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PORT PIRIE URANIUM PLANT

Possible Use for Production of
Magnesia

by

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SUMMARY

Background

Since the uranium treatment plant at Port Pirie ceased operation at the end of 1961, various attempts have been made to find a suitable use for the plant itself, preferably so that the plant might continue in Port Pirie as a working industry. The South Australian Government Department of Mines has sought potential users amongst chemical and mineral companies. Amdel has previously investigated aspects of the plant's suitability for use in the production of magnesia from sea-water but the plant was not considered large enough by the companies interested in this field of operations.

No new applications with better potential than the manufacture of magnesia were found in subsequent investigations, so consideration was then directed to the possible use of the bicarbonate process for the production of high purity magnesia in the Port Pirie plant.

Objective

The broad objective of this work was to examine the feasibility and economics of magnesia manufacture at Port Pirie by the bicarbonate process.

Summary of Work Done

An appraisal of the bicarbonate process was conducted with reference to its suitability for operation in the existing plant at Port Pirie. A preliminary flow sheet and materials balance was derived for a plant output of 50 ton per day of high purity magnesia. This was reported in a Progress Report which is included in this report as Appendix A.

A market survey was carried out to determine the uses and available markets for magnesia in Australia. This survey is described in the body of this report.

Conclusion and Recommendations

Although the plant at Port Pirie could be modified to produce high purity magnesia by the bicarbonate process, the present state of the market does not warrant retaining the plant for the production of this material.

Although Australian requirements of magnesia in 1966 are estimated to be 40, 000 tons, only about 10% would be required as high purity magnesia. The largest consumption is in refractories, but this market is largely supplied from low cost imports with which Australian manufacturers cannot compete. In addition, the use of high purity magnesia in refractories for higher service temperatures e. g. in steel making, has not developed in Australia to the same extent as overseas. If it does develop it is considered that production of medium-high purity magnesia (98% MgO) from sea-water would be the best source of supply.

1. INTRODUCTION

Previous investigations at Amdel into possible uses for the uranium treatment Plant at Port Pirie had included consideration of production of magnesia for chemical and refractory use. The Port Pirie Plant was originally designed for operations such as leaching, counter-current decantation, ion-exchange and precipitation. Although the Plant could be modified if required, the permissible expenditure would depend on economics of the proposed process. The economics of chemical industry generally in South Australia are adversely affected by the lack of substantial local markets and distances from other markets within Australia. Any material produced should therefore possess some degree of exclusiveness such as in being derived from a local mineral source not readily available elsewhere, or in being required in substantial quantities by a local market not readily supplied from other sources.

For these reasons, investigations have been directed towards processing mineral deposits which are readily available in the vicinity of Port Pirie. Some mineral processing operations such as leaching of metallic ores were quickly discarded because indicated reserves and production rates were not sufficient to provide a reasonable load for the plant. The production of magnesium oxide was considered because local raw materials could be used and there appeared to be possible markets for use as refractories for steelmaking (at Whyalla) as well as in other refractories and chemical uses in South Australian and other States.

Production of magnesia of refractory grade (or better) could be undertaken in three ways. In probable ascending order of product purity these are as follows: -

1. Calcination of mineral magnesite.
2. Precipitation from sea-water ("Dolime" process)
3. Leaching from calcined magnesite
   (bicarbonate process)

Consideration of these processes in relation to utilization of the Port Pirie Plant immediately favours the two latter processes, because a simple calcination operation (i. e. the first process) could be undertaken with equal convenience elsewhere, particularly at the point of mining the magnesite.

In 1961 some consideration was given to the suitability of the Port Pirie Plant for producing magnesia from sea-water. A general scheme was outlined for adaptation of the Plant to the system used by a Kaiser Chemical Division Plant in California. [1] Subsequently discussions took place between the Department of Mines and several overseas companies which showed

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[1] Interim Report on Amdel Project 1/1/39 by D. Hall, September 1961.

interest in the proposed undertaking. Nothing developed from these discussions because the companies considered that without major additions being made to the Port Pirie Plant, it could provide only a fraction of the capacity necessary for economic operation.

In 1965 when the present project was commenced, an appraisal was made of the bicarbonate process for production of high grade magnesia at Port Pirie using magnesite from Port Germein as the likely raw material. A preliminary flow sheet was prepared for use at the Plant to produce 50 tons per day of product. (see Appendix A).

During these studies no investigation was made of the market for the product in Australia. The requirement for use as refractories was known to be substantial and other well established uses were as an alkali and for manufacture of magnesium salts. Statistics published by the Commonwealth Bureau of Mineral Resources also indicated substantial mine production of magnesite in New South Wales (approximately 60, 000 tons per year minimum) while other information suggested that reserves were limited and imports generally substantial.

The need for more accurate market survey was apparent because any engineering design, however approximate, would require a stated plant capacity as its starting point.

An investigation of available markets was undertaken to provide information relative to the economics of establishing a magnesia plant at Port Pirie. This report describes the methods and results of this market investigation and indicates their effect on the previous proposals.

2. AIM OF THE MARKET SURVEY

The primary aim of the survey was to determine current consumption of magnesia in Australia, and in South Australia particularly. Because the term "magnesia" includes calcined magnesite (either caustic-calcined or dead-burnt grades) as well as chemically precipitated grades, all types were included in the scope of the investigation with a secondary aim of determining consumption of dead-burnt grades (virtually all in refractories) compared with caustic and chemical grades (chemical purposes and some refractory materials).

It is usual to consider the major users of the product in question, so that when sources of supply are also taken into account a general picture is obtained of the supply, principal areas of consumption, and the identity of major producers and consumers.

3. METHODS OF THE SURVEY.

The general method adopted to determine current consumption of magnesia in Australia was to collect up-to-date statistical information on production, imports and export of magnesite. Burned (calcined) magnesite was known to be the usual source of both dead-burnt and caustic magnesia.

There is no Australian plant producing precipitated magnesia on a large scale. Other published information, particularly that from the Commonwealth Bureau of Mineral Resources gave indications of uses of raw magnesite, while information on the consumption as refractories and in the steel industry was obtained from companies operating in these fields.

4. RESULTS OF THE SURVEY

4.1 Australian Production of Magnesite

Production of magnesite has always been considerably higher in New South Wales than in other States. In Western Australia there has been moderate production, up to almost 10,000 tons in some years, but in Table 1 only the amounts produced in New South Wales and South Australia have been recorded separately.

Production of magnesite has declined steadily in recent years. In New South Wales the main producing areas are at Young and Fifield, but production from leases at Fifield held by the BHP Co.Ltd has declined considerably, apparently because of depleted reserves. Other production is continuing in the same area however, the material being largely used for manufacture of refractories. Only a few hundred tons of South Australian magnesite have been produced annually and most of it is used for the manufacture of magnesium salts in Adelaide. There has been no recent production from the deposits near Port Germein which are controlled by the BHP Co.Ltd.

4.2 Magnesite Exports and Imports

Exports of magnesite have generally been small. In 1961 some 2700 tons were exported, most of the material being raw magnesite from Western Australia. Subsequently exports fell until in 1964 and 1965 exports again rose above 2000 tons. The bulk of this material is known to be high purity caustic calcined magnesia produced in New South Wales as a premium grade material and exported for the production of fused magnesia. Owing to the small quantities involved, exports have been considered as part of the total Australian demand rather than being given separate consideration in this survey.

In contrast to exports, imports of magnesite have been substantial for some years, and until recently have tended to increase as local production decreased. This situation is shown in Table 2.

Consideration of the quantities imported under each item of the detailed classification published by the Commonwealth Statistician shows that the imports were predominantly in the form of dead-burnt magnesite, and that caustic calcined material and other grades made up less than 1% of the total. Separate imports of refractory bricks and shaped materials containing magnesite were of the order of 5000 tons in 1963-64 and nearly 7000 tons in 1964-65. Current figures however, indicate an annual import rate of about 4000 tons of which the magnesite content has been estimated at 3000 tons.

4.3 Principal Uses of Magnesia

Taken together, the imports of dead-burnt magnesite (which is primarily used to manufacture refractories), and of refractory bricks etc. emphasize the importance of this application in relation to the total consumption of magnesia in Australia. With the additional knowledge of production in New South Wales the Bureau of Mineral Resources estimated that production of refractories accounted for 89% of apparent consumption in 1964.

The steel industry is the largest user of basic refractories which contain dead-burnt magnesite. Other similar types are also used in base metal smelters and in cement kilns.

It is believed that the change to basic oxygen process steel manufacture in Australia, in place of the open hearth process, is causing a marked change in the consumption of magnesite for refractories in steel furnaces. The refractory material at present favoured by BHP for use in the basic oxygen process is based on dolomite with only a small amount of magnesite also present. Steel is now manufactured at Whyalla and Newcastle by the basic oxygen process and the Port Kembla facilities are also expected to change from open hearth production in the next few years.

Whereas magnesite based refractories have been satisfactory for open hearth steel furnaces in the past, overseas reports indicate that basic oxygen furnaces require higher purity refractory material (e.g. 98% MgO from sea-water) to be able to withstand the higher operating temperatures. This practice is not followed in Australia since as mentioned above a dolomite-based refractory material is used by BHP. It is not known however, whether or not future technical development may cause a swing towards the use of magnesia refractories by BHP.

The other uses of magnesia as a pure material or technical grade of caustic-calcined magnesite, are chiefly in the manufacture of chemicals, cements and insulating materials. Apart from pharmaceutical use of high grade magnesia the production of magnesium salts also requires calcined magnesite as raw material. F.H. Faulding and Co. Ltd, produce magnesium sulphate and nitrate but the total amount of raw magnesite used is now only approaching the equivalent of 500 tons of magnesia per annum.

4.4 Apparent Consumption of Magnesia

By addition of the annual totals in Tables 1 and 2 an approximate figure may be obtained for the apparent annual consumption of magnesia in Australia. This excludes any allowance for imported magnesite bricks and for changes in stocks, but includes current exports of calcined magnesite. The apparent consumption for the last 3 years is as follows:

Year	Tons
1963	58,800
1964	60,100
1965	42,100

The consumption in 1966 is expected to be lower than in 1965 owing to the prevailing situation in the steel industry. If consumption were to drop slightly to around 40,000 tons then from all information received an approximate split-up of the total might be as follows:

Use	Tons
Refractories for steel manufacture	15,000
Chemical and miscellaneous uses including exports	7,000
Other refractories	18,000

The total amount consumed in South Australia is expected to be small. At present the consumption by the Whyalla steel works of refractory materials manufactured at Newcastle is less than 2000 tons per year. The estimated total consumption in South Australia could exceed 5000 tons but an accurate assessment has not been attempted owing to the over-riding importance of the economic factors described below.

4.5 Prices and Sources of Supply

Calcined magnesite has been imported from a large number of different countries in past years, but since the beginning of 1963, when imports rose considerably, Japan and USA have been the major suppliers. These two countries together have supplied more than two thirds of total imports since 1963. In 1965 there were substantial imports from India but these have now virtually ceased. More than 99% of the quantity imported was received into New South Wales ports presumably because much of the material from Japan was shipped as back cargo in vessels engaged in coal shipment from Australia.

The average cost of imports in 1965 was calculated from the Commonwealth Statistician's current import tabulations. The following figures were obtained for the major sources of supply:

Country	$A per ton fob
India	45
Japan	50
USA	65

The addition of duty and freight charges (possibly at back loading rates) would bring the landed cost of supplies from India and Japan to the range of $55-60 per ton. The cost of material from USA would be about $75 per ton presumably for 98% magnesia derived from sea-water. The source of Japanese material is unknown.

The price of calcined magnesite from two NSW producers who are the most substantial Australian suppliers is approximately $95 per ton.

Material at this price is not competitive with imported material. In addition, the reserves of magnesite in the BHP leases at Fifield NSW are reported to be low and mining from this source has diminished. Also the present and proposed establishment of refractory manufacturing plants in Australia by companies with American affiliations is likely to favour increasingly the use of high purity magnesia from sea-water rather than calcined magnesite.

5. DISCUSSION

5.1 Market for High Purity Magnesia

The product from the bicarbonate process proposed for the Port Pirie Plant (see Appendix A) probably would contain 99.0-99.5% MgO, but from the information obtained in this market survey it is considered that the market for high purity magnesia would be relatively small.

The applications of magnesia which have been disclosed by the survey may be broadly classified as follows:

1. Refractories:
   a. for steel manufacture
   b. others
2. Chemical and other uses:
   a. pharmaceutical and special chemical
   b. ordinary chemical applications, cements, insulation, etc.

Magnesia of high purity would only be necessary for the pharmaceutical and special chemical applications; all refractory applications being adequately served by material of up to 98% purity(e.g. as in magnesia obtained from sea-water). There is an added complication in that the steel industry in Australia is at present reducing its consumption of magnesite refractories, whereas this sector of industry in particular would have been expected to require high purity magnesia for higher temperatures of service. It is expected that the use of high purity magnesia in refractories for industries other than steel making will increase slowly for the sake of benefits such as longer working life that may be obtained, but there has been no major technological change to compare with the introduction of the basic oxygen steel process.

If as estimated in Section 4.4 the market for all chemical uses of magnesia in 1966 is 7000 tons the probable amount of high purity magnesia required would be only half that amount. Even allowing for some current exports of high purity magnesia derived from beneficiated magnesite, the maximum demand for the material produced by the bicarbonate process would be approximately 4000 tons per year.

There appears to be a much more substantial market available for material which is suitable for refractory use in the higher range of service temperatures. As mentioned above, this purpose is apparently served by magnesia obtained from sea-water by the dolomite treatment process, as the product contains about 98% MgO, 1.5% CaO and 0.5% SiO_2. The low silica content would enable the material to be formed into refractories by direct sinter bonding, a process which is claimed to yield improved properties in the modern basic refractories containing high purity magnesia. Magnesia obtained from the bicarbonate process probably would be purer than necessary for this application and would not be cheaper than sea-water magnesia. On this basis the market potential for sea-water magnesia would be greater than for bicarbonate process magnesia. Developments in the market should be observed to determine the future pattern of magnesia consumption in refractories because there may be justification for the establishment of a plant for production of magnesia from sea-water when the market is larger. The use of the Port Pirie Uranium Plant for this purpose however, has apparently not appealed to potential producers because a larger scale of operations is considered advisable for economy.

5.2 Cost and Supply Considerations Relevant to Production of Magnesia

As indicated in Section 4.5 the landed cost in New South Wales of dead-burnt magnesia from USA is estimated at $75 per ton and cheaper materials are available from Japan and India. The cost of production of magnesia at Port Pirie by the bicarbonate process has not been estimated but the cost of raw magnesite and fuel alone for the process proposed (see Appendix A) has been calculated at $35 per ton of product. Transport costs from South Australia to markets in New South Wales would add considerably to selling costs if normal rates applied.

The supply of raw materials for the manufacture of magnesia either from sea water or from magnesite involves materials which are largely controlled at present by the BHP Co. Ltd.

Although other supplies may be available the most likely sources are the Ardossan deposits of dolomite, for use in the sea-water treatment process, and the Port Germein Gorge deposits of magnesite as raw material for the bicarbonate process. The dolomite deposits are actively worked by the BHP Co. Ltd, and are the only noteworthy Australian source of this material. The magnesite deposits have been subject to some investigation by BHP[1], and mining rights are held under special conditions by BHP without the deposits being worked at present. It is therefore probable that BHP participation would be necessary to make any magnesia project a success since the Company would also be a major user of the product.

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1. JOHNS, K., (1963), South Australian Department of Mines Bulletin No. 38.

6. CONCLUSION AND RECOMMENDATIONS

Since 1962 more than half of the magnesia consumed in Australia has been imported. This market survey has shown that imported material is available at low prices and that apparent Australian consumption of magnesite is falling. The fall in consumption is occurring because Australian consumers of refractories are not tending to use high purity magnesia in basic refractories as has occurred overseas. This applies particularly to the Australian steel industry at present.

Since a substantial part of the local market for magnesia can be satisfied with calcined magnesite the market available for purer grades obtained by chemical processing of sea-water or magnesite is correspondingly reduced. It is therefore considered that the market does not warrant the establishment of even a small plant such as has been proposed at Port Pirie to produce 50 tons per day or approximately 15,000 tons per year of high grade magnesia. It has been estimated that this product might only be aimed at a market requiring 4000 tons per annum, while total demand for all grades in 1966 is expected to be approximately 40,000 tons.

The market for magnesia is strongly influenced by the present availability of imported material and by technical trends in the use of refractories.

Both these factors may change rapidly in the future and it is quite possible that a higher total demand would then justify the establishment of a chemical magnesia plant in Australia. For this reason, and with South Australian deposits of magnesite and dolomite in mind, it is recommended that the situation be kept under review possibly via liaison with companies which would be potential producers. In this respect it is considered also that the production of magnesia from sea-water would have the greatest potential of the probable chemical processes.

The current economic situation relative to use of magnesia in Australia does not encourage retaining the Uranium Treatment Plant at Port Pirie as a possible producer of magnesia in the immediate future.

7. ACKNOWLEDGMENTS

Valuable assistance has been received in the collection of information for this report from Mr J.R. Adam of the South Australian Department of Mines and Dr Z. Kalix of the Bureau of Mineral Resources Canberra. The BHP Co. Ltd has also assisted by means of some projected consumption estimates obtained from the Raw Materials and Exploration Division of the Company and with other information contained in its Annual Reports.

The assistance from all these sources is gratefully acknowledged.

APPENDIX A

PORT PIRIE URANIUM PLANT

1. REVIEW OF PROGRESS

During the period covered by this report an appraisal has been made of the possibility of utilizing the Port Pirie Uranium Plant for the production of 50 tons per day of high grade magnesia using the Bicarbonate Process.[1]

The investigation has shown that the process appears to be technically feasible and that a large part of the equipment existing at the Port Pirie Uranium Plant would be required for magnesia production. It is recommended that a more detailed study of the economics of the process and of the process itself be made.

A small amount of experimental work which was carried out failed to indicate any leach liquor additive which would improve the solubility of magnesium bicarbonate. The results are given in Appendix C.

2. FLOW SHEET

The flowsheet for the proposed Bicarbonate Process is given in Figure A-1.

3. PRODUCTION OF MAGNESIA

Estimates which follow are based on production of 50 tons of MgO per day.

3.1 Ore

Magnesite is available from deposits in the Port Germein Gorge. The leases at the present time are held by the BHP. The reserves of ore are reported[2] to be large and accessible by underground mining. The composition of the various strata associated with the magnesite deposit is given in Table A-1. Ore A consists of large blocky fragments having a density of about 2 tons per yard.

The cost of mining the ore is not known. The market value of crude magnesite ex mine is about $9 per ton and the Port Germein deposit seems to be marginal for mining of Ore A. To mine Ore A, Ore B would probably need to be mined also, and so would be available at little additional cost. The ore would need to be broken at the mine to about 3-inch size, and its cost could then be assumed to be approximately:

$9 per ton for Ore A or $1320 for 147 ton per day.
$5 per ton for Ore B or $ 825 for 165 ton per day.

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1. DOERNER, H.A. et al, (1946) Technical Paper 684, U.S. Bureau of Mines.
2. JOHNS, R.K., (1963) Bulletin No. 38 Geol Survey of South Australia.

3.2 Transport of Ore

The ore would be transported by road freight from the mine to Port Pirie, 22 miles, at 5c per ton mile, i. e $1.10 per ton.

To produce 50 ton MgO per day assuming an overall recovery of 75% of the MgO in the ore the transport costs would be approximately:

$160 for Ore A (147 ton per day)
$180 for Ore B (165 ton per day)

3.3 Ore Crushing - at Plant

Ore from a coarse ore storage bin is fed to a grizzly and then to a cone crusher and screen. The plus ¼-inch material from the screen is returned to the cone crusher and the minus ¼-inch material conveyed to a fine ore storage bin. Operation would be required on a one shift per day basis, the throughput being 18 ton per hour Ore A or 21 ton per hour Ore B.

3.4 Ore Calcination

Taking Ore B as the worse case and allowing for a 75% overall recovery of MgO from the process a throughput of 15,700 lb per hour of ore is required at the initial calcination stage. Assuming a residence time of 45 minutes in a fluid-bed reactor which is fired by fuel oil burnt in the bed, a fluidizing gas velocity of 4 foot per second can be obtained from the combustion gases and CO_2 from the ore calcination if the reactor has a diameter of 8 feet. The bed depth for the output required would then be 3.5 feet. These conditions appear reasonable but would require experimental investigation to establish the feasibility of this operation. Alternatively, conventional calcination kilns could be considered.

In either case, some of the MgO will be unavailable as a result of incomplete calcination or due to the formation of magnesium silicates. If 90% of the MgO is recoverable, the reactor product will have a composition of 65% MgO and 35% calcined impurities (mainly silica) or 5600 lb Mg and 3000 lb calcined impurities per hour.

The heat requirement for the reaction (see Appendix B) is 13.7×10^6 Btu per hour. If sufficient heat is recovered from the products to balance losses from the furnace, then the process heat requirement is also 13.7×10^6 Btu per hour. Fuel oil has a calorific value of 18,000 Btu per pound so that 762 lb fuel oil per hour is required or 365 lb per ton MgO final product. Fuel cost approximates $20 per ton, i. e fuel cost is $3.3 per ton of product or $170 per day.

The combustion gases are drawn off through cyclone dust traps and some of the heat liberated in this operation (say 1×10^6 Btu per hour) is used to warm the bicarbonate solution. The exhaust gases are then sent to storage in a gasholder, or used directly in the leaching stage.

3.5 Grinding and Classification

The 5600 lb MgO plus 3000 lb impurities, after cooling are mixed with 26,000 lb of barren liquor recovered from product precipitation. Approximately 700,000 Btu per hour will be evolved by the exothermic hydration of MgO and the pulp temperature will rise by 23°F. The heat evolved during grinding is assumed to equal the heat losses, hence 170,000 lb of cooling water at 60°F will be required to lower the pulp temperature to about 65°F by means of a suitable heat exchanger. At Port Pirie refrigeration of the cooling water may be necessary and high ambient temperatures may double the cooling water requirements.

A ball mill in closed circuit with a bowl classifier is used to yield a product that is 98% minus 150 mesh.

3.6 Leaching

The slurried calcine flows continuously to the first 5 of 6 4000 gallon leaching tanks. 20% of the slurry goes to each of tanks 1 to 5 (i.e. 18.7 lb MgO, 10.0 lb impurities and 8.7 gallon water per minute). Water plus barren liquor is pumped into tank 1 at 440 gallon per minute and cascades through tanks 2 to 6. Flue gases from the precipitation section containing 48% CO_2 are passed into tanks 1 and 2 and the effluent gases treated to recover CO_2 if required. Tanks 3, 4, 5 and 6 are supplied with CO_2 and the effluent gas returned to a gasholder.

A summary of the leaching system is given in Table A-2.

The cooled and enriched flue gases available for introduction to tanks 1 and 2 have a mass flow of 203 lb CO_2 per minute, hence are available well in excess of requirements. The net requirements of CO_2 supply for tanks 3 to 6 (111 lb) are derived from the decomposition of the precipitated carbonate to magnesia, which makes available 85 lb per minute CO_2. The additional 26 lb per hour of CO_2 required can be recovered from the flue gas effluent from the leaching and precipitation vessels (129 lb per minute available).

Each leaching vessel will require a heat exchanger since approximately 5.5×10^6 Btu per hour will be liberated, raising the pulp temperature 27°F. At Port Pirie this may require twice the calculated 200,000 lb per hour of cooling water at 60°F.

3.7 Filtration

Following leaching rapid filtration of the liquor is required. The drum filter at Port Pirie, with an area of 240 ft^2 should be adequate to filter approximately 480 gallon per minute of leach liquor, rejecting 55 lb impurities per minute. If necessary the liquor could be passed through a centrifuge to produce a smaller volume of liquor of higher pulp density. Overflow from the centrifuge would be clarified in a pressure filter.

3. 8 Precipitation

The effluent gas from the fluid bed is passed through the first two precipitation tanks. This raises the temperature to 120°F and drives off CO_2. About two thirds of the magnesia is precipitated as the carbonate, while the effluent gas is enriched from 40% to 48% by the 57 lb per minute CO_2 liberated.

Aeration in three remaining tanks with air at 1100 cu ft per minute in each tank precipitates 95% of the magnesia leaving a barren solution (0. 1% MgO).

3. 9 Second Filtration

The pulp (480 gallon per minute containing 78 lb MgO) is passed into a thickener. The underflow is removed and filtered on the product filter. The filter cake will contain 6 to 10 parts of water per part MgO and can be pressed to reduce this ratio to 1: 3. The barren solution is pumped through a heat exchanger to cool to 65°F then supplied to ball mill, classifiers and leaching tanks. The 163 lb of $MgCO_3$ produced per minute will contain 234 lb of water, free and combined. Waste heat from the gases leaving the product calcination furnace can be used to evaporate most of this water.

3. 10 Product Calcination

The almost dry $MgCO_3$ is passed into a kiln and the remaining moisture and CO_2 expelled. This will require external heating to supply about 6×10^6 Btu per hour, equivalent to 330 lb fuel oil per hour or approximately $1. 4 per ton of product. Nearly pure MgO will be discharged and approximately 2×10^6 Btu per hour become available for predrying the magnesium carbonate. 85 lb pure CO_2 per minute will be liberated and sent to the CO_2 distribution system to be used for leaching.

4. EQUIPMENT

The following major items of equipment would be required:

a. Not available at the Port Pirie Uranium Plant:

Grizzly and cone crusher
Multistage fluid-bed reactor
Ball mill and bowl classifier
Gas handling equipment
Product calcination kiln
Heat exchanger equipment
Cooling water supply

b. Available at the Port Pirie Uranium Plant:

Leaching vessels (leaching tanks 4000 gallon)
Precipitation vessels (pulp holding tanks 14, 000 gallon)
Leach liquor filter (residue filter)
Magnesium carbonate filter (product filter)
Magnesium carbonate drying oven (product oven)
Magnesium carbonate thickener (CCD tank).

However, considerable modifications to some of this equipment would be required.

5. COST ESTIMATES

No attempt has been made to derive cost estimates for the various stages of the process. The value of caustic magnesia is approximately \$90 per ton, and of refractory grade material \$50 per ton. The cost of the ore on arrival at the plant is approximately \$20 per ton of recoverable magnesia.

Fuel costs for primary calcination and product calcination total approximately \$5 per ton of MgO, but a more detailed economic appraisal would be necessary to determine whether the process could be attractive.

6. CONCLUSIONS AND RECOMMENDATION

It appears that the use of the Port Pirie Uranium Plant for the production of magnesia is technically feasible. A considerable part of the equipment required is already available, although certain modifications would be needed. The greatest problem may result from the high ambient temperatures exisiting at Port Pirie during summer, and the consequent need for effective cooling systems. The economy of operation is not known but the little data derived suggests that a reasonable margin is available.

A detailed study of the adaptation of the Port Pirie Plant to the Bicarbonate Process, and a determination of the economics of the process are recommended. Should the process prove economically attractive a study of the behaviour of magnesite calcination in a fluid bed will be required.

TABLE A-1: CROSS SECTION OF STRATA IN MAIN WORKINGS
: (BHP, Port Germein Gorge)

		Thickness		MgO	CaO	Insol
		ft	inches	%	%	%
Hanging wall:	Interbedded chert and dolomite	3	0			
	Black chert	2	6			
	Interbedded chert and dolomite	1	3			
	Cherty sandstone	0	6			
	Interbedded chert and magnesite	0	6			
Workings:	Hard grey magnesite Bed A	3	0			
	Impure cherty magnesite Bed A	1	0	46	Ore A 0.7	2.5
	Hard pale grey magnesite Bed B	1	3			
Footwall:	Interbedded chert and magnesite	2	0	40	Ore B 3	10
	White magnesite with brecciola structure	1	0			
	Thin bedded and contorted black chert	8	0			
	Magnesite with brecciola structure	2	6			
	Black chert	2	0			

TABLE A-2: PREDICTED OPERATION OF LEACHING SYSTEM

		Tanks					
		1	2	3	4	5	6
Feed,	lb/min MgO	18.7	18.7	18.7	18.7	18.7	-
Total water feed,	lb/min	4490	4580	4670	4760	4850	4850
Retention time,	min	8.9	8.7	8.6	8.4	8.2	8.2(a)
Estimated discharge conc, lb MgO/100 gal		2.8	5.6	10.2	14.3	18.2	18.2
CO_2 requirement,	lb/min	37	37	37	37	37	-

(a) Total retention time in 6 tanks = 51 minutes.

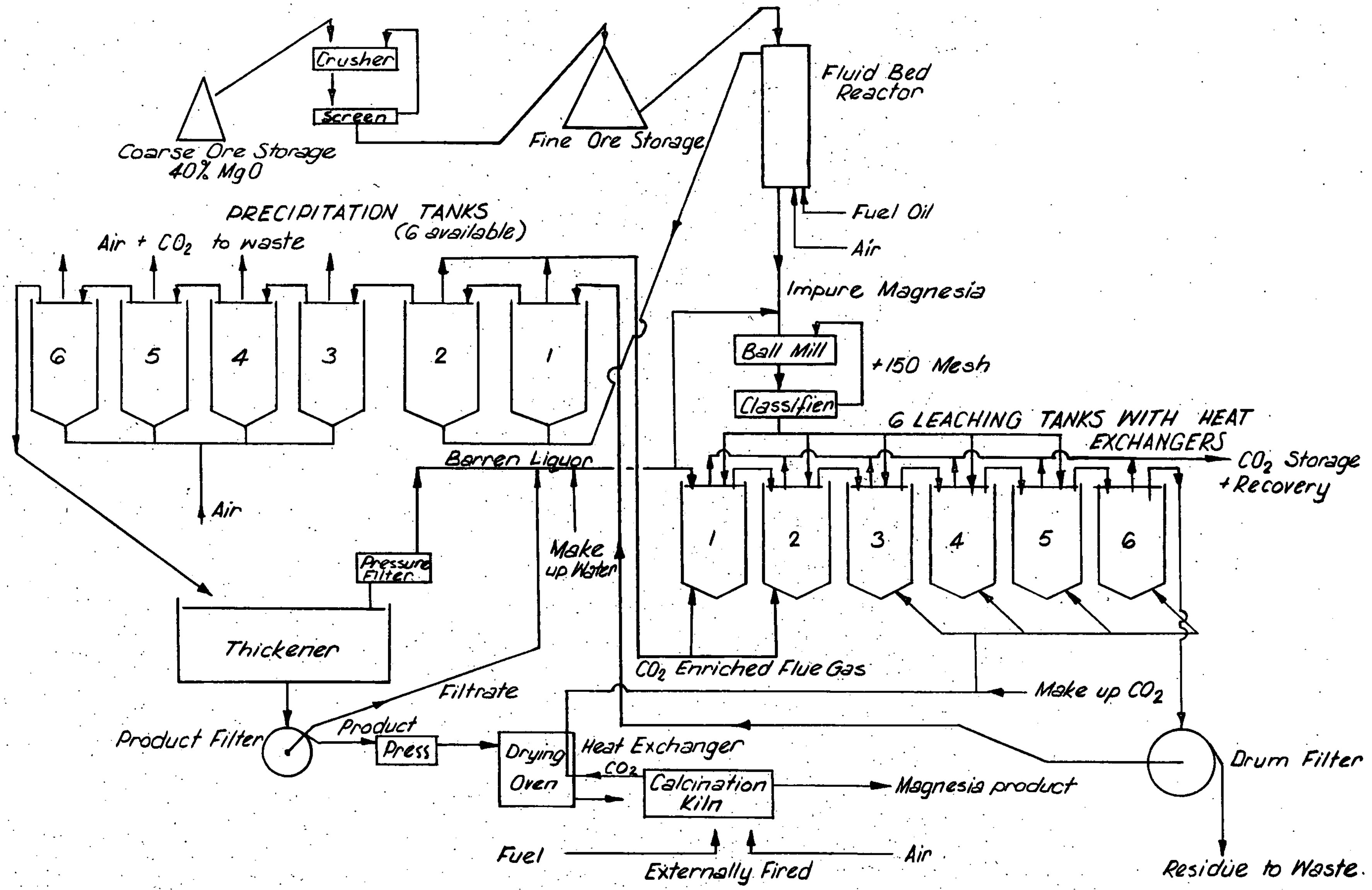

FIG. A-1: FLOWSHEET FOR PRODUCTION OF MAGNESIA BY THE BICARBONATE PROCESS

APPENDIX B

HEAT REQUIREMENTS FOR CALCINATION OF MAGNESITE ORE

$$MgCO_3 \longrightarrow MgO + CO_2 \text{ (at } 750^0C)$$

Heat of Reaction at 1023^0K

$$C_p\ MgO = 10.18 + 1.74 \times 10^{-3}T - 1.48 \times 10^5 T^{-2}$$

$$C_p\ CO_2 = 10.55 + 2.16 \times 10^{-3}T - 2.04 \times 10^5 T^{-2}$$

(1) $$C_p\ (MgO+CO_2) = 20.73 + 3.90 \times 10^{-3}T - 3.52 \times 10^5 T^{-2}$$

(2) $$C_p\ MgCO_3 = 18.62 + 13.8 \times 10^{-3}T - 4.16 \times 10^5 T^{-2}$$

The difference between (1) and (2) is:

$$\Delta C_p = 2.11 - 9.9 \times 10^{-3}T + 0.64 \times 10^5 T^{-2}$$

Assume initial temperature 25^0C, decomposition temperature 750^0C.

$$\int_{298}^{1023} \Delta C_p\, dT = \left[2.11\ (1023 - 298)\right] - \left[9.9 \times 10^{-3}\ \frac{1023^2 - 298^2}{2}\right] - \left[0.64 \times 10^5\ (1023^{-1} - 298^{-1})\right]$$

$$= 2.11 \times 725 - 9.9 \times 10^{-3}\ \frac{1046500 - 88800}{2} - 0.64 \times 10^5\ (1023^{-1} - 298^{-1})$$

$$= 1530 - 474 + 147$$

$$= 1203 \text{ cal}$$

Now ΔH_{298} is given by

$$(\Delta H_{f,298}\ MgO) + (\Delta H_{f,298}\ CO_2) - (\Delta H_{f,298}\ MgCO_3)$$

$$\therefore\ \Delta H_{298} = -94,050 - 143,700 + 262,000$$

$$= 24,250 \text{ cal}$$

And $$\Delta H_{1023} = \Delta H_{298} + \int_{298}^{1023} \Delta C_p\, dT = 24,250 + 1203$$

$$= 25.4 \text{ kg cal/mole}$$

Heat required to raise $MgCO_3$ from 298^0K to 1023^0K

$$C_p \; MgCO_3 = 18.62 + 13.80 \times 10^{-3}T - 4.16 \times 10^5 T^{-2}$$

$$\int_{298}^{1023} \Delta C_p \, dT = 18.62\,(1023 - 298) + 6.90 \times 10^{-3}\,(1023^2 - 298^2)$$

$$+ 4.16 \times 10^5\,(1023^{-1} - 298^{-1})$$

$$= 18.62 \times 725 + 6.90 \times 958 - 4.16 \times 0.0024 \times 10^5$$

$$= 13,500 + 6611 - 990$$

$$= 19.52 \text{ kg cal/mole}$$

Total Heat Requirements

$$25.4 + 19.5 = 44.9 \text{ kg cal/mole}$$

$$= 535 \text{ cal/g } MgCO_3$$

$$= 962 \text{ Btu/lb } MgCO_3$$

Quartz

No reaction over the range 298^0K to 1023^0K (neglect phase change)

$$C_p = 11.22 + 8.20 \times 10^{-3}T - 2.70 \times 10^5 T^{-2}$$

$$\int_{298}^{1023} \Delta C_p \, dT = 11.22\,(1023 - 298) + 4.10 \times 10^{-3}\,(1023^2 - 298^2)$$

$$-270 \times 10^5\,(1023^{-1} - 298^{-1})$$

$$= 11.22 \times 725 + 4.10 \times 958 - 2.70 \times 10^5 \times (-0.0024)$$

$$= 8134 + 3928 + 648$$

$$= 12.7 \text{ kg cal per mole or } 212 \text{ cal/g}$$

$$= 382 \text{ Btu per lb}$$

Ore A. Assume $MgCO_3$ content of 95%

Heat requirement $(962 \times 0.95) + (382 \times 0.05)$

$= 933$ Btu per lb feed

Ore B. Assume $MgCO_3$ content of 85%

Heat requirement $(962 \times 0.85) + (382 \times 0.15)$

$= 874$ Btu per lb

Calcination rate (24 hr/day feed)

Ore A. 6 ton/hr 13,440 lb/hr
Heat requirement 12.9 x 10^6 Btu per hr

Ore B. 7 ton/hr 15,680 lb/hr
Heat requirement 14.1 x 10^6 Btu per hr

APPENDIX C

SOLUBILITY TESTS ON MgO

1. EXPERIMENTAL PROCEDURE

200 ml of water plus 5% of a salt additive were saturated with CO_2. (CO_2 was bubbled through the solution continuously).

MgO was added in small amounts and the beaker was shaken until the MgO was completely dissolved. More MgO was added until the solution was saturated.

MgO dissolved per litre was then determined.

2. RESULTS

Solvent		MgO g/litre
CO_2 saturated water		12.2
- ditto -	5% NH_4Cl	12.0
" " "	5% $(NH_4)_2SO_4$	9.2
" " "	5% NH_4CO_3	4.0
" " "	5% $NaHCO_3$	8.0

It was found that if MgO was added in excess $MgCO_3$ was precipitated.

TABLES 1 and 2

TABLE 1: AUSTRALIAN PRODUCTION OF MAGNESITE 1960-1965 AND EQUIVALENT MAGNESIA CONTENT

Unit: tons (Figures rounded to nearest 100 tons)

	Calender year[(a)]					
State	1960	1961	1962	1963	1964	1965
N. S. W.	61,700	88,500	61,700	49,900	29,300	22,600
S. A.	500	700	300	500	400	700
Others	-	9,600	200	6,500	1,600	1,500
Total magnesite	62,200	98,800	62,200	56,900	31,300	24,800
Equivalent magnesia	29,600	47,000	29,600	27,100	14,900	11,800

(a) Source: Bureau of Mineral Resources, "The Australian Mineral Industry, Quarterly Review and Statistics" 1965. Figures for 1965 by private communication from the Bureau.

TABLE 2: IMPORTS OF CALCINED MAGNESITE 1960-1965[a]

Unit: tons (Figures rounded to nearest 100 tons

Calender year:	1960	1961	1962	1963	1964	1965
Total imported:	13,900	15,700	6,900	31,700	45,200	30,300

(a) Source: Bureau of Mineral Resources, "The Australian Mineral Industry 1964 Review". Figures for 1965 were obtained from the Commonwealth Bureau of Census and Statistics.