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ASSISTANCE TO SOLAR SALT INDUSTRY

DP/KIR/88/002

KIRIBATI

Terminal Report*

Prepared for the Government of Kiribati
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

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* This document has not been edited

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ABSTRACT

A two-week mission, from September 6 to 20, 1989, was made as part of the DP/KIR/88/002, in Christmas Island (Kiritimati), Republic of Kiribati, in the Central Pacific, to determine the present operational conditions of the Solar Salt Pilot Plant built in 1984 to produce 500 tons of salt per annum and also to design a plant capable of producing 25,000 tons per annum (tpa).

The visit permitted to define that the infrastructure built as pilot plant is currently out of operation but that it could produce about 3,000 tpa with the construction of a couple of dikes which, located strategically in two sectors of the Manülu Lagoon, would allow a different management of the brine, improving the productive capacity of the lagoon, and letting it ready for a future large scale development.

Regarding the objective of a 25,000 tpa production, it is observed that the geographic isolation, the scarcity of technical, human and service resources, an the initial difficulties inherent to marketing from Christmas Island, oblige to a production strategy that must be initiated on short term with a maximum 10,000 tpa and a minimum investment.

From this result, feasible within a term of two to three years, which implies an acceptable knowledge of the managament of a solar saline and of the marketing of the product, could then be developed the infrastructure to increase the production to 25,000 tpa or more, since the renewable reserves of brine of high concentration may yield up to several hundreds of thousands of first-quality salt a year.

INTRODUCTION

The UNDP/UNIDO Project for the development of solar saline in Kiritimati goes back to 1979. The construction of the pilot plant for 500 tpa was completed in 1984; in 1985, 70 tons were harvested; in 1986, 275 metric tons; in 1987, there was no production due to the rains caused by the phenomenon EL NIÑO, and at present (September 1989), due to the low density of brine in the Manülu Lagoon 16° Bé during visit days) and the grave problems of leakage in the floor of the crystallizer and the rest of the ponds which prevent the watertightness of the brine, it follows that this plant is out of operation.

This situation is in disagreement with the favourable conditions the Kiritimati have to develope a solar saline of international character.

The area where the pilot plant operates is located in the North-Western corner of the Manülu Lagoon (Annex I, Photos 1-5), a natural depression with an area of eight square kilometres, with a water column of brine of four metres average depth.

Taking advantage of an area slightly more elevated and currently dry on the floor of the central part of the Lagoon, it is requested that the Kiribati Government builds a retaining wall dike that separate this Lagoon in two large sections: North and South. This separating dike was already initiated in 1985 on advise by UNIDO Consultant Mr Chester Jenkins, although its construction stopped 100 metres from its commencement.

Our present proposal is that the separating wall is completed up to the end of the Lagoon, that is, some 2.7 kilometres in length in a West-East direction, and to put up a gate at the end of the same for the control of the passage of water to the Northern sector.

The Southern sector, larger in size, would serve to stock brine of low and medium density, and the Northern sector will contain high-density brine, ready to be carried to the crystallizers for the precipitation of sodium chloride.

To ensure that the Northern sector maintains a high concentration of salt, it is necessary to complete another separating dike, one kilometre in length, to avoid the entry of marine waters of low salinity that eventually intrude the North-Western section of the Manülu Lagoon and that undoubtedly is one of the negative factors that determine that the pilot plant be out of operation.

Once this last dike is built, the Northern sector of the Lagoon will be in a permanent capacity to stock heavy brine in quantities sufficient to feed the crystallizers that must be built at the banks of it.

The cost of the separating wall dikes is relatively low since the embankment material that would be used in its construction is reef mud, which can be found in abundance, loose, of easy extraction in the banks of the Lagoon and near the pilot plant.

Considering a fact this division of the Lagoon, I propose to utilize all the ponds of the pilot plant (two hectares of surface) to be used as crystallizers and thus increase the salt production to 500 tpa to 3,000 tpa.

The required investment needed to reach this production figure is almost exclusively that originated by the construction of two separating wall dikes. The cost, calculated approximately, is of about US$200,000.00 and its construction will last five months. Parallel to this increase of 3,000 tons of salt per annum at the pilot plant, is proposed the construction of an additional infrastructure to increase the production to 10,000 tpa. This requires the construction of six additional Has of crystallizer ponds, a pump station with two 50-litre-per-second-capacity pumps, a small plant to process and pack the salt, one payloader for the harvest and ensilage of salt, a warehouse for storing 3,000 metric tones of gross bulk salt and another for storing the processed products. The cost of this infrastructure and equipment will be presented in detail in a near future after a detailed study has been made prior agreement with UNIDO, the consultant and the plant constructors.

I. ACTIVITIES

A. Consolidation of a 500 tpa Pilot Plant (Annex II , Photos 6)

The pilot plant was designed to produce 500 tons of salt per year in five crystallizers with a total area of one half hectare. The rest of the pools, with an area of one and one half hectares, are utilized as ponds for the concentration of brine that has been pumped from the Manülu Lagoon to an area known as M-4 (Annex II). The brine in this part of the Lagoon is of medium density, about 10-12° Bé. In the concentrator pools, and due to the effect of solar evaporation, the brines increase their salinity while the different salts considered impure are precipitated, specially calcium sulphate or gypsum, which forms crusts at the bottom of the pools. Finally, after a period of several months, the brines, mainly with sodium chloride in solution, are carried to the five small crystallizers where the salt is being deposited, in solid form, in a layer of about 7 cms. of width (for each harvest cycle), which lasts about five months.

According to the extrapolation of the results obtained by Jenkins for the harvest of crystallizer No. 5 during 1986, the production of salt in Christmas Island can be estimated in 1,304 tons/Ha. per year. This figure, divided by 4,570 mts 2 (total area of the crystallizers), results in 595 MT/year, similar to the theoric calculation for this pilot plant.

However, the production in 1989 will be zero tons due to the lack of heavy brine to feed the crystallizers as well as to the problems of leakage in the pools.

During the visit (September 1989), some corrective measures were initiated in the ponds in order to improve the situation. An increase in the pumping from 7 hours/day to 16 hours/day, for a period of three months, was initiated to inject brine to all the pools that quickly lose water due to the leakage during the 16-hour break between one pumping session an another. By this overpumping, the level of water will be raised to the maximum allowed in all the ponds.

The brine flow was changed by injection from the M-3 area (16 -19° Bé during the visit days, September 6 to 20, 1989). It is expected that the continuous precipitation of gypsum and the microscopic algae will seal the pores of the reef floor of the ponds. This seal will be about 3 mm-4 mm thick in December 1989.

To improve the pumping capacity from area M-3 to the pilot plant, it was ordered the transfer of the Lombardini Pump, of 5", located in Sector M-4 (Photos 1 and 2), to the Northern sector in area M-3. With this pump, in addition to two small ones utilized to pump the heavy brine from the latter sector, ten litres per second are injected to facilitate the movement of brine to the pools in less time.

Once obtained the sealing of the floors, the transfer of the brines, alredy at high density (about 24° Bé), will be initiated in January 1990, provided there are no strong intrusions of light waters in the critic sector of Lagoon.

In February, will be initiated the feeding of brine of 24.5° Bé to the present crystallizers and the rest of the pools.

All the operation described above is intended to reinitiate the production of salt in the pilot plant, but a decision must be urgently taken in order for the yield of 1990 to be positive. Without the construction of the pair of dikes already indicated, we may again fall in a vicious circle due to the dilution of heavy brines and the loss of another year in production.

B. Pilot Plant: 500 tpa vs 3,000 tpa.

The accumulated experience in the management of the pilot plant has permitted to define some important facts:

- Favourable environmental conditions exist for the production of salt in Christmas Island.
- The salt obtained can be a high-quality product.
- The lack of some works, such as the separating wall dikes already mentioned, prevents the continuity of the production of salt and keeps the pilot plant out of operation for long periods of time.

If the Government of Kiribati wishes to increase the production on a commercial scale, and for this, amongst other activities, it is necessary the construction of said wall dikes, then, as a logical proposition, the immediate construction of these is required in order to save time in the preparation of high-salinity brine in the Northern sector, for the future increase to 10,000 tpa, and, in the short term, to increase the production of the pilot plant to 2,300-3,000 tpa.

C. Calculation for the Building of the Wall Dikes

- Wall dike to divide Manülu Lagoon in Northern Sector and Southern Sector (Annex I, Photos 7,8, 9).

The dike will start on the right-hand corner of pond No. 1 of the pilot plant and run in a West-East direction over the now dry floor due to the low level of the lagoon, up to the Eastern end of the bank of an natural canal through which the brine currently flows to the Northern sector. The length up to that point is approximately 1,950 lineal metres. Then the dike must run over the 30-metre wide canal. In the middle of the same, a floodgate, similar to that made at the Ava Lagoon, must be constructed in order to control the passage towards the Manülu Lagoon. With this floodgate at the middle of the canal, the passage of brine would be effectively controlled, allowing the regulation of the flow and the entry salinity to the Northern sector. Finally, the dike must extend another 800 metres beyond the canal, also over a reef floor, currently dry, to reach up to the farthest bank of the lagoon where higher elevations rise over the lagoon level and coconut plantations are located.

SUMMARY

Total Length: 1,950 metres + 30 metres + 800 metres = 2,700 lineal metres.

Dike Section: 7.1 square metres.

Required Volumen: 7.1 square metres x 2,700 metres = 17,000 cubic metres, approximately.

- Wall dike in the North-Western sector to avoid the intrusion of low-salinity waters (tide water intrusion) from a branch of the Ava Lagoon (Annex I , detail).

The dike starts at the pilot plant and borders the Nort-Western end of the Manülu Lagoon and continues up to an elevated zone covered with bushes, in which the sea water does not enter, even in extremely high floods or rains.

Total Length: 1,000 metres.

Section: 7.1 square metres.

Volumen: 7,100 cubic metres.

Total Volume Required for the construction of the two wall-dikes: 24,000 cubic metres.

The dikes will be used for the traffic of vehicles, therefore, a good work of compactation must be done to extend to the maximum the useful life-span, taking into consideration the negative effect of rain oven non-compacted materials.

The necessary equipment for earth movement (embankment), assuming a building time of five months, is the following:

- 3 dump trucks
- 1 grader backhoe (retroexcavator)
- 1 compacting machine.

Taking as reference price US#4.76/m3 in 1985, estimated by the Ministry of Works in Tarawa to calculate the costs of an embankment made for a 15,000 tpa-project (copy annexed), we have the following: 24,000 m3 x $4.76/m3(*) = US$114,240.00 <(*) US$166,759 ÷ 35,000 m3 = US$4.76/m3>.

Assuming a current inflation rate of 100%, including the work of the compacting machine, it is estimated a total of US$228,480.00.

Total:

Construction of Dikes:	US$ 228,480.00
Sluice gates	US$ 10,000.00
	US$ 238,480.00.

D. Operational Management of the Pilot Plant (Work for UNV)

In order to obtain on a short term the recovery of the production of salt in the pilot plant, a working plan was designed, which was submitted to Mr Aung Ze Ya, United Nations Volunteer, to be carried out between September 1989 and March 1990.

Following is transcription of the communication:

"September 19, 1989 Instructions to Mr Aung Ze Ya:

"1. Transfer the Lombardini Pump to the M-3 sector of the Manülu Lagoon. Place it in the middle of P-3 and C-1.

"2. Remove the brick test ponds and the separating dike between P-1 and P-4 (to make it one pond).

"3. Continue the flow in all the pilot plant ponds (± 2 Has.) to allow a tiny layer of gypsum and algae in the least time possible. Keep all the ponds covered with water not less than 14° Bé (1.1100 sec.).

"4. When the Lombardini Pump of 5" starts to operate from M-3, it will be possible to pump from 08:00 to 16:00 or less, depending on the level in all ponds (they must have the maximum level), withouth damage to the top of the dikes.

"<u>Note</u>: When the operation commences with pump 5", pumps of 2" and 3" will be serviced and stored in the warehouse for use in case of emergencies.

"5. When the layer of gypsum and algae at the floor reach 3-4 mm thickness, the ponds will be ready to be fed with brine of 24-25° Bé (1.200 sec.).

"6. Very important: It will be necessary to cover the inclined walls of all the ponds (P-1, P-2, P-3, P-4, P-5, P-6, and P-7) with flat stones, as was done with the present crystallizers. This work should be done by some local contractor with a couple of trucks that should load the flat stones, which are abundant along the beach near the town of Banana. This work will avoid the washing out and draining of sand and shelves from the dikes to the ponds.

"7. Sandpaper and paint as soon as possible the salt grinding machine, since this will be the only one available for the next harvest in early 1990. It should be kept in operation at least once a week in order to maintain the motor in operational conditions in view of the extremely corrosive environment of the Lagoon.

"8. Also repair the portable compacting machine, roller type, sandpaper it, weld its broken parts and paint it. This machine is currently abandoned in the dry floor at area M-3. This machine must be repaired in order to break the superficial coral crust in order to produce small grains and help the levelling of the floors chosen for the new crystallizers (± 6/Ha.)

"The chosen area was marked with iron bars of ten metres each, following the same direction of the perimetric dike of the pilot plant constructed in the M-3 sector, in an area of 650 metres in length and 130 metres in width, parallel to the perimetric dyke of sector M-4.

"9. Control the salinity in area M-3 for the keeping of the highest possible density (Bé) but not allowing that area M-4 and the Manülu Lagoon (South) dry excessively. Every month open to its maximum the floodgate of the AVA Lagoon during some five days depending on the salinity in M-4; it must be about 10-12° Bé, and sector M-3 must be about 21-23° Bé. At that time, feed the current crystallizers and the ponds from P-1 to P-8, which will act also as crystallizers.

"10. The construction of the separator dike that divides the Manülu Lagoon in two ponds (Northern and Southern areas), will be made when the Government of Kiribati and UNIDO make a decision about the report that will be presented by UNIDO consultant (H. T.) The same goes for the dike, which will avoid the intrusion of sea waters in Area M-3

E. <u>Solar Salt Plant for 10.000 Tons Per Year</u>

The proposal of the consultant to design a plant to produce 10,000 tpa instead of 25,000 tpa is based in the simple observation of the material conditions existing at Kiritimati and the reading of reports about the historic development of the pilot plant which indicate little co-operation from the Government of Kiribati to carry out the project.

No doubt that Christmas Island is one of the most isolated places in the world. There are difficulties for the transportation of ay type of machinery, spare parts, etc. The port is small and does not have facilities. There only exists airplane transportation between Hawaii and Christmas Island, which brings in indispensable merchandise to the island once a week.

In connection with the availability of labour, it is observed that there does not exist professional or technical personnel for the operation of a commercial solar salt plant, which requires engineers, mechanics, electrical engineers, chemists, administrators and others. It could be thought that this problem could be resolved through the importation of qualified labour hand but this requires a logistical support at present inexisting in the island.

A plant to process 25,000 tpa necessitates a small infrastructure but with a minimum of two shifts. Otherwise, the equipment must be bigger and therefore, more costly and complicated to maintain.

For example, 25,000 metric tons for a shift of 1,496 hours(*)/year requires a plant to grind and pack 16,700 kilograms of salt per hour <(*) See Operation of Plant Section in this Report>.

- For two shifts:

The same 25,000 metric tons ÷ 2,992 hours/year = 8.3 metric tons/hour.

- For three shifts:

The same 25,000 metric tons ÷ 4,488 hours/year = 6,5 metric tons/hour.

Considering that the Government of Kiribati has strong financial limitations, it must be thought of a reduced initial investment, for example choosing the smallest plant (7 metric tons/hour) which has its negative aspects since it will require three labour shifts to process 25,000 metric tons/year, with the consequent duplication or triplication of personnel.

However, if a solar plant with a capacity of 10,000 metric tons/year is constructed, the grinding, bagging and packing plant of 7 metric tons/hour could be built with a lesser investment in the processing plant and also reducing in one third the investment costs related to the construction of the ponds, walls, slopes, floodgates, pump station, etc., which would be required for the production of 25,000 metric tons/year.

Another important aspect is that of the harvest equipment. For a production of 25,000 tpa, it is necessary to have a salt harvester, even if a small one (which is quite expensive and requires a good maintenance.

Besides, it will be needed a pay-loader to utilize it in the stowing of the salt and its transportation to ıe silos for grinding. If a plant with a capacity of 10,000 tpa is built, only one pay-loader will be used for the harvest operation and also for its operations in the grinding plant.

From the positive experiencie accumulated during 2-3 years of management of 10,000 tpa, and additional investment could be made for the construction of new crystallizer ponds to increase the production to 20,000 tpa, but using the same processing plant of 7 metric tons/hour, this time with two labour shifts. Additionaly, a small harvester should be acquired.

F. Identification of Markets for Solar Salt

This objective of the mission was not carried out in a personal manner by the consultor of UNIDO since the work was concentrated in the study of the situation at Kiritimati, to initiate the consolidation of the pilot plant (2,500 tpa) and the design of the plant of 10,000 tpa (first stage).

In this report, are presented as Annexes two studies made in May and November 1986 by the enterprise PA Management Consultants, of New Zealand. Based on the reading of this report, the following comments are made:

- Even if New Zealand is a strong producer of salt in the Pacific region (approximately 60,000 tons in 1985), it imports salt from Bonaire, Netherlands Antilles in the Caribbean Sea. The interest in importing salt from so far away a saline (twice the distance between Kiritimati and New Zealand) is based on the quality of the salt, which is very clean and does not present organic material nor any other impurities. The use of this type of salt is indispensable in pulp and paper industries, as well as in petro-chemical uses (chloride, THT, fertilizers, etc.), amongst other uses.

In this respect, New Zealand is important to take into account, since the production of salt at Kiritimati will be developed with first quality salt (harvesting salt on salt floor), as good as the best in the world), which is not the case with New Zealand, which imports 75% of the Pacific production.

- There exists a potential market of 5,000 metric tons/year for bagged coarse salt from Kiritimati to the Auckland area (page 6, Study November 1986), at present supplied from Bonaire and Australia. A competitive price is required and first quality salt.

- The Hawaii market is considered as potentially attractive for the salt coming from Kiritimati (Study May 1986, Page 14). the relative nearness between the two islands will allow very attractive freight prices.

- There also exists a market for fine salt in New Zealand (Page 5, Study November 1986). As of the strategy for the 10,000 metric tons/year of the first stage, is proposed tooffer to the national market and to the neighbours of the Pacific area 3,000 metric tons/year (3 million bags) of fine table salt of the best quality, packed in plastic bags of 1 kilogram. As an advertising message of great attraction for the consumer, I propose as logotype, covering the front of the bag, the beautiful flag of Kiribati, in full colour, and the words "KIRIBATI SALT."

- The freight policy is a question that must be resolved to allow for the integral development of the project. According to a report by Mr Johan Elvence (UNCDF/PPED SEPT. 17, 1987, Page 4), a great defect is observed in this aspect for the future commercialization. The Government of Kiribati must offer a very special treatment in the freight costs of its own national lines to lower their prices and not place them at almost twice the cost of other foreign lines that pass through the region.

- Another negative point is the lack of communication and control between the administrative headquarter of the solar salt, located in Tarawa, and the Solar Salt Plant in Kiritimati. The great distance (4,500 kilometres) and the lack of effective communication equipments--telephone, fax--difficult the logistic support and the co-ordination of activities. One example of that is that at present the Government is urgently requesting from Suva, hundreds of shovels and thousands of 25 Kg. plastic bags, when in actual fact the pilot plant is out of operation and will not require these materials for at least eight months.

In a near future, there will have to be a centralization of the management of the saline, so that it operates as an autonomous enterprise and it must be located in Kiritimati.

G. Salt Processing Plant (10,000 tpa)

It has been proposed to install a plant to process the gross salt obtained in the two-hectare pilot plant, plus six hectares of crystallizers that should be built in the North-Western end of the ManÜlu Lagoon. This plant will have a simple process and operation due to its geographic position and the existing resources in the island. To that effect and considering the antecedents established by the existence of a pilot crystallization zone which has allowed the obtainment of good quality salt that will have a future purity of 98.5% NaCl, the following process is submitted for consideration to both UNIDO and the Government of Kiribati.

H. Determination of the Production

For the time being, the saline will be designed to yield 10,000 metric tons (MT) of gross salt per year, which will be processed in the following manner:

-	Gross salt in bulk in bags of 25 Kg,	3,000 MT.
-	Thick refined salt in bags of 25 Kg,	4,000 MT.
-	Fine refined salt in packages of 1 Kg,	3,000 MT
	Total	10,000 MT.

- Gross salt in bulk will be obtained for the manufacture of ice and any other industrial use.
- Refined gross salt will be utilized in the refrigeration of fresh fish and in the conservation of dry fish or salted fish.

- Fine refined salt will be utilized for human consumption and the preservation of foods.

A calendar is established, which may be modified according to the traditional working conditions in Kiribati:

365 days/year
- 54 Sundays
- 54 Saturdays
- 15 days of collective vacation
- 15 days of corrective maintenance
- 4 national holidays
- 1 international Labour day
- 1 Christmas day.

Summary:

365 calendar days
- 145 inactive days
220 working days.

Calculation of one shift of 8 daily hours:

220 effective days x 8 hours = 1,760 hours

Efficiency factor: 85% = 1,496 hours.

10,000 MT ÷ 1496 = 6.68 MT/hour.

A maximum capacity of 7 MT/hour for the design of the salt processor equipment, which will work from Monday to Friday of each week during the effective season and a group of workers will be destined to the cleaning of the equipment on Saturdays. The general corrective maintenance will be programmed for the middle of the year and the vacations at the end of the year (December).

I. Description of the Process (see annexed diagram)

The gross salt piled up at the deposits will be transported by means of a dump truck (1) to a stock pile of daily service (2) located near the plant and where it receives the heating of the sun and the ventilation of the wind to clear or reduce the relative humidity (in summer); from there, it will be introduced to the plant by a pay-loader (3). The salt is then placed by the pay-loader in the feeding hopper (4) which will have on its lower part a regulating mechanism to establish the quota of salt that corresponds to the production established programme of up to 7 MT per hour; from this hopper, the salt goes to a conveyor belt which has a mechanism on its initial part that disperses at maximum the salt over the surface of the conveyor belt, so that neon lamps located strategically permit to detect the possible presence of foreign objects that could be mixed with the salt, and the removal of these by a worker assigned thereto. Also in this low velocity conveyor belt will be installed potent electromagnets to retain metallic objects (ferrous) which accidentally might be present in the salt and that could produce substantial damage to the equipments of the grinder; this conveyor belt will discharge the salt over a primary mill (5) which will function as lump breaker, and with its roller of helicoidal grooves will establish a maximum of 20[illegible] mm. in the crystal coming from the salt stock pile; the salt continues up to the disk mill (6) where it is crushed to a granulometrical size that varies from 0.3 to 1.5 mm. This mill has a regulation mechanism that allows to modify its granulometric ranges in full activity. It is the job of the quality control department to establish by samples the adequate adjustment for the type of salt that is being processed.

During the grinding process, the salt will receive, inside the mill, the part of the necessary additive to guarantee its fluidity. Said additive will be furnished by the dosimetre (7); the salt moves to the bowl lift (8) which carries it to the sieve (9) where the granulometric selection of the salt will be made. For this case, two types of salt will be established: gross, with grains from 0.8 to 1.5 mm, and fine salt, from 0.3 to 1.8 mm; the first type fall by gravity to the silo (10) from which it is poured by the disintegrating action of the vibrating cone (11) to the bagger balance (12). This equipment fills 25 Kg. bags in a systematic manner, with a yield of 350 bags/hour. The filled bags fall onto a flat conveyor belt (13) with wooden walls to keep the bags in an upright position and are conducted up to the sealer (14) where they are vulcanized with heat. The fine salt is carried by a screw conveyor (15) to the silo (16) from where it is poured through the vibrating cone to the packing machines (17) at a speed of fifty 1 Kg. bags per minute; the bags are placed in the same 25 Kg. bags and sealed. The gross salt bags, as well as the bag unities are placed by workers in the paddles (19) which contain up to one metric ton, and transported by a hoist (20) up to the finished salt warehouse.

For the filling of the bags with gross salt, the same equipment is utilized but without operating the mills and the sieve which will be replaced by the by-pass which allows the passage of salt in its natural condition.

J. <u>Tecnology</u>

A salt grinder should be installed, made up of strong equipments of easy operation and low maintenance.

The process to be utilized to transform gross salt extracted from the saline into salt fit for human consumption is very simple. We can sum it up as a process for the grinding, incorporation of additives and packing of the salt; for this reason, it will be only necessary to follow certain rules to obtain the greater efficiency of the equipment and the best quality of the final product, as per example, the ranges of purity (percentage of NaCl) and humidity (H2O) of the final product will be directly proportional to the type of salt which is taken from the stockpile. For that reason, it will be always utilized the best-quality salt to be obtained from the saline. You must always observe the salt from the stockpile. The looseness of the crystals (there should not be big lumps) and that it humidity be really low. For this factor and since for the time being there is established only one daily labour shift, it is recommended that the timetable be adjusted to the lapse of time during which the environmental humidity is lower during the day. You must also count with a clear area (court-yard) with salt floor, where you can put with the pay-loader the daily quota to be processed, so that it receives the benefit of the sun heat and airing. Of course, all these will be done during the summer, but in the rainy seadon there will be a revaluation of the cycles that allow that the gross salt in the warehouses contain a humidity that guaranties its processing, to be utilized. However, during the lapses of intense winter, it will be proceeded to the bagging of the gross salt for the ice factories and gross salt for the preservation of fish.

K. <u>Design of the Saline for 10,000 tpa</u>

Besides the two hectares already built for pilot plant, that will produce about 2,500-3,000 tpa, it will be required the construction of six additional hectares of crystallizers to produce another 8,000 tpa (Annex). There are established three new crystallizers of two hectares each. It is calculated that the crust of salt over the floor of each crystallizer pond will be about 6.5 cm. width at the moment of harvest.

For the purposes of this report, this width is estimated according to calculation made by Jenkins, of 1,304 MT/year per hectare, according to his calculation in the pilot plant.

Calculations: 10,000 square metres x 0.065 metres = 650 cubic metres = 650 MT.

650 MT/Ha x (02) harvests per year = 1,300 MT/year.

Each crystallizer of two hectares will produce in theory 1,300 MT per harvest and 2,600 MT/year.

- (03) new crystallizers x 2,600 MT = 7,800
- Pilot Plant (2 Has) = 2,600

  Total 10,400 MT/year.

- Calculation for the Construction of Crystallizer

  Slope: 1.5:1

  Transversal section: 6.06 sq. metres

  Typical:

- Section of the Wall = $\frac{6.6 \times 3.5}{2} \times 1.20 = 6.06$ sq. metres
- Total Length of the Wall-Dikes: 2,500 metres
- Required Volumen: 2,500 x 6.06 = 15,150 cubic metres
- Cost 1986: $4.76/cub. m. x 15,150 = $72,114

Assuming a present inflation rate of 100% = $144,228 Subtotal

Pumping Station

-(02) 50 litres/sec. pumps each at an approximate price CIF Christmas of $30,000 per unit (as per information sent by fax from Hawaii by Mr Irono Vernon, purchase agent of the Kiribati Government.

- (02) pumps x $30,000 each = $60,000

- Concrete support and conexions = $20.000 Subtotal

Summary

-	Construction of Crystallizers	144,228
-	Pumping Station	80.000
		224,228
-	10% Contingent expenses	32.422
	Sub Total	US$256,650

This is an approximate subtotal for the construction of the crystallizer ponds and the hydraulic system to pump brine to them.

The other investments are the following:

- Grinding plant, bagging and packing (diagram annexed)
- Pay-loader
- Warehouse for processed salt
- Office, dining-room, shop
- Vehicles
- Access, roads.

L. Management of Brine, Harvest, Storage

Salt produced by this saline will be utilized to process it in a simple functioning grinder, that is, without process of washing and drying of the salt. Therefore, its crystallization process must be carefully controlled to avoid the addition of foreign salts that might contaminate the final product. To that effect, it is convenient:

1. To feed the crystallizers only with brine that has reached the saturation point, that is 24.5° Bé, to avoid the lesser contents of calcium $CaSO_4$ in the salt.

2. To daily control the concentration of the crystallizers and avoid the precipitation of magnesium Mg (do not reach 29.5° Bé).

3. Considering that the sustenance of the floors of the crystallizers is excellent, but is formed by coralline residue that normally is trapped in the inferior surface of the salt crust when the harvesting is made, in order to avoid that it will be necessary to leave a crust of countersalt with a width up to 10 cm. high, to guarantee the cleanness of the harvesting.

The harvesting process recommened is the following:

1. To empty the crystallizers until the residue of brine is totally drained.

2. To cut the superior crust of exploitable, being careful not to damage the countersalt, put it in a longitudinal way, pick it up with the pay-loader and carry it with the dump trucks up to the draining and drying yards near the roofed warehouse.

3. All the preceding steps will be made during the summer to avoid the dissolution of the salt, especially the countersalt crust that should be covered with saturated brine immediately after the end of the harvest.

4. The drained salt in the yards will be loaded by the pay-loader over the hopper of the inclined conveyor to pile it up within the roofed warehouses, to avoid its erosion by the effect of the winter strong rains and to guarantee its utilization during the whole year (3,000 MT cap.)

The type of parabolic warehouse is the most recommended for the stocking of the bulk and refined salts, due to the space economy and the possibility to carry them pre-fabricated to Kiritimati Island.

It is recommended to build modular sections that allow future increase of its capacity.

When the planning of the solar salt is made, the most strategic place will be chosen to establish the industrial zone, offices, deposits, shops, salt processing plant, streets, sidewalks, etc. It will be very important the following:

a) highness over sea leavel to guarantee the drainage even during strong rains;

b) orientation of the buildings having in mind the wind direction to avoid the negative effects of the rain and the air;

c) adequate concentration to take advantage of the distribution of the services: water, light, sewer, etc.;

d) access facilities for the entrance of the harvested salt and the exit of the finished product to the warves.

M. Artemia Production in Christmas Island

The possibility to produce Artemia in a commercial scale in this atoll was raised for the first time by Dr. Phillipe Helfrich, currently a Marine Biologist for the Hawaii University. He has made important studies in the decade of the 1970's on the ecological conditions in some lagoons where brine shrimp developed. He began the fertilization studies of the brine to produce enough food (microscopic algae) and sustain great populations of Artemia.

These studies required considerable efforts and money since, besides the experiments and analyses made in the field, hundreds of tons of fertilizers were sprayed over the lagoons, communication channels between ponds, floodgates and access roads were made and also a small packing machine to process the cysts obtained in some lagoons was built.

For reasons not well known, the project was paralized and part of the installations are utilized as fish farms by the

Ministry of Natural Resources.

Undoubtedly, one of the reasons to prevent the presence of great quantities of Artemia (commercial production) is the scarcity of food, constituted by the microscopic algae. In the salines, where the presence of Artemia is abundant, micro algae are also abundant, in order to serve as the grazing of Artemia. It is always observed in the different ponds, that the waters acquire yellowish, reddish or other colorations. These colours are caused by the different species of micro algae that form populations of millions of cells per litre which, of course, feed the Artemia, eating each Artemia thousands per day. There are 30,000 Artemia per cubic metre in the ponds with a good primary production.

In Christmas Island (Kiritimati) the natural conditions for the feeding of Artemia are limited. The atoll is in the centre of the Pacific, and for thousands of kilometres there are no discharge of rivers or marine continental waters that could provide nutrients. On the other hand, the sea bottom around the atoll is thousands of metres deep, which prevents the upwelling phenomena through which nutrients from the bottom are lifted up to the surface by the currents.

A proof of the scarcity of nutrients and the subsequent scarcity of micro-algae and, in general, of phytoplankton and zooplankton, is shown by the transparency of the water surrounding the ocean and within the brine lagoons (ManÜlu Lagoon, for example). During the visit to the atoll, snorkeling was made in the ManÜlu Lagoon to knwow better the depth and salinity of the brine in nine stations. The results are in the Annex . The transparence of the water was notorious and there was no seeing Artemia population due to the presence of fish because of the low salinity.

All the bottom of the Manülu Lagoon is covered by a jelly layer of 20-80 cms. thick of bright orange colour (Photo 10-11). The bottom, biologically speaking, is constituted by mucilagenous colonies of benthic cianophyta that covers eight kilometres of the floor of the Lagoon. These colonies do not serve as food for Artemia.

- Possibilities of Exploitation of Artemia on Short Term

We could take advantage in dividing the Manülu Lagoon in two sectors. The Northern sector, with more concentrated brine (15-24° Bé), could be utilized to develop the big populations of Artemia. Inorganic fertilizers would be applied to encourage the growth of micro-algae. The flood gate between the Southern and the Northern sectors will be used as a filter and would serve to control fishes and Artemia predators currently present in the Southern sector because of the low-salinity water.

The volumen of the Northern sector can be estimated in several million cubic metres of brine.

With a good treatment of regular fertilizations, an effective change of water in the pond cultures (through the pump stations) and an adequate knowledge of the population dynamics, it can be predicted a commercial production that can exceed in terms of economic income, the production of salt in the 25,000-tpa project.

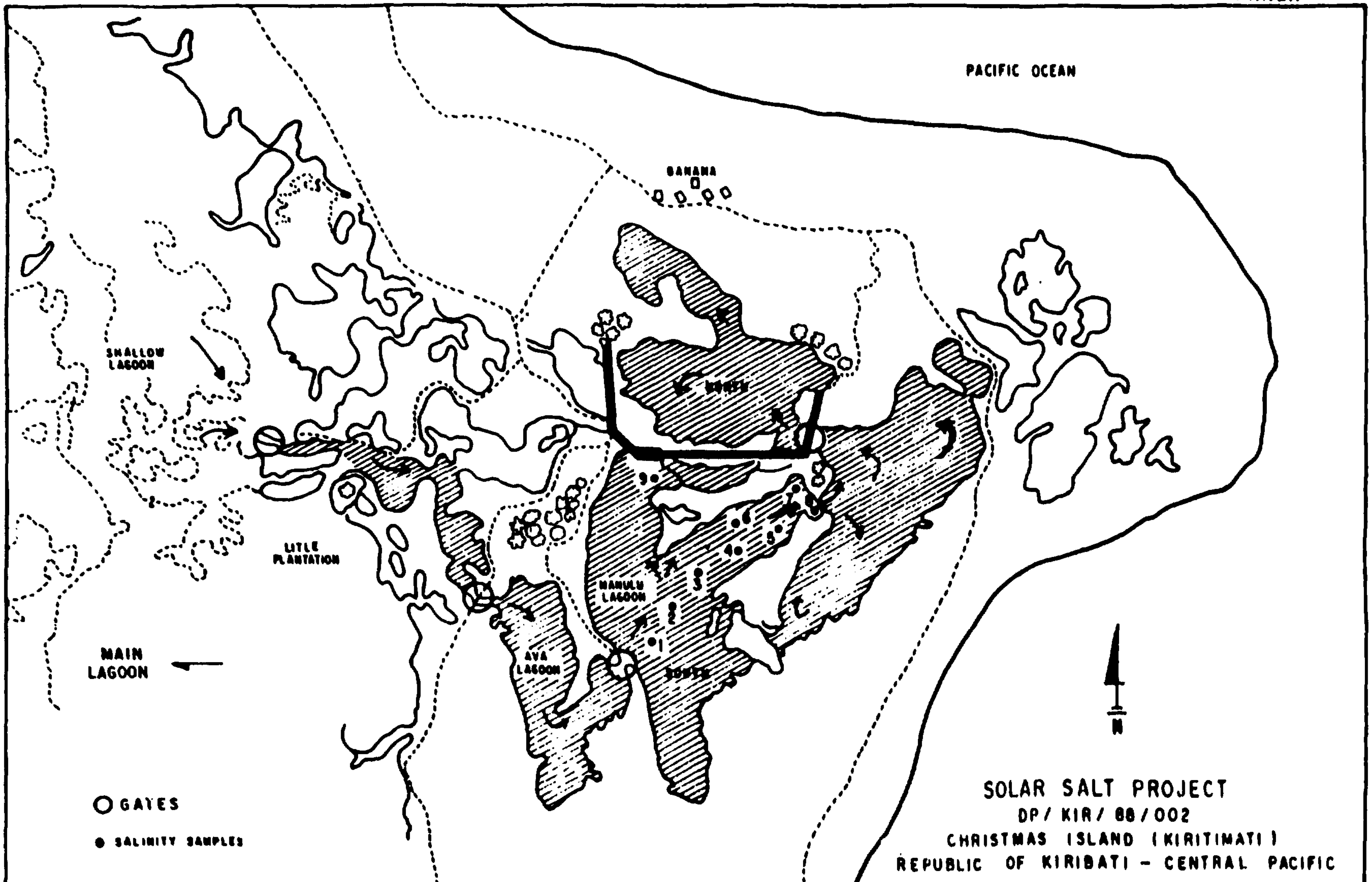
The proposition in relation to Artemia is that first the circulation of brine be consolidated by means of the construction of the separating wall dikes in the Manülu Lagoon and then the presence of predators is controlled, especially with the management of the salinity in the Northern sector. Finally, the fertillization process which costs will decrease with the increasing traffic of vessels, which will carry the salt from the projected 10.000 tpa plant and its future extensions.

Héctor Teruel Bullido

MANULU LAGOON

LOCATION OF PILOT PLANT AND PROPOSED SEPARATOR DYKES

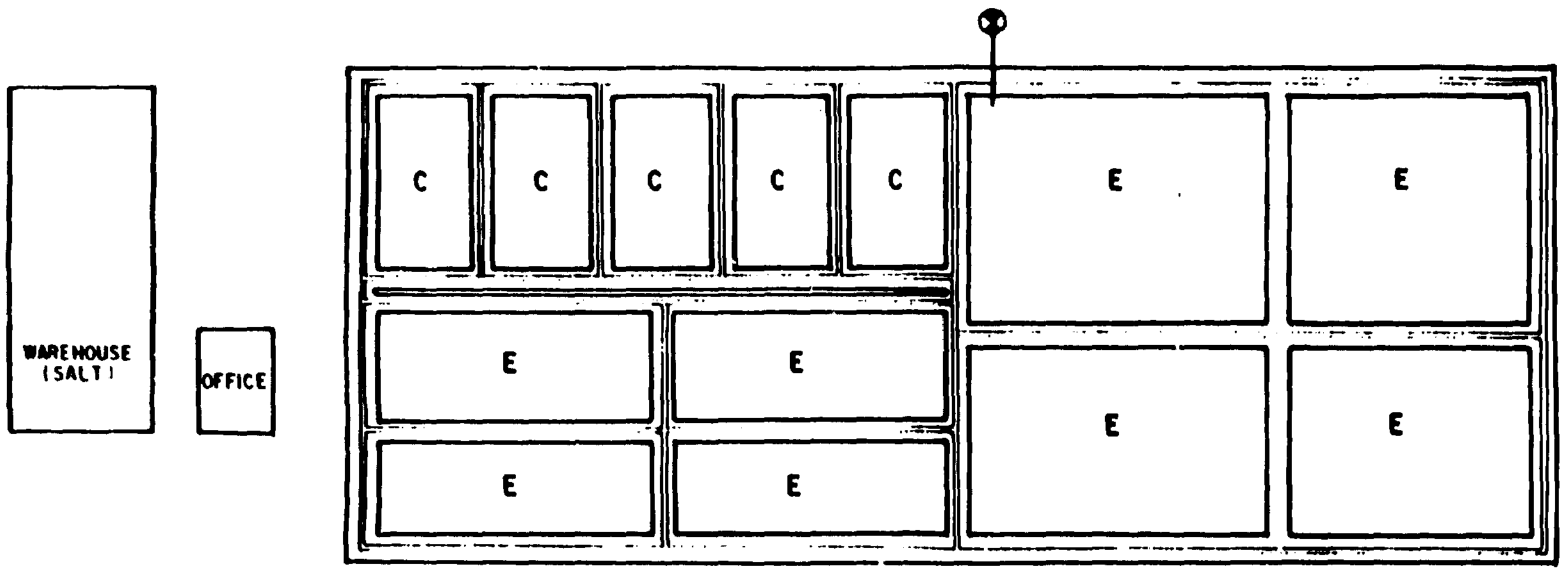
ANNEX



SOLAR SALT PROJECT
DP/ KIR/ 88/002
CHRISTMAS ISLAND (KIRITIMATI)
REPUBLIC OF KIRIBATI – CENTRAL PACIFIC

HECTOR TERUEL
UNIDO CONSULTANT
SEPT 1989

PILOT PLANT 500 TPA
(PROPOSSED 2500)

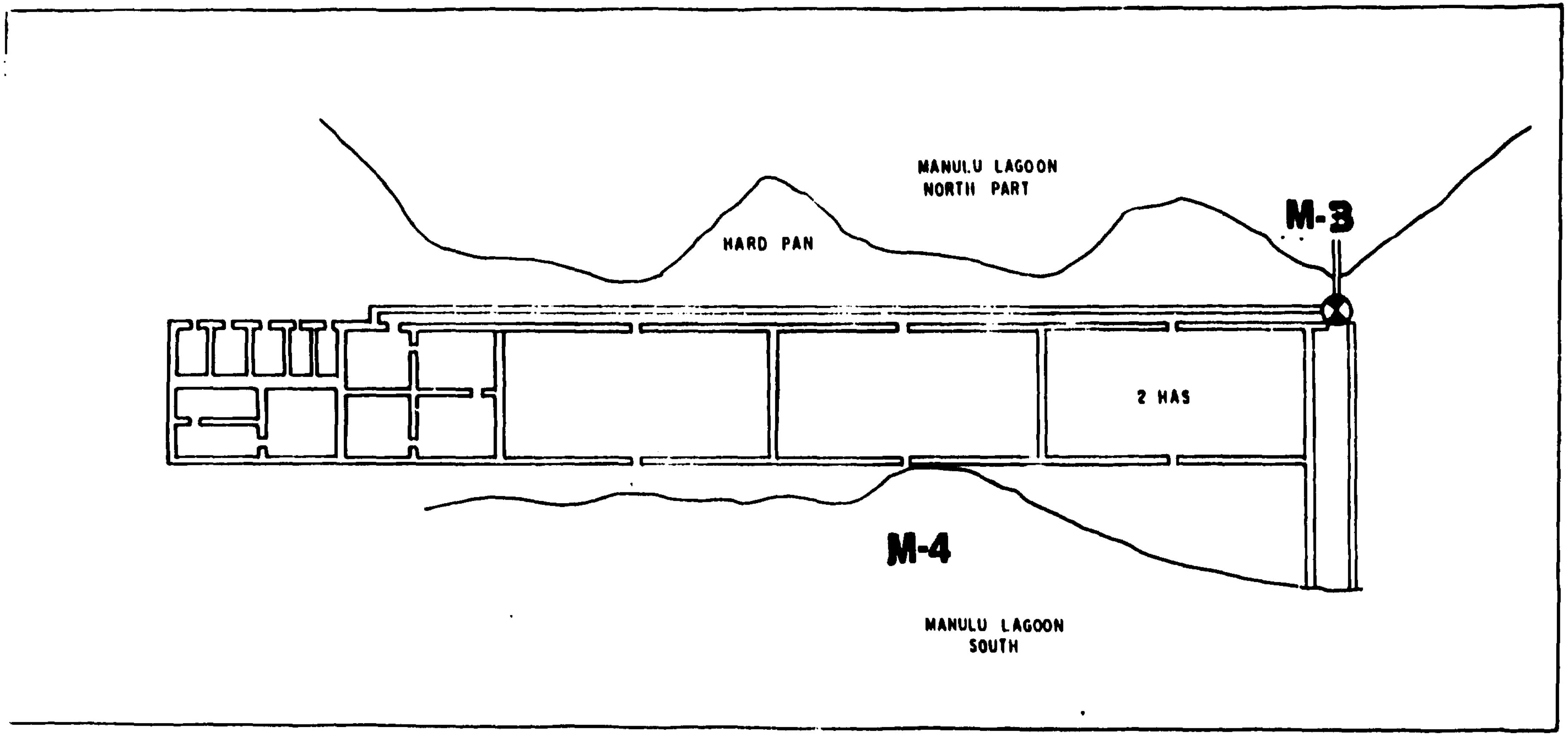


C = ACTUALLY CRISTALLIZER
E = " " " EVAPORATORS
C + E : PROPOSSED CRISTALLIZER

SOLAR SALT PROJECT
DP/KIR/88/002
CHRISTMAS ISLAND (KIRITIMATI)
REPUBLIC OF KIRIBATI - CENTRAL PACIFIC

HECTOR TERUEL
UNIDO CONSULTANT
SEPT 1989

SOLAR SALT PROJECT 10.000 TON PER YEAR
(8 HAS CRISTALLIZER PONDS)



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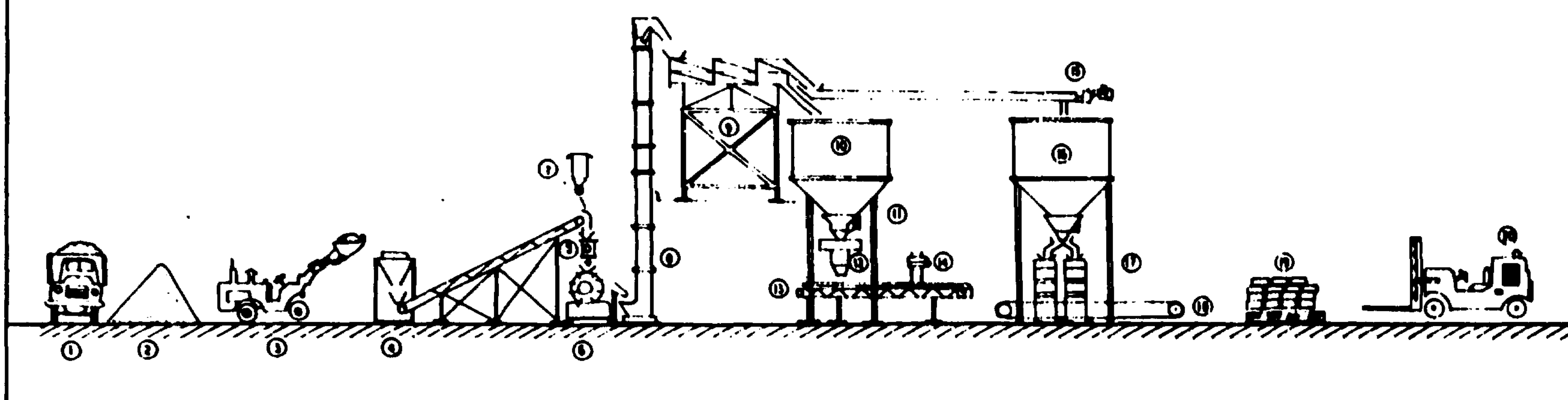
SALT GRINDING
FUNCTION DIAGRAM

ANNEX

LEGEND

1. DUMP TRUCK
2. SALT IN THE SILO
3. PAY LOADER
4. FEEDING MILL-HOPPER
5. HAMMER - MILL
6. DISC - MILL
7. ADITIVE DOSAGE
8. BOWL LIFT
9. SIEVE
10. SILO FOR BULK SALT
11. VIBRATING CONE
12. BAGGER
13. BAGS TRANSPORTING
14. BAGS SEALER
15. ENDLESS TRANSPORTING
16. SILO FOR FINE SALT
17. PACKER MACHINE
18. PACKETS TRANSPORTING
19. PADDLES
20. HOIST



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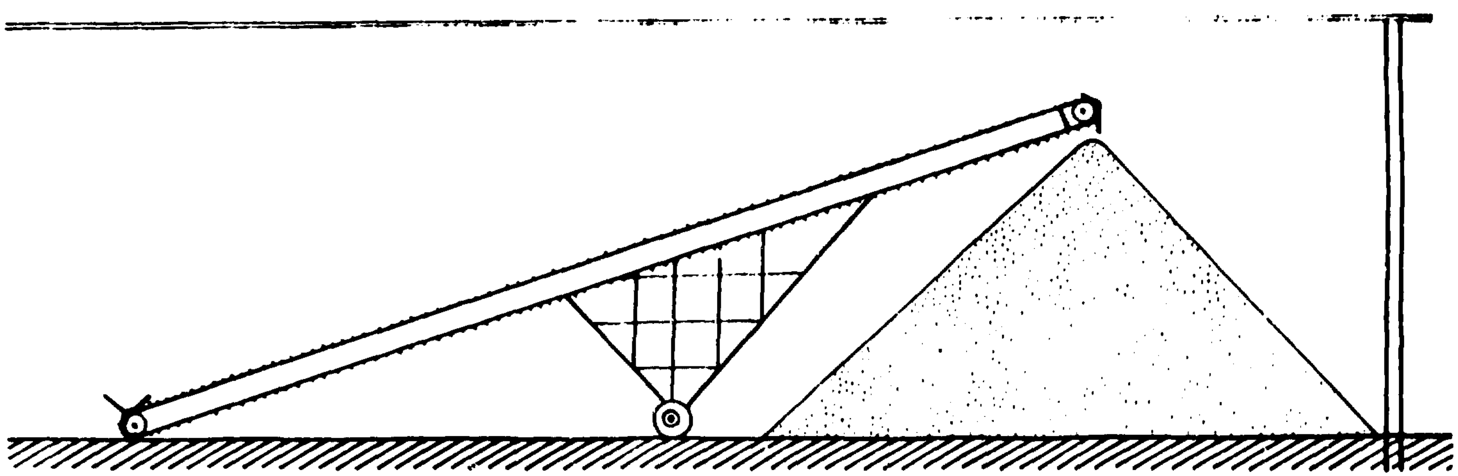
WAREHOUSE FOR STOCKING BULK SALT WITH MOVILE ENDLESS TRANSPORTING

ANNEX



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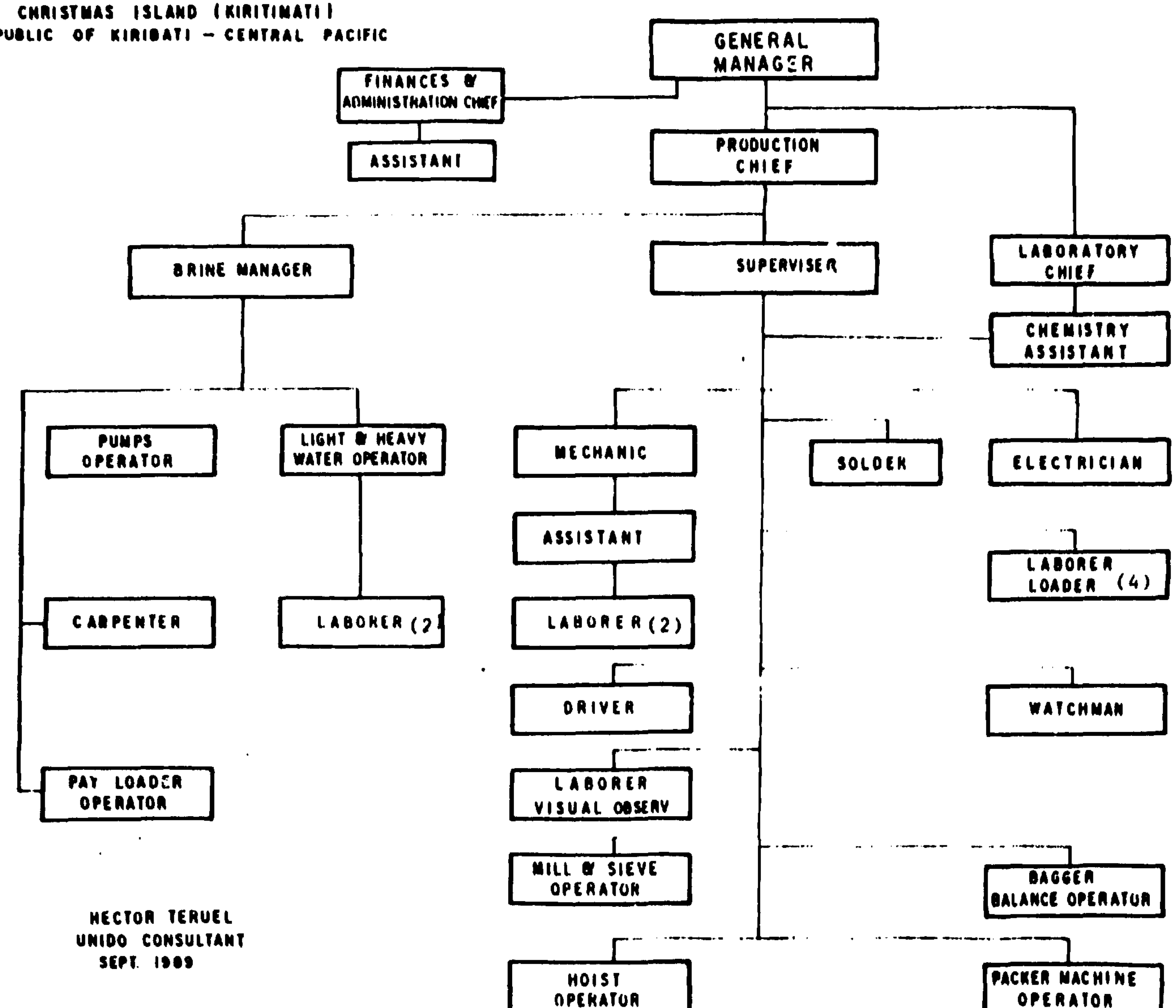
ORGANIGRAM 10.000 T.P.A. SOLAR SALT PLANT



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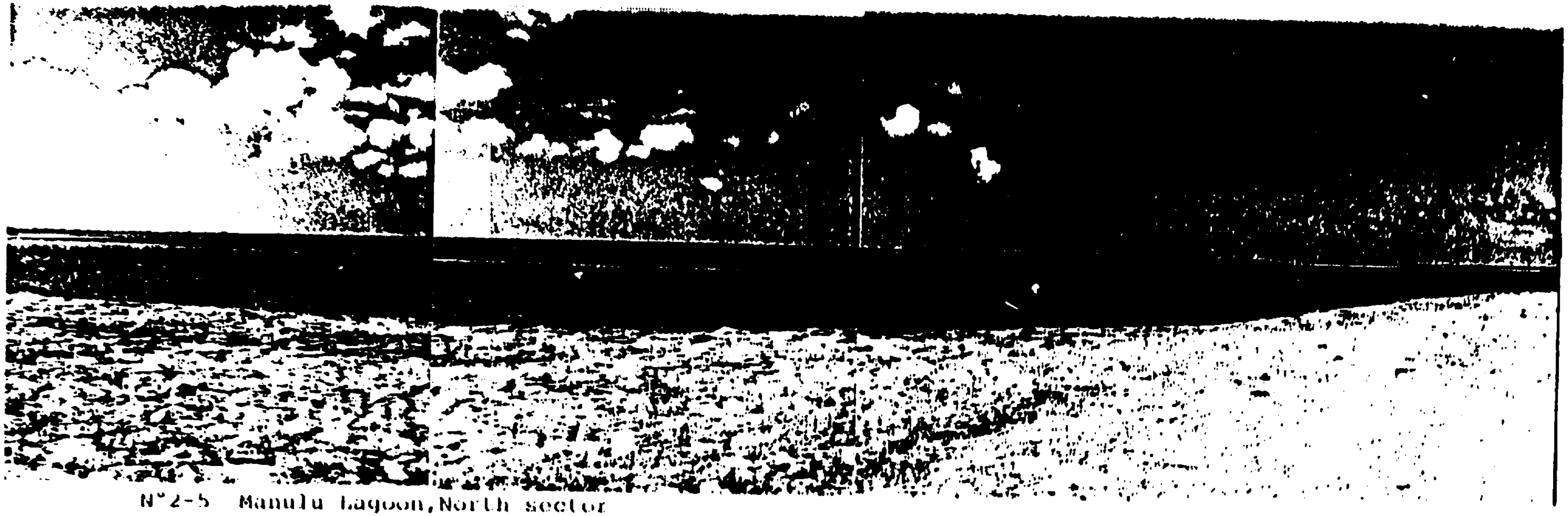
TOTAL 30 PERSONS

N°1. Manulu Lagoon. In the bottom left,warehouse for salt of pilot plant. In the horizon from West to East,the hard pan divide the lagoon in two section: North and South. In very high tide the hard pan is covered by the brine forming only one lagoon.

KIRITIMATI- Republic of Kiribati.



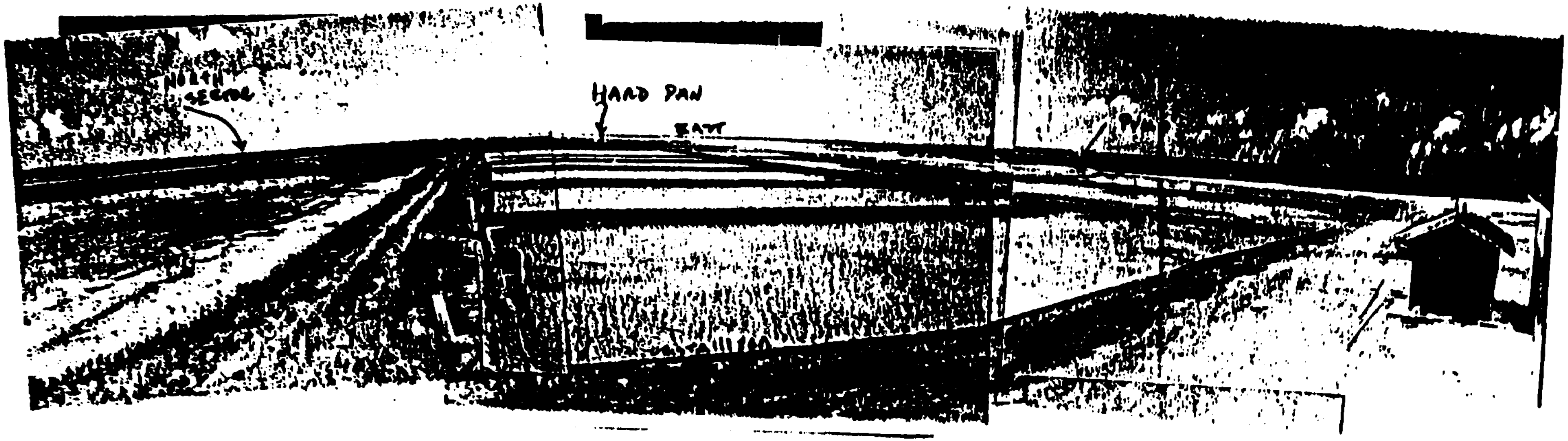
N°2-5 Manulu Lagoon,North sector

Aerial wiev north part Manulu Lagoon.

Central part M.Lagoon.Average depth 4m.

N° 6 Pilot Plant for the production of 500 tons/salt per year.In front the five cristallizers;in the bottom right ,Manulu Lagoon area M-4.It can be observed the actually position of Lombardini pump 5". In the left side,Manulu Lagoon north sector,area M-3(high concentrate brine). In the center,trough the horizon, the hard pan which divide eventually the Lagoon in two sector.

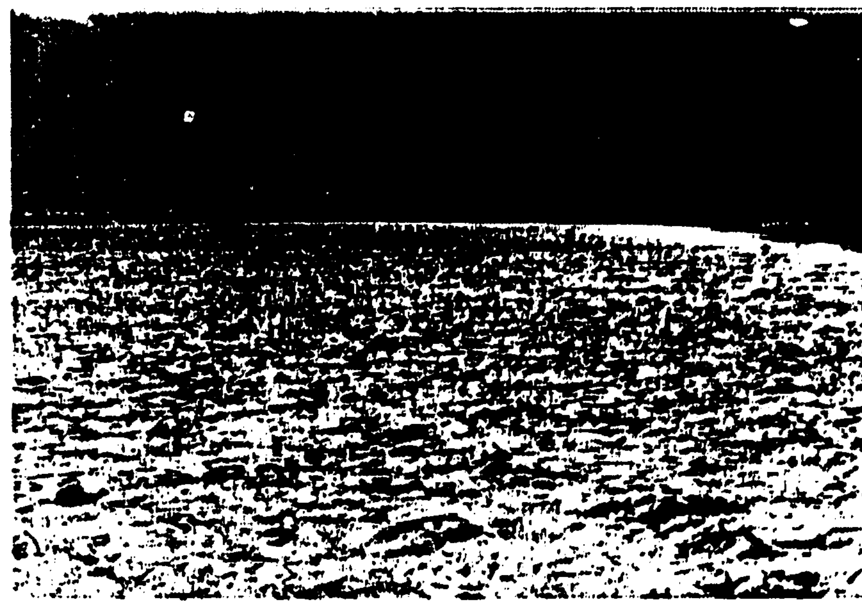
Kiritimati-Republic of Kiribati



N°7 Over the hard pan should be located the separator wall-dike,to divide the Lagoon in low-medium salinity brine and high salinity brine sectors.

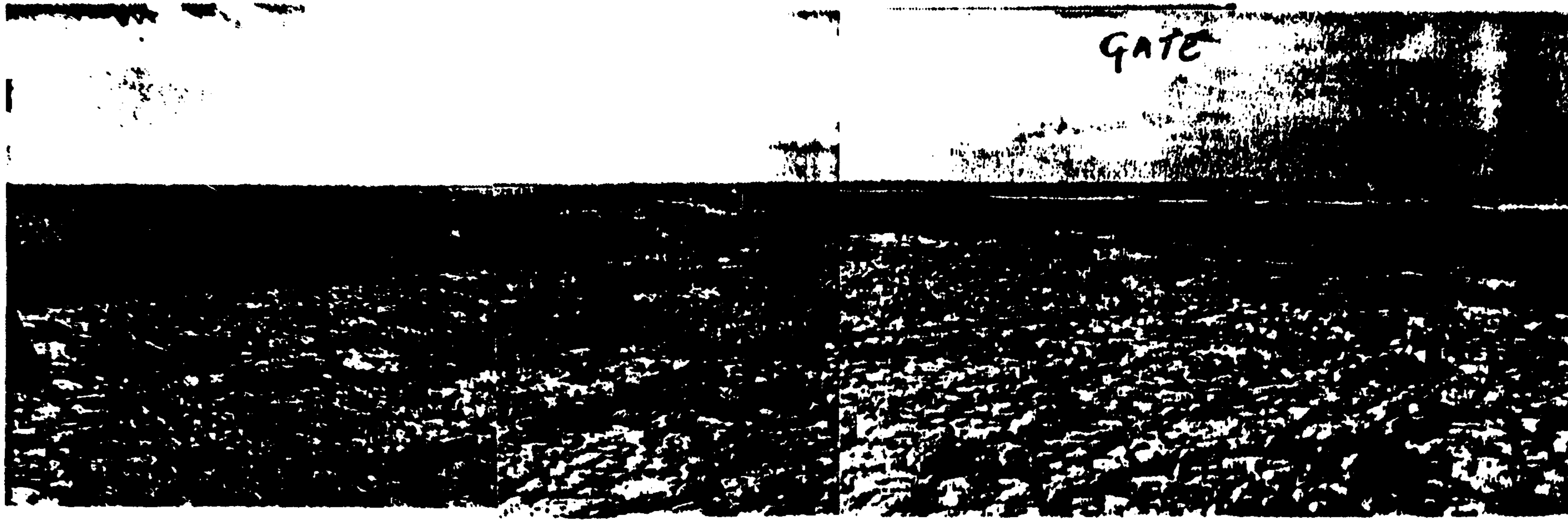
Kiritimati-Republic of Kiribati. Sept.1989

N°8-9. Left, separator dike initiated by Jenkins,85' stopped at 100 m from initiation. From here to the bottom of the Lagoon,around 2700 lineal meters.



hard pan for the location of separator dikes . It can be seen the sticks,representing the axis of future separator dike.

Kiritimati- Republic of Kiribati.



N°8-9. At the end of 1950 lineal meter from pilot plant, the hard pan reach a chanel 30 m wide which can be use for the controling of the brine flow between South and North Sectors.

N°8-9 cont. In the North-West part of Manulu Lagoon there exist a dangerous area where intrusion of low salinity water coming from Ava Lagoon, affect seriously the M-3 area, producing the dilution of the brine stocked there. A separator dike of 1000 meter length, as show in the picture, should be built in a short time possible.

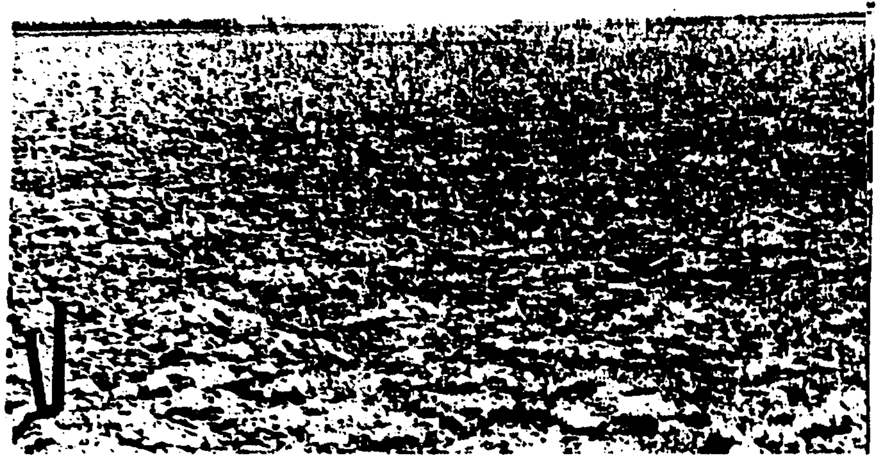
N° 10-11. left; bottom mats of microalgae covering 8 square kilometers in Manulu Lagoon.

A sample of muscilagenous mat of microalgae(Benthic cianophyta)

- 41 -

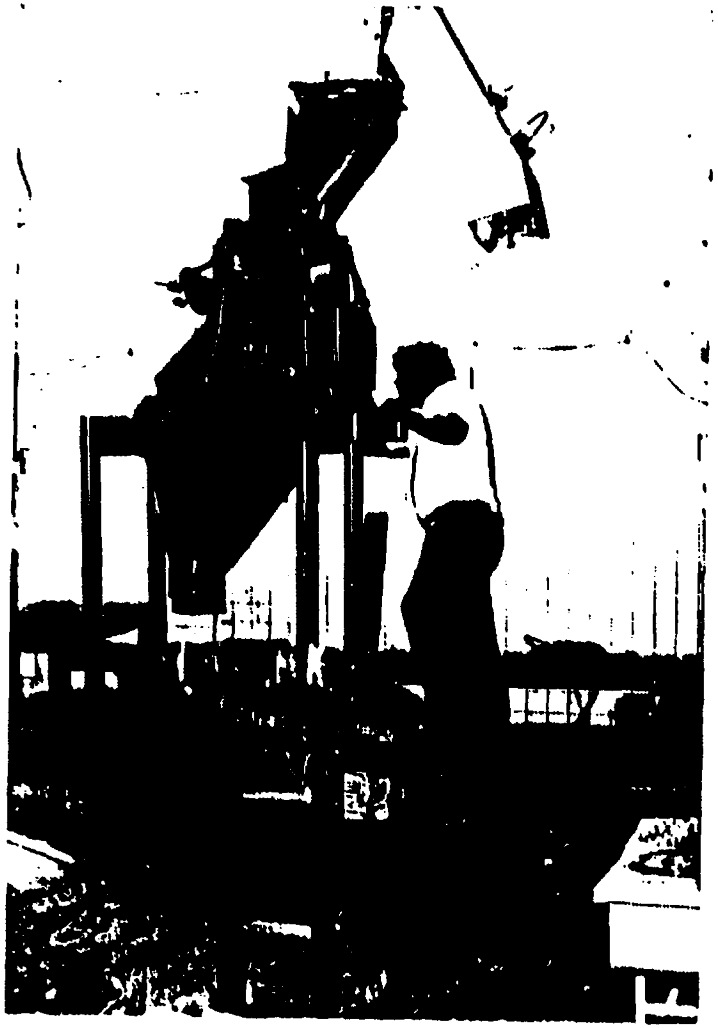
N° 12-13

Left; Marked perimetric area for the new six hectares of cristallizer, ± 650 m lenght.



Marked wide of new cristallizer proposal for 10.000 tpa project. ± 150 m

Kiritimati- Republic of Kiribati



N° 14-15. Top, bagger machine. Libra, Germany
300 bags 25kg/ per hour.

Example of packing machine. Woodman, USA
40, 1kg bag/ per minute