68/83
(3)

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1968 / 83

Study Tour of USA, Canada, and Sierra Leone

by

J. Ward

Record No. 1968 / 83

Study Tour of USA, Canada, and Sierra Leone

by

J. Ward

CONTENTS

SUMMARY

This record has been prepared as the result of an official visit overseas by the author to the United States of America, Canada and Sierra Leone to study major deposits of heavy minerals and to collect first-hand information on future potential supplies, projected demand, and trends in the treatment of titanium and other beach-sand minerals.

It is concluded that Australia will maintain its position as the leading supplier of natural rutile and zircon to world markets in the foreseeable future; that world demand for natural rutile will outstrip supply by the early 1970's; and that world producers of TiO_2 pigments will become increasingly dependent on other materials of high TiO_2 content, such as beneficiated ilmenite, in which development, ilmenite producers in Western Australia are leaders in the field.

STUDY TOUR OF U.S.A., CANADA, AND SIERRA LEONE

By

J. WARD

RECORD 1968/83

INTRODUCTION

During May and June, 1968 the author made an official visit to the United States of America, Canada and Sierra Leone to study important deposits of titanium and zirconium minerals and to collect first hand information on future supplies and demand and the trends in the treatment of titanium and other beach-sand minerals.

The mineral sand industry in Australia continues to grow in size and importance and Australia retains its position as the leading supplier of rutile,zircon,and ilmenite to world markets. In recent years domestic producers have provided some 95 percent of the world's rutile supplies, 75 percent of the world's zircon supplies and about 20 percent of ilmenite supplies, to contribute in 1967, $35 million to Australia's export earnings.

However, new factors have arisen recently, particularly in the field of titanium supplies, which are of special interest to the Australian industry. The first of these is the development of rutile deposits in Sierra Leone which could provide significant tonnages of rutile in years to come. The other important factor is the development of the chloride process for TiO_2 pigment production vis a vis the sulphate process; the extra demand for Australian rutile introduced by this development and the potential use of beneficiated ilmenite, in which Australian mineral sand producers are vitally interested, as a new, high-grade raw source of TiO_2 for pigment production.

While in the United States heavy mineral alluvial deposits were inspected at Highland and Trail (Florida) and at Folkston (Ga), and production of rutile from hard-rock operations at Beaver Dam (W.Va) and hard-rock ilmenite production of Tahawus (N.Y. State) was studied. Chloride TiO_2 plants were visited at Antioch (Calif.) and at Ashtabula (Ohio) as was sulphate plant at Sayreville and the titanium sponge plant at Henderson (Nev.). Discussions were held with officers of the Stanford Research Institute at Menlo Park (Calif.) and with officers of the U.S. Department of Mines in Washington D.C. Talks were had with principals of pigment-producing companies and other consumers of rutile, zircon, and ilmenite in Los Angeles (Calif.), New York, Boston, Pittsburgh and Milwaukee. In Canada, the Department of Energy, Mines and Resources was visited and the future of Sorel slag discussed with representatives of Quebec Iron and Titanium Corporation.

In Sierra Leone, West Africa, the alluvial operations of Sherbro Minerals Ltd. at Gbangbama were inspected.

HEAVY MINERAL DEPOSITS

In the United States the detrital deposits of Trail Ridge (Fla) (titanium minerals and zircon) and the hard-rock deposits of Tahawus (N.Y.) constitute by far the most important deposits of titanium minerals and zircon and the following notes on the heavy-mineral resources of the United States deal principally with these deposits.

Trail Ridge

The Trail Ridge feature consists of a broad elevated ridge extending some 200 miles southward from southeastern Georgia deep into north-central Florida. The "ridge" is generally thought to have developed as a long spit which extended southward during the Pleistocene, covering the limestone "backbone" of Florida with a veneer of sand derived from the disintegration of Piedmont cystalline rocks and Tertiary sandstones which crop out to the north and west.

The Trail Ridge deposit proper lies approximately 45 miles inland from the west of Florida along the western side of the main ridge feature. The deposit is about 19 miles long, is from a mile to two miles wide and is up to 30 feet thick. Elevation of the ore body base ranges from 145 to more than 200 feet above sea level. On the east side, the ore body lies against and on barren, coarse sand. In the central part, it lies on an indurated layer of concentrated, organic material comprised of fragments of roots, branches and trunks of trees. At its western margin, the deposit in many places lies on pre-pleistocene clayey sand.

The Du Pont Company operates two heavy mineral mining and concentrating plants on the Trail Ridge orebody. The Trail Ridge plant, near Starke, was built in 1948. The Highland plant near Lawtey, was built in 1955. Flowsheets for the two plants are similar (Figure 1), and each plant has a rated capacity of about 100,000 t.p.a. of titanium minerals.

Mineralogy

The primary detrital heavy mineral suite in the Trail Ridge deposit consists of altered ilmenite, leucoxene, rutile, staurolite, tourmaline, spinel (var. gahnite), kyanite, sillimanite, corundum, topaz, and zircon. Small amounts of authigenic pyrite have been noted in association with present-day swamps. The heavy mineral fraction assays approximately 54 percent titanium minerals, 15 percent zircon, 14 percent staurolite, 6 percent sillimanite, 5 percent tourmaline and 3 percent kyanite.

The iron-rich titanium minerals of the Trail Ridge deposit have undergone extensive alteration by oxidation and leaching of the iron. The TiO_2 content of the mineral grains drops rapidly from the surface to a depth of about 10 feet and then remains essentially constant to the bottom. The general term ilmenite has been applied to the more magnetic titanium minerals. The grains are black with a metallic lustre and range from 62 to 70% TiO_2. The so-called leucoxene constitutes the less magnetic opaque titanium minerals and contains 70-90% TiO_2 depending on the stage of alteration of ilmenite to leucoxene.

The true rutile grains are very fine (-150 mesh) and are present as dark-red elliptical grains rarely showing distinct faces.

Organic material composed of carbonised plant residues and kaolinite occurs throughout the deposit. In localized areas the organic remains and clay are present in high enough concentrations to cement the sand grains into a poorly-consolidated sandstone. The term "hardpan" is used locally when referring to these sands. The cemented areas are lenticular and occur at random with no apparent correlation as to depth.

Mining

After the surface over the orebody is cleared of trees and the area blasted to break up the hardpan layers, the area is dredged. Blasting of the hardpan has now, in general, been discontinued. The dredge is a suction type equipped with a cutterhead and rated at about 1200 tons per hour. The presence of roots in the orebody frequently caused plug-ups. A "root-hog" has been designed to overcome this. The "root-hog" consists of a steel base divided into two compartments by parallel bars with 5 inch spacing. The dredge pump receives only the material that passes through the 5 inch openings. The bars start at the bottom of the box and slope upwards 15° to the back. At the back, there is a combination hammer mill and wood chipper consisting of a heavy rotor with hard-faced teeth that mesh between forced dies. The rotor turns at 300 r.p.m. crushing the hardpan and roots until they pass through the parallel bars.

Wet Milling

The dredge pump discharges into a 24-inch pipeline of 40 foot sections supported on pontoons. These connect the dredge with the floating wet mill. The slurry from the dredge discharges onto two vibrating head-feed screens with $\frac{1}{4}$ inch openings.

The oversize falls by gravity into a hammer mill where lumps of hardpan are disaggregated. The discharge from the hammer mill flows by gravity to a screen with 1-inch openings. The + 1-inch oversize is made up primarily of roots which are discharged into the pond as waste. The undersize is pumped back to the head feed screens. The undersize ($-\frac{1}{4}$") from the head feed screens flows by gravity to two large rougher feed sumps. Concentration is by three stages of spirals. The final concentrate from a 4 percent heavy-mineral feed averages about 85 percent heavy minerals with a recovery rate of about 88 percent. The bulk of the loss consists of coarse-grained silicates and altered, porous leucoxene.

The mixed concentrates are collected in two sumps and pumped by 4-inch pipeline to the land-based dry mill area. Pumping distances up to four miles are achieved. Booster stations are located at 1500 feet intervals along the pipeline.

Dry Plant

The mixed concentrate is cleaned with caustic soda, dried through two oil-fired, countercurrent rotary dryers and passed over high-tension rolls. Magnetic treatment of the conductor fraction gives a so-called ilmenite concentrate containing 89 percent titanium minerals and averaging 64.5% TiO_2; and a rutile - leucoxene concentrate containing 98.5 percent titanium minerals and averaging 80% TiO_2. The overall TiO_2 recovery in the dry plant exceeds 97 percent.

The non-conductors consist principally of staurolite and zircon. Staurolite is removed by high-intensity magnets. The staurolite concentrate assays 45-50% Al_2O_3 and 13-15% Fe_2O_3. It is marketed for use in Portland Cement manufacture where it replaces kaolinite as a source of Al_2O_3 and reduces the amount of slag needed to obtain the 3% Fe_2O_3 required in the cement.

The staurolite magnetic tailings contain 30-35% zircon, 15-20% aluminium silicate minerals and about 50% quartz. The zircon is concentrated by spirals, dired, cleaned magnetically and calcined at 1000°F in an oil-fired kilm.

Land Restoration

A Y-valve at the end of the tail line discharges tailings from alternate sides of the wet plant leaving a gently undulating surface which requires little or no further levelling. Tailings are planted with love grass and slash pine as part of the land reclamation programme.

Reserves

Reserves of the Trail Ridge deposit are given as 540 million short tons of ore averaging 1.5% TiO_2 i.e. about 8 million tons of contained TiO_2.

Folkston (Ga) Deposits

The Humphreys Mining Company operates a small heavy mineral plant at Folkston about 40 miles north of Jacksonville. The deposit is similar to the Trail Ridge deposit except that it is younger, is only 90 feet above sea level, the mineral is far less weathered and the orebody is limited to a depth of about 10 feet. Mining and plant operation is basically the same as used by Du Pont at Trail Ridge. The Folkston plant has a capacity of about 50,000 tons of titanium minerals a year, and produces about 10-12,000 tons of zircon a year and limited tonnages of monazite. Life of the deposits is reported to be about 8-10 years at the current rate of production.

New Jersey Ilmenite Deposits

The Glidden Company of Cleveland, Ohio, has operated an ilmenite plant at Lakehurst in Ocean County, N.J. since 1962. The heavy mineral sands deposit averages 20 feet in thickness and contains 4.5 percent heavy minerals of which 80-85 percent is ilmenite and leucoxene and about 3 percent is rutile. The plant has an annual capacity of about 60,000 tons of titanium minerals.

Virginia Rutile Deposits

In 1959 M & T Chemicals Inc. began production of rutile from their aplite deposit located in the Piedmont plain about 25 miles northwest of Richmond, in Hanover County, Va. The parent rock of the deposit is an aplite rock of gneissic structure. A clay layer covers most of the ore body and below the clay mantle the aplite rock is highly kaolinized and slime losses from this layer may run as high as 50 percent. The titanium mineralization is in stringers, veins, and pods. The principal titanium minerals is rutile with lesser amounts of ilmenite and sphene. The ore is mined to a depth of 40 feet by conventional open-pit methods. The ore is crushed wet in a hammer-mill, ground to 20 mesh in a closed-circuit rodmill and deslimed in cyclones. Gravity separation is in three stages - two stages of spirals followed by

Deister tables. The aplite rock, the chief product of the plant, is removed in the light mineral tailings. Concentrate from the tables is dried and a final product of granular rutile (approximately 97% TiO_2) is produced by magnetic and electrostatic methods. The bulk of the rutile is ground to 325 mesh in a dry ball-mill for use in ceramics. Small tonnages of granular ilmenite are also produced for use principally in titanium alloy production. Flowsheet of the operation is summarised in Figure 2. No statistical data are available concerning production rates, but annual output of rutile concentrates is understood to be between 4,000 and 5,000 short tons.

Tahawus Ilmenite Deposits

The largest known deposits of titaniferous iron ores in the United States occur near Lake Sanford, Essex County, N.Y. The orebody crops out on the side of Sanford Hill overlooking Sanford Lake and is composed of lenticular veins of closely-associated magnetite and ilmenite separated by gabbroic and anorthosite waste zones and inclusions. The deposit is about 2,400 feet long, and has a maximum width of 900 feet. The vertical extent of the body is unknown. The ore averages 32 percent ilmenite, 37 percent magnetite, 16 percent feldspar, and 15 percent ferromagnesian silicates.

National Lead Company has worked the deposits since 1942. The company's flowsheet is summarized in Figure 3.

The ore is extracted by open-pit bench-mining methods. Broken ore is loaded into 22 ton - dump trucks with electric and diesel shovels and hauled to the primary crusher. The ore is reduced to a 9-inch product by jaw and cone crushers. Rodmills further reduce the ore to 28 mesh and magnetite is removed by low-intensity magnetic separators and sintered. The ilmenite-rich fraction is sized with hydrosizers into eight fractions ranging from 20 mesh to minus 150 mesh. The sized fractions are concentrated on gravity tables, dried, and the gangue material removed by high-intensity magnets. The final ilmenite concentrate averages about 45 percent TiO_2.

Production statistics are not available but current production of ilmenite is understood to be about 500,000 tons per annum. Reserves are said to be of the order of 120 million tons containing about 24 million tons of TiO_2.

Allard Lake (Canada) Deposits

The Canadian titanium industry is based on the ilmenite-hematite deposits of the Lac Tio-Allard Lake area of Quebec where reserves are put at a minimum of 150 million tons averaging 35 percent TiO_2 and 40 percent iron. Ilmenite is associated with finely disseminated hematite in dykes, irregular lenses, and sill-like bodies which occur within a large mass of anorthosite. The deposits have been worked since 1950 by Quebec Iron and Titanium Corporation (QIT), owned two-thirds by Kennecott Copper Corporation and one-third by The New Jersey Zinc Company (Gulf and Western Industries, Inc.). Mining is a standard, open-pit operation. The ilmenite - hematite ore is crushed in a jaw-crusher, railed 27 miles to Harve St. Pierre and then shipped 550 miles up the St. Lawrence River to Sorel, Quebec. At Sorel the beneficiated ore is calcined in rotary kilns, to lower the sulphur content, cooled, mixed with powdered anthracite and smelted in electric-arc furnaces. Titanium slag and molten iron ore are tapped intermittently from the furnace. Two grades of titanium slag are produced, a pigment-grade slag containing 70-72 percent TiO_2, and a metal-grade slag running 74-76 percent TiO_2. A representative assay of standard Sorel slag is given below.

TiO_2	70-72%
FeO	12.0-15.0
Metallic Fe	1.5 maximum
SiO_2	3.5 - 5.0
Al_2O_3	4.0 - 6.0
CaO	1.2 maximum
MgO	4.5 - 5.5
Cr_2O_3	0.5 - 0.6
V_2O_5	0.5 - 0.6
MnO	0.2 - 0.5
C	0.03 - 0.10
S	0.03 - 0.10
P_2O_5	0.025 maximum
Ti_2O_3	10.0 - 15.0

The iron, as tapped from the furnaces, contains 1.8 - 2.5 percent carbon, 0.11 percent sulphur and 0.025 phosphorus. In 1967, 538,000 tons of titanium slag and some 366,000 tons of pig iron was produced at Sorel.

Sorel slag is supplied to the two Canadian pigment producers - Canadian Titanium Pigments Limited, a wholly-owned subsidiary of National Lead Company, operating at Varennes, Quebec, and Tioxide of Canada Limited, a wholly-owned subsidiary of British Titan Products Company Limited, operating at Tracy, Quebec. Significant tonnages are also shipped to United States' pigment producers (New Jersey Zinc and American Cynanamid) and to European pigment producers. Sorel slag has been the favoured raw feed for TiO_2 pigment plants in areas where disposal of effluent has been a major problem associated with the sulphate process. However, with the swing to chloride-process plants, some erosion of the market for Sorel slag is likely and Q.I.T. is currently investigating the possibility of beneficiating slag to a grade which would be acceptable to pigment producers employing a chloride process.

TiO_2 PIGMENTS

It is noteworthy that all the pigment producers interviewed in the course of the tour were most reluctant to provide details of the flowsheets adopted for the production of TiO_2 pigments. Although they were most willing to discuss production and consumption trends, the various company representatives were not at liberty to make available specific information concerning their pigment plants. In fact, company policy disallows visits to plants employing a chloride process for the production of TiO_2 pigment. This policy is fairly general throughout the chemical industry in the United States where the high-competitive nature of the industry causes operators to be extremely conscious of leakage of information.

In general, the sulphate process involves the digestion of titaniferous ore (usually ilmenite or Sorel slag) in sulphuric acid with the formation of titanyl and ferrous sulphates. The temperature of the solution is reduced and the ferrous sulphate separated out by fractional crystallization. The filtrate is hydrolysed and the titanium hydrate precipitate is filtered, dried and calcined to titanium dioxide. In contrast to the sulphate process, the chloride process is conducted under substantially dry conditions and many of the operations are carried out in the vapour phase. Briefly, finely divided rutile and coke are chlorinated using a fluidised bed technique at temperatures in the range of 850-1000°C. The resulting titanium tetracholoride is condensed and separated from impurities (mainly chlorides of iron, vanadium, sodium, calcium, magnesium, and tin) either chemically or by fractional condensation. The titanium tetrachloride is burnt to titanium dioxide with the recovery of chlorine. Although the chemistry of both processes is relatively simple, the recovery of TiO_2 and its subsequent treatment to provide a saleable product requires a high degree of technological expertise, particularly in the case of the chloride process.

Current Capacity and Future Expansion

Details of TiO_2 pigment plants in the United States and Canada are summarised in Table 1.

The United States is by far the world's leading producer and consumer of TiO_2 pigments. Capacity currently installed is estimated to be about 750,000 short tons of which about 200,000 tons is based on a chloride process. Up to now, no plans have been announced to expand sulphate-route capacity which is expected to remain at the current level of about 550,000 t.p.a. In contrast, plans are in hand to expand chloride-route capacity to about 270,000 t.p.a. by 1970. Thus, by the early 1970's, about one-third of installed TiO_2 pigment capacity in the United States projected to 820,000 tons, will probably be based on a chloride process. It should be noted that currently, rated installed capacity is significantly higher than effective installed capacity. With the advent of chloride-process pigment, consumers have become more exacting in regard to product specification, and as a result a proportion of installed capacity at most sulphate-route is now no longer effective.

Sources of Raw Material

It is obvious from Table 1 that TiO_2 pigment producers in the United States who use a chloride-type process are virtually dependent on Australian supplies of rutile. The exception is du Pont who uses some Florida "rutile" in its New Johnsonville plant. Pittsburgh Plate Glass will no doubt use rutile from Sierra Leone in its Natrium plant. However, production from Sierra Leone will in effect be captive to Pittsburgh Plate Glass and to British Titan Products, and pigment producers understandably prefer to obtain supplies of titaniferous ore from sources other than those controlled by their competitors in the pigment field. In contrast, pigment producers using the sulphate-route are well supplied from indigenous sources of titaniferous material either in the form of raw ilmenite or as Sorel slag. However, a few producers, notably American Cynamid Co., with only limited ilmenite resources of their own continue to import significant tonnages of ilmenite from Australia.

As far as future supplies of raw material for the TiO_2 pigment industry is concerned, it is fairly clear that Australian supplies of natural rutile will be unable to fully satisfy projected demand. By the mid-1970's United States requirements of rutile for this use will alone be of the order of 300,000 tpa (world rutile requirements for pigment could be of the order of 400,000 t.p.a. by then); and this does not take into account rutile requirements for the expanding titanium sponge industry nor the increased consumption of rutile for electric welding rod coatings. Australian output of rutile is not expected to increase much above 300,000 t.p.a. and, on present performance, Sherbro Minerals Ltd. in Sierra Leone will have some difficulty in achieving its goal of 100,000 t.p.a. By and large, beneficiated ilmenite, or other forms of synthetic rutile, will become increasingly inviting as feed, particularly for TiO_2 production by a chloride process. Shipments of beneficiated ilmenite have been made from Western Australia on a semi-commercial scale, and pigment producers both in Europe and in the United States are currently testing this material. Results of tests to date are reported to be most encouraging. As might be expected, large, integrated U.S. producers, notably du Pont and National Lead, are working on upgrading processes, using ilmenite concentrates produced from their own mines, as the basic feed.

Chloride versus Sulphate Process

Having in mind the impact that development of the chloride process for TiO_2 production has had on the Australian rutile industry and the potential of chloride-process pigments as an outlet for upgraded ilmenite produced in Australia, it is pertinent to examine the views expressed by TiO_2 pigment producers regarding the competitive position of the relatively new chloride process vis a vis the more orthodox sulphate-route process. Advantages and disadvantages of the chloride process are summarised below:

Advantages: (1) Lower capital cost. Data are not available concerning the capitalization involved in the two processes, but it is generally accepted within the industry that capital costs of a chloride-process plant are significantly lower than those of a sulphate-process plant which, depending on the scale of the plant, may be as much as $2,000 per installed ton-capacity.

(2) Lower operating costs. With Australian rutile available at about $100 per ton c.i.f. (contract price), and with low-cost by-product reagents (e.g. chlorine), operating costs of chloride process plants are appreciably lower than those of sulphate process plants. Sulphate plants have been placed at a greater disadvantage in this regard with the increase in sulphur prices and the concomitant rise in sulphuric acid costs.

(3) Flexibility in scale. It is generally accepted that sulphate process plants require an operating capacity of at least 50,000 t.p.a. to achieve worthwhile economies of scale. Optimum capacity of chloride-process plants is said to be as little as 20,000 t.p.a. In fact, it is possible that chloride-process plants of 2-3,000 t.p.a. will be operated using purchased titanium tetrachloride.

(4) Higher-grade pigment. Despite improvements achieved in producing higher grade pigment by the sulphate process, chloride-process pigment continues to be regarded as the highest grade of TiO_2 pigment available.

(5) Lack of effluent problems. The sulphate process is bedevilled, particularly in urban areas, with the effluent problem associated with the disposal of ferrous sulphate. Ferric chloride constitutes the only effluent problem of the chloride process, and, if a high TiO_2 ore e.g. rutile is used, the volume of ferric chloride produced is negligible.

Disadvantages: (1) Restricted supply of raw material. Until beneficiated ilmenite is proved to be suitable, economic feed for the chloride process, the process is restricted to natural rutile, supplies of which, as pointed out above, are not adequate to meet future demands.

(2) Requirement of high degree of technological expertise. Many years of research and millions of dollars have been spent on the development of chloride processes with varying degrees of success. Of the five chloride-process plants commissioned in the United States in recent years, only three (those of du Pont, National Lead and American Potash and Chemical Corporation) are fully functional. Those of Cabot Corporation and American Cyanamid are currently shut down pending plant modification.

(3) Product limitation. To all purposes and intent the chloride processes produce one grade of TiO_2 pigment and this is a particularly high quality one. In contrast, the sulphate process allows for a wide range of pigments of varying grades. Basically, the sulphate process produces an anatase-type pigment which can be further processed to the better-quality rutile-type pigments. The chloride process produces a rutile-type pigment, direct.

(4) Market limitation. The overall market is restricted for chloride-type pigment because of the exceptionally high quality of the pigment. In contrast, sulphate-process pigments are adequate, cheaper and preferred for many uses where a high-quality pigment is not necessary. In the United States, chloride-process pigment is used principally in high-quality paints which comprise only about 15 percent of the overall market for TiO_2 pigments.

TITANIUM METAL

As is the case with TiO_2 pigment plants, a high degree of secrecy is maintained at plants producing titanium sponge in the United States. However, the writer was given a conducted tour through most of the Henderson plant of Titanium Metal Corporation of America (TMCA). TMCA is the leading world producer of titanium sponge. Plant operations are described below.

Titanium Metal Corporation of America

The plant is situated at Henderson about 15 miles south of Las Vegas. The plant was originally commissioned during World War II as a magnesium producer and is strategically situated in the midst of a chemical complex which includes Stauffer Chemicals, a chlorine producer, and Dow Chemicals, a leading supplier of magnesium. TMCA reconstructed and extended the original magnesium plant; the magnesium cells are still in operation but this section of the plant is now reaching absolescence.

At the Henderson plant titanium tetrachloride is produced by the fluidised-bed technique from the chlorination of rutile and finely divided coke. The $TiCl_4$ is reduced to sponge by bubbling the gaseous tetrachloride through molten magnesium. Magnesium and chlorine are recovered electrolytically from the resultant magnesium chloride. TMCA has recently commissioned a pilot-plant for the electrolytic production of titanium metal; but the process is on the secret list and no details are available.

At Henderson, titanium sponge and titanium scrap is melted in electric furnaces, the melt cooled in water-jacketed moulds and cast into billets and ingots of up to 5 tons. Specifications for titanium in aircraft components requires double melting of the sponge. The bulk of production is shipped from Henderson in the form of a titanium - vanadium - aluminium alloy.

Production capacity and future expansion

Details of production capacities of titanium sponge plants in the United States and of expansional plans are summarised in Table 2. U.S. sponge capacity of about 20,000 t.p.a. is expected to increase to at least 30,000 t.p.a. by 1970's. Estimates of world requirements of titanium sponge in the early 1970's differ, but generally fall between 35,000 and 40,000 tons. In the United States, immediate demand for titanium has fallen off, due in the main, to a slowing down in the S.S.T. programme. According to TMCA, orders for the supersonic jet programme involving delivery in 1968 have now been put back to the latter half of 1969.

Choice of Raw Materials

In the United States, titanium sponge is produced exclusively from Australian rutile. TMCA attempted to use Florida "rutile" in the Henderson plant, but the high iron content and other impurities of this feed made it unsuitable for sponge production. Japanese sponge producers have based their industry on titanium slag, nut are now reported to be switching to natural rutile as the main source of raw material. Total output of rutile (about 15,000 t.p.a.) from the Tin Can Bay plant of Queensland Titanium Mines Pty. Ltd. is shipped to Henderson for sponge production. Rutile output by QTM is to be increased eventually to 25,000 t.p.a. to meet increased demand by Titanium Metals Corporation.

Requirements of feed for sponge production are most stringent. Assays for calcium, magnesium, sodium and potassium must be negligible as these elements form non-volatile chlorides in the chlorination process, the chlorides forming a coating around the rutile grains and hindering the formation of $TiCl_4$. Low concentrations of aluminium, silicon, iron, tin, zirconium and even chromium are permissible as the chlorides and oxychlorides of these elements are volatile and can be separated from the $TiCl_4$ by fractional distillation. The exception is vanadium, which forms an oxychloride with a boiling point close to that of $TiCl_4$, and which involves chemical treatment for its removal.

Titanium sponge plants are normally associated with chemical complexes which ensure a cheap supply of chlorine for $TiCl_4$ production, and ready availability of magnesium (or sodium) for the subsequent reduction of the tetrachloride to titanium sponge.

Costs

Titanium sponge production is a capital intensive business. Of course, the exact capitalisation of plant involved depends to some degree on such variables as scale of production etc., and estimates of capital costs range upward from $3,500 per installed ton capacity of sponge. Electricity costs are also an important item with electricity required for most stages of the process - chlorination, melting of sponge and final recovery of magnesium and chlorine. Unit electricity costs for TMCA are understood to be relatively low as the Henderson plant draws power from the nearby Boulder Dam scheme.

The product value of the industry is high - of the order of $US3,000 per ton of sponge, and it is understandable that the cost of titanium ore feed is not as critical as in the case of say, TiO_2 pigment: rather, the emphasis is on the grade of ore rather than its cost, and so natural rutile continues to be the feed favoured. However, high-grade beneficiated ilmenite could, in the longer term, augment supplies of natural rutile for this purpose. It is understood that up-graded ilmenite will soon be tested for suitability as an alternate feed to natural rutile for metal production.

Titanium sponge (99.3% Ti) produced in the United States sells for $1.32 per pound compared with a landed price of about $1.25 per pound for Japanese sponge and slightly less than $1.00 per pound for Russian material of similar grade. TMCA maintains that the price of Japanese sponge allows little, if any, profit margin, and they consider that the price of Russian sponge is nothing short of "dumping".

Welding Rod Coatings

A wide range of materials can substitute for rutile in its role as a coating for electric welding rods. Specifications of raw materials used in this role are not nearly as critical as those for pigment and sponge use and titaniferous materials comparatively low in TiO_2 meet welding-rod requirements. Of a total of 326,000 short tons of welding rods containing titaniferous materials in their coatings produced in the United States in 1965, 51 percent contained rutile; 15 percent, ilmenite; 21 percent, a mixture of rutile and manufactured titanium dioxide; 9 percent, manufactured dioxide; 1 percent slag; and 3 percent miscellaneous mixtures. However, the manufacturers contacted pointed out that natural rutile has a combination of chemical and physical properties far superior to those of its competitors, and they see little chance of a major swing away from rutile unless rutile prices increase significantly. However, they agree that beneficiated ilmenite could constitute a serious threat to natural rutile if the price difference in the two materials was sufficient to offset the natural advantages of rutile.

The manufacture of electric welding rods is in the hands of many diversified operators, and it is difficult to obtain precise information concerning current levels of consumption and future trends in demand. However, world consumption of rutile for this use is estimated to be about 100,000 tons per annum, and, assuming that demand will increase concomitantly with general economic and industrial development, consumption of natural rutile, or other titaniferous material should increase to the equivalent of about 140,000 tons of TiO_2 per annum by the early 1970's.

SHERBRO MINERALS LIMITED - SIERRA LEONE

Following a general survey of West African colonies carried out by the U.K. Overseas Geological Survey in the early 1950's during which rutile occurrences were noted in Sierra Leone, Pittsburgh Plate Glass Company and British Titan Products Limited jointly explored and tested rutile deposits in Sierra Leone under an exclusive licence from the Government. Sherbro Minerals Limited was formed by PPG's Chemical Division and British Titan in 1964. Pittsburgh Plate Glass is solely responsible for the management of the Company and holds an interest of 80 percent, the other 20 percent belonging to British Titan. The Company has an exclusive 25 year-rutile mining lease from the Sierra Leone Government with a renewal option at the end of the period.

Full-scale mining operations were commenced in the Gbangbama area about 170 miles south-east of Freetown towards the end of 1966. The company's dredge foundered in late 1967 and dredging operations were not resumed until June 1968.

Geological Environment of the Deposits

The heavy-mineral deposits occur in the Bullom Series, Pleistocene and Recent sediments which form the western coastal plain of Sierra Leone. It is likely that the bulk of the heavy-mineral concentration has been derived from certain facies and sub-facies of the high-grade schists, gneisses and granulites of the Kasila Series. The physical condition of the mineral grains suggests that only limited transportation has taken place, and, as far as the lower sections of the deposits are concerned it is possible that concentration has resulted from in situ weathering and re-working.

Mineral Composition

The predominant mineral of the Gbangbama and Lanti heavy-mineral assemblages is rutile which comprises up to 80 percent of the heavy-mineral concentrate. Ilmenite is present to the extent of 10-15 percent. In general, the amount of zircon which does not appear to be related to the rutile content, is fairly constant, and seldom exceeds about 5 percent of the heavy-mineral fraction. Garnet, kyanite, sillimanite and epidote make up the bulk of the "others". Tourmaline, staurolite, corundum, sphere, pyroxene, monazite, magnetite and chromite occur only in the form of rare grains. Limonite occurs as separate grains and as a coating on other mineral grains.

Reserves

Measured and indicated reserves of rutile are put at 12 million tons. Original drilling was carried out by means of a hand auger on a 200' x 200' grid. It seems likely that there was considerable salting of samples particularly those taken from the lower sections of the holes. Drilling is now being undertaken to depths of up to 60 feet with a mechanical core-barrel type of drill and over a much closer grid. Other depositional basins, similar to Gbangbama and Lanti are known and are potentially rutile-bearing.

Mining

Mining to a depth of 50 feet is carried out with a suction dredge floating in a pond supplied with water from the nearby Jong River. The dredge is fitted with a large cutter head, but, because of the tough nature of the ground, the head often has to be replaced in as little as one week. Two monitors have now been fitted to the dredge, and these are proving moderately successful particularly in the softer areas. However, they are ineffective when dealing with the bands of laterite which eventually collapse in on the cutter-head sometimes resulting in severe damage to the A frame supporting the cutter-head axle. Bulldozers are now being used to push the relatively unconsolidated, upper section of the ground into the dredge pond, and to rip out the laterite bands. It appears that the orebody cannot be effectively exploited by means of suction dredging alone. Selective mining with either a section dredge or bucket dredge in combination with a walking drag-line or other forms of earth moving equipment, would appear to be the answer.

Wet Concentration

The wet plant is supported on two floating barges connected in series with the dredge pontoon. The first barge carries two nests of de-sliming cones. Clay constitutes a major problem in the recovery of heavy mineral. The more sandy sections of the orebody contain up to 20 percent of slimes and the slime content of the clayey sections is in excess of 50 percent.

The de-slimed feed is pumped to the concentration barge proper where the -22 fraction is concentrated by means of Reichert cones and spirals to a heavy-mineral concentrate containing about 15 percent quartz. Although the dredge has a rated capacity of 1400 t.p.h. the actual feed to the cones, after laterite, clay balls, and pebbles etc. have been eliminated, is reduced to about 430 t.p.h. The original ore averages about $1\frac{3}{4}$ percent rutile; feed to the cones contains about 4% rutile by weight and represents a recovery of about 70 percent.

Dry Plant

The wet concentrate is pumped to the land-based dry plant where it is acid cleaned and dried in an oil-fired rotary kiln. The dried mixed concentrate is sized into a +60 and -60 fraction in the approximate ratio of 1:3. The sized fractions are separated by standard electrostatic and electromagnetic methods into a rutile concentrate (95-97% TiO_2), a zircon-quartz-garnet tailing, and an ilmenite concentrate which is stockpiled.

Transportation

Rutile concentrate is hauled in covered diesel trucks over 16 miles of road to docks at Niti on the tidal Gbangbama Creek. Stored in silos it is loaded by conveyor belt into 2,000-ton covered hopper barges which are towed by a special loader barge some 18 miles to deep water for loading into ocean-goings ships anchored in the Sherbro Estuary.

Production - Current and Future

Production statistics are not available. However, the company advises that during the first year of operation i.e. 1967, the plant operated at about 30% efficiency. This would suggest an output of about 30,000 tons of rutile in 1967. The dry plant is now producing about 75 tons of rutile a day - an annual rate of about 27,000 tons. It is therefore unlikely that production in 1968 will exceed 20,000 tons. Company representatives are of the opinion that planned output of 100,000 t.p.a. will not be achieved until 1970.

Original plans were to eventually expand production to 200,000 t.p.a. If in fact a production rate of 100,000 t.p.a. is achieved there is no reason from an operational point of view why this rate should not be doubled. The mining section of the operation currently constitutes the main bottle-neck. Capacity of the dry plant can readily be expanded to meet increased production from the dredge when this is achieved. However, the operating company is very wary of future political developments in Sierra Leone. Currently, anti-Western propaganda is on the increase and with future nationalisation of the country's mines a real possibility, Sherbro Minerals have no firm plans for the expansion of production capacity above 100,000 t.p.a.

CONCLUSIONS

The principal findings of the tour are summarised below.

(1) Production of heavy mineral from alluvial deposits in the United States presents no threat to the Australian mineral sands industry. Ilmenite reserves in Florida and Georgia are large, but the grade of ore is comparatively low - about 3 percent compared with say 20 percent worked in Western Australia. The mineral-bearing sands in Florida are badly indurated, necessitating pre-treatment with caustic soda. No true rutile concentrate is recovered from the deposit; a non-magnetic fraction composed mainly of leucoxene and assaying about 80 percent TiO_2 is produced as a co-product of ilmenite. The only production of rutile concentrate in the United States is that recovered from hard-rock mining operations at Beaver Dam, Va. Production from this source is less than 5,000 tons per annum. The U.S. Government is very conscious of the lack of indigenous sources of rutile, and a large-scale Government-sponsored exploration programme has been initiated in an attempt to make up this deficiency. Exploration has resulted in the discovery of a promising hard-rock, rutile-topaz deposit near Denver, Colorado.

(2) Huge deposits of massive ilmenite occur both in the United States (Tahawus, N.Y.) and at Lake Allard in Canada. However, the ilmenite is comparatively low in titanium dioxide (45% TiO_2 compared with say 54-60% TiO_2 of Australian ilmenites, and the extra treatment associated with the crushing and sizing of the ore to liberate the ilmenite from the accompanying iron ore (or the costs of electric smelting), makes for high-cost operations. Profitable exploitation of ilmenite from these sources is, to a large extent dependent on an assured market for the iron ore or pig iron, as the case may be.

(3) In the United States particularly, there has been a sharp swing from the sulphate method for the production of TiO_2 pigments (based on ilmenite) to the more recently - developed chloride process (based on natural rutile). By the early 1970's it is estimated that about one-third of projected capacity for TiO_2 pigment production, will be based on a chloride process. Domestic pigment producers accept that supplies of natural rutile will not be sufficient to satisfy future requirements and pigment producers are vitally interested in the development of a competitively-priced, beneficiated ilmenite. The Western Australian ilmenite producer, Western Titanium N.L., is the acknowledged leader in this field. However, integrated operators in the United States e.g. National Lead Co. are actively engaged on research in this field.

(4) Demand for titanium metal in the United States has not come up to immediate expectations, due mainly to a slowing-down of the S.S.T. project. There is excess production capacity for titanium sponge and domestic sponge producers are apprehensive of cheap Russian and Japanese metal flooding the United States' market.

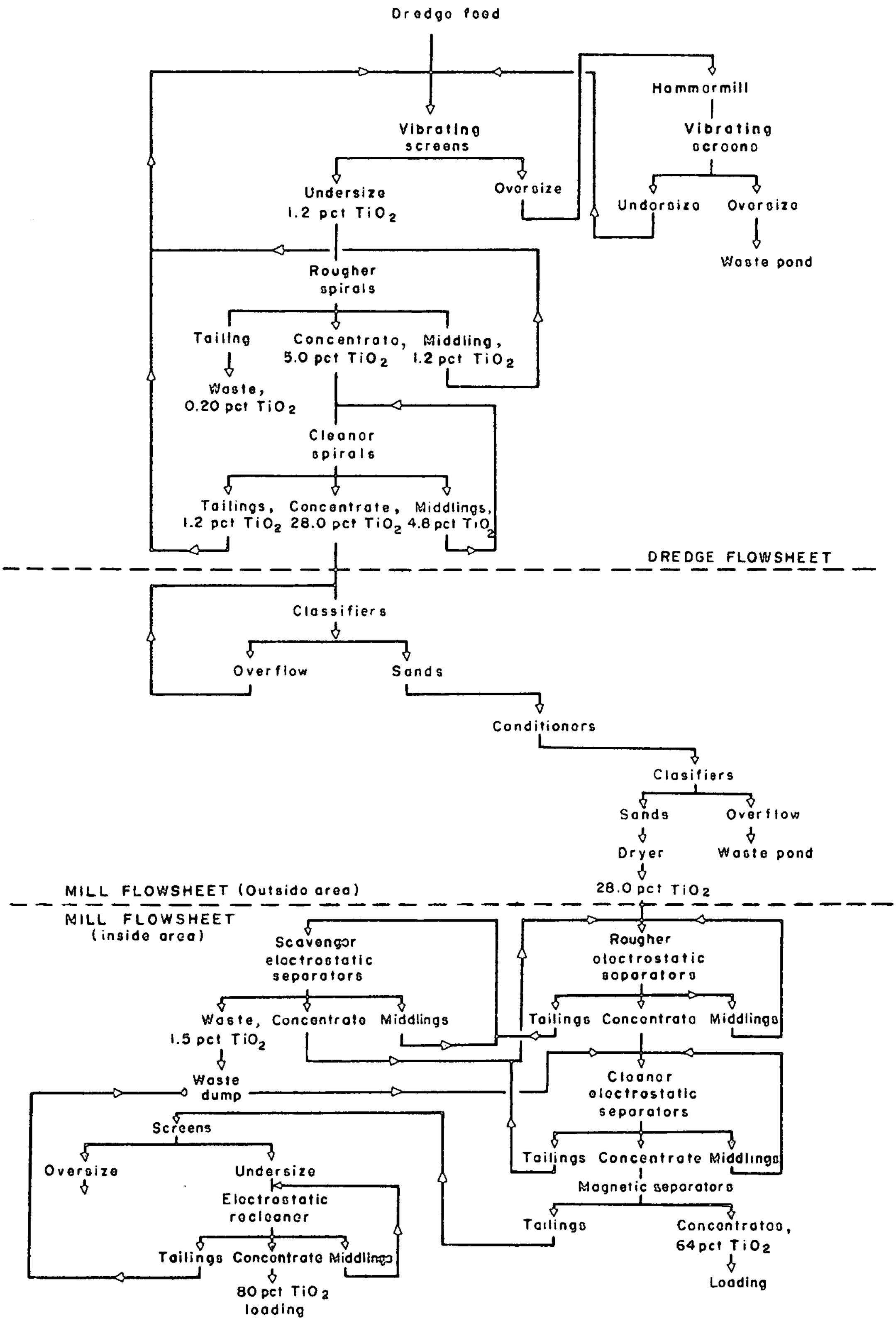
(5) In Sierra Leone, Sherbro Minerals Ltd. is developing an alluvial deposit which potentially is a major world source of rutile. The grade of ore is high (about 2 percent rutile compared with say 0.3 - 0.5 percent rutile in Australian beach sand deposits); and reserves are large - of the order of 12 million tons of rutile. However, the occurrence of extensive beds of laterite results in major difficulties in the mining operation and recovery of rutile is poor because of the high percentage of clay in the ore and the consequent slime problems involved. Also, the ore contains only a minor amount of zircon which, in Australian deposits, makes a significant contribution to the value of the ore. Production initially was planned for 100,000 tons of rutile per annum, but production in 1967, the first year of operation, was about only 25-30,000 tons. Company representatives are of the opinion that output of 100,000 t.p.a. will not be achieved until 1970. The ultimate capacity of the plant was originally seen as 200-300,000 tons of rutile per annum. However, the political climate in Sierra Leone is currently anti-West, and Sherbro Minerals Ltd. is hesitant to sink additional capital into the project.

TABLE 1 TiO_2 PIGMENT PRODUCTION CAPACITY IN NORTH AMERICA

COMPANY	LOCATION OF PLANT	CURRENT ANNUAL CAPACITY (SHORT TONS)	PROCESS USED	TYPE OF FEED	REMARKS
UNITED STATES					
National Lead Company	Sayreville, N.J.	167,000 36,000	Sulphate chloride	ilmenite rutile	National Lead Co. uses ilmenite from its own operation at Tahawus and rutile from its Australian subsidiary Mineral Deposit Ltd.
	St. Louis, Mo.	108,000	sulphate	ilmenite	
E.I. du Pont de Nemours & Co. Inc.	Edgemoor, Del.	75,000 15,000	sulphate chloride	ilmenite rutile	Du Pont uses ilmenite from its Trail Ridge deposits and rutile from Rutile and Zircon Mines (Newcastle) Ltd. augmented with leucoxene from Trail Ridge.
	New Johnsonville, Tenn.	68,000	sulphate and chloride	ilmenite rutile and leucoxene	
	Baltimore, Md.	56,000	sulphate	ilmenite	Sulphate process is to be discontinued at the Baltimore plant.
Glidden Corporation	Hawkins Point, Md.	56,000	sulphate	ilmenite	Ilmenite from Lakehurst, N.J. alluvial deposits 25,000 ton capacity to be installed using chloride process under licence from AMPOT. To be commissioned in 1970 and will use rutile supplied by Rutile and Zircon Mines (Newcastle) Ltd.
American Cyanamid Co.	Savannah, Ga.	72,000 20,000	sulphate chloride	slag and ilmenite rutile	Uses Sorel slag and Australian ilmenite. Rutile supplied by Cudgen R-Z Ltd.
The New Jersey Zinc Company	Gloucester City, N.J.	46,000	sulphate	Sorel Slag	Supplied by Q.I.T.
American Potash and Chemical Corp.	Hamilton, Miss.	30,000	chloride	rutile	Supplied by Associated Minerals Consolidated
Cabot Titania Corp.	Ashtabula, Ohio.	20,000	chloride	rutile	Supplied by Murphyores.
Pittsburgh Plate Glass Company	Natrium, W.Va.	-	chloride	rutile	20,000 t.p.a. chloride plant to be on stream in 1969 using rutile from Sierra Leone.
Sherwin Williams Co.	Ashtabula, Ohio	-	chloride	rutile	Chloride process under licence from du Pont due to start 1969-70 using rutile supplied by R & Z Mines (Newcastle) Ltd.
CANADA					
Tioxide of Canada Limited	Ville-de-Tracy, Quebec	27,000	sulphate	Sorel slag	
Canadian Titanium Pigments Limited	Varennes, Quebec	30,000 -	sulphate chloride	Sorel slag ?	A 10,000 t.p.a. extension of the Varennes plant, based on a chloride process is to be commissioned towards the end of 1968. It is possible that beneficiated Sorel slag will be used as the feed.

TABLE 2 U.S. TITANIUM SPONGE PRODUCERS

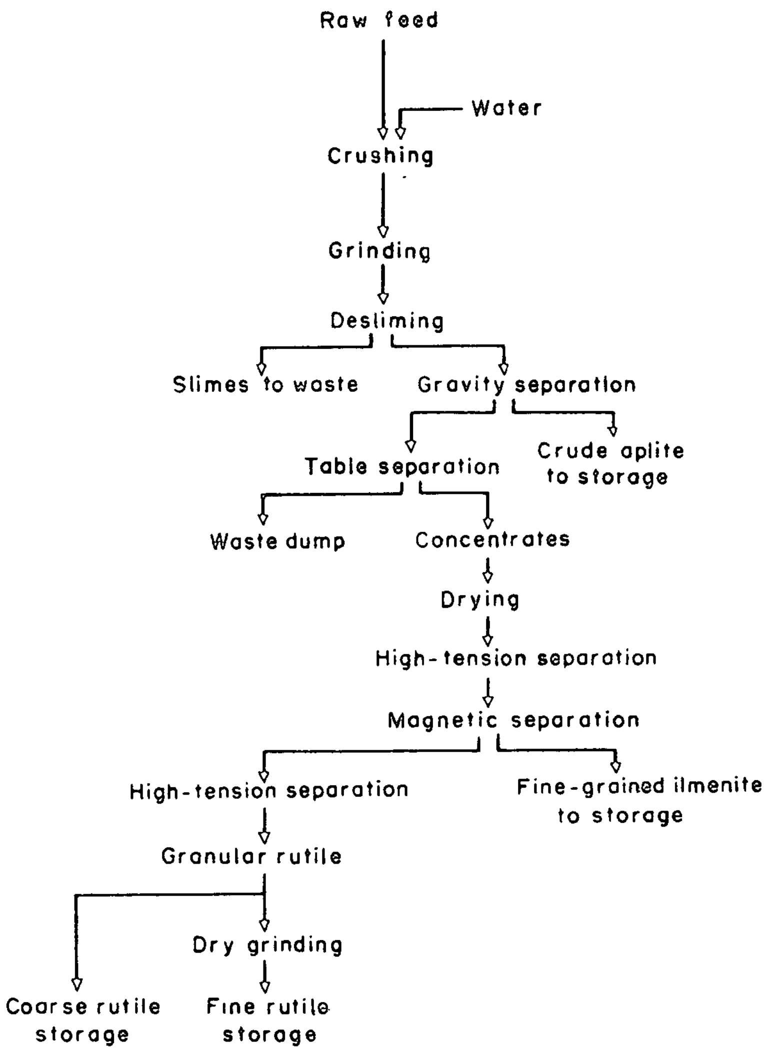
COMPANY	COMPANY CONTROL	LOCATION OF PLANT		ANNUAL CAPACITY (Short tons)		
		Sponge	Mill Products	Sponge	Melt	
Titanium Metals Corporation of America	Owned jointly by National Lead Co. and by Allegheny Ludlum Steel	Henderson (Nev)	Toronto, Ohio	12,000	13,000	Sponge capacity is being expanded to 16,000 t.p.a. Melt facilities are to be expanded to 18,000 t.p.a. by 1969-70.
Reactive Metals Inc.	Owned jointly by National Distillers & Chemical Corp. and by U.S. Steel	Ashtabula, Ohio	Niles, Ohio	6,000	6,000	Sponge capacity is to be increased to 8,500 t.p.a. and melt capacity to at least 9,000 t.p.a. by 1970.
Oregon Metallurgical Corp.	Owned 29% by Armco Steel 23% by Ladish Co.	Albany, (Ore)	Ingot & castings produced at Oregon plant	2,000	3,000	Increasing sponge capacity to 4,500 t.p.a. by mid-1969 and 6,000 t.p.a. by 1970; melt capacity is to be expanded to 4,500 t.p.a. by mid-1968 and to at least 12,000 t.p.a. by 1971.



To accompany Record 1968/83.

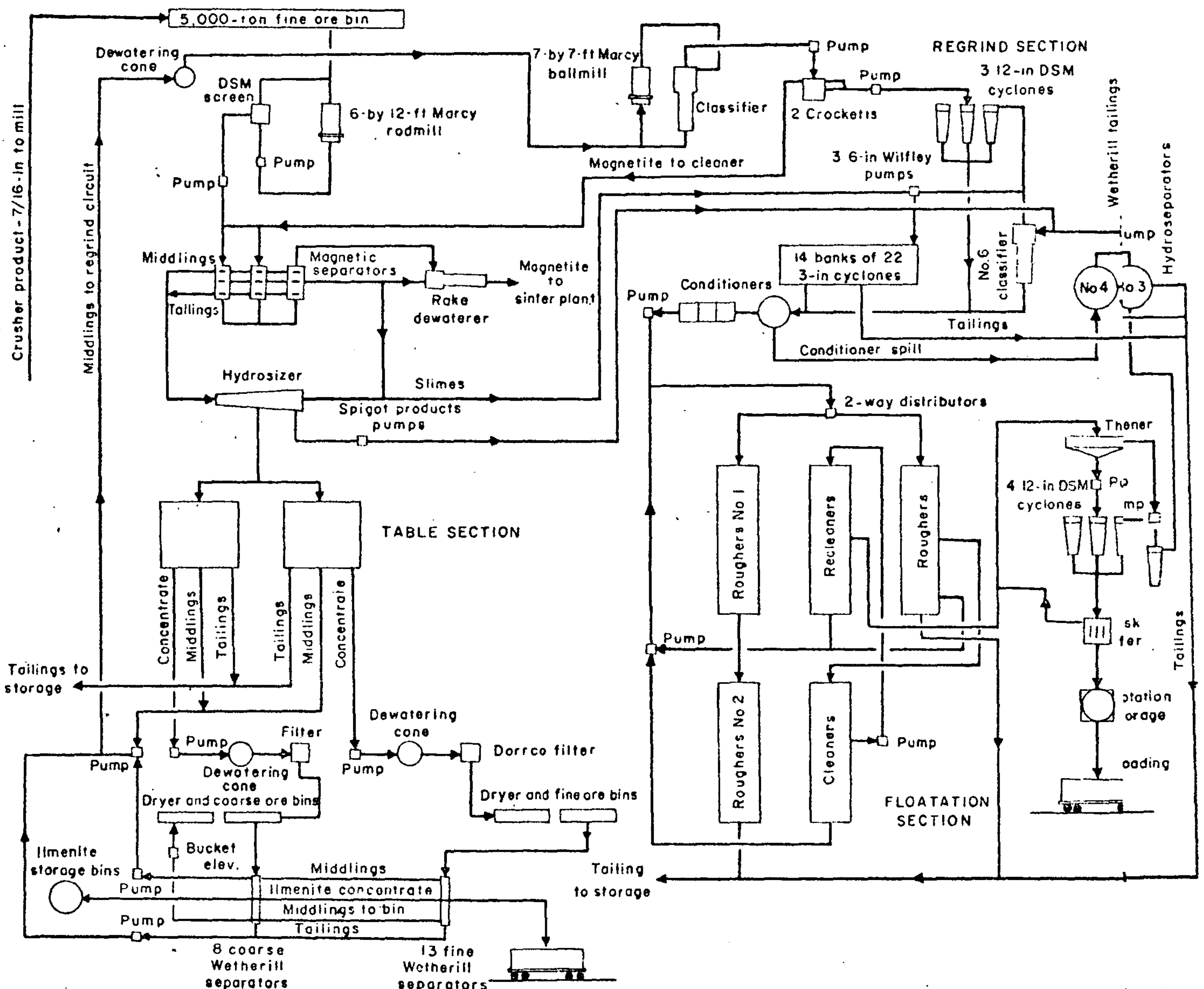
M(E)100 EJ

FIGURE 1. - Flowsheet for Highland Plant of E.I. du Pont de Nemours and Co., Inc.



To accompany Record 1968/83. M(E)101 EJ

FIGURE 2.- Flowsheet of Rutile and Ilmenite Section of M & T Chemicals, Inc., Plant, Hanover County, Va.



To accompany Record 1968/83.

M()102 EJ

FIGURE 3.- Flowsheet for Ilmenite Plant of National Lead Co., Tahawus, N.Y.