PRELIMINARY DESIGN OF A LIME BURNING PLANT

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PREFACE

Since science has been invading the commercial world it has spread its influence to the manufacture of lime. A scientific construction of the kiln and an orderly method of procedure were demanded to reduce the cost and speed up the production of lime.

Oklahoma ranks very high in the production of natural gas and extremely low in the production of any grade of lime. It is abundant in natural resources and especially in its limestone deposits. Its limestone resources have as yet been practically untouched. There are formations of all geologic ages from the Cambrian to the Cretaceous, many of which would make an excellent grade of lime. These limestone formations are widely distributed over the southern and eastern parts of the state. They occur extensively in the Arbuckle Mountains, Wichita Mountains, and in the counties east of Jefferson County, also along the Red River in the southern and southeastern parts of the State. Many outcrops appear in the foothills of the Ozarks in the northeast corner, as well as in the northern part of the State along the Kansas border as far west as Kay County. (7).

In the Biennial Census of Manufactures of 1935, Oklahoma was credited with only one establishment producing lime. The Mineral Yearbook of 1937 shows that Oklahoma shipped into the State in 1936 11,789 short tons of lime, with no exporting of the commodity (4). In view of these facts, and the fact that Oklahoma has unlimited resources for producing lime there seems to be no reason why the importation of lime should not cease. Oklahoma should be exporting large amounts to other states and above all be producing its own lime for local consumption.

The purpose of this problem is to make a preliminary design of a lime burning plant. A native limestone is to be used and the kiln is to be fired with natural gas.

ACKNOWLEDGMENT

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INTRODUCTION

Few, perhaps, realize on first thought the importance of lime in the affairs of man. One can scarcely recall any sort of building operations in which lime does not take some part. Its importance as a fertilizer, in the purification of water, in metallurgy, in paper mills and in tanneries can scarcely be over-estimated. Lime has been used since earliest historic times and has become indispensable in the everyday life of all civilized peoples. The burning of lime dates back to early historic times. The ancient Egyptians and Babylonians used it in their buildings; the Greeks realized its medical value; and since then its field of usefulness has gradually grown until it is indispensable in modern everyday life. The methods used in the early days were very crude and anyone was expected to be able to burn lime. The first lime was probably burned by piling up logs and rock and setting fire to the pile. Obviously this produced a very inferior grade of lime. A second crude method was the use of what was known as the "pot" kiln. This kiln, in the shape of a truncated cone or cylinder, was built of limestone or sandstone and lined with fire brick. It was charged with rock and wood, or coal, well mixed. After the charge had burned itself out the lime was drawn and the kiln recharged.

A third type of kiln, used by those who burned only a small amount of lime for home use, was built of the limestone rock itself. It was usually about twelve feet square and about twelve feet in height. The charge consisted of limestone and fuel, which had previously been well mixed. This kiln also produced a very poor grade of lime.

Comparison is best shown between the old kilns and the modern kilns by stating what can be expected of modern kilns. An up to date kiln should have continuous mechanical feed of the rock and also continuous mechanical discharge of lime. It should have accurate control of the temperature, with recording thermocouples in the burning zone and at the top of the kiln. Accurate control of all the following items is necessary; the draft, the burning period and the combustion. The temperature of the flue gas must be kept at a minimum to insure a high efficiency. A recording carbon dioxide apparatus, to keep a close check on the percent of carbon dioxide in the flue gas, is very essential. With these variables controlled, modern kilns produce a uniform quality of product many times superior to that made by the ancient kilns.

In general, a shaft kiln resembles a short wide stack of either square, round or elliptical cross section. It consists of a casing of steel which is lined with refractory material. The long vertical chamber formed by this lining may be divided into three sections by horizontal planes. The top section, called the hopper, is used for storing and preheating the stone. Its sides slope inward so that the stone may slide down into the middle section, called the shaft. The calcining of the stone takes place in this vertical walled shaft. At the bottom of the shaft the third section or cooling zone is located and it is used for cooling the lime after the burning is complete. Obviously the top of the cooling zone must have the same cross sectional area as the shaft. The sides of the cooling zone are drawn inward leading to the drawing door, through which lime is removed.

The burning of lime may be defined as the process of converting limestone into lime through the agency of heat. Limestone decomposes according to the reaction:

$$CaCO_3 = CaO + CO_2 - \text{heat}$$

The reaction is endothermic, absorbing about 43,000 calories per molecular weight. It can be shown by theoretical considerations that such a reaction cannot take place, except at the boundary between $CaCO_3$ and CaO. Since the two solid phases are fixed in position, it might be expected that the line of calcination would start at the outside of the piece and advance inward. C. C. Furnas (8) has shown that calcination proceeds in just this manner and only over a very narrow zone, practically a line. As a first approximation, this line of calcination advances at a constant rate, measured in centimeters per hour. It is dependent only on the temperature of the surroundings and independent of size or shape of the particle, degree of calcination, or amount of previous heating. The rate at which this line of calcination advances is constant throughout the entire period; thus, the length of time required to calcine is directly proportional to the size of rock. The size is defined as the greatest thickness of the piece, where the thickness is defined as the smallest of the three dimensions as contrasted with breadth and length. Furnas has also shown that temperature advances much faster than calcination; that is, the acquiring of a high temperature at the center of a piece occurs long before calcination takes place there. This means that the portion of the piece inside of the calcined zone is always in a metastable state, but still unable to decompose until the phase boundary advances to it. The limiting factor in the rate of calcination at low temperatures is thus the inherent rate of advance of this boundary line of the two solid phases. However, as the temperature of the surroundings is raised, the rate of advance of the phase boundary is so increased that resistance to heat transfer begins to have an effect. This resistance to heat transfer is for the most part at the line of calcination and not throughout the body of the calcined material. The center temperature, although it is sufficiently high for calcination, lags behind the outside temperature until calcination is completed. This means that, after the temperature reaches a certain point, the 43,000 calories per molecular weight are being absorbed at the phase boundary so rapidly that no additional heat gets past the boundary to go into the center of the piece.

Calcination temperatures are reported as being from 1652° F. to 1742° F. The center of a piece of rock acquires an average temperature of 1722° F. during calcination. But this so-called "calcination temperature" is meaningless because calcination theoretically should proceed at any temperature if the carbon dioxide pressure is low enough. If a piece of limestone is being calcined at ordinary pressure the outside of the piece should theoretically be at some temperature greater than 1750° F. The center should maintain a constant temperature between 1652° F. and 1742° F. until calcination of the piece is complete and then it should rise to the temperature of the outside. This is exactly what happens as may be proved by taking the temperature history of a piece of limestone during calcination. In the preceding discussion it is pointed out that heat flow and calcination are not identical and that it is erroneous to consider them as such. When the external temperature is below 1742° F. the center then acquires temperature much ahead of calcination, but if the external temperature is greater than 1742° F. then the attainment of the outside temperature at the center is evidence that calcination is complete. It then seems reasonable to suppose that the major driving force of the calcination is the equilibrium carbon dioxide pressure of the calcium carbonate as shown by the curve in Figure 1 (10). If this is true, the rate of calcination should be approximately proportional to the equilibrium carbon dioxide pressure. The curves for the rate of calcination and the equilibrium carbon dioxide pressure are quite similar as shown by comparison (8). However, the sharp rise in the equilibrium curve starts at a lower temperature and this would indicate that another factor besides the pressure of the carbon dioxide tends to limit the speed of the reaction. This factor must be the resistance to heat transfer. Hence there are two controlling factors in calcination, specific rate of advance of the phase boundary and rate of heat transfer.

Many cases occur in engineering practice where the performance of a large and expensive structure cannot be calculated in advance because of the extreme complication of the governing laws. This is somewhat the case in the construction of a shaft kiln. It is possible, however, to construct a model or pilot kiln and carry out experiments with it and be reasonably certain that the large structure would approximate the performance of the model. A great saving in time and money can be made in this manner. It is felt that model tests can predict with considerable accuracy the following characteristics of a kiln (17).

1. The distribution of temperature throughout the kiln at any stage of the burn.
2. The heat lost in the stack.
3. The heat lost through the walls.
4. The amount of fuel required.
5. The time required to reach a given temperature.

The model has the disadvantage of not being able to reproduce the burner flame to scale, so that a model would not be suitable for trying out burners.

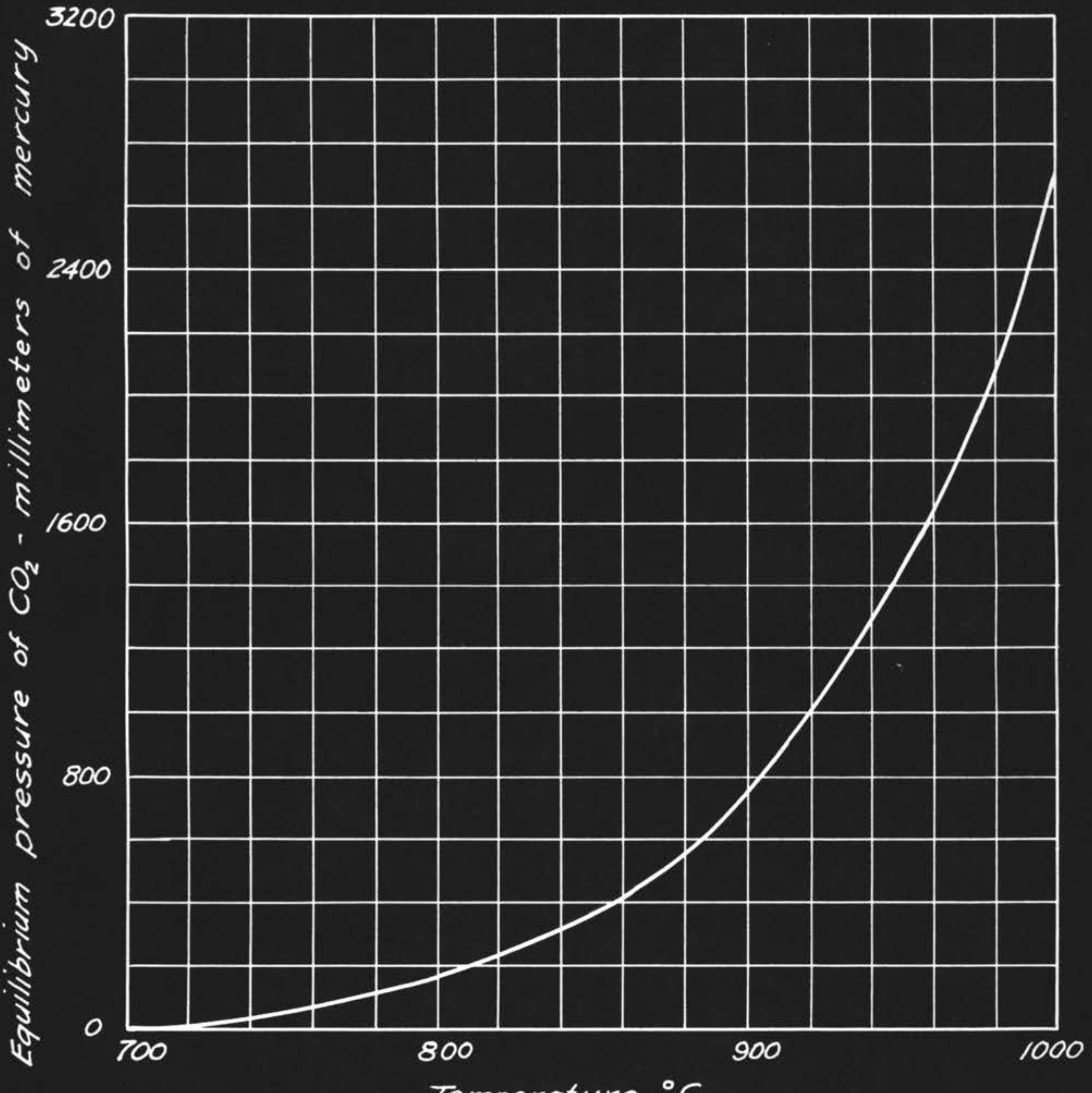


Figure 1

Johnson's Data of Equilibrium Carbon Dioxide Pressure in the Decomposition of Calcium Carbonate

EXPERIMENTAL

A natural draft, straignt shaft pilot kiln (Figure 2) was constructed one foot inside diameter and eight feet in height including the stack. The frame of the kiln was that of an old muffle furnace. The shaft was built of fire brick using fire clay as mortar, the bricks being staggered to give greater strength; they were also backed with a mixture of crushed fire brick and clay. Still greater strength was insured by reinforcing the upper half of the shaft with strap iron. The stack of the kiln could be raised or lowered with a chain and pulley and in this manner it was possible to charge the kiln while in operation.

The limestone was obtained from Sand Springs, Oklahoma, and crushed by hand to an average size of two inches. This stone was analyzed by the procedure found in the American Society of Testing Materials (Standard Methods, 1936, Part II, C25-29). The following analysis was obtained:

	%
Silica (SiO_2) and other insolubles	1.35
Al_2O_3 and Fe_2O_3	2.76
CaO	52.30
MgO	1.94
CO_2	41.14
H_2O	.43
	99.92
$CaCO_3$	93.30
$MgCO_3$	4.08
Total Solids	58.35

The pilot kiln was fired with natural gas utilizing an old burner which was adjusted to give the desired air-fuel ratio. The outer edge of the burner was placed tangent to the circumference of the kiln to give the flame a whirling motion on entering.

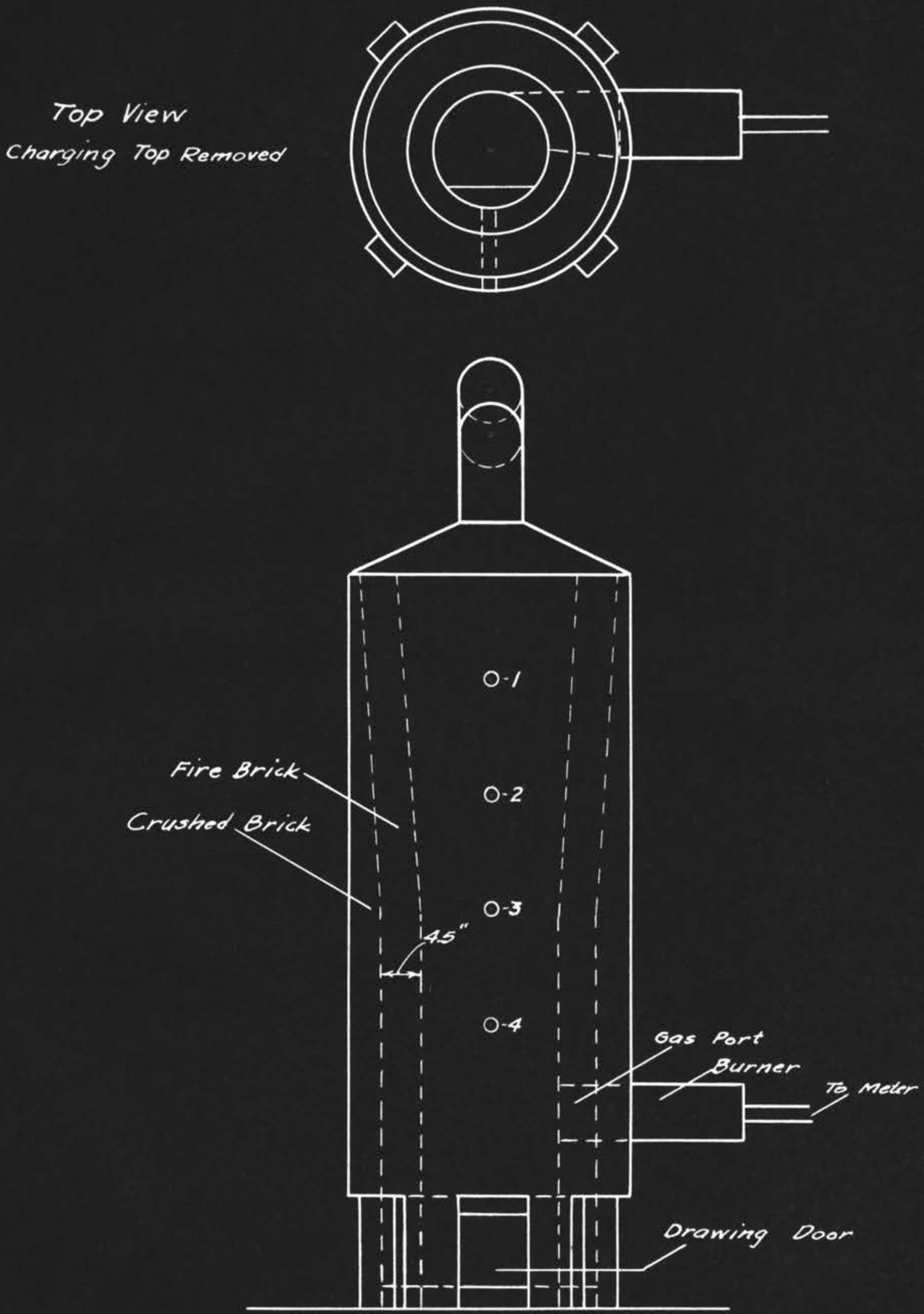
In the testing of the pilot plant three preliminary and two final tests were made. The kiln was completely charged at the beginning of the test and drawing of lime and charging of limestone were made every four hours. Samples of the flue gas were taken every thirty minutes from the top of the kiln with a continuous sampling apparatus. This apparatus consisted of a rubber hose connected to the sampling tube of the kiln and then fastened to a water suction. These gas samples were then analyzed for CO_2, O_2, and CO in a standard Orsat apparatus. The temperatures of the room, flue gas and kiln were taken every thirty minutes. The temperature of the kiln above the burner was taken in four places, designated as 1, 2, 3, and 4 on Figure 2, and labeled in the same manner in the data. A standardized thermocouple connected to a millivoltmeter was used in obtaining the temperatures. The gas was measured with a 1½ inch meter, (10 L. T. -B Iron Case Meter) manufactured by the Metric Works, Grie, Pennsylvania. For weighing the lime and limestone a Howe Scale (capacity 300 pounds) was used.

The following data and information were used in the calculations.

Heating value of the fuel in B. T. U. per cubic foot..............................	1000
Heat required to process one pound of CaO in B. T. U. (1).....................	2136

Analysis of fuel:

Compound	Percent
N_2	8



Pilot Kiln

Figure 2

Scale 3/4" = 1'

Compound	Percent
C_2H_6	18
CH_4	74
Average molecular weight of fuel	19.46

Two hours were taken from the actual burning time to allow the kiln to become sufficiently hot to cause calcination.

Table No. 1

TEST ON PILOT LIME PLANT

Time	Temperature °F.						Gas Analysis		
	Room	Flue Gas	Kiln						
			1	2	3	4	CO_2	O_2	CO
8:30	77	91.4	95	125	147	521	7	4.5	---
9	77	122	95	131	212	968	9.3	5	---
9:30	77	122	95	131	185	1292	8.7	7.3	---
10	77	123.8	104	158	212	1404	10.5	4.8	---
10:30	78.8	140	122	259	475	1463	11.5	5.2	---
11	80.6	152.6	122	287	491	1562	11.5	4.3	1.5
11:30	82.5	172.4	149	361	509	1517	11.3	5	1.7
12									
12:30	82.5	208.4	298	716	824	1577	11.2	6.2	1.1
1	83.3	217	329	784	1094	1616	11	5.8	.7
1:30	86	251.6	374	770	1066	1526	10.4	6.6	1
2	Drew 100 pounds of $CaCO_3$ and added same to top.								
	86	248	349	792	997	1481	14.6	3.2	1.2
2:30	86	248	311	833	1261	1544	15.2	2.8	1.4
3	86	284	392	887	1364	1636	14.5	2.9	2.2
3:30	87.8	312.8	392	977	1391	1652	14.8	1.8	1.9
4	88	323.6	482	1022	1427	1670	14.6	2.4	3
4:30	88	352.4	509	1068	1571	1706	14.2	5.2	1.4
5	88	372	554	1234	1562	1706	14.3	3.9	2.3
5:30	88	401	581	1247	1576	1706	13	5	1
6	Drew 65 pounds of CaO and added 100 pounds of $CaCO_3$.								

(Table No. 1 - Continued)

Time	Temperature °F.						Gas Analysis		
	Room	Flue Gas	Kiln						
			1	2	3	4	CO_2	O_2	CO
6:30	88	253.4	302	617	1292	1589	13.8	6.8	1.9
7	86	298.4	428	1144	1337	1589	12	5	3.5
7:30	84.2	338	455	950	1405	1652	14.5	4.5	1.7
8	84.2	388.4	500	1058	1481	1706	14.6	5	2.4
8:30	83.5	420.5	554	1144	1571	1706	14	5	2
9	82.5	446	611	1256	1589	1706	13.6	5.4	2
9:30	82.5	473	644	1313	1634	1706	13.6	4.6	2
10	Drew 65 pounds of CaO and added 90 pounds of $CaCO_3$.								
10:30	80.5	329	446	831	1499	1706	18.3	4.7	1.8
11	80.5	410	536	917	1571	1706	17.2	4.2	2
11:30	80.5	428	554	1157	1589	1706	16.3	5.1	1.1
12	80.5	428	611	1256	1607	1706	14.2	5	1.8
12:30	80.5	482	644	1337	1607	1706	14.3	5.2	1.3
1	80.5	500	671	1409	1706	1706	14.7	5.3	2.2
1:30	80.5	560	698	1760	1706	1706	14	4.3	2.1
2	Drew 65 pounds CaO.								
2:30	80.5	860	1027	1157	1369	1443	15	10	
3	78.8	887	777	925	1108	1216	16	2.8	
3:30	78.8	905	850	1050	1240	1420	14	6	
4	78.8	973	1025	1144	1382	1634	9.8	8.2	
4:30	78.8	1004	1135	1220	1414	1680	13.6	3.4	
5	78.8	1040	1247	1427	1625	1706	8	11	
5:30	78.8	1040	1247	1445	1652	1706	7.6	12.5	
	Drew remainder of CaO.								

262.5 pounds of CaO were produced in this test; 130 pounds of $CaCO_3$ were not calcined; and 2,400 cubic feet of gas were used.

Average flue gas sample	
CO_2	13.7
O_2	4.8
CO	1.4
N_2	80.1

Average flue temperature	504° F.
Average temperature of drawn CaO and $CaCO_3$	1200° F.
Average humidity	64%
B. T. U. used in this test	2,171,400

Run No. I

Calculations

Fuel Analysis

Compound	Percent	Moles	Moles O_2 required	
			C	H_2
N_2	8	8		
C_2H_6	18	18	36	27
CH_4	74	74	74	74
			110	101

Moles of O_2 in air 80.1 x 21/79 = 21.6

Moles of excess O_2 4.8 - .7 = 4.1

Moles of O_2 required for combustion 21.6 - 4.1 = 17.5

Excess O_2 4.1/17.5 x 100 = 23.4

Total Carbon 13.7 + 1.4 = 15.1

Carbon from gas 17.5 x 110/211 = 9.13

Carbon from stone 15.1 - 9.13 = 5.97

Pounds of lime 5.97 x 44 x 58.35/41.14 = 376

Moles of fuel 100

Pounds of fuel per 100 moles 19.46 x 100 = 1946

Pounds of fuel 1946 x 9.13/110 = 162

Pounds of lime per pound of fuel 376/162 = 2.32

Cu. ft. per pound of fuel 379/19.46 = 19.5

B. T. U. per pound of fuel 19.5 x 1000 = 19,500

B. T. U. per 2.32 pounds of lime 2.32 x 2136 = 4,950

Theoretical Efficiency % 4,950/19,500 x 100 = 25.35

Actual Efficiency % 262.5 x 2136/2,171,400 = 25.8

Heat Balance

	B. T. U.	Percent
Heat put in:		
From fuel	2,171,400	100
Heat used:		
To burn the lime	560,000	25.8
Heat lost:		
By hot lime	172,000	7.9
By stack gases	282,500	13.0
By radiation and conduction (by difference)	1,156,900	53.3
		100.0

Fuel ratio:

Theoretical	9.11
Actual	2.32

Table No. 2

CHECK TEST ON PILOT LIME PLANT

Time	Temperature °F.								
	Room	Flue Gas	Kiln				Gas Analysis		
			1	2	3	4	CO_2	O_2	CO
7	78.8	127	122	185	257	565	6.4	5.2	3
7:30	78.8	131	140	185	337	802	9.4	5.4	1.5
8	80.6	136	149	266	554	950	9.2	7.4	1.4
8:30	80.6	154	161	338	671	1040	12.4	2.3	2
9	82.4	179.6	185	536	977	1355	11.5	6.2	0
9:30	84	190	230	527	1112	1481	12.4	2.9	2.8
10	84	226	329	698	1238	1472	11	7.2	.8
10:30	86	248	356	770	1445	1499	9.7	8.8	
11	87.8	287	361	842	1445	1535	12	5.4	.6
11:30	87.8	291	356	919	1517	1544	12.8	4.8	.4
12	87.8	341	525	1013	1562	1616	13	5.4	.6
12:30	91	359	509	1085	1562	1589	13.2	5.5	.5
1	93	275	320	788	1220	1589	16	5.5	1.5
	Drew 100 pounds of $CaCO_3$ and added to top.								
1:30	93.2	284	311	689	1355	1607	16.8	4.2	.4
2	93.2	347	356	788	1517	1706	14.8	6.8	.1
2:30	93.2	392	509	1085	1517	1706	14.2	5.4	.4
3	93.2	428	581	1175	1553	1706	15	5.5	.5
3:30	93.2	442	626	1202	1562	1706	11.5	8	.3
4	93.2	455	653	1274	1571	1706	11	8.3	.7
4:30	93.2	473	667	1292	1589	1706	11.5	8	.4
5	Drew 80 pounds of CaO and added 100 pounds of $CaCO_3$.								

(Table No. 2 - Continued)

Time	Temperature °F.						Gas Analysis		
	Room	Flue Gas	Kiln				CO_2	O_2	CO
			1	2	3	4			
5:30	93.2	248	320	464	1292	1670	16.5	4	2.5
6	91.4	280	341	888	1430	1706	15.8	4.7	1.5
6:30	89.6	329	406	950	1427	1706	15	5	2
7	87.8	365	451	1058	1481	1706	14.8	5.7	1.1
7:30	87.8	386.6	482	1085	1499	1706	13.2	6.6	1.2
8	86	392	507	1157	1517	1706	12.8	7.6	1.2
8:30	86	446	554	1202	1571	1706	13.5	6.5	1
9	Drew 80 pounds of CaO and add 100 pounds $CaCO_3$.								
	87.8	273	329	451	1427	1706	19	4	1
9:30	87.8	352	392	725	1517	1706	16.2	5	2.1
10	86	383	478	1058	1517	1706	15.7	5	2.1
10:30	86	428	536	1130	1589	1706	16.4	4.8	1.6
11	86	473	626	1191	1589	1706	15.3	5.1	1.5
11:30	84	518	654	1292	1616	1706	14.5	5.5	1.5
12	84	572	680	1337	1706	1706	15.2	4.4	1.4
12:30	84	608	712	1382	1706	1706	14.8	4.2	1.3
1	Drew 80 pounds of CaO.								
	86	662	905	1418	1482	1706	21	4.5	1.3
1:30	84	842	997	1101	1517	1706	19.6	4	1.4
2	84	860	1068	1144	1634	1706	19	3.2	.8
2:30	82.4	860	1175	1202	1706	1706	18.2	3.2	
3	82.4	860	1202	1234	1706	1706	15.6	6.7	
3:30	82.4	860	1220	1292	1706	1706	17.2	3.5	
	Drew all of CaO.								

296 pounds of CaO were produced in this test; 120 pounds of $CaCO_3$ were not calcined; and 2,480 cubic feet of gas were used.

Average flue gas sample	
CO_2	14.7
O_2	5.4
CO	.9
N_2	79

Average flue temperature	520° F.
Average temperature of drawn CaO and $CaCO_3$	1200° F.
Average humidity	60%
B. T. U. used in this test	2,244,000

Run No. II

Calculations

Moles of O_2 in air	79 x 21/79	=	21
Moles of excess O_2	5.4 - .45	=	4.95
Moles of O_2 required for combustion	21-4.95	=	16.05
Excess O_2	4.95/16.05 x 100	=	30.8
Total carbon	14.7 + .9	=	15.6
Carbon from gas	16.05 x 110/211	=	8.38
Carbon from stone	15.6 - 8.38	=	7.22
Pounds of lime	7.22 x 44 x 58.35/41.14	=	453
Moles of fuel			100
Pounds of fuel per 100 moles	19.46 x 100	=	1946
Pounds of fuel	1946 x 8.38/110	=	148
Pounds of lime per pound of fuel	453/148	=	3.05
Cu. ft. per pound of fuel	379/1946	=	19.5
B. T. U. per pound of fuel	19.5 x 1000	=	19,500
B. T. U. per 3.05 pounds of lime	3.05 x 2136	=	6,520
Theoretical Efficiency %	6,520/19,500	=	33.4
Actual Efficiency %	296 x 2136/2,244,000	=	28.1

Heat Balance

	B. T. U.	Percent
Heat put in:		
From fuel	2,244,000	100
Heat used:		
To burn lime	631,500	28.1
Heat lost:		
By hot lime	193,000	8.56
By stack gas	249,140	11.1
By radiation and conduction (by difference)	1,170,360	52.24

Fuel ratio:

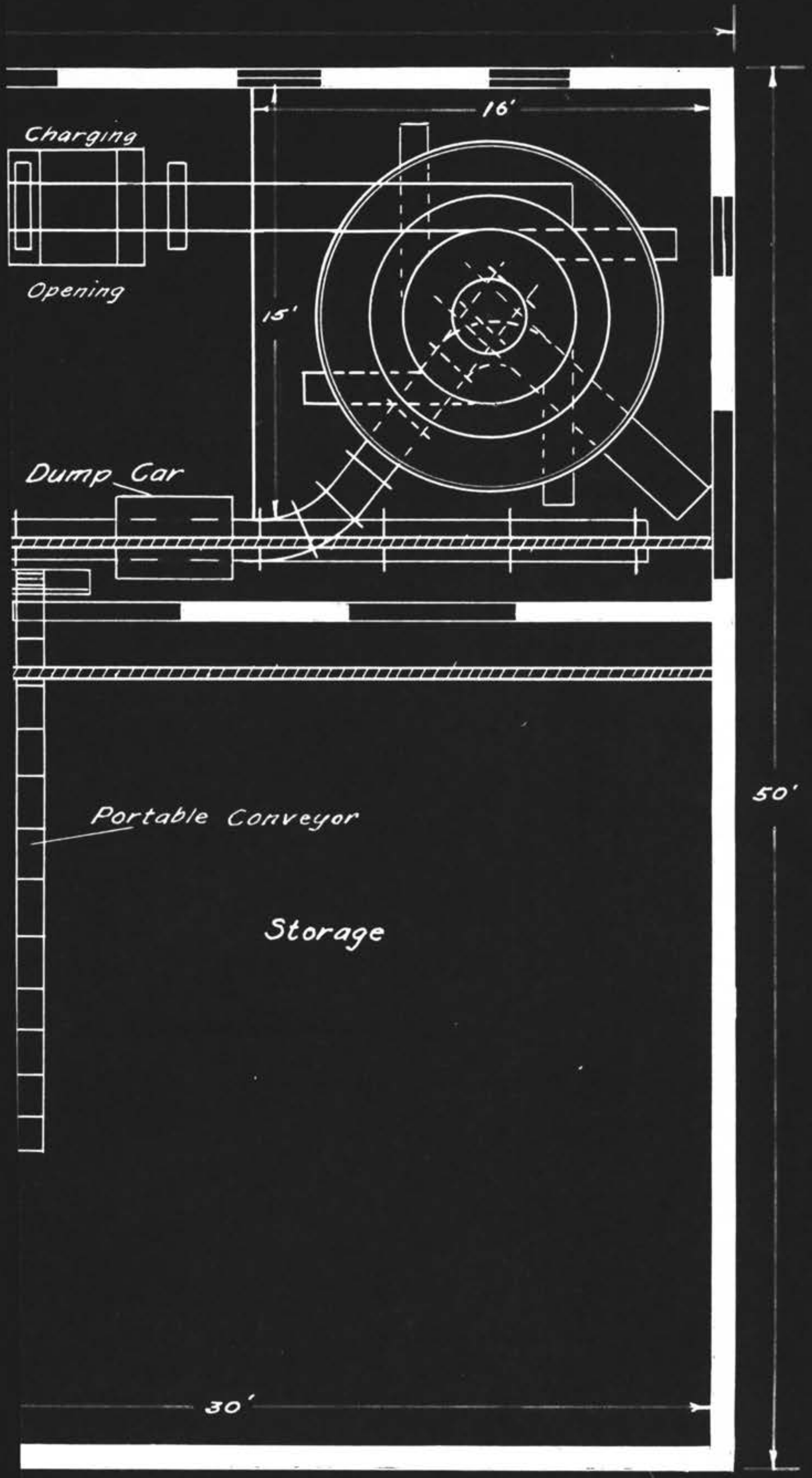
Theoretical	9.11
Actual	2.50

DESIGN

A projected lime plant is to produce 25 tons of Agricultural Lime per 24 hours. It is assumed that the rock is available at the plant crusher to be crushed to kiln size. The rock will be delivered in lumps varying in size from 6 inches to 1 foot. Natural gas, electricity, and water are all available at the plant location. The flow sheet of the plant is to be as follows:

Crusher (Average size of product, 4 inches)
l
Conveyor
l
Grizzly (Waste rock)
l
Storage (45 tons of rock)
l
Charging equipment for kiln
l
Kiln
l
Discharging equipment
l
Elevator and conveyor
l
Storage bins
l
Grinder (For final product)
l
Supply room

Plan and elevation sketches (Figure 3 and Figure 4), showing the design of the plant have been prepared. Approximate dimensions and outlines of all storage bins are shown. Types, capacities, and lengths of conveyors, and types and capacities for all other equipment have been listed.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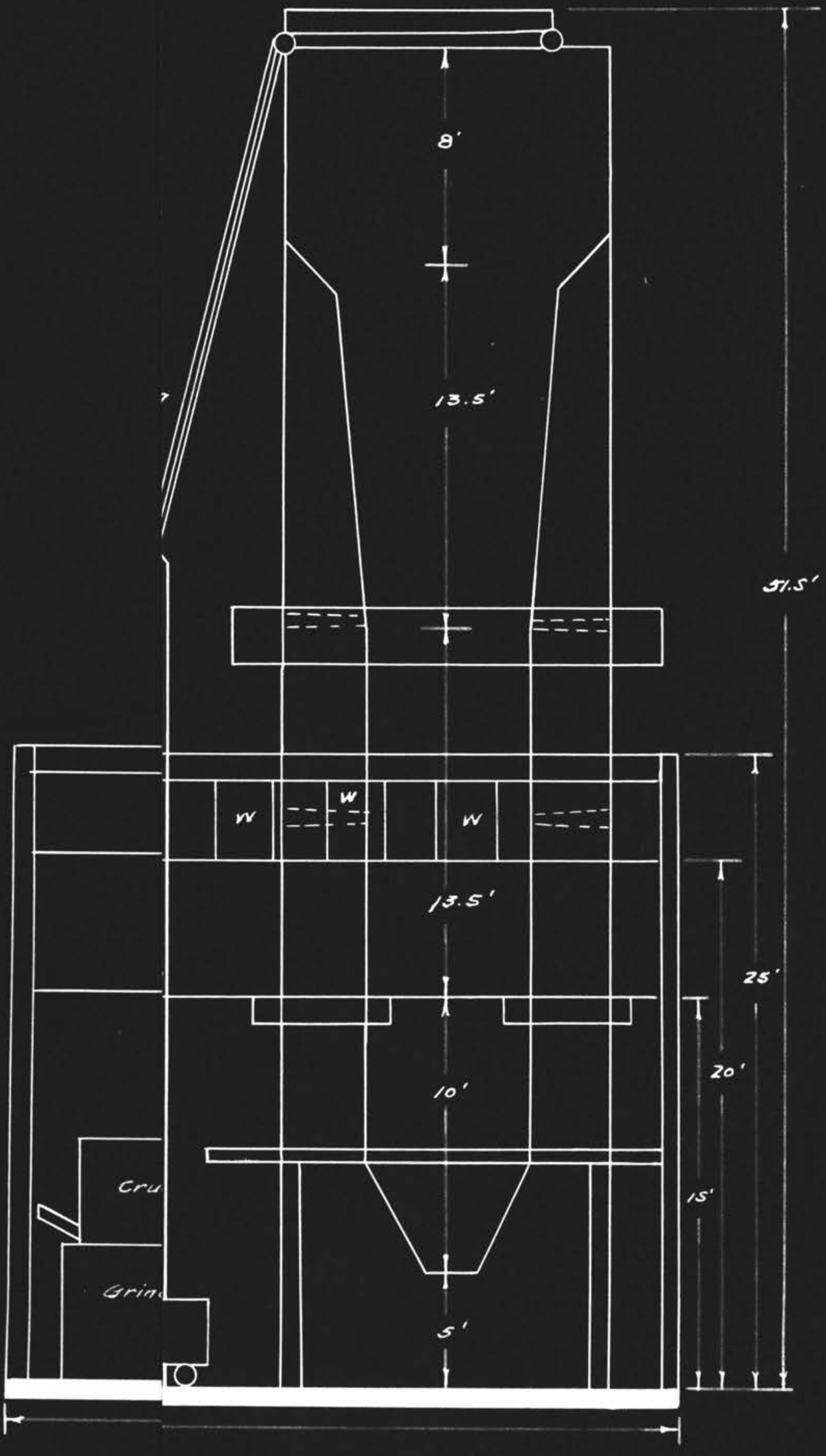
8'
13.5'
31.5'
W
W
W
13.5'
25'
20'
10'
Cru
15'
Grin
5'

Specifications:

Crusher: Traylor Type A
Jaw opening 10 by 16 inches
Capacity 10 hours 25-40 tons
Horsepower 14
Floor space 8 by 5 feet
Height 10 feet
Gravity feed to belt conveyor
Cost $1400 Labor $123

Conveyor: Belt Type
Width 12 inches
Length 30 feet
Height 3 feet
Cost $550 Labor $150

Grizzly: Bar opening 3.5 inches
Floor space 2 by 3.5 feet
Height 4 feet
Cost $150 Labor $20

Storage: 45 tons of rock
10 by 10 feet

Charging equipment:
Conveyor with charging bucket
Capacity 1000 pounds
Height 51.5 feet
Cost $3000 Labor $800

Kiln: 12 feet outside diameter
6 feet inside diameter
50 feet in height
Assumed 36 cubic feet per ton of rock or lime

Cooling zone
Capacity 225 cubic feet
Height 10 feet
Fire brick lining, 18 inches, height 8 feet

Burning zone
Capacity 900 cubic feet
Height 27 feet
Fire brick lining, 18 inches, height 27 feet

Hopper
Capacity 900 cubic feet
Height 8 feet

Two thermocouples, one at bottom of burning zone, other on top of kiln
Recording carbon dioxide apparatus connected to top part of kiln
Platform at middle of burning zone
Cost $10,100, labor included.

Discharging equipment:
Standard gage dump cars and track
Capacity 4 yards
4 cars required
Cost $850 Labor $240

Portable conveyor and elevator:
Belt 12 inches wide
Length 20 feet
Bucket 12 inches wide
Height 10 feet
Cost $800 Labor $300

Storage bins:
2 rooms
30 by 30 by 15 feet
Maximum capacity 3 weeks

Grinder: Mogul Junior Hammer Mill:
Opening 15 by 20 inches
Capacity 4 to 6 tons per hour
Horsepower 25-35
Floor space 6 by 7 feet
Height 5 feet
Cost $1800 Labor $500

Building: Wood frame
Cost $4100 Labor $1600

SUMMARY AND CONCLUSIONS

The limestone calcined in this experiment made good agricultural lime. Although the percent of iron in the final lime would not allow it to be used as hydrated lime.

Natural gas proved to be an excellent fuel. Its cleanness, ease of handling and the radiant characteristics of its flame makes it ideal for the calcining of limestone.

The cost of fuel per ton of lime is easily calculated from the lime-fuel ratio in the last experiment.

2.5 pounds of lime per pound of fuel
2000/2.5 x 1 = 800 pounds of fuel
800/19.46 x 379 = 15,600 cu. ft. per ton of lime
1000 cu. ft. of natural gas at $ .14
Then 15.6 x .14 = $2.18 per ton of lime

The distribution of temperatures over the height of the large plant kiln would probably be very close to 450° F. for the stack, 625° F. for the limestone in the top of the hopper, 1185° F. for the middle portion, 1575° F. for the part one-fourth above the burner and 1700° F. for that directly above the burner. These temperatures are taken directly from the test data secured when the kiln had been in operation long enough to insure optimum results.

The heat losses are best and most conveniently shown in the heat balance following the data on each test. The three different values for heat losses check quite closely in the two runs.

In both tests the time required for the kiln to reach its operating temperatures was about four hours. It would probably take somewhat longer on the large scale, but the amount of fuel would be increased in proportion to the rock. This item is not important because it is planned to keep the plant in continuous operation.

A rough approximation of the initial cost of this plant would be $26,500.

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I, Woodrow W. Chew, was born near Burlington, Oklahoma, January 29, 1913. I attended elementary school and secondary school at Alva, Oklahoma, graduating in 1931 from Alva High School. I entered Northwestern State Teachers College at Alva, Oklahoma, in 1931 and attended three years. I then transferred to New Mexico Agricultural and Mechanical College, where I received my Bachelor of Science Degree in 1936. I entered the Graduate School of the Oklahoma Agricultural and Mechanical College in September, 1936. The requirements for the degree of Master of Science will be completed in July, 1938.

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