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To: Manganese Nodule Report Review Committee

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Mr Temu Okotai* (Deputy Chairman);
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Mr Don Dorrell*;
Mr Raymond Newnham*;
Mr Gordon Davis;
Mr Stuart Kingan;
Capt Don Silk;
Mr Graham Vaugham-Jones;

From: Tap Pryor

Date: 19 July 1996

Ref: Deep-Sea Nodule Mining Prefeasibility Study

Gentlemen:

We have received the attached Executive Summary. Those whose names are starred are also receiving a copy of the limited Final Report. Should anyone else on the above distribution list care to check out a review copy of the Final Report, a few are available in my office for this purpose.

There is no plan to make this public at present. It is presumed that such a release should coincide with a financial commitment from one of the selected sources who have now or will soon receive a confidential review copy.

Kia manuia,

Tap Pryor

The U.S. Trade and Development Agency

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THE GOVERNMENT OF COOK ISLANDS

COOK ISLANDS

DEEP-SEA NODULE MINING PREFEASIBILITY STUDY

July 1996

Job No. 23134-000
Bechtel Corporation
Mining & Metals
San Francisco, CA

This report was funded by the U.S. Trade and Development Agency (TDA), an export promotion agency of the United States Government. The opinions, findings, conclusions, or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position or policies of TDA.

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IMPORTANT NOTICE

This Study is intended for the sole use of the Cook Islands Government (the Client) in support of their consideration of whether and how to proceed with a deep sea nodule mining project in the Cook Islands Exclusive Economic Zone (the Project). This Study is not intended to be or to provide the basis for any credit or other investment evaluation and should not be construed or otherwise considered as a recommendation that any recipient of this Study participate in the financing for the Project.

Bechtel Financing Services, Inc., has prepared material contained in this Study which is believed to be accurate as of its date, with respect to the Project. No representation or warranty, expressed or implied, is made with respect to the completeness, accuracy or validity of this Study or any findings, conclusions, recommendations, information, estimates, projections, assumptions or other material set forth herein or as to any other matter concerning this Study of the Project. The summaries of and references to all documents, statutes, reports and other instruments referred to herein do not purport to be complete, comprehensive or definitive, and each such summary and reference is qualified in its entirety by reference to each such document, statue, report or interment.

This notice must accompany any copies made of this Study.

SECTION 1

SECTION 1
INTRODUCTION

1.1 PURPOSE OF STUDY

The purpose of this prefeasibility study is to examine various aspects of exploiting the deep-sea polymetallic nodule resources in the Cook Islands Exclusive Economic Zone. The study deals with the following subjects:

- Harvesting of nodules by the use of modern bottom trawling technology
- Handling and transportation of the nodules to a processing plant
- Examination of various processes of extracting valuable metals from the nodules
- Refining intermediate process products to pure metals
- Development of capital and operating cost estimates for the entire operation
- Development of a financial model for the project and performing a financial analysis of the project economics, including sensitivity studies
- Generating a plan for exploration, sample collection, equipment and process testing as necessary for the performance of basic engineering design and the development of an upgraded capital and operating cost estimate for the project
- Development of a schedule for the engineering, procurement, construction and preoperational testing of all facilities

This study does not deal with the sale of product metals, nor does it attempt to forecast future metal market trends.

Due to the fact that neither nodule samples nor the results of metallurgical testwork - if any had been performed on Cook Islands nodule samples - were available, this study is based on several scientific publications dealing with the Cook Islands deep-sea nodules. The characteristics and presentation of data in scientific papers do not always correspond to the needs of an engineering study. For this reason, in some areas it was necessary to base the conceptual design on interpolations and assumptions. The lack of specific data will be corrected during Phase II of the project.

1.2 SCOPE OF THE PROJECT

The Cook Islands Deep-Sea Nodule Mining Project is a grass-roots project for exploiting the manganese nodule deposits in the territorial waters of the Cook Islands. It can be divided into four phases, as follows:

- Phase I consists of the present prefeasibility study.
- Phase II encompasses exploration work at the target harvesting site, recovery of bulk sample of the nodules, bench testing and pilot-plant testing of the smelting process, plant site selection, designing of the trawl, outfitting a trawler and conducting test harvesting, and establishing the environmental baseline conditions in the harvest area.
- Phase III is the engineering, procurement and construction of the project and preoperational testing of the facilities.
- Phase IV designates full-scale production.

There will be a 3-month period between Phase II and Phase III to update the capital and operating cost estimates contained in this report to a ±15 percent accuracy.

Physically, the project extends into several geographic areas as follows:

- Harvesting will take place in the Aitutaki Passage near latitude 16°S and longitude 160°W. Four dedicated trawlers will be used for harvesting. Each trawler will transfer the nodules into a bulk carrier vessel of about 30,000 tons capacity for transportation to the smelter. There will be three transport vessels employed by the project. One will be stationed at the harvesting site to receive the nodules from the trawlers, while the other two will be sailing to or from the processing plant.

- For the purpose of this study only, the smelter is assumed to be located at Marsden Point near Whangarei, New Zealand. Existing harbor facilities will be used to unload the transport ships. The nodules will be stored at the plant site and reclaimed for smelting. The smelter will utilize coal for the reducing process and elementary sulfur for converting cobalt, nickel and copper to a sulfide matte. The granulated matte will be processed in a hydrometallurgical refinery adjacent to the smelter. The residue of the smelting operation (slag) will be stored at the plant.

1.3 BACKGROUND

The existence of manganese nodules on the ocean floor was discovered about 120 years ago; however, detailed and systematic study of their location, abundance and chemical composition did not commence until the late 1950s. Two developments spurred high levels of activities during the next decade or so. One was the discovery of the existence in the nodules of significant quantities of strategic metals, such as nickel, cobalt and copper, besides the basic iron and manganese. The other was the political instability in prime strategic metal-producing regions, such as the Shaba Province of Zaire.

The result of these two factors was the emergence of numerous exploration and development projects financed by various governments and private organizations. The primary target metals of these efforts were nickel and cobalt. The harvesting of the nodules was proposed to be by means of technologically complex mechanical or hydraulic systems that involved deep-sea submersible robot machinery and plants or similarly complicated devices.

Most of the manganese nodule resources lie in international waters and, ever since the ratification in December 1982 of the Law of the Sea Convention, come under the jurisdiction of the United Nations. The prospect of having to deal with such a complex organization in the course of permitting, the high cost of the harvesting systems, the inherent risks of developing a pioneering technology, and the long prospective payback on investment discouraged most private investors and many governments from pursuing the commercial exploitation of manganese nodules. Nevertheless, several governments, including those of China, Finland, France, Germany, India, Japan, and Korea are still actively engaged in research related to deep-sea mineral resources, including nodules.

During the years 1974 through 1990, the government of the Cook Islands negotiated for and cooperated with exploratory expeditions by several nations and organizations in the Cook Islands Exclusive Economic Zone, which covers an area of approximately 2.5 million km^2. Within this area lie the Aitutaki Passage and the South Penrhyn Basin, both characterized by waters of some 5,000 metres in depth. The seabed there forms a flow channel for cold, mineral-rich, highly oxygenated Antarctic bottom water currents. The combination of these factors and the prevailing high-pressure conditions at the abyssal depths is believed to result in the deposition of metal oxides on solids reaching the seabed and, thus, the formation of metal oxide nodules. The exploratory expeditions in the area of the Aitutaki Passage and the South Penrhyn Basin revealed a great abundance of nodules, which in certain places cover up to 90 percent of the seabed and contain up to 50 kilograms of nodules per m^2. Additionally, nodules in this area contain exceptionally high quantities of cobalt.

In 1993 the East-West Center, Hawaii, performed an assessment of the Cook Islands manganese nodule resources and concluded that the in-place mineable nodules in an area of some 650,000 km^2 in size contain about 32.5 million tons of cobalt. Assuming that only 50 percent of the nodules can be harvested and only 80 percent of the cobalt contained in the harvested nodules can be recovered, the deposits represent 13 million tons of cobalt to be produced. Since the world cobalt consumption amounts to approximately 25,000 tons per year, the Cook Islands cobalt resource by itself could satisfy the current world demand for 520 years. The current value of this quantity of cobalt at a price of US $25.00 per pound is US $710 billion.

The government of the Cook Islands is anxious to utilize the nation's deep-sea nodule resources and obtained a grant from the U.S. Trade and Development Agency for the partial financing of the current study. An equal share of the cost of the study is paid by Bechtel. The prime objective of the study is to identify and investigate novel methods of harvesting, handling and processing the nodules. Novel methods in this context means technologies and processes that have been used in endeavors other than the mineral industry, or in applications within the mineral industry which are not related to nodule processing.

SECTION 2

SECTION 2
SUMMARY

2.1 INTRODUCTION

This study is based on published information relating to the physical and chemical properties of the deep-sea polymetallic nodules on the sea bottom in the Exclusive Economic Zone of the Cook Islands. It is also based on the application of several known and proven technologies used in various endeavors, technologies which are expected to prove satisfactory in applications related to the harvesting, handling and processing of the nodules. The execution plan outlined in this study gives a detailed program for tests to prove the applicability of all of those technologies to a degree that will enable detail engineering, procurement and construction to proceed.

2.2 DESCRIPTION OF OPERATIONS

The harvesting of the nodules, which lie in waters of 5,000 metres in depth, will be by means of trawling the sea floor with special bottom trawls towed by custom-designed, computer-controlled trawlers. Four trawlers will be required to produce 833 tons per day of wet nodules each to meet the requirement of 2,652 tons per year cobalt production. In addition to the cobalt, the plant will produce 1,718 tons of nickel and 955 tons of copper per year. Nodules will be transferred at sea to 30,000-ton transport ships for delivery at the process plant. The base of the harvesting operations will be on Rarotonga in the Cook Islands.

For the purpose of this study, it is assumed that the process plant will be located on Marsden Point near the town of Whangarei, New Zealand. Ships will be unloaded at the existing port facilities into storage ponds which will be constructed for the project.

Reclaimed nodules will be dried in a rotary kiln, then mixed with coal and heated in a second rotary kiln to achieve partial reduction of the contained metal oxides. The sinter product of the reduction kiln will be transferred to an electric furnace for rendering a molten metal alloy consisting of iron, cobalt, nickel, copper and trace elements, on the one hand, and a slag containing manganese and iron oxides, on the other hand. Periodically, the slag will be tapped and granulated for disposal or stockpiling, while the metal alloy will be transferred to one of two rotary converters.

In the converter, the iron will be reoxidized and absorbed in silica flux. In the second step of the refining process, the metal alloy will be contacted with sulfur to convert the metals to a sulfide matte prior to granulation.

The granulated matte will be ground with water in a tower mill and pumped to the hydrometallurgical refinery for the extraction of metals. The chlorine leaching process will be used to dissolve the metal contents of the matte. Solids and liquid separation, solvent extraction and electrowinning processes will be used to remove impurities and to produce refined cobalt and nickel and an unrefined copper powder that will be sold as copper refinery feed. The cobalt and nickel will be of high quality and purity and will be ready to be sold to users.

2.3 CAPITAL COST ESTIMATE

The capital cost estimate is based on the process flow diagrams, plant general arrangement drawings, electrical one-line diagrams, and mechanical and electrical equipment lists. Budget prices were obtained for ships, harvesting machinery and instrumentation, and major plant equipment. In-house historical price information was used for the electrical equipment and some of the other equipment. Yard piping and electrical ducts and conductors were taken off on the basis of the plant layout, while the process piping, conduits and wire, as well as the instrumentation, were factored on the basis of historical data of similar process plants. Construction labor productivity and costs are based on recent construction projects in New Zealand.

Excluded from the estimate are such items as financing charges and interest during construction, escalation, taxes and duties, as detailed in Section 6, Capital Cost Estimate.

Table 2-1 shows the summary of the estimated capital costs.

Table 2-1

PROJECT SUMMARY CAPITAL COSTS

(Costs and Manhours in 1,000s)

	Manhours (hours)	Installation Labor Costs (US $)	Equipment Material & Subcontract Costs (US $)	Total Costs (US $)
Plant Equipment			192,623	192,623
Bulk materials			43,109	43,109
Subcontracts	55		5,100	5,100
Installation labor	1,346	53,798	0	53,798
Total Direct Costs	1,401	53,798	240,832	294,630
Spare parts				4,570
Common distributables				6,920
Ocean freight and inland freight				9,480
EPCM services				31,370
Project insurance				1,730
Contingency				47,400
Total Project Costs				396,100
Phase II work				11,000
Development costs				9,000
Owner's costs				19,000
Total Costs				435,100

2.4 OPERATING COST ESTIMATE

The direct operating cost estimate is based on the following: The schedule of ship and plant operating personnel was built up, relying on past experience with similar operations. Consumable quantities were determined on the basis of the process calculations. Budget prices were obtained from sources in New Zealand, or taken from historical information. Labor costs for the marine operations were obtained from shipping operators, while the plant operator and administrative labor costs were taken from data published by the government of New Zealand.

The cost of royalties, permits and licenses, if any, were excluded from the estimate, as were escalation, possible overtime and the like, as detailed in Section 7, Operating Cost Estimate.

Table 2-2 shows the summary of the estimated operating costs.

Table 2-2

OPERATING COST SUMMARY

	Total Cost (US $/y)
Marine operations:	
Harvesting	7,707,000
Transportation	9,914,000
Subtotal	17,621,000
Smelting:	
Consumables	16,044,500
Labor	2,522,000
Subtotal	18,566,500
Refining:	
Consumables	3,517,410
Labor	838,000
Subtotal	4,355,410
Maintenance labor	2,328,700
General and administration	4,163,500
TOTAL	47,035,110

2.5 FINANCIAL ANALYSIS

Bechtel Financing Services, Inc. developed a computer model of the project commercial operations to test its economic performance. It was assumed that the Owner will fund the project with 30 percent equity and 70 percent debt. The Base Case evaluates the project on a pretax basis with no fees or royalties paid. On that basis, the return on investment (ROI) was calculated to be 22 percent, return on equity (ROE) 29 percent, and the minimum debt service coverage ratio 139 percent. The project economics are highly sensitive to product prices, and potential investors will need to develop price assumptions in concert with metal marketing experts to determine the actual project economic viability.

A sensitivity analysis was conducted to determine the economic impact of changes in the assumed values of selected project assumptions, using ROI, ROE and DSCR as indicators of the project's sensitivity to each particular assumption. For consistency, each assumption was varied by the same percentage amount relative to the Base Case. The factors selected were:

- Capital costs, including vessels and process plant EPC costs
- Operating costs
- Product prices (all products)

The results of this sensitivity analysis are presented in Table 2-3 below.

Table 2-3

RESULTS OF SENSITIVITY ANALYSIS

Sensitivity Factor	ROI (%)	ROE (%)	Min. DSCR (%)
Base Case	22	29	139
Capital cost +15%	20	25	121
Capital cost -15%	25	34	162
Operating costs +15%	21	27	128
Operating costs -15%	24	31	150
Product prices +15%	26	35	170
Product prices -15%	19	22	108

Details of the financial analysis and the sensitivity studies are given in Section 8, Project Economics.

SECTION 3

SECTION 3
MARINE OPERATIONS

3.1 INTRODUCTION

The harvesting of deep-sea manganese nodules has been the subject of R&D work for approximately twenty years. The 1993 East-West Center study "Cook Islands Manganese Nodule Resource Assessment, Economic and Policy Analysis" states that three systems of those that were considered have reached a stage of development where pilot-scale models were tested in an ocean environment. Paraphrasing the more detailed discussion in the report, the systems can be described as follows.

The fluid dynamic Jet Mining Device was developed by the Xenex Corporation of Hawaii. It is based on collection of the nodules by the use of water jets incorporated in a remotely controlled collector. The transportation of the nodules to the surface is via a pipeline, where the lifting power is provided by a venturi-type intake and water jets along the pipe.

The Japanese-developed Continuous Line Bucket system consists of a moving cable loop to which dredge buckets are fastened at certain intervals. The descending leg carries empty buckets, which drag on the seabed where the loop touches down, filling up the buckets along the way. The ascending leg brings up the buckets filled with the harvested nodules. The nodules are emptied automatically into the mining ship.

The French research effort produced a system based on Self-Propelled Miners, which harvest, process and store the nodules before ascending to the surface and linking up with a collection vessel for unloading.

The disadvantages of all three systems are their high capital and operating costs; however, they may be justified when the target harvesting quantity is sufficiently high. This is not the case with the proposed Cook Islands Deep-Sea Nodule Mining Project. The basic criterion for the Cook Islands operation is the production of 2,652 tons of cobalt per year, which represents approximately

10 percent of the current world consumption of the metal. In order to produce such quantities, 1,097,360 tons of wet nodules must be harvested annually.

Because of this relatively low production rate, a consultant of the government of the Cook Islands suggested a simple harvesting method: using trawlers and bottom trawls, such as are used in harvesting bottom-dwelling fish and shellfish. The current study made an evaluation of trawling and then proceeded with the utilization of such a harvesting method. There are elements of uncertainty related to harvesting by trawls, the main one being that bottom trawling has never been done in waters deeper than about 1,200 metres, and the Cook Islands nodules lie at approximately 5,000 metres in depth. Oceanographic research vessels have brought up nodules from those depths in numerous nodule resource sites by the use of dredges, reporting no difficulties with the operation. These sampling operations produced a few hundred kilograms of nodules at a time, far less than required for a commercial operation.

PMB Engineering, Bechtel's marine and offshore entity, evaluated the proposed trawling operation and a basic trawl design provided by a prominent supplier of trawls and fishing gear. It also used sophisticated computer simulation programs to examine the expected behavior of the trawling system, including the trawl rope, during deployment, trawling and retrieval. The studies found the proposed method technically feasible with no fatal flaws; however, they pointed to the need for a rigorous design, testing and evaluation program in the course of the implementation of the project.

In order to satisfy the needs of a commercial operation, properly sized trawls and hoisting winches should be designed and tested prior to the commencement of operations, and certainly prior to a final commitment to the project. In discussing the harvesting process, it is assumed that the testing during the Phase II activities of the project will have proved the described equipment and methods of operation to be sound and practical.

3.2 HARVESTING

The harvesting of the nodules will be by the use of beam trawls towed on the seabed by trawlers. In the harvest area - tentatively located between south latitudes 15° 30' and 16° 30' and west longitudes

159° and 160° - the water depth is approximately 5,000 metres. In order to produce 2,652 tons of cobalt, 1,097,360 tons of wet nodules must be harvested annually. Allowing for 330 harvesting days per year, this necessitates a daily harvesting rate of 3,325 tons.

The trawlers will be approximately 100 metres in length, with a 20-metre beam and 3.5-metre draft. They will be equipped with differential GPS and dynamic positioning systems so as to accurately control movement to the extent of being able to execute fully preprogrammed harvesting cycles. The position of the trawlers will be determined on the basis of the differential GPS, and their movements will be adjusted to ensure that the trawls, while being lowered, will follow a predetermined path relative to the long-baseline reference points (described below). The use of this method is expected to ensure efficient harvesting and to minimize excessive overlaps or unharvested gaps between consecutive harvesting passes. So that the movements of the trawlers can be controlled properly, they will be outfitted with appropriate bow thrusters and servo apparatus to allow computerized control.

The harvest area of each trawler will be demarcated by a number of hydroacoustical transponders attached to weights for anchoring them to the seabed to form a long-baseline array of locators. The location of the transponders will be approximately at the corners of a square with 5,000-metre sides, or as dictated by the bottom terrain, and will be validated by the differential GPS of the trawler. Each transponder is powered by a battery that provides more than one year of service. When a transponder needs to be relocated because the harvesting operation moves on, a signal will be sent to detach it from the anchor, which will cause the transponder unit to float to the surface for collection by the trawler. After recharging of the battery, the transponder will be redeployed with a new anchor.

The trawls will be of the beam trawl design with a rigid front frame of 12-metre opening width. Across the bottom of the opening, a foot chain of heavy steel will be strung with sufficient slack so that it will drag in the top layer of the sediment, or a rake-type bar will be deployed to cause the nodules to bounce up in front of the trawl. The top and sides of the trawl frame will be fitted with hydrofoils to give proper orientation to the trawl (i.e., to keep it upright) during lowering and trawling. The bottom of the trawl net will be made of steel netting to ensure its contact with the bottom, while the sides and top will be made of SPECTRA filament to make it float. The size of the net openings will be 15 millimetres. The bottom will be protected by wear liners to minimize the abrasion damage to the net.

Each trawl will be equipped with a sonar transponder which will query the long-baseline transponders and from their response calculate its own location within a 1-metre radius. The same instrument package will contain an altitude sonar to sense the distance between the trawl and the seabed. Net guard monitors will keep track of the stretch in the net in order to sense the process of filling up with nodules. Although it is possible to communicate the measured data from the trawl to the trawler by wireless hydroacoustical means, the signals travel with the speed of sound, which results in a significant lag. This is not acceptable for proper real-time control; therefore, an electric conduit will be provided inside the hoist cable for the transmission of signals.

Trawling will be at a speed of 1 metre per second (two knots). At such a speed, the rope will extend down at an angle of about 60 degrees from vertical and require a length of about 7,900 metres from the trawler to the trawl. Lowering and raising the trawl will be at a speed of 2 metres per second, which results in a harvesting cycle of approximately 180 minutes, allowing eight trawls per day at 100 percent availability.

Each trawl will be suspended on a SPECTRON™ 12 braided rope with an embedded armored and sheathed electric cable. The weight of the rope, the trawl and the drag forces on the loaded trawl moving through water will add a load on the cable; however, the design will be based on a total payload capacity of 60 tons. The elastic limit of the cable will be selected to provide a sufficient safety factor. Since the specific gravity of the nodules is 2.0, the payload weight in air is 120 tons. The theoretical harvest rate for each trawler is then 960 tons per day.

The trawlers will be designed to take on a nodule load of 2,500 tons, which represents 2.6 days of continuous harvesting. At the end of that period, the trawler will rendezvous with a transport ship and transfer its cargo by pumping a mixture of seawater and nodules, using a Marconaflo pump installed in the nodule hold of the trawler. The time required for meeting the transport ship, transloading the nodules, and returning to the harvest area is estimated to be 9 hours (0.4 day). Each trawler's average productivity is 2,500 tons in 3 days, or 833 tons per day. This rate will yield 3,332 tons of nodules per day, which is slightly over the 3,325 tons of metallurgical balance requirement.

The harvesting operation is envisioned, subject to trial harvesting, as follows: The trawler will get into position using its GPS instrumentation such that, proceeding at a predetermined speed and direction, the trawl will be at the designated starting point of the harvesting pass when it reaches the seabed. The position of the trawl will be monitored through the combination of the differential GPS and long-baseline hydroacoustical positioning system and fed into a database. The trawler will stop at the beginning of the trawl pass and use the cable winch to reel in the cable and move the trawl in the direction of the trawler. During this operation, the propulsion system of the trawler will be used to maintain the trawler's position. The operation will proceed until the trawl is loaded. At that time, the trawler will turn around and backtrack while recovering cable until it is positioned directly over the trawl. The position of the end of the harvesting pass is entered into the database for future reference. The trawler then proceeds to raise the trawl. The load of nodules will be dragged onto the deck and emptied into the nodule-receiving pit located in the stern, while the trawler returns to a position to initiate the next harvesting pass. The passes will be determined in advance to suit the overall harvesting plan. During the deployment, trawling and recovery of the trawl, a drag conveyor automatically will transfer the nodules from the receiving pit to the nodule hold.

The trawl is essentially a passive device; its behavior depends on the setting of its hydrofoils, the speed of the trawler, and the speed and direction of the currents. If these factors are consistent, then the behavior of the trawl is predictable and consistent. At the beginning of a campaign, several harvesting test runs are expected to be necessary to fix the spatial relationship between the trawler and the trawl during harvesting passes. Once this relationship is established, the passes are expected to be quite consistent and the position of the trawler can be adjusted from pass to pass to achieve an acceptable harvesting pattern that results in a high nodule recovery rate.

Two options have been considered regarding the fleet of trawlers. One involved the acquisition of used trawler vessels and their conversion for the purpose of nodule harvesting. The other consisted of custom building special-purpose harvesting trawlers. For the purpose of this study, the second case was selected for very practical reasons. The only advantage of buying and converting used trawlers is the possibly lower initial investment, although the purchases would have to be made in a volatile market. The disadvantages of used vessels are several. The vessels are likely to be of different design, size and construction. The conversion would involve separate design and retrofit work for each vessel, and the dissimilar physical shape would necessitate separate analysis and programming for the dynamic positioning systems. Their propulsion plant and machinery also are likely to be different. This fact would have a negative impact on the operation of the fleet, as they would affect maintenance and spare parts inventory. For the same reason, the crews would not be fully interchangeable, which would create logistical problems. With new vessels designed for the specialized functions of nodule harvesting, the above disadvantages would not exist. An additional advantage would be that with proper maintenance, the new vessels are likely to provide service for twenty to twenty-five years.

3.3 ENVIRONMENTAL IMPACT OF HARVESTING

Any mining operation will have an impact of some degree upon the environment. The disturbance can encompass the localized destruction of flora and the habitat of fauna, the introduction of foreign agents into surface waters, and the emission of particulate matter into the air which later settles out to cover potentially large areas.

Harvesting deep-sea nodules also will have an impact on the benthic environment. The trawl will be towed upon the surface of the seabed and will disturb the top layer of the sediment. This action will result in the harming or destruction of life along the path of the trawl. During harvesting, sediment will be picked up by the trawls in addition to the nodules. Most, if not all, of this sediment is expected to be washed away during the raising of the load. This particulate matter will be suspended in the water column for a period of time before settling back onto the seabed. Tests conducted during the Deep Ocean Mining Environmental Study (DOMES) of the National Oceanic and Atmospheric Administration indicate that the extent of the plume is smaller than had been expected, and the effects of sediment settlement do not appear to have a potential for significant or adverse impact.

There are factors that tend to mitigate the adverse effects of the proposed Cook Islands nodule harvesting. Due to the long distance between trawl and trawler, it is very unlikely that the harvesting passes can be controlled with such accuracy that the consecutive passes will form a contiguous disturbed area. It is expected that strips of undisturbed areas will be left between passes where, except for the settling out of the stirred-up sediment, the seabed will be unaffected. These areas are likely to act as recolonization seed patches for marine fauna.

Additionally, the area of harvesting will be small relative to the 650,000 km^2 size of the nodule-bearing area. At the planned harvesting rate, 110 km^2 will be harvested annually. For each of the four trawlers, this represents an area of 5.2 km^2. During an assumed 25-year harvesting operation, the total harvested area will be about 3,000 km^2, which is less than 0.5 percent of the entire nodule-bearing area.

It is reasonable to state that the disturbance of such a small portion of the seabed over such a long period of time will have an insignificant overall environmental impact.

3.4 TRANSFER OPERATION

Consideration was given to transferring the harvested nodules to bottom-dumping barges and transporting them to Aitutaki Atoll for a nodule storage, reclamation and shiploading facility to be established in shallow water. This scenario was eliminated from consideration in favor of transferring the nodules directly into transport vessels at the harvesting site. The main reasons were as follows:

- Transfer to barges offers no advantage over transfer to transport ships.
- Using direct trawler-to-transport-ship transfer eliminates the need for a barge fleet.
- There would be no need to establish a costly near-shore facility for handling nodules and loading ships, resulting in lower capital and operating costs and the avoidance of any environmental impact on the island and the surrounding lagoon.

The transfer of the nodules from the trawler will by means of a special pumping system. In order to achieve this, the hold of the trawler will be built with the bottom sloping toward the center, where a Marconaflo pump will be installed. The Marconaflo pump unit consists of a vertical slurry pump and high-pressure water jet nozzles that rotate in a horizontal plane. When in operation, a high-pressure pump supplies water to the nozzles, which shoot streams of water at the nodules, flushing them toward the intake of the slurry pump. The water, together with the entrained nodules, will be pumped out of the hold.

Marconaflo materials handling systems have been used by industry for more than twenty years to handle materials ranging from iron ore to limestone, sand, phosphate rock and coal. The system is reliable and proven in well over fifty installations; however, there are some unknowns regarding its application in handling deep-sea nodules. In Section 9 of this report, a test program is outlined to clear up those questions.

When a trawler has a full load of nodules, it will rendezvous with the transport vessel. A rubber hose will be lowered from the transport vessel to the trawler and connected to the discharge of the Marconaflo pump.

Every hour approximately 400 tons of nodules, together with about 1,000 m^3 of water, will be pumped from the trawler to the transport ship until all of the nodules are transferred. The water will be decanted continuously from the holds of the transport ship. At the end of the operation, the hold with the nodules will be drained. The transfer of the nodules in a fully loaded trawler is expected to take about six and a half hours.

3.5 TRANSPORTATION

The smelter and refinery for the processing of the nodules is tentatively located near Whangarei, on the North Island of New Zealand. The distance between the harvesting site and the processing plant is approximately 4,000 kilometres. Assuming 12 knots (21 kilometres per hour) sailing speed, 16 days are needed for the round-trip voyage between the harvesting site and the plant.

Carrier vessels with 30,000 tons capacity and approximately 175 metres length, 25 metres beam and 10 metres draft, will be used for transporting the nodules from the harvest site to the process plant. One ship can accommodate 10.4 days of harvesting by four trawlers. Unloading is estimated to take 1.1 days, for a total net cycle time of 27.5 days for receiving the harvested nodules, making the round trip, and unloading at the smelter. Three vessels can accommodate the harvest of 31.2 days, resulting in a ship utilization of 88 percent, which allows for miscellaneous activities and occurrences such as preparation for unloading, ship resupply, minor repairs, and delays in transit.

3.6 SHIP UNLOADING

The unloading of nodules will be by use of two Marconaflo pumps, using seawater as the pumping medium. The rate of unloading for each unit will be approximately 600 tons per hour of wet nodules carried in 1,400 m^3 per hour of water.

The loaded ship will tie up at an existing wharf, which will be equipped with two rail-mounted hoisting derricks to support the Marconaflo pumps, used for unloading the vessel. The holds of the ship will be flooded with seawater, and the Marconaflo units will be hoisted on board and lowered into selected holds. The pumps will be started and high-pressure water jets, directed downward, will be turned on to create a pool for the pump to start moving the mixture of nodules and water. As soon as the pump is below the surface of the nodules, the water nozzles on the side of the Marconaflo unit will be turned on to aid in slurrying the load. The lowering of the pump unit will continue until the hold is emptied to the required level. Then the pump and the high-pressure water flow will be stopped and the Marconaflo unit will be moved to the next designated hold. The process will be repeated until the ship is unloaded.

The pump discharges will be connected to rubber hoses, which will continue in pipelines to the shore and on to the nodule storage. Each unloading unit will be complete with its own pipeline.

The water nozzles of the Marconaflo units will be supplied with high-pressure seawater from a closed-loop seawater system. A makeup water pump will take suction from the bay and deliver water as required to the storage tank of the system.

3.7 OPERATIONAL STRUCTURE

The base of the harvesting operations will be at Rarotonga. A warehouse for spare parts and supplies, including food, will be provided, and a helicopter will be available for emergency use by the harvesting trawlers and the transport ship stationed at the harvest site.

The crews of the harvesting trawlers will be on duty for four weeks and off duty for two weeks. Every time a transport ship sails to the harvest site, it will stop at Rarotonga to take on board the crews of two trawlers and such supplies as are necessary. At the harvest site, the fresh crews will replace crews on two trawlers, which will board the loaded transport ship for the trip back to Rarotonga. After the debarkation of the crews, the transport ship will proceed to New Zealand.

There will be a working mate and two officers on each trawler, plus three complete crews so as not to exceed the 60 hour per week maximum workload. The crewing of the transport ships will be arranged similarly.

The crews on the transport ships will work six weeks with two weeks off. The crew change will take place either at Rarotonga or in New Zealand, as determined by operations.

The transport ships will take on supplies and fuel during nodule unloading in New Zealand and will transfer the supplies and fuel to the trawlers at sea while on station to receive the nodules from the trawlers.

3.8 OBSERVATIONS

In the course of collecting information relating to marine operations, indications were given by individuals in the shipping and fishing industries of interest in the project maritime operations. Various scenarios were suggested in connection with the harvesting and transportation. They ranged from the trawlers being owned by the project and operated on a contract basis by others, to the trawlers being owned and operated by others, to the entire fleet for harvesting and transporting the nodules being owned and operated by others on a long-term per-ton-of-nodule or percentage-of-contained-metal-values basis.

Scenarios such as the above should be investigated during the Phase II activities, as they may result in a more economical overall operating system with lower capital investment on the part of the Owner. Utilizing the expertise of organizations already in marine operations also may save initial learning-related inefficiencies. However, this study is based on the vessels being owned and operated by the project.

SECTION 4

SECTION 4
PROCESSING

4.1 GENERAL

The harvested nodules will be delivered by transport ships to the process plant at an annual rate of 1,097,360 wet tons, which equals 665,000 dry tons. The nodules will be unloaded at the smelter by the use of a Marconaflo hydraulic pumping system and stored in circular storage basins; 130,000 tons of nodules can be stored in the two ponds, at full capacity, to provide the process plant with feedstock for 50 days.

The extraction of cobalt, nickel and copper will be in a two-stage process, first using pyrometallurgy to make a granulated sulfide matte. At the planned production rate, approximately 8,200 tons of matte will be made annually. This product will be treated further in the hydrometallurgical plant to make pure cathode cobalt, nickel and copper in quantities of approximately 2,652, 1,718 and 955 tons per year, respectively. It is possible that an outside metal refiner with an existing plant can be found who would be interested in buying and processing the matte for a fee or a percentage of the contained metal values. If such should be the case, then the hydrometallurgical plant would not be built, and the sulfide matte would be shipped in standard sea containers for off-site processing.

Two pyrometallurgical processes have been considered for the first step of metal extraction. One consists of the use of two proprietary smelting furnaces - designed by Ausmelt - installed in series, the first to perform the initial melting and reduction of the nodules, and the second for the final cleaning and conversion to matte. The other involves the use of a rotary kiln dryer, a rotary reduction kiln, an electric melting furnace, and Peirce-Smith converters for the final cleaning and production of a sulfide matte. The two processes are discussed in the following sections.

The process flow diagrams are contained in Appendix A at the end of this report, while the process design criteria is in Appendix B.

4.2 PYROMETALLURGICAL PLANT

4.2.1 Top-Submerged Lance Furnace Smelting

The proposed Ausmelt smelting process is based on two fixed furnaces per smelting line installed in series. A lance is lowered into each furnace from the top for the injection of pulverized coal as the fuel and of oxygen-enriched air to establish combustion in the molten metal bath under the layer of slag. The insertion of the lance is critical, as an outside coating of solidified slag needs to be formed on it for thermal protection. The cooling of the lance is achieved by the injected mixture of coal and gas. The feed is added through a feed port on the top of the furnace.

Wet nodules are fed into the first furnace in each line, where their water content flashes and the nodules melt. The molten mass flows in a continuous stream by gravity into the second furnace in the line, where flux is added to remove the manganese and most of the iron, and coal is injected to achieve the reduction of cobalt, nickel and copper into a metal alloy. After the reduction is complete and a sufficient quantity of molten alloy is accumulated, the addition of coal will be interrupted and pyrite will be added to produce a sulfide matte, which is tapped off for granulation. At the end of this process step, the addition of coal reductant resumes and the metal bath is allowed to build up again. Slag is tapped continuously, with the molten slag transferred via a launder system to a granulation pit. Granulated slag is stockpiled for potential future reclaiming and manganese extraction.

The Ausmelt process is new, and there are now about half a dozen installations in use worldwide. Its attractiveness lies in the simplicity of the process, inasmuch as wet nodules can be fed directly into the smelting furnace and matte can be produced without a mechanical transfer of molten materials between unit operations. The relatively low cost of the basic furnace equipment also makes this an attractive alternative.

Considerable time and effort were spent in the study to develop the plant with its auxiliary facilities so that its capital cost could be estimated. In the course of this work, numerous findings, discussed in the following text, came to light.

Offgas Handling

Due to the fact that all of the heat energy to the process is supplied in the form of coal rather than coal and electric power, the consumption of coal is three times as large as for the conventional dryer–reduction kiln–electric furnace–converter smelting process. This results in several major impacts upon the support facilities:

- The coal handling system, because of the much greater tonnages, should be designed differently, with more reliance on mechanized stockpiling and reclaiming equipment, making the system more complex and costly.
- The furnace offgas handling ducts should be large because of the greater quantity of gases, the presence of steam in the smelter furnace offgas, and the higher gas temperature. Also because of the higher temperatures, the ducts have to have thicker refractory lining and more expensive expansion joints, suspension systems, and structural supports.
- In order to minimize the size of gas cleaning equipment, costly waste heat boilers need to be installed in the exhaust system.

Furnace Gas Supply

The furnaces are heated by injecting into them, through a lance, a mixture of pulverized coal and oxygen-enriched air. The injection is under relatively high pressure, requiring a large compressor installation. Additionally, an oxygen plant should be provided, which significantly adds to the capital and operating costs.

Sulfur Balance

The converting furnace operation is based on the use of pyrite as the sulfurizing agent. According to Ausmelt, if elemental sulfur is added to the converter furnace, only less than

10 percent of it is used to convert the cobalt-nickel-copper alloy to sulfides. The balance is exhausted with the offgas. When pyrite is used, however, half of its sulfur content remains in the melt to form iron sulfide, while the other half exits with the offgas. The iron sulfide matte then collects the metallic cobalt and the sulfides of nickel and copper. This peculiarity of the process has far-reaching effects on the plant's operation:

- A facility should be added for receiving and handling the pyrite.
- The sulfur in the offgas has to be removed in a gas scrubber using lime. This necessitates the addition of lime-handling facilities. Also, the process produces significant quantities of gypsum that must be disposed.
- Whereas in the other smelting method the iron content of the alloy, and thus of the matte, is minimized by oxidation in the converter, in the Ausmelt process the iron content actually is increased by the addition of pyrite. This results in an increase in the tonnage of the matte by a factor of four, necessitating correspondingly larger facilities for granulating and handling of the matte and for subsequent matte grinding in the hydrometallurgical plant.
- Due to the increased quantity of matte, the water cooling system associated with matte granulation must be larger in size.
- The chlorine treatment of the matte should be sized for the greater quantity of matte. The iron content of the matte is approximately 20 times greater than in the matte produced by the conventional process. This necessitates a correspondingly larger facility, including solvent extraction settlers.
- The iron is removed from the process stream in the form of ferric chloride. This hazardous by-product must be disposed, and the quantity of chlorine leaving in the by-product has to be added to the process, requiring a larger chlorine-handling facility and resulting in higher operating costs due to the higher chlorine consumption.
- The sulfur in the matte leaves the process as elemental sulfur. While in the conventional smelting process this by-product can be recycled, in the Ausmelt process it has to be disposed as waste.

Process Availability

Ausmelt uses an availability of 85 percent for the furnaces and recommends the installation of two parallel furnace lines. According to information relating to the operation of an Ausmelt furnace in Arizona, this projection seems overly optimistic. For this reason, the study incorporated three parallel smelter lines, with two operating and the third available for maintenance and refractory repairs. Through this arrangement, an overall availability of 60 percent is expected to be achieved.

Conclusion

Taking the above-listed factors into account, the conclusion was reached that using the Ausmelt process would not be advantageous for the project. Work on the associated flow diagrams and plant arrangement drawings was stopped, and this alternative was dropped from further consideration.

4.2.2 Electric Furnace Smelting

A single process line is planned for this design, the overall availability of which is projected to be 85 percent. Due to the wide use of this "conventional" smelting process, experience shows that such an availability level can be attained readily.

Wet nodules will be fed to a rotary dryer that will be fired at the feed end with pulverized coal. Dried nodules will be transferred by conveyor via a surge bin to a rotary reduction kiln. Crushed coal and dryer electrostatic precipitation (ESP) solids will be metered to the reduction kiln along with dry nodules. The reduction kiln will be fired with pulverized coal from the discharge end to a temperature of 850°C to 950°C, which will result in a partial reduction of the metal oxides contained in the nodules.

The calcine will be discharged into transfer pots and will be moved by rail-mounted cars and crane to the charge bins of the electric furnace. Final melting of the nodules will take place in the electric furnace, where manganese and most of the iron, in the form of oxides, will report to the slag, which will be tapped and granulated for stockpiling. The molten alloy of cobalt, nickel, copper, and some iron will be tapped into preheated, refractory lined pots for transfer into one of two Peirce-Smith converters.

Flux will be added in the converter, the bath will be blown to oxidize the iron, and the iron-oxide will be collected as slag. The converter slag will be recycled to the electric furnace. The blown bath will be sulfurized to convert the alloy into sulfide matte, which then will be granulated.

4.2.3 Processing Comments

Mannesmann Demag, the potential supplier of the electric furnace, indicated that the use of a rotary kiln for partial reduction of the nodules may not be necessary. It even may be detrimental to the process, as too much fines may be generated in the kiln for the electric furnace to handle. Tests are recommended to be performed to achieve the nodule melting and reduction in a single unit operation in the electric furnace. If such a process proves to be feasible, its use may result in the simplification of the plant design and a reduction in both the capital and operating costs.

4.3 HYDROMETALLURGICAL PLANT

4.3.1 General

The extraction of metals from the matte will be accomplished by the chlorine leach, solvent extraction and electrowinning (EW) processes. Cobalt and nickel will be recovered as high-quality cathode metal, while copper will be produced as a powder comparable in quality to cement copper and will require further refining.

Most of the contained sulfur will be recovered as molten elemental sulfur. The sulfur will be recycled to the smelting operations.

4.3.2 Matte Grinding and Storage

Granulated matte will be received in a storage bin, from where it will be metered into a tower mill for comminution by wet grinding. Sufficient fresh water will be added so that the ground product has a pulp density of 75 percent solids. To achieve the necessary degree of liberation, the matte will be ground to a nominal minus 44 µm in size. This pulp will be pumped to a matte storage tank where it will be diluted with return EW anolytes to about 25 percent solids and stored as feed to the leaching operations.

4.3.3 Leaching

Ground matte slurry will be split 75 percent to 25 percent, with the 75 percent fraction flowing to cementation leaching and the 25 percent going to completion leaching.

Leaching will take place in a two-step countercurrent leach circuit in which the first step will be cementation leaching and the second step will be the completion leaching. Solids will flow forward from the cementation to the completion leaching, while liquids will flow from completion to cementation via copper removal.

4.3.4 Cementation Leaching

In the cementation tanks the ground matte, containing some metallic nickel, will be contacted with solution from the completion leaching step. Soluble copper ions will cement out on the metallic nickel present in the matte, forming metallic copper, while a corresponding amount of nickel metal will be dissolved. As there will be an excess of nickel metal present, the cementation step will remove all cupric (Cu^{++}) ions present. Slurry from the cementation tanks will be separated into solid and liquid fractions by filtration. Solids will go to completion leaching, while liquids will advance to the iron oxidation stage.

There will be a total of three agitated cementation reactors installed in series, made of rubber-lined FRP. The tanks will be sealed and vented to the chlorine scrubber. The cementation step will occur at 50°C to 60°C with a residence time of six to eight hours.

4.3.5 Completion Leaching

Completion leaching is the chlorination leaching of the combined 25 percent of the ground matte slurry, the solids filtered out at the end of the cementation process, and recycled anolytes. Recycled chlorine gas will be injected into the completion leach reactors. Since this gas is estimated to contain 15 percent by volume of air, it will serve as a powerful oxidizing agent. As required, chlorine gas at 100 percent concentration (makeup gas) will be added to complete the desired reactions. The actual oxidizing agent will be the cupric-cuprous copper couple, and the chlorine will serve to reoxidize copper to the 2-plus state. Thus, enough copper in solution must circulate through the two-step leaching to put all of the metals into solution, including cemented copper and metals contained in sulfide form. During this process the sulfur in the matte will be converted to elemental sulfur; however, about 2 percent of the sulfur will be oxidized to sulfuric acid (in a reaction that also produces hydrochloric acid). The completion leaching will occur in three agitated rubber-lined reactors at 110°C with a residence time of about four to six hours. A fourth, unagitated reactor vessel serves as a thickener and cooling liquor circulating tank.

The slurry from the completion leaching will be filtered to yield a solid and a liquid fraction. The liquid fraction, containing essentially all of the metal values, will be recycled to cementation leaching as described previously.

Offgas from the completion reactors will contain dilution air plus about 1 percent of the total process chlorine, and will be processed through a lime ($Ca(OH)_2$) vent gas scrubber. The chlorination leach of the various minerals will be highly exothermic and will cause the slurry to boil. This boiling will result in the conversion of about 2 tons per hour of water into water vapor. This vapor will be recovered as impure condensate by a surface condenser.

4.3.6 Iron Oxidation and Removal

In iron oxidation, the leach solution, containing a variety of heavy metal ions, will be subjected to oxidation by the addition of chlorine gas and by blowing air through the solution. The strongly oxidizing chlorine will ensure that all iron will be in the ferric (Fe^{+++}) form. Iron and some manganese will be removed using tributyl phosphate (TBP) solvent extraction in a series of mixer-settlers. The metal will be extracted into the organic phase and then will be removed by stripping with water, thus generating a waste strip liquor of ferric chloride solution. This can be disposed or sold as water treatment agent.

4.3.7 Cobalt Solvent Extraction

Purified liquor from the iron oxidation will be contacted with an organic solution of triisooctyl amine (TIOA) in a series of mixer-settlers. HCl attached to the amine molecules will be exchanged for the cobalt in the liquor forming the organometallic compound TIOA- $CoCl_2$. This complex, in turn, will be contacted with return anolyte to strip the $CoCl_2$ into the advance electrolyte strip solution. Only enough water will be added to this strip liquor to extract the cobalt to a strength of 85 grams per litre Co^{++}.

4.3.8 Cobalt Solution Purification

In order to minimize the amount of free hydrochloric acid and soluble lead compounds in the cobalt circuit, the advance electrolyte circulating between the cobalt stripping and cobalt electrowinning will be purified by neutralization with cobalt carbonate. The first process step will be to dilute the incoming strip liquor with cobalt EW anolyte from 85 grams per litre down to 60 to 65 grams per litre, which is where the lead will tend to come out of solution. After dilution, the solution will be contacted with the cobalt carbonate in a series of four agitated tanks, followed by a clarifying filter press.

Cobalt carbonate will be made by bleeding off a fraction of the cobalt EW anolyte and reacting it with sodium carbonate (Na_2CO_3). The product of this reaction will be sodium chloride (NaCl) and water-insoluble cobalt carbonate. Filtrate, containing primarily sodium chloride, will be removed from the process. The $CoCO_3$ cake will be separated from the slurry by filtration on a filter press. The filter cake will be mixed with the diluted cobalt strip liquor. The addition of cobalt carbonate will neutralize the acids, increase the solution alkalinity (pH), and cause lead to precipitate as sulfate. In this fashion the cobalt electrolyte will be purified continuously.

4.3.9 Cobalt Electrowinning

Cobalt will be electrowon on starter sheets using ruthenium-oxide-coated DSA titanium anodes. The passage of electrical current through the EW cells will result in the deposition of 316 kilograms per hour of cobalt metal and the release of chlorine gas that was associated with the cobalt in its aqueous chloride solution. The anodes will be enclosed in fabric bags, which will allow the collection of the chlorine gas. The bags will minimize further the mixing of the cobalt-depleted solution (anolyte) and cobalt-rich solution (catholyte). The chlorine gas will be recycled to leaching. A total of 18 EW cells will be required for the cobalt production, 2 for starter sheets and 16 for commercial cathodes. The cells will be designed for 1 m^2 electrodes. Each cell will contain 39 cathodes and 40 anodes. Current density will be 230 A/m^2, and overall current efficiency is expected to be 97 percent. The commercial cathodes will be stripped once a week, crushed to product size, put through the degassing furnace, and packaged in steel drums. The starter cells will employ titanium mother blanks and will operate on a two-day cycle of stripping.

4.3.10 Nickel Solution Purification

Aqueous solution (raffinate) leaving the cobalt solvent extraction circuit will be fed to the nickel solution purification circuit. The first step is to pass the raffinate through a carbon column to clean up any entrained organic from the cobalt solvent extraction step. Then, as with cobalt purification, the raffinate will be contacted with nickel carbonate and the reactions will precipitate nickel hydroxide, lead sulfate, manganese dioxide, and other slightly soluble sulfates.

The reactions take place in three agitated reaction tanks in series. The tanks are sealed and vented to the chlorine scrubber. The solids slurry exiting the third reactor tank is fed to a filter press which delivers clarified advance electrolyte to the nickel EW and a filter cake containing the impurities. This latter will be fed to a dissolving tank where it will react with dilute sulfuric acid which will redissolve the nickel hydroxide. This dissolving step will be followed by cake washing on a second filter press. The resultant cake will contain the unwanted lead and manganese compounds, while the nickel sulfate filtrate will be recycled to the completion leaching.

4.3.11 Nickel Electrowinning

Nickel will be electrowon on starter sheets and DSA titanium anodes. Anodes will be contained in fabric bags, minimizing anolyte mixing with the catholyte and permitting the capture of chlorine gas from the anodes. EW will be performed in 12 EW cells of 1 m^2 electrodes. Each cell will contain 39 cathodes and 40 anodes. Current density will be 230 A/m^2, and overall current efficiency is expected to be 97 percent. Under normal operating conditions, the EW facility will produce 209 kilograms of cathode nickel per hour. These cathode deposits will be stripped once a week, sheared to customer size preferences, and packaged for delivery. The two starter sheet cells will employ titanium mother blanks and will operate on a two-day cycle of stripping and starter sheet assembly using a semi-automatic machine.

4.3.12 Sulfur Treatment

Solids from the completion leach and filtration stage will consist primarily of elemental sulfur. This material will be dried in a Holoflite-type dryer and melted in a steam-heated (165°C steam) sulfur melting vessel. Liquid sulfur from the melting operation will be recycled to the smelter converters for making sulfide matte. Process losses of sulfur will be replaced by adding commercial sulfur to the melting vessel.

4.3.13 Copper Removal

The completion leach filtrate will be sent to the copper removal step, where copper will be present as both cuprous and cupric chlorides ($CuCl$ and $CuCl_2$). This liquor will be processed through a seven-cell EW operation using titanium cathodes and titanium DSA anodes. The products of the EW will be copper powder - which will be suitable for refinery or smelter feed - and chlorine gas. As with the cobalt and nickel EW, due to the generation of chlorine gas, the anodes will be encased in bags. Collected chlorine gas will be combined with similar gas streams, compressed, and used for chlorination in the completion leach reactors.

Copper EW will operate at high current density (300-400 A/m^2) and will employ electric vibrators to agitate the cathodes continuously. The inlet liquor will contain a total of 40 grams per litre copper (Cu^+ and Cu^{++} ions) and will depart at 10 grams per litre.

Copper will be collected from the cathodes as a powder which will fall to the bottom of the EW cells. The powder will be recovered, washed, filtered, packaged and sold for further refining.

4.3.14 Chlorine System

Anode gases from the EW tanks will be collected under negative pressure via liquid-ring compressors, which will be of all-titanium construction with water seals and water cooling. The chlorine will be returned to the leach circuit at 1.5 bar gauge pressure.

Wet gases from the completion leach will first contact a surface condenser to remove the steam from the gas stream. A scrubbing tower will follow the surface condenser to remove the chlorine gas. This will be achieved by circulating a 12 percent milk-of-lime slurry as the neutralizing agent. Approximately 2 percent of the circulating flow will be discarded to maintain the converted amounts of calcium hypochlorite and calcium chloride in a state of equilibrium. The chlorine scrubbing tower will be provided with two sumps to maintain a constant supply of 12 percent milk-of-lime to the scrubbing section, which will be fitted with disk-and-donut trays in the top section and a shed-deck grid in the lower section for improved gas mass transfer. The system will be sized to accept, in addition to the completion leach vent gases, the total chlorine flow from EW in case of an upset which would prevent returning the chlorine to the leach section. The vent fan will be powered by a steam turbine.

4.3.15 Nickel Carbonate Circuit

A portion of the nickel EW anolyte will be diverted to a nickel carbonate reactor, where it will combine with soda ash to make a precipitate of nickel carbonate, plus sodium chloride and sodium sulfate in solution. The nickel carbonate slurry will be washed on a filter press to separate the waste solution - which is the system purge for sodium and sulfate ions - and a carbonate cake. This latter will be dried in a small steam-tube dryer, and the dry nickel carbonate will be distributed to user points.

SECTION 5

SECTION 5
PLANT DESCRIPTION

5.1 GENERAL

The processing of the nodules will take place in an integrated smelter and metal refinery. The plant site is assumed to be located adjacent to the shore to allow the unloading of transport ships next to the plant. A wharf will be provided by others for unloading. The plant will contain facilities to receive, store and reclaim the nodules and coal; a smelter to extract from the nodules cobalt, nickel and copper and concentrate them in an intermediate product; a refinery to render purified metals; a stockpile for smelter residue that will contain, for possible future extraction, all of the manganese values; and ancillary facilities such as offices, shops, warehouse and utilities.

In the following subsections a description of the facilities is given. A listing of major equipment with sizes and estimated drive sizes is contained in Appendix C at the end of this report.

5.2 PLANT LOCATION

The study is based on a generic plant layout. Although the plant site selection will be done by the Owner of the project, in order to make possible a realistic economic evaluation, a hypothetical plant site was needed to be used for cost estimating purposes. Sites in Australia and New Zealand were considered for locating the plant; however, a plant location in Australia was not pursued for the purposes of this study, as sailing distance from the harvest site to Australia is considerably greater than to New Zealand.

A visit was made to New Zealand to screen a number of plausible locations for the plant site. Seven potential sites were considered. They are listed in the order of preference suggested for the final site selection process. In the following paragraphs, comments are made about the sites that were screened. The first five of the screened sites were visited. For the purpose of this study, Marsden Point near the town of Whangarei is assumed to be the plant site.

- Whangarei.

  Whangarei is located on the east coast of the North Island in Bream Bay, in an industrialized area with a good supply of skilled labor and some degree of underemployment due to the recent modernization of a large refinery. The port of Whangarei itself is not suitable for the unloading of the nodule transport ships, and there is not sufficient land available there to accommodate the plant.

  Marsden Point, across the bay from Whangarei, is the site of New Zealand's oil refinery and a two-unit oil-fired power plant that has been out of service for over fifteen years. Northland Port Corporation owns land in that area and is planning to expand the harbor and establish a lumber export facility. Land would be available for the process plant. An extension of an existing pier is planned so that the facility will be able to receive nodule transport ships.

  The electric power supply is not very strong at the moment because of the power plant not operating; however, C.R.A. of Australia, through its New Zealand subsidiary, E.P.G. Ltd., is said to be planning a coal-fired power plant to replace the existing oil-fired one.

  With reference to consumables for the plant, coal from the Waikato area can be brought in by rail. Sulfur is available from the adjacent refinery. Limestone is mined a few kilometres from the site to supply a cement plant in Whangarei. Silica sand is available from a nearby location. Sufficient water can be provided for the operation of the plant.

  The Whangarei Regional Council has developed an air quality model of the Marsden Point area based on real-time monitoring of the refinery emissions over several years. This model can be used in the assessment of air quality impact of the proposed process plant. The Marsden Point refinery has obtained a new discharge consent just recently. This development should be helpful in the permitting process for a smelter and refinery.

- Timaru.

  The town of Timaru lies about 160 kilometres southwest of Christchurch. It has a good harbor with some land available at the harbor for limited industrial development, such as the receiving and storage facilities for nodules. The port of Timaru can handle vessels with 9.5 metres draft at its existing wharves. Receiving one nodule shipment every two weeks would fit into the current operations. Land for the process plant is available approximately 35 kilometres from the port. The transportation of nodules can be done over existing rail lines. Good electric power supply is available at the potential plant site. Bituminous coal from mines near Westport can be delivered by rail. The regional planning authority is receptive to development. The labor situation is favorable, with skilled labor readily available. The port operates under open-shop rules, and there has been no strike for eight years.

- Napier.

  Located on the east coast of the North Island in Hawke Bay, the town has a deepwater port near the center of town with warehouses and some light industrial development. The area is said to be slowly converting to a retirement/resort type community. There is no room to locate a smelter at the port; however, about 5 kilometres south of the port and the town there is a medium size fertilizer plant near the shore in an area that seems to be on the way to becoming an industrial park. The smelter and refinery could be located near the fertilizer plant, with the nodules rail-transported from the port. The highway and railway run along the shoreline adjacent to the potential plant site. A 220 kV power line runs nearby; there is a small thermal generating plant at Whirinaki, about 15 kilometres north of Napier. Coal and other supplies can be delivered to the plant by rail. It should be noted that Napier and neighboring Hastings were destroyed about 60 years ago by a strong earthquake, indicating that this area is one of the most active seismic regions of New Zealand.

- Clifford Bay.

  Clifford Bay is situated on the north end of the South Island. This is the planned site of a new ferry terminal for transporting freight between the North and South Islands. Lake Grassmere lies west of the planned ferry terminal. Land, presently in agricultural use, is available on the west side of the lake. Clifford Bay is protected from southeasterly swells by Cape Campbell. There is westerly short-period wave activity in the Cook Strait, but this can be countered by a breakwater. Except for the adjacent salt works, the Clifford Bay site is completely undeveloped. It is accessible via highway No. 1 to the village of Seddon, from there by 6 kilometres of paved plus 4 kilometres of gravel road. Rail connection is 4 kilometres from the site. The nearest 115 kV ac power line is about 25 kilometres distant from the site, although a 350 kV HVdc line runs about 10 kilometres from the potential site. An adequate flat area lies between two cliffs of about 40 and 80 metre heights respectively. Level alluvial ground starts about 30 metres from the water line and about 5 metres above the high water level. All services, including water, would have to be brought in, and a wharf with a breakwater would be required for the port facility.

- Tauranga.

  Located on the east coast of the North Island in the Bay of Plenty, Tauranga is the largest export port of New Zealand with a fair industrial base. The port is located on flat land on the north side of Tauranga Harbour, facing the town of Tauranga. The port appears to be rather confined, lying next to a large timber handling facility and a light industrial area. The town of Tauranga has many resort hotels and motels, most overlooking the harbor and the port. It is highly probable that a proposed smelter would be objectionable because of its visual impact. The stockpiling of the smelter slag may be a problem due to the lack of adequate space. Tauranga lies close to the Waikato coal region.

- Westport.

  Located on the west coast of the South Island, Westport is situated at the estuary of the Buller River near Cape Foulwind. It is a poor port with constant problems with shifting sandbars and high swells. Its breakwaters had to be extended three times due to sanding. The maximum draft it can handle is about 4.5 metres. It is not suited for porting 30,000-ton vessels.

- Manukau Harbour.

  Manukau Harbour is the western harbor of Auckland. Situated close to the Waikato coal fields, it is an area of potential development with good electric power supply available. A steel plant is located there at the present. Manukau is a shallow harbor with shifting sandbars at its entrance. With the entrance being on the west coast, it is subject to severe wave conditions. The development of a deepwater port would be a problem and is not likely to be permitted.

5.3 NODULE HANDLING

The unloading of the nodules will be by the use of Marconaflo units, the operation of which is described in Section 3.4, Transfer Operation, of this report. Two Marconaflo units will unload the transport ship simultaneously. Each will be supplied with high-pressure seawater by onshore pumps to provide the conveying medium for the nodules. The mixture of nodules and water will be conducted to and from the Marconaflo units through separate pipelines to the nodule storage. A rail-mounted crane will be provided for each Marconaflo unit so they can be moved to, lowered into, and lifted from the various holds of the transport ship.

The nodule storage facility will contain two circular storage basins of 110-metre diameter. The basins will have 3-metre-high perimeter walls, and the bottoms will be sloping toward the center. An overflow in the wall will decant the excess water, which will be recirculated in the unloading process. A truss, supporting a launder with discharge spigots along its bottom, will span the space between a tubular center support structure and the rim wall of the basin. The Marconaflo pipeline will discharge into the launder. By moving the launder radially and opening various spigots in its bottom, the nodules can be discharged into the basin over its entire area. It is the intent that the nodules should be stacked about 2 metres higher than the top of the perimeter wall, so as to maximize the storage capacity.

The structure at the center of the storage basins will serve two functions. It will support the launder truss, and it will double as a housing for the reclaim Marconaflo unit. Each basin will have a drain to decant the contained water; however, under operating conditions, they will be filled with water to the level of the decant weir.

Reclamation of the nodules will be by means of the Marconaflo unit located at the center of the storage basin. Only one unit will be used at a time. A high-pressure pump will supply water to the Marconaflo nozzles from a seawater tank. The Marconaflo discharge will be piped to a dewatering facility, which will be located at the top of the smelter feed bin. The flow will be discharged into an impact box from which it will drop onto a vibrating screen below. The screen oversize will drop onto a belt conveyor discharging into the dryer feed bin, while the underflow will be collected in a sump. A pump will deliver the underflow water to a desanding cyclone, located above the primary dewatering screen floor. The cyclone overflow will drain by gravity back into the seawater tank for recycling. The underflow will discharge onto a second vibrating screen with a fine screen cloth. The solids will drop onto a belt conveyor discharging into the dryer feed bin, and the underflow will be piped to the seawater tank. Since the smelter feed bins will have a total storage capacity of 800 dry tons (about eight hours of plant feed), only uninstalled spares will be provided for the dewatering facility equipment.

5.4 SMELTING

Nodules will be drawn from the 7.5-metre diameter by 14-metre high dryer feed bin by a weight-controlled belt feeder and discharged onto the dryer feed conveyor. The dryer will be a 4.1-metre diameter by 35-metre long rotary kiln with castable refractory lining. It will be fired from the feed end using pulverized coal as fuel. Offgases will be ducted to an ESP for cleaning, with the collected precipitate discharged onto the dryer product conveyor.

Dried nodules will be transported by a belt conveyor to one of two 6-metre diameter by 10-metre high dry nodule storage bins with a total capacity of 800 tons to provide eight hours of plant feed. Weight-controlled belt feeders will draw from the storage bins and discharge to the first of a series of two belt conveyors, which will feed the reduction kiln. Lump coal from a 6-metre diameter by 10-metre high coal storage bin also will be fed onto the reduction kiln feed conveyor, which will discharge into the 4-metre diameter by 60-metre long reduction kiln.

The kiln will be refractory lined and onboard fan cooled. It will be fired by pulverized coal at the discharge end. The offgas will be treated in a scrubber to remove the particulate matter before exhausting to the stack. Hot calcined nodules will be received in a surge bin and discharged into a transfer container supported on rail-mounted transfer cars. The containers will be moved to the electric furnace building and lifted by a 50-ton crane to any of the eight charge bins of the electric smelting furnace.

The furnace will be a 25 MW electric furnace with an inside diameter of 15 metres. Slag, containing manganese oxide, iron oxide and silica, will be tapped intermittently from the furnace and transferred via a heated launder to the slag granulation pit. The granulated slag will be lifted by a drag conveyor to a 75-ton truck loading bin. A 35-ton truck will drive under the bin for loading and hauling the slag to the disposal stockpile. Water from the granulation pit will be pumped to a 10-metre diameter clarifier prior to being pumped to the cooling tower and then recycled.

Reduced metal alloy will be tapped periodically and collected in preheated, refractory-lined transfer pots for further treatment in one of two 4.5-metre diameter by 10.6-metre long rotary converters. The loaded pots will be transferred by a 50-ton crane. Silica will be added to the converters and air will be injected through a blower system. Molten sulfur will be pumped into the converters as required from the sulfur holding tank in the refinery in order to convert the cobalt-nickel-copper alloy to sulfides. The molten sulfide matte will be poured into preheated pots and transported to the matte granulation facility, which will be similar to the slag granulation facility. Granulated matte will be lifted by a drag conveyor to the 6-ton capacity matte holding bin. Slag from the converter will be tapped into pots as required and returned to the electric smelting furnace. Offgas from the electric smelting furnace and the converters will be cleaned before discharging into the stack. A lime scrubber will be used to trap the sulfur dioxide in the converter offgas. The resulting gypsum precipitate will be disposed with the slag.

The furnace will be equipped with electrode cooling fans and a jacket-type water cooling system complete with water treatment unit, pumps, tanks and cooling tower.

5.5 REFINING

The refining process will start with grinding the granulated matte in a tower mill to produce a slurry. A weigh feeder will feed the matte from the storage bin into the tower mill. The slurry will be pumped through an HDPE pipeline to an agitated storage tank in the hydrometallurgical plant, where it will be diluted with spent electrolyte.

Three quarters of the flow from the storage tank will be pumped to the cementation leach process step, which will take place in a series of three agitated reactor tanks. The effluent from the last tank will be pumped to a titanium solid bowl centrifuge for removing most of the solids from the slurry. The solids will be collected in a sump and the liquid pumped to a filter press for separating out all of the solids. The filtrate will be pumped to iron oxidation prior to the cobalt and nickel extraction, while the filter cake will be added to the centrifuge solids sump, where the combined solids will be reslurried with a small quantity of recirculated filtrate and pumped to the completion leaching.

The reslurried solids from the cementation leaching and the remaining one quarter of the flow from the matte slurry holding tank will be combined in the first of three brick-lined agitated completion leaching tanks, arranged in series. A mixture of chlorine gas and air will be injected into the tanks. All metals will be dissolved in this stage of the process, whether in metallic or sulfide form, and elemental sulfur will remain in the liquid in a finely distributed solids form.

Since the reactions in this process step are exothermic, some of the water in the slurry will boil off.

The effluent of the last leaching tank will be pumped into a brick-lined unagitated tank with a conical bottom. This fourth tank serves as a thickener device for separating the solids out of the slurry and will have an overflow box. A pump will take suction from the overflow box and recirculate part of the flow through a water-cooled heat exchanger to lower the temperature of the slurry from the completion leaching. The other part of the flow will be piped to the completion leach solution head tank. The underflow from the thickener tank will be pumped to a washing filter. The washed solids, consisting of fine solid sulfur, will be dewatered in a centrifuge, dried in a steam-heated Holoflite screw conveyor–type dryer, and discharged into a steam-heated sulfur melting and holding vessel. Molten sulfur will be pumped as required to the converters in the smelter for recycling in the sulfidation process. Sulfur will be added to the melting vessel to make up for the process losses. Wash liquid and the liquid from the centrifuge will be pumped to the completion leach solution head tank mentioned above.

Both the cementation and completion leaching tanks, as well as the thickener, will be connected to a vent system. The collected offgas will flow through a condenser to separate the water vapor. The gas then will flow through a scrubber, where milk-of-lime slurry will be used to absorb the chlorine gas. The vent system will operate under negative pressure, generated by a centrifugal fan installed between the scrubber exhaust and the vent stack.

The cementation leach solution from the head tank will flow by gravity to seven EW cells where the metallic copper will be extracted from the solution while freeing the chlorine gas. Chlorine will be collected via a duct system, compressed and recycled to the process. Cathode copper will be in the form of powder and will settle to the bottom of the EW cells. The bottoms will be shaped to form sumps with sloping sides and will have nozzle connections at their low points. The copper powder slurry will be removed and pumped to a centrifuge for dewatering. The copper product will be collected in drums and sold for further treatment in a copper refinery prior to industrial use. The reason for this is that the copper contains cobalt and nickel impurities and various trace elements. The anolyte from the EW tanks will be collected and pumped for reuse in the cementation and completion leaching.

Filtrate from the cementation leaching will be pumped to the nickel/cobalt extraction section of the plant. The first step in this process will take place in a series of three agitated FRP tanks. A mixture of chlorine gas and air will be blown into the tanks to oxidize the iron and manganese. The effluent will be clarified by pumping through a frame pressure filter, cooled by water through a heat exchanger, and collected in a tank. The solution will be pumped, for the solvent extraction of the iron, to a series of four mixer-settlers, where it will be contacted in a countercurrent flow with TBP. The loaded organic will be stripped with water in three countercurrent mixer-settlers. The strip solution of ferric chloride will be disposed or sold as water treatment agent, while the stripped TBP will be recycled.

The purified deironized solution will be collected in a tank and pumped for the solvent extraction of cobalt. This will take place in a series of four mixer-settlers, where the solution will be contacted in a countercurrent stream with TIOA, which removes the cobalt from the solution. The organic will be stripped with cobalt anolyte in two mixer-settlers to produce cobalt advance electrolyte, while the aqueous solution (raffinate) from the solvent extraction will flow to the nickel EW.

The cobalt solution will be purified prior to the EW. First, the solution will be diluted in an FRP tank with anolyte from the cobalt EW cells, then pumped through one of two activated carbon polishing filters to remove the last traces of organics. While one filter operates, the other is regenerated. Polished solution is introduced to a series of three agitated reactor tanks, where it will be diluted further with cobalt anolyte, then reacted with cobalt carbonate to precipitate the heavy metals and other impurities. The resultant slurry from this purification step will be processed through a plate-and-frame filter press to produce a polished advance electrolyte and a filter cake for recycling to the completion leach step.

The EW of cobalt will take place in 18 polymer-concrete cells (2 cells on the starter sheet cycle and the remainder on a commercial cathodes cycle). The starter sheets will be grown on titanium mother blanks and DSA-coated titanium anodes. The commercial cathodes will be grown on 1.4-millimetre thick starter sheets. There will be a total of 39 cathodes of 1 m^2 active area and 40 anodes in each cell. The cobalt cathodes will be washed, dried, crushed into small chips, annealed (degassed), and loaded into containers for shipping. Anolyte will be recycled in the process.

Nickel solution will be purified by reaction with an excess of nickel carbonate. The resulting filter cake will contain too much nickel for disposal, so it will be redissolved in diluted sulfuric acid to recover the nickel sulfate for recycling to the process. The remaining cake should contain all of the lead, manganese and other metallic impurities for disposal. The EW of nickel will be the same as for cobalt, but with only 12 cells in operation. The nickel cathodes will be washed, dried and sheared into customer-preferred shapes before being packaged into containers for shipping. The anolyte will be recycled in the process.

Chlorine anode gas from the copper, cobalt and nickel EW will be collected under suction from two all-titanium, liquid-ring seal compressors. Compressed chlorine, mixed with vaporized makeup chlorine, will be recycled to the completion leach reactor vessels.

5.6 RESIDUE STOCKPILING

The smelter will produce approximately 1,450 tons of residue - or slag - per day, which contains about 330 tons of manganese. The residue will be granulated for easy handling and discharged into an elevated hopper with a loadout gate at its bottom. Trucks, with 40 tons capacity, will drive under the bin and load the residue. They will transport the load to a stockpile for rear dumping. Thirty-six truckloads per day will be moved. At the beginning of the operations, one truck will suffice for this service. As the extent and the height of the stockpile grow, a second truck will be needed around the tenth year of operation.

In order to stockpile 25 years of residue production of 11.3 million dry tons, an 80-metre high stockpile will be built with sloping sides and a base of 540 m^2. The manganese content of such a stockpile is approximately 2.6 million tons. Although the availability of manganese from terrestrial sources is so abundant that it currently is not economical to extract it from the residue of nodule smelting, the situation may change in the future. For this reason, it is prudent to stockpile the residue for potential future use. Alternately, the residue can be used for road building or landfill.

5.7 MATERIALS HANDLING

5.7.1 Coal

Coal will be received in bottom-dumping 40-ton railcars at a rate of 12 cars per day. The coal train will be spotted on the coal-handling spur by the railway. During unloading operations, a car puller will be used to move the cars.

Coal will be discharged into a receiving hopper, reclaimed by a belt feeder, and transported via a belt conveyor to a conical stockpile. A tubular steel tower with openings in its side will confine the falling coal to control the dust emission. Additionally, water sprays will be used to abate dusting.

Reclaiming will be by means of a front-end loader, which will dump the coal into a reclaim hopper. A belt feeder will draw coal from the hopper and discharge into a lump breaker. The sized coal will travel via a belt conveyor to a splitter chute, where the flow will be diverted either into the coal pulverizing plant or onto another belt conveyor for delivery to the reduction coal feed bin. Pulverized coal will be transported pneumatically to the use points, i.e., to the burners of the dryer and reduction kilns, or to the injection lances of the smelting and reduction shaft furnaces.

5.7.2 Flux

Flux will be delivered in trucks and stored in a covered shed for reclamation by a front-end loader into a reclaim hopper. A belt feeder will draw from the hopper, and the flux will be conveyed to a scalping screen. The oversize will be crushed and combined with the screen undersize for transportation by belt conveyor into a 2-metre diameter by 3-metre high silica flux feed bin. A feeder system, consisting of one belt feeder and two belt conveyors, will serve each converter to deliver measured amounts of flux on demand.

5.7.3 Sulfur

Sulfur will be received in bulk containers and stored in the vicinity of the sulfur melter. Sulfur will be added to the melter as required, using a hoist.

5.7.4 Fuel Oil

Fuel oil will be delivered by trucks and received into a storage tank. A pump will transfer the oil via a distribution pipe system to the use points.

5.7.5 Hydrated Lime

Hydrated lime will be received in bags and dissolved in an agitated mixing tank. A pump will transfer the milk-of-lime to the sump of the scrubber as required.

5.8 NONPROCESS FACILITIES

A one-story building will be provided to accommodate nonprocess facilities such as the offices, laboratories, change rooms, shops and a warehouse. The offices will be located in one end of the building, while the shop and warehouse will occupy the other end, as shown on the site plan, Drawing No. 000-M-201 in Appendix A.

The general office will occupy an area of 800 m^2, divided into individual offices, lunchroom, conference room and service rooms. An additional 500 m^2 will be allocated for the metallurgical laboratory and its associated offices and computer rooms. In addition to the comfort heating and ventilation system, industrial exhaust systems will be provided in the laboratory as required. The change rooms will have a floor area of 300 m^2.

The shops will be allocated 1,000 m^2 of floor area, while the warehouse will occupy 600 m^2. In addition to the enclosed warehouse, there will be a fenced area outside the building for laydown and storage.

5.9 UTILITIES

5.9.1 Water Supply and Distribution

Water is assumed to be purchased from available sources. A tank will be provided for combined plant water and fire protection water storage. The distribution of plant water will be through underground pipes. A portion of the incoming water will be chlorinated for use as potable water, which will be stored in a dedicated tank and distributed via the potable water pipe system.

Water will be used for the granulation of the slag. It is estimated that the water evaporated in the granulation process and taken up by the slag will be approximately 150 m^3 per day. There will be no water discharge from the plant other than the moisture content of the granulated slag.

5.9.2 Fire Protection

The bottom portion of the plant water storage tank will be dedicated to fire protection water. One electric and one diesel-engine driven pump will be installed in parallel to supply water to the closed-loop buried fire water distribution system, which will be pressurized constantly by a jockey pump.

Pressurized spray systems will be provided in the conveyor tunnels, warehouses and offices as determined by the requirements of the insurer and approved by the Owner.

5.9.3 Electrical Power Supply and Distribution

Electrical power will be delivered to the plant via 115 kV, 50 Hz, 3-phase overhead lines. One 30 MVA transformer will step down the voltage to 11.5 kV for the smelting furnace feed, while two 16 MVA transformers installed in parallel will reduce the voltage to 3.3 kV for medium voltage plant distribution. Power will be stepped down to 420 V in the local electrical rooms for low-voltage use. The distribution system is shown on the electrical one-line diagrams contained in Appendix A.

5.9.4 Compressed Air

Two air compressors installed in a compressor room will supply pressurized air to a reticulation system for the purpose of plant maintenance use.

5.9.5 Sanitary Sewer

The plant will utilize a modularized below-grade packaged sewage treatment plant. Effluent will be pumped to the slag granulation operation.

5.9.6 Communications

A communications system customary for industrial plants will be provided. The system will include a telephone network and two-way radios as required. Instrumentation data communication will utilize a fiber optic system.

SECTION 6

SECTION 6
CAPITAL COST ESTIMATE

6.1 CAPITAL COST SUMMARY

The capital cost estimate for this prefeasibility study is defined in the following sections and tables for processing the nodules to produce the nickel, cobalt and copper products. Costs are in first quarter 1996 US dollars with no future escalation provided and are summarized in Table 6-1, including the Phase II and Owner's costs. A summary of the direct costs by facility is shown in Table 6-2. The accuracy of the estimate is ±25 percent.

6.2 ESTIMATE BASIS

6.2.1 Scope Definition

The estimate is based on the mechanical and electrical equipment lists and the following drawings, all of which are included in Appendices A and C:

	Drawings
• Site plan	1
• Flow diagrams	16
• Electrical single lines	5
• Plans and sections of the process facilities	6

6.2.2 Quantity Development

The take-off of civil quantities (concrete and structural steel) was based on historical data related to similar facilities and plant sections. Roofing and siding quantities were developed from the general arrangement drawings.

Table 6-1

PROJECT SUMMARY

(Costs and Manhours in 1,000s)

	Manhours (hours)	Installation Labor Costs (US $)	Equipment Material & Subcontract Costs (US $)	Total Cost (US $)
Plant equipment			192,623	192,623
Bulk materials			43,109	43,109
Subcontracts	55		5,100	5,100
Installation labor	1,346	53,798	-	53,798
Total Direct Costs	1,401	53,798	240,832	294,630
Spare parts				4,570
Common distributables				6,920
Ocean freight and inland freight				9,480
EPCM services				31,370
Project insurance				1,730
Contingency				47,400
Total Project Costs				396,100
Phase II testwork				11,000
Development Costs				9,000
Owner's costs				19,000
Total Costs				435,100

Table 6-2

FACILITY SUMMARY

(Cost in $1,000s)

	Facility Description	Plant Equipment (US $)	Bulk Materials (US $)	Installation (US $)	Subcontracts (US $)	Total (US $)
0100	Marine facilities	116,475	30	2,528		119,033
0200	Nodule storage and reclaim	1,759	3,335	5,820		10,914
0320	Drying	5,630	2,624	3,560		11,814
0330	Prereduction	5,213	5,972	3,658		14,843
0340	Smelting	38,551	4,522	10,652		53,725
0350	Converting	7,515	12,352	8,147		28,014
0360	Product granulation	278	722	618		1,618
0400	Hydrometallurgy plant	6,382	5,809	6,838	52	19,081
0510	Coal receiving, storage and reclaim	1,955	2,170	2,603		6,728
0520	Flux and reagent receiving and storage	223	762	708		1,693
0600	Site development and utilities	8,642	4,811	8,666	5,048	27,167
	TOTAL	192,623	43,109	53,798	5,100	294,630

Mechanical bulks are derived from the equipment list with provisions made for insulation, duct work and refractory lining.

Yard piping was taken off from the plot plan for yard piping and all-in process piping was factored of the basis of mechanical equipment.

Electrical bulk materials and instrumentation have been factored and were based on the mechanical equipment. Yard electrical equipment was defined from the electrical equipment list and the single line diagrams.

6.2.3 Labor

Labor rates are based on current Bechtel construction activities in New Zealand and reflect the recent experience of productivity rates. The hourly rates (all-in at $40.00) include the base wages, fringe benefits, small tools and consumables, insurance, construction equipment, contractor nonmanual costs, overhead and profit. New Zealand craft productivity was derived by multiplying North American Mining and Metals standards by a factor of 1.2.

6.2.4 Common Distributables

An allowance for common distributables was added at 3.5 percent of the direct costs to cover such expenses as common warehousing, salaries of managers, temporary facilities and vehicles, and surveying and testing services. Trawlers and transport ships were exempted.

6.2.5 Ocean Freight and Inland Freight

The following allowances were added: 10 percent for ocean freight for imported equipment; and 2 percent for inland freight and port fees for local and imported material and equipment.

6.2.6 Spare Parts

Spare parts were provided for at 5 percent of the equipment costs, except for the electrowinning cells and ships, which have no such provision included.

6.2.7 Engineering, Procurement and Construction Management

Engineering, procurement and construction management costs were estimated at 15 percent of the field direct costs, except for ships, which bear a 1 percent allowance.

6.2.8 Project Insurance

A provision for all-risk insurance was made in the amount of 0.5 percent of all of the above costs.

6.2.9 Escalation

No future escalation beyond the first quarter of 1996 was provided.

6.2.10 Contingency

Contingency is an amount of money allowed in an estimate for costs which, based on past experience, are likely to be incurred but are difficult or impossible to identify at the time the estimate is prepared. It is an amount which is expected to be expended during the course of the project for the scope as defined. Contingency does not include scope changes. Examples of contingency items include:

- Estimating errors or omissions
- Design development
- Pricing changes

- Schedule delays
- Delays for equipment and material deliveries
- Contractor's claims and their impacts

A provision of 15 percent was included, except for the ships, where 10 percent was provided for contingency.

6.3 PRICING

The estimate is based on first quarter 1996 US dollars and future escalation is excluded.

The exchange rates used in the development of this estimate are as follows:

Currency Rates			
New Zealand dollar	1 NZ $	=	US $0.67
Norwegian Crown	1 Crown	=	US $0.15

Plant equipment prices are based on 45 percent budgetary quotes, 39 percent phone quotes and 3 percent recent price quotes for major items. The remaining equipment was estimated using in-house data. The breakdown for the pricing is shown in the following tabulation.

	Budget Quotes ($1,000)	Phone Quotes ($1,000)	Recent Quotes ($1,000)	Estimated Values ($1,000)	Total ($1,000)
Marine facility	41,149	75,000	—	326	116,475
Process plant	45,244	—	5,089	17,173	67,506
Site development and utilities	291	—	171	8,180	8,642
Total	86,684	75,000	5,260	25,679	192,623
Percent of overall equipment (%)	45	39	3	13	—

A summary of the equipment costs by type of equipment is found in Table 6-3.

Table 6-3

PLANT EQUIPMENT SUMMARY

Description	Quantity	Unit	Cost (US $1,000s)	Q/B
Mechanical				
Agitator and mixer	41	ea	1,002	QP
Boiler	1	ea	220	
Electrolytic cell	37	ea	377	QP
Crane	11	ea	2,521	BP
Compressor	5	ea	198	BP
Cyclone cluster	4	ea	267	Q
Belt conveyors	1,022	lm	2,871	
Drag and crew conveyors	4	ea	168	
Dust collectors and scrubbers	2	ea	1,132	BP
Electrostatic precipitator	1	ea	1,955	
Dryers	5	ea	2,210	QP
Anodes, mother blanks, cathodes	4,362	ea	2,182	QP
Electrode handling equipment	6	ea	165	
Stripping machine	2	ea	200	
Fans	31	ea	1,492	
Smelting furnace	1	ea	35,000	Q
Converting furnace	2	ea	2,533	B
Feeders	13	ea	345	
Filters	16	ea	328	QP
Gas power generator	1	ea	1,400	
Heat exchangers	16	ea	315	BP
Heat exchanger - cooling tower	2	ea	400	
Surface mobile equipment	16	ea	795	
Harvesting trawlers	4	ea	24,000	Q
Trawl winch	4	ea	4,620	Q
Transporter ships	3	ea	75,000	T
Grinding mill	2	ea	192	QP
Pumps	144	ea	1,098	QP/B
Kiln	1	ea	4,200	Q
Screen	4	ea	230	QP
Centrifuge	3	ea	225	Q
Thickener clarifier mechanism	1	ea	200	Q
Vendor representative	217	days	217	
Miscellaneous mechanical equipmeni	1	lot	1,031	
Marconaflo systems	8	ea	4,385	Q
Trawler positioning system	4	lot	2,100	Q
Trawl winch rope with embedded cat	4	lot	3,720	Q
Nodule harvesting trawl	4	lot	1,720	Q
Trawl dynamic positioning system	4	ea	1,480	Q
Water cooled hood	2	ea	900	
Hot metal transfer ladles	10	ea	440	
Tuyere punching machine	2	ea	740	B
Laboratory/shop equipment	1	lot	650	
Mechanical Subtotal			185,224	
Electrical and Instrumentation				
Electrical equipment	1	lot	6,056	
Electrical Subtotal			6,056	
Instrumentation (factored)	1	lot	1,343	
Instrumentation Subtotal			1,343	
Plant Equipment Total			192,623	

Q = Quote
B = Prior Quote
P = Partial
T = Telephone Quote

Bulk materials and subcontracts were based on recent project experience in New Zealand and on current in-house data, and these costs are summarized by major categories in Tables 6-4 and 6-5

6.4 ESTIMATE QUALIFICATIONS

The following items are presented as qualifications to the estimate:

- The project will be constructed on a greenfield site with no unusual soil conditions or required major earthwork. Spread footings can be utilized.
- Initial fills of reagents and resins are included.
- There is no labor availability problem.
- An existing port will be available at no capital cost.
- Utilities will be available at the site battery limits.
- Allowances have been provided for the administration building furnishing and equipment as follows:
  - Laboratory equipment $350,000
  - Shop equipment $100,000
  - Office equipment and furnishing $200,000

6.5 ESTIMATE EXCLUSIONS

The following items are excluded from the estimate:

- Financing charges and interest during construction
- Cost of any future studies except for an update of this study in Phase II
- Plant operating supplies, fuels beyond initial fills and marine insurance
- Escalation beyond first quarter 1996
- Taxes and duties

Table 6-4

BULK MATERIALS SUMMARY

Description	Quantity	Unit	Material Cost (US $1,000)
General civil/site development	1	lot	375
Fencing and gates	1,360	lm	136
Concrete all-in foundations and structure	13,830	m^3	3,734
Slab on grade	2,540	m^3	559
Elevated concrete	1,290	m^3	258
Structural steel	4,855	ton	14,565
Miscellaneous steel	1,285	ton	5,397
Siding	22,930	m^2	608
Roofing	9,790	m^2	264
Tanks and mechanical bulks	1	lot	684
Bins and silos	1	lot	4,685
Ductwork	1	lot	1,950
Installation materials	1	lot	1,233
Refractory	1	lot	125
Piping	1	lot	4,167
Electrical equipment bulk provision	1	lot	740
Raceway	1	lot	1,706
Wire and cable	1	lot	1,900
Instrumentation	1	lot	23
Bulk Materials Total			43,109

Table 6-5

SUBCONTRACT SUMMARY

Description	Quantity	Unit	Material Cost (US $1000)
Pavement	30,000	m^2	750
Unit construction	4,494	m^2	4,350
Subcontract Total			5,100

6.6 PHASE II COSTS

A provision for a Phase II period of approximately one year was provided to test the harvesting method, select the site and to perform metallurgical testwork. This cost item is provided with its own contingency as shown below:

Table 6-6
PHASE II COSTS

Description	Cost (US $1,000s)
Program management	500
Owner's costs	250
Oceanographic exploration	1,320
Metallurgical testwork	240
Test harvesting	4,500
Site selection	300
Feasibility study update	1,000
Contingency	2,790
TOTAL	11,000

6.7 OWNER'S COSTS (PHASE III)

A provision for the Owner's costs, which includes the following items, also is part of this estimate as shown below:

Table 6-7

OWNER'S COSTS

Item	Cost (US $1,000s)
Environmental impact statement at 1 percent of direct costs	3,000
Owner's project management 5 people for 4 years at $200,000 per year	4,000
Land acquisition - allowance	1,000
Process license - allowance	1,000
Utilities hookups - allowance	500
Staffing and recruiting	3,000
Startup and commissioning allowance	500
Training of operators	1,700
Taxes and insurance allowance	2,000
Contingency	2,300
TOTAL	19,000

SECTION 7

SECTION 7
OPERATING COST ESTIMATE

7.1 INTRODUCTION

7.1.1 Cost Centers and Cost Summary

The operating cost estimate for the Cook Islands Deep-Sea Nodule Mining Project is divided into five cost centers as follows:

- Marine operations consisting of harvesting and transportation of the nodules
- Smelter, including nodule unloading, smelting and slag disposal
- Hydrometallurgical refining to produce metals
- Maintenance for fixed plant facilities
- General and administration

Summary tabulations are given in the following sections on the buildup of the costs in the various centers. The estimated operating cost summary is shown in Table 7-1.

Table 7-1

OPERATING COST SUMMARY

	Total Cost (US $/y)
Marine operations:	
Harvesting	7,707,000
Transportation	9,914,000
Subtotal	17,621,000
Smelting:	
Consumables	16,044,500
Labor	2,522,000
Subtotal	18,566,500
Refining:	
Consumables	3,517,410
Labor	838,000
Subtotal	4,355,410
Maintenance labor	2,328,700
General and administration	4,163,500
TOTAL	47,035,110

7.1.2 Estimate Basis

The operating cost estimate is based on the process presented in the preceding sections of this report and on the material balances as shown in the process design criteria in Appendix B. The accuracy of the estimates is ± 25 percent.

The operating costs for the marine operations were developed on the basis of information obtained from interviews with experienced marine shipping operators. Bechtel developed the flowsheets for the smelting and refining areas of the plant and estimated the consumable quantities and labor requirements. The process inputs and outputs are summarized in Table 7-2.

The cost inputs are presented in Table 7-4. The labor costs are taken from a national (New Zealand) wage and price survey and presented as total remuneration costs, including the base salary and value of all benefits, as of the fourth quarter of 1995. Electricity and coal budgetary prices were obtained from Northpower, Ltd. and Solid Energy North, respectively. Other consumable prices were available from Bechtel studies of similar operations. Maintenance supplies have been estimated at 4.5 percent of the plant equipment cost. A 10 percent contingency has been added for the consumables only, given the level of process definition developed for the study. General administration staff was estimated for the operation, and an allowance was made for office supplies, travel costs and the like.

The quantitative basis of the estimate is listed in Tables 7-3 and 7-4.

Table 7-2

MATERIAL INPUT / OUTPUT

OCEAN NODULE PROCESSING PLANT
(MAJOR ITEMS)

INPUTS	Quantity (t/y)
Ocean nodules smelted (dry)	665,000
Coal	85,870
Silica	9,300
Sulfur	530
Chlorine	1,030
Soda ash	760
OUTPUTS	
Matte produced[(1)]	8,215
Metal to converter[(2)]	27,280
Cobalt cathode chips	2,652
Nickel cathode (1" x 1" squares)	1,718
Copper powder	955
Electric furnace slag[(3)]	451,670

(1) Matte Composition:
Ni 21.4%, Co 32.7%, Cu 12.1%,
Fe 5.1%, S 28.7%, Mn 0.07%

(2) Alloy composition:
Fe 70.2%, Co 9.9%, Ni 6.5%,
Cu 3.6%, Mn 3.9%, Pb 2.5%, S 3.4%

(3) Slag composition:
SiO_2 23.0%, FeO 32.3%, MnO 29.4%
CaO 4.5%, MgO 3.9%, CoO 0.12%, NiO 0.01%

Table 7-3

UNIT PRICES FOR OPERATING COST ESTIMATES

Item	Unit	Unit Cost (US $)
Silica	t	3.00
Sulfur	t	42.00
Coal	t	42.00
Refractories	allowance	400,000.00
Electrode paste	t	440.00
Electrode casings	t	1,350.00
Tapping lances	each	6.40
Grinding balls	allowance	30,000.00
HCl (35%)	t	156.00
Hydrated lime	t	105.00
Soda ash	t	150.00
Chlorine	t	475.00
Solvesso 150	L	0.37
Kerosene	L	0.42
Alamine 336	kg	4.25
TBP	kg	4.00
Water treatment chemicals	allowance	8,000.00
EW electrode bags	each	30.75
EW anode recoats	each	750.00
EW cathodes	each	775.00
EW hanger bars	each	160.00
Ni cathode boxes	each	14.15
Co cathode drums	each	14.15
Drum pallets	each	4.10
Fuels:		
Diesel fuel	L	0.20
No. 2 fuel oil	t	300.00
Lubricants, smelting	allowance	16,000.00
Lubricants, refining	allowance	10,000.00
Power	MWh	41.30
Water	m^3	0.20
Labor costs:		
General manager		150,000.00
Plant manager		81,200.00
Superintendent		54,600.00
Clerk		40,000.00
Senior staff		29,400.00
Chemist; instruments		29,600.00
Shift supervisor		32,500.00
Foremen		29,500.00
Day labor		23,500.00

Table 7-4
MARINE OPERATIONS OPERATING COST

	Vessels (no.)	Unit Cost (US $)	Total Cost (US $/y)
A. Harvesting Vessels			
Consumables:			
Rope			1,330,000
Fuel			2,325,000
Food			192,000
Maintenance parts			400,000
Ship overhaul, 4 year			1,000,000
Subtotal			5,247,000
Labor:			
Working master	1	30,000	30,000
Officers	2	28,000	56,000
Helmsman	3	14,000	42,000
Sonar/navigation	3	14,000	42,000
Engine room	6	12,000	72,000
Deck hands	6	12,000	72,000
Trawl handler	6	12,000	72,000
Cook	2	12,000	24,000
Subtotal	29		410,000
Six crews required			2,460,000
TOTAL HARVESTING COSTS			7,707,000
B. Transport Vessels			
Consumables:			
Fuel			2,772,000
Food			126,000
Maintenance parts			300,000
Ship overhaul, 5 year			1,200,000
Subtotal			4,398,000
Labor:			
Captain	1	60,000	60,000
Officers	3	50,000	150,000
Chief engineer	1	40,000	40,000
2nd & 3rd engineers	2	35,000	70,000
Helmsmen	3	20,000	60,000
Engineers	6	18,000	108,000
Deck hands	6	12,000	72,000
Stewards	3	14,000	42,000
Subtotal	25		602,000
Other expenses:			
Port berthing charge			756,000
Cargo charges			2,352,000
Subtotal			3,108,000
TOTAL NODULE TRANSPORTATION COSTS			8,108,000
TOTAL MARINE OPERATIONS COSTS			15,815,000

7.1.3 Exclusions

No allowance was made for the following potential expenses:

- Royalties, permits and licenses
- Escalation (all costs are in first quarter 1996 US dollars)
- Credit for the sales of any products other than cobalt, nickel and copper
- Costs for environmental compliance other than those indicated on the process flow diagrams
- First-year startup costs or possible productivity gains
- Major rebuild costs
- Overtime costs

7.2 MARINE OPERATIONS

Four harvesting trawlers will operate on a 330 day per year basis. Vessels will be at the harvest area during the entire operating year, with crews working for four-week periods with two weeks off, requiring a total of six crews. Trawler crews will be transported from Aitutaki to the trawlers by the nodule transport vessels. Three nodule transport ships, operating two weeks receiving nodules and four weeks round-trip transit time, will be required. These crews will work six-week periods with two weeks off, requiring a total of four crews. The operating costs below include a trawler overhaul at four-year intervals and a nodule transport vessel overhaul at five-year intervals. The operating cost breakdown is shown below in Table 7-4.

7.3 SMELTING

Summaries of the annual direct production costs for the smelting process shown in the process flow diagrams are provided in Tables 7-5 and 7-6. Included in these tables are the summarized operating consumables, electric power, fuels, maintenance parts, and direct production labor. The estimates include the costs for operating the main process equipment and the auxiliary and ancillary facilities. Table 7-5 summarizes the annual consumptions and costs for the consumable operating supplies, fuels and electric power. Table 7-6 describes the labor requirements and cost.

7.4 MATTE REFINERY

The estimated operating costs of the hydrometallurgical processing to yield the refined metals products as shown in the process flow diagrams are provided in Tables 7-7 and 7-8. Included in these tables are the summarized operating consumables, electric power, fuels, maintenance parts, and direct production labor. The estimates include the costs for operating the main process equipment. Table 7-7 summarizes the annual consumptions and costs for the consumable operating supplies, fuels and electric power. Table 7-8 describes the labor requirements and costs.

7.5 MAINTENANCE

The maintenance parts and supplies for the marine operations are shown in Table 7-4.

The land-based smelting and refinery facility maintenance parts and supplies were estimated at 4.5 percent of the plant equipment cost and are shown in Tables 7-5 and 7-7, respectively.

The land-based facilities will share a common maintenance labor pool. The makeup and annual cost for this pool are shown below in Table 7-9.

Table 7-5

SUMMARY OF SMELTING CONSUMABLES

Classification	Unit	Quantity (per year)	Unit Cost (US $)	Total Cost (US $/y)
Consumables:				
Silica	t	9,300	3.00	27,900
Sulfur[1]	t	530	42.00	22,260
Refractories	allowance			400,000
Electrode paste	t	1,000	440.00	440,000
Electrode casings	t	90	1,350.00	121,500
Tapping lances	each	17,050	6.40	109,120
Water (@ 8% of slag weight)	m^3	36,134	0.20	7,227
Subtotal				1,128,007
Fuels:				
Coal	t	85,870	42.00	3,606,540
No. 2 fuel oil	t	3,250	300.00	975,000
Lubricants	allowance			16,000
Subtotal				4,597,540
Power	MWh	163,900	41.30	6,769,070
Maintenance parts (@ 4.5% of plant equipment cost)				2,604,580
Contingency (@ 10% of consumables)[2]				945,303
TOTAL SMELTING CONSUMABLES COSTS				16,044,500

(1) Net sulfur purchased after credit of 2,140 t/y recycle from chlorine leach process

(2) Excluding electric furnace power

Table 7-6

SMELTING LABOR COSTS

Category	Personnel Per Shift	Personnel Total	Salary (US $/y)	Total Cost (US $/y)
Shift foreman	4	16	32,500	520,000
Material handling and drying:				
Operators	2	8	29,500	236,000
Helper	2	8	23,500	188,000
Reduction kiln:				
Operators	1	4	29,500	118,000
Helper	1	4	23,500	94,000
Electric smelting furnace:				
Operators	1	4	29,500	118,000
Tapper	2	8	23,500	188,000
Helper	1	4	23,500	94,000
Converter:				
Skimmer	1	4	29,500	118,000
Puncher	1	4	23,500	94,000
Gas cleaning operators:	1	4	29,500	118,000
Steam plant operators:	1	4	29,500	118,000
Effluent treatment/water supply:				
Operator	1	4	29,500	118,000
Helper	1	4	23,500	94,000
Slag handling:				
Operator	1	4	29,500	118,000
Helper	1	4	23,500	94,000
Matte grinding operator:	1	4	23,500	94,000
TOTAL SMELTING LABOR		92		2,522,000

Table 7-7

SUMMARY OF MATTE REFINERY CONSUMABLES

Commodity	Units	Quantity (per year)	Unit Cost (US $)	Total Cost (US $/y)
Grinding balls	allowance			30,000
Soda ash	t	760	150.00	114,000
HCl (35%)	t	265	156.00	41,340
Hydrated lime	t	60	105.00	6,300
Solvesso 150	L	1,500	11.00	16,500
Alamine 336	kg	240	4.25	1,020
Kerosene	L	1,500	0.42	630
TBP	kg	230	4.00	920
Chlorine	t	1,030	475.00	489,250
Water chemicals	allowance			8,000
EW electrode bags	each	300	30.75	9,225
EW Ti cathodes	each	60	775.00	46,500
EW anode recoats	each	260	750.00	195,000
EW hanger bars	each	220	160.00	35,200
Product drums & boxes	each	21,400	14.15	302,810
Drum pallets	each	5,350	4.10	21,935
Miscellaneous items(1)	allowance			160,000
Subtotal				1,478,630
Fuels and lubricants:				
Diesel	L	667,000	0.20	133,400
Lubricants and tires	allowance			10,000
Subtotal				143,400
Electric power	MWh	17,830	41.30	736,380
Maintenance parts (@ 4.5% of plant equipment cost)				900,000
Contingency (@ 10% of consumables)(2)				259,000
TOTAL REFINERY CONSUMABLES COSTS				3,517,410

(1) Miscellaneous includes: filter cloths, precoat, miscellaneous chemicals, IX resins, activated carbon, H_2SO_4, NaOH, laboratory supplies, tankhouse supplies, safety supplies, etc.

(2) Excluding electrowinning power

Table 7-8

MATTE REFINERY LABOR COSTS

Category[1]	Personnel (no.)	Salary Including Benefits (US $/y)	Total Cost (US $/y)
Foremen	4	32,500	130,000
Operators	24	29,500	708,000
TOTAL REFINERY LABOR	28		838,000

(1) The refinery shares supervision and day labor already included in smelting operating labor, and maintenance listed in Table 7-9 following.

Table 7-9

MAINTENANCE LABOR COSTS

Category	Personnel Per Shift (no.)	Total Personnel (no.)	Salary Total (US$/y)	Total Salary (US $/y)
Foreman	3	12	32,500	390,000
Mechanic	4	16	29,500	472,000
Mechanical helper	3	12	23,500	282,000
Electrician	2	8	29,500	236,000
Electrical helper	2	8	23,500	188,000
Instrument	3	12	29,600	355,200
General helper	4	16	23,500	376,000
Vehicle and stationary		1	29,500	29,500
TOTAL		85		2,328,700

7.6 GENERAL AND ADMINISTRATIVE COSTS

Included in this section are management, administration and technical personnel for the complete project. The costs for these are summarized in Table 7-10.

In addition, general administration incidentals include the office supplies, insurance on the land-based fixed assets, marine insurance for the ocean-based assets, and miscellaneous costs. These latter include, among others: travel; entertainment; computer services; miscellaneous contracts; equipment leases and rents; licenses; advertising; donations; dues and memberships; public relations; process research; phone, radio and telex; local taxes; unscheduled overtime and the like.

Table 7-10

GENERAL AND ADMINISTRATIVE COSTS

Category	Personnel Per Shift	Personnel Total	Salary (US $/y)	Total Cost (US $/y)
Laboratory personnel:				
Chief chemist		1	32,500	32,500
Chemist	2	8	29,600	236,800
Sampler	2	8	23,500	188,000
Subtotal		17		457,300
Plant management and administration personnel:				
Plant manager		1	81,200	81,200
Superintendent	1	4	54,600	218,400
Planner		1	54,600	54,600
Administrative assistant		2	29,400	58,800
Engineers		3	29,600	88,800
Plant metallurgist	1	4	29,400	117,600
Metallurgical accounting		2	29,500	59,000
Maintenance superintendent	1	4	54,600	218,400
Secretary		4	29,500	118,000
Security		6	23,500	141,000
Subtotal		25		1,155,800
General administration labor:				
General manager		1	150,000	150,000
Chief administrator		1	81,200	81,200
Comptroller		1	81,200	81,200
Purchaser		1	60,000	60,000
Marketing director		1	60,000	60,000
Accountants, clerks		5	40,000	200,000
Secretary		4	29,500	118,000
Subtotal		14		750,400
General administration incidentals:				
Supplies				200,000
Insurance - marine assets				700,000
Insurance - land assets				400,000
Miscellaneous				500,000
Subtotal				1,800,000
TOTAL GENERAL AND ADMINISTRATION		56		4,163,500

SECTION 8

SECTION 8
PROJECT ECONOMICS

8.1 COBALT INDUSTRY OVERVIEW

8.1.1 Introduction

The Cook Islands Deep-Sea Nodule Mining Project will produce three end-products: cobalt and nickel metal and copper powder. Of these, cobalt will account for over 90 percent of the revenues. Because the world market for cobalt is much smaller and less liquid than are the markets for nickel and copper, and thus could have a significant impact on the project's feasibility, the following overview of the cobalt industry has been prepared.

8.1.2 Output Trends

As shown in Figure 8-1, annual cobalt production has ranged from 17,000 to 37,000 metric tons during the past 25 years, but has exhibited no clear growth trend. The production declines of the 1990s have been due largely to political and social unrest and inadequate investment in Zaire, which was the world's dominant producer. Even allowing for the events in Zaire, which may not persist over the long run, it appears that cobalt consumption is not likely to grow as fast as the world economy in general, as shown by comparison of the cobalt bars and the world GDP line in Figure 8-1. This is partly confirmed by U.S. consumption, which has grown significantly slower than the GDP since 1993. (From 1990 to 1993, U.S. consumption slumped sharply, probably due to reduced military aircraft engine procurement.)

8.1.3 Major Suppliers

Table 8-1 shows that seven firms currently account for 70 to 85 percent of the world's total cobalt production. Gecamines (Zaire), with a production averaging over 10,000 tons per year, dominated the market until 1991. At its projected level of output of over 2,600 tons per year, the project would be the world's fifth largest cobalt producer, accounting for over 10 percent of the

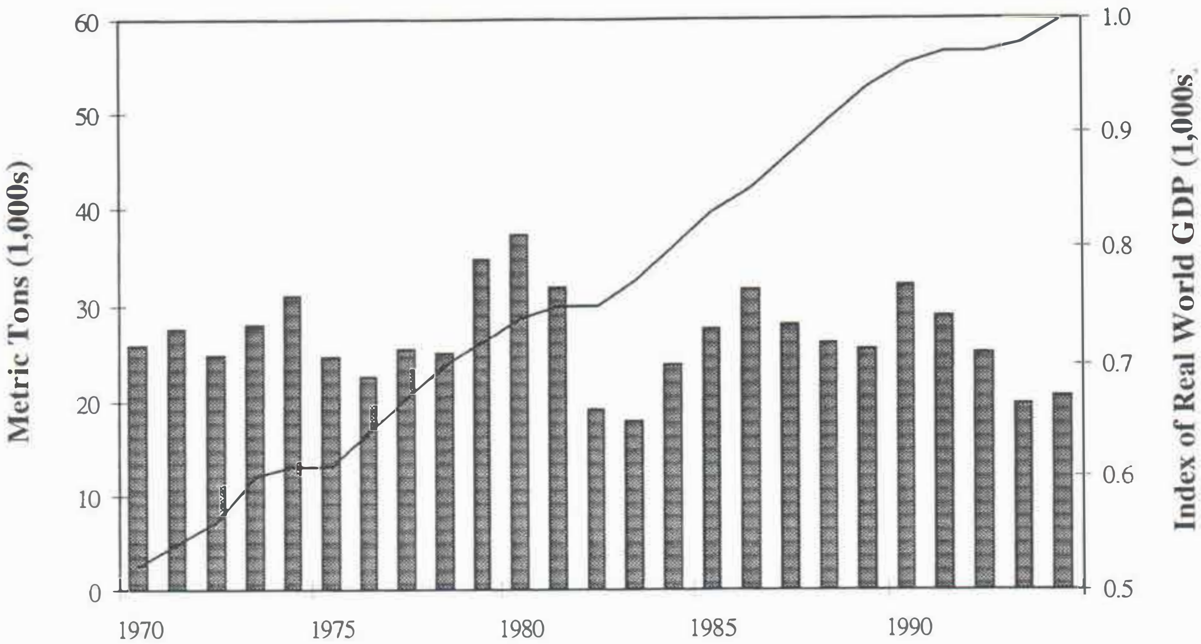

Figure 8-1. World Metal Output of Cobalt and World Real GDP

Table 8-1

WORLD COBALT METAL PRODUCTION BY SOURCE

(Metric tons)

Source	1993[1] (tons)	1994[1] (tons)	1995[2] (tons)	1996[2] (tons)
Gecamines	2,200	3,300	4,100	5,500
ZCCM	4,211	2,639	2,800	4,000
Falconbridge	2,414	2,823	2,800	2,900
Inco	1,410	1,250	1,400	1,580[3]
ICCI	1,218	1,820	1,750	2,000
OMG	2,200	3,000	3,200	3,500
Sumitomo	190	161	150	150
Other Western World	1,000	1,200	1,500	2,000
TOTAL WESTERN WORLD	14,843	16,193	17,700	21,630
Non-West	3,800	3,500	2,900	3,000
WORLD TOTAL	18,643	19,693	20,600	24,630

(1) CDI "Cobalt Facts" plus author's estimates
(2) Author's estimates
(3) Inco cobalt production dependent on nickel production

world's estimated 1996 output. Major future expansions of global production capacity could come from the Diamond Fields project in Canada (controlled by Inco), Australia and Cuba, as well as expansion of the capacity of existing mines. As in the case of about 60 percent of current cobalt production, Diamond Fields, Australia and Cuba are primarily nickel resources; and cobalt production will be determined largely by nickel production.

Another major factor in the supply of cobalt is the release to the market of U.S. Defense Logistic Agency stockpiles. These releases apparently are being managed to maximize the revenue to the U.S. Treasury and may be completed or near completion before Cook Islands production could come onstream. Releases from stockpiles of the former Soviet Union apparently are now small and nearing completion.

The worldwide cobalt refinery capacities are shown in Table 8-2. Although the capacity figures contain a significant amount of cobalt compounds and are, therefore, not strictly comparable to the production figures shown in Table 8-1, Table 8-2 nonetheless suggests that the global refining capacity will be adequate for the indefinite future. It is not clear, however, whether all of this capacity is efficient economically or whether refiners are interested in taking on new cobalt supply sources.

8.1.4 Major Consumers

Figure 8-2 illustrates how cobalt is used in the U.S. Fragmentary evidence suggests that the U.S. consumption patterns are more or less typical of the rest of the world. Inasmuch as the U.S. typically accounts for about 30 percent of world cobalt consumption, this is not surprising. However, because of its aircraft engine and utility turbine industries, the U.S. share of superalloy consumption is relatively high. Compared to Japan, the U.S. consumption for chemical applications is fairly low. It appears that the share of superalloy/hardfacing applications has remained constant at somewhat over 40 percent, while the share of chemical applications has increased, and the share of magnetics has declined. Demand probably will continue to be fairly high in the superalloy area since much of it is accounted for by aircraft engines and power generation turbines, two applications that are expected to grow at a fairly healthy rate for the indefinite future.

Table 8-2

WORLDWIDE ANNUAL COBALT REFINERY CAPACITY

December 31, 1994[1]
(Metric tons cobalt content)

Source	tons
Belgium[2]	1,200
Brazil	300
Canada[3]	3,900
China[4]	500
Finland[2],[4]	3,000
France[5]	600
Japan[2]	480
Norway	2,900
Russia[4]	8,000
South Africa, Republic of[4],[6]	750
United States[7]	900
Zaire	18,000
Zambia	5,000
WORLDWIDE TOTAL	45,500

(1) Data rounded by the U.S. Bureau of Mines to three significant digits; may not add to total shown
(2) Includes oxide and salts
(3) Includes oxide
(4) Estimated
(5) Cobalt chloride
(6) Includes sulfate
(7) Standby capacity

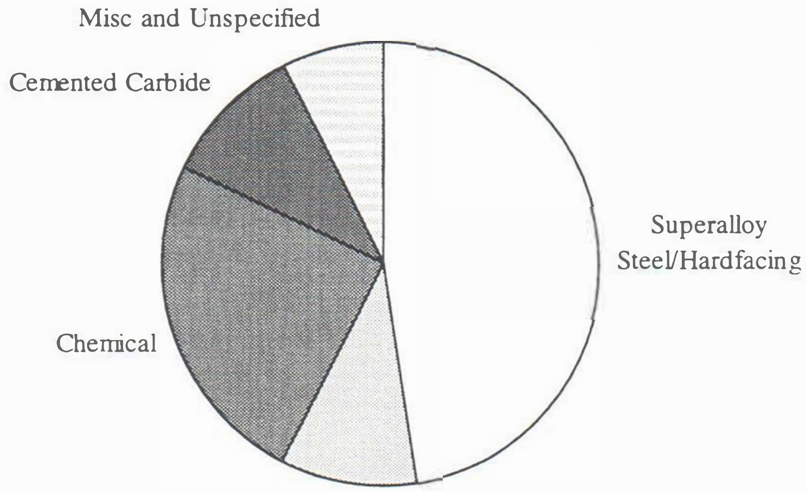

Figure 8-2. U.S. Reported Consumption of Cobalt by Sector

Figure 8-3 shows that the developed countries of the world currently consume about 80 percent of the refined cobalt. This share probably will decline in the future, as the developing countries, particularly China, and their cobalt consumption, are likely to continue to grow at a faster pace.

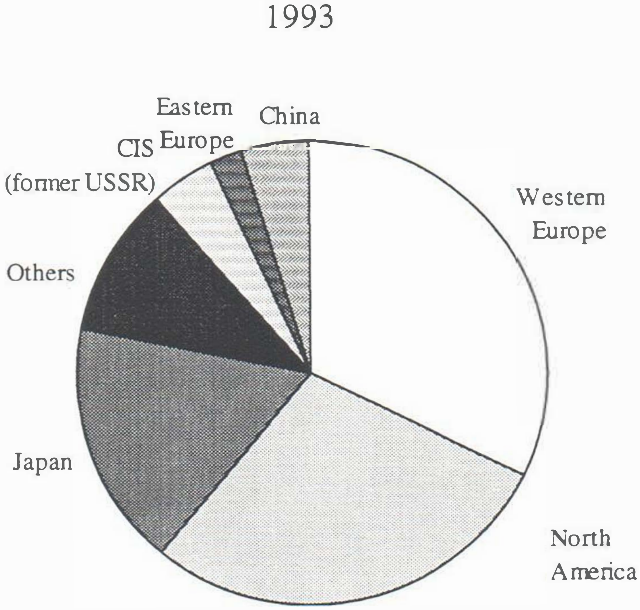

Figure 8-3. Worldwide Consumption of Refined Cobalt

8.1.5 Market Structure

Cobalt is not traded on a regular commodity-market basis as are other metals such as copper, nickel, zinc and lead. While there are cobalt traders and contracts over various periods, it appears that most cobalt is sold on a spot-market basis by producers or producers' agents. Because cobalt is usually a by-product of nickel or copper production, its own production is not dictated by market conditions. Thus, in periods of excess cobalt supply (due to the production of copper and nickel growing faster than the demand for cobalt), producers typically build up cobalt inventories. When the demand for cobalt grows faster than the production of copper and nickel, producers release their inventories to the market. Since the size of cobalt inventories are not large relative to the total metals production of the producing companies, it is relatively easy for producers to hold large inventories when necessary. The producers' ability and willingness to build and release inventories tends to stabilize prices in the cobalt market.

Estimates of the size of producers' inventories seem to be a matter of informed judgment rather than hard data. Anecdotal evidence suggests that inventories have been coming down in recent years. Over a long-term planning horizon, such as the horizon for this project, it seems reasonable to assume that inventories will fluctuate around a more or less constant level and therefore have little impact on long-run pricing and output.

In further investigations concerning the commercial viability of the Cook Islands project, additional study of the cobalt market should be undertaken. This study should determine the volume of cobalt sold under long-term contract, the types of customers likely to negotiate such contracts, and the contracts' terms and conditions.

8.2 COBALT MARKET PRICE

8.2.1 Cobalt Price History

Figure 8-4 shows the history of cobalt spot market prices from 1985 to 1995. During the 1980s and before, the cobalt market was controlled mainly by Gecamines (Zaire) and ZCCM (Zambia), and cobalt prices ranged from $7 to $15 per pound. Beginning in the 1990s, Zaire and Zambia encountered severe production problems and cobalt metal production sharply declined. The production decline from these two major sources coincided with the rapid escalation of prices from 1990 to 1995. It is reasonable to infer that this price escalation was due in large part to the coinciding drop in supply.

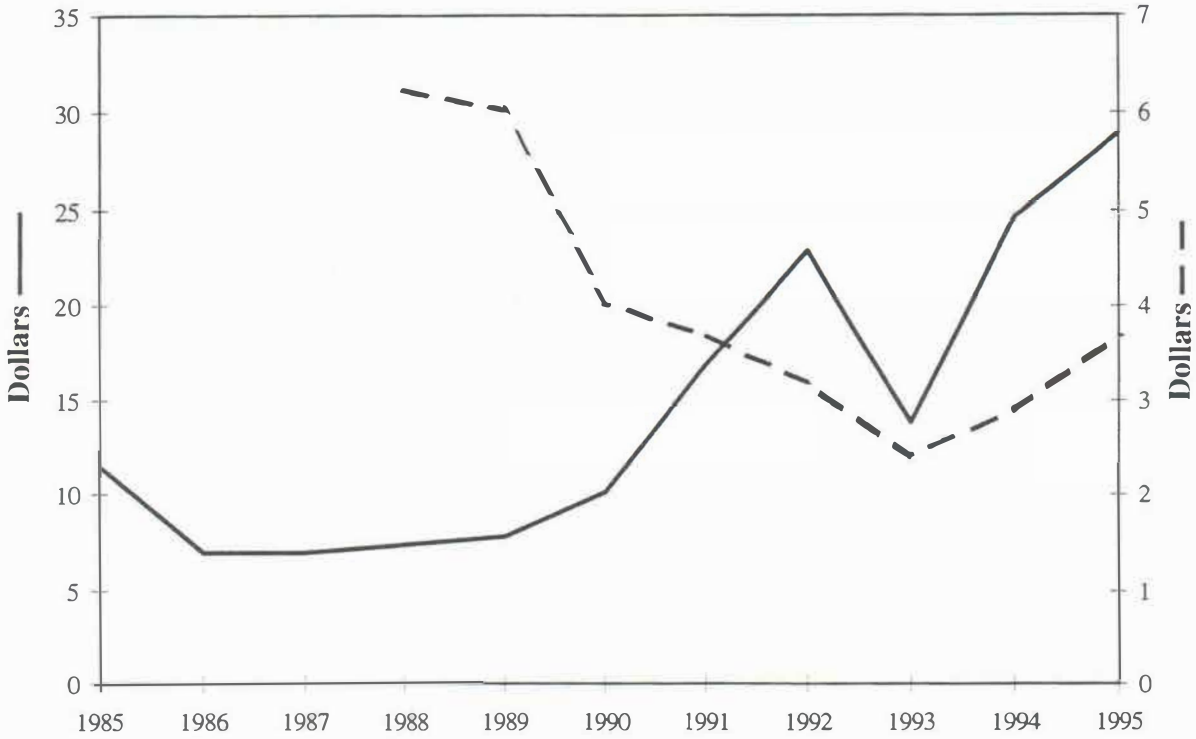

Figure 8-4. Cobalt and Nickel Prices Per Pound
Average U.S. Spot Cathode

8.2.2 Factors Influencing Future Prices

The most likely scenario for future demand for cobalt would seem to be slow growth, somewhat less than the world GDP growth. Probably the major uncertainty concerning demand is the long-run possibility of substitution of other materials for cobalt in some applications. It appears that some substitutability is possible, and it could become quite prevalent if the current cobalt price level is sustained. Another factor that helps limit price escalation is the possibility of recovery of cobalt from secondary and intermediate materials. A market study should evaluate where substitution and recovery might occur, at what prices, and to what extent.

Several potential factors on the supply side could influence cobalt prices. If supply increases faster than demand, prices will fall. This would certainly be the case if Gecamines were to regain its historical levels of production. This would require a reduction of political unrest in Zaire and an ability and willingness of the government to invest (or let others invest) in production and refining. The prospects for a government that would accommodate significantly increased production appear unlikely in the short run. However, over the time frame for the project, the emergence of an enterprise-oriented government that would aggressively expand production of Gecamines cannot be discounted completely.

Another factor which could influence supply is potential new cobalt production from major nickel deposits, particularly Diamond Fields, Australia and Cuba. This study was not able to develop a clear picture of how much cobalt would come from Diamond Fields when it reaches full production, but some estimates put it as high as 3,600 tons per year. Cuba also has the capacity to be a major cobalt supplier through its nickel mining activities. Currently, Cuban output is curtailed by the U.S. trade embargo and its indirect effects on other countries. Should diplomatic relations between the U.S. and Cuba become less hostile, the Cuban contribution to the cobalt market could exceed 2,000 tons per year. This increase in world supply could have a significant depressing effect on the price of cobalt.

In addition to new supply sources, improvements in cobalt extraction processes could boost production at existing cobalt operations. New cobalt leaching technology which improves recovery significantly is now being deployed at locations in Australia. If this technology proliferates, world supplies of cobalt could expand and prices could decline.

To maintain the recent high price level of about $28 per pound would require an increase in world cobalt demand corresponding to the growth in cobalt production. Some simple assumptions will give a general notion of the potential range of prices. Assuming that the growth of world cobalt demand is 2 percent per year, then by the year 2005 production could increase by about 5,000 tons without having a negative impact on prices. A production increase of this magnitude could be provided by Gecamines alone returning to its previous level of output, even without any contribution from Cook Islands, Diamond Fields, Australia or Cuba. If Cook Islands, Diamond Fields and Cuba came into production and Gecamines returned to its previous level of production, it seems likely that cobalt prices would recede to well under $20 in 1995 dollars.

8.3 PROJECT COMMERCIAL STRUCTURE

8.3.1 Limited Recourse Financial Structure

A preliminary project commercial structure was developed on Bechtel's understanding of the metals industry, on the likely concerns of potential lenders, on the interests of the Cook Islands Government (CIGOV), and on the interests of potential project sponsors. The final project structure ultimately will reflect the results of the Phase II testing and the specific requirements of each of the actual project participants.

It is assumed that the project sponsors will choose to employ a limited recourse financial structure for the project. In limited recourse structures, lenders and investors look to project cash flows for repayment of debt and return on investment. The financial risks of equity investors in the project are limited to the amount of their investments. A limited recourse structure allows sponsors to take equity interests in the project and attract debt financing without placing their other corporate assets at risk.

Limited recourse financing of the project would employ a combination of debt and equity to fund the construction costs of trawlers, transport ships and processing facilities. Debt financing would likely be sourced from a combination of export credit agencies, other international financing institutions such as the Asian Development Bank (ADB), International Finance Corporation (IFC), and Overseas Private Investment Corporation (OPIC), and international commercial banks. Equity financing would be provided by the project sponsors, which might include minerals companies, product off-takers, EPC contractors, and equipment suppliers. In addition, regional investment funds and international financing agencies also may consider equity participation.

A special purpose company (SPC) would be formed to own and operate the project's assets. The SPC then would borrow directly from lenders, and the project sponsors would invest equity in the SPC without being subject to direct recourse from lenders in the event the project encounters financial distress. Because debt capital is so critical to a limited recourse project structure, the lenders' requirements will dictate many of the project's credit supports and commercial and security provisions.

8.3.2 Primary Credit Support Agreements

To obtain limited recourse financing, several important commercial arrangements must be developed to assure the project's financial viability and to provide the credit support necessary to satisfy potential lenders. These arrangements would mitigate the significant commercial risks to which the project is exposed, and would include contracts relating to the construction of the processing facilities and ships, materials supply, product off-take, and provision of operations and maintenance services. Lenders focus on the substance and creditworthiness of each contracting party and may require letters of credit or other financial guarantees in support of contractual obligations and warranties. The likely commercial arrangements required for the project to attract limited recourse financing are described below.

Shareholders Agreement

A group of project sponsors would form a special purpose company (the "project company") to build, own and operate the project. The sponsors would enter into a shareholders agreement which would provide for the by-laws of the project company, delineate operational issues and define profit distributions.

Government Approvals and Permits

It is expected that the CIGOV would commit to long-term access and nodule harvesting rights for the project company, in addition to providing the necessary environmental, construction and operating permits, and guaranteeing noninterference and clearance of tax and dividend policies. The New Zealand Government would be expected to provide similar approvals for facilities located in New Zealand.

Lump Sum Turnkey EPC Contract

The project company would contract with a creditworthy contractor for the provision of engineering, procurement, and construction (EPC) services. This contract would provide for a guarantee of mechanical completion of the project for a fixed price, supported by liquidated damages for delays in the project schedule and performance shortfalls.

Marine Services Contract

The project company would engage an experienced and creditworthy entity to operate and maintain the trawling and transport shipping services under a long-term agreement.

Operations and Maintenance Contract

Operations and maintenance of the processing facility would be provided under a long-term contract with a reputable and creditworthy O&M contractor. This contract could include performance guarantees, operating margin incentives and penalty provisions.

Materials Supply Contract

The project company would establish long-term supply agreements for critical inputs to production, such as coal and electric power.

Product Marketing Contract

A long-term agreement would be established with an experienced and creditworthy entity to market the project's products through a product marketing contract. The marketing contract might include firm volume commitments and floor price guarantees to mitigate some of the market and cobalt price risks of the project.

Debt Service Reserve Fund

A debt service reserve fund would be established to satisfy lender requirements for a reserve to cover unforeseen events. Typically this reserve fund would be large enough to cover at least six months of debt service.

Insurance

In addition to standard property and casualty insurance, lenders may require the project company to secure political risk insurance to protect them from various forms of political risk, such as expropriation and political violence.

8.3.3 Sponsors

A sponsor group would be established to fund the Phase II costs and provide the bulk of the project equity. It is likely that the sponsor firms also would provide contract services to the project company in their particular areas of expertise to help mitigate the key project risks. Firms that might participate in the sponsor group would include creditworthy entities with expertise in the following areas:

- Shipping and trawling operations, including shipbuilding
- Metals refining and smelting operations
- EPC of processing facilities
- Metals marketing

As noted above, lenders would require that the major project risks be mitigated through the key commercial arrangements. To the extent that the sponsors seek to provide these commercial services, they would contract independently with the project company to do so.

8.4 ECONOMIC ANALYSIS

8.4.1 Summary

Bechtel developed a computer model of the expected project commercial operations to test the project's economic performance. Using this model, economic projections were prepared to evaluate the project's financial performance. In addition, a series of sensitivity analyses were conducted to determine the project's economic viability under a range of scenarios. For the purposes of this analysis, it was assumed that the project will be funded with 30 percent equity and 70 percent debt in a limited recourse financial structure.

Results of the Base Case analysis indicate that the project is economically viable on a pretax basis, provided that cobalt prices do not fall substantially below the assumed $25 per pound level. With a calculated pretax return on equity (ROE) of 28.8 percent, the Base Case provides potential investors with returns that they would likely require for a project of this type. The projected minimum debt service coverage ratio of 139 percent might be acceptable to potential lenders, but additional analysis of the project's exposure to various risk factors would have to be completed using the Phase II test results to determine an acceptable level of debt service coverage.

Sensitivity analyses indicate that the project is relatively more sensitive to changes in product prices and capital costs than to changes in operating costs. The project also was analyzed with cobalt prices of $20 and $15 per pound (a price last seen as recently as 1993). In the latter scenario the project was not viable and did not generate enough cash flow to cover debt service requirements. An Alternate Case also was tested which included royalty and up-front license fees to the CIGOV, as well as corporate income taxes. The project returns still were viable under this scenario, with a project ROE of 23 percent and minimum debt service coverage ratio of 131 percent.

The results of all cases tested are highly dependent on product pricing assumptions. Because prices have been historically volatile, potential investors should consult with an experienced metals marketing firm to determine the pricing assumptions appropriate for this project.

Attached at the end of this section is output from the model for the Base Case, including the data and key results, annual sources and uses of funds, income statement and cash flow statement.

8.4.2 Assumptions and Data Sources

The analysis is based on escalated U.S. dollars, with all original cost estimates expressed in April 1996 dollars, which then are subjected to 3.0 percent inflation per year. Detailed assumptions of both capital and operating costs are included in Sections 6 and 7 of this prefeasibility study. Table 8-3 summarizes the sources for key information and assumptions used in this analysis.

Table 8-3

SOURCES OF INFORMATION AND ASSUMPTIONS

Information and Assumptions	Source
Capital and Owner's costs	Bechtel
Engineering parameters	Bechtel
Operating costs	Bechtel and Cook Islands Government

The Base Case assumes that the project will be implemented in three phases as described in Section 9, including this prefeasibility study as Phase I. In Phase II, a number of technical and field operating tests will be completed to confirm the resource availability and the technical aspects of the proposed harvesting methods and smelting operations. Phase II activities probably would be funded by the project sponsors prior to financial closing.

Following the successful completion of the Phase II tests, it is assumed that the sponsors will arrange financing and that the Phase III activities would begin at financial closing. Phase III includes the actual construction of trawlers, transport ships and processing facilities. Commercial operations would begin at the completion of Phase III construction.

The timing assumptions are listed in Table 8-4.

Table 8-4

TIMING PARAMETERS

Parameter	Assumptions
Cost estimate date	April 1996
Financial closing	December 1997
Start of construction (Phase III)	January 1998
Start of full operations	January 2001
Project life	25 years

Capital Costs

The analysis is based on total unescalated capital costs of $435 million. Monthly vessel, EPC and Owner's costs are assumed to be expended on a straight-line basis throughout the construction period.

Trawler and Transport Ship Costs. These costs include the cost of building and outfitting these vessels to meet the unique requirements of nodule harvesting and transportation to the processing facility.

EPC. EPC costs cover the estimated costs of constructing the nodule processing and smelting facilities, as well as the costs of the associated infrastructure.

Owner's Costs. The Owner's costs reflect the sponsors' costs incurred prior to commercial operations, including training of staff, oversight, permitting and startup costs.

Development Costs. The development costs reflects the sponsors' recovery of costs incurred prior to financial closing. They include an allowance of $11 million for the Phase II activities, including vessel outfitting, sea trials of the trawler harvesting techniques, mapping of nodule resources, and tests of the smelting and refining processes. In addition, these costs include allowances for financial and legal advisor costs and other costs related to reaching financial closing.

Initial Working Capital. The initial working capital is an allowance to cover working capital requirements which commence at the beginning of project operations. A detailed discussion of working capital calculations is contained in Subsection "Working Capital" below.

Engineering and Operating Data

The operation is expected to harvest and process approximately 1.1 million wet tons of nodules per year, based on four trawlers operating 330 days per year. It was assumed that three vessels will be required to transport the harvested nodules from the Cook Islands to the processing facility. In addition, the services of a research vessel will be engaged to monitor the environmental effects and to assist in mapping and defining the nodule deposits.

The processing facility will operate at a constant production rate to process the nodules. In the first full year of operation, the overall production efficiency is expected to be 80 percent of full capacity as the facility ramps up to full production levels by the end of the first operating year. During this period, fixed operating costs (i.e., insurance, labor, etc.) will accrue at the same rate as they would under 100 percent production efficiency.

Revenues

The project's sole source of revenue is the sale of cobalt and nickel metal and copper powder. For the Base Case analysis, Bechtel assumed that the initial product prices are about 10 percent below the current spot-market prices[1] and that these prices would escalate at 3.0 percent annually over the life of the project. In April 1996 dollars, the assumed prices were: cobalt at $25 per pound, nickel at $3.33 per pound, and copper at $1.00 per pound.

It should be noted that the prices of these metals have been quite volatile in the past and may well continue to fluctuate significantly in the future. These price assumptions were used as an indicator of the project's economics under current market conditions and do not purport to predict future price movements or imply a prediction of price stability during the life of this project. Potential investors should investigate the economics of this project using price expectations developed by experts in metals marketing.

It is expected that a creditworthy entity with metals marketing expertise will provide product marketing services to the project company under a marketing agreement. This agreement could include a floor pricing mechanism sufficient to guarantee the operating margins and debt service.

Operating Costs

All operating costs were estimated in April 1996 dollars and then escalated at 3.0 percent annually over the life of the project. The operating costs of marine operations (i.e., trawling, research vessel and transport shipping) were assumed to vary relative to the number of each type of ship deployed. Processing costs are comprised of variable costs (i.e., power, coal, marketing fees), which change with the quantity of nodules processed, and fixed costs (i.e., labor,

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(1) It was assumed that the price of copper powder is approximately 85 percent of the price for copper cathode.

insurance). A detailed breakdown of most of these costs is provided in Section 7 of this report. Additional operating costs include:

Research Vessel. These costs include the expense of operating and maintaining a specially equipped vessel to monitor the environmental impact and to the map seabed resources as required. It was assumed that this vessel will be leased, and the CIGOV has provided an estimated cost for this activity.

Insurance and Miscellaneous Expenses. This is an allowance for property and casualty insurance and other miscellaneous operating expenses that might be incurred.

Marketing Fees. These would be paid to a metals marketing firm for selling the project's products. An allowance has been made for these fees to be 0.5 percent of the gross product revenues.

Working Capital

As noted above, it was assumed that a base amount of working capital for the first year of operations will be funded at financial closing. For each operating year, the required amount of working capital was calculated as follows:

Working Capital	=	+ Receivables
		- Payables
		+ Operating cash
		+ Inventories

Receivables. Receivables were estimated as 45 days of revenues.

Payables. Payables were estimated as 45 days of operating expenses.

Operating Cash. Operating cash was calculated as 30 days of operating expenses.

Inventories. Inventories assume a value for finished products in inventory (30 days of revenues of all products).

Each year the required level of working capital is compared to the previous year's amount and increases or decreases in the total amount are then funded from the current year's cash flow.

Financing Assumptions

It was assumed that the project will be financed on a limited recourse basis, wherein lenders depend solely on the assets and cash flow of the project for repayment without having any claims on the sponsors. Typical of such financings, Bechtel assumed a debt/equity ratio of 70/30, and assumed that debt and equity capital is provided pro rata during the construction period.

Also, it was assumed that lenders will require level principal repayments and Bechtel has assumed loan interest rates, tenor and fees that were representative of the specific project risks and location. Bechtel assumed that debt financing is obtained at a 10.0 percent interest rate with a 3-year drawdown and an 8-year repayment period. In addition, provisions were included for a debt service reserve fund to be funded at the completion of construction and to be maintained at an amount equal to 6 months of the current year's debt service. Required increases in this reserve fund would be paid out of the operating cash flows and would be senior to any distributions to equity.

8.4.3 Methodology and Results

The following economic performance metrics were considered in the course of the financial analysis.

Return on Investment

ROI is the internal rate of return on the project's unleveraged pretax annual cash flow, beginning at financial closing. It is independent of financial structure (e.g., the inclusion of debt financing), and thus is a basic and fundamental indicator of the project's economics. It is one of the most common profitability criteria used in the capital budgeting processes of industrial companies. The ROI calculation used in this analysis was based on the project's pretax cash flow, determined as:

Cash Flow	=	+ Revenues
		- Operating expenses
		- Increase in working capital
		- Capital costs

Return on Equity

ROE is the internal rate of return on the pretax net equity cash flow for a project which includes debt in its capital structure. As such, it is based on the cash flow after the repayment of principal and interest to the project's lenders.

Debt Service Coverage Ratio

DSCR indicates the project's annual ability to repay debt. It is calculated as the annual ratio of funds available for debt service (earnings before depreciation, interest and taxes) to the total current portion of debt service payable (principal plus interest). Potential lenders would likely determine a minimum annual DSCR value based on the project's exposure to specific operating and commercial risks. This exposure will, by necessity, be based on the results of the Phase II investigations, which will help establish the baseline measures of operating performance.

8.4.4 Base Case Results

The Base Case analysis projects positive cash flow in all operating years and demonstrates an ROI of 22.4 percent and an ROE of 28.8 percent. These economic indicators are most likely above the minimum threshold levels that potential lenders and investors might require for a project of this type. Potential investors will evaluate these returns in light of their ability to hold profits offshore of their home countries in an effort to avoid or defer corporate income taxes.

The minimum DSCR value was found to be 139 percent, which, while positive, cannot be deemed acceptable or unacceptable for a project of unknown risk. As noted above, however, potential lenders will determine an acceptable minimum level of DSCR by performing sensitivity analyses based on the Phase II results.

The details of the Base Case financial analysis are included at the end of this section for reference.

8.4.5 Sensitivity Analysis

A sensitivity analysis was conducted to determine the economic impact of changes in the assumed values of selected project assumptions. This analysis tests the relative impact of changes in individual project assumptions, using ROI, ROE and DSCR as indicators of the project's sensitivity to each particular assumption.

Based on Bechtel's understanding of the project's economics, three assumptions were selected to be tested in this manner. For consistency, each assumption was varied by the same percentage amount relative to the Base Case. The factors selected were:

- Capital costs, including vessels and process EPC costs
- Operating costs
- Product prices (all products)

The results of this sensitivity analysis are presented in Table 8-5.

Table 8-5

RESULTS OF SENSITIVITY ANALYSIS

Sensitivity Factor	ROI (%)	ROE (%)	Min. DSCR (%)
Base Case	22	29	139
Capital cost +15%	20	25	121
Capital cost -15%	25	34	162
Operating costs +15%	21	27	128
Operating costs -15%	24	31	150
Product prices +15%	26	35	170
Product prices -15%	19	22	108

These results indicate that the project's economics are relatively more sensitive to changes in the product prices and capital costs, respectively, than to changes in the operating costs. The results imply that the project's economics could be most significantly improved by securing higher product prices and would benefit less from comparably reduced operating costs.

8.4.6 Alternate Cobalt Price Sensitivities

As noted throughout this discussion, prices for these products have been historically volatile and are difficult to predict. Cobalt prices have been particularly volatile over the past few years, and, because cobalt provides the bulk of the project revenues, several alternate cobalt price scenarios were considered. Note that the indicated cobalt prices are as of April 1996, which then were escalated at an annual rate of 3 percent over the life of the project. The results of this analysis are summarized in Table 8-6.

Table 8-6

ALTERNATE COBALT PRICE SENSITIVITIES

Cobalt Price (April 1996 $)	ROI (%)	ROE (%)	Min. DSCR (%)
$25.00 per pound (Base Case)	22	29	139
$20.00 per pound	18	21	101
$15.00 per pound	12	13	63

If the long-term price of cobalt falls to $20 per pound (in April 1996 dollars) the project remains economically viable, although a minimum DSCR value of only 101 percent would be a concern for potential lenders. At $15 per pound (also in April 1996 dollars) the project fails to generate enough revenue to cover debt service, even with the complete drawdown of the debt service reserve fund. At this price, which was seen as recently as 1993, additional funds would be needed from outside sources to maintain operations. Further analysis indicates that the project "breaks-even" as long as the long-term cobalt price does not drop from the assumed level by more than about one third, (i.e., as long as the price stays above $16.75 in April 1996 dollars).

8.4.7 Alternate Case: After-Tax Returns with Government Fees and Royalties

An Alternate Case was analyzed to show the potential impact of government fees, royalties and taxes on the project economics. As in many comparable mining projects, the CIGOV is likely to require an up-front license fee to gain initial access rights to the EEZ, and royalty payments in exchange for the right to develop and exploit the nodule resources. Finally, since the CIGOV has not finalized its tax policy relative to this project, U.S. corporate tax treatment was applied as an indicator of possible after-tax returns. The following paragraphs give a description of Bechtel's assumptions relative to these factors.

CIGOV License Fee. The CIGOV license fee is an allowance of $15 million for a payment to CIGOV at financial closing for project approvals and access rights, although the actual terms and conditions of this fee have yet to be negotiated with the CIGOV.

Royalties. These are expected to be paid to the CIGOV in exchange for guaranteed access to the resource area and for the right to harvest the nodules. While the terms of such royalty payments have yet to be negotiated, an allowance of 2.5 percent of the operating income was included as an approximation of this expense.

Income Taxes. In this analysis it was assumed that U.S. tax and accounting standards would be applied to the project because the CIGOV's corporate tax policy toward this project has not yet been determined. The corporate income tax rate used in this analysis was 35 percent of the taxable income, calculated as follows:

Taxable Income	=	+ Operating income
		- Net interest expense
		- Depreciation

No allowance was made for withholding taxes on expatriated dividends or on interest payments, nor for any tax holidays or other incentives which might be negotiated with the CIGOV. Tax losses are carried forward for five years before they expire.

Depreciation. For tax purposes, the escalated project capital costs are depreciated on an accelerated basis, using a 7-year recovery period and a modified accelerated cost recovery system (MACRS) amortization schedule, as is consistent with U.S. depreciation rules for mining and metals processing assets. For book income purposes, these assets have an assumed useful life of 25 years and have been depreciated on a straight-line basis.

8.4.8 Alternate Case Results

The Alternate Case results indicate that even with government payments and taxes included the project is still viable. With an ROI of 17.5 percent and an ROE of 22.0 percent, the project still would be likely to attract the interest of potential investors. The minimum DSCR is 131 percent in this case, and lenders would need to evaluate the project's credit capacity in light of project-specific risks. For the Alternate Case, the long-term price of cobalt must stay above $17.25 (in April 1996 dollars) for the project to meet its debt service obligations.

Base Case (converged)

TIMING DATA		
Cost Estimate Year, Month (1-12)	1996	3
First Model Year	1996	
Financial Closing Year, Month (1-12)	1997	12
First Operation Year, Month (1-12) (Calc'd)	2001	1
Economic Life (years)	25	
Book Life (years)	25	

ECONOMICS DATA	
General Inflation Rate	3.0%
Capital Cost Esc Rate	3.0%
Processing Cost Esc Rate	3.0%
Product Price Esc Rate	3.0%
Cobalt Price Esc Rate	3.0%
O & M Escalation Rate	3.0%

PRODUCT PRICING DATA	
Prices in 1996 $/lb	
Cobalt ($/lb)	25.00
Nickel ($/lb)	3.33
Copper ($/lb)	1.00

SENSITIVITY DATA	
Capital Cost Sens Factor	1.00
Production Sens Factor	1.00
Product Price Sens Factor	1.00
Cobalt Price Sens Factor	1.00
Operating Cost Sens Factor	1.00

OPERATIONS DATA	
No. of Trawlers	4
Trawler Operating Days (per year)	330
Nodule Production (tons/trawler/day)	833
No. of Transport Ships	3
Production Efficiency (Year 1)	80%

PRODUCTION DATA (mtpa)	
Cobalt	2,652.0
Nickel	1,718.0
Copper	955.0

OPERATING COSTS (Unesc. 1996$)	
Trawling Cost ('000$/trawler/yr)	1,927
Research Vessel Cost ('000$/yr)	429
Shipping Costs ('000$/ship/yr)	3,305
Power ($/mt of nodules)	6.82
Coal ($/mt of nodules)	3.28
Other Consumables ($/mt of nodules)	7.68
Labor ('000$/yr)	5,689
Administration & Overhead ('000$/yr)	4,164
Insurance ('000$/year)	500
Marketing Fees (pct. of revenue)	0.50%
CIGOV Royalty (pct. of operating income)	0.00%

TAX & ACCOUNTING DATA	
Corporate Tax Rate	0%
Tax 15 Yr Straight Line Depreciation Pct	0%
Tax 7 Yr MACRS Depreciation Pct	100%
Book 15 Yr Straight Line Depreciation Pct	100%
Cash Deposit Interest Rate	6%

KEY RESULTS	
Project Returns	
Return on Investment (Pre-Tax Unleveraged IRR)	22.4%
Unleveraged NPV @ 15% ('000$)	196,850
Return on Equity (Pre-Tax Leveraged IRR)	28.8%
Leveraged NPV @ 15% ('000$)	216,426
Debt Service Coverage	
Average Senior Debt Service Coverage	202%
Minimum Senior Debt Service Coverage	139%

FINANCING DATA	
Senior Debt Advance Ratio (% Ttl Capital)	70%
Senior Debt Commitment Amt ('000$)	443,690
Senior Debt Term (Yrs Post-Completion)	8
Senior Debt Grace Prd (Mos Post-Compl.)	6
Senior Debt Interest Rate (Pre-Compl.)	10.0%
Senior Debt Interest Rate (Post-Compl.)	10.0%
Senior Debt Commitment Fees (%)	0.5%
Senior Debt Upfront Financing Fee (%)	1.0%
Senior Debt Other Closing Fees (%)	1.0%
Senior Debt Exposure Fee (%)	2.0%
Funded Reserves Amount ('000$)	47,142
Senior Debt Service Reserves Requirement (Mos Senior Debt Service)	6

WORKING CAPITAL DATA	
Cash (Days Op. Expenses)	30
Accounts Receivable (Days Revenues)	45
Accounts Payable (Days Op. Expenses)	45
Product Inventory (Days Revenues)	30

CAPITAL COST DATA (1996 '000$)	1996	1997	1998	1999	2000	2001	Total
Trawlers	-	-	16,667	16,667	16,667	-	50,000
Transport Ships	-	-	25,000	25,000	25,000	-	75,000
Processing Facilities	-	-	90,367	90,367	90,367	-	271,100
Owner's Costs	-	-	6,333	6,333	6,333	-	19,000
Development Costs (Includes Phase 2 Tests)	-	20,000	-	-	-	-	20,000
CIGOV License Fee	-	-	-	-	-	-	-
Capital Costs	-	20,000	138,367	138,367	138,367	-	435,100

ANNUAL SOURCES AND USES OF FUNDS
(Thousands of US$)

Base Case

Years	1996	1997	1998	1999	2000	2001	Total
Sources of Funds							
Senior Debt	-	21,379	111,503	122,510	188,297	-	443,690
Equity	-	9,163	47,787	52,504	80,699	-	190,153
Sources of Funds	-	30,542	159,290	175,015	268,995	-	633,842
Uses of Funds							
Trawlers	-	-	17,835	18,370	18,922	-	55,127
Transport Ships	-	-	26,753	27,556	28,382	-	82,691
Process Facilities	-	-	96,704	99,605	102,593	-	298,901
Owner's Costs	-	-	6,777	6,981	7,190	-	20,948
Development Costs	-	21,062	-	-	-	-	21,062
License Fees	-	-	-	-	-	-	-
Initial Working Capital	-	-	-	-	28,817	-	28,817
Capital Costs	-	21,062	148,070	152,512	185,904	-	507,547
Senior Debt Interest	-	-	7,161	18,809	31,596	-	57,566
Senior Debt Exposure Fees	-	422	2,199	2,416	3,714	-	8,751
Senior Debt Commitment Fees	-	185	1,860	1,278	639	-	3,962
Senior Debt Loan Upfront Fees	-	4,437	-	-	-	-	4,437
Senior Debt Other Closing Fees	-	4,437	-	-	-	-	4,437
Senior Debt Financing Costs	-	9,480	11,221	22,503	35,949	-	79,153
Funded Reserves	-	-	-	-	47,142	-	47,142
Financing Costs	-	9,480	11,221	22,503	83,091	-	126,295
Uses of Funds	-	30,542	159,290	175,015	268,995	-	633,842

Permanent Sources of Financing

Sources	000$	%
Senior Debt	443,690	70.0%
Equity	190,153	30.0%
Total Sources	633,842	100.0%

Uses		
Capital Costs	507,547	80.1%
Financing Costs	126,295	19.9%
Total Uses	633,842	100.0%

CASH FLOW STATEMENT

(Thousands of U.S.$)

Years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Base Case																
Cobalt	-	-	-	-	-	136,923	176,289	181,577	187,025	192,635	198,415	204,367	210,498	216,813	223,317	230,017
Nickel	-	-	-	-	-	11,815	15,212	15,668	16,138	16,622	17,121	17,635	18,164	18,709	19,270	19,848
Copper	-	-	-	-	-	1,972	2,539	2,615	2,694	2,775	2,858	2,944	3,032	3,123	3,217	3,313
Product Revenues	-	-	-	-	-	150,710	194,040	199,861	205,857	212,032	218,393	224,945	231,694	238,644	245,804	253,178
Trawling	-	-	-	-	-	9,023	9,294	9,572	9,860	10,155	10,460	10,774	11,097	11,430	11,773	12,126
Research Vessel	-	-	-	-	-	502	517	533	549	565	582	600	618	636	655	675
Shipping	-	-	-	-	-	11,608	11,956	12,315	12,684	13,065	13,457	13,861	14,276	14,705	15,146	15,600
Power	-	-	-	-	-	7,030	9,051	9,322	9,602	9,890	10,187	10,492	10,807	11,131	11,465	11,809
Coal	-	-	-	-	-	3,378	4,349	4,479	4,614	4,752	4,895	5,042	5,193	5,349	5,509	5,674
Other Consumables	-	-	-	-	-	7,914	10,190	10,495	10,810	11,134	11,468	11,812	12,167	12,532	12,908	13,295
Labor	-	-	-	-	-	6,660	6,860	7,066	7,278	7,496	7,721	7,952	8,191	8,437	8,690	8,951
Administration & Overhead	-	-	-	-	-	4,874	5,021	5,171	5,326	5,486	5,651	5,820	5,995	6,175	6,360	6,551
Insurance	-	-	-	-	-	585	603	621	640	659	679	699	720	742	764	787
Marketing Fees	-	-	-	-	-	754	970	999	1,029	1,060	1,092	1,125	1,158	1,193	1,229	1,266
CIGOV Royalties	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expenses	-	-	-	-	-	52,328	58,810	60,574	62,392	64,263	66,191	68,177	70,222	72,329	74,499	76,734
Operating Income	-	-	-	-	-	98,382	135,230	139,287	143,465	147,769	152,202	156,768	161,471	166,315	171,305	176,444
Income Taxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Increase in Working Capital	-	-	-	-	28,817	-	8,637	1,124	1,157	1,192	1,228	1,265	1,303	1,342	1,382	1,423
Increase in Fixed Capital Investment	-	30,542	159,290	175,015	193,036	-	-	-	-	-	-	-	-	-	-	-
Interest Income	-	-	-	-	-	2,829	2,829	2,662	2,496	2,329	2,163	1,997	1,830	853	-	-
Cash Available for Senior Debt Service	-	(30,542)	(159,290)	(175,015)	(221,853)	101,211	129,421	140,825	144,804	148,906	153,137	157,500	161,999	165,827	169,923	175,021
Senior Debt Principal (Drawdown) Repayment	-	(21,379)	(111,503)	(122,510)	(188,297)	27,731	55,461	55,461	55,461	55,461	55,461	55,461	55,461	27,731	-	-
Senior Debt Interest	-	-	-	-	-	42,982	38,823	33,277	27,731	22,184	16,638	11,092	5,546	693	-	-
Cash Flow After Senior Debt Service	-	(9,163)	(47,787)	(52,504)	(33,557)	30,498	35,137	52,087	61,612	71,261	81,038	90,947	100,992	137,403	169,923	175,021
Increase in Reserves	-	-	-	-	47,142	(0)	(2,773)	(2,773)	(2,773)	(2,773)	(2,773)	(2,773)	(16,292)	(14,212)	-	-
Cash Available for Distribution	-	(9,163)	(47,787)	(52,504)	(80,699)	30,498	37,910	54,860	64,385	74,034	83,811	93,720	117,283	151,615	169,923	175,021
Common Equity Contributions	-	9,163	47,787	52,504	80,699	-	-	-	-	-	-	-	-	-	-	-
Common Equity Distributions	-	-	-	-	-	30,498	37,910	54,860	64,385	74,034	83,811	93,720	117,283	151,615	169,923	175,021
Net Equity Cash Flow																
Common Equity Contributions	-	(9,163)	(47,787)	(52,504)	(80,699)	-	-	-	-	-	-	-	-	-	-	-
Common Equity Distributions	-	-	-	-	-	30,498	37,910	54,860	64,385	74,034	83,811	93,720	117,283	151,615	169,923	175,021
Residual Value	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Equity Cash Flow	-	(9,163)	(47,787)	(52,504)	(80,699)	30,498	37,910	54,860	64,385	74,034	83,811	93,720	117,283	151,615	169,923	175,021
Cum Net Equity Cash Flow	-	(9,163)	(56,950)	(109,454)	(190,153)	(159,655)	(121,745)	(66,885)	(2,500)	71,534	155,345	249,065	366,348	517,963	687,886	862,906
Return on Equity	28.8%															
NPV @ 10%	542,028															
NPV @ 15%	216,426															
NPV @ 20%	82,186															
Cum Return on Equity	na	na	na	na	na	na	na	na	0%	8%	13%	17%	20%	22%	24%	25%
Cum NPV @ 10%	-	(7,572)	(43,476)	(79,337)	(129,444)	(112,229)	(92,775)	(67,182)	(39,877)	(11,334)	18,041	47,903	81,876	121,801	162,479	200,569
Cum NPV @ 15%	-	(6,928)	(38,349)	(68,369)	(108,490)	(95,305)	(81,053)	(63,119)	(44,817)	(26,517)	(8,503)	9,014	28,076	49,504	70,386	89,090
Cum NPV @ 20%	-	(6,363)	(34,017)	(59,338)	(91,769)	(81,555)	(70,975)	(58,216)	(45,738)	(33,781)	(22,501)	(11,990)	(1,028)	10,780	21,809	31,276

COOK ISLANDS NODULE MINING

CASH FLOW STATEMENT
(Thousands of U.S.$)

Cook25_1

Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Base Case																
Cobalt	236,917	244,025	251,346	258,886	266,653	274,652	282,892	291,378	300,120	309,123	318,397	327,949	337,787	347,921	-	6,205,922
Nickel	20,443	21,057	21,688	22,339	23,009	23,699	24,410	25,143	25,897	26,674	27,474	28,298	29,147	30,022	-	535,501
Copper	3,413	3,515	3,620	3,729	3,841	3,956	4,075	4,197	4,323	4,453	4,586	4,724	4,866	5,012	-	89,391
Product Revenues	260,773	268,596	276,654	284,954	293,503	302,308	311,377	320,718	330,340	340,250	350,457	360,971	371,800	382,954	-	6,830,814
Trawling	12,490	12,865	13,251	13,648	14,058	14,479	14,914	15,361	15,822	16,297	16,785	17,289	17,808	18,342	-	328,972
Research Vessel	695	716	738	760	782	806	830	855	881	907	934	962	991	1,021	-	18,312
Shipping	16,068	16,550	17,047	17,558	18,085	18,627	19,186	19,762	20,355	20,965	21,594	22,242	22,909	23,597	-	423,220
Power	12,163	12,528	12,904	13,291	13,690	14,101	14,524	14,959	15,408	15,870	16,346	16,837	17,342	17,862	-	318,610.0
Coal	5,845	6,020	6,201	6,387	6,578	6,776	8,979	7,188	7,404	7,626	7,855	8,090	8,333	8,583	-	153,099.2
Other Consumables	13,694	14,105	14,528	14,964	15,413	15,875	16,351	16,842	17,347	17,867	18,403	18,958	19,524	20,110	-	358,703.2
Labor	9,219	9,496	9,781	10,074	10,376	10,687	11,008	11,338	11,678	12,029	12,390	12,761	13,144	13,539	-	242,820.9
Administration & Overhead	6,747	6,950	7,158	7,373	7,594	7,822	8,057	8,298	8,547	8,804	9,068	9,340	9,620	9,909	-	177,718
Insurance	810	835	860	885	912	939	968	997	1,026	1,057	1,089	1,122	1,155	1,190	-	21,342
Marketing Fees	1,304	1,343	1,383	1,425	1,468	1,512	1,557	1,604	1,652	1,701	1,752	1,805	1,859	1,915	-	34,154
CIGOV Royalties	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expenses	79,036	81,407	83,849	86,365	88,955	91,624	94,373	97,204	100,120	103,124	106,218	109,404	112,686	116,067	-	2,076,951
Operating Income	181,737	187,190	192,805	198,589	204,547	210,683	217,004	223,514	230,220	237,126	244,240	251,567	259,114	266,888	-	4,753,863
Income Taxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Increase in Working Capital	1,466	1,510	1,555	1,602	1,650	1,700	1,751	1,803	1,857	1,913	1,970	2,029	2,090	(71,766)	-	-
Increase in Fixed Capital Investment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	557,883
Interest Income	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,987
Cash Available for Senior Debt Service	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,215,967
Senior Debt Principal (Drawdown) Repayment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senior Debt Interest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	198,967
Cash Flow After Senior Debt Service	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,017,000
Increase in Reserves	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cash Available for Distribution	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,017,000
Common Equity Contributions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	190,153
Common Equity Distributions	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,207,153
Net Equity Cash Flow																
Common Equity Contributions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(190,153)
Common Equity Distributions	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,207,153
Residual Value	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Equity Cash Flow	180,271	185,679	191,250	196,987	202,897	208,984	215,253	221,711	228,362	235,213	242,270	249,538	257,024	338,654	-	4,017,000
Cum Net Equity Cash Flow	1,043,178	1,228,857	1,420,107	1,617,094	1,819,991	2,028,975	2,244,229	2,465,940	2,694,302	2,929,515	3,171,785	3,421,322	3,678,346	4,017,000	4,017,000	
Return on Equity																
NPV @ 10%																
NPV @ 15%																
NPV @ 20%																
Cum Return on Equity	26%	27%	27%	28%	28%	28%	28%	28%	29%	29%	29%	29%	29%	29%	29%	
Cum NPV @ 10%	236,235	269,631	300,902	330,183	357,600	383,273	407,312	429,821	450,898	470,634	489,114	506,417	522,620	542,028	542,028	
Cum NPV @ 15%	105,842	120,846	134,284	146,320	157,100	166,755	175,403	183,148	190,085	196,298	201,863	206,847	211,312	216,426	216,426	
Cum NPV @ 20%	39,401	46,375	52,362	57,500	61,910	65,696	68,945	71,734	74,128	76,183	77,946	79,460	80,759	82,186	82,186	

INCOME STATEMENT
(Thousands of U.S.$)

Years	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Base Case															
Cobalt	-	136,923	176,289	181,577	187,025	192,635	198,415	204,367	210,498	216,813	223,317	230,017	236,917	244,025	251,346
Nickel	-	11,815	15,212	15,668	16,138	16,622	17,121	17,635	18,164	18,709	19,270	19,848	20,443	21,057	21,688
Copper	-	1,972	2,539	2,615	2,694	2,775	2,858	2,944	3,032	3,123	3,217	3,313	3,413	3,515	3,620
Product Revenues	-	150,710	194,040	199,861	205,857	212,032	218,393	224,945	231,694	238,644	245,804	253,178	260,773	268,596	276,654
Trawling	-	9,023	9,294	9,572	9,860	10,155	10,460	10,774	11,097	11,430	11,773	12,126	12,490	12,865	13,251
Research Vessel	-	502	517	533	549	565	582	600	618	636	655	675	695	716	738
Shipping	-	11,608	11,956	12,315	12,684	13,065	13,457	13,861	14,276	14,705	15,146	15,600	16,068	16,550	17,047
Power	-	7,030	9,051	9,322	9,602	9,890	10,187	10,492	10,807	11,131	11,465	11,809	12,163	12,528	12,904
Coal	-	3,378	4,349	4,479	4,614	4,752	4,895	5,042	5,193	5,349	5,509	5,674	5,845	6,020	6,201
Other Consumables	-	7,914	10,190	10,495	10,810	11,134	11,468	11,812	12,167	12,532	12,908	13,295	13,694	14,105	14,528
Labor	-	6,660	6,860	7,066	7,278	7,496	7,721	7,952	8,191	8,437	8,690	8,951	9,219	9,496	9,781
Administration & Overhead	-	4,874	5,021	5,171	5,326	5,486	5,651	5,820	5,995	6,175	6,360	6,551	6,747	6,950	7,158
Insurance	-	585	603	621	640	659	679	699	720	742	764	787	810	835	860
Marketing Fees	-	754	970	999	1,029	1,060	1,092	1,125	1,158	1,193	1,229	1,266	1,304	1,343	1,383
CIGOV Royalties	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expenses	-	52,328	58,810	60,574	62,392	64,263	66,191	68,177	70,222	72,329	74,499	76,734	79,036	81,407	83,849
Operating Income	-	98,382	135,230	139,287	143,465	147,769	152,202	156,768	161,471	166,315	171,305	176,444	181,737	187,190	192,805
Depreciation	-	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315
Senior Debt Interest	-	42,982	38,823	33,277	27,731	22,184	16,638	11,092	5,546	693	-	-	-	-	-
Interest Income	-	2,829	2,829	2,662	2,496	2,329	2,163	1,997	1,830	853	-	-	-	-	-
Income Before Taxes	-	35,913	76,920	86,357	95,915	105,599	115,412	125,357	135,440	144,160	148,990	154,129	159,422	164,874	170,490
Income Taxes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Income	-	35,913	76,920	86,357	95,915	105,599	115,412	125,357	135,440	144,160	148,990	154,129	159,422	164,874	170,490

INCOME STATEMENT
(Thousands of U.S.$)

Years	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total
Base Case													
Cobalt	258,886	266,653	274,652	282,892	291,378	300,120	309,123	318,397	327,949	337,787	347,921	-	6,205,922
Nickel	22,339	23,009	23,699	24,410	25,143	25,897	26,674	27,474	28,298	29,147	30,022	-	535,501
Copper	3,729	3,841	3,956	4,075	4,197	4,323	4,453	4,586	4,724	4,866	5,012	-	89,391
Product Revenues	284,954	293,503	302,308	311,377	320,718	330,340	340,250	350,457	360,971	371,800	382,954	-	6,830,814
Trawling	13,648	14,058	14,479	14,914	15,361	15,822	16,297	16,785	17,289	17,808	18,342	-	328,972
Research Vessel	760	782	806	830	855	881	907	934	962	991	1,021	-	18,312
Shipping	17,558	18,085	18,627	19,186	19,762	20,355	20,965	21,594	22,242	22,909	23,597	-	423,220
Power	13,291	13,690	14,101	14,524	14,959	15,408	15,870	16,346	16,837	17,342	17,862	-	318,610.0
Coal	6,387	6,578	6,776	6,979	7,188	7,404	7,626	7,855	8,090	8,333	8,583	-	153,099.2
Other Consumables	14,964	15,413	15,875	16,351	16,842	17,347	17,867	18,403	18,956	19,524	20,110	-	358,703.2
Labor	10,074	10,376	10,687	11,008	11,338	11,678	12,029	12,390	12,761	13,144	13,539	-	242,820.9
Administration & Overhead	7,373	7,594	7,822	8,057	8,298	8,547	8,804	9,068	9,340	9,620	9,909	-	177,718
Insurance	885	912	939	968	997	1,026	1,057	1,089	1,122	1,155	1,190	-	21,342
Marketing Fees	1,425	1,468	1,512	1,557	1,604	1,652	1,701	1,752	1,805	1,859	1,915	-	34,154
CIGOV Royalties	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Expenses	86,365	88,955	91,624	94,373	97,204	100,120	103,124	106,218	109,404	112,686	116,067	-	2,076,951
Operating Income	198,589	204,547	210,683	217,004	223,514	230,220	237,126	244,240	251,567	259,114	266,888	-	4,753,863
Depreciation	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	22,315	-	557,883
Senior Debt Interest	-	-	-	-	-	-	-	-	-	-	-	-	198,967
Interest Income	-	-	-	-	-	-	-	-	-	-	-	-	19,987
Income Before Taxes	176,274	182,232	188,368	194,689	201,199	207,904	214,811	221,925	229,252	236,799	244,572	-	4,017,000
Income Taxes	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Income	176,274	182,232	188,368	194,689	201,199	207,904	214,811	221,925	229,252	236,799	244,572	-	4,017,000

SECTION 9

SECTION 9
PROJECT IMPLEMENTATION

9.1 INTRODUCTION

The Cook Islands Deep-Sea Nodule Mining Project encompasses four phases. The current study represents Phase I of the project. Phase II will consist of exploration work at the targeted harvest site, metallurgical testwork on nodule samples, and other tests to prove the viability of trawling and materials handling methods. Also included in Phase II are the selection of a site for the process plant and the completion of the permitting process. The basic and detail engineering, as well as the procurement, construction and preoperational testing activities, will fall within the scope of the Phase III work. Phase IV will begin with the commencement of commercial harvesting and plant operations. Figure 9-1, a bar graph type summary schedule, is presented at the end of this section.

9.2 EXPLORATION AND TESTWORK

9.2.1 General

This part of the project will consist of several tasks, such as the exploration of the seabed in the proposed harvesting area, recovery of nodules for test purposes, establishment of environmental baseline conditions, test harvesting of nodules, bench-scale and pilot-plant testing of the smelting process, and testing of the suitability of the proposed Marconaflo system for handling the nodules.

The various parts of the program are discussed in some detail in the following paragraphs.

9.2.2 Exploration

Large-Scale Mapping

The area bordered by south latitudes 15° 30' and 16° 30', and west longitudes 159° and 160° is to be mapped with a hull-mounted multibeam sonar system to establish a bathymetry map. If practical, backscatter data will be recorded and analyzed to develop a broad-scale nodule abundance map.

On the basis of the generated maps, an area will be selected for detail mapping.

Detail Mapping

An area of approximately 1,100 km^2 (about 35 by 35 kilometres) will be selected for deep-towed vehicle mapping. This area is estimated to suffice for harvesting nodules at the planned rate during the first ten years of operations. The goal of the mapping is the production of the following:

- Bathymetry with 1-metre contour lines
- A high-resolution imaging map to identify seabed irregularities
- Backscatter measuring and analysis to determine and map nodule abundance

Nodule Recovery

Approximately 15 wet tons of nodules will be recovered from the area selected for detail mapping. The location of the nodule collection points will be logged, together with observations regarding the circumstances of collection and nodule size distribution.

Video Recording

At twenty locations in the detail-mapped area, photographs and video recordings will be produced to document the nodule densities for correlation with the nodule density data derived from the backscatter analysis. At five of these locations, a chain, similar to the foot chain to be used on the harvesting trawl, will be affixed to the tow sled and dragged in the sediment for an as-yet-to-be-specified distance. The interaction between the chain and the seabed will be video recorded for evaluation.

Fauna Inventory

At five locations in the detail-mapped area, core samples will be taken by multiple-core-type samplers and the sediment examined for living organisms. Life forms will be identified and inventoried. At two of the locations, a tripod-mounted instrument package will be placed on the seabed for long-term observations. Time-lapse photographs will be taken to record fauna activity in the covered area. Temperature, current and sediment load data also will be collected and stored. At the end of the observation period, the instruments will be collected and the data evaluated.

Water Temperature and Current Data

At five locations in the detail-mapped area, water temperature, sediment load, and current direction and velocity will be measured and the measurements recorded. At first, measurements will be taken near the surface to identify the warm top layer and its currents. Below the warm zone, the measurements will be taken at every 500 metres in depth, as well as immediately above the seabed so as to establish the baseline conditions in the water column.

9.2.3 Test Harvesting

Harvesting of the nodules is the least-known aspect of the entire project. Small quantities of nodules have been recovered by bottom trawls from waters similar in depth to those of the Aitutaki Passage; however, no harvesting ever has taken place to recover production-scale quantities on a sustained basis by the use of bottom trawls.

For this reason, it is imperative to test the proposed harvesting method in a full-scale operation at the proposed harvesting area, and to monitor and record the behavior of the trawl during the operations. In order to achieve this, a trawler should be outfitted with production-size harvesting equipment, instrumentation and auxiliary equipment as required. The following paragraphs deal with the various components of the harvesting system.

Trawler

A trawler of sufficient size should be chartered for a period of two months, plus transit time to and from the harvesting site, plus the time required to install and later dismantle the following equipment:

- Trawl winch
- Trawl hoist
- Auxiliary power generation plant (2 MW)
- HRP 400 long-baseline locator system computer and transponders
- Differential GPS system

Trawl

The conceptual design of the trawl is described in Section 3.2 of this report. To ascertain that the trawl will function properly, a one-quarter-scale model will be built and tested at an appropriate test facility, such as the one belonging to the U.S. Navy at Bethesda, Maryland, or at the test tank at Shimensaki, Japan, owned by Nichimo, Ltd., the parent company of NET Systems of Bainbridge Island, Washington.

After the tests and the evaluation of the video recording of the interaction of a sample foot chain and the seabed, a full-scale trawl will be built for the trial harvesting. A total of six months' lead time may be required, plus the time required to ship the trawl to the yard where the trawler will be outfitted.

Cable

A full-length cable, including an embedded electric cable, will be purchased for the test harvesting. The lead time for manufacture is estimated to be six months.

Hoisting Winch

The winch required for the operation is larger than any winch made by the prospective suppliers. It will be custom-designed, custom-built equipment based on known technology. The design and fabrication require a lead time of nine months. Additional time is required for shipping to the yard where the trawler will be outfitted.

Auxiliary Power Plant

If auxiliary power generation is required to drive the trawl hoist, a package-type diesel generator will have to be rented and installed on board the trawler. The fuel will be supplied from the tank of the trawler.

Long-Baseline Locator System

The system will consist of four hyrdoacoustical transponders anchored on the seabed, a battery-powered instrument package mounted on the trawl, a transponder and an HRP 400 processing unit located on the trawler. The entire system is built on order from standard components and requires a lead time of six months.

Global Positioning System

It is highly probable that the chartered trawler already is equipped with a differential GPS. If not, the package is available readily.

9.2.4 Metallurgical Testwork

A two-pronged effort is planned in this area. The first and main effort will be a comprehensive examination of the nodules and their processing through the pyrometallurgical and hydrometallurgical treatment.

A testing organization will be selected to perform the related tasks, the first of which will be a literature search to identify applicable processes for deep-sea nodules. Mineralogical examinations would be performed on selected nodules. Following these examinations, thermal processing tests would be conducted, followed by hydrometallurgical tests. Each of these test series would be performed sequentially, as the outcome of one would affect the substance of the following tests. The tests would be concluded with the producion of a report containing the test results and recommendations for the processes, including the design parameters.

Independent of the above-described effort, the prospective designer and supplier of the electric smelting furnace will be retained to conduct tests on a representative sample of nodules to determine the practicality of the melting and reduction of the nodules in a single-process step in the electric furnace, rather than achieving partial nodule reduction in a rotary kiln before melting and final reduction. Although these parallel efforts may appear to be redundant, it is desirable to have them both performed, as the furnace supplier has more thorough specialized experience regarding the capabilities of the equipment, while the testing organization can develop information that is comprehensive. The results of the two tests will be evaluated, compared and reconciled by the project metallurgists.

9.2.5 Nodule Pumping Test

Although the Marconaflo system is a tried and proven means of transporting solids in slurry form, with well over fifty installations, some in operation for more than twenty years, there are two areas in handling nodules that should be investigated.

The first one is the behavior of nodules around the intake of the Marconaflo pump. During steady-state operation, the Marconaflo pump is located at the bottom level of the nodule storage, with the high-pressure water jets undercutting the mass of nodules and flushing the nodules toward the vertical slurry pump. Calculations indicate that the slurry should contain 30 to 50 percent nodules by weight in order to achieve desirable flow conditions in the pipeline. Because the nodules are spherical in shape, it is not known whether they are prone to sluffing, particularly when the reclaim cavity around the pump is small, as at the beginning of the pumping cycle. An experiment is proposed to fill a properly-sized container with nodules and direct a high-pressure water jet at its bottom to simulate the conditions at the pump intake. It is possible that this experiment should be conducted during the test harvesting aboard the trawler. Alternatively, it can be done onshore. About 40 tons of nodules would be required.

The second question relates to the unloading of the nodules from the transport vessel. Unlike the Marconaflo units on the trawlers, which are installed in the hold at its lowest point, the unloading Marconaflo pumps will be lowered into the holds. This necessitates a design where high-pressure water jets are installed not only in a horizontal plane but also on the bottom of the pump and pointing downward. The purpose of these vertical jets is to slurry the solids under the pump so as to create a pool in which the pump can operate. During transportation, the nodule cargo in the transport ship is drained in order to steady the cargo and minimize its weight. The purpose of the proposed test is to determine whether the water jets can create a pool in a drained load of nodules, or whether the hold needs to be flooded prior to lowering the Marconaflo unit down into the mass of nodules. Similar to the first experiment, this one also can be made aboard the trawler or on land with the same material that is used for the first test.

9.2.6 Site Selection and Permitting

Within the Phase II program, the Owner will evaluate the findings of the site-screening effort conducted in the course of this study and initiate a detailed selection process with the aid of project personnel and a local consultant. While the site selection is in progress, the project team, including the local consultant, will assemble the data required for the commencement of the permitting process.

If the plant is to be located in New Zealand, the document "Assessment of Environmental Effects" will be prepared for the project in conformance with the requirements of the Resource Management Act. Applications also will be prepared and lodged with the regional and district councils for land use, air discharge, water discharge and water use consents, thereby starting the statutory permitting process. With proper preparation and close cooperation with the regional and district councils, the permitting process is expected to take 9 to 12 months to complete.

9.2.7 Feasibility Study Update

At the end of the Phase II work, the feasibility study capital and operating cost estimates will be updated to a ±15 percent accuracy, using information developed during Phase II, firm quotation on vessels and major process equipment, firm consumables prices, and various site-specific data.

A financial analysis and sensitivity studies will be produced on the basis of the new estimates. The updated report will serve the purpose of enabling the Owner to make a rational decision whether or not to proceed with project. Also, it will aid in arranging financing, should that be necessary.

Table 9-1 presents a summary tabulation of the Phase II costs.

Table 9-1

PHASE II COSTS

Description	Cost (US $1,000)
Program management	500
Owner's costs	250
Oceanographic exploration	1,320
Metallurgical testwork	240
Test harvesting	4,500
Site selection	300
Feasibility study update	1,000
Contingency	2,790
TOTAL	11,000

9.3 BASIC ENGINEERING

Basic engineering will begin with a review of the results of the exploration and testing program. On the basis of the review, a detailed engineering, procurement and construction program will be developed.

Design criteria for the process, environmental design, mechanical, civil, structural, electrical and control systems will be developed. Project procedures will be established and published. Specifications and firm-price bid documents will be produced for the major and long lead-time equipment, including the harvesting and transport vessels, kilns, electric furnace, electrostatic precipitator, converters, cranes, Marconaflo units, special hydrometallurgical plant equipment, high-voltage electric switchgear, transformers and rectifiers, among others. Price quotations will be obtained for these items, bids will be evaluated, and purchase documents will be prepared. Should the Owner so decide, in order to accelerate the implementation schedule, design-engineering-only contracts may be awarded for critical items such as the electric furnace and trawlers.

Optimization studies will be made regarding the plant design as required and their results will be used in firming up the plant design. The equipment list for the mechanical and electrical equipment will be refined. General arrangement drawings, plot plan, earthwork drawings, electrical one-line diagrams, piping and instrumentation diagrams and other basic documents will be completed. During these activities, construction specialists will be part of the project team so as to ensure by their timely input that the constructability aspects of the plant are taken into account during the design. Early involvement by construction personnel has beneficial effects on the cost and duration of construction.

9.4 DETAIL ENGINEERING, PROCUREMENT AND CONSTRUCTION

During this period of the project, purchase orders will be issued for the equipment already bid and evaluated, and work will proceed with the detail engineering. Procurement personnel will be augmented to support the purchasing and contracting activities.

The construction of the project can be achieved by contracting all of the work and managing and coordinating the contractors, or Bechtel can contract items such as the mass earthwork, siding and roofing, underground piping, etc., and perform all other work on a direct-hire basis. This latter arrangement has several advantages; the main one is that with the detail engineering and procurement proceeding in parallel and overlapping with construction, significant shortening of the project implementation period can be achieved. Generally, a shorter implementation period results in a significant increase in the net present value of the project.

During the entire basic and detail engineering phase of the project, project controls personnel will be an integral part of the project team. Their task will be to establish a detailed work plan and schedule for all aspects of engineering, procurement and construction. Also, they will monitor and report on the adherence to the plan. They will also monitor and report on deviations from the estimated costs of the project and give timely notice when design, quantity or price changes cause deviations from the project plan so that steps can be taken to control potential slippages of costs and schedule.

During the middle of the detail engineering effort, specialists will join the project to establish a program for preoperational testing and identify the need for training future plant operators. They will assemble operating manuals and establish training programs and, should the Owner so desire, hold training classes for the operating personnel.

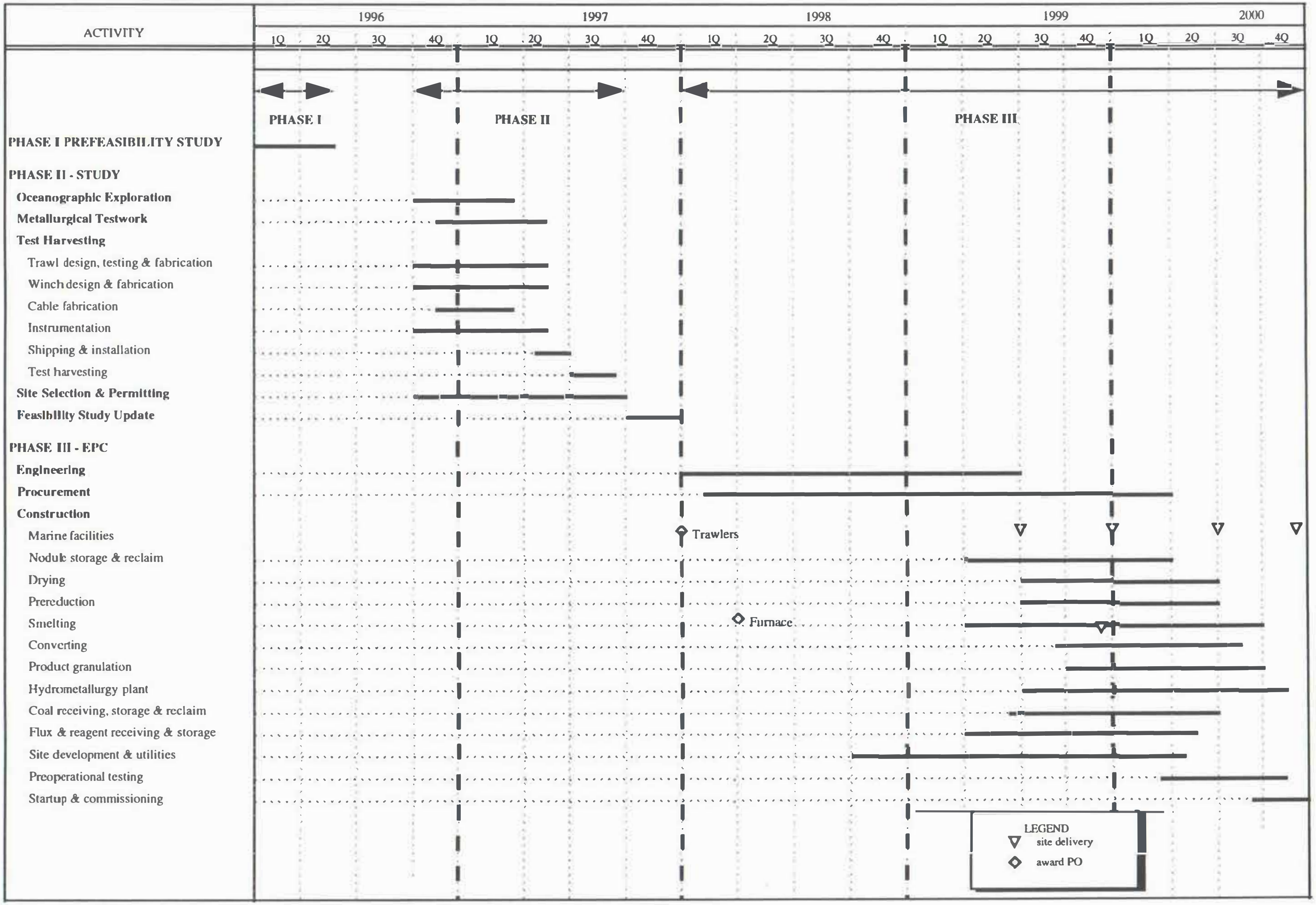

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Figure 9-1. Project Summary Schedule

Bechtel
Mining and Metals

APPENDIX B

APPENDIX B

DEEP-SEA NODULE MINING STUDY

PROCESS DESIGN CRITERIA

DEEP SEA NODULE MINING STUDY

PROCESS DESIGN CRITERIA

23134-DCB-001

FOR

THE GOVERNMENT OF COOK ISLANDS
COOK ISLANDS

BECHTEL CORPORATION

JOB No. 23134-000

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SECTION

1.0 GENERAL

1.1 Introduction

This document provides the process design criteria for the Cook Islands Deep Sea Nodule Mining Study, the purpose of which is to investigate the economic viability of exploiting deep sea manganese nodules situated on the seabed in the Exclusive Economic Zone of the Cook Islands.

The Cook Islands Deep Sea Nodule Project will encompass a variety of activities at several geographical locations. Harvesting will take place in approximately 5 000 m deep waters north of Aitutaki atoll in the South Pacific Ocean. The harvested nodules will be transported by ship to a processing plant tentatively located in New Zealand. The smelting process will extract cobalt, nickel and copper along with other trace metals from the nodules, concentrating them in a sulfide matte. The matte will be granulated and refined in an adjacent hydrometallurgical refinery to produce purified metal.

1.2 Source Codes

The source code letters listed for each criterion refer to the origin of that criterion value. Where an integer is entered as a source code, this code number refers to specific source documents that are referenced in Section 6. In certain cases, two source codes may be referenced. The following letter code designators are used:

Code	Description
A	Criteria provided by Client
B	Standard industry practice
C	Bechtel recommendation
D	Vendor-originated criteria
E	Criterion from process calculations
F	Engineering handbook data
G	Assumed data
H	Criteria provided by "Technology Supplier"

1.3 Definition of Design Value Terms

The process criteria are listed as **Balance**. The context in which this term is used is in accordance with the following definitions:

Annual Rate: Flow rate per number of operating days.

Operating Days: The number of plant operating days per year is 310 days for the smelting operation (7 440 h/y) and 344 days for the refinery operation (8 250 h/y).

Utilization: A utilization factor of unity represents the capability of, and requirement for, any equipment or facility being on-line for 24 hours per day for all calendar days in the year. A utilization of less than unity reflects the combined effect of allowed availability for that facility and the utilization effect from the on-line time of upstream or downstream equipment, or from other factors. For this criteria, the utilization factors are 0.85 and 0.942 for smelting and refining, respectively.

Balance Value: The **Balance** values in this design criteria are intended as attainable continuous rates and do not include any additional design allowance(s). The daily **Balance** values relate to the annual production by multiplying them by the number of operating days per year.

2.0 PROCESS SUMMARY

Harvested nodules will be dried, mixed with fluxes and coal (reductant) and fed to a reduction kiln to prepare calcine for feeding a submerged-arc, electric smelting furnace. Furnace products will be a metal alloy containing mainly: cobalt, nickel, copper and iron; a slag containing mostly all of the manganese; and dusts for recycle to the reduction kiln.

The alloy will be transferred to one of two converters (one on standby) where most of the iron will be blown into the converter slag in a first step, then molten sulfur will be fed to the converter to form matte for feed to the refinery.

Slags will be granulated and disposed of, or stockpiled for eventual recovery of manganese. Dusts will be recycled. Smelter gases will be cleaned prior to discharge from a central stack.

Smelter matte will be transferred to the refinery where it will be treated according to the MCLE chlorine leach process practiced by Sumitomo Metal Mining Co., Ltd. In a first step, the matte will be finely ground and slurried prior to being fed to a two-stage, countercurrent leaching which uses chlorine and cupric chloride to put the metals into solution while reducing the sulfur to elemental sulfur for recycle to smelting.

The chloride solution from leaching will be purified to remove iron, manganese, lead, etc. Copper will be removed by electrowinning as impure copper powder. Nickel and cobalt will be separated by solvent extraction then electrolyzed to their respective cathode deposits on starter sheets. Nickel cathodes will be sheared to customer shapes, then packaged in steel drums. Cobalt cathodes will be broken to chips, vacuum degassed, then packaged in steel drums.

Electrolytic cell gases will be collected under partial vacuum, compressed and recycled to leaching. Chlorine-containing vent gases will be cleaned in a lime scrubber before discharge.

3.0 MEASUREMENT UNITS AND SYMBOLS

The Modernized Metric System of measurement used in this study and report are in accordance with (USA) ASTM E380, Standard Practice for Use of the International System (SI) of Units. A period, not comma, is used as the decimal marker. A small space (with no comma) is used to separate groups of three integers.

The reference conditions for gas volume are 0°C and 101.325 kPa, corresponding with a molar (ideal) gas volume of 22.414 m^3/(kg.mol). This is shown as "m^3 (normal)" or abbreviated to (non-SI) "Nm^3". The unit "t", rather than Mg, is used for 1 000 kg mass.

SI Base Units: (dimensionally independent)

Measured Attribute	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Permitted Base Units:

Measured Attribute	Unit	Symbol	Definition
Time	minute	min	60 s
	hour	h	60 min
	day	d	24 h
	(calendar) year	y	365 d
Mass	metric ton	t	1 000 kg

(Note: SI prefixes, as listed below, are used only with SI base units. It is incorrect to use these prefixes with the "permitted base units.")

4.0 SITE DATA

The smelter and refinery facilities will be located at a site to be selected by the Owner; however, in order to have a basis of reference for processing, the town of Whangarei on the North Island of New Zealand was assumed to be the site of the processing plant. Once the actual site is selected by the Owner, this design criteria will be revised to reflect the appropriate site data.

5.0 ENVIRONMENTAL CRITERIA

Due to the fact that a plant site has not been selected, no specific environmental criteria can be established. Nevertheless, this study is based on environmental criteria generally applicable to plants located in the United States of America with appropriate design and equipment for gas cleaning, dust emission control, water management, etc.

6.0 DESIGN CRITERIA REFERENCE LIST

6.1 "Operation of the MCLE (Matte Chlorine Leach Electrowinning) Plant for Nickel Refining at Sumitomo Metal Mining Co., Ltd.," S. Makino and F. Yano, EPD Congress 1966, pp. 297-311.

6.2 "Deep-Sea Nodules Processing," S. Jorget, Minemet Researche, EEC DGIII, 1989.

7.0 PRODUCTION SUMMARY

7.1 Annual Production Parameters

Pyrometallurgy (Smelting)	Units	Balance	Code
Feed Material as Received:			
Deep sea nodules (wet)	t/y	1 097 360	A
Deep sea nodules (dry)	t/y	665 000	E
Free moisture	%	30	A
Feed Material to Dryer:			
Deep sea nodules (wet)	t/y	1 032 609	E
Deep sea nodules (dry)	t/y	665 000	E
Free moisture	%	25	G

Pyrometallurgy (Cont'd)	Units	Balance	Code
Key Consumables and Fuels:			
Converting silica flux	t/y	9 300	E
Converting sulfur	t/y	2 604	E
Drying plant coal	t/y	26 040	E
Kiln coal	t/y	59 830	E
Smelting power	MWh	142 000	E
Converter fuel oil # 2 (holding, etc.)	t/y	1 125	E
Launder and ladle heating fuel oil (# 2)	t/y	2 125	E
Discard slag	t/y	451 670	E

Hydrometallurgy (Refining)	Units	Balance	Code
Key Consumables and Fuels:			
Chlorine	t/y	1 030	E
Soda ash	t/y	760	E
Hydrated lime	t/y	22	E
Boiler fuel oil (#6)	m^3/y	206	E
Products:			
Cobalt cathode metal	t/y	2 652	E
Nickel cathode metal	t/y	1 718	E
Copper powder	t/y	955	E
Composition:			
copper	wt %	99.5	E
nickel	wt %	0.5	E
Effluents:			
Stack gas	m^3/h	82	E
Chlorine	ppmv	13	E
Ferric chloride solution	m^3/h	0.8	E
$FeCl_3$	wt %	13.5	E
Specific gravity	Sp Gr	1.12	F
Manganese dioxide cake, wet	kg/h	6.08	E
Solids,	wt %	88	E
Composition, dry cake:			
MnO_2	wt %	18	E
$Ni(OH)_2$	wt %	52	E
$PbSO_4$	wt %	21	E
$Fe(OH)_3$	wt %	9	E

Hydrometallurgy (Cont'd)	Units	Balance	Code
By-Products:			
Sulfur residue	t/y	2 193	E
Sulfur	wt %	97.8	E
Unleached residues	wt %	2.2	E

7.2 Overall Balance

	Units	Co	Ni	Cu	Code
In nodules	t/y	3 123	1 807	993	E
Out in slag	t/y	433	48	1	E
Out in matte	t/y	2 690	1 759	992	E
Out in metal sales	t/y	2 652	1 718	955	E
Recovery to matte from nodules	%	86	97	99	E
Recovery to products from matte	%	99	98	96	E
Recovery to products from nodules	%	85	95	96	E

(Note: Recovery is based on computer equilibrium calculations. Actual recoveries most likely will be slightly lower. Previously performed testwork by Inco Research (R. Sridhar, et al.) verified the calculations).

7.3 Operating Schedules

	Units	Smelter	Refinery	Code
Calendar days per year	no.	365	365	B
Effective operating days at 24 hours	no.	310	344	E
Operating hours	no.	7 440	8 250	E
Equivalent availability	%	85	94.2	C

8.0 CHARACTERISTICS OF PROCESS MATERIALS

8.1 Introduction

The following sections describe the compositions and properties of the raw materials, intermediate materials and final products involved in the smelting process.

Where variability of characteristics will have an important effect on process parameters, e.g., natural matte grade, oxygen demand and gas rates, these variations are accounted for in the calculated **Balance** criteria values listed in the appropriate facility section. The ranges of composition of concentrates applied to this purpose also are given below.

8.2 Mineralogy of Nodules

The mineralogy of the south Penrhyn Basin nodules was determined by X-ray diffraction. δ-MnO_2 was the only manganese oxide mineral present, although weakly-defined todorokite was noted in the nodule from one sampling station. Varying amounts of montmorillonite and phillipsite or feldspar also were present.

Optical studies on polished sections of nodules show the interior of the nodules to consist of weak concentric banding around what appears to be an almost completely replaced volcanic core which sometimes contains a small discrete palagonite or more rarely shark's tooth nucleus. At higher magnifications under S.E.M. or optical microscope, polished sections of nodules typically show little structure in the interior part from poorly defined growth cusps and laminations. Banding is, however, much better defined in the outer 1 to 4 millimetres of the nodule.

Note: The above comments are from a paper in the South Pacific Marine Geological Notes, Vol. 1, No. 7 (August 1978), "Notes on the Surface Texture, Internal Structure and Mineralogy of Manganese Nodules from the South Penrhyn Basin," by G. P. Glasby.

8.3 Chemical Composition of Nodules and Process Raw Materials

Chemical Composition of Deep Sea Nodules:

The composition of the nodules was compiled from several sources and should be used only to characterize them, and not as a basis of definitive process design.

Element	Content (%)	Source
Fe	15.4	1
Mn	14.9	1
Si	6.7	2
Al	3.3	2
Na	2.7	2
Ca	2.2	2
Ti	1.7	2
Mg	1.6	2
K	0.7	2
Co	0.47	3
Ni	0.27	3
Cu	0.15	3
Pb	0.1	1

1 Source: South Pacific Geological Notes, Vol. 1, No. 3, November, 1976
2 Source: South Pacific Geological Notes, Vol. 1, No. 7, August, 1978
3 Source: Cook Islands Manganese Nodule Resource Assessment, East-West Center, 1993

In addition to the above listed elements, there are other trace elements present in the nodules. The following table gives the listing of such elements, although the listing may not be complete and needs to be verified in laboratory tests of nodule samples.

Element	Content (ppm)	Source
Ag	64.0	1
Au	1.3	1
Pt	2.6	1
Pd	3.4	1
Th	43.0	2
Nb	87.0	2
Zr	629.0	2

1 Source: Chemical analysis of one nodule by Falconbridge Nikkelverk A/S in Kristiansand, Norway
2 Source: Manganese Nodules from the South Penrhyn Basin; South Pacific Marine Geological Notes, November, 1976 - C. W. Landmesser et al.

The following mineralogical composition from IFREMER (French Research Institute for Oceanography) was used for the preparation of the process design within this study:

Compound	wt %	wt % metallic
$Cu(OH)_2$	0.23	0.15
$Co(OH)_2$	0.74	0.47
$Ni(OH)_2$	0.43	0.27
$FeO \cdot 3H_2O$	19.65	
$Fe_2O_3 \cdot 6H_2O$	20.13	16.8 (total iron)
$Pb(OH)_2$	0.12	0.10
$Mn(OH)_2$	25.09	15.5
SiO_2	14.33	6.7
Al_2O_3	6.23	3.3
TiO	2.84	1.7
Na_2O	3.64	2.7
K_2O	0.84	0.7
CaO	3.08	2.2
MgO	2.65	1.6
Total	100.00	

Chemical Composition of High Grade Flux:

Component	Units	Balance	Code
SiO_2	wt %	90	G
Moisture, as received	wt %	3	G

8.4 Physical Characteristics, Process Raw Materials

Deep Sea Nodules:

The physical properties of the nodules, based on telephone information from the South Pacific Applied Geoscience Commission, headquartered at Suva, Fiji, are as follows:

Specific gravity (wet): 1.8 to 2.6 with an average of 2.0

Water content: 27 to 31.1% with an average of 30%

Size range: 2 to 12 cm; with very few nodules larger than 8 cm, but quite a few in the lower size range

Bulk density: 1.2 to 1.4 t/m^3

Silica Fluxes:

Component	Units	Fine Flux	Coarse Flux	Code
Bulk density @ 0% H_2O	t/m^3	81	87	G
Angle of repose @ 0% H_2O	deg	39	31	B
Drawdown angle @ 0% H_2O	deg	60	65	B
Screen size, as received:				
-300 mm	wt %		100	G

8.5 Properties of Fuels

Properties of Diesel Oil:

Property	Units	No. 2 Diesel	Code
Grade	no.	2	B
Specific gravity (15°C)	Sp Gr	0.8576	B
Flash point	°C	99	B
Pour point	°C	+10	B
Sulfur	wt %	0.4	B

Property	Units	No. 2 Diesel	Code
Saybolt viscosity @ 100°F	s	42	B
Net heating value (avg)	GJ/t	43.7	B
	GJ/m^3	37.5	B

Properties of Coal

	Unit	Balance	Code
Analysis:			
Carbon	wt % (dry)	71.7	B
Sulfur	wt % (dry)	0.7	B
Hydrogen	wt % (dry)	5.1	B
Silica	wt % (dry)	6.1	B
Alumina	wt % (dry)	2.8	B
Water	wt % (dry)	5.0	B
Net heating value	GJ/t	29.25	B
Ground coal size, P_{80}	micron	74	B

9.0 MATERIALS HANDLING

The materials handling facility will receive, store, prepare and distribute the operating feed materials and consumables including the nodules, fluxes, fuel and reductant, and smelter recycle materials such as reverts. For study purposes, it is assumed that the nodules will arrive at the site by ship.

	Unit	Balance	
Ship capacity:			
Nodules	t (wet)	30 000	G
Coal	t (wet)	30 000	G
Fuel oil	t	N/A	B
Sulfur	t	N/A	B
Truck capacity:			
Flux	t	25	G

	Unit	Balance	
Receiving stockpile capacity:			
Nodules	t (wet)	180 000	G
Coal	t (wet)	20 000	G

	Unit	Balance	Code
Sulfur	t	500	G
Flux	t (wet)	1 500	G
Fuel oil storage tank	m^3	650	G

10.0 NODULE DRYING

Nodule feedrate	t/h (wet)	119.2	E
Nodule feed moisture:			
Contained	%	18.2	E
Free	%	25	G
Nodule discharge moisture:			
Contained	%	18.2	E
Free	%	0.2	G
Nodule inlet temperature	°C	25	G
Nodule outlet temperature	°C	75 - 100	G
Dryer fuel	type	ground coal	G
Fuel required	MJ/t feed	740	E
Dryer firing temperature	°C	900 - 1 000	B
Dryer exit gas temperature	°C	150 - 160	B
Dryer exit gas dust load	g/m^3	30 - 50	B

11.0 REDUCTION KILN

Rates and analysis are based on new nodule feed only - i.e., no recycle material included.

Kiln feed rate	t/h	89.3	E
Reduction coal	kg/t ore	67.6	E
Kiln calcine discharge	t/h	60.6	E
Calcine analysis (major components):			
CoO	wt %	0.86	E
NiO	wt %	0.35	E
FeO	wt %	32.3	E
MnO	wt %	29.3	E
SiO_2	wt %	21.1	E
MgO	wt %	3.9	E

	Unit	Balance	Code
CaO	wt %	5.4	E
C	wt %	0.9	E
Other	wt %	5.89	E
Calcine temperature	°C	850 - 950	B
Firing fuel	type	ground coal	G
Firing fuel required	MJ/t feed	657	E
Kiln exit gas temperature	°C	400 - 450	B
Kiln exit gas dust load	g/m^3	100 - 200	B

12.0 ELECTRIC FURNACE SMELTING

Hot calcine transfer	type	refractory-lined container	B
Power consumption	kWh/t calcine	300 - 350	E
Furnace power	MW	25	C
Slag temperature:			
Liquidus	°C	1 300 - 1 400	E
As tapped	°C	1 500 - 1 550	C
Alloy temperature	°C	1 400 - 1 450	C
Offgas temperature	°C	1 500 - 1 600	C

Discard slag analysis (includes recycled converter slag):

CoO	wt %	0.12	E
NiO	wt %	0.01	E
FeO	wt %	32.3	E
MnO	wt %	29.4	E
SiO_2	wt %	23.0	E
MgO	wt %	3.9	E
CaO	wt %	4.5	E
Other	wt %	6.77	E

	Unit	Balance	Code
Alloy analysis:			
Fe	wt %	70.2	E
Co	wt %	9.9	E
Ni	wt %	6.5	E
Ca	wt %	3.6	E
Mn	wt %	3.9	E
Pb	wt %	2.5	E
S	wt %	3.4	E
Offgas dust load	g/m^3	10 - 50	B
Alloy production	t/h	3.65	E
Slag production:			
New feed	t/h	56.1	E
Converter recycle	t/h	0 - 150	E
Discard (average)	t/h	60.7	E

13.0 CONVERTING

Converters, required	no.	2 (1 operating, 1 standby)	C
Ladle and launder heating fuel	type	no. 2	C
	MJ/t alloy	3 400	E
Converter availability	%	70	C
Blowing air oxygen efficiency	%	92	C
Blowing air	Nm^3/t alloy	6 100	E
Normal blowing rate	Nm^3/h	42 000	C
Blowing time	h/d	13.6	E
Converter slag iron: silica	wt ratio	2.2:1	C
Slag analysis (all converter slag returned to electric furnace):			
SiO_2	wt %	11.3	E
Fe (75% FeO, 25% Fe_2O_3)	wt %	24.8	E
Co	wt %	0.72	E
Ni	wt %	0.12	E
Mn	wt %	1.42	E
Cu	wt %	0.04	E
O_2	wt %	balance	E
Sulfur efficiency	%	90	B

	Unit	Balance	Code
Converter matte analysis:			
Co	wt %	32.7	E
Ni	wt %	21.4	E
Fe	wt %	5.1	E
Cu	wt %	12.1	E
Mn	wt %	0.07	E
S	wt %	28.7	E

14.0 MATTE GRANULATION

Granulation water to matte ratio	wt:wt	15:1	C
Matte dewater device	type	screen/dryer	C

15.0 AISLE AND GENERAL

Alloy ladle, active capacity	t	18	C
Converter slag ladle, active capacity	t	14	A,C
Alloy forming skull/revert	%	5	C
Matte forming skull/revert	%	5	C
Converter slag forming skull/revert	%	10	C
Aisle crane capacity:			
Main hoist	t	50	C
Auxiliaries (2)	t	15	C

16.0 HYDROMETALLURGY (COBALT-NICKEL-COPPER REFINERY)

16.1 Synthetic Matte Feed - Chemical Composition

The composition of synthetic matte from the converter has been characterized below, but not as a basis for a definitive process design.

Element	Content (wt %)
Co	32.7
Ni	21.4
Cu	12.1
Fe	5.1
Pb	0.09
Mn	0.07
S	28.54

	Unit	Balance	Code
16.2 Matte Feed Grinding			
Synthetic matte feed, dry	kg/h	996	E
Grinding mill	type	tower mill	C
Bond index	kWh/t	17	G
Size:			
Feed 100% minus	mm	2.0	G
Product 75% minus	micron	44	C
Pulp:			
Solids	%	75	C
Specific gravity	Sp Gr	2.64	E
Flow	m^3/h	0.5	E
16.3 Matte Slurry Makeup Tank			
Ground matte pulp	m^3/h	0.5	E
Dilution liquors	m^3/h	2.3	E
Co EW anolyte	vol %	55	E
Ni EW anolyte	vol %	42	E
$NiSO_4$ return solution	vol %	3	E
Diluted pulp:			
Solids	wt %	25.4	E
Specific gravity	Sp Gr	1.35	E
Flow rate	m^3/h	2.2	E
16.4 Cementation Reactors			
Feeds:			
Matte slurry	m^3/h	2.2	E
Cu EW spent liquor	m^3/h	2.4	E
Scavenge sulfur	kg/h	44	C
Ni (metal)/Cu ions	kg/kg	2.8 to 3.0	C

	Unit	Balance	Code
Reaction vessels:			
Vessels	no.	3	C
Temperature	°C	60	C
Residence time	hours	6 - 8	C
Size	m dia x m	2.5 x 2.5	C
Materials of construction		SS/RL	C
Agitation		yes	C
Sealed		yes	C

16.5 Cementation Filtration

Filtration steps	no.	2	C
1st step	type	filter press	C
2nd step	type	centrifuge	C
Cake washing		no	C
Filter cake, solids	wt %	47	C
Filtrate (pregnant liquor)	m^3/h	3.6	E
Temperature	°C	54	E
Specific gravity	Sp Gr	1.39	E
Composition:			
Co	g/L	106	E
Ni	g/L	75	E
Cu	g/L	$<10^{-4}$	E
Fe	g/L	12	
Mn	g/L	0.2	
HCl	g/L	10	E
H_2SO_4	g/L	4	E
Cl^-	g/L	230	E
SO_4^{--}	g/L	5	E
H_2O	g/L	balance	E

16.6 Completion Leach Reactors

Feeds:			
Matte slurry	m^3/h	0.7	E
Cementation filter, solids	kg/h	802	E
Filtrate recycles	m^3/h	1.3	E
Chlorine recycles	Am^3/h	318	E
Cl_2	vol %	85	C
Air	vol %	15	C
Makeup chlorine	Am^3/h	45	E
Cl_2	vol %	100	B

	Unit	Balance	Code
Reaction vessels:			
Number – leach	no.	3	C
– cooling tank	no.	1	C
Temperature	°C	110	C
Residence time	hours	4 - 6	C
Size – leach	m dia x m	2.0 x 2.0	C
– cooling	m dia x m	2.5 x 2.5	C
Materials of construction		SS/Pb-lined/acid brick	C
Agitation		yes	C
Sealed		yes	C

16.7 Completion Leach Cooling and Filtration

	Unit	Balance	Code
Inlet temperature	°C	110	E
Outlet temperature	°C	55	C
Duty	GJ/h	0.54	E
Filtration steps	no.	2	C
1st step	type	centrifuge	C
2nd step	type	filter press	C
Cake washing		yes	C
Repulp water	m^3/h	0.13	E
Wash water	m^3/h	0.5	E
Filter cake, solids	wt %	88	C
Filtrate (Cu EW advance)	m^3/h	2.3	E
Temperature	°C	55	C
Specific gravity	Sp Gr	1.582	E
Composition:			
Co	g/L	172	E
Ni	g/L	112	E
Cu	g/L	59	E
Fe	g/L	21	E
Mn	g/L	0.4	E
HCl	g/L	17	E
H_2SO_4	g/L	8	E
Cl^-	g/L	427	E
SO_4^{--}	g/L	3	E
H_2O	g/L	balance	E

	Unit	Balance	Code
16.8 Copper Electrowinning			
Operating temperature	°C	60 - 65	B, 6
Current density	A/m^2	330	B, 6
Current efficiency	%	>100	B, 6
Cell voltage	V	3.0 - 3.1	B, 6
Power consumption	kWh/t	2 500	C
Copper EW cells:			
Product		copper powder	B, 6
Rate	t/d	2.778	E
Composition:			
copper	%	>99.0	B, 6
nickel	%	0.5	B, 6
Cells	no.	7	E
Size, l x w x h	m	4.0 x 1.4 x 1.1	C
Material		FRP	C
Cathodes:			
size, l x w	m	1.0 x 1.0	C
material		12 - gauge titanium	C
number per cell	no.	23	B, 6
Anodes:			
size, l x w	m	1.0 x 1.0	C
material		DSE titanium	B, 6
number per cell	no.	24	B, 6
16.9 Iron Oxidation Step			
Mother liquor feed	m^3/h	3.5	E
Temperature	°C	54	E
Specific gravity	Sp Gr	1.39	E
Composition:			
Fe	g/L	12	E
Mn	g/L	0.2	E

	Unit	Balance	Code
Oxidation reactions:			
Temperature	°C	70	C
Oxidizing agent		Cl_2 + air	C
Couples:			
#1		$Fe^{++} + 1/2\ Cl_2 \rightarrow Fe^{+++} + Cl^-$	F
#2		$Mn^{++} + Cl_2 \rightarrow Mn^{4+} + 2Cl^-$	F
Chlorine consumption	kg/h	29.5	C
Chlorine efficiency	%	95	C

16.10 Iron Removal

	Unit	Balance	Code
Type		solvent extraction	B
Extractant		TBP (tri-butyl phosphate)	B
Diluent		kerosene	D
Strength, extractant	vol %	10	D
Stages:			
Extraction	no.	3	C
Scrub	no.	1	C
Stripping	no.	2	C
Operating temperature	°C	40	B
Iron extraction	%	99.3	C
Stripping parameters:			
Strip agent		water	B
$FeCl_3$	g/L	150	C
Rate	m^3/h	0.8	C
Specific gravity	Sp Gr	1.120	F

16.11 Cobalt Recovery

	Unit	Balance	Code
Type		solvent extraction	B
Extractant		TIOA (Alamine 336)	B
Diluent		Solvesso 150	B
Strength, extractant	vol %	13	B
Stages:			
Extraction	no.	4	B
Organic wash	no.	2	B
Stripping	no.	2	B

	Unit	Balance	Code
Extraction parameters:			
Temperature	°C	40	B
Co efficiency	%	99.3	C
Stripping parameters:			
Strip liquor		cobalt EW anolyte	B
Co^{++}	g/L	28	C
Cl^{-}	g/L	34	C
Advance electrolyte:			
Co^{++}	g/L	85	C
Cl^{-}	g/L	102	C
Organic washing:			
Wash agent		cobalt EW rich electrolyte	B
Co^{++} in electrolyte	g/L	85	B
Co^{++} in spent wash	g/L	65	B
Ni^{++} in spent wash	g/L	20	B
Ni removal from organic	%	100	B
Equipment parameters:			
Mixer residence time	min	4	C
Settler area	$m^3/h/m^2$	5	C
Aq:Or ratios:			
extraction		1.2:1.0	C
scrub		1:2	C
strip		1:2	C
Advance electrolyte purification:			
Organic inlet	ppmv	100	
Organic outlet	ppmv	10	
1st step		air flotation column	C
2nd step		carbon columns	B
Flow rate	m^3/h	7.9	E

	Unit	Balance	Code
16.12 Nickel Recovery			
Type:		IX cobalt removal and solution purification	B
Cobalt removal:			
Removal agent		solid ion exchange resin	B
Resin		Dow XFS 4195	D
Flow velocity	m/h	8.77	D
Resin capacity	kg-mols Co/m^3	0.5	D
Cobalt removal efficiency	%	99.3	D
Cobalt elution:			
Solution		3N HCl	D
Flowrate	m^3/h	0.06	E
Consumption 35% HCl	kg/h	21.4	E
Eluate	g/L Co	55	E
	g/L HCl	54	E
Solution purification:			
Removal agent		nickel carbonate	E
Temperature	°C	70	C
Removal efficiency:			
$PbSO_4$	%	100	E
MnO_2	%	100	E
$Fe(OH)_3$	%	100	E
H_2SO_4	%	100	E
HCl	%	100	E
Flow rate	m^3/h	3.5	E
$NiCO_3$ addition	kg/h	102	E
Reaction tanks	no.	4	C
Residence time, total	hours	1	C
Nickel carbonate filter	type	filter press	C
Repulp tanks	no.	1	C
Second carbonate filter	type	filter press	C

	Unit	Balance	Code
Cake dissolver tanks	no.	2	C
Residence time, total	min	30	C
Size, dia. m x h	m	1.5 x 1.5	E
Dissolving agent:			
type		35% HCl	E
flow rate	kg/h	12.7	E
Advance electrolyte purification:			
Organic inlet	ppmv	100	E
Organic outlet	ppmv	<10	E
1st step		air flotation column	C
2nd step		carbon columns	B
Flow rate	m^3/h	4.4	E

16.13 Cobalt Electrowinning

	Unit	Balance	Code
Operating temperature	°C	45	C
Current density, avg	A/m^2	232	C
Current density, maxm	A/m^2	267	C
EW plant availability	%	94.2	C
Current efficiency	%	97 - 98	C
Cathodes:			
Material, mother blanks		Ti	C
Material, commercial cells		Co starter sheets	B, 6
Size, w x l	mm	1 000	C
Number per cell	no.	38	C
Life, starters	days	2	C
Life, commercial	days	5	C
Anodes:			
Material		DSA-Ti	B, 6
Size, w x l	m	1 000	C
Number per cell	no.	39	C
Life	years	5	D
Diaphragm bag		polypropylene	C

	Unit	Balance	Code
Cell electrical:			
Voltage	V	3.1	B
Current, avg	A	18 100	E
Current, maxm	A	20 800	C
Rectifier rating	$kW_{dc\ avg}$	900	E
Rectifier rating	$kW_{dc\ maxm}$	1 030	E
Rectifier losses	%	5	B
Rectifier rating	kW_{ac}	1 085	E
Production rating:			
Power rating	kWh/kg_{ac}	3 140	C
Cathode Co	kg/d	7 753	E
Cell rating	kg/cell per day	430	E
Stripping cycle:			
Starter blank cycle	day	2	C
Starter sheet cells	no.	2	C
Starter sheet thickness	mm	1.4	E
Starter blank machine	type	semi-automatic	C
Commercial cycle:			
Commercial cycle	day	5	C
Commercial cells	no.	16	C
Final commercial thickness	mm	4.8	E
Stripping method	type	semi-automatic	C
Cathode cobalt size reduction:			
Type		Full-Nelson crusher	
Typical chip, l x w x t	mm	15 x 20 x 4	B
Bulk density	kg/L	3.7 - 4.3	C
Degassing furnace:			
Degassing cycle	hours	24	A
Furnace stations	no.	2	C
Temperature	°C	800	A
Hours @ temperature	hours	12	A
Outgassing pressure	torr	1.0	G
Cycle load	kg Co	3 885	E
Basket size - dia	mm	700	C
- height	mm	600	C
- kg Co	kg	1 000	E

	Unit	Balance	Code
Baskets per furnace	no.	4	E
Furnace power	kVA	200	D
Product packaging:			
Type		metal drums	C
Capacity	kg Co	250	C
Drums per year	no.	10 600	E
Electrolyte water balance:			
Control		evaporator	C
Type		kettle	C
Water evaporated	kg/h	189	E
Duty	GJ/h	2.88	E

16.14 Nickel Electrowinning

Operating temperature	°C	60 - 65	B
Current density, avg	A/m^2	232	B
Current density, maxm	A/m^2	267	B
EW plant availability	%	94.2	C
Current efficiency	%	97 - 98	B
Cathodes:			
Material, mother blanks		Ti	C
Material, commercial cells		Ni starter sheets	B
Size, w x l, r	mm	1 000	C
Number per cell	no.	38	C
Life, starters	days	2	B
Life, commercial	days	5	B
Anodes:			
Material		DSA-Ti	B
Size, w x l	mm	1 000	C
Number per cell	no.	39	C
Life	years	5	B
Diaphragm bag		polypropylene	C

	Unit	Balance	Code
Cell electrical:			
Voltage	V	3.1	B
Current, avg	A	18 100	E
Current, maxm	A	20 800	C
Rectifier rating	$kW_{dc\ avg}$	675	E
Rectifier rating	$kW_{dc\ maxm}$	775	E
Rectifier losses	%	5	B
Rectifier rating	kW_{ac}	825	E
Production rating:			
Power rating	kWh/kg_{ac}	3 140	C
Cathode Ni	kg/d	5 024	E
Cell rating	kg/cell per day	430	E
Stripping cycle:			
Starter sheet cycle	day	2	C
Starter blank cells	no.	2	C
Starter sheet thickness	mm	1.4	E
Starter blank machine	type	semi-automatic	C
Commercial cycle:			
Commercial cells	no.	10	C
Final thickness	mm	4.8	E
Stripping method		semi-automatic	C
Cell nickel:			
Size reduction		hydraulic shear	C
Ni squares, l x w	mm	25 x 25 or 100 x 100	
Ni strips, l x w	mm	1 000 x 100	
Product packaging:			
Type		metal drums	C
Capacity	kg Ni squares	250	C
Drums per year	no.	6 900	E
Electrolyte water balance:			
Control		evaporator	C
Type		kettle-reboiler	C
Water evaporated	kg/h	2 460	E
Duty	GJ/h	7.58	E

	Unit	Balance	Code
16.15 Chlorine System			
Cell gases:			
Chlorine	vol %	85	C
Air	vol %	15	C
Flow rate	Nm^3/h	588	E
Chlorine compressors:			
Type		liquid-ring seal	C
Compressors	no.	2	C
Rating Nm^3/h		600	C
Suction pressure	mm H_2O	-100	C
Discharge pressure	kPa	250	B
Makeup chlorine:			
Chlorine composition	%	100	B
State		liquid	B
Flow rate	t/y	1 030	E
16.16 Vent System			
Vent gases to condenser:			
Chlorine	vol %	0.04	E
CO_2	vol %	0.5	E
N_2	vol %	0.9	E
O_2	vol %	0.2	E
H_2O	vol %	98.4	E
Flow rate	Nm^3/h	4 070	E
Temperature	°C	100	E
Vent condenser:			
Outlet temperature	°C	50	C
Duty	GJ/h	8.0	E
Type		surface condenser	C
Material, shell and tubes		Ti	C
Vent scrubber:			
Scrubbing agent		milk-of-lime	C
Strength	%	12	C
Chlorine removal	%	>99.9	C
Chlorine in exit gas	ppmv	13	E
Stack gas flow rate	Nm^3/h	73	E

	Unit	Balance	Code
16.17 Nickel Carbonate System			
$NiCO_3$ produced	kg/h	102	E
Na_2CO_3	kg/h	91.1	E
Ni anolyte	m^3/h	0.93	E
Slurry, solids	%	5.4	E
Slurry tanks:			
Tanks	no.	4	C
Residence time	hours	1	C
$NiCO_3$ filter:			
Type		drum filter	C
Washing ratio	m^3/m^3	1.0	C
Cake moisture	%	12	C
Na_2SO_4 - NaCl waste solution:			
Flow rate	m^3/h	1.7	E
Specific gravity	Sp Gr	1.04	
Na_2SO_4	kg/h	22.5	E
NaCl	kg/h	80.5	E

APPENDIX C

APPENDIX C

DEEP-SEA NODULE MINING STUDY

MECHANICAL AND ELECTRICAL MAJOR EQUIPMENT LIST

MECHANICAL EQUIPMENT LIST

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

MECHANICAL EQUIPMENT LIST REV.A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0100: MARINE FACILITIES										
0100-CN-001/004	4 EA	JIB CRANE (TRAWLER MOUNTED)		30kW			15T Capacity	0100.NCN 1		A
0100-CN-009/010	2 EA	DOCK JIB CRANE-RAIL MOUNTED		19kW			15T capacity	0100.NCN 3		A
0100-ME-001/004	4 EA	HARVESTING TRAWLERS					2500T nodule capacity, 120mL X 16mW, nodule hold 30mL X 15mW X 6mD with sloped bottom	0100.NME 1	Marine Steel Limited	A
0100-ME-005/007	3 EA	TRANSPORTER SHIPS					30,000T Capacity, 175m Long, 25m beam 10m draft	0100.NME 2		A
0100-PP-001/004	4 EA	SLURRY PUMP (TRAWLER MOUNTED)		112kW			987 m3/h @ 25m TH	0100.NPP 1		A
0100-PP-005/012	8 EA	HIGH PRESSURE WATER PUMP (TRAWLER MOUNTED)		373kW			405 m3/h @ 211m TH	0100.NPP 3	KVS	A
0100-PP-015	1 EA	MAKEUP WATER PUMP		37kW			504 m3/hr@ 15TH(vertical)	0100.NPP 7		A
0100-PP-021/026	6 EA	DECANT PUMP (TRANSPORTER SHIP MOUNTED)		18.6kW			227 m3/h @ 15m TH	0100.NPP 4	KVS	A
0100-PP-031/032	2 EA	SHIP UNLOADING SLURRY PUMP		300kW			1482 m3/h @ 38m TH	0100.NPP 5	KVS	A
0100-PP-060/065	6 EA	SHIP UNLOADING HIGH PRESSURE WATER PUMP		373kW			405 m3/h @ 211m TH	0100.NPP 6	KVS	A
0100-ZM-001/004	4 EA	MARCONAFLO SYSTEM (TRAWLER MOUNTED)					Model DJ12TS2, Dynajet @ 400t/h	0100.NZM 1	KVS	A
0100-ZM-005/008	4 LOT	MARCONAFLO CONTROLS, HOSES, AND ACCESSORIES (TRAWLER MOUNTED)					Misc. items	0100.NZM 2	KVS	A
0100-ZM-009	1 EA	SEA WATER INTAKE SCREEN		1kW			Motorized screen	0100.NZM 10		A

Facility 0100: MARINE FACILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0100-ZM-017/020	4 LOT	TRAWLER POSITIONING SYSTEM					Misc. items including global positioning system, long base line locator system	0100.NZM 3	Simrad	A
0100-ZM-026/027	2 EA	MARCONAFLO SYSTEM (SHIP UNLOADING)					Model DJ16TS2, Dynajet @ 600t/h	0100.NZM 4	KVS	A
0100-ZM-029/030	2 LOT	MARCONAFLO CONTROLS, HOSES, AND ACCESSORIES					Misc. items	0100.NZM 5		A
0100-ZM-060/063	4 EA	TRAWL WINCH		1-100kW, 4-110kW			Includes hydraulic pumps, controls, and accessories	0100.NME 1.1	Ulstein	A
0100-ZM-073/076	4 LOT	TRAWL WINCH ROPE WITH EMBEDDED CABLE					Spectron 12 braided rope with armored & sheathed 4X10 AWG cable, 8000m Long	0100.NZM 6	Vector	A
0100-ZM-079/082	4 LOT	NODULE HARVESTING TRAWL					Capacity 120T	0100.NZM 7	Net Systems	A
0100-ZM-085/88	4 EA	TRAWL DYNAMIC POSITIONING SYSTEM					Simrad equipment for location trawl position	0100.NZM 9	Simrad	A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0200: NODULE STORAGE AND RECLAIM										
0200-BN-010	1 EA	NODULE STORAGE BIN					7.5m Dia X 14m High	0200.MAA 1		A
0200-CS-001/002	2 EA	CYCLONE CLUSTER					227m3/h @ 15m head 0.5m Dia	0200.NCS1 1	Krebs Engineers	A
0200-CV-016	1 EA	NODULE TRANSFER CONVEYOR		3.7kW			100T/h, 1m Wide X 11.5m Long, belt type	0200.NCVB 1		A
0200-CV-018	1 EA	DRYER FEED TRANSFER CONVEYOR		22.3kW			100T/h, 1mWide X 8.5m Long, belt type	0200.NCVB 3		A
0200-CV-035	1 EA	DRYER FEED CONVEYOR		75kW			100T/h, 1m Wide X 98m Long, belt type	0200.NCVB 2		A
0200-FE-004	1 EA	VIBRATING FEEDER		3.73kW			10-100 TPH	0200.NFE7 1		A
0200-PP-013/014	2 EA	SLURRY PUMP		75kW			618 m3/h @ 38m TH	0200.NPP 1		A
0200-PP-017/018	2 EA	CYCLONE FEED PUMP		75kW			560m3/h @ 25m TH	0200.NPP 2		A
0200-PP-029/030	2 EA	SHIP UNLOADING SUPPLY PUMP		75kW			1200m3/h @ 15mTH	0200.NPP 7		A
0200-PP-043/044	2 EA	HIGH PRESSURE WATER PUMP		373kW			504 m3/h @ 176m TH	0200.NPP 4		A
0200-PP-055	1 EA	SUMP PUMP		15kW			90m3/h @ 25m TH	0200.NPP 6		A
0200-SC-001/002	2 EA	NODULE DEWATERING SCREEN		3.7kW			2m X 1.3m	0200.NSC1 1	Derrick Corp.	A
0200-SC-004	1 EA	FINES DEWATERING SCREEN		3.7kW			2m X 1.3m	0200.NSC1 2		A

Facility 0200: NODULE STORAGE AND RECLAIM

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0200-SU-001	1 EA	SCREEN U'SIZE SUMP					200m3 cap	0200.MDA 2		A
0200-TK-001/002	2 EA	NODULE STORAGE PONDS					110m Dia X 4m high sidewall, sloping bottom (concrete)	0200.MAA 3		A
0200-TK-015	1 EA	WATER STORAGE TANK					378m3 Capacity, 8m Dia. X 6m High	0200.MAA 4		A
0200-ZM-009/010	2 EA	MARCONAFLO UNIT					Model DJ08TS2, Dynajet unit, 100 tph capacity	0200.NZM 1	KVS	A
0200-ZM-077/078	2 EA	PONDS ROTATING FEED LAUNDER					24"sq, 55m Long c/w service walkway	0200.NZM 2		A

Facility 0320: DRYING

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0320-BN-019 & 024	2 EA	COAL STORAGE BIN					6m Dia. X 10m High, CS, 150T capacity	0320.MAA 5		A
0320-BN-022/023	2 EA	DRY NODULE STORAGE BIN					6m Dia X 10m High, CS, lined	0320.MAA 4		A
0320-BN-025	1 EA	PULVERIZED COAL DAY BIN					2m Dia X 3m High, CS	0320.MAA 1		
0320-CV-005	1 EA	ESP DRAG CONVEYOR		3.7kW			Chair type	0320.NCVC 1		A
0320-CV-006	1 EA	KILN FEED CONVEYOR		37kW			1mW X 105mL, 100T/h capacity, 22m Lift, belt type	0320.NCVB 3		A
0320-CV-009	1 EA	PULVERIZER FEED CONVEYOR		30kW			10t/h capacity, 1m Wide X 126m Horizontal, 11m Lift, belt type	0320.NCVB 4		A
0320-CV-019	1 EA	DRYER PRODUCT CONVEYOR		112kW			100t/h, 1mW X 138m Long horizontal X 30m Lift, belt type	0320.NCVB 2		A
0320-CV-036	1 EA	KILN FEED TRANSFER CONVEYOR		15kW			1m Wide X 16.5m Long, belt type	0320.NCVB 5		A
0320-DC-002	1 EA	DRYER OFF-GAS ELECTROSTATIC PRECIPITATOR		5kW			127,300 Nm3/h gas volume @ 160C	0320.NDC3 1		A
0320-DR-001	1 EA	NODULE DRYER		112kW			4.1m Dia X 35m long rotary dryer, coal fired	0320.NDR 1	Fuller	A
0320-DR-001-1	1 EA	DRYER COMBUSTION CHAMBER						0320.NDR 2		A
0320-DU-001	1 LOT	DUCTWORK						0320.MDU 1		
0320-FA-002	1 EA	DRYER COMBUSTION AIR FAN		80kW				0320.NFA 1		A

Facility 0320: DRYING

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0320-FA-003	1 EA	INDUCED DRAFT FAN		187kW			Capacity 130,000 Nm3/h	0320.NFA 2		A
0320-FA-022	1 EA	PRIMARY AIR FAN		37kW				0320.NFA 3		A
0320-FE-007/008	2 EA	DRY NODULE FEEDER		7.5kW			0-50T/h, 10m Long	0320.NFE 2		A
0320-FE-010	1 EA	COAL FEEDER		2.2kW			0-10T/h, 10m Long	0320.NFE 3		A
0320-FE-025	1 EA	COAL VIBRATING FEEDER					10m Long	0320.NFE 1		A
0320-PP-089	1 EA	ESP PNEUMATIC PUMP		22.3kW				0320.NPP 1		A
0320-ZM-011	1 EA	COAL DIVERTER GATE		0.2kW				0320.NZM 2		A
0320-ZM-012	1 EA	DRY NODULE DIVERTER GATE		0.2kW				0320.NZM 1		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0330: PRE-REDUCTION										
0330-BN-026	1 EA	PULVERIZED COAL DAY BIN					2m Dia X 3m High, CS	0330.MAA 1		A
0330-BN-027	1 EA	CALCINE SURGE BIN						0330.MAA 2		A
0330-BN-031	1 EA	ESP DUST BIN						0330.MAA 3		A
0330-BU-001	1 LOT	KILN BURNER SYSTEM					Cap. 50 GJ/h complete with controls and accessories	0330.NBU 1		A
0330-CS-001	1 EA	KILN OFF-GAS CYCLONE						0330.NCS1 1		A
0330-DC-004	1 EA	KILN OFF-GAS SCRUBBER						0330.NDC4 1		A
0330-DU-001	1 LOT	KILN OFF-GAS DUCTING						0330.MDU 1		A
0330-FA-005	1 EA	PRIMARY AIR FAN		37kW			Cap....	0330.NFA 1		A
0330-FA-006	1 EA	COMBUSTION AIR FAN		22kW			Cap. 20,000 Nm3/h	0330.NFA 2		A
0330-FA-007	1 EA	KILN INDUCED DRAFT FAN		150kW			Cap. 80,000 Nm3/h	0330.NFA 3		A
0330-FA-024/027	4 EA	ON-BOARD FANS		19kW			Cap. 10,000 m3/h	0330.NFA 4		A
0330-HX-001	1 EA	KILN OFF-GAS COOLER						0330.NHX2 1		A
0330-PP-036	1 EA	SCRUBBER SUMP PUMP		11kW				0330.NPP 1		A

Facility 0330: PRE-REDUCTION

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0330-PP-067	1 EA	KILN AREA SUMP PUMP		11kW				0330.NPP 2		A
0330-RO-001	1 EA	REDUCTION KILN		298kW			4m X 60m Long, refractory lined	0330.NRO1 1	Fuller	A
0330-RR-001/002	2 EA	CALCINE TRANSFER CAR						0330.NRR 1		A
0330-ST-001/002	2 EA	CALCINE CONTAINER						0330.MDA 2		A
0330-SU-002	1 EA	KILN OFF-GAS SCRUBBER SUMP						0330.MDA 1		A

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

MECHANICAL EQUIPMENT LIST REV.A

Facility 0340: SMELTING

Equipment No.	Quantity	Equipment Title	M/R No.	MOTOR DATA Rating: kW	MOTOR DATA RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0340-BN-001/008	8 EA	FURNACE FEED BINS					Refractory lined, cap.....,	0340.MAA 1		A
0340-BN-028	1 EA	TRUCK LOADING BIN					100T capacity	0340.MAA 2		A
0340-CN-011	1 EA	FURNACE CHARGE CRANE		186kW			50T Main Hoist Capacity, 25m span, 38m lift, top running bridge crane for maintenance & service	0340.NCN 1		A
0340-CP-001	1 EA	AIR COMPRESSOR		7.5kW			60 m3/H	0340.NCP1 1		A
0340-CV-021	1 EA	SLAG GRANULATION PIT BUCKET EXCAVATOR		15kW			75 t/h Capacity	0340.NBM 1		A
0340-CV-022	1 EA	SLAG CONVEYOR		37kW			75 t/h Capacity, 1m Wide X 27m Long Horizontal, 20m Lift, flex-o-wall type belt	0340.NCVB 2		A
0340-DC-005	1 EA	FURNACE OFF-GAS SCRUBBER					Capacity 5000 Nm3/h	0340.NDC4 1		A
0340-DU-003	1 LOT	SMOKE HOOD AND VENT DUCTING						0340.MDU5 1		A
0340-FA-009	1 EA	SMOKE HOOD VENT FAN		11kW			5000 Nm3/h	0340.NFA 1		A
0340-FA-010	1 EA	FURNACE BOTTOM COOLING FAN		56kW			60,000 m3/h	0340.NFA 2		A
0340-FA-011	1 EA	ELECTRODE COOLING FAN		3.7kW			3,000 m3/h	0340.NFA 3		A
0340-FA-012	1 EA	TAPPING VENT FAN		5.6kW			4,000 m3/h	0340.NFA 4		A
0340-FA-014	1 EA	FURNACE ID FAN		19kW			5,000 Nm3/h capacity	0340.NFA 5		A

Facility 0340: SMELTING

Equipment No.	Quantity	Equipment Title	M/R No.	MOTOR DATA Rating: kW	MOTOR DATA RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0340-FC-001	1 EA	ELECTRICAL SMELTING FURNACE		25000kW			Refractory lined complete with transformers rating 30MVA, metal runners, bus bars and control s. 15m I.D. 25MW capacity	0340.NFC1 1	Demag	A
0340-HX-002	1 EA	JACKET COOLING SYSTEM					Escalated Quote '91-'96 (1.17)	0340.NHX2 1		A
0340-HX-005	1 EA	FURNACE OFF-GAS COOLER					Capacity 5000 Nm3/hr	0340.NHX2 2		A
0340-PP-055/056	2 EA	FURNACE OFF-GAS SCRUBBER PUMP		19kW			1 Operating + 1 Standby	0340.NPP 1		A
0340-PP-068	1 EA	SMELTING AREA SUMP PUMP		11kW			4" size	0340.NPP 2		A
0340-PP-090/091	2 EA	SLAG GRANULATION WATER RETURN PUMP		37kW				0340.NPP 3		A
0340-SU-003	1 EA	FURNACE OFF-GAS SCRUBBER SUMP						0340.MDA 1		A
0340-SX-001	1 EA	ELECTRIC FURNACE EMERGENCY BYPASS STACK					1m Dia. X 50m High, refractory lined	0340.MSX 1		A
0340-SX-004	1 EA	SMELTER STACK					3mDia X 50m High, Corten stl.	0340.MSX 2		A
0340-ZM-011	1 EA	FURNACE OFF-GAS COMBUSTION CHAMBER					3m X 3m CS, refractory lined	0340.NZM 3		A
0340-ZM-031/032	1 LOT	SLAG LAUNDER					0.8m X 0.8m CS, refractory lined, total length 50m	0340.NZM 2		A
0340-ZM-035/036	2 EA	TAPPING MACHINES					With refractory lined alloy launders and cast slag launders	0340.NZM 1		A

Facility 0350: CONVERTING

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0350-BN-011	1 EA	SILICA FLUX FEED BIN					2m Dia. X 3m High, CS	0350.MAA 1		A
0350-CN-012	1 EA	CONVERTING FURNACE CRANE		2-56kW, 3-7.5kW			50T Main hoist, 2-15T auxiliary hoist, crane: 24m span, 19m lift, & 64m run	0350.NCN4 1		A
0350-CV-026/027	2 EA	DROP-OUT CHAMBER DRAG CONVEYOR		7.5kW			20t/h capacity, chair type	0350.NCVC 1		A
0350-CV-031	1 EA	FLUX TRANSFER CONVEYOR A		1.1kW			0.5W X 7mL, 1.5T/h Capacity, belt type	0350.NCVB 2		A
0350-CV-032	1 EA	FLUX TRANSFER CONVEYOR B		1.1kW			0.5W X 7mL, 1.5T/h Capacity, belt type	0350.NCVB 3		A
0350-CV-037	1 EA	FLUX TRANSFER CONVEYOR A		1.1kW			0.5m Wide X 6m Long, belt type	0350.NCVB 4		A
0350-CV-038	1 EA	FLUX FEED CONVEYOR B		1.1kW			1m Wide X 6m Long, belt type	0350.NCVB 5		A
0350-DC-007/008	2 LOT	VENTURI SCRUBBER					35,600 Nm3/h	0350.NDC4 1		A
0350-DU-001	1 LOT	DUCTWORK						0350.MDU 1		
0350-FA-009A/010B	4 EA	STEAM CONDENSER FORCED DRAFT FAN		11kW				0350.NFA 1		A
0350-FA-015/016	2 EA	SCRUBBER INDUCED DRAFT FAN		75kW			35,000 Nm3/h	0350.NFA 2		A
0350-FA-017/018	2 EA	CONVERTER AIR BLOWER		1680kW			45,000 Nm3 @ 120 kPa	0350.NFA 3		A
0350-FA-019/020	2 EA	CONVERTER COMBUSTION AIR FAN						0350.NFA 4		

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

MECHANICAL EQUIPMENT LIST REV.A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0350: CONVERTING										
0350-FA-030/031	2 EA	ROOF VENTILATOR		19kW			20,400 Nm3/h @ 6.35mm w.g.	0350.NFA 6		A
0350-FC-002/003	2 EA	PEIRCE SMITH CONVERTING FURNACE		63kW			4.5m X 10.6m Long rotary converter, w/shell, spring tension heads, charging mouth with rectractable cover, DC motor and variable speed drive, creep speed & emergency drive	0350.NFC2 1		A
0350-FE-011/012	2 EA	FLUX BELT FEEDER		2.2kW			1.5T/h Capacity, 3m Long	0350.NFE 1		A
0350-HX-003/004	2 EA	FURNACE OFF-GAS COOLER						0350.NHX2 2		A
0350-HX-009/010	2 EA	AIR COOLED HOOD STEAM CONDENSER		11kW			Fin Fan Cooler, condensing 35kpa steam, heater duty: ____ BTU/h per heat exchanger	0350.NHX1 1		A
0350-PP-057/058	2 EA	SCRUBBER SLURRY PUMP		11kW				0350.NPP 1		A
0350-PP-069	1 EA	CONVERTING AREA SUMP PUMP		11kW				0350.NPP 2		A
0350-PP-092	1 EA	MATTE GRANULATION WATER RETURN PUMP						0350.NPP 3		A
0350-SU-001/002	2 EA	SCRUBBER SUMPS						0350.MDA 1		A
0350-ZM-039/040	2 EA	WATER COOLED HOOD					Water cooled fabricated hood with closed loop recirculation water system	0350.NZM 1		A
0350-ZM-041/042	2 EA	PRIMARY FUME HOOD DROP OUT BOXES						0350.NZM 2		A
0350-ZM-043/052	10 EA	HOT METAL TRANSFER LADLES					18T Capacity	0350.NZM 3		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0350: CONVERTING										
0350-ZM-066/067	2 EA	WATER COOLED HOOD STEAM DRUM						0350.NZM 4		A
0350-ZM-068/069	2 EA	TUYERE PUNCHING MACHINE						0350.NZM 5		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0360: PRODUCT GRANULATION										
0360-CV-007	1 EA	MATTE TRANSFER CONVEYOR		2.2kW			0.6m Wide X 100m Long, 2t/h capacity, belt type	0360.NCVB 1		A
0360-CV-030	1 LM	MATTE GRANULATION PIT BUCKET EXCAVATOR		7.5kW			2t/h capacity	0360.NBM 1		A
0360-ZM-070/071	2 LOT	MATTE GRANULATION LAUNDER					concrete with preheat burners	0360.MLA 1		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-AG-300	1 EA	MATTE SLURRY TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 1		A
0400-AG-301/303	3 EA	AGITATOR (CEMENTATION LEACH)		3.7kW			SS, R/L	0400.NAG 2		A
0400-AG-304/306	3 EA	AGITATOR (OXIDATION LEACH)		3.7kW			SS, R/L	0400.NAG 3		A
0400-AG-307/309	3 EA	OXIDATION LEACH TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 4		A
0400-AG-310/313	4 EA	MIXER SETTLER (TBP MIXING)		2.25kW			FRP construction, SS impeller blade	0400.NAG 5	Hazen Quinn	A
0400-AG-314/316	3 EA	MIXER SETTLER (ORGANIC STRIPPING)		2.25kW			FRP construction, SS impeller blade	0400.NAG 6	Hazen Quinn	A
0400-AG-317/320	4 EA	MIXER SETTLER (TIOA MIXING)		2.25kW			FRP construction, SS impeller blade	0400.NAG 7	Hazen Quinn	A
0400-AG-321/323	3 EA	MIXER SETTLER (TIOA STRIPPING)		2.25kW			FRP construction, SS impeller blade	0400.NAG 8	Hazen Quinn	A
0400-AG-323/325	3 EA	REACTION TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 9		A
0400-AG-326	1 EA	LEACH SOLIDS TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 10		A
0400-AG-327	1 EA	ACID MIX TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 11		A
0400-AG-328	1 EA	SODA ASH MIX TANK AGITATOR		3.7kW			SS	0400.NAG 12		A
0400-AG-329/331	3 EA	REACTION TANK AGITATOR		3.7kW			SS, R/L	0400.NAG 13		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-AG-332	1 EA	SODA ASH MIX TANK AGITATOR		3.7kW			SS	0400.NAG 14		A
0400-AG-333	1 EA	CoCO3 MIX TANK AGITATOR		3.7kW			SS	0400.NAG 15		A
0400-AG-334	1 EA	LIME SLURRY TANK AGITATOR		7.5kW			SS	0400.NAG 16		A
0400-AG-335	1 EA	STRIP MIX TANK AGITATOR		3.7kW			SS	0400.NAG 17		A
0400-AG-336	1 EA	CoCO3 MIX TANK AGITATOR		3.7kW			SS	0400.NAG 18		A
0400-AG-337	1 EA	NICKEL EVAPORATOR AGITATOR		2.5kW			Titanium	0400.NAG 19	Cosmos	A
0400-AG-338	1 EA	COBALT EVAPORATOR AGITATOR		2.5kW			Titanium	0400.NAG 20	Cosmos	A
0400-AG-339	1 EA	NiCO3 MIX TANK AGITATOR		2.5kW			SS	0400.NAG 21		A
0400-BN-300	1 EA	MATTE RECEIVING BIN					30T Capacity, 2.5m Dia. X 3m High, 60 degree cone bottom	0400.MAA 1		A
0400-CL-304/315	12 EA	NICKEL ELECTROWINNING CELLS					Size: 6.2mL X 1.4mW X 1.5mD, Polymer concrete	0400.NCL 2		A
0400-CL-316/333	18 EA	COBALT ELECTROWINNING CELLS					Size: 6.2mL X 1.4mW X 1.5mD, Polymer concrete	0400.NCL 3		A
0400-CL-334/340	7 EA	COPPER ELECTROWINNING CELL					Size: 4mL X 1.4mW X 1.1mD, FRP	0400.NCL 1	American Fiberglass	A
0400-CN-300	1 EA	TANKHOUSE CRANE		18.6kW				0400.NCN 1		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-CN-301	1 EA	SERVICE CRANE		18.6kW			15T Capacity	0400.NCN 2		A
0400-CP-300/301	2 EA	CHLORINE COMPRESSOR		3.7kw			Nash, Titanium, 1 operating 1 standby	0400.NCP1 1		A
0400-CS-300	1 EA	SOLID BOWL CENTRIFUGE		22.3kW			Solid Bowl - Titanium	0400.NSP1 1	Bird Machine Co.	A
0400-CS-301	1 EA	LEACH SLURRY CENTRIFUGE		22.3kW			Solid Bowl - Titanium	0400.NSP1 2	Bird Machine Co.	A
0400-CS-302	1 EA	COPPER PRECIPITATE CENTRIFUGE		22.3kW			Solid Bowl	0400.NSP1 3	Bird Machine Co.	A
0400-CV-301	1 LM	MATTE SCREW CONVEYOR		0.75kW			2m Long, 1.5T/h capacity, CS	0400.NCVK 1		A
0400-DC-300	1 EA	LIME SCRUBBER					700Nm3/h capacity, FRP	0400.NDC4 1		A
0400-DR-300	1 EA	SULFUR DRYER		1.5kW			holoflite, steam jacketed	0400.NDR 1		A
0400-EE-300	730 EA	COBALT ELECTROWINNING ANODES					Ruthenium-oxide coated DSA titanium anodes in fabric bags	0400.NEE1 1	Heraeus Engelhard	A
0400-EE-301	94 EA	COBALT ELECTROWINNING MOTHER BLANKS					Titanium	0400.NEE2 1		A
0400-EE-302	490 EA	NICKEL ELECTROWINNING ANODES					Ruthenium-oxide coated DSA titanium anodes in fabric bags	0400.NEE1 2	Heraeus Engelhard	A
0400-EE-303	64 EA	NICKEL ELECTROWINNING MOTHER BLANKS					Titanium	0400.NEE2 2		A
0400-EE-304	180 EA	COPPER ELECTROWINNING ANODES					Titanium DSA anodes	0400.NEE1 3	Heraeus Engelhard	A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-EE-305	204 EA	COPPER ELECTROWINNING CATHODES					Titanium	0400.NEE5 1	T.A. Caid	A
0400-EE-306	1,500 EA	ANODE BAGS & SPACERS						0400.NEE1 4		A
0400-EE-307	1,100 EA	TI-CLAD HANGER BARS						0400.NEE 1		A
0400-EM-020	1 EA	WEIGHING MACHINE (COPPER)						0400.NEM 7		A
0400-EM-300	1 EA	CATHODE WASHING MACHINE (NICKEL)						0400.NEM2 1		A
0400-EM-301	1 EA	STRIPPING MACHINE (NICKEL)						0400.NEM6 1		A
0400-EM-302	1 EA	SHEARING MACHINE (NICKEL)		7.5kW			100MM pieces, hydraulic	0400.NEM 1	Niagara	A
0400-EM-303	1 EA	WEIGHING MACHINE (NICKEL)					500kg, automataic with label printer	0400.NEM 4		A
0400-EM-305	1 EA	CATHODE WASHING MACHINE (COBALT)						0400.NEM2 2		A
0400-EM-306	1 EA	STRIPPING MACHINE (COBALT)						0400.NEM6 2		A
0400-EM-307	1 EA	CHIP BREAKER (COBALT)						0400.NEM 2		A
0400-EM-308	1 EA	ANNEALING FURNACE (COBALT)		5.75kW			760 Dia X 2400mm High, 800degreeC, 250kW heater, w/vacuum pumps and controls	0400.NEM 5		A
0400-EM-309	1 EA	WEIGHING MACHINE (COBALT)					500kg capacity, automatic w/label printer	0400.NEM 6		A

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

MECHANICAL EQUIPMENT LIST REV.A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-FA-300	1 EA	SCRUBBER EXHAUST FAN		2.25kw			700Nm3/h capacity, FRP	0400.NFA 1		A
0400-FA-301	1 LOT	BUILDING VENT FANS		11.2kW			FRP construction	0400.NFA 2		A
0400-FE-301	1 EA	MATTE FEEDER		0.22kW			1.5T/h capacity	0400.NFE 1		A
0400-FE-302/303	2 EA	SODA ASH FEEDER						0400.NFE 2		A
0400-FL-300	1 EA	LEACH SLURRY FILTER PRESS		2.25kW			5m3/h, 0.6m X 0.6m 20 chamber Polyprop.	0400.NFL5 1	WGA	A
0400-FL-301	1 EA	LEACH SLURRY FILTER PRESS					15m3/h, 0.6m X 0.6m, 20 chamber, Polyprop.	0400.NFL 2	WGA	A
0400-FL-305	1 EA	LEAD CAKE FILTER PRESS					5m3/h, Polyprop.	0400.NFL 5		A
0400-FL-306	1 EA	ELECTROLYTE FILTER					18m3/h, basket filter	0400.NFL 6		A
0400-FL-307	1 EA	NICKEL SULFATE FILTER PRESS					0.1m3/h	0400.NFL 7		A
0400-FL-309	1 EA	LEACH SOLUTION FILTER					13m3/h	0400.NFL 9		A
0400-FL-310	1 EA	ELECTROLYTE FILTER					32m3/h, basket filter	0400.NFL 10		A
0400-FL-311/312	2 EA	CARBON COLUMNS					8m3/h, FRP shell, activated carbon filter media	0400.NFL 4		A
0400-FL-314/315	2 EA	CARBON COLUMNS					5m3/h, FRP shell, activated carbon filter media	0400.NFL 8		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-FL-316	1 EA	IRON OXIDATION LEACH SLURRY FILTER PRESS					3.8m3/h, poly	0400.NFL 11		A
0400-FL-318	1 EA	NiCO3 FILTER PRESS					Polyprop.	0400.NFL 12		A
0400-FL-319	1 EA	CoCO3 FILTER PRESS					Polyprop.	0400.NFL 13		A
0400-FL-320/321	2 EA	COBALT IX COLUMNS					3.5m3/h, FRP shell, Dow XSF-4195 resin media	0400.NFL 14		A
0400-HX-300	1 EA	THICKENER COOLING HEAT EXCHANGER					Plate & Frame, Titanium	0400.NHX2 1		A
0400-HX-301	1 EA	CHLORINE VAPOR CONDENSER					Plate & Frame, Titanium	0400.NHX1 1		A
0400-HX-302	1 EA	LEACH SOLUTION HEAT EXCHANGER					Plate & Frame, Titanium	0400.NHX 1		A
0400-HX-303	1 EA	SULFUR MELTER					Steam heated coils	0400.NHX 2		A
0400-HX-304	1 EA	LEACH SOLUTION HEAT EXCHANGER					Plate & Frame, Titanium	0400.NHX 3		A
0400-HX-305	1 EA	FILTRATE HEATER					Plate & Frame, Titanium	0400.NHX5 1		A
0400-HX-306	1 EA	ELECTROLYTE HEATER					Plate & Frame, Titanium	0400.NHX5 2		A
0400-HX-307	1 EA	FILTRATE HEATER					Plate & Frame, Titanium	0400.NHX5 3		A
0400-HX-308	1 EA	ELECTROLYTE HEATER					Plate & Frame, Titanium	0400.NHX5 4		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-ML-300	1 EA	MATTE GRINDING TOWER MILL		18.65kW			1.5T/h capacity	0400.NML 1	Svedala	A
0400-PP-300	1 EA	SLURRY FEED PUMP (CEMENTATION)					2.6m3/h, air operated diaphragm	0400.NPP 1		A
0400-PP-301	1 EA	SLURRY FEED PUMP (OXIDATION)					0.9m3/h, air operated, diaphragm	0400.NPP 2		A
0400-PP-302/303	2 EA	CENTRIFUGE FEED PUMP					5.0m3/h, centrifugal	0400.NPP 3		A
0400-PP-304	1 EA	PREGNANT SOLUTION FEED PUMP		0.74kW			4m3/h, centrifugal steel R/L	0400.NPP 4		A
0400-PP-305	1 EA	LEACH SOLIDS RECIRCULATION PUMP					3m3/h, air operated, diaphragm	0400.NPP 42		A
0400-PP-306/307	2 EA	COMPLETION LEACH SLURRY PUMP					2m3/h, centrifugal	0400.NPP 43		A
0400-PP-308/309	2 EA	LEACH SOLUTION PUMP		0.74kW			5.0m3/h, centrifugal, polyprop.	0400.NPP 6		A
0400-PP-310	1 EA	LEACH SLURRY FEED PUMP					5m3/h capacity, centrifugal	0400.NPP 7		A
0400-PP-311	1 EA	OXIDATION LEACH FEED PUMP					3.2m3/h, air operated, diaphragm	0400.NPP 5		A
0400-PP-313	1 EA	SPENT LIME DISCHARGE PUMP		1.1kW			2m3/h, 100kPa, RLS, centrifugal	0400.NPP 9		A
0400-PP-314	1 EA	LEACH SOLUTION PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 10		A
0400-PP-315	1 EA	COPPER PRECIPITATE SLURRY PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 11		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-PP-316	1 EA	ELECTROLYTE RETURN PUMP					5.5m3/h, air operated, diaphragm	0400.NPP 12		A
0400-PP-317	1 EA	CLEAR LIQUID RETURN PUMP					5m3/h, air operated, diaphragm	0400.NPP 14		A
0400-PP-318	1 EA	CENTRIFUGE FEED PUMP		1.1kW			4m3/h, centrifugal	0400.NPP 13		A
0400-PP-319/320	2 EA	MOLTEN SULFUR PUMP		1.1kW				0400.NPP 15		A
0400-PP-321/322	2 EA	PURIFIED LIQUOR PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 16		A
0400-PP-323/324	2 EA	MIXER-SETTLER FEED PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 17		A
0400-PP-325	1 EA	STRIP WATER PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 18		A
0400-PP-326	1 EA	BARREN ORGANIC SUPPLY PUMP (TBP)		0.74kW			3.0m3/h, centrifugal	0400.NPP 19		A
0400-PP-327/331	2 EA	DILUENT SUPPLY PUMP		0.74kW			3.0m3/h, centrifugal	0400.NPP 44		A
0400-PP-328/329	2 EA	IRON EXTRACTION EFFLUENT PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 20		A
0400-PP-330	1 EA	BARREN ORGANIC SUPPLY PUMP (TIOA)		0.74kW			3.0m3/h, centrifugal	0400.NPP 21		A
0400-PP-332/333	2 EA	REACTION TANK FEED PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 22		A
0400-PP-334	1 EA	SOLUTION PUMP		0.74kW			3.0m3/h, centrifugal	0400.NPP 23		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-PP-335/336	2 EA	FILTER FEED PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 24		A
0400-PP-337	2 EA	FILTRATE PUMP		1.1kW			5.0m3/h, centrifugal	0400.NPP 25		A
0400-PP-339/340	2 EA	ELECTROLYTE RECIRCULATION PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 26		A
0400-PP-341	1 EA	NICKEL ANOLYTE RETURN PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 27		A
0400-PP-342	1 EA	SLURRY PUMP		0.74kW			3m3/h, centrifugal	0400.NPP 28		A
0400-PP-343	1 EA	FILTRATE RETURN PUMP					3m3/h, air operated, diaphragm	0400.NPP 29		A
0400-PP-344	1 EA	WASTE DISPOSAL PUMP					3m3/h, air operated, diaphragm	0400.NPP 30		A
0400-PP-345/346	2 EA	SODA ASH SLURRY PUMP					3m3/h, air operated, diaphragm	0400.NPP 31		A
0400-PP-351/352	2 EA	COBALT REACTION TANK FEED PUMP		1.1kW			5.0m3/h, centrifugal	0400.NPP 34		A
0400-PP-353	1 EA	CLEANING SOLUTION PUMP		0.74kW			3m3/h, centrifugal	0400.NPP 35		A
0400-PP-354/355	2 EA	FILTER FEED PUMP		1.1kW			5.5m3/h, centrifugal	0400.NPP 36		A
0400-PP-356/357	2 EA	FILTRATE FEED TANK		1.1kW			5m3/h, centrifugal	0400.NPP 37		A
0400-PP-358/359	2 EA	ELECTROLYTE RETURN PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 38		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-PP-360	1 EA	COBALT ANOLYTE RETURN PUMP		1.1kW			5m3/h, centrifugal	0400.NPP 39		A
0400-PP-361	1 EA	CoCO3 SOLUTION PUMP		0.74kW			3m3/h, centrifugal	0400.NPP 41		A
0400-PP-362/363	2 EA	CoCO3 RETURN PUMP		0.74kW			3m3/h, air operated, diaphragm	0400.NPP 40		A
0400-PP-364/365	2 EA	CONDENSATE SUPPLY PUMP		1.1kW			...m3/h capacity, RLS	0400.NPP 8		A
0400-PP-366	1 EA	LIME SLURRY FEED PUMP		3.7kW			Size: 3" X 2", R/L	0400.NPP 45		A
0400-PP-367	1 EA	LIME SLURRY RECIRCULATION PUMP		5.6kW			Size: 4" X 3", R/L	0400.NPP 46		A
0400-PP-368/369	2 EA	SUMP PUMP		5.6kW			Size: 3" SS, R/L	0400.NPP 47		A
0400-PP-370	1 EA	ANOLYTE RETURN PUMP					3m3/h, air operated, diaphragm	0400.NPP 48		A
0400-PP-371	1 EA	DILUTE ANOLYTE PUMP		1.1kW			4m3/h, centrifugal, polyprop.	0400.NPP 49		A
0400-PP-372	1 EA	CoCO3 METERING PUMP		0.18kW				0400.NPP 50		A
0400-PP-374	1 EA	Ni ANOLYTE PUMP		2.23kW			20.7m3/h, FRP	0400.NPP 52		A
0400-PP-375	1 EA	Ni ANOLYTE RETURN PUMP		2.23kW			20.7m3/h, FRP	0400.NPP 53		A
0400-PP-376	1 EA	NiCO3 METERING PUMP		0.18kW			0.06m3/h, 65% solids sp.gr.1.87	0400.NPP 51		A

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Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-PP-377	1 EA	CO ANOLYTE PUMP		3.7kW			31.6m3/h, FRP	0400.NPP 54		A
0400-PP-378	1 EA	CO ANOLYTE RETURN PUMP		3.7kW			31.6m3/h, FRP	0400.NPP 55		A
0400-SU-300	1 EA	LEACH SOLIDS SUMP					1.5m3 capacity, FRP	0400.MDA 1		A
0400-SU-301	1 EA	CLEAR LIQUID SUMP					1.5m3 capacity, FRP	0400.MDA 2		A
0400-SU-302	1 EA	LEACH FILTRATE SUMP					FRP	0400.MDA 4		A
0400-SU-303	1 EA	SCRUBBER SUMP					FRP	0400.MDA 3		A
0400-SX-300	1 EA	SCRUBBER EXHAUST STACK					FRP	0400.MSX 1		A
0400-TK-300	1 EA	MATTE SLURRY TANK					2mDia X 2.5mHigh, SS, R/L	0400.MAA 2		A
0400-TK-301/303	3 EA	CEMENTATION LEACH TANK					2.5mDia. X 2.5mHigh, FRP, R/L	0400.MAA 3		A
0400-TK-304/306	3 EA	COMPLETION LEACH TANK					1.8mDia. X 2mHigh, FRP, R/L	0400.MAA 4		A
0400-TK-307	1 EA	PREGNANT LIQUID TANK					2mDia. X 2.5mHigh, FRP	0400.MAA 5		A
0400-TK-308	1 EA	FILTRATE RECEIVING TANK					2mDia. X 2.5mHigh, FRP	0400.MAA 6		A
0400-TK-309	1 EA	OXIDATION THICKENER TANK					2.5mDia. X 2.5mHigh, FRP	0400.MAA 7		A

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Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-TK-310	1 EA	CONDENSATE TANK					2.5mDia. X 2.5mHigh, FRP	0400.MAA 8		A
0400-TK-311	1 EA	LEACH SOLUTION HOLDING TANK					1.0mDia X 1.5mHigh, FRP	0400.MAA 9		A
0400-TK-312	1 EA	LEACH SOLUTION HEAD TANK					1.5mDia X 1.0mHigh, FRP	0400.MAA 10		A
0400-TK-313	1 EA	CHLORINE DEGASSER					1mDia X 1mHigh, FRP	0400.MAA 11		A
0400-TK-314	1 EA	CHLORINE CONDENSATE TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 12		A
0400-TK-315	1 EA	ELECTROLYTE RECEIVING TANK					3mDia X 3mHigh, FRP	0400.MAA 13		A
0400-TK-316/318	3 EA	OXIDATION LEACH TANK					1.0mDia X 1.0mHigh, FRP, w/internal steam and cooling coils	0400.MAA 14		A
0400-TK-319	1 EA	LEACH SOLUTION TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 15		A
0400-TK-320	1 EA	STRIP WATER HOLDING TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 16		A
0400-TK-321	1 EA	BARREN ORGANIC STORAGE TANK (TBP)					1.5mDia X 1.5mHigh, FRP	0400.MAA 17		A
0400-TK-322	1 EA	DILUENT TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 45		A
0400-TK-324	1 EA	IRON EXTRACTION EFFLUENT TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 18		A
0400-TK-325	1 EA	BARREN ORGANIC STORAGE TANK (TIOA)					1.5mDia X 1.5mHigh, FRP	0400.MAA 19		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0400: HYDROMETALLURGY PLANT										
0400-TK-326	1 EA	DILUENT TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 46		A
0400-TK-328	1 EA	SX EFFLUENT HOLDING TANK					2.5mDia X 2.5mHigh, FRP	0400.MAA 20		A
0400-TK-329/331	3 EA	REACTION TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 21		A
0400-TK-332	1 EA	FILTRATE HOLDING TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 23		A
0400-TK-333	1 EA	ELECTROLYTE HEAD TANK					1.5mDia X 1.0mHigh, FRP	0400.MAA 24		A
0400-TK-334	1 EA	ELECTROLYTE RECEIVING TANK					3mDia X 3mHigh, FRP	0400.MAA 25		A
0400-TK-335	1 EA	CHLORINE DEGASSER					1mDia X 1mHigh, FRP	0400.MAA 26		A
0400-TK-336	1 EA	CHLORINE CONDENSATE TANK					1.0mDia X 1mHigh, FRP	0400.MAA 27		A
0400-TK-337	1 EA	LEACH SOLIDS MIX TANK					1.5mDia X 1.5mHigh, FRP, R/L	0400.MAA 28		A
0400-TK-338	1 EA	FILTRATE TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 29		A
0400-TK-339	1 EA	FILTERED SOLIDS TANK					1.5mDia X 1.5mHigh, FRP R/L	0400.MAA 30		A
0400-TK-340	1 EA	SODA ASH ANOLYTE MIXING TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 31		A
0400-TK-343	1 EA	COBALT SX SOLUTION TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 34		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-TK-344	1 EA	HEATED CLEANING SOLUTION TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 35		A
0400-TK-345	1 EA	HEATED CLEANING SOLUTION TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 22		A
0400-TK-346/348	3 EA	REACTION TANK (COBALT)					1.0mDia X 1.0mHigh, FRP	0400.MAA 36		A
0400-TK-349	1 EA	FILTRATE HOLDING TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 37		A
0400-TK-350	1 EA	ELECTROLYTE HEAD TANK					1.5mDia X 1mHigh, FRP	0400.MAA 38		A
0400-TK-351	1 EA	ELECTROLYTE RECEIVING TANK					2.5mDia X 2.5mHigh, FRP	0400.MAA 39		A
0400-TK-352	1 EA	COBALT ANOLYTE TANK					1.5mDia X 1.5mHigh, FRP	0400.MAA 40		A
0400-TK-353	1 EA	CHLORINE DEGASSER					1mDia X 1mHigh, FRP	0400.MAA 41		A
0400-TK-354	1 EA	CHLORINE CONDENSATE TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 42		A
0400-TK-355	1 EA	SODA ASH ANOLYTE MIX TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 43		A
0400-TK-357	1 EA	ANOLYTE TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 44		A
0400-TK-358	1 EA	HYDRATED LIME MIX TANK					1.0mDia X 1.0mHigh, CS	0400.MAA 47		A
0400-TK-359	1 EA	WASTE MATERIAL TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 48		A

Facility 0400: HYDROMETALLURGY PLANT

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0400-TK-360	1 EA	ANOLYTE RECEIVING TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 49		A
0400-TK-361	1 EA	STRIP MIX TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 50		A
0400-TK-362	1 EA	CoCO3 MIX TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 51		A
0400-TK-364	1 EA	NICKEL EVAPORATOR					1.1mDia X 2.0mLong, titanium w/internal bundle	0400.MAA 52	Cosmos	A
0400-TK-365	1 EA	NiCO3 SLURRY TANK					1.0mDia X 1.0mHigh, FRP	0400.MAA 54		A
0400-TK-366	1 EA	COBALT EVAPORATOR					1.0mDia X 1.0mLong, titanium w/steam jacket	0400.MAA 53	Cosmos	A
0400-ZM-300	1 EA	CHLORINE VAPORIZER					Steam Heated	0400.NZM 1		A
0400-ZM-301	1 EA	ELECTRODE HANDLING STRONG BACK (COBALT)					Stainless Steel	0400.NZM 2		A
0400-ZM-302	1 EA	ELECTRODE HANDLING STRONG BACK (NICKEL)					Stainless Steel	0400.NZM 3		A

Facility 0510: COAL RECEIVING, STORAGE AND RECLAIM

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0510-BN-014	1 EA	COAL RECEIVING HOPPER					10m3 capacity, CS, complete with bar grate	0510.MAA 1		A
0510-BN-016	1 EA	COAL RECLAIM HOPPER					10 m3 Capacity	0510.MAA 2		A
0510-BN-032	1 EA	PULVERIZED COAL DAY BIN						0510.MAA 3		A
0510-CR-001	1 EA	COAL CRUSHER		37kW			150T/h Capacity	0510.NCR 1		A
0510-CS-004	1 EA	COAL COLLECTOR CYCLONE						0510.NCS1 1		A
0510-CV-012	1 EA	STOCKPILE FEED CONVEYOR		75kW			1.2m X 300m L, Cap. 160T/hr	0510.NCVB 1		A
0510-CV-014	1 EA	COAL BIN FEED CONVEYOR		37kW			1m W X 60m L, Cap. 30T/hr, multi-fold type	0510.NCVB 2		A
0510-CV-039	1 EA	COAL SCREW CONVEYOR					10m long	0510.NCVK 1		A
0510-DC-010	1 EA	COAL UNLOADING DUST COLLECTOR					Complete with bags, hopper, and airlock	0510.NDC 1		A
0510-DC-013	1 EA	COAL DUST COLLECTOR						0510.NDC 2		A
0510-FA-021	1 EA	DUST COLLECTOR FAN		56kW			60,000 Nm3/hr	0510.NFA 1		A
0510-FA-034	1 EA	COAL PULVERIZER FAN						0510.NFA 3		A
0510-FA-035	1 EA	COAL DUST COLLECTOR FAN						0510.NFA 2		A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0510: COAL RECEIVING, STORAGE AND RECLAIM										
0510-FE-006	1 EA	COAL HOPPER BELT FEEDER		19kW			150T/h Capacity	0510.NFE1 1		A
0510-FE-009	1 EA	COAL BELT FEEDER		7.5kW			25T/h Capacity	0510.NFE1 2		A
0510-ME-060/061	1 EA	FRONT END LOADER					With 3m3 bucket	0510.NME 1		A
0510-ME-062	1 EA	RAILCAR PULLER						0510.NME 2		
0510-ML-001	1 EA	COAL PULVERIZER		15kW			10t/h Capacity	0510.NML 1		A
0510-PP-092	1 EA	PULVERIZED COAL PNEUMATIC PUMP						0510.NPP 1		A

Facility 0520: FLUX AND REAGENT RECEIVING AND STORAGE

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0520-BN-009	1 EA	RECEIVING HOPPER					9m3 capacity, CS	0520.MAA 1		A
0520-CR-002	1 EA	JAW CRUSHER		7.5kW			5t/h capacity	0520.NCR5 1		A
0520-CV-001	1 EA	SCALPING SCREEN FEED CONVEYOR		7.5kW			0.4m Wide X Long, 5t/h capacity	0520.NCVB 1		A
0520-CV-034	1 EA	FLUX FEED CONVEYOR		11kW			0.4m Wide X 45m Long, 3t/h capacity	0520.NCV 4		A
0520-FE-001	1 EA	BELT FEEDER		5.6kW			5t/h capacity	0520.NFE1 1		A
0520-MA-001	1 EA	SCRAP MAGNET		0.5kW				0520.NMA 1		A
0520-SC-003	1 EA	SCALPING SCREEN		2.2kW			5t/h capacity	0520.NSC1 1		A

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
000-LP-01	1 EA	LIGHTING PANEL					24CKTS, 230VOLTS, 3PHASE INCLUDEED IN SWITCHGEAR PRICING	0600.TLA 1		
0000-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 1		
0000-CB-01/03	3 EA	SF6 BREAKER					600AMPS, 110KV	0600.TAA 8		
0000-CCVT-01	1 EA	COUPLING CAPACITOR VOLTAGE TRANSFORMER						0600.TAA 2		
0000-DS-01	1 EA	AIR BREAK SWITCH					600AMPS,Incoming line motor operated switch	0600.TAA 4		
0000-DS-01A	1 EA	AIR BREAK SWITCH					600AMPS,Incoming line By Pass Switch,gang operated	0600.TAA 5		
0000-DS-02/07	6 EA	AIR BREAK SWITCH					600AMPS, 3-POLE,Breaker and Bus & Breaker disconnect switches,gang operated	0600.TAA 6		
0000-DS-08/10	3 EA	AIR BREAK SWITCH					600AMPS,110kV, 3-POLE,Breaker By Pass disconnect switches,gang operated	0600.TAA 7		
0000-LA-01	3 EA	LIGHTNING ARRESTER, STATION TYPE					110KV line	0600.TAA 1		
0000-LP-01/02	2 EA	LIGHTING PANEL					24CKTS, 230VOLTS, 3PHASE INCLUDEED IN SWITCHGEAR PRICING	0600.TLA 1		
0000-LT-01	1 EA	LINE TRAP					110KV	0600.TAA 3		
0000-P-TX-01/02	2 EA	OUTDOOR SUBSTATION POWER TRANSFORMER					16MVA, 110KV-3.6KV, 50HZ	0600.TBA 1		
0000-P-TX-03	1 EA	OUTDOOR SUBSTATION POWER TRANSFORMER					30 MVA, 110KV-3.6KV, 50HZ for smelter furnace	0600.TBA 2		

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0000-SG-01	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 3150AMPS, 50HZ consisting of vacuum circuit breakers	0600.TAA 9		
0100-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 2		
0100-MCC-01	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ w/ vertical sections (5ea) main breaker 800 AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 40-63AMPS (2ea) 100-300AMPS (1ea) fnvr motor starters size 1 (2ea) size 2 (5ea) size 3 (4ea) size 4 (2ea) size 6	0600.TCA 1		
0100-P-TX-04	1 EA	TRANSFORMER UNIT					Dry type, 630KVA, 50HZ	0600.TBA 5		
0200-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 3		
0200-MCC-02	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ w/vertical sections (9ea) main breaker 1000AMPS (1ea) sub-feeder breakers 3P 6-32 AMPS (3ea) 40-63 AMPS (2ea) 100-300 AMPS (1ea) fvnr motor starters size 1 (10ea) size 2 (3ea) size 3 (1ea) size 4 (1ea) size 6 (5ea)	0600.TCA 2		
0320-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 4		
0320-MCC-03	1 EA	400V MOTOR CONTROL CENTER					2000AMPS, 3PHASE, 4W, 50HZ w/vertical sections (8ea) main breaker 1000AMPS (1ea) sub-feeder breakers 3P 15-32AMPS (3ea) 40-100 AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (10ea) size 2 (3ea) size 3 (1ea) size 4 (3ea) size 6 (3ea)	0600.TCA 3		

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

MECHANICAL EQUIPMENT LIST REV.A

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0600: SITE DEVELOPMENT & UTILITIES										
0320-MCC-12	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ w/ vertical sections (5ea) main breaker 800 AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 40-63AMPS (2ea) 100-300AMPS (1ea) fnvr motor starters size 1 (2ea) size 2 (5ea) size 3 (4ea) size 4 (2ea) size 6	0600.TCA 1		
0320-P-TX-07/08	2 EA	TRANSFORMER SWITCHGEAR					630KVA, 3PH, 50HZ, 3.6KV-420V	0600.TBA 6		
0320-SG-05	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 1250AMPS, 50HZ, consists of vacuum circuit breakers main tie main breakers 1250AMPS, (3ea) motor contoller for 1680KW induction motor (2ea) motor controller for 187KW induction motor (4ea) fedder for 500KW load (2ea)	0600.TAA 13		
0320-SG-23	1 EA	LOW VOLTAGE SWITCHGEAR					2000AMPS, 3PHASE, 50HZ, w/feeder circuit breakers main tie main breaker 200AMPS (3ea) sub-feeder breakers 3P, 630AMPS (4ea) 1250AMPS (2ea)	0600.TAA 17		
0330-MCC-04	1 EA	400V MOTOR CONTROL CENTER					1600AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (6ea) main breaker 1600AMPS (1ea) sub-feeder breakers 3P 15-32AMPS (3ea) 40-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (1ea) size 2 (7ea) size 3 (2ea) size 4 (2ea) size 6	0600.TCA 4		
0340-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 5		
0340-MCC-05	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (8ea) main breaker 1000AMPS (1ea) sub-feeder breakers 3P 15-32AMPS (3ea) 40-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (2ea) size 2 (13ea) size 3 (2ea) size 4 (1ea) size 6	0600.TCA 5		

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0350-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 6		
0350-MCC-06	1 EA	400V MOTOR CONTROL CENTER					2000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (14ea) main breaker 1600AMPS (1ea) sub-feeder breakers 3P 15-32AMPS (3ea) 40-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (7ea) size 2 (17ea) size 3 (1ea) size 4 (1ea) size 6	0600.TCA 6		
0400-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 7		
0400-MCC-10	1 EA	400V MOTOR CONTROL CENTER					2000AMPS, 3PHASE, 4W, 50HZ w/vertical sections (8ea) main breaker 1000AMPS (1ea) sub-feeder breakers 3P 15-32AMPS (3ea) 40-100 AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (10ea) size 2 (3ea) size 3 (1ea) size 4 (3ea) size 6 (3ea)	0600.TCA 3		
0400-MCC-11	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (8ea) main breaker 800AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 63-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (18ea) size 2 (1ea) size 3 (1ea) size 4 (3ea) size 6	0600.TCA 8		
0400-P-TX-05/06	2 EA	TRANSFORMER					1600KVA, 3PH, 50HZ, 3.6KV-420V	0600.TBA 7		
0400-SG-21	1 EA	LOW VOLTAGE SWITCHGEAR					2000AMPS, 3PHASE, 50HZ, w/feeder circuit breakers main tie main breakers 1250AMPS, sub-feeder breakers 3p 630AMPS (15ea)	0600.TAA 15		
0510-MCC-07	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (7ea) main breaker 800AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 63-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (3ea) size 2 (7ea) size 3 (1ea) size 4 (3ea) size 6	0600.TCA 9		

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0600: SITE DEVELOPMENT & UTILITIES										
0510-MCC-13	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (13ea) main breaker 600AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 63-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (22ea) size 2 (27ea) size 4 (1ea)	0600.TCA 7		
0520-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 8		
0520-MCC-08	1 EA	400V MOTOR CONTROL CENTER					1000AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (6ea) main breaker 800AMPS (1ea) sub-feeder breakers 3P 6-32AMPS (3ea) 63-100AMPS (1ea) 150-300AMPS (1ea) fvnr motor starters size 1 (3ea) size 2 (7ea) size 3 (1ea) size 4 (1ea) size 6	0600.TCA 10		
0600-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 9		
0600-BO-001	1 EA	AUXILIARY BOILER		1-56kW, 2-18.6kW			4545 kg/hr, fuel oil fired	0600.NBO 1		A
0600-BS-01/03	45 LM	BUS - ELECTRICAL					4000A,3.6kV,3PH,3W,INDOOR/OUTDOOR W/FITTINGS	0600.TMA 1		
0600-CN-013	1 EA	CLARIFIER MECHANISM MONORAIL HOIST		5.6kW			5T capacity	0600.NCN 1		A
0600-CP-002/003	2 EA	PLANT AIR COMPRESSOR		112kW				0600.NCP1 1		A
0600-DR-003/004	2 EA	PLANT AIR DRYER		5kW				0600.NDR1 1		A
0600-EG-01	1 EA	STANDBY GENERATOR					1200KW, 3PHASE, 50HZ, complete w/accessories INCLUDED IN MECHANICAL ACCOUNT	0600.TGA 1		

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0600-GE-005	1 EA	EMERGENCY DIESEL GENERATOR					....kW capacity	0600.NGE 1		A
0600-HX-011	1 EA	FURNACE COOLING TOWER		3-11kW				0600.NHX3 1		A
0600-HX-012	1 EA	GRANULATION AREA COOLING TOWER		3-18.6kW				0600.NHX3 2		A
0600-MCC-09	1 EA	400V MOTOR CONTROL CENTER					600AMPS, 3PHASE, 4W, 50HZ, w/vertical sections (5ea) main breaker 2000AMPS (1ea) sub-feeder breakers 3P 40-63AMPS (3ea) 100-300AMPS (31ea) fvnr motor starters size 2 (20ea) size 3 (1ea) size 4 (1ea) size 6 (2ea)	0600.TCA 11		
0600-ME-008/009/010	3 EA	PICK-UP						0600.NME 1		
0600-ME-011	1 EA	MOBILE CRANE					5T	0600.NME 2		
0600-ME-012	1 EA	FUEL/LUBE TRUCK						0600.NME 3		
0600-ME-013/014/015	3 EA	FORK LIFTS						0600.NME 4		
0600-ME-016	1 EA	AMBULANCE						0600.NME 5		
0600-ME-017/018	2 EA	FLAT BED TRUCK						0600.NME 6		
0600-ME-019	1 EA	FRONT END LOADER						0600.NME 7		

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0600: SITE DEVELOPMENT & UTILITIES										
0600-P-TX-09	1 EA	TRANSFORMER					630KVA, 3PH, 50HZ, 3.6KV-420V	0600.TBA 8		
0600-PP-070/071	2 EA	FUEL OIL UNLOADING PUMP		11kW				0600.NPP 2		A
0600-PP-072/073	2 EA	FUEL OIL SUPPLY PUMP		7.5kW				0600.NPP 3		A
0600-PP-074/076	3 EA	FURNACE COOLING WATER SUPPLY PUMP		300kW			1363m3/Hr @ 49m TH	0600.NPP 1		A
0600-PP-077/079	3 EA	FURNACE COOLING WATER RETURN PUMPS		187kW			1363m3/Hr @ 29m TH	0600.NPP 8		A
0600-PP-080/081	2 EA	GRANULATION CLARIFIER U'FLOW PUMP		37.3kW				0600.NPP 4		A
0600-PP-082/083/084	3 EA	GRANULATION CLARIFIER O'FLOW PUMP		30kW				0600.NPP 5		A
0600-PP-085/086/087	3 EA	GRANULATION WATER SUPPLY PUMP		37kW				0600.NPP 6		A
0600-PP-088	1 EA	GRANULATION CLARIFIER AREA SUMP PUMP		18.6kW				0600.NPP 7		A
0600-PP-089	1 EA	EMERGENCY FIRE PUMP		75kW	1800rpm	1.20	227m3/Hr @ 70.4m TH	0600.NPP 9	Goulds Pumps	A
0600-PP-090	1 EA	EMERGENCY DIESEL FIRE PUMP			1800rpm		227m3/Hr @ 70.4m TH diesel driven	0600.NPP 10	Goulds Pumps	A
0600-PP-091	1 EA	EMERGENCY JOCKEY FIRE PUMP		22.4kW	3600rpm		57m3/Hr @ 70.4m TH	0600.NPP 11	Goulds Pumps	A

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0600-SG-02	1 EA	SWITCHGEAR SG-06(SMELTER BUILDING) METAL ENCLOSED SWITCHGEAR					11KV, 3150 AMPS, consists of vacuum circuit breaker Feeder Breaker for transformer 30 MVA for SG-06(Furnished in Smelter Package)	0600.TAA 10		
0600-SG-03	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 1250AMPS, 50HZ, consists of vacuum circuit breakers,main tie main breakers (3 ea) 1250AMPS, motor controller for 373kW induction motor (8 ea) motor controller 300kW induction (6 ea), feeder breakers (2 ea) 630AMPS	0600.TAA 11		
0600-SG-03	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 1250AMPS, 50HZ, consists of vacuum circuit breakers,main tie main breakers (3 ea) 1250AMPS, motor controller for 373kW induction motor (8 ea) motor controller 300kW induction (6 ea), feeder breakers (2 ea) 630AMPS	0600.TAA 11		
0600-SG-04	1 EA	AIR BREAK SWITCH					600AMPS, 3-POLE,Breaker and Bus & Breaker disconnect switches,gang operated	0600.TAA 6		
0600-SG-04	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 630AMPS, 50HZ, consists of vacuum circuit breakers main & tie breakers 630AMPS, (3ea) motor contoller for 300KW induction motor (4ea) motor controller for 187KW induction motor (4ea) feeder breakers 630AMPS (2ea)	0600.TAA 12		
0600-SG-05	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 1250AMPS, 50HZ, consists of vacuum circuit breakers 3 main tie-main breakers 1250AMPS, motor controller for 1680KW induction motor (3ea) motor controller for 187KW induction motor (4ea) fedder for 500KW load (2ea)	0600.TAA 14		

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	MOTOR DATA Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
0600-SG-07	1 EA	METAL ENCLOSED SWITCHGEAR					3.6KV, 1250AMPS, 50HZ, consists of vacuum circuit breakers 3 main tie-main breakers 1250AMPS, motor controller for 1680KW induction motor (3ea) motor controller for 187KW induction motor (4ea) fedder for 500KW load (2ea)	0600.TAA 14		
0600-SG-22	1 EA	SF6 BREAKER					600AMPS, 110KV	0600.TAA 8		
0600-SG-22	1 EA	400V LOW VOLTAGE SWITCHGEAR					3150AMPS, 3PHASE, 4W, 50HZ w/ feeder breakers 630A (6ea)	0600.TAA 16		
0600-ST-003	1 EA	CLARIFIER BOIL BOX						0600.MDA 1		A
0600-TK-003/004	2 EA	FUEL OIL STORAGE					379m3 capacity	0600.MAA 1		A
0600-TK-006	1 EA	GRANULATION CLARIFIER TANK					681m3/Hr capacity, 30.5m Dia.	0600.MAA 3		A
0600-TK-007	1 EA	GRANULATION CLARIFIER OVERFLOW TANK						0600.MAA 2		A
0600-TK-008	1 EA	FIRE WATER TANK					568m3 capacity	0600.MAA 4		A
0600-TM-001	1 EA	GRANULATION CLARIFIER MECHANISM		5.6kW, 1.1kW			681m3/Hr capacity, (Gimco BGO drive) clarifier complete with drive and lift motors, feedwell, rake arms, walkway, etc.	0600.NTM 1	Eimco	A
0600-VS-001/002	2 EA	PLANT AIR RECEIVER						0600.NVS 1		A

ELECTRICAL EQUIPMENT LIST

EQUIP LISTING: Sort By Facility
FACILITY RANGE: All
EQUIP RANGE: All
COMMODITY RANGE: T - TZZZZZZZ
M/R RANGE: All
SUPPLIER RANGE: All

COOK ISLAND DEEP SEA NODULE MINING STUDY

SMELTING AND CONVERTING

ELECTRICAL EQUIPMENT LIST REV.A

RUN DATE: Apr 17, 1996
RUN TIME: 10:32 AM
JOB NUMBER: 23134

Facility 0600: SITE DEVELOPMENT & UTILITIES

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
000-LP-01	1 EA	LIGHTING PANEL					24CKTS, 230VOLTS, 3PHASE INCLUDEED IN SWITCHGEAR PRICING	0600.TLA 1		
0000-BC-01	1 EA	BATTERY CHARGER/BATTERY SYSTEM						0600.TEA 1		
0000-CB-01/03	3 EA	SF6 BREAKER					600AMPS, 110KV	0600.TAA 8		
0000-CCVT-01	1 EA	COUPLING CAPACITOR VOLTAGE TRANSFORMER						0600.TAA 2		
0000-DS-01	1 EA	AIR BREAK SWITCH					600AMPS,Incoming line motor operated switch	0600.TAA 4		
0000-DS-01A	1 EA	AIR BREAK SWITCH					600AMPS,Incoming line By Pass Switch,gang operated	0600.TAA 5		
0000-DS-02/07	6 EA	AIR BREAK SWITCH					600AMPS, 3-POLE,Breaker and Bus & Breaker disconnect switches,gang operated	0600.TAA 6		
0000-DS-08/10	3 EA	AIR BREAK SWITCH					600AMPS,110kV, 3-POLE,Breaker By Pass disconnect switches,gang operated	0600.TAA 7		
0000-LA-01	3 EA	LIGHTNING ARRESTER, STATION TYPE					110KV line	0600.TAA 1		
0000-LP-01/02	2 EA	LIGHTING PANEL					24CKTS, 230VOLTS, 3PHASE INCLUDEED IN SWITCHGEAR PRICING	0600.TLA 1		
0000-LT-01	1 EA	LINE TRAP					110KV	0600.TAA 3		
0000-P-TX-01/02	2 EA	OUTDOOR SUBSTATION POWER TRANSFORMER					16MVA, 110KV-3.6KV, 50HZ	0600.TBA 1		
0000-P-TX-03	1 EA	OUTDOOR SUBSTATION POWER TRANSFORMER					30 MVA, 110KV-3.6KV, 50HZ for smelter furnace	0600.TBA 2		

Equipment No.	Quantity	Equipment Title	M/R No.	[--- MOTOR DATA ----] Rating: kW	RPM	Unit Wt (t)	Equipment Size & Description	Costcode Item #	Supplier	Rev
Facility 0600: SITE DEVELOPMENT & UTILITIES										
0600-SG-22	1 EA	SF6 BREAKER					600AMPS, 110KV	0600.TAA 8		
0600-SG-22	1 EA	400V LOW VOLTAGE SWITCHGEAR					3150AMPS, 3PHASE, 4W, 50HZ w/ feeder breakers 630A (6ea)	0600.TAA 16		

APPENDIX A

APPENDIX A

DRAWINGS

DRAWING NO.	REV.	TITLE
000-B-001	A	Smelter Plant Block Flow Diagram
000-B-002	A	Hydrometallurgical Plant Block Flow Diagram- Sht.1
000-B-003	A	Hydrometallurgy Plant Block Flow Diagram- Sht.2
100-B-001	A	Marine and Portside Facilities Flow Diagram
200-B-001	A	Nodule Storage and Reclaim Flow Diagram
320-B-001	A	Nodule Drying Flow Diagram
330-B-001	A	Nodule Pre-Reduction Flow Diagram
340-B-001	A	Electric Smelting Furnace Flow Diagram
350-B-001	A	Converting & Matte Granulation Flow Diagram
400-B-001	A	Matte Grinding and Leaching Flow Diagram
400-B-002	A	Copper Electrowinning Flow Diagram
400-B-003	A	Solvent Extraction Flow Diagram
400-B-004	A	Nickel Electrowinning Flow Diagram
400-B-005	A	Cobalt Electrowinning Flow Diagram
510-B-001	A	Coal Receiving and Storage Flow Diagram
520-B-001	A	Silica Flux Receiving and Storage Flow Diagram
000-E-001	A	Main Substation Electrical One Line Diagram
100-E-001	A	Marine Facilities Electrical One Line Diagram
300-E-001	A	Drying/Smelting/Converting Electrical One Line Diagram
400-E-001	A	Hydrometallurgy Plant Electrical One Line Diagram
600-E-001	A	FA6 0600 - Utilities Electrical One Line Diagram
000-M-001	A	Site Plan
340-M-001	A	Smelter Plan
340-M-002	A	Smelter Sections Sheet1
340-M-003	A	Smelter Sections Sheet 2
400-M-001	A	Hydrometallurgy Plant Plans
400-M-002	A	Hydrometallurgy Plant Sections
510-M-001	A	Coal Handling Plan and Sections
520-M-001	A	Silica Handling & Misc. Plan and Sections
600-M-001	A	Plant Underground Piping Plan