Minerals Yearbook

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DEPARTMENT
OF THE
INTERIOR

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MINES

1989

SODA ASH

By Dennis S. Kostick

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The U.S. soda ash industry operated at 97% of rated capacity to produce a record 9.9 million short tons. The increase in production was because of the strength of export sales, which also was a record, and moderate growth in certain domestic markets, such as in soaps and detergents and pulp and paper. Although consumption in these two domestic markets was higher than in the previous year, total domestic consumption declined. Most of the decrease was attributed to certain sectors that switched back to using caustic soda when prices and availability became favorable by midyear.

The high operating rate of the domestic soda ash industry prompted an increase in the offlist price of the material as supplies became tight. Several consumers, concerned about future availability, negotiated new contracts at higher prices. The strong world demand for soda ash also made U.S. exports grow 18% over the previous year. The environmental and political events in the world, which began to occur in 1989, should provide excellent opportunities for U.S. soda ash in the future.

DOMESTIC DATA COVERAGE

Domestic production data for soda ash are developed by the Bureau of Mines from monthly, quarterly, and annual voluntary surveys of U.S. operations. Of the six soda ash operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1.

TABLE 1

SALIENT SODA ASH STATISTICS

(Thousand short tons and thousand dollars)

	1985	1986	1987	1988	1989
United States:					
Production[1]	8,511	8,438	8,891	9,632	9,915
Value[1]	$622,253	$553,517	$593,685	$644,973	$764,146
Production, Wyoming trona	11,823	13,237	13,869	15,116	16,286
Exports[2]	1,747	2,049	2,224	2,467	2,919
Value[2]	$173,937	$241,238	$253,200	$286,945	$365,469
Imports for consumption	56	106	150	133	142
Value	$8,089	$15,023	$18,334	$15,999	$17,396
Stocks, Dec. 31: Producers'	[r]392	294	259	[r]288	243
Consumption:					
Apparent	6,750	6,593	6,852	7,269	7,183
Reported	NA	NA	6,724	7,159	7,131
World: Production	[r]32,111	[r]32,367	33,332	[p]34,234	[e]34,910

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Includes natural and synthetic for 1985 and 1986; natural only thereafter. Soda liquors and mine waters converted to soda ash equivalent in 1987 and thereafter; 69,963 tons in 1987, 80,871 tons in 1988, and 104,749 tons in 1989.

[2]Export data for 1985-1988 were adjusted by the Bureau of Mines to reconcile data discrepancies among the Bureau of the Census, the American Natural Soda Ash Corp, and Statistics Canada.

ISSUES

Environmental concerns of emissions of chlorine-based compounds, such as those used in chlorofluorocarbons (CFC's) and in paper bleaching, have reduced chlorine demand and production of coproduct caustic soda since 1988. As a result, caustic soda prices increased while supplies became tight. Certain chemical consumers, such as the pulp and paper, chemical, and alumina industries, began switching to less expensive soda ash. However, after mid-1989, many customers reverted to caustic soda as prices and availability became balanced. Because of the discovery of trace amounts of carcinogenic dioxin (2,3,7,8-TCDD) and furan (2,3,7,8-TCDF) from paper bleaching, many paper mills stayed with soda ash.

The international awareness of environmental problems is growing, and the effects of chlorinated compounds are under investigation. If the demand for chlorine, which cannot be easily stored, continues to decline while the demand for caustic soda remains strong, soda ash demand may soar. One soda ash producer announced plans to make caustic soda directly from trona rather than the traditional route of using salt as the feedstock. Some chlorine and caustic soda manufacturers reportedly are also evaluating the possibilities of producing caustic soda directly. The future outlook for this scenario depends on the production economics of making caustic soda from trona and the transportation costs from Green River, WY, to caustic soda markets.

Another environmental issue that has growing national importance is recycling. Glass containers, the preferred packaging medium for many years, have undergone years of strong competition from plastic materials, especially in the beverage container sector. Public con-

TABLE 3

SODA ASH SUPPLY-DEMAND RELATIONSHIPS[1]

(Thousand short tons)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
WORLD PRODUCTION										
United States	8,275	8,281	7,819	8,467	8,511	8,511	8,438	8,891	9,632	9,915
Rest of world	22,972	22,599	21,731	22,278	23,714	23,600	23,929	24,441	24,602	24,995
Total	31,247	30,880	29,550	30,745	32,225	32,111	32,367	33,332	34,234	34,910
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY										
U.S. production capacity	9,620	10,360	11,160	11,160	11,160	11,160	10,560	10,485	10,485	10,560
Wyoming trona ore production	12,906	12,457	10,831	11,510	11,704	11,823	13,237	13,869	15,116	16,286
Domestic sources	8,275	8,281	7,819	8,467	8,511	8,511	8,438	8,891	9,632	9,915
Imports	18	12	18	20	17	56	106	150	133	142
Industry stocks, Jan. 1[2]	68	133	263	324	307	322	392	294	259	288
Total U.S. supply	8,361	8,426	8,100	8,811	8,835	8,889	8,936	9,335	10,024	10,345
Distribution of U.S. supply:										
Industry stocks, Dec. 31[2]	133	263	324	307	322	392	294	259	288	243
Exports	1,094	1,051	1,109	1,636	1,648	1,747	2,049	2,224	2,467	2,919
Industrial demand[3]	7,134	7,112	6,667	6,868	6,865	6,750	6,593	6,852	7,269	7,183
U.S. DEMAND PATTERN[4]										
Glass	3,851	3,700	3,500	3,450	3,400	3,400	3,475	3,685	3,737	3,631
Container	2,773	2,627	2,500	2,400	2,300	2,200	2,150	2,322	2,346	2,162
Flat	616	555	500	575	600	700	750	905	939	1,000
Fiber	193	260	220	230	250	275	300	275	272	265
Other	269	258	280	245	250	225	275	183	180	204
Chemicals	1,426	1,420	1,300	1,400	1,550	1,500	1,300	1,364	1,593	1,557
Soaps and detergents	499	500	500	620	600	600	650	754	791	860
Pulp and paper	250	210	275	200	250	350	200	69	122	126
Water treatment	250	250	230	230	300	300	250	79	121	102
Flue gas desulfurization	NA	NA	NA	NA	300	175	200	202	220	230
Distributors	NA	NA	NA	NA	NA	NA	NA	385	412	419
Other[5]	856	1,032	862	968	464	425	715	186	163	206
Total U.S. consumption	7,132	7,112	6,667	6,868	6,864	6,750	6,790	6,724	7,159	7,131
Undistributed[6]	2	—	—	—	1	—	- 197	128	109	52
Total U.S. primary demand	7,134	7,112	6,667	6,868	6,865	6,750	6,593	6,852	7,269	7,183
VALUES[7]										
Average annual value—natural soda ash (Dollars per ton, f.o.b.)	89.85	91.19	88.35	76.95	67.00	67.82	65.29	66.78	66.96	77.07

[e] Estimated. NA Not available; included in "Other."

[1] Natural and synthetic except where noted.

[2] Natural soda ash only in 1980 and 1987-89; natural and synthetic from yearend 1981-1986.

[3] Also known as apparent consumption (production + imports − exports + / − stock changes) and is equal to Total U.S. primary demand.

[4] Estimated consumption for 1980-1986 was based on industry sources; reported consumption 1987 and thereafter were from quantitative and qualitative quarterly surveys of producers' sales. Other end use categories were incorporated in the survey.

[5] Includes soda ash used in petroleum and metal refining, leather tanning, enamels, etc.

[6] Represents the amount of discrepancy between "Total U.S. consumption" (obtained from estimated and reported consumption surveys) and "Total U.S. primary demand," which is the calculated quantity of soda ash available for consumption. The discrepancy is because of the fluctuating balance of inventory in transit from plants to domestic or export destinations.

[7] Values are the combined total revenue of California and Wyoming natural soda ash sold at list-prices, spot-prices, discount, long-term contracts, and for export, divided by the quantity of soda ash sold, bulk, f.o.b. plant. The value may or may not be synonymous with the posted list prices of the commodity.

Source: Bureau of Mines.

TABLE 4

SODA ASH YEAREND PRICES

		1988	1989
Sodium carbonate (soda ash):			
Dense, 58%, Na_2O 100-lb:			
Paper bags, carlot, works, f.o.b.	per ton	$141.00	$146.00
Bulk, carlot, same basis tons	do.	93.00	93.00
Light 58%, 100-lb:			
Paper bags, carlot, same basis	do.	150.00	150.00
Bulk, carlot, same basis tons	do.	123.00	123.00

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V.235, No.1, Dec. 30, 1988, p. 33; and v. 237, No. 1, Jan. 1, 1990, p. 39.

soda ash are listed in the appropriate trade tables in this report.

Officials of the antidumping directorate of the European Community Commission (ECC) made a surprise visit to the corporate offices and plants of six West European synthetic soda ash producers to obtain information about alleged anticompetitive practices in the European Community (EC) market.[7] The companies were Solvay et Cie. of Belgium, Akzo N.V. of the Netherlands, Imperial Chemical Industries PLC of England, Rhône-Poulenc S.A. of France, and Chemische Fabrik Kalk and Matthes and Weber G.m.b.H. of the Federal Republic of Germany. The combined output of these producers represented about 20% of world soda ash production. The Commission had reason to believe that all six producers conspired to prevent competition in the EC soda ash market by blocking U.S. imports in the early 1980's, when antidumping duties were levied. The current duty is 67.5 European Currency Units (ECUs), about $67.13 per short ton. ECC investigators also investigated U.S. producers at yearend and indicated that a decision would be forthcoming in early 1990. European soda ash consumers would prefer to have an alternate source of soda ash, namely the United States. With two Wyoming soda ash plants co-owned by French companies, the U.S. soda ash industry is hopeful that the investigation will result in reduced or eliminated duties, which would increase U.S. export sales to Europe.

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF SODA ASH

Year	Disodium carbonate[1]	
	Quantity (short tons)	Value[2] (thousand dollars)
1985[3]	56,202	8,089
1986[3]	105,965	15,023
1987[3]	150,103	18,334
1988[3]	132,948	15,999
1989	141,967	17,396

[1] Beginning in 1989, import data were reclassified under the Harmonized Commodity Description and Coding System (HS Code No. 2836200000). Prior years were classified under the Tariff Schedule of the United States, Annotated, TSUSA No. 4208400 (calcined) and No. 4208600 (hydrated and sesquicarbonate).

[2] Customs, Insurance, and freight (c.i.f.) value at U.S. ports.

[3] Also contains hydrated sodium carbonate, and sesquicarbonate.

Source: Bureau of the Census.

TABLE 6

U.S. EXPORTS OF SODA ASH

(Thousand short tons and thousand dollars)

Year	Disodium carbonate[1]	
	Quantity	Value[2]
1985[3]	1,747	173,937
1986[3]	2,049	241,238
1987[3]	2,224	253,200
1988[3]	2,467	286,945
1989	2,919	365,469

[1] Beginning in 1989, export data were reclassified under the Harmonized Commodity Description and Coding System (HS Code No. 2836200000). Prior years were classified under Schedule B No. 4208400.

[2] Free alongside ship (f.a.s.) value at U.S. ports.

[3] Adjusted by the Bureau of Mines to account for discrepancies in data.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

For the previous several years, international tariffs on imports of soda ash from the United States have blocked U.S. efforts to increase export sales. In 1989, however, an easement of these trade barriers began with the announcement that Taiwan was reducing the import tariff from 12.5% to 10%, which equals a $5.90 per short ton savings for Taiwanese consumers. Reducing the tariff could result in greater overseas trade as well as better trading relationships.[8]

WORLD REVIEW

Industry Structure

The developed nations are generally the largest consumers of soda ash. Although the production and consumption quantities vary among the countries, the end-use patterns are basically the same (e.g. glass, chemicals, and detergents are the major sectors). Although the United States is the largest soda ash-producing country in the world, foreign ownership in the U.S. soda ash industry is presently 30% of nameplate capacity.

Eleven countries have the capability to produce more than 1 million tons annually. The major ones include, in descending order, the United States, the U.S.S.R., China, the Federal Republic of Germany, France, Bulgaria, and India. Most of these countries have large populations, which require consumer products made with soda ash. The developing nations tend to have greater soda ash demand and higher rates of growth.

Capacity

World soda ash production capacity is about 38.3 million tons, divided among 35 countries. Approximately 72% of world capacity is synthetic soda ash, 28% natural. The United States represents 27% of world capacity, and 94% of the total natural capacity.

The largest soda ash company in the world, excluding State-owned facilities, is Solvay et Cie. of Belgium. It operates nine plants in seven countries and has a combined annual capacity of more than 4 million tons. FMC Wyoming Corp. of the United States is the second largest with 2.85 million tons of capacity.

The data in table 9 are rated capacities for mines and refineries as of December 31, 1989. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operat-

TABLE 7

REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS IN 1989

(Short tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percent of total
Atlantic:											
Baltimore, MD	—	—	110	—	29	—	—	—	—	139	—
Charleston, SC	—	74	—	—	3	—	—	—	—	77	—
Miami, FL	—	—	2	206	—	—	—	—	—	208	—
New York, NY	36	—	18	—	21	22	—	119	—	216	—
Philadelphia, PA	—	—	469	—	—	—	—	—	—	469	—
Savannah, GA	—	—	—	65	—	—	—	—	—	65	—
Gulf:											
Galveston, TX	—	—	2	40	—	—	14	28	—	84	—
New Orleans, LA	—	10	226	20	—	—	18	—	—	274	—
Port Arthur, TX	—	7,799	357,205	19,029	—	—	85,281	—	—	469,314	16
Pacific:											
Anchorage, AK	7,811	—	—	—	—	—	—	—	—	7,811	—
Los Angeles, CA	—	8,925	123,022	—	17,032	—	27,558	456,188	—	632,725	22
San Diego, CA	6,032	—	—	—	—	—	—	—	—	6,032	—
San Francisco, CA	—	—	—	—	—	—	—	47	—	47	—
Seattle, WA	8,968	—	—	—	—	—	—	117	—	9,085	—
Portland, OR	—	—	96,717		46,217		93,240	1,045,926	98,762	1,380,862	47
North Central:											
Detroit, MI	190,490	—	—	—	—	—	—	—	—	190,490	7
Duluth, MN	17	—	—	—	—	—	—	—	—	17	—
Great Falls, MT	60,968	—	—	—	—	—	—	—	—	60,968	2
Pembina, ND	9,802	—	—	—	—	—	—	—	—	9,802	—
Northeast:											
Buffalo, NY	410	—	—	—	5	—	—	—	—	415	—
Ogdensburg, NY	22	—	—	—	—	—	—	—	—	22	—
St. Albans, VT	80	—	—	—	—	—	—	—	—	80	—
Southwest:											
Laredo, TX	150,106	—	—	—	—	—	—	—	—	150,106	5
Nogales, AZ	94	—	—	—	—	—	—	—	—	94	—
Total	434,836	16,808	577,771	19,360	63,307	22	206,111	1,502,425	98,762	2,919,402	100
Percent of total	15	1	20	1	2	—	7	51	3	100	

Source: Bureau of the Census.

ing rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Natural soda ash mine capacity assumes two daily mine shifts and one daily maintenance shift per 5-day work week. Considerations were made for operations that mine underground trona, surface sodium salts, and sodium carbonate-bearing brines. Natural and synthetic soda ash refining capacities are based on 360 working days per year with scheduled short-term maintenance periods once or twice per year, depending on the physical characteristics of the plant.

The U.S. soda ash industry rated capacity was derived by averaging each producer's third and fourth highest months of output during the past year. These months were used because the first and second highest months were not realistic for sustained production rates. The range between each producer's third and fourth highest months were close and probably more indicative of what each plant can effectively sustain on a monthly basis, given favorable market conditions. The calculated averages were aggregated and annualized. Individual rated capacities may or may not be synonymous with plant nameplate capacities.

Australia

ICI Australia Operations Pty. Ltd. sold its Osborne synthetic soda ash plant, salt fields, quarry, a bulk terminal, and bagging facilities to Penrice Pty. for $35 million.[9]

TABLE 8

SODA ASH: WORLD PRODUCTION, BY COUNTRY[1]

(Short tons)

Country	1985	1986	1987	1988[p]	1989[e]
Albania[e]	34,200	35,300	34,000	33,100	33,100
Australia[e]	330,000	330,000	330,000	330,000	330,000
Austria[e]	165,000	165,000	165,000	160,000	165,000
Belgium	492,164	530,934	493,804	417,731	420,000
Brazil	197,000	222,000	187,000	203,300	220,000
Bulgaria	1,142,695	1,162,070	1,179,679	[e]1,210,000	1,210,000
Canada[e]	385,000	385,000	360,000	360,000	360,000
China[e]	2,220,000	2,310,000	2,610,000	2,855,000	[3]3,285,000
Colombia	124,791	124,473	128,820	125,759	128,000
Czechoslovakia	123,459	124,561	[e]121,000	[e]121,000	121,000
Denmark[2]	126	129	[e]130	[e]130	130
Egypt	54,132	[e]55,000	[e]55,000	52,592	52,000
France[e]	1,500,000	1,375,000	1,400,000	1,400,000	1,430,000
German Democratic Republic	974,442	975,544	984,000	1,008,000	992,000
Germany, Federal Republic of	1,556,462	1,589,531	1,596,000	1,548,000	1,655,000
Greece[e]	1,100	1,100	1,100	1,100	1,100
India	896,839	962,978	1,068,800	[e]1,058,000	1,100,000
Italy[e]	680,000	650,000	675,000	675,000	680,000
Japan	1,165,254	1,125,292	1,210,849	1,193,935	1,235,000
Kenya[4]	251,062	261,964	252,043	242,500	260,000
Korea, Republic of	276,559	291,245	318,016	[e]309,000	309,000
Mexico[e 5]	[3]504,205	500,000	475,000	[r]475,000	475,000
Netherlands[e]	420,000	420,000	420,000	420,000	430,000
Pakistan	130,169	144,286	147,051	147,826	143,000
Poland	1,035,069	1,061,252	1,025,000	1,003,200	1,003,000
Portugal[e]	165,000	170,000	[r]175,000	[r]170,000	165,000
Romania[e]	[3]921,531	940,000	950,000	950,000	880,000
Spain[e]	610,000	580,000	610,000	620,000	620,000
Switzerland[e]	50,000	48,000	25,000	—	—
Taiwan	123,479	147,002	140,359	139,804	138,000
Turkey	[e]331,000	[e]365,000	415,000	418,000	425,000
U.S.S.R.[6]	5,418,956	5,546,824	5,566,000	5,618,000	5,400,000
United Kingdom[e]	1,100,000	1,100,000	1,100,000	1,100,000	1,100,000
United States[7]	8,511,055	8,438,192	8,890,746	9,632,031	[3]9,914,966
Yugoslavia	220,053	229,245	222,158	235,774	230,000
Total	[r]32,110,802	[r]32,366,922	33,331,555	34,233,782	34,910,296

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 27, 1990. Synthetic unless otherwise specified.
[2]Production for sale only; excludes output consumed by producers.
[3]Reported figure.
[4]Natural only.
[5]Includes natural and synthetic. In 1988 and 1989, Mexico allegedly produced an estimated 180,000 metric tons per year of natural soda ash.
[6]Excludes potash for 1985-87.
[7]Includes natural and synthetic for 1985-86, natural only thereafter.

Botswana

In June, financing of the Sua Pan soda ash project was finalized in an agreement among Soda Ash Botswana Ltd., three South African shareholders, and a consortium of South African banks. The agreement includes commercial loans at the 17.5% South African prime rate and lower interest rate export credits. The principal engineering contractors have been chosen with completion scheduled for mid-1991.[10]

Mexico

Vitro S.A. of Monterrey, the largest glass and raw material for glass manufacturing company in Mexico, acquired for $265 million Anchor Glass Container Corp. and Latchford Glass Co. in the United States.[11] The buyout involved more than 20 glass container plants. The acquisition made Vitro the largest glass container manufacturer in the United States and probably the largest single consumer of soda ash in North America.

OUTLOOK

Although world demand for soda ash has grown about 2.4% per year since the early 1970's, the environmental, energy, and economic issues of the 1980's reduced the international growth rate of soda ash to slightly more than 1% per annum. Developed nations, where soda ash consumption is mature and growth rates are proportional to population changes, are more concerned about environmental quality, energy efficiency, recycling, and consumer preferences, all of which have an adverse affect on soda ash usage. These issues will be of greater importance in the 1990's. Lesser developed countries still have a greater demand for soda ash, but often have less hard currency to purchase all their requirements.

The U.S. annual growth rate for domestic consumption since the 1973 energy crisis, which changed the operating factors between competing natural and synthetic soda ash industries, to the present has been less than 1%. The forecast of 1.2% made in the 1985 Mineral Facts and Problems did not fully anticipate the inroads made by plastic bottles, cullet, and liquid deter-

TABLE 9

WORLD SODA ASH ANNUAL PRODUCTION CAPACITY,[1] DEC. 31, 1989

(Thousand short tons)

	Natural	Synthetic	Total
North America: 200			
Canada	—	495	495
Mexico	300	240	540
United States	10,200	—	10,200
Total	10,500	735	11,235
South America:			
Brazil	—	220	220
Colombia	—	120	120
Total	—	340	340
Europe, Western:			
Austria	—	195	195
Belgium	—	440	440
France	—	1,650	1,650
Germany, Federal Republic of	—	1,800	1,800
Italy	—	775	775
Netherlands	—	420	420
Portugal	—	140	140
Spain	—	775	775
Turkey	—	365	365
United Kingdom	—	1,100	1,100
Total	—	7,660	7,660
Europe, Eastern:			
Albania[e]	—	30	30
Bulgaria	—	1,900	1,900
Czechoslovakia	—	150	150
German Democratic Republic	—	990	990
Poland	—	1,100	1,100
Romania	—	1,100	1,100
U.S.S.R.	30	[2]5,895	5,925
Yugoslavia	—	290	290
Total	30	11,455	11,485
Africa:			
Chad	NA	—	NA
Egypt	—	45	45
Kenya	330	—	330
Sudan	NA	—	NA
Total	330	45	375
Asia:			
China	11	3,289	3,300
India	—	1,135	1,135
Iran	—	66	66
Japan	—	1,565	1,565
Korea, North	—	110	110
Korea, Republic of	—	350	350
Pakistan	—	160	160
Taiwan	—	150	150
Total	11	6,825	6,836

See footnotes at end of table.

gents. Although U.S. production was close to what was forecast by 1990, the export market grew greater than anticipated, mainly through the efforts of the industry's export association.

Exports

The outlook for soda ash is excellent. Export opportunities are favorable, particularly to new regions such as the Middle East and Western and Eastern Europe. If the ruling in the EC antidumping investigation is favorable to the United States, additional U.S. soda ash may be exported to Western Europe in the near future. The changes in the political situation in the U.S.S.R. and the East European countries may also lead to more U.S. exports to meet the growing demand for consumer products in those areas. The limiting factor, however, may be the lack of available hard currency and the internal manufacturing capabilities of the industries that use soda ash.

The environmental problems in Eastern Europe are critical. Inefficient and polluting synthetic soda ash plants may be targeted for shutdown in order to resolve some of the pollution problems. These problems are similar to those that adversely affected several U.S. synthetic facilities in the late 1970's and finally led to their closures. Any changes in East Europe's soda ash production capacity could signal opportunities for the U.S. soda ash industry.

The future of U.S. exports to China is uncertain. China has been debottlenecking several synthetic soda ash plants and constructing new ones but production cannot keep pace with demand. China was forced to reduce its soda ash consumption by limiting imports because of economic problems. Although Bulgaria had supplied some of China's requirements, future shipments could be curtailed in order to satisfy the East European countries' needs, thereby reducing Bulgaria's level of exports. This could allow the United States the opportunity to continue to export to China, pending the availability of U.S. product. Despite these obstacles, total U.S. exports could grow by several hundreds of thousands of tons in the next several years.

Glass

Although glass is the largest end use of soda ash, domestic consumption in

TABLE 9-Continued

WORLD SODA ASH ANNUAL PRODUCTION CAPACITY,[1] DEC. 31, 1989

(Thousand short tons)

	Natural	Synthetic	Total
Oceania:			
Australia	—	385	385
Total	—	385	385
World total	10,871	27,445	38,316

[e] Estimated. NA Not available, although production is known to occur.
[1] From natural sources of trona and sodium carbonate-bearing brines and from the manufacture by the Solvay, ammonium chloride, and caustic carbonation processes.
[2] Includes soda ash obtained as a byproduct of aluminum processing from nepheline-bearing ore at at least four locations.

the glass container sector is declining because of the increasing use of cullet; the national interest in recycling; and the continuing competition with polyethylene terephthalate (PET) plastic containers.

The glass container shipments were higher in 1989 than in previous years, mainly because ethylene feedstock shortages for plastic resin caused prices of plastics to increase, thereby increasing glass usage. This situation is temporary. However, the public's perception that glass is completely recyclable compared with plastics will raise the quantity of cullet now being consumed. This trend will probably be short-lived as plastic manufacturers develop biodegradable materials, such as polyhydroxybutyrate-hydroxyvalerate (PHBV), which completely decompose into inert compounds. Aside from the problems with plastics' recyclability, the public also is concerned about the dioxin emissions from incineration of polyvinyl chloride (PVC) bottles.

Municipal landfills are a growing national problem. Glass reportedly accounts for 8.4% of disposable household waste. The U.S. Environmental Protection Agency has a goal of reducing the nation's waste by 25% by 1992. It is probable that new taxes will be placed on items manufactured at the source of production to encourage greater use of recycled products. Rebates would be given for every ton of recycled material utilized. It is also likely that domestic glass container manufacturers will strive to add more cullet in new batch mixtures, which will reduce the amount of soda ash consumption, in order to use most of the collected glass.

The glass container industry is changing. Two facilities closed in 1989 and Vitro S.A. of Mexico bought Anchor Glass Container Corp. and Latchford Glass Co. There reportedly are plans to close more plants, thereby reducing domestic capacity and improving industry operating rates. As plants operated at higher rates, production costs decreased. Soda ash sales for glass containers should remain at the same levels despite the closures.

Soda ash for flat glass and fiber glass is expected to decline in the automotive industries. Consumption will probably be the same in the building construction sector. Strong demand is not anticipated until the mid-1990's.

Soap and Detergents

The world consumes about 10 million tons of laundry detergents annually, which are composed of many active and inert chemical ingredients. Household liquid detergents and phosphate-free detergents are considered environmentally safe products. More soda ash has been added as a phosphate-replacement builder in various detergent formulations in order to meet regional phosphate discharge requirements.

The environmental movement in Europe has also prompted foreign detergent manufacturers to consider changing formulations to reduce phosphate content. In the Federal Republic of Germany, consumption of phosphates in detergents dropped from 276,000 tons in 1975 to 80,000 tons in 1987.

Consumer preferences may ultimately decide the preferred detergent and format (i.e. liquid versus powdered, unit dose packets versus bulk). Depending on the choice, the growth of future soda ash sales is uncertain, despite the current level of sales.

Pulp and Paper

The U.S. pulp industry is growing at about 2.75% per year. Amid this prosperous outlook, changes are taking place to alter the pulp and papermaking processes. Pulp mills are striving to address the environmental issues regarding dioxins and furans, improve productivity, reduce costs, and improve paper quality. One solution is alkaline paper-sizing, which produces alkaline-based paper rather than acid-based. The conversion is not being implemented as fast as the environmental issue is mounting. Other alternatives include substituting certain pulping chemicals.

Dioxins, created from chlorine molecules introduced in the paper bleaching process, have been detected in bleached paper products as reported in a study of the 104 kraft-pulp mills in the United States. To avert the public's reaction to the issue, the industry began investigating substituting chlorine-based chemicals for nonchlorine pulping and bleaching agents, such as oxygen and hydrogen peroxide. About 1.8 million tons of chlorine are used in pulp bleaching annually. Industry sources estimate a 25% to 30% reduction in chlorine consumption by 1995. If this forecast is accurate, coproduct caustic soda, which is used to delignify wood pulp, could be in short supply. This situation could result in additional quantities of soda ash being used instead of caustic soda, although it would take 1.3 tons of soda ash to have the same chemical effect of 1.0 ton of caustic soda. FMC Wyoming Corp. and Tenneco Minerals Co. have announced plans to produce caustic soda from their Green River, WY, soda ash operations. Although the majority of the output is for captive needs, the opportunity will demonstrate the economic feasibility of producing caustic soda from nonsalt feedstocks. Soda ash consumption in the pulp and paper sector could increase during the next few years depending on the strength of chlorine demand; however, assertive strategic planning by one or more chlorine-caustic soda producers to produce their own caustic soda from trona could alter this outlook.

Flue Gas Desulfurization

With changes to the Clean Air Act, the nation's powerplants will be required to reduce emissions of sulfur and nitrogen compounds produced from burning fossil fuels. Although most high-sulfur coal is used in eastern powerplants where inexpensive calcium-based compounds are located, sodium-based sulfur dioxide removal agents, such as trona and nahcolite, have opportunities for commercial development in the West.

In 1989, nearly 0.5 million tons of soda ash was used for reducing harmful stackgas emissions in the West and Midwest. Transportation costs will reduce the competitiveness of sodium minerals in the East in the future; however, the concern regarding water quality and quantity will be major issues in the Western United States in the 1990's. Several wet-scrubbing utility plants, which use tremendous amounts of water, are evaluating the economics of replacing traditional wet-scrubbing systems using lime with dry-injection technologies using calcium- and sodium-based agents. The addition of some sodium minerals removes additional sulfur and a substantial amount of the nitrogen materials. Eastern powerplants will probably use low-sulfur coal rather than use trona or nahcolite resources found in the West. As Western powerplants retrofit older facilities with dry-injection scrubbing equipment to conserve water, demand for soda ash will increase.

BACKGROUND

Soda ash is the eleventh largest inorganic chemical in terms of production of all inorganic and organic chemicals, excluding petrochemical feedstocks. In 1989, soda ash represented about 2.4% of the total $32 billion nonfuel mineral industry that was surveyed by the Bureau of Mines. The average U.S. citizen consumes about 40,000 pounds of new minerals in the form of consumer goods each year. Based on the 1989 U.S. population of nearly 248 million, the 1989 per capita consumption of soda ash was 58 pounds, compared with copper, 20 pounds; aluminum, 45 pounds; salt, 345 pounds; cement, 742 pounds; and iron and steel, 863 pounds. An infant born in 1988 would require 4,344 pounds of soda ash in a lifetime, based on an average life expectancy of 74.9 years.

Natural soda ash was probably first obtained as evaporite incrustations along the edges of alkaline lakes in Lower Egypt. It was used around 3500 B.C. to make ornamental glassware, as evidenced by many of the early Egyptian glass artifacts. The Egyptians also mixed lime and soda ash to make caustic soda. The caustic soda was combined with silicate minerals obtained from the Sinai desert. This made a soluble silica that was added to aluminum-rich Nile River silt, producing a silica-aluminate cement mortar with superior bonding properties. Soda ash was also used in the mummification process. Natural soda ash was placed on the deceased to dry out the body, which was then wrapped in cloth for 70 days.

In the Old Testament, soda ash was referred to as neter; it has also been known as natrium, kali, trona, and natron. Until the 18th century, soda ash was obtained mainly by burning seaweeds and marine plants, leaching the soluble material from the ashes, and evaporating the solutions to dryness. About 13 tons of ash yielded 1 ton of sodium carbonate and 30 pounds of iodine as a byproduct. The final material was very impure but could be used in the manufacture of glass and soap and detergents. Pliny, a Roman historian, listed soda ash in the manufacture of glass, as a medicine for colic pains and skin eruptions, and for making bread, in the first century A.D.

In 1791, Nicolas Leblanc, a French chemist, developed a process for making soda ash from "salt cake" (from salt and sulfuric acid), coal, and limestone. The French Revolution interfered with its development; his patent and factory were confiscated, and he received only token compensation. Napoleon returned the factory to Leblanc who, unable to raise enough capital to reopen it, committed suicide in 1806. More than 30 years passed before the process first became successful in Liverpool, England. The process was not used successfully in the United States except during a short period from July 1884 to January 1885 at Laramie, WY.

Ernest and Alfred Solvay developed an improved method for making soda ash from salt, coke, and limestone, with ammonia as a catalyst in the early 1860's. That process was first used in the United States in 1884 at Syracuse, NY, in a plant that continued to produce soda ash until 1986. It was the first of about 17 synthetic Solvay plants that were in operation by 1939 in the United States and, ironically, the last one to close. The Solvay process gained in popularity over the years and is now the basic method used throughout the world for making synthetic soda ash.

The site of the first commercial production of natural soda ash in the United States was from two deposits known as the Soda Lakes near the present town of Fallon, NV. Asa L. Kenyon acquired title to Little Soda Lake in 1855 and sold it to Higgins and Duffy in 1868, when the first 300 tons of natural soda ash was produced. Production at adjacent Big Soda Lake began in 1875 and reached its peak in 1887. The brines became diluted when the lake levels rose in 1907 because regional dam construction affected the local water table.

Searles Lake in California was originally mined for borax as early as 1874. Soda ash production began in 1926 by the West End Chemical Co. American Potash Corp., formerly the American Trona Corp., was the second company to produce soda ash in 1931.

Definitions, Grades, and Specifications

The following terms are used in the soda ash industry:

Ammonia-Soda Process.—Also known as the Solvay process and lime-soda process.

Dense Soda Ash.—Has a bulk density of 60 to 66 pounds per cubic foot. It is produced by hydrating light soda ash followed by dehydration through calcination to produce denser crystals. In Eastern Europe, dense ash is made by compressing light ash between rollers to increase the density, followed by screening.

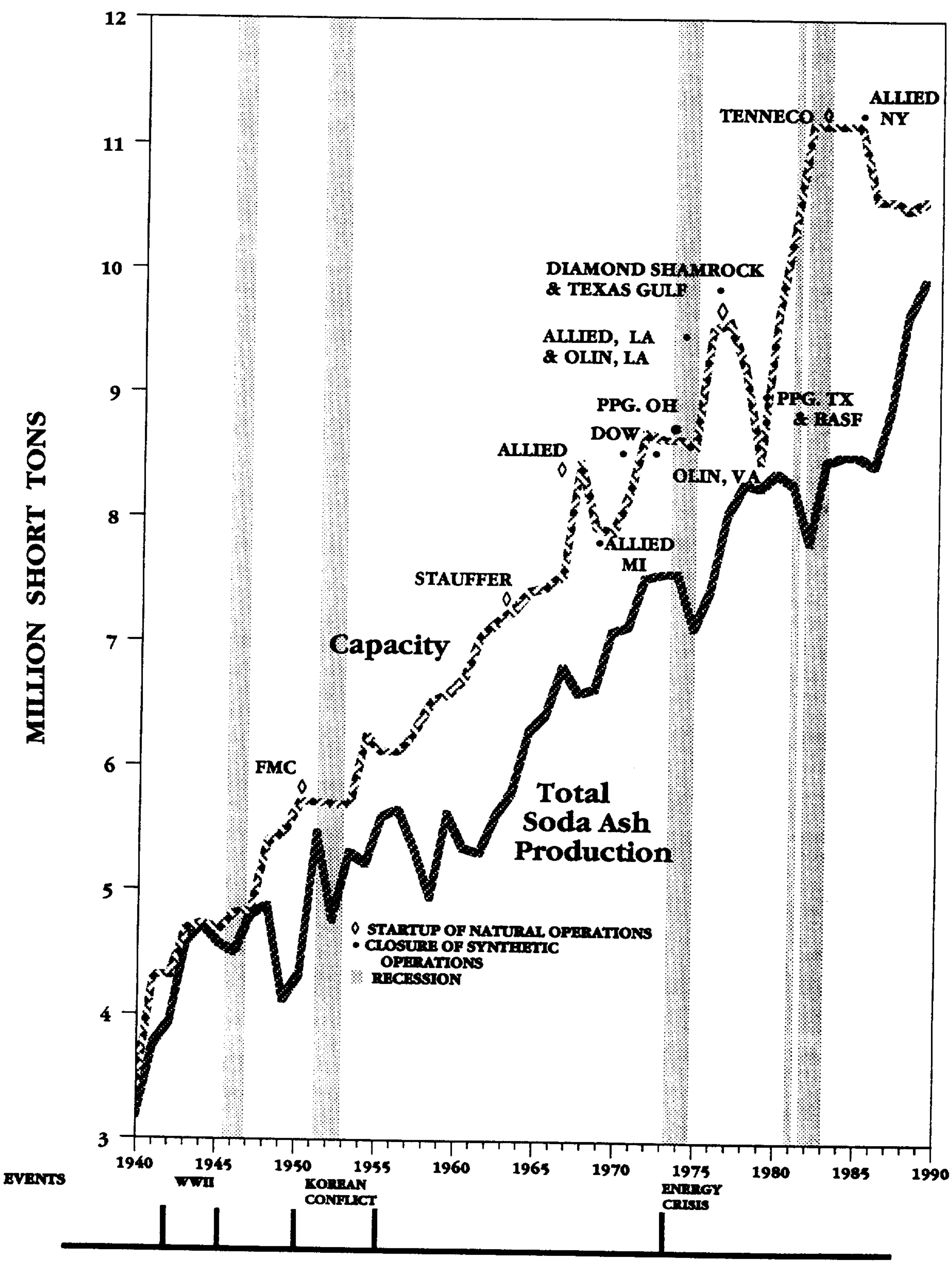
Light Soda Ash.—Has a bulk density of 32 to 39 pounds per cubic foot. It is produced by calcining the sodium sesquicarbonate precipitate recovered from the carbonation towers or vacuum crystallizers.

Natural Soda Ash.—Soda ash produced from trona ore, sodium carbonate-bearing brines, or surface mineralization.

Soda Ash.—Synonymous with sodium carbonate. It is a general term that

FIGURE 2

HISTORICAL CHRONOLOGY OF U.S. SODA ASH ACTIVITIES



can apply to soda ash produced from natural sources or from various chemical processes.

Sodium Sesquicarbonate.—Can refer to the name for the chemical composition of trona, or the chemical process that produces a light to intermediate grade of soda ash having an average bulk density of 50 pounds per cubic foot.

Synthetic Soda Ash.—Term for soda ash produced from one of several chemical processes, such as the Solvay process.

Trona.—The principal ore from which soda ash is made. It is composed of sodium carbonate, sodium bicarbonate, and water. The monoclinic crystals are prismatic to tabular with colors ranging from translucent (spar variety) to shades of brown, which vary depending on the amounts of contained organic matter. Trona has a specific gravity of 2.17 with a hardness of 2.5 to 3, on the Mohs' scale. About 1.8 tons of trona are required to produce 1 ton of soda ash.

The terms "soda ash" and "sodium carbonate" are used interchangeably. The material manufactured from Wyoming trona normally contains more than 99.8% sodium carbonate, and the sodium chloride content ranges between 0.01% to 0.02%. The amount of iron is less than 10 parts per million. Searles Lake brines are processed to yield a product of similar high quality with salt and sodium sulfate as the principal trace impurities. The average material produced by a Solvay soda ash plant is about equal to the natural product in sodium carbonate content, but often contains a larger quantity of salt. Dense soda ash, because of its greater bulk density, may command a higher price than the light variety, and is preferred for glass manufacture because the light soda ash leads to frothing in the glass melt. Light soda ash is preferred by many chemical and detergent industries because it dissolves more readily. Sodium sesquicarbonate has an intermediate bulk density and is used in some detergents and bath salts.

Typical official specifications for soda ash include American National Standard K60, 11-1956 (R1969) "Standard Specifications for Soda Ash," which appears as the American Society for Testing and Materials (ASTM) Designation D458-74 (Reapproved 1979); and British Standard (BS) 3674: 1963 "Specification for Sodium Carbonate (Technical Grades)." The British Standard specifies, among other requirements, not less than 57.25% Na_2O and not more than 0.005% Fe_2O_3; the ASTM, a minimum of 99.16% Na_2CO_3. Both standards specify methods of testing.

Industry Structure

The U.S. soda ash industry is comprised of six companies, five in Wyoming and one in California. All produce natural soda ash only either from sodium carbonate-rich brines or from underground mining of trona ore. Foreign investment in U.S. soda ash operations has risen from 10% of capacity in 1981, when Société Nationale Elf Aquitaine of France bought Texasgulf Chemical Co., to 30% in 1989. Three of the six U.S. companies have either Australian or French partners.

Geology-Resources

The definitions of resources, reserves, and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals." Briefly, "resources" describe the quantity of ore present, regardless of grade or ease of extraction. The "reserves" are the portion of the resource, which is economic to mine using the current technology and value of the commodity.

There are more than 60 identified natural sodium carbonate deposits in the world, the largest of which is the trona deposit in southwest Wyoming. Although several of these deposits have been quantified, most are economically insignificant or too remote to be commercially developed. Table 10 lists the countries with known soda ash deposits. All soda ash deposits can be classified in one of five modes of occurrences. In decreasing order of economic importance they are: buried, surface or subsurface brines, crystalline shoreline or bottom crusts, shallow lake bottom crystals, and surface efflorescences.

The trona found in the Green River Formation in southwest Wyoming is an excellent example of a buried trona deposit. The Wilkins Peak Member contains 42 beds of trona, 25 of which have a thickness of 3 feet or more. Eleven of these exceed 6 feet in thickness and cover an area of more than 1,200 square miles. The trona beds were deposited about 50 million years ago in the early to middle Eocene epoch in an ancient freshwater lake, named "Lake Gosiute" by Clarence King in 1878. The sodium and carbonate constituents of trona owe their respective origins to the leaching of the extensive pyroxene-andesite volcanic ash layers and the seasonal influxes of carbonate-rich sediments into the local depositional basin. In addition, subterranean thermal springs contributed a significant quantity of dissolved alkaline carbonates as well as sodium, calcium, silica, and bicarbonate ions. Trona can precipitate only in the presence of abundant carbon dioxide, which probably was supplied from the atmosphere and/or the biogenic decay of Eocene plant and aquatic remains. For 4 million years, Lake Gosiute went through many stages of filling and evaporation, thereby depositing over 42 beds of trona on the lake bottom along with repetitive beds of marlstone, limestone, oil shale, and sandstone-mudstone. The decrease of the inflow to the lake was probably in response to climatic changes that resulted in the final evaporation of the waters. The former Lake Gosiute is the present Green River Basin.

Assuming 1.8 tons of trona yields approximately 1 ton of soda ash, about 52 billion tons of identified soda ash resources could be obtained from the 62 billion tons of bedded trona and the 52 billion tons of interbedded or intermixed trona and halite that are in beds greater than 4 feet thick. Approximately 37 billion tons of reserve base soda ash could be obtained from the 40 billion tons of halite-free trona and the 27 billion tons of interbedded or intermixed trona and halite in beds more than 6 feet thick. Although about 16 million tons of trona are presently being mined there annually, Wyoming could supply all domestic requirements for more than 3,100 years at the 1989 demand level. As technology improves in the future, mining of the subeconomic grades of ore would further extend the life of the trona deposit to over 5,100 years. With Wyoming reserves estimated at 22 billion tons, the United States, through this one deposit, could provide the supply needed to meet the current annual world soda ash demand levels for about 630 years.

The U.S. Government established a Known Sodium Leasing Area (KSLA) in Wyoming within the perimeter of the trona depositional basin. The trona located within the KSLA is subject to Federal and State leasing regulations and private lease agreements. Although most of the leasable trona averages 93% sodium sesquicarbonate, several areas contain lower grade trona because of local depositional contamination along the lake margins, thereby reducing the reserve estimates of that particular area.

A series of Pleistocene playa lakes rich in evaporite minerals found in California comprise the second largest reserves of sodium carbonate in the United States. Subsurface sodium carbonate-bearing brines and crystalline material comprise the resource at Searles Lake, which is a nearly dry playa 9 miles long by 7 miles wide with an area of about 40 square miles. Surface sodium-bearing crystalline minerals predominate at Owens Lake, which was first mined in 1885 by the Inyo Development Co. Both deposits have combined reserves of about 900 million tons.

Two potential sources of soda ash—nahcolite (natural sodium bicarbonate) and dawsonite (sodium-aluminum-carbonate)—are associated with oil shale in the Piceance Creek basin in northwest Colorado. Identified resources of 32 billion tons of nahcolite and 19 billion tons of dawsonite, equivalent to 20 billion tons and 7 billion tons, respectively, of sodium carbonate resources, would be available as a byproduct of oil shale processing or as single mineral extraction. These deposits were formed in middle Eocene time with the nahcolite occurring as aggregates (62%), disseminated crystals (24%), and impure beds (14%).

The only other commercial natural soda ash deposit in the Western Hemisphere, excluding those in the United States, occurs at Lake Texcoco, near Mexico City, Mexico. Two caliché layers at a depth of 150 feet act as a filter and reservoir for the sodium carbonate-rich brine resource. With an average concentration of about 7% sodium carbonate, the resource contains about 200 million tons of available soda ash.

The Rift Valley of eastern Africa has several alkaline lakes resembling those of California. Only Lake Magadi in Kenya is presently in production. The soda ash reserves of these lakes are renewed annually from natural active volcanic sources. Other African countries that may become future suppliers of soda ash are Chad, Ethiopia, Niger, the Republic of South Africa, Tanzania, and Uganda. Botswana is developing its Sua Pan salt and soda ash deposit and final completion of the project is scheduled for 1991. Elsewhere, deposits of natural soda ash occur in Bolivia, Brazil, Canada, India, Pakistan, the U.S.S.R., and Venezuela. Plans are underway to develop deposits in China at Xilin Gol and in the Wulan Buh desert area. A trona deposit in Turkey near Beypazari is also under consideration for development.

Technology

Soda ash from Wyoming trona is mined, crushed, dried, dissolved, filtered, recrystallized, and redried. In California, soda ash from sodium carbonate-bearing brines is solution mined, carbonated, filtered, dried, decomposed, bleached, and recrystallized to dense soda ash.

Mining.—Commercial mining of Wyoming trona began in 1950. Between 1950 and 1989, more than 230 million tons of trona (equal to about 128 million tons of soda ash) have been mined. Only about 0.6% of the 40 billion tons of halite-free trona reserve base has been used since mining began.

Underground mining of Wyoming trona is similar to coal mining, except that trona is a harder mineral than coal. The five present Wyoming soda ash producers use room-and-pillar, longwall, shortwall, and solution mining techniques individually or in combination. The room-and-pillar method has an ore extraction efficiency rate of about 45% (55% of ore remains as pillars for structural integrity), the longwall and shortwall methods each have efficiency rates of about 75%, and solution mining has an efficiency rate of about 30%. These rates are important when calculating the amount of reserves that are minable. Based on the types of mining techniques, the author used a 60% average extraction efficiency rate to calculate reserves; the remaining 40% stays in-place as pillars for structural integrity and is unavailable for present extraction. The ore is undercut, drilled, blasted, mucked, crushed, and transported to the surface by well-established methods and various state-of-the-art mining equipment. The conventional blasting method using prilled ammonium nitrate and fuel oil (ANFO) is a standard and reliable method. Continuous mining uses vehi-

TABLE 10

WORLD NATURAL SODA ASH RESERVES AND RESERVE BASE

(Million short tons)

	Reserves	Reserve base[1]
North America:		
United States:		
California[2]	900	1,400
Colorado[3 4]	2,600	4,300
Wyoming[3]	22,000	37,000
Total	25,500	42,700
Mexico	200	500
Total	25,700	43,200
Europe:		
Turkey	216	260
Africa:		
Botswana	400	NA
Chad	8	NA
Kenya[5]	56	NA
Uganda	18	NA
Total	482	NA
Asia:		
China[6]	232	232
World total[7]	26,600	43,700

NA Not available.

[1] The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

[2] Includes Owens Lake and Searles Lake.

[3] Represents only the quantity recoverable based on an average rate of 60% extraction efficiency from room-and-pillar, longwall, and shortwall methods of underground mining. This extraction rate does not apply to brines or surface evaporite lake beds. When solution mining of trona and nahcolite is commercially used, a 30% extraction efficiency rate is expected.

[4] The sodium carbonate content of nahcolite reserves and reserve base are 0.8 billion tons and 1.26 billion tons, respectively. The sodium carbonate content of dawsonite reserves and reserve base are 1.82 billion tons, and 3.0 billion, tons respectively.

[5] Annual leaching of volcanic rocks replenishes the resources at Lake Magadi.

[6] Proven reserves in Inner Mongolia, 100 million tons; Tongbai, Henan, 132 million tons.

[7] Data may not add to total shown because of independent rounding.

Note.—There are at least 62 identified natural sodium carbonate depósits in the world, some of which have been quantified. The countries and number of deposits include Australia (1), Bolivia (2), Botswana (1), Brazil (1), Canada (3), Chad (9), China (9), Egypt (1), Ethiopia (1), India (2), Kenya (3), Mexico (1), Namibia (1), Niger (1), Pakistan (1), the Republic of South Africa (1), Tanzania (5), Turkey (1), Uganda (1), the U.S.S.R. (4), the United States (20), and Venezuela (1).

TABLE 11

SODIUM CARBONATE-BEARING MINERALS

Mineral	Composition	Percent Na_2CO_3 [1]
Themonatrite (monohydrate)	$Na_2CO_3{\cdot}H_2O$	85.5
Trona (sesquicarbonate)	$Na_2CO_3{\cdot}NaHCO_3{\cdot}2H_2O$	70.4
Nahcolite (sodium bicarbonate)	$NaHCO_3$	63.1
Bradleyite	$Na_2PO_4{\cdot}MgCO_3$	47.1
Pirssonite	$Na_2CO_3{\cdot}CaCO_3{\cdot}H_2O$	43.8
Northupite	$Na_2CO_3{\cdot}NaCl{\cdot}MgCO_3$	40.6
Tychite	$2MgCO_3{\cdot}2Na_2CO_3{\cdot}Na_2SO_4$	42.6
Natron (sal soda or washing soda)	$Na_2CO_3{\cdot}10H_2O$	37.1
Dawsonite	$NaAl(CO_3)(OH)_2$	35.8
Gaylussite	$NaCO_3{\cdot}CaCO_3{\cdot}5H_2O$	35.8
Shortite	$Na_2CO_3{\cdot}2CaCO_3$	34.6
Burkeite	$Na_2CO_3{\cdot}2Na_2SO_4$	27.2
Hanksite	$2Na_2CO_3{\cdot}9Na_2SO_4{\cdot}KCl$	13.6

[1] Includes bicarbonate converted to carbonate.

cles equipped with a rotating cylindrical cutter. Continuous miners are used by T.g. Soda Ash Inc., in its shortwall technique. The longwall technique was used by General Chemical Corp. (formerly Allied Chemical Co.), and is now used by FMC Wyoming Corp. Adopted from coal mining use, the longwall method uses a special track-mounted shearer that moves in front of a hydraulic-operated roof support system.

FMC has pioneered the use of solution mining to dissolve and recover deeply buried trona. Using an array of injection and recovery wells, a solvent, dilute sodium hydroxide, is introduced under pressure to dissolve the underlying trona. This technique has had moderate success since its first commercial debut in 1985.

To reduce mining costs and maintain their competitiveness in the world, many Wyoming soda ash companies implemented continuous belt and mobile track conveyor systems to transport trona underground more efficiently. This new haulage system has replaced ore-carrying shuttle cars, reduced the mine workforce, and increased the quantity of ore mined per shift. Companies have also been considering eliminating conventional mining but retaining other mining methods, sometime in the foreseeable future, in order to further reduce labor, safety, and other operating costs.

Subterranean brines between 50 and 350 feet below the surface at Searles Lake in California are extracted using an array of injection and recovery wells drilled down to specific depths where mineral concentrations favor maximum extraction. The Argus plant of Kerr-McGee Chemical Corp. uses sodium carbonate-rich brines found in the Mixed Layer zone, 220 feet to 310 feet below the surface. Solar concentration ponds are used to aerate and concentrate the brine to improve processing efficiency.

Beneficiation.—Crushed trona is calcined in a rotary kiln at 325° to 400° F to dissociate the ore by the monohydrate process, which produces only dense soda ash with carbon dioxide and water as byproducts. The calcined material is combined with water to dissolve the soda ash and to allow separating and discarding of the insoluble material such as shale and shortite by settling and/or filtration. The waste material is piped in a slurry to containment basins, also known as tailing ponds. The resulting clear liquid is concentrated as necessary by triple-effect evaporators or mechanical vapor recompression crystallizers, and the dissolved soda ash precipitates as crystals of sodium carbonate monohydrate, $Na_2CO_3{\cdot}H_2O$. The crystallization temperature is about 212° F, which is below the transition temperature of monohydrate to anhydrous soda ash. Other dissolved impurities, such as sodium chloride or sodium sulfate, remain in solution. The crystals and liquor are separated by centrifugation. The sodium carbonate monohydrate crystals are calcined a second time at 300° F to remove water of crystallization. The resultant finished product is cooled, screened, and shipped by rail or truck in bags or bulk.

An alternate method of soda ash production from trona is the sesquicarbonate process. Crushed trona is first dissolved and filtered to remove insoluble impurities. The liquor is evaporated in vacuum crystallizers and the sodium sesquicarbonate precipitate is cooled to 100° F and centrifuged to produce a pure product, which has uses as such. The sesquicarbonate can be further calcined at 400° F to produce anhydrous soda ash of light to intermediate density.

The complex brines of the lower level of Searles Lake are first treated with carbon dioxide gas in carbonation towers to convert the sodium carbonate in solution to sodium bicarbonate, which will precipitate under these conditions. The sodium bicarbonate is separated from the remainder of the brine by settling and filtration and is then calcined to convert the product back to soda ash. The decarbonated brine is cooled to recover borax and Glauber's salt. A second dissolving, precipitating with carbon dioxide, filtering, and calcining the light soda ash to dense, refines the product to better than 99% sodium carbonate.

At Owens Lake in California, crude soda ash has been mined and processed by Lake Minerals Corp., by simply digging perimeter channels allowing the interstitial fluids to drain. The surface was tilled to promote evaporation to reduce moisture content, followed by harvesting with front-end loaders.

At Lake Magadi, Kenya, crude trona is dredged from surface crusts, crushed, washed, and calcined to convert the sodium sesquicarbonate to soda ash. At Lake Texcoco in Mexico, underground brines are recovered and sent to a surface spiral concentrator to promote the solar concentration of the sodium carbonate in solution. On the Kola Peninsula in the U.S.S.R., soda ash is recovered from processing nepheline-bearing rocks. Nepheline, a sodium-potassium-aluminum silicate is calcined in rotary kilns to yield alumina, potash, and soda ash. The alumina content of the rocks is about one-half bauxite but the mining and processing produces byproduct soda ash. The Petukhi and Tanatar (Mikhaylovskiy) natural soda ash lakes in Altay Kray of West Siberia provide some source of natural product.

Synthetic soda ash using the Solvay process uses salt and limestone as raw materials. A purified sodium chloride brine is saturated with ammonia and carbon dioxide gas to produce ammonium bicarbonate, which reacts with the salt to form sodium bicarbonate and ammonium chloride. The sodium bicarbonate is calcined at 350° to 425° F to light soda ash, and the gases produced are recycled back to the liquid phase. The liquid containing ammonium chloride is reacted with milk of lime to recover the ammonia and to produce byproduct calcium chloride. Limestone and coke are required to make the milk of lime. Dense soda ash is produced by hydrating light ash to produce larger sodium carbonate monohydrate crystals. The crystals are dehydrated in dryers to change the bulk density. To produce 1.0 ton of synthetic soda ash requires about 2.8 tons of steam, 1.7 tons of salt, 1.4 tons of limestone, 0.6 ton of coal for the boilers, and about 0.2 ton of coal for the dryers. Disposition of effluent streams containing high concentrations of calcium chloride and sodium chloride is a major problem for all Solvay soda ash plants. The Solvay process discharges about 1.7 tons of waste products.

Other chemical processes can produce synthetic soda ash. The Japanese ammonium chloride coproduction process, a variation of the Solvay process, converts all the sodium content of the salt into soda ash, whereas the Solvay process converts only about 70% of the sodium. The Japanese process also produces byproduct ammonium chloride that can be used as a fertilizer for growing rice in wetlands. The New Asahi process was also developed in Japan and uses less energy than the traditional Solvay process. An electrolysis-free process to produce vinyl chloride monomer with coproduct soda ash was developed in the Netherlands but is not in commercial operation. The method yields soda ash instead of caustic soda, and uses steam and carbon dioxide instead of electricity. The energy consumption is reported to be one-half that of the Solvay process.

Recycling.—There is no recycling of soda ash by producers; however, many glass-container manufacturers are using cullet glass, thereby reducing soda ash consumption.

Byproducts and Coproducts

Borax, potassium chloride, sodium chloride, and sodium sulfate are produced as coproducts with soda ash by Kerr-McGee in California. In Wyoming, only value-added products, such as sodium bicarbonate, sodium hydroxide, sodium sesquicarbonate, and sodium tripolyphosphate are produced from trona ore. Soda ash-bearing purge liquors and waste streams, normally considered waste byproducts, have been sold to powerplants for fluegas desulfurization because of their sodium carbonate content.

Sodium hydroxide (caustic soda) can be substituted for soda ash in some applications, but usually only at a higher cost and when available. About 1.3 tons of soda ash must be used to have the same chemical effect as 1.0 ton of caustic soda. Soda ash is usually shipped in dry, bulk form whereas caustic soda is transported as a liquid in various-sized closed containers.

An alternate source of soda ash is nahcolite, natural-occurring sodium bicarbonate found in a vast deposit in Colorado. The nahcolite could be converted to soda ash by calcination.

Economic Factors

Prices.—The list prices of natural and synthetic soda ash historically were identical until the mid-1970's when higher energy costs and costs to implement the controls imposed by antipollution legislation caused the synthetic soda ash price to increase compared with that of the natural material. New natural soda ash producers came onstream in 1976 and 1982 and contributed to slight changes in price-value trends. Changes in the domestic demand pattern also influences average annual values, especially after 1980, when domestic demand declined.

The list prices quoted in trade journals or by producers differ from the annual average values reported to and by the Bureau of Mines. The values are the combined total revenue of California and Wyoming natural soda ash sold at list-prices, spot-prices, discount, long-term contracts, and for export, divided by the quantity of soda ash sold on a bulk f.o.b. plant basis. This value may or may not necessarily correspond to the posted list prices.

TABLE 12

TIME-VALUE RELATIONSHIPS FOR SODA ASH

Year	Average annual value (dollars per ton) — Natural soda ash: Actual value[1]	Based on constant 1989 dollars[2]
1970	21.03	63.24
1971	21.21	60.33
1972	22.28	60.52
1973	25.36	64.71
1974	33.87	79.22
1975	42.20	89.88
1976	49.70	99.48
1977	54.19	101.70
1978	54.51	95.35
1979	64.55	103.72
1980	89.85	132.42
1981	91.19	122.52
1982	88.35	111.59
1983	76.95	93.54
1984	67.00	78.57
1985	67.82	77.24
1986	65.29	72.46
1987	66.78	71.84
1988	66.96	69.72
1989	77.07	77.07

[1] Values are the combined total revenue of California and Wyoming natural soda ash sold at list-prices, spot-prices, discount, long-term contracts, and for export, divided by the quantity of bulk soda ash sold, f.o.b. plant. The average annual value may not necessarily correspond to posted list prices for soda ash.

[2] From final 1989 implicit price deflators for Gross National Product, by the Council of Economic Advisors. Based on 1982 = 100.

Tariffs.—The United States has a 1.2% ad valorem tariff on imports of soda ash from countries having most-favored-nation (MFN) status. There is an 8.5% ad valorem tariff on imports from non-MFN sources.

Many nations levy import tariffs or antidumping duties of varying percentages on U.S. soda ash. In Western Europe, an antidumping duty of 67.5 European Currency Units (about $67.13 per ton) is imposed on any U.S. soda ash sold on the continent.

Taxes.—The total effective tax rate on the Wyoming trona industry is about 12.64% and comes from two major taxes. The trona severance tax of 5.5% is a State excise tax on minerals as they are removed from the ground, and is applied as a percentage of assessed valuation. The collected taxes are disbursed to the Permanent Wyoming Mineral Trust Fund (2.0%), the General Fund (2.0%), and the Capital Facilities Revenue Account (1.5%). The property, or ad valorem, tax is about 7.14% of the assessed value of trona produced from the mines. The ad valorem taxes on trona are higher than any other Wyoming minerals, including oil, gas, and coal. Other ad valorem taxes are placed on the assessed value of real property (buildings and equipment), and State sales and use taxes on equipment and facilities.

Royalties.—Soda ash mined on Federal lands is subject to the Mineral Leasing Act of 1920, which provides royalty payments to the United States Government. The Federal royalty is 5% of the quantity or gross value of the output of the product at the point of shipment to market. Each Federal lease also has other costs, such as bonds, acreage rental fees, sodium prospecting permit application fees, and permit bonds.

In Wyoming, the soda ash deposit within the Known Sodium Leasing Area is under the jurisdiction of the U.S. Government (administered by the Bureau of Land Management), the State, and the Union Pacific Railroad, which was given alternate 1-square-mile sections north and south of the railway that was constructed in the 1860's. Of the nearly 915,000 total acres of sodium mineral estate, the Federal ownership is 55.7%; Union Pacific owns 38.1%, and the State, 6.2%. Sixteen lessees hold 53 active and inactive Federal leases, having a total of 75,783 acres. In order to prevent a possible land monopoly, no lessee may hold more than 15,360 acres of Federal land but may lease more private or State land. The State royalty rate is tied to the Federal rate of 5%; however, the private royalty rate varies. One-half of all Federal royalties collected by the Minerals Management Service is disbursed back to Wyoming for various State and local programs.

In California, the Federal Government maintains 33 sodium mineral leases having 26,799 acres. The major lessee is Kerr-McGee Chemical Corp., which produces soda ash, sodium sulfate, and salt on its sodium leases on Searles Lake.

Depletion Provisions.—The mineral depletion allowance granted to the mining industry through legislation passed by the U.S. Government has been an important inducement for companies willing to accept the risk and high cost of mining development. The concept of depletion allowances for minerals is similar to the depreciation of other assets. Although cost depletion and percentage depletion are two methods used to compute depletion deductions, most companies prefer to use the latter. About 100 mineral categories are entitled to percentage depletion. The rates range between 5% and 22% of the gross income from the mineral property, depending on the mineral and location (foreign or domestic), and are subject to a limitation of 50% of the net income from the property. The significance of percentage depletion is that the deduction is based on the quantity of the first marketable product (soda ash and not trona) and not necessarily on the amount invested. The mineral depletion allowance for soda ash is 14% for U.S. companies mining from domestic or foreign sources.

Operating Factors

Operating factors are different for mining companies than for manufacturing facilities engaged in producing natural soda ash and synthetic soda ash, respectively. The shift in U.S. soda ash production from synthetic to natural has been caused by higher costs attributed to the greater energy and labor requirements of the Solvay process and to environmental regulations. Within the natural soda ash industry, the operating factors vary for producing the commodity from brines and from trona ore.

Environmental Requirements.—U.S. natural soda ash facilities do not have difficult problems disposing of effluents. Residual insoluble material is piped to surface tailing ponds, and allowed to settle. Some soda ash in solution that is not economically recoverable from processing is discharged and is converted to sodium decahydrate in the ponds and precipitates on the bottom of ponds to become an additional source of soda ash if needed. For example, FMC has been dredging some of its sodium decahydrate, which has been accumulating since 1950. Some pond water is recirculated into the mines and used as drilling and cutting coolant. Because of changes in environmental legislation in Wyoming, Tenneco Minerals has begun discharging its waste material into abandoned sections of its underground mine, thereby using less surface area on the surface for tailing ponds. The expense of underground discharge is partially offset with the reduction in costs of constructing and maintaining surface tailing ponds.

The alkaline surface ponds, with a potential of hydrogen (pH) up to 10.5, have posed some problems for migratory fowl that land on the ponds. The alkaline solutions strip the insulative natural oils from the fowls' feathers, thereby increasing the vulnerability of the birds to death from hypothermia. Also, birds have drowned because of the weight of sodium decahydrate that crystallizes on them when the temperature falls below 40° F. All trona producers have established a rehabilitation program to recover and release contaminated birds and to minimize the mortality and morbidity rate.

Land surrounding trona operations in Wyoming is relatively undeveloped, and the influx of large numbers of workers has caused great strain on the local facilities for housing, schools, shopping, and entertainment. Soda ash companies have provided financial assistance to aid local governments in handling any overloads caused by the migration of their employees and families into the community. The companies have given financial aid to employees purchasing homes in the surrounding communities, and other fringe benefits, such as low-cost transportation to and from work.

Toxicity.—Although soda ash is not considered a highly toxic substance, contact with the eyes may be injurious and prolonged contact with the skin may cause irritation, especially to those who have allergic reactions to alkaline materials. It has also been found to be corrosive to the stomach lining if ingested. It has an acute oral lethal dose (LD50) of 2.8 grams per kilogram (when tested on a rat) and a primary skin irritation index (PSII) of 2.54 (when tested on a rabbit). Simultaneous exposure to soda ash and lime dusts should be minimized because in the presence of moisture, as from perspiration, the two materials combine to form caustic soda, which is very harmful. Soda ash is not flammable, and the dust is not explosive.

Employment.—According to the Wyoming Office of the State Inspector of Mines, the Wyoming soda ash industry in 1980 employed 3,931 people, of which 1,817 were underground workers, to produce 12.9 million tons of trona. In 1989, 2,939 people were employed, of which 1,199 underground workers produced 16.2 million tons of ore. From 1980 through 1989, the underground workforce was reduced about 34%, while the quantity of trona increased 26%. This represented a 90% increase in the amount of ore mined per worker per year; 7,100 tons in 1980 and 13,511 in 1989.

Energy Requirements.—Natural soda ash plants consume considerably less energy per unit of product produced than do synthetic soda ash facilities. As the cost of energy has increased since the 1973 energy crisis, the differential in production costs between natural and synthetic soda ash has become greater. This is one of the major reasons that U.S. natural soda ash has maintained its competitiveness in the world market.

An early Bureau of Mines energy study, using 1973 data, indicated that 15.8 million British thermal units (Btu) was required to produce 1 ton of synthetic soda ash, whereas the energy requirement to produce the same quantity from trona was 7.2 million Btu. The domestic soda ash industry has reduced its energy requirements significantly since 1973, by replacing gas-fired dryers with steam-tube units and installing mechanical vapor recompression units to replace triple-effect evaporators. The industry has also converted to coal exclusively or combined with other fuel sources. Plants operated by T.g. and Tenneco, and the Argus plant operated by Kerr-McGee use coal only. As a result of these energy saving measures, the Wyoming soda ash industry lowered its energy requirement to a range of from 4.5 to 6 million Btu, depending on the individual producer. An estimated one-half of the energy consumed in natural soda ash refining using triple-effect evaporators is for evaporating; one-third is for calcining, and the remainder, for drying.

These energy requirements exclude the amount of energy needed to ship soda ash to foreign markets. Although it has been estimated that it would take about 2.9 million Btu of additional energy to transport soda ash by rail and by ship to Western Europe, natural soda ash production nevertheless requires less energy than the Solvay process or any other synthetic technique.

Transportation.—The western geographic locations of the domestic natural soda ash industry often pose problems because of the great shipping distance to most foreign customers. Even within the United States, the majority of domestic consumption is in the Midwest and east of the Mississippi River. Overland and ocean transportation rates become important factors in the delivered price of soda ash and must be considered seriously in negotiations with foreign consumers who often have alternate supply sources. Bulk freight rates can usually be reduced by shipping in larger volumes, such as in 7,500-ton units.

The railroad is the dominant mode of transportation for the shipment of soda ash. In Wyoming, the Union Pacific Railroad provides the main service to the industry. All bulk soda ash that is railed is carried in covered hopper cars, each handling about 98 tons. Although the railroad companies make their cars available, most soda ash companies have their own sizable fleet.

Beginning in 1985, soda ash was shipped in large quantities by truck. Bonneville Transloaders Inc. trucked soda ash from Green River to the Burlington Northern Railroad's line at Shoshone. Of the nearly 9 million tons of soda ash produced in Wyoming, Bonneville trucks about 850,000 tons out of Green River. Other trucking companies have started similar operations with the Southern Pacific (shipping over 250,000 tons per year) and Denver & Rio Grande Railroads to compete with Union Pacific.

The railroads have been involved in establishing soda ash bulk loading terminals at ports to handle large volumes of material for export. Kansas City Southern Railroad's terminal at Port Arthur, TX, has a railcar unloading capacity of about 1,000 tons per hour. Material is conveyed to a ship loader spout for transfer to bulk cargo ocean vessels. Port Arthur was the third largest port of the 24 ports that shipped soda ash in 1989, most of which was shipped to South America. Longview, WA, which is in the Portland, OR, customs district, has a bulk loading terminal that transferred the most soda ash, 47%, in 1989.

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