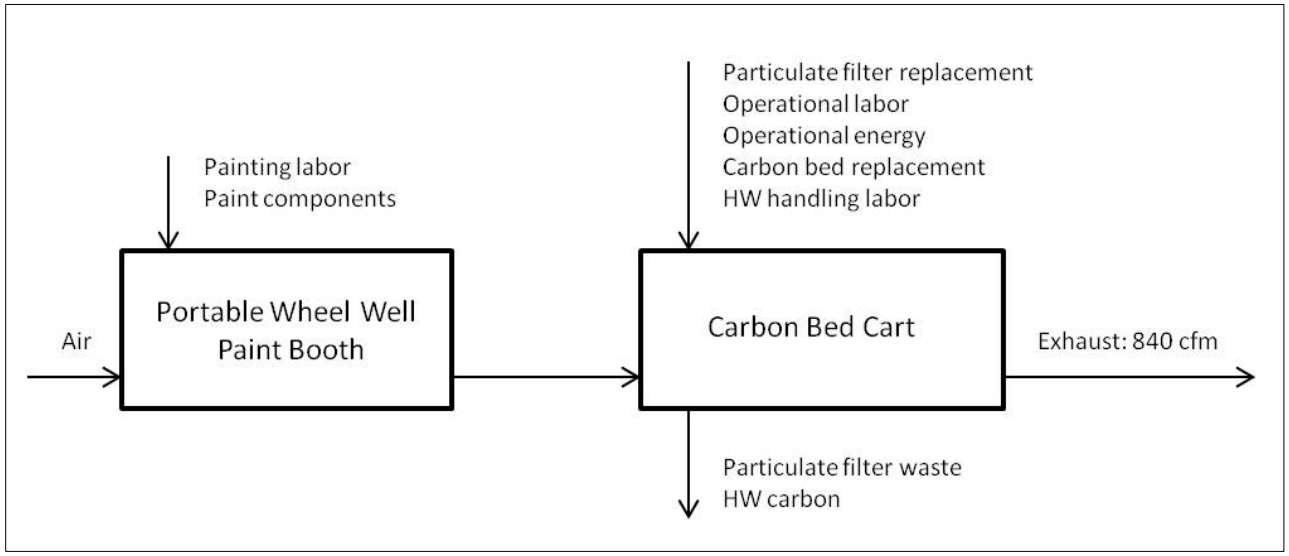

Figure 59. Current portable paint booth exhaust treatment process flow schematic.

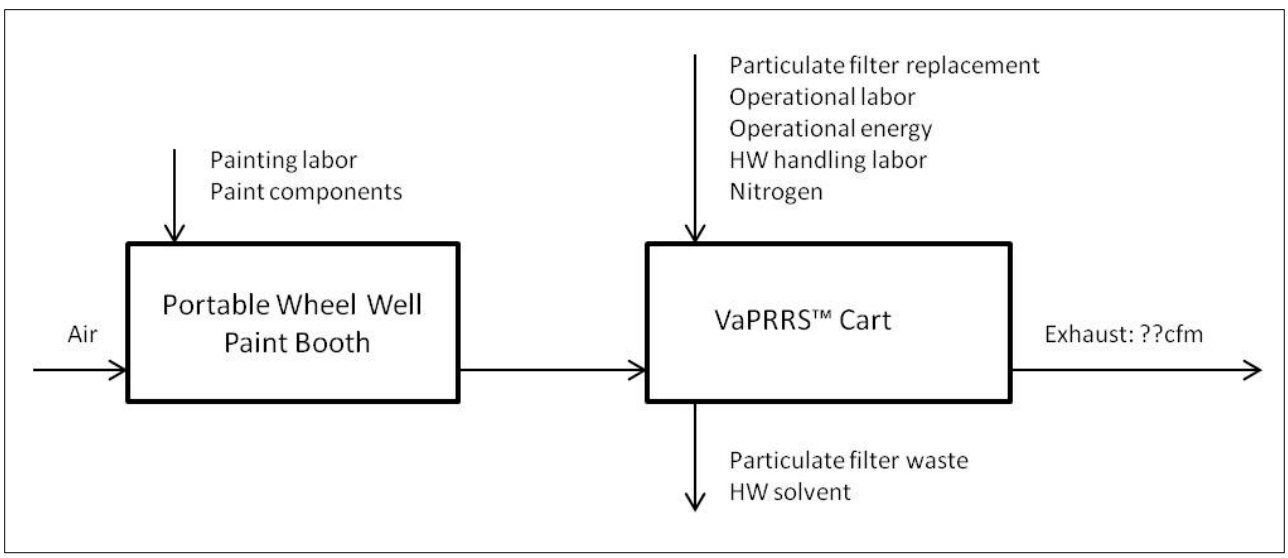

Figure 60. New portable paint booth's exhaust treatment process flow schematic.

Table 6, Table 7, and Table 8 list elements that would be used to compare direct operational costs, indirect operational costs, and capital costs of the current and new systems.

Table 6. Direct operational cost elements.

Cost Element	Estimated Cost ($)	
	Current Treatment Cart	New Treatment Cart
Part. filter replacement*		
Part. filter waste*		
Part. filter labor*		
Operational labor		
Operational energy		
Carbon bed replacement		0
HW handling labor		
HW carbon		0
HW solvent	0	
Nitrogen	0	

*Likely to be similar cost for both existing and new technologies.
NOTE: All values known to be zero are shown as such.

Table 7. Indirect operational cost elements.

Cost Element	Estimated Cost ($)	
	Current Treatment Cart	New Treatment Cart
Test/Analyze waste stream*		
Waste transportation		
Envr. mgmt. plan*		
Reporting requirements*		
Document maintenance*		
Permitting*		

*Likely to be similar cost for both existing and new technologies

Table 8. Capital cost elements.

Cost Element	Estimated Cost ($)	
	Current Treatment Cart	New Treatment Cart
Equipment purchase		
Site preparation		
Installation		
Training of operators		

7.2 COST ANALYSIS AND COMPARISON

As stated above, the unsuccessful test has made it less meaningful to complete a cost analysis. However, estimations of the equipment costs were provided by Global Finishing so that a rough comparison is provided here.

7.2.1 Estimated Cost Comparison

The costs of a new cart similar to the current cart would be approximately $65,000. The cost would be approximately $125,000 for a new VaPRRS cart alone, without the filters and nitrogen equipment. The cost of the ACFC for the filters is $71.53 per square meter. There is 25.65 kg of ACFC at 0.180 kg per square meter, which translates to a total cost of $10,200 for the ACFC. The cost of the cryogenic equipment used in the prototype was $1,755 for the Dewar and $2,074 for the evaporator with the valve kit. Adding those items to the $4,000 estimated cost for constructing the filters gives an approximate cost of $143,000 for the VaPRRS cart with the filter material. This total suggests that the equipment cost for the VaPRRS cart is $78,000 or 120% more expensive than the current cart. A higher cost for VaPRRS was expected, but with a smaller difference. It was also expected that the operational costs of the VaPRRS cart would be less than the current cart, enough so that it would prove to be more economical over the long term (expected 10-yr life cycle). The differences in operational costs between the two carts ultimately comes down to the cost of replacement and disposal of the GAC beds with the current cart versus the energy, nitrogen, and solvent disposal cost requirements to regenerate the ACFC filters for the VaPRRS cart.

The VaPRRS cart used 22,555 kJ per aircraft (6.27 kWh per plane) for regeneration. If we assume a going cost rate of $0.087 per killowatt hour, the total energy cost for regenerating the filters is $0.55 per aircraft. The amount of nitrogen used to regenerate and purge the filter vessels is estimated at 5,709 L of nitrogen gas per aircraft (the actual nitrogen data from the cart was unavailable during the desorption test). If we assume the cost is on the high range of estimates at $1 per liter for liquid nitrogen, then the nitrogen cost is estimated at $8.10 per aircraft (gas volume to liquid volume ratio is 705:1). The sum of these two costs is $8.65 per aircraft.

The current cart contains six GAC beds, each with dimensions of 24 in. wide x 24 in. long x 4 in. deep. Each bed contains approximately 24 lb of carbon, has a loading capacity of 4 lb of solvent, and costs approximately $150. So, the current cart's total loading capacity is 24 lb (10.9 kg) of solvent, and the total cost to replace is $900. The inlet concentration data from this test indicates that there was 4.84 kg of solvent used during the coating of the one aircraft. This value is calculated by weight, averaging the solvent contents from the different coatings. Based on this data, it is expected that the GAC beds will need to be changed after 2.25 aircraft. Hill processes approximately 25 aircraft a year which translates to $10,000 per year in material costs to replace the filters. The total cost to dispose of the used beds is approximately $2,800 per year (1,867 lb at $1.50 per pound, which surprisingly is disposed of as non-hazardous waste). So, the total yearly cost difference between the two carts is approximately $12,600 per year. The estimated payback of the VaPRRS cart would be 6.2 yr, producing a $48,000 savings over the VaPRRS cart's expected 10 yr life expectancy.

As shown by Table 5–Table 8, a proper cost evaluation would need to consider more information. However, it is expected that these additional cost elements will either cancel each other out or be insignificant compared to the cost figures presented in the rough estimate, as outlined in the paragraphs above.

8. IMPLEMENTATION ISSUES

This demonstration was not completed successfully. As discussed in Section 6, the VaPRRS treatment cart was not able to recover and condense solvent during the desorption phase of operation. This issue prevented meeting the performance metrics to pass five of eight performance criteria. It also prevented a complete cost assessment. With the cart in this same condition, further implementations of this particular application would not be recommended. However, it is believed that the cart can be modified to correct the problem seen during this demonstration. However, complete evaluation and validation of this technology cannot occur until that happens.

Hill AFB has expressed a strong desire to have this treatment cart operational. Without additional federal funding, the only option to meet this desire is for Global Finishing to determine the definitive cause of the problem and provide a solution. If this occurs, there could be an effort to fund and execute another field test. This report will then be amended to include the results. Technology transfer efforts are suspended until this occurs.

Some implementation issues to consider if this technology is properly validated include: intellectual property rights are held by the University of Illinois and the U.S. Army (should be non-issue with future government implementations); each unit would be custom made to accommodate an application; available carbon fiber varies in uniformity; and the filters are currently crafted by researchers. It is expected that the need for high customization of this technology could be curtailed with each progressive application. The filter construction, for example, could easily be contracted out with specific design specifications. However, the issue of scale-up provides challenges, as shown by this demonstration effort, and would still require significant technical assistance.

Probably the most difficult aspect of transferring VaPRRS will be the design customization or the ability to create a new design for a new application. It has been realized that with each new application reviewed, new factors seem to present themselves to the extent that all design characteristics must be reconsidered. Each design effort must consider the contaminant(s) properties, air flow rate, regeneration timeframe, footprint, power availability, and other details unique to the application. The filter array design process must then include consideration of many dependent specifications. These specifications include the level of activation for the carbon fiber cloth, the mass of carbon cloth, the layers of cloth per filter, the physical size of the filters, the pressure drop through the filters, the power requirements, and the arrangement of the filters to achieve the desired overall electrical resistance (series/parallel). However, most of these considerations not involving electricity are common with adsorption-based systems.

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Appendix A: Points of Contact

POINT OF CONTACT Name	ORGANIZATION Name Address	Phone Fax E-mail	Role in Project
K. James Hay	U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, 2902 Newmark Dr., P.O. Box 9005, Champaign, IL 61826-9005	(217) 373-3485, Fax (217) 373-3430, kent.j.hay@usace.army.mil	Project Manager, technical support
Patrick D. Sullivan	Air Force Research Laboratory, AFRL/RXQL, 139 Barnes Drive, Suite 2, Tyndall AFB, FL 32403-5323	(850) 283-2898, Fax (850) 283-6064, Patrick.Sullivan@tyndall.af.mil	System design, filter manufacture, Air Force coordination
Mark J. Rood	University of Illinois, Dept. of Civil and Environmental Engineering, 205 N. Mathews Ave., Urbana, IL 61801-2352	(217) 333-6963, Fax (217) 333-6968, mrood@illinois.edu	Technical support, field testing and analysis.
Ken Walter	309 AMXG/ENO Hill AFB, UT 84056-5231	(801) 586-6731 (801) 430-4816 Ken.Walter@HILL.af.mil	Environmental Contact at Hill AFB
Glen Baker	Process Engineering, Aircraft Coatings Application and Removal, 309AMXG/EN, Hill AFB, UT 84056-5231	Fax: 801-777-4352 Cell: 801-940-6261 Glen.Baker2@HILL.af.mil	Process Engineering Contact at Hill AFB
Brandon Leinon	Global Finishing Solutions, 12731 Norway Road, Osseo, WI 54758	(715) 597-8151, BLeinon@globalfinishing.com	Subcontractor for VaPRRS™ system construction
John Creed	Hunter Manufacturing Company, 30525 Aurora Rd, Solon, OH, 44139	(440) 248-6111, john.creed@huntermfgco.com	Primary Contractor for VaPRRS ™ system construction

Appendix B: Installation, Operation, and Maintenance Manual for VAPRRS Filtration System

This appendix contains the first 30 pages of the manual created by Global Finishing for the VAPRRS™ Filtration System (220 pages total). The included pages contain detailed electrical diagrams, a parts list, a logic diagram, descriptions of the sequences of operation, and a preventative maintenance checklist. The omitted pages consist of auxiliary equipment specifications and manuals. The full manual is available from Global Finishing Solutions (see contact info at bottom of manual pages) or from the ERDC-CERL principal investigator, K. James Hay (Kent.J.Hay@usace.army.mil).

Installation, Operation, and Maintenance Manual

Customer: U of I/ACOE/Hunter Manufacturing

End-User: Hill AFB, UT

Customer P.O. #: 4500028887

Global Model #: VAPRRS Filtration System

Global Serial #: 92035

Read and keep this manual for future reference.

All personnel operating the equipment described in this manual should review and understand all instructions before use.

12731 Norway Road • P.O. Box 250 • Osseo, Wisconsin 54758

Phone:(800)848-8738 • Fax: (715)597-2193

www.globalfinishing.com

Revision: 01-02-06

Global Finishing Solutions L.L.C.

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General Information

IMPORTANT!
Read and save these instructions before attempting to assemble, install, operate, or maintain the product described. Protect yourself and others by observing all safety information. Failure to comply with instructions could result in personal injury and/or property damage. Retain these instructions for future reference.

Introduction

A Message for the Purchaser

The management and employees at Global would like to thank you for selecting our product for your industry. Our product conforms to Occupational Safety & Health Administration (OSHA) and National Fire Prevention Association (NFPA) regulations for your safety. The employees of Global understand the importance of a quality system and strive to manufacture the best product on the market.

IMPORTANT!
This equipment is designed expressly for the removal of particulate matter only. Reduction of volatile organic compounds (VOCs) requires either coating reformulation or optional, additional equipment.

Safety Information

IMPORTANT!
This manual contains statements relative to worker safety. Read this manual thoroughly and comply as directed. Operate this equipment in accordance with the guidelines set forth in this manual. It is impossible to list all potential hazards of this equipment. Instruct all personnel involved with this equipment in the safe conduct and operation of the system. Global recommends that only qualified personnel operate and maintain this equipment.

General Safety

Operation and maintenance of this product must be performed properly by qualified personnel who observe the warnings in all documentation and notes provided with and on the product.

Follow all general standards for installation and safety for work on installations. Follow all good practices for the proper use of lifting tackle and equipment. The use of protective equipment such as safety goggles and protective footwear must be considered.

If any pumps or compressors are included as part of this installation, they must be connected in compliance with data in the documentation provided.

Guards and covers that prevent contact with electrically energized or moving parts are required to direct the flow of air for effective cooling. They must not be removed or left open during operation.

Sound pressure levels over 85 decibels may cause damage to your health. Where applicable, use earplugs or take other safety measures to protect yourself.

Safety Notes

- The product must be installed and serviced only by a trained, qualified service technician. Incorrect installation may void the warranty.
- All persons who will operate, service, inspect, or otherwise handle this product must read and understand the safe operating practices, safety precautions, and warning messages in this documentation.
- Disconnect and lock out the main electrical service before installing, adjusting, or servicing the product.
- Electrical installation should be completed by a qualified electrician. Installation must meet all applicable national, state, and local electrical codes.
- Ensure that all electrical components are grounded to a central ground.
- Become familiar with all controls.
- Safety signs, panels, and labels that are normally affixed to the product must be replaced immediately if illegible or missing.
- New or replacement parts that are installed during repair or maintenance must include all safety signs, panels, and labels as specified by the manufacturer. These must be affixed to the new or replacement parts as specified by the manufacturer.
- If this product is a spray or powder coating booth, some activities may require the use of respiratory protection.

Safety Precautions

- Install the product in compliance with the standards of the NFPA.
- Comply with all local electrical, safety, and fire codes and regulations, the National Electrical Code (NEC), and OSHA guidelines.
- If this product is a spray or powder coating booth, turn the exhaust fan on before using the booth. Ensure that the exhaust fan is operating correctly before entering the booth.
- For booths, check local codes to see if a booth interlock is required. A booth interlock will prevent the spray devices from operating unless the booth fan is operating.
- A fire suppression system (sprinklers or dry chemical) may be required by the NFPA. A fire suppression system is not supplied with this product.
- The use of a solenoid valve may be required by the NFPA. Solenoid valves are not supplied with this product except by optional purchase.
- When spraying in a booth, use an OSHA-approved paint spray respirator.
- Do not operate a spray booth when the manometer indicates the filter pad needs to be replaced.
- Treat used arrestor filter pads and any other paint-contaminated items as flammable products and dispose of them properly and safely.
- If applicable, duct the exhaust air from the fan away from the working environment to the outdoors. (Do not operate a paint booth unless exhaust has been ducted properly.)
- Isolate the outdoor vent from air-conditioning intakes, windows, and any other equipment that may re-circulate the exhaust indoors.
- For products with a manometer: Do not overfill the manometer, allowing fluid to collect in the flexible plastic connecting loop in the back of the manometer. This could cause a serious reading error. If the manometer is subject to overflow, make sure that the fluid has not passed into the plastic connecting loop.

SAFETY HAZARD!

There are inherent hazards associated with the operation and service of this equipment. For your personal safety, observe all of the safety information. Failure to observe these safety practices can result in personal injury or death.

Department Reference Guide

Use the following guide to help you determine whether to contact the parts department or the customer service department with your questions. To contact either department, call **(800) 848-8738**. Then follow the voice prompts for the correct department. You may leave a message on the voice mail system, and someone will get back to you as soon as possible. If you prefer to send a fax, dial (715) 597-2193. Be sure to address the correct department on your fax.

When you order parts for your product, it is important to know the following information BEFORE ordering. You can find this information about your product on the front cover of this operation and maintenance manual. Please have the following items at hand when you are placing an order:

- Model number
- Serial number

Located on the front cover of this manual or on the ID plate on the man door or fire curtain

- Part number, description, and part quantity
- Purchase order number
- Preferred shipping method (UPS, Federal Express, truck, air, etc.)
- Complete shipping and billing addresses

Parts Department

All standard and custom products are designed and built by Global Finishing Solutions. All parts are retained on file for immediate reference, replacement, and availability.

Pricing for Parts

Current prices and delivery costs will be quoted F.O.B. from Osseo, Wisconsin, Postal Code 54758.

Supplier to Stock New/Replacement Parts

For replacement parts and supplies, contact the parts department. We will help you locate your nearest distributor.

NOTE

If you have questions about the warranty, please contact your distributor prior to contacting Global Finishing Solutions.

Customer Service

Global Finishing Solutions provides ongoing customer and technical support for its customers. You can reach a customer service representative during regular business hours.

Returning Parts

- All goods to be returned for credit or exchange must be accompanied by a Return Goods Authorization form. Call Global Finishing Solutions to request form. Goods are subject to a 30% handling charge.
- Special non-stock items can be accepted only with the approval of our suppliers and are subject to any additional handling and restocking charges.

Availability and Service

Critical operational parts for productions and customer safety will be shipped overnight when possible.

Operation and Maintenance Manuals

Global includes an electronic copy of the operation & maintenance manual with each job. You may purchase additional electronic or printed manuals by contacting customer service.

Other Services

- Installation questions
- Arrange for an installation
- Arrange for a service call
- Notify Global Finishing Solutions of undelivered parts or other shipment problems

Limited Warranty

GLOBAL (the Sellers) warrants to the original end-user buyer (the buyer) that the equipment manufactured by, and purchased from, the Seller (the Equipment), if properly installed in accordance with the Seller's Service Manual, operated, and maintained, and used under normal conditions, shall be free from defects in workmanship and materials for a period of one (1) year from the date the Equipment is shipped from the facilities of the Seller. The obligation of the Seller, and the Buyer's SOLE AND EXCLUSIVE REMEDY hereunder, shall be limited to one of the following, at the Seller's option:

(01) The repair or replacement of defective parts or components (collectively, the Parts) of the Equipment; provided, however, the Buyer shall be responsible for the payment of all labor costs associated with any such repair or replacement.

(02) In the event the Seller is unable to repair or replace the defective Parts, the Buyer shall be entitled to a refund of the cost of the Parts.

The Seller shall have no obligation under this Limited Warranty for ordinary wear and tear of the Equipment; if installation of the Equipment does not comply with local, state and federal requirements or laws; or if the Equipment is modified by any other person or organization. The Seller makes no warranty of any kind whatsoever with respect to Parts, which are manufactured or supplied by other persons or organizations (an OEM); provided, however, the Seller shall reasonably assist the Buyer in connection with warranties, if any, provided by an OEM.

Warranty Performance Procedures

In the event the Buyer believes the Seller may be responsible for the performance of any warranty obligation, the Buyer must immediately send written notice of a claimed defect, and must immediately refrain from any further use of the affected Equipment. No attempted repair of the claimed defect may be made without the prior written consent of the Seller. Before any Parts can be returned to the Seller, the Buyer must contact the Seller and request a Return Authorization. Upon the Buyer's receipt of the Return Authorization form, the Parts may be shipped, freight prepaid, to the facility designated on the Return Authorization. All Parts returned for repair, replacement, or refund (a refund may be made in the form of a credit to the Buyer's account), must be accompanied by the Return Authorization. All returned parts are subject to a thirty percent (30%) handling charge. Parts manufactured or supplied by an OEM are subject to the warranties, if any provided by such OEM's; and repair or replacement of such Parts are subject to the approval of the OEM. The Buyer shall be responsible for the payment of any handling or restocking charges associated with OEM Parts.

Disclaimers of Warranties

THE WARRANTIES CONTAINED HEREIN ARE EXPRESSLY IN LIEU OF ANY OTHER EXPRESSED OR IMPLIED WARRANTIES, OR ANY OTHER OBLIGATION ON THE PART OF THE SELLER, INCLUDING WITHOUT LIMITATION, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. ANY MODELS, DRAWINGS, PLANS, SPECIFICATIONS, AFFIRMATION OF FACT, PROMISES, OR OTHER COMMUNICATIONS BY THE SELLER WITH THE REFERENCE TO THE EQUIPMENT OR THE PERFORMANCE OF THE EQUIPMENT ARE SOLELY FOR THE CONVENIENCE OF THE BUYER AND SHALL NOT IN ANY WAY MODIFY THE EXPRESSED WARRANTIES AND DISCLAIMERS SET FORTH HEREIN. THE BUYER ACKNOWLEDGES IT IS PURCHASING THE EQUIPMENT SOLELY ON THE BASIS OF THE COMMITMENTS FOR THE SELLER AS EXPRESSLY SET FORTH HEREIN. NO AGENTS OR OTHER PARTIES ARE AUTHORIZED TO MAKE ANY WARRANTIES ON BEHALF OF THE COMPANY OR TO ASSUME FOR THE COMPANY ANY OTHER LIABILITY OR OBLIGATION IN CONNECTION WITH THE EQUIPMENT.

Consequential Damages

The Seller shall not be liable for any incidental or consequential damages arising from the use of the equipment by the Buyer, the breach of any warranties, the failure to deliver, delay in delivery, delay on nonconforming condition, or for any other breach of contract or duty between the Seller and the Buyer.

Limitation of Actions

Any action resulting from the breach of any warranty contained herein by the Seller must be commenced within one (1) year after the cause of action accrues. In no event shall the Seller's total liability for any or all breaches of any warranty exceed the actual purchase price paid by the Buyer for the Equipment.

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PREVENTIVE MAINTENANCE SERVICES

Why is preventive maintenance service important?

- Extends the life of the equipment
- Minimizes unscheduled downtime that can cause major problems in production
- Maintains consistency in your product quality

Preventive Maintenance can be defined as a program in which wear, tear, and change are anticipated, and continuous corrective actions are taken to ensure peak efficiency and performance to minimize premature deterioration. Minimize downtime by correcting minor problems before they become major repairs. A detailed service record is instrumental tracking booth performance, a service report baseline of booth performance can be established as all of the critical set points and readings are recorded.

Preventive Maintenance involves a planned and controlled program of systematic inspections, adjustment, lubrication, and replacement of components, as well as performance testing and analysis. However, we realize that equipment grows old, uses change, and techniques vary. Our experienced staff takes these circumstances into consideration so an effective maintenance program is performed to keep your equipment running safely and efficiently.

THE PROGRAM

Servicing Packages

Tailored to meet your needs, service engineers will provide maintenance and cleaning to ensure that your equipment maintains optimal performance. The program can include anything from the general maintenance of the booth to cleaning, and the replacement of filters.

Filter Packages

The key to optimal spraybooth performance is the regular monitoring and changing of filters. GFS can supply flexible filter packages that will accommodate all types of spraybooths. Based on your projected demands, GFS will provide scheduled "Just in Time" delivery, reducing your management time and storage space needs, while keeping your booth running efficiently and providing superior finishes!

Periodic Assessments

Complying with health and safety regulations is very important to your business. Our service engineers will assess your equipment to help you avoid costly down times and keep your operation running smoothly.

THE BENEFIT

Reduced Operating Costs

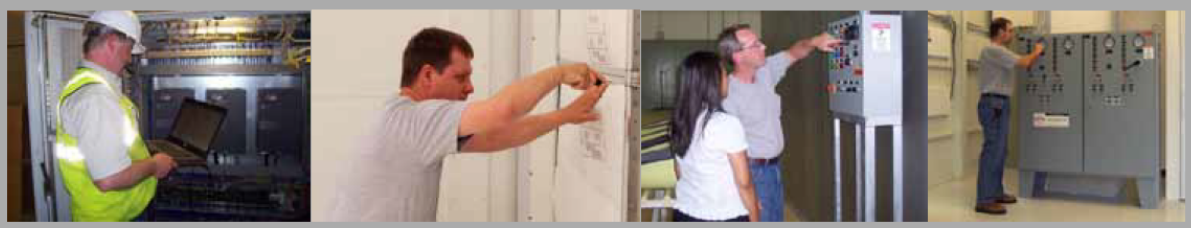
GFS' Preventive Maintenance program helps keep fuel costs down by maintaining a paintbooth that is clean and runs at its optimum performance all year long. The program also provides regularly scheduled maintenance visits that will result in a reduction of emergency service calls throughout the year, therefore reducing the amount of down time and increasing productivity.

Improved Quality Finishes

Poorly maintained spraybooths are usually full of contaminants and do not produce a good quality finish. Scheduled filter changes along with preventive maintenance will maintain quality and reduce costly repaints.

Complete Service

GFS Technicians can provide services for Spraybooths, Paintbooths, Large Equipment and Large Vehicle Booths, Body Shop Refinishing Spraybooths, Finishing Systems, Aviation Paintbooths, Industrial Finishing Equipment including Ovens and Washers.



Preventive Maintenance Checklist

Preventive maintenance programs insure safe and reliable operation and contribute to the longevity of the equipment. The following is a suggested routine maintenance program broken down into lists of periodic tasks.

It is the responsibility of the end user to develop an inspection, testing, and maintenance program to ensure that the equipment is in safe working order. Hours of operation and work environment should be considered when establishing frequency of maintenance.

It is suggested that logs are kept so that any variation from normal readings can uncover trouble areas and help prevent serious problems from developing.

It is imperative that all personnel involved with this equipment be instructed in the safe conduct and operation of the system. Routine maintenance and safety checks should be performed by qualified personnel only. Contact the GFS Technical Service Group for availability of Preventive Maintenance Contracts and Other Services.

☐ **Exhaust Fan(s)**

A) Lubrication: Fan & Motor Bearings ..... ☐
B) Belts: Check Condition (replace if needed), Adjust Tension ..... ☐
C) Sheave: Check Set-screws and Record setting ..... ☐
D) Impeller: Inspect (clean as needed), Check Set-screws ..... ☐

☐ **Air Make-up Unit(s)**

A) Lubrication: Fan & Motor Bearings ..... ☐
B) Belts: Check Condition (replace if needed), Adjust Tension ..... ☐
C) Sheave: Check Set-screws and Record setting ..... ☐
D) Blower: Inspect (clean as needed), Check Set-screws on Bearings and Blower(s) ..... ☐
E) Burner:
1) Clean as needed - Manifold ports, Flame rod, Igniter & Pilot assembly ..... ☐
2) Set Airflow SWITCH(ES) ..... ☐
3) Check / Adjust: Pilot Flame, Low fire, High fire - Temp. Rise ..... ☐
F) Controls: Flame Safety Relay - Test Flame Failure Shutdown, Note Fault History, Current Run Hours & Cycle # ..... ☐
G) Dirty Filter Switch: Check Operation & Adjust Trip Point as needed ..... ☐
H) Terminal Strips: Check / Tighten All Terminations ..... ☐
I) Damper: Check Operation, Clean and Adjust as needed ..... ☐

☐ **Filters**

A) Intake: Inspect & Replace as needed ..... ☐
B) Exhaust: Inspect & Replace as needed ..... ☐
C) Manometer(s)/Filter Draft Gauge(s): Adjust/Set Zero, Fill Gauge Oil as needed ..... ☐

☐ **Booth Balance**

A) Check Booth / Building Balance ..... ☐
B) Check Booth Airflow ..... ☐
C) Check Current Draw: Exhaust Motor(s) & AMU(s) ..... ☐
D) Adjust Sheaves and / or VFD Settings to Achieve Proper Booth Airflow & Balance ..... ☐

☐ **Control Panel**

A) Pilot / Indicator Lights: Check Operation & Replace any Burned Out Bulbs ..... ☐
B) Temperature Control: Verify Operation (adjust as needed) ..... ☐
C) Operation: Observe System Start Sequence (adjust Timers as needed) ..... ☐
D) Photohelic (Auto-balance & Consta-flow): Set Zero, Verify Operation, Adjust Setpoints for Optimum Control ..... ☐
E) Ventilation (VFD Systems Over 7.5 HP): Verify Fan Operation & Inspect Filters (Clean as needed) ..... ☐
F) PLC (Paint/Bake Systems Serial 30000 & Newer): Verify Auto Reset is Enabled ..... ☐

☐ **Misc. & Optional Items**

A) Air Solenoid Valve: Verify Operation ..... ☐
B) Light Lens Switches: Verify Operation & Adjust as needed ..... ☐
C) Door Switches: Verify Operation & Adjust as needed ..... ☐
D) Dirty Filter Shutdown: Verify Operation & Adjust as needed ..... ☐
E) Airflow Switches: Verify Operation & Adjust as needed ..... ☐

OVERVIEW OF MAINTENANCE TRAINING

Upon request GFS can also provide your operating and maintenance personnel with hands-on training, or technical assistance, during our visit.

Operators

Controls: Main Disconnect, Pilot / Indicator Lights, Switches and Pushbuttons, Temp. Selector/Controller, Photohelic, Bake Cycle Timer

Manometer: Setting Zero, Reading Filter Loading

Safeties: Air Solenoid Valve, Light Lens Switches, Door Switches and Dirty Filter Shutdown

Maintenance Training

System Overview: Start-up Sequence, Electrical Schematic, Interlocks

Resets: Exhaust Overload, VFD Faults

AMU: Blower Motor Overload, High Temp Limit, Flame Failure, High/Low Gas Pressure limit

Questions or Requests

We will be glad to discuss your service needs and help determine which program is a good choice for you.

GLOBAL FINISHING SOLUTIONS

techservices@globalfinishing.com

(800)848-8738

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Notes:
1) All times are estimates
2) Labor rates include travel time.
3) Travel time may be divided between multiple customers in one area.
4) Additional expenses including but not limited to:
Fuel, lodging, meals (per diem), airline tickets, etc…will be in addition to the hourly labor rate.
5) Replacement belts and filters can be provided by GFS for additional cost
This must be requested in advance.
6) Customer must supply means to access equipment Ladders, manlifts, etc…
7) Equipment must be shutdown to perform service.

SPARE PARTS LIST

Part Number	
242-005	STATIC PRES TIP FOR .25 STEEL TUBE
242-007	TUBING POLYETHYLENE .250 OD .170 ID
242-014	SWITCH PROXIMITY CL 1 DIV 2
208-030	HINGE 2.5WX10LX.125T HALF SWAGED ST
208-030A	HINGE PIN .375 DIA FOR 2.5WX10LX.12
208-037	DOOR LATCH BRIXON #83P CAST STEEL
208-040	DOOR PULL STANDARD ZINC
208-094	DOOR LATCH BRIXON #2P CAST IRON
208-119	HINGE 2.5WX4LX.125T PARTLY SWAGED
208-119A	HINGE PIN 2.5WX4LX.125T P SWAGED
216-309	FILTER CLIP C-78-4 FARR FILTER
248-003	SEAL TAPE .50 X .25 CLOSED CELL
248-011	RUBBER STRIP .125 X 3.0 WIDE
248-082	SEAL TAPE P SEAL-EPDM 1.25 X.50
134-268	VFD 5.0 HP 380-480 VOLT VT MIT SERIES A
134-306	VFD 5.0 HP 400V MIT D700 SERIES D
Z92035A FILTER STAGE 3 24" X 24" A-3000 BAG FILTER P/N: 4109222	Z92035A FILTER STAGE 3 24" X 24" A-3000 BAG FILTER P/N: 4109222
Z92035A FILTER STAGE 1 24" X 24" ULTRA MEDIA P/N: 4100392	Z92035A FILTER STAGE 1 24" X 24" ULTRA MEDIA P/N: 4100392
Z92035A FILTER STAGE 2 24" X 24" OSM 100 PANEL P/N: 4101398	Z92035A FILTER STAGE 2 24" X 24" OSM-100 PANEL P/N: 4101398
Z92035A MONITOR CHEMGARD MSA QUOTE 100430	A-3800-XX-1-1-1-0-0-0-0-0-D-0-N-C MSA CHEMGARD PHOTOACOUSTIC INFRARED GAS MONITOR. XX = FOR METHYL N-PROPYL KETONE. 1 = ONE SAMPLE POINT. 1 = INTERNAL SAMPLING PUMP. 1 = 0-1000 PPM. 0 = NO ALARM. 1 = ONE STANDARD END OF LINE FILTERS. 1 = 1 FILTERS. 0 = NO RELAYS. D = DISPLAY. 0 = NO SECOND SENSOR. N = NEMA 4X ENCLOSURE. C = CUSTOM GAS.
Z92035A CALIBRATION KIT MSA QUOTE 100430	A-CAL-50F-10028028-00-0-10028034 MSA CALIBRATION KIT INCLUDING CASE AND THE FOLLOWING: 50 = KIT NUMBER FOR CHEMGARD. F = REGULATOR 1.5 LPM. 10028028 = CYLINDER 20.8% OXYGEN IN NITROGEN, 98 LITER 00 = NO SECOND KIT. 0 = NO SECOND REGULATOR. 10028034 = CYLINDER OF .6% PROPANE IN AIR.
Z92035A HOSE ADAPTER 18" DIA P/N: 15218	Z92035A HOSE ADAPTER 18" DIA P/N: 15218
Z92035A ADAPTER FLANGED 18" DIA P/N: 15118	Z92035A ADAPTER FLANGED 18" DIA P/N: 15118
Z92035A PINTLE EYE 3 OD PMP96250	Z92035A PINTLE EYE 3 OD PMP96250

SPARE PARTS LIST

Part Number	
Z92035A CASTER WHEEL ALBION 61X106201SLCB 6" DIA W/SWIVEL LOCK AND CAM BRAKE	Z92035A CASTER WHEEL ALBION 61X106201SLCB 6" DIA W/SWIVEL LOCK AND CAM BRAKE
Z92035A SIEMENS 8 POINT OUTPUT CARD 6ES7 222-1HF22-0XA0	Z92035A SIEMENS 8 POINT OUTPUT CARD 6ES7 222-1HF22-0XA0
Z92035A DIN RAIL ADAPTER DRA-2	Z92035A DIN RAIL ADAPTER DRA-2
Z92035A AC CURRENT TRANSDUCER, FIXED CORE 4-20mA OUT ACTR050-42L-F	Z92035A AC CURRENT TRANSDUCER, FIXED CORE 4-20mA OUT ACTR050-42L-F
Z92035A SIEMENS 8 POINT ANALOG INPUT CARD 6ES7 231-OHF22-0XA0	Z92035A SIEMENS 8 POINT ANALOG INPUT CARD 6ES7 231-OHF22-0XA0
Z92035 BRASS CRYOGENIC SOLENOID VALVE 24VDC. MMC#50585K999	Z92035 BRASS CRYOGENIC SOLENOID VALVE 24VDC. MMC#50585K999
Z92035A PINTLE EYE 3 OD PMP96250	PURCHASED FROM: WISCONSIN OVEN CORPORATION 2675 MAIN ST. PO BOX 873 EAST TROY, WI. 53120 262-642-3938
Z92035A SIEMENS 8 POINT INPUT CARD 6ES7 221-1BF22-0XA0	Z92035A SIEMENS 8 POINT INPUT CARD 6ES7 221-1BF22-0XA0
Z92035A SIEMENS 8 POINT OUTPUT CARD 6ES7 222-1HF22-0XA0	Z92035A SIEMENS 8 POINT OUTPUT CARD 6ES7 222-1HF22-0XA0
Z92035A CURRENT APERTURE ACU-AMP ACT200-10-F, AC CURRENT 0-200 AMP 0-10VDC SIGNAL	Z92035A CURRENT APERTURE ACU-AMP ACT200-10-F, AC CURRENT 0-200 AMP 0-10VDC SIGNAL
Z92035A MONITOR ULTIMAX MSA QUOTE 101606	ULTIMAX-PL-A-64-0-3-S-0-0-0-1-1-1-1-1. MSA ULTIMAX SERIES GAS MONITOR W/LCD DISPLAY & INTERCHANGEABLE SMART SENSORS A = GP PLASTIC W/DISPLAY. 64 = LOW SOLVENT TOLERANT OXYGEN SENSOR. 0 = N.A. VERSION. 3 = 3-WIRE MA OUTPUT. S = SENSOR MNTD ON CTL UNIT. 0 = NO RELAYS & NO LED'S. 0 = ENGLISH. 0 = NO POWER SUPPLY. DC BY OTHERS. 1 = FLOW CAP ASSMY. 1 = RESET/CAL SWITCH. 1 = MNTG BRKTS INCL. 1 = HARDCOPY & CD INCL. 0 = NO CUSTOM FEATURES.
Z92035A SAMPLING MODULE	10058101 MSA SAMPLING MODULE ASSEMBLY, ASPIRATOR, FOR ULTIMAX.
Z92035A CALIBRATION KIT	A-CAL-40-F-10028028-00-0-49350. MSA CALIBRATION KIT INCL CARRYING CASE, TUBING, FITTINGS, & INDICATED SPAN GAS & REG. 40 = FOR ULTIMAX. F = 1.50 LPM (467896) REG. 10028028 = CYLINDER ZERO AIR 20.8% OXYGEN IN NITROGEN. 00 = 2ND CALIBRATION KIT NOT SELECTED. 0 = 2ND REG NOT SELECTED. 49350 = CYLINDER OF 5% OXYGEN IN NITROGEN.
Z92035A CONTROL VALVE	3522-7. SAMSON SERIES 3520 PNEUMATIC CONTROL VALVE INCLUDING 3277 ACTUATOR & 3730-1 POSITIONER.
Z92035A REDUCING VALVE	44-1. SAMSON PRESSURE REDUCING VALVE TYPE M 44-1. 1/2" GLOBE VALVE W/NPT CONNECTION & SET POINT OF 2-30 PSIG

SPARE PARTS LIST

Part Number	
Z92035 BRASS CRYOGENIC SOLENOID VALVE 24VDC. MMC#50585K999	Z92035 BRASS CRYOGENIC SOLENOID VALVE 24VDC. MMC#50585K999
Z92035 SAGE THERMAL MASS FLOW METER FOR FLOW RATE OF NITROGEN GAS	PART # SIP-05-050-DC24-N2 SAGE METERING PRIME MASS FLOW METER SIP- TRANSMITTER INTEGRAL WITH FLOW TUBE 05- 1/2" PROBE DIAMETER 050- 1/2" INLINE STYLE FLOW BODY DC24- 24 VDC OPERATING POWER N2 NITROGEN CALIBRATION
Z92035A 18E-4-80H-11C-12 PAYNE VARIABLE VOLTAGE CONTROL SCR	Z92035A 18E-4-80H-11C-12 PAYNE VARIABLE VOLTAGE CONTROL SCR
Z92035A 1/2" S/S TANK FLANGE #11671-01835	Z92035A 1/2" S/S TANK FLANGE #11671-01835
Z92035A SIEMENS 8 POINT ANALOG INPUT CARD 6ES7 231-OHF22-0XA0	Z92035A SIEMENS 8 POINT ANALOG INPUT CARD 6ES7 231-OHF22-0XA0
Z92035 CURRENT TRANSFORMER 60:5 PART# CR2RL-600	Z92035 CURRENT TRANSFORMER 60:5 PART# CR2RL-600
Z92035 CURRENT TRANSDUCER 3 ELEMENTS 0-5 VOLT OUPUT PART# CR4170-5	Z92035 CURRENT TRANSDUCER 3 ELEMENTS 0-5 VOLT OUPUT PART# CR4170-5
Z92035 VOLTAGE TRANSDUCER3 PH / 3W 0-5 VOLT PART# CR4550-500	Z92035 VOLTAGE TRANSDUCER3 PH / 3W 0-5 VOLT PART# CR4550-500
Z92035 5VDC MEAN WELL POWER SUPPLY PART#: DR-60-5	Z92035 5VDC MEAN WELL POWER SUPPLY PART#: DR-60-5
Z92035 FUSE 600 VOLT 3 AMP CC KLDR LITTLEFUSE PART# KLDR003	Z92035 FUSE 600 VOLT 3 AMP CC KLDR LITTLEFUSE PART# KLDR003
Z92035 3AAA6 THERMOCOUPLE 4" PROBES/ 8 FOOT LEADS	Z92035 3AAA6 THERMOCOUPLE 4" PROBES/ 8 FOOT LEADS
z92035 5WMZ7 24VDC 1/4IN VALVE NORMALLY CLOSED	z92035 5WMZ7 24VDC 1/4IN VALVE NORMALLY CLOSED
Z92035A ONE TANK OF LIQ NITROGEN	Z92035A ONE TANK OF LIQ NITROGEN
Z92035A ABV01.2NN BALL VALVES	Please Ship UPS Ground using our account# 587-382
Z92035 MOTOR DRIVEN 316 STAINLESS STEEL BALL VALVE MMC PART NO 46005K82	Z92035 MOTOR DRIVEN 316 STAINLESS STEEL BALL VALVE MMC PART NO 46005K82
Z92035A 13-PLG-II EXH GFC 6195977	2000 CFM @ 5" SP. 5 HP 3 PH TEFC EPACT MOTOR. 3600 RPM. 213T FR. FIXED DRIVE. ARR 9. CW ROT. SPARK "C" CONSTRUCTION. SHAFT SEAL - FELT W/RUB RING. VFD RATED MOTOR. BELT GUARD. SHAFT GUARD. ALUM INLET CONE. O/M'S.
304608	5 HP, 3600 RPM, TF, 60 CYCLE, 3 PH, 184T TFR, 460/230/208 V
345142	BELT AX34
351845	BUSHING SDS X 1 11/16 TB WOODS
351918	PULLEY, 4.6 X 2B SDS TB WOODS
352100	PULLEY 2AK41QT TB WOODS
352394	BUSHING QT X 1 1/8 TB WOODS
360268	BEARING, P2B-DLAH-111 #055143M 1-11/16IN
366189	SHAFT 1.688 X 28.25 2K

SPARE PARTS LIST

Control Panel	
101-074	CPLG RIGID CONDUIT .75
101-346	CONDUIT TEE .50 MALLABLE IRON
101-347	CONDUIT TEE .75 MALLABLE IRON
101-349	CONDUIT COVER .50 MALLABLE IRON
101-352	CONDUIT COVER GASKET .50 MALLABLE
101-469	1/2IN SEAL OFF XP UNIVERSAL
101-472	3/4IN SEAL OFF ELBOW XP
101-587	CONDUIT LIQUID TIGHT FLEX .75
101-588	LIQUID TIGHT CONNECTOR ST. .75
101-589	LIQUID TIGHT CONNECTOR 90 DEG .7500
101-590	CONDUIT LIQUID TIGHT FLEX .5
101-591	LIQUID TIGHT CONNECTOR ST. .500
101-593	LIQUID TIGHT CONNECTOR 90 DEG .50
101-610	CORD CONNECTOR .25NPT .135-.200
103-016	FUSE 250V 5 AMP CLASS RK5
103-021	FUSE 250V 10 AMP CLASS RK5
103-047	FUSE 600V 3 AMP CLASS RK5
103-102	FUSE BLOCK 250V 30 AMP 1 POLE
103-113	FUSE BLOCK 600V 30A 2POLE CLASS H
103-133	FUSE 2.5 A ELECTRONIC GLASS FA
103-162	FUSE 600V 10 AMP CLASS J
103-167	FUSE 600V 30 AMP CLASS J
103-172	FUSE 600V 60 AMP CLASS J
103-180	FUSE BLOCK 600V 30A 3POLE CLASS J
103-181	FUSE BLOCK 600V 60A 3POLE CLASS J
103-200	FUSE BLOCK 600V 30A 2POLE CLASS CC
105-018	SQD TRANS 1000VA OPEN 1PH 480-240/1
106-003	WIRE DUCT 1.5W X 3.0H
106-008	WIRE DUCT COVER 1.5
106-011	WIRE DUCT 1.0 ADHESIVE BACKING
106-012	WIRE DUCT 1.5 ADHESIVE BACKING
106-014	WIRE DUCT 1.5W X 2.0H
106-033	PHOENIX UT4 TERMINAL BLOCK
106-035	PHOENIX TERMINAL GROUND BLOCK
106-036	TERMINAL BLOCK END CLAMP
106-037	PHOENIX TERMINAL BLOCK END BARRIER
106-042	DIN RAIL
106-080	TERMINAL BLOCK - FUSED
107-001	ENCL NEMA 12 42X36X12 METAL
107-072	ENCL NEMA 12 42X36X10
107-125	ENCL BACK PANEL 10X8
107-152	ENCL BACK PANEL 42X36
107-175	ENCL NEMA 12 10x8x4

SPARE PARTS LIST

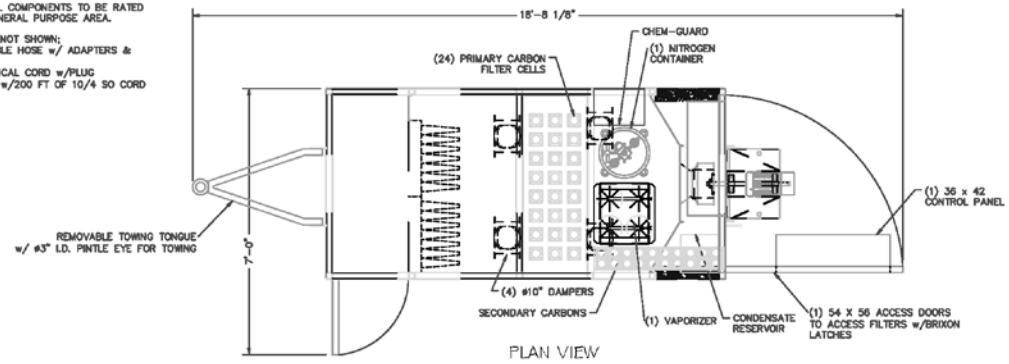
Control Panel	
107-230	ENCL NEMA 4 20X16X08 METAL
107-255	THERMOSTAT COOLING N.O.
107-281	ENCL FILTER/GRILL 4IN PF GRAY
107-290	ENCL COOLING FAN/FILTER 6IN 120V
107-291	ENCL FILTER/GRILL 6IN
107-292	ENCL COOLING FAN/FILTER 8IN 120V
107-293	ENCL FILTER/GRILL 8IN
111-056	RELAY BASE 1-POLE DIN IDEC
111-057	RELAY SPDT 120VAC COIL IDEC
111-060	RELAY BASE 2-POLE DIN IDEC
111-063	RELAY DPDT 120VAC COIL IDEC
111-281	PILOT LIGHT 22MM 120VAC GREEN LED
117-107	POWER SUPPLY 120VAC/24VDC 3A MWL
117-306	WIRE THERMOCOUPLE LEAD TYPE J
117-309	THERMOCOUPLE W/ TRANSMITTER 0-500 DEGREES F BLACK
117-332	TEMP HIGH LIMIT CONTROL 1/16 DIN
117-846	PRESSURE TRANSMITT +/0.5INWC 4-20MA
117-847	PRESSURE TRANSMITTER -2.5INWC 4-20MA
117-848	PRESSURE TRANSMITT +/-0.1WC 4-20MA
118-147	SQD CONTACTOR IEC 32 AMP 120V COIL
118-206	SQD CONTACTOR IEC 80 AMP
118-220	CONTACTOR IEC 50 AMP 120V COIL
118-431	PLC SIEMENS 224XP (2x COM PORTS)
118-437	SIEMENS TP177A 5.7IN B-W SINGLE PORT
118-450	PLC EXPANSION MODULE 4AO SCP
118-451	HMI/PLC COMMUNICATION CABLE TD200
123-012	BREAKER 3P 20A 600V HDL36020
123-017	BREAKER 3P 100A 600V HDL36100
123-020	ROTARY OPERATING MECH 9421LJ1 H&J
123-021	BREAKER POWER DISTRIBUTOR PDC6HD6
127-218	9001KR9RO5 PUSHBUTTON E. STOP
127-228	9001KA2 CONTACT BLOCK NORMALY OPEN
127-229	9001KA3 CONTACT BLOCK NORM. CLOSED
127-234	9001KR1U PUSH BUTTON
127-356	SHAFT EXTENTION KIT
127-403	GROUND BAR 15 SPACE
127-404	GROUNDING BAR LUG
127-405	GROUND BAR 7 SPACE
131-500	1492-PDM3111 DIST. BLK. 3POLE 1TO1

NOTES:

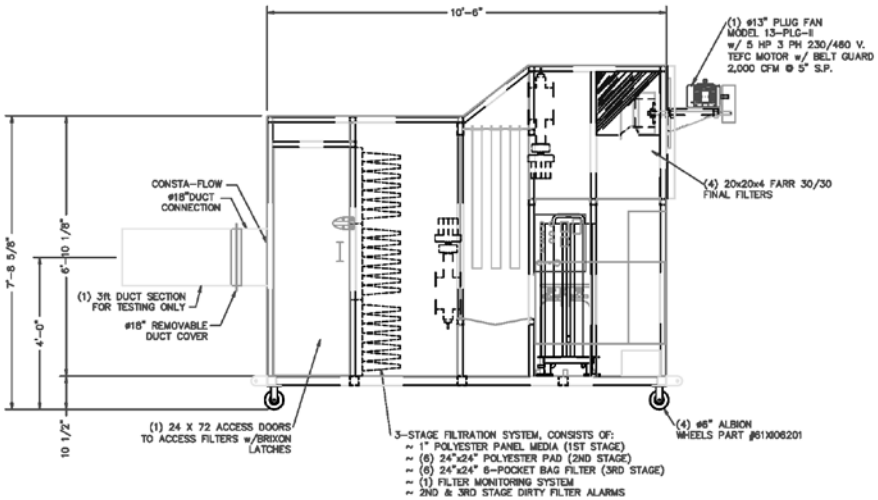
1. THE ENVIRONMENTAL UNIT IS FABRICATED FROM 12 GAGE HOT ROLLED STEEL & 12 GAGE STAINLESS STEEL, FACTORY PAINTED GRAY ENAMEL.

2. ALL ELECTRICAL COMPONENTS TO BE RATED FOR USE IN A GENERAL PURPOSE AREA.

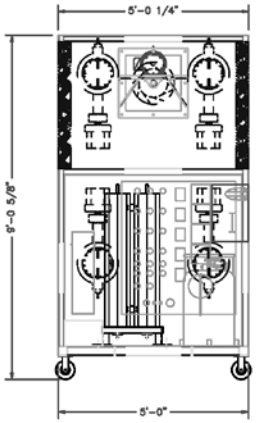
3. INCLUDED BUT NOT SHOWN;
   (2) 25FT FLEXIBLE HOSE w/ ADAPTERS & CLAMPS.
   (50 FT) ELECTRICAL CORD w/PLUG
   (1) MALE PLUG w/200 FT OF 10/4 SO CORD



PLAN VIEW



RIGHT SIDE ELEVATION



BACK END ELEVATION

BARRIE, ONTARIO, CANADA
MONTERREY, NUEVO LEON, MEXICO
DALLAS, TEXAS, USA
OSSEO, WI, USA
PHONE: 1 800-486-3072 or 1 800-648-8738

GFS®

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CONCEPT REVISION

REV-1	DATE:	BY:	REV-5	DATE:	BY:	REV-9	DATE:	BY:	REV-13	DATE:	BY:
REV-2	DATE:	BY:	REV-6	DATE:	BY:	REV-10	DATE:	BY:	REV-14	DATE:	BY:
REV-3	DATE:	BY:	REV-7	DATE:	BY:	REV-11	DATE:	BY:	REV-15	DATE:	BY:
REV-4	DATE:	BY:	REV-8	DATE:	BY:	REV-12	DATE:	BY:	REV-16	DATE:	BY:

GLOBAL FINISHING SOLUTIONS

APPROVED BY
PROJECT MGR.
REVIEWED BY
DATE

DESCRIPTION: POWER CART
SCALE: 3/4"=1'-0"
DRAWN BY: JCS
DATE: 4/22/10
CUSTOMER: HUNTER MANUFACTURING CO for HUNTER MANUFACTURING CO

WORK ORDER NUMBER: 56819
DRAWING NUMBER: 92035-01
SHEET 1 of 1

Digital Inputs:

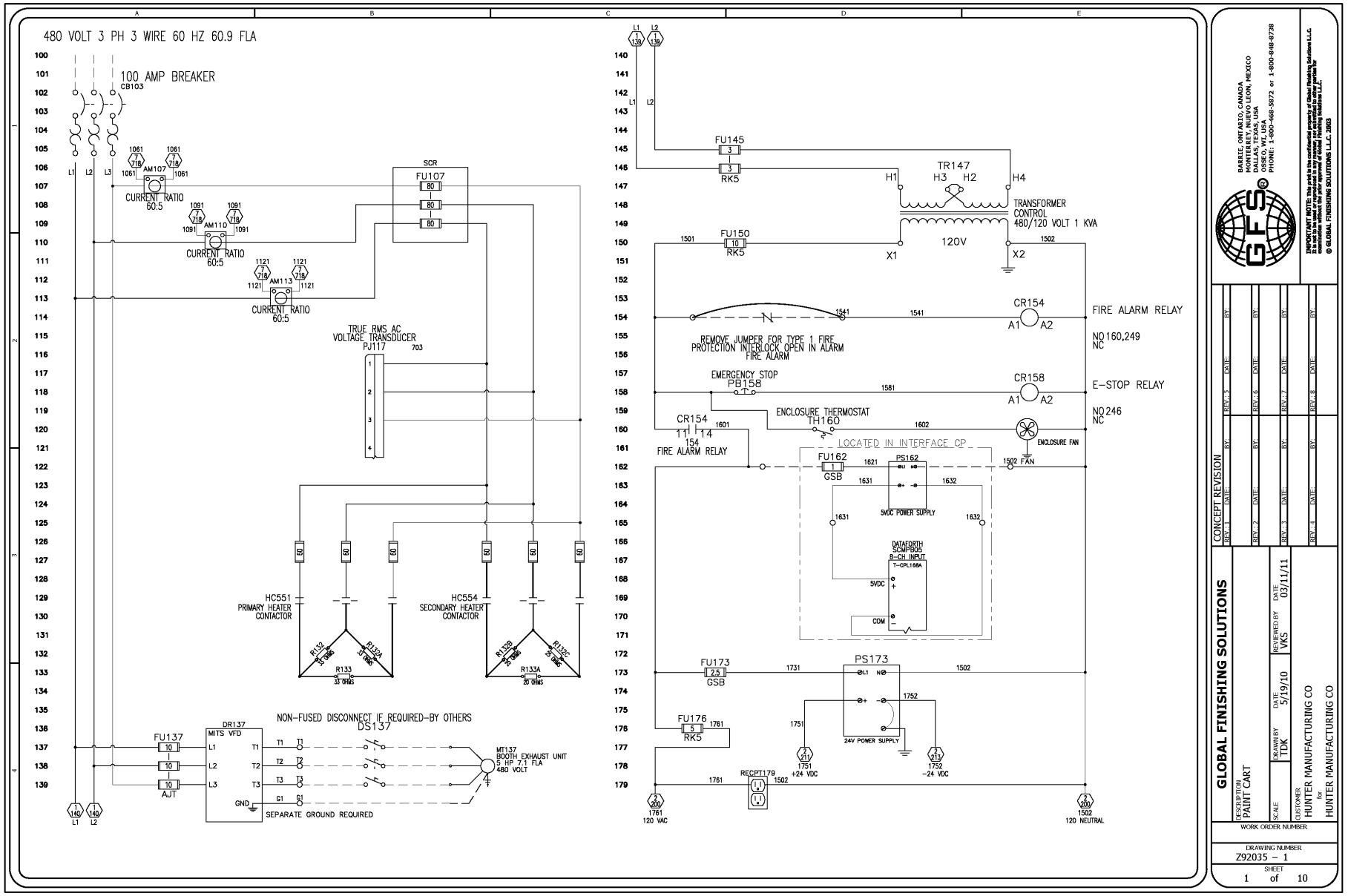
- E-Stop
- Start PB
- Stop PB
- Clean Filters 1 PB
- Clean Filters 2 PB
- Cancel Clean
- Door Closed LS
- Plug Fan Running
- Damper 1 Open LS
- Damper 1 Closed LS
- Damper 2 Open LS
- Damper 2 Closed LS
- SCR Running
- SCR Fault
- O2 Level acceptable

Digital Outputs:

- Running PL
- Cleaning PL
- Plug Fan STF
- Damper 1 Open
- Damper 1 Close
- Damper 2 Open
- Damper 2 Close
- Valve 3 "Primary Filter to Reservoir"
- Valve 4 'Vaporizer to Reservoir"
- Valve 5 'Reservoir Main'
- Valve 6 'Vaporizer to Atmosphere'
- Valve 7 'Nitrogen to

Analog Inputs:

- Consta-Flow Pressure
- Temp Feedback 1
- Temp Feedback 2
- Temp Power Unit Current Fbk
- Filter Mon #1 Pressure
- Filter Mon #2 Pressure
- Filter Mon #3 Pressure
- LEL Monitor
- O2 Level


480 VOLT 3 PH 3 WIRE 60 HZ 60.9 FLA
100 AMP BREAKER
CB103
CURRENT RATIO 60:5
SCR
FU107
TRUE RMS AC VOLTAGE TRANSDUCER
PJ117
HC551 PRIMARY HEATER CONTACTOR
HC554 SECONDARY HEATER CONTACTOR
NON-FUSED DISCONNECT IF REQUIRED-BY OTHERS
DS137
DR137
MITS VFD
FU137
AJT
MT137 BOOTH EXHAUST UNIT 5 HP 7.1 FLA 480 VOLT
SEPARATE GROUND REQUIRED
FU145
RK5
TR147
TRANSFORMER CONTROL 480/120 VOLT 1 KVA
120V
FU150
CR154
FIRE ALARM RELAY
NO 160,249
NC
REMOVE JUMPER FOR TYPE 1 FIRE PROTECTION INTERLOCK OPEN IN ALARM FIRE ALARM
EMERGENCY STOP
PB158
CR158
E-STOP RELAY
NO 246
NC
ENCLOSURE THERMOSTAT
TH160
ENCLOSURE FAN
LOCATED IN INTERFACE CP
FU162
GSB
PS162
5VDC POWER SUPPLY
DATAFORTH SCMP8020 8-CH INPUT
T-CPL168A
FU173
PS173
24V POWER SUPPLY
FU176
RECPT179
+24 VDC
-24 VDC
120 VAC
120 NEUTRAL
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CONCEPT REVISION
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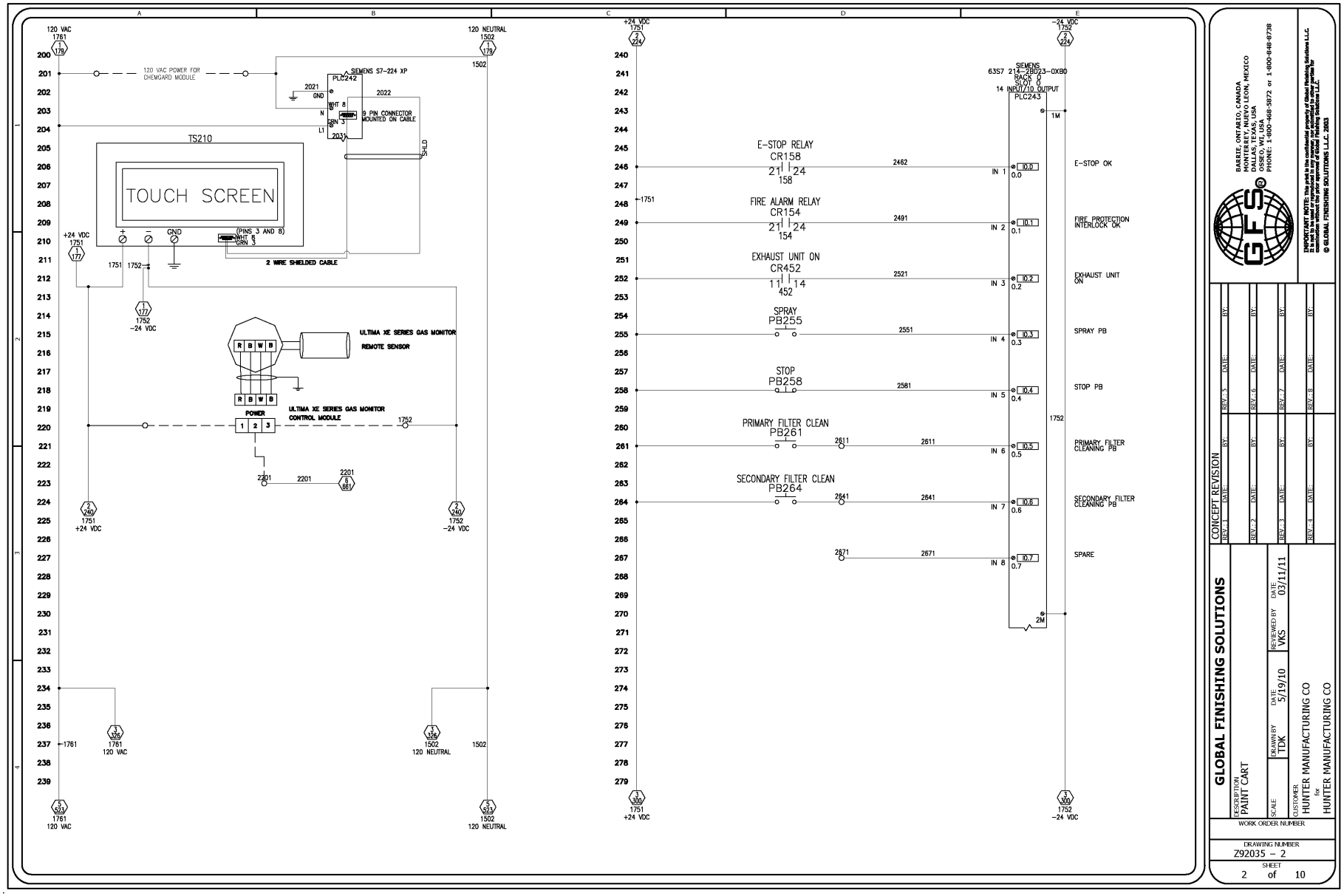
REVIEWED BY VKS
DATE 05/11/11
CUSTOMER HUNTER MANUFACTURING CO for HUNTER MANUFACTURING CO
WORK ORDER NUMBER
DRAWING NUMBER Z92035 – 1
SHEET 1 of 10


120 VAC
1761
120 NEUTRAL
1502
120 VAC POWER FOR CHEMGARD MODULE
SIEMENS S7-224 XP
PLC242
9 PIN CONNECTOR MOUNTED ON CABLE
TS210
TOUCH SCREEN
(PINS 3 AND 8)
2 WIRE SHIELDED CABLE
ULTIMA XE SERIES GAS MONITOR REMOTE SENSOR
ULTIMA XE SERIES GAS MONITOR CONTROL MODULE
POWER
+24 VDC
1751
-24 VDC
1752
SIEMENS
63S7 214-2BD23-0XB0
RACK 0
SLOT 0
14 INPUT/10 OUTPUT
PLC243
E-STOP RELAY
CR158
FIRE ALARM RELAY
CR154
EXHAUST UNIT ON
CR452
SPRAY
PB255
STOP
PB258
PRIMARY FILTER CLEAN
PB261
SECONDARY FILTER CLEAN
PB264
E-STOP OK
FIRE PROTECTION INTERLOCK OK
EXHAUST UNIT ON
SPRAY PB
STOP PB
PRIMARY FILTER CLEANING PB
SECONDARY FILTER CLEANING PB
SPARE
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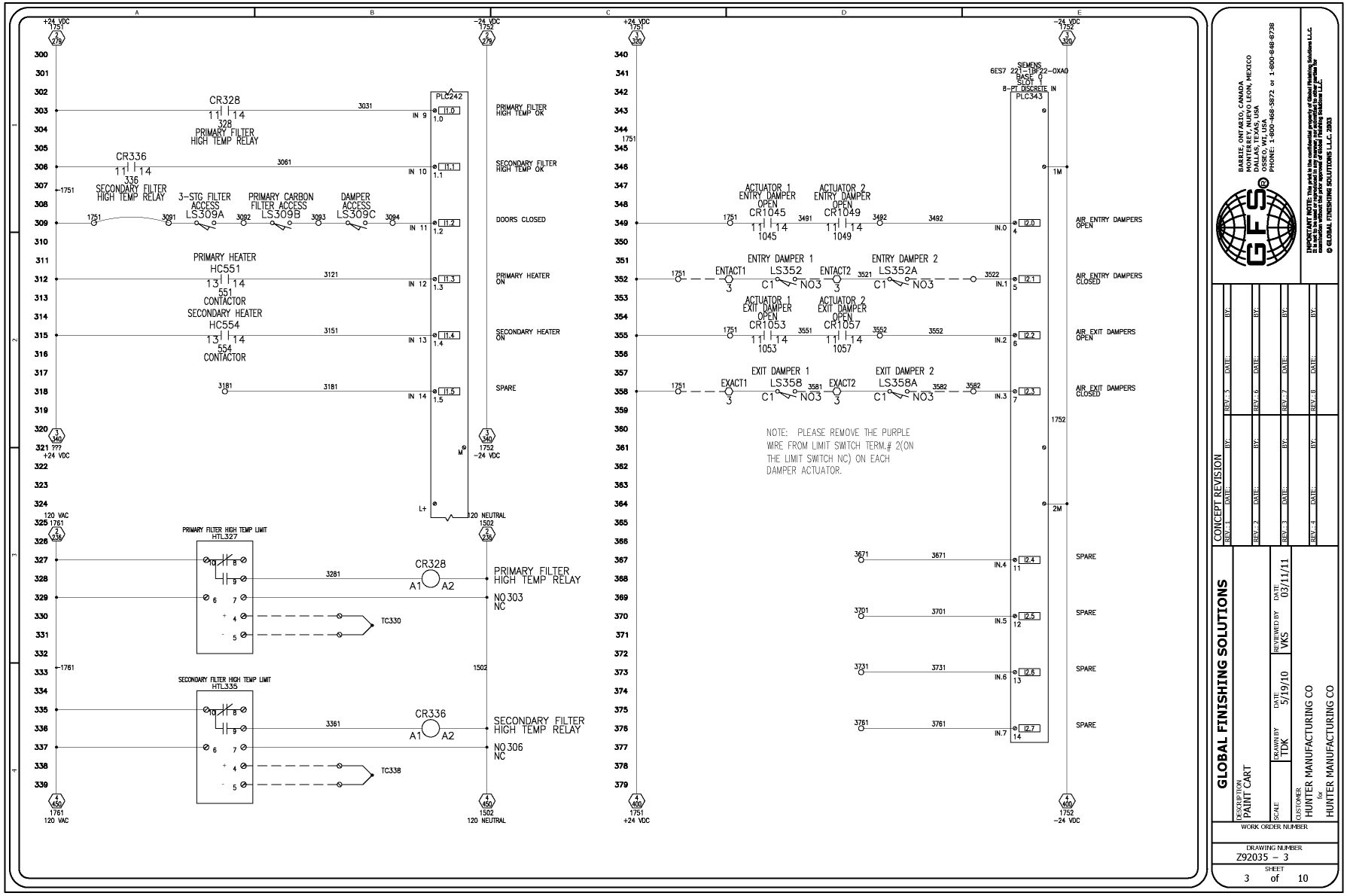
HUNTER MANUFACTURING CO
for
HUNTER MANUFACTURING CO
WORK ORDER NUMBER
DRAWING NUMBER
Z92035 – 2
SHEET
2 of 10



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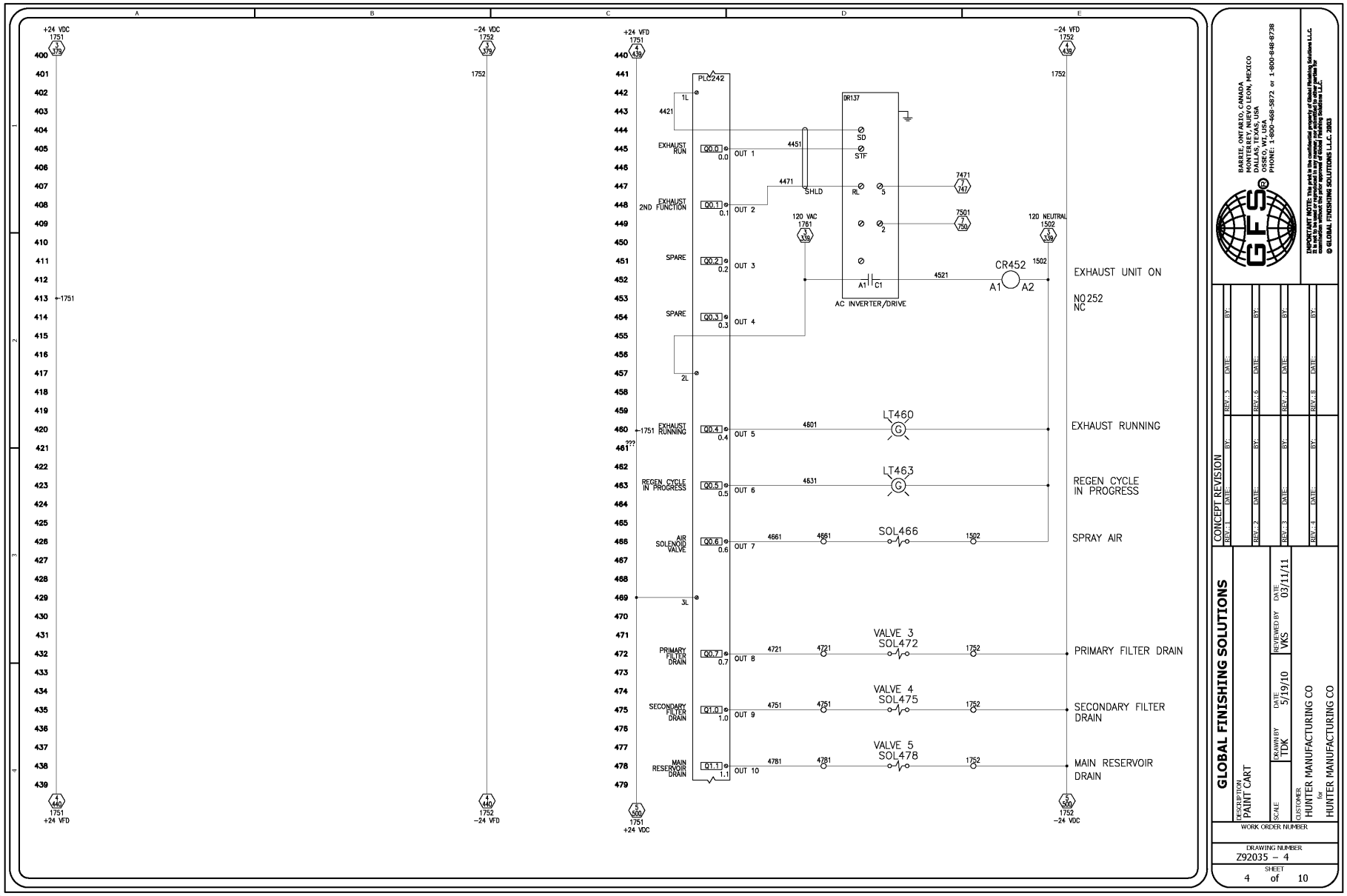
CUSTOMER: HUNTER MANUFACTURING CO for HUNTER MANUFACTURING CO

WORK ORDER NUMBER

DRAWING NUMBER: Z92035 – 3

SHEET 3 of 10


+24 VDC
-24 VDC
+24 VFD
-24 VFD
PLC242
DR137
AC INVERTER/DRIVE
EXHAUST RUN
EXHAUST FUNCTION
2ND FUNCTION
SPARE
EXHAUST RUNNING
REGEN CYCLE IN PROGRESS
AIR SOLENOID VALVE
PRIMARY FILTER DRAIN
SECONDARY FILTER DRAIN
MAIN RESERVOIR DRAIN
120 VAC
120 NEUTRAL
CR452
LT460
LT463
SOL466
VALVE 3 SOL472
VALVE 4 SOL475
VALVE 5 SOL478
EXHAUST UNIT ON
NO 252
NC
EXHAUST RUNNING
REGEN CYCLE IN PROGRESS
SPRAY AIR
PRIMARY FILTER DRAIN
SECONDARY FILTER DRAIN
MAIN RESERVOIR DRAIN
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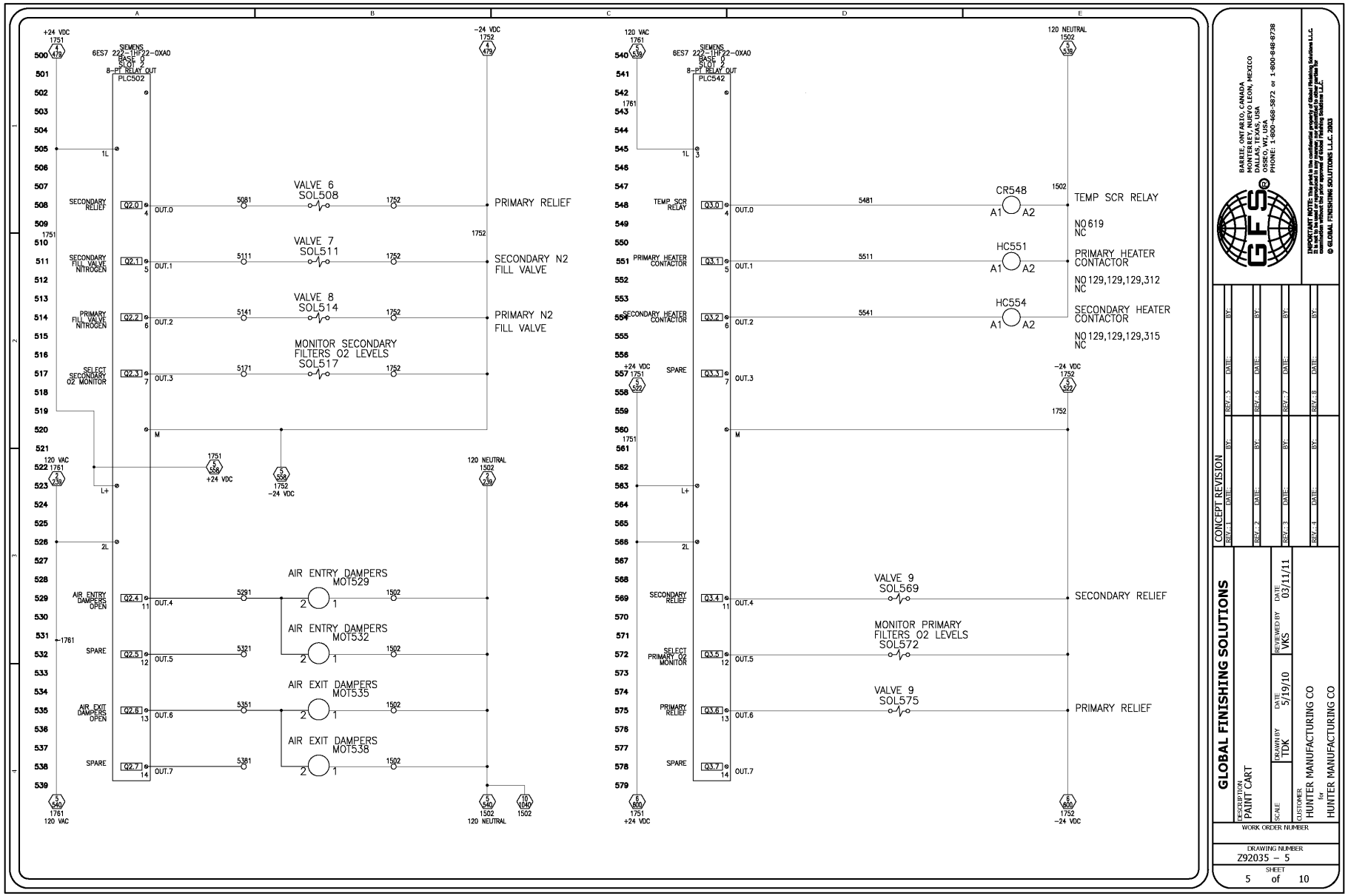
CUSTOMER
HUNTER MANUFACTURING CO
for
HUNTER MANUFACTURING CO
DRAWING NUMBER
Z92035 – 4
SHEET
4 of 10



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GLOBAL FINISHING SOLUTIONS

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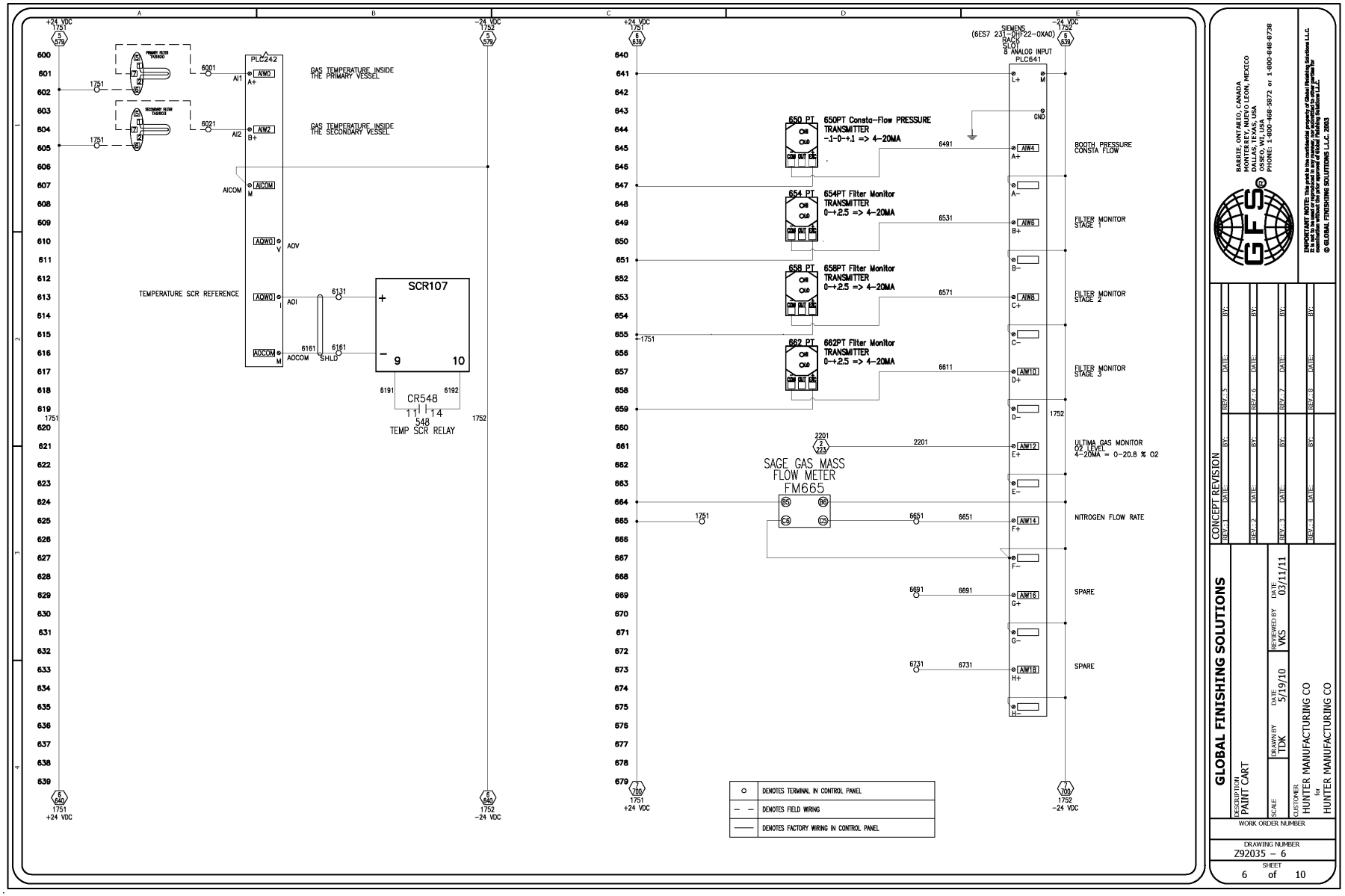
DATE: 03/11/11
CUSTOMER: HUNTER MANUFACTURING CO for HUNTER MANUFACTURING CO

WORK ORDER NUMBER

DRAWING NUMBER: Z92035 – 5

SHEET 5 of 10


PLC242
GAS TEMPERATURE INSIDE THE PRIMARY VESSEL
GAS TEMPERATURE INSIDE THE SECONDARY VESSEL
TEMPERATURE SCR REFERENCE
SCR107
CR548
TEMP SCR RELAY
SIEMENS (6ES7 231-0HF22-0XA0)
RACK 0
SLOT 6
8 ANALOG INPUT
PLC641
650 PT
650PT Consta-Flow PRESSURE TRANSMITTER -.1-0-+.1 => 4-20MA
654 PT
654PT Filter Monitor TRANSMITTER 0-+2.5 => 4-20MA
658 PT
658PT Filter Monitor TRANSMITTER 0-+2.5 => 4-20MA
662 PT
662PT Filter Monitor TRANSMITTER 0-+2.5 => 4-20MA
BOOTH PRESSURE CONSTA FLOW
FILTER MONITOR STAGE 1
FILTER MONITOR STAGE 2
FILTER MONITOR STAGE 3
ULTIMA GAS MONITOR O2 LEVEL 4-20MA = 0-20.8 % O2
SAGE GAS MASS FLOW METER FM665
NITROGEN FLOW RATE
SPARE
SPARE
DENOTES TERMINAL IN CONTROL PANEL
DENOTES FIELD WIRING
DENOTES FACTORY WIRING IN CONTROL PANEL
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DATE 5/19/10
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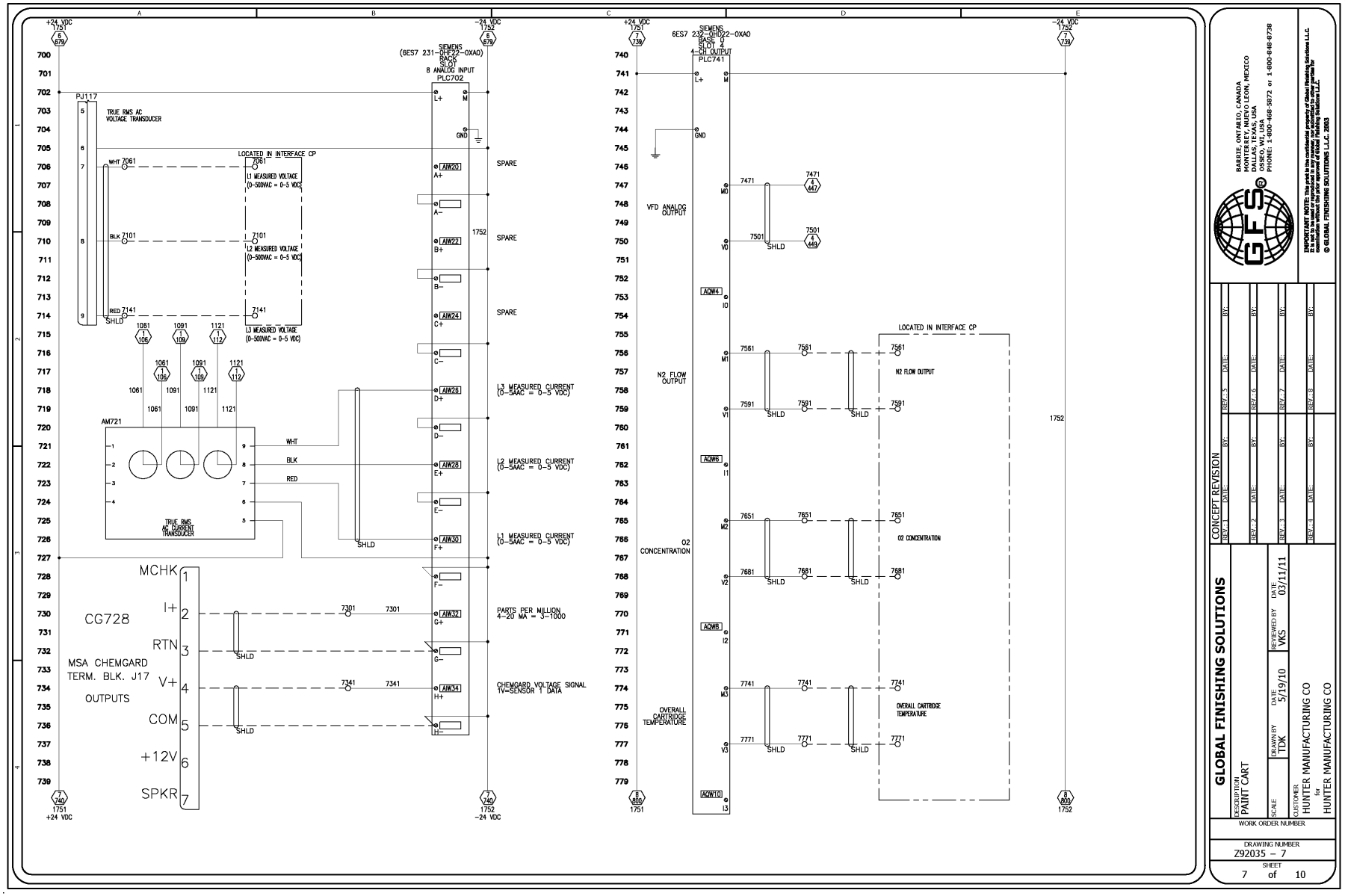
DATE 03/11/11
HUNTER MANUFACTURING CO
DRAWING NUMBER Z92035 - 6
SHEET 6 of 10



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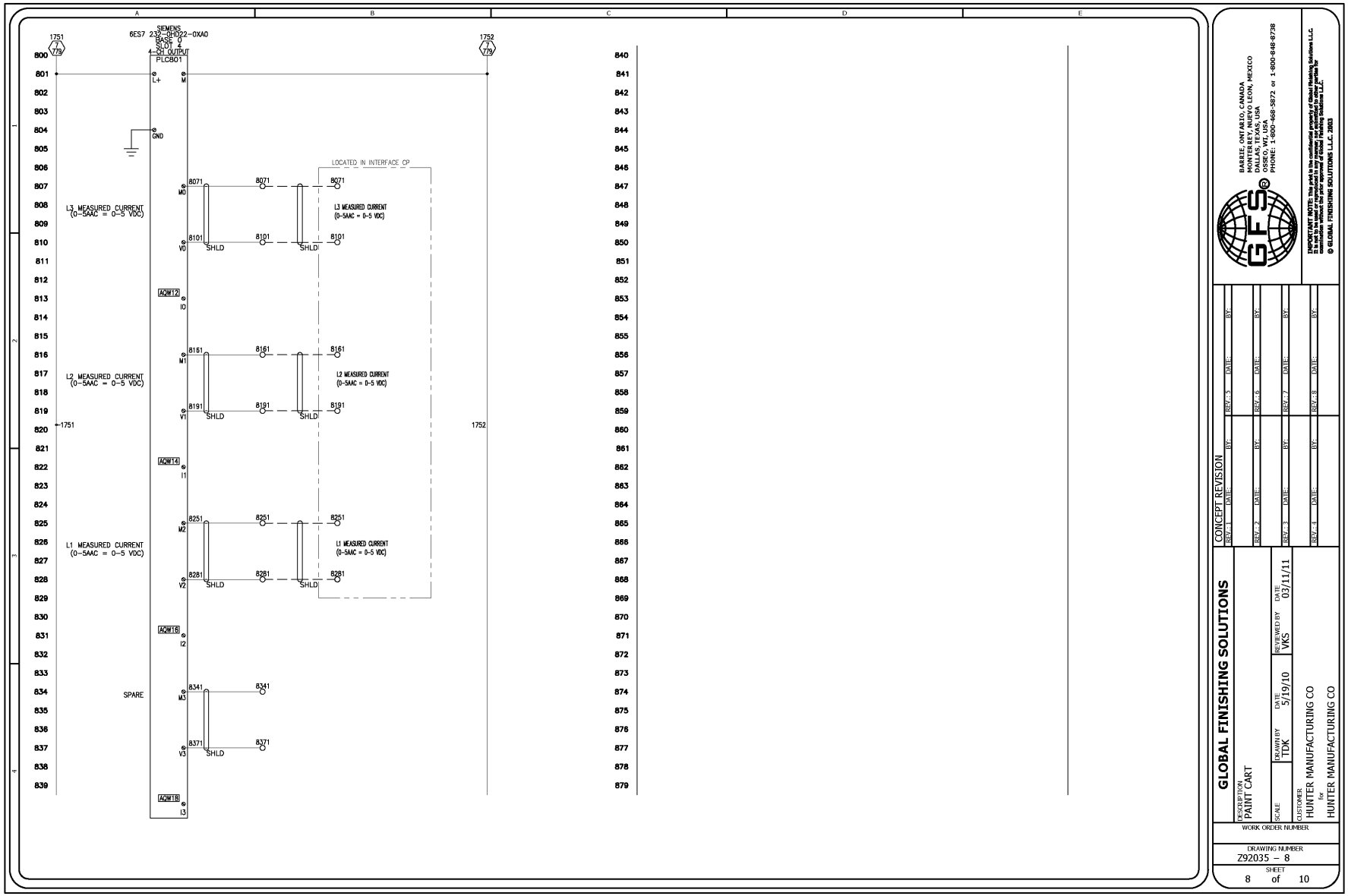
CUSTOMER: HUNTER MANUFACTURING CO for HUNTER MANUFACTURING CO

WORK ORDER NUMBER

DRAWING NUMBER: Z92035 – 7

SHEET 7 of 10


SIEMENS
6ES7 232-0HD22-0XA0
BASE 0
SLOT 4
4-CH OUTPUT
PLC801
1751
1752
L+
M
GND
LOCATED IN INTERFACE CP
L3 MEASURED CURRENT
(0-5AAC = 0-5 VDC)
L2 MEASURED CURRENT
(0-5AAC = 0-5 VDC)
L1 MEASURED CURRENT
(0-5AAC = 0-5 VDC)
SPARE
SHLD
ACW12
ACW14
ACW16
ACW18
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HUNTER MANUFACTURING CO
WORK ORDER NUMBER
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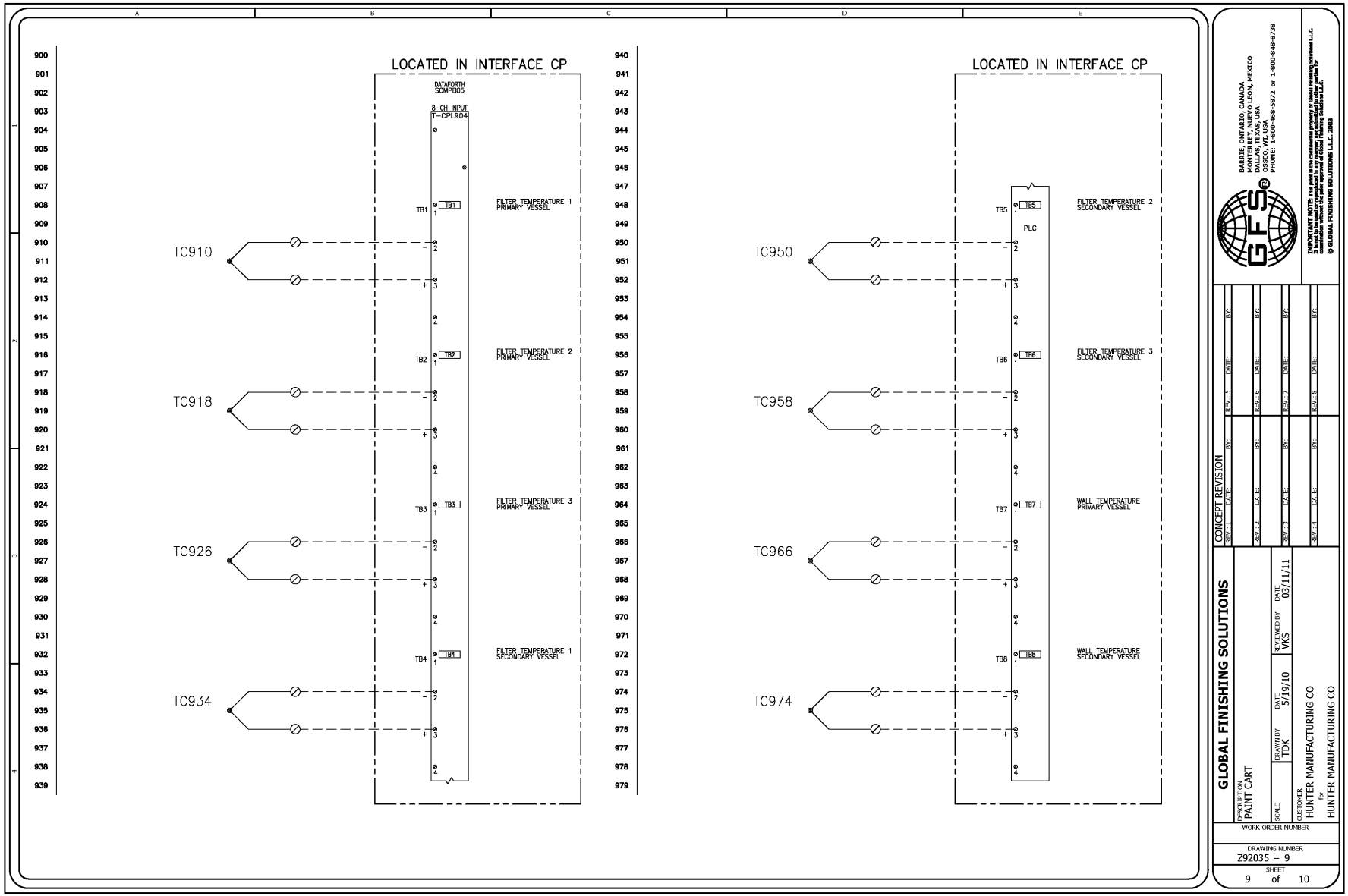
LOCATED IN INTERFACE CP
DATAFORTH
SCMP805
8-CH INPUT
T-CPL904
TC910
TC918
TC926
TC934
TB1
TB2
TB3
TB4
FILTER TEMPERATURE 1
PRIMARY VESSEL
FILTER TEMPERATURE 2
PRIMARY VESSEL
FILTER TEMPERATURE 3
PRIMARY VESSEL
FILTER TEMPERATURE 1
SECONDARY VESSEL
LOCATED IN INTERFACE CP
PLC
TC950
TC958
TC966
TC974
TB5
TB6
TB7
TB8
FILTER TEMPERATURE 2
SECONDARY VESSEL
FILTER TEMPERATURE 3
SECONDARY VESSEL
WALL TEMPERATURE
PRIMARY VESSEL
WALL TEMPERATURE
SECONDARY VESSEL
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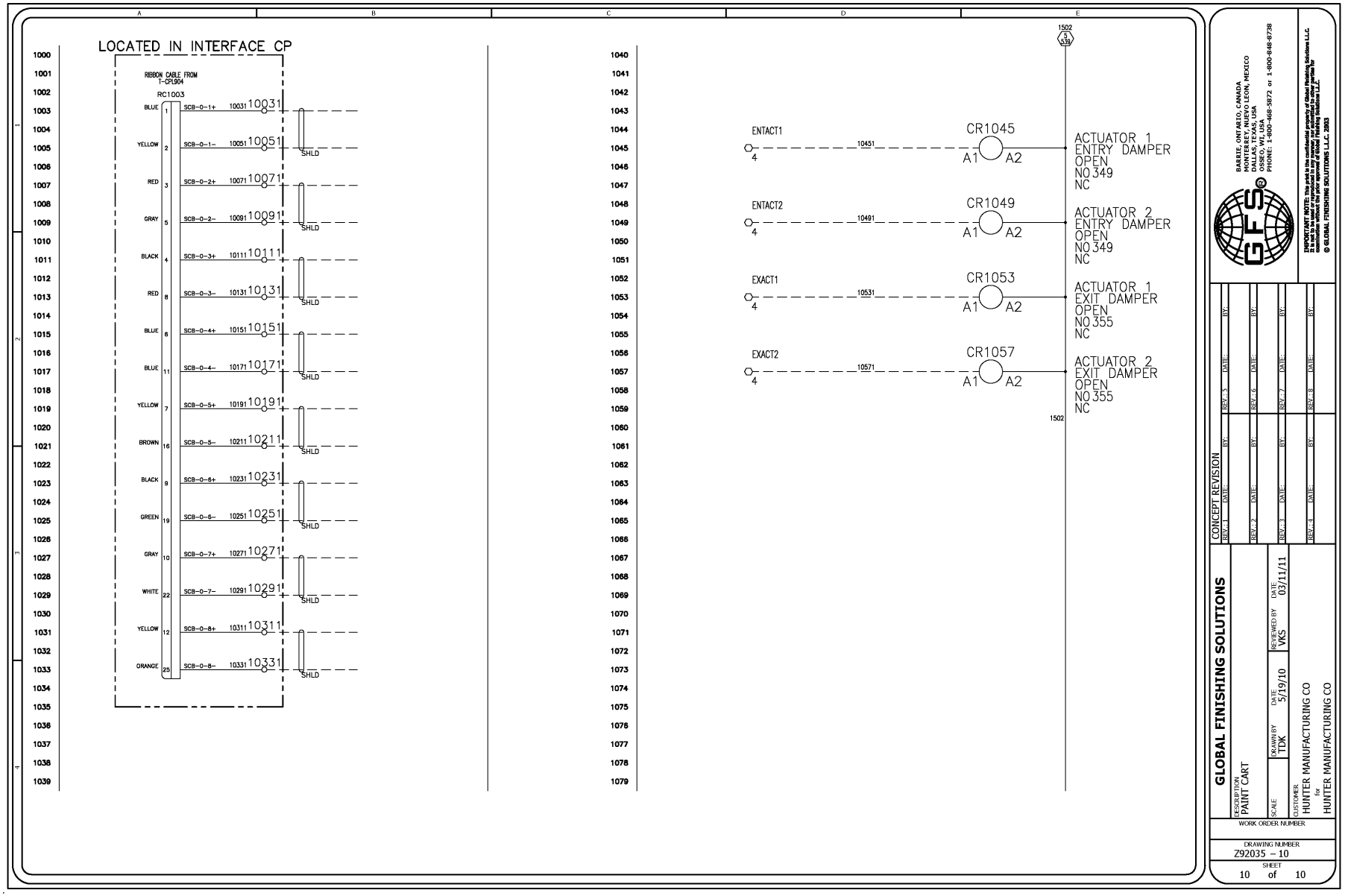
CUSTOMER
HUNTER MANUFACTURING CO
for
HUNTER MANUFACTURING CO
WORK ORDER NUMBER
DRAWING NUMBER
Z92035 – 9
SHEET
9 of 10


LOCATED IN INTERFACE CP
RIBBON CABLE FROM T-CP1904
RC1003
BLUE 1 SCB-0-1+ 10031 10031
YELLOW 2 SCB-0-1- 10051 10051 SHLD
RED 3 SCB-0-2+ 10071 10071
GRAY 5 SCB-0-2- 10091 10091 SHLD
BLACK 4 SCB-0-3+ 10111 10111
RED 8 SCB-0-3- 10131 10131 SHLD
BLUE 6 SCB-0-4+ 10151 10151
BLUE 11 SCB-0-4- 10171 10171 SHLD
YELLOW 7 SCB-0-5+ 10191 10191
BROWN 16 SCB-0-5- 10211 10211 SHLD
BLACK 9 SCB-0-6+ 10231 10231
GREEN 19 SCB-0-6- 10251 10251 SHLD
GRAY 10 SCB-0-7+ 10271 10271
WHITE 22 SCB-0-7- 10291 10291 SHLD
YELLOW 12 SCB-0-8+ 10311 10311
ORANGE 25 SCB-0-8- 10331 10331 SHLD
1502
ENTACT1 4 10451 CR1045 A1 A2 ACTUATOR 1 ENTRY DAMPER OPEN NO 349 NC
ENTACT2 4 10491 CR1049 A1 A2 ACTUATOR 2 ENTRY DAMPER OPEN NO 349 NC
EXACT1 4 10531 CR1053 A1 A2 ACTUATOR 1 EXIT DAMPER OPEN NO 355 NC
EXACT2 4 10571 CR1057 A1 A2 ACTUATOR 2 EXIT DAMPER OPEN NO 355 NC
1502
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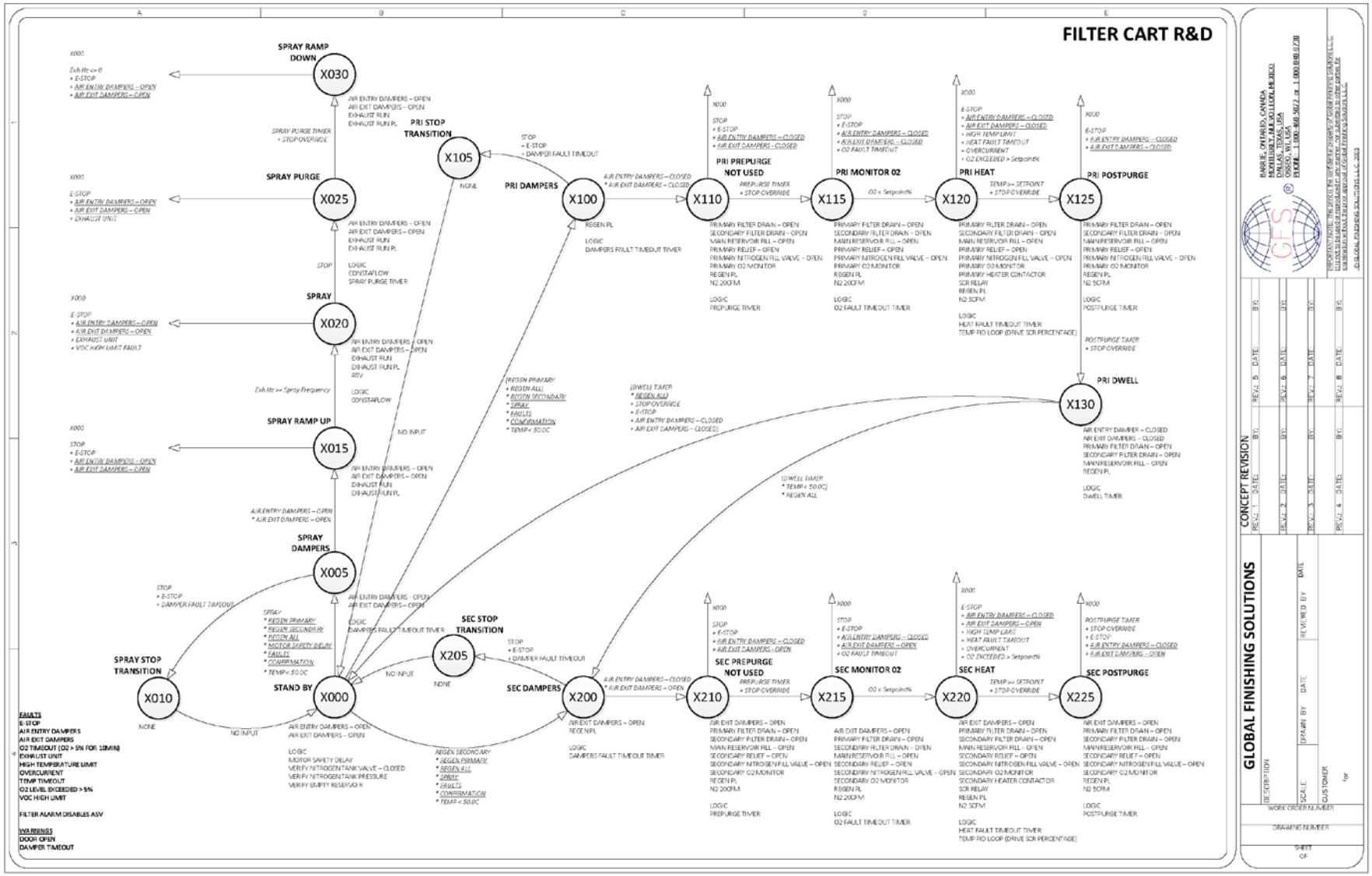
CUSTOMER HUNTER MANUFACTURING CO
for HUNTER MANUFACTURING CO
WORK ORDER NUMBER
DRAWING NUMBER Z92035 – 10
SHEET 10 of 10


FILTER CART R&D
SPRAY RAMP DOWN
X030
SPRAY PURGE
X025
SPRAY
X020
SPRAY RAMP UP
X015
SPRAY DAMPERS
X005
STAND BY
X000
SPRAY STOP TRANSITION
X010
PRI STOP TRANSITION
X105
PRI DAMPERS
X100
PRI PREPURGE NOT USED
X110
PRI MONITOR 02
X115
PRI HEAT
X120
PRI POSTPURGE
X125
PRI DWELL
X130
SEC STOP TRANSITION
X205
SEC DAMPERS
X200
SEC PREPURGE NOT USED
X210
SEC MONITOR 02
X215
SEC HEAT
X220
SEC POSTPURGE
X225
FAULTS
E-STOP
AIR ENTRY DAMPERS
AIR EXIT DAMPERS
O2 TIMEOUT (O2 > 5% FOR 10MIN)
EXHAUST UNIT
HIGH TEMPERATURE LIMIT
OVERCURRENT
TEMP TIMEOUT
O2 LEVEL EXCEEDED > 5%
VOC HIGH LIMIT
FILTER ALARM DISABLES ASV
WARNINGS
DOOR OPEN
DAMPER TIMEOUT
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CUSTOMER
WORK ORDER NUMBER
DRAWING NUMBER
SHEET OF

Sequence of Operation

The following is intended to serve as a general sequence of operation for the various modes of operation of the VAPPRS Portable Paint System.

For optimal operation the system will require the following utilities:

- 100 AMP 480/60/3 Power
- 20 PSI Minimum liquid nitrogen source or equivalent nitrogen gas supply (Required during Regeneration Mode, Minimum 75 CFM gas flow rate during purge)
- 20 PSI Maximum compressed air supply (Required for the oxygen monitoring pump during Regeneration Mode).

Note: If at any time during the system's operation the unit needs to be shut down due to an emergency situation or malfunction the operator may push the Emergency E-Stop button on the face of the control panel and the unit will automatically divert to a standby mode regardless of its current mode of operation.

Paint Mode

Prior to beginning painting operation make sure to check the following:

- The flexible air duct is secured to both the Filtration Cart as well as the Paint Cart and is free of leaks. It is recommended to place the system so that the duct run is no longer than necessary and is straight from the Paint cart to the Filtration cart. Bends and additional length will add to the static pressure of the system and reduce the performance.
- Electrical power is connected to the plug provided on the Filtration cart.
- All service and access doors are closed and seals are tight.
- All filters are in good condition and have not reached their holding capacity.
- All discharge filters are free from obstruction.

Operator Sequence

- Turn the disconnect on the face of the control panel to power the cart. The cart will power up and the VOC monitor will sound when it powers on.
- Once the touch screen has started up it will display a stand by screen at which point the cart is ready for operation.
- On the face of the control panel select the green Start Button. This will begin the paint mode of operation. The internal control dampers will open, once they have opened the fan will begin to ramp and will continue to until it has reached it operating set point.
- At this time painting may begin.
- Once painting is completed and all painters have exited the paint cart, select the red Stop button on the face of the control panel. The system will begin to shut down. Please note that the exhaust fan will continue to purge the system after the button has been pushed and a countdown will begin on the touch screen. Once the purge is complete the fan will shut down and go to Standby mode.
- From Standby mode the operator may select the next mode of operation or if complete with work, turn the disconnect switch Off and store the cart as necessary.

Note: All paint mode pressure and airflow setting are programmable through the touch screen as determined by the administrator. These settings are password protected and cannot be changed without the password. All of these settings and as well as the real-time operating parameters will be displayed on the touch screen.

Primary Regeneration Mode

The Regeneration mode is to be done after Paint mode when it is determined that the carbon filters have reached their holding capacity and are in need of Regeneration (cleaning). The frequency of this operation is to be determined based on the frequency and duration of the painting operations. It has been estimated that a regeneration will be required for every 2 full aircraft wheel well sets that are painted.

Prior to beginning regeneration make sure to check the following:

- Electrical power is connected to the plug provided on the Filtration cart.
- All service and access doors are closed and seals are tight.
- The liquid nitrogen or equivalent gas nitrogen supply has been connected to the evaporator (in the rear of the cart).
- The compressed air supply has been connected to the quick connect on the Ultima X oxygen monitoring system.
- The liquid capture reservoir located in the rear of the cart is connected to the drain piping and all unions have been tightened.

Operator Sequence

- If not already in the On position, turn the disconnect on the face of the control panel to power the cart. The cart will power up and the VOC monitor will sound when it powers on.
- Once the touch screen has started up it will display a stand by screen at which point the cart is ready for operation.
- Turn the Nitrogen supply to the cart on allowing flow from the source of supply. The nitrogen will not flow in to the cart at this time as the system's control valve will be turned off.
- Close the rear access door of the cart.
- Press the yellow Primary Regen button. The touch screen will then prompt the operator to regenerate the primary only or regenerate both the primary and secondary carbon filters. If both is selected the cart will regen the primary first and then the secondary.
- Select the desired regeneration mode. At this time there is no further operation interaction required until the mode has completed.
- Once the mode is selected the internal control dampers will close isolating the carbon filtration chamber and nitrogen will begin flowing into the chamber. The touch screen will display both the temperature and oxygen levels within the chamber.
- Once the chamber has been purged with nitrogen and the oxygen levels have dropped below 4 ½% heating will begin and current will flow through the filters. At this time the nitrogen control valve will modulate back to reduce the flow to a level which will maintain the oxygen level below 5% within the chamber. If at any time the oxygen level within the chamber increases above 5% the current to the filters will immediately be stopped and heating will discontinue. At this time a fault will appear on the screen and the mode must be restarted.

- If oxygen levels increase during heating mode check the nitrogen source to ensure nitrogen is feeding into the chamber as well as the plastic tubing/condensate reservoir on the oxygen monitor to ensure it has not filled with condensation.
- Heating will continue until the filters have reached a surface temperature of approximately 150-degrees Celsius. Once temperature has been reached the current will be stopped to the filters and nitrogen will continue to flow to purge the chamber.
- Once the post heating purge is completed as prompted on the touch screen the operator will be instructed to close the nitrogen supply valve and remove and drain the liquid capture reservoir. Do so at this time.
- The unit will remain in a standby mode where the primary filter chamber will be isolated until the temperature within has dropped below 50-degrees Celsius. All controls will be locked out during the cool down period. **Do not disconnect power to the cart during cool down mode. Keep the unit on and in standby mode until it has cooled. A prompt on the screen will display the temperature and indicate when the unit has adequately cooled.**
- Once the unit has cooled the operator will be allowed to select the next mode of operation or disconnect power and store the unit.

Note: If at any time during Regeneration mode a fault occurs the specific fault will display on the touch screen. All fault settings are preset by GFS and should not be changed unless authorized by a GFS technician. All fault settings are password protected.

If a fault occurs while the unit is heating and the temperature within the filter chamber is above 50-degrees Celsius, the unit must cool before the mode can be restarted.

Secondary Regeneration Mode

The Regeneration mode is to be done after Paint mode when it is determined that the carbon filters have reached their holding capacity and are in need of Regeneration (cleaning). The frequency of this operation is to be determined based on the frequency and duration of the painting operations. It has been estimated that a regeneration will be required for every 2 full aircraft wheel well sets that are painted. It is recommended that the secondary filters be regenerated each time the primary filters are regenerated, however no less than every 3 primary regenerations.

Note: If during primary regeneration, the operator elects to also regenerate the secondary filters, this individual mode of operation is not necessary. It will be performed automatically once the primary filters have been regenerated.

Prior to beginning regeneration make sure to check the following:

- Electrical power is connected to the plug provided on the Filtration cart.
- All service and access doors are closed and seals are tight.
- The liquid nitrogen or equivalent gas nitrogen supply has been connected to the evaporator (in the rear of the cart).
- The compressed air supply has been connected to the quick connect on the Ultima X oxygen monitoring system.
- The liquid capture reservoir located in the rear of the cart is connected to the drain piping and all unions have been tightened.

Operator Sequence

- If not already in the On position, turn the disconnect on the face of the control panel to power the cart. The cart will power up and the VOC monitor will sound when it powers on.
- Once the touch screen has started up it will display a stand by screen at which point the cart is ready for operation.
- Turn the Nitrogen supply to the cart on allowing flow from the source of supply. The nitrogen will not flow in to the cart at this time as the system's control valve will be turned off.
- Close the rear access door of the cart.
- Press the yellow Secondary Regen button. At this time there is no further operation interaction required until the mode has completed.
- Once the mode is selected the internal control dampers adjust and will allow the nitrogen to vent out though the primary chamber after it has passed through the secondary. The touch screen will display both the temperature and oxygen levels within the chamber.
- Once the chamber has been purged with nitrogen and the oxygen levels have dropped below 4 ½% heating will begin and current will flow through the filters. At this time the nitrogen control valve will modulate back to reduce the flow to a level which will maintain the oxygen level below 5% within the chamber. If at any time the oxygen level within the chamber increases above 5% the current to the filters will immediately be stopped and heating will discontinue. At this time a fault will appear on the screen and the mode must be restarted.
    - If oxygen levels increase during heating mode check the nitrogen source to ensure nitrogen is feeding into the chamber as well as the plastic tubing/condensate reservoir on the oxygen monitor to ensure it has not filled with condensation.
- Heating will continue until the filters have reached a surface temperature of approximately 150-degrees Celsius. Once temperature has been reached the current will be stopped to the filters and nitrogen will continue to flow to purge the chamber.
- Once the post heating purge is completed as prompted on the touch screen the operator will be instructed to close the nitrogen supply valve and remove and drain the liquid capture reservoir. Do so at this time.
- The unit will remain in a standby mode where the secondary filter chamber will be isolated until the temperature within has dropped below 50-degrees Celsius. All controls will be locked out during the cool down period. **Do not disconnect power to the cart during cool down mode. Keep the unit on and in standby mode until it has cooled. A prompt on the screen will display the temperature and indicate when the unit has adequately cooled.**
- Once the unit has cooled the operator will be allowed to select the next mode of operation or disconnect power and store the unit.

Note: If at any time during Regeneration mode a fault occurs the specific fault will display on the touch screen. All fault settings are preset by GFS and should not be changed unless authorized by a GFS technician. All fault settings are password protected.

If a fault occurs while the unit is heating and the temperature within the filter chamber is above 50-degrees Celsius, the unit must cool before the mode can be restarted.

Operator Sequence

- If not already in the On position, turn the disconnect on the face of the control panel to power the cart. The cart will power up and the VOC monitor will sound when it powers on.
- Once the touch screen has started up it will display a stand by screen at which point the cart is ready for operation.
- Turn the Nitrogen supply to the cart on allowing flow from the source of supply. The nitrogen will not flow in to the cart at this time as the system's control valve will be turned off.
- Close the rear access door of the cart.
- Press the yellow Secondary Regen button. At this time there is no further operation interaction required until the mode has completed.
- Once the mode is selected the internal control dampers adjust and will allow the nitrogen to vent out though the primary chamber after it has passed through the secondary. The touch screen will display both the temperature and oxygen levels within the chamber.
- Once the chamber has been purged with nitrogen and the oxygen levels have dropped below 4 ½% heating will begin and current will flow through the filters. At this time the nitrogen control valve will modulate back to reduce the flow to a level which will maintain the oxygen level below 5% within the chamber. If at any time the oxygen level within the chamber increases above 5% the current to the filters will immediately be stopped and heating will discontinue. At this time a fault will appear on the screen and the mode must be restarted.
  - If oxygen levels increase during heating mode check the nitrogen source to ensure nitrogen is feeding into the chamber as well as the plastic tubing/condensate reservoir on the oxygen monitor to ensure it has not filled with condensation.
- Heating will continue until the filters have reached a surface temperature of approximately 150-degrees Celsius. Once temperature has been reached the current will be stopped to the filters and nitrogen will continue to flow to purge the chamber.
- Once the post heating purge is completed as prompted on the touch screen the operator will be instructed to close the nitrogen supply valve and remove and drain the liquid capture reservoir. Do so at this time.
- The unit will remain in a standby mode where the secondary filter chamber will be isolated until the temperature within has dropped below 50-degrees Celsius. All controls will be locked out during the cool down period. **Do not disconnect power to the cart during cool down mode. Keep the unit on and in standby mode until it has cooled. A prompt on the screen will display the temperature and indicate when the unit has adequately cooled.**
- Once the unit has cooled the operator will be allowed to select the next mode of operation or disconnect power and store the unit.

Note: If at any time during Regeneration mode a fault occurs the specific fault will display on the touch screen. All fault settings are preset by GFS and should not be changed unless authorized by a GFS technician. All fault settings are password protected.

If a fault occurs while the unit is heating and the temperature within the filter chamber is above 50-degrees Celsius, the unit must cool before the mode can be restarted.