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Agenda item IV/4

SULPHUR: SUPPLY, DEMAND AND PRICE FORECASTS UP TO 1980 1/

by

J. Lastowiecki

Centrala Importowo-Eksportowa Chemikalii Sp.
Warsaw Poland

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SUMMARY

SULPHUR: SUPPLY, DEMAND AND PRICE FORECASTS UP TO 1980 1/

by

J. Lastowiecki

Centrala Importowo-Eksportowa Chemikalii Sp
Warsaw Poland

Sulphur, one of the basic raw materials, appears in nature in quantities that can be extracted to meet the requirements of industry in full. Thus, except in the cases in which compulsory recovery takes place, the volume of sulphur output and production is determined by demand for this raw material.

The pattern of sulphur consumption indicates that sulphuric acid, chiefly employed in the production of fertilizers, absorbs 80-90 per cent. The remaining 10-20 per cent is used by textile industry, carbon disulphide, dyestuffs industry, TiO_2, cellulose, paper industry, tire industry etc.

From the above, it appears that the world demand for sulphur depends upon the development of sulphuric acid production and upon the dynamics of phosphatic fertiliser production.

The percentage share of individual raw materials on which the world production of sulphuric acid is based is at present as follows:

- pyrites 35 per cent
- elemental sulphur 45 per cent
- other sulphur sources 20 per cent

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1. Introductory

Sulphur is one of the oldest minerals known to and applied by mankind. Over thousand years of its development the latter has been accompanied by the raw material.

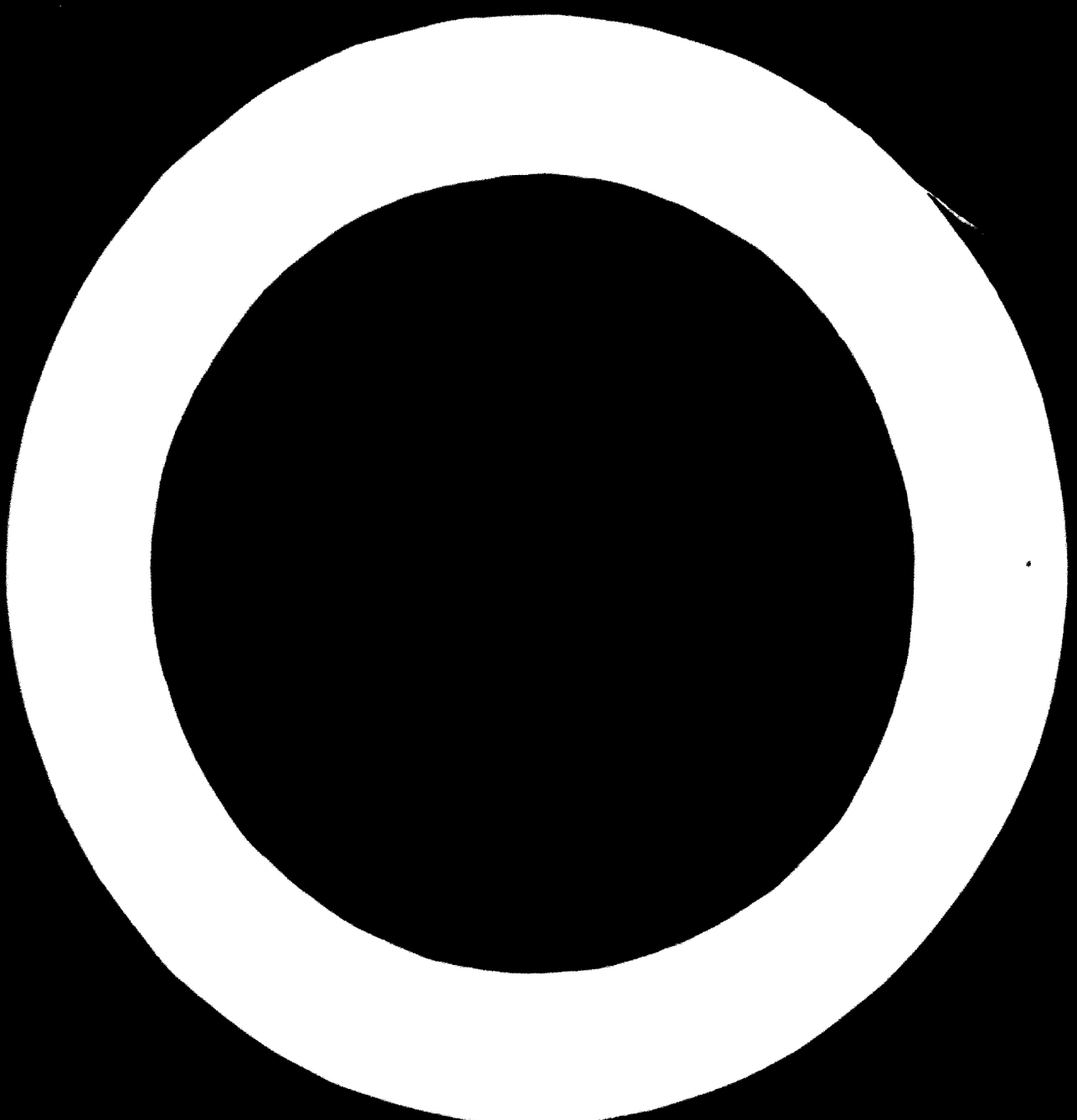
As early as some 2,000 years B.C. the Egyptians used sulphur for linen bleaching and medical compounds. In 1894 an important event in the history of sulphur was Herman Frasch's hot-water melting process to obtain brimstone. Its uninterrupted march has lasted since that time.

In the first half of this century sulphur became one of the main pillars in chemical industry and the quantities of sulphuric acid produced from sulphur are one of the measures and determinants for the place held by individual countries on the list of world chemical powers.

2. World Consumption of Sulphur

Alongside of the gradual world development of industry, including that of chemicals, the role of sulphur and demand for that raw material started to increase.

The requirement was first met by native (i.e.mined) sulphur and by sulphur-carrying raw materials such as pyrite, anhydrite and gypsum. Until the 1920's the basic raw materials for producing sulphuric acid were pyrites (together with mar-



For the introduction to the [illegible] raw materials, it may well be noted that [illegible] the different variants in terms of technical and economic aspects. The theme is supported by the respective tables of comparative costs of sulphur and production based on various raw materials.

On the basis of these findings, it is proposed that

- a part of installations based on pyrites and other raw materials will be reconstructed and adapted to sulphur processing into sulphuric acid,
- a preponderant part of new investment in sulphuric acid will be designed and erected on the basis of sulphur as the raw material.

Based on the aforesaid assumptions, statistical figures concerning the consumption of sulphur and the respective estimate of sulphuric acid consumption in industry, particular consideration being given to the industry of phosphatic fertilizers, a forecast for sulphur demand till 1980 has been presented.

The next part of the paper contains materials relevant to the world resources of sulphur and sulphur-carrying raw materials, the extraction and production technology of sulphur, cost estimates connected with those operations as well as a forecast of the pattern of sulphur production up to 1980.

In the subsequent part is presented:

- a balance of production and consumption of sulphur in all forms and, against that background, that of elemental sulphur,
- a review of world trade in elemental sulphur, main producers' export quantities and main importers' purchases being taken into consideration.

Finally, a trial of price prediction with respect to elemental sulphur during the coming decade is undertaken on the basis of the trends of prices for elemental sulphur over the past 25 years, a probable pattern of supply and demand conditioned by new consideration, the air pollution problem and the necessity to de-sulphurize gas, crude oil and industrial gases being taken into account.

As a part of the general programme of the Second Interregional Fertilizer Symposium poised against the world fertilizer situation, the report devotes particular attention to the developing countries and their problems connected with the development of phosphatic fertilizer industry and the production of such fertilizers in terms of sulphur supply and demand in those countries.

In line with his viewpoint that a world-wide use of elemental sulphur for the production of sulphuric acid and the increase of installations for such production will substantially decrease the manufacturing costs, the author includes a proposal for Poland's participation in the world trade in sulphur and in the export of sulphuric acid installations. Export of sulphuric acid plants belongs to the field in which her engineering industry specializes.

oasite) because brimstone whose production initiated in the United States by a method of underground melting by the end of the 19th century was still too dear to be used for making an inexpensive and mass product. At that time also the waste SO_2 derived by roasting sulphide ores containing a non-ferrous metal base was utilised.

In the United States, a relatively rapid changeover into brimstone took place and to-day the production of sulphuric acid based on that source accounts for 87 per cent there while Europe having rich deposits of pyrite continues to derive a considerable portion of sulphuric acid from that raw material, pyrite being a dominant raw material in such countries as the Soviet Union, Sweden, Norway, the German Federal Republic and Spain. The position of brimstone began to change and strengthen alongside of American increased supplies, and over the last decade the consumption of brimstone radically increased and changed the existing structure of sulphur utilisation in all forms as a result of considerable quantities of sulphur recovered by desulphurizing sour gas, thus reducing the cost of sulphur.

Sulphur is used for quite a number of different purposes and therefore it is often taken as a conclusive index of industrial activity. A preponderant part of sulphur serves as a chemical raw material to produce other articles and it seldom appears in a final product.

It is estimated that sulphur (in all forms) up to about 80 per cent, on the average, is earmarked for the production of sulphuric acid.

In terms of final products, it should be averred that the main consumer of sulphur is the fertiliser industry which takes up appr. 50 per cent. of sulphur, out of which 41 per cent. being used for the production of phosphatic fertilisers. The next consumers of sulphur are the viscose-fibre industry (about 7 per cent.), the pulp-and-paper industry (appr. 5 per cent.), pigments (TiO_2) production (appr. 5 per cent.), iron and steel pickling 2 per cent., some 31 per cent. of sulphur being used for the production of other articles such as plant-protecting agents, rubber goods, explosives, etc.

The development of sulphuric acid industry, which is a result of an ever-growing output of phosphatic fertilisers and other branches of industry that use that semi-product, is the basic factor which conditions the drive and volume of sulphur demand. The respective analysis shows that there is a close correlation and interrelation between the production of sulphuric acid, the production of phosphatic fertilisers and the consumption of sulphur.

Unfortunately, the specialist literature is lacking statistical data relevant to the world consumption of sulphur, only the market-economy countries consumption figures being published. The data in various materials available are not identical and they often differ even to a considerable extent.

However, to illustrate the order of magnitude regarding consumption and the above mentioned close interdependencies, the following data are given below:

1. World production of sulphuric acid (100% H_2SO_4) in '000 metric tons

(Source : Statistical Yearbook, United Nations, 1969)

	1955	1960	1962	1965	1966	1967
Total '000 t	31.370	48.920	53.090	67.740	73.940	76.900
Annual average growth rate in %	-	7,7	5,0	9,2	9,1	4,1

The average annual rate about 7.5 per cent.

2. World production of phosphatic fertilisers in '000 metric tons P_2O_5

(Source : FAO Production Yearbook - 1969)

	1948/'49 1952/'53	1952/'53 1956/'57	1964/ /'65	1965/ /'66	1966/ /'67	1967/ /'68	1968/ /'69
Total '000 t P_2O_5	6.056	7.520	13.843	15.076	16.286	17.206	17.466
Average annual growth rate in %	..	6,0	10,5	8,9	8,0	5,6	1,5

The average annual rate about 8.2 per cent

3. World consumption of phosphatic fertilisers in '000 metric tons P_2O_5

	1948/49 1952/53	1952/53 1956/57	1961/62	1965/66	1966/67	1967/68	1968/69
Total '000 t P_2O_5	5.100	7 [illegible]	12.936	[illegible]07	15.[illegible]4d	16.411	17.275
Average annual growth rate in %	-	9,7	10,8	9,0	6,1	5,6	5,3

The average annual rate about 8.6 per cent.

According to the above mentioned statistical figures, the average growth rate regarding the world production of sulphuric acid and the world production of phosphatic fertilisers were some 7 - 8 per cent. per annum during the years 1953 - 1967. It is obvious that the downward activity in the fertiliser sector which took place as a result of different difficulties and circumstances in the 1966-70 period added to the decrease in that area.

The table given below illustrates the consumption of sulphur in all forms in the market-economy countries as well as the production of phosphatic and oral fertilisers in those countries, and the respective indices of growth (the data for sulphur consumption being worked out on the basis of the bi-monthly publication "Sulphur", those of the production of sulphuric acid - on the basis of the U.N. Statistical Year-

book and the Monthly Bulletin of Statistics, and those of phosphatic fertilisers - on the basis of the FAO Production Yearbook and the Monthly Bulletin of Agricultural Statistics).

Consumption of sulphur against the background of sulphuric acid and phosphatic fertilisers in market-economy countries

Year	Sulphur consumption in all forms		Sulphuric acid production		Phosphatic fertiliser production	
	m.t.	% index	m.t. H_2SO_4	% index	m.t. P_2O_5	% index
1955	14,7	100	32,5	100	7,0	100
1960	17,8	121	40,3	124	8,5	121
1965	24,4	166	54,2	167	12,2	174
1969[a)]	28,3	193	63,4	195	13,8	197

a) provisional data

b) economic years 1955/56, 1960/61, 1965/66 and 1968/69

The structure and dynamics of sulphur consumption are interesting which points are illustrated by the following table on the basis of market-economy countries:

Development of sulphur consumption in market-economy countries in m. t. S

Year	Sulphur in all forms	including		
		Brimstone	Pyrite-based sulphur	Other sources-based sulphur
1965	24,4	14,1	6,3	4,0
1966	25,7	15,0	6,4	4,3
1967	26,3	15,4	6,5	4,4
1968	27,4	16,0	7,0	4,3
1969[a)]	28,3	16,6	7,3	4,4
1970[b)]	29,4	17,5		

a) provisional data

b) estimated

Sources: The British Sulphur Corp. "Sulphur", Nos. 74/1968, 80/1969, 86 and 87/1970, and Statistical Supplement No. 1/1970.

Likewise interesting would be the figures regarding the world consumption of sulphur in all forms. In view of the lack of the relevant literature and data, those regarding the production of sulphuric acid will be taken into consideration in order to calculate the respective consumption volume.

Assuming that 0.333 t. of sulphur is necessary to get 1 t. of H_2SO_4 (100%) and that about 80 per cent. of sulphur is used for the production of sulphuric acid, the following

picture will be obtained.

World consumption of sulphur in all forms (estimate)

Years	1953	1960	1962	1965	1966	1967
World consumption of sulphur in m.t.	13.071	20.097	22.121	28.225	30.799	32.075
Rate of annual world consumption in %	-	7,6	5,0	9,2	9,0	4,1

Average annual rate about 7,3 per cent.

From the above-given juxtaposition, it appears that the growth of demand for sulphur increased, on the average, by about 2 m. tons per year from 1960.

The consumption dynamics of individual sulphur-carrying raw materials (mainly brimstone and pyrites) was substantially different as a result of changing market-trend patterns and prices of both the raw materials. Until the mid-60's the consumption of brimstone was increasing much more rapidly compared with the development of pyrite consumption. The years 1965 - 68 brought a change in those tendencies which were an immediate outcome of the market-trend situation in the world sulphur market where in the conditions of the sharp demand preponderance over supply of brimstone and its extremely high price the productive capacities of pyrite industry were increased and the growth of consumption of sulphur obtained from pyrites was augmented.

It was in 1968 that as a result of an increased export of sulphur from Poland and the Canadian sulphur recovered from natural gas a new stage in the market-trend situation was initiated, which situation is described by a majority of specialists as a structural predominance of supply over demand and which situation has existed till now. The situation was and continues to be a reason for changes in the structure of consumption in favour of a substantial increase in the share of brimstone.

3. World Production of Sulphur

a) World sulphur resources

Sulphur resources in the world are enormous and can cover demand for that raw material in the foreseeable future. Sulphur occurs in the Earth's crust in the amount of about 0.06 per cent. in the form of native sulphur, sulphides and sulphates. All these forms are of a practical industrial importance if they occur in such quantities and conditions that make their economic exploitation possible. Despite the fact that the biggest sulphur resources are in coal, anhydrite, gypsum and sea water, it is not recuperated from any of those products except anhydrite and gypsum, in small quantities though.

Estimated sulphur resources in the world (in m. tons)

Area	Petroleum	Natural gas	Native ore	Dome	Sulfide ores	Pyrites	Total
U.S.A.	30	25	100	100	25	25	305
Canada	5	100	-	-	25	25	155
Mexico	5	-	-	50	10	5	70
Central and Latin America	30	-	100	-	50	50	230
Western Europe	-	25	5	-	5	25	60
Eastern Europe	20	20	100	-	100	150	390
Near East and Southern Asia	340	500	200	-	5	50	1095
Far East and South-East Asia	10	10	50	-	20	20	110
Africa	5	-	-	-	20	20	45
Oceania	-	-	-	-	5	5	10
Total	445	680	555	150	265	375	2470

Data according to U.S. sources.

It seems that the above-mentioned resources of sulphur may be considered as quite well diagnosed and often proved, but in the case of native and dome sulphur and that from pyrites it should be assumed, according to a very rough estimation, that they are three times as big. From the commercial viewpoint, the most important resources of sulphur are in

Canada with her 100 m. tons sulphur from gas, Poland, where sulphur deposits are estimated at some 100 m. tons, Iraq with estimated reserves accounting for 200 m. tons of sulphur, and the Near East where sulphur is obtainable from gas and petroleum.

b) World production of sulphur

Let us first quote the data regarding world sulphur production excerpted from the Statistical Yearbook, United Nations, 1969, in thousand metric tons.

	1953	1960	1962	1965	1966	1967
Sulphur from pyrites	5381	9447	9582	10159	9718	10321
Brimstone	5491	7790	8318	9664	10806	10570
Sulphur recovered as a by-product	723	2958	4287	6142	6233	6916
Total	11595	20195	22187	25965	26757	27807
Average annual growth rate in %	-	10,5	4,9	5,7	3,0	3,9

The average annual growth rate 7.7 per cent.

It should be mentioned, however, that the data published by the Statistical Yearbook cover only brimstone and sulphur obtained from pyrites and they do not include the sulphur produced in considerable quantities from other sources as smelter gases, etc.

The quantities obtained from other sources are fairly big and reach about 15 per cent. of the total production of sulphur. The British Sulphur Corp. estimates the quantities at 5.9 m.tons in 1967, 6.3 m. tons in 1968 and 6.7 m. tons in 1969, respectively, and informs that during the 1967-69 period the world production of sulphur in all forms was as follows:

World production of sulphur in all forms in thousand tons

	1967	1968	1969
Limestone	17.901	19.007	21.085
Pyrite	10.368	10.815	11.065
Other forms	5.950	6.321	6.671
Total	34.237	36.943	38.807
including			
Western Europe	7.243	7.496	7.768
Eastern Europe	7.442	8.377	9.220
Asia	2.798	2.940	3.134
North America	12.345	14.384	14.858
Central America	1.977	1.785	1.806
South America	206	175	192
Africa	542	558	544
Oceania	237	212	199
Others (China, North Korea, Cuba)	965	1.037	1.085

It should be noted that the average annual rate of pro-

duction growth in sulphur in all forms amounted to 7.7 per cent. over some 15 past years, whereas the dynamics of that growth for sulphur from pyrites was 6.5 per cent., and that of brimstone was 12.9 per cent. Over the past 3 years those proportions deepened as a result of an ever-growing production of Canadian sulphur recuperated from gas.

The development of world sulphur production, especially that of brimstone, was not so uniform as the average annual growth index. The production of sulphur through a number of years was not uniform and showed certain, often quite considerable deviations which point was closely connected with the existing demand and the accompanying market-trend situation.

Sulphur is produced by about 50 countries out of which 40 countries produce brimstone: among the latter's biggest producers in the world are the United States, Canada, Poland, Mexico and France, whose participation is as follows:

U.S.A.	-	41 per cent.
Canada	-	18 per cent.
Poland	-	9 per cent.
Mexico	-	8 per cent.
France	-	8 per cent.
Total		84 per cent.

e) <u>Costs of sulphur production</u>

The costs of sulphur production vary to a considerable

extent. The very big differencies depend upon the source and the production process employed, production conditions and a number of other factors. According to some specialists, the estimated production costs of 1 ton of sulphur are as follows:

Frasch:	low cost	- $ 10
	medium cost	- $ 15
	high cost	- $ 23
Sour gas:	natural gas	- $ 15
	rafineries	- $ 20
Smelter gas:		- $ 18
Pyrites:		- $ 35
Gypsum:		- $ 35
Utility stack gas:		- $ 43
Other native:		- $ 35

4. Sulphur Demand and Supply Till 1970

Over the past twenty years the situation of supply and demand faced a series of numerous cyclic fluctuations and swings which, according to some sources, were something like a "seesaw" or a "sinusoid". When looking backwards, it is rather difficult to recollect a period free from short- or oversupply.

Let us briefly outline that historical period.

Since 1913 the United States became the leading producer and have held that prime position ever since. In 1948/49 de-

mand for sulphur exceeded production possibilities and in 1950 a shortage appeared. That first shock to the industrial world was followed by sales restrictions and an increased production of sulphuric acid from pyrites.

In 1954 Mexico began to produce sulphur by the Frasch method, but the period 1953-56 was featured by short supplies with higher prices, from 1957 to 1962, for a change, supplies with weak prices were going on, and next, in 1963, once more against all expectations, after a lengthy period of overproduction an acute shortage of sulphur started quite unexpectedly and lasted till 1967. The period of oversuppy in 1957-62 coincided with the beginning of gas-based sulphur production in France in 1957 and that in Poland in 1961. The second period of oversupply, which started in 1968 and has lasted till to-day, is, on the one hand, a result of a rapidly growing production of the so-called "compulsory" or "fatal" sulphur obtained from natural gas in Canada and, to a less degree though a result of the growing deliveries of Polish sulphur to the world market, but - on the other - it is mainly a result of a parallel considerable decrease in production rate and the consumption of phosphatic fertilizers, the chief consumer of sulphur, which brought about the respective repercussions and a deeper market disequilibrium. The year 1967, in which the world supply of sulphur balanced demand, was a momentum which initiated a new period of so far unnoted preponderance of supply, accompanying rapid price reductions and some producers' piling up stocks.

According to some specialists, by the end of 1967 sulphur stocks in market-economy countries accounted for 3,6 m. tons, going up to 5.1 m. tons in 1968, 7.2 m. tons in 1969, and coming to 8.8 m. tons by the end of 1970.

That new situation in the world market of sulphur did not influence the trends of production development in the same way.

In Canada, despite disadvantageous overproduction effects on a world scale for producers and increased stocks, the output of the "fatal" sulphur enjoyed a further increase. It was connected with a rapidly and steadily increasing output of gas which, like other power raw materials, is highly required, its production bringing sulphur as a necessary by-product. The same refers to brimstone recuperated from petroleum. In 1968 the production of sulphur from gas in Canada accounted for about 3.2 m. tons, followed by 3.8 m. tons in 1969 and by about 4.5 m. tons in 1970.

Growing marketing difficulties influenced the production of brimstone in the United States. In 1969 and 1970 some sulphur mines were closed (in 1969 and till the end of July 1970 six sulphur mines were closed according to the European Economic News of the 7th August, 1970), as a result of which the production of brimstone in 1969 was 8.7 m. tons compared with that in 1968 when it accounted for 8.9 m. tons.

In the remaining principal sulphur-producing countries, i.e. Mexico and France, changes in sulphur production were relatively insignificant. In Mexico and France, that production

was maintained at the level of about 1.7 m. tons.

A strong growth took place in Poland's production of brimstone, accounting for some 1,316 thousand tons in 1968, 1,942 thousand tons in 1969 and 2,684 thousand tons in 1970.

That large supply of brimstone in the world market over the recent years and its very low prices also brought about structural changes in its favour. It is a well known fact that the plans of putting in motion an Antwerp sulphuric acid factory by the West-German Bayer combine were changed and that in the end its production was based on sulphur, and not on pyrite previously contemplated. Such a tendency is observed in the German Federal Republic which up to now uses substantial quantities of pyrites, in Italy, etc. The facts prove that there is a conviction that the present situation of the excess of supply over demand and the resulting low level of brimstone prices are of a stable and lasting nature and that it is profitable to base production on that raw material without any risk to its successive shortage in the future.

The second characteristic feature of the current demand is the fact of growing demand for and consumption of sulphur in the liquid form. Its chief consumers are the United States of America and Western Europe including Belgium, the United Kingdom, Eire, the German Federal Republic and France.

It is estimated that in 1969 and 1970 those countries import of liquid sulphur was as follows:

	1969	1970
Belgium	259,000 t	351,000 t
Holland	429,000 t	409,000 t
United Kingdom	380,000 t	450,000 t
Eire	79,000 t	96,000 t
German Federal Republic	140,000 t	150,000 t
Total	1,287,000 t	1,456,000 t

which figures account for some 45 per cent. of Europe's import and for about 16 per cent. of the total world import.

It was at the beginning of the 1950's that sulphur in the United States of America was transported in the solid state while at present almost all sulphur produced by the Frasch method is sent in the liquid state by railway tankcars, barges and sea tankers. The United States began their liquid sulphur overseas transport in 1964 when 2 specially constructed tankers were commissioned for operation. At present liquid sulphur is delivered to European clients by American, French, Mexican and, recently, Polish suppliers. Liquid sulphur heated up during transportation is delivered to special terminals that can store a few score of thousand tons kept in liquid form in the ports near the buyers' final destinations. Such terminals have so far been installed in Rotterdam (Holland), Immingham (Great Britain), Rouen (France) and Dublin (Eire).

From the terminals, sulphur is next delivered to the buyers' factories by barges of a respectively lower draught through canals and rivers or by motor tankcars by land.

Liquid sulphur is $ 1.5-2,/t more expensive than the lump one, but - on the whole - it is more advantageous and compensates by far the slightly higher price. The advantages of using liquid sulphur include labour costs, discharge costs (customarily accounting for $ 0.70-1,0,/t in the case of lump sulphur), dust loss, contamination and melting costs.

The American firm Duval Corp. supplies sulphur in the lump form from the United States to Antwerp where the sulphur is subjected to a melting process and is finally delivered in the liquid form to the buyers.

At present new terminals are under construction in Calais (France), Rotterdam (Holland) for the Polish sulphur, and in Runcorn (at Manchester in Great Britain),

5. World Trade in Brimstone

Taking into account the fact that the pyrite-based sulphur in the total world production of sulphur in all forms accounts for about 30 per cent. and in the world export for about 25 per cent., it seems purposeful to limit the analysis of trade only to brimstone which is the basic article of world export.

The following figures illustrate the volume of world brimstone exports:

Export of brimstone (in '000 tons)

Countries	1965	1966	1967	1968	1969	1970
Canada	1359	1269	1677	1876	2132	2520
U.S.A.	2666	2409	2172	1576	1566	1330
Mexico	1340	1490	1638	1336	1143	661
France	913	892	1010	1046	889	1130
Poland	235	272	406	963	1446	1773
Other countries	217	317	406	535	584	736
Total	6930	6649	7309	7332	7760	8150
Average annual growth rate in %	-	-4,1	9,9	0,3	5,8	5,0

The average annual growth rate 3,4 per cent.

The above-given data have been worked out partly on the basis of own information sources and that of the British Sulphur Corp.

From the above-given figures, it appears that Canada, Poland, U.S.A., France and Mexico belong to the group of chief brimstone exporters in the world and that their total export accounts for 91 per cent. of the present overall export.

The most intensive growth of export took place in Canada, Mexico, France and Poland while that of the United States was rather stable except the years 1965'67 when the American export increased. It is, however, Canada that has ranked first in the dynamics of growth. Her export initiated with the

quantity of 130,000 tons 11 years ago developed so surprisingly that Canada is now the biggest exporter of sulphur in the world. A similar vigour was next shown by Poland which was the second biggest world exporter in 1970. It seems worth noticing that Poland's export of sulphur continues to develop.

After quite a rapid intensification of export following her beginning of production, Mexico substantially decreased her export after 3 years which fact is, no doubt, connected with the present slowing down in the world market of sulphur.

With some fluctuations, France has maintained her exports almost unchangeably for a few years at the level of about 1 m. tons.

In the above-quoted table, only five main producers and exporters of sulphur were mentioned although the list is, in fact, much longer. The remaining quantities involved are, however, much smaller and at present they have no bearing whatsoever upon the situation of the sulphur market and upon market trends. To the latter exporters, belong the Soviet Union which exports about 300/400 tons of brimstone, Iran which is entering the market in an ever-intensive way, Bolivia, the German Federal Republic, etc.

To illustrate the percentage share of the five main exporters in terms of tonnage sulphur exports and to evaluate their current position, the following table is quoted:

Exporters

Year	U.S.A.	Canada	Mexico	France	Poland	Total %
1954	100	-	-	-	-	100
1955	90,0	-	10,0	-	-	100
1960	50,0	3,6	34,7	11,7	-	100
1965	39,8	20,2	22,9	13,6	3,5	100
1970	18,0	34,0	8,9	15,2	23,9	100

The above-mentioned juxtaposition illustrates the ever-changing participation of individual countries in sulphur export over the period under review. The United States, which were practically the only exporter in 1954, moved to the third place of world suppliers in 1970. Their place was taken over by Canada. In analyzing the export figures, one should not disregard the fact that the United States and France are not only the exporters but also importers of sulphur and therefore the net export of each of them was lower. In 1969, for example, the United States imported 1,665,000 tons of sulphur from Mexico and Canada and in 1970 they imported 1,394,000 tons. If this point were taken into account, the percentage share of individual exporters in export would undergo a further change.

While the export of sulphur is concentrated to a high degree with the five main producers, demand for sulphur appears in almost all the remaining countries of the world. In 1969 and 1970 its biggest importers were the following countries:

Country	1969	1970
U.S.A.	1665 t. tons	1394 t. tons
Great Britain	757 "	916 "
Australia	437 "	271 "
Holland	588 "	409 "
France	270 "	356 "
India	369 "	464 "
Belgium	263 "	351 "
Czechoslovakia	265 "	281 "
German Federal Republic	289 "	279 "
Brazil	196 "	282 "
Italy	222 "	281 "

Such countries as New Zealand, Greece, Eire, Hungary, Tunesia, Austria, Cuba, The Republic of South Africa and Taiwan imported sulphur up to 100,000 - 200,000 tons a year.

The most absorptive markets for sulphur are highly industrialised countries as well as some developing ones which extend their fertiliser industries to meet the ever-growing needs connected with the nutrition of their population. Western Europe continues to be a big selling market and its share in the total import in 1970 accounted for about 40 per cent. That market area is supplied by North American countries (the U.S.A. and Canada) as well as by Mexico and Poland, while the United States market's suppliers are only Canada and Mexico.

An essential role in the geographical distribution of sales markets is played by freight rates because they, inter alia, influence the profit aspect and directions of export. The rates differ according to the size of the given lot, the type of ship, port, loading and discharging rates, seasons and market trends in the freight market.

The range of the freight rates depending from the aforesaid factors is very big and it is difficult to compare them. However, in view of the fact that the freight costs largely affect the resultant net (FOB) price in exporting such a relatively cheap mass raw material as sulphur, it seems worth while to give some figures and to quote average guiding rates for main transport sailings.

The sea transport of brimstone in thousand tons on main world routes was as follows:

	1968	1969
U.S.A. (Mexico - U.K.) Continent	1298	1135
U.S.A. (Canada - Australia) New Zealand	547	487
Carriages between American ports	1032	1030

As regards the pattern of sulphur freight tonnage in the tramp market, a vast majority, i.e. about 92 per cent. of tonnage, covered ships below 9,500 tons, 5 per cent. covered 9,500 - 15,000 tons, 2 per cent. covered the 15,000 - 25,000 ton ships and only about 1 per cent. included the ships of over 25,000 tons.

The average freight rates in carrying sulphur in the lots of about 10 - 15 thousand tons were as follows (in U.S. $ per t f.i.o):

	1969	1970
U.S. Gulf - Western Europe	6 - 8	7,50 - 10,0
Vancouver - Australia	8 - 10	11,50 - 12,50
Vancouver - India ports	11 - 14,50	14,50 - 17,-
Vancouver - Continental ports	8 - 10	10,50 - 12,50
Gdańsk - Western Europe	3,50 - 4,0	4,50 - 5,50
Gdańsk - India ports	12 - 14	15,- - 17,-
Gdańsk - the Mediterranean ports	5,50- 6,50	7,- - 9,-

The sulphur exporting countries situated near the purchase markets (France and Poland in relation to Europe, Canada and Mexico in relation to the United States) take advantage of a certain kind of "geographical rent" compared with those which have to pay more for sulphur transport. It should be stressed that it was only in the second half of the last year that freight rates were tending downwards.

Apart from that, the direction and volume of exports are influenced by such factors as sulphur forms (lump, granulated or liquid), capital links, treaty conditions, etc.

The trade in brimstone should be considered as a substantial one because 8,150,000 tons in 1970 accounted for about 37 per cent. against the total world quantity produced, and even for about 20 per cent. compared with the total quantity of sulphur produced in all forms and the trade

turnover is and will be an important element in furnishing many countries which have not that raw material or have it only limited quantities.

Liquid sulphur deserves attention because of its ever-growing trade turnover.

Despite a high dynamics of turnover in brimstone in the past years, and, in turn, a very insignificant growth over the last 3 years, it seems that the rate of growth in the future trade should be estimated at a level of about 5 - 5.5 per cent. per annum on the average.

6. Prices of Brimstone Until 1970

The ever-changing situation with regard to supply and demand in the world sulphur market was the basic factor which conditioned the shaping of prices of that raw material. In the conditions of international sulphur market, an important role is played, after all, by the stocks of that raw material which influence sometimes in a mitigating way and over many months, the acute fluctuations of the supply and demand patterns.

The periodical fluctuations of the prices in the world sulphur market are illustrated by the table given below.

World prices per 1 ton of brimstone (FOB - in U.S.A. $)

Year	$/1 ton	Year	$/1 ton
1954	30	1963	20
1955	30	1964	20

(continued.....)

1956	28	1965	24
1957	27	1966	30
1958	25	1967	39
1959	24	1968	41
1960	23	1969	37
1961	22	1970	18
1962	22		

The above-quoted prices are average (various deviations having been in the respective individual suppliers' quotations), but they give some viewpoint on the average level of prices in individual years and on their trends over a longer period of time.

A low level of prices in the world market appeared in the years 1961/64 because it was a period of an intensified supply (Canada's entrance) and the producers' ever-growing stocks which amounted to 5 m. tons by the end of 1963.

Beginning with 1965 the next years show a definite increase in prices which fact was a result of augmented demand for sulphur as during that period a rapid growth of productive capacities in sulphuric acid and a disbalance in the raw material occured. In the years 1950/1960, i.e. during a decade, the growth of sulphuric acid productive capacities closed with the sum of about 23 m. tons. Almost the same growth was reached during the years 1963/1967, i.e. within 4 years.

That high level of prices, never experienced before in the history of sulphur, reached its peak in 1968 when the

price almost doubled compared with that in the previous period and reached the level of over $ 40/t FOB. Although an excess of supply over demand appeared in 1968, it did not influence any reduction in prices for brimstone. For at that time all surpluses were earmarked to restore substantially reduced stocks of that raw material in the years 1965 - 67. The effects of overproduction with respect to prices became sensible but at the beginning of 1969 when some producers' sulphur stocks approached the so-called "reasonable level". That increase in prices did, no doubt, reflect all features of a market-trend increase. But as a result it encouraged producers to increase the production of sulphur as a very remunerative item and, at the same time, the price increase unnoted before undermined the economic aspects of the production of sulphuric acid and acted discouragingly upon the buyers who started to turn their back at the so-called "whimsy" raw material and began to look toward a more stable one, according to their opinion, i.e. toward pyrites.

That situation whose signs started to become visible at the beginning of 1968 brought, in consequence, to a rapid breakdown in sulphur prices which began to drop in a sharp way and reached their average level of $ 16-20/t FOB in 1970, thus a lower level than that during the 1961/64 depression. As a result, the product became an unrivalled source for the production of sulphur derivatives.

Suppliers started to compete in a strong way in order to find outlets. On 27th September the "Chemical Week" described

that competition as a "price war", and the periodical "Sulphur" (No. 87 of 1970) informed that the prices of Canadian Sulphur, FOB Vancouver, had fluctuated within U.S. $ 15.5 - 17.5 per ton.

7. Brimstone Demand, Supply and Price-Trend Forecasts for 1971 - 1980

The previous chapters illustrated the situation in the field of world production of sulphuric acid and phosphatic fertilizers which sectors determined a definite demand for sulphur-carrying raw materials, next the production of sulphur and its supply, world trade in brimstone and price trends during the period of over one decade.

Such an approach gives some idea on the relations and conditions so far existing in the sulphur sector. On the basis of those facts and experience gained in the past, one could draw certain conclusions, speculate a little and attempt to evaluate a long-term outlook for sulphur supply, demand and price trends.

It is rather difficult to make forecasts in general, and in the case of sulphur in particular because of the number of factors involved.

I do not pretend to presenting a faultless statement. As a consolation, let us recollect the many errors made by numerous specialists, economists and institutes in not too distant past with regard to their calculations and forecasts

at the time of overproduction which was supposed to last for a long time and reversely at the time of shortage which was supposed to last for ever.

Nevertheless, the topic of sulphur itself is interesting, all the more that sulphur is an important raw material for the production of fertilisers which, being employed intensively, may upheave productivity per hectare, thus increasing crops, and may become a tool in the struggle against world hunger in many developing countries where a part of population is nuorished on the verge of existence.

A. Sulphur consumption forecasts

It is well known that sulphur is one of the basic raw materials used in chemical industry and in the future demand for sulphur will no doubt continue to increase alongside of an expected rapid development of that industry. However, the consumption of sulphur (in all forms) has been shaping mainly according to the development in the sulphuric acid production which, in turn, had depended on the use and production of phosphatic fertilizers.

Logically enough, in forecasting the development of sulphur demand, it will be possible to rely mainly on the predictable development of requirements and on the production development of phosphatic fertilizers and sulphuric acid.

It appears from the table quoted in the initial part of this paper that the production of phosphatic fertilizers in

the world went up in the period 1952/53 - 1968/69 from 6,056,000 tons to 17,466,000 tons, i.e. by 188 per cent., but their production rate in individual periods was not similar.

While the years from 1964/65 to 1966/67 showed a very substantial growth of production, the next years from 1966/67 to 1968/69 were marked by an insignificant increase of appr. 3.5 per cent. per annum, which was considered to be almost a stagnation border.

Over a long period of time, however, the average index of production was about 8 per cent. per annum.

Similar was the case of sulphuric acid whose production between 1953 - 1967 increased from 31,370,000 tons to 76,980,000 tons, i.e. by 145 % at the average index growth per annum of about 7.5 per cent., the very low growth index of about 4 per cent. in 1967 not to be forgotten.

In general, taking into account the fact that the industries of fertilizers and sulphuric acid are the biggest consumers and knowing the average rate of growth, it would seem that it could be relatively easy to deduct the volume of expected sulphur consumption for that purpose as well as, in an indirect way though, the overall requirement figures in 1975 and 1980. This would, of course, be a certain simplification.

In order to evaluate the expected development of phosphatic fertlizer production and that of sulphur consumption in the nearest 10 years, we shall additionally take recourse to other tables covering a period less distant than that at the

beginning, i.e. the years 1960 - 1969 with respect to market-economy countries only.

Dynamics of sulphur consumption and H_2SO_4 and P_2O_5 production in market-economy countries

	Million tons	Growth in the period	Average annual rate of growth
Sulphur consumption 1960 - 1969	17.8 - 28.3	58.9 %	5.3 %
Sulphuric acid production 1960 - 1969	40.3 - 63.4	57.3 %	5.2 %
Phosphatic fertilizer production 1960-61, 1968/69	8.5 - 13.8	62.3 %	5.5 %

From the above-mentioned table, it appears that during the aforesaid 9 years the average annual rate was about 5-5.5 per cent. It is obvious that the growth of demand and the extent of rate of annual growth may be and certainly will be influenced also by other factors which are impossible to be foreseen with strict accuracy. It is a well known fact, for example, that the growth of annual rate of sulphur consumption in other industries, apart from the fertilizer sector, is somewhat lower, i.e. within appr. 5 per cent. The growth of consumption in traditional markets is unknown; still less is known the volume of new sulphur applications which are now actively sought. It should be mentioned that as a result of the sulphur surplus which is becoming visible there have been

trials to apply sulphur to other ends than the traditional ones, for example such as an additive for asphalt, as beds for motorways or airport runways, for impregnating tiles and slag blocks as well as in building, for it appears that liquid sulphur sets better than masonry mortar (it might be mentioned that this point is interesting for low-cost housing in developing countries).

Apart from the production of fertilizers which are tradidional consumers, sulphur should be employed on an ever-growing scale in feeding plants to stimulate their growth (especially in tropical and subtropical regions whose soil is structurally short of sulphur). The shortage of sulphur is deepened by the current increased use of high-percentage fertlizers which do not contain sulphur at all or contain it in small quantities. Sulphur is necessary for the production of fertlizers as well as for the soil direct. An increased use of sulphur in agriculture is badly needed.

On the other hand, there may appear some factors which will influence a decrease in sulphur consumption, e.g. in the production of titanium dioxide, where the existing sulphate process was in some cases replaced by a chloride one which is considered as more convenient. As a result of certain changes in the production process, somewhat less sulphur per one ton of pulp and paper is used in the pulp-and-paper industry. In some regions, where electric power is cheap, it may happen that a tendency to eliminate sulphur in the production of phosphoric acid will appear sporadically although

cheap sulphur expected over a long period of time will eliminate such cases according to the author.

On the whole, it seems that it would be unrealistic to adopt the future consumption growth index at the rate of 7 - 8 per cent. and therefore an annual average index of 5.5 - 6 per cent. should rather be adopted.

The rate of growth in the overall consumption of brimstone, pyrite and sulphur from other sources should also be fixed.

The question of an alternate choice of those raw materials by the producers of sulphuric acid is connected to a high degree with the price level of brimstone. In view of a more convenient and economical employment of brimstone for production purposes, which point will be dealt with in the last part of this paper, the author is of the opinion that the consumption of brimstone will increase in the nearest years. This growth is estimated at about 7 per cent. in the market-economy countries and at 10 per cent. in the centrally-planned-economy countries in connection with a more intensive development of fertilizer production there while the growth of pyrites will be about 1 per cent. or less each year.

At such an assumption, the consumption of sulphur in the years 1971 - 1980 would be as follows:

World demand for sulphur in 1971 - 1980

Year	World demand for sulphur in all forms	including			Total demand for sulphur in all forms in market-economy countries	including		
		brim-stone	pyrite	other sources		brim-stone	pyrite	other sources
	growth	growth	growth 1 %		growth 5.5 %	growth 7 %	growth 1 %	
1971	38,7	21,7	11,4	5,6	31,4	18,7	7,6	5,1
1972	41,1	23,5	11,5	6,1	33,1	20,0	7,7	5,4
1973	43,7	25,5	11,6	6,6	34,9	21,4	7,7	5,8
1974	46,5	27,7	11,7	7,1	36,8	22,9	7,8	6,1
1975	49,4	29,9	11,8	7,7	38,8	24,5	7,9	6,4
1976	52,6	32,5	11,9	8,2	40,9	26,2	8,0	6,7
1977	55,9	35,2	12,0	8,7	43,1	28,0	8,0	7,1
1978	59,6	38,2	12,1	9,3	45,5	30,0	8,1	7,4
1979	63,5	41,5	12,2	9,8	48,0	32,1	8,2	7,7
1980	67,7	45,0	12,3	10,4	50,6	34,3	8,3	7,8

The above-quoted calculation made by means of a logically justified and common to all countries growth index of the consumption of sulphur as one of the basic raw materials which assure a dynamic development of chemical industry throughout the world is also confirmed in a calculation based on the development forecast for the industry of phosphatic fertilisers.

The production of the above-mentioned fertilizers expressed in the pure P_2O_5 content amounted to:

appr. 10.5 m. tons in 1961/62
"" 17.5 m. tons in 1968/69
"" 18.8 m. tons in 1969/70.

According to some, frequently official forecasts and intentions, the production should account for:

appr. 32.5 m. tons in 1975,
and 55.0 m. tons in 1985.

It is expected that the most intensive increase will be achieved by the Soviet Union and European socialist countries (from 1.1 in 1961/62 and 3.5 in 1968/69 to 17.0 in 1980, appr. 20 m. tons in 1985) and by Asian countries (from 0.7 in 1961/62 and 1.7 in 1968/69 to 12.5 m. tons in 1985).

In evaluating the above-mentioned figures as over-optimistic, one may, however, accept without any major error that in 1980 the world production of phosphatic fertilizers will reach the high of 35 m. tons of P_2O_5 which will mean a growth by 100 per cent. compared with that in 1968/69, including about 14 m. tons in the European socialist countries together with the U.S.R.R. and appr. 4 m. tons in Asian countries.

If the production of H_2SO_4 increases by the same percentage it will account for appr. 160 m. tons by 1980 compared with appr. 80 m. tons in 1968/69.

To secure that production level, it will be necessary to have about 53.5 m. tons of sulphur. In accordance with the previous evaluation, the amount of sulphur required for the production of sulphuric acid accounts for about 80 per cent. of the total use of sulphur. In connection with the above, the estimate of sulphur needs in all forms and in terms of all directions in 1980, calculated on the basis of prospects for the development of phosphatic fertilizer industry, will close with the figure of about 67 m. tons, thus almost identical with that calculated on the generally adopted growth index of consumption of this raw material in the world.

In summing up the question, it is expected that world demand for sulphur in all forms will account for about 49.4 m. tons in 1975 and for 67.7 m. tons in 1980, the structure of use to be changed in favour of brimstone and that from other sources at the cost of pyrites. The percent share of brimstone will increase from the present 56 per cent, to 66 per cent. in 1980, while the share of pyrites will drop from 30 per cent. to 20 per cent. This will be connected with relatively low prices for brimstone and a restructive action against air pollution.

B. Sulphur supply forecasts

Demand for sulphur is covered by sulphur in various forms and from various sources.

The highest share is held by elemental sulphur, i.e. brimstone (native sulphur, Frasch sulphur and the sulphur obtained from natural gas and crude oil), pyrites and smelter gases being the next sources.

It seems that in connection with the present situation, conditioned by big supplies of brimstone and its low prices, it may be assumed that in the coming years the production of pyrites will show an insignificant growth to meet but the own increase in demand in the countries which produce that raw material or that the production of pyrites may show a stagnant tendency in view of lower needs in importing countries.

As regards the sulphur obtained from the so-called other sources (i.e. from copper, lead and zinc smelters), it is extremely difficult to evaluate its growth. It may be taken for granted that gradual rigours and regulations regarding air pollution will be introduced in numerous countries in connection with that rapidly growing and vital point. At present enormous quantities of sulphur (estimated at many million tons a year on the world scale) are emitted to the atmosphere, over 60 per cent. of same originating from coal combustion, about 25 per cent. from petroleum products and over 10 per cent. from metallurgical operations. It seems that the growth of sulphur from the world metallurgical operations may be estimated at 2-2.5 m. tons, on an average, between 1970 and 1975 up to about 8 m. tons and by some 2.5-3 m. tons up to about 11 m. tons in the next years.

The most essential point is the estimation of perspectives in the development of brimstone production.

There are numerous unknown points in this respect as well. To make it short, the problem boils down to two pricinal elements, i.e. to the expected production volume of the so-called "fatal" sulphur obtained from natural gas and crude oil and to the expected production volume of native sulphur and the Frasch-process sulphur, the question of the productive capacities held and that of the factual production to be conditioned by actual demand being distinguished.

In connection with the big demand for gas as a source of power, its production and the growth of sulphur thus recovered as a by-product will be on the increase. The growth of sulphur quantities will, likewise, be brought about by the air pollution legislation and the necessity to lower the sulphur content in crude oil and oils. It is estimated that the growth of sulphur from that source, i.e. of the so-called "fatal" sulphur will augment by about 6.2 m. tons by 1975 and by further 9.4 m. tons by 1980 thus producing about 15.2 m. tons of "fatal" sulphur in 1975 and 24.6 m. tons in 1980.

The main growth to be taken into account will be that in Canada and the Soviet Union which are big producers of natural gas. The growth in the United States, Japan, the German Federal Republic, the Near East and Venezuela should also be taken into consideration.

As regards native sulphur, it is rather difficult to foresee the volume of individual producers' output which is quite big and can be bigger owing to large resources and the fact that a relatively short investment cycle by applying the underground melting process may add to putting new capacities into operation, but this volume of production is determined by the balance between consumption and the "fatal" sulphur.

It is estimated, however, that in 1975 the present production will be accompanied by that of some 2.5 m. tons, and that some further 4 m. tons will come by 1980, thus bringing about 16.5 m. tons in 1975 and 20.5 m. tons by 1980.

In summing up, it seems that the production in million tons would be as follows:

	1975	1980
Brimstone	31,7	about 45,1
Pyrites	about 12,0	about 12,0
Other sources	about 8,0	about 11,0
	51,7	68,1

C. Price trend forecasts till 1980

From the previous estimation regarding the probable pattern between demand and supply, it appears that the coming decade would have to face not only a full coverage but also a preponderant supply over demand.

In consequence, increased stocks would, in turn, affect the price trends. In fact, the situation is even now prevailing as the FOB prices have dropped to the level of $ 16-20/t, on an average.

In considering the possibilities of shaping price trends till 1980, it should seem necessary to take the following flow of reasoning into account.

It is a fact that demand for brimstone will be increasing as a result of the development in fertilisers and other industries that need this raw material. At the current supply figures well exceeding demand and low prices, the growth of new productive capacities will be based mainly on brimstone. The production of "fatal" sulphur will be paralel with that growth or even higher. The "fatal" sulphur will tend to influence price reductions because of its compulsory character; in other words, despite their existence, the production costs of this type of sulphur could reasonably enough debit the main product, i.e. gas.

It is also obvious that the fatal sulphur is unable to meet full demand for sulphur and that the producers of mined sulphur or that obtained by an underground melting process bear its definite production costs. Thus, a further drop in prices which are on the borderline of production costs would in consequence force those producers to limit or stop their production, which action would involve a shortage of sulphur

and increased prices. Bearing these aspects in mind, it seems that a further decline in prices which have already reached their lowest level would be impossible. Neither should one expect too high prices and high cyclic fluctuations similar to those in the past, for new factors such as the aforesaid air pollution legislation, the existence of fatal sulphur, etc., which were of no bearing in the past, will be influential.

Taking into consideration the production costs of sulphur, it should rather be expected that over the coming decade only a modest and moderate increase in sulphur prices could take place.

It seems that the price should be within the range of $ 18-22/t FOB, on the average, depending on the quantity of the respective lot, kind of sulphur and export destinations.

8. Economic Aspects Regarding the Sulphuric Acid Production from Sulphur and Pyrites

The countries that plan to develop their phosphatic fertilizer production, and those with developing economies in particular, are faced by a question of basic importance, i.e. by the choice of the cheapest method of sulphuric acid production. It is evident that wherever it is not necessary to clean metallurgical gases compulsorily or to continue the exploitation of pyrite deposits for social reasons, the only rational method of obtaining sulphuric acid now is the pro-

duction of acid from brimstone. The basic advantages to employ sulphur instead of pyrites in producing H_2SO_4 are as follows:

- almost a threefold decrease in industrial machinery tonnage at a high daily output; this is reflected not only by lower capital expenditures, a shorter construction period and a smaller scope of building and assembly work, but also by lower exploitation costs (amortisation charges, repairs, etc.),
- over a twofold lower transport of raw materials to the factory and a possibility to store them practically at any place due to the small mass of the raw material and the fact that no residues have to be removed,
- a considerable improvement of sanitary conditions as sulphuric acid installations do not produce dust caused by pyrites and residues; apart from that, the amount of fumes harmful for the environment is much lower as a result of this production process,
- a substantial, at least a sevenfold, decrease in the number of staff which point substantially decreases the prime costs of production and accompanying investment costs (social and housing facilities, etc.),
- a better quality of acid: the acid produced from sulphur is almost equal to battery acid and the technically pure one,
- easy operations in terms of technology process and a possibility of introducing full automation,
- a threefold lower processing cost compared with that to be borne in the case of pyrites.

The above-mentioned advantages are proved by comparing the following selected technical and economic indices for sulphuric-acid installations based on sulphur and pyrites in a factory with 1,100 tons of 100-percent H_2SO_4 per 24 hours (365,000 tons per year):

Item	Measure unit	Sulphur-carrying raw material		Ratio 4:3
		pyrite 40%	sulphur 99.96%	
1	2	3	4	5
1. Apparatus weight	tons	11,000	4,000	0.36
2. Installation costs including assembly	m. ₽	14,3	5,3	0.36
3. Consumption indices:				
Sulphur-carrying raw materials	t/t	0,85	0,335	0,4
Electric power	kWh/t	120	50	0,42
Thermal energy in terms of steam	t/t	0,2	0,15	0,75
Cooling and production engineering water	cu. m/t	80	45	0,56
4. Number of direct production staff	persons	112	15	0,13
5. Amount of by-products				
Steam	t/t	1,0	1,1	1,1
Pyrite residues	t/t	0,63	-	-

An estimated calculation of processing costs, without those of sulphur-carrying raw materials, of 1 ton of 100-per-cent sulphuric acid at a production capacity of 1,100 tons per 24 hours is as follows:

Cost components	Unit price	Costs	
		Pyrite	Sulphur
Electric power	1 $/kWh	1,20	0,50
Thermal energy	1 $/t	0,20	0,15
Water	1 $/cu.m.	0,80	0,45
Direct labour	2.5 $/man hour	1,50	0,20
Amortisation (10% of expenditures)		3,90	1,40
Other costs (repairs, overheads of the factory, etc.)		3,10	1,12
Total gross processing costs		10,70	3,82
Crediting:			
steam	1 $/t	-1,0	-1,10
pyrite residues	3.5 $/t	-2,20	-
Total net processing costs		US $ 7,50	US $ 2,72

Irrespective of a slow process of liquidating out-of-date pyrite-based plants in a number of countries and replacing them by new plants based on sulphur, there is an economic possibility to change the existing pyrite furnaces into brimstone facilities.

Such modifications may be arranged under an overhaul programme. The time required for such modifications amounts from 7 to 28 days. The question of changing pyrite furnaces should be of interest to the countries which exploit poor deposits of pyrites that must next be enriched.

Taking this opportunity, I would like to mention that the Polish enterprise "Polimex-Cekop" has worked out a number of projects regarding the changingover of sulphuric-acid factories from pyrites into sulphur. Worthy of stressing is the fact that the existing equipment up to almost 98 per cent. remains unchanged. Such a modification is particularly advantageous in the light of the above-mentioned comparisons regarding the use of materials and the costs of acid production.

The aforesaid enterprise is also engaged in the deliveries of complete industrial plants and equipment for sulphuric-acid factories as well as in their modernization by introducing up-to-date technical achievements. Poland delivers sulphuric-acid factories of a capacity ranging from 50,000 to 300,000 and even 500,000 tons of 100 percent H_2SO_4 per year.

The factories of Polish make consist of the following equipment:

- storing and filtering facilities for lump and liquid sulphur which are supplied according to the buyer's request,
- production installation to be used according to the choosen method, e.g. a simple conversion with the standard absorption facilities or that of double conversion and reabsorption,
- storing and transport facilities for sulphuric acid.

The enterprise "Polimex-Cekop" delivers sulphuric-acid factories for various starting raw materials, i.e. pyrites, solid and liquid sulphur, smelter gases and cake. The aforementioned enterprise also furnishes production technology and know-how facilities. It is also engaged in staff training both on the spot and in Poland.

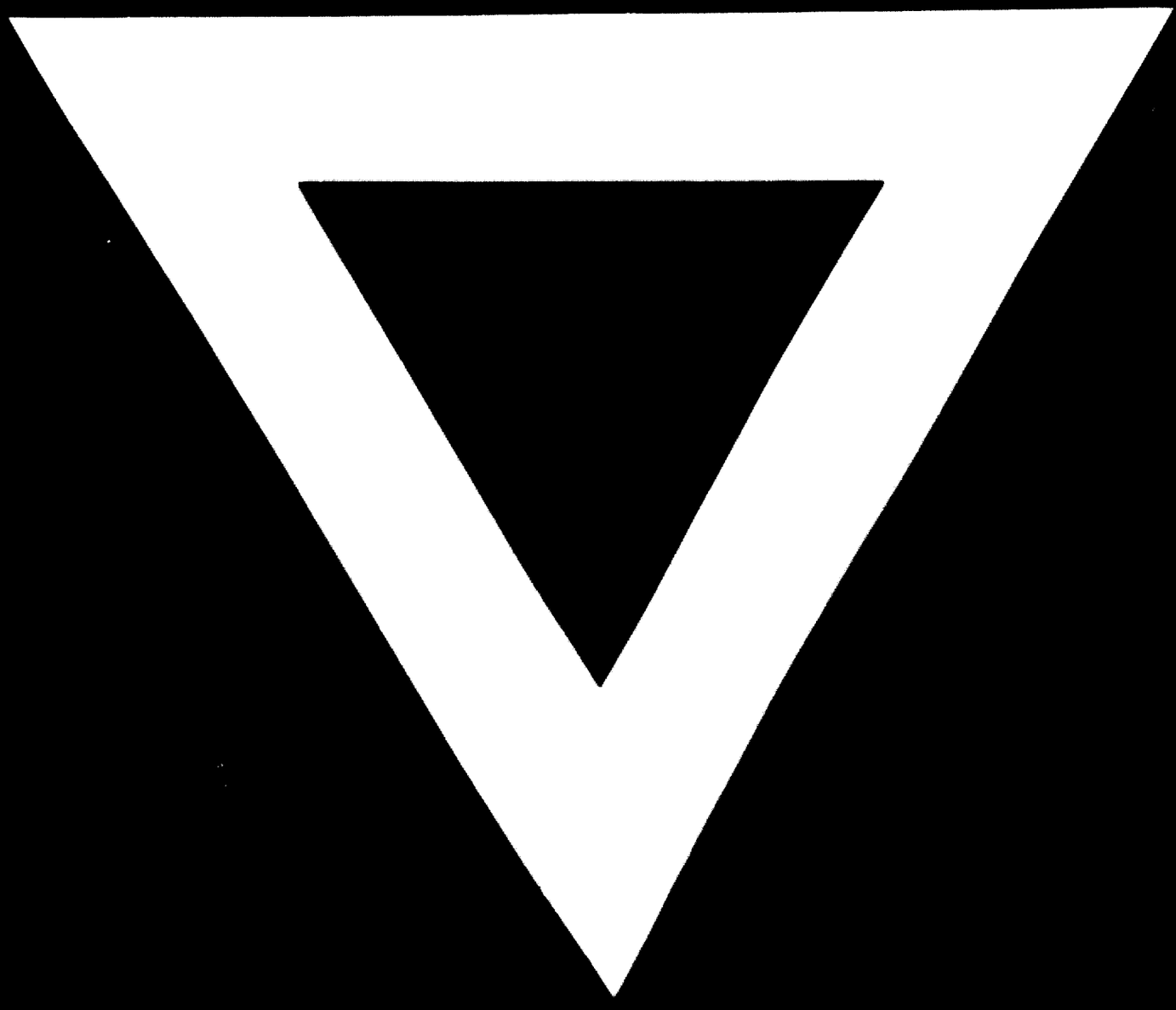
Poland has so far delivered 17 factories of sulphuric acid to various countries and at present she is executing a few further orders including a sulphuric-acid factory to be erected in Duisburg in the German Federal Republic. The factory's capacity will be 300,000 tons of sulphuric acid a year.

Having a large production of sulphur and being the second exporter in terms of volume, Poland offers her possibilities and readiness to all developing countries interested in the

complete factories of sulphuric acid or in having their factories modernized. At the request of buyers and customers, sulphur deliveries are guaranteed as well.

In summing up, it could be averred that the expected increase in demand for sulphur is fully covered by production possibilities and deliveries at prices that guarantee a remunerative development of the production of sulphuric acid and phosphatic fertilizers based on brimstone.

The situation in individual geographical regions in the world may, of course, shape in a somewhat different way and this question would require further studies and elaborations.



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