COATING ALTERNATIVES GUIDE (CAGE)

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

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1.0 INTRODUCTION

Many manufactured items are painted or coated in order to protect the substrate, 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. According to recent estimates, air emissions from industrial surface coating operations in 1992 accounted for nearly 24 percent of all VOC emissions to air from industrial processes (U.S. EPA 1993). This equaled more than 2.6 million tons (2.4 million metric tons) of VOCs.

As coatings users come under increasing pressure from environmental regulatory agencies to reduce their emissions of HAPs and VOCs, coatings suppliers are rapidly developing new lines of low- and no-VOC/HAP coatings. Due to the pace of new product development, coatings users, particularly small businesses, frequently are not aware of new products and of the degree to which these products can reduce their process emissions. Even when businesses are aware of new coatings, they may question whether these products can meet their operational, aesthetic, and performance requirements.

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To assist the end user with sorting through information about lower-emitting coatings, Research Triangle Institute (RTI) is working in cooperation with the U.S. Environmental Protection Agency's Air and Energy Engineering Research Laboratory (AEERL) to develop the *C*oating *A*lternatives *G*uid*e* (CAGE). The goal of this work is to develop a computer-based tool that coating users, and those providing technical assistance to them, can use to select technically appropriate, cost-effective, and low-emitting coatings. CAGE is designed to provide information on coating equipment and chemistries in a user-friendly, decision-tree format.

The technical effort is focused initially on developing CAGE to provide information about alternative coatings for metal parts and products painting. CAGE is being developed in three phases:

1) development of a prototype system using a limited set of coating options,
2) testing the prototype logic system with the help of coating users and state and local pollution prevention assistance offices, and
3) expansion of CAGE to include additional coatings and detailed information about coating options.

This paper describes progress in development of the logic framework for the prototype CAGE system.

2.0 THE CAGE CONCEPT

RTI, in collaboration with EPA, is developing CAGE to address the information needs of smaller businesses that use coatings. It is expected that the primary audiences for CAGE will be those at the business responsible for selecting coatings and the staff of technical assistance programs who conduct pollution prevention assessments for small businesses.

The traditional approach to providing information to smaller businesses generally focuses 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 Disseminating the Documents. For the information to be used, it must first get to the intended audience. Many times businesses are not aware of the existence of the document, do not know where to obtain the document, or find that the copies of the document they would like are not available.

Information Is Not Complete. Many times resource guides do not have complete information about all relevant options, so that the information seeker must identify, locate, and read multiple documents in order to have complete information about relevant options.

Documents Include Information Irrelevant to the User. For written documents on

complex subjects, such as coatings, to be of use to a broad audience, they must contain a tremendous amount of information. However, only a small portion of that information is likely to be directly relevant to the needs of a particular user. This forces the user to search through the document to determine which portions may be relevant--a time-consuming process that may deter small businesses from examining the information.

Information Is Not Current. The "shelf life" for a written document in a rapidly changing field such as coatings technology may be as short as a year or less. This time frame may be even shorter if the document contains information such as names and telephone numbers of product vendors or technical contacts. Most guides are not updated or are updated infrequently.

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.

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 the organizations that provide technical assistance to them). These users need not only information about the coating chemistries that can reduce emissions from coating operations, but also expertise to help focus their search on those coating chemistries that can best meet their specific performance and other requirements. To meet these needs, CAGE will provide 1) information about a variety of low-emitting coatings and 2) a relative ranking of coatings based on information provided by the user about 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, 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.

The rationale for developing CAGE is similar to that for the *S*olvent *A*lternatives *G*uid*e* (SAGE), which RTI developed in collaboration with the EPA, to identify alternative cleaning chemistries and equipment for small businesses. SAGE has been used successfully to distribute information about alternative cleaning options to a broad audience. More than 2,000 copies of SAGE have been distributed to date through EPA electronic bulletin boards and EPA's Control Technology Center. Many of the users of SAGE are small business assistance providers that take laptop computers to small businesses and run the SAGE program to identify cleaning chemistry and equipment options while they are conducting pollution prevention assessments. New versions of SAGE continue to be developed and distributed through the Internet. It is expected that CAGE will be as successful as SAGE in helping to disseminate information to small

businesses.

Because CAGE is primarily aimed at small businesses, the system is currently being developed using expert system software that runs in a DOS operating system. 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 systems and may not have the hardware to adopt Windows.

3.0 TECHNICAL DEVELOPMENT OF CAGE

The remainder of this paper focuses on the development of the logic system in CAGE for ranking coating options. The development of the logic system for ranking options in CAGE consists of three main parts:

1) developing the set of coatings to include in CAGE,
2) developing the set of questions that will be used to elicit key applications information from the user, and
3) developing the logical reasoning and scoring systems that determine how the user's answers to the questions affect the ranking of coatings.

Each of these items is discussed below.

3.1 Coatings Included in CAGE

The alternative coatings included in CAGE represent "generic" formulations 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 this 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 options when contacting a vendor.

Several generic coating systems are included in the current prototype for CAGE. Each of the coating chemistries in the system is currently available with VOC and HAP contents less than 3.5 lb/gal (420 g/l). Current systems are divided into primers and topcoats. The types of coatings included in these categories are shown in Table 1.

Table 1. Coating Selections Available in CAGE

Primers	Topcoats
Alkyd (high solids, solvent-borne)	Alkyd (high solids, solvent-borne)
Alkyd (water-reducible)	Alkyd (water-reducible)
Epoxy (2-component, solvent-borne)	Latex
Epoxy (2-component, water-reducible)	Powder (baked finish only)
Latex	Acrylic
	Epoxy
	Polyester
	Urethane (2-component)
	Urethane (1-component, baked finish only)

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

Table 2. Approximate VOC Content Range for Coating Selections

Coating Type	Approximate VOC Content Range	
	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 set of coatings included in CAGE has been limited intentionally to simplify the development of the prototype system. This set of coatings was 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.

3.2 Information Gathered by CAGE to Rank Alternative Coatings

Developing a ranking of potential coating alternatives requires a variety of information from the coating user regarding the operational, performance, appearance, and other requirements of the coating system. The system 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.

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 current coatings that are 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 dry, force dry, or baked). This information helps to establish a "baseline" for the type of coating needed.

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 manufacturing. Future development of CAGE may include other metal substrates as well as non-metallic substrates such as wood and plastics.

The system then gathers information about the relative importance to the user 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 strongly.

CAGE then asks questions regarding the types of operational and performance requirements that the user has. 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 sun exposure, heat, chemical resistance, abrasion resistance, and 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.

3.3 Solution Ranking by CAGE

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

In general, 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. For the prototype, 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. After all questions have been asked, coatings are ranked based on a score normalized to a top total score of 100 points.

4.0 NEXT STEPS

4.1 Current Plans

CAGE is still in the early stages of development, and much work remains before the system can realize its full potential. Several items that will be addressed as this research continues are listed below.

Reports. 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 will be the information it provides to the user about the 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 the user with the information the user needs to begin discussions with coatings formulators about specific alternative coatings.

Expanded Expert Input. Rankings from 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 will not be 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 expects to 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 users to test and identify problems.

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 to the user, of equal interest may be the logical reasoning behind 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 in the reports provided by CAGE.

4.2 Future Work

Long term development of the CAGE system will seek to expand system capabilities in a number of areas, as described below.

System Maintenance. New developments in coating technology will require that CAGE be maintained and updated in order to stay current.

Coating Equipment Selection. CAGE may be developed to look at not only coating selection, but also coating equipment selection. Coating equipment selection is important not only because it determines the types of coatings that can be used in specific applications, but also because low-efficiency equipment can greatly increase VOC emissions. A more comprehensive CAGE program would consider not only coating selection, but also coating equipment selection.

Additional Substrate Materials. The current focus of CAGE is on aluminum and steel finishing, which is a major sector of the painting market. Other metal substrates could also be added to CAGE. In addition, wood and plastic substrates represent a major portion of paint applications. Future CAGE "modules" could be created to address factors unique to selection of coatings for these substrates.

Windows-based CAGE. Since computer operating systems continue to move towards Windows-type operating environments, CAGE could be made available in a Windows-compatible version. This would offer opportunities to add capabilities to CAGE such as graphics and a mouse-driven user interface.

REFERENCE

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