Research Report
KTC-07-22/SPR326-06-1F

KENTUCKY TRANSPORTATION CENTER

PREVENTION OF VOC RELEASES FROM BRIDGE PAINTING OPERATIONS

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Research Report
KTC-07-22/SPR-326-06-1F
Prevention of VOC Releases from Bridge Painting Operations

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<tr><td colspan="3">16. Abstract
Bridge maintenance painting employs solvent-based coatings that generate volatile organic compounds (VOCs) that contribute to air-quality problems. Methods for capturing VOCs during normal Kentucky Transportation Cabinet (KYTC) maintenance painting operations were investigated. One method, activated carbon adsorption, is adaptable to KYTC operations. Related factors including area of bridge, coating systems, containment volumes and VOC out gassing rates were reviewed. A commercial source of activated carbon adsorption equipment was identified and issues related to employing that technology for bridge painting were identified.</td></tr>
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EXECUTIVE SUMMARY

The objectives of this research were to identify potential methods for solvent/volatile organic compound (VOC) capture from KYTC bridge maintenance painting operations, determine key parameters relative to their deployment on typical KYTC bridges and provide recommendations for conducting a follow-on experimental maintenance painting project employing that technology.

Maintenance painting operations employ solvent-based coatings that release VOCs into the atmosphere. That creates low-lying ozone (smog) considered a pollutant and regulated by state and federal resource agencies. While KYTC maintenance painting operations conform to current air quality regulations, VOCs generated by those activities contribute to ozone concentrations in several Kentucky counties that are above or near regulatory non-attainment status. In recent years, those regulations have become more restrictive and pending legislation may pose significant limitations to future KYTC maintenance painting (and road building) activities.

The principle finding of this study was that the activated carbon adsorption method might be adopted by KYTC to capture VOCs released by bridge coatings during application and curing. Currently KYTC specifies that contractors employ containment enclosures for bridge maintenance painting operations including coatings application. The containment can be connected to an activated carbon adsorption system by ducting and blowers. VOC-contaminated air can be ducted into the activated carbon adsorption system that captures the VOCs and exhausts the cleaned air into the atmosphere. This method has a high efficiency and is scalable to meet a range of bridge painting operations.

Several typical KYTC bridge types were investigated to determine the amount of activated carbon necessary to capture VOCs emitted by common KYTC-approved maintenance coatings and other system requirements. A commercial firm was identified that could furnish an activated carbon adsorption system by monthly lease and could provide a turn-key service including delivery and pick up of the system and environmentally compliant disposal of the captured VOCs. Recommendations were provided for development of an experimental project using this technology including structure selection, contactor requirements, KYTC review of worker safety issues and KTC project monitoring.

It is recommended that KYTC further pursue use of this technology by conducting an experimental/ prototype project to further investigate VOC capture using the activated carbon adsorption technology. This work should include industrial hygienist review of worker safety/containment design issues. It should employ proven “off the shelf” technology to limit research variables. The project should be conducted in a county that is currently is not meeting ozone air quality standards.

INTRODUCTION

Background

Most structural coatings are formulated with organic solvents, which aid in their handling and application. During curing of coatings, the solvents “flash off” or evaporate into the atmosphere. Large percentages of those solvents are comprised of volatile organic compounds (VOCs) so termed because they have sufficiently high vapor pressures under normal conditions (temperature and atmospheric pressure) to vaporize and enter the atmosphere. Those can act as air pollutants contributing to low-level ozone (smog) and certain of these are thought to be carcinogens. Not only must the level of VOCs in a coating conform to legislated levels, but also the level must be addressed by coatings manufacturer because it affects coating application properties and subsequent coatings performance.

One important aspect of solvents in coatings is the amount/types of VOCs contained in coatings. Under the Clean Air Act (and its amendments) regulation of those was address by restricting the solvent contents/types provided in coatings at the manufacturing level. In the 1990s, the EPA and coatings industry sought to arrive at consensus VOC regulations, but failed to do so. Due to regulatory variances among states, VOC limits differ throughout the U.S. There is a general nationwide limit of 450 g/L for industrial maintenance (architectural) coatings, but in California, the limit ranges from 250 to 420 g/L, depending on the regulatory district. Outside of California, the Ozone Transport Commission, a consortium of Northeastern and Mid-Atlantic states has promulgated new rules limiting the VOC content of coatings to 340 g/L (1). For about 8 years beginning in about 1996, KYTC-approved coatings contained a maximum of 2.8 lbs of solvents per gallon (340g/L) of coating. In recent years, this limit has been increased to 420g/L.

Some coatings contain solvents that are classified as acceptable (e.g. VOC-exempt) under USEPA VOC regulations (e.g. acetone, methylene chloride, and water). As part of the Clean Air Act Amendments of 1990 (CAAA), the USEPA established a category of VOCs known as hazardous air pollutants (HAPs). Those are known to cause cancer, other serious health problems and/or severe ecological effects. Those solvents (e.g. toluene, xylene, methanol, and ethyl benzene) are termed Hazardous Air Pollutants or “HAPs”. Their release into the atmosphere are prohibited or severely restricted. As the VOC exemption is determined solely by the ability of a solvent to form ozone, a VOC-exempt solvent can be hazardous (i.e. a HAP). Solvent types/concentrations in KYTC-approved coatings vary by coating type and manufacturer. Typically, contractors are allowed to add approved solvents to coatings to improve spray out. Those solvent additions are limited in type and quantity by coatings manufacturers. In the middle ground of solvents are those containing VOCs that are regulated, but whose use is not restricted like HAPs. The primary concern with their release relates to their ability to photo-chemically react with oxygen in the atmosphere and form ozone. As their ability to do that varies between VOCs from different solvent types, regulators are now considering "relative reactivity" in forming ozone to determine allowable concentrations in coatings or releases from point sources.

Coatings manufacturers provide some coatings containing HAPs and contractors commonly use solvents containing HAPs. This is because many coatings containing VOC-exempt solvents have performance or application limitations that make them undesirable (or less desirable) for bridge painting. The current coatings used on bridges that offer the best performance and reasonable application requirements contain solvents/VOCs that fall into that middle ground of solvents whose primary environmental shortcoming is ozone generation. Those VOCs are regulated from point sources with an annual limitation of 100 tons per year. HAPs are regulated from point sources with an annual limitation of 25 tons annually (combined HAPs) or 10 tons (single HAP) for "area" sources.

The Kentucky Transportation Cabinet (KYTC) conducts bridge painting projects that entail the generation and release of volatile organic compounds (VOCs) into the atmosphere. As previously noted, regulations promulgated under the Clean Air Act of 1963 and succeeding legislation apply to point sources (e.g. factories) that generate more than 100 tons of VOCs per year. Some resource agencies have begun to expand the focus of their regulations in this area to address non-point sources such as bridge painting that occur within a state over a given time period (e.g. a year). KYTC may eventually be impacted by such regulations if state environmental laws are made more restrictive. Additionally, there are several 8-hour ozone non-attainment areas in Kentucky. By capturing solvents generated during coating spray-out on bridge painting operations, KYTC could assist those areas of the state in achieving U.S. Environmental Protection Agency (USEPA) ozone attainment levels and in maintaining compliance in areas where ozone levels are near the ozone non-attainment threshold.

KYTC is seeking to minimize its generation of harmful wastes that contribute to environmental problems. A major source of hazardous wastes produced by KYTC comes from bridge painting operations. KYTC has addressed the generation of hazardous (lead contaminated) paint residue from surface preparation operations conducted prior to paint application including the use of recycling and chemical waste treatment to eliminate generation of hazardous wastes into the waste stream (3, 4). Another issue related to bridge painting is the generation of VOCs (solvents) from coatings application and their release into the environment. This has two potential impacts. KYTC officials don't want to perform actions that could have a deleterious effect on ozone in problematic areas. Secondly, the State Implementation Plan (SIP) for ozone non-attainment areas is typically much more restrictive toward road-building activities than for ones in regulatory compliance making it more difficult for KYTC to program new/improved transportation projects in the non-attainment areas due to concerns about increased ozone generation by mobile sources (automobiles and trucks). Capturing VOCs in those areas would prevent exacerbating problematic conditions and could benefit both local agencies and KYTC.

In general, the USEPA prefers to address environmental wastes by material substitution, followed in preference by recycling, and lastly by treatment and disposal. Certainly low VOC and 0 VOC coatings are available including coatings containing exempt VOCs (e.g. acetone, methylene chloride). However, an important category of coatings, the zinc-rich primers, typically employ solvents that contain VOC compounds that are non-exempt though they may not be classified as HAPs (e.g. VM & P naphtha in Aromatic 100 solvent). Another coating widely used by KYTC, calcium sulfonate alkyds, contains mineral spirits which is also regulated as a non-exempt VOC solvent. Currently, there are no suitable low-VOC solvents to replace mineral spirits and provide and durable calcium sulfonate alkyds. The use of 0 VOC coatings is problematic due to application/durability issues. Currently available 0 VOC coatings do not meet the performance levels of comparable KYTC-specified coatings. Their use would result in higher life-cycle costs for bridge painting projects and the need to repaint on a more frequent basis.

Solvent (VOC) capture and recovery provides a means of addressing the VOC issue while still allowing the use of current KYTC qualified coatings and solvents. Solvent capture/recovery has been used by industry for chemical process operations. It has also been used for both metal cleaning and coatings application processes. The U.S. Navy employs solvent capture on some large-scale ship painting operations.

The intent of the proposed study is to determine the feasibility of applying solvent (VOC) capture to routine KYTC bridge painting operations (both maintenance and new construction) and, if they prove feasible, provide sufficient engineering information to enable its employment on an experimental project (to be conducted subsequent to the completion of this study).

Study Objectives/Tasks

The study objectives were approved by the Study Advisory Committee. Those were to:

1. Review the three methods of solvent recovery and determine which is more practical for use in bridge painting operations.
2. Identify solvents used in KYTC-qualified coatings.
3. Interface with manufacturers of that equipment and obtain specifications, costs and other relevant information (e.g. VOC recovery efficiencies for specific solvents). Contractors may be able to lease the necessary equipment. It also may be possible to obtain the use of the equipment as a turnkey service (including recycling/disposal of the captured solvent).
4. Work through KYTC to obtain guidance for this effort from Environmental and Public Protection Cabinet (EPPC) Division of Air Quality Division for Air Quality officials.
5. Prepare suggested special notes for experimental projects using solvent recovery in conjunction with paint application operations.
6. Present the study findings in a final report for KYTC officials to use in deciding whether to use solvent (VOC) capture on a future experimental project.

To address those goals, KTC researchers were assigned five tasks. Those were to:

Task 1 Review the current EPPC air quality regulations and identify counties in non-attainment/borderline attainment status for 8 hour-ozone levels.
Task 2 Obtain solvent (VOC) types/contents of KYTC qualified coatings. Determine potential impacts of solvent (VOC) releases from KYTC bridge painting operations. Assess the benefits of capturing those solvent (VOC) releases.

Task 3 Review the condensation and charcoal absorption methods for capturing solvents (VOCs). Determine which method is best suited for use with KYTC bridge painting operations.
Task 4 Contact manufacturers of solvent (VOC) capture equipment. Based upon theoretical solvent (VOC) out-gassing amounts and rates from typical bridge painting operations, size potential equipment for solvent (VOC) capture. Identify suitable equipment and determine whether it must be purchased or leased, or whether is may be acquired as a turnkey service (including solvent recycling/disposal). If recycling and disposal are both options, obtain cost estimates for solvent (VOC) capture employing both methods. Contact paint contractors and obtain their input regarding the practicality of solvent (VOC) capture for bridge painting operations.
Task 5 Prepare a final report reviewing all research work performed. Provide recommended practices for conducting experimental bridge painting projects employing solvent (VOC) capture and provide specific technical recommendations that can be incorporated in special notes for a future experimental project incorporating this technology.

WORK ADDRESSING STUDY TASKS

Task 1 Review the Current EPPC Air Quality Regulations

Air quality enforcement in Kentucky is provided by the Environmental and Public Protection Cabinet (EPPC) Department for Environmental Protection Division of Air Quality. Currently state air quality regulations conform to those issued by the USEPA and are less restrictive than those of the Southwest Air Quality District or Ozone Transport Commission. Division of Air Quality officials indicated that KYTC bridge painting operations currently conformed to Kentucky air quality regulations including quantities of solvents employed in coatings and the total VOC releases by bridge painting (2). The former relates the controls impacting the coatings manufacturing process. The latter determination is related to the temporary nature of bridge painting operations (e.g. non-point sources).

During the course of this study (2005-07), the number of areas within Kentucky where 8-hour ozone measurements exceeded the regulatory threshold (i.e. ozone non-attainment areas) or areas where the ozone measurements are near the regulatory threshold reduced significantly. In 2005 there were 6 ozone non-attainment counties. Currently, three counties in Kentucky fall under some degree of non-attainment (Boone, Campbell, and Kenton) with several counties close to non-attainment status. Those are of interest for the focused application of solvent capture on bridge painting operations.

Task 2 Solvent Types/Contents of KYTC-Qualified Coatings

This information was provided by the KYTC Division of Materials for the three coatings systems most commonly used on KYTC bridges. They include a 2-coat systems consisting of a moisture-cure polyurethane primer and a two-component polyaspartate topcoat (System 1), a 2-coat system consisting of an epoxy primer and a two-component aliphatic polyurethane topcoat (System 2) and a single coat of calcium sulfonate alkyd

(System 3). Based upon theoretical coverage rates and solvent contents from the coatings manufacturers, the VOC contents in pounds of VOC per 1000 ft^2 of steel covered were determined to be 20.7 lbs, 33 lbs and 17.5 lbs respectively assuming 100 percent transfer efficiency during coatings application (5).

Task 3 Review of Solvent Capture Methods

KYTC requires the use of containment enclosures on bridges during cleaning and painting. During painting, the enclosure could be kept under negative pressure (as is typically done during abrasive blasting of lead paints in urban areas) by use of exhaust fans that routes air into ducts and subsequently into treatment equipment. The system operates the containment under negative pressure (the outside air pressure is greater than the air pressure in the containment due to the continual exhausting of air from within the containment). This prevents airborne pollutants from escaping into the atmosphere. The combination of the containment enclosure, ducts, and treatment equipment constitute a closed system in which VOCs released during coating curing can be captured for subsequent recycling or disposal. There are three primary types of solvent capture/VOC extraction systems for gaseous wastes (i.e. VOC polluted air from painting operations) – liquid absorption, activated carbon adsorption and condensation (6).

The liquid absorption method uses a “scrubbing” process whereby the gaseous wastes flowing into the base of a column (packed or tray) filled with heavy oil rises into the top of the column. The VOCs are transferred into the oil. The VOC saturated oil exits at the bottom of the column and is subsequently distilled to separate the VOCs and oil. This method has a high recovery efficiency (above 95 percent) and can be used for a variety of gas flow rates ranging from 200-100,000 ft^3/min. It functions over a wide range of VOC concentrations (500-5,000 ppm) and works well with humid air streams. The disadvantage of liquid absorption is that it may result in a new waste stream (polluted oil).

The activated carbon adsorption method entails the flow of gaseous emissions through a column filled with activated carbon granules. Activated carbon is a carbonaceous material, typically coal, that is processed in powder, granular or palletized form to impart high surface area including pores that make the material reactive (adsorptive) to gases and liquids. VOCs are adsorbed in the surface of the carbon and in its pores. The carbon can adsorb 15-20 percent by weight of VOCs. This method can be used use for a wide range of gas flow rates (100-60,000 ft^3/min.). It can also be used for a wide range of VOC concentrations (20-50,000 ppm). It can also handle fluctuations in gas flow rates and VOC concentrations. The activated carbon absorption method has high capture efficiency (90-98 percent). Humid air streams are not problematic for the types of VOCs generated by painting. However, moisture will interfere with carbon adsorption. After adsorbing the VOCs, steam or a hot gas can be passed through the bed of carbon releasing VOCs which can be recovered by decanting or condensation. This regeneration step allows the VOCs to be as recycled as a solvent and permits reuse of the activated carbon. The regeneration equipment can be incorporated into activated carbon adsorption system.

Generally, the condensation method is employed where high amounts of VOCs are generated relative to the air flow used to transport the VOCs to the treatment portion of the capture system. Refrigeration equipment is used to lower the temperature below the VOC dew point to condense the VOCs which are subsequently collected for recycling or burning. The condensation method has a lower VOC capture efficiency (between 50-90 percent). Hybrid condensation methods have capture efficiencies above 90 percent. This method is does not require the VOCs to contact other streams such as oils or carbon. It may require special equipment to address explosion concerns and doesn't work well for low concentrations of VOCs.

Review of the characteristics of the three processes did not reveal a clear choice for application on bridge painting operations. The next step was to contact manufacturers of solvent capture/recovery systems and identify factors (e.g. practicality, available equipment or costs) that would favor one method over the others.

Task 4 Information from Manufacturers of Solvent Capture Equipment

KTC researchers used the Internet to identify firms that provided equipment for solvent capture/recovery. Manufacturers of liquid absorption and condensation equipment indicated that their units were impractical for bridge painting based upon equipment size/capacity/cost or the quantities of VOCs and quantity of air flow that they anticipated. Several recommended that KTC researchers focus on the activated carbon adsorption method. Several sources of material and equipment were contacted. Only one firm, the Tigg Corporation of Bridgeville, PA provided activated carbon in relatively smaller canisters that could be used in the field for bridge painting projects.

KTC researchers contacted Tigg representatives and discussed the potential for using carbon adsorption for capturing VOCs from bridge containment enclosures during/subsequent to coatings spray out. Tigg representatives requested information related to containment volume and solvent production to aid in identifying equipment requirements along with the anticipated VOC production from the coatings being applied.

KTC researchers met with KYTC bridge painting personnel to determine containment sizes and steel surface areas painted on typical bridges that would be amenable for inclusion in an experiment project to demonstrate the technology. KYTC personnel identified overpass (deck girder) bridges as the best candidates due to their limited size and the potential for good siting of the solvent capture equipment relative to the bridge containment.

Two scenarios emerged: 1) a smaller two-lane overpass bridge over a two-lane road and 2) a larger three- or four-lane bridge over a divided four-lane highway. The two bridge types were estimated to have about 20,000 ft^2 and 40,000 ft^2 of steel to be painted respectively. The smaller bridge would probably be painted in two separate operations, each encompassing half of the bridge (to allow one lane of traffic). Each containment would enclose about 10,000 ft^2 of steel. The larger bridge would probably be painted in three operations-one each from an abutment to the middle of one set of lanes and the third from the middle of the two roadways to the center pier located in the median. For convenience, its was anticipated that each of those containments would enclose an equal amount of steel to be painted-approximately 13,300 ft^2 in area.

The amount of VOCs to be captured in each painting operation would vary based upon which KYTC approved coatings system was used. Quantities of VOCs (lbs) for the two bridge types using the three previously discussed coatings systems are provided in Tables 1 and 2 for coatings application efficiencies (i.e. the percentage of a coating that is sprayed out and transferred to a work piece) of 100, 50 and 33 percent respectively. Application efficiencies will vary based upon variables including application method (brushing/rolling or spraying), ambient conditions in the spray area, operator skill and type of coatings employed.

Two types of containment enclosures were envisioned for both overpass bridges. The first type would be grounded and the second would be suspended. For both bridges a height of 24 ft was used for the grounded containment and 6 ft was selected for height of the suspended containment. The smaller bridge had a containment footprint 60 ft long by 30 ft wide. The large bridge had a foot print 100 ft long by 40 ft wide.

Some basic information on typical KYTC painting operations was provided to Tigg for equipment sizing and costing. Sizing of carbon adsorption canisters would be based upon the weight of the VOCs (lbs) generated in coating spray out in one containment enclosure. Fresh activated carbon canisters could be employed (if necessary) for each containment. As spray out in a containment will probably be continuous, canister change-out should only be performed between containments to prevent VOC releases. Canisters and other containers of activated carbon can be supplied in a wide range of sizes. A user may wish to obtain a single large container of the material that is capable of handling VOCs from a complete project rather than switch between smaller canisters. Necessary weights of activated carbon are provided for the two typical bridge types and three KYTC-approved maintenance coatings systems (at different coating application efficiencies) in Tables 3 and 4. A large amount of airflow must occur in the containment to ensure complete transport of evaporating solvents/VOCs to the activated carbon. Tigg recommended 5 air changes per hour minimum in any containments. The containment enclosure volumes and necessary flow rates for the two typical KYTC overpass bridges are provided in Table 5.

The initial technical review under this study had determined that VOC capture using the activated carbon adsorption method was feasible from a technical perspective. However, further evaluation was necessary to determine whether it was practical from an engineering perspective (including additional costs imposed by VOC capture). Tigg could supply a turnkey trailer mounted VOC capture system consisting of a 6,000 lb canister of activated carbon, 6,000 CFM blower with pre-filter (to prevent misting paint from entering the carbon adsorption canister), interconnecting ductwork, 100 ft of duct and two 48”x 48” louvers (to promote airflow into the containment). The cost of providing the unit on site for one month and transporting it back to Tigg along with subsequent USEPA compliant VOC disposal (by incineration) would be about $35,000. If extra 6,000-lb activated carbon canisters were necessary they could be supplied/processed for about $10,000 each. Larger containers could be supplied if the user wished to avoid changing out canisters or if a containment/spray out warranted a larger capacity container. Based upon recent KYTC bridge maintenance painting costs, the cost for deploying this technology would add about 10-20 percent to the cost of a project depending upon its size.

KTC researchers also reviewed the impact of this technology on the progress of painting operations. Many KYTC maintenance painting projects now employ abrasive blasting for surface preparation. In most cases, especially in urban areas, KYTC requires contractors to employ containment enclosures with negative pressure. Typically, vacuum trucks are employed to accomplish this with ducting attached to the containment enclosure. The ducting probably can be used in conjunction with the activated carbon adsorption system supplied by Tigg minimizing the time required between abrasive blasting and painting. As the Tigg equipment is trailer mounted, it could be readily moved about the job site to accommodate contractor scheduling.

Another factor relates to VOC evaporation during coatings application and curing. Contacts with technical representatives of the three coatings firms providing the KYTC-approved maintenance coating systems revealed that 5 air changes per hour would probably accelerate drying times in containment and possibly lead to a significant reduction in the time that a contractor needs to complete his work including final inspections. This may be very beneficial in reducing lane closure time and consequently motorist disruptions (and contractor lane rentals or other disincentives if they are applied). Maintaining air flow through the containment for 8 hours after spray out would be sufficient to capture well over 90 percent of the VOCs emitted from coatings during curing. It is possible that due to the rapid air changes, the subject coatings systems would cure sufficiently within about 2 hours to permit final inspection and containment removal.

An additional factor relates to the impact of this process on worker safety. For this approach to work, the activated carbon adsorption system must be operated during coatings application (spray out) and for some time thereafter. Issues that must be addressed are worker exposure to solvents, containment design/ventilation and fire and explosion hazards. Currently, KYTC requires spray out in containment. KYTC monitors its personnel for VOC exposure. Air flow in a contractor’s containment needs to be evaluated to determine that it provides sufficient engineering controls in addition to personal protection used by the contractor’s painters. Containment ventilation and design parameters must be considered to provide proper air flow within the containment along with the necessary flow rate in the ducts to achieve the targeted number of air changes. Preliminary analyses need to be made of the projected air/VOC concentrations within the containment and exhaust system to ensure that no explosion/fire hazard exists. An industrial hygienist familiar with painting containment enclosures can perform the necessary worker safety reviews.

Task 5 Recommended Practices for Experimental Solvent Capture

Based upon literature reviews, solvent (VOC) capture has not been employed on a bridge maintenance painting project in the U.S. (or elsewhere worldwide). The technology is relatively straightforward and one manufacturer of the equipment will provide it on a lease basis enabling an experimental bridge maintenance painting project to be performed with limited additional expenditures needed to investigate this method and determine its feasibility and potential benefits. It is likely that the activated carbon adsorption method can capture over 90 percent of all VOCs emitted during spray out and curing. It would be beneficial to apply the technology in one of the three ozone non-attainment counties. For the initial (experimental) project a small overpass bridge is recommended having less than 20,000 ft^2 of steel to be painted. A small mainline bridge with good access for the activated carbon adsorption system/trailer can also be considered. It is recommended that the selected project be performed on a low ADT route to permit extended lane closures under the overpass due to the presence of containment enclosures.

The special notes for the experimental project can use any KYTC-approved coatings system for maintenance painting. Any sizing of the activated carbon adsorption system should incorporate the assumption of 15 percent VOC pick-up by the activated carbon before the system becomes saturated and fails to further function. The experimental special notes should identify the type and estimated volume of containment (grounded or suspended). Prior to the onset of work, the contractor should provide the Engineer with drawings, engineering calculations and equipment lists for his containment and the incorporation of the activated carbon adsorption system. KYTC should have an industrial hygienist familiar with painting containment enclosures perform a worker safety review and determine that the contractor’s containment/air flow ducting are satisfactory and compatible with the Tigg-specified air flow rate of 5 air changes per hour (along with any other flow requirements).

The contractor should also be required to take periodic air flow measurements in the exhaust duct to verify that proper flow rate was maintained during coatings application and follow-on VOC adsorption during coating cure out. The contractor would install the activated carbon adsorption system and operate it at the beginning of each coatings application, through completion of that task and for a continuous period of 24 hours thereafter. He will maintain his containment enclosure for that period of time along with traffic control. During and after spray out, KTC researchers would periodically measure VOC content in the containment, the environment, the exhaust duct between the containment and the activated carbon adsorption systems and the air outlet from that system.

It would be desirable for the contractor to lease the activated carbon adsorption system from Tigg for this experimental project. That would reduce the potential for problems due to adsorption system design and would also alleviate concerns about disposal of the captured VOCs. If a contractor was able to locate equipment from another firm who had previous experience with activated carbon adsorption, it would be permitted if approved by the Engineer. *If this method was subsequently used on a routine basis, contractors might choose to engineer their own systems.*

After the canister(s) were returned to Tigg (or other system vendor) for VOC disposal, that company would be required to allow KTC researchers to take grab samples of the saturated activated carbon and perform thermal-gravimetric analyses to verify that it had adsorbed the VOCs generated during coatings spray out and curing.

CONCLUSIONS

The study has identified a solvent/VOC method, activated carbon adsorption that is amenable to being used in conjunction with KYTC bridge maintenance painting operations. The method has a high VOC capture efficiency and when used in conjunction with normal KYTC-specified structural containment for bridge painting, it should be capable of capturing over 90 percent of all VOCs generated during coatings application and curing. Its use would ensure that KYTC maintenance painting activities don't contribute to ozone non-attainment and marginal attainment problems. Additionally, it may offer further benefits in promoting rapid coatings curing and the subsequent reduction of motorist disruptions by reducing lane closure time during painting operations or allowing a painting contractor to complete work in a timelier manner. If this technology proves amenable to widespread use, KYTC coatings officials should discuss possible formulation modifications with coatings manufacturers to reduce coating cure times.

RECOMMENDATIONS

The following recommendations are provided:

- Conduct an experimental bridge maintenance painting project employing VOC capture technology.
- Perform a preliminary review of worker safety issues on that project.
- Specify the use existing "off the shelf" technology for VOC capture.
- Conduct the project in an ozone non-attainment or marginal attainment county.

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TABLES

Table 1 VOC Generation (lbs) for Three KYTC-Qualified Bridge Maintenance Coatings Systems on Typical Two Lane Overpass Bridge to be Painted Using Two Equal Containments			
Containment (10,000 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	207	414	621
Coatings System 2	330	660	990
Coatings System 3	175	350	525
Total Bridge (20,000 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	414	828	1,242
Coatings System 2	660	1,320	1,980
Coatings System 3	350	700	1,050

Table 2 VOC Generation (lbs) for Three KYTC-Qualified Bridge Maintenance Coatings Systems on Typical Three or Four Lane Overpass Bridge to be Painted Using Three Equal Containments			
Containment (13,300 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	662	1,324	1,986
Coatings System 2	1,056	2,112	3,168
Coatings System 3	561	1,121	1,683
Total Bridge (40,000 ft^2 of Painted Steel	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	1,986	3,972	5,958
Coatings System 2	3,168	6,336	9,504
Coatings System 3	1,683	3,366	4,914

Table 3 Activated Carbon (lbs) Necessary for VOC Adsorption for Three KYTC-Qualified Bridge Maintenance Coatings Systems on Typical Two Lane Overpass Bridge to be Painted Using Two Equal Containments (Based upon 15 % VOC Adsorption)			
Containment (10,000 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	1,387	2,774	4,161
Coatings System 2	2,211	4,422	6,633
Coatings System 3	1,173	2,345	3,518
Total Bridge (20,000 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	2,774	5,548	8,322
Coatings System 2	4,422	8,844	13,266

Coatings System 3	2,346	4,690	7,036

Table 4 Activated Carbon (lbs) Necessary for VOC Adsorption for Three KYTC-Qualified Bridge Maintenance Coatings Systems on Typical Three or Four Lane Overpass Bridge to be Painted Using Three Equal Containments			
Containment (13,300 ft^2 of Painted Steel)	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	5,509	8,871	13,306
Coatings System 2	6,738	14,150	21,226
Coatings System 3	3,759	7,511	11,276
Total Bridge (40,000 ft^2 of Painted Steel	100 % Coatings App. Efficiency	50 % Coatings App. Efficiency.	33 % Coatings App. Efficiency
Coatings System 1	13,306	26,612	39,919
Coatings System 2	21,226	42,451	63,677
Coatings System 3	11,276	22,552	32,924

Table 5 Containment Enclosure Volumes and Air Flow Requirements for Typical KYTC Overpass Bridges		
A. Small Two-Lane Bridge to be Painted Using Two Equal Containments		
Grounded Containment	Volume (ft^3)	Recommended Air Flow (ft^3/min).
60’ Long x 30’Wide x 24’ High	21,600	1,800
Suspended Containment	Volume (ft^3)	Recommended Air Flow (ft^3/min).
60’ Long x 30’ Wide x 6’ High	5,400	450
B. Large Three or Four-Lane Bridge to be Painted Using Three Equal Containments		
Grounded Containment	Volume (ft^3)	Recommended Air Flow (ft^3/min).
100’ Long x 40’ Wide x 24’ High	32,000	2,670
Suspended Containment	Volume (ft^3)	Recommended Air Flow (ft^3/min).
100’ Long x 40’ Wide x 6’ High	8,000	1,683

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