INVESTIGATIONS OF LIGHTWEIGHT AGGREGATES IN ALASKA

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INTRODUCTION

Increased construction costs coupled with the current large demand for aggregate materials prompted an investigation by the Mineral Industry Research Laboratory to find deposits of shale suitable for the manufacture of lightweight aggregate near the cities of Anchorage and Fairbanks. This work was conducted under the auspices of Master of Science theses for the bacculauriate years of 1965[29] and 1966[22].

Lightweight concrete aggregate may be defined as any inert material, which, when combined with cement, will form a concrete of significantly less unit weight and with lower thermal conductivity than that produced by incorporating conventional aggregate. Lightweight aggregates may be divided into three classes: natural aggregates, by-products, and manufactured aggregates. Among the natural aggregates are volcanic ash, tuff, scoria, diatomite, breccia and vegetable products such as peat, straw and sawdust. By-product aggregates include cinders and furnace slags. Manufactured materials include expanded vermiculite, perlite, slag, clay, shale and slate. Investigations undertaken by MIRL were confined to expanding shales.

Use

Expanded shale is used for nearly all concrete applications. These include:

1. Concrete block
2. Insulating concrete

3. Structural concrete
4. Precast concrete
5. Prestressed concrete
6. Thin shell concrete construction
7. Aggregate for bituminous road construction
8. Jet plane runways and aprons
9. Loose insulation fill
10. Piers and superstructures of bridges and decks

The inherent advantage of lightweight aggregate is its low unit weight. A cubic foot of normal concrete weighs between 130 and 160 pounds, while lightweight aggregate concrete can weigh as little as 85 and up to 110 pounds per cubic foot with strengths comparable to that of normal weight concrete. From a structural standpoint, the dead load of normal weight concrete can be substantially reduced by using lightweight aggregate without any reduction in its load carrying capacity. Important savings can be realized from the reduction of the reinforcing steel required in horizontal slabs, beams and girders made from lightweight aggregate. Further reduction in cost may be realized through smaller column sizes, smaller footings or foundations, reduced lateral loads for seismic design, savings in air conditioning and heating costs due to better insulating qualities, and possible floor and wall thickness reductions for fire resistant regulations.[43] Savings may also be realized due to reduction in beam size because of lower concrete forming time. A 30% reduction in mass weight can result in reduced shoring and form construction requirements.

Desirable Characteristics of Expanded Shales

The desirable requirements for bloating clays or shales include: (9, 10, 11, 12, 13).

1. Aggregate Properties
    a. Uniform deposit chemically
    b. Crushing not to produce in excess of 20% minus eight mesh fines
    c. Bloating temperature between 1800-2300 degrees Fahrenheit
    d. Wide range of bloating
    e. Bulk density of aggregate between 45-75 pounds per cubic foot
    f. Absorption 0-18%
    g. Rounded shape to insure good workability
    h. Chemical inertness to insure strength of concrete
2. Geographic and Geologic properties to insure low production costs:
    a. Location close to market
    b. Presence of proper transportation facilities such as railroads and highways
    c. Presence of cheap fuel
    d. Sufficient size of deposit to insure several years production
    e. Thin overburden
    f. Location above groundwater or presence of proper conditions for a drain

Production of Expanded Shale

There are basically two different processing methods used to produce lightweight shale aggregate in the United States: the rotary kiln and the traveling grate methods. The rotary kiln method is used to produce by far the greater volume of aggregate, due principally to the superior qualities of the product over that made in the grate system.

Two types of aggregate, coated and sinter, are produced in a rotary kiln. Coated aggregate is produced by heating closely sized shale particles in the kiln until the particles expand to aggregate size; glassy outer coating is formed during the process. Sinter aggregate is manufactured by processing large diameter shale particles with subsequent crushing and gradation to aggregate specifications.

The traveling grate can produce a sinter type aggregate. This product is made by preparing a charge of shale and a small amount of coal or coke and passing it over an ignition hood on a traveling grate. The fuel is ignited, producing the heat required for shale expansion. The furnace product is then crushed and sized for use in concrete.

The rotary kiln process has the advantage of production of a uniform coated aggregate with low water absorption characteristics. Maintenance costs for this type of kiln are generally low and the operating reliability high. However, its disadvantages are:[48]

1. Fewer raw materials can be satisfactorily processed.

2. The initial cost of a kiln (and the installation cost) is usually high.
3. Unless properly designed and furnished with heat recuperating devices and a good cooler, the fuel consumption of a rotary kiln can be quite high.
4. The space requirement of a rotary kiln is usually greater than that of a traveling grate.
5. The feed size range to a rotary kiln usually must be quite narrow.

Materials with a very low bloating range may be satisfactorily processed in a traveling grate but will fuse since the grate is not influenced by balling of viscous particles as is the rotary kiln. Grate products generally suffer from high water absorption, poor quality control, and the grate method has high maintenance cost and high power consumption.[48]

Known Alaskan Lightweight Aggregates

The search for lightweight aggregate in Alaska is not new, for studies have been conducted and commercial attempts at production have been made. Although commercial production of lightweight aggregate has failed in the past it is important that new methods, deposits and ideas continue to be investigated, since what was not possible ten years ago may be possible today, or ten years from now.

At present the lightweight aggregate industry in Alaska is nonexistant. Several deposits which appear to have potential for lightweight aggregate production have been studied by the U. S.

Geological Survey[13], the U. S. Bureau of Mines [46,55] and the Mineral Industry Research Laboratory [22, 29] of the University of Alaska.

Eckhart and Plafker[13] sampled and tested shales and argillite from the Kings River, Sutton and Lawing areas, Alaska, concluding that these deposits would be suitable for production of lightweight aggregate.

Results of investigations of 35 deposits of clay, shale, argillite, limestone, gypsum and pumice were published by the Bureau of Mines[46] in 1953. After publication of this report, work was conducted by the U. S. Bureau of Mines in Alaska on mineral wool, expanded shale and limestone[55]. They produced an excellent mineral wool experimentally by mixing equal portions of shale and limestone from deposits near Cantwell, Alaska. Shale deposits tested for aggregate production were located at Mile 67, Glenn Highway; Mile 16, Matanuska Branch of the Alaska Railroad; and a railroad cut along Indian River, 166 miles north of Anchorage. The first two samples produced favorable aggregate characteristics.

Future of the Industry

Lightweight aggregates are relatively new compared to many other construction materials, but their use in the lower 48 states is now well established and markets are increasing. The industry should continue to grow as uses for lightweight aggregate become more diversified and lightweight products become more widely accepted by the construction industry.

Most producers in the United States and Canada are members of active organizations that are engaged in informing architects, engineers, and the public of the properties and uses of lightweight aggregates.

The major use of expanded shale aggregate has been in the concrete block or concrete masonry industry. Even though the block market is the largest user at the present time, it is felt that the structural concrete market will continue to increase in importance.

Bloating Mechanism

Expansion of shales is a bloating process in which two conditions must occur simultaneously. These are (1) the material must acquire a high temperature glassy phase with a viscosity high enough to trap a gas and (2) a gas must be liberated at the temperature at which the glassy phase is produced. The gas produced is trapped by the viscous glass, causing the shale to bloat.

Utley, Lovell and Spicer[28] have generalized the stages that occur when shales and clays are heated in an oxidizing atmosphere, as follows:

1. Drying and removal of free water to 200 degrees centigrade
2. Absorbed water dehydration period (200-480 degrees centigrade)
3. Chemically combined water dehydration period (480-700 degrees centigrade)
4. Oxidation period--iron, sulfur, carbon, etc. (500-1000 degrees centigrade)

5. Dissociation-reduction period--carbonates, sulfates, ferric to ferrous oxides (500-1000 degrees centigrade)
6. Vitrification period--first glass formation (900-1300 degrees centigrade)
7. Pyroplastic condition--period of bloating of most clays and shales (1150-1320 degrees centigrade)
8. Melting period--loss of vesicular structure and shape (1300-1500 degrees centigrade)

Deposit Locations

The Alaskan deposits which were tested are referred to as the Sutton, Kings River, Lawing, Moose Creek, Houston, and Elliott Highway deposits. The Sutton deposit was sampled from the road cut at Mile 16 on the Sutton Subdivision of the Alaska Railroad. The Kings River deposit was sampled from a road cut, 67 miles northeast of Anchorage, on the Glenn Highway. The Lawing on the Anchorage-Seward Highway; which is accessible from both the highway and the Alaska Railroad. The Moose Creek and Houston deposits are located in the vicinity of Moose River and Houston in southcentral Alaska, and were sampled by the Alaska Sand and Gravel Company, Anchorage, Alaska. The Elliott Highway deposits were sampled from road cuts at Miles 35, 44.7, 56, and 59, on the Highway between Fairbanks and Livengood (see Figure 1).

Approximately 100 to 150 pounds of shale were selected from each area, care being exercised to select portions of shale representing various bedding planes. The deposit at 34.5 mile is banded, being composed of alternating layers of red and green

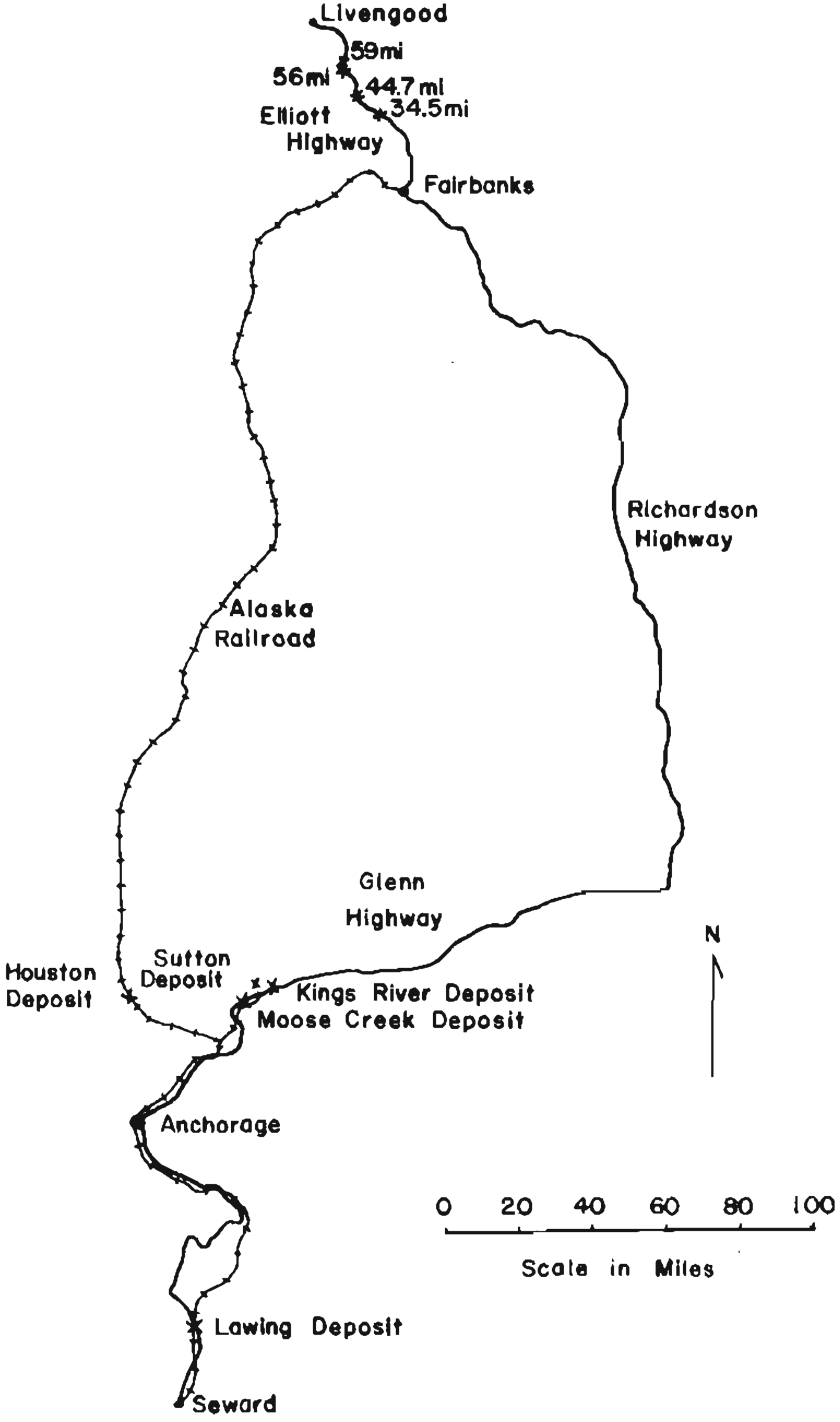


Fig. 1. -- Map of Deposit Locations

shale. Grab samples of each band were taken.

LABORATORY INVESTIGATIONS

Aggregate testing of the shale deposits was patterned after that published by the U. S. Bureau of Mines, I. C. No. 8122[5]. These procedures have been used by consulting firms and the Bureau as criteria for advancing shales for further testing in rotary kilns.

Laboratory tests designed to evaluate aggregate potential of the shales includes:

1. Drying characteristics
2. Crushing characteristics
3. Pelletizing characteristics
4. Slow-fire characteristics
5. Expansion properties
6. Bleb structure
7. Concrete strength
8. Concrete thermal conductivity

Preliminary Expansion Test

Initial tests were performed on each shale to determine if it would expand. The material was subjected to a temperature of 2300 degrees F. and retained in the furnace 10 minutes. The shale was considered to adequately expand when 75 percent would float on carbon tetrachloride, which has a specific gravity of 1.6.

Shales from Sutton, Kings River, Lawing, and the Elliott

Highway expanded satisfactorily. Samples from the Moose Creek and Houston deposits expanded slightly just prior to fusing but failed to meet the requirement of a specific gravity of 1.6.

The deposits which indicated favorable bloating properties were subjected to further testing while those that failed to adequately bloat were eliminated.

Physical Properties and Crushing Characteristics

An indication of the physical properties and crushing characteristics of shales is needed to provide information for crushing and screening circuit design. A shale which produces excessive amounts of minus eight mesh material would require special screening circuits to preclude "logging" or sticking of the fines in a rotary kiln. A shale which produces a size consist of 80% plus eight mesh may have the properties necessary for the production of a coated aggregate, i.e., presized particles which have been bloated to aggregate size and not crushed after bloating. Others may require the production of large sized shale particles with subsequent crushing and sizing to aggregate gradation, a process which destroys the outer vitrous coating formed during vitrification. Shales which produce a large amount of fines could be used provided that (1) the cost of mining was low enough to allow the fines to be wasted or (2) pugging and extruding machinery are incorporated into the plant circuit.

Two grab samples of each of the shales were selected, one exposed to open air while the other was placed in an oven maintained at 220 degrees Fahrenheit. These were observed at intervals for a two day period to ascertain the degree of splitting or spalling, if any. The remainder of the shales was crushed with a jaw crusher adjusted to a one inch closed set and then put through a roll crusher at one-half inch. Two representative split samples of each shale, weighing approximately four pounds each, were retained from the jaw and roll crusher products. These were used for screen analyses the results of which are presented in Tables 1 through 11, (Appendix).

The particles were observed to determine shape, thickness, type of fracture and layers of impurities such as sand, sandstone, calcite, etc.

Further crushing and screening tests would be necessary in the event a shale was selected for commercial production of aggregate. Size distributions obtained from cone, impact, and toothed roll type crushers may produce a better size consist for a particular type product.

Firing Tests

Firing tests were conducted in a Burrell High Temperature Furnace, Model 50, capable of obtaining a maximum temperature of 2650 degrees Fahrenheit. This furnace is heated by non-metallic, resistance-type heating elements with temperature controlled by a Brown Pyr-O-Vane Millivoltmeter Controller, reported to be accurate to plus or minus ten degrees Fahrenheit.

Slow-Fire Tests

The slow-fire tests were designed to give information concerning pelletizing properties, indications of the bloating range, sticking and melting temperature of the samples, percent absorption, expansion, shrinkage and color of the fired specimens. Such information is of value for setting limits for quick-fire tests and for design criteria for pugging and extruding plants.

A split sample of each shale was ground to minus 20 mesh. One hundred grams of this was made into a plastic mass by mixing with demineralized water; the working properties were noted in each case. Small briquettes were made from this mixture and marked for shrinkage due to drying at 230 degrees Fahrenheit.

Ten grams of the minus 65 mesh shale were mixed with 100 cubic centimeters of distilled water for pH determination. A pH determination usually permits the identification of a bloating material; non-bloaters having a pH of less than five and bloaters a pH greater than five.[31]

Pelletizing characteristics for the Elliott Highway shales are listed in Table 1. These include color, pH, strength, drying shrinkage, water of plasticity, drying requirements and working or forming characteristics. Tables 12 through 16, (Appendix) indicate pelletizing characteristics for Anchorage vicinity shales.

Six of the dry briquettes from each shale were placed in the Burrel Furnace and the temperature was raised 400 degrees Fahrenheit per hour for three hours. The heating rate was then sharply increased and briquettes were withdrawn at 1800 degrees Fahrenheit and at 100 degree increments until 2400 degrees Fahrenheit or melting occurred. The physical properties of color, hardness, percent absorption, percent expansion, percent shrinkage, apparent

TABLE 1

PELLETIZING CHARACTERISTICS

Characteristics	Unfired Properties 34.5 mile	44.7 mile	56 mile	59 mile
Color	light pink-grey	dark grey	light grey	medium grey
pH at 24°C.	9.5	7.5	9.1	9.2
Strength	low	low	low	low
Drying Shrinkage (%)	2.0	2.5	2.5	1.9
Water of Plasticity (%)	17.0	18.0	18.0	17.0
Drying Temperature	230°F.	230°F.	230°F.	230°F.
Working or Forming Characteristics	poorly plastic, poor wet strength, gritty	fairly plastic, fair wet strength gritty	fairly plastic, fair wet strength, slightly sticky and gritty	fairly plastic, fair wet strength, gritty but sticky

specific gravity and bulk specific gravity were determined. These are listed in Table 2 for Elliott Highway shales and Tables 17 through 21, (Appendix) for Anchorage vicinity shales.

Quick-Fire Tests

The quick-fire tests were designed to provide data necessary for establishment of temperature and retention time for initial rotary kiln testing. Samples of each shale were fired in the Burrel Furnace at temperatures of 1800 through 2300 degrees Fahrenheit in 100 degree increments or until over-bloating or fusing occurred. This procedure produced a series of samples representative of the entire bloating range.

Three size ranges, 3/4 x 1/2 inch, 1/2 x 1/4 inch and 1/4 inch x 8m of each shale were evaluated at retention times of five, ten and fifteen minutes each. This was necessary since kiln feed is generally composed of approximately these sizes.

At first, approximately 20 grams of material were placed in a fire clay scorifying dish and put into the furnace. It was found that spalling or splitting occurred and that shale particles overlain by others did not bloat. The latter condition was corrected by using smaller sample weights to insure unit coverage of the fire clay dish. Spalling was prevented by preheating all samples to 600 degrees Fahrenheit.

Bulk specific gravity, apparent specific gravity and percent absorption were obtained for each quick-fire test performed. These are listed in Tables 22 through 27, (Appendix).

TABLE 2

SLOW-FIRE PROPERTIES

Sample	Temp. (°F.)	Color	Hardness	Per cent Absorption	Per cent Expansion	Per cent Shrinkage	Apparent Sp.Gr.	Bulk Sp.Gr.
34.5	1850	tan	hard	----	----	---a	----	----
	1940	tan-brown	very hard	12.4	----	0.0	2.50	1.91
	2040	brown	steel hard	10.9	----	5.0	2.46	1.98
	2125	dark brown	steel hard	2.3	----	8.9	2.26	2.15
	2200	very dk.br.	steel hard	1.0	8.0	expanded	2.08	1.88
	2300	violet-blue	vitreous	5.1	40.0	expanded	0.95	0.91
44.7	1850	white-tan	hard	26.7	----	4.0	2.15	2.00
	1940	tan	very hard	12.1	----	4.0	2.37	2.09
	2040	red-tan	steel hard	8.9	----	5.0	2.37	2.25
	2125	dark brown	steel hard	4.4	----	9.0	2.33	2.12
	2200	very dk.br.	steel hard	1.0	4.0	expanded	1.98	1.94
	2300	very dk.br.	vitreous	2.2	25.0	expanded	1.11	1.08
56 mile	1850	cream-tan	hard	17.1	----	1.0	2.56	1.78
	1940	tan	very hard	15.6	----	2.2	2.57	1.84
	2040	dark tan	steel hard	11.8	----	5.0	2.50	1.93
	2125	very dk.br.	steel hard	3.8	----	0.0	2.16	2.02
	2200	very dk.br.	steel hard	2.1	30.0	expanded	1.05	1.03
	2300	very dk.br.	vetreous	2.2	70.0	expanded	0.94	0.92
59 mile	1850	tan	hard	16.1	----	1.0	2.66	1.86
	1940	tan	very hard	13.4	----	4.2	2.55	1.90
	2040	red-brown	steel hard	10.1	1.0	expanded	2.41	1.94
	2125	brown	steel hard	0.9	5.0	expanded	1.74	1.71
	2200	dark brown	steel hard	3.0	50.0	expanded	0.98	0.95
	2300	black-brown	vitreous	melted	70.0(b)	expanded	melted	melted

a. specimen crumbled when placed in furnace
b. approximate, specimen fused and stuck to crucible

Bleb and Surface Structure

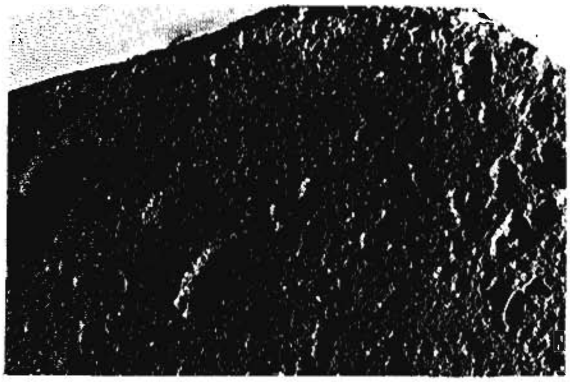
Examination of bleb structure was made by cutting selected pieces of the bloated shales with a diamond saw and subsequent observation through a binocular microscope. Good aggregate materials have a uniform pore structure with few oversize blebs.

Particle shapes and surface coating of the bloated aggregate were noted. Rounded or nodular shapes are desired for good concrete aggregate. These generally result from the expansion of clays or shales which have been pulverized, pugged, extruded, and then fired. Long irregular particles are less desirable for concrete aggregate as they reduce the workability of concrete and decrease the ultimate obtainable strength. The amount of irregular particles can often be reduced by proper crushing techniques which tend to produce cubic particles. Plate 1 shows bleb structure for an Elliot Highway shale. Note the outer vitreous layer indicating the degree of vitrification.

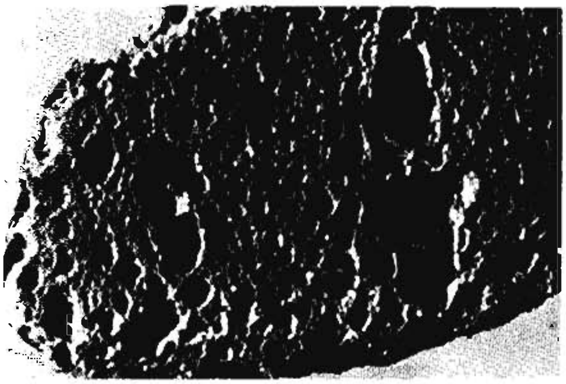
Evaluation of Lightweight Aggregate in Concrete

Tests were designed to give an indication of the concrete making properties of each shale lightweight aggregate. These provide further indications as to the feasibility of expensive rotary kiln testing of a deposit and provide criteria which may help a commercial company select a particular deposit for such investigations.

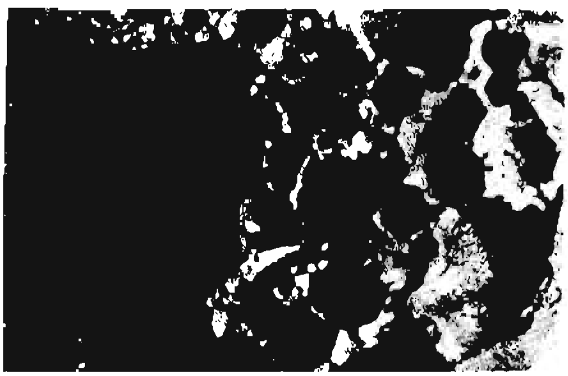
Sufficient aggregate was expanded from each of the expanding shales to make concrete for compression and thermal conductivity tests. Expansion was achieved in a large electric kiln



Test Sample After Quick-fire Test @ 1900° F.



Test Sample After Quick-fire Test @ 2000° F.



Test Sample After Quick-fire Test @ 2250° F.

Plate One

manufactured by Smith Engineering Company. It is capable of attaining a temperature of 2300 degrees Fahrenheit for short periods of time. Kiln temperature is controlled by a Model JL Gardsman Indicating Pyrometric Controller, manufactured by West Instrument Corporation.

The large inside diameter of the kiln easily accomodated the 6 x 4 x 10 inch fire clay dishes used for shale bloating. It has the disadvantage of a 100 degree Fahrenheit temperature drop during insertion of the shale to the kiln. This necessitated calibration of bloating temperature and time to obtain the density required of the expanded aggregate. An average density of 1.50 was attempted by this process for each shale.

Three different size ranges were processed for each shale, 3/4 x 1/2 inch, 1/2 x 1/4 inch and 1/4 inch x 8m. Enough shale to cover the bottom of the fire clay dish was preheated to 500 degrees Fahrenheit and then placed in the kiln for the required length of time to produce a density of approximately 1.50. The bloated shale was then screened to produce 3/4 inch x 4m, 4m x 8m, 8m x 16m, 16m x 30m, 30m x 50m, 50m x 100m and 100m x 9, U. S. Standard size fractions.

Aggregate gradation was prepared in accordance with one selected by the U. S. Bureau of Reclamation for testing Haydite expanded shale, as cited by Hamlin and Templin[32]. The test specimens were made with equal volumes of coarse and fine aggregate. Unit weight of coarse and fine aggregate was determined by the ASTM[33] Method C330 for dry loose unit weights. Combined aggregate weights were also obtained by this method.

Fineness modulus of the aggregate used was determined in accordance with ASTM[33] Method C125. The fineness modulus of an aggregate is the sum of the cumulative percentages retained in the sieve analysis divided by 100, when the following Tyler screens are used: 100, 48, 28, 14, 8, 4, 3/8 inch, 3/4 inch, 1 1/2 inch and coarser, if required, with each succeeding sieve having an opening double that of the preceding screen. The combined fineness of the coarse and fine aggregate is computed by taking a direct proportion of the fineness modulus of each and the quantities of each:

$$M = \%F(Mf) = \%C(Mc)$$

where

M = Fineness modulus combined aggregate
Mf = Fineness modulus fine aggregate
Mc = Fineness modulus coarse aggregate
%F = Weight percent fine aggregate
%C = Weight percent coarse aggregate

Proportions of cement to aggregate were selected to yield mixtures containing six sacks of cement per cubic yard of concrete for the Elliott Highway shales, and seven sacks for Kings River, Lawing and Sutton aggregates. The method of calculating the weight of cement to obtain six sacks concrete was based upon that reported by the American Concrete Institute[34]. Specimens from Sutton, Lawing and Kings River were based upon a mixture of 800 grams Type I Portland cement and 1200 grams aggregate. In order to insure uniformity between batches, the following mix procedures were adopted for the Elliott Highway shales.

1. The coarse aggregate (3/4 inch x 4m) was thoroughly mixed with the fine aggregate (4m x 9).

2. The combined aggregate and cement were mixed dry.
3. Water was added in small increments until good workability was obtained.
4. The batch mix was tamped into two inch molds.
5. One 1 x 6 x 6 inch mold was filled and tamped.
6. The concrete was allowed to set for 24 hours, and was then removed from the molds.
7. Curing was then accomplished in moisture cans for seven and 28 days.
8. Bulk density and percent absorption were obtained at 28 days.

Concrete mix specifications are listed in Tables 28 through 31, (Appendix). These give gradation unit weight, and fineness modulus of the coarse and fine aggregate as well as characteristics of the combined aggregate for the Elliott Highway shales.

The following procedure was used for the Anchorage vicinity shales: (1) the aggregate was sized according to Table 3, (2) the coarse aggregate (-.742 + 4 mesh) was mixed with sufficient water to wet the particle surfaces, (3) the cement and fine aggregate (-4 mesh) were mixed dry, (4) the coarse and fine materials were mixed, and (5) enough water was added to obtain good workability. The batch was then tamped into 3, 2 inch cube molds for strength tests, and 2, 6 inch by 6 inch by 1 inch molds for thermal conductivity tests. The concrete was allowed to set for 6 hours before it was removed from the molds and stored overnight under wet towels. The 2 inch cubes were then cured in an auto-clave for 3 hours at 422 degrees Fahrenheit and 300 psi

TABLE 3

SCREEN ANALYSIS OF AGGREGATE FOR CONCRETE MIX OF ANCHORAGE VICINITY SHALES

U. S. Standard Screen			Cumulative Weight Per Cent	
Passed	Retained	Weight Per Cent	Retained	Passed
3/4-inch	3/8-inch	25	25	100
3/8-inch	4-mesh	25	50	75
4-mesh	8-mesh	5	55	50
8-mesh	16-mesh	10	65	45
16-mesh	30-mesh	13	78	35
30-mesh	50-mesh	11	89	22
50-mesh	100-mesh	7	96	11
100-mesh	--------	4	100	4

steam pressure.

Compressive Strength Tests

Compressive strength tests of the two inch cubes from the Elliott Highway were performed at seven days and at 28 days with an electrically operated hydraulic press manufactured by Soiltest under the trade name "Versa-Tester". The load was applied at a constant rate of 60 pounds per square inch per second until failure occurred. These values give indications of the strength and bonding properties of the aggregate in concrete. Specifications for concrete block require a minimum compressive strength of 1000 pounds per square inch and structural concrete a minimum of 2500 pounds per square inch.

A load rate of 0.035 inches per minute was used for the Anchorage vicinity concrete specimens. Compressive strength, density and percent absorption are listed in Table 4.

Thermal Conductivity Test

The apparatus used to measure thermal conductivity was constructed to meet the specifications of ASTM C 177-45[4]. A guarded hot plate was constructed with the guard thermostatically controlled and temperatures measured by thermocouples. The interior plate was made of 1/4 inch aluminum and measured 4 inches by 4 inches. The guard plate was also constructed of 1/4 inch aluminum and extended 2 inches beyond the central plate. The guard and central plate were separated by a 1/8 inch air gap. Thermocouples were mounted in the plate and the guard. The heating

TABLE 4

COMPRESSION STRENGTH TEST

Sample	Lbs./Ft.^{3} Density	7 Day(psi)	28 Day(psi)	Strength,psi**
Sutton 1	75.13	----	----	2380
Sutton 2	73.28			1900
Sutton 3	76.32			2750
Kings River 1	69.85	----	----	1850
Kings River 2	68.48			1700
Kings River 3	66.62			1625
Lawing 1	71.90	----	----	1925
Lawing 2	69.90			1800
Lawing 3	77.08			2200
Average				
Sutton	74.91	----	----	2343
Kings River	68.32			1725
Lawing	72.96			1975
34.5 mile	113.3	2900	3900	----
			5438	
			3825	
44.7 mile	94.5	1925	3125*	----
			1975*	
			4500	
56 mile	94.5	1775	2425	----
			3000	
			2450	
			2775	
59 mile	98.1	2425	3662	----
			2900	
			2438	
			3900	

* Air voids due to difficulty of tamping large aggregate in 2 x 2 inch mold.

** Cured by auto-clave for 3 hours at 422°F, 300 psi steam pressure.

element used was nichrome wire. The guard and plate were encased in 1 to 2 inches of polyurethane expanded foam insulation, leaving an opening for the test sample. A 6 inch by 6 inch by 1 inch test sample is accommodated on the hot plates; a water cooled heat sink rests on the sample, (Figure 2).

Other items of equipment used with the hot plates were (1) a voltage regulator to maintain constant voltage, (2) two variacs to control the plate temperatures, (3) a variable resistor, operated by a thermostatically controlled relay, to reduce the power input to the guard plate, (4) a wattmeter to measure the central plate power, (5) an ice bath for a temperature reference, and (6) a millivolt potentiometer to measure the thermocouple temperatures, (Figures 3 and 4).

The test samples were cut and ground to an accurate thickness of 1 inch, dried, and weighed to determine specific gravity. Each sample to be tested was placed in the apparatus and the hot plate voltage set to the desired level. The guard plate and the thermostat were adjusted to the temperature of the hot plate and the system was allowed to stabilize. After stabilization the temperature drop between the hot and cool plates was recorded. The thermal conductivity in B.T.U. per hour per square foot of plate area per degree F. per foot of sample thickness was calculated by the formula:[4]

$$k = \frac{QL}{A(t1-t2}$$

where:

k = thermal conductivity in B.T.U./Hr./Sq. Ft./Deg. F./Ft.
Q = B.T.U. per hour (watts times 3.413)
L = thickness of test sample in feet
A = flat surface of hot plate in square feet
t1 = temperature of hot plate in degrees F.
t2 = temperature of cool plate in degrees F.

The results of the thermal conductivity test are listed in Table 5.

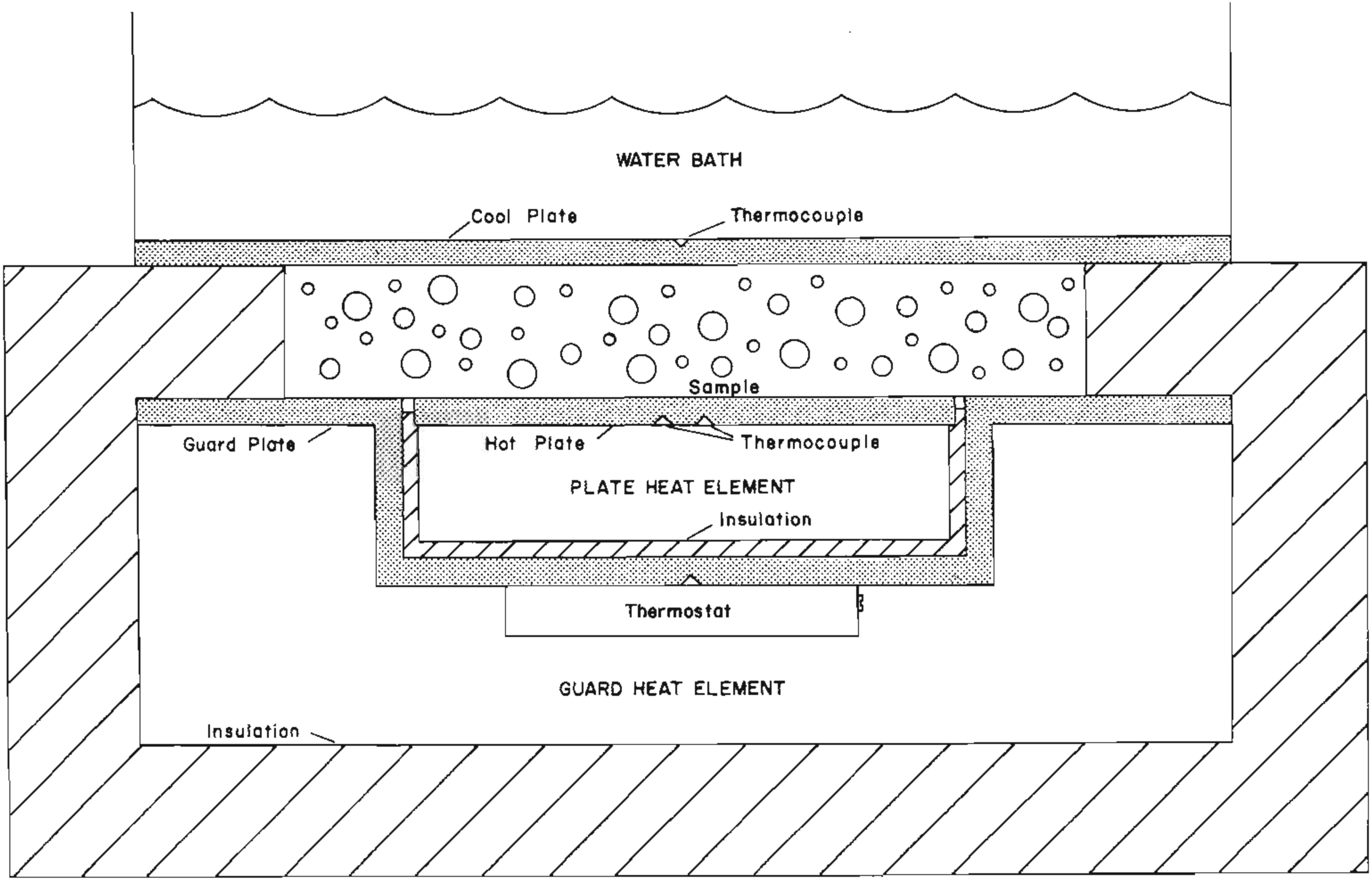


Fig. 2. -- Sectional View of Heat Transfer System

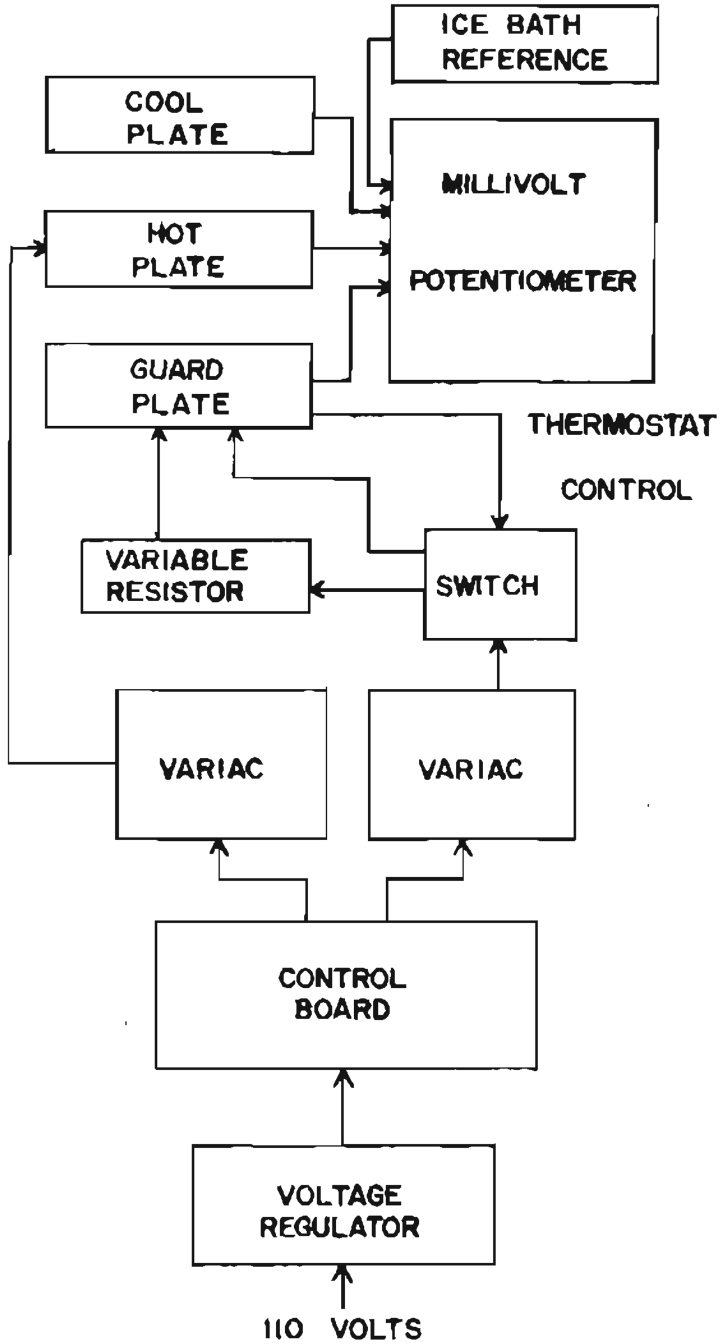


Fig. 3.--Block Diagram of Thermal Conductivity Apparatus

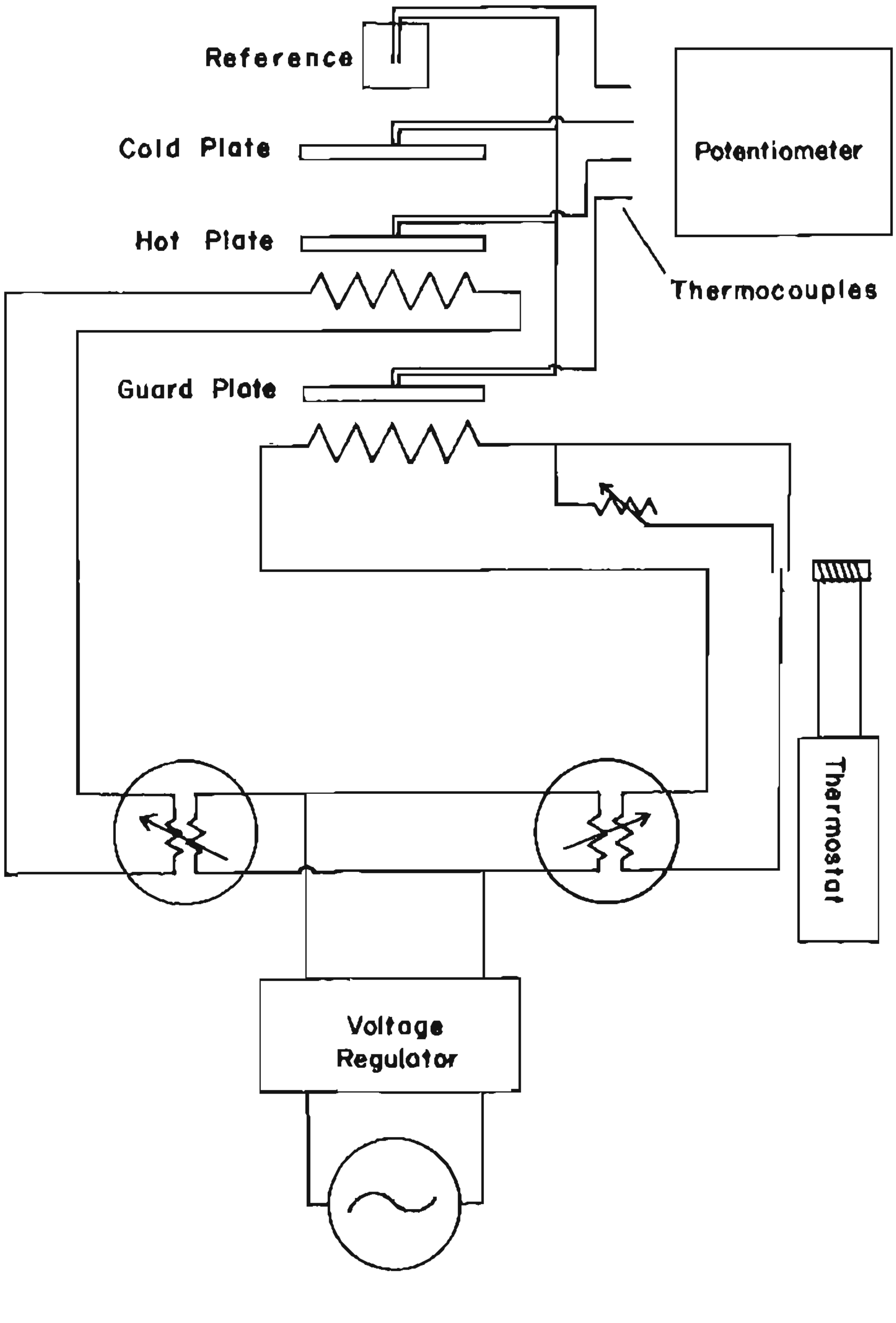


Fig. 4.-- Schematic of Thermal Conductivity Apparatus

TABLE 5

THERMAL CONDUCTIVITY

Sample	k factor run 1	k factor run 2
Sutton	.585	.569
	.588	.588
	.589	.589
Kings River	.529	.527
	.530	.525
	.532	.530
Lawing	.559	.564
	.560	.568
	.558	.565
Cork, Chipboard	0.34	0.37
34.5 mile shale	6.76	6.61
44.7 mile shale	7.26	7.18
56 mile shale	6.56	6.54
59 mile shale	6.59	6.48

ANALYSIS OF TESTING

Preliminary Expansion Tests

Preliminary tests as described were necessary in order to reject shales which do not expand from further testing. A check of the 34.5 mile sample which was reported as non-bloating shale[20,29] established that this shale did produce a product of such density to warrent further testing. Shale samples from Sutton, Lawing and Kings River expanded satisfactorily. Samples from Houston and Moose Creek did not and further testing of these shales was stopped.

Drying Characteristics

Each shale was observed under conditions of room temperature and at 200 degrees Fahrenheit. No evidence of spalling or splitting occurred. Splitting did occur, however, for all shales tested when placed in a furnace above 1800 degrees Fahrenheit without preheating. Since a rotary kiln first drys, then bloats suddenly, it is believed that each of the four shales successfully pass the drying tests.

Crushing Characteristics

Stage crushing of the shales through jaw and roll crushers established that all shales tested contained less than 20% minus eight mesh material, averaging close to 10%. The samples tested had been exposed to the weather, indicating that crushing properties may improve with the depth of deposit. Other types of crushers are generally more suitable for size reduction of platy material and tests with these probably would establish even better crushing characteristics.

Slow-Firing Tests

The slow-fire tests provide information which is necessary for design of a pelletizing circuit in the event excess fines are to be recovered and manufactured. 34.5 mile shale had poor working or forming characteristics as did the Lawing shale, while the rest of the shales were fairly plastic and had fair wet strength. These designations are admittedly vague but were developed by comparisons with a clay sample which has "good" working characteristics. A temperature of 2300 degrees Fahrenheit was needed to produce a bloated product of 34.5 mile shale. At this temperature, the outer coating of the pellet was fused and stuck strongly to the fire clay dish. A temperature of 2300 degrees Fahrenheit was also required for 44.7 mile shale expansion to a density less than 1.60. Density of 1.60 is considered the maximum allowable for lightweight aggregate, since densities in excess of this would exceed maximum unit weights for aggregates as specified by ASTM Standards[32]. Sutton, Kings River, Lawing, 56 mile and 59 mile shales produced excellent bloats at 2200 degrees Fahrenheit. A temperature slightly less than this would produce a satisfactory aggregate density.

The apparent specific gravity, bulk specific gravity and percent absorption were computed by the following formulas:[41]

Apparent specific gravity = A/A-C

Bulk specific gravity = A/B-C

Absorption percent = B-A/A x 100

where:

A = weight in grams of oven dried aggregate
B = weight in grams of saturated surface dried aggregate
C = weight in grams of saturated aggregate (24 hour soak suspended in water)

A surface dry condition was obtained by blotting the aggregate particles with absorbent paper. Weighing was accomplished using a scale accurate to 0.1 grams. Suspended weights were measured utilizing a pan balance with wire cage suspended in water attached to it.

Expansion and shrinkage data were calculated from changes in length of the pellets. Expansion of the bloated pellets ranged from 25% for 44.7 mile shale to 70% for 56 and 59 mile shales. 34.5 shale had a 40% expansion at 2300 degrees Fahrenheit.

Percent absorption for each shale was high at 1800 degrees Fahrenheit, decreasing to a minimum at bloating temperatures with the formation of a non-pervious outer coating on each pellet. This value was extremely low for each shale.

Quick-Fire Tests

An evaluation of quick-fire tests is best accomplished by constructing density-time temperature curves. By doing so, shales which have an irratic bloat, or short expansion range, can be readily detected. An extremely short bloating range will result in a non-uniform rotary kiln product due to difficulty of kiln control. On the other hand, an excessively long expansion time may require a kiln of such length as to be economically unfeasible.

Temperature-density curves, Figures 1 through 4, (Appendix) were constructed from laboratory test data for each shale sample. An example curve is presented as Figure 5.

ASTM Specifications C331/64T, C332-61 and C33064T[33] require unit weights of 55 to 70 pounds per cubic foot. The actual density of aggregate particles to meet these requirements varies with packing, maximum permissible densities being not far from 1.25 for coarse aggregate and 1.60 for fine aggregate[41]. A range of 1.0 and 1.60 was arbitrarily selected for evaluation of the bloating range meeting aggregate specifications.

34.5 mile shale requires a bloating time of 15 minutes to reach a maximum density of 1.2 for 3/4 x 1/2 inch sizes. This is the minimum density obtainable, as 1/2 x 1/4 inch and 1/4 inch x 8m particles begin to fuse, thereby losing gas as the time of bloating increases beyond five minutes. At this density (1.2) the particles have a sticky outside coating and could cause problems in rotary kiln production of aggregate. It was found that a bloating temperature of 2100 degrees Fahrenheit for ten minutes could be used for all size ranges without producing appreciable sticking of the aggregate. This results in a product having a density range of approximately 1.4 for coarse particles, to 1.7 for fines.

The 34.5 mile shale is banded with alternate layers of red and green shale. Previous tests with this sample were

EXAMPLE

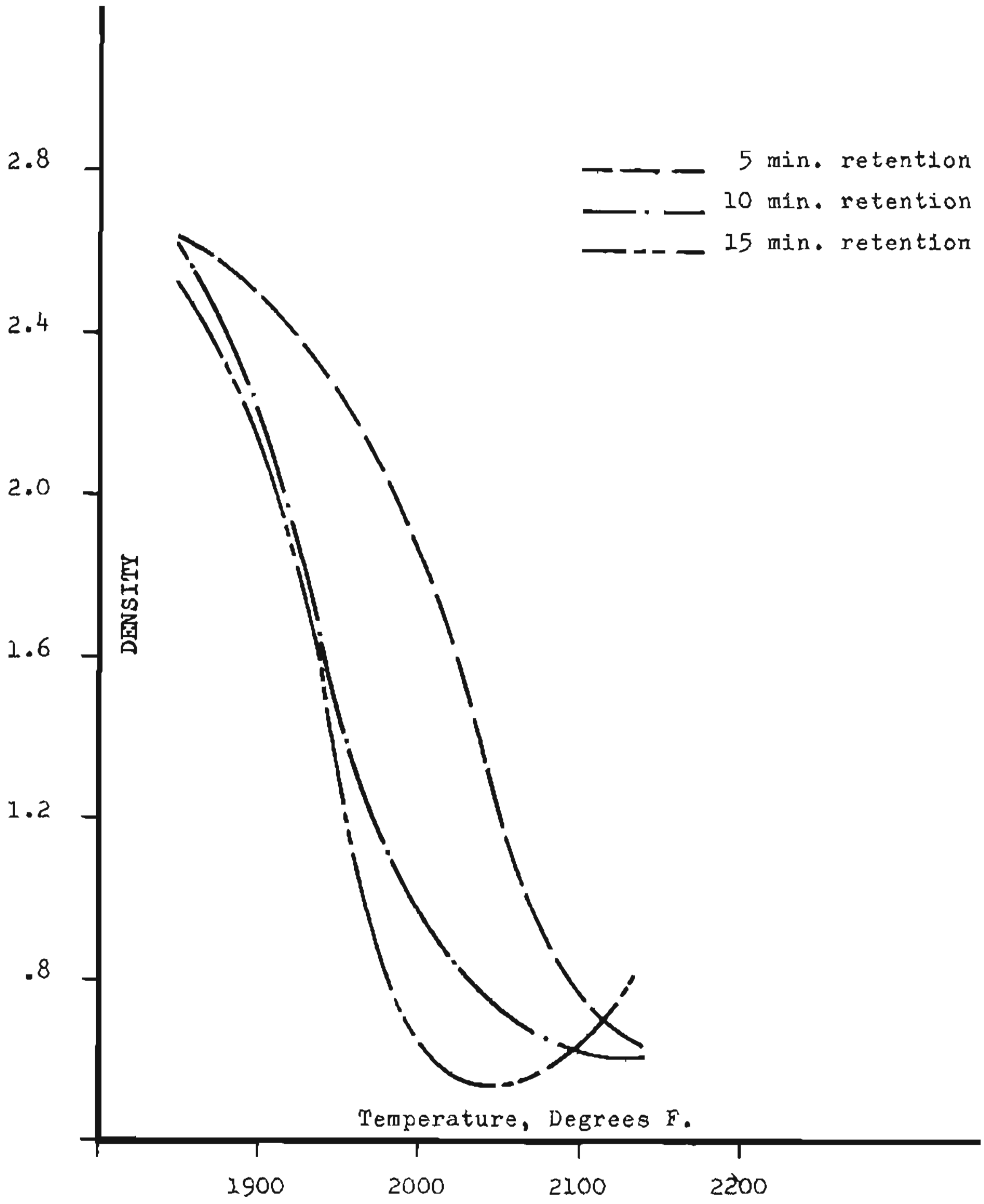


FIGURE 5, EXPANSION CURVE, 59 MILE 1/4"x 8m SHALE composed of a mixture of the two layers. Density curves of each of the bands are presented as Figure 1a, (Appendix) of the 1/2 x 1/4 inch size fraction. Examination of these curves shows little difference in the expansion characteristics of each.

A bloating range of about 85 degrees Fahrenheit is all that could be expected from this shale. Further temperature increases would produce a lighter product, but not without sticking. The shale aggregate produced has an exceedingly low water absorption percent. This may be observed in Table 22, (Appendix).

Quick-fire characteristics for 44.7 mile shale are excellent. A bloating range of between 75 degrees Fahrenheit and 160 degrees Fahrenheit is possible, depending upon the time selected for expansion. Minimum densities for all sizes of kiln feed were possible at retention times of five, ten and fifteen minutes. No sticking was noted for particles having a density of greater than 1.0.

The presence of banding, or foreign substances in the sample, was not found. The fact that the expansion curves are very smooth indicates that the shale sample is of uniform composition. Percent water absorption of the aggregate may be observed in Table 24, (Appendix). Throughout each quick-fire test, a coated aggregate with low water absorption is possible with this shale.

Expansion curves for 56 mile shale are quite erratic in the 3/4 x 1/2 inch and 1/2 x 1/4 inch fractions. The 1/4 inch x 8m fraction produces a smooth density change versus temperature for five and ten minutes retention times and a steep curve for

15 minute retention. This is believed due to the extremely short bloating range, in the order of approximately 45 to 70 degrees Fahrenheit, depending upon size of aggregate and time used for expansion. This shale could cause problems in rotary kiln production due to this short range. The sample used for the tests was weathered and had been exposed to surface drainage. It is quite possible that a better density-temperature range could be produced by selecting an unexposed sample.

Percent absorption of this shale at lightweight density is good, on the order of 5-6%. Aggregate shape tends to be quite round, a property not too often associated with shale aggregate.

The bloating range for 59 mile shale ranges from 45 to 75 degrees Fahrenheit. Bloating occurs at relatively low temperatures as may be observed from Figures 3 and 4, (Appendix). Aggregate shapes were generally angular with a few percentage of spherical pieces. Water absorption, Table 14, (Appendix) was generally low. This shale has excellent quick-fire properties indicating that a range of lightweight aggregate weights could be produced.

Expansion curves for the Anchorage vicinity shales are presented as averages of the size gradation products. Note that these curves are expressed in pounds/ft^3 rather than density. These curves were compared to a standard commercial bloating shale presented by Hamlin and Templin. The weights are actual weights as determined by laboratory procedures and do not represent aggregate density as obtained by the ASTM container method. The comparison is stated by Mr. Loskamp as "being significant in the portion below 80 pounds per cubic foot."

Shales from the Sutton and Kings River deposits were found to be somewhat better than the standard in the significant portion. The Lawing shale did not compare favorably with the standard due to the presence of refractory material which did not bloat. This shale did compare favorably, however, after removal of the nonbloating product.

Analysis of Bleb Structure

Samples representing the entire temperature range for each shale were cut with a diamond saw to enable examination of vesicular structure. Photographs of selected samples of the Elliott Highway shales are presented as Plate 1. Formation, size and shape of the vesicular structure were observed. Each shale had uniform vesicular structure in the aggregate range, tending to overdevelop as temperatures were increased beyond the density required for lightweight aggregate.

Compressive Strength

No attempt was made to evaluate concrete strength versus density of aggregate produced. These studies and many others would have to be performed on rotary kiln produced aggregate and such information may or may not conform to the information given here. These tests are, then, an indication that the bloated shale could produce required strengths for lightweight aggregate. All shales tested suggest strength capabilities suitable for the manufacture of concrete.

Concrete Thermal Conductivity Tests

These tests indicate that the shales produced concrete with a thermal conductivity of at least two-thirds that of normal weight concrete. These values are approximate as good thermal conductivity could not be obtained to accurately check the calibration of the apparatus used. Corkboard, composed of cork particles pressed together, was used for calibration. Solid cork has a value of near 0.27; a value of 0.37 was obtained with the corkboard used. This value was considered close enough for round comparison of shale aggregate values with those of normal concrete.

CONCLUSIONS

The results of the preliminary tests performed indicate that shale deposits from 44.7 and 59 mile on the Elliott Highway, and the Sutton and Kings River shales, near Anchorage, may be suitable for production of lightweight aggregate. These shales should be sampled systematically and tested under commercial conditions.

Shales from 34.5 and 56 mile, Moose Creek, and Houston should be tested further prior to their adaption as shale aggregate.

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APPENDIX

TABLE I

SCREEN ANALYSIS OF RAW MATERIAL*

Size	Crushed material, per cent weight	
	Sutton # 1 air dry	Sutton #1 oven dry
+ 3/4 inch	2.7	2.1
- 3/4 inch + 1/2 inch	20.7	17.0
- 1/2 inch + 1/4 inch	67.0	62.7
- 1/4 inch + 8-mesh	7.6	15.4
- 8-mesh	2.0	2.8
	Sutton #2 air dry	Sutton #2 oven dry
+ 3/4 inch	2.9	4.5
- 3/4 inch + 1/2 inch	23.7	18.6
- 1/2 inch + 1/4 inch	58.1	60.3
- 1/4 inch + 8-mesh	12.1	12.3
- 8-mesh	3.2	4.3
	Sutton #3 air dry	Sutton #3 oven dry
+ 3/4 inch	6.0	1.9
- 3/4 inch + 1/2 inch	19.3	24.0
- 1/2 inch + 1/4 inch	55.4	57.9
- 1/4 inch + 8-mesh	17.4	15.0
- 8-mesh	1.9	1.2
	Sutton #4 air dry	Sutton #4 oven dry
+ 3/4 inch	6.9	6.2
- 3/4 inch + 1/2 inch	21.7	14.6
- 1/2 inch + 1/4 inch	53.9	50.1
- 1/4 inch + 8-mesh	16.3	25.2
- i-mesh	1.2	3.9
	Sutton #5 air dry	Sutton #5 oven dry
+ 3/4 inch	4.8	4.8
- 3/4 inch + 1/2 inch	23.5	17.1
- 1/2 inch + 1/4 inch	53.3	45.7
- 1/4 inch + 8-mesh	16.9	26.7
- 8-mesh	1.5	5.7

*Tyler Mesh

TABLE II

Size	Crushed material,	per cent weight
	Kings River #1 air dry	Kings River #1 oven dry
+ 3/4 inch	14.2	13.2
- 3/4 inch + 1/2 inch	37.1	34.5
- 1/2 inch + 1/4 inch	32.4	36.8
- 1/4 inch + 8-mesh	10.8	10.8
-8-mesh	5.5	4.7
	Kings River #2 air dry	Kings River #2 oven dry
+ 3/4 inch	13.7	10.3
-3/4 inch + 1/2 inch	35.7	27.2
- 1/2 inch + 1/4 inch	39.4	36.1
- 1/4 inch + 8-mesh	8.9	16.3
-8-mesh	2.3	10.1
	Kings River #3 air dry	Kings River #3 oven dry
+ 3/4 inch	10.9	13.0
- 3/4 inch + 1/2 inch	28.0	35.6
- 1/2 inch + 1/4 inch	38.0	33.3
- 1/4 inch + 8-mesh	15.3	11.4
-8-mesh	7.8	6.7
	Kings River #4 air dry	Kings River #4 oven dry
+ 3/4 inch	12.8	13.9
- 3/4 inch + 1/2 inch	30.5	38.4
-1/2 inch + 1/4 inch	34.9	34.5
- 1/4 inch + 8-mesh	15.3	8.4
-8-mesh	6.5	4.8
	Kings River #5 air dry	Kings River #5 oven dry
+ 3/4 inch	11.0	15.7
- 3/4 inch + 1/2 inch	29.6	33.4
- 1/2 inch + 1/4 inch	40.7	34.8
- 1/4 inch + 8-mesh	12.5	11.2
- 8-mesh	6.2	4.9

TABLE III

Size	Crushed material, per cent weight	
	Lawing #1 air dry	Lawing #1 oven dry
+ 3/4 inch	23.2	23.5
- 3/4 inch + 1/2 inch	21.2	13.8
- 1/2 inch + 1/4 inch	30.0	25.9
- 1/4 inch + 8-mesh	17.5	19.8
- 8-mesh	8.1	16.7
	Lawing #2 air dry	Lawing #2 oven dry
+ 3/4 inch	20.5	16.6
- 3/4 inch + 1/2 inch	21.9	22.4
- 1/2 inch + 1/4 inch	26.5	29.7
- 1/4 inch + 8-mesh	17.1	18.4
- 8-mesh	14.0	12.9
	Lawing #3 air dry	Lawing #3 oven dry
+ 3/4 inch	26.5	22.4
- 3/4 inch + 1/2 inch	22.7	22.4
- 1/2 inch + 1/4 inch	26.0	27.0
- 1/4 inch + 8-mesh	14.3	16.4
- 8-mesh	10.5	11.8
	Lawing #4 air dry	Lawing #4 oven dry
+ 3/4 inch	37.4	39.5
- 3/4 inch + 1/2 inch	17.6	15.4
- 1/2 inch + 1/4 inch	20.0	22.7
- 1/4 inch + 8-mesh	13.8	14.5
- 8-mesh	11.2	7.9
	Lawing #5 air dry	Lawing #5 oven dry
+ 3/4 inch	22.0	16.5
- 3/4 inch + 1/2 inch	17.3	20.9
- 1/2 inch + 1/4 inch	29.9	38.5
- 1/4 inch + 8-mesh	19.5	18.8
- 8-mesh	11.3	15.3

TABLE IV

SCREEN ANALYSES, JAW CRUSHER PRODUCT, FOR

34.5 MILE SHALE*

Minus One Inch Closed Set, Test No. 1

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		567.5	34.8	34.8	
	3/4"				65.2
1/2"		354.5	21.7	56.5	
	1/2"				43.5
1/4"		332.0	20.3	76.8	
	1/4"				23.2
8m		224.0	13.8	90.6	
	8m				9.4
pan		154.0	9.4	100.0	
Totals		1632.0	100.0		

Minus One Inch Closed Set, Test No. 2

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		411.5	31.2	31.2	
	3/4"				68.8
1/2"		257.0	19.5	50.7	
	1/2"				49.3
1/4"		330.5	25.0	75.7	
	1/4"				24.3
8m		189.0	14.3	90.0	
	8m				10.0
pan		132.5	10.0	100.0	
Totals		1320.5	100.0		

* Tyler Mesh

TABLE V

SCREEN ANALYSES, ROLL CRUSHER PRODUCT, FOR

34.5 MILE SHALE

One-Half Inch Roll Set, Test No. 1

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.00
3/4"		774.0	17.70	17.70	
	3/4"				82.32
1/2"		1162.0	26.58	44.28	
	1/2"				55.72
1/4"		1311.0	29.99	74.27	
	1/4"				25.73
8m		665.0	15.21	89.48	
	8m				10.52
pan		460.0	10.52	100.00	
	Totals	4372.0	100.00		

One-Half Inch Roll Set, Test No. 2

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.00
3/4"		917.0	18.48	18.48	
	3/4"				81.52
1/2"		1244.0	25.07	43.55	
	1/2"				56.45
1/4"		1516.0	30.55	74.10	
	1/4"				25.90
8m		762.0	15.36	89.46	
	8m				10.54
pan		523.0	10.54	100.00	
	Totals	4962.0	100.00		

TABLE VI

SCREEN ANALYSES, JAW CRUSHER PRODUCT, FOR

44.7 MILE SHALE

Minus One Inch Closed Set, Test No.1

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.00
3/4"		655.0	32.2	32.2	
	3/4"				67.8
1/2"		424.0	20.9	53.1	
	1/2"				46.9
1/4"		461.5	22.8	75.9	
	1/4"				24.1
8m		287.5	14.1	90.0	
	8m				10.0
pan		204.0	10.0	100.0	
	Totals	2032.0	100.0		

Minus One Inch Closed Set, Test No. 2

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.0
3/4"		599.0	32.8	32.8	
	3/4"				67.2
1/2"		274.5	15.0	47.8	
	1/2"				52.2
1/4"		405.5	22.3	70.1	
	1/4"				29.9
8m		309.5	16.9	89.0	
	8m				13.0
pan		237.5	13.0	100.0	
	Totals	1826.0	100.0		

TABLE VII

SCREEN ANALYSES, ROLL CRUSHER PRODUCT, FOR 44.7 MILE SHALE

One-Half Inch Roll Set, Test No. 1

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.0
3/4"		701.0	34.4	34.4	
	3/4"				65.6
1/2"		395.0	19.4	53.8	
	1/2"				46.2
1/4"		512.5	25.1	78.9	
	1/4"				21.1
8m		264.0	12.9	91.8	
	8m				8.2
pan		167.0	8.2	100.0	
	Totals	2039.5	100.0		

One-Half Inch Roll Set, Test No.2

Mesh On	Mesh Pass	Weight On (gr.)	Per cent On	Cumulative Per cent On	Cumulative Per cent Pass
	1"				100.0
3/4"		563.0	32.54	32.54	
	3/4"				67.46
1/2"		360.0	20.82	53.36	
	1/2"				46.64
1/4"		489.0	28.26	81.62	
	1/4"				18.38
8m		221.0	12.77	94.39	
	8m				5.61
pan		97.0	5.61	100.00	
	Totals	1730.0	100.00		

TABLE VIII

SCREEN ANALYSES, JAW CRUSHER PRODUCT, FOR

56 MILE SHALE

Minus One Inch Closed Set, Test No.1

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		828.0	32.7	32.7	
	3/4"				67.3
1/2"		647.0	25.5	58.2	
	1/2"				41.8
1/4"		601.5	23.7	81.9	
	1/4"				18.1
8m		273.5	10.8	92.7	
	8m				7.3
pan		184.5	7.3	100.0	
	Totals	2534.5	100.0		

Minus One Inch Closed Set, Test No. 2

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		795.5	30.8	30.8	
	3/4"				69.2
1/2"		683.5	26.4	57.2	
	1/2"				42.8
1/4"		633.5	24.5	81.7	
	1/4"				18.3
8m		305.0	11.8	93.5	
	8m				6.5
pan		167.0	6.5	100.0	
	Totals	2585.5	100.0		

TABLE IX

SCREEN ANALYSES, ROLL CRUSHER PRODUCT, FOR

56 MILE SHALE

One-Half Inch Roll Set, Test No.1

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.00
3/4"		362.0	15.11	15.11	
	3/4"				84.89
1/2"		502.0	20.93	36.04	
	1/2"				63.96
1/4"		777.0	32.39	68.43	
	1/4"				31.57
8m		473.0	19.70	88.13	
	8m				11.87
pan		285.0	11.87	100.00	
	Totals	2401.0	100.00		

One-Half Inch Roll Set, Test No.2

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.00
3/4"		617.0	15.40	15.40	
	3/4"				84.60
1/2"		1018.0	25.40	40.80	
	1/2"				59.20
1/4"		1359.0	33.92	74.72	
	1/4"				25.28
8m		613.0	15.30	90.02	
	8m				9.98
pan		400.0	9.98	100.00	
	Totals	4007.0	100.00		

TABLE X

SCREEN ANALYSES, JAW CRUSHER PRODUCT, FOR

59 MILE SHALE

Minus One Inch Closed Set, Test No.1

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		422.5	19.4	19.4	
	3/4"				80.6
1/2"		406.0	18.6	38.0	
	1/2"				62.0
1/4"		600.0	27.6	65.6	
	1/4"				34.4
8m		435.5	20.0	85.6	
	8m				14.4
pan		313.5	14.4	100.0	
	Totals	2175.5	100.0		

Minus One Inch Closed Set, Test No. 2

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		423.5	22.0	22.0	
	3/4"				78.0
1/2"		393.5	20.4	42.4	
	1/2"				57.6
1/4"		559.5	29.1	71.5	
	1/4"				28.5
8m		341.0	17.7	89.2	
	8m				10.8
pan		207.0	10.8	100.0	
	Totals	1924.5	100.0		

TABLE XI

SCREEN ANALYSES, ROLL CRUSHER PRODUCT, FOR

59 MILE SHALE

One-Half Inch Roll Set, Test No. 1

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.00
3/4"		989.0	20.16	20.16	
	3/4"				79.84
1/2"		1238.0	25.23	45.39	
	1/2"				54.61
1/4"		1531.0	31.21	76.60	
	1/4"				23.40
8m		690.0	14.07	90.67	
	8m				9.33
pan		458.0	9.33	100.00	
	Totals	4906.00	100.00		

One-Half Inch Roll Set, Test No.2

Mesh		Weight	Per cent	Cumulative Per cent	
On	Pass	On (gr.)	On	On	Pass
	1"				100.0
3/4"		284.0	10.0	10.0	
	3/4"				90.0
1/2"		623.0	22.0	32.0	
	1/2"				68.0
1/4"		1025.0	36.2	68.2	
	1/4"				31.8
8m		574.0	20.3	88.5	
	8m				11.5
pan		326.0	11.5	100.0	
	Totals	2832.0	100.0		

TABLE XII

PELLETIZING CHARACTERISTICS

Characteristics	Sutton #1 air dry	Sutton #1 oven dry	Sutton #2 air dry	Sutton #2 oven dry	Sutton #3 air dry	Sutton #3 oven dry
Color	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown
pH	8.5	8.3	8.4	8.1	8.25	8.7
Strength	Fair	Fair	Fair	Fair	Fair	Fair
Per cent drying shrinkage	2.2	2.5	2.1	2.3	2.3	2.4
Per cent water for plasticity	25	26	25	25	24	26
Drying requirements	None	None	None	None	None	None
Working or forming characteristics	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Fair plasticity moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty

TABLE XIII

PELLETIZING CHARACTERISTICS

Characteristics	Sutton #4 air dry	Sutton #4 oven dry	Sutton #5 air dry	Sutton #5 oven dry	Kings River #1 air dry	Kings River #1 oven dry
Color	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown
pH	8.8	8.6	8.45	8.55	9.1	8.85
Strength	Fair	Fair	Fair	Fair	Low	Low
Per cent drying shrinkage	2.4	3.0	3.2	3.0	2.0	2.4
Per cent water for plasticity	25	24	24	25	23	23
Drying requirements	None	None	None	None	None	None
Working or forming characteristics	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Fair plasticity, moderate working, slightly gritty	Slight plasticity, short working, gritty	Slight plasticity, short working, gritty

TABLE XIV

PELLETIZING CHARACTERISTICS

Characteristics	Kings River #2 air dry	Kings River #2 oven dry	Kings River #3 air dry	Kings River #3 oven dry	Kings River #4 air dry	Kings River #4 oven dry
Color	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown	Gray-brown
pH	8.9	8.75	9.2	8.5	9.0	8.9
Strength	Low	Low	Low	Low	Low	Low
Per cent drying shrinkage	2.0	2.6	2.4	2.2	2.1	2.5
Per cent water for plasticity	23	24	23	24	23	24
Drying requirements	None	None	None	None	None	None
Working or forming characteristics	Slight plasticity, short working, gritty	Slight plasticity, short working, gritty	Slight plasticity short working, gritty	Slight plasticity, short working, gritty	Slight plasticity, short working, gritty	Slight plasticity, short working, gritty

TABLE XV

PELLETIZING CHARACTERISTICS

Characteristics	Kings River #5 air dry	Kings River #5 oven dry	Lawing #1 air dry	Lawing #1 oven dry	Lawing #2 air dry	Lawing #2 oven dry
Color	Gray-brown	Gray-brown	Silver-gray	Silver-gray	Silver-gray	Silver-gray
pH	8.9	9.1	8.4	8.4	8.8	8.5
Strength	Low	Low	Very low	Very low	Very low	Very low
Per cent drying shrinkage	2.0	2.2	1.0	0.8	1.0	0.7
Per cent water for plasticity	23	24	22	22	21	22
Drying requirements	None	None	None	None	None	None
Working or forming characteristics	Slight plasticity, short working, gritty	Slight plasticity, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty

TABLE XVI

PELLETIZING CHARACTERISTICS

Characteristics	Lawing #3 air dry	Lawing #3 oven dry	Lawing #4 air dry	Lawing #4 oven dry	Lawing #5 air dry	Lawing #5 oven dry
Color	Silver-gray	Silver-gray	Silver-gray	Silver-gray	Silver-gray	Silver-gray
pH	8.6	8.4	8.7	8.5	8.95	9.0
Strength	Very low	Very low	Very low	Very low	Very low	Very low
Per cent drying shrinkage	0.4	0.7	1.0	0.6	0.8	1.2
Per cent water for plasticity	22	21	21	22	23	22
Drying requirements	None	None	None	None	None	None
Working or forming characteristics	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty	Not plastic, short working, gritty

TABLE XVII

SLOW-FIRE PROPERTIES

Sample	Temp. Deg. F.	Color	Hardness	Absorption per cent	Shrinkage per cent	Apparent sp.gr.
Sutton	1800	Red-tan	Crumbly	18.3	2.0	2.2
#1	2000	Red-br	Hard	6.2	5.1	2.2
air	2100	Red-bl	Steel hard	3.1	Expanded	1.9
dry	2200	Black	Steel hard	0.8	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	16.1	2.2	2.2
#1	2000	Red-br	Hard	9.5	5.5	2.2
oven	2100	Red-bl	Steel hard	1.6	Expanded	1.7
dry	2200	Black	Steel hard	0.4	Expanded	1.2
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	18.2	2.2	2.2
#2	2000	Red-br	Hard	7.7	5.7	2.0
air	2100	Red-bl	Steel hard	3.1	Expanded	1.7
dry	2200	Black	Steel hard	1.7	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	16.9	2.1	2.1
#2	2000	Red-br	Hard	7.0	5.2	2.1
oven	2100	Red-bl	Steel hard	6.5	Expanded	1.9
dry	2200	Black	Steel hard	0.8	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	15.9	1.8	2.2
#3	2000	Red-br	Hard	12.3	6.2	2.2
air	2100	Red-bl	Steel hard	4.9	Expanded	1.9
dry	2200	Black	Steel hard	0.3	Expanded	1.0
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	12.9	2.1	2.2
#3	2000	Red-br	Hard	12.3	4.4	2.1
oven	2100	Red-bl	Steel hard	1.5	Expanded	1.9
dry	2200	Black	Steel hard	0.4	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted

TABLE XVIII

SLOW-FIRE PROPERTIES

Sample	Temp. Deg. F.	Color	Hardness	Absorption per cent	Shrinkage per cent	Apparent sp. gr.
Sutton	1800	Red-tan	Crumbly	15.2	1.8	2.3
#4	2000	Red-br	Hard	9.2	5.2	2.1
air	2100	Red-bl	Steel hard	4.5	Expanded	1.9
dry	2200	Black	Steel hard	1.6	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	16.7	2.0	2.2
#4	2000	Red-br	Hard	10.5	5.1	2.2
oven	2100	Red-bl	Steel hard	5.1	Expanded	1.9
dry	2200	Black	Steel hard	0.4	Expanded	1.2
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	13.6	2.3	2.4
#5	2000	Red-br	Hard	7.7	6.3	2.2
air	2100	Red-bl	Steel hard	3.1	Expanded	1.9
dry	2200	Black	Steel hard	0.8	Expanded	1.2
	2300	Black	Vitreous	Fused	Expanded	Melted
Sutton	1800	Red-tan	Crumbly	16.4	2.5	2.2
#5	2000	Red-br	Hard	15.0	6.5	2.2
oven	2100	Red-bl	Steel hard	6.3	Expanded	2.0
dry	2200	Black	Steel hard	0.6	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	19.3	1.0	2.3
River	2000	Brown	Hard	13.1	7.1	2.1
#1	2100	Bl-br	Steel hard	3.3	Expanded	1.7
air	2200	Bl-br	Steel hard	5.0	Expanded	1.1
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	17.2	1.2	2.2
River	2000	Brown	Hard	12.7	6.6	2.1
#1	2100	Bl-br	Steel hard	1.8	Expanded	1.6
oven	2200	Bl-br	Steel hard	0.0	Expanded	1.1
dry	2300	Black	Vitreous	Fused	Expanded	Melted

TABLE XIX

SLOW-FIRE PROPERTIES

Sample	Temp. Deg. F.	Color	Hardness	Apsorption per cent	Shrinkage per cent	Apparent sp.gr.
Kings	1800	Tan	Crumbly	17.7	1.5	2.3
River	2000	Brown	Hard	11.5	6.0	2.2
#2	2100	Bl-br	Steel hard	3.2	Expanded	1.7
air	2200	Bl-br	Steel hard	0.9	Expanded	1.0
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	16.6	0.9	2.2
River	2000	Brown	Hard	10.9	7.1	2.1
#2	2100	Bl-br	Steel hard	3.2	Expanded	1.8
oven	2200	Bl-br	Steel hard	2.3	Expanded	1.2
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	17.7	1.0	2.4
River	2000	Brown	Hard	7.4	6.8	2.1
#3	2100	Bl-br	Steel hard	2.8	Expanded	1.8
air	2200	Bl-br	Steel hard	2.9	Expanded	1.2
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	17.2	2.0	2.1
River	2000	Brown	Hard	12.5	5.8	2.1
#3	2100	Bl-br	Steel hard	3.4	Expanded	1.7
oven	2200	Bl-br	Steel	1.6	Expanded	1.1
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	18.3	1.2	2.2
River	2000	Brown	Hard	14.8	7.2	2.1
#4	2100	Bl-br	Steel hard	3.3	Expanded	1.5
air	2200	Bl-br	Steel hard	0.0	Expanded	1.1
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	17.7	0.8	2.1
River	2000	Brown	Hard	10.8	6.8	2.0
#4	2100	Bl-br	Steel hard	4.6	Expanded	1.7
oven	2200	Bl-br	Steel hard	1.7	Expanded	1.1
dry	2300	Black	Vitreous	Fused	Expanded	Melted

TABLE XX

SLOW-FIRE PROPERTIES

Sample	Temp. Deg. F.	Color	Hardness	Absorption per cent	Shrinkage per cent	Apparent sp.gr.
Kings	1800	Tan	Crumbly	17.2	1.0	2.2
River	2000	Brown	Hard	14.8	5.9	2.0
#5	2100	Bl-br	Steel hard	3.3	Expanded	1.5
air	2200	Bl-br	Steel hard	0.8	Expanded	1.0
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Kings	1800	Tan	Crumbly	15.6	1.0	2.1
River	2000	Brown	Hard	9.7	7.0	1.9
#5	2100	Bl-br	Steel hard	2.9	Expanded	1.7
oven	2200	Bl-br	Steel hard	1.0	Expanded	0.9
dry	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	16.0	0.5	2.1
#1	2000	Brown	Crumbly	20.6	Expanded	1.9
air	2100	Bl-br	Hard	13.6	Expanded	1.5
dry	2200	Bl-br	Steel hard	4.6	Expanded	0.8
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	16.7	1.0	2.1
#1	2000	Brown	Crumbly	20.1	Expanded	2.0
oven	2100	Bl-br	Hard	11.9	Expanded	1.6
dry	2200	Bl-br	Steel hard	1.5	Expanded	0.8
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	18.8	0.9	1.9
#2	2000	Brown	Crumbly	21.4	Expanded	1.8
air	2100	Bl-br	Hard	15.4	Expanded	1.7
dry	2200	Bl-br	Steel hard	6.7	Expanded	1.2
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	19.4	0.5	1.9
#2	2000	Brown	Crumbly	21.4	Expanded	1.8
oven	2100	Bl-br	Hard	18.0	Expanded	1.7
dry	2200	Bl-br	Steel hard	6.5	Expanded	1.2
	2300	Brown	Vitreous	Fused	Expanded	Melted

TABLE XXI

SLOW-FIRE PROPERTIES

Sample	Temp. Deg. F.	Color	Hardness	Absorption per cent	Shrinkage per cent	Apparent sp.gr.
Lawing	1800	Tan	Crumbly	21.5	0.6	2.0
#3	2000	Brown	Crumbly	21.5	Expanded	2.0
air	2100	Bl-br	Hard	16.2	Expanded	1.7
dry	2200	Bl-br	Steel hard	4.7	Expanded	1.3
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	16.4	0.9	2.0
#3	2000	Brown	Crumbly	18.3	Expanded	2.0
oven	2100	Bl-br	Hard	12.3	Expanded	1.6
dry	2200	Bl-br	Steel hard	7.8	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	18.6	1.0	2.2
#4	2000	Brown	Crumbly	17.5	Expanded	1.9
air	2100	Bl-br	Hard	12.5	Expanded	1.6
dry	2200	Bl-br	Steel hard	1.6	Expanded	1.0
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	17.5	1.0	2.0
#4	2000	Brown	Crumbly	18.6	Expanded	1.9
oven	2100	Bl-br	Hard	16.1	Expanded	1.5
dry	2200	Bl-br	Steel hard	6.0	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	14.7	0.8	2.2
#5	2000	Brown	Crumbly	16.2	Expanded	2.0
air	2100	Bl-br	Hard	11.0	Expanded	1.7
dry	2200	Bl-br	Steel hard	1.5	Expanded	1.1
	2300	Black	Vitreous	Fused	Expanded	Melted
Lawing	1800	Tan	Crumbly	21.5	0.8	2.1
#5	2000	Brown	Crumbly	22.4	Expanded	1.9
oven	2100	Bl-br	Hard	21.2	Expanded	1.8
dry	2200	Bl-br	Steel hard	7.5	Expanded	1.3
	2300	Black	Vitreous	Fused	Expanded	Melted

TABLE XXII

QUICK-FIRING TEST

34.5 MILE SHALE

Size 3/4 x 1/2 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.44	2.63	3.00	2.35	3.00	9.26
1940	2.58	2.63	0.77	2.56	2.56	0.00
2040	2.23	2.28	1.04	1.98	2.07	2.35
2125	1.66	1.69	0.56	1.70	1.78	2.80
2200	1.38	1.40	0.95	1.44	1.46	1.12
2300*	1.40	1.41	0.47	1.37	1.39	0.89
Retention time 10 minutes						
1850	2.69	2.76	0.95	2.62	2.67	0.81
1940	2.49	2.55	0.98	2.45	2.49	0.64
2040	1.76	1.83	2.06	1.61	1.68	3.10
2125	1.31	1.34	1.02	1.41	1.43	0.85
2200	1.19	1.23	2.50	1.05	1.07	1.67
2300*	1.25	1.27	1.24	1.40	1.40	0.00
Retention time 15 minutes						
1850	2.53	2.59	0.88	2.75	2.81	0.68
1940	2.39	2.42	0.54	2.48	2.53	0.91
2040	1.79	1.84	1.67	1.72	1.73	1.62
2125	1.24	1.28	2.56	1.40	1.43	1.37
2200	0.98	1.02	1.89	1.00	1.00	0.00
2300	fused			fused		

*fused

TABLE XXII (cont.)

QUICK-FIRING TEST

34.5 MILE SHALE

Size 1/2 x 1/4 inch

Temp. (°F.)	SAMPLE NO. 1 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	SAMPLE NO. 2 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.50	2.68	1.96	2.61	2.68	0.98
1940	2.60	2.65	0.74	2.50	2.58	1.17
2040	2.02	2.02	0.00	2.04	2.04	0.00
2125	1.67	1.72	0.18	1.57	1.62	1.82
2200	1.36	1.38	1.11	1.35	1.38	1.62
2300	1.31	1.33	0.82	1.25	1.29	2.25
Retention time 10 minutes						
1850	2.68	2.82	1.82	2.51	2.56	0.72
1940	2.43	2.50	1.11	2.42	2.48	1.15
2040	2.00	2.11	2.63	1.85	1.87	0.68
2125	1.22	1.46	2.16	1.41	1.43	0.94
2200	1.45	1.48	1.62	1.37	1.37	0.00
2300	1.17	1.21	2.86	1.08	1.10	2.04
Retention time 15 minutes						
1850	2.62	2.70	1.12	2.70	2.71	0.37
1940	2.16	2.21	0.94	1.78	2.22	1.25
2040	1.80	1.80	0.00	1.68	1.79	2.35
2125	1.40	1.41	1.70	1.51	1.55	1.61
2200	1.32	1.36	1.82	1.44	1.47	1.72
2300	fused			fused		

TABLE XXII (cont.)

QUICK-FIRING TEST

34.5 MILE SHALE

Size 1/4 x 1/8 inch

Temp. (°F.)	SAMPLE NO. 1 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	SAMPLE NO. 2 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
			Retention time 5 minutes			
1850	2.50	2.69	2.86	2.61	2.76	2.12
1940	2.64	2.64	0.00	2.54	2.54	0.00
2040	2.38	2.38	0.00	2.38	2.38	0.00
2125	1.28	1.32	2.00	1.74	1.80	1.85
2200	1.46	1.47	2.00	1.33	1.38	2.27
2300	fused			fused		
			Retention time 10 minutes			
1850	2.67	2.67	0.00	2.52	2.65	1.89
1940	2.61	2.61	0.00	2.50	2.50	0.00
2040	2.06	2.06	0.00	1.86	1.90	1.28
2125	1.71	1.71	0.00	1.67	1.67	0.00
2200	1.35	1.35	0.00	1.33	1.33	0.00
2300*	1.47	1.38	4.54	1.42	1.42	0.00
			Retention time 15 minutes			
1850	2.69	2.69	0.00	2.68	2.68	0.00
1940	2.50	2.50	0.00	2.69	2.69	0.00
2040	2.00	2.00	0.00	2.27	2.27	0.00
2125	1.57	1.57	0.00	1.56	1.59	1.43
2200	1.41	1.44	1.61	1.53	1.57	1.52
2300	fused			fused		

*fused

TABLE XXIII

QUICK-FIRING TEST

44.7 MILE SHALE

Size 3/4 x 1/2 inch

Temp. (°F.)	SAMPLE NO. 1 Bulk Sp.Gr.	SAMPLE NO. 1 Apparent Sp.Gr.	SAMPLE NO. 1 Per cent Absorption	SAMPLE NO. 2 Bulk Sp.Gr.	SAMPLE NO. 2 Apparent Sp.Gr.	SAMPLE NO. 2 Per cent Absorption
Retention time 5 minutes						
1850	2.55	2.68	1.86	2.34	2.62	3.00
1940	2.32	2.55	3.80	2.09	2.37	5.60
2040	1.54	1.82	9.80	1.98	2.21	5.10
2125	0.99	1.20	16.90	1.29	1.61	15.10
2200	0.62	0.69	17.50	0.85	1.00	18.00
2300	fused			fused		
Retention time 10 minutes						
1850	2.32	2.53	2.85	2.32	2.51	2.13
1940	1.94	2.20	6.06	1.86	2.16	6.45
2040	1.25	1.56	20.00	1.27	1.55	14.47
2125	0.83	0.95	14.30	0.83	0.87	16.67
2200	0.70	0.77	16.39	0.78	0.87	12.98
2300*	0.64	0.68	9.09	0.61	0.64	7.14
Retention time 15 minutes						
1850	2.07	2.23	2.45	2.39	2.63	3.08
1940	1.61	1.81	6.90	1.80	2.02	4.76
2040	1.14	1.32	12.30	1.13	1.36	14.03
2125	0.71	0.75	9.43	0.70	0.79	16.39
2200*	0.73	0.78	7.79	0.55	0.58	10.26
2300*	0.55	0.57	6.49	0.58	0.61	5.56

*fused

TABLE XXIII (cont.)

QUICK-FIRING TEST

44.7 MILE SHALE

Size 1/2 x 1/4 inch

Temp. (°F.)	SAMPLE NO. 1 Bulk Sp.Gr.	SAMPLE NO. 1 Apparent Sp.Gr.	SAMPLE NO. 1 Per cent Absorption	SAMPLE NO. 2 Bulk Sp.Gr.	SAMPLE NO. 2 Apparent Sp.Gr.	SAMPLE NO. 2 Per cent Absorption
Retention time 5 minutes						
1850	2.32	2.57	4.20	2.29	2.46	4.40
1940	2.18	2.42	4.60	2.22	2.40	3.33
2040	1.88	2.15	6.70	1.42	1.78	14.10
2125	0.91	1.08	17.00	0.99	1.20	18.30
2200	0.68	0.77	18.20	0.76	0.84	12.90
2300	0.67	0.68	17.60	fused		
Retention time 10 minutes						
1850	2.39	2.53	2.23	2.43	2.62	2.40
1940	2.14	2.24	2.13	2.02	2.23	4.76
2040	1.13	1.29	11.36	1.18	1.35	10.87
2125	0.74	0.82	11.60	0.74	0.82	14.28
2200*	0.61	0.66	11.86	0.61	0.66	7.14
2300*	0.61	0.63	5.66	0.65	0.68	3.85
Retention time 15 minutes						
1850	1.85	2.00	4.17	2.32	2.68	3.84
1940	1.70	1.92	6.52	1.81	1.81	7.69
2040	1.05	1.17	9.76	0.94	0.94	11.54
2125	0.73	0.80	11.84	0.71	0.71	17.78
2200*	0.70	0173	6.25	0.58	0.58	8.62
2300*	0.62	0.64	5.89	0.63	0.63	5.88

*fused

TABLE XXIII (cont.)

QUICK-FIRING TEST

44.7 MILE SHALE

Size 1/4 x 1/8 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.00	3.00	3.80	2.25	2.57	5.60
1940	2.40	2.40	0.00	1.96	2.37	4.00
2040	1.95	2.26	4.50	2.24	2.33	3.50
2125	1.23	1.42	7.40	2.24	1.43	10.00
2200	0.72	0.74	4.30	0.79	0.91	14.20
2300	fused			0.69	0.78	16.00
Retention time 10 minutes						
1850	2.54	2.54	0.00	2.08	2.27	4.00
1940	1.81	2.13	8.16	2.06	2.20	3.03
2040	1.29	1.50	11.11	1.36	1.54	7.01
2125	0.88	0.96	7.41	0.87	0.94	6.67
2200	0.66	0.71	8.57	0.68	0.75	13.33
2300*	0.63	0.66	6.06	0.67	0.70	7.14
Retention time 15 minutes						
1850	1.82	2.00	5.00	2.31	2.85	5.26
1940	1.62	1.75	4.76	1.88	2.14	4.35
2040	1.17	1.29	7.41	1.06	1.27	15.15
2125	0.76	0.84	13.64	0.67	0.74	14.28
2200*	0.75	0.79	6.67	0.64	0.69	10.00
2300*	0.60	0.63	8.33	0.61	0.64	8.89

*fused

TABLE XXIV

QUICK FIRING TEST

56 MILE SHALE

3/4 x 1/2 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.37	2.81	6.67	2.46	2.63	2.65
1940	2.47	2.54	1.26	2.00	2.30	6.52
2040	1.98	2.08	2.41	1.00	1.11	10.00
2125	0.92	0.99	2.78	0.93	1.00	5.00
2200	0.55	0.59	9.68	0.36	0.38	17.57
2300	fused					
Retention time 10 minutes						
1850	2.20	2.59	6.82	2.36	2.68	5.05
1940	1.71	1.91	6.12	1.60	1.82	7.49
2040	1.35	1.44	4.84	1.36	1.45	4.52
2125	0.49	0.52	8.16	0.37	0.38	8.57
2200*	0.33	0.36	25.92	fused		
2300	fused			fused		
Retention time 15 minutes						
1850	2.42	2.55	1.96	2.40	2.57	2.78
1940	1.33	1.45	6.25	1.52	1.68	6.25
2040	0.65	0.67	3.64	0.60	0.62	3.66
2125	0.52	0.54	8.00	0.50	0.57	8.25
2200	fused			fused		
2300	fused			fused		

*fused

TABLE XXIV (cont.)

QUICK FIRING TEST

56 MILE SHALE

Size 1/2 x 1/4 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.50	2.69	4.65	2.32	2.67	5.00
1940	2.46	2.63	2.65	2.25	2.45	3.70
2040	1.70	1.75	1.79	1.12	1.21	5.08
2125	0.81	0.86	7.25	0.94	1.00	5.88
2200	0.92	0.95	3.50	0.52	0.55	10.45
2300	fused			fused		
Retention time 10 minutes						
1850	2.38	2.59	3.51	2.48	2.74	3.85
1940	1.33	1.56	11.11	1.68	1.98	8.96
2040	0.69	0.67	11.11	1.22	1.39	10.26
2125	0.44	0.45	6.90	0.75	0.79	6.78
2200*	0.46	0.50	16.12	fused		
2300	fused			fused		
Retention time 15 minutes						
1850	2.27	2.50	4.00	2.37	2.73	5.63
1940	1.72	1.83	2.13	1.18	1.26	7.22
2040	0.77	0.81	6.25	1.09	1.20	8.33
2125	0.42	0.47	7.90	0.29	0.30	7.69
2200	fused			fused		
2300	fused			fused		

*fused

TABLE XXIV (cont.)

QUICK-FIRING TEST

56 MILE SHALE

Size 1/4 x 1/8 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
			Retention time 5 minutes			
1850	3.00	3.00	0.00	2.86	2.86	0.00
1940	2.35	2.47	2.13	2.07	2.23	3.45
2040	1.45	1.57	5.45	1.46	1.58	5.26
2125	0.86	0.90	5.26	0.80	0.84	4.92
2200*	0.46	0.47	6.06	0.54	0.55	4.76
2300	fused			fused		
			Retention time 10 minutes			
1850	2.20	2.54	6.06	2.75	3.00	3.03
1940	1.69	2.00	9.09	1.86	2.16	7.46
2040	1.20	1.34	9.09	1.00	1.06	10.53
2125	0.50	0.60	33.33	0.51	0.53	9.09
2200	0.51	0.58	25.00	fused		
2300	fused			fused		
			Retention time 15 minutes			
1850	2.32	2.44	2.27	2.58	2.91	4.48
1940	1.74	1.90	5.08	1.78	1.88	5.10
2040	0.80	0.84	5.40	1.20	1.29	4.76
2125	0.67	0.69	4.22	0.61	0.64	6.52
2200	fused			fused		
2300	fused			fused		

*fused

TABLE XXV

QUICK-FIRING TEST

59 MILE SHALE

Size 3/4 x 1/2 inch

Temp. (°F.)	SAMPLE NO. 1 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	SAMPLE NO. 2 Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.45	2.95	7.04	2.50	2.27	3.33
1940	2.15	2.35	5.47	2.45	2.70	3.70
2040	0.92	1.01	9.45	1.64	1.81	5.80
2125	0.78	0.87	13.10	0.55	0.58	8.10
2200*	0.41	0.48	36.00	0.48	0.41	36.00
2300	fused			fused		
Retention time 10 minutes						
1850	2.29	2.61	5.32	2.28	2.60	5.33
1940	1.21	1.38	10.30	1.40	1.55	7.14
2040	1.00	1.11	10.13	0.73	0.77	7.59
2125*	0.35	0.36	11.30	0.48	0.50	6.25
2200*	0.90	1.08	18.51	fused		
2300	fused			fused		
Retention time 15 minutes						
1850	2.12	2.43	5.88	2.48	2.53	0.80
1940	1.22	1.33	6.55	1.20	1.31	6.54
2040	0.65	0.71	12.50			
2125*	0.58	0.62	12.19			
2200	fused					
2300	fused					

*fused

TABLE XXV (cont.)

QUICK-FIRING TEST

59 MILE SHALE

Size 1/2 x 1/4 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.48	2.68	2.98	2.56	2.81	3.39
1940	2.11	2.39	5.45	2.15	2.45	5.63
2040	0.75	0.83	11.63	1.38	1.50	5.55
2125	0.73	0.80	8.33	0.87	0.95	5.00
2200	fused			0.42	0.48	2.14
2300	fused			fused		
Retention time 10 minutes						
1850	2.41	2.60	3.08	2.41	2.60	3.08
1940	1.05	1.17	10.00	1.26	1.36	5.56
2040	0.59	0.64	14.75	0.76	0.79	5.71
2125*	0.27	0.29	21.70	0.39	0.41	17.65
2200*	0.82	1.08	28.60	fused		
2300	fused			fused		
Retention time 15 minutes						
1850	2.29	2.45	1.23	1.35	1.40	2.86
1940	1.06	1.12	5.26	0.85	0.92	8.57
2040*	0.34	0.35	7.69	0.54	0.55	3.70
2125*	0.39	0.41	9.67	fused		
2200	fused			fused		
2300	fused			fused		

*fused

TABLE XXV (cont.)

QUICK-FIRING TEST

59 MILE SHALE

Size 1/4 x 1/8 inch

	SAMPLE NO. 1			SAMPLE NO. 2		
Temp. (°F.)	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption	Bulk Sp.Gr.	Apparent Sp.Gr.	Per cent Absorption
Retention time 5 minutes						
1850	2.50	2.69	2.86	2.60	2.89	3.85
1940	1.95	2.28	7.31	2.10	2.33	4.76
2040	0.65	0.72	15.30	1.22	1.31	5.26
2125	0.49	0.71	18.20	0.58	0.61	9.09
2200	fused			0.59	0.67	20.00
2300	fused			fused		
Retention time 10 minutes						
1850	2.36	2.60	3.85	2.40	2.53	3.74
1940	1.50	1.67	6.67	1.56	1.65	3.57
2040	0.63	0.65	2.63	0.87	0.95	9.09
2125*	0.64	0.75	11.11	0.44	0.61	25.00
2200*	0.80	1.00	25.00	fused		
2300	fused			fused		
Retention time 15 minutes						
1850	2.32	2.52	3.44	2.00	2.00	0.00
1940	1.54	1.70	5.88	1.71	1.71	0.00
2404*	0.56	0.59	7.69	0.49	0.39	50.00
2125*	0.74	0.78	7.14	fused		
2200	fused			fused		
2300	fused			fused		

*fused

TABLE XXVI

QUICK FIRING TEST

Temp. Deg. F.	Sutton #1 Air Dry		Kings River #5 Air Dry		Lawing #3 Air dry	
	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent
	Size -3-mesh +8-mesh Retention 5 min.					
1800	149.8	4.7	144.1	0.5	159.7	4.9
1900	106.1	5.9	119.8	6.5	129.8	6.7
2000	64.3	6.9	68.6	3.0	104.2	7.0
2100	Fused	----	Fused	----	65.5	8.1
	Retention 10 min.					
1800	136.0	4.1	144.1	3.7	146.0	4.2
1900	78.6	5.2	104.2	5.3	112.9	9.2
2000	41.8	4.3	42.4	6.8	73.6	10.2
2100	Fused	----	Fused	---	Fused	----
	Retention 15 min.					
1800	134.2	4.5	137.3	2.3	148.5	4.0
1900	73.0	6.1	88.6	6.8	121.1	10.0
2000	39.3	5.6	48.3	6.3	83.6	9.5
	Size -.525 in +3-mesh Retention 5 min.					
1800	135.4	5.5	166.6	2.8	160.4	4.3
1900	94.2	9.3	144.1	4.7	157.2	5.9
2000	54.7	8.5	56.2	7.5	57.4	11.1
2100	26.8	10.3	34.3	10.9	71.8	9.0
	Retention 10 min.					
1800	126.7	7.9	155.4	3.8	158.5	3.0
1900	72.4	7.4	96.7	7.0	147.9	6.3
2000	30.1	12.6	38.1	6.9	122.3	5.9
2100	Fused	----	Fused	---	Fused	----
	Retention 15 min.					
1800	117.3	5.7	146.0	4.5	159.7	5.8
1900	56.8	8.3	85.5	7.6	144.8	8.6
2000	28.1	11.0	33.1	8.1	57.4	11.3
	Size -.742 in +.525 in Retention 5 min.					
1800	164.1	3.8	161.0	3.0	176.6	5.3
1900	135.4	4.2	130.4	6.3	162.2	7.4
2000	57.4	5.3	69.3	8.1	101.7	11.2
2100	35.6	5.4	Fused	---	75.5	13.3
	Retention 10 min.					
1800	156.6	4.1	156.6	3.1	172.2	5.3
1900	66.1	4.0	100.5	6.7	150.4	8.9
2000	38.7	6.7	31.2	9.7	94.8	11.1
2100	Fused	----	Fused	---	Fused	----
	Retention 15 min.					
1800	145.4	2.9	167.9	3.4	174.1	6.4
1900	101.6	3.3	84.2	8.4	134.8	9.2
2000	33.1	7.0	33.1	9.8	64.9	7.7

TABLE XXVI (cont.)

Temp. Deg. F.	Sutton #1 Oven Dry		Kings River #5 Oven Dry		Lawing #3 Oven Dry	
	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent
Size -3-mesh +8-mesh Retention 5 min.						
1800	137.3	2.1	161.0	4.5	157.2	2.9
1900	103.6	3.7	112.3	8.0	117.9	7.8
2000	101.7	0.6	58.0	16.1	86.7	8.2
2100	75.5	2.0	Fused	----	50.5	12.5
Retention 10 min.						
1800	131.7	3.8	147.0	5.6	152.3	5.1
1900	82.4	6.0	91.1	10.8	111.1	10.9
2000	43.1	5.8	36.8	11.1	62.4	11.1
2100	Fused	---	Fused	----	Fused	----
Retention 15 min.						
1800	124.8	4.7	144.1	4.4	132.3	7.1
1900	77.4	4.4	83.6	7.3	104.8	10.1
2000	46.2	5.7	38.7	11.1	63.6	8.6
Size -.525 in. +3-mesh Retention 5 min.						
1800	154.8	4.2	157.2	3.3	161.6	5.7
1900	120.4	3.7	132.9	5.3	146.0	8.4
2000	83.6	2.2	61.2	4.8	101.7	14.4
2100	54.3	3.2	33.1	12.6	53.7	13.5
Retention 10 min.						
1800	140.4	2.8	148.5	5.3	161.6	4.8
1900	89.2	4.3	108.6	7.8	120.4	10.6
2000	55.5	2.9	33.7	8.2	88.6	11.3
2100	Fused	---	Fused	----	59.9	10.7
Retention 15 min.						
1800	134.8	4.8	148.5	5.5	152.9	7.4
1900	79.9	4.3	89.9	8.9	124.2	8.6
2000	59.9	4.2	24.3	14.2	68.0	12.7
Size -.742 in. +.525 in. Retention 5 min.						
1800	151.6	6.6	147.9	5.1	168.5	4.0
1900	105.5	6.9	121.1	3.0	147.3	4.3
2000	89.9	7.8	78.6	8.0	93.0	9.7
2100	Fused	---	Fused	----	65.5	11.3
Retention 10 min.						
1800	133.5	7.4	163.5	3.8	169.7	8.2
1900	84.9	7.9	116.7	6.7	117.3	8.0
2000	29.3	11.9	34.3	8.8	46.2	9.3
2100	Fused	----	Fused	----	Fused	----
Retention 15 min.						
1800	143.5	5.9	150.4	2.4	149.1	4.2
1900	71.8	8.2	85.5	5.8	122.9	6.6
2000	37.4	8.6	39.9	8.8	54.9	10.7

TABLE XXVII

Temp. Deg. F.	Sutton #5 Air Dry		Kings River #2 Air Dry		Lawing #2 Air Dry	
	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent	Weight Lb/ft^3	Absorption per cent
	Size -3-mesh Retention 5 min.					
1800	151.6	3.1	170.4	1.8	167.9	1.6
1900	129.8	3.8	122.9	4.1	139.2	5.5
2000	88.6	2.9	68.0	111.7	7.3	
2100	64.9	4.0	49.9	7.5	109.2	8.6
	Retention 10 min.					
1800	152.3	1.1	170.0	2.0	157.9	3.1
1900	110.4	1.7	111.1	12.3	137.9	4.4
2000	75.5	2.3	59.3	6.7	89.9	6.3
2100	Fused	---	Fused	----	Fused	----
	Retention 15 min.					
1800	141.0	3.3	163.5	0.8	156.0	5.5
1900	106.7	2.6	96.1	2.8	143.5	6.6
2000	64.9	19.2	43.1	7.0	78.0	10.7
	Size -.525 in. +3-mesh Retention 5 min.					
1800	152.3	3.0	164.7	2.7	162.2	2.5
1900	100.5	3.0	123.6	5.9	154.8	7.4
2000	70.5	6.8	68.0	10.2	84.9	9.1
2100	31.8	6.4	36.8	8.9	69.3	9.0
	Retention 10 min.					
1800	138.5	4.2	162.9	1.6	164.1	4.8
1900	71.8	5.6	82.4	6.9	145.4	6.0
2000	56.8	4.5	36.8	8.9	103.0	7.0
2100	Fused	----	Fused	----	Fused	----
	Retention 15 min.					
1800	126.7	4.4	147.3	5.5	157.2	6.4
1900	72.4	5.6	77.4	6.4	132.9	6.1
2000	45.6	15.0	33.1	8.1	49.9	9.4
	Size -.742 in. +.525 in. Retention 5 min					
1800	137.9	4.7	166.6	3.3	161.6	4.7
1900	140.2	6.4	134.2	6.3	145.4	7.4
2000	61.2	6.1	64.9	9.1	98.6	12.8
2100	28.1	9.7	30.0	15.3	72.4	8.7
	Retention 10 min.					
1800	122.9	6.4	151.0	4.8	160.4	6.5
1900	74.3	3.5	93.6	8.3	130.4	8.7
2000	31.2	6.3	36.8	10.0	70.5	11.3
2100	Fused	----	Fused	----	Fused	----
	Retention 15 min.					
1800	116.7	4.9	139.8	4.4	148.5	5.2
1900	71.8	4.0	82.4	6.0	121.7	9.8
2000	25.0	9.2	24.3	13.0	69.3	13.4

TABLE XXVII (cont.)

Temp. Deg. F.	Sutton #5 Oven Dry Weight Lb/ft^3	Sutton #5 Oven Dry Absorption per cent	Kings River #2 Oven Dry Weight Lb/ft^3	Kings River #2 Oven Dry Absorption per cent	Lawing #2 Oven Dry Weight Lb/ft^3	Lawing #2 Oven Dry Absorption per cent
Size -3-mesh +8-mesh Retention 5 min.						
1800	157.9	4.2	156.6	6.0	151.6	5.6
1900	138.5	3.7	137.3	7.8	146.6	8.0
2000	81.7	1.9	72.4	0.7	105.5	11.5
2100	51.2	4.9	Fused	----	63.6	15.2
Retention 10 min.						
1800	137.3	4.0	151.6	5.9	143.5	7.1
1900	86.1	9.1	111.1	11.3	135.4	8.7
2000	56.7	7.4	45.6	11.0	84.9	12.4
2100	Fused	----	Fused	----	Fused	----
Retention 15 min.						
1800	131.1	3.2	145.4	3.1	150.4	9.0
1900	83.6	8.4	94.8	3.1	139.8	9.6
2000	58.7	7.2	43.7	9.1	84.9	12.4
Size -.525 in. +3-mesh Retention 5 min.						
1800	154.8	2.6	164.7	1.8	166.0	1.8
1900	107.3	4.7	113.6	2.5	155.4	10.7
2000	51.2	6.8	38.7	6.3	106.1	3.9
2100	33.7	7.5	26.8	13.3	53.7	10.3
Retention 10 min.						
1800	144.8	2.1	152.3	2.0	159.1	3.6
1900	89.2	1.9	92.4	5.0	155.4	6.9
2000	29.3	5.2	33.7	9.6	99.8	8.7
2100	Fused	----	Fused	----	Fused	----
Retention 15 min.						
1800	134.2	2.3	136.7	0.7	156.6	4.5
1900	71.8	4.3	83.6	2.6	86.1	6.5
2000	31.2	7.3	28.7	6.0	78.6	6.5
Size -.742 in. +.525 in. Retention 5 min.						
1800	141.6	5.7	162.9	4.4	167.9	5.8
1900	116.7	6.0	124.8	7.5	161.6	7.0
2000	48.7	4.0	57.4	11.5	79.3	9.7
2100	27.5	7.1	33.7	11.5	51.2	13.8
Retention 10 min.						
1800	144.8	6.3	166.0	3.0	161.6	4.5
1900	84.9	8.3	120.4	8.7	127.9	9.6
2000	27.5	8.4	27.5	9.3	76.8	8.8
2100	Fused	----	Fused	----	Fused	----
Retention 15 min.						
1800	134.2	5.2	159.7	5.8	168.5	5.5
1900	75.5	5.7	108.6	7.6	137.9	8.8
2000	25.0	7.0	41.2	7.6	36.8	13.0

TABLE XXVIII

CONCRETE MIX SPECIFICATIONS, 34.5 MILE SHALE

Coarse Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per Cent Retained	Cumulative Per Cent Passed
3/4"			0.0	0.0	
	3/4"				100.0
3/8"		1.00	50.0	50.0	
	3/8"				50.0
4m		1.00	50.0	100.0	
	4m				0.0
Totals		2.00	100.0		

Unit Weight Loose Dry= 54.0 pounds per cubic foot
Fineness Modulus = 6.0

Fine Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per Cent Retained	Cumulative Per Cent Passed
4m		0.00	0.0		
	4m				100.0
8m		0.25	10.0	10.0	
	8m				90.0
16m		0.50	20.0	30.0	
	16m				70.0
30m		0.62	25.0	33.0	
	30m				45.0
50m		0.57	23.0	78.0	
	50m				22.0
100m		0.32	13.0	91.0	
	100m				9.0
pan		0.23	9.0	100.0	
	pan				0.0
Totals		2.50	100.0		

Unit Weight Loose Dry= 69.5 pounds per cubic foot
Fineness Modulus = 3.64

Combined Aggregate:

Unit Weight Loose Dry= 77.1 pounds per cubic foot
Fineness Modulus = 4.68
Six Sack
Equivalent Concrete= 1.21 pounds
Water Required =230 milliliters

TABLE XXIX

CONCRETE MIX SPECIFICATIONS, 44.7 MILE SHALE

Coarse Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
3/4"			0.0	0.0	
	3/4"				100.0
3/8"		0.82	50.0	50.0	
	3/8"				50.0
4m		0.82	50.0	100.0	
	4m				0.0
Totals		1.64	100.0		

Unit Weight Loose Dry= 39.37 pounds per cubic foot
Fineness Modulus = 6.00

Fine Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
4m			0.0	0.0	
	4m				100.0
8m		0.25	10.0	10.0	
	8m				90.0
16m		0.50	20.0	30.0	
	16m				70.0
30m		0.62	25.0	55.0	
	30m				45.0
50m		0.57	23.0	78.0	
	50m				22.0
100m		0.32	13.0	91.0	
	100m				9.0
pan		0.23	9.0	100.0	
	pan				0.0
Totals		2.50	100.0		

Unit Weight Loose Dry= 60.32 pounds per cubic foot
Fineness Modulus = 3.64

Combined Aggregate:

Unit Weight Loose Dry= 62.4 pounds per cubic foot
Fineness Modulus = 4.82
Six Sack
Equivalent Concrete= 1.38 pounds
Water Required =520 milliliters

TABLE XXX

CONCRETE MIX SPECIFICATIONS, 56 MILE SHALE

Coarse Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
3/4"		0.00	0.0	0.0	
	3/4"				100.0
3/8"		0.75	50.0	50.0	
	3/8"				50.0
4m		0.75	50.0	100.0	
	4m				0.0
Totals		1.50	100.0		

Unit Weight Loose Dry= 40.13 pounds per cubic foot
Fineness Modulus = 6.00

Fine Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
	4m				100.0
8m		0.25	10.0	10.0	
	8m				90.0
16m		0.50	20.0	30.0	
	16m				70.0
30m		0.62	25.0	55.0	
	30m				45.0
50m		0.57	23.0	78.0	
	50m				22.0
100m		0.32	13.0	91.0	
	100m				9.0
pan		0.23	9.0	100.0	
	pan				
Totals		2.50	100.0		

Unit Weight Loose Dry= 66.67 pounds per cubic foot
Fineness Modulus = 3.68

Combined Aggregate:

Unit Weight Loose Dry= 62.4 pounds per cubic foot
Fineness Modulus = 5.97
Six Sack
Equivalent Concrete= 1.30 pounds
Water Required =557 milliliters

TABLE XXXI

CONCRETE MIX SPECIFICATIONS, 59 MILE SHALE

Coarse Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
3/4"		0.00	0.0	0.0	
	3/4"				100.0
3/8"		0.82	50.0	50.0	
	3/8"				50.0
4m		0.82	100.0	100.0	
	4m				0.0
Totals		1.64	150.0		

Unit Weight Loose Dry= 49.2 pounds per cubic foot
Fineness Modulus = 6.00

Fine Aggregate:

Mesh Retained	Mesh Passed	Weight (Pounds)	Per cent On	Cumulative Per cent Retained	Cumulative Per cent Passed
4m		0.00	0.0		
	4m				100.0
8m		0.25	10.0	10.0	
	8m				90.0
16m		0.50	20.0	30.0	
	16m				70.0
30m		0.62	25.0	55.0	
	30m				45.0
50m		0.57	23.0	78.0	
	50m				22.0
100m		0.32	13.0	91.0	
	100m				9.0
pan		0.23	9.0	100.0	
	pan				0.0
Totals		2.50	100.0		

Unit Weight Loose Dry= 75.9 pounds per cubic foot
Fineness Modulus = 3.64

Combined Aggregate:

Unit Weight Loose Dry= 65.8 pounds per cubic foot
Fineness Modulus = 4.58
Six sack
Equivalent Concrete= 1.31 pounds
Water Required =400milliliters

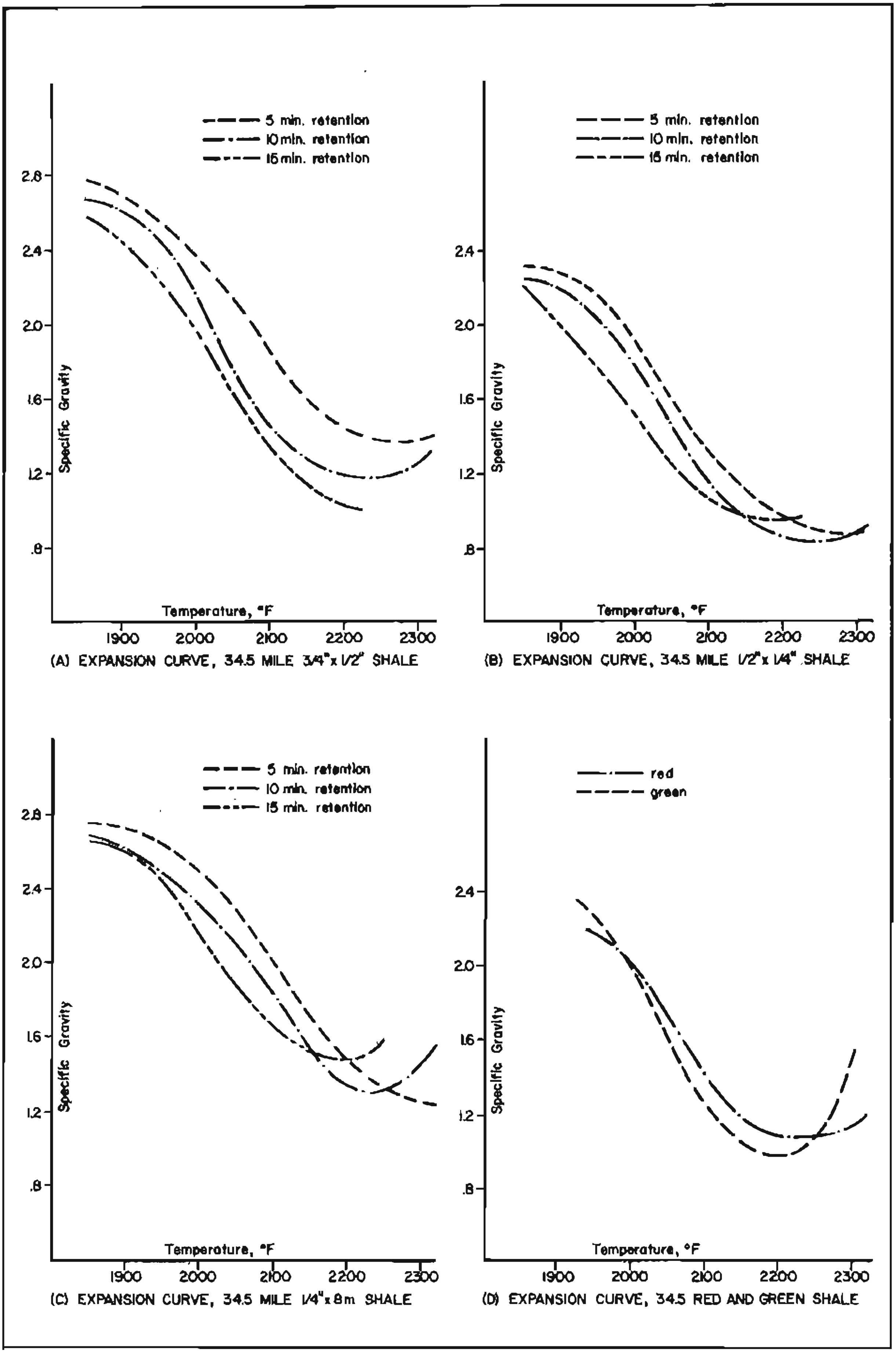
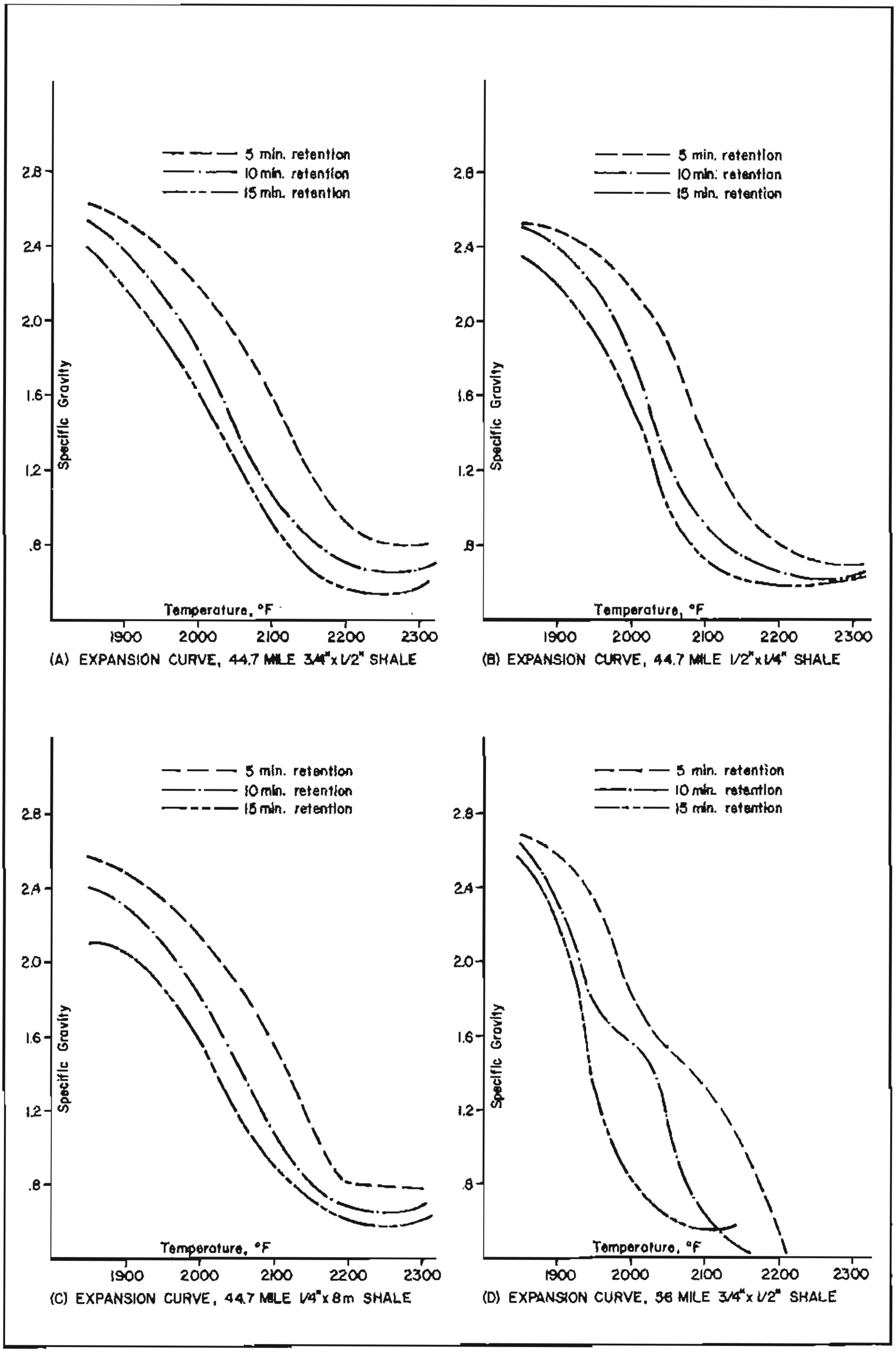

5 min. retention
10 min. retention
15 min. retention
Specific Gravity
Temperature, °F
(A) EXPANSION CURVE, 34.5 MILE 3/4"x 1/2" SHALE
(B) EXPANSION CURVE, 34.5 MILE 1/2"x 1/4" SHALE
(C) EXPANSION CURVE, 34.5 MILE 1/4"x 8m SHALE
red
green
(D) EXPANSION CURVE, 34.5 RED AND GREEN SHALE

FIG. 1



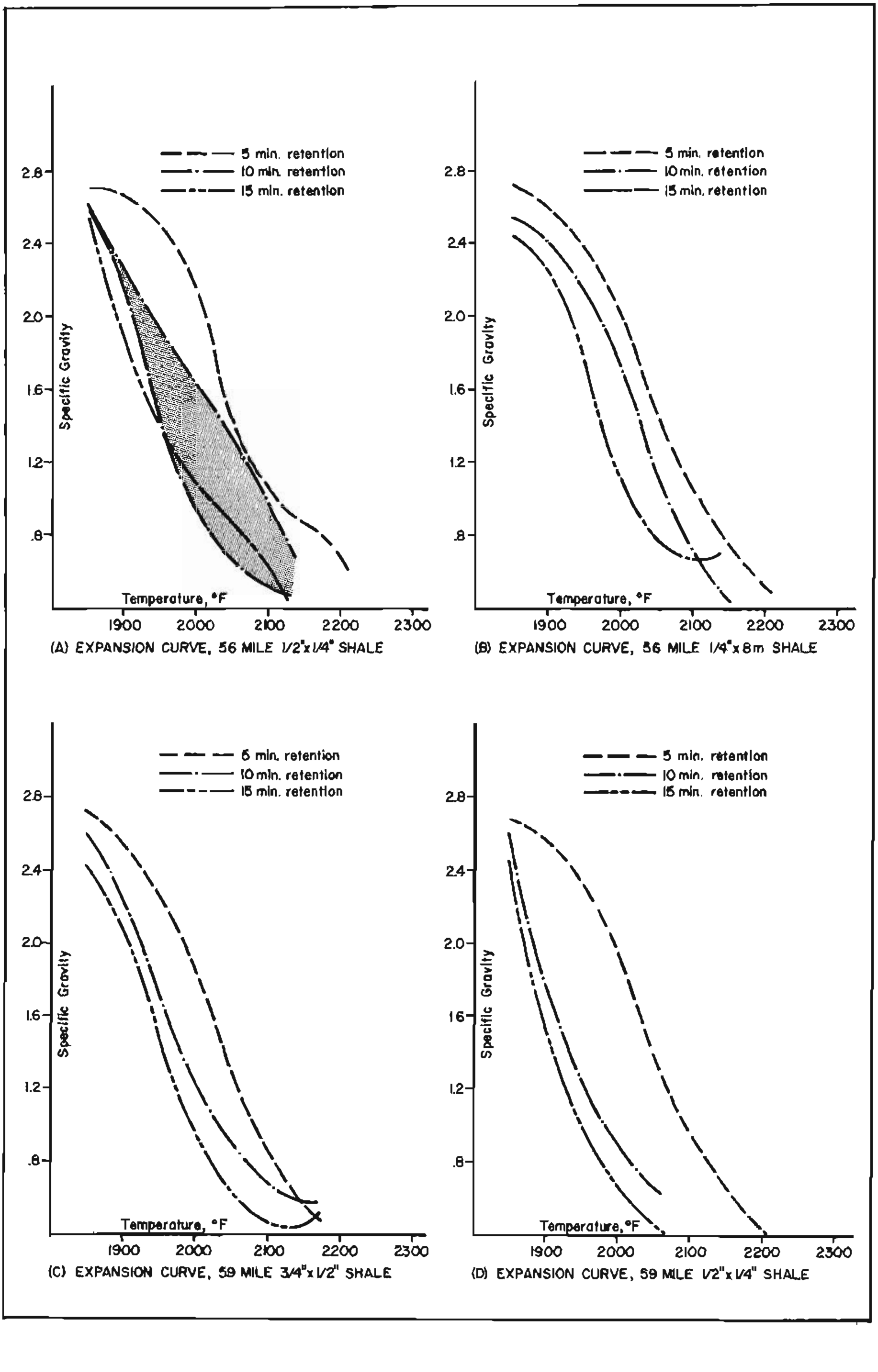
(A) EXPANSION CURVE, 44.7 MILE 3/4"x 1/2" SHALE

(B) EXPANSION CURVE, 44.7 MILE 1/2"x 1/4" SHALE

(C) EXPANSION CURVE, 44.7 MILE 1/4"x 8m SHALE

(D) EXPANSION CURVE, 56 MILE 3/4"x 1/2" SHALE

FIG. 2



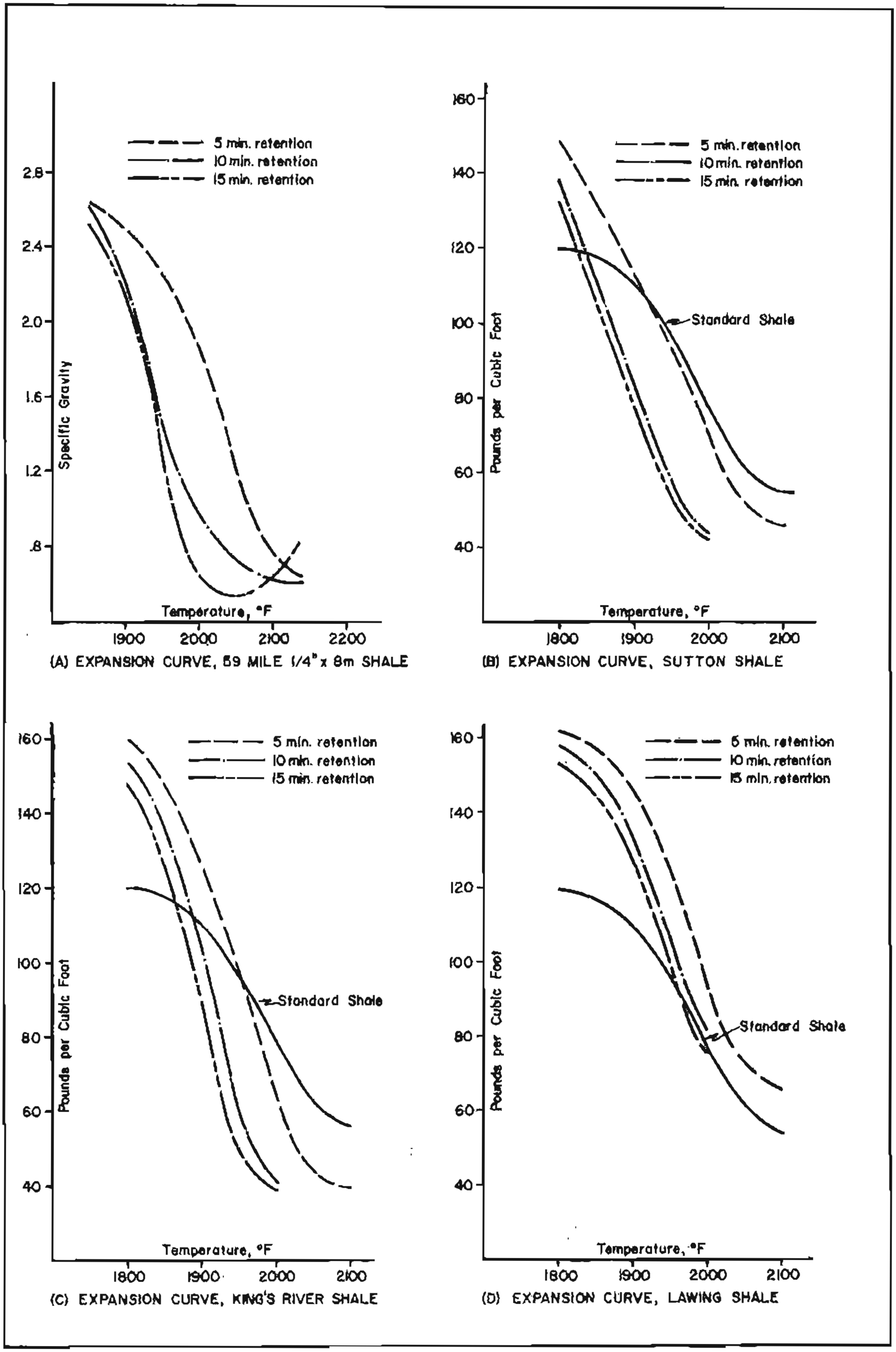
(A) EXPANSION CURVE, 56 MILE 1/2"x1/4" SHALE

(B) EXPANSION CURVE, 56 MILE 1/4"x8m SHALE

(C) EXPANSION CURVE, 59 MILE 3/4"x1/2" SHALE

(D) EXPANSION CURVE, 59 MILE 1/2"x1/4" SHALE

FIG. 3



(A) EXPANSION CURVE, 59 MILE 1/4" x 8m SHALE

(B) EXPANSION CURVE, SUTTON SHALE

(C) EXPANSION CURVE, KING'S RIVER SHALE

(D) EXPANSION CURVE, LAWING SHALE

FIG. 4