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Phase II Report

PREFEASIBILITY STUDY

For

Production of Lime

In

Jordan

Submitted To

The Hashemite Kingdom of Jordan

Represented By

The National Planning Council

Swindell-Dressler Company
A Division of Pullman Incorporated
441 Smithfield Street
Pittsburgh, Pennsylvania 15222
U.S.A.

July 1975

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SUMMARY

Until Jordan is able to broaden its industrial base the future market demand for lime appears, at present, to be limited to approximately 3,000 mt per year.

Based upon a minimum sized plant designed to produce approximately 13,000 mt annually, it is economically unfeasible to operate at a rate of 3,000 mt per year. It is therefore recommended that no lime plant be erected until the currently anticipated demand is supplemented by that of new major users of lime. One of these may well be the manufacture of sand-lime brick which is about to be studied by the JHC-UNDP.

Preliminary tests on one Jordanian limestone indicate that it is suitable for calcining in a vertical shaft kiln. Limestone is distributed over many parts of the Kingdom.

General descriptions are given of the process and equipment used in calcining and hydrating lime. The production of sand-lime brick is also described and technical references included.

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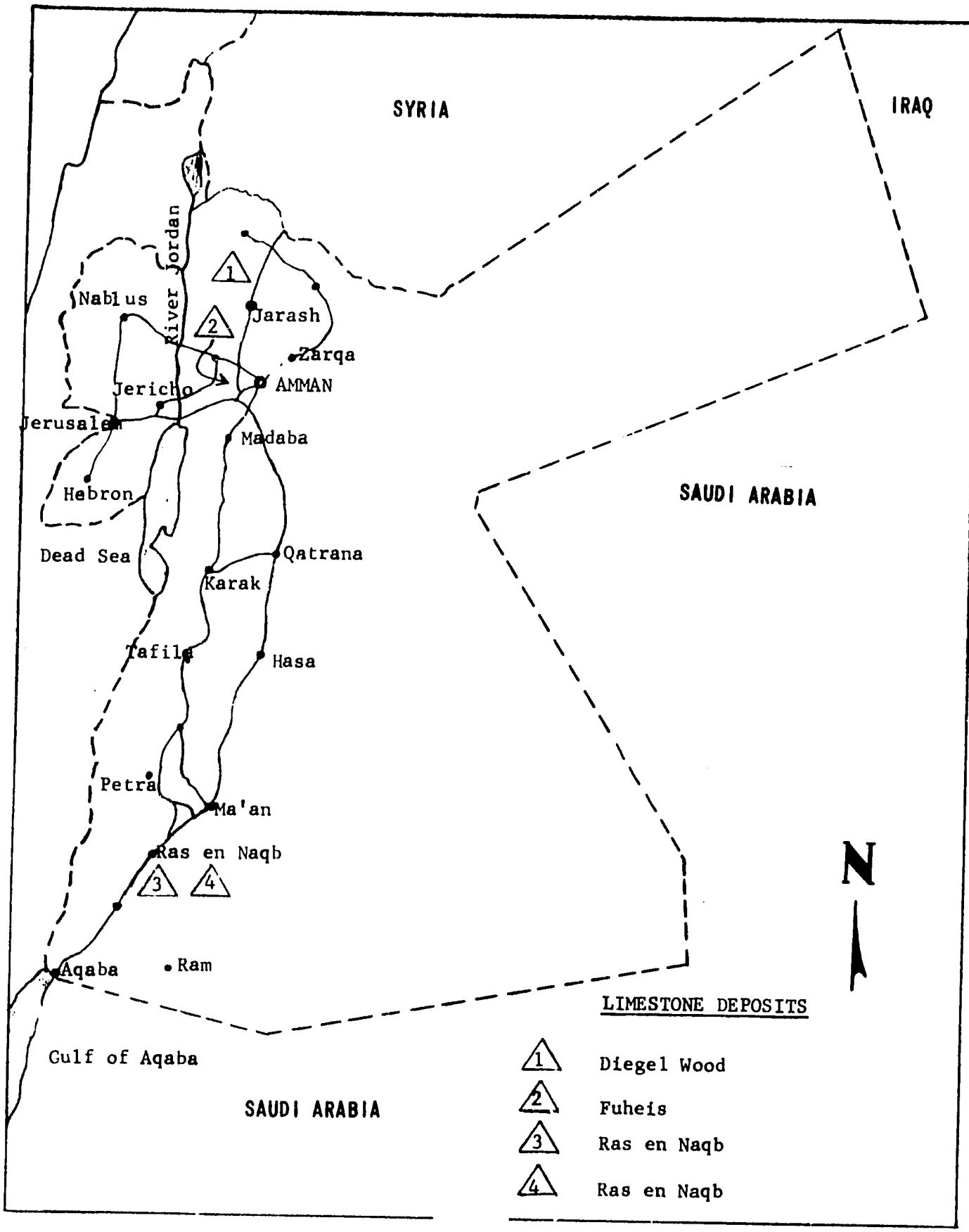

THE HASHEMITE KINGDOM OF JORDAN

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Recognition is also due the many industrial and business enterprises whose personnel were so helpful in surveys involving marketing research. Individual mention should go to a wide range of people in all of the groups but space will not permit the listing of such a large number of names. The Contractor does, however, wish to thank the Committee of the National Planning Council as a body and as individuals for their devoted service in supplying information, guidance, and criticism at all stages of the work.

The members of the Contractor's field staff are pleased to add that they found most Jordanians very receptive to the possibility of new products and markets and also found all who were contacted to have a sense of urgency to accelerate the general development of the Kingdom.

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ABBREVIATIONS

MNE	The Ministry of National Economy
NRA	The Natural Resources Authority
MRD	The Mineral Resources Division (of NRA)
NPC	The National Planning Council (formerly the Jordan Development Board)
JCI	The Jordan Ceramic Industries Co., Ltd.
JCID	The Jordan Centre for Industrial Development
JHC	The Jordan Housing Corporation
SDC	The Swindell-Dressler Company
UNIDO	United Nations Industrial Development Organization
USA	United States of America
JD	Jordanian Dinar
GOJ	Government of Jordan

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INTRODUCTION

The National Planning Council was established by provisional law No. 68 of November 25th, 1971 to replace the Jordan Development Board. According to this law, NPC is responsible for the preparation and formation of long and short-term comprehensive well integrated plans and cooperation with the Budget Department in setting up priorities among the selected development projects for implementation in the GOJ budget. The NPC is responsible for manpower planning, following the implementation of development projects, obtaining loans for financing the execution of projects, and the creation of planning cells in the various ministries.

Pursuant to this responsibility, the National Planning Council contracted with the Swindell-Dressler Company, a Division of Pullman Incorporated of Pittsburgh, Pennsylvania, U.S.A., hereinafter termed the "Contractor" to conduct a study of the feasibility of manufacturing products of glass and certain building materials and components in Jordan, for both national consumption and for export. Swindell-Dressler subcontracted with the Agri Division of Dunlap and Associates, Inc., Manhattan, Kansas, U.S.A., for assistance on the marketing and pricing aspects of this project.

A Phase I report, "Prefeasibility Study for Glass, Building Material and Components Industry" was submitted to NPC in August 1972 Among other items this report recommended that the production of lime and gypsum, in a common facility, be considered during the Phase II investigation.

The Phase II study revealed that the foreseeable market for lime and gypsum was not sufficient to justify the economical production of these materials,

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either separately or in combination. The Contractor therefore decided to report on these two products separately so that it would be more convenient for NPC to refer to either product in the future when the market demand may justify further consideration.

It should be noted that since the Phase I report was accepted by NPC, the United Nations Centre for Housing, Building and Planning has assigned a 2-man consultant team to work with JHC on studying the manufacture and use of building lime and sand-lime bricks.

The map of the Hashemite Kingdom of Jordan, which follows the Summary, shows the principal cities and towns in Jordan together with some of the deposits of limestone which have been investigated by the MRD of NRA.

Although the Phase II study showed that the manufacture of lime was not economically feasible the Contractor has included much of the technical data collected because it is believed that this will be of value in the future when the production of lime is considered again.

The mention of any firm, product or process in this report is not to be construed as a recommendation or endorsement but merely a citation that it is typical in its field.

I. HISTORY AND USES OF LIME

A. History

Lime is apparently one of the oldest basic chemical materials on earth. Archaeologists have discovered primitive kilns which they believe to have been used during the stone age for the burning of lime. Lime plaster, 4500 years old, is still in good condition in some of the Egyptian pyramids.

In some of the earliest kilns alternate layers of limestone and wood were stacked up to heights of three meters, and the sides plastered with wet clay leaving holes at the bottom for air inlets and the top open for exhausting the products of combustion. A later development, called a "bell pit" kiln, was excavated out of solid rock and was operated either intermittently or continuously. Some of the earliest shaft kilns were intermittent in operation and consisted of a "pot" or flare-shaped chamber about six meters in diameter with a height of eight meters. Solid fuel was fired through openings under the kiln.

The production of lime is one of a half dozen basic industries; the others being gas and oil, coal, iron, sulfur and salt. The manufacture of lime is second in tonnage only to sulfuric acid.

B. Uses

The many uses of lime include the following:

- Chemical & Industrial
  - Metallurgy
  - Chemical Manufacturing

- Sanitation
- Water Treatment
- Pulp and Paper
- Ceramics
- Food and Byproducts
- Petroleum

Construction

- Mortar & Plaster
- Sand-Lime Brick
- Soil Stabilization

Agriculture

- Soil Treatment
- Lakes and Ponds

II. MARKET STUDY

Lime is a commonly used material, but due to the widespread occurrence of limestone and the relatively low cost of burned lime it generally cannot be economically transported over long distances. Reference to Table II-1 will show that other countries of the Middle East have sizable lime-production capacities which are not being fully utilized.

Lebanon has an estimated capacity of 350,000 mt per year but uses locally only about 50 000 mt, leaving an export supply of 300,000 mt. Although Lebanon has exported to Syria, Kuwait, Qatar, Iraq, Algeria, Nigeria and Jordan the total foreign market for Lebanese lime amounts to only 200,000 mt annually. Lebanon therefore has an excess lime production capacity of approximately 100,000 mt per year.

Kuwait has a manufacturing capacity of about 12,000 mt per year and is reported to consume only 3,200 mt locally, leaving a sizable excess production capability.

In Saudi Arabia two lime plants in the city of Jeddah alone have an excess capacity of about 18,000 mt per year. A new lime plant, with a capacity of 20,000 mt annually, has been licensed for the city of Riyadh.

Reports indicate that neither Syria or Iraq currently produce lime in sizable amounts, however, Iraq is planning a new facility to produce 30,000 mt per year. Kuwait also has plans to build new manufacturing capacity for an additional 31,000 mt annually.

If petrochemical, aluminum and steel facilities, proposed for the Gulf Area are erected there will be a large increase in lime requirements for these and

Table II-1 - Estimates of Lime Production in Other Middle Eastern Countries

Country	Reported Mfg. Capacity Mt/Yr	Estimated Production Mt/Yr	Estimated Local Consumpation Mt/Yr	Estimated Export Capacity Mt/Yr	Wholesale Price Per mt	Planned Expansion Mt/Yr
Lebanon	350,000	250,000	50,000	300,000	LL 55	None
Kuwait	12,000	3,200	3,200	8,800	$US 41	31,000
Saudi Arabia(1)	33,000	15,000	15,000	18,000	SR 200	20,000
Iraq(2)	---	---	---	---	---	30,000
Syria	N.A.(3)	N.A.	2,500	---	N.A.	---

(1) This information covers production facilities in the Jeddah area. There are at least three additional factories in the eastern part of the country.

(2) Iraq is not known to have any modern lime-production facilities. Statistics indicate that about 300 mt per year are imported. It can be assumed that some very small-scale manufacturing facilities exist in Iraq.

(3) Not available.

auxiliary uses. It is expected, however, that Saudi Arabia and Kuwait will capture most of this new market due to their proximity and plentiful supplies of oil and gas.

Jordan would find it difficult to compete for any of this new export business because of the cost of transportation and lack of low-priced fuel. The feasibility of developing sufficient market demand to justify an economical sized lime production facility will therefore depend almost entirely upon domestic consumption.

Since there has been no appreciable commercial production of lime on the East Bank of the Kingdom of Jordan, the import figures may be taken as a close estimate of past consumption in the country. Table II-2 shows the quantity and value of imports into Jordan each year from 1966 (the first year that statistics were found) through 1972.

Projections were made for future consumption based upon the past usage plus a conservatively anticipated average growth rate of 4% per year for the overall national economy. The Jordan Paper Company, which formerly used lime, reported that it plans to use no more lime in the paper making process. Table II-3 shows the estimated lime consumption in Jordan for the years 1974 through 1985. In addition to the projected rate of increase of 4% per year, this table also shows the estimated amounts of lime which might be used if sand-lime brick were to be manufactured in Jordan. See Table A-1 for calculations on the estimated requirements for lime in sand-lime brick.

TABLE II-2 IMPORTS OF LIME INTO JORDAN BY YEAR

Year	Metric Tons	Value (JD)	Average JD/mt
1966	1,648	14,104	8.558
1967	1,461	12,062	8.256
1968	2,025	16,736	8.265
1969	2,605	21,561	8.277
1970	2,382	19,670	8.258
1971	2,368	20,379	8.606
1972	2,092	19,719	9.462

TABLE II-3 - PROJECTED CONSUMPTION OF HYDRATED LIME IN JORDAN

Year	Actual Imports mt (1)	Average Cost Imports JD/mt (1)	Estimated Consumption without S-L Brick mt (2)	Estimated Requirements For S-L Brick mt (3)	Estimated total Consumption Including S-L Brick mt
1966	1,648	8.558			
1967	1,461	8.256			
1968	2,025	8.265			
1969	2,605	8.277			
1970	2,382	8.258			
1971	2,368	8.606			
1972	2,092	9.426			
1973	- -	- -			
1974	- -	- -			
1975	- -	- -			
1976	- -	- -	2,760	1,600	4,360
1977	- -	- -	2,870	3,400	6,270
1978	- -	- -	2,990	5,500	8,490
1979	- -	- -	3,110	7,600	10,710
1980	- -	- -	3,230	12,200	15,430
1981	- -	- -	3,360	16,900	20,260
1982	- -	- -	3,490	21,900	25,390
1983	- -	- -	3,630	22,800	26,430
1984	- -	- -	3,780	23,700	27,480
1985	- -	- -	3,930	24,700	28,630

(1) As reported by the Department of Statistics, The Hashemite Kingdom of Jordan.

(2) Average of imports for years 1969 through 1972 increased at 4% per year beginning in 1974.

(3) "S-L Brick" means sand-lime brick. See Table A-1 for derivation of requirements.

III. RAW MATERIALS

For the efficient production of good lime, the limestone should be hard and strong and contain a low concentration of impurities. The stone should not be coarsely crystalline because some such stones tend to decrepitate while undergoing calcination thereby causing the voids between the larger stones to become reduced. This in turn causes a restriction in the flow of the products of combustion through the stone in the kiln thereby reducing the rate at which the limestone can be "burned" or calcined. This is especially true of the vertical shaft kiln. Other types such as the rotary kiln would not be seriously affected by decrepitation.

The crushing strength of raw stone varies widely from 80 kg/cm^2 to 1900 kg/cm^2. In order to produce a "pure" chemical lime the stone used should contain 99% calcium carbonate because the percentage of impurities is almost doubled during calcination.

Before calcination in a shaft type kiln the stone must be sized so that all of the lumps are as nearly as possible the same size. A typical size would be 75 to 150 mm. Frequently up to 25% of the quarried material must be discarded as being too fine. Approximately two tons of selected stone must be charged into the kiln in order to produce one ton of quicklime (CaO).

Limestone is rather plentiful in [redacted] and chemical analyses have been made by NRA on samples from a number of locations. The results of some of these tests are given in Table III-1.

TABLE III-1

CHEMICAL ANALYSES OF JORDANIAN LIMESTONES

Constituent	Sample Identification Percent of Constitutent			
	KK2	KK3	S2	S4
Loss on Ignition	41.99	42.72	43.50	43.03
CaO	53.16	54.81	48.55	49.65
MgO	0.60	0.46	6.85	5.49
SiO_2	3.08	0.65	0.76	0.76
Fe_2O_3	0.19	0.19	0.16	0.44
Al_2O_3	0.89	0.34	0.11	0.23
TiO_2	<0.1	<0.1	<0.1	<0.1
SO_3	0.76	0.18	0.40	0.40
P_2O_5	0.07	0.005	0.028	0.09
Totals	100.74	99.35	100.36	100.09

Location of deposits:

KK2 - Diegel Wood north of Jarash

KK3 - Fuheis near cement factory

S2 - From Ras en Naqb

S4 - From Ras en Naqb

The NRA reports that good limestone is also found near Ma'an.

A sample (No. SD-30) of limestone was taken by the Contractor from a quarry in Amman (across the Madaba Road from the mechanized bakery) and given chemical and physical tests. This material was from the location sampled by JCID in connection with the study for the ceramic plant of JCI. The chemical composition is shown in Table III-2 together with the calculated quicklime analysis which was obtained by deducting the loss on ignition. The analysis range of typical commercial quicklimes is also given.

TABLE III-2

CHEMICAL ANALYSIS OF LIMESTONE FROM AMMAN

Constituent	SD-30 Limestone %	SD-30 Calculated Quicklime %	Typical Commercial Quicklimes %
Loss on Ignition	41.57	--	0.5 - 2.4
CaO	51.61	89.45	93.0 - 98.0
MgO	0.59	1.02	0.3 - 2.5
SiO_2	4.66	8.07	0.2 - 1.5
Fe_2O_3	0.40	0.69	0.1 - 0.4
Al_2O_3) TiO_2)	0.69	1.19	0.1 - 0.5
Totals	99.52	100.42	

The Contractor also conducted a crushing test on a 5-cm cube sawed from a piece of Amman limestone. This showed a crushing strength of 312 kg/cm^2.

A sample of the Amman limestone (SD-30) was fired at 1038° C. and no decrepitation was evident. This stone is rather fine-grained and therefore decrepitation was not expected to be a problem.

The supply of limestone in Jordan is not only plentiful but most deposits are reasonably free from impurities. The iron oxide (Fe_2O_3) varies from 0.19% to 0.44% in the five (5) samples analyzed and it is expected that some of this would be removed during the hydration and subsequent size classification process. In any case the amount of iron in the limestone should present no difficulties if the lime is to be used principally in the building industry or for general purposes such as sanitation and water treatment.

Reference to Tables III-1 and -2 shows that several varieties of limestone are found in Jordan ranging from a very low magnesia stone with 0.6% MgO up to moderately low with 6.85% MgO. There are Jordanian deposits of dolomitic limestone containing as much as 19% magnesia.

IV. DESCRIPTION OF PROCESS

Reference to Figure IV-1, Process Flow Chart will show the various operations required to produce lime.

Theoretically lime is produced from limestone by the following rather simple chemical reaction:

$$CaCO_3 + \text{Heat} \rightleftharpoons CaO + CO_2$$

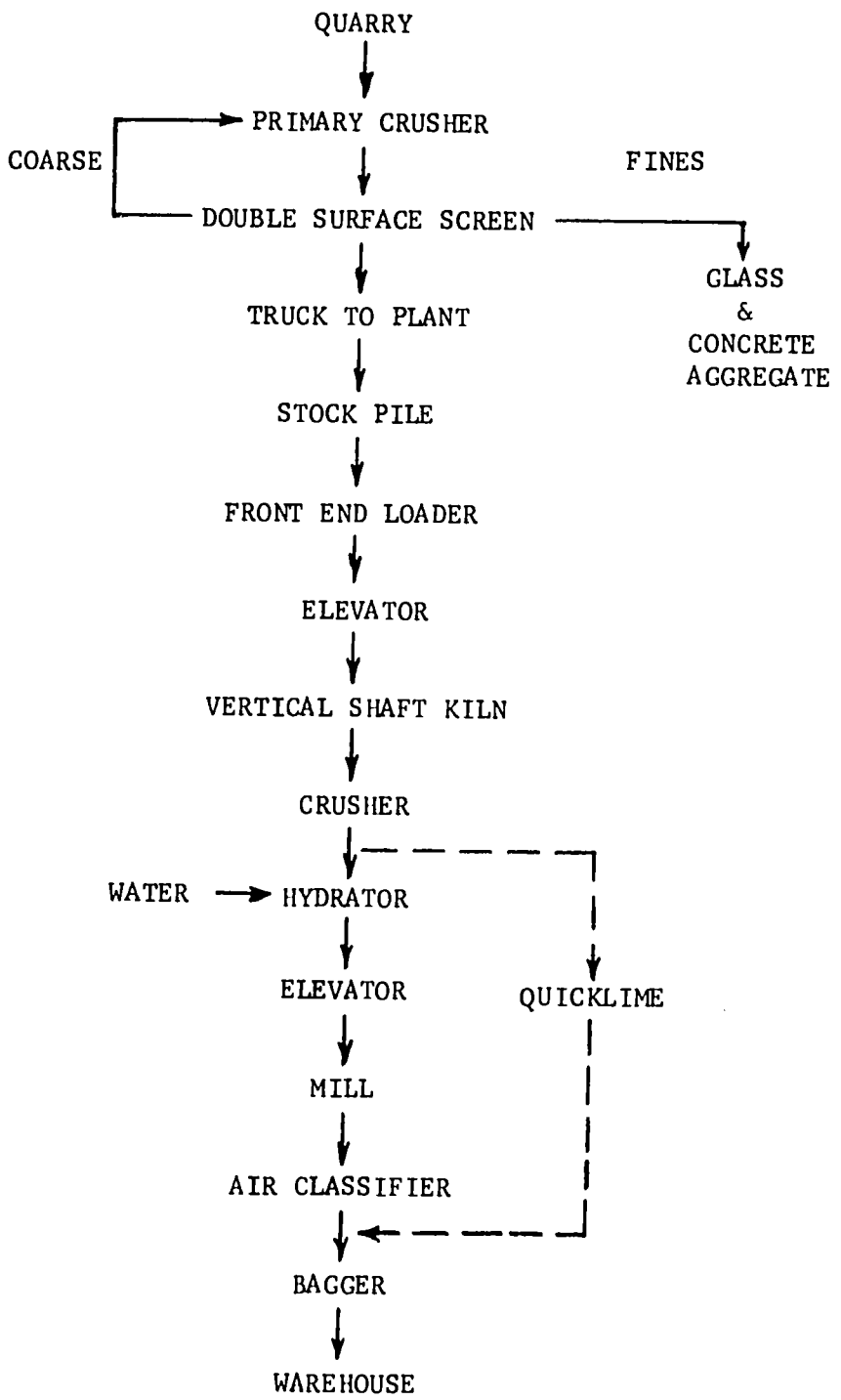
Calcium Carbonate	Calcium Oxide	Carbon Dioxide
100 Units by Weight	56 Units	44 Units

Actually the manufacture of lime begins with the quarrying of the raw limestone. The combination of manpower and mechanization currently being used in Jordan to produce limestone aggregate should prove to be economical for mining stone to be burned into lime. Depending upon (1) the proximity of the calcining plant to the quarry, (2) the disposition of the stone fines and (3) prevailing winds and dust conditions it is probably advisable in most cases to crush and size the stone at the quarry.

The sized stone is trucked to the calcining plant and stockpiled. This raw material can be moved to the charging platform of the vertical shaft kiln by means of a bucket elevator or skip hoist. If manpower is dependable and in good supply the stone can be charged by hand into the shaft kiln.

The kiln is tended on each shift by one fireman who watches for such occurrences as stone falling into the fire boxes and for stone "arching" or hanging up in the kiln. The arching requires that the stone be dislodged with a bar inserted through "poke" holes in the wall of the kiln. The typical temperature for calcining ranges from 900 to 1,350^{o} C. and the heat required may vary from 800,000 to 2,800,000 kg cal/mt.

FIGURE IV-1. PROCESS FLOW CHART



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Calcination of limestone in a vertical shaft kiln is essentially a continuous process, the burned lime (quick lime) being removed periodically in batches from the gates at the lower part of the kiln. A discussion of the advantages and disadvantages of various types of kilns is given in Chapter V. This Description of Process is based upon the vertical shaft kiln because it is believed to be the most suitable for beginning production on a moderate scale.

The quick lime is transported to a crusher via hand carts, conveyor or motor truck depending upon the size of the operation and the availability of manpower. The quick lime is crushed to a lump size of about 15 mm and then stored in a bin above the hydrator.

The following equation shows the chemical reaction involved in the hydration of quick lime:

$$CaO + \text{Water} \rightarrow Ca(OH)_2$$

Calcium Oxide		Calcium Hydroxide
56 Units by Weight	18 Units	74 Units

Efficient continuous hydrating equipment adds the proper amount of water to the quick lime, mixes and agitates the materials and holds the temperature within proper operating range. Preheated water is generally used to accelerate the hydration; however, once begun, the process itself generates considerable heat. If the temperature is allowed to exceed 100°C. the hydration may be retarded; therefore, the equipment must be capable of controlling the temperature to assure complete conversion. Theoretically only 24.5% water is required for the hydration process but in actual practice 50 to 65% is added.

To obtain a good uniform product the hydrated lime is usually milled and then air classified. During this classification much of the impurities such as uncalcined and unhydrated particles are removed by gravity and any excess moisture from the hydration process is also removed. A typical hydrate of lime would have the chemical analysis shown in Table IV-1.

TABLE IV-1 TYPICAL CHEMICAL ANALYSIS OF COMMERCIAL HYDRATED LIME

Constituent	%
CaO	71 - 74
MgO	0.5 - 2
H_2O	24 - 25
CO_2	0.3 - 0.7
SiO_2	0.2 - 0.5
Al_2O_3	0.1 - 0.3

A good hydrate should have no more than 0.5% on 30-mesh nor more than 15% on a 200-mesh sieve.

Following the air classification the hydrate is ready for packing. It is usually packed in multi-layer paper bags containing 33-1/3 kilograms. This product may be preserved indefinitely in paper bags if stored in a cool dry place. As indicated on the flow diagram the material quick lime can be removed from the process before hydration takes place; however, most of the lime is sold as the hydrate.

V. KILN COMPARISONS

The modern kilns available for calcining limestone may be grouped into three general classifications: (1) vertical shaft, (2) rotary and (3) special types.

A. Vertical Shaft

This is the oldest type of kiln now in use and its general operation was described in Chapter IV. The diameter of a simple vertical shaft kiln is limited by the ability of the combustion equipment to force heat into the center of the kiln. A number of proprietary models have evolved which apply heat directly to the center of the kiln. Other types claim fuel savings by recirculation of the products of combustion.

Shaft kilns can produce from 40 up to 200 mt per day, the most economical units naturally being those near the top of the range. A typical plant might consist of three vertical kilns and two continuous hydrators to produce 200 mt per 24 hours. A plant could be operated with a single kiln but the scheduling of production, maintenance and shipping would be less efficient than that of a multikiln facility.

Advantages of Vertical Type

Higher fuel efficiency.

Lower capital investment.

Simplicity in construction and operation.

Generally smaller capacity of individual units which gives more flexibility of operation.

Large "turndown" range - down to 1/10 of full capacity.

Minimum degredation of lumps due to slow movement in kiln.

Disadvantages of Vertical Type

Higher labor cost per unit of product.

Quality of product not consistently as good as that from the rotary kiln.

Larger feed size results in more wasted raw materials (fines).

B. Rotary Kiln

This type is similar in construction and operation to the rotary kilns used to produce Portland cement. This type is used when a large volume of lime is required on a continuous basis. Some of the larger units can produce up to 550 mt per day. The advantages of the rotary style over the vertical shaft kiln are (1) they supply good uniform quality lime such as that required for a chemical operation and (2) they can treat fine particle sizes of stone in the range of 6 to 60 mm. The chief disadvantages are (1) a rather large investment, (2) an inflexible operation regarding quantity of product and economical unit costs and (3) higher unit fuel costs than shaft type.

C. Special Types

There are a number of special types of lime burning kilns that are in use around the world. Three typical varities are described below:

1. Fluo-Solids

This kiln uses a fine-grained raw material which is air-suspended during the calcination. One advantage of this kiln is that it can process coarse crystalline stone which decrepitates during the burning. The capacity ranges from 100 to 200 mt per day.

2. Rotating Hearth

This kiln utilizes a hearth rotating inside a stationary housing. It can handle a wide variety of feed sizes and has a high degree of temperature control. Kilns of this type producing 100 to 200 mt per day are in use.

3. Vibrating Hearth

This type is not in wide use. It moves the material from higher to lower levels by horizontal movement of various hearths. It can accept smaller particle sizes than shaft kilns.

Maintenance

Due to wear on the refractory surfaces and some of the mechanical parts most lime kilns require two shutdowns, of about 15 days each, per year. Therefore, the capacity should be rated on the basis of 335 operating days per year.

VI. ESTIMATED CAPITAL COST

A. Quarry Equipment

Due to the small tonnage required in early years the limestone should be purchased from a quarrying firm and delivered to the calcining plant, properly sized.

B. Calcining Plant Equipment

	JD	
1 Front end loader	9,500	
1 Bucket elevator	2,300	
1 Shaft kiln complete	48,400	
1 Impact crusher	2,400	
1 Hydrator, mill & air classifier	16,200	
1 Bagging equipment & dust collection	6,500	
	85,300	
Ocean freight	10,000	
Subtotal		95,300
Building for hydrator, bagger & warehouse		
60 m x 15 m x JD 15 =	13,500	
Misc. equipment	4,000	
Spares	1,000	
Subtotal		113,800
Freight & erection		45,000
Total Plant Equip.		JD 158,800

Fifteen year depreciation on plant:

$$\text{JD } \frac{158{,}800}{15} = \text{JD } 10{,}590/\text{yr.}$$

C. Working Capital

		JD
1 Month manufacturing cost	(See Chap. VII)	4,150
1 Month finished goods inventory		
250 mt @ JD 11		2,750
		6,900

D. Start Up & Training Costs

Foreign Technicians in Jordan:		
2 Process Engineers @ JD 390/month		
for 2 months	=	1,560
Living expenses @ JD 5.350/day		
2 x 2 x 30 x 5.350	=	640
2 Round trip air tickets		
at JD 250	=	500
		JD 2,700

E. Total Capital Requirement

Plant & equipment		158,800
Training cost		2,700
Contingency 5%		8,000
Working Capital		6,900
	Total	176,400

VII. FINANCIAL ANALYSIS

A. Estimated Sales

Average Projected Annual Sales 1976-1980 is 2992 mt (assume 3000 mt).

Estimated selling price for 1976 is based upon the average 1972 price of JD 9.426/mt escalated at 5% per year or JD 10.912 rounded to JD 11.000.

Estimated Annual Gross Sales:

3000 x 11.000 = JD 33,000/yr.

B. Estimated Manufacturing Cost

		JD
1.	Raw limestone, delivered	2,320
2.	Direct labor	9,900
3.	Management personnel	8,990
4.	Depreciation	10,590
5.	Fuel	3,960
6.	Electric power	4,820
7.	Water	220
8.	Paper Bags	4,500
9.	General supplies	450
10.	Misc., Insurance, etc.	4,000
	Total	49,750

NOTE: No estimate was made for overhead items such as sales costs.

C. Estimated Return on Investment

Estimated Annual Sales		JD 33,000
Estimated Total Capital Requirements	(See Chapter VI)	176,400
Estimated Manufacturing Cost		49,750

$$\frac{(33,000 - 49,750) \times 100}{176,400} \qquad -9.5\% \text{ (Loss)}$$

To break even with no charges for interest on borrowed money:

$$\frac{49,750}{11.000} = 4,520 \text{ mt/year which would be required in sales}$$

D. Details Manufacturing Cost

1. Purchase of raw limestone

Assume purchase of quarried stone since initial requirements are small.

Hydrate required 3000 mt/yr.

56/74 x 3000 = 2270 mt CaO

Approximately two mt of stone are required for one mt CaO.

2 x 2270 = 4540 mt stone delivered.

Assume that fines can be profitably disposed of.

Estimated cost of sized stone delivered - JD 0.510/mt.

4540 x 0.510 = JD 2320/yr.

2. Direct Labor

		Monthly Rate JD	Annual Cost JD
4	Kiln loader/tender	50	2,400
4	Hydrator/mill operator	45	2,160
2	Bagging/warehouse	25	600
1	Maintenance, leader	50	600
4	Maintenance, shift	45	2,160
1	Janitor	20	240
1	Spare laborer	25	300
	Basic Labor Total		8,460
	17% Fringe Costs		1,440
		Total	9,900

3. Management Personnel

1	Plant manager	225	2,700
1	Office manager	75	900
4	Shift supervisors	75	3,600
1	Clerk	40	480
	Basic Total		7,680
	17% Fringe Costs		1,310
		Total	8,990

4. Depreciation

(See Chapter VI) JD 10,590

5. Fuel

Estimate 9,000,000 Btu/mt of CaO

No. 5 oil in Jordan is rated at 19,000 Btu/Lb.

19,000 x 2.2046 = 41,887.4 Btu/kg

Estimate cost of oil at JD 8.160/mt

$$\frac{9,000,000}{41,887.4 \times 1000} = 0.214 \quad \text{mt oil/mt lime}$$

$$3000 \text{ mt hydrate} \times \frac{56}{74} = 2270 \text{ mt CaO}$$

2270 x 0.214 x 8.16 = JD 3960/yr.

6. Electric Power

Estimate 40 kw

40 x 24 hr. x 335 days = 321,600 kwh

Estimate average cost of JD 0.015/kwh

321,600 x 0.015 = JD 4820/yr.

7. Water

0.45 mt water required/mt hydrate

0.45 x 3,000 = 1350 mt

For personnel

30 men x 0.05 m^3 x 360 days = 540 mt

Other - estimate 1,000 mt

Total 2,890 mt

Estimated cost JD 0.075/mt or m^3

2,890 x 0.075 = JD 220/yr.

8. Paper Bags

Estimated at JD 0.050 each

$$\frac{3{,}000{,}000 \times 0.050}{33.3 \text{ kg each}} = \text{JD } 4500/\text{year}$$

9. Supplies

Estimated at JD 0.150/mt

$$3000 \times 0.150 = \text{JD } 450$$

E. Discussion

The capital cost estimate is based on a plant with a capacity of 40 mt per day which is considered to be the smallest feasible plant from the standpoint of operating economy. The projected basic market demand for ordinary usage does not exceed 12 mt per day until after 1985, therefore additional uses will have to be developed before a minimum sized plant will be feasible.

The basic projection does not include the lime that might be required if sand-lime bricks were to be manufactured. If only small percentages of building construction in Jordan were to use sand-lime bricks, it is anticipated that the proposed lime plant would operate at the break even point of 4,520 mt within two years.

APPENDIX

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(Table A-1)

VIII. RECOMMENDATIONS

It is recommended that a lime production facility not be built in the Kingdom of Jordan at this time. This Phase II Study shows that the minimum-sized plant, considered feasible, would operate at a loss for a number of years.

As a result of additional interviews with Jordanian building contractors, subsequent to the initial market studies in 1971, it is not believed that lime plaster will gain appreciable acceptance in the near future. The consumption of lime for plaster was therefore not included in the latest market projection

Barring the establishment of new industries using sizeable quantities of lime, it is believed that a new lime plant will not be justified for perhaps the next ten years. As mentioned earlier, during the market discussions in Chapter II, the sand-lime brick industry is one which would be a major consumer of hydrated lime. Certain food processing industries, such as citrus and sugar, would also use quantities of lime.

The JHC-UNDP is in the process of implementing a study of the production of building lime and sand-lime bricks in Jordan. This project will utilize imported slag-lime brick to erect a number of dwelling units and this appears to be an excellent opportunity to compare the costs of this material in place with that of others that JHC has studied in the past. The degree of public acceptance can also be determined and this, with the cost comparisons, will help to predict the future volume of sand-lime brick construction that can be anticipated in Jordan.

SAND-LIME BRICK

Description of Process

Sand-lime brick are composed chiefly of two raw materials. The main portion of the body is a sharp-grained quartz sand, containing at least 90% SiO_2. This sand should all pass a 20 mesh screen and 75 to 80% by weight should be retained on 100 mesh. In this connection it should be noted that some of the waste sand from the proposed Jordanian Sheet Glass plant probably could be used in sand-lime brick. The sand which is oversize and undersize for the glass operation, and yet is suitable for sand-lime brick, may amount to as much as 25% of all of the sand that is quarried for glass manufacturing.

The lime used should be a high-calcium hydrate. The lime must be fully hydrated before the bricks are formed otherwise subsequent hydration will cause expansion and rupturing of the brick. For this reason magnesian and dolomitic limes are not suitable because they hydrate too slowly. The lime should not contain more than 1.5% MgO. The quantity of hydrated lime used may vary from 6 to 12%.

After the ingredients are batched, blended and aged, to assure complete hydration, the brick are formed by pressing. The pressed brick are placed in autoclave chambers and steam cured for a period of 4 to 8 hours after which they may be shipped to the user.

Uses of Slag-Lime Bricks

These bricks can be used in almost any location where fired clay bricks might be specified. This includes applications that are above ground or below ground level.

Re ences on Sand-Lime Brick

Boynton — "Chemistry and Technology of Lime and Limestone", Wiley, New York, 1966 pp. 375-376.

Dobson — "Manufacture of Bricks and Tiles", Technical Press, London, 1936, pp. 168-170.

Ladoo & Myers — "Non Metallic Metals", McGraw Hill, New York, 1951, pp. 470-474.

Searle — "Limestone and Its Products", Ernest Benn, London, 1935, pp. 584-587.

Searle — "Modern Brickmaking", Ernest Benn, London, 1956, pp. 671-674.

Stowell — "Limestone As a Raw Material In Industry", Oxford University Press, London, 1963 pp. 51-52.

-- "Engineering Materials", Pitman, New York, 1958, pp. 184-185.

-- "Lime and Limestone", Encyclopedia Chemical Technology, 1967, Vol. 12 p. 453.

-- Technical brochures from Atlas-Mak Maschinenbau Gmbh, Werk Atlas, 28 Brennen, West Germany.

Specifications

It is widely accepted that sand-lime bricks should meet the specifications set forth in the British Standard Specification No. 187.

TABLE A-1 PROJECTED CONSUMPTION OF HYDRATED LIME IN MANUFACTURE OF SAND-LIME BRICK IN JORDAN

Year	Building Construction Low Projection M^2 (1)	Estimated Share S-L Brick %	Construction Using S-L Brick M^2	S-L Brick Projection mt (2)	Hydrated Lime Required mt (3)
1976	580,000	5	29,000	16,600	1,600
1977	610,000	10	61,000	34,900	3,400
1978	660,000	15	99,000	56,600	5,500
1979	680,000	20	136,000	77,800	7,600
1980	730,000	30	219,000	125,300	12,200
1981	759,200	40	303,700	173,700	16,900
1982	789,600	50	394,800	225,800	21,900
1983	821,200	50	410,600	234,900	22,800
1984	854,000	50	427,000	244,200	23,700
1985	888,200	50	444,100	254,000	24,700

(1) See Table VI-7, Page VI-20, Part No. 1, Phase I Report of Feasibility Study, "Glass, Building Material and Components Industry", August 1972, for years up to 1981. Projected at a uniform rate of increase of 4% per year for years beginning 1981.

(2) Based on average of 572 kg of brick/M^2 floor area. Developed from data supplied in connection with the JHC-UNDP pilot project for sand-lime brick.

(3) Based on 8% manufacturing loss and 7% addition of quick lime resulting in an overall requirement of 9.72% by weight of hydrated lime.

NOTE: The consumption of sand-lime bricks in Jordan and hence the quantity of hydrated lime to be used for this purpose will be difficult to predict accurately until after the sand-lime brick project is completed by JHC.