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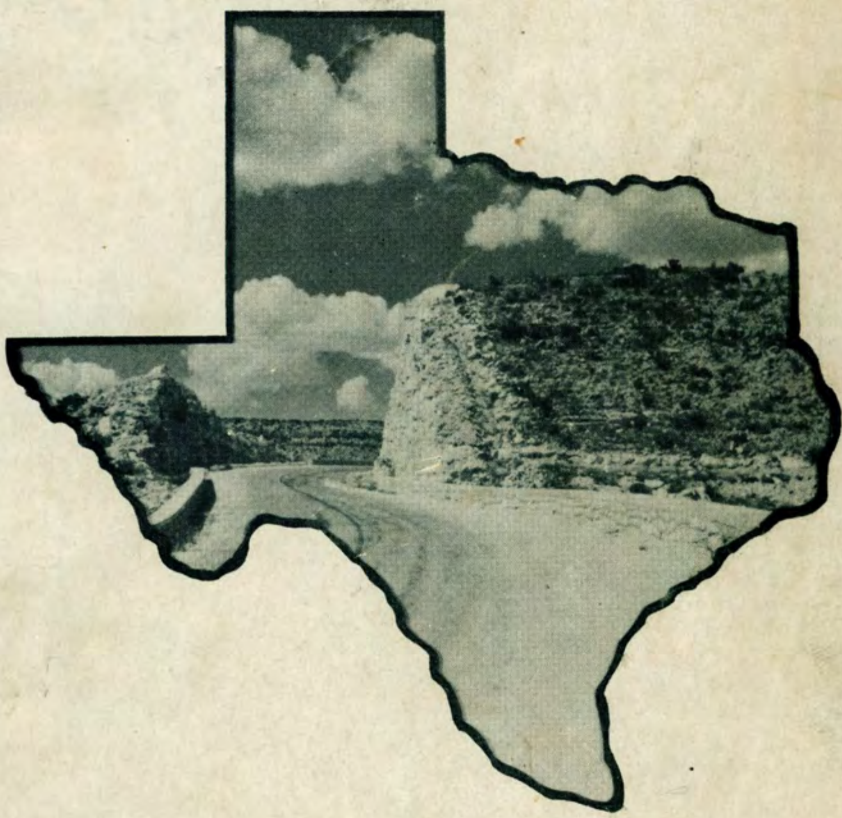
Texas Highway Department



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INFORMATION EXCHANGE

Issue No. 70, June 1, 1939

THE LOS ANGELES RATTLER "S" GRADING ABRASION TEST

Texas Highway Department Concrete and Aggregate
Research Investigational Project No. 100-B

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THE LOS ANGELES RATTLER "S" GRADING ABRASION TEST

SYNOPSIS:

Before the completion, in 1937, of Concrete Research Investigational Project No. 100, titled "The Los Angeles Rattler Abrasion Test," the writer recognized the need of an abrasion test applicable to aggregate sizes smaller than the smallest sizes which could be tested according to A.A.S.H.O. Method T-96. It was not, however, until the latter part of 1938 that the development of such a test, which constitutes this investigation, was begun.

Several preliminary decisions, determining the course of the investigation, were made prior to the beginning of the actual work. It was decided that the "S" grading test should be correlated with the standard Los Angeles Rattler abrasion test; that the "S" grading test charge should be composed of 3/8-inch to No. 10 sieve material; that "S" grading test values were to be approximately equal to, rather than in some ratio to, the respective standard values; that the standard "B" grading test should be considered as the standard for correlation; that crushed limestone be used for the work of correlation; and, that all stones be crushed in the same crusher.

Five limestones were selected and sampled for the work of correlation. The range in resistance to abrasion of these five limestones covered, and slightly overlapped, the present Texas Highway Department abrasive loss specification range for aggregate for use in asphaltic construction and maintenance. A very tough stone and a very friable stone were selected and sampled so that extreme conditions, or end-points, might be observed. Thirteen stones of varying physical and petrographic characteristics were selected and sampled. These stones were used as a check upon the correlation. Each sample was carefully crushed, blended, screened, and stored so that quality and particle size segregation would be minimized.

Daily checks on equipment and testing procedure were made and recorded so that maximum accuracy might be secured.

Five hundred and ninety-five abrasion tests were made in the regular test series. A complete sieve analysis was made on each of the degraded test charges. Numerous incidental abrasion tests also were made.

The various possible variables in the development of the new test included the total size, or weight, of the test charge; four different abrasive charge ball weights; the number of balls comprising, or the total weight of, the abrasive charge; the sieve to be used for determining the per cent wear; and, the number of revolutions of the Rattler. In the correlation of the "S" grading test with the standard "B" grading test, each of these variables was investigated singly and in all pertinent combinations with one or more of the others. In this manner the undesirable combinations were eliminated and the optimum test evolved.

The degree of correlation obtained, or the ability of the "S" grading test to duplicate standard test values, was checked by means of tests on thirteen stones of varying characteristics with a wide range in resistance to abrasion.

Special factors in the development of the "S" grading test were investigated. These factors included the effect of particle angularity on the correlation; the degree of correlation of the standard "A" and "B" grading tests; the accuracy of duplication of "S" grading test values.

The "S" grading test as applied to crushed stone was demonstrated by argument to be equally applicable to gravel.

Conclusions and recommendations follow.

CONCLUSIONS:

Many negative conclusions leading to positive answers were developed in the course of the investigation. Many minor, or subsidiary, conclusions also were developed. As these negative and subsidiary conclusions are available in the discussion they will be omitted here. The chief positive conclusions are as follows:

1. In the correlation of the "S" grading test with the standard Los Angeles Rattler abrasion test, it was found that:

a. The best grading of the test charge is as follows: 50 per cent by weight of 3/8-inch (round-hole screen) to 1/4-inch (round-hole screen) size, and 50 per cent by weight of 1/4-inch (round-hole screen) to No. 10 (square-mesh sieve) size.

b. The optimum total weight of the test charge is 5000 grams.

c. The optimum abrasive charge consists of fourteen 1-7/8-inch steel balls. Each ball shall weigh 422.5 $\pm$ 17.5 grams, and the total abrasive charge shall weigh 5834 $\pm$ 25 grams.

d. The No. 20 sieve (U. S. Standard sieve series) is the best sieve for determining the per cent wear.

e. The best testing procedure, with the above exceptions, complies with the procedure specified in A.A.S.H.O. Method T-96.

Therefore, the optimum "S" grading test, or the "S" grading test which yields the closest numerical and actual correlation with the standard test, combines the foregoing features.

2. Concerning the optimum "S" grading test (as in Conclusion 1), the standard "A" grading test, the standard "B" grading test, and the interrelation of these tests:

a. The average numerical deviation (per cent wear) of "A" test values from respective "B" test values, of "S" test values from respective "B" test values, and of "S" test values from respective "A" test values is as follows:

	Eighteen stones (one rhyolite, five quartzitic stones, and twelve limestones and dolomitic limestones) with a range in standard "B" wear values of 20.84 to 49.65 per cent	Preceding eighteen stones plus Trap (standard "B" wear equals 9.43 per cent) and Cordova Cream limestone (standard "B" wear equals 72.44 per cent)
Average Deviation (Per Cent Wear) "A" from "B"	1.05	1.14
Average Deviation (Per Cent Wear) "S" and "B"	1.50	1.80
Average Deviation (Per Cent Wear) "S" from "A"	1.25	1.67

b. On the basis of the average behavior of a number of stones, the smaller sizes of a particular stone may be actually more resistant, or actually less resistant to abrasion than are the larger sizes. Thus, the actual correlation of the "S" grading test with the standard test may be, and usually is, much better than the numerical correlation.

c. Allowing for the initial average test charge particle size differential the complete "S" grading test charge degradation is very similar in all phases to the complete "A" and "B" test charge degradation.

d. The "S" grading test duplicates test values more accurately than do either of the two standard tests.

e. The relative angularity of "S" and "B" grading test charge particles does not affect the relative wear to an appreciable extent.

3. The "S" grading test as applied to crushed stone is equally applicable to crushed, or uncrushed, gravel.

4. Taking into consideration the foregoing conclusions, the major conclusion is that the "S" grading test as developed in this investigation is an eminently satisfactory abrasion test for the aggregate sizes for which it is intended.

RECOMMENDATIONS:

It is unhesitatingly recommended that:

1. The "S" grading test as set forth in Conclusion 1, and, in more detail, in section E of "Procedure," be made the standard Texas Highway Department abrasion test for aggregate smaller than that which can be tested according to A.A.S.H.O. Method T-96.

2. "S" grading test values be given precedence over standard "A" or "B" grading test values, should both be available, where grading specifications for the aggregate clearly require the "S" grading test.

PURPOSE:

The standard Los Angeles Rattler abrasion test (A.A.S.H.O. designation: Method T-96) permits a choice between two gradings for the test charge: "A" grading (1-1/2 inches to 3/8-inch); "B" grading (3/4-inch to 3/8-inch). As the smallest size used in either of these two test charges is retained on the 3/8-inch square mesh sieve, it is apparent that material smaller than that retained upon the 3/8-inch sieve, or, approximately, the 1/2-inch round-hole screen, cannot be tested according to the standard method.

The Texas Highway Department uses a very large amount of aggregate smaller than 1/2-inch in size in the construction and maintenance of asphaltic concrete and asphaltic surface course roads. (The term "seal-coat size," or "seal-coat material" as hereinafter used, shall be understood to designate material smaller than 1/2-inch in size.) So far, the only method of testing seal-coat material for resistance to abrasion is to make the standard Los Angeles Rattler abrasion test on the larger sizes of the material in the quarry or pit in question, and then make the very questionable assumption that the smaller sizes are of the same quality as the larger. (The term "resistance to abrasion," as used in this report, shall be understood to mean "resistance to the Rattler abrasion test," which subjects aggregates to impact as well as to abrasion.)

If the aggregate to be used be crushed stone, the problem of sampling depends upon two chief methods of production of the seal-coat size.

(1) Should the quarry stone be totally reduced to this size, the stone in the quarry must be sampled, crushed, and tested using either the "A" or "B" grading test charge. The greatest fundamental deficiency in the antiquated Deval abrasion test for stone was that the test could not be applied to the finished product. The gradings required of the standard Los Angeles Rattler test charges bring us face to face with the same old problem when seal-coat sizes are being produced. Quarry sampling is satisfactory only when the stone is of uniform quality throughout the quarry. Unfortunately, this condition is the exception rather than the rule. In many quarries in this state the most conscientious sampler could not hope, with any number of quarry samples, to adequately represent the quality of the finished product.

(2) Should the seal-coat material be produced simultaneously with, or as a by-product from, larger sizes of crushed stone from which an "A" or "B" grading test charge could be obtained, these larger sizes would be tested. While more satisfactory than quarry sampling, this method of sampling leaves much to be desired. When crushing stone of non-uniform toughness, the more friable portions are naturally further reduced in size than are the tougher portions. Thus, except when produced from a very uniform quarry, the seal-coat sizes are very likely to differ in quality from the larger sizes.

If the aggregate to be used be gravel, the only available check upon the quality of the seal-coat material is to make an "A" or "B" grading test on the larger sizes of gravel in the deposit from which the smaller sizes are being produced. In case the seal-coat material consists almost wholly of gravel crushed from the larger sizes this method is fairly satisfactory. Where the seal-coat material is the product of screening, rather than of crushing, this method is very unsatisfactory. Few gravel pits produce material which is uniform in toughness. Most gravels are a heterogenous mixture of two or more of the chief types of pebbles; siliceous, calcareous, arenaceous, argillaceous, ferromagnesian igneous and feldspathic igneous. In a mixed gravel these types are seldom, if ever, distributed evenly throughout all sizes. Therefore, the average toughness of the smaller sizes is almost sure to differ from that of the larger.

It is frequently the case, both with crushed stone and gravel, particularly in maintenance work, that orders for seal-coat material are placed subsequent to the production of the material. If no tests were made on the stone or gravel at the time of production, there would be no way to secure any abrasive test result.

Thus, it may be seen that there is no satisfactory abrasive test wherewith to control the quality of the aggregate used for base preservative, seal-coat, and single, double, or triple asphalt surface treatment, nor can the smaller sizes of the blended aggregates used in the construction of asphaltic concrete pavement be tested.

The purpose, therefore, of this investigation was to develop a satisfactory abrasion test for aggregate with a grading finer than the grading required by the standard Los Angeles Rattler "B" grading test charge.

MATERIALS AND EQUIPMENT:

Correlation stone samples: Five large samples (approximately one ton each) of limestone in the practical specification range of resistance to abrasion.

End-point stone samples: Two large samples of stone, one extremely tough, the other extremely friable.

Correlation-check stone samples: Thirteen smaller samples of stone of varying physical and petrographic characteristics.

A complete description of these various stones will be given later under "Procedure."

Abrasion machine: The standard Los Angeles Rattler abrasion machine, which conforms in all essential respects to the machine recommended in A.A.S.H.O. Method T-96. For a detailed description of this machine see Concrete Research Investigational Project No. 100.

Crusher: Universal jaw crusher, capable of receiving 4-inch stone.

Miscellaneous: Equipment incidental to abrasion tests, equipment incidental to sieve analyses, microscope, and camera.

PROCEDURE, TEST RESULTS AND DISCUSSION:

A. Preliminary Decisions:

1. "S" Grading Test to Be Correlated with Standard Los Angeles Rattler Abrasion Test:

The proposed test was named the "Los Angeles Rattler 'S' Grading Abrasion Test." The first problem was to determine the best method of developing this test. It was decided that the "S" grading test should be correlated with the standard Los Angeles Rattler abrasion test for the following reasons:

(1) The standard test is understood and accepted by engineers and producers as the authoritative test for measuring the abrasive resistance of aggregates.

(2) Standard test values have been correlated with service values, not only in Texas, but in many other states. Thus, although abrasive wear limits may vary widely in different sections of the country, the standard test values have a very definite meaning for engineers, producers, and contractors, and it would be undesirable to introduce an alien series of test values.

(3) The standard test has proved itself to be a good measure of the service value of aggregates.

2. Grading of the Test Charge:

It was essential to select the most practicable and useful grading for the test charge.

Tables 1A and B show some of the various items (Texas State Highway Department Standard Specifications, 1938) which require the Los Angeles Rattler abrasion test. All of the items shown specify gradings which cannot be represented adequately by an "A" or "B" grading test charge. All of the screen sizes shown are round-hole screens with the exception of the numbered sieves.

Table 1A shows the complete specified gradings for aggregate for asphaltic surface courses and rock asphalt pavement. Items 301- are for base preservative, 303- for seal coat, 304- for single asphalt surface treatment, 305- for double asphalt surface treatment, 306- for triple asphalt surface treatment, 313 for cold mix blended rock asphalt pavement, and 315 for Duraco pavement.

Table 1A

Complete Specified Gradings for Aggregate for Asphaltic Surface Courses and Rock Asphalt Pavement

Specification Item No.	Specified Grading (Per Cent Retained)					
	3/4"	1/2"	3/8"	1/4"	No. 10	No. 20
301.2 & 306.2, No. 3			0		50-90	98-100
301A.2			0		50-90	95-100
303.2 & 303A.2		0	0-10		95-100	
304.2 & 304A.2	0	5-20			95-100	
305.2, No. 1	*	0-10		70-100	95-100	
305.2, No. 2			0	2-20	70-100	95-100
305 & 6A.2, No. 2	0	0-10		65-85	90-100	98-100
306.2, No. 2	0	0-20		80-100		
306A.2, No. 3			0	0-20	85-100	98-100
313.2	**0-10				25-55	
315.2	**0-10			40-60	55-70	

* 0 Retained 5/8" - ** 0 Retained 1"

Table 1B shows a portion of the specified gradings for aggregate for asphaltic concrete pavement. The specified sizes with a particle diameter greater than 1/2-inch are not shown here as these sizes can be included in an "A" or "B" grading test charge. The specified sizes smaller than the No. 40 sieve opening are not shown here as it was considered impracticable to apply an abrasive test to these sizes. Thus, all but one of the gradings shown in this table are complete only for the 1/2-inch to No. 40 range. The specified amount passing the No. 10 is also shown. Items 309- and 311- are for cut back asphaltic concrete pavement, 310- for emulsified asphaltic concrete pavement, and 317- and 318- for hot mix asphaltic concrete pavement. The letters in parenthesis refer to the respective types under each specification item.

Table 1B

Portions of Specified Gradings for Aggregate for Asphaltic Concrete Pavement

Specification Item No.	Specified Grading (Per Cent between Screen and Sieve Sizes)				
	1/2"-1/4"	3/8"-10	1/4"-10	10-40	Pass. 10
309.3 (J)	10-25		10-20	3-10	
309.3 (K)	20-40		10-20	5-20	
309.3 (L) & 310.3 (T)	25-40		10-25	5-20	
309.3 (M) & 310.3 (U)	30-60		20-40	5-20	
310.3 (R)	10-20		10-20	5-15	
310.3 (S)	20-40		10-25	5-20	
311.3 (N)	10-20		10-20		10-35
311.3 (O)	20-40		10-20		10-35
311.3 (P)	20-40		10-25		10-35
311.3 (Q)	30-60		20-40		15-35
317.3 (A)	10-25		7-20	3-12	
317.3 (B) & 318.3 (W)	10-50		10-25		20-35
317.3 (C) & 318.3 (X)	15-30		5-20	5-15	
317.3 (D) & 318.3 (Y)	10-30		15-30	10-25	
317.3 (F) & 318.3 (ZZ)		60-75		3-10	
317.3 (E) & 318.3 (Z)			0-5	15-40	

One of the variables in the Rattler test is the particle size of the material being tested. In order to limit this variable the test charge is composed of definite percentages of certain sizes. The problem here was to select a grading which would be best adapted to the greatest number of cases, as shown in Tables 1A and B, and, at the same time, present the least number of technical difficulties. Due consideration was given to each of the following points:

(1) Each individual item in Tables 1A and B.

(2) At least twice as much material is used (construction and maintenance) under the specification items listed in Table 1A as is used under the items listed in Table 1B.

(3) With the exception of Item No. 311.3Q, all of the gradings shown in Table 1B comprise only a portion, and, in some cases, a relatively small portion, of the respective total gradings.

(4) In all specified gradings a relatively small amount of material will pass the 3/8-inch square mesh sieve (the lower limit for the standard "A" and "B" grading test charge) and be retained upon the 3/8-inch round-hole screen.

(5) Texas State Highway Department specifications require the use of round-hole screens down to, and including, the 1/4-inch screen.

These points being taken into consideration, it was decided that the "S" grading test charge should be composed of equal portions, by weight, of 3/8-inch (round-hole) to 1/4-inch (round-hole) size, and 1/4-inch (round-hole) to No. 10 (square-mesh) sieve size.

3. "S" Grading Test Values to Be Approximately Equal to the Respective Standard Test Values:

It was decided that the "S" grading test should be correlated with the standard test so that "S" grading test values should be approximately equal, numerically, to the respective standard test values, rather than in ratio to the standard values. In other words, it was considered desirable that with standard test values of 20 and 40 per cent the respective "S" grading test values should be approximately 20 and 40, rather than, for example, 10 and 20, or 40 and 80 per cent.

4. "B" Grading Test as Standard for Correlation:

The standard test permits a choice of two gradings of the test charge. The "A" and "B" grading tests are supposed to yield equal test values. This correlation, though good, is not perfect. (See Concrete Research Investigational Project No. 100.) As the "S" grading test was to be correlated with the standard test, very concise standard test values were essential. Totally unnecessary complications would have been sure to ensue had the correlation been attempted using both the "A" and "B" grading test values. It was therefore decided that the "S" grading test should be correlated with the "B" grading test only. The "B" grading test was selected in preference to the "A" grading test because the "B" grading test charge (passing the 3/4-inch sieve and retained on the 3/8-inch sieve) is more nearly representative of the bulk of the aggregate (larger than the 3/8-inch round-hole screen opening) used for asphalt surface courses and asphaltic concrete than is the "A" grading test charge (passing the 1-1/2-inch sieve and retained upon 3/8-inch sieve).

5. Crushed Limestone Used for Correlation:

The chief consideration in the selection of materials to be used in the correlation were uniformity within each sample and range in resistance to abrasion. It is obvious that it would be useless to correlate the "S" grading test with the "B" grading test if the particles in the "S" grading test charge were not known to be of the same toughness, or equally as resistant to abrasion, as the particles in the "B" grading test charge.

Uncrushed gravel was, therefore, immediately eliminated from consideration. There is absolutely no way of guaranteeing that the finer particles of any given uncrushed gravel are of the same toughness as the coarser particles. In fact, most gravels are composed of particles of varying petrographic and physical characteristics, the petrographic types obviously being distributed disproportionately according to size.

Crushed gravel was also eliminated, but for different reasons. By crushing selected gravel smaller sizes could be obtained which would be comparable in toughness to the larger sizes, but this method of securing material was deemed entirely impracticable because: (1) the cost, in time and labor required to hand-pick a sufficient amount of gravel, was prohibitive; (2) the accessible gravels in this state do not present the range in toughness, or resistance to abrasion, demanded by this investigation.

Thus, crushed stone, from the outset the most logical choice, likewise became the only alternative. By careful selection samples of stone of requisite uniformity and toughness could be procured. It was decided to use various limestones for the main group of experimental correlations for the following reasons:

(1) A very high percentage of both commercial and non-commercial crushed stone aggregate production in this state is composed of limestone.

(2) Limestone presents a wide range in structural characteristics (dense, or compact, granular, etc.) and a very wide range in resistance to abrasion.

(3) Stones other than limestones (quartzites, sandstones, igneous stones, etc.) could be used as a check upon the correlations whenever deemed necessary.

6. <u>All Stones Crushed in Same Crusher</u>:

It is the opinion of some engineers that the shape of the particles in the test charge exerts a great influence on the Rattler test results. (It is the writer's opinion that the influence of particle shape on test values is considerably overestimated, but no definite statement can be made prior to the completion of Concrete Research Investigational Project No. 100-D, titled "Causes for Variation in The Los Angeles Rattler Abrasion Test.") It is further held that the manner of fracture of a given stone will vary as the crusher type and jaw setting varies.

However great or slight the influence of particle shape on test values, or however large or small the effect of the crusher type on the particle shape, it was considered desirable to eliminate this "crusher type variable" as far as possible. Accordingly, all stones used for correlation (later note Chico stone as a partial exception) were procured in large blocks and put through the same crusher with identical jaw settings.

B. <u>Stones for Correlation</u>:

1. <u>Selection, Sampling, and Description of</u>:

a. <u>Correlation Stones</u>:

The 1938 Texas Highway Department Specifications limit the per cent of wear of aggregates to be used in asphaltic construction and maintenance to 27.5, 30.0 and 35.0, depending upon the specific use to which the material is to be put. It was decided to procure large samples of five different stones which would effectively cover, and slightly overlap, this range in resistance to abrasion.

After a review of hundreds of routine laboratory Rattler test results, and after some preliminary tests, always keeping in mind the vital prerequisite of uniformity within each sample, the following stones were selected in the order in which they are named:

Chico Limestone: A dense, highly compacted, somewhat fossiliferous (fossils mostly microscopic), yellow-gray limestone produced by the Southwest Stone Company two miles southeast of Chico, Texas. This stone, one of the Concrete Research standard aggregates, already crushed (approximately 100 per cent passing the 2-inch round-hole screen), was available at the laboratory. A 2500-pound sample of this stone, all of which was retained on the 3/8-inch sieve, was taken from the bin.

Courchesne Limestone: A dense, highly compacted, dark gray, dolomitic limestone produced by A. Courchesne near El Paso, Texas. The writer, with the assistance of Mr. Carroll R. Stevens, Jr., Resident Engineer at El Paso, secured an 1850-pound sample of this stone from the quarry. Each chunk was hand-picked.

Maryneal Limestone: A semi-granular, yellow-white limestone from an old abandoned quarry site near Maryneal, Texas. The writer secured a 2400-pound sample of this stone from the quarry. Each chunk was hand-picked.

Dudley Limestone: A dense, highly compacted, dark blue, dolomitic limestone produced by the Dudley Stone Company from the south face of Franklin Mountain near El Paso. An 1830-pound sample of this stone was secured from the quarry by Mr. Carroll R. Stevens, Jr., Resident Engineer. Each chunk was hand-picked.

Ogden Limestone: A semi-granular, highly fossiliferous (fossils microscopic), white limestone produced by the Servtex Materials Company from the Ogden quarry twelve miles southwest of New Braunfels. A 2500-pound sample of this stone was secured from the quarry by the writer and members of the Concrete Research Section personnel. Each chunk was hand-picked.

These five limestones will be hereinafter referred to as "correlation stones."

b. End-Point Stones:

It was further decided to procure a sample of a very tough stone and a sample of a very friable stone so that extreme conditions, or end-points, might be obtained. The following stones were selected:

Trap: A black, ferromagnesian igneous stone produced by the Uvalde Rock Asphalt Company near Blewett, Texas. The writer, with the assistance of Mr. Cooney Timberlake, general foreman for the company, secured a 680-pound sample of this stone from the production site. This material is so uniform that sampling was an easy matter.

Cordova Cream Limestone: A very granular, loosely compacted, highly fossiliferous (fossils microscopic), white limestone, produced by the Texas Quarries, Inc., at Cedar Park, Texas. Members of the Concrete Research personnel secured a 2000-pound sample of this stone from the Texas Quarries stone mill in Austin, Texas.

These two stones will be hereinafter referred to as "end-point stones."

c. Correlation-Check Stones:

It was further decided to procure samples of stones of varying physical and petrographic characteristics for the purpose of amplifying and checking whatever correlation might be obtained with the five correlation stones and the two end-point stones. These various stone samples were secured at the request of the writer. The samplers were instructed to secure uncrushed stone, each sample to be of uniform character throughout. It was made clear to the samplers that these were to be type samples, and were not to be considered necessarily representative of the quarry, or locality, from which they were taken. The following stones, named according to their respective geographic locations, were received by the Concrete Research Section:

Allamore Rhyolite: A light, pink-brown, feldspathic igneous stone produced by the Gifford-Hill Company at Allamore. (Sample: 251 pounds)

Beckmann Limestone: A very fine grained, though rather poorly compacted, white limestone produced by McDonough Brothers at Beckmann. (Sample: 331 pounds)

Brownwood Limestone: A very dense, highly compacted, fossiliferous (fossils microscopic), yellow limestone produced by the H. & H. Rock Company at Brownwood. (Sample: 318 pounds)

Denison Limestone: A fairly dense, well-compacted white limestone produced by J. C. Field at Denison. (Sample: 238 pounds)

Dittlinger Limestone: A granular, porous, highly fossiliferous (fossils microscopic), white limestone produced by the Servtex Materials Company at Dittlinger. (Sample: 230 pounds)

Hamlin Limestone: A fairly dense, well-compacted, gray, dolomitic limestone produced by the Acme Stone Company at Hamlin. (Sample: 338 pounds)

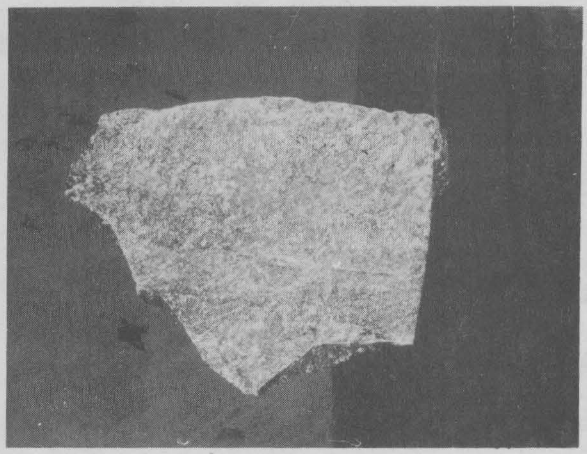
Huntsville Quartzite: A fairly fine-grained blue-gray quartzite produced by the Walker County Stone Company near Huntsville. (Sample: 353 pounds)

Huntsville Quartzitic Sandstone: A fairly fine-grained, light gray quartzitic sandstone produced by the Walker County Stone Company near Huntsville. (Sample: 430 pounds)

Palo Pinto Limestone: A very dense, highly compacted, fossiliferous (fossils barely microscopic), light yellow-gray limestone produced by R. W. Briggs & Company in Palo Pinto County. (Sample: 257 pounds)

Quitaque Quartzite: A very fine-grained, pink quartzite, containing very hard, calcareous concretions, from Briscoe County near Quitaque. (Sample: 257 pounds)

Servtex Limestone: A dense, highly compacted, light gray limestone produced by the Servtex Materials Company from the Ogden quarry twelve miles southwest of New Braunfels. (This stone is designated "Servtex," rather than



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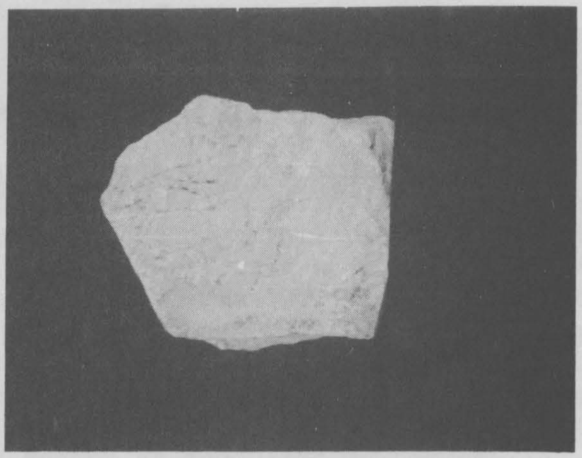

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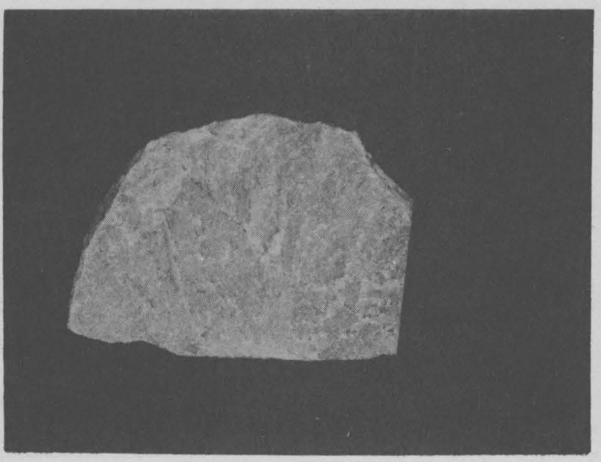
Dudley Limestone
(Very dark blue)

600T-6796

Chico Limestone
(Yellow-gray)



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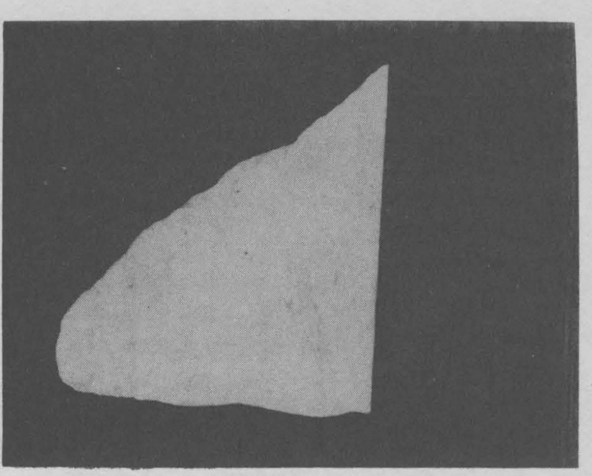
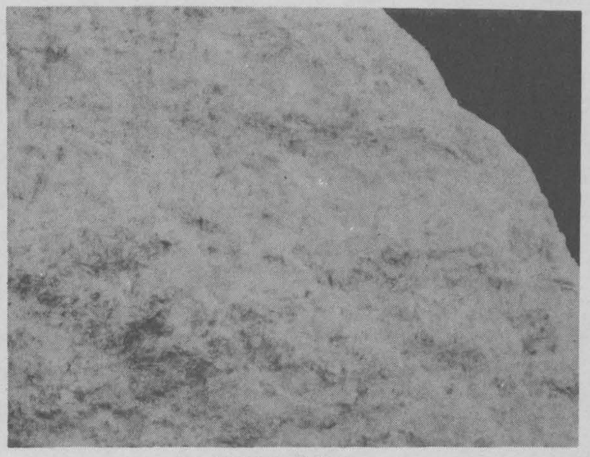


600T-6506

600T-4765



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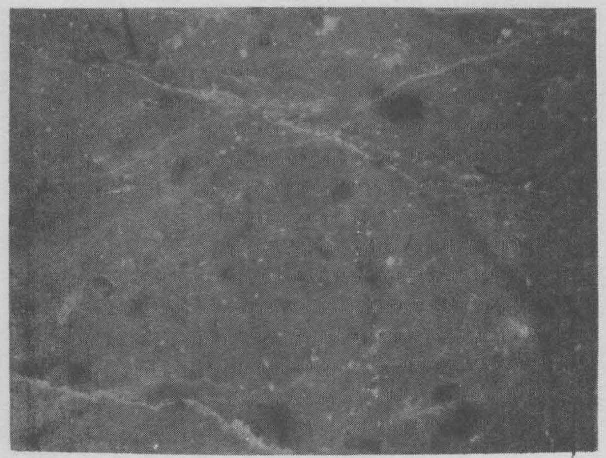
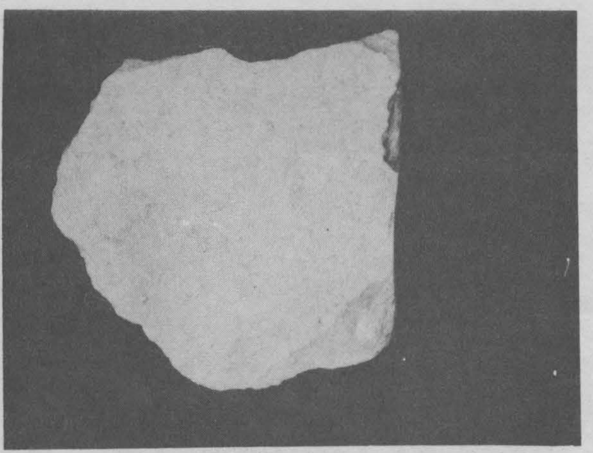


600T-6789

Courchesne Limestone
(Dark gray)

600T-6799

Maryneal Limestone
(Yellow-white)



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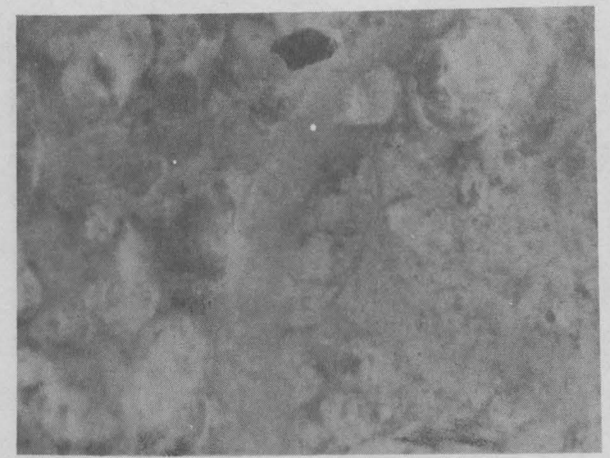
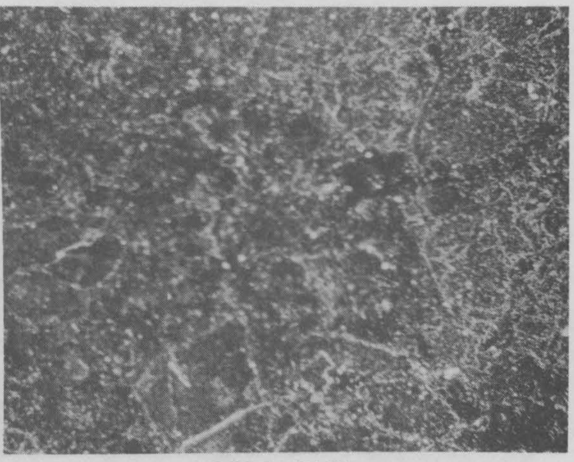
600T-6522

600T-4772

600T-4783



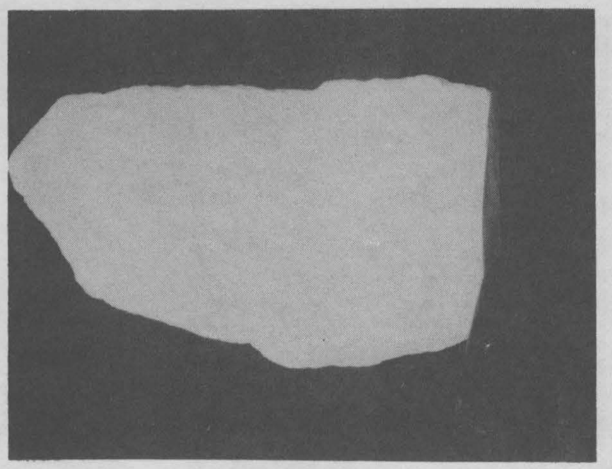
600T-6887



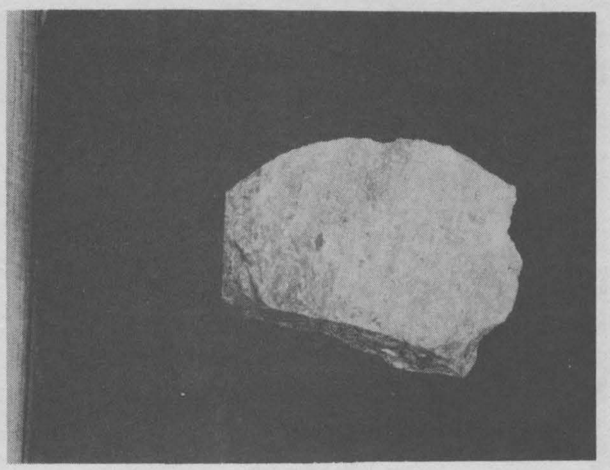
600T-6787

Ogden Limestone
(White)

Trap
(Dead black)



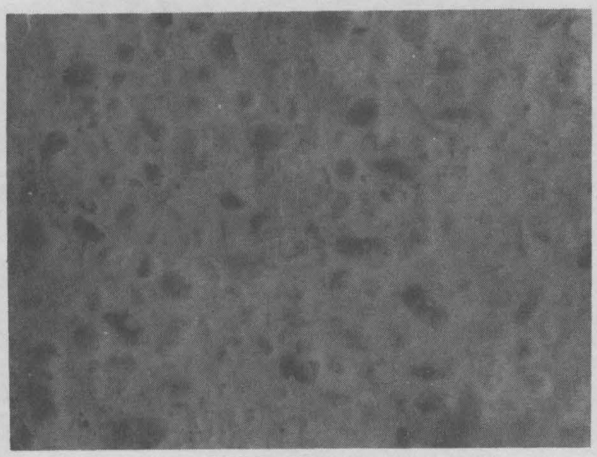
600T-6509



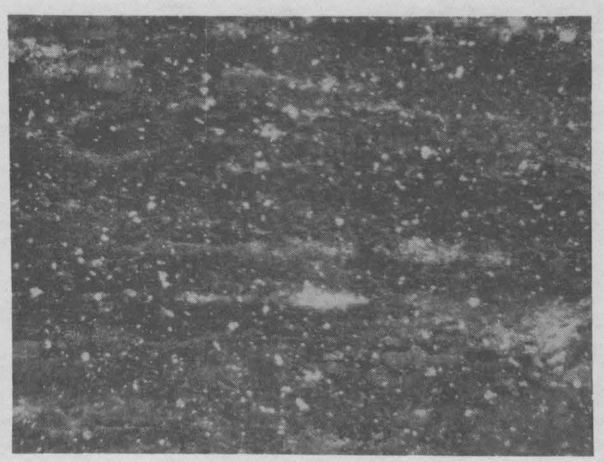
600T-6504

600T-4767

600T-4768



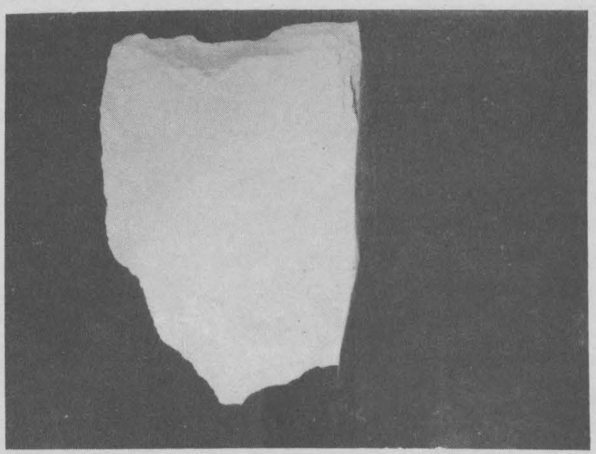
600T-6805



600T-6788

Cordova Cream Limestone
(White)

Allamore Rhyolite
(Pink-brown)

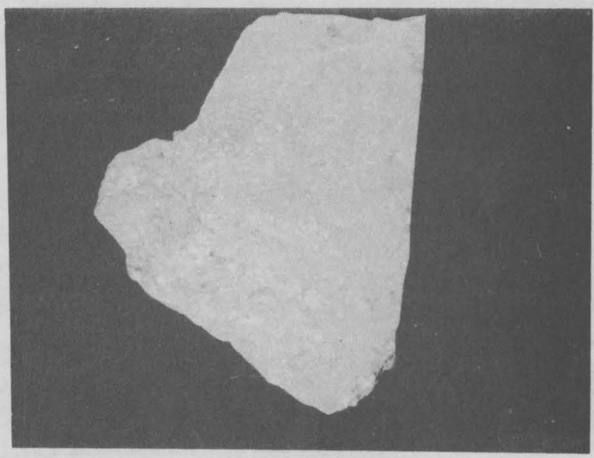


600T-6508

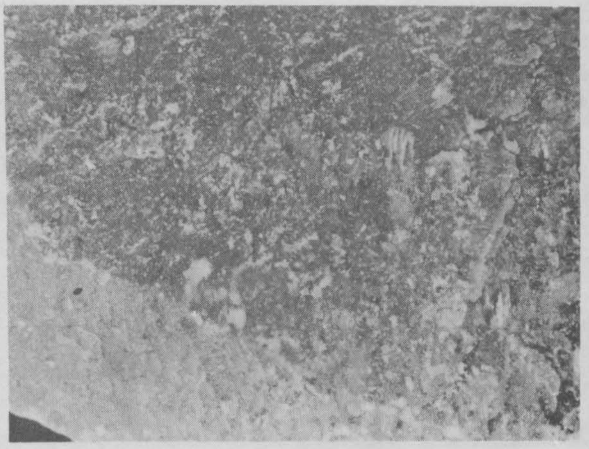
600T-4770

600T-6803

Beckmann Limestone
(White)



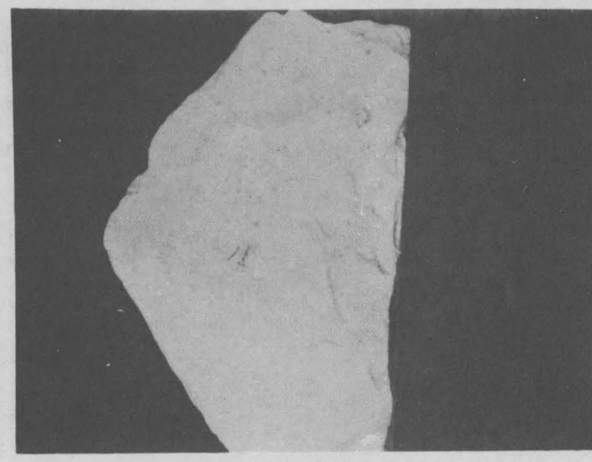
600T-6517



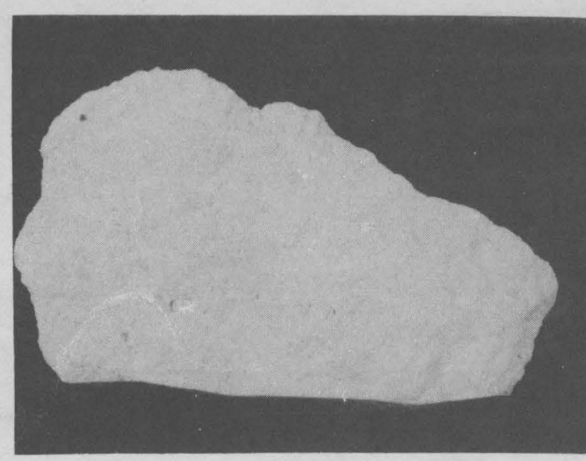
600T-4779

600T-6886

Brownwood Limestone
(Yellow)

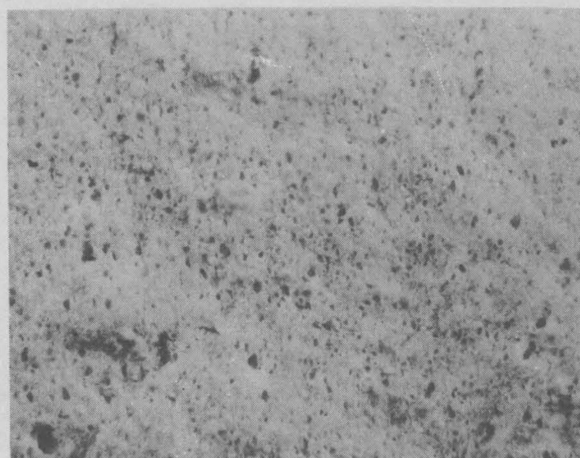


600T-6503



600T-6510

600T-4773



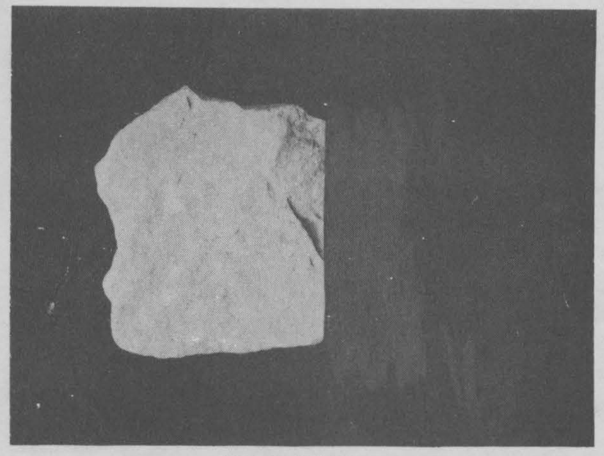
600T-4771

600T-6802

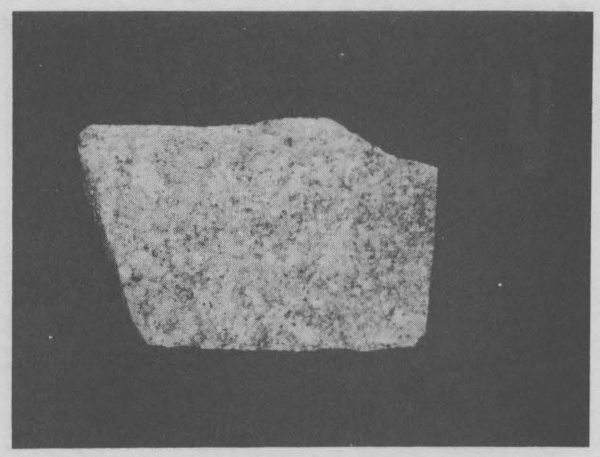
600T-6801

Denison Limestone
(White)

Dittlinger Limestone
(White)

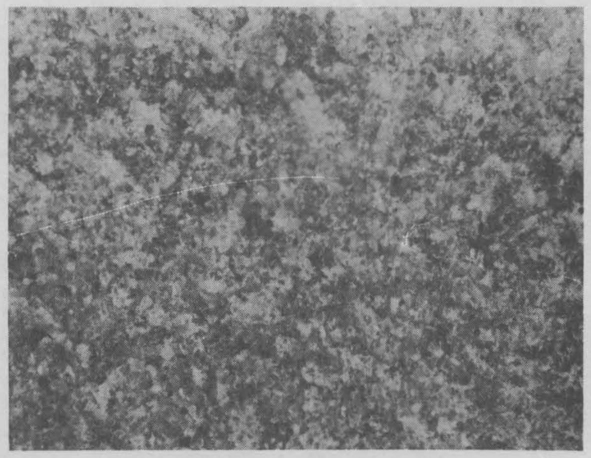


600T-6711

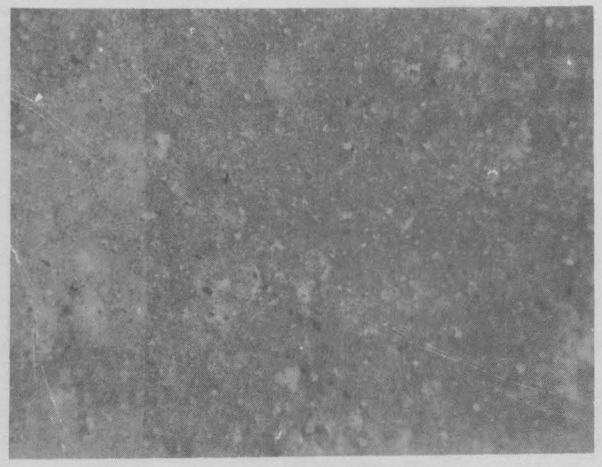


600T-6502

600T-4777



600T-4782

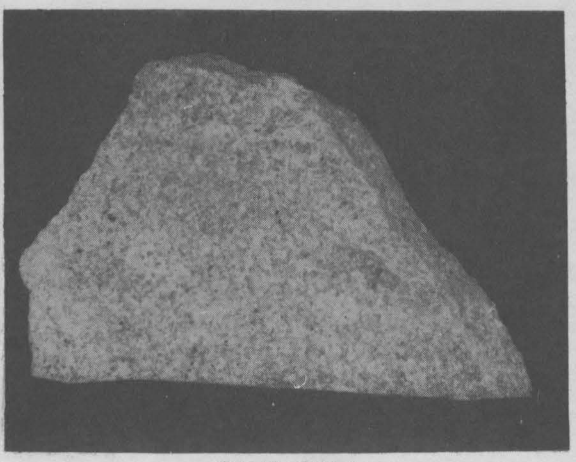


600T-6793

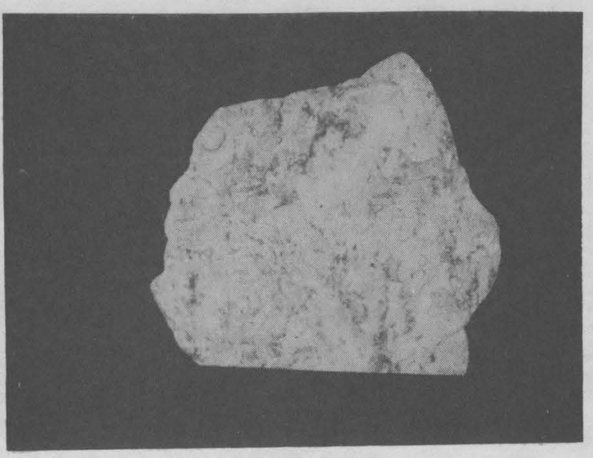
Hamlin Limestone
(Gray)

600T-6791

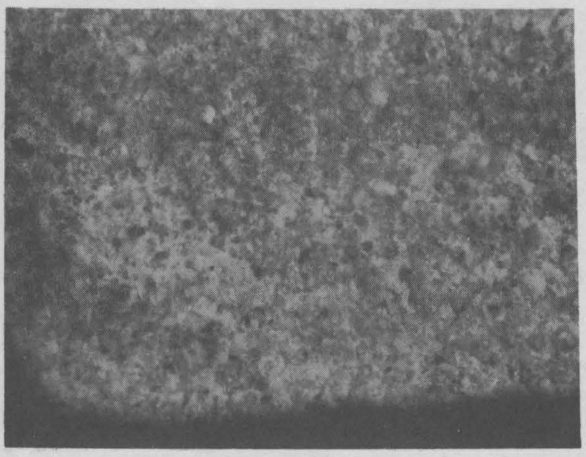
Huntsville Quartzite
(Blue-Gray)



600T-6514



600T-6505



600T-4778

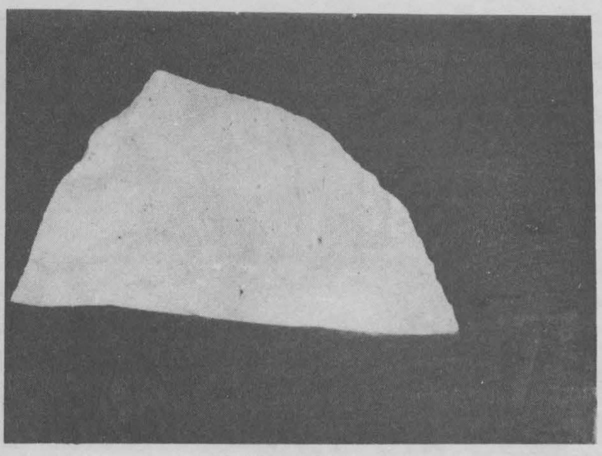
600T-4766

600T-6797

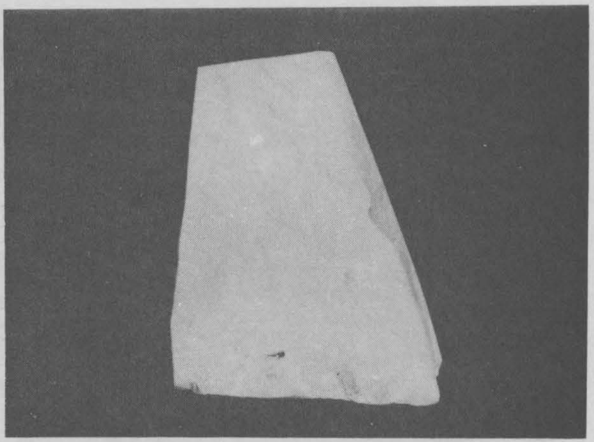
600T-6795

Huntsville Quartzitic Sandstone
(Gray)

Palo Pinto Limestone
(Light Yellow-gray)



600T-6521



600T-6511

600T-4769

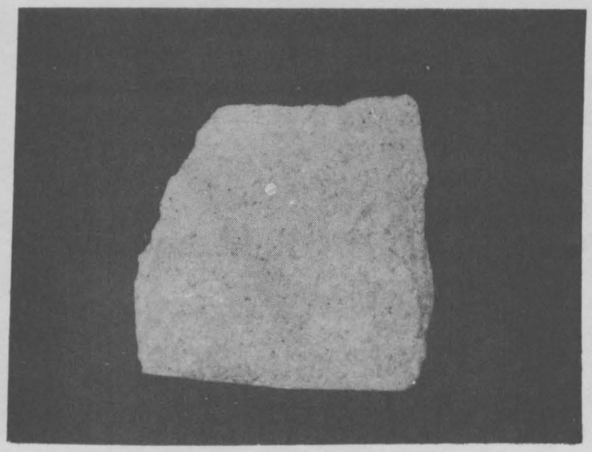
600T-4774

600T-6798

600T-6804

Quitaque Quartzite
(Pink)

Servtex Limestone
(Light gray)



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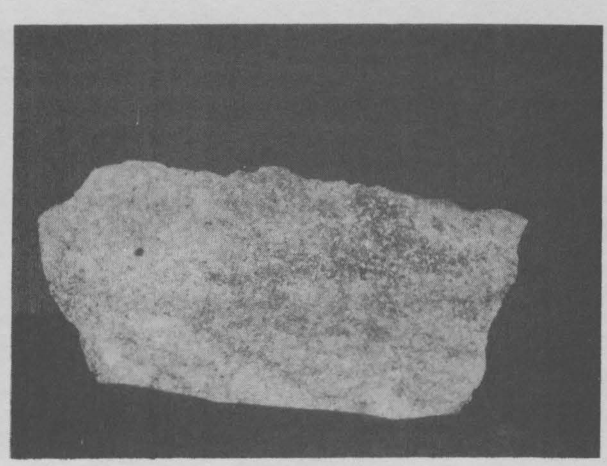

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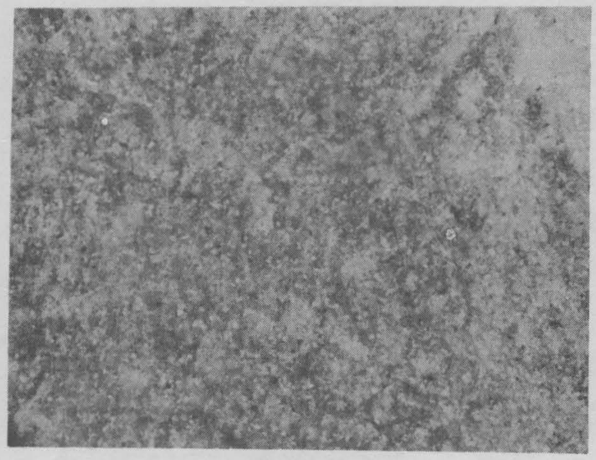
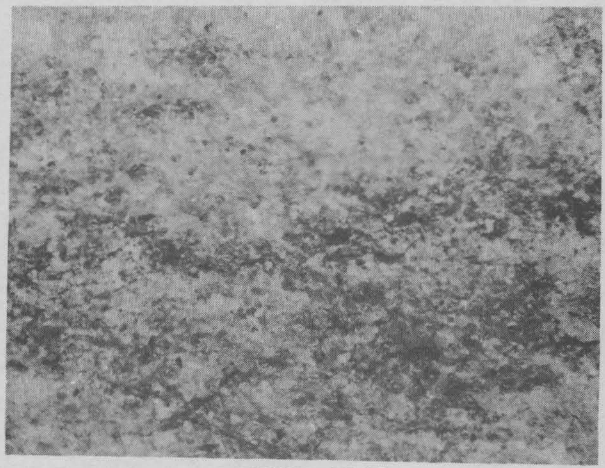


600T-4781



600T-4762

600T-6792

Trinity Quartzite
(Gray)

600T-6794

Trinity Quartzitic Sandstone
(Dark gray)

"Ogden," so that it will not be confused with the "Ogden correlation stone.") (Sample: 348 pounds)

Trinity Quartzite: A fine-grained, gray quartzite from Trinity County. (Sample: 216 pounds)

Trinity Quartzitic Sandstone: A fairly coarse-grained, gray, quartzitic sandstone from Trinity County. (Sample: 292 pounds)

(The two stones from Huntsville are not very widely different in physical and petrographic characteristics, but are designated as "quartzite" and "quartzitic sandstone" in order to avoid confusion, the description being applied on the basis of visual inspection without the aid of a microscope. The same is true of the two quartzitic stones from Trinity County except that the difference is more marked.)

These thirteen stones will be hereinafter referred to as "correlation-check stones."

Photographs of representative pieces of these twenty stones are presented in order that some idea may be had of their textures and general appearances. The top picture is exactly natural size. The middle picture, taken through a small hand lens, is 2.7 times natural size. The bottom picture is a photomicrograph of a polished face, taken with reflected light. The enlargement is approximately twenty-four diameters.

Representative samples of these stones are being held in the Concrete Research Section.

2. Preparation of:

Each of the correlation stones and the end-point stones were prepared as follows:

(1) The chunks were sledged to sizes suitable for crushing. (The Universal jaw crusher used throughout this investigation will take 4-inch stone.) Identical jaw settings were used in each crushing phase for all stones. This was done in order to secure the greatest possible uniformity.

(2) The initial crushing was made with the jaws wide open. This produced material which contained a small percentage of particles retained upon the 1-1/2-inch sieve. This oversize was recrushed with a slightly smaller jaw setting so that all the material passed the 1-1/2-inch sieve. In all crushing phases the jaws were originally set so that a small percentage of the material would be retained upon the sieve, or screen, through which the material was to be passed, and the oversize recrushed. This was done so that each size would contain its normal quota of material which would barely pass the sieve in question.

(3) The material passing the 1-1/2-inch sieve was passed over the 3/8-inch sieve, that which passed being discarded. This, although entailing a great waste of expensive stone, was done so that the seal-coat sizes should not contain any material not adequately represented by the standard tests. With such uniform stones this was doubtless an unnecessary precaution, but it was desired to obviate the argument that the seal-coat sizes contained material from the initial crushing which might possibly be slightly more friable than the coarser material from which the standard wear samples were taken.

(4) The 1-1/2 to 3/8-inch material was blended very thoroughly and "pancaked" in thin layers on the floor to facilitate sampling.

(5) This blended material was sampled systematically for six "A" and six "B" grading tests. The excess of material retained on the 3/4-inch sieve in this sample was re-crushed so that it would pass this sieve. Thus, the "B" grading tests represented all the blended material and not merely the smaller sizes. An additional sample of approximately one hundred pounds was sacked and held pending unforeseen contingencies.

(6) The remainder of the blended material was crushed to pass the 3/8-inch round-hole screen. The material passing the 3/8-inch screen was separated into two sizes; 3/8 to 1/4-inch (round-hole screens) size and 1/4-inch to No. 10 sieve size. All sieving and screening operations in the preparation of all stone samples were made carefully by hand.

(7) Each of these two gradings of stone (3/8 to 1/4-inch and 1/4-inch to No. 10), together constituting the "S" grading material, were blended very thoroughly, thus securing the maximum possible uniformity in both quality and particle size distribution. Both gradings were stored very carefully so that size segregation would be minimized.

The only exception to this procedure occurred with Chico stone (paragraph (1) above) which was already crushed to pass the 2-inch screen. Thus, part of the Chico "A" grading test charges, and a small part of the "B" grading test charges, contained particles which were not crushed in the laboratory crusher.

Each of the correlation-check stones was prepared in the same manner as were the correlation stones and end-point stones except that a quantity of the sizes sufficient to prepare only three "A," three "B," and three "S" grading test charges were prepared. The remainder of each blended sample (passing the 1-1/2-inch sieve and retained on the 3/8-inch sieve) was sacked and stored. (The correlation-check stone samples were prepared subsequent to the completion of the tests on the correlation and end-point stones.)

3. Preliminary Tests on:

a. Specific Gravity and Absorption:

The specific gravities and total absorptions of representative samples of all stones used for correlation were determined. The samples were immersed, boiled for four hours, and immersion continued for twenty or more hours in order to secure complete saturation. Apparent specific gravities (weight of stone plus water to fill permeable voids/volume of stone plus permeable voids) were determined with the samples in a saturated, surface-dry condition. Bulk specific gravities (weight of bone-dry stone/volume of stone plus permeable voids) were calculated from the respective apparent gravities and total absorptions. The total absorption (bone-dry to saturated, surface-dry) were calculated on the basis of bone-dry weights.

Table 2 shows the results of these tests. Each value is the average of two test results.

Table 2

Specific Gravities and Absorptions of

Stones for Correlation

Stone		Specific Gravity Apparent	Specific Gravity Bulk	Total Absorption (%)
Correlation Stones	(Dudley	2.74	2.73	0.37
	(Chico	2.70	2.68	0.71
	(Courchesne	2.72	2.70	0.58
	(Maryneal	2.54	2.46	3.36
	(Ogden	2.46	2.33	5.56
End-Point Stones	(Trap	3.15	3.13	0.48
	(Cordova C.	2.22	1.92	15.90
Correlation-Check Stones	(Allamore	2.60	2.57	1.24
	(Beckmann	2.42	2.26	7.11
	(Brownwood	2.71	2.70	0.42
	(Denison	2.59	2.51	3.21
	(Dittlinger	2.30	2.11	9.18
	(Hamlin	2.67	2.58	3.50
	(Huntsville (Q)	2.31	2.19	5.64
	(Huntsville (QS)	2.37	2.27	4.45
	(Palo Pinto	2.65	2.62	1.27
	(Quitaque	2.38	2.29	3.77
	(Servtex	2.62	2.57	2.08
	(Trinity (Q)	2.31	2.19	5.27
	(Trinity (QS)	2.34	2.26	3.38

b. Actual Particles Per Pound:

As the number and angularity of the particles comprising the test charge are factors, however large or small they may be, in the Rattler test, it was decided to make actual particle counts on each size of all the stones used for correlation. These particle counts were made on large, representative samples. Screen analyses of the 1/4-inch to No. 10 cuts were also made using two intermediate round-hole screens, the 5-millimeter (0.197-inch) and 3-millimeter (0.118-inch).

Table 3A shows the results of the particle counts (expressed in particles per pound) on the "A" and "B" grading test charge sizes.

Table 3A

Actual Number of Particles Per Pound
in the "A" and "B" Grading Test
Charge Sizes

Stone	Actual Particles Per Pound 1-1/2" - 1"	1" - 3/4"	3/4" - 1/2"	1/2" - 3/8"
Dudley	13.45	32.04	83.51	233.7
Chico	11.94	30.43	80.00	191.2
Courchesne	12.46	29.89	89.29	263.9
Maryneal	12.96	31.22	90.95	242.5
Ogden	13.98	31.84	92.95	253.9
Trap	10.17	25.97	70.37	195.2
Cordova C.	15.06	34.59	102.6	269.6
Allamore	12.89	24.80	79.53	210.6
Beckmann	13.63	37.59	93.82	272.8
Brownwood	12.98	28.19	85.45	209.0
Denison	12.91	32.36	84.77	250.9
Dittlinger	16.80	37.35	108.8	274.5
Hamlin	12.22	26.89	81.88	219.3
Huntsville (Q)	14.92	35.45	120.2	282.3
Huntsville (QS)	14.33	33.27	108.2	280.7
Palo Pinto	12.05	27.23	85.83	248.6
Quitaque	15.98	35.92	102.7	306.8
Servtex	13.38	30.14	102.2	295.3
Trinity (Q)	15.47	34.90	109.3	321.5
Trinity (QS)	14.35	35.49	100.8	266.0

Table 3B shows the results of the particle counts on the "S" grading test charge sizes. The screen analyses of the 1/4-inch screen to No. 10 sieve materials (expressed in per cent by weight) are likewise shown. (In Table 3B all screens are round-hole with the exception of the No. 10 sieve.)

Table 3B

Screen Analyses of, and Actual Number
of Particles Per Pound in, the "S"
Grading Test Charge Sizes

Stone	Screen Analyses 1/4" - No. 10 Size 1/4"-5m	5m-3m	3m-10	Actual Particles Per Pound 3/8"-1/4"	1/4"-5m	5m-3m	3m-10
Dudley	41.5	47.5	11.0	1185	3409	10996	28468
Chico	37.0	48.3	14.7	1168	3077	9462	27659
Courchesne	36.6	51.2	12.2	1265	3195	9552	26913
Maryneal	37.3	47.9	14.8	1268	3106	9432	26891
Ogden	39.4	48.7	11.9	1392	3345	9542	25472
Trap	39.3	48.6	12.1	1123	2832	8719	22370
Cordova C.	37.0	48.3	14.7	1602	3853	10833	32551

(Continued next page)

Table 3B (Continued)

Stone	Screen Analyses 1/4" - No. 10 Size			Actual Particles Per Pound			
	1/4"-5m	5m-3m	3m-10	3/8"-1/4"	1/4"-5m	5m-3m	3m-10
Allamore	39.6	48.4	12.0	1337	3077	10227	26612
Beckmann	31.6	52.6	15.8	1526	3905	12463	29719
Brownwood	42.5	46.6	10.9	1180	3360	9959	25492
Denison	39.9	48.7	11.4	1425	3247	9235	24984
Dittlinger	39.6	47.9	12.5	1532	3577	10369	28359
Hamlin	42.2	46.5	11.3	1200	3288	9655	29628
Huntsville (Q)	37.0	49.9	13.1	1461	3998	13057	30562
Huntsville (QS)	37.6	49.3	13.1	1653	3859	12366	30589
Palo Pinto	32.5	53.2	14.3	1532	3172	9286	23411
Quitaque	36.0	51.2	12.8	1516	3898	11402	31628
Servtex	32.5	51.5	16.0	1594	3733	11365	28716
Trinity (Q)	38.7	50.5	10.8	1765	4404	12409	33755
Trinity (QS)	32.3	51.9	15.8	1590	3807	10474	28236

The relation of the number of particles per pound to the angularity of the particles will be demonstrated and discussed later.

C. Test Methods:

1. Daily Checks:

Each and every day that Rattler tests were made the following checks were made and recorded:

(1) The accuracy of the 5000-gram capacity Toledo scales, adjustments being made when necessary.

(2) The condition of all sieves and screens used, repairs and replacements being made when necessary.

(3) The accuracy of the revolution-counter on the Rattler: the counter functioned perfectly throughout this investigation.

(4) The efficacy of the gasket on the Rattler door, repairs and replacements being made when necessary.

(5) The rate of revolution of the Rattler: the rate was constant at thirty-one revolutions per minute throughout this investigation.

(6) The weight of the abrasive charge: the weight of each individual ball was taken, replacements being made when the balls ceased to meet specification requirements; the total weight of each abrasive charge was taken and recorded (see Appendices - Test Data).

2. Abrasion Tests:

a. Preparation of the Test Charges:

Each test charge was prepared as follows:

(1) The proper amount, plus a small excess, of each of the required

sizes was sampled from the blended material (see B.: 2.). Each size was washed thoroughly and dried to constant weight (twenty to twenty-four hours) at a temperature of 230°F.

(2) The "S" grading sizes were rescreened after washing and drying so that small particles broken off during the washing process would be removed. The 3/8 to 1/4-inch size was passed over the 1/4-inch screen and the 1/4-inch to No. 10 size was passed over the No. 10 sieve.

(3) Using 5000-gram capacity Toledo scales, sensitive to less than 0.5-gram, the washed, bone-dry sizes were combined exactly in the following proportions (by cumulative weights) according to the grading desired:

Grading of Test Charge	Sieve Size Passing	Sieve Size Retained	Per Cent	Grams
"A" (Standard)	(1-1/2"	1"	25	1250
	(1"	3/4"	25	1250
	(3/4"	1/2"	25	1250
	(1/2"	3/8"	25	1250
"B" (Standard)	(3/4"	1/2"	50	2500
	(1/2"	3/8"	50	2500
"S"	(*3/8"°	*1/4"°	50	(Depend. size test charge)
	(*1/4"°	No. 10	50	

*Round-hole screen

b. Abrasive Charges:

Four classes of steel balls were used in this investigation; 1-7/8, 1-1/2, 1-1/4, and 1-inch diameters. For convenience these classes were named, according to their respective approximate weights, as follows: 420, 225, 130, and 65-gram balls.

A.A.S.H.O. Method T-96 limits the weight of the individual 420-gram balls, to 422.5 ± 17.5 grams, and also limits the total weight of the abrasive charge for the standard "A" and "B" grading tests to 5000 ± 25 grams (12 balls) and 4583 ± 25 grams (11 balls), respectively. These specifications were complied with ~~when making~~ standard tests.

In this investigation specification requirements were set up arbitrarily for the weight of the individual balls in the abrasive charges used when making "S" grading tests. The following specifications were complied with throughout this investigation:

Class of Ball	Weight of Individual Ball
420-gram	422.5 ± 17.5 grams
225-gram	220.0 ± 10.0 "
130-gram	128.0 ± 5.0 "
65-gram	64.0 ± 5.0 "

Table 4 (Continued)

Sieve Size	Nominal Opening (Inches)	Nom. Wire Diameter (Inches)	Maker
1/4"O	0.250		Humboldt
No. 10	0.0787	0.0299	Precision
" 12	0.0661	0.0272	Humboldt
" 16	0.0460	0.0257	Tyler
" 20	0.0331	0.0165	Humboldt
" 30	0.0232	0.0130	Precision
" 40	0.0165	0.0098	Humboldt
" 50	0.0117	0.0074	"
" 60	0.0098	0.0064	"
" 80	0.0070	0.0047	Precision
" 100	0.0059	0.0040	Humboldt
" 200	0.0029	0.0021	"

All sieves complied with the standards prescribed in A.A.S.H.O. Method T-27-38 and A.S.T.M. Designation E11-38T, with the following exceptions: the 1-inch sieve opening was 0.02-inch too large; the 1/2-inch sieve opening was 0.01-inch too large. These discrepancies were, however, inconsequential.

Later it will be desired to discuss the reduction in particle size of the various original test charges and also to deal with the various particle diameters. It also will be desired to present certain data graphically.

For these purposes the nominal sieve openings appearing in Table 4 will not suffice. Were spherical particles being tested the nominal opening of a square mesh sieve, which is measured square across the opening, would serve as the effective opening. Because of the angularity of the particles, however, the effective opening of a square mesh sieve is regarded as the average of the square and the diagonal measurements. This is not strictly true in any one case but approaches correct results on the average more nearly than does the assumption that the nominal opening is the effective opening.

The average diameter of the particles between two sieve sizes is regarded as the antilog of the average of the log of the effective opening of the sieve through which the material passed and the log of the effective opening of the sieve upon which the material is retained. This is in keeping with the fact that, between two screen sizes, less than half of a normal material will be retained upon the half-way screen. While not strictly true in any one case, this assumption is more accurate than assuming the average particle diameter to be a straight average of the two effective sieve openings.

Table 5 presents the effective openings of the sieves used in the sieve analyses, and the average particle diameter of the various particle sizes. The "Nominal Opening (d)" (from Table 4) indicates the measurement square across the opening. The "Effective Opening (d_1)" (except for the round-hole screens) was derived as follows: $d_1 = \frac{d + 1.4142\, d}{2}$. The "Particle Size" is indicated by the sieve through which the particle passed followed by the sieve upon which it is retained. The "Average Particle Diameter (d_2)" indicates the average diameter of the particles in the corresponding "Particle Size" and was calculated as follows: $d_2 = \text{antilog } \frac{\log 1\text{st } d_1 + \log 2\text{nd } d_1}{2}$

where 1st d_1 equals the effective opening of the sieve through which the material passed, and 2nd d_1 equals the effective opening of the sieve upon which the material is retained.

Table 5

Effective Sieve Openings and Average Particle Diameters

Sieve	Nominal Opening(d) (Inches	Effective Opening(d_1) (Inches)	Particle Size	Average Particle Diameter(d_2) (Inches)
1-1/2"	1.50	1.811		
1"	1.05	1.267	1-1/2" - 1"	1.515
3/4"	0.742	0.896	1" - 3/4"	1.065
1/2"	0.525	0.634	3/4" - 1/2"	0.754
3/8"	0.371	0.448	1/2" - 3/8"	0.533
3/8"°	0.375	0.375	3/8" - 3/8"°	0.410
1/4"°	0.250	0.250	3/8"° - 1/4"°	0.306
No. 10	0.0787	0.0950	1/4"° - 10	0.154
*5mm°	0.197	0.197	*1/4"° - 5mm°	0.222
*3mm°	0.118	0.118	*5mm° - 3mm°	0.152
No. 10	0.0787	0.0950	*3mm° - 10	0.105
No. 12	0.0661	0.0789	10 - 12	0.0871
" 16	0.0460	0.0555	12 - 16	0.0666
" 20	0.0331	0.0400	16 - 20	0.0471
" 30	0.0232	0.0280	20 - 30	0.0335
" 40	0.0165	0.0199	30 - 40	0.0236
" 50	0.0117	0.0141	40 - 50	0.0168
" 60	0.0098	0.0118	50 - 60	0.0129
" 80	0.0070	0.00845	60 - 80	0.00999
" 100	0.0059	0.00712	80 - 100	0.00776
" 200	0.0029	0.00350	100 - 200	0.00499

*The millimeter screens and the respective "particle sizes" are used only in connection with the "actual particles per pound" data (see Table 3B)

It will be understood that the procedure described under "Test Methods" applies to all tests subsequently enumerated unless it is specifically stated to be otherwise.

D. Correlation of the "S" Grading Test with the Standard "B" Grading Test:

Concrete Research Investigational Project No. 100 showed the standard Los Angeles Rattler abrasion test to be a very good, though not a perfect, measure of the quality, or service value, of mineral aggregates. (The "B" and "D" grading tests in Investigational Project No. 100 are respectively identical with the "A" and "B" grading tests in this investigation.) The problem here being to evolve a satisfactory abrasion test using the new and untried "S" grading test charge, it is essential to have a very definite starting point, or base of operations. For the time being, therefore, the standard test, or, to be more explicit, the standard "B" grading test (see Section A:4), will be considered to be the perfect measure of quality. In other words, it will be assumed, temporarily, that the closer the "S" grading test values approach the "B" grading test values the more satisfactory the test.

In considering the problem graphically the "B" grading test values constitute the base-line. Figure 1 illustrates the nature of this base-line. Five stones, "V, W, X, Y and Z" are assumed to have standard "B" grading test values of 22, 26, 31, 34 and 39, respectively. Using the same vertical and horizontal scale, the wears (per cent) are plotted along the abscissas against the service values (hypothetical values temporarily assumed to be equal to the respective "B" wears) along the ordinates. The resulting curve is, of necessity, a 45° straight line.

Should the "S" wears be plotted along the ordinates (using the same scale) in place of the service values, the standard base-line would become the locus of all points where "S" was equal to "B." Thus, the less the total vertical deviation of all plotted "S" values from the "S=B" line the more perfect the correlation, and, axiomatically, the more perfect the test.

1. <u>Standard "A" and "B" Grading Tests</u>:

Four standard "A" and four standard "B" grading tests were run on each of the five correlation stones and the two end-point stones. The results of these tests appear in Appendices I and II.

Tables 6 and 7 present the average sieve analysis data on the correlation stones and end-point stones test charges after the "A" and "B" grading tests, respectively. Each value in these tables is the average of four test values, as shown in the Appendices. In these and similar tables the correlation stones are indicated as follows: Dudley - "D," Chico - "Ch," Courchesne - "C," Maryneal - "M," and Ogden - "O"; the end-point stones are indicated as follows: Trap - "T," and Cordova Cream - "CC." The per cent retained upon the No. 12 sieve is shown correct to two places, the complements of these values constituting the respective standard wears (per cent).

Table 6

Average Sieve Analysis Data on
Correlation Stones and End Point
Stones Test Charges after Standard "A" Grading Test

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1"	7.3	9.4	6.3	4.9	4.6	16.3	0.4
3/4"	25.0	21.9	21.8	21.3	18.9	36.1	2.7
1/2"	35.8	30.3	30.1	27.9	25.1	53.4	4.0
3/8"	51.1	41.6	40.0	36.1	32.5	69.4	5.7
3/8"o	55.7	46.3	44.6	39.5	35.5	73.6	6.4
1/4"o	64.6	56.0	53.6	47.7	44.3	81.4	9.0
No. 10	77.0	71.9	69.9	63.0	59.1	88.9	22.4
*No. 12	78.54	73.41	71.63	64.54	60.84	89.52	24.58
No. 16	81.6	76.8	75.7	67.4	64.3	90.9	29.4
No. 20	84.2	79.5	79.0	69.7	67.2	91.8	32.9
No. 30	86.5	82.0	81.8	71.6	69.8	92.6	35.5
No. 40	88.4	84.0	84.2	73.4	72.0	93.3	38.6
No. 50	90.2	85.8	86.4	75.4	74.3	94.0	41.7
No. 60	91.0	86.4	87.3	76.3	75.5	94.3	43.7
No. 80	92.2	87.7	88.9	78.0	77.5	94.8	47.5
No. 100	92.8	88.3	89.7	79.2	78.8	95.2	50.7
No. 200	94.2	90.1	91.8	83.0	82.0	95.9	62.3
*Wear (%)	21.46	26.59	28.37	35.46	39.16	10.48	75.42

Table 7

Average Sieve Analysis Data on
Correlation Stones and End Point
Stones Test Charges after Standard "B" Grading Test

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/2"	9.8	4.9	3.7	4.0	3.6	24.7	0.0
3/8"	34.5	22.2	16.7	17.1	15.3	59.0	0.6
3/8"o	44.1	30.0	24.6	22.9	20.1	67.8	1.1
1/4"o	59.5	46.7	40.8	38.4	35.9	80.3	4.0
No. 10	77.5	71.2	68.0	63.7	59.6	89.9	24.5
*No. 12	79.16	73.20	70.18	65.94	61.67	90.57	27.56
No. 16	82.6	77.2	75.4	69.5	66.0	91.8	33.0
No. 20	85.3	80.5	79.2	71.9	69.2	92.7	36.6
No. 30	87.6	83.0	82.4	73.9	71.7	93.5	39.0
No. 40	89.4	84.9	84.9	75.5	73.8	94.1	41.7
No. 50	91.0	86.6	87.0	77.2	75.9	94.7	44.5
No. 60	91.7	87.2	87.9	77.9	76.8	95.0	46.2
No. 80	92.7	88.2	89.3	79.4	78.6	95.4	49.4
No. 100	93.3	88.8	90.0	80.3	79.6	95.7	52.3
No. 200	94.5	90.2	91.9	83.4	82.5	96.3	63.1
*Wear (%)	20.84	26.80	29.82	34.06	38.33	9.43	72.44

Nature of Resulting Curve Assuming Standard "B" Grading Test To Be the Perfect Measure of Quality

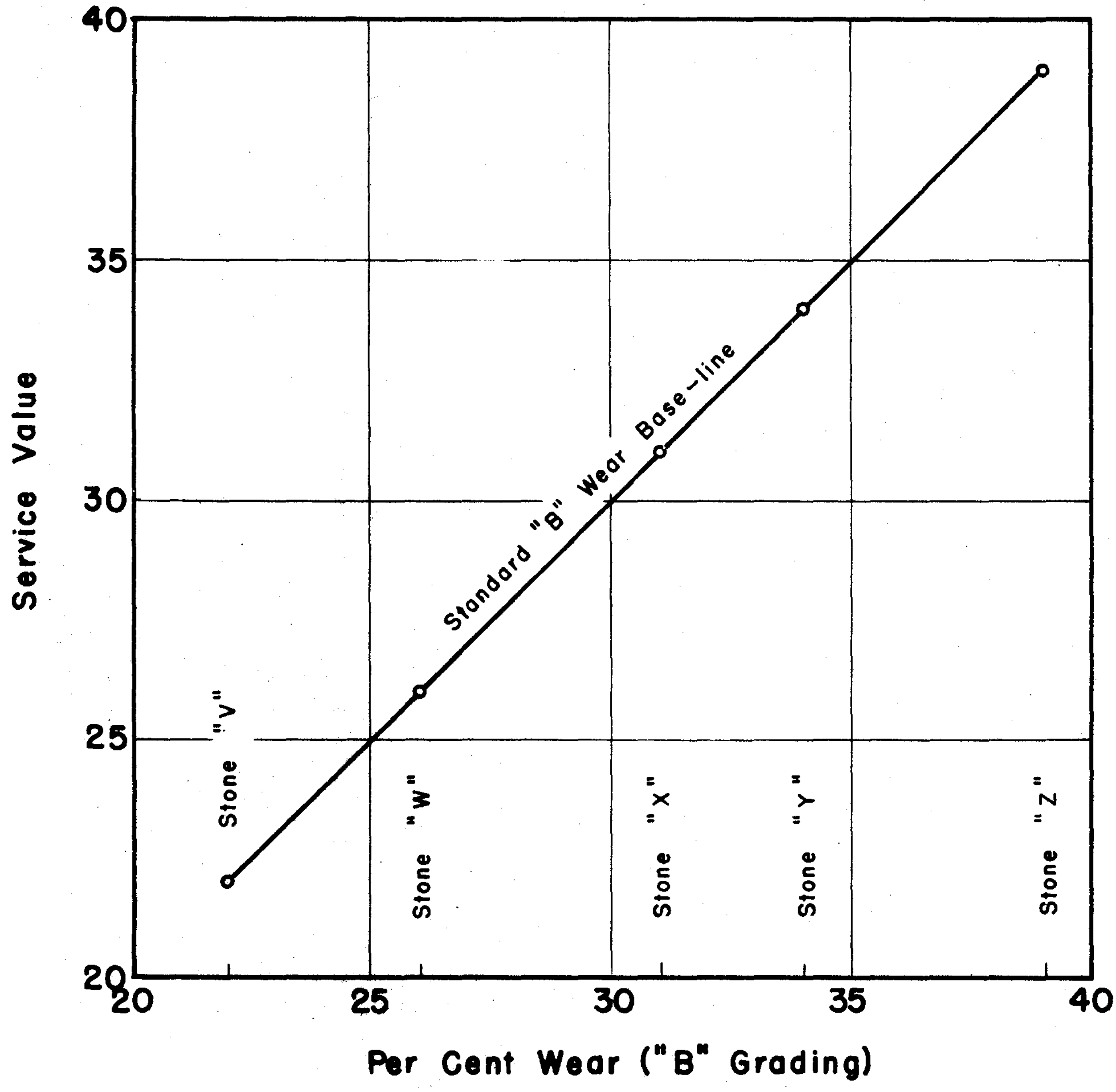


Figure 1

Figures 2 and 3 present the data in Tables 6 and 7, respectively. The average cumulative per cents retained on, or passing, the various sieves, or screens, are plotted against the respective effective sieve openings (see Table 5), which are plotted logarithmically.

Figure 4 is intended merely as an aid in comparing certain features of Figures 2 and 3. The two data lines on this figure represent the average degradation of the "A" and "B" test charges of the five correlation stones (taken from Tables 6 and 7). Cordova Cream was omitted from this average because the progressive degradation of this stone so obviously is abnormal. Although the degradation of Trap is quite normal this stone also was omitted from the average because it occupies the extreme in our toughness range opposite to that of Cordova Cream.

A comparison of Figures 2 and 3, supplemented by Figure 4, shows that:

(1) The degradation of the "B" grading test charge particles is very similar to the degradation of the "A" grading test charge particles, except for the natural difference in the amount of the larger particle sizes occasioned by the difference in the initial average particle diameters. (From Table 5: initial average particle diameters of the "A" and "B" grading test charges equal 0.967-inch and 0.643-inch, respectively.) This similarity, with minor variations, holds good for all seven stones from the toughest (Trap, with a "B" wear of 9.43 per cent) through the most friable (Cordova Cream, with a "B" wear of 72.44 per cent).

(2) The additional ball used in the abrasive charge in the "A" grading test gradually overcomes the initial average particle size differential until, in the particle size range of 0.06 to 0.2-inch (Figures 2 and 3), the per cent of material larger, or smaller, than a given size is equal for both "A" and "B" gradings with a given stone. The No. 12 sieve, with an effective opening of 0.0798-inch, falls within this particle size range. The two standard wears (per cent passing the No. 12) therefore are approximately equal. Note, in Figure 4, that an average of the five correlation stones shows the progressive degradation of the "A" and "B" test charges to be equal at a point somewhere between the No. 10 and No. 12 sieve, or approximately at the 0.086-inch particle size point.

(3) Having finally overcome the initial average particle size differential, the additional ball used in the "A" grading test naturally causes somewhat more degradation of the "A" grading test charge than is occasioned in the "B" grading test charge.

(4) For all stones except Cordova Cream limestone the rate of progressive degradation into the finer sizes decreases regularly. (Nota bene: while the rate of progressive degradation decreases regularly for each stone the rate of decrease is by no means constant for all six stones.)

(5) The rate of degradation of Cordova Cream limestone, which is very friable, does not decrease regularly. Note, in Figures 2 and 3, the triple curve in the Cordova Cream line as opposed to the single curve of all other lines. Two theories have been evolved to account for this phenomenon, but as these theories are tedious and cannot be substantiated by test results no explanation will be offered.

In the succeeding discussion only Figure 3 will be considered. In the first place, the figures, with the exceptions noted above, are very similar, and in the second place, the "B" grading test results are of primary interest in this investigation.

A study of Figure 3 is extremely instructive. The most important general feature to be observed is that the lines not only do not parallel each other, but tend to converge at widely different rates. There is even divergence of some of the lines through certain particle size ranges. In other words, the progressive degradation of one stone is not necessarily similar to that of another stone. This general fact is of vital importance in the interpretation of subsequent results. Besides the wide difference in the rate of progressive degradation of the two end-point stones (Trap and Cordova Cream) the following specific points should be noted:

(1) The Ogden and Maryneal lines tend to converge rapidly in sizes less than 0.08-inch. This means that the difference in the resistance to abrasion between Maryneal and Ogden stones is less in the finer sizes than in the larger sizes.

(2) The degradation of the Courchesne stone is similar to that of the Maryneal stone in the 3/8-inch sieve size and is approaching that of the Dudley stone in the finer sizes. Thus, it might be said that in the beginning of the particle degradation Courchesne simulates the action of a friable stone, becoming progressively tougher as the particle degradation progresses.

(3) The Courchesne and Chico lines actually cross at the No. 40 sieve point. This is a very drastic departure from that which might normally be expected, and means that the Courchesne is more friable than the Chico in the larger sizes and less friable in the smaller sizes. It is impossible to say just where the dividing line between these "larger" and "smaller" sizes may be. The progressive degradation of the original test charge particle makes the question very complicated, but this theoretical dividing line is, of course, at some point greater than 0.02-inch, and is probably at a point somewhat greater than 0.2-inch.

(4) There is a general tendency for all the lines, irrespective of individual idiosyncrasies, to converge as the particle size decreases. This trend apparently begins at about the 0.25-inch particle size point, and is a result of the natural tendency for the numerical differences in the per cents passing a given sieve (in the smaller sieve size range) to decrease as the sieve size decreases, although the relative differences between three or more stones may be maintained. This must be borne in mind when interpreting subsequent results.

Figure 5 presents the data on the correlation stones in Tables 6 and 7 in a different light. The per cent retained on, or passing, each sieve, or screen, for each stone, is plotted against the per cent wear of that stone. Thus, the No. 12 sieve, being the sieve through which the wear is determined, is a straight line. In this figure the sieves larger than the 3/8-inch screen have been omitted from the "A" grading analysis and the sieves larger than the 1/4-inch screen have been omitted from the "B" grading analysis.

The chief dissimilarity between the "A" and "B" grading curves is occasioned by the difference in the "A" and "B" wears (per cent passing the No. 12).

Degradation of Standard "A" Grading Test Charges
(Correlation Stones and End-Point Stones)

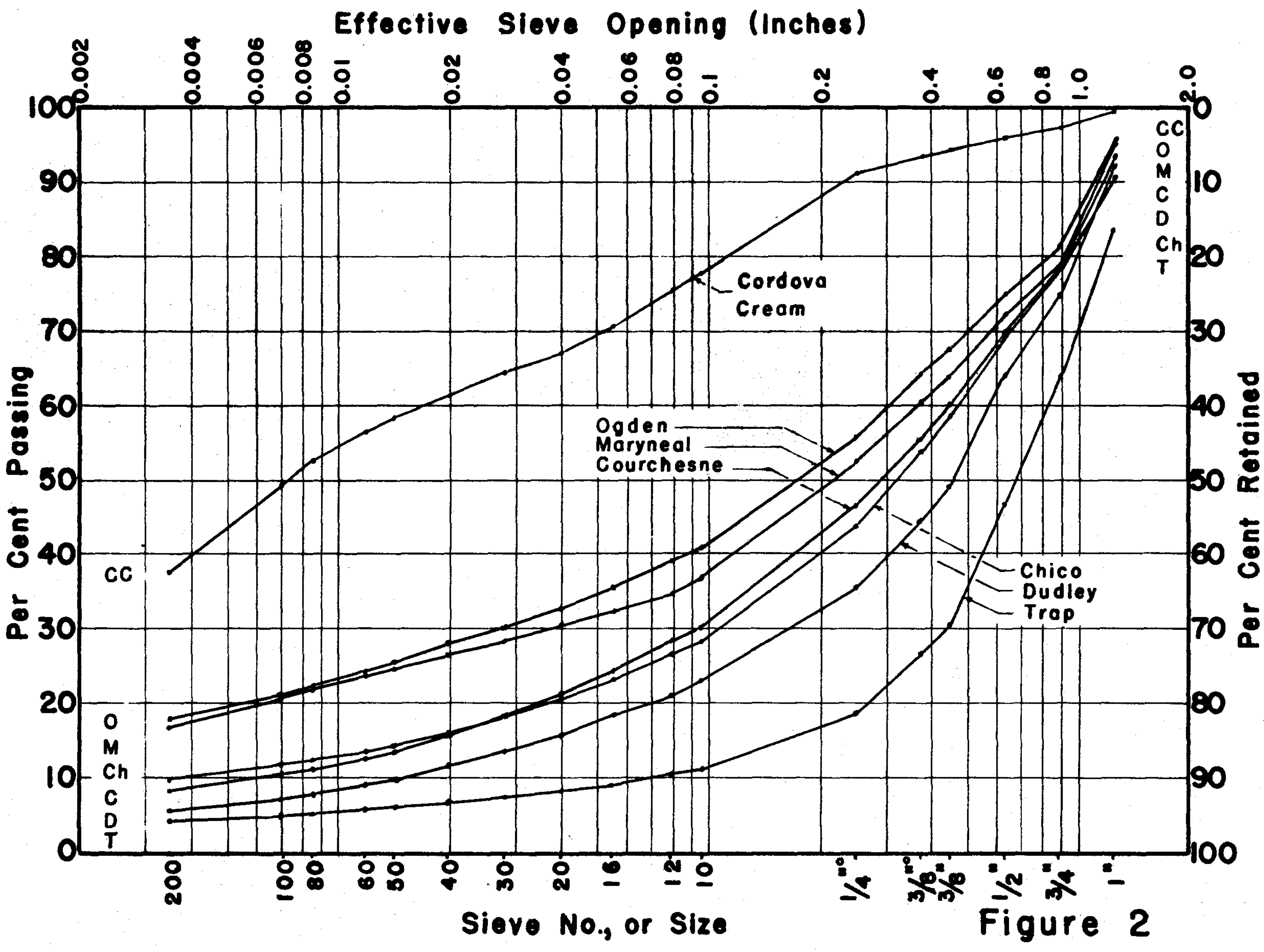


Figure 2

Degradation of Standard "B" Grading Test Charges
(Correlation Stones and End-Point Stones)

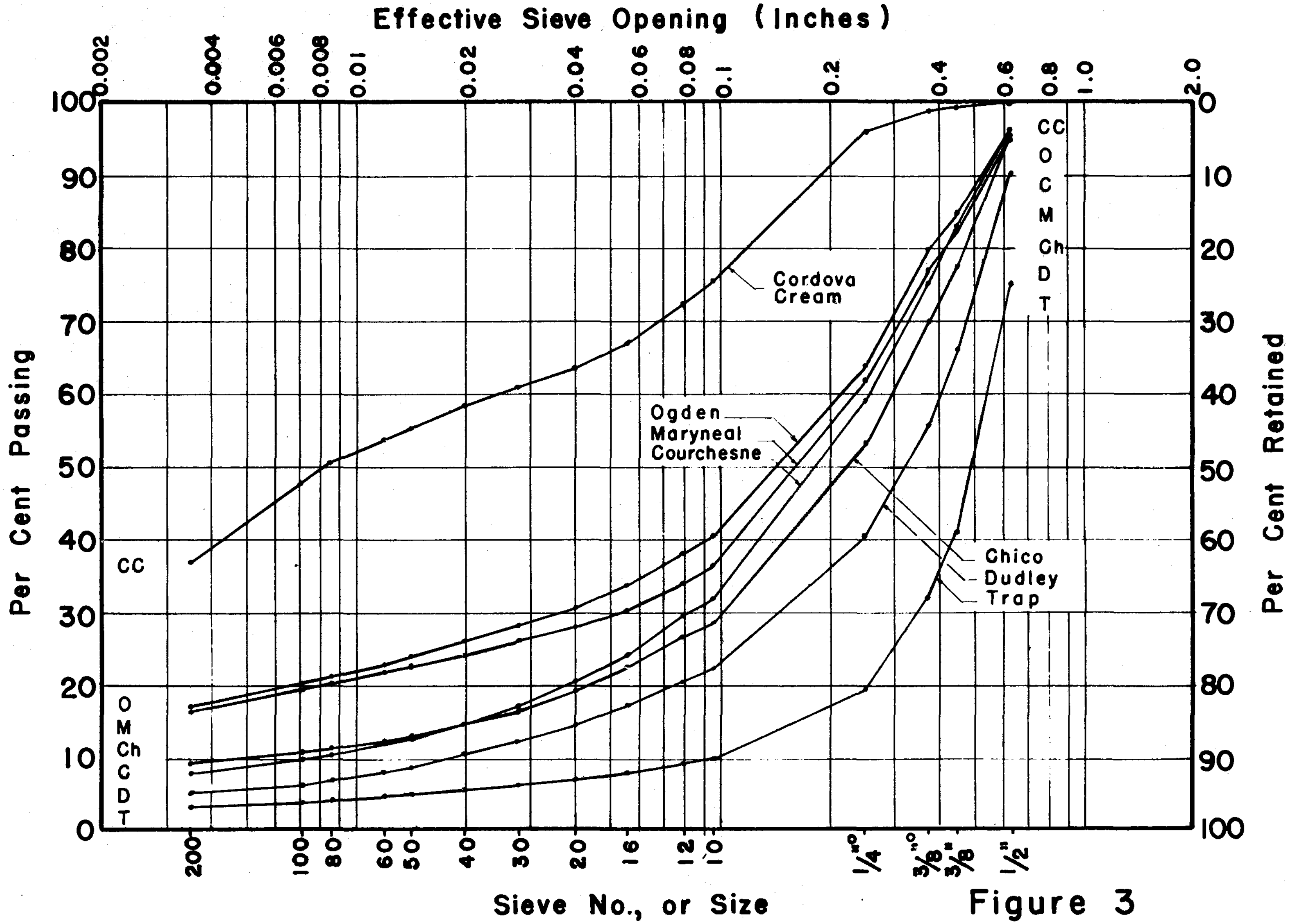


Figure 3

Degradation of Standard Test Charges
(Average of the Five Correlation Stones)

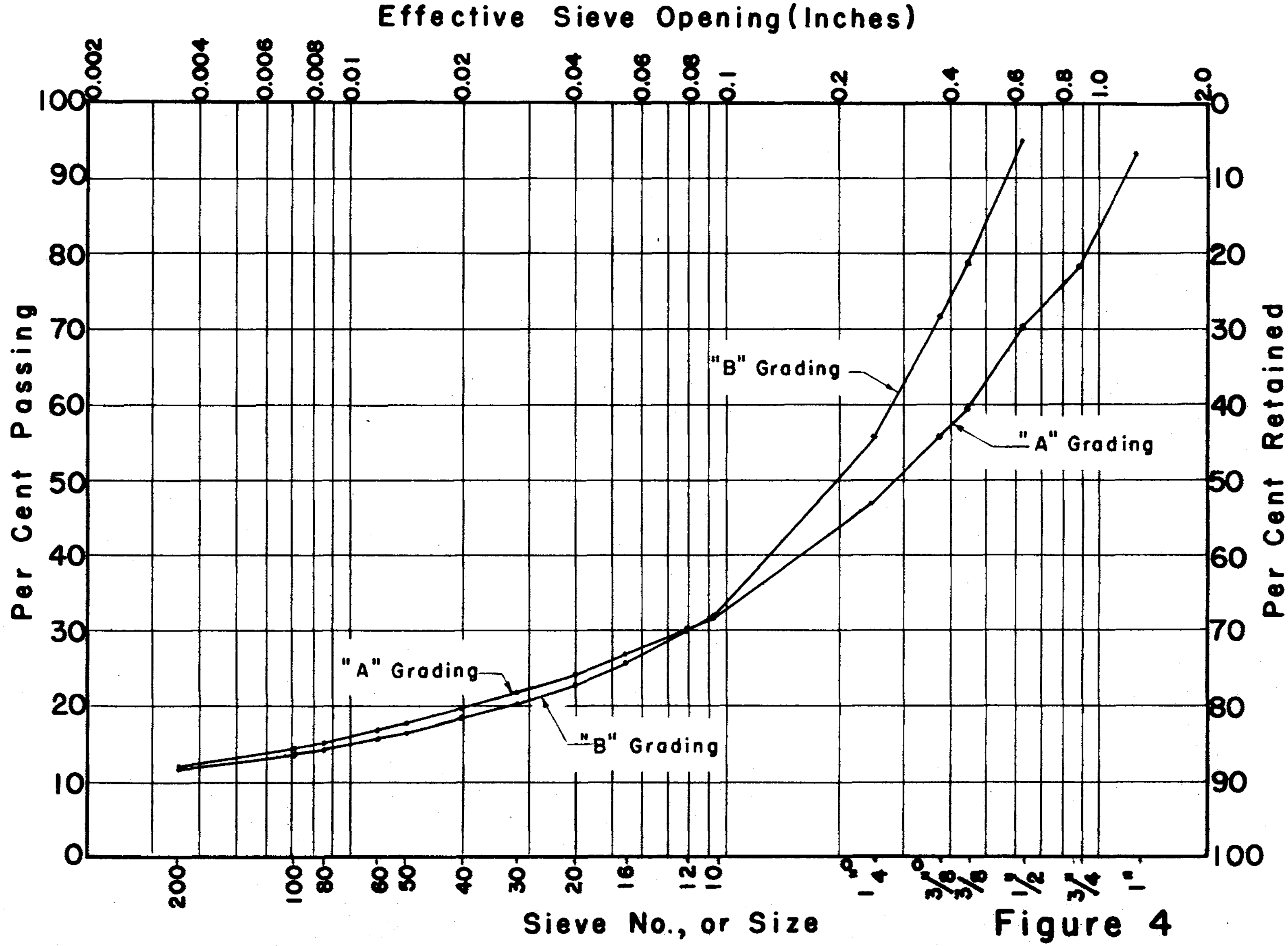


Figure 4

Degradation of Standard Test Charges

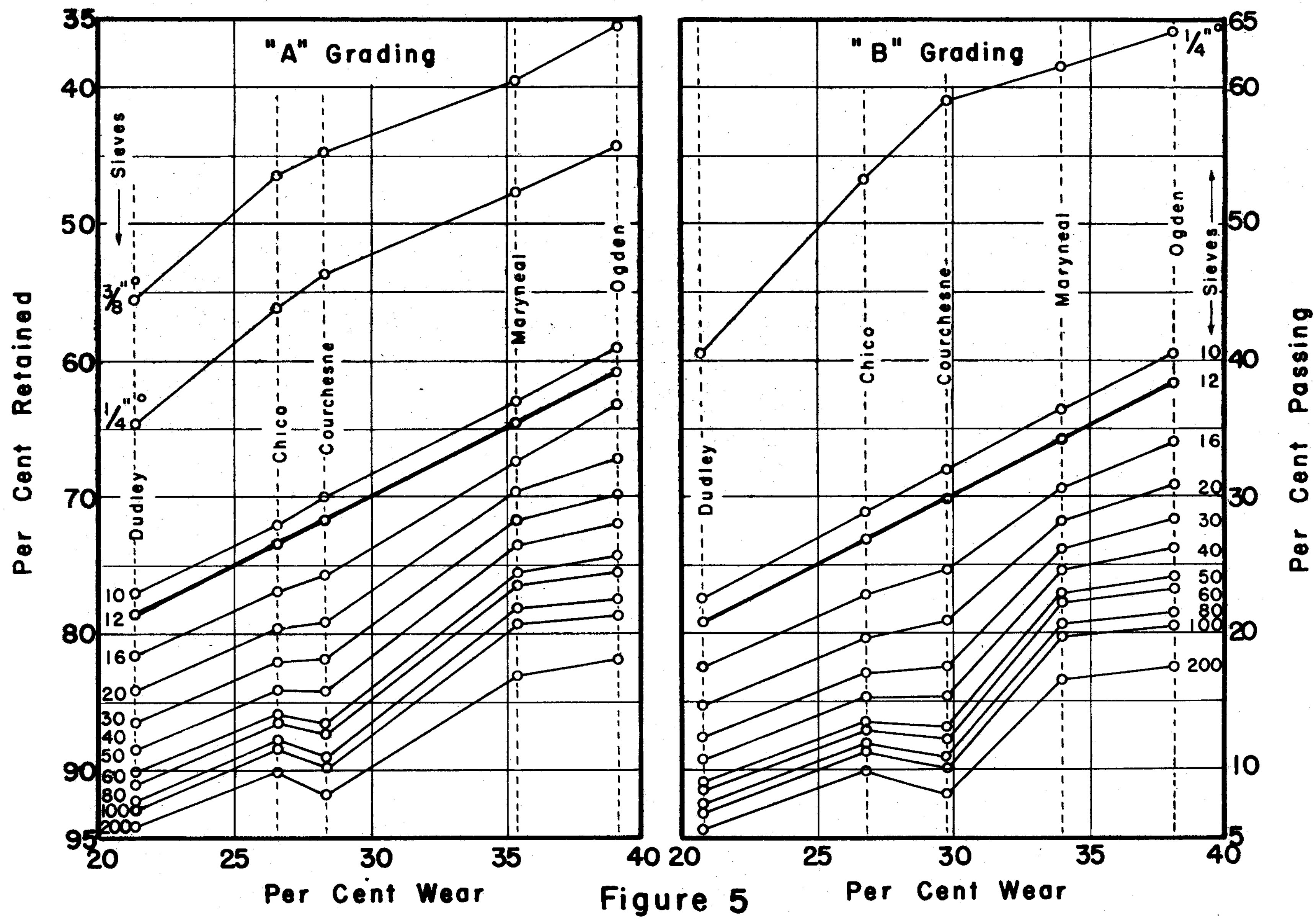


Figure 5

Considering the "B" grading only, the following points should be noted:

(1) The horizontal spacing of the five stones on the basis of the standard "B" wear test makes it possible to view the degradation of these stones into sizes both larger and smaller than the effective opening of the No. 12 in relation to the resistance to abrasion of these stones as measured by the "B" test.

(2) There is a greater range in the resistance to abrasion between Dudley, Chico and Courchesne stones as evidenced by the 1/4-inch screen than is evidenced by the No. 12 sieve, while Courchesne, Maryneal and Ogden present less range.

(3) As the sieve size decreases, the behavior of two of the stones, as judged on the basis of the No. 12 sieve line, becomes highly erratic. Courchesne stone becomes increasingly tougher and Maryneal stone becomes increasingly more friable.

(4) By employing a straightedge it may be seen that the Dudley, Chico, and Ogden points form a practically straight line for any given sieve size (not including the 1/4-inch screen). Note that the angular digression of this straight line from the horizontal becomes slowly but surely less as the sieve size decreases. This trend already has been noted in Figure 3. (See paragraph (4), page 48, in the discussion of Figure 3.)

(5) Again employing a straightedge it may be seen that, in the finer sieve sizes, there is no straight line system coupling either Courchesne or Maryneal points with each other, or with other points, which is consistant with the general trend explained in the preceding paragraph.

Thus, an analysis of our standard "B" grading test data furnishes us with some advance information as to what may be expected from the "S" grading test, which will employ a sieve smaller than the No. 12 for determining the per cent wear. It is evident that very close numerical correlation of "S" and "B" test values for all stones will be very difficult, if not impossible. It may be possible to obtain a fairly close numerical correlation with Dudley, Chico and Ogden stones, while with Courchesne and Maryneal stones the numerical correlation will probably be poor. The abnormal degradation of Cordova Cream makes it impossible to predict the results which may be obtained with this stone.

2. Preliminary Decisions:

a. Sieve for Determining Per Cent Wear:

At the outset of the work of correlation it was necessary to select the sieve wherewith to determine the per cent wear. It was considered desirable that the degree of symmetry between the proposed test and the standard test be as high as possible. The average particle diameter (see Table 5) of the "B" grading test charge is 0.643-inch, and the effective opening of the No. 12 sieve is 0.0798-inch. This means that, on the average, the particles must be reduced to 12.4 per cent of their original diameters before they are regarded as loss. The average particle diameter of the "S" grading test charge is 0.230-inch. If the same ratio were maintained the wear, or loss, would be determined by the amount of material passing a sieve with an effective opening of 0.0285-inch, or, approximately, the No. 30 sieve. Preliminary tests (not recorded in the Appendices), however, showed that the weight of the abrasive charge required to make "S" test values, determined as loss through the No. 30, equal to the respective "B" test values was tremendously in excess of the standard "B" grading abrasive charge. Were the No. 16 sieve made the basis for determining wear, the average "S" grading particle would have to be reduced to only 24.1 per cent of its original diameter in order to be regarded as loss. Thus, as a compromise, the No. 20 sieve, with an effective opening of 0.0400-inch, was selected as a starting point with the full realization that test results might later indicate a change. The use of this sieve requires a reduction of the average particle to 17.3 per cent of its original diameter before it is regarded as loss, and, though considerably more abrasive charge weight is required with the "S" test than with the standard "B" test, the situation in this respect is much better than with the No. 30.

b. Abrasive Charge Ball Sizes:

The ratio of the average "B" grading test charge particle diameter to the weight of one of the standard balls is 0.643 (inches) to 420 (grams). If the same ratio were maintained in the "S" grading test the ball should weigh 150 grams. It appears reasonable to suppose that the closest correlation would be obtained by using "S" grading abrasive charge balls approximately in ratio to the average particle diameter. Realizing, however, that nothing was actually known of the action of the smaller test charge particles, particularly of the cushioning effect, it was considered advisable to use balls of three different weights in addition to the standard 420-gram balls. It was decided to use ball bearings of standard (hardware) sizes so that replacement might be easy. Accordingly, 65-gram (1-inch), 130-gram (1-1/4-inch), and 225-gram (1-1/2-inch) balls were selected.

3. Correlation with the Following Constants: 5000 Gram Test Charge; 500 Rattler Revolutions; Wear Equals Per Cent Passing the No. 20 Sieve:

It will be understood that all of the "S" grading tests in this series had the above-mentioned constants.

a. Varying the Number of Balls of Each Class:

The end-point stones (Trap and Cordova Cream) were not included in the following series of tests. While it was desirable to observe the action of the "S" grading test in cases of extreme toughness and friability it was considered undesirable that these extreme cases, so far removed from the actual specification range, should influence the evolution of the test.

"S" grading tests were run on each of the five correlation stones with each of the four classes of balls. In each of these twenty conditions the number of balls were varied until an average value for three "S" tests of identical character was obtained, which was closer to the "B" test value (see Table 7) in question than could be obtained with any other number of balls. (Two possible exceptions to this statement may be noted: the average "S" value for Maryneal stone using the 65-gram balls differed from the "B" value by 0.65 per cent; the average "S" value for Ogden stone using the 130-gram balls differed from the "B" value by 0.57 per cent.) As one 420-gram ball caused a considerable spread in the "S" wears, particularly with the softer stones, the averages of three "S" values, both above and below the "B" value in question, were obtained for both Maryneal and Ogden stones using the 420-gram balls.

This series comprised one hundred and forty-two tests, the results of which appear in Appendix III. Results were very uniform throughout with a very few isolated exceptions and one notable exception. Erratic results were obtained with Ogden stone using 65-gram balls. No explanation can be offered for the peculiar behavior of this sub-group of tests.

Tables 8A, B, C, and D present the results of this series of tests. Each of the values in these tables is an average of three test values except those for Maryneal stone with eleven 420-gram balls (not shown in its actual form in Table 8D) and Ogden stone with eighty-nine 65-gram balls, which are averages of five and four test results respectively. In case it is desired to refer to the individual test results, the following list of Appendix III test series numbers shows the individual tests which were averaged to secure the data for Tables 8A, B, C, and D.

Correlation Stones	Appendix III - Test Series Numbers			
	65-Gm. Balls	130-Gm. Balls	225-Gm. Balls	420-Gm. Balls
Dudley	3,4,5	12,13,14	23,24,25	32,33,34
Chico	39,40,41	47,48,49	54,55,56	62,63,64
Courchesne	67,68,69	79,80,81	91,92,93	99,103,104
Maryneal	110,111,112	121,122,123	132,135,136	(See follow-
Ogden	159,165,6,7	176,178,179	186,187,188	ing paragraph)

Note in Table 8D that the number of 420-gram balls used with Maryneal and Ogden stones are shown as 11.39 and 13.70, respectively, and the per cent wear in each case exactly equal to the respective "B" wear. The average results on Maryneal stone using eleven balls (tests No. 143, 144, 145, 146 and 148) and twelve balls (tests No. 142, 147, and 149) were interpolated, on the basis of the plus and minus variation of the two average "S" wears from the "B" wear, to secure the data as shown. The average results on Ogden stone using thirteen balls (tests No. 194, 195 and 197) and fourteen balls (tests No. 193, 196 and 198) were interpolated on the same basis to secure the data as shown. (Also see page 53.)

Table 8A

Average Sieve Analysis Data on Correlation Stones
5000-Gram Test Charges after "S" Grading
Test with 65-Gram Balls

Item		Correlation Stones				
		D	Ch	C	M	O
No. of 65-Gm. Balls		108	103	123	81	89
	(1/4"o	12.6	9.2	6.8	7.4	4.4
	(No. 10	58.4	50.2	47.7	45.2	39.6
Sieve	(No. 12	64.6	54.5	53.4	50.9	44.8
Analysis	(No. 16	73.6	67.3	63.5	59.4	54.7
(Average	(*No. 20	79.21	73.43	70.39	65.34	61.54
Cumulative	(No. 30	82.9	76.9	75.1	68.9	65.8
% Retained)	(No. 40	86.1	81.1	79.7	72.6	70.1
	(No. 50	88.5	83.6	82.9	75.3	73.2
	(No. 60	89.4	84.6	84.2	76.4	74.6

(Continued next page)

Table 8A (Continued)

Item		D	Ch	C	M	O
		Correlation Stones				
	(No. 80	90.7	86.0	85.9	78.0	76.3
	(No. 100	91.3	86.6	87.0	79.1	77.7
	(No. 200	92.7	88.1	89.0	81.8	80.8
*"S" Wear (%)		20.79	26.57	29.61	34.66	38.46

Table 8B

Average Sieve Analysis Data on Correlation Stones
5000-Gram Test Charges after "S" Grading
Test with 130-Gram Balls

Item		Correlation Stones				
		D	Ch	C	M	O
No. of 130-Gm. Balls		49	46	57	36	43
	(1/4"o	12.0	6.7	5.4	4.6	3.3
	(No. 10	60.4	51.6	46.6	45.4	37.6
	(No. 12	65.8	56.7	52.4	50.6	43.4
Sieve	(No. 16	73.9	67.5	62.7	60.0	53.9
Analysis	(*No. 20	79.36	73.53	70.00	65.97	61.10
(Average	(No. 30	83.5	78.2	75.6	70.3	65.8
Cumulative	(No. 40	86.5	81.5	79.7	73.3	70.3
% Retained)	(No. 50	88.8	84.1	83.1	76.0	73.5
	(No. 60	89.6	84.9	84.3	77.0	75.0
	(No. 80	91.1	86.3	86.4	78.7	77.0
	(No. 100	91.7	87.0	87.4	79.7	78.1
	(No. 200	93.1	88.5	89.6	82.5	81.1
*"S" Wear (%)		20.64	26.47	30.00	34.03	38.90

Table 8C

Average Sieve Analysis Data on Correlation Stones
5000-Gram Test Charges after "S" Grading
Test with 225-Gram Balls

Item		Correlation Stones				
		D	Ch	C	M	O
No. of 225-Gm. Balls		27	26	31	21	24
	(1/4"o	11.8	6.0	5.0	3.8	3.1
Sieve	(No. 10	59.8	51.3	45.9	44.1	39.8
Analysis	(No. 12	64.7	56.5	51.9	49.4	44.8
(Average	(No. 16	73.2	66.6	62.7	59.3	55.2
Cumulative	(*No. 20	79.33	73.21	70.17	65.57	62.05
% Retained)	(No. 30	83.5	78.1	75.8	70.1	66.9
	(No. 40	86.6	81.5	79.9	73.4	71.3

(Continued next page)

Table 8C (Continued)

Item		D	Ch	C	M	O
	(No. 50	89.0	84.1	83.3	76.2	74.6
	(No. 60	89.9	85.0	84.6	77.2	76.0
	(No. 80	91.3	86.5	86.6	79.0	77.8
	(No. 100	91.9	87.2	87.6	80.1	79.0
	(No. 200	93.3	88.8	89.9	83.0	81.9
*"S" Wear (%)		20.67	26.79	29.83	34.43	37.95

Table 8D

Average Sieve Analysis Data on Correlation Stones
5000-Gram Test Charges after "S" Grading
Test with 420-Gram Balls

Item		Correlation Stones D	Ch	C	M	O
No. of 420-Gm. Balls		13	14	16	11.39	13.70
	(1/4"o	10.8	7.5	5.8	4.0	3.3
	(No. 10	61.0	52.6	47.5	44.9	39.5
	(No. 12	65.9	57.8	52.3	50.3	44.3
Sieve	(No. 16	74.3	67.0	63.2	59.9	54.9
Analysis	(*No. 20	79.57	73.35	70.47	65.94	61.67
(Average	(No. 30	83.2	78.1	76.1	70.2	66.8
Cumulative	(No. 40	86.8	81.5	80.2	73.4	71.1
% Retained)	(No. 50	89.2	84.2	83.6	76.1	74.5
	(No. 60	90.1	85.1	84.8	77.1	75.9
	(No. 80	91.4	86.5	86.9	79.0	78.0
	(No. 100	92.1	87.3	87.8	80.0	79.1
	(No. 200	93.6	88.9	90.1	82.8	82.1
*"S" Wear (%)		20.43	26.65	29.53	34.06	38.33

Figures were prepared presenting the data in Tables 8A, B, C, and D graphically. Any one of the four resulting sets of curves is almost identical with each of the other three. A comparison of Tables 8- show this to be a fact. Because of this similarity only one of the four figures is presented here. Figure 6 is a graphical representation of the sieve analysis data in Table 8B, selected at random from Tables 8-.

It must be borne in mind that the number of balls were varied so that, with any given stone, the per cent passing the No. 20 sieve was approximately equal regardless of the class of balls. It is significant that the degradation of each of the five stones is almost identical, not only at the No. 20 point, but at all other points as well, for all ball sizes. It was expected that such a wide variation in the ball size would cause a marked difference in the progressive degradation, but such is not the case.

A comparison of Figure 6 (which for all practical purposes represents the data in Tables 8A, C, and D, as well as B) and Figure 3 shows that the degradation of the "S" test charge is very similar to that of the "B" test charge except for the natural difference occasioned by the initial average particle diameter differential. For each stone the per cent passing the No. 20 (Figure 6 is, of course, approximately equal to the per cent passing the No. 12 (Figure 3). Keeping this balance point in mind note that the relative positions of the lines are very similar in both figures.

Thus it may be seen that the progressive degradation of the "S" test charge is very similar to that of the "B" test charge regardless of the size of the balls used in the "S" test.

It now becomes necessary to study the actual difference in the total weight of abrasive charge required to make "S" wears approximately equal to the respective "B" wears.

Table 9 presents a summary of results secured by varying the abrasive charges. The standard "B" wears are taken from Table 7. The "S" wears and the number of balls used are taken from Table 8. The weight of the abrasive charge is, in each case, the average weight of the abrasive charges (see Appendix III) used in the tests comprising the average result in question. The values opposite the item "Difference 'B' and 'S' (%)" are the numerical differences between the "S" wears and the respective "B" wears, indicated as "±" on the basis of the standard "B" value. The actual values for Maryneal and Ogden stones using 420-gram balls are shown in this table rather than the interpolated values as shown in Table 8D.

Table 9

Abrasive Charges Required to Make "S" Wear Approximately Equal to Respective "B" Wear

Item		Dudley	Chico	Cour.	Mary.	Ogden
Standard "B" Wear (%)		20.84	26.80	29.82	34.06	38.33
	("S" Wear (%)	20.79	26.57	29.61	34.66	38.46
65-	(Diff. "B" & "S" (%)	-0.05	-0.23	-0.21	+0.60	+0.13
Gram	(No. of Balls	108	103	123	81	89
Balls	(Wt. of Ab.Chg.(Gm.)	7097	6767	8083	5322	5847
	("S" Wear (%)	20.64	26.47	30.00	34.03	38.90
130-	(Diff. "B" & "S" (%)	-0.20	-0.33	+0.18	-0.03	+0.57
Gram	(No. of Balls	49	46	57	36	43
Balls	(Wt. of Ab.Chg.(Gm.)	6279	5917	7304	4623	5527
	("S" Wear (%)	20.67	26.79	29.83	34.43	37.95
225-	(Diff. "B" & "S" (%)	-0.17	-0.01	+0.01	+0.37	-0.38
Gram	(No. of Balls	27	26	31	21	24
Balls	(Wt. of Ab. Chg. (Gm.)	6061	5834	6958	4715	5387

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Degredation of "S" Grading Test Chages
(Correlation Stones; Using 130-Gram Balls)

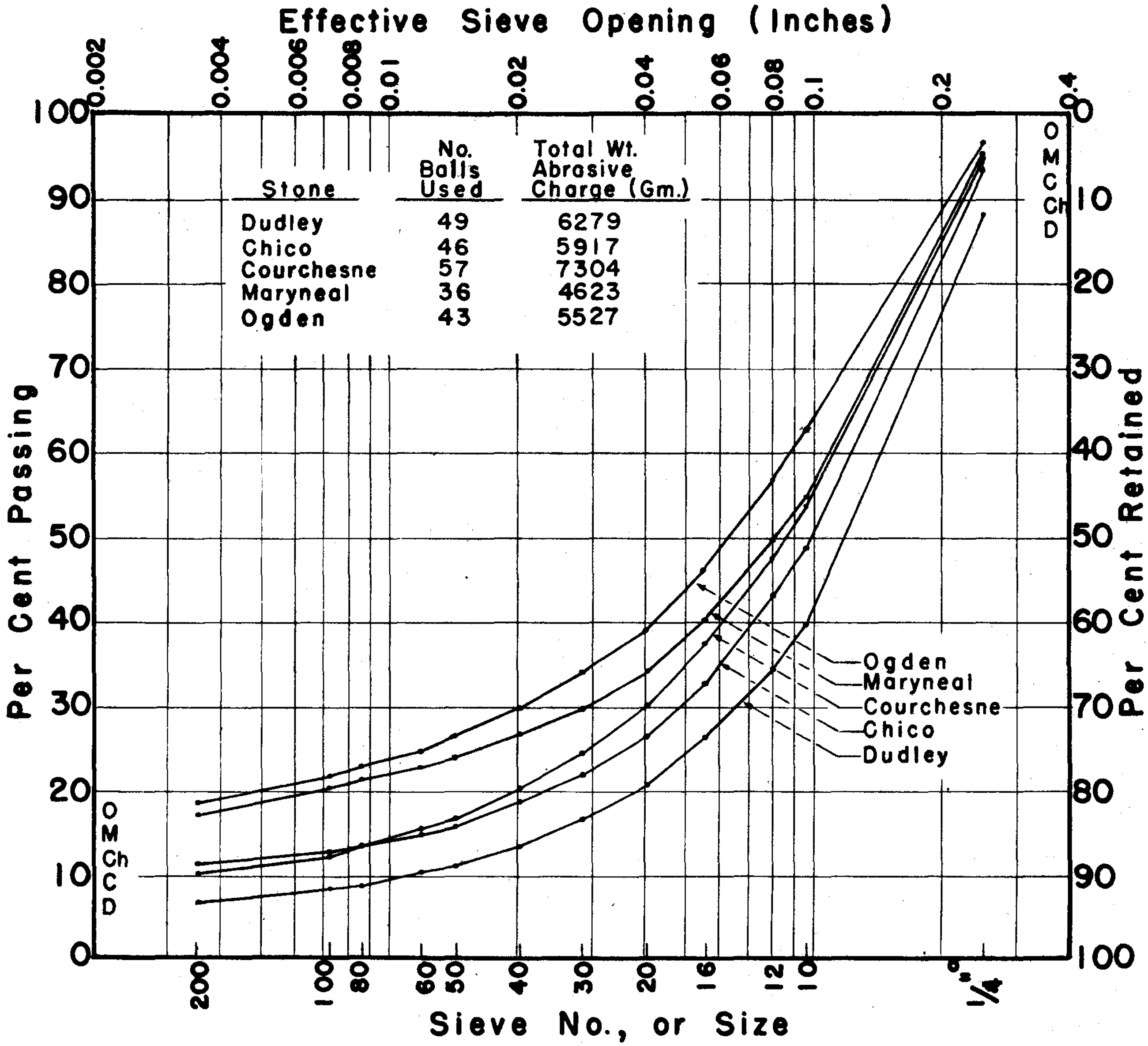

Figure 6

Table 9 (Continued)

Item		Stone				
		Dudley	Chico	Cour.	Mary.	Ogden
	("S" Wear (%)	20.43	26.65	29.53	32.76	36.83
	(Diff. "B" & "S" (%)	-0.41	-0.15	-0.29	-1.30	-1.50
420-	(No. of Balls	13	14	16	11	13
Gram	(Wt. of Ab. Chg. (Gm.)	5480	5905	6794	4623	5428
Balls	("S" Wear (%)				36.09	38.97
	(Diff. "B" & "S" (%)				+2.03	+0.64
	(No. of Balls				12	14
	(Wt. of Ab. Chg. (Gm.)				5053	5867

Figure 7 presents the data in Table 9 in graphical form. The "S" grading test values (per cent wear) are plotted against the total weight of abrasive charge used. The dotted lines indicate the standard "B" wear values of the five stones. Note that the "S" wear points for Maryneal and Ogden stones have been placed squarely upon the respective "B" wear lines. The ordinate values for these points were secured by interpolation on the basis of the plus and minus variation of the "S" wears from the respective "B" wears, as were the sieve analyses in Table 8D. The horizontal deviations of the plotted "S" test points from the respective "B" wear lines are equivalent to the ± differences shown in Table 9.

An analysis of Figure 7 discloses several interesting features:

(1) With the exception of the 420-gram balls with Dudley stone (an unaccountable variation) the total weight of the 130, 225, and 420-gram ball abrasive charges varied a maximum of 510 grams (Courchesne stone). The decreased abrasive action of a smaller ball apparently is compensated for by the increased spread of the abrasive charge consisting of a larger number of small balls.

(2) The 65-gram ball abrasive charge required considerably more total weight than did the other abrasive charges, except for Ogden stone. It is not at all clear why the difference in total weight of the charge was much greater between the 65-gram balls and the other ball sizes than between any of the remaining three sizes. It is presumed that there is a critical point in the ball size (somewhere between 65 and 130 grams) at which the smaller ball suddenly becomes much less destructive. This theory is substantiated by the fact that the difference in the total weight of the 65-gram ball charges and the other three charges becomes markedly less when testing the more friable stones (Maryneal and Ogden).

(3) Except for the 65-gram ball points, the Dudley, Chico, and Ogden points, in comparison with Courchesne and Maryneal points, lie roughly on a horizontal line, which, on this figure, would signify a constant abrasive charge. The Courchesne points lie considerably above this line and the Maryneal points considerably below. This is consistent with the observations made on Figure 5. It is increasingly evident that the "S" and "B" tests on Courchesne and Maryneal stones will not offer a close numerical correlation.

b. Best Average Abrasive Charges:

Having determined the abrasive charges required to make the "S" wear of each of the correlation stones approximately equal to its respective "B" wear, it became necessary to determine the number of balls of each class most likely to give the best average results with all stones. All of the one hundred and forty-two test results secured in the preceding test series were used in order to determine the approximate "wear per ball" (in the critical "B" wear range) for each stone with each class of balls. After considering and balancing these data the following abrasive charges were selected:

Class of Balls	Optimum Number Balls
65-gram	99
130-gram	45
225-gram	25
420-gram	14

(One hundred 65-gram balls were selected at first, but the results of the first run (tests No. 6, 42, 70, 113, 168, 199 and 212, in Appendix III) indicated a change to ninety-nine.)

Using these abrasive charges three "S" grading tests were run on each of the five correlation stones and each of the two end point stones. This series comprised seventy-five tests, the results of which appear in Appendix III. (Some of the tests required in this series had already been run in the preceding series in which the number of balls in each class were varied.)

Tables 10A, B, C, and D present the results of this series of tests. Each of the values in these tables is an average of three test values. In case it is desired to refer to the individual test results the following list of Appendix III test series numbers shows the individual tests which were averaged to secure the data for Table 10.

	Appendix III Test Series Numbers			
Stones	Ninety-nine 65-Gm.Balls	Forty-five 130-Gm.Balls	Twenty-five 225-Gm.Balls	Fourteen 420-Gm.Balls
Dudley	7,8,9	16,17,18	27,28,29	*31,35,36
Chico	43,44,45	50,51,52	57,58,59	*62,*63,*64
Courchesne	71,72,73	83,84,85	95,96,97	*98,105,106
Maryneal	114,115,116	125,126,127	138,139,140	150,151,152
Ogden	169,170,171	180,181,182	*185,189,190	*193,*196,*198
Trap	200,201,202	203,204,205	206,207,208	209,210,211
Cordova C.	213,214,215	216,217,218	219,220,221	222,223,224

*From preceding test series.

Table 10A

Average Sieve Analysis Data on 5000-Gram Test Charges after "S" Grading Test With Ninety-nine 65-Gram Balls

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/4"O	15.4	10.1	10.6	4.8	4.1	24.5	0.2
No. 10	61.7	53.9	55.8	38.9	37.3	74.5	6.1

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Total Weight of Abrasive Charge Required to Make the "S" Wear Approximately Equal to the Respective "B" Wear

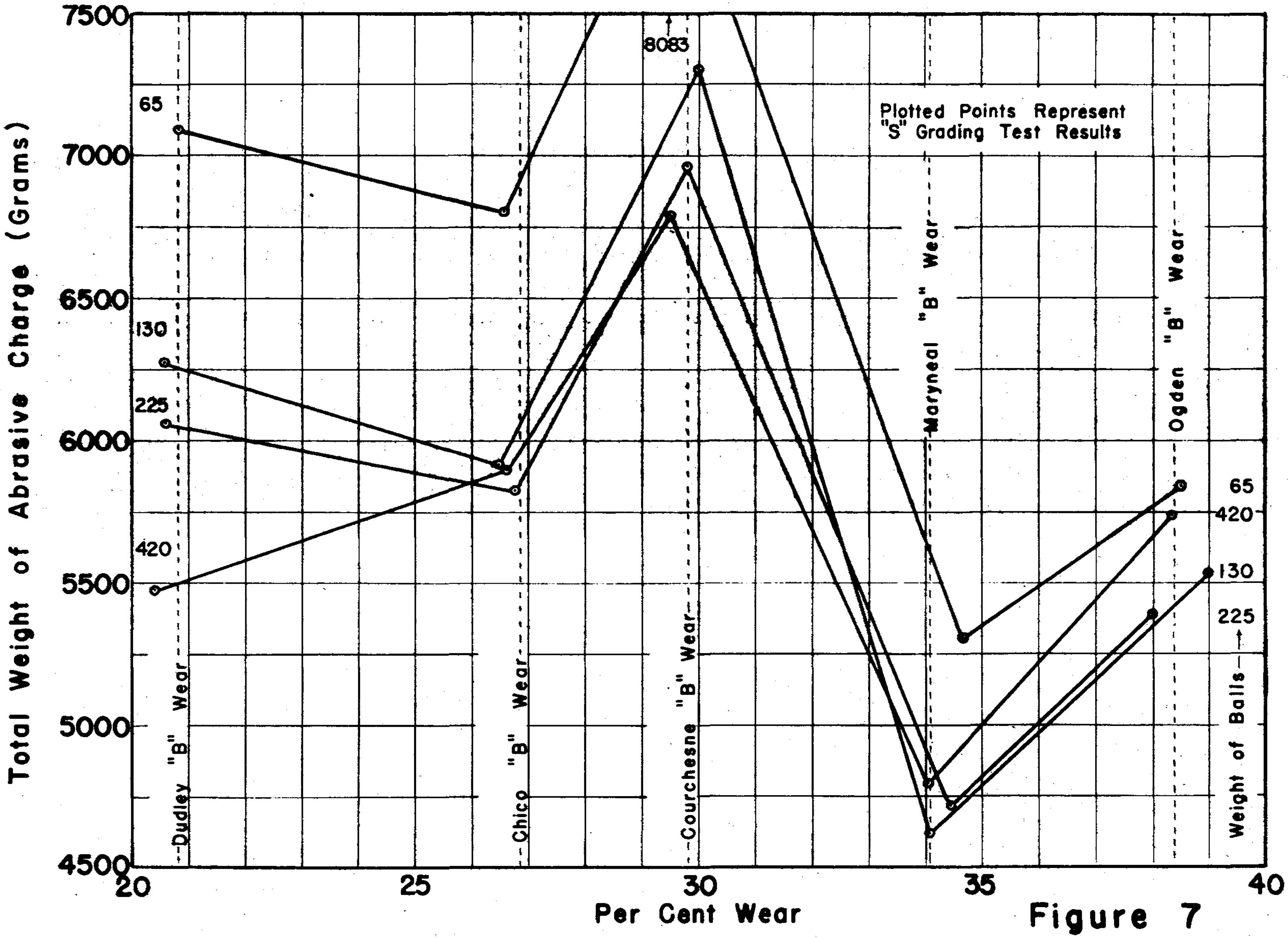


Figure 7

Table 10A (Continued)

Sieve	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
	D	Ch	C	M	O	T	CC
No. 12	67.1	59.1	61.8	44.1	42.3	78.8	8.8
No. 16	75.5	68.7	70.8	53.7	52.5	84.6	15.7
*No. 20	80.97	74.85	76.75	60.43	59.71	88.14	22.47
No. 30	84.2	78.5	80.4	64.5	64.1	90.0	27.5
No. 40	87.3	82.1	84.1	68.9	68.8	91.9	32.6
No. 50	89.4	84.4	86.5	72.1	72.1	93.1	37.0
No. 60	90.4	85.5	87.6	73.5	73.6	93.6	39.6
No. 80	91.3	86.6	88.8	75.5	75.6	94.2	43.7
No. 100	92.1	87.4	89.7	76.9	77.0	94.7	48.0
No. 200	93.4	88.9	91.5	80.8	80.6	95.6	61.2
*Wear (%)	19.03	25.15	23.25	39.57	40.29	11.86	77.53

Table 10B

Average Sieve Analysis Data on 5000-Gram Test Charges after "S" Grading Test with Forty-five 130-Gram Balls

Sieve	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
	D	Ch	C	M	O	T	CC
1/4"○	14.7	8.5	10.0	3.3	2.5	19.9	0.1
No. 10	59.7	54.8	57.3	38.1	36.2	72.7	8.3
No. 12	68.5	60.8	62.4	44.0	42.0	77.4	12.0
No. 16	76.3	68.8	70.3	54.0	51.9	83.1	19.4
*No. 20	81.49	75.09	76.35	60.99	59.41	86.87	26.29
No. 30	84.6	78.6	80.0	65.1	63.9	89.0	30.5
No. 40	87.6	82.2	83.6	69.4	68.7	91.0	35.4
No. 50	89.7	84.6	86.2	72.7	72.1	92.4	39.3
No. 60	90.6	85.5	87.2	74.1	73.5	93.0	41.5
No. 80	91.6	86.7	88.5	76.1	75.5	93.7	45.3
No. 100	92.2	87.5	89.4	77.5	76.9	94.2	49.1
No. 200	93.4	88.9	91.0	80.9	80.0	95.0	61.0
*Wear (%)	18.51	24.91	23.65	39.01	40.59	13.13	73.71

Table 10C

Average Sieve Analysis Data on 5000-Gram Test Charges after "S" Grading Test with Twenty-Five 225-Gram Balls

Sieve	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
	D	Ch	C	M	O	T	CC
1/4"○	13.0	8.1	8.9	3.3	3.1	18.0	0.1
No. 10	62.7	53.7	55.9	39.0	37.3	72.4	10.5
No. 12	67.7	59.3	61.0	45.0	43.9	76.3	14.9

Table 10C (Continued)

Sieve	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
	D	Ch	C	M	O	T	CC
No. 16	75.6	63.3	69.6	55.0	53.9	82.3	23.2
*No. 20	80.97	74.86	75.98	62.06	61.27	86.28	29.73
No. 30	84.3	78.6	79.8	66.2	66.1	88.6	33.8
No. 40	87.4	82.4	83.8	70.6	70.5	90.8	38.3
No. 50	89.7	84.9	86.4	73.8	73.8	92.2	41.9
No. 60	90.6	85.9	87.5	75.3	75.2	92.9	44.0
No. 80	91.7	87.1	88.9	77.2	77.2	93.6	47.6
No. 100	92.4	87.9	89.9	78.6	78.6	94.2	51.4
No. 200	93.7	89.4	91.7	82.0	81.3	95.2	62.5
*Wear (%)	19.03	25.14	24.02	37.94	38.73	13.72	70.27

Table 10D

Average Sieve Analysis Data on 5000-Gram Test Charges after "S" Grading Test with Fourteen 420-Gram Balls

Sieve	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
	D	Ch	C	M	O	T	CC
1/4"o	11.4	7.5	8.1	3.2	3.0	14.3	0.1
No. 10	58.6	52.6	51.8	39.8	38.7	65.9	10.5
No. 12	64.9	57.8	58.7	45.5	43.4	73.7	14.8
No. 16	73.0	67.0	67.8	55.3	54.2	80.4	24.0
*No. 20	78.81	73.35	74.21	62.21	61.03	84.81	30.83
No. 30	82.9	78.1	79.0	66.6	66.3	87.4	34.6
No. 40	86.2	81.5	82.8	70.7	70.7	89.8	38.8
No. 50	88.7	84.2	85.6	73.9	74.1	91.5	42.3
No. 60	89.6	85.1	86.8	75.3	75.5	92.2	44.3
No. 80	91.0	86.5	88.5	77.3	77.7	93.1	47.7
No. 100	91.7	87.3	89.4	78.7	78.8	93.7	51.5
No. 200	93.1	88.9	91.2	82.0	81.8	94.9	63.2
*Wear (%)	21.19	26.65	25.79	37.79	38.97	15.19	69.17

Figures 8 and 9 are graphical representations of the correlation stones data in Tables 10A and B and Tables 10C and D, respectively. The per cent of the "S" grading test charge (after degradation) for each stone retained on, or passing, each sieve is plotted against the "B" wear values (per cent) of that stone. (The 1/4-inch screen has been omitted from these figures.) Thus the degradation of the "S" grading test charges may be viewed in relation to the resistance to abrasion of the stones as measured by the "B" wear test, and the degradation of the "S" test charges may be compared directly with that of the "B" test charges (Figure 5).

Note in Figures 8 and 9 that the actual per cent of any one stone passing a particular sieve may vary slightly as the ball size is varied. This is because the average abrasive charges (see D (b)) for all five stones could

Degredation of "S" Grading Test Charges
(Constant 5000 Gram Test Charge)

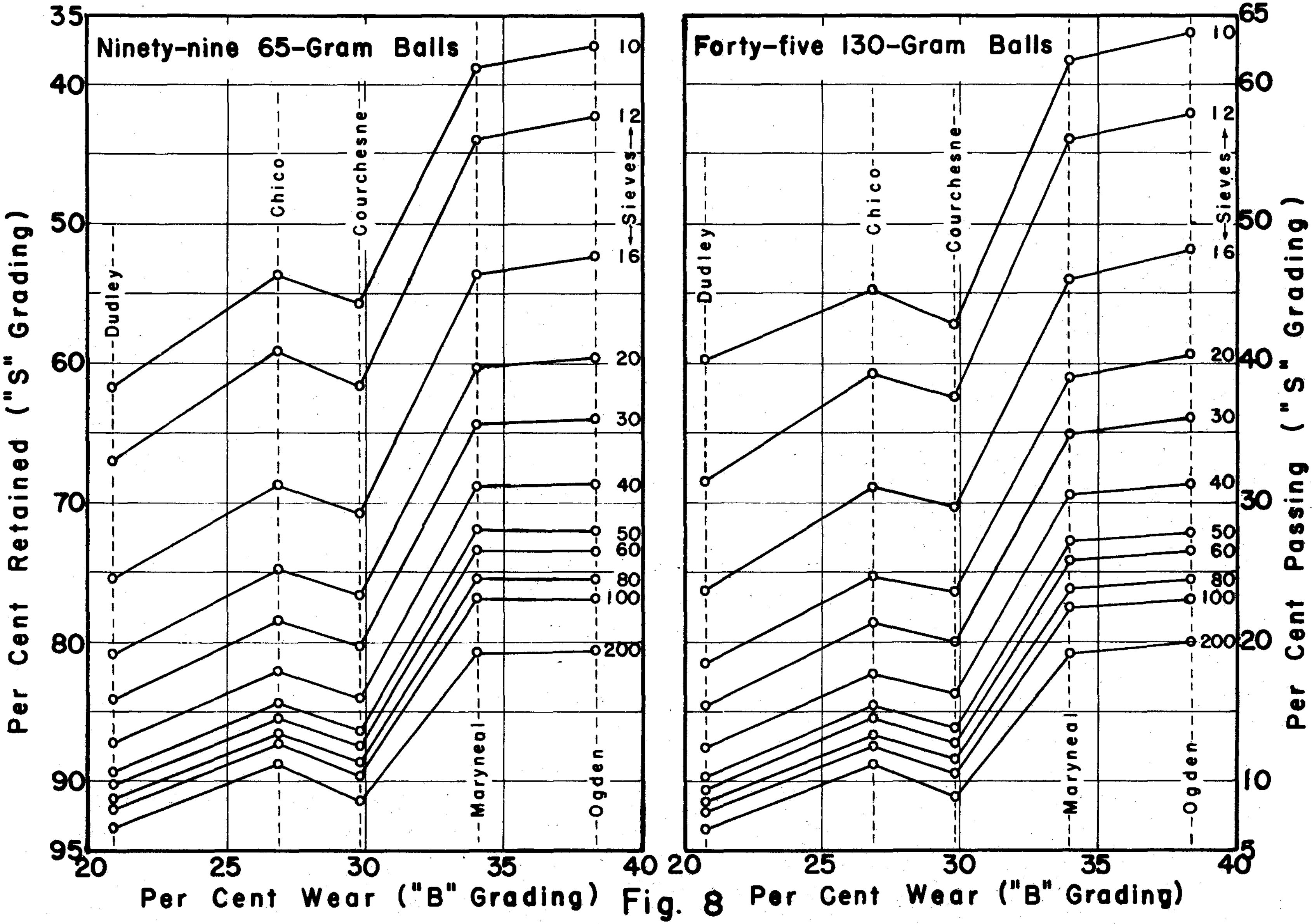


Fig. 8

Degredation of "S" Grading Test Charges
(Constant 5000 Gram Test Charge)

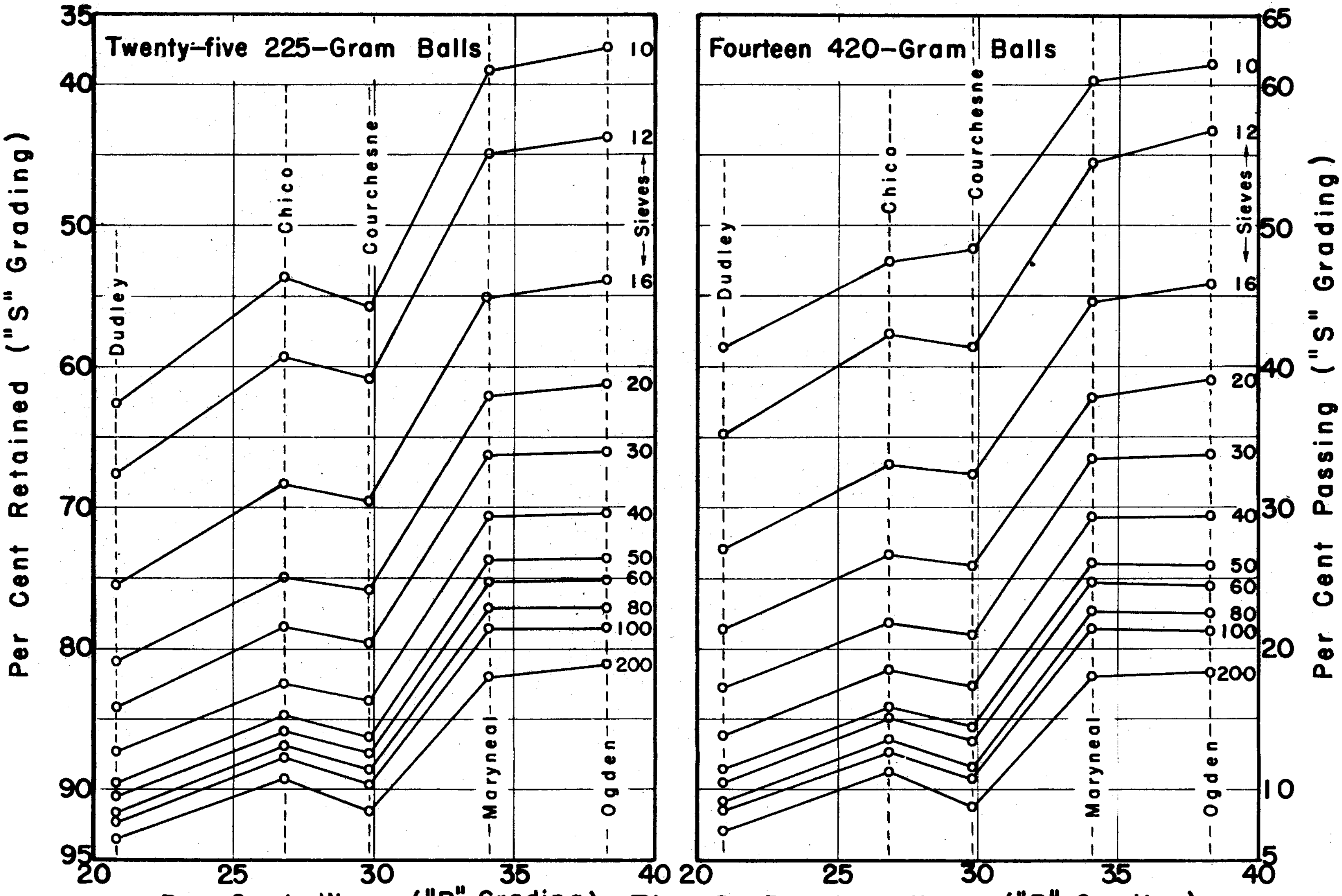


Fig. 9

not be selected in exact balance. Discounting this condition, an examination of Figures 8, 9 and 5 shows that:

(1) The "S" grading test charges are degraded in almost identical fashion regardless of the weight of the individual balls in the abrasive charges. (Note one exception to this general trend: Courchesne stone with 420-gram balls in sizes larger than the No. 20 sieve.)

(2) The "S" grading test charges are degraded in a manner similar to the "B" grading test charges. The similarities are obvious. The differences are occasioned by the initial average test charge particle size differential.

Figures 8 and 9 will be found to be extremely useful as the investigation progresses.

Having acquainted ourselves with the background we are now in a position to observe intelligently the actual degree of correlation thus far obtained.

Table 11A presents a summary of the correlation of the "S" and "B" tests obtained using four ball weights, a constant 5000-gram test charge, 500 Rattler revolutions, and the No. 20 sieve for determining the "S" wear. The standard "B" wear values are taken from Table 7, and the "S" wear values from Tables 10-.

Table 11A

Summary of Correlation Data
(C nstants for "S" Grading Test: 5000-Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve.)

Stones		"B" Wear (%)	"S" Wear (Per Cent) 99 65-Gm. Balls	45 130-Gm. Balls	25 225-Gm. Balls	14 420-Gm. Balls
	(Dudley	20.84	19.03	18.51	19.03	21.19
Corre-	(Chico	26.80	25.15	24.91	25.14	26.65
lation	(Courchesne	29.82	23.25	23.65	24.02	25.79
Stones	(Maryneal	34.06	39.57	39.01	37.94	37.79
	(Ogden	38.33	40.29	40.59	38.73	38.97
E. P.	(Trap	9.43	11.86	13.13	13.72	15.19
Stones	(Cordova Cream	72.44	77.53	73.71	70.27	69.17

Table 11B presents the deviations of the "S" values from the respective "B" values as shown in Table 11A. The plus values are the numerical deviations (per cent wear) where "S" is greater than "B," and the minus values are the numerical deviations where "S" is less than "B." The "Total Deviation" is the arithmetic sum of the "Total +" values and the "Total -" values. The "Average Deviation" is the "Total Deviation" divided by the number of stones under consideration.

Table 11B

Deviation of "S" Wear from "B" Wear
(Data taken from Table 11A)

Item		Deviation ("S" from "B") 99 65-Gm. Balls	45 130-Gm. Balls	25 225-Gm. Balls	14 420-Gm. Balls
Correlation Stones	(Dudley	-1.81	-2.33	-1.81	+0.35
	(Chico	-1.65	-1.89	-1.66	-0.15
	(Courchesne	-6.57	-6.17	-5.80	-4.03
	(Maryneal	+5.51	+4.95	+3.88	+3.73
	(Ogden	+1.96	+2.26	+0.40	+0.64
End-Point Stones	(Trap	+2.43	+3.70	+4.29	+5.76
	(Cordova C.	+5.09	+1.27	-2.17	-3.27
Correlation & End-Point Stones	(Total (+)	14.99	12.18	8.57	10.48
	(Total (-)	10.03	10.39	11.44	7.45
	(Total	25.02	22.57	20.01	17.93
	(Average	3.57	3.22	2.86	2.56
Correlation Stones	(Total (+)	7.47	7.21	4.28	4.72
	(Total (-)	10.03	10.39	9.27	4.18
	(Total	17.50	17.60	13.55	8.90
	(Average	3.50	3.52	2.71	1.78

Figure 10 presents the data on the correlation and end-point stones in Table 11A graphically. The "S" wears are plotted against the respective "B" wears. The "S" = "B" line includes no actual "S" values. It is the standard base-line as demonstrated in Figure 1. The vertical deviation of the plotted points from the base-line constitute the numerical deviation of the "S" test values from the respective "B" test values. The total plus, the total minus, the total, and the average deviations (from Table 11B) are shown in tabular form on this figure for convenience.

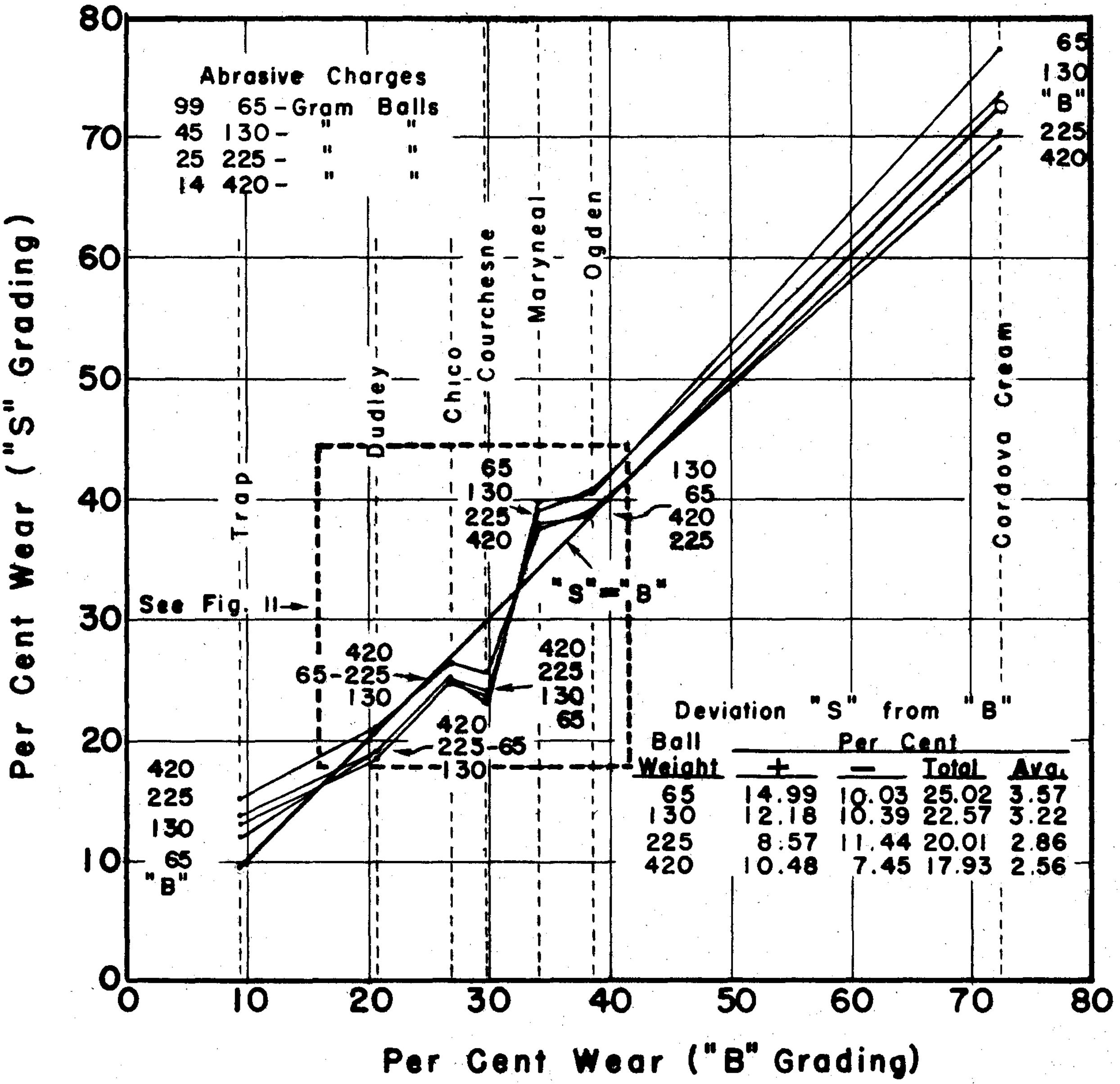
Figure 10 shows that:

(1) Ninety-nine 65-gram balls give rather poorly balanced results, the total plus deviation exceeding the total minus deviation by 4.96 per cent (wear). Ninety-eight balls would have yielded a better balanced correlation. It must be understood, however, that the actual degree of correlation (the total and/or the average deviation) would be affected very little by such a change, as a reduction of the total plus deviation would be accompanied by an approximately equal increase of the total minus deviation.

(2) The 130, 225 and 420-gram ball abrasive charges give better balanced correlations than could have been obtained with any other than the number of balls used.

(3) Giving equal weight to all seven conditions (stones), including the extremes in toughness and friability, the average deviations show the correlation to improve uniformly as the ball weight increases. The 65-gram

Correlation of "S" Test With "B" Test (Constants: 5000-Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve)



Deviation "S" from "B"

Ball Weight	Per Cent +	Per Cent −	Total	Avg.
65	14.99	10.03	25.02	3.57
130	12.18	10.39	22.57	3.22
225	8.57	11.44	20.01	2.86
420	10.48	7.45	17.93	2.56

Figure 10

ball charge offers the poorest average numerical correlation (average deviation equals 3.57 per cent), the 130-gram ball charge being somewhat better (3.22 per cent), and the 225-gram ball charge being still better (2.86 per cent). The 420-gram ball charge offers the best average numerical correlation (average deviation equals 2.56 per cent) in spite of the fact that the deviation in the case of Trap is considerably greater than with any other class of balls, and the deviation in the case of Cordova Cream is greater than with the 130 or 225-gram balls.

Figure 11 presents the data on the correlation stones in Table 11A. It is merely an enlargement of the section indicated on Figure 10. The deviations (from Table 11B) are shown in tabular form. Temporarily excluding the end-point stones from consideration, Figure 11 shows that:

(1) The 65 and 225-gram ball charges probably would have yielded somewhat better balanced correlations had one more ball been used in each case. The actual degree of correlation, however, would have been affected only slightly, as a reduction of the total minus deviation would be accompanied by an approximately equal increase of the total plus deviation.

(2) An almost perfectly balanced correlation was obtained with the 420-gram ball abrasive charge, the total plus deviation exceeding the total minus deviation by only 0.54 per cent.

(3) Giving equal weight to all five conditions (stones) the average deviations show that the 65 and 130-gram ball charges offer the poorest numerical correlation (average deviations equal 3.50 and 3.52 per cent, respectively), the 225-gram ball charge being considerably better (2.71 per cent). The 420-gram ball charge offers decidedly the best correlation, the average deviation for the five stones being 1.78 per cent.

Considering Figures 10 and 11 together, it is clear that the best correlation of the "S" and "B" tests (using a 5000-gram test charge, 500 Rattler revolutions, and the No. 20 sieve for determining the per cent wear) is obtained by using an abrasive charge of fourteen 420-gram balls.

It is true that, on the average, "S" test values obtained with this abrasive charge present the widest deviation from the respective "B" test values for the two end-point stones. Both of these stones, however, represent conditions so far removed from the practical specification range that this is a theoretical, rather than a practical, objection. (The "B" wear of Trap is approximately one-third of the lowest wear limit specified, and the "B" wear of Cordova Cream is approximately twice the highest wear limit specified.)

Giving equal weight to all seven stones, including the extremes of resistance to abrasion, the 420-gram ball abrasive charge clearly is superior to the other charges, though not a great deal better than the 225-gram ball charge. Excluding the extremes, and considering only the practical specification range, the 420-gram ball charge is greately superior to the other charges.

Having decided that the 420-gram balls constitute the best abrasive charge it will be well to observe the complete degredation of all of the "S" grading test charges using this abrasive charge. Figure 12 presents the data in Table 10D in a form with which we are already familiar. This figure is a representation of the graphical data in Figure 9 (420-gram ball chart), except that in this case the end-point stones are included. In comparing Figures 3 and 12, it is very important to bear in mind the initial particle size differential. The larger sizes (retained upon the 3/8-inch sieve) being reduced to an average particle diameter of 0.230-inch (average "S" grading test charge particle) before the abrasion test is begun, the trends apparent in Figure 3 naturally are accentuated in Figure 12. Note the similarity in all major trends. An undesirable exception is furnished by Trap, which, on the basis of the degradation of the "B" test charge, is degraded disproportionately by the "S" grading test. As the per cent wear of Trap, however, is far below the lowest specified abrasive wear limit, this is not a very practical objection.

c. Sieve for Determining Per Cent Wear:

Using the No. 20 sieve to determine the "S" wear, an abrasive charge of fourteen 420-gram balls yielded a good average numerical correlation. The following question immediately arises: "Would some sieve other than the No. 20 yield a better average numerical correlation?" Fortunately no tests need be run to answer this question. The data are ready at hand. It is unnecessary to analyze the situation in detail with numerical values. A glance at the 420-gram ball degradation chart (Figure 9) shows that all segments of the No. 16 sieve line parallel the respective segments of the No. 20 sieve line almost exactly. Thus it is evident that approximately the same degree of correlation would be obtained with the No. 16 sieve as was obtained with the No. 20 sieve should an abrasive charge decreased by the proper amount be used. In addition to the fact that the use of the No. 16 in place of the No. 20 would improve the numerical correlation only slightly, if at all, there would be an obvious disadvantage in the substitution. The average "B" grading test charge particle must be reduced to 12.4 per cent of its original diameter (0.643-inch) before it will pass the No. 12 sieve (effective opening of 0.0798-inch) and be regarded as loss. The use of the No. 16 sieve (effective opening of 0.0555-inch) would require that the average "S" grading test charge particle be reduced to only 24.1 per cent of its original average diameter (0.230-inch) to be considered loss. Thus, in order to maintain some degree of symmetry between the "B" and "S" tests, a sieve with an effective opening smaller than that of the No. 16 should be used if possible.

Again referring to Figure 9 (420-gram ball chart) it may be seen that all segments of the No. 30 sieve line parallel the respective segments of the No. 20 sieve line almost exactly. Thus, approximately the same degree of correlation would be obtained with the No. 30 sieve as was obtained with the No. 20 sieve should an abrasive charge increased by the proper amount be used. The substitution of the No. 30 for the No. 20 sieve would entail an obvious disadvantage. The "B" grading test requires a 5000-gram test charge and a 4583-gram (approximately) abrasive charge. The fourteen 420-gram ball abrasive charge weighed approximately 5880 grams. Were a sieve smaller than the No. 20 used to determine the per cent wear, the disproportion in the weight of the test charge and the abrasive charge would be increased still further.

Correlation of "S" Test With "B" Test Varying the Abrasive Charge Only (Constants: 5000 Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve)

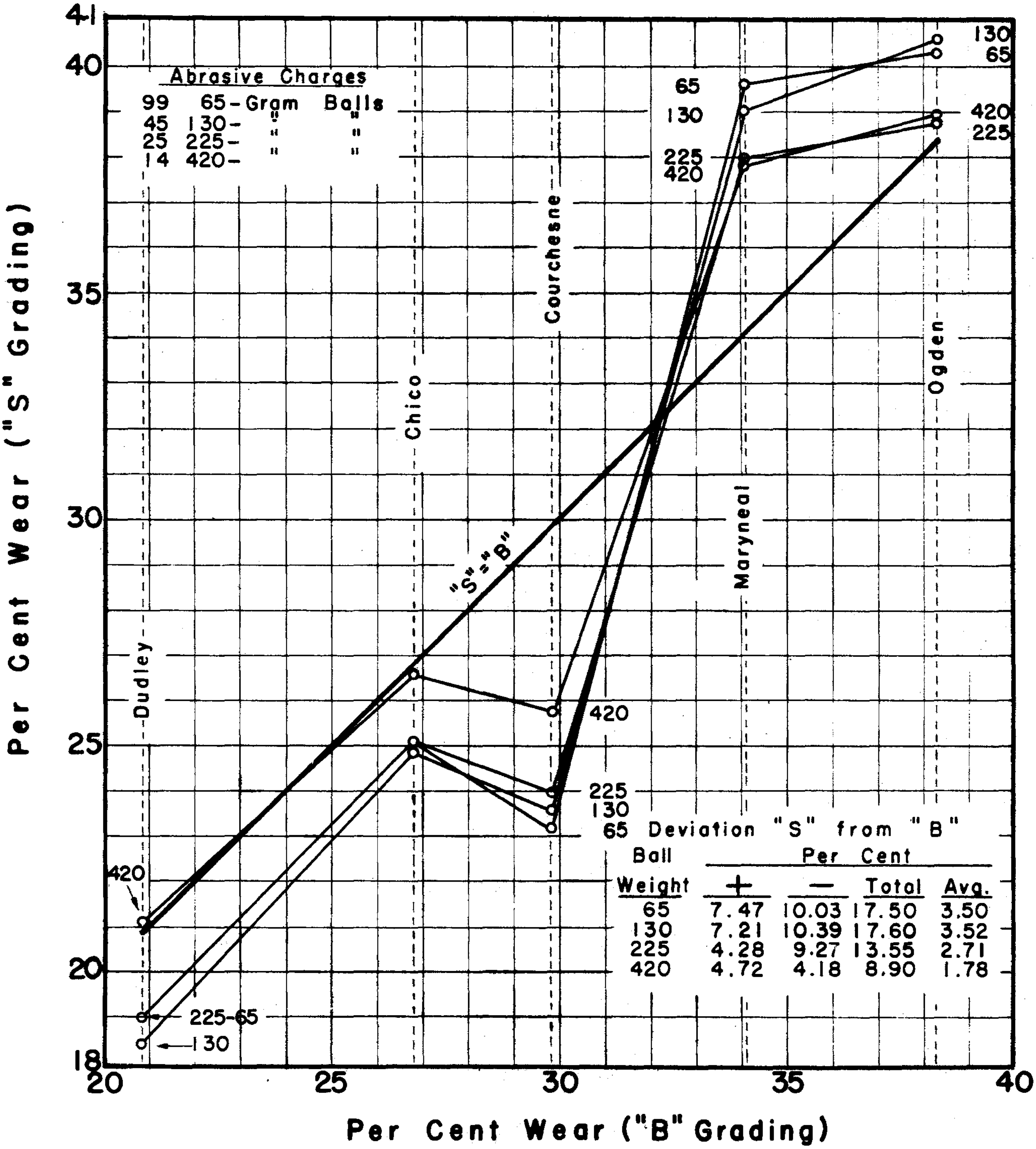


Figure 11

Degredation of 5000-Gram "S" Grading Test Charges; Fourteen 420-Gram Ball Abrasive Charge

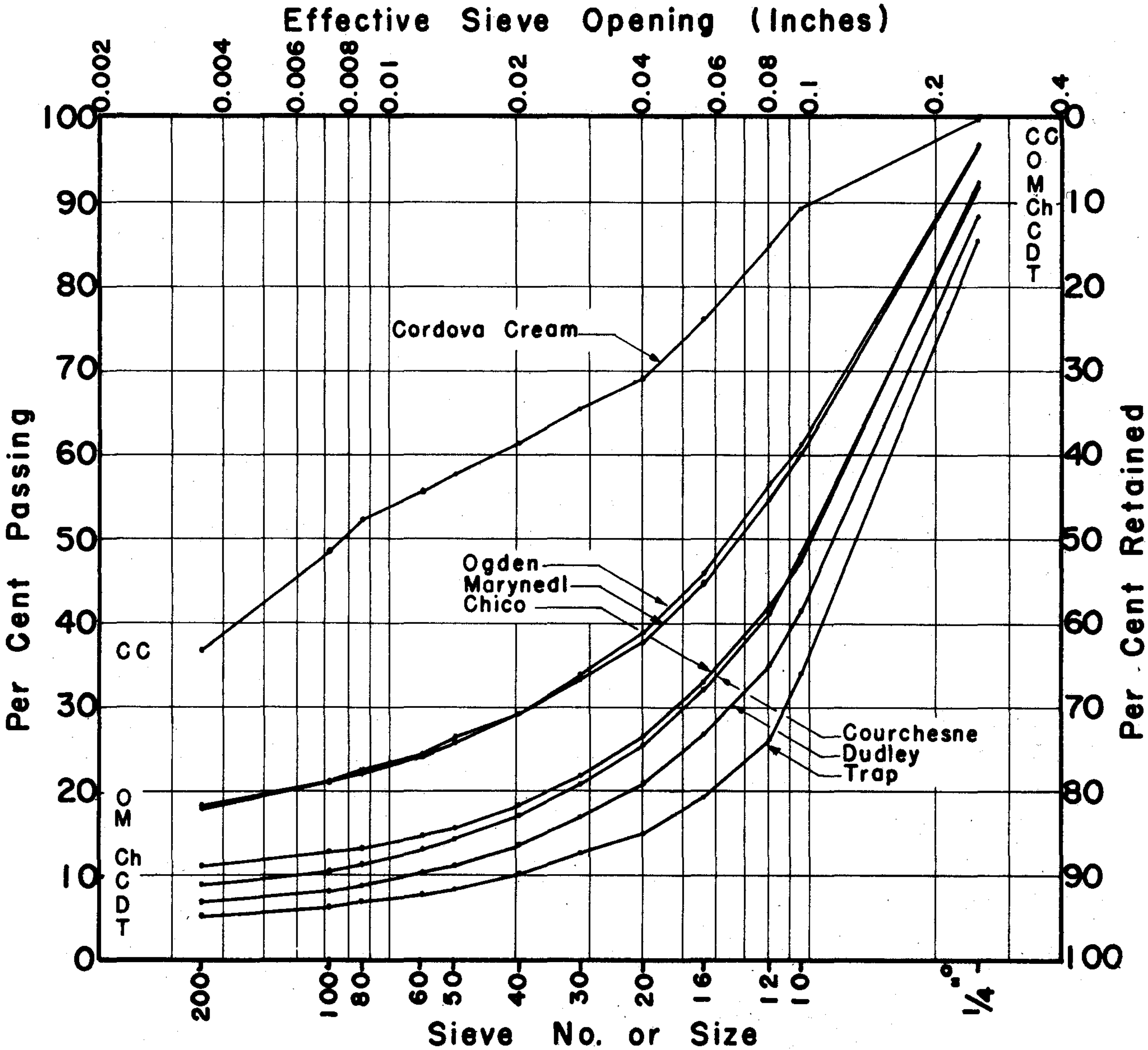


Figure 12

Thus it is evident that the numerical correlation could not be materially improved by making some sieve other than the No. 20 the basis for determining the per cent wear. Furthermore, such a substitution would decrease, in one respect or another, the degree of symmetry between the "B" and "S" grading tests.

Figures 8 and 9 show that the above remarks apply equally as well to the 65, 130, and 225-gram ball abrasive charge results. Therefore, any combination of any one of these three abrasive charges with some sieve other than the No. 20 for determining wear would not yield as good a correlation as has been obtained with the 420-gram balls and the No. 20 sieve.

d. Actual Correlation Better than Numerical Correlation:

The best average numerical correlation thus far obtained was secured with a 5000-gram test charge, a fourteen 420-gram ball abrasive charge, 500 Rattler revolutions, and the No. 20 sieve for determining the per cent wear. The average deviation of the "S" wear from the "B" wear, including Trap and Cordova Cream, was 2.56 per cent (Figure 10), and, in the practical specification range (excluding Trap and Cordova Cream) (Figure 11), 1.78 per cent.

It is now proposed to show that the actual correlation is better than this numerical correlation.

Had an exact numerical correlation been obtained (still assuming the standard "B" test to be perfect), the "S" grading test would have been obviously in error. This is not the non sequitur it might appear to be. One point must be thoroughly understood. The "B" grading test degrades particles with an initial average diameter (0.6435-inch) 2.4 times the size of the "S" grading particle (average diameter of 0.230-inch). In other words, the initial average particle size differential must be borne in mind.

If the rate of progressive degradation of two stones decidedly is dissimilar, the two "S" values should not have the same numerical relation as the two "B" values, and therefore "S" should not be equal to "B" in both cases.

Considering only the standard "B" test, the most obvious example of dissimilarity in the rate of progressive degradation of two stones is furnished by Chico and Courchesne stones. (Review discussion of Figure 3.) Note, in Figure 3, that the loss through sieves larger than the No. 40 is greater for the Courchesne than for the Chico, and the loss through sieves smaller than the No. 40 is greater for the Chico than for the Courchesne. This does not mean that, in relation to Chico, all Courchesne particle sizes with a diameter greater than 0.02-inch are more friable and that all particle sizes with a diameter less than 0.02-inch are tougher. Remember that the degradation is progressive, beginning with particles larger than 0.448-inch diameter. The relative difference in resistance to abrasion must begin at a point, or in a particle size range, considerably greater than the 0.02-inch size. It is impossible to say just where this point, or range, may be, but it is estimated to begin in a size range greater than 0.2-inch. Such a change in resistance to abrasion would, of necessity, be overcome gradually, so that it would become obvious in sizes considerably smaller than the sizes in which the relative change in toughness occurred.

Now let us take Chico and Courchesne "S" grading test charges. In this case the particles already have been reduced to an average diameter of 0.230-inch, or a particle size range of 0.375-inch (3/8-inch screen) to 0.095-inch (No. 10 sieve). Therefore the relative difference between the two stones, on the basis of resistance to abrasion, actually has been changed, and should be, and is evidenced by the two pairs of "S" and "B" values.

Thus far only the specific case of Chico vs Courchesne has been considered. Now, if it can be demonstrated that the smaller sizes of a stone are more, or less, resistant to abrasion than the larger sizes, relative to the average behavior of a number of stones, then it will be yet more evident that all "S" test values should not be numerically equal to their respective "B" test values.

Figure 5 ("B" grading chart) furnishes an excellent medium for this demonstration. In this figure the No. 12 sieve, being the basis for determining the per cent wear, produces a straight line. On the basis of the standard wear test this represents the average behavior of the five correlation stones. It now is desired to analyze the behavior of each of the stones in relation to the average behavior of all five stones in particle size ranges less than 0.0798-inch (effective opening of the No. 12). The No. 20, 50, and 200 sieve data were selected for this purpose, the other data being omitted in order to avoid confusion in interpreting results. (Figure 5 shows that sieves other than the No. 20, 50, and 200 follow the general trend almost exactly.)

Figure 13 presents these data. The plotted points are the complements of the respective values in Table 7, and are identical with the respective points in Figure 5. The solid straight lines are linear curves of regression, and are fitted to the plotted points mathematically by the method of least squares, thus assuring the best fit in each case. The linear equation, $y=bx+a$, is derived from the simultaneous equations $\sum y = na + b\sum x$, and $\sum xy = a\sum x + b\sum x^2$. In this case the per cent of a given stone passing a given sieve constitutes the y value, and the "B" wear (per cent) of that stone constitutes the x value. Thus each linear curve of regression expresses the average behavior of the five stones on the sieve in question.

Figure 13 shows that:

(1) Chico and Ogden follow the average behavior of all five stones almost exactly, irrespective of the particle size.

(2) Dudley loses somewhat more than the average through sieves smaller than the No. 12, but follows the average behavior of all five stones fairly closely. This shows that the smaller sizes are slightly less resistant to abrasion than are the larger sizes. Note that this difference is not cumulative, or progressive. This is demonstrated by the fact that the deviation from the average is approximately constant irrespective of the sieve size.

(3) Courchesne loses considerably less than the average through sieves smaller than the No. 12. Thus the smaller sizes are more resistant to abrasion than are the larger sizes. Note that this difference increases through the No. 50 (and possibly further) as the sieve size decreases.

(4) Maryneal loses considerably more than the average through sieves smaller than the No. 12. Thus the smaller sizes are less resistant to abrasion than are the larger sizes. Note that this difference increases through the No. 50 (and possibly further) as the sieve size decreases.

Comparison of Individual and Average Degradation of Standard "B" Grading Test Charges

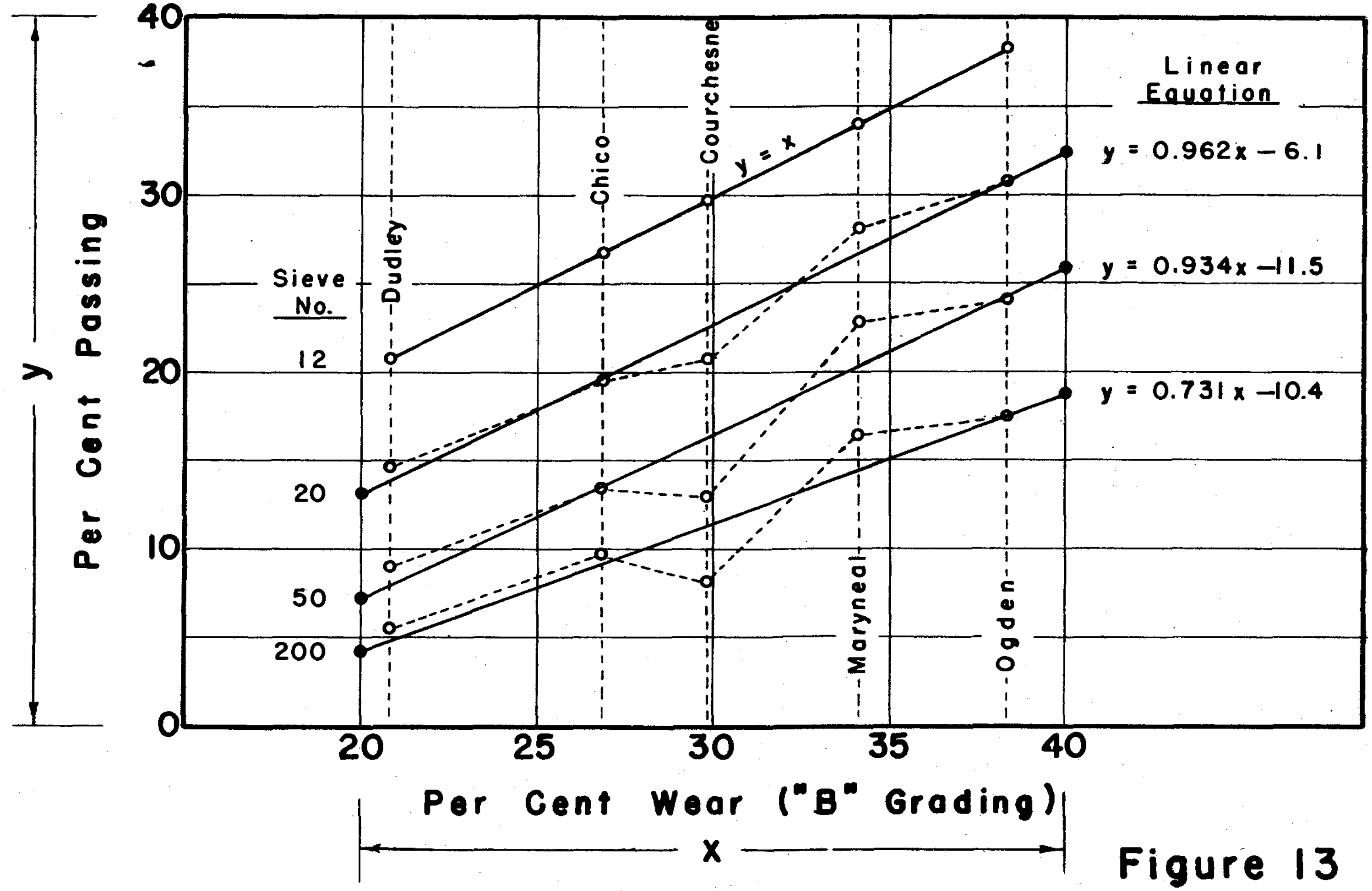


Figure 13

(5) The slope of the average lines becomes slowly but surely less as the sieve size decreases. (See Section D, study of Figure 3, paragraph 4 and "B" grading, paragraph 4.)

Thus it may be stated that, on the basis of the average degradation of the standard "B" grading test charges into sizes smaller than the No. 12 sieve size, Chico and Ogden react normally, Dudley reacts in an approximately normal manner, and Courchesne and Maryneal react abnormally, Courchesne smaller sizes actually being tougher than the larger sizes, and Maryneal smaller sizes actually being more friable than the larger sizes.

Therefore, it is evident that each and all of the "S" values should not be numerically equal to the respective "B" values. On the basis of the data in Figure 12, Chico and Ogden "S" values should be approximately equal to the "B" values, Dudley "S" should be somewhat higher than Dudley "B," Courchesne "S" should be considerably lower than Courchesne "B," and Maryneal "S" should be considerably higher than Maryneal "B." Figure 11 shows that, with one exception, this is exactly the case. Dudley provides the exception, the "S" value being equal almost exactly to the "B" value.

4. <u>Special "S" Grading Tests with Chico Trial Stone</u>:

Inasmuch as the average diameter of the "S" grading test charge particle is considerably smaller than that of the "B" grading test charge particle, it was a distinct surprise to the writer that the 420-gram ball abrasive charge produced the best average correlation. Apparently the increased cushioning, or shock-absorbing action of the larger number of smaller particles partially compensates the effect of the decreased particle diameter.

It was decided to investigate the effect of a smaller test charge upon the correlation. Should better results be secured, well and good; should poorer results be secured, the excellent correlation already obtained would be strengthened greatly by the negative answer.

It was further decided to use all four classes of abrasive charge balls, as nothing was known relative to the action of a test charge of less than 5000 grams.

Some preliminary tests were deemed necessary. In order to conserve the original blended samples an additional 1500 pounds of Chico stone was secured from the Concrete Research bin and "S" grading sizes were prepared and carefully blended in the same manner as were the original correlation samples, except that no standard test charge sizes were prepared. This stone hereinafter will be referred to as "Chico Trial Stone."

Twenty-six "S" grading tests were made on this stone for various purposes. The size of the test charge and the abrasive charges were varied. The data obtained will not be analyzed, but the test results are given in Appendix IV.

A special test series (comprising forty-eight tests) also was run in order to observe the action of smaller test charges. The total weight of the test charge was varied as follows: 5000, 4000, 3000, 2000, 1000, and 500 grams. The four abrasive charges selected for the correlation with the 5000-gram test charge were used in this series, each abrasive charge being a constant throughout the range of test charge sizes. Two tests were made for an average for each condition. The results of these tests appear in Appendix V.

Tables 12A, B, C, and D present these data. Each value is the average of the two respective test values in Appendix V. (To designate the loss through any given sieve as "per cent wear" would be meaningless and misleading under these circumstances.)

Table 12A

Average Sieve Analysis Data on Chico Trial Stone Test Charges of Varying Size, Using Ninety-nine 65-Gram Balls

		Size of Test Charge (Grams)					
	Sieve	5000	4000	3000	2000	1000	500
	(1/4"°	7.8	4.0	2.2	1.1	0.4	0.1
	(No. 10	54.0	42.1	28.7	18.3	6.1	0.6
	(No. 12	59.9	48.1	35.9	23.5	8.4	0.8
Avg.	(No. 16	69.1	59.3	47.7	34.6	14.4	1.1
% Re-	(No. 20	75.3	67.3	57.1	44.8	22.8	1.7
tained	(No. 30	79.2	72.6	64.1	53.1	31.9	4.0
(Cumu-	(No. 40	82.6	77.2	70.1	60.7	41.1	10.9
lative)	(No. 50	84.9	80.5	74.7	66.6	49.4	20.8
	(No. 60	85.9	81.8	76.7	69.5	53.9	27.1
	(No. 80	87.0	83.5	79.1	72.9	58.9	35.1
	(No.100	87.8	84.7	80.8	75.4	62.8	41.4
	(No.200	89.3	86.9	84.1	80.0	70.9	54.6

Table 12B

Average Sieve Analysis Data on Chico
Trial Stone Test Charges of Varying Size,
Using Forty-Five 130-Gram Balls

	Sieve	Size of Test Charge (Grams) 5000	4000	3000	2000	1000	500
Avg. % Retained (Cumulative)	(1/4"○	7.7	3.9	2.5	2.0	1.1	0.2
	(No. 10	54.7	43.2	35.3	30.6	14.8	1.9
	(No. 12	60.3	49.6	41.9	36.4	18.5	2.4
	(No. 16	69.4	60.9	53.6	47.3	27.9	4.6
	(No. 20	75.6	68.7	62.6	56.5	38.0	10.1
	(No. 30	79.4	73.6	68.1	62.9	45.6	17.1
	(No. 40	82.9	78.3	73.9	69.3	54.6	28.8
	(No. 50	85.2	81.5	77.9	73.7	61.3	39.3
	(No. 60	86.2	82.9	79.6	76.0	64.6	43.9
	(No. 80	87.2	84.5	81.6	78.4	68.6	50.8
	(No.100	88.1	85.6	83.1	80.2	71.6	55.9
	(No.200	89.5	87.7	85.9	83.7	77.4	65.7

Table 12C

Average Sieve Analysis Data on Chico
Trial Test Stone Charges of Varying Size,
Using Twenty-five 225-Gram Balls

	Sieve	Size of Test Charge (Grams) 5000	4000	3000	2000	1000	500
Avg. % Retained (Cumulative)	(1/4"○	6.3	4.4	4.3	3.3	1.3	0.2
	(No. 10	53.0	45.4	43.5	40.5	18.9	3.3
	(No. 12	58.4	50.9	48.5	46.1	22.5	4.7
	(No. 16	68.0	61.4	59.2	56.1	33.0	10.1
	(No. 20	74.6	69.0	66.8	63.8	43.2	19.2
	(No. 30	78.5	73.9	71.9	69.0	50.7	28.2
	(No. 40	82.2	78.4	76.7	74.1	58.6	39.8
	(No. 50	84.6	81.6	80.1	77.8	64.6	49.1
	(No. 60	85.7	82.9	81.5	79.4	67.6	53.9
	(No. 80	86.8	84.5	83.3	81.4	71.2	59.7
	(No.100	87.7	85.6	84.5	82.8	73.8	63.7
	(No.200	89.3	87.8	87.0	85.6	79.1	72.3

Table 12D

Average Sieve Analysis Data on Chico
Trial Stone Test Charges of Varying Size,
Using Fourteen 420-Gram Balls

	Sieve	Size of Test Charge (Grams) 5000	4000	3000	2000	1000	500
	(1/4"o	6.0	6.8	6.6	4.8	1.1	0.0
	(No. 10	52.9	50.5	50.2	43.0	21.9	3.9
	(No. 12	58.0	55.1	55.3	48.7	26.2	6.5
Average	(No. 16	67.2	64.6	64.2	58.4	37.9	15.8
% Re-	(No. 20	73.9	71.6	70.8	65.8	48.0	28.4
tained	(No. 30	77.9	76.1	75.4	70.7	55.2	39.1
(Cumu-	(No. 40	81.7	80.0	79.4	75.6	62.6	50.1
lative)	(No. 50	84.2	82.8	82.2	79.0	68.1	58.4
	(No. 60	85.3	84.0	83.5	80.5	70.7	62.5
	(No. 80	86.5	85.4	85.0	82.4	74.0	67.2
	(No. 100	87.3	86.4	86.0	83.7	76.3	70.6
	(No. 200	89.0	88.3	88.1	86.3	80.9	77.5

Figures 14, 15, and 16 are semi-logarithmic presentations of portions of the data in Tables 12-.

Figure 14 (data from Table 12A) shows the degradation of the various size test charges using an abrasive charge of ninety-nine 65-gram balls. There naturally is increased degradation as the size of the test charge is decreased, but the increase is by no means regular in all phases of the degradation. The rate of progressive degradation changes radically.

Figure 15 (data from Table 12D) shows the degradation of the various size test charges using an abrasive charge of fourteen 420-gram balls. There is relatively little difference in the degradation of the 5000, 4000, and 3000-gram test charges, the rate of progressive degradation changing more rapidly as the size of the test charge is further decreased.

Similar figures representing the data in Tables 12B and C were likewise made, but as the trend of the data was intermediate between those shown in Figures 14 and 15 only the two extremes in abrasive charge ball sizes are shown.

A comparison of Figures 14 and 15 shows, in brief, that the 65-gram balls cause a much more rapid increase in degradation, as the size of the test charge decreases, than do the 420-gram balls. The degradation of the 2000-gram test charge with 65-gram balls almost is identical with the degradation of the 1000-gram test charge using 420-gram balls.

Degredation of Chico Trial Stone "S" Grading Test Charges
(Varying Weight of Test Charge; Constant Abrasive
Charge of Ninety-nine 65-Gram Balls)

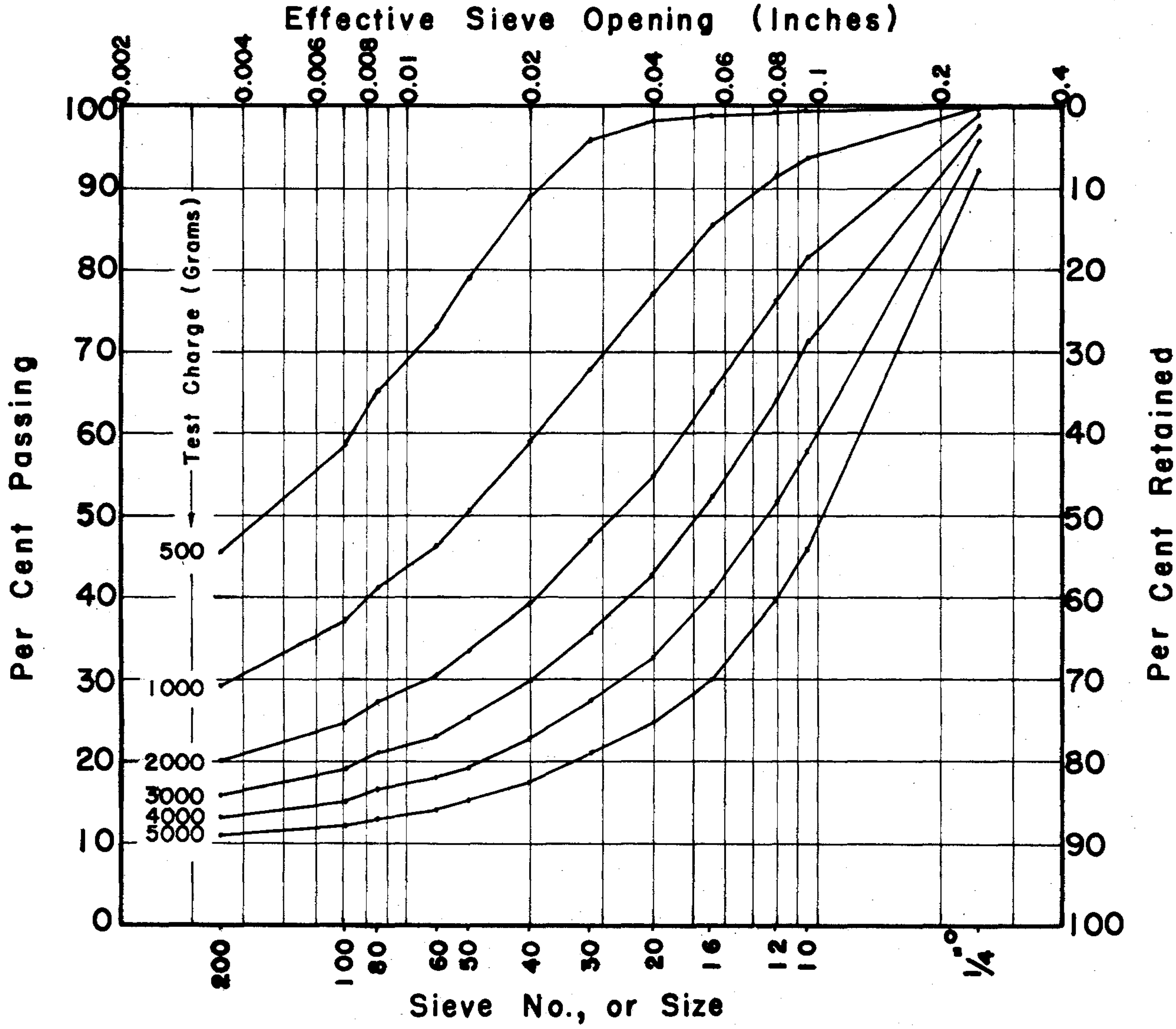


Figure 14

Degredation of Chico Trial Stone "S" Grading Test Charges
(Varying Weight of Test Charge; Constant Abrasive
Charge of Fourteen 420—Gram Balls)

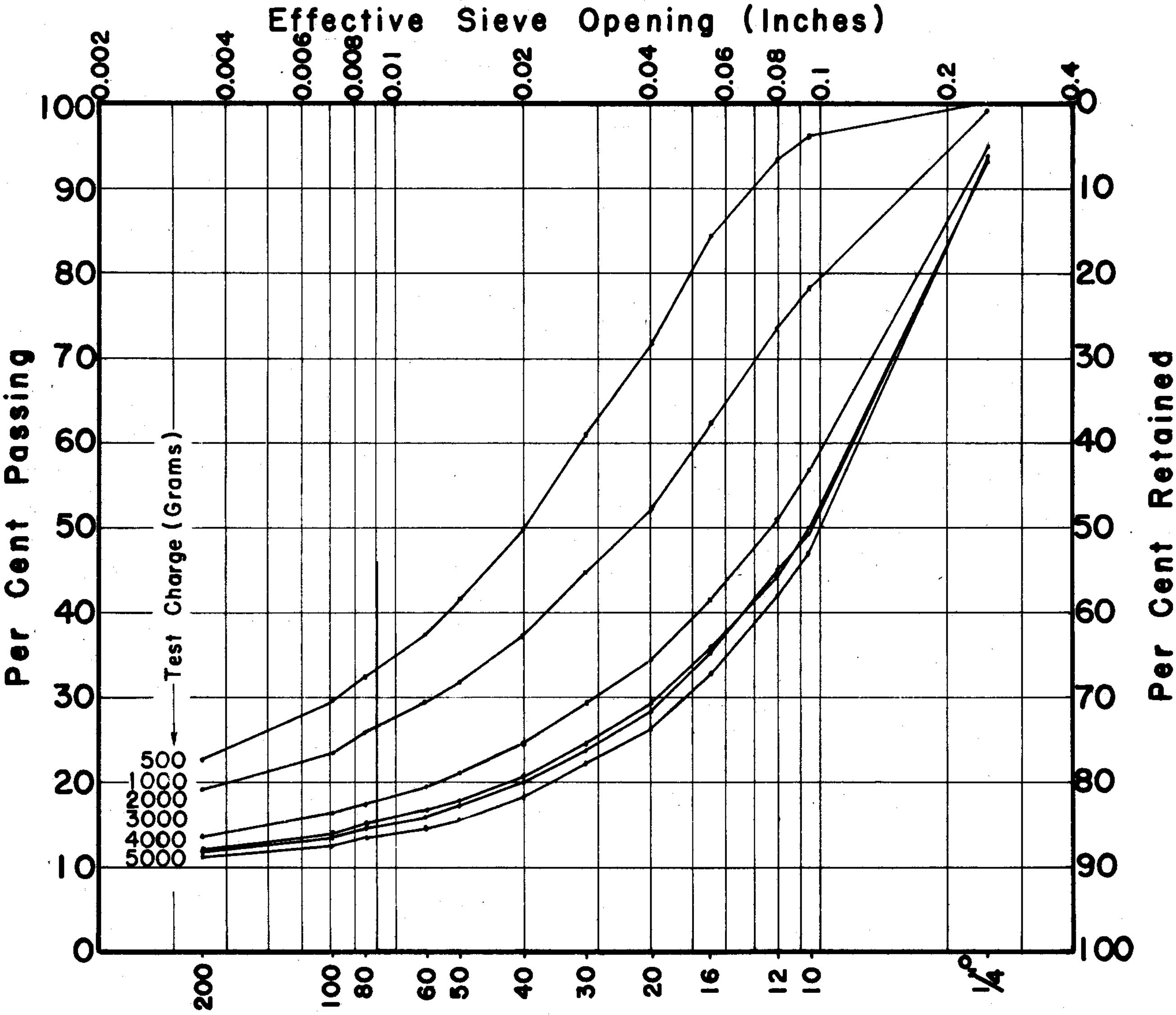


Figure 15

It is clear that the decreased cushioning, or shock-absorbing, action in the smaller test charges changes the progressive degradation radically. It is equally clear that the difference in degradation occasioned by 65 and 420-gram ball abrasive charges (with intermediate stages furnished by 130 and 225-gram ball charges) is much greater in the smaller test charges than in the larger.

Figures 14 and 15, and the discussion thereof, confirm the opinion that the correlation of "S" values with "B" values, using a test charge smaller than 5000 grams, should employ all four classes of balls.

It now becomes necessary to select the optimum size test charge, Figure 16 (data from Tables 12-) shows the degradation of the 1000 and 3000-gram test charges with each of the four classes of balls. The broken line represents the average degradation of the 5000-gram test charge with the four abrasive charges. Each point on this line is the average of the four respective values in Tables 12-. The maximum deviation of any single value from this average is 1.2 per cent. Therefore, for practical purposes, the broken line represents the degradation of the 5000-gram test charge with any one of the four abrasive charges.

Figures also were prepared showing the degradation of the 4000, 2000, and 500-gram test charges with each of the four abrasive charges. The trends of the 4000 and 2000-gram test charge data were intermediate, respectively, to the trends of the 5000 and 3000-gram data, and the 3000 and 1000-gram data. The trend of the 500-gram test charge data was an accentuation of the trend apparent in the 1000-gram test charge data, as may be seen, in part, in Figures 14 and 15.

Two chief factors were considered in selecting the size of the test charge for further investigation: (1) The degradations with the different abrasive charges should differ markedly from each other and from that of the 5000-gram test charge; should there be no marked differences there could be no marked change in the correlation, either for better or for worse. (2) The degradation should maintain the same general characteristics as that of the "B" grading (Figure 3). Were the "S" grading test charge degradation too radically different from that of the "B" grading test charge (as an extreme example note the 500-gram test charge in Figure 14) the entire spirit of the correlation would be lost, even though, by varying the total weight of the abrasive charge, results with one stone on any one sieve could be made to check.

It was realized that, by reducing the total weight of the abrasive charge so that the smaller "S" test charge loss through the No. 20 would be approximately equal to the "B" wear, the degradations would not deviate so radically from the normal (the "B," or the 5000-gram "S," test charge) as those shown in the three preceding figures.

The ratio of the average "B" grading test charge particle diameter to the weight of the test charge is 0.643 (inches) to 5000 (grams). If the same ratio were maintained in the "S" grading test the test charge should weigh 1788 grams.

Considering the above mentioned factors, and the data in Figure 16, a 2000-gram "S" grading test charge was selected for further correlation with the "B" grading test.

5. Correlation with the Following Constants:
2000-Gram Test Charge; 500 Rattler Revolutions;
Wear Equals Per Cent Passing the No. 20 Sieve:

It will be understood that all of the "S" grading tests in this series had the above-mentioned constants.

a. Varying the Abrasive Charge:

"S" grading tests were run on each of the five correlation stones with the 65-gram ball abrasive charge. The number of balls were varied until the sum of the plus deviations of the "S" values from the respective "B" values ("S" greater than "B") was, as nearly as possible, equal to the sum of the minus deviations of the "S" values from the respective "B" values ("S" less than "B").

This procedure was repeated with the 130, the 225, and the 420-gram balls.

The optimum number of balls of each size was found to be as follows:

Class of Balls	Optimum Number of Balls
65-Gram	40
130-Gram	27
225-Gram	18
420-Gram	11

After the optimum number of balls had been ascertained each test was repeated twice so that an average of three test values might be obtained. Three tests also were made on Trap and Cordova Cream with each of the four abrasive charges.

This series comprised one hundred and twenty-four tests, the results of which appear in Appendix VI.

Tables 13A, B, C, and D present the results of this test series. Each of the values in Tables 13- is an average of the three respective test values in Appendix VI. (The individual tests may be identified by the number of balls in the abrasive charge.)

Degredation of Chico Trial Stone
"S" Grading Test Charges

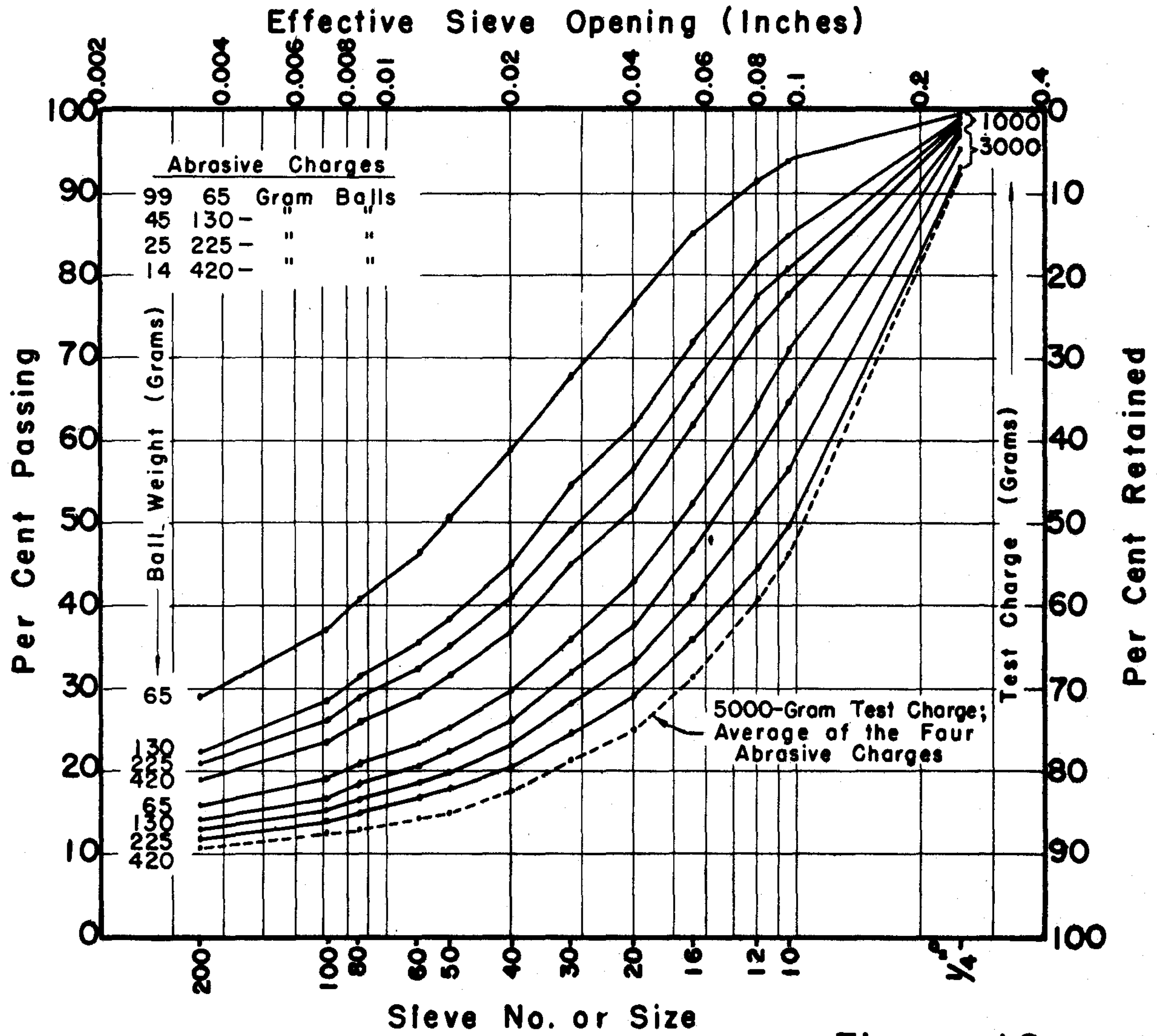


Figure 16

Table 13A

Average Sieve Analysis Data on 2000-Gram Test Charges after "S" Grading Test with Forty 65-Gram Balls

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/4"o	13.8	9.8	9.8	3.9	3.6	29.7	0.0
No. 10	60.7	53.4	53.7	36.7	36.2	76.6	1.3
No. 12	66.9	60.3	60.6	43.5	42.8	80.1	2.6
No. 16	75.3	69.5	70.1	53.7	53.4	85.1	7.6
*No. 20	80.63	75.43	76.00	60.40	60.55	88.03	14.60
No. 30	84.6	80.2	80.6	65.9	66.4	90.2	21.9
No. 40	87.5	83.4	83.8	69.7	70.5	91.7	27.9
No. 50	89.6	85.8	86.3	73.0	73.8	92.8	32.9
No. 60	90.7	86.9	87.5	74.6	75.6	93.4	35.8
No. 80	91.8	88.2	88.8	76.9	77.5	94.1	40.8
No. 100	92.4	88.9	89.6	78.0	78.7	94.4	44.2
No. 200	94.0	90.6	91.4	81.8	82.4	95.3	58.6
*Wear (%)	19.37	24.57	24.00	39.60	39.45	11.97	85.40

Table 13B

Average Sieve Analysis Data on 2000-Gram Test Charges after "S" Grading Test with Twenty-Seven 130-Gram Balls

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/4"o	15.1	10.7	11.0	3.5	3.8	26.8	0.0
No. 10	63.1	54.0	55.8	36.6	36.7	73.7	0.4
No. 12	68.2	60.2	61.8	42.7	42.5	77.7	1.0
No. 16	75.4	68.6	69.8	52.4	52.6	83.1	4.3
*No. 20	80.12	74.13	75.35	59.07	59.17	86.37	10.47
No. 30	84.0	78.8	79.9	64.7	65.0	88.9	17.9
No. 40	86.9	81.9	83.2	68.6	69.1	90.6	24.4
No. 50	89.1	84.4	85.7	71.9	72.6	91.9	29.7
No. 60	90.0	85.5	87.1	73.6	74.2	92.6	32.8
No. 80	91.4	86.8	88.5	75.8	76.6	93.4	37.9
No. 100	91.9	87.5	89.4	77.2	77.8	93.8	41.7
No. 200	93.5	89.3	91.5	81.6	81.4	94.9	56.4
*Wear (%)	19.88	25.87	24.65	40.93	40.83	13.63	89.53

Table 13C

Average Sieve Analysis Data on 2000-Gram Test Charges after "S" Grading Test with Eighteen 225-Gram Balls

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/4"o	19.0	13.5	12.8	3.6	4.0	26.9	0.0
No. 10	65.0	58.7	58.7	38.2	39.2	74.4	0.2
No. 12	69.9	64.0	63.8	44.5	45.5	78.0	0.5
No. 16	76.3	70.6	71.4	53.2	53.6	83.1	3.0
*No. 20	80.90	75.67	76.53	59.27	59.88	86.32	8.45
No. 30	84.5	79.9	80.3	64.4	65.0	88.9	16.0
No. 40	87.0	82.9	83.3	68.3	69.0	90.5	22.6
No. 50	89.1	85.0	85.7	71.6	72.3	91.9	28.3
No. 60	90.1	86.2	86.7	73.2	74.0	92.6	31.5
No. 80	91.3	87.4	88.2	75.4	76.1	93.4	37.1
No.100	92.0	88.1	88.9	76.7	77.4	93.8	40.6
No.200	93.4	89.9	90.6	80.9	81.0	95.1	54.8
*Wear (%)	19.10	24.33	23.47	40.73	40.12	13.68	91.55

Table 13D

Average Sieve Analysis Data on 2000-Gram Test Charges after "S" Grading Test with Eleven 420-Gram Balls

	Average Per Cent Retained (Cumulative)						
	Correlation Stones					E. P. Stones	
Sieve	D	Ch	C	M	O	T	CC
1/4"o	16.9	11.7	12.0	3.1	3.4	25.9	0.0
No. 10	64.4	55.5	57.0	35.6	37.0	72.4	0.1
No. 12	69.1	61.0	63.4	41.9	43.1	76.6	0.4
No. 16	75.6	68.7	69.8	51.6	52.5	82.0	2.7
*No. 20	80.20	73.83	75.08	58.08	58.92	85.52	8.22
No. 30	83.7	78.3	79.5	63.3	64.5	88.1	15.3
No. 40	86.5	81.4	82.8	67.4	68.7	89.9	21.8
No. 50	88.6	83.8	85.4	70.8	72.1	91.4	27.6
No. 60	89.7	85.0	86.6	72.6	73.9	92.1	30.6
No. 80	90.9	86.3	88.3	74.9	76.1	93.0	36.3
No.100	91.6	87.0	89.1	76.2	77.4	93.5	39.9
No.200	93.3	88.9	91.1	80.7	81.2	94.8	54.3
*Wear (%)	19.80	26.17	24.92	41.92	41.08	14.48	91.78

Figures 17 and 18 present the data (omitting the 1/4-inch screen) in Tables 13A and B, and Tables 13C and D, respectively. As the stones are plotted along the abscissas according to their respective "B" wears these figures may be compared directly with Figures 5, 8, and 9. Without going into detail, it may be seen, by a comparison of Figures 17 and 18 with Figures 8 and 9, that the degradation of the 2000-gram test charges is very similar to that of the 5000-gram test charge. In view of the data obtained from the special tests on Chico Trial stone (Section D:4) the similarity is surprising. The similarities in the degradation of the "B" test charge (Figure 5) and the 2000-gram "S" test charge (Figures 17 and 18) are apparent; the differences are, for the most part, occasioned by the initial particle size differential.

Table 14A presents a summary of the correlation of the "S" and "B" tests obtained using four ball weights, a 2000-gram test charge, 500 Rattler Revolutions, and the No. 20 sieve for determining the "S" wear. The standard "B" wear values are taken from Table 7, and the "S" wear values from Tables 13-.

Table 14A

Summary of Correlation Data
(Constants for "S" Grading Test: 2000-Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve)

Stones		"B" Wear (%)	"S" Wear (Per Cent) 40 65-Gm. Balls	27 130-Gm. Balls	18 225-Gm. Balls	11 420-Gm. Balls
	(Dudley	20.84	19.37	19.88	19.10	19.80
Corre-	(Chico	26.80	24.57	25.87	24.33	26.17
lation	(Courchesne	29.82	24.00	24.65	23.47	24.92
Stones	(Maryneal	34.06	39.60	40.93	40.73	41.92
	(Ogden	38.33	39.45	40.83	40.12	41.08
E. P.	(Trap	9.43	11.97	13.63	13.68	14.48
Stones	(Cordova C.	72.44	85.40	89.53	91.55	91.78

Table 14B presents the deviations of the "S" values from the respective "B" values as shown in Table 14A.

Table 14B

Deviation of "S" Wear from "B" Wear
(Data Taken from Table 14A)

Item		Deviation ("S" from "B") 40 65-Gm. Balls	27 130-Gm. Balls	18 225-Gm. Balls	11 420-Gm. Balls
Correlation Stones	(Dudley	-1.47	-0.96	-1.74	-1.04
	(Chico	-2.23	-0.93	-2.47	-0.63
	(Courchesne	-5.82	-5.17	-6.35	-4.90
	(Maryneal	+5.54	+6.87	+6.67	+7.86
	(Ogden	+1.12	+2.50	+1.79	+2.75
End-Point Stones	(Trap	+2.54	+4.20	+4.25	+5.05
	(Cordova C.	+12.96	+17.09	+19.11	+19.34
Correlation and End-Point Stones	(Total (+)	22.16	30.66	31.82	35.00
	(Total (-)	9.52	7.06	10.56	6.57
	(Total	31.68	37.72	42.38	41.57
	(Average	4.53	5.39	6.05	5.94
Correlation Stones	(Total (+)	6.66	9.37	8.46	10.61
	(Total (-)	9.52	7.06	10.56	6.57
	(Total	16.18	16.43	19.02	17.18
	(Average	3.24	3.29	3.80	3.44

Figure 19 presents the data on the correlation and end-point stones in Table 14A graphically. Figure 20 presents the data on the correlation stones in Table 14A. It is merely an enlargement of the section indicated on Figure 19. The deviations (from Table 14B) are shown in tabular form on these figures for convenience.

A comparison of Figures 19 and 10, which include the extreme conditions, shows that:

(1) When testing the extreme condition of toughness (Trap) the 2000-gram test charge yields approximately as good a numerical correlation as the 5000-gram test charge, but when testing the extreme condition of friability (Cordova Cream) the 2000-gram test charge is radically in error.

(2) The best average numerical correlation (the lowest average deviation) secured with the 2000-gram test charge (average deviation equals 4.50 per cent wear with an abrasive charge of forty 65-gram balls) is considerably worse than the worst average numerical correlation obtained with the 5000-gram test charge (average deviation equals 3.57 per cent with an abrasive charge of ninety-nine 65-gram balls).

Figure 20 shows that there is very little difference, in the degree of numerical correlation obtained with the 2000-gram test charge, between any two of the four abrasive charges.

A comparison of Figures 20 and 11, which exclude the extreme conditions, shows that:

Degradation of "S" Grading Test Charges
(Constant 2000 Gram Test Charge)

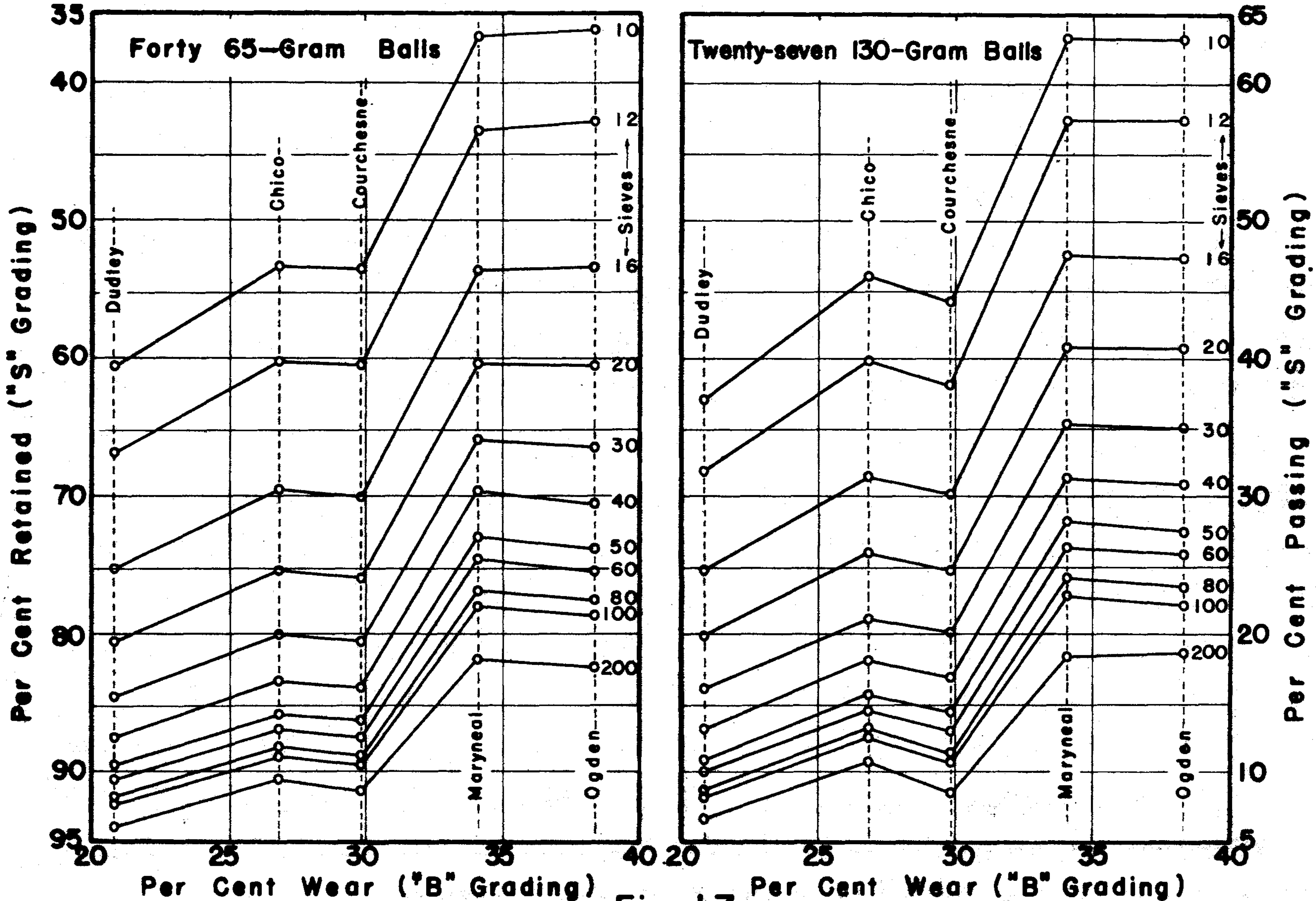


Fig. 17

Degradation of "S" Grading Test Charges
(Constant 2000 Gram Test Charge)

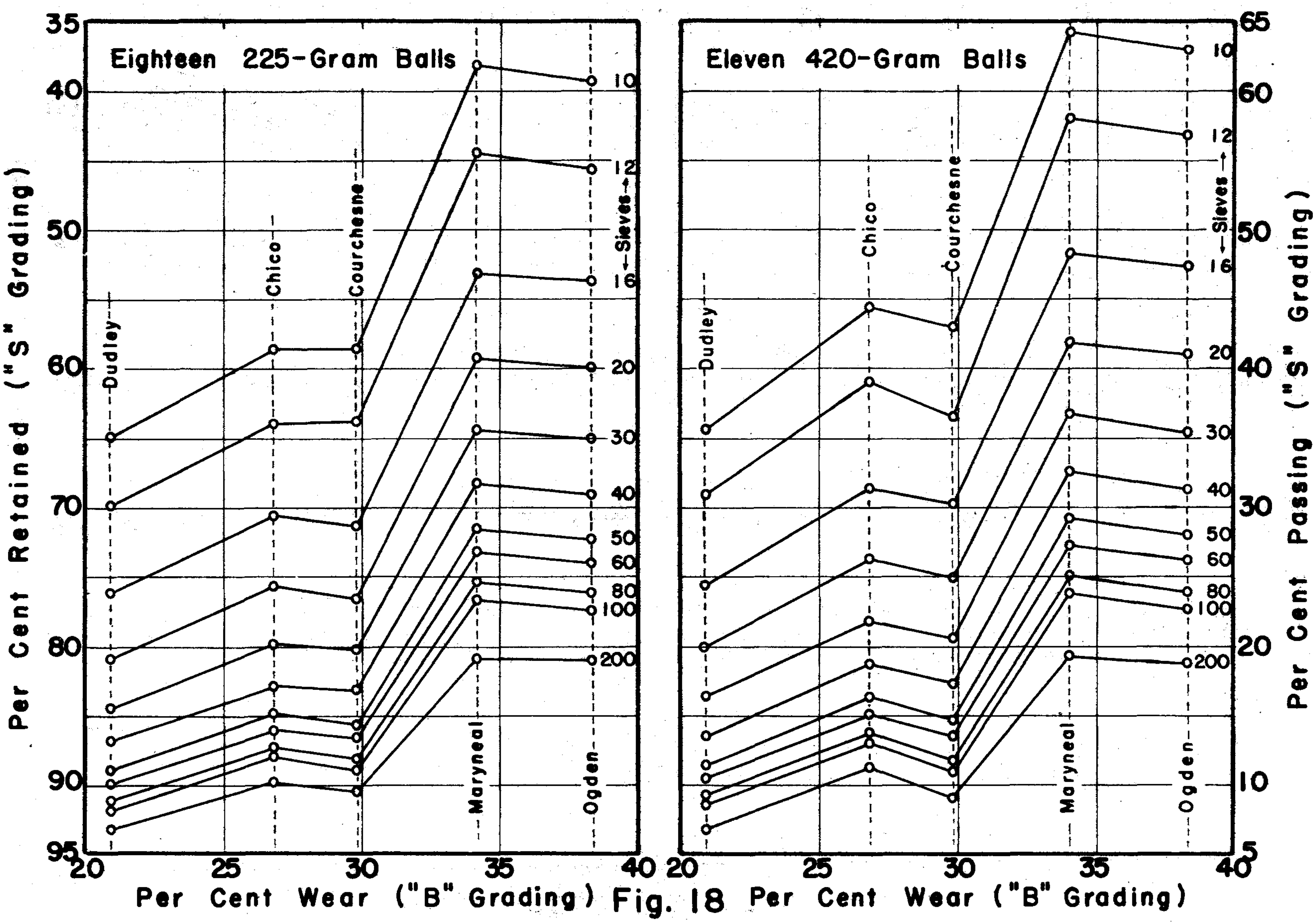


Fig. 18

Correlation of "S" Test With "B" Test (Constants: 2000-Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve.)

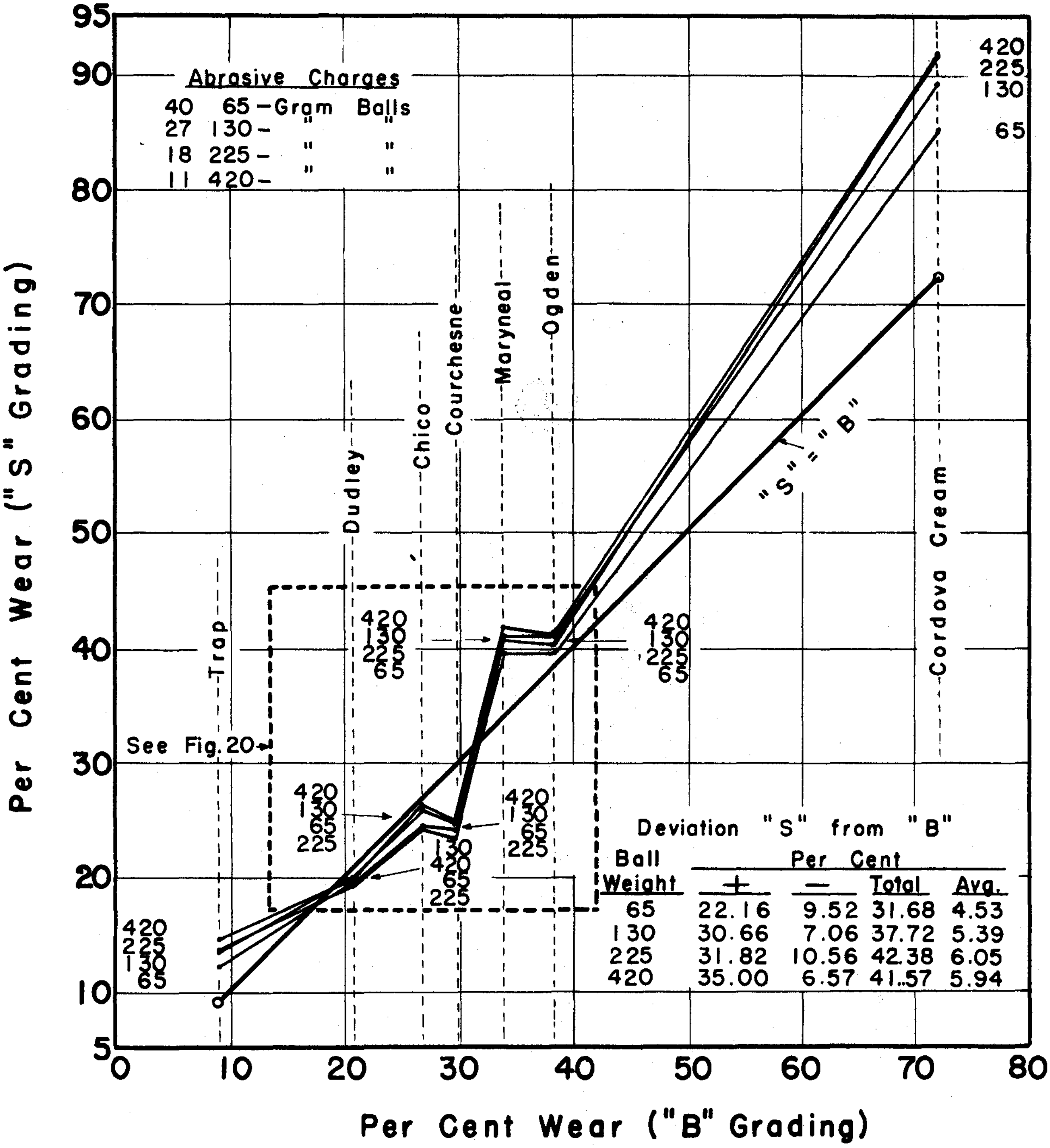


Figure 19

Correlation of "S" Test With "B" Test (Constants: 2000-Gram Test Charge; 500 Rattler Revolutions; "S" Wear Equals Per Cent Passing No. 20 Sieve)

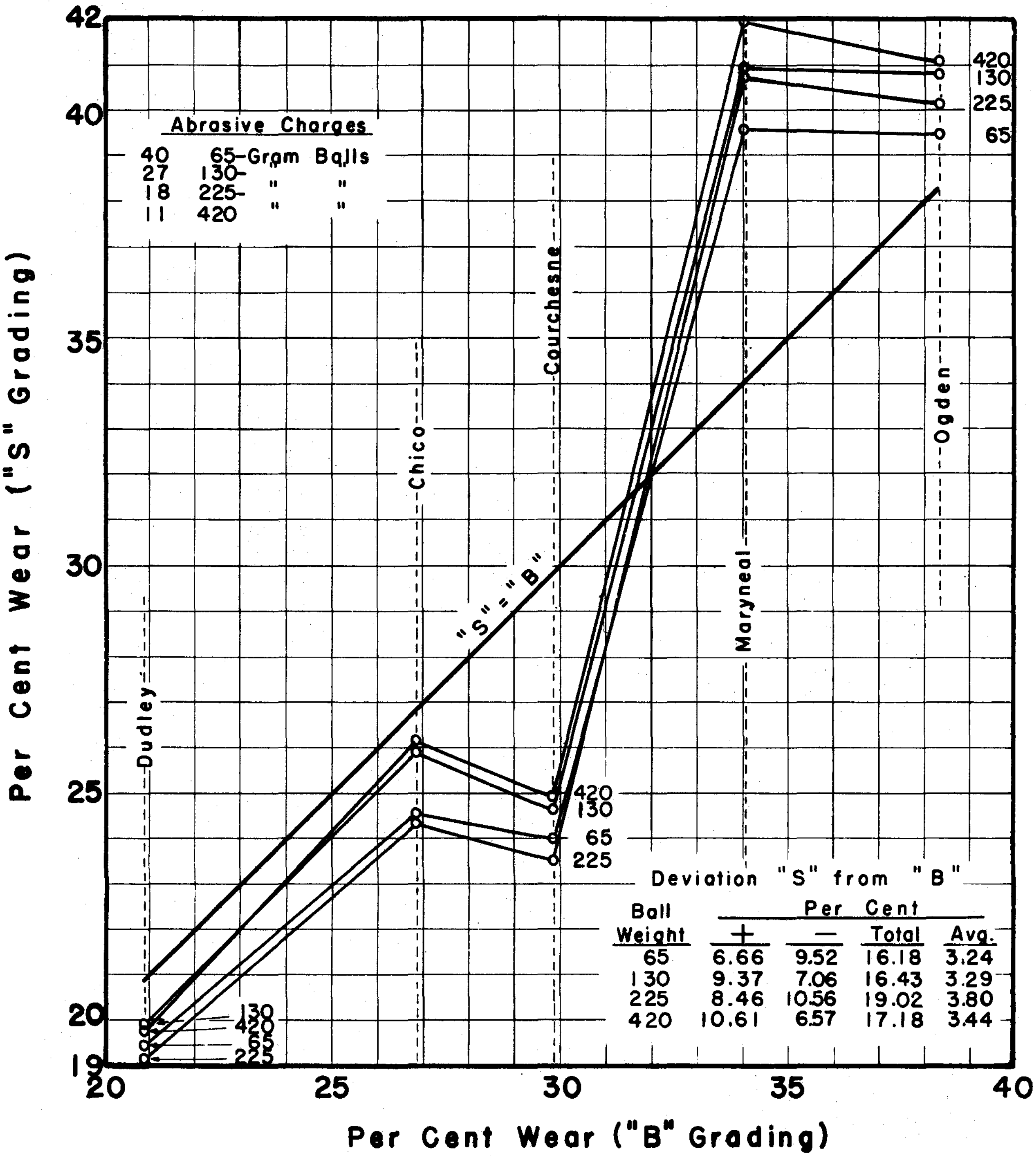


Figure 20

(1) The best average numerical correlation (the lowest average deviation) secured with the 2000-gram test charge (average deviation equals 3.24 per cent) is only slightly better than the worst average numerical correlation obtained with the 5000-gram test charge (average deviation equals 3.52 per cent).

(2) The lowest average deviation with the 2000-gram test charge (3.24 per cent) is almost twice the lowest average deviation obtained with the 5000-gram test charge (1.78 per cent).

Thus, taking into consideration both the practical specification range and the extreme conditions of resistance to abrasion, it is clear that the 2000-gram "S" grading test charge is much inferior to the 5000-gram charge. Furthermore, it is not reasonable to suppose that a test charge intermediate in weight between 2000 and 5000 grams would improve the 5000-gram test charge correlation materially, if at all.

b. Sieve for Determining Per Cent Wear:

Using the No. 20 sieve to determine the per cent wear the 2000-gram test charge was found to be inferior to the 5000-gram test charge. Would some sieve other than the No. 20 yield a better correlation? Figures 17 and 18 answer this question. Note that each segment of the sieve lines adjacent to the No. 20 sieve line is almost exactly parallel with the corresponding segment of the No. 20 sieve line. Therefore, the correlation could not be materially improved by substituting any sieve (within reason) in place of the No. 20 for determining the per cent wear.

6. Rattler Revolutions Kept Constant at 500:

The following possible variables in the correlation of the "S" grading test with the "B" grading test have been disposed of: (1) grading of the test charge; (2) total weight of the test charge; (3) sieve for determining wear; (4) size, or weight, of the individual abrasive charge balls; (5) number of balls constituting, or total weight of, the abrasive charge.

But one possible variable remains; namely, the number of revolutions of the Rattler.

It was decided that the "S" grading test should employ 500 Rattler revolutions for the following major reasons:

(1) A good numerical correlation has already been obtained, the actual correlation being much better than the numerical. It is almost certain that the numerical correlation could not be improved materially by varying the number of Rattler revolutions.

(2) Should the "S" test employ a different number of revolutions than is used for the standard test, dissatisfaction and misunderstanding would be certain to ensue. Producers and engineers alike would ask "why?" The only answer which could be given to this question would be "to improve the numerical correlation between the two tests." The logical, and very evident, rebuttal to this answer would be that such action was unjustifiable on the grounds that the spirit of the standard test was violated. An amplification of this statement will constitute the third point.

(3) The standard abrasion test measures the resistance of an aggregate to a specified amount of abrasion. Thus, aggregates may be evaluated on the basis of their service value, or in comparison with one another. As it is not the purpose of this investigation to question the accuracy of the standard test as a measure of quality, we are interested only in comparative values. Standard test values may show stone "X" to have a wear of 20 per cent and stone "Y" to have a wear of 40 per cent. Thus, in comparing "X" and "Y," we may say that: (1) "Y" wears 20 per cent more than "X"; (2) "Y" wears twice as much as "X." This numerical difference, or this ratio, depending upon the purposes of the comparison, should not be altered. Should the number of Rattler revolutions be varied the test values of two stone would not bear a constant relation to each other. A simple demonstration of this statement follows:

A "B" grading test charge of Dudley limestone was run 300 revolutions in the Rattler. The charge was removed and shaken thoroughly over the No. 12 sieve. Care was taken to lose no dust. The material retained upon the No. 12 sieve was weighed and the per cent wear calculated. The entire test charge (that retained, and that passing, the No. 12) was returned to the Rattler and the test continued, the per cent wear being obtained in like manner at the end of 500, 750, 1000, and 2000 revolutions. A second sample was run in identical fashion so that an average value might be obtained. The above test was repeated using Ogden Limestone. (The test charges were not washed prior to determining the per cent wear, but as both stones received the same treatment this is not objectionable.) (The standard "B" grading abrasive charge was employed in all tests.)

Table 15 presents the results of this test series. Each value is the average of two test values. The "Ratio" was secured by dividing the per cent wear of Ogden by the per cent wear of Dudley.

Table 15

Effect of Varying the Number of Rattler Revolutions

No. of Rattler Revolutions	Per Cent Wear		Numerical Difference	Ratio
	Dudley	Ogden		
300	12.7	24.6	11.9	1.9
*500	20.7	38.1	17.4	1.8
750	30.7	51.9	21.2	1.7
1000	39.7	64.1	24.4	1.6
2000	68.9	95.7	26.8	1.4

*Standard Test.

Table 15 shows that the relationship (as measured by abrasive test values) between two stones may vary markedly as the number of Rattler revolutions varies. It is clear, therefore, that a factor which so obviously alters the basic principle of the standard test should not be introduced into the "S" grading test.

E. <u>The Standard "S" Grading Test</u>:

In view of the results obtained, the following Los Angeles Rattler test was selected as the standard "S" grading test:

<u>Test Charge</u>: The test charge shall consist of 2500 grams of 3/8-inch (round-hole screen) to 1/4-inch (round-hole screen) material and 2500 grams of 1/4-inch (round-hole screen) to No. 10 (square mesh sieve) material. The screens and sieve shall comply with the requirements listed in A.A.S.H.O. Method T-27-38 and A.S.T.M. Designation E11-38T.

<u>Abrasive Charge</u>: The abrasive charge shall consist of fourteen 1-7/8-inch steel balls. The weight of each ball shall be 422.5 $\pm$ 17.5 grams, and the total weight of the charge shall be 5834 $\pm$ 25 grams.

(This ball is the standard Los Angeles Rattler abrasive charge ball as specified in A.A.S.H.O. Method T-96. The standard "A" and "B" grading abrasive charges of 5000 $\pm$ 25 grams (twelve balls) and 4583 $\pm$ 25 grams (eleven balls) indicate an average ball weight of 416.7 grams. The "S" grading abrasive charge of 5834 $\pm$ 25 grams assumes the same average ball weight and allows the same tolerance. Note, in Appendix III, that some of the fourteen ball charges exceeded this tolerance by a small amount (maximum of 61 grams). Total abrasive charge weights had not been specified at that time. In addition to the fact that the variation was not great, note that the average numerical correlation could have been affected only slightly, as a decrease of the plus deviations would have been accompanied by a corresponding increase of the minus deviations.)

<u>Sieve for Determining Wear</u>: After the abrasion test, that portion of the test charge, expressed as a percentage by weight of the total test charge, which passes a No. 20 sieve (U. S. standard sieve series) shall be known as the per cent wear. The sieve shall comply with requirements listed in A.A.S.H.O. Method T-27-38 and A.S.T.M. Designation E11-38T.

The standard "S" grading test shall conform with the procedure given in A.A.S.H.O. Method T-96 with the above exceptions, and the following exceptions:

(1) The degraded test charge shall be sieved over the No. 20 after washing. This is important. In some types of stone the dust binds relatively large particles together. While washing may remove the very fine dust it will not remove these larger particles which will pass the No. 20. (If desirable, the degraded test charge may be sieved over the No. 20 prior to washing that which is retained, but in this case the material must be sieved on the No. 20 again after washing and drying.) (Care should be taken not to overload the sieve, nor should very large pieces be shaken on the sieve.)

(2) The parenthetical note in Method T-96 regarding the loss after 100 revolutions should be ignored. Our conclusions (see Concrete Research Project No. 100) show the 100-Revolution loss to be worthless as an indicator of the uniformity of the sample.

F. Check on Accuracy of Correlation:

In order to check the accuracy of the correlation of the standard "B" and "S" grading tests the thirteen correlation-check stones were tested. Three "A," three "B," and three "S" grading tests were made on each stone. The standard "S" grading test (Section E) was employed. These test results appear in Appendices VII, VIII, and IX, respectively.

Tables 16A, B, and C present, respectively, the sieve analysis data on the various "A," "B," and "S" grading test charges after testing. Each value in these tables is the average of the three respective values as shown in the Appendices.

It was necessary to designate the various stones by symbols, as follows:

Correlation-Check Stones	Symbol
Allamore Rhyolite	AR
Beckmann Limestone	BL
Brownwood Limestone	BrL
Denison Limestone	DL
Dittlinger Limestone	DtL
Hamlin Limestone	HL
Huntsville Quartzite	HQ
Huntsville Quartzitic Sandstone	HQS
Palo Pinto Limestone	PPL
Quitaque Quartzite	QQ
Servtex Limestone	SL
Trinity Quartzite	TQ
Trinity Quartzitic Sandstone	TQS

Table 16A

Average Sieve Analysis Data on
Correlation-Check Stones Test
Charges after Standard "A" Grading Test

	Average Per Cent Retained (Cumulative)						
Sieve	AR	BL	BrL	DL	DtL	HL	HQ
1"	5.4	3.2	7.1	9.2	2.8	4.1	4.9
3/4"	24.2	10.9	22.6	21.9	14.0	16.2	20.4
1/2"	37.1	17.2	30.7	31.0	19.6	23.1	27.6
3/8"	49.0	23.0	42.7	38.8	23.9	29.9	37.2
3/8"°	53.0	26.1	46.9	42.1	26.0	32.5	40.6
1/4"°	62.6	36.4	57.1	51.2	32.9	39.6	48.9
No. 10	75.9	56.4	71.0	65.9	47.2	53.5	63.3

(Continued next page)

Table 16A (Continued)

Sieve	Average Per Cent Retained (Cumulative)						
	AR	BL	BrL	DL	DtL	HL	HQ
*No. 12	77.44	58.57	72.71	67.97	49.19	55.75	65.26
No. 16	80.4	63.0	76.1	71.4	52.6	59.4	68.6
No. 20	82.8	66.5	78.8	74.2	55.3	62.5	71.4
No. 30	85.0	69.1	81.1	76.4	57.8	65.0	74.1
No. 40	86.9	71.8	83.2	78.6	61.1	67.3	77.3
No. 50	88.6	74.0	85.1	80.3	64.5	69.3	81.6
No. 60	89.5	75.1	86.0	81.2	66.4	70.3	83.7
No. 80	90.6	76.6	87.3	82.5	69.2	71.5	86.7
No.100	91.3	77.6	88.0	83.2	71.0	72.2	88.2
No.200	93.1	80.5	90.1	85.4	76.8	74.3	92.7
*Wear (%)	22.56	41.43	27.29	32.03	50.81	44.25	34.74

Sieve	Average Per Cent Retained (Cumulative)					
	HQS	PPL	QQ	SL	TQ	TQS
1"	4.9	6.4	4.5	3.9	4.7	5.7
3/4"	20.4	22.8	22.0	19.1	19.1	17.2
1/2"	28.3	31.7	32.2	26.5	27.7	23.5
3/8"	37.7	40.8	43.2	35.1	36.3	29.9
3/8"°	40.9	44.7	47.4	38.6	40.0	32.3
1/4"°	49.2	53.9	58.7	49.4	49.5	39.1
No. 10	63.3	68.1	73.9	66.0	65.1	52.5
*No. 12	65.37	70.27	75.86	68.21	67.23	54.51
No. 16	68.8	73.6	79.1	72.3	70.9	58.6
No. 20	71.9	76.6	82.0	75.7	73.6	62.7
No. 30	75.0	79.1	84.0	78.6	76.0	67.0
No. 40	78.6	81.3	85.9	81.2	78.3	73.3
No. 50	82.6	83.4	87.6	83.4	80.8	79.2
No. 60	84.6	84.4	88.5	84.5	82.1	81.6
No. 80	87.6	85.8	89.9	86.0	85.5	85.0
No.100	89.0	86.6	90.8	86.8	87.1	86.8
No.200	93.6	89.1	93.4	89.2	92.2	91.9
*Wear (%)	34.63	29.73	24.14	31.79	32.77	45.49

Table 16B

Average Sieve Analysis Data on Correlation-Check Stones Test Charges after Standard "B" Grading Test

Sieve	Average Per Cent Retained (Cumulative)						
	AR	BL	BrL	DL	DtL	HL	HQ
1/2"	12.4	2.3	7.4	6.1	1.7	3.7	5.0
3/8"	32.5	9.8	25.2	18.3	7.6	13.5	18.2
3/8"O	39.7	14.1	32.9	24.7	10.7	18.1	23.7
1/4"O	57.5	30.2	50.2	40.9	22.5	32.2	39.5
No. 10	76.9	57.1	71.1	65.6	47.0	57.4	62.4
*No. 12	78.77	60.07	73.46	68.03	50.35	60.27	64.81
No. 16	82.1	64.9	77.2	72.5	54.1	64.6	69.1
No. 20	84.1	68.5	80.1	75.5	57.2	67.6	72.3
No. 30	86.6	71.4	82.5	78.0	60.3	69.8	75.1
No. 40	88.4	73.7	84.5	80.0	63.1	71.7	78.2
No. 50	89.9	75.6	86.2	81.5	66.2	73.0	82.4
No. 60	90.6	76.5	86.9	82.2	67.9	73.7	84.4
No. 80	91.5	77.9	88.0	83.3	70.5	74.3	87.2
No.100	92.0	78.5	88.6	83.9	71.9	74.7	88.5
No.200	93.5	81.0	90.4	85.5	77.2	75.8	92.8
*Wear (%)	21.23	39.93	26.54	31.97	49.65	39.73	35.19

Sieve	Average Per Cent Retained (Cumulative)					
	HQS	PPL	QQ	SL	TQ	TQS
1/2"	3.7	6.1	6.6	2.7	3.4	3.1
3/8"	14.9	19.5	24.0	15.4	16.3	11.0
3/8"O	20.7	26.4	32.8	22.0	21.9	14.6
1/4"O	35.9	43.5	51.4	39.4	38.5	26.9
No. 10	60.8	67.5	74.3	64.8	63.1	50.5
*No. 12	63.59	70.17	76.65	67.92	66.55	53.61
No. 16	68.5	74.5	80.4	72.8	71.1	58.9
No. 20	72.2	77.8	83.3	76.5	74.2	63.6
No. 30	75.6	80.3	85.4	79.7	76.7	68.5
No. 40	79.5	82.5	87.4	82.2	79.1	74.8
No. 50	83.4	84.3	88.9	84.4	81.4	80.5
No. 60	85.2	85.1	89.8	85.3	82.8	82.9
No. 80	88.1	86.4	90.9	86.7	85.9	86.1
No.100	89.5	87.0	91.6	87.4	87.9	87.6
No.200	93.9	89.1	94.0	89.5	92.4	92.6
*Wear (%)	36.41	29.83	23.35	32.08	33.45	46.39

Table 16C

Average Sieve Analysis Data on Correlation-Check Stones Test Charges After Standard "S" Grading Test

Sieve	Average Per Cent Retained (Cumulative)						
	AR	BL	BrL	DL	DtL	HL	HQ
1/4"O	6.8	2.1	7.1	4.9	1.1	1.0	2.7
No. 10	52.6	36.6	48.7	44.6	25.3	28.6	38.7
No. 12	59.4	43.5	55.5	51.6	31.8	36.7	45.7
No. 16	69.0	54.1	65.6	62.1	41.8	49.1	56.0
*No. 20	75.41	61.08	72.04	68.74	48.85	57.03	62.93
No. 30	80.4	66.4	76.7	73.8	54.7	62.9	68.2
No. 40	83.8	70.6	80.7	77.5	59.9	67.3	73.7
No. 50	86.5	73.7	83.6	80.1	64.7	70.3	79.9
No. 60	87.6	75.0	84.8	81.3	67.0	71.4	82.7
No. 80	89.1	76.7	86.3	82.6	70.1	72.7	86.1
No.100	89.8	77.6	87.1	83.2	71.7	73.2	87.8
No.200	91.8	79.9	89.0	84.9	76.6	74.4	92.4
*Wear (%)	24.59	38.92	27.96	31.26	51.15	42.97	37.07

Sieve	Average Per Cent Retained (Cumulative)					
	HQS	PPL	QQ	SL	TQ	TQS
1/4"O	2.2	5.4	7.7	5.1	3.7	1.0
No. 10	37.4	45.8	56.3	45.0	43.1	27.1
No. 12	44.7	52.6	62.7	52.4	50.3	34.6
No. 16	55.5	63.0	71.6	62.7	60.1	46.3
*No. 20	62.93	69.81	77.28	69.59	66.15	54.82
No. 30	69.1	74.7	81.1	74.9	70.6	62.7
No. 40	75.3	78.8	84.5	79.1	74.8	71.8
No. 50	81.0	81.8	86.9	82.3	78.2	79.0
No. 60	83.6	83.2	88.2	83.6	80.2	81.8
No. 80	87.0	84.8	89.7	85.4	84.3	85.3
No.100	88.7	85.6	90.7	86.2	86.3	87.1
No.200	93.5	87.2	93.5	88.5	91.6	92.6
*Wear (%)	37.07	30.19	22.72	30.41	33.85	45.18

Figures 21, 22, and 23 present, respectively, the data in Tables 16A, B, and C. We already are familiar with this method of graphical presentation of degradation. In each case the stones are plotted along the absissas according to the actual wear values obtained, whether "A," "B," or "S". (In previous graphs of this nature depicting the degradation of "S" grading test charges the stones have been plotted along the absissas according to their respective "B" wear values.) Thus the progressive degradation of the test charges may be viewed in relation to the resistance to abrasion as measured by the particular test under consideration.

In order that the meaning of these figures may be interpreted correctly it must be understood clearly that the chief dissimilarities are occasioned by the horizontal spacing of the stones according to their wears. (As an extreme case note the unfortunate deviation of the "A" and "B" wears for Hamlin limestone.) Taking into account this condition it may be seen that the progressive degradation of all stones is very similar regardless of the test to which they are subjected.

The "A" and "S" grading test charge degradations (Figures 21 and 23) are presented only for the purpose of demonstrating that the degradation is similar regardless of the test. The "B" grading test charge degradation (Figure 22) alone will be considered from this point on.

Having become accustomed, in analyzing "B" grading test charge degradation, to the appearance of Figures 5 and 13, Figure 22 is rather startling. Taking the apparently discordant features we see that:

(1) The excessive slope of the lines connecting the Denison and Servtex points is occasioned chiefly by the very slight difference in the per cent wear. Thus, a small difference in the per cent passing a given sieve other than the No. 12 causes a large difference in the slope of the line. The same is true for the Hamlin and Beckmann points.

(2) Excessive irregularities are caused by the quartzitic stones. These stones have much less passing the finer sieves than do limestones with approximately equal wears. This effect is not nearly so pronounced with Quitaque quartzite because it is so resistant to abrasion (23.35 per cent wear) in the larger, as well as in the smaller sizes. The general effect would have been even more irregular had one or more limestones chanced to fall between Trinity quartzite and Huntsville quartzitic sandstone.

The chaotic appearance of Figure 22 makes it difficult to visualize the actual uniformity of the results. Limestones and quartzitic stones, being inherently different, should be considered separately. Figure 24 presents the degradation of the correlation-check limestones and Allamore rhyolite. Figure 25 presents the degradation of the correlation-check quartzitic stones. (Rhyolite might have been included in either group or omitted altogether. Results would not have been affected appreciably.)

In Figure 24 note again the excessive slope of the Denison-Servtex and Hamlin-Beckmann lines. In addition to the cause already noted, it is evident that Denison becomes increasingly less resistant to abrasion than Servtex as the particle size decreases, and/or Servtex becomes increasingly more resistant to abrasion than Denison. The same may be said for Hamlin and Beckmann limestones.

The general trend of the data in Figure 24 is almost identical with that in Figures 5 and 13.

What a different picture is presented by Figure 25. The data has a remarkably uniform trend. The essential difference between the degradation of limestone and quartzitic stone is apparent.

Degradation of Correlation-Check Stones
Standard "A" Grading Test Charges

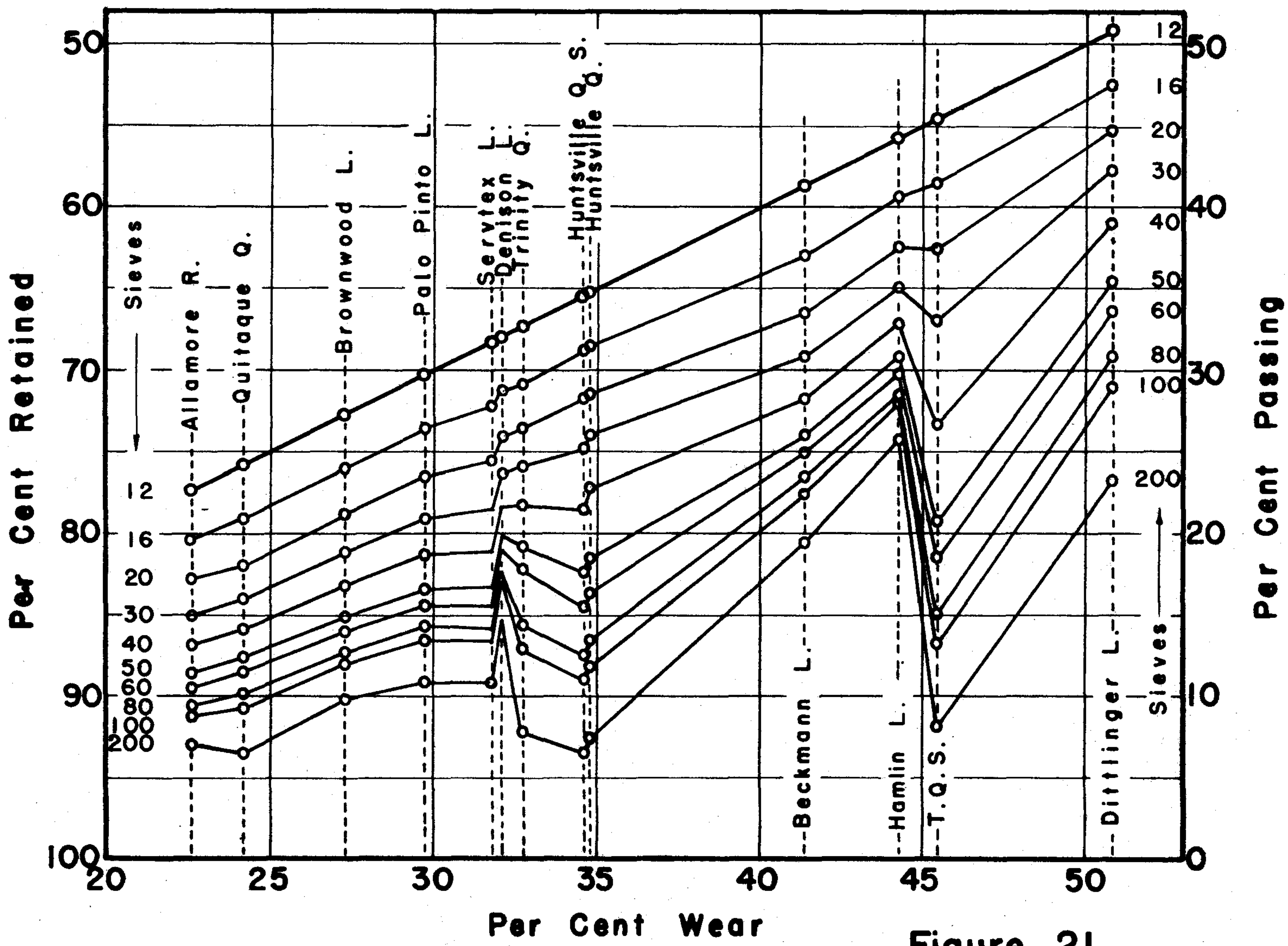


Figure 21

Degredation of Correlation-Check Stones
Standard "B" Grading Test Charges

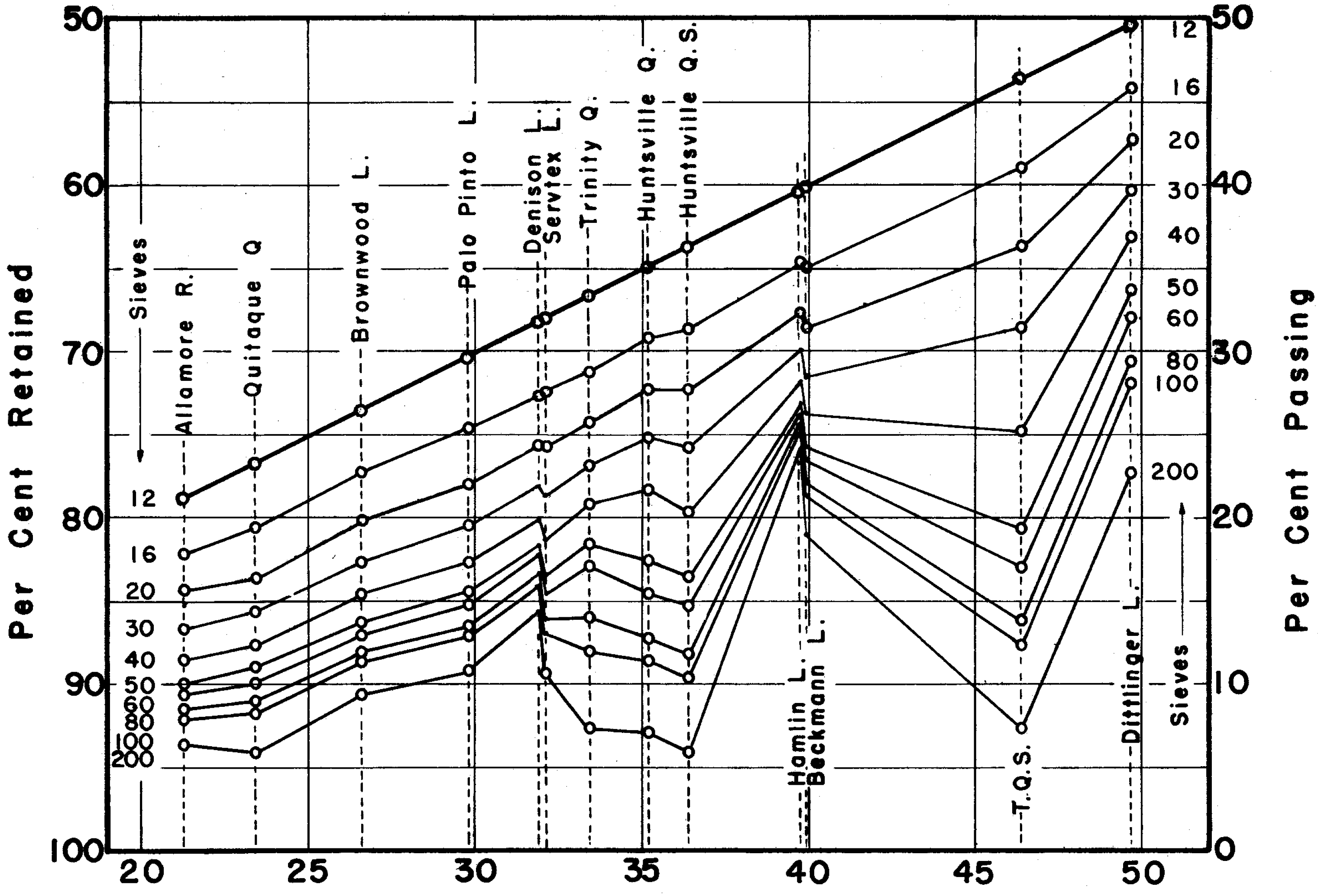


Figure 22

Degredation of Correlation–Check Stones
Standard "S" Grading Test Charges

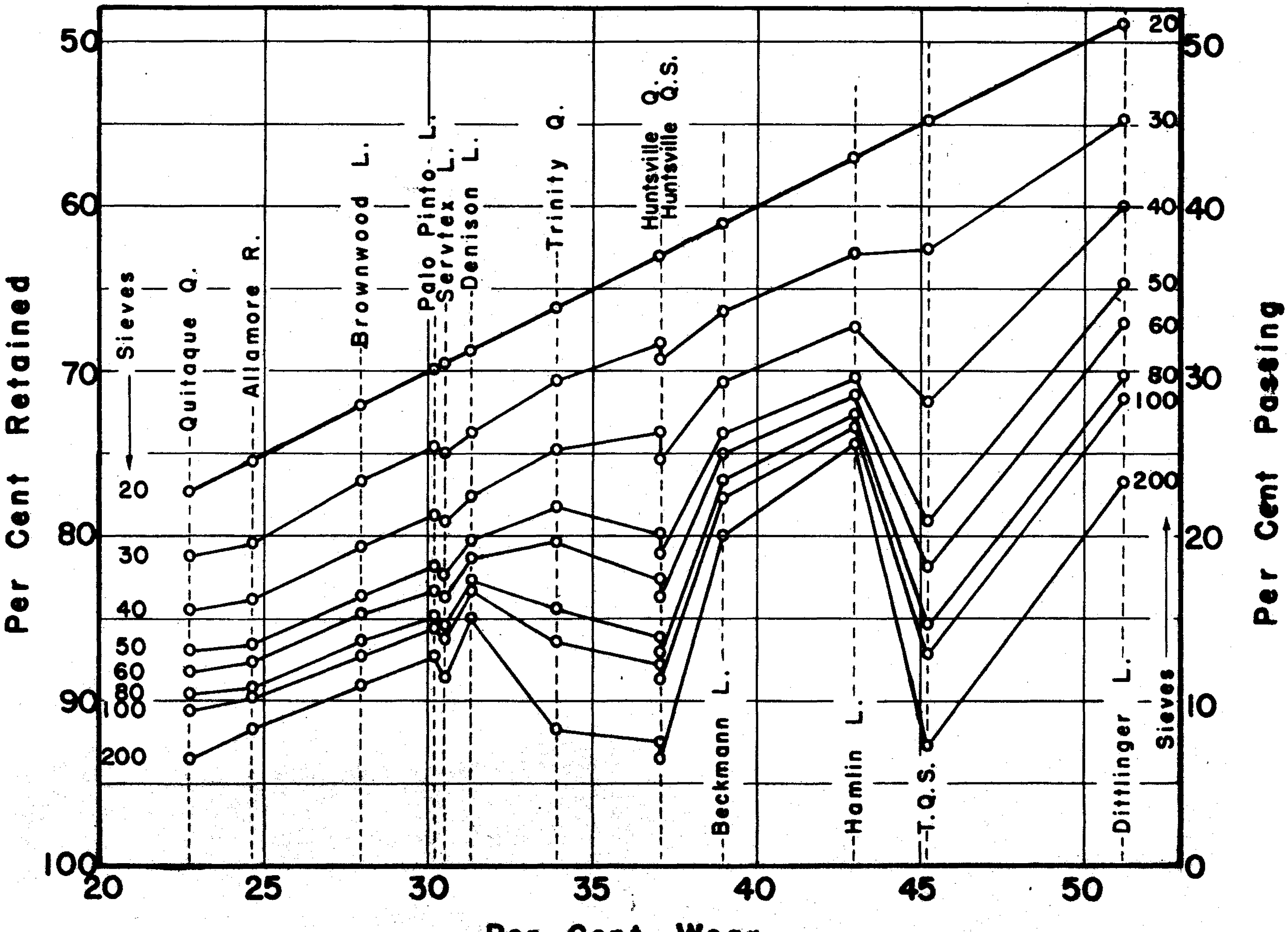


Figure 23

Degradation of Correlation-Check Limestones and Rhyolite Standard "B" Grading Test Charges

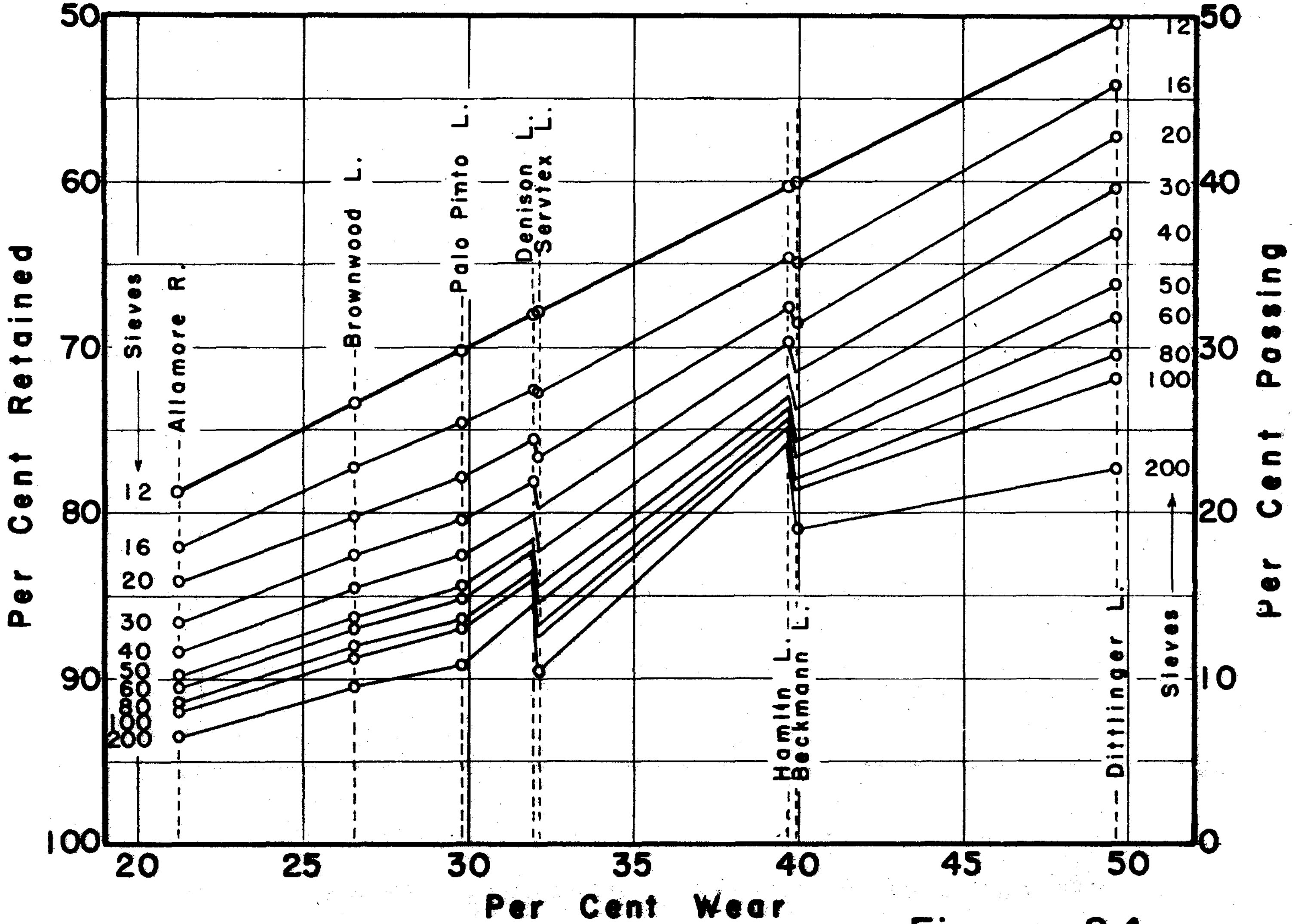


Figure 24

Degredation of Correlation-Check Quartzitic Stones Standard "B" Grading Test Charges

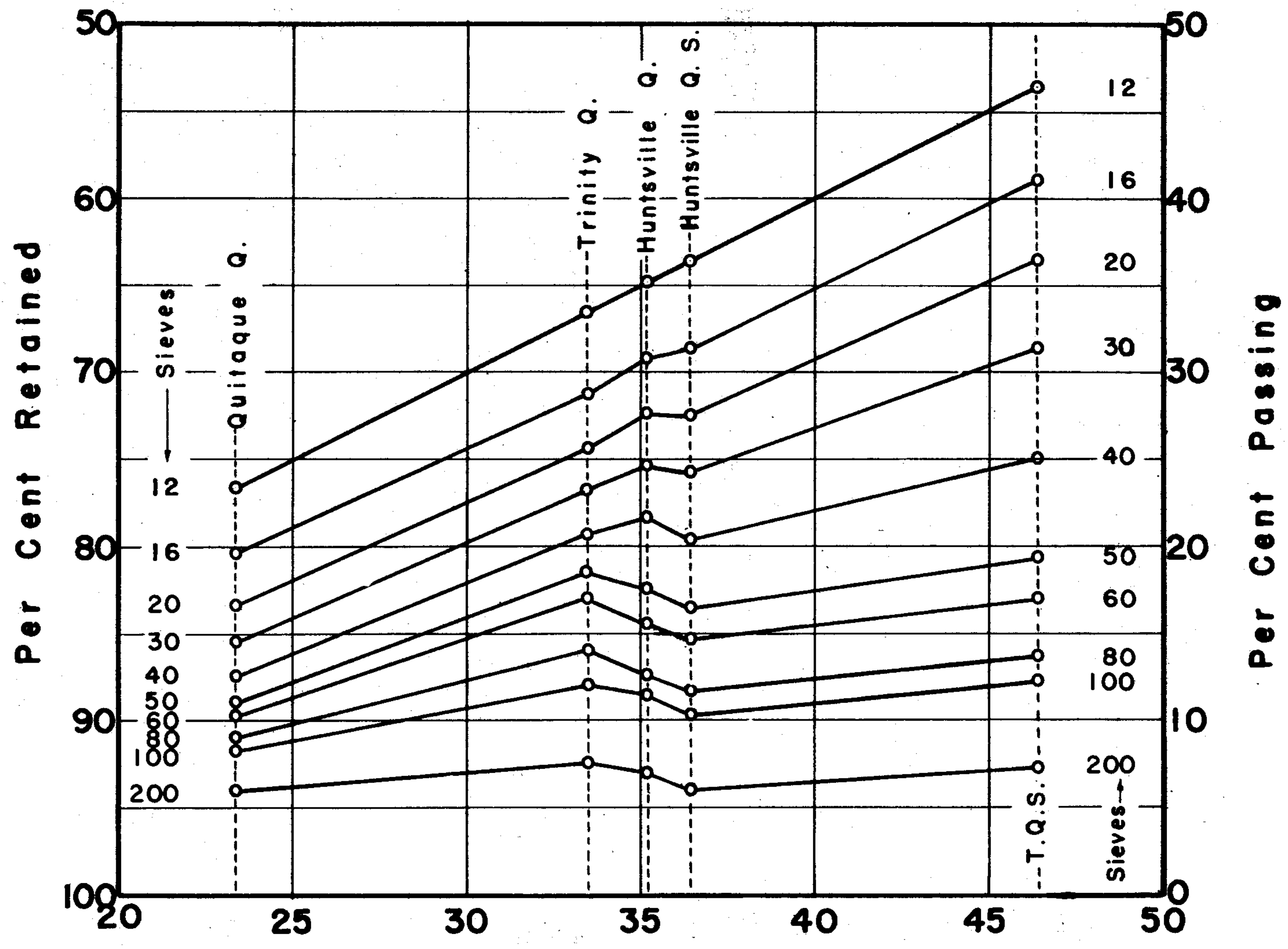


Figure 25

It has already been observed that, given two limestones of unequal wear, the numerical difference in the amount passing a given sieve tends to decrease as the sieve size decreases. (See discussion of Figures 5 and 13.) With the quartzitic stones this trend is accentuated greatly. It is, in fact, so pronounced that Trinity quartzitic sandstone, with a wear of 46.39 per cent, has only 1.4 per cent more passing the No. 200 sieve than has Quitaque quartzite, which has a wear of 23.35 per cent. Considering all five quartzitic stones, it may be seen that the maximum difference in the amount passing the No. 200 is only 1.6 per cent. This phenomenon cannot be satisfactorily explained by the writer.

The accuracy of the actual correlation, or the ability of the standard "S" grading test to duplicate "B" grading test values, will not be ascertained.

Table 17 presents a summary of the correlation-check data. The "B" wears are taken from Table 16B and the "S" wears from Table 16C.

Table 17

Summary of Correlation-Check Data

Correlation-Check Stones	Wear (Per Cent) "B"	"S"	Deviation "S" from "B"
Allamore Rhyolite	21.23	24.59	+3.36
Beckmann Limestone	39.93	38.92	-1.01
Brownwood Limestone	26.54	27.96	+1.42
Denison Limestone	31.97	31.26	-0.71
Dittlinger Limestone	49.65	51.15	+1.50
Hamlin Limestone	39.73	42.97	+3.24
Huntsville Quartzite	35.19	37.07	+1.88
Huntsville Q. Sandstone	36.41	37.07	+0.66
Palo Pinto Limestone	29.83	30.19	+0.36
Quitaque Quartzite	23.35	22.72	-0.63
Servtex Limestone	32.08	30.41	-1.67
Trinity Quartzite	33.45	33.85	+0.40
Trinity Q. Sandstone	46.39	45.18	-1.21
		Total (+)	12.82
		Total (-)	5.23
		Total	18.05
		Average	1.39

Figure 26 presents the data in Table 17 graphically. The total and average deviations (per cent wear) are shown in tabular form on the figure for convenience.

The plus deviation exceeds the minus deviation by 7.59 per cent wear, but as thirteen stones are being considered this is not excessive. No better balanced correlation could have been obtained. An abrasive charge of thirteen 420-gram balls would result in a tremendous increase of the total minus deviation, and would have decreased the total plus deviation to approximately zero.

The average deviation of 1.39 (per cent wear) is considered to be an excellent result. The physical and petrographic characteristics of the stones varied widely, and the wears ("B" test) ranged from 21.23 to 49.65 per cent.

The average numerical deviation of "S" values from "B" values is less than had been anticipated. The opinion that a satisfactory "S" grading test has been developed now amply is confirmed.

No attempt will be made to analyze in detail the major numerical discrepancies between the "S" and "B" test values on the basis of the "B" grading test charge degradation as was done with the correlation stones. The number and variety of the correlation-check stones makes the question a complicated one. It may be remarked, however, that Figure 24 furnishes an explanation for the "S" wear of Hamlin and Dittlinger limestones, and partially accounts for the "S" wear of Allamore Rhyolite. It is fortunate for the numerical correlation that the peculiar trend of progressive degradation of the quartzitic stones did differ widely from that of the limestones in sieve sizes larger than the No. 30.

In order to obtain the final numerical correlation value, all of the twenty stones which have been used should be considered as one group. The average numerical deviation (per cent wear) of all "S" test values from the respective "B" test values, including the extreme conditions (Trap and Cordova Cream), is 1.80. In the more practical specification range (excluding Trap and Cordova Cream) the average deviation is 1.50.

G. Special Factors to Be Considered in Connection with the Correlation:

An attempt to explain all the major discrepancies in the correlation of the "S" and "B" values would doubtless involve a large number of complex factors. Such an attempt will not be made. It is considered desirable, however, to demonstrate one general factor, and to discuss one special case of discrepancy in the correlation.

1. Effect of Test Charge Particle Angularity:

It was considered possible that certain discrepancies in the correlation might be occasioned by variation of the test charge particle angularity. In order to investigate this possibility an index figure was evolved, and named "Factor of Angularity." This factor was derived as follows:

(1) All test charge particles were assumed to be spheres and the theoretical number of particles per pound were calculated for each size of each test charge (including the 1/4-inch to 5mm, the 5mm to 3mm, and the 3mm to No. 10 sizes in the 1/4-inch to No. 10 portion of the "S" grading test charge) for each stone. The following formula was evolved and employed for this purpose:

theoretical particles per pound $= \frac{52.804}{Gd^3}$, where G = the bulk specific gravity (Table 2), and d = the average particle diameter (Table 5).

(2) The theoretical number of particles per pound (each particle size) was divided into the respective number of actual particles per pound (Tables 3A and B). This ratio constituted the factor of angularity for the particular size under consideration. The thinner, the flatter, and the more angular a particle, the less will be the volume of that particle in relation to its diameter. Thus, the higher the factor of angularity, the thinner, flatter and more angular the particles. (An unavoidable error is introduced into the results by prismatic fracture, but ordinarily this error is small.)

Check on Correlation of "S" Test With Standard "B" Test

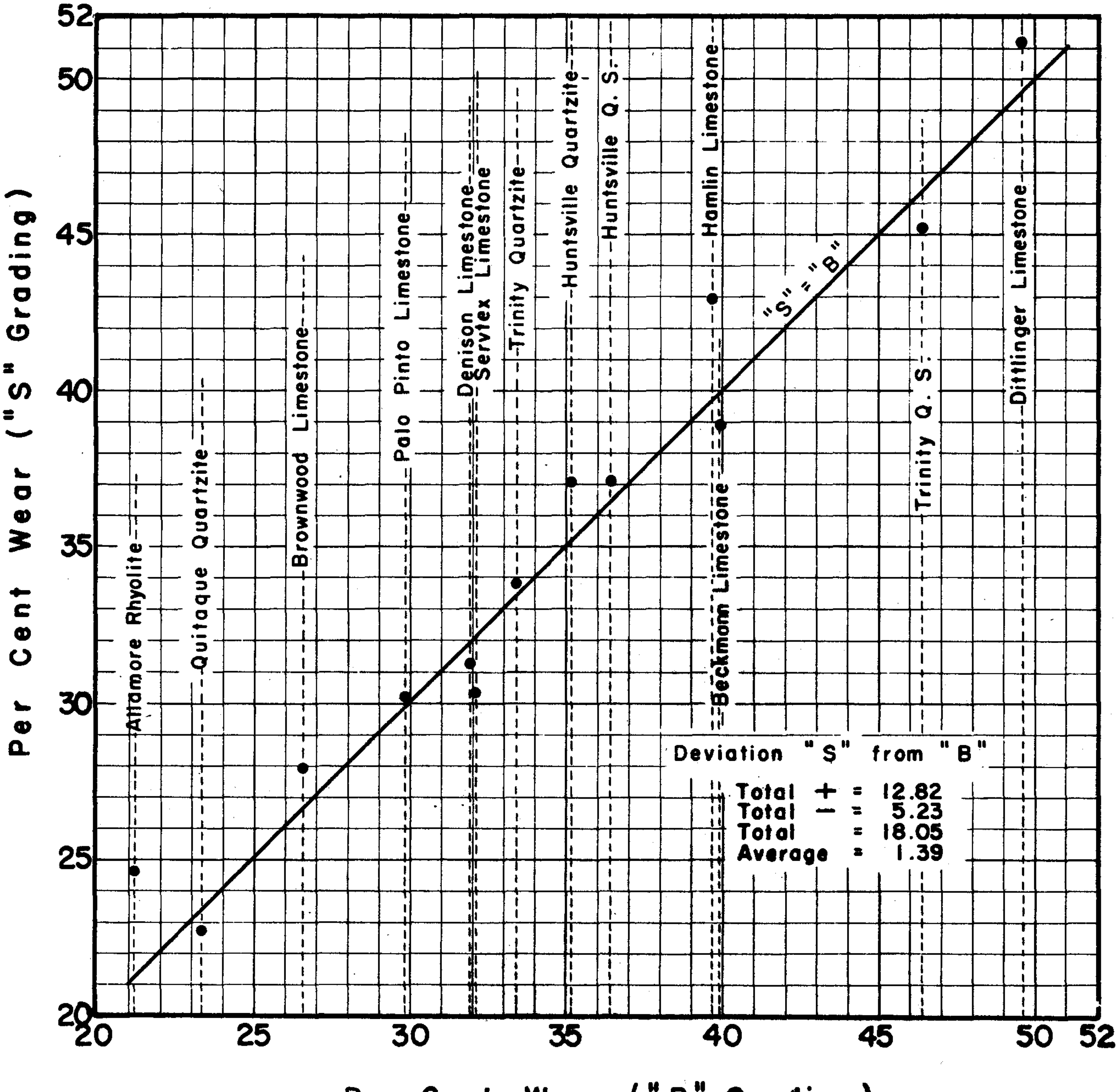


Figure 26

(3) The complete factor of angularity for the "A," the "B," and the "S" test charge for each stone was obtained by averaging the factors of angularity of the various particle sizes employed in the test charge. (A weighted average for the 1/4-inch to No. 10 size was secured by applying the screen analysis data in Table 3B).

Thus the factor of angularity furnishes a relative measure of the angularity of various sizes of various stones.

Table 18 shows the results of these calculations. The angularity of the "A" grading test charges will not be analyzed, but the results are presented for those who may be interested. The two end-point stones are not considered. The values under "Deviation ("S" from "B")" are the numerical deviations of "S" from "B," designated as plus where "S" is greater than "B" and as minus where "S" is less than "B."

Table 18

Relative Angularity of Test Charge Particles

Stone	Factor of Angularity "A"	"B"	"S"	Deviation ("S" from "B")
Dudley L.	2.025	1.840	1.845	+0.005
Chico L.	1.796	1.605	1.692	+0.087
Courchesne L.	2.015	2.000	1.789	-0.211
Maryneal L.	1.846	1.763	1.618	-0.145
Ogden L.	1.824	1.727	1.635	-0.092
Allamore R.	1.712	1.605	1.761	+0.156
Beckmann L.	1.865	1.744	1.833	+0.089
Brownwood L.	1.885	1.745	1.762	+0.017
Denison L.	1.694	1.590	1.585	-0.005
Dittlinger L.	1.915	1.762	1.617	-0.145
Hamlin L.	1.749	1.668	1.578	-0.090
Huntsville Q.	1.859	1.754	1.813	+0.059
Huntsville Q. S.	1.922	1.910	1.918	+0.008
Palo Pinto L.	1.851	1.846	1.895	+0.049
Quitaque Q.	2.054	1.961	1.821	-0.140
Servtex L.	2.086	2.154	2.064	-0.090
Trinity Q.	1.985	1.981	1.979	-0.002
Trinity Q. S.	1.886	1.786	1.778	-0.008

It may be seen that the numerical range in the factors of angularity does not appear to be great, but, so far as the writer knows, there are no criteria available for judging these data.

In this case we are interested only in the relative angularity of the "B" and "S" test charges. It is presumed that increased angularity results in decreased resistance to abrasion. Therefore, with a given stone, all other things being equal, an "S" test charge with a given factor of angularity should show more wear than a "B" test charge with a lower factor of angularity, and vice versa.

Figure 27 presents the average effect of relative angularity on the relative wear. The numerical deviations of the "S" wears from the respective "B" wears (from Tables 11-B and 17) are plotted along the absissas. The numerical deviations of the factors of angularity of the "S" test charges from the factors of angularity of the respective "B" test charges (Table 18) are plotted along the ordinates. The linear curve of regression expresses the average behavior of the eighteen stones. "r" is the "measure of correlation" and is derived as follows: $r = \sqrt{\dfrac{a\sum y + b\sum xy - nc^2}{\sum y^2 - nc^2}}$ where c is the arithmetic mean of the y values. Thus r may range from one, signifying perfect correlation, to zero, signifying no correlation.

The linear curve of regression shows a slight trend in the direction which might be anticipated, but the excessively low value of r (0.07) shows the correlation to be of absolutely no value. There are by far too many exceptions. It is not intended to imply that the particle shape exerts no influence on resistance to abrasion, but these data make it clear that the effect of particle shape is sufficiently small so that it may be discounted, or counteracted, by other inherent characteristics of stone.

2. The Special Case of Courchesne Limestone:

The standard "B" wear of Courchesne Limestone is 29.82 per cent and the standard "S" wear is 25.79 per cent. It has been demonstrated thoroughly that the smaller sizes of Courchesne are more resistant to abrasion than are the larger sizes. Examination of the unpolished stone disclosed nothing, but when a piece of Courchesne stone was polished and examined under the microscope it was found that a vast number of fine lines covered the surface. There was no particular pattern to be observed. The lines ran in every conceivable direction and intersected each other at all angles. Thinking that this particular piece might be the exception, other pieces were polished and observed. The same condition was apparent in every case. The photomicrograph of Courchesne stone (page 19) gives some idea of what was observed under the microscope. Besides the very apparent lines, close observation will disclose numerous faint lines. The photomicrograph is as representative as it was possible to secure. Some areas were not as heavily lined as the section shown, while other areas were more heavily lined.

These lines are actually the surface indications of cracks which extend in all directions through the stone. This was definitely ascertained by observing right-angle faces on the same piece of stone, and also by identifying the same crack-line (only applicable to the larger cracks) on opposite sides of a thin section (not the petrographic "thin-section") of stone. It is presumed that local diastrophic movement resulted in cracking this stone.

Relation of Relative ("S" to "B") Wear to Relative ("S" to "B") Test Charge Particle Angularity

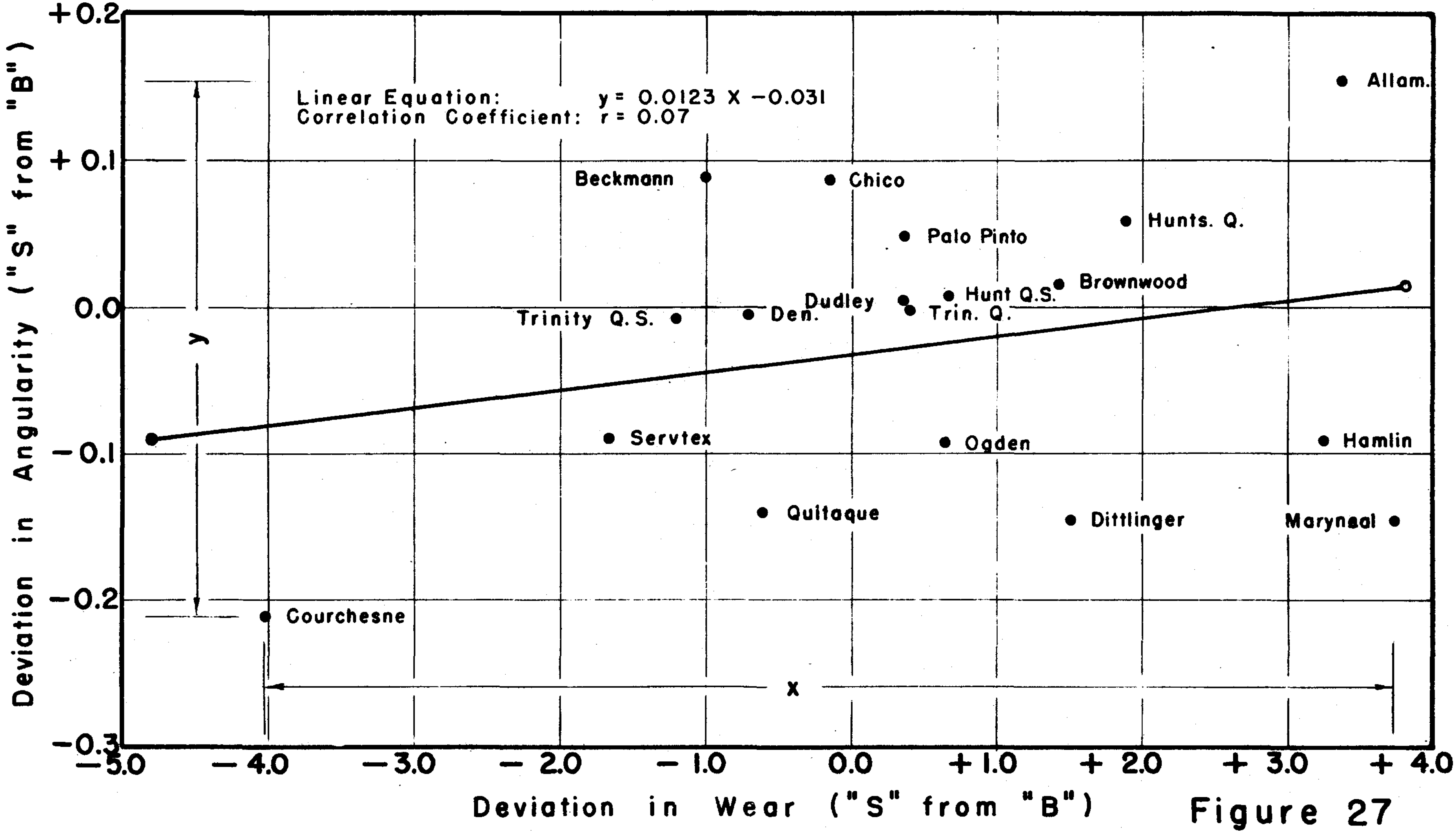


Figure 27

Courchesne is a very compact stone. Apparently the cracks are recemented thoroughly. The theory is, however, that, although well cemented, these cracks constitute irregular planes of weakness through the stone. (This weakness should be regarded as relative, and not as actual.) Thus, under impact, the stone particles would be fractured more easily through these planes of weakness than through the localities in which there were no planes of weakness. As degradation progressed, the number and extent of these weak planes would be decreased. Therefore, the smaller particles, containing relatively fewer weak planes than the larger particles, would be relatively more resistant to impact.

This condition was not observed in any other than Courchesne limestone. (Occasional recemented cracks are common in many stones.)

The writer believes the above theory to be the correct explanation of the peculiar degradation of Courchesne limestone, but does not intend to imply that all similar degradations are attributable to the same cause. Recemented portions of stone can be stronger than the undisturbed portions. Various stones may have inherent characteristics of which nothing is, at present, known. For example, note the peculiar degradation of Maryneal limestone, for which no explanation can be offered.

H. Degree of Numerical Correlation of the Standard "A" and "S" Grading Tests:

The "S" grading test was correlated with the standard "B" grading test (see section A:3), but it now becomes desirable to observe the degree of correlation of the standard "A" and "S" grading tests.

In order to better understand the "A" and "S" correlation, the numerical correlation of the "A" and "B" tests should be observed. The average deviation of the "A" test values from the "B" test values (Tables 6, 7, 16A, and 16B) is 1.14 per cent (wear) for all twenty stones, and 1.05 per cent for all stones excepting Trap and Cordova Cream. Some "A" values are higher than the respective "B" values, and vice versa. No definite trend in the deviations could be observed. Therefore, almost anything in the way of numerical correlation, within a limited range, might be expected from the "A" and "S" tests.

Table 19 presents the numerical deviation of the "S" test values from the "A" test values. The data were secured from the values in Tables 6, 11A, 16A, and 16C. The individual deviations are not shown. The "Total" deviation is the arithmetic sum of the "Total (+)" ("S" values greater than "A" values) and the "Total (-)" ("S" values less than "A" values) deviations. The "Average" deviation is the total deviation divided by the number of stones under consideration.

Table 19

Deviation of "S" Wear from "A" Wear

Item	Deviation (Per Cent Wear) Excluding End-Point Stones (Eighteen Stones)	Deviation (Per Cent Wear) Including End-Point Stones (Twenty Stones)
Total (+)	11.74	16.45
Total (-)	10.71	16.96
Total	22.45	33.41
Average	1.25	1.67

Table 19 shows that this correlation is almost perfectly balanced with respect to plus and minus deviations, and that the numerical deviation of "S" values from "A" values is somewhat less than the numerical deviation of "S" values from "B" values (1.50 excluding end-point stones and 1.80 including end-point stones). This excellent result is better than was anticipated. It must be admitted, however, that fortune favored this particular correlation. As the average deviation of the "A" values from the "B" values was slightly more than one per cent, and as the individual deviations had no particular trend (regarding plus and minus deviation), the average deviation of "S" values from "A" values might just as easily have been slightly in excess of "S" and "B" deviations.

It is a practical, though not a scientific, point in favor of the standard "S" test that no dissatisfaction among producers and engineers is caused by the deviation of the "A" and "B" grading tests.

I. Accuracy of Duplication of Standard "S" Grading Test Values:

A test must yield reasonably consistent results in order to be considered a good test. It is necessary, therefore, to analyze the standard "S" grading test results with the purpose of determining the accuracy of duplication of test values. As the "S" test has been compared with the standard test throughout this investigation the accuracy of duplication of "S" test values should likewise be compared with that of "A" and "B" test values.

Taking one stone, the numerical deviation (per cent wear) of each individual "A" test value from the average value was taken and the average of these deviations was secured. This average value constituted the average numerical deviation (per cent wear) of individual values from the average value. As the magnitude of the numerical deviation naturally depends, to a considerable extent, upon the magnitude of the test values, the percentage deviation is a better measure, for this type of data, than is the numerical deviation. The average numerical deviation was, therefore, expressed as a percentage of the average test values. The value thus obtained constituted the average per cent deviation for the stone in question.

This procedure was repeated with all twenty sets of "A" grading tests. (Individual test values from Appendices I and VII, and average values from Tables 6 and 16A.) The twenty average per cent deviations were averaged. This value constituted the average per cent deviation for the standard "A" grading test.

The above procedure was repeated for the standard "B" grading test. (Individual test values from Appendices II and VIII, and average test values from Tables 7 and 16B.)

The above procedure was repeated for the standard "S" grading test. (Individual test values from Appendices III and IX, and average values from Tables 11A and 16C.)

Table 20 presents the results of these calculations. The "Average Per Cent Deviation" has been explained above. The "Maximum Per Cent Deviation" is the greatest average per cent deviation for one stone in each series of twenty.

Table 20

Per Cent Deviation of Individual Test Values from Average Test Values

Item	Per Cent Deviation "A" Test	"B" Test	"S" Test
Average	1.58	1.58	1.11
Maximum	5.43	4.19	3.33

The number of individual test values comprising each average is not great (three or four "A" and "B" values and three "S" values), but the large number of conditions (twenty stones) gives weight to the results. The low values show that all three tests yield individual values which are very close to the respective average values. Both the average and maximum deviations are considerably less with the "S" test than with the "A" or "B" tests.

J. Standard "S" Grading Test Equally Applicable to Gravel:

So far, the standard "S" grading test has been considered only in connection with crushed stone. The only real difference between a crushed stone and the respective petrographic type of gravel is the particle angularity. The effect of particle angularity on abrasion test values is small. Assuming, however, that the effect were much greater, the standard "S" grading test still equally is applicable to gravel, whether crushed or uncrushed, and to crushed stone. The "S" grading test charge was designed for testing aggregate for use in asphaltic concrete and, particularly, asphalt surface courses. In these types of construction the aggregate on the road receives strain, impact, and abrasion. Assume that the angular particles of a crushed limestone have the same inherent strength as the rounded particles of a limestone gravel. If the particle shape renders the crushed stone more liable to degradation than the gravel, then it is desirable, and not undesirable, that the abrasion test gives evidence of this fact.

K. Final Argument in Favor of the Standard "S" Grading Test:

A good numerical, and an excellent actual, correlation of the "S" grading test with the standard test has been obtained. Had two stones with approximately normal degradations been selected for the work of correlation in place of Courchesne and Maryneal limestones there is no doubt that the same "S" grading test would have been developed. But how different would have been the practical results after the adoption of the test into the specifications. Sooner or later marked numerical discrepancies between "S" test values and standard test values would have been noted. These discrepancies would have been inexplicable, and confidence in the test would have waned. The writer considers it extremely fortunate that Courchesne and Maryneal limestones were included among the correlation stones.

All data, whether favorable or unfavorable to the standard "S" grading test, have been presented. It is presumed that arguments previously presented have been digested, and that a recapitulation is unnecessary. But one further point remains to be considered.

The standard Los Angeles Rattler abrasion test has been assumed to be perfect throughout the work of correlation. This was done because it was essential to have a fixed base-line, but the assumption must now be questioned.

The standard test has proved itself to be a good, though naturally not a perfect, measure of the service value of aggregates. Thus the standard "S" test, being correlated so closely with the standard test, must likewise be a good measure of service values. But let us assume a marked numerical discrepancy between an "S" test value and a standard test value on the same aggregate, and further assume the discrepancy to be inexplicable on the basis of a complete analysis of the degraded standard test charge. Would this situation constitute a point against the standard "S" grading test? Not necessarily. The situation would require further analysis. The standard test, not being perfect, might be the test which was in error.

The standard test subjects particles of a certain size to impact and abrasion, and, after degradation, particles less than a certain size are considered loss. The "S" grading test subjects much smaller particles to impact and abrasion, and, after degradation, particles must be much smaller than the degraded standard test charge particles in order to be considered loss. Consider these vital differences, and remember that the average "S" test value is very close to the average standard test value. Now, is it not logical to assume that with a given stone, the "S" grading test measures the abrasive value of the "S" grading particles more accurately than the standard "A" or "B" test measures the abrasive value of the "S" grading particles? In Figures 10, 11, and 26 the "S" test values are shown as deviations from the "S" = "B" line, which is also (Figure 1) the "Service Value" = "B" base-line. It now is logical to assume that an equally accurate, if not more accurate, picture of the situation would be obtained by showing "B" test values as deviations from the "S" = "B" line where this line is also the "Service Value" = "S" base-line.

It is not within the scope of this investigation to correlate "S" test values with service values. This will be done as soon as possible. As an abrasion test measures only the immediate structural strength of an aggregate, other quality specifications will be given due weight. Thus the most economically practicable abrasive wear limits can be specified for various types of construction and maintenance.

APPENDIX I

Test Data for Standard "A" Grading Tests on Correlation Stones and End-Point Stones

Test		Abrasive Charge (Gm.)	Rattler Test Date	*"A" Wear (%)	Sieve Analyses on Test Charges After Test — Per Cent Retained (Cumulative) — Nominal Opening (Inches) 1	3/4	1/2	3/8	3/8°	1/4°	Sieve No. 10	*12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
Dudley	A-1	5024	11/22/38	20.98	7.5	24.9	36.2	51.4	56.9	65.6	77.3	79.02	82.0	84.3	86.6	88.4	90.2	90.9	92.2	92.8	94.1	5.9
"	A-2	5019	11/25/38	21.94	8.9	25.0	35.0	50.8	54.7	63.4	76.8	78.06	81.4	84.2	86.5	88.4	90.3	91.1	92.3	93.0	94.2	5.8
"	A-3	5021	11/26/38	21.12	8.3	26.9	36.6	51.3	56.4	64.3	76.9	78.88	81.7	84.3	86.5	88.5	90.3	91.0	92.2	92.8	94.2	5.8
"	A-4	5019	11/29/38	21.80	4.5	23.2	35.4	50.8	54.6	65.0	77.0	78.20	81.4	83.9	86.3	88.3	90.1	90.8	92.0	92.7	94.2	5.8
Chico	A-1	5016	10/25/38	25.80	11.2	26.3	34.4	44.9	48.7	57.5	72.8	74.20	77.4	80.2	82.4	84.4	86.1	86.7	88.0	88.6	90.3	9.7
"	A-2	5016	10/25/38	26.62	6.8	19.7	29.1	39.7	45.4	55.3	71.9	73.38	77.0	79.7	82.2	84.2	86.0	86.6	87.8	88.4	90.1	9.9
"	A-3	5017	10/26/38	26.84	10.3	21.4	28.6	40.7	45.7	55.7	71.7	73.16	76.5	79.3	81.8	83.9	85.7	86.4	87.7	88.4	90.1	9.9
"	A-4	5015	10/27/38	27.08	9.5	20.2	29.2	41.1	45.6	55.4	71.2	72.92	76.2	79.0	81.6	83.7	85.4	86.1	87.3	88.0	89.8	10.2
Courchesne	A-1	5017	10/26/38	28.34	3.7	22.3	29.8	40.1	44.5	53.3	69.7	71.66	75.5	78.9	81.8	84.2	86.3	87.2	88.7	89.5	91.6	8.4
"	A-2	5015	10/27/38	28.62	4.6	21.4	29.5	39.3	44.2	53.2	69.9	71.38	75.5	78.9	81.9	84.4	86.6	87.5	89.0	89.9	91.9	8.1
"	A-3	5013	10/28/38	28.20	9.5	22.3	31.7	40.5	45.0	54.3	70.3	71.80	75.8	78.9	81.7	84.0	86.2	87.1	88.6	89.4	91.5	8.5
"	A-4	5011	11/ 1/38	28.30	7.6	21.4	29.5	40.2	44.6	53.8	69.8	71.70	75.9	79.2	82.0	84.3	86.7	87.6	89.2	90.0	92.1	7.9
Maryneal	A-1	5016	10/25/38	34.80	6.9	18.9	27.0	35.1	39.3	47.6	63.6	65.20	68.1	70.5	72.4	74.2	76.1	77.0	78.8	79.9	83.7	16.3
"	A-2	5017	10/26/38	35.50	2.5	21.8	28.2	38.2	40.6	48.3	62.9	64.50	67.4	69.6	71.5	73.3	75.3	76.2	78.0	79.2	83.0	17.0
"	A-3	5015	10/27/38	36.02	5.5	22.2	27.9	34.9	37.9	46.6	62.5	63.98	66.8	69.1	71.1	72.8	74.8	75.8	77.5	78.7	82.5	17.5
"	A-4	5013	10/28/38	35.52	4.8	22.2	28.7	36.4	40.1	48.2	62.9	64.48	67.5	69.7	71.6	73.3	75.4	76.3	77.6	79.2	82.9	17.1
Ogden	A-1	5005*	1/25/39	39.80	3.1	18.2	24.0	30.8	34.1	43.1	58.6	60.20	63.8	66.8	69.4	71.6	74.0	75.1	77.1	78.4	81.6	18.4
"	A-2	5004	1/26/39	38.30	3.9	19.7	26.1	33.5	36.1	45.1	59.8	61.70	65.0	67.9	70.3	72.5	74.8	75.9	78.0	79.2	82.4	17.6
"	A-3	5001	1/27/39	39.16	3.6	17.5	24.2	31.9	35.0	44.2	58.9	60.84	64.4	67.2	69.7	72.0	74.3	75.4	77.4	78.7	81.9	18.1
"	A-4	5001	1/28/39	39.36	7.7	20.1	26.3	34.0	36.7	44.8	59.2	60.64	64.2	66.9	69.7	71.9	74.3	75.5	77.6	78.9	82.2	17.8
Trap	A-1	5005	1/25/39	10.98	17.1	36.0	51.5	67.8	72.7	80.2	88.3	89.02	90.5	91.5	92.4	93.1	93.8	94.1	94.7	95.1	95.8	4.2
"	A-2	5004	1/26/39	10.74	12.2	34.9	54.9	69.3	73.4	81.3	88.7	89.26	90.7	91.6	92.5	93.1	93.8	94.0	94.6	94.9	95.7	4.3
"	A-3	5001	1/27/39	10.26	15.2	34.2	52.1	69.3	72.9	81.7	89.0	89.74	91.0	92.0	92.7	93.4	94.0	94.4	94.9	95.2	96.0	4.0
"	A-4	5001	1/30/39	9.92	20.5	39.2	55.2	71.1	75.3	82.3	89.6	90.08	91.3	92.2	93.0	93.6	94.3	94.6	95.1	95.5	96.2	3.8
Cordova C.	A-1	5000	2/4/39	75.34	0.6	1.7	3.5	5.1	5.6	8.4	22.5	24.66	29.4	32.8	35.3	38.4	41.4	43.3	46.9	50.1	61.9	38.1
"	A-2	4994	2/ 7/39	74.70	0.6	4.2	5.0	7.0	7.8	10.4	23.0	25.30	30.0	33.6	36.2	39.3	42.5	44.5	48.0	51.3	62.9	37.1
"	A-3	5019	2/ 8/39	75.66	0.0	2.7	4.0	5.7	6.5	9.1	22.5	24.34	29.3	32.7	35.3	38.4	41.6	43.5	47.1	50.5	62.0	38.0
"	A-4	4999	2/ 9/39	75.98	0.4	2.3	3.6	5.2	5.9	8.0	21.7	24.02	28.9	32.6	35.1	38.2	41.4	43.4	47.9	50.8	62.6	37.4

A P P E N D I X II

Test Data for Standard "B" Grading Tests on Correlation Stones and End-Point Stones

Test		Abrasive Charge (Gm.)	Rattler Test Date	*"B" Wear (%)	Screen Analyses on Test Charges after Test: Per Cent Retained (Cumulative): Nominal Opening (Inches) 1/2	3/8	3/8°	1/4°	Sieve No. 10	*12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
Dudley	B-1	4605	11/22/38	21.36	10.6	34.9	44.5	59.4	77.3	78.64	82.4	85.3	87.5	89.3	91.0	92.0	92.7	93.3	94.5	5.5
"	B-2	4599	11/25/38	20.58	10.2	35.3	44.9	60.3	78.1	79.42	83.0	85.6	87.7	89.5	91.1	91.7	92.7	93.3	94.5	5.5
"	B-3	4606	11/26/38	20.66	9.3	33.4	43.7	58.2	77.1	79.34	82.6	85.3	87.6	89.4	91.0	91.6	92.7	93.2	94.4	5.6
"	B-4	4598	11/29/38	20.74	9.3	34.5	43.5	60.1	77.6	79.26	82.6	85.2	87.6	89.4	91.0	91.7	92.7	93.3	94.6	5.4
Chico	B-1	4592	10/25/38	26.14	4.6	20.8	28.9	46.7	71.9	73.86	78.0	81.1	83.5	85.4	87.0	87.6	88.6	89.2	90.6	9.4
"	B-2	4591	10/26/38	26.62	5.1	23.5	30.8	48.0	71.4	73.38	77.5	80.5	83.0	85.0	86.7	87.3	88.4	89.0	90.4	9.6
"	B-3	4591	10/27/38	27.84	4.3	21.1	29.0	45.2	70.5	72.16	76.7	79.8	82.4	84.4	86.1	86.7	87.8	88.3	89.8	10.2
"	B-4	4590	10/28/38	26.60	5.5	23.3	31.5	47.1	71.2	73.40	76.5	80.6	83.0	84.9	86.6	87.2	88.2	88.8	90.2	9.8
Courchesne	B-1	4592	10/25/38	29.32	3.9	17.0	25.4	41.3	68.6	70.68	75.9	79.5	82.7	85.1	87.2	87.9	89.2	90.0	91.7	8.3
"	B-2	4591	10/26/38	30.00	4.1	17.0	24.6	41.1	67.8	70.00	75.2	79.1	82.3	84.8	87.0	87.8	89.3	90.0	92.0	8.0
"	B-3	4591	10/27/38	29.86	3.2	16.4	23.9	40.7	68.0	70.14	75.4	79.2	82.4	84.9	87.0	87.9	89.2	90.0	91.9	8.1
"	B-4	4590	10/28/38	30.08	3.8	16.6	24.6	40.0	67.8	69.92	75.3	79.2	82.2	84.8	87.0	87.9	89.4	90.1	92.0	8.0
Maryneal	B-1	4591	10/26/38	33.72	4.2	18.4	24.2	39.5	64.0	66.28	69.7	72.0	73.9	75.4	77.1	77.8	79.2	80.1	83.2	16.8
"	B-2	4591	10/27/38	34.58	4.0	15.9	22.1	37.6	63.4	65.42	69.0	71.5	73.5	75.1	76.8	77.6	79.0	80.0	83.2	16.8
"	B-3	4590	10/28/38	33.90	4.7	17.0	22.8	38.3	63.7	66.10	69.7	72.2	74.2	75.9	77.6	78.3	79.7	80.6	83.7	16.3
"	B-4	4590	10/29/38	34.04	3.3	17.3	22.6	38.1	63.6	65.96	69.6	72.0	74.0	75.6	77.3	78.1	79.6	80.5	83.6	16.4
Ogden	B-1	4599	1/25/39	38.30	2.7	13.6	19.0	34.9	59.5	61.70	66.0	69.4	71.9	74.1	76.2	77.2	78.9	80.0	82.8	17.2
"	B-2	4591	1/26/39	38.00	3.8	15.7	19.8	35.9	59.7	62.00	66.2	69.3	71.9	74.0	76.0	76.9	78.6	79.7	82.5	17.5
"	B-3	4591	1/27/39	38.34	3.6	16.3	21.4	37.1	59.7	61.66	66.1	69.2	71.7	73.7	75.8	76.8	78.5	79.6	82.3	17.7
"	B-4	4590	1/28/39	38.68	4.4	15.8	20.2	35.6	59.5	61.32	65.7	69.0	71.5	73.6	75.6	76.5	78.3	79.3	82.5	17.5
Trap	B-1	4599	1/25/39	9.36	25.2	56.3	65.7	79.4	89.9	90.64	91.9	92.8	93.6	94.2	94.8	95.1	95.5	95.8	96.5	3.5
"	B-2	4591	1/26/39	9.54	24.3	58.6	67.3	80.3	89.8	90.46	91.7	92.7	93.5	94.0	94.6	94.9	95.4	95.7	96.3	3.7
"	B-3	4591	1/27/39	9.20	25.0	61.9	69.9	81.5	90.2	90.80	92.0	92.9	93.6	94.2	94.8	95.1	95.6	95.8	96.4	3.6
"	B-4	4590	1/28/39	9.60	24.5	59.2	68.[illegible]	80.1	89.8	90.40	91.7	92.6	93.4	94.0	94.6	94.9	95.3	95.6	96.2	3.8
Cordova Cream	B-1	4588	2/ 6/39	72.30	0.0	0.3	1.0	4.0	24.2	27.70	32.8	36.6	39.0	41.7	44.5	46.1	49.3	52.2	63.0	37.0
"	B-2	4588	2/ 7/39	72.14	0.0	0.7	1.1	4.3	25.6	27.86	33.4	36.9	39.3	42.0	44.7	46.5	49.6	52.5	63.1	36.9
"	B-3	4607	2/ 8/39	72.42	0.0	0.7	1.2	4.2	24.2	27.58	32.9	36.5	38.8	41.6	44.3	46.0	49.2	52.2	63.1	36.9
"	B-4	4583	2/ 9/39	72.88	0.0	0.6	1.0	3.6	24.0	27.12	32.8	36.4	38.8	41.6	44.4	46.1	49.4	52.2	63.1	36.9

APPENDIX III

Test Data for "S" Grading Tests

(Constants: 5000-Gram Test Charge; 500 Rattler Revolutions; Wear Equals Per Cent Passing No. 20 Sieve)

Character of Test									Screen Analyses of Test Charges after Test											
									Per Cent Retained (Cumulative)											
									Sieve No.											
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	*"S" Wear (%)	Screen 1/4"ᵒ	10	12	16	*20	30	40	50	60	80	100	200	Pass 200 (%)
1	Dudley	65	112	7330	1	2/8/39	22.36	12.5	58.2	62.9	72.0	77.64	83.7	85.2	87.7	88.8	90.0	90.7	92.2	7.8
2	"	65	104	6800	1	2/10/39	19.40	12.4	62.1	66.8	75.1	80.60	83.9	87.0	89.2	90.2	91.3	91.9	93.2	6.8
3	"	65	108	7104	1	2/18/39	20.96	10.8	57.4	63.6	73.3	79.04	82.7	86.0	88.3	89.3	90.7	91.2	92.6	7.4
4	"	65	108	7087	2	2/20/39	20.94	14.2	57.9	64.6	73.4	79.06	82.7	85.9	88.4	89.3	90.7	91.3	92.7	7.3
5	"	65	108	7099	3	2/21/39	20.48	12.8	59.8	65.6	74.1	79.52	83.2	86.5	88.7	89.6	90.8	91.5	92.7	7.3
6	"	65	100	6569	1	3/10/39	19.52	13.8	62.0	67.5	74.8	80.48	83.5	86.7	88.9	89.8	90.9	91.6	93.1	6.9
7	"	65	99	6504	1	3/13/39	19.24	14.9	61.8	66.7	75.1	80.76	84.0	87.2	89.4	90.3	91.3	92.0	93.4	6.6
8	"	65	99	6504	2	3/15/39	19.28	15.6	61.4	66.9	75.3	80.72	84.0	87.1	89.1	90.1	91.1	91.9	93.2	6.8
9	"	65	99	6504	3	3/16/39	18.56	15.6	61.9	67.7	76.0	81.44	84.6	87.6	89.7	90.7	91.7	92.4	93.7	6.3
10	"	130	53	6788	1	11/30/38	23.12	10.6	56.0	61.2	70.7	76.88	81.6	84.9	87.5	88.5	90.0	90.7	92.2	7.8
11	"	130	44	5628	1	12/1/38	18.84	12.4	63.1	67.9	75.9	81.16	85.0	87.5	89.8	90.6	91.7	92.3	93.5	6.5
12	"	130	49	6280	1	12/2/38	20.98	12.3	60.6	65.3	73.3	79.02	83.4	86.3	88.6	89.5	90.9	91.6	93.0	7.0
13	"	130	49	6279	2	12/ 6/38	20.52	10.6	60.1	66.6	74.1	79.48	83.4	86.4	88.8	89.6	91.0	91.7	93.1	6.9
14	"	130	49	6278	3	12/7/38	20.42	13.2	60.6	65.5	74.2	79.58	83.7	86.7	89.0	89.8	91.3	91.9	93.3	6.7
15	"	130	47	6011	1	12/14/38	19.16	14.1	62.9	67.0	75.7	80.84	84.9	87.5	89.9	90.7	92.0	92.6	93.9	6.1
16	"	130	45	5792	1	2/24/39	18.40	14.2	53.0	68.8	76.4	81.60	84.5	87.5	89.6	90.4	91.5	92.1	93.3	6.7
17	"	130	45	5791	2	2/28/39	18.68	14.5	61.1	67.9	75.9	81.32	84.7	87.7	89.8	90.7	91.6	92.3	93.4	6.6
18	"	130	45	5791	3	3/3/39	18.44	15.5	65.1	68.9	76.7	81.56	84.6	87.7	89.7	90.6	91.6	92.3	93.6	6.4
19	"	225	30	6733	1	11/30/38	23.22	9.4	55.8	61.0	70.5	76.78	81.4	84.7	87.5	88.5	90.1	90.8	92.4	7.6
20	"	225	28	6286	1	12/1/38	21.58	10.0	58.3	63.5	72.6	78.42	82.8	85.8	88.4	89.3	90.7	91.5	91.6	8.4
21	"	225	28	6285	2	12/6/38	21.38	9.9	58.7	65.6	73.0	78.62	82.7	85.9	88.5	89.4	90.9	91.6	93.2	6.8
22	"	225	28	6286	3	12/7/38	21.64	10.9	58.4	63.3	72.8	78.36	83.0	86.3	88.7	89.6	91.1	91.8	93.3	6.7
23	"	225	27	6061	1	12/9/38	20.90	10.0	58.8	64.5	73.2	79.10	83.3	86.5	88.9	89.8	91.1	91.7	93.1	6.9
24	"	225	27	6061	2	12/12/38	20.68	13.5	60.2	64.7	73.5	79.32	83.6	86.6	89.1	90.0	91.4	92.1	93.5	6.5
25	"	225	27	6061	3	12/12/38	20.44	11.9	60.3	64.8	72.8	79.56	83.7	86.7	89.1	89.9	91.4	92.0	93.4	6.6
26	"	225	26	5836	1	12/14/38	19.68	11.9	61.9	66.6	74.9	80.32	84.5	87.3	89.5	90.5	91.8	92.4	93.8	6.2
27	"	225	25	5610	1	2/27/39	19.42	12.6	62.1	67.5	75.2	80.58	84.1	87.3	89.6	90.5	91.6	92.4	93.6	6.4
28	"	225	25	5610	2	3/1/39	18.74	12.6	63.5	67.6	76.0	81.26	84.3	87.5	89.7	90.5	91.6	92.3	93.5	6.5
29	"	225	25	5610	3	3/6/39	18.92	13.7	62.6	68.1	75.7	81.08	84.4	87.5	89.8	90.7	91.8	92.5	94.0	6.0
30	"	420	16	6801	1	11/30/38	24.44	10.5	55.3	60.0	69.3	75.56	80.6	84.1	86.9	87.9	89.6	90.5	92.2	7.8
31	"	420	14	5920	1	12/1/38	21.84	11.4	56.2	63.4	72.4	78.16	82.6	85.8	88.4	89.3	90.8	91.4	92.9	7.1
32	"	420	13	5480	1	12/2/38	21.04	10.9	60.0	64.5	73.4	78.96	81.5	86.5	89.0	89.8	91.1	91.8	93.2	6.8
33	"	420	13	5479	2	12/6/38	20.26	10.7	61.4	66.6	74.9	79.74	83.9	86.9	89.3	90.2	91.6	92.2	93.8	6.2
34	"	420	13	5431	3	12/7/38	19.98	10.9	61.6	66.6	74.5	80.02	84.1	87.1	89.4	90.3	91.6	92.3	93.7	6.3
35	"	420	14	5898	2	12/14/38	21.38	10.6	59.0	64.3	72.6	78.62	82.9	86.1	88.7	89.6	91.1	91.8	93.2	6.8
36	"	420	14	5865	3	2/23/39	20.36	12.3	60.7	67.1	74.0	79.64	83.2	86.6	88.9	89.9	91.1	91.9	93.2	6.8
37	Chico	65	105	6854	1	2/8/39	27.86	7.2	49.3	55.8	65.5	72.14	76.4	80.3	82.9	84.0	85.2	85.9	87.6	12.
38	"	65	101	6603	1	2/10/39	25.66	9.3	51.6	58.4	67.9	74.34	78.3	81.9	84.4	85.3	86.5	87.2	88.7	11.[illegible]
39	"	65	103	6771	1	2/18/39	27.18	9.0	43.0	46.9	66.7	72.82	77.2	80.7	83.3	84.3	85.7	86.3	87.8	12.2
40	"	65	103	6757	2	2/20/39	26.82	8.6	53.2	57.6	66.9	73.18	77.4	81.0	83.6	84.6	86.1	86.7	88.3	11.7

A P P E N D I X III (Continued)

Character of Test									Screen Analyses of Test Charges after Test												
									Per Cent Retained (Cumulative)												Pass 200 (%)
									Screen	Sieve No.											
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	**"S" Wear (%)		1/4"	10	12	16	*20	30	40	50	60	80	100	200	
41	Chico	65	103	6774	3	2/21/39	25.72		9.9	54.4	58.9	68.2	74.28	76.0	81.6	84.0	84.9	86.1	86.9	88.3	11.7
42	"	65	100	6569	1	3/10/39	26.56		8.4	50.9	57.4	66.9	73.44	77.2	81.0	83.5	84.5	85.7	86.5	88.1	11.9
43	"	65	99	6504	1	3/13/39	24.80		10.2	55.1	59.3	69.4	75.20	78.8	82.3	84.6	85.6	86.7	87.4	89.0	11.0
44	"	65	99	6504	2	3/14/39	25.86		9.6	53.6	58.6	67.9	74.14	77.9	81.5	83.9	85.0	86.1	86.9	88.5	11.5
45	"	65	99	6504	3	3/16/39	24.80		10.5	52.9	59.4	68.9	75.20	78.9	82.5	84.8	85.8	87.0	87.8	89.3	10.7
46	"	130	50	6439	1	10/26/38	28.80		5.9	47.5	54.0	64.6	71.20	76.5	80.2	82.9	83.9	85.5	86.2	87.9	12.1
47	"	130	46	5923	1	10/31/38	26.72		5.8	50.3	56.6	68.0	73.28	78.2	81.5	84.2	85.1	86.5	87.2	88.8	11.2
48	"	130	46	5923	2	11/3/38	26.46		6.7	52.2	57.1	67.1	73.54	78.2	81.4	83.9	84.8	86.2	86.8	88.3	11.7
49	"	130	46	5904	3	11/5/38	26.22		6.7	52.3	56.4	67.4	73.78	78.3	81.6	84.1	84.9	86.3	86.9	88.4	11.6
50	"	130	45	5792	1	2/24/39	24.94		7.1	53.7	60.1	68.4	75.06	78.3	81.9	84.3	85.3	86.5	87.2	88.6	11.4
51	"	130	45	5791	2	2/28/39	24.42		9.0	56.2	61.5	69.5	75.58	79.3	82.8	85.1	86.0	87.2	87.9	89.2	10.8
52	"	130	45	5791	3	3/3/39	25.38		9.3	54.6	60.9	68.5	74.62	78.3	82.0	84.3	85.3	86.5	87.3	88.9	11.1
53	"	225	27	6057	1	10/26/38	27.92		5.2	49.2	54.5	65.2	72.08	76.9	80.6	83.4	84.4	86.0	86.8	88.4	11.6
54	"	225	26	5836	1	10/31/38	26.76		6.3	50.9	56.2	66.6	73.24	78.4	81.8	84.5	85.4	86.9	87.7	89.3	10.7
55	"	225	26	5836	2	11/4/38	26.70		5.9	52.6	57.4	66.9	73.30	78.1	81.4	84.0	84.9	86.3	87.0	88.6	11.4
56	"	225	26	5830	3	11/5/38	26.92		5.7	50.4	56.4	66.4	73.08	77.7	81.2	83.8	84.7	86.2	86.9	88.4	11.6
57	"	225	25	5610	1	2/27/39	25.80		7.8	51.1	57.9	67.4	74.20	78.0	81.9	84.5	85.5	86.7	87.6	89.0	11.0
58	"	225	25	5610	2	3/1/39	25.18		8.2	55.3	59.9	68.3	74.82	78.6	82.4	84.9	85.9	87.0	87.8	89.1	10.9
59	"	225	25	5610	3	3/6/39	24.44		8.4	54.7	60.0	69.1	75.56	79.2	82.8	85.3	86.3	87.5	88.4	90.0	10.0
60	"	420	10	4195	1	10/26/38	20.52		10.5	61.0	65.9	74.3	79.48	83.1	85.7	87.6	88.4	89.4	89.9	91.1	8.9
61	"	420	16	6775	1	10/31/38	30.92		5.4	45.8	50.7	61.5	69.08	75.0	79.0	82.1	83.2	84.9	85.8	87.7	12.3
62	"	420	14	5918	1	11/4/38	26.42		7.3	53.1	58.4	67.3	73.58	78.2	81.5	84.1	85.1	86.5	87.2	88.8	11.2
63	"	420	14	5923	2	11/5/38	26.94		7.5	52.4	57.5	66.8	73.06	78.0	81.4	84.0	84.9	86.3	87.0	88.6	11.4
64	"	420	14	5874	3	11/9/38	26.60		7.7	52.4	57.4	66.8	73.40	78.2	81.7	84.4	85.3	86.8	87.6	89.2	10.8
65	Courchesne	65	121	7937	1	2/10/39	28.66		6.5	46.6	53.9	64.1	71.34	76.0	80.5	83.7	85.0	86.7	87.7	89.9	10.1
66	"	65	124	8146	1	2/13/39	30.68		7.2	47.2	51.8	62.4	69.32	74.6	79.1	82.4	83.8	85.8	86.5	88.8	11.2
67	"	65	123	8081	1	2/20/39	29.58		7.2	48.5	53.2	63.5	70.42	75.2	79.7	83.0	84.4	86.4	87.2	89.3	10.7
68	"	65	123	8084	2	2/21/39	29.10		6.4	47.6	54.1	64.1	70.90	75.8	80.3	83.4	84.6	86.2	87.3	89.2	10.8
69	"	65	123	8085	3	2/24/39	30.14		6.8	47.1	53.0	62.9	69.86	74.4	79.0	82.2	83.6	85.2	86.4	88.5	11.5
70	"	65	100	6569	1	3/10/39	24.30		9.8	55.3	61.3	69.6	75.70	79.2	82.9	85.5	86.6	87.8	88.8	90.8	9.2
71	"	65	99	6504	1	3/13/39	23.44		10.8	54.9	61.1	70.5	76.56	80.2	83.9	86.4	87.4	88.7	89.6	91.4	8.6
72	"	65	99	6504	2	3/15/39	23.10		10.5	57.1	62.3	71.0	76.90	80.4	84.0	86.3	87.4	88.6	89.5	91.2	8.8
73	"	65	99	6504	3	3/16/39	23.20		10.5	55.3	61.9	70.8	76.80	80.6	84.3	86.7	87.9	89.1	90.0	91.8	8.2
74	"	130	46	5915	1	10/29/38	24.54		7.9	53.3	59.9	69.2	75.46	80.0	83.4	86.1	87.1	88.7	89.5	91.3	8.7
75	"	130	50	6427	1	10/31/38	26.76		6.1	50.6	56.3	66.7	73.24	78.4	82.0	85.0	86.0	87.7	88.6	90.5	9.5
76	"	130	54	6934	1	11/3/38	28.68		6.2	49.0	54.4	64.5	71.32	76.5	80.4	83.5	84.6	86.5	87.4	89.5	10.5
77	"	130	56	7186	1	11/5/38	29.32		5.7	47.8	52.8	63.6	70.68	76.1	80.1	83.4	84.5	86.4	87.7	89.5	10.5
78	"	130	56	7182	2	11/7/38	28.96		5.7	48.7	53.8	64.1	71.04	76.5	80.4	83.8	84.9	86.9	87.8	89.9	10.1
79	"	130	57	7308	1	11/13/38	29.96		5.9	45.4	51.9	62.6	70.04	75.7	79.7	83.2	84.4	86.4	87.4	89.6	10.4
80	"	130	57	7296	2	11/14/38	29.40		5.3	47.8	53.0	63.2	70.60	75.9	80.1	83.4	84.6	86.7	87.7	90.0	10.0
81	"	130	57	7307	3	11/16/38	30.64		5.1	46.5	52.2	62.2	69.36	75.2	79.4	82.8	84.0	86.0	87.0	89.3	10.7
82	"	130	47	6011	1	12/14/38	24.04		8.2	56.1	60.8	70.0	75.96	80.6	83.9	86.7	87.6	89.2	90.0	91.9	8.1
83	"	130	45	5792	1	2/24/39	23.68		9.0	57.2	62.1	70.4	76.32	79.9	83.6	86.1	87.1	88.4	89.3	90.8	9.2
84	"	130	45	5791	2	3/1/39	23.72		10.4	56.8	62.1	70.1	76.28	80.0	83.6	86.1	87.1	88.3	89.2	90.6	9.4
85	"	130	45	5791	3	3/3/39	23.56		10.5	58.0	63.1	70.4	76.44	80.1	83.7	86.3	87.4	88.7	89.6	91.5	8.5
86	"	225	26	5834	1	10/29/38	25.08		7.0	52.4	58.5	68.4	74.92	79.7	83.2	86.0	87.1	88.8	89.6	91.4	8.6
87	"	225	29	6509	1	11/1/38	28.66		5.4	48.7	53.9	64.1	71.34	76.9	80.7	83.9	85.0	86.9	87.8	89.9	10.1
88	"	225	30	6732	1	11/4/38	28.70		5.1	47.9	53.5	64.5	71.30	76.5	80.4	83.6	84.8	85.7	87.7	89.8	10.2
89	"	225	32	7177	1	11/5/38	30.36		4.5	46.1	51.4	62.2	69.64	75.0	79.1	82.6	83.9	85.9	86.9	89.2	10.8

A P P E N D I X III (Continued)

Character of Test								Screen Analyses of Test Charges after Test — Per Cent Retained (Cumulative)												
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	*"S" Wear (%)	Screen 1/4"	Sieve No. 10	12	16	*20	30	40	50	60	80	100	200	Pass 200 (%)
90	Courchesne	225	32	7183	2	11/7/38	30.56	4.9	44.9	50.7	61.7	69.44	75.4	79.7	83.2	84.5	86.6	87.7	90.0	10.0
91	"	225	31	6958	1	11/13/38	29.76	4.5	47.0	52.3	62.9	70.24	76.0	79.9	83.4	84.6	86.6	87.7	89.8	10.2
92	"	225	31	6958	2	11/14/38	29.78	5.3	44.5	52.1	62.5	70.22	75.8	80.1	83.4	84.7	86.8	87.7	90.1	9.9
93	"	225	31	6958	3	11/16/38	29.94	5.2	46.3	51.3	62.6	70.06	75.5	79.6	83.2	84.4	86.5	87.4	89.8	10.2
94	"	225	26	5836	2	12/14/38	24.88	7.0	54.5	59.3	68.6	75.12	80.0	83.5	86.2	87.4	89.1	90.0	91.8	8.2
95	"	225	25	5610	1	2/27/39	24.76	8.3	54.2	60.7	68.8	75.24	79.2	83.3	86.0	87.2	88.6	89.6	91.4	8.6
96	"	225	25	5610	2	3/1/39	23.98	9.2	57.3	61.4	69.7	76.02	79.9	83.8	86.4	87.5	88.8	89.8	91.5	8.5
97	"	225	25	5610	3	3/6/39	23.32	9.2	56.1	61.0	70.4	76.68	80.3	84.2	86.8	87.9	89.2	90.2	92.1	7.9
98	"	420	14	5895	1	10/29/38	26.04	7.7	51.4	58.1	67.5	73.96	79.0	82.7	85.6	86.6	88.4	89.3	91.2	8.8
99	"	420	16	6775	1	10/31/38	29.14	5.9	47.8	53.1	63.6	70.86	76.3	80.4	83.8	85.0	87.1	88.0	90.3	8.7
100	"	420	17	7211	1	11/4/38	31.20	4.3	45.3	51.0	61.3	68.80	74.7	78.9	82.5	83.8	85.9	86.9	89.3	10.7
101	"	420	18	7684	1	11/5/38	33.02	4.3	42.4	47.6	59.1	66.98	72.8	77.4	81.1	82.5	84.8	85.8	88.3	11.7
102	"	420	19	8125	1	11/7/38	34.14	4.6	41.1	46.7	57.6	65.86	72.4	77.0	81.3	82.8	85.2	86.5	89.1	10.9
103	"	420	16	6802	2	11/13/38	29.46	5.8	48.3	52.3	63.4	70.54	76.0	80.1	83.4	84.6	86.8	87.6	89.8	10.2
104	"	420	16	6804	3	11/14/38	29.98	5.7	46.3	51.6	62.6	70.02	75.9	80.1	83.5	84.9	86.9	87.9	90.2	9.8
105	"	420	14	5898	2	12/14/38	26.60	7.0	50.3	57.7	66.8	73.40	78.8	82.5	85.5	86.7	88.6	89.5	91.5	8.5
106	"	420	14	5865	3	2/28/39	24.72	9.7	53.8	60.4	69.0	75.28	79.1	83.1	85.8	87.0	88.4	89.3	91.0	9.0
107	Maryneal	65	88	5736	1	2/8/39	37.42	4.6	40.9	46.5	56.1	62.58	66.5	70.4	73.5	74.8	76.6	77.7	80.9	19.1
108	"	65	80	5230	1	2/11/39	32.86	8.3	48.7	52.6	61.4	67.14	70.8	74.1	76.7	77.8	79.6	80.4	83.1	16.9
109	"	65	82	5496	1	2/18/39	35.42	7.5	45.8	49.8	58.8	64.58	68.4	71.9	74.7	75.9	77.7	78.6	81.5	18.5
110	"	65	81	5315	1	2/20/39	34.50	7.4	46.2	50.8	59.6	65.50	69.1	72.9	75.5	76.7	78.4	79.3	82.2	17.8
111	"	65	81	5328	2	2/21/39	34.04	8.0	45.9	51.5	60.2	65.96	69.6	73.2	75.8	76.9	78.4	79.5	82.0	18.0
112	"	65	81	5322	3	3/1/39	35.44	6.7	43.4	50.4	58.5	64.56	68.1	71.8	74.5	75.7	77.3	78.5	81.3	18.7
113	"	65	100	6569	1	3/10/39	41.66	4.0	35.7	41.8	51.4	58.34	62.4	67.0	70.4	72.0	74.1	75.6	79.8	20.2
114	"	65	99	6504	1	3/13/39	39.62	4.7	39.7	44.2	53.7	60.38	64.6	68.9	72.1	73.5	75.5	76.9	80.8	19.2
115	"	65	99	6504	2	3/14/39	40.52	4.6	38.3	43.1	52.8	59.48	63.5	67.9	71.2	72.7	74.7	76.1	80.2	19.8
116	"	65	99	6504	3	3/16/39	38.56	5.2	38.8	45.1	54.6	61.44	65.5	69.8	72.9	74.4	76.3	77.7	81.5	18.5
117	"	130	50	6427	1	10/31/38	44.50	1.7	31.9	36.9	48.3	55.50	61.5	65.6	69.5	71.0	73.6	75.0	79.0	21.0
118	"	130	40	5150	1	11/2/38	38.48	3.1	37.7	44.2	54.7	61.52	66.6	70.2	73.3	74.4	76.5	77.7	80.9	19.1
119	"	130	35	4509	1	11/3/38	34.08	4.3	45.6	50.7	60.3	65.92	70.4	73.3	75.9	76.9	78.6	79.5	82.2	17.8
120	"	130	35	4491	2	11/5/38	32.52	5.0	47.3	52.7	61.9	67.48	71.6	74.6	77.1	78.1	79.8	80.7	83.5	16.5
121	"	130	36	4624	1	11/14/38	33.98	4.7	45.5	50.8	60.0	66.02	70.2	73.2	75.9	76.9	78.6	79.6	82.4	17.6
122	"	130	36	4629	2	11/16/38	33.40	4.9	46.1	51.3	60.5	66.60	70.9	73.9	76.5	77.5	79.2	80.2	82.8	17.2
123	"	130	36	4615	3	12/2/38	34.70	4.1	44.6	49.6	59.5	65.30	69.7	72.8	75.5	76.6	78.4	79.3	82.2	17.8
124	"	130	47	6011	1	12/14/38	38.96	3.3	38.9	44.3	54.2	61.04	66.4	70.1	73.3	74.7	77.0	78.1	81.2	18.8
125	"	130	45	5792	1	2/24/39	40.04	2.5	36.0	42.6	52.6	59.96	64.0	68.5	72.0	73.4	75.4	76.8	80.2	19.8
126	"	130	45	5791	2	2/28/39	38.32	3.9	39.3	45.1	55.1	61.68	65.8	70.1	73.3	74.7	76.7	78.1	81.2	18.8
127	"	130	45	5791	3	3/8/39	38.66	3.6	39.0	44.3	54.4	61.34	65.5	69.7	72.9	74.3	76.1	77.6	81.2	18.8
128	"	225	27	6060	1	11/1/38	41.54	1.7	38.4	39.8	51.0	58.46	64.0	68.9	71.6	73.0	75.4	76.7	80.4	19.6
129	"	225	23	5160	1	11/2/38	38.36	2.4	37.6	44.1	55.0	61.64	66.8	70.4	73.5	74.7	76.8	77.9	81.2	18.8
130	"	225	18	4042	1	11/4/38	31.30	5.0	48.5	54.1	63.2	68.70	72.5	75.3	77.7	78.6	80.2	81.1	83.6	16.4
131	"	225	20	4490	1	11/5/38	32.94	4.3	45.8	51.2	60.9	67.06	71.3	74.3	77.0	78.0	79.8	80.8	83.6	16.4
132	"	225	21	4715	1	11/9/38	32.92	4.4	45.8	50.8	61.0	67.08	71.5	74.7	77.4	78.4	80.1	81.2	83.9	16.1
133	"	225	22	4936	1	11/13/38	35.24	3.5	43.5	48.7	58.4	64.76	69.4	72.7	75.6	76.6	78.5	79.6	82.6	17.4
134	"	225	22	4937	2	11/14/38	36.00	3.4	40.2	48.0	57.4	64.00	68.5	71.8	74.8	75.9	77.9	79.0	81.7	18.3
135	"	225	21	4715	2	11/16/38	34.92	3.7	43.8	49.3	58.9	65.08	69.7	72.9	75.7	76.7	78.5	79.6	82.5	17.5
136	"	225	21	4714	3	12/2/38	35.46	3.3	42.8	48.1	58.0	64.54	69.1	72.5	75.4	76.5	78.5	79.5	82.7	17.3
137	"	225	26	5836	1	12/14/38	37.86	3.5	37.8	44.8	54.9	62.14	67.1	70.9	74.3	75.5	77.8	79.0	82.5	17.5
138	"	225	25	5610	1	2/27/39	38.22	3.1	37.6	44.4	55.0	61.78	66.0	70.4	73.6	75.1	77.0	78.4	81.6	18.4
139	"	225	25	5610	2	3/1/39	38.18	3.3	39.8	45.4	54.6	61.82	65.8	70.3	73.6	75.0	76.9	78.4	81.5	18.5

A P P E N D I X III (Continued)

Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	*"S" Wear (%)	Screen 1/4"*	Sieve No. 10	12	16	*20	30	40	50	60	80	100	200	Pass 200 (%)
	Character of Test							Screen Analyses of Test Charges after Test — Per Cent Retained (Cumulative)												
140	Marynea l	225	25	5610	3	3/6/39	37.42	3.5	39.6	45.1	55.5	62.58	66.9	71.2	74.2	75.8	77.6	79.1	82.8	17.2
141	"	420	16	6775	1	10/31/38	43.80	1.4	32.1	37.2	48.8	56.20	62.2	66.4	70.2	71.6	74.2	75.6	79.6	20.4
142	"	420	12	5059	1	11/2/38	36.12	1.1	40.9	47.3	57.7	63.88	(Mechanical shaker sample ruined)							
143	"	420	11	4635	1	11/4/38	33.28	4.1	45.7	51.4	60.7	66.72	70.8	73.9	76.5	77.5	79.3	80.3	83.0	17.0
144	"	420	11	4620	2	11/5/38	32.18	5.5	48.5	53.3	62.0	67.82	71.6	74.5	77.1	78.1	79.9	80.8	83.7	16.3
145	"	420	11	4608	3	11/9/38	31.86	4.5	48.5	53.3	62.4	68.14	72.2	75.2	77.7	78.7	80.4	81.4	84.1	15.9
146	"	420	11	4626	4	11/13/38	32.98	3.9	46.6	51.7	61.1	67.02	71.3	74.4	76.9	77.9	79.7	80.6	83.3	16.7
147	"	420	12	5060	2	11/15/38	36.06	3.9	40.6	47.7	57.5	63.94	68.5	71.8	74.7	75.8	77.8	78.8	81.8	18.2
148	"	420	11	4624	5	11/16/38	33.52	5.0	46.9	51.0	60.8	66.48	70.7	73.8	76.5	77.5	79.2	80.2	83.0	17.0
149	"	420	12	5040	3	12/2/38	36.10	3.9	42.0	47.5	57.6	63.90	68.7	72.0	75.1	76.2	78.1	79.1	82.2	17.8
150	"	420	14	5898	1	12/14/38	37.68	3.2	40.2	45.2	55.7	62.32	67.5	71.2	74.3	75.7	77.9	79.1	82.1	17.9
151	"	420	14	5865	2	2/28/39	37.28	3.5	39.3	45.7	55.7	62.72	66.6	70.9	74.1	75.5	77.3	78.8	81.8	18.2
152	"	420	14	5882	3	3/3/39	38.42	2.8	39.9	45.7	54.5	61.58	65.8	70.1	73.3	74.8	76.7	78.2	82.2	17.8
153	Ogden	65	95	6195	1	2/8/39	39.78	4.1	39.4	44.4	53.6	60.22	65.0	69.3	72.5	73.3	75.7	77.0	80.0	20.0
154	"	65	91	5953	1	2/11/39	37.74	4.5	41.1	45.6	55.7	62.26	67.3	71.4	74.7	76.0	78.0	79.0	82.0	18.0
155	"	65	92	6152	1	2/18/39	41.26	3.6	36.2	41.5	51.6	58.74	63.7	68.2	71.7	73.1	75.3	76.4	79.5	20.5
156	"	65	92	6033	2	2/20/39	38.86	4.0	38.9	42.9	54.3	61.14	65.5	70.1	73.3	74.7	76.9	77.8	80.9	19.1
157	"	65	92	6052	3	2/21/39	42.16	3.4	34.4	39.6	50.7	57.84	62.8	67.5	70.9	72.3	74.3	75.7	78.6	21.4
158	"	65	91	5985	2	2/24/39	41.64	3.1	34.2	41.1	50.9	58.36	62.9	67.5	70.9	72.3	74.2	75.6	78.5	21.5
159	"	65	89	5846	1	2/27/39	36.92	5.5	41.8	47.3	56.7	63.08	67.2	71.4	74.4	75.7	77.4	78.8	81.5	18.5
160	"	65	90	5910	1	3/1/39	39.40	4.3	38.7	44.7	53.8	60.60	64.6	69.1	72.2	73.5	75.3	76.6	79.[illegible]	20.7
161	"	65	88	5779	1	3/3/39	37.36	5.1	41.9	46.5	56.1	62.64	66.6	70.9	73.7	75.1	76.8	78.0	81.2	18.8
162	"	65	88	5779	2	3/3/39	37.66	4.9	40.6	47.0	55.7	62.34	66.3	70.5	73.4	74.7	76.4	77.8	81.0	19.0
163	"	65	90	5910	2	3/6/39	37.26	5.6	41.9	46.3	56.1	62.74	66.9	71.1	74.2	75.5	77.3	78.6	81.9	18.1
164	"	65	90	5910	3	3/6/39	36.94	5.2	42.1	47.6	56.6	63.06	67.1	71.5	77.4	75.8	77.6	78.9	82.2	17.8
165	"	65	89	5848	2	3/7/39	38.54	3.9	39.4	44.4	54.5	61.46	65.7	69.9	73.1	74.5	76.2	77.5	80.8	19.2
166	"	65	89	5848	3	3/8/39	39.42	4.1	38.3	43.6	53.5	60.58	65.0	69.4	72.5	73.9	75.7	77.0	80.2	19.8
167	"	65	89	5848	4	3/8/39	38.96	4.3	38.8	44.0	54.1	61.04	65.4	69.8	72.9	74.3	76.0	77.4	80.6	19.4
168	"	65	100	6569	1	3/10/39	41.16	3.7	35.7	41.9	52.1	58.84	63.1	67.9	71.3	72.8	74.8	76.3	79.8	20.2
169	"	65	99	6504	1	3/13/39	40.70	3.9	37.4	41.8	52.2	59.30	63.8	68.4	71.7	73.2	75.2	76.6	80.1	19.9
170	"	65	99	6504	2	3/14/39	40.16	4.1	38.1	42.8	52.5	59.84	64.2	68.9	72.2	73.7	75.6	77.1	80.7	19.3
171	"	65	99	6504	3	3/16/39	40.00	4.2	36.3	42.3	52.7	60.00	64.4	69.1	72.5	74.0	76.0	77.4	81.0	19.0
172	"	130	35	4508	1	2/1/39	33.84	3.6	46.0	51.3	60.2	66.16	70.2	73.9	76.5	77.7	79.1	80.1	82.5	17.5
173	"	130	40	5152	1	2/2/39	36.58	4.0	41.8	46.8	57.0	63.42	68.7	72.3	75.3	76.6	78.5	79.6	82.3	17.7
174	"	130	44	5667	1	2/3/39	39.92	3.3	37.2	42.6	53.2	60.08	65.8	69.6	73.0	74.4	76.6	77.8	80.3	19.7
175	"	130	42	5385	1	2/7/39	37.48	3.3	40.5	45.6	55.7	62.52	67.2	71.5	74.7	76.0	77.7	78.9	81.8	18.2
176	"	130	43	5515	1	2/8/39	38.86	3.4	37.0	43.4	53.8	61.14	65.7	70.2	73.4	74.9	76.7	77.9	80.9	19.1
177	"	130	42	5393	2	2/11/39	37.22	3.2	41.6	46.1	56.5	62.78	67.7	72.0	75.2	76.5	78.6	79.4	82.4	17.6
178	"	130	43	5533	2	2/18/39	39.64	2.8	37.6	42.4	53.1	60.36	65.1	69.6	72.9	74.3	76.4	77.4	80.5	19.5
179	"	130	43	5533	3	2/20/39	38.20	3.6	38.2	44.3	54.9	61.80	66.5	71.1	74.3	75.7	77.9	78.9	81.8	18.2
180	"	130	45	5792	1	2/24/39	40.76	2.3	35.8	42.2	51.5	59.24	63.5	68.2	71.7	73.1	75.1	76.5	79.4	20.6
181	"	130	45	5791	2	3/1/ 39	40.68	2.8	37.1	42.3	51.9	59.32	63.8	68.6	72.0	73.4	75.4	76.8	79.6	20.4
182	"	130	45	5791	3	3/7/39	40.34	2.5	35.8	41.4	52.3	59.66	64.5	69.3	72.6	74.1	76.0	77.5	81.0	19.0
183	"	225	20	4490	1	2/1/39	34.18	3.6	44.2	49.6	59.3	65.82	69.7	73.6	76.4	77.6	79.1	80.2	82.7	17.3
184	"	225	23	5163	1	2/2/39	36.70	3.6	41.4	46.3	56.5	63.30	68.7	72.2	75.5	76.9	78.9	80.1	82.7	17.3
185	"	225	25	5610	1	2/4/39	39.10	3.3	36.4	43.7	53.8	60.90	66.5	70.3	73.6	75.0	77.2	78.4	81.1	18.9
186	"	225	24	5386	1	2/6/39	37.94	3.4	39.7	45.0	55.2	62.06	66.8	71.3	74.6	76.1	77.8	79.0	82.0	18.0
187	"	225	24	5388	2	2/7/39	37.50	3.0	40.3	45.1	55.4	62.50	67.3	71.6	75.0	76.4	78.2	79.4	82.3	17.7
188	"	225	24	5388	3	2/8/39	38.40	2.8	39.5	44.3	54.9	61.60	66.6	70.9	74.2	75.5	77.4	78.5	81.4	18.6

A P P E N D I X III (Continued)

Test No.	Stone	Character of Test: Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	**"S" Wear (%)	Screen Analyses of Test Charges after Test — Per Cent Retained (Cumulative): Screen 1/4"	Sieve No. 10	12	16	*20	30	40	50	60	80	100	200	Pass 200 (%)
189	Ogden	225	25	5610	2	2/27/39	38.50	3.1	37.4	43.6	53.8	61.50	66.0	70.8	74.2	75.6	77.5	79.0	81.8	18.2
190	"	225	25	5610	3	3/1/39	38.60	3.0	38.0	44.5	54.0	61.40	65.8	70.4	73.7	75.1	76.9	78.3	81.1	18.9
191	"	420	11	4623	1	2/1/39	33.76	4.1	44.8	50.4	60.0	66.24	70.5	74.2	76.9	78.2	79.7	80.7	83.0	17.0
192	"	420	12	5050	1	2/2/39	35.00	4.4	44.5	49.4	59.0	65.00	70.3	73.7	76.7	78.0	79.9	81.0	83.4	16.6
193	"	420	14	5870	1	2/4/39	39.40	2.9	37.7	42.9	53.8	60.60	66.6	70.4	73.8	75.2	77.4	78.6	81.3	18.7
194	"	420	13	5430	1	2/6/39	37.14	3.8	41.5	46.3	56.3	62.86	67.8	72.0	75.3	76.6	78.4	79.5	82.3	17.7
195	"	420	13	5428	2	2/7/39	36.80	3.7	39.7	46.2	56.2	63.20	67.8	72.1	75.3	76.7	78.5	79.6	82.6	17.4
196	"	420	14	5868	2	2/8/39	39.04	3.0	38.4	43.2	53.9	60.96	66.0	70.5	74.0	75.4	77.3	78.6	81.7	18.3
197	"	420	13	5425	3	2/11/39	36.56	4.1	42.6	46.8	57.1	63.44	68.1	72.6	75.7	77.1	79.2	80.2	83.1	16.9
198	"	420	14	5864	3	2/11/39	38.46	3.2	40.0	44.2	55.0	61.54	66.3	71.1	74.5	76.0	78.3	79.2	82.4	17.6
199	Trap	65	100	6569	1	3/10/39	12.42	22.6	73.1	77.7	83.6	87.58	89.4	91.3	92.6	93.2	93.8	94.3	95.3	4.7
200	"	65	99	6504	1	3/13/39	11.42	23.5	76.5	79.7	85.2	88.58	90.4	92.2	93.3	93.8	94.4	94.9	95.7	4.3
201	"	65	99	6504	2	3/15/39	12.64	24.6	72.6	77.3	83.7	87.36	89.3	91.3	92.5	93.1	93.8	94.3	95.1	4.9
202	"	65	99	6504	3	3/16/39	11.52	25.3	74.3	79.3	85.0	88.48	90.4	92.2	93.4	93.9	94.5	95.0	95.9	4.1
203	"	130	45	5792	1	2/27/39	13.28	19.5	72.8	77.2	83.0	86.72	88.9	91.0	92.3	93.0	93.7	94.2	95.0	5.0
204	"	130	45	5791	2	2/28/39	13.16	19.7	70.3	76.6	83.0	86.84	89.0	91.0	92.4	93.0	93.7	94.2	95.1	4.9
205	"	130	45	5791	3	3/3/39	12.94	20.6	75.1	78.5	83.4	87.06	89.1	91.1	92.4	93.0	93.7	94.2	95.0	5.0
206	"	225	25	5610	1	2/27/39	14.12	17.0	71.6	75.7	81.8	85.88	88.2	90.4	91.9	92.6	93.4	94.0	94.9	5.1
207	"	225	25	5610	2	3/1/39	13.70	18.3	73.5	75.8	82.4	86.30	88.6	90.8	92.3	92.9	93.6	94.2	95.1	4.9
208	"	225	25	5610	3	3/6/39	13.34	18.8	72.1	76.3	82.8	86.66	88.9	91.1	92.5	93.2	93.9	94.5	95.6	4.4
209	"	420	14	5883	1	3/1/39	15.24	17.2	59.1	74.2	80.3	84.76	87.3	89.7	91.4	92.1	92.9	93.6	94.6	5.4
210	"	420	14	5881	2	3/6/39	15.00	8.0	69.5	73.8	80.7	85.00	87.5	90.0	91.6	92.4	93.3	93.9	95.1	4.9
211	"	420	14	5882	3	3/7/39	15.34	17.7	69.2	73.2	80.3	84.66	87.3	89.7	91.4	92.1	93.1	93.7	94.9	5.1
212	Cordova C.	65	100	6569	1	3/10/39	79.14	0.1	5.1	7.8	14.0	20.86	25.2	30.8	35.3	37.8	42.1	46.4	60.1	39.9
213	"	65	99	6504	1	3/14/39	79.42	0.1	5.3	7.4	13.9	20.58	25.4	30.9	35.4	38.1	42.2	46.5	59.7	40.3
214	"	65	99	6504	2	3/17/39	76.36	0.2	6.6	9.6	16.8	23.64	28.8	33.8	38.0	40.5	44.7	49.0	62.0	38.0
215	"	65	99	6504	3	3/17/39	76.82	0.2	6.4	9.4	16.4	23.18	28.2	33.1	37.5	40.1	44.3	48.5	61.8	38.2
216	"	130	45	5792	1	2/27/39	71.94	0.1	8.5	12.9	21.2	28.06	32.2	37.1	41.0	43.1	47.0	50.7	61.1	38.9
217	"	130	45	5791	2	2/28/39	75.24	0.1	7.8	10.9	17.9	24.76	29.0	33.9	38.0	40.1	44.0	47.9	60.7	39.3
218	"	130	45	5791	3	3/3/39	73.96	0.1	8.6	12.2	19.1	26.04	30.4	35.2	39.0	41.2	44.9	48.8	61.2	38.8
219	"	225	25	5610	1	2/27/39	69.34	0.1	10.6	15.6	24.1	30.66	34.7	39.2	42.8	44.8	48.5	52.1	62.0	38.0
220	"	225	25	5610	2	3/3/39	70.04	0.0	11.6	15.8	23.4	29.96	34.0	38.5	42.1	44.1	47.6	51.5	63.2	36.8
221	"	225	25	5610	3	3/6/39	71.42	0.1	9.2	13.3	22.0	28.58	32.6	37.3	40.9	43.0	46.7	50.5	62.4	37.6
222	"	420	14	5882	1	3/3/39	68.90	0.0	11.4	15.3	24.2	31.10	34.8	39.1	42.6	44.6	48.0	51.7	63.4	36.6
223	"	420	14	5881	2	3/6/39	69.68	0.1	9.4	13.9	23.4	30.32	34.1	38.3	41.7	43.7	47.2	51.0	62.6	37.4
224	"	420	14	5881	3	3/8/39	68.92	0.1	10.7	15.1	24.5	31.08	34.9	39.1	42.6	44.6	48.0	51.8	63.5	36.5

APPENDIX IV

Test Data for "S" Grading Tests

(Constants: Chico Trial Stone; 500 Rattler Revolutions; Wear Equals Per Cent Passing No. 20 Sieve)

Test No.	Character of Test: Size Test Charge (Gm.)	Size Balls (Gm.)	No. Balls	Abrasive Charge (Gm.)	Rattler Test Date	*"S" Wear (%)	Sieve Analyses of Test Charges After Test — Per Cent Retained (Cumulative): Screen 1/4"	Sieve No. 10	12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
1	5000	65	70	4532	2/1/39	20.08	11.5	60.0	67.0	75.2	79.92	83.1	85.7	87.3	88.1	88.8	89.3	90.2	9.8
2	"	65	93	6055	2/2/39	24.98	8.0	54.5	59.3	69.0	75.02	79.4	80.3	84.7	85.6	86.9	87.5	88.8	11.2
3	"	65	103	6711	2/6/39	26.30	7.5	53.3	57.6	67.5	73.70	77.9	81.5	84.1	85.1	86.3	87.0	88.6	11.4
4	4000	130	38	4875	2/8/39	28.65	4.9	48.8	53.8	67.1	71.35	76.3	80.3	83.2	84.4	85.7	86.5	88.2	11.8
5	"	225	24	5388	2/7/39	30.50	5.1	47.4	51.8	62.7	69.95	74.9	79.3	82.5	83.7	85.2	86.1	88.0	12.0
6	"	225	20	4490	2/8/39	25.18	6.3	53.1	59.0	68.2	74.82	78.7	82.2	84.7	85.7	86.9	87.7	89.1	10.9
7	"	225	21	4716	2/10/39	26.37	5.5	49.3	56.8	66.9	73.62	77.9	81.7	84.5	85.5	86.8	87.6	89.2	10.8
8	"	420	13	5428	2/7/39	26.63	8.2	52.3	58.2	67.2	73.37	77.7	81.4	84.0	85.0	86.3	87.1	88.8	11.2
9	3000	65	70	4560	2/6/39	34.20	3.7	38.9	45.8	58.0	65.79	71.6	76.8	80.4	81.8	83.5	84.5	86.7	13.3
10	"	65	52	3380	2/7/39	25.43	4.7	51.9	57.2	67.9	74.56	78.9	82.4	85.1	86.1	87.3	88.0	89.5	10.5
11	"	65	57	3727	2/8/39	28.27	5.1	46.5	53.3	64.4	71.66	76.3	80.5	83.4	84.6	85.9	86.8	88.5	11.5
12	"	65	54	3529	2/10/39	26.90	4.0	50.4	55.4	65.9	73.03	77.2	81.0	83.7	84.7	85.9	86.7	88.2	11.8
13	"	130	37	4765	2/6/39	33.23	4.0	42.9	48.0	59.3	66.76	72.5	77.3	80.7	82.1	83.8	84.8	86.9	13.1
14	"	130	30	3865	2/7/39	27.07	6.7	51.5	56.0	66.6	72.93	77.6	81.4	84.2	85.3	86.5	87.4	89.0	11.0
15	"	225	21	4713	2/4/39	26.90	8.8	52.8	58.4	66.7	73.09	77.6	80.8	83.7	84.7	86.3	87.1	88.4	11.6
16	"	225	21	4713	2/6/39	27.53	8.3	51.5	56.4	66.0	72.46	76.7	80.6	83.6	84.8	86.2	87.0	88.8	11.2
17	"	420	11	4589	2/4/39	22.54	13.1	59.2	64.9	72.4	77.46	81.3	84.0	86.1	87.0	88.2	88.8	89.9	10.1
18	"	420	13	5430	2/6/39	27.83	8.6	52.8	57.2	66.2	72.16	77.0	80.9	83.7	84.8	86.1	87.0	88.7	11.3
19	"	420	12	4993	2/7/39	24.67	10.5	55.6	61.5	69.5	75.33	79.2	82.6	85.0	86.1	87.2	88.0	89.6	10.4
20	2000	65	45	2965	3/30/39	26.15	6.9	51.7	58.3	67.6	73.85	78.5	81.8	84.1	85.3	86.5	87.4	89.1	10.9
21	"	65	39	2567	3/30/39	22.45	7.2	61.1	64.4	72.2	77.55	81.2	84.1	86.2	87.1	88.1	88.9	90.3	9.7
22	"	130	27	3473	3/30/39	24.40	9.8	57.2	62.5	70.7	75.60	79.6	82.6	84.7	85.7	86.9	87.7	89.3	10.7
23	"	130	24	3086	3/30/39	21.50	10.4	63.7	67.5	73.7	78.50	81.7	84.2	86.1	87.0	88.0	88.7	90.0	10.0
24	"	225	17	3816	3/30/39	22.15	13.0	63.0	66.8	72.9	77.85	81.1	83.7	85.7	86.6	87.7	88.4	89.8	10.2
25	"	225	19	4264	3/30/39	25.40	8.6	58.7	62.7	69.1	74.60	78.4	81.5	83.8	84.9	86.1	87.0	88.7	11.3
26	"	420	12	5033	3/30/39	27.65	7.8	56.3	59.4	66.5	72.35	76.5	79.9	82.3	83.6	84.9	85.8	87.7	12.3

A P P E N D I X V

Test Data for "S" Grading Tests

(Constants: Chico Trial Stone; 500 Rattler Revolutions; Ninety-nine 65-gram Balls, Forty-five 130-gram Balls, Twenty-five 225-gram Balls, and Fourteen 420-gram Balls)

Character of Test						Sieve Analyses of Test Charges After Test											
						Per Cent Retained (Cumulative)											
						Sieve No.											
Test Charge (Gm.)	Size Balls (Gm.)	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	Screen 1/4"O	10	12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
5000	65	6504	1	3/16/39	8.1	54.1	60.5	69.6	75.8	79.3	82.8	85.1	86.0	87.1	87.9	89.3	10.7
5000	65	6504	2	3/17/39	7.2	54.0	59.4	68.6	74.9	79.2	82.5	84.8	85.9	87.0	87.8	89.4	10.6
4000	65	6504	1	3/17/39	3.9	41.7	48.2	59.5	67.4	72.6	77.0	80.2	81.5	83.1	84.3	86.4	13.6
4000	65	6504	2	3/17/39	4.2	42.5	48.1	59.2	67.3	72.7	77.4	80.8	82.2	83.9	85.1	87.4	12.6
3000	65	6504	1	3/17/39	2.4	29.1	36.4	48.2	57.5	64.4	70.3	74.7	76.7	79.0	80.6	83.8	16.3
3000	65	6504	2	3/17/39	2.1	28.4	35.5	47.2	56.7	63.9	70.0	74.7	76.7	79.2	81.0	84.5	15.6
2000	65	6504	1	3/17/39	1.0	18.3	23.5	34.6	44.9	53.1	60.7	66.6	69.4	72.7	75.2	79.7	20.3
2000	65	6504	2	3/17/39	1.2	18.3	23.6	34.6	44.7	53.2	60.8	66.7	69.6	73.1	75.6	80.4	19.6
1000	65	6504	1	3/17/39	0.4	6.2	8.3	14.4	22.8	31.7	41.0	49.2	53.6	58.5	62.3	70.2	29.8
1000	65	6504	2	3/17/39	0.4	6.1	8.5	14.4	22.9	32.1	41.3	49.7	54.3	59.3	63.3	71.6	28.4
500	65	6504	1	3/17/39	0.0	0.6	0.8	1.0	1.6	3.8	10.2	20.0	26.4	34.4	40.6	53.4	46.6
500	65	6504	2	3/17/39	0.2	0.6	0.8	1.2	1.8	4.2	11.6	21.6	27.8	35.8	42.2	55.8	44.2
5000	130	5791	1	3/7/39	6.9	54.9	59.8	69.2	75.3	79.1	82.6	85.0	85.9	87.0	87.9	89.4	10.6
5000	130	5791	2	3/15/39	8.5	54.5	60.9	69.7	75.9	79.7	83.2	85.4	86.5	87.5	88.3	89.7	10.3
4000	130	5791	1	3/7/39	3.5	43.6	49.2	60.6	68.3	73.1	77.9	81.1	82.5	84.1	85.2	87.4	12.6
4000	130	5791	2	3/15/39	4.3	42.8	50.0	61.3	69.2	74.1	78.8	82.0	83.4	84.9	86.0	88.1	11.9
3000	130	5791	1	3/7/39	2.6	35.3	41.1	53.0	62.0	67.4	73.3	77.4	79.1	81.1	82.6	85.5	14.5
3000	130	5791	2	3/15/39	2.4	35.3	42.7	54.2	63.2	68.9	74.6	78.5	80.2	82.2	83.7	86.3	13.7
2000	130	5791	1	3/7/39	2.4	30.9	36.2	47.0	56.1	62.3	68.8	73.2	75.6	78.0	79.8	83.3	16.7
2000	130	5791	2	3/15/39	1.7	30.3	36.7	47.6	57.0	63.6	69.8	74.3	76.5	78.9	80.7	84.1	15.9
1000	130	5791	1	3/7/39	1.0	14.3	17.5	26.8	36.6	44.2	53.4	60.2	63.4	67.5	70.7	76.5	23.5
1000	130	5791	2	3/15/39	1.2	15.3	19.6	29.1	39.4	47.1	55.9	62.5	65.9	69.8	72.6	78.4	21.6
500	130	5791	1	3/7/39	0.2	1.6	2.0	4.0	9.0	15.8	27.2	38.0	42.8	49.6	54.8	64.6	35.4
500	130	5791	2	3/15/39	0.2	2.2	2.8	5.2	11.2	18.4	30.4	40.6	45.0	52.0	57.0	66.8	33.2
5000	225	5610	1	3/8/39	6.7	53.7	58.7	68.3	74.7	78.6	82.4	84.8	85.9	87.0	87.9	89.5	10.5
5000	225	5610	2	3/20/39	6.0	52.4	58.2	67.7	74.5	78.5	82.0	84.4	85.5	86.7	87.5	89.2	10.8
4000	225	5610	1	3/8/39	4.9	45.6	50.9	61.6	69.0	73.9	78.6	81.8	83.0	84.6	85.7	87.9	12.1
4000	225	5610	2	3/20/39	3.9	45.2	51.0	61.3	69.0	74.0	78.3	81.4	82.8	84.4	85.5	87.7	12.3
3000	225	5610	1	3/8/39	4.6	43.5	48.4	59.2	66.9	71.8	76.8	80.2	81.6	83.3	84.5	87.0	13.0
3000	225	5610	2	3/20/39	4.1	43.6	48.6	59.2	66.7	72.1	76.7	80.0	81.5	83.3	84.5	87.0	13.1
2000	225	5610	1	3/8/39	3.6	40.7	46.2	56.3	64.1	69.0	74.2	78.0	79.6	81.6	83.0	85.7	14.3
2000	225	5610	2	3/20/39	3.0	40.4	46.0	56.0	63.5	69.0	74.0	77.6	79.3	81.3	82.7	85.6	14.4
1000	225	5610	1	3/8/39	1.6	19.8	22.9	33.6	43.8	50.7	58.7	64.6	67.7	71.2	73.8	79.0	21.0
1000	225	5610	2	3/20/39	1.1	18.0	22.1	32.4	42.6	50.8	58.5	64.6	67.5	71.2	73.8	79.3	20.7
500	225	5610	1	3/8/39	0.2	3.0	4.2	9.6	19.2	27.8	40.0	49.6	54.4	60.0	64.0	72.6	27.4
500	225	5610	2	3/20/39	0.2	3.6	5.2	10.6	19.2	28.6	39.6	48.6	53.4	59.4	63.4	72.0	28.0
5000	420	5882	1	3/13/39	6.9	52.9	58.5	67.5	74.2	78.0	81.9	84.4	85.5	86.7	87.5	89.1	10.9
5000	420	5880	2	3/21/39	5.4	52.9	57.5	67.0	73.7	77.8	81.5	84.0	85.1	86.4	87.2	88.9	11.1
4000	420	5882	1	3/13/39	6.7	50.8	55.0	64.8	71.9	76.2	80.3	83.0	84.2	85.5	86.5	88.4	11.6
4000	420	5880	2	3/20/39	7.0	50.2	55.2	64.4	71.4	76.0	79.8	82.6	83.9	85.3	86.3	88.3	11.7
3000	420	5882	1	3/13/39	7.4	50.7	55.5	64.5	71.2	75.6	79.7	82.5	83.8	85.3	86.3	88.3	11.7
3000	420	5880	2	3/20/39	5.9	49.7	55.1	64.0	70.5	75.2	79.2	82.0	83.3	84.8	85.8	87.9	12.1
2000	420	5882	1	3/13/39	5.3	41.6	48.0	58.1	65.7	70.5	75.6	79.1	80.6	82.4	83.7	86.3	13.7
2000	420	5880	2	3/20/39	4.3	44.4	49.4	58.7	66.0	71.0	75.6	79.0	80.5	82.5	83.7	86.4	13.6
1000	420	5882	1	3/13/39	1.2	22.2	26.3	38.1	48.1	55.1	63.0	68.4	71.0	74.2	76.5	80.9	19.1
1000	420	5880	2	3/20/39	1.0	21.7	26.2	37.7	47.9	55.3	62.2	67.9	70.5	73.9	76.2	80.9	19.1
500	420	5882	1	3/15/39	0.0	4.6	7.8	17.2	29.8	40.0	51.6	59.8	63.8	68.4	72.0	78.8	21.2
500	420	5880	2	3/20/39	0.0	3.2	5.2	14.4	27.0	38.2	48.6	57.0	61.2	66.0	69.2	76.2	23.8

APPENDIX VI

Test Data for "S" Grading Tests

(Constants: 2000-Gram Test Charge; 500 Rattler Revolutions; Wear Equals Per Cent Passing No. 20 Sieve)

Character of Test								Sieve Analyses of Test Charges after Test													
								Per Cent Retained (Cumulative)													Pass 200 (%)
								Screen	Sieve No.												
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	*"S" Wear (%)	1/4"	10	12	16	*20	30	40	50	60	80	100	200	
1	Dudley	65	46	3014	1	4/1/39	22.35	11.8	59.1	63.4	71.6	77.65	82.1	85.6	88.1	89.4	90.7	91.4	93.3	6.7
2	"	65	41	2690	1	4/5/39	20.10	14.6	59.5	66.3	74.5	79.90	84.0	87.0	89.2	90.2	91.4	92.0	93.5	6.5
3	"	65	40	2625	1	4/6/39	19.05	15.1	60.6	67.1	75.6	80.95	84.9	87.7	89.9	90.9	92.0	92.6	94.1	5.9
4	"	65	40	2625	2	4/10/39	19.40	11.9	61.3	67.2	75.4	80.60	84.5	87.4	89.5	90.6	91.7	92.4	94.0	6.0
5	"	65	40	2624	3	4/11/39	19.65	14.3	60.2	66.4	75.0	80.35	84.4	87.4	89.5	90.5	91.7	92.3	93.8	6.2
6	"	130	29	3729	1	4/3/39	21.30	13.5	62.8	66.8	73.2	78.70	82.4	85.6	87.9	89.1	90.3	91.1	92.9	7.1
7	"	130	25	3215	1	4/5/39	18.35	18.9	65.4	70.7	77.1	81.65	85.1	87.6	89.7	90.5	91.8	92.3	93.4	6.6
8	"	130	26	3345	1	4/6/39	18.00	20.3	66.7	71.8	77.7	82.00	85.4	87.8	89.9	90.7	91.9	92.4	93.7	6.3
9	"	130	27	3475	1	4/8/39	19.15	16.5	63.7	69.1	76.4	80.85	84.6	87.4	89.5	90.4	91.8	92.3	93.7	6.3
10	"	130	27	3475	2	4/10/39	20.60	12.9	61.8	67.1	74.8	79.40	83.6	86.5	88.8	89.7	91.2	91.7	93.3	6.7
11	"	130	27	3475	3	4/12/39	19.90	15.8	63.7	68.4	74.9	80.10	83.9	86.8	88.9	90.0	91.2	91.8	93.4	6.6
12	"	225	20	4488	1	3/31/39	22.30	16.3	58.6	64.3	72.4	77.70	82.1	85.1	87.6	88.8	90.1	91.0	92.8	7.2
13	"	225	18	4040	1	4/4/39	19.30	19.6	64.7	70.1	76.2	80.70	84.2	86.8	88.8	89.8	90.9	91.6	93.2	6.8
14	"	225	18	4041	2	4/6/39	19.90	15.9	61.8	67.5	75.2	80.10	84.0	86.7	89.0	90.0	91.2	91.8	93.0	7.0
15	"	225	18	4041	3	4/7/39	18.10	21.5	68.4	72.1	77.6	81.90	85.2	87.6	89.6	90.6	91.7	92.5	94.0	6.0
16	"	420	12	5033	1	3/31/39	21.75	15.2	60.5	65.2	73.0	78.25	82.2	85.3	87.6	88.8	90.1	91.0	92.8	7.2
17	"	420	11	4615	1	4/4/39	19.45	20.5	64.7	69.7	75.8	80.55	83.9	86.6	88.6	89.6	90.8	91.5	93.1	6.9
18	"	420	10	4191	1	4/6/39	18.10	19.8	66.2	71.0	77.7	81.90	85.4	87.9	89.7	90.7	91.7	92.3	93.8	6.2
19	"	420	11	4595	2	4/7/39	19.45	13.8	64.3	69.3	76.2	80.55	84.1	86.8	88.9	90.0	91.2	91.9	93.6	6.4
20	"	420	11	4600	3	4/10/39	20.50	16.4	64.2	68.4	74.8	79.50	83.1	86.1	88.3	89.4	90.7	91.4	93.2	6.8
21	Chico	65	46	3014	1	4/1/39	28.10	9.0	48.1	54.8	65.3	71.90	77.1	80.8	83.4	84.7	86.1	87.1	88.9	11.1
22	"	65	41	2690	1	4/5/39	25.80	8.5	51.5	58.5	68.6	74.20	79.3	82.6	84.9	86.0	87.2	87.8	89.5	10.5
23	"	65	40	2625	1	4/6/39	24.25	9.8	52.7	60.4	69.6	75.75	31.0	84.2	86.9	88.0	89.6	90.2	91.9	8.1
24	"	65	40	2625	2	4/10/39	25.30	9.2	53.0	59.7	68.9	74.70	79.5	82.7	85.0	86.1	87.3	88.0	89.8	11.2
25	"	65	40	2624	3	4/11/39	24.15	10.5	54.4	60.7	70.0	75.85	80.1	83.2	85.5	86.6	87.8	88.5	90.1	9.9
26	"	130	29	3729	1	4/3/39	28.10	8.3	53.2	57.7	65.8	71.90	76.9	80.5	83.1	84.4	85.8	86.6	88.7	11.3
27	"	130	25	3215	1	4/5/39	23.85	13.1	58.8	64.1	71.1	76.15	80.2	82.9	85.0	86.0	87.2	87.8	88.9	11.1
28	"	130	26	3345	1	4/6/39	23.95	12.5	57.7	63.6	70.8	76.05	80.1	82.9	55.2	86.1	87.4	88.1	89.5	10.5
29	"	130	27	3475	1	4/8/39	25.30	11.3	53.8	60.3	69.3	74.70	79.3	82.5	85.0	86.0	87.5	88.2	89.8	10.2
30	"	130	27	3475	2	4/10/39	26.50	9.8	52.4	59.3	68.0	73.50	78.3	81.5	83.9	85.1	86.3	87.1	89.0	11.0
31	"	130	27	3475	3	4/12/39	25.80	11.0	55.7	61.1	68.5	74.20	78.7	81.8	84.2	85.4	86.5	87.3	89.1	10.9
32	"	225	20	4488	1	3/31/39	28.10	8.1	49.8	58.1	65.7	71.90	76.6	80.1	82.7	84.0	85.5	86.5	88.4	11.6
33	"	225	18	4040	1	4/4/39	24.50	12.6	58.7	64.5	70.7	75.50	79.4	82.2	84.3	85.4	86.6	87.2	89.0	11.0
34	"	225	18	4041	2	4/6/39	24.15	13.5	57.0	63.0	70.4	75.85	80.9	84.0	86.2	87.4	88.7	89.5	91.3	8.7
35	"	225	18	4041	3	4/7/39	24.35	14.4	60.4	64.5	70.7	75.65	79.5	82.4	84.6	85.7	86.9	87.7	89.5	10.5
36	"	420	12	5033	1	3/31/39	28.15	9.6	51.1	58.5	65.7	71.85	76.3	79.8	82.5	83.8	85.1	86.2	88.2	11.8
37	"	420	11	4615	1	4/4/39	26.35	13.1	55.5	61.3	68.6	73.65	78.2	81.3	83.7	84.7	86.1	86.8	88.3	11.7
38	"	420	10	4191	1	4/6/39	22.50	15.7	60.9	65.7	72.7	77.50	81.8	84.6	86.9	87.8	89.2	89.8	91.3	8.7
39	"	420	11	4595	2	4/7/39	25.60	10.1	56.4	61.7	69.3	74.40	78.8	81.9	84.3	85.4	86.7	87.4	89.4	10.6
40	"	420	11	4600	3	4/10/39	26.55	12.0	54.5	59.9	68.1	73.45	77.8	81.1	83.5	84.8	86.1	86.9	89.0	11.0

A P P E N D I X VI (Continued)

Character of Test									Sieve Analyses of Test Charges after Test												
									Per Cent Retained (Cumulative)												Pass 200 (%)
									Screen	Sieve No.											
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	*"S" Wear (%)		1/4"°	10	12	16	*20	31	40	50	60	80	100	200	
41	Courchesne	65	46	3014	1	4/3/39	27.70		6.2	51.6	57.0	65.7	72.30	77.5	81.4	84.2	85.7	87.3	88.2	90.6	9.4
42	"	65	41	2690	1	4/5/39	25.05		9.6	53.6	60.2	68.9	74.95	79.9	83.2	85.9	87.0	88.6	89.3	90.6	9.4
43	"	65	40	2625	1	4/6/39	23.85		10.4	53.9	60.7	70.3	76.15	80.2	83.4	85.6	86.7	87.8	88.5	90.1	9.9
44	"	65	40	2625	2	4/10/39	24.60		9.2	52.9	59.7	69.4	75.40	80.4	83.8	86.6	87.8	89.5	90.2	92.1	7.9
45	"	65	40	2624	3	4/11/39	23.55		9.7	54.2	61.3	70.6	76.45	81.1	84.3	86.7	88.0	89.2	90.0	92.0	8.0
46	"	130	29	3729	1	4/1/39	26.75		8.8	55.1	60.3	67.2	73.25	78.2	81.9	84.7	86.1	87.7	88.7	91.0	9.0
47	"	130	25	3215	1	4/5/39	22.95		15.3	58.8	64.7	71.7	77.05	81.0	84.0	86.3	87.4	88.6	89.4	91.3	8.7
48	"	130	26	3345	1	4/6/39	22.90		14.3	60.1	65.4	72.1	77.10	82.3	85.3	87.6	88.8	90.1	90.8	92.8	7.2
49	"	130	27	3475	1	4/8/39	24.55		11.5	55.5	61.4	70.0	75.45	80.1	83.5	86.0	87.4	88.9	89.8	91.9	8.1
50	"	130	27	3475	2	4/10/39	25.35		9.9	53.7	60.2	69.0	74.65	79.4	82.9	85.5	86.9	88.4	89.3	91.6	8.4
51	"	130	27	3475	3	4/12/39	24.05		11.7	58.2	63.9	70.4	75.95	80.1	83.2	85.6	86.9	88.2	89.0	91.0	9.0
52	"	225	20	4488	1	3/31/39	26.95		10.1	53.5	58.6	67.3	73.05	77.9	81.7	84.4	85.9	87.5	88.7	90.8	9.2
53	"	225	18	4040	1	4/4/39	23.80		12.9	59.1	63.8	71.2	76.20	80.4	83.3	85.8	86.8	88.3	89.0	90.7	9.3
54	"	225	18	4041	2	4/6/39	23.20		12.3	58.4	63.9	71.6	76.80	80.0	82.8	85.0	86.0	87.4	87.9	89.2	10.8
55	"	225	18	4041	3	4/7/39	23.40		13.1	58.7	63.8	71.3	76.60	80.5	83.7	86.2	87.4	88.9	89.7	91.9	9.1
56	"	420	12	5033	1	3/31/39	27.45		11.2	56.8	62.6	66.3	72.55	77.3	81.0	83.8	85.3	86.9	88.0	90.3	9.7
57	"	420	11	4615	1	4/4/39	25.05		12.6	56.9	62.3	69.6	74.95	79.1	82.5	85.0	86.3	87.7	88.5	90.7	9.3
58	"	420	10	4191	1	4/6/39	22.60		14.1	59.9	65.4	72.8	77.40	81.3	83.9	85.9	86.9	87.9	88.6	90.1	9.9
59	"	420	11	4595	2	4/7/39	24.60		11.5	56.6	62.5	70.2	75.40	79.8	82.9	85.6	86.7	88.5	89.3	91.2	8.8
60	"	420	11	4600	3	4/10/39	25.10		11.9	57.5	62.4	69.5	74.90	79.6	83.0	85.6	86.7	88.6	89.4	91.4	8.6
61	Maryneal	65	46	3014	1	4/1/39	44.15		2.6	34.5	38.9	48.4	55.85	62.0	66.6	70.2	72.2	74.4	76.4	80.8	19.2
62	"	65	41	2690	1	4/5/39	40.60		3.3	35.2	41.8	51.8	59.40	64.9	68.8	72.4	74.0	76.6	77.6	80.8	19.2
63	"	65	40	2625	1	4/6/39	40.55		3.6	34.6	42.6	52.6	59.45	65.4	69.3	72.7	74.2	76.7	77.8	81.5	18.5
64	"	65	40	2625	2	4/10/39	39.30		4.0	37.9	43.6	54.1	60.70	66.1	69.9	73.2	74.7	77.1	78.2	81.9	18.1
65	"	65	40	2624	3	4/11/39	38.95		4.1	37.6	44.3	54.5	61.05	66.2	70.0	73.1	74.8	76.8	78.0	82.1	17.9
66	"	130	29	3729	1	4/3/39	46.20		2.4	32.6	36.7	46.4	53.80	59.4	64.1	67.7	69.8	72.2	73.7	78.9	21.1
67	"	130	25	3215	1	4/5/39	38.90		4.5	39.3	45.7	55.2	61.10	65.9	69.8	72.9	74.5	76.5	77.7	81.8	18.2
68	"	130	26	3345	1	4/6/39	39.50		4.6	39.2	45.2	54.4	60.50	65.4	69.2	72.3	74.0	76.2	77.4	81.7	18.3
69	"	130	27	3475	1	4/8/39	39.50		4.0	37.7	43.8	53.8	60.50	66.5	70.3	73.4	75.1	77.3	78.5	82.8	17.2
70	"	130	27	3475	2	4/10/39	42.00		3.1	34.0	40.6	51.1	58.00	63.6	67.7	71.0	72.8	75.0	76.5	80.9	19.1
71	"	130	27	3475	3	4/12/39	41.30		3.4	38.1	43.6	52.2	58.70	64.0	67.9	71.2	72.9	75.1	76.5	81.0	19.0
72	"	225	20	4488	1	3/31/39	45.00		2.1	33.7	38.1	47.4	55.00	60.9	64.9	68.6	70.6	73.0	74.9	79.6	20.4
73	"	225	18	4040	1	4/4/39	41.65		3.3	36.3	42.9	52.1	58.35	63.2	67.1	70.6	72.2	74.6	75.8	79.5	20.5
74	"	225	18	4041	2	4/6/39	41.75		3.3	36.6	43.6	52.1	58.25	63.9	68.0	71.3	73.0	75.1	76.4	80.9	19.1
75	"	225	18	4041	3	4/7/39	38.80		4.3	41.8	47.1	55.4	61.20	66.1	69.8	72.8	74.5	76.6	77.8	82.2	17.8
76	"	420	12	5033	1	3/31/39	45.35		1.7	33.0	38.5	47.2	54.65	60.1	64.5	68.2	70.3	72.7	74.5	79.3	20.7
77	"	420	11	4615	1	4/4/39	42.80		3.1	34.8	41.2	50.7	57.20	62.5	66.6	70.0	71.9	74.1	75.5	80.3	19.7
78	"	420	10	4191	1	4/6/39	38.45		5.3	40.6	46.5	56.0	61.55	66.7	70.2	73.4	74.8	77.1	78.2	81.3	18.7
79	"	420	11	4595	2	4/7/39	40.20		3.3	37.9	44.3	53.7	59.80	64.9	68.7	72.0	73.6	76.1	77.2	81.0	19.0
80	"	420	11	4600	3	4/10/39	42.75		2.9	34.0	40.1	50.5	57.25	62.6	66.9	70.3	72.2	74.5	76.0	80.8	19.2
81	Ogden	65	46	3014	1	4/3/39	45.50		2.1	31.8	36.5	46.5	54.50	60.5	65.3	69.2	71.2	73.5	75.0	79.5	20.5
82	"	65	41	2690	1	4/5/39	41.35		3.5	34.1	40.5	51.5	58.65	64.7	69.1	72.5	74.3	76.4	77.7	81.5	18.5
83	"	65	40	2625	1	4/6/39	40.10		3.2	35.8	42.2	53.0	59.90	65.8	70.0	73.2	75.0	76.9	78.1	81.8	18.2
84	"	65	40	2625	2	4/10/39	39.00		3.5	36.3	43.4	54.0	61.00	67.2	71.4	74.8	76.5	78.5	79.8	83.6	16.4
85	"	65	40	2624	3	4/11/39	39.25		4.0	36.4	42.9	53.3	60.75	66.1	70.2	73.4	75.2	77.1	78.3	81.9	18.1

A P P E N D I X VI (Continued)

Character of Test								Sieve Analyses of Test Charges after Test													
								Per Cent Retained (Cumulative)													Pass 200 (%)
Test No.	Stone	Size Balls (Gm.)	No. of Balls	Abrasive Charge (Gm.)	Run No.	Rattler Test Date	"S" Wear (%)	Screen 1/4"	Sieve No. 10	12	16	*20	31	40	50	60	80	100	200		
86	Ogden	130	29	3729	1	4/1/39	44.80	2.2	33.5	37.9	47.6	55.20	61.4	66.3	70.1	72.1	74.5	76.2	80.5		19.5
87	"	130	25	3215	1	4/5/39	38.85	4.7	39.4	46.1	55.1	61.15	66.4	70.2	73.5	75.1	77.2	78.3	80.9		19.1
88	"	130	26	3345	1	4/6/39	39.75	3.8	39.1	44.7	53.7	60.25	65.4	69.3	72.8	74.3	76.6	77.6	80.9		19.1
89	"	130	27	3475	1	4/8/39	39.80	3.8	37.4	43.6	53.6	60.20	65.8	69.6	73.2	74.8	77.2	78.3	81.7		18.3
90	"	130	27	3475	2	4/10/39	40.85	3.4	36.1	42.6	52.8	59.15	65.4	69.6	73.2	74.7	77.3	78.4	81.9		18.1
91	"	130	27	3475	3	4/12/39	41.85	4.1	36.6	41.4	51.3	58.15	63.8	68.0	71.4	73.2	75.3	76.7	80.7		19.3
92	"	225	20	4488	1	3/31/39	44.80	1.8	33.0	38.0	47.6	55.20	61.2	66.1	69.9	71.9	74.1	76.1	80.2		19.8
93	"	225	18	4040	1	4/4/39	40.95	4.1	37.0	43.9	53.0	59.05	63.7	67.8	71.1	72.8	74.9	76.3	80.2		19.8
94	"	225	18	4041	2	4/6/39	40.90	2.9	37.4	44.3	52.5	59.10	64.8	68.8	72.3	73.9	76.3	77.4	80.3		19.7
95	"	225	18	4041	3	4/7/39	38.50	5.1	43.3	48.3	55.4	61.50	66.4	70.4	73.5	75.2	77.2	78.5	82.4		17.6
96	"	420	12	5033	1	3/31/39	44.45	2.0	33.6	38.5	48.0	55.55	61.2	66.2	69.8	71.7	74.1	76.1	80.1		19.9
97	"	420	11	4615	1	4/4/39	42.50	3.2	35.8	42.5	50.9	57.50	63.1	67.3	70.8	72.5	75.0	76.2	79.5		20.5
98	"	420	10	4191	1	4/6/39	38.60	5.2	40.6	46.5	55.3	61.40	66.3	70.1	73.1	74.8	76.7	77.8	81.5		18.5
99	"	420	11	4595	2	4/7/39	40.05	3.2	38.4	44.2	53.9	59.95	65.6	69.7	72.9	74.8	76.8	78.1	82.1		17.9
100	"	420	11	4600	3	4/10/39	40.70	3.7	36.7	42.7	52.6	59.30	64.8	69.0	72.5	74.3	76.5	77.8	82.0		18.0
101	Trap	65	40	2625	1	4/10/39	11.70	28.7	76.6	80.6	85.5	88.30	90.4	91.8	92.9	93.4	94.1	94.5	95.3		4.7
102	"	65	40	2624	2	4/13/39	11.80	30.8	77.1	80.3	85.3	88.20	90.3	91.7	92.9	93.4	94.2	94.5	95.4		4.6
103	"	65	40	2624	3	4/14/39	12.40	29.7	76.1	79.4	84.4	87.60	89.9	91.5	92.7	93.3	93.9	94.3	95.3		4.7
104	"	130	27	3475	1	4/10/39	13.95	25.9	71.6	76.4	82.5	86.05	88.7	90.5	91.8	92.5	93.4	93.8	94.9		5.1
105	"	130	27	3473	2	4/13/39	13.70	27.5	74.0	77.9	83.1	86.30	88.9	90.6	91.9	92.6	93.4	93.8	95.0		5.0
106	"	130	27	3473	3	4/14/39	13.25	27.0	75.5	78.8	83.6	86.75	89.1	90.7	91.9	92.6	93.3	93.7	94.9		5.1
107	"	225	18	4041	1	4/11/39	13.65	26.0	73.1	77.4	83.1	86.35	89.1	90.8	92.2	92.8	93.6	94.1	95.4		4.6
108	"	225	18	4040	2	4/13/39	13.40	28.9	75.9	78.9	83.7	86.60	89.0	90.6	91.9	92.6	93.4	93.8	95.0		5.0
109	"	225	18	4040	3	4/14/39	14.00	25.8	74.1	77.7	82.6	86.00	88.5	90.2	91.6	92.3	93.1	93.6	94.8		5.2
110	"	420	11	4600	1	4/10/39	14.60	23.5	72.1	76.1	82.0	85.40	88.0	89.8	91.3	92.0	92.9	93.4	94.8		5.2
111	"	420	11	4600	2	4/11/39	14.80	24.7	69.9	75.3	81.5	85.20	88.0	89.9	91.4	92.0	93.0	93.5	94.8		5.2
112	"	420	11	4600	3	4/13/39	14.05	29.6	75.1	78.4	82.6	85.95	88.4	90.1	91.5	92.2	93.1	93.5	94.9		5.1
113	Cordova Cream	65	40	2625	1	4/10/39	82.10	0.1	2.2	4.1	10.6	17.90	25.0	30.5	35.1	37.9	42.5	45.8	60.8		39.2
114	"	65	40	2624	2	4/13/39	87.15	0.0	0.8	2.0	6.0	12.85	20.1	26.7	31.7	34.8	39.6	43.4	58.5		41.5
115	"	65	40	2624	3	4/14/39	86.95	0.0	0.9	1.8	6.2	13.05	20.5	26.6	32.0	34.8	40.2	43.4	56.5		43.5
116	"	130	27	3475	1	4/10/39	87.40	0.0	0.5	1.4	6.1	12.60	20.2	26.5	31.3	34.4	39.3	43.2	58.6		41.4
117	"	130	27	3473	2	4/13/39	90.65	0.0	0.3	0.7	3.3	9.35	16.5	23.3	28.6	31.8	36.7	40.7	56.3		43.7
118	"	130	27	3473	3	4/14/39	90.55	0.0	0.3	0.8	3.6	9.45	17.0	23.4	29.2	32.1	37.8	41.1	54.4		45.6
119	"	225	18	4041	1	4/11/39	90.95	0.0	0.2	0.6	3.4	9.05	17.1	23.5	29.4	32.3	38.2	41.5	55.1		44.9
120	"	225	18	4040	2	4/13/39	91.70	0.0	0.2	0.5	2.9	8.30	15.7	22.4	27.8	31.1	36.2	40.1	55.6		44.4
121	"	225	18	4040	3	4/14/39	92.00	0.0	0.2	0.4	2.6	8.00	15.3	22.0	27.8	31.0	36.8	40.1	53.7		46.3
122	"	420	11	4600	1	4/10/39	89.55	0.0	0.2	0.7	4.0	10.45	17.6	23.8	29.4	32.2	38.0	41.3	55.2		44.8
123	"	420	11	4600	2	4/11/39	93.15	0.0	0.0	0.2	2.0	6.85	13.9	20.9	26.5	29.9	34.9	39.1	54.9		45.1
124	"	420	11	4600	3	4/13/39	92.65	0.0	0.1	0.3	2.2	7.35	14.3	20.7	26.8	29.8	35.9	39.2	52.9		47.1

APPENDIX VII

Test Data For Standard "A" Grading Tests on Correlation-Check Stones

Test	Abrasive Charge (Gm.)	Rattler Test Date	*"A" Wear (%)	Sieve Analyses of Test Charges After Test: Per Cent Retained (Cumulative): Nominal Opening (Inches) 1	3/4	1/2	3/8	3/8°	1/4"°	Sieve No. 10	*12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
Allamore A-1	5018	5/2/39	22.14	4.0	25.4	39.1	50.9	54.1	63.3	76.4	77.86	80.7	83.2	85.3	87.1	88.8	89.6	90.8	91.4	93.2	6.8
" A-2	5014	5/3/39	22.76	4.7	24.4	36.2	49.1	52.9	62.4	75.8	77.24	80.1	82.6	84.9	86.8	88.5	89.3	90.6	91.2	93.0	7.0
" A-3	5011	5/11/39	22.78	7.4	22.8	35.9	47.0	52.1	62.0	75.4	77.22	80.4	82.7	84.8	86.9	88.6	89.5	90.5	91.2	93.0	7.0
Beckman A-1	5018	5/2/39	41.24	2.3	8.4	15.7	21.5	25.4	36.3	56.6	58.76	63.3	66.8	69.2	71.9	74.0	75.2	76.7	77.7	80.6	19.4
" A-2	5014	5/3/39	41.80	4.1	11.6	17.2	22.8	25.4	35.8	56.1	58.20	62.4	65.9	68.6	71.3	73.5	74.6	76.1	77.0	79.9	20.1
" A-3	5003	5/24/39	41.26	3.3	12.7	18.8	24.6	27.6	37.2	56.6	58.74	63.3	66.7	69.5	72.2	74.4	75.6	77.1	78.0	80.9	19.1
Brownwood A-1	5011	5/18/39	27.44	6.4	22.8	30.6	42.1	46.4	56.7	70.9	72.56	75.9	78.7	81.1	83.1	85.0	85.9	87.2	87.8	90.0	10.0
" A-2	5006	5/19/39	27.04	8.2	21.2	28.6	42.3	46.7	57.3	71.4	72.96	76.3	79.0	81.3	83.3	85.1	85.9	87.2	87.9	90.0	10.0
" A-3	5005	5/23/39	27.38	6.8	23.8	33.0	43.6	47.6	57.2	70.8	72.62	76.0	78.8	80.9	83.3	85.3	86.3	87.5	88.3	90.4	9.6
Denison A-1	5007	5/22/39	30.00	10.1	26.2	34.8	42.6	45.8	54.1	68.0	70.00	73.1	75.8	77.8	80.0	81.7	82.6	83.8	84.5	86.7	13.3
" A-2	5003	5/24/39	31.44	9.4	20.7	30.4	39.1	42.4	51.8	66.5	68.56	72.0	74.7	77.1	79.0	80.6	81.4	82.7	83.2	85.4	14.6
" A-3	5005	5/31/39	34.64	8.0	18.9	27.7	34.6	38.2	47.7	63.3	65.36	69.1	72.0	74.4	76.8	78.7	79.7	81.0	81.8	84.2	15.8
Dittlinger A-1	5003	5/24/39	50.96	3.8	17.7	23.3	27.0	28.6	34.5	47.2	49.04	52.2	55.0	57.4	60.8	64.2	66.2	69.1	70.9	76.7	23.3
" A-2	5006	5/25/39	49.76	2.5	12.2	18.2	23.5	26.2	32.8	48.1	50.24	53.7	56.5	58.9	62.1	65.4	67.4	70.1	71.8	77.4	22.6
" A-3	5005	5/31/39	51.72	2.1	12.1	17.3	21.1	23.3	31.3	46.3	48.28	51.9	54.5	57.2	60.4	63.8	65.7	68.5	70.3	76.2	23.8
Hamlin A-1	5012	5/15/39	43.32	5.2	14.1	22.9	30.5	33.4	41.2	54.6	56.68	60.3	63.1	65.5	67.8	69.8	70.8	72.0	72.8	74.9	25.1
" A-2	5009	5/17/39	44.82	2.2	17.5	24.0	29.7	32.2	38.9	52.8	55.18	58.9	62.2	64.9	67.2	69.3	70.2	71.5	72.1	74.1	25.9
" A-3	5011	5/18/39	44.62	5.0	17.0	22.5	29.5	31.8	38.8	53.2	55.38	59.0	62.1	64.5	67.0	68.9	70.0	71.1	71.8	73.8	26.2
Huntsville(Q) A-1	5009	5/17/39	34.46	5.2	20.5	28.0	37.5	40.8	49.4	63.5	65.54	68.7	71.5	74.4	77.4	81.6	83.7	86.8	88.2	92.8	7.2
" A-2	5011	5/18/39	34.32	3.9	20.8	28.8	38.0	41.6	49.7	63.8	65.68	69.0	71.8	74.4	77.7	82.0	84.1	87.0	88.5	93.0	7.0
" A-3	5006	5/19/39	35.44	5.6	19.9	25.9	36.1	39.3	47.7	62.5	64.56	68.1	71.0	73.5	76.9	81.3	83.4	86.4	87.9	92.3	7.7
Huntsville(QS) A-1	5009	5/17/39	33.84	9.0	22.3	29.8	39.0	42.1	50.4	64.0	66.16	69.5	72.5	75.6	79.0	83.0	85.0	88.0	89.4	94.0	6.0
" A-2	5011	5/18/39	34.30	4.4	22.0	30.3	39.1	42.5	50.0	63.7	65.70	69.1	72.2	75.0	78.9	82.8	84.8	87.6	89.1	93.7	6.3
" A-3	5006	5/19/39	35.76	1.2	17.0	24.7	34.9	38.2	47.1	62.2	64.24	67.8	71.1	74.4	77.9	82.1	84.0	87.1	88.5	93.2	6.8
Palo Pinto A-1	5006	5/19/39	29.54	9.6	25.1	32.9	42.9	46.2	54.8	68.3	70.46	73.7	76.5	79.0	81.1	83.0	83.9	85.4	86.1	88.6	11.4
" A-2	5007	5/22/39	29.84	4.6	21.4	30.9	39.8	43.9	53.3	68.0	70.16	73.6	76.8	79.4	81.5	83.6	84.6	86.1	86.9	89.3	10.7
" A-3	5005	5/23/39	29.80	5.0	22.0	31.4	39.6	43.9	53.5	68.0	70.20	73.6	76.5	78.9	81.4	83.5	84.6	85.9	86.8	89.3	10.7
Quitaque A-1	5014	5/3/39	23.78	4.1	23.1	33.2	44.2	48.6	59.7	74.2	76.22	79.2	81.7	83.7	85.7	87.3	88.2	89.6	90.6	93.2	6.8
" A-2	5008	5/5/39	24.02	6.0	22.3	33.2	44.0	47.2	59.3	74.3	75.98	79.3	82.6	84.9	86.6	88.3	89.2	90.7	91.4	94.1	5.9
" A-3	5011	5/11/39	24.62	3.3	20.7	30.3	41.3	46.3	57.0	73.2	75.38	78.8	81.6	83.5	85.5	87.2	88.2	89.5	90.4	93.0	7.0
Servtex A-1	5008	5/5/39	30.82	5.0	21.3	28.3	36.7	40.3	51.2	67.3	69.18	72.9	76.2	79.1	81.5	83.6	84.7	86.2	86.9	89.2	10.8
" A-2	5008	5/9/39	31.96	4.7	17.8	26.8	34.5	37.8	49.0	65.7	68.04	72.2	75.6	78.3	81.1	83.4	84.5	85.9	86.8	89.2	10.8
" A-3	5012	5/15/39	32.58	2.0	18.3	24.4	34.1	37.7	48.0	64.9	67.42	71.8	75.2	78.4	80.9	83.3	84.3	85.8	86.6	89.1	10.9
Trinity(Q) A-1	5008	5/9/39	32.02	5.2	20.6	30.5	38.6	42.2	50.9	66.0	67.98	71.7	74.2	76.4	78.9	81.7	82.9	86.0	87.8	92.8	7.2
" A-2	5011	5/11/39	33.72	2.9	15.9	24.0	33.3	37.2	47.5	64.2	66.28	70.1	72.7	75.2	77.4	79.7	81.1	84.7	86.2	91.5	8.5
" A-3	5012	5/15/39	32.58	6.1	20.8	28.5	37.0	40.5	50.1	65.2	67.42	71.0	73.9	76.5	78.6	80.9	82.4	85.7	87.3	92.4	7.6
Trinity(QS) A-1	5018	5/2/39	46.74	4.4	15.7	21.6	28.2	30.4	37.4	51.4	53.26	57.5	61.7	66.2	72.3	78.2	80.6	84.2	85.6	91.0	9.0
" A-2	5008	5/5/39	44.62	7.3	19.4	25.7	32.0	34.3	40.6	53.5	55.38	59.1	63.3	67.1	74.1	79.9	82.3	85.5	87.2	92.4	7.6
" A-3	5008	5/9/39	45.10	5.5	16.5	23.1	29.6	32.1	39.2	52.7	54.90	59.3	63.0	67.6	73.6	79.5	81.9	85.4	87.5	92.3	7.7

A P P E N D I X VIII

Test Data For Standard "B" Grading Tests on Correlation-Check Stones

Test		Abrasive Charge (Gm.)	Rattler Test Date	"FB" Wear (%)	Sieve Analyses of Test Charges after Test: Per Cent Retained (Cumulative): Nominal Opening (Inches) 1/2	3/8	3/8	1/4"	Sieve No. 10	*12	16	20	30	40	50	60	80	100	200	Pass 200 (%)
Allamore	B-1	4605	5/2/39	21.94	11.9	29.8	37.0	56.1	76.3	78.06	81.5	84.1	86.0	88.0	89.6	90.4	91.3	91.8	93.3	6.7
"	B-2	4605	5/3/39	20.94	14.5	34.6	41.3	58.9	77.4	79.06	82.3	84.6	86.8	88.5	90.0	90.6	91.6	92.0	93.6	6.4
"	B-3	4598	5/11/39	20.80	10.9	33.2	40.8	57.4	77.0	79.20	82.5	84.7	86.9	88.6	90.1	90.7	91.7	92.2	93.7	6.3
Beckman	B-1	4605	5/2/39	39.60	2.5	10.8	14.8	31.8	57.6	60.40	65.0	68.5	71.5	73.7	75.6	76.5	77.9	78.5	81.0	19.0
"	B-2	4605	5/3/39	40.28	2.6	9.4	14.1	29.5	57.0	59.72	64.5	68.0	70.7	73.0	74.9	75.8	77.0	77.7	80.1	19.9
"	B-3	4596	5/24/39	39.90	1.9	9.2	13.4	29.2	56.8	60.10	65.2	68.9	72.0	74.3	76.3	77.3	78.7	79.4	81.8	18.2
Brownwood	B-1	4603	5/18/39	25.96	7.0	25.8	33.8	51.1	71.6	74.04	77.6	80.4	82.6	84.6	86.2	87.0	88.0	88.6	90.4	9.6
"	B-2	4599	5/19/39	26.86	7.4	24.7	32.2	49.8	70.9	73.14	77.0	80.0	82.5	84.4	86.1	86.8	88.0	88.5	90.3	9.7
"	B-3	4598	5/23/39	26.80	7.7	25.0	32.8	49.7	70.8	73.20	77.1	80.0	82.5	84.5	86.2	87.0	88.0	88.6	90.4	9.6
Denison	B-1	4600	5/22/39	30.52	6.6	19.6	26.4	42.3	67.4	69.48	73.9	76.8	79.4	81.3	82.8	83.5	84.6	85.6	86.8	13.2
"	B-2	4596	5/24/39	31.42	6.4	19.1	25.0	42.0	66.2	68.58	73.0	76.0	78.2	80.2	81.7	82.4	83.4	83.8	85.4	14.6
"	B-3	4594	5/31/39	33.98	5.2	16.3	22.6	38.3	63.1	66.02	70.6	73.8	76.5	78.4	80.0	80.8	81.8	82.4	84.3	15.7
Dittlinger	B-1	4596	5/24/39	49.88	1.8	8.0	11.1	22.6	47.6	50.12	54.6	57.7	60.7	63.5	66.6	68.2	70.9	72.2	77.5	22.5
"	B-2	4595	5/25/39	48.06	1.5	7.8	10.8	22.4	47.1	51.94	54.4	57.6	60.8	63.7	66.9	68.5	71.2	72.5	77.7	22.3
"	B-3	4594	5/31/39	51.00	1.7	6.9	10.3	22.5	46.2	49.00	53.3	56.2	59.4	62.2	65.2	66.9	69.5	70.9	76.4	23.6
Hamlin	B-1	4600	5/15/39	38.22	3.5	13.7	18.5	33.7	59.0	61.78	66.0	68.9	71.0	73.0	74.3	74.9	75.6	76.0	77.1	22.9
"	B-2	4600	5/17/39	40.04	3.8	13.2	18.1	32.0	57.0	59.96	64.4	67.4	69.5	71.4	72.8	73.5	74.1	74.5	75.6	24.4
"	B-3	4603	5/18/39	40.94	3.9	13.5	17.6	31.0	56.2	59.06	63.5	66.5	68.8	70.7	72.0	72.7	73.3	73.7	74.7	25.3
Huntsville (Q)	B-1	4600	5/17/39	34.72	5.9	19.4	25.1	40.0	62.8	65.28	69.5	72.7	75.3	78.6	82.7	84.8	87.4	88.9	93.1	6.9
"	B-2	4603	5/18/39	34.96	4.8	17.8	23.5	39.3	62.4	65.04	69.2	72.5	75.4	78.4	82.5	84.5	87.4	88.6	92.9	7.1
"	B-3	4598	5/23/39	35.88	4.3	17.5	22.6	39.2	61.9	64.12	68.6	71.8	74.6	77.6	81.9	83.9	86.8	88.0	92.3	7.7
Huntsville (QS)	B-1	4600	5/17/39	36.18	3.3	13.8	20.2	35.9	61.1	63.82	68.7	72.3	75.9	79.5	83.4	85.3	88.2	89.5	93.9	6.1
"	B-2	4603	5/18/39	36.32	3.6	14.8	19.8	35.4	60.6	63.68	68.3	72.2	75.4	79.5	83.4	85.3	88.0	89.6	93.9	6.1
"	B-3	4599	5/19/39	36.72	4.3	16.0	22.2	36.4	60.7	63.28	68.4	72.2	75.4	79.4	83.3	85.1	88.0	89.3	93.8	6.2
Palo Pinto	B-1	4599	5/19/39	29.08	7.4	21.0	28.5	45.5	68.4	70.92	74.9	78.0	80.2	82.4	84.1	84.9	86.0	86.6	88.7	11.3
"	B-2	4600	5/22/39	30.08	5.9	18.8	25.8	42.1	67.0	69.92	74.2	77.7	80.4	82.6	84.5	85.4	86.7	87.4	89.5	10.5
"	B-3	4598	5/23/39	30.32	4.9	18.8	25.0	42.9	67.2	69.68	74.4	77.6	80.3	82.5	84.3	85.1	86.5	87.0	89.1	10.9
Quitaque	B-1	4605	5/ 3/39	23.00	8.6	26.4	34.0	52.2	74.7	77.00	80.5	83.7	85.7	87.6	89.2	90.0	91.1	91.8	94.2	5.8
"	B-2	4603	5/5/39	22.86	6.8	23.9	33.8	52.8	74.9	77.14	80.8	83.6	85.6	87.6	89.1	90.0	91.1	91.8	94.1	5.9
"	B-3	4598	5/11/39	24.20	4.4	21.6	30.6	49.3	73.2	75.80	80.0	82.7	84.9	86.9	88.4	89.3	90.5	91.3	93.7	6.3
Servtex	B-1	4603	5/5/39	31.46	3.9	16.0	22.8	40.4	65.6	68.54	72.9	76.7	79.8	82.2	84.3	85.2	86.7	87.3	89.4	10.6
"	B-2	4600	5/9/39	31.62	2.5	15.8	22.3	40.2	65.2	68.38	73.3	76.8	80.0	82.4	84.6	85.5	86.9	87.5	89.6	10.4
"	B-3	4600	5/15/39	33.16	1.7	14.3	20.8	37.6	63.5	66.84	72.2	76.0	79.4	82.0	84.2	85.2	86.6	87.3	89.4	10.6
Trinity (Q)	B-1	4600	5/9/39	32.48	3.5	17.1	23.4	39.3	64.6	67.52	71.9	75.0	77.4	79.9	82.2	83.6	86.6	88.5	93.1	6.9
"	B-2	4598	5/11/39	34.48	3.3	15.8	21.3	37.7	62.8	65.52	70.2	73.4	76.0	78.2	80.5	81.9	85.2	86.8	91.8	8.2
"	B-3	4600	5/15/39	33.40	3.5	16.0	22.0	38.4	63.6	66.60	71.1	74.1	76.6	79.2	81.4	82.8	85.8	87.6	92.3	7.7
Trinity (QS)	B-1	4605	5/2/39	46.12	2.9	10.7	14.3	26.6	51.0	53.88	59.1	63.8	68.8	74.9	80.6	82.9	86.1	87.5	92.6	7.4
"	B-2	4603	5/5/39	45.88	3.7	11.4	15.0	27.8	51.2	54.12	59.4	64.1	69.2	75.1	80.7	82.9	86.2	87.7	92.7	7.3
"	B-3	4600	5/9/39	47.18	2.6	10.9	14.5	26.2	49.4	52.82	58.2	63.0	67.6	74.5	80.3	82.8	85.9	87.6	92.6	7.4

A P P E N D I X IX

Test Data for Standard "S" Grading Tests on Correlation-Check Stones

Test		Abrasive Charge (Gm.)	Rattler Test Date	*"S" Wear (%)	Sieve Analyses of Test Charges after Test — Per Cent Retained (Cumulative) — Screen 1/4"	Sieve No. 10	12	16	*20	30	40	50	60	80	100	200	Pass 200 (%)
Allamore	S-1	5856	5/2/39	24.10	7.0	54.2	60.4	69.6	75.90	80.8	84.1	86.8	87.9	89.4	90.0	92.0	8.0
"	S-2	5852	5/4/39	24.88	6.2	52.6	59.0	68.6	75.12	80.3	83.7	86.4	87.6	89.1	89.8	91.8	8.2
"	S-3	5841	5/11/39	24.80	7.3	50.9	58.7	68.8	75.20	80.0	83.5	86.2	87.3	88.8	89.5	91.5	8.5
Beckman	S-1	5856	5/2/39	38.64	2.2	38.5	44.6	54.4	61.36	67.0	70.9	74.0	75.3	77.1	77.9	80.3	19.7
"	S-2	5852	5/3/39	39.10	2.0	35.7	43.1	54.0	60.90	66.3	70.5	73.6	75.0	76.6	77.6	79.8	20.2
"	S-3	5841	5/11/39	39.02	2.1	35.6	42.7	53.8	60.98	65.8	70.3	73.6	74.8	76.5	77.4	79.7	20.3
Brownwood	S-1	5834	5/18/39	27.52	7.5	49.6	56.0	65.9	72.48	76.7	80.9	83.7	84.9	86.3	87.1	89.0	11.0
"	S-2	5828	5/19/39	28.22	6.6	47.9	55.0	65.4	71.78	76.5	80.7	83.6	84.8	86.3	87.1	89.0	11.0
"	S-3	5825	5/23/39	28.14	7.2	48.6	55.5	65.4	71.86	77.0	80.6	83.6	84.7	86.3	87.0	89.0	11.0
Denison	S-1	5827	5/22/39	29.86	5.7	46.6	53.7	63.6	70.14	75.2	78.7	81.2	82.3	83.7	84.2	85.9	14.1
"	S-2	5823	5/24/39	31.10	4.8	44.7	51.4	62.2	68.90	73.5	77.6	80.3	81.5	82.7	83.4	85.1	14.9
"	S-3	5823	5/31/39	32.82	4.1	42.4	49.8	60.5	67.18	72.6	76.2	78.8	80.0	81.4	82.0	83.8	16.2
Dittlinger	S-1	5823	5/24/39	50.62	1.0	26.1	32.6	42.4	49.38	55.5	60.6	65.4	67.6	70.7	72.3	77.2	22.8
"	S-2	5823	5/26/39	51.70	1.1	24.3	30.7	41.2	48.30	54.1	59.5	64.3	66.6	69.7	71.3	76.3	23.7
"	S-3	5823	5/31/39	51.14	1.1	25.6	32.1	41.9	48.86	54.4	59.7	64.4	66.7	69.3	71.4	76.3	23.7
Hamlin	S-1	5837	5/15/39	42.32	1.2	29.2	37.4	49.6	57.68	63.1	67.9	70.9	72.2	73.4	73.9	75.1	24.9
"	S-2	5837	5/17/39	43.32	0.9	28.5	36.4	49.0	56.68	62.8	66.9	69.9	70.9	72.3	72.7	73.8	26.2
"	S-3	5834	5/18/39	43.28	0.8	28.0	36.2	48.7	56.72	62.8	67.0	70.0	71.2	72.5	73.0	74.2	25.8
Huntsville (Q)	S-1	5834	5/18/39	37.30	2.5	38.1	45.1	55.4	62.70	68.0	73.6	79.8	82.7	86.1	87.8	92.3	7.7
"	S-2	5834	5/18/39	37.16	2.7	39.2	45.8	56.2	62.84	68.2	73.6	79.8	82.6	86.1	87.8	92.4	7.6
"	S-3	5828	5/19/39	36.76	2.8	38.9	46.1	56.5	63.24	68.5	73.9	80.1	82.8	86.2	87.8	92.4	7.6
Huntsville (QS)	S-1	5837	5/17/39	37.18	2.0	37.3	44.3	54.9	62.82	69.1	75.2	80.9	83.5	87.0	88.7	93.6	6.4
"	S-2	5834	5/18/39	36.94	2.3	37.0	44.9	55.6	63.06	69.2	75.6	81.2	83.8	87.2	88.9	93.7	6.3
"	S-3	5828	5/19/39	37.10	2.3	37.9	45.0	55.9	62.90	68.9	75.2	80.9	83.4	86.8	88.4	93.1	6.9
Palo Pinto	S-1	5828	5/19/39	29.86	5.7	46.9	53.2	63.6	70.14	74.9	79.1	82.0	83.3	84.8	85.7	85.8	14.2
"	S-2	5827	5/22/39	30.08	5.4	46.1	52.6	63.2	69.92	74.8	79.1	82.2	83.6	85.2	86.0	88.4	11.6
"	S-3	5823	5/31/39	30.64	5.0	44.5	51.9	62.3	69.36	74.5	78.3	81.3	82.6	84.4	85.1	87.4	12.6
Quitaque	S-1	5852	5/ 3/39	22.38	8.2	58.4	63.5	71.9	77.62	81.3	84.7	87.1	88.2	89.8	90.8	93.5	6.5
"	S-2	5848	5/ 5/39	22.72	7.3	55.1	62.2	71.4	77.28	81.2	84.6	87.0	88.3	89.8	90.8	93.6	6.4
"	S-3	5841	5/11/39	23.06	7.7	55.3	62.5	71.5	76.94	80.9	84.3	86.7	88.0	89.6	90.5	93.3	6.7
Servtex	S-1	5848	5/ 5/39	30.22	5.3	45.9	53.1	63.1	69.78	75.4	79.2	82.4	83.7	85.5	86.3	88.5	11.5
"	S-2	5842	5/10/39	30.32	5.3	45.5	52.7	62.9	69.68	74.4	79.0	82.1	83.6	85.2	86.0	88.3	11.7
"	S-3	5837	5/15/39	30.68	4.7	43.8	51.5	62.2	69.32	75.0	79.0	82.2	83.6	85.4	86.2	88.6	11.4
Trinity (Q)	S-1	5842	5/ 9/39	33.82	3.8	43.0	50.3	59.7	66.18	70.4	74.8	78.2	80.3	84.3	86.4	91.8	8.2
"	S-2	5841	5/11/39	34.22	3.5	42.4	49.8	59.7	65.78	70.6	74.4	77.9	79.9	84.1	85.8	91.3	8.7
"	S-3	5837	5/15/39	33.50	3.8	44.0	50.8	60.8	66.50	70.9	75.2	78.6	80.5	84.5	86.6	91.8	8.2
Trinity (QS)	S-1	5856	5/ 2/39	45.60	1.0	27.6	35.1	45.8	54.40	62.3	71.5	78.6	81.5	85.0	86.8	92.0	8.0
"	S-2	5848	5/ 5/39	45.08	1.0	26.9	34.3	46.4	54.92	62.9	71.9	79.1	81.8	85.4	87.2	93.2	6.8
"	S-3	5842	5/10/39	44.86	0.9	26.8	34.4	46.6	55.14	63.0	72.0	79.2	82.0	85.6	87.3	92.5	7.5

Photograph No. 18-24k-6362, taken by Frank Cawthorn, District 18, has been selected as the picture of the week ending May 13, 1939, and for the month of May.

The angle at which the shot was made, with respect to the lighting, resulted in an unusually sharp picture. The principle point of interest is centrally located and the picture has good story telling qualities.