OKLAHOMA GEOLOGICAL SURVEY

ROBERT H. DOTT, Director

Bulletin No. 60

ROCK WOOL POSSIBILITIES IN OKLAHOMA

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Norman

1939

THE BOARD OF REGENTS

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ROCK WOOL POSSIBILITIES IN OKLAHOMA

ABSTRACT

This report discusses the possibility of establishing a rock wool industry in Oklahoma. Deposits of potential woolrock are described and chemical and physical characteristics of 80 samples are given. Chemical, metallurgical, and economic factors of the industry are discussed with reference to Oklahoma. A new type gas-burning plant furnace designed by the author is explained and illustrated. A map and other illustrations accompany the text and some related data are included in the appendices.

During the course of the investigations, large quantities of satisfactory raw material (woolrock) were found in various parts of Oklahoma. Many of the large deposits of woolrock could be mined by the cheapest of methods. Fuel for a rock wool industry is available, in the form of cheap natural gas, and large coal reserves, which could be used for producing coke. Asphalt and petroleum oils are available for the manufacture of related products. Transportation facilities are adequate, and with the wide choice of locations available for obtaining raw material, it would seem that Oklahoma offers an exceptionally favorable opportunity to the rock wool manufacturer.

This report is primarily of an economic nature. Locations and economic features of the woolrock deposits found in the state, and factors affecting possible local manufacturing operations, have been stressed. Many different types of raw material are described, but many more deposits will doubtless be discovered.

INTRODUCTION

The importance and benefits of the use of insulating materials in construction and industry are rapidly becoming more generally known, and new uses for such materials are being developed constantly. Rock wool, admittedly, offers one of the most efficient and permanent types of insulation, and consequently, the market demand for this and other kinds of mineral wool is now more than 10 times that of 1928. Continued rapid expansion of the industry can be expected since improved methods of manufacture and distribution, together with the development of new uses, will undoubtedly disclose many important, undeveloped markets. The use of rock wool for insulating houses is increasing in importance. Insulation makes dwellings much cooler in summer and warmer in winter, and effects pronounced reductions in the cost of heating. An appreciable reduction of the cost of rock wool to the consumer would open to the industry the immense field of low cost housing, both old and new. Such reduction can only be effected by lowering the costs of production and distribution. It would seem that this is another of the industries that would benefit greatly by de-centralization.

Purpose and Nature of the Investigation. The principal objectives of this work were to locate suitable raw materials, to encourage the establishment of a rock wool manufacturing industry in Oklahoma and to point out, where possible, factors that might assist in lowering the cost of the product in this trade area.

Oklahoma and the entire Southwest is in particular need of a low cost, efficient, insulating medium. This area is subjected to extremes of both heat and cold that seriously affect living conditions, especially in homes of the lower cost class. Rock wool produced locally should find a ready market throughout the Southwest and adjoining regions.

Rock wool is produced by melting the raw material and blowing it, with live steam, into fine, wool-like fibers. The most important raw material is impure limestone, whose impurities consist principally of sand or other forms of silica, or clay. Pure limestone is not suitable, for when heated, it calcines to lime, and does not melt. Pure silica, on the other hand, forms glass. A proper mixture of the two is necessary to produce the flexible, wool-like fibers.

Experiments by the Illinois Geological Survey[1] indicate that a rock containing 20 to 30 percent carbon dioxide produces satisfactory rock wool, and a rock of this composition is called a woolrock. Satisfactory wool can be prepared from mixtures of rocks that by themselves, are of unsuitable composition.

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1. Lamar, J. E., Willman, H. B., Fryling, Charles F., and Voskuil, Walter H., "Rock Wool from Illinois Mineral Resources": *Ill. Geol. Survey Bull.* 61, p. 17, 1934.

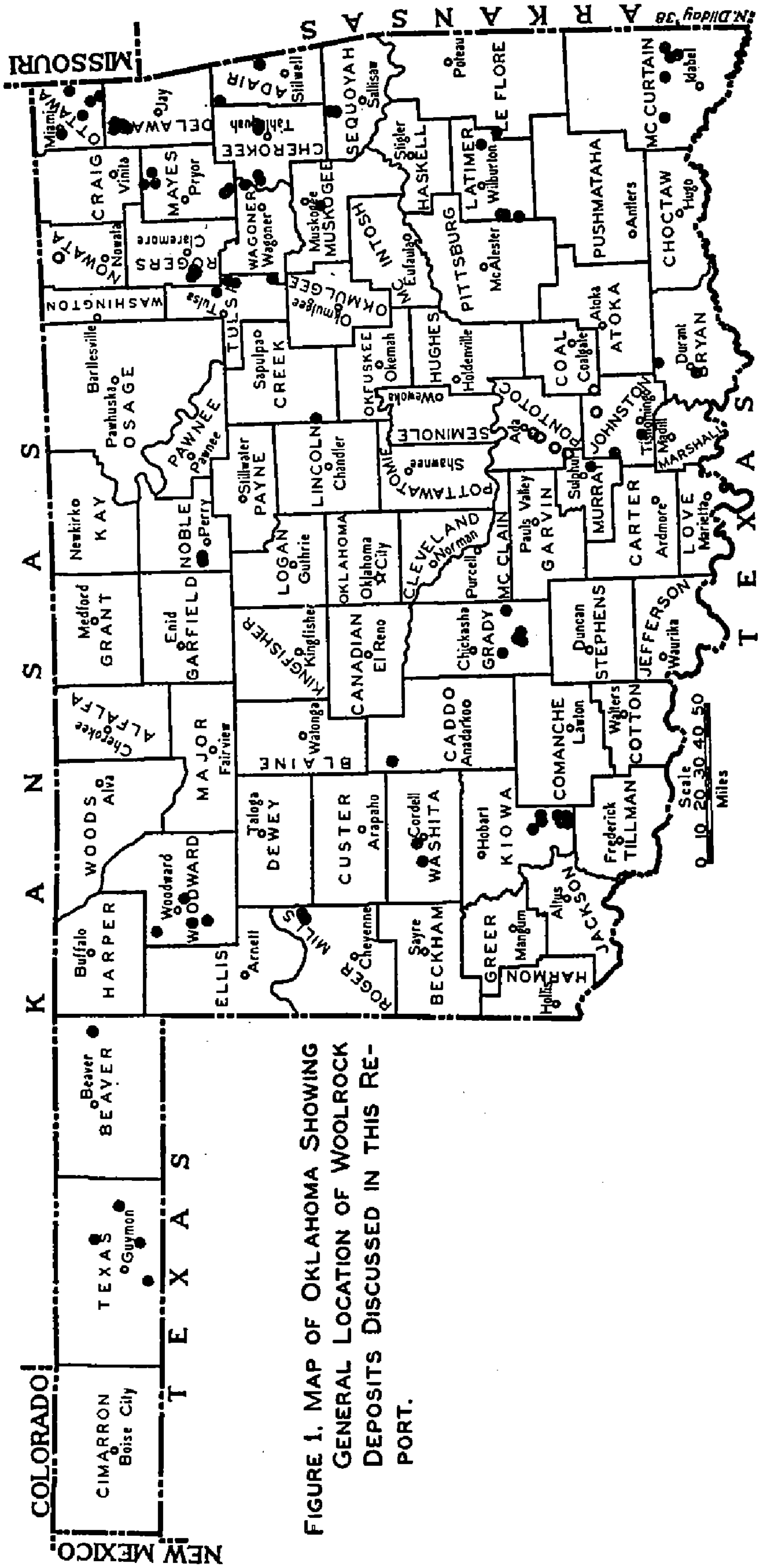


FIGURE 1. MAP OF OKLAHOMA SHOWING GENERAL LOCATION OF WOOLROCK DEPOSITS DISCUSSED IN THIS REPORT.

Oklahoma contains large deposits of limestones that offer a wide range of composition, and many samples are on file at the Oklahoma Geological Survey. These samples were tested in the Industrial Research Laboratory of the Geological Survey, to determine which of them would make satisfactory rock wool.

Area Investigated. In 1936-37 the Oklahoma Geological Survey, cooperating with the Works Progress Administration, (with assistance from the State Highway Commission, School Land Commission, and various county and municipal units) prosecuted a state-wide survey of native mineral resources (Project 65-65-538). More inaccessible portions of the state could not be examined carefully, and in certain areas known to contain limestones, particularly Pontotoc, Nowata, Washington, Kay, and Osage Counties, field work and sampling were not completed due to lack of time, personnel, and equipment. More than half the counties were prospected more or less thoroughly. Although a majority of the personnel engaged in this work was inexperienced and untrained, a large quantity of valuable information was acquired, and several thousand samples of material were collected and examined for possible commercial value. Chemical analyses were made in the laboratory of the Oklahoma Geological Survey by chemists employed on the same project. Among these samples were some that had characteristics of natural woolrock. These were subjected to actual blowing tests and 80 of them, that produced rock wool of various grades, are described in detail in this report. The methods of sampling used and the field descriptions of deposits were of a reconnaissance nature, but the information is sufficiently accurate for all preliminary uses, such as the consideration of possible plant or mine locations. Samples from most parts of Oklahoma were examined, and the locations of those described herein are shown on figure 1.

Laboratory Procedure. All samples, on arrival at the laboratory, were crushed to minus ¼-inch mesh by jaw crusher, and then reduced to a weight of approximately 10 pounds by repeated passing through a Jones type sample splitter. From this resulting sample two small representative samples, about 200 grams each, were withdrawn. One of these small samples was pulverized and analyzed chemically, and the other was examined mineralogically. Special note was made of the carbon dioxide (CO_2) content, and all samples containing that compound roughly between the limits of 20 and 30 percent were subjected to actual blowing tests.

The wool blowing procedure used was designed only to determine whether a rock could be melted in a commercially feasible manner, and would then form rock wool when blown. A 1000 gram sample, or larger, of the minus ¼-inch mesh material was first calcined for 3 hours at a temperature of 1000 to 1100° C. and then transferred to a No. 4 graphite crucible provided with a graphite cover in which a small notch was cut fitting directly over the crucible pouring lip. Special basket tongs were constructed to fit the crucible and cover. To facilitate handling and pouring, these tongs were provided with long handles bent 90° from the vertical axis of the crucible basket. Cylindrical lugs in the jaws, fitting into notches in the pouring rack, provided a fixed axis of rotation for the pouring operation.

The melting furnace used was a standard cylindrical, gas burning type equipped with a motor blower. Furnace temperatures exceeding 1600° C. were easily obtained. The time required for melting a charge was from 2 to 3 hours. The condition of the charge was tested by inserting a steel rod into the crucible and observing the adhering coating of slag. When the sample contained no unmelted inclusions and appeared to be a homogeneous mixture, it was considered ready for blowing. All temperatures were measured with an optical pyrometer which, though not exact, was sufficiently accurate for practical purposes.

The crucible, with molten charge, was transferred quickly to the pouring rack and tilted by hand. The pouring rate varied from 30 to 50 seconds according to the viscosity of the melt. A uniform slag stream was maintained, as nearly as possible, of approximately ¼-inch diameter. Steam blowing pressure was 80 lbs. per sq. in. at the nozzle on most tests, using a horizontal slot type of steam orifice ¾-inch long and 3/64-inch wide. The later development of a V-shaped nozzle utilizing the restricted throat principle permitted the reduction of steam pressure to 60 lbs. per sq. in. The wool was blown into a partially screened corner of the room, collected from the floor and walls and sacked, together with any shot formed.

Details of sample preparation and wool blowing equipment are illustrated in figures 2 to 5 inclusive.

RESULTS OF THE INVESTIGATION

This investigation has disclosed that Oklahoma contains immense quantities of rock that could be utilized for the manufacture of all types or grades of rock wool. Many large deposits of suitable material are exceptionally well situated geographically. Initial cost of material should be low and mining costs, in most instances, would not be excessive. Efficient labor, low cost fuel, adequate transportation, and other facilities are readily available.

Oklahoma has large reserves of natural gas available to industry at low cost. Gas was used as fuel throughout this investigation and the scale of operation was sufficiently large to demonstrate that, with properly designed equipment and procedure, it should be possible to construct efficient, commercial-sized, gas-burning rock wool furnaces. One proposed type of gas burning plant, that should prove satisfactory, has been designed in the offices of the Oklahoma Geological Survey and is discussed in the chapter following.

Distribution of Woolrock

Satisfactory woolrock has been found in most parts of Oklahoma as shown by the 80 samples described on following pages. While those samples represent a very large quantity of potential woolrock, many more deposits will undoubtedly be discovered by further prospecting.

A number of woolrock deposits in different parts of Oklahoma have characteristics that make them worthy of special note. As those deposits offer the best opportunities, known at present, for prospective development, they are described here in some detail. For more exact areal details the Geologic Map of Oklahoma and publications of the Oklahoma Geological Survey

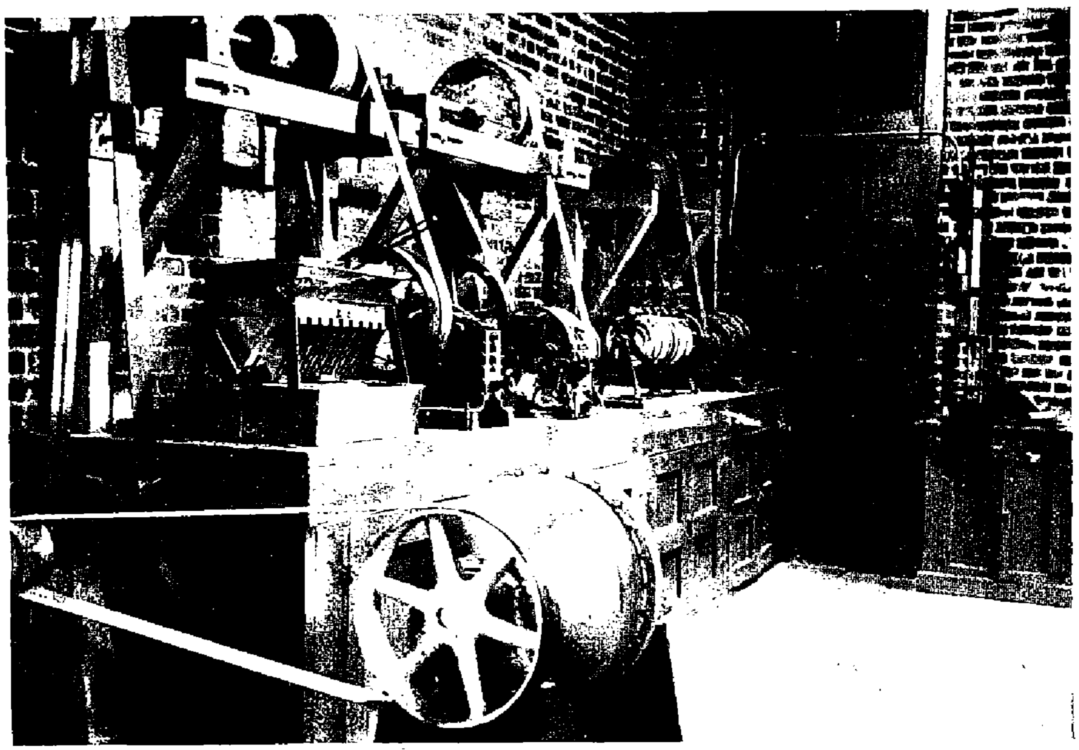


FIG. 2. SAMPLE PREPARATION EQUIPMENT, OKLAHOMA GEOLOGICAL SURVEY LABORATORY.

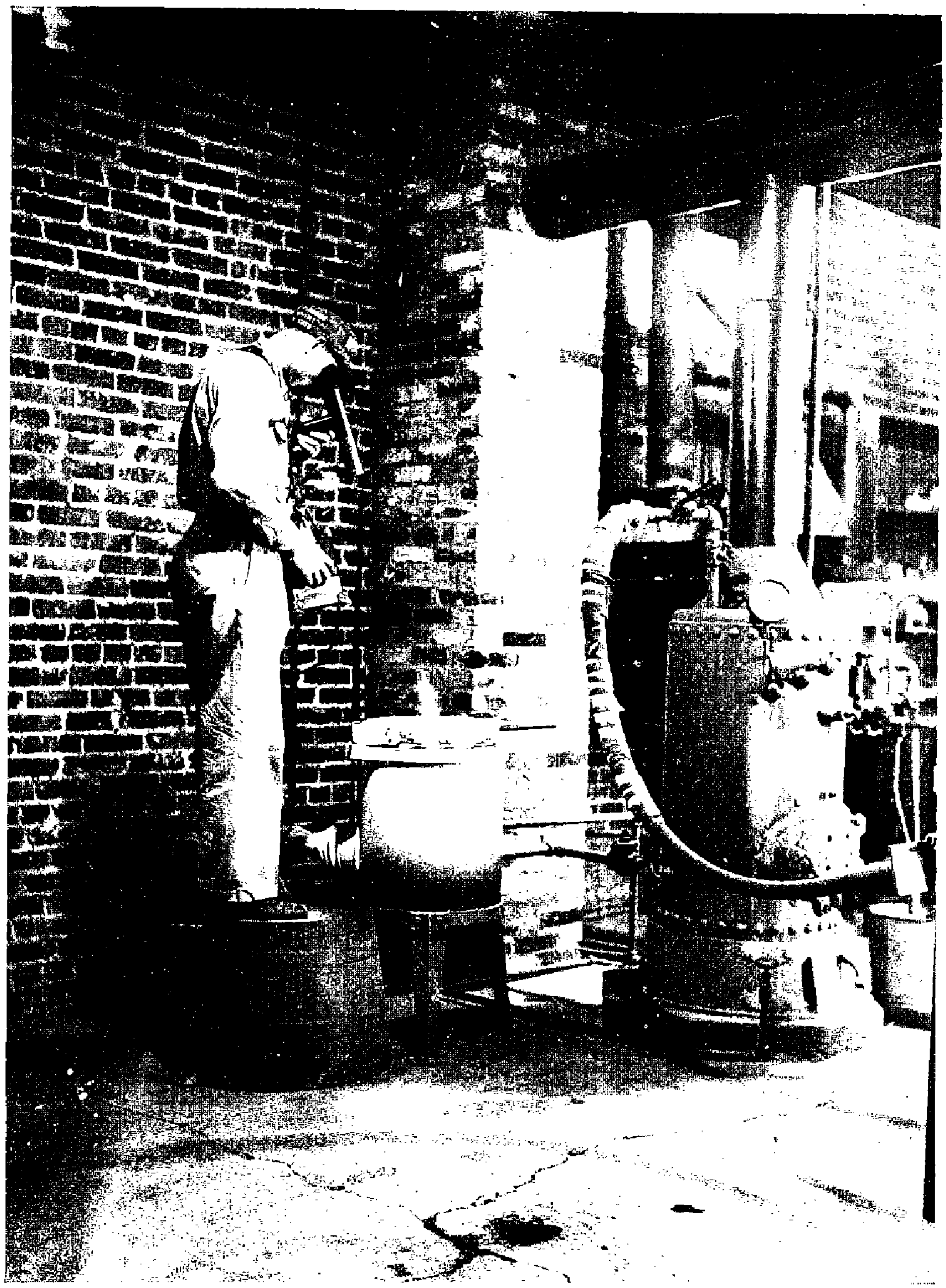


Fig. 3. Method of Determining Temperature of Melting Crucible Using Optical Pyrometer.

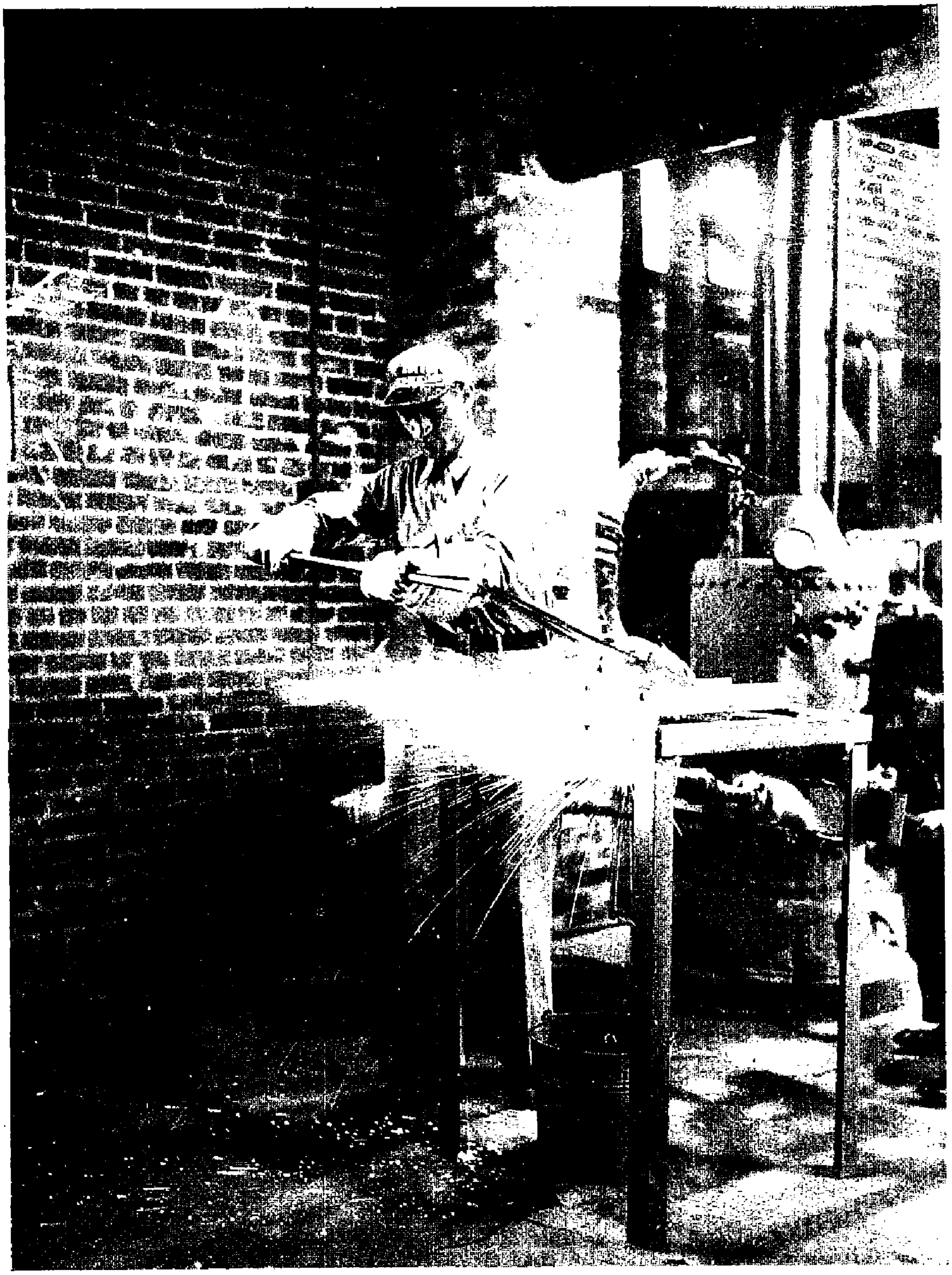


FIG. 4. BLOWING ROCK WOOL IN THE LABORATORY.

FIG. 5. ROCK WOOL PRODUCED IN ONE TRIAL BLOWING.

should be consulted. Some additional, unpublished details are in the Survey files.

EASTERN OKLAHOMA

A thick series of limestones, chert, and calcareous shales crop out over a large part of the northeastern part of the state. Samples from many beds of the following units, listed from oldest to youngest, have proved to be good woolrock: Boone limestone; limestone which has been called "Mayes", and variously referred to the Moorefield, Batesville, and Fayetteville formations; and the Pitkin limestone. All are of Mississippian age, and crop out on the southwest flank of the Ozark Mountains.

The *Boone limestone* varies in thickness from 100 to about 450 feet and is composed of interstratified beds of chert and cherty limestone. The proportion of chert to limestone varies greatly in this formation and ranges from nearly all chert to nearly all limestone. Wide variation in composition occurs within the formation at short vertical intervals, a condition that is favorable to selective mining methods, permitting the operator to produce any desired quality of material. The Boone limestone occupies nearly all of Delaware and Adair Counties, southeastern Ottawa County, the southeastern corner of Craig County, the east half of Mayes County, and the northeast part of Cherokee County, and extending into northern Sequoyah County.

Samples numbered 2, 9, 10, 13, 16, 17, 53, 54, 56, 57, and 64 are all from the Boone limestone at widely dispersed points, indicating that the formation undoubtedly contains vast quantities of potential woolrock. The large area covered should offer many choice mine locations where conditions would be favorable to cheap and efficient operation on any scale.

The *"Mayes"* is a dark colored limestone, locally argillaceous, with an average thickness of about 40 feet. It crops out around the margin of the Boone limestone and is prominent in Ottawa and Mayes Counties, also cropping out in the southeast corner of Craig County and the northwest corner of Delaware County.

Samples numbered 14, 15, 39, 40, and 55, taken from widely separated points, would indicate that the Mayes limestone is an exceptionally good potential source of woolrock. The formation offers many quarry sites where mining costs should be low and large quantities of material of uniform quality could be produced.

The *Pitkin limestone* varies from rusty-brown, granular, earthy strata to bluish fine-textured, massive beds. The granular type is most common and the best source of woolrock. The formation crops out in numerous patches brought up by faulting, and also in exposures along Grand River and its eastern tributaries in Wagoner, Mayes, Craig, northern Delaware, and Ottawa Counties. Many favorable quarry sites are available and the formation appears to contain large quantities of woolrock, as indicated by samples numbered 7, 8, and 76.

From the information available it would seem that the northeastern part of Oklahoma contains a potential woolrock producing area, embracing some 3500 square miles, in which satisfactory material could be produced within a reasonable distance from any desired point.

CENTRAL OKLAHOMA

Although woolrock deposits are not so numerous throughout central Oklahoma as they are in some other parts of the state, one of these deposits is truly outstanding and should be carefully considered by the prospective manufacturer.

The *Verden sandstone,* a bed in the Marlow member of the Whitehorse formation, of Permian age, is an odd sedimentary unit studied principally in Grady County.[2] The formation consists of one bed of massive, fossiliferous, coarse-grained, calcareous sandstone 8 to 10 feet in thickness. It is exposed in a single line of outcrops, not more than 500 feet wide, capping long, narrow hills, that extend across the country like a gigantic abandoned and dissected railroad grade. The northern end of the ex-

2. Bass, N. W., "Verden Sandstone of Oklahoma—An Exposed Shoestring Sand of Permian Age": *Bull. Amer. Assoc. Petro. Geol.*, Vol. 23. pp. 559-582, 1939.

posures under discussion is in the east-central part of Caddo County, with the line of outcrops extending southeast through Grady County, into the northern part of Stephens County, a distance of some 40 miles.

Numerous samples of the Verden sandstone, of which samples numbered 18, 19, 20, and 21 are representative, were tested in the laboratory and all produced excellent rock wool, so evidently the entire visible formation can be classed as first grade woolrock. Mining operations should be both simple and inexpensive. Very little overburden is present and, as the beds all form the tops of hills, gravity methods of handling could be used efficiently. The rock is brittle and breaks easily, a characteristic which should be favorable to both mining and crushing costs. The area is well served by railroads and improved highways can be reached within short distances. Electric power and natural gas are readily available.

Another potential source of woolrock in the central part of the state, but one which has not been adequately studied or mapped, is a series of thin, lenticular beds of red to black dolomitic material that have the appearance of conglomerate, and occur in the lower part of the Permian series. This occurrence does not seem to be a continuous bed but is found as a series of separate outcropping deposits, covering areas of from 5 to 160 acreas each, extending in a narrow band through central Logan, Oklahoma, and Cleveland Counties.

A number of preliminary tests of these pseudo-conglomerates have been made, one of material from the NW¼ sec. 22, T. 14 N., R. 2 W., Oklahoma County. All produced commercial grades of rock wool. These samples were not accurately located so are not included in this report.

WESTERN OKLAHOMA

The only important, but very interesting, source of woolrock found to date in western Oklahoma is a material known as caliche. This rock appears to have been formed by infiltration of calcareous solutions into original soil or alluvium, effecting some mineralogical alteration and subsequently cementing the loose original material to form a soft, porous, calcareous rock. Caliche occurs in irregular lenticular deposits, usually found at or near the surface, varying in thickness from a few inches to 15 feet or more, and in area from a few acres to several square miles. Large quantities of the material have been used throughout the Southwest for the surfacing of secondary highways.

Caliche occurs in western Oklahoma, the Oklahoma and Texas Panhandle areas, and large deposits have been found in eastern New Mexico. In Oklahoma, deposits have been found and tested for woolrock qualities in Comanche, Kiowa, Washita, Roger Mills, Woodward, Beaver, and Texas Counties as represented by samples numbered 3, 11, 25, 26, 27, 28, 29, 30, 31, 32, 58, 59, 66, 67, 68, 69, 74, 75, 77, 78, 79, and 80. Texas County, especially, contains numerous large deposits of caliche that could be utilized for the manufacture of rock wool.

Caliche has several advantageous properties and characteristics not common to other types of woolrock. It goes into molten solution at reasonable temperatures (as low as 1425° C.) and, in that state, readily blends with other materials. Though all caliche deposits are not good woolrock as found, those tested produced liquid slags to which small quantities of other rock, containing the deficient minerals, were easily added and absorbed with good rock wool resulting. River and blow sand, soil, limestone, and other caliche with opposite deficiencies, have been blended and good grades of rock wool have resulted. A manufacturing system designed with adequate controls, both at mines and plant, could easily maintain uniformity in quality of the product. Moreover, such a system would permit the production of different types of wool if desired for different or specialized uses.

Caliche as raw material, should cost less to produce than other woolrocks. Mining is usually done with plows, scrapers, draglines, and similar equipment. Land values are low in areas where caliche is found. Many tons of the material have been placed on roads at a total cost not exceeding 25 cents per ton, this including purchase, mining, loading on trucks, and a short haul.

WOOLROCK MIXTURES

No samples of natural woolrock were available from several important areas in the state, so a few tests of mixtures of materials from the vicinity of Ada were made with very satisfactory results. The Ada area, in Pontotoc, Murray, Johnston, and Coal Counties is of great importance because of the large reserves of natural gas, immense deposits of limestone and shale, and good transportation facilities.

Kay, Pawnee, Payne, Osage, Seminole, and Washington Counties all contain numerous outcrops of limestones and shales, and woolrock mixtures made from these rocks should be as satisfactory as those from the Ada area.

Detailed Description of Samples

The samples described in this section are only those from which commercial grades of rock wool were manufactured successfully in the laboratory. Other samples, about one hundred in number, were tested but either failed to go into molten solution at practical temperatures or produced unsatisfactory grades of rock wool. Many of the deposits represented by these unsatisfactory samples might be classed as sub-woolrock, but the quantities and distribution of good woolrock in the state are so great that it is not considered necessary to describe in detail such lower grade deposits.

Sample No. 1

LOCATION: SW¼ SE¼ SW¼ sec. 17, T. 19 N., R. 24 E. ADAIR COUNTY
GEOLOGICAL FORMATION: Burgen (?) sandstone, Ordovician.
FIELD SHEET NO. 225-1 LABORATORY NO. 4940

Chemical Components (per cent)

Silica (SiO_2)	48.98	Calcium Oxide (CaO)	14.56
Alumina (Al_2O_3)	1.66	Magnesium Oxide (MgO)	10.80
Iron Oxide (Fe_2O_3)	2.14	CARBON DIOXIDE (CO_2)	23.14
Manganese Dioxide (MnO_2)	none	Total	101.29

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
14.0	1.0	3.0	White	Fine and flexible. Good grade of wool	1410° C.

REMARKS: This is a dolomitic sandstone member of the Burgen sandstone. The bed at this point is 15 feet thick and crops out near water level, along the north bank of Illinois River for a distance of about 1500 feet. A number of similar outcrops are found in the area. The rock produced a very good wool. It would be necessary to mine this woolrock by underground methods but the cost should not be excessive.

SAMPLE No. 2

LOCATION: NE¼ NW¼ NW¼ sec. 34, T. 17 N., R. 26 E. ADAIR COUNTY
GEOLOGICAL FORMATION: St. Joe member of the Boone limestone, Mississippian.
FIELD SHEET NO. 237-2 LABORATORY NO. 2227

Chemical Components (per cent)

Silica (SiO_2)	32.20	Calcium Oxide (CaO)	30.52
Alumina (Al_2O_3)	4.25	Magnesium Oxide (MgO)	4.16
Iron Oxide (Fe_2O_3)	0.43	CARBON DIOXIDE (CO_2)	28.49
Manganese Dioxide (MnO_2)	trace	Total	100.05

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	3.0	6.6	Brown tint	Medium, flexible.	1488° C.

REMARKS: This bed occurs at the base of the Boone limestone. At the point sampled it is 8 feet thick and the outcrop exposed is about 600 feet long. The Boone limestone covers large areas in the northeastern part of the state and ranges in thickness from 100 to 450 feet. The formation is composed of interstratified chert and cherty limestones of various proportions. Careful sampling in any area would undoubtedly disclose a number of beds of natural woolrock. In general, underground mining and controlled mixing of different beds will be necessary but some surface deposits of woolrock will be found.

SAMPLE No. 3

LOCATION: NE¼ NW¼ NW¼ sec. 14, T. 4 N., R. 27 E. BEAVER COUNTY
GEOLOGICAL FORMATION: Ogallala formation, Tertiary.
FIELD SHEET NO. 101-2 LABORATORY NO. 4710

Chemical Components (per cent)

Silica (SiO_2)	33.90	Calcium Oxide (CaO)	33.29
Alumina (Al_2O_3)	1.48	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.50	CARBON DIOXIDE (CO_2)	26.12
Manganese Dioxide	none	Combined water (H_2O)	1.27
		Total	97.56

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average	White	Soft and flexible. Good grade of wool.	1481° C.
13.5	1.5	5.7			

REMARKS: This sample is caliche, a loosely cemented, calcareous material. It is rather soft, easily mined and inexpensive to purchase. At present caliche is used only in the construction of secondary roads and highways. Many deposits and large quantities of caliche occur in the northwestern part of Oklahoma and the Texas Panhandle. Chemical compositions vary considerably but the material is exceptionally amenable to mixing with other materials such as soil, sand, limestone, or high lime-content caliche, thereby obtaining the proper chemical composition, for the manufacture of rock wool. These added materials are usually easily available at a cost even lower than that of caliche. With proper plant control most of the deposits could be utilized.

SAMPLE No. 4

LOCATION: NE¼ NW¼ NE¼ sec. 10, T. 5 S., R. 9 E. BRYAN COUNTY
GEOLOGICAL FORMATION: Caddo limestone, Lower Cretaceous.
FIELD SHEET NO. 147 LABORATORY NO. 3999

Chemical Components (per cent)

Silica (SiO_2)	28.64	Calcium Oxide (CaO)	36.00
Alumina (Al_2O_3)	2.44	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.36	CARBON DIOXIDE (CO_2)	26.90
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	3.12
		Total	99.46

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average	White	Fine and flexible. Good grade of wool.	1446° C.
12.0	1.0	3.6			

REMARKS: The Caddo formation of the Washita group crops out in Love, Marshall, Bryan, and Choctaw Counties, south of the Goodland limestone outcrops. The thickness varies up to 150 feet but this sample represents only 4 feet near the middle of the formation. Large quantities are available that can be mined by cheap opencut methods. Thickness of overburden will increase to the south. Accessibility and shipping facilities are favorable.

SAMPLE No. 5

LOCATION: SW¼ SE¼ SW¼ sec. 5, T. 7 S., R. 9 E. BRYAN COUNTY
GEOLOGICAL FORMATION: Bennington limestone, Lower Cretaceous.
FIELD SHEET NO. 156-1 LABORATORY NO. 4005

Chemical Components (per cent)

Silica (SiO_2)	36.94	Calcium Oxide (CaO)	21.62
Alumina (Al_2O_3)	7.11	Magnesium Oxide (MgO)	2.44
Iron Oxide (Fe_2O_3)	9.15	CARBON DIOXIDE (CO_2)	19.27
Manganese Dioxide (MnO_2)	0.63	Combined water (H_2O)	none
		Total	97.16

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
17.0	1.5	4.3	Gray	Good grade of wool.	1442° C.

REMARKS: This sample represents one of the ferruginous limestone beds of the Bennington formation, about 4 feet thick. The deposit is accessible but will require prospecting by core or churn drill to determine economic value. The high iron content was reduced to metallic iron in the gas fired laboratory furnace.

SAMPLE No. 6

LOCATION: SE¼ SE¼ SW¼ sec. 9, T. 11 N., R. 13 W. CADDO COUNTY
GEOLOGICAL FORMATION: Whitehorse sandstone, Permian.
FIELD SHEET NO. 84-1 LABORATORY NO. 4970

Chemical Components (per cent)

Silica (SiO_2)	20.44	Calcium Oxide (CaO)	23.65
Alumina (Al_2O_3)	3.52	Magnesium Oxide (MgO)	15.04
Iron Oxide (Fe_2O_3)	1.00	CARBON DIOXIDE (CO_2)	33.44
Manganese Dioxide (MnO_2)	none	Combined water (H_2O)	none
		Total	97.09

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	1.4	9.2	White	Erratic fiber size. Fair wool only.	1449° C.

REMARKS: This sample represents a coarse-grained dolomitic bed in the Rush Springs member of the Whitehorse formation 3 to 5 feet thick. The material did not melt evenly or mix properly in molten solution, and a large variation in fiber diameters resulted. Very fine fibers were interwoven with coarse fibers, and while the wool may have a good insulating value, it can not be called a first grade product. Manufacture on a commercial scale would probably permit the production of a better material.

SAMPLE No. 7

LOCATION: SW¼ SE¼ NE¼ sec. 9, T. 17 N., R. 20 E. CHEROKEE COUNTY
GEOLOGICAL FORMATION: Pitkin limestone, Mississippian.
FIELD SHEET NO. 62-4 LABORATORY NO. 4506

Chemical Components (per cent)

Silica (SiO_2)	27.36	Calcium Oxide (CaO)	36.52
Alumina (Al_2O_3)	2.14	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	5.36	CARBON DIOXIDE (CO_2)	27.72
Manganese Dioxide (MnO_2)	trace	Total	99.10

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	1.0	3.6	Gray	Fine and flexible. Good grade of wool.	1488° C.

REMARKS: This sample is from one of the numerous outcrops of the Pitkin limestone occurring along the southern edge of the Ozarks. At the point sampled, the exposure is 30 feet thick and about 2700 feet long. This deposit could be mined by open cut and stripping methods but many of the similar deposits would require underground methods. The iron content was nearly all reduced to the metallic state in melting, so did not affect the quality of the wool materially.

SAMPLE No. 8

LOCATION: NE¼ SE¼ NW¼ sec. 18, T. 17 N., R. 20 E. CHEROKEE COUNTY
GEOLOGICAL FORMATION: Fayetteville shale (?), Mississippian.
FIELD SHEET NO. 80-4 LABORATORY NO. 4974

Chemical Components (per cent)

Silica (SiO_2)	30.68	Calcium Oxide (CaO)	34.84
Alumina (Al_2O_3)	3.17	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.57	CARBON DIOXIDE (CO_2)	29.39
Manganese Dioxide (MnO_2)	none	Combined water (H_2O)	none
		Total	99.65

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
(not	available)		White	Very good grade of wool.	1573° C.

REMARKS: This sample is probably from a lenticular limestone of the Fayetteville shale. The remarks pertaining to sample No. 7 apply, except that this deposit is not so favorable for mining. The melting point is comparatively high.

SAMPLE No. 9

LOCATION: NW¼ NW¼ SE¼ sec. 12, T. 17 N., R. 22 E. CHEROKEE COUNTY
GEOLOGICAL FORMATION: St. Joe member of the Boone limestone, Mississippian.

FIELD SHEET NO. 172-4 LABORATORY NO. 4496

Chemical Components (per cent)

Silica (SiO_2)	40.58	Calcium Oxide (CaO)	33.86
Alumina (Al_2O_3)	0.49	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.29	CARBON DIOXIDE (CO_2)	24.38
Manganese Dioxide (MnO_2)	trace	Total	100.60

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.1	White	Fair grade of wool.	1549° C.

REMARKS: This bed of the St. Joe limestone is only 3 feet thick and could be mined only by underground methods. Production at present would not be economically feasible.

SAMPLE No. 10

LOCATION: NW¼ NW¼ SE¼ sec. 12, T. 17 N., R. 22 E. CHEROKEE COUNTY
GEOLOGICAL FORMATION: St. Joe member of the Boone limestone, Mississippian.
FIELD SHEET NO. 172-4F LABORATORY NO. 4504

Chemical Components (per cent)

Silica (SiO_2)	26.08	Calcium Oxide (CaO)	41.42
Alumina (Al_2O_3)	0.58	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.36	CARBON DIOXIDE (CO_2)	31.77
Manganese Dioxide (MnO_2)	none	Total	100.21

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.3	2.2	White	Fair grade of wool.	1573° C.

REMARKS: As under sample No. 9. While this sample produced a fair grade of wool the quality could be greatly improved by the addition of a small amount of silica (common sand) to the furnace charge.

SAMPLE No. 11

LOCATION: SW¼ SW¼ SE¼ sec. 19, T. 2 N., R. 11 W. COMANCHE COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 577-3 LABORATORY NO. 2491

Chemical Components (per cent)

Silica (SiO_2)	54.86	Calcium Oxide (CaO)	19.72
Alumina (Al_2O_3)	5.83	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.93	CARBON DIOXIDE (CO_2)	14.43
Manganese Dioxide (MnO_2)	0.06	Combined water (H_2O)	none
		Total	97.83

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	1.5	7.9	White	Coarse and brittle fibres. Similar to some bat wools.	1542° C.

REMARKS: This material is caliche; see remarks under sample 3. This particular sample has a low content of the bases as indicated by the low carbon dioxide content. It can be classed properly as a sub-woolrock. By admixing different quantities of limestone or high calcium caliche in the furnace charge any desired quality of rock wool could be produced. Any quantity of satisfactory limestone is readily available in the immediate vicinity.

SAMPLE No. 12

LOCATION: SW¼ NE¼ NW¼ sec. 30, T. 15 N., R. 7 E. CREEK COUNTY
GEOLOGICAL FORMATION: Pawhuska formation, Pennsylvanian.
FIELD SHEET NO. 82-1 LABORATORY NO. 5147

Chemical Components (per cent)

Silica (SiO_2)	50.66	Calcium Oxide (CaO)	15.61
Alumina (Al_2O_3)	0.66	Magnesium Oxide (MgO)	8.08
Iron Oxide (Fe_2O_3)	3.50	CARBON DIOXIDE (CO_2)	20.42
Manganese Dioxide (MnO_2)	0.51	Combined water (H_2O)	none
		Total	99.44

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
7.0	1.5	3.8	White	Fine and flexible. Good grade of wool.	1449° C.

REMARKS: This sample represents a bed of calcareous sandstone in the upper part of the Pawhuska formation. Measurements of thickness and extent of the bed at the point sampled are not available at present, but similar beds are exposed over a large area extending through Osage, Pawnee and northwestern Creek Counties. Efficient prospecting should disclose many deposits of woolrock suitable for commercial exploitation. Open pit quarry methods of mining would provide efficient and cheap production. Stripping, where necessary, would not be expensive.

SAMPLE No. 13

LOCATION: NW¼ NE¼ SW¼ sec. 8, T. 24 N., R. 23 E. DELAWARE COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 51-11 LABORATORY NO. 2011

Chemical Components (per cent)

Silica (SiO_2)	37.92	Calcium Oxide (CaO)	34.62
Alumina (Al_2O_3)	0.61	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.36	CARBON DIOXIDE (CO_2)	27.16
Manganese Dioxide (MnO_2)	0.03	Total	100.70

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.0	4.7	White	Good grade of wool.	1549° C.

REMARKS: This sample is from an exposure of the Boone limestone 30 feet thick and 760 feet long. The chemical composition of the formation varies greatly within short distances and careful sampling would be necessary to outline, or block out, deposits suitable for the production of woolrock. The formation covers large areas in Ottawa, Craig, Mayes, Delaware, Cherokee, and Adair Counties and unlimited quantities of woolrock could undoubtedly be located by prospecting. At the point sampled the overburden is 8 feet thick and quarry methods of mining could be used. This deposit is near the site of the Pensacola hydroelectric project.

SAMPLE No. 14

LOCATION: SW¼ NE¼ NE¼ sec. 28, T. 25 N., R. 23 E. DELAWARE COUNTY
GEOLOGICAL FORMATION: Batesville (?) formation (Mayes limestone), Mississippian.
FIELD SHEET NO. 231-2 LABORATORY NO. 4075

Chemical Components (per cent)

Silica (SiO_2)	44.28	Calcium Oxide (CaO)	31.89
Alumina (Al_2O_3)	0.43	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.71	CARBON DIOXIDE (CO_2)	23.14
Manganese Dioxide (MnO_2)	none	Total	100.45

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	0.7	2.2	White	Fine and soft. Fair grade of wool.	1504° C.

REMARKS: This sample represents one exposure of a portion of the Mayes limestone 5 feet thick and 660 feet long with an average overburden of 4 feet. This deposit, and other similar occurrences in the vicinity, could be mined cheaply by open pit and quarry methods.

SAMPLE No. 15

LOCATION: SW¼ SE¼ NE¼ sec. 32, T. 25 N., R. 23 E. DELAWARE COUNTY
GEOLOGICAL FORMATION: Batesville (?) formation (Mayes limestone), Mississippian.
FIELD SHEET NO. 233-2 LABORATORY NO. 4081

Chemical Components (per cent)

Silica (SiO_2)	41.00	Calcium Oxide (CaO)	32.81
Alumina (Al_2O_3)	0.34	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.86	CARBON DIOXIDE (CO_2)	24.02
Manganese Dioxide (MnO_2)	none	Total	100.03

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
22.5	1.5	6.7			1488° C.

REMARKS: This deposit of Mayes limestone is one of a number of similar outcrops exposed along the trace of the Seneca fault. The outcrop sampled is immediately above water level on the north bank of Grand River, is 3 feet thick and 900 feet long. The overburden is composed of about 10 feet of soil. Stripping and quarrying methods of mining could be used at reasonable cost.

SAMPLE No. 16

LOCATION: NW¼ NW¼ NE¼ sec. 9, T. 24 N., R. 23 E. DELAWARE COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 249-4 LABORATORY NO. 4100

Chemical Components (per cent)

Silica (SiO_2)	36.58	Calcium Oxide (CaO)	35.99
Alumina (Al_2O_3)	0.81	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.29	CARBON DIOXIDE (CO_2)	25.78
Manganese Dioxide (MnO_2)	none	Combined water (H_2O)	0.50
		Total	99.45

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
7.0	0.7	2.4	White	Fine and flexible. Good grade of wool.	1527° C.

REMARKS: See remarks under sample No. 13. This sample is a bed of cherty limestone 10 feet thick cropping out and forming a bluff west of the Grand River bottom land. The formation covers large areas and many deposits of good grade woolrock could doubtless be located by proper prospecting and sampling.

SAMPLE No. 17

LOCATION: NW¼ SW¼ SE¼ sec. 4, T 24 N., R. 23 E. DELAWARE COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 253-9 LABORATORY NO. 4127

Chemical Components (per cent)

Silica (SiO_2)	52.12	Calcium Oxide (CaO)	25.54
Alumina (Al_2O_3)	0.54	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.36	CARBON DIOXIDE (CO_2)	19.45
Manganese Dioxide (MnO_2)	trace	Total	100.01

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.5	2.3	White	Fine texture. Fair grade of wool.	1549° C.

REMARKS: See remarks under samples Nos. 13 and 16. This sample represents a cherty limestone bed 20 feet thick with about 15 feet of overburden composed of soil and limestone remnants. Quarry methods of mining would be applicable.

SAMPLE No. 18

LOCATION: SW¼ NE¼ SE¼ sec. 9 T. 5 N., R. 7 W. GRADY COUNTY
GEOLOGICAL FORMATION: Verden sandstone, Permian.
FIELD SHEET NO. 798-1 LABORATORY NO. 4981

Chemical Components (per cent)

Silica (SiO_2)	34.32	Calcium Oxide (CaO)	21.14
Alumina (Al_2O_3)	0.76	Magnesium Oxide (MgO)	13.12
Iron Oxide (Fe_2O_3)	1.22	CARBON DIOXIDE (CO_2)	28.86
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	none
		Total	99.42

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.0	5.4	White	Long fibered and flexible. Very good grade of wool.	1410° C.

REMARKS: This sample represents one of the best woolrock deposits disclosed by this investigation. The Verden sandstone was sampled in Grady, Stephens, and Caddo Counties, where it is exposed as a line of outcrops extending across the country, forming the tops of a series of long, narrow, residual hills. This series of hills resembles roughly an abandoned and eroded railroad grade some 40 miles long. The rock is a coarse-grained sandstone with calcareous cement in the proper proportions to form a first grade woolrock.

The rock wool produced in the laboratory is long-fibered, flexible, strong, very white and comparable in every way with first grade wools now available on the market. The melting temperature is comparatively low, a property which will favorably affect plant upkeep and production costs. The different exposures of the rock are remarkably uniform in character and good wool was made from every sample tested.

Mining operations should prove to be both simple and economical. The rock is brittle and easily broken. Simple quarry mining methods will be efficient and inexpensive. Many of the deposits are easily accessible and convenient to highways and railroads. As the rock forms the tops of hills, gravity can be utilized in loading, crushing, and other handling operations.

The different deposits of the rock now exposed average 8 to 10 feet in thickness and are 300 feet to a mile in length, providing quantities of material sufficient for large and long-lived operations.

SAMPLE No. 19

LOCATION: SE¼ NW¼ NW¼ sec. 1, T. 4 N., R. 7 W. GRADY COUNTY
GEOLOGICAL FORMATION: Verden sandstone, Permian.
FIELD SHEET NO. 801-2 LABORATORY NO. 4982

Chemical Components (per cent)

Silica (SiO_2)	42.26	Calcium Oxide (CaO)	16.26
Alumina (Al_2O_3)	0.99	Magnesium Oxide (MgO)	11.74
Iron Oxide (Fe_2O_3)	1.93	CARBON DIOXIDE (CO_2)	25.57
Manganese Dioxide (MnO_2)	0.09	Combined water (H_2O)	0.22
		Total	99.06

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.1	Very white	Soft and flexible. Good grade of wool.	1527° C.

REMARKS: This rock wool is an excellent grade of material produced from the Verden sandstone. Remarks under sample No. 18 are applicable to this sample also.

SAMPLE No. 20

LOCATION: SE¼ SE¼ NE¼ sec. 12, T. 4 N., R. 7 W. GRADY COUNTY
GEOLOGICAL FORMATION: Verden sandstone, Permian.
FIELD SHEET NO. 802-1 LABORATORY NO. 4983

Chemical Components (per cent)

Silica (SiO_2)	36.88	Calcium Oxide (CaO)	19.61
Alumina (Al_2O_3)	1.17	Magnesium Oxide (MgO)	12.18
Iron Oxide (Fe_2O_3)	1.79	CARBON DIOXIDE (CO_2)	27.54
Manganese Dioxide (MnO_2)	none		
		Total	99.17

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.3	5.0	White	Soft and flexible. Good grade of wool.	1532° C.

REMARKS: This is another sample from an outcrop of the Verden sandstone. Remarks under sample No. 18 are applicable here also.

SAMPLE No. 21

LOCATION: SE¼ SW¼ SE¼ sec. 1, T. 4 N., R. 7 W. GRADY COUNTY
GEOLOGICAL FORMATION: Verden sandstone, Permian.
FIELD SHEET NO. 805-1 LABORATORY NO. 4985

Chemical Components (per cent)

Silica (SiO_2)	36.30	Calcium Oxide (CaO)	20.24
Alumina (Al_2O_3)	1.05	Magnesium Oxide (MgO)	12.98
Iron Oxide (Fe_2O_3)	2.29	CARBON DIOXIDE (CO_2)	26.75
Manganese Dioxide (MnO_2)	none		
		Total	99.61

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
7.0	1.5	2.4	White	Fine and soft. Good grade of wool.	1527° C.

REMARKS: Remarks under sample No. 18 will apply here also. This particular sample produced wool with finer fibers than usual but of good commercial grade.

SAMPLE No. 22

LOCATION: NE¼ NE¼ NE¼ sec. 15, T. 5 N., R. 5 W. GRADY COUNTY
GEOLOGICAL FORMATION: Duncan sandstone, Permian.
FIELD SHEET NO. 1066-1 LABORATORY NO. 4998

Chemical Components (per cent)

Silica (SiO_2)	31.44	Calcium Oxide (CaO)	18.85
Alumina (Al_2O_3)	3.05	Magnesium Oxide (MgO)	13.62
Iron Oxide (Fe_2O_3)	1.93	CARBON DIOXIDE (CO_2)	28.42
Manganese Dioxide	0.06		
		Total	97.37

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.1	White	Very fine fibered. Fair grade of wool.	1527° C.

REMARKS: This is a dolomitic bed of the Duncan sandstone about 6 feet thick, covered with 1 foot of overburden. No estimate was made, but large quantities of similar material undoubtedly underlie the surrounding areas. The rock could be mined easily by quarry methods.

SAMPLE No. 23

LOCATION: NW¼ SE¼ NW¼ sec. 13, T. 4 S., R. 5 E. JOHNSTON COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 130-3 LABORATORY NO. 4966

Chemical Components (per cent)

Silica (SiO_2)	44.40	Calcium Oxide (CaO)	29.10
Alumina (Al_2O_3)	0.99	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.43	CARBON DIOXIDE (CO_2)	23.50
Manganese Dioxide (MnO_2)	trace	**Total**	100.42

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	3.0	9.9	White	Coarse fibered wool.	1504° C.

REMARKS: This sample is from a conglomeratic bed of the Trinity sand. This is a small, unimportant deposit, but large quantities of such conglomerate occur, although the thickness and extent of individual deposits vary greatly. The wool produced was rather coarse and somewhat glassy, and while such wool could be used in making some types of bats and other preformed shapes, this source of woolrock supply is of minor importance.

SAMPLE No. 24

LOCATION: sec. 26, T. 2 S., R. 4 E. JOHNSTON COUNTY
GEOLOGICAL FORMATION: Lower Arbuckle limestone, Cambrian.
FIELD SHEET NO. (special) LABORATORY NO. 6421

Chemical Components (per cent)

Silica (SiO_2)	38.56	Calcium Oxide (CaO)	19.30
Alumina (Al_2O_3)	0.48	Magnesium Oxide (MgO)	12.42
Iron Oxide (Fe_2O_3)	1.36	CARBON DIOXIDE (CO_2)	28.51
Manganese Dioxide (MnO_2)	0.02	Total	100.65

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	0.7	2.7	White	Good grade of wool.	1442° C.

REMARKS: This sample is a siliceous dolomite found in the lower part of the Arbuckle limestone. Many such deposits occur in different parts of the Arbuckle section and unlimited quantities of good woolrock could be defined in both the Arbuckle and Wichita mountain areas. The wide choice of location and situation should result in economical mining and production operations. The wool produced is of good commercial grade and the low melting temperature (1442° C.) would affect plant upkeep and other costs favorably.

Sample No. 25

LOCATION: SE¼ SE¼ NW¼ sec. 16, T. 2 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 40-4 LABORATORY NO. 3089

Chemical Components (per cent)

Silica (SiO_2)	18.34	Calcium Oxide (CaO)	36.34
Alumina (Al_2O_3)	11.11	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.93	CARBON DIOXIDE (CO_2)	29.74
Manganese Dioxide (MnO_2)	none		
		Total	97.46

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	6.0	Gray	Medium coarse. Fair grade of wool.	1527° C.

REMARKS: This material is caliche similar to the deposit covered by the remarks under sample No. 3. While this particular sample of rock wool is not of the best grade, the material blends easily with other minerals and any type of wool desired could be manufactured economically in an efficient plant.

Sample No. 26

LOCATION: NW¼ NE¼ NW¼ sec. 21, T. 2 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 45-2 LABORATORY NO. 3402

Chemical Components (per cent)

Silica (SiO_2)	20.30	Calcium Oxide (CaO)	37.00
Alumina (Al_2O_3)	4.28	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.72	CARBON DIOXIDE (CO_2)	31.89
Manganese Dioxide (MnO_2)	trace	Total	97.57

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	4.0	20.0	White	Coarse and brittle. Poor grade of wool.	1488° C.

REMARKS: This sample of rock wool was made from a caliche as described under samples Nos. 3, 25 and others. The wool produced is of poor grade but a good wool could be produced by the addition of common sand or other siliceous rock. The sample was included in this list to demonstrate the fact that a molten solution at reasonable temperatures can be made of caliches of widely varying characteristics. This property greatly facilitates the correction of mineral composition by the addition of other types of rock.

SAMPLE No. 27

LOCATION: NW¼ NW¼ NW¼ sec. 15, T. 2 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 47-1 LABORATORY NO. 3097

Chemical Components (per cent)

Silica (SiO_2)	16.40	Calcium Oxide (CaO)	38.80
Alumina (Al_2O_3)	7.97	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.29	CARBON DIOXIDE (CO_2)	31.86
Manganese Dioxide (MnO_2)	none		
		Total	97.32

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	1.5	9.4	White	Rather coarse. Fair grade of wool for bats.	1556° C.

REMARKS: This is another sample of caliche as described under samples Nos. 3, 25, and 26. Those remarks are applicable here.

SAMPLE No. 28

LOCATION: NE¼ NW¼ NW¼ sec. 15, T. 2 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 47-3. LABORATORY NO. 3099

Chemical Components (per cent)

Silica (SiO_2)	22.66	Calcium Oxide (CaO)	33.50
Alumina (Al_2O_3)	8.94	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.86	CARBON DIOXIDE (CO_2)	27.12
Manganese Dioxide (MnO_2)	0.34	Combined water (H_2O)	3.98
		Total	98.40

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
45.0	3.0	13.8	White	Coarse.	1571° C.

REMARKS: See remarks under sample Nos. 3, 25, 26, and 27.

SAMPLE No. 29

LOCATION: SW¼ SW¼ NE¼ sec. 15, T. 2 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 65-3 LABORATORY NO. 3101

Chemical Components (per cent)

Silica (SiO_2)	30.86	Calcium Oxide (CaO)	30.44
Alumina (Al_2O_3)	7.41	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.43	CARBON DIOXIDE (CO_2)	26.58
Manganese Dioxide (MnO_2)	none		
		Total	97.72

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	1.5	18.2	White	Coarse and glassy. Bat material only.	1527° C.

REMARKS: This sample is from another deposit of caliche and the remarks under samples 25 to 28 apply here also.

SAMPLE No. 30

LOCATION: SE¼ NE¼ NE¼ sec. 15, T. 3 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 101-1 LABORATORY NO. 3403

Chemical Components (per cent)

Silica (SiO_2)	34.29	Calcium Oxide (CaO)	24.80
Alumina (Al_2O_3)	14.42	Magnesium Oxide (MgO)	1.71
Iron Oxide (Fe_2O_3)	0.37	CARBON DIOXIDE (CO_2)	19.18
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	5.24
		Total	100.03

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
18.0	1.5	8.6	White	Coarse and brittle.	1527° C.

REMARKS: See remarks under samples Nos. 3, 25, and 26.

SAMPLE No. 31

LOCATION: SW¼ SW¼ SE¼ sec. 16, T. 3 N., R. 16 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 102-2 LABORATORY NO. 3405

Chemical Components (per cent)

Silica (SiO_2)	31.36	Calcium Oxide (CaO)	32.00
Alumina (Al_2O_3)	2.65	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.79	CARBON DIOXIDE (CO_2)	26.90
Manganese Dioxide (MnO_2)	0.57	Combined water (H_2O)	2.83
		Total	98.10

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	1.5	9.8	White	Medium coarse.	1563° C.

REMARKS: This sample produced a fair rock wool but could be improved by the addition of silica. See remarks preceding.

SAMPLE No. 32

LOCATION: NW¼ NW¼ SW¼ sec. 25, T. 4 N., R. 17 W. KIOWA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 431-1 LABORATORY NO. 4190

Chemical Components (per cent)

Silica (SiO_2)	31.03	Calcium Oxide (CaO)	26.67
Alumina (Al_2O_3)	13.61	Magnesium Oxide (MgO)	2.21
Iron Oxide (Fe_2O_3)	0.73	CARBON DIOXIDE (CO_2)	21.27
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	4.50
		Total	100.02

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.7	3.3	White	Fine and flexible. Good grade of wool.	1449° C.

REMARKS: This sample of caliche produced a good rock wool. The deposit is easily accessible, is 6 feet thick and is covered with 2 feet of overburden. Mining could be done with plows and scrapers or draglines at very low cost. The deposit is probably not uniform throughout but the quality could be easily controlled at the plant. Remarks on caliche samples immediately foregoing apply here also.

SAMPLE No. 33

LOCATION: SE¼ NW¼ SE¼ sec. 22, T. 5 N., R. 21 E. LATIMER COUNTY
GEOLOGICAL FORMATION: Wapanucka limestone, Pennsylvanian.
FIELD SHEET NO. 45-1. LABORATORY NO. 2712

Chemical Components (per cent)

Silica (SiO_2)	30.06	Calcium Oxide (CaO)	34.67
Alumina (Al_2O_3)	1.35	Magnesium Oxide (MgO)	1.82
Iron Oxide (Fe_2O_3)	3.56	CARBON DIOXIDE (CO_2)	28.80
Manganese Dioxide (MnO_2)	0.17	Combined water (H_2O)	0.23
		Total	100.66

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
11.0	1.5	3.8	Gray	Fine short-fibered. Fair grade of wool.	1549° C.

REMARKS: This sample represents a siliceous outcrop of the Wapanucka limestone of proper quality to produce rock wool. As the silica content in the formation varies greatly, a detailed survey would be necessary to determine exact areas of potential woolrock. Mining by open cut quarry methods would be applicable and the outcrop is easily accessible.

SAMPLE No. 34

LOCATION: NE¼ SW¼ NW¼ sec. 11, T. 4 N., R. 17 E. LATIMER COUNTY
GEOLOGICAL FORMATION: Wapanucka limestone, Pennsylvanian.
FIELD SHEET NO. 66-1 LABORATORY NO. 2725

Chemical Components (per cent)

Silica (SiO_2)	23.66	Calcium Oxide (CaO)	39.52
Alumina (Al_2O_3)	1.22	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.29	CARBON DIOXIDE (CO_2)	32.91
Manganese Dioxide (MnO_2)	0.08		
		Total	98.68

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.4	White	Good grade of wool.	1527° C.

REMARKS: This sample is from a faulted and fractured section of the Wapanucka limestone. The area is accessible and mining operations would not be costly if the quantity of proper material should warrant development.

SAMPLE No. 35

LOCATION: SE¼ NW¼ SE¼ sec. 14, T. 4 N., R. 17 E. LATIMER COUNTY
GEOLOGICAL FORMATION: Wapanucka limestone, Pennsylvanian.
FIELD SHEET NO. 124-1 LABORATORY NO. 2742

Chemical Components (per cent)

Silica (SiO_2)	35.22	Calcium Oxide (CaO)	33.78
Alumina (Al_2O_3)	1.81	Magnesium Oxide (MgO)	1.28
Iron Oxide (Fe_2O_3)	1.29	CARBON DIOXIDE (CO_2)	27.98
Manganese Dioxide (MnO_2)	trace	Total	101.36

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.3	6.6	White	Flexible, long-fibered. Good grade of wool.	1563° C.

REMARKS: This is another sample of Wapanucka limestone similar to sample No. 33. Remarks under samples 33 and 34 apply here also.

SAMPLE No. 36

LOCATION: NW¼ SW¼ NW¼ sec. 3, T. 4 N., R. 17 E. LATIMER COUNTY
GEOLOGICAL FORMATION: McAlester shale, Pennsylvanian.
FIELD SHEET NO. 214-1 LABORATORY NO. 4024

Chemical Components (per cent)

Silica (SiO_2)	32.15	Calcium Oxide (CaO)	23.60
Alumina (Al_2O_3)	1.77	Magnesium Oxide (MgO)	2.08
Iron Oxide (Fe_2O_3)	12.90	CARBON DIOXIDE (CO_2)	25.68
Manganese Dioxide (MnO_2)	0.25	Combined water (H_2O)	0.56
		Total	99.47

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
8.0	1.5	3.9	Light brown	Fine and long-fibered. Good commercial quality.	1465° C.

REMARKS: This sample probably represents some of the so-called "clay-ironstone" concretions of the lower McAlester. The outcrop is small and further investigation is necessary to determine the quantity of similar material available. The sample is especially interesting, because of the high iron content. A much better grade of rock wool was produced than was expected as the gas-fired laboratory furnace reduced most of the iron content to metallic iron which separated from the molten slag and did not seriously affect the character of the wool.

Sample No. 37

LOCATION: NW¼ NW¼ SE¼ sec. 8, T. 4 N., R. 22 E. Le FLORE COUNTY
GEOLOGICAL FORMATION: Atoka formation, Pennsylvanian.
FIELD SHEET NO. 303-1 LABORATORY NO. 4239

Chemical Components (per cent)

Silica (SiO_2)	33.22	Calcium Oxide (CaO)	30.39
Alumina (Al_2O_3)	1.27	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	8.51	CARBON DIOXIDE (CO_2)	26.00
Manganese Dioxide (MnO_2)	0.71		
		Total	100.10

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	1.5	3.9	Gray	Good grade of wool.	1465° C.

REMARKS: This deposit is probably a lenticular siliceous limestone in the Atoka formation. The surface exposure is too small to estimate the size or quantity of material. The rock has a high iron content which responded to treatment as described under sample No. 36. As the dip is very steep and the deposit not of great thickness, rather expensive underground methods of mining would be necessary.

Sample No. 38

LOCATION: NE¼ NE¼ NE¼ sec. 33, T. 21 N., R. 19 E. MAYES COUNTY
GEOLOGICAL FORMATION: Fayetteville formation, Mississippian.
FIELD SHEET NO. 67-1 LABORATORY NO. 1622

Chemical Components (per cent)

Silica (SiO_2)	36.74	Calcium Oxide (CaO)	33.94
Alumina (Al_2O_3)	1.32	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.00	CARBON DIOXIDE (CO_2)	26.63
Manganese Dioxide (MnO_2)	trace		
		Total	99.63

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
14.0	1.5	4.5	White	Fine long fibered. Very good wool.	1542° C.

REMARKS: The limestone of the Fayetteville should provide large quantities of satisfactory woolrock in this vicinity. Mining costs should be low as cheap open pit quarry methods could be used.

SAMPLE No. 39

LOCATION: SE¼ NE¼ NE¼ sec. 32, T. 23 N., R. 20 E. MAYES COUNTY
GEOLOGICAL FORMATION: Batesville (?) formation (Mayes limestone), Mississippian.
FIELD SHEET NO. 88-4 LABORATORY NO. 3176

Chemical Components (per cent)

Silica (SiO_2)	49.62	Calcium Oxide (CaO)	26.08
Alumina (Al_2O_3)	1.05	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	3.25	CARBON DIOXIDE (CO_2)	19.74
Manganese Dioxide (MnO_2)	0.07	Combined water (H_2O)	0.32
		Total	100.19

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	1.5	4.1	White	Very soft and flexible. Excellent wool.	1512° C.

REMARKS: This limestone formation covers a large area in Mayes County and offers a wide choice of locations for mining operations. This particular sample produced an exceptionally good grade of rock wool, and other samples, all producing good commercial grades of wool, indicate that the formation would be an exceptionally good source of woolrock.

SAMPLE No. 40

LOCATION: SE¼ NW¼ SW¼ sec. 25, T. 23 N., R. 20 E. MAYES COUNTY
GEOLOGICAL FORMATION: Batesville (?) formation (Mayes limestone), Mississippian.
FIELD SHEET NO. 94-1 LABORATORY NO. 3185

Chemical Components (per cent)

Silica (SiO_2)	46.00	Calcium Oxide (CaO)	29.18
Alumina (Al_2O_3)	none	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.64	CARBON DIOXIDE (CO_2)	20.42
Manganese Dioxide (MnO_2)	none		
		Total	97.24

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	1.5	6.3	White	Good grade of wool.	1573° C.

REMARKS: See remarks under sample 39. This outcrop offers good mining possibilities as it exceeds 40 feet in thickness and a mile in length.

Sample No. 41

LOCATION: SE¼ SE¼ NE¼ sec. 5, T. 23 N., R. 20 E. MAYES COUNTY
GEOLOGICAL FORMATION: Fayetteville formation, Mississippian.
FIELD SHEET NO. 109-2 LABORATORY NO. 3196

Chemical Components (per cent)

Silica (SiO_2)	36.70	Calcium Oxide (CaO)	33.94
Alumina (Al_2O_3)	0.50	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.50	CARBON DIOXIDE (CO_2)	25.52
Manganese Dioxide (MnO_2)	none		
		Total	98.16

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
16.0	3.0	7.2	White	Long flexible fibers. Good grade of wool.	1504° C.

REMARKS: This is another sample of limestone from the upper Fayetteville formation. Remarks under sample 38 apply here also. A large quantity of material is available at this location.

Sample No. 42

LOCATION: SW¼ NE¼ NE¼ sec. 27, T. 19 N., R. 19 E. MAYES COUNTY
GEOLOGICAL FORMATION: Fayetteville formation, Mississippian.
FIELD SHEET NO. 313-2A LABORATORY NO. 3542

Chemical Components (per cent)

Silica (SiO_2)	20.66	Calcium Oxide (CaO)	33.46
Alumina (Al_2O_3)	1.82	Magnesium Oxide (MgO)	3.50
Iron Oxide (Fe_2O_3)	9.19	CARBON DIOXIDE (CO_2)	31.32
Manganese Dioxide (MnO_2)	0.28	Combined water (H_2O)	0.51
		Total	100.74

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
14.0	1.0	3.0	White	Fine and flexible. Good grade of wool.	1527° C.

REMARKS: This is another sample from an outcrop of limestone in the upper Fayetteville, as described in remarks under samples 38 and 41. This outcrop is 1.25 miles long, exceeds 40 feet in thickness, and has an overburden of 10 to 40 feet of thin limestones, sandstones, and shales.

Sample No. 43

LOCATION: NE¼ SE¼ NE¼ sec. 34, T. 19 N., R. 19 E. MAYES COUNTY
GEOLOGICAL FORMATION: Fayetteville formation, Mississippian.
FIELD SHEET NO. 314-3A LABORATORY NO. 3546

Chemical Components (per cent)

Silica (SiO_2)	36.86	Calcium Oxide (CaO)	29.20
Alumina (Al_2O_3)	0.76	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	3.86	CARBON DIOXIDE (CO_2)	24.94
Manganese Dioxide (MnO_2)	0.32	Combined water (H_2O)	0.84
		Total	96.78

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.3	White	Soft long fibers. Good grade of wool.	1504° C.

REMARKS: See remarks under samples 38, 41, and 42. The outcrop is a continuation of that described under sample 42.

Sample No. 44

LOCATION: NW¼ SW¼ SW¼ sec. 7, T. 6 S., R. 26 E. McCURTAIN COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 108-1 LABORATORY NO. 4595

Chemical Components (per cent)

Silica (SiO_2)	33.22	Calcium Oxide (CaO)	38.17
Alumina (Al_2O_3)	0.64	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.36	CARBON DIOXIDE (CO_2)	27.54
Manganese Dioxide (MnO_2)	none	Total	100.93

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
22.0	1.5	4.1	White	Fine and soft. Good grade of wool.	1545° C.

REMARKS: This deposit is probably a lenticular calcareous bed in the Trinity sand. As the bed is only 7 inches thick at the point sampled it has no present commercial value as wool-rock. Other and thicker deposits may be found by future prospecting.

Sample No. 45

LOCATION: SW¼ SE¼ SE¼ sec. 2, T. 6 S., R. 26 E. McCURTAIN COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 109-1 LABORATORY NO. 4596

Chemical Components (per cent)

Silica (SiO_2)	39.70	Calcium Oxide (CaO)	32.42
Alumina (Al_2O_3)	1.12	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.14	CARBON DIOXIDE (CO_2)	24.99
Manganese Dioxide (MnO_2)	none	Total	101.37

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
11.0	1.5	4.9	White	Fine and soft. Very good wool.	1504° C.

REMARKS: See remarks under sample No. 44, which apply here also.

SAMPLE No. 46

LOCATION: SW¼ NW¼ SW¼ sec. 35, T. 5 S., R. 22 E. McCURTAIN COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 122-1 LABORATORY NO. 4598

Chemical Components (per cent)

Silica (SiO_2)	29.00	Calcium Oxide (CaO)	41.64
Alumina (Al_2O_3)	1.44	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.50	CARBON DIOXIDE (CO_2)	29.92
Manganese Dioxide (MnO_2)	none	Total	102.50

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
7.0	0.4	2.9	White	Very fine and soft. Fair grade of wool.	1504° C.

REMARKS: This is another thin calcareous bed in the Trinity sand. The thickness of 10 inches would preclude present consideration as a possible source of woolrock.

SAMPLE No. 47

LOCATION: SE¼ NE¼ NE¼ sec. 20, T. 6 S., R. 26 E. McCURTAIN COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 211-1 LABORATORY NO. 5116

Chemical Components (per cent)

Silica (SiO_2)	45.50	Calcium Oxide (CaO)	25.41
Alumina (Al_2O_3)	1.12	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	5.86	CARBON DIOXIDE (CO_2)	21.03
Manganese Dioxide (MnO_2)	0.36	Total	99.28

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	3.0	8.4	White	Flexible long fibers.	1442° C.

REMARKS: This limestone bed of the lower Trinity sand is 14 feet thick and the visible deposit covers about 40 acres.

Overburden is up to 4 feet of soil and timber. Mining by open cut methods would be cheap and the low melting temperature should cause processing costs to be low.

SAMPLE No. 48

LOCATION: NW¼ NW¼ SW¼ sec. 6, T. 6 S., R. 25 E. McCURTAIN COUNTY
GEOLOGICAL FORMATION: Trinity sand, Lower Cretaceous.
FIELD SHEET NO. 217-1 LABORATORY NO. 5120

Chemical Components (per cent)

Silica (SiO_2)	36.30	Calcium Oxide (CaO)	31.56
Alumina (Al_2O_3)	5.34	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.72	CARBON DIOXIDE (CO_2)	26.66
Manganese Dioxide (MnO_2)	0.27	Total	101.85

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	1.5	5.1	White	Fine long fibers. Good grade of wool.	1504° C.

REMARKS: This deposit of limestone is 10 feet thick. Only a small area is visible. Overburden is 1 to 4 feet of soil and timber. See remarks under sample 47.

SAMPLE No. 49

LOCATION: SW¼ SW¼ SW¼ sec. 7, T. 1 S., R. 4 E. MURRAY COUNTY
GEOLOGICAL FORMATION: Simpson group, Ordovician.
FIELD SHEET NO. 59-1 LABORATORY NO. 4452

Chemical Components (per cent)

Silica (SiO_2)	31.26	Calcium Oxide (CaO)	36.48
Alumina (Al_2O_3)	0.66	Magnesium Oxide (MgO)	0.52
Iron Oxide (Fe_2O_3)	1.43	CARBON DIOXIDE (CO_2)	29.61
Manganese Dioxide (MnO_2)	0.04		
		Total	100.00

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	1.5	8.6	White	Coarse and glassy. Inferior grade of wool.	1504° C.

REMARKS: This sample represents a siliceous-limestone phase of the upper Simpson (Bromide or McLish). The outcrop is 120 feet thick at the point sampled and the bed is conveniently situated for quarrying. Good roads afford easy access. The addition of a clay material would improve the quality of the rock wool produced.

SAMPLE No. 50

LOCATION: SE¼ NW¼ NW¼ sec. 15, T. 14 N., R. 18 E. MUSKOGEE COUNTY
GEOLOGICAL FORMATION: Boggy shale, Pennsylvanian.
FIELD SHEET NO. 72-1 LABORATORY NO. 1052

Chemical Components (per cent)

Silica (SiO_2)	46.64	Calcium Oxide (CaO)	23.00
Alumina (Al_2O_3)	5.65	Magnesium Oxide (MgO)	0.84
Iron Oxide (Fe_2O_3)	4.15	CARBON DIOXIDE (CO_2)	18.97
Manganese Dioxide (MnO_2)	0.06		
		Total	99.31

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.0	4.5	Gray	Fine and soft. Fair grade of wool.	1442° C.

REMARKS: This material is a calcareous shale. A thickness of 4 feet is exposed at point sampled. Overburden is 2 feet thick. Detailed prospecting would probably outline large quantities of similar material. Mining should be both easy and cheap.

SAMPLE No. 51

LOCATION: NE¼ SE¼ NE¼ sec. 10, T. 21 N., R. 2 W. NOBLE COUNTY
GEOLOGICAL FORMATION: Wellington formation, Permian.
FIELD SHEET NO. 125-2 LABORATORY NO. 5156

Chemical Components (per cent)

Silica (SiO_2)	34.48	Calcium Oxide (CaO)	21.55
Alumina (Al_2O_3)	3.32	Magnesium Oxide (MgO)	11.10
Iron Oxide (Fe_2O_3)	1.00	CARBON DIOXIDE (CO_2)	27.81
Manganese Dioxide (MnO_2)	none		
		Total	99.26

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
52.0	3.0	15.0	White	Coarse and glassy. Low grade of wool.	1549° C.

REMARKS: This sample represents one of the argillaceous dolomitic limestones, or mudstones, found in the Wellington formation of Permian age. Many similar deposits occur in north-central Oklahoma. While the wool produced is an inferior grade, the rock did form a liquid slag at a reasonable temperature. This is an example of the necessity of forming silicates of the higher degrees when treating rock containing multiple bases. (see p. 93). This sample is metallurgically a sesqui-silicate but the addition of silica is necessary to obtain good rock wool.

SAMPLE No. 52

LOCATION: NE¼ SE¼ NE¼ sec. 10, T. 21 N., R. 2 W. NOBLE COUNTY
GEOLOGICAL FORMATION: Wellington formation, Permian.
FIELD SHEET NO. 129-1 LABORATORY NO. 5157

Chemical Components (per cent)

Silica (SiO_2)	37.54	Calcium Oxide (CaO)	18.65
Alumina (Al_2O_3)	5.26	Magnesium Oxide (MgO)	11.10
Iron Oxide (Fe_2O_3)	1.00	CARBON DIOXIDE (CO_2)	26.40
Manganese Dioxide (MnO_2)	none		
		Total	99.95

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
16.0	3.0	6.3	White	Slightly brittle. Fair grade of wool.	1449° C.

REMARKS: See remarks under sample 51. This bed of argillaceous dolomitic limestone is only 15 inches thick, so is not of present commercial interest. A somewhat better grade of wool was produced than that of sample 51, but the addition of silica would improve the quality still more.

SAMPLE No. 53

LOCATION: SW¼ SE¼ NE¼ sec. 19, T. 27 N., R. 25 E. OTTAWA COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 41-2 LABORATORY NO. 1089

Chemical Components (per cent)

Silica (SiO_2)	30.75	Calcium Oxide (CaO)	36.14
Alumina (Al_2O_3)	1.48	Magnesium Oxide (MgO)	0.33
Iron Oxide (Fe_2O_3)	0.59	CARBON DIOXIDE (CO_2)	26.98
Manganese Dioxide (MnO_2)	0.05	Combined water (H_2O)	3.34
		Total	99.66

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.0	3.7	White	Fine and soft. Very good wool.	1556° C.

REMARKS: This sample is from a cherty member of the Boone limestone similar to sample 13. The stratum sampled is 12 feet thick and is exposed along a creek bank for 0.25 mile. The Boone formation covers an immense area in the northeastern part of Oklahoma and large deposits of good natural woolrock can be found throughout that area. The large number of available deposits should permit the choice of quarry and plant sites so situated that both mining and processing costs would be remarkably low. The proximity of proposed hydro-electric power installations offers interesting manufacturing possibilities.

SAMPLE No. 54

LOCATION: SE¼ NE¼ SW¼ sec. 23, T. 26 N., R. 24 E. OTTAWA COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 332-2 LABORATORY NO. 3828

Chemical Components (per cent)

Silica (SiO_2)	19.35	Calcium Oxide (CaO)	43.99
Alumina (Al_2O_3)	0.31	Magnesium Oxide (MgO)	0.40
Iron Oxide (Fe_2O_3)	0.79	CARBON DIOXIDE (CO_2)	35.20
Manganese Dioxide (MnO_2)	0.07	Total	100.11

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
22.0	0.5	3.0	White	Fine and soft. Very good grade of wool.	1542° C.

REMARKS: This sample represents another area of cherty limestone in the Boone formation. Remarks under sample 53 apply here also.

SAMPLE No. 55

LOCATION: NW¼ NE¼ NE¼ sec. 26, T. 28 N., R. 22 E. OTTAWA COUNTY
GEOLOGICAL FORMATION: Batesville (?) formation (Mayes limestone), Mississippian.
FIELD SHEET NO. 465-2 LABORATORY NO. 3721

Chemical Components (per cent)

Silica (SiO_2)	24.96	Calcium Oxide (CaO)	40.46
Alumina (Al_2O_3)	0.82	Magnesium Oxide (MgO)	0.30
Iron Oxide (Fe_2O_3)	1.17	CARBON DIOXIDE (CO_2)	32.18
Manganese Dioxide (MnO_2)	0.03	Combined water (H_2O)	0.07
		Total	99.99

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
7.0	1.0	2.4	White	Fine and soft. Good grade of wool.	1542° C.

REMARKS: This sample comes from an outcrop of the Mayes limestone at the southwest corner of the town of Miami. As noted heretofore the Mayes offers many areas of potential woolrock. This outcrop extends for more than a mile along the north bank of Neosho River and the sample represents a section 10 feet thick. Many rock quarries have been operated on this and other similar exposures.

SAMPLE No. 56

LOCATION: NE¼ NE¼ NE¼ sec. 1, T. 25 N., R. 23 E. OTTAWA COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 348-4 LABORATORY NO. 2619

Chemical Components (per cent)

Silica (SiO_2)	45.50	Calcium Oxide (CaO)	29.00
Alumina (Al_2O_3)	0.84	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.36	CARBON DIOXIDE (CO_2)	22.26
Manganese Dioxide (MnO_2)	none		
		Total	97.96

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	4.0	11.0	White	Medium to coarse fibers. Fair grade of wool.	1527° C.

REMARKS: This sample represents an 18-foot section of the Boone limestone. See remarks under sample 53.

SAMPLE No. 57

LOCATION: NW¼ NW¼ NW¼ sec. 1, T. 26 N., R. 23 E. OTTAWA COUNTY
GEOLOGICAL FORMATION: Boone limestone, Mississippian.
FIELD SHEET NO. 429-3 LABORATORY NO. 3719

Chemical Components (per cent)

Silica (SiO_2)	41.70	Calcium Oxide (CaO)	30.20
Alumina (Al_2O_3)	0.40	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.14	CARBON DIOXIDE (CO_2)	23.76
Manganese Dioxide (MnO_2)	trace		
		Total	97.20

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
22.0	2.0	9.1	White	Medium to coarse fibers. Fair grade of wool.	1504° C.

REMARKS: This sample represents a 15-foot section of cherty Boone limestone. See remarks under sample 53.

SAMPLE No. 58

LOCATION: NE¼ SW¼ SW¼ sec. 10, T. 16 N., R. 21 W.
ROGER MILLS COUNTY
GEOLOGICAL FORMATION: Ogallala (?) formation, Tertiary.
FIELD SHEET NO. 14-1 LABORATORY NO. 4771

Chemical Components (per cent)

Silica (SiO_2)	39.40	Calcium Oxide (CaO)	32.41
Alumina (Al_2O_3)	0.16	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.64	CARBON DIOXIDE (CO_2)	25.43
Manganese Dioxide (MnO_2)	none		
		Total	98.04

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	2.0	17.6	White	Coarse and brittle. Low grade wool.	1527° C.

REMARKS: This material is caliche that contains insufficient basic components. See remarks under samples 3 and 25 to 32. Caliche mixes readily with other rocks in molten solution at practical temperatures. This particular sample has an acid-base ratio of 2.22 and sufficient limestone should be added to form a sesqui-silicate slag with a ratio of about 1.5.

SAMPLE No. 59

LOCATION: NE¼ SW¼ SW¼ sec. 10, T. 16 N., R. 21 W. ROGER MILLS COUNTY
GEOLOGICAL FORMATION: Ogallala (?) formation, Tertiary.
FIELD SHEET NO. 14-5 LABORATORY NO. 4773

Chemical Components (per cent)

Silica (SiO_2)	46.74	Calcium Oxide (CaO)	28.93
Alumina (Al_2O_3)	0.43	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.57	CARBON DIOXIDE (CO_2)	22.70
Manganese Dioxide (MnO_2)	none		
		Total	99.37

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	4.5	13.0	White	Medium coarse fibers. Fair wool for some uses.	1527° C.

REMARKS: This sample is similar to sample 58.

SAMPLE No. 60

LOCATION: SW¼ NW¼ NE¼ sec. 29, T. 21 N., R. 15 E. ROGERS COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 198-4 LABORATORY NO. 4363

Chemical Components (per cent)

Silica (SiO_2)	31.88	Calcium Oxide (CaO)	37.60
Alumina (Al_2O_3)	1.09	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.07	CARBON DIOXIDE (CO_2)	27.37
Manganese Dioxide (MnO_2)	none		
		Total	99.01

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
13.0	1.5	4.0	White	Fine and flexible. Good grade of wool.	1542° C.

REMARKS: This sample is from a cherty section of the Oologah limestone. The exposure sampled is 17.5 feet thick and the formation can be traced for many miles. As the mineral composition varies considerably at different points detailed sampling would be necessary to outline definitely any areas for commercial exploitation. Careful examination of the formation will undoubtedly disclose many areas where woolrock can be mined and processed economically.

SAMPLE No. 61

LOCATION: SW¼ NW¼ NE¼ sec. 29, T. 21 N., R. 15 E. ROGERS COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 198-7 LABORATORY NO. 4366

Chemical Components (per cent)

Silica (SiO_2)	49.44	Calcium Oxide (CaO)	28.17
Alumina (Al_2O_3)	0.70	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.86	CARBON DIOXIDE (CO_2)	20.68
Manganese Dioxide (MnO_2)	none	Total	100.85

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.4	White	Fine and flexible. Good grade of wool.	1527° C.

REMARKS: Remarks under sample 60 apply here.

SAMPLE No. 62

LOCATION: SW¼ NW¼ NE¼ sec. 29, T. 21 N., R. 15 E. ROGERS COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 198-14 LABORATORY NO. 4373

Chemical Components (per cent)

Silica (SiO_2)	33.90	Calcium Oxide (CaO)	35.43
Alumina (Al_2O_3)	1.11	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.93	CARBON DIOXIDE (CO_2)	25.52
Manganese Dioxide (MnO_2)	none		
		Total	98.89

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	2.0	5.5	White	Fine long fibers. Good grade of wool.	1527° C.

REMARKS: Remarks under sample 60 apply here.

SAMPLE No. 63

LOCATION: NE¼ NE¼ NE¼ sec. 24, T. 21 N., R. 14 E. ROGERS COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 1020-17. LABORATORY NO. 2466

Chemical Components (per cent)

Silica (SiO_2)	31.30	Calcium Oxide (CaO)	29.04
Alumina (Al_2O_3)	1.65	Magnesium Oxide (MgO)	5.22
Iron Oxide (Fe_2O_3)	3.15	CARBON DIOXIDE (CO_2)	29.50
Manganese Dioxide (MnO_2)	none	Combined water (H_2O)	3.38
		Total	100.64

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	5.6	Gray	Fine to medium fibers. Good grade of wool.	1527° C.

REMARKS: This sample is from another outcrop of the Oologah limestone similar to that described as sample 60. Those remarks apply here.

SAMPLE No. 64

LOCATION: SE¼ SE¼ SE¼ sec. 11, T. 13 N., R. 23 E. SEQUOYAH COUNTY
GEOLOGICAL FORMATION: Boone (?) limestone, Mississippian.
FIELD SHEET NO. 67-2 LABORATORY NO. 773

Chemical Components (per cent)

Silica (SiO_2)	33.86	Calcium Oxide (CaO)	35.98
Alumina (Al_2O_3)	none	Magnesium Oxide (MnO)	none
Iron Oxide (Fe_2O_3)	1.63	CARBON DIOXIDE (CO_2)	28.23
Manganese Dioxide (MnO_2)	0.14	Total	99.84

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
12.0	0.8	2.6	White	Fine and soft. Very good wool.	1527° C.

REMARKS: This formation was not definitely identified in the field but is probably a part of the Boone limestone. The sample represents a 15-foot section in a quarry from which building stone has been produced. The Boone crops out in many places in this area and could be mined economically along those outcrops. Overburden would make it necessary to use underground mining methods to remove rock from any considerable distance into the hillsides.

SAMPLE No. 65

LOCATION: NW¼ NW¼ NE¼ sec. 15, T. 13 N., R. 23 E. SEQUOYAH COUNTY
GEOLOGICAL FORMATION: St Joe (?) limestone, Mississippian.
FIELD SHEET NO. 112-1 LABORATORY NO. 1557

Chemical Components (per cent)

Silica (SiO_2)	46.52	Calcium Oxide (CaO)	22.78
Alumina (Al_2O_3)	3.32	Magnesium Oxide (MgO)	trace
Iron Oxide (Fe_2O_3)	5.79	CARBON DIOXIDE (CO_2)	18.04
Manganese Dioxide (MnO_2)	0.03	Combined water (H_2O)	0.69
		Total	97.17

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
17.5	1.5	6.4	Gray	Medium coarse fibers. Fair grade of wool.	1571° C.

REMARKS: This sample is a 2-foot section of a ferruginous and somewhat shaly bed of the Boone limestone. Mining operations would be rather expensive so the deposit is not commercially attractive at this time.

SAMPLE No. 66

LOCATION: NE¼ NE¼ SE¼ sec. 28, T. 2 N., R. 16 E. TEXAS COUNTY
GEOLOGICAL FORMATION: Ogallala formation, Tertiary.
FIELD SHEET NO. 95-1 LABORATORY NO. 5017

Chemical Components (per cent)

Silica (SiO_2)	48.33	Calcium Oxide (CaO)	19.06
Alumina (Al_2O_3)	1.53	Magnesium Oxide (MgO)	8.10
Iron Oxide (Fe_2O_3)	1.29	CARBON DIOXIDE (CO_2)	20.32
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	1.54
		Total	100.17

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
35.0	3.0	13.0	White	Coarse and brittle. Inferior grade of wool.	1488° C.

REMARKS: This sample is from a large deposit of caliche covering several square miles with a thickness of 3 to 10 feet. As discussed in remarks under sample 3, this material mixes easily with other minerals and, in this instance, the addition of limestone in proper quantity should result in the production of a good grade of rock wool.

SAMPLE No. 67

LOCATION: NE¼ NW¼ NW¼ sec. 28, T. 4 N., R. 16 E. TEXAS COUNTY
GEOLOGICAL FORMATION: Ogallala formation, Tertiary.
FIELD SHEET NO. 101-1 LABORATORY NO. 5020

Chemical Components (per cent)

Silica (SiO_2)	42.24	Calcium Oxide (CaO)	27.22
Alumina (Al_2O_3)	2.03	Magnesium Oxide (MgO)	2.18
Iron Oxide (Fe_2O_3)	1.29	CARBON DIOXIDE (CO_2)	22.62
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	1.90
		Total	99.48

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	3.0	15.8	White	Coarse and glassy. Inferior grade of wool.	1488° C.

REMARKS: This sample is from another large deposit of caliche and remarks under samples 3 and 66 apply.

SAMPLE No. 68

LOCATION: NE¼ NE¼ SE¼ sec. 25, T. 3 N., R. 18 E. TEXAS COUNTY
GEOLOGICAL FORMATION: Ogallala formation, Tertiary.
FIELD SHEET NO. 103-1 LABORATORY NO. 5021

Chemical Components (per cent)

Silica (SiO_2)	35.62	Calcium Oxide (CaO)	20.41
Alumina (Al_2O_3)	0.95	Magnesium Oxide (MgO)	13.40
Iron Oxide (Fe_2O_3)	1.07	CARBON DIOXIDE (CO_2)	27.20
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	1.54
		Total	100.19

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
10.0	1.0	3.2	White	Fine and soft. Very good wool.	1410° C.

REMARKS: This sample of caliche contained constituents in the proper proportions to produce a very good grade of rock wool. No control mixing of other minerals would be necessary. See remarks under samples 3 and 66. This deposit is 3 feet thick with 1 foot of soil overburden and covers about 3 square miles. The material could be mined easily and cheaply by use of plows and dragline or other similar loading equipment.

SAMPLE No. 69

LOCATION: NE¼ NE¼ NE¼ sec. 16, T. 1 N., R. 14 E. TEXAS COUNTY
GEOLOGICAL FORMATION: Ogallala formation, Tertiary.
FIELD SHEET NO. 109-1 LABORATORY NO. 5023

Chemical Components (per cent)

Silica (SiO_2)	31.02	Calcium Oxide (CaO)	35.57
Alumina (Al_2O_3)	1.00	Magnesium Oxide (MgO)	1.00
Iron Oxide (Fe_2O_3)	1.14	CARBON DIOXIDE (CO_2)	28.40
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	1.43
		Total	99.56

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.7	2.5	White	Fine and soft. Good grade of wool.	1527° C.

REMARKS: This sample represents another deposit of caliche that produced good rock wool. The bed is about 4 feet thick and covers one section of land. See remarks under sample 68.

SAMPLE No. 70

LOCATION: NE¼ NW¼ NW¼ sec. 36, T. 17 N., R. 14 E. TULSA COUNTY
GEOLOGICAL FORMATION: Cherokee shale, Pennsylvanian.
FIELD SHEET NO. 230-3 LABORATORY NO. 4472

Chemical Components (per cent)

Silica (SiO_2)	36.52	Calcium Oxide (CaO)	32.60
Alumina (Al_2O_3)	1.67	Magnesium Oxide (MgO)	trace
Iron Oxide (Fe_2O_3)	5.00	CARBON DIOXIDE (CO_2)	23.23
Manganese Oxide (MnO_2)	0.28	Total	99.30

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
8.0	0.9	2.8	Gray	Fine and soft. Fair grade of wool.	1481° C.

REMARKS: This sample is from a thin bed of arenaceous limestone in the upper part of the Cherokee shale formation, below the Ft. Scott limestone and Broken Arrow coal. The sample has no commercial significance.

SAMPLE No. 71

LOCATION: SE¼ SE¼ NE¼ sec. 3, T. 18 N., R. 14 E. TULSA COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 1003-6 LABORATORY NO. 1162

Chemical Components (per cent)

Silica (SiO_2)	35.06	Calcium Oxide (CaO)	31.18
Alumina (Al_2O_3)	2.64	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	3.93	CARBON DIOXIDE (CO_2)	24.46
Manganese Dioxide (MnO_2)	0.06		
		Total	97.33

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.7	2.8	White	Fine, slightly brittle. Fair grade of wool.	1556° C.

REMARKS: This sample represents an 8- to 10-foot section of siliceous limestone just above the base of the Oologah limestone formation. The exposure is about 175 feet long with an overburden up to 5 feet in thickness. The rock could be mined economically by stripping and open cut methods.

SAMPLE No. 72

LOCATION: NW¼ NW¼ NW¼ sec. 14, T. 19 N., R. 14 E. TULSA COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 1006-2 LABORATORY NO. 1368

Chemical Components (per cent)

Silica (SiO_2)	29.64	Calcium Oxide (CaO)	27.02
Alumina (Al_2O_3)	18.18	Magnesium Oxide (MgO)	0.40
Iron Oxide (Fe_2O_3)	3.00	CARBON DIOXIDE (CO_2)	21.64
Manganese Dioxide (MnO_2)	none	Total	99.88

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
60.0	4.0	19.1	White	Coarse but flexible. Fair grade of wool.	1443° C.

REMARKS: This is another sample from a slightly higher bed of the Oologah limestone. The section sampled is 30 feet thick with no overburden. The addition of sand or other siliceous material would improve the quality of the rock wool.

Sample No. 73

LOCATION: NE¼ NE¼ SW¼ sec. 28, T. 20 N., R. 14 E. TULSA COUNTY
GEOLOGICAL FORMATION: Oologah limestone, Pennsylvanian.
FIELD SHEET NO. 1012-6 LABORATORY NO. 2255

Chemical Components (per cent)

Silica (SiO_2)	22.18	Calcium Oxide (CaO)	36.96
Alumina (Al_2O_3)	6.92	Magnesium Oxide (MgO)	0.86
Iron Oxide (Fe_2O_3)	1.72	CARBON DIOXIDE (CO_2)	29.94
Manganese Dioxide (MnO_2)	trace		
Phosphorus Pentoxide (P_2O_5)	0.84	Total	98.58

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.7	3.9	Gray	Excess of shot. Inferior grade of of wool.	1488° C.

REMARKS: This is a sample of the upper part of the Oologah limestone, probably the Altamont member, from the Quarry of the Hughes Stone Co., at Garnett. The sample produced a rather poor grade of rock wool but the quality could be greatly improved by the addition of silica to the furnace charge.

Sample No. 74

LOCATION: SW¼ NW¼ SW¼ sec. 1, T. 9 N., R. 19 W. WASHITA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 36-1 LABORATORY NO. 4783

Chemical Components (per cent)

Silica (SiO_2)	45.10	Calcium Oxide (CaO)	22.95
Alumina (Al_2O_3)	1.52	Magnesium Oxide (MgO)	2.86
Iron Oxide (Fe_2O_3)	1.86	CARBON DIOXIDE (CO_2)	21.13
Manganese Dioxide (MnO_2)	none	Combined water (H_2O)	2.04
		Total	97.46

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
14.0	1.0	3.8	White	Fine and soft. Very good grade of wool .	1442° C.

REMARKS: This sample is from a deposit of caliche 4.5 feet thick covering an area of about 320 acres. Overburden of soil is 18 inches thick and the deposit could be mined by stripping and open cut methods very economically. See remarks under samples 3 and 69.

Sample No. 75

LOCATION: NW¼ SE¼ SE¼ sec. 28, T. 10 N., R. 17 W. WASHITA COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 41-15-1 LABORATORY NO. 4793

Chemical Components (per cent)

Silica (SiO_2)	39.78	Calcium Oxide (CaO)	30.36
Alumina (Al_2O_3)	1.50	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.00	CARBON DIOXIDE (CO_2)	23.42
Manganese Dioxide (MnO_2)	trace	Combined water (H_2O)	1.93
		Total	97.99

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
9.0	1.0	3.2	White	Fine short fibers. Fair grade of wool.	1542° C.

REMARKS: This sample of caliche is from a deposit 6 feet thick with no overburden at the point sampled. See remarks under samples 66 to 69.

SAMPLE No. 76

LOCATION: SW¼ NE¼ SE¼ sec. 26, T. 18 N., R. 19 E. WAGONER COUNTY
GEOLOGICAL FORMATION: Morrow-Pitkin, Pennsylvanian-Mississippian.
FIELD SHEET NO. 506-1 LABORATORY NO. 3264

Chemical Components (per cent)

Silica (SiO_2)	36.36	Calcium Oxide (CaO)	30.60
Alumina (Al_2O_3)	2.10	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	4.72	CARBON DIOXIDE (CO_2)	24.94
Manganese Dioxide (MnO_2)	0.09	Combined water (H_2O)	0.51
		Total	99.32

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	1.5	3.9	Light green	Fine and soft. Good grade of wool.	1471° C.

REMARKS: The limestones of the Morrow and Pitkin are in contact in this area. This sample represents a section 60 feet thick, exposed for three-quarters of a mile along the northeast bank of Grand River. The deposit is covered with 30 feet of brown sandstone. A combination of caving and quarry methods of mining should produce woolrock at a reasonable cost.

SAMPLE No. 77

LOCATION: NW¼ SE¼ SW¼ sec. 15, T. 22 N., R. 21 W. WOODWARD COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 39-2 LABORATORY NO. 621

Chemical Components (per cent)

Silica (SiO_2)	50.88	Calcium Oxide (CaO)	26.40
Alumina (Al_2O_3)	0.90	Magnesium Oxide (MgO)	0.46
Iron Oxide (Fe_2O_3)	0.50	CARBON DIOXIDE (CO_2)	21.21
Manganese Dioxide (MnO_2)	0.14	Total	100.49

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
30.0	1.5	10.6	White	Coarse long fibers. Fair grade of wool.	1473° C.

REMARKS: This sample is from a deposit of caliche 5 to 6 feet thick with very little overburden. The addition of a small amount of clay or soil would improve the quality of the wool. See remarks under samples 2 and 66 to 69.

SAMPLE No. 78

LOCATION: SE¼ NE¼ SW¼ sec. 10, T. 21 N., R. 21 W. WOODWARD COUNTY
GEOLOGICAL FORMATION: Ogallala (?) formation, Tertiary.
FIELD SHEET NO. 61-4 LABORATORY NO. 626

Chemical Components (per cent)

Silica (SiO_2)	44.46	Calcium Oxide (CaO)	29.46
Alumina (Al_2O_3)	1.56	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	1.22	CARBON DIOXIDE (CO_2)	23.11
Manganese Dioxide (MnO_2)	0.14	Total	99.95

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
14.0	0.7	4.0	White	Fine and soft. Good grade of wool.	1504° C.

REMARKS: This sample of caliche produced an excellent grade of wool. No blending is necessary. The deposit is 4 feet thick with an average 2 feet of overburden and covers some 160 acres.

SAMPLE No. 79

LOCATION: SE¼ NE¼ NW¼ sec. 15, T. 24 N., R. 22 W. WOODWARD COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 118-1 LABORATORY NO. 4137

Chemical Components (per cent)

Silica (SiO_2)	33.06	Calcium Oxide (CaO)	35.86
Alumina (Al_2O_3)	0.98	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	0.64	CARBON DIOXIDE (CO_2)	26.58
Manganese Dioxide (MnO_2)	none		
		Total	97.12

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
15.0	0.7	3.5	White	Fine and soft. Good grade of wool.	1457° C.

REMARKS: This sample of caliche is similar to sample 78. The deposit is 6 feet thick with 2.5 feet of overburden and covers about 80 acres.

SAMPLE No. 80

LOCATION: SW¼ SW¼ SE¼ sec. 34, T. 23 N., R. 20 W. WOODWARD COUNTY
GEOLOGICAL FORMATION: Quaternary (?)
FIELD SHEET NO. 137-4 LABORATORY NO. 2475

Chemical Components (per cent)

Silica (SiO_2)	43.68	Calcium Oxide (CaO)	28.62
Alumina (Al_2O_3)	0.55	Magnesium Oxide (MgO)	none
Iron Oxide (Fe_2O_3)	2.65	CARBON DIOXIDE (CO_2)	22.79
Manganese Dioxide (MnO_2)	none		
		Total	98.29

Physical Characteristics of Wool

Fiber Diameter (Microns)			Color	Apparent Texture	Blowing temperature
Maximum	Minimum	Average			
10.0	0.7	2.8	White	Fine and soft. Good grade of wool.	1504° C.

REMARKS: This sample is from another caliche deposit producing good rock wool without blending. The deposit is 4 feet thick with 1 foot of overburden and covers an area of about 80 acres. See remarks under sample 3.

OUTSTANDING WOOLROCK MIXTURES

No detailed investigation has been made of the possibilities of producing rockwool from mixtures of rocks that are not individually satisfactory. No samples of natural woolrock were available from several important state areas so a few tests of mixtures of materials were made with very satisfactory results. These tests indicate that raw material for the manufacture of rockwool can be produced in nearly every part of Oklahoma.

ADA AREA, PONTOTOC, MURRAY, JOHNSTON, AND COAL COUNTIES

The Ada area contains large reserves of natural gas, has good transportation facilities and immense deposits of limestones and shales. Tests indicate that most of the limestones and shales can be mixed to produce very good grades of rockwool at reasonable cost.

The shales used in all tests were the Sylvan, of Ordovician age, and the Caney, of Mississippian age. These shales crop out in many parts of the area and quantities available for mining can be considered unlimited. The samples of Sylvan shale used in the tests were obtained from the quarries of the Oklahoma Portland Cement Co., in secs. 25 and 36, T. 3 N., R. 5 E., Pontotoc County. The Caney shale was obtained from road cuts along the south line of sec. 31, T. 1 S., R. 8 E., Coal County, and the west line of sec. 20, T. 2 S., R. 8 E., Johnston County. The compositions of these shales do not vary greatly and they should prove to be satisfactory blending material wherever found.

The following described samples of limestone all produced rockwool at reasonable melting temperatures when mixed with shales in such proportion that the mixtures contained approximately 25% carbon dioxide. No complete chemical analyses were made and the CO_2 contents were determined roughly as the losses in weight on ignition.

(1) Limestone from the upper part of the Viola formation was obtained from the stock bins of the Oklahoma Portland Cement Co. at Ada. Loss on ignition was 41.99% and excellent wool was produced by mixing with Sylvan shale in the proportion of 3.82 limestone to 6.17 shale.

(2) Same as No. 1, but obtained from the quarry in sec. 25, T. 3 N., R. 5 E., Pontotoc County.

(3) From the middle part of the Viola limestone in a road cut in sec. 2, T. 2 N., R. 5 E., Pontotoc County. Loss on ignition, 36.89%.

(4) Oil Creek formation of the Simpson group. Thin-bedded limestone cropping out on highway in sec. 19, T. 2 N., R. 5 E., Pontotoc County. Loss on ignition, 25.16%. This sample produced a fair grade of wool without blending but the quality was improved by the addition of a small quantity of shale.

(5) Upper Arbuckle limestone in sec. 2, T. 1 N., R. 4 E., Murray County. Loss on ignition, 32.43%. This sample produced excellent wool when mixed with Sylvan shale in the proportion of 5.98 limestone to 4.02 shale.

(6) Upper Arbuckle limestone in sec. 1, T. 1 N., R. 4 E., Murray County. Loss on ignition, 43.05%. A ratio of 3.5 limestone to 6.0 shale was used to produce good wool.

(7) Same formation and character as No. 6. From sec. 13, T. 1 N., R. 4 E., Murray County. Loss on ignition, 43.13%.

(8) Thin-bedded limestone in the lower Pennsylvanian series from sec. 17, T. 3 N., R. 6 E., Pontotoc County. Loss on ignition, 42.41%.

(9) Limestone in the upper part of the Hunton group from sec. 29, T. 3 N., R. 6 E., Pontotoc County. Loss on ignition, 41.66%. A ratio of 3 limestone to 2 shale produced a fair grade of wool.

(10) Similar to sample No. 8. Located in sec. 16, T. 3 N., R. 6 E., Pontotoc County. Loss on ignition, 36.63%.

(11) This material, from the upper part of the Viola limestone, was obtained from the stock bins of the Dolese Bros. quarry in sec. 31, T. 1 S., R. 8 E., Coal County. Near the south end of the quarry an east-west fault has placed the Viola limestone in contact with the Caney shale thereby making both necessary materials easily available at one location. The limestone had a loss on ignition of 39.29% and an exceptionally good wool resulted from a mixture proportioned 5.83 limestone to 4.17 shale.

(12) This sample was from the upper part of the Arbuckle limestone exposed in a small quarry in sec. 36, T. 1 S., R. 6 E., Johnston County. Loss on ignition, 36.97%. Very good wool was produced using the proportion of 6.76 limestone to 3.24 shale.

The tests made indicate that the area contains immense quantities of satisfactory raw material for the manufacture of rock wool and a large choice of locations is available for quarry operations. The area offers many advantages to a prospective manufacturer.

OTHER AREAS

Several counties in Oklahoma have not been investigated sufficiently to determine their woolrock possibilities. Limestones are known to occur in some of these counties, but the data now available indicate that the materials are too high in lime content to be natural woolrocks. One occurrence of natural woolrock in Nowata County is described by Norman Plummer[3] of the Kansas Geological Survey as follows:

COFFEYVILLE

Location of Outcrops Sampled. Quarry on east side of U. S. Highway 169 at Bells Spur about 12 miles south of Coffeyville, Kansas, in the NW¼ of NE¼ sec. 30, T. 28 N., R. 16 E., Nowata County, Oklahoma.

Stratigraphy. The Lenapah limestone of the Marmaton group is made up of three beds where sampled. The lower 15 feet is a light-gray, massive limestone (sample No. 1). Above this is a 1-foot bed of blue-gray shale (sample No. 2), and above the shale approximately 6 feet of light-gray limestone which weathers gray and light yellowish-brown (sample No. 3). * * * *

Results of Tests. The carbon-dioxide content of the samples tested follows: No. 3, 38 per cent; No. 2, 8.4 per cent, and No. 1, 21.37 per cent. The carbon-dioxide content of sample No. 1 is within the limits for a natural woolrock and was subjected to the blowing test without mixing with other material. Although this sample is quite close to the lower limit of 20 per cent carbon dioxide for a woolrock, it proved to be easily fusible in the blowing test, producing an excellent quality of white wool at slightly over 1500° C. with 60 pounds steam pressure.

No successful wools were produced using samples No. 2 and No. 3, but if the carbon-dioxide content were correctly adjusted by the addition of a siliceous rock to the upper limestone and the thin middle shale, it would be possible to use the entire 20 feet of the Lenapah limestone.

Remarks. The Bells Spur quarry is on U. S. Highway 169, and the Union Traction Company electric railroad. This railroad is now used to haul the limestone taken from the quarry to Coffeyville. Other transportation facilities available at Coffeyville include the

3. Plummer, Norman, "Rock Wool Resources of Kansas": *Mineral Resources Circular* 8, *State Geol. Survey of Kansas*, pp. 10-13, Dec. 15, 1937.

Missouri Pacific and the Missouri, Kansas and Texas railroads, and U. S. Highway 166. Gas and oil are available from both the southeastern Kansas and the northern Oklahoma fields.

Kay, Pawnee, Payne, Osage, Seminole, and Washington counties all contain numerous outcrops of limestone formations as shown on the Geologic Map of Oklahoma and Oklahoma Geological Survey Bulletin 26. These limestones alternate with shales, and wool rock mixtures made from these rocks should be as satisfactory as those of the Ada area. A careful survey would also undoubtedly disclose other deposits of natural wool rock in the area.

THE MANUFACTURE OF ROCK WOOL

Mineral wool has been manufactured in the United States for many years but has only recently become a product of economic importance. The initial plant was put in operation in 1888 in Cleveland, Ohio and the volume of production increased slowly until it was estimated by Thoenen[4] to be 50,000 tons in 1928. During the past 10 years the advantages of insulating have become generally known and the present annual production of mineral wool is more than 10 times that of 1928 and is continuing to increase rapidly.

THE STANDARD CUPOLA METHOD

In general, present manufacturing methods are the same as those employed in the earlier plants except that equipment has, of course, been improved and made more efficient. Except for a few reverberatory furnace installations, all rockwool is produced by blast furnaces or cupolas, similar to those used in the iron industry. The earlier refractory lined furnace has become obsolete and the water cooled type of cupola is in general use. A furnace of this type and a flow sheet showing the passage of material through a manufacturing plant are illustrated in fig. 6.

Briefly, the manufacturing method consists of crushing and sizing the rock, charging the cupola with alternate layers of rock

4. The Origin of Rock Wool, *Stone*, vol. 57, no. 12, Dec. 1936.
Thoenen, J. R., "Mineral Wool", *U. S. Bureau of Mines Information Circular* 6984, Jan. 1938.

and coke and introducing air under pressure to effect combustion and melting. Both coke and rock are usually sized to from ¾ inch to 4 inches, the undersized material being rejected and the oversized recrushed.

Many of the following operating data were compiled by Thoenen who, in 1937, estimated that in the United States there were the equivalent of 150 cupolas manufacturing mineral wool. Cupola capacity, in tons of loose wool per 24 hours, was estimated to range from 5 to 20 tons and to average 10 tons. From this, the productive capacity was estimated to be 500,000 tons of loose wool annually. Plants representing one-third the entire capacity reported the distribution of products made as, roughly, 35 percent loose wool, 33 percent granulated wool, 32 percent fabricated products.

Cupolas range in size from 26 to 72 inches in diameter and 7 to 16 feet high. Water jackets range from 4 to 5 inches thick. Circulating water pressure ranges from 25 to 100 pounds per square inch and the quantity used from 25 to 50 gallons per minute per cupola.

Melting temperatures are estimated to range from a low of 2,300° F. (1260° C.) to a high of 3,400° F. (1871° C.). The average for a number of lead-slag plants was 3,350° F. (1843° C.), for rock wool plants 3,070° F. (1685° C.), and for iron-slag plants 2,900° F. (1593° C.).

Blast air pressures range from 1.7 ounces to 1.5 pounds per square inch. The quantity of air used ranges from 60 to 1,200 cubic feet per minute per cupola or from 6 to 86 cubic feet per pound of loose wool. Blast air is introduced to the cupolas from 4 to 24 inches above the cupola floor.

The majority of present plants draw slag from cupolas in a single stream although some use two streams per cupola and others use three. The diameter of the slag stream at the point at which it is cut by the steam or air jet ranges from ¼ to ¾ inch, but ¼ to ⅜ inch seems to be preferred. The distance the slag is permitted to drop to the blowing nozzle ranges from 3

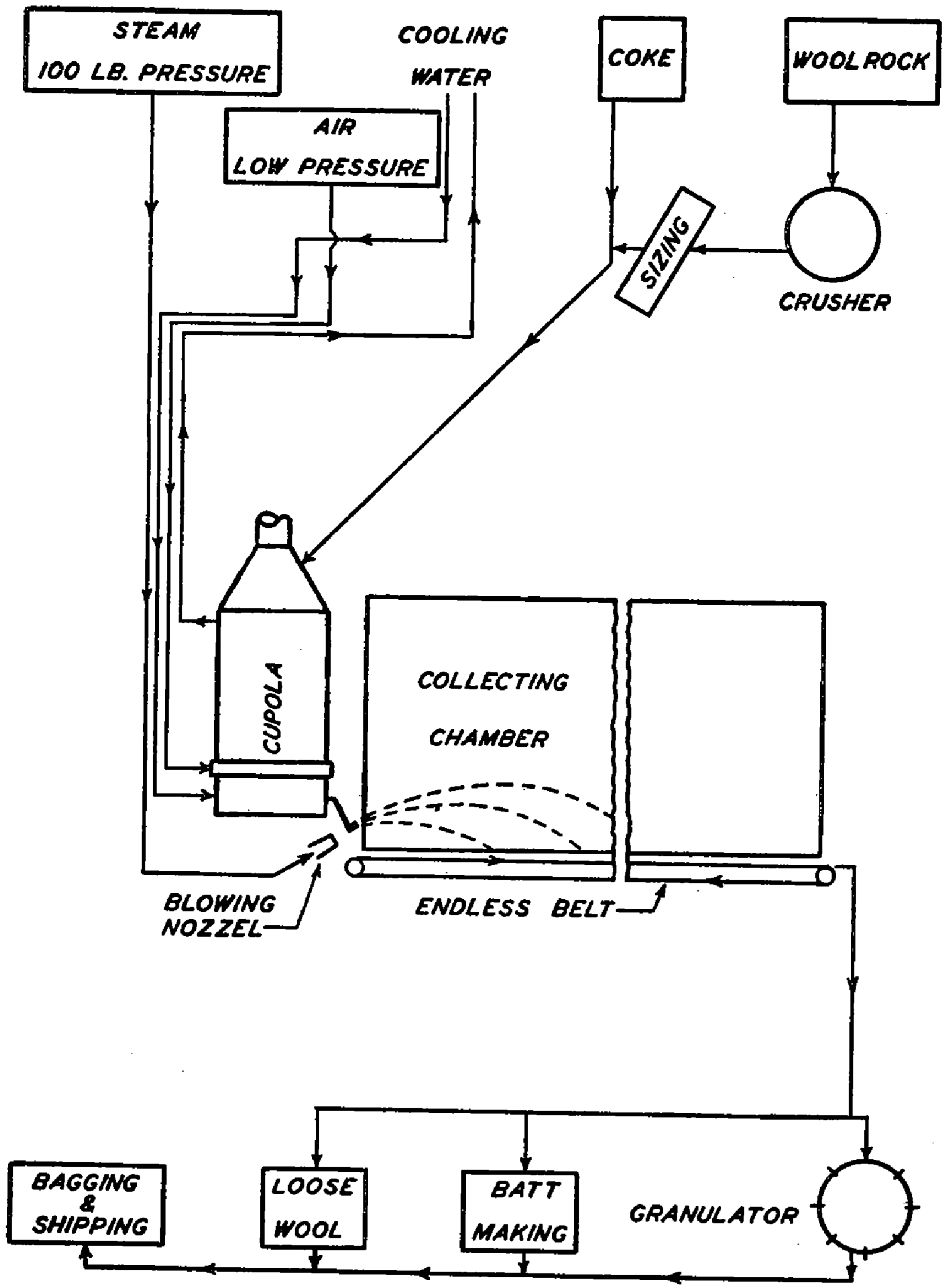


FIG. 6. A. FLOWSHEET OF TYPICAL ROCK WOOL PLANT.

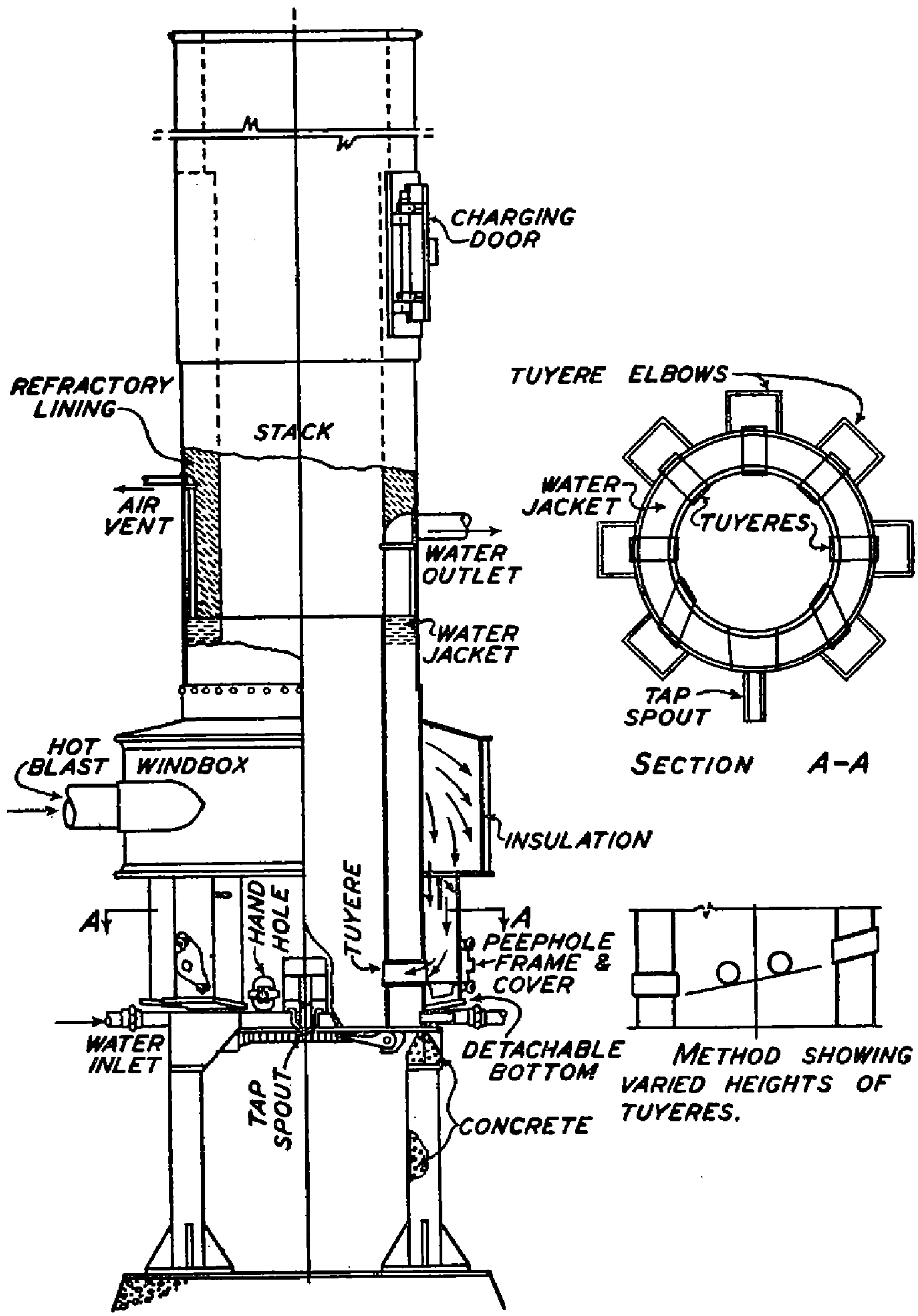


FIG. 6. B. STANDARD TYPE OF WATER COOLED BLAST FURNACE.

to 15 inches. In some plants this distance is varied to produce the types of wool desired.

Most plants use the conventional V-type of blowing nozzle. In a few plants the U-shaped orifice is used and others use shapes developed locally. The area of orifice opening ranges from 0.075 to 0.84 square inch.

While most plants use steam for blowing, a few are using compressed air. Steam pressures range from 45 to 125 pounds per square inch, and air pressures from 50 to 95 pounds.

Using Napier's proximate rule for calculating the quantity of steam flowing from a round orifice and applying this to the nozzle orifice as used, the steam used for blowing wool should range from 0.077 to 1.36 pounds per second, or from 0.17 to 7.0 pounds per pound of loose wool. Assuming that a pound of steam at atmospheric pressure occupies 26.83 cubic feet, the volume used would range from 4.5 to 188 cubic feet per pound of wool. During this investigation laboratory blowing tests required an average of 3.33 pounds of steam per pound of crude wool.

Where air is used, the quantity varies from 7.6 to 50 cubic feet per pound of wool.

The quantity of light paraffin oil sometimes used to oil the wool ranges from 0.5 to 10 gallons per ton of loose wool.

Details of the handling and processing of rockwool, after it is blown into the collection chamber, vary with different manufacturers. Many such details are covered by patent and a list of those, together with related patents, is given in appendix III. In general, the wool is blown into a collection chamber equipped with some type of conveyor or travelling floor which is often arranged to act as a screen for the removal of excess shot. The loose wool is either packed in bags as such or is converted into granulated wool by beating and breaking up the wool fibers, at the same time removing additional shot.

When wool bats are to be made the blown wool is distributed evenly over the conveyor and passed under rolls arranged to compress the material to the desired thickness and density. The blanket of felted wool so formed is then cut to standard sizes, either mechanically or by hand. The most common type of bats are completed by fastening the wool to a paper backing with some form of adhesive material such as asphaltic cement. The finished bats are packed in paper boxes or wrapped in rolls.

Economic Factors of the Cupola Method

No actual figures are available on the cost of producing rock wool by the cupola method. Some particular factors that must influence this cost are discussed as follows:

(1) *Fuel.*—Fuel is the second most important raw material in the manufacture of rock wool. Cupola plants should be located in an area where both woolrock and blast furnace grade of coke are readily obtainable. During 1937 the average price of coke at ovens[5] ranged from $4.29 per ton for Connelsville furnace grade (beehive coke) to $10.50 per ton for Buffalo foundry grade (by-product coke). Chicago foundry coke averaged $10.06 per ton. Roughly, an average of one ton of coke will be used to melt about 2 tons of rock. If the cheaper grade of coke is available at the plant at a cost of approximately $7.00, the fuel cost per ton of rock melted will be $3.50. This cost will be nearly doubled if by-product coke is used. Most of the plants in operation at this time specify by-product coke.

(2) *Quality of Woolrock.*—The woolrock used in blast furnace practice must have appreciable physical strength. Cupolas can not treat fine material so this must be rejected, preferably at the mine. Loss occasioned by removal of fines ranges from 5 to 20 percent, with consequent increase in the net cost of raw material. It would be impossible to treat caliche, calcareous shale, and similar materials in a cupola type furnace.

(3) *Shot loss.*—A portion of the molten rock does not make wool when blown, but forms globular shot ranging in size from microscopic particles to shot 1/8 inch in diameter. Most of these shot must be removed from the wool, and for loose wool the

5. U. S. Bureau of Mines, *Minerals Yearbook*, 1938.

average quantity removed amounts to about 20 percent of the raw woolrock used and more than 25 percent for granulated wool, as additional shot are rejected during the granulating process. Since cupolas can not treat fine material the shot can not be returned to the furnace, and therefore constitutes a loss.

(4) *Plant control.*—Uniform operating conditions and quality of furnace charge should be carefully maintained. Any abrupt or unforeseen change would probably retard the flow of material at some point in the operation, necessitating a complete shut-down with consequent loss in production and costly repairs. The flexibility of cupola operation is more limited than that of other types of furnaces.

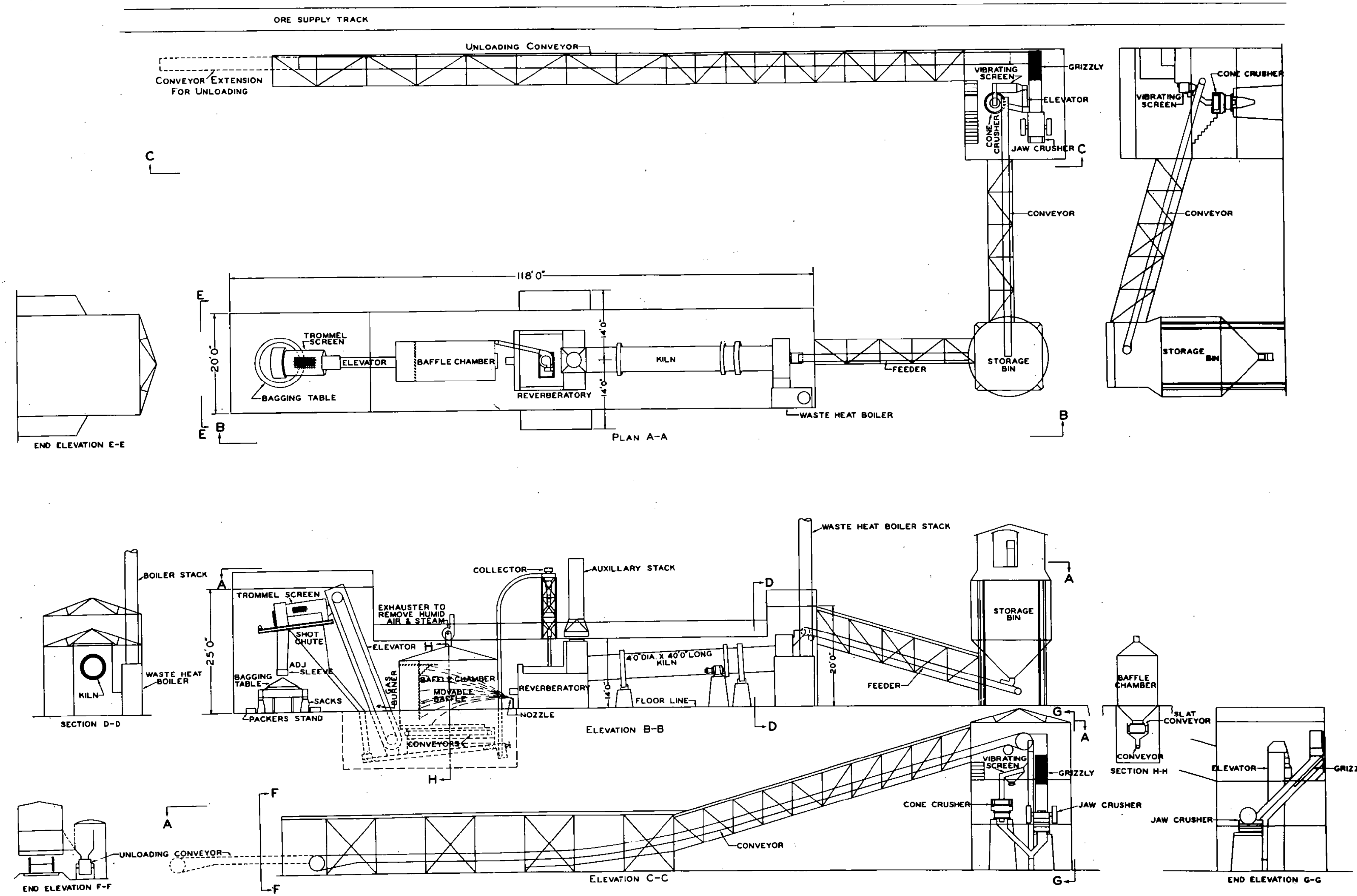
Suggested New Type of Gas Burning Plant

Natural gas for industrial use is both plentiful and cheap in Oklahoma, and if it can be successfully used as fuel for the manufacture of rock wool, such use should assist materially in lowering the cost of production. In addition to low cost, natural gas offers the advantages of ease of handling and distribution, furnace operation would be simplified and temperature control throughout the operation would be efficient and very flexible.

A number of rock wool manufacturers have attempted to use gas burning furnaces, usually of the reverberatory type, but such attempts have met with only partial success. Slag, as raw material, is much more amenable to treatment in such simple furnaces than woolrock which, in addition to being melted, must first go through the calcining stage with attendant evolution of large volumes of gas (CO_2). In an intermittent, or batch, process the reverberatory furnace should be satisfactory, but the requirement of the industry is for a continuous process producing a constant flow of material through the plant. The most serious difficulties encountered in obtaining continuous operation with reverberatory equipment can be summarized as follows:

(1) Cold raw material added to the pool of molten solution creates a condition of variable temperature in the solution, making it difficult to attain constant pouring temperature and

Fig. 7. Plan For Rock Wool Plant Illustrating Suggested Process For Using Gas as Fuel.



satisfactory mixture of the constituent mineral compounds. Such conditions tend to cause clogging or erratic flow at the tap hole, with consequent interruption of production, or results in the production of an inferior grade of rock wool and an excessive quantity of shot.

(2) The fast evolution, from added raw material, of large volumes of gas in the hearth causes frothing which disperses incompletely melted material through the molten solution, resulting in erratic pouring conditions. This gas also makes it difficult to control both furnace and pouring temperatures.

(3) Heat can not be distributed efficiently to meet the requirements of the different stages of the process. Calcining, and heating of the added material up to the melting point, must be performed at temperatures in excess of those actually required, which results in high stack temperatures and inefficient use of fuel.

Early in 1936 the author was considering the difficulties to be overcome in the use of gas for rockwool production, and decided that a combination furnace utilizing the principles of two well known types of furnaces—reverberatory and rotary kiln—might be one method of solving the problem. Later, with the assistance of Mr. Geo. McD. Johns,[6] those principles were incorporated in the design of a plant with an efficient operating capacity of about 50 tons of raw material per day. This preliminary plant design is illustrated in figure 7.

PLANT DESIGN

In the manufacture of portland cement a mineral mixture, very similar in composition to natural woolrock, is fed into a long, slowly revolving, rotary kiln. In passing through the kiln the material is progressively dehydrated, calcined, and clinkered. The final product, or clinker, emerges in a plastic condition very nearly ready to go into molten solution. Heat is applied at the discharge, or hot end of the kiln and travels with decreasing intensity to the feed end and stack, thus proportioning the avail-

6. Consulting Mechanical Engineer, Sappington, St. Louis County, Missouri.

able heat to the requirement of the reactions taking place at any point in the kiln and facilitating economical and efficient use of fuel.

With few variations, woolrock can be processed to the clinker stage by the dry process methods used in standard portland cement practice. Cement plant design factors are proved and well known, and can readily be applied to rock wool furnace design.

The cost of producing woolrock clinker should be appreciably less than that of cement clinker. Cement material must be ground exceedingly fine, and such grinding constitutes a major item of production cost. Secondary crushing to a size of approximately ⅜ or ½ inch should prove satisfactory for woolrock, and would be much less expensive. During and after the calcining stage woolrock becomes rather soft and friable and is consequently reduced to small sizes by the milling effect obtained in the rotating kiln. Control of heat and composition of material should be relatively simple and economical, compared to the cost of similar control in the manufacture of cement.

After bringing woolrock to the clinker state, very little additional heat is required to put the material into molten solution. Reverberatory type melting furnaces are standard equipment for many metallurgical operations and factors of design and performance are commonly known. If hot clinker should be fed directly into a reverberatory furnace, heated to a slightly higher temperature than that of the kiln, a liquid slag would be readily formed. By combining these two furnace types, a unit is obtained wherein all heat required for the process is introduced at the reverberatory, or melting, end and is efficiently distributed as it passes through the rotary kiln to the waste heat boiler and stack. The reverberatory furnace hearth can be designed with the capacity and pool area necessary for complete mixing and conditioning of the molten material, thereby obtaining constant composition and temperature at the blowing nozzle.

Individual manufacturers of rock wool have, in general, developed their own procedures and until recently, have been reluctant to divulge any pertinent information. The furnace design suggested here may have been previously conceived but the author knows of no plants now using such equipment. Other, and possibly more efficient and less costly types of furnaces may have been, or will be designed to successfully use gas for fuel, and this particular combination furnace is only suggested in the endeavor to stimulate interest in the use of Oklahoma's wool-rock and natural gas. This furnace should overcome the difficulties encountered in ordinary reverberatory practice, mentioned previously, and facilitate continuous and economical production of rock wool.

COMPARATIVE OPERATING FEATURES

In comparison with the standard blast furnace, an efficient gas burning plant would provide operating features as follows:

(1) Gas consumption should be approximately 10,000 cu. ft. per ton of woolrock. Natural gas for industrial use can be purchased in Oklahoma at from 2 to 10 cents per 1000 cu. ft. This would result in a fuel cost of from 20 cents to $1.00 per ton of raw material as compared to the $3.50 to $7.00 per ton cost prevailing in cupola practice.

(2) Flexible and accurate control of heat and the flow of material would be obtained, resulting in increased efficiency and more accurate control of quality of the product.

(3) Continuous operation could be maintained readily, and the comparative ease of making emergency repairs should reduce the probability of minor troubles necessitating complete plant shut-down.

(4) The furnace will accept fine material that can not be processed in a cupola, and excess shot produced can be returned to the reverberatory hearth, thereby reducing mining and processing costs.

IMPROVED BLOWING NOZZLE

At the suggestion of Mr. Johns, a steam blowing nozzle was designed to use the well-known expanding jet principle.

Kent[7] gives a steam velocity through an orifice of 900 feet per second at 90 pounds absolute pressure. In an expanding nozzle, the area of the throat being known, the area of any section beyond the throat is inversely proportional to the velocity and directly proportional to the specific volume and to the dryness. Using a throat area of 0.07 inch and a mouth area of 0.123 inch and a steam volume of 26.27 cubic feet per pound, and neglecting dryness factors, the application of this principle gives a mouth velocity of 2775 feet per second or about three times the velocity at an orifice.

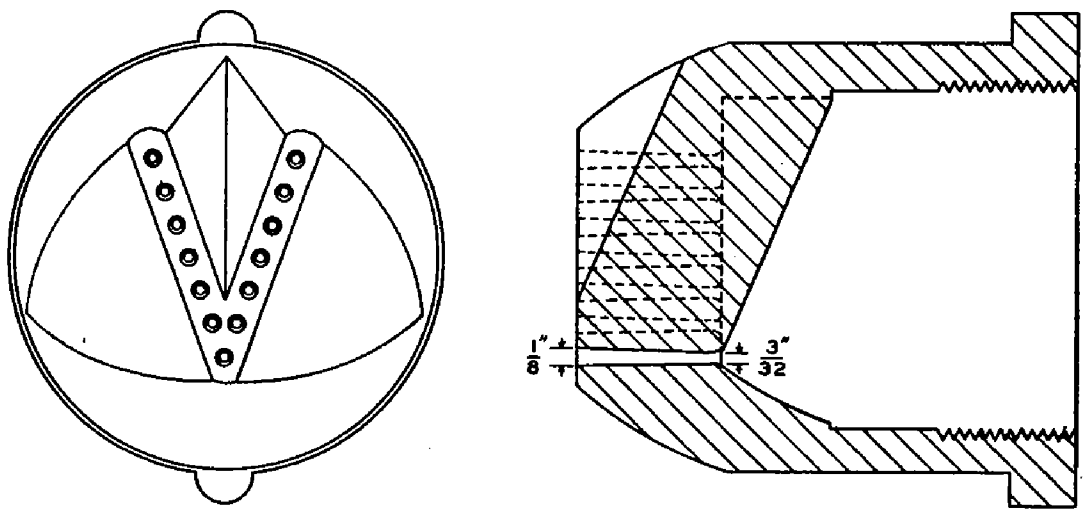


FIG. 8. MULTIPLE EXPANDING JET TYPE BLOWING NOZZLE.

Figure 8 illustrates a multiple expanding jet nozzle that proved very satisfactory in laboratory tests. Shredding action was exceptionally good and much lower boiler pressures were required. A good grade of rock wool resulted and the proportion of shot formed was materially reduced.

PLANT COST ESTIMATE

The rock wool plant shown in fig. 7 outlines the manufacturing process only to the packing of loose wool for distribution. Equipment for the production of granulated wool, bats and other pre-formed shapes, is not included in the illustration, as the nature and cost of such equipment varies greatly with different manufacturers. The following cost estimate was com-

7. Kent, William, *Mechanical Engineers Pocketbook,* Ninth Edition.

puted with the assistance of the Colorado Iron Works Company of Denver, Colorado and includes all new, heavy duty equipment, erected in Oklahoma. Ample allowance was made for unforeseen expense and alterations, but storage and office buildings are not included in the estimate.

No.	Item	Weight	Cost
1.	Unloading Conveyor	15,000 lbs.	$ 4000.00
2.	Unloading Conveyor—House and Structure	34,500	4150.00
3.	Crusher Building	50,000	5650.00
4.	Grizzly	5,800	540.00
5.	Crushers	22,775	7238.00
6.	Vibrating Screen	1,095	715.00
7.	Bucket Elevator	3,000	1160.00
8.	Inclined Conveyor	3,162	1115.00
9.	Bin	33,000	3546.00
10.	Feeder	2,900	1060.00
11.	Feeder Structure	10,500	1267.00
12.	]		
13.	]Kiln	107,452	6900.00
14.	]		
15.	Reverbatory	136,000	4470.00
16.	Chamber & Baffle	7,800	880.00
17.	Wool Conveyor	3,750	980.00
18.	Wool Elevator	6,750	1734.00
19.	Trommel Screen	9,000	1725.00
20.	Chutes & Hoppers	4,500	1150.00
21.	Shot Conveyor	760	340.00
22.	Pneumatic Equipment	5,000	1055.00
23.	Bagging Table	2,215	280.00
24.	Furnace Building	85,400	9500.00
25.	Electric Wiring & Lights		1250.00
26.	Excavation		250.00
27.	Concrete, 208 cubic yards		4000.00
28.	Boiler, Piping, Fittings & Stack		5000.00
29.	Freight		1500.00
30.	Totals	550,000 lbs.	$71,455.00

PRODUCTION COST ESTIMATE

The following estimate of the cost of producing loose rock-wool with gas burning equipment, is based on a minimum capacity of 40 tons of raw woolrock per day and 12,000 tons per year. The plant as designed should have an actual capacity of 50 tons per day or more, and the net cost per ton would be reduced substantially if operated at full capacity. Liberal allowances have been made in computing the cost items, and the total cost per ton estimated should not be exceeded in actual production. Sales expense and taxes are not included in the estimate.

(A) RAW MATERIAL COST:

		Cost per ton	Total cost per ton
1.	Blasting, block holing, etc. Powder used 1.35 lb. @ 12c per lb. is 16c cu. yd.	$ 0.108	
2.	Air drilling, 50 tons per hour @ 1.40	0.028	
3.	Cable tool drilling, .48 ft. hole per cu. yd. @ 50c is 24c per cu. yd.	0.160	
	Cost of breaking ore	0.296	
4.	Percent of waste (10%) gives total cost per ton		$ 0.33
5.	Loading on cars or delivery to plant storage, truck and labor		0.50

Mining investment:

Truck	$ 1,500.00
Ramp	500.00
Equipment	4,000.00
	$ 6,000.00

		Cost per ton	Total cost per ton
6.	Depreciation @ 20% 1,200.00	0.10	
7.	Compensation insurance	0.03	
8.	Maintenance $400.00 per year	0.03	
9.	Interest on investment @ 6%	0.03	
10.	Royalty	0.10	
		0.29	0.29
	Cost on cars or in plant storage, per ton		1.12
	Cost per ton of wool produced, (65% recovery)		1.72

(B) PLANT OVERHEAD:

Based on 26 tons of finished product for 300 days, or 7,800 tons per year.

Superintendent	$56.00 per week	
Bookkeeper	25.00	
Stenographer	15.00	
Auto truck	15.00	
Office supplies	15.00	
	$126.00 per week, $6552 per yr.	0.89

(C) Fuel:
Gas, 9500 cu. ft. per ton @ 8c per M. 0.76

(D) WATER:
360 gal. per ton @ 50c per M. 0.18

(E) POWER AND LIGHT:
Crushing, 75 HP for 8 hours
Plant, 25 HP for 24 hours
75 HP x .746 x 8 is 447.6 KWH per day
25 HP x .746 x 24 is 447.6 KWH per day

Total 895.2 KWH per day

895.2 x 300 is 268,560 KWH per year.

5,000 KWH @	5c	$ 250.00	
25,000 KWH @	4c	1,000.00	
30,000 KWH @	3c	900.00	
30,000 KWH @	2.5c	750.00	
178,560 KWH @	2c	3,571.00	
		$ 6,471.00	0.83

(F) LABOR:

Unloading cars:		
4 men @ $0.40=1.60 x 8 hours @ $12.80 day	$ 76.80 week	
3 shifts of 5 men for 6 days @ $0.50 hr.	360.00	
3 machinists @ $1.00 per hr. for 6 days	144.00	
	$580.80 week	
Per day cost is $96.80 for 26 tons, or	$ 3.72	
Compensation insurance	.24	
	$ 3.96	3.96

(G) MISCELLANEOUS:
Oil, grease & supplies $1.30 per day .05

(H) DEPRECIATION:

Motor truck				
Motor truck	$ 1,500 @	20%	$ 300.00	
Hand tools	500	20%	100.00	
Buildings & structures	34,393	10%	3,439.00	
Crush. & convey. mach.	32,562	10%	3,256.00	
Rotary Kiln	7,000	10%	700.00	
Reverberatory furnace	4,500	10%	450.00	
Laboratory	1,000	10%	100.00	
Office equipment	500	10%	50.00	
	$ 81,955		$8,395.00	
				1.07

(I) MAINTENANCE:				
Motor truck	per year		$ 130.00	
Hand tools, etc			200.00	
Buildings & structures	2%		548.00	
Crush. & convey. mach.	7%		1,991.00	
Rotary kiln	20%		1,400.00	
Reverberatory	20%		900.00	
			$5,169.00	0.66
(J) INTEREST ON INVESTMENT:				
(Exclusive of mining plant)		$ 71,455.00		
Small tools		500.00		
Truck		1,500.00		
Office equipment		500.00		
Office building		2,000.00		
Laboratory		1,000.00		
Storage building		5,000.00		
Repair materials		1,000.00		
		$ 82,955.00		
Working capital, 90 days		25,000.00		
Total		$ 107,955.00		
Interest at 6%	$6,480.00 per year			0.83
(K) ALLOWANCE FOR INITIAL PLANT				.50
			Total	$11.45

RECAPITULATION:

		per ton
A	Material delivered in storage or on cars	$ 1.72
B	Plant overhead	0.89
C	Fuel, Gas	0.76
D	Water	0.18
E	Power and Light	0.83
F	Plant Labor	3.96
G	Miscellaneous	0.05
H	Depreciation	1.07
I	Maintenance	0.66
J	Interest	0.83
K	Allowance for initial plant	0.50
	TOTAL COST PER TON OF LOOSE WOOL	$11.45

CHEMISTRY OF WOOLROCK

Prior to 1934 very little information was published or available on the chemical and other technical phases of the rock

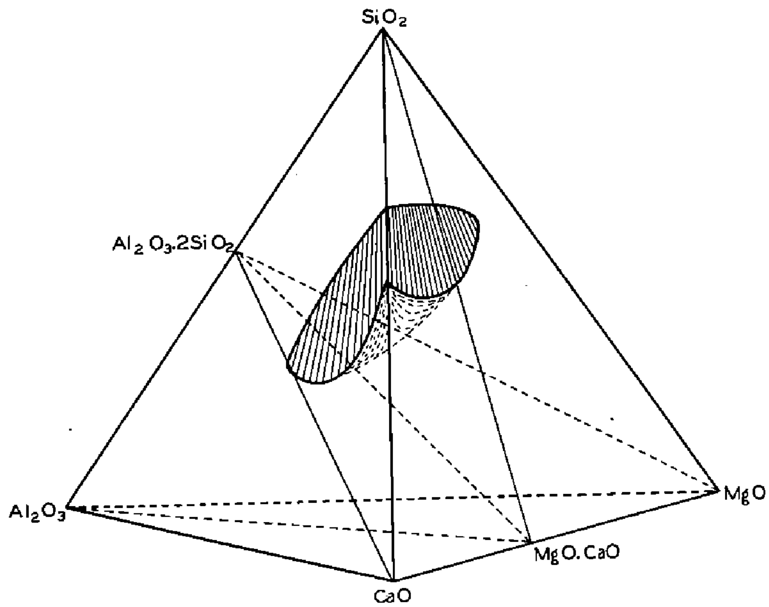


FIG. 9. DIAGRAMMATIC REPRESENTATION OF COMPOSITION RANGE SUITABLE FOR ROCK WOOL PRODUCTION.

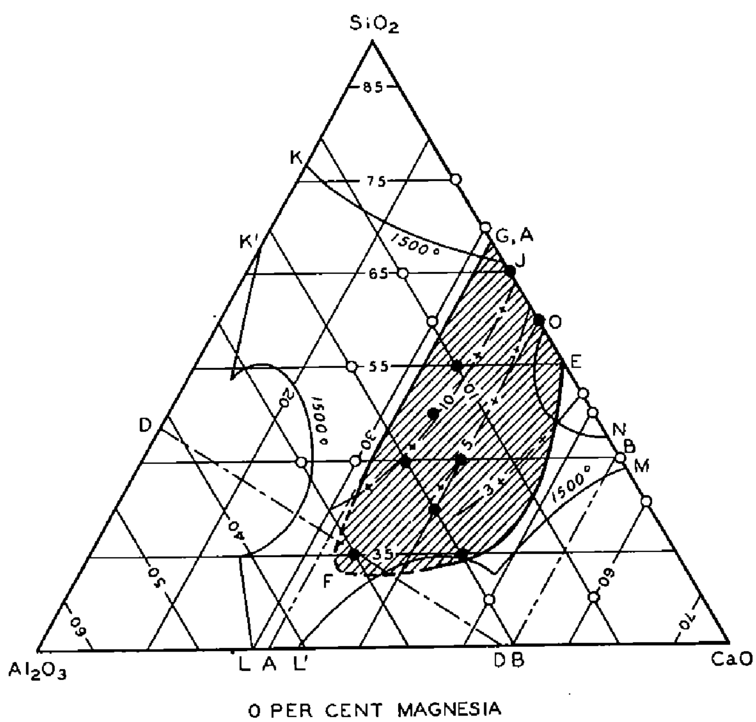


FIG. 10. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE TERNARY SYSTEM CONSISTING OF SiO_2-Al_2O_3-CaO.

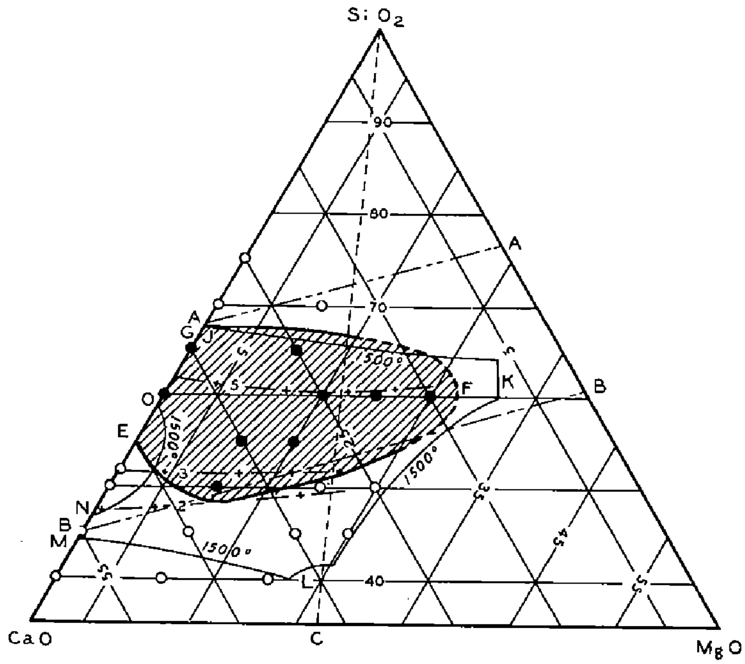


FIG. 11. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE TERNARY SYSTEM CONSISTING OF SiO_2-CaO-MgO.

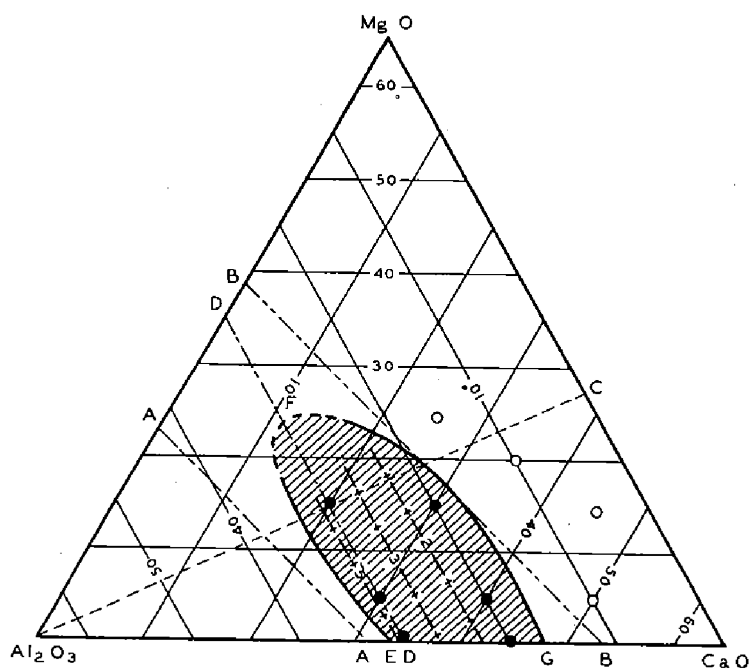


FIG. 12. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE QUATERNARY SYSTEM CONSISTING OF SiO_2-CaO-MgO-Al_2O_3 AT 35 PER CENT SILICA.

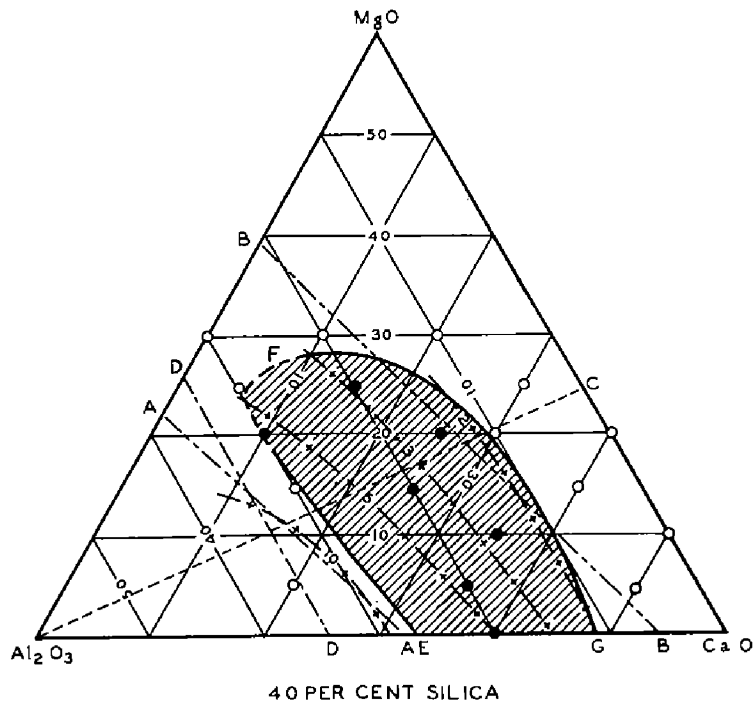


FIG. 13. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE QUATERNARY SYSTEM AT 40 PER CENT SILICA.

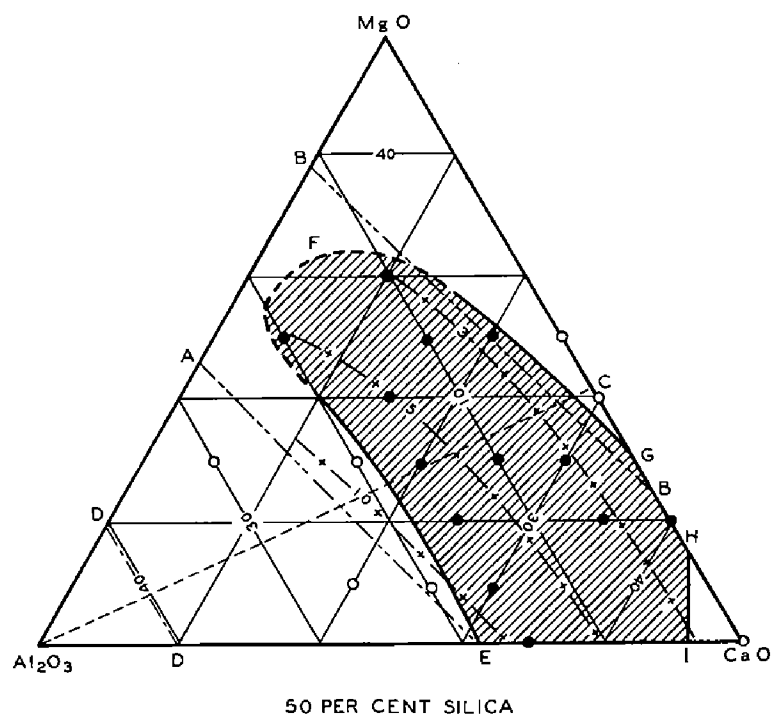


FIG. 14. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE QUATERNARY SYSTEM AT 50 PER CENT SILICA.

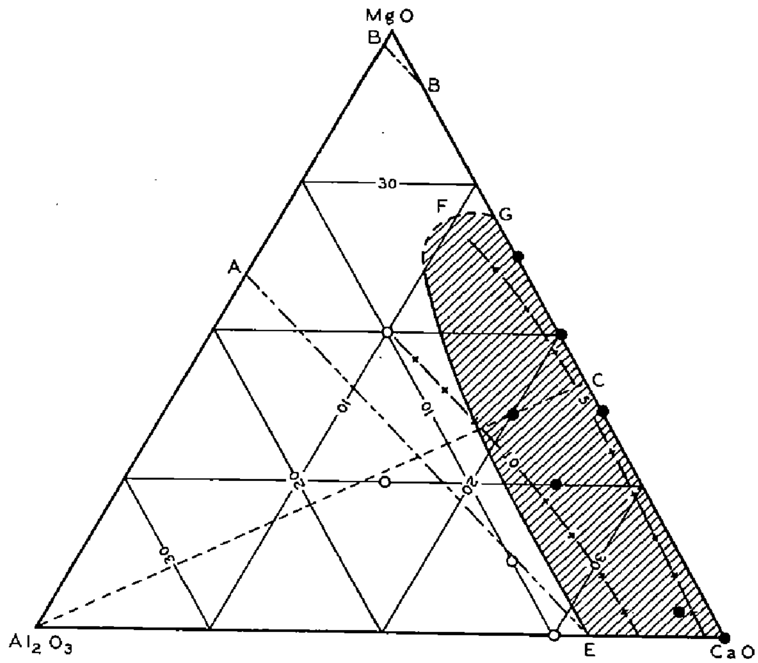


FIG. 15. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE QUATERNARY SYSTEM AT 60 PER CENT SILICA.

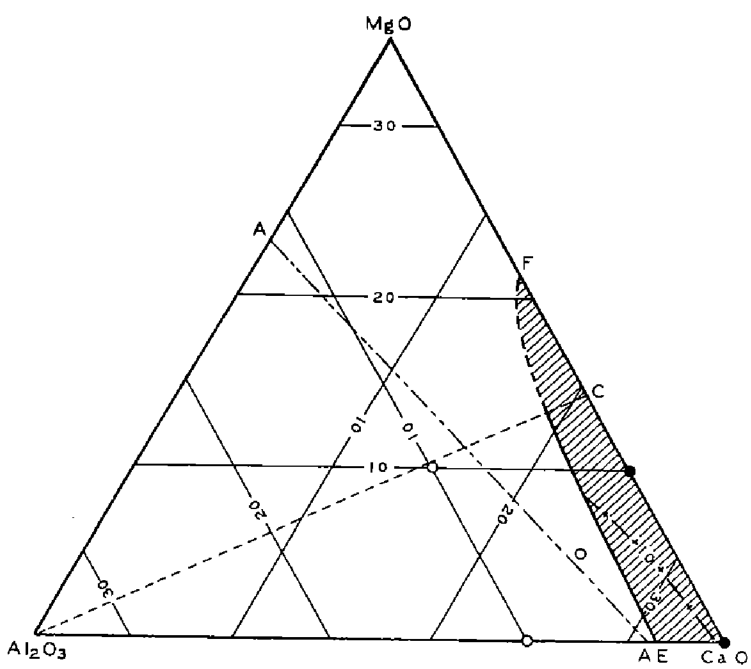


FIG. 16. DIAGRAM SHOWING RANGE OF COMPOSITIONS SUITABLE FOR ROCK WOOL PRODUCTION IN THE QUATERNARY SYSTEM AT 65 PER CENT SILICA.

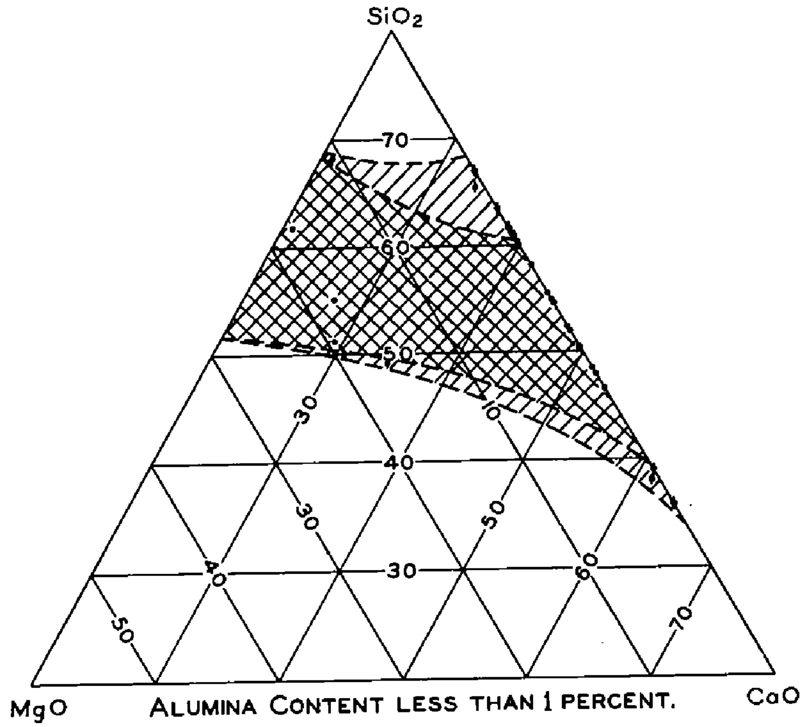


FIG. 17. DIAGRAM SHOWING RANGE OF COMPOSITIONS OF NATIVE ROCKS, IN THE TERNARY SYSTEM CONSISTING OF SiO_2-CaO-MgO, FROM WHICH ROCK WOOL WAS PRODUCED IN THE LABORATORY.

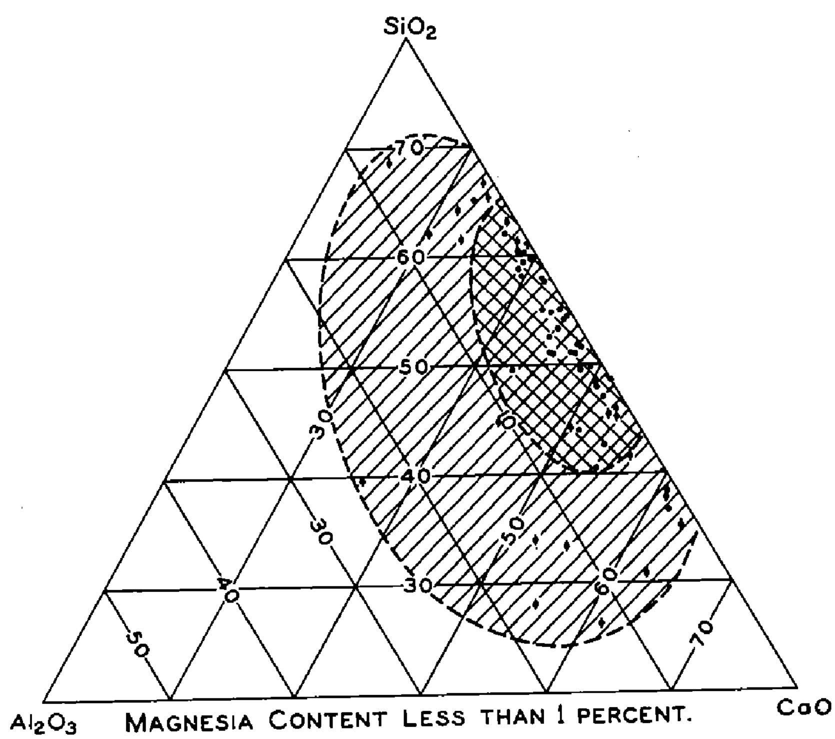


FIG. 18. DIAGRAM SHOWING RANGE OF COMPOSITIONS OF NATIVE ROCKS, IN THE TERNARY SYSTEM CONSISTING OF SiO_2-Al_2O_3-CaO, FROM WHICH ROCK WOOL WAS PRODUCED IN THE LABORATORY.

TABLE I

Tabulation of Chemical Analyses and Averaged Analysis (per cent)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	CO_2	H_2O (comb)	Total
1	48.98	1.66	2.14	....	14.56	10.80	23.14	....	101.29
2	32.20	4.25	0.43	Tr.	30.52	4.16	28.49	....	100.05
3	33.90	1.48	1.50	....	33.29	....	26.12	1.27	97.56
4	28.64	2.44	2.36	Tr.	36.00	....	26.90	3.12	99.46
5	36.94	7.11	9.15	0.63	21.62	2.44	19.27	....	97.16
6	20.44	3.52	1.00	....	23.65	15.04	33.44	....	97.09
7	27.36	2.14	5.36	Tr.	36.52	....	27.72	....	99.10
8	30.68	3.17	1.57	....	34.84	....	29.39	....	99.65
9	40.58	0.49	1.29	Tr.	33.86	....	24.38	....	100.60
10	26.08	0.58	0.36	....	41.42	....	31.77	....	100.21
11	54.86	5.83	2.93	0.06	19.72	....	14.43	....	97.83
12	50.66	0.66	3.50	0.51	15.61	8.08	20.42	....	99.44
13	37.92	0.61	0.36	0.03	34.62	....	27.16	....	100.70
14	44.28	0.43	0.71	....	31.89	....	23.14	....	100.45
15	41.00	0.34	1.86	....	32.81	....	24.02	....	100.03
16	36.58	0.81	0.29	....	35.99	....	25.78	0.50	99.45
17	52.12	0.54	2.36	Tr.	25.54	....	19.45	....	100.01
18	34.32	0.76	1.22	Tr.	21.14	13.12	28.86	....	99.42
19	42.26	0.99	1.93	0.09	16.26	11.74	25.57	0.22	99.06
20	36.88	1.17	1.79	....	19.61	12.18	27.54	....	99.17
21	36.30	1.05	2.29	....	20.24	12.98	26.75	....	99.61
22	31.44	3.05	1.93	0.06	18.85	13.62	28.42	....	97.37
23	44.40	0.99	2.43	Tr.	29.10	....	23.50	....	100.42
24	38.56	0.48	1.36	0.02	19.30	12.42	28.51	....	100.65
25	18.34	11.11	1.93	....	36.34	....	29.74	....	97.46
26	20.30	4.28	1.72	Tr.	37.00	....	31.89	2.38	97.57
27	16.40	7.97	2.29	....	38.80	....	31.86	....	97.32
28	22.66	8.94	1.86	0.34	33.50	....	27.12	3.98	98.40
29	30.86	7.41	2.43	....	30.44	....	26.58	....	97.72

TABLE I (Cont'd)

Tabulation of Chemical Analyses and Averaged Analysis (per cent)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	CO_2	H_2O (comb)	Total
30	34.29	14.42	0.37	Tr.	24.80	1.71	19.18	5.24	100.03
31	31.36	2.65	1.79	0.57	32.00	....	26.90	2.83	98.10
32	31.03	13.61	0.73	Tr.	26.67	2.21	21.27	4.50	100.02
33	30.06	1.35	3.56	0.17	34.67	1.82	28.80	0.23	100.66
34	23.66	1.22	1.29	0.08	39.52	....	32.91	....	98.68
35	35.22	1.81	1.29	Tr.	33.78	1.28	27.98	....	101.36
36	32.15	1.77	12.90	0.25	23.60	2.08	25.68	0.56	99.47
37	33.22	1.27	8.51	0.71	30.39	....	26.00	....	100.10
38	36.74	1.32	1.00	Tr.	33.94	....	26.63	....	99.63
39	49.62	1.05	3.25	0.07	26.08	....	19.74	0.32	100.19
40	46.00	....	1.64	....	29.18	....	20.42	....	97.24
41	36.70	0.50	1.50	....	33.94	....	25.52	....	98.16
42	20.66	1.82	9.19	0.28	33.46	3.50	31.32	0.51	100.74
43	36.86	0.76	3.86	0.32	29.20	....	24.94	0.84	96.78
44	33.22	0.64	1.36	....	38.17	....	27.54	....	100.93
45	39.70	1.12	1.14	....	32.42	....	24.99	....	101.37
46	29.00	1.44	0.50	....	41.64	....	29.92	....	102.50
47	45.50	1.12	5.86	0.36	25.41	....	21.03	....	99.28
48	36.30	5.34	1.72	0.27	31.56	....	26.66	....	101.85
49	31.26	0.66	1.43	0.04	36.48	0.52	29.61	....	100.00
50	46.64	5.65	4.15	0.06	23.00	0.84	18.97	....	99.31
51	34.48	3.32	1.00	....	21.55	11.10	27.81	....	99.26
52	37.54	5.26	1.00	....	18.65	11.10	26.40	....	99.95
53	30.75	1.48	0.59	0.05	36.14	0.33	26.98	3.34	99.66
54	19.35	0.31	0.79	0.07	43.99	0.40	35.20	....	100.11
55	24.96	0.82	1.17	0.03	40.46	0.30	32.18	0.07	99.99
56	45.50	0.84	0.36	....	29.00	....	22.26	....	97.96
57	41.70	0.40	1.14	Tr.	30.20	....	23.76	....	97.20

TABLE I (Cont'd)

Tabulation of Chemical Analyses and Averaged Analysis (per cent)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	CaO	MgO	CO_2	H_2O (comb)	Total
58	39.40	0.16	0.64	....	32.41	....	25.43	....	98.04
59	46.74	0.43	0.57	....	28.93	....	22.70	....	99.37
60	31.88	1.09	1.07	....	37.60	....	27.37	....	99.01
61	49.44	0.70	1.86	....	28.17	....	20.68	....	100.85
62	33.90	1.11	2.93	....	35.43	....	25.52	....	98.89
63	31.30	1.65	3.15	....	29.04	5.22	29.50	3.38	100.64
64	33.86	....	1.63	0.14	35.98	....	28.23	....	99.84
65	46.52	3.32	5.79	0.03	22.78	Tr.	18.04	0.69	97.17
66	48.33	1.53	1.29	Tr.	19.06	8.10	20.32	1.54	100.17
67	42.24	2.03	1.29	Tr.	27.22	2.18	22.62	1.90	99.48
68	35.62	0.95	1.07	Tr.	20.41	13.40	27.20	1.54	100.19
69	31.02	1.00	1.14	Tr.	35.57	1.00	28.40	1.43	99.56
70	36.52	1.67	5.00	0.28	32.60	Tr.	23.23	....	99.30
71	35.06	2.64	3.93	0.06	31.18	....	24.46	....	97.33
72	29.64	18.18	3.00	....	27.02	0.40	21.64	....	99.88
73	22.18	6.92	1.72	Tr.	36.96	0.86	29.94	....	98.58
74	45.10	1.52	1.86	....	22.95	2.86	21.13	2.04	97.46
75	39.78	1.50	1.00	Tr.	30.36	....	23.42	1.93	97.99
76	36.36	2.10	4.72	0.09	30.60	....	24.94	0.51	99.32
77	50.88	0.90	0.50	0.14	26.40	0.46	21.21	....	100.49
78	44.46	1.56	1.22	0.14	29.46	....	23.11	....	99.95
79	33.06	0.98	0.64	....	35.86	....	26.58	....	97.12
80	43.68	0.55	2.65	....	28.62	....	22.79	....	98.29
Average	35.95	2.61	2.28	0.07	29.87	2.35	25.63	0.55	99.31

wool industry. In that year the Illinois Geological Survey completed a very detailed program of research on rock wool and potential sources of raw material in the state of Illinois.[8] Much of the information contained in that bulletin is of a general nature and applicable to the study of Oklahoma materials, so it was deemed unnecessary to duplicate such work in this investigation. This information has been used freely and confidently in the investigation of Oklahoma materials and the preparation of this report.

As the primary objective of this investigation is to encourage the establishment of a rock wool industry in the state of Oklahoma, the principle use of chemistry has been to assist in the search for suitable local deposits of raw materials. After the industry is established in the state a more detailed chemical, physical, and economic study of the manufactured products would be of value.

Influence of Chemical Factors

A natural woolrock is a sedimentary material that is suited to the production of a commercial grade of rock wool without the addition of fluxing agents. Its mineral combinations must be so proportioned that a molten solution or slag will be formed at economically feasible temperature. An impure siliceous limestone can be considered for purposes of comparison, a type woolrock. Both chemical and physical properties are controlling factors governing the quality of wool produced and a satisfactory woolrock must have, among others, the characteristics discussed hereafter.

MELTING TEMPERATURE OF WOOLROCK

A furnace charge should be in complete molten solution, ready for blowing, at a temperature not greatly exceeding 1500° C. Higher temperatures appreciably increase both initial plant cost and production costs. Both chemical and mineral composition affect the temperature requirement as discussed in the following chapter on metallurgical factors.

8. Lamar, J. E., Willman, H. B., Fryling, Charles F., and Voskuil, Walter H., "Rock Wool from Illinois Mineral Resources": *Ill. Geol. Survey Bull.* 61, 1934.

COMPOSITION OF WOOLROCK

Sedimentary rocks that have proved to be woolrocks are in general composed of one or more of the basic oxides of aluminum (Al_2O_3), calcium (CaO), and magnesium (MgO), combined to form silicates with the acid silicon dioxide (SiO_2) in various ratios of acid to base. Iron is nearly always present in natural rocks, and manganese, phosphorus, sodium, potassium, and other elements are often found. Such elements are unnecessary to the formation of wool, and if included in the composition of the wool fibers to any appreciable extent, have a deleterous effect on the quality of the product. An excess of iron (2% or more), if allowed to combine with the wool forming minerals in the molten solution, will result in the production of wools colored various shades of brown.. Such discoloration is intensified when sulphur is present in appreciable quantities, while manganese also acts as a coloring impurity. All the extraneous elements mentioned tend to decrease the stability of the finished rock wool, as compounds are formed that cannot properly resist attack by moisture and atmospheric gases, and a rapid break down of the fiber structure results. Such compounds also are subject to excessively fast crystal growth at moderate temperatures, which causes devitrification and consequent disintegration of the wool fibers. This change from an isotropic, glassy solid solution to a complex semi-crystalline mass, develops planes of weakness and internal stresses which make the fibers brittle and friable.

COMPOSITION LIMITS

The work of the Illinois Geological Survey indicated that in general, all common sedimentary rocks containing carbon dioxide (CO_2) roughly between the limits of 20 and 30 per cent are potential woolrocks. A fast and simple determination of loss on combustion permits the elimination of many rock samples from further consideration. When a sample falls within those limits, this preliminary test should be followed by complete chemical analysis and an experimental blowing test. This procedure has been checked and followed during this investigation.

The experimental production of rock wools from synthetic mixtures of the oxides of the principle elements found in natural woolrocks provides a good illustration of the approximate limits of composition suitable for the manufacture of rock wool. Limits defined by this method are not strictly applicable to natural rocks because modifying elements are always present in such rocks to an extent that would appreciably alter limits so derived. The method does, however, provide a valuable basis for comparison, so the results of such an investigation are included in this report.

The experimental data obtained on synthetic mixtures are shown in diagramatic form in figures 9 to 16 inclusive.[9] These composition diagrams represent an equilateral tetrahedron (Fig. 9) and the surfaces of such tetrahedron (Figs. 10 to 16). Pure components are represented by the apexes; binary systems of combination by the edges; ternary systems by the triangular exterior surfaces; and the quaternary system by points forming a surface within the tetrahedron. Figures 10 and 11 illustrate the alumina-silica-lime ternary and the lime-silica-magnesia ternary respectively. Figures 12 to 16 are cross sections parallel to the faces of the tetrahedron. To facilitate illustration, the silica content of all samples plotted on the same diagram (figures 12 to 16) was held constant, thereby permitting the use of triangular co-ordinates. The sum of the four co-ordinates of any point is 100, obtained by adding the percentage of silica to the sum of the other three components.

Figures 17 and 18 are three-component diagrams similar to those of Figures 10 and 11 but represent a number of actual field samples from different parts of Oklahoma. The cross-hatched areas indicate samples that produced good commercial grades of rock wool and the adjacent hatched areas cover zones in which the quality of wool produced was erratic, some good and some of inferior grade. This might be called the sub-woolrock area, or the transition zone between woolrock and non-woolrock.

In further explanation of Figures 10 to 16, lines AA and

9. Figures 9 to 16 inclusive are reproduced by permission, from *Ill. Geol. Survey Bull.* 61, 1934.

BB enclose an area wherein all compositions, calculated to a rock basis, contain a carbon dioxide content between the limits of 20 and 30 per cent. Lines CC delimit those compositions conforming to the dolomitic proportion of one molecule of magnesia to one molecule of lime and lines DD similarly delimit compositions of the kaolinitic proportion of one molecule of alumina to two molecules of silica. Areas enclosed by lines EFG represent ranges of composition suitable for the production of rock wool. Lines JKLMNO trace the 1500° C. isotherm within which samples were completely melted. Samples indicated outside of this isotherm would not be completely melted at 1500° C. but would produce wool from the melted portions. The cross-dash lines are lines of equal fiber diameter in microns.

Table I is a tabulation of the chemical analyses of the 80 samples described in detail. A computed average analysis of all the samples is given at the foot of the table.

Fiber Characteristics

The average fiber diameter of rock wool has a direct bearing on the insulating efficiency, and consequent value of the product. Coarse fibered wools do not pack well and leave large air pockets which permit excessive transmission of heat by convection. Fine fibered wools tend to pack too closely, increasing the bulk density to a point where excessive heat is transmitted by conduction through the compacted fibrous material. The best possible grade of rock wool would have fiber characteristics permitting the inclusion of the greatest possible number of *dead* air spaces, with the smallest possible area of fiber surface contact, when compacted to a bulk density providing sufficient strength to support its own weight and other stresses incident to structural application. Factors controlling the insulating efficiency of such rock wool would be the thermal conductivities of dead air and of the material composing the fibers.

Rock wools were produced in the laboratory having average fiber diameters ranging from 1 micron to 30 microns, but those with average fiber diameters of from 2 to 12 microns are thought to be most efficient for general use in insulation. These limits are variable however, as no standard specifications have been evolved. Coarse wools could be made into fabricated forms or be used for other special purposes. The best grades of wool, produced experimentally from natural rocks, were those of 3 to 7 microns average fiber diameter, and while no exact relation has yet been established between fiber diameter and bulk density, such wools are satisfactory commercial insulators at bulk densities of 4 to 12 lbs. per cubic foot, with the greatest efficiency generally considered to be at a density of about 10 lbs. per cubic foot. (See Appendix I)

Fiber length of rock wools is another important factor. Long fibered wools are necessary for the manufacture of bats and other felted products. Some uses, such as blowing the material into the walls of old structures, require short fibered or granulated wool. This type of product is usually made by mechanically beating and breaking up the longer fibered material.

Control of Fiber Size

A number of variable factors, more or less controllable in commercial plant operations, affect the diameters and lengths of the wool fibers produced. Some of these factors can be briefly discussed as follows:

Viscosity of the melt.—The viscosity of the molten mineral solution is the prime factor in determining the size of the rock wool fibers produced. In general, other conditions being the same, both fiber diameter and length increase with increased viscosity of the slag. Highly viscous slags either produce long, coarse, and brittle threads of little value as commercial insulation, or merely blow into particles without the formation of any fibrous material. Slags of low viscosity either produce very fine textured and short fibered wools, or merely form quantities of spherical shot with very few fibers. Such fine, short fibered wools tend to pack excessively, with consequent large decrease of insulating efficiency. The usual method of determining that a slag has the proper viscosity for the production of rockwool is to make a series of actual blowing tests, changing variables such as temperature and steam blowing pressure. Viscosity can be determined by a rather difficult laboratory procedure. McCaffery,[10] experimenting with a number of four-component blast furnace slags, found that at a temperature range between 1400 and 1600° C., fiber diameters increased from an average of 2 microns, for a viscosity of 1 poise, to an average of 15 microns for a viscosity of 50 poises. The majority of the samples producing wools equivalent to commercial grades had viscosities of from 1 to 20 poises with most of such samples falling within the range of 4 to 10 poises.

Pouring Temperature.—The temperature of the stream of liquid slag as it enters the blowing jet is another factor governing fiber size. The temperature loss between the furnace and the jet can be controlled to some extent, by varying the distance the molten stream drops. Excessive length of drop causes excessive cooling, resulting in a viscous slag which produces coarse fibered rock wool. In present practice drops between tap hole and steam jet vary from 4 to 12 inches. No exact data are available on blowing temperatures, but they are known to vary widely in actual practice. As viscosity is affected by both chemical composition and temperature, the most efficient blowing temperature must be determined by trial for each individual supply of raw material.

Melting and proper blowing temperatures may differ greatly. The physical and mineralogical characteristics of a woolrock may necessitate a melting temperature much higher than that required to keep the slag in liquid solution after melting is completed. Under such conditions erratic changes in the temperature of the issuing molten slag might result, with consequent variations in the quality of wool produced. Such variations can be minimized by soaking, or conditioning the pool of molten slag in the crucible or hearth zone of the furnace at a constant temperature, over a fixed period of time.

Chemical control.—As in other similar industries, rock wool factories can maintain efficient control of their products by in-

10. McCaffery, Richard S., *Amer. Inst. of Min. and Met. Engineers, Tech. Pub.* 383, 1931.

stalling a system of continuous, or regulated intermittent sampling and analysis of the incoming raw material. After standards of material have been fixed by preliminary investigation and trial, any serious departure from those standards could be quickly detected and corrective ingredients added to the furnace charge.

The work of the Illinois Geological Survey with wools from synthetic mixtures shows that fiber diameter varies with the acid base ratio.[11] Roughly, most wools with average fiber diameters between 2 and 10 microns were produced from mixtures with acid-base ratios of from 0.5 to 1.5. At an average fiber diameter of 35 microns the acid-base ratio was 2.5. This relation should simplify chemical methods of plant control.

METALLURGY OF WOOLROCK

All mineral wools are derived from natural rock or some other form of mineral aggregate, and the most important and difficult part of the manufacturing procedure is the production of a molten solution, or slag, that can be blown and shredded into a commercial grade of wool.

Many metallurgical slags, from blast furnace and similar operations, have proved to be satisfactory material for the manufacture of mineral wool, and all woolrocks must be reduced to slags during the manufacturing process. As slags are highly important to many metallurgical processes, their compositions and characteristics have been studied intensively. In conjunction with the chemical studies of woolrock, a brief discussion of metallurgical factors should be of interest.

Metallurgically, slags are thought to be igneous solutions of the oxides and of the chemical compounds that may have been formed on melting, the compositions of such compounds depending principally on chemical equilibrium but also being influenced by thermal factors such as differential melting points of constituent compounds, conditions in effect during the melting

11. The chemical method used in computing these ratios was: Acid=gram mols of SiO_2, Al_2O_3, and Fe (Calculated as Fe_2O_3) in 100 grams of material. Base=gram mols of CaO and MgO in 100 grams of material. This method differs from the metallurgical method of computing silicate degrees which is discussed later in this report.

process, and time allowed and temperature maintained in the conditioner or crucible.

The common bases found in woolrocks, CaO, MgO, Al_2O_3, Fe0, and Mn0 form silicates which are soluble in each other when molten. When frozen, these silicates form either complex isomorphous mixtures or amorphous glassy solid solutions, the latter form being preferable for the manufacture of satisfactory rock wool.

Silicate Degree of Rock Wool Slags

Silicates are defined in degree by the ratio of oxygen in the base to that in the acid. The result obtained by dividing the oxygen of the acid, (silica), by the oxygen of the bases is used to express the silicate degree, which is merely the expression of the amount of silica oxygen compared to 1 base oxygen. The metallurgical classifications, which are somewhat different from the chemical classifications, are given in Table II.

TABLE II.

Metallurgical Classification of Silicates

Name	Silicate Degree O base :O acid	Formulae	
		RO (base)	R_2O_3 (base)
Subsilicate	2:1	$4RO.SiO_2=R_4SiO_6$	$4R_2O_3.3SiO_2=R_8Si_3O_{18}$
Monosilicate	1:1	$2RO.SiO_2=R_2SiO_4$	$2R_2O_3.3SiO_2= R_4Si_3O_{12}$
Sesquisilicate	2:3	$4RO.3SiO_2=R_4Si_3O_{10}$	$4R_2O_3.9SiO_2=R_8Si_9O_{30}$
Bisilicate	1:2	$RO.SiO_2=RSiO_3$	$R_2O_3.3SiO_2= R_2Si_3O_9$
Trisilicate	1:3	$2RO.3SiO_2=R_2Si_3O_8$	$2R_2O_3.9SiO_2=R_4Si_9O_{24}$

The calculation of silicate degree is simplified by the use of Table III. The equivalent value obtained from the table, divided into the percentage of the respective compound as determined by chemical analysis, gives the proportional acid or base value of that compound as contained in the mixture.

TABLE III.
EQUIVALENT VALUES OF SLAG-FORMING COMPOUNDS

Compound	Mol. weight	O in 1 mol. Wt.	O in 1 mol. Atoms	Equivalent value
SiO_2	60	32	2	30
Al_2O_3	102	48	3	34
FeO	72	16	1	72
MnO	40	16	1	71
CaO	56	16	1	56
MgO	40	16	1	40

The natural woolrocks described in this report covered a wide range of silicate degrees as shown by Figure 19. Satisfactory wools were produced within a range of 0.6 to 3.5 but the predominant groupings near the 1.5 and 2.5 degrees are significant in regard to the metallurgical aspects next discussed.

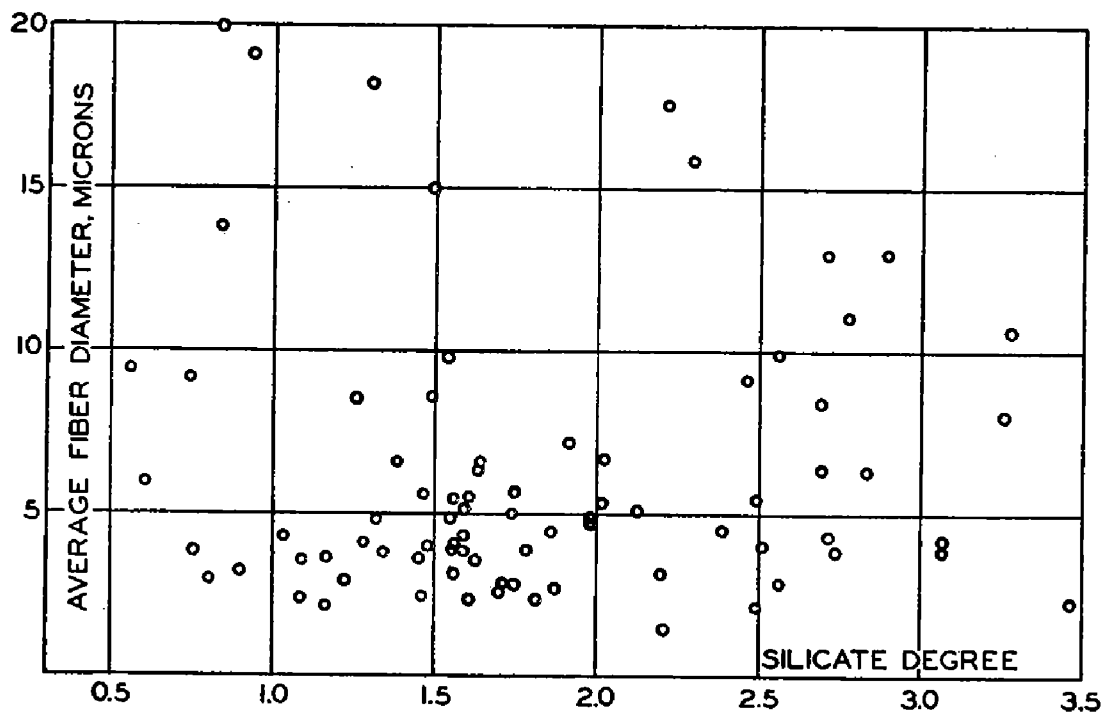


FIG. 19. SILICATE DEGREE AND FIBRE SIZE OF DESCRIBED SAMPLES OF ROCK WOOL.

METALLURGICAL FACTORS OF ROCK WOOL

Mineral composition. When woolrocks are melted to form silicate slags, the quick chilling occasioned by blowing makes the products appear glassy and possibly represent solid solutions.

TABLE IV.

SILICATE DEGREES OF EXPERIMENTALLY PRODUCED ROCK WOOLS

Sample No.	Degree	Sample No.	Degree	Sample No.	Degree	Sample No.	Degree
1	2.702	21	1.627	41	1.905	61	3.011
2	1.377	22	1.327	42	0.804*	62	1.608
3	1.719	23	2.553	43	2.060*	63	1.416
4	1.282	24	1.877	44	1.542	64	1.697
5	1.582*	25	0.611	45	1.997	65	2.683
6	0.747	26	0.836	46	1.219	66	2.672
7	1.165*	27	0.571	47	2.685*	67	2.283
8	1.390	28	0.849	48	1.621	68	1.607
9	2.128	29	1.297	49	1.475	69	1.468
10	1.141	30	1.248	50	2.388*	70	1.745*
11	3.256*	31	1.538	51	1.491	71	1.706*
12	3.077*	32	1.098*	52	1.612	72	0.927*
13	1.970	33	1.334*	53	1.452	73	0.815
14	2.489	34	1.038	54	0.7905	74	2.738
15	2.205	35	1.665	55	1.081	75	2.213
16	1.818	36	1.553	56	2.769	76	1.811*
17	3.461	37	1.592*	57	2.456	77	3.276
18	1.543	38	1.861	58	2.218	78	2.514
19	2.213	39	3.071*	59	2.902	79	1.625
20	1.732	40	2.828	60	1.481	80	2.595

* In some cases where the Fe_2O_3 content is high, reduction to metallic iron sometimes takes place during fusion, hence the value given for the silicate degree may be in error.

If cooled slowly, however, the slags would show crystalline aggregates from which the mineral composition could be determined by microscopic examination and other observations. An examination of the literature on the subject shows that nearly all of the minerals formed are either monosilicates or bisilicates and that slags of intermediate or greater silicate degrees are mixtures of those minerals in an amorphous solution of the excess constituent compounds. Silicates of 3 or greater degree do not seem to form any crystalline minerals.

To avoid brittleness, irregular fibers, and lack of stability occasioned by crystal growth, rock wool should have a non-crystalline, glassy structure. It may be that such structure is obtained regardless of the mineral compositions, because of the fast cooling of the fibers when formed at the blowing jet, but several considerations make that supposition questionable. During this investigation it was found that a majority of the better grade wools were formed from slags near the 1.5 and 2.5 silicate degree points as shown by the sample descriptions and Figure 19.

These samples were all obtained from rocks occurring naturally and the irregular variations of compositions of such rocks make it difficult to obtain accurate comparative measurements and other exact data. A study of accurately proportioned synthetic mixtures might afford such data if the materials were well mixed and ground to nearly colloidal size.

It has been shown by Hofman and Mostowitsch[12] and others that the mineral-formation temperatures of silicate slags are lower than the temperatures at which the formed minerals melt. This phenomenon is apparent in the manufacture of portland cement clinker and vitrified clay products. The author suggests that it is probable that the different mineral-forming groups of components are segregated to an appreciable extent in rock wool slags and that, under proper conditions of silicate degree, crystalline minerals are formed in the wool fibers to an extent that affects the quality and stability of the product. If this supposition is correct it would evidently be advisable for a manufacturer to use woolrock of the intermediate or higher silicate degrees.

Melting points. In general, with the number and proportion of bases to each other being constant, a mineral mixture becomes more infusible with increased silicate degree although certain bisilicates and trisilicates are exceptions to this rule. It is also known that a silicate of several bases is more readily fusible than one of few bases. The composition of the bases also has an important effect as Al_2O_3, CaO, and MgO form difficultly fusible silicates and FeO and MnO give comparatively readily fusible silicates. Na_2O and K_2O give very easily fusible silicates and their inclusion with other bases appreciably increases the fusibility of the mixture. When all, or a majority, of these different bases are mixed and go into solution, the melting point of the resulting homogeneous mass is lowered. Such mixtures can be considered similar to metallic alloys in which eutectic mixtures of two or more constituents have lower melting points than any of the individual compounds. The desirability of multiple base woolrock for low melting points is demonstrated by many of the samples described in this report.

12. Transactions A. I. M. E., 1903, vol. XXXIX, 628.

Viscosity of slags. Silicates of a single base of Al_2O_3 or CaO cannot be used for the manufacture of rockwool; the melting temperatures are too high for commercial installations and, if a slag could be obtained, the viscosity would be too high for the formation of fibers. A number of samples of such mono-base rock were tested and rejected during this investigation.

Calcium-magnesium silicates can be used for woolrock if in the lower silicate degrees. Above the degree of 2.0 they become too viscous to form fibers. Siliceous dolomites with the approximate ratios of 1 MgO: 1.5 CaO: 3 SiO_2 produced good rock wool at pouring temperatures of 1410° to 1450° C.

Alumina tends to increase the viscosity of slags and, when not controlled by the presence of remedial bases, will prevent the formation of satisfactory wool fibers, especially in slags of high silicate degree.

Iron and manganese produce very liquid silicates and their presence in a mixture often permits the production of wool which would be impossible with the other constituents alone. The inclusion of these bases in a woolrock generally indicates a slag of high silicate degree. Samples including such mixtures produced satisfactory wools with silica contents up to 3.5 degrees. Iron or manganese slags of low silicate degree were found to be too fluid to produce rock wool. Very few if any fibers were formed and the charge blew entirely into fine shot.

Summary

More detailed metallurgical studies of woolrock would undoubtedly disclose many facts of interest and value to the rockwool industry, especially in the simplification of exact plant and product control.[4]

The results of this investigation tend to show:

(1) Multiple base wool rocks should be more satisfactorily and economically processed than those with few bases.

(2) Accurate control of silicate degree in relation to the characteristics of the various bases should permit the predeter-

mination of required temperatures and the accurate control of fiber size and other characteristics.

(3) Bases often considered impurities, such as FeO, MnO, Na_2O and K_2O may often be advantageously included in a mixture without deleterious results to the finished rock wool.

ECONOMIC FACTORS

In general, the ultimate success of a commercial rock wool industry depends upon the production and delivery of desirable rock wool to the market at a cost lower than materials coming from competing districts and below a price that will turn the customer to a competing product made from other materials. The insulation market is highly competitive and every item of production cost, including the assembly of the raw materials, their processing, and the transportation and distribution costs must be carefully scrutinized and calculated. Plant sites must be selected that will enable the manufacturer to deliver the product to an adequate consuming area at the lowest aggregate cost.

An analysis of the economic possibilities of rock wool manufacture in Oklahoma must, therefore, encompass a study of markets, of transportation facilities, and of the conditions of production in each area or group of areas in which favorable deposits are known to exist.

Oklahoma is peculiarly well suited for the development of a rock wool industry. Climatic conditions and types of industry common to the Southwest make that area an important potential market for insulation materials. The state is well located geographically with reference to this large southwestern market and adequate transportation facilities are available. Fuel is cheap and abundant, and the wide distribution of large deposits of natural woolrock offers a wide choice of plant locations.

Function of Insulating Materials

The function of insulating materials may be described as the reduction of undesired heat transfers. It is of greatest significance in the escape of heat from buildings, heating plants, boilers, etc., but is also of importance in preventing the entry of solar heat into buildings and dwellings. Rock wool has a multitude of uses in industrial processes, in manufactured articles, and in construction. New uses for the material are being devised constantly, so the following compilation is merely suggestive:

AS HEAT INSULATION FOR:

a. Pipes: To prevent freezing of house and underground pipes, and to prevent loss of heat from pipes carrying steam, molten sulphur, hot oil, etc.

b. Ovens; furnaces, and stoves, including steam boilers, fractionating columns, towers, annealing, baking, and enameling ovens, retorts, metallurgical and chemical furnaces.

c. Refrigerators, ice boxes, water coolers, and refrigerator cars.

d. Building walls, floors, and ceilings in the form of granulated wool, rock wool blankets, rock cork, and rock felt.

e. Storage tanks for oil, gasoline, etc.

FOR SOUND CONTROL:

Acoustic tiles, mats placed under carpets, in walls, and in partitions. It has been extensively used for insulating broadcasting studios.

MISCELLANEOUS:

Packing for acid carboys, filter medium for corrosive fluids, air filter in hot-air heating, as a component of insulating cement, for prevention of entrance of vermin, fire prevention, constituent of polishing wheels, lining between planking and metal sheathing of ships, printers' blankets, etc.

Building Insulation

The purpose of house and building insulation is to reduce the escape of heat from the interior during the cold seasons and the entry of heat in the summer season. Consequently its market outlet possibilities extend over the entire country. The economic justification of building insulation is a saving in the annual fuel bill as well as an increase in the comfort of the home. The value of insulation in effecting fuel savings is indicated by data compiled by the U. S. Bureau of Standards:

	Fuel Savings (%)
No insulation, weather stripped	15-20
Same, double windows	25-30
(a) ½ inch insulation, not weather stripped	20-30
(b) ½ inch insulation, weather stripped	40
(c) ½ inch insulation, with double window	50
(d) 1 inch insulation, not weather stripped	30-40
(e) 1 inch insulation, weather stripped	50
(f) 1 inch insulation, with double window	60

Effective heat conservation is a result of both good construction and proper use of insulating materials. The avenues of heat escape are many and varied and each must be closed by use of the proper method or material. The principal avenue of heat escape is through the ceiling of the upper rooms and the roof. Second in importance is the dissipation of heat through windows, both by reason of the high radiating properties of glass and very frequently, by reason of ill-fitting window frames. These two avenues probably account for most of the unnecessary heat losses.

Insulation of a house, therefore, to be effective must not be confined to the selection and installation of insulating materials in the walls, ceilings, and roof, but must also include care in the construction of all parts of the house, and in the reduction of radiation from windows. If this is not done, the effect of installing insulating materials in the frame of the house may be nullified by the escape or entrance of heat due to poor construction.

Market for Insulating Material in the Dwelling House Field

The insulation of dwelling houses is becoming more prevalent as the economic value and comfort of heat conservation and air conditioning is becoming more widely recognized. The potential demand for rock wool in the housing field is somewhat difficult to estimate quantitatively due to the complex nature of the market. Insulation in new construction is generally accepted and this market may be expected to grow in proportion to the rate of revival of house construction. Existing structures can be improved by insulation and probably will offer the more immediate market outlet. The extent of this market cannot, however, be estimated by a mere count of the number of existing structures. Market possibilities naturally vary with the value of the house, whether it is occupied by the owner or is tenanted, and whether it is urban or rural. Moreover, market areas differ in potentialities because of the unequal distribution of population and concentration in large urban centers. For purposes of analysis, the southwestern house insulation market is divided into states, within each of which the number of dwellings, classified according to value, whether owned or rented, is shown in tables V and VI.

TABLE V.

TENURE OF FARM AND NON-FARM HOMES IN THE SOUTHWEST—1930

State	Owned	Rented	Unknown	Total
Arkansas	168,767	251,897	17,975	438,639
Colorado	131,571	127,979	7,774	267,324
Kansas	267,115	210,106	9,967	487,188
Louisiana	165,791	307,273	12,359	485,363
Missouri	459,810	461,203	18,463	939,476
New Mexico	54,439	40,428	3,679	98,546
Oklahoma	225,266	320,555	18,343	564,164
Texas	557,686	779,269	43,141	1,380,096
TOTALS	2,030,385	2,498,710	131,701	4,660,796

TABLE VI.

NUMBER AND VALUE OF NON-FARM HOMES IN THE SOUTHWEST—1930

State	Under $3000	$3000-$4999	$5000-$7499	$7500 $9999	$10,000-$14,999	$15,000-& over	Not reported
Arkansas	50,220	14,617	7,834	2,253	2,127	1,364	3,239
Colorado	44,741	24,275	15,746	4,382	3,221	2,195	1,992
Kansas	93,480	45,175	22,892	5,259	3,777	2,027	4,014
Louisiana	57,746	19,336	15,069	5,895	5,788	4,829	2,408
Missouri	110,902	68,660	57,328	22,992	19,836	14,178	6,197
New Mexico	22,285	3,750	2,370	562	542	374	833
Oklahoma	83,186	30,841	17,435	5,246	4,819	4,154	3,802
Texas	181,983	87,255	51,849	15,379	14,492	12,804	10,993
TOTALS	644,543	293,909	190,523	61,968	54,602	41,895	33,478

The values given are those gathered by the Bureau of the Census and represent home values as of April 1, 1930. They can be used as a guide in estimating the percentage of total number of houses that are potential markets for rock wool. Obviously, houses valued at less than $1500 do not warrant substantial expenditures for improvements, and would be poor prospects for insulation. Probably extensive remodeling would be necessary if insulating materials were to be of any value in preventing heat entrance or escape. This group may also include a high proportion of old houses whose economic life is nearly spent. These facts may also apply to some extent to houses in the next higher valuation group, i. e., $2,000 to $2,999.

In the non-farm group of houses occupied by tenants, the market for insulation is probably less promising than in homes occupied by the owner. The incentive to improve a rental building becomes effective only if a higher rental results from it, and until evidence of such returns becomes apparent, it is unlikely that many landlords will undertake to improve their properties in this manner.

Freight Rates

The principle variable in the cost of delivering the manufactured product to the market is the freight rate. The relations of the freight rate structure to the delivered cost of rock wool products is complicated because of the differences in size of potential markets within reach of the producing plant, and the possibility of using rail, truck, and possibly water transportation, or a combination of these services. The various freight rate combinations should be determined to each of several important market areas as a preliminary step to evaluation of total cost items. With this in mind, freight rates from Oklahoma City to the various markets have been compiled and are included in Appendix IV.

Market Survey of Rock Wool in the Southwest[13]

In making a test rock wool market survey, the Industrial Division of the Oklahoma City Chamber of Commerce sent a letter, including the following excerpts, to 192 lumber companies operating 2110 line yards throughout the Southwest:

> There is under consideration, the erection of a plant to manufacture rock wool in Oklahoma City, and we have been requested to make a market survey to determine

13. The author is indebted to Mr. Ernest L. Little, manager, Industrial Division of the Oklahoma City Chamber of Commerce, for much of the material contained in this chapter.

the potential market throughout the Southwest.

The total amount of rock wool marketed in the Southwest is required in order to determine what production facilities should be provided, taking in consideration competitive products.

We are therefore taking the liberty of inquiring if you will kindly advise us the total amount, in quantity, of rock wool that your company merchandises annually, or an estimated amount of the actual requirements in your markets.

The summary of the replies is tabulated herewith:

TABLE VII

Reply No.	Location	No. Line Yards	Amt. Per Year
1	Ashland, Arkansas	12	None
2	Fort Smith, Arkansas	7	Small amount[1]
3	Independence, Arkansas	13	5,000 feet
4	Jonesboro, Arkansas	24	Small amount[2]
5	Prescott, Arkansas	4	Small amount[3]
6	West Memphis, Arkansas	3	80 tons
7	Coffeyville, Kansas	7	½ car
8	Downs, Kansas	31	Small amount[4]
9	El Dorado, Kansas	7	Small amount
10	Everest, Kansas	6	500 sq. yds.[5]
11	Garden City, Kansas	3	None
12	Harveyville, Kansas	5	Small amount[6]
13	Haven, Kansas	3	None
14	Hiawatha, Kansas	4	Small amount[7]
15	Hutchinson, Kansas	3	None
16	Leavenworth, Kansas	14	30 tons
17	Manhattan, Kansas	12	45,000 sq. ft.[8]
18	Mankato, Kansas	15	None
19	Marion, Kansas	3	None[9]
20	McPherson, Kansas	5	None
21	Norton, Kansas	3	None
22	Olathe, Kansas	14	10,000 sq. ft.[10]
23	Ottawa, Kansas	3	20,000 ft.
24	Sterling, Kansas	6	1 car[11]
25	Waterville, Kansas	6	Small amount[12]
26	Wichita, Kansas	7	Small amount[13]
27	Wichita, Kansas	16	Small amount[14]
28	Wichita, Kansas	18	None
29	Wichita, Kansas	26	6 carloads[15]
30	Wichita, Kansas	11	None
31	Wichita, Kansas	14	None
32	Wichita, Kansas	10	Small amount
33	Minneapolis, Minnesota	123	10 cars
34	Cabool, Missouri	3	Small amount
35	Cape Girardeau, Mo.	3	15,000 sq. ft.
36	Ferguson, Missouri	12	12 tons[16]
37	Forest City, Missouri	5	3,000 sq. ft.
38	Jefferson City, Mo.	3	Small amount[17]
39	Kansas City, Missouri	17	Large amount[18]
40	Kansas City, Missouri	10	1 car[19]
41	Kansas City, Missouri	4	None

Reply No.	Location	No. Line Yards	Amt. Per Year
42	Kansas City, Missouri	43	1 car[20]
43	Kansas City, Missouri	14	200,000 sq. ft.[21]
44	Kansas City, Missouri	9	None
45	Kansas City, Missouri	10	Small amount
46	Kansas City, Missouri	4	Small amount
47	Kansas City, Missouri	26	30 ft.[22]
48	Kansas City, Missouri	6	Small amount[23]
49	Kansas City, Missouri	11	Small amount
50	Kansas City, Missouri	64	Small amount
51	Perryville, Missouri	3	Small amount
52	Salem, Missouri	3	20,000 sq. ft.[24]
53	St. Charles, Missouri	3	3 cars[25]
54	St. James, Missouri	5	5,000 sq. ft.[26]
55	St. Louis, Missouri	6	6 cars[27]
56	St. Louis, Missouri	3	4 cars[28]
57	St. Louis, Missouri	20	2 cars
58	St. Louis, Missouri	3	2 carloads[29]
59	St. Louis, Missouri	6	Large buyers[30]
60	Thayer, Missouri	4	None
61	Tipton, Missouri	3	Small amount[31]
62	West Plains, Missouri	4	None
63	Fairbury, Nebraska	8	2 carloads
64	Roswell, New Mexico	10	50,000 sq. ft.[32]
65	Ada, Oklahoma	5	$3,000[33]
66	Alva, Oklahoma	8	2,000 sq. ft.
67	Ardmore, Oklahoma	19	4 cars[34]
68	Ardmore, Oklahoma	6	2 cars
69	Chickasha, Oklahoma	3	Small amount
70	Chickasha, Oklahoma	10	5 cars
71	Elk City, Oklahoma	3	None
72	Muskogee, Oklahoma	3	4 cars[35]
73	Muskogee, Oklahoma	3	9,000 sq. ft.
74	Oklahoma City, Okla.	27	None
75	Oklahoma City, Okla.	8	None
76	Oklahoma City, Okla.	3	Small amount
77	Oklahoma City, Okla.	9	10 cars
78	Oklahoma City, Okla.	19	15,000 Sq. ft.
79	Pawhuska, Oklahoma	3	1 ton[36]
80	Sulphur, Oklahoma	6	None[37]
81	Denison, Texas	11	None[38]
82	Fort Worth, Texas	17	None
83	Fort Worth, Texas	5	None[39]
84	Gainesville, Texas	32	No infor.
85	Houston, Texas	23	Small amount[40]
86	Waco, Texas	27	Small amount[41]
87	Waco, Texas	92	Small amount[42]

COMMENTS

1. Fort Smith, Arkansas:—"We have handled but very little rock wool. What we have on hand cost us more money than a product that was put on the market later than we purchased ours. Due to the fact that there have been so many applicators handling this product, we have not decided fully to push the same, in this territory. We realize there is quite a bit of this product being sold and, no doubt, if

the product proves satisfactory there will be considerable used in this territory."

2. Jonesboro, Arkansas:—Our sales on rock wool in the past have amounted to practically nothing. Most of our residential construction for the past two or three years have been on F. H. A. Title Two Loans, and the average cost per residence has been about $3,000.00. Houses of this type and cost do not permit the installation of rockwool or other similar insulation. Rock wool is a commodity that none of our local Yards have pushed, but as people become more educated in building more comfortable homes, we expect to do a nice volume of business on this item.
3. Prescott, Arkansas:—We wish to advise that we sell very little of this item which is possibly due to the present cost. So if the item can be produced at a lower cost, it is likely that sale of rock wool in our territory will increase. We have no figures available that we might give you on the estimated or actual requirements in our markets, however, we do believe that there is a tendency to use more insulation and with some contacts with the specifying architects and engineers and with a reasonable price, we think a demand may be created.
4. Downs, Kansas:—"We have sold some of this material but not any large amounts. We would be pleased to have your prices and if something comes up in the future would be glad to take it up with you."
5. Everest, Kansas:—"We have merchandised about 500 square yards and we think that it will be only a short time before it will be used in all of the better houses built just the same as sash and weather strips are used now."
6. Harveyville, Kansas:—"Our lumber yards are in small towns and have not used very much rock wool. But there is lots of talk of using rock wool when new homes are built."
7. Hiawatha, Kansas:—"Four houses here last year."
8. Manhattan, Kansas:—"Total sales in 1937 amounted to forty-five thousand square feet. Last season was our first in the merchandising of this product and we should show considerable gain this year."
9. Marion, Kansas: "Have never sold rock wool here. We see some peddlers come along with loads of it taking contracts direct."

10. Olathe, Kansas:—"We might say that while rock wool has been liberally used in the larger cities and industrial centers, its uses in the rural districts where we operate have been rather limited. Again we might say that operating in a strictly agricultural district which has suffered six or seven years of continued drouth and short crops, any information we would give you would hardly represent the consumption under normal conditions. All new construction, even in suburban districts, are using insulation, the type of which depends largely on the individual owner. In the past we have used about ten thousand square feet annually and are sure that there will be an increased consumption."

11. Sterling, Kansas:—"Insulation has been sold to the public, but it takes time for the public to prepare itself to use insulation. The financial question is, of course, the important one. If rock wool is to be sold it must have a financing program in advance of selling.

    Our outlets in the territory that we cover are approximately a carload a year."

12. Waterville, Kansas:—"There is without a doubt quite a potential market for insulation all through this section, but to date, very little insulating has been done, which I think in a large measure is due to the fact that the average lumber yard manager is very slow in taking hold of the proposition. At the present time, I would say, and I think that you will agree with me, that insulation is pretty much a specialty item, insofar as the small town is concerned; and while there is a possibility of a pretty good outlet for this product, it is going to require some considerable effort by the jobbers to get the average small town manager interested; and until this is done, the consumption of rock wool in the small communities is going to be rather limited."

13. Wichita, Kansas:—"We do not stock rock wool—have had very few calls for this product, and have sold a very small amount during the past two years. We sell quite a lot of insulation board which is made from cane fiber or wood fiber, but frankly speaking, we have not been able to do much with rock wool."

14. Wichita, Kansas:—"This is to advise you that we do not sell any quantity of rockwool insulation.

There are several insulation companies located in Wichita who sell this material direct, and the quantity which we handle would not amount to enough to take into consideration.''

15. Wichita, Kansas:—''For the year of 1937 we marketed approximately 6 carloads. The principal part of this was used in the territory tributary to Wichita. We used small quantities at Shawnee and Tulsa but these were all shipped out of Wichita.

    Our sales were made through the lumber dealers exclusively. We are of the opinion our volume represented a small amount of the total as the companies manufacturing this class of insulation have been very active in our territory.

16. Ferguson, Missouri:—''Making a broad guess, we might buy ten or twelve tons of rock wool in the course of a year.''

17. Jefferson City, Missouri: — ''We did handle some rock wool, but quit handling it. We do know, however, that a number of the other dealers here are selling rock wool.''

18. Kansas City, Missouri:—''We regret to advise you that the amount of rock wool sold in our Oklahoma yards is practically nil. However, we do sell a considerable quantity at some of our Missouri points.''

19. Kansas City, Missouri:—''We operate yards in the country and as yet the market for this product has not developed to any great extent. We have, however, the past three or four years sold about a carload each year of rock wool.''

20. Kansas City, Missouri:—''We serve Kansas, Missouri and Nebraska. During 1937 we purchased approximately one carload of rock wool Bats.''

21. Kansas City, Missouri:—''We sell 200,000 square feet of 4-inch rock wool Bats annually.''

22. Kansas City, Missouri:—''We sold 30,000 feet in 1937. No doubt lower cost would help a greater distribution.''

23. Kansas City, Missouri:—''Our rockwool sales have been comparatively small. We believe this insulation business is merely in its infancy and we definitely intend to work this type of business.''

24. Salem, Missouri:—''We sell a great deal of insulating material but rock wool is not sold as extensively

as Balsam wool, etc. Last year we sold in Salem probably 20,000 feet of rock wool. As to its possibilities here, there is no limit."

25. St. Charles, Missouri:—"Our requirements of rock wool for the past two years has been approximately two carloads of the bat type and one-fourth carload of the loose type packed in bags."
26. St. James, Missouri:—"Five yards use 5,000 square feet, should sell 50,000 sq. ft."
27. St. Louis, Missouri:—"We do not imagine that our total amount for both Bats and loose wool would run over a half dozen cars for the year of 1937. We should be moving a car or two a month."
28. St. Louis, Missouri:—"We sell about four carloads of rock wool per year. Our sales on this product are a small percentage of the total that is sold in this market."
29. St. Louis, Missouri:—"We purchased several cars of rock wool insulation annually and from all appearances our purchases should somewhat increase this year. We cannot estimate the actual requirements in this market."
30. St. Louis, Missouri:—"We do not make the information public that you ask, but we are handling the commodity right along and are reckoned as pretty large buyers of it."
31. Tipton, Missouri:—"There has been very little rock wool sold in our town and locality, in fact only one job was enough to amount to anything, but there is more talk and more people are becoming insulation-minded all the time and I do think that with the return of normal times and with the building revival that is expected to follow that there will be more insulation used in all new buildings than ever before."
32. Roswell, New Mexico:—"Our sales of the product was equal to about 50,000 feet last year. We do not handle the blow type and some two carloads of this kind were also used in this territory."
33. Ada, Oklahoma:—"Our records for 1937 show we merchandised $3,000.00 in rock wool, and the prospects are for a much larger sale of this merchandise for this year. Assuring you we would be interested in seeing a plant for the manufacture of rock wool erected in Oklahoma City, we are."

34. Ardmore, Oklahoma:—"The use of this product we feel is just really getting started. We believe that the town of Ardmore and its territory used possibly four cars of this material last year, however, its use is becoming more general. We believe that the cost of manufacture will be worked down and once the general public becomes conversant with its splendid qualities that Ardmore and surrounding territory will be good for easily double this amount each year. You understand that this is only an estimate on our part."

35. Muskogee, Oklahoma:—"Will say that we are very much sold on the idea of rock wool for insulation and we think that the public is becoming very interested in this product. We disposed of four cars last year but think the potential sale of this commodity is very large."

36. Pawhuska, Oklahoma:—"We did not go in for this item very strong last year. The sales that were made in Pawhuska were largely by Tulsa and Wichita specialists. Our purchases last year were 1 ton, sales made by out of town firms would be from 5 to 8 ton."

37. Sulphur, Oklahoma:—"We have never handled this product at all but recently some 8 or 10 homes have been insulated we understand here in town. We believe that insulation is going to be a factor in home building even in the smaller places, however, up to this time we have never handled any of this product."

38. Denison, Texas:—"We beg to advise that most of our branch yards are located in small towns where there is no market for rock wool. There has been some of this material used in Denison and Sherman, Texas. However, we are not in a position to furnish you with information relative to the quantities that have been used. There is, of course, a potential market for this class of merchandise in the smaller cities throughout the country, but this market will have to be created, and perhaps by reason of a factory near at hand, this market could be cultivated with the result that a large quantity of this material might be used. Very sorry that I can give you no more definite information, but thank you for writing me."

39. Fort Worth, Texas:—"In the past year we have sold no rock wool because the price has been too high,

If rock wool could be made to sell cheap enough, lots of it could be sold. The price has been the only thing that has kept it down in this section of the country."

40. Houston, Texas:—"Our retail branches being located in small towns sell but little rock wool. None of the branches carry the item in stock but order as sold."

41. Waco, Texas:—"We cannot intelligently reply to the above letter. Our yards are all in small towns serving rural sections, and the sale of rock wool with us has been practically nothing to date. We can see a future for it, but it will be slow sale with our yards until further educational data is pushed into rural sections."

42. Waco, Texas:—"This is a hard question to answer, and while the volume in this territory is not so much at the present time we do anticipate a heavy demand inasmuch as the public is certainly becoming insulation conscious and insulation is a necessity in connection with air conditioning."

Summary

The market survey would seem to indicate that a large potential market for rock wool exists in the Southwest, but that prevailing costs and methods of distribution are not entirely attractive to local retail distributors. It should be possible and practical for a local manufacturing industry to furnish rock wool to the trade at a reasonable cost, and to assist distributors and retailers by making it unnecessary for them to stock large quantities of the material. An intensive educational campaign and general assistance and training in problems of application of insulation would undoubtedly speed the growth of the industry.

The oil industry of the southwest offers an especially attractive outlet for large quantities of rock wool if the present cost could be materially reduced. Refineries, pipe lines, and oil storage tank farms could all use advantageously much more rock wool than they are now purchasing. The possible low cost of production in Oklahoma together with lower transportation costs should enable the producer of locally manufactured rock wool to develop these large potential markets.

Appendix I

THERMAL CONDUCTIVITY OF VARIOUS INSULATING MATERIALS[14]

	Density (Lb./) (cu. ft.)	*Conductivity at Mean Temp. of: 20°F	100°F	200°F
Air-Cell, 4 ply per in. (corrugated asbestos)	13.0	0.425	0.516	0.630
Air-Cell, 6 ply per in. (corrugated asbestos)	17.7	0.475	0.536	0.612
Armorack (hair felt)	26.3	0.263	0.317	0.385
Aurora felt (rock wool)	22.9	0.263	0.300	0.344
Careycel (cellular asbestos paper)	17.8	0.324	0.379	0.446
Celotex (sugar cane fiber)	16.9	0.347	0.358	0.373
Cork covering	14.6	0.347	0.389	0.444
Corkboard	10.1	0.291	0.320	0.355
Flaxlinum (flax fiber)	14.3	0.262	0.329	0.413
Glass wool (loose)	1.5	0.260	0.375	0.522
	4.0	0.215	0.287	0.380
	6.0	0.196	0.262	0.346
Hair felt	8.2	0.284	0.323	0.372
	11.4	0.257	0.305	0.359
	12.8	0.280	0.314	0.354
Insulate board (wood pulp)	15.2	0.282	0.317	0.360
Kork-O-Board (peat moss)	14.9	0.315	0.351	0.398
Magnesia, 85%	16.9	0.385	0.413	0.447
Multiply (laminated asbestos paper)	25.5	0.286	0.337	0.400
Sponge felt (laminated asbestos paper)	31.1	0.345	0.385	0.432
Perfecto covering (wool felt)	23.8	0.298	0.327	0.363
Protecto covering (hair felt and wool felt)	16.7	0.244	0.323	0.424
Rocktex wool (loose rock wool)	4.0	0.180	0.269	0.380
	6.0	0.190	0.274	0.380
	8.0	0.205	0.273	0.358
	10.0	0.190	0.255	0.342
	12.0	0.220	0.271	0.337
Rocktex blanket (rock wool felted between wire mesh)	16.6	0.226	0.283	0.356
Rubber board (expanded)	5.7	0.230	0.256	0.289
Seapack board (ceiba pod fiber)	5.9	0.180	0.244	0.321
Weatherwood board (felted wood fiber)	18.1	0.320	0.360	0.409
Weatherwood tile (felted wood fiber)	16.2	0.285	0.337	0.403
Wool felt covering (smooth felt)	23.0	0.330	0.390	0.462

14 Heilman, R. H., "Heat Insulation in Air-Conditioning": *Industrial and Engineering Chemistry*, Industrial Edition, Vol. 28, No. 7, July, 1936, pp. 782-786.

* British thermal units of heat transmitted per hour, through 1 sq. ft. of material 1 inch thick at temperatures shown.

Appendix II

COMPANIES MANUFACTURING ROCK AND SLAG WOOL

MEMBER OF INDUSTRY	HOME OFFICE LOCATION	PLANT LOCATION
Air-O-Cel Industries, Inc.	Stephenson Bldg. Detroit, Michigan	Detroit, Michigan
Alton Mineral Wool Co. C. K. Perrin, Sales Mgr. (St. Louis, Mo.)	P. O. Box 268, Alton, Ill.	Alton, Illinois
American Rock Wool Corp. Michael Luery, President	Wabash, Indiana	Wabash, Indiana
Baldwin-Hill Company W. H. Hill, President	501 Klagg Avenue Trenton, N. J.	Trenton, N. J.
Campoe, Inc. Lee R. Campbell, President	Hazel Park, Michigan	Hazel Park, Michigan
The Philip Carey Co. W. L. Steffens, Vice-Pres.	Lockland, Cincinnati, Ohio	Lockland, Cincinnati, Ohio
The Celotex Co. T. B. Munroe, Vice-Pres.	919 N. Michigan Avenue Chicago, Illinois	(No rock wool plant. Sells such products mfgd. by others)
Clifty Rock Wool Co. M. R. Smith	Portland, Indiana	Portland, Indiana
Coast Insulating Co. C. L. Newport, Sales Mgr.	634 S. Western Avenue Los Angeles, California	Torrance, California
Columbia Mineral Wool Co. E. F. Cusick, Gen. Mgr.	9 South Clinton Street Chicago, Illinois	S. Milwaukee, Wis.
The Eagle-Picher Sales Co. T. C. Carter, Vice-Pres.	Court & Main Streets Cincinnati, Ohio	Joplin, Mo. and Newark, N. J.
Edwards Insulation Company	Temple, Texas	Temple, Texas
Ehret Magnesia Mfg. Co. A. M. Ehret, Jr., Pres.	Valley Forge, Pa.	(No plant)
El Paso Rock Fleece Corp. S. A. Brandon, Vice-Pres.	El Paso, Texas	El Paso, Texas ("Rock Fleece" from slag)
Federal Rock Wool Company	Kansas City, Missouri	(See "*Rock Products*", vol. 41, no. 1, January, 1938.)
Gen. Insulating & Mfg. Co. Charles J. Cella, Pres.	404 Central Nat. Bk. Bldg. Alexandria, Indiana	Alexandria, Indiana
G. & W. H. Corson, Inc. Philip L. Corson, Pres.	Plymouth, Pa.	(Rock wool from limestone)
Insulating Products Co. Mr. McGee, President.	Aurora, Illinois	Aurora, Illinois

MEMBER OF INDUSTRY	HOME OFFICE	PLANT LOCATION
Johns-Manville Sales Corp. P. A. Andrews, Exec. V. P.	22 East 40th Street New York, N. Y.	Alexandria, Indiana, and Waukegan, Ill., and Manville, N. J. — expect to build plant at Watson (near Los Angeles, California)
Kalman Steel Corp. Geo. F. Routh, Vice-Pres.	Bethlehem, Pa.	Bethlehem, Pa.
Keasbey & Mattison Co. Harry Hockrath	Ambler, Pa.	(No plant)
Lagro Rock Wool Corp. C. V. McKinney, Pres.	Lagro, Indiana	Lagro, Indiana
Ludowici-Celadon Co. H. F. Beyer, Vice-Pres.	104 S. Michigan Ave. Chicago, Illinois	New Lexington, Ohio (Plant not yet in operation)
James D. McCarty	Springdale, Pa.	
Marblehead Lime Co.	160 N. LaSalle St. Chicago, Illinois	Marblehead, Ill.
Mineral Felt Co. F. W. Simmons, Pres.	Toledo, Ohio	Distributors
Mineral Insulation Co. Orval White, Pres.	Chicago Ridge, Ill.	Chicago Ridge, Ill. (Plant not yet in operation)
Ohio Insulation Co.	Elbon & Cecilia Sts. Toledo, Ohio	Toledo, Ohio
Owens-Illinois Glass Co. J. S. Irvine, Gen. Sales Mgr.—Newark	Toledo, Ohio	Newark, Ohio
The C. W. Poe Co. C. W. Poe, Pres.	2795 East 83rd St. Cleveland, Ohio	Cleveland, Ohio
Refractory & Engr. Corp. H. N. Clarke, President	381 Fourth Ave. New York, N. Y.	Port Kennedy, Pa.
Riverton Lime Co., Inc. E. I. Williams, Sales Mgr.	Riverton, Virginia	Riverton, Va. (Plant not yet in operation)
Rock Wool Corp. of America	30 W. Washington St. Chicago, Ill.	Distributors
Rock Wool Products Co., Inc. C. H. Latchem, Gen. Mgr.	Wabash, Indiana	Wabash, Indiana
Frederick W. Rowoldt Co.	625 Ill. Ave. Aurora, Illinois	Aurora, Illinois
The Ruberoid Co. W. B. Harris, Vice-Pres.	502 Fifth Avenue New York	Joliet, Illinois
St. Louis Fire Brick Co. J. W. Odell, Sales Mgr.	3050 E. Slauson Avenue Huntington Park, Calif.	Huntington Park, Calif.
Salem Lime & Stone Co. T. M. Cavanaugh, Secy.	Salem, Indiana	Salem, Indiana

MEMBER OF INDUSTRY	HOME OFFICE LOCATION	PLANT LOCATION
Seneca Rock Wool Co. Karl J. Heilmann	c/o Heilmann Bros. Tiffin, Ohio	Tiffin, Ohio
The Standard Lime & Stone Co. F. O. Russell	2004 First Nat'l. Bk. Bldg. Baltimore, Maryland	Millville, West Va.
Standard Rock Wool Inc.	Yorktown, Indiana	Yorktown, Indiana
Tennessee Products Corp. J. C. Carlin	14 Cummins Station Nashville, Tenn.	Rockdale, Tenn.
The Terminaul Corp. of Am. J. C. Wood, Jr., Pres.	1603 Fulford Street Kalamazoo, Mich.	Kalamazoo, Mich.
Thermoproof Insulation Co.	Alton, Illinois	
Union Fibre Co., Inc. W. L. Miller, Vice-Pres.	Winona, Minnesota	Wabash, Indiana
U. S. Gypsum Co. C. F. Henning, Vice-Pres.	300 W. Adams Street Chicago, Ill.	(No plant)
U. S. Mineral Wool Co. E. F. Cusick, Gen. Mgr.	280 Madison Avenue New York, N. Y.	Stanhope, N. J.
Weber Insulations, Inc. Elger Secrict, Mgr.	East Chicago, Ill.	East Chicago, Ill.
Weber Insulation Products Co. F. Elizer, Sales Mgr.	2454 East 52nd St. Los Angeles, Calif.	Los Angeles, Calif.
White Bros. Smelting Corp. C. B. White, Pres.	Bridesburg-on-the-Delaware Philadelphia, Pa.	Philadelphia, Pa.
Zier Products Co. A. T. Shrum	New Albany, Indiana	New Albany, Ind.
Verdigris Valley Vitrified Brick Co.	Neodesha, Kansas	Plant completed Jan. 1938 —use shale & limestone.

Appendix III

LIST OF PATENTS RELATING TO THE MANUFACTURE OF ROCK WOOL*

RECENT PATENTS OF INTEREST

Patent Number	Issued To	Date
1,928,264	E. R. Powell (2)	Sept. 26, 1933
1,948,395	E. R. Powell (2)	Feb. 20, 1934
Re 19,627	E. R. Powell (1)	June 25, 1935
1,656,828	E. R. Powell	Jan. 17, 1928
1,899,056	E. R. Powell (2)	Feb. 20, 1933
1,996,082	E. R. Powell (1)	Apr. 2, 1935
2,055,446	E. R. Powell (1)	Sept. 23, 1936

OTHER RELATED PATENTS:

Patent Number	Issued To	Date
Re 5,950	Johns	June 30, 1874
Re 6,894	Player	Feb. 1, 1876
Re 16,548	Waddell	Feb. 8, 1921
Re 19,302	Gottwald	Sept. 4, 1934
Re 19,919	Bechtner	Apr. 7, 1936
Re 20,029	Fischer	July 7, 1936
77,275	Glanding	Apr. 28, 1868
130,578	Hartman	Aug. 20, 1872
134,628	Bartlett	Jan. 7, 1873
140,184	Chambers	June 24, 1873
149,319	Karcheski	Oct. 6, 1873
180,470	Elbers	Aug. 1, 1876
195,483	Cobb	Aug. 28, 1876
205,199	Merrell	June 25, 1878
218,340	Toope	Aug. 5, 1879
231,662	Fowler	Aug. 31, 1880
231,832	Merriam	August 31, 1880
234,417	Merriam	Nov. 16, 1880
236,198	Weyde	Jan. 4, 1881
248,324	Johns	Oct. 18, 1881
278,046	Rhodes	May 22, 1883
286,922	Hammill	Oct. 16, 1883
299,111	Burns	May 27, 1884
310,957	Muirhead	Jan. 20, 1885
327,810	Merriam	Oct. 6, 1885
328,226	Kennedy et al.	Oct. 13, 1885
328,227	Kennedy et al.	Oct. 13, 1885
332,258	Lamkin	Dec. 15, 1885
340,073	Ainsworth	Apr. 20, 1886
231,832	Merriam	Aug. 31, 1880
349,183	Stewart	Sept. 14, 1886
354,158	Martin	Dec. 14, 1886
366,221	Kelly	July 12, 1887
372,486	Parrott	Nov. 1, 1887
383,599	Suhr	May 29, 1888
397,822	Suhr	Feb. 12, 1889
400,047	Bryan	Mar. 26, 1889
400,756	Deeds	Apr. 2, 1889
402,798	Boardman	May 7, 1889
433,471	Johns	Aug. 5, 1890
436,244	Kennedy	Sept. 9, 1890
438,698	Menuez	Oct. 21, 1890

Patent Number	Issued To	Date
441,163	Johns	Nov. 25, 1890
447,360	Rockwell	Mar. 3, 1891
452,733	Rockwell	May 19, 1891
452,763	Salathe	May 19, 1891
453,115	Hubbell	May 26, 1891
454,548	Sperry	June 23, 1891
460,765	Thomson	Oct. 6, 1891
467,041	Morris	Jan. 12, 1892
483,243	Westphalen	Sept. 27, 1892
490,641	Devey	Jan. 31, 1893
497,382	Martin	May 16, 1893
505,916	Hoffman	Oct. 3, 1893
531,999	Hunleth	Jan. 1, 1895
533,771	Wood	Feb. 5, 1895
548,515	Cabot	Oct. 22, 1895
555,205	Brice	Feb. 25, 1896
568,518	Carmichael	Sept. 29, 1896
588,204	Westman	Aug. 17, 1897
595,168	Crote	Dec. 7, 1897
605,042	Doak	May 31, 1898
629,164	Hurley	July 18, 1898
636,618	Leder	Nov. 14, 1899
651,425	McConnell	June 12, 1900
664,957	Laraway	Jan. 1, 1901
666,807	Just	Jan. 29, 1901
668,684	Kelly	Feb. 26, 1901
672,214	Kelly	Apr. 16, 1901
674,774	Kelly	May 21, 1901
677,109	Yaryan	June 25, 1901
683,208	Kelly	Sept. 24, 1901
688,420	Kelly	Dec. 10, 1901
689,129	Salamon	Dec. 17, 1901
694,859	Hipple	Mar. 4, 1902
696,343	Kelly	Mar. 25, 1902
703,199	Heany	June 24, 1902
703,516	Arnn	July 1, 1902
732,207	Mitchell	June 30, 1903
735,218	DeLong	Aug. 4, 1903
737,099	Hall	Aug. 25, 1903
737,751	Lougee	Sept. 1, 1903
758,243	Goldman	Apr. 26, 1904
758,245	Goldman	Apr. 26, 1904
758,246	Goldman	Apr. 26, 1904
758,247	Goldman	Apr. 26, 1904
785,765	Roevens	Mar. 28, 1905
802,377	Ekert	Oct. 24, 1905
806,608	Whitney et al.	Dec. 5, 1905
811,227	Kelly	Jan. 30, 1906
822,087	Timm	May 29, 1906
829,483	McConnell	Aug. 28, 1906
838,616	Goldman	Dec. 18, 1906
848,422	Wynne	Mar. 26, 1907
871,524	Pulvermann	Nov. 19, 1907

Patent Number	Issued To	Date
884,456	Booth	Apr. 14, 1908
893,707	Colloseus	July 21, 1908
903,878	Mock	Nov. 17, 1908
932,080	Woods	Aug. 24, 1909
959,620	Seigle	May 31, 1910
973,280	Knight	Oct. 18, 1910
980,606	Colloseus	Jan. 3, 1911
982,964	Jantzen	Jan. 31, 1911
1,076,657	Schol	Oct. 21, 1913
1,158,667	Fairchild	Nov. 2, 1915
1,169,079	Lappen (3)	Jan. 18, 1916
1,177,267	Perry	Mar. 28, 1917
1,002,303	Newsome	Sept. 5, 1911
1,008,204	Seghers	Nov. 7, 1911
1,009,630	Barringer	Nov. 21, 1911
1,015,598	Tone	Jan. 23, 1912
1,022,778	Ellis	Apr. 9, 1912
1,047,370	Bergquist	Dec. 17, 1912
1,056,915	Lappen (3)	Mar. 25, 1913
1,105,786	Hohaus (3)	Aug. 4, 1914
1,123,401	Scott	Jan. 5, 1915
1,123,841	Brown	Jan. 5, 1915
1,137,814	Von Pazsiczky	May 4, 1915
1,139,983	Lappen (3)	May 18, 1915
1,151,563	Brown (3)	Aug. 31, 1915
1,156,206	Brown (3)	Oct. 12, 1915
1,163,605	Schol	Dec. 7, 1915
1,175,224	Bleecker	Mar. 14, 1916
1,183,694	Sutter	May 16, 1916
1,190,857	Burgher	July 11, 1916
1,192,661	Marsden	July 25, 1916
1,192,662	Marsden	July 25, 1916
1,206,983	Bliss	Dec. 5, 1916
1,226,779	Lappen (3)	May 22, 1917
1,227,767	Feigen	May 29, 1917
1,228,485	Seigle (1)	June 5, 1917
1,228,609	Schmid	June 5, 1917
1,240,385	Sweetland	Sept. 18, 1917
1,252,468	MacFarland et al.	Jan. 8, 1918
1,256,875	Classen	Feb. 19, 1918
1,297,297	Johnson	Mar. 11, 1919
1,297,480	Lappen	Mar. 18, 1919
1,299,663	Bennett	Apr. 8, 1919
1,326,007	Swanberg	Dec. 23, 1919
1,336,403	Weiss	Apr. 6, 1920
1,338,734	Johnson	May 4, 1920
1,357,920	Abraham	Nov. 2, 1920
1,358,858	Krejci et al.	Nov. 16, 1920
1,374,885	Bathaway	Apr. 12, 1921
1,387,391	Hall	Aug. 9, 1921
1,399,848	Carlson	Dec. 13, 1921
1,400,312	Perry	Dec. 13, 1921
1,404,142	Reidel	Jan. 17, 1922
1,408,760	Mitchell	Mar. 7, 1922
1,421,306	Rawlings	June 27, 1922
1,421,914	Coleman	July 4, 1922
1,426,163	Emrick	Aug. 15, 1922
1,427,014	Von Pazsiczky	Aug. 22, 1922

Patent Number	Issued To	Date
1,440,978	Feigen	Jan. 2, 1923
1,456,687	Berry	May 29, 1923
1,470,723	Gillies	Oct. 16, 1923
1,471,421	Sem	Oct. 23, 1923
1,488,721	Waddell	Apr. 1, 1924
1,499,774	Headson (1)	July 1, 1924
1,499,781	Pilliod (1)	July 1, 1924
1,500,207	Shaw	July 8, 1924
1,503,337	Seigel	July 29, 1924
1,513,088	Charlton	Oct. 28, 1924
1,513,723	Bohlander	Oct. 28, 1924
1,515,653	Bertelson	Nov. 18, 1924
1,542,559	Kopp	June 16, 1925
1,568,415	Pilliod (1)	Jan. 5, 1926
1,577,074	Perry et al.	Mar. 16, 1926
1,580,199	Hering	Apr. 13, 1926
1,584,386	Lindsay	May 11, 1926
1,590,739	Evans	June 29, 1926
1,591,676	Gallinowsky	July 6, 1926
1,599,376	Smith	Sept. 7, 1926
1,611,907	Hall	Dec. 28, 1926
1,613,725	Sabin	Jan. 11, 1927
1,627,982	Maguet	May 10, 1927
1,629,256	Carroll (1)	May 17, 1927
1,636,511	Hering	July 19, 1927
1,637,497	O'Dowd	Aug. 2, 1927
1,646,388	Bullard	Oct. 25, 1927
1,659,240	Clarke	Feb. 14, 1928
1,661,254	Gillies	Mar. 6, 1928
1,668,575	Swanson et al.	May 8, 1928
1,678,345	Mattison	July 24, 1928
1,678,346	Mattison	July 24, 1928
1,678,659	Wallace	July 31, 1928
1,679,251	Lindsay	July 31, 1928
1,687,599	Upson	Oct. 16, 1928
1,691,763	Mottweiler et al.	Nov. 13, 1928
1,694,947	Lindsay	Dec. 11, 1928
1,704,174	Clarke	Mar. 5, 1929
1,710,320	Perry	Apr. 23, 1929
1,713,309	Upson	May 14, 1929
1,734,209	Huffine	Nov. 5, 1929
1,769,181	Jackson	July 1, 1930
1,769,300	Lonergan	July 1, 1930
1,769,301	Lonergan	July 1, 1930
1,769,519	King et al.	July 1, 1930
1,771,216	Gossler	July 22, 1930
1,780,623	Loetscher	Nov. 4, 1930
1,797,443	Powell	Mar. 24, 1931
1,802,543	Upson	Apr. 28, 1931
1,804,254	Friedrich	May 5, 1931
1,807,178	Seil	May 26, 1931
1,822,509	Smith	Sept. 8, 1931
1,822,987	Cooper	Sept. 15, 1931
1,823,405	Mazer	Sept. 15, 1931
1,825,424	Russell et al.	Sept. 29, 1931
1,827,035	Mottweiler et al.	Oct. 13, 1931
1,828,293	Powell (2)	Oct. 20, 1931
1,830,253	Bechtner	Nov. 3, 1931

Patent Number	Issued To	Date
884,456	Booth	Apr. 14, 1908
893,707	Colloseus	July 21, 1908
903,878	Mock	Nov. 17, 1908
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959,620	Seigle	May 31, 1910
973,280	Knight	Oct. 18, 1910
980,606	Colloseus	Jan. 3, 1911
982,964	Jantzen	Jan. 31, 1911
1,076,657	Schol	Oct. 21, 1913
1,158,667	Fairchild	Nov. 2, 1915
1,169,079	Lappen (3)	Jan. 18, 1916
1,177,267	Perry	Mar. 28, 1917
1,002,303	Newsome	Sept. 5, 1911
1,008,204	Seghers	Nov. 7, 1911
1,009,630	Barringer	Nov. 21, 1911
1,015,598	Tone	Jan. 23, 1912
1,022,778	Ellis	Apr. 9, 1912
1,047,370	Bergquist	Dec. 17, 1912
1,056,915	Lappen (3)	Mar. 25, 1913
1,105,786	Hohaus (3)	Aug. 4, 1914
1,123,401	Scott	Jan. 5, 1915
1,123,841	Brown	Jan. 5, 1915
1,137,814	Von Pazsiczky	May 4, 1915
1,139,983	Lappen (3)	May 18, 1915
1,151,563	Brown (3)	Aug. 31, 1915
1,156,206	Brown (3)	Oct. 12, 1915
1,163,605	Schol	Dec. 7, 1915
1,175,224	Bleecker	Mar. 14, 1916
1,183,694	Sutter	May 16, 1916
1,190,857	Burgher	July 11, 1916
1,192,661	Marsden	July 25, 1916
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1,227,767	Feigen	May 29, 1917
1,228,485	Seigle (1)	June 5, 1917
1,228,609	Schmid	June 5, 1917
1,240,385	Sweetland	Sept. 18, 1917
1,252,468	MacFarland et al.	Jan. 8, 1918
1,256,875	Classen	Feb. 19, 1918
1,297,297	Johnson	Mar. 11, 1919
1,297,480	Lappen	Mar. 18, 1919
1,299,663	Bennett	Apr. 8, 1919
1,326,007	Swanberg	Dec. 23, 1919
1,336,403	Weiss	Apr. 6, 1920
1,338,734	Johnson	May 4, 1920
1,357,920	Abraham	Nov. 2, 1920
1,358,858	Krejci et al.	Nov. 16, 1920
1,374,885	Bathaway	Apr. 12, 1921
1,387,391	Hall	Aug. 9, 1921
1,399,848	Carlson	Dec. 13, 1921
1,400,312	Perry	Dec. 13, 1921
1,404,142	Reidel	Jan. 17, 1922
1,408,760	Mitchell	Mar. 7, 1922
1,421,306	Rawlings	June 27, 1922
1,421,914	Coleman	July 4, 1922
1,426,163	Emrick	Aug. 15, 1922
1,427,014	Von Pazsiczky	Aug. 22, 1922
1,440,978	Feigen	Jan. 2, 1923
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1,471,421	Sem	Oct. 23, 1923
1,488,721	Waddell	Apr. 1, 1924
1,499,774	Headson (1)	July 1, 1924
1,499,781	Pilliod (1)	July 1, 1924
1,500,207	Shaw	July 8, 1924
1,503,337	Seigel	July 29, 1924
1,513,088	Charlton	Oct. 28, 1924
1,513,723	Bohlander	Oct. 28, 1924
1,515,653	Bertelson	Nov. 18, 1924
1,542,559	Kopp	June 16, 1925
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1,590,739	Evans	June 29, 1926
1,591,676	Gallinowsky	July 6, 1926
1,599,376	Smith	Sept. 7, 1926
1,611,907	Hall	Dec. 28, 1926
1,613,725	Sabin	Jan. 11, 1927
1,627,982	Maguet	May 10, 1927
1,629,256	Carroll (1)	May 17, 1927
1,636,511	Hering	July 19, 1927
1,637,497	O'Dowd	Aug. 2, 1927
1,646,388	Bullard	Oct. 25, 1927
1,659,240	Clarke	Feb. 14, 1928
1,661,254	Gillies	Mar. 6, 1928
1,668,575	Swanson et al.	May 8, 1928
1,678,345	Mattison	July 24, 1928
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* The majority of these patents are either expired or are of small interest at the present time.

(1) Indicates the Johns-Manville Co., Assignees.
(2) Indicates the Banner Rock Co., Assignees.
(3) Indicates the Union Fibre Co., Assignees.

Appendix IV*

Freight rates from Oklahoma City on rock or mineral wool, 24,000 lb. Minimum carload, to:

STATE	CITY	RATE PER 100 LBS.
Oklahoma	Tulsa	$ 0.26
	Ardmore	0.25
	Woodward	0.32
Texas	Dallas	0.35
	Houston	0.52
	San Antonio	0.52
	Corpus Christi	0.59
	El Paso	0.72
Louisiana	Shreveport	0.46
	New Orleans	0.65
Arkansas	Little Rock	0.45
Tennessee	Memphis	0.53
Mississippi	Jackson	0.64
Missouri	Kansas City	0.44
	St. Louis	0.54
Kansas	Wichita	0.31
	Topeka	0.40
Nebraska	Omaha	0.52
	Grand Island	0.50
Colorado	Pueblo	0.81
	Denver	0.92
	Grand Junction	1.51
New Mexico	Albuquerque	0.67
Wyoming	Casper	0.80

Freight rates to Oklahoma City, Oklahoma, on rock or mineral wool, 24,000 lb. Min. carload, from:

STATE	CITY	RATE PER 100 LBS.
Illinois	Joliet	$ 0.65
	Waukegan	0.65
	Aurora	0.65
Indiana	Wabash	0.71
	Alexandria	0.67
	Lagro	0.71
Michigan	Kalamazoo	0.76
	Detroit	0.76
Ohio	Cleveland	0.76
	Newark	0.76
	Toledo	0.76
Wisconsin	South Milwaukee	0.65
New York	Corning	0.90
Tennessee	Rockdale	0.65
New Jersey	Newark	0.95
Pennsylvania	Bethlehem	0.94
Texas	El Paso	0.72
Utah	Midvale	1.54
	min. wt. 24,000 lbs.	1.38
	min. wt. 30,000 lbs. Bats:	1.39
California	Los Angeles	1.52
Oklahoma	Ninnekah Loose in bags	0.18

Freight rate per ton of raw woolrock to Oklahoma City, carload lots, from:

Ninnekah, Grady County	$ 0.69
Guymon, Texas County	1.65

* These freight rates are included here for comparative purposes only, as they are subject to frequent change.

Appendix V

PRELIMINARY GAS FURNACE DESIGN DATA

The following design data were based on an analysis of siliceous limestone in the range suitable for making rock wool, containing 9.64 per cent free moisture. The amount of free moisture is believed to be liberal for any ordinary stone, and the calculations provide for driving off this amount of moisture.

MATERIAL: Woolrock

Weight: 16 cu. ft. per ton or 125 lbs. per cu. ft.

ANALYSIS:

Free H_2O	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	$CaCo_3$	$MgCo_3$	Comb. H_2O	Excess CaO	Total
9.64	34.68	1.81	1.14	0	40.80	8.47	1.82	1.64	100.00

One ton of this woolrock (2000 lbs.) will contain:

Moisture	192.80 lbs.)	229.20 lbs.
Combined water	36.40)	
SiO_2	693.60	
Al_2O_3	36.20	
Fe_2O_3	22.80	
$CaCo_3$	816.00	
$MgCO_3$	169.40	
Excess CaO	32.80	1770.80
		2000.00 lbs.

Solids, excepting $CaCO_3$ and $MgCO_3$, with Specific Heats figured for the mixture:

			Sp. Ht. at 1600 deg. F.	(pro-rate)
SiO_2	693.60 lbs.	88.4%	0.25	0.225
Al_2O_3	36.20	4.6	0.28	0.013
Fe_2O_3	22.80	2.9	0.31	0.009
Excess CO	32.80	4.2	0.23	0.01
	784.40	100.1%	Sp. Ht. mixture	0.257

Calcining the woolrock produces the following solids:

			Sp. Ht. at 3000 deg. F.	(pro-rate)
SiO_2	693.60 lbs.	52.6%	0.31	0.163
Al_2O_3	36.20	2.8	0.35	0.098
Fe	15.95	1.2	0.46	0.055
CaO	489.76	37.1	0.28	0.075
MgO	80.64	6.1	0.35	0.027
	1316.15	99.8%	Sp. Ht. mixture	0.418

or 65.8% of the raw material.

Also the following gases are evolved:

Water vapor	229.20 lbs.	6200 cu. ft.
Oxygen	6.85	76 " "
CO_2	447.80	1863 " "
	683.85	8139 " "

Giving:

Solids	1316.15
Gases	683.85
Total	2000.00 lbs. (one ton)

FUEL: Natural gas.

For fuel, using an average natural gas:

H_2	4.5%	0.000252 lb.
CH_4	83.0	0.037051
C_2H_6	12.0	0.0096
N	0.5	0.000391
	100.00	0.047294 lb. per cu. ft.

This gives 21 cu. ft. to one pound of gas.

Its constituents as follows:

		Hydrogen	Carbon	Nitrogen
H_2	0.000252	0.000252		
CH_4	0.037051	0.009331	0.02772	
C_2H_6	0.0096	0.002	0.0076	
N	0.000391			0.000391
	0.047294	0.011583	0.03532	0.000391
	100%	24.5%	74.9%	0.6%

The calculated heat value of this gas will be, per cu. ft.:

H_2 to H_2O (steam, 212 deg.)	51700 x 0.0116	599.72	BTU
C to CO_2	14600 x 0.0354	516.84	"
N (small quantity)		....	
	Gross heat	1116.56	BTU

The air for burning this fuel will be, per cu. ft. of gas:

C to CO_2	Oxygen	—0.094 lb.
H_2 to H_2O	"	—0.093
		0.187
	Nitrogen	0.620
	Air	0.807 lb.

To this air we will add for atmospheric moisture 0.21 cu. ft. H_2O
and for excess air for combustion, 5% 0.50 " " air.

0.71

Total 10.71 cu. ft. of air per cu. ft. of gas, divided as follows:

H_2O	0.22 cu. ft.	0.017 lbs.
O	2.20	0.1958
N	8.29	0.6466
	10.71 cu. ft.	0.8594 lbs.

The moisture in the air will lower the fuel value of the gas:

To convert H_2O to steam, 0.017 x 1100	18.7	BTU
To raise this to flame temperature, 4200 deg. minus 212 gives 0.017 x 3988 x 1 sp. ht.	67.79	
To raise excess air to flame temperature, 4200 minus 60 gives 0.041 x 4140 x 0.31 sp. ht.	52.62	
	139.11	BTU

Then practical fuel value of gas is, 1117 minus 139, or 978 BTU

The products of combustion will be, per lb. of gas burned:

Excess air 5%, 0.041 x 21		0.861 lb.	3.7%
CO_2 (of combustion)		2.716	13.9
H_2O "	2.196)		
" from air	.23)	2.426	12.4
		13.58	69.3
		19.583	99.3

The flame temperature, from formula:

H_2 24.5% C 74.9% CO_2 2.716 lb. N 13.58 lb. and corrected for H_2O
H_2 24.5 C 74.9 CO_2 2.716 N 13.58 Water 0.23 f 19.58
Then: 616 C plus 2220 H minus 44 H_2O gives 4187° F. above 60°
f plus 0.18 H plus 0. 02 H_2O

HEAT UTILIZATION

Assuming a stack or waste gas temperature of 1500° F. and a melting temperature of 3000° F.

The heat required, per ton of woolrock, to evaporate moisture and combined water:

229.20 lbs, H_2O from 60° to 212° F. at 1100 BTU per lb.			
229.2 x 1100		252,120	
Steam raised from 212° to 1500° F.:			
229.2 x 1288 x .55 sp. ht.		162,365	
			414,485 BTU
To raise 785 lb. dry woolrock (minus $CaCO_3$ & $MgCO_3$) from 60° to 1500° F. (aver. sp. ht. .26)		314,314	
For disassociation:			
$CaCO_3$ at 816 lb. x 780 BTU (cement practise)		634,480	
$MgCO_3$ at 169 lb. x 620 BTU (cement practice)		104,780	
			1,055,574 BTU
To raise solids from 1600 to 3000° F.:			
1316 lb. x 1400° x 0.418 sp. ht.		770,123	
Exothermic 1316 lb. x 200 BTU	263,200		
Heat of fusion " x 180 BTU	236,880		
		26,320	
			743,803
Total heat to melt solids			2,213,862
To discharge combustion products at 1500° F.			
5286 lb. x 1440 x 0.263 sp. ht.			2,001.914
Radiation, both furnace & kiln			1,393,054
Total BTU required			5,608,830

At 978 BTU per cu. ft. of gas:

Gas required is	5375 cu. ft.	270 lbs.
Air " "	61422	5016
Total	67157 cu. ft.	5288 lbs.

Combustion products are:

CO_2	734 lbs.
H_2O	656
N	3666
Air	232
Total	5288 lbs.

Starting with the furnace combustion, flame temperature 4187° F.

BTU supplied		5,608,830
Loss of BTU to solids	734,803	
Loss in radiation, furnace 12%	673,060	
	1,407,863	
Minus exothermic	26,320	
		1,381,543
		4,227,287

Temperature at furnace exit into kiln:

$$\frac{4{,}227{,}287}{5286 \times .263 \text{ sp. ht.}} \text{ equals } 3041° \text{ F.}$$

Heat expended in kiln:

To raise temperature of material	314,314	
In disassociation	741,260	
In drying	414,485	
In radiation 12.8%	719,994	2,180,063
	BTU remaining	2,047,224

Temperature of combustion and gas products at exit of kiln:

$$\frac{2{,}047{,}224}{5286 \times .263 \text{ sp. ht.}} \text{ equals } 1472° \text{ F.}$$

HEAT BALANCE:

In gaseous products:					
Drying H_2O	229 lb.		414,485	BTU	7.3%
CO_2	448	192,000 BTU			
O	7	2,520			
Combustion gases	5286	2,001,914			
Disassociation 1/3rd		256,840			
Total			2,443,274		43.4
In solid products:					
Molten solution	1316 lb.	897,736			
Disassociation 2/3rds		492,840	1,390,576		27.6
Total radiation			1,393,054		25.0
Total heat			5,641,389	BTU	100.2%

Reducing these figures to the utilization of 40 tons of woolrock per day of 24 hours:

1.66 tons per hour.
55 lbs. per minute.
715 cu. inches or 0.413 cu. ft. per minute.
Molten product 35.75 lb. per minute.
" " 363 cu. in. or 0.21 cu. ft. per min.
" " calculated at 170 lb. per cu. ft.

Gaseous products, at atmospheric temperature:

In the furnace	1858 cu. ft. per minute
" " kiln (Including H_2O)	2086 " " " "
Fuel gas	158 " " " "
Air	1700 " " " "

FURNACE DATA

From available data on the performance of rotary kilns in the cement industry, a kiln 60 ft. long x 6 ft. diameter performs as follows:

Raw material	57 tons per day of 24 hours
Finished clinker	37 " " " " " "
Fuel used (coal)	120 lbs. per barrel of clinker (cement)
" " (")	16.6 lbs. per minute
Raw material used	80 " " "

For 16.6 lbs. of coal per minute the products of combustion will be:

H_2O	7 lb.	140 cu. ft.
CO_2	45	365
N	128	1628
Excess air 20%	33	412
	20	162 from disassociation
		2707 cu. ft.

CO_2)
MgO)

This 6 ft. diameter kiln has a refractory lining 9″ thick which makes the internal diameter 4.5 ft. with an area of 15.8 sq. ft.

Then, $\frac{2707 \text{ cu. ft.}}{15.8}$ is 171 ft. per minute or 2.8 ft. per second as the velocity of the combustion gases through the kiln.

Holding the same velocity for woolrock at 40 tons per day, we have $\frac{1858}{171}$ or 10.8 sq. ft. of area and a diameter of 4 plus feet.

4 ft. diameter being the smallest standard kiln refractory block made, we will use a 4 ft. internal diameter. This is 5½ ft. external diameter.

Considering the flow of solids through the kiln, allowing 90 minutes in the kiln, for a production of 80 lb. per minute from a 6 x 60 ft. cement kiln there will be $\frac{90}{60}$ x 80 or 120 lbs. per foot of kiln length or 138 cu. in. per inch and 138 sq. in. as area of the segment representing the kiln space occupied by the material. The maximum depth of this segment is 6 inches.

Using a slope of ½ inch per foot, the screw pitch per revolution of the 6 x 60 ft. kiln is 2.75 inches and 261 revolutions will be required to pass material through the kiln. Allowing 90 minutes kiln time, the speed of rotation is 2.9 r.p.m.

In a 5½ x 40 ft. kiln the screw pitch per revolution will be 2 inches and 240 revolutions will be required at 2.6 r.p.m. Kiln load will be 124 pounds of raw material per foot of length. Deducting 10% of the load as moisture removed during the first few feet of kiln travel, leaves 111 pounds or 1532 cubic inches per foot with a cross section of 127 square inches. The maximum depth of material is 5.9 inches.

UTILIZATION OF WASTE HEAT FOR STEAM GENERATION.

Heat in gaseous products at 1472° F. is 2,857,339 BTU., or at stack temperature of 500° F. is 5286 lb. x .22 x 500 or 581,500 BTU. The difference is 2,275,840 BTU, and at 80% boiler efficiency this is lowered to 1,820,671 BTU available for steam making. 1186 BTU per lb. of steam at 80 lb. gage pressure is 1535 lb. of steam per ton of woolrock and, at 40 tons of material per 24 hours, 2548 lb. per hour or 42 lbs. per minute. This is equivalent to something over 63 B.H.P. and the size of boiler will be somewhat larger than 4 ft. x 14 ft.

Stack: Using Meade's formula for a rotary cement kiln stack:

E equals effective area in square feet.

H " height of chimney in feet.
B " barrels of cement per hour.
K " coefficient for "dry" process.
d " diameter of chimney in inches.

We will assume a stack of 36 feet high above the kiln. 9 barrels of cement per hour equals the required production of 1.66 tons per hour. Then,

$$E \text{ equals } \frac{B \times K}{16.65 \times \text{sq. rt. of } H}$$

or 8.1 sq. ft. and d equals 13.54 x sq. rt. of E plus 4, or 48 inches.

REVERBERATORY FURNACE

At 363 cu. in. per minute production of molten product, to hold material in the furnace for one hour will require a crucible or hearth capacity of 21,780 cu. in. or 12.6 cu. ft. Assuming 8 ft. as the length of the bath and assuming the depth to be 12″ maximum at the center and tapering to 0 at the sides, the average depth will be 6″ and the width of the bath will be approximately 36″. Approximate interior dimensions of the furnace will be 10 feet long by 4 feet wide.