

SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE J400

REV.
JAN85

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(R) 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 coatings 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 plated plastics if the results are interpreted with respect to the limitations and intent implied by the original testing procedure and rating system.

2. Summary of Method—The test consists of projecting a standardized road gravel by means of a controlled air blast onto a suitable test panel. The testing apparatus is contained in a box on wheels, 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 connected to a funnel 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 or 0 °F. After gravel impact, masking 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 Standards¹ or by counting the number and sizes of all chips.

3. Equipment and Materials

3.1 Gravelometer—A gravel projecting test apparatus which is constructed according to the design specifications shown in Figure 1².

3.2 Gravel—The gravel for this test shall be water-worn road gravel³, not crushed limestone or rock, which will pass through 5/8 in (15.86 mm) space screen when graded, but be retained on 3/8 in (9.53 mm) space screen. It is important to note that mesh screen is not a substitute for space screen. The gravelometer has 3/8 in (9.53 mm) space screen in the bottom to separate fractured pieces of rock and dust smaller than 3/8 in (9.53 mm) so that the retained gravel on this screen may be reused; however, even this reusable gravel will tend to blunt or fragment after repeated impacts, so a periodic gravel change after reasonable service use is mandatory.

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

² A similar type of commercial apparatus meeting these specifications can be obtained from: The Q-Panel Co., 15610 Industrial Parkway, Cleveland, OH.

³ Gravel meeting these specifications can be obtained from: The Q-Panel Co., 15610 Industrial Parkway, Cleveland, OH.

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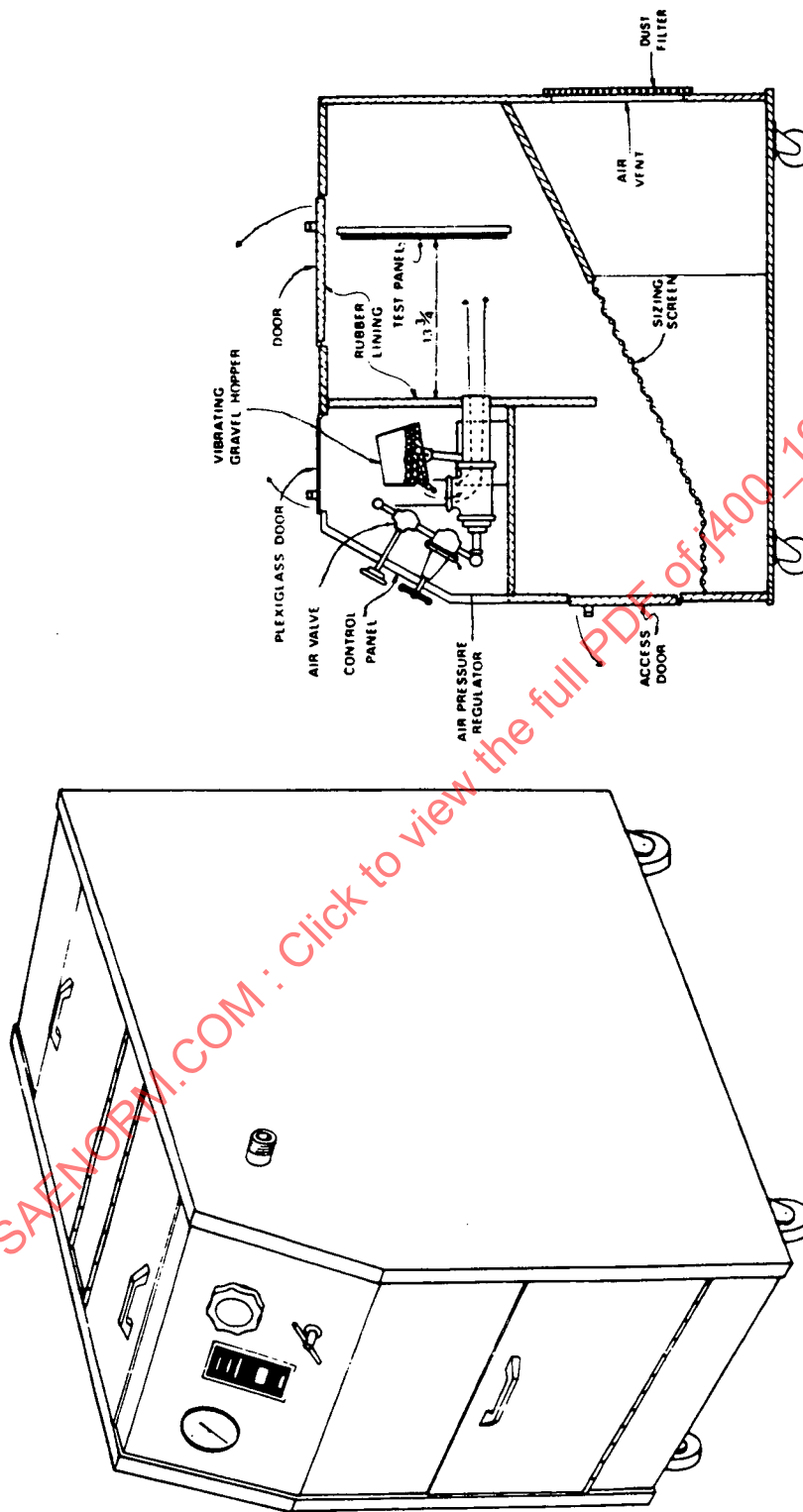


FIGURE 1—GRAVELOMETER

- 3.3 Masking Tape**—4 in (10 cm) wide, Minnesota Mining and Manufacturing Company, No. 202-2, or equivalent.
- 3.4 Temperature Conditioning Equipment**—Gravelometer tests are usually run at room temperature or a lower temperature, generally 0 °F (-17.8 °C), which shall be mutually agreed upon by supplier and purchaser. When tests are to be conducted at temperatures lower than room temperature, one of the following must be used:
- 3.4.1 PREFERRED METHOD**—A cold room (or freezer of sufficient size) in which the gravelometer and test panels both are maintained at the specified temperature of testing.
- 3.4.2** A freezer in which the test panels are cooled to 10 °F (5.6 °C) below the test temperature before they are individually transferred and tested immediately in a gravelometer at room temperature located nearby.
- 3.5 Tally Counter**—A mechanical counter such as a Veeder Root Tally, Model No. SC-149000, four counters wide by one tier high, or an equivalent type, which is used to tally the number of chips of four specified sizes on the tested panel.
- 3.6 Transparent Grid**—A chip counting aid constructed of transparent plastic approximately 1/8 x 5 x 5 in (3.176 mm x 12.7 cm x 12.7 cm), on which a 4 x 4 in (10.16 x 10.16 cm) grid of 1 in (2.54 cm) squares has been etched or scribed.
- 3.7 Chipping Rating Standards**—A set of photographic transparencies, each depicting one size of chip and the fewest number of chips in each rating category. See Figure 2 for a representation of these transparencies.
- 3.8 Test Panels**—The test panels should be flat and their size should be 4 x 12 in (10.16 x 30.48 cm) in order to fit into the panel holder of the gravelometer. The test panel material, the panel's thickness or gage, and preliminary surface treatments (such as phosphatizing or anodizing) should be the same for all tests in any one series and as representative as possible of the actual part. Any deviations in these three parameters may produce misleading test results. Specification of these parameters shall be by mutual agreement between supplier and purchaser. A typical test panel specification would be: 4 x 12 in (10.16 x 30.48 cm) 20 gage, 0.0359 in (0.091 cm) phosphated, cold rolled steel.

4. Procedure

- 4.1** Paint or process the test panels as specified for the systems under test. It should be noted that gravelometer 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 to $\pm 10\%$ of the coating's thickness of ± 0.1 mil, whichever is greater.
- 4.2** Age prepare test panels a minimum of 72 h at room temperature before initiation of gravelometer testing.
- 4.3** Condition test panels for a minimum of 1 h at the specified test temperature, mutually agreed upon by supplier and purchaser, in accordance with the appropriate method specified in 3.4. Make certain the test panels are separated and have free access to the conditioning environment so that optimum heat transfer is facilitated.
- 4.4** Adjust air pressure on the gravelometer to 70 ± 3 psi (482.6 ± 20.68 kPa) with the air valve open. Keep lid to gravel chamber on the gravelometer closed during this operation as a safety precaution.
- 4.5** After the air pressure is adjusted, shut off air valve, open the lid to the gravel chamber, and collect 1 pt (0.47317 L) of graded gravel (approximately 250—300 stones) in a suitable container. Gravel should be collected by scraping across the screen to allow fines to fall through. (No more than two or three pints of gravel shall be allowed to collect on the screen.)

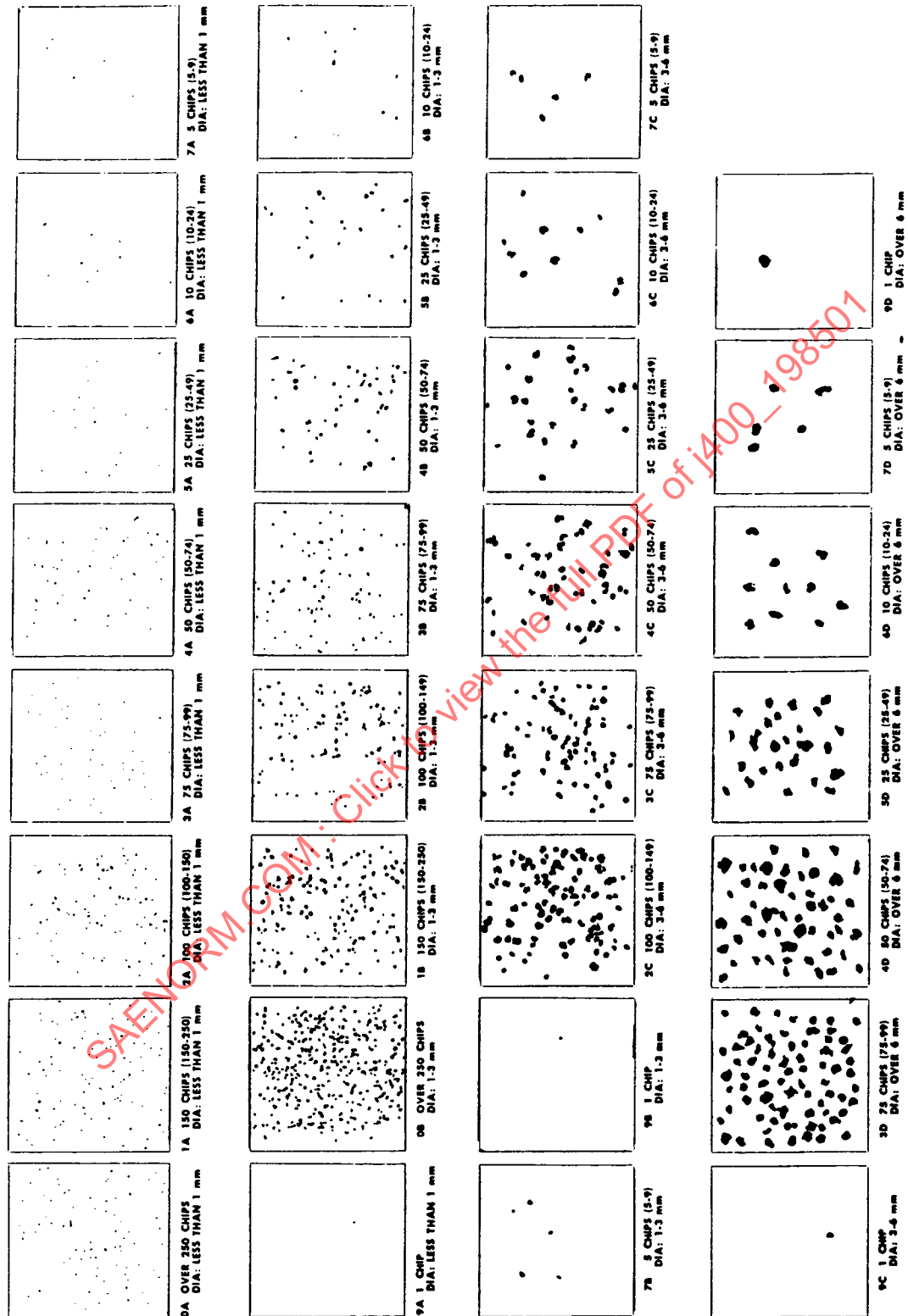


FIGURE 2—CHIPPING RATING STANDARDS (REPRESENTATION ONLY)

- 4.6 Place one test panel conditioned at the desired test temperature in the panel holder with the coated side facing the gravel projecting mechanism, close lid to gravel chamber only. Panel holder should have heavy aluminum back up plate to provide for rigid support⁴. Open the air valve and feed 1 pt (0.47317 L) of gravel slowly over a period of 5—10 s into the funnel⁵. Do not dump the gravel into the funnel because an instantaneous charge such as this may partially choke the pipe tee and lead to inconsistent results due to low particle velocity.
- 4.7 Shut of air valve, open lid to gravel chamber, and remove the tested panel. If necessary, allow panels to return to room temperature and dry to remove any condensed moisture.
- 4.8 Cover the tested panel with a 4 in (10 cm) strip of masking tape, press down firmly, and then pull off slowly to remove chips of paint that have not been completely separated from the panel.
- 4.9 Determine the degree of chipping by one of the following methods of the Gravelometer Rating System.

5. Gravelometer Rating System

5.1 Methods Available

- 5.1.1 There are two methods available for determining the degree of chipping of the tested panel. 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 Standards¹ 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.
- 5.1.2 With both methods, the chipped area to be evaluated on the tested panel should be the 4 x 4 in (10 x 10 cm) square that exhibits the worst degree of chipping.

5.2 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 letters 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.

- 5.2.1 **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 x 10 cm test area.

⁴ Back up plate shall be 7 gage, 0.1793 x 4 x 12 in (0.455 x 10.16 x 30.48 cm).

⁵ When the test panel has to be cooled to a temperature 10 °F lower than the specified test temperature in a freezer located next to a gravelometer at room temperature, the total elapsed time between removal of the panel from the freezer and completion of the gravelometer run shall be no more than 15 s. The 10 °F lower conditioning temperature is to provide a working margin for the panel temperature rise toward the specified testing temperature during the transferring and testing interval.

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		

5.2.2 SIZE OF CHIPS—The size of the chips 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. Two general types of chipping occur: glassy fracturing or flaking of the film from impact of the gravel and knife-like cut-throughs or gouges caused by sharp edges on the gravel. With true fracturing the longest average dimension of the chip is used for size measurements; with cut-throughs or gouges where little material is actually lost, the most representative shorter dimensions or axis are used. Examples of chip size determination, expressed by dimension (d), are shown in Figure 3.

TABLE 2—SIZE CATEGORIES FOR CHIP RATING

Rating Letter	Size of Chips (see "d," Figure 2)
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)

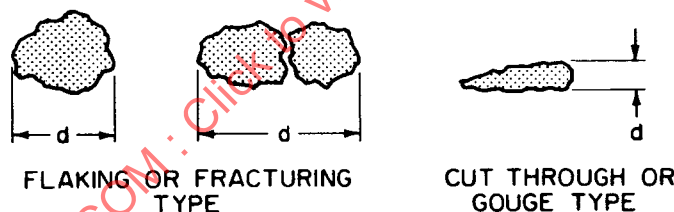


FIGURE 3—CHIP SIZE MEASUREMENT APPROXIMATION

5.2.3 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. In cases where multiple layers of different primers and/or sealers, multiple topcoats, or other more complex film/substrate combinations are encountered, the point of failure notation can be expanded accordingly in the sense of the descriptive terms of Table 3, once suitable agreement between vendor and purchaser has been established.

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

5.3 Details of Method I and Method II

5.3.1 METHOD I—EXACT COUNTING PROCEDURE

5.3.1.1 Counting can be facilitated by the use of a transparent overlay onto which has been etched a grid of 1 in (2.5 cm) squares. The grid is placed over the area to be treated as a guide to remembering the areas that have been counted.

5.3.1.2 The mechanical tally is used to record the number of chips, using one counter for each of the four sizes.

5.3.1.3 The operator examines the area within each 1 x 1 in (2.5 x 2.5 cm) square, decides on the size of each chip as it is encountered, and registers it on the appropriate counter. After all 16 squares have been rated, the number of chips of each size can be read on the tally. A 4 x 4 in (10 x 10 cm) area can be rated in this manner in about 90 s.

5.3.1.4 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. For example, for a panel on which there are 20 chips less than 1 mm (A size), 40 chips of 1—3 mm (B size), and 3 chips of 3—6 mm (C size) with primer-topcoat failure, the number-letter 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).

5.3.2 METHOD II—VISUAL COMPARISON PROCEDURE

5.3.2.1 Chipping Rating Standards¹ are utilized. These have been prepared so that chips of only one 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.

5.3.2.2 Visually compare the area to be rated with the standards. Since each standard exhibits only one chip size 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.

5.3.2.3 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).

6. 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 be considered suspect.