COMPOSITION AND REMOVAL OF AUTOMOBILE WINDSHIELD FILMS

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In an effort to alleviate the problem of impaired visibility caused by automobile windshield films, the origin and nature of the dirt and residues that form windshield films and the most effective methods of removing them were investigated. Samples were collected from windshields and from pavement surfaces, and their composition was determined by infrared spectrophotometry, X-ray diffractometry, and binocular and petrographic microscopy. Cleaning agents and cleaning procedures were evaluated in the laboratory using an automobile windshield. The materials comprising the films are mostly those on or derived from the pavement surface. They consist of organic constituents, which are mainly oil, oxidized oil, rubber, asphalt, and grease. Insect fragments and residues of insect fluids are usually abundant. The inorganic constituents are almost entirely minerals, usually quartz and layered silicates such as mica and clay minerals. As a general rule, the mineral composition of the films reflects the lithology of the aggregates used in the road. Of the commonly used generic types of cleaning agents, the alcohol-detergent type was found to be superior to the predominantly detergent, predominantly alcohol, ammonia, and silicone emulsion types.

•WITH today's increasingly motorized society, the problem of impaired visibility caused by windshield films is even more prevalent. In the proposal for this study, Sherwood (9) noted that concern for this problem was expressed by the Virginia State Police. This paper is a result of that concern.

After preliminary investigations, several questions concerning the visibility problem arose. The more important of these questions pertained to (a) the composition of the materials that form windshield and road surface films, (b) the origin and nature of windshield films, (c) the current methods and materials used to clean windshields, and (d) the most effective and efficient methods of removing films from windshields.

PREVIOUS RESEARCH

An extensive search of the literature in the field of driver visibility revealed that very little has been done in this area. Some solvent manufacturers and oil companies have performed intermittent research on windshield film removal, but their findings have never been compiled as formal reports. Whenever possible, these sources were personally contacted for information and advice. The research findings that have been published fall into three general categories: (a) research on road splash patterns and fenders and mudflaps—Giles (6), Forbes (5), Maycock (7), and Anderson and Carlson (3); (b) research on windshield, dash, and wiper characteristics—Sutro (12) and Allen (1); and (c) research in the area of water repellants for aircraft windshields—Thomas (13) and Stedman (10). Most of this work, while interesting as background reading, was inapplicable to the problem investigated (9).

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COMPOSITION STUDIES

Procedures

It was important to know the composition of windshield films in order to study the nature of the materials involved and to evaluate the cleaning agents and methods being used to remove them. Windshield films, especially those formed during the early stages of a rain, appear to originate from two sources: (a) materials splashed up from the roadway, and (b) materials deposited on the windshield from the air or inadvertently placed there by people, i.e., service station attendants.

To study the materials splashed up from the road, pavements were watered down, lightly scrubbed, and the water and any material in suspension were collected. The samples were taken to the laboratory and analyzed by infrared, X-ray, and microscopic methods. Thirteen samples of materials washed from both asphalt and concrete pavements were collected from sampling sites located in the northern, eastern, and central parts of Virginia.

The second type of film-producing material, that already on a windshield before a rain, was also studied. The sample for this investigation was obtained by scraping windshields with a razor blade and collecting the material in a plastic container. This material was similarly analyzed by infrared, X-ray, and microscopic methods. About 50 windshields were scraped; all were located in Charlottesville, Virginia.

The organic content of the samples was determined by infrared analysis. The road scrubbings and windshield scrapings were first leached with carbon tetrachloride, a medium-strength, organic solvent. The leachate was then boiled down to a thick syrup and infrared spectra were obtained. After inspection of the spectra and comparison with known spectra, a semiquantitative organic analysis was obtained for the samples.

Following leaching of the road scrubbings and windshield scrapings for infrared analysis, the remaining particulate matter was allowed to dry and both random and oriented X-ray slides were made of the material; then the mineral constituents were identified by examination of the resulting diffractograms.

Results and Discussion

Before discussing the results of the compositional studies, it should be pointed out that not all variables are considered and that the quantity and composition of windshield films may vary with other factors such as geography, climate, time of the day, season of the year, and type of windshield involved.

Infrared Studies—The leachings and infrared spectra were used to determine the amount and types of organic compounds in the road and windshield samples. It should be stressed that the organic constituents are important because they act as the binder of a windshield film. In most instances the particulate matter in a film would not adhere to the windshield without the organic matter to act as a binder.

The amount of organic matter in the road scrubbings averaged 2.7 percent and the windshield scrapings contained 33 percent organic constituents. The reason for the high percentage of organics in the windshield sample was that many insect remains had been scraped from the windshields. When the insect remains were discounted, the organic compositions of the road scrubbings and windshield scrapings were closely similar. Furthermore, local conditions did not seem to influence the organic composition of film-producing materials.

A summary of the organic compounds found in the samples tested is given in Table 1. It should be pointed out that the undissolved chitin was not identified from infrared spectra but was recognized macroscopically. The major organic fluids found in the specimens were oil and oxidized oil; both probably originated from

TABLE 1

SUMMARY OF THE INFRARED ANALYSIS OF THE ORGANIC CONSTITUENTS OF WINDSHIELD FILM-PRODUCING MATERIALS

Constituent	Probable Common Compound
Undissolved chitin[a]	Insect skeletons
Straight-chained hydrocarbons	Oil
Aromatic groups	Rubber, asphalt
Heavy hydrocarbons	Grease
Complex, unsaturated esters	Insect fluids

[a]Identified macroscopically.

motor vehicles in the form of dripping oil and exhaust fumes. Very small amounts of rubber, asphalt, and grease were also detected. In other studies (4), insoluble soaps have been found in windshield films, but no such compounds were detected in the samples in this investigation.

The amount of organic constituents was greater in the samples washed from asphalt roadways than in those from concrete roadways. The composition of the samples, however, was the same; i.e., the additional organic material was not largely asphalt. These data indicate that asphalt surfaces retain more film-producing materials than do concrete surfaces. A possible explanation for this phenomenon is that asphalt, perhaps more adhesive than concrete, may attract and loosely hold more organics than does the concrete. Alternatively, organics may adhere to organic compounds such as asphalt to a greater degree than to inorganic compounds such as concrete. Therefore, although the concrete may receive as much organic matter as does asphalt, it may be relatively more easily flushed clean (by rain) of the organics than is the asphalt pavement. In any case, only material on the pavement surface would be washed up or splashed up, and the concrete roadways would always yield less film-producing materials than would the asphalt roadways.

X-Ray Diffraction and Microscopic Studies of Composition of Particulate Matter—The central conclusion from these studies, which is presented at the outset because it provides a perspective for the following information, is that the mineral composition of the particulate matter found on windshields very strongly reflects the composition of the stone used as aggregate in the pavement. This implies that there is no particular group of minerals that characterizes windshield films, regardless of geographic location. Rather, the kinds of mineral particles found in the windshield films may change from region to region in response to the type of stone used in the pavements.

However, insofar as there are relatively few minerals that constitute the bulk of the rocks commonly quarried for use as aggregate (sandstone, limestone, granite, basalt, etc.), the species of minerals in windshield dirt are in general limited and are usually feldspar, quartz, micas, amphiboles, pyroxenes, carbonates, and clays. Those that are ubiquitous in nature—e.g., quartz and clay—are also more widely encountered in windshield material.

X-Ray Studies—A summary of the mineral constituents found in the samples washed from pavements is given in Table 2. When X-ray intensity was considered as a measure of volume as opposed to presence of a particular diffraction peak in the samples, it was found that the main minerals in the road scrubbings were illite-mica and quartz. Lesser amounts of expandable clay, feldspar, kaolinite, and calcite were also present. The windshield scrapings contained quartz, illite-mica, and feldspar.

With the exception of calcite, these findings were expected because the minerals identified are among the ones most commonly found in nature. Calcite, which is somewhat soluble under natural conditions, might not be expected in such abundance. It was found, however, that the calcite occurred only in samples washed from pavements constructed with calcite-bearing aggregate. The calcite powder had obviously been washed from the exposed surfaces of the aggregate.

Microscopic Studies—Microscopic studies were performed only on samples collected from windshields. The two types of samples were as follows:

1. Material deposited on and subsequently scraped from 4- by 5-in. glass plates mounted on the windshields of State Police cars stationed in Charlottesville and Lynchburg, and Highway Department vehicles stationed in Charlottesville and Staunton. The plates were allowed to remain on the windshields for periods of two to eight months, during which time they were not cleaned and were simply allowed to collect the normal accumulation of windshield deposits.

TABLE 2

SUMMARY OF X-RAY ANALYSES OF THE MINERAL CONSTITUENTS IDENTIFIED IN THE SAMPLES WASHED FROM PAVEMENTS

Mineral	Percent of 13 Samples in Which Present	Mineral	Percent of 13 Samples in Which Present
Quartz	100	Feldspar	70
Illite-mica	100	Kaolinite	55
Expandable clay	70	Calcite	40

2. Material collected from automobiles in the Charlottesville area by scraping windshields in the University of Virginia and public parking lots. The material from 50 cars was combined and constituted the sample.

Both types of samples were leached with CCl_4 to dissolve the organic material and to separate the light and heavy fractions. The particulate matter was then separated into size fractions by sieving, and a portion of each fraction taken for a fragment mount in liquids of the appropriate refractive index.

The results of the flotation and sieving of sample 2 are given in Table 3.

There was no observable mineral matter in the lightweight fractions. All three lightweight fractions appeared to be composed exclusively of biologically derived material with little difference between the materials except size. In the coarsest material (+40 mesh) all the material appeared to be insect or plant fragments, spore cases, pollen, seeds, and exoskeletons.

The fraction passing the No. 40 and retained on the No. 100 (-40+100) had the same composition as the +40—smaller fragments of the same things. There were, however, more hairs and fibers and discrete pollen (?) particles. The finest (-100) fraction contained the same type of material as the -40+100 fraction.

The heavy fractions were composed largely of mineral matter with some exceptions. The coarsest material (+40) was composed of apparently lithic fragments (≅ 0.5 to 1.5 mm), which in turn were aggregates of smaller (≅ 0.01 to 0.07 mm) mineral grains.

The -40+100 fractions were composed mostly of particles with the aggregate structure described. There were some individual mineral grains present, mostly of quartz; others in order of abundance were calcite, mica, and feldspar.

The finest (-100) fraction contained almost entirely tiny individual grains of minerals, with some small aggregates and clusters as described earlier. Particle shapes were mostly equidimensional and varied from angular to subrounded. There were numerous elongated lath-shaped fragments. The fraction, in order of abundance, was composed of micas (chlorite and biotite), quartz, calcite, feldspar (microcline and plagioclase), and epidote.

In each of the size fractions of the heavy material there was a small amount of extraneous material in the form of hairs, fibers, chitin, and spores, similar to the material on the lightweight fraction.

Most stone used in portland cement and bituminous concrete in the Charlottesville area is supplied by two local quarries; the first is in the Catoctin greenstone, which is a dense meta-basalt composed essentially of chlorite, hornblende, epidote, feldspar, quartz, calcite, and tremolite; the second quarry is in the Lovingston (granite) gneiss, which is composed essentially of feldspar, quartz, and biotite, and has appreciable amounts of other minerals including calcite and epidote.

It is apparent that the suite of minerals comprising the rocks quarried in the Charlottesville area are well represented in the dirt accumulating on automobile windshields there. Thus, from the results of the microscopic and X-ray diffraction analyses one may establish the principle that the mineralogical component of windshield films derives from the accumulation on the windshield of the products of normal attrition and abrasion of the stone of which the pavement is composed.

It should also be observed that an additional geological principle may be operating here. The end products of weathering of essentially all silicate rocks, regardless of their original mineralogy, are quartz and clay. Other products from these and other types of rocks (e.g., carbonates) are materials in solution and not of concern here. Thus, if the first-generation fragments of a given pavement are fine-grained enough and the pavement of sufficient age, one may find to some extent in windshield dirt the normal

TABLE 3

SIEVE SIZE ANALYSIS OF LIGHT AND HEAVY FRACTIONS OF SCRAPED WINDSHIELD MATERIAL

Sieve Size	Weight Percent	
	Heavy Fraction[a]	Light Fraction[a]
+40	2.44	26.5
-40+100	38.3	38.3
-100	57.0	31.0
Loss	2.47	4.45

[a]Proportions of total sample of light and heavy fractions were 25 and 75 percent respectively.

end products of weathering (that is, clay and fine-grained quartz) regardless of the original lithology of the stone in the pavement.

The recognition that the particulate matter in windshield dirt may be largely mineral raises the question of the possibility of the abrasion and scratching of windshields during the cleaning or auto-wiping procedure when the accumulated dirt being removed is derived from pavements constructed of stone whose mineral components are harder than glass.

Allen (2) concluded that micro-scratches and abrasion of windshields caused by windshield wiper action or cleaning can be sufficient to impair the windshield. His results are summarized as follows: Thirteen used windshields were randomly selected for test. Code monograms on each indicated they probably were the original-equipment windshields. Photographs were made of the scattered light surrounding automobile headlights viewed through the windshields. Damage from windshield wiper action seemed to be related to miles of travel. Damage from cleaning and ice-scraping operations was unrelated to age in this small sample. Pitting from small high-velocity particles also appeared. On a subjective rating scale, 8 of the 13 windshields were judged to be damaged enough to cause a noticeable increase in glare, especially at night, and to warrant consideration of replacement with a new windshield. Four were judged to be unsafe for night driving.

Most of the common rock-forming minerals will scratch glass; these include quartz, feldspar, amphibole, pyroxene, olivine, and some of the iron oxide minerals. Other iron oxide minerals, the carbonates (calcite and dolomite) and the micas and clays will not scratch glass.

The implications of this information are clear; most of the time, most motorists will be driving with dust or dirt on their windshields that is capable of scratching the glass. It is conceivable that automobiles being driven exclusively within, for example, areas of limestone terrane (over bituminous surfaced roads as opposed to portland cement concrete, which would contain sand) may be relatively free of abrasive dust. In general, the precaution of flushing the windshield before any wiping procedure should be taken. It is realized that flushing is only convenient before cleaning from the outside, and that it cannot effectively be done using the windshield washers when traveling on the highway. Another procedure that should be followed routinely is to wipe the wiper blades free of any adhering particles.

SERVICE STATION SURVEY

Procedure

To ascertain what cleaning implements and agents were currently being employed in removing automobile windshield films, a poll of service stations in central Virginia was conducted. The types of data collected included the name of station and its location; the oil company; the situation (rural, suburban, urban); the station size (number of islands); the type of windshield solvent used; and the type of wiping implement used.

Results and Discussion

Two hundred and eighteen service stations, representing 21 oil companies, were canvassed. The stations were located as follows: Richmond (60 stations), Charlottesville (58 stations), Harrisonburg (26 stations), Staunton (26 stations), Waynesboro (26 stations), and various rural locales (22 stations). Sixty-seven percent of the stations were in urban areas, 23 percent in suburban areas, and 10 percent in rural areas. The size of the stations ranged from one to four gas pump islands; 51 percent were one-island stations, 45 percent were two-island stations, and 3.5 percent were three-island stations.

The stations polled used 36 different cleaning agents (Table 4). Actually, the number of solvents in use may not be so great because one solvent manufacturer often supplies many companies, which have different brand names for the same cleaner.

It is interesting to note that water was by far the most commonly used solvent. As is shown in the section on cleaner evaluations, water was the poorest cleaner tested.

TABLE 4

CLEANING AGENTS USED BY SERVICE STATIONS IN CENTRAL VIRGINIA

Cleaning Agent	No. of Stations	Percentage of Station Total (218)	Cleaning Agent	No. of Stations	Percentage of Station Total (218)
Water	55	25.2	Durkee-Atwood glass cleaner	4	1.8
Ammonia and water	25	11.5	Mobil 101 concentrate	4	1.8
Detergent towels[a]	25	11.5	G. M. windshield concentrate	3	1.4
Trico solvent	23	10.5	Gulf Klear-Shield	3	1.4
DuPont glass cleaner	14	6.4	Household detergent	3	1.4
Atlas Glass-Kleen	10	4.6	Phillips 66 glass cleaner	3	1.4
Car wash soap	7	3.2	Scott glass cleaner	3	1.4
Windex glass cleaner	7	3.2	Skyline glass cleaner	2	0.9
Bon Ami liquid	5	2.3	17 others	17	7.7
Shell windshield concentrate	5	2.3	Unknown	1	0.5
Windex with ammonia glass cleaner	5	2.3			

[a]A type of two-layer paper towel; one layer, impregnated with detergent, is used for cleaning, and the reverse side is used for wiping and drying.

Eighteen of the stations using water added a commercial solvent as an antifreeze agent during the winter months and, as a result, probably afforded better windshield service at that time of the year. The popularity of water at service stations is undoubtedly due to its convenience and economy.

Cleaning implements used at the stations are given in Table 5. The total percentage is greater than 100 because many stations used more than one type of cleaning implement. Most of the stations made an effort to use a good cleaning implement such as paper towels; unfortunately, at the same time they used inferior solvents such as water or ammonia and water.

Service station attendants were generally apathetic on the subject of windshield cleaning. It was noted also that, through either lack of training or negligence, attendants often themselves contributed to windshield film. Attendants often sprayed their solvents in one spot and then did not wipe the windshield dry. The result was a partially cleaned windshield and a dried soap film. In other instances, attendants were seen wiping the crankcase dipstick on a paper towel or rag and then using this same paper towel or rag to "clean" the windshield. A thin oil film was left on the windshield. By other, less obvious, means, attendants may leave oily films on windshields; e.g., through continuous turning of paper towels while wiping the glass, they deposit oil picked up from their hands onto the windshield. Even if the attendants' hands are clean, there are enough fatty acids in the skin to be transmitted to the paper towel, and these fats are then rubbed onto the glass, creating a film (8).

Another shortcoming with most windshield service is the failure to clean the wiper blades. No matter how clean a windshield is, one swipe with dirty blades will leave an obscuring film.

In all fairness, it should be pointed out that the indifference of attendants is not always the cause of poor windshield service. Lack of training also appears to be a contributing factor. Some oil companies are now initiating dealer training programs in an attempt to provide better service to motorists, but the job is far from complete.

TABLE 5

CLEANING IMPLEMENTS USED BY SERVICE STATIONS IN CENTRAL VIRGINIA

Cleaning Implement	No. of Stations	Percentage of Station Total (218)
Paper towels	145	66.5
Bug sponge	53	24.3
Detergent towels	25	11.5
Clean cloth rags	23	10.5
Dirty cloth rags	15	6.9
Sponges	9	4.1
Bug brushes	3	1.4
Chamois	1	0.5

CLEANING IMPLEMENT AND CLEANING AGENT EVALUATIONS

Procedures

To evaluate the efficiency of the commonly used cleaning implements and agents as determined from the service station survey, and some other randomly chosen ones, a controlled laboratory experiment was devised. An automobile windshield was obtained, mounted on an eye-level frame, equipped with vacuum wipers, and divided into four sections with vertical strips of black tape on the inside of the glass (Fig. 1).

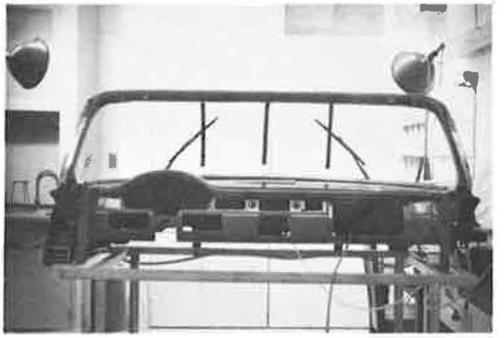

Figure 1. Apparatus used in evaluations of windshield cleaning implements and cleaning agents.

Three sections of the windshield were smeared with a mixture of used crankcase oil and a fine-grained soil rich in clay, quartz, and mica. This mixture approximated the composition of an ordinary windshield film except that the amount of organic material was higher. The fourth section of the windshield was cleaned with a laboratory glass cleaner and was used as a standard for "cleanness." Cleaning implements and cleaning agents were tested separately. The soiled sections of the windshield were first cleaned with water and various cleaning implements and the sections rated for cleanness. Following each test the windshield was thoroughly cleaned with laboratory glass cleaner and dried; then various solvents were used after the sections had been smeared again with the oily mixture. This time only paper towels were used for wiping. After wiping dry, a fine mist of water was sprayed on each of the four sections. If the previously soiled sections of the windshield ran free of water as did the standard clean section, they were rated as clean. If not, the degree of "beading-up" (taken as an indicator of film residue) was rated. The ratings were made by a panel of five people who did not know what implements or solvents had been used. These people were of varied backgrounds and education, and the panel was not always composed of the same persons. Tests were repeated to check for reproducibility of results.

It is realized that this testing technique is biased toward those cleaners containing wetting agents, but it is also realized that these agents aid in obtaining a clear, film-free windshield.

Results and Discussion

The technique for evaluating cleaning implements and solvents proved fairly successful and results were generally reproducible. In no case were the judges in radical disagreement; some might rate a solvent as good and others as very good, but the instance of some rating it good and others poor did not occur.

Cleaning Implements—Four types of cleaning implements were tested: (a) detergent towels, (b) ordinary paper towels, (c) rags, and (d) sponges. The four were rated for their film-removing ability in the order given.

Figure 2 shows that all four cleaning implements removed some of the film, but only the detergent towel provided a good cleaning job. In fact, the detergent towel section appeared as film-free as the standard clean section of the windshield. The excellence of the detergent towel was undoubtedly related to the fact that it contained chemicals capable of dissolving the oily film. Only water was available as a solvent with the other implements, and the result was a poorly cleaned windshield.

The sponge yielded the worst cleaning job because it smeared the oil on the glass; also, the windshield could not be thoroughly dried with this moist material.

The rag appeared to have removed almost as much of the oil from the glass as had the ordinary paper towel. Windshields cleaned with both, however, showed beading of the water, and obviously the windshield had not actually been cleaned. Also, it should be pointed out that the rag tested had been freshly laundered, which is not always the case at service stations. It has been shown, however, that even freshly laundered rags often contain soapy calcium and magnesium stearates. When windshields are wiped with these rags, the stearates are deposited on the glass. During a rain, troublesome, smeared films are then formed (4).

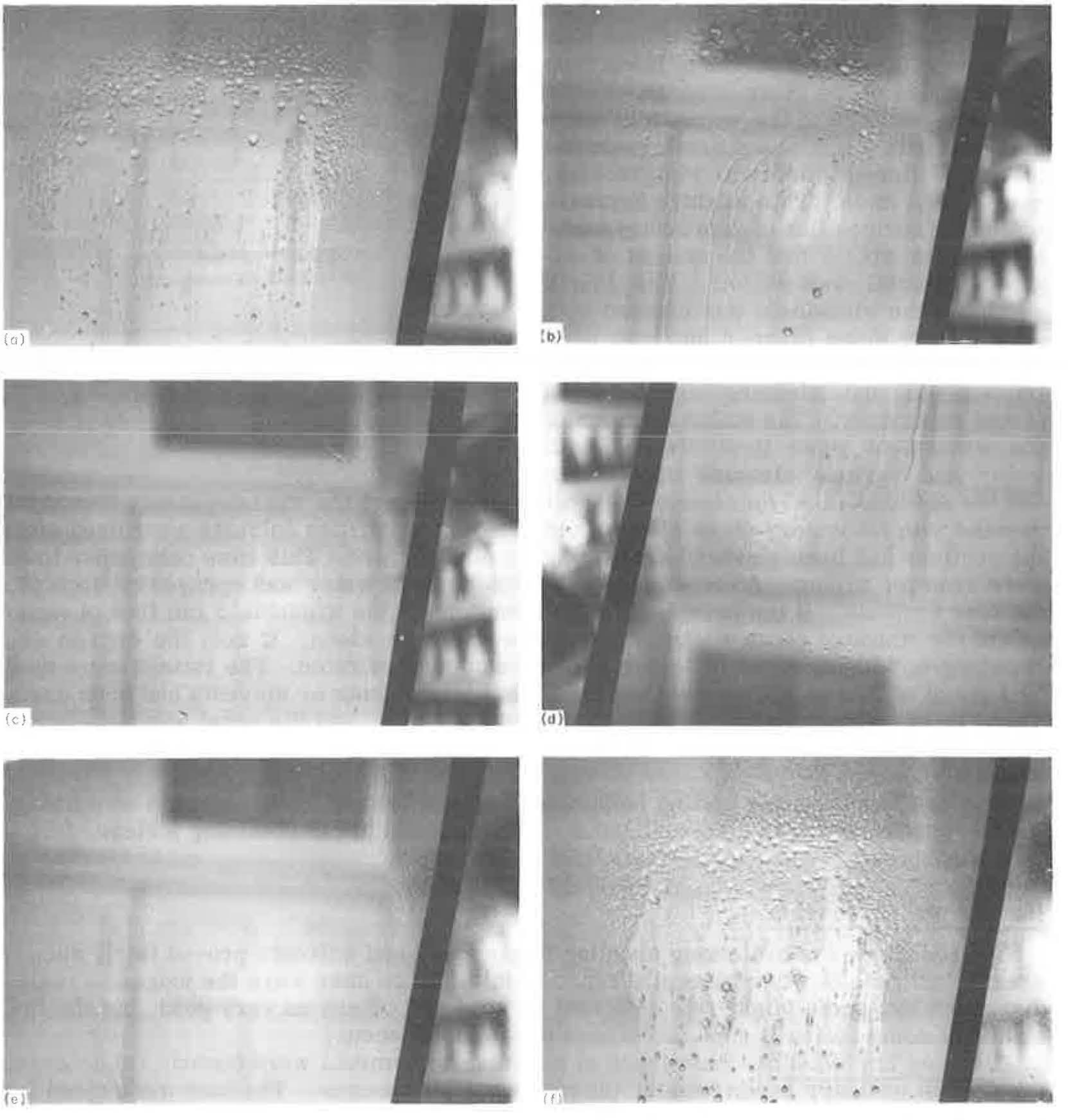

Figure 2. Sections of windshield after being cleaned with various implements and then sprayed with a fine mist of water: (a) rag cleaned, (b) paper towel cleaned, (c) sponge cleaned, (d) detergent towel cleaned, (e) standard clean section, and (f) uncleaned.

Because rags are very porous, their use for cleaning glass is even more undesirable. Film-producing, fatty acids from an attendant's hands are easily transmitted through the cloth onto the windshield. The resultant film causes diminished visibility in rain or glaring light (8).

Cleaning Agents—Seven types of cleaning agents were tested in the experiments: detergent towel, alcohol-detergent type, predominantly detergent type, predominantly alcohol type, ammonia type, silicone emulsion type, and water. All of these, except water, have some capacity to dissolve the oily organic constituents of a windshield film. One type of cleaner in fairly common use, the abrasive type, was not tested.

Photographic comparisons of the tests are shown in Figure 3, and a summary of test evaluations is given in Table 6. It should be realized that these evaluations do not imply

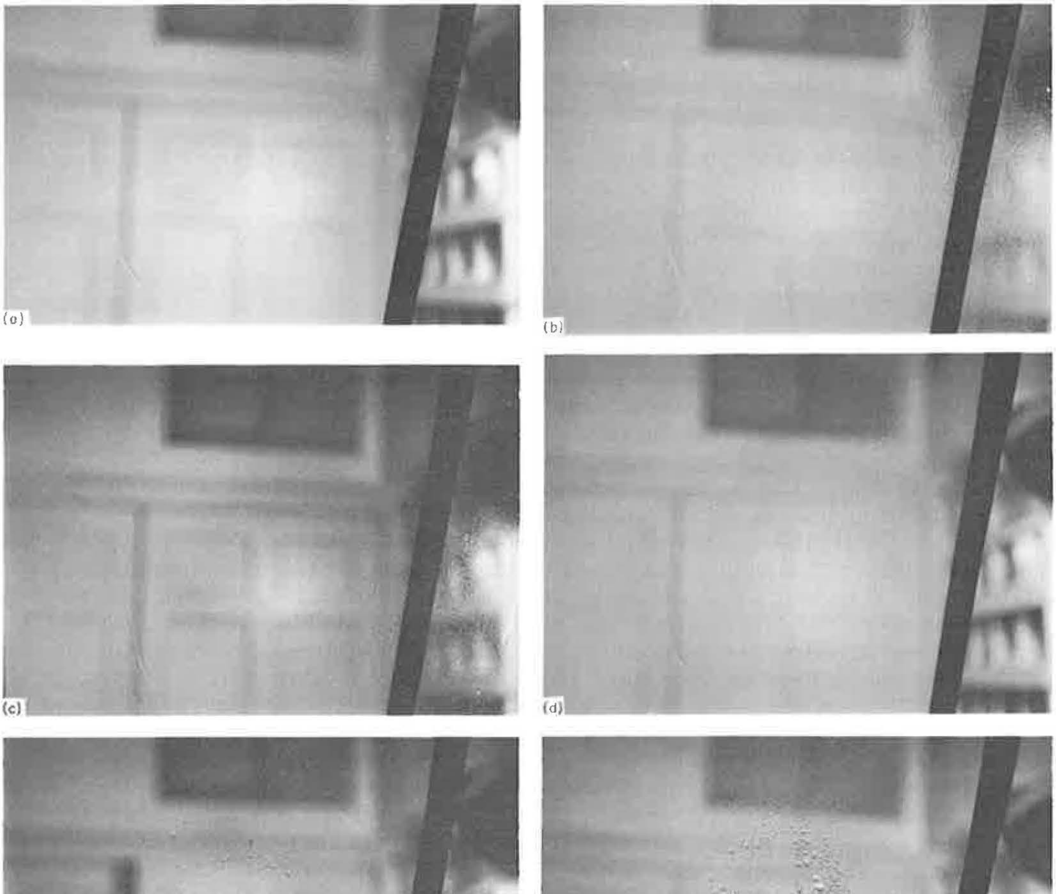

Figure 3. Sections of windshield after being cleaned with various solvents, wiped dry with paper towels (detergent towel provided its own wiping material), and sprayed with a fine mist of water: (a) cleaned with alcohol-detergent type, (b) cleaned with detergent towel, (c) cleaned with predominantly detergent type, (d) cleaned with predominantly alcohol type, (e) cleaned with ammonia type, (f) cleaned with silicone emulsion type, (g) standard clean section, and (h) cleaned with water.

that the poorer rated solvents are not useful for purposes other than windshield cleaning. One should also keep in mind that these evaluations are based entirely on one particular testing method.

TABLE 6

SUMMARY OF EFFECTIVENESS OF CLEANING AGENTS

Agent	Rating
1. Alcohol-detergent type	Very good
2. Detergent towel	Very good
3. Predominantly detergent type	Good
4. Predominantly alcohol type	Good
5. Ammonia type	Fair
6. Silicone emulsion type	Poor
7. Water	Very poor

The alcohol-detergent type solvent cleaned as well as the laboratory glass cleaner, and the detergent towel used with water performed almost as well. Water did not bead on the glass after cleaning but flowed freely as it did on the standard clean section of the windshield.

The predominantly detergent and predominantly alcohol types of cleaners performed almost as well as the alcohol-detergent type and the detergent towel. Only slight beading on the glass was noticed after cleaning.

Ammonia types of cleaners did only a fair job of cleaning the windshield film. This situation was perhaps caused by the lack of a wetting agent in the solvents. A point worth mentioning is that ammonia should not be used in high concentrations because it may cause discoloration of paint and corrosion of metals.

The silicone emulsions tested did an obviously poor job of cleaning. They were rated as slightly better than water, but the difference between the two was often difficult to distinguish. A further disadvantage of these cleaners is that they cannot be used in windshield washers because of the high pressure needed to dispense them. There is, however, one notable benefit that accrues from use of cleaners containing silicone emulsions—they can be used as temporary protection against fogging (11).

After evaluation of the cleaners, the question of solvent performance in windshield washers arose, and as a supplementary experiment the better cleaners were selected and sprayed simultaneously with water onto the soiled windshield. The wipers were kept in operation. This experiment approached the circumstances surrounding a splash type of film during the early stages of a rain. It was found that the cleaners worked well in the spot where they hit the windshield, but the solvents did not spread and clean the entire glass. The wipers, surprisingly, did not aid in spreading the cleaners but simply swept the cleaners to the edge of the windshield, where they drained off. It was then postulated that under actual conditions the wind induced by a moving automobile might provide better spreading of the solvent. In a test with an automobile, the same situation of one-spot cleaning prevailed, but only temporarily. It was found that if large amounts of the solvent were repeatedly sprayed on with the washers the entire windshield could be cleaned.

SUMMARY

The major results and conclusions are as follows:

1. The materials producing windshield films during the early stages of a rain appear to be either those splashed up from the road surface or those already on the windshield, deposited there from the environment or inadvertently placed there by people.

2. Of the materials splashed up from the road surface, 2.7 percent is composed of organic constituents. These constituents, as analyzed by infrared spectrophotometry, are primarily oil and oxidized oil with very small amounts of rubber, asphalt, and grease.

3. Of the materials deposited on the windshield from the air or placed there by man, 33 percent is composed of organic constituents. These constituents also contain oil, oxidized oil, rubber, asphalt, and grease, but very large amounts of insect remains are also present.

4. The main mineral constituents of both types of film-producing materials are quartz and layered silicates such as mica and clay minerals. Minor mineral constituents are feldspar and calcite.

5. Geographic location does not seem to affect the organic composition of film-producing materials but does affect the mineral composition of these materials; the

mineral composition apparently reflects the lithology of the particular aggregates used in the road.

6. The organic constituents appear to act as the binder of windshield films, holding the particulate matter together and adhering to the glass of the windshield.

7. The amount of organic matter on asphalt road surfaces is greater than that on concrete road surfaces, but the organic composition is the same.

8. The most commonly used cleaning agents at service stations in central Virginia are water, ammonia, detergent towels, and Trico solvent; and the most commonly used cleaning implements are paper towels, bug sponges, detergent towels, and rags.

9. Service stations tend to use good cleaning implements but poor cleaning agents.

10. Service station attendants polled in the survey were generally apathetic concerning the subject of windshield service and often were observed using poor cleaning methods such as touching the windshield, using dirty towels or rags for wiping, spraying a solvent in only one spot, or failing to clean the wiper blades.

11. The only cleaning implement found to do a respectable job when used with water alone was the detergent towel.

12. Test results of commonly used types of cleaning agents revealed the following ratings: very good, alcohol-detergent type and detergent towel; good, predominantly detergent type and predominantly alcohol type; fair, ammonia type; poor, silicone emulsion type; and very poor, water.

13. In automobile windshield washer experiments, it was found that solvents cleaned only in the spot that they hit unless very large amounts of the solvents were used.

RECOMMENDATIONS

As a result of this study, the following recommendations are made. Note that many of these recommendations deal with films formed during the early stages of a rain, but others are given because they pertain to windshield service in general.

1. It is recommended that service stations use an alcohol or alcohol-detergent type of windshield solvent and that detergent towels be used for wiping. If detergent towels are not used, clean paper towels should be used. Sponges and rags are not recommended for wiping. A bug sponge or other light abrasive material should be kept on hand for loosening stubborn windshield deposits such as tar, paint, or insects.

2. Service station attendants, either through training programs or in some other way, should be advised in proper windshield cleaning methods. It is recommended that the section of the windshield to be cleaned should first be flushed with a heavy stream of water and then sprayed all over with a fine mist of the solvent (not in just one spot), that clean paper towels or detergent towels be used for wiping without excessive turning of the towel, that the windshield should be thoroughly dried with the towel, and that the wiper blades should be cleaned. Such practices as using rags, or soiled paper towels, or touching the windshield with the hands should be discouraged.

3. Windshield washer reservoirs should be filled with a solvent other than water. Any of the alcohol or detergent types of commercial cleaners are recommended. An acceptable all-weather solvent can be made easily by mixing 4 parts methanol (wood alcohol) or isopropanol (rubbing alcohol), approximately 1 part household liquid detergent, and 5 parts water. Note that the proportion of detergent suggested is approximate. Viscous and more concentrated detergents should only be $\frac{1}{4}$ to $\frac{1}{2}$ part to avoid foaming or bubbling of the mixture when it is sprayed on the windshield.

4. In the early stages of a rain, when splash films appear on the windshield, motorists are advised to turn on their wipers and to pump large amounts of solvent through their windshield washers. In the experiments involved in this study, this wiping and washing exercise eliminated the worst of films.

5. It is recommended that windshield washer nozzles be designed to spray across the entire windshield instead of in just one or two spots. This arrangement would allow the entire windshield to be quickly and effectively cleaned.

6. Wipers should be run at slow speed except during very heavy rainfall. The wipers give better service at this speed because they are in closer contact with the windshield.

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REFERENCES

1. Allen, M. J. Daytime Automobile Windshield and Dash Panel Characteristics. Amer. Jour. of Optometry and Archives of Amer. Acad. of Optometry, Vol. 40, No. 2, 1963, pp. 61-72.
2. Allen, M. J. Automobile Windshields-Surface Deterioration. Amer. Jour. of Optometry and Archives of Amer. Acad. of Optometry, Vol. 46, No. 8, 1969, pp. 594-598.
3. Anderson, J. W., and Carlson, G. C. Vehicle Spray Pattern Study. Minnesota Highway Dept., Investigation No. 338, 1966, 34 pp.
4. Barker, R. C. Written communication, Nov. 1968 and Jan. 1969.
5. Forbes, T. W. A Study of Accident Hazard in Relation to Fenders and Mudguards for Motor Vehicles. Traffic Safety, Vol. 6, No. 1, 1962, pp. 16-19.
6. Giles, C. G. A Note on the Problem of Splashing When Vehicles Travel on a Wet Road. Road Research Laboratory, Great Britain, Research Note RN/3766/CGG, 1960.
7. Maycock, G. The Problem of Water Thrown up by Vehicles on Wet Roads. Road Research Laboratory, Great Britain, 1963.
8. Peacock, C. Written communication, Nov. 1968.
9. Sherwood, W. C. Proposal—Composition and Removal of Automobile Windshield Films. Virginia Highway Research Council, 1967, 4 pp.
10. Stedman, D. F. Safety in the Rain. Shell Aviation News, No. 343, 1967, pp. 2-5.
11. Stoltz, E. I. Written communication, Nov. 1968.
12. Sutro, P. J. Windshield Visibility Clearance. Traffic and Safety, Vol. 1, No. 1, 1957, pp. 15-28.
13. Thomas, F. W. Rain Repellent Polymers. Lockheed Georgia Quarterly, 1965-66, pp. 6-9.