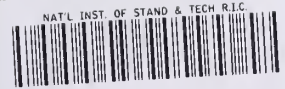


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Graffiti Removers: Evaluation and Preliminary Selection Criteria

M. Godette
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Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
James A. Baker, III, *Under Secretary*
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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ABSTRACT

A program was undertaken to determine the performance of graffiti removers so that performance criteria for selection of these types of materials could be recommended. The results of laboratory tests of removal efficiency, range of effectiveness, remover-substrate compatibility, migration (spreading), and flash point are presented. From the results obtained, tentative criteria for selection of graffiti removers are recommended.

The marking materials (graffiti) used were spray paints of major generic types, crayon and felt-tip pen markers. The substrates used were clay brick, ceramic tile, limestone, sandstone, aluminum and wood. Ninety-nine commercial materials which are marketed for use as graffiti removers were used in the study.

This report is on the removal of marking materials from brick. The results showed that all markings can be removed with a high degree of effectiveness. No single remover was effective on all markings, but a set of five selected removers used in sequence, was effective against all.

The compatibility of the most effective removers with various building materials was also studied. Care must be taken to select a remover which will neither discolor the substrate being cleaned nor adjacent areas.

Key Words: Graffiti; graffiti removers; removal; materials; paint; spray paints; effectiveness; remover-substrate compatibility; substrate.

1. INTRODUCTION

The vandalous use of spray paints and other marking materials to deface the surfaces of buildings has increased tremendously in the last decade. These markings, commonly known as "graffiti", are unsightly and expensive to remove. Nationally, the graffiti problem is estimated to cost 600 million dollars annually [1]*.

Proper maintenance of building surfaces requires the availability of suitable removers which will remove the markings without damaging the substrates and presenting undue hazards to the users of such cleaning materials. Substantial savings could be made by the Department of Housing and Urban Development (HUD) if effective removers were identified and criteria for their selection and use were developed. Therefore, HUD initiated a program to identify and evaluate effective commercial cleaning materials for the removal of markings from various substrates (building surfaces).

This study of graffiti removers was conducted in four phases. Phase I included a literature survey of methods for the removal of markings from building materials; the identification of materials used in public housing, and the identification of graffiti-resistant materials. Phase II was an evaluation of the effectiveness of commercial products proposed for use as graffiti removers. Phase III complemented Phase II in that proposed graffiti-resistant coatings were evaluated for performance, including durability. Phase IV was the development of interim criteria for the performance of graffiti removers and graffiti-resistant coatings. This report presents the results of the activities of Phase II and IV and covers methods of test, and interim performance criteria. The initial task, Phase I, resulted in a letter report to the sponsor (HUD). Information from Phase III is contained in a report presently under editorial review [2].

The objectives of the work described in this report were:

1. To identify commercially available removers suitable for the removal of spray paint, crayon and felt-tip pen markings from commonly exposed building materials.
2. To select tests for evaluating removal efficiency and physical properties of graffiti removers.
3. To evaluate commercially available graffiti removers and recommend interim performance criteria for their selection.

A good remover is characterized by its ability to act quickly and to be easily removed with the marking material without damaging the substrate. Many removers are effective on smooth non-porous substrates, but few are effective on porous and absorptive materials.

From a review of the literature, through contact with industry and public housing engineers, and through visits to commercial sources, 99 potential graffiti removers were identified and samples obtained. The products included liquids, emulsions, pastes, gels and powders. Information on the properties of the removers and the manufacturer's recommended precautions in their use are given in table 1. Among the removers were products claimed to be suitable for application to steel, concrete, sandstone, limestone, brick and wood.

A rapid qualitative screening test was employed to eliminate, from further study, those graffiti removers that showed insufficient effectiveness, unsatisfactory flow properties, or extraordinary hazards. Then, the most promising removers or procedures were more quantitatively evaluated for removal effectiveness.

The marking (graffiti) materials and devices selected for the study were aerosol paints, crayons, lipstick and felt-tip pen markers. The selection of marking materials to be used in the program was based on those general types frequently used by the graffiti artist, and their availability in local stores. The resin type, color and sample number of each spray paint are listed in table 2. In addition to the spray paints, the following materials were used:

*Figures in brackets indicate references in this report.

Felt-Tip Pens - The pens were blue, red, black, red, black, pink and manufactured* by Carter Ink, Skilcraft, Zip Mark and Flair Mft. Co. Two pens made in Japan, could not be identified by either trade name or manufacturer.

Crayons - The crayons were orange, green, green and purple and manufactured by the Crayola Company.

Lipstick - The lipsticks were pink, gold frost and burnt sugar and manufactured by Avon, Max Factor and Elizabeth Arden Company, respectively.

In addition to the brick whose properties are listed in table 3, the following building materials, similar to those found in public housing, were used as experimental substrates. Future reference to these materials implies the type and grade listed below:

1. Aluminum (Architectural) - 6061-T6
2. Briar Hill Sandstone - ASTM Specification C-616
3. Matte Tile - U.S. Dept. of Commerce Spec. USAS A1371-1967
4. Indiana Limestone - ASTM Specification C-568
5. Wood (white pine) - prime grade, kiln dried exterior siding

As a basis for establishing limits of performance for graffiti removers, it is necessary to be able to evaluate the degree to which the uniform appearance of the substrate can be restored following defacement by graffiti. To do this, a Hunter Color-Difference Meter [3] was used to measure changes in appearance. This instrument determines small color differences, observable in daylight illumination, between opaque surfaces such as paint specimens. The apparatus consists of means for locating the surface of the specimen, a light source furnishing a beam incident on the specimen, and a receptor located to receive the rays reflected by the specimen. The receptor is a photosensitive device responding to visible radiation. This instrument is designed to provide color difference measurements in approximate agreement with average visual judgments of color difference [4].

Measurements were made on each specimen before application of the graffiti and after the cleaning process. The change produced by the incomplete removal of the applied graffiti and the effect of the removal process is expressed as "color change."

The color change, ΔE , in NBS units [4] was computed from these measurements and expressed in terms of color retention, C.R. which was defined as [5]:

$$C.R. = 100 - \Delta E^{**}.$$

* Identification of commercial products is included only to adequately specify the test conditions. Identification does not imply recommendation or endorsement by the National Bureau of Standards.

**The color difference parameters, Rd (the 45°, 0° luminous daylight reflectance), a (red-green) and b (yellow-blue) were measured with a color difference meter. The color change in NBS units were calculated by the following formula:

$$\text{Color change } (\Delta E) = \sqrt{(10\sqrt{Rd})^2 + \Delta a^2 + \Delta b^2}$$

An NBS unit is equivalent to the AE, as determined in method 6123 of Federal Test Method Standard 141 [4] and 100 would represent complete return to original appearance after being stained and cleaned.

As will be seen from the results presented in Section 2, it is possible to distinguish between removers of different effectiveness. This is a necessary requirement for the recommendation of practical criteria for the selection of graffiti removers.

2. LABORATORY EVALUATION OF COMMERCIALY AVAILABLE GRAFFITI REMOVERS

This section presents the rationale for the evaluation of graffiti removers and gives the results of the selected tests. Determinations of removal efficiency and measurements of physical properties of removers are used in assessing their quality.

The following tests were chosen to measure those physical properties which are directly related to the performance of graffiti removers. These are the tests which were used to obtain the data presented below and which are referenced in the interim performance criteria of Section 4.

2.1 Preliminary Screening

A qualitative screening test was used in the initial evaluation. In this test, spray paints of various types (table 2) were applied to matte tile. Some of the generic types have more than one representative due to the variations in their ease of removal from tile. Such factors as vehicle type, quantity of vehicle, quantity of pigment and pigment type affect the removal process. The purposes of the test were:

1. To assess the effectiveness and general characteristics of each remover.
2. To eliminate from further study those removers that were ineffective on many markings.

Each of the 36 paints (table 2) was sprayed onto matte tiles, baked at $49 \pm 2^\circ\text{C}$ for 16 hours, and stored at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours. Duplicate sets of 36 tiles, each with a different paint, were prepared. Each remover was then applied to the sets in accordance with the respective supplier's directions. When wrinkling, crazing, lifting, or swelling occurred, the tiles were rinsed with water from a garden hose at a rate of five gallons per minute for a period not longer than 30 seconds to attempt to remove the paint film. Time of removal and percent area affected were recorded.

Those removers providing for the complete removal of the markings within 60 seconds after application of the remover on the marked surface are listed in table 4. These removers were selected for further evaluation. The results showed:

1. The time needed to dislodge the paint could be determined by observation of signs such as wrinkling, cracking, lifting or swelling.
2. The time varied widely between removers.
3. In general, those removers containing bodying or thickening agents (e.g., ceresin or paraffin wax) tended to be more effective.

2.2 Removal Effectiveness - Specific

To be most useful, a graffiti remover must remove a wide range of marking materials. As a measure of usefulness, a test was carried out with each of the 24 removers to determine how many different paints it could remove. Paints were applied to brick, removed and the difference between the original and final appearance (color retention) of each brick determined. The number of paints removed with an efficiency (color retention value) of 90 or greater was recorded.

The purpose of this test was to determine the number of spray paints which could be removed with a high degree of effectiveness by each remover.

The 36 paints (table 2) were sprayed onto brick, baked at $49 \pm 2^\circ\text{C}$ for 16 hours and stored at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours. Each remover was applied to a set of 36 painted bricks in accordance with the supplier's directions except that the dwell time prior to washing was extended to 30 minutes. The brick was then washed with 5 gal/min of high pressure (1600-1900 psi), water to attempt to remove the paint film. Photoelectric measurements of changes in appearance were made by a color difference meter both before application of the paint and after the removal process.

The criterion for removal was that the brick should have a color retention value of at least 90. Table 5 indicates that only three products removed 18 or more of the paints; the most effective product (No. 85) removed 23, the least effective removed only 3. Table 6 identifies the specific paints removed effectively by each remover. The number of specimens retaining a color retention value (C.R.) of 90 or more was recorded.

2.3 Removal Effectiveness - General Purpose

Removal effectiveness, for the purpose of this report, was defined as the extent (average color retention value) to which duplicate sets of 36 painted bricks were restored to their original appearance.

The purpose of this test was to determine the extent to which a remover could restore a substrate, marred by a variety of paints, to its original appearance. Preparation of specimens and the cleaning process were as described in Section 2.2. Photoelectric measurements of changes in appearance both before application of the paint and after the removal process afforded a ranking of the removers according to the extent that duplicate sets of painted bricks were restored to their original appearance.

Table 5 lists the 24 removers in order of effectiveness as determined by the average color retention for brick painted with each of the 36 paints. The number of spray paints removed from brick with an effectiveness (color retention) of at least 90 is also shown for each remover. Removers numbers 85, 88, 82, 90 and 83 were the five most effective removers. However, since several paints were not removed by any of the above removers, they would not be the best five to cover removal of all 36 paints.

Table 7 lists five removers that could be used in sequence for the effective removal of a wide variety of spray paints from brick and other substrates. The compatibility of the removers with various substrates is also indicated. (This will be discussed further in Section 2.5).

2.4 Removal Test of Felt-Tip Pen, Crayon and Lipstick Markings

Since felt-tip pen markings are probably the most difficult of all markings to remove, the removers were next tested for their ability to remove felt-tip pen, crayon and lipstick markings.

The purpose of this test was to identify those removers suitable for the removal of felt-tip pen, crayon and lipstick markings from brick.

The color of the face of brick to be defaced (duplicates for each remover) was determined by a color difference meter [3]. The bricks were then marked with parallel lines, two inches long, using 4 felt-tip pens, 3 lipsticks and 4 crayons. Color and manufacturer are listed in Section 1. The marked samples were then baked at $49 \pm 2^\circ\text{C}$ for 16 hours, removed and conditioned at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours.

The removal process consisted of applying 50 cm^3 of each remover (table 8) over the marked area. Application was in accordance with the supplier's directions, except that the dwell time prior to washing was extended to 30 minutes to obtain maximum removal effectiveness. Then, the markings were washed from the coated brick with 5 gal/min of high pressure (1600-1900 psi) water to remove the paint film. After drying, photometric measurements of

the appearance were made by a color difference meter [3] and used with the results of measurements made before application of the markings to determine the color retention.

It is shown (table 8), that the average color retention value for each set of bricks is approximately 78. This low value reflects the difficulty experienced in removing felt-tip pen markings from porous substrates. Generally, those removers found effective for the removal of paint or felt-tip pen markings were also effective for the removal of crayon, chalk and lipstick as well.

2.5 Remover-Substrate Compatibility

An ideal remover should be able to remove marking materials but should not otherwise affect the appearance of the substrate. To determine the suitability of the removers for use on brick, limestone, aluminum and wood, the change in appearance (color retention) was determined after applying each remover to those materials for one hour, rinsing with water and drying for 24 hours.

The purpose of this test was to determine the effect of each remover on substrates (building surfaces) encountered in public housing developments.

Duplicate 100 x 100 x 6.25 mm specimens were cut from brick, limestone, white pine siding and architectural aluminum. Each specimen was cleaned with 5 percent by weight trisodium phosphate solution and a cellulose sponge, rinsed thoroughly with running water, and dried at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours.

Next, the color of the front side of each specimen was determined by a color difference meter. The measured side was then covered with 25 cm^3 of remover by brush. After exposure for 1 hour at $23 \pm 2^\circ\text{C}$, the specimens were removed and cleaned as before. After storage at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours, the color change was determined as outlined in Method 6123 of Fed. Test Method Std. 141a [4].

Effects of removers on the color retention of aluminum, brick, limestone and wood are indicated in table 9. The wood was most easily altered in appearance, with the limestone being second in order. Surprisingly, even the appearance of the brick was susceptible to change by certain removers.

Tentative performance criteria, for selection of graffiti removers for use on specific substrates, based on the effects of 24 removers on brick, aluminum, limestone and wood, are indicated in Section 4.3. Removers numbers 83 and 27 met the tentative minimum criteria acceptable for application to all four substrates.

2.6 Migration

Removers frequently migrate into or through porous materials to which they are applied. The extent of migration for removers applied to limestone and sandstone was determined by measuring the distance traveled from the point of contact in one hour under specific conditions. These substrates, limestone and sandstone, represent those building materials most susceptible to the migration of solvents.

Ability of a remover to migrate into a substrate may aid the removal of marking materials embedded in it or it may contribute to unnecessary defacement by carrying waxes, or solvents to areas which were previously free of markings.

The purpose of this test was to determine the distance traveled from the point of contact with the stone.

Duplicate 25 x 25 x 75 mm specimens of Indiana limestone and Briar Hill sandstone were allowed to stand vertically in a dish (55 mm in diameter) filled to the 6.25 mm level with each remover at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh. After one hour, the specimens were removed and the depth of migration (visible on the sides of the specimens) beyond the 6.25 mm level was measured by ruler to the nearest mm.

Only fourteen removers (figure 1) showed little or no migration into Briar Hill sandstone; however, on Indiana limestone, their migration averaged 10 mm. Removers that migrated 12.5 mm into limestone usually showed even greater migration into sandstone.

2.7 Evaporation Rate

Removers that contain large quantities of volatile solvents may be unacceptable for reasons of air pollution, toxicity and fire hazards. Also evaporative loss of solvents may reduce the effectiveness for the removal of markings. The rate of evaporation of removers was determined by exposing a fixed volume and surface area to the atmosphere at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh, and recording the loss during the first minute.

The purpose of this test was to determine the relative rates of evaporation of solvents from removers at a normal temperature of application.

Portions (duplicates) of the thoroughly mixed sample (not more than 0.03 gms) were transferred to flat-bottomed pans (60 mm in diameter). The pans and contents were weighed to the nearest one-tenth of a mg and exposed to an atmosphere of $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh. After 1 minute, the pans were weighed again and the average weight loss per minute was determined.

Data in table 1 includes evaporation rates for the 99 removers. Generally, effective removers retained their solvents; less effective removers lost solvents rapidly. Remover numbers 76, 80, 67 and 11 lost more than one percent of the weight applied during one minute of exposure. Twenty of the 24 most effective removers lost less than one percent during the same period.

Rapid evaporation of solvents may cause hazards for the user if the vapors are toxic or flammable (see Section 2.8).

2.8 Flash Point

The vapors from low boiling solvents in many paint removers may present fire hazards. To simulate actual conditions, removers were exposed to elevated temperatures in the presence of an open flame.

The purpose of this test [8] was to determine the flash point -- the lowest temperature at which the remover gives off vapors in sufficient quantity to be ignited by an open flame.

The basic test method shall be as specified in ASTM Designation: D130-59T. The sample is placed in the cup of a Tag Open Tester [8] and heated at a constant rate. A small test flame is passed at a uniform rate across the cup at intervals of 0.5°C rise in temperature. The flash point is taken as the lowest temperature at which application of the test flame causes the vapor at the surface of the liquid to flash.

Data in table 1 indicate that the removers have a wide range of flash points. Most of the top ranked removers in table 1 (numbers 85, 88, 82, 83, 69 and 11) flashed at a temperature greater than 37.8°C and would not be classed as flammable.

2.9 Nonvolatile Content

To be most useful, a graffiti remover must contain sufficient solvents to penetrate the markings and soften, dissolve or lift them from the substrate. The purpose of this test was to determine the amount of available solvent in each remover.

Basically the procedure is as described in Method 4041 of Federal Test Method Standard 141a. A portion of the thoroughly mixed sample (not more than 0.3 gms) was transferred to a flat bottom pan (60 mm in diameter). The pan and contents were weighed to the nearest one-tenth of a mg and placed in a gravity convection oven at 105°C for 30 minutes. After cooling in a desiccator, the dish was weighed again to the nearest one-tenth mg. The percent nonvolatile was calculated from the weight of the residue in the dish and the weight of the sample taken.

The removers (table 1) showed a wide range of nonvolatile contents. The samples ranged from a low of 0.3% to a high of 48.7% for non-powder type removers.

3. DISCUSSION

The results of the laboratory tests reported in Section 2 show that with selections of removers, it is possible to remove each of 36 spray paints from brick to the extent that there is at least a color retention value of 90 as compared to the original unpainted brick. Further, the smallest set of removers capable of removing any one of the 36 paints from brick to give a color retention value of 90 contains five removers. The most effective set of five removers for spray paints on brick was identified and consisted of remover numbers 85, 88, 82, 38 and 67.

The study of the effects of removers on the various substrates showed that care must be exercised in selecting the removers to ensure that they do not discolor the substrate to an unacceptable degree. Other considerations in selection of removers should be avoidance of hazardous materials, whether toxic or flammable, wherever this can be done without serious loss of removal effectiveness. Lastly, it is important to note that removal effectiveness or convenience of use may be impaired if the rate of evaporation is high, or if the remover tends to migrate too far in the substrate.

The selection of removers for use with unidentified markings on a given substrate cannot be made in a definitive manner. However, the tables given in Section 2 show removers which can be used on brick with reasonable confidence. Similar tables can be drawn up for markings on other substrates.

Taking into account the factors mentioned above, and based on the data reported in Section 2, tentative selection criteria for graffiti removers to be used for markings on specified substrates have been drawn up. These tentative criteria are presented in Section 4.

4. RECOMMENDED SELECTION CRITERIA FOR GRAFFITI REMOVERS

The recommended selection criteria for graffiti removers which are given below are based on the results reported in Section 2. The quantitative values given in each criterion reflect our present best judgment. However, it must be recognized that further experience may suggest that the values should be changed or that a different set of criteria is needed.

4.1 Removal Effectiveness - Specific

Requirement

A set of removers should be available which, between them, will be highly effective in removing all common marking materials. In addition, to simplify remover selection, removers which are highly effective for specific materials should also be effective on as many other common marking materials as possible.

Criterion

When a remover is tested as outlined below, a minimum color retention value of 90 shall be obtained for at least 14 of the 36 spray painted bricks.

Test

The 36 paints (table 2) are sprayed onto brick, baked at $49 \pm 2^\circ\text{C}$ for 16 hours and stored at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours. Each remover is applied to a set of 36 painted bricks in accordance with the supplier's directions except that the dwell time prior to washing is extended to 30 minutes. The brick is then washed with 5 gal/min of high pressure (1600-1900 psi) water to remove the paint film. Photoelectric measurements of changes in appearance are made by a color difference meter both before application of the paint and after the removal process.

Commentary

This criterion was designed to enable users to select removers for the removal of specific markings with a high degree of effectiveness while retaining the convenience of a remover which will remove several types. Results were dependent upon test samples (spray paints) used and probably would have been slightly different if other materials had been used.

4.2 Removal Effectiveness - General Purpose

Requirement

Where convenience of selection of a remover for an unknown marking is more important than having the highest effectiveness of removal, removers should be available which are at least moderately effective in removing a wide range of materials.

Criterion

When tested as outlined below, the average color retention for duplicate sets of 36 different paints (table 2) shall be not less than 75.

Test

The 36 paints (table 2) are sprayed onto brick, baked at $49 \pm 2^\circ\text{C}$ for 16 hours and stored at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours. Each remover is applied to a set of 36 painted bricks in accordance with the supplier's directions except that the dwell time prior to washing is extended to 30 minutes. The brick is then washed with 5 gal/min of high pressure (1600-1900 psi) water to remove the paint film. Photoelectric measurements of changes in appearance are made by a color difference meter both before application of the paint and after the removal process.

Commentary

The effectiveness of a general purpose remover must be judged on its ability to remove a wide variety of markings. This criterion is based on an average effectiveness in removing 36 different commercially available spray paints. Results would probably be different if a different selection of marking materials had been used.

4.3 Remover-Substrate Compatibility

Requirement

Removers should remove markings without impairing the integrity and appearance of the substrate.

Criterion

When the remover is tested as outlined below, the substrate's color retention shall comply with the following requirements:

	Aluminum (6061-T6)	Brick (Table 2)	Limestone (Indiana)	Wood (White pine)
Color retention (min)	97.0	96.0	95.0	90.0

Test

Duplicate 100 x 100 x 6.25 mm specimens are cut from brick, limestone, white pine siding and architectural aluminum. Each specimen is cleaned with 5 percent by weight trisodium phosphate solution and a cellulose sponge, rinsed thoroughly with running water, and dried at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh for 24 hours.

Next, the color of the front side of each specimen is determined by a color difference meter. The measured side is then covered with 25 cm³ of remover by brush. After exposure for 1 hour at 23 ± 2°C, the specimens are removed and cleaned as before. After storage at 23 ± 2°C and 50 ± 5% rh for 24 hours, the color change is determined as outlined in Method 6123 of Fed. Test Method Std. 141a [4].

Commentary

Removers which are effective in the removal of common marking materials frequently alter the appearance of the substrate. These criteria were established to minimize damage or discoloration which might be caused to common architectural materials by graffiti removers. The limits were determined by testing 24 removers. Bases for selecting the above criteria included the number of removers meeting the criteria, the observed change in appearance and the average color change as determined by a color difference meter.

4.4 Evaporation

Requirement

The remover should be capable of remaining in contact with the marred substrate for sufficient time to effect removal.

Criterion

The evaporation loss during the first minute of exposure shall be less than one percent of the weight of remover applied.

Test

Portions (duplicates) of the thoroughly mixed sample (not more than 0.3 gms) are transferred to flat-bottomed pans (60 mm in diameter). The pans and contents are weighed to the nearest one-tenth of a mg and exposed to an atmosphere of 23 ± 2°C and 50 ± 5% rh. After 1 minute, the pans are weighed again and the average weight loss per minute is determined.

Commentary

The user's work task is facilitated by the use of removers which remain in contact with the defaced area for sufficient time to effect removal of the markings. This property results in a need for fewer applications and a shorter removal time. This criterion was selected to identify those removers most likely to remain on the affected area for long periods of time. The degree of toxicity and air pollution effect were not considered.

A low rate of evaporation prolongs the time in which the solvent is able to saturate the affected area and provide effective removal. Twenty of the 24 effective removers had an evaporation rate less than one percent by weight of the exposed remover.

4.5 Flash Point

Requirement

The user should not be exposed to undue hazard because of the flammable nature of the removers.

Criterion

Removers shall be classified as follows:

	<u>Extremely Flammable</u>	<u>Flammable</u>
Flash Point	-6°C	-6 to 26.7°C

Test

The basic test method shall be as specified in ASTM Designation: D130-59T. The sample is placed in the cup of a Tag Open Tester [8] and heated at a constant rate. A small test flame is passed at a uniform rate across the cup at intervals of 0.5°C rise in temperature. The flash point is taken as the lowest temperature at which application of the test flame causes the vapor at the surface of the liquid to flash.

Commentary

The vapors from low-flashing removers may present undue fire hazards to the user. This criterion was selected to identify those removers which could be used safely during the removal process. Typical precautions in using low-flashing removers include the exclusion of open flames and providing adequate ventilation during use. Removers show a wide range of flash points; however, most effective removers flashed at a temperature greater than 37.8°C and would not be classed as flammable. These classifications are in accord with the Federal Hazardous Substances Labeling Act [6].

5. SUMMARY AND CONCLUSIONS

The results reported in Section 2 show that a wide range of markings can be removed from brick. Results also show that some of the removers used on brick, can also be used on other substrates currently used in public housing.

From the experiments on the use of a wide range of graffiti and paint removers in the removal of 36 spray paints, felt-tip pen, crayon and lipstick markings, it was concluded that:

1. A quantitative rating of the effectiveness of graffiti removal and restoration of color of substrate can be based on measurements with a color difference meter.
2. While no one remover was effective against all markings on brick, several removers effectively attacked a wide variety of markings.
3. A selection of removers is usually required to ensure removal of markings of unknown types.
4. Since many removers stain one or more of the substrates on which they might be used, care must be taken in their selection.

On the basis of the work described, the tentative performance criteria presented in Section 4 provide a rational basis for the selection of effective removers for spray paint, felt-tip pen, crayon and lipstick markings on specific substrates.

Five removers which can be used to remove a variety of unknown spray paints from brick effectively are Nos. 85, 88, 62, 38 and 67. Of these five removers Nos. 38 and 67 can be used for aluminum, Nos. 88, 38 and 67 for wood and No. 38 for limestone without affecting the color of the substrate.

Table 1. Properties of Graffiti Removers

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
1	Aerosol spray	8	27.0	1.3	Yellow stain	24	Swallowing may be fatal or cause blindness. Flammable - vapor harmful. Do not get in eyes or on skin. Do not store above 120°F.
2	Aerosol spray (detergent)	10	5.3	3.7	Yellow stain	27	Vapor may be harmful. Do not store above 120°F.
3	Aerosol spray	6	3.0	1.3	No discernible color change	13	Harmful if swallowed. Avoid breathing of spray or vapor. Keep out of eyes. Flammable. Do not use near fire, sparks or flame. Exposure to temperatures above 130°F may cause bursting.
4	Aerosol spray	5	5.0	0.3	No discernible color change	18	Excessive inhalation of mist or vapor may be harmful. Avoid contact with eyes and sensitive skin. Do not store in direct sunlight or above 120°F
5	Aerosol spray	6	3.6	0.3	Yellow stain	>38	Do not store above 120°F.
6	Aerosol spray	8	1.2	0.4	Yellow stain	> 43	Do not take internally. Avoid contact with eyes.
7	Aerosol spray	5	7.0	0.4	No discernible color change	> 43	Use with adequate ventilation and avoid breathing vapors. Avoid contact with eyes and skin. Do not expose can to heat or store above 120°F.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
8	Aerosol spray (detergent)	11	2.4	3.6	--*	21	Do not use near open flame. Do not keep where temperature will exceed 120°F.
9	Aerosol spray	6	3.8	2.6	Dark gray stain	21	Do not store above 120°F. Avoid breathing of vapors and repeated contact with skin. Keep out of eyes. Use with adequate ventilation.
10	Aerosol spray (detergent)	8	1.9	5.7	--	20	Do not store above 120°F. Avoid contact with eyes.
11	Aerosol spray	3	3.4	14.0	No discernible color change	> 38	Do not store above 120°F. Spray in ventilated area. May be harmful if swallowed. Avoid contact with skin. Use only on cold or warm surfaces. Contact with hot surfaces or with flames may produce irritating or toxic gases.
12	Aerosol spray	6	2.8	2.2	No discernible color change	26	Do not store above 120°F. Avoid breathing vapor or repeated contact with skin.
13	Liquid cleaner	10	0.3	7.1	No discernible color change	> 38	May cause eye and skin irritation. Harmful if swallowed. Avoid freezing.

*Test not made - insufficient sample.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
14	Aerosol spray	4	6.5	0.7	No discernible color change	> 38	Harmful or fatal if swallowed. Vapor harmful. Eye and skin irritant.
15	Thick blue liquid	6	0.0	4.2	Dark gray stain	> 38	May be harmful if swallowed.
16	Liquid cleaner	11	0.2	1.3	No discernible color change	> 38	Prolonged contact with skin may cause irritation.
17	Liquid cleaner	11	0.2	8.1	--	--	Non-corrosive. Non-toxic.
18	Liquid paint stripper	1	0.0	9.6	Dark gray stain	> 38	Use only with adequate ventilation. Avoid prolonged breathing of vapor. Avoid contact with skin, eyes and clothing. Store out of direct sunlight and away from heat.
19	Liquid paint	6	0.0	3.9	No discernible color change	> 38	Store out of direct sunlight and away from heat. Avoid prolonged breathing of vapor. Avoid contact with skin, eyes or clothing.
20	Liquid	6	1.2	5.4	No discernible color change	--	May be harmful or fatal if swallowed. Combustible. Do not use near heat or flame. Avoid prolonged breathing of vapor.
21	Liquid detergent	8	0.2	19.5	--	--	Non-toxic, non-volatile, non-flammable. Keep out of reach of children.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (Loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (From Manufacturer's Label)
22	Liquid detergent	8	0.3	10.1	--	--	Keep out of reach of children.
23	Liquid detergent	11	0.1	5.5	--	--	Keep out of reach of children and rinse thoroughly if sprayed in eyes.
24	Liquid paint stripper	7	0.1	6.5	No discernible color change	29	Poison. Avoid breathing or contact with skin or eyes. Contact with flame or hot surfaces may produce toxic gases. Use only with adequate ventilation.
25	Aerosol spray	6	6.9	1.7	No discernible color change	>38	Use with adequate ventilation, do not take internally. Avoid prolonged or repeated breathing of vapors or contact with skin. Keep away from sunlight or direct heat.
26	Aerosol spray	6	6.3	18.0	No discernible color change	35	Extremely flammable. Keep from heat or flame. Harmful or fatal if swallowed. Vapor harmful. Avoid inhalation of vapor. Use in well ventilated areas. Avoid contact with eyes. Do not store where temperatures exceed 130°F.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
27	Liquid paint stripper	7	0.1	4.9	No discernible color change	>38	Avoid breathing or contact with skin or eyes. Contact with flame or hot surfaces may produce toxic gases.
28	Liquid cleaner	8	0.0	4.4	No discernible color change	>38	Open can carefully - contains methylene chloride. Use with adequate ventilation. Keep can in cool place. If skin is irritated, rinse with water.
29	Liquid	5	0.0	1.6	No discernible color change	temp. const. at 33	Apply in ventilated area. May be harmful if swallowed. Avoid prolonged breathing of vapor. Use only on cold or warm surfaces. Contact with hot surfaces may produce toxic gases.
30	Liquid detergent	11	0.5	10.5	No discernible color change	--	Harmful if swallowed. Avoid contact with eyes, mucous membranes and skin.
31	Liquid cleaner	5	0.7	1.5	No discernible color change	27	Flammable. Keep away from heat, sparks and open flame. Keep container closed. Use adequate ventilation. Harmful if swallowed.
32	Liquid cleaner	11	0.2	14.3	No discernible color change	>38	Keep from freezing.
33	Liquid cleaner	11	0.1	19.4	No discernible color change	>38	Protect hands and eyes from contact with chemical.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
34	Liquid cleaner	6	0.1	5.6	Dark gray and yellow stains	>38	Handle carefully and store in a dry moderate temperature area.
35	Liquid cleaner	11	0.2	4.9	No discernible color change	>38	Avoid contact with eyes, mucous membranes and skin. Avoid prolonged breathing of vapors.
36	White powder	--	0.0	95.0	White precipitate in pores of brick	--	No precautions listed.
37	Liquid paint stripper	7	0.0	7.1	No discernible color change	>38	Do not take internally. Contact with flame or hot surfaces may produce toxic gases. Contact with skin may cause irritation. Use only with adequate ventilation.
38	Liquid paint	7	0.1	5.0	No discernible color change	>38	Use with adequate ventilation. Avoid breathing of vapors or contact with skin or eyes. Do not take internally. Avoid contact with flame or hot surfaces. May produce toxic gases. Store in a cool place.
39	Liquid detergent	11	0.1	8.8	--	>38	No precautions listed.
40	Liquid cleaner	6	0.1	0.5	No discernible color change	28	Harmful or fatal if swallowed. Combustible. Keep away from heat and open flame.
41	Paste cleaner	10	0.1	17.6	--	--	Keep out of reach of children.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
42	Thick liquid paint stripper	6	0.0	5.6	No discernible color change	28	Extremely flammable. May be fatal or cause blindness if swallowed. Vapor harmful. Skin and eye irritant. Use only with adequate ventilation. Keep away from heat, sparks and open flame.
43	Liquid paint	6	0.0	3.0	No discernible color change	28	Extremely flammable. May be fatal or cause blindness if swallowed. Vapor harmful. Skin and eye irritant. Use only with adequate ventilation. Keep away from heat, sparks and open flame.
44	White powder	11	0.0	96.9	No discernible color change	--	Prolonged contact with wet skin may produce burns. Avoid contact with eyes.
45	Liquid	6	2.5	2.4	No discernible color change	23	Harmful or fatal if swallowed. Vapor harmful. Use in well ventilated areas only. Avoid repeated contact with eyes and skin.
46	Liquid	3	0.1	11.5	No discernible color change	>38	None listed.
47	Liquid	1	0.2	10.5	No discernible color change	>38	None listed.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
48	Liquid paint stripper	6	0.6	3.4	No discernible color change	>38	Poison and flammable. May be fatal or cause blindness if swallowed. Do not use near fire or flame. Use only with adequate ventilation.
49	Liquid cleaner	5	0.1	0.4	--	>38	Flammable mixture. Do not use near fire or flame. Use with adequate ventilation. Avoid prolonged or repeated breathing of vapors and prolonged or repeated contact with the skin
50	Aerosol spray	8	11.1	4.2	Yellow stains	>38	Use with adequate ventilation. Avoid contact with skin. Do not store above 120°F.
51	Aerosol spray	6	3.4	14.3	Yellow stains	24	Extremely flammable. Keep away from heat or flame. Avoid contact with eyes. Do not store above 130°F.
52	Aerosol spray	6	0.7	10.1	No discernible color change	24	None given.
53	Aerosol spray	10	1.1	4.6	No discernible color change	> 38	Do not store at temperatures above 120°F. Do not spray in presence of sparks or open flame. Avoid contact with eyes
54	Aerosol spray	6	4.1	0.3	No discernible color change	30	Avoid prolonged contact with the skin. Keep out of eyes. Provide adequate ventilation.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
55	Aerosol spray	6	3.2	6.5	No discernible color change	27	Extremely flammable. Keep away from heat or flame.
56	Aerosol spray	6	1.7	2.0	No discernible color change	22	Flammable. Irritating to eyes. Harmful or fatal if swallowed. Do not store above 120°F. Avoid breathing of vapor or repeated contact with skin. Use with adequate ventilation. Keep out of eyes.
57	Aerosol spray	8	9.1	6.8	No discernible color change	>38	None given.
58	Aerosol spray	6	3.1	0.1	No discernible color change	>38	Exposure to high temperature may cause bursting. Avoid inhalation of fumes.
59	Liquid detergent	11	0.1	13.9	--	--	Safe. Non-toxic.
60	Liquid cleaner	6	0.0	0.3	No discernible color change	>38	Use in well ventilated area. Avoid contact with skin or eyes.
61	Liquid detergent	8	0.2	23.8	--	--	None given.
62	Liquid detergent	11	0.2	13.1	--	--	Keep out of reach of children.
63	Liquid cleaner	6	0.4	4.7	No discernible color change	33	None given.
64	White powder	11	0.0	71.9	No discernible color change	--	None given.
65	Yellow solid	7	0.0	63.0	Dark gray stain	--	None given.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (in contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
66	Liquid cleaner	6	0.7	8.7	No discernible color change	>38	Harmful or fatal if swallowed. Avoid contact with eyes or open cuts. Avoid prolonged contact with painted or plastic surfaces.
67	Liquid cleaner	9	6.3	9.1	Yellow stains	>38	Rapidly absorbed through the skin. Causes severe burns. Vapor harmful. Store in cool place. Use with adequate ventilation.
68	Liquid cleaner	10	0.3	16.4	No discernible color change	>38	Use with adequate ventilation. Avoid prolonged or repeated contact with skin.
69	Viscous liquid paint stripper	8	0.1	9.0	Yellow stains plus orange residue	>38	Use with adequate ventilation. Keep away from heat and open flame. Avoid prolonged or repeated breathing of vapor. Avoid prolonged or repeated contact with skin. Store in cool place.
70	Liquid cleaner	--	0.3	9.3	Yellow stains	--	Avoid contact with eyes.
71	Liquid cleaner	--	0.2	15.4	Yellow stains	>38	Avoid contact with eyes.
72	Liquid detergent	--	0.2	10.0	--	--	Keep out of reach of children.
73	Liquid cleaner	--	5.1	14.4	Yellow stains	>38	None given.
74	Liquid cleaner	--	0.5	7.2	Yellow stains	38	Use with adequate ventilation. Avoid prolonged or repeated breathing of vapor. Avoid contact with skin or eyes. Store in cool place.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
75	Liquid paint remover	11	0.2	24.8	--	--	None given.
76	Viscous liquid paint remover	6	5.0	3.3	--	--	Flammable mixture. Keep away from open flame. Use with proper ventilation. Avoid prolonged or repeated breathing of vapors and contact with the skin.
77	Viscous liquid paint remover	10	0.2	39.9	No discernible color change	38	Avoid contact with skin, eyes, clothing.
78	Liquid cleaner	11	0.2	11.1	Yellow stain	>38	No precautions. Fireproof, no fumes, non-explosive.
79	Liquid cleaner	7	0.5	16.8	Orange precipitate	>38	Keep away from heat, open flame, sparking equipment. Use with adequate ventilation. Avoid prolonged breathing of vapor. Avoid prolonged or repeated contact with skin
80	Liquid cleaner	6	8.1	20.7	No discernible color change	>38	Use with adequate ventilation. Avoid prolonged breathing of vapors and prolonged contact with skin. Avoid contact with eyes.
81	Liquid cleaner	6	5.1	20.1	No discernible color change	>38	Use with adequate ventilation. Avoid prolonged breathing of vapors and prolonged contact with skin. Avoid contact with eyes.
82	Viscous liquid paint remover	2	0.1	8.8	No discernible color change	>38	None given.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (in contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
83	Viscous liquid	8	0.1	5.6	No discernible color change	>38	May be fatal or cause blindness if swallowed. Avoid contact with skin or eyes. Use with adequate ventilation.
84	Viscous liquid	6	0.0	1.6	No discernible color change	38	Avoid contact with eyes. Wash hands after each use.
85	Viscous paint remover	6	0.0	48.7	Yellow stains	>38	Avoid contact with eyes, skin. Poisonous. Do not take internally.
86	Liquid cleaner	8	0.0	14.8	Yellow stain	>38	Keep out of reach of children.
87	Liquid cleaner	6	0.0	42.1	No discernible color change	>38	May be toxic if swallowed. May cause skin irritation. Avoid prolonged exposure to vapor. Avoid contact with skin, eyes or clothing.
88	Liquid paint stripper	1	1.0	23.1	Dark gray stain	38	Avoid contact with skin or clothing.
89	Viscous liquid paint remover	6	0.0	4.6	Orange residue and stain	38	Combustible mixture. Use with adequate ventilation. Avoid breathing or lengthy contact with skin. Contact with flame or heated surfaces may produce toxic gases.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
90	Viscous liquid paint stripper	5	0.5	3.5	No discernible color change	27	Keep away from heat, sparks and open flame. Use with adequate ventilation. Avoid prolonged or repeated breathing of vapors and contact with skin and eyes.
91	Viscous liquid paint stripper	6	0.0	4.8	No discernible color change	37	Use with adequate ventilation. Avoid prolonged or repeated breathing or contact with skin or eyes.
92	Viscous liquid paint stripper	6	0.1	3.8	No discernible color change	37	May be fatal or cause blindness if swallowed. Vapor harmful. Skin and eye irritant.
93	Liquid cleaner	6	0.1	0.0	No discernible color change	>38	May be toxic if swallowed. May cause skin irritation. Avoid prolonged exposure to vapor. Avoid contact with skin, eyes or clothing.
94	Viscous graffiti remover	8	0.7	40.0	Yellow stain	>38	No precautions listed.
95	Viscous liquid paint stripper	7	0.8	5.0	No discernible color change	>38	No precautions listed.
96	Viscous paint stripper	8	1.0	6.0	No discernible color change	>38	No precautions listed.
97	Viscous paint stripper	6	0.6	10.0	Yellow stain	>38	No precautions listed.

Table 1. (continued)

Remover No.	Nature of Product	pH	% Evaporation (loss 1st min)	% Residue (Drying at 100°C)	Effect on Substrate (In contact with brick 96 hours)	Flash Point °C	Recommended Precautions (from Manufacturer's Label)
98	Viscous paint stripper	7	0.9	3.4	No discernible color change	>38	No precautions listed.
99	Viscous liquid paint stripper	8	-.7	40.8	Yellow stains	>38	No precautions listed.

Table 2. Generic Types of Aerosol Paint Used
to Test Remover Effectiveness

Resin Type	Color	Sample No.
(a) <u>Alkyd</u>		
Vinyl Toluene Soya Alkyd Resin	Orange, Blue	1, 2
Vinyl Toluene Soya Alkyd, Ester Gum	Red	3
Mixture of Plasticized Coconut-Oil Alkyd Resin, Ester Gum and Cellulose Esters	Brown	4
Plasticized Coconut-Oil Alkyd Resin, Ester Gum	Green	5
Linseed Alkyd, Styrene Copolymer	Red, Red	6, 7
Acrylic Castor-Tall Oil Alkyd	Red	8
Fish Oil and Soya Alkyd	Ivory	9
Soya Isophthalic Alkyd	Red, Black, Red	10, 11, 12
Vinyl Toluene Linseed-Soya Alkyd and Sulfonamide Amidaldehyde	Orange	13
Soya, Alkyd, Tall Oil Alkyd, Ester Gum and Phenolic Resin	Red	14
(b) <u>Acrylic-Alkyd</u>		
Acrylic-Vinyl Toluene Safflower Alkyd	Blue	15
(c) <u>Alkyd-Epoxy</u>		
Epoxy Ester Soya Alkyd	Black	16
(d) <u>Alkyd-Cellulose</u>		
Cellulose Nitrate, Castor Oil Alkyd and Maleic Resin	White	17
Cellulose Nitrate and Oil Modified Alkyd	Black, Red	18, 19
Cellulose Nitrate and Coconut- Oil Modified Alkyd	Gray, Green	20, 21
(e) <u>Acrylic</u>		
Silicone Acrylic Ester Resin	Red	22
Acrylic Ester Resin and Sulfonamide Amidaldehyde Resin	Orange, Gold	23, 24
Acrylic Resin	Gold, Gold	25, 26

Table 2. (continued)

	<u>Resin Type</u>	<u>Color</u>	<u>Sample No.</u>
(f)	<u>Acrylic-Cellulose</u>		
	Nitrocellulose and Acrylic Resin	Gray	27
(g)	<u>Epoxy</u>		
	Epoxy Ester Resin	Gold	28
	Dehydrated Castor Oil and Modified Epoxy Resin	White, Black Red, Turquoise	29, 30 31, 32
(h)	<u>Linseed Oil</u>		
	Linseed Styrene Resin	Blue, Red	33, 34
	Linseed Styrene, Coumarone Resin	Green	35
(i)	<u>Coumarone-Indene Resin</u>		
	Coumarone-Indene Resin and Soya Oil Dicyclopentadiene	Aluminum	36

³Brick was tested in accordance with ASTM C 67-66 [6], except that results were expressed in SI units. Each value in the table represents the average of the results for five specimens.

Table 4. Time Required for Complete Removal of Major Generic Types of Spray Paints from Matte Tile by the 24 Most Effective Removers

Remover No.	#18 (Alkyd Cellulose)	#3 (Linseed Oil)	#16 (Alkyd Epoxy)	#3 Time	#8 Alkyds Time	#10 Time	#13 Time	#24 Time	#25 (Acrylic) Time	#15 (Acrylic) Time	#27 Acrylic Cellulose Time
	Time (1)	Time	Time	Time	Time	Time	Time	Time	Time	Time	Time
11	7	4	15	5	10	5	8	4	5	4	6
24	7	3	25	7	6	5	4	8	4	11	10
27	9	3	15	40	8	15	3	4	4	5	13
37	20	18	14	50	40	30	37	10	9	15	14
38	15	28	30	40	30	27	18	18	10	16	30
42	4	5	8	7	9	12	6	4	11	6	4
43	5	9	6	10	12	6	7	6	9	8	4
45	8	9	6	7	9	8	10	14	9	10	10
48	10	12	9	10	12	12	20	15	25	12	8
67	30	8	8	8	14	45	30	40	40	14	7
68	40	9	7	7	16	50	10	50	45	11	10
69	45	7	10	6	18	55	50	55	50	8	14
75	50	10	15	9	20	40	40	20	50	7	12
79	55	14	14	5	9	60	55	44	49	6	16
80	40	20	20	8	10	10	59	55	15	9	20
82	5	6	25	15	8	8	10	10	20	8	18
83	4	12	30	20	7	9	8	14	30	10	9
85	9	5	12	10	5	5	6	20	4	6	8
88	10	9	18	9	10	12	5	23	9	9	7
89	12	8	9	8	15	10	40	45	10	30	15
90	14	14	10	14	20	8	50	50	35	35	14
91	9	16	14	15	19	7	12	55	40	40	14
92	8	20	16	18	14	15	18	40	38	8	20
99	6	9	20	14	20	20	20	30	42	10	30

Paints baked on tile at 48.9°C for 16 hours.

1) Time = Time of residence of remover (seconds) prior to water rinse.

Table 5. Ranking of Removers According to Average Color Retention* of 36 Spray-Painted Brick

Remover	Average Color Retention of 36 Bricks	Number of Paints Removed to Give C.R. >90
85	88	23
88	87	19
82	86	18
90	86	14
83	85	14
69	83	13
11	83	12
92	82	13
38	81	14
89	80	13
27	75	11
24	74	10
91	74	9
67	72	8
43	71	9
37	69	9
75	66	9
42	66	11
48	58	6
68	58	6
99	58	12
80	49	6
79	48	4
76	46	3

*Color Retention = $100 - \Delta E$, where ΔE is color change in NBS units.

Table 6. Effectiveness of Removers in Removing Spray Paints from Bricks

Remover	Paint Numbers																																				
	1	2	4B	5	6B	6	7	10	11	12	14	16	17	18	19	20	21	22	23	24	25	26	27	44	45	46	47	48	49	50	51	52	60	61	62	63	
85	R*	R	R	-**	R	R	R	R	R	R	-	R	R	R	R	R	R	R	R	-	R	-	-	R	-	R	R	R	-	R	-	-	-	-	-	-	
88	R	R	-	-	R	-	-	R	-	R	-	R	-	R	-	R	-	R	-	R	-	R	-	-	R	-	R	-	R	-	-	-	-	-	-	-	
82	R	R	-	R	-	R	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
90	R	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
83	R	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
69	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
11	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
92	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
38	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
89	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
27	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
24	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	
91	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
67	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
43	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
37	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
75	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
42	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
48	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
68	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
99	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
80	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
79	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-
76	-	-	-	-	R	-	-	R	-	R	-	-	R	-	R	-	R	-	R	-	R	-	-	R	-	-	R	-	R	-	-	-	-	-	-	-	-

* R = Removed Effectively (Color Retention >90).

** - = Poor Removal Efficiency (Color Retention <90).

Table 7. Five Removers Which Will Remove 36 Spray Paints from Brick and Their Compatibility with Common Substrates*

Remover	pH of Remover	Aluminum (6061-T6)	Wood (White Pine)	Limestone (Indiana)	Brick (Table 2)
85	11	I	I	I	C
88	1	I	C	I	C
82	2	I	I	I	C
38	7	C	C	C	C
67	9	C	C	I	C

C - Compatible

I - Incompatible

*Determined by measuring the color retention of the substrate after exposure to the removers for 1 hour at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ rh (see Section 2.4).

Table 8. Ranking of Removers According to Effectiveness of Removal of Felt-Tip Pen, Crayon and Lipstick Markings from Brick

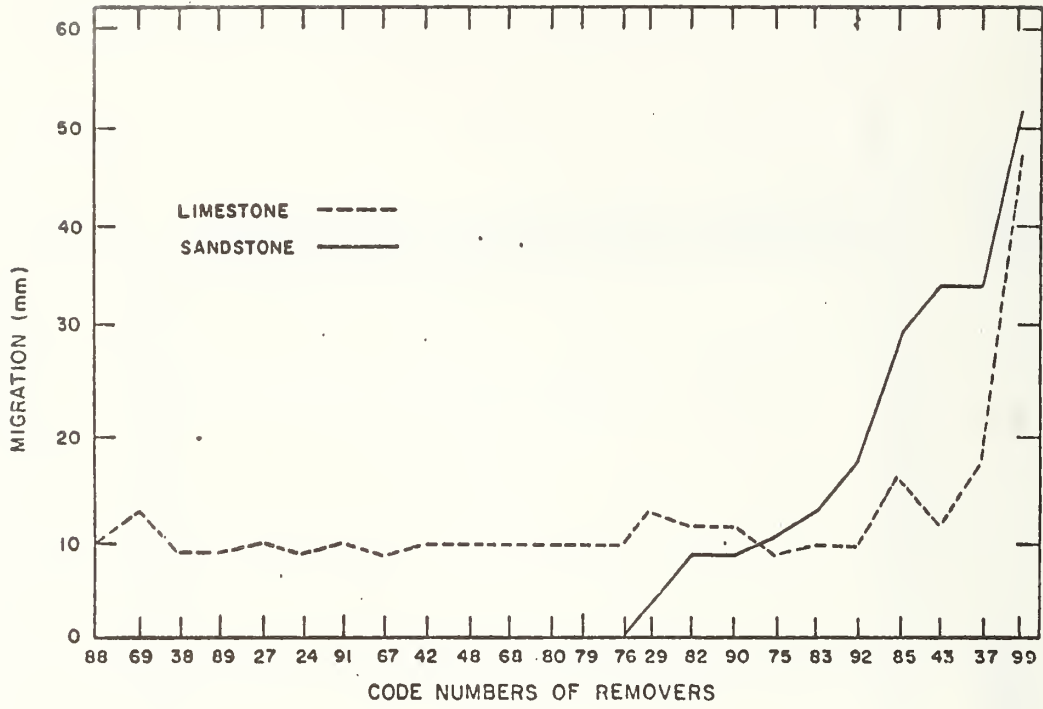
Remover No.	Average Color Retention of Duplicate Specimens
88	85
83	85
11	84
63	84
28	84
86	83
94	82
87	82
24	82
43	80
85	80
82	79
27	78
89	78
91	76
90	75
38	74
67	74
79	73
99	73
37	73
48	71
45	71
42	70
69	70
75	70
68	70
80	70
92	70

Table 9. Effect of Removers on the Color Retention of Unmarked Building Materials^a

Remover	pH of Remover	Aluminum (6061-T6)	Brick (Table 2)	Limestone (Indiana)	Wood (White Pine)
		Color Retention			
43	6	94.6		88.7	98.0
42	6	98.1		95.3	78.9
79	7	96.4		87.4	98.5
80	6	87.5		78.6	94.1
83	8	96.5		96.7	92.7
85	11	98.5		85.3	84.4
82	2	98.6		93.1	86.7
27	7	98.4		95.7	98.2
99	8	98.2		90.8	92.4
88	1	98.4		92.1	96.9
75	4	97.4		95.2	92.6
37	7	97.3		95.9	96.6
24	7	98.6		91.8	95.0
92	7	98.0		95.2	51.8
90	6	98.3		87.4	96.3
68	10	92.0		77.7	89.3
91	7	98.2		93.5	98.8
67	9	97.0		73.9	95.0
69	8	97.2		91.7	82.4
48	6	97.3		96.8	98.5
45	6	97.5		93.3	92.1
11	3	95.0		93.3	92.1
38	7	98.5		94.6	94.8
89	6	98.4		95.8	87.8

^aSubstrates exposed to removers for 1 hour (23°C ± 2° and 50 ± 5% rh); then washed and dried.

Figure 1. Distance of Migration of Removers When Applied to Limestone and Sandstone for 1 Hour



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17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons) Graffiti; graffiti removers; removal; materials; paint; spray paints; effectiveness; remover-substrate compatibility; substrate.				
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