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A Coating Alternatives Guide (CAGE) for Metal Parts and Products Painting

by

Dean R. Cornstubble
Jesse N. Baskir
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, North Carolina 27709-2194

and

Michael Kosusko
U.S. Environmental Protection Agency
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division
Research Triangle Park, North Carolina 27711

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INTRODUCTION

In the miscellaneous metal parts coating industry, manufacturers paint or coat their products to protect the substrate from corrosion, enhance the appearance of the product, or both. Conventional liquid paints and coatings contain a substantial quantity of organic solvent that evaporates during the curing or drying of the coating. Consequently, surface coating operations are a major source of Hazardous Air Pollutant (HAP) and Volatile Organic Compound (VOC) emissions. In 1992, air emissions from industrial surface coating operations accounted for nearly 24 percent of all VOC emissions to the atmosphere from industrial processes.[1] This was more than 2.6 million tons (2.4 million metric tons) of VOCs.

Coating suppliers are constantly researching and developing new low- and no-VOC/HAP products in response to environmental regulatory requirements. Coating users, particularly small businesses, may be unaware of new products and how these products can reduce their process emissions. In most cases where users are aware of new products, they are skeptical of whether these new products can meet their operational, appearance, and performance requirements.

To disseminate information about lower-emitting coatings, Research Triangle Institute (RTI) is working in cooperation with the U.S. Environmental Protection Agency's Air Pollution

Prevention and Control Division (APPCD)[a] to develop the Coating Alternatives Guide (CAGE). The objective of this work is to develop a computer-based expert system and database that coating users, and those providing technical assistance to them, can use to select technically innovative, cost-effective, and low-polluting coatings. CAGE is designed to provide information on coating equipment and coating alternatives in a user-friendly, question-driven format.

The technical effort for this project is focused initially on developing CAGE to provide information to end users concerning alternative coatings for metal parts and products painting. Future development of CAGE will include other metal substrates as well as non-metallic substrates such as wood and plastics. This paper describes the initial phases of development of the CAGE system.

BACKGROUND

Traditional approaches to providing information to smaller businesses generally focus on gathering information on a topic and creating a written document which is then made available through business assistance hotlines, resource centers, and other distribution systems. Unfortunately, written documents generally have limited utility for meeting the information needs of a small business for many reasons. These include difficulties in disseminating the documents, incomplete information, information irrelevant to the user, or out-of-date information.

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The difficulties in gathering and distributing coatings information suggest an information diffusion approach based on electronic information media. Electronic media provide the ability to manufacture and distribute essentially unlimited copies of information virtually instantaneously and at little cost. Diverse sources of information can be collected into a single information base, to which information can be easily added over time. When information is updated, it can be made available almost immediately. Electronic media also lend themselves to user-directed information searches which allow the user to screen out irrelevant information.

It is recognized that some small businesses may not be skilled in the use of computers; however, computer usage has made significant in-roads, and this trend is likely to continue. Because CAGE is primarily aimed at small businesses, the system is based on expert system software that runs in a DOS operating environment. A DOS-based system was chosen rather than a Windows system because many small businesses that have computers are using older AT-based computers operating with DOS and may not have the hardware to adopt Windows.

The development of CAGE is based on the premise that an electronic information base available for personal computers can serve as an effective tool to assist coatings users and state and local technical assistance organizations. These users need information about the coatings that can reduce emissions from coating operations and expertise to help focus their search on those coatings that can best meet their specific performance and other requirements. To meet these needs, CAGE provides 1) information about a variety of low-emitting coatings and 2) a relative ranking of those coatings based on information provided by the user concerning a specific application.

The ranking of options is based on the user's answers to a series of questions about performance requirements, operational limitations of the painting line, appearance requirements, exposure environment, and cost considerations. CAGE does not rank coatings based on environmental factors. CAGE includes information only about lower-emitting coatings; conventional low-solids, solvent-borne coatings are not in the system, and, therefore, are not ranked.

CAGE consists of four distinct parts: questions, alternative coatings, ranking of coating alternatives, and the database of information on each alternative.

QUESTIONS

Determining the applicability of potential coating alternatives to the end user requires a variety of information from the coating user regarding the operational, performance, appearance, and other requirements of the coating system. CAGE gathers information by asking a series of questions similar to those a coatings "expert" might ask of a user in order to narrow the list of likely coating selections. These questions are directed at the user's current painting process, substrate material, appearance and performance requirements, and willingness to change its current painting process. These determine whether CAGE will recommend alternatives requiring process changes.

CAGE begins by requesting information about the user's current process in order to determine whether the user is seeking to choose a primer, a topcoat, or both. The program then gathers information about the coatings that are currently being used, the types of cleaning and pretreatment that are conducted, the application equipment that is currently used, the number of color changes that typically occur during a day, and the current curing method (air dried, force

dried, or baked). This information helps to establish a "baseline" for the type of coating needed. The computer uses this information to determine which environmentally safe coating alternative will be a suitable substitute, which can be integrated into the user's current process with only slight modifications (unless the user decides on investing in changing its process to accommodate new technologies).

Coating selection is also based on the substrate material. CAGE is currently being developed to address metal parts coating, with a focus initially on steel and aluminum substrates which are the major metallic substrates used in metal parts manufacturing.

The system then gathers information about the relative importance of coating appearance, compared to the performance characteristics of the coating. Coating selection in certain cases is primarily a matter of selecting a coating that looks good (e.g., the metal components of a stapler); whereas, in other cases, the coating must be able to protect the substrate from corrosive environments (e.g., metal components of outboard motors). In some cases, both properties are important (e.g., certain automotive components). The user's selection will determine whether high performance coatings will be weighted more heavily.

CAGE then asks questions regarding the user's operational and performance requirements. Operational requirements indicate how quickly the coating must dry or become tack-free in order to ensure that the current rate of production is not compromised. Performance requirements relate to the level of physical and chemical stress that the final dry coating must be able to withstand, such as exposure to sunlight, temperature limitations, and chemical, abrasion, or impact resistance.

Finally, the system considers a user's willingness to change current equipment, and the degree to which cost considerations will affect the selection. Users who are unwilling to modify their current application equipment or who are unable or unwilling to spend more for their coating will be more constrained in their choice of alternatives than users who may be willing to consider redesign of their current coating line or a more expensive coating option in order to reduce their emissions.

ALTERNATIVE COATINGS

The alternative coatings included in CAGE are "generic" representations rather than specific vendor products. This approach was selected for several reasons. Although including specific coating formulations in CAGE would provide the user with more detailed information about coatings, doing so would require the use of information from coatings vendors about the characteristics of their products. It would not be possible to verify all vendor claims about their products. In addition, including specific product formulations in CAGE would create a situation in which CAGE would be ranking rival products from vendors for particular applications. This would not be appropriate because in many cases vendors formulate products specifically to meet the demands of the customer's application. In addition, a single vendor may offer a large and diverse product line that changes as new products are introduced. Including all of these in CAGE and keeping information in the system current would be expensive and extremely difficult.

Finally, CAGE is not intended to be a replacement for the technical representative of the coatings vendor. Rather, CAGE is intended to narrow the range of formulations that the coatings user investigates. CAGE also can help the user understand performance issues and limitations of

certain classes of coatings so that the user can be more knowledgeable about coating technologies when contacting a vendor.

The current set of generic coating systems included in CAGE represent VOC and HAP contents less than 3.5 lb/gal (420 g/ℓ). These systems are divided into primers and topcoats. The types of coatings included in these categories are shown in Table 1.

Table 1. Coating Alternatives Available in CAGE

Primers	Topcoats
Alkyd (high solids, solvent-borne)	Alkyd (high solids, solvent-borne)
Alkyd (water-reducible)	Alkyd (water-reducible)
2-Component epoxy (solvent-borne)	Latex
2-Component epoxy (water-reducible)	Powder (acrylic, epoxy, polyester)
Latex	Two component urethanes (solvent-borne)
	One component urethanes (solvent-borne)

The expected VOC content range for these formulations will depend on whether the coating is an air dried, baked, or a two-component coating. Typical VOC content ranges for these coatings are shown in Table 2.

Table 2. Approximate VOC Content Range for Coating Selections

	Approximate VOC content range	
Coating alternatives	**lb/gal**	**g/ℓ**
2-Component	2.8	335
Latex	1.5	180
Powder	~ 0	~ 0
Solvent-borne air dry	2.5 - 3.5	300 - 420
Solvent-borne baked finish	2.0 - 2.8	240 - 335
Water-reducible air dry	2.5 - 3.0	300 - 360
Water-reducible baked finish	1.5 - 2.5	180 - 300

The initial coatings included in CAGE have been limited intentionally to simplify the development of the preliminary stage of the system. These coatings were selected to provide a representative sample of alternative system chemistries currently available, and will be expanded as the logic for the system is refined and verified.

RANKING OF COATING ALTERNATIVES

Information regarding the logic of selecting coatings was gathered primarily through a series of discussions with coating experts. This information was supplemented with additional information from the literature regarding coatings properties.

Alternatives in CAGE are ranked based on the user's response to questions. "Scores" for each option are tallied by the system based on the user's response to each question where scoring occurs. Currently, alternatives receive a higher score if the coating will do a good job of meeting the user's need, a lower score if the coating does not meet the user's need effectively, and no change in score otherwise. If a coating cannot be used for the user's current operation (e.g., if the finish is baked and the user does not have, and will not purchase, the necessary curing equipment), the coating is eliminated from further consideration.

CAGE keeps track of each coating's score, based on the user's response to questions, and also maintains a tally of the maximum score possible for a coating. Coatings are ranked based on a score normalized to a maximum total score of 100 points after all questions asked have been answered.

DATABASE OF INFORMATION ON EACH ALTERNATIVE

For the end user, CAGE would essentially be useless without an information reference identifying key considerations when using a new alternative coating technology. This reference

information refers to the database contained within the CAGE system. As an integral part of CAGE, generic and specific information on each coating alternative is provided to the user in the form of text files, which the user may view on the screen, transfer to a disk, or both. Each text file has several categories of information for each alternative, arranged in bullet form. These include: (1) *General Information,* on overall performance, use, and curing considerations; (2) *Performance*, listing and describing red flags to watch out for in applying the coating to achieve desired performance; (3) *Equipment, Operator, and Economic Considerations,* providing tips on application technique, operator safety and handling, and general economics of use and application; (4) *Environmental,* providing any potential VOC and/or HAP regulations to be cognizant of; and (5) *References,* identifying industry, consultant, and academic references to each bullet item in the file.

CURRENT STATUS AND SHORT TERM PLANS

CAGE is still in the early stages of development, and much work remains before the system can realize its full potential. Several areas will be addressed as the development of CAGE continues are expanded expert input, user testing, reporting, additional coating alternatives, and providing "transparent" logic to the user.

Expanded Expert Input. Rankings produced by CAGE do not represent "right" and "wrong" answers to the question of coating selection, but rather present a relative preference for certain coatings in particular applications, based on the expert experience that has been built into the system. To a certain degree, coating experts may disagree as to the "best" coating selection for a given application, especially when ranking the "generic" options which are included in CAGE. As CAGE development continues, additional experts will be consulted regarding the

logical selection process. This will help ensure that the results from CAGE are not biased by the preferences of a single coatings expert.

User Testing. The questions used in CAGE will need to be reviewed and refined to streamline the logical flow and to ensure that the broad range of potential users can understand the questions that the system asks. RTI will test the CAGE system through reviews by members of small business technical assistance organizations, such as the state and local pollution prevention technical assistance programs that make up the National Pollution Prevention Roundtable. The system will also be given to coatings experts and users to identify problems and make recommendations for improvement.

Reporting. Development to date on CAGE has focused on the logical process for selecting coatings based on user-defined needs. However, an equally important aspect of the system is the information it provides to the user about coatings alternatives, their strengths, their weaknesses, and the specific areas that may be of concern given the user's needs and the limitations of the coating of interest. The report will provide vital information the user needs to begin discussions with coatings formulators about specific alternative coatings.

Additional Coating Alternatives. CAGE currently contains a limited set of possible coating chemistries. RTI will gather further information about coating systems and add them to CAGE to provide a broader set of possible alternatives for the user to consider.

Providing "Transparent" Logic. While obtaining a ranking of possible alternative coatings may be useful, of equal interest may be why CAGE ranked coatings a particular way for a particular scenario. If CAGE operates as a "black box," the user will not have access to valuable information regarding coating selection. RTI will explore ways to ensure that the

logical reasoning in CAGE is "transparent" to the user by providing explanatory notes attached to each question asked and in the text of the reports generated by CAGE.

LONG TERM DEVELOPMENT

Long term development of the CAGE system will seek to expand system capabilities in a number of areas, including additional substrate materials, coating application equipment selection, a Windows version of CAGE, and system maintenance.

Additional Substrate Materials. The current focus of CAGE is on aluminum and steel substrates, which covers a majority of the metal painting market. Other metal substrates could also be added to CAGE. In addition, non-metallic substrates, including wood and plastics, will be included. Future CAGE "modules" could be created to address factors unique to the selection of coatings for these substrates.

Coating Application Equipment Selection. Future versions of CAGE will consider coating application equipment selection. Application equipment selection is important not only because it determines the types of coatings that can be used in specific applications, but also because low-transfer efficiency equipment, which traditionally generates high VOC emissions, could be replaced with more efficient equipment that reduces both emissions and paint consumption.

Windows Version of CAGE. Since computer operating systems continue to move towards Windows operating environments, CAGE could be made available as a Windows software package. This would offer opportunities to add capabilities to CAGE such as graphics and a mouse-driven user interface.

System Maintenance. New developments in coating technology will require that CAGE be maintained and updated in order to stay current. This will include not only new additions but also updating existing information and improving relative ranking scores.

REFERENCE

1. U.S. Environmental Protection Agency (U.S. EPA). October 1993. National Air Pollutant Emission Trends, 1900-1992. EPA-454/R-93-032 (NTIS PB94-152097).

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16. ABSTRACT The paper discusses the initial development of a Coating Alternatives Guide (CAGE) for metal parts and products painting. It is an innovative technology transfer approach that provides a tool to improve technology diffusion and assistance. It will provide vital, user-accessible information on coating equipment and chemistries in a computerized, decision-tree format so that coaters can select technically appropriate, cost effective, and low-emitting coatings and equipment for their use. In 1992, air emissions from industrial surface coating operations accounted for nearly 24% of all volatile organic compound (VOC) emissions from industrial processes. This equaled more than 2.4 million metric tons (2.6 million tons) of VOCs in the U. S. In addition to being VOCs, many of these compounds are also toxic organics. Often the most cost-effective method for reducing emissions from coating operations is the use of alternative, low-emitting coatings. Research Triangle Institute and other research organizations have been collaborating with the U. S. Environmental Protection Agency's National Risk Management Research Laboratory on the identification and evaluation of low-VOC coating alternatives. CAGE will assist small, medium, and large businesses in identifying and evaluating coating technologies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Coatings Metal Coatings Organic Compounds Volatility	Pollution Prevention Stationary Sources Volatile Organic Compounds (VOCs)	13B 11C 11F 07C 20M

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