NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report 32-1295

Effects of Sterilization on the Energy-Dissipating Properties of Balsa Wood

A. B. Sorkin

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Preface

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The contributions of Messrs. Charles Savage and Jordan Heiberger (JPL Section 351) in the successful completion of this investigation are gratefully acknowledged. Dr. Arno P. Schniewind of the University of California Forest Products Laboratory participated as a consultant to this effort.

Contents

I. **Introduction** 1

A. Background on Balsa Wood as an Impact Limiter Material 1

B. Objectives and Approach 2

C. Study of Balsa Wood Technology and Procurement of Material 2

1. Cell structure of balsa wood and its effect on properties 2

2. Procurement of material for this program 2

D. Summary of Conclusions 3

II. **Sterilization Effects** 4

A. Approach to Study of Sterilization Effects and Comparison of Test Results in Moist, Dry, and Sterilized Conditions 4

1. Conditioning and sterilization 4

III. **Screening** 6

A. Feasibility of Selecting Specific Trees for the Application 6

B. Logging, Transportation, and Sawmill Operations 6

C. Description of Possible Selection Tests Studied 8

1. Bending stiffness 9

2. Hardness 9

3. Density 10

4. Other testing 10

D. Correlation of Selection Tests with Specific Energy 10

IV. **Feasibility of Balsa Properties' Improvement** 11

A. Background 11

B. Balsa–Plastic Impregnation and Irradiation Study Results 12

V. **Conclusions** 12

Appendix A. JPL Crush Test (Specific Energy) Determination 13

Appendix B. Data Compilation 14

References 28

Bibliography 28

Contents (contd)

Tables

1. Summary of data derived from 1,241 crush tests as a function of condition 6

2. Variation of specific energy within a stick 11

3. Variation of density within a stick 11

Figures

1. Cell structure of a block of hardwood approximately 1/32 in. high 2

2. Photomicrograph of balsa cell structure in a plane perpendicular to tree axis 3

3. Photomicrograph of balsa cell structure in a plane parallel to a tree axis . . . 3

4. Schematic presentation of a wood cell structure 3

5. Balsa conditioning room with partial view of wood evaluated in this program 5

6. Typical trace of crush test ram vs depth of ram penetration for balsa in each condition from a single stick 6

7. Balsa tree being felled in a jungle area of Ecuador 7

8. Balsa rafts in log pond at sawmill in Guayaquil, Ecuador 8

9. Bend test apparatus being used to test stick of balsa 9

10. Apparatus used for balsa hardness determination 10

A-1. Apparatus used to conduct crush tests on balsa for determination of specific energy values 13

Abstract

The interest in the possible planetary landing of sterilized instrumented payloads has necessitated considerable study of impact limiters. Attenuation of impact forces on a payload by the dissipation .. energy through the crushing of a radio-frequency-transparent material is the primary approach. Balsa wood has been found to offer a combination of properties that make it a very attractive candidate for impact limiter construction.

An investigation was made of the energy-dissipating properties of balsa wood in the sterilized, dry, and moist conditions. Ethylene oxide plus thermal sterilization was found to enhance the specific energy of balsa to 23,097 ft-lb/lb (average value of 596 samples in the density range of 6 to 10 lb/ft^3) as compared with an average of 20,400 ft-lb/lb for samples in the moist (6–8% H_2O) condition. A study was made of possible screening tests that might facilitate the selection of balsa wood with uniform properties. No test was found that correlated with specific energy. Density variation within the range studied (6–10 lb/ft^3) did not have a significant relation to crushing properties, refuting previous indications of a relationship.

The feasibility of enhancing or reducing scatter in the energy-dissipating properties of balsa was investigated. Plastic impregnation followed by irradiation induced polymerization was studied but failed to improve balsa's already outstanding specific energy.

Effects of Sterilization on the Energy-Dissipating Properties of Balsa Wood

I. Introduction

A. Background on Balsa Wood as an Impact Limiter Material

One of the most promising approaches to the development of a hard lander to deliver an instrument payload to a planetary surface involves the use of a crushable, radio-frequency-transparent energy-dissipating material. The energy dissipated by the crushing of this material upon impact should decrease the deceleration forces imposed on the payload to a tolerable level. One of the leading candidate materials for impact limiter applications is balsa wood because of its high specific energy (energy dissipation per unit weight, see Appendix A) as well as its proven fabricability into impact limiters (Ref. 1). Most proposed designs involve orientation of individual blocks of balsa such that the grain is parallel to applied load. Adhesive bonding joins the blocks to each other and to the payload. The ability to produce a spherical limiter in this manner has been an advantage over the state of the art in phenolic honeycomb, another candidate material. No major problems have arisen in obtaining good adhesive bonded joints if standard practices are employed. However, two areas of concern exist in the application of balsa wood for advanced programs. First, the sterilization requirements imposed on future landers are of concern since the effects of heat and chemical sterilization treatments on the properties of balsa wood have not been clearly established. Second, the wide scatter observed in the energy-dissipating capability of balsa wood specimens in the "same" condition (Refs. 2 and 3) constitutes a problem in establishment of a design for fabricating limiters of reproducible performance. It was advocated that more restrictive selection criteria might be developed to reduce the scatter. All previous balsa studies were not oriented to the testing of large numbers of specimens in identical conditions and, therefore, could not document the statistical design values of balsa properties. In the event that sterilization treatments were found to degrade the energy-dissipating capability of balsa wood, the development of methods of preventing or compensating for degradation would be required.

B. Objectives and Approach

With these problem areas in mind, this advanced development program was planned and initiated for the following purposes: (1) to determine the effects of ethylene oxide plus heat sterilization on balsa properties including establishment of design values of specific energy and mean crushing stress, (2) to evaluate procedures that could be used in selecting balsa wood at the mill with uniformly high energy-dissipation properties, and (3) to establish the feasibility of improving balsa wood uniformity by increasing strength properties through plastic impregnation and irradiation methods.

The approach followed was to evaluate a large number of balsa wood sticks which represented a cross section of a large supplier's production. The specific energy of this population was determined after it had undergone sterilization and had been compared with unsterilized wood, thus defining any gain or loss in properties as a result of sterilization and statistically establishing minimum design values.

For the purpose of selecting wood with the highest specific energy, standard wood test methods were applied to the entire population of wood and compared with specific energy data. The degree of correlation was determined to establish the usefulness of the test candidates.

C. Study of Balsa Wood Technology and Procurement of Material

1. Cell structure of balsa wood and its effect on properties. Balsa wood is a highly anisotropic and hydroscopic solid matrial. All wood originates as living matter with cellular structure. The anisotropic physical and mechanical properties of wood are derived from the fine structure of the cells (Fig. 1), the chemical composition, and the packing of the cells to form the aggregate. The differences in the orientation and continuity of these elements in longitudinal and transverse directions influence the properties. The cellular structure of balsa wood, as exhibited in microscopic examination (Figs. 2 and 3), differs from most woods. In ordinary woods the thickness of the walls of the cells is generally a considerable proportion of the diameter (Fig. 4). The cells that are parallel to the axis of the tree are made up principally of woody fiber (F); those that extend in a radial direction usually have a cellulose structure with little woody fiber and are defined as "medullary rays (MR)," because of their position and composition. The microscopic structure of all woods involves, in addition, the existence of ducts or vessels (K) scattered through the wood in a longitudinal direction;

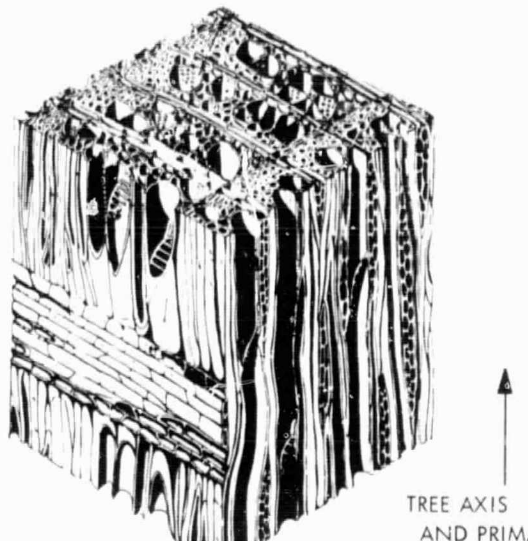

Fig. 1. Cell structure of a block of hardwood approximately 1/32-in. high. The same basic orientation of fibers and ray cells exists in all types of woods. (Drawing courtesy of U. S. Forest Products Laboratory)

these serve as a circulatory system for the transmission of liquids and gases during the growth of the tree. The lightness of balsa is one of its most unique features. This is due to the fact that woody fibers of the ordinary type seem to be absent in this wood, their place being taken by a cellulose tissue with exceedingly thin, unlignified walls. Balsa's medullary rays are uniformly spaced and make up about 23% of the wood by volume. The ducts or vessels are large and remote from each other, and occur singly, or in groups, in the strands between the medullary rays constituting a very small proportion of the wood. A fixed stress applied "across the grain" (radially) causes much more distortion by flattening the individual cells than does a similar stress applied parallel to the grain where it acts uniformy on the cell wall material as the individual cells support each other to prevent buckling. Balsa's utility in energy dissipation is dependent upon compressive loading parallel to the grain.

2. Procurement of material for this program. Six hundred sticks of balsa were purchased directly from Balsa Ecuador Corporation. Procurement of the balsa was intended to duplicate a typical stick size ($3\frac{1}{4} \times 3\frac{1}{4} \times 36$ in.) and density range (8 ± 2 lb/ft^3) used in impact limiter work with the exception of the added requirement for actual weighing of the sticks at the mill to determine density rather than the estimating methods normally em-

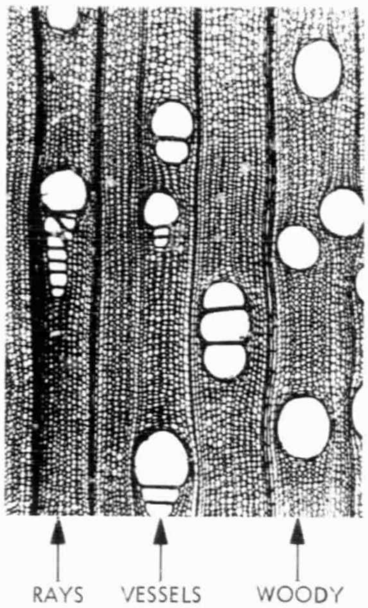

Fig. 2. Photomicrograph of balsa cell structure in a plane perpendicular to tree axis (i.e., radial) enlarged 25 times (Photo courtesy of N.Y.S. College of Forestry)

Fig. 3. Photomicrograph of balsa cell structure in a plane parallel to tree axis enlarged 25 times (Photo courtesy of N.Y.S. College of Forestry)

ployed. Enhanced freedom from common balsa defects was facilitated by directing the supplier to select only wood that minimized the allowable defects according to MIL-S-7998. Low-density balsa bands (corcho) within a stick and sound knots were not allowable in this procurement. During shipment from Ecuador, the 600 balsa sticks were protected from physical damage and excessive moisture by balsa containers. Upon receipt, the wood was allowed to stabilize in a room of approximately 50% relative humidity.

D. Summary of Conclusions

Balsa wood has been found to be a very attractive candidate material for impact limiter construction. The findings of this program will enable designers to proceed with details of fabrication based upon a well established set of average crushing properties in the sterilized condition derived during this effort. Ethylene oxide plus thermal sterilization was found to enhance the specific energy of balsa to 23,097 ft-lb/lb (average of 600 samples in the density range of 6 to 10 lb/ft^3) as compared with an average of 20,400 ft-lb/lb for samples in the moist (6–8% H_2O) condition. No useful screening test was found

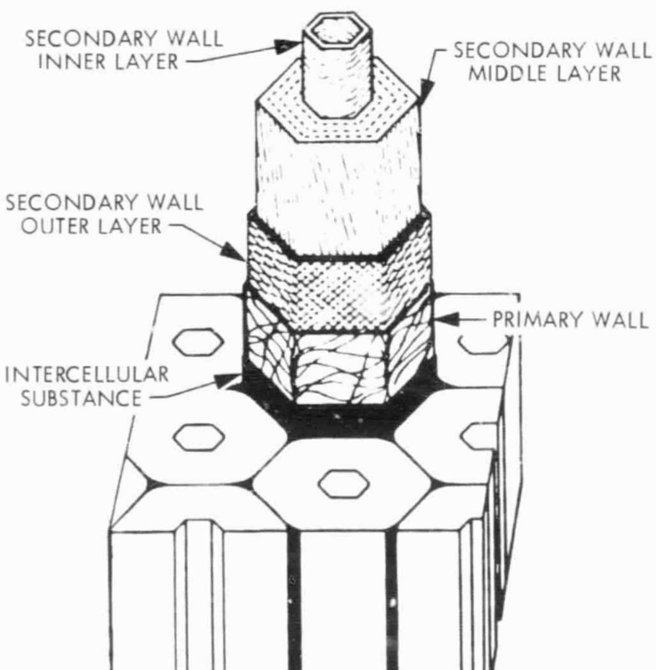

Fig. 4. Schematic presentation of a wood cell structure (Courtesy of Dadswell and Wardrol)

that correlated with specific energy. Density within the range studied (6 to 10 lb/ft^3) did not have a significant relation to crushing properties, refuting previous indications of a relationship. Evaluation of plastic impregnated samples of balsa resulted in values exhibiting no improvement in specific energy. It may be concluded that no means presently exists for improving balsa wood's uniformity of properties.

II. Sterilization Effects

A. Approach to Study of Sterilization Effects and Comparison of Test Results in Moist, Dry, and Sterilized Conditions

1. Conditioning and sterilization. Upon receipt of the two groups (7 ± 1 and 9 ± 1 lb/ft^3) of 300 balsa sticks each from Ecuador, all sides were planed to derive $3 \times 3 \times 36$-in. dimensions. After planing, the "fresh" surfaces were inspected for the following defects:

(1) Splits.

(2) Punctures or impressions.

(3) Blue stain. Stain produced by fungi that feed on contents of cells but do not cause appreciable cell wall destruction.

(4) Mineral stain. Stain produced by deposition of mineral substances in cellular structure.

(5) Pinworm holes.

(6) Bird's-eye. A grain irregularity consisting of a small central spot with wood fibers arranged about it in the form of an ellipse so as to give the appearance of an eye.

(7) Knots.

(8) Pith or low density material.

Each defect observed was marked and avoided in sample location selection if it was deemed to be significant. The most frequently found defects were splits, stains, and pinworm holes. Staining was not considered a significant defect to the extent observed in these sticks. All sticks were serialized with 7-1, 7-2, etc., 9-1, 9-2, etc., in which the first number is a density group (as ordered) designation. Twelve location numbers were also applied along the length of one side of each stick to identify sample location. Conditioning was accomplished by stacking the sticks in a room at 50% relative humidity and 72°F temperature, where the balsa moisture content could stabilize at 6–8% (Fig. 5).

Two weeks were allowed for stabilization before gross density was determined. Weighing of each stick was accomplished within the conditioning room.

A $3 \times 3 \times 3$-in. block was removed from the ends of each stick for sterilization treatment. The first step in sterilization was an ETO decontamination per JPL Spec. VOL-50503-ETS in which the specimens were exposed to an atmosphere of filtered air at 50°C, 35 to 55% relative humidity with 450 to 650 mg of ethylene oxide per liter. Six 30-h cycles were used. After ETO decontamination, the blocks were placed in a vacuum chamber for 24 h so that all residual ETO could be removed from the wood cells prior to heat sterilization.

Heat sterilization per JPL Spec. VOL-50503-ETS consisted of six cycles of 92 h each at 135°C in a dry nitrogen atmosphere. After completion of the last cycle all blocks were sealed in plastic bags with silica gel to prevent moisture pickup. Measurements of randomly selected blocks were made to detect dimensional changes. No dimensions changed more than approximately 2%. The weight of each block was measured to determine density.

Crush tests were performed on 596 samples in the "moist" condition, 596 samples in the sterilized condition, and 49 samples in the oven-dried condition. No more than one block per condition was tested from the same stick in this phase. All crush tests were carried out using the technique described in Appendix A.

The sterilized blocks were slightly darkened as a result of the treatment. All sterilized and dry samples remained sealed in plastic bags with silica gel until they were weighed and immediately crush-tested. Examination of samples after testing revealed 41 out of 596 samples split in a direction parallel to the grain. The occurrence of splitting increased with increasing density. The mean value of mean stress was 1454 lb/in.^{2} with a standard deviation of 364 lbs/in.^{2} The mean value of thickness efficiency was 0.849 with a standard deviation of 0.027. The mean value of specific energy was 23,097 ft-lb/lb with a standard deviation of 3674 ft-lb/lb. The mean density was 7.68 lb/ft^3.

Analysis of the 596 crush-tested moist samples produced the following results: (1) mean value of mean stress was 1342 lb/in.^{2} with a standard deviation of 337 lbs/in.^{2} (2) Mean value of thickkness efficiency was 0.839 with a

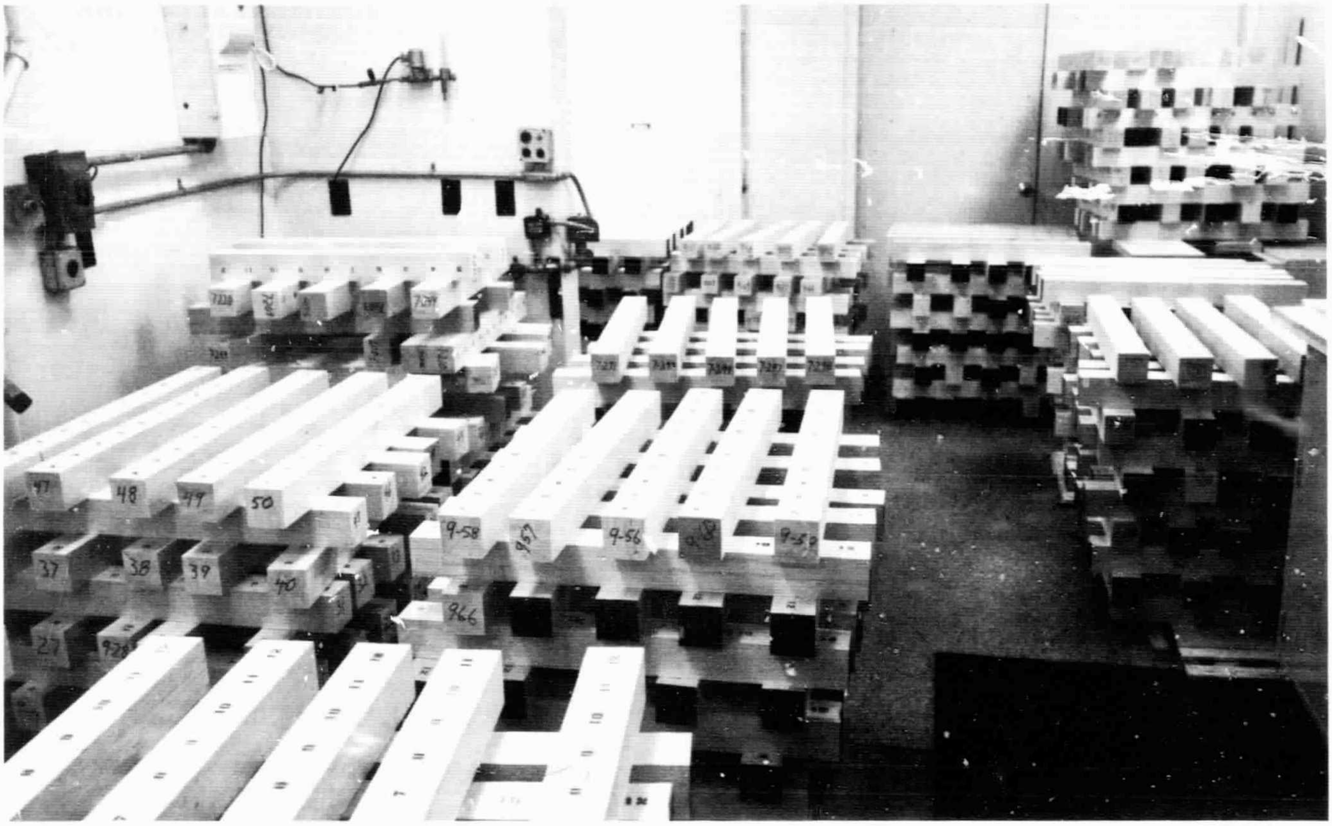

Fig. 5. Balsa conditioning room with partial view of wood evaluated in this program

standard deviation of 0.0180. (3) Mean value of specific energy was 20,400 ft-lb/lb with a standard deviation of 3339 ft-lb/lb. Splitting was observed in 13 of the 596 samples tested, all of which were fairly high density. Mean density was 7.98 lb/ft^3.

Comparing the results of tests in the sterilized and moist conditions, it is obvious that sterilization improves rather than degrades energy dissipation properties.

However, from Ref. 3 we know that lowering the moisture content produces higher specific energy values. Since sterilized wood has nearly a zero moisture content, it may be unfair to compare its properties with moist, unsterilized wood. Therefore, a series of tests were performed on oven-dried wood as a further point of comparison.

The crush tests results performed on 49 randomly selected oven-dried samples were as follows: (1) Mean value of mean stress was 1383 lb/in.^{2} with a standard deviation of 379 lbs/in.^{2}; (2) Mean value of thickness efficiency was 0.885 with a standard deviation of 0.024; (3) Mean value of specific energy was 22,900 ft-lb/lb with a standard deviation of 3869 ft-lb/lb. Mean density was 7.75 lbs/ft^3.

An increased splitting tendency was observed in the dry samples (16 out of 49 tested) as compared with the moist (12 out of 596 tested). Since only 49 samples were tested, the results were compared with the moist and sterilized samples from the same sticks, and it was established that oven-drying balsa results in an energy dissipation capability of intermediate magnitude.

Typical traces of crush test load vs depth of ram penetration for blocks in each condition from one stick are shown in Fig. 6. The mean crush test data is summarized in Table 1. Data on individual tests is given in Appendix B.

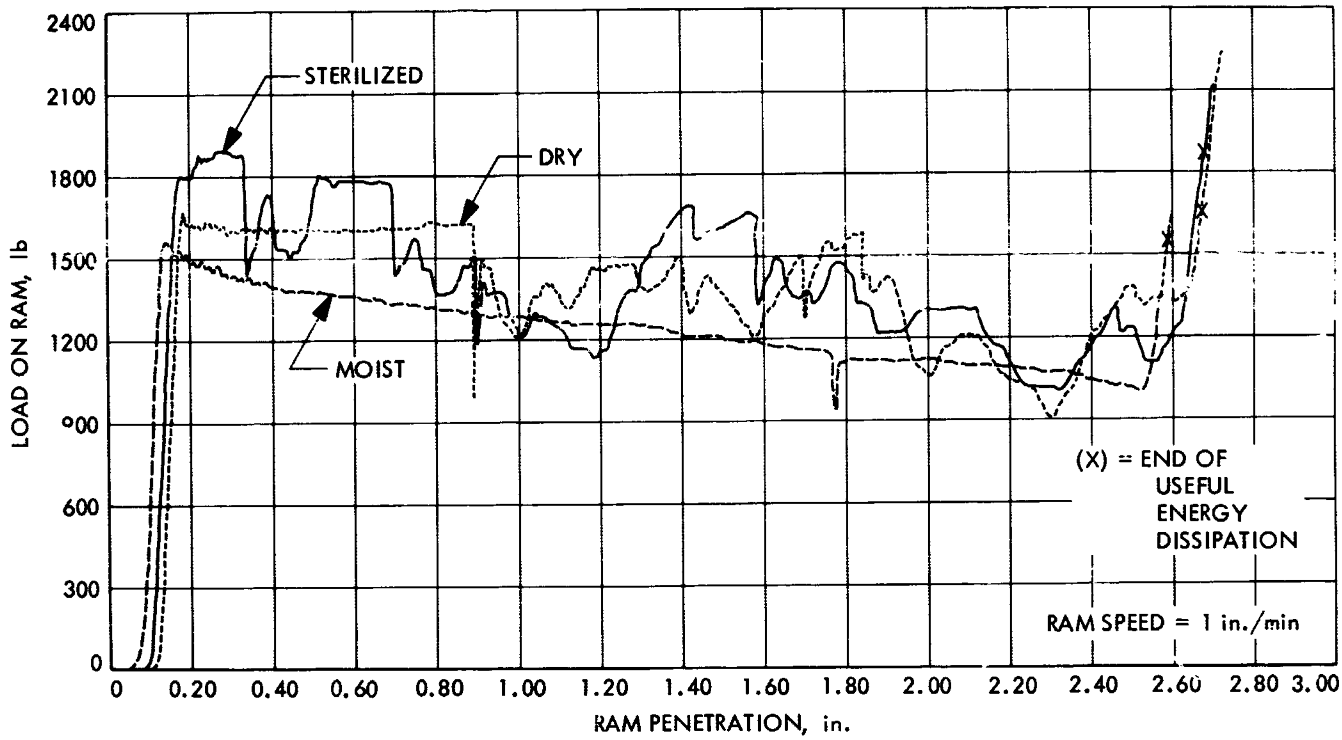

Fig. 6. Typical trace of crush test ram vs depth of ram penetration for balsa in each condition from a single stick

Table 1. Summary of data derived from 1,241 crush tests as a function of condition

Condition	Mean specific energy / Standard deviation, ft-lb/lb	Mean stress / Standard deviation, psi	Mean thickness efficiency / Standard deviation	Mean density, lb/ft^3
Moist	20,400/3,339	1,342/337	0.839/0.018	7.98
Dry	22,900/3,869	1,383/379	0.885/0.024	7.75
Sterilized	23,097/3,674	1,454/364	0.849/0.027	7.68

III. Screening

A. Feasibility of Selecting Specific Trees for the Application

One of the objectives of this program was to study selection criteria for the procurement of uniformly high-quality balsa wood required for future impact limiters. It was hoped that a way could be found whereby wood with the desired properties could be selected in the jungle or at the mill without the need for any screening tests. Factors affecting the quality and energy-dissipating capability of balsa wood were not given in the literature and were not known by the wood experts who were consulted. In an effort to gain first-hand information on balsa wood production which would provide a basis for selecting high-grade material, the facilities of the Balsa Ecuador Lumber Corporation (BELC), the world's largest producer of balsa wood, were visited. Observations during the trip were made in the following areas: (1) the logging and transportation operations in the jungle and (2) the sawmill operations in Guayaquil.

B. Logging, Transportation, and Sawmill Operations

The balsa tree (*Ochroma lagopus*) grows wild in the coastal jungles of Ecuador. This tree is fast growing and attains cutting maturity in 6 to 10 yr. At this age, it will yield two 16-ft logs with a diameter of about 15 to 18 in. The trees are selected for cutting on the basis of size and are felled (Fig. 7), stripped of bark, and cut into logs by a logging crew. While the logs are green they are highly

Fig. 7. Balsa tree being felled in a jungle area of Ecuador

susceptible to insect and fungal infestation, which would markedly degrade the quality of the finished product. To prevent degradation, the logs are sprayed with an oil-base hexaclorobenzene insecticide-fungicide shortly after cutting.

The green logs are transported by teams of oxen and then by truck to embarkation sites about 20 to 30 miles from the logging areas. The time period from cutting to arrival at the embarkation site is usually 8 days. The logs are sprayed again with the insecticide-fungicide oil and are assembled into rafts consisting of 400–600 logs in the river. The whole raft is covered with banana leaves to protect the logs from the sun, thus minimizing checking or splitting. The raft is then floated down the river with raft men on board to guide it during the journey of several days to the sawmill (Fig. 8).

One of the most important capabilities of the mill visited is its kiln drying capacity. The lumber is dried in nine kilns, each having a capacity of 50,000 board feet of green lumber. The drying schedules vary from four to twelve 24-h days. The final moisture content after drying varies from 5 to 12%. Kiln drying is important since it kills all the fungal spores and hyphae in the wood and thus prevents the wood from rotting if it is exposed to moisture in the future. Some producers air-dry their wood, which is, therefore, susceptible to rotting.

Inspection procedures followed at the mill are simple yet effective for most of the applications for the balsa wood. Visual inspection is used on the higher grades of wood to cull out physical defects such as knots, pith, pinholes, splits, and pinworm holes. Grading for density is usually done by "hand weighing" by trained inspectors into three broad density ranges.

It was observed that no readily discernable clues are available in the jungle to select the best 5% of balsa logs which would be desired for impact limiter application.

Fig. 8. Balsa rafts in log pond at sawmill in Guayaquil, Ecuador

Sawing operations often reveal, for the first time, the variations in quality and density within a single log in an unpredictable distribution. Some people believed it possible to select, by inspection, trees in the jungle that possessed wood in a certain density range, or possibly wood with superior specific energy. Discussion with experts of Balsa Ecuador revealed there is no known correlation between the appearance of a tree and its compressive properties. Furthermore, no correlation has been observed with other factors such as age, size, and location of the tree. Even if some correlation could have been found it would be very difficult to implement at the logging level of production as the personnel doing this work are native contractors, remote from civilization, loosely supervised, and unskilled in this type of selection. The only hope appeared to be in performing some type of selection method at the mill after the wood was processed. The knowledge in hand at that time indicated density to be the best criteria (in addition to visual inspection for defects) for selection of wood for initial purchase and was thus used. However, it has now been proven that density is not a very good indication of specific energy.

C. Description of Possible Selection Tests Studied

Since it was determined that the selection of balsa for impact limiter use would be best accomplished at the mill, a series of standard wood tests were selected for evaluation of their relationship to energy dissipation properties. Discussions with wood technologists resulted in selection of the following nondestructive tests for study: hardness, bending stiffness, gross density, and moisture content. The tests were selected as common industry methods conforming to ASTM D143-52 (1965) which could be performed, with some simplifications, by semiskilled personnel in a South American mill. Some additional studies of toughness, dynamic modulus, and impact tests were also included as a secondary effort. The results of these tests were subjected to stepwise, multiple, linear regression analysis for determination of possible correlations between the proposed selection tests, and energy dissipation as determined by crush testing. Following is a brief description of the test methods.

*1. **Bending stiffness.*** The modulus of elasticity in the grain direction can be directly related to stiffness. Stiffness is important in the wood industry because strength properties can be estimated from automatic mechanical stress-rating machines which operate on the principle of determining stiffness from load-deflection relations within the elastic range. The machines now in use measure load-deflection relations continuously on each piece as it passes through, and stamp them as qualifying for one of about five stiffness and stress grades, or as a reject.

The static bending test assembly shown in Fig. 9 was patterned after the device suggested in test method ASTM D142-52 (1965) for use on the balsa sticks remaining after removal of sterilization samples. The distance between supports was 28-in. The load was applied by using a wood bearing block. Deflection of the neutral plane at the center of the length was measured with respect to points in the neutral plane above the supports with a microformer. Microformer output (deflection) was recorded vs load on a BLH "Mark G" test machine. The load required to produce an elastic deflection of 0.75-in. was determined from the chart as the bend test value used for later comparisons and analysis.

*2. **Hardness.*** A 3 × 3 × 3-in. sample taken from a location in each stick adjacent to the "moist" crush test samples was used for hardness determination per ASTM D143-52 (1965). The sample is oriented as shown in Fig. 10 with grain parallel to the direction of indenter motion. The indenter is 0.444 in. diam at the end and is forced into the wood until it has penetrated 0.222 in. as determined by the collar contacting the speciman, which produces a signal from a coupled microformer. The load at this point is recorded as the hardness value.

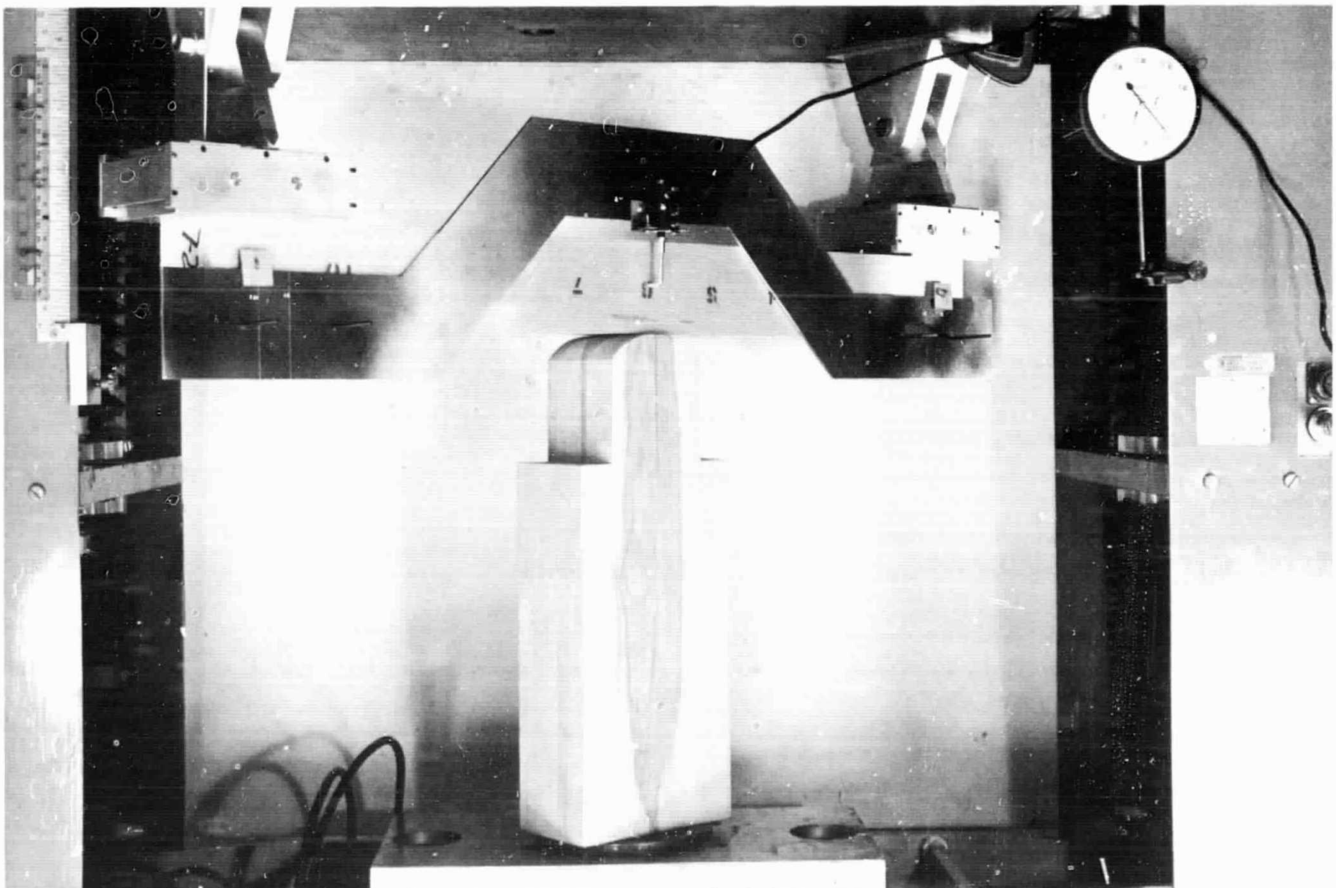

Fig. 9. Bend test apparatus being used to test stick of balsa

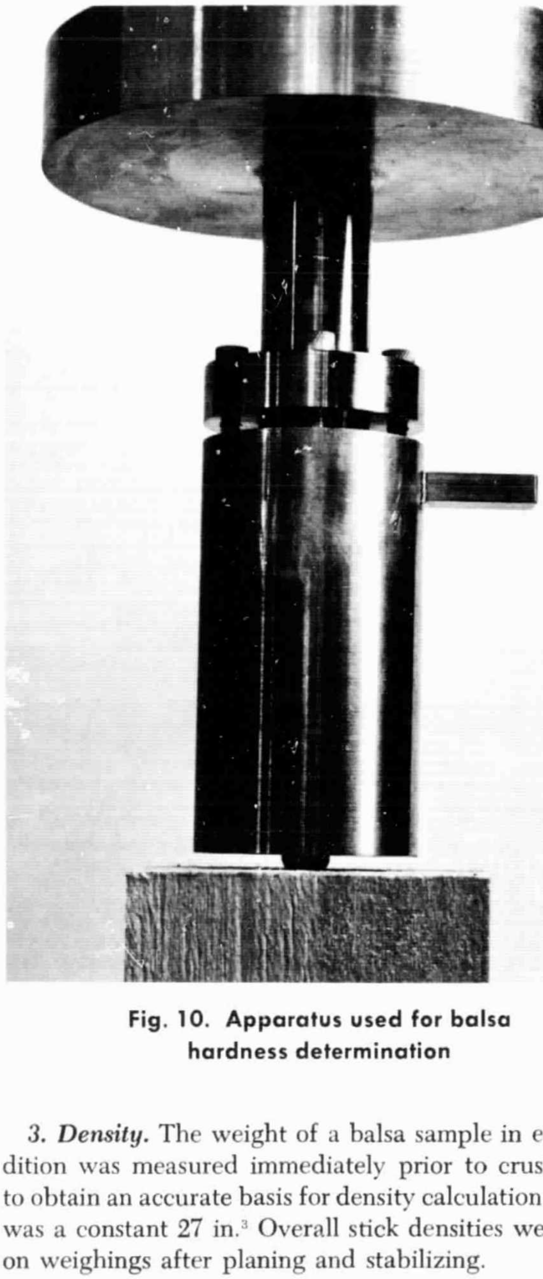

Fig. 10. Apparatus used for balsa hardness determination

3. ***Density.*** The weight of a balsa sample in each condition was measured immediately prior to crush-testing to obtain an accurate basis for density calculation. Volume was a constant 27 $in.^3$ Overall stick densities were based on weighings after planing and stabilizing.

4. ***Other testing.*** Several tests were performed on a very limited number of samples to provide some indication of their possible value in correlation to specific energy. These tests included toughness, modified Izod impact, and dynamic modulus. Toughness tests per ASTM D143-52 (1965) were conducted on 25 samples $0.79 \times 0.79 \times 11$ in. from different sticks using a Forest Products Laboratory type toughness machine. The specimen was supported near the ends and fractured by an impact at the center from a swinging pendulum. The extent of pendulum travel after impact is a measure of specimen toughness. Dynamic modulus testing of each specimen used in toughness testing was measured before impacting with a Magnetester. This device indicates the natural resonant frequency which is related to modulus of elasticity. The Izod-type impact test for plastics (ASTM D256-56) was modified by using unnotched specimens $0.5 \times 0.5 \times 3$ in., all of which were taken from one $3 \times 3 \times 3$ in. piece from one stick with the 3-in. dimension parellel to the grain. These samples were held from one end and fractured by impact from a swinging pendulum of a Tinius-Olson impact machine.

D. Correlation of Selection Tests with Specific Energy

The results of the selection tests used were found to have a generally poor correlation to specific energy. Computerized, stepwise, multiple linear regression analysis of the test results was performed to find if any tests or combination of tests had a statistically significant correlation to specific energy in the sterilized condition.

Bending stiffness values were found to be in the range 191 to 499 lb. Again, no useful correlations with specific energy were found.

The hardness test was found to have some statistical significance, but would not be very useful. For example, considering the weakest 5% of the sterilized specific energy samples, application of the hardness test to selection would have screened out 13 of the 24 samples in this group while also rejecting 55 others not in the low-specific-energy group. Balsa wood hardness depends quite heavily on location of the indentation with respect to the growth rings. Since growth rings in balsa are often ¾ to 1 in. wide, the 0.444-in.-diam penetrator many times acts as a "micro" hardness indicator rather than the more desirable "macro" hardness which would have to be determined by a penetrator of over 1-in. diam to overlap growth rings and average the variations in "micro" hardness. Balsa hardness values obtained in this program range between 47 and 247 lb. A hardness test using a large-penetrator diameter might offer some promise as a screening technique.

Gross density values were not found to have a useful correlation to specific energy within the range studied (5.72–10.1 lb/ft^3). No improvement in possible correlation was found when individual crush sample densities were studied as a function of specific energy values in any of the conditions evaluated.

Study of the limited results (25 random samples) derived in toughness and dynamic modulus tests failed to reveal a correlation with specific energy. Evaluation of

Table 2. Variation of specific energy (ft-lb/lb) within a stick

Stick No.	Location from end, in.							
	12	15	18	21	24	27	30	33
7-123	20,313	22,634	19,881	18,994	19,411	19,551	19,043	20,805
7-229	15,497	14,408	14,309	14,161	14,927	14,577	14,956	16,285
9-98	19,630	18,297	19,465	18,646	18,778	19,339	18,665	18,670

Table 3. Variation of density (lb/ft^3) within a stick

Stick No.	Location from end, in.							
	12	15	18	21	24	27	30	33
7-123	8.70	8.45	8.25	8.15	8.15	8.15	8.15	8.00
7-229	6.32	6.40	6.40	6.40	6.55	6.40	6.40	6.40
9-98	9.55	9.68	9.55	9.55	9.55	9.68	9.55	9.55

25 Izod impact test results on samples removed from a single 3 × 3 × 3 in. block indicated that impact strength was in part a function of radial position from the tree center.

As a means of better understanding balsa crush properties' variations, three sticks were crush-tested in seven adjacent locations in the moist condition. The results shown in Table 2 compare these values with the moist values obtained on a single location (12 in. from end) in each stick earlier in this program. Almost a 10% deviation from previous values was found, but no relationship to axial location in a stick or tree was noted.

Density variations within a stick are shown in Table 3 for the same block crush tested in Table 2.

IV. Feasibility of Balsa Properties' Improvement

A. Background

Interest in balsa energy dissipation improvement is motivated primarily by a desire to reduce scatter and achieve more uniformity. Additionally, weight savings would be possible if the mean specific energy were increased.

Considerable effort has been expended in some recent studies towards the development of radiation processed wood–plastic combinations, supported by the Division of Isotopes Development–U. S. Atomic Energy Commission, and conducted at West Virginia University (W.V.U.) (Ref. 4). Commercial processors using these techniques exist at American Novawood Corp. and Lockheed Georgia Nuclear Laboratory. The following excerpt from Ref. 4 will describe the technique:

> "When the cells of wood are filled or partially filled with a suitable liquid monomer which is subsequently caused to polymerize, there results a material which, while retaining most of the desirable characteristics of wood, possesses many improved properties. For example, such properties as toughness, hardness, bending strength and compressive strength are enhanced by the process. An inherently simple and practical process for manufacturing wood-plastic combinations comprises the impregnation of wood with a suitable monomer followed by exposure to gamma radiation to convert the monomer to a solid polymer (plastic). The penetrating power of gamma radiation, combined with its ability to initiate free-radical type polymerizations enables one to effect polymerization of the monomer at a more or less uniform rate throughout specimens of various sizes and shapes. The utilization of gamma radiation also eliminates the need for chemical catalysts (and, therefore, the hazards attendant to storing and handling catalyzed monomers) and obviates the many problems associated with initiating and controlling the reaction with heat. During the very early phases of this research, polymer loadings were controlled by removal of air from the wood followed by an overnight atmospheric pressure soak in monomer. It became apparent, however, that this treating cycle did not give full loadings, or even uniform partial loadings."

Recently developed elevated pressure treating cycles have overcome the difficulties referred to on sapwood of the loblolly pine and sapwood of the white pine, and the results have been extended to several other species. With the cooperation of the U.S.A.E.C., a trip was made to West Virginia University to discuss experiments that would indicate the applicability of these techniques to balsa wood. Conferences with wood technologists and chemical engineers at W. V. U. resulted in a series of partial loading experiments on 3 × 3 × 3 in. balsa samples, provided by JPL from this program, for treatment by

W. V. U. and later crush property evaluation at JPL. Additional samples were also submitted to American Novawood Corp. for treatment using vapor-phase impregnation methods to achieve partial loadings.

All impregnated samples were weighed for density change determination, and crush-tested for comparison with crush properties of samples tested from the same sticks.

B. Balsa–Plastic Impregnation and Irradiation Study Results

Approximately 15 samples were treated by West Virginia University and American Novawood Corp. using various liquid and vapor impregnation techniques with a considerable variation in polymer loadings—4 to 79%. Irradiation from isotope sources induced polymerization and possibly some grafting to the wood cells. Crush tests were performed on each sample and compared with data on moist sample's specific energy from the same sticks. In every case a degradation of specific energy resulted from the treatments. Some degradation of specific energy may be attributed to the filling of balsa cells with plastic causing a substantial weight penalty. Even though the area under the crush curve was increased in several cases, the density increased to an even greater extent and reduced specific energy.

V. Conclusions

This program has derived several significant conclusions which should be very useful in future planetary impact limiter designs involving balsa wood.

(1) Ethylene oxide plus heat sterilization results in an enhancement of balsa wood's energy dissipation capability. The energy dissipation property values which should be utilized in sterilized limiter design are as follows:

Specific energy = 23,097 ft-lb/lb (standard deviation of 3674 ft-lb/lb)

Mean crush stress = 1454 lb/in.^{2} (standard deviation of 364 lb/in.^{2})

Thickness efficiency = 0.849 (standard deviation of 0.027)

The occasional splitting of sterilized balsa samples during crushing may be of some significance in limiter design and may require the use of a fiberglass cloth limiter covering to inhibit fragmentation.

No significant balsa wood dimensional changes were observed as a result of sterilization.

(2) Selection of balsa wood for impact limiter applications can be most practically accomplished by specification of wood meeting MIL-S-7998 requirements with additional specification of gross density in the range 6–10 lb/ft^3 determined by actual weighing at the mill. Examination for defects such as splits must be done in a complete manner by examining all surfaces visually. Radiography could be used in suspect areas. A complete series of hardness, moisture content, bending stiffness, and density measurements did not reveal a useful relationship of these properties to specific energy which would permit a simple method of selection at the mill of wood possessing an improved uniformity. Limited toughness and dynamic modulus tests also failed to reveal a relationship to specific energy.

(3) Attempts to enhance or reduce scatter in the specific energy of balsa wood by monomer impregnation followed by irradiation-induced polymerization resulted in degraded properties. It may be concluded that no feasible means presently exists of improving balsa wood's already outstanding energy dissipation capabilities.

Appendix A
JPL Crush Test (Specific Energy) Determination

This test has been developed to determine specific energy of a material to be used as an energy dissipator. The "block" sample used is $3 \times 3 \times 3$ in. with grain orientation parallel to the direction of movement of a cylindrical ram crushing an area of 1-in.[2] (Fig. A-1). The balsa sample is enclosed within a restraining fixture and is tested in compression until the load increases rapidly indicating the end of useful energy dissipation. The ram is tapered to avoid increasing effects of frictional forces as it is driven into the balsa sample at a rate of 1 in./min. A chart of load vs ram travel (Fig. 6) is used to determine the mean crushing stress (area under the useful portion of the curve divided by length of effective stroke at the onset of specimen "uncrushability"). The value of specific energy is derived by dividing mean stress by sample density and multiplying by thickness efficiency. The thickness efficiency is simply a measure of the maximum stroke capability of an energy dissipator (assuming no elastic rebound) and is limited by the onset of specimen "uncrushability." It is calculated by dividing total stroke length by specimen height. The formula for specific energy is, therefore:

$$\text{specific energy} = \left[\frac{\text{mean crush stress}}{\text{sample density}}\right] \times \text{thickness efficiency}$$

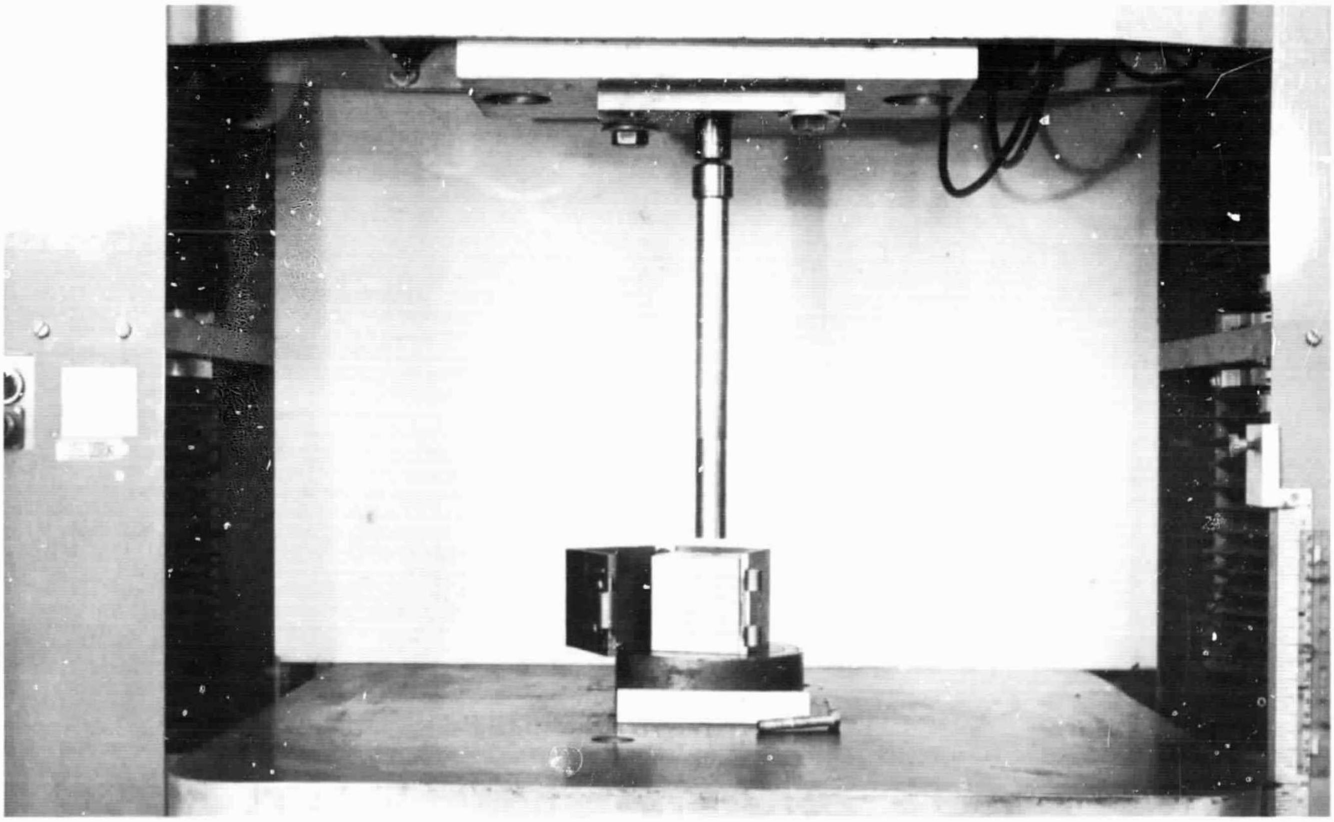

Fig. A-1. Apparatus used to conduct crush tests on balsa for determination of specific energy values

Appendix B
Data Compilation

This appendix lists all data derived from each balsa wood stick. A summary of properties can be found within the main body of the report.

Glossary of Terms and Symbols Used in List

No. = stick identification number

Den. = density of stick, lb/ft^3

M.C. = moisture content taken from meter, %

B.L. = bending load, lb

H = hardness, lb

Moist block = block stabilized and crush-tested in 50% relative humidity room

Sterile block = block subjected to sterilization cycles and crush-tested while dry

Dry block = block oven dried and crush-tested in this condition

ρ = block density in condition tested, lb/ft^3

β = thickness efficiency

$\bar{\sigma}$ = mean crushing stress, psi

KE = specific energy, ft-lb/lb

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7001	7.13	7.3	291.	66.	6.94	.849	821.	14449.	6.45	.859	911.	17470.
7002	8.05	7.5	318.	138.	8.14	.836	1551.	22919.	7.75	.856	1557.	24753.
7003	8.26	7.3	349.	88.	7.78	.813	1096.	16492.	7.47	.856	1330.	21952.
7004	8.10	8.1	365.	124.	8.17	.839	1359.	20095.	7.59	.859	1469.	23933.
7005	8.06	7.0	360.	122.	.21	.833	1507.	21987.	7.49	.853	1610.	26358.
7006	7.14	7.8	291.	61.	7.38	.806	1103.	17334.	6.73	.863	1074.	19813.
7007	7.12	7.0	305.	85.	7.31	.853	860.	14433.	6.55	.869	1080.	20631.
7008	7.56	7.3	318.	89.	8.14	.869	1225.	18822.	7.88	.839	1816.	27860.
7009	8.26	7.1	415.	108.	8.62	.856	1160.	16576.	7.83	.853	1249.	19567.
7010	6.77	7.0	235.	90.	7.25	.846	1122.	18826.	6.75	.859	1474.	27016.
7011	7.90	6.8	342.	162.	8.00	.839	1535.	23178.	7.35	.899	1388.	24439.
7012	7.60	6.0	349.	57.	8.02	.879	1022.	16142.	7.27	.883	1369.	23932.
7013	6.86	7.0	267.	75.	7.06	.866	964.	17030.	6.51	.883	1220.	23813.
7014	7.46	7.0	289.	91.	7.45	.859	923.	15318.	7.13	.839	1380.	23396.
7015	7.35	6.0	270.	79.	7.21	.876	1174.	20531.	6.80	.856	1461.	26455.
7016	7.97	6.1	353.	126.	8.58	.843	1377.	19473.	8.09	.886	1547.	24394.
7017	7.48	6.1	293.	102.	8.79	.863	1299.	18350.	7.30	.873	1358.	23367.
7018	7.50	7.1	307.	85.	7.48	.853	911.	14953.	6.92	.866	1278.	23030.
7019	7.88	7.0	330.	111.	8.40	.833	1334.	19041.	7.69	.849	1461.	23215.
7020	7.82	6.5	316.	120.	8.07	.849	1520.	23012.	7.51	.846	1790.	29028.
7021	7.46	6.3	365.	70.	7.52	.866	955.	15824.	6.90	.873	1108.	20161.
7022	7.90	7.0	345.	96.	8.10	.859	1265.	19311.	7.37	.829	1684.	27280.
7023	6.98	6.4	283.	71.	6.99	.846	1136.	19794.	6.52	.876	1270.	24555.
7024	7.72	7.0	318.	105.	7.95	.846	1436.	22004.	7.06	.836	1345.	22937.
7025	6.52	6.8	270.	82.	6.93	.856	982.	17466.	6.59	.876	1197.	22897.
7026	7.39	7.3	284.	105.	7.42	.826	1054.	16887.	6.56	.849	1228.	22864.
7027	7.19	6.1	310.	114.	7.25	.856	1377.	23384.	6.65	.879	1468.	27936.
7028	7.64	7.0	324.	91.	7.47	.853	1228.	20180.	6.96	.853	1300.	22932.
7029	7.63	7.5	307.	135.	7.75	.839	1180.	18407.	7.35	.893	1813.	31673.
7030	7.81	7.1	306.	101.	7.99	.859	1211.	18755.	7.58	.866	1340.	22043.
7031	7.08	6.0	366.	112.	6.97	.853	1117.	19669.	6.32	.766	1066.	18593.
7032	7.38	6.7	330.	111.	7.61	.846	1561.	24985.	7.86	.843	1712.	26410.
7033	7.00	6.3	330.	61.	7.00	.869	1174.	20986.	6.58	.853	1251.	23340.
7034	7.91	7.0	357.	88.	8.17	.839	1347.	19919.	7.35	.859	1374.	23109.
7035	7.42	7.1	312.	89.	7.07	.859	974.	17036.	6.76	.849	1143.	20666.
7036	7.93	6.7	318.	106.	8.72	.846	1334.	18631.	8.04	.873	1355.	21162.
7037	8.08	7.7	327.	85.	7.92	.853	1143.	17724.	7.07	.859	1093.	19110.
7038	7.56	7.1	282.	101.	8.35	.849	1265.	18518.	7.88	.853	1539.	23990.
7039	8.23	6.5	336.	85.	8.78	.866	1292.	18347.	8.51	.866	1716.	25143.
7040	7.65	7.0	319.	100.	7.65	.863	1345.	21840.	6.86	.873	1580.	28920.
7041	6.99	6.6	306.	88.	6.89	.863	1181.	21288.	6.45	.879	1331.	26116.
7042	7.92	7.0	341.	96.	7.61	.853	1291.	20827.	6.87	.889	1435.	26727.
7043	7.93	6.8	379.	79.	8.38	.843	1432.	20720.	8.17	.869	1673.	25620.
7044	8.05	7.6	360.	73.	8.00	.853	1157.	17752.	7.18	.859	1204.	20731.
7045	6.93	7.3	269.	72.	6.49	.856	845.	16028.	5.72	.856	978.	21065.
7046	7.81	7.3	348.	108.	7.75	.853	1328.	21042.	6.97	.869	1289.	23133.
7047	6.92	6.9	262.	84.	6.76	.856	1013.	18455.	6.01	.853	1272.	25956.
7048	6.47	6.8	240.	72.	6.80	.869	1126.	20707.	6.32	.893	1195.	24275.
7049	7.51	7.1	330.	79.	7.86	.859	1079.	16973.	7.31	.906	1217.	21709.
7050	7.58	6.6	294.	84.	7.56	.846	1268.	20149.	7.16	.839	1716.	28970.
7051	7.00	7.6	289.	76.	7.42	.869	990.	16693.	6.99	.876	1010.	18230.
7052	6.99	6.2	259.	61.	6.93	.873	957.	17341.	6.39	.869	1004.	19647.
7053	7.06	8.1	293.	72.	7.40	.866	999.	16834.	6.87	.889	1022.	19031.
7054	7.63	6.9	323.	72.	7.72	.859	1244.	19927.	7.23	.899	1153.	20650.
7055	7.60	7.4	317.	72.	7.90	.886	868.	14008.	7.51	.866	1310.	21752.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7056	7.17	7.9	329.	118.	7.03	.869	1248.	22211.	6.44	.866	1283.	24833.
7057	8.06	6.8	306.	113.	8.65	.859	1302.	18616.	7.80	.853	1640.	25791.
7058	7.25	7.3	307.	90.	7.42	.853	1293.	21380.	7.02	.859	1490.	26273.
7059	7.96	7.0	317.	88.	8.02	.856	1270.	19514.	7.37	.866	1442.	24392.
7060	7.32	7.7	294.	114.	7.54	.859	1102.	18084.	6.86	.903	1461.	27662.
7061	7.54	7.4	279.	114.	7.13	.826	1439.	24002.	6.35	.873	1307.	25842.
7062	7.16	6.9	335.	64.	7.04	.866	1112.	19676.	6.32	.883	912.	18320.
7063	7.83	6.9	298.	60.	6.97	.876	857.	15504.	6.39	.856	1073.	20681.
7064	7.51	7.6	235.	84.	8.52	.839	1345.	19062.	8.69	.906	1343.	20147.
7065	7.49	7.1	312.	77.	7.76	.866	1287.	20671.	7.37	.849	1720.	28529.
7066	7.08	7.5	312.	72.	7.00	.873	794.	14251.	6.07	.873	890.	18422.
7067	7.59	8.1	352.	85.	7.34	.849	1178.	19628.	6.44	.859	1165.	22377.
7068	7.76	7.8	371.	121.	7.99	.839	1400.	21167.	7.25	.869	1425.	24573.
7069	6.94	6.2	276.	87.	7.21	.879	1204.	21129.	7.31	.879	1575.	27255.
7070	7.29	6.9	330.	126.	7.10	.843	1593.	27215.	6.99	.903	1647.	30617.
7071	7.72	7.2	294.	97.	8.17	.839	1364.	20165.	7.28	.856	1340.	22662.
7072	7.35	6.9	318.	76.	6.94	.876	1220.	22150.	6.13	.873	1181.	24212.
7073	7.24	8.0	282.	161.	7.31	.826	1325.	21552.	6.78	.829	1506.	26522.
7074	7.30	7.1	306.	115.	7.64	.839	1609.	25458.	7.04	.859	1397.	24534.
7075	7.17	6.6	320.	106.	7.69	.849	1190.	18916.	7.55	.846	1755.	28294.
7076	7.75	7.7	335.	130.	7.86	.873	1335.	21326.	7.44	.866	1495.	25050.
7077	7.75	7.5	306.	87.	7.78	.846	1275.	19968.	6.86	.853	1230.	22004.
7078	7.79	7.1	313.	72.	7.92	.859	1351.	21101.	7.45	.873	1328.	22379.
7079	7.81	7.2	342.	84.	7.52	.846	1074.	17392.	6.68	.856	1146.	21143.
7080	7.03	6.7	276.	132.	7.18	.839	1457.	24494.	6.86	.849	1505.	26824.
7081	7.43	7.5	268.	101.	7.54	.836	1202.	19190.	7.02	.856	1288.	22625.
7082	7.60	7.5	329.	68.	7.18	.876	923.	16209.	6.32	.883	1014.	20366.
7083	7.74	7.2	283.	78.	7.07	.869	1089.	19273.	6.45	.889	1143.	22684.
7084	7.78	6.6	325.	72.	7.73	.853	996.	15801.	7.21	.849	1127.	19096.
7085	6.90	6.5	293.	60.	6.96	.859	872.	15494.	6.34	.886	965.	19413.
7086	6.84	7.3	264.	60.	6.83	.863	718.	13046.	7.41	.453	1050.	9235.
7087	7.67	7.1	329.	59.	7.51	.863	769.	12714.	6.58	.846	803.	14860.
7088	7.88	7.0	366.	88.	8.57	.863	1169.	16953.	8.30	.839	1597.	23253.
7089	7.58	7.5	369.	72.	7.57	.859	953.	15584.	7.02	.873	1177.	21067.
7090	7.59	6.5	423.	101.	7.55	.859	1260.	20640.	7.00	.889	1314.	24025.
7091	7.42	7.0	306.	106.	7.14	.866	1269.	22142.	6.63	.889	1211.	23358.
7092	7.67	7.0	321.	83.	7.13	.853	1307.	22509.	6.73	.879	1250.	23486.
7093	6.73	7.0	240.	64.	6.71	.883	760.	14408.	6.06	.863	924.	18940.
7094	7.62	7.0	318.	97.	7.99	.849	1150.	17603.	8.09	.853	1335.	20269.
7095	6.62	7.1	264.	78.	6.66	.863	1040.	19376.	6.45	.856	1312.	25046.
7096	6.93	7.0	294.	84.	7.27	.863	1262.	21558.	6.75	.896	1157.	22116.
7097	7.23	7.0	294.	90.	6.96	.853	1092.	19254.	6.31	.859	1248.	24466.
7098	6.93	7.1	297.	64.	6.59	.859	844.	15832.	5.87	.863	998.	21097.
7099	7.55	7.9	348.	71.	7.62	.866	1230.	20109.	6.92	.849	1625.	28726.
7100	6.69	6.1	258.	64.	6.55	.859	1027.	19402.	6.13	.889	1060.	22147.
7101	5.72	7.5	205.	79.	5.83	.853	721.	15185.	5.52	.859	795.	17808.
7102	7.26	7.5	287.	67.	7.66	.849	950.	15158.	7.24	.859	1037.	17711.
7103	7.52	7.8	318.	91.	7.09	.843	1090.	18666.	6.56	.873	1238.	23696.
7104	7.56	7.2	336.	90.	7.89	.853	1103.	17167.	7.71	.879	1300.	21344.
7105	7.77	7.9	350.	102.	7.57	.843	1218.	19537.	6.96	.853	1305.	23014.
7106	7.00	6.9	292.	121.	7.24	.863	1139.	19538.	6.76	.839	1445.	25812.
7107	6.22	6.9	251.	72.	7.30	.869	868.	14895.	5.22	.879	931.	22557.
7108	7.27	7.5	299.	132.	8.38	.849	1322.	19279.	7.14	.846	1429.	24357.
7109	7.86	7.3	329.	109.	7.58	.856	1498.	24357.	6.63	.866	1299.	24398.
7110	7.72	6.8	326.	97.	7.62	.846	1096.	17506.	6.94	.869	1243.	2239[illegible].

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7111	7.66	6.8	366.	88.	7.66	.856	1192.	19173.	7.25	.863	1267.	21680.
7112	7.92	7.6	341.	91.	7.89	.853	1106.	17204.	7.11	.869	1252.	22028.
7113	7.45	7.2	343.	83.	7.20	.866	1230.	21290.	6.44	.873	1268.	24744.
7114	7.42	7.1	289.	101.	7.55	.846	1003.	16184.	7.11	.846	1093.	18714.
7115	7.74	6.5	330.	103.	7.99	.849	1454.	22247.	7.55	.869	1473.	24410.
7116	7.75	6.6	320.	132.	7.78	.843	1662.	25921.	7.33	.866	1647.	28026.
7117	8.01	7.8	329.	114.	7.83	.843	1297.	20081.	7.09	.856	1288.	22400.
7119	7.96	7.2	348.	132.	8.54	.839	1690.	23914.	7.30	.856	1568.	26480.
7120	7.88	7.1	334.	107.	7.93	.849	1294.	19940.	7.18	.846	1318.	22332.
7121	7.87	7.5	315.	138.	7.96	.836	1290.	19508.	7.07	.836	1364.	23217.
7122	7.89	7.0	380.	118.	7.71	.859	1230.	19740.	7.07	.836	1305.	22200.
7123	8.26	7.2	354.	96.	8.66	.846	1440.	20245.	8.14	.829	1354.	19846.
7124	7.47	7.0	253.	131.	7.45	.843	967.	15742.	7.33	.806	1244.	19705.
7125	7.56	6.5	316.	97.	7.61	.849	1265.	20336.	7.13	.869	1213.	21299.
7126	6.14	6.8	244.	66.	6.06	.856	784.	15949.	5.75	.989	907.	22462.
7127	7.03	6.3	313.	121.	7.14	.873	1080.	19002.	6.55	.896	1115.	21948.
7128	7.20	6.9	285.	60.	6.51	.866	837.	16037.	6.06	.849	1025.	20696.
7129	6.98	7.5	268.	96.	7.14	.823	1234.	20452.	6.75	.846	1242.	22414.
7130	7.52	6.9	302.	97.	7.76	.863	1271.	20337.	7.23	.896	1144.	20411.
7131	7.67	7.0	318.	108.	7.73	.846	1348.	21229.	6.94	.856	1358.	24096.
7132	6.68	6.5	271.	85.	6.85	.859	1041.	18815.	6.31	.859	1381.	27063.
7133	8.27	6.2	350.	96.	8.54	.846	1445.	20613.	7.85	.843	1558.	24076.
7134	7.21	7.0	311.	113.	7.66	.853	1500.	24013.	6.55	.869	1328.	25372.
7135	7.70	6.9	310.	88.	7.07	.839	1023.	17484.	6.06	.839	1142.	22785.
7136	7.59	6.9	241.	90.	7.68	.833	859.	13408.	6.86	.836	1233.	21627.
7137	7.60	7.1	348.	88.	7.55	.856	1272.	20754.	7.10	.863	1364.	23854.
7138	7.54	7.0	347.	76.	7.71	.859	1230.	19740.	6.97	.879	1159.	21030.
7139	7.81	6.2	343.	76.	7.72	.856	1115.	17804.	6.96	.849	1268.	22271.
7140	7.25	7.1	305.	123.	7.58	.846	1344.	21587.	7.16	.836	1470.	24711.
7141	7.31	7.1	252.	81.	7.23	.853	937.	15915.	7.34	.846	1225.	20333.
7142	7.31	6.3	299.	91.	7.30	.846	1249.	20845.	6.86	.839	1438.	25315.
7143	6.70	6.2	247.	70.	6.78	.883	960.	17992.	6.23	.879	884.	17964.
7144	7.31	6.4	312.	89.	7.34	.869	1137.	19393.	6.85	.873	1227.	22511.
7145	7.24	6.1	294.	63.	7.00	.866	807.	14374.	6.44	.859	990.	19027.
7146	6.89	6.7	241.	78.	7.57	.843	1010.	16192.	7.14	.863	1172.	20271.
7147	7.57	6.0	271.	62.	8.52	.849	1112.	15958.	8.26	.856	1237.	18461.
7148	6.97	6.5	294.	60.	6.90	.873	1101.	20036.	6.14	.903	887.	18773.
7149	6.44	6.5	259.	64.	6.21	.843	889.	17356.	6.08	.863	894.	18238.
7150	7.47	6.3	281.	117.	7.58	.826	1507.	23636.	7.00	.859	1360.	24025.
7151	7.61	6.7	374.	85.	7.88	.866	1056.	16723.	7.33	.876	1450.	24965.
7152	7.08	7.0	331.	102.	7.85	.843	903.	13962.	7.33	.879	1215.	21000.
7153	7.49	7.0	263.	109.	7.69	.833	1392.	21682.	7.06	.859	1390.	24363.
7154	6.73	7.0	271.	84.	6.89	.843	1152.	20286.	6.62	.876	1273.	24223.
7155	7.19	7.0	205.	75.	7.76	.849	1207.	19004.	7.37	.829	1301.	21075.
7156	7.67	7.3	405.	76.	7.64	.839	1250.	19771.	6.89	.859	1120.	20119.
7157	6.56	7.1	281.	79.	6.54	.843	1218.	22611.	6.17	.843	953.	18734.
7158	7.82	7.3	336.	72.	7.82	.839	1190.	18389.	7.25	.849	1390.	23424.
7159	6.51	7.0	278.	90.	7.54	.836	1147.	18313.	7.07	.856	1319.	22973.
7160	7.63	7.1	340.	103.	7.82	.816	1459.	21919.	7.42	.849	1496.	24633.
7161	7.28	7.0	318.	96.	7.69	.839	1190.	18692.	7.28	.853	1359.	22899.
7162	6.96	6.9	282.	73.	7.16	.846	1055.	17960.	6.72	.856	1164.	21353.
7163	7.62	6.9	314.	120.	7.86	.859	1418.	22313.	7.47	.879	1293.	21913.
7164	6.91	6.1	294.	84.	7.16	.849	1223.	20893.	6.59	.866	1356.	25645.
7165	7.73	6.5	372.	117.	7.73	.843	1465.	22977.	7.02	.869	1427.	25453.
7166	6.96	6.7	273.	85.	7.03	.823	1197.	20166.	6.62	.859	1123.	20976.

No.	Den.	M. C	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7167	7.17	6.9	251.	79.	7.49	.819	1170.	18416.	8.30	.833	1708.	24674.
7168	7.15	6.4	300.	90.	7.45	.849	1251.	20527.	6.93	.849	1324.	23357.
7169	7.32	6.4	287.	72.	7.35	.849	1016.	16892.	6.89	.866	1206.	21831.
7170	7.31	7.0	298.	101.	7.30	.843	1211.	20135.	6.85	.869	1259.	23015.
7171	6.15	6.2	241.	78.	5.85	.833	938.	19231.	5.04	.849	938.	22749.
7172	6.72	6.3	258.	63.	6.79	.856	810.	14694.	6.21	.863	961.	19208.
7173	7.31	6.2	287.	63.	7.47	.853	1181.	19410.	7.07	.849	1376.	23786.
7174	6.86	6.5	264.	60.	6.89	.853	771.	13733.	6.63	.863	1098.	20541.
7175	7.45	6.4	241.	82.	7.42	.816	918.	14524.	7.97	.819	1568.	23188.
7176	6.93	6.2	306.	60.	6.97	.869	1018.	18267.	6.58	.863	1241.	23427.
7177	7.11	6.5	294.	78.	7.17	.853	1050.	17965.	6.55	.876	1213.	23352.
7178	7.43	6.4	299.	91.	7.58	.843	1318.	21094.	7.04	.853	1284.	22371.
7179	7.57	6.2	359.	79.	7.30	.846	1360.	22697.	6.69	.856	1279.	23548.
7180	7.71	6.5	294.	115.	7.73	.836	1228.	19110.	7.04	.843	1425.	24534.
7181	7.35	6.3	283.	114.	7.38	.839	1295.	21190.	6.80	.839	1588.	28187.
7182	7.59	6.2	287.	109.	7.93	.829	1477.	22224.	7.27	.856	1568.	26582.
7183	7.98	6.0	354.	72.	8.40	.846	1313.	19041.	8.03	.873	1355.	21199.
7184	7.83	6.2	368.	120.	8.04	.839	1297.	19482.	7.37	.856	1309.	21894.
7185	7.49	6.5	227.	102.	7.69	.819	1300.	19925.	7.00	.836	1422.	24436.
7186	7.80	6.0	298.	114.	8.72	.823	1486.	20180.	9.30	.819	1990.	25236.
7187	7.78	6.0	285.	85.	8.44	.823	1243.	17447.	8.35	.833	1579.	22649.
7188	6.59	6.0	259.	72.	7.20	.846	1027.	17375.	6.97	.849	1127.	19752.
7189	6.98	6.2	321.	96.	7.09	.849	1280.	22075.	6.42	.879	1095.	21575.
7190	7.31	6.8	263.	75.	7.34	.853	984.	16454.	6.66	.883	1204.	22957.
7191	7.08	6.1	280.	114.	7.40	.823	1370.	21928.	6.78	.809	1866.	32081.
7192	6.94	7.2	294.	88.	6.82	.843	1176.	20917.	6.16	.849	1202.	23868.
7193	7.11	6.2	294.	117.	7.18	.839	1066.	17930.	6.72	.849	1148.	20882.
7194	7.78	6.2	312.	79.	7.59	.843	1069.	17079.	6.86	9	873.	15927.
7195	7.81	6.5	311.	85.	7.76	.859	1230.	19596.	7.02	.[illegible]3	1290.	22830.
7196	6.22	6.0	270.	61.	6.21	.839	835.	16246.	6.39	.846	1044.	19872.
7197	7.69	6.0	314.	60.	8.04	.843	592.	8936.	8.30	.833	1166.	16842.
7198	7.61	6.2	357.	67.	7.96	.849	1129.	17340.	6.94	.859	855.	15236.
7199	6.14	6.0	244.	70.	6.16	.853	907.	18076.	5.45	.883	1055.	24578.
7200	6.51	6.5	273.	67.	6.56	.849	1075.	20017.	6.08	.873	1163.	24002.
7201	7.01	7.1	233.	96.	7.37	.826	1057.	17055.	7.33	.846	1422.	23630.
7202	7.88	7.1	322.	108.	8.59	.843	1406.	19842.	7.42	.899	1335.	23277.
7203	7.01	7.1	341.	72.	7.55	.839	921.	14737.	7.45	.853	1019.	16784.
7204	6.99	6.8	324.	73.	7.34	.863	1093.	18492.	7.00	.866	1137.	20247.
7205	7.04	7.0	281.	111.	6.78	.846	1176.	21133.	6.61	.889	1280.	24807.
7206	7.25	7.5	285.	76.	7.14	.856	1022.	17633.	6.56	.853	1347.	25186.
7207	7.28	7.2	323.	83.	6.93	.856	1104.	19623.	6.03	.853	1253.	25514.
7208	7.25	6.8	312.	88.	7.14	.863	1378.	23954.	6.44	.889	1377.	27379.
7209	7.18	7.2	276.	82.	7.23	.849	1058.	17905.	6.96	.853	1352.	23841.
7210	6.85	6.1	257.	107.	6.90	.839	1321.	23119.	6.52	.839	1433.	26539.
7211	8.05	7.0	336.	105.	8.04	.849	1336.	20304.	7.51	.843	1626.	26271.
7212	7.57	7.2	366.	66.	7.64	.866	1089.	17775.	6.89	.873	1252.	22832.
7213	6.78	6.0	203.	95.	7.44	.849	1084.	17821.	6.83	.853	1033.	18560.
7214	7.34	7.2	303.	84.	8.04	.853	1178.	17980.	7.86	.833	1620.	24691.
7215	6.26	5.9	300.	53.	6.18	.876	866.	17668.	5.89	.873	954.	20362.
7216	6.17	6.9	235.	58.	6.37	.866	743.	14541.	5.93	.859	906.	18908.
7217	8.04	6.1	377.	74.	8.21	.846	1233.	18276.	7.47	.856	1188.	19603.
7218	7.59	6.6	324.	89.	7.78	.829	1354.	20781.	7.30	.866	1440.	24588.
7219	6.55	6.4	313.	65.	6.71	.853	916.	16766.	6.17	.849	1117.	22136.
7220	6.97	6.0	282.	72.	6.37	.863	905.	17657.	5.90	.876	905.	19340.
7221	7.11	6.2	268.	73.	7.27	.853	1014.	17128.	6.76	.853	1122.	20369.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7222	7.19	6.5	200.	76.	7.69	.823	808.	12448.	7.79	.823	1097.	16683.
7223	6.86	6.5	351.	90.	7.71	.843	1266.	19926.	7.62	.849	1545.	24788.
7224	6.30	6.3	275.	71.	6.56	.879	1063.	20499.	6.16	.899	1244.	26156.
7225	7.11	6.3	374.	88.	8.11	.849	1336.	20128.	7.38	.859	1365.	22270.
7226	6.90	6.1	303.	91.	6.94	.836	1403.	24303.	6.63	.873	1316.	24918.
7227	6.91	6.8	275.	69.	7.25	.853	1000.	16923.	6.56	.863	935.	17696.
7228	7.47	7.1	271.	60.	6.75	.859	718.	13167.	5.93	.853	820.	16969.
7229	6.38	6.8	240.	60.	6.31	.849	797.	15445.	5.92	.856	952.	19828.
7230	7.99	6.8	253.	72.	7.33	.836	1140.	18723.	6.89	.879	1072.	19702.
7231	7.47	6.9	348.	79.	7.95	.843	1093.	16684.	8.51	.836	1924.	27204.
7232	6.22	7.0	236.	60.	6.31	.843	818.	15718.	5.92	.856	891.	18565.
7233	7.63	7.2	264.	122.	8.37	.816	1324.	18590.	8.17	.849	1569.	23473.
7234	6.52	6.5	233.	57.	6.59	.859	779.	14611.	6.20	.889	784.	16190.
7235	6.91	7.1	278.	90.	6.80	.843	1268.	22609.	6.27	.866	1257.	24998.
7236	7.46	6.5	316.	60.	7.90	.853	1099.	17064.	7.33	.856	1127.	18959.
7237	6.31	6.8	246.	54.	6.32	.869	758.	15001.	5.75	.866	752.	16309.
7238	6.26	7.0	242.	74.	6.75	.839	1226.	21945.	6.55	.839	1480.	27303.
7239	6.07	6.4	219.	79.	6.04	.843	1162.	23314.	5.58	.889	1137.	26081.
7240	7.26	7.0	231.	56.	6.69	.853	686.	12590.	5.85	.843	735.	15247.
7241	6.85	6.9	315.	63.	6.94	.849	927.	16312.	6.37	.863	1070.	20863.
7242	6.03	7.6	191.	55.	6.10	.846	883.	17630.	5.85	.856	1143.	24100.
7243	6.52	7.2	209.	51.	6.45	.836	643.	11988.	5.99	.839	861.	17386.
7244	6.98	6.5	294.	84.	7.02	.863	1056.	18690.	6.27	.343	1453.	28117.
7245	6.44	7.1	244.	76.	6.51	.866	976.	18688.	5.94	.873	1186.	25055.
7246	7.17	7.0	282.	77.	7.24	.846	977.	16440.	6.55	.889	905.	17690.
7247	7.00	6.5	293.	91.	6.99	.833	1082.	18559.	6.55	.849	1334.	24889.
7248	7.56	7.0	302.	79.	7.41	.829	1074.	17307.	6.76	.846	1140.	20539.
7249	7.31	6.1	260.	94.	8.06	.843	1178.	17735.	8.16	.869	1374.	21081.
7250	7.67	7.0	329.	78.	7.66	.843	1109.	17560.	7.14	.849	1355.	23189.
7251	6.77	7.2	270.	73.	6.85	.853	953.	17093.	6.27	.899	1028.	21237.
7252	7.89	7.0	289.	136.	8.42	.813	1286.	17851.	7.65	.839	1323.	20900.
7253	8.08	7.0	352.	108.	8.10	.843	1249.	18707.	7.42	.873	1222.	20682.
7254	6.14	6.3	264.	47.	5.86	.853	639.	13395.	5.06	.843	623.	14953.
7255	7.32	6.9	299.	78.	7.51	.849	1110.	18075.	6.89	.853	1106.	19702.
7256	6.17	7.0	251.	59.	5.79	.856	744.	15842.	5.07	.863	750.	18370.
7257	7.00	6.4	337.	67.	6.90	.833	1202.	20870.	6.14	.856	1192.	23923.
7258	7.89	7.2	348.	115.	7.79	.833	1620.	24914.	7.37	.829	1973.	31964.
7259	6.16	7.0	272.	72.	6.25	.849	1054.	20595.	5.61	.883	1141.	25848.
7260	6.42	6.9	269.	72.	6.55	.856	1059.	19928.	6.10	.859	1181.	23947.
7261	8.04	6.3	396.	73.	7.88	.846	1011.	15628.	7.16	.876	976.	17197.
7262	7.81	6.0	324.	97.	7.68	.833	1212.	18913.	6.90	.846	1143.	20161.
7263	7.77	6.8	356.	102.	8.03	.823	1440.	21235.	8.74	.859	1474.	20872.
7264	7.74	6.9	325.	87.	7.38	.839	1490.	24385.	6.83	.849	1451.	25967.
7265	6.24	6.2	256.	60.	6.65	.859	844.	15698.	6.32	.856	1078.	21002.
7266	7.96	7.0	317.	108.	7.86	.826	1475.	22313.	7.16	.886	1450.	25836.
7267	8.08	6.0	392.	156.	7.64	.836	1529.	24102.	6.48	.863	1132.	21698.
7268	8.15	7.1	329.	84.	8.34	.863	954.	14205.	7.82	.883	1084.	17616.
7269	5.94	7.0	211.	63.	6.08	.843	998.	19892.	5.82	.839	938.	19472.
7270	7.75	6.6	292.	125.	8.00	.809	1437.	20914.	7.76	.819	1768.	26857.
7271	7.25	7.0	350.	68.	7.30	.833	938.	15407.	6.69	.849	950.	17360.
7272	7.54	6.1	265.	72.	6.89	.849	1192.	21163.	6.45	.856	994.	18985.
7273	7.74	6.3	355.	76.	7.61	.839	1116.	17728.	7.27	.846	1221.	20451.
7274	7.08	6.4	294.	90.	7.03	.843	1233.	21270.	6.55	.859	1190.	22474.
7275	7.17	7.2	277.	96.	7.44	.806	1195.	18633.	6.90	.833	1231.	21369.
7276	7.43	6.0	264.	60.	7.66	.853	982.	15721.	7.89	.856	1169.	18261.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
7277	5.99	6.2	222.	60.	6.34	.843	784.	15014.	5.62	.856	782.	17137.
7278	6.65	6.0	221.	123.	6.86	.819	1278.	21962.	6.41	.826	1541.	28576.
7279	5.96	6.0	[illegible]	73.	5.89	.826	851.	17188.	5.55	.843	986.	21551.
7280	[illegible]	[illegible]	276.	61.	6.27	.863	977.	19356.	5.80	.879	1027.	22393.
7281	[illegible]	[illegible]	[illegible]	77.	7.99	.846	791.	12059.	7.24	.849	1204.	20332.
7282	7.38	6.1	324.	110.	7.35	.829	602.	9775.	6.80	.843	1301.	23200.
7283	7.75	6.1	[illegible]	126.	7.48	.803	1697.	26216.	6.93	.849	1828.	32235.
7284	6.66	6.5	282.	61.	6.10	.846	625.	12492.	5.89	.846	784.	16212.
7285	7.47	[illegible]	299.	72.	7.44	.829	1185.	19020.	7.13	.833	1404.	23598.
7286	[illegible]	6.1	309.	84.	7.34	.836	1216.	19941.	6.90	.843	1304.	22911.
7287	[illegible]	6.0	270.	88.	6.14	.833	1104.	21535.	5.65	.869	1013.	22447.
7288	[illegible]	6.5	306.	85.	7.41	.843	1048.	17152.	6.86	.839	1233.	21711.
7289	7.13	7.3	250.	72.	8.02	.819	926.	13631.	7.83	.836	1113.	17107.
7290	6.84	6.5	271.	84.	6.80	.833	1188.	20918.	6.30	.829	1426.	27033.
7291	7.35	6.3	313.	65.	[illegible]	.856	854.	14764.	6.44	.869	1004.	19518.
7292	6.73	6.1	[illegible]	67.	6.58	.849	884.	16434.	6.23	.849	1115.	21889.
7293	7.91	[illegible]	[illegible]	79.	8.34	.833	1022.	14688.	7.79	.856	884.	13989.
7294	7.93	6.2	351.	92.	8.23	.863	1204.	18174.	7.42	.889	1339.	23084.
7295	6.72	6.5	257.	54.	5.99	.849	684.	13976.	5.63	.856	765.	16737.
7296	7.93	6.2	347.	83.	8.06	.846	1150.	17378.	7.52	.866	1137.	18844.
7297	7.55	6.5	426.	60.	8.14	.869	804.	12360.	7.57	.883	794.	13341.
7298	7.50	6.7	330.	90.	7.21	.846	999.	16863.	6.83	.856	1288.	23231.
7299	7.84	6.1	311.	150.	7.90	.843	1470.	22558.	7.45	.883	1419.	24193.
7300	8.05	6.2	317.	129.	7.82	.846	1251.	19492.	7.25	.863	1355.	23186.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9001	8.64	7.0	402.	134.	8.54	.829	1559.	21792.	7.57	.836	1730.	27519.
9003	8.99	7.7	428.	105.	9.07	.823	1756.	22915.	8.41	.843	1873.	27010.
9004	8.55	8.0	283.	163.	9.86	.813	1886.	22365.	8.79	.819	1326.	17794.
9005	8.89	6.5	427.	73.	8.92	.846	1247.	17025.	7.97	.839	1502.	22755.
9006	9.43	7.3	426.	163.	9.67	.823	1875.	22970.	9.03	.819	2058.	26876.
9007	10.06	7.2	444.	150.	9.57	.843	1610.	20411.	8.71	.839	1933.	26819.
9008	9.17	6.8	417.	146.	9.21	.846	1341.	17727.	8.75	.843	1498.	20773.
9009	8.96	6.2	413.	133.	9.65	.809	1679.	20262.	9.58	.859	1841.	23773.
9010	9.10	7.0	374.	155.	10.82	.816	1880.	20411.	10.33	.809	2508.	28292.
9011	8.40	7.2	324.	178.	8.89	.813	2183.	28725.	8.48	.816	2238.	30990.
9012	9.41	6.5	422.	90.	9.69	.836	1391.	17266.	9.10	.833	1543.	20317.
9013	8.66	7.3	361.	117.	10.72	.823	1848.	20411.	9.14	.859	1404.	18996.
9014	8.88	6.0	434.	125.	8.55	.843	1399.	19840.	7.83	.866	1560.	24817.
9015	8.71	6.2	402.	113.	8.90	.836	1644.	22220.	8.54	.843	2006.	28495.
9016	9.59	7.2	426.	119.	9.59	.826	1562.	19362.	9.45	.853	1664.	21598.
9017	9.74	7.0	472.	102.	10.13	.839	1628.	19418.	9.43	.866	1606.	21235.
9018	9.51	7.6	430.	133.	9.69	.829	1667.	20530.	8.89	.859	1802.	25069.
9019	9.03	7.0	426.	92.	9.54	.856	1300.	16793.	8.79	.859	1623.	22832.
9020	8.79	6.1	393.	117.	8.99	.856	1814.	24858.	8.48	.846	2102.	30176.
9021	9.23	7.0	420.	108.	9.38	.836	1400.	17959.	8.89	.846	1705.	23355.
9022	9.50	7.1	440.	127.	9.51	.829	1585.	19897.	8.17	.859	1397.	21150.
9023	8.18	7.0	420.	76.	8.31	.876	1320.	20031.	7.88	.879	1327.	21324.
9024	9.27	7.5	450.	99.	9.09	.849	1138.	15316.	8.23	.843	1328.	19572.
9025	9.34	7.1	396.	96.	9.34	.819	1868.	23582.	8.96	.819	2039.	26830.
9026	8.72	7.0	351.	125.	8.89	.823	1401.	18664.	8.02	.819	1773.	26079.
9027	9.35	7.4	408.	79.	10.07	.829	1265.	14987.	9.76	.863	1345.	17112.
9028	9.09	6.2	484.	105.	8.23	.833	1214.	17685.	7.34	.849	1454.	24212.
9029	9.34	7.6	450.	161.	9.86	.836	1886.	23007.	9.72	.829	2048.	25144.
9030	9.73	7.5	480.	174.	10.06	.846	1913.	23156.	9.48	.849	2324.	29965.
9031	8.59	7.5	349.	105.	8.35	.823	1333.	18897.	7.90	.823	1566.	23468.
9032	9.46	6.5	480.	83.	9.17	.843	1275.	16868.	8.59	.856	1522.	21817.
9033	8.85	7.0	387.	126.	8.38	.816	1488.	20857.	7.73	.839	1700.	26546.
9034	8.95	7.0	389.	136.	9.07	.806	1713.	21901.	9.05	.799	2297.	29218.
9035	9.03	7.5	429.	101.	8.95	.816	1567.	20572.	8.61	.839	1521.	21347.
9036	8.72	7.0	371.	125.	8.54	.826	1807.	25161.	8.09	.833	1927.	28555.
9037	9.71	7.0	444.	191.	9.88	.803	2153.	25187.	9.38	.826	2264.	28686.
9038	9.03	6.9	367.	144.	9.26	.823	1853.	23705.	9.47	.856	2049.	26668.
9039	9.73	7.2	450.	134.	9.30	.836	1776.	22978.	8.62	.849	1877.	26615.
9040	8.40	6.8	366.	150.	8.24	.823	1513.	21737.	7.66	.829	1595.	24839.
9041	8.99	6.4	350.	109.	8.38	.849	1404.	20480.	7.45	.846	1686.	27550.
9042	9.23	7.4	431.	134.	9.05	.816	1755.	22796.	8.28	.836	1635.	23744.
9043	8.94	6.3	415.	110.	9.61	.836	1434.	17957.	9.52	.813	1991.	24457.
9044	9.34	7.0	459.	112.	9.36	.836	1828.	23516.	8.58	.863	1732.	25070.
9045	8.71	6.7	342.	135.	8.96	.826	1543.	20475.	8.62	.809	1908.	25781.
9046	9.07	6.2	372.	115.	9.14	.823	1814.	23494.	8.55	.823	2137.	29592.
9047	8.02	7.0	320.	132.	8.21	.823	1440.	20761.	8.19	.833	1473.	21571.
9048	8.93	7.0	379.	119.	9.48	.799	1552.	18834.	9.28	.799	1757.	21774.
9049	[illegible]	7.0	342.	117.	8.44	.816	1452.	20207.	7.89	.829	1739.	26316.
9050	9.29	6.5	433.	113.	8.59	.829	1448.	20110.	7.80	.853	1258.	19785.
9051	8.51	7.0	363.	94.	8.59	.853	1600.	22854.	8.06	.849	1825.	27691.
9052	8.83	7.0	374.	99.	9.19	.826	1708.	22102.	8.83	.833	1917.	26011.
9053	9.38	7.5	491.	108.	8.69	.829	1291.	17732.	7.71	.849	1364.	21643.
9054	9.09	7.1	450.	117.	8.28	.819	1304.	18571.	7.96	.809	1597.	23374.
9055	9.22	6.2	409.	175.	9.30	.806	2221.	27710.	9.14	.816	2321.	29815.
9056	9.24	7.7	469.	84.	8.66	.836	1326.	18420.	8.37	.839	1595.	23023.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9057	9.31	6.9	384.	110.	9.44	.806	1685.	20716.	8.81	.823	1821.	24494.
9058	9.86	7.2	419.	225.	9.61	.849	2682.	34119.	8.96	.856	2255.	31002.
9059	8.67	7.0	379.	95.	8.81	.826	1311.	17701.	8.13	.833	1387.	20447.
9060	9.52	7.2	451.	117.	9.26	.826	1659.	21312.	8.55	.823	1756.	24312.
9061	8.79	6.2	338.	145.	8.47	.843	1560.	22347.	7.90	.863	1394.	21903.
9062	9.97	6.5	395.	119.	9.74	.829	1665.	20411.	8.28	.836	1419.	20620.
9063	9.32	7.2	380.	227.	9.93	.809	2106.	24696.	9.85	.803	2360.	27682.
9064	9.22	7.0	421.	95.	9.20	.829	1236.	16035.	8.86	.853	1237.	17134.
9065	8.90	6.5	433.	111.	8.96	.829	1655.	22048.	8.74	.843	1892.	26271.
9066	9.25	7.5	384.	131.	8.78	.806	1586.	20968.	8.03	.829	1624.	24136.
9067	9.94	7.2	451.	139.	9.76	.819	1821.	22002.	9.06	.806	2152.	27554.
9068	9.37	6.9	486.	82.	9.71	.849	1312.	16530.	9.06	.839	1585.	21141.
9069	9.31	7.4	409.	104.	9.00	.819	1495.	19581.	8.13	.829	1860.	27310.
9070	9.21	7.0	390.	107.	9.03	.826	1812.	23850.	8.16	.846	1322.	19741.
9071	8.23	6.3	411.	86.	8.31	.836	1039.	15049.	8.17	.833	1207.	17701.
9072	8.08	7.2	317.	77.	8.13	.839	950.	14114.	7.88	.836	1104.	16869.
9073	8.43	6.8	417.	60.	9.07	.833	1795.	23708.	8.95	.833	2169.	29058.
9074	9.72	7.3	404.	116.	10.71	.779	2266.	23742.	10.19	.803	2131.	24166.
9075	8.38	7.3	339.	165.	9.03	.819	1563.	20411.	8.82	.833	1627.	22107.
9077	8.32	6.4	367.	153.	8.51	.799	1987.	26866.	8.00	.829	1927.	28749.
9078	8.80	6.5	429.	118.	8.71	.829	1585.	21732.	8.28	.839	1597.	23293.
9079	9.01	6.9	462.	60.	8.00	.856	1143.	17608.	7.34	.859	1174.	19784.
9080	8.87	7.0	425.	89.	9.34	.836	1410.	18164.	9.20	.829	1609.	20880.
9081	8.41	7.2	352.	124.	8.37	.819	1414.	19930.	8.07	.826	1514.	22299.
9082	8.22	7.0	401.	59.	8.23	.839	1085.	15937.	8.10	.856	1164.	17713.
9083	8.39	7.8	364.	109.	8.14	.833	1452.	21365.	7.57	.849	1416.	22882.
9084	8.54	7.0	368.	90.	8.69	.846	1348.	18890.	8.30	.873	1353.	20481.
9085	8.57	7.5	358.	164.	8.42	.806	1519.	20923.	7.86	.829	1657.	25167.
9086	9.52	7.5	378.	155.	10.36	.799	1880.	20883.	10.48	.786	2191.	23649.
9087	8.87	7.1	377.	145.	9.00	.833	1687.	22456.	8.41	.849	1981.	28788.
9088	9.49	7.3	486.	126.	9.28	.833	1778.	22951.	8.74	.836	1549.	21333.
9089	8.47	7.2	344.	105.	8.71	.819	1887.	25564.	8.45	.829	2038.	28780.
9090	9.13	8.4	420.	115.	9.68	.813	1551.	18747.	9.52	.869	1673.	21981.
9091	9.31	7.2	453.	170.	9.50	.856	1508.	19563.	9.33	.833	1694.	21768.
9092	8.88	7.2	397.	108.	8.71	.833	1802.	24804.	8.33	.829	2026.	29046.
9093	8.88	7.4	423.	154.	8.92	.819	1426.	18863.	8.47	.816	1763.	24453.
9094	9.32	7.8	453.	106.	9.40	.829	1831.	23257.	8.93	.836	2010.	27076.
9095	9.13	8.1	329.	199.	9.23	.826	1512.	19476.	8.90	.849	1381.	18958.
9096	9.42	7.0	443.	130.	9.69	.843	1783.	22310.	9.14	.843	2011.	26670.
9097	8.59	7.8	389.	168.	8.86	.839	1807.	24630.	8.45	.819	1800.	25106.
9098	9.58	7.3	413.	78.	9.51	.823	1571.	19565.	9.06	.829	1800.	23713.
9100	8.09	7.8	328.	138.	8.06	.816	1170.	17057.	8.02	.813	1404.	20483.
9101	8.51	7.2	360.	88.	9.21	.826	1521.	19631.	9.69	.819	1973.	24001.
9102	8.78	6.8	336.	101.	8.62	.836	1580.	22046.	9.02	.776	1720.	21304.
9103	8.26	6.9	379.	66.	8.11	.856	950.	14422.	7.57	.836	1056.	16800.
9104	8.65	7.1	432.	113.	8.37	.819	1307.	18418.	7.44	.839	1430.	23233.
9105	9.23	6.1	369.	96.	8.68	.863	1107.	15839.	7.97	.879	1072.	17021.
9106	8.55	6.5	438.	108.	7.82	.826	1483.	22544.	7.20	.869	1381.	24006.
9107	8.47	6.5	371.	127.	8.85	.756	1371.	16868.	8.52	.836	1529.	21592.
9108	9.59	6.9	422.	105.	9.65	.783	1567.	18296.	8.96	.833	1838.	24584.
9109	9.39	7.0	390.	128.	9.38	.819	1712.	21515.	8.72	.816	2027.	27303.
9110	8.41	6.5	318.	101.	8.54	.823	1697.	23544.	7.99	.849	1327.	20303.
9111	9.76	7.2	459.	133.	8.86	.829	1600.	21547.	7.88	.856	1631.	25523.
9112	9.44	6.3	420.	223.	9.62	.813	2100.	25522.	9.09	.829	2226.	29241.
9113	9.42	7.0	420.	107.	9.57	.823	1736.	21494.	9.31	.826	2046.	26124.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9114	9.67	7.4	498.	153.	9.54	.823	1625.	20170.	9.06	.823	2025.	26475.
9115	8.89	6.9	380.	73.	8.52	.816	1160.	15992.	8.40	.819	1334.	18733.
9116	9.91	6.5	468.	110.	9.62	.826	1608.	19873.	8.75	.839	1866.	25769.
9117	9.78	7.2	414.	178.	9.86	.806	1928.	22686.	9.36	.839	2342.	30248.
9118	8.57	6.8	374.	162.	8.93	.833	1754.	23534.	8.68	.823	1989.	27138.
9119	8.99	6.6	383.	94.	9.12	.829	1525.	19970.	8.52	.843	1536.	21862.
9120	8.51	7.1	360.	150.	8.76	.816	1454.	19492.	8.47	.823	1909.	26694.
9121	8.76	7.3	411.	162.	8.86	.809	1827.	24013.	8.28	.826	1983.	28465.
9122	9.13	6.9	449.	137.	8.92	.823	1457.	19347.	8.59	.829	1896.	26334.
9123	8.59	7.4	397.	150.	8.61	.829	1739.	24119.	8.33	.836	1886.	27250.
9124	9.35	6.8	476.	101.	9.17	.833	1212.	15834.	8.41	.839	1745.	25061.
9125	9.30	7.1	383.	138.	9.24	.836	1448.	18856.	8.88	.806	2023.	26438.
9126	9.49	7.0	463.	156.	9.40	.839	1878.	24145.	8.69	.843	2082.	29046.
9127	10.11	6.9	479.	151.	10.07	.789	2146.	24208.	9.19	.806	2285.	28864.
9128	9.46	7.0	393.	137.	10.45	.833	1576.	18073.	9.65	.863	2168.	27891.
9129	8.90	7.2	369.	97.	9.26	.829	1065.	13732.	8.69	.836	1412.	19551.
9130	8.17	7.0	449.	96.	9.48	.829	1513.	19046.	8.64	.833	1516.	21044.
9131	8.76	7.5	385.	164.	8.09	.816	1447.	21016.	7.49	.819	1512.	23788.
9132	8.40	7.1	389.	103.	9.37	.843	1470.	19030.	9.51	.829	1840.	23103.
9133	8.90	7.2	369.	116.	8.28	.829	1556.	22425.	7.66	.893	1567.	26265.
9134	9.06	7.0	401.	118.	8.82	.829	1469.	19890.	8.24	.843	1527.	22470.
9135	9.08	7.1	364.	179.	8.93	.853	1167.	16033.	8.13	.866	1096.	16803.
9136	8.51	7.0	462.	84.	9.02	.809	2261.	29214.	8.27	.856	1671.	24897.
9137	9.20	7.0	366.	123.	8.55	.846	1731.	24648.	7.85	.849	1477.	23013.
9138	9.66	7.6	428.	102.	9.34	.826	1526.	19426.	9.10	.829	1631.	21391.
9139	9.21	7.2	467.	157.	9.98	.816	2084.	24534.	9.96	.823	2730.	32451.
9140	9.58	7.1	462.	120.	8.78	.826	1780.	24114.	8.07	.839	1314.	19663.
9141	9.46	7.0	414.	179.	11.00	.779	2507.	25560.	9.96	.806	2389.	27716.
9142	8.36	7.5	455.	107.	8.65	.816	1190.	16156.	8.11	.809	1604.	23034.
9143	9.51	7.2	420.	144.	9.10	.833	1852.	24393.	8.82	.826	2346.	31628.
9144	7.94	8.0	384.	192.	10.48	.796	1842.	20137.	10.92	.783	2691.	27760.
9145	7.94	7.8	366.	107.	7.76	.839	1071.	16670.	7.33	.846	1474.	24494.
9146	9.34	8.1	390.	120.	9.05	.806	1435.	18408.	8.64	.809	1696.	22875.
9147	9.21	7.2	498.	148.	8.79	.836	1682.	23028.	7.96	.843	1816.	27673.
9148	9.04	7.2	394.	76.	9.81	.839	1483.	18270.	9.67	.873	1648.	21423.
9149	8.65	7.6	366.	101.	8.35	.836	1235.	17795.	7.83	.856	1307.	20558.
9150	10.05	7.5	499.	145.	10.60	.796	2151.	23261.	10.22	.826	2404.	27985.
9151	9.37	7.1	486.	108.	9.31	.833	1680.	21616.	8.74	.863	1781.	25317.
9152	9.62	7.0	436.	87.	8.93	.839	1428.	19317.	7.79	.873	1456.	23475.
9153	8.96	7.1	390.	83.	9.30	.806	1160.	14473.	9.43	.809	1422.	17574.
9154	8.24	7.2	360.	117.	8.04	.809	1148.	16622.	7.95	.829	1342.	20158.
9155	8.37	7.0	315.	89.	8.54	.819	1290.	17818.	8.02	.836	1333.	20017.
9156	8.01	6.9	396.	100.	8.69	.826	1451.	19849.	8.34	.849	1138.	16688.
9157	9.93	6.2	436.	111.	9.10	.833	2356.	31028.	10.03	.829	2602.	30961.
9158	8.24	6.5	369.	169.	8.41	.816	2524.	35250.	8.10	.833	2025.	29960.
9159	9.07	7.1	492.	154.	10.51	.806	2047.	22600.	8.37	.876	1961.	29552.
9160	8.69	7.0	415.	126.	8.97	.806	1745.	22558.	8.76	.823	2079.	28090.
9161	8.74	6.5	435.	134.	8.93	.826	1666.	22182.	8.44	.843	1579.	22694.
9162	9.59	6.8	441.	97.	9.45	.823	2113.	26465.	8.74	.853	1678.	23572.
9163	8.75	7.1	381.	107.	9.28	.819	1451.	18429.	8.61	.826	2216.	30600.
9164	8.16	7.2	318.	85.	8.10	.836	1113.	16542.	8.16	.826	1596.	23267.
9165	7.98	7.6	318.	89.	8.61	.833	1240.	17271.	8.97	.833	1442.	19258.
9166	9.13	7.2	402.	96.	9.17	.829	1351.	17589.	8.41	.833	1255.	17881.
9167	8.37	7.0	380.	85.	8.34	.826	1502.	21411.	7.68	.856	1377.	22097.
9168	8.60	6.2	371.	171.	8.51	.846	1710.	24467.	8.07	.853	1645.	25007.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9169	8.23	6.8	380.	96.	8.23	.809	1703.	24116.	7.88	.823	1508.	22675.
9170	9.50	7.1	389.	125.	9.64	.783	1462.	17099.	9.21	.793	1605.	19881.
9171	8.06	7.3	318.	93.	7.97	.809	1177.	17202.	7.61	.813	1327.	20411.
9172	8.37	7.3	323.	129.	8.20	.819	1517.	21814.	7.71	.823	1593.	24479.
9173	8.41	6.3	327.	107.	8.47	.833	1639.	23196.	7.95	.843	1795.	27396.
9174	8.20	6.1	449.	136.	8.41	.846	1686.	24412.	7.72	.853	1591.	25291.
9175	8.34	7.1	375.	109.	8.74	.853	1715.	24099.	7.45	.893	1403.	24193.
9176	8.52	7.0	387.	120.	8.48	.823	1537.	21462.	7.86	.826	1739.	26301.
9177	8.11	6.9	332.	77.	7.85	.839	1276.	19642.	7.49	.849	1305.	21294.
9178	8.65	7.2	425.	120.	8.99	.809	1528.	19803.	8.61	.829	1906.	26425.
9179	8.12	6.2	354.	89.	7.76	.846	1178.	18485.	7.20	.869	1197.	20811.
9180	8.44	6.8	402.	132.	8.54	.846	1431.	20411.	7.93	.843	1679.	25668.
9181	7.17	6.9	348.	87.	8.44	.829	1161.	16424.	7.80	.833	1428.	21922.
9182	7.00	7.0	335.	111.	8.13	.829	1327.	19492.	7.41	.869	1360.	22972.
9183	7.13	7.7	393.	66.	8.58	.863	1408.	20378.	7.88	.853	1272.	19827.
9184	7.57	6.9	419.	126.	8.31	.823	1632.	21946.	8.37	.826	1887.	26803.
9185	7.19	6.2	406.	84.	8.38	.843	1470.	21269.	7.83	.866	1301.	20705.
9186	7.90	6.6	423.	137.	8.90	.836	1735.	23447.	7.66	.839	1497.	23601.
9187	7.11	6.8	374.	86.	8.59	.829	1590.	22084.	8.40	.826	1870.	26473.
9188	7.35	7.2	393.	68.	8.83	.826	1408.	18946.	8.40	.836	1496.	21439.
9189	7.36	6.2	379.	83.	8.74	.839	1509.	20872.	8.42	.856	1657.	24234.
9190	7.35	7.0	412.	107.	8.68	.843	1698.	23725.	7.97	.849	1555.	23837.
9191	7.98	7.1	305.	79.	8.00	.839	1121.	16925.	7.42	.849	1089.	17932.
9192	8.60	7.2	413.	79.	8.41	.833	1617.	23044.	7.92	.839	1635.	24951.
9193	8.58	8.0	432.	98.	8.00	.843	1304.	19764.	7.17	.839	1409.	23740.
9194	8.09	6.5	355.	82.	8.02	.833	1212.	18115.	7.55	.853	1361.	22125.
9195	9.13	7.8	365.	145.	9.93	.813	1782.	20990.	9.23	.809	1980.	24992.
9196	9.03	7.8	465.	96.	8.89	.826	1463.	19570.	8.24	.836	1529.	22330.
9197	9.22	7.0	408.	119.	9.20	.826	1691.	21849.	9.10	.813	2095.	26920.
9198	9.28	7.1	402.	85.	9.07	.839	1535.	20443.	8.57	.873	1371.	20109.
9199	8.15	7.4	354.	89.	8.51	.813	1367.	18789.	8.09	.819	1485.	21656.
9200	8.59	7.1	398.	162.	8.45	.823	2028.	28406.	7.95	.829	1918.	28808.
9201	8.34	6.1	390.	90.	8.20	.846	1388.	20622.	7.73	.843	1162.	18218.
9202	8.16	6.1	355.	120.	8.57	.823	1328.	18363.	8.26	.833	1425.	20690.
9203	8.10	6.1	412.	91.	7.48	.853	1235.	20258.	6.90	.886	1100.	20328.
9204	9.35	6.2	528.	117.	9.64	.843	1880.	23664.	9.00	.873	1758.	24532.
9205	8.53	7.1	366.	72.	8.62	.823	1394.	19144.	8.79	.806	1901.	25089.
9206	8.88	6.8	432.	102.	9.58	.826	1916.	23773.	9.24	.846	1970.	25950.
9207	8.75	6.1	409.	97.	8.85	.823	1646.	22036.	8.03	.846	1731.	26248.
9208	8.50	6.0	423.	81.	8.93	.833	1828.	24532.	8.74	.863	1899.	26996.
9209	7.97	6.8	333.	120.	8.72	.816	1643.	22126.	7.92	.846	1681.	25859.
9210	8.74	6.2	364.	73.	8.51	.853	1792.	25852.	7.78	.863	1568.	25034.
9211	7.02	6.2	353.	83.	7.73	.859	1065.	17028.	7.34	.863	1010.	17081.
9212	7.62	6.1	432.	153.	8.97	.863	1577.	21821.	8.37	.853	1725.	25291.
9213	7.19	6.1	404.	90.	8.55	.839	1533.	21656.	8.13	.836	1570.	23241.
9214	7.39	6.3	387.	101.	9.09	.806	1809.	23101.	8.99	.836	1905.	25498.
9215	6.73	6.2	284.	73.	7.54	.859	1067.	17512.	6.82	.879	1354.	25135.
9216	6.95	6.4	339.	95.	8.44	.823	1110.	15572.	8.85	.823	1362.	18234.
9217	8.59	6.1	364.	132.	8.66	.833	1560.	21573.	8.23	.826	1928.	27856
9218	9.08	6.2	402.	113.	8.99	.803	1673.	21499.	8.45	.819	1575.	21976.
9219	8.04	6.5	353.	108.	8.10	.826	1137.	16684.	7.64	.856	1328.	21428.
9220	8.39	6.0	314.	101.	8.34	.839	1135.	16446.	9.03	.816	1812.	23564.
9221	7.32	6.1	378.	116.	8.59	.803	1356.	18236.	8.45	.806	1666.	22861.
9222	7.02	6.2	425.	76.	8.24	.836	1381.	20167.	7.88	.863	1179.	18586.
9223	6.99	6.2	395.	86.	7.97	.829	1491.	22323.	7.33	.839	1521.	25082.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9224	6.95	6.2	382.	67.	8.66	.846	1483.	20843.	8.26	.843	1539.	22606.
9225	7.04	6.1	353.	121.	8.27	.869	1402.	21211.	8.04	.846	1885.	28526.
9226	7.15	6.1	414.	75.	8.40	.843	1536.	22192.	7.65	.873	1550.	24809.
9227	8.12	6.0	437.	137.	10.14	.846	2314.	27782.	9.71	.843	2698.	33713.
9228	6.96	6.0	364.	103.	8.28	.823	1280.	18294.	7.88	.843	1387.	21361.
9229	7.55	6.0	405.	100.	8.54	.849	1425.	20411.	8.06	.826	1889.	27869.
9230	6.98	6.2	357.	113.	8.10	.839	1309.	19524.	7.44	.859	1344.	22344.
9231	8.50	6.2	396.	101.	8.50	.839	1564.	22239.	7.66	.853	1387.	22212.
9232	8.46	6.0	374.	89.	8.10	.839	1252.	18672.	7.44	.839	1314.	21339.
9233	8.12	6.0	333.	89.	8.27	.846	1410.	20759.	7.78	.859	1241.	19746.
9234	8.15	6.1	360.	83.	7.88	.839	1333.	20448.	7.09	.843	1200.	20533.
9235	7.95	6.2	383.	76.	7.55	.846	1230.	19840.	7.41	.853	1235.	20450.
9236	8.09	6.3	331.	115.	8.06	.836	1214.	18127.	7.30	.846	1412.	23564.
9237	8.52	6.1	431.	77.	7.83	.833	1065.	16300.	7.31	.853	1160.	19467.
9238	8.13	6.0	336.	142.	8.51	.819	1351.	18722.	8.09	.816	1657.	24074.
9239	8.16	6.1	403.	87.	7.86	.843	1195.	18436.	7.52	.843	1626.	26221.
9240	8.48	6.2	384.	95.	8.58	.819	1368.	18802.	7.89	.866	1389.	21942.
9241	8.12	6.1	364.	120.	7.85	.846	1188.	18432.	7.16	.843	1266.	21456.
9242	9.14	6.2	546.	133.	9.52	.866	1742.	22797.	8.99	.866	1703.	23611.
9243	8.09	6.0	357.	70.	8.11	.846	1084.	16265.	7.30	.833	1406.	23091.
9244	8.47	6.1	382.	115.	8.27	.836	1355.	19716.	7.69	.849	1402.	22281.
9245	8.52	6.2	359.	91.	8.90	.816	1420.	18732.	8.92	.819	939.	12414.
9246	8.27	6.3	313.	108.	8.64	.839	1297.	18147.	7.97	.846	1296.	19798.
9247	9.06	6.1	359.	86.	9.74	.833	993.	12229.	8.38	.833	1044.	14922.
9248	9.02	6.1	333.	136.	9.95	.799	1795.	20758.	10.26	.826	2235.	25907.
9249	8.54	6.1	393.	109.	8.34	.839	1400.	20273.	7.96	[illegible]	1695.	25325.
9250	8.12	6.9	342.	91.	7.95	.839	1383.	21027.	7.35	.846	1448.	23970.
9251	9.29	6.0	389.	107.	11.12	.833	2347.	25301.	10.95	.833	2640.	28897.
9252	7.99	6.0	312.	85.	7.82	.826	1291.	19639.	7.37	.846	1176.	19436.
9253	8.32	6.0	374.	118.	8.37	.829	1233.	17594.	7.18	.829	1344.	22332.
9254	8.25	6.0	374.	112.	8.44	.839	1523.	21808.	7.92	.816	1684.	24988.
9255	8.45	6.0	372.	151.	8.66	.833	1888.	26120.	8.51	.846	1530.	21898.
9256	8.43	6.0	378.	97.	8.35	.823	1401.	19861.	8.33	.829	1520.	21793.
9257	8.80	6.0	436.	140.	8.89	.803	2009.	26105.	8.40	.819	1804.	25343.
9258	8.19	6.0	357.	103.	7.37	.833	1135.	18460.	6.55	.843	1145.	21201.
9259	9.00	6.0	378.	150.	9.38	.829	1706.	21699.	9.21	.826	1904.	24562.
9260	8.46	6.0	339.	72.	8.41	.833	1226.	17471.	7.61	.856	[illegible]	18181.
9261	8.62	6.0	392.	102.	9.36	.836	1788.	22994.	8.85	.859	809.	11310.
9262	8.41	6.0	347.	184.	9.09	.789	2250.	28133.	9.27	.833	2587.	33440.
9263	9.65	6.7	439.	113.	9.28	.819	1495.	18987.	8.65	.823	1663.	22772.
9264	8.02	6.0	432.	71.	8.16	.833	1358.	19953.	7.93	.873	1339.	21209.
9265	8.86	6.5	383.	162.	8.89	.836	1603.	21705.	8.37	.853	1511.	22164.
9266	8.09	6.8	340.	103.	7.11	.833	1468.	24736.	6.85	.856	1356.	24401.
9267	8.39	6.0	377.	141.	8.55	.836	1663.	23404.	8.06	.843	1716.	25835.
9268	7.85	6.0	366.	62.	7.62	.856	1270.	20524.	7.23	.856	1321.	22520.
9269	8.65	6.1	372.	129.	8.95	.826	1620.	21536.	8.95	.846	1573.	21408.
9270	8.79	6.0	432.	111.	8.45	.833	1483.	21024.	7.79	.876	1403.	22700.
9271	8.87	6.1	456.	120.	8.44	.829	1445.	20445.	7.49	.843	1536.	24862.
9272	8.80	6.1	364.	107.	8.38	.836	1364.	19588.	7.71	.869	1108.	17986.
9273	8.29	6.0	366.	89.	8.76	.833	1648.	22544.	8.75	.843	2110.	29253.
9274	8.31	6.0	342.	85.	8.35	.849	1162.	17004.	7.48	.853	1071.	17567.
9275	8.44	6.2	425.	120.	8.38	.836	1553.	22298.	7.95	.846	1577.	24175.
9276	7.89	6.2	351.	140.	7.85	.826	1543.	23380.	7.37	.843	1572.	25875.
9277	7.76	6.0	279.	104.	7.73	.836	1517.	23609.	7.30	.866	1857.	31721.
9278	8.55	6.1	386.	205.	8.52	.823	2072.	28778.	7.66	.833	1934.	30242.

No.	Den.	M. C.	B. L.	H	Crush properties in moist condition				Crush properties in sterilized condition			
					ρ	β	$\bar{\sigma}$	KE	ρ	β	$\bar{\sigma}$	KE
9279	8.09	6.4	288.	94.	9.16	.846	1240.	16486.	9.88	.829	1559.	18639.
9280	7.90	6.2	325.	84.	8.20	.853	1244.	18623.	7.75	.873	1092.	17702.
9281	8.53	6.0	372.	113.	8.81	.836	1529.	20901.	9.59	.829	493.	6144.
9282	8.04	6.5	339.	153.	8.13	.839	1423.	21154.	7.61	.839	1535.	24380.
9283	8.34	6.7	342.	160.	8.74	.839	1207.	16691.	8.10	.846	1653.	24849.
9284	9.14	6.5	455.	247.	9.09	.836	2858.	37848.	9.27	.839	2509.	32696.
9285	8.06	[illegible].5	307.	107.	7.96	.843	1126.	17160.	7.28	.846	1311.	21912.
9286	8.38	7.2	364.	216.	8.76	.823	1595.	21560.	8.47	.833	2008.	28427.
9287	8.38	6.3	360.	87.	7.73	.846	1190.	18738.	7.48	.839	1276.	20604.
9288	8.82	6.3	371.	139.	8.82	.823	1773.	23802.	7.73	.853	1591.	25245.
9289	8.59	6.5	425.	103.	8.48	.826	1533.	21496.	7.78	.883	1387.	22667.
9290	8.53	6.1	330.	107.	8.52	.839	1238.	17544.	7.90	.839	1354.	20702.
9291	8.02	6.5	354.	83.	7.97	.856	1148.	17743.	7.27	.853	1312.	22152.
9292	8.40	7.0	329.	138.	8.59	.813	1440.	19608.	8.31	.839	1328.	19304.
9293	8.15	6.7	350.	74.	8.24	.846	1315.	19434.	7.71	.836	1386.	21643.
9294	8.80	6.1	390.	150.	8.89	.829	1756.	23581.	8.27	.846	1530.	22532.
9295	8.58	6.4	350.	103.	8.79	.833	1231.	16730.	8.31	.846	1325.	19408.
9296	8.06	6.7	358.	89.	8.21	.836	1185.	17365.	7.97	.856	1363.	21060.
9297	8.86	7.5	378.	79.	8.54	.843	1038.	14753.	7.83	.863	1281.	20301.
9298	9.20	7.0	445.	138.	9.21	.829	1754.	22721.	8.71	.833	1968.	27083.
9299	8.66	6.8	384.	109.	9.24	.839	1659.	21687.	8.48	.813	1713.	23632.
9300	8.74	6.7	461.	126.	8.82	.836	1618.	22074.	9.92	.813	2254.	26587.

No.	Crush properties in dry condition			
	ρ	β	$\bar{\sigma}$	KE
7003	7.23	.876	1186.	20690.
7013	6.73	.883	1204.	22717.
7025	6.59	.906	1014.	20062.
7040	7.07	.916	1267.	23624.
7044	7.41	.889	1047.	18083.
7048	6.35	.909	1028.	21181.
7060	7.09	.853	1741.	30151.
7080	6.78	.903	1509.	28941.
7091	6.73	.909	1118.	21735.
7095	6.20	.883	1186.	24308.
7107	5.34	.889	880.	21111.
7115	7.61	.893	1576.	26610.
7126	5.80	.879	929.	20263.
7148	6.41	.923	901.	18662.
7195	7.23	.896	1153.	20570.
7206	6.71	.889	1247.	23799.
7212	7.16	.903	1100.	19969.
7224	6.25	.916	946.	19952.
7246	6.72	.893	942.	18015.
7251	6.44	.919	1002.	20590.
7268	7.95	.909	1070.	17625.
7277	5.87	.853	855.	17866.
7280	5.89	.899	942.	20704.
7294	7.69	.896	1280.	21458.
9007	8.95	.863	1686.	23401.
9018	9.17	.893	1392.	19502.
9030	9.52	.853	2069.	26662.
9041	7.73	.886	1319.	21750.
9058	9.05	.906	1901.	27363.
9073	8.81	.853	1919.	26747.
9087	8.50	.873	1857.	27452.
9105	8.07	.909	991.	16065.
9116	9.00	.923	1533.	22615.
9128	9.93	.863	1844.	23046.
9135	8.37	.883	1098.	16666.
9145	7.27	.859	1248.	21242.
9152	8.26	.896	1425.	22257.
9163	8.81	.813	2009.	26682.
9175	8.03	.903	1602.	25926.
9182	7.64	.873	1520.	25006.
9190	8.20	.889	1689.	26374.
9204	9.09	.889	1815.	25570.
9212	8.52	.886	1619.	24224.
9215	7.10	.879	1072.	19115.
9225	8.06	.863	1591.	24515.
9236	7.54	.839	1380.	22128.
9277	7.41	.853	1910.	31626.
9284	8.72	.846	2400.	33503.
9299	8.62	.879	1718.	25214.

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