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POSSIBLE PRODUCTION OF CALCIUM SILICATE BUILDING PRODUCTS FROM FELDSPAR PLANT TAILINGS

by

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Introduction

Calcium silicate bonded building products consist of highly siliceous sand material bonded together with hydrated calcium silicates. It was originally proposed for the Spruce Pine tailings project to try to make calcium silicate building material only out of high quartz products from reprocessing of tailings, because it is reported in literature and by other investigators that feldspar in the sand has a detrimental effect on the sand lime brick quality. The reaction between lime and feldspar releases soluble Na and K-salts and causes efflorescence and lower strength in bricks. Since high quartz sand from tailings reprocessing was not available, a few test series were run to find out what kind of bricks could be expected from unprocessed tailings with high feldspar content when used as they are, or after grinding, or when used in mixtures of both. Two different calcium silicate products were investigated, pressed sand lime bricks, and foamed light weight building block or panel material. The tailings materials used were Lawson United Feldspar and Mineral Company tailings, coarse tailings, and fine filter cake from International Minerals and Chemical Corporation's feldspar mine at Spruce Pine, North Carolina. Tailings from Feldspar Corporation were not tested, because this company is in the process of installing facilities to reprocess their tailings for feldspar and quartz recovery as recommended in Feldspar Tailings Report No. 3. Silica from Feldspar Corporation's reprocessing plant should be a good calcium-silicate raw material, and should be tested later when available. The pertinent data of tailings and lime samples used are presented on Table 1 and 2.

Sand Lime Brick from Feldspar Tailings

Sand lime brick are manufactured by mixing of quicklime or hydrated lime and high silica sand in a ratio of 85 to 95 percent sand to 15 to 5 percent lime and adjusting of moisture for good hydration and for easy pressing and forming. The moist sand lime mixture is pressed at 4,000 to 8,000 P.S.I., and steam cured in autoclaves at pressures of up to 275 P.S.I. for periods of four to five hours. Hydrated calcium silicates form at these temperatures and pressures in steam atmosphere through the reaction of the cationic quartz with the anionic lime. The hydrated calcium silicates, mainly monocalcium silicate hydrate, called tobermorit, is the same binding agent as is found in Portland cements. In the case of Portland cement, anion and cation are provided in the cement and aggregate is only a filler; in the case of sand lime bricks, the quartz aggregate reacts with the lime and particle to particle cementation by tobermorit takes place. Table 3 gives the general reactions that take place in reactor and autoclave.

Sand lime brick manufacturing is not new, but the technical aspects of consistent economic production have been solved only in recent years in Europe where sand lime bricks are very popular. Sand lime bricks can be made with high compressive strength (A.S.T.M.

requires 4,500 P.S.I. average of 5 bricks for grade SW), low adsorption, with high resistance to freeze and thaw; in colors of natural silver gray or colored in pastel shades. The bricks can be split for a textured surface. The bricks retain their exact dimensions during autoclave curing which makes complete automation of the brick making process possible. The bricks can be shipped immediately after removal from the pressure vessel. Figure 1 shows a schematic flowsheet of a sand lime brick plant. Plant and production cost estimates are given as follows.

Capital and Operating Cost for a Sand Lime Brick Plant

Capital Cost - 2 press plants producing 30 million bricks per year during a two shift operation. $800-900,000

Material Requirements and Other Cost Per 1,000 Bricks -

Sand from Spruce Pine, 2.5 tons @ $1	$2.50
Lime from Knoxville, 600 lbs. @ $18/ton	5.40
Fuel, 1.6 mi. B.T.U.	1.60
Lights and Power, 20 kw hrs.	0.20
Total labor and maintenance, 2 man hrs.	5.00
Mold cost	1.25
Depreciation, 10 years @ 30 mi. bricks/year	3.00
Total cost per 1,000 bricks -	$18.95

A plant site of at least 2 acres and a total power supply of at least 200 HP is required.

Sand Lime Brick Test Work

Tailings material, quicklime or hydrate and water were mixed throughly by hand in plastic bags, and kept over night before pressing. 20 bricks were pressed at either 6,000 or 8,000 P.S.I. in a one by two inch stainless steel die on the Laboratory Carver Press. The bricks were autoclaved for four hours at 275 P.S.I. saturated steam in a Cenco A.S.T.M. Autoclave. Ten bricks of each test run were crushed in the Carver Press to determine the average compressive strength. For cold water and boiling water absorption tests, three to five bricks of each run were submerged for 24 hours in water at room temperature and for five hours in boiling water. The main variable in the few test series were the lime sand ratio, different tailings samples as is, mixtures of tailings sand as is and ground, and the forming pressure either 6,000 or 8,000 P.S.I. The test results are reported on Table 4.

It is to be noticed that most brick made meet the required A.S.T.M. compressive strength of SW bricks of 4,500 P.S.I. There are no A.S.T.M. requirements for adsorption measurements on sand lime bricks, and when testing very small test bricks, as was done at the Asheville Laboratory, because of equipment limitations, high absorption values are usually obtained. The absorption values obtained and reported are probably higher than what can be expected with standard size bricks. It was suspected that soluble Na and K-salts would be released by the reaction of lime on feldspar and that the salts would show in weather-exposed-bricks as efflorescence. Chemical analysis of boiling water-leached brick material showed only very small amounts of soluble Na_2O and K_2C in the water. (A maximum of 0.33 percent Na_2O and 0.10 percent K_2O). Only extensive freeze and thaw tests and atmospheric weathering tests can give the final answer. Literature research and correspondence with knowledgeable people in the sand lime brick field may shed more light on this problem.

Foamed Lightweight Building Materials from Feldspar Tailings.

Foamed lightweight building materials are manufactured by mixing fine ground siliceous sands with quicklime or hydrated lime and water. The mixture is intensively mixed and aluminum powder is added to form hydrogen bubbles in the mixture. The material is poured into forms, where it further expands and solidifies. The forms are then removed and the final hardening process is conducted in autoclaves in the same way that sand lime bricks are hardened. The properties of lightweight calcium silicate building products are strength with low weight and the possibility to manufacture fairly large building elements that can be sawed, nailed, drilled, grooved and tonged similar to wood, but have the advantage of resistance to weather and decay, and are termite proof.

The foamed calcium silicate industry is highly developed in Sweden and Germany, and it is rapidly expanding in Europe. In a short test series, a few samples of light weight foamed calcium silicate were made using Lawson United Feldspar Company's tailings, ground and unground, quicklime or hydrated lime and small amounts of white cement to accelerate initial setting in forms. Quite a few mixing tests had to be conducted to obtain the desired low bulk weights of less than 62.4 lb/cb.ft. Blocks of good strength and appearance were obtained with 58 lb/cb.ft. The blocks were cured in the Cenco Laboratory Autoclave in steam atmosphere for four hours at 275 P.S.I. The compressive strength could not be determined, but should be around 500-1,000 P.S.I, which would be sufficient for wall partitions and nonstructural building requirements. Table 5 presents the results of test work at the Asheville Laboratory. Because of early termination of the Spruce Pine Tailings Project, only a very few tests had been conducted.

Conclusion

Laboratory test work showed that sand lime bricks meeting A.S.T.M. SW strength requirements could be made from Spruce Pine tailings inspite of the high feldspar content. Weathering tests for efflorescence should be made before final conclusions can be drawn; it is also advisable to run absorption tests on full size bricks.

Laboratory test work produced interesting samples of light weight foamed calcium silicate building material. More Laboratory test work is needed to gain information about best consistent manufacturing conditions.

Table 1

Samples Used for Sand Lime Brick and Light Weight Brick Test Work

A. Sand Samples

Company -	Lawson United		International Minerals Co.			
Sample Designation -	LT	LT-200	IMC-C	IMC-C-200	IMC-FC	IMC-FC-200
Material -	Tailings As Is	Tailings Ground to -200 Mesh	Coarse Tailings	Coarse T. Ground to -200 Mesh	Filter Cake As Is	Filter Cake Ground to -200 Mesh
Size Analysis - Tyler Mesh:						
+20	2.4	-	1.0	-	-	-
-20+28	2.8	-	12.2	-	0.2	-
-28+35	8.0	-	19.1	-	0.1	-
-35+48	10.0	-	18.1	-	0.4	-
-48+65	11.6	-	14.6	-	0.5	-
-65+100	12.0	-	12.0	-	1.1	-
-100+150	11.9	-	8.4	-	2.4	-
-150+200	11.0	-	6.1	-	6.0	-
-200+270	7.2	-	3.0	-	9.8	-
-270+325	6.7	6.4	2.0	28.8	12.6	9.2
-325+400	2.8	93.6	0.7	71.2	6.4	90.8
-400	13.7	-	1.8	-	59.0	-
Chemical Analysis:						
% K_2O	2.90	x*	2.70	x	4.20	x
% Na_2O	3.68	x	2.89	x	4.00	x
% CaO	1.02	x	0.72	x	1.17	x
% MgO	-	-	-	-	-	-
% Fe_2O_3	0.60	x	0.66	x	0.93	x
% SiO_2	77.8	x	81.0	x	69.3	x
% Al_2O_3	13.5	x	11.5	x	18.6	x
% Ign. Loss	0.54	x	0.40	x	1.63	x
Approximate Mineral Composition:						
Potash Spar	13	x	11	x	19	x
Soda Spar	31	x	23	x	33	x
Lime Spar	4	x	3	x	6	x
Muscovite	6	x	5	x	7	x
Clay	4	x	2	x	8	x
Quartz	43	x	56	x	28	x

*x = Same as unground

Table 2

B. Lime Samples

Company -	Quicklime Williams, Knoxville	Hydrate Foote, Knoxville
Size Analysis - Tyler Mesh:		
Passing 200 mesh	98%	99.5
Passing 325 mesh	-	95.9
Chemical Analysis:		
% CaO	96.4	74.6
% MgO	0.6	0.5
% SiO_2	0.3	0.2
% Fe_2O_3	0.2	0.1
% Al_2O_3	0.4	0.3
% Ign. Loss	1.7	24.3

Table 3

Sand Lime Brick Reaction

1. Hydrating of Raw Material:

CaO	+	SiO_2	+	H_2O	gives	$Ca(OH)_2$	+	SiO_2	+	Heat
Quicklime		Sand		Water		Hydrate		Sand		

2. Pressing (4,000-8,000 P.S.I.)

3. Hardening in Steam Pressure Vessel:

$Ca(OH)_2$	+	SiO_2	+	H_2O	4-8 hrs. at	gives	$(CaO)x$	$(SiO_2)y$	$(H_2O)z$
Hydrate		Sand		Water	150-175 P.S.I.		Monocalcium	Hydrate	Silicate

Table 4

Sand Lime Brick Test Results

Test	Sand 1 Material	Sand 1 Grams	Sand 2 Material	Sand 2 Grams	Lime Grams	H_2O Grams	Pressed at P.S.I.	Remarks about Pressings
LT-1	LT	425	LT-200	425	150 CaO	100	6,000	Good shapes
LT-2	LT	425	LT-200	425	210 Ca(OH)	50	6,000	Good shapes
IT-3	IMC-C	425	IMC-C-200	425	150 CaO	120	6,000	Good shapes
IT-4	IMC-C	850	-	-	150 CaO	120	6,000	Good shapes
IT-5	IMC-C	425	IMC-C-200	425	150 CaO	120	8,000	Good shapes
IT-6	IMC-C	850	-	-	150 CaO	120	8,000	Good shapes
IT-7	IMC-FC	425	IMC-FC-200	425	150 CaO	120	6,000	Good shapes
IT-7A	IMC-FC	425	IMC-FC-200	425	150 CaO	150	6,000	Hydrated 60 PSI, 30 minutes.
IT-7B	IMC-FC	425	IMC-FC-200	425	150 CaO	150	6,000	Good shapes
IT-8	IMC-FC	850	-	-	150 CaO	150	6,000	Good shapes
IT-9	IMC-C	900	-	-	100 CaO	120	6,000	18 out of 20 bricks
IT-9A	IMC-C	900	-	-	100 CaO	120	6,000	Hydrated 60 PSI, 30 minutes.
IT-9B	IMC-C	900	-	-	100 CaO	120	6,000	Hydrated 60 PSI, 30 minutes.
IT-10	IMC-C	450	IMC-C-200	450	100 CaO	120	6,000	Good shapes
IT-11	IMC-C	425	IMC-FC	425	150 CaO	120	6,000	
IT-12	IMC-C	900	-	-	100	120	8,000	All bricks
LT-13	LT	900	-	-	100	100	8,000	Disintegrated in
LT-14	LT	850	-	-	150	120	6,000	Not run
LT-15	LT	850	-	-	150	120	8,000	Not run
LT-16	LT	900	-	-	100	100	6,000	Not run
LT-17	LT	900	-	-	143 $Ca(OH)_2$	70	6,000	
LT-17A	LT	850	-	-	210 $Ca(OH)_2$	50	6,000	

LT = Lawson Tailings as is.
LT-200 = Lawson Tailings ground to minus 200 mesh.
IMC-C = International Minerals and Chemicals Corporation coarse tailings as is.
IMC-C-200 = International Minerals & Chemicals Corp. coarse tailings ground to -200 mesh
IMC-FC = International Minerals & Chemicals Corp. filter cake as is.
IMC-FC-100 = International Minerals & Chemicals Corp. filter cake ground to -200 mesh.

Cured at Hrs.-P.S.I.	Compressive Strength PSI	Absorption Cold	Absorption Boiling	Apparent SPG	Remarks
4 - 275	6,100	16.6	16.6	1.80	
4 - 275	4,800	19.4	19.4	1.73	
4 - 275	8,000+	14.9	15.1	1.90	
4 - 275	7,125	12.4	12.5	1.97	
4 - 275	8,000+	14.1	15.0	1.89	
4 - 275	6,813	11.2	11.5	1.98	
4 - 275	-	-	-	-	8 of 20 cracked in autoclave
4 - 275	2,200	Let stand too long dry			1 of 10 cracked in autoclave
4 - 275	1,850	20.3	20.9	1.63	
4 - 275	5,937	17.8	18.1	1.73	
cracked in autoclave					
4 - 275	All bricks cracked in autoclave				
4 - 275	2,765	11.9	14.2	1.97	7 of 20 cracked in autoclave
4 - 275	6,237	9.6	9.3	1.90	
4 - 275	5,012	8.2	8.9	1.93	
broken - water in pan after pressing.					
autoclave because of high water level.					
-	-	-	-	-	
-	-	-	-	-	
-	-	-	-	-	
4 - 275	2,750	15.0	15.3	1.86	
4 - 275	2,275	14.5	15.5	1.93	

Table 5

Foamed Calcium Silicate Test Results

Test 3	Sand 1		Sand 2		Cement	Lime	H_2O	Al
	Material	Grams	Material	Grams	Grams	Grams	Grams	Grams
F-1	Law T	2,000	-	-	300	-	1,100	0.5
F-2	-	-	Law T-200	2,000	-	300 CaO	1,100	0.5
F-3	Law T	1,000	Law T-200	1,000	860	-	1,080	0.75
F-4	Law T	1,000	Law T-200	1,000	800	100 CaO	1,040	1.5
F-5	Law T	1,000	Law T-200	1,000	100	300 CaO	1,040	3.0
F-6	Law T	1,000	Law T-200	1,000	100	400 CaO	1,100	1.0
F-7	Law T	1,000	Law T-200	1,000	100	400 CaO	1,100	1.5
F-8	Law T	1,000	Law T-200	1,000	100	400 CaO	1,100	2.0
F-9	Law T	1,000	Law T-200	1,000	100	400 CaO	1,300	1.0
F-9A	Law T	1,000	Law T-200	1,000	100	400 CaO	1,500	1.0
F-9B	Law T	1,000	Law T-200	1,000	100	400 CaO	1,700	1.0
F-12	Law T	1,000	Law T-200	1,000	100	570 $Ca(OH)_2$	1,200	1.0
F-13	Law T	2,000	-	-	100	570	1,200	1.0
F-14	Law T	3,000	Law T-200	3,000	300	1,710 $Ca(OH)_2$	3.600	3.0
F-15	Law T	2,000	Law T-200	2,000	200	1,140 $Ca(OH)_2$	2,400	2.0
F-16	Law T	-	Law T-200	4,000	200	1,140 $Ca(OH)_2$	2,400	2.0

Law T = Lawson Tailings as is.
Law T-200 = Lawson Tailings ground to minus 200 mesh.

Mixing Time						
Mixer Time	Wet	After Al Added	App. SPG	Remarks Raw	Cured Hrs.-PSI	Remarks Cured
Paddle	10 min.	2 min.	1.28	Fairly strong	-	-
Paddle	10 min.	2 min.	1.13	Very soft	4 - 275	-
Paddle	10 min.	2 min.	1.32	-	Under water 2 wks., strong	
Paddle	10 min.	5 min.	-	-	-	-
Paddle	10 min.	5 min.	-	-	4 - 275	Cracked-app. not hydrated
Paddle	15 min.	2 min.	-	Did not expand too good - not enough H_2O		
Paddle	15 min.	2 min.	1.17	Did not expand too good - not enough H_2O		
Paddle	15 min.	2 min.	-	Did not expand too good - not enough H_2O		
Paddle	15 min.	1 min.	-	-	-	Broke
Paddle	15 min.	1 min.	0.98	-	-	Large cracks
Paddle	15 min.	1 min.	0.73	-	-	Some cracks, fair
Paddle	15 min.	30 sec.fast, 30 sec.slow	1.00	Good expansion	4 - 275	Some cracks in upper piece
Paddle	15 min.	30 sec.fast, 30 sec.slow	0.98	Good expansion	4 - 275	Autoclave: good
Egg beater	15 min.	30 sec.fast, 30 sec.slow	0.94	Excellent expansion	3 - 275	Good appearan
Egg beater	15 min.	30 sec.fast, 30 sec.slow	0.93	Excellent expansion	4 - 275	Good appearan
Egg beater	15 min.	30 sec.fast, 30 sec.slow	0.94	Excellent expansion	4 - 275	Good appearan

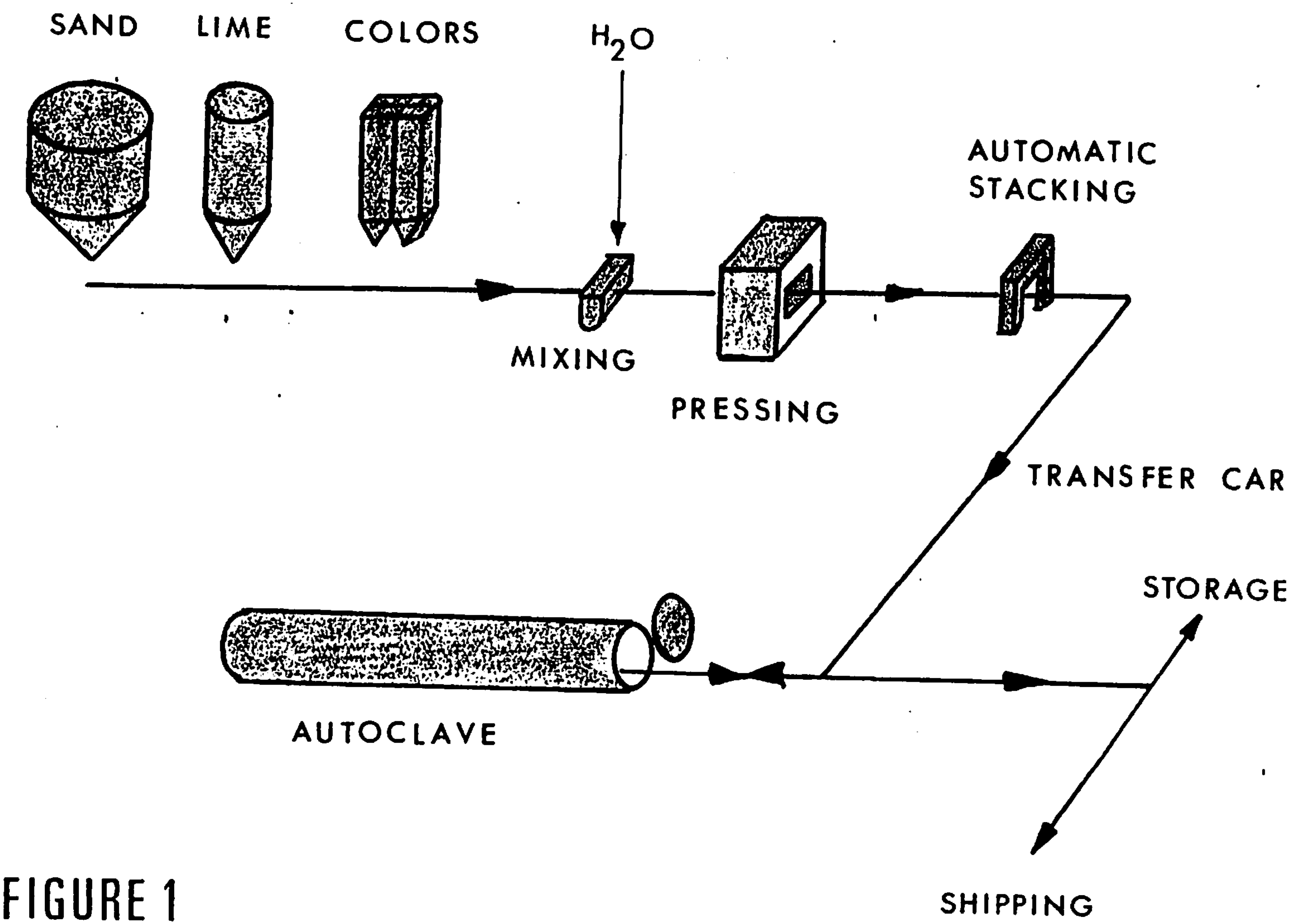

FIGURE 1
SAND LIME BRICK PLANT
SCHEMATIC

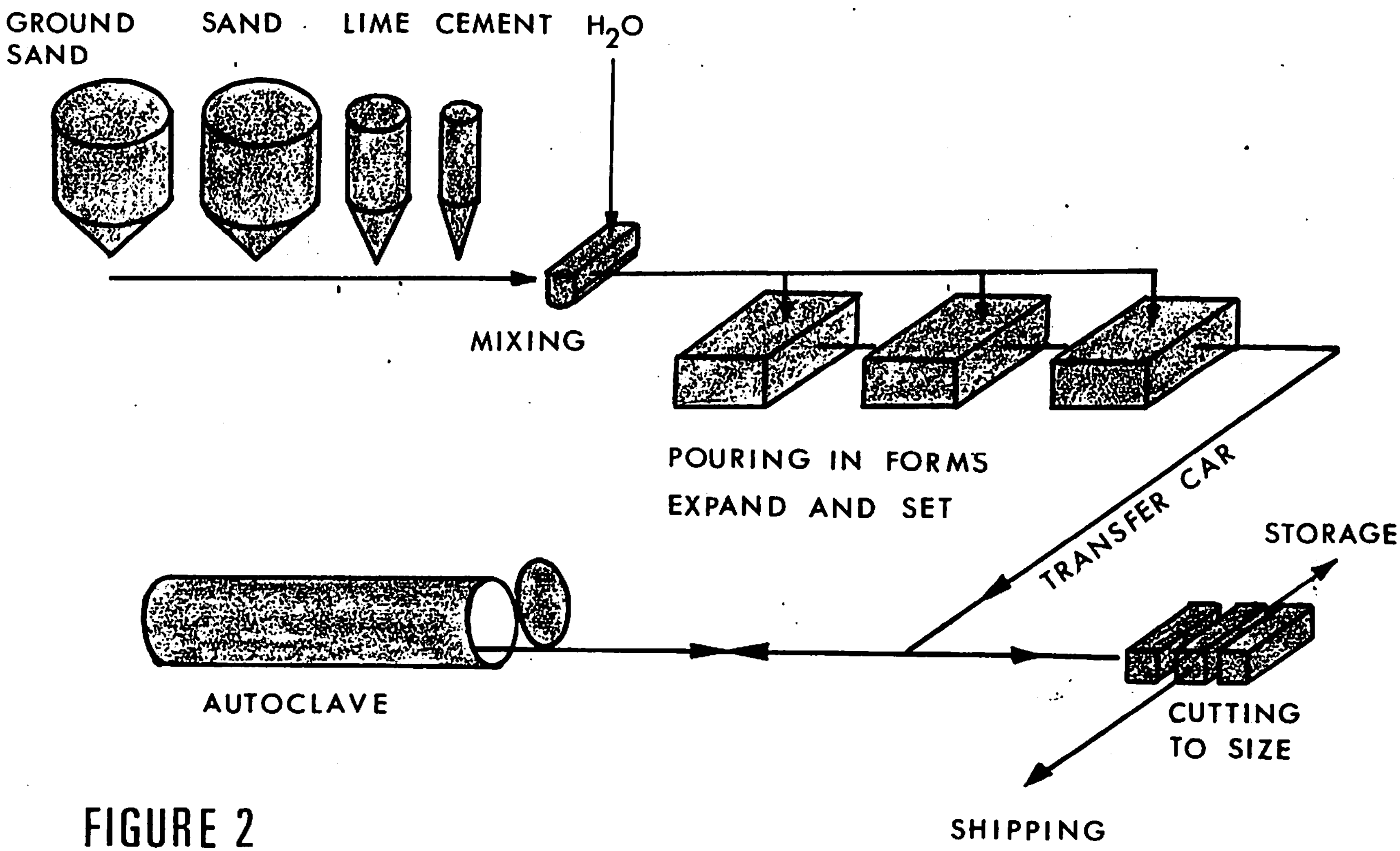

FIGURE 2
FOAMED CALCIUM-SILICATE PLANT SCHEMATIC