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CANADA

DEPARTMENT OF MINES AND RESOURCES

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BUREAU OF MINES

OTTAWA

SILICA IN CANADA

by

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Mineral Resources Division

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Statistics show that in 1948 Canada imported industrial minerals and their products to the value of approximately $107,000,000. These imports included 584,000 tons of silica sand at a cost to Canadian consumers of approximately $4,500,000. This was chiefly high quality material for use in the glass, artificial abrasives, and sodium silicate industries. They included also products made from silica sand, chiefly glass, valued at $26,000,000. With the expansion of these industries and of the steel and metals industries consumption of silica sand has shown a steady increase, with the result that more attention than in the past is being given to the possible greater utilization of Canadian sandstones and quartzite deposits as sources of high quality silica sand. Cheap supplies of such material would undoubtedly attract further industry to Canada and would enable present industries to compete more favourably with foreign producers in any market.

For various reasons, however, relatively few Canadian deposits have been developed to the extent that seems economically possible and many others have received little attention from the production viewpoint. Markets for silica sand in central Canada appear to justify the expenditute of considerable sums of money by private enterprise to find suitable deposits in selected areas.

In the hope of encouraging a more extensive development of deposits in this and other sections of Canada, the Bureau of Mines undertook a detailed study of the supply of this basic raw material and also did experimental work on the processing of low-grade silica rocks to produce high quality silica sand. The work gave excellent results on very low-grade material.

This report gives an account of the work and discusses various features of it; describes the different rock forms of silica; gives the principal industrial uses and specifications for silica; and discusses the economics of the silica industry. A feature of particular interest is the descriptive account in tabular form of Canadian deposits, including chemical analyses.

FORMS OF SILICA

Silicon, next to oxygen, is the most common element in known terrestrial matter, and in the combined form as oxide of silicon (SiO_2, silica) either with other elements or as free silica constitutes 59.08 per cent of the lithosphere.* However, it is free silica in the forms of quartz, quartzite, sandstone, and natural silica sands that is so important to modern industry.

* Data of Geochemistry F.W. Clarke Bulletin 770 U.S. Geological Survey.

Quartz

Silica in this form is of igneous origin and occurs relatively pure as crystals, veins, or large intrusive masses. Vein quartz is usually important as a source of gold and for its silica content in smelter operations.

Quartzite

This is a metamorphosed sedimentary silica rock in which the grains have been cemented by a siliceous cement. This rock breaks across the original silica.

Sandstone

This is a sedimentary rock in which the silica grains are held together by a variety of cements in varying degrees of compactness. This rock breaks along the cemented boundaries and in doing so leaves the silica grains in much the same shape as they were deposited in the original sediments.

Natural Silica Sands

These may be formed by the breakdown of any of the above rocks and consist essentially of quartz grains with varying quantities of impurities. Such deposits occur as beaches along lakes and oceans and as ancient beaches.

Other Forms

Known Canadian deposits of such other forms of free silica as chalcedony, chert, flint, opal, and diatomaceous earth are relatively small and the quantities used in industry are small.

Canadian Consumption of Silica Sand*

Table No. 1

Industry	1946 Short Tons	1946 Cost at Works $	1947 Short Tons	1947 Cost at Works $
Glass	123,910	769,605	172,859	1,098,099
Artificial abrasives	83,636	504,873	90,527	556,181
Iron and steel and their products	68,168	488,488	63,209 (2)	460,272 (2)
	275,714	1,762,966	326,595	2,114,541
Fertilizers	44,070		69,669	
Cement plants	31,222		36,223	
Chemicals (1)	19,456		25,000 (3)	
Other (1)	26,938		30,000 (3)	
Grand Total (1)	397,400		487,487	

* Total consumption in 1948 is estimated at 550,000 tons.
(1) Includes ground quartz.
(2) Of which 50,988 tons valued at $346,677 was for moulds for steel ingots and direct steel castings.
(3) Estimated.

INDUSTRIAL USES AND SPECIFICATIONS FOR SILICA

Silica is used chiefly in the form of silica sand which is obtained by breaking down quartz, quartzite, or sandstone and from natural silica sands.

Silica Sand

Glass

One of the largest uses of silica sand is for making glass. Chemical composition and grain size must be closely controlled in supplying sand to this industry. An idea of the variations in chemical composition permissible in the glass industry is given in the following table prepared by the U.S. Bureau of Standards.

Permissible variations in chemical composition, silica sand in glass industry (U. S. Bureau of Standards).

Table No. 2

	SiO_2 Minimum per cent	Al_2O_3 Maximum per cent	Fe_2O_3 Maximum per cent	CaO+MgO Maximum per cent
First quality optical	99.8	0.1	0.02	0.01
Second quality flint glass containers and tableware	98.5	0.5	0.035	0.2
Third quality, flint glass	95.0	4.0	0.035	0.5
Fourth quality, sheet rolled, and polished glass	98.5	0.5	0.06	0.5
Fifth quality, sheet rolled, and polished glass	95.0	4.0	0.06	0.5
Sixth quality, green and window glass	98.0	0.5	0.3	0.5
Seventh quality green glass	95.0	4.0	0.3	0.5
Eighth quality amber glass	98.0	0.5	1.0	0.5
Ninth quality amber glass	95.0	4.0	1.0	0.5

In general, each glass manufacturing company sets up its own specifications for sands which are usually more rigid than those quoted above. If a supplier could guarantee a uniform chemical analysis some relaxation in specifications might be allowed.

Grains must be between 28 and 150 Tyler mesh (0.2 to 0.5 mm) with an absolute minimum of coarse or fines. Thus grain size for the ideal glass sand would be between 60 and 80 mesh. Grain shape is not particularly important although angular grains are considered to be slightly superior to rounded grains.

Artificial Abrasives

This industry, developed near the sources of cheap hydro-electric power, is an important Canadian user of silica sand, silicon carbide being the particular abrasive in which silica sand is a chief constituent. In general, the sand should be slightly coarser than that required in the glass industry. The chemical composition should be about the same as that of second quality glass sand with a little more rigid alumina specification and a less rigid non-oxide specification. However, these specifications vary considerably from company to company and from product to product.

Steel Foundry Industry

This industry is also a major user of silica sand. A wide variety of grain sizes is used and suppliers are required to blend different sized sands to produce a whole range of foundry sands, from very coarse to very fine. The grains must be rounded, as was clearly shown in a series of experiments conducted in England during World War II and reported in Refractories Journal, March 1945, under the title "The Effect of Grain Shape on the Moulding Properties of Synthetic Moulding Sands". Chemical composition is not of prime importance except that no organic matter should be present and the silica content should not be below 96 per cent.

Other Uses

Substantial quantities of silica sand are used by the sodium silicate industry; as a filler in fertilizer; in filtration beds; and in certain chemical industries. For use in the sodium silicate industry silica sand must be equivalent in chemical analysis to second quality glass sand, but should be more closely sized and slightly coarser than glass sands. .For use as a filler and in filtration beds freedom from organic matter and a high percentage of inert silica are important.

Ground Quartz

When silica sand quartz, or quartzite is ground to produce fine (say 90% minus 100 mesh or finer) silica sand the material is known as ground quartz, silica flour, and/or flint, depending upon the industry using the material and the degree of fineness required. The paint and building products, ceramic, and cleansing products industries are the chief users of fine silica.

Each industry has a set of specifications for the fine silica used but in general the important items are fineness, colour, and purity.

Lump Quartz and Coarse Sand

Silica Brick

Broken and screened quartz and quartzite are used to make silica brick refractories, chiefly for use in the steel industry.

Natural Abrasive

The coarser sized sands are used extensively as an abrasive in sand-blasting operations in many industries. The grains are usually obtained from broken quartz or quartzites as the silica must be extremely tough and durable.

Ferrosilicon

Broken sandstone as quartzite ranging in size from 1" to 6" is used in large electro-metallurgical furnaces to produce silicon metal and alloys.

Quartz Crystals

Quartz crystals when free from flaws and of suitable size are used in communications work for their piezo-electric properties.

CANADIAN DEPOSITS

Deposits of silica occur in all provinces of Canada.

All the information on known Canadian deposits is listed in the following tables, to indicate the widespread occurrence of fairly good silica material, and in the hope that these deposits will be used as a basis for exploration by any interested company or individuals. However, these are all readily accessible deposits and are probably not the best that can be found, as only a limited amount of money and effort have been devoted to development of the industry. Modern methods of prospecting would doubtless disclose deposits of high grade silica.

Newfoundland is not included in the table but undoubtedly as more information is obtained, occurrences of high-grade silica will be found there as well.

PRINCIPAL KNOWN SILICA DEPOSITS

Table No. 3

Province	Type of Deposit	Formation	Principal Occurrences	Operating Plants	Typical Sample Chemical Analysis / SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Finished Sand Analysis / SiO_2	Al_2O_3	Fe_2O_3	Ref. See Footnote No.
Nova Scotia	Beach Sand		Barrington		81.02	11.68	0.90		2.28	0.44	83.88	10.76	0.06	1
			Port Mouton		81.60	18.1	0.60		1.3	Tr	99.6	0.28	0.03	2
	Quartzite	Goldenville	S.W. to N.E. Nova Scotia	Chegoggin Point	97.14	0.97	0.51	0.25	0.28	0.10				3
	Sandstone	"	Hantsport Windsor		96.30	1.61	0.92				99.48	0.40	0.03	4
	Unconsolidated sand		River Denys											
Prince Edward Island	Beach Sand		Souris		95.92	1.29	0.21							5
					95.72	2.66	0.10		Tr	0.10				6
New Brunswick	Sandstone		Kennebecasis Bay		95.95	2.41	0.49				96.80	1.59	0.71	6
	Sandstone		Hillsboro Bay		98.15	1.38	0.32		Tr	Tr				6

Table No. 3 (continued)

Province	Type of Deposit	Formation	Principal Occurrences	Operating Plants	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ref. See Footnote No.
Quebec	Quartzite	Kayoo-Raska	Lone Pilgrim Island		98.24	1.52	0.24	0.10	0.16	0.29				6
			Great Pilgrim Island		98.18	1.34	0.24	0.14	0.25	0.45				6
Quebec			St. Pascal		95.40	1.65	0.35		0.86	0.75				6
	Sandstone	Potsdam	Meldchewlle	Meldchewlle	97.08	0.55	0.39		0.13	0.20				6
			St. Canut	St. Canut	99.20	0.07	0.48		0.05					6
			East Templeton	East Templeton	98.59	0.38	0.63				99.54	0.14	0.19	7
	Quartzite		St. Donat de Montcalm		97.74	0.99	0.23							8
			Kasil								99.4	0.35	0.05	9
	Quartz		Ste. Julienne	Ste. Julienne	97.78	0.99	0.19	0.06	0.34	0.18				10

References

1. Bureau of Mines Investigation 2093 Feb. 1947.
2. Annual Report Department of Mines-N.S. 1947.
3. Bureau of Mines Investigation 46-1 Jun. 1946.
4. Bureau of Mines Investigation 2524 Mar. 1949.
5. Bureau of Mines Analysis August 1948.
6. Silica in Canada - Mines Branch Report 555 L.H. Cole.
7. Bureau of Mines Investigation 2517 Jan. 1949.
8. Report Quebec Bureau of Mines Aug. 1939.
9. Concrete and Quarry 1933.
10. Bureau of Mines Test Work 1940.

Table No. 3 (continued)

Province	Type of Deposit	Formation	Principal Occurrences	Operating Plants	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ref. See Footnote No.
Ont.	Sandstone	Potsdam	Kingston	Kingston	98.65	0.60	0.32				99.32	0.35	0.06	11-12
			Hart Road Bastard Tp.		99.40	0.30	0.27							13
			Brockville		97.40	1.21	0.39		0.07	0.14				14
			Perth Smiths Falls		98.47	0.25	0.17		0.40	0.09				14
			Nepean Tp.		98.80	0.18	0.12							14
Ont.	Sandstone	Oriskany	Nelles Corner		92.59	0.18	0.18		$CaCO_3$ 3.59	$MgCO_3$ 0.57				14
Ont.	Sandstone	Sylvania	Essex Co.											14
Ont.	Quartzite		Georgian Bay	Killarney										14
			Manitoulin Island	Sheguindah	98.42	0.92	0.24	0.03		0.07	99.07	0.62	0.043	15

Table No. 3 (continued)

Province	Type of Deposit	Formation	Principal Occurrences	Operating Plants	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ref. See Footnote No.
Ont.				Whitefish Falls	96.80	1.60	0.41		1.00	0.36				14
			Algoma	Bellevue	98.20	0.61	0.49		0.70	0.29				14
	Sand-stone		Port Arthur		92.40	0.16	0.64		2.40	0.61				14
	River Sand		Missinaibi R.								97.72	0.42	0.32	14
			Mattagami R.								99.8			16

References
11. Bureau of Mines Test Work 1948.
12. J.T. Donald & Co., Montreal.
13. Ont. Dept. of Mines Vol. LV. Part V, 1946.
14. Silica in Canada Mines Branch Report 555 L.H. Cole.
15. Bureau of Mines Investigation 2445 - 1948.

Table No. 3 (continued)

Province	Type of Deposit	Formation	Principal Occurrences	Operating Plants	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Ref. See Footnote No.
Manitoba	Sandstone	Winnipeg	Lake Winnipeg		95.52 97.48	2.20 1.36	0.19 0.096		0.27 0.14	0.16 0.10				17 17
Saskatchewan	Sandstone		Inadaweka Lake		98.60	1.20								17
	Sand		Red Deer River		98.50	0.54	0.14	0.22	0.03	0.03	99.65		0.027	18
					97.40	0.93	0.073	0.056	0.043	0.086				18
Alberta														
British Columbia	Quartz		Oliver	Oliver	98.0		1.1		0.3					19

References 17. Silica in Canada Pt. II Mines Branch Report 686 L.H. Cole.
18. Bureau of Mines - Investigation 2198 June 1947.
19. The Consolidated Mining and Smelting Co. of Canada, Ltd. - 1949.

ECONOMICS

A great many factors must be considered in deciding on a location for a silica producing plant, probably the most important being the location of markets for the products. Silica is produced very cheaply at many points and freight is usually the major item of cost at any silica-using plant in Canada. Consequently to be profitable, a silica plant must be within economic freight range of markets for the whole production.

In Canada about 80 per cent of the present market for silica is in the region bordering the St. Lawrence River and the Great Lakes between Quebec City and Sarnia, Ontario, most plants being within a few miles of water transportation. This area is supplied chiefly by rail shipments of silica sand from Illinois, Michigan, Ohio, Pennsylvania, and New Jersey. The price of sand f.o.b. quarry averages $2 to $3 per ton at present, but with freight charges, the laid down price at plants is 2 to 3 times the quarry price. In the past considerable sand was imported into Canada from Belgium but with higher production costs in that country and greatly increased ocean freight rates, this sand now has extreme difficulty in competing with American sand in the Canadian market.

Prospective Canadian producers must keep in mind that the silica sand industry is highly competitive and that foreign producers may at any time enter the Canadian market at prices much below the profitable Canadian level due to changing world conditions bearing on such items as wages, transportation charges, and other economic factors.

Prospecting and Exploration

So far little money has been spent in a search for and exploration of deposits of silica sand. As indicated above, market outlets are a primary consideration in a search for deposits. When a definite area is decided upon, and a deposit appearing to be of merit is found the outcrops should be sampled and a program of reconnaissance drilling should be carried out. The samples can then be bulk sampled to determine whether cheap benefication methods can produce suitable silica. If this proves successful the deposit should be closely drilled to make sure that ample tonnages are available for future operations.

Plant Operations

The location of the processing plant will be dictated by location of rail lines, navigable waters, roads, power, water supply, etc.

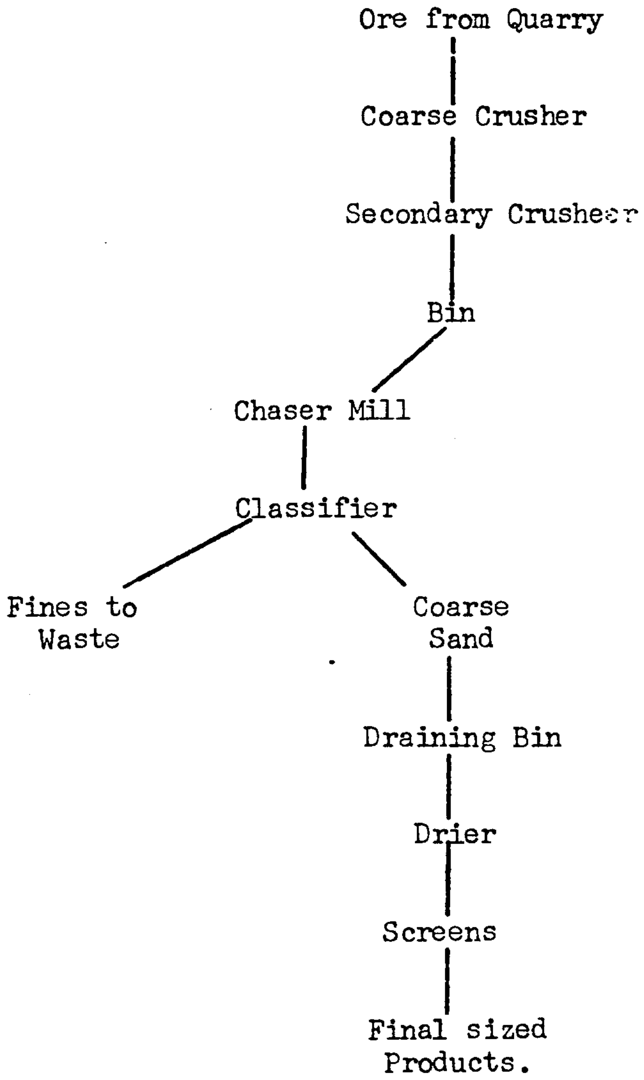
The test work, which should be done by a competent metallurgical firm on a representative sample, will indicate the type of plant to be used. The type of material used - whether quartz, quartzite, or sandstone - will largely determine the size, capacity, maintenance, and running costs of a silica plant. It seldom pays to break down quartzite or quartz to make silica sand no matter how pure they may be, and in general it is much cheaper to break down any sandstone. Silica in all forms is highly abrasive. Consequently, the ideal raw material from the viewpoint of low-cost production would be an unconsolidated sand with the proper grain distribution and a minimum of impurities. However, such deposits are usually too impure to enable the production of suitable sand. The next best is soft friable sandstones, from which type of rock most of the silica sands are produced.

The cost of drying the final product is a major cost item in running a wet reduction plant. Thus, the nearness of the plant to a cheap source of fuel is of importance. The handling of any dry silica material entails rigid control of dust to prevent silicosis.

The quality of the material produced must be kept uniform as all manufacturers insist on constant chemical analysis and grain size. Consequently the producer should be prepared to spend considerable money on scientific control. This may increase costs by several cents a ton but it will pay to do so, as manufacturers, once they are assured of a continuous supply of quality controlled sand, are loathe to change to other sources.

STANDARD MILLING EQUIPMENT

The flow sheet given below is fairly standard in the use of the above equipment.



Water washing to remove the impurities contained in the original rock is the greatest factor in the beneficiation of raw material to produce silica sand. When these rocks are crushed and ground the impurities such as iron-bearing minerals, feldspars, etc., tend to break down finer than the silica and consequently the fines can be washed out with a minimum loss of silica and with a good removal of impurities. Also the wet method has made silicosis control relatively simple in most plants. If coarse lump quartz or quartzite is required, the fines from crushing are usually washed out and discarded, leaving a rather pure lump quartz.

Some plants have added flotation to remove further impurities after washing out the fines and some have gone as far as acid leaching of the sands to reduce the iron oxide content of the final product. Experience has shown that the chaser mills produce the maximum of silica grains with a minimum of fines and at the same time give the grains a thorough cleansing action. However, these mills have a relatively low capacity and high maintenance costs and some work has been done toward replacing them by tube mills and other types of mills. Very few Canadian raw materials tested have given a high quality sand by use of the chaser or other types of mills.

BUREAU OF MINES INVESTIGATIONS

Following many tests in its laboratories in the past, the Bureau of Mines came to the conclusion that most of the Canadian silica rocks are too high in impurities to produce high quality glass sands economically. Prior to undertaking the present work it was thought that if a cheaper milling circuit could be devised some of the Canadian material could probably be used to produce high quality sands. In the work the Bureau has had the use of a laboratory test unit of a newly developed dry grinding mill called the "Aerofall" mill. A series of test runs in this mill on quartzites and sandstones gave good results in producing quality sands.

Aerofall Mill Tests

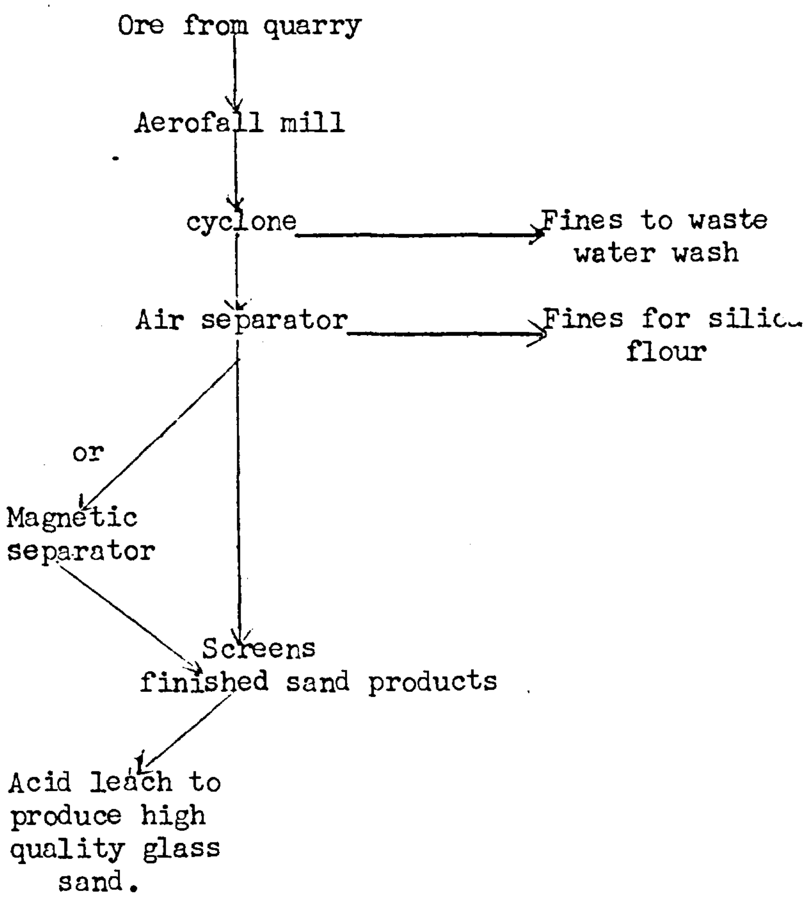
The "Aerofall" mill reduces up to 18-inch run-of-mine material to fine mesh sizes in one operation. All parts are under vacuum and a dust-free atmosphere can be maintained. The reduction of power and labour costs is accomplished by cutting out the many stages usually necessary in a sand plant. The size of product is controlled by an air stream passing through the mill. The mill product is then further separated by cyclone and multiclone into coarse and fine products. The mill works particularly well with most silica rocks as the impurities are chiefly more friable than quartz. Most are considerably heavier, and have a finer natural grain size. Consequently, the fines on separation contain the concentration of impurities, leaving relatively clean silica grains.

The velocity of the sand grains from the mill to cyclone is such that the grains tend to sand-blast themselves free of most clinging impurities. It was very noticeable in this work that the grains all appeared to be highly polished, with few combined particles.

This reduction of impurities is evident in Table No. 6 and Fig. No. 1 (near the end of the report) which show the iron reduction obtained in a series of tests on a particular sandstone.

The Aerofall mill circuit can be completely automatic from ore feed to final product.

Typical Flow Sheet



Trials were conducted on several types of silica rocks as shown in the following table.

Tests on Silica Rocks

Table No. 4

Identification	Type of Rock	Analysis SiO_2	Analysis Impurities
A	Quartzite - Extremely abrasive hard.	98.5	Alumina = 1.0% Iron Oxide = 0.15% Titanium Oxide = 0.05%
B	Sandstone - Very hard almost a quartzite.	98.2	Iron Oxide = 0.6% (as iron sulphides)
C	Sandstone - Medium hardness.	97.0	Iron Oxides = 1.0% clay etc.
D	Sandstone - Soft, friable.	98.5	Iron oxide = 0.3% calcareous cement.

At the start of the trials none of these materials appeared to be suitable as a source of high grade glass sand that would consistently run over 99.0% SiO_2, less than 0.50% Al_2O_3, and under 0.04% iron oxide. As shown in the table below, however, high quality sands were made from each raw material. The sands produced are either -20 +100 or -28 +150 mesh. In most cases, to ensure a low iron oxide content, an acid leach appears to be necessary.

Results of Tests on Silica Rocks

Table No. 5

Identification	Cyclone Product			After MAG Sep			After Acid Leach		
A	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
				99.01	0.54	0.027[1]			
B			0.40	99.54	0.14	0.19[2]			0.04
C			0.16	98.93	0.53	0.067			0.019
D	99.30	0.41	0.11			0.08			0.03

1. J.T. Donald & Co. Montreal Oct. 27/48
2. After tabling, not magnetic separation.

In table No. 5 the best recovery of products and the reduction of iron oxide and alumina are shown. Tables No. 6 and 6A compare Aerofall mill tests with those of standard milling equipment to the extent that this is possible from available data.

Each sandstone or quartzite required a series of tests to determine the exact water gauge that would give the maximum impurity elimination, with near maximum production of glass sand size product, and the best capacity. Curves for these tests are shown in Figure No. 1.

A disadvantage of the Aerofall unit is that relatively dry feed is necessary to obtain maximum efficiency. By dry feed is meant that containing less than 1 per cent moisture. The main difference in operation of the unit when wet rock was used was a drop in production as shown in Figure No. 2.

AEROFALL MILL TESTS

Table No. 6

Identification	Recovery			Iron Oxide Distribution			Alumina Distribution		
	% Glass Sand	Discarded Fines	Recovery Fines	Glass Sand	Discarded Fines	Recovered Fines	Glass Sand	Discarded Fines	Recovered Fines
A	61.0	14.0	25.0	15.2 12.7*	67.8	17.0	42.4	31.6	26.0
B	69.2	30.8		17.5 (1)	54.2		26.6	73.4	
C	71.1	14.9	14.0	29.7	70.3		41.7	58.3	
D	79.2	15.3	5.5	27.2	64.2	8.6	40.9	59.1	

* After Magnetic Separation.

(1) After Tabling.

STANDARD MILLING

Table No. 6A

Identification	Recovery			Iron Oxide Distribution			Alumina Distribution		
	% Glass Sand	Discarded Fines	Recovery Fines	Glass Sand	Discarded Fines	Recovered Fines	Glass Sand	Discarded Fines	Recovered Fines
A	43.5	56.5		7.8*	92.2				
B	65.6	34.4		20.4 (1)	79.6				
C	No comparable results								
D	80.0	20.0		32.0					

* After Washing and Magnetic Separation.

(1) After Tabling.

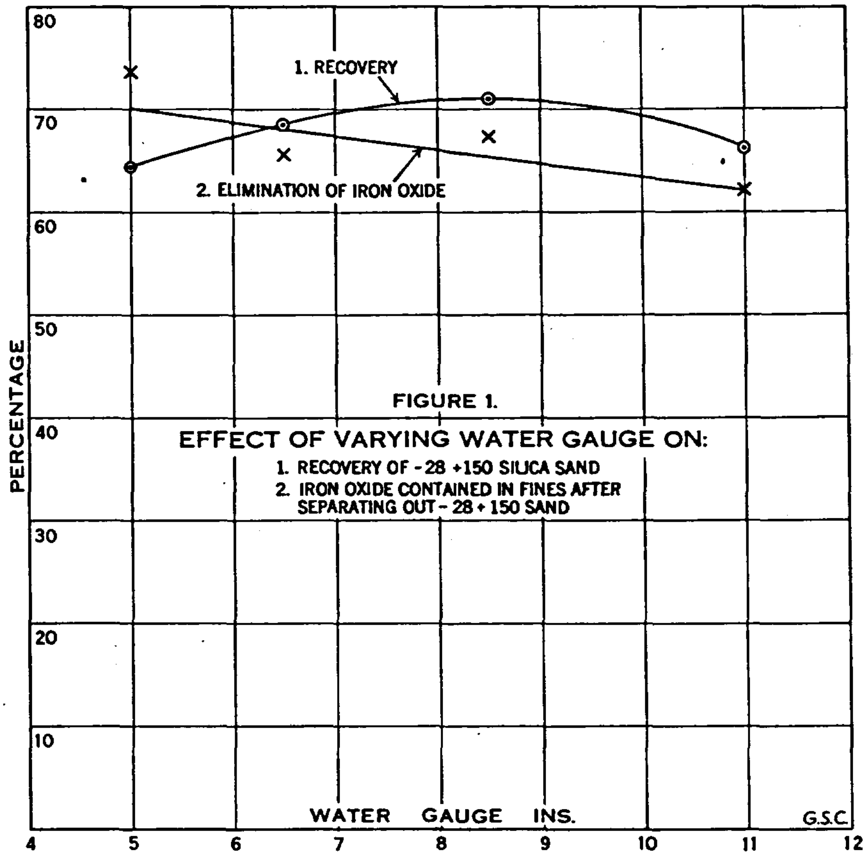


FIGURE 1.

EFFECT OF VARYING WATER GAUGE ON:

1. RECOVERY OF -28 +150 SILICA SAND
2. IRON OXIDE CONTAINED IN FINES AFTER SEPARATING OUT - 28 + 150 SAND

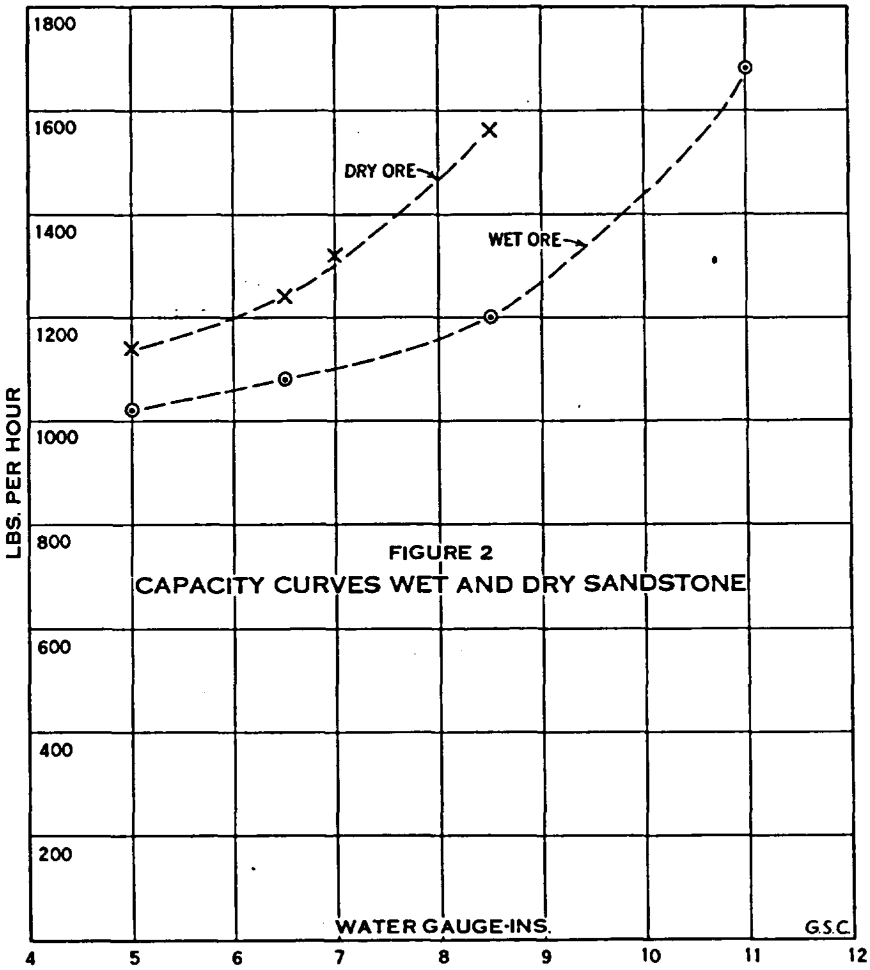


FIGURE 2

CAPACITY CURVES WET AND DRY SANDSTONE

CONCLUSIONS

1. Markets for silica sand in Central Canada justify the expenditure of considerable sums of money by private enterprise to find suitable deposits in selected areas.

2. A cheap supply of high quality silica would undoubtedly attract further industry to the country and allow present plants to compete more favourably with foreign producers.

3. Considerable information is available on Canadian deposits of silica, but no high grade silica deposits are known from which quality glass sands could be produced without extensive beneficiation.

4. Recent experimental work at the Bureau of Mines has indicated that much might be done in processing Canadian silica rocks to produce high quality silica sands. It is stressed that the test work on production of silica sands has been carried out in a small scale test unit and no commercial plants are available to check the results of this test.