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AN ANALYSIS OF THE SULPHUR INDUSTRY IN ALBERTA

by

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PREFACE

This study* would not have been completed nor would I have progressed this far in my postgraduate studies had it not been for two men; they are Dr. E. J. Hanson, Head of the Department of Political Economy, and Dr. W. D. Gainer, Professor of Economics, University of Alberta. I am especially grateful for their personal interest and encouragement.

Generous assistance was provided by so many persons connected with the sulphur industry that lack of space precludes individual mention of all of them. However, it would be remiss not to acknowledge the assistance and invaluable information provided by Messrs. J. G. DeSorcy and N. Lashuk of the Oil and Gas Conservation Board, Calgary; Mr. Elgin D. Bell, Manager of Local Operations, Texas Gulf Sulphur Co., Calgary; Mr. L. B. Gittinger, Assistant Vice-President, Freeport Sulphur Co., New York; Mr. W. J. Mickle, Managing Director, International Sulphur Co., Calgary; Dr. Donald E. Armstrong, Director of the School of Commerce, McGill University; and Mr. C. M. Bartley, Department of Mines and Technical Surveys, Ottawa.

In a work of this nature it is difficult to segregate one's own ideas. No doubt many of the thoughts which appear in this report have been gleaned from minds of others, knowingly or not. For the assistance of others I am grateful; however, for the errors contained in this work the responsibility is my own.

Finally, I owe a debt of gratitude, which I shall not forget, to my superiors in the Department of Industry and Development who arranged for the financial support which enabled me to complete my postgraduate studies, and to the Research Council of Alberta which financed the preparation of this report.

October 11, 1961. Wm. G. Brese

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* The report is based on a thesis submitted by W. G. Brese to the University of Alberta for a Master of Arts degree, October 1961.

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ABSTRACT

Canada is on the eve of becoming the world's second largest producer of elemental sulphur, mainly on the impetus of sulphur produced in Alberta. For many years the United States held a commanding lead in the production of sulphur, but in recent years Mexico and France became significant sulphur producers. Canada is now stepping into the spotlight as well.

In Alberta, where the major developments in sulphur production are occurring, few are aware of the significance and importance attached to this imminent development, due, in part, to a dearth of published information on this subject. Whatever information is available is scattered throughout various periodicals and newspaper articles. The Research Council of Alberta sponsored this study in an effort to provide a consolidated source of information on the Alberta sulphur industry. How much sulphur will be produced? Where will Alberta sulphur find a market? What are the marketing problems? Are there extraordinary circumstances that surround Alberta sulphur production? The writer hopes that some of the answers to these and other questions concerned with the Alberta sulphur industry will be found in the pages which follow.

CHAPTER I. INTRODUCTION

The importance of sulphur in the modern complex industrial society of our present day world cannot be overemphasized. It may be said that sulphur is the sine qua non of modern manufacturing. Sulphur consumption is so closely correlated to industrial progress that a nation's consumption of sulphur is frequently used as a barometer of industrial activity or as a yardstick of a country's standard of living.

Because sulphur is not a commodity used directly by consumers, widespread ignorance abounds as to its commercial value and utilization, even though the use of brimstone dates back to antiquity. Biblical references and references in the Greek classics suggest that man first became attracted to this bright yellow mineral 3,000 or 4,000 years B.C. The fact that sulphur can easily be ignited likely accounts for its early use in religious ceremonies. No doubt it was soon discovered that the evil smelling fumes, which are emitted when it burns, had application for use as a fumigant and bleaching agent. However, not until the Romans employed the use of sulphur as an ingredient of gunpowder was sulphur used in anything but negligible quantities.

The discovery of new methods for manufacturing sulphuric acid in the 18th century marked the beginnings of what might be called a chemical industry and sulphur consumption took on new and significant proportions. As the Industrial Revolution gained momentum and industrial processes were expanded, the industrial complex became more intricate. The consumption of sulphur boomed mainly on the impetus of sulphuric acid consumption. In the past as in the world today, the manufacture of sulphuric acid is by far the largest single use of sulphur.

Either in the form of sulphuric acid or as a primary raw material, sulphur finds its way into almost every major manufacturing process. The following listing illustrates this fact, as does table 9 (page 33):

<u>Industries and Products in Which Sulphur is Employed</u>

Acids
Alcohols
Alum
Ammonium Sulphate
Aniline
Bleaching Agent
Bromine
Carbon Dioxide
Carbon Disulphide
Carbon Tetrachloride
Casein
Caustic Soda
Cellophane
Celluloid
Cellulose Esters
Cements
Chlorine
Coke
Copper
Dehydrating Agent
Detergents
Dyes
Ebonite
Electroplating
Explosives
Fertilizers
Fire Extinguishers
Fire Proofing Agents
Fireworks
Food Preservatives
Fumigant
Fungicide
Glue
Glycerin
Inorganic or Organic Acids
Insecticide
Leather
Livestock Food
Lubricants
Magnesium
Matches
Medicine
Metallurgy
Paints and Pigments
Paper Pulp
Petroleum Products
Pharmaceuticals
Phenol
Photography
Plastics
Plate Glass
Rayon
Refrigerants
Resins
Road Surfacing Materials
Rubber Goods
Soap
Soda
Solvents
Steel Pickling and Galvanizing
Storage Batteries
Sugar
Sulphonated Oils
Synthetic Fibres
Synthetic Rubber
Textiles
Tires, Rubber
Water Purification

Sulphur is widely distributed in nature in both the free and the combined state. It is found in the earth's crust in elemental form, and as sulphides and sulphates.

Elemental sulphur occurs in many localities often as chemically pure crystals mixed with gypsum and limestone. The well known deposits of the Gulf Coast of the United States and the Sicilian deposits are of this type, and are of sedimentary origin. Elemental sulphur deposits associated with extinct volcanic action are mined in Japan and Chile.

The above mentioned sources constitute deposits of elemental sulphur from natural sources. Sulphur in the form of its compounds is also produced from native pyrite and pyrrhotite, mineral combinations of iron and sulphur. Sulphur dioxide gas is readily produced when pyrite is heated and the sulphur dioxide may be used directly in the manufacture of sulphuric acid. Smelter gas given off during the smelting of sulphide ores is also used as a source of sulphur dioxide which may be used to produce sulphuric acid.

A source of elemental sulphur which has gained markedly in its importance very recently is sulphur obtained from hydrogen sulphide gas associated with the production of crude oil and natural gas. Sulphur from this source is commonly referred to as "recovery" sulphur and on the basis of present technology is in every respect equal if not superior to sulphur produced from other sources in terms of color and purity.

Since the latter part of the 18th century Sicily's primitive mining and rudimentary refining methods provided the world with sulphur. During the first half of the 19th century under monopolistic control the price of sulphur rapidly rose from $25 per ton to $75 per ton. This high price of Sicilian sulphur provided the necessary impetus to discover alternative sources of supply and a method to produce sulphuric acid from pyrites was found. The shift to pyrites resulted in Sicilian overproduction and falling prices; thus the alternative of using pyrites as a source of supply of sulphur placed an effective upper limit on the price of elemental sulphur. This fact remain true even in our present day.

At the beginning of the 20th century a brilliant German inventor, Herman Frasch, developed a revolutionary process for mining elemental sulphur from the salt domes of the Gulf Coast of the United States. The sulphur was melted with superheated water and then raised to the surface while molten. Native sulphur mined in this fashion became known as "Frasch" sulphur and in a short time became a formidable competitor of Sicilian sulphur. By the early 1920's Frasch sulphur dominated world markets, a favored position which it still holds (see figure 1).

For many years only relatively minor quantities of sulphur were recovered from waste gas and natural gas containing hydrogen sulphide which is known as "sour" or "acid" gas. However, in recent years due to the discovery of enormous quantities of sour natural gas both in southwestern France and in Western Canada, particularly in Alberta, the picture has changed very radically. These two countries, first France followed by Canada, have rather unexpectedly become major world producers of sulphur.

In order to understand and appreciate the present sulphur situation one must be familiar with the events of the past decade. To say flatly that there is at present an oversupply situation in the sulphur industry and that Alberta is contributing and will continue to contribute to this situation even more in the future, although perhaps true to some degree, does not tell enough of the story.

As recently as 1950, the U.S. Frasch sulphur mines produced 48% of the total world production of sulphur, the latter amounting to 10.8 million long tons. Total U.S. production of all types of sulphur was just under 5.4 million long tons. Instead of settling down to an even peacetime production, the demand for sulphur showed a very sudden increase as a result of the outbreak of the Korean war. The utilization of sulphur rose to

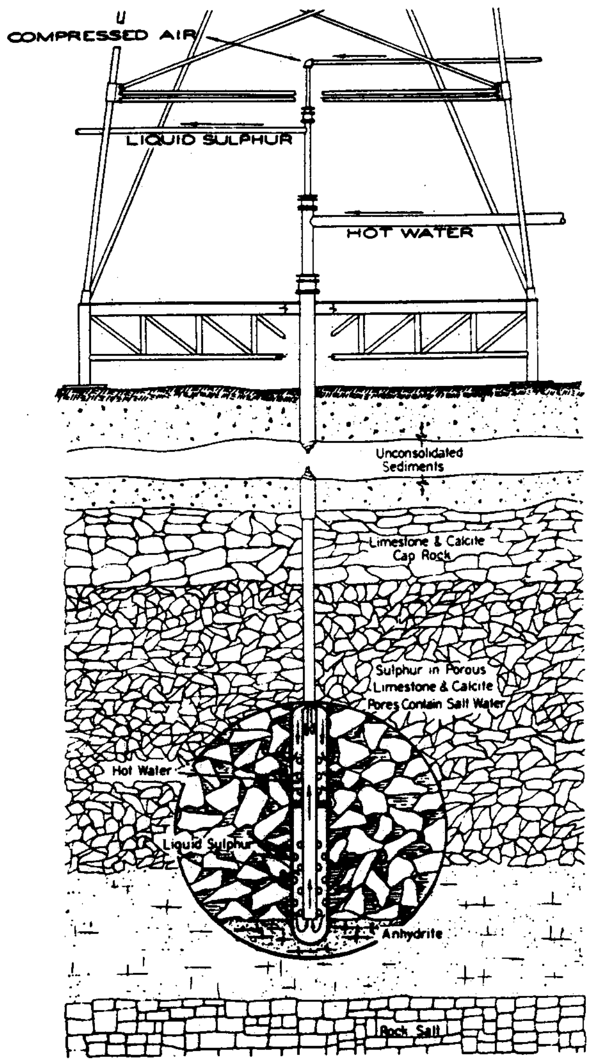

Figure 1. Sketch showing Frasch sulphur mine piping (Courtesy of Texas Gulf Sulphur Company)

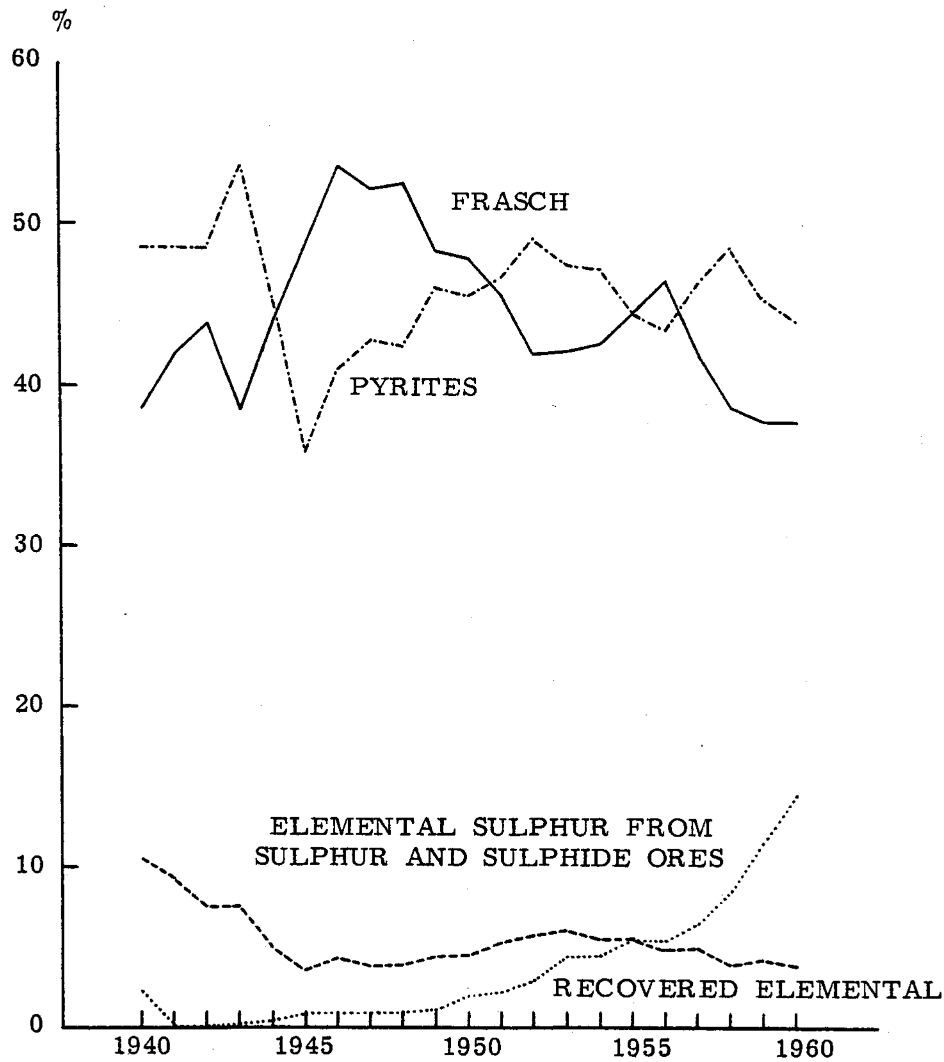

Figure 2. Relative importance of Free World sulphur production from different sources, 1940-1960

Table 1. Relative importance of Free World sulphur production from different sources, 1940-1960
('000 long tons of sulphur equivalent)

Year	Frasch		Recovered elemental		Elemental from sulphur and sulphide ores		Pyrites		
	Quantity	% of Total	Quantity	% of Total	Quantity	% of Total	Quantity	% of Total	TOTAL
1940	2732	38.6	163	2.3	738	10.5	3445	48.7	7,079
1941	3139	41.9	10	0.1	697	9.3	3642	48.6	7,489
1942	3461	43.8	10	0.1	598	7.6	3838	48.5	7,906
1943	2539	38.4	19	0.3	507	7.7	3543	53.6	6,607
1944	3218	49.2	40	0.6	330	5.0	2953	45.1	6,541
1945	3753	59.5	64	1.0	230	3.7	2264	35.9	6,311
1946	3860	53.6	78	1.1	309	4.3	2953	41.0	7,200
1947	4441	52.2	91	1.1	336	3.9	3642	42.8	8,510
1948	4869	52.5	102	1.1	372	4.0	3937	42.4	9,280
1949	4745	48.3	114	1.2	429	4.4	4527	46.1	9,816
1950	5192	47.9	212	2.0	508	4.7	4921	45.4	10,833
1951	5278	45.6	270	2.3	622	5.3	5413	46.7	11,583
1952	5293	41.9	397	3.1	733	5.8	6200	49.1	12,624
1953	5155	42.1	534	4.4	747	6.1	5807	47.4	12,243
1954	5590	42.6	603	4.6	742	5.6	6200	47.2	13,136
1955	6214	44.4	765	5.5	779	5.6	6240	44.5	13,998
1956	7182	46.4	830	5.4	764	4.9	6700	43.3	15,476
1957	6481	42.0	1010	6.6	802	5.1	7150	46.3	15,443
1958	5845	38.7	1310	8.7	612	4.0	7350	48.6	15,117
1959	5847	37.8	1790	11.5	664	4.3	7180	46.4	15,481
1960	6205	37.7	2390	14.5	649	3.9	7233	43.9	16,477

Source: United States Bureau of Mines

more than 150% of the peak World War II years and a very serious sulphur shortage developed as a result. The Frasch producers undertook to increase their production, while the U.S. government placed sulphur on the strategic commodities list and regulated exports.

Because of the restrictions placed on U.S. exports, British sulphur users, who had relied on Frasch sulphur for 90% of their requirements, switched many sulphuric acid plants over to the use of pyrites as a sulphur substitute. This transition has not been reversed today since considerable expense is involved in the conversion. By 1954 only 36% of the sulphur consumed in the United Kingdom was elemental. Thus a significant market for elemental sulphur was lost.

Another development of the sulphur shortage was the entry of Mexico into the production of Frasch sulphur in 1955. One cannot say that the Mexican sulphur industry would not have been established unless the Korean War shortage had occurred, but this situation did provide circumstances particularly conducive to its establishment. Mexican sulphur interests had little difficulty, in the light of the serious sulphur shortage, in arranging for a multimillion dollar loan from the U.S. Export-Import Bank and thus a significant increase in sulphur production capacity was established. However, before this production facility got into full production the sulphur shortage abated. Frasch sulphur production (U.S. and Mexico) rose from 5,192,000 long tons in 1951 to 7,182,000 long tons in 1956, an increase of 38%.

The sulphur shortage led to a marked increase in sulphur production which finally resulted in a sulphur surplus with the advent of the 1957 recession. Complicating the situation was the fact that sulphur recovery facilities in France processing sour natural gas from the Lacq field came into production in 1956. Initial production during the first year was negligible but by 1958 France produced 126,500 long tons. This was more than tripled in 1959 and has continued to increase. The sulphur shortage of 1951-1952 had changed markedly to one of oversupply by 1958 and a period of oversupply diametrically opposed to conditions at the beginning of the decade began to evolve.

With this picture in mind one can readily appreciate the consequences of Alberta recovery sulphur coming on the scene. Round figure estimates place Alberta sulphur productive capacity at approximately 2,300,000 long tons annually by 1965. As a result and at a rather inopportune time Canada will become the world's second largest producer of elemental sulphur. Figure 3 depicts this development. The consequences of the development and the prospects for the Alberta sulphur industry constitute the main subject matter of the following chapters.

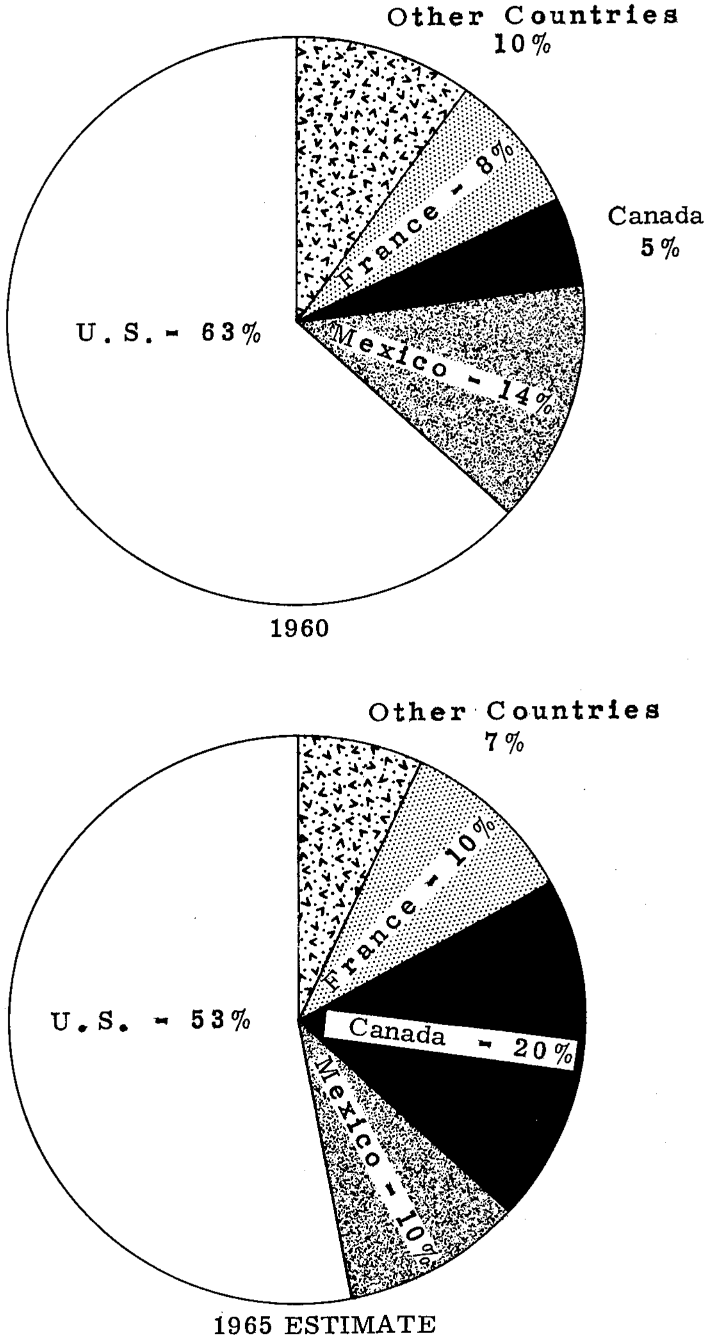

Figure 3. How Canada's share of the world's elemental sulphur production will be increasing, 1960 and 1965 estimate

CHAPTER II. THE SULPHUR INDUSTRY IN ALBERTA

The Alberta sulphur industry came of age in April of 1961 when cumulative production surpassed 1,000,000 long tons (see table 2). This feat was accomplished nine years after sulphur was first produced in this province. Within two years the second million long tons of sulphur will have been produced and thereafter annual production will grow apace.

The history of the sulphur industry in Alberta is really the history of the natural gas industry, which gained its real impetus from the oil discovery of 1947. Exploration for oil led to gas discoveries, and in time gas reserves in excess of the needs of Alberta had been discovered. The export of natural gas from the province resulted in increased production of both sweet and sour natural gas and along with the sour gas production the recovery sulphur industry developed.

Before the natural gas may be marketed it must be processed to make it suitable for sale. By authority of section 38 of the Alberta Oil and Gas Conservation Board Act, the Board is empowered to declare the provisions which must be met before natural gas may be sold for local use or for export. Sample specifications are shown in table 3.

Even sweet gas may be of the "wet" variety and contain propane, butane, or condensates, a certain proportion of which must be removed before the gas is deemed by the Oil and Gas Conservation Board to be saleable. In addition if the gas is of the "sour" variety, removal of the hydrogen sulphide is required. The H_2S must be removed because it is toxic, odorous, and corrosive. Normally it is unprofitable to recover sulphur in amounts of less than 20 to 30 tons per day. In any event, all H_2S not converted to sulphur must be incinerated to SO_2 and discharged to the atmosphere through a stack of sufficient height to limit the ground level concentrations of SO_2 to the satisfaction of the Provincial Department of Health.

Recovery sulphur production is unique in that in almost every case sulphur is produced as a consequence of producing sour natural gas. Primarily it is the utilization of gas, not sulphur, which dictates the amount of sulphur produced.

The commercial gas fields of Alberta vary considerably in their hydrogen sulphide content, from as little as 1% or 2% H_2S, to as much as 30% or 40%. Table 4 summarizes the concentrations and estimated reserves. A discovery known as the Panther River Dome, which is located 35 miles north of Banff, is reported to contain 86% H_2S, 13% CO_2, and 1% methane. The extent of this discovery or a reliable estimate as to its reserves has not yet been published, and the figure shown in table 4, (page 19), is considered to be a conservative estimate. This extreme find could affect sulphur production markedly in the future.

Another development of a somewhat different nature which could affect Alberta sulphur production considerably in the future is the anticipated production of oil from the Athabasca oil sands. The Athabasca oil sands contain oil reserves of between 100 billion and 300 billion barrels, with a sulphur content of 5% by weight. Sulphur reserves would be of the order of 900 million tons.

Work is continuing on developing an economical method to separate the oil from the sands. It is purely speculative to estimate when large scale production from this source might be anticipated, but significant developments before the end of the decade seem assured.

From the foregoing it might be inferred that Alberta recovery sulphur is a by-product of natural gas. The complexity of the natural gas industry, however, precludes generalization of this type. If all of the sour gas fields contained even remotely similar proportions of H_2S, generalization of this type might be possible, but this is not the case. For this reason some people in the industry prefer to refer to sulphur produced in Alberta as by-product, co-product, or main-product depending on their point of view. There is a considerable difference of opinion as to the strict definition of these terms. From the accompanying table which shows sulphur reserves (table 4), it will be noted that the H_2S content of the sour gas varies from 0.7% in the Carstairs field to 38% in the Crossfield field.

A rule of thumb suggested in some quarters[1] is that sulphur produced from gas fields containing less than 10% H_2S should be considered by-product sulphur, sulphur produced from fields with an H_2S content of 10% - 20% would be designated as co-product sulphur and greater than 20% H_2S, main-product sulphur. This criterion has not been accepted by the industry and no generally acceptable definition of terms exists. In some cases, production planning may be drawn from fields with varying H_2S content; thus the H_2S content of the gas stream being processed may be varied from time to time. This matter of terminology is mentioned here to point out the fact that although the sulphur being produced is homogeneous, its conditions of production are certainly heterogeneous. The economic aspects of the classification of by-product, co-product, and main-product sulphur are discussed in Chapter V (page 50).

In this connection it may further be noted that even though the H_2S content of certain fields maybe considered negligible and the H_2S might be thought of as a nuisance factor, when this gas is processed in substantial volumes the quantities of sulphur recovered may be sizeable. For example, the gas processing plant at Homeglen-Rimbey, which is operated by the British American Oil Co. Ltd., handles gas with an H_2S content of only 2.1%. However, with a throughput capacity of 326 M Mcf of gas per day, this plant can produce 250 long tons of sulphur daily, or 90,000 long tons per year.

With the exception of the Petrogas Processing Ltd. plant at East Calgary, which uses the new hot potassium carbonate process, the sulphur plants in Alberta all use an amine process for H_2S removal. The operations of a typical plant are broken down into two phases, the first being gas processing and H_2S removal and the second, elemental sulphur recovery. In the initial stage the raw sour gas is contacted with a water solution of mono-

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1 Daily Oil Bulletin, Calgary, January 13, 1959, p. 4. Quoted from a brief presented by Mr. J. Carrington, Freeport Sulphur Co. to the Oil and Gas Conservation Board.

Table 2. Sulphur production and sales - Alberta, 1952-1961

Year	Production long tons	Sales long tons	Stockpiled long tons	Sales as a percent of production %
1952	7,975	3,772	4,203	47.3
1953	16,337	14,350	1,987	87.8
1954	19,928	16,665	3,263	83.6
1955	25,977	23,194	2,783	89.3
1956	29,878	31,057	-1,179	103.9
1957	89,915	83,327	6,588	92.7
1958	109,219	81,725	27,494	74.8
1959	214,910	98,696	116,214	45.9
1960	348,145	233,505	114,640	67.1
1961 (Jan.-June)	216,355	141,571	74,784	65.4
Cumulative to June 1961	1,078,639	727,862	350,777	67.5

Source: Alberta Bureau of Statistics, private communication.

Table 3. Sample of product specifications for saleable natural gas

Residue Sales Gas

1. Shall not contain more than 0.25 grains of hydrogen sulphide per 100 cubic feet.

2. Shall not contain more than 10 grains of total sulphur per 100 cubic feet.

3. Shall not contain more than 2 per cent by volume of carbon dioxide.

4. Shall not contain more than 4 pounds of water vapor per 1,000,000 cubic feet.

5. Shall be commercially free from sand, dust, gums, and impurities which may be injurious to pipelines or which may interfere with its transmission through pipelines or its commercial utilization.

6. Shall not have a hydrocarbon dew point in excess of 15°F. at pressures up to 900 psig.

7. Shall not exceed 100°F. in temperature at battery limit where the transmission company takes delivery.

8. Pressure of 925 pounds per square inch gauge at battery limit where the transmission company takes delivery.

Source: Alberta Oil and Gas Conservation Board, private communication.

Table 4. Remaining recoverable reserves of sulphur - Alberta, 1961

Field or area	Pools	Percentage H_2S	Remaining recoverable sulphur reserves
			thousands of long tons
Berland River	Leduc	15.4	2,050
Burnt Timber	Mississippian	6.3	310
Calgary	Mississippian & Wabamun	20.3	14,140
Carstairs & Crossfield	Mississippian	0.7	440
Crossfield East	Mississippian	38.1	440
Harmattan Elkton	Mississippian	1.0	400
Homeglen-Rimbey & Westerose South	Leduc	2.1	1,730
Innisfail	Leduc	14.0	630
Jumping Pound	Mississippian	3.5	650
Lookout Butte	Mississippian	3.0	220
Minnehik-Buck Lake	Mississippian	2.0	150
Moose Mountain	Mississippian	11.0	220
Nevis (Erskine, Fenn-Big Valley & Stettler)	Nisku & Leduc	6.4	1,690
Okotoks	Wabamun	34.4	4,010
Olds	Wabamun	6.0	270
Panther River	Wabamun	87.0	3,190
Pincher Creek	Mississippian	10.8	6,660
Redwater	Leduc	2.8	80
Sarcee	Mississippian	6.0	300
Savanna Creek	Mississippian	14.0	3,450
Simonette	Wabamun & Leduc	19.2	1,590
Turner Valley	Mississippian	4.0	250
Waterton	Mississippian & Devonian	22-28	15,860
Wildcat Hills	Mississippian	4.0	990
Wildhorse Creek	Mississippian	5.8	230
Wimborne	Leduc	13.0	1,290
Windfall (Pine Creek & Beaver Creek)	Leduc & Wabamun	15-20	16,630
Total			77,870

Source: Alberta Oil and Gas Conservation Board, private communication.

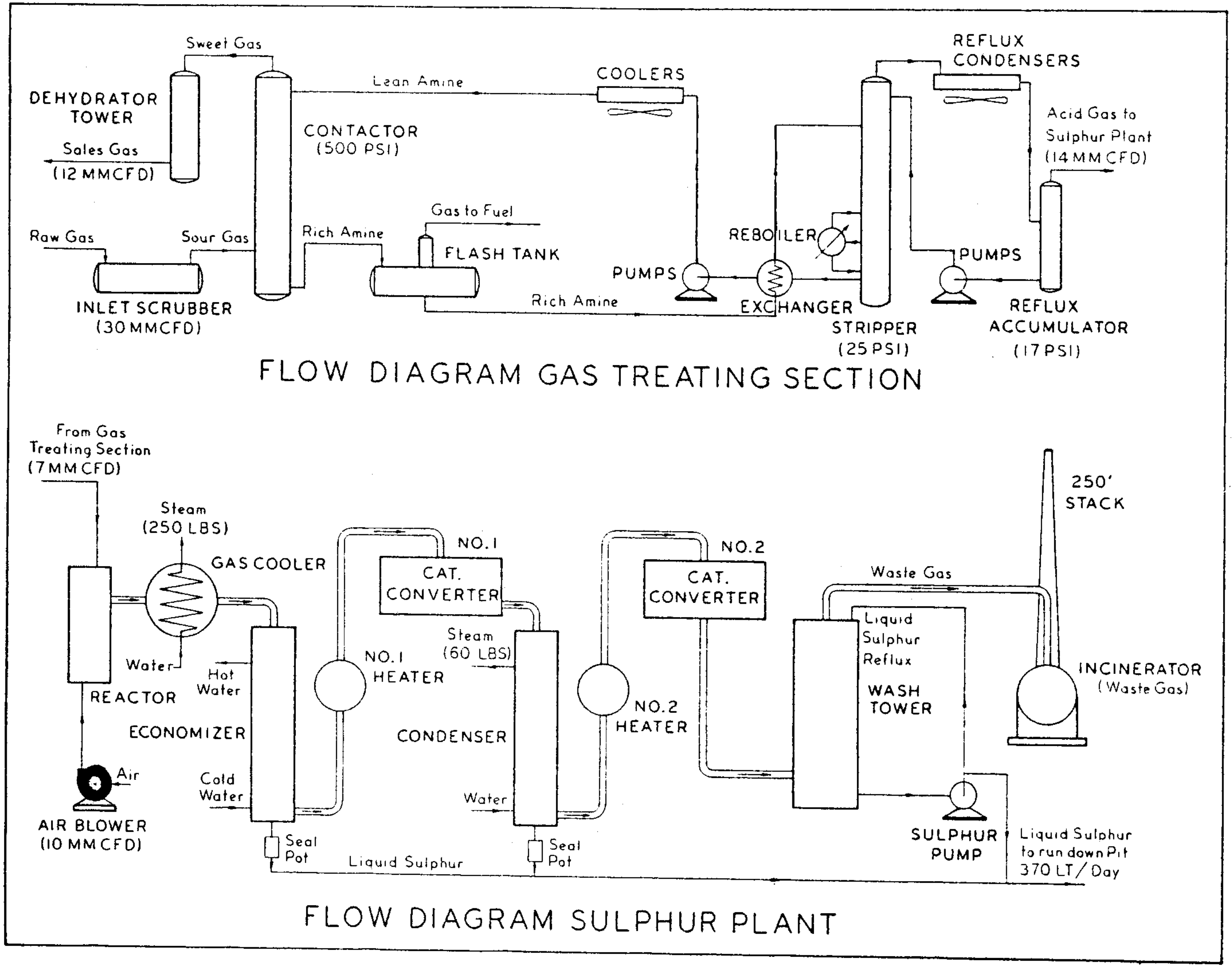

Figure 4. Flow diagrams, gas processing plant, Okotoks, Alberta

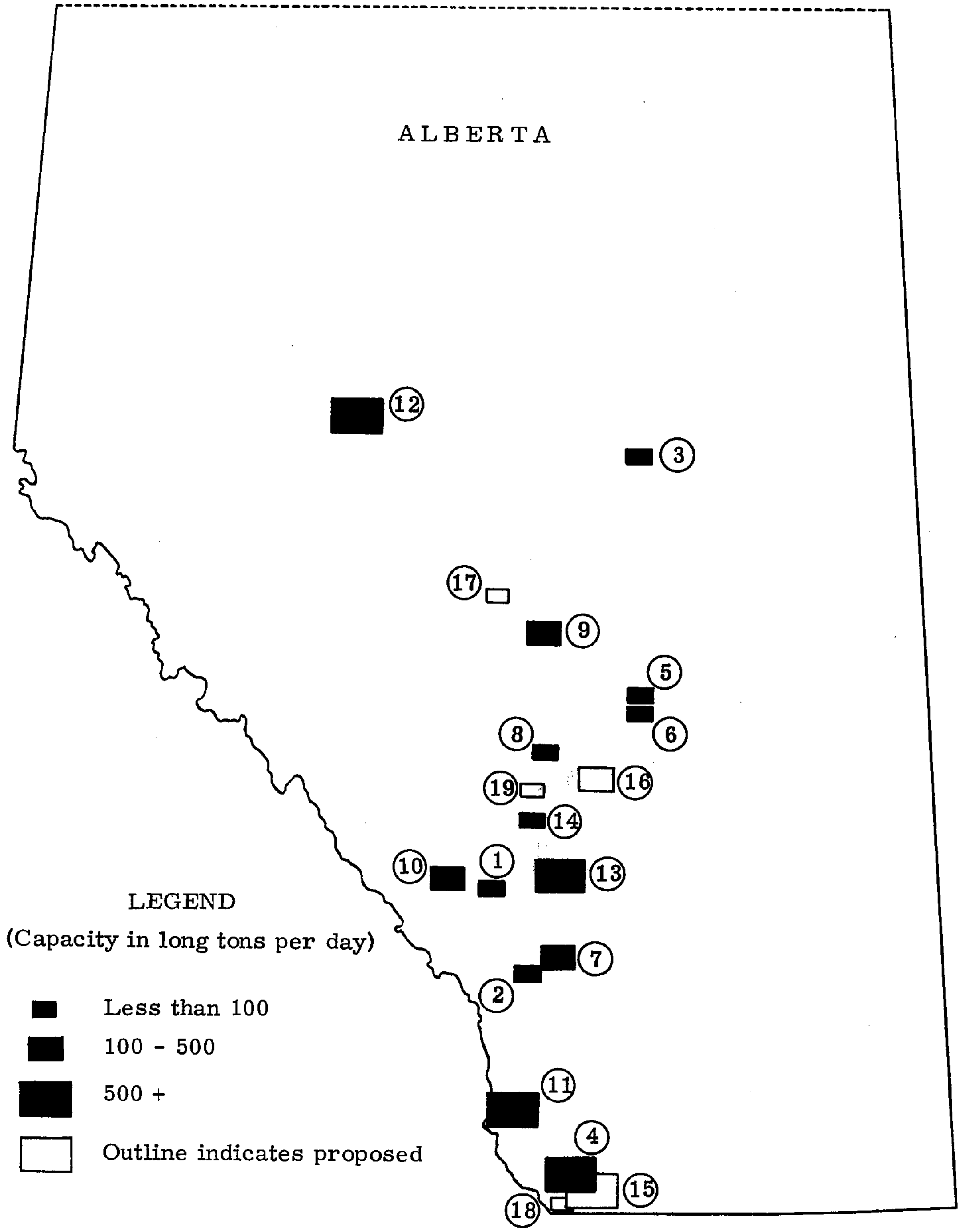

Figure 5. Map showing location of recovery sulphur plants - Alberta, 1961

Table 5. Location and capacity of recovery sulphur plants - Alberta, 1961-1963

Name of operator	Location	Sulphur productive capacity	Cumulative productive capacity
		long tons per day	
Existing Plants			
1. Shell Oil Company of Canada Ltd.	Jumping Pound	100	100
2. Royalite Oil Company Ltd.	Turney Valley	30	130
3. Imperial Oil Limited	Redwater	9	139
4. British American Oil Company Ltd.	Pincher Creek	675	814
5. California Standard Oil Company Ltd.	Nevis	120	934
6. British American Oil Company Ltd.	Nevis	76	1010
7. Texas Gulf Sulphur Company	Okotoks	370	1380
8. Canadian Oil Companies Ltd.	Innisfail	100	1480
9. British American Oil Company Ltd.	Rimbey	250	1730
10. Western Leaseholds Ltd.	Wildcat Hills	105	1835
11. Jefferson Lake Petro-chemicals of Canada Ltd.	Coleman	375	2210
12. Pan-American Petro-leums Ltd.	Windfall	1800*	4010
13. Petrogas Processing Ltd.	East Calgary	860	4870
14. Home Oil Company Ltd.	Carstairs	60	4930
15. Shell Oil Company of Canada Ltd.	Waterton	1400	6330
Proposed or Under Construction			
16. British American Oil Company Ltd.	Wimborne	100	6430
17. Canadian Delhi Oil Ltd.	Minnehik-Buck Lake	20	6450
18. British American Oil Company Ltd.	Lookout Butte	35	6485
19. Operator Unknown	Olds	35	6520

* This figure is the planned ultimate capacity of the plant. As of December 1961 sulphur productive capacity was 650 long tons per day. Expansion is planned for 1963.

Source: Alberta Oil and Gas Conservation Board, private communication plus direct contact with the industry.

ethanolamine which acts as an absorbent for the H_2S. The H_2S is then stripped from the amine solution and converted to elemental sulphur by the conventional Claus process. In this process the H_2S is burned with a deficiency of air and the sulphur dioxide produced combines with more hydrogen sulphide over a catalyst to produce elemental sulphur. After the elemental sulphur condenses, it is transported by insulated pipeline to a storage area where it is simply flooded into a dyked area and allowed to solidify. Sulphur may be stored exposed to the elements indefinitely with little or no deterioration.

As of February, 1962, fifteen sulphur recovery plants will be in production in Alberta with two more proposed for construction in 1962 and two in 1963. These are listed in table 5, and their locations and relative sizes are shown on the map in figure 5. The combined capacity of the 15 plants by February of 1962 will be over 6,300 long tons of sulphur per day. The four plants contemplated for construction in 1962 or 1963 will serve to increase this figure by 200 long tons per day, making a total productive capacity of 6,520 long tons daily or 2,347,000 long tons of sulphur per year.

Figure 6 which shows this growth of capacity draws attention to the sharp increase in sulphur production coming in the wake of the approval of export of 580 M Mcf of additional natural gas to major markets in Eastern Canada and the Southwestern United States.

A forecast of sulphur production for 1962-5 appears in table 6. The figures are derived by estimating throughput of sour natural gas for each plant on the basis of known gas contracts and estimating the contracts which do not exist on the basis of 1 M Mcf per 10 billion cu. ft. of gas reserves. At present it appears that production will be approximately 70% of capacity by 1965. This could be increased by more gas sales, or the recycling of gas, removing the H_2S and returning the gas to the formation.

At present it cannot be predicted with any degree of accuracy what sulphur production in Alberta will be after 1965. Most certainly it will be greater, but by how much is not presently known. The pipeline facilities which are being built to transport Alberta gas to distant markets have been designed to handle a throughput approximately twice that of original commitments. It is confidently expected that sometime between 1965 and 1967 another round of gas export applications will be made perhaps to double the quantity of gas exports. However, at this stage reliable estimates cannot be made as to the probable effect on sulphur production since it is not known which fields would be tapped or what the H_2S content of new discoveries in the interim might be. Officials in the industry doubt that sulphur production would be similarly doubled. Conjecture on this subject is that sulphur productive capacity will be increased to 3,000,000 - 3,500,000 tons by 1966 or 1967.

In any event, even before 1965 Alberta will be in a position to produce well over 2,300,000 long tons of sulphur per year. Mainly on the strength of Alberta's sulphur production Canadian elemental sulphur production will likely exceed 3,000,000 long tons annually. Elemental sulphur is produced in seven provinces, with British Columbia next in importance to Alberta. Thus by 1965 Canada will become the world's second largest producer of elemental sulphur and account for approximately 20% of the Free World production or some 40% of the United States production.

Table 6. Forecast of sulphur production - Alberta, 1962-1965

Producing plants		Annual production - long tons			
Company	Location	1962	1963	1964	1965
British American Oil Co. Ltd.	Nevis	14,900	17,600	17,700	17,900
British American Oil Co. Ltd.	Pincher Creek	223,000	236,000	236,000	236,000
British American Oil Co. Ltd.	Rimbey	69,000	79,000	79,000	79,000
California Standard Company	Nevis	31,000	36,400	36,400	36,400
Canadian Oil Companies Ltd.	Innisfail	23,000	23,000	20,000	20,000
Imperial Oil Limited	Redwater	1,800	2,300	2,300	2,300
Royalite Oil Co. Ltd.	Turner Valley	10,100	11,800	11,800	11,800
Shell Oil Co. of Canada Ltd.	Jumping Pound	28,000	27,000	26,000	25,000
Texas Gulf Sulphur Co.	Okotoks	124,000	117,000	110,000	107,000
Sub-total		524,800	550,100	539,200	535,400

Plants under construction or proposed Company	Location	Annual production - long tons 1962	1963	1964	1965
British American Oil Co. Ltd.	Lookout Butte	-	-	-	12,000
Home Oil Company Ltd.	Carstairs	14,000	16,000	16,000	16,000
Jefferson Lake Petrochemicals Ltd.	Coleman	90,000	120,000	120,000	120,000
British American Oil Co. Ltd.	Wimborne	-	40,000	54,000	54,000
Pan-American Petroleum Corp.	Windfall	160,000	223,000	223,000	223,000
Petrogas Processing Ltd.	Calgary	200,000	259,000	259,000	259,000
Operator Unknown	Olds	- -	7,000	11,000	12,000
Shell Oil Co. of Canada Ltd.	Waterton	300,000	330,000	360,000	400,000
Western Leaseholds Ltd.	Wildcat Hills	30,000	38,000	38,000	38,000
Canadian Delhi Oil Ltd.	Minnehik-Buck Lake	-	5,000	5,000	5,000
Total		1,318,800	1,588,100	1,625,200	1,674,400

Note: Forecast based on existing contract quantities of gas. Contracts assumed when they did not exist on the basis of 1 million cu. feet per day per 10 billion cu. feet of gas reserves.

Source: Alberta Oil and Gas Conservation Board, private communication plus personal estimates.

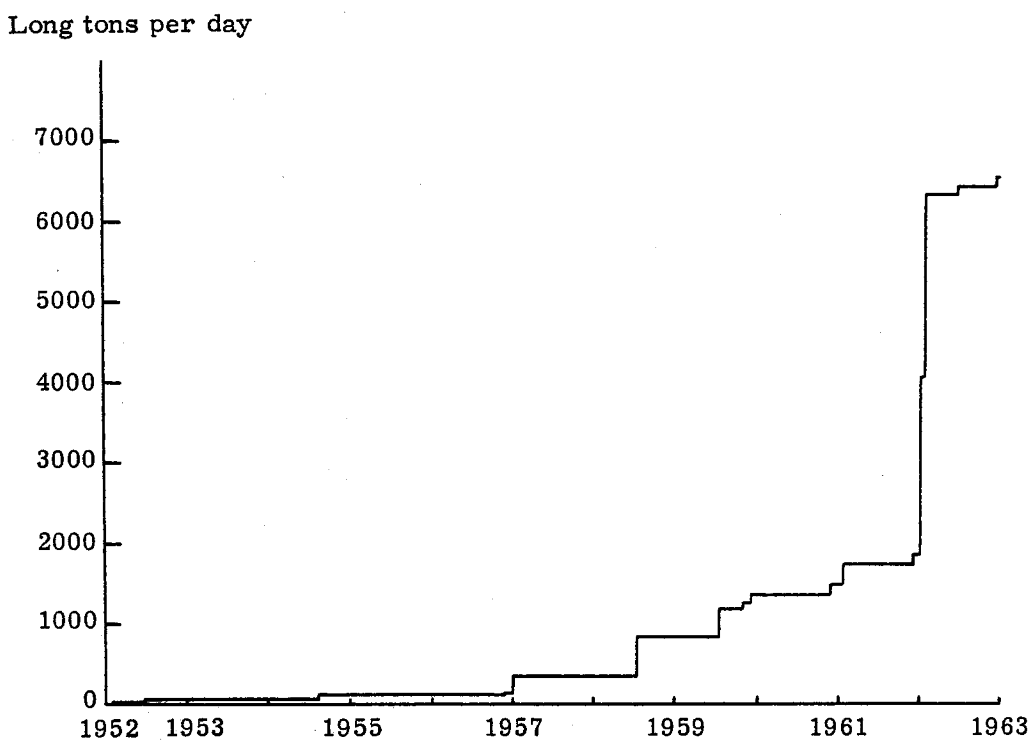

Figure 6. Cumulative sulphur productive capacity – Alberta, 1952-1963

CHAPTER III. POSSIBLE MARKETS FOR ALBERTA SULPHUR AND THE TRANSPORTATION PROBLEM

The total Free World apparent consumption of sulphur in all forms amounted to approximately 18,300,000 long tons in 1960. It is not suprising to find that the seven largest sulphur consumers are the leading industrial nations, namely: United States, Japan, Germany, United Kingdom, Italy, France, and Canada, in that order. These countries make use of approximately three-quarters of the total Free World sulphur consumption.

Canada ranks only seventh in world consumption of sulphur, using 957,000 long tons of sulphur in all forms in 1960. However, the Canadian per capita consumption of sulphur in all forms is the highest in the world. The relatively large quantities of sulphur that go into the manufacture of pulp and paper are primarily responsible for this.

Current per capita consumption of sulphur in all forms

	Lbs.
Canada	130
United States	75
Europe	37
Asia, Australia, and New Zealand	9
South America	6

Canada is certainly a study in contrasts as far as sulphur production and consumption are concerned. Canada is both a producer and exporter of recovery sulphur, an importer of Frasch sulphur, a user of pyrites and smelter off gases as a source of sulphur, and an exporter of pyrites. This apparent confusion is partly the result of the distances that separate the production of elemental sulphur from the major consuming areas and the fact that the basic metallic mineral industry is so important to our economy. By-products of the smelting industry enjoy captive markets for sulphur substitutes, and large amounts of pyrite and pyrrhotite are produced by base-metal smelters in British Columbia, Manitoba, Ontario, and Quebec. For many years these plants have been Canada's chief source of sulphur, with the remaining deficiencies being made up by Frasch sulphur imports. These imports amounted to 332,000 long tons in 1959 and 329,000 long tons in 1960.

Leaving for more detailed consideration in a later chapter* an examination of the markets Alberta sulphur might penetrate, we will in the following section examine only the magnitude of likely markets. Starting with Canada, it is noted in table 8 that British Columbia, Ontario, and Quebec are the major sulphur consuming provinces. Their sulphur utilization is based on the fact that large pulp and paper mills and major chemical plants are located in these provinces. The Prairie Provinces are not industrialized to the same extent, a fact which is reflected in their consumption of sulphur. Alberta's sulphur consumption results mainly from requirements of fertilizer manufacturers and wood pulp operations.

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* See Chapter V.

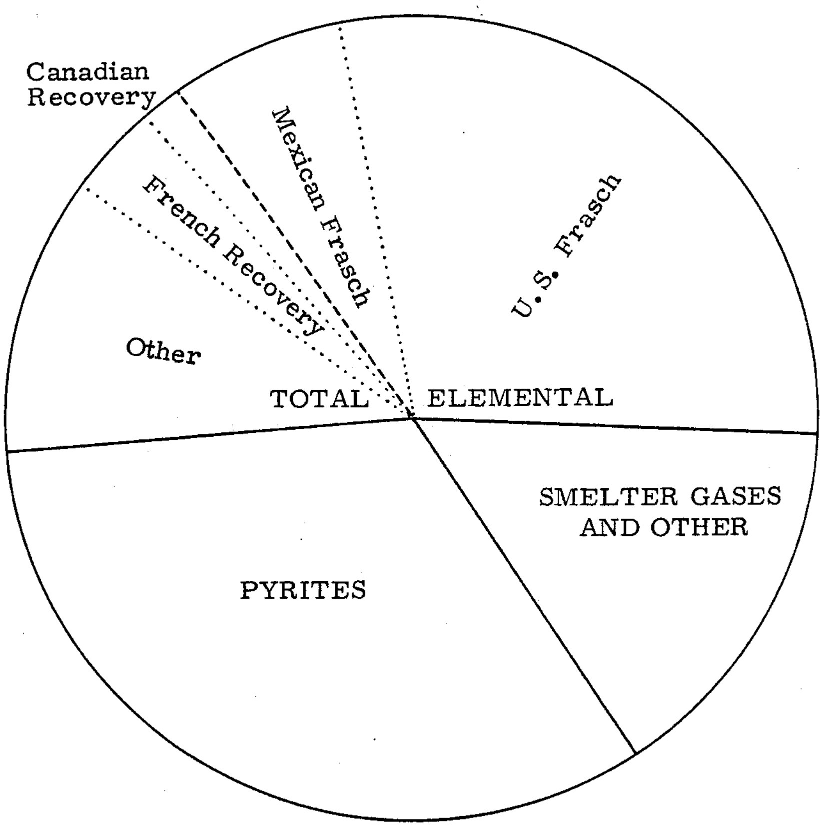

Figure 7. Source of total Free World consumption of sulphur in all forms, 1960

Table 7. Free World consumption of sulphur in all forms, 1958-1960
('000 long tons sulphur equivalent)

Sulphur material	United States			Total Free World		
	1958	1959	1960	1958	1959	1960
Elemental						
Frasch						
United States	3,075	3,550	3,400	4,675	5,150	5,100
Mexico	600	625	600	1,100	1,100	1,250
Other elemental						
Canada	10	25	150	100	150	300
France (Lacq)	-	-	-	100	375	650
Other	665	775	850	1,675	1,825	2,000
Total elemental	4,350	4,975	5,000	7,650	8,600	9,300
Pyrites	550	550	550	5,575	5,775	5,900
Smelter gases & other	450	425	450	2,450	2,575	2,700
Total sulphur	5,350	5,950	6,000	15,675	16,950	17,900

Source: L. B. Gittinger, Sulphur, Mining Congress Journal, February, 1961.

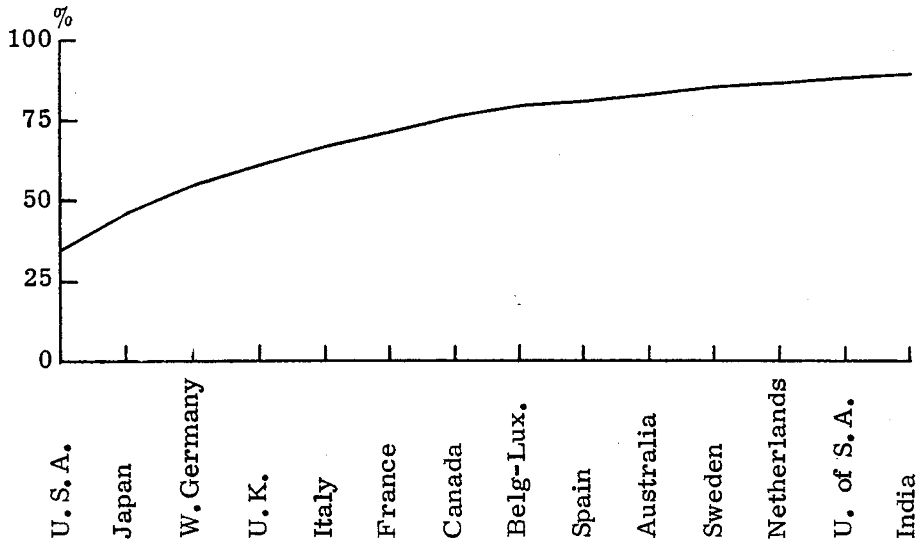

Figure 8. Cumulative consumption of sulphur as a percentage of total Free World consumption, 1960

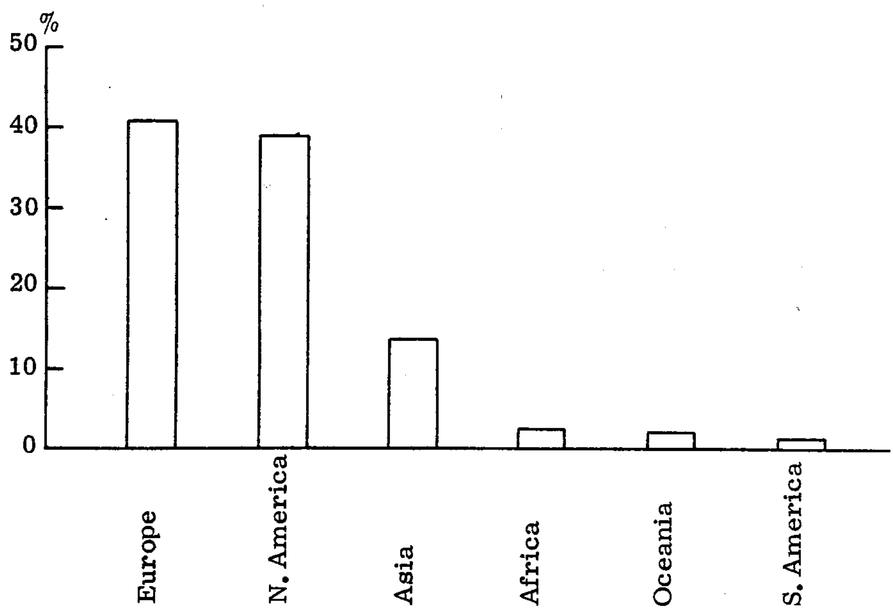

Figure 9. Geographical consumption of sulphur as a percentage of total Free World consumption, 1960

Source for figures 8 and 9: Freeport Sulphur Co., Market Research Department

Table 8. Consumption of sulphur in the central and western provinces of Canada, 1960

Province	Quantity (long tons)
Alberta	50,000[1]
British Columbia	60,000[2]
Saskatchewan and Northwest Territories	25,000[3]
Manitoba, Ontario and Quebec	365,000[4]
TOTAL	500,000

Source: (1) Alberta Bureau of Statistics.

(2) British Columbia Research Council.

(3) Estimate based on a knowledge of the quantity of sulphur used in northern mining operations.

(4) Markets for Alberta Liquefied Petroleum Gases, Pentanes Plus and Sulphur - Hu Harries & Associates, Edmonton, 1959; plus an estimate for Manitoba.

In Saskatchewan the uranium mine at Uranium City is the major user. Manitoba also uses sulphur for the manufacture of sulphuric acid which is used primarily in smelting and metal refining operations.

The possibility of sulphur consumption in Western Canada expanding considerably in the next few years cannot be ruled out, but in terms of the quantities of sulphur which will be produced such an increase in consumption would do little to change the oversupply situation. Therefore, a consideration of the foreign export position of the Alberta sulphur industry is essential. In this area of investigation many research organizations have prepared reports on the subject of world consumption of sulphur by countries. As it is beyond the scope of this report to duplicate these efforts, the writer has examined every available report on the subject and has chosen to lean heavily on the statistical work done by the Market Research Division of Freeport Sulphur Company, New York.

The fact that the United States is the world's largest user of sulphur as well as being the world's biggest producer places it in the position of being a very attractive market but also a formidable competitor. The consumption pattern of the United States is somewhat similar to that of Canada with sulphate and sulphite wood pulp treatment and sulphuric acid accounting for a major share of the total quantity of sulphur consumed. A breakdown of the use pattern of sulphur in the United States appears in table 9.

Table 10 summarizes the main use areas. The states with the largest sulphur consumption are situated on the east coast of the United States relatively close to the main United States source of Frasch sulphur, located on the Gulf coast of Texas and Louisiana.

The states of Illinois, Michigan, Wisconsin, Minnesota, Indiana, Washington, Idaho, Oregon, Montana, Alaska, and California, which are marked with an asterisk, are of particular interest being closer to Alberta. The sulphur requirements of these states amounted to 988,000 long tons in 1960.

Due to the proximity to South America of the United States and Mexican Frasch producers and the nearness of the recovery sulphur production facilities at Lacq, France to Western Europe, Alberta's overseas markets, on the basis of present transportation technology, will be confined largely to the markets in Asia and Oceania. These markets which would be served from the Pacific coast have a potential as indicated by import statistics of eastern Pacific countries (excluding Japan which is self-sufficient) in the neighbourhood of 500,000 long tons. Allowance has to be made for the fact that statistics are unavailable for users such as Korea and Pakistan.

The greatest problem facing Alberta sulphur producers is one that cannot be sidestepped or avoided; it is the cost of transporting Alberta sulphur to major consuming areas. Alberta sulphur is produced some 600 to 700 miles from tidewater and overseas export markets, or 1,300 miles from the Lakehead. The industrial centres, such as the Chicago area or the San Francisco area, are 1,600 miles from Alberta. As a consequence, transportation costs and the location of competitive production take on paramount importance as a deciding factor in determining which markets may be served in the future.

Table 9. Sulphur use pattern - United States, 1960

Use	Percent of total
	%
Sulphuric Acid:	
Fertilizers	33.0
Chemicals	18.5
Titanium and other pigments	7.5
Iron and steel	7.0
Rayon and film	4.5
Petroleum	3.0
Miscellaneous	6.5
	80.0
Non-acid:	
Pulp and paper	7.5
Carbon disulphide	4.5
Ground and refined	5.0
Chemicals and miscellaneous	3.0
	20.0
Total	100.0

Source: U.S. Bureau of Mines.

Table 10. Sulphur surplus and deficit in specified areas - United States, 1960
('000 long tons)

Area & state	Deficit	Surplus
Midwest		
Nebraska & South Dakota	-	-
North Dakota	-	18
Minnesota*	9	-
Kansas, Iowa & Missouri	153	-
Wisconsin*	99	-
Illinois*	359	-
Tennessee & Kentucky	83	-
Ohio	235	-
Indiana*	128	-
Michigan*	123	-
Midwest Area:	1189	18
Deficit in States which might be served by Alberta sulphur	718	

Area & state	Deficit	Surplus
Mountain & West		
New Mexico, Arizona, Nevada, Utah, Colorado & Hawaii	186	-
Idaho*	29	-
Montana*		
Wyoming	9	-
Washington*	(100)(1)	-
Oregon*	30	-
California*	(100)(2)	10
Alaska*	11	-
Mountain & West:	265	10
Deficit in States which might be served by Alberta sulphur (see (1) & (2) below)	270	
TOTAL Deficit which might be served by Alberta sulphur	988	

* States which the author believes might be served by Alberta sulphur.

Author's revisions:

(1) Washington uses most of the sulphur consumed in Montana, Wyoming and Washington. Since the latter is a likely market for Alberta sulphur, a deficit of 100,000 long tons has been estimated.

(2) California is a large exporter of sulphur. Certain regions in California, therefore, import approximately 100,000 long tons of Frasch sulphur annually. (See: George C. Branner, "Sulfur in California and Nevada", United States Department of the Interior, Washington, 1959, p. 16).

Source: Market Research Department, Freeport Sulphur Co., New York.

Table 11. Sulphur imports by specified country, 1958-1959

Country	1958 Quantity (long tons)	1959 Quantity (long tons)
Indonesia	7,800	11,200
India	107,100	134,800
Union of South Africa	126,900	114,000
Australia	155,400	151,400
New Zealand	65,100	88,100
Ceylon	2,000	2,500
Total	464,300	502,000

Source: Foreign Trade Service, Department of Trade & Commerce, Ottawa.

The modes of transport being used at present are truck-trailer for short haul local consumption; the railroad tank car, gondola, or box car for more distant markets; and ocean vessels for overseas markets. Ever since sulphur was first produced in Alberta, producers have been negotiating with the railroads to secure more favourable transportation rates in order that the periphery of their market areas might be extended. The prospect of substantial tonnages of sulphur being moved regularly throughout the year has resulted in a considerable improvement in the freight tariff. However, despite the concessions made by the railways, the substantial size of the transport charges which face sulphur producers in Alberta are evidenced by the rates shown in table 12.

The rate of 35 cents per hundredweight to Vancouver for export which was reduced from 45 cents per hundredweight in June, 1961, represents a cost of $7.84 per long ton which must be incurred in order that Alberta sulphur reach tidewater. The sulphur producers are still pressing for more favourable rail rates, but the extent to which rail carriers could or would make further concessions is uncertain. The rates for wheat under the Crowsnest Pass Agreement, which will be in effect in perpetuity unless changed by an Act of Parliament, are 20 cents per hundredweight to Vancouver and 26 cents per hundredweight to the Lakehead for export. A 54 cents per hundredweight rate is in effect to both points on wheat used for domestic consumption. It is difficult to envisage sulphur rates being reduced much more.

At tidewater the sulphur is either loaded directly into the holds of freighters or stockpiled for future shipment. One of the two efficient bulk loading facilities at the west coast is situated at Port Moody, twelve miles east of Vancouver. This installation is capable of loading up to 1,000 tons of bulk sulphur per hour from gondola cars. The second, located on the north shore near the Lions Gate Bridge, has comparable capacities. A third bulk loading terminal, which would be located in the heart of Vancouver harbour, is presently being considered. These installations compare favourably with those used to load ocean vessels with bulk Frasch sulphur at Beaumont and Galveston in Texas and Port Sulphur in Louisiana, each of which has a rated capacity in the neighbourhood of 1,200 tons per hour. The loading facilities at Bayonne, France, are also comparable, their rated capacity being 1,000 tons per hour.

Sulphur loading charges at the west coast are:

Up to and including 3000 long tons - $1.25 per long ton,
over 3000 long tons - $1.18 per long ton,

Plus 3¢ per short ton cargo rates assessed by the National Harbour Board.

Difficulties are encountered in attempting to arrive at ocean freight rates for transporting Alberta sulphur from the Port of Vancouver to overseas markets. As yet there have been no regular sizeable overseas shipments of sulphur, and ocean rates on sulphur are normally "open" rates dependent on the demand for shipping services and the volume of traffic being handled. At the moment there is speculation that the rate for a full ship (approximately 10,000 tons) likely will be between $7 - $10 per ton from Vancouver to Far Eastern destinations.

As a matter of comparison the following freight rates were applicable as of May, 1961, on sulphur out of U.S. Gulf coast ports to various destinations:

Destination	Rate per ton
Netherlands	$ 5.00
United Kingdom, East Coast	7.05 - $7.25
United Kingdom, West Coast	7.55
Brazil	8.00 - $8.50
New Zealand	10.30
Australia	10.85
India	12.50

The foregoing concerns itself only with shipment of sulphur in solid bulk form. There is, however, an increasing trend towards the transportation of sulphur in its liquid state. Molten sulphur delivery lowers the consumer's handling costs, reduces contamination, corrosion, and wind loss. Present modes of molten sulphur transport are confined to truck, railway tank car, barge and boat for coastal shipping. The impact of this development on the Alberta sulphur industry will be dealt with at greater length in Chapters IV and V.

The possibility of pipeline transport of sulphur has received considerable attention although no practical application has been implemented as yet. The pipelining of pure liquid hydrogen sulphide which could be converted to sulphur at the market, is technically feasible but highly unlikely because of the extreme toxicity and the resultant hazards associated with leaks or breaks. Pipelining of a slurry of powdered sulphur in water is also feasible with existing experience in slurry transport of coal and gilsonite. The cost decreases rapidly with increasing line size and capacity, and a very large throughput is necessary to make such transport attractive. A slurry of sulphur in natural gas liquids is more attractive economically should large quantities of such liquids be moved, but may face technical difficulties due to sulphur plating out on the pipe wall.

A further pipeline possibility, rising out of research in the Petroleum Division of the Research Council of Alberta is the movement of solid billets or capsules of sulphur in an oil stream. Although this development is as yet in its early stages it may become important in the future.

Table 12. Rail rates on sulphur from Alberta points to specified destinations, October 1, 1961

	Rate per cwt. ¢	Rate per long ton $
From Alberta points such as:		
Calgary		
Cochrane		
Drywood		
Nevis		
Okotoks		
To points such as:		
Seattle, Wash.	61 1/2	13.78
Tacoma, Wash.	61 1/2	13.78
Bellingham, Wash.	61 1/2	13.78
Portland, Ore.	61 1/2	13.78
San Francisco, Calif.	75	16.80
Los Angeles, Calif.	89	19.94
Chicago, Ill.	57 1/2	12.88
Dakota City, Iowa	57 1/2	12.88
Duluth, Minn.	57 1/2	12.88
Munsing, Mich.	57 1/2	12.88
Park Falls, Wis.	57 1/2	12.88
Mason City, Iowa	57 1/2	12.88
Fort William, Ont.	57	12.77
Vancouver, B.C. (for export)	35	7.84

Note: All rates quoted are for 100,000 lb. minimum except the Vancouver (for export) rate which is for 150,000 lb. minimum.

Source: Alberta Freight Bureau.

CHAPTER IV. AN ANALYSIS OF THE COMPETITIVE FACTORS INVOLVED IN THE MARKETING OF ALBERTA SULPHUR

Since the problem of marketing Alberta sulphur in foreign and overseas markets is of recent origin for many Alberta producers, the important competitive factors involved in this situation will be considered here in detail.

In all likelihood, Alberta sulphur will be marketed in areas which are presently being supplied by the Frasch producers either in the United States or in Mexico. The recovery sulphur being produced at Lacq, France (annual capacity 1,400,000 long tons) should effectively rule out the possibility of Alberta sulphur finding an immediate market in western or central Europe. Common market ties plus the distance factor create difficult barriers which deter Alberta sulphur from reaching these market areas. Since the United States and Mexican Frasch producers will be the principal competitors facing Alberta sulphur marketers, the Frasch producing countries will be considered here in turn.

Not all of the sulphur produced in the United States is of Frasch origin, but the latter accounts for 4,943,000 long tons or approximately 75% of the 6,660,000 long tons of sulphur produced in 1960. However, because of the fact that over half the remaining 1,600,000 long tons is captive production from pyrites and off-gases, the remainder being recovery sulphur, only the Frasch sulphur is of major importance from the point of view of competition for the major markets.

Frasch sulphur has been produced on the Gulf coast of the United States since the turn of the century. It is mined in the states of Texas and Louisiana. Figure 10 shows the location of the twelve producing mines. Four companies are responsible for the production of practically all of the Frasch sulphur. These firms are listed in table 13 which also provides data on the number and location of domes in operation. It will be noted that the largest sulphur producer is the Freeport Sulphur Company, followed closely by the Texas Gulf Sulphur Company. Between them in 1960 these two firms produced approximately 90% of the United States Frasch sulphur.

The famous Boling dome, which began production in 1929 and has since produced over 50,000,000 long tons of sulphur, is Texas Gulf's primary source of supply. In 1960 Boling contributed over one-half of Texas Gulf's production (1,225,000 long tons). This dome is reputed to be one of the most economical sulphur domes in production in terms of ratio of hot water to tons of sulphur produced. Texas Gulf has been a particularly strong marketer on the east coast of the United States. Frasch sulphur imported into California originates in Texas as well.

The Freeport Sulphur Company whose most important mine is Grande Ecaille, has traditionally served a large part of the market in the mid-continent area of the United States, using the Mississippi water system quite extensively for the transportation of sulphur to points of consumption. Jefferson Lake Sulphur Company together with Duval Sulphur and Potash Company, the firm which operates Orchard dome in Texas, produced 548,000 long tons of sulphur in 1960 or 11% of the total. A fifth Frasch operation owned by the United States Sulphur Company commenced initial small scale production at High Island, Texas in 1961.

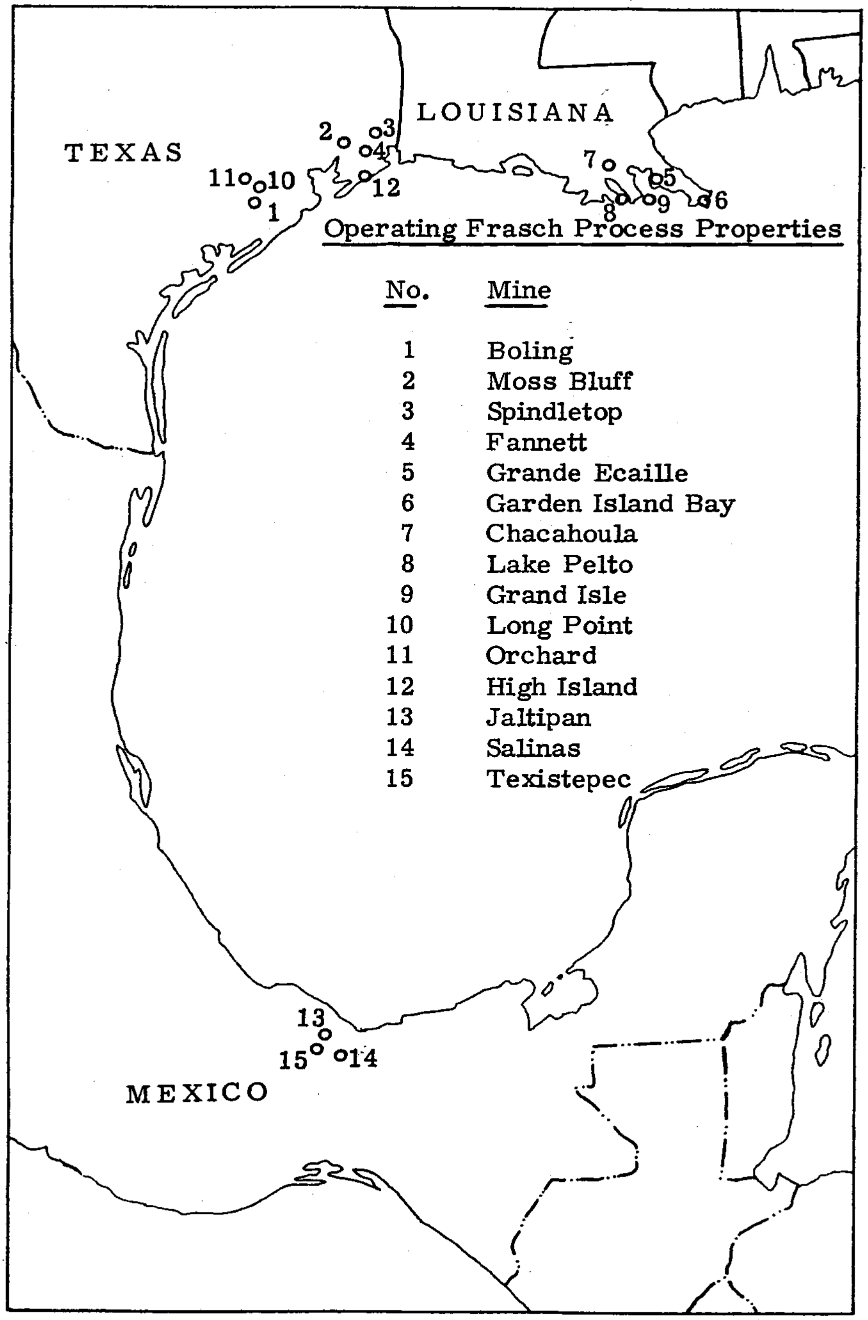

Figure 10. Map showing location of operating Frasch sulphur mines – United States and Mexico, 1961

Table 13. U.S. Frasch sulphur production, by firm, 1960

Firm & location of domes	Frasch sulphur production	Percent of total
	long tons	%
Texas Gulf Sulphur Company		
1. Boling, Texas		
2. Moss Bluff, Texas		
3. Spindletop, Texas		
4. Fannett, Texas		
Production --------	2,170,000	44
Freeport Sulphur Company		
5. Grande Ecaille, La.		
6. Garden Island Bay, La.		
7. Chacahoula, La.		
8. Lake Pelto, La.		
9. Grand Isle, La.		
Production --------	2,200,000	45
Jefferson Lake Sulphur Company		
Starks, La.*		
10. Long Point, Texas		
Clemens, Texas*		
Production --------	363,000	7
Duval Sulphur & Potash Company		
11. Orchard, Texas		
Production --------	185,000 est.	4
The U.S. Sulphur Company		
12. High Island, Texas		
Production --------	25,000 est.	-
Total production -----	4,943,000	100

* Closed in 1960.

Source: U.S. Bureau of Mines - plus company reports.

The Mexican Frasch sulphur industry is of fairly recent origin (1955) and in a relatively short time it has succeeded in becoming an important world supplier of sulphur. Of the total of 1,342,000 long tons of sulphur produced in Mexico in 1960, 1,240,000 long tons, or 92% of the total, was of Frasch origin. The remainder, which comes from oil refineries and volcanic deposits, is used in domestic markets within the country while Frasch sulphur is entirely dependent on export markets for its sales.

Table 14. Mexican Frasch sulphur production, by firm, 1960

Firm & location of dome	Frasch sulphur production	Percent of total
	long tons	%
Pan American Sulphur Co.		
13. Jaltipan		
Production	1,022,000	82
Gulf Sulphur Corporation		
14. Salinas		
Production	203,000	16
Texas Gulf Sulphur Co.		
Nopalapa*		
Production	15,000	2
Texas International Sulphur Co.		
15. Texistipec		
Production	500	-
Total production	1,240,500	100%

* Closed in 1960.

Source: Sulphur, The Magazine of World Sulphur, June, 1961, p. 12.

The Mexican producers are listed in table 14. The Jaltipan dome of the Pan American Sulphur Company, which produced 1,022,000 long tons in 1960, has been referred to as "the sulphur miner's dream" because its formations are particularily conducive to the production of sulphur by the Frasch process. At Jaltipan approximately

1,600 gal. of hot water are required to produce one long ton of sulphur. This compares with 3,000 gal. per long ton for several United States domes. The Texas Gulf's Boling dome of course is an exception since it is reported to require only 1,300 gal. of hot water per long ton of sulphur. Jaltipan is located only 26 miles from tidewater and is served by rail, but the possibility of pipelining molten sulphur to tidewater loading facilities is presently under active consideration.

Alberta sulphur is certainly able to meet sulphur produced by its competitors on equal footing from the point of view of quality of product. Recovery sulphur produced in Alberta is of the bright variety, 99.9% pure. In fact, some samples of Alberta sulphur have been found to exceed this figure, with negligible traces of impurities.

Basically, the two types of sulphur known to the trade are "bright" and "dark". Bright sulphur commands a price differential of $1.00 per long ton over the dark variety. Chemically, these two types of sulphur are similar, the dark sulphur being discoloured by certain hydrocarbon impurities. In the manufacture of sulphuric acid the utilization of dark sulphur produces "stack mist" which can result in a serious pollution problem.

Approximately 50% of the United States Frasch sulphur production is of the dark variety as it comes from the mines. Mexican Frasch sulphur is nearly all of a very dark type. In fact, the trade was on the point of creating a third grade of sulphur, "Mexican black", when the Pan American Sulphur Company devised an economical method for purifying its dark sulphur. As a consequence, Mexican sulphur now being sold is 99.9% pure and bright in colour, and almost all United States producers of dark sulphur are following suit and cleaning up their sulphur. Now, to all intents and purposes, the largest proportion of Frasch sulphur sold is of the bright variety. Alberta sulphur, also bright, is equal, if not superior, to the sulphur produced elsewhere. From the point of view of most consumers, sulphur is now considered to be a homogeneous product.

Sulphur is normally sold by contract with the time period covered by the contract often varying from one to three years. Consumers usually call for bids and then negotiate a contract with the most favourable supplier. The contracts usually specify minimum quantities to be purchased and delivery dates. The purchaser also may be protected against a drop in price. Since continuity of supply is very important, producers are often required to keep on hand approximately a 12-month supply. In the past, when the price of sulphur was very stable, continuity of supply was a very important factor in sulphur marketing. Often it was the determining factor. With increased sulphur production and mounting stockpiles, the continuity of supply factor has lost its importance and price has emerged as the determining factor.

Since the beginning of World War I, price competition has not been an outstanding factor in the marketing of Frasch sulphur. In fact, the Frasch sulphur industry has been written* about as being the classic example of monopoly control, although there is no record of United States antitrust cases in this connection. The history of price stability, however, clearly does have the markings of a type of monopolistic competition known as

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* Montgomery, R. H.: The Brimstone Game (New York, 1940).

oligopoly. Oligopolistic competition appears in industries which contain few firms, each producing close substitutes. Because the products are such good substitutes, each firm must consider the possible reactions of its rivals before changing the price of the product. This uncertainty concerning competitors' reactions often leads to periods of price stability which may or may not be punctuated by price wars. Stable prices may be explained in terms of very successful price leadership*. Figure 11 and table 15 provide information on posted United States sulphur prices from 1929 to 1961.

Active price competition became an important factor in the marketing of sulphur in recent years with the entry of Mexican sulphur into traditional United States markets. A backward glance suggests that the United States Frasch producers had been away from price competition for so long that they were not prepared to cope with it. The United States Frasch producers cut their price for sulphur in an attempt to keep Mexican sulphur out of their markets. This action appears only to have had the effect of seriously reducing the earnings of United States producers while the Mexican sulphur industry fared remarkably well. The costs of producing Mexican Frasch sulphur approximate those of United States Frasch production. However, the Mexican sulphur interests had the advantage of being able to transport sulphur to United States coastal markets at a lower cost because the United States Frasch producers were forced by law to use United States vessels to serve United States ports, while the Mexican Frasch producers were able to use foreign bottoms. The freight saving, which amounted to approximately $1.50 per long ton, gave the Mexican interests an advantage which enabled them to penetrate the United States coastal markets. Mexican sulphur sales in the United States amounted to approximately 612,000 long tons in 1959. It is an interesting sidelight that Texas Gulf Sulphur, the company that initiated a significant round of price cutting, lost most of the business to the Mexican sulphur interests. Texas Gulf was the major supplier of the coastal market areas which were particularly vulnerable to Mexican sulphur imports. Freeport Sulphur Company had to follow suit and did some price cutting as well, but its sales remained firm although its earnings from sulphur declined appreciably.

Thus after a long period of price stability, price competition did become an important factor in the marketing of sulphur. Currently, prices have again become stable with Mexico apparently satisfied with its share of the market. With large quantities of Alberta sulphur about to be produced, Frasch interests are no doubt fearful of the recurrence of price competition.

Apparently realizing their vulnerable position with respect to price competition, the United States Frasch producers have taken steps to compete in other ways. Consequently, non-price competition is being cultivated and is assuming new importance. A very important consideration in this respect is the extension of special services to sulphur customers. A recent development is the establishment of local distribution terminals in major consuming areas to supply users with sulphur either in solid or liquid form. The trend to deliver sulphur in molten form at the same price as solid sulphur is a very attractive improvement in customer service. Much of the sulphur used domestically has to be in molten form to be pumped to

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* See Chapter VI.

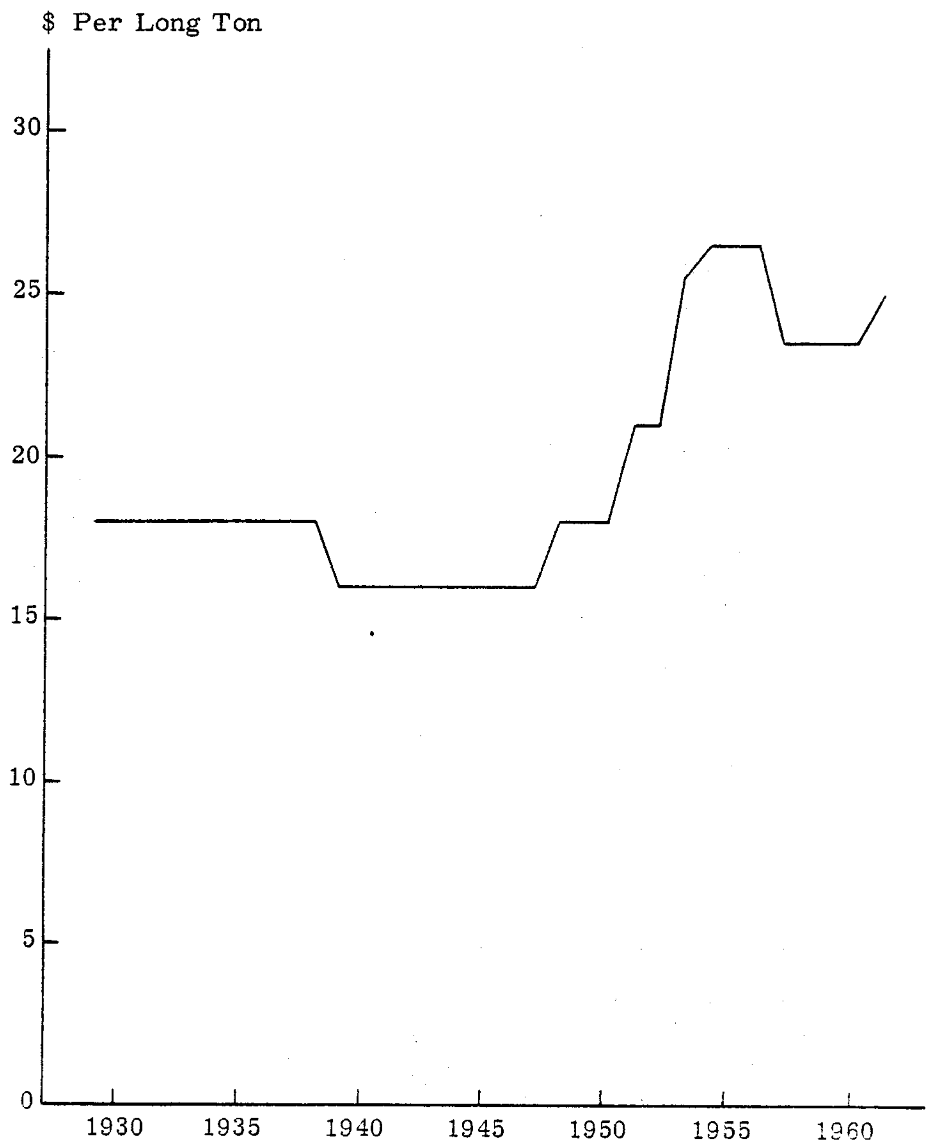

Figure 11. Price history of sulphur, 1929-1962

Table 15. Price history of sulphur - U.S. 1929-1961

(dollars per long ton)

Year	Crude	Year	Crude
1929	18.00	1945	16.00
		1946	16.00
1930	18.00	1947	16.00
1931	18.00	1948	18.00
1932	18.00	1949	18.00
1933	18.00		
1934	18.00	1950	18.00
		1951	21.00
1935	18.00	1952	21.00
1936	18.00	1953	25.50
1937	18.00	1954	26.50
1938	18.00		
1939	16.00	1955	26.50
		1956	26.50
1940	16.00	1957	23.50
1941	16.00	1958	23.50
1942	16.00	1959	23.50
1943	16.00		
1944	16.00	1960	23.50
		1961	23.50

Note: Prices are "spot prices" taken on or near July 1 of each year. Whenever a range of prices was given in the source, the lowest was used.

Price bases for sulphur, crude are:

1929-1932	Bulk,	carlots
1933	Bulk,	carlots, mines
1934-1938	Bulk,	1,000 ton contracts, mines
1939-1942	Bulk,	f.o.b. cars, contracts, mines
1943	Bulk,	contracts, mines
1944-1956	Bulk,	carlots, contracts, mines
1957	Bulk,	f.o.b. cars, mines
1958-1961	Bulk,	bright, domestic, f.o.b. cars, mines

Source: Oil, Paint and Drug Reporter.

the burners of modern acid plants, thus receipt of molten sulphur saves remelting costs. Also wind losses, contamination in transit, and corrosion from sulphur dust are avoided. When a user becomes accustomed to using a convenient local supply of molten sulphur, an effective tie between supplier and customer is established.

Both Texas Gulf Sulphur Company and Freeport Sulphur Company spent millions of dollars during 1959 and 1960 establishing molten sulphur handling facilities as part of their program to expand customer services. Texas Gulf completed construction of a mammoth new storage and shipping terminal at Beaumont, Texas, in 1960. This terminal is designed to handle the bulk of the company's sulphur production, both in the solid and liquid state. All modes of transportation such as rail, truck, barge, and ocean vessel can be accommodated at this terminal.

Following the plans made in 1958 when the first liquid storage terminal was built at Cincinnati to serve customers in the Ohio Valley, similar terminals have been built by Texas Gulf at Tampa, Florida; Carteret, New Jersey (storage capacity 26,000 long tons); and Norfolk, Virginia (capacity 20,000 long tons). Two more terminals are under construction.

During 1961 Texas Gulf inaugurated a new method of transporting sulphur with the S.S. Marine Sulphur Queen, a converted Liberty ship, carrying molten sulphur to east coast terminals. This vessel is capable of taking on 15,000 long tons of sulphur. By the end of 1961, Texas Gulf expects that 40% of all of its sulphur shipments will be in the molten form.

A similar molten sulphur distribution program has been implemented by the Freeport Sulphur Company. Freeport made its first molten sulphur shipments in December of 1960 using barges to supply Midwest markets via the Mississippi and connecting water systems. Coastal shipments made by ocean vessel began early in 1961.

It is estimated that more than $20,000,000 will be spent on new marine equipment and terminal facilites, which will be owned by the transportation companies and operated on a long-term contract by Freeport. Plans call for facilities capable of handling some 1.5 million long tons of sulphur in the molten form annually, or nearly two-thirds of the company's annual sales. Freeport's upriver molten sulphur storage terminals have been built near Chicago at Jolliet, Illinois (capacity of 30,000 long tons) and near Pittsburg at Wellsville, Ohio (capacity of 20,000 long tons). These terminals will serve the major sulphur users in these areas with Jolliet primarily serving the states of Illinois, Indiana, Michigan, and Wisconsin. The Wellsville terminal will serve Ohio, Western New York, and Pennsylvania. Consumers in Ontario will be served by both terminals. Freeport has also established terminals at Tampa, Florida (capacity of 30,000 long tons); Boston, Massachusetts; Bucksport, Maine (capacity of 20,000 long tons); and Everett, Massachusetts (capacity of 10,000 long tons). New storage and loading facilities have also been added at Port Sulphur, Freeport's main distribution point, to accommodate the expanded liquid sulphur service. In 1961 four new 9,000 long ton capacity tanks have been added to Freeport's molten sulphur storage capacity making a total capacity of almost 60,000 long tons. Freeport operates a leased tanker, the S.S. Louisiana Sulphur, which has 16,000 long tons capacity to serve coastal markets.

Pan American Sulphur Company, the major Frasch producer in Mexico, spent $2,500,000 in 1961 on molten sulphur facilities. These include a converted tanker, the S.S. Etude, which has a capacity of 15,000 long tons; a terminal at Tampa (capacity of 20,000 long tons molten and 50,000 long tons bulk); and additional loading and handling facilities in Mexico. It is reported that this firm is also studying construction of similar terminal facilities in other markets. Tampa, Florida, apparently warrants the establishment of such terminal facilities on the strength of its booming triple phosphate fertilizer industry, which now manufactures two-thirds of the world's consumption of concentrated fertilizer.

In addition to apparent non-price competitive factors, there are special hidden inducements and concessions which are offered to sulphur users. It is known commonly that few sulphur consumers pay the posted price for sulphur. Hidden concessions may take the form of freight rebates or construction cost allowances. The latter are sometimes offered to pyrite users in an effort to induce them to change over to elemental sulphur. These factors are difficult to assess due to the secrecy that surrounds them. However, they must not be overlooked since in certain cases they no doubt assume considerable significance and are factors which have to be reckoned with.

Alberta sulphur attempting to find its way into overseas markets will have to compete not only with Mexican sulphur but also with the United States Frasch producers acting in concert. Under the terms of the Webb-Pomerene Act, United States companies are permitted to form a single corporation within an industry to transact business in export markets. In mid 1958 the four United States Frasch producers re-established the Sulphur Export Corporation which is commonly known as Sulexco. Sulexco had previously been operated by Texas Gulf and Freeport from 1922 to 1952 when it was disbanded. The present Sulexco organization is shared by the Frasch producers according to the following distribution: Texas Gulf, 37%; Freeport, 37%; Jefferson Lake, 18%; and Duval, 8%. Sulexco was formed to meet competition from foreign sources and to deal more effectively with buying combines. The advantage of this arrangement to member companies is obvious since they are able to maintain one price for export, thus obviating competition among themselves.

However, there are advantages available to the customer who deals with Sulexco, although some users dislike buying from a single seller. The two special services that Sulexco offers to its customers are technical aid and ocean freight assistance. The latter can be quite substantial since by pooling its shipments and transporting sulphur in large quantities, Sulexco is able to pare as much as $3.00 per long ton from handling and shipping charges. Since in many cases sulphur is sold f.o.b. the loading port, this saving often is passed on to the buyer. Sulexco controls shipments in excess of 1,000,000 long tons of sulphur annually, and it is able to arrange forward freight commitments at the most favourable rates, terms, and conditions. Thus, Sulexco can be effective in arranging for its customer's shipments to arrive on schedule, at the lowest possible cost.

Sulexco offers technical assistance to sulphur customers in all parts of the world. This feature may have a particular attraction in underdeveloped countries where industrialization is just beginning and technical assistance is required. An advantage which is not advertised in the Sulexco literature but which is reported to be of considerable consequence is Sulexco's ability to extend credit to foreign purchasers. In certain instances this could be an important factor, one which could not readily be matched by an independent sulphur marketer.

No such organization as Sulexco exists in Canada since legislation permitting such action is nonexistent. Alberta sulphur marketers selling in overseas markets have the option of handling their own sales or assigning their sulphur sales to an international marketing agency. These agencies, an example being the International Sulphur Company Limited, have international connections and are able to offer technical aid and advantageous freight arrangements to their customers.

The costs of marketing through an agent usually amount to $0.50 per long ton; this compares with $1.00 per long ton charged by Sulexco. The cost of employing an agent must be balanced against the advantages of collective marketing. If a number of producers sold their sulphur through a marketing agent, a joint stockpile might be established at focal points such as export ports or major consuming centres. Individual producers could reduce handling costs by shipping molten sulphur to the focal point where the sulphur could either be stockpiled or vatted for trans-shipment. The transportation and handling savings which might be realized through collective shipment to overseas markets could well outweigh the agent's commission and help to make Alberta sulphur more competitive. A selling agent is often in the position of being able to book return cargos from destinations, thus further reducing shipping costs.

The cost of marketing through an agent must of course be weighed against independent action. To date no precedent has been set. Some Alberta sulphur producers have made overseas sales through an agent while others have negotiated their own sales. Since overseas export of Alberta sulphur is as yet in its infancy, no pattern has emerged. The international connections which come of the Alberta sulphur producers have through their parent firms in the United States and other parts of the world may prove to be of benefit in marketing sulphur.

It is important to realize that there is more involved in marketing sulphur than meeting or beating the price of your competitor. To sell sulphur in the Chicago area, for example, a sulphur marketer would reasonably have to meet the molten sulphur services presently offered to consumers by Frasch suppliers. Alternatively, the marketer might try to sell bulk sulphur at a lower price, intending to offset advantages of local molten services.

There already appears to be a trend of molten tank car delivery of Alberta sulphur to United States markets. The distance factor certainly does not preclude the transportation of molten sulphur to distant markets. The uninsulated steam-coil equipped tank cars which are used to ship molten sulphur usually have a capacity of 10,000 gal. (65 long tons of sulphur). In transit, molten sulphur plates-out on the inside of the tank, thus creating a narrow band of insulation since sulphur's insulating properties are excellent. Experience reveals that molten sulphur left in uninsulated cars for eight days in 40° below zero weather required only four hours steaming time to be unloaded. Since the railroad offers 4-day service to Chicago from Calgary, with an extra day being required from other Alberta points, no difficulty is envisaged in shipping molten sulphur to this market. The distance from Okotoks, for example, to Chicago is 1,618 miles and to San Francisco it is 1,605 miles.

CHAPTER V. FUTURE PROSPECTS FOR THE ALBERTA SULPHUR INDUSTRY

As has been pointed out in Chapter II, annual sulphur production in Alberta by 1965 will be just under 2,000,000 long tons. If the new plants follow the pattern set by many of the recently completed plants and stockpile a substantial proportion of their initial production, there could be a stockpile of 2,500,000 - 3,000,000 long tons of sulphur in 1965. In an attempt to answer the question, "What is to become of this sulphur?", it is interesting to examine the possible courses of action open to Alberta sulphur producers.

What will sulphur producers do as their stockpiles of sulphur increase steadily during the next four or five years? Will sulphur producers be content to market only a small portion of their total production at prevailing f.o.b. plant prices in the uncertain hope that growth of prospective markets will reduce their stockpiles, or will they aggressively attempt to sell sulphur primarily through price competition after non-price factors such as molten delivery have been met? As a matter of fact, the situation cannot be divided into two separate distinct alternatives; this has been done here merely to stress the extremes of the possible courses of action in order that the pros and cons of each might be discussed. The writer here has attempted to place himself in the position of an individual sulphur producer, weighing the alternatives open to him in deciding upon a marketing program. In all likelihood the sulphur industry may follow some sort of a "through the middle" course which will attempt to encompass the best facets of both plans.

It should, however, be pointed out here when discussing what the Alberta sulphur industry might or might not do, that it is really a misnomer to talk about an "industry" at all. With few exceptions, the firms which produce sulphur in Alberta have in the past, and may in the future, be concerned primarily with the production and sale of oil and gas. Many of these firms just recently have become sulphur producers. However, in time some semblence of a "sulphur industry" will no doubt emerge.

Returning to the alternatives open to the sulphur industry, stockpiling and relying on future demand vis-à-vis immediate aggressive marketing, the latter will be considered first. Because the demand for sulphur is very inelastic, there being no economic substitute for sulphur, lowering the price or for that matter raising the price does not have a significant effect on the amount of sulphur consumed. Sulphur is relatively inexpensive and in many industries it is not a major item in the costs of production and therefore changes in the price of sulphur have little effect on the amount consumed.

In assessing the success of using price competition as a means to obtain markets for Alberta sulphur, the cost of producing this sulphur becomes a very important factor. Past experience has indicated that price cuts would in all probability result in a price war and a substantial reduction in price. Costs of production plus transportation and handling charges together comprise the long run floor below which prices cannot be cut.

The subject of the cost of sulphur production, either Frasch or recovery, is one that receives very little attention in published material dealing with the sulphur industry. Frasch sulphur production costs are closely guarded secrets that the Frasch producers do not reveal for obvious reasons. Because the efficiencies of the Frasch domes vary so much, it is understandable that accurate cost figures for the industry are unavailable. However, it is estimated in journal articles that Frasch sulphur production costs are of the order of $10.00 to $11.00 per long ton*. Some of the less efficient mines are no doubt more costly to operate and such notable low cost producing mines as Boling dome cost less to operate. It is rumored that Boling dome sulphur is produced at a cost of $6.00 per long ton. This figure may be somewhat low, based as it is on previous years operations. Over 50,000,000 long tons of sulphur have been produced from Boling dome, and it seems reasonable to assume that the costs of operation would increase as deeper sulphur wells are mined.

It is not known outside the industry what the production costs of Freeport's new offshore dome at Grand Isle are. Rumors, however, suggest that initial production costs are very high, perhaps in the order of $16.00 per long ton.

As with Frasch operations, the costs of producing recovery sulphur in Alberta vary considerably among the different producers. These variations in costs arise, however, not primarily from differing efficiencies of plant operations but because of the different circumstances of production. This matter is clarified when the definition of the types of sulphur being produced is considered again. In Chapter II, three different connotations were used in referring to recovery sulphur: "main-product", "co-product", and "by-product". This terminology takes on important significance when considering recovery sulphur production costs.

There is a distinct difference in the cost of producing sulphur at a plant which processes raw gas with an H_2S content of 34% compared with another plant processing raw gas with a 2% or less H_2S content. This is the variation which exists in Alberta sulphur plants. For example, the Texas Sulphur Company plant at Okotoks is capable of producing 370 long tons of sulphur per day from gas containing 34% H_2S. If the sulphur produced from this plant were sold for $15.00 per long ton (not for $22.00, the figure which appears in the application for approval which was submitted to the Oil and Gas Conservation Board), sulphur sales still would comprise more than 80% of the total revenue derived from the sale of the products produced from this plant. The sulphur produced under these circumstances may correctly be termed "main-product" sulphur, with this plant being the extreme case.

By-product sulphur is the other extreme, being produced by plants processing raw gas containing relatively minor proportions of H_2S. A plant which might fall into this category is the Rimbey gas plant operated by the British American Oil Company Limited, but owned jointly by twenty-seven companies. This plant is one of the largest gas processing plants in Canada and is capable of producing 326 M Mcf. of residue gas daily plus 86,000 gal. of propane, 112,000 gal. of butane, 12,600 bbls. of stabilized condensate as well as 250 long tons of sulphur per day. The H_2S content of the raw gas is only 2.1%, but the throughput of the plant is so sizeable that even a relatively minor amount of H_2S results in substantial sulphur production. On the basis of $15.00 per long ton, sulphur sales from this plant only would amount to less than 7% of total revenue, assuming the following prices for the other products: gas, 12¢ per Mcf; propane, 4¢ per gal.; butane, 3¢ per gal.; and condensate, $2.20 per bbl.

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* See The Sulphur Industry; E. F. Hutton and Company, New York, 1959, p. 8.

The sulphur productive capacity of each of the plants cited is similar but the conditions of production could not be more different. The one plant was built specifically to produce sulphur and its total throughput will be responsive to changes in the price of sulphur. By-product sulphur is produced incidentally and its production is governed by the sales position of the main products of the plants, the residue gas and natural gas liquids.

Between the two extremes, in what might be termed a "twilight zone", is found "co-product" sulphur. Plants producing co-product sulphur process raw gas containing an intermediate H_2S content and potential sulphur sales could be significant in the total revenue picture. While recognizing that this situation exists, the writer has deliberately avoided using any criterion which would define co-product sulphur. This is done because such a demarcation could only be made if the prices on all of the products being produced were fixed and a known proportion of total production could be marketed. Since this is not the case, it is meaningless to attempt to define co-product sulphur. At a certain price for sulphur, with the prices of the other products being given, sulphur sales could account for perhaps 25% of the total revenue of a plant. However, if the price of sulphur fell or the sulphur could not be sold, the importance of sulphur in the total revenue picture could alter appreciably and perhaps even shift into the by-product category.

The cost accountants attempting to allocate costs are faced with the insoluble problem of joint product costing in this connection. They might well contend that main-product sulphur should carry a proportionate share of the costs incurred in plant construction and operation. As well, the costs of pipeline gathering systems, exploration, and drilling may be applied to main-product sulphur. Thus, main-product sulphur would be the most expensive type to produce.

If the cost accountants could agree on a definition for co-product sulphur, it seems reasonable that they might charge less of the cost burden against co-product sulphur, since it is of lesser importance from the point of view of revenue. They might assume that the H_2S extracted in the gas processing section is supplied to the sulphur recovery units free of charge, and only the amortization of the sulphur recovery unit and its operating costs might be applied against co-product sulphur.

By-product sulphur, as its name implies, could be treated as a free good. The costs of extracting the H_2S and converting it to elemental sulphur would in this case be borne entirely by the other products, namely: residue gas and natural gas liquids.

Following the principles outlined previously and using information gleaned from a submission* made to the Alberta Oil and Gas Conservation Board, a cost of production figure for main-product sulphur of $14.00 per long ton was derived. The actual figure, which is obtained by adding an estimate of depreciation based on 10% of the total cost of the plant to the operating costs and dividing by the sulphur production ca-

* Submission For Approval to Construct the Okotoks Gas Processing Plant and Gathering System, made by Texas Gulf Sulphur Company and Devon-Palmer Oils Limited, March, 1958. Appendix h.

pacity, is $15.87 per long ton. This figure was scaled down since the plant has been in operation for a few years and depreciation and operating costs should be reduced somewhat.

It is much more difficult to estimate the cost of producing co-product sulphur. The writer has seen company cost estimates of $10.00 per long ton for sulphur produced by what may be termed co-product plants with capacities of 100 long tons per day. From discussions with industry officials, it appears that economies of large scale operation of major plants should reduce the $10.00 figure appreciably. Therefore, the writer has assumed that co-product sulphur will be produced at a cost in the range of $6.00 to $10.00 per long ton, depending upon the size of the plant. Since the larger plants may dominate this category, the average cost of producing co-product sulphur will likely be closer to $6.00 per long ton than $10.00 per long ton.

It seems improbable that the cost accountants will be able to arrive at a fixed and inflexible criterion for costing sulphur. This might be possible if the prices of the other products did not fluctuate and if they all could be sold. But prices and sales do fluctuate and a cost allocation which seems reasonable today may have to be revised radically ten years from now. If gas prices fell or if returns from the sales of natural gas liquids declined, it might become expedient to charge a large share of the costs of production against sulphur. This possibility is very easy to overlook in the present atmosphere of steadily increasing sales of residue gas, L.P.G.'s, and condensate.

Since success or failure in terms of price competition rests largely on what action, if any, the competitors take, an Alberta sulphur producer contemplating the use of price competition to sell sulphur will no doubt be interested in the recent experience of Mexican sulphur in this connection. An interesting account of sulphur price war appears in a recent article*. When the Mexican Frasch producers, led by the Pan-American Sulphur Company, began to market their sulphur late in 1955, the United States Frasch producers were selling sulphur at the long established price of $31.00 per long ton f.o.b. Gulf Coast for export sales and $28.00 per long ton for domestic sales. The United States Frasch producers had enjoyed a higher price for export because European users were faced with the alternative of higher cost pyrites as a source of sulphur. Originally, the Mexican interests concentrated on penetrating the Western European sulphur market, particularly Britain and France. To do this they planned to sell their sulphur at $29.00 per long ton f.o.b. port which was approximately $2.00 per long ton less than the United States posted price. This proved to be so successful that the Freeport Sulphur Company cut its export price by $3.00 per long ton in February, 1956, a move which was quickly followed by the Texas Gulf Sulphur Company. Mexican sulphur at $28.00 per long ton f.o.b. port was then competitive in the United States domestic market as well as the export market. Mexican sulphur had an added advantage in United States coastal markets by virtue of the fact that foreign bottoms could be used to transport the sulphur; thus a saving of approximately $1.50 per long ton was offered the customer. American producers must by law ship goods to United States ports in United States ships and thus this advantage of $1.50 per long ton remains in favour of their Mexican rivals.

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* The little mothers and Pan-American sulphur, Fortune, July 1960, p. 96.

By 1957 Mexican sulphur production had almost reached one million long tons and marked inroads had been made into the United States domestic and export market. In September of 1957, Texas Gulf Sulphur Company made a bold move apparently designed to stop the success of its Mexican competitors. Texas Gulf cut the domestic price of sulphur by $3.00 per long ton, bringing it down to $25.00 per long ton f.o.b. mine. Freeport met this domestic price and slashed the export price by $3.00 per long ton. Both companies suffered a great loss in profits and increased sulphur sales very little by these tactics. The price war cost the United States Frasch producers an estimated $35,000,000 in foregone revenue. Texas Gulf's earnings per share fell from $3.23 in 1955 to $1.27 in 1960, with sulphur sales in both years being very comparable. The effect on Freeport's earnings are hidden due to the fact that the firm is engaged in other lines of business.

Price cutting did not succeed as a means of stopping the entry of Mexican sulphur into United States sulphur markets. The Mexican interests, after securing sales of better than 600,000 long tons in the United States, apparently were satisfied and price cutting ceased. The Mexican industry was able to withstand the price war; in fact, it appears that the United States Frasch producers have even been forced to allow the Mexican sulphur industry to assume the role of price leadership. Price increases of $2.00 per long ton announced by Mexican sulphur producers in December of 1960 were quickly followed by the United States sulphur producers. Instead of changing their posted prices, the United States Frasch producers withdrew the transportation allowances which had represented the gap between posted and actual prices.

It is noteworthy that the success of the Mexican intrusion into United States markets was largely due to the fact that the Mexican interests were able to meet the United States Frasch producers on their own ground. Production costs were similar. As well, the Mexican producers were aided by a freight advantage and the important element of surprise attack. The American Frasch producers apparently had difficulty in coping with unaccustomed price competition, and there appeared little they could do to stop Mexican sulphur from entering their markets. Since then, however, the secondary line of defence, that of non-price competition, has been brought into the picture. Millions of dollars have been spent by the United States Frasch producers in trying to secure customer attachments which it is hoped will balance against price competition.

Alberta sulphur producers attempting to make inroads into United States markets will be faced with two very important barriers. The first is a freight disadvantage and the second is non-price competition in the form of customer service. The freight disadvantage must be absorbed, but the customer service will either have to be met or offset by price cuts.

At this point it is of interest to examine the latitude that the Alberta sulphur industry has in cutting price and yet covering transportation, handling, and production costs. The production cost is assumed to exclude the concept of a normal profit.

When viewed in this fashion the importance which must be attached to the inescapable transportation problem is evident. An examination of the net return to Alberta sulphur producers from sales in various markets reveals clearly that many producers cannot afford very much price competition and yet sell their sulphur for a return in excess of costs.

Table 16. Return to Alberta sulphur producers from sales in various possible market areas

	Great Lakes Region Can.	Midwest U.S.	North-western U.S.	Cali-fornia	Aust-ralia	India
Price delivered	$29.00	$27.00	$26.00	$32.00	$30.00	$33.00
Loading costs (for bulk sulphur)	1.25	1.25	1.25	1.25	1.25	1.25
Rail tariff	16.35	12.88	13.78	18.35	7.84	7.84
Dock handling (assumes shipments in excess of 3,000 long tons)					1.18	1.18
Ocean freight					9.00	10.00
Return to producer to cover costs	$11.40	$12.87	$10.97	$12.40	$10.73	$12.73

In this connection there is another extremely important consideration which has a bearing on the outcome of price competition. Should Alberta sulphur succeed too well in United States markets there is always the danger that tariffs, embargos, or quotas might be placed on United States sulphur imports. Traditionally sulphur has been traded as a free good, but it seems a reasonable possibility that further severe loss of United States sulphur markets to foreign sulphur producers could result in protection being imposed to protect the United States Frasch industry.

United States Frasch sulphur production has fallen from 6.4 million long tons in 1956 to 4.9 million long tons in 1960. Exports have remained virtually unchanged from 1.7 million long tons in 1956 to 1.8 million long tons in 1960, while imports of Mexican and Canadian sulphur have jumped from 212,000 long tons in 1956 to 755,000 long tons in 1960. With production declining, exports holding steady, and imports rising, the logical move seems to be tariff protection, particularily when Canadian sulphur interests appear to be on the brink of attempting to sell a million or more long tons of sulphur into the United States market.

As an alternative to selling sulphur through aggressive marketing, which relies mainly on price competition, the Alberta sulphur industry could stockpile the bulk of its sulphur production and wait for the growth in future demand to solve the problem. This solution is advocated by the major United States Frasch producers. They contend that the oversupply situation is merely a short-run phenomenon which will disappear before the end of the decade. The remarkably stable growth in sulphur consumption is held to be the saving factor.

The methods used to forecast future Free World sulphur productive capacity and consumption vary somewhat but the conclusions arrived at by the forecasters are quite similar. On the basis of certain important assumptions, which will be dealt with later, it is estimated that sulphur consumption and productive capacity will be in balance before 1970. Some writers are more specific and state that this situation should develop as early as 1968. These forecasts have been made by both major United States Frasch producers. However, since their assumptions and conclusions are substantially in agreement, only one forecast will be considered here. This forecast was prepared by Dr. D. Armstrong for Freeport Sulphur Company and is the integral part of a report entitled, The World Sulphur Markets*. By forecasting increases in world sulphur consumption and sulphur productive capacity under certain important assumptions, Armstrong concludes that by 1968 sulphur consumption and productive capacity will balance. The ramifications that this situation could have on the marketing program of Alberta sulphur interests is of such significance that a detailed examination of this forecast follows.

Chapter 4 of Armstrong's report is entitled, "The Future Sulphur Balance". The first part of the chapter is devoted to a detailed dynamic analysis of future world sulphur productive capacity. It is readily recognized that in making a forecast of this type, certain very necessary assumptions have to be made. Without them a forecast simply would not exist. Armstrong's major assumptions are enumerated here for purposes of clarity:

1. The United States and Mexican Frasch sulphur producers will not undertake any new projects. Capacities of existing facilities have been based on past production performance. The timing of the abandonment of certain smaller mines was based on expert opinion in the industry. Armstrong refers to the foregoing as being a drastic and unrealistic assumption which rests on the premise that no new Frasch sulphur production capacity will be developed.

2. Pyrites productive capacity for most countries was assumed arbitrarily to be 10% greater than 1957 production, and capacity is expected to increase along with economic growth.

3. The capacity of sulphur production from native and sulphate minerals is equal to 1957 production and no further growth in these facilities is considered to be likely in the near future.

4. Where specific plans are known regarding increases in capacity of recovered sulphur or sulphur in gases, these were taken into account; otherwise, capacity from these sources is assumed to grow along with general economic growth.

5. Japan is expected to remain self-sufficient, with capacity growing to meet domestic needs.

Several other special assumptions were made concerning individual countries whose sulphur productive capacity is of lesser importance. The main body of the forecast

* Armstrong, D. E.: The world sulphur markets: a background for the evaluation of the Canadian sulphur problem, prepared for Freeport Sulphur Company, Montreal, 1960.

of future capacity hinges on the above-mentioned assumptions which purposely were designed to be on the conservative side.

The task of forecasting a nation's sulphur consumption is essentially one of forecasting the rate of growth in industrial production. Armstrong's estimates in this connection, shown in tables 17 and 18, were made very carefully and particularily the forecast of United States consumption, which is very important due to its size, was made with painstaking care. A 3.3% per annum rate of growth in sulphur consumption selected for the United States as a whole was cross-checked and confirmed by a forecast made for various industrial groups. Canada's growth rate was estimated to be 4.5% per annum and a rate of 6% per annum was applied to the rest of the Free World. The latter rate was purposely reduced from 7% to be conservative.

When the forecast of consumption is plotted against that of productive capacity, an intersection takes place in 1968, as seen in figure 12. Excess capacity in the sulphur industry by that time would have disappeared.

Armstrong concludes from his forecast that the problems facing the Alberta sulphur industry should be resolved by 1968 or shortly thereafter due to the growth in the utilization of sulphur throughout the world. Armstrong says, "The problem of marketing Alberta sulphur should be solved within a reasonably short time".*

Should Alberta sulphur producers accept this conclusion, they may well be lulled into unfounded complacency. The writer feels there is reason to question Armstrong's hypothesis mainly because it is difficult to envisage his assumption that no new Frasch projects will be undertaken. To expect the Frasch producers to sit back and not be tempted to increase productive capacity in the face of growing markets seems very improbable. Just recently one new small Frasch operation, that of the United States Sulphur Corporation at High Island dome in Texas, has commenced operation in spite of the apparent oversupply situation. Another Frasch sulphur project is being promoted by the newly formed American Sulphur Company. Armstrong's other assumptions regarding capacity, although arbitrary, seem to be realistic. However, his forecast for Canadian sulphur productive capacity is very conservative and will almost certainly be low. He assumed that Canadian productive capacity of recovery sulphur would reach 2,600,000 long tons by 1965 and remain static. Further gas export which seems imminent should certainly prove this assumption to be incorrect. Any increase in sulphur productive capacity, whether it is United States or Mexican Frasch sulphur, Alberta recovery sulphur, or any other sulphur, certainly will defer the date when adjustment between anticipated demand and supply would take place.

Another reason why Alberta sulphur producers might not want to rely too heavily on the conclusions of forecasters with regard to future growth of markets and productive capacity is that history has so often proven forecasts to be wrong, not because they have not been prepared carefully and expertly, but conditions can change so rapidly.

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* Armstrong, D. E.: The world sulphur markets: a background for the evaluation of the Canadian sulphur problem, prepared for Freeport Sulphur Company, Montreal, 1960, p. 156.

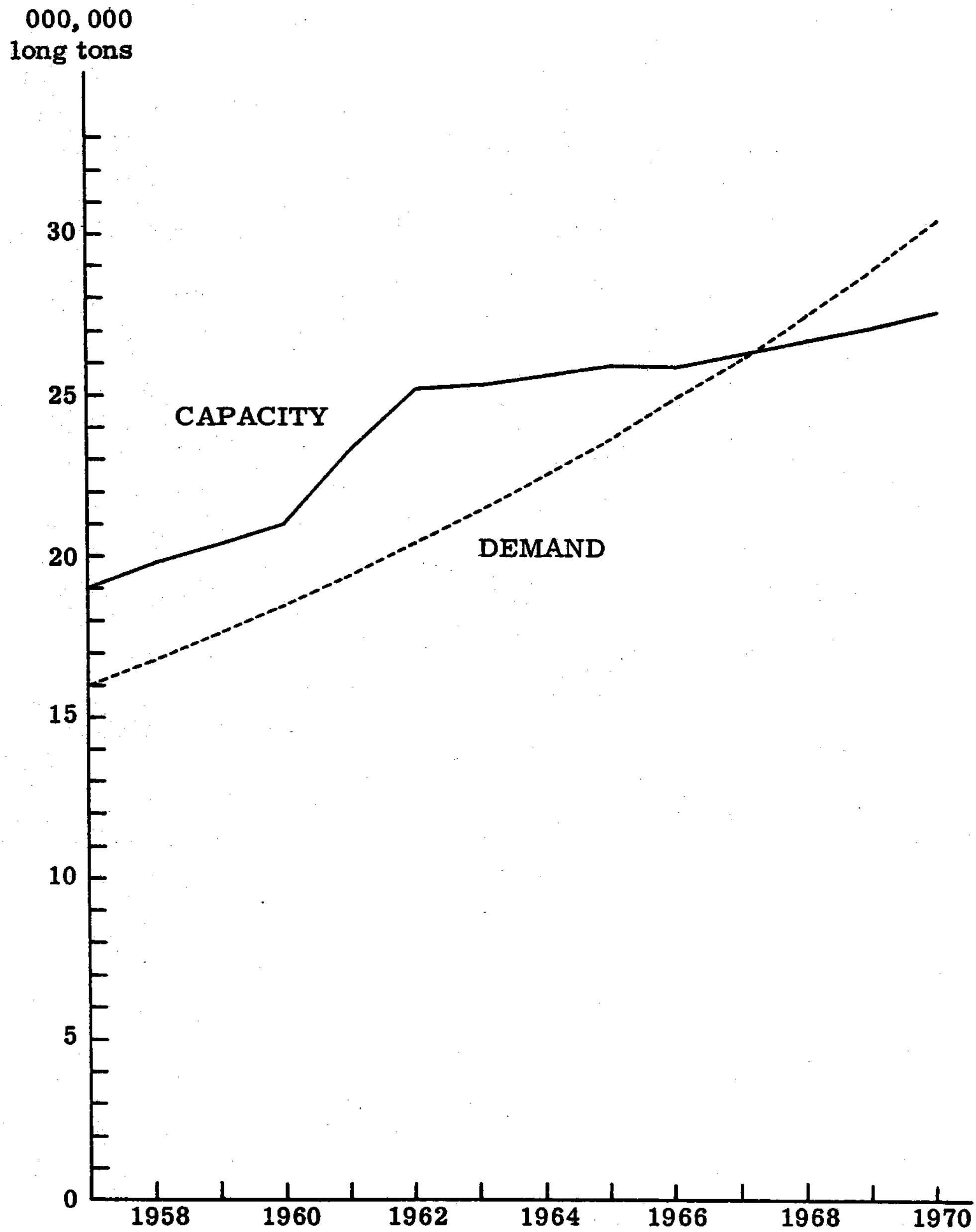

Figure 12. Projected Free World capacity and demand for sulphur in all forms, 1957-1970

Table 17. Projected demand for sulphur United States, Canada & other Free World, 1957-1970
('000 long tons)

Year	United States	Canada	Other Free World	Total
1957	5,569	769	9,623	15,961
1958	5,752	804	10,200	16,756
1959	5,943	840	10,813	17,596
1960	6,139	878	11,461	18,478
1961	6,341	917	12,149	19,407
1962	6,551	958	12,878	20,387
1963	6,767	1,001	13,650	21,418
1964	6,990	1,046	14,469	22,505
1965	7,221	1,094	15,337	23,652
1966	7,459	1,143	16,258	24,860
1967	7,705	1,194	17,233	26,132
1968	7,959	1,248	18,267	27,474
1969	8,222	1,304	19,363	28,889
1970	8,493	1,363	20,525	30,381

Source - D. E. Armstrong: The world sulphur markets: a background for the evaluation of the Canadian sulphur problem, prepared for Freeport Sulphur Company, Montreal, 1960, p. 114.

Table 18. Projected world sulphur productive capacity by specified country, 1957-1970
('000 long tons)

Year	United States	Mexico	Canada	Europe	Japan	Other	Total Free World
1957	7,977	1,900	530	5,995	1,838	774	19,014
1958	8,360	1,900	622	6,144	1,948	784	19,758
1959	8,343	1,900	795	6,532	2,065	795	20,430
1960	8,278	1,900	967	6,899	2,189	807	21,040
1961	9,614	1,900	1,040	7,620	2,320	820	23,314
1962	9,351	1,900	2,971	7,694	2,460	833	25,209
1963	9,140	1,900	3,071	7,774	2,607	847	25,339
1964	9,079	1,900	3,159	7,858	2,764	862	25,622
1965	9,120	1,900	3,177	7,947	2,929	877	25,950
1966	8,793	1,900	3,190	8,042	3,105	894	25,924
1967	8,837	1,900	3,204	8,142	3,291	912	26,286
1968	8,932	1,900	3,219	8,248	3,489	930	26,718
1969	8,978	1,900	3,234	8,361	3,698	950	27,121
1970	9,077	1,900	3,250	8,480	3,920	971	27,598

Source - D. E. Armstrong: The world sulphur markets: a background for the evaluation of the of the Canadian sulphur problem, prepared for Freeport Sulphur Company, Montreal, 1960, p. 105.

For example, what forecaster looking ahead in 1952 or 1953 at the height of the sulphur shortage could have envisaged a pressing sulphur surplus in less than a decade. With this experience so close at hand, surely these forecasts must be tempered with the question: Can there not be another unexpected increase in sulphur production, such as occurred at Lacq or Alberta, somewhere in the near future?

A final reason for doubting that time alone and growth of markets will solve the sulphur problem is really a direct outgrowth of the following question: If Alberta sulphur recovery plants were operating to capacity by 1965, where would producers sell their annual production of 2,300,000 long tons plus a possible accumulated stockpile of 2,500,000 - 3,000,000 long tons?

In an attempt to answer this question, the writer compiled the accompanying table (table 19) which shows the size of possible markets for Alberta sulphur in 1960 and 1965. From an examination of the table, it appears that total sulphur requirements in markets which could be served by Alberta sulphur will be in excess of Alberta's sulphur productive capacity by 1965. If the total figure shown, 3,000,000 long tons, is divided by Alberta's estimated annual sulphur productive capacity of 2,300,000 long tons, it is evident that sales of Alberta sulphur would have to exceed 77% of the requirements in each market to match productive capacity. It is easy to envisage this happening in certain market areas, but not in all of them.

If Alberta sulphur producers could sell 1,000,000 long tons or more in the United States, 500,000 long tons in Canada, and 500,000 long tons in Asia and Oceania in 1965, there would be no sulphur problem. Growth of markets would certainly look after the stockpiles.

A consideration of the possible breakdown of sales which appears in the preceding paragraph is in order: firstly, to see if sales of this magnitude in the areas mentioned are possible; and secondly, to consider what might be the possible effects of such sales occurring.

Sales of Alberta sulphur in the United States could well reach 1,000,000 long tons in 1965. The Pacific Northwestern States and California could absorb 300,000 long tons and the Midwestern States could absorb 700,000 long tons. It may be somewhat optimistic to assume that Alberta sulphur would capture 300,000 long tons of the 338,000 long tons of expected sulphur consumption in the Pacific Northwest and California. However, Alberta sulphur has a decided freight advantage over Frasch sulphur in all of the States in this area except California. Actually, the freight disadvantage that Alberta sulphur has in California (approximately $18.35 per long ton from Alberta versus $16.00 per long ton by rail from Freeport, Texas) is not great when compared with the Chicago area, for example, where Alberta sulphur will face an approximate $8.00 per long ton freight disadvantage. Allowing for the fact that Frasch production and recovery sulphur from Worland, Wyoming, will capture some of the market (perhaps 38,000 long tons), the 300,000 long ton figure was chosen. The Pacific Northwest and California areas appear to be favourable markets for Alberta sulphur.

It is going to be difficult for Alberta sulphur producers to sell 700,000 long tons of sulphur in the Midwest States by 1965. With an $8.00 per long ton or greater freight

Table 19. Size of possible markets for Alberta sulphur, 1960 and 1965 estimate (Figures shown represent sulphur requirements which would be imported.*)

	1960 Quantity (long tons)	1965 est. Quantity (long tons)
Canada:		
British Columbia	60,000	
Alberta, Saskatchewan and N.W.T.	75,000	
Manitoba, Ontario & Quebec	365,000	
Sub-total	500,000(1)	640,000(2)
U.S. Northwestern States and California:		
Idaho	29,000	
Washington and Montana	100,000	
Oregon	30,000	
Alaska	11,000	
California	100,000	
Sub-total	270,000(3)	338,000(4)
U.S. Midwestern States:		
Minnesota	9,000	
Illinois	359,000	
Wisconsin	99,000	
Indiana	128,000	
Michigan	123,000	
Sub-total	718,000(3)	872,000(4)
Far East & Oceania:		
Australia	200,000(5)	270,000(6)
New Zealand	100,000(5)	180,000(7)
India	150,000(8)	400,000(8)
Union of South Africa	120,000(5)	200,000(7)
Other (Korea, Indonesia, etc.)	40,000(7)	100,000(7)
Sub-total	610,000	1,150,000
Total:	2,098,000	3,000,000

* Excluding Alberta, British Columbia, Saskatchewan and N.W.T.

Table 19. Size of possible markets for Alberta sulphur, 1960 & 1965 estimate (continued)

Sources:

(1) See source table 8, p. 31.

(2) Assumed to increase at 5% per annum.

(3) See source table 10, p. 34.

(4) Assumed to increase at 4% per annum.

(5) Figures arrived at by comparing import figures (see table 11. p. 35) with U.S. and Mexican exports to Australia and New Zealand (see table 20. p. 65).

(6) Sulphur, The Magazine of World Sulphur, June, 1961.

(7) Estimated.

(8) J. R. Midwinter, "India expands fertilizer industry", Foreign Trade, Ottawa, May 20, 1961.

disadvantage (freight charges from Alberta to Chicago amount to $12.77 per long ton versus approximately $4.50 per long ton to Chicago from the Gulf Coast by barge) and facing established customer service facilities, much of the success that Alberta sulphur might have in the Midwest will depend on how determined Frasch producers are to hold their sales. Since they have already committed huge sums to molten handling facilities, they cannot be expected to give up easily. However, there is a chance that Frasch interests may really be convinced that markets for sulphur will grow so rapidly in the next six or seven years that they may prefer to lose sales and stockpile their sulphur to prevent a fall in the price. As markets grow in the future, they could supply what is required. This simply would be following the advice that they are giving. However, the success of Alberta sulphur in the Midwest region does not hinge on the foregoing. Alberta sulphur does have less of a freight cost in serving the Midwest area than either the California or overseas market areas, and therefore considerably more price competition can be endured to secure sales.

Coming back to the Canadian sulphur market in central and western regions, it seems reasonable to assume that Alberta sulphur would supply 500,000 long tons of the 640,000 long tons required. The remaining 140,000 long tons might be split into 100,000 long tons in distant points of consumption in Ontario and Quebec, and 40,000 long tons in British Columbia. The latter could be served by the sulphur recovery plant at Taylor Flats, British Columbia. It is doubtful that United States Frasch sulphur would supply much of the 100,000 long tons deficiency in Ontario and Quebec since elemental sulphur production in these areas and in the Maritimes should be increased sufficiently by 1965 to supply this amount.

The figure of 500,000 long tons of Alberta sulphur destined for users in the Far East and Oceania appears often in the forecasts that have been made. United States and Mexican Frasch producers will have perhaps a $6.00 per long ton freight advantage in these markets. This is less than the advantage they have in the Midwestern United States areas. In the major consuming areas of the Far East and Oceania: namely, India, Australia, New Zealand, and the Union of South Africa, Commonwealth ties and favourable trading relations in the past stand in favour of Alberta sulphur. Also, many customers in these areas welcome another source of supply. The figure of 500,000 long tons out of a total market potential of 1,150,000 long tons is perhaps ambitious but not unrealistic.

The foregoing statements hinge on the assumption that Alberta sulphur will be allowed free entry into United States markets. The writer feels there is reason to believe that the United States government will be under considerable pressure to impose tariffs or quotas on Alberta sulphur. If the United States Frasch producers could expect to increase their sales in other markets to offset the inroads of Alberta sulphur in domestic markets, all might be well. However, if it is assumed that Alberta sulphur would be successful in the Canadian market and supply perhaps 500,000 long tons of Canada's requirements, this would mean that approximately 300,000 long tons of Frasch sulphur imports would be cut off. As seen in table 20 the United States in 1960 sold nearly 500,000 long tons of sulphur in the Asian and Oceania market. Mexican sulphur sales amounted to approximately 200,000 long tons. If Alberta sulphur supplied 500,000 long tons of the 1965 estimated requirements of this area (1,150,000 long tons) and Mexico made any progress at all, United States sales would be reduced.

Table 20. Destination of Mexican and U.S. sulphur exports, 1959-1960

Destination	Mexico 1959	Mexico 1960	U.S. 1959	U.S. 1960
	long tons		long tons	
Canada	4,299	-	287,500	296,548
United States	673,655	633,753	-	-
Europe	198,582	293,232	643,984	753,417
South America	11,728	15,095	210,560	203,462
Mid East	29,186	46,430	30,431	23,342
India	19,638	30,507	124,699	144,835
Indonesia	-	1,400	7,700	3,100
Australia	46,638	74,199	123,084	147,000
New Zealand	21,620	45,908	84,039	86,873
Union of South Africa	59,481	66,683	61,385	58,000
Other	-	-	38,526	57,619
Total	1,064,827	1,207,207	1,611,908	1,774,196

Source: Foreign Trade Service, Canada Department of Trade and Commerce.

Furthermore, prospects for increasing United States sulphur sales in Europe are not too bright. The United States sulphur sales in 1960 were above those of 1959, but increased efforts by Mexico and particularly France will make United States progress difficult in the European market. Also, if Alberta sulphur succeeds too well in overseas markets and displaces Mexican sulphur, the Mexican sulphur interests may renew their efforts in United States markets in an attempt to make up lost sales. This could lead to an even greater build up of pressure for United States protection.

In short, it appears that conditions are ripe for agitation for United States protection against sulphur imports. It must be remembered that the growth of the United States domestic market alone would utilize all of the existing sulphur productive capacity before the end of the decade. A complete ban on sulphur imports is not envisaged since sulphur users would likely have strong objections to such a development, but there seems to be a danger of some measure of protection being implemented.

However, there are other developments which would serve to alleviate the situation even if United States protection did materialize. Alberta sulphur might find a market in Japan or Mainland China. These countries have been omitted from the forecast, Japan because it has been self-sufficient in the past as far as sulphur requirements are concerned and China primarily for lack of specific information.

The Japanese government has in the past imposed a ban on sulphur imports, thus forcing the utilization of indigenous sources of sulphur which are quite costly. However, a Japanese trade mission which visited Canada in September of 1961 aroused some hope that this situation might alter and that Alberta sulphur might find a market in Japan.

The problem of feeding a gigantic population will no doubt result in much wider use of chemical fertilizers and China may become a sulphur customer. Little is know known concerning her requirements other than that in the past China has been self-sufficient as far as sulphur is concerned. However, if Canada's recent successful wheat sales to China are any indication, or if the United States continues its policy on the sale of strategic goods to communistic countries, Alberta sulphur should have a good chance of supplying a large part of China's growing needs. This assumes that her indigenous sulphur resources will not be able to cope with these requirements.

Finally, technological advances may help to provide solutions to the Alberta sulphur problem. These solutions will likely take two forms: firstly, transportation improvements; and secondly, new uses for sulphur. In the matter of transportation, the various possibilities for pipeline transportation have already been mentioned. The possibility of using the Port of Churchill to serve European markets might become feasible. Handling facilities at Churchill are being improved to accommodate nickel concentrate export, and Alberta sulphur might well benefit by use of the port. This development would, of course, depend on the transportation costs to the European market being competitive with Frasch producers. Earlier in this report, it was suggested that Alberta sulphur would not be able to penetrate the European market due to France's production and the distance factor. This suggestion is true in the short run, but if the growth of the European market outstrips France's productive capacity in the future and if the transportation disadvantage could be overcome, Alberta sulphur might find an outlet in Europe. The seasonal disadvantage of the Port of Churchill could be overcome by year round stockpiling at the port and creating stockpiles in the consuming areas in Europe which might serve users during the closed shipping season.

Other possibilities in connection with transportation are in the visionary stage. These include shipping Alberta sulphur produced in the north to the Arctic Ocean via water transportation to a coastal stockpiling point and from this point it might be transported to markets by under-ice submarine. Consideration should be given to the idea that either public or private stockpiling and handling facilities be built at the head of the Great Lakes or at Vancouver in order that Alberta sulphur might be competitive with customer service offered by Frasch producers. This consideration might include both bulk and molten facilities. Sulphur producers, while paying a toll for these services, would certainly benefit in terms of meeting the competition on even ground. Since Alberta sulphur is homogenous, no difficulties are foreseen in each producer contributing to the stockpile and withdrawing from it as sales are made.

It is only very recently that a concerted effort has been made to find new uses for sulphur. The major world sulphur producers formed the Sulphur Institute in 1960, with offices in Washington, D.C., and London, England. The Sulphur Institute is patterned after the American Petroleum Institute with members contributing towards its support. This organization's main objective is to conduct research into developing new uses for sulphur. The Institute has underway a two-part program aimed at finding new uses for sulphur in agriculture and the manufacturing industry. Examples of new uses for sulphur under consideration are the use of sulphur in the building trades for decoration, surfacing, and bonding. Experiments also are being conducted into using sulphur as a substitute for paint for highway markings. New technology in fertilizer manufacture and application also are being studied. Other institutions including the Research Council of Alberta are exploring new uses for sulphur and methods of transportation.

Another factor which will serve to assist the marketing of Alberta sulphur is the development of new cheaper methods of H_2S removal and conversion to elemental sulphur. Frasch sulphur production techniques likewise are not beyond improvement with the use of atomic blasts to provide the heat required in Frasch operations under study. However, information released to date indicates that costs would be of the order of $8.00 per long ton by this method.*

The prospect that Alberta sulphur interests will be able to sell all of the sulphur they are capable of producing before the end of the decade seems remote. However, the encouraging technological advances that have been made and will be made as a result of pressures that will mount in the near future should do much to alleviate the situation.

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* Dale, J. H. and Hart, R. C.: Nuclear fire and brimstone, Chem. Eng. Progr., July 1960.

CHAPTER VI. OLIGOPOLY AND THE PRICING PROBLEM

As studies in economics progress, one finds oneself more and more often attempting to find real world parallels or situations that fit into the theoretical framework which is under study, or vice versa. Of course, the really practical purpose of learning how, for example, a purely competitive industry functions within the framework of certain conditions is to be able to apply this knowledge either to solve or to understand and appreciate real world problems.

The purpose of this chapter is to integrate some of the economic characteristics of the sulphur industry into the framework of economic price theory. Rarely does one find a better example of an oligopolistic situation than is found in the selling position of the North American sulphur interests. The following discussion will be concerned with what is meant by an oligopolistic industry and how aspects of the sulphur industry fit various oligopolistic forms. It is hoped that the reader who is not particularly concerned with the theoretical aspects of the sulphur industry will benefit from the conclusions regarding possible pricing policies which are discussed at the end of the chapter. In our present day economy where pure competition rarely is found outside certain sectors of the agricultural industry and where monopoly predominates in the field of public utilities, a very significant proportion of business enterprise is characterized by monopolistic competition. Industries characterized by monopolistic competition contain a large number of firms each selling very similar products. These products are not homogenous as in the case of pure competition nor are they competing with remote substitutes as in the case of monopoly. Retail trade is often cited as an example of monopolistic competition.

A particular species of monopolistic competition commonly found in manu facturing industries is that of oligopoly. "Oligopoly" strictly defined means "competition among few sellers". The word comes from Greek words oligoi meaning "few" and polein meaning "to sell".

It is only in the past two or three decades that the subject of oligopoly has received widespread attention from economic theorists. Traditional economic theory dealt with economic problems couched in the assumptions of perfect competition, which were realistic enough during the late eighteenth and early nineteenth centuries, while monopoly was often treated separately as a special limiting case. The gulf between received comparatively little attention. This likely was due in part to the fact that oligopoly has emerged as a widespread phenomenon of considerable importance during this century, and the unique characteristics of oligopoly provide such special problems for the economic theorist to grapple with.

Oligopoly in the economic sense has a broader meaning than is implied by the semantic definition of the word itself. The distinctive feature of oligopoly in terms of economics is revealed in Joel Dean's definition, "Oligopoly is the form of imperfect competition which obtains when sellers are few in number and any one of them is of such size that an increase or decrease in his output will appreciably affect the market price".*

* Dean, J.: Managerial Economics (New York, 1951), p. 52.

Before an individual firm operating under oligopolistic conditions can make a decision concerning price and output policy, it must consider carefully what effects its decisions might have on the policies of competitors. It is this condition of uncertainty about the price and output reaction of competitors that is at the root of the oligopoly problem. Matters are complicated even further by the fact that there are numerous different types of oligopolistic situations. Classifications made by different writers vary considerably. The most common classification segregates oligopoly according to whether or not the product of the industry is differentiated. Accordingly, "pure" oligopoly exists when the firms in the industry are producing perfect substitutes, that is, no product differentiation between firms. Examples may be found in industries producing steel, cement, or sulphur. In the minds of customers the products are homogeneous or at least they are sold meeting uniform and clearly defined classification as to quality, form, et cetera. By the same token, "differentiated" oligopoly exists when the products of the industry are considered by the customers to be heterogeneous whether in actual fact they are or not; that is, customer service, advertising, et cetera, may be used to try to differentiate the product. Much finer distinctions* are made on the basis of: freedom of entry ("open" as opposed to "closed" oligopoly); the presence or absence of collusion ("collusive" versus "non-collusive" oligopoly); or price leadership ("big firm" oligopoly as opposed to "full" oligopoly where leadership is absent). Other classifications deal with situations where a few firms dominate the industry and many small firms act as followers. This condition is referred to as "oligopoly with a competitive fringe".**

The foregoing does not exhaust the list of classification possibilities by any means. However, it does serve to point out why it is so difficult to generalize when dealing with the oligopoly problem. B. F. Haley emphasizes this by saying, "Each oligopolistic industry is to some extent unique and not too much is gained from the multiplication of theoretical models".***

Examples of the three common classifications of oligopolistic situations (organized collusive oligopoly, unorganized collusive oligopoly, and unorganized noncollusive oligopoly) are seemingly in evidence in the world sulphur situation, but none of these theoretical models as such can be applied directly to the Alberta sulphur industry.

The operations of Sulexco in the marketing of United States Frasch sulphur in export markets appears to be a good example of the organized collusive oligopoly model. However, we do not know if the profit maximizing motive exists in Sulexco as it does in the model. Sulexco appears to be in a position to behave like a cartel. The four Frasch producers assign their selling rights for export sales to this organization; the price is fixed and each member shares in the proceeds according to a predetermined percentage arrangement.

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* Machlup, F.: The Economics of Sellers Competition (Baltimore, 1952), Chapter 11, particularly pp. 359-367.

** Bain, J. S.: Pricing Distribution and Employment (New York, 1953), p. 71.

*** Haley, B. F.: Value and distribution. In A Survey of Contemporary Economics, (H. S. Ellis, editor), Philadelphia, Toronto, 1948, p. 17.

Table 21. Distribution of sulphur selling rights, based on productive capacities by plant - Alberta, 1963

Operator and location of plant	Sulphur productive capacity (long tons per day)	Breakdown of sulphur selling rights, by firm as a percent of plant capacity: Firm*	Percent of plant capacity
Shell Oil Co. of Canada Ltd. Jumping Pound	100	Shell Oil	100
Royalite Oil Company Ltd. Turner Valley	30	Royalite Oil	100
Imperial Oil Limited Redwater	9	Imperial Oil	100
British American Oil Co. Ltd. Pincher Creek	675	B.A. Oil	100
California Standard Oil Co. Ltd. Nevis	120	Calif. Standard	27
		Home Oil	15
		Tennessee Gas	10
		Canadian Fina	8 1/2
		United Oil	8 1/2
		Canadian Superior Oil	5
		Others	26
British American Oil Co. Ltd. Nevis	76	B.A. Oil	100
Texas Gulf Sulphur Co. Okotoks	370	Texas Gulf	75
		Shell Oil	25
Canadian Oil Companies Ltd. Innisfail	100	Canadian Oil	21
		Calgary & Edmonton Corp.	19
		Security Freehold	10 1/2
		Canadian Superior Oil	11 1/2
		Hudson's Bay Oil	11 1/2
		Imperial Oil	10 1/2
		Others	16
British American Oil Co. Ltd. Rimbey	250	B.A. Oil	33
		Calif. Standard	36
		Shell Oil	6 1/2
		Husky Oil	6
		Phillips Oil	6
		Imperial Oil	3 1/2
		Others	9

Western Leaseholds Ltd.			
Wildcat Hills	105	Imperial Oil	23
		Shell Oil	37
		B.A. Oil	11 1/2
		Hudson's Bay Oil	3
		C.P. Oil	2
		Others	23 1/2
Jefferson Lake Petrochemicals of Can. Ltd.			
Coleman	375	Jeff Lake	100
Pan-American Petroleums Ltd.			
Windfall	1800	Texas Gulf	100
Petrogas Processing Ltd.			
East Calgary	860	Jeff Lake*	100
Home Oil Company Ltd.			
Carstairs	60	Home Oil	37
		Tennessee Gas	17
		Canadian Superior Oil	17
		Alminex Oil	11
		Texaco Exploration	6
		Others	12
Shell Oil Co. of Canada Ltd.			
Waterton	1400	Shell Oil	90
		Others	10
British American Oil Co. Ltd.			
Wimborne	100	Assumed B.A. Oil	100
Canadian Delhi Oil Ltd.			
Minnehik-Buck Lake	20	Assumed Can. Delhi Oil	100
British American Oil Co. Ltd.			
Lookout Butte	35	Assumed B.A. Oil	100
Operator Unknown			
Olds	35	-	100
Total	6520		

* Abbreviated name.

Source: Submissions for approval made to the Alberta Oil and Gas Conservation Board, plus direct contact with individual firms.

Because sales are made through a single organization, the problems of policing would-be price cutters in the cartel are absent and Sulexco operates without a fear of breakdown through non-cooperation and surprise price cutting. Because of the absence of price competition among the members, it is readily understood why buyers in foreign markets are known to have an aversion to dealing with this organization. This fact is to the advantage of Alberta sulphur marketers looking for customers. The prospect of being able to buy Alberta sulphur from a number of different suppliers is looked upon with favour, particularly by buyers in the countries in Eastern Asia.

Ever since the United States Frasch sulphur industry really became an important sulphur producer in the early part of this century, price leadership has played an important part in the pricing of sulphur. This price leadership, a characteristic of the second case of organized non-collusive oligopoly, has been extremely effective and price competition initiated by United States Frasch sulphur interests has been noticeably absent. There were periods in the history of the United States Frasch industry when it was feared that the price war which the sulphur interests dreaded would materialize. A notable period was just immediately after the end of World War I when Texas Gulf Sulphur Company commenced to market sulphur; the firm had successfully entered the industry under the impetus of wartime demands for sulphur but did not produce sulphur until the war ended. At that time there were two other sulphur producers, Freeport Sulphur Company and the Union Sulphur Company. The latter firm was the original concern established by Herman Frasch. A timely expansion in sulphur consumption, resulting from a post-war boom and new uses for sulphur requiring considerable quantities of sulphur, caused no upset in the pattern of orderly marketing.* Successful price leadership by the United States Frasch producers was extended into foreign markets during 1952 to 1958 when Sulexco was temporarily disbanded.

Unfortunately, the Alberta sulphur industry does not fall neatly into the third theoretical case, viz. that of unorganized noncollusive oligopoly. The situation that faces the marketers of Alberta sulphur is certainly an oligopolistic situation but it is too complex a situation to be easily classified into a ready-made theoretical category.

The Alberta sulphur industry is comprised of a relatively few major sulphur marketers and a number of firms with rather minor interests in sulphur (see table 21 and table 22 in this connection). The product itself is homogeneous. These two facts in themselves fit the oligopolistic situation. If the firms with minor sulphur interests were to assign their sales to the more important marketers, the situation would be simplified somewhat. As it stands we have a situation which is very close to oligopoly with a competitive fringe.

If the conventional case of unorganized noncollusive oligopoly were under study, it would be a straightforward matter to analyse the pricing problem. An individual Alberta sulphur marketer does, however, face several problems which are absent in the ordinary case. First there is the matter of a market price for sulphur. In Alberta f.o.b. plant prices are determined by bid and are kept as secret as possible. As a result a market

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* Haynes, W.: Brimstone, the stone that burns (New York, 1959), p. 100.

price as such, which normally prevails in other industries, is absent in the Alberta sulphur industry. In most plants the output decision is also absent since sulphur production is contingent on natural gas sales.

Because of these complicating factors an individual seller of sulphur cannot predict with any degree of accuracy what the reactions of his competitors will be to any action he may take. As production increases and stockpiles mount, the individual seller is faced with the decision of selling sulphur now or waiting until the market grows and selling at an assumed better price perhaps 8 years from now. If sulphur is presently selling for $12.00 per long ton, he will have to realize more than $19.00 per long ton in 8 years if a 6% return on his inventory valued at the present price of $12.00 per long ton is required. An individual seller may well proceed to cut price and get contracts of two- or three-year duration while his competitors do not follow suit. The actions of the competitors would be learned only when the bids were opened.

The foregoing complications which have been pointed out indicate why it is so difficult to speculate on the type of a price situation that might develop in the future. Speculation of this type can only be done within a framework of specified assumptions and even then the writer recognizes the limited usefulness of such an approach. The following is the writer's glimpse into the future, bearing in mind that a multitude of outside interferences which are excluded by assumption could alter radically any envisaged situation.

If there were no oversupply situation, the Alberta sulphur industry is so constituted that effective price leadership would likely develop. As seen in table 22, four firms might well control sales of approximately 90% of the sulphur produced in Alberta. Any one of the firms might well become a successful price leader if sulphur were in under- rather than oversupply. However, the latter is the situation at present and the possibility of the emergence of price leadership by a dominant firm under these circumstances must be ruled out. The mounting stockpiles of sulphur will in all likelihood put considerable pressure, particularily on smaller firms with limited financial resources, to reduce the price and sell what sulphur they can.

Assuming for the moment that free entry into foreign markets was allowed, an immediate period of price erosion is foreseen. It seems likely that the smaller firms anxious to dispose of their sulphur production will lead the price cutting. Prices could fall rather quickly until the production of these firms was committed, after which some price recovery may be in evidence. The large firms with more financial resources may prefer to stockpile more of their sulphur production in anticipation of this price recovery. They may set certain minimum prices for their sulphur and bid accordingly. As the smaller firms drop out of the bidding after their production is committed, the firms with the higher prices may get the contracts, probably to the chagrin of the eager price cutters. Thereafter pricing may be more cautious.

Those firms which are able to secure large sulphur sales contracts at favourable prices may be in a position to purchase sulphur from some of the smaller firms. The latter may find it to their advantage to sell to a middle man with a good contract price rather than try to bid for contracts themselves. Some evidence of this practice has already put in an appearance. One can readily see the advantage to the firm with large contracts and

Table 22. Distribution of sulphur selling rights, based on productive capacities of sulphur plants, by firm - Alberta, 1963

Firm and location of plants in which firm has a share of sulphur production	Share of sulphur productive capacity (long tons per day)	Percent of total Alberta sulphur productive capacity* %
Texas Gulf Sulphur Co. Ltd.		
Okotoks	277	
Windfall	1800	
Total	2077	32
Shell Oil Co. of Canada Ltd.		
Jumping Pound	100	
Okotoks	93	
Rimbey	16	
Wildcat Hills	39	
Waterton	1260	
Total	1508	23
Jefferson Lake Petrochemicals of Can. Ltd.		
Coleman	375	
East Calgary	860	
Total	1235	19
British American Oil Co. Ltd.		
Pincher Creek	675	
Nevis	76	
Rimbey	83	
Wildcat Hills	12	
Wimborne	100	
Lookout Butte	35	
Total	981	15

California Standard Oil Co. Ltd.		
Nevis	32	
Rimbey	90	
Total	122	2
Home Oil Co. Ltd.		
Nevis	18	
Carstairs	22	
Total	40	1
Total capacity accounted for	5963	92

* Total Alberta productive capacity - 6520 long tons per day - 1963.

Source: Submissions for approval made to the Alberta Oil and Gas Conservation Board, plus direct contact with individual firms.

substantial production, absorbing the production of the smaller producer rather than facing a cut in the price. This would, of course, depend on the quantities involved and the size of the price cuts thought to be in the offing.

After a rather hectic period of price adjustment the writer would estimate that the price would tend to stabilize somewhere between \$8.00 and \$10.00 per long ton f.o.b. plant. The price might well dip below this range especially while certain marketers are extending themselves to sell their sulphur. A price for sulphur between \$8.00 and \$10.00 per long ton f.o.b. plant would cover the costs of production of most of the co-product plants and yet be competitive in the major market areas.

It seems doubtful that the United States sulphur producers would have enough influence to be able to exclude Alberta sulphur from the United States completely by some form of tariff barrier. Countervailing power on behalf of the immediate users, the manufacturers, and the ultimate users, particularly the farmers using fertilizer, should preclude this. However, some form of protection is foreseen. This protection would, of course, be implemented against all sulphur imports with the result that both Alberta and Mexican sulphur suppliers would have to compete with the United States for other markets. A much more difficult pricing situation would be envisaged as a result, and tariff barriers once raised are lowered again only with difficulty.

The prospect of a long period of sulphur oversupply and low prices could have beneficial effects as far as Canadian industrial development is concerned. However, domestic consumption of sulphur is not expected to be of the proportions to reduce appreciably the magnitude of the sulphur problem. Perhaps Canada could become a leading world producer of fertilizer based on low-cost Alberta sulphur. The location of fertilizer plants would, of course, depend on important factors of transportation costs. Another possibility is the development of metallurgical refining processing based on sulphuric acid. The pulp and paper industry might receive further impetus since sulphur is an important raw material in wood processing operations.

In the final analysis, the problem which confronts the Alberta sulphur industry is the same as that which confronts so many industries in Canada today. Actions or reactions on the part of the United States, Canada's largest customer, often dictate the path which the industry is to follow.

The Alberta sulphur industry is peculiar in that sulphur production will be forthcoming in spite of what may happen; this fact serves to aggrevate the situation. The real hope for a solution to the problem will hinge in the main on technological developments in both transportation and new uses for sulphur. As sulphur production increases and stockpiles mount more effort will be bent in the direction of remedying the situation. No doubt scientific endeavour will pick up the challenge to provide solutions not thought of today.

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