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**LIGHTWEIGHT ALUMINA REFRACTORY AGGREGATE
PHASE II—PILOT SCALE DEVELOPMENT**

Topical Report

**By
T. G. Swansiger
A. Pearson**

November 1994

Work Performed Under Contract No. FC07-89ID12903

**For
U.S. Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania**

**By
Aluminum Company of America
Alcoa Center, PA**

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1994 November 21

REPORT NO. 06-94-27

**LIGHTWEIGHT ALUMINA
REFRACTORY AGGREGATE**

**PHASE II - PILOT-SCALE
DEVELOPMENT**

**TASK 5 - REPORT ON EXPERIMENTAL
RESULTS**

CONTRACT NO. DE-FC07-89ID12903

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**SPONSORED BY THE OFFICE OF THE
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WASHINGTON, DC**

MASTER

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Sponsored by the Office of the Assistant Secretary
for Energy Efficiency and Renewable Energy
Office of Industrial Technologies
Washington, D.C.

Prepared by
Aluminum Company of America
Alcoa Center, PA

ABSTRACT

This report summarizes experimental work performed at Alcoa Technical Center on Phase II of Department of Energy Contract No. DE-FC07-89ID12903 for development of a high alumina, lightweight refractory aggregate. Kilogram quantities of refractory aggregate were prepared from both a paste and a pelletized form of extruder feed material in both bench and pilot-scale equipment. The 99+ % alumina aggregate exhibited a bulk density approaching 2.5 g/cm^3 and a fired strength slightly lower than fused alumina. Based on initial evaluation by two refractory manufacturers in brick or castable applications, the new aggregate offered adequate strength with thermal conductivity reductions up to 34%, depending on the temperature and application of the new aggregate in these initial trials. The new aggregate was simply substituted for Tabular™ in the refractory formulation. Thus, there is room for improvement through optimization of the formulation with the lightweight aggregate. The new aggregate offers a unique combination of density, strength, and thermal properties not available in current aggregate. To this point in time, technical development has led to a pelletized formulation with borderline physical form leaving the Eirich mixer. The formulation requires further development to provide more latitude for the production of pelletized material without forming paste, while still reducing the bulk density slightly to reach the 2.5 g/cm^3 target. The preferred, pelletized process flowsheet was outlined and a preliminary economic feasibility study performed based on a process retrofit into Alcoa's Arkansas tabular production facilities. Based on an assumed market demand of 20,000 mt/year and an assumed selling price of \$0.65/lb (25% more than the current selling price of Tabular™, on a volume basis), the economics were favorable. The decision on whether to proceed into Phase III (full-scale demonstration) of the contract will be based on a formal market survey that had commenced in 1994 October.

SUMMARY

Phase II of the Alcoa/DOE contract was successfully executed consisting of bench and pilot-scale experiments that involved 52 individual runs consuming in excess of 1000 kg of aluminous raw materials. This work represented further development of certain formulations derived from Phase I of the contract with a focus on scale-up to pilot equipment to produce required quantities of aggregate for initial evaluation by refractory manufacturers. Both paste and pelletized formulations were developed to allow for support from toll processors if the development proceeded into Phase III (the full-scale demonstration). Phase II of the contract required increased involvement of the Arkansas Technology Group, as well as input and testing by two refractory manufacturers. A total of three distinctly different lightweight aggregate formulations were tested in end-use products. Two of these formulations were paste compositions that were evaluated in bricks by Harbison-Walker. The third formulation was a pelletized composition that was evaluated by Thermal Ceramics in castable applications. Reports on this initial evaluation by both refractory manufacturers were favorable and both manufacturers expressed further interest in the new aggregate. The pelletized formulation is favored because of reduced capital equipment requirement, compared to a paste formulation. The current pelletized formulation consists of a blend of 60% A-13/30% A-13M/10% CP-2 and two binders at a combined loading of 7 wt%. The pelletized process was subjected to an economic feasibility study based on a production of 20,000 mt/year and a retrofit into the Arkansas plant tabular production facility. With the assumptions made including: a) a 20,000 mt/yr production level, b) realistic process recycle and losses, and c) a \$0.65/lb selling price, the economics were favorable. However, the formal market survey just recently commenced and will be the overriding factor in deciding whether to continue with this development into Phase III of the contract. This final phase of the contract would be a full-scale demonstration of the process with a focus to produce at least 54.4 mt (120,000 lb) of the aggregate for incorporation into products, followed by end-user testing.

ACKNOWLEDGMENTS

The efforts of the following Alcoa personnel are recognized during the execution of this contract phase:

Messrs. D. W. Severa and J. L. Pszczolkowski for the pilot-scale sample preparation, firing, and data generation involving density, shrinkage, and strength measurements.

Mr. Alan Pearson is recognized as the Principal Investigator for this contract with responsibility for overall project direction and management, including planning of experiments, and guidance and consulting whenever needed.

CONTENTS

ABSTRACT.....	ii
SUMMARY.....	iii
ACKNOWLEDGMENTS.....	iii
CONTENTS.....	iv
LISTING OF TABLES AND FIGURES.....	vi
NOMENCLATURE.....	vii
OBJECTIVE.....	1
INTRODUCTION.....	1
CONTRACT PHASES	2
EXPERIMENTAL PLAN.....	4
EXPERIMENTAL.....	4
RAW MATERIALS.....	5
ALUMINAS.....	5
BINDERS/BURNOUTS	5
Methocel 20-214	5
Mogul 1607.....	5
Nalco 1181	6
Water	6
MIXING PROCEDURE.....	6
EQUIPMENT.....	6
DRY BLENDERS.....	6
MIXERS.....	6
EXTRUDERS.....	7
3" Macquiceram.....	7
1" Ingersoll Rand	7
GAS FIRED CONVERTERS.....	7
PRODUCT CHARACTERIZATION	7
DENSITY.....	7
SHRINKAGE.....	8
CRUSHING STRENGTH.....	8
MICROSTRUCTURE.....	8
DENSITY/RAW MATERIAL COST MODEL.....	8
EXPERIMENTAL RESULTS AND DISCUSSION	8
MIXER/FORMULATIONS.....	9
HOBART MIXER TRIALS.....	9
SIMPSON MIXER TRIALS (ALL PASTE FORMULATIONS).....	12
SIGMA BLADE MIXER TRIALS (Paste Formulation).....	22
SUMMARY OF PASTE FORMULATION EXPERIMENTS.....	23
EIRICH MIXER TRIALS (Pelletized Formulation).....	24
Runs in RV02 Eirich	24
Runs in R-7 Eirich.....	25
TOLL PROCESSING BY H-W	29
INTERMEDIATE STRENGTH OF EXTRUDED FORMS DURING SINTERING	31

CONTENTS (continued):

REFRACTORY MANUFACTURER EVALUATION OF LWA	31
HARBISON-WALKER	33
THERMAL CERAMICS	33
FEASIBILITY STUDY OVERVIEW	34
CONCLUSIONS	34
RECOMMENDATIONS.....	37
SAFETY	37
REFERENCES	38
Appendix A - Master spreadsheet.....	39
Appendix B - Refractory Property Data.....	40
Appendix B-1 Raw Data and Green Density Calculations	41
Appendix B-2 Raw Data and Fired Density Calculations	42
Appendix B-3 Raw Data and Shrinkage Calculations	43
Appendix B-4 Raw Data and Green Strength Calculations	44
Appendix B-5 Raw Data and Fired Strength Calculations	45
Appendix B-5a Weibull Modulus Calculation for Aggregate Strength.....	46
Appendix C-1 - Statistical Data for Run 3	47
Appendix C-2 - Statistical Data for Run 6	48
Appendix C-3 - Statistical Data for Run 8	49
Appendix C-4 - Statistical Data for Expt. Design (Runs 6,8-14)	50
Appendix C-5 - Harbison-Walker Report on Evaluation (Runs 6 and 8)	51
Appendix C-6 - Thermal Ceramics Report on Evaluation (Runs 47-52).....	52

LISTING OF TABLES AND FIGURES

		<u>Page</u>
TABLE 1	EXPT DESIGN 24147 STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING HOBART MIXER AND 1" LAB EXTRUDER	10
TABLE 2	EXPT DESIGN 24147 SUMMARY OF ROUTINE AND SPECIAL ANALYSES FOR ANALYSIS OF VARIANCE	11
TABLE 3	RUNS 1-10 STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING SIMPSON MIX MULLER AND 3" EXTRUDER	13
TABLE 4	EXPERIMENTAL DESIGN OUTLINE AND RESULTS WITH EXTRUDER VARIABLES (RUN 2: EXPT. 17248-2 ³ DESIGN)	16
TABLE 5	DENSITY AND FIRED STRENGTH RESULTS FOR RUN 6	18
TABLE 6	DENSITY AND FIRED STRENGTH RESULTS FOR RUN 8	19
TABLE 7	EXPERIMENTAL DESIGN INVOLVING MIXER, FORMULATIONS, AND METHOCEL DISPERSION	20
TABLE 8	SPECIAL RUNS INVOLVING MIXER/EXTRUDER EQUIPMENT AND FORMULATION/BINDER OPTIONS	21
TABLE 8a	RESULTS ON FIRED DENSITY AND FIRED STRENGTH SUBJECTED TO STATISTICAL EVALUATION FOR THE EXPERIMENT DESIGN	23
TABLE 9	STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING EIRICH RV02 MIXER	26
TABLE 10	STANDARD DATA SUMMARY FOR FORMULATIONS/VARIABLES USING R7 EIRICH MIXER AND 3" EXTRUDER	28
TABLE 11	CHARACTERIZATION OF RUNS #6, #8 (PASTE FORMULATIONS) UTILIZED BY HARBISON-WALKER IN BRICK FORMULATION	30
TABLE 12	CHARACTERIZATION OF RUNS #47-52 (EIRICH R7 PELLETIZED FORMULATION) UTILIZED BY THERMAL CERAMICS IN CASTABLES	32
TABLE 13	SUMMARY OF ECONOMIC SIMULATIONS FOR THE LWA PROCESS AS A FUNCTION OF PRODUCTION LEVEL, SELLING PRICE, AND PROCESS SCENARIOS	35
FIGURE 1	LIGHTWEIGHT TABULAR PROCESS USING A-13/A-13M FORMULATION	36

NOMENCLATURE

A-13	Alcoa calcined alumina (unground), designated A-13
A-13M	Alcoa calcined alumina (ground to -325 mesh), designated A-13M
ATC	Alcoa Technical Center
CP-2	Alcoa activated alumina (controlled-pore), 2 μm nominal size
C-30	Alcoa hydrated alumina, designated C-30
H-W	Harbison-Walker Refractory Company
LWA	Lightweight aggregate
R-M	Refractory manufacturer
Tabular™	Alcoa Tabular alumina, designated T-64

OBJECTIVE

The specific objective of this contract between Alcoa and the Department of Energy is to develop a lightweight, high alumina refractory aggregate with the following specification targets:

- Compared to Alcoa Tabular™ alumina, achieve a 30% reduction in particle density from approximately 3.6 to 2.5 g/cm³.
- Compared to existing high alumina aggregate (Tabular™/Fused), retain ~50% of the crushing strength.
- Compared to Alcoa Tabular™ alumina, develop a lightweight aggregate product having a selling price not to exceed 25% more than the present selling price of Tabular™, on a product volume basis.

Secondary objectives that must also be met, some of which impact on the primary objectives, include developing an aggregate that: (a) is 99+ % alumina, (b) possesses thermal stability similar to Tabular™, and (c) is process compatible with existing tabular production facilities.

Specific goals for Phase II of this contract dealt with laboratory and pilot-scale laboratory work to demonstrate further the feasibility of producing lightweight aggregates. The term 'feasibility' includes both technical and economic aspects of the process. For Phase II to be successful, the following three goals need to be achieved:

1. A process demonstrated at a pilot scale and defined in sufficient detail to allow capital and operating cost projections for a full-scale process.
2. Convincing evidence that this type of aggregate would find a significant market (say >10,000 mt/yr) in insulating applications at the projected selling price to yield an adequate return on investment.
3. A belief by Alcoa that the desired material could be manufactured with the required quality and for a cost that would justify new capital expenditure.

INTRODUCTION

This contract was based on a proposal submitted by Alcoa in response to DOE Solicitation for Federal Assistance Application No. DE-PS07-88ID12782 for Refractory Materials Research and Development. This application was for cost-sharing research for the development of new refractory materials or improvements to existing refractory materials, with end-use applications directed toward those refractories used by the aluminum, glass, cement, and iron and steel industries. These new or improved refractory materials should have the potential to lead to a reduction of energy consumption in one or more of the above end-use industries of 0.01 quadrillion BTU annually. If successful, this energy savings will enhance the competitive position of the domestic end-use industries.

A brief summary of the contract history follows.

CONTRACT PHASES

The contract is broken down into three phases. It is expected that the work will be performed in the sequence indicated; however, there will be iteration as approaches are explored and new information is developed. The project is managed by the Chemical Systems Division, but other Alcoa Technical Center (ATC) Divisions are accessible for expertise in ceramics, polymers, and surface chemistry. In addition, support groups such as the Information Department and Analytical Chemistry were utilized. The contract also involved working with the Product Development Group of the Industrial Chemicals' Business Unit located at Alcoa's Arkansas Operations which has the ultimate responsibility for translating any process developed to commercial production.

Phase I - October 20, 1989 to May 31, 1991

Phase I: This was the initial information gathering and screening stage of the project. The existing literature was studied and summarized to identify approaches to manufacturing low density alumina aggregate. In addition, Alcoa experts in related areas including alumina, sintering, polymer science, and emulsion chemistry were consulted, as needed. Also, personnel of the Alcoa Arkansas Operation Technology Group were consulted for past experience as well as compatibility of potential approaches to existing operations. With this background, new approaches were postulated and bench-scale testing was performed for preliminary verification of processing approaches. Materials were purchased or synthesized as necessary, and test specimens were formed into green shapes and sintered. Bulk density, shrinkage, crushing strength, and microstructure were characterized as the screening parameters. The green forming method depended on the specific approach being investigated. Preliminary economic analysis of promising approaches was generated in this step with the involvement of the Arkansas Technology Group.

Phase II - September 01, 1991 to September 30, 1994

Phase II: This is the current phase of the contract and the subject of this report. For this reason, Phase II will be outlined in detail. As outlined in the Phase II experimental plan, kilogram quantities of materials were produced for further testing and performance evaluations that more closely simulated actual application conditions. In this phase, there was increased involvement of the Arkansas Technology Group as well as input and testing by two refractory manufacturers. Because of the variety of application and end-use conditions, it was viewed as essential that the expertise and facilities of refractory producers be utilized in the technical evaluation of candidate materials. Processes that still looked encouraging during this phase underwent a more critical economic analysis.

Task 1. Prepare for new material production

Alcoa prepared and executed an experimental plan for production of lightweight aggregate. In preparation for the production, test, and characterization experimental plan, Alcoa obtained the input of refractory manufacturers with regard to the quantities of aggregate needed for fabricating specimens and the tests to be performed on these specimens.

Task 2. Produce new lightweight aggregates

Alcoa prepared new lightweight aggregates using approaches developed in Phase I of this project and outlined in the experimental plan. Production of these new lightweight

aggregates was performed under simulated full-scale, time-temperature production conditions at laboratory and pilot-scale, utilizing ~1100 kg of aluminous materials for production of new lightweight aggregate formulations. Produced aggregates were characterized for density and strength to ensure suitability for use in refractory formulations.

Task 3. Produce, test and characterize refractory specimens

Refractory manufacturers prepared several refractory formulations (bricks and castables) from several formulations of the new lightweight aggregate. Refractory specimens were characterized against standard materials for physical and thermal properties including density and thermal conductivity.

Task 4. Full-scale feasibility analysis

Alcoa prepared an economic analysis for the production of lightweight aggregate using previous research results and estimates of production costs, based on a retrofit of this process into the existing tabular production facilities. Industrial interest in pursuing the best alternatives identified were solicited from the refractory manufacturers who characterized the refractory specimens in Task 3. These data were analyzed to determine if the technical, economic, and industrial interest factors supported effort toward full-scale evaluation.

Task 5. Report Phase II

Alcoa will report acquired data and project results. Reports will include incurred costs, quarterly written reports, topical, and final reports. The Phase II final report shall fully present the Phase II research in sufficient detail to determine if full-scale evaluation is warranted and include a recommendation as to the desirability of proceeding to Phase III. Review meetings will be held after submission of the experimental plan and near the end of Phase II.

Phase III - Tentative: January, 1995 to September, 1996 (final decision on this phase not known until December, 1994)

Phase III: This phase will be a plant demonstration of the technology to prove the manufacturing process and to provide test market quantities for use by refractory manufacturers and evaluation by end-users. The quantity of lightweight refractory aggregate to be produced was determined by one key factor: a full-scale sintering campaign for a period of one week (including start-up, achievement of steady-state, production of on-spec fired shapes for a period of 3 days, and shut-down). The estimate planned for processing 190.5 mt (420,000 lb) of aluminous raw materials, resulting in 108.9 mt (240,000 lb) of on-spec fired refractory shapes. After crushing to the desired aggregate sizes, it was assumed that a minimum of 54.4 mt (120,000 lb) would be available for fabrication into end use products by two refractory manufacturers with each refractory manufacturer (R-M) to receive 27.2 mt (60,000 lb) of aggregate sized to their specification. Each R-M will prepare at least two insulating products for testing by two or more end-users. Phase III will involve toll processing outside of Alcoa for the raw material mixing, extrusion, and drying. Alcoa's Arkansas plant would fire, crush, and size the refractory. Prior to the primary production run, pre-qualification of the toll processor using 7.26 mt (16,000 lb) of aluminous raw materials would be performed to assure satisfactory performance of equipment for the mixing, extrusion, and drying steps. Further documentation of the planning for Phase III is beyond the scope of this report.

EXPERIMENTAL PLAN

The objective of this program is to determine the feasibility of producing high alumina, lightweight aggregate (LWA). To achieve the specific goals detailed in the Objective section, the following deliverables were outlined to summarize the work:

1. Further optimization of the formulation and the mixing/forming steps of the process at the bench-scale and pilot-scale.
2. Selection and acquisition of processing equipment to be used in pilot-scale production of aggregate including raw material preparation, mixing, extrusion, drying, and sintering.
3. Shake-down processing equipment and develop experimental procedures to produce sufficient quantities of aggregate for refractory evaluation. This will include procedures necessary to ensure a safe operation.
4. Identify refractory manufacturers to work with, define work to be performed by them, and write purchase requisitions for subcontracting necessary services.
5. Produce experimental aggregate and provide the required quantities to R-M's for initial evaluations.
6. Obtain feedback from refractory manufacturers regarding performance and potential interest in refractory compositions. Use this information along with Alcoa experience to estimate commercial viability of new material.
7. Generate a preliminary flow sheet and cost estimate for a commercial scale facility using input from item 2 above.
8. Determine and propose to DOE work required in Phase III of project.
9. Write report covering Phase II activities.

EXPERIMENTAL

Phase II of this contract represented an optimization of the process from Phase I with further scale-up to allow production of aggregate in the required quantities for initial evaluation by refractory manufacturers. The R-M's who agreed to cooperate with Alcoa on this contract were Harbison-Walker (Pittsburgh, PA) and Thermal Ceramics (Augusta, GA). The refractory formulation(s) optimized were those that showed the most promise in Phase I of this contract.

RAW MATERIALS

The raw materials utilized included various alumina products, including Alcoa A-13, CP (controlled pore) aluminas, and C-30 hydrated alumina. In addition, binders and burnouts were added to impart porosity upon drying and firing.⁶

ALUMINAS

Aluminas used in this work for the matrix included the following:

- A-13 Alcoa calcined alumina, unground
- A-13M Alcoa calcined alumina, ground to nominally -325 mesh
- CP-2 Alcoa activated (rehydratable) alumina, 2 μ m particle size
- C-30 Alcoa hydrated alumina

BINDERS/BURNOUTS

In order to extrude a ceramic material, a binder or plasticizer must be added to the solids to impart fluid and yet plastic properties to the mixture. Based on the performance in Phase I, Methocel 20-214, manufactured by Dow Chemical, was adopted as the binder in the formulation.

Methocel 20-214

Methocel cellulose ethers are water-soluble polymers derived from cellulose. Methocel products are used as thickeners, binders, film formers, and water retention agents. A broad range of Methocel products are available. There are two different chemical types and each is available in different grades, physical forms, and viscosities. By choosing a specific Methocel product, it is possible to obtain the optimum degree of thickening, binding, moisture retention, and other properties desired in a given formulation. Methocel 20-214, designated Type F, is a hydroxypropyl methylcellulose product made using propylene oxide and methyl chloride. Methocel 20-214 will decompose at $\sim 225^{\circ}\text{C}$.

Burnout is the term used to describe an additive that is organic in composition. Burnouts are used to occupy volume in a green refractory. Upon firing, porosity is created. Three burnouts were utilized while attempting to optimize the formulation. These burnouts are described below.

Mogul 1607

Mogul 1607 is a heavyweight cereal binder made from precooked yellow corn. Based on information from the manufacturer, Mogul when decomposed will leave behind 0.5 wt% ash. The magnesium oxide in the ash is a concern because it can cause increased densification of alumina during sintering. For 5 wt% loading of Mogul in ceramic (with ash equal to 0.5% of Mogul and the ash containing 7 wt% Mg by ATC analysis), the ash will contribute 17.5 ppm Mg to the ceramic. Based on Thermal Gravimetric (TGA)/Differential Thermal Analysis (DTA) curves developed by ATC for this binder, Mogul will decompose at $\sim 310^{\circ}\text{C}$. An advantage to using Mogul, in addition to its relatively low cost of \$0.23/lb, was that it reduced the stickiness of the extrudate imparted by the Methocel.

Nalco 1181

Nalco 1181 is a superabsorbent polymer. This class of polymers is capable of absorbing a few hundred times their weight in water and retain it even under pressure. Its function in this refractory application is to hold water and impart properties to the formulation indicative of mixtures containing much less water.

Water

Water can also be considered a burnout material. Water is required to impart fluidity to the ceramic binders during mixing and extrusion. Water is the lowest cost burnout available. However, the water loading must be optimized to provide good forming properties, both during mixing and extrusion.

MIXING PROCEDURE

The mixing procedure depended on whether the formulation was a paste or pelletized mixture. For a paste mixture, the Methocel was dispersed in hot water, per manufacturer instructions, to form a Methocel solution. For a pelletized mixture, the aluminas and all binders/burnouts were dry blended by the intense mixing action within the Eirich mixer.

EQUIPMENT

Phase II of the contract utilized bench and pilot-scale mixers and extruders, depending on the batch size of the material being processed. Formulation development generally utilized only small scale equipment to produce samples for characterization. Larger quantities of the new aggregate needed for vendor evaluation and characterization were prepared using pilot-scale equipment either at Alcoa or a toll processor's facility. The converters used for firing small samples from any batch size were those described in the literature reference by MacZura.⁽¹⁾ Large-scale, static firing of refractory for eventual R-M evaluation was done in 34 kg (75 lb) lots by Harbison-Walker at their Garber Research laboratory near Pittsburgh.

DRY BLENDERS

Patterson-Kelley V-Blender - Two sizes of bench-scale V-blenders and one large, pilot-scale V-blender were available. The proper choice of equipment was made depending on the volume of material to be dry blended.

MIXERS

Hobart - Two sizes of bench-scale Hobart mixers were available. These machines were excellent for mixing small batches of paste-like formulations, starting with binder solution in the bowl, followed by addition of the dry components.

Simpson Mix Muller - This item was a Model LF series, with a nominal capacity (bowl volume) of 66 liters. The working capacity was 7 to 21.2 liters (maximum equals 32% of bowl capacity).

Sigma Blade Mixer/Extruder - (off site testing at Charles Ross & Son Company) - This unit was a 6.4 l (1.7 gal - nominal capacity) AMK Kneader/Extruder having a 1.90 cm (0.75 in.) circular die. The working capacity of this machine was 3.785 l (1 gal).

Eirich Mixers - Two sizes of mixers were available.

RV02 - This model had a bowl capacity of 20.3 liters, with working capacities for mixing or pelletizing of 10 or 7 liters, respectively.

R-7 - This model had a bowl capacity of 175 liters, with working capacities for mixing or pelletizing of 73.6 or 56.6 liters, respectively. It was found that the pin rotor was not satisfactory for this formulation that approached a paste consistency. An optional star rotor performed markedly better. Limited machine variables, such as rotor speed and direction and bowl speed, are controlled via switches on the control panel. Additional variation in rotor speed can be attained by switching pulleys and belts.

EXTRUDERS

3" Macquicram

This extruder had a 7.62 cm (3 in.) auger (screw) and a 2 H.P. motor. The single hole die had a diameter of 1.778 cm (0.70 in.). A wire chopper with actuator was custom designed and purchased from Starkey Machines, Inc.

1" Ingersoll Rand

This extruder (bench-top) was an air driven unit with a 2.54 cm (1 in.) screw. The single hole die had a diameter of 0.634 cm (0.5 in.).

GAS FIRED CONVERTERS

For this experimental work, bench-scale, batch-operated, gas-fired converters were used. Two of these units were available, each having a 30 in. diameter shell and an 18 in. inside diameter. Actual sample chambers were 11.43 x 11.43 x 7.62 cm (4.5 x 4.5 x 3 in.) deep, formed from alumina bricks. Heat-up rate from ambient to 1830°C required ~3.5 hours. An over-night cool-down period was required before the samples could be retrieved. Temperature monitoring was through a sight port utilizing an optical pyrometer.

PRODUCT CHARACTERIZATION

The product characterization methods for density, shrinkage, and strength employed during Phase I of this contract were carried into Phase II.

DENSITY

The calculation of density and other physical properties utilized ASTM Method C20-80a, that gives standard test procedures for apparent porosity, water adsorption, apparent

specific gravity, and bulk density of burned refractory brick and shapes by the boiling water method.

SHRINKAGE

Both linear and volumetric shrinkages were calculated from size measurements taken before and after firing the machined, test specimens.

CRUSHING STRENGTH

The diametral compression test was found to be a simple and practical method to measure the tensile strength of brittle materials. In order to test approximately spherical specimens of the same size, it was necessary to manually crush and sort the individual test specimens. Groups of at least 20 nearly spherical samples were selected at one specimen size, -8+10 mesh. The only criterion applied to the final sample selection was that the grains had approximately equiaxed cross sections suitable for compression testing. The maximum test load at fracture and the average screen opening size were used to calculate the fracture stress.

MICROSTRUCTURE

Phase I of this contract focused on numerous formulations involving binders, burnouts, and aluminous species. Because of the narrow focus on formulations in Phase II, few samples were submitted for examination of the microstructure.

DENSITY/RAW MATERIAL COST MODEL

The raw material cost model, developed in Phase I, was used extensively during Phase II for selection of the proper combination of binders, burnouts, and free moisture. In addition to tracking the raw material weights and costs, the model was found to be accurate enough to rely on for selection of variables to result in the target fired density, based on a calculated green density and known shrinkage values. The selection of the binder/burnout levels was critical because free water usage had to be minimized so that a paste was not formed in the Eirich mixer portion of the development effort.

EXPERIMENTAL RESULTS AND DISCUSSION

The runs performed during Phase II of this project numbered in excess of 50 and consumed approximately 1134 kg (2500 lb) of aluminous raw materials. Some runs were comprised of several experiments. The runs are reported in chronological order so that the logic of the research and development effort may be followed. The runs are numbered and reported in logical groups, where possible. The shift in focus from paste to pelletized formulations and the scale-up to pilot scale equipment to make the volumes of aggregate required by the refractory manufacturers for testing will be evident. A master spreadsheet summarizing all the experiments conducted during this phase is given in Appendix A. Data from this spreadsheet will be broken-out and placed in smaller tables used to support discussion of the experimental groupings. These experimental groupings were by mixer type: Hobart, Simpson mix-muller, RV02 Eirich, and R-7 Eirich mixer. Further detailing of the aggregate property data acquired was split by physical property category and reported in Appendices, as follows:

Appendix B-1	Raw Data and Green Density Calculations
Appendix B-2	Raw Data and Fired Density Calculations
Appendix B-3	Raw Data and Shrinkage Calculations
Appendix B-4	Raw Data and Green Strength Calculations
Appendix B-5	Raw Data and Fired Strength Calculations
Appendix B-5a	Weibull Modulus Calculations for Aggregate Strength

MIXER/FORMULATIONS

Two distinct physical formulations, paste and pelletized, were developed during Phase II. The initial work in Phase I dealt totally with paste formulations having ~28 to 35% moisture. During consideration of the equipment needed for a demonstration process in Phase III and based on contact with 11 vendors who were potential toll processors, it was found that most did not have the equipment to support a paste formulation. It was found that the potential tollers, and particularly those willing to bid on the job, had Eirich mixers that require a drier formulation (less water and more burnouts) to allow for pelletization. A rough estimate of the throughput and the capital equipment required for a commercial process also supported the use of a pelletized formulation. Because of the rapid throughput of Eirich machines and the elimination of separate dry blending equipment, Eirich mixers would be preferred because they minimize capital costs. Mixer/extruders in one machine were also considered even though they are expensive. A pelletized formulation containing about 28% moisture and several burnouts was developed. To form porosity in a refractory, either water or burnout materials must be used to create void volume upon drying or firing.

HOBART MIXER TRIALS

Run 0 (tests 1-8):

Early-on, small quantities of aggregate mix were prepared using a small Hobart mixer, followed by extrusion using the 1 in. bench scale extruder. The Hobart mixer produces a paste formulation. Through a small experimental design, designated Run 0, involving four variables at two levels, the effect of: a) alumina matrix raw materials split, b) alumina classification cut size, c) firing temperature, and d) Methocel loading, was studied based on extruded samples after firing. Experimental responses included bulk density, crush strength, Weibull modulus, and grain size. Table 1 summarizes the standard data summary, including formulation and binder details, and the refractory properties. Table 2 lists additional data including, A-13 cut size, firing temperature, and some non-standard aggregate properties, such as grain size and Weibull modulus for the crushing strength. In addition, mercury porosimetry data for the 8 samples in the test are given.

Statistical evaluation of the results from the experimental design was summarized. The experiment was an unreplicated 2^{4-1} fractional factorial design in the variables A-13/A-13M ratio, A-13 cut size, firing temperature, and Methocel loading. The response variables examined were fired density, fired strength, and Weibull modulus. The findings determined from these experiments were:

- The density and strength response depend significantly on the A-13/A-13M ratio. For the density response, the 40/60 ratio gives a higher density response than the 60/40 ratio. The same trend is noted for the strength response.

TABLE 1
EXPT DESIGN 24147
STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING HOBART MIXER AND 1" LAB EXTRUDER

RUN NO.	BINDER	BINDER LOADING WT % nominal	BINDER	BINDER LOADING WT %	OTHER	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
		as soln																				
0-1	METHOCEL	2.0	---	---	---	---	490	60	40	---	---	27.5	PASTE	1.21	2.43	54.6	0.266	37.98	15.65	3.91	39.03	1.05
0-2	METHOCEL	4.5	---	---	---	---	450	40	60	---	---	33.5	PASTE	1.10	2.11	37.9	0.241	46.39	22.03	3.93	47.07	0.68
0-3	METHOCEL	4.5	---	---	---	---	480	60	40	---	---	32.1	PASTE	1.20	2.38	63.3	0.360	39.14	16.48	3.91	40.26	1.12
0-4	METHOCEL	2.0	---	---	---	---	490	40	60	---	---	27.5	PASTE	1.09	2.15	42.4	0.296	45.05	20.98	3.91	46.05	1.00
0-5	METHOCEL	4.5	---	---	---	---	450	60	40	---	---	33.5	PASTE	1.18	2.43	63.3	0.329	36.89	15.19	3.85	38.99	2.10
0-6	METHOCEL	2.0	---	---	---	---	490	40	60	---	---	27.5	PASTE	1.10	2.21	54.3	0.289	43.67	19.79	3.92	44.53	0.86
0-7	METHOCEL	2.0	---	---	---	---	490	60	40	---	---	27.5	PASTE	1.20	2.42	67.9	0.222	37.04	15.32	3.85	39.15	2.11
0-8	METHOCEL	4.5	---	---	---	---	525	40	60	---	---	33.3	PASTE	1.14	2.18	52.2	0.157	43.75	20.08	3.87	45.23	1.48

TABLE 2

EXPT DESIGN 24147
SUMMARY OF ROUTINE AND SPECIAL ANALYSES FOR ANALYSIS OF VARIANCE

EXPT.	A-13M %	A-13 %	A-13 CUT SIZE microns	FIRING TEMP. °C	METHOCEL LOADING % nominal	BULK DENSITY g/cc	CRUSH STRENGTH MPa	WEIBULL MODULUS ---	GRAIN SIZE microns	MERCURY POROSIMETRY EVALUATION ON GRAINS				
										Hg Density g/cc	Pore Vol cc/g >18 micron	Totl Intrusion cc/g	Mean Diam microns	Skeletal Den. g/cc
1	60	40	-270	1780	2.0	2.43	54.8	3.23	4.3	2.43	0.011	0.137	9.6	3.65
2	40	60	-270	1780	4.5	2.11	37.9	4.26	5.0	2.22	0.018	0.150	8.8	3.33
3	60	40	NONE	1780	4.5	2.38	63.3	3.56	4.8	2.50	0.013	0.096	8.5	3.28
4	40	60	NONE	1780	2.0	2.15	42.4	3.36	4.4	2.29	0.083	0.181	17.2	3.90
5	60	40	-270	1862	4.5	2.43	63.3	3.23	13.5	2.59	0.020	0.113	10.4	3.65
6	40	60	-270	1862	2.0	2.21	54.3	3.70	10.4	2.30	0.040	0.181	14.9	3.94
7	60	40	NONE	1862	2.0	2.42	67.9	4.68	29.9	2.56	0.030	0.132	14.2	3.87
8	40	60	NONE	1862	4.5	2.18	52.2	5.85	11.5	2.35	0.066	0.167	16.4	3.85

- There is a hint of a significant effect for the firing temperature. This is stronger for the strength response than for the density. In both cases, the strength increases with the firing temperature.
- It does not appear that the Weibull modulus depends significantly on any of the variables.

This relationship between density and strength is not unexpected for ceramic materials. This quantitative defining of this relationship is important because this project has target values for both density and strength.

SIMPSON MIXER TRIALS (ALL PASTE FORMULATIONS)

Run 1:

Very quickly after starting Phase II, the batch size for an experiment was increased to pilot-scale. The Hobart mixer was replaced by a Simpson mix-muller and the 1 in. extruder replaced by the 3 in. Macquiceram. Batch size increased from about 0.5 kg to about 8 kg for the Simpson mix-muller. The first experiment used the 40% A-13/60% A-13M formulation found to give higher density and strength properties. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, and B-3. This first larger scale experiment resulted in a fired density of 3.23 g/cm^3 , that exceeded the 2.5 g/cm^3 target.

Run 2: (3-factor experiment focused on extrusion variables)

The focus of the next experiment was on adjustment of the formulation to give lower density and also on the impact of extrusion variables. The formulation was changed to give a 60% A-13/40% A-13M mixture. This single mix was extruded through the 3 in. extruder while varying: a) extrusion speed, b) use of vacuum in the deairing hopper, and c) rolling of the sliced extrudate in a ball former in a 2^3 full replicate design consisting of eight tests. For comparison, during this scale-up phase, the same material was extruded using the 1 in. bench-scale extruder. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3, and B-5. The experimental design is given in Table 4 below.

Analysis of variance of the responses (except fired strength, that was only determined for two of the eight samples) indicated no significant main effects or interactions for the responses vacuum, speed, and rolling. This finding allowed the operators to select extrusion operating variables based on requirements other than resulting extrudate properties.

TABLE 3

RUNS 1 - 10
STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING SIMPSON MIX MULLER AND 3" EXTRUDER

RUN NO.	BINDER	BINDER LOADING DRY WT%	BINDER	BINDER LOADING WT %	OTHER	OTHER LOADING WT %	DRY SOLIDS grams	A-13M	A-13	CP-2	C-30	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP S.Q. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
RUN 1	METHOCCEL 20-214	1.55					10,300	60	40			26.1	PASTE	1.45	3.23			11.08	3.43	3.64	18.76	7.68
RUN 1	METHOCCEL 20-214	1.55					SWOLLEN	60	40			SEE ABOVE	PASTE	1.39	3.09			17.20	5.77	3.73	22.48	5.28
RUN 2A	METHOCCEL 20-214	1.62					8,275	40	60			26.9	PASTE	1.17	2.28	46.7	0.266	41.63	16.38	3.68	43.10	1.47
RUN 2B	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.21	2.35	51.2	0.282	39.49	16.62	3.68	40.97	1.48
RUN 2C	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.21	2.35			39.38	16.75	3.68	40.90	1.52
RUN 2D	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.19	2.32			40.06	17.25	3.68	41.61	1.55
RUN 2E	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.17	2.25			41.65	18.58	3.68	43.38	1.53
RUN 2F	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.20	2.32			40.14	17.33	3.67	41.74	1.60
RUN 2G	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.19	2.29			40.89	17.66	3.67	42.47	1.56
RUN 2H	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.22	2.35			39.30	16.72	3.67	40.92	1.62
RUN 2A	METHOCCEL 20-214	1.62					SEE ABOVE	40	60			SEE ABOVE	PASTE	1.19	2.31			40.37	17.49	3.67	41.96	1.59
RUN 3-1	METHOCCEL 20-214	1.62					8,250	40	60			27.0	PASTE	1.27	2.47	56.2	0.346	36.23	14.78	3.67	38.02	1.79
RUN 3-2	METHOCCEL 20-214	1.62					8,250	40	60			27.0	PASTE	1.31	2.53			34.83	13.81	3.67	36.58	1.75
RUN 3-3	METHOCCEL 20-214	1.62					8,250	40	60			27.0	PASTE	1.21	2.34			39.54	16.89	3.68	41.11	1.57
RUN 3-4	METHOCCEL 20-214	1.62					8,250	40	60			27.0	PASTE	1.18	2.32	44.2	0.263	40.16	17.31	3.68	41.72	1.56
RUN 3-5	METHOCCEL 20-214	1.62					8,250	40	60			27.0	PASTE	1.17	2.30			40.76	17.72	3.68	42.18	1.42
RUN 3-6	METHOCCEL 20-214	1.62					7,770	40	60			27.0	PASTE	1.19	2.32			40.29	17.37	3.68	41.73	1.44
RUN 3-7	METHOCCEL 20-214	1.57					8,250	40	60			27.0	PASTE	1.15	2.24			42.37	16.94	3.68	43.60	1.43
RUN 3-8	METHOCCEL 20-214	1.57					8,250	40	60			27.0	PASTE	1.14	2.23	43.8	0.276	42.42	16.99	3.68	43.66	1.44
RUN 3-9	METHOCCEL 20-214	1.57					8,250	40	60			27.0	PASTE	1.12	2.22			42.87	19.34	3.68	44.31	1.44
RUN 3-10	METHOCCEL 20-214	1.57					8,250	40	60			27.0	PASTE	1.15	2.26			41.70	16.44	3.68	43.16	1.46
RUN 3-11	METHOCCEL 20-214	1.57					8,250	40	60			27.0	PASTE	1.11	2.21			43.19	19.59	3.68	44.60	1.41
RUN 3-12	METHOCCEL 20-214	1.57					10,190	40	60			27.0	PASTE	1.12	2.18	43.7	0.235	43.67	20.08	3.67	45.29	1.62

TABLE 3 (continued)

RUNS 1 - 10
STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING SIMPSON MIX MILLER AND 3" EXTRUDER

RUN NO.	BINDER LOADING DRY WT%	BINDER LOADING WT %	OTHER LOADING WT %	DRY SOLIDS grams	A-13M A-13 CP-2 C-30 %	ACTUAL MOIST. %	WATER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP.S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
RUN 4-1	METHOCEL 20-314 1.62			8,250	50 50	27.0	PASTE	1.14	2.27	41.3	0.319	41.48	18.31	3.67	43.05	1.57
RUN 4-2	METHOCEL 20-314 1.54			8,681	50 50	26.0	PASTE	1.36	2.61			32.33	12.37	3.66	34.30	1.87
RUN 4-3	METHOCEL 20-314 1.60			8,390	50 50	26.7	PASTE	1.24	2.43	37.9	0.253	37.41	15.41	3.66	36.98	1.57
RUN 5	METHOCEL 20-314 1.61			8,328	45 55	26.8	PASTE	1.21	2.37	42.4	0.335	39.01	16.49	3.68	40.52	1.51
RUN 6-1	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.23	2.41	42.4	0.269	37.50	15.54	3.66	39.36	1.86
RUN 6-2	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.24	2.45			36.50	14.89	3.66	38.39	1.89
RUN 6-3	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.22	2.42			37.38	15.42	3.67	39.06	1.70
RUN 6-4	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.23	2.43			37.18	15.30	3.67	38.95	1.77
RUN 6-5	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.23	2.43	41.5	0.224	37.15	15.28	3.67	38.89	1.74
RUN 6-6	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.25	2.48			36.03	14.55	3.67	37.76	1.73
RUN 6-7	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.27	2.48	52.1	0.316	35.69	14.39	3.66	37.81	1.92
RUN 6-8	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.23	2.40			36.05	15.85	3.66	39.66	1.63
RUN 6-9	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.26	2.46			36.14	14.87	3.66	38.10	1.96
RUN 6-10	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.29	2.52			34.95	13.89	3.67	36.77	1.82
RUN 6-11	METHOCEL 20-314 1.57			8,514	50 50	26.4	PASTE	1.25	2.46			36.32	14.74	3.67	38.10	1.78
RUN 6-12	METHOCEL 20-314 1.57			10,510	50 50	26.4	PASTE	1.25	2.45	43.1	0.300	36.58	14.91	3.67	38.34	1.76
RUN 7-1	METHOCEL 20-314 1.01			10,280	35 65	18.7	PASTE	1.31	2.39	39.2	0.221	38.21	15.97	3.67	39.86	1.65
RUN 7-1	METHOCEL 20-314 1.01			10,280	35 65	18.7	PASTE	1.32	2.38	45.4	0.226	38.44	16.12	3.68	40.07	1.63

TABLE 3 (continued)

RUNS 1 - 10
STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING SIMPSON MIX MILLER AND 3" EXTRUDER

RUN NO.	MIXER LOADING DRY WT%	MIXER LOADING WT %	OTHER LOADING WT %	DRY SOLIDS g/lbs	A-13M % A-13 % CP-2 % C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coil d Vm	APPARENT POROSITY %	H ₂ O ADSORP %	APP SQ. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
RUN 8-1	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.31	2.41	46.9	0.219	37.46	15.53	3.86	39.38	1.92
RUN 8-2	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.30	2.39			38.20	16.01	3.86	40.06	1.86
RUN 8-3	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.31	2.40			37.69	15.71	3.85	39.72	2.03
RUN 8-4	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.31	2.41			37.53	15.56	3.86	39.38	1.85
RUN 8-5	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.32	2.42	40.6	0.246	37.34	15.43	3.86	39.20	1.86
RUN 8-6	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.32	2.43			36.77	15.11	3.85	38.83	2.06
RUN 8-7	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.34	2.45	43.6	0.240	36.32	14.80	3.85	38.35	2.03
RUN 8-8	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.33	2.45			36.40	14.87	3.85	38.50	2.10
RUN 8-9	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.32	2.43			36.74	15.11	3.84	38.89	2.15
RUN 8-10	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.28	2.36			36.83	16.47	3.86	40.74	1.91
RUN 8-11	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.29	2.39			38.10	15.97	3.86	40.05	1.95
RUN 8-12	METHOCEL 20-314 1.01			10,708	35	65	PASTE	1.31	2.44	43.5	0.284	36.61	15.00	3.85	38.64	2.03
RUN 9	METHOCEL 20-314 1.01			10,280	35	65	PASTE	1.34	2.43	55.3	0.336	37.09	15.28	3.86	38.99	1.90
RUN 10	METHOCEL 20-314 1.37			8,514	50	50	PASTE	1.42	2.75	74.2	0.286	27.93	10.15	3.82	30.81	2.88
RUN 32	METHOCEL 20-314 1.0	Mogul 1807	Nabco 1181	9,650	20	80	PASTE	1.26	2.44	N.D.	N.D.	37.00	15.20	3.87	38.80	1.79

Table 4. Experimental Design Outline and Results with Extruder Variables
(Run 2: Expt. 12748- 2³ Design)

RUN	A vacuum	B speed	C rolling	D green density g/cm ³	E fired density g/cm ³	F volume shrinkage %	G fired strength MPa
1	no	low	no	1.17	2.26	48.5	46.7
2	yes	low	no	1.21	2.35	48.8	51.2
3	no	high	no	1.21	2.35	48.7	N.D.
4	yes	high	no	1.19	2.32	48.7	N.D.
5	no	low	yes	1.17	2.25	48.5	N.D.
6	yes	low	yes	1.20	2.32	48.3	N.D.
7	no	high	yes	1.19	2.29	48.2	N.D.
8	yes	high	yes	1.22	2.35	48.5	N.D.

Notes: Vacuum = 15 in. Hg
Speed = graduation 3 or 5
Rolling = immediately after extrusion or no rolling
Each response for properties is the average of five measurements.
N.D. - not determined.

Run 3: Batches 1 to 12

This run represented the first attempt to produce a large lot of fired aggregate. Twelve identical batches were processed, each about 8 kg in size. The formulation used was 60% A-13/40% A-13M. The Methocel loading for these batches was about 1.6 wt%. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3, B-5, and C-1. The bulk density is of primary importance for the aggregate formulation. For these 12 batches, the average bulk density was 2.30 g/cm³ with a standard deviation of 0.111 g/cm³. Appendix C-1 contains additional detailed property information on the 12 batches comprising Run 3. Statistical evaluation of the bulk density for the 12 batches revealed that the first two batches had densities significantly different from the others. The material from Run 3 was sent to H-W for proposed evaluations, but was later returned at Alcoa's request without further processing.

Run 4: Batches 1 to 3

Three identical batches were processed, each about 8 kg in size. The formulation used was 50% A-13/50% A-13M. This formulation adjustment was made to increase the density slightly, so as to maximize strength, compared to Run 3. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run are included in Appendices B-1, B-2, B-3, and B-5. Run 4 exhibited an average fired density of 2.44 g/cm³ and an average fired strength of 39.6 MPa.

Run 5

This run was conducted followed by sample analysis concurrently with Run 4. A further modification of the formulation was made for a 55% A-13/45% A-13M mix. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run are included in Appendices B-1, B-2, B-3, and B-5. Run 5 exhibited a fired density of 2.37 g/cm^3 and a fired strength of 42.4 MPa.

Run 6: Batches 1 to 12

This run represented a second attempt to prepare a large lot of aggregate for refractory manufacturer characterization. Twelve identical batches were processed, each about 8.5 kg in size. The formulation used was 50% A-13/50% A-13M. The Methocel loading for these batches was about 1.6 wt%. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run are included in Appendices B-1, B-2, B-3, B-5, and C-2. For these 12 batches, the average bulk density was 2.45 g/cm^3 with a standard deviation of 0.04 g/cm^3 . Four of the 12 lots were characterized for fired crushing strength, see Appendix B-5. The average crushing strength was 44.8 MPa. Appendix C-2 contains additional detailed information on the fired density of the 12 batches comprising Run 6. These 12 batches from Run 6 were sent to H-W for toll processing to prepare aggregate (fire, crush, and size). Fired densities and fired strengths of the ATC fired and H-W fired samples from Run 6 (both determined by ATC) are shown below in Table 5. The agreement between the ATC and H-W fired specimens was termed satisfactory, based on visual comparison of the fired density and fired strength data above. Run 6 was one of two formulations evaluated by Harbison-Walker in refractory brick.

Run 7-1:

This run processed two 10.3 kg batches of aggregate mix having a 35% A-13M/65% C-30 formulation. This was the first attempt to use C-30 in the formulation at the pilot scale. The concept of using C-30 hydrate was first evaluated during Phase I of this contract. The purpose of using hydrate is to utilize the chemically combined water as another form of burnout in the structure. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3, and B-5. Run 7 exhibited an average fired density of 2.38 g/cm^3 and an average fired strength of 42.3 MPa. No adverse effects of using alumina hydrate (C-30) in the formulation were evident. Of concern would be the rapid evolution of water from the structure during a rapid ramp-up of the temperature during sintering. Static sintering would not be considered to provide this rapid heat-up. The open porosity should easily release the steam even during rapid heat-up. However, this must be verified in dynamic sintering trials in pilot or commercial firing equipment.

Table 5. Density and Fired Strength Results for Run 6.

H-W FIRED BATCH NOS.	INDIVIDUAL FIRED DENSITY	H-W BATCH FIRED DENSITY	INDIVIDUAL FIRED STRENGTH	H-W BATCH FIRED STRENGTH
H-W #1	g/cm ³	g/cm ³	MPa	MPa
10	2.516			
11	2.462			
12	2.454		43.1	
2	2.452			
Average	2.470	2.48	43.1	58.3
H-W #2	g/cm ³	g/cm ³	MPa	MPa
1	2.413		42.4	
3	2.424			
4	2.430			
5	2.432		41.5	
Average	2.425	2.38	42.0	43.4
H-W #3	g/cm ³	g/cm ³	MPa	MPa
6	2.476			
7	2.483		52.1	
8	2.400			
9	2.464			
Average	2.456	2.44	52.1	56.6
GRAND AVERAGE	2.45	2.43	45.7	52.7

Run 8-1: Batches 1 to 12

This run represented a third attempt to prepare a large lot of aggregate for refractory manufacturer characterization. Twelve identical batches were processed, each about 10.3 kg in size. The formulation used was 35% A-13M/65% C-30. The Methocel loading for these batches was about 1.01 wt%. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3, B-5, and C-3. For these 12 batches, the average bulk density was 2.42 g/cm³ with a standard deviation of 0.04 g/cm³. Four of the 12 lots were characterized for fired crushing strength, see Appendix B-5. The average crushing strength was 43.7 MPa. Appendix C-3 contains additional detailed information on the fired density of the 12 batches comprising run 8. These 12 batches from run 8 were sent to H-W for toll processing to

prepare aggregate (fire, crush, and size). Fired densities and fired strengths of the ATC fired and H-W fired samples from Run 8 (both determined by ATC) are shown below in Table 6.

Table 6. Density and Fired Strength Results for Run 8.

H-W FIRED BATCH NOS.	INDIVIDUAL FIRED DENSITY	H-W BATCH FIRED DENSITY	INDIVIDUAL FIRED STRENGTH	H-W BATCH FIRED STRENGTH
H-W #4	g/cm ³	g/cm ³	MPa	MPa
9	2.432			
10	2.358			
11	2.386			
12	2.441		43.5	
average	2.404	2.44	43.5	37.8
H-W #5	g/cm ³	g/cm ³	MPa	MPa
5	2.419		40.8	
6	2.434			
7	2.453		43.6	
8	2.448			
average	2.438	2.44	42.2	41.6
H-W #6	g/cm ³	g/cm ³	MPa	MPa
1	2.413		46.9	
2	2.386			
3	2.400			
4	2.412			
average	2.403	2.43	46.9	41.1
GRAND AVERAGE	2.42	2.44	43.7	40.2

The agreement in properties between the ATC and H-W fired specimens was termed satisfactory, based on visual comparison of the fired density and fired strength data above. Run 8 was one of two formulations evaluated by Harbison-Walker in refractory brick.

Runs 9, 10, 11, 12, 13, and 14:

Runs 9 through 14, combined with data from Runs 6 and 8 comprised an experimental design with: a) mixer, b) formulations, and c) binder dispersion as variables. The two mixers evaluated were the Simpson mix muller and the sigma blade mixer. Formulations evaluated were: a) 35% A-13M/65% C-30, and b) 50% A-13/50% A-13M. The Methocel dispersion variable was either wet or dry dispersion. Wet dispersion was the usual hot dispersion of Methocel in water to form a solution. The viscous solution was then used along with dry, pre-blended powder to make a paste formulation. Dry dispersion can be performed in high shear or high intensity mixers such as the sigma blade and Eirich, respectively. In dry blending, the dry powders and dry binders are added to the mixer, followed by a short period of dry blending before water addition. This experimental design is outlined in Table 7 below. Complete standard data from the runs comprising the design are summarized in Table 8, followed by a discussion of only those data pertinent to the statistical evaluation, given in Table 8a, for the individual runs comprising the design.

Table 7. Experimental Design Involving Mixer, Formulations, and Methocel Dispersion.

EXPT DESIGN TEST NO.	RUN NO.	MIXER	METHOCEL DISPERSION	DRY SOLIDS grams	A-13 %	A-13M %	C-30 %
1	8	SIMPSON	WET	10,280	0	35	65
c	6	SIMPSON	WET	8,514	50	50	0
b	9	SIMPSON	DRY *	10,280	0	35	65
bc	10	SIMPSON	DRY *	8,514	50	50	0
a	11	SIGMA	WET	5,140	0	35	65
ac	12	SIGMA	WET	4,257	50	50	0
ab	13	SIGMA	DRY **	5,140	0	35	65
abc	14	SIGMA	DRY **	4,257	50	50	0

Notes: * using V-blender
 ** using sigma mixer

Run 9:

This run was the first attempt to perform dry blending in the Simpson mixer. The experiment utilized a 35%A-13/65% C-30 formulation. The pertinent results are summarized below in Table 8a.

Run 10:

This run was the second attempt to perform dry blending in the Simpson mixer. The experiment utilized a 50%A-13/50% A-13M formulation. The pertinent results are summarized below in Table 8a.

TABLE 8

SPECIAL RUNS INVOLVING MIXER/EXTRUDER EQUIPMENT AND FORMULATION / BINDER OPTIONS

RUN NO.	BINDER LOADING DRY WT %	BINDER LOADING WT %	OTHER LOADING WT %	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
RUN 6-1	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.23	2.41	42.4	0.269	37.50	15.54	3.86	39.36	1.86
RUN 6-2	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.24	2.45			36.50	14.89	3.86	38.39	1.89
RUN 6-3	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.22	2.42			37.38	15.42	3.87	39.08	1.70
RUN 6-4	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.23	2.43			37.18	15.30	3.87	38.95	1.77
RUN 6-5	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.23	2.43	41.5	0.224	37.15	15.28	3.87	38.69	1.74
RUN 6-6	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.25	2.46			36.03	14.55	3.87	37.76	1.73
RUN 6-7	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.27	2.48	52.1	0.316	35.69	14.39	3.86	37.61	1.92
RUN 6-8	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.23	2.40			36.05	15.85	3.86	39.66	1.63
RUN 6-9	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.26	2.46			36.14	14.67	3.86	36.10	1.96
RUN 6-10	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.29	2.52			34.95	13.89	3.87	36.77	1.82
RUN 6-11	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.25	2.46			36.32	14.74	3.67	36.10	1.76
RUN 6-12	METHOCCEL 20-214 1.57				10,510	50	50			26.4	PASTE	1.25	2.45	43.1	0.300	36.56	14.91	3.87	36.34	1.76
RUN 8-1	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.31	2.41	46.9	0.219	37.46	15.53	3.86	39.36	1.92
RUN 8-2	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.30	2.39			36.20	16.01	3.86	40.06	1.86
RUN 8-3	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.31	2.40			37.69	15.71	3.85	39.72	2.03
RUN 8-4	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.31	2.41			37.53	15.56	3.86	39.36	1.85
RUN 8-5	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.32	2.42	40.6	0.246	37.34	15.43	3.86	39.20	1.86
RUN 8-6	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.32	2.43			36.77	15.11	3.85	38.63	2.06
RUN 8-7	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.34	2.45	43.6	0.240	36.32	14.80	3.85	38.35	2.03
RUN 8-8	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.33	2.45			36.40	14.87	3.85	38.50	2.10
RUN 8-9	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.32	2.43			36.74	15.11	3.84	38.69	2.15
RUN 8-10	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.28	2.38			36.63	16.47	3.86	40.74	1.91
RUN 8-11	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.29	2.39			36.10	15.97	3.86	40.05	1.95
RUN 8-12	METHOCCEL 20-214 1.01				10,708	35			65	18.7	PASTE	1.31	2.44	43.5	0.264	36.61	15.00	3.85	36.64	2.03
RUN 9	METHOCCEL 20-214 1.01				10,280	35			65	18.7	PASTE	1.34	2.43	55.3	0.336	37.09	15.28	3.86	38.99	1.90
RUN 10	METHOCCEL 20-214 1.57				8514	50	50			26.4	PASTE	1.42	2.75	74.2	0.286	27.93	10.15	3.82	30.61	2.66
RUN 11	METHOCCEL 20-214 1.01				5,140	35			65	18.7	PASTE	1.10	2.06	32.9	0.256	46.25	22.28	3.86	47.64	1.59
RUN 12	METHOCCEL 20-214 1.57				4,257	50	50			26.4	PASTE	1.11	2.14	33.8	0.316	44.55	20.83	3.86	46.26	1.71
RUN 13	METHOCCEL 20-214 1.01				5,140	35			65	18.7	PASTE	1.50	2.69	63.2	0.244	29.83	11.09	3.83	32.43	2.60
RUN 14	METHOCCEL 20-214 1.57				4,257	50	50			24.8	PASTE	1.27	2.44	43.0	0.253	36.95	15.16	3.87	36.72	1.77

Run 31

This run will be discussed out of sequence in this section because it is the last of the Simpson mixer runs to be performed.

All of the development work after Run 15 focused on Eirich mixers. During this time, the formulation was modified (more binders, less free moisture) to make a pelletized form for extrusion. The purpose of this run was to use the formulation as developed while adding 100% of the required moisture calculated to attain the target bulk density. While using a Simpson mixer, this required water addition could be made without the requirement to maintain a pelletized form. The properties could be compared with Run 31 made in an Eirich mixer (see Appendix A). The formulation used was 80% A-13/20% A-13M. The Methocel loading for this run was about 1 wt%. The formulation contained Mogul 1607 and Nalco 1181, in addition to the Methocel. Experimental results are given in the master spreadsheet (Appendix A) and in Table 3 that summarizes all the Simpson mix-muller experiments. More detailed data for this run were included in Appendices B-1, B-2, and B-3. Note that the target bulk density was attained. No strength measurements were determined. This experiment confirmed the ability of the Simpson mixer to process a formulation developed for the Eirich mixers.

SIGMA BLADE MIXER TRIALS (Paste Formulation)

Runs 11-14:

Four sigma blade mixer trials were performed in Phase II. A sigma blade mixer is unique in that the mixing and extrusions can be done by the same piece of equipment. These trials were performed at the Ross Mixer Laboratory in Long Island, N.Y., using a sigma blade, Model AMK Kneader extruder. Raw materials from Alcoa were shipped to this laboratory. Data from these four tests were combined with data from Runs 6, 8, 9, and 10 to complete an experimental design. Experimental conditions and formulations were given in Table 7.

Pertinent results from experiments 9 through 14 are given in the master spreadsheet (Appendix A) and in Table 8 that summarizes all the runs comprising this experimental design. More detailed data for this run were included in Appendices B-1, B-2, B-3, B-5, and C-4. Appendix C-4 contains additional detailed information on the responses examined via statistical methods. Table 8a below summarizes the fired density and fired strength responses, as measured in the runs and as predicted by models resulting from statistical evaluation of the data.

Statistical evaluation was made for the fired density and the fired strength responses. Statistical analysis was made using JMP software. Pertinent output is included in Appendix C-4. For the fired strength response, significant main effects were mixer and dispersion. Significant interactions were mixer-formulation and mixer-dispersion-formulation. Higher strengths resulted from: Simpson mixer and a dry dispersion of the Methocel. For the mixer-formulation interaction, a higher strength resulted from the 'alumina' formulation prepared in the Simpson mixer. For the 3-factor interaction, the highest strength results from the 'Simpson', 'dry', 'alumina' combination for mixer, dispersion, formulation variables, respectively. For the fired density response, no main effects or interactions were significant.

Table 8a. Results on Fired Density and Fired Strength Subjected to Statistical Evaluation for the Experiment Design

Run No.	Mixer	Dispersion	Formulation	Fired Density g/cm ³	Fired Strength MPa	Pred. Fired Density g/cm ³	Pred. Fired Strength MPa
8	Simpson	Wet	Hydrate	2.42	43.7	2.34	38.8
11	Sigma	Wet	Hydrate	2.08	32.9	2.16	37.8
9	Simpson	Dry	Hydrate	2.43	55.3	2.50	60.2
6	Simpson	Wet	Alumina	2.45	44.8	2.52	49.7
13	Sigma	Dry	Hydrate	2.69	63.2	2.62	58.3
12	Sigma	Wet	Alumina	2.14	33.8	2.06	28.9
10	Simpson	Dry	Alumina	2.75	74.2	2.68	69.3
14	Sigma	Dry	Alumina	2.44	43.0	2.52	47.9

SUMMARY OF PASTE FORMULATION EXPERIMENTS

It is significant that the paste formulation was successfully scaled-up from bench to pilot scale with attainment of target fired density and strengths nearly equivalent to those of Phase I experiments. At this point in the development effort, a forward look to Phase III of the contract resulted in anticipating who would perform the toll processing functions of blending, mixing, extrusion, and drying. Alcoa's domestic plants do not have the equipment to perform the mixing/forming/drying for the new lightweight aggregate process. The steps of firing and crushing/sizing of the aggregate were planned using Alcoa facilities. To our dismay, after contact with as many as 11 possible toll processors, none could or would support our effort in Phase III by tolling a paste formulation. The reason most vendors could not support the effort was that they did not have the mixing equipment to handle a paste formulation. A few of the tollers did, however, have Eirich mixers that require a pelletized formulation. Only three tollers bid on the Phase III contract; only two of these bids were reasonable in relation to the others.

From a capital equipment viewpoint, Eirich mixers are cost-effective because they eliminated the need for: a) hot dispersion of the Methocel to make a solution, and b) dry blending equipment that is costly and relatively inefficient for mixing of dry solids. Consideration was given to sigma blade mixers both with and without extruders on the front-end. However, the cost per ft³ of throughput for these devices was determined to be several times higher than for Eirich mixers. Specifically, a comparison was made as to the capital cost per ft³ of mixing capacity for a sigma blade kneader extruder (66.8 ft³ mixing capacity), a Simpson mix muller (90 ft³ mixing capacity), and a Eirich mixer (74 ft³ mixing capacity). If the capital cost per ft³ of mixing capacity for the Eirich is X, then the cost for the Simpson mixer is 2.3 X and the cost for the sigma blade (with extruder) is 3.1 X. It follows that a decision was made to pursue a pelletized formulation that could utilize the Eirich mixers both in Phase III and in a commercial process. Because the formulation must be carefully controlled, especially with regard to the water addition, a batch process is preferred over a continuous operation for the mixing step. Eirich mixers are ideally suited

to perform the blending, mixing, and pelletizing operation on a batch basis. In order to achieve a formulation using less water, additional loadings of binders or burnouts must be substituted for the water. The formulation focused on the use of Mogul 1607, a relatively low cost corn based binder. To minimize the effect of water in the mix while attempting to make a pelletized form for extrusion, Nalco 1181 was added. This additive holds the water, even under pressure as during extrusion.

EIRICH MIXER TRIALS (Pelletized Formulation)

Alcoa Technical Center had two sizes of Eirich mixers available: an RV02 and a R-7. The size and capacity of each machine were discussed previously. The initial focus on Eirich mixer trials were to determine: a) if dry mixing in the Eirich adequately blends the alumina materials and binders, b) if dry dispersion of the Methocel and subsequent addition of water was equivalent to hot dispersion, and c) if the paste formulation could be modified to reduce the free water and still attain the target density by increasing the loading of other binders. Burnouts to partially replace the free moisture included Mogul 1607, a relatively low cost corn based binder, and water adsorbing polymers such as Nalco 1181 or Waterlock A-180. Nalco 1181 is a polymer that retains water in an amount equal to many times its weight in the formulation. Methocel was still required in the mix to impart plastic properties while holding a large quantity of water. The combination of binders and the free moisture content had to be optimized to change the formulation from a paste to a pelletized mix. It was found that the Mogul binder also served to reduce the stickiness of the extruded shapes that could contribute to processing problems during drying and sintering in a commercial process.

Runs in RV02 Eirich

The small Eirich was utilized first to establish a revised formulation using batch sizes comprised of about 5 kg of aluminous materials. Several Eirich machine variables were available to change, including bowl speed and rotor direction and speed. It was found that these variables contributed to success or failure of pelletized mixes because the addition of water required was borderline for a pelletized product. There was a strong tendency to form a paste in the Eirich. To compensate for this, the amount of water was reduced, but this caused an undesired increase in density. For this reason, further modifications of formulation and procedures were required.

Runs 15 to 21:

This experimental series utilized the same alumina mixes as in previous work leading to this point in Phase II. However, to attain a formulation containing less free moisture while still exhibiting the same target fired density of 2.5 g/cm^3 required higher binder loadings. Mogul 1607 is a low cost binder, compared to Methocel. Runs were conducted to evaluate loadings from 4 to 8 wt% Mogul, while reducing the Methocel from previous levels to 0.1 wt%. Another reason for reducing the Methocel loading, in addition to cost, was that higher levels of Methocel resulted in a sticky extrudate that could cause operating problems during and after drying. Experimental results are given in the master spreadsheet (Appendix A) and in Table 9 that summarizes all the RV02 experiments. More detailed data for this run were included in Appendices B-1, B-2, and B-3. No strength measurements were made for this series of tests because the focus was to first adjust the formulation to give pelletized granules and the proper density after firing. The efficacy of adsorbent polymers was tested. The benefit sought was to allow free moisture to be added at levels

approaching a paste formulation, while causing the mixture to behave as though lower levels of water were used.

In this series of runs, the actual moisture that could be tolerated during Eirich mixing fell short of that needed to reach the target fired density. Thus, fired density ranged from a low of 2.81 to a high of 3.08 for this series. From the description of the mixer discharge, it was noted that the physical form of the mixes was borderline pelletized product.

Runs 22 to 30 and 34:

Because of the concern over magnesium oxide impurity in the Mogul ash (after combustion), the loading was reduced from 8 to a level of 5 wt%. MgO in ppm levels is capable of increasing the sintering or densification of aluminas. This increased densification could be counter-productive while trying to attain a porous aggregate under conditions of controlled densification to a final target density. Experimental results are given in the master spreadsheet (Appendix A) and in Table 9 that summarizes all the RV02 experiments. More detailed data for this run are included in Appendices B-1, B-2, and B-3. Fired densities in this series were high, ranging from a low of 2.56 to a high of 2.99 g/cm³. No strength measurements were made for most of this series of tests because the focus was to adjust the formulation to give pelletized granules and the proper density after firing. Strength measurements were made only for runs 28, 29, and 30. These measurements ranged from 48.2 to 55.6 MPa and were generally in the same range as for all previous measurements for Phase II formulations.

Runs 37 to 46

The final series of tests in the small Eirich focused on a 60% A-13/40% A-13M formulation. In a few cases CP-2 was substituted for a portion of the A-13M component. The Mogul loading targeted 5 wt%. Nalco 1181 was tested in a few cases. Experimental results are given in the master spreadsheet (Appendix A) and in Table 9 that summarizes all the RV02 experiments. More detailed data for this run were included in Appendices B-1, B-2, and B-3. The fired density for this series ranged from a low of 2.20 to a high of 2.80 g/cm³. The low density (below target) was attained because of excessive water addition. The mix was characterized as poor, with paste being the physical form, rather than pellets. Strength measurements were made for only for runs 41 and 43 through 46. These measurements ranged from 38.2 to 55.8 MPa and were generally in the same range as for all previous measurements for Phase II formulations.

Runs in R-7 Eirich

The larger Eirich mixer was used to process 45.5 kg batches of aluminous components. A few R-7 Eirich runs were interspersed during the Phase II development when an RV02 Eirich formulation appeared to be successful enough for scale-up. It was during the attempted scale-up from the RV02 to the R-7 Eirich that it was learned that the machine variables were extremely important in view of the borderline, pelletized formulation. For example, the 'TIPS' speed of the R-7 Eirich rotor was slowed as far as possible by changing a pulley. The pin rotor was found to mull the mix into a paste. A star rotor was purchased and proved to be critical to the successful processing of a pelletized formulation in the R-7 Eirich. A total of ten R-7 Eirich runs were performed. The first four were development runs and the last six were production runs aimed at producing a rather large quantity of aggregate for testing by Thermal Ceramics.

TABLE 9

STANDARD DATA SUMMARY FOR FORMULATION VARIABLES USING ENRICH RV02 MIXER

RUN NO.	BINDER LOADING DRY WT %	BINDER	BINDER LOADING WT %	OTHER	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-38 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FIRE DENSITY g/cc	STRENGTH FIRE MPa	STRENGTH FIRE Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP.S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
15	---	---	MOGUL 1607 8.0			5,140	35			65	18.0	GOOD, GRANULAR	1.71	2.86			26.43	9.24	3.89	28.11	1.68
16	---	---	MOGUL 1607 8.0			5,321	50	50			23.4	POOR, PASTY	1.71	3.08			18.19	5.91	3.76	22.64	4.45
17	METHOCCEL 20-214 0.10	---	MOGUL 1607 4.0			5,140	35			65	18.0	FAR, GRINKS	1.75	3.04			20.77	6.84	3.83	23.66	2.89
18	METHOCCEL 20-214 0.10	---	MOGUL 1607 4.0			5,321	50	50			24.0	GOOD, GRANULAR	1.69	3.11			16.05	5.35	3.74	21.77	5.12
19A	---	---	MOGUL 1607 4.0			5,140	35			65	17.0	FAR, BALLED	1.74	2.98			22.37	7.50	3.84	25.04	2.67
19B	---	---	---			---	---	---	---	---	17.1		1.74	3.00			21.78	7.25	3.84	24.52	2.74
20	METHOCCEL 20-214 0.20	---	MOGUL 1607 5.0			5,140	35			65	17.8	GOOD, GRANULAR	1.64	2.84			26.69	9.40	3.87	28.69	2.00
21A	METHOCCEL 20-214 0.20	---	MOGUL 1607 5.0	NALCO 1181	0.35	5,140	35			65	19.2	GOOD, GRANULAR	1.62	2.88			25.47	8.84	3.86	27.63	2.16
21B	---	---	---			---	---	---	---	---	20.3		1.59	2.81			27.10	9.64	3.86	29.32	2.22
22	METHOCCEL 20-214 0.50	---	MOGUL 1607 5.0			5,321	50	50			25.2	POOR, PASTE	1.58	2.96			22.27	7.51	3.81	25.51	3.24
23	METHOCCEL 20-214 0.50	---	MOGUL 1607 5.0	NALCO 1181	0.5	5,321	50	50			27.8	GOOD, GRANULAR	1.54	2.94			24.21	8.23	3.88	26.05	1.84
24	METHOCCEL 20-214 0.50	---	MOGUL 1607 5.0	WATERLOCK A-100	0.5	5,321	50	50			27.5	GOOD, GRANULAR	1.55	2.99			22.79	7.63	3.87	24.90	2.11
25	METHOCCEL 20-214 1.00	---	MOGUL 1607 2.0			5,321	50	50			26.8	POOR, PASTY	1.31	2.59			33.34	12.89	3.88	35.02	1.88
26	METHOCCEL 20-214 1.00	---	MOGUL 1607 2.0	NALCO 1181	0.5	5,321	50	50			27.8	GOOD, GRANULAR	1.52	2.93			24.18	8.26	3.86	26.42	2.24
27	METHOCCEL 20-214 1.00	---	MOGUL 1607 2.0	NALCO 1181	0.5	5,321	40	60			28.2	GOOD, GRANULAR	1.48	2.85			27.01	9.49	3.90	28.50	1.49
28	METHOCCEL 20-214 1.00	---	MOGUL 1607 2.0	NALCO 1181	0.5	5,321	25	75			29.1	GOOD, GRANULAR	1.38	2.58	55.8	0.237	33.92	13.15	3.90	35.20	1.28
29	METHOCCEL 20-214 1.50	---	MOGUL 1607 3.0	NALCO 1181	0.5	5,321	25	75			28.8	GOOD, GRANULAR	1.40	2.60	49.0	0.216	33.43	12.66	3.90	34.79	1.36
30	METHOCCEL 20-214 1.50	---	MOGUL 1607 3.0	WATERLOCK A-180	0.5	5,321	25	75			29.0	GOOD, GRANULAR	1.38	2.56	48.2	0.208	34.48	13.46	3.91	35.64	1.16
34	METHOCCEL 20-214 1.50	---	MOGUL 1607 5.0	NALCO 1181	0.5	5,321	20	80			27.1	GOOD, GRANULAR	1.41	2.63			32.11	12.19	3.88	33.80	1.69
37	METHOCCEL 20-214 1.50	---	MOGUL 1607 3.0			5,321	40	60			27.5	POOR, PASTE	1.21	2.38			39.04	16.44	3.90	40.30	1.26
38	METHOCCEL 20-214 1.50	---	MOGUL 1607 5.0			5,321	40	60			27.5	POOR, PASTE	1.38	2.63			32.78	12.45	3.92	33.81	1.03
39	METHOCCEL 20-214 2.00	---	MOGUL 1607 3.0			5,321	40	60			28.4	POOR, PASTE	1.31	2.53			35.23	13.92	3.91	36.39	1.16
40	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0			5,321	40	60			26.2	FAR, GRINKS	1.45	2.78			29.18	10.50	3.92	30.18	1.00
41	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0			5,321	30	60	10		26.8	GOOD, GRANULES	1.47	2.67	55.8		31.45	11.80	3.89	33.02	1.57
42	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0	NALCO 1181	0.5	5,321	40	60			27.7	GOOD, GRANULES	1.47	2.60			28.45	10.19	3.91	29.76	1.31
43	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0			4,850	30	60	10		30.0	POOR, PASTE	1.18	2.20	48.4		43.40	19.70	3.89	44.62	1.22
44	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0	NALCO 1181	0.5	4,625	30	60	10		30.1	GOOD, GRANULES	1.44	2.62	38.6		32.78	12.53	3.89	34.27	1.49
45	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0	NALCO 1181	0.5	4,625	40	60			29.8	GOOD, GRANULES	1.45	2.71	38.2		30.50	11.26	3.90	31.91	1.41
46	METHOCCEL 20-214 2.00	---	MOGUL 1607 5.0			4,650	30	60	10		28.2	GOOD, GRANULES	1.37	2.51	41.1		35.37	14.08	3.89	36.86	1.49

Runs 31, 33, 35, and 36

This series of runs utilized a formulation containing 80% A-13/20% A-13M, with two levels of Methocel ranging from 1.0 to 1.75 wt% and three levels of Mogul ranging from 2 to 5 wt%. Nalco 1181 was also used at a level of 0.5 wt%. Experimental results are given in the master spreadsheet (Appendix A) and in Table 10 that summarizes all the R-7 Eirich experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3 and B-5. The fired density for this series ranged from a low of 2.59 to a high of 2.69 g/cm³. Fired strength, determined only for run 36, was 46.1 MPa. Of importance was the physical form of the mixed material leaving the Eirich mixer. Table 10 details this information. Runs 31 and 32 were paste in the Eirich. Runs 35 and 36 were marginal, because they formed a paste in the Eirich that pelletized only as it was being discharged.

Of these four runs, only run 36 was fired in its entirety by Harbison-Walker. The earlier runs did not possess a fired density, based on small samples of the lot fired at ATC, to warrant firing of the complete batch. A secondary reason not to fire these batches was that paste, not pellets, formed in the Eirich. Thus, the formulation was not adequately optimized for Eirich use. All the runs except for run 36 utilized ATC's R-7 Eirich that had a pin rotor. During this test work, Eirich machine variables were found to be important because the formulation with the required water addition for density formed a marginal product in the Eirich (paste, not pellets). The rotor was slowed as far as possible by a pulley and belt change to avoid mulling the mix. It was recognized that a star rotor (as in the RV02 Eirich) would have advantage over the pin rotor because it would lift the product away from the rotor path during mixing. A star rotor was purchased but not delivered until after Run 36. Run 36 was performed in Harbison-Walker's R-7 Eirich that had a star rotor. Unfortunately, due to contaminants evidently pick-up in H-W's R-7 Eirich, the large batch could not be used. Fired samples from Run 36 were characterized for density. Samples fired at Alcoa and Harbison-Walker showed different densities of 2.59 and 2.80 g/cm³, respectively, each based on an average of 10 specimens. Based on the green density, a fired density around 2.5 g/cm³ was expected. The shrinkage determined after sintering for Run 36 was slightly higher than normal. An increased level of impurity (MgO) that impacts on densification was likely present in the batch. In addition to a tan color after firing at H-W, higher than normal shrinkage values measured on machined, Alcoa fired specimens also indicated an impurity problem. The reason for the density difference between Alcoa and H-W fired material from the same Eirich batch is unknown. It was noted that the H-W fired samples displayed considerably more colored area. It was observed that the color correlated with higher density for the specimens.

Because of the difficulties attaining the target fired density along with the required pelletized condition of the discharge from the Eirich mixer, a decision was made to return to the small Eirich for additional development work (Runs 37 through 46, previously discussed under the RV02 Eirich section). The formulation for Run 46 was considered to be perfected and ready for scale-up in the R-7 Eirich.

Runs 47 to 52

This series of runs would be considered production runs aimed solely at generating sufficient quantity of the aggregate for evaluation by Thermal Ceramics in two product formulations. This series of runs utilized 42 kg batches and a formulation containing 60% A-13/30% A-13M/10% CP-2. Binders included Mogul 1607 at 5.0 wt% and Methocel 20-214 at 2.0 wt%. The moisture level attained was 28.2%. With proper diligence, meaning rapid addition of the water as a spray and no further mixing after the water

TABLE 10
STANDARD DATA SUMMARY FOR FORMULATIONS VARIABLES USING R7 ERICH MIXER AND 3" EXTRUDER

RUN NO.	BINDER LOADING DRY WT %	BINDER LOADING WT %	OTHER LOADING WT %	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc	STRENGTH FRED MPa	STRENGTH FRED Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
31	METHOCEL 20-214 1.00	MOGUL 1807 2.0	NALCO 1181 0.5	74,800	20	80	---	---	29.0	POOR, PASTE	1.41	2.67			30.91	11.56	3.87	32.79	1.88	
33	METHOCEL 20-214 1.50	MOGUL 1807 3.0	NALCO 1181 0.5	43,091	20	80	---	---	28.6	POOR, PASTE	1.39	2.62			32.38	12.36	3.88	34.13	1.75	
35	METHOCEL 20-214 1.50	MOGUL 1807 5.0	NALCO 1181 0.5	42,185	20	80	---	---	26.5	POOR, PASTE *	1.39	2.69			31.31	11.66	3.91	32.47	1.16	
36	METHOCEL 20-214 1.75	MOGUL 1807 4.75	NALCO 1181 0.5	42,185	20	80	---	---	28.3	POOR, PASTE *	1.31	2.59	46.1	0.166	33.91	13.12	3.92	34.97	1.06	
47	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	FAIR, CHUNKS	1.37	2.52	39.2		35.10	13.93	3.89	36.62	1.52	
48	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	PASTE & GRANULES	1.36	2.51	37.1		34.58	13.60	3.84	36.95	2.37	
49	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	GOOD, GRANULES	1.41	2.56	44.3		34.19	13.34	3.90	35.56	1.39	
50	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	GOOD, GRANULES	1.36	2.54	37.6		34.78	13.70	3.89	36.22	1.44	
51	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	GOOD, GRANULES	1.40	2.55	38.1		34.31	13.44	3.89	35.83	1.52	
52	METHOCEL 20-214 2.00	MOGUL 1807 5.0		42,184	30	60	10	---	28.2	GOOD, GRANULES	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	

* Pelletized by rotor upon discharge through bottom door.
N.D. = NOT DETERMINED

addition, pelletized material was prepared in the R-7 Eirich for the final four runs. Experimental results are given in the master spreadsheet (Appendix A) and in Table 10 that summarizes all the R-7 Eirich experiments. More detailed data for this run were included in Appendices B-1, B-2, B-3 and B-5. Only Runs 47 to 51 were characterized. Run 52 was done at a later date on a rush basis to provide additional material for sizing and was not characterized since it utilized the same formulation and processing procedures as Runs 47 through 51. The average density for the large batches fired by Harbison-Walker comprising the lot for Thermal Ceramics was 2.63, slightly above the 2.5 g/cm³ target. ATC fired specimens from these same lots resulted in an average density of 2.54 g/cm³. This difference again points to the possibility of a contaminant, this time from the H-W furnace lining or atmosphere. Alcoa's small converters and Eirich mixers were dedicated solely to this contract, a fact that eliminated any outside sources of contamination. Fired strength for this series averaged 39.3 MPa.

TOLL PROCESSING BY H-W

Runs identified as 6 and 8 (a total of 228 kg) were toll processed by H-W (fired, crushed, sized) and subsequently evaluated in their test program for bricks. Table 11 summarizes the formulations and characterization tests made on these runs. Both of these runs were paste formulations, made using a Simpson mix muller and extruded using the 3 in. extruder. The other major difference in the two formulations was that Run 8 utilized C-30 hydrate as a replacement for the A-13 material. It was previously noted that the use of C-30 hydrate was without any apparent adverse effects, at least in static sintering situation. The measured properties were comparable. The C-30 formulation required less water, a possible advantage for a pelletized formulation that must minimize the free moisture addition. Raw material cost for C-30, substituted for A-13, should also be slightly lower.

Based on limited data acquired during the crushing/sizing of the fired material into aggregate, the measured weight loss due to crushing of Run 8 was 7.1%. Sizing of the material on vibrating screens resulted in another 4.6% weight loss. For design purposes, combining these two losses results in ~11.7% total loss due to processing. In the pilot system these fines were lost to the dust collection system. In a plant process, perhaps the fines could be recovered. It remains to be determined if recovered fines would be usable because they may lack the required macroporosity.

Referring to Table 11, the average fired density for the paste formulations was 2.45 and 2.42 g/cm³, for Runs 6 and 8, respectively. Strength values for these runs were approximately the same at 44 MPa. Closed porosity was about 2% for the LWA, which is the nominal level throughout this development work. There was excellent agreement between the fired density measurements for the material fired at ATC or at Harbison-Walker.

Runs 47 through 52 (a total of 253 kg) were toll processed by H-W (fired, crushed, sized) and returned to Alcoa for shipment to Thermal Ceramics for evaluation in castables. These runs produced a borderline, pelletized extruder feed from a R-7 Eirich mixer. The formulation used was 60% A-13/30% A-13M/10% CP-2, with 5.0 wt% Mogul 1607 and 2.0 wt% Methocel 20-214. The free moisture content was 28.2 wt%. Because of the thermal conductivity method used by Thermal Ceramics for castables, the total quantity of sized aggregate needed for evaluation in two castables was estimated at 142.9 kg (315 lb).

TABLE 11

Characterization of Runes #6 #8 (Paste Formulations) Utilized by Harbison-Walker in Brick Formulation.

RUN NO.	BINDER	BINDER LOADING DRY WT %	BINDER	BINDER LOADING WT %	OTHER	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FIRE DENSITY g/cc Note 1	FIRE DENSITY g/cc Note 2	STRENGTH FIRE MPa	STRENGTH FIRE Coef of Var	APPARENT POROSITY %	H2O ADSORP %	APP.S.G. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
RUN 6-1	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.23	2.41	Note 3	42.4	0.269	37.50	15.54	3.86	39.36	1.86
RUN 6-2	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.24	2.45				36.50	14.89	3.86	38.39	1.89
RUN 6-3	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.22	2.42				37.38	15.42	3.87	39.08	1.70
RUN 6-4	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.23	2.43				37.18	15.30	3.87	38.95	1.77
RUN 6-5	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.23	2.43		41.5	0.224	37.15	15.26	3.87	38.89	1.74
RUN 6-6	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.25	2.46				36.03	14.55	3.87	37.76	1.73
RUN 6-7	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.27	2.48		52.1	0.316	35.69	14.39	3.86	37.61	1.92
RUN 6-8	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.23	2.40				36.05	15.85	3.86	39.66	1.63
RUN 6-9	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.26	2.46				36.14	14.67	3.86	38.10	1.96
RUN 6-10	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.29	2.52				34.95	13.89	3.87	36.77	1.82
RUN 6-11	METHOCCEL 20-214	1.57					8514	50	50			26.4	PASTE	1.25	2.46				36.32	14.74	3.87	38.10	1.78
RUN 6-12	METHOCCEL 20-214	1.57					10,510	50	50			26.4	PASTE	1.25	2.45		43.1	0.300	36.56	14.91	3.87	38.34	1.76
							104,184						AVERAGE VALUES	1.25	2.45	2.43	44.8	0.277	36.62	14.95	3.87	38.42	1.80
RUN 8-1	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.31	2.41	Note 4	46.9	0.219	37.46	15.53	3.86	39.38	1.92
RUN 8-2	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.30	2.39				36.20	16.01	3.86	40.06	1.86
RUN 8-3	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.31	2.40				37.69	15.71	3.85	39.72	2.03
RUN 8-4	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.31	2.41				37.53	15.56	3.86	39.38	1.85
RUN 8-5	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.32	2.42		40.8	0.246	37.34	15.43	3.86	39.20	1.86
RUN 8-6	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.32	2.43				36.77	15.11	3.85	38.83	2.06
RUN 8-7	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.34	2.45		43.6	0.240	36.32	14.80	3.85	38.35	2.03
RUN 8-8	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.33	2.45				36.40	14.87	3.85	38.50	2.10
RUN 8-9	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.32	2.43				36.74	15.11	3.84	38.89	2.15
RUN 8-10	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.28	2.36				36.83	16.47	3.86	40.74	1.91
RUN 8-11	METHOCCEL 20-214	1.01					10,280	35			65	18.7	PASTE	1.29	2.39				36.10	15.97	3.86	40.05	1.95
RUN 8-12	METHOCCEL 20-214	1.01					10,708	35			65	18.7	PASTE	1.31	2.44		43.5	0.264	36.61	15.00	3.85	38.64	2.03
							123,780						AVERAGE VALUES	1.31	2.42	2.45	43.7	0.247	37.33	15.46	3.85	39.31	1.98

Note 1: Fired at ATC with density determined at ATC.

Note 2: Fired at H-W with density determined at ATC.

Note 3: Average fired density for 3 composite batches fired at H-W with analysis at ATC.

Note 4: Average fired density for 4 composite batches fired at H-W with analysis at ATC.

To prepare for this quantity, 272.2 kg (600 lb) of fired aggregate was processed in Runs 47 to 52. Another reason for preparing the excess of material was that Thermal Ceramics specified two distinct size formulations for their evaluation. Dust losses and off-spec material as a result of crushing and sizing were expected to contribute to the need for excess material. A summary of the characterization of the pelletized material from these runs is given in Table 12. Note that the formulation was altered from the paste recipe and required more binder and just slightly more water. Note that the ATC fired specimens resulted in a density of 2.54, very close to the 2.5 g/cm³ target. However, the large lots fired at H-W resulted in a density of 2.63, probably due to a contaminant in the H-W furnace lining or atmosphere. Fired strength was approximately 40 MPa. The pelletized formulation would be considered borderline because to reduce the density further would require more water or burnouts. The mix will not tolerate more water and still remain in a pelletized form. The importance of retaining a pelletized form is that the Eirich mixer will not process and discharge a paste mix. Formation of a paste in the Eirich mixer would result in severe processing problems.

INTERMEDIATE STRENGTH OF EXTRUDED FORMS DURING SINTERING

Based on preliminary tests in which lightweight aggregate precursor shapes were heated at 500°C to burnout the binders followed by crude assessment of remaining adhesion by rubbing the shapes between the fingers, a concern was raised that the extruded shapes would not survive passage through the converter. The concern is that there will be a period of movement through the converter when the binder has decomposed (leaving a porous, weak structure) and sintering of the particles has not yet begun. During this period, the shapes would be susceptible to disintegration. It remains to be determined how critical this factor will be in dynamic sintering equipment. Variables that impact on this factor include: a) the time in the shaft furnace (after binder burnout and before the start of sintering) that the specimens are in this fragile condition, b) the particle-to-particle abrasion as the shapes travel through the furnace, and c) the compressive load due to the height of the bed on specimens in the furnace. Further experimentation with the formulation is proposed to improve this situation by employing inorganic binders, while maintaining the 99+% alumina purity specification. It is also strongly recommended that a pilot-scale dynamic sintering trial be performed by a toll processor during the pre-qualification trial of Phase III.

REFRACTORY MANUFACTURER EVALUATION OF LWA

The two refractory manufacturers involved in the testing of aggregate in actual product formulations were Harbison-Walker and Thermal Ceramics. These manufacturers were selected to broaden industry coverage of refractories because H-W specializes in bricks, for the glass, steel, and aluminum industries, while Thermal Ceramics specializes in castable refractories for the petrochemicals industry. The test results from each played an important part in the decision whether to proceed or not with Phase III of this contract (the demonstration phase). The other key components of the decision to proceed or not were: a) the economic feasibility study, and b) the market survey for this new LWA, more correctly termed a premium grade, medium weight aggregate material.

TABLE 12

Characterization of Runs #47 -52 (Ehrich R7 Palletized Formulation) Utilized by Thermal Ceramics in Castables.

RUN NO.	BINDER	BINDER LOADING DRY WT %	BINDER	BINDER LOADING WT %	OTHER	OTHER LOADING WT %	DRY SOLIDS grams	A-13M %	A-13 %	CP-2 %	C-30 %	ACTUAL MOIST. %	MIXER PRODUCT	GREEN DENSITY g/cc	FRED DENSITY g/cc Note 1	FRED DENSITY g/cc Note 2	STRENGTH FRED MPa	STRENGTH FRED Coal of Var	APPARENT POROSITY %	H2O ADSORP %	APP.S.Q. g/cc	TOTAL POROSITY %	CLOSED POROSITY %
47	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	FAIR, CHUNKS	1.37	2.52	2.61	39.2		35.10	13.93	3.89	36.62	1.52
48	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	PASTE & GRANULES	1.36	2.51	2.60	37.1		34.58	13.80	3.84	36.95	2.37
49	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	GOOD, GRANULES	1.41	2.56	2.64	44.3		34.19	13.34	3.90	35.58	1.39
50	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	GOOD, GRANULES	1.38	2.54	2.64	37.6		34.78	13.70	3.89	36.22	1.44
51	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	GOOD, GRANULES	1.40	2.55	2.64	38.1		34.31	13.44	3.89	35.83	1.52
52	METHOCEL 20-214	2.00	MOGUL 1807	5.0			42,184	30	60	10	---	28.2	GOOD, GRANULES	N.D.	N.D.	N.D.	N.D.		N.D.	N.D.	N.D.	N.D.	N.D.
							253,104						AVERAGE VALUES	1.38	2.54	2.63	39.3		34.59	13.64	3.88	36.24	1.65

Note 1: Fired at ATC with density determined at ATC.

Note 2: Fired at H-W with density determined at ATC.

Note 3: N.D. = Not Determined

HARBISON-WALKER

Under subcontract to Alcoa, Harbison-Walker entered an agreement to evaluate (form, fire, test, and report) this new aggregate in a single product formulation. The evaluation included two Alcoa LWA formulations using Alcoa Runs 6 and 8 in a high alumina brick formulation. As control samples the contractor included two lab made standards using Tabular™ or bubble alumina in the refractory brick formulation. The tests performed on the brick samples included: a) bulk density, b) apparent porosity, c) modulus of rupture, d) cold crushing strength, and e) thermal conductivity (hot wire method only). Approximately 120 kg of each Alcoa run was supplied to H-W for use in their evaluation.

The report from Harbison-Walker is provided in Appendix C-5. Of importance is the thermal conductivity reduction, compared to published values for the standard product made with Tabular™ alumina. For Run 6 compared to the standard brick, the reduction in thermal conductivity ranged from 19.6% at 204°C (400°F) to 31.8% at 982°C (1800°F). For Run 8 compared to the standard brick, the reduction in thermal conductivity ranged from 15.1% at 204°C (400°F) to 28.5% at 982°C (1800°F). The summary of the H-W report stated that the new aggregate resulted in the manufacture of a strong, 2.47-2.53 g/cm³ (154-158 pcf) high alumina brick with a unique combination of properties, including density, strength, refractoriness, chemical purity, and thermal conductivity. The high purity of the lightweight aggregate suggests that it could be used to manufacture a lightweight refractory brick having an alumina content of up to 99% and a service temperature of ~1815°C (3300°F). Harbison-Walker also expressed an interest in this LWA for refractory plastics and castables.

THERMAL CERAMICS

Under subcontract to Alcoa, Thermal Ceramics entered an agreement to evaluate (form, fire, test, and report) this new aggregate in two product formulations. The evaluation included Kao-Tab 95 (a cement based castable containing ~75% aggregate and 25% cement) and Cerrox 700 (a cement free mix containing about 45 wt% aggregate that is cast thixotropically with the bond phase providing the flow), with comparison against lab formed, standard products of each. The tests performed on Kao-Tab 95 included: a) thermal conductivity, b) coefficient of thermal expansion, c) cold crushing strength, d) modulus of rupture, e) linear shrinkage, f) percent linear change, and g) hot load creep to 1371°C (2500°F). Items (d) through (f) were tested after firing to 815°C (1500°F) and 1760°C (3200°F) and cooled, while item (a) was run on just the LWA composition. Approximately 90.7 kg (200 lb) of LWA of a specified, proprietary size blend was provided for these tests under the Kao-Tab product line. This large quantity was needed to cast a slab for conductivity measurement and was key to forcing production of larger pilot quantities of material than originally planned for in Phase II. The Cerrox 700 compositions were subjected to these tests after firing to 1760°C (3200°F) and cooled: a) modulus of rupture, b) linear shrinkage, and c) percent linear shrinkage. Approximately 52.2 kg (115 lb) of LWA of a specified, proprietary size blend was provided for these tests under the Cerrox product line.

The report from Thermal Ceramics is provided in Appendix C-6. Of prime importance is the thermal conductivity reduction, compared to published values for the standard product. Reduction in thermal conductivity for the Kao-Tab 95 ranged from 19 to 34% for temperatures ranging from 1371°C (2500°F) to 260°C (500°F), respectively. Even though direct substitution of the LWA for Tabular™ did not likely result in the optimum properties,

the conclusion from the study was that the new aggregate has commercial promise. A castable or thixotropic casting mix would have to be redesigned around the aggregate to attain optimum performance. Thermal Ceramics also expressed an interest in this LWA for other refractory mixes.

FEASIBILITY STUDY OVERVIEW

An economic feasibility study was conducted for the lightweight aggregate process as a retrofit into the existing tabular production facilities within Alcoa. Because this evaluation is primarily for Alcoa's information to decide on the economic feasibility of this proposed process, details of the assumptions comprising this study are considered to be beyond the scope of this report. In addition, many of the details are considered Alcoa proprietary information. Only a summary of these results are presented, in Table 13. The variables in this study included: a) three nominal LWA production levels, b) three LWA selling prices, referenced to the current selling price of Alcoa Tabular™, on a volume basis, and c) three process scenarios. The nominal production levels were 10,000, 20,000 and 40,000 mt/yr. Selling prices were 15, 25, and 35% over the current price of Tabular™, on a volume basis. The process scenarios included worst, likely, and best case assumptions. The LWA process will have a level of recycle of fines that will not be negligible. Recycle of these fines within the process consumes binders/burnouts and processing capacity. These scenarios deal with assumptions on how these fines are handled. The notes at the bottom of Table 13 list the scenario bases. Assuming the 'likely' scenario represents a conservative but realistic view of the economics, and if a threshold R.O.I. of 15% is targeted, then a nominal production level of 20,000 mt/yr and a selling price of approximately 25% more than for Tabular™ on a volume basis is required. This translates to a selling price for the LWA equal to \$0.652/lb. A market survey is ongoing to determine whether the market and selling price will support further development of this new aggregate process. Based on the fines recycle anticipated for this process at a nominal production level of 20,000 mt/yr (44.1 million lb/yr), the actual production level would be ~34.8 million lb/yr. A schematic flowsheet for the LWA process is shown in Figure 1.

CONCLUSIONS

1. A pelletized lightweight aggregate formulation has been developed and scaled-up to pilot equipment.
2. The 99+% alumina aggregate exhibits a bulk density approaching 2.5 g/cm³ and a fired strength slightly lower than fused alumina.
3. Based on initial evaluation by two refractory manufacturers in brick and castable applications, the new aggregate offers adequate strength and thermal conductivity reductions up to ~34%, depending on the temperature and application. The new aggregate offers a unique combination of density, strength, and thermal properties not currently available in commercial aggregate.
4. Technical development has led to a pelletized formulation with borderline physical form leaving the Eirich mixer. The formulation requires further development to provide more latitude for the production of pelletized material without forming paste, while still attaining the bulk density target of 2.5 g/cm³.

Table 13

Summary of Economic Simulations for the LWA Process as Function of Production Level, Selling Price, and Process Scenarios

NOMINAL CAPACITY		SELLING PRICE	LWA SELLING PRICE	LIKELY CASE SCENARIO		WORST CASE SCENARIO		BEST CASE SCENARIO	
MT/YR	MILLION LB/YR	% (1)	\$/LB	ACTUAL PRODUCTION	R.O.I.	ACTUAL PRODUCTION	R.O.I.	ACTUAL PRODUCTION	R.O.I.
				MILLION LB/YR	%	MILLION LB/YR	%	MILLION LB/YR	%
20,000	44.1	15	\$0.600	34.8	6.5	34.8	-1.5	43.1	19.8
20,000	44.1	25	\$0.652	34.8	14.2	34.8	6.2	43.1	29.3
20,000	44.1	35	\$0.705	34.8	22.1	34.8	14.1	43.1	39.1
10,000	22.1	15	\$0.600	17.4	-5.6	17.4	-13.3	21.6	7.2
10,000	22.1	25	\$0.652	17.4	1.9	17.4	-5.8	21.6	16.5
10,000	22.1	35	\$0.705	17.4	9.5	17.4	1.8	21.6	25.9
40,000	88.2	15	\$0.600	69.6	12.4	69.6	4.3	86.2	25.7
40,000	88.2	25	\$0.652	69.6	20.1	69.6	12.1	86.2	35.4
40,000	88.2	35	\$0.705	69.6	28.1	69.6	20.0	86.2	45.2

NOTES: (1) % INCREMENTAL COST INCREASE OVER T-64 ON A VOLUME BASIS.

(2) R.O.I. CALCULATED AS NET PROFIT AFTER TAXES DIVIDED BY TOTAL CAPITAL INVESTMENT.

(3) ECONOMIC ANALYSIS SCENARIOS:

WORST CASE: PRODUCT FINES RECYCLED WITH NO CREDIT CLAIMED FOR ALUMINA VALUE.

LIKELY CASE: PRODUCT RECYCLE WITH CREDIT CLAIMED EQUAL TO RAW MATERIAL COST FOR A-13M.

BEST CASE: PRODUCT FINES ADDED TO PRODUCT WITH NO ADVERSE EFFECTS (NO RECYCLE WITHIN PROCESS).

FIGURE 1
LIGHTWEIGHT TUBULAR PROCESS
USING
A-13/A-13M FORMULATION

A-13 – Unground product
 A-13 M – Ground to - 325 mesh

5. The only technical issue with this new lightweight aggregate is the lack of intermediate strength after binder burnout and before sintering. Additional formulation development and testing is required to assure that this factor is not a show-stopper.
6. The pelletized process flowsheet was outlined and a preliminary economic feasibility study performed based on a process retrofit into the Arkansas tabular production facilities. Based on assumed market demand and selling price levels, the economics of the process were favorable. The decision on whether to proceed into Phase III of the contract will be based on a formal market survey that has commenced in 1994 October. This study will firm-up the assumptions dealing with market size and aggregate selling price.

RECOMMENDATIONS

1. Optimize the pelletized formulation further, with a focus on a closer approach to the targeted 2.5 g/cm^3 bulk density and improved pelletized physical form from the Eirich mixers. As part of the formulation optimization, include the use of C-30 hydrate as a full or partial substitute for A-13 material.
2. Evaluate the use of inorganic binders to provide intermediate bonding strength after the organic binders are burned out and before sintering begins. These inorganic binders must not violate the target objective of a 99+ % alumina refractory.
3. Because of the importance of intermediate strength during the dynamic firing process, verify during the Phase III pre-qualification of toll processors that the intermediate strength problem can be solved or is not a problem. It is imperative to attain this knowledge before the attempt is made to process the full Phase III production through the Arkansas plant converters.
4. Because the market survey is not completed as of this writing, any recommendation on whether or not to proceed with Phase III is deferred. From a technical and performance viewpoint, the new lightweight aggregate performs adequately and offers improved refractory properties not available from any competitive aggregate. The decision to proceed with Phase III will hinge on the demand and selling price combination available in the world market.

SAFETY

Safety is an important aspect of any experimental program. In this work high temperature firing and noxious vapors presented the most severe hazards. The material safety data sheets (MSDS) were considered to be an important aspect of safety awareness. These documents were reviewed for all materials used. Hoods over the converters and isolation of these units helped to minimize operator exposure to any fumes. Other working hazards that would become more threatening for large scale operation include dust problems, a concern both for the safety of the operator because of inhalation and also because of the explosion hazard for some of the organic dusts.

REFERENCES

1. MacZura, G., "Production Processes, Properties, and Applications for Tabular Alumina Refractory Aggregates," as published in Alumina Chemicals: Science and Technology Handbook, L. D. Hart, editor, Am. Ceramic Society, Westerville, Ohio, 109-170, 1990.

Appendix A – Master Spreadsheet

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PHASE 8 - DOE LT WAT REFACTORY - PLUT SCALE RUNS

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U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP	DQ	DR	DS	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC	ED	EE	EF	EG	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET	EU	EV	EW	EX	EY	EZ	FA	FB	FC	FD	FE	FF	FG	FH	FI	FJ	FK	FL	FM	FN	FO	FP	FQ	FR	FS	FT	FU	FV	FW	FX	FY	FZ	GA	GB	GC	GD	GE	GF	GG	GH	GI	GJ	GK	GL	GM	GN	GO	GP	GQ	GR	GS	GT	GU	GV	GW	GX	GY	GZ	HA	HB	HC	HD	HE	HF	HG	HH	HI	HJ	HK	HL	HM	HN	HO	HP	HQ	HR	HS	HT	HU	HV	HW	HX	HY	HZ	IA	IB	IC	ID	IE	IF	IG	IH	II	IJ	IK	IL	IM	IN	IO	IP	IQ	IR	IS	IT	IU	IV	IW	IX	IY	IZ	JA	JB	JC	JD	JE	JF	JG	JH	JI	JJ	JK	JL	JM	JN	JO	JP	JQ	JR	JS	JT	JU	JV	JW	JX	JY	JZ	KA	KB	KC	KD	KE	KF	KG	KH	KI	KJ	KL	KM	KN	KO	KP	KQ	KR	KS	KT	KU	KV	KW	KX	KY	KZ	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ	LK	LM	LN	LO	LP	LQ	LR	LS	LT	LU	LV	LW	LX	LY	LZ	MA	MB	MC	MD	ME	MF	MG	MH	MI	MJ	MK	ML	MM	MN	MO	MP	MQ	MR	MS	MT	MU	MV	MW	MX	MY	MZ	NA	NB	NC	ND	NE	NF	NG	NH	NI	NJ	NK	NL	NM	NN	NO	NP	NQ	NR	NS	NT	NU	NV	NW	NX	NY	NZ	OA	OB	OC	OD	OE	OF	OG	OH	OI	OJ	OK	OL	OM	ON	OO	OP	OQ	OR	OS	OT	OU	OV	OW	OX	OY	OZ	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	PK	PL	PM	PN	PO	PP	PQ	PR	PS	PT	PU	PV	PW	PX	PY	PZ	QA	QB	QC	QD	QE	QF	QG	QH	QI	QJ	QK	QL	QM	QN	QO	QP	QQ	QR	QS	QT	QU	QV	QW	QX	QY	QZ	RA	RB	RC	RD	RE	RF	RG	RH	RI	RJ	RK	RL	RM	RN	RO	RP	RQ	RR	RS	RT	RU	RV	RW	RX	RY	RZ	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM	SN	SO	SP	SQ	SR	SS	ST	SU	SV	SW	SX	SY	SZ	TA	TB	TC	TD	TE	TF	TG	TH	TI	TJ	TK	TL	TM	TN	TO	TP	TQ	TR	TS	TT	TU	TV	TW	TX	TY	TZ	UA	UB	UC	UD	UE	UF	UG	UH	UI	UJ	UK	UL	UM	UN	UO	UP	UQ	UR	US	UT	UU	UV	UW	UX	UY	UZ	VA	VB	VC	VD	VE	VF	VG	VH	VI	VJ	VK	VL	VM	VN	VO	VP	VQ	VR	VS	VT	VU	VV	VW	VX	VY	VZ	WA	WB	WC	WD	WE	WF	WG	WH	WI	WJ	WK	WL	WM	WN	WO	WP	WQ	WR	WS	WT	WU	WV	WW	WX	WY	WZ	XA	XB	XC	XD	XE	XF	XG	XH	XI	XJ	XK	XL	XM	XN	XO	XP	XQ	XR	XS	XT	XU	XV	XW	XX	XY	XZ	YA	YB	YC	YD	YE	YF	YG	YH	YI	YJ	YK	YL	YM	YN	YO	YP	YQ	YR	YS	YT	YU	YV	YW	YX	YY	YZ	ZA	ZB	ZC	ZD	ZE	ZF	ZG	ZH	ZI	ZJ	ZK	ZL	ZM	ZN	ZO	ZP	ZQ	ZR	ZS	ZT	ZU	ZV	ZW	ZX	ZY	ZZ

PHI-EPT SUMMARY

Appendix B – Refractory Property Data

Appendix B-1	Raw Data and Green Density Calculations
Appendix B-2	Raw Data and Fired Density Calculations
Appendix B-3	Raw Data and Shrinkage Calculations
Appendix B-4	Raw Data and Green Strength Calculations
Appendix B-5	Raw Data and Fired Strength Calculations
Appendix B-5a	Weibull Modulus Calculation for Aggregate Strength

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Appendix B-1 – Raw Data and Green Density Calculations

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EXPT DESIGN 24127
GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	EXP. REF.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
EXTRUDED > 60%A-13M & 40%A-13(-270) W/ 2 WT% METHOCEL						
24127-19A	1	1.255	0.711	1.0813	0.880	1.23
24127-19B	1	1.326	0.725	1.2148	1.001	1.21
24127-19C	1	1.269	0.678	1.0362	0.858	1.21
24127-19D	1	1.252	0.556	0.8245	0.684	1.20
24127-19E	1	1.402	0.643	1.1776	0.993	1.19
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 4.68 WT% METHOCEL						
24127-24A	2	1.339	0.677	1.0217	0.953	1.07
24127-24B	2	1.389	0.696	1.1815	1.055	1.12
24127-24C	2	1.343	0.709	1.0777	1.004	1.07
24127-24D	2	1.264	0.726	1.0388	0.911	1.14
24127-24E	2	1.308	0.625	0.9141	0.840	1.09
EXTRUDED > 60%A-13M & 40%A-13UG W/ 4.4 WT% METHOCEL						
24127-21A	3	1.331	0.784	1.3579	1.091	1.24
24127-21B	3	1.338	0.807	1.3197	1.135	1.16
24127-21C	3	1.479	0.793	1.6033	1.362	1.18
24127-21D	3	1.285	0.746	1.1797	0.967	1.22
24127-21E	3	1.301	0.847	1.3544	1.126	1.20
EXTRUDED > 40%A-13M & 60%A-13UG W/ 2 WT% METHOCEL						
24127-22A	4	1.312	0.641	0.9489	0.867	1.09
24127-22B	4	1.341	0.719	1.1182	1.015	1.10
24127-22C	4	1.259	0.736	1.0208	0.916	1.11
24127-22D	4	1.305	0.794	1.1512	1.062	1.08
24127-22E	4	1.246	0.621	0.8066	0.757	1.07
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 6 WT% METHOCEL						
24127-18A	O2	1.171	0.724	0.8144	0.780	1.04
24127-18B	O2	1.115	0.72	0.7156	0.703	1.02
24127-18C	O2	1.161	0.686	0.7489	0.726	1.03
24127-18D	O2	1.172	0.775	0.9011	0.836	1.08
24127-18E	O2	1.178	0.739	0.8625	0.805	1.07

FIRED TO 1780°C

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	EXP.	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	REF.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
EXTRUDED > 60%A-13M & 40%A-13(-270) W/ 4.68 WT% METHOCEL						
24127-20F	5	1.264	0.794	1.1917	0.996	1.20
24127-20G	5	1.247	0.862	1.2141	1.053	1.15
24127-20H	5	1.255	0.801	1.1639	0.991	1.17
24127-20I	5	1.251	0.763	1.1186	0.938	1.19
24127-20J	5	1.243	0.778	1.1139	0.944	1.18
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 2 WT% METHOCEL						
24127-17F	6	1.238	0.701	0.9262	0.844	1.10
24127-17G	6	1.273	0.67	0.9454	0.853	1.11
24127-17H	6	1.217	0.62	0.7987	0.721	1.11
24127-17I	6	1.247	0.704	0.9599	0.860	1.12
24127-17J	6	1.293	0.698	0.9866	0.917	1.08
EXTRUDED > 60%A-13M & 40%A-13UG W/ 2 WT% METHOCEL						
24127-23F	7	1.309	0.853	1.3896	1.148	1.21
24127-23G	7	1.193	0.766	0.9891	0.856	1.16
24127-23H	7	1.347	0.824	1.4224	1.174	1.21
24127-23I	7	1.227	0.806	1.1567	0.953	1.21
24127-23J	7	1.23	0.809	1.1606	0.961	1.21
EXTRUDED > 40%A-13M & 60%A-13UG W/ 4.63 WT% METHOCEL						
24127-16F	8	1.237	0.704	0.9437	0.846	1.12
24127-16G	8	1.255	0.812	1.1503	1.004	1.15
24127-16H	8	1.225	0.743	0.9707	0.876	1.11
24127-16I	8	1.208	0.708	0.9441	0.811	1.16
24127-16J	8	1.218	0.785	1.0746	0.915	1.17

FIRED TO 1862°C

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE-RUN #1

SAMPLE		GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
SIZED SAMPLE REG EXT > 60%A-13M & 40%A-13UG W/ 1.55 WT% METHOCEL						
12742-A	2	1.499	1.159	2.9636	2.045	1.45
12742-B	2	1.447	1.116	2.6591	1.835	1.45
12742-C	2	1.498	1.105	2.8187	1.947	1.45
12742-D	4	1.446	1.055	2.4859	1.733	1.43
12742-E	4	1.461	1.134	2.7559	1.901	1.45
12742-F	4	1.42	1.111	2.5480	1.759	1.45
SIZED SAMPLE SWOLLEN EXT > 60%A-13M & 40%A-13UG W/ 1.55 WT% METHOCEL						
12742-SA	2	1.83	1.043	3.8125	2.743	1.39
12742-SB	2	1.83	1.104	4.0477	2.904	1.39
12742-SC	2	1.83	1.091	3.9759	2.870	1.39
12742-SD	4	1.831	1.086	3.9954	2.860	1.40
12742-SE	4	1.83	1.109	4.0573	2.917	1.39
12742-SF	4	1.83	1.099	4.0286	2.891	1.39

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
NO.	NO.	cm	cm	grams	cc	g/cc
LS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-A1	2	1.709	0.797	2.1168	1.828	1.16
12748-A2	2	1.801	0.971	2.8892	2.474	1.17
12748-A3	2	1.645	1.099	2.7014	2.336	1.16
12748-A4	2	1.661	1.302	3.3145	2.821	1.17
12748-A5	2	1.621	1.161	2.8225	2.396	1.18
LS EXT, V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-B1	2	1.762	0.978	2.8737	2.385	1.21
12748-B2	2	1.609	1.178	2.8308	2.395	1.18
12748-B3	2	1.601	0.879	2.1669	1.770	1.22
12748-B4	2	1.623	1.009	2.5245	2.087	1.21
12748-B5	2	1.646	0.969	2.4923	2.062	1.21
HS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-C1	2	1.749	0.882	2.5809	2.119	1.22
12748-C2	2	1.686	1.036	2.7486	2.313	1.19
12748-C3	2	1.744	1.007	2.9711	2.406	1.24
12748-C4	2	1.637	1.442	3.6781	3.035	1.21
12748-C5	2	1.646	1.122	2.8702	2.387	1.20
HS EXT, V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-D1	2	1.777	1.102	3.2146	2.733	1.18
12748-D2	2	1.797	1.194	3.6219	3.028	1.20
12748-D3	2	1.675	1.039	2.7809	2.289	1.21
12748-D4	2	1.749	1.073	3.0141	2.578	1.17
12748-D5	2	1.544	1.177	2.6701	2.204	1.21
LS EXT, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-E1	2	2.044	0.863	3.2606	2.832	1.15
12748-E2	2	1.811	1.207	3.7211	3.109	1.20
12748-E3	2	1.863	0.946	3.0634	2.579	1.19
12748-E4	2	1.685	1.251	3.3033	2.790	1.18
12748-E5	2	1.873	1.133	3.5754	3.122	1.15
LS EXT,V,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-F1	2	1.862	0.947	3.0989	2.579	1.20
12748-F2	2	1.899	0.809	2.6828	2.291	1.17
12748-F3	2	1.836	0.797	2.6115	2.110	1.24
12748-F4	2	1.786	0.876	2.5736	2.195	1.17
12748-F5	2	1.899	1.063	3.6977	3.011	1.23
HS EXT, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-G1	2	1.99	0.902	3.2921	2.805	1.17
12748-G2	2	1.91	0.89	3.1167	2.550	1.22
12748-G3	2	1.977	0.876	3.1487	2.689	1.17
12748-G4	2	1.773	0.765	2.2032	1.889	1.17
12748-G5	2	1.886	1.091	3.6763	3.048	1.21
HS EXT,V,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12748-H1	2	1.711	1.061	3.0315	2.440	1.24
12748-H2	2	1.796	0.712	2.1648	1.804	1.20
12748-H3	2	1.749	1.039	2.9609	2.496	1.19
12748-H4	2	1.811	1.057	3.3219	2.723	1.22
12748-H5	2	1.798	0.784	2.4443	1.991	1.23
SM EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
12750-A1	2	1.231	0.696	0.9996	0.828	1.21
12750-A2	2	1.254	0.707	1.0609	0.873	1.21
12750-A3	2	1.235	0.739	1.0474	0.885	1.18
12750-A4	2	1.189	0.784	1.0381	0.871	1.19
12750-A5	2	1.216	0.69	0.9601	0.801	1.20
12750-A6	2	1.192	0.647	0.8231	0.722	1.14

VARIABLES: LS-LOW SPEED, HS-HIGH SPEED, V-VACUUM, R-ROLLED, SM-SMALL

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
BATCH #1 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-1A	2	1.634	0.846	2.2402	1.774	1.26
25530-6-1B	2	1.633	0.847	2.2547	1.774	1.27
25530-6-1C	2	1.635	0.915	2.6783	1.921	1.39
25530-6-1D	2	1.634	0.723	1.8447	1.516	1.22
25530-6-1E	2	1.634	0.755	1.9246	1.583	1.22
BATCH #2 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-2A	2	1.634	1.112	3.0930	2.332	1.33
25530-6-2B	2	1.632	0.943	2.5336	1.973	1.28
25530-6-2C	2	1.633	0.989	2.6634	2.071	1.29
25530-6-2D	2	1.633	0.896	2.4827	1.877	1.32
25530-6-2E	2	1.632	0.924	2.5409	1.933	1.31
BATCH #3 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-3A	2	1.683	0.995	2.6593	2.214	1.20
25530-6-3B	2	1.684	0.818	2.2968	1.822	1.26
25530-6-3C	2	1.694	0.839	2.2433	1.891	1.19
25530-6-3D	2	1.659	0.819	2.1106	1.770	1.19
25530-6-3E	2	1.645	0.738	1.8806	1.568	1.20
BATCH #4 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-4A	2	1.63	0.873	2.1503	1.822	1.18
25530-6-4B	2	1.694	0.872	2.3382	1.965	1.19
25530-6-4C	2	1.719	0.921	2.5047	2.137	1.17
25530-6-4D	2	1.696	0.874	2.3424	1.974	1.19
25530-6-4E	2	1.695	0.832	2.2304	1.877	1.19
BATCH #5 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-5A	2	1.732	0.933	2.5907	2.198	1.18
25530-6-5B	2	1.707	1.048	2.8448	2.398	1.19
25530-6-5C	2	1.707	1.041	2.7794	2.382	1.17
25530-6-5D	2	1.732	0.884	2.4423	2.083	1.17
25530-6-5E	2	1.758	0.893	2.5365	2.168	1.17
BATCH #6 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-6A	2	1.73	1.065	2.9992	2.503	1.20
25530-6-6B	2	1.617	1.104	2.6898	2.267	1.19
25530-6-6C	2	1.731	1.012	2.8429	2.382	1.19
25530-6-6D	2	1.705	0.932	2.5313	2.128	1.19
25530-6-6E	2	1.756	0.96	2.7601	2.325	1.19

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
BATCH #7 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-7A	2	1.679	1.155	2.8648	2.557	1.12
25530-6-7B	2	1.705	1.135	2.9737	2.591	1.15
25530-6-7C	2	1.719	1.013	2.7461	2.351	1.17
25530-6-7D	2	1.666	0.985	2.4188	2.147	1.13
25530-6-7E	2	1.629	0.967	2.3581	2.015	1.17
BATCH #8 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-8A	2	1.679	1.13	2.9242	2.502	1.17
25530-6-8B	2	1.818	0.933	2.6976	2.422	1.11
25530-6-8C	2	1.805	0.966	2.7721	2.472	1.12
25530-6-8D	2	1.704	0.985	2.5784	2.246	1.15
25530-6-8E	2	1.602	0.832	1.9032	1.677	1.13
BATCH #9 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-9A	2	1.741	1.07	2.8879	2.547	1.13
25530-6-9B	2	1.728	1.098	2.9050	2.575	1.13
25530-6-9C	2	1.677	0.952	2.3495	2.103	1.12
25530-6-9D	2	1.677	0.983	2.4491	2.171	1.13
25530-6-9E	2	1.753	0.946	2.5165	2.283	1.10
BATCH #10 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-10A	2	1.653	1.306	3.1884	2.803	1.14
25530-6-10B	2	1.724	1.058	2.8397	2.470	1.15
25530-6-10C	2	1.752	1.127	3.0908	2.717	1.14
25530-6-10D	2	1.83	0.938	2.9259	2.467	1.19
25530-6-10E	2	1.754	0.969	2.6788	2.341	1.14
BATCH #11 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-11A	2	1.752	1.243	3.3252	2.997	1.11
25530-6-11B	2	1.726	1.066	2.7688	2.494	1.11
25530-6-11C	2	1.712	0.999	2.5996	2.300	1.13
25530-6-11D	2	1.689	0.878	2.1363	1.967	1.09
25530-6-11E	2	1.634	1.021	2.4189	2.141	1.13
BATCH #12 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL						
25530-6-12A	2	1.752	1.215	3.2768	2.929	1.12
25530-6-12B	2	1.839	1.064	3.2401	2.826	1.15
25530-6-12C	2	1.688	1.233	3.0031	2.759	1.09
25530-6-12D	2	1.776	1.058	2.8934	2.621	1.10
25530-6-12E	2	1.688	1.176	2.9427	2.632	1.12

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID. NO.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
RUN 4 - BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.62 WT% METHOCEL						
25530-21-1A	4	1.713	0.933	2.4196	2.150	1.13
25530-21-1B	4	1.699	1.139	2.9281	2.582	1.13
25530-21-1C	4	1.572	0.895	1.9893	1.737	1.15
25530-21-1D	4	1.686	1.19	3.1588	2.657	1.19
25530-21-1E	4	1.737	1.142	3.0394	2.706	1.12
RUN 4 - BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.54 WT% METHOCEL						
25530-21-2A*	4	1.739	1.143	3.7338	2.715	1.38
25530-21-2B*	4	1.587	1.226	3.3121	2.425	1.37
25530-21-2C*	4	1.536	1.342	3.3362	2.487	1.34
25530-21-2D*	4	1.688	1.229	3.7455	2.750	1.36
25530-21-2E*	4	1.777	1.395	4.7101	3.460	1.36
RUN 4 - BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.595 WT% METHOCEL						
25530-22-3A	4	1.689	1.129	3.1495	2.530	1.25
25530-22-3B	4	1.689	0.974	2.7022	2.182	1.24
25530-22-3C	4	1.638	1.232	3.2429	2.596	1.25
25530-22-3D	4	1.791	1.228	3.8193	3.094	1.23
25530-22-3E	4	1.689	1.021	2.8013	2.288	1.22
RUN 5 > 45%A-13M & 55%A-13UG W/ 1.607 WT% METHOCEL						
25530-22-5A	4	1.689	1.266	3.3831	2.836	1.19
25530-22-5B	4	1.689	0.964	2.6265	2.160	1.22
25530-22-5C	4	1.688	0.977	2.6519	2.186	1.21
25530-22-5D	4	1.741	1.031	3.0085	2.454	1.23
25530-22-5E	4	1.689	0.903	2.4735	2.023	1.22

***NOTE: EXCESS ALUMINA WAS KNEADED INTO MIX BY HAND**

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 6 BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-28-1A	2	1.673	0.845	2.2399	1.858	1.21
25530-28-1B	2	1.673	0.863	2.2876	1.897	1.21
25530-28-1C	2	1.673	0.923	2.5199	2.029	1.24
25530-28-1D	2	1.673	0.948	2.5861	2.084	1.24
25530-28-1E	2	1.673	1.015	2.8255	2.231	1.27
RUN 6 BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-29-2A	2	1.685	0.864	2.3929	1.927	1.24
25530-29-2B	2	1.685	0.897	2.4827	2.000	1.24
25530-29-2C	2	1.686	0.967	2.6946	2.159	1.25
25530-29-2D	2	1.685	0.953	2.6429	2.125	1.24
25530-29-2E	2	1.685	1.012	2.7948	2.257	1.24
RUN 6 BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-29-3A	2	1.697	0.878	2.4302	1.986	1.22
25530-29-3B	2	1.698	0.883	2.4209	2.000	1.21
25530-29-3C	2	1.698	0.889	2.4151	2.013	1.20
25530-29-3D	2	1.698	0.947	2.6467	2.144	1.23
25530-29-3E	2	1.697	0.993	2.7549	2.246	1.23
RUN 6 BATCH #4 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-29-4A	2	1.673	0.896	2.4162	1.970	1.23
25530-29-4B	2	1.673	0.961	2.6099	2.113	1.24
25530-29-4C	2	1.673	0.952	2.5762	2.093	1.23
25530-29-4D	2	1.673	0.935	2.5498	2.055	1.24
25530-29-4E	2	1.672	0.955	2.5556	2.097	1.22
RUN 6 BATCH #5 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-30-5A	2	1.685	0.839	2.2851	1.871	1.22
25530-30-5B	2	1.685	0.941	2.5953	2.098	1.24
25530-30-5C	2	1.685	0.933	2.5457	2.081	1.22
25530-30-5D	2	1.685	0.857	2.3636	1.911	1.24
25530-30-5E	2	1.685	0.939	2.5851	2.094	1.23
RUN 6 BATCH #6 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-30-6A	2	1.698	0.956	2.7212	2.165	1.26
25530-30-6B	2	1.685	0.983	2.7228	2.192	1.24
25530-30-6C	2	1.698	0.981	2.7822	2.221	1.25
25530-30-6D	2	1.698	1.025	2.8999	2.321	1.25
25530-30-6E	2	1.698	1.059	2.9949	2.398	1.25

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 6 BATCH #7 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-31-7A	2	1.66	1.068	2.9417	2.311	1.27
25530-31-7B	2	1.66	1.059	2.9218	2.292	1.27
25530-31-7C	2	1.659	1.059	2.9036	2.289	1.27
25530-31-7D	2	1.66	1.119	3.0877	2.422	1.27
25530-31-7E	2	1.659	1.137	3.1214	2.458	1.27
RUN 6 BATCH #8 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-31-8A	2	1.672	0.856	2.3121	1.879	1.23
25530-31-8B	2	1.672	0.916	2.5042	2.011	1.25
25530-31-8C	2	1.672	0.925	2.4877	2.031	1.22
25530-31-8D	2	1.671	0.967	2.5786	2.121	1.22
25530-31-8E	2	1.672	1.039	2.7919	2.281	1.22
RUN 6 BATCH #9 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-31-9A	2	1.684	0.978	2.7522	2.178	1.26
25530-31-9B	2	1.684	0.979	2.7516	2.181	1.26
25530-31-9C	2	1.683	1.022	2.8592	2.274	1.26
25530-31-9D	2	1.683	0.984	2.7588	2.189	1.26
25530-31-9E	2	1.683	1.019	2.8536	2.267	1.26
RUN 6 BATCH #10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-32-10A	2	1.696	1.029	2.9874	2.325	1.29
25530-32-10B	2	1.696	0.963	2.8048	2.176	1.29
25530-32-10C	2	1.696	0.977	2.8559	2.207	1.29
25530-32-10D	2	1.696	0.928	2.6779	2.096	1.28
25530-32-10E	2	1.696	1.017	2.9655	2.298	1.29
RUN 6 BATCH #11 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-32-11A	2	1.658	0.969	2.6157	2.092	1.25
25530-32-11B	2	1.658	0.99	2.6823	2.137	1.25
25530-32-11C	2	1.658	0.987	2.6608	2.131	1.25
25530-32-11D	2	1.658	1.001	2.7068	2.161	1.25
25530-32-11E	2	1.657	1.019	2.7387	2.197	1.25
RUN 6 BATCH #12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25530-33-12A	2	1.62	0.864	2.1964	1.781	1.23
25530-33-12B	2	1.619	0.911	2.3391	1.875	1.25
25530-33-12C	2	1.619	0.981	2.5146	2.020	1.25
25530-33-12D	2	1.619	1.055	2.7206	2.172	1.25
25530-33-12E	2	1.619	1.066	2.8038	2.195	1.28

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 7 BATCH 1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-39-A		1.742	0.893	2.7616	2.128	1.30
25530-39-B		1.743	0.932	2.8903	2.224	1.30
25530-39-C		1.743	0.841	2.6618	2.007	1.33
25530-39-D		1.743	0.902	2.8268	2.152	1.31
25530-39-E		1.734	0.966	2.9731	2.281	1.30
RUN 7 BATCH 2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-41-A		1.644	0.949	2.7053	2.014	1.34
25530-41-B		1.644	0.786	2.2052	1.668	1.32
25530-41-C		1.644	0.869	2.3939	1.845	1.30
25530-41-D		1.644	0.919	2.5915	1.951	1.33
25530-41-E		1.644	0.872	2.4621	1.851	1.33

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID. NO.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
RUN 8 BATCH #1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-46-1A	2	1.628	0.884	2.4071	1.840	1.31
25530-46-1B	2	1.628	0.829	2.2188	1.726	1.29
25530-46-1C	2	1.627	0.936	2.5364	1.946	1.30
25530-46-1D	2	1.629	0.966	2.6369	2.013	1.31
25530-46-1E	2	1.629	0.968	2.6959	2.017	1.34
RUN 8 BATCH #2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-47-2A	2	1.615	0.947	2.5161	1.940	1.30
25530-47-2B	2	1.607	0.891	2.3635	1.807	1.31
25530-47-2C	2	1.616	0.819	2.2007	1.680	1.31
25530-47-2D	2	1.619	1.009	2.7103	2.077	1.30
25530-47-2E	2	1.615	0.849	2.2323	1.739	1.28
RUN 8 BATCH #3 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-47-3A	2	1.679	0.905	2.6351	2.004	1.32
25530-47-3B	2	1.679	0.841	2.4147	1.862	1.30
25530-47-3C	2	1.681	0.944	2.7574	2.095	1.32
25530-47-3D	2	1.679	0.861	2.4654	1.906	1.29
25530-47-3E	2	1.681	0.943	2.7293	2.093	1.30
RUN 8 BATCH #4 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-47-4A	2	1.693	0.862	2.5758	1.940	1.33
25530-47-4B	2	1.693	0.953	2.8377	2.145	1.32
25530-47-4C	2	1.693	0.859	2.4844	1.934	1.28
25530-47-4D	2	1.693	0.914	2.7146	2.058	1.32
25530-47-4E	2	1.693	0.928	2.7399	2.089	1.31
RUN 8 BATCH #5 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-48-5A	2	1.621	0.908	2.4878	1.874	1.33
25530-48-5B	2	1.655	0.849	2.4098	1.826	1.32
25530-48-5C	2	1.656	0.899	2.5669	1.936	1.33
25530-48-5D	2	1.655	0.859	2.4248	1.848	1.31
25530-48-5E	2	1.653	0.864	2.4039	1.854	1.30
RUN 8 BATCH #6 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-48-6A	2	1.659	0.915	2.6279	1.978	1.33
25530-48-6B	2	1.666	0.814	2.3114	1.774	1.30
25530-48-6C	2	1.669	0.807	2.3537	1.766	1.33
25530-48-6D	2	1.667	0.796	2.3287	1.737	1.34
25530-48-6E	2	1.666	0.751	2.1466	1.637	1.31

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 8 BATCH #7 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-49-7A	2	1.647	0.867	2.4321	1.847	1.32
25530-49-7B	2	1.649	0.824	2.3731	1.760	1.35
25530-49-7C	2	1.647	0.907	2.6211	1.932	1.36
25530-49-7D	2	1.569	0.839	2.1619	1.622	1.33
25530-49-7E	2	1.647	0.857	2.4481	1.826	1.34
RUN 8 BATCH #8 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-49-8A	2	1.673	0.911	2.6686	2.003	1.33
25530-49-8B	2	1.675	0.916	2.6749	2.018	1.33
25530-49-8C	2	1.676	0.764	2.2546	1.686	1.34
25530-49-8D	2	1.672	0.834	2.3852	1.831	1.30
25530-49-8E	2	1.674	0.863	2.5423	1.899	1.34
RUN 8 BATCH #9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-49-9A	2	1.683	0.803	2.3235	1.786	1.30
25530-49-9B	2	1.684	0.875	2.5506	1.949	1.31
25530-49-9C	2	1.686	0.956	2.8753	2.134	1.35
25530-49-9D	2	1.686	0.821	2.4338	1.833	1.33
25530-49-9E	2	1.687	0.899	2.6878	2.009	1.34
RUN 8 BATCH #10 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-50-10A	2	1.632	0.894	2.4059	1.870	1.29
25530-50-10B	2	1.632	0.843	2.2413	1.763	1.27
25530-50-10C	2	1.633	0.834	2.2286	1.747	1.28
25530-50-10D	2	1.658	0.876	2.4201	1.891	1.28
25530-50-10E	2	1.632	0.916	2.4689	1.916	1.29
RUN 8 BATCH #11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-50-11A	2	1.582	0.811	2.0692	1.594	1.30
25530-50-11B	2	1.579	0.766	1.9629	1.500	1.31
25530-50-11C	2	1.579	0.779	1.9564	1.525	1.28
25530-50-11D	2	1.583	0.713	1.7974	1.403	1.28
25530-50-11E	2	1.579	0.848	2.1545	1.661	1.30
RUN 8 BATCH #12 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25530-50-12A	2	1.544	0.735	1.8069	1.376	1.31
25530-50-12B	2	1.544	0.759	1.8716	1.421	1.32
25530-50-12C	2	1.544	0.751	1.8432	1.406	1.31
25530-50-12D	2	1.545	0.754	1.8465	1.414	1.31
25530-50-12E	2	1.544	0.836	2.0702	1.565	1.32

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL						
25655-1-A		1.608	0.931	2.5544	1.891	1.35
25655-1-B		1.608	0.888	2.4246	1.803	1.34
25655-1-C		1.608	0.998	2.7116	2.027	1.34
25655-1-D		1.608	0.941	2.5381	1.911	1.33
25655-1-E		1.608	0.876	2.3829	1.779	1.34
RUN 10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL						
25655-2-A		1.635	0.992	2.9415	2.083	1.41
25655-2-B		1.636	0.954	2.8918	2.005	1.44
25655-2-C		1.635	0.883	2.6362	1.854	1.42
25655-2-D		1.635	0.881	2.6549	1.850	1.44
25655-2-E		1.635	0.888	2.6239	1.864	1.41

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (WET DISP.)						
25655-7A *		1.468	0.829	1.5666	1.403	1.12
25655-7B *		1.453	0.754	1.3839	1.250	1.11
25655-7C *		1.542	0.706	1.4571	1.318	1.11
25655-7D *		1.528	0.676	1.3603	1.240	1.10
25655-7E *		1.523	0.674	1.3473	1.228	1.10
RUN 12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (WET DISP.)						
25655-8A		1.636	0.866	2.0181	1.820	1.11
25655-8B		1.636	0.923	2.1543	1.940	1.11
25655-8C		1.636	0.947	2.2117	1.991	1.11
25655-8D		1.636	0.906	2.1026	1.905	1.10
25655-8E		1.634	0.905	2.0915	1.898	1.10
RUN 13 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (DRY DISP.)						
25655-9A		1.648	0.939	3.0082	2.003	1.50
25655-9B		1.648	0.922	2.9482	1.967	1.50
25655-9C		1.647	0.956	3.1057	2.037	.52
25655-9D		1.647	0.962	3.0671	2.050	.50
25655-9E		1.647	0.899	2.8712	1.915	1.50
RUN 14 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (DRY DISP.)						
25655-10A		1.661	0.681	1.8526	1.476	1.26
25655-10B		1.661	0.708	1.9439	1.534	1.27
25655-10C		1.661	0.826	2.3757	1.790	1.33
25655-10D		1.662	0.732	1.9921	1.588	1.25
25655-10E		1.661	0.705	1.8923	1.528	1.24

***SAMPLES SHAPED BY HAND RATHER THAN MACHINED - POOR GREEN STRENGTH**

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 15 > 35%A-13M & 65%C-30 W/ 8 WT% MOGUL 1607						
25655-20A		1.623	0.849	3.0038	1.756	1.71
25655-20B		1.67	0.926	3.4694	2.028	1.71
25655-20C		1.722	0.971	3.8625	2.261	1.71
RUN 16 > 50%A-13M & 50%A-13UG W/ 8 WT% MOGUL 1607						
25655-22A		1.578	0.876	2.9353	1.713	1.71
25655-22B		1.701	0.939	3.6431	2.134	1.71
25655-22C		1.676	0.796	2.9532	1.756	1.68
25655-22D		1.687	0.81	3.1572	1.811	1.74
RUN 17 > 35%A-13M & 65%C-30 W/ 4WT% MOGUL 1607 & .1 WT% METHOCEL						
25655-24A		1.645	0.7	2.5877	1.488	1.74
25655-24B		1.646	1.025	3.8039	2.181	1.74
25655-24C		1.645	0.97	3.6275	2.062	1.76
25655-24D		1.645	0.865	3.2484	1.838	1.77
25655-24E		1.582	0.802	2.7596	1.576	1.75
RUN 18 > 50%A-13M & 50%A-13UG W/4WT% MOGUL 1607 & .1 WT% METHOCEL						
25655-25A		1.688	0.857	3.2547	1.918	1.70
25655-25B		1.725	0.987	3.8773	2.307	1.68
25655-25C		1.675	0.832	3.1068	1.833	1.69
25655-25D		1.636	0.92	3.2723	1.934	1.69
25655-25E		1.638	0.827	2.9664	1.743	1.70
RUN 19A > 35%A-13M & 65%C-30 W/ 4WT% MOGUL 1607 (17% MOISTURE)						
25655-26A		1.674	0.801	3.0744	1.763	1.74
25655-26B		1.674	0.772	2.9594	1.699	1.74
25655-26C		1.674	0.892	3.4098	1.963	1.74
25655-26D		1.674	0.829	3.1830	1.825	1.74
25655-26E		1.674	0.866	3.3026	1.906	1.73
RUN 19B > 35%A-13M & 65%C-30 W/ 4WT% MOGUL 1607 (17.1% MOISTURE)						
25655-27A		1.623	0.871	3.1646	1.802	1.76
25655-27B		1.698	0.738	2.9125	1.671	1.74
25655-27C		1.703	0.831	3.3015	1.893	1.74
25655-27D		1.699	0.922	3.6281	2.090	1.74
25655-27E		1.699	0.964	3.7915	2.186	1.73
RUN 20 > 35%A-13M & 65%C-30 W/ 5WT% MOGUL 1607 & .2WT% METHOCEL						
25655-28A		1.623	0.903	3.0888	1.868	1.65
25655-28B		1.623	0.791	2.6797	1.636	1.64
25655-28C		1.623	0.914	3.0826	1.891	1.63
25655-28D		1.623	0.876	2.9454	1.812	1.63
25655-28E		1.623	0.861	2.9116	1.781	1.63
RUN 21A > 35%A-13M & 65%C-30 W/ 5WT% MOGUL & .2WT% METHOCEL & .35WT% NALCO *						
25655-29A		1.661	0.874	3.0716	1.894	1.62
25655-29B		1.661	0.874	3.0656	1.894	1.62
25655-29C		1.661	0.88	3.0938	1.907	1.62
25655-29D		1.661	0.864	3.0549	1.872	1.63
25655-29E		1.661	0.848	2.9921	1.837	1.63
RUN 21B > 35%A-13M & 65%C-30 W/ 5WT% MOGUL & .2WT% METHOCEL & .35WT% NALCO #						
25655-30A		1.622	0.993	3.2346	2.052	1.58
25655-30B		1.622	0.994	3.3387	2.054	1.63
25655-30C		1.622	0.986	3.2618	2.037	1.60
25655-30D		1.622	0.878	2.9038	1.814	1.60
25655-30E		1.622	0.924	2.9925	1.909	1.57

• 19.2WT% MOISTURE

20.3WT% MOISTURE

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 22 > 50%A-13M & 50%A-13UG W/5WT% MOGUL 1607 & .5 WT% METHOCEL						
25655-37A		1.668	0.827	2.8443	1.807	1.57
25655-37B		1.668	0.833	2.8348	1.820	1.56
25655-37C		1.668	0.818	2.7926	1.787	1.56
25655-37D		1.664	0.921	3.1341	2.003	1.56
25655-37E		1.666	0.875	2.9822	1.907	1.56
RUN 23 > 50%A-13M & 50%A-13UG W/5WT%MOGUL & .5 WT%METHOCEL & .5WT%NALCO						
25655-38A		1.645	0.999	3.2750	2.123	1.54
25655-38B		1.645	0.932	3.0598	1.981	1.54
25655-38C		1.647	0.907	2.9527	1.932	1.53
25655-38D		1.646	0.928	3.0772	1.975	1.56
25655-38E		1.647	0.847	2.7971	1.805	1.55
RUN 24 > 50%A-13M & 50%A-13UG W/5WT%MOGUL & .5 WT%METHOCEL & .5WT%SGP						
25655-39A		1.700	0.867	3.0307	1.968	1.54
25655-39B		1.700	0.873	3.0392	1.982	1.53
25655-39C		1.698	0.945	3.3264	2.140	1.55
25655-39D		1.699	0.895	3.1593	2.029	1.56
25655-39E		1.700	0.876	3.1035	1.988	1.56

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID. NO.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
RUN 25 > 50%A-13M & 50%A-13UG W/ 2 WT%MOGUL &1WT%METHOCEL						
25655-44A		1.754	1.031	3.3172	2.491	1.33
25655-44B		1.754	1.046	3.2940	2.527	1.30
25655-44C		1.754	1.015	3.1991	2.453	1.30
25655-44D		1.754	0.925	2.9501	2.235	1.32
25655-44E		1.754	0.889	2.8167	2.148	1.31
RUN 26 > 50%A-13M & 50%A-13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25655-45A		1.664	1.095	3.6431	2.381	1.53
25655-45B		1.664	1.023	3.3126	2.225	1.49
25655-45C		1.665	0.931	3.0350	2.027	1.50
25655-45D		1.664	0.922	3.0597	2.005	1.53
25655-45E		1.664	0.904	3.0122	1.966	1.53
RUN 27 > 40%A-13M & 60%A-13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25655-46A		1.651	0.844	2.6575	1.807	1.47
25655-46B		1.650	0.877	2.7554	1.875	1.47
25655-46C		1.650	0.950	3.0123	2.031	1.48
25655-46D		1.650	0.972	3.0866	2.078	1.49
25655-46E		1.650	0.989	3.1153	2.115	1.47
RUN 28 > 25%A-13M & 75%A-13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25655-47A		1.624	0.949	2.6724	1.966	1.36
25655-47B		1.623	1.028	2.8786	2.127	1.35
25655-47C		1.623	1.072	3.0109	2.218	1.36
25655-47D		1.624	1.078	3.0561	2.233	1.37
25655-47E		1.611	1.005	2.7994	2.049	1.37
RUN 29 > 25%A-13M & 75%A-13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25655-48A		1.637	0.968	2.8491	2.037	1.40
25655-48B		1.636	1.001	2.9463	2.104	1.40
25655-48C		1.636	0.987	2.8933	2.075	1.39
25655-48D		1.636	0.984	2.8894	2.068	1.40
25655-48E		1.636	0.986	2.9046	2.073	1.40
RUN 30 > 25%A-13M & 75%A-13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &.5WT%A-180						
25655-49A		1.611	0.951	2.6273	1.938	1.36
25655-49B		1.610	0.969	2.6754	1.973	1.36
25655-49C		1.609	1.002	2.7564	2.037	1.35
25655-49D		1.609	0.977	2.6883	1.987	1.35
25655-49E		1.609	0.984	2.7188	2.001	1.36

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GAS	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	CONV.	DIAM.	THK.	WT.	VOL	DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 31 T1 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-1A		1.664	0.969	2.9674	2.107	1.41
25740-5-1B		1.664	0.899	2.7226	1.955	1.39
25740-5-1C		1.664	0.915	2.7637	1.990	1.39
25740-5-1D		1.664	0.951	2.8511	2.068	1.38
25740-5-1E		1.664	0.887	2.6656	1.929	1.38
RUN 31 T2 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-2A		1.690	0.938	3.0021	2.104	1.43
25740-5-2B		1.690	0.942	2.9579	2.113	1.40
25740-5-2C		1.690	0.925	2.9439	2.075	1.42
25740-5-2D		1.690	0.851	2.6716	1.909	1.40
25740-5-2E		1.690	0.819	2.5941	1.837	1.41
RUN 31 T3 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-3A		1.652	0.961	2.9061	2.060	1.41
25740-5-3B		1.652	0.936	2.8101	2.006	1.40
25740-5-3C		1.652	0.896	2.7334	1.921	1.42
25740-5-3D		1.652	0.908	2.7612	1.946	1.42
25740-5-3E		1.652	0.901	2.7307	1.931	1.41
RUN 31 T4 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-4A		1.678	0.930	2.8437	2.057	1.38
25740-5-4B		1.677	0.927	2.8528	2.048	1.39
25740-5-4C		1.678	0.865	2.6217	1.913	1.37
25740-5-4D		1.614	0.861	2.4487	1.762	1.39
25740-5-4E		1.614	0.936	2.6829	1.915	1.40
RUN 31 T5 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-5A		1.690	0.956	3.0221	2.144	1.41
25740-5-5B		1.690	0.852	2.6996	1.911	1.41
25740-5-5C		1.612	0.888	2.5413	1.812	1.40
25740-5-5D		1.613	0.881	2.5277	1.800	1.40
25740-5-5E		1.613	0.900	2.6107	1.839	1.42
RUN 31 T6 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-6A		1.650	0.986	3.0004	2.108	1.42
25740-5-6B		1.650	0.951	2.8176	2.033	1.39
25740-5-6C		1.650	0.913	2.7661	1.952	1.42
25740-5-6D		1.651	0.841	2.5528	1.800	1.42
25740-5-6E		1.650	0.883	2.6910	1.888	1.43
RUN 31 T7 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-5-7A		1.663	0.971	2.9549	2.109	1.40
25740-5-7B		1.662	0.959	2.9933	2.081	1.44
25740-5-7C		1.662	0.946	2.9141	2.052	1.42
25740-5-7D		1.662	0.898	2.7049	1.948	1.39
25740-5-7E		1.663	0.898	2.7601	1.951	1.42
RUN 32 > 20%A13M & 80%A13UG W/ 2 WT%MOGUL &1WT%METHOCEL &.5WT%NALCO						
25740-8-1A		1.678	0.988	2.7116	2.185	1.24
25740-8-1B		1.675	0.964	2.6781	2.124	1.26
25740-8-1C		1.675	0.915	2.5965	2.016	1.29
25740-8-1D		1.675	0.885	2.4246	1.950	1.24
25740-8-1E		1.675	0.875	2.4514	1.928	1.27

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV. NO.	GREEN DIAM. cm	GREEN THK. cm	GREEN WT. grams	GREEN VOL. cc	GREEN DENSITY g/cc
RUN 33 T1 > 20%A13M & 80%A13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &5WT%NALCO						
25740-14-1A		1.594	0.989	2.7561	1.974	1.40
25740-14-1B		1.594	0.993	2.7216	1.982	1.37
25740-14-1C		1.594	0.956	2.5973	1.908	1.36
25740-14-1D		1.594	0.904	2.5219	1.804	1.40
25740-14-1E		1.594	0.867	2.4507	1.730	1.42
RUN 33 T2 > 20%A13M & 80%A13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &5WT%NALCO						
25740-14-2A		1.584	0.984	2.7278	1.939	1.41
25740-14-2B		1.584	0.935	2.5914	1.843	1.41
25740-14-2C		1.584	0.936	2.5949	1.844	1.41
25740-14-2D		1.584	0.897	2.4965	1.768	1.41
25740-14-2E		1.584	0.845	2.3472	1.665	1.41
RUN 33 T3 > 20%A13M & 80%A13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &5WT%NALCO						
25740-14-3A		1.623	0.936	2.6912	1.936	1.39
25740-14-3B		1.623	0.925	2.6814	1.914	1.40
25740-14-3C		1.623	0.906	2.6106	1.874	1.39
25740-14-3D		1.623	0.905	2.5892	1.872	1.38
25740-14-3E		1.623	0.892	2.5903	1.845	1.40
RUN 33 T4 > 20%A13M & 80%A13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &5WT%NALCO						
25740-14-4A		1.611	0.907	2.5794	1.849	1.40
25740-14-4B		1.611	0.897	2.5696	1.828	1.41
25740-14-4C		1.611	0.883	2.5263	1.800	1.40
25740-14-4D		1.611	0.874	2.5136	1.782	1.41
25740-14-4E		1.611	0.788	2.2082	1.606	1.37
RUN 33 T5 > 20%A13M & 80%A13UG W/ 3 WT%MOGUL &1.5WT%METHOCEL &5WT%NALCO						
25740-14-5A		1.662	0.942	2.8448	2.044	1.39
25740-14-5B		1.662	0.910	2.6465	1.974	1.34
25740-14-5C		1.662	0.892	2.6786	1.935	1.38
25740-14-5D		1.662	0.856	2.5161	1.857	1.35
25740-14-5E		1.662	0.842	2.5409	1.827	1.39

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GAS CONV.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 34 > 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-17-1A		1.655	1.025	3.0984	2.205	1.41
25740-17-1B		1.656	1.000	3.0486	2.154	1.42
25740-17-1C		1.656	0.976	2.9802	2.102	1.42
25740-17-1D		1.656	0.949	2.8807	2.044	1.41
25740-17-1E		1.656	0.880	2.6619	1.895	1.40
RUN 35 T1> 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-19-1A		1.713	0.873	2.8137	2.012	1.40
25740-19-1B		1.715	0.804	2.5843	1.857	1.39
25740-19-1C		1.575	0.825	2.2182	1.607	1.38
25740-19-1D		1.715	0.702	2.2445	1.622	1.38
25740-19-1E		1.715	0.768	2.4562	1.774	1.38
RUN 35 T2> 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-19-2A		1.707	0.815	2.6262	1.865	1.41
25740-19-2B		1.707	0.805	2.5598	1.842	1.39
25740-19-2C		1.707	0.759	2.4138	1.737	1.39
25740-19-2D		1.707	0.743	2.3734	1.700	1.40
25740-19-2E		1.707	0.746	2.3638	1.707	1.38
RUN 35 T3> 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-19-3A		1.720	0.812	2.6475	1.887	1.40
25740-19-3B		1.734	0.759	2.5268	1.792	1.41
25740-19-3C		1.734	0.887	2.8885	2.095	1.38
25740-19-3D		1.734	0.826	2.7389	1.951	1.40
25740-19-3E		1.734	0.805	2.6461	1.901	1.39
RUN 35 T4> 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-19-4A		1.747	0.750	2.5244	1.798	1.40
25740-19-4B		1.747	0.755	2.5507	1.810	1.41
25740-19-4C		1.747	0.835	2.8118	2.002	1.40
25740-19-4D		1.747	0.773	2.5789	1.853	1.39
25740-19-4E		1.747	0.785	2.6321	1.882	1.40
RUN 35 T5> 20%A13M & 80%A13UG W/ 5 WT%MOGUL &1.5WT%METHOCEL &.5WT%NALCO						
25740-19-5A		1.722	0.766	2.4538	1.784	1.38
25740-19-5B		1.722	0.714	2.3382	1.663	1.41
25740-19-5C		1.722	0.671	2.1505	1.563	1.38
25740-19-5D		1.722	0.744	2.3868	1.733	1.38
25740-19-5E		1.722	0.782	2.4949	1.821	1.37

SAMPLE ID.	GAS CONV.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	NO.	cm	cm	grams	cc	g/cc
RUN 36 T1> 20%A13M & 80%A13UG W/ 4.75 WT%MOGUL & 1.75WT%METHOCEL & 5WT%NALCO						
25740-25-1A		1.710	0.799	2.4156	1.835	1.32
25740-25-1B		1.710	0.733	2.2075	1.683	1.31
25740-25-1C		1.710	0.776	2.3413	1.782	1.31
25740-25-1D		1.710	0.780	2.3492	1.791	1.31
25740-25-1E		1.710	0.778	2.3218	1.787	1.30
RUN 36 T2> 20%A13M & 80%A13UG W/ 4.75 WT%MOGUL & 1.75WT%METHOCEL & 5WT%NALCO						
25740-25-2A		1.699	0.768	2.2748	1.741	1.31
25740-25-2B		1.699	0.747	2.2110	1.694	1.31
25740-25-2C		1.699	0.789	2.3344	1.789	1.31
25740-25-2D		1.699	0.746	2.2006	1.691	1.30
25740-25-2E		1.699	0.695	2.0546	1.576	1.30
RUN 36 T3> 20%A13M & 80%A13UG W/ 4.75 WT%MOGUL & 1.75WT%METHOCEL & 5WT%NALCO						
25740-25-3A		1.687	0.790	2.2906	1.766	1.30
25740-25-3B		1.687	0.777	2.2746	1.737	1.31
25740-25-3C		1.687	0.793	2.3103	1.773	1.30
25740-25-3D		1.687	0.776	2.2550	1.735	1.30
25740-25-3E		1.687	0.827	2.4154	1.849	1.31
RUN 36 T4> 20%A13M & 80%A13UG W/ 4.75 WT%MOGUL & 1.75WT%METHOCEL & 5WT%NALCO						
25740-25-4A		1.726	0.737	2.2766	1.724	1.32
25740-25-4B		1.726	0.779	2.4052	1.823	1.32
25740-25-4C		1.726	0.786	2.4239	1.839	1.32
25740-25-4D		1.726	0.751	2.3169	1.757	1.32
25740-25-4E		1.726	0.695	2.1328	1.626	1.31
RUN 36 T5> 20%A13M & 80%A13UG W/ 4.75 WT%MOGUL & 1.75WT%METHOCEL & 5WT%NALCO						
25740-25-5A		1.714	0.770	2.3522	1.777	1.32
25740-25-5B		1.714	0.812	2.4685	1.874	1.32
25740-25-5C		1.714	0.834	2.5438	1.924	1.32
25740-25-5D		1.714	0.772	2.3673	1.781	1.33
25740-25-5E		1.714	0.847	2.5722	1.954	1.32

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	cm	cm	grams	cc	g/cc
RUN 47-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-21-A1	1.648	0.631	1.8304	1.346	1.36
25247-21-A2	1.648	0.651	1.8797	1.389	1.35
25247-21-A3	1.649	0.707	2.0086	1.510	1.33
25247-21-A4	1.511	0.679	1.6385	1.218	1.35
25247-21-A5	1.633	0.639	1.8154	1.338	1.36
RUN 47-B > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-21-B1	1.632	0.668	1.8139	1.397	1.30
25247-21-B2	1.652	0.673	1.9677	1.443	1.36
25247-21-B3	1.603	0.672	1.8654	1.356	1.38
25247-21-B4	1.629	0.673	1.9252	1.403	1.37
25247-21-B5	1.651	0.655	1.9270	1.402	1.37
RUN 47-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-21-C1	1.616	0.664	1.8865	1.362	1.39
25247-21-C2	1.690	0.671	2.0572	1.505	1.37
25247-21-C3	1.611	0.686	1.9226	1.398	1.37
25247-21-C4	1.654	0.672	2.0146	1.444	1.40
25247-21-C5	1.586	0.664	1.8243	1.312	1.39
RUN 47-D > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-21-D1	1.658	0.679	2.0306	1.466	1.39
25247-21-D2	1.635	0.656	1.9458	1.377	1.41
25247-21-D3	1.660	0.656	1.9696	1.420	1.39
25247-21-D4	1.656	0.661	2.0082	1.424	1.41
25247-21-D5	1.639	0.706	2.0611	1.490	1.38
RUN 47-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-21-E1	1.574	0.678	1.8101	1.319	1.37
25247-21-E2	1.661	0.679	2.0177	1.471	1.37
25247-21-E3	1.639	0.662	1.9547	1.397	1.40
25247-21-E4	1.684	0.687	2.1580	1.530	1.41
25247-21-E5	1.684	0.646	1.9933	1.439	1.39

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE ID.	GREEN DIAM.	GREEN THK.	GREEN WT.	GREEN VOL.	GREEN DENSITY
NO.	cm	cm	grams	cc	g/cc
RUN 48-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-25-A1	1.656	0.789	2.3711	1.699	1.40
25247-25-A2	1.643	0.930	2.7230	1.972	1.38
25247-25-A3	1.728	0.812	2.5653	1.904	1.35
25247-25-A4	1.647	0.770	2.2557	1.640	1.38
25247-25-A5	1.666	0.965	2.9348	2.104	1.40
RUN 48-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-25-C1	1.607	0.823	2.2758	1.669	1.36
25247-25-C2	1.653	0.809	2.3813	1.736	1.37
25247-25-C3	1.570	0.792	2.1038	1.533	1.37
25247-25-C4	1.640	0.806	2.3955	1.703	1.41
25247-25-C5	1.620	0.811	2.3221	1.672	1.39
RUN 48-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-25-E1	1.672	0.778	2.1838	1.708	1.28
25247-25-E2	1.674	0.769	2.2862	1.692	1.35
25247-25-E3	1.670	0.782	2.2692	1.713	1.32
25247-25-E4	1.697	0.800	2.4444	1.809	1.35
25247-25-E5	1.674	0.780	2.2436	1.717	1.31
RUN 49-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-26-A1	1.627	0.788	2.3419	1.638	1.43
25247-26-A2	1.628	0.750	2.2482	1.561	1.44
25247-26-A3	1.655	0.738	2.2377	1.588	1.41
25247-26-A4	1.673	0.789	2.4455	1.734	1.41
25247-26-A5	1.681	0.794	2.4447	1.762	1.39
RUN 49-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-26-C1	1.670	0.800	2.5034	1.752	1.43
25247-26-C2	1.644	0.812	2.4640	1.724	1.43
25247-26-C3	1.676	0.818	2.5114	1.805	1.39
25247-26-C4	1.632	0.812	2.4008	1.699	1.41
25247-26-C5	1.698	0.804	2.6151	1.821	1.44
RUN 49-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-26-E1	1.686	0.816	2.5197	1.822	1.38
25247-26-E2	1.657	0.822	2.4883	1.773	1.40
25247-26-E3	1.636	0.828	2.4061	1.741	1.38
25247-26-E4	1.669	0.803	2.3948	1.757	1.36
25247-26-E5	1.632	0.806	2.3375	1.686	1.39
RUN 50-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-28-A1	1.665	0.899	2.7307	1.957	1.40
25247-28-A2	1.661	0.870	2.6060	1.885	1.38
25247-28-A3	1.658	0.882	2.6502	1.904	1.39
25247-28-A4	1.653	0.868	2.5779	1.863	1.38
25247-28-A5	1.628	0.901	2.6177	1.876	1.40
RUN 50-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-28-C1	1.706	0.876	2.7399	2.002	1.37
25247-28-C2	1.682	0.862	2.6546	1.915	1.39
25247-28-C3	1.713	0.864	2.7243	1.991	1.37
25247-28-C4	1.683	0.886	2.7922	1.971	1.42
25247-28-C5	1.660	0.857	2.4763	1.855	1.34

GREEN DENSITIES OF LIGHTWEIGHT AGGREGATE

SAMPLE	GREEN	GREEN	GREEN	GREEN	GREEN
ID.	DIAM.	THK.	WT.	VOL.	DENSITY
NO.	cm	cm	grams	cc	g/cc
RUN 50-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-28-E1	1.710	0.905	2.8561	2.078	1.37
25247-28-E2	1.684	0.900	2.7851	2.005	1.39
25247-28-E3	1.689	0.904	2.7493	2.025	1.36
25247-28-E4	1.708	0.924	2.8880	2.117	1.36
25247-28-E5	1.612	0.904	2.5742	1.845	1.40
RUN 51-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-29-A1	1.656	0.922	2.8431	1.986	1.43
25247-29-A2	1.624	0.888	2.6031	1.839	1.42
25247-29-A3	1.664	0.909	2.7643	1.977	1.40
25247-29-A4	1.639	0.920	2.7406	1.941	1.41
25247-29-A5	1.716	0.901	2.8773	2.084	1.38
RUN 51-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-29-C1	1.665	0.931	2.8397	2.027	1.40
25247-29-C2	1.689	0.913	2.8782	2.046	1.41
25247-29-C3	1.645	0.903	2.7224	1.919	1.42
25247-29-C4	1.690	0.906	2.8348	2.032	1.39
25247-29-C5	1.712	0.899	2.8599	2.069	1.38
RUN 51-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel					
25247-29-E1	1.720	0.915	2.9173	2.126	1.37
25247-29-E2	1.713	0.928	2.9432	2.139	1.38
25247-29-E3	1.736	0.918	3.0112	2.173	1.39
25247-29-E4	1.695	0.920	2.8689	2.076	1.38
25247-29-E5	1.717	0.909	2.9595	2.105	1.41

Appendix B-2 – Raw Data and Fired Density Calculations

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DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D.	EXP. REF.	DRY WEIGHT	SUS. WEIGHT	SAT. WEIGHT	BULK DENSITY	APP. POROSITY	H2O ABS.	APP. S.G.	TOTAL POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
EXTRUDED > 60%A-13M & 40%A-13(-270) W/ 2 WT% METHOCCEL									
24127-19A	1	1.0482	0.7811	1.2098	2.44	37.70	15.46	3.91	38.75
24127-19B	1	1.1769	0.8768	1.3609	2.42	38.01	15.68	3.91	39.10
24127-19C	1	1.0023	0.7464	1.1571	2.43	37.69	15.49	3.91	38.87
24127-19D	1	0.7982	0.5951	0.9197	2.45	37.43	15.27	3.92	38.40
24127-19E	1	1.1397	0.8496	1.3257	2.39	39.07	16.37	3.92	40.03
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 4.68 WT% METHOCCEL									
24127-24A	2	0.9608	0.7166	1.1683	2.12	45.94	21.66	3.92	46.72
24127-24B	2	1.1135	0.8317	1.3578	2.11	46.44	22.01	3.94	46.98
24127-24C	2	1.0137	0.7572	1.2399	2.09	46.86	22.38	3.94	47.39
24127-24D	2	0.9768	0.7295	1.1863	2.13	45.86	21.51	3.94	46.43
24127-24E	2	0.8601	0.6406	1.0537	2.08	46.87	22.58	3.91	47.84
EXTRUDED > 60%A-13M & 40%A-13UG W/ 4.4 WT% METHOCCEL									
24127-21A	3	1.2798	0.9539	1.4805	2.42	38.11	15.73	3.92	39.12
24127-21B	3	1.2429	0.9255	1.4679	2.28	41.48	18.16	3.90	42.60
24127-21C	3	1.5116	1.1259	1.7618	2.37	39.35	16.60	3.91	40.45
24127-21D	3	1.1094	0.8262	1.2904	2.38	38.99	16.36	3.91	40.13
24127-21E	3	1.2764	0.9502	1.4744	2.43	37.77	15.56	3.90	39.00
EXTRUDED > 40%A-13M & 60%A-13UG W/ 2 WT% METHOCCEL									
24127-22A	4	0.9204	0.6859	1.1158	2.13	45.45	21.29	3.91	46.37
24127-22B	4	1.0831	0.8066	1.3172	2.11	45.85	21.68	3.91	46.86
24127-22C	4	0.9902	0.7375	1.1918	2.17	44.38	20.42	3.91	45.40
24127-22D	4	1.1166	0.8318	1.3523	2.14	45.28	21.17	3.91	46.26
24127-22E	4	0.7822	0.5824	0.9409	2.18	44.27	20.35	3.90	45.34
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 6 WT% METHOCCEL									
24127-18A	O2	0.7509	0.5615	0.9278	2.04	48.29	23.63	3.95	48.65
24127-18B	O2	0.6614	0.4945	0.8257	1.99	49.61	24.92	3.95	49.98
24127-18C	O2	0.6925	0.5178	0.8584	2.03	48.71	24.03	3.95	49.07
24127-18D	O2	0.8311	0.6214	1.0344	2.01	49.23	24.54	3.95	49.59
24127-18E	O2	0.7975	0.5962	1.0002	1.97	50.17	25.49	3.95	50.55

FIRED TO 1780°C

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D.	EXP. REF.	DRY WEIGHT (g)	SUS. WEIGHT (g)	SAT. WEIGHT (g)	BULK DENSITY (g/cc)	APP. POROSITY (%)	H2O ABS. (%)	APP. S.G. (g/cc)	TOTAL POROSITY (%)
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
EXTRUDED > 60%A-13M & 40%A-13(-270) W/ 4.68 WT% METHOCEL									
24127-20F	5	1.1188	0.8289	1.2853	2.44	36.48	14.93	3.85	38.59
24127-20G	5	1.1399	0.8458	1.3217	2.39	38.20	16.00	3.86	40.00
24127-20H	5	1.0927	0.8095	1.2568	2.44	36.69	15.06	3.85	38.81
24127-20I	5	1.0502	0.7779	1.2038	2.46	36.06	14.67	3.85	38.23
24127-20J	5	1.0458	0.7738	1.2055	2.42	36.99	15.32	3.83	39.32
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 2 WT% METHOCEL									
24127-17F	6	0.8965	0.6688	1.0742	2.20	43.83	19.88	3.93	44.60
24127-17G	6	0.9138	0.6819	1.0890	2.24	43.04	19.23	3.93	43.77
24127-17H	6	0.7734	0.5767	0.9219	2.23	43.02	19.26	3.92	43.88
24127-17I	6	0.9301	0.6928	1.1084	2.23	42.90	19.23	3.91	43.94
24127-17J	6	0.9563	0.7128	1.1601	2.13	45.56	21.38	3.92	46.44
EXTRUDED > 60%A-13M & 40%A-13UG W/ 2 WT% METHOCEL									
24127-23F	7	1.3482	0.9998	1.5548	2.42	37.23	15.37	3.86	39.15
24127-23G	7	0.9592	0.7107	1.1228	2.32	39.70	17.11	3.85	41.69
24127-23H	7	1.3797	1.0228	1.5766	2.48	35.55	14.31	3.85	37.59
24127-23I	7	1.1221	0.8308	1.2851	2.46	35.88	14.57	3.84	38.13
24127-23J	7	1.1255	0.8325	1.2963	2.42	36.83	15.22	3.83	39.21
EXTRUDED > 40%A-13M & 60%A-13UG W/ 4.63 WT% METHOCEL									
24127-16F	8	0.8855	0.6576	1.0646	2.17	44.00	20.29	3.87	45.50
24127-16G	8	1.0783	0.8012	1.2877	2.21	43.04	19.48	3.88	44.48
24127-16H	8	0.9098	0.6741	1.1041	2.11	45.19	21.42	3.85	47.00
24127-16I	8	0.8847	0.6567	1.0548	2.22	42.73	19.28	3.87	44.33
24127-16J	8	1.0028	0.7467	1.2023	2.19	43.79	19.95	3.90	44.86

FIRED TO 1862°C

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE		DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
SIZED SAMPLE REG. EXT > 60%A-13M & 40%A-13UG W/ 1.55WT% METHOCEL (4.2% SOL)									
12742-A*	II	3.6359	2.6338	3.7744	3.18	12.14	3.82	3.62	20.15
12742-B*	II	2.9926	2.1865	3.1014	3.26	11.89	3.65	3.70	18.06
12742-C*	II	3.3263	2.4134	3.4442	3.22	11.44	3.56	3.63	19.17
12742-D*	IV	2.9673	2.1537	3.0585	3.27	10.08	3.08	3.64	17.85
12742-E*	IV	3.3482	2.4170	3.4388	3.27	8.87	2.71	3.58	17.92
12742-F*	IV	3.0206	2.1949	3.1339	3.21	12.07	3.76	3.65	19.42
SIZED SAMPLE SWOLLEN EXT > 60%A-13M & 40%A-13UG W/ 1.55WT% METHOCEL (4.2% SOL)									
12742-SA	II	3.7196	2.7533	4.0994	2.75	28.21	10.24	3.84	30.78
12742-SB*	II	4.6474	3.4149	4.8458	3.24	13.87	4.28	3.76	18.64
12742-SC	II	3.9971	2.9602	4.3682	2.83	26.36	9.31	3.84	28.89
12742-SD*	IV	4.7575	3.4647	4.9177	3.26	11.03	3.38	3.67	17.98
12742-SE*	IV	4.7921	3.4757	4.9496	3.24	10.69	3.30	3.63	18.55
12742-SF*	IV	4.8145	3.5026	5.0113	3.18	13.04	4.10	3.66	20.06
BALLS FROM REG. EXT > 60%A-13M & 40%A-13UG W/ 1.55WT% METHOCEL (4.2% SOL)									
12742-G21	II	7.3813	5.0150	7.3947	3.09	0.56	0.18	3.11	22.30
12742-G22	II	6.8469	4.9898	7.5111	2.71	26.34	9.73	3.68	31.97
12742-G23	II	7.0929	5.1536	7.3656	3.20	12.33	3.86	3.65	19.67
12742-G24	II	5.6069	4.0723	6.1981	2.63	27.81	10.58	3.64	33.93
12742-G25	II	6.6069	4.8026	7.1572	2.80	23.37	8.35	3.65	29.71
12742-H41	IV	4.4984	3.2506	4.7769	2.94	18.25	6.21	3.59	26.17
12742-H42	IV	6.0532	4.3912	6.5864	2.75	24.29	8.84	3.63	30.92
12742-H43	IV	6.3456	4.5876	6.9172	2.72	24.54	9.03	3.60	31.77
12742-H44	IV	6.5911	4.4647	6.6061	3.07	0.70	0.23	3.09	22.90
12742-H45	IV	5.2874	3.4846	5.2973	2.91	0.55	0.19	2.92	26.93
ROD SLICES FROM REG. EXT > 60%A-13M & 40%A-13UG W/ 1.55WT% METHOCEL (4.2% SOL)									
12742-I 21	II	3.2952	2.4192	3.6029	2.78	25.99	9.37	3.75	30.26
12742-I 22*	II	3.9360	2.8216	4.0598	3.17	10.00	3.15	3.52	20.37
12742-J 21	II	2.6796	1.9661	2.9203	2.80	25.23	9.01	3.74	29.65
12742-J 22*	II	3.7188	2.6737	3.8272	3.21	9.40	2.92	3.55	19.24
12742-K 41*	IV	2.8891	2.0787	2.9861	3.17	10.69	3.37	3.55	20.24
12742-L 41	IV	3.0130	2.1487	3.0695	3.26	6.14	1.88	3.48	18.03
12742-L 42*	IV	3.3877	2.4212	3.4595	3.25	6.92	2.13	3.49	18.27
12742-M 41*	IV	4.5989	3.2726	4.6904	3.23	6.45	2.00	3.46	18.74

***NOTE: SAMPLE DISCOLORED AFTER FIRING**

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D. NO.	GAS CONV. NO.	DRY WEIGHT (g)	SUS. WEIGHT (g)	SAT. WEIGHT (g)	BULK DENSITY (g/cc)	APP. POROSITY (%)	H2O ABS. (%)	APP. S.G. (g/cc)	TOTAL POROSITY (%)
LS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-A1	2	2.0580	1.5272	2.4351	2.26	41.54	18.38	3.87	43.22
12748-A2	2	2.8111	2.0883	3.3229	2.27	41.45	18.26	3.88	42.96
12748-A3	2	2.6232	1.9501	3.1038	2.27	41.66	18.38	3.89	43.04
12748-A4	2	3.2183	2.3923	3.8119	2.26	41.81	18.50	3.88	43.21
12748-A5	2	2.7471	2.0420	3.2508	2.27	41.67	18.39	3.88	43.07
LS EXT, V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-B1	2	2.7931	2.0753	3.2631	2.34	39.57	16.88	3.88	41.09
12748-B2	2	2.7570	2.0496	3.2463	2.30	40.89	17.80	3.89	42.29
12748-B3	2	2.1107	1.5678	2.4496	2.39	38.43	16.10	3.88	40.04
12748-B4	2	2.4576	1.8272	2.8669	2.36	39.37	16.70	3.89	40.79
12748-B5	2	2.4277	1.8049	2.8295	2.36	39.22	16.60	3.89	40.65
HS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-C1	2	2.5131	1.8652	2.9254	2.36	38.89	16.46	3.87	40.62
12748-C2	2	2.6778	1.9909	3.1464	2.31	40.55	17.55	3.89	41.95
12748-C3	2	2.8945	2.1508	3.3453	2.42	37.74	15.62	3.88	39.30
12748-C4	2	3.5864	2.6662	4.1923	2.34	39.70	16.95	3.89	41.13
12748-C5	2	2.7976	2.0794	3.2769	2.33	40.03	17.18	3.88	41.48
HS EXT, V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-D1	2	3.1360	2.3305	3.6813	2.31	40.37	17.44	3.88	41.84
12748-D2	2	3.5339	2.6255	4.1376	2.33	39.92	17.13	3.88	41.46
12748-D3	2	2.7133	2.0150	3.1603	2.36	39.03	16.52	3.87	40.65
12748-D4	2	2.9391	2.1826	3.4782	2.26	41.61	18.40	3.87	43.17
12748-D5	2	2.6048	1.9355	3.0396	2.35	39.38	16.74	3.88	40.90
LS EXT, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-E1	2	3.1670	2.3516	3.7601	2.24	42.11	18.78	3.87	43.67
12748-E2	2	3.6051	2.6761	4.2474	2.29	40.88	17.87	3.87	42.53
12748-E3	2	2.9665	2.2044	3.5070	2.27	41.49	18.27	3.88	42.95
12748-E4	2	3.2055	2.3809	3.7947	2.26	41.67	18.44	3.88	43.20
12748-E5	2	3.4599	2.5711	4.1336	2.21	43.12	19.53	3.88	44.53
LS EXT, V, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-F1	2	3.0203	2.2448	3.5388	2.33	40.07	17.22	3.88	41.53
12748-F2	2	2.6137	1.9407	3.0876	2.27	41.32	18.19	3.87	42.91
12748-F3	2	2.5433	1.8888	2.9508	2.39	38.37	16.07	3.87	40.01
12748-F4	2	2.5070	1.8606	2.9638	2.27	41.41	18.28	3.87	43.07
12748-F5	2	3.6025	2.6746	4.2091	2.34	39.53	16.89	3.87	41.19
HS EXT, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-G1	2	3.2115	2.3845	3.7973	2.27	41.46	18.30	3.87	43.06
12748-G2	2	3.0399	2.2563	3.5521	2.34	39.53	16.90	3.87	41.23
12748-G3	2	3.0690	2.2792	3.6282	2.27	41.45	18.28	3.87	43.01
12748-G4	2	2.1465	1.5949	2.5428	2.26	41.81	18.52	3.88	43.27
12748-G5	2	3.5844	2.6622	4.2037	2.32	40.18	17.33	3.88	41.75
HS EXT, V, R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12748-H1	2	2.9559	2.1960	3.4307	2.39	38.45	16.11	3.88	40.03
12748-H2	2	2.1114	1.5681	2.4665	2.34	39.53	16.87	3.87	41.13
12748-H3	2	2.8891	2.1466	3.3979	2.30	40.66	17.66	3.88	42.16
12748-H4	2	3.2426	2.4063	3.7849	2.35	39.34	16.77	3.87	41.08
12748-H5	2	2.3828	1.7689	2.7675	2.38	38.52	16.19	3.87	40.23
SMALL EXTRUDER > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
12750-A1	2	0.9743	0.7235	1.1382	2.34	39.52	16.87	3.87	41.15
12750-A2	2	1.0341	0.7684	1.2077	2.35	39.52	16.84	3.88	41.03
12750-A3	2	1.0225	0.7591	1.2011	2.31	40.41	17.52	3.87	42.05
12750-A4	2	1.0122	0.7512	1.1888	2.31	40.36	17.50	3.87	42.06
12750-A5	2	0.9355	0.6948	1.0956	2.33	39.95	17.17	3.87	41.53
12750-A6	2	0.8025	0.5962	0.9549	2.23	42.49	19.05	3.88	43.96

VARIABLES: LS-LOW SPEED, HS-HIGH SPEED, V-VACUUM, R-ROLLED

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D.	GAS CONV.	DRY WEIGHT	SUS. WEIGHT	SAT. WEIGHT	BULK DENSITY	APP. POROSITY	H2O ABS.	APP. S.G.	TOTAL POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
BATCH #1 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-1A	2	2.1807	1.6219	2.5169	2.43	37.56	15.46	3.89	38.96
25530-6-1B	2	2.1971	1.6292	2.5275	2.44	36.78	15.08	3.86	38.73
25530-6-1C	2	2.6105	1.9321	2.8994	2.69	29.87	11.10	3.84	32.40
25530-6-1D	2	1.7966	1.3348	2.0866	2.38	38.57	16.19	3.88	40.14
25530-6-1E	2	1.8723	1.3914	2.1717	2.39	38.37	16.04	3.88	39.89
BATCH #2 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-2A	2	3.0136	2.2376	3.4081	2.57	33.70	13.13	3.87	35.50
25530-6-2B	2	2.4688	1.8339	2.8301	2.47	36.27	14.68	3.88	37.92
25530-6-2C	2	2.5943	1.9266	2.9624	2.50	35.54	14.23	3.87	37.26
25530-6-2D	2	2.4181	1.7959	2.7425	2.55	34.27	13.46	3.87	36.01
25530-6-2E	2	2.4848	1.8445	2.8201	2.54	34.37	13.53	3.87	36.20
BATCH #3 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-3A	2	2.5878	1.9237	3.0324	2.33	40.10	17.23	3.89	41.53
25530-6-3B	2	2.2364	1.6601	2.5725	2.44	36.84	15.07	3.87	38.60
25530-6-3C	2	2.1841	1.6219	2.5658	2.31	40.44	17.53	3.87	42.04
25530-6-3D	2	2.0546	1.5273	2.4152	2.31	40.61	17.60	3.88	42.03
25530-6-3E	2	1.8308	1.3592	2.1414	2.33	39.71	17.02	3.87	41.37
BATCH #4 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-4A	2	2.0937	1.5543	2.4555	2.32	40.15	17.33	3.87	41.80
25530-6-4B	2	2.2763	1.6909	2.6659	2.33	39.96	17.17	3.88	41.52
25530-6-4C	2	2.4411	1.8133	2.8685	2.31	40.50	17.56	3.88	42.05
25530-6-4D	2	2.2796	1.6945	2.6707	2.33	40.06	17.21	3.88	41.50
25530-6-4E	2	2.1736	1.6138	2.5486	2.32	40.12	17.30	3.87	41.75
BATCH #5 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-5A	2	2.5240	1.8767	2.9676	2.31	40.66	17.63	3.89	42.04
25530-6-5B	2	2.7679	2.0581	3.2413	2.33	40.01	17.15	3.89	41.40
25530-6-5C	2	2.7068	2.0129	3.1934	2.29	41.22	18.03	3.89	42.56
25530-6-5D	2	2.3794	1.7676	2.8107	2.27	41.35	18.18	3.88	42.86
25530-6-5E	2	2.4738	1.8383	2.9076	2.31	40.57	17.59	3.88	42.05
BATCH #6 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-6A	2	2.9203	2.1715	3.4181	2.34	39.93	17.10	3.89	41.32
25530-6-6B	2	2.6195	1.9465	3.0755	2.31	40.39	17.46	3.88	41.88
25530-6-6C	2	2.7687	2.0586	3.2544	2.31	40.62	17.60	3.89	42.00
25530-6-6D	2	2.4699	1.8354	2.8986	2.32	40.32	17.41	3.88	41.81
25530-6-6E	2	2.6859	1.9963	3.1493	2.32	40.19	17.30	3.88	41.65

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
BATCH #7 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-7A	2	2.7894	2.0739	3.3261	2.22	42.86	19.30	3.89	44.20
25530-6-7B	2	2.8968	2.1525	3.4506	2.22	42.66	19.18	3.88	44.10
25530-6-7C	2	2.6744	1.9868	3.1667	2.26	41.72	18.46	3.88	43.22
25530-6-7D	2	2.3555	1.7517	2.8039	2.23	42.62	19.09	3.89	43.92
25530-6-7E	2	2.2991	1.7071	2.7274	2.25	41.98	18.69	3.87	43.55
BATCH #8 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-8A	2	2.8513	2.1191	3.3601	2.29	41.00	17.90	3.88	42.44
25530-6-8B	2	2.6286	1.9534	3.1429	2.20	43.24	19.62	3.88	44.64
25530-6-8C	2	2.7021	2.0081	3.2177	2.23	42.63	19.14	3.88	44.04
25530-6-8D	2	2.5136	1.8668	2.9961	2.22	42.73	19.25	3.87	44.24
25530-6-8E	2	1.8542	1.3777	2.2064	2.23	42.50	19.05	3.88	43.95
BATCH #9 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-9A	2	2.8153	2.0924	3.3579	2.22	42.88	19.33	3.88	44.27
25530-6-9B	2	2.8289	2.1023	3.3662	2.23	42.51	19.05	3.88	43.93
25530-6-9C	2	2.2883	1.7001	2.7329	2.21	43.05	19.49	3.88	44.50
25530-6-9D	2	2.3996	1.7820	2.8574	2.22	42.57	19.14	3.87	44.10
25530-6-9E	2	2.4490	1.8199	2.9301	2.20	43.33	19.70	3.88	44.74
BATCH #10 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-10A	2	3.1069	2.3099	3.6957	2.24	42.49	19.01	3.89	43.84
25530-6-10B	2	2.7651	2.0553	3.2875	2.24	42.40	18.95	3.88	43.79
25530-6-10C	2	3.0105	2.2385	3.5806	2.24	42.48	18.99	3.89	43.81
25530-6-10D	2	2.8507	2.1168	3.3349	2.33	39.75	17.04	3.87	41.38
25530-6-10E	2	2.6102	1.9378	3.0847	2.27	41.37	18.23	3.87	42.99
BATCH #11 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-11A	2	3.2381	2.4076	3.8650	2.22	43.01	19.42	3.89	44.34
25530-6-11B	2	2.6975	2.0064	3.2291	2.20	43.48	19.77	3.89	44.73
25530-6-11C	2	2.5315	1.8805	3.0120	2.23	42.47	19.04	3.88	43.96
25530-6-11D	2	2.0792	1.5441	2.5035	2.16	44.23	20.47	3.87	45.71
25530-6-11E	2	2.3529	1.7478	2.8052	2.22	42.77	19.28	3.88	44.26
BATCH #12 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
25530-6-12A	2	3.2009	2.3758	3.8350	2.19	43.46	19.87	3.87	45.05
25530-6-12B	2	3.1588	2.3482	3.7329	2.27	41.46	18.23	3.89	42.85
25530-6-12C	2	2.9269	2.1707	3.5538	2.11	45.33	21.48	3.86	46.99
25530-6-12D	2	2.8736	2.1306	3.4543	2.16	43.87	20.27	3.86	45.62
25530-6-12E	2	2.8660	2.1259	3.4535	2.15	44.25	20.56	3.86	45.92

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 4 - BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.62 WT% METHOCEL									
25530-21-1A	4	2.3539	1.7475	2.8077	2.21	42.80	19.34	3.87	44.38
25530-21-1B	4	2.8506	2.1163	3.3936	2.23	42.51	19.11	3.87	44.09
25530-21-1C	4	1.9349	1.4342	2.2945	2.24	41.80	18.64	3.85	43.66
25530-21-1D	4	3.0753	2.2836	3.6052	2.32	40.10	17.28	3.87	41.71
25530-21-1E	4	2.9571	2.1966	3.5259	2.22	42.79	19.29	3.88	44.27
25530-21-1F	4	8.2976	6.1685	9.7768	2.29	40.99	17.88	3.89	42.39
25530-21-1G	4	8.0578	5.9862	9.4665	2.31	40.48	17.54	3.88	42.00
25530-21-1H	4	8.0998	6.0127	9.5681	2.27	41.30	18.18	3.87	42.93
25530-21-1I	4	8.4308	6.2656	9.9240	2.30	40.82	17.76	3.88	42.27
25530-21-1J	4	8.3171	6.1767	9.8187	2.28	41.23	18.11	3.87	42.79
RUN 4 - BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.54 WT% METHOCEL									
25530-21-2A	4	3.6393	2.6978	4.0708	2.64	31.43	11.89	3.85	33.60
25530-21-2B	4	3.2280	2.3957	3.6199	2.63	32.01	12.18	3.87	33.95
25530-21-2C	4	3.2522	2.4128	3.6656	2.59	33.00	12.75	3.86	34.97
25530-21-2D	4	3.6498	2.7117	4.0913	2.64	32.00	12.13	3.88	33.73
25530-21-2E	4	4.5914	3.4082	5.1476	2.63	31.98	12.15	3.87	33.88
25530-21-2F	4	9.0558	6.7071	10.1311	2.64	31.40	11.91	3.84	33.75
25530-21-2G	4	9.4908	7.0459	10.6202	2.65	31.60	11.94	3.87	33.48
25530-21-2H	4	8.5804	6.3670	9.6387	2.61	32.35	12.37	3.86	34.30
25530-21-2I	4	10.3302	7.6611	11.7642	2.51	34.95	13.92	3.86	36.93
25530-21-2J	4	11.3091	8.3982	12.7191	2.61	32.63	12.51	3.87	34.44
RUN 4 - BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.595 WT% METHOCEL									
25530-22-3A	4	3.0698	2.2825	3.5415	2.43	37.47	15.41	3.89	38.92
25530-22-3B	4	2.6338	1.9553	3.0420	2.42	37.56	15.55	3.87	39.29
25530-22-3C	4	3.1585	2.3467	3.6356	2.44	37.02	15.15	3.88	38.61
25530-22-3D	4	3.7229	2.7656	4.3056	2.41	37.84	15.70	3.88	39.44
25530-22-3E	4	2.7290	2.0279	3.1653	2.39	38.36	16.04	3.88	39.90
25530-22-3F	4	8.9910	6.6851	10.3690	2.43	37.41	15.37	3.89	38.86
25530-22-3G	4	8.4651	6.2880	9.7691	2.42	37.46	15.45	3.88	39.08
25530-22-3H	4	8.6999	6.4694	10.0318	2.43	37.39	15.36	3.89	38.82
25530-22-3I	4	9.8553	7.3143	11.3437	2.44	36.94	15.15	3.87	38.73
25530-22-3J	4	8.8921	6.6103	10.2121	2.46	36.65	14.89	3.89	38.16
RUN 5 > 45%A-13M & 55%A-13UG W/ 1.607 WT% METHOCEL									
25530-22-5A	4	3.2948	2.4468	3.8676	2.31	40.32	17.44	3.87	41.91
25530-22-5B	4	2.5572	1.9002	2.9783	2.36	39.06	16.52	3.88	40.58
25530-22-5C	4	2.5836	1.9182	3.0188	2.34	39.54	16.90	3.87	41.20
25530-22-5D	4	2.9375	2.1805	3.4208	2.36	38.97	16.50	3.87	40.67
25530-22-5E	4	2.4052	1.7883	2.7989	2.37	38.96	16.42	3.89	40.38
25530-22-5F	4	7.5735	5.6372	8.7864	2.40	38.51	16.06	3.90	39.76
25530-22-5G	4	9.2349	6.8565	10.7504	2.36	38.92	16.46	3.87	40.59
25530-22-5H	4	7.2289	5.3697	8.4074	2.37	38.80	16.35	3.88	40.39
25530-22-5I	4	7.7123	5.7399	9.0035	2.36	39.56	16.79	3.90	40.80
25530-22-5J	4	8.2714	6.1494	9.5433	2.43	37.48	15.42	3.89	38.95

***NOTE: EXCESS ALUMINA KNEADED INTO MIX BY HAND**

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 6 BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-28-1A	2	2.1996	1.6309	2.5505	2.38	38.16	16.00	3.86	40.08
25530-28-1B	2	2.2334	1.6569	2.5919	2.38	38.34	16.10	3.86	40.16
25530-28-1C	2	2.4588	1.8267	2.8302	2.44	37.01	15.15	3.88	38.62
25530-28-1D	2	2.5246	1.8723	2.9056	2.44	36.87	15.14	3.86	38.80
25530-28-1E	2	2.7613	2.0453	3.1578	2.47	35.64	14.40	3.84	37.82
25530-28-1F*	2	8.7134	6.4660	10.0465	2.43	37.23	15.35	3.87	39.04
25530-28-1G*	2	8.0043	5.9404	9.2942	2.38	38.46	16.16	3.87	40.21
25530-28-1H*	2	8.4361	6.2584	9.7631	2.40	37.86	15.78	3.86	39.70
25530-28-1I*	2	7.8022	5.7881	9.0251	2.40	37.78	15.72	3.86	39.62
25530-28-1J*	2	8.8080	6.5326	10.1803	2.41	37.62	15.63	3.86	39.51
RUN 6 BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-29-2A	2	2.3357	1.7327	2.6794	2.46	36.31	14.76	3.86	38.20
25530-29-2B	2	2.4240	1.8002	2.7822	2.46	36.48	14.82	3.87	38.17
25530-29-2C	2	2.6305	1.9499	3.0176	2.46	36.26	14.76	3.85	38.28
25530-29-2D	2	2.5807	1.9149	2.9632	2.45	36.49	14.87	3.86	38.33
25530-29-2E	2	2.7363	2.0286	3.1515	2.43	36.98	15.22	3.85	38.96
RUN 6 BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-29-3A	2	2.3709	1.7605	2.7328	2.43	37.22	15.31	3.87	38.92
25530-29-3B	2	2.3617	1.7542	2.7319	2.41	37.86	15.72	3.88	39.49
25530-29-3C	2	2.3503	1.7452	2.7287	2.38	38.47	16.15	3.87	40.14
25530-29-3D	2	2.5819	1.9153	2.9612	2.46	36.27	14.73	3.86	38.16
25530-29-3E	2	2.6877	1.9962	3.0948	2.44	37.06	15.19	3.88	38.72
RUN 6 BATCH #4 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-29-4A	2	2.3558	1.7493	2.7186	2.42	37.43	15.45	3.87	39.12
25530-29-4B	2	2.5456	1.8903	2.9337	2.43	37.20	15.29	3.87	38.88
25530-29-4C	2	2.5121	1.8665	2.8986	2.43	37.45	15.43	3.88	39.03
25530-29-4D	2	2.5013	1.8538	2.8719	2.45	36.40	14.86	3.85	38.46
25530-29-4E	2	2.4938	1.8501	2.8787	2.42	37.42	15.48	3.86	39.27
RUN 6 BATCH #5 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-30-5A	2	2.2272	1.6525	2.5699	2.42	37.36	15.43	3.86	39.18
25530-30-5B	2	2.5306	1.8796	2.9093	2.45	36.78	15.01	3.88	38.44
25530-30-5C	2	2.4877	1.8453	2.8705	2.42	37.34	15.43	3.86	39.21
25530-30-5D	2	2.3054	1.7125	2.6509	2.45	36.82	15.03	3.88	38.46
25530-30-5E	2	2.5222	1.8725	2.9022	2.44	36.90	15.11	3.87	38.64
25530-30-5F*	2	6.6700	4.9548	7.6682	2.45	36.79	15.01	3.88	38.42
25530-30-5G*	2	8.0318	5.9593	9.2565	2.43	37.14	15.29	3.86	38.98
25530-30-5H*	2	7.3019	5.4238	8.4452	2.41	37.84	15.70	3.88	39.46
25530-30-5I*	2	7.3119	5.4289	8.4488	2.41	37.65	15.60	3.87	39.35
25530-30-5J*	2	7.6313	5.6632	8.7825	2.44	36.91	15.13	3.87	38.72
RUN 6 BATCH #6 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-30-6A	2	2.6539	1.9716	3.0386	2.48	36.05	14.54	3.88	37.69
25530-30-6B	2	2.6534	1.9713	3.0403	2.47	36.19	14.63	3.88	37.82
25530-30-6C	2	2.7134	2.0152	3.1035	2.49	35.84	14.42	3.87	37.54
25530-30-6D	2	2.8314	2.1002	3.2458	2.46	36.17	14.68	3.86	38.09
25530-30-6E	2	2.9213	2.1684	3.3426	2.48	35.88	14.47	3.87	37.68

* UNMACHINED SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 6 BATCH #7 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-31-7A	2	2.8688	2.1289	3.2909	2.46	36.33	14.76	3.87	38.15
25530-31-7B	2	2.8530	2.1141	3.2691	2.46	36.03	14.63	3.85	38.12
25530-31-7C	2	2.8306	2.1012	3.2442	2.47	36.19	14.66	3.87	37.96
25530-31-7D	2	3.0126	2.2362	3.4594	2.46	36.53	14.88	3.87	38.30
25530-31-7E	2	3.0541	2.2624	3.4959	2.47	35.82	14.51	3.85	37.98
25530-31-7F*	2	7.5543	5.6025	8.5174	2.58	33.04	12.79	3.86	35.08
25530-31-7G*	2	7.1763	5.3176	8.2698	2.42	37.04	15.28	3.85	39.11
25530-31-7H*	2	7.1107	5.2753	8.1597	2.46	36.37	14.80	3.86	38.25
25530-31-7I*	2	7.0646	5.2483	8.0980	2.47	36.26	14.67	3.88	37.90
25530-31-7J*	2	7.9043	5.8649	8.9227	2.58	33.30	12.92	3.86	35.25
RUN 6 BATCH #8 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-31-8A	2	2.2552	1.6754	2.6072	2.41	37.78	15.66	3.88	39.37
25530-31-8B	2	2.4429	1.8142	2.8103	2.45	36.88	15.08	3.87	38.57
25530-31-8C	2	2.4279	1.8034	2.8152	2.39	38.28	16.00	3.88	39.89
25530-31-8D	2	2.5168	1.8697	2.9269	2.37	38.79	16.34	3.88	40.36
25530-31-8E	2	2.7246	2.0233	3.1644	2.38	38.54	16.19	3.87	40.19
RUN 6 BATCH #9 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-31-9A	2	2.7215	2.0149	3.1068	2.48	35.29	14.20	3.84	37.56
25530-31-9B	2	2.6853	1.9933	3.0749	2.48	36.02	14.55	3.87	37.81
25530-31-9C	2	2.7870	2.0688	3.2050	2.45	36.79	15.04	3.87	38.55
25530-31-9D	2	2.6927	1.9967	3.0873	2.46	36.18	14.70	3.86	38.15
25530-31-9E	2	2.7863	2.0661	3.1993	2.45	36.45	14.87	3.86	38.41
RUN 6 BATCH #10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-32-10A	2	2.9164	2.1643	3.3269	2.50	35.31	14.12	3.87	37.16
25530-32-10B	2	2.7370	2.0320	3.1059	2.54	34.35	13.52	3.87	36.16
25530-32-10C	2	2.7867	2.0698	3.1704	2.52	34.86	13.81	3.88	36.57
25530-32-10D	2	2.6130	1.9398	2.9833	2.50	35.49	14.21	3.87	37.27
25530-32-10E	2	2.8948	2.1472	3.2925	2.52	34.72	13.78	3.86	36.68
RUN 6 BATCH #11 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-32-11A	2	2.5515	1.8936	2.9274	2.46	36.36	14.78	3.87	38.17
25530-32-11B	2	2.6177	1.9441	2.9937	2.49	35.82	14.41	3.87	37.52
25530-32-11C	2	2.6019	1.9292	2.9870	2.45	36.41	14.85	3.86	38.38
25530-32-11D	2	2.6422	1.9616	3.0264	2.47	36.08	14.58	3.87	37.84
25530-32-11E	2	2.6739	1.9858	3.0765	2.44	36.91	15.10	3.87	38.59
RUN 6 BATCH #12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25530-33-12A	2	2.1451	1.5918	2.4671	2.44	36.79	15.06	3.87	38.61
25530-33-12B	2	2.2825	1.6950	2.6262	2.44	36.91	15.10	3.87	38.60
25530-33-12C	2	2.4537	1.8227	2.8212	2.45	36.81	15.02	3.88	38.44
25530-33-12D	2	2.6545	1.9715	3.0472	2.46	36.51	14.84	3.87	38.18
25530-33-12E	2	2.7361	2.0311	3.1226	2.50	35.41	14.17	3.87	37.21
25530-33-12F*	2	7.1299	5.2919	8.2055	2.44	36.92	15.13	3.87	38.70
25530-33-12G*	2	7.2671	5.3911	8.3488	2.45	36.57	14.93	3.86	38.45
25530-33-12H*	2	8.7120	6.4688	10.0358	2.44	37.11	15.24	3.87	38.82
25530-33-12I*	2	6.8823	5.1106	7.9109	2.45	36.73	14.99	3.87	38.43
25530-33-12J*	2	6.6292	4.9184	7.5947	2.47	36.08	14.61	3.86	37.95

• UNMACHINED SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

RUN 6

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
HW FIRING #1 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
HW#1-A	\$\$\$	6.4477	4.7852	7.4028	2.46	36.49	14.86	3.87	38.30
HW#1-B	\$\$\$	5.9353	4.4088	6.8134	2.46	36.52	14.84	3.88	38.17
HW#1-C	\$\$\$	5.5060	4.0900	6.3233	2.46	36.60	14.89	3.88	38.24
HW#1-D	\$\$\$	6.5727	4.8784	7.6084	2.40	37.94	15.81	3.87	39.69
HW#1-E	\$\$\$	6.9392	5.1536	7.9294	2.49	35.67	14.31	3.87	37.38
HW#1-F	\$\$\$	5.7635	4.2698	6.6049	2.46	36.03	14.64	3.85	38.17
HW#1-G	\$\$\$	5.4268	4.0264	6.2190	2.47	36.13	14.64	3.86	38.00
HW#1-H	\$\$\$	5.0476	3.7465	5.8032	2.45	36.74	15.01	3.87	38.52
HW#1-I	\$\$\$	5.5639	4.0996	6.2054	2.63	30.46	11.56	3.79	33.81
HW#1-J	\$\$\$	5.4181	4.0164	6.1598	2.52	34.60	13.73	3.85	36.68
HW FIRING #2 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
HW#2-A	\$\$\$	7.7491	5.7645	8.9360	2.44	37.42	15.36	3.89	38.79
HW#2-B	\$\$\$	7.4031	5.5205	8.6646	2.35	40.12	17.09	3.92	41.02
HW#2-C	\$\$\$	7.9114	5.8831	9.1633	2.40	38.17	15.87	3.89	39.58
HW#2-D	\$\$\$	6.9305	5.1645	8.0629	2.38	39.07	16.39	3.91	40.10
HW#2-E	\$\$\$	8.1937	6.0912	9.4031	2.47	36.52	14.80	3.89	38.03
HW#2-F	\$\$\$	6.1857	4.6155	7.3132	2.29	41.80	18.28	3.93	42.56
HW#2-G	\$\$\$	8.2066	6.1010	9.4387	2.45	36.91	15.06	3.89	38.41
HW#2-H	\$\$\$	6.6593	4.9694	7.8717	2.29	41.77	18.26	3.93	42.52
HW#2-I	\$\$\$	6.5037	4.8471	7.5569	2.39	38.87	16.24	3.91	39.88
HW#2-J	\$\$\$	6.4111	4.7816	7.5532	2.31	41.21	17.87	3.92	42.06
HW FIRING #3 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL									
HW#3-A	\$\$\$	6.4242	4.7734	7.3684	2.47	36.39	14.74	3.88	37.99
HW#3-B	\$\$\$	6.5302	4.8528	7.5439	2.42	37.67	15.57	3.88	39.21
HW#3-C	\$\$\$	7.0424	5.2351	8.0511	2.49	35.82	14.37	3.88	37.35
HW#3-D	\$\$\$	6.4077	4.7627	7.3834	2.44	37.23	15.27	3.88	38.75
HW#3-E	\$\$\$	6.5031	4.8505	7.5647	2.39	39.11	16.37	3.92	39.98
HW#3-F	\$\$\$	6.8662	5.0995	7.8437	2.49	35.62	14.28	3.87	37.32
HW#3-G	\$\$\$	5.9299	4.4106	6.8329	2.44	37.28	15.27	3.89	38.68
HW#3-H	\$\$\$	6.3022	4.6921	7.2491	2.46	37.03	15.07	3.90	38.26
HW#3-I	\$\$\$	6.2869	4.6718	7.2617	2.42	37.64	15.55	3.88	39.19
HW#3-J	\$\$\$	5.9028	4.3937	6.8237	2.42	37.90	15.65	3.90	39.15

NOTE: ALL SAMPLES 'AS DRIED' (UNMACHINED)

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 7 BATCH #1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-39A	4	2.0946	1.5539	2.4358	2.37	38.69	16.34	3.86	40.50
25530-39B	4	2.1942	1.6289	2.5551	2.36	38.97	16.50	3.87	40.66
25530-39C	4	2.0213	1.5009	2.3376	2.41	37.80	15.70	3.87	39.48
25530-39D	4	2.1459	1.5934	2.4856	2.40	38.07	15.88	3.87	39.75
25530-39E	4	2.2565	1.6765	2.6239	2.37	38.78	16.33	3.88	40.34
25530-39F*	4	7.0862	5.2639	8.1785	2.42	37.48	15.46	3.88	39.10
25530-39G*	4	5.8339	4.3332	6.7919	2.37	38.96	16.47	3.88	40.56
25530-39H*	4	5.9479	4.4179	6.8734	2.42	37.69	15.61	3.88	39.32
25530-39I*	4	6.7655	5.0229	7.7897	2.44	37.02	15.18	3.87	38.75
25530-39J*	4	5.8823	4.3709	6.8323	2.38	38.60	16.20	3.88	40.13
RUN 7 BATCH #2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-41A	4	2.0571	1.5271	2.3799	2.40	37.85	15.74	3.87	39.57
25530-41B	4	1.6742	1.2424	1.9423	2.38	38.31	16.06	3.87	40.08
25530-41C	4	1.8179	1.3498	2.1259	2.34	39.69	16.99	3.87	41.32
25530-41D	4	1.9648	1.4589	2.2801	2.39	38.40	16.10	3.87	40.06
25530-41E	4	1.8697	1.3891	2.1648	2.40	38.04	15.83	3.88	39.62
25530-41F*	4	5.9086	4.3892	6.8337	2.41	37.84	15.70	3.88	39.45
25530-41G*	4	7.9797	5.9281	9.2222	2.42	37.72	15.62	3.88	39.32
25530-41H*	4	5.9761	4.4387	6.9345	2.39	38.40	16.09	3.88	40.02
25530-41I*	4	5.8299	4.3317	6.7816	2.37	38.85	16.37	3.88	40.39
25530-41J*	4	5.7985	4.3074	6.7637	2.35	39.29	16.70	3.88	40.86

* UNMACHINED SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 8 BATCH #1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-46-1A	2	1.8318	1.3571	2.1175	2.40	37.57	15.64	3.85	39.65
25530-46-1B	2	1.6877	1.2519	1.9593	2.38	38.39	16.14	3.86	40.24
25530-46-1C	2	1.9309	1.4330	2.2394	2.39	38.26	16.03	3.87	40.02
25530-46-1D	2	2.0043	1.4857	2.3179	2.40	37.68	15.69	3.85	39.67
25530-46-1E	2	2.0639	1.5288	2.3763	2.43	36.86	15.18	3.85	39.00
25530-46-1F*	2	6.7945	5.0393	7.8143	2.44	36.75	15.05	3.86	38.67
25530-46-1G*	2	6.2058	4.6044	7.1414	2.44	36.88	15.12	3.86	38.72
25530-46-1H*	2	7.0641	5.2389	8.1354	2.43	36.99	15.21	3.86	38.91
25530-46-1I*	2	7.2737	5.3965	8.4112	2.41	37.73	15.69	3.86	39.56
RUN 8 BATCH #2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-47-2A	2	1.9267	1.4265	2.2235	2.41	37.24	15.45	3.84	39.44
25530-47-2B	2	1.7951	1.3307	2.0828	2.38	38.25	16.08	3.85	40.21
25530-47-2C	2	1.6776	1.2453	1.9422	2.40	37.97	15.82	3.87	39.70
25530-47-2D	2	2.0585	1.5285	2.3949	2.37	38.83	16.39	3.87	40.48
25530-47-2E	2	1.6956	1.2583	1.9717	2.37	38.70	16.33	3.87	40.46
RUN 8 BATCH #3 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-47-3A	2	2.0222	1.4959	2.3208	2.44	36.20	14.81	3.83	38.59
25530-47-3B	2	1.8461	1.3686	2.1396	2.39	38.07	15.95	3.85	40.02
25530-47-3C	2	2.0912	1.5500	2.4162	2.41	37.52	15.59	3.85	39.52
25530-47-3D	2	1.8715	1.3885	2.1762	2.37	38.68	16.33	3.86	40.48
25530-47-3E	2	2.0709	1.5345	2.3991	2.39	37.96	15.90	3.85	40.00
RUN 8 BATCH #4 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-47-4A	2	1.9532	1.4488	2.2423	2.45	36.43	14.85	3.86	38.34
25530-47-4B	2	2.1729	1.6118	2.5041	2.43	37.12	15.29	3.86	39.00
25530-47-4C	2	1.8841	1.3977	2.1929	2.36	38.83	16.44	3.86	40.65
25530-47-4D	2	2.0584	1.5281	2.3812	2.41	37.84	15.73	3.87	39.56
25530-47-4E	2	2.0787	1.5417	2.4002	2.41	37.45	15.51	3.86	39.35
RUN 8 BATCH #5 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-48-5A	2	1.8889	1.4021	2.1821	2.41	37.59	15.57	3.87	39.34
25530-48-5B	2	1.8266	1.3555	2.1075	2.42	37.35	15.42	3.87	39.15
25530-48-5C	2	1.9638	1.4568	2.2675	2.42	37.46	15.51	3.86	39.32
25530-48-5D	2	1.8377	1.3637	2.1290	2.39	38.06	15.90	3.87	39.85
25530-48-5E	2	1.8196	1.3500	2.1087	2.39	38.10	15.94	3.86	39.92
25530-48-5F*	2	6.6434	4.9255	7.6460	2.43	36.85	15.14	3.86	38.83
25530-48-5G*	2	7.5815	5.6292	8.7381	2.43	37.20	15.30	3.87	38.91
25530-48-5H*	2	10.0925	7.4875	11.5814	2.46	36.37	14.80	3.86	38.24
25530-48-5I*	2	6.0143	4.4542	6.9332	2.42	37.07	15.32	3.84	39.23
RUN 8 BATCH #6 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-48-6A	2	1.9943	1.4775	2.2952	2.43	36.80	15.13	3.85	38.90
25530-48-6B	2	1.7532	1.2998	2.0273	2.40	37.68	15.68	3.86	39.63
25530-48-6C	2	1.7852	1.3228	2.0492	2.45	36.34	14.83	3.85	38.44
25530-48-6D	2	1.7854	1.3227	2.0482	2.45	36.22	14.76	3.85	38.35
25530-48-6E	2	1.6266	1.2059	1.8719	2.44	36.83	15.13	3.85	38.82

• UNMACHINED SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 8 BATCH #7 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-49-7A	2	1.8498	1.3707	2.1361	2.41	37.41	15.52	3.85	39.46
25530-49-7B	2	1.8042	1.3366	2.0669	2.46	35.97	14.60	3.85	38.11
25530-49-7C	2	1.9924	1.4751	2.2803	2.47	35.76	14.49	3.84	38.02
25530-49-7D	2	1.6452	1.2192	1.8874	2.45	36.25	14.77	3.85	38.32
25530-49-7E	2	1.8617	1.3794	2.1345	2.46	36.13	14.70	3.85	38.24
25530-49-7F*	2	6.9607	5.1672	7.9846	2.46	36.34	14.75	3.87	38.11
25530-49-7G*	2	6.3063	4.6743	7.2317	2.46	36.19	14.72	3.85	38.23
25530-49-7H*	2	7.1967	5.3367	8.2388	2.47	35.91	14.52	3.86	37.88
25530-49-7I*	2	6.6896	4.9625	7.7008	2.44	36.93	15.16	3.86	38.80
RUN 8 BATCH #8 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-49-8A	2	2.0329	1.5060	2.3373	2.44	36.62	15.02	3.85	38.74
25530-49-8B	2	2.0372	1.5104	2.3447	2.43	36.86	15.14	3.86	38.83
25530-49-8C	2	1.7269	1.2793	1.9743	2.48	35.60	14.37	3.85	37.76
25530-49-8D	2	1.8066	1.3381	2.0811	2.42	36.94	15.24	3.84	39.09
25530-49-8E	2	1.9357	1.4344	2.2172	2.47	35.96	14.59	3.85	38.06
RUN 8 BATCH #9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-49-9A	2	1.7609	1.3044	2.0358	2.40	37.59	15.66	3.85	39.69
25530-49-9B	2	1.9397	1.4379	2.2384	2.42	37.31	15.45	3.85	39.30
25530-49-9C	2	2.1827	1.6162	2.5004	2.46	35.93	14.60	3.84	38.16
25530-49-9D	2	1.8544	1.3747	2.1384	2.42	37.19	15.36	3.85	39.17
25530-49-9E	2	2.0677	1.5294	2.3665	2.46	35.69	14.49	3.83	38.12
RUN 8 BATCH #10 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-50-10A	2	1.8253	1.3528	2.1196	2.37	38.38	16.17	3.85	40.37
25530-50-10B	2	1.6966	1.2564	1.9770	2.35	38.91	16.58	3.84	41.02
25530-50-10C	2	1.6875	1.2526	1.9647	2.36	38.93	16.48	3.87	40.64
25530-50-10D	2	1.8348	1.3621	2.1442	2.34	39.56	16.91	3.87	41.23
25530-50-10E	2	1.8687	1.3842	2.1703	2.37	38.37	16.19	3.85	40.45
RUN 8 BATCH #11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-50-11A	2	1.5735	1.1652	1.8181	2.40	37.46	15.59	3.84	39.63
25530-50-11B	2	1.4873	1.1032	1.7212	2.40	37.85	15.77	3.86	39.71
25530-50-11C	2	1.4786	1.0961	1.7169	2.37	38.39	16.17	3.85	40.34
25530-50-11D	2	1.3616	1.0092	1.5804	2.38	38.31	16.12	3.85	40.29
25530-50-11E	2	1.6325	1.2115	1.8963	2.38	38.52	16.21	3.87	40.28
RUN 8 BATCH #12 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25530-50-12A	2	1.3681	1.0140	1.5789	2.41	37.32	15.45	3.85	39.33
25530-50-12B	2	1.4194	1.0523	1.6373	2.42	37.25	15.40	3.85	39.22
25530-50-12C	2	1.3963	1.0343	1.6135	2.40	37.50	15.60	3.85	39.61
25530-50-12D	2	1.4025	1.0403	1.6231	2.40	37.85	15.78	3.86	39.72
25530-50-12E	2	1.5669	1.1618	1.8038	2.43	36.90	15.16	3.86	38.86
25530-50-12F*	2	8.3164	6.1662	9.5446	2.45	36.35	14.81	3.86	38.34
25530-50-12G*	2	6.9576	5.1578	7.9783	2.46	36.19	14.71	3.85	38.21
25530-50-12H*	2	7.2714	5.3926	8.3455	2.46	36.37	14.82	3.86	38.31
25530-50-12I*	2	7.3646	5.4508	8.3392	2.54	33.74	13.27	3.84	36.13

• UNMACHINED SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
HW FIRING #4 > 35%A-13M & 65%C-30 W/ 1 WT% METHOCEL									
HW#4-A	\$\$\$	5.3758	3.9746	6.2051	2.40	37.18	15.47	3.83	39.63
HW#4-B	\$\$\$	5.8935	4.3803	7.3670	1.97	49.34	25.08	3.88	50.57
HW#4-C	\$\$\$	5.3188	3.9491	6.1579	2.40	37.99	15.82	3.87	39.68
HW#4-D	\$\$\$	5.1445	3.8273	6.0921	2.26	41.84	18.48	3.89	43.10
HW#4-E	\$\$\$	5.2538	3.9061	6.1135	2.37	38.95	16.41	3.89	40.38
HW#4-F	\$\$\$	5.2299	3.8757	6.0149	2.44	36.70	15.06	3.85	38.76
HW#4-G	\$\$\$	5.4814	4.0753	6.8548	1.97	49.41	25.13	3.89	50.60
HW#4-H	\$\$\$	4.9667	3.6828	5.7136	2.44	36.78	15.08	3.86	38.73
HW#4-I	\$\$\$	5.5839	4.1322	6.4358	2.42	36.98	15.30	3.83	39.28
HW#4-J	\$\$\$	5.4466	4.0377	6.2789	2.42	37.14	15.33	3.85	39.12
HW FIRING #5 > 35%A-13M & 65%C-30 W/ 1 WT% METHOCEL									
HW#5-A	\$\$\$	6.2908	4.6849	7.8988	1.95	50.03	25.64	3.91	50.97
HW#5-B	\$\$\$	5.8913	4.3798	7.1854	2.09	46.13	22.03	3.89	47.40
HW#5-C	\$\$\$	5.4825	4.0909	6.4294	2.34	40.49	17.32	3.93	41.27
HW#5-D	\$\$\$	5.1986	3.8778	6.3382	2.11	46.32	21.99	3.92	47.07
HW#5-E	\$\$\$	5.4509	4.0539	6.7078	2.05	47.36	23.13	3.89	48.55
HW#5-F	\$\$\$	5.5195	4.1063	6.4065	2.39	38.56	16.12	3.89	39.89
HW#5-G	\$\$\$	4.6279	3.4418	5.3721	2.39	38.55	16.13	3.89	39.94
HW#5-H	\$\$\$	6.0045	4.4656	6.9313	2.43	37.59	15.48	3.89	39.00
HW#5-I	\$\$\$	5.2701	3.9162	6.0723	2.44	37.21	15.27	3.88	38.77
HW#5-J	\$\$\$	5.9803	4.4503	7.2811	2.11	45.95	21.82	3.90	47.08
HW FIRING #6 > 35%A-13M & 65%C-30 W/ 1 WT% METHOCEL									
HW#6-A	\$\$\$	5.6194	4.1969	6.6184	2.31	41.26	17.83	3.94	41.87
HW#6-B	\$\$\$	5.9399	4.4418	7.1354	2.20	44.38	20.19	3.95	44.76
HW#6-C	\$\$\$	5.4579	4.0801	6.5434	2.21	44.07	19.95	3.95	44.50
HW#6-D	\$\$\$	4.9786	3.7009	5.7339	2.44	37.15	15.22	3.88	38.65
HW#6-E	\$\$\$	5.0145	3.7386	5.8203	2.40	38.71	16.12	3.92	39.66
HW#6-F	\$\$\$	5.1517	3.8374	5.9767	2.40	38.56	16.06	3.91	39.68
HW#6-G	\$\$\$	5.7608	4.2734	6.6694	2.40	37.92	15.82	3.86	39.77
HW#6-H	\$\$\$	5.1809	3.8499	5.9825	2.42	37.59	15.52	3.88	39.14
HW#6-I	\$\$\$	5.0272	3.7308	5.8178	2.40	37.88	15.77	3.87	39.66
HW#6-J	\$\$\$	5.6880	4.2311	6.5776	2.42	37.91	15.69	3.89	39.28
HW FIRING #7(REFIRE) > 35%A-13M & 65%C-30 W/ 1 WT% METHOCEL									
HW#7-A	\$\$\$	5.5263	4.0895	6.2912	2.50	34.74	13.88	3.83	37.12
HW#7-B	\$\$\$	5.4314	4.0249	6.2332	2.45	36.31	14.81	3.85	38.39
HW#7-C	\$\$\$	5.7156	4.2176	6.5243	2.47	35.06	14.19	3.80	37.93
HW#7-D	\$\$\$	5.9424	4.3982	6.8331	2.43	36.58	15.03	3.84	38.86
HW#7-E	\$\$\$	5.8281	4.3159	6.7151	2.42	36.97	15.27	3.84	39.15
HW#7-F	\$\$\$	5.7387	4.2484	6.5513	2.48	35.29	14.20	3.84	37.58
HW#7-G	\$\$\$	5.9663	4.4102	6.8228	2.47	35.50	14.40	3.82	38.05
HW#7-H	\$\$\$	6.0338	4.4743	6.9524	2.43	37.07	15.27	3.86	39.01
HW#7-I	\$\$\$	5.5796	4.1311	6.4025	2.45	36.23	14.79	3.84	38.47
HW#7-J	\$\$\$	5.8570	4.3421	6.7549	2.42	37.21	15.38	3.85	39.19

NOTE: ALL SAMPLES 'AS DRIED' (UNMACHINED)

NOTE: THIS IS ALCOA RUN #8 MATERIAL
(C-30 FORMULATION) FIRED BY H-W

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL									
25655-1A	2	1.9379	1.4391	2.2424	2.41	37.91	15.76	3.87	39.57
25655-1B	2	1.8402	1.3648	2.1187	2.43	36.94	15.18	3.86	38.85
25655-1C	2	2.0568	1.5260	2.3782	2.41	37.71	15.67	3.86	39.54
25655-1D	2	1.9259	1.4284	2.2261	2.41	37.63	15.63	3.86	39.52
25655-1E	2	1.8072	1.3412	2.0919	2.40	37.92	15.80	3.87	39.70
25655-1F*	2	8.2389	6.1028	9.4328	2.47	35.85	14.53	3.85	38.02
25655-1G*	2	8.9641	6.6439	10.2750	2.46	36.10	14.67	3.85	38.16
25655-1H*	2	7.9755	5.9142	9.1576	2.45	36.45	14.87	3.86	38.40
25655-1I*	2	7.5803	5.6221	8.7449	2.42	37.29	15.41	3.86	39.19
RUN 10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL									
25655-2A	2	2.8591	2.1196	3.1623	2.73	29.08	10.64	3.85	31.31
25655-2B	2	2.8116	2.0848	3.0893	2.79	27.65	9.91	3.86	29.88
25655-2C	2	2.5611	1.8956	2.8175	2.77	27.81	10.04	3.84	30.41
25655-2D	2	2.5822	1.9085	2.8349	2.78	27.28	9.82	3.82	30.18
25655-2E	2	2.5506	1.8899	2.8205	2.73	29.00	10.61	3.85	31.34
25655-2F*	2	14.0787	10.4012	15.5073	2.75	27.98	10.18	3.82	30.93
25655-2G*	2	12.8012	9.4272	14.0705	2.75	27.34	9.95	3.78	30.94
25655-2H*	2	12.5260	9.2344	13.8316	2.72	28.40	10.45	3.79	31.75
25655-2I*	2	10.4212	7.6735	11.4313	2.76	26.88	9.72	3.78	30.53

* 'AS DRIED' SAMPLES (UNMACHINED)

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (WET DISP.)									
25655-7A\$	2	1.1874	0.8807	1.4508	2.08	46.20	22.25	3.86	47.83
25655-7B\$	2	1.0484	0.7779	1.2798	2.08	46.10	22.14	3.86	47.67
25655-7C\$	2	1.1053	0.8212	1.3570	2.06	46.98	22.84	3.88	48.32
25655-7D\$	2	1.0298	0.7657	1.2647	2.06	47.07	22.88	3.89	48.30
25655-7E\$	2	1.0206	0.7573	1.2471	2.08	46.24	22.26	3.86	47.80
25655-7F*	2	4.9314	3.6577	6.0052	2.09	45.74	21.84	3.86	47.38
25655-7G*	2	4.9675	3.6796	6.0565	2.08	45.82	21.99	3.85	47.65
25655-7H*	2	3.8007	2.8166	4.6400	2.08	46.03	22.15	3.85	47.79
25655-7I*	2	4.6189	3.4231	5.6321	2.08	45.87	22.00	3.85	47.62
25655-7J*	2	5.3951	4.0012	6.6038	2.07	46.44	22.47	3.86	48.07
RUN 12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (WET DISP.)									
25655-8A	2	1.9141	1.4197	2.3134	2.14	44.68	20.92	3.86	46.35
25655-8B	2	2.0411	1.5146	2.4655	2.14	44.63	20.86	3.87	46.23
25655-8C	2	2.0963	1.5552	2.5316	2.14	44.58	20.83	3.86	46.22
25655-8D	2	1.9948	1.4806	2.4176	2.12	45.12	21.26	3.87	46.67
25655-8E	2	1.9822	1.4707	2.4039	2.12	45.19	21.34	3.86	46.79
25655-8F*	2	6.8564	5.0814	8.2751	2.14	44.42	20.75	3.85	46.22
25655-8G*	2	6.1058	4.5255	7.3506	2.15	44.06	20.45	3.85	45.86
25655-8H*	2	6.8802	5.0978	8.2799	2.16	43.99	20.41	3.85	45.84
25655-8I*	2	6.9451	5.1467	8.3765	2.14	44.32	20.67	3.85	46.13
RUN 13 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (DRY DISP.)									
25655-9A	2	2.2820	1.6890	2.5366	2.68	30.04	11.19	3.84	32.56
25655-9B	2	2.2395	1.6581	2.4878	2.69	29.93	11.12	3.84	32.39
25655-9C	2	2.3578	1.7442	2.6061	2.73	28.81	10.56	3.83	31.47
25655-9D	2	2.3271	1.7225	2.5842	2.69	29.84	11.08	3.84	32.35
25655-9E	2	2.1776	1.6116	2.4206	2.68	30.04	11.19	3.84	32.57
25655-9F*	2	7.9215	5.8620	8.8155	2.67	30.27	11.32	3.83	32.81
25655-9G*	2	8.4632	6.2545	9.3808	2.70	29.35	10.87	3.82	32.19
25655-9H*	2	8.5758	6.3403	9.5477	2.67	30.30	11.37	3.82	33.02
25655-9I*	2	8.8486	6.5447	9.8308	2.68	29.89	11.13	3.83	32.55
RUN 14 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (DRY DISP.)									
25655-10A	2	1.7959	1.3326	2.0693	2.43	37.11	15.27	3.86	38.93
25655-10B	2	1.8767	1.3937	2.1605	2.44	37.01	15.17	3.87	38.69
25655-10C	2	2.3009	1.7070	2.6251	2.50	35.31	14.13	3.86	37.22
25655-10D	2	1.9831	1.4711	2.2689	2.48	35.82	14.46	3.86	37.73
25655-10E	2	1.8284	1.3565	2.1200	2.39	38.19	16.00	3.86	40.01
25655-10F*	2	6.9563	5.1628	7.9457	2.49	35.55	14.27	3.87	37.38
25655-10G*	2	6.4635	4.8009	7.4838	2.40	38.03	15.83	3.88	39.65
25655-10H*	2	5.8449	4.3402	6.6692	2.50	35.39	14.15	3.87	37.13
25655-10I*	2	6.2154	4.6124	7.1443	2.45	36.69	14.99	3.87	38.51
25655-10J*	2	6.2291	4.6255	7.2549	2.36	39.01	16.52	3.87	40.66
25655-10K*	2	6.5359	4.8524	7.5807	2.39	38.29	16.03	3.87	39.99

\$ POOR GREEN STRENGTH - SAMPLES SHAPED MANUALLY

*** 'AS DRIED' SAMPLES (UNMACHINED)**

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 15 > 35%A-13M & 65%C-30 W/ 8 WT% MOGUL 1607									
25655-20A	2	2.1144	1.5728	2.3108	2.86	26.61	9.32	3.89	28.23
25655-20B	2	2.4413	1.8154	2.6732	2.84	27.03	9.53	3.89	28.71
25655-20C	2	2.7208	2.0228	2.9615	2.89	25.64	8.87	3.89	27.39
RUN 16 > 50%A-13M & 50%A-13UG W/ 8 WT% MOGUL 1607									
25655-22A	2	2.6499	1.9431	2.8079	3.05	18.27	5.98	3.74	23.24
25655-22B	2	3.2961	2.4189	3.4856	3.08	17.77	5.77	3.75	22.59
25655-22C	2	2.6658	1.9613	2.8190	3.10	17.86	5.76	3.77	22.14
25655-22D	2	2.8080	2.0709	2.9794	3.08	18.87	6.12	3.80	22.57
RUN 17 > 35%A-13M & 65%C-30 W/ 4WT% MOGUL 1607 & .1 WT% METHOCEL									
25655-24A	2	1.9038	1.4095	2.0374	3.02	21.28	7.04	3.84	24.05
25655-24B	2	2.7997	2.0709	2.9914	3.03	20.83	6.87	3.83	23.81
25655-24C	2	2.6671	1.9761	2.8515	3.04	21.06	6.93	3.85	23.68
25655-24D	2	2.3891	1.7665	2.5448	3.06	20.01	6.54	3.83	23.10
25655-24E	2	2.0322	1.5031	2.1701	3.04	20.67	6.81	3.83	23.68
RUN 18 > 50%A-13M & 50%A-13UG W/ 4WT% MOGUL 1607 & .1 WT% METHOCEL									
25655-25A	2	2.9993	2.2019	3.1619	3.11	16.94	5.44	3.75	21.74
25655-25B	2	3.6431	2.6633	3.8209	3.14	15.36	4.90	3.71	21.16
25655-25C	2	2.8865	2.1226	3.0618	3.06	18.66	6.09	3.77	23.01
25655-25D	2	3.0731	2.2501	3.2304	3.13	16.05	5.13	3.72	21.47
25655-25E	2	2.7565	2.0200	2.8992	3.13	16.23	5.19	3.73	21.46
RUN 19A > 35%A-13M & 65%C-30 W/ 4 WT% MOGUL 1607 (17% MOISTURE)									
25655-26A	2	2.3882	1.7713	2.5809	2.94	23.80	8.09	3.86	26.11
25655-26B	2	2.2397	1.6589	2.4044	3.00	22.09	7.38	3.84	24.74
25655-26C	2	2.6165	1.9373	2.8113	2.98	22.29	7.47	3.84	25.01
25655-26D	2	2.3779	1.7591	2.5462	3.01	21.38	7.10	3.83	24.32
25655-26E	2	2.4949	1.8472	2.6808	2.98	22.30	7.47	3.84	25.03
RUN 19B > 35%A-13M & 65%C-30 W/ 4 WT% MOGUL 1607 (17.1% MOISTURE)									
25655-27A	2	2.3366	1.7289	2.5018	3.01	21.37	7.09	3.83	24.27
25655-27B	2	2.1551	1.5939	2.3048	3.02	21.06	6.97	3.83	24.06
25655-27C	2	2.4439	1.8092	2.6125	3.03	20.99	6.92	3.84	23.79
25655-27D	2	2.6817	1.9881	2.8841	2.98	22.59	7.57	3.85	25.03
25655-27E	2	2.8024	2.0764	3.0182	2.97	22.91	7.72	3.85	25.46
RUN 20 > 35%A-13M & 65%C-30 W/ 5WT% MOGUL 1607 & 2 WT% METHOCEL									
25655-28A	2	2.2527	1.6732	2.4549	2.87	25.87	9.00	3.88	27.81
25655-28B	2	1.9576	1.4528	2.1372	2.85	26.24	9.20	3.87	28.35
25655-28C	2	2.2508	1.6712	2.4687	2.81	27.32	9.71	3.87	29.30
25655-28D	2	2.1516	1.5974	2.3589	2.82	27.22	9.66	3.87	29.22
25655-28E	2	2.1258	1.5785	2.3259	2.84	26.77	9.44	3.87	28.75
RUN 21A > 35%A-13M & 65%C-30 W/ 5WT% MOGUL & 2 WT% METHOCEL & .35WT% NALCO *									
25655-29A	2	2.2759	1.6894	2.4732	2.89	25.17	8.70	3.87	27.26
25655-29B	2	2.2702	1.6855	2.4757	2.86	26.01	9.08	3.87	28.03
25655-29C	2	2.2912	1.6992	2.4968	2.86	25.78	9.00	3.86	28.04
25655-29D	2	2.2634	1.6784	2.4594	2.89	25.10	8.69	3.86	27.40
25655-29E	2	2.2161	1.6449	2.4095	2.89	25.29	8.75	3.87	27.39
RUN 21B > 35%A-13M & 65%C-30 W/ 5WT% MOGUL & 2 WT% METHOCEL & .35WT% NALCO #									
25655-30A	2	2.3978	1.7794	2.6396	2.78	28.11	10.11	3.87	30.17
25655-30B	2	2.4741	1.8319	2.6962	2.85	25.70	9.00	3.84	28.29
25655-30C	2	2.4160	1.7915	2.6459	2.82	26.91	9.54	3.86	29.17
25655-30D	2	2.1525	1.5969	2.3558	2.83	26.79	9.47	3.86	28.95
25655-30E	2	2.2175	1.6458	2.4397	2.78	27.99	10.05	3.87	30.03

• 19.2% MOISTURE

20.3% MOISTURE

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 22 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL 1607 & .5WT% METHOCEL									
25655-37A	4	2.6833	1.9786	2.8758	2.98	21.46	7.20	3.80	25.08
25655-37B	4	2.6717	1.9742	2.8751	2.96	22.58	7.64	3.82	25.71
25655-37C	4	2.6298	1.9441	2.8278	2.97	22.41	7.55	3.82	25.45
25655-37D	4	2.9537	2.1816	3.1803	2.95	22.69	7.69	3.81	25.91
25655-37E	4	2.8105	2.0765	3.0202	2.97	22.22	7.48	3.82	25.40
RUN 23 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL & .5WT% METHOCEL & .5WT% NALCO									
25655-38A	4	3.0709	2.2826	3.3251	2.94	24.38	8.30	3.88	26.21
25655-38B	4	2.8678	2.1318	3.1003	2.95	24.01	8.13	3.88	25.82
25655-38C	4	2.7674	2.0586	3.0038	2.92	25.01	8.57	3.89	26.66
25655-38D	4	2.8868	2.1445	3.1195	2.95	23.87	8.09	3.88	25.83
25655-38E	4	2.6194	1.9462	2.8294	2.96	23.78	8.04	3.88	25.71
RUN 24 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL & .5WT% METHOCEL & .5WT% SGP									
25655-39A	4	2.8429	2.1113	3.0613	2.98	22.99	7.71	3.87	25.04
25655-39B	4	2.8493	2.1161	3.0726	2.97	23.35	7.86	3.87	25.38
25655-39C	4	3.1179	2.3151	3.3453	3.02	22.07	7.32	3.87	24.19
25655-39D	4	2.9611	2.1984	3.1834	3.00	22.57	7.53	3.87	24.69
25655-39E	4	2.9089	2.1582	3.1327	2.98	22.97	7.72	3.86	25.22

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 25 > 50%A-13M & 50%A-13UG W/ 2 WT% MOGUL 1607 & 1 WT% METHOCEL									
25655-44A	2	3.2003	2.3787	3.5991	2.61	32.68	12.50	3.88	34.31
25655-44B	2	3.1751	2.3608	3.5978	2.56	34.17	13.35	3.89	35.70
25655-44C	2	3.0829	2.2915	3.4764	2.59	33.21	12.80	3.88	34.82
25655-44D	2	2.8498	2.1145	3.2137	2.58	33.11	12.81	3.86	35.05
25655-44E	2	2.7128	2.0158	3.0646	2.58	33.54	13.01	3.88	35.21
RUN 26 > 50%A-13M & 50%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5 WT% NALCO									
25655-45A	2	3.4981	2.5936	3.7818	2.94	23.88	8.13	3.86	26.25
25655-45B	2	3.1834	2.3633	3.4526	2.91	24.71	8.48	3.87	26.79
25655-45C	2	2.9160	2.1638	3.1612	2.91	24.58	8.43	3.86	26.76
25655-45D	2	2.9349	2.1780	3.1764	2.93	24.19	8.25	3.87	26.36
25655-45E	2	2.8923	2.1442	3.1227	2.95	23.55	7.99	3.85	25.96
RUN 27 > 40%A-13M & 60%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO									
25655-46A	2	2.5501	1.8981	2.7967	2.83	27.44	9.70	3.90	28.91
25655-46B	2	2.6437	1.9690	2.8950	2.85	27.14	9.53	3.91	28.48
25655-46C	2	2.8905	2.1511	3.1578	2.86	26.55	9.28	3.90	28.07
25655-46D	2	2.9611	2.2027	3.2339	2.86	26.45	9.24	3.89	28.07
25655-46E	2	2.9292	2.1800	3.2129	2.83	27.47	9.71	3.90	28.96
RUN 28 > 25%A-13M & 75%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO									
25655-47A	2	2.5628	1.9084	2.9002	2.58	34.02	13.20	3.90	35.27
25655-47B	2	2.7602	2.0553	3.1256	2.57	34.14	13.28	3.90	35.40
25655-47C	2	2.8861	2.1488	3.2600	2.59	33.65	12.99	3.90	34.94
25655-47D	2	2.9287	2.1804	3.3085	2.59	33.67	13.01	3.90	34.97
25655-47E	2	2.6849	1.9988	3.0404	2.57	34.13	13.28	3.90	35.43
RUN 29 > 25%A-13M & 75%A-13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO									
25655-48A	2	2.6988	2.0095	3.0392	2.61	33.06	12.65	3.90	34.34
25655-48B	2	2.7892	2.0757	3.1457	2.60	33.32	12.82	3.90	34.70
25655-48C	2	2.7421	2.0400	3.1041	2.57	34.02	13.24	3.89	35.45
25655-48D	2	2.7338	2.0347	3.0771	2.61	32.93	12.60	3.90	34.30
25655-48E	2	2.7471	2.0447	3.1062	2.58	33.83	13.11	3.90	35.17
RUN 30 > 25%A-13M & 75%A-13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% A-180									
25655-49A	2	2.4858	1.8522	2.8116	2.58	33.96	13.15	3.91	35.09
25655-49B	2	2.5311	1.8861	2.8665	2.57	34.21	13.29	3.91	35.33
25655-49C	2	2.6067	1.9425	2.9609	2.55	34.78	13.63	3.91	35.88
25655-49D	2	2.5485	1.8975	2.8948	2.55	34.72	13.63	3.90	35.99
25655-49E	2	2.5723	1.9160	2.9212	2.55	34.71	13.60	3.91	35.90

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 31 T1 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-1A	2	2.8252	2.0994	3.1527	2.67	31.09	11.63	3.88	32.81
25740-5-1B	2	2.5974	1.9312	2.9027	2.67	31.43	11.79	3.89	33.03
25740-5-1C	2	2.6449	1.9628	2.9656	2.63	31.98	12.16	3.87	33.93
25740-5-1D	2	2.7214	2.0216	3.0491	2.64	31.89	12.08	3.88	33.65
25740-5-1E	2	2.5432	1.8895	2.8444	2.66	31.54	11.88	3.88	33.28
RUN 31 T2 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-2A	2	2.8684	2.1306	3.1926	2.69	30.53	11.34	3.88	32.34
25740-5-2B	2	2.8295	2.1022	3.1626	2.66	31.41	11.81	3.88	33.16
25740-5-2C	2	2.8167	2.0925	3.1379	2.69	30.73	11.44	3.88	32.51
25740-5-2D	2	2.5559	1.8983	2.8527	2.67	31.10	11.65	3.88	32.91
25740-5-2E	2	2.4809	1.8458	2.7514	2.73	29.87	10.94	3.89	31.37
RUN 31 T3 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-3A	2	2.7724	2.0602	3.0859	2.69	30.56	11.34	3.88	32.29
25740-5-3B	2	2.6824	1.9905	3.0012	2.65	31.54	11.92	3.87	33.52
25740-5-3C	2	2.6104	1.9360	2.9061	2.68	30.48	11.36	3.86	32.59
25740-5-3D	2	2.6332	1.9561	2.9285	2.70	30.37	11.25	3.88	32.17
25740-5-3E	2	2.6111	1.9363	2.9031	2.69	30.20	11.22	3.86	32.35
RUN 31 T4 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-4A	2	2.7157	2.0209	3.0312	2.68	31.23	11.65	3.90	32.66
25740-5-4B	2	2.7261	2.0243	3.0415	2.67	31.01	11.60	3.87	32.87
25740-5-4C	2	2.5088	1.8638	2.8137	2.63	32.10	12.19	3.88	33.84
25740-5-4D	2	2.3463	1.7421	2.6199	2.66	31.17	11.70	3.87	33.04
25740-5-4E	2	2.5642	1.9048	2.8585	2.68	30.86	11.51	3.88	32.65
RUN 31 T5 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-5A	2	2.8863	2.1421	3.2193	2.67	30.91	11.57	3.87	32.88
25740-5-5B	2	2.5763	1.9116	2.8707	2.68	30.70	11.46	3.86	32.71
25740-5-5C	2	2.4261	1.8027	2.7057	2.68	30.96	11.56	3.88	32.70
25740-5-5D	2	2.4222	1.7959	2.7006	2.67	30.77	11.53	3.86	32.93
25740-5-5E	2	2.4919	1.8498	2.7698	2.70	30.21	11.19	3.87	32.15
RUN 31 T6 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-6A	2	2.8637	2.1245	3.1953	2.67	30.97	11.61	3.86	33.01
25740-5-6B	2	2.6916	1.9964	3.0287	2.60	32.66	12.56	3.86	34.68
25740-5-6C	2	2.6411	1.9584	2.9450	2.67	30.80	11.54	3.86	32.94
25740-5-6D	2	2.4363	1.8088	2.7177	2.67	30.96	11.59	3.87	32.85
25740-5-6E	2	2.5680	1.9049	2.8514	2.71	29.94	11.07	3.86	32.03
RUN 31 T7 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-5-7A	2	2.8177	2.0951	3.1290	2.72	30.11	11.08	3.89	31.73
25740-5-7B	2	2.8620	2.1226	3.1745	2.71	29.71	10.95	3.86	31.84
25740-5-7C	2	2.7903	2.0695	3.0983	2.70	29.94	11.07	3.86	32.06
25740-5-7D	2	2.5834	1.9183	2.8892	2.65	31.50	11.87	3.87	33.35
25740-5-7E	2	2.6328	1.9528	2.9339	2.68	30.69	11.47	3.86	32.78
RUN 32 > 20%A13M & 80%A13UG W/2 WT%MOGUL 1607 & 1 WT% METHOCEL & .5WT%NALCO									
25740-8-1A	2	2.5863	1.9196	2.9906	2.41	37.75	15.68	3.87	39.51
25740-8-1B	2	2.5562	1.8964	2.9519	2.41	37.49	15.53	3.86	39.33
25740-8-1C	2	2.4773	1.8389	2.8383	2.47	36.12	14.62	3.87	37.91
25740-8-1D	2	2.3167	1.7191	2.6691	2.43	37.09	15.26	3.87	38.91
25740-8-1E	2	2.3403	1.7371	2.6881	2.45	36.57	14.91	3.87	38.35

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 33 T1 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-14-1A	2	2.6056	1.9370	2.9169	2.65	31.77	11.98	3.89	33.39
25740-14-1B	2	2.5766	1.9145	2.9014	2.60	32.91	12.64	3.88	34.60
25740-14-1C	2	2.4541	1.8218	2.7862	2.54	34.44	13.57	3.87	36.25
25740-14-1D	2	2.3818	1.7715	2.6720	2.64	32.23	12.22	3.89	33.74
25740-14-1E	2	2.3139	1.7192	2.5858	2.66	31.38	11.79	3.88	33.11
RUN 33 T2 > 20%A13M & 80%A13UG W/3 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-14-2A	2	2.5701	1.9097	2.8763	2.65	31.68	11.95	3.88	33.39
25740-14-2B	2	2.4373	1.8079	2.7348	2.62	32.10	12.24	3.86	34.13
25740-14-2C	2	2.4427	1.8142	2.7342	2.65	31.68	11.97	3.87	33.49
25740-14-2D	2	2.3505	1.7465	2.6293	2.65	31.58	11.90	3.88	33.30
25740-14-2E	2	2.2081	1.6376	2.4763	2.62	31.98	12.18	3.86	34.05
RUN 33 T3 > 20%A13M & 80%A13UG W/3 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-14-3A	2	2.5333	1.8818	2.8456	2.62	32.40	12.36	3.88	34.16
25740-14-3B	2	2.5238	1.8754	2.8348	2.62	32.42	12.36	3.88	34.10
25740-14-3C	2	2.4573	1.8268	2.7555	2.64	32.11	12.17	3.89	33.72
25740-14-3D	2	2.4444	1.8146	2.7511	2.60	32.75	12.58	3.87	34.62
25740-14-3E	2	2.4427	1.8153	2.7342	2.65	31.72	11.97	3.88	33.41
RUN 33 T4 > 20%A13M & 80%A13UG W/3 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-14-4A	2	2.4288	1.8041	2.7207	2.64	31.85	12.05	3.88	33.62
25740-14-4B	2	2.4184	1.7968	2.7156	2.62	32.35	12.33	3.88	34.06
25740-14-4C	2	2.3793	1.7673	2.6658	2.64	31.89	12.08	3.88	33.66
25740-14-4D	2	2.3656	1.7558	2.6548	2.62	32.17	12.26	3.87	34.08
25740-14-4E	2	2.0793	1.5433	2.3383	2.61	32.58	12.49	3.87	34.48
RUN 33 T5 > 20%A13M & 80%A13UG W/3 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-14-5A	2	2.6861	1.9948	3.0183	2.62	32.46	12.40	3.87	34.26
25740-14-5B	2	2.4949	1.8541	2.8346	2.54	34.65	13.66	3.88	36.26
25740-14-5C	2	2.5219	1.8739	2.8375	2.61	32.75	12.55	3.88	34.44
25740-14-5D	2	2.3702	1.7602	2.6844	2.56	34.00	13.30	3.87	35.76
25740-14-5E	2	2.3907	1.7789	2.6753	2.66	31.75	11.94	3.90	33.19
RUN 34 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-17-6A	2	2.8695	2.1318	3.2298	2.61	32.81	12.59	3.88	34.53
25740-17-6B	2	2.8308	2.1032	3.1722	2.64	31.94	12.10	3.88	33.66
25740-17-6C	2	2.7671	2.0566	3.0962	2.65	31.66	11.93	3.88	33.32
25740-17-6D	2	2.6671	1.9809	2.9969	2.62	32.46	12.40	3.88	34.24
25740-17-6E	2	2.4584	1.8279	2.7505	2.66	31.66	11.92	3.89	33.25

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 35 T1 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-19-1A	2	2.5862	1.9288	2.8841	2.70	31.18	11.55	3.92	32.18
25740-19-1B	2	2.3743	1.7687	2.6663	2.64	32.53	12.34	3.91	33.74
25740-19-1C	2	2.0392	1.5191	2.2919	2.63	32.70	12.43	3.91	33.90
25740-19-1D	2	2.0621	1.5364	2.3009	2.69	31.24	11.62	3.91	32.43
25740-19-1E	2	2.2568	1.6821	2.5101	2.72	30.59	11.26	3.92	31.72
RUN 35 T2 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-19-2A	2	2.4157	1.8002	2.6864	2.72	30.55	11.24	3.91	31.72
25740-19-2B	2	2.3554	1.7536	2.6524	2.61	33.04	12.65	3.90	34.35
25740-19-2C	2	2.2147	1.6526	2.4522	2.76	29.70	10.76	3.93	30.62
25740-19-2D	2	2.1811	1.6250	2.4408	2.67	31.83	11.94	3.91	33.03
25740-19-2E	2	2.1725	1.6192	2.4301	2.67	31.77	11.89	3.91	32.89
RUN 35 T3 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-19-3A	2	2.4334	1.8156	2.6941	2.76	29.68	10.75	3.93	30.61
25740-19-3B	2	2.3209	1.7295	2.5941	2.68	31.60	11.81	3.91	32.76
25740-19-3C	2	2.6535	1.9781	2.9602	2.69	31.23	11.59	3.92	32.32
25740-19-3D	2	2.5169	1.8754	2.7908	2.74	29.92	10.92	3.91	31.12
25740-19-3E	2	2.4322	1.8110	2.7192	2.67	31.60	11.84	3.90	32.91
RUN 35 T4 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-19-4A	2	2.3185	1.7297	2.5564	2.80	28.78	10.29	3.93	29.75
25740-19-4B	2	2.3517	1.7494	2.6357	2.65	32.04	12.11	3.89	33.53
25740-19-4C	2	2.5818	1.9239	2.8796	2.69	31.16	11.57	3.91	32.33
25740-19-4D	2	2.3731	1.7684	2.6496	2.68	31.38	11.69	3.91	32.54
25740-19-4E	2	2.4174	1.8005	2.6877	2.72	30.47	11.22	3.91	31.74
RUN 35 T5 > 20%A13M & 80%A13UG W/5 WT%MOGUL 1607 &1.5 WT% METHOCEL &.5WT%NALCO									
25740-19-5A	2	2.2514	1.6783	2.5282	2.64	32.57	12.33	3.92	33.64
25740-19-5B	2	2.1471	1.5993	2.3915	2.70	30.85	11.42	3.91	32.11
25740-19-5C	2	1.9738	1.4719	2.2039	2.69	31.43	11.69	3.92	32.45
25740-19-5D	2	2.1914	1.6318	2.4652	2.62	32.85	12.53	3.90	34.13
25740-19-5E	2	2.2911	1.7074	2.5663	2.66	32.04	12.05	3.91	33.18

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D.	GAS CONV.	DRY WEIGHT	SUS. WEIGHT	SAT. WEIGHT	BULK DENSITY	APP. POROSITY	H2O ABS.	APP. S.G.	TOTAL POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 36 T1 > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-1A	4	2.2239	1.6592	2.5009	2.63	32.91	12.49	3.93	33.81
25740-25-1B	4	2.0314	1.5149	2.2796	2.65	32.46	12.25	3.92	33.45
25740-25-1C	4	2.1642	1.6111	2.4526	2.56	34.27	13.37	3.90	35.57
25740-25-1D	4	2.1623	1.6114	2.4467	2.58	34.05	13.19	3.91	35.15
25740-25-1E	4	2.1387	1.5942	2.4165	2.59	33.78	13.03	3.92	34.85
RUN 36 T2 > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-2A	4	2.0935	1.5613	2.3711	2.58	34.28	13.30	3.92	35.24
25740-25-2B	4	2.0349	1.5165	2.3129	2.55	34.91	13.70	3.91	35.99
25740-25-2C	4	2.1497	1.6003	2.4601	2.49	36.10	14.48	3.90	37.37
25740-25-2D	4	2.0259	1.5091	2.3074	2.53	35.26	13.94	3.91	36.43
25740-25-2E	4	1.8888	1.4098	2.1135	2.68	31.93	11.93	3.93	32.76
RUN 36 T3 > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-3A	4	2.1081	1.5699	2.4010	2.53	35.24	13.94	3.91	36.46
25740-25-3B	4	2.0929	1.5615	2.3522	2.64	32.79	12.43	3.93	33.69
25740-25-3C	4	2.1336	1.5895	2.4237	2.55	34.78	13.64	3.91	35.93
25740-25-3D	4	2.0760	1.5469	2.3731	2.51	35.96	14.35	3.91	37.06
25740-25-3E	4	2.2243	1.6579	2.5238	2.56	34.59	13.51	3.92	35.65
RUN 36 T4 > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-4A	4	2.0934	1.5576	2.3608	2.60	33.29	12.81	3.90	34.71
25740-25-4B	4	2.2132	1.6497	2.5069	2.57	34.26	13.31	3.92	35.32
25740-25-4C	4	2.2308	1.6598	2.5409	2.52	35.19	13.94	3.90	36.58
25740-25-4D	4	2.1306	1.5905	2.3848	2.67	32.00	11.97	3.93	32.81
25740-25-4E	4	1.9617	1.4634	2.2046	2.64	32.77	12.42	3.92	33.70
RUN 36 T5 > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-5A	4	2.1657	1.6155	2.4365	2.63	32.98	12.54	3.92	33.92
25740-25-5B	4	2.2716	1.6941	2.5553	2.63	32.94	12.53	3.92	33.92
25740-25-5C	4	2.3408	1.7459	2.6323	2.63	32.89	12.49	3.92	33.85
25740-25-5D	4	2.1802	1.6256	2.4716	2.57	34.44	13.41	3.92	35.44
25740-25-5E	4	2.3677	1.7658	2.6737	2.60	33.70	12.96	3.92	34.67
RUN 36 ## > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-1F	4	7.1479	5.3291	8.0336	2.64	32.75	12.43	3.92	33.79
25740-25-1G	4	7.0492	5.2552	7.8072	2.75	29.70	10.79	3.92	30.81
25740-25-3F	4	5.9393	4.4298	6.6538	2.66	32.13	12.07	3.92	33.10
25740-25-3G	4	6.2681	4.6762	7.0052	2.68	31.65	11.79	3.93	32.58
25740-25-5F	4	9.1083	6.7923	10.3086	2.58	34.14	13.22	3.92	35.11
RUN 36 \$\$ > 20%A13M & 80%A13UG W/4.75 WT%MOGUL & 1.75 WT%METHOCEL & 5WT%NALCO									
25740-25-1H	4	7.8208	5.8364	8.6212	2.80	28.74	10.27	3.93	29.65
25740-25-2F	4	5.5596	4.1514	6.1331	2.80	28.94	10.35	3.94	29.72
25740-25-2G	4	5.8943	4.4012	6.5188	2.78	29.49	10.63	3.94	30.27
25740-25-3H	4	5.6750	4.2359	6.3110	2.73	30.65	11.24	3.93	31.49
25740-25-5G	4	6.4505	4.8158	7.1430	2.76	29.76	10.77	3.93	30.57

> WHITE 'AS DRIED' SAMPLES

\$\$ > ORANGE 'AS DRIED' SAMPLES

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
LD.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
FIRING#8 > 20%A13M & 80%A13UG W/4.75WT%MOGUL & 1.75 WT%METHOCEL & .5WT%NALCO									
HW#8-A	\$\$\$	6.0193	4.4929	6.6248	2.81	28.40	10.09	3.93	29.27
HW#8-B	\$\$\$	5.8831	4.3889	6.5107	2.76	29.58	10.70	3.93	30.54
HW#8-C	\$\$\$	5.7272	4.2753	6.2816	2.85	27.63	9.71	3.93	28.49
HW#8-D	\$\$\$	5.5807	4.1648	6.1503	2.80	28.69	10.24	3.93	29.59
HW#8-E	\$\$\$	4.8846	3.6468	5.3857	2.80	28.82	10.29	3.93	29.63
HW#8-F	\$\$\$	5.8017	4.3312	6.3837	2.82	28.36	10.06	3.93	29.19
HW#8-G	\$\$\$	6.0494	4.5156	6.6446	2.83	27.96	9.87	3.93	28.82
HW#8-H	\$\$\$	5.3498	3.9907	5.8987	2.80	28.77	10.29	3.92	29.76
HW#8-I	\$\$\$	5.1483	3.8418	5.6801	2.79	28.93	10.36	3.93	29.84
HW#8-J	\$\$\$	5.2749	3.9345	5.8358	2.77	29.50	10.67	3.92	30.50

ALCOA RUN #36 FIRED BY H-W

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 47A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-24A1	2	1.6747	1.2548	1.9173	2.52	36.62	14.53	3.98	36.68
25247-24A2	2	1.7197	1.2795	1.9724	2.47	36.47	14.74	3.89	37.83
25247-24A3	2	1.8380	1.3672	2.1142	2.45	36.97	15.07	3.89	38.36
25247-24A4	2	1.4989	1.1141	1.7164	2.48	36.11	14.55	3.88	37.66
25247-24A5	2	1.6594	1.2335	1.9066	2.46	36.73	14.94	3.88	38.24
RUN 47B > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-24B1	2	1.6598	1.2347	1.9055	2.47	36.63	14.85	3.89	38.02
25247-24B2	2	1.7998	1.3409	2.0601	2.49	36.19	14.51	3.91	37.31
25247-24B3	2	1.7054	1.2690	1.9412	2.53	35.08	13.87	3.90	36.45
25247-24B4	2	1.7597	1.3090	2.0104	2.50	35.74	14.29	3.89	37.15
25247-24B5	2	1.7612	1.3133	2.0142	2.51	36.10	14.41	3.92	37.05
RUN 47C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-24C1	2	1.7247	1.2843	1.9660	2.52	35.40	14.03	3.90	36.62
25247-24C2	2	1.8798	1.4033	2.1445	2.53	35.71	14.12	3.93	36.47
25247-24C3	2	1.7580	1.3090	2.0047	2.52	35.46	14.08	3.90	36.70
25247-24C4	2	1.8420	1.3722	2.0962	2.54	35.11	13.84	3.91	36.27
25247-24C5	2	1.6672	1.2414	1.9055	2.50	35.88	14.34	3.90	37.11
RUN 47D > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-24D1	2	1.8580	1.3838	2.1090	2.55	34.61	13.55	3.91	35.82
25247-24D2	2	1.7794	1.3245	2.0148	2.57	34.10	13.27	3.90	35.43
25247-24D3	2	1.8801	1.3412	2.0465	2.66	23.59	8.88	3.48	33.22
25247-24D4	2	1.8368	1.3664	2.0843	2.55	34.48	13.52	3.89	35.91
25247-24D5	2	1.8850	1.4024	2.1431	2.54	34.85	13.73	3.89	36.25
RUN 47E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-24E1	2	1.6558	1.2380	1.8929	2.52	36.20	14.36	3.95	36.66
25247-24E2	2	1.8452	1.3747	2.1036	2.52	35.45	14.05	3.91	36.59
25247-24E3	2	1.7878	1.3304	2.0299	2.55	34.61	13.58	3.90	35.98
25247-24E4	2	1.9730	1.4700	2.2348	2.57	34.23	13.31	3.91	35.38
25247-24E5	2	1.8228	1.3585	2.0750	2.54	35.20	13.88	3.91	36.27

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE	GAS	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
I.D.	CONV.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	S.G.	POROSITY
NO.	NO.	(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
RUN 48-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-25-A1	2	2.1647	1.6094	2.4415	2.59	33.27	12.83	3.89	34.83
25247-25-A2	2	2.4867	1.8357	2.8082	2.55	33.06	12.97	3.81	35.95
25247-25-A3	2	2.3395	1.7392	2.6512	2.56	34.18	13.36	3.89	35.74
25247-25-A4	2	2.0592	1.5159	2.3309	2.52	33.34	13.23	3.78	36.71
25247-25-A5	2	2.6770	1.9684	3.0279	2.52	33.12	13.15	3.77	36.71
RUN 48-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-25-C1	2	2.0745	1.5276	2.3448	2.53	33.08	13.07	3.78	36.41
25247-25-C2	2	2.1749	1.6008	2.4572	2.53	32.96	13.02	3.78	36.38
25247-25-C3	2	1.9203	1.4180	2.1851	2.50	34.52	13.83	3.81	37.29
25247-25-C4	2	2.1860	1.6139	2.4704	2.54	33.20	13.05	3.81	36.07
25247-25-C5	2	2.1184	1.5616	2.3994	2.52	33.54	13.30	3.79	36.66
RUN 48-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-25-E1	2	1.9950	1.4832	2.3053	2.42	37.74	15.60	3.89	39.21
25247-25-E2	2	2.0864	1.5526	2.3906	2.48	36.30	14.62	3.90	37.63
25247-25-E3	2	2.0729	1.5412	2.3848	2.45	36.97	15.09	3.89	38.45
25247-25-E4	2	2.2316	1.6601	2.5492	2.50	35.72	14.27	3.89	37.13
25247-25-E5	2	2.0517	1.5254	2.3695	2.42	37.65	15.54	3.89	39.11
RUN 49-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-26-A1	2	2.1365	1.5887	2.4144	2.58	33.66	13.05	3.89	35.18
25247-26-A2	2	2.0514	1.5248	2.3132	2.59	33.21	12.80	3.88	34.82
25247-26-A3	2	2.0420	1.5185	2.3122	2.57	34.04	13.27	3.89	35.55
25247-26-A4	2	2.2312	1.6616	2.5308	2.56	34.47	13.47	3.91	35.70
25247-26-A5	2	2.2301	1.6574	2.5352	2.53	34.76	13.72	3.88	36.36
RUN 49-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-26-C1	2	2.2851	1.7007	2.5758	2.60	33.22	12.76	3.90	34.59
25247-26-C2	2	2.2509	1.6815	2.5413	2.61	33.78	12.94	3.94	34.42
25247-26-C3	2	2.2944	1.7082	2.6020	2.56	34.41	13.45	3.90	35.70
25247-26-C4	2	2.1931	1.6319	2.4783	2.58	33.70	13.04	3.90	35.09
25247-26-C5	2	2.3865	1.7746	2.6970	2.58	33.66	13.05	3.89	35.19
RUN 49-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-26-E1	2	2.2995	1.7107	2.6211	2.52	35.33	14.03	3.89	36.73
25247-26-E2	2	2.2718	1.6913	2.5697	2.58	33.91	13.15	3.90	35.21
25247-26-E3	2	2.1966	1.6329	2.4953	2.54	34.64	13.64	3.89	36.20
25247-26-E4	2	2.1870	1.6265	2.4930	2.52	35.31	14.03	3.89	36.77
25247-26-E5	2	2.1338	1.5880	2.4251	2.54	34.80	13.69	3.90	36.15
RUN 50-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-28-A1	2	2.4907	1.8584	2.8202	2.58	34.26	13.27	3.93	35.13
25247-28-A2	2	2.3772	1.7697	2.6985	2.55	34.59	13.56	3.90	35.89
25247-28-A3	2	2.4171	1.7980	2.7441	2.55	34.56	13.57	3.89	36.00
25247-28-A4	2	2.3503	1.7481	2.6755	2.53	35.07	13.88	3.89	36.52
25247-28-A5	2	2.3896	1.7777	2.7140	2.54	34.65	13.62	3.89	36.07
RUN 50-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-28-C1	2	2.5003	1.8589	2.8495	2.52	35.25	14.01	3.89	36.77
25247-28-C2	2	2.4228	1.8013	2.7497	2.55	34.47	13.53	3.89	36.01
25247-28-C3	2	2.4866	1.8476	2.8324	2.52	35.11	13.95	3.88	36.75
25247-28-C5	2	2.2605	1.6810	2.5907	2.48	36.30	14.65	3.89	37.75

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D. NO.	GAS CONV. NO.	DRY WEIGHT (g)	SUS. WEIGHT (g)	SAT. WEIGHT (g)	BULK DENSITY (g/cc)	APP. POROSITY (%)	H2O ABS. (%)	APP. S.G. (g/cc)	TOTAL POROSITY (%)
RUN 50-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-28-E1	2	2.6048	1.9378	2.9540	2.56	34.36	13.45	3.89	35.79
25247-28-E2	2	2.5333	1.8830	2.8773	2.54	34.60	13.62	3.88	36.18
25247-28-E3	2	2.5073	1.8648	2.8612	2.51	35.52	14.16	3.89	36.96
25247-28-E4	2	2.4994	1.8587	2.8274	2.57	33.86	13.16	3.89	35.37
25247-28-E5	2	2.3478	1.7456	2.6624	2.55	34.32	13.44	3.89	35.85
RUN 51-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-29-A1	2	2.5900	1.9260	2.9250	2.58	33.53	12.97	3.89	35.05
25247-29-A2	2	2.3740	1.7657	2.6800	2.59	33.47	12.93	3.89	34.96
25247-29-A3	2	2.5202	1.8732	2.8597	2.55	34.41	13.51	3.88	36.00
25247-29-A4	2	2.6332	1.9579	3.0004	2.52	35.22	13.99	3.89	36.73
25247-29-A5	2	2.6226	1.9495	2.9854	2.52	35.02	13.88	3.88	36.58
RUN 51-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-29-C1	2	2.5934	1.9288	2.9320	2.58	33.75	13.10	3.89	35.24
25247-29-C2	2	2.6252	1.9516	2.9704	2.57	33.88	13.19	3.89	35.45
25247-29-C3	2	2.4842	1.8481	2.8066	2.58	33.64	13.02	3.89	35.08
25247-29-C4	2	2.5846	1.9223	2.9268	2.57	34.07	13.28	3.89	35.55
25247-29-C5	2	2.6121	1.9414	2.9697	2.53	34.78	13.73	3.88	36.37
RUN 51-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel									
25247-29-E1	2	2.6601	1.9781	3.0182	2.55	34.43	13.50	3.89	35.93
25247-29-E2	2	2.6871	1.9990	3.0577	2.53	35.01	13.83	3.89	36.42
25247-29-E3	2	2.7458	2.0409	3.1192	2.54	34.63	13.64	3.88	36.21
25247-29-E4	2	2.6202	1.9487	2.9761	2.54	34.64	13.62	3.89	36.11
25247-29-E5	2	2.6984	2.0059	3.0580	2.56	34.18	13.37	3.88	35.75

DENSITIES OF LIGHTWEIGHT REFRACTORY (DOE)

SAMPLE I.D. NO.	GAS CONV. NO.	DRY WEIGHT (g)	SUS. WEIGHT (g)	SAT. WEIGHT (g)	BULK DENSITY (g/cc)	APP. POROSITY (%)	H2O ABS. (%)	APP. S.G. (g/cc)	TOTAL POROSITY (%)
Composite 500 Lb. Run HW Firing 2/25/94									
1	HW	6.9794	5.1940	7.7870	2.68	31.15	11.61	3.90	32.57
2	HW	6.9749	5.1913	7.9080	2.56	34.35	13.42	3.90	35.69
3	HW	6.0660	4.5140	6.7720	2.68	31.27	11.67	3.90	32.70
4	HW	6.7324	5.0083	7.5396	2.65	31.89	12.03	3.89	33.37
5	HW	6.4929	4.8281	7.2695	2.65	31.81	12.00	3.89	33.38
Avg.					2.645	32.091	12.144	3.895	33.543
Std. Dev.					0.050	1.302	0.737	0.004	1.254
75 Lb. Run HW Firing - Run 47									
1	HW	7.0074	5.2181	7.8800	2.62	32.78	12.49	3.90	34.06
2	HW	6.5751	4.8933	7.3980	2.62	32.85	12.55	3.90	34.24
3	HW	6.6640	4.9608	7.5218	2.59	33.49	12.91	3.90	34.82
4	HW	5.8548	4.3593	6.6376	2.56	34.36	13.41	3.90	35.63
5	HW	5.8454	4.3535	6.5729	2.63	32.78	12.48	3.91	34.02
Avg.					2.605	33.254	12.770	3.903	34.552
Std. Dev.					0.027	0.687	0.399	0.003	0.679
75 Lb. Run HW Firing - Run 48									
1	HW	5.9680	4.4395	6.7246	2.60	33.11	12.72	3.89	34.58
2	HW	6.3334	4.7100	7.0959	2.65	31.96	12.08	3.89	33.50
3	HW	5.1974	3.8676	5.8673	2.59	33.50	12.93	3.90	34.89
4	HW	6.1805	4.5936	6.9612	2.60	32.97	12.67	3.88	34.61
5	HW	5.4986	4.0889	6.2485	2.54	34.72	13.68	3.89	36.22
Avg.					2.597	33.253	12.814	3.890	34.760
Std. Dev.					0.039	1.000	0.578	0.005	0.972
75 Lb. Run HW Firing - Run 49									
1	HW	6.3771	4.7419	7.1557	2.63	32.26	12.25	3.89	33.82
2	HW	6.7693	5.0317	7.5886	2.64	32.04	12.14	3.88	33.68
3	HW	7.2365	5.3787	8.1190	2.63	32.20	12.23	3.88	33.85
4	HW	6.8451	5.0883	7.6684	2.65	31.91	12.06	3.88	33.54
5	HW	5.1175	3.8051	5.7409	2.64	32.20	12.22	3.89	33.78
Avg.					2.637	32.123	12.180	3.886	33.733
Std. Dev.					0.005	0.144	0.077	0.002	0.125
75 Lb. Run HW Firing - Run 50									
1	HW	6.0410	4.4955	6.7688	2.65	32.02	12.08	3.90	33.43
2	HW	7.3336	5.4560	8.2072	2.66	31.75	11.95	3.89	33.23
3	HW	6.7224	5.0012	7.5457	2.63	32.36	12.28	3.89	33.82
4	HW	6.2173	4.6248	7.0010	2.61	32.98	12.64	3.89	34.46
5	HW	5.9521	4.4290	6.6735	2.64	32.14	12.16	3.90	33.57
Avg.					2.639	32.249	12.223	3.895	33.701
Std. Dev.					0.019	0.464	0.264	0.002	0.474
75 Lb. Run HW Firing - Run 51									
1	HW	6.0630	4.5116	6.7908	2.65	31.93	12.04	3.90	33.36
2	HW	7.3815	5.4923	8.2974	2.62	32.65	12.45	3.90	34.08
3	HW	7.7524	5.7691	8.6902	2.65	32.10	12.13	3.90	33.52
4	HW	6.6339	4.9363	7.4639	2.62	32.84	12.55	3.90	34.25
5	HW	6.9989	5.2076	7.8545	2.64	32.32	12.26	3.90	33.76
Avg.					2.635	32.370	12.286	3.896	33.796
Std. Dev.					0.015	0.375	0.212	0.001	0.373
Grand Avg.									
Std. Dev.									
					2.626				
					0.026				

Appendix B-3 – Raw Data and Shrinkage Calculations

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SAMPLE SHRINKAGE CALCULATIONS

SAMPLE	EXPT.	GREEN	GREEN	FIRE	FIRE	VOLUME	VOLUME	SHRINK.	SHRINK.	SHRINK.
I.D.	REF.	DIAM.	THICK.	DIAM.	THICK.	GREEN	FIRE	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
EXTRUDED > 60%A-13M & 40%A-13UG W/ 2 WT% METHOCEL										
24127-19A	1	12.55	7.11	9.91	5.66	879.52	436.57	50.4	20.4	21.0
24127-19B	1	13.26	7.25	10.45	5.81	1001.19	498.31	50.2	19.9	21.2
24127-19C	1	12.69	6.78	10.05	5.42	857.52	429.95	49.9	20.1	20.8
24127-19D	1	12.52	5.56	9.87	4.43	684.50	338.94	50.5	20.3	21.2
24127-19E	1	14.02	6.43	11.11	5.13	992.65	497.32	49.9	20.2	20.8
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 4.68 WT% METHOCEL										
24127-24A	2	13.39	6.77	10.55	5.39	953.32	471.18	50.6	20.4	21.2
24127-24B	2	13.89	6.96	11.06	5.55	1054.64	533.20	49.4	20.3	20.4
24127-24C	2	13.43	7.09	10.66	5.69	1004.36	507.83	49.4	19.7	20.6
24127-24D	2	12.64	7.26	10.07	5.75	911.00	457.95	49.7	20.8	20.3
24127-24E	2	13.08	6.25	10.43	5.00	839.82	427.20	49.1	20.0	20.3
EXTRUDED > 60%A-13M & 40%A-13UG W/ 4.4 WT% METHOCEL										
24127-21A	3	13.31	7.84	10.48	6.29	1090.84	542.58	50.3	19.8	21.3
24127-21B	3	13.38	8.07	10.53	6.45	1134.68	561.70	50.5	20.1	21.3
24127-21C	3	14.79	7.93	11.61	6.34	1362.38	671.19	50.7	20.1	21.5
24127-21D	3	12.85	7.46	10.12	5.93	967.46	476.99	50.7	20.5	21.2
24127-21E	3	13.01	8.47	10.21	6.67	1125.97	546.09	51.5	21.3	21.5
EXTRUDED > 40%A-13M & 60%A-13UG W/ 2 WT% METHOCEL										
24127-22A	4	13.12	6.41	10.51	5.10	866.59	442.45	48.9	20.4	19.9
24127-22B	4	13.41	7.19	10.76	5.85	1015.49	531.95	47.6	18.6	19.8
24127-22C	4	12.59	7.36	10.05	5.92	916.26	469.62	48.7	19.6	20.2
24127-22D	4	13.05	7.94	10.46	6.43	1062.02	552.54	48.0	19.0	19.8
24127-22E	4	12.46	6.21	9.87	4.99	757.21	381.79	49.6	19.6	20.8
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 6 WT% METHOCEL										
24127-18A	O2	11.71	7.24	9.24	5.69	779.73	381.54	51.1	21.4	21.1
24127-18B	O2	11.15	7.20	8.78	5.66	703.03	342.68	51.3	21.4	21.3
24127-18C	O2	11.61	6.86	9.21	5.41	726.24	360.42	50.4	21.1	20.7
24127-18D	O2	11.72	7.75	9.27	6.18	836.08	417.10	50.1	20.3	20.9
24127-18E	O2	11.78	7.39	9.32	5.86	805.42	399.78	50.4	20.7	20.9

FIRE TO 1780°C

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE	EXPT.	GREEN	GREEN	FIRE	FIRE	VOLUME	VOLUME	SHRINK.	LINEAR	LINEAR
I.D.	REF.	DIAM.	THICK.	DIAM.	THICK.	GREEN	FIRE	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
EXTRUDED > 60%A-13M & 40%A-13(-270) W/ 4.68 WT% METHOCEL										
24127-20F	5	12.64	7.94	9.76	6.21	996.33	464.60	53.4	21.8	22.8
24127-20G	5	12.47	8.62	9.63	6.71	1052.76	488.73	53.6	22.2	22.8
24127-20H	5	12.55	8.01	9.66	6.25	990.85	458.06	53.8	22.0	23.0
24127-20I	5	12.51	7.63	9.66	5.97	937.84	437.54	53.3	21.8	22.8
24127-20J	5	12.43	7.78	9.61	6.06	944.09	439.55	53.4	22.1	22.7
EXTRUDED > 40%A-13M & 60%A-13(-270) W/ 2 WT% METHOCEL										
24127-17F	6	12.38	7.01	9.75	5.63	843.82	420.35	50.2	19.7	21.2
24127-17G	6	12.73	6.70	9.98	5.37	852.75	420.07	50.7	19.9	21.6
24127-17H	6	12.17	6.20	9.56	4.96	721.21	356.03	50.6	20.0	21.4
24127-17I	6	12.47	7.04	9.83	5.64	859.80	428.03	50.2	19.9	21.2
24127-17J	6	12.93	6.98	10.22	5.59	916.52	458.57	50.0	19.9	21.0
EXTRUDED > 60%A-13M & 40%A-13UG W/ 2 WT% METHOCEL										
24127-23F	7	13.09	8.53	10.31	6.74	1147.94	562.69	51.0	21.0	21.2
24127-23G	7	11.93	7.66	9.37	6.07	856.25	418.56	51.1	20.8	21.5
24127-23H	7	13.47	8.24	10.57	6.49	1174.23	569.49	51.5	21.2	21.5
24127-23I	7	12.27	8.06	9.64	6.34	953.05	462.74	51.4	21.3	21.4
24127-23J	7	12.30	8.09	9.71	6.40	961.28	473.92	50.7	20.9	21.1
EXTRUDED > 40%A-13M & 60%A-13UG W/ 4.63 WT% METHOCEL										
24127-16F	8	12.37	7.04	9.76	5.54	846.06	414.48	51.0	21.3	21.1
24127-16G	8	12.55	8.12	9.92	6.45	1004.46	498.51	50.4	20.6	21.0
24127-16H	8	12.25	7.43	9.70	5.93	875.69	438.22	50.0	20.2	20.8
24127-16I	8	12.08	7.08	9.58	5.64	811.44	406.54	49.9	20.3	20.7
24127-16J	8	12.18	7.85	9.68	6.31	914.65	464.38	49.2	19.6	20.5

FIRED TO 1862°C

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	VOLUME	VOLUME	SHRINK.	LINEAR	LINEAR
LD.	CONV.	DIAM.	THICK.	DIAM.	THICK.	GREEN	FIRE	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
SIZED SAMPLE REG EXT > 60%A-13M & 40%A-13UG W/ 1.55 WT% METHOCEL										
12742-A*	2	14.99	11.59	12.29	10.09	2045.39	1196.97	41.5	12.9	18.0
12742-B*	2	14.47	11.16	11.50	8.97	1835.23	931.70	49.2	19.6	20.5
12742-C*	2	14.98	11.05	12.29	9.29	1947.49	1102.07	43.4	15.9	18.0
12742-D*	4	14.46	10.55	11.65	8.75	1732.52	932.72	46.2	17.1	19.4
12742-E*	4	14.61	11.34	11.81	9.45	1901.09	1035.19	45.5	16.7	19.2
12742-F*	4	14.20	11.11	11.58	9.43	1759.46	993.16	43.6	15.1	18.5
SIZED SAMPLE SWOLLEN EXT > 60%A-13M & 40%A-13UG W/ 1.55 WT% METHOCEL										
12742-SA	2	18.30	10.43	14.51	8.25	2743.32	1364.20	50.3	20.9	20.7
12742-SB*	2	18.30	11.04	14.49	8.78	2903.76	1447.84	50.1	20.5	20.8
12742-SC	2	18.30	10.91	14.51	8.66	2869.57	1432.00	50.1	20.6	20.7
12742-SD*	4	18.31	10.86	14.72	8.82	2859.54	1500.98	47.5	18.8	19.6
12742-SE*	4	18.30	11.09	14.91	9.18	2916.91	1602.83	45.1	17.2	18.5
12742-SF*	4	18.30	10.99	14.84	8.95	2890.61	1548.03	46.4	18.6	18.9

*** NOTE : SAMPLE DISCOLORED AFTER FIRING**

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
LS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-A1	2	17.09	7.97	13.66	6.41	1828.23	939.40	48.6	19.6	20.1
12748-A2	2	18.01	9.71	14.41	7.83	2473.64	1276.97	48.4	19.4	20.0
12748-A3	2	16.45	10.99	13.13	8.84	2335.71	1196.94	48.8	19.6	20.2
12748-A4	2	16.61	13.02	13.32	10.45	2821.24	1456.18	48.4	19.7	19.8
12748-A5	2	16.21	11.61	12.99	9.36	2396.01	1240.46	48.2	19.4	19.9
LS EXT,V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-B1	2	17.62	9.78	14.07	7.86	2384.74	1222.08	48.8	19.6	20.1
12748-B2	2	16.09	11.78	12.84	9.46	2395.23	1224.93	48.9	19.7	20.2
12748-B3	2	16.01	8.79	12.82	7.06	1769.54	911.32	48.5	19.7	19.9
12748-B4	2	16.23	10.09	12.93	8.09	2087.46	1062.27	49.1	19.8	20.3
12748-B5	2	16.46	9.69	13.15	7.81	2061.93	1060.70	48.6	19.4	20.1
HS EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-C1	2	17.49	8.82	13.97	7.04	2119.03	1079.08	49.1	20.2	20.1
12748-C2	2	16.86	10.36	13.47	8.35	2312.94	1189.90	48.6	19.4	20.1
12748-C3	2	17.44	10.07	13.91	8.13	2405.54	1235.48	48.6	19.3	20.2
12748-C4	2	16.37	14.42	13.08	11.61	3034.95	1560.05	48.6	19.5	20.1
12748-C5	2	16.46	11.22	13.19	9.01	2387.49	1231.13	48.4	19.7	19.9
HS EXT,V > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-D1	2	17.77	11.02	14.17	8.84	2733.04	1394.06	49.0	19.8	20.3
12748-D2	2	17.97	11.84	14.34	9.65	3028.24	1558.53	48.5	19.2	20.2
12748-D3	2	16.75	10.39	13.39	8.36	2289.47	1177.22	48.6	19.5	20.1
12748-D4	2	17.49	10.73	14.00	8.60	2577.92	1323.87	48.6	19.9	20.0
12748-D5	2	15.44	11.77	12.34	9.46	2203.74	1131.39	48.7	19.6	20.1
LS EXT,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-E1	2	20.44	8.63	16.35	6.87	2831.80	1442.39	49.1	20.4	20.0
12748-E2	2	18.11	12.07	14.51	9.71	3109.09	1605.62	48.4	19.6	19.9
12748-E3	2	18.63	9.46	14.98	7.62	2578.73	1342.98	47.9	19.5	19.6
12748-E4	2	16.85	12.51	13.49	10.02	2789.63	1432.13	48.7	19.9	19.9
12748-E5	2	18.73	11.33	14.99	9.09	3121.73	1604.19	48.6	19.8	20.0
LS EXT,V,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-F1	2	18.62	9.47	14.93	7.59	2578.69	1328.77	48.5	19.9	19.8
12748-F2	2	18.99	8.09	15.15	6.52	2291.33	1175.34	48.7	19.4	20.2
12748-F3	2	18.36	7.97	14.71	6.44	2110.05	1094.46	48.1	19.2	19.9
12748-F4	2	17.86	8.76	14.28	7.09	2194.61	1135.51	48.3	19.1	20.0
12748-F5	2	18.99	10.63	15.27	8.54	3010.74	1563.96	48.1	19.7	19.6
HS EXT,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-G1	2	19.90	9.02	15.96	7.24	2805.45	1448.42	48.4	19.7	19.8
12748-G2	2	19.10	8.90	15.36	7.18	2550.04	1330.44	47.8	19.3	19.6
12748-G3	2	19.77	8.76	15.84	7.02	2689.10	1383.37	48.6	19.9	19.9
12748-G4	2	17.73	7.65	14.21	6.16	1888.72	976.92	48.3	19.5	19.9
12748-G5	2	18.86	10.91	15.15	8.79	3047.88	1584.54	48.0	19.4	19.7
HS EXT,V,R > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12748-H1	2	17.11	10.61	13.71	8.51	2439.52	1256.30	48.5	19.8	19.9
12748-H2	2	17.96	7.12	14.37	5.72	1803.77	927.68	48.6	19.7	20.0
12748-H3	2	17.49	10.39	13.98	8.33	2496.23	1278.64	48.8	19.8	20.1
12748-H4	2	18.11	10.57	14.55	8.46	2722.71	1406.65	48.3	20.0	19.7
12748-H5	2	17.98	7.84	14.44	6.29	1990.60	1030.09	48.3	19.8	19.7
SM EXT > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
12750-A1	2	12.31	6.96	9.87	5.59	828.35	427.70	48.4	19.7	19.8
12750-A2	2	12.54	7.07	10.06	5.72	873.18	454.65	47.9	19.1	19.8
12750-A3	2	12.35	7.39	9.89	5.96	885.25	457.86	48.3	19.4	19.9
12750-A4	2	11.89	7.84	9.52	6.31	870.50	449.15	48.4	19.5	19.9
12750-A5	2	12.16	6.90	9.74	5.54	801.32	412.78	48.5	19.7	19.9
12750-A6	2	11.92	6.47	9.48	5.22	722.02	368.45	49.0	19.3	20.5

VARIABLES: LS-LOW SPEED, HS-HIGH SPEED, V-VACUUM, R-ROLLED, SM-SMALL

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
BATCH #1 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-1A	2	16.34	8.46	13.05	6.86	1774.04	917.56	48.3	18.9	20.1
25530-6-1B	2	16.33	8.47	13.05	6.85	1773.97	916.22	48.4	19.1	20.1
25530-6-1C	2	16.35	9.15	13.04	7.39	1921.08	986.94	48.6	19.2	20.2
25530-6-1D	2	16.34	7.23	12.99	5.81	1516.11	769.99	49.2	19.6	20.5
25530-6-1E	2	16.34	7.55	12.98	6.07	1583.22	803.21	49.3	19.6	20.6
BATCH #2 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-2A	2	16.34	11.12	13.01	8.95	2331.84	1189.78	49.0	19.5	20.4
25530-6-2B	2	16.32	9.43	13.02	7.61	1972.61	1013.20	48.6	19.3	20.2
25530-6-2C	2	16.33	9.89	13.00	7.97	2071.37	1057.88	48.9	19.4	20.4
25530-6-2D	2	16.33	8.96	13.02	7.24	1876.59	963.94	48.6	19.2	20.3
25530-6-2E	2	16.32	9.24	13.03	7.48	1932.87	997.42	48.4	19.0	20.2
BATCH #3 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-3A	2	16.83	9.95	13.41	8.00	2213.51	1129.89	49.0	19.6	20.3
25530-6-3B	2	16.84	8.18	13.41	6.61	1821.91	933.57	48.8	19.2	20.4
25530-6-3C	2	16.94	8.39	13.49	6.82	1890.94	974.76	48.5	18.7	20.4
25530-6-3D	2	16.59	8.19	13.24	6.63	1770.38	912.81	48.4	19.0	20.2
25530-6-3E	2	16.45	7.38	13.12	5.95	1568.48	804.40	48.7	19.4	20.2
BATCH #4 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-4A	2	16.30	8.73	12.94	7.07	1821.71	929.77	49.0	19.0	20.6
25530-6-4B	2	16.94	8.72	13.46	7.03	1965.32	1000.31	49.1	19.4	20.5
25530-6-4C	2	17.19	9.21	13.64	7.42	2137.47	1084.23	49.3	19.4	20.7
25530-6-4D	2	16.96	8.74	13.46	7.06	1974.48	1004.58	49.1	19.2	20.6
25530-6-4E	2	16.95	8.32	13.48	6.73	1877.38	960.47	48.8	19.1	20.5
BATCH #5 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-5A	2	17.32	9.33	13.75	7.51	2198.20	1115.15	49.3	19.5	20.6
25530-6-5B	2	17.07	10.48	13.52	8.42	2398.38	1208.80	49.6	19.7	20.8
25530-6-5C	2	17.07	10.41	13.55	8.39	2382.36	1209.85	49.2	19.4	20.6
25530-6-5D	2	17.32	8.84	13.76	7.15	2082.75	1063.24	49.0	19.1	20.6
25530-6-5E	2	17.58	8.93	13.92	7.18	2167.60	1092.68	49.6	19.6	20.8
BATCH #6 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-6A	2	17.30	10.65	13.72	8.57	2503.41	1267.01	49.4	19.5	20.7
25530-6-6B	2	16.17	11.04	12.82	8.88	2267.14	1146.25	49.4	19.6	20.7
25530-6-6C	2	17.31	10.12	13.78	8.17	2381.57	1218.46	48.8	19.3	20.4
25530-6-6D	2	17.05	9.32	13.58	7.52	2127.91	1089.20	48.8	19.3	20.4
25530-6-6E	2	17.56	9.60	13.93	7.73	2324.93	1178.07	49.3	19.5	20.7

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
BATCH #7 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-7A	2	16.79	11.55	13.24	9.27	2557.25	1276.28	50.1	19.7	21.1
25530-6-7B	2	17.05	11.35	13.52	9.12	2591.40	1309.30	49.5	19.6	20.7
25530-6-7C	2	17.19	10.13	13.66	8.13	2350.99	1191.47	49.3	19.7	20.5
25530-6-7D	2	16.66	9.85	13.15	7.89	2147.22	1071.56	50.1	19.9	21.1
25530-6-7E	2	16.29	9.67	12.97	7.81	2015.39	1031.86	48.8	19.2	20.4
BATCH #8 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-8A	2	16.79	11.30	13.29	9.04	2501.90	1254.03	49.9	20.0	20.8
25530-6-8B	2	18.18	9.33	14.36	7.47	2421.92	1209.82	50.0	19.9	21.0
25530-6-8C	2	18.05	9.66	14.25	7.73	2471.84	1232.82	50.1	20.0	21.1
25530-6-8D	2	17.04	9.85	13.52	7.94	2246.29	1139.89	49.3	19.4	20.7
25530-6-8E	2	16.02	8.32	12.69	6.68	1677.02	844.87	49.6	19.7	20.8
BATCH #9 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-9A	2	17.41	10.70	13.81	8.61	2547.25	1289.67	49.4	19.5	20.7
25530-6-9B	2	17.28	10.98	13.64	8.79	2575.01	1284.42	50.1	19.9	21.1
25530-6-9C	2	16.77	9.52	13.24	7.60	2102.77	1046.36	50.2	20.2	21.0
25530-6-9D	2	16.77	9.83	13.33	7.85	2171.25	1095.52	49.5	20.1	20.5
25530-6-9E	2	17.53	9.46	13.82	7.54	2283.20	1131.04	50.5	20.3	21.2
BATCH #10 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-10A	2	16.53	13.06	13.07	10.46	2802.71	1403.37	49.9	19.9	20.9
25530-6-10B	2	17.24	10.58	13.69	8.52	2469.73	1254.11	49.2	19.5	20.6
25530-6-10C	2	17.52	11.27	13.86	9.03	2716.95	1362.40	49.9	19.9	20.9
25530-6-10D	2	18.30	9.38	14.49	7.49	2467.14	1235.12	49.9	20.1	20.8
25530-6-10E	2	17.54	9.69	13.85	7.76	2341.38	1169.10	50.1	19.9	21.0
BATCH #11 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-11A	2	17.52	12.43	13.80	9.91	2996.60	1482.25	50.5	20.3	21.2
25530-6-11B	2	17.26	10.66	13.63	8.53	2494.18	1244.60	50.1	20.0	21.0
25530-6-11C	2	17.12	9.99	13.56	7.99	2299.65	1153.87	49.8	20.0	20.8
25530-6-11D	2	16.89	8.78	13.33	7.04	1967.18	982.48	50.1	19.8	21.1
25530-6-11E	2	16.34	10.21	12.93	8.15	2141.01	1070.15	50.0	20.2	20.9
BATCH #12 > 40%A-13M & 60%A-13UG W/ 1.62 WT% METHOCEL										
25530-6-12A	2	17.52	12.15	13.90	9.72	2929.10	1474.98	49.6	20.0	20.7
25530-6-12B	2	18.39	10.64	14.52	8.46	2826.15	1400.85	50.4	20.5	21.0
25530-6-12C	2	16.88	12.33	13.43	9.92	2759.29	1405.25	49.1	19.5	20.4
25530-6-12D	2	17.76	10.58	14.17	8.50	2620.96	1340.44	48.9	19.7	20.2
25530-6-12E	2	16.88	11.76	13.43	9.49	2631.73	1344.34	48.9	19.3	20.4

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	- %
RUN 4 - BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.62 WT% METHOCEL										
25530-21-1A	4	17.13	9.33	13.57	7.52	2150.23	1087.59	49.4	19.4	20.8
25530-21-1B	4	16.99	11.39	13.47	9.11	2582.26	1298.20	49.7	20.0	20.7
25530-21-1C	4	15.72	8.95	12.49	7.22	1737.07	884.61	49.1	19.3	20.5
25530-21-1D	4	16.86	11.90	13.37	9.55	2656.76	1340.77	49.5	19.7	20.7
25530-21-1E	4	17.37	11.42	13.73	9.10	2706.17	1347.32	50.2	20.3	21.0
RUN 4 - BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.54 WT% METHOCEL										
25530-21-2A	4	17.39	11.43	13.84	9.21	2714.78	1385.55	49.0	19.4	20.4
25530-21-2B	4	15.87	12.26	12.62	9.87	2425.12	1234.60	49.1	19.5	20.5
25530-21-2C	4	15.36	13.42	12.19	10.79	2486.71	1259.27	49.4	19.6	20.6
25530-21-2D	4	16.88	12.29	13.41	9.88	2750.34	1395.42	49.3	19.6	20.6
25530-21-2E	4	17.77	13.95	14.09	11.22	3459.70	1749.46	49.4	19.6	20.7
RUN 4 - BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.595 WT% METHOCEL										
25530-22-3A	4	16.89	11.29	13.38	9.10	2529.55	1279.51	49.4	19.4	20.8
25530-22-3B	4	16.89	9.74	13.41	7.85	2182.27	1108.71	49.2	19.4	20.6
25530-22-3C	4	16.38	12.32	12.98	9.86	2596.14	1304.72	49.7	20.0	20.8
25530-22-3D	4	17.91	12.28	14.21	9.83	3093.71	1558.95	49.6	20.0	20.7
25530-22-3E	4	16.89	10.21	13.39	8.18	2287.57	1151.87	49.6	19.9	20.7
RUN 5 > 45%A-13M & 55%A-13UG W/ 1.607 WT% METHOCEL										
25530-22-5A	4	16.89	12.66	13.42	10.16	2836.50	1437.10	49.3	19.7	20.5
25530-22-5B	4	16.89	9.64	13.39	7.75	2159.86	1091.32	49.5	19.6	20.7
25530-22-5C	4	16.88	9.77	13.42	7.88	2186.40	1114.60	49.0	19.3	20.5
25530-22-5D	4	17.41	10.31	13.85	8.32	2454.40	1253.47	48.9	19.3	20.4
25530-22-5E	4	16.89	9.03	13.41	7.25	2023.19	1023.96	49.4	19.7	20.6

***NOTE: EXCESS ALUMINA KNEADED INTO MIX BY HAND**

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm ^3	%	%	%
RUN 6 BATCH #1 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-28-1A	2	16.73	8.45	13.29	6.76	1857.54	937.75	49.5	20.0	20.6
25530-28-1B	2	16.73	8.63	13.26	6.93	1897.11	957.00	49.6	19.7	20.7
25530-28-1C	2	16.73	9.23	13.27	7.41	2029.00	1024.82	49.5	19.7	20.7
25530-28-1D	2	16.73	9.48	13.26	7.63	2083.96	1053.66	49.4	19.5	20.7
25530-28-1E	2	16.73	10.15	13.29	8.13	2231.25	1127.79	49.5	19.9	20.6
RUN 6 BATCH #2 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-29-2A	2	16.85	8.64	13.34	6.92	1926.65	967.18	49.8	19.9	20.8
25530-29-2B	2	16.85	8.97	13.32	7.16	2000.24	997.73	50.1	20.2	20.9
25530-29-2C	2	16.86	9.67	13.35	7.77	2158.89	1087.61	49.6	19.6	20.8
25530-29-2D	2	16.85	9.53	13.33	7.63	2125.11	1064.82	49.9	19.9	20.9
25530-29-2E	2	16.85	10.12	13.37	8.12	2256.68	1140.01	49.5	19.8	20.7
RUN 6 BATCH #3 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-29-3A	2	16.97	8.78	13.39	6.99	1985.86	984.30	50.4	20.4	21.1
25530-29-3B	2	16.98	8.83	13.40	7.05	1999.52	994.23	50.3	20.2	21.1
25530-29-3C	2	16.98	8.89	13.38	7.10	2013.11	998.30	50.4	20.1	21.2
25530-29-3D	2	16.98	9.47	13.37	7.56	2144.44	1061.39	50.5	20.2	21.3
25530-29-3E	2	16.97	9.93	13.38	7.99	2245.96	1123.44	50.0	19.5	21.2
RUN 6 BATCH #4 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-29-4A	2	16.73	8.96	13.24	7.18	1969.65	988.53	49.8	19.9	20.9
25530-29-4B	2	16.73	9.61	13.24	7.70	2112.54	1060.12	49.8	19.9	20.9
25530-29-4C	2	16.73	9.52	13.23	7.65	2092.75	1051.65	49.7	19.6	20.9
25530-29-4D	2	16.73	9.35	13.24	7.50	2055.38	1032.59	49.8	19.8	20.9
25530-29-4E	2	16.72	9.55	13.20	7.67	2096.84	1049.62	49.9	19.7	21.1
RUN 6 BATCH #5 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-30-5A	2	16.85	8.39	13.30	6.73	1870.90	934.99	50.0	19.8	21.1
25530-30-5B	2	16.85	9.41	13.31	7.55	2098.35	1050.49	49.9	19.8	21.0
25530-30-5C	2	16.85	9.33	13.33	7.48	2080.52	1043.88	49.8	19.8	20.9
25530-30-5D	2	16.85	8.57	13.32	6.85	1911.04	954.53	50.1	20.1	20.9
25530-30-5E	2	16.85	9.39	13.32	7.53	2093.90	1049.28	49.9	19.8	20.9
RUN 6 BATCH #6 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCCEL										
25530-30-6A	2	16.98	9.56	13.41	7.65	2164.82	1080.46	50.1	20.0	21.0
25530-30-6B	2	16.85	9.83	13.27	7.84	2192.01	1084.29	50.5	20.2	21.2
25530-30-6C	2	16.98	9.81	13.40	7.85	2221.44	1107.05	50.2	20.0	21.1
25530-30-6D	2	16.98	10.25	13.43	8.23	2321.07	1165.85	49.8	19.7	20.9
25530-30-6E	2	16.98	10.59	13.39	8.45	2398.06	1189.89	50.4	20.2	21.1

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 6 BATCH #7 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-31-7A	2	16.60	10.68	13.20	8.63	2311.41	1181.00	48.9	19.2	20.5
25530-31-7B	2	16.60	10.59	13.18	8.56	2291.93	1167.87	49.0	19.2	20.6
25530-31-7C	2	16.59	10.59	13.18	8.52	2289.17	1162.41	49.2	19.5	20.6
25530-31-7D	2	16.60	11.19	13.20	9.04	2421.79	1237.10	48.9	19.2	20.5
25530-31-7E	2	16.59	11.37	13.19	9.14	2457.78	1248.89	49.2	19.6	20.5
RUN 6 BATCH #8 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-31-8A	2	16.72	8.56	13.26	6.89	1879.47	951.47	49.4	19.5	20.7
25530-31-8B	2	16.72	9.16	13.24	7.35	2011.21	1011.94	49.7	19.8	20.8
25530-31-8C	2	16.72	9.25	13.25	7.43	2030.97	1024.50	49.6	19.7	20.8
25530-31-8D	2	16.71	9.67	13.27	7.77	2120.65	1074.61	49.3	19.6	20.6
25530-31-8E	2	16.72	10.39	13.28	8.38	2281.27	1160.73	49.1	19.3	20.6
RUN 6 BATCH #9 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-31-9A	2	16.84	9.78	13.37	7.88	2178.27	1106.31	49.2	19.4	20.6
25530-31-9B	2	16.84	9.79	13.34	7.86	2180.50	1098.56	49.6	19.7	20.8
25530-31-9C	2	16.83	10.22	13.36	8.23	2273.57	1153.72	49.3	19.5	20.6
25530-31-9D	2	16.83	9.84	13.35	7.93	2189.04	1110.01	49.3	19.4	20.7
25530-31-9E	2	16.83	10.19	13.36	8.21	2266.90	1150.92	49.2	19.4	20.6
RUN 6 BATCH #10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-32-10A	2	16.96	10.29	13.45	8.28	2324.64	1176.43	49.4	19.5	20.7
25530-32-10B	2	16.96	9.63	13.38	7.73	2175.54	1086.88	50.0	19.7	21.1
25530-32-10C	2	16.96	9.77	13.45	7.86	2207.17	1116.75	49.4	19.5	20.7
25530-32-10D	2	16.96	9.28	13.44	7.45	2096.47	1056.93	49.6	19.7	20.8
25530-32-10E	2	16.96	10.17	13.46	8.18	2297.54	1163.95	49.3	19.6	20.6
RUN 6 BATCH #11 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-32-11A	2	16.58	9.69	13.11	7.78	2092.10	1050.21	49.8	19.7	20.9
25530-32-11B	2	16.58	9.90	13.08	7.92	2137.44	1064.22	50.2	20.0	21.1
25530-32-11C	2	16.58	9.87	13.13	7.94	2130.96	1075.08	49.5	19.6	20.8
25530-32-11D	2	16.58	10.00	13.10	8.00	2159.03	1078.26	50.1	20.0	21.0
25530-32-11E	2	16.57	10.19	13.12	8.17	2197.40	1104.53	49.7	19.8	20.8
RUN 6 BATCH #12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25530-33-12A	2	16.20	8.64	12.80	6.92	1780.87	890.46	50.0	19.9	21.0
25530-33-12B	2	16.19	9.11	12.81	7.30	1875.43	940.83	49.8	19.9	20.9
25530-33-12C	2	16.19	9.81	12.79	7.86	2019.54	1009.84	50.0	19.9	21.0
25530-33-12D	2	16.19	10.55	12.79	8.46	2171.88	1086.93	50.0	19.8	21.0
25530-33-12E	2	16.19	10.66	12.83	8.55	2194.52	1105.37	49.6	19.8	20.8

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
LD.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 7 BATCH #1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-39A	4	17.42	8.93	13.19	6.74	2128.32	920.96	56.7	24.5	24.3
25530-39B	4	17.43	9.32	13.17	7.05	2223.82	960.40	56.8	24.4	24.4
25530-39C	4	17.43	8.41	13.15	6.38	2006.69	866.49	56.8	24.1	24.6
25530-39D	4	17.43	9.02	13.16	6.81	2152.24	926.29	57.0	24.5	24.5
25530-39E	4	17.34	9.66	13.08	7.29	2281.21	979.56	57.1	24.5	24.6
RUN 7 BATCH #2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-41A	4	16.44	9.49	12.45	7.24	2014.46	881.39	56.2	23.7	24.3
25530-41B	4	16.44	7.86	12.46	5.95	1668.46	725.51	56.5	24.3	24.2
25530-41C	4	16.44	8.69	12.44	6.58	1844.65	799.75	56.6	24.3	24.3
25530-41D	4	16.44	9.19	12.46	6.96	1950.78	848.66	56.5	24.3	24.2
25530-41E	4	16.44	8.72	12.43	6.59	1851.01	799.68	56.8	24.4	24.4

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
RUN 8 BATCH #1 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-46-1A	2	16.28	8.84	12.24	6.65	1840.14	782.48	57.5	24.8	24.8
25530-46-1B	2	16.28	8.29	12.25	6.26	1725.65	737.80	57.2	24.5	24.8
25530-46-1C	2	16.27	9.36	12.26	7.07	1945.99	834.62	57.1	24.5	24.6
25530-46-1D	2	16.29	9.66	12.25	7.29	2013.30	859.19	57.3	24.5	24.8
25530-46-1E	2	16.29	9.68	12.28	7.32	2017.47	866.96	57.0	24.4	24.6
RUN 8 BATCH #2 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-47-2A	2	16.15	9.47	12.15	7.13	1939.92	826.67	57.4	24.7	24.8
25530-47-2B	2	16.07	8.91	12.09	6.74	1807.17	773.75	57.2	24.4	24.8
25530-47-2C	2	16.16	8.19	12.18	6.16	1679.79	717.74	57.3	24.8	24.6
25530-47-2D	2	16.19	10.09	12.17	7.63	2077.18	887.55	57.3	24.4	24.8
25530-47-2E	2	16.15	8.49	12.14	6.35	1739.17	735.02	57.7	25.2	24.8
RUN 8 BATCH #3 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-47-3A	2	16.79	9.05	12.61	6.78	2003.73	846.74	57.7	25.1	24.9
25530-47-3B	2	16.79	8.41	12.61	6.35	1862.03	793.04	57.4	24.5	24.9
25530-47-3C	2	16.81	9.44	12.60	7.13	2095.06	889.04	57.6	24.5	25.0
25530-47-3D	2	16.79	8.61	12.63	6.48	1906.31	811.84	57.4	24.7	24.8
25530-47-3E	2	16.81	9.43	12.61	7.11	2092.84	887.95	57.6	24.6	25.0
RUN 8 BATCH #4 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-47-4A	2	16.93	8.62	12.69	6.48	1940.49	819.57	57.8	24.8	25.0
25530-47-4B	2	16.93	9.53	12.74	7.18	2145.34	915.28	57.3	24.7	24.7
25530-47-4C	2	16.93	8.59	12.70	6.48	1933.73	820.87	57.6	24.6	25.0
25530-47-4D	2	16.93	9.14	12.74	6.89	2057.55	878.31	57.3	24.6	24.7
25530-47-4E	2	16.93	9.28	12.71	7.01	2089.06	889.40	57.4	24.5	24.9
RUN 8 BATCH #5 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-48-5A	2	16.21	9.08	12.19	6.86	1873.88	800.61	57.3	24.4	24.8
25530-48-5B	2	16.55	8.49	12.45	6.41	1826.39	780.34	57.3	24.5	24.8
25530-48-5C	2	16.56	8.99	12.49	6.81	1936.29	834.38	56.9	24.2	24.6
25530-48-5D	2	16.55	8.59	12.44	6.50	1847.90	790.03	57.2	24.3	24.8
25530-48-5E	2	16.53	8.64	12.42	6.51	1854.17	788.70	57.5	24.7	24.9
RUN 8 BATCH #6 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-48-6A	2	16.59	9.15	12.45	6.88	1977.90	837.56	57.7	24.8	25.0
25530-48-6B	2	16.66	8.14	12.53	6.12	1774.45	754.65	57.5	24.8	24.8
25530-48-6C	2	16.69	8.07	12.53	6.11	1765.53	753.41	57.3	24.3	24.9
25530-48-6D	2	16.67	7.96	12.56	6.02	1737.30	745.87	57.1	24.4	24.7
25530-48-6E	2	16.66	7.51	12.49	5.64	1637.12	691.02	57.8	24.9	25.0

SAMPLE SHRINKAGE CALCULATIONS

SAMPLE	CONV.							SHRINK.		SHRINK.
		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	
I.D.	NO.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 8 BATCH #7 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-49-7A	2	16.47	8.67	12.39	6.54	1847.12	788.51	57.3	24.6	24.8
25530-49-7B	2	16.49	8.24	12.41	6.23	1759.78	753.57	57.2	24.4	24.7
25530-49-7C	2	16.47	9.07	12.41	6.81	1932.34	823.72	57.4	24.9	24.7
25530-49-7D	2	15.69	8.39	11.81	6.33	1622.17	693.41	57.3	24.6	24.7
25530-49-7E	2	16.47	8.57	12.38	6.46	1825.82	777.61	57.4	24.6	24.8
RUN 8 BATCH #8 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-49-8A	2	16.73	9.11	12.59	6.87	2002.63	855.26	57.3	24.6	24.7
25530-49-8B	2	16.75	9.16	12.58	6.92	2018.43	860.12	57.4	24.5	24.9
25530-49-8C	2	16.76	7.64	12.61	5.77	1685.51	720.60	57.2	24.5	24.8
25530-49-8D	2	16.72	8.34	12.52	6.27	1831.17	771.91	57.8	24.8	25.1
25530-49-8E	2	16.74	8.63	12.57	6.51	1899.38	807.87	57.5	24.6	24.9
RUN 8 BATCH #9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-49-9A	2	16.83	8.03	12.67	6.05	1786.38	762.78	57.3	24.7	24.7
25530-49-9B	2	16.84	8.75	12.67	6.61	1948.86	833.38	57.2	24.5	24.8
25530-49-9C	2	16.86	9.56	12.69	7.22	2134.33	913.17	57.2	24.5	24.7
25530-49-9D	2	16.86	8.21	12.72	6.23	1832.94	791.68	56.8	24.1	24.6
25530-49-9E	2	16.87	8.99	12.72	6.81	2009.46	865.39	56.9	24.2	24.6
RUN 8 BATCH #10 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-50-10A	2	16.32	8.94	12.27	6.77	1870.11	800.51	57.2	24.3	24.8
25530-50-10B	2	16.32	8.43	12.27	6.34	1763.43	749.67	57.5	24.8	24.8
25530-50-10C	2	16.33	8.34	12.29	6.29	1746.74	746.18	57.3	24.6	24.7
25530-50-10D	2	16.58	8.76	12.49	6.68	1891.31	818.45	56.7	23.7	24.7
25530-50-10E	2	16.32	9.16	12.29	6.89	1916.13	817.36	57.3	24.8	24.7
RUN 8 BATCH #11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-50-11A	2	15.82	8.11	11.91	6.12	1594.13	681.81	57.2	24.5	24.7
25530-50-11B	2	15.79	7.66	11.89	5.78	1499.97	641.77	57.2	24.5	24.7
25530-50-11C	2	15.79	7.79	11.88	5.87	1525.43	650.67	57.3	24.6	24.8
25530-50-11D	2	15.83	7.13	11.90	5.39	1403.27	599.48	57.3	24.4	24.8
25530-50-11E	2	15.79	8.48	11.90	6.40	1660.54	711.81	57.1	24.5	24.6
RUN 8 BATCH #12 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25530-50-12A	2	15.44	7.35	11.61	5.54	1376.17	586.49	57.4	24.6	24.8
25530-50-12B	2	15.44	7.59	11.63	5.77	1421.10	612.95	56.9	24.0	24.7
25530-50-12C	2	15.44	7.51	11.62	5.66	1406.13	600.23	57.3	24.6	24.7
25530-50-12D	2	15.45	7.54	11.63	5.70	1413.57	605.51	57.2	24.4	24.7
25530-50-12E	2	15.44	8.36	11.61	6.33	1565.27	670.13	57.2	24.3	24.8

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
RUN 9 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL										
25655-1A	2	16.08	9.31	12.18	7.09	1890.65	826.10	56.3	23.8	24.3
25655-1B	2	16.08	8.88	12.15	6.70	1803.33	776.81	56.9	24.5	24.4
25655-1C	2	16.08	9.98	12.16	7.58	2026.71	880.29	56.6	24.0	24.4
25655-1D	2	16.08	9.41	12.14	7.12	1910.96	824.15	56.9	24.3	24.5
25655-1E	2	16.08	8.76	12.16	6.69	1778.96	776.93	56.3	23.6	24.4
RUN 10 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL										
25655-2A	2	16.35	9.92	12.98	7.96	2082.75	1053.30	49.4	19.8	20.6
25655-2B	2	16.36	9.54	12.99	7.68	2005.42	1017.82	49.2	19.5	20.6
25655-2C	2	16.35	8.83	12.97	7.07	1853.90	934.09	49.6	19.9	20.7
25655-2D	2	16.35	8.81	12.99	7.09	1849.70	939.62	49.2	19.5	20.6
25655-2E	2	16.35	8.88	12.99	7.17	1864.40	950.23	49.0	19.3	20.6

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm^3	%	%	%
RUN 11 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (WET DISP.)										
25655-7A *	2	14.68	8.29	11.06	6.29	1403.12	604.30	56.9	24.1	24.7
25655-7B *	2	14.53	7.54	10.94	5.71	1250.24	536.74	57.1	24.3	24.7
25655-7C *	2	15.42	7.06	11.74	5.35	1318.45	579.13	56.1	24.2	23.9
25655-7D *	2	15.28	6.76	11.58	5.09	1239.60	536.07	56.8	24.7	24.2
25655-7E *	2	15.23	6.74	11.41	5.08	1227.86	519.43	57.7	24.6	25.1
RUN 12 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (WET DISP.)										
25655-8A	2	16.36	8.66	12.93	6.99	1820.43	917.83	49.6	19.3	21.0
25655-8B	2	16.36	9.23	12.93	7.44	1940.25	976.92	49.6	19.4	21.0
25655-8C	2	16.36	9.47	12.93	7.63	1990.70	1001.87	49.7	19.4	21.0
25655-8D	2	16.36	9.06	12.96	7.33	1904.51	966.95	49.2	19.1	20.8
25655-8E	2	16.34	9.05	12.92	7.32	1897.76	959.68	49.4	19.1	20.9
RUN 13 > 35%A-13M & 65%C-30 W/ 1.01 WT% METHOCEL (DRY DISP.)										
25655-9A	2	16.48	9.39	12.41	7.17	2002.95	867.27	56.7	23.6	24.7
25655-9B	2	16.48	9.22	12.45	7.06	1966.69	859.47	56.3	23.4	24.5
25655-9C	2	16.47	9.56	12.44	7.29	2036.74	886.05	56.5	23.7	24.5
25655-9D	2	16.47	9.62	12.42	7.31	2049.52	885.63	56.8	24.0	24.6
25655-9E	2	16.47	8.99	12.42	6.85	1915.30	829.90	56.7	23.8	24.6
RUN 14 > 50%A-13M & 50%A-13UG W/ 1.57 WT% METHOCEL (DRY DISP.)										
25655-10A	2	16.61	6.81	13.27	5.51	1475.62	762.05	48.4	19.1	20.1
25655-10B	2	16.61	7.08	13.23	5.74	1534.13	789.08	48.6	18.9	20.3
25655-10C	2	16.61	8.26	13.31	6.76	1789.82	940.57	47.4	18.2	19.9
25655-10D	2	16.62	7.32	13.28	5.93	1588.04	821.37	48.3	19.0	20.1
25655-10E	2	16.61	7.05	13.27	5.75	1527.63	795.24	47.9	18.4	20.1

* POOR GREEN STRENGTH - SAMPLES SHAPED BY HAND RATHER THAN MACHINED

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 15 > 35%A-13M & 65%C-30 W/ 8 WT% MOGUL 1607										
25655-20A	2	16.23	8.49	12.13	6.46	1756.44	746.52	57.5	23.9	25.3
25655-20B	2	16.70	9.26	12.66	7.04	2028.31	886.20	56.3	24.0	24.2
25655-20C	2	17.22	9.71	12.86	7.32	2261.39	950.79	58.0	24.6	25.3
RUN 16 > 50%A-13M & 50%A-13UG W/ 8 WT% MOGUL 1607										
25655-22A	2	15.78	8.76	12.62	7.08	1713.20	885.61	48.3	19.2	20.0
25655-22B	2	17.01	9.39	13.59	7.59	2133.85	1100.96	48.4	19.2	20.1
25655-22C	2	16.76	7.96	13.35	6.44	1756.11	901.44	48.7	19.1	20.3
25655-22D	2	16.87	8.10	13.45	6.56	1810.53	932.05	48.5	19.0	20.3
RUN 17 > 35%A-13M & 65%C-30 W/ 4 WT% MOGUL 1607 & .1WT% METHOCEL										
25655-24A	2	16.45	7.00	12.38	5.28	1487.71	635.57	57.3	24.6	24.7
25655-24B	2	16.46	10.25	12.35	7.74	2181.09	927.18	57.5	24.5	25.0
25655-24C	2	16.45	9.70	12.40	7.36	2061.55	888.81	56.9	24.1	24.6
25655-24D	2	16.45	8.65	12.35	6.54	1838.39	783.43	57.4	24.4	24.9
25655-24E	2	15.82	8.02	11.90	6.06	1576.44	673.99	57.2	24.4	24.8
RUN 18 > 50%A-13M & 50%A-13UG W/ 4 WT% MOGUL 1607 & .1 WT% METHOCEL										
25655-25A	2	16.88	8.57	13.38	6.90	1917.85	970.18	49.4	19.5	20.7
25655-25B	2	17.25	9.87	13.71	7.96	2306.67	1175.11	49.1	19.4	20.5
25655-25C	2	16.75	8.32	13.41	6.72	1833.34	949.11	48.2	19.2	19.9
25655-25D	2	16.36	9.20	13.04	7.44	1933.94	993.61	48.6	19.1	20.3
25655-25E	2	16.38	8.27	13.01	6.70	1742.70	890.67	48.9	19.0	20.6
RUN 19A > 35%A-13M & 65%C-30 W/ 4 WT% MOGUL 1607 (17%M)										
25655-26A	2	16.74	8.01	12.92	6.26	1762.92	820.71	53.4	21.8	22.8
25655-26B	2	16.74	7.72	12.76	5.94	1699.10	759.59	55.3	23.1	23.8
25655-26C	2	16.74	8.92	12.81	6.87	1963.20	885.41	54.9	23.0	23.5
25655-26D	2	16.74	8.29	12.67	6.34	1824.55	799.34	56.2	23.5	24.3
25655-26E	2	16.74	8.66	12.76	6.67	1905.98	852.94	55.2	23.0	23.8
RUN 19B > 35%A-13M & 65%C-30 W/ 4 WT% MOGUL 1607 (17.1%M)										
25655-27A	2	16.23	8.71	12.27	6.63	1801.96	783.96	56.5	23.9	24.4
25655-27B	2	16.98	7.38	12.86	5.60	1671.17	727.38	56.5	24.1	24.3
25655-27C	2	17.03	8.31	12.85	6.30	1892.87	817.03	56.8	24.2	24.5
25655-27D	2	16.99	9.22	12.88	6.99	2090.29	910.75	56.4	24.2	24.2
25655-27E	2	16.99	9.64	12.88	7.32	2185.51	953.75	56.4	24.1	24.2
RUN 20 > 35%A-13M & 65%C-30 W/ 5 WT% MOGUL 1607 & .2WT% METHOCEL										
25655-28A	2	16.23	9.03	12.16	6.80	1868.16	789.71	57.7	24.7	25.1
25655-28B	2	16.23	7.91	12.15	5.94	1636.45	688.70	57.9	24.9	25.1
25655-28C	2	16.23	9.14	12.19	6.89	1890.92	804.11	57.5	24.6	24.9
25655-28D	2	16.23	8.76	12.18	6.58	1812.30	766.67	57.7	24.9	25.0
25655-28E	2	16.23	8.61	12.16	6.47	1781.27	751.38	57.8	24.9	25.1
RUN 21A > 35%A-13M & 65%C-30 W/ 5 WT% MOGUL & .2WT% METHOCEL & .35WT% NALCO (19.2%M)										
25655-29A	2	16.61	8.74	12.40	6.58	1893.83	794.62	58.0	24.7	25.3
25655-29B	2	16.61	8.74	12.45	6.62	1893.83	805.91	57.4	24.3	25.0
25655-29C	2	16.61	8.80	12.44	6.63	1906.83	805.83	57.7	24.7	25.1
25655-29D	2	16.61	8.64	12.44	6.52	1872.16	792.46	57.7	24.5	25.1
25655-29E	2	16.61	8.48	12.45	6.38	1837.49	776.69	57.7	24.8	25.0
RUN 21B > 35%A-13M & 65%C-30 W/ 5 WT% MOGUL & .2WT% METHOCEL & .35WT% NALCO (20.3%M)										
25655-30A	2	16.22	9.93	12.17	7.49	2051.83	871.27	57.5	24.6	25.0
25655-30B	2	16.22	9.94	12.17	7.49	2053.89	871.27	57.6	24.6	25.0
25655-30C	2	16.22	9.86	12.19	7.40	2037.36	863.63	57.6	24.9	24.8
25655-30D	2	16.22	8.78	12.18	6.61	1814.20	770.17	57.5	24.7	24.9
25655-30E	2	16.22	9.24	12.17	6.92	1909.25	804.96	57.8	25.1	25.0

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 22 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL 1607 & .5WT% METHOCEL										
25655-37A	4	16.68	8.27	13.18	6.62	1807.12	903.19	50.0	20.0	21.0
25655-37B	4	16.68	8.33	13.17	6.68	1820.23	909.99	50.0	19.8	21.0
25655-37C	4	16.68	8.18	13.16	6.55	1787.45	890.93	50.2	19.9	21.1
25655-37D	4	16.64	9.21	13.15	7.41	2002.88	1006.37	49.8	19.5	21.0
25655-37E	4	16.66	8.75	13.16	7.01	1907.43	953.50	50.0	19.9	21.0
RUN 23 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL & .5WT% METHOCEL & .5WT% NALCO										
25655-38A	4	16.45	9.99	12.94	8.01	2123.18	1053.39	50.4	19.8	21.3
25655-38B	4	16.45	9.32	12.92	7.44	1980.78	975.41	50.8	20.2	21.5
25655-38C	4	16.47	9.07	12.94	7.26	1932.34	954.76	50.6	20.0	21.4
25655-38D	4	16.46	9.28	12.99	7.42	1974.68	983.36	50.2	20.0	21.1
25655-38E	4	16.47	8.47	12.95	6.79	1804.51	894.33	50.4	19.8	21.4
RUN 24 > 50%A-13M & 50%A-13UG W/ 5 WT% MOGUL & .5WT% METHOCEL & .5WT% SGP										
25655-39A	4	17.00	8.67	13.33	6.89	1967.92	961.54	51.1	20.5	21.6
25655-39B	4	17.00	8.73	13.33	6.96	1981.53	971.31	51.0	20.3	21.6
25655-39C	4	16.98	9.45	13.29	7.51	2139.92	1041.79	51.3	20.5	21.7
25655-39D	4	16.99	8.95	13.33	7.13	2029.08	995.04	51.0	20.3	21.5
25655-39E	4	17.00	8.76	13.35	7.02	1988.34	982.63	50.6	19.9	21.5

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 25 > 50%A-13M & 50%A-13UG W/ 2 WT% MOGUL 1607 & 1WT% METHOCEL										
25655-44A	2	17.54	10.31	13.86	8.22	2491.19	1240.19	50.2	20.3	21.0
25655-44B	2	17.54	10.46	13.86	8.32	2527.44	1255.28	50.3	20.5	21.0
25655-44C	2	17.54	10.15	13.83	8.06	2452.53	1210.79	50.6	20.6	21.2
25655-44D	2	17.54	9.25	13.88	7.48	2235.07	1131.80	49.4	19.1	20.9
25655-44E	2	17.54	8.89	13.88	7.10	2148.08	1074.30	50.0	20.1	20.9
RUN 26 > 50%A-13M & 50%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25655-45A	2	16.64	10.95	13.18	8.84	2381.28	1206.07	49.4	19.3	20.8
25655-45B	2	16.64	10.23	13.11	8.20	2224.70	1106.90	50.2	19.8	21.2
25655-45C	2	16.65	9.31	13.16	7.46	2027.06	1014.71	49.9	19.9	21.0
25655-45D	2	16.64	9.22	13.17	7.44	2005.06	1013.52	49.5	19.3	20.9
25655-45E	2	16.64	9.04	13.18	7.27	1965.91	991.87	49.5	19.6	20.8
RUN 27 > 40%A-13M & 60%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25655-46A	2	16.51	8.44	13.09	6.84	1806.87	920.50	49.1	19.0	20.7
25655-46B	2	16.50	8.77	13.06	7.07	1875.24	947.10	49.5	19.4	20.8
25655-46C	2	16.50	9.50	13.06	7.71	2031.33	1032.83	49.2	18.8	20.8
25655-46D	2	16.50	9.72	13.07	7.85	2078.37	1053.20	49.3	19.2	20.8
25655-46E	2	16.50	9.89	13.06	7.95	2114.72	1064.98	49.6	19.6	20.8
RUN 28 > 25%A-13M & 75%A-13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25655-47A	2	16.24	9.49	12.94	7.68	1965.75	1010.00	48.6	19.1	20.3
25655-47B	2	16.23	10.28	12.91	8.31	2126.77	1087.78	48.9	19.2	20.5
25655-47C	2	16.23	10.72	12.88	8.64	2217.79	1125.73	49.2	19.4	20.6
25655-47D	2	16.24	10.78	12.94	8.69	2232.96	1142.82	48.8	19.4	20.3
25655-47E	2	16.11	10.05	12.86	8.14	2048.55	1057.29	48.4	19.0	20.2
RUN 29 > 25%A-13M & 75%A-13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25655-48A	2	16.37	9.68	13.07	7.85	2037.33	1053.20	48.3	18.9	20.2
25655-48B	2	16.36	10.01	13.05	8.11	2104.22	1084.75	48.4	19.0	20.2
25655-48C	2	16.36	9.87	13.08	8.03	2074.79	1079.00	48.0	18.6	20.0
25655-48D	2	16.36	9.84	13.01	7.94	2068.48	1055.52	49.0	19.3	20.5
25655-48E	2	16.36	9.86	13.07	7.98	2072.68	1070.64	48.3	19.1	20.1
RUN 30 > 25%A-13M & 75%A-13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% A-180										
25655-49A	2	16.11	9.51	12.73	7.66	1938.48	974.93	49.7	19.5	21.0
25655-49B	2	16.10	9.69	12.74	7.84	1972.72	999.41	49.3	19.1	20.9
25655-49C	2	16.09	10.02	12.77	8.08	2037.37	1034.86	49.2	19.4	20.6
25655-49D	2	16.09	9.77	12.78	7.87	1986.53	1009.55	49.2	19.4	20.6
25655-49E	2	16.09	9.84	12.80	7.93	2000.77	1020.43	49.0	19.4	20.4

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 31 T1 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-1A	2	16.64	9.69	13.24	7.73	2107.27	1064.25	49.5	20.2	20.4
25740-5-1B	2	16.64	8.99	13.25	7.17	1955.04	988.65	49.4	20.2	20.4
25740-5-1C	2	16.64	9.15	13.28	7.31	1989.84	1012.52	49.1	20.1	20.2
25740-5-1D	2	16.64	9.51	13.23	7.58	2068.12	1042.03	49.6	20.3	20.5
25740-5-1E	2	16.64	8.87	13.24	7.07	1928.94	973.39	49.5	20.3	20.4
RUN 31 T2 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-2A	2	16.90	9.38	13.53	7.51	2104.10	1079.75	48.7	19.9	19.9
25740-5-2B	2	16.90	9.42	13.46	7.51	2113.07	1068.61	49.4	20.3	20.4
25740-5-2C	2	16.90	9.25	13.51	7.41	2074.94	1062.23	48.8	19.9	20.1
25740-5-2D	2	16.90	8.51	13.51	6.82	1908.94	977.65	48.8	19.9	20.1
25740-5-2E	2	16.90	8.19	13.43	6.53	1837.16	925.03	49.6	20.3	20.5
RUN 31 T3 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-3A	2	16.52	9.61	13.16	7.64	2059.84	1039.19	49.5	20.5	20.3
25740-5-3B	2	16.52	9.36	13.18	7.50	2006.25	1023.25	49.0	19.9	20.2
25740-5-3C	2	16.52	8.96	13.21	7.20	1920.51	986.80	48.6	19.6	20.0
25740-5-3D	2	16.52	9.08	13.16	7.25	1946.24	986.14	49.3	20.2	20.3
25740-5-3E	2	16.52	9.01	13.16	7.20	1931.23	979.34	49.3	20.1	20.3
RUN 31 T4 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-4A	2	16.78	9.30	13.29	7.39	2056.63	1025.14	50.2	20.5	20.8
25740-5-4B	2	16.77	9.27	13.38	7.37	2047.55	1036.26	49.4	20.5	20.2
25740-5-4C	2	16.78	8.65	13.36	6.90	1912.89	967.28	49.4	20.2	20.4
25740-5-4D	2	16.14	8.61	12.86	6.87	1761.57	892.34	49.3	20.2	20.3
25740-5-4E	2	16.14	9.36	12.87	7.45	1915.02	969.18	49.4	20.4	20.3
RUN 31 T5 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-5A	2	16.90	9.56	13.47	7.64	2144.47	1088.72	49.2	20.1	20.3
25740-5-5B	2	16.90	8.52	13.51	6.81	1911.18	976.22	48.9	20.1	20.1
25740-5-5C	2	16.12	8.88	12.85	7.11	1812.31	922.07	49.1	19.9	20.3
25740-5-5D	2	16.13	8.81	12.89	7.05	1800.26	919.99	48.9	20.0	20.1
25740-5-5E	2	16.13	9.00	12.86	7.16	1839.08	930.00	49.4	20.4	20.3
RUN 31 T6 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-6A	2	16.50	9.86	13.21	7.91	2108.31	1084.11	48.6	19.8	19.9
25740-5-6B	2	16.50	9.51	13.21	7.63	2033.47	1045.73	48.6	19.8	19.9
25740-5-6C	2	16.50	9.13	13.22	7.28	1952.22	999.27	48.8	20.3	19.9
25740-5-6D	2	16.51	8.41	13.19	6.73	1800.44	919.59	48.9	20.0	20.1
25740-5-6E	2	16.50	8.83	13.16	7.03	1888.07	956.22	49.4	20.4	20.2
RUN 31 T7 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-5-7A	2	16.63	9.71	13.21	7.70	2109.08	1055.32	50.0	20.7	20.6
25740-5-7B	2	16.62	9.59	13.28	7.69	2080.51	1065.15	48.8	19.8	20.1
25740-5-7C	2	16.62	9.46	13.26	7.54	2052.31	1041.23	49.3	20.3	20.2
25740-5-7D	2	16.62	8.98	13.22	7.16	1948.17	982.80	49.6	20.3	20.5
25740-5-7E	2	16.63	8.98	13.27	7.17	1950.52	991.63	49.2	20.2	20.2
RUN 32 > 20%A13M & 80%A13UG W/ 2 WT% MOGUL & 1 WT% METHOCEL & .5WT% NALCO										
25740-8-1A	2	16.78	9.88	13.32	7.88	2184.89	1098.06	49.7	20.2	20.6
25740-8-1B	2	16.75	9.64	13.34	7.69	2124.20	1074.80	49.4	20.2	20.4
25740-8-1C	2	16.75	9.15	13.32	7.32	2016.23	1020.02	49.4	20.0	20.5
25740-8-1D	2	16.75	8.85	13.26	7.03	1950.12	970.80	50.2	20.6	20.8
25740-8-1E	2	16.75	8.75	13.31	6.99	1928.09	972.57	49.6	20.1	20.5

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 33 T1 > 20%A13M & 80%A13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-14-1A	2	15.94	9.89	12.66	7.91	1973.62	995.71	49.5	20.0	20.6
25740-14-1B	2	15.94	9.93	12.66	7.96	1981.60	1002.01	49.4	19.8	20.6
25740-14-1C	2	15.94	9.56	12.76	7.65	1907.76	978.26	48.7	20.0	19.9
25740-14-1D	2	15.94	9.04	12.68	7.21	1803.99	910.47	49.5	20.2	20.5
25740-14-1E	2	15.94	8.67	12.72	6.95	1730.16	883.18	49.0	19.8	20.2
RUN 33 T2 > 20%A13M & 80%A13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-14-2A	2	15.84	9.84	12.65	7.87	1939.08	989.11	49.0	20.0	20.1
25740-14-2B	2	15.84	9.35	12.64	7.51	1842.52	942.37	48.9	19.7	20.2
25740-14-2C	2	15.84	9.36	12.62	7.50	1844.49	938.14	49.1	19.9	20.3
25740-14-2D	2	15.84	8.97	12.62	7.18	1767.63	898.12	49.2	20.0	20.3
25740-14-2E	2	15.84	8.45	12.66	6.75	1665.16	849.69	49.0	20.1	20.1
RUN 33 T3 > 20%A13M & 80%A13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-14-3A	2	16.23	9.36	12.91	7.46	1936.43	976.52	49.6	20.3	20.5
25740-14-3B	2	16.23	9.25	12.96	7.42	1913.68	978.82	48.9	19.8	20.1
25740-14-3C	2	16.23	9.06	12.89	7.24	1874.37	944.79	49.6	20.1	20.6
25740-14-3D	2	16.23	9.05	12.93	7.22	1872.30	948.03	49.4	20.2	20.3
25740-14-3E	2	16.23	8.92	12.94	7.10	1845.40	933.72	49.4	20.4	20.3
RUN 33 T4 > 20%A13M & 80%A13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-14-4A	2	16.11	9.07	12.80	7.23	1848.79	930.35	49.7	20.3	20.5
25740-14-4B	2	16.11	8.97	12.88	7.16	1828.41	932.90	49.0	20.2	20.0
25740-14-4C	2	16.11	8.83	12.84	7.04	1799.87	911.57	49.4	20.3	20.3
25740-14-4D	2	16.11	8.74	12.88	6.98	1781.53	909.45	49.0	20.1	20.0
25740-14-4E	2	16.11	7.88	12.80	6.32	1606.23	813.25	49.4	19.8	20.5
RUN 33 T5 > 20%A13M & 80%A13UG W/ 3 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-14-5A	2	16.62	9.42	13.24	7.53	2043.63	1036.72	49.3	20.1	20.3
25740-14-5B	2	16.62	9.10	13.24	7.26	1974.21	999.54	49.4	20.2	20.3
25740-14-5C	2	16.62	8.92	13.19	7.13	1935.16	974.25	49.7	20.1	20.6
25740-14-5D	2	16.62	8.56	13.22	6.86	1857.06	941.62	49.3	19.9	20.5
25740-14-5E	2	16.62	8.42	13.16	6.71	1826.68	912.69	50.0	20.3	20.8
RUN 34 > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-17-1A	2	16.55	10.25	13.18	8.17	2205.00	1114.66	49.4	20.3	20.4
25740-17-1B	2	16.56	10.00	13.16	7.97	2153.82	1084.08	49.7	20.3	20.5
25740-17-1C	2	16.56	9.76	13.16	7.76	2102.13	1055.51	49.8	20.5	20.5
25740-17-1D	2	16.56	9.49	13.18	7.57	2043.98	1032.80	49.5	20.2	20.4
25740-17-1E	2	16.56	8.80	13.14	7.01	1895.36	950.60	49.8	20.3	20.7
RUN 35 T1 > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-19-1A	2	17.13	8.73	13.49	6.84	2011.96	977.62	51.4	21.6	21.2
25740-19-1B	2	17.15	8.04	13.61	6.38	1857.26	928.17	50.0	20.6	20.6
25740-19-1C	2	15.75	8.25	12.47	6.51	1607.33	795.07	50.5	21.1	20.8
25740-19-1D	2	17.15	7.02	13.50	5.54	1621.64	792.99	51.1	21.1	21.3
25740-19-1E	2	17.15	7.68	13.42	6.04	1774.10	854.34	51.8	21.4	21.7
RUN 35 T2 > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-19-2A	2	17.07	8.15	13.49	6.39	1865.15	913.30	51.0	21.6	21.0
25740-19-2B	2	17.07	8.05	13.56	6.39	1842.27	922.80	49.9	20.6	20.6
25740-19-2C	2	17.07	7.59	13.30	5.93	1736.99	823.85	52.6	21.9	22.1
25740-19-2D	2	17.07	7.43	13.49	5.93	1700.38	847.56	50.2	20.2	21.0
25740-19-2E	2	17.07	7.46	13.47	5.92	1707.24	843.62	50.6	20.6	21.1
RUN 35 T3 > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-19-3A	2	17.20	8.12	13.45	6.35	1886.70	902.21	52.2	21.8	21.8
25740-19-3B	2	17.34	7.59	13.78	6.03	1792.38	899.30	49.8	20.6	20.5
25740-19-3C	2	17.34	8.87	13.62	6.96	2094.65	1014.04	51.6	21.5	21.5
25740-19-3D	2	17.34	8.26	13.59	6.50	1950.60	942.85	51.7	21.3	21.6
25740-19-3E	2	17.34	8.05	13.70	6.38	1901.01	940.48	50.5	20.7	21.0
RUN 35 T4 > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-19-4A	2	17.47	7.50	13.58	5.83	1797.78	844.42	53.0	22.3	22.3
25740-19-4B	2	17.47	7.55	13.91	6.04	1809.77	917.87	49.3	20.0	20.4
25740-19-4C	2	17.47	8.35	13.85	6.64	2001.53	1000.36	50.0	20.5	20.7

SAMPLE SHRINKAGE CALCULATIONS

25740-19-4D	2	17.47	7.73	13.79	6.11	1852.91	912.56	50.8	21.0	21.1
25740-19-4E	2	17.47	7.85	13.72	6.19	1881.68	915.14	51.4	21.1	21.5
RUN 35 TS > 20%A13M & 80%A13UG W/ 5 WT% MOGUL & 1.5 WT% METHOCEL & .5WT% NALCO										
25740-19-5A	2	17.22	7.66	13.62	6.15	1783.96	896.02	49.8	19.7	20.9
25740-19-5B	2	17.22	7.14	13.62	5.65	1662.85	823.18	50.5	20.9	20.9
25740-19-5C	2	17.22	6.71	13.53	5.30	1562.71	762.01	51.2	21.0	21.4
25740-19-5D	2	17.22	7.44	13.64	5.90	1732.72	862.13	50.2	20.7	20.8
25740-19-5E	2	17.22	7.82	13.56	6.16	1821.22	889.59	51.2	21.2	21.3

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ³	mm ³	%	%	%
RUN 36 T1 > 20%A13M & 80%A13UG W/ 4.75 WT% MOGUL & 1.75 WT% METHOCEL & .5WT% NALCO										
25740-25-1A	4	17.10	7.99	13.33	6.04	1834.97	842.92	54.1	24.4	22.0
25740-25-1B	4	17.10	7.33	13.22	5.56	1683.39	763.18	54.7	24.1	22.7
25740-25-1C	4	17.10	7.76	13.46	6.03	1782.15	858.02	51.9	22.3	21.3
25740-25-1D	4	17.10	7.80	13.44	6.06	1791.33	859.73	52.0	22.3	21.4
25740-25-1E	4	17.10	7.78	13.37	6.07	1786.74	852.20	52.3	22.0	21.8
RUN 36 T2 > 20%A13M & 80%A13UG W/ 4.75 WT% MOGUL & 1.75 WT% METHOCEL & .5WT% NALCO										
25740-25-2A	4	16.99	7.68	13.28	5.98	1741.16	828.30	52.4	22.1	21.8
25740-25-2B	4	16.99	7.47	13.39	5.79	1693.55	815.32	51.9	22.5	21.2
25740-25-2C	4	16.99	7.89	13.40	6.19	1788.76	872.95	51.2	21.5	21.1
25740-25-2D	4	16.99	7.46	13.41	5.79	1691.28	817.76	51.6	22.4	21.1
25740-25-2E	4	16.99	6.95	13.09	5.31	1575.65	714.60	54.6	23.6	23.0
RUN 36 T3 > 20%A13M & 80%A13UG W/ 4.75 WT% MOGUL & 1.75 WT% METHOCEL & .5WT% NALCO										
25740-25-3A	4	16.87	7.90	13.28	6.09	1765.82	843.53	52.2	22.9	21.3
25740-25-3B	4	16.87	7.77	13.08	5.95	1736.76	799.51	54.0	23.4	22.5
25740-25-3C	4	16.87	7.93	13.27	6.20	1772.53	857.48	51.6	21.8	21.3
25740-25-3D	4	16.87	7.76	13.31	6.02	1734.53	837.61	51.7	22.4	21.1
25740-25-3E	4	16.87	8.27	13.22	6.42	1848.52	881.23	52.3	22.4	21.6
RUN 36 T4 > 20%A13M & 80%A13UG W/ 4.75 WT% MOGUL & 1.75 WT% METHOCEL & .5WT% NALCO										
25740-25-4A	4	17.26	7.37	13.56	5.72	1724.40	826.05	52.1	22.4	21.4
25740-25-4B	4	17.26	7.79	13.58	6.04	1822.67	874.83	52.0	22.5	21.3
25740-25-4C	4	17.26	7.86	13.62	6.13	1839.05	893.11	51.4	22.0	21.1
25740-25-4D	4	17.26	7.51	13.34	5.76	1757.16	805.05	54.2	23.3	22.7
25740-25-4E	4	17.26	6.95	13.41	5.40	1626.13	762.68	53.1	22.3	22.3
RUN 36 T5 > 20%A13M & 80%A13UG W/ 4.75 WT% MOGUL & 1.75 WT% METHOCEL & .5WT% NALCO										
25740-25-5A	4	17.14	7.70	13.36	6.02	1776.65	843.92	52.5	21.8	22.1
25740-25-5B	4	17.14	8.12	13.35	6.25	1873.56	874.85	53.3	23.0	22.1
25740-25-5C	4	17.14	8.34	13.36	6.46	1924.32	905.60	52.9	22.5	22.1
25740-25-5D	4	17.14	7.72	13.48	6.06	1781.26	864.85	51.4	21.5	21.4
25740-25-5E	4	17.14	8.47	13.38	6.54	1954.31	919.56	52.9	22.8	21.9

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm ^3	%	%	%
RUN 47A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-24A1	2	16.480	6.310	13.13	5.06	1345.96	685.12	49.1	19.8	20.3
25247-24A2	2	16.480	6.510	13.15	5.21	1388.62	707.59	49.0	20.0	20.2
25247-24A3	2	16.490	7.070	13.13	5.63	1509.91	762.30	49.5	20.4	20.4
25247-24A4	2	15.110	6.790	11.99	5.41	1217.55	610.84	49.8	20.3	20.6
25247-24A5	2	16.330	6.390	13.05	5.07	1338.33	678.14	49.3	20.7	20.1
RUN 47B > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-24B1	2	16.320	6.680	13.95	5.19	1397.35	793.24	43.2	22.3	14.5
25247-24B2	2	16.520	6.730	13.21	5.36	1442.53	734.62	49.1	20.4	20.0
25247-24B3	2	16.030	6.720	12.80	5.33	1356.21	685.86	49.4	20.7	20.1
25247-24B4	2	16.290	6.730	13.04	5.35	1402.64	714.49	49.1	20.5	20.0
25247-24B5	2	16.510	6.550	13.20	5.23	1402.25	715.71	49.0	20.2	20.0
RUN 47C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-24C1	2	16.160	6.640	12.84	5.32	1361.88	688.86	49.4	19.9	20.5
25247-24C2	2	16.900	6.710	13.43	5.37	1505.17	760.70	49.5	20.0	20.5
25247-24C3	2	16.110	6.860	12.86	5.49	1398.31	713.09	49.0	20.0	20.2
25247-24C4	2	16.540	6.720	13.21	5.42	1443.88	742.84	48.6	19.3	20.1
25247-24C5	2	15.860	6.640	12.64	5.34	1311.79	670.08	48.9	19.6	20.3
RUN 47D > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-24D1	2	16.580	6.790	13.22	5.44	1465.98	746.71	49.1	19.9	20.3
25247-24D2	2	16.350	6.560	13.07	5.22	1377.30	700.34	49.2	20.4	20.1
25247-24D3	2	16.600	6.560	13.28	5.14	1419.74	711.95	49.9	21.6	20.0
25247-24D4	2	16.560	6.610	13.26	5.27	1423.68	727.76	48.9	20.3	19.9
25247-24D5	2	16.390	7.060	13.07	5.61	1489.54	752.67	49.5	20.5	20.3
RUN 47E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-24E1	2	15.740	6.780	12.60	5.39	1319.25	672.08	49.1	20.5	19.9
25247-24E2	2	16.610	6.790	13.27	5.37	1471.29	742.69	49.5	20.9	20.1
25247-24E3	2	16.390	6.620	13.08	5.25	1396.71	705.45	49.5	20.7	20.2
25247-24E4	2	16.840	6.870	13.49	5.44	1530.14	777.52	49.2	20.8	19.9
25247-24E5	2	16.840	6.460	13.48	5.12	1438.82	730.70	49.2	20.7	20.0

SAMPLE SHRINKAGE CALCULATIONS

									SHRINK.	SHRINK.
SAMPLE		GREEN	GREEN	FIRE	FIRE	GREEN	FIRE	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm ^3	%	%	%
RUN 48-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-25-A1	2	16.56	7.89	13.22	6.26	1699.37	859.26	49.4	20.7	20.2
25247-25-A2	2	16.43	9.30	13.20	7.35	1971.73	1005.83	49.0	21.0	19.7
25247-25-A3	2	17.28	8.12	13.66	6.38	1904.29	935.00	50.9	21.4	20.9
25247-25-A4	2	16.47	7.70	13.07	6.15	1640.47	825.12	49.7	20.1	20.6
25247-25-A5	2	16.66	9.65	13.30	7.67	2103.62	1065.59	49.3	20.5	20.2
RUN 48-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-25-C1	2	16.07	8.23	12.77	6.46	1669.25	827.38	50.4	21.5	20.5
25247-25-C2	2	16.53	8.09	13.12	6.41	1736.14	866.59	50.1	20.8	20.6
25247-25-C3	2	15.70	7.92	12.54	6.29	1533.25	776.85	49.3	20.6	20.1
25247-25-C4	2	16.40	8.06	13.08	6.38	1702.60	857.29	49.6	20.8	20.2
25247-25-C5	2	16.20	8.11	12.91	6.47	1671.63	846.93	49.3	20.2	20.3
RUN 48-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-25-E1	2	16.72	7.78	13.30	6.11	1708.21	848.86	50.3	21.5	20.5
25247-25-E2	2	16.74	7.69	13.35	6.12	1692.49	856.65	49.4	20.4	20.3
25247-25-E3	2	16.70	7.82	13.30	6.18	1712.89	858.58	49.9	21.0	20.4
25247-25-E4	2	16.97	8.00	13.50	6.32	1809.44	904.64	50.0	21.0	20.4
25247-25-E5	2	16.74	7.80	13.31	6.19	1716.70	861.26	49.8	20.6	20.5
RUN 49-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-26-A1	2	16.27	7.88	13.02	6.28	1638.29	836.12	49.0	20.3	20.0
25247-26-A2	2	16.28	7.50	13.06	6.00	1561.20	803.76	48.5	20.0	19.8
25247-26-A3	2	16.55	7.38	13.24	5.89	1587.60	810.93	48.9	20.2	20.0
25247-26-A4	2	16.73	7.89	13.34	6.39	1734.44	893.10	48.5	19.0	20.3
25247-26-A5	2	16.81	7.94	13.37	6.39	1762.16	897.13	49.1	19.5	20.5
RUN 49-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-26-C1	2	16.70	8.00	13.31	6.38	1752.32	887.70	49.3	20.3	20.3
25247-26-C2	2	16.44	8.12	13.19	6.51	1723.65	889.53	48.4	19.8	19.8
25247-26-C3	2	16.76	8.18	13.39	6.50	1804.64	915.30	49.3	20.5	20.1
25247-26-C4	2	16.32	8.12	13.02	6.50	1698.58	865.42	49.1	20.0	20.2
25247-26-C5	2	16.98	8.04	13.61	6.44	1820.63	936.90	48.5	19.9	19.8
RUN 49-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-26-E1	2	16.86	8.16	13.43	6.43	1821.78	910.86	50.0	21.2	20.3
25247-26-E2	2	16.57	8.22	13.23	6.49	1772.58	892.18	49.7	21.0	20.2
25247-26-E3	2	16.36	8.28	13.08	6.62	1740.55	889.53	48.9	20.0	20.0
25247-26-E4	2	16.69	8.03	13.27	6.39	1756.78	883.76	49.7	20.4	20.5
25247-26-E5	2	16.32	8.06	13.00	6.43	1686.03	853.47	49.4	20.2	20.3
RUN 50-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-28-A1	2	16.65	8.99	13.28	7.14	1957.39	988.97	49.5	20.6	20.2
25247-28-A2	2	16.61	8.70	13.18	6.93	1885.16	945.48	49.8	20.3	20.7
25247-28-A3	2	16.58	8.82	13.27	7.01	1904.26	969.50	49.1	20.5	20.0
25247-28-A4	2	16.53	8.68	13.24	6.92	1862.75	952.73	48.9	20.3	19.9
25247-28-A5	2	16.28	9.01	13.04	7.22	1875.53	964.23	48.6	19.9	19.9
RUN 50-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-28-C1	2	17.06	8.76	13.63	6.97	2002.40	1016.98	49.2	20.4	20.1
25247-28-C2	2	16.82	8.62	13.41	6.89	1915.35	973.12	49.2	20.1	20.3
25247-28-C3	2	17.13	8.64	13.60	6.90	1991.21	1002.34	49.7	20.1	20.6
25247-28-C4	2	16.83	8.86			1971.02	0.00	100.0	100.0	100.0
25247-28-C5	2	16.60	8.57	13.18	6.81	1854.75	929.11	49.9	20.5	20.6

SAMPLE SHRINKAGE CALCULATIONS

SAMPLE		GREEN	GREEN	FIRED	FIRED	GREEN	FIRED	SHRINK.	LINEAR	LINEAR
I.D.	CONV.	DIAM.	THICK.	DIAM.	THICK.	VOLUME	VOLUME	VOLUME	THICK.	DIAM.
NO.	NO.	mm	mm	mm	mm	mm ^3	mm ^3	%	%	%
RUN 50-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-28-E1	2	17.10	9.05	13.65	7.17	2078.41	1049.24	49.5	20.8	20.2
25247-28-E2	2	16.84	9.00	13.48	7.13	2004.55	1017.56	49.2	20.8	20.0
25247-28-E3	2	16.89	9.04	13.46	7.16	2025.43	1018.81	49.7	20.8	20.3
25247-28-E4	2	17.08	9.24	13.61	7.31	2117.08	1063.46	49.8	20.9	20.3
25247-28-E5	2	16.12	9.04	12.95	7.18	1844.96	945.70	48.7	20.6	19.7
RUN 51-A > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-29-A1	2	16.56	9.22	13.26	7.32	1985.83	1010.85	49.1	20.6	19.9
25247-29-A2	2	16.24	8.88	13.00	7.06	1839.39	937.09	49.1	20.5	20.0
25247-29-A3	2	16.64	9.09	13.30	7.26	1976.79	1008.62	49.0	20.1	20.1
25247-29-A4	2	16.39	9.20	13.10	7.33	1941.04	987.95	49.1	20.3	20.1
25247-29-A5	2	17.16	9.01	13.70	7.16	2083.77	1055.46	49.3	20.5	20.2
RUN 51-C > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-29-C1	2	16.65	9.31	13.33	7.38	2027.06	1029.93	49.2	20.7	19.9
25247-29-C2	2	16.89	9.13	13.49	7.21	2045.59	1030.50	49.6	21.0	20.1
25247-29-C3	2	16.45	9.03	13.17	7.18	1919.15	978.11	49.0	20.5	19.9
25247-29-C4	2	16.90	9.06	13.50	7.17	2032.32	1026.30	49.5	20.9	20.1
25247-29-C5	2	17.12	8.99	13.67	7.09	2069.46	1040.57	49.7	21.1	20.2
RUN 51-E > 55.8%A-13UG & 27.9%A-13M & 9.3% CP-2 & 5% Mogul & 2% Methocel										
25247-29-E1	2	17.20	9.15	13.78	7.21	2126.02	1075.28	49.4	21.2	19.9
25247-29-E2	2	17.13	9.28	13.67	7.34	2138.71	1077.27	49.6	20.9	20.2
25247-29-E3	2	17.36	9.18	13.97	7.25	2172.86	1111.27	48.9	21.0	19.5
25247-29-E4	2	16.95	9.20	13.52	7.28	2075.95	1045.14	49.7	20.9	20.2
25247-29-E5	2	17.17	9.09	13.83	7.19	2104.72	1080.10	48.7	20.9	19.5

Appendix B-4 – Raw Data and Green Strength Calculations

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**EXPT DESIGN 24127
GREEN STRENGTH OF SAMPLES IN CHATILLON COMPRESSION TESTER**

SAMPLE ID. NO.	EXPT. REF. NO.	DIAMETER IN.	LENGTH IN.	C-PEAK LB.	STRESS PSI	STRESS MPA.
EXTRUDED > 40% A-13 (-270) & 60% A-13 M W/ 2.0 WT% METHOCEL						
12719-1	#1	0.4845	0.2845	25.80	119.2	0.82
12719-2	#1	0.4915	0.2890	21.14	94.7	0.65
12719-3	#1	0.4820	0.2860	17.56	81.1	0.56
12719-4	#1	0.4810	0.2665	15.96	79.3	0.55
12719-5	#1	0.4810	0.2450	10.82	58.5	0.40
12719-6	#1	0.4740	0.2505	22.12	118.6	0.82
12719-7	#1	0.4900	0.2710	15.10	72.4	0.50
EXTRUDED > 60% A-13 (-270) & 40% A-13 M W/ 4.68 WT% METHOCEL						
12724-1	#2	0.4810	0.2760	24.44	117.2	0.81
12724-2	#2	0.5105	0.2710	31.98	147.2	1.01
12724-3	#2	0.4925	0.2965	37.94	165.4	1.14
12724-4	#2	0.4725	0.2820	32.16	153.7	1.06
12724-5	#2	0.4810	0.3020	39.54	173.3	1.20
12724-6	#2	0.4795	0.2785	27.88	132.9	0.92
12724-7	#2	0.4835	0.2920	32.00	144.3	1.00
12724-8	#2	0.5015	0.2770	33.22	152.2	1.05
EXTRUDED > 40% A-13 UG & 60% A-13 M W/ 4.4 WT% METHOCEL						
12721-1	#3	0.5035	0.2860	38.32	169.4	1.17
12721-2	#3	0.5065	0.3070	48.24	197.5	1.36
12721-3	#3	0.5130	0.3035	46.90	191.8	1.32
12721-4	#3	0.5220	0.3205	45.72	174.0	1.20
12721-5	#3	0.5115	0.2745	43.92	199.1	1.37
12721-6	#3	0.5025	0.3075	39.72	163.6	1.13
12721-7	#3	0.5045	0.3210	40.94	160.9	1.11
EXTRUDED > 60% A-13 UG & 40% A-13 M W/ 2.0 WT% METHOCEL						
12722-1	#4	0.4930	0.2210	12.24	71.5	0.49
12722-2	#4	0.5025	0.2785	13.66	62.1	0.43
12722-3	#4	0.5070	0.2700	12.96	60.3	0.42
12722-4	#4	0.5030	0.2270	9.58	53.4	0.37
12722-5	#4	0.4855	0.2585	10.86	55.1	0.38
12722-6	#4	0.5180	0.2480	7.84	38.9	0.27

EXPT. DESIGN
GREEN STRENGTH OF SAMPLES IN CHATILLON COMPRESSION TESTER

SAMPLE ID. NO.	EXPT. REF. NO.	DIAMETER IN.	LENGTH IN.	C-PEAK LB.	STRESS PSI	STRESS MPA
EXTRUDED > 40% A-13 (-270) & 60% A-13 M W/ 4.68 WT% METHOCEL						
12720-1	#5	0.5005	0.3250	45.40	177.7	1.23
12720-2	#5	0.4915	0.3095	45.88	192.0	1.32
12720-3	#5	0.4880	0.3125	42.78	178.6	1.23
12720-4	#5	0.4910	0.2800	36.46	168.8	1.16
12720-5	#5	0.4800	0.3165	39.02	163.5	1.13
12720-6	#5	0.4900	0.3150	44.34	182.9	1.26
12720-7	#5	0.4850	0.3115	46.40	195.5	1.35
12720-8	#5	0.4855	0.2615	35.12	176.1	1.21
EXTRUDED > 60% A-13 (-270) & 40% A-13 M W/ 2.0 WT% METHOCEL						
12717-1	#6	0.4775	0.2565	12.96	67.4	0.46
12717-2	#6	0.5310	0.2705	17.24	76.4	0.53
12717-3	#6	0.4850	0.2510	10.32	54.0	0.37
12717-4	#6	0.4835	0.3245	17.98	73.0	0.50
12717-5	#6	0.5010	0.2765	16.00	73.5	0.51
12717-6	#6	0.4980	0.2705	14.86	70.2	0.48
12717-7	#6	0.4975	0.2495	12.72	65.2	0.45
12717-8	#6	0.5215	0.2605	16.34	76.6	0.53
12717-9	#6	0.5125	0.2780	16.24	72.6	0.50
EXTRUDED > 40% A-13 UG & 60% A-13 M W/ 2.0 WT% METHOCEL						
12723-1	#7	0.5070	0.2985	18.94	79.7	0.55
12723-2	#7	0.5330	0.3020	20.88	82.6	0.57
12723-3	#7	0.5070	0.2815	15.40	68.7	0.47
12723-4	#7	0.4930	0.3205	20.86	84.0	0.58
12723-5	#7	0.5580	0.3295	22.38	77.5	0.53
12723-6	#7	0.5430	0.3015	18.54	72.1	0.50
12723-7	#7	0.5365	0.3205	25.14	93.1	0.64
EXTRUDED > 60% A-13 UG & 40% A-13 M W/ 4.63 WT% METHOCEL						
12716-1	#8	0.4915	0.2995	36.32	157.1	1.08
12716-2	#8	0.4960	0.2910	38.90	171.6	1.18
12716-3	#8	0.4790	0.3040	39.78	173.9	1.20
12716-4	#8	0.4835	0.2920	34.70	156.5	1.08
12716-5	#8	0.4760	0.2845	42.14	198.1	1.37
12716-6	#8	0.5040	0.2650	35.08	167.2	1.15

Appendix B-5 – Raw Data and Fired Strength Calculations

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SUMMARY OF FIRED STRENGTH DATA FROM EXPERIMENTAL DESIGN 24127

	A	B	C	D	E	F	G	H	I	J
1	DATE TESTED		91-07-11	91-07-11	91-07-11	91-07-11	91-07-11	91-07-11	91-07-11	91-07-11
2	SAMPLE IDENTIFICATION NUMBER		24127-19	24127-24	24127-21	24127-22	24127-20	24127-17	24127-23	24127-16
3	EXPERIMENT NUMBER		#1	#2	#3	#4	#5	#6	#7	#8
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN	GRAIN	GRAIN	GRAIN	GRAIN
5	EXPT DESIGN CODE ID									
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10	-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465	0.07283465	0.07283465	0.07283465	0.07283465	0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3	3	3	3	3	3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO	NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA	MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED
17		NO	#1	#2	#3	#4	#5	#6	#7	#8
18		1	19.0	20.2	39.2	21.3	38.5	26.2	44.5	29.4
19		2	36.4	26.4	42.9	22.2	38.7	39.4	46.3	43.6
20		3	36.6	26.6	44.7	25.0	42.4	42.2	49.1	45.9
21		4	39.9	31.3	45.7	32.2	43.8	43.1	51.9	46.3
22		5	44.5	31.3	46.1	32.7	45.0	43.3	52.4	47.3
23		6	46.1	32.0	46.3	33.6	46.3	43.3	57.5	47.5
24		7	50.5	32.4	47.5	35.7	47.5	46.1	57.7	48.7
25		8	51.2	34.1	51.7	37.5	48.0	46.6	60.9	49.4
26		9	53.1	36.2	55.6	38.5	55.2	47.5	62.6	50.5
27		10	54.0	37.3	60.3	40.6	60.9	52.6	68.1	51.2
28		11	55.8	37.8	62.8	44.7	64.0	54.7	69.8	51.7
29		12	61.2	38.5	65.6	47.0	65.1	55.6	73.5	52.8
30		13	61.6	39.2	65.8	47.3	66.5	57.9	73.7	54.9
31		14	61.9	40.3	68.4	48.4	70.9	58.4	76.0	58.9
32		15	63.5	43.1	73.2	50.1	70.9	62.1	80.9	60.0
33		16	67.0	48.4	78.8	52.1	71.1	65.1	81.1	60.5
34		17	69.8	48.9	79.9	57.0	94.5	65.3	82.5	60.7
35		18	70.4	49.8	89.5	58.6	95.2	66.7	87.8	61.9
36		19	73.2	50.1	89.2	58.6	98.3	68.4	88.1	61.9
37		20	76.2	54.7	102.7	64.9	103.8	102.2	94.1	61.9
38										
39	MEAN		54.6	37.9	63.3	42.4	63.3	54.3	67.9	52.2
40	ST. DEVIATION		14.5	9.1	19.0	12.6	20.9	15.7	15.1	8.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.266	0.241	0.300	0.296	0.329	0.289	0.222	0.157
42	MIN		19.0	20.2	39.2	21.3	38.5	26.2	44.5	29.4
43	MAX		76.2	54.7	102.7	64.9	103.8	102.2	94.1	61.9
44	RANGE		57.2	34.5	63.5	43.6	65.3	76.0	49.6	32.4
45										
46	AUXILIARY DATA:									
47	WEIBULL MODULUS		3.23	4.264	3.564	3.355	3.266	3.704	4.68	5.854
48	WEIBULL PLOT R SQUARED		0.964	0.987	0.95	0.991	0.946	0.95	0.983	0.942
49										
50	PARTICLE DENSITY (G/CC)		2.43	2.11	2.38	2.15	2.43	2.21	2.42	2.18
51	PARTICLE TOTAL POROSITY (VOL. %)		39.03	47.07	40.26	46.05	38.99	44.53	39.15	45.23
52										

B5-1

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-19	24127-19
3	EXPERIMENT NUMBER		# 1	# 1
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	38.4	44.5
19		2	63.2	73.2
20		3	44.2	51.2
21		4	53.2	61.6
22		5	60.8	70.4
23		6	34.4	39.9
24		7	57.8	67.0
25		8	31.4	36.4
26		9	52.8	61.2
27		10	31.6	36.6
28		11	39.8	46.1
29		12	60.2	69.8
30		13	45.8	53.1
31		14	48.2	55.8
32		15	65.8	76.2
33		16	53.4	61.9
34		17	46.6	54.0
35		18	43.6	50.5
36		19	16.4	19.0
37		20	54.8	63.5
38				
39	MEAN		47.1	54.6
40	ST. DEVIATION		12.6	14.5
41	COEFF. OF VARIATION =STDEV/MEAN		0.266	0.266
42	MIN		16.4	19.0
43	MAX		65.8	76.2
44	RANGE		49.4	57.2
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-24	24127-24
3	EXPERIMENT NUMBER		# 2	# 2
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	27.6	32.0
19		2	41.8	48.4
20		3	47.2	54.7
21		4	27.0	31.3
22		5	29.4	34.1
23		6	17.4	20.2
24		7	32.2	37.3
25		8	42.2	48.9
26		9	27.0	31.3
27		10	33.2	38.5
28		11	43.2	50.1
29		12	37.2	43.1
30		13	32.6	37.8
31		14	28.0	32.4
32		15	22.8	26.4
33		16	43.0	49.8
34		17	31.2	36.2
35		18	33.8	39.2
36		19	34.8	40.3
37		20	23.0	26.6
38				
39	MEAN		32.7	37.9
40	ST. DEVIATION		7.9	9.1
41	COEFF. OF VARIATION =STDEV/MEAN		0.241	0.241
42	MIN		17.4	20.2
43	MAX		47.2	54.7
44	RANGE		29.8	34.5
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-21	24127-21
3	EXPERIMENT NUMBER		#3	#3
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	37.0	42.9
19		2	40.0	46.3
20		3	41.0	47.5
21		4	56.6	65.6
22		5	33.8	39.2
23		6	54.2	62.8
24		7	48.0	55.6
25		8	69.0	79.9
26		9	63.2	73.2
27		10	38.6	44.7
28		11	85.6	99.2
29		12	59.0	68.4
30		13	56.8	65.8
31		14	88.6	102.7
32		15	44.6	51.7
33		16	68.0	78.8
34		17	77.2	89.5
35		18	52.0	60.3
36		19	39.8	46.1
37		20	39.4	45.7
38				
39	MEAN		54.6	63.3
40	ST. DEVIATION		16.4	19.0
41	COEFF. OF VARIATION =STDEV/MEAN		0.300	0.300
42	MIN		33.8	39.2
43	MAX		88.6	102.7
44	RANGE		54.8	63.5
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-22	24127-22
3	EXPERIMENT NUMBER		# 4	# 4
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	18.4	21.3
19		2	27.8	32.2
20		3	32.4	37.5
21		4	56.0	64.9
22		5	33.2	38.5
23		6	40.8	47.3
24		7	30.8	35.7
25		8	21.6	25.0
26		9	28.2	32.7
27		10	29.0	33.6
28		11	40.6	47.0
29		12	41.8	48.4
30		13	49.2	57.0
31		14	45.0	52.1
32		15	50.6	58.6
33		16	19.2	22.2
34		17	38.6	44.7
35		18	35.0	40.6
36		19	50.6	58.6
37		20	43.2	50.1
38				
39	MEAN		36.6	42.4
40	ST. DEVIATION		10.8	12.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.296	0.296
42	MIN		18.4	21.3
43	MAX		56.0	64.9
44	RANGE		37.6	43.6
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-20	24127-20
3	EXPERIMENT NUMBER		#5	#5
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	82.2	95.2
19		2	37.8	43.8
20		3	38.8	45.0
21		4	55.2	64.0
22		5	33.2	38.5
23		6	89.6	103.8
24		7	41.0	47.5
25		8	61.2	70.9
26		9	52.6	60.9
27		10	47.6	55.2
28		11	36.6	42.4
29		12	41.4	48.0
30		13	61.2	70.9
31		14	61.4	71.1
32		15	40.0	46.3
33		16	33.4	38.7
34		17	84.8	98.3
35		18	56.2	65.1
36		19	57.4	66.5
37		20	81.6	94.5
38				
39	MEAN		54.7	63.3
40	ST. DEVIATION		18.0	20.9
41	COEFF. OF VARIATION =STDEV/MEAN		0.329	0.329
42	MIN		33.2	38.5
43	MAX		89.6	103.8
44	RANGE		56.4	65.3
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-17	24127-17
3	EXPERIMENT NUMBER		#6	#6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	37.2	43.1
19		2	48.0	55.6
20		3	36.4	42.2
21		4	50.4	58.4
22		5	56.2	65.1
23		6	34.0	39.4
24		7	47.2	54.7
25		8	37.4	43.3
26		9	50.0	57.9
27		10	53.6	62.1
28		11	56.4	65.3
29		12	37.4	43.3
30		13	59.0	68.4
31		14	41.0	47.5
32		15	88.2	102.2
33		16	39.8	46.1
34		17	45.4	52.6
35		18	40.2	46.6
36		19	57.6	66.7
37		20	22.6	26.2
38				
39	MEAN		46.9	54.3
40	ST. DEVIATION		13.5	15.7
41	COEFF. OF VARIATION =STDEV/MEAN		0.289	0.289
42	MIN		22.6	26.2
43	MAX		88.2	102.2
44	RANGE		65.6	76.0
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-23	24127-23
3	EXPERIMENT NUMBER		# 7	# 7
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	63.6	73.7
19		2	54.0	62.6
20		3	69.8	80.9
21		4	65.6	76.0
22		5	52.6	60.9
23		6	76.0	88.1
24		7	40.0	46.3
25		8	49.8	57.7
26		9	81.2	94.1
27		10	38.4	44.5
28		11	45.2	52.4
29		12	58.8	68.1
30		13	75.8	87.8
31		14	63.4	73.5
32		15	49.6	57.5
33		16	60.2	69.8
34		17	71.2	82.5
35		18	44.8	51.9
36		19	42.4	49.1
37		20	70.0	81.1
38				
39	MEAN		58.6	67.9
40	ST. DEVIATION		13.0	15.1
41	COEFF. OF VARIATION =STDEV/MEAN		0.222	0.222
42	MIN		38.4	44.5
43	MAX		81.2	94.1
44	RANGE		42.8	49.6
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		91-07-11	91-07-11
2	SAMPLE IDENTIFICATION		24127-16	24127-16
3	EXPERIMENT NUMBER		# 8	# 8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	44.2	51.2
19		2	42.0	48.7
20		3	53.4	61.9
21		4	52.4	60.7
22		5	45.6	52.8
23		6	53.4	61.9
24		7	47.4	54.9
25		8	25.4	29.4
26		9	53.4	61.9
27		10	51.8	60.0
28		11	44.6	51.7
29		12	40.0	46.3
30		13	52.2	60.5
31		14	50.8	58.9
32		15	41.0	47.5
33		16	39.6	45.9
34		17	42.6	49.4
35		18	40.8	47.3
36		19	37.6	43.6
37		20	43.6	50.5
38				
39	MEAN		45.1	52.2
40	ST. DEVIATION		7.1	8.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.157	0.157
42	MIN		25.4	29.4
43	MAX		53.4	61.9
44	RANGE		28.0	32.4
45				

	A	B	C	D
1	DATE TESTED		92-01-23	92-01-23
2	SAMPLE IDENTIFICATION NUMBER		12748-A	12748-B
3	EXPERIMENT NUMBER		2	2
4	SAMPLE SHAPE		GRAN	GRAN
5	EXPT DESIGN CODE ID			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED
17		NO.		
18		1	50.3	51.0
19		2	45.9	48.2
20		3	40.3	62.8
21		4	38.8	45.2
22		5	31.1	57.2
23		6	55.4	43.8
24		7	47.7	46.1
25		8	55.4	95.9
26		9	38.0	39.2
27		10	45.7	53.8
28		11	35.2	32.4
29		12	40.1	72.1
30		13	40.8	64.4
31		14	50.3	41.7
32		15	46.8	39.9
33		16	27.8	54.2
34		17	54.7	42.9
35		18	91.3	44.5
36		19	43.8	51.7
37		20	53.8	36.8
38				
39	MEAN		46.7	51.2
40	ST. DEVIATION		13.3	14.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.286	0.282
42	MIN		27.8	32.4
43	MAX		91.3	95.9
44	RANGE		63.5	63.5
45				
46	AUXILIARY DATA:			
47	WEBULL MODULUS			
48	WEBULL PLOT R SQUARED			
49				
50	PARTICLE DENSITY (G/CC)			
51	PARTICLE TOTAL POROSITY (VOL. %)			
52				

B5-10

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-01-23	92-01-23
2	SAMPLE IDENTIFICATION		12748-A	12748-A
3	EXPERIMENT NUMBER (RUN NO.):		2	2
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	43.4	50.3
19		2	39.6	45.9
20		3	34.8	40.3
21		4	31.6	36.6
22		5	26.8	31.1
23		6	47.8	55.4
24		7	41.2	47.7
25		8	50.4	58.4
26		9	32.8	38.0
27		10	39.4	45.7
28		11	30.4	35.2
29		12	34.6	40.1
30		13	35.0	40.6
31		14	43.4	50.3
32		15	40.4	46.8
33		16	24.0	27.8
34		17	47.2	54.7
35		18	78.8	91.3
36		19	37.8	43.8
37		20	46.4	53.8
38				
39	MEAN		40.3	46.7
40	ST. DEVIATION		11.5	13.3
41	COEFF. OF VARIATION $\pm$ STDEV/MEAN		0.286	0.286
42	MIN		24.0	27.8
43	MAX		78.8	91.3
44	RANGE		54.8	63.5
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-01-23	92-01-23
2	SAMPLE IDENTIFICATION		12748-B	12748-B
3	EXPERIMENT NUMBER (RUN NO.)		2	2
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	44.0	51.0
19		2	41.6	48.2
20		3	54.0	62.6
21		4	39.0	45.2
22		5	49.4	57.2
23		6	37.8	43.8
24		7	39.8	46.1
25		8	82.8	95.9
26		9	33.8	39.2
27		10	46.4	53.8
28		11	28.0	32.4
29		12	62.2	72.1
30		13	55.6	64.4
31		14	36.0	41.7
32		15	34.4	39.9
33		16	46.8	54.2
34		17	37.0	42.9
35		18	38.4	44.5
36		19	44.6	51.7
37		20	31.8	36.8
38				
39	MEAN		44.2	51.2
40	ST. DEVIATION		12.5	14.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.282	0.282
42	MIN		28.0	32.4
43	MAX		82.8	95.9
44	RANGE		54.8	63.5
45				

SUMMARY OF FIRED STRENGTH DATA FROM RUN-3, ID _25530

	A	B	C	D	E	F
1	DATE TESTED		92-02-20	92-02-20	92-02-20	92-02-20
2	SAMPLE IDENTIFICATION NUMBER		25530-6-1	25530-6-4	25530-6-8	25530-6-12
3	EXPERIMENT NUMBER		3	3	3	3
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN
5	EXPT DESIGN CODE ID					
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283485	0.07283485	0.07283485	0.07283485
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3	3	3
11	CROSS-HEAD SPEED (mm/MN)		15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED
17		NO				
18		1	35.7	34.8	49.4	26.4
19		2	23.8	43.3	42.9	44.7
20		3	42.8	41.0	38.8	58.1
21		4	51.7	57.5	52.6	34.3
22		5	53.1	39.4	41.5	51.0
23		6	59.5	42.9	37.8	50.5
24		7	43.6	50.3	53.1	42.4
25		8	45.0	28.5	25.7	32.9
26		9	63.3	64.7	27.1	47.5
27		10	69.3	60.7	38.2	46.8
28		11	36.8	52.1	62.8	38.0
29		12	44.5	37.1	44.7	34.5
30		13	55.1	41.7	45.9	48.8
31		14	58.6	38.0	75.5	53.8
32		15	50.1	48.2	52.4	33.1
33		16	74.2	50.5	39.6	34.5
34		17	78.6	24.3	44.5	35.9
35		18	41.2	62.8	47.0	39.6
36		19	63.5	40.1	32.2	64.0
37		20	103.6	28.4	28.7	61.4
38						
39	MEAN		58.2	44.2	43.8	43.7
40	ST. DEVIATION		19.5	11.6	12.1	10.3
41	COEFF. OF VARIATION = STDEV/MEAN		0.346	0.263	0.276	0.235
42	MIN		23.8	24.3	25.7	26.4
43	MAX		103.6	64.7	75.5	64.0
44	RANGE		79.9	40.3	49.8	37.5
45						
46	AUXILIARY DATA:					
47	WEBULL MODULUS					
48	WEBULL PLOT R SQUARED					
49			2.47	2.32	2.23	2.18
50	PARTICLE DENSITY (G/CC)					
51	PARTICLE TOTAL POROSITY (VOL. %)					
52						

B5-13

Means with confid. interval
Means

Summary of Fit

Rsquare 0.135236
Root Mean Square Error 13.8512
Mean of Response 46.98875
Observations (or Sum Wgts) ...

80

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	2280.254	760.085	3.9617
Error	76	14581.046	191.856	Prob>F
C Total	79	16861.300		0.0111

Mean Estimates

Level number	Mean	Std Error
1	56.2300	3.0972
4	44.2150	3.0972
8	43.8000	3.0972
12	43.7100	3.0972

Means Comparisons**Dif=Mean[I]-Mean[J]**

	1	4	8	12
1	0.0000	12.0150	12.4300	12.5200
4	-12.0150	0.0000	0.4150	0.5050
8	-12.4300	-0.4150	0.0000	0.0900
12	-12.5200	-0.5050	-0.0900	0.0000

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q *

2.62680

Abs(Dif)-LSD

	1	4	8	12
1	-11.5057	0.5093	0.9243	1.0143
4	0.5093	-11.5057	-11.0907	-11.0007
8	0.9243	-11.0907	-11.5057	-11.4157
12	1.0143	-11.0007	-11.4157	-11.5057

Positive values show pairs of means that are significantly different.

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-02-20	92-02-20
2	SAMPLE IDENTIFICATION		25530-6-1	25530-6-1
3	EXPERIMENT NUMBER (RUN NO.:)		3	3
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	30.8	35.7
19		2	20.4	23.6
20		3	36.8	42.6
21		4	44.6	51.7
22		5	45.8	53.1
23		6	77.2	89.5
24		7	37.6	43.6
25		8	38.8	45.0
26		9	54.6	63.3
27		10	59.8	69.3
28		11	31.8	36.8
29		12	38.4	44.5
30		13	48.4	56.1
31		14	50.6	58.6
32		15	43.2	50.1
33		16	64.0	74.2
34		17	67.8	78.6
35		18	35.6	41.2
36		19	54.8	63.5
37		20	89.4	103.6
38				
39	MEAN		48.5	56.2
40	ST. DEVIATION		16.8	19.5
41	COEFF. OF VARIATION =STDEV/MEAN		0.346	0.346
42	MIN		20.4	23.6
43	MAX		89.4	103.6
44	RANGE		69.0	79.9
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-02-20	92-02-20
2	SAMPLE IDENTIFICATION		25530-6-4	25530-6-4
3	EXPERIMENT NUMBER (RUN NO.)		3	3
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	30.0	34.8
19		2	37.4	43.3
20		3	35.4	41.0
21		4	49.6	57.5
22		5	34.0	39.4
23		6	37.0	42.9
24		7	43.4	50.3
25		8	24.6	28.5
26		9	55.8	64.7
27		10	52.4	60.7
28		11	45.0	52.1
29		12	32.0	37.1
30		13	36.0	41.7
31		14	32.8	38.0
32		15	41.6	48.2
33		16	43.6	50.5
34		17	21.0	24.3
35		18	54.2	62.8
36		19	34.6	40.1
37		20	22.8	26.4
38				
39	MEAN		38.2	44.2
40	ST. DEVIATION		10.0	11.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.263	0.263
42	MIN		21.0	24.3
43	MAX		55.8	64.7
44	RANGE		34.8	40.3
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-02-20	92-02-20
2	SAMPLE IDENTIFICATION		25530-6-8	25530-6-8
3	EXPERIMENT NUMBER (RUN NO.:)		3	3
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	42.6	49.4
19		2	37.0	42.9
20		3	31.6	36.6
21		4	45.4	52.6
22		5	35.8	41.5
23		6	32.6	37.8
24		7	45.8	53.1
25		8	22.2	25.7
26		9	23.4	27.1
27		10	31.2	36.2
28		11	54.0	62.6
29		12	38.6	44.7
30		13	39.6	45.9
31		14	65.2	75.5
32		15	45.2	52.4
33		16	34.2	39.6
34		17	38.4	44.5
35		18	40.6	47.0
36		19	27.8	32.2
37		20	24.8	28.7
38				
39	MEAN		37.8	43.8
40	ST. DEVIATION		10.4	12.1
41	COEFF. OF VARIATION =STDEV/MEAN		0.276	0.276
42	MIN		22.2	25.7
43	MAX		65.2	75.5
44	RANGE		43.0	49.8
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-02-20	92-02-20
2	SAMPLE IDENTIFICATION		25530-6-12	25530-6-12
3	EXPERIMENT NUMBER (RUN NO.):		3	3
4	SAMPLE SHAPE		GRAIN	GRAIN
5	EXPT. DESIGN ID CODE			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		ND	ND
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	22.8	26.4
19		2	38.6	44.7
20		3	48.4	56.1
21		4	29.6	34.3
22		5	44.0	51.0
23		6	43.6	50.5
24		7	36.6	42.4
25		8	28.4	32.9
26		9	41.0	47.5
27		10	40.4	46.8
28		11	32.8	38.0
29		12	29.8	34.5
30		13	40.4	46.8
31		14	46.4	53.8
32		15	28.6	33.1
33		16	29.8	34.5
34		17	31.0	35.9
35		18	34.2	39.6
36		19	55.2	64.0
37		20	53.0	61.4
38				
39	MEAN		37.7	43.7
40	ST. DEVIATION		8.9	10.3
41	COEFF. OF VARIATION =STDEV/MEAN		0.235	0.235
42	MIN		22.8	26.4
43	MAX		55.2	64.0
44	RANGE		32.4	37.5
45				

	A	B	C	D	E
1	DATE TESTED		92-03-26	92-03-26	92-03-26
2	SAMPLE IDENTIFICATION NUMBER		25530-21-1	25530-22-1	25530-22-2
3	EXPERIMENT NUMBER		4	4	5
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN
5	BATCH NO.		1	3	
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED
17					
18			41.5	31.5	31.5
19			44.3	32.0	60.7
20			40.3	35.9	31.5
21			37.1	40.3	29.2
22			23.2	32.9	54.5
23			50.5	40.5	71.5
24			72.3	55.1	32.0
25			42.5	40.5	55.5
26			29.4	25.3	35.2
27			34.5	42.9	45.2
28			19.9	43.5	51.7
29			43.5	29.9	25.5
30			35.5	23.2	59.5
31			24.3	27.5	52.4
32			43.5	34.5	53.5
33			33.5	29.4	20.9
34			35.5	44.5	34.5
35			54.9	39.5	25.4
36			50.1	50.0	40.3
37			55.1	45.3	31.1
38					
39	MEAN		41.3	37.9	42.4
40	ST. DEVIATION		13.2	9.5	14.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.319	0.253	0.335
42	MIN		19.9	23.2	20.9
43	MAX		72.3	60.0	71.5
44	RANGE		52.4	36.8	51.0
45					
46	AUXILIARY DATA:				
47	WEBULL MODULUS				
48	WEBULL PLOT R SQUARED				
49			2.27	2.43	2.37
50	PARTICLE DENSITY (G/CC)				
51	PARTICLE TOTAL POROSITY (VOL. %)				
52					

BS-19

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-03-26	92-03-26
2	SAMPLE IDENTIFICATION		25530-21-1	25530-21-1
3	EXPERIMENT NUMBER (RUN NO.):		4	4
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1	1
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	35.8	41.5
19		2	38.2	44.3
20		3	34.8	40.3
21		4	32.0	37.1
22		5	20.0	23.2
23		6	43.6	50.5
24		7	62.4	72.3
25		8	36.8	42.6
26		9	25.4	29.4
27		10	30.0	34.8
28		11	17.2	19.9
29		12	37.8	43.8
30		13	31.6	36.6
31		14	21.0	24.3
32		15	37.8	43.8
33		16	29.2	33.8
34		17	31.6	36.6
35		18	56.0	64.9
36		19	43.2	50.1
37		20	48.4	56.1
38				
39	MEAN		35.6	41.3
40	ST. DEVIATION		11.4	13.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.319	0.319
42	MIN		17.2	19.9
43	MAX		62.4	72.3
44	RANGE		45.2	52.4
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-03-26	92-03-26
2	SAMPLE IDENTIFICATION		25530-22-1	25530-22-1
3	EXPERIMENT NUMBER (RUN NO.)		4	4
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		3.0	3.0
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	27.2	31.5
19		2	27.6	32.0
20		3	31.0	35.9
21		4	34.8	40.3
22		5	28.4	32.9
23		6	35.2	40.8
24		7	48.4	56.1
25		8	35.2	40.8
26		9	21.8	25.3
27		10	37.0	42.9
28		11	37.6	43.6
29		12	25.8	29.9
30		13	20.0	23.2
31		14	24.0	27.8
32		15	29.8	34.5
33		16	25.4	29.4
34		17	38.4	44.5
35		18	34.2	39.6
36		19	51.8	60.0
37		20	40.0	46.3
38				
39	MEAN		32.7	37.9
40	ST. DEVIATION		8.3	9.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.253	0.253
42	MIN		20.0	23.2
43	MAX		51.8	60.0
44	RANGE		31.8	36.8
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-03-26	92-03-26
2	SAMPLE IDENTIFICATION		25530-22-2	25530-22-2
3	EXPERIMENT NUMBER (RUN NO.:)		5	5
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	27.3	31.6
19		2	52.4	60.7
20		3	27.2	31.5
21		4	25.2	29.2
22		5	47.0	54.5
23		6	62.0	71.8
24		7	27.6	32.0
25		8	48.8	56.5
26		9	31.2	36.2
27		10	39.0	45.2
28		11	44.6	51.7
29		12	24.6	28.5
30		13	51.4	59.6
31		14	45.2	52.4
32		15	46.2	53.5
33		16	18.0	20.9
34		17	29.8	34.5
35		18	22.8	26.4
36		19	34.8	40.3
37		20	26.8	31.1
38				
39	MEAN		36.6	42.4
40	ST. DEVIATION		12.2	14.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.335	0.335
42	MIN		18.0	20.9
43	MAX		62.0	71.8
44	RANGE		44.0	51.0
45				

SUMMARY OF FIRED STRENGTH DATA FROM RUN-6, ID _25530-28/30/31/33

	A	B	C	D	E	F
1	DATE TESTED		92-04-16	92-04-16	92-04-16	92-04-16
2	SAMPLE IDENTIFICATION NUMBER		25530-28-1	25530-30-1	25530-31-1	25530-33-1
3	EXPERIMENT NUMBER		6	6	6	6
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN
5	BATCH NO.		1	5	7	12
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465	0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3	3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED
17						
18			39.4	43.6	74.6	32.7
19			34.3	28.7	33.1	30.8
20			40.1	30.1	50.1	51.4
21			29.7	42.2	42.6	35.9
22			42.6	37.6	77.9	38.2
23			35.6	34.6	62.6	55.6
24			65.8	41.0	32.9	45.9
25			26.7	64.0	63.3	37.5
26			41.0	35.9	29.7	29.2
27			43.6	30.6	41.5	40.3
28			37.3	46.6	46.0	32.9
29			61.0	31.3	66.1	37.5
30			33.4	33.4	35.0	49.6
31			49.8	43.6	62.6	45.2
32			40.8	56.3	76.6	31.1
33			31.3	51.4	36.6	57.0
34			36.4	40.8	35.9	62.6
35			64.9	47.0	40.3	45.0
36			36.0	40.3	65.6	30.1
37			65.3	50.3	62.6	72.8
38						
39	MEAN		42.4	41.5	62.1	43.1
40	ST. DEVIATION		11.4	9.3	16.5	12.1
41	COEFF. OF VARIATION = STDEV/MEAN		0.269	0.224	0.316	0.3
42	MIN		26.7	26.7	29.7	29.2
43	MAX		65.6	64.0	76.6	72.8
44	RANGE		37.1	35.2	46.9	43.6
45						
46	AUXILIARY DATA:					
47	WEBULL MODULUS					
48	WEBULL PLOT R SQUARED					
49						
50	PARTICLE DENSITY (G/CC)		2.41	2.43	2.46	2.45
51	PARTICLE TOTAL POROSITY (VOL. %)					
52						

B5-23

MPa By BATCH

RUN #6

Means with confid. interval

Means

Summary of Fit	
Requare	0.107937
Root Mean Square Error	12.58581
Mean of Response	44.775
Observations (or Sum Wgts)	80

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	1456.631	485.544	3.0653
Error	76	12038.599	158.403	Prob>F
C Total	79	13495.230		0.0330

Mean Estimates			
Level	number	Mean	Std Error
1	20	42.4450	2.8143
5	20	41.4800	2.8143
7	20	52.1000	2.8143
12	20	43.0750	2.8143

Means Comparisons

	7	12	1	5
Diff=Mean[i]-Mean[j]				
7	0.0000	9.0250	9.6550	10.6200
12	-9.0250	0.0000	0.6300	1.5950
1	-9.6550	-0.6300	0.0000	0.9650
5	-10.6200	-1.5950	-0.9650	0.0000

Alpha= 0.05
Comparisons for all pairs using Tukey-Kramer HSD

2.62680				
Abs(Diff)-LSD	7	12	1	5
7	-10.4546	-1.4296	-0.7896	0.1654
12	-1.4296	-10.4546	-9.8246	-8.8596
1	-0.7896	-9.8246	-10.4546	-9.4896
5	0.1654	-8.8596	-9.4896	-10.4546

Positive values show pairs of means that are significantly different.

BATCH	MPa
1	39.4
1	34.3
1	40.1
1	29.7
1	42.6
1	35.5
1	65.8
1	28.7
1	41.0
1	43.6
1	37.3
1	51.0
1	33.4
1	49.8
1	40.8
1	31.3
1	36.4
1	64.9
1	38.0
1	65.3
5	43.8
5	28.7
5	30.1
5	42.2
5	37.5
5	34.8
5	41.0
5	64.0
5	35.9
5	30.6
5	46.6
5	31.3
5	33.4
5	43.6
5	56.3
5	51.4
5	40.8
5	47.0
5	40.3
5	50.3
7	74.6
7	33.1
7	50.1
7	42.8
7	77.9
7	62.6
7	32.9
7	63.3
7	29.7
7	41.5
7	48.0
7	68.1
7	35.0
7	62.6
7	78.6
7	36.8
7	35.9
7	40.3
7	65.8
7	62.6
12	32.7
12	30.8
12	51.4
12	35.9
12	38.2
12	55.6
12	45.9
12	37.5
12	29.2
12	40.3
12	32.9
12	37.5
12	49.6
12	45.2
12	31.1
12	57.0
12	62.8
12	45.0
12	30.1
12	72.8

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-04-16	92-04-16
2	SAMPLE IDENTIFICATION		25530-28-1	25530-28-1
3	EXPERIMENT NUMBER (RUN NO.)		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1	1
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	34.0	39.4
19		2	29.6	34.3
20		3	34.6	40.1
21		4	25.6	29.7
22		5	36.8	42.6
23		6	30.6	35.5
24		7	56.8	65.8
25		8	24.8	28.7
26		9	35.4	41.0
27		10	37.6	43.6
28		11	32.2	37.3
29		12	44.0	51.0
30		13	28.8	33.4
31		14	43.0	49.8
32		15	35.2	40.8
33		16	27.0	31.3
34		17	31.4	36.4
35		18	56.0	64.9
36		19	32.8	38.0
37		20	56.4	65.3
38				
39	MEAN		36.6	42.4
40	ST. DEVIATION		9.9	11.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.269	0.269
42	MIN		24.8	28.7
43	MAX		56.8	65.8
44	RANGE		32.0	37.1
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-04-16	92-04-16
2	SAMPLE IDENTIFICATION		25530-30-1	25530-30-1
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		5	5
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	37.8	43.8
19		2	24.8	28.7
20		3	26.0	30.1
21		4	36.4	42.2
22		5	32.4	37.5
23		6	30.0	34.8
24		7	35.4	41.0
25		8	55.2	64.0
26		9	31.0	35.9
27		10	26.4	30.6
28		11	40.2	46.6
29		12	27.0	31.3
30		13	28.8	33.4
31		14	37.6	43.6
32		15	48.6	56.3
33		16	44.4	51.4
34		17	35.2	40.8
35		18	40.6	47.0
36		19	34.8	40.3
37		20	43.4	50.3
38				
39	MEAN		35.8	41.5
40	ST. DEVIATION		8.0	9.3
41	COEFF. OF VARIATION =STDEV/MEAN		0.224	0.224
42	MIN		24.8	28.7
43	MAX		55.2	64.0
44	RANGE		30.4	35.2
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-04-16	92-04-16
2	SAMPLE IDENTIFICATION		25530-31-1	25530-31-1
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		7	7
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	64.4	74.6
19		2	28.6	33.1
20		3	43.2	50.1
21		4	36.8	42.6
22		5	67.2	77.9
23		6	54.0	62.6
24		7	28.4	32.9
25		8	54.6	63.3
26		9	25.6	29.7
27		10	35.8	41.5
28		11	41.4	48.0
29		12	58.8	68.1
30		13	30.2	35.0
31		14	54.0	62.6
32		15	67.8	78.6
33		16	31.8	36.8
34		17	31.0	35.9
35		18	34.8	40.3
36		19	56.8	65.8
37		20	54.0	62.6
38				
39	MEAN		45.0	52.1
40	ST. DEVIATION		14.2	16.5
41	COEFF. OF VARIATION $\pm$ STDEV/MEAN		0.316	0.316
42	MIN		25.6	29.7
43	MAX		67.8	78.6
44	RANGE		42.2	48.9
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-04-16	92-04-16
2	SAMPLE IDENTIFICATION		25530-33-1	25530-33-1
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		12	12
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	28.2	32.7
19		2	26.6	30.8
20		3	44.4	51.4
21		4	31.0	35.9
22		5	33.0	38.2
23		6	48.0	55.6
24		7	39.6	45.9
25		8	32.4	37.5
26		9	25.2	29.2
27		10	34.8	40.3
28		11	28.4	32.9
29		12	32.4	37.5
30		13	42.8	49.6
31		14	39.0	45.2
32		15	26.8	31.1
33		16	49.2	57.0
34		17	54.2	62.8
35		18	38.8	45.0
36		19	26.0	30.1
37		20	62.8	72.8
38				
39	MEAN		37.2	43.1
40	ST. DEVIATION		10.4	12.1
41	COEFF. OF VARIATION $\pm$ STDEV/MEAN		0.280	0.280
42	MIN		25.2	29.2
43	MAX		62.8	72.8
44	RANGE		37.6	43.6
45				

	A	B	C	D	E	F	G	H	I	J
1	DATE TESTED		92-04-16	92-04-16	92-04-16	92-04-16		92-07-10	92-08-31	92-08-31
2	SAMPLE IDENTIFICATION NUMBER		25530-28-1	25530-30-1	25530-31-1	25530-33-1				
3	EXPERIMENT NUMBER		6	6	6	6		6	6	6
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN		GRAIN	GRAIN	GRAIN
5	BATCH NO.		1	5	7	12		HW-F1	HW-F2	HW-F3
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10		-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85		1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465	0.07283465	0.07283465		0.07283465	0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON		CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3	3	3		3	3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2		15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO		NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL		DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA		MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED		CONVERTED	CONVERTED	CONVERTED
17		NO.								
18		1	39.4	43.8	74.6	32.7		44.5	51.4	41.9
19		2	34.3	26.7	33.1	30.8		49.8	31.5	58.1
20		3	40.1	30.1	50.1	51.4		42.6	38.2	38.0
21		4	29.7	42.2	42.6	35.9		45.7	36.8	63.3
22		5	42.6	37.5	77.9	38.2		61.9	44.5	38.0
23		6	35.5	34.8	62.6	55.6		52.4	60.9	62.8
24		7	65.8	41.0	32.9	45.9		37.1	39.2	61.2
25		8	28.7	64.0	63.3	37.5		60.9	47.7	86.2
26		9	41.0	35.9	29.7	29.2		53.8	49.8	54.5
27		10	43.6	30.6	41.5	40.3		85.7	45.4	58.4
28		11	37.3	48.8	48.0	32.9		75.1	35.2	66.0
29		12	51.0	31.3	66.1	37.5		51.2	36.4	45.0
30		13	33.4	33.4	35.0	49.6		36.6	56.8	48.4
31		14	49.8	43.6	62.6	45.2		59.3	35.0	44.3
32		15	40.8	56.3	78.6	31.1		65.6	41.0	46.3
33		16	31.3	51.4	38.8	57.0		79.9	57.2	65.8
34		17	38.4	40.8	35.9	62.8		70.7	39.2	67.9
35		18	64.9	47.0	40.3	45.0		48.4	46.6	95.9
36		19	38.0	40.3	65.8	30.1		72.8	40.1	47.7
37		20	65.3	50.3	62.6	72.8		71.6	35.0	43.6
38										
39	MEAN		42.4	41.5	52.1	43.1		58.3	43.4	58.6
40	ST. DEVIATION		11.4	9.3	16.5	12.1		14.4	8.4	15.3
41	COEFF. OF VARIATION =STDEV/MEAN		0.269	0.224	0.316	0.280		0.248	0.193	0.271
42	MIN		28.7	26.7	29.7	29.2		36.6	31.5	38.0
43	MAX		65.8	64.0	78.6	72.8		85.7	60.9	95.9
44	RANGE		37.1	35.2	48.9	43.6		49.1	29.4	57.9
45										
46	AUXILIARY DATA:									
47	WEBULL MODULUS									
48	WEBULL PLOT R SQUARED									
49										
50	PARTICLE DENSITY (G/CC)		2.41	2.43	2.48	2.45		2.48	2.38	2.44
51	PARTICLE TOTAL POROSITY (VOL. %)									
52										

B5-30

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-10	92-07-10
2	SAMPLE IDENTIFICATION			
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		HW-F1	HW-F1
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	38.4	44.5
19		2	42.8	49.6
20		3	36.8	42.6
21		4	39.4	45.7
22		5	53.4	61.9
23		6	45.2	52.4
24		7	32.0	37.1
25		8	52.6	60.9
26		9	46.4	53.8
27		10	74.0	85.7
28		11	64.8	75.1
29		12	44.2	51.2
30		13	31.6	36.6
31		14	51.2	59.3
32		15	56.8	65.8
33		16	69.0	79.9
34		17	61.0	70.7
35		18	41.8	48.4
36		19	62.8	72.8
37		20	61.8	71.6
38				
39	MEAN		50.3	58.3
40	ST. DEVIATION		12.4	14.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.246	0.246
42	MIN		31.6	36.6
43	MAX		74.0	85.7
44	RANGE		42.4	49.1
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-08-31	92-08-31
2	SAMPLE IDENTIFICATION			
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		HW-F2	HW-F2
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	44.4	51.4
19		2	27.2	31.5
20		3	33.0	38.2
21		4	31.8	36.8
22		5	38.4	44.5
23		6	52.6	60.9
24		7	33.8	39.2
25		8	41.2	47.7
26		9	42.8	49.6
27		10	39.2	45.4
28		11	30.4	35.2
29		12	31.4	36.4
30		13	49.0	56.8
31		14	30.2	35.0
32		15	35.4	41.0
33		16	49.4	57.2
34		17	33.8	39.2
35		18	40.2	46.6
36		19	34.6	40.1
37		20	30.2	35.0
38				
39	MEAN		37.5	43.4
40	ST. DEVIATION		7.2	8.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.193	0.193
42	MIN		27.2	31.5
43	MAX		52.6	60.9
44	RANGE		25.4	29.4
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-08-31	92-08-31
2	SAMPLE IDENTIFICATION			
3	EXPERIMENT NUMBER (RUN NO.):		6	6
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		HW-F3	HW-F3
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	36.2	41.9
19		2	48.4	56.1
20		3	32.8	38.0
21		4	54.6	63.3
22		5	32.8	38.0
23		6	54.2	62.8
24		7	52.8	61.2
25		8	74.4	86.2
26		9	47.0	54.5
27		10	50.4	58.4
28		11	57.0	66.0
29		12	38.8	45.0
30		13	41.8	48.4
31		14	38.2	44.3
32		15	40.0	46.3
33		16	56.8	65.8
34		17	58.6	67.9
35		18	82.8	95.9
36		19	41.2	47.7
37		20	37.6	43.6
38				
39	MEAN		48.8	56.6
40	ST. DEVIATION		13.2	15.3
41	COEFF. OF VARIATION =STDEV/MEAN		0.271	0.271
42	MIN		32.8	38.0
43	MAX		82.8	95.9
44	RANGE		50.0	57.9
45				

	A	B	C	D
1	DATE TESTED		92-05-07	92-05-07
2	SAMPLE IDENTIFICATION NUMBER		25530-39	25530-41
3	EXPERIMENT NUMBER		7	7
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1	2
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.07283465	0.07283465
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3	3
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED
17		NO.		
18		1	43.6	44.3
19		2	28.5	42.2
20		3	39.2	66.7
21		4	38.7	41.5
22		5	35.7	45.4
23		6	37.8	28.5
24		7	28.7	49.6
25		8	37.1	36.8
26		9	47.7	35.0
27		10	41.2	65.1
28		11	35.2	62.1
29		12	44.0	42.4
30		13	31.7	47.6
31		14	60.9	44.3
32		15	38.0	37.3
33		16	30.1	31.7
34		17	42.6	41.2
35		18	35.2	44.7
36		19	57.5	48.0
37		20	30.4	53.6
38				
39	MEAN		39.2	45.4
40	ST. DEVIATION		8.7	10.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.221	0.226
42	MIN		28.5	28.5
43	MAX		60.9	66.7
44	RANGE		32.4	38.2
45				
46	AUXILIARY DATA:			
47	WEBULL MODULUS			
48	WEBULL PLOT R SQUARED			
49				
50	PARTICLE DENSITY (G/CC)		2.39	2.38
51	PARTICLE TOTAL POROSITY (VOL. %)			
52				

B5-34

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-05-07	92-05-07
2	SAMPLE IDENTIFICATION		25530-39	25530-39
3	EXPERIMENT NUMBER (RUN NO.):		7	7
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1	1
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	37.6	43.6
19		2	24.6	28.5
20		3	33.8	39.2
21		4	33.4	38.7
22		5	30.8	35.7
23		6	32.6	37.8
24		7	24.8	28.7
25		8	32.0	37.1
26		9	41.2	47.7
27		10	35.6	41.2
28		11	30.4	35.2
29		12	38.0	44.0
30		13	27.4	31.7
31		14	52.6	60.9
32		15	32.8	38.0
33		16	26.0	30.1
34		17	36.8	42.6
35		18	30.4	35.2
36		19	49.6	57.5
37		20	26.2	30.4
38				
39	MEAN		33.8	39.2
40	ST. DEVIATION		7.5	8.7
41	COEFF. OF VARIATION =STDEV/MEAN		0.221	0.221
42	MIN		24.6	28.5
43	MAX		52.6	60.9
44	RANGE		28.0	32.4
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-05-07	92-05-07
2	SAMPLE IDENTIFICATION		25530-41	25530-41
3	EXPERIMENT NUMBER (RUN NO.:)		7	7
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		2	2
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	38.2	44.3
19		2	36.4	42.2
20		3	57.6	66.7
21		4	35.8	41.5
22		5	39.2	45.4
23		6	24.6	28.5
24		7	42.8	49.6
25		8	31.8	36.8
26		9	30.2	35.0
27		10	56.2	65.1
28		11	53.6	62.1
29		12	36.6	42.4
30		13	41.1	47.6
31		14	38.2	44.3
32		15	32.2	37.3
33		16	27.4	31.7
34		17	35.6	41.2
35		18	38.6	44.7
36		19	41.4	48.0
37		20	46.4	53.8
38				
39	MEAN		39.2	45.4
40	ST. DEVIATION		8.8	10.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.226	0.226
42	MIN		24.6	28.5
43	MAX		57.6	66.7
44	RANGE		33.0	38.2
45				

SUMMARY OF FIRED STRENGTH DATA FROM RUN-8, ID _25530-48/48/49/50

	A	B	C	D	E	F
1	DATE TESTED		92-07-02	92-07-02	92-07-02	92-07-02
2	SAMPLE IDENTIFICATION NUMBER		25530-48	25530-48	25530-49	25530-50
3	EXPERIMENT NUMBER		8	8	8	8
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN
5	BATCH NO.		1	5	7	12
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073	0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0	3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED
17		NO				
18		1	38.0	53.5	39.6	47.5
19		2	32.4	34.5	28.0	34.1
20		3	37.5	25.5	45.2	33.8
21		4	34.5	35.7	42.4	31.1
22		5	30.8	51.4	48.4	60.3
23		6	60.3	51.4	51.7	32.9
24		7	51.9	45.0	37.3	67.9
25		8	46.6	29.9	39.9	49.6
26		9	45.2	39.4	41.5	37.1
27		10	67.4	32.4	49.1	34.3
28		11	46.8	34.3	40.1	29.4
29		12	54.0	43.8	51.4	44.5
30		13	48.0	27.8	28.7	42.4
31		14	59.8	56.1	44.0	45.0
32		15	49.8	58.4	60.7	33.6
33		16	33.8	35.7	38.9	75.8
34		17	50.8	32.2	70.4	39.6
35		18	57.7	50.8	49.6	38.9
36		19	52.8	34.3	33.6	48.0
37		20	40.8	43.8	30.6	45.2
38						
39	MEAN		46.9	40.8	43.6	43.5
40	ST. DEVIATION		10.3	10.0	10.4	12.4
41	COEFF. OF VARIATION = STDEV/MEAN		0.219	0.246	0.240	0.284
42	MIN		30.8	25.5	28.0	29.4
43	MAX		67.4	58.4	70.4	75.8
44	RANGE		36.6	32.9	42.4	46.3
45						
46	AUXILIARY DATA:					
47	WEBULL MODULUS					
48	WEBULL PLOT R SQUARED					
49						
50	PARTICLE DENSITY (G/CC)		2.41	2.42	2.45	2.44
51	PARTICLE TOTAL POROSITY (VOL. %)					
52						

B5-37

Means with confid. interval

Means

Summary of Fit

Rsquare 0.040907
Root Mean Square Error 10.83156
Mean of Response 43.70875
Observations (or Sum Wgts)

80

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Model	3	380.3074	126.769	1.0805	
Error	76	8916.5165	117.323		
C Total	79	9296.8239			0.3625

Mean Estimates

Level number	Mean	Std Error
1	46.9450	2.4220
5	40.7950	2.4220
7	43.5550	2.4220
12	43.5400	2.4220

Means Comparisons

Dif=Mean[i]-Mean[j]

	1	7	12	5
1	0.00000	3.39000	3.40500	6.15000
7	-3.39000	0.00000	0.01500	2.76000
12	-3.40500	-0.01500	0.00000	2.74500
5	-6.15000	-2.76000	-2.74500	0.00000

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q *

2.62680

Abs(Dif)-LSD

	1	7	12	5
1	-8.99741	-5.60741	-5.59241	-2.84741
7	-5.60741	-8.99741	-8.98241	-6.23741
12	-5.59241	-8.98241	-8.99741	-6.25241
5	-2.84741	-6.23741	-6.25241	-8.99741

Positive values show pairs of means that are significantly different.

BATCH	MPa
1	38.0
1	32.4
1	37.5
1	34.5
1	30.8
1	60.3
1	51.9
1	46.6
1	45.2
1	67.4
1	46.8
1	64.0
1	48.0
1	59.8
1	49.8
1	33.8
1	50.8
1	57.7
1	52.8
1	40.8
5	53.5
5	34.5
5	25.5
5	35.7
5	51.4
5	51.4
5	45.0
5	29.9
5	39.4
5	32.4
5	34.3
5	43.8
5	27.8
5	56.1
5	58.4
5	35.7
5	32.2
5	50.8
5	34.3
5	43.8
7	39.6
7	28.0
7	45.2
7	42.4
7	48.4
7	51.7
7	37.3
7	39.9
7	41.5
7	49.1
7	40.1
7	51.4
7	28.7
7	44.0
7	60.7
7	38.9
7	70.4
7	49.6
7	33.6
7	30.6
12	47.5
12	34.1
12	33.6
12	31.1
12	60.3
12	32.9
12	67.9
12	49.6
12	37.1
12	34.3
12	29.4
12	44.5
12	42.4
12	45.0
12	33.6
12	75.8
12	39.6
12	38.9
12	48.0
12	45.2

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25530-46	25530-46
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1	1
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	32.8	38.0
19		2	28.0	32.4
20		3	32.4	37.5
21		4	29.8	34.5
22		5	26.6	30.8
23		6	52.0	60.3
24		7	44.8	51.9
25		8	40.2	46.6
26		9	39.0	45.2
27		10	58.2	67.4
28		11	40.4	46.8
29		12	46.6	54.0
30		13	41.4	48.0
31		14	51.6	59.8
32		15	43.0	49.8
33		16	29.2	33.8
34		17	43.8	50.8
35		18	49.8	57.7
36		19	45.6	52.8
37		20	35.2	40.8
38				
39	MEAN		40.5	46.9
40	ST. DEVIATION		8.9	10.3
41	COEFF. OF VARIATION =STDEV/MEAN		0.219	0.219
42	MIN		26.6	30.8
43	MAX		58.2	67.4
44	RANGE		31.6	36.6
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25530-48	25530-48
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		5	5
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	46.2	53.5
19		2	29.8	34.5
20		3	22.0	25.5
21		4	30.8	35.7
22		5	44.4	51.4
23		6	44.4	51.4
24		7	38.8	45.0
25		8	25.8	29.9
26		9	34.0	39.4
27		10	28.0	32.4
28		11	29.6	34.3
29		12	37.8	43.8
30		13	24.0	27.8
31		14	48.4	56.1
32		15	50.4	58.4
33		16	30.8	35.7
34		17	27.8	32.2
35		18	43.8	50.8
36		19	29.6	34.3
37		20	37.8	43.8
38				
39	MEAN		35.2	40.8
40	ST. DEVIATION		8.7	10.0
41	COEFF. OF VARIATION =STDEV/MEAN		0.246	0.246
42	MIN		22.0	25.5
43	MAX		50.4	58.4
44	RANGE		28.4	32.9
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25530-49	25530-49
3	EXPERIMENT NUMBER (RUN NO.)		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		7	7
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	34.2	39.6
19		2	24.2	28.0
20		3	39.0	45.2
21		4	36.6	42.4
22		5	41.8	48.4
23		6	44.6	51.7
24		7	32.2	37.3
25		8	34.4	39.9
26		9	35.8	41.5
27		10	42.4	49.1
28		11	34.6	40.1
29		12	44.4	51.4
30		13	24.8	28.7
31		14	38.0	44.0
32		15	52.4	60.7
33		16	33.6	38.9
34		17	60.8	70.4
35		18	42.8	49.6
36		19	29.0	33.6
37		20	26.4	30.6
38				
39	MEAN		37.6	43.6
40	ST. DEVIATION		9.0	10.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.240	0.240
42	MIN		24.2	28.0
43	MAX		60.8	70.4
44	RANGE		36.6	42.4
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25530-50	25530-50
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		12	12
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	41.0	47.5
19		2	29.4	34.1
20		3	29.0	33.6
21		4	26.8	31.1
22		5	52.0	60.3
23		6	28.4	32.9
24		7	58.6	67.9
25		8	42.8	49.6
26		9	32.0	37.1
27		10	29.6	34.3
28		11	25.4	29.4
29		12	38.4	44.5
30		13	36.6	42.4
31		14	38.8	45.0
32		15	29.0	33.6
33		16	65.4	75.8
34		17	34.2	39.6
35		18	33.6	38.9
36		19	41.4	48.0
37		20	39.0	45.2
38				
39	MEAN		37.6	43.5
40	ST. DEVIATION		10.7	12.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.284	0.284
42	MIN		25.4	29.4
43	MAX		65.4	75.8
44	RANGE		40.0	46.3
45				

	A	B	C	D	E	F	G	H	I	J	K
1	DATE TESTED		92-07-02	92-07-02	92-07-02	92-07-02		92-09-08	92-09-08	92-09-08	92-09-08
2	SAMPLE IDENTIFICATION NUMBER		25530-48	25530-48	25530-49	25530-50		HW#4	HW#5	HW#6	HW#4
3	EXPERIMENT NUMBER		8	8	8	8		8	8	8	8
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN		GRAIN	GRAIN	GRAIN	GRAIN
5	BATCH NO.		1	5	7	12		9,10,11,12	5,6,7,8	1,2,3,4	9,10,11,12
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10		-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85		1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073	0.073	0.073		0.073	0.073	0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON		CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0	3.0	3.0		3.0	3.0	3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2		15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO		NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA		MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED		CONVERTED	CONVERTED	CONVERTED	CONVERTED
17		NO									* UNDERFIRED
18		1	38.0	53.5	39.8	47.5		35.9	35.9	30.8	19.2
19		2	32.4	34.5	28.0	34.1		33.1	39.9	32.2	13.0
20		3	37.5	25.5	45.2	33.6		41.0	32.9	35.5	19.2
21		4	34.5	35.7	42.4	31.1		35.9	39.6	35.7	24.6
22		5	30.8	51.4	48.4	60.3		46.1	36.9	36.8	19.7
23		6	60.3	51.4	51.7	32.9		26.4	36.4	54.5	17.1
24		7	51.9	45.0	37.3	67.9		28.7	27.8	40.3	18.3
25		8	48.6	29.9	39.9	49.6		29.9	36.8	38.2	22.7
26		9	45.2	39.4	41.5	37.1		38.0	41.9	38.5	18.1
27		10	67.4	32.4	49.1	34.3		30.1	57.0	32.9	7.9
28		11	48.6	34.3	40.1	29.4		43.6	54.9	40.3	31.7
29		12	54.0	43.8	51.4	44.5		31.5	41.9	49.8	19.0
30		13	48.0	27.8	28.7	42.4		51.4	31.5	34.8	20.4
31		14	59.9	55.1	44.0	45.0		36.4	67.9	49.1	17.8
32		15	49.6	58.4	60.7	39.6		44.0	42.8	45.9	24.6
33		16	33.9	35.7	38.9	75.8		45.2	45.7	32.4	25.3
34		17	50.8	32.2	70.4	39.6		49.1	51.7	34.3	19.9
35		18	57.7	50.8	49.6	38.9		39.4	30.4	49.6	15.1
36		19	52.8	34.3	33.6	46.0		31.7	37.8	47.5	21.6
37		20	40.8	43.8	30.8	45.2		37.5	40.1	60.9	18.1
38											
39	MEAN		48.9	40.8	43.6	43.5		37.8	41.6	41.1	19.7
40	ST. DEVIATION		10.3	10.0	10.4	12.4		7.1	9.8	8.4	4.9
41	COEFF. OF VARIATION $\pm$ STDEV/MEAN		0.210	0.246	0.240	0.284		0.189	0.236	0.204	0.250
42	MIN		30.8	25.5	28.0	29.4		26.4	27.8	30.8	7.9
43	MAX		67.4	58.4	70.4	75.8		51.4	67.9	60.9	31.7
44	RANGE		36.6	32.9	42.4	46.3		25.0	40.1	30.4	23.9
45											
46	AUXILIARY DATA:										
47	WEBULL MODULUS										
48	WEBULL PLOT R SQUARED										
49											
50	PARTICLE DENSITY (G/CC)		2.41	2.42	2.45	2.44		2.44	2.44	2.43	1.97
51	PARTICLE TOTAL POROSITY (VOL. %)										
52											
53	* strength samples were crushed from the sample used for density										
54											

B5-44

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		HW#4	HW#4
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		9,10,11,12	9,10,11,12
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	31.0	35.9
19		2	28.6	33.1
20		3	35.4	41.0
21		4	31.0	35.9
22		5	39.8	46.1
23		6	22.8	26.4
24		7	24.8	28.7
25		8	25.8	29.9
26		9	32.8	38.0
27		10	26.0	30.1
28		11	37.6	43.6
29		12	27.2	31.5
30		13	44.4	51.4
31		14	31.4	36.4
32		15	38.0	44.0
33		16	39.0	45.2
34		17	42.4	49.1
35		18	34.0	39.4
36		19	27.4	31.7
37		20	32.4	37.5
38				
39	MEAN		32.6	37.8
40	ST. DEVIATION		6.1	7.1
41	COEFF. OF VARIATION =STDEV/MEAN		0.189	0.189
42	MIN		22.8	26.4
43	MAX		44.4	51.4
44	RANGE		21.6	25.0
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		HW#4	HW#4
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		9,10,11,12	9,10,11,12
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	16.6	19.2
19		2	11.2	13.0
20		3	16.6	19.2
21		4	21.2	24.6
22		5	17.0	19.7
23		6	14.8	17.1
24		7	15.8	18.3
25		8	19.6	22.7
26		9	15.6	18.1
27		10	6.8	7.9
28		11	27.4	31.7
29		12	16.4	19.0
30		13	17.6	20.4
31		14	15.4	17.8
32		15	21.2	24.6
33		16	21.8	25.3
34		17	17.2	19.9
35		18	13.0	15.1
36		19	18.6	21.6
37		20	15.6	18.1
38				
39	MEAN		17.0	19.7
40	ST. DEVIATION		4.3	4.9
41	COEFF. OF VARIATION =STDEV/MEAN		0.250	0.250
42	MIN		6.8	7.9
43	MAX		27.4	31.7
44	RANGE		20.6	23.9
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		HW#5	HW#5
3	EXPERIMENT NUMBER (RUN NO.:)		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		5,6,7,8	5,6,7,8
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	31.0	35.9
19		2	34.4	39.9
20		3	28.4	32.9
21		4	34.2	39.6
22		5	33.6	38.9
23		6	31.4	36.4
24		7	24.0	27.8
25		8	31.8	36.8
26		9	36.2	41.9
27		10	49.2	57.0
28		11	47.4	54.9
29		12	36.2	41.9
30		13	27.2	31.5
31		14	58.6	67.9
32		15	36.8	42.6
33		16	39.4	45.7
34		17	44.6	51.7
35		18	26.2	30.4
36		19	32.6	37.8
37		20	34.6	40.1
38				
39	MEAN		35.9	41.6
40	ST. DEVIATION		8.5	9.8
41	COEFF. OF VARIATION =STDEV/MEAN		0.236	0.236
42	MIN		24.0	27.8
43	MAX		58.6	67.9
44	RANGE		34.6	40.1
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		HW#6	HW#6
3	EXPERIMENT NUMBER (RUN NO.):		8	8
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.		1,2,3,4	1,2,3,4
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	26.4	30.6
19		2	27.8	32.2
20		3	33.2	38.5
21		4	30.8	35.7
22		5	31.8	36.8
23		6	47.0	54.5
24		7	34.8	40.3
25		8	33.0	38.2
26		9	33.2	38.5
27		10	28.4	32.9
28		11	34.8	40.3
29		12	43.0	49.8
30		13	30.0	34.8
31		14	42.4	49.1
32		15	39.6	45.9
33		16	28.0	32.4
34		17	29.6	34.3
35		18	42.8	49.6
36		19	41.0	47.5
37		20	52.6	60.9
38				
39	MEAN		35.5	41.1
40	ST. DEVIATION		7.2	8.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.204	0.204
42	MIN		26.4	30.6
43	MAX		52.6	60.9
44	RANGE		26.2	30.4
45				

SUMMARY OF FIRED STRENGTH DATA FROM RUNS 9/10/11/12/13/14-25830

	A	B	C	D	E	F	G	H
1	DATE TESTED		92-07-02	92-07-02	92-07-02	92-07-02	92-07-02	92-07-02
2	SAMPLE IDENTIFICATION NUMBER		25855-1	25855-2	25855-7	25855-8	25855-9	25855-10
3	EXPERIMENT NUMBER		9	10	11	12	13	14
4	SAMPLE SHAPE		GRAIN	GRAIN	GRAIN	GRAIN	GRAIN	GRAIN
5	BATCH NO.							
6	SAMPLE SIZE (MESH)		-8+10	-8+10	-8+10	-8+10	-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85	1.85	1.85	1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073	0.073	0.073	0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0	3.0	3.0	3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2	15.2	15.2	15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO	NO	NO	NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL	DIAMETRAL
14	DATA:		FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS	FRAC. STRESS
15	UNITS:		MPA	MPA	MPA	MPA	MPA	MPA
16	DATA TYPE:		CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED	CONVERTED
17		NO						
18		1	68.1	63.8	38.0	20.9	70.9	33.8
19		2	92.0	86.0	36.2	64.2	72.5	24.8
20		3	33.6	50.5	41.5	22.5	77.9	42.6
21		4	36.6	73.2	23.9	38.9	42.2	32.4
22		5	61.4	115.9	34.3	25.0	77.9	34.8
23		6	84.6	49.4	19.9	25.5	70.4	32.0
24		7	92.5	62.6	32.9	32.7	41.0	55.6
25		8	69.6	69.1	22.2	23.2	67.7	42.9
26		9	61.7	69.6	46.6	60.8	76.0	51.9
27		10	44.0	109.6	45.7	38.9	57.0	58.9
28		11	63.8	62.1	29.2	34.8	35.5	46.7
29		12	63.8	55.4	26.0	20.6	36.4	44.7
30		13	39.9	63.5	36.4	27.6	72.3	23.9
31		14	31.5	80.4	23.4	39.2	61.9	46.4
32		15	33.6	77.4	23.6	36.6	87.6	34.1
33		16	40.6	68.8	31.7	40.3	59.3	61.2
34		17	66.8	61.3	35.5	31.5	64.2	63.5
35		18	45.2	100.6	41.2	55.8	64.1	54.7
36		19	66.4	72.5	24.3	26.6	57.0	55.8
37		20	66.2	111.2	44.7	29.9	61.4	36.4
38								
39	MEAN		55.3	74.2	32.8	33.8	63.2	43.0
40	ST. DEVIATION		18.6	21.2	8.9	10.7	15.4	10.9
41	COEFF. OF VARIATION = STDEV/MEAN		0.336	0.286	0.258	0.318	0.244	0.253
42	MIN		31.5	49.4	19.9	20.6	35.5	23.9
43	MAX		92.5	115.9	46.6	55.8	87.6	58.9
44	RANGE		60.9	66.5	26.6	35.2	52.1	35.0
45								
46	AUXILIARY DATA:							
47	WEBULL MODULUS							
48	WEBULL PLOT R SQUARED							
49								
50	PARTICLE DENSITY (G/CC)		2.43	2.75	2.08	2.14	2.69	2.44
51	PARTICLE TOTAL POROSITY (VOL. %)							
52								

BS-49

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-1	25655-1
3	EXPERIMENT NUMBER (RUN NO.:)		9	9
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	58.8	68.1
19		2	79.4	92.0
20		3	29.0	33.6
21		4	31.6	36.6
22		5	53.0	61.4
23		6	73.2	84.8
24		7	79.8	92.5
25		8	51.4	59.6
26		9	44.6	51.7
27		10	38.0	44.0
28		11	46.4	53.8
29		12	46.4	53.8
30		13	34.4	39.9
31		14	27.2	31.5
32		15	29.2	33.8
33		16	35.0	40.6
34		17	49.0	56.8
35		18	39.0	45.2
36		19	59.0	68.4
37		20	50.2	58.2
38				
39	MEAN		47.7	55.3
40	ST. DEVIATION		16.0	18.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.336	0.336
42	MIN		27.2	31.5
43	MAX		79.8	92.5
44	RANGE		52.6	60.9
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-2	25655-2
3	EXPERIMENT NUMBER (RUN NO.)		10	10
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	46.4	53.8
19		2	74.2	86.0
20		3	43.6	50.5
21		4	63.2	73.2
22		5	100.0	115.9
23		6	42.6	49.4
24		7	54.0	62.6
25		8	59.6	69.1
26		9	51.4	59.6
27		10	94.6	109.6
28		11	45.0	52.1
29		12	47.8	55.4
30		13	46.2	53.5
31		14	69.4	80.4
32		15	66.8	77.4
33		16	60.2	69.8
34		17	70.2	81.3
35		18	86.8	100.6
36		19	62.6	72.5
37		20	96.0	111.2
38				
39	MEAN		64.0	74.2
40	ST. DEVIATION		18.3	21.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.286	0.286
42	MIN		42.6	49.4
43	MAX		100.0	115.9
44	RANGE		57.4	66.5
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-7	25655-7
3	EXPERIMENT NUMBER (RUN NO.):		11	11
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		ND	ND
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	32.8	38.0
19		2	31.2	36.2
20		3	35.8	41.5
21		4	20.6	23.9
22		5	29.6	34.3
23		6	17.2	19.9
24		7	28.4	32.9
25		8	19.2	22.2
26		9	40.2	46.6
27		10	39.4	45.7
28		11	25.2	29.2
29		12	22.4	26.0
30		13	31.4	36.4
31		14	20.2	23.4
32		15	20.4	23.6
33		16	27.4	31.7
34		17	30.6	35.5
35		18	35.6	41.2
36		19	21.0	24.3
37		20	38.6	44.7
38				
39	MEAN		28.4	32.9
40	ST. DEVIATION		7.3	8.5
41	COEFF. OF VARIATION =STDEV/MEAN		0.258	0.258
42	MIN		17.2	19.9
43	MAX		40.2	46.6
44	RANGE		23.0	26.6
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-8	25655-8
3	EXPERIMENT NUMBER (RUN NO.):		12	12
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	18.0	20.9
19		2	46.8	54.2
20		3	19.4	22.5
21		4	33.6	38.9
22		5	21.6	25.0
23		6	22.0	25.5
24		7	28.2	32.7
25		8	20.0	23.2
26		9	43.8	50.8
27		10	33.6	38.9
28		11	30.0	34.8
29		12	17.8	20.6
30		13	23.8	27.6
31		14	33.8	39.2
32		15	31.6	36.6
33		16	34.8	40.3
34		17	27.2	31.5
35		18	48.2	55.8
36		19	23.0	26.6
37		20	25.8	29.9
38				
39	MEAN		29.2	33.8
40	ST. DEVIATION		9.2	10.7
41	COEFF. OF VARIATION =STDEV/MEAN		0.316	0.316
42	MIN		17.8	20.6
43	MAX		48.2	55.8
44	RANGE		30.4	35.2
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-9	25655-9
3	EXPERIMENT NUMBER (RUN NO.):		13	13
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	61.2	70.9
19		2	62.6	72.5
20		3	67.2	77.9
21		4	36.4	42.2
22		5	67.2	77.9
23		6	60.8	70.4
24		7	35.4	41.0
25		8	58.4	67.7
26		9	65.6	76.0
27		10	49.2	57.0
28		11	30.6	35.5
29		12	31.4	36.4
30		13	62.4	72.3
31		14	53.4	61.9
32		15	75.6	87.6
33		16	51.2	59.3
34		17	46.8	54.2
35		18	72.6	84.1
36		19	49.2	57.0
37		20	53.0	61.4
38				
39	MEAN		54.5	63.2
40	ST. DEVIATION		13.3	15.4
41	COEFF. OF VARIATION =STDEV/MEAN		0.244	0.244
42	MIN		30.6	35.5
43	MAX		75.6	87.6
44	RANGE		45.0	52.1
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-07-02	92-07-02
2	SAMPLE IDENTIFICATION		25655-10	25655-10
3	EXPERIMENT NUMBER (RUN NO.):		14	14
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	29.0	33.6
19		2	21.4	24.8
20		3	36.8	42.6
21		4	28.0	32.4
22		5	30.0	34.8
23		6	27.6	32.0
24		7	48.0	55.6
25		8	37.0	42.9
26		9	44.8	51.9
27		10	50.8	58.9
28		11	42.0	48.7
29		12	38.6	44.7
30		13	20.6	23.9
31		14	41.8	48.4
32		15	29.4	34.1
33		16	44.2	51.2
34		17	46.2	53.5
35		18	47.2	54.7
36		19	48.2	55.8
37		20	31.4	36.4
38				
39	MEAN		37.2	43.0
40	ST. DEVIATION		9.4	10.9
41	COEFF. OF VARIATION =STDEV/MEAN		0.253	0.253
42	MIN		20.6	23.9
43	MAX		50.8	58.9
44	RANGE		30.2	35.0
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		25655-47	25655-47
3	EXPERIMENT NUMBER (RUN NO.):		28	28
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	48.2	55.8
19		2	53.0	61.4
20		3	37.8	43.8
21		4	52.8	61.2
22		5	45.4	52.6
23		6	50.0	57.9
24		7	37.4	43.3
25		8	74.4	86.2
26		9	38.0	44.0
27		10	49.2	57.0
28		11	47.0	54.5
29		12	39.6	45.9
30		13	70.2	81.3
31		14	57.0	66.0
32		15	37.4	43.3
33		16	62.4	72.3
34		17	50.0	57.9
35		18	36.6	42.4
36		19	32.8	38.0
37		20	40.8	47.3
38				
39	MEAN		48.0	55.6
40	ST. DEVIATION		11.4	13.2
41	COEFF. OF VARIATION =STDEV/MEAN		0.237	0.237
42	MIN		32.8	38.0
43	MAX		74.4	86.2
44	RANGE		41.6	48.2
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		25655-48	25655-48
3	EXPERIMENT NUMBER (RUN NO.:)		29	29
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	33.2	38.5
19		2	46.0	53.3
20		3	46.4	53.8
21		4	34.2	39.6
22		5	30.2	35.0
23		6	55.8	64.7
24		7	28.0	32.4
25		8	47.6	55.2
26		9	43.2	50.1
27		10	55.2	64.0
28		11	38.6	44.7
29		12	35.6	41.2
30		13	36.4	42.2
31		14	42.2	48.9
32		15	42.0	48.7
33		16	41.8	48.4
34		17	56.2	65.1
35		18	35.6	41.2
36		19	37.4	43.3
37		20	60.2	69.8
38				
39	MEAN		42.3	49.0
40	ST. DEVIATION		9.1	10.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.216	0.216
42	MIN		28.0	32.4
43	MAX		60.2	69.8
44	RANGE		32.2	37.3
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-09-08	92-09-08
2	SAMPLE IDENTIFICATION		25655-49	25655-49
3	EXPERIMENT NUMBER (RUN NO.):		30	30
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	41.6	48.2
19		2	43.8	50.8
20		3	37.2	43.1
21		4	42.8	49.6
22		5	55.2	64.0
23		6	41.8	48.4
24		7	30.4	35.2
25		8	31.8	36.8
26		9	40.2	46.6
27		10	31.6	36.6
28		11	32.6	37.8
29		12	36.4	42.2
30		13	46.6	54.0
31		14	38.6	44.7
32		15	56.0	64.9
33		16	32.8	38.0
34		17	44.6	51.7
35		18	36.4	42.2
36		19	54.4	63.0
37		20	57.0	66.0
38				
39	MEAN		41.6	48.2
40	ST. DEVIATION		8.6	9.9
41	COEFF. OF VARIATION =STDEV/MEAN		0.206	0.206
42	MIN		30.4	35.2
43	MAX		57.0	66.0
44	RANGE		26.6	30.8
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-11-05	92-11-05
2	SAMPLE IDENTIFICATION		25740-25	25740-25
3	EXPERIMENT NUMBER (RUN NO.):		36 L.D.	36 L.D.
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	36.8	42.6
19		2	43.4	50.3
20		3	37.6	43.6
21		4	41.2	47.7
22		5	34.6	40.1
23		6	51.6	59.8
24		7	49.2	57.0
25		8	48.0	55.6
26		9	46.2	53.5
27		10	37.8	43.8
28		11	32.6	37.8
29		12	46.0	53.3
30		13	29.2	33.8
31		14	36.0	41.7
32		15	39.6	45.9
33		16	38.4	44.5
34		17	41.0	47.5
35		18	33.4	38.7
36		19	27.8	32.2
37		20	44.8	51.9
38				
39	MEAN		39.8	46.1
40	ST. DEVIATION		6.6	7.6
41	COEFF. OF VARIATION $\pm$ STDEV/MEAN		0.166	0.166
42	MIN		27.8	32.2
43	MAX		51.6	59.8
44	RANGE		23.8	27.6
45				

FIRED CRUSH STRENGTH DATA (DIAMETRAL COMPRESSION)

	A	B	C	D
1	DATE TESTED		92-11-05	92-11-05
2	SAMPLE IDENTIFICATION		25740-25	25740-25
3	EXPERIMENT NUMBER (RUN NO.):		36 H.D.	36 H.D.
4	SAMPLE SHAPE		GRAIN	GRAIN
5	BATCH NO.			
6	SAMPLE SIZE (MESH)		-8+10	-8+10
7	SAMPLE SIZE (mm)		1.85	1.85
8	SAMPLE SIZE (INCHES)		0.073	0.073
9	TEST INSTRUMENT		CHATILLON	CHATILLON
10	CROSS-HEAD SPEED SETTING		3.0	3.0
11	CROSS-HEAD SPEED (mm/MIN)		15.2	15.2
12	PAD (MANILA FOLDER) Y OR N		NO	NO
13	TEST SAMPLE ORIENTATION		DIAMETRAL	DIAMETRAL
14	DATA:		C-PEAK	FRAC. STRESS
15	UNITS:		LBS	MPA
16	DATA TYPE:		RAW	CONVERTED
17		NO.		
18		1	42.0	48.7
19		2	49.6	57.5
20		3	63.2	73.2
21		4	48.4	56.1
22		5	66.8	77.4
23		6	34.4	39.9
24		7	33.0	38.2
25		8	53.8	62.3
26		9	40.2	46.6
27		10	49.8	57.7
28		11	48.2	55.8
29		12	44.6	51.7
30		13	59.4	68.8
31		14	39.6	45.9
32		15	33.8	39.2
33		16	47.0	54.5
34		17	48.2	55.8
35		18	53.0	61.4
36		19	41.4	48.0
37		20	73.4	85.0
38				
39	MEAN		48.5	56.2
40	ST. DEVIATION		10.9	12.6
41	COEFF. OF VARIATION =STDEV/MEAN		0.225	0.225
42	MIN		33.0	38.2
43	MAX		73.4	85.0
44	RANGE		40.4	46.8
45				

DOE Light Weight Refractory Fired Grain Crushing Strengths

1/12/94			2/24/94							
Run #	47-A	47-E	48-A	48-E	49-A	49-E	50-A	50-E	51-A	51-E
1	60.2	27.8	21.6	29.6	37.6	28.2	41.6	47.2	59.0	63.8
2	27.8	29.2	26.0	38.6	68.2	42.6	47.8	48.4	38.8	44.0
3	25.6	44.2	60.2	20.6	36.4	62.0	24.4	17.6	62.6	40.6
4	40.8	43.2	30.4	36.8	44.2	37.2	27.8	45.6	37.8	43.6
5	27.8	56.4	56.0	24.2	33.0	25.8	52.0	29.8	25.0	61.4
6	50.2	51.0	21.0	25.0	54.4	20.0	36.4	38.0	31.2	40.2
7	51.8	29.2	36.6	36.6	30.2	75.8	27.8	29.2	28.4	39.4
8	29.6	58.0	48.6	23.2	52.6	69.6	31.4	40.8	31.0	31.0
9	27.8	35.0	39.4	50.8	29.8	54.4	30.2	55.0	49.0	42.4
10	47.8	28.4	56.6	39.8	41.8	49.2	29.8	34.8	44.2	29.0
11	83.4	38.0	22.2	33.2	24.0	49.8	27.4	40.4	27.8	35.2
12	37.2	45.4	41.6	55.8	47.4	40.6	29.8	27.2	22.6	39.2
13	20.2	52.6	40.0	19.8	47.8	38.6	43.6	38.0	45.8	22.8
14	52.0	56.2	37.8	42.2	30.0	40.2	58.8	71.4	43.6	20.8
15	27.8	31.4	20.0	51.4	28.6	48.0	43.8	29.2	26.6	52.8
16	21.0	39.0	58.4	25.4	41.2	29.0	89.6	24.0	22.6	21.8
17	48.0	20.2	30.6	26.6	44.0	35.2	21.8	25.0	39.2	25.6
18	27.0	50.2	55.2	52.2	52.8	25.4	60.0	26.6	40.6	31.8
19	29.2	35.4	31.6	46.6	71.0	32.0	14.8	38.2	63.6	26.0
20	39.2	24.6	31.6	40.6	74.4	77.4	27.0	32.4	48.6	24.4
Avg.	38.72	39.77	38.27	35.95	44.47	44.05	38.29	36.94	39.40	36.79
Std. Dev.	15.78	11.62	13.53	11.42	14.47	16.77	17.19	12.43	12.77	12.47
Run Avg.	39.25		37.11		44.26		37.62		38.10	
Av. Stdev	13.70		12.47		15.62		14.81		12.62	
Grand Av	39.27									
Stdev	13.85									

B5-61

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Appendix B-5a – Weibull Modulus Calculation for Aggregate Strength

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WEIBULL CALC-24127-#1

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	(1/(1-F))	LN (1/(1-F))	LNLN(1/(1-F))	LN(STRESS)-MPa
3	1	19.0	0.0476	0.9524	1.0500	0.048790	-3.020227	2.944565
4	2	36.4	0.0952	0.9048	1.1053	0.100083	-2.301751	3.594092
5	3	36.6	0.1429	0.8571	1.1667	0.154151	-1.869825	3.600441
6	4	39.9	0.1905	0.8095	1.2353	0.211309	-1.554433	3.685340
7	5	44.5	0.2381	0.7619	1.3125	0.271934	-1.302197	3.795341
8	6	46.1	0.2857	0.7143	1.4000	0.336472	-1.089240	3.831151
9	7	50.5	0.3333	0.6667	1.5000	0.405465	-0.902720	3.922341
10	8	51.2	0.3810	0.6190	1.6154	0.479573	-0.734859	3.936008
11	9	53.1	0.4286	0.5714	1.7500	0.559616	-0.580505	3.971568
12	10	54.0	0.4762	0.5238	1.9091	0.646627	-0.435985	3.988884
13	11	55.8	0.5238	0.4762	2.1000	0.741937	-0.298490	4.022643
14	12	61.2	0.5714	0.4286	2.3333	0.847298	-0.165703	4.113795
15	13	61.6	0.6190	0.3810	2.6250	0.965081	-0.035543	4.121342
16	14	61.9	0.6667	0.3333	3.0000	1.098612	0.094048	4.125094
17	15	63.5	0.7143	0.2857	3.5000	1.252763	0.225351	4.150974
18	16	67.0	0.7619	0.2381	4.2000	1.435085	0.361224	4.204272
19	17	69.8	0.8095	0.1905	5.2500	1.658228	0.505750	4.244956
20	18	70.4	0.8571	0.1429	7.0000	1.945910	0.665730	4.254873
21	19	73.2	0.9048	0.0952	10.5000	2.351375	0.855000	4.293588
22	20	76.2	0.9524	0.0476	21.0000	3.044522	1.113344	4.333904

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	(1/(1-F))	LN (1/(1-F))	LNLN(1/(1-F))	LN(STRESS)-MPa
3	1	20.2	0.0476	0.9524	1.0500	0.048790	-3.020227	3.003754
4	2	26.4	0.0952	0.9048	1.1053	0.100083	-2.301751	3.274044
5	3	26.6	0.1429	0.8571	1.1667	0.154151	-1.869825	3.282778
6	4	31.3	0.1905	0.8095	1.2353	0.211309	-1.554433	3.443121
7	5	31.3	0.2381	0.7619	1.3125	0.271934	-1.302197	3.443121
8	6	32.0	0.2857	0.7143	1.4000	0.336472	-1.089240	3.465099
9	7	32.4	0.3333	0.6667	1.5000	0.405465	-0.902720	3.479488
10	8	34.1	0.3810	0.6190	1.6154	0.479573	-0.734859	3.528278
11	9	36.2	0.4286	0.5714	1.7500	0.559616	-0.580505	3.587702
12	10	37.3	0.4762	0.5238	1.9091	0.646627	-0.435985	3.619250
13	11	37.8	0.5238	0.4762	2.1000	0.741937	-0.298490	3.631596
14	12	38.5	0.5714	0.4286	2.3333	0.847298	-0.165703	3.649834
15	13	39.2	0.6190	0.3810	2.6250	0.965081	-0.035543	3.667745
16	14	40.3	0.6667	0.3333	3.0000	1.098612	0.094048	3.696901
17	15	43.1	0.7143	0.2857	3.5000	1.252763	0.225351	3.763592
18	16	48.4	0.7619	0.2381	4.2000	1.435085	0.361224	3.880180
19	17	48.9	0.8095	0.1905	5.2500	1.658228	0.505750	3.889704
20	18	49.8	0.8571	0.1429	7.0000	1.945910	0.665730	3.908484
21	19	50.1	0.9048	0.0952	10.5000	2.351375	0.855000	3.913124
22	20	54.7	0.9524	0.0476	21.0000	3.044522	1.113344	4.001678

B5a-2

WEIBULL CALC-24127-#3

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	$(1/(1-F))$	$\text{LN } (1/(1-F))$	$\text{LNLN}(1/(1-F))$	$\text{LN}(\text{STRESS})\text{-MPa}$
3	1	39.2	0.0476	0.9524	1.0500	0.048790	-3.020227	3.667745
4	2	42.9	0.0952	0.9048	1.1053	0.100083	-2.301751	3.758202
5	3	44.7	0.1429	0.8571	1.1667	0.154151	-1.869825	3.800536
6	4	45.7	0.1905	0.8095	1.2353	0.211309	-1.554433	3.821050
7	5	46.1	0.2381	0.7619	1.3125	0.271934	-1.302197	3.831151
8	6	46.3	0.2857	0.7143	1.4000	0.336472	-1.089240	3.836163
9	7	47.5	0.3333	0.6667	1.5000	0.405465	-0.902720	3.860856
10	8	51.7	0.3810	0.6190	1.6154	0.479573	-0.734859	3.945018
11	9	55.6	0.4286	0.5714	1.7500	0.559616	-0.580505	4.018485
12	10	60.3	0.4762	0.5238	1.9091	0.646627	-0.435985	4.098527
13	11	62.8	0.5238	0.4762	2.1000	0.741937	-0.298490	4.139965
14	12	65.6	0.5714	0.4286	2.3333	0.847298	-0.165703	4.183293
15	13	65.8	0.6190	0.3810	2.6250	0.965081	-0.035543	4.186820
16	14	68.4	0.6667	0.3333	3.0000	1.098612	0.094048	4.224821
17	15	73.2	0.7143	0.2857	3.5000	1.252763	0.225351	4.293588
18	16	78.8	0.7619	0.2381	4.2000	1.435085	0.361224	4.366791
19	17	79.9	0.8095	0.1905	5.2500	1.658228	0.505750	4.381390
20	18	89.5	0.8571	0.1429	7.0000	1.945910	0.665730	4.493683
21	19	99.2	0.9048	0.0952	10.5000	2.351375	0.855000	4.596969
22	20	102.7	0.9524	0.0476	21.0000	3.044522	1.113344	4.631416

B5a-3

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	(1/(1-F))	LN (1/(1-F))	LNLN(1/(1-F))	LN(STRESS)-MPa
3	1	21.3	0.0476	0.9524	1.0500	0.048790	-3.020227	3.059634
4	2	22.2	0.0952	0.9048	1.1053	0.100083	-2.301751	3.102194
5	3	25.0	0.1429	0.8571	1.1667	0.154151	-1.869825	3.219977
6	4	32.2	0.1905	0.8095	1.2353	0.211309	-1.554433	3.472320
7	5	32.7	0.2381	0.7619	1.3125	0.271934	-1.302197	3.486606
8	6	33.6	0.2857	0.7143	1.4000	0.336472	-1.089240	3.514580
9	7	35.7	0.3333	0.6667	1.5000	0.405465	-0.902720	3.574798
10	8	37.5	0.3810	0.6190	1.6154	0.479573	-0.734859	3.625442
11	9	38.5	0.4286	0.5714	1.7500	0.559616	-0.580505	3.649834
12	10	40.6	0.4762	0.5238	1.9091	0.646627	-0.435985	3.702632
13	11	44.7	0.5238	0.4762	2.1000	0.741937	-0.298490	3.800536
14	12	47.0	0.5714	0.4286	2.3333	0.847298	-0.165703	3.851052
15	13	47.3	0.6190	0.3810	2.6250	0.965081	-0.035543	3.855966
16	14	48.4	0.6667	0.3333	3.0000	1.098612	0.094048	3.880180
17	15	50.1	0.7143	0.2857	3.5000	1.252763	0.225351	3.913124
18	16	52.1	0.7619	0.2381	4.2000	1.435085	0.361224	3.953946
19	17	57.0	0.8095	0.1905	5.2500	1.658228	0.505750	4.043177
20	18	58.6	0.8571	0.1429	7.0000	1.945910	0.665730	4.071235
21	19	58.6	0.9048	0.0952	10.5000	2.351375	0.855000	4.071235
22	20	64.9	0.9524	0.0476	21.0000	3.044522	1.113344	4.172635

B5a-4

WEIBULL CALC-24127-#5

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	(1/(1-F))	LN (1/(1-F))	LNLN(1/(1-F))	LN(STRESS)-MPa
3	1	38.5	0.0476	0.9524	1.0500	0.048790	-3.020227	3.649834
4	2	38.7	0.0952	0.9048	1.1053	0.100083	-2.301751	3.655840
5	3	42.4	0.1429	0.8571	1.1667	0.154151	-1.869825	3.747332
6	4	43.8	0.1905	0.8095	1.2353	0.211309	-1.554433	3.779593
7	5	45.0	0.2381	0.7619	1.3125	0.271934	-1.302197	3.805704
8	6	46.3	0.2857	0.7143	1.4000	0.336472	-1.089240	3.836163
9	7	47.5	0.3333	0.6667	1.5000	0.405465	-0.902720	3.860856
10	8	48.0	0.3810	0.6190	1.6154	0.479573	-0.734859	3.870565
11	9	55.2	0.4286	0.5714	1.7500	0.559616	-0.580505	4.010116
12	10	60.9	0.4762	0.5238	1.9091	0.646627	-0.435985	4.110000
13	11	64.0	0.5238	0.4762	2.1000	0.741937	-0.298490	4.158247
14	12	65.1	0.5714	0.4286	2.3333	0.847298	-0.165703	4.176200
15	13	66.5	0.6190	0.3810	2.6250	0.965081	-0.035543	4.197328
16	14	70.9	0.6667	0.3333	3.0000	1.098612	0.094048	4.261431
17	15	70.9	0.7143	0.2857	3.5000	1.252763	0.225351	4.261431
18	16	71.1	0.7619	0.2381	4.2000	1.435085	0.361224	4.264694
19	17	94.5	0.8095	0.1905	5.2500	1.658228	0.505750	4.549113
20	18	95.2	0.8571	0.1429	7.0000	1.945910	0.665730	4.556439
21	19	98.3	0.9048	0.0952	10.5000	2.351375	0.855000	4.587579
22	20	103.8	0.9524	0.0476	21.0000	3.044522	1.113344	4.642639

B5a-5

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	$(1/(1-F))$	$\text{LN } (1/(1-F))$	$\text{LNLN}(1/(1-F))$	$\text{LN}(\text{STRESS})\text{-MPa}$
3	1	26.2	0.0476	0.9524	1.0500	0.048790	-3.020227	3.265234
4	2	39.4	0.0952	0.9048	1.1053	0.100083	-2.301751	3.673644
5	3	42.2	0.1429	0.8571	1.1667	0.154151	-1.869825	3.741852
6	4	43.1	0.1905	0.8095	1.2353	0.211309	-1.554433	3.763592
7	5	43.3	0.2381	0.7619	1.3125	0.271934	-1.302197	3.768954
8	6	43.3	0.2857	0.7143	1.4000	0.336472	-1.089240	3.768954
9	7	46.1	0.3333	0.6667	1.5000	0.405465	-0.902720	3.831151
10	8	46.6	0.3810	0.6190	1.6154	0.479573	-0.734859	3.841151
11	9	47.5	0.4286	0.5714	1.7500	0.559616	-0.580505	3.860856
12	10	52.6	0.4762	0.5238	1.9091	0.646627	-0.435985	3.962796
13	11	54.7	0.5238	0.4762	2.1000	0.741937	-0.298490	4.001678
14	12	55.6	0.5714	0.4286	2.3333	0.847298	-0.165703	4.018485
15	13	57.9	0.6190	0.3810	2.6250	0.965081	-0.035543	4.059307
16	14	58.4	0.6667	0.3333	3.0000	1.098612	0.094048	4.067275
17	15	62.1	0.7143	0.2857	3.5000	1.252763	0.225351	4.128833
18	16	65.1	0.7619	0.2381	4.2000	1.435085	0.361224	4.176200
19	17	65.3	0.8095	0.1905	5.2500	1.658228	0.505750	4.179753
20	18	66.7	0.8571	0.1429	7.0000	1.945910	0.665730	4.200806
21	19	68.4	0.9048	0.0952	10.5000	2.351375	0.855000	4.224821
22	20	102.2	0.9524	0.0476	21.0000	3.044522	1.113344	4.626891

B5a-6

WEIBULL CALC-24127-#7

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	$(1/(1-F))$	$\text{LN } (1/(1-F))$	$\text{LNLN}(1/(1-F))$	$\text{LN}(\text{STRESS})\text{-MPa}$
3	1	44.5	0.0476	0.9524	1.0500	0.048790	-3.020227	3.795341
4	2	46.3	0.0952	0.9048	1.1053	0.100083	-2.301751	3.836163
5	3	49.1	0.1429	0.8571	1.1667	0.154151	-1.869825	3.894432
6	4	51.9	0.1905	0.8095	1.2353	0.211309	-1.554433	3.949492
7	5	52.4	0.2381	0.7619	1.3125	0.271934	-1.302197	3.958381
8	6	57.5	0.2857	0.7143	1.4000	0.336472	-1.089240	4.051275
9	7	57.7	0.3333	0.6667	1.5000	0.405465	-0.902720	4.055299
10	8	60.9	0.3810	0.6190	1.6154	0.479573	-0.734859	4.110000
11	9	62.6	0.4286	0.5714	1.7500	0.559616	-0.580505	4.136268
12	10	68.1	0.4762	0.5238	1.9091	0.646627	-0.435985	4.221426
13	11	69.8	0.5238	0.4762	2.1000	0.741937	-0.298490	4.244956
14	12	73.5	0.5714	0.4286	2.3333	0.847298	-0.165703	4.296748
15	13	73.7	0.6190	0.3810	2.6250	0.965081	-0.035543	4.299897
16	14	76.0	0.6667	0.3333	3.0000	1.098612	0.094048	4.330859
17	15	80.9	0.7143	0.2857	3.5000	1.252763	0.225351	4.392918
18	16	81.1	0.7619	0.2381	4.2000	1.435085	0.361224	4.395779
19	17	82.5	0.8095	0.1905	5.2500	1.658228	0.505750	4.412777
20	18	87.8	0.8571	0.1429	7.0000	1.945910	0.665730	4.475382
21	19	88.1	0.9048	0.0952	10.5000	2.351375	0.855000	4.478017
22	20	94.1	0.9524	0.0476	21.0000	3.044522	1.113344	4.544199

B5a-7

	A	B	C	D	E	F	G	H
1								1A
2	N	STRESS	F	1-F	$(1/(1-F))$	$\text{LN } (1/(1-F))$	$\text{LNLN}(1/(1-F))$	$\text{LN}(\text{STRESS})\text{-MPa}$
3	1	29.4	0.0476	0.9524	1.0500	0.048790	-3.020227	3.382033
4	2	43.6	0.0952	0.9048	1.1053	0.100083	-2.301751	3.774288
5	3	45.9	0.1429	0.8571	1.1667	0.154151	-1.869825	3.826113
6	4	46.3	0.1905	0.8095	1.2353	0.211309	-1.554433	3.836163
7	5	47.3	0.2381	0.7619	1.3125	0.271934	-1.302197	3.855966
8	6	47.5	0.2857	0.7143	1.4000	0.336472	-1.089240	3.860856
9	7	48.7	0.3333	0.6667	1.5000	0.405465	-0.902720	3.884953
10	8	49.4	0.3810	0.6190	1.6154	0.479573	-0.734859	3.899138
11	9	50.5	0.4286	0.5714	1.7500	0.559616	-0.580505	3.922341
12	10	51.2	0.4762	0.5238	1.9091	0.646627	-0.435985	3.936008
13	11	51.7	0.5238	0.4762	2.1000	0.741937	-0.298490	3.945018
14	12	52.8	0.5714	0.4286	2.3333	0.847298	-0.165703	3.967191
15	13	54.9	0.6190	0.3810	2.6250	0.965081	-0.035543	4.005906
16	14	58.9	0.6667	0.3333	3.0000	1.098612	0.094048	4.075180
17	15	60.0	0.7143	0.2857	3.5000	1.252763	0.225351	4.094674
18	16	60.5	0.7619	0.2381	4.2000	1.435085	0.361224	4.102366
19	17	60.7	0.8095	0.1905	5.2500	1.658228	0.505750	4.106190
20	18	61.9	0.8571	0.1429	7.0000	1.945910	0.665730	4.125094
21	19	61.9	0.9048	0.0952	10.5000	2.351375	0.855000	4.125094
22	20	61.9	0.9524	0.0476	21.0000	3.044522	1.113344	4.125094

B5a-8

	LN LN(1/(1-F))	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa	LN(STRESS)-MPa
1	-3.0202	2.9446	3.0038	3.6677	3.0596	3.6498	3.2652	3.7953	3.382
2	-2.3017	3.5941	3.274	3.7582	3.1022	3.6558	3.6736	3.8362	3.7743
3	-1.8698	3.6004	3.2828	3.8005	3.22	3.7473	3.7418	3.8944	3.8261
4	-1.5544	3.6853	3.4431	3.821	3.4723	3.7796	3.7636	3.9495	3.8362
5	-1.3022	3.7953	3.4431	3.8312	3.4866	3.8057	3.7689	3.9584	3.856
6	-1.0892	3.8312	3.4651	3.8362	3.5146	3.8362	3.7689	4.0513	3.8609
7	-0.90272	3.9223	3.4795	3.8609	3.5748	3.8609	3.8312	4.0553	3.8849
8	-0.73486	3.936	3.5283	3.945	3.6254	3.8706	3.8412	4.11	3.8991
9	-0.58051	3.9716	3.5877	4.0185	3.6498	4.0101	3.8609	4.1363	3.9223
10	-0.43599	3.9889	3.6193	4.0985	3.7026	4.11	3.9628	4.2214	3.936
11	-0.29849	4.0226	3.6316	4.14	3.8005	4.1582	4.0017	4.245	3.945
12	-0.1657	4.1138	3.6498	4.1833	3.851	4.1762	4.0185	4.2968	3.9672
13	-0.03554	4.1213	3.6677	4.1868	3.856	4.1973	4.0593	4.2999	4.0059
14	0.09405	4.1251	3.6969	4.2248	3.8802	4.2614	4.0673	4.3309	4.0752
15	0.22535	4.151	3.7636	4.2936	3.9131	4.2614	4.1288	4.3929	4.0947
16	0.36122	4.2043	3.8802	4.3668	3.9539	4.2647	4.1762	4.3958	4.1024
17	0.50575	4.245	3.8897	4.3814	4.0432	4.5491	4.1797	4.4128	4.1062
18	0.66573	4.2549	3.9085	4.4937	4.0712	4.5564	4.2008	4.4754	4.1251
19	0.855	4.2936	3.9131	4.597	4.0712	4.5876	4.2248	4.478	4.1251
20	1.1133	4.3339	4.0017	4.6314	4.1725	4.6426	4.6269	4.5442	4.1251

WEIBULL PLOT: Expt. Design 24127-#1

WEIBULL PLOT: Expt. Design 24127-#2

WEIBULL PLOT: Expt. Design 24127-#3

WEIBULL PLOT: Expt. Design 24127-#4

WEIBULL PLOT: Expt. Design 24127-#5

WEIBULL PLOT: Expt. Design 24127-#6

WEIBULL PLOT: Expt. Design 24127-#7

WEIBULL PLOT: Expt. Design 24127-#8

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Appendix C-1 – Statistical Data for Run 3

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SAMPLE	BATCH	DRY	SUS.	SAT.	BULK	APP.	H2O	APP.	TOTAL
LD.	NO.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS.	SG.	POROSITY
NO.		(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
25530-6-1A	1	2.1807	1.6219	2.5169	2.43	37.56	15.46	3.89	38.96
25530-6-1B	1	2.1971	1.6292	2.5275	2.44	36.78	15.08	3.86	38.73
25530-6-1C	1	2.6105	1.9321	2.8994	2.69	29.87	11.10	3.84	32.40
25530-6-1D	1	1.7966	1.3348	2.0866	2.38	38.57	16.19	3.88	40.14
25530-6-1E	1	1.8723	1.3914	2.1717	2.39	38.37	16.04	3.88	39.89
AVERAGE					2.47	36.23	14.78	3.87	38.02
25530-6-2A	2	3.0136	2.2376	3.4081	2.57	33.70	13.13	3.87	35.50
25530-6-2B	2	2.4688	1.8339	2.8301	2.47	36.27	14.68	3.88	37.92
25530-6-2C	2	2.5943	1.9266	2.9624	2.50	35.54	14.23	3.87	37.26
25530-6-2D	2	2.4181	1.7959	2.7425	2.55	34.27	13.46	3.87	36.01
25530-6-2E	2	2.4848	1.8445	2.8201	2.54	34.37	13.53	3.87	36.20
AVERAGE					2.52	34.83	13.81	3.87	36.58
25530-6-3A	3	2.6878	1.9237	3.0324	2.33	40.10	17.23	3.89	41.53
25530-6-3B	3	2.2364	1.6601	2.5725	2.44	36.84	15.07	3.87	38.60
25530-6-3C	3	2.1841	1.6219	2.5658	2.31	40.44	17.53	3.87	42.04
25530-6-3D	3	2.0546	1.5273	2.4152	2.31	40.61	17.60	3.88	42.03
25530-6-3E	3	1.8308	1.3592	2.1414	2.33	39.71	17.02	3.87	41.37
AVERAGE					2.34	39.54	16.89	3.88	41.11
25530-6-4A	4	2.0937	1.5543	2.4555	2.32	40.15	17.33	3.87	41.80
25530-6-4B	4	2.2763	1.6909	2.6659	2.33	39.96	17.17	3.88	41.52
25530-6-4C	4	2.4411	1.8133	2.8685	2.31	40.50	17.56	3.88	42.05
25530-6-4D	4	2.2798	1.6945	2.6707	2.33	40.06	17.21	3.88	41.50
25530-6-4E	4	2.1736	1.6138	2.5486	2.32	40.12	17.30	3.87	41.75
AVERAGE					2.32	40.16	17.31	3.88	41.72
25530-6-5A	5	2.524	1.8767	2.9676	2.31	40.66	17.63	3.89	42.04
25530-6-5B	5	2.7679	2.0581	3.2413	2.33	40.01	17.15	3.89	41.40
25530-6-5C	5	2.7068	2.0129	3.1934	2.29	41.22	18.03	3.89	42.56
25530-6-5D	5	2.3794	1.7676	2.8107	2.27	41.35	18.18	3.88	42.86
25530-6-5E	5	2.4738	1.8383	2.9076	2.31	40.57	17.59	3.88	42.05
AVERAGE					2.30	40.76	17.72	3.88	42.18
25530-6-6A	6	2.9203	2.1716	3.4181	2.34	39.93	17.10	3.89	41.32
25530-6-6B	6	2.6195	1.9465	3.0755	2.31	40.39	17.46	3.88	41.88
25530-6-6C	6	2.7687	2.0588	3.2544	2.31	40.62	17.60	3.89	42.00
25530-6-6D	6	2.4699	1.8354	2.8986	2.32	40.32	17.41	3.88	41.81
25530-6-6E	6	2.6859	1.9983	3.1493	2.32	40.19	17.30	3.88	41.65
AVERAGE					2.32	40.29	17.37	3.88	41.73
25530-6-7A	7	2.7894	2.0739	3.3261	2.22	42.86	19.30	3.89	44.20
25530-6-7B	7	2.8968	2.1525	3.4506	2.22	42.66	19.18	3.88	44.10
25530-6-7C	7	2.6744	1.9868	3.1667	2.26	41.72	18.46	3.88	43.22
25530-6-7D	7	2.3555	1.7617	2.8039	2.23	42.62	19.09	3.89	43.92
25530-6-7E	7	2.2991	1.7071	2.7274	2.25	41.98	18.69	3.87	43.55
AVERAGE					2.24	42.37	18.94	3.88	43.80
25530-6-8A	8	2.8513	2.1191	3.3601	2.29	41.00	17.90	3.88	42.44
25530-6-8B	8	2.6286	1.9534	3.1429	2.20	43.24	19.62	3.88	44.64
25530-6-8C	8	2.7021	2.0081	3.2177	2.23	42.83	19.14	3.88	44.04
25530-6-8D	8	2.5138	1.8668	2.9961	2.22	42.73	19.25	3.87	44.24
25530-6-8E	8	1.8542	1.3777	2.2064	2.23	42.60	19.05	3.88	43.95
AVERAGE					2.23	42.42	18.99	3.88	43.86
25530-6-9A	9	2.8153	2.0924	3.3579	2.22	42.88	19.33	3.88	44.27
25530-6-9B	9	2.8289	2.1023	3.3662	2.23	42.51	19.05	3.88	43.93
25530-6-9C	9	2.2883	1.7001	2.7329	2.21	43.05	19.49	3.88	44.50
25530-6-9D	9	2.3996	1.782	2.8574	2.22	42.57	19.14	3.87	44.10
25530-6-9E	9	2.449	1.8199	2.9301	2.20	43.33	19.70	3.88	44.74
AVERAGE					2.22	42.87	19.34	3.88	44.31
25530-6-10A	10	3.1069	2.3099	3.6957	2.24	42.49	19.01	3.89	43.84
25530-6-10B	10	2.7651	2.0553	3.2876	2.24	42.40	18.95	3.88	43.79
25530-6-10C	10	3.0105	2.2385	3.5808	2.24	42.48	18.99	3.89	43.81
25530-6-10D	10	2.8507	2.1168	3.3349	2.33	39.75	17.04	3.87	41.38
25530-6-10E	10	2.6102	1.9378	3.0847	2.27	41.37	18.23	3.87	42.99
AVERAGE					2.26	41.70	18.44	3.88	43.16
25530-6-11A	11	3.2381	2.4076	3.865	2.22	43.01	19.42	3.89	44.34
25530-6-11B	11	2.6975	2.0064	3.2291	2.20	43.48	19.77	3.89	44.73
25530-6-11C	11	2.5315	1.8605	3.012	2.23	42.47	19.04	3.88	43.96
25530-6-11D	11	2.0792	1.5441	2.5035	2.16	44.23	20.47	3.87	45.71
25530-6-11E	11	2.3529	1.7478	2.8052	2.22	42.77	19.28	3.88	44.26
AVERAGE					2.20	43.19	19.59	3.88	44.60
25530-6-12A	12	3.2009	2.3768	3.835	2.19	43.46	19.87	3.87	45.05
25530-6-12B	12	3.1588	2.3482	3.7329	2.27	41.46	18.23	3.89	42.85
25530-6-12C	12	2.9269	2.1707	3.5538	2.11	45.33	21.48	3.86	46.99
25530-6-12D	12	2.8736	2.1306	3.4543	2.16	43.67	20.27	3.86	45.82
25530-6-12E	12	2.866	2.1259	3.4535	2.15	44.25	20.56	3.86	45.92
AVERAGE					2.18	43.67	20.08	3.87	45.29

Means with confid. interval
Means
Summary of Fit

Requires 0.839987
Root Mean Square Error 0.045295
Mean of Response 2.301
Observations (or Sum Wgts)

60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	0.61230000	0.055664	22.9068
Error	48	0.11664000	0.002430	Prob>F
C Total	59	0.72894000		0.0000

Mean Estimates

Level number	Mean	Std Error
1	2.48500	0.02205
2	2.52600	0.02205
3	2.34400	0.02205
4	2.32200	0.02205
5	2.30200	0.02205
6	2.32000	0.02205
7	2.23600	0.02205
8	2.23400	0.02205
9	2.21800	0.02205
10	2.28400	0.02205
11	2.20600	0.02205
12	2.17600	0.02205

Means Comparisons

Diff=Mean[i]-Mean[j]

	2	1	3	4	6	5	10	7	8	9	11	12
2	0.000000	0.060000	0.182000	0.204000	0.206000	0.224000	0.262000	0.290000	0.292000	0.310000	0.370000	0.350000
1	-0.06	0.000000	0.122000	0.144000	0.146000	0.164000	0.202000	0.230000	0.232000	0.250000	0.260000	0.290000
3	-0.182	-0.122	0.000000	0.022000	0.024000	0.042000	0.080000	0.108000	0.110000	0.128000	0.130000	0.168000
4	-0.204	-0.144	-0.022	0.000000	0.002000	0.020000	0.058000	0.086000	0.088000	0.106000	0.108000	0.146000
6	-0.206	-0.146	-0.024	-0.002	0.000000	0.018000	0.056000	0.084000	0.086000	0.104000	0.106000	0.144000
5	-0.224	-0.164	-0.042	-0.020	-0.018	0.000000	0.038000	0.066000	0.068000	0.086000	0.088000	0.126000
10	-0.262	-0.202	-0.080	-0.058	-0.056	-0.038	0.000000	0.028000	0.030000	0.048000	0.050000	0.088000
7	-0.290	-0.230	-0.108	-0.086	-0.084	-0.066	-0.028	0.000000	0.002000	0.020000	0.022000	0.060000
8	-0.292	-0.232	-0.110	-0.088	-0.086	-0.068	-0.030	-0.002	0.000000	0.018000	0.020000	0.058000
9	-0.310	-0.250	-0.128	-0.106	-0.104	-0.086	-0.048	-0.022	-0.018	0.000000	0.010000	0.040000
11	-0.370	-0.260	-0.130	-0.108	-0.106	-0.088	-0.050	-0.022	-0.020	-0.010	0.000000	0.030000
12	-0.350	-0.290	-0.168	-0.146	-0.144	-0.126	-0.088	-0.060	-0.058	-0.040	-0.030	0.000000

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q^{*}
3.43374

Abs(Diff)-LSD

	2	1	3	4	6	5	10	7	8	9	11	12
2	-0.10705	-0.04705	0.074947	0.096947	0.098947	0.116947	0.154947	0.182947	0.184947	0.202947	0.212947	0.242947
1	-0.04705	-0.10705	0.014947	0.036947	0.038947	0.056947	0.094947	0.122947	0.124947	0.142947	0.152947	0.182947
3	0.074947	0.014947	-0.10705	-0.08505	-0.08305	-0.06505	-0.02705	0.000947	0.002947	0.020947	0.030947	0.060947
4	0.096947	0.036947	-0.08505	-0.10705	-0.10505	-0.08705	-0.04905	-0.02105	-0.01905	-0.00105	0.008947	0.038947
6	0.098947	0.038947	-0.08305	-0.10505	-0.10305	-0.08505	-0.04705	-0.01905	-0.01705	-0.00905	0.006947	0.036947
5	0.116947	0.056947	-0.06505	-0.08705	-0.08505	-0.10705	-0.06905	-0.04105	-0.03905	-0.02105	-0.01105	0.018947
10	0.154947	0.094947	-0.02705	-0.04905	-0.05105	-0.06905	-0.10705	-0.07905	-0.07705	-0.05905	-0.04905	-0.01805
7	0.182947	0.122947	0.000947	-0.02105	-0.02305	-0.04105	-0.07905	-0.10705	-0.10505	-0.08705	-0.07705	-0.04705
8	0.184947	0.124947	0.002947	-0.01905	-0.02105	-0.03905	-0.07705	-0.10505	-0.10305	-0.08505	-0.07505	-0.04505
9	0.202947	0.142947	0.020947	-0.00105	-0.00305	-0.02105	-0.05905	-0.08705	-0.08505	-0.10705	-0.09705	-0.06705
11	0.212947	0.152947	0.030947	0.008947	0.006947	-0.01105	-0.04905	-0.07705	-0.07505	-0.09705	-0.10705	-0.07705
12	0.242947	0.182947	0.060947	0.038947	0.036947	0.010947	-0.01905	-0.04705	-0.04505	-0.06705	-0.07705	-0.10705

Positive values show pairs of means that are significantly different.

BULKDEN

Quantiles

maximum	100.0%	2.6900
	99.5%	2.6900
	97.5%	2.6270
	90.0%	2.4670
quartile	75.0%	2.3300
median	50.0%	2.2900
quartile	25.0%	2.2200
	10.0%	2.2000
	2.5%	2.1310
	0.5%	2.1100
minimum	0.0%	2.1100

Moments

Mean	2.30100
Std Dev	0.11115
Std Err Mean	0.01435
upper 95% Mean	2.32971
lower 95% Mean	2.27229
N	60.00000
Sum Wgts	60.00000

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Appendix C-2 – Statistical Data for Run 6

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COMPARISON OF MEAN PILED DENSITY DATA FOR RUN 6 (12 BATCHES)

SAMPLE LD.	BATCH NO.	DRY WEIGHT (g)	SUS. WEIGHT (g)	SAT. WEIGHT (g)	BULK DENSITY (g/cc)	APP. POROSITY (%)	H2O ABS. (%)	APP. S.G. (g/cc)	TOTAL POROSITY (%)
25530-28-1A	1	2.1896	1.6309	2.5505	2.38	38.16	16.00	3.86	40.08
25530-28-1B	1	2.2334	1.6569	2.5919	2.38	38.34	16.10	3.86	40.16
25530-28-1C	1	2.4588	1.8267	2.8302	2.44	37.01	15.15	3.88	38.82
25530-28-1D	1	2.6246	1.8723	2.8056	2.44	36.87	15.14	3.86	38.80
25530-28-1E	1	2.7813	2.0453	3.1578	2.47	35.64	14.40	3.84	37.82
25530-28-1F*	1	8.7134	6.4660	10.0465	2.43	37.23	15.35	3.87	39.04
25530-28-1G*	1	8.0043	5.9404	9.2942	2.38	38.46	16.16	3.87	40.21
25530-28-1H*	1	8.4361	6.2584	9.7631	2.40	37.86	15.78	3.86	39.70
25530-28-1I*	1	7.8022	5.7881	9.0251	2.40	37.78	15.72	3.86	39.62
25530-28-1J*	1	8.6080	6.5326	10.1803	2.41	37.62	15.63	3.86	39.51
25530-29-2A	2	2.3357	1.7327	2.6784	2.46	36.31	14.76	3.86	38.20
25530-29-2B	2	2.4240	1.8002	2.7822	2.46	36.48	14.82	3.87	38.17
25530-29-2C	2	2.6305	1.9489	3.0176	2.46	36.26	14.78	3.85	38.28
25530-29-2D	2	2.5807	1.9149	2.8632	2.45	36.49	14.87	3.86	38.33
25530-29-2E	2	2.7363	2.0286	3.1515	2.43	36.88	15.22	3.85	38.86
25530-29-3A	3	2.3709	1.7805	2.7328	2.43	37.22	15.31	3.87	38.82
25530-29-3B	3	2.3817	1.7542	2.7318	2.41	37.86	15.72	3.88	39.49
25530-29-3C	3	2.3503	1.7452	2.7287	2.38	38.47	16.15	3.87	40.14
25530-29-3D	3	2.5819	1.9153	2.8612	2.46	36.27	14.73	3.86	38.16
25530-29-3E	3	2.6877	1.9862	3.0948	2.44	37.06	15.19	3.88	38.72
25530-29-4A	4	2.3558	1.7403	2.7186	2.42	37.43	15.45	3.87	39.12
25530-29-4B	4	2.6456	1.8903	2.9337	2.43	37.20	15.29	3.87	38.88
25530-29-4C	4	2.5121	1.8665	2.8986	2.43	37.45	15.43	3.88	39.03
25530-29-4D	4	2.5013	1.8538	2.8719	2.45	36.40	14.86	3.85	38.46
25530-29-4E	4	2.4938	1.8501	2.8787	2.42	37.42	15.48	3.86	39.27
25530-30-5A	5	2.2272	1.6525	2.5899	2.42	37.36	15.43	3.86	39.18
25530-30-5B	5	2.5306	1.8786	2.9093	2.45	36.78	15.01	3.88	38.44
25530-30-5C	5	2.4877	1.8453	2.8705	2.42	37.34	15.43	3.86	39.21
25530-30-5D	5	2.3054	1.7125	2.6509	2.45	36.82	15.03	3.88	38.46
25530-30-5E	5	2.5222	1.8725	2.8022	2.44	36.90	15.11	3.87	38.64
25530-30-5F*	5	6.6700	4.9548	7.6682	2.45	36.79	15.01	3.88	38.42
25530-30-5G*	5	8.0318	5.9593	9.2585	2.43	37.14	15.29	3.86	38.88
25530-30-5H*	5	7.3019	5.4238	8.4452	2.41	37.84	15.70	3.88	39.46
25530-30-6I*	5	7.3119	5.4289	8.4488	2.41	37.65	15.60	3.87	39.35
25530-30-6J*	5	7.6313	5.6632	8.7825	2.44	36.91	15.13	3.87	38.72
25530-30-6A	6	2.6539	1.9716	3.0386	2.48	36.05	14.64	3.88	37.69
25530-30-6B	6	2.6534	1.9713	3.0403	2.47	36.19	14.63	3.88	37.82
25530-30-6C	6	2.7134	2.0152	3.1035	2.49	35.84	14.42	3.87	37.54
25530-30-6D	6	2.8314	2.1002	3.2458	2.48	36.17	14.68	3.86	38.09
25530-30-6E	6	2.9213	2.1884	3.3426	2.48	35.88	14.47	3.87	37.68
25530-31-7A	7	2.8688	2.1289	3.2800	2.46	36.33	14.76	3.87	38.15
25530-31-7B	7	2.8530	2.1141	3.2691	2.46	36.03	14.63	3.85	38.12
25530-31-7C	7	2.8306	2.1012	3.2442	2.47	36.19	14.66	3.87	37.96
25530-31-7D	7	3.0126	2.2362	3.4694	2.46	36.63	14.88	3.87	38.30
25530-31-7E	7	3.0541	2.2624	3.4959	2.47	35.82	14.51	3.85	37.98
25530-31-7F*	7	7.5543	5.6025	8.5174	2.58	33.04	12.79	3.86	35.08
25530-31-7G*	7	7.1763	5.3176	8.2888	2.42	37.04	15.28	3.85	39.11
25530-31-7H*	7	7.1107	5.2753	8.1597	2.46	36.37	14.80	3.86	38.25
25530-31-7I*	7	7.0846	5.2483	8.0980	2.47	36.26	14.67	3.88	37.80
25530-31-7J*	7	7.9043	5.9649	8.9227	2.58	33.30	12.92	3.86	35.25
25530-31-8A	8	2.3552	1.6764	2.6072	2.41	37.78	15.66	3.88	39.37
25530-31-8B	8	2.4429	1.8142	2.8103	2.45	36.88	15.08	3.87	38.57
25530-31-8C	8	2.4279	1.8034	2.8152	2.39	38.28	16.00	3.88	39.89
25530-31-8D	8	2.6168	1.9697	2.9269	2.37	38.79	16.34	3.88	40.36
25530-31-8E	8	2.7248	2.0233	3.1644	2.38	38.54	16.19	3.87	40.19
25530-31-8A	9	2.7215	2.0149	3.1068	2.48	36.29	14.20	3.84	37.68
25530-31-8B	9	2.6853	1.9833	3.0749	2.48	36.02	14.55	3.87	37.81
25530-31-8C	9	2.7870	2.0683	3.2050	2.45	36.79	15.04	3.87	38.55
25530-31-8D	9	2.6927	1.9967	3.0873	2.46	36.18	14.70	3.86	38.15
25530-31-8E	9	2.7863	2.0661	3.1993	2.45	36.45	14.87	3.86	38.41
25530-32-10A	10	2.9164	2.1643	3.3269	2.50	35.31	14.12	3.87	37.16
25530-32-10B	10	2.7370	2.0320	3.1059	2.54	34.35	13.52	3.87	36.16
25530-32-10C	10	2.7867	2.0688	3.1704	2.52	34.86	13.81	3.88	36.57
25530-32-10D	10	2.6130	1.8398	2.8833	2.50	35.49	14.21	3.87	37.27
25530-32-10E	10	2.8948	2.1472	3.2925	2.52	34.72	13.78	3.86	36.68
25530-32-11A	11	2.5515	1.8636	2.9274	2.48	36.36	14.78	3.87	38.17
25530-32-11B	11	2.6177	1.9441	2.9937	2.49	35.82	14.41	3.87	37.52
25530-32-11C	11	2.6019	1.9292	2.9870	2.45	36.41	14.85	3.86	38.38
25530-32-11D	11	2.6422	1.9616	3.0264	2.47	36.08	14.58	3.87	37.84
25530-32-11E	11	2.6730	1.9858	3.0765	2.44	36.91	15.10	3.87	38.59
25530-33-12A	12	2.1451	1.5818	2.4671	2.44	36.79	15.06	3.87	38.61
25530-33-12B	12	2.2826	1.6950	2.6282	2.44	36.81	15.02	3.88	38.44
25530-33-12C	12	2.4637	1.8227	2.8212	2.45	36.51	14.84	3.87	38.18
25530-33-12D	12	2.6545	1.9715	3.0472	2.46	36.51	14.17	3.87	37.21
25530-33-12E	12	2.7361	2.0311	3.1226	2.50	35.41	14.17	3.87	37.21
25530-33-12F*	12	7.1299	5.2919	8.2055	2.44	36.82	15.13	3.87	38.70
25530-33-12G*	12	7.2671	5.3911	8.3488	2.45	36.57	14.93	3.86	38.45
25530-33-12H*	12	8.7120	6.4688	10.0358	2.44	37.11	15.24	3.87	38.82
25530-33-12I*	12	6.8823	5.1108	7.9109	2.45	36.73	14.99	3.87	38.43
25530-33-12J*	12	6.6282	4.9184	7.5947	2.47	36.08	14.61	3.86	37.95
AVERAGE					2.45	36.65	14.97	3.87	38.45
ST DEV					0.04	1.04	0.66	0.01	0.98

BULK By BATCH

Means with confid. interval

RUN # 6

Means

Summary of Fit

Regression 0.578913
 Root Mean Square Error 0.027828
 Mean of Response 2.44825
 Observations (or Sum Wgts) 80

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	0.07269500	0.006609	8.5337
Error	68	0.05286000	0.000774	Prob>F
C Total	79	0.12555500		0.0000

Mean Estimates

Level	number	Mean	Std Error
1	10	2.41300	0.00880
2	5	2.45200	0.01245
3	5	2.42400	0.01245
4	5	2.43000	0.01245
5	10	2.43200	0.00880
6	5	2.47800	0.01245
7	10	2.48300	0.00880
8	5	2.40000	0.01245
9	5	2.48400	0.01245
10	5	2.51600	0.01245
11	5	2.48200	0.01245
12	10	2.45400	0.00880

Means Comparisons

DH=Mean(I)-Mean(J)	10	7	6	9	11	12	2	5	4	3	1	8
10	0.000000	0.033000	0.040000	0.052000	0.054000	0.062000	0.064000	0.084000	0.088000	0.092000	0.103000	0.118000
7	-0.033	0.000000	0.007000	0.019000	0.021000	0.029000	0.031000	0.051000	0.053000	0.059000	0.070000	0.083000
6	-0.04	-0.007	0.000000	0.012000	0.014000	0.022000	0.024000	0.044000	0.046000	0.052000	0.063000	0.076000
9	-0.052	-0.019	-0.012	0.000000	0.002000	0.010000	0.012000	0.032000	0.034000	0.040000	0.051000	0.064000
11	-0.054	-0.021	-0.014	-0.002	0.000000	0.008000	0.010000	0.030000	0.032000	0.038000	0.049000	0.062000
12	-0.062	-0.029	-0.022	-0.01	-0.008	0.000000	0.002000	0.022000	0.024000	0.030000	0.041000	0.054000
2	-0.064	-0.031	-0.024	-0.012	-0.01	-0.002	0.000000	0.020000	0.022000	0.028000	0.039000	0.052000
5	-0.064	-0.051	-0.044	-0.032	-0.03	-0.022	-0.02	0.000000	0.002000	0.008000	0.019000	0.032000
4	-0.066	-0.053	-0.046	-0.034	-0.022	-0.024	-0.022	-0.002	0.000000	0.006000	0.017000	0.030000
3	-0.062	-0.059	-0.052	-0.04	-0.038	-0.03	-0.028	-0.008	-0.006	0.000000	0.011000	0.024000
1	-0.103	-0.07	-0.063	-0.051	-0.049	-0.041	-0.039	-0.019	-0.017	-0.011	0.000000	0.013000
8	-0.116	-0.083	-0.076	-0.064	-0.062	-0.054	-0.052	-0.032	-0.03	-0.024	-0.013	0.000000

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

Abs(DH)-LSD	10	7	6	9	11	12	2	5	4	3	1	8
10	-0.05957	-0.01859	-0.01857	-0.00757	-0.00557	0.010415	0.004434	0.032415	0.028434	0.032434	0.051415	0.058434
7	-0.01859	-0.04212	-0.04459	-0.03259	-0.03059	-0.01312	-0.02059	0.000881	0.001415	0.007415	0.027881	0.031415
6	-0.01957	-0.04459	-0.05957	-0.04757	-0.04557	-0.02859	-0.03557	-0.00759	-0.01357	-0.00757	0.011415	0.018434
9	-0.00757	-0.03259	-0.04757	-0.05957	-0.05757	-0.04159	-0.04757	-0.01959	-0.02557	-0.01957	-0.00059	0.004434
11	-0.00557	-0.03059	-0.04557	-0.05757	-0.05857	-0.04359	-0.04857	-0.02159	-0.02757	-0.02157	-0.00259	0.002434
12	0.010415	-0.01312	-0.02859	-0.04159	-0.04359	-0.04212	-0.04959	-0.02012	-0.02759	-0.02159	-0.00112	0.002415
2	0.004434	-0.02059	-0.03557	-0.04757	-0.04957	-0.04959	-0.05957	-0.03159	-0.03757	-0.03157	-0.01259	-0.00757
5	0.032415	0.00881	-0.00759	-0.01959	-0.02159	-0.02012	-0.03159	-0.04212	-0.04959	-0.04359	-0.02312	-0.01859
4	0.028434	0.001415	-0.01357	-0.02557	-0.02757	-0.02759	-0.03757	-0.04959	-0.05957	-0.05357	-0.03459	-0.02957
3	0.032434	0.007415	-0.00757	-0.01957	-0.02157	-0.02159	-0.03157	-0.04359	-0.05357	-0.05957	-0.04059	-0.03557
1	0.051415	0.027881	0.011415	-0.00059	-0.00259	-0.00112	-0.01259	-0.02312	-0.03459	-0.04059	-0.04212	-0.03859
8	0.058434	0.031415	0.018434	0.004434	0.002434	0.002415	-0.00757	-0.01859	-0.02957	-0.03557	-0.03859	-0.05957

Positive values show pairs of means that are significantly different.

BULK

Quantiles

maximum	100.0%	2.5800
	99.5%	2.5800
	97.5%	2.5790
	90.0%	2.4990
quartile	75.0%	2.4700
median	50.0%	2.4500
quartile	25.0%	2.4300
	10.0%	2.4000
	2.5%	2.3800
	0.5%	2.3700
minimum	0.0%	2.3700

Moments

Mean	2.44925
Std Dev	0.03983
Std Err Mean	0.00445
upper 95% Mean	2.45811
lower 95% Mean	2.44039
N	80.00000
Sum Wgts	80.00000

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Appendix C-3 – Statistical Data for Run 8

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SAMPLE	BATCH	DRY	SUS	SAT	BULK	APP	H2O	APP.	TOTAL
ID.	NO.	WEIGHT	WEIGHT	WEIGHT	DENSITY	POROSITY	ABS	SG	POROSITY
NO.		(g)	(g)	(g)	(g/cc)	(%)	(%)	(g/cc)	(%)
25530-46-1A	1	1.8318	1.3571	2.1175	2.40	37.57	15.64	3.85	39.65
25530-46-1B	1	1.6877	1.2519	1.9593	2.38	38.39	16.14	3.85	40.24
25530-46-1C	1	1.9309	1.4330	2.2394	2.39	38.26	16.03	3.87	40.02
25530-46-1D	1	2.0043	1.4857	2.3179	2.40	37.68	15.69	3.85	39.87
25530-46-1E	1	2.0639	1.5288	2.3763	2.43	36.86	15.18	3.85	39.00
25530-46-1F*	1	6.7945	5.0393	7.8143	2.44	36.75	15.05	3.86	38.67
25530-46-1G*	1	6.2058	4.6044	7.1414	2.44	36.88	15.12	3.86	38.72
25530-46-1H*	1	7.0641	5.2389	8.1354	2.43	36.99	15.21	3.86	38.91
25530-46-1I*	1	7.2737	5.3965	8.4112	2.41	37.73	15.69	3.86	39.56
25530-47-2A	2	1.9267	1.4265	2.2235	2.41	37.24	15.45	3.84	39.44
25530-47-2B	2	1.7951	1.3307	2.0828	2.38	38.25	16.08	3.85	40.21
25530-47-2C	2	1.6776	1.2453	1.9422	2.40	37.97	15.82	3.87	39.70
25530-47-2D	2	2.0585	1.5285	2.3949	2.37	38.83	16.39	3.87	40.48
25530-47-2E	2	1.6956	1.2583	1.9717	2.37	38.70	16.33	3.87	40.46
25530-47-3A	3	2.0222	1.4959	2.3208	2.44	36.20	14.81	3.83	38.59
25530-47-3B	3	1.8461	1.3686	2.1396	2.39	38.07	15.95	3.85	40.02
25530-47-3C	3	2.0912	1.5500	2.4162	2.41	37.52	15.59	3.85	39.52
25530-47-3D	3	1.8715	1.3885	2.1762	2.37	38.68	16.33	3.86	40.48
25530-47-3E	3	2.0709	1.5345	2.3991	2.39	37.96	15.90	3.85	40.00
25530-47-4A	4	1.9532	1.4488	2.2423	2.45	36.43	14.85	3.86	38.34
25530-47-4B	4	2.1729	1.6118	2.5041	2.43	37.12	15.29	3.86	39.00
25530-47-4C	4	1.8841	1.3977	2.1929	2.36	38.83	16.44	3.86	40.65
25530-47-4D	4	2.0584	1.5281	2.3812	2.41	37.84	15.73	3.87	39.56
25530-47-4E	4	2.0787	1.5417	2.4002	2.41	37.45	15.51	3.86	39.35
25530-48-5A	5	1.8889	1.4021	2.1821	2.41	37.59	15.57	3.87	39.34
25530-48-5B	5	1.8266	1.3555	2.1075	2.42	37.35	15.42	3.87	39.15
25530-48-5C	5	1.9638	1.4568	2.2675	2.42	37.46	15.51	3.86	39.32
25530-48-5D	5	1.8377	1.3637	2.1290	2.39	38.06	15.90	3.87	39.85
25530-48-5E	5	1.8186	1.3500	2.1087	2.39	38.10	15.94	3.86	39.92
25530-48-5F*	5	6.6434	4.9255	7.6460	2.43	36.85	15.14	3.86	38.83
25530-48-5G*	5	7.5815	5.6292	8.7381	2.43	37.20	15.30	3.87	38.91
25530-48-5H*	5	10.0925	7.4875	11.5814	2.46	36.37	14.80	3.86	38.24
25530-48-5I*	5	6.0143	4.4542	6.9332	2.42	37.07	15.32	3.84	39.23
25530-48-6A	6	1.9943	1.4775	2.2952	2.43	36.80	15.13	3.85	38.90
25530-48-6B	6	1.7532	1.2998	2.0273	2.40	37.68	15.68	3.86	39.83
25530-48-6C	6	1.7852	1.3228	2.0492	2.45	36.34	14.83	3.85	38.44
25530-48-6D	6	1.7854	1.3227	2.0482	2.45	36.22	14.76	3.85	38.35
25530-48-6E	6	1.6266	1.2059	1.8719	2.44	36.83	15.13	3.85	38.82
25530-49-7A	7	1.8498	1.3707	2.1361	2.41	37.41	15.52	3.85	39.46
25530-49-7B	7	1.8042	1.3366	2.0669	2.46	35.97	14.60	3.85	38.11
25530-49-7C	7	1.9924	1.4751	2.2803	2.47	35.76	14.49	3.84	38.02
25530-49-7D	7	1.6452	1.2182	1.8874	2.45	36.25	14.77	3.85	38.32
25530-49-7E	7	1.8817	1.3794	2.1345	2.46	36.13	14.70	3.85	38.24
25530-49-7F*	7	6.9607	5.1672	7.8846	2.46	36.34	14.75	3.87	38.11
25530-49-7G*	7	6.3063	4.6743	7.2317	2.46	36.19	14.72	3.85	38.23
25530-49-7H*	7	7.1967	5.3367	8.2388	2.47	35.91	14.52	3.86	37.88
25530-49-7I*	7	6.8886	4.8625	7.7008	2.44	36.93	15.16	3.86	38.80
25530-49-8A	8	2.0329	1.5060	2.3373	2.44	36.62	15.02	3.85	38.74
25530-49-8B	8	2.0372	1.5104	2.3447	2.43	36.86	15.14	3.86	38.83
25530-49-8C	8	1.7269	1.2793	1.9743	2.48	35.60	14.37	3.85	37.76
25530-49-8D	8	1.8066	1.3381	2.0811	2.42	36.94	15.24	3.84	39.09
25530-49-8E	8	1.9357	1.4344	2.2172	2.47	35.96	14.59	3.85	38.06
25530-49-9A	9	1.7609	1.3044	2.0358	2.40	37.59	15.66	3.85	39.69
25530-49-9B	9	1.9397	1.4379	2.2384	2.42	37.31	15.45	3.85	39.30
25530-49-9C	9	2.1827	1.6162	2.5004	2.46	35.93	14.60	3.84	38.16
25530-49-9D	9	1.8544	1.3747	2.1384	2.42	37.19	15.36	3.85	39.17
25530-49-9E	9	2.0677	1.5294	2.3665	2.46	35.69	14.49	3.83	38.12
25530-50-10A	10	1.8253	1.3528	2.1186	2.37	38.38	16.17	3.85	40.37
25530-50-10B	10	1.6966	1.2564	1.9770	2.35	38.91	16.68	3.84	41.02
25530-50-10C	10	1.6875	1.2526	1.9647	2.36	38.93	16.48	3.87	40.64
25530-50-10D	10	1.8348	1.3821	2.1442	2.34	39.66	16.91	3.87	41.23
25530-50-10E	10	1.8687	1.3842	2.1703	2.37	38.37	16.19	3.85	40.45
25530-50-11A	11	1.5735	1.1652	1.8181	2.40	37.46	15.69	3.84	39.63
25530-50-11B	11	1.4873	1.1032	1.7212	2.40	37.85	15.77	3.86	39.71
25530-50-11C	11	1.4786	1.0961	1.7169	2.37	38.39	16.17	3.85	40.34
25530-50-11D	11	1.3616	1.0092	1.6804	2.38	38.31	16.12	3.85	40.29
25530-50-11E	11	1.6325	1.2115	1.8963	2.38	38.52	16.21	3.87	40.28
25530-50-12A	12	1.3681	1.0140	1.5789	2.41	37.32	15.45	3.85	39.33
25530-50-12B	12	1.4194	1.0523	1.6373	2.42	37.25	15.40	3.85	39.22
25530-50-12C	12	1.3963	1.0343	1.6135	2.40	37.50	15.60	3.85	39.61
25530-50-12D	12	1.4025	1.0403	1.6231	2.40	37.85	15.78	3.86	39.72
25530-50-12E	12	1.5669	1.1618	1.8038	2.43	36.80	15.16	3.86	38.86
25530-50-12F*	12	8.3164	6.1662	9.5446	2.45	36.35	14.81	3.86	38.34
25530-50-12G*	12	6.9576	5.1578	7.9783	2.46	36.19	14.71	3.85	38.21
25530-50-12H*	12	7.2714	5.3926	8.3455	2.46	36.37	14.82	3.86	38.31
25530-50-12I*	12	7.3646	5.4508	8.3392	2.54	33.74	13.27	3.84	36.13
AVERAGE					2.42	37.25	15.41	3.85	39.22
ST DEV					0.04	1.00	0.64	0.01	0.90

BULK DEN By BATCH

Means with confid. interval

RUN #8

Means

Summary of Fit

Response 0.550655
Root Mean Square Error 0.025995
Mean of Response 2.416584
Observations (or Sum Wgts) 76

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	0.05301054	0.004819	7.1299
Error	64	0.04355778	0.000676	
C Total	75	0.09656832		

Mean Estimates

Level	number	Mean	Std Error
1	9	2.41333	0.00867
2	5	2.38600	-0.01163
3	5	2.40000	0.01163
4	5	2.41200	0.01163
5	9	2.41888	0.00867
6	5	2.43400	0.01163
7	9	2.45333	0.00867
8	5	2.44800	0.01163
9	5	2.43200	0.01163
10	5	2.36800	0.01163
11	5	2.38600	0.01163
12	9	2.44111	0.00867

Means Comparisons

Difference (i-Meanj)

	7	8	12	6	9	5	1	4	3	11	2	10
7	0.000000	0.045333	0.012222	0.019333	0.021333	0.034444	0.040000	0.041333	0.053333	0.087333	0.067333	0.095333
8	-0.045333	0.000000	0.006667	0.014000	0.016000	0.029111	0.034667	0.038000	0.048000	0.082000	0.062000	0.090000
12	-0.012222	-0.006667	0.000000	0.007111	0.009111	0.022222	0.027778	0.029111	0.041111	0.055111	0.055111	0.083111
6	-0.019333	-0.014000	-0.007111	0.000000	0.002000	0.016111	0.020667	0.022000	0.034000	0.048000	0.048000	0.076000
9	-0.021333	-0.016000	-0.009111	-0.002000	0.000000	0.013111	0.018667	0.020000	0.032000	0.046000	0.046000	0.074000
5	-0.034444	-0.029111	-0.022222	-0.016111	-0.013111	0.000000	0.005556	0.008889	0.018889	0.032889	0.032889	0.060889
1	-0.040000	-0.034667	-0.027778	-0.020667	-0.018667	-0.008889	0.000000	0.001333	0.013333	0.027333	0.027333	0.055333
4	-0.041333	-0.038000	-0.029111	-0.022000	-0.020000	-0.008889	-0.001333	0.000000	0.012000	0.026000	0.026000	0.054000
3	-0.053333	-0.048000	-0.041111	-0.034000	-0.032000	-0.018889	-0.013333	-0.012000	0.000000	0.014000	0.014000	0.042000
11	-0.087333	-0.082000	-0.055111	-0.048000	-0.046000	-0.032889	-0.027333	-0.026000	-0.014000	0.000000	0.000000	0.028000
2	-0.067333	-0.062000	-0.055111	-0.048000	-0.046000	-0.032889	-0.027333	-0.026000	-0.014000	-0.000000	0.000000	0.028000
10	-0.095333	-0.090000	-0.083111	-0.076000	-0.074000	-0.060889	-0.055333	-0.054000	-0.042000	-0.028000	-0.028000	0.000000

Alpha = 0.05

Comparisons for all pairs using Tukey-Kramer HSD

3.33175

Abs(Diff)-LSD

	7	8	12	6	9	5	1	4	3	11	2	10
7	-0.04167	-0.04385	-0.02935	-0.02985	-0.02785	-0.00712	-0.00167	-0.00785	0.004149	0.018149	0.018149	0.046149
8	-0.04385	-0.05577	-0.0423	-0.04177	-0.03977	-0.02007	-0.01452	-0.01977	-0.00777	0.006231	0.006231	0.034231
12	-0.02935	-0.0423	-0.04167	-0.04207	-0.04007	-0.01935	-0.01379	-0.02007	-0.00807	0.005927	0.005927	0.033927
6	-0.02985	-0.04177	-0.04207	-0.05577	-0.05377	-0.03407	-0.02852	-0.03377	-0.02177	-0.00777	-0.00777	0.020231
9	-0.02785	-0.03977	-0.04007	-0.05377	-0.05177	-0.03407	-0.03052	-0.03577	-0.02377	-0.00977	-0.00977	0.018231
5	-0.00712	-0.02007	-0.01935	-0.03407	-0.03607	-0.04167	-0.03601	-0.0423	-0.0303	-0.0163	-0.0163	0.011705
1	-0.00167	-0.01452	-0.01379	-0.02852	-0.03052	-0.03601	-0.04167	-0.04785	-0.03585	-0.02185	-0.02185	0.006149
4	-0.00785	-0.01977	-0.02007	-0.03377	-0.03577	-0.0423	-0.04785	-0.05577	-0.04377	-0.02977	-0.02977	-0.00177
3	0.004149	-0.00777	-0.00807	-0.02177	-0.02377	-0.0303	-0.03601	-0.04377	-0.05577	-0.04177	-0.04177	-0.01377
11	0.018149	0.006231	0.005927	-0.00777	-0.00977	-0.0163	-0.02185	-0.02977	-0.04177	-0.05577	-0.05577	-0.02777
2	0.018149	0.006231	0.005927	-0.00777	-0.00977	-0.0163	-0.02185	-0.02977	-0.04177	-0.05577	-0.05577	-0.02777
10	0.046149	0.034231	0.033927	0.020231	0.018231	0.011705	0.006149	-0.00177	-0.01377	-0.02777	-0.02777	-0.05577

Positive values show pairs of means that are significantly different.

Appendix C-4 – Statistical Data for Expt. Design (Runs 6, 8-14)

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Response: FIRED_STRENGTH-MPa Summary of Fit

Rsquare 0.998824
Root Mean Square Error 0.753602
Mean of Response 48.8625
Observations (or Sum Wgts)

8

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
MIXER	1	1	254.25125	447.6911	0.0002
DISPERSION	1	1	810.03125	1426.321	0.0000
MIXER*FORMULAT	1	1	193.06125	339.9464	0.0003
MIXER*DISPERSI*FORMULAT	1	1	1	189.15125	
	333.0616		0.0004		

Whole-Model Test

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Model	4	1446.4950	361.624	636.7550	
Error	3	1.7037	0.568		
C Total	7	1448.1988			0.0001

NOTE: RESIDUALS ARE RANDOMLY DISTRIBUTED

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
SIGMA	43.22500000	0.3768012297	43.2250
SIMPSON	54.50000000	0.3768012297	54.5000

DISPERSION Profile Plot

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
DRY	58.92500000	0.3768012297	58.9250
WET	38.80000000	0.3768012297	38.8000

MIXER*FORMULAT Profile Plot

Least Squares Means

Level	Least Sq Mean	Std Error
SIGMA,ALUMINA	38.31250000	0.4614853735
SIGMA,HYDRATE	48.13750000	0.4614853735
SIMPSON,ALUMINA		59.41250000
SIMPSON,HYDRATE		49.58750000

0.461
0.461

MIXER*DISPERSI*FORMULAT

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
189.15125	333.0616	1	0.0004

Least Squares Means

Level	Least Sq Mean	Std Error	
SIGMA, DRY, ALUMINA	43.51250000	0.5957750554	
SIGMA, DRY, HYDRATE	63.06250000	0.5957750554	
SIGMA, WET, ALUMINA	33.11250000	0.5957750554	
SIGMA, WET, HYDRATE	33.21250000	0.5957750554	
SIMPSON, DRY, ALUMINA		74.33750000	0.595
SIMPSON, DRY, HYDRATE		54.78750000	0.595
SIMPSON, WET, ALUMINA		44.48750000	0.595
SIMPSON, WET, HYDRATE		44.38750000	0.595

Correlations Variable

	BULKDEN-G/CC	FIRED_STRENGTH-MPa
BULKDEN-G/CC	1.0000	0.9288
FIRED_STRENGTH-MPa	0.9288	1.0000

Scatter Plot Matrix

Outlier Distance [Mahalanobis]

Response: BULKDEN-G/CC Summary of Fit

Rsquare 0.872016
Root Mean Square Error 0.12682
Mean of Response 2.425
Observations (or Sum Wgts)

8

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
MIXER	1	1	0.06125000	3.8083	0.1461
DISPERSION	1	1	0.18605000	11.5679	0.0424
MIXER*FORMULAT	1	1	0.03645000	2.2663	0.2293
MIXER*DISPERSI*FORMULAT	1	1	0.04500000	0.04500000	
	2.7979		0.1930		

Whole-Model Test

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	0.32875000	0.082187	5.1101
Error	3	0.04825000	0.016083	Prob>F
C Total	7	0.37700000		0.1057

MIXER

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.06125000	3.8083	1	0.1461

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
SIGMA	2.337500000	0.0634100413	2.33750
SIMPSON	2.512500000	0.0634100413	2.51250

DISPERSION Profile Plot

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
DRY	2.577500000	0.0634100413	2.57750
WET	2.272500000	0.0634100413	2.27250

MIXER*FORMULAT

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.03645000	2.2663	1	0.2293

Least Squares Means

Level	Least Sq Mean	Std Error	
SIGMA,ALUMINA	2.270000000	0.0776611228	
SIGMA,HYDRATE	2.405000000	0.0776611228	
SIMPSON,ALUMINA		2.580000000	0.0
SIMPSON,HYDRATE		2.445000000	0.0

MIXER*DISPERSI*FORMULAT

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.04500000	2.7979	1	0.1930

Least Squares Means

Level	Least Sq Mean	Std Error	
SIGMA, DRY, ALUMINA	2.347500000	0.1002600785	
SIGMA, DRY, HYDRATE	2.632500000	0.1002600785	
SIGMA, WET, ALUMINA	2.192500000	0.1002600785	
SIGMA, WET, HYDRATE	2.177500000	0.1002600785	
SIMPSON, DRY, ALUMINA		2.807500000	0.100
SIMPSON, DRY, HYDRATE		2.522500000	0.100
SIMPSON, WET, ALUMINA		2.352500000	0.100
SIMPSON, WET, HYDRATE		2.367500000	0.100

Response: BULKDEN-G/CC Summary of Fit

Rsquare 0.493501
Root Mean Square Error 0.178396
Mean of Response 2.425
Observations (or Sum Wgts)

8

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
DISPERSION	1	1	0.18605000	5.8460	0.0520

Whole-Model Test

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Model	1	0.18605000	0.186050	5.8460	
Error	6	0.19095000	0.031825		
C Total	7	0.37700000			0.0520

DISPERSION

Effect Test

Sum of Squares	F Ratio	DF	Prob>F
0.18605000	5.8460	1	0.0520

Least Squares Means

Level	Least Sq Mean	Std Error	Mean
DRY	2.577500000	0.0891978139	2.57750
WET	2.272500000	0.0891978139	2.27250

Column 1

Test for Normality

Shapiro-Wilk W Test

W	Prob<W
0.910888	0.4181

DENSITY RESPONSE - SINCE NO PTS FALL
OFF LINE, NOTHING IS SIGNIFICANT FOR
DENSITY RESPONSE

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Appendix C-5 – Harbison-Walker Report on Evaluation (Runs 6 and 8)

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HARBISON-WALKER REFRACTORIES
Division of INDRESCO Inc.
Garber Research Center
1001 Pgh.-McKeesport Blvd., West Mifflin, PA 15122

PETER T. TROELL
MANAGER - RESEARCH

May 4, 1993

TELEPHONE (412) 469-3880

Mr. Thomas G. Swansiger
Aluminum Company of America
Alcoa Technical Center
Alcoa Center, PA 15069

Dear Tom:

Enclosed are two copies of Harbison-Walker's report on the Phase II development work we conducted for the lightweight aggregate project.

Very truly yours,

Thomas R. Kleeb
Laboratory Manager, Operations

Attachments (2)

HARBISON-WALKER REFRACTORIES

Division of INDRESCO Inc.

DATE May 3, 1993

LABORATORY REPORT

LAB. No. E 6817

SUBJECT: High Alumina Materials - Others
Alcoa Lightweight Aggregate
Garber Research Center

cc: A. Pearson (ALCOA)
T.G. Swansiger (ALCOA)
Garber Research Ctr.
Research File

Alcoa Lightweight Aggregate Project for
U.S. Department of Energy: Alcoa P.O. TC 360781QA

ABSTRACT

A lightweight, high purity aggregate developed by Alcoa was evaluated in high alumina brick. It was found that the use of this aggregate resulted in the manufacture of a strong, 154-158 pcf high alumina brick with a unique combination of properties, including density, strength, refractoriness, chemical purity and thermal conductivity.

BACKGROUND

The work reported here is part of a project contracted to Alcoa Chemical Systems Division by the U.S. Department of Energy. The goal of this project was to develop a high purity, lightweight refractory aggregate for use in insulating refractories. Under Phase I of this contract, Alcoa developed a 99+% alumina grain which had a BSG of about 2.5 gms/cc and a crushing strength exceeding that of fused alumina grains.

In Phase II work, Alcoa manufactured several pilot plant-sized lots of this aggregate at their technical center. Material from runs 6 and 8 were fired, crushed and graded at Garber Research Center under P.O. TC 389884 QA. Both lots were evaluated as lightweight aggregates in high purity insulating brick in the current study, which was billed under P.O. TC 360781 QA.

PROCEDURE

In this study, two standards were made. The first, Mix A, was a dense, mullite-bonded 90% alumina brick based on tabular alumina. The second standard, Mix B, was a mullite bonded brick composition chemically similar to Mix A, but designed to have lower density through the use of bubble alumina aggregate. The dense standard is similar to products used in various industries where high hot strength and outstanding refractoriness are required. The lighter-

HARBISON-WALKER REFRACTORIES
Division of INDRESCO Inc.

LABORATORY REPORT

SUBJECT: High Alumina Materials - Others

E 6817

weight Mix B is typical of brick used where high refractoriness and reasonable strength are combined with lower thermal conductivity.

Like the two standards, Mixes C and D were bonded by a high purity mullite matrix. These mixes were essentially identical, except that Mix C was based on lightweight aggregate from production Run #6 and the lightweight aggregate in Mix D was from production Run #8. All test specimens were hydraulically pressed at 10,000 psi or higher except for Mix B. Brick from Mix B were pressed to a desired density to avoid crushing of the relatively weak bubble alumina aggregate.

RESULTS AND DISCUSSION

As shown in the Laboratory Data, the mix made with Run #6 lightweight aggregate, Mix C, had somewhat lower density and somewhat higher porosity compared to Mix D made with Run #8 aggregate. Differences in strength were insignificant. Mix C showed lower thermal conductivity, as would be expected due to its lower density.

The bulk density of Mix C was intermediate between the dense and lightweight standards but both the flexural and compressive strengths were about 70 to 80% of those of the dense standard and more than double those of the bubble alumina-containing standard. As expected, Mix C had higher thermal conductivity than the lightweight standard, but its conductivity was still only about two-thirds that of the dense standard.

CONCLUSIONS

It is concluded that the experimental lightweight aggregate evaluated in Mixes C and D is a unique material that provides an answer to the goal of reduced energy consumption where refractories of this type can be used and could offer a technical advantage to refractory manufacturers. The most common aggregates used in 90% alumina brick include tabular, or other dense crystalline aluminas, and fused alumina. The only lightweight, high purity aggregate commercially available at a reasonable cost is bubble alumina. This is widely used in refractories, but poor bubble strengths and variable bubble size distributions prevent lightweight brick with optimum properties from being developed. Alcoa's lightweight aggregate has grain strengths that are high enough to allow conventional crushing and grading techniques to be used when preparing the grain. Refractory brick manufacture is also made easier because the high grain strengths allow high forming pressures to be used.

The fired refractory composition appears to fill a niche between about 115 and 190 pcf in commercially available high purity, high alumina brick product lines with a unique, and until

HARBISON-WALKER REFRACTORIES

Division of INDRESCO Inc.

LABORATORY REPORT

SUBJECT: High Alumina Materials - Others

E 6817

now unavailable, combination of density, strength, chemical purity and thermal conductivity. It's refractoriness is such that a continuous use temperature of about 3150°F is probably possible.

RECOMMENDATIONS

It is recommended that a quantity of refractory brick similar to Mix C be manufactured and offered to a refractory consumer for evaluation. Although it was not evaluated as such in this work, the high purity of the lightweight aggregate suggests that it could be used to manufacture a lightweight refractory brick having an alumina content of up to 99% and a service temperature of about 3300°F.

The high strength of the lightweight aggregate also suggests its potential use in refractory plastics and castables. If possible, a limited amount of development work is recommended to evaluate the suitability of this grain for these products.

L.D. Fitch *T.R. Kleeb*
Reported by L.D. Fitch and T.R. Kleeb

Approved by

John T. Tamm

tjk

High Alumina Materials - Others

E 6817

Laboratory Data

Mix Designation: Aggregate:	A Tabular Alumina	B Bubble Alumina	C Run #6 LWA	D Run #8 LWA
Aggregate Content, Wt %:	--	--	68	68
Bulk Density, pcf (Av 6):	188	116	154	158
Apparent Porosity, % (Av 3):	15.7	44.1	31.5	29.4
Apparent Specific Gravity (Av 3):	3.58	3.42	3.58	3.57
Modulus of Rupture, psi (Av 3):	3000	950	2420	2280
Cold Crushing Strength, psi (Av 3):	17,090	3180	11,530	12,210
Thermal Conductivity, BTU-in/ft ² -hr-°F (ASTM C-1113, Hot Wire Method)				
400°F	37.8	15.0	30.4	32.1
600°F	34.5	14.0	25.0	27.1
1000°F	32.0	12.3	20.8	22.3
1400°F	28.8	11.5	19.5	20.3
1800°F	27.0	11.8	18.4	19.3

tjk

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Appendix C-6 – Thermal Ceramics Report on Evaluation (Runs 47-52)

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Thermal Ceramics

P. O. Box 923
Augusta, GA 30903

Tel 706-796-4200
Fax 706-796-4398

December 16, 1994

Mr. T.G. Swansiger
Aluminum Company of America
Chemical Systems Division
Alcoa Technical Center
100 Technical Drive
Alcoa Center, PA 15069-0001

Mr. Swansiger,

Please find attached a hard copy of the summary report for Alcoa's LWA. Thermal Ceramics feels that your product is commercially feasible. We would like to know the cost of the material and an expected date that Alcoa could begin supplying Thermal Ceramics.

Walt Campbell, Manager, Castable Refractories, will be billing you for the feasibility study Thermal performed on your LWA before the end of 1994.

If you have any questions, please give me a call at 706-796-4490.

Sincerely,

Joseph W. Breuer
Senior, R&D Engineer

JWB/dno

attachments

cc: 08-3539-00

C6-1

Morgan

Thermal Ceramics

THERMAL CERAMICS SUMMARY REPORT

FOR ALCOA

Shown in Tables I and II, are the results of Thermal Ceramics evaluation of Alcoa's light weight aggregate (LWA) in two of our formulas, KAO-TAB 95 and CEROX 700. In both mixes we substituted the LWA for Alcoa's T-64 alumina.

Testing methods are generally Thermal Ceramic test methods modified from ASTM Test methods, for example:

C-860	Ball-In-Hand,
C-134	Measured Bulk Density,
C-133	MOR and CCS,
C-113	Reheat Change,
C-417-93	Thermal Conductivity-Castables.

As shown in Table I, Kao-Tab 95 is a high alumina cement based castable containing about 75% aggregate and 25% cement. The mix with LWA required about 6% more water to achieve the same ball-in-hand as the standard mix based upon T-64 aggregate. I attribute this to the more porous nature of the LWA. Consequently, due in part to the increased water content, the resulting densities and strengths are less than the standard T-64 mix. However, this loss of strength is diminished at the higher firing temperature of 3200°F. Linear stability is not harmed by the lower grain density, as indicated by the linear shrinkage; the coefficient of thermal expansion is also the same as the T-64 mix.

As one might expect by the lower density, the thermal conductivity of the LWA based castable is lower than the T-64 containing mix. At higher temperatures this advantage seems to diminish.

Table II presents the results of the LWA study in CEROX 700. This mix is cast thixotropically, the bonds phase providing flow. CEROX 700 is a cement free formulation. The formula for Cerrox 700 also calls for only about 45% T-64 alumina or LWA grog. We screened the as received LWA grog to -1/4+8, 14M/F and 325M screen curves and then reassembled a 6M/F screen curve after the T-64 alumina curve. As can be seen, in Cerrox 700 we were able to cast it with only 0.5% more water than the standard CEROX 700 mix. Because of the LWA grain density, the samples with LWA fired to 2800°F are slightly less dense than those with T-64 alumina. However, the LWA samples are stronger fired at 2800°F and upon reheating to 3200F/5 hrs. They also shrink somewhat more upon reheating.

In an effort to explain the additional water needed for casting the KAO-TAB 95 LWA mix, we checked the bulk density and specific gravity of the LWA versus T-64 and found the following:

<u>6M/F</u>	<u>LWA</u>	<u>T-64</u>
Bulk Density,	118.5	141.4
Specific gravity	3.946	3.773

This difference in bulk density and the accompanying grain porosity may in part explain the additional water needed for casting in KAO-TAB 95. Also KAO-TAB 95 uses about 30% more LWA than the CERCX 700 mix.

In my opinion, Alcoa's LWA has commercial promise. However, a castable or thixotropic casting mix would have to be redesigned around the aggregate, because in my opinion, a direct substitution would not yield the optimum properties. Thermal Ceramics is interested in exploring further the use of Alcoa's LWA aggregate and it needs an estimated material cost and start up time of production of the LWA aggregate.

Joseph W. Breuer

TABLE I
KAOTAB 95 - ALCOA T64 AND LWA BASED

	KAOTAB 95 STANDARD PUBLISHED	KAOTAB 95 STANDARD	KAOTAB LWA AGGREGATE
6M/F T64 Al2O3	-	IN	-
6M/F ALCOA LW AGG.	-	-	IN
HAC	-	IN	IN
CEMENT MODIFIERS	-	IN	IN
WATER, %		7	13
MIX TIME, MIN.		5	6
REMARKS		GOOD BALL IN HAND	GOOD BALL IN HAND BUT DRYER THAN STANDARD
PHYSICAL PROPERTIES			
DRIED 220F			
DENSITY, PCF	-	180.0	156.0
MOR, psi	1300-1900	1755	875
CCS, psi	5000-8000	8435	3845
1500F/HRS.			
DENSITY, PCF	-	169.0	146.5
MOR, psi	800- 1600	2160	740
CCS, psi	6000-10000	9140	3600
LINEAR SHRINKAGE, %	-0.1 to -0.3	0.0	-0.1
3200F/HRS.			
DENSITY, PCF	163-173	164.5	145.0
MOR, psi	1400-1900	1680	1435
CCS, psi	6000-9000	4435	3700
LINEAR SHRINKAGE, %	0.0 to -1.5	+0.5	-0.1
THERMAL CONDUCTIVITY			
BTU*in./hr.*ft.^2*F			
MEAN TEMP. @ 500F	20.2	16.5	13.4
@1000F	16.7	13.8	11.2
@1500F	14.4	12.2	10.4
@2000F	13.2	11.2	10.1
@2500F	12.4	10.6	10.0
COEFFICIENT OF			
REVERSIABLE LINEAR			
EXPANSION, in/in/F	-	5.0X10^-6	5.0X10^-6

TABLE II
CEROX 700 - ALCOA T64 AND LWA BASED .

	CEROX 700 STANDARD PUBLISHED	CEROX 700 T64 AGG. STANDARD	CEROX 700 ALCOA LW AGG.
-1/4+8M T64 Al2O3	-	IN	-
14M/F T64 Al2O3	-	IN	-
325M T64 Al2O3	-	IN	-
-1/4+8M L.W. Al2O3	-	-	IN
14M/F L.W. Al2O3	-	-	IN
325M L.W. Al2O3	-	-	IN
BOND PHASE	-	IN	IN
WATER, %		5.5	6.0
DENSITY, PCF	173.0	174.7	167.8
MOR, psi	1600	1725	1820
3200F/5HR			
DENSITY, PCF	-	176.8	171.1
MOR, psi	-	1470	1925
LINEAR CHANGE, %	-0.4	-0.2	-0.4

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