The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J400

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Test for Chip Resistance of Surface Coatings

1. ***Scope—***This SAE Recommended Practice covers a laboratory procedure for testing and evaluating the resistance of surface coating to chipping by gravel impact. The test is designed to reproduce the effect of gravel or other media striking exposed paint or coated surfaces of an automobile and has been correlated with actual field results. The specific intent of the test is to evaluate organic surface coatings or systems on flat test panels; however, It may be possible to extend this type of testing to finished parts or other types of materials such as anodized aluminum or plated plastics if the results are interpreted with respect to the limitations and intent implied by the original testing procedures and rating system.

This document may involve hazardous materials, operations, and equipment. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this document to consult and establish safety and health practices and determine the applicability of regulatory limitations prior to use.

All dimensions are nominal unless otherwise noted.

2. ***Reference***

2.1 **Related Publication—**The following publication is provided for information purposes only and is not a required part of this document.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE 680046—Measurement of Chipping of Organic Coatings for Automobiles, John T. Young and Donald R. Hays, Ford Motor Co., Indust. and Chemical Products Div., Warrendale, PA, USA, Society of Automotive Engineers, Inc., 1968

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3. Summary of Method—The test consists of projecting standardized road gravel by means of a controlled air blast onto a suitable test panel. The testing apparatus is called a gravelometer, designed to contain road gravel, a test panel holder, and a gravel projecting mechanism. The projecting mechanism, located in front of the test panel, consists of an air nozzle in the base of an inverted pipe tee. The stem of the pipe tee points upward and is located beneath a vibrating hopper into which the gravel is poured. The gravel, falling into the air blast, is projected toward and impacts upon the test panel, which is usually held perpendicular to the impinging gravel. All testing is conducted under controlled temperature conditions, generally room temperature (ambient) or –29 °C ± 3 °C (–20 °F ± 5 °F). After the gravel impact, tape is applied to remove any loose paint chips remaining on the panel, and the degree of chipping is determined by visual comparison with the SAE Chipping Rating Standards[1], by counting the number and sizes of all chips, or by other methods deemed suitable between the contractual parties involved.

4. Equipment and Materials

4.1 Gravelometer—A gravel projecting test apparatus which is constructed according to the design specifications shown in Figure 1.

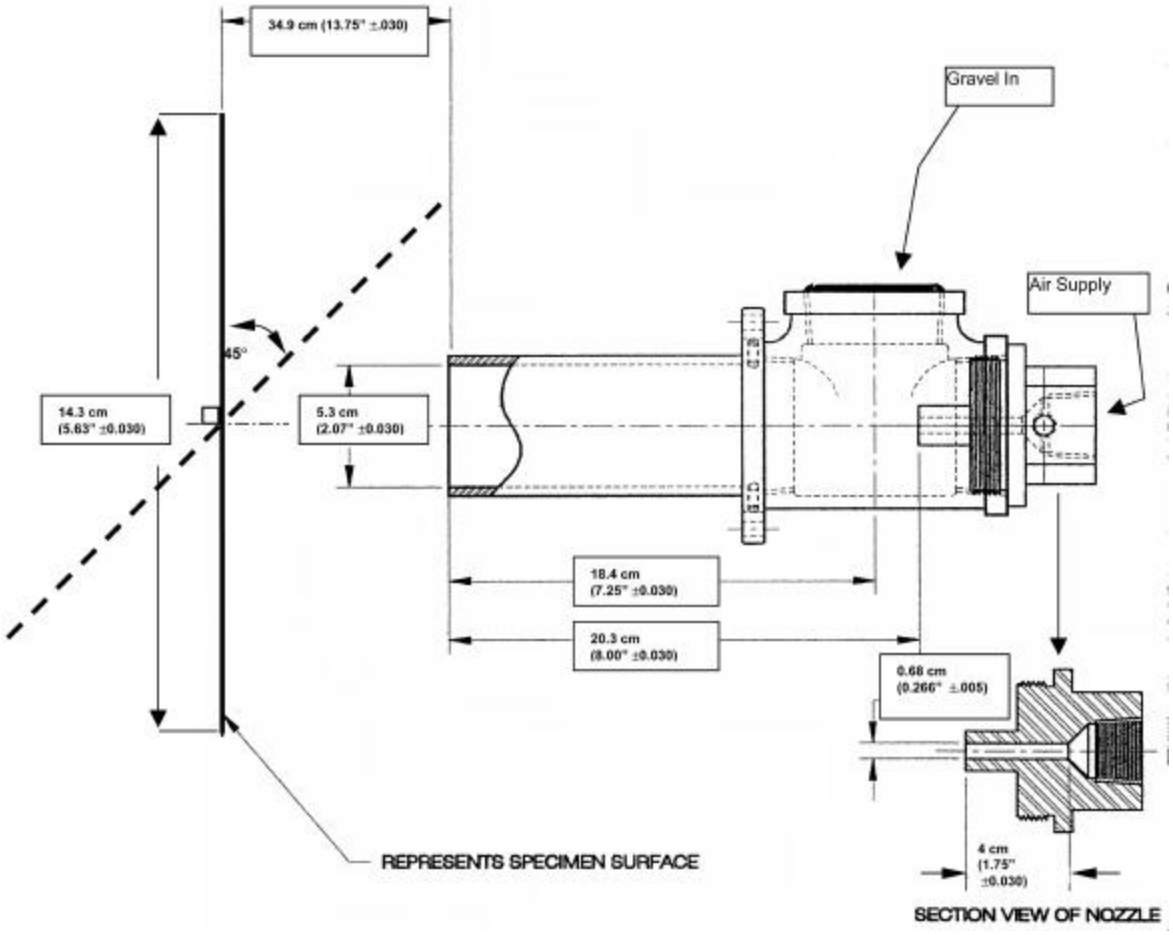

FIGURE 1—TEST APPARATUS

1. Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001—Identified as EA-400.

4.1.1 OPERATION/MAINTENANCE CHECKLIST—The operation/maintenance checklist shown in Figure 2 shall be completed at least once a month for testers that are operated on a weekly basis and once every 6 months for testers that are operated less frequently.

NOTE— Values in chart are specific to the standard gravel testing protocol. Different specifications may be necessary for other media types.

If the answer to any of the following questions is NO, discontinue testing until the problem has been corrected.

Gravelometer Checklist

Question	Yes	No	Data
Is a pipe size ID of 2.54 cm (1 in) airline connected from the supply pipe to the gravelometer?			
Are the pipe joints free of leaks?			
Does the air pressure hold 483 kPa (70 ± 3 psi) for 10 secs?			
Is the air pressure gauge calibrated?			
Date Last Calibrated:			
Date Last Replaced:			
Is nozzle orifice clear?			
Insert a 6.75 mm (17/64 in.) drill bit or 6.75 ± 0.01mm (0.266 ± .005 in.) plug gauge into nozzle to verify that the nozzle orifice is clear.			
Is the distance of nozzle to sample surface 55.25 cm (21.75 ± .030 in.)?			
Is the distance of gun barrel to sample 34.93 cm (13.75 ± .030 in.)?			
Is sample mounting bracket level top-to-bottom/front-back?			
Is the backer panel edge supported (not solid)?			
Is backer panel tight?			
Are the backer panel angles correct?			
Are stones hitting target in an even/centered pattern?			
Is the gravel screened?			
For older cabinet type gravelometers, is the amount of gravel collected on screen less than 10 pt.?			
Is the correct type and size of gravel being used?			
Does 1pt of gravel empty from the hopper in 7 to 10 seconds?			
Is the filter clear of obstructions?			
Date of last filter cleaning or replacement.			
For older type gravelometers, replace vibrator and bushings if gravel takes longer than 10 s to empty.			
For gravelometers with electronic feed mechanisms, adjust vibrator speed and hopper height so that hopper empties in 7 to 10 seconds.			
Compressor Capacity and Type:			

Below Ambient Testing Information (if required)

Question	Yes	No	Data
Are panels frozen prior to testing?			
How long are panels conditioned in freezer?			
What is the conditioning temperature?			
What is the ambient temperature?			
Time panels exposed to ambient prior to test.			
How far is the QGR from freezer?			

FIGURE 2—CHECKLIST

4.2 Gravel— The gravel for this test shall be water-worn road gravel, not crushed limestone or rock. The gravel will pass through 15.86 mm (5/8 in) space screen when graded, but be retained on 9.53 mm (3/8 in) space screen. It is important to note that mesh screen is not a substitute for space screen. The gravelometer has 9.53 mm (3/8 in) space screen in the bottom to separate fractured pieces of rock and dust smaller than 9.53 mm (3/8 in) so that the retained gravel on this screen may be reused. Because the gravel tends to blunt or fragment after repeated impacts, it should be changed at a regular frequency. For testers that are operated on a weekly basis, 2 pints of gravel shall be replaced with fresh gravel each month. For testers that are operated on less frequent basis, 2 pints of gravel shall be replaced with fresh gravel at least every 6 months.

Gravel must be washed prior to initial use.

Other media may be used as agreed upon by contractual parties.

NOTE— Pint measurements refer to a 1 pint container full to the top.

4.3 Paint Removal Tape—10 cm (4 in) wide or 5 cm (2 in) wide, 3M product #898 filament strapping tape or equivalent. Other tape may be used as agreed upon by contractual parties.

NOTE— The adhesion strength of the tape use makes a significant impact on how much separated paint is removed.

4.4 Temperature Conditioning Equipment—Gravelometer tests are usually run at ambient or a lower temperature, generally –29 °C (–20 °F), which shall be mutually agreed upon by contractual parties. Tests conducted at different temperatures will employ the following:

4.4.1 METHOD A—A cold room or chamber in which the gravelometer and test panels are maintained at the specified temperature of testing.

For freezers that employ a defrosting mechanism, document the method of defrosting and any temperature changes.

4.4.2 METHOD B—A freezer in which the test panels are cooled to 5.6 °C (10 °F) below the test temperature before they are individually transferred and tested immediately in a gravelometer at room temperature located nearby.

4.4.3 METHOD C—Ambient: room maintained at a temperature between 20 °C (68 °F) and 30 °C (86 °F).

4.5 Transparent Grid—A chip counting aid constructed of transparent plastic approximately 3.2 mm x 12.7 cm (1/8 x 5 x 5 in), on which a 10.16 x 10.16 cm (4 x 4 in) grid of 2.54 cm (1 in) squares has been etched or scribed.

4.6 Chipping Rating Standards—A photographic transparency, depicting the size and shape of each chip. See Figure 3 for representation of this transparency. Figure 3 IS A REPRESENTATION ONLY.

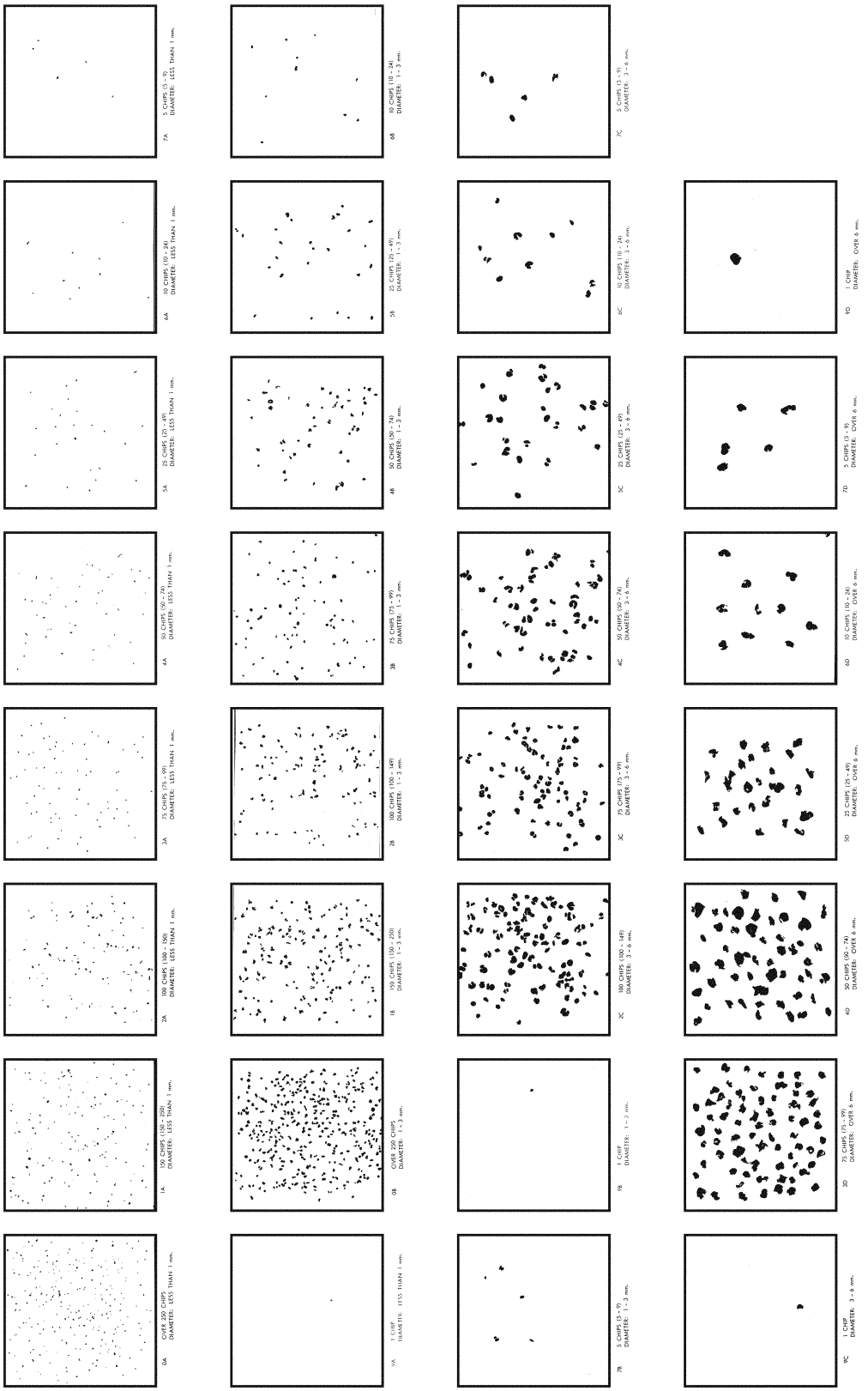

FIGURE 3—CHIPPING RATING STANDARDS (REPRESENTATION ONLY)

4.7 Test Specimens—It is recommended that three replicates of each test specimen be exposed in the gravelometer. The number of replicates will be agreed upon between contractual parties. The test specimens are typically flat and 10.16 x 30.48 cm (4 x 12 in) in size in order to fit into the panel holder of the gravelometer. The test panel material, the panel's thickness or gauge, and preliminary surface treatments (such as phosphating or anodizing) should be the same for all tests in any series and as representative as possible of the actual part. Any deviations in these parameters may produce misleading test results.

For profiled test specimens, or nonstandard test specimens, limits for uniform thickness, uniform backing, and uniform specimen holders must be determined and agreed upon by contractual parties.

5. Setup and Procedures

5.1 Setup

5.1.1 Paint or process the test panels as specified for the systems under test.

It should be noted that the chipping test results will be dependent upon the nature of the coating's formulation, the method and degree of drying or curing of the various coats, and the film thickness involved. Uniformity of film thickness is extremely important, and each component of the system should be controlled as uniformly as possible.

5.1.2 The test specimens must reach the test temperature for a minimum of 15 minutes prior to testing in accordance with the appropriate method specified in 4.5.

In the conditioning environment, proper heat transfer can be facilitated by separating the test specimens so that the conditioned air can circulate freely about the specimen.

5.1.3 Fill a 0.473 L (1 pt) container to the top with grated/screened gravel.

During exposure of multiple specimens, no more than 10 pt of gravel shall be allowed to collect on the sizing screen. Once 10 pt have collected on the screen, scrape the gravel across the screen so that the small rocks will fall beneath the screen. Remove the gravel that remains on top of the screen from the gravelometer for re-use. Remove and discard any stones that have lodged in the screen.

5.1.4 Other media can be used as agreed upon by contractual parties.

5.1.5 Adjust air pressure on the gravelometer to 483 kPa ± 21 kPa (70 psi ± 3 psi) with the air valve open.

For older cabinet type gravelometers, keep lid to gravel chamber on the gravelometer closed during this operation as safety precaution.

5.1.6 Set feed rate so that the hopper empties in 7 to 10 s/pt.

5.1.7 Other air pressures can be used as agreed upon by contractual parties.

5.2 Procedure

5.2.1 OLD CABINET TYPE GRAVELOMETER

a. After the air pressure is adjusted, shut off air valve, and open the lid to the specimen chamber. Place one test specimen conditioned at the desired test temperature in the panel holder with the coated side facing the gravel projecting mechanism. Mount the specimen as tightly as possible so as not to affect the angle of the panel orientation or allow movement during the test.
b. The specimen holder shall have an edge-supported backer plate. Other specimen mounting fixtures may be used as agreed upon by contractual parties.
c. Close lid to panel chamber.
d. Open the gravel feed door and pour gravel from the one pint container obtained from step 5.1.3 into the top of the gravel hopper. Do not allow gravel to fall into the nozzle entrance. Open the air valve to allow the air to project the gravel at the sample.

NOTE 1—The gravel hopper must empty within 7 to 10 s. If gravel remains in the hopper after 10 s, stop the test and investigate the cause. The operator may not touch the gravel during the test or otherwise physically help the gravel into the funnel.

NOTE 2—It is important to note that the vibrator may become frozen when the chamber is installed in a cold room or freezer. If the vibrator is frozen, discontinue the test until the vibrator has thawed and is operating correctly.

NOTE 3—Shut off air valve, open lid to specimen chamber, and remove the test specimen.

5.2.2 MODULAR GRAVELOMETER WITH ELECTRONIC FEED MECHANISM

a. Pull back on the specimen mounting clamp to open the specimen holder on the specimen holder assembly.
b. Clamp to close the specimen holder.
c. Pour gravel from the one pint container obtained from step 5.1.3 into hopper.
d. Set the Test Timer.

5.2.3 There are two ways to operate a test on these units. A Timed Test is a test that shuts off the machine after the preset amount of time has passed. A Manual Test requires the operator to shut off the machine after the desired amount of time has passed.

5.2.3.1 Timed Test

a. Make sure the control switch is set to STOP.
b. Set the Test Timer to the desired test time. This is typically < 10 s.
c. Turn the main power switch to ON.
d. Flip the control switch to TIMED START.

5.2.3.2 Manual Test

a. The manual test requires the operator to manually stop the test. Once started, it will not stop by itself.
b. Make sure the control switch is on OFF.
c. Switch the main power control switch
d. Switch the control switch to MANUAL.
e. After the desired amount of time has passed, flip the control switch to OFF.
f. Once the test is complete, remove the test panel from the specimen holder by pulling back on the specimen clamp and pulling out the test specimen.
g. Remove the rocks from the return receptacle and screen before reuse.

h. If necessary, allow panels to return to room temperature and dry with a soft cloth to remove any condensed moisture.
i. Using the tape referenced in 4.4, remove all loose or damaged paint.
j. Cover the tested area of the specimen with a strip of tape or multiple strips of tape side by side. Firmly adhere the tape to the test specimen by applying uniform pressure. (Uniform pressure can be applied by using items like a tongue depressor or a pencil eraser.) There can be no air bubbles trapped beneath the tape.
k. Remove the tape by pulling straight up.
l. Apply new strip(s) of tape to the specimen and repeat the paint removal process in the opposite direction.
m. Continue this procedure using new strips of tape until all loose or damaged paint is removed.
n. Other tapes or loose paint removal methods may be used as agreed upon by contractual parties.
o. Determine the degree of chipping by one of the following methods of the Gravelometer Rating System.

6. Gravelometer Rating System

6.1 Methods Available

NOTE— other methods may be employed as agreed upon between contractual parties.

6.1.1 There are two methods available for determining the degree of chipping from gravel on the tested panel (other media will require other evaluation methods.) In Method I, the exact number of chips in each size range is tabulated for the specified test area, while Method II utilizes a visual comparison of the tested panel with the SAE Chipping Rating Standards shown in Figure 3 which depict various degrees of chipping severity and are arranged sequentially from best to worst according to chipping size and frequency.

Method I is the most precise and should be used where definitive accuracy is required or as the referee method in case differences arise between laboratories; however, it is more time-consuming than the visual comparison method.

Method II is much faster and, while more of an approximation than the first method, can be used for many routine laboratory evaluations where the accuracy of Method I is not required. Method II also lends itself to field survey work where the chipped areas can be rated by direct comparison with the chipping Rating Standards.

6.1.2 With both methods, the chipped area to be evaluated on the tested panel should be the 10.16 x 10.16 cm (4 x 4 in) square that exhibits the center of the chipped pattern.

6.2 Basic Structure of Rating System—Generally, the basic structure of the chip rating system consists of one or more number-letter combinations in which rating numbers 10-0 indicate the number of chips of each size and rating letter A-D designate the sizes of the corresponding chips. A point of failure notation may also be included in the rating if more descriptive refinement is desired.

6.2.1 NUMBER OF CHIPS—A whole rating number selected from the range of 10-0 in Table 1 is used to indicate the number of chips of each size in the 10.16 x 10.16 cm (4 x 4 in) test area.

TABLE 1—NUMBER CATEGORIES FOR CHIP RATING

Rating Number	Number of Chips	Rating Number	Number of Chips
10	0	4	50–74
9	1	3	75–99
8	2–4	2	100–149
7	5–9	1	150–250
6	10–24	0	>250
5	25–49		

6.2.2 SIZE OF CHIPS—The size of the chip is specified by a rating letter selected from A-D in Table 2. Due to the irregular nature of chipping, the size cannot always be measured exactly so it has to be approximated.

TABLE 2—SIZE CATEGORIES FOR CHIP RATING

Rating Letter	Size of Chips
A	>1 mm (>approximately 0.03 in)
B	1–3 mm (approximately 0.03–0.12 in)
C	3–6 mm (approximately 0.12–0.25 in)
D	>6 mm (>approximately 0.25 in)

6.2.3 POINT OF FAILURE—The coating layer at which the most predominant chipping failure occurs is designated as the point of failure. The notations in Table 3 can be used to designate this information if desired. Other notations may be used with agreement between contractual parties.

TABLE 3—POINT OF FAILURE NOTATION

Notation	Level of Failure	Failure Type
(S/P)	Substrate to Primer	Adhesional
(S/T)	Substrate to Topcoat	Adhesional
(P)	Prime	Cohesional
(P/T)	Primer to Topcoat	Adhesional
(T)	Topcoat	Cohesional

6.3 Details of Method I and Method II

6.3.1 METHOD I—EXACT COUNTING PROCEDURE

6.3.1.1 Counting can be facilitated by the use of a transparent overlay onto which has been etched a grid of 2.54cm (1 in) squares. The grid is placed over the area to be treated as a guide to remembering the areas that have been counted.

6.3.1.2 The operator examines the area within a 2.54 x 2.54 cm (1 x 1 in) square, decides on the size of each chip as encountered, and records it. Rate all 16 squares and record the results.

6.3.1.3 The actual number of chips counted for each size is then converted into the number-letter combinations utilizing Tables 1 and 2. The number-letter rating is then arranged with the most numerous size first, followed by the next more numerous, etc. This may then be followed by the Point of Failure notation.

For example, for a panel on which there are 20 chips less than 1 mm (A size), 40 chips of 1 to 3 mm (B size), and 3 chips of 3 to 6 mm (C size) with primer-topcoat failure, the number of chips on the rating would be 5B-6A-8C (P/T). This rating can be condensed by converting the total number of chips on the panel to the corresponding number category, which is then followed by the size designations in the same order. In this example, with a total of 63 chips, the rating would be summarized as 4 BAC (P/T).

6.3.2 METHOD II—VISUAL COMPARISON PROCEDURE—The Chipping Rating Standards shown in Figure 3 are utilized.

These have been prepared so the chips of only 1 size are shown in each illustration. The number of chips illustrated in each standard is the fewest number of chips in each rating number category; for example, the No. 5 standards all show 25 chips, the No. 3 standards show 75 chips. All of the No. 8 and No. 10 categories and the lower number D size categories have not been included in order to keep the photographs to a manageable number.

6.3.2.1 Visually compare the area to be rated with the standards.

Since each standard exhibits only one chip and actual chipping seldom occurs in only one size, one or more standards should be superimposed until that combination of standards which more nearly resembles the panel is obtained. Record the standards that were used to achieve the match with the panel under examination.

6.3.2.2 As with Method I, the most numerous chips should be listed first, the next most numerous second, etc. Again, the number-letter ratings may be summarized to give a condensed single number rating based on the total number of chips of all sizes followed by the letter ratings to indicate the relative number of chips of each size.

For example, a panel requiring the superimposition of a 6A standard, a 5B standard, and an 8C standard would be described as 5B-6A-8C (P/T) and summarized as 4 BAC (P/T).

7. ***Precision—***Because of the possibility of slight variations in the number, size, type, and distribution of gravel in each test sequence, some variation in the raw counts of chips in the various size categories will be reflected in the data. However, when these counts are converted into the condensed rating of Method I or the rating that can be obtained by Method II, if the results differ by greater than one number-letter rating, they should by considered suspect.

8. ***Reporting of Results—***Reports of the gravelometer tests shall include the number-letter rating and all applicable test conditions that deviated from the standard as outlined. In addition, reports should include the material type, thickness, and any preliminary surface treatment of the test panel together with the type of surface coating(s), baking, or pertinent processing schedules, and the film thicknesses of finishing system being evaluated.

9. ***Notes***

9.1 **Marginal Indicia—**The change bar (l) located in the left margin is for the convenience of the user in locating areas where revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE TEXTILES AND FLEXIBLE PLASTICS COMMITTEE

SAE J400 Revised NOV2002

Rationale—Editorial revisions made to add frequency of use of checklist in 4.1.1 that was unintentionally left out of submitted document.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Recommended Practice covers a laboratory procedure for testing and evaluating the resistance of surface coating to chipping by gravel impact. The test is designed to reproduce the effect of gravel striking exposed paint or coated surfaces of an automobile and has been correlated with actual field results. The specific intent of the test is to evaluate organic surface coatings or systems on flat test panels; however, it may be possible to extend this type of testing to finished parts or other types of materials such as anodized aluminum or coated plastics if the results are interpreted with respect to the limitations and intent implied by the original testing procedure and rating system.

Reference Section

GMR-767—The Measurement of Chipping of Automotive Finishes, Hays, Donald R., Detroit, MI, General Motors Laboratories, 1968

Developed by the SAE Textiles and Flexible Plastics Committee