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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
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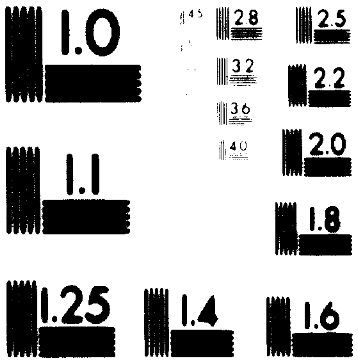

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SALT PRODUCTION AND -PREPARATION PLANT
OF THE
COMPANHIA NACIONAL DE ALCALIS (CNA), CABO FRIO, BRAZIL

FINAL REPORT

prepared by

dr.-ing. S. Galimberti and Mr. W.F. Leuner (dipl.-ing.)

of the

DEUTSCHE BERATUNGSGESELLSCHAFT FÜR SALINENTECHNIK MBH. (DBS)
MUNICH - SELIGENSTADT

on behalf of the

UNIDO, VIENNA

according to contract 70/59.

Dated January 1971

1. Synopsis

At the Solvay Soda plant of the Companhia Nacional de Alcalis (CNA), near Cabo Frio (State of Rio de Janeiro), salt is one of the basic raw materials used in its production process.

The meteorological conditions of this area and some of the specific local conditions make it difficult to extract the necessary quantities of salt from the almost unlimited supplies of the nearby Araruama lagoon.

For this reason the following features had to be examined:

I - The present state of salt production

II - The possibilities of taking immediate steps to increase production

III - The usefulness of the expansion plans to increase salt production, which are being worked out at present by CNA

IV - The possibilities to increase production and improve rentability, by adapting modern techniques and changing process technological steps.

V - The possibilities of a wider range of uses for the vacuum salt produced

VI - The possibility of using the by-products derived from the brine and mother liquor, respectively.

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3. Introduction

The Companhia Nacional de Alcalis has erected near Arraial do Cabo, 13 km from Cabo Frio, in the State of Rio de Janeiro, a soda ash plant, which operates according to the Solvay process. Along with this, salt plants, caustic lime and lime water plants were also built.

The plant's capacity is of approximately 100.000 tons per annum of Solvay soda, with the possibility of an increase of 20 %.

The plant's raw materials come from the nearby Araruama lagoon. The supplies of lime are obtained by scraping the bottom of the lagoon which is covered with a 0,6 to 1,2 m thick deposit of [illegible] shells. These shells are dredged out and after careful washing, are loaded on 200 ton motor-barges. These barges bring the shells to the plant through the lagoon and then along a canal in which the water level is kept artificially high enough to allow navigation.

The waters of the Araruama lagoon, which communicate with the Ocean through a narrow canal near Cabo Frio, are the source of supply of Sodium Chloride. These waters in fact have a medium density of 5,8° Bé, which is 35 % higher than in sea water. The density (Annex 2) is maintained almost constant throughout the year by the great extension and depth of the lagoon.

The salt production, however, is far below the soda plant's needs, so much so that it is necessary to purchase raw salt with the consequent economic disadvantages. The nearest Brasilian salt plants are [illegible].500 km away. The probable doubling of the soda plant would further aggravate this economic situation.

The CNA are, therefore studying means and ways of improvement and to increase the production of sodium chloride.

With these requirements and programmes in mind, and in the light of the present situation, the following study has been prepared by DBS, on behalf of the UNIDO, Vienna, for the CNA.

It is the object of this report to suggest suitable measures, in respect of the different sections of the plant, to achieve the required NaCl quantity and to reduce production costs simultaneously.

4. Findings, Conclusions and Recommendations (Preliminary section)

In the course of examining the salt production and salt preparation plant of CNA, DBS have noted the following main deficiencies:

- the very low concentration of the brine reaching the pre-concentration ponds (marneis). This leads to an easy multiplication of shells which damage the concentration surfaces and consequently reduce their utilization;
- substantial losses, within the entire solar plant due to seepage of the brine;
- the insufficient concentration of the brine in the storage ponds: when the brine enters the submerged combustion plant, it is only of 21° Bé;
- the crystallization plant (= submerged combustion plant) produces, in spite of the several changes and improvements, only 50 % of the capacity;
- the power consumption and the maintenance of the submerged combustion plant are too high;
- the vacuum plant produced only centrifuge humid salt.

Subsequent to the thorough investigation of these manifold problems in the various sections of the plant, DBS concluded to recommend the following stagewise measures to be elaborated in order to increase productivity:

- completion and expansion of large pre-concentration ponds now under construction along the lagoon;
- to seal off the concentration ponds, so to avoid loss due to seepage;
- to increase the brine concentration in the storage ponds to approximately 25° Bé;
- stagewise elimination of the submerged combustion plant (ultimately crystallization will not be necessary);
- simultaneously and parallel with above construction of a brine purification section;

construction of a new plant for the preparation of the by-salts, which are recovered during purification of the brine;

expansion of the vacuum-salt plant, producing high quality table- and industrial salt.

5. The present Brine and Salt Production Plant of CNA

(DBS flow-sheet No. 1)

CNA's equipment for brine and salt is of greatest importance in respect of the soda plant and the vacuum plant for the production of salt for human consumption.

In both of the further manufacturing stages, as a basic raw material purified and saturated NaCl brine is required.

In the existing plants two separate sections of equipment can be defined.

a) the solar plant to enrich the lagoon water of 5,8° Bé to a brine of 21° Bé and

b) the thermal-mechanical plant to enrich the brine from 21° Bé to 25° Bé, with connected crystallization-, dewatering- and salt solution plant, (which is the submerged combustion plant), along with brine purification unit.

In the following chapters the various stages of these two main departments will be described in detail, as per DBS flow-sheet No. 1.

5.1 Solar Evaporation

Solar evaporation takes place by exposing the water of the lagoon to the sun and the wind on the large surface of the evaporation ponds. These ponds cover an area of about 800 hectares and are divided into two different sections. The first is of about 500 hectares and is divided into numerous small ponds of 60 x 70 metres dimension, called "marneis". The banks are made of soil lined by boards held by small pegs, and wooden gates allow the movements of the water, of which the depth is under 10 cm. A series of canals feed the ponds and allow them to drain. This area is surrounded by draining canals of a lower level so as to prevent the outside water reaching the ponds themselves.

All the area on which the "marneis" have been built is of a sandy soil and therefore permeable. It is mostly fine white sand, with traces of black mud, and seldom containing clay. The bottom of the ponds are covered with algae, 2 - 4 cm thick, of a gelatineous consitency and a yellow-greenish colour degrading into black at the bottom.

The water, which is pumped from the lagoon, at a density of 5,8° Bé, reaches 7,5° to 8° Bé when pumped out. Approximately 3,600.000 to 4,000.000 cubic metres are produced, whilst 40,000.000 cu.m are pumped into the "marneis". A comparison of this data with the volume reduction of the brine, from 5,8° Bé to 7,5° Bé, the extension of the surface, and the average evaporation, (over 600 mm/year), shows clearly that the output of the ponds is really poor.

From the "marneis" the water is pumped to the second section of the ponds covering about 300 hectares of evaporation ponds called "concentradores", each of 40 x 30 metres dimension. These also include a series of very small ponds of 7 x 7 metres in size; brine thickness approx. 3 cm (cristallizadores), covering about 50 hectares, which, as their name clearly indicates, were originally built for producing salt. This section is also formed of a large number of very small ponds of a regular shape, divided by narrow banks, lined by boards, held up by small pegs and provided with gates which allow all the movements of the brine. Here too, the bottom of the ponds have an even surface, covered with algae. The depth of the water is kept even lower and rarely exceeds 5 cm. Here calcium sulphate incrustation can be found, which, for the limited brine thickness, prevents the free flowing of the water in the ponds and canals. To the calcium sulphate is often added the sand carried by the wind, which accumulates on the inner walls of the banks. Drainage canals protect the bottom of the "concentradores" from possible rising of the water bearing stratum.

From the 4.000.000 cubic metres that are, on average, pumped into this sector from the "marneis", about 400.000 cubic metres of 21° Bé density brine are obtained. Here too, the production suffers losses due to infiltration. In fact, from the 4.000.000 cubic metres at 7,5° Bé, one should, theoretically, obtain approximately 800.000 cubic metres of brine at 21° Bé.

5.2 Brine Storage at 21° Bé

The brine produced in the second stage of the solar plant (concentradores y cristallisadores) with a density of around 21° Bé is pumped from the pumping station (4) to the reservoir through an approximately 1,5 km long pipeline, having a diameter of 500 mm.

The pumping station, consisting of 3 pumps, two with a capacity of 720 cu.m./h and one with 360 cu.m./h. These can be operated in parallel so that the total capacity is around 1,100 cu.m./h. Because of gypsum deposits of up to 2.5 cm in the pipeline, only the capacity of one large pump, i.e. 720 cu.m./h, can be utilized at the present time.

The reservoir for the brine with a density of 21° Bé has a capacity of about 500,000 cu.m. It has been built by means of an earth dam on a slope near the plant. The bottom is lined with a thick layer of clay to prevent seepage. The banks are protected by stone wattle-work and a crust of calcium sulphate has formed on its surface. Removal of the brine and its transport to the thermal plant is accomplished by a floating pump.

In order to be able to save as much brine as possible in the case of a rain forecast, a smaller reservoir with a capacity of around 40,000 cu.m. is available. The enriched brine with a density of from for example 16 - 18° Bé is then pumped into this until the end of the rainfall.

Even though the pumping station (4) can convey large quantities of brine, the effective capacity is still dependent on the inflow from the large-area concentrating basins.

5.3 Brine Concentration from 21° Bé to 25° Bé (Nordac Flow Diagram 7654/B and 137504)

The brine from the storage basins is pumped at a density of 21° Bé into the first part of the submerged combustion plant for further concentration to about 25° Bé (theoretical quantity: 100 cu.m./h). The brine is heated to about 50 - 55° C in the plated heat-exchanger (H 5), which is fed 26 cu.m./h of water at about +85° C . (The hot water is produced through use of the condensate on the scrubber).

Because of the increase in the brine temperature the precipitation and incrustation of the $CaSo_4$ begins in this part of the plant. This causes decreased efficiency, making a weekly cleaning necessary. An originally installed reversal on this heat-exchanger had to be altered, since the pressure was too high resulting in leaks.

The pre-heated brine with a density of 21° Bé is then circulated and mixed with about 450 cu.m./h of brine with a density of 24.5° Bé and a temperature of 40° C, resulting in a brine mixture with a temperature of about 42° C and a density of about 23.5° Bé. This brine is then fed into the 2nd pre-heating stage consisting of 3 heat-exchangers (H2 - H4).

The heating is accomplished here in the same manner as described above using 700 cu.m./h of water at 85° C. The entire quantity of brine of 550 cu.m./h is heated thereby to about 60° C (theoretical temperature: 75° C), during the process of which calcium sulphate is again precipitated and becomes incrusted on the titanium plates of the heat-exchanger. As a consequence, these plates also must be cleaned weekly, since the efficiency falls, with the progressive incrustation, to 60 % in this time. The rated capacity is achieved only with completely clean equipment.

In the next phase the brine comes into the 3-stage pre-concentrator (1), in which the concentration is raised to about 24.5° Bé (theoretical density: 25° Bé). The method of operation of this plant is as follows: the heated brine is sprayed from above into the first third of the about 1[illegible] x 7.[illegible] x 9.6 meter large concrete pre-concentrator. 6 ventilators are built into one of the 7 meter broad side walls, while the other serves as the exhaust side. Around 32.000 cu.m./h of fresh air are blown through the entire pre-concentrator across the direction of flow of the brine, and as a result the trickling-down brine mist gives up a portion of its water content ot the drier air. Rubber strips, which are suspended vertically to the air flow, provide for a good mixing of the air and the brine. The brine collecting in the sump of the 1st stage is again pumped upwards and fed to the 2nd and 3rd step of the plant in the manner described above, in other words, there is a twofold recirculation of the brine.

With this process about 20 cu.m. of water per hour are withdrawn from the brine, which are conveyed through the forced fresh air to the chimney and removed to the outside with the smoke.

On the installation of the plant instead of the present rubber strips, timber rods with a cross-section of 4 by 4 cm were installed, however, the intervals between them were rapidly closed by the incrusting of the $CaSo_4$ and the efficiency was reduced to zero. In addition the timber rods which had to be pulled out upwards for cleaning became incrusted to a solid block which after closing down the plant practically had to be hacked out by mining methods. The rubber strips installed by the CNA represent an improvement because of their mobility, however, they must be constantly cleaned to ensure optimal operation of the plant.

A further difficulty developed in the pre-concentrator because the plastic filters attached to the discharge opening, which are intended to retain the brine drops, became incrusted to a solid wall through deposits of $CaSO_4$ and thus rendered the plant completely ineffective.

In this case also the operation can be maintained only through a weekly cleaning, despite this however the efficiency is reduced within 5 to 6 days to about 60 %.

During our tests the CNA engineers attempted to replace the plastic fibre partially with louvre-arranged boards in order to obtain longer operational periods. Whether this method will be successful can only be determined after it has been tested in operation for several weeks.

According to the planning for the plant the brine coming from the pre-concentrator with a density of about 24.5° Bé is to be conveyed to an overflow tank filled with Raschig rings in order to separate the $CaSO_4$. Since this operation was too expensive the Raschig rings were replaced by shells in arrangement with the supplier of the plant. After a short period of operation it turned out that here also the gypsum filled up the intervals and it became so incrusted that a large block was formed which had to be removed with compressed air hammers. The plant ceased to operate.

After these experiences the tank was rebuilt in such a way that now the brine flows freely through one part, whereas the other part serves as the washing plant for the plates of the heat-exchangers.

After leaving the tank the brine flow is divided in such a way that 450 cu.m./h return for pre-heating while 80 cu.m./h are directed into two storage containers, each with a capacity of 1000 cu.m.

With reference to the brine pre-heating and concentration plant the following may be said in summary: the 4.5 - 6.5 g/l $CaSO_4$ contained in the brine with a density of 21° Bé hampers the whole operation considerably, reduces the efficiency of the entire plant and causes high maintenance costs. The assumption of the planners that the $CaSO_4$ would first be precipitated in the gypsum retaining tanks must be regarded as erroneous.

5.4 Salt Crystallization by the Submerged Combustion Plant (Nordac Flow Diagram 7654/b and 137504)

The brine which has been concentrated to a density of 24.5 - 24.8° Bé and cooled is withdrawn at the rate of 80 cu.m/h from the above-mentioned brine storage containers and heated in the heat-exchanger (H 1) again to a temperature of about 60° C and then pumped into the evaporators (E1 - E4).

According to plan about 4.2 tons of NaCl per hour are to crystallize of 20 cu.m. brine/hour. Each of the evaporators operate under atmospheric pressure and in doing so, about 14 cu.m. of water evaporate per hour.

The design of this type of evaporator is unusual for the saline industry. It consists of a conical boiler into which 3 oil submerged burners are inserted from above about 20 - 30 cm deep into the brine. The crystallization process is effected through direct heating by means of a flame, whereby the amount of brine in the boiler is controlled by a regulating system. The smoke fumes arising from the combustion as well as a part of the controllable air of combustion escape through the brine and then reach the scrubber. An exchange of heat is made here in such a way that the hot smoke fumes warm sprayed water in a counterstream and are thus cooled off. The hot water is used in the heat-exchangers to heat the brine. The heat recovery is said to amount to about 50 % of the oil calories.

When the plant was put into operation the scrublers were provided with a filling of Raschig rings which, however, had to be removed, because also here incrustations developed. The operation is now accomplished with five cruciform arranged spray tubes without any filling and the same effect is obtained.

The transport of the salt crystals precipitated in the lower part of the evaporators and the mother liquor to the decanters (D1 - D4) is made by an air-lift. The temperature of this salt-brine mixture is around 90° C.

The separation of the salt crystals from the mother liquor is made in the decanters. The salt sludge collecting in the lower part of the conical container is kept in motion by a paddle agitator, and a laterally attached Mohno pump conveys it to the pusher centrifuges for further dewatering. The very fine salt (average grain size 0.3 mm) leaves the pusher centrifuges with a moisture content of around 3 - 4 % and is then rinsed with sweet water in a dissolving basin. Combustion residues float on the surface of the brine due to this process.

At this production stage the brine has been processed to an extent that it can be fed to the chemical purification plant, which is installed ahead of the soda plant.

The operation of the above outlined crystallization plant presents major problems.

Through the direct heating of the brine the sulphur which is 1 - 2 % in the heating oil gets into the liquid so that chemical reactions take place producing sulphur compounds in the mother liquor.

The ph-value therefore sinks to 5 - 6 and the aggresive lye causes heavy corrosion on the following equipment, particularly in the pusher centrifuges. This means that the screening plates of these pusher centrifuges only last about 3 moths. By then the holes have become so enlarged that the salt is thrown out with the filtrate.

In order to reduce this, calcium hydroxide (about 3 - 4 kg per ton of salt) was added and the sludge is cooled with brine at 25° C before the entry of the salt into the pusher centrifuges. On the pipelines and pumps following the evaporators heavy corrosion damage occurs also after a relatively short operating time. The control and the monitoring, particularly of the crystallizers, is very difficult, since a part of the instruments do not work or cannot resist to the operating conditions.

If for example incrustations occur in the regulating system of the evaporators, the level of the brine can sink rapidly. The combustion gases then reach the brine intake directly and cause such incrustations that the pipe can become clogged.

In the decanters fractures occur on the obviously too weakly constructed agitators. Further the Mohno pumps also lead to complaints since breaks often occur on the driving gears. The CSA engineers now intend to construct a pilot plant with a hydrocyclone to avoid use of the decanters.

All of these difficulties mean that the entire plant can only be operated under most difficult conditions and cannot reach its planned output. Frequent repair and cleaning work lead to long down-times and excessive maintenance costs.

Finally there is the high power consumption, namely around 80 kWh per ton of salt as well as around 230 - 240 kg of oil per ton of salt. (The planned oil consumption was to be 210 kg per ton of salt). From the operating records it can be seen that the oil consumption has also reached the figure of 300 kg per ton of salt and higher.

The plants as described under points 5.3 and 5.4 could produce 80 - 100.000 tons of salt, during a working time of 8.600 hours. In the submerged combustion plant the number of personel is 34 of which 9 - 10 persons are working during one shift.

For the above quantity of salt the 21° Bé brine produced is insufficient. For this reason such brine must be put into the plant at 25° Bé, which is produced of purchased sea salts from other seaworks, at least 2.500 km away.

5.5 Salt Crystallization by Vacuum Evaporation Plant (CNA Flow Diagram 1753 A 2)

The CNA procured a vacuum plant consisting of two evaporators for the production of caustic soda through evaporation of an impure 10 % solution which comes from the soda plant. This vacuum plant has not been used for the foreseen purpose.

Instead they started to produce vacuum salt for human consumption in this plant. As basic product the brine with a density of 21° Bé from the storage tank was used, which was fed directly to the heating chambers of the parallel operating evaporators. Each evaporator is designed for an output of 25 tons per day. Because of gypsum deposits in the equipment, however, only 20 tons per day were attained, that is a daily production of 40 tons.

In obtaining this the use of live steam at 2,5 ata amounted to about 10 tons per ton of salt.

On the test day the values for the vacuum (in mm of mercuryU were read from the two evaporators as follows:

Evaporator 1	640 mm	Pump	670 mm
Evaporator 2	580 mm	Pump	690 mm

The vapour condensate is deposited in the condensers (B 5, B 6), which are cooled by seawater (around 240 cu.m./h) and the condensate is fed into the tank (S 7).

The salt produced in the evaporator is pumped to a decanter and then reaches a pusher centrifuge, in which it is dewatered to about 2 % residual moisture.

The centrifuge humid salt then falls without further processing directly into a ground-level chamber, in which it is filled by hand into 60 kg sacks and loaded onto trucks.

The work force of the plant is 6 men per shift, a total of 24 workers.

The quality of this evaporator salt is suitable for table salt according to the analysis (see Annex 3). Since it is not dried and not free flowing, however, it cannot be sold as high-quality product. The cost for delivery in 60 kg sacks is 105.39 Cruzeiros/ton, ex works.

As the production costs in this plant are too high, the engineers fo the CNA are contemplating to convert the parallel operating evaporators into a two-stage flashing chamber evaporator plant. We were asked to give our opinion on this or make recommendations.

Our detailed comments are in point 8.

6. Possibilities to improve the production and increase the yield of solar evaporation plant

The foregoing description (as per 5.), the visit to the plant and talks with the technicians of the plant, have brought to light that some sectors of the salt production are not working satisfactorily, with serious consequences on the working of the whole plant, and on costs. A close examination has, therefore, been made in order to be able to propose the taking of appropriate measures.

As the problems concern a solar plant, first of all the meteorological conditions have been looked into.

6.1 Possibility for better utilization of meteorological conditions

The CNA have a well equipped weather station. It has, therefore, been possible to examine a complete series of data concerning the temperature, the winds, the humidity, the rainfall, the insolations and the evaporation. It is evident at a first glance that the climate is temperate, with small seasonal differences. In fact, the monthly average temperatures between 1960 and 1969 reach a maximum of 30,5° C (in March) and a minimum of 17,1° C (in July), whilst the average annual temperatures are between a maximum of 26,1° C and a minimum of 19,6° C.

Please find all the data on the evaporation and rainfall for the period July 1950 - June 1970 in the attached Annex 3.

During this period the yearly averages of evaporation and rainfall stand at 1,425 mm and 756,7 mm, respectively, with evaporation exceeding rainfall by 668,2 mm. The disparities between these averages are, however, considerable so much so that in some years the total rainfall has been equal to the yearly evaporation. (Please see Annexes 4 and 5).

These data alone are enough to show that the meteorological conditions at Cabo Frio are not suitable for salt production in a solar evaporation plant. A more detailed study has confirmed this first impression. In fact, the tables as per Annex 4 and 5, indicating the rainfalls and evaporation, show the distribution of rainfalls over the year, even in the peak months of the evaporation period. The enclosed Annex 6, which indicates rainfall during two average years (July 1968 to June 1970) confirm this.

Insolations and winds are also distributed uniformly throughout the year. Eighty percent of the rain falls during the night, when the wind drops.

Contrary to most regions where solar salt is produced, there is no long period of dry and hot weather. There is merely a period in which the weather conditions improve slightly. During the good season, the average daily evaporation rate is very low (only 6 mm against 12 - 15 mm of the Mediterranean area). This low figure of evaporation is on the borderline below which salt cannot be produced at all. By these low figures one has to consider rainfall even in the productive season.

Considering the weather conditions at Cabo Frio, therefore, the possibility of producing highly concentrated brine by solar evaporation of sea water is limited. Production increase by means of solar evaporation can only be practicable under prevailing weather conditions if the advantageous periods are utilized to their optimal extent. For this object the following ways could be adopted:

Raising the brine concentration at the entry to the solar plant;

increase of the specific evaporation rate;

to reduce the loss of concentrated brain due to heavy rain.

Please see indications to these possibilities under point 6.2, 6.4 and 6.6.

6.2 Special Techniques

On account of the special weather conditions of this area, as described above, a special saline technique was developed and further improved, which is based on Portuguese experience.

It is necessary to take full advantage of the meteorologically favourable periods by speedy action. Contrary to usual practice it is necessary to keep the water at the lowest possible level. This in turn would lead to highest possible daily increase in density.

This rapid production system protects the brine from the rain. The evaporation ponds are consequently very small and sometimes subdivided by boards so as not to leave unbroken spaces open to the winds.

In this way, waves do not form and splashing is reduced; this also eliminates losses through brine splashing over the banks and seeping away into the highly permeable soil.

On rain free days the concentration of brine takes place rapidly in shallow ponds: within 4 to 5 days from 12° Bé to 21° Bé. It is, therefore, essential to bring the concentrated brine quickly out of the ponds into the deep storage ponds before it starts raining again.

For this reason deep collection ponds should be constructed within the concentration ponds and/or those available should be put into use. Over and above this, the pipeline from pumping station (4) to the large storage containers by the factory must be kept free of incrustation so to ensure greatest conveying capacity.

6.3 Impermeability of soil

The sandy nature of the soil on which the factory and the ponds are built is yet another unfavourable condition. It is in fact due to infiltrations that even the limited and expected results are not always achieved. A thick impermeable carpet of gelatinous algae, which lines the sandy foundations of the ponds makes them almost water-tight. Waters must be shallow and move quietly to allow algae to settle on the bottom of the ponds. Any counter-pressure on the foundation of the ponds by elevation of the sea-water stratum should also be avoided. This would lift the algae and would bring about the cracking up of the protective impermeable lining. For this purpose drainage canals have been built around the evaporation area.

Another important source of loss through infiltration may be attributed to the presence of shells which enter from the lagoon with the water and then perforate the algae lining. This to reach the sand underneath, which is their natural environment. The shells thus damage the protective coating, through which water is lost. Only the increase of the density prevents these shells from thriving.

6.4 Short term increase of production

The production difficulties of the brine are due to the unfavourable weather conditions and the permeability of the ponds themselves. It is essential, therefore, to reduce the great losses due to soil permeability to a minimum. Therefore, the algae must be well preserved.

A quick solution that the CNA technicians are studying at the moment is that of reducing the flow of the brine through the evaporation ponds. This could be obtained by feeding the ponds not in series but in parallel.

It has also been considered to stop the growth of the shells with chemicals until it will be possible to increase the density of the brine. This process may not damage the algae. With this in mind, samples of algae and shells have been examined by Prof. Renzo Stefani, Director of the Biological Institute of Cagliari University on request of DBS. The algae were found to be "cianoficee" belonging to the "chroococcacee" group similar to the "aphanothece salina". The molluscs are "lamellibranchia of Veneridi family".

Prof. Stefani holds the view that it is possible to eliminate these molluscs from the "marneis". In fact, once the ponds have been sterilized by temporary increase of density. New animals shall not enter as "veliger" with the water pumped from the lagoon. The water can be sterilized by various methods: insufflation of active chlorine, ultra-sound treatment, ultra-violet rays or with biological systems. Further studies and tests shall be necessary. Following those, one will have to decide which are the most appropriate methods of killing the larva of the lamellibranchia.

A reduction of infiltration could be achieved by adding small quantities of bentonite (a few grammes per cubic metre) to the waters pumped in the first evaporation ponds ("marneis"). The water would have to be only slightly troubled so that the bentonite should not deposit on the algae but should slowly seep through the sand in order to block same. It would perhaps be more economical to use instead of bentonite, the mud discharged by the plant. It remains, however, important not to damage the algae.

As mentioned under point 6, production of brine can also be augmented by increasing the specific evaporation rate.

Decisive factors like wind, quantity of rain, of insolation just as the composition of different salts in the lagoon water are factors that cannot be changed. However, extent of the use of solar energy may be determined.

By adding appropriate colour compounds to the brine during evaporation, a more intensive absorption of the infiltrating solar energy can be achieved. This, in turn, accelerates the evaporation of the solution. As seawater above 1.400 nm (nano-meter) absorbs rays strongly, the absorbtion under 1.400 nm (wavelengths) is of particular importance. The special colour compounds developed by the chemical industry for this purpose (Nigrosin WLN liquid and solivap green) show very good results in the range of 400 to 900 nm.

The concentration of colour compounds depends on the thickness of the brine layer. Thus, for instance, for a brine layer of 1 cm thickness 0,07 % Nigrosin WLN are required, whilst for a brine layer of 10 cm thickness only 0,007 % are required.

In the existing solar plant, colour compounds should only be applied in the "concentradores", because losses due to seepage are the lowest here. At a brine thickness of about 3 cm in this pond the concentration of colour compounds should amount to 0,021 %. The actual requirement of colour compounds should be defined on account of experiments carried out in the plant. This is necessary to maintain concentration of 0,021 % as constant, whilst brine is being pumped out of the pond.

In Italy and Australia this colour compound treatment leads to an increase of 10 - 15 % in the specific evaporation rate. The price of colour compound amounts in Germany to some DM 3.15 equalling roughly to Cruzeiros 4.15 per kg.

6.5 Possibilities of a Further Mechanization

In the process of modernization and mechanization, the operations most affected have been the harvesting, the transporting, the washing and the stockpiling of the solar plant. This, however, does not apply to the CNA plant, where the process is limited to concentrating the lagoon water.

In this sector modern techniques have caused efficient pumps to be installed and a road network to be built which enables men and machines to reach every point of the salt works. All this has already been carried out by the CNA. If, in the near future, it should be necessary to reduce men power, mechanization could be increased by installing automatic pumps and an automatic control system of density and levels.

6.6 Recommendations to Increase Yield

The need to meet the plant's requirements in salt, and by so doing to reduce the quantity of salt bought at high prices and the production costs, the CNA have planned and started to build a large pre-concentration basin in the lagoon itself. (Annex 7) To cut off a part of the lagoon will mean that it would receive no fresh water other than rainfall. In this way, the water could reach a higher density before being pumped into the "marneis". Furthermore, owing to the higher density, the shells would disappear and the impermeability of the ponds would naturally increase. The large new pre-evaporating basin built in the

Massambaba Gulf will cover a surface of about 1.000 hectares and contain 12.000.000 cubic metres; in a year's time, given the climatic conditions, the water density can reach 8° Bé. Assuming that the water in the lagoon maintains a constant density, and that the density in the pre-concentration basin is kept at 8° Bé, it will be possible to pump yearly more than 6.000.000 cubic metres of 8° Bé brine to the next stage of evaporation. In this way, with the rise of density, the shells will disappear from the first evaporation ponds and algae will be able to increase and flourish, and the 21° Bé brine production will double.

In the pilot pre-concentrating pond, constructed about one year ago, which is 52 ha in size and 0,30 m deep, the brine is now concentrated to 10° Bé.

Recently an other pre-concentrating pond of about 105 ha and 0,35 m of depth has been built. In this pond the lagoon water has concentrated in the meantime to 6,2° Bé.

The advantage of this large pre-concentration basin is not only that of increasing production. It is also a help to produce a constant amount of brine unaffected by the meteorological oscillations, and will thus ensure a greater regularity of production. This is due to the extension and depth of the basin.

Another advantage to have this large basin is that it has low maintenance costs compared with the other ones. This is because operations are simple, its maintenance can be done mechanically and the banks are short in relation to the covered area.

In view of these considerations we approve of the CNA plans as those are an efficient way to increase production of salt. They also point clearly to the future lines of development of the salt plant. By these new and deep basins it is possible not only to increase production but also to obtain brine up to 25° Bé.

The main advantage of this nearly saturated brine is, that it has only a low $CaSO_4$ content. Consequently the gypsum sedimentation is reduced in the susequent equipment and the heat transfer will be improved. This leads to lesser power consumption.

For expansion plans it means a precondition that the great loss through seepage in the "concentradores" and "cristallisadores" either be eliminated or at least considerably reduced.

A definite solution of this problem would be the lining of the solar ponds with brine resistant, high pressure polyaethylen sheets, a safe and successfully tested method. The sheets would be rolled out on the sandy bottom of the pond, where they are kept weighed down by sand. After welding the sheet strips into a blanket sheet, a layer of sand is to cover its whole surface. The ends of the sheets are pulled up over the edge of the pond and fixed by digging them into the earth dams.

To make the "cristallisadores" tight, a sheet of 0,10 mm thickness (Annex 8) and for the "concentradores" a sheet of 0,15 mm can be applied.

This material is available in a width of 4 m by 50 m length and 6 m width by 25 m length respectively. The costs of such sheets amount to some DM 37,50/100 m^2 (= Cruzeiros 49,50/100 m^2), cif Brasilian harbour. In view of the high loss due to seepage these costs could be amortized in relatively short time.

It improves economics if two 4 m wide sheets are welded in the workshop and thus the 8 m wide strips can be rolled on the bottom of the pond with the help of a simple device.

7. Possibilities to improve production and increase yield of salt for the Soda Plant

Under point 5.3 and 5.4 we have described in detail the deficiencies and difficulties encountered in the plant as a whole. The plant has been put into operation about 4 years ago. During the two subsequent years, the suppliers have carried out changes so to eliminate disturbances and to arrive at the planned capacity. This, however, has not been achieved. - Ever since then, engineers of the CNA have continued their efforts to cut down sources of trouble by further changes in all sections of the plant and thus to arrive at continuous production at plant capacity.

In spite of all these efforts, not more than 50 - 60 % of the plant capacity could be achieved.

It is, therefore, a matter of serious consideration, which changes could be carried out in the existing plant with best results.

7.1 Possible changes in the Submerged Combustion Plant

If one considers the main deficiencies in the foregoing, incrustation by $CaSO_4$ in the brine causes the worst damage to the equipment in this process step. It should, therefore, be the object to find a process to precipitate the gysum from the brine before same enters the heat-exchanger.

Under prevailing conditions this could be done in two ways:

either

a) to instal a one-stage brine purifying equipment to precipitate the $CaSO_4$ by chemicals

or

b) to instal a brine treatment equipment, in which pre-heated brine circulates. This precipitates $CaSO_4$ by the so-called gypsum mud process.

As the installation b) involves a change in the thermal equipment, it is a) that seems to be more advisable.

The second main deficiency in the production process is in the pre-concentrator, which is a part of the submerged combustion plant. Its efficiency could be improved if gypsum was precipitated before the brine concentration. - As soon as the brine of 25° Bé has been produced in the solar plant, the process step of pre-concentration is to be eliminated. This because the pre-heated brine would be lead directly to the evaporators.

The directly heated evaporators are causing particular problems and are in themselves a great deficiency. They are directly heated by burners and these produce soot and particles of sulphur, which mix with the brine. - The CNA requested DBS to examine whether by installing special oil burners, made in West Germany, better results could be obtained. - Oil burners in which the flame is free from soot and sulphur to great extent do not solve the problem because some, if lesser particles do get mixed into the product. - Indirect burner heating is theoretically possible. By that the burner is combined with a hot air producer. This indirect burner heating brings about a loss of 10 - 15° C in the thermic efficiency.

It might be purposeful to look at the investment, which this type of alteration would involve. There are three burners at an estimated cost of DM 200.000 = Cruzeiros 263.00, for each of the four evaporators. This means for the evaporator plant DM 800.000 = Cruzeiros 1.053.000. Such costs are in no relation with the small improvement they actually mean. It also needs to be considered that deficiencies of connected departments in the same submerged combustion plant are not eliminated by such changes. Anyhow, if these plans were to be followed through - first a pilot plant would be necessary.

The deficiencies which have occured in the decanters (breakage on the agitator and the Mohno pump) can only be corrected definitively by replacing them with equipment more reliable in the operation.

We shall have to wait for the results from the tests now being carried out by CNA to replace the decanters with the aid of hydrocyclones before anything can be stated about them. Basically, however, it can be stated that hydrocyclones operate perfectly only if the proportion of solid substances in the liquid is not higher than 100 grams per liter.

Probably DSM screens could be successfully employed here. This can be ascertained on short notice by a test with the original product by the future supplier.

The corrosion in the pipelines, valves and centrifuges, attributable to the sulphur content in the brine, can be eliminated by the installation of an indirect heating plant in the crystallizers.

Under the present circumstances pure nickel would have to be used for all parts coming into contact with the product. The costs for this would, however, be extremely high and therefore may not be considered.

In order to round off the picture, it must also be mentioned that changes would have to be made in the control-regulating system. This would lead to additional costs.

The complicated process will probably not lead to optimal operation, even after completion of all these expensive alterations.

The salt produced in the plant is far too expensive. This is also due to the high power costs. For the production of 1 ton of salt from 21° Bé brine, 240 kg of fuel oil and 80 kW of current are required. According to the prices indicated to us (Annex 11) the power costs per ton of salt amount to around Cruzeiros 25, while the production price per ton/salt from the submerged combustion plant is around Cruzeiros 87,66.

It must be considered that the capacity of the submerged combustion plant is rated at 400 t/day. This is to be increased to about 700 t/day so to meet the increasing salt requirements of the soda plant. The plant runs at 50 - 60 %.

This facts all in all lead up to the conclusion that the submerged combustion process should not be maintained.

The considerations outlined in all the above, bring about the recommendation of other possible processes for the production of the necessary quantity of suitable brine (not crystallized salt) for the soda plant.

7.2 Possible changes of the entire process of salt production for the soda plant

As first possibility one would have to consider the replacement of the existing concentration and crystallization plant (the entire submerged combustion plant) by a vacuum evaporation plant, as used in salt industry.

This alternative, however, involves the great disadvantage that substantial new investments would be necessary. To apply such larger parts of the existing plant, which have not been depreciated yet, is not possible in this alternative. Therefore, the question is, whether such parts could possibly be utilized in a satisfactory reconstruction of the plant.

Summarizing once again the entire production process of CNA, the following can be stated:

a) In the present solar plant only brine, but no salt is being produced as a raw material for the soda plant.

b) In the existing process the crystallization stage is only for purification purposes.

c) The soda plant requires a purified, saturated brine as a basic product and not necessarily salt crystals

Therefore the question should be as to how a purified and saturated brine could be produced from the brine with a density of 21° Bé (or after alteration of the solar plant from brine of 25° Bé).

The possibility to purify the brine with chemicals is obvious. This particularly since the brine now produced in the submerged combustion plant must pass through a purification plant (CNA Flow Sheet 1612 a3), before it enters into the soda plant.

In order to precipitate by-salts, indesirable here, the 21° Bé brine could be conveyed directly from the large storage tank to a two- or three-stage brine purification system. The by-salts $CaSO_4$, $MgCl_2$ and $MgSO_4$ would then be precipitated in this system.

The precipitation could be carried out either by soda and lime solution, as is now done in the purifiers, or by using soda and sodium hydroxide. A choice between the two possibilities depends first of all on the price of the chemicals to be added, and on the possibility of use of the sludges arising from the process.

Based on an average analysis of the 21° Bé brine, these approximate quantities of by-salts are to be precipitated:

$CaSO_4$	-	4 g/l
$MgCl_2$	-	23 g/l
$MgSO_4$	-	17 g/l

In case of precipitation of soda and lime-milk the theoretical requirements of chemicals are

Na_2CO_3	-	43,6 kg/cu.m
$Ca(OH)_2$	-	28,0 kg/cu.m

The quantity of mud is, in this case

$CaCO_3$	-	41,15 kg/cu.m
$Mg(OH)_2$	-	22,3 kg/cu.m

The values in case of precipitation by soda and a solution of sodiumhydroxyde amount to

Na_2CO_3	-	3,07 kg/cu.m
NaOH	-	30,6 kg/cu.m

with a sludge portion of

$CaCO_3$	-	2,9 kg/cu.m
$Mg(OH)_2$	-	22,3 kg/cu.m

As the brine has a high magnesium content, it is advisable to have a two- or even three-stage process in the purifying plant so to obtain a possibly pure $Mg(OH)_2$.

The purifying plant should be planned in such a way that $CaCO_3$ is precipitated in the first stage, $Mg(OH)_2$ in the secondm respectively a mixture of by-salts in the third stage.

It is important for the smooth functioning of the brine purification plant that the chemicals should be added at an optimal rate. A smooth precipitation at the different process stages can be ensured by this and by installing reaction tanks with agitators before the decanters. The brine thus would pass through the plant in 30 minutes or more. The brine may not be pumped into the decanters but should flow freely, so as not to destroy the flocculence in the brine. The decantation time is approx. 3 m/h and this also indicates the size of the decanters. - The height of the thickeners with revolving arms is approx. 7 - 8 meters, which ensures the required thickened sludge. At least

15-fold increase of the sedimentation speed could be arrived at by adding as little as 1 to 3 g/cu.m of a special flocculation agent.

The final layout of the brine purifyer can be prepared after experiments with the CNA brine only.

As far as it can be seen now, the existing brine purification system, with two cyclators of 19 m dia. , should be completed to purify raw brine of 21° Bé. However, the temperature of the brine may not sink under 18° C during the purifying process, otherwise it would have to be pre-heated. The required purity of maximum 0,025 g/l MgO and CaO is surely obtainable.

At the moment the available brine is of 21° Bé only, therefore an enrichment to 25° Bé must be attained after purifying. We believe that for the time being the available pre-concentrator (1) of the submerged combustion plant and connected equipment could be used for this purpose. This until the brine with 25° Bé will be produced in the solar plant. Please note, howver, that also in this respect, further investigations are necessary before the final layout is made.

7.3 Indications to select the economically most feasible process

When the possibilities as described under point 7.1 and 7.2 are looked into, even without exact figures on hand, the following may be observed:

7.3.1 Investments

7.3.1.1 Submerged Combustion Plant

The reconstruction of this particular part could never be carried out completely and anyhow such works would involve substantial investment. The available brine purification system would remain to be necessary.

7.3.1.2 Multi-Stage Vacuum Plant

The construction of a new crystallization plant with vacuum evaporator requires more investment than a reconstruction. Besides it does not seem to be reasonable, particularly because the soda plant operates with salt in brine form, consequently crystal-salt is not needed at all.

7.3.1.3 The purification of brine

The direct cleaning of brine with a density of 21° Bé now and 25° Bé on our advice later, requires the smallest investment, particularly as available parts of the plant can be used.

7.3.2 Operating and maintenance costs

7.3.2.1 Submerged Combustion Plant

The high costs can probably not be reduced.

7.3.2.2 Multi-Stage Vacuum Plant

The costs are lower than those of the submerged combustion plant.

7.3.2.3 The purification of the brine

This plant has the lowest costs

7.3.3 Energy and consumption of chemicals

7.3.3.1 Submerged Combustion Plant and the purification of brine

Electric power: 80 kW/t salt
Heating oil : 230 - 240 kg/t salt
CaO : 39,5 kg/cu.m brine
Na_2CO_3 : 65,8 kg/cu.m brine

7.3.3.2 Multi-Stage Vacuum Plant

Electric power: approximately 40 kW/t salt
Steam at 4 ata: maximum 1,5 t per ton of salt
Chemicals : purification of brine prior to entering the plant only with CaO.

7.3.3.3 Purification of brine

Electric power:	very low, however exact values can only be given after experiments.
Chemicals :	exact values would also have to be experimented first.

The values as included in 7.3.3.1 may not be exceeded.

Presently, as a temporary measure, to enrich the brine from 21° to 25° Bé, power would be required.

The above figures indicate that the alternative of direct purification of the brine at 21° and 25° Bé respectively, should be considered as an optimal solution and therefore requires detailed investigations.

8. Vacuum Salt Plant

8.1 Possiblilities for the improvement of the existing plant

We have reported under point 5.5 that the steam consumption of this plant amounts to 10/t per ton of salt (steam pressure 2,5 ata). At the same time the production is 20 % under capacity.

To improve productivity the following measures could be adopted:

8.1.1 Pre-heating of brine with vapour, vapour-condensate and live steam condensate

The most effective means is to insert a pre-heater in the live steam condensate conduit. The brine should be pre-heated up to 80° C. By that, gypsum would be precipitated in the pre-heater and not in the heating chamber (trocador). Two pre-heaters should be parallel installed, so that one or the other could be operated continuously, even during cleaning either.

8.1.2 Checking of the vacuum conduit

As the measured values in both apparatuses are different, it is important to find the eventual leakage points. (Please see point 5.5). Furthermore, particular attention should be paid to the ventilation of the condenser. The adjustment of the ventilation must be carefully tested: if the ventilation is on a too small scale, the vacuum is insufficient; if it is too strong, vapour condensate may be lost.

8.1.3 Reconstruction of the two-stage plant

The engineers of CNA have considered this and it seems to be possible. It also might improve results. To achieve the same total output with the two-stage plant, it is necessary to enlarge the heating chambers.

For the alterations it is essential to work out construction details as well as the measures and data of capacity within the various apparatuses.

8.2 Extension of the existing plant for the production of marketable table salt of higher value

The humid salt (moisture content 2 %) produced now in the evaporation plant is according to its analysis and grain size suitable for first quality table salt. For this reason an extension of this plant is an economically feasible proposition, provided the product will find a good market.

For the further preparation of the approximately 2,1 t/h salt and its packaging into bags of 60 kg each, the following equipment is necessary:

One fluid bed drier-cooler, ventilators, cyclon and pipelines to dry the salt up to 0,2 % moisture and to cool same to 40 - 45° C.

Oscillating screen to separate grain sizes under 0,2 mm dia. (These can be used either dissolved or for the production of lickstones).

Dosing weighfeeder, dosage apparatus for anticaking agent with electric control system. With this equipment the exact weight of the product and the dosage of the chemicals can be electronically guided. Iodine can be added at this point by connecting the relevant apparatus.

Flowmixer, by which the chemicals can be thoroughly mixed with the salt.

Silos with rubber lined compartments as store tanks, in front of the bagging unit. The size depends on the equipment; one- or more-shift packager.

Net weight bagging scale with manual welding machine and conveyor.

Various conveyors leading to different apparatuses, depending on their layout.

The investment costs for a plant briefly outlined as above, would amount to something like DM 600.000 equalling to Cruzeiros 790.000, cif Brasilian harbour.

9. Possibility for Production of By-salts

It is commonly known that the salts in sea water are very numerous: almost all the elements are to be found in it, even if some of these in very small quantities (Annex 9).

The main salt contained in sea water is sodium chloride, and to obtain this, the water must reduce volume about 40 times. As a result, other salts are also concentrated so that some of them can be extracted (Annex 10).

Usually in the normal process of solar evaporation the mother liquor is treated as follows:

a) extraction of magnesium sulphate from hot mother liquor by means of natural cooling, thus by exposure during the winter;

b) extraction of bromine by means of chlorine of the pre-heated brines;

c) extraction by solar evaporation of mixed salts($NaCl$ + $MgSO_4$); these salts by cooling, could produce sodium sulphate;

d) extraction of potassium salts by further solar evaporation;

e) production of 50 % solution of magnesium chloride (38° Bé brine) also by solar evaporation; even a higher concentration or crystallized magnesium chloride is obtained by artificial evaporation.

However, Cabo Frio weather conditions, with low evaporation possibilities and small temperature drops make the above-mentioned processes unfeasible.

As the natural process steps of solar evaporation and cooling cannot be considered in this connection at Cabo Frio, for the by-salt production chemical and thermal process steps are necessary.

The construction of plants for this production of by-salts should, however, only then be subjected to detailed consideration when the brine production for the soda plant is ensured at economical prices.

Notwithstanding this even at present CNA seem to have a good chance in connection with magnesium. (Please see Annex 15).

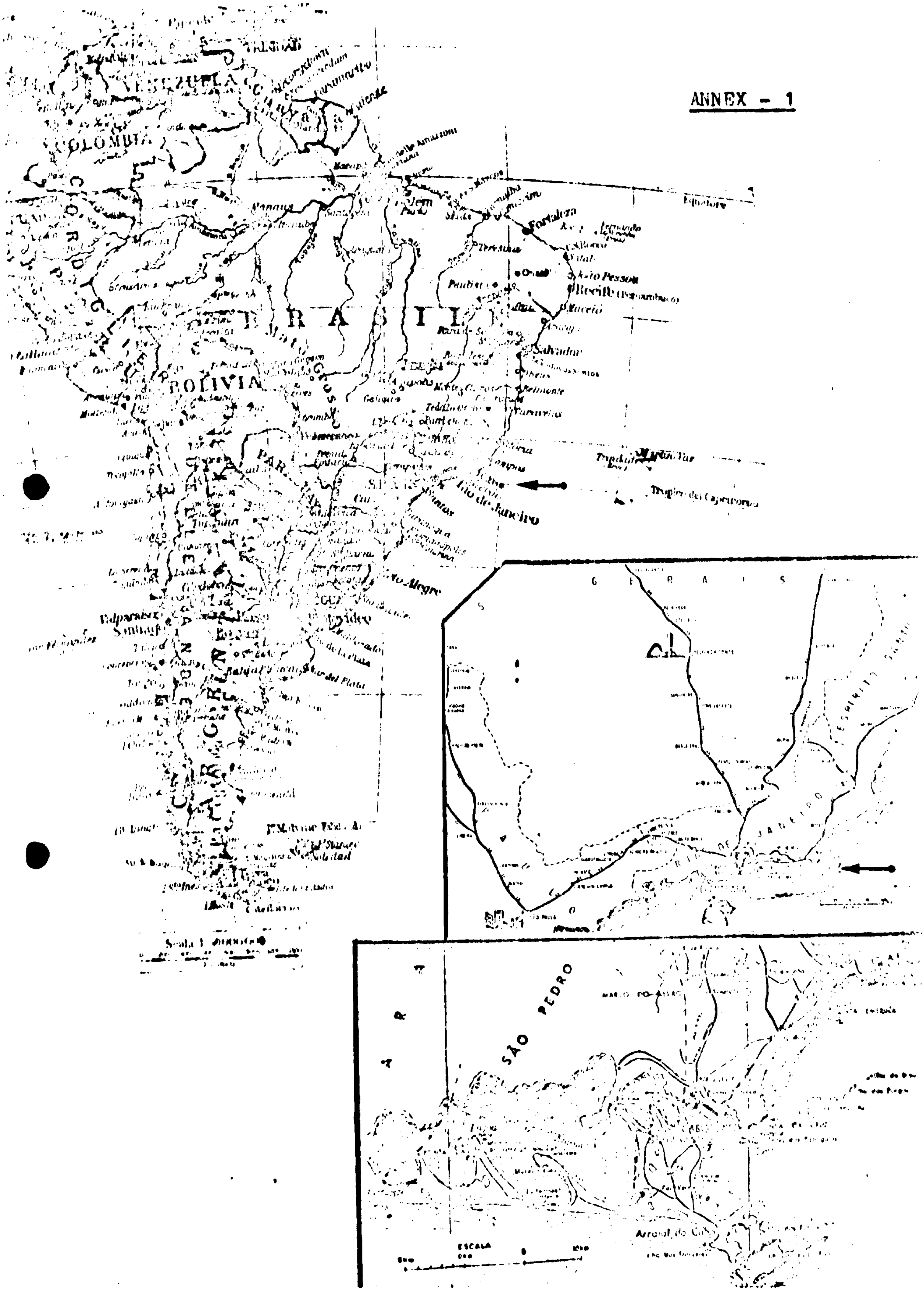
The further preparation of $Mg(OH)_2$ could be an interesting proposition, as same is precipitated during purification. With a view to separate $Mg(OH)_2$ in the precipitation process, the three-stage purification plant is of advantage.

In case precipitation is done by lime-milk it must be checked to what extent $Mg(OH)_2$ would be impurified. The $Mg(OH)_2$, which appears in mud form during the purification of brine, can be dewatered by filters or solid bowl centrifuges and then dried. This gives a saleable product.

Through the purification plant other by-salts could also be obtained. This would, however, be subject of a marketing and feasibility study. Here it should be mentioned that if other chemicals were applied for purification f.i. fertilizers could be manufactured. These questions are still to be tested technically.

It is our considered opinion that amongst the substantial brine quantities, which are produced by C[illegible], the preconditions for economical by-salt production are given.

ANNEX - 1


VENEZUELA
COLOMBIA
GUYANA
Equatore
Manaus
Belem
Fortaleza
Recife
Maceio
Salvador
BRASIL
BOLIVIA
PARAGUAY
Rio de Janeiro
Trindade
Martin Vaz
Tropico del Capricorno
Porto Alegre
Montevideo
Valparaiso
Santiago
Mar del Plata
Scala
GERAIS
ESPIRITO SANTO
RIO DE JANEIRO
SÃO PEDRO
Arroial do Cabo
ESCALA

ANNEX 2

CHEMICAL ANALYSIS OF SALT

	NaCl %	CaO %	MgO %	insoluble %	humidity %	$CaSO_4 \cdot 2aq$ %	$MgSO_4 \cdot 7aq$ %	$MgCl_2 \cdot 6aq$ %
a) Salt from Submerged Combustion Plant:								
CNA - Sample								
	95,10	0,22	0,31	0,02	3,81			
	94,69	0,21	0,40	0,01	3,97			
	93,81	0,18	0,40	0,015	3.53			
	94,21	0,21	0,43	0,03	4,16			
	96,22	0,115	0,29	0,02	2,98			
DBS - Sample								
	95,50	0,094	0,296	trace	2,596	0,288	0,726	0,890

(there is no Fe - Ca - CO_2; pH approx. 5,5)

	NaCl %	CaO %	MgO %	insoluble %	humidity %	$CaSO_4 \cdot 2aq$ %	$MgSO_4 \cdot 7aq$ %	$MgCl_2 \cdot 6aq$ %
b) Vacuum Salt								
DBS - Sample								
	97,66	0,043	0,171	trace	1,483	0,133	0,304	0,615

ANALYSIS OF GRANULATION

Salt submerged combustion plant

DBS Sample

more than 0,7 mm = trace
" " 0,5 mm = "
" " 0,40 mm = 7,5
" " 0,35 mm = 26,2
" " 0,29 mm = 35,4
" " 0,17 mm = 24,0
less " 0,17 mm = 0,9

Vacuum Salt

DBS Sample

more than 1 mm = 2,74
" " 0,70 mm = 0,90
" " 0,5 mm = 40,50
" " 0,4 mm = 22,20
" " 0,35 mm = 14.40
" " 0,29 mm = 6,50
less " 0,29 mm = 7,76

ANNEX 2 cond.

Chemical Analysis of Brine and Mother Liquor

	Cl g/l	SO_4 g/l	Ca g/l	Mg g/l	NaCl g/l	$CaSO_4$ g/l	$MgSO_4$ g/l	$MgCl_2$ g/l	KCl g/l	$MgBr_2$ g/l
a) **Seawater**										
Cabo Frio 2.11.1967	19,96	2,73	0,42	1,34	28,52	1,43	2,15	3,57	-	-
Seawater 3,6° Bé (theoretical)	19,30	2,72	0,42	1,35	27,20	1,42	2,14	3,59	0,72	0,07
b) Brine 21° Bé										
Sample DBS	150,00	16,3	1,91	9,06	218	6,45	14,70	23,90	4,95	0,90
Brine (theoretical)	138,81	14,80	0,96	9,76	196	3,27	15,60	25,90	5,19	0,55
c) Mother liquor 32° Bé										
Sample CNA	190,00 189,00 200,00 190,00		0,006 0,143 0,499 0,698	51,6 56,2 54,9 52,4						
Sample DBS	213,00	77,0	--	51,0	189	--	96,5	123	13,25	4,35
theoretical	227,40	69,50	--	54,60	189	--	87,0	143	30,20	3,17

ANNEX 3

EVAPORATION AND RAINFALL OF THE LAST 20 YEARS AND DENSITY OF THE LAGOON

Period - July 1950 to June 1970

Year	Evaporation mm	Rainfall mm	Net-Evaporation mm	Density Lagoon °Bé
50-51	1.308,2	781,9	526,3	-
51-52	1.287,6	758,7	528,9	-
52-53	1.466,7	703,5	763,2	-
53-54	1.609,0	643,9	965,1	-
54-55	1.484,1	587,5	896,6	-
55-56	1.646,4	627,0	1.019,4	-
56-57	1.659,4	885,1	774,3	-
57-58	1.584,4	730,8	853,6	-
58-59	1.561,4	727,1	834,3	-
59-60	1.561,0	668,0	893,0	-
60-61	1.420,4	695,5	724,9	6,0
61-62	1.398,2	745,9	652,3	6,0
62-63	1.341,8	538,5	803,3	5,9
63-64	1.325,4	844,5	480,9	6,2
64-65	1.089,9	1.186,8	96,9	6,0
65-66	1.364,5	807,6	556,9	5,5
66-67	1.198,8	1.047,4	151,4	5,1
67-68	1.386,5	700,9	685,6	4,5
68-69	1.437,7	808,0	629,7	4,9
69-70	1.369,1	646,6	722,5	5,3
Total 20 years	28.500,5	15.135,2	13.365,3	
Average 20 years	1.425,0	756,7	668,2	

ANNEX 4

ALTURA TOTAL MENSAL DE PRECIPITACAO EM MM. MEDIA EM PLUVIOMETRO

(Monthly rainfall in mm, measured in the Pluviometer)

Month/Year	50/51	51/52	52/53	53/54	54/55	55/56	56/57	57/58	58/59	59/60
July	27.7	24.1	26.2	37.4	20.0	9.2	15.5	26.6	124.2	8.5
August	52.4	24.0	11.6	35.0	4.5	11.4	63.4	8.1	24.0	63.2
September	21.5	7.1	61.6	21.5	20.7	12.6	30.1	50.2	55.6	7.9
October	78.6	40.5	29.3	18.9	71.7	51.1	37.9	13.0	61.3	79.5
November	103.2	57.5	106.1	109.6	31.5	102.4	66.7	61.5	61.3	94.9
December	79.4	65.3	112.5	46.6	60.9	109.2	119.0	135.3	10.8	24.5
January	34.7	102.8	20.9	7.0	75.4	0.5	19.2	22.0	93.8	32.5
February	52.1	232.4	154.4	2.4	0.0	98.3	68.9	16.9	36.2	126.5
March	72.8	31.3	27.9	84.9	81.0	44.9	61.7	141.7	143.4	97.0
April	122.3	61.2	68.6	113.0	58.8	64.2	304.0	131.0	14.5	28.8
Mai	101.3	33.5	69.1	142.2	108.4	51.6	91.2	90.9	62.0	87.1
June	35.7	79.0	15.3	25.7	54.6	71.6	7.5	33.6	40.0	27.6
Total	781.9	758.7	703.5	643.9	587.5	627.0	885.1	730.8	727.1	668.0
Average	65.2	63.2	58.6	53.7	49.0	52.3	73.8	60.9	60.6	55.7

ANNEX 4 cond.

ALTURA TOTAL MENSAL DE PRECIPITACAO EM MM. MEDIA EM PLUVIOMETRO

(Monthly rainfall in mm, measured in the Pluviometer)

Month/Year	60/61	61/62	62/63	63/64	64/65	65/66	66/67	67/68	Total	Middle
July	38.2	34.4	46.2	9.8	75.6	38.6	63.8	99.7	725.7	40.3
August	21.9	6.4	17.4	15.2	21.2	38.5	51.4	4.3	473.9	26.3
September	18.4	3.2	28.5	1.2	29.0	14.0	24.6	49.6	457.5	25.4
October	12.2	0.9	95.6	29.4	143.9	61.2	77.3	27.7	920.0	51.1
November	74.1	20.0	112.7	67.8	116.8	40.1	154.4	142.8	1.523.1	84.6
December	51.8	167.0	43.2	271.6	162.0	54.9	60.9	88.0	1.662.0	93.3
January	121.3	175.3	49.5	55.7	76.2	155.7	182.1	66.2	1.290.8	71.7
February	97.8	204.2	28.8	156.1	31.3	1.6	93.8	42.9	1.444.6	80.3
March	26.9	37.1	2.7	139.7	98.5	78.7	157.7	34.4	1.362.3	75.7
April	49.6	3.2	75.1	22.2	304.5	225.7	96.5	43.0	1.786.8	99.3
Mai	114.2	63.8	25.0	47.9	101.3	74.3	60.8	58.7	1.383.3	76.8
June	69.1	30.4	13.8	27.3	26.5	24.3	25.0	43.6	650.6	36.1
Total	695.5	745.9	538.5	844.5	1.186.8	807.6	1.047.4	700.9	13.680.6	759.9
Average	58.0	62.2	44.9	70.4	98.9	67.3	87.3	58.4	1.140.0	63.3

ANNEX 5

ALTURA TOTAL MENSAL DE EVAPORACAO EM MM. EM SUPERFICIE ABERTA DE 1 m^2

(Monthly evaporation height in mm, measured in a 1 m^2 pond)

Month/Year	48/49	49/50	50/51	51/52	52/53	53/54	54/55	55/56	56/57	57/58	58/59
July	73.0	80.4	76.8	83.2	75.6	88.7	85.7	104.4	95.3	76.5	72.0
August	98.3	107.3	102.2	88.9	112.7	102.8	112.2	115.2	108.5	110.3	119.7
September	126.4	119.7	109.1	110.6	89.6	119.7	96.1	137.8	123.0	82.8	119.8
October	166.0	111.9	120.4	115.5	132.0	154.2	120.7	122.7	152.6	167.8	122.7
November	142.0	138.9	109.9	120.5	131.5	145.1	145.8	151.5	164.8	144.0	164.8
December	164.0	139.1	149.0	135.9	168.8	180.8	161.1	136.7	165.7	161.8	197.5
January	145.5	142.0	152.2	134.5	199.3	241.3	152.8	249.2	227.0	227.5	165.0
February	176.3	150.6	152.7	108.8	144.4	173.1	188.9	190.3	175.0	195.0	152.6
March	201.2	131.9	114.7	144.8	154.6	173.3	152.8	167.7	144.2	162.8	92.1
April	121.0	104.7	85.5	87.2	110.5	104.0	110.9	125.5	134.6	109.9	155.8
Mai	104.0	76.2	70.1	85.9	78.6	64.9	82.9	85.6	95.0	77.4	104.4
June	76.0	65.9	65.6	71.8	69.1	61.1	74.2	59.3	73.7	68.6	95.0
Total	1.593.7	1.368.6	1.308.2	1.287.6	1.466.7	1.609.0	1.484.1	1.646.4	1.659.4	1.584.4	1.561.4
Average	132.8	114.1	109.0	107.3	122.2	134.1	123.7	137.2	138.3	132.0	130.1

The values refer to the years 48/49 and 49/50

ANNEX 5 cond.

ALTURA TOTAL MENSAL DE EVAPORACAO EM MM. EM SUPERFICIE ABERTA DE 1 m^2

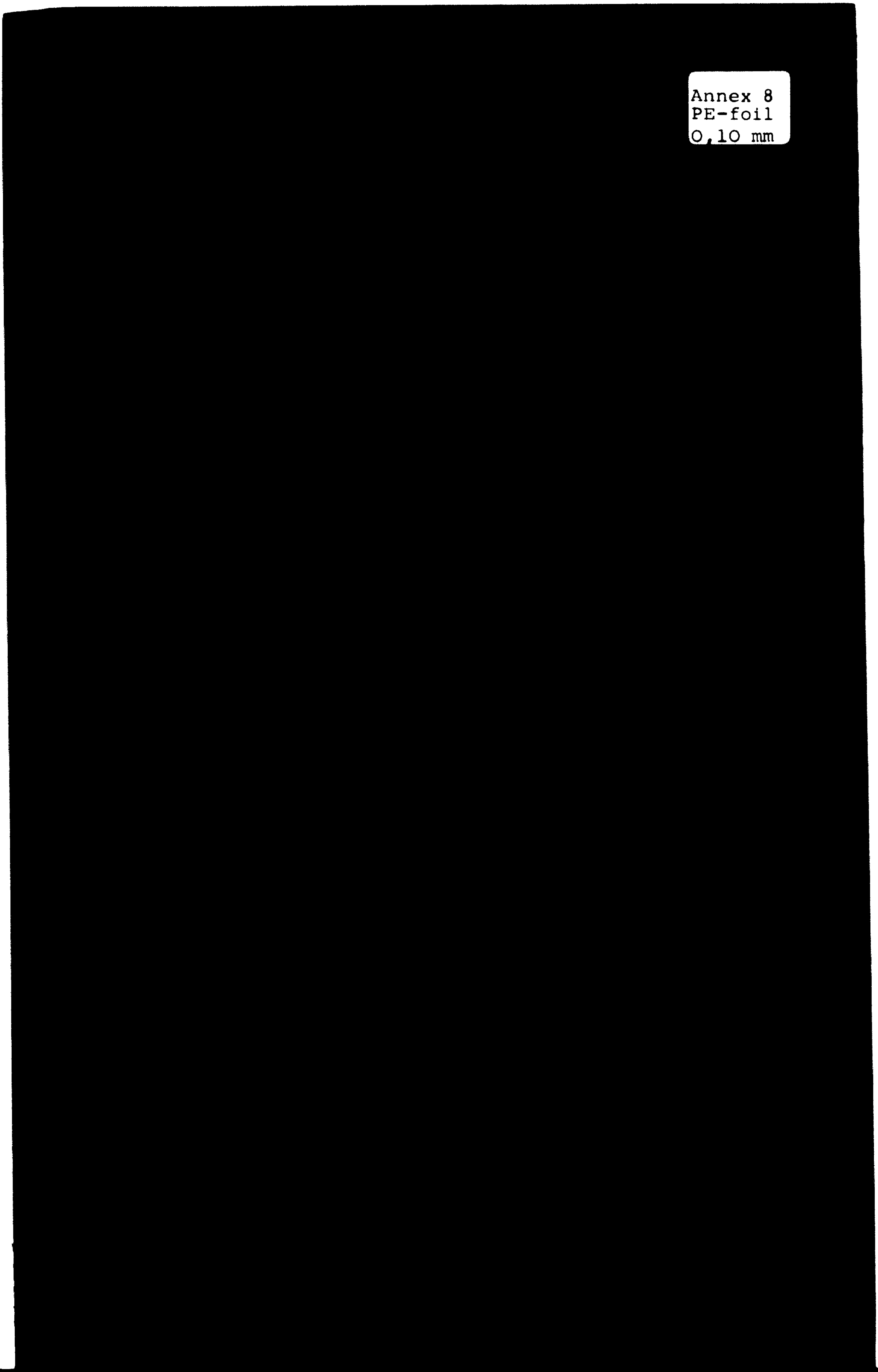
(Monthly evaporation height in mm, measured in a 1 m^2 pond)

Month/Year	59/60	60/61	61/62	62/63	63/64	64/65	65/66	66/67	67/68	Total	Middle
July	112.4	89.7	91.3	70.4	84.9	61.0	63.2	72.7	74.2	1.631.4	81.6
August	100.2	97.0	102.3	91.2	94.7	89.3	90.8	79.7	106.7	2.030.0	101.5
September	125.4	109.3	116.0	102.8	118.5	114.5	105.4	102.8	110.1	2.239.4	112.0
October	153.4	159.0	156.2	101.6	123.5	83.1	116.2	103.4	145.2	2.628.1	131.4
November	149.1	120.3	179.0	103.8	157.7	106.4	133.6	104.7	116.0	2.729.4	136.5
December	179.9	140.7	128.8	133.5	151.0	105.1	165.6	145.7	128.8	3.039.5	152.0
January	171.1	149.0	139.3	172.3	138.9	113.8	145.4	113.9	168.2	3.348.2	167.4
February	128.8	129.6	92.6	131.8	119.1	107.7	161.3	134.4	129.6	2.942.6	147.1
March	114.7	154.6	142.9	156.3	122.9	94.6	148.8	100.5	144.0	2.819.4	141.0
April	161.7	116.4	109.8	111.0	92.7	87.3	85.9	87.5	96.3	2.198.2	109.9
Mai	87.1	82.2	71.8	92.4	66.4	63.4	72.9	84.3	94.0	1.639.5	82.0
June	77.2	72.6	68.2	74.7	55.1	63.7	75.4	69.2	73.4	1.410.3	70.5
Total	1.561.0	1420.4	1.398.2	1.341.8	1.325.4	1.089.9	1.364.5	1.198.8	1.386.5	28.656.0	1.432.9
Average	130.1	118.4	116.5	111.8	110.4	90.8	113.7	99.9	115.5	2.388.0	119.4

R A I N F A L L

Day	July 68	August 68	September 68	October 68	November 68	December 68	January 69	February 69	March 69	April 69	Mai 69	June 69	July 69	August 69	September 69	October 69	November 69	December 69	January 70	February 70	March 70	April 70	Mai 70	June 70
1	0.0	0.0	0.0	4.5	0.0	46.4	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	26.2	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.3	0.2	0.0	22.2	0.0	0.0	6.2	0.0	0.0	0.2	0.0	20.4	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	10.0	0.0	0.0	13.3	0.0	0.0	0.0	28.4	0.0	0.4	0.0	23.8	0.0	7.8	0.1	3.2	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	16.5	0.0	0.0	1.4	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	25.4	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	4.2	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	8.6	0.0	3.4	0.0	0.0	0.0	0.4	0.0	0.0
8	0.0	5.6	0.0	0.0	0.0	9.0	6.9	0.0	6.4	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	6.0	0.0	0.0
9	0.0	1.1	0.0	2.2	0.0	15.1	0.0	0.0	1.3	0.4	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.5	49.8	0.0	0.0	19.0	0.0	0.0
10	3.7	3.1	0.0	6.8	0.0	4.5	4.1	0.0	5.4	0.6	0.0	0.0	0.0	0.0	0.0	0.2	11.9	7.2	3.1	0.0	0.0	6.4	0.0	0.0
11	1.7	3.4	0.0	27.5	0.8	0.6	8.2	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	24.6	0.3	1.2	0.0	0.0	11.7	9.7	0.0
12	0.0	2.2	0.0	3.5	0.8	0.0	2.5	0.0	0.0	0.4	0.0	0.0	10.2	0.0	0.7	0.0	0.0	0.0	11.6	0.0	0.0	0.0	0.0	0.0
13	0.6	5.3	1.4	6.9	0.0	0.0	0.0	0.0	50.8	0.5	4.0	0.0	0.0	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0	0.0	0.3	0.0
14	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	15.7	0.0	0.0	0.0	0.0	1.3	0.0	0.8	0.5	0.0	0.0	0.3	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	8.1	1.8	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	2.6
16	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	4.5	0.0	0.0	0.2	0.0	0.0	0.7	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	55.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
18	4.2	2.7	0.0	0.9	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3
19	1.0	0.0	0.0	0.0	5.9	0.0	0.0	36.4	0.0	0.0	0.0	0.2	0.0	0.2	0.0	28.5	0.1	0.0	27.5	3.1	0.0	1.4	0.0	0.0
20	0.0	0.0	0.0	0.5	0.0	0.0	0.0	10.8	0.0	0.0	0.0	18.4	0.0	2.9	3.0	7.5	0.0	0.0	6.1	0.4	0.0	0.0	1.7	0.0
21	7.3	0.0	21.9	1.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	43.2	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.8	0.0
22	0.0	5.8	0.2	8.3	0.0	0.0	23.6	0.0	0.0	0.0	0.0	17.3	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.6	0.0
23	1.0	4.9	0.0	0.1	0.0	0.0	35.7	0.0	0.0	0.3	0.0	1.4	0.0	0.0	0.0	13.1	0.0	0.1	0.0	3.0	0.0	0.0	0.0	2.6
24	0.0	0.2	0.0	0.0	0.0	0.0	9.1	1.4	0.0	0.3	0.0	4.2	0.0	0.0	0.0	0.0	0.0	94.3	0.0	2.0	0.0	0.0	0.0	3.4
25	2.1	0.0	0.0	0.3	0.0	0.0	3.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	2.3	0.0	8.8	0.0	0.3	0.8	0.0	0.0	2.4
26	0.4	4.0	0.0	0.0	0.1	0.0	1.6	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	15.7	2.7	0.0	0.0	0.0	25.7
27	3.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	1.1	0.0	0.0	2.3	0.0	0.0	0.4	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.2	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
29	6.0	0.0	4.0	0.0	1.3	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0		0.0	2.8	0.0	0.0
30	0.0	0.0	20.1	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.3	6.5	0.0	0.0		0.0	3.1	0.0	0.0
31	0.0	3.6		0.0		0.0	0.0		0.0		0.0		0.0	0.0		10.8		0.0	0.0		0.0		0.0	0.0
Tot.	31.3	46.8	74.4	62.7	72.2	113.6	95.2	48.7	92.9	60.6	12.3	97.3	13.4	59.7	5.3	132.9	60.2	137.7	118.3	11.6	1.1	53.8	15.1	37.0

SOME FIGURES
OF THIS DOCUMENT
ARE TOO LARGE
FOR MICROFICHING
AND WILL NOT
BE PHOTOGRAPHED.



Annex 8
PE-foil
0,10 mm

ANNEX 9

Concentration of dissolved substances in seawater

A) g/kg		B) mg/kg		C) gamma/kg	
Clorine	19.35	Strontium	13.00	Selenium	4.00
Sodium	10.76	Aluminium	1.8 Mx	Cesium	2.00
Magnesium	1.27	Fluorine	1.4	Uranium	2.00
SO_4	2.56	Silicon	1.2 Mx	Molydenum	0.7 Mx
Calcium	0.41	NO_3	0.6 Mx	Nickel	0.5 Mx
Potassium	0.37	Lithium	0.1	Gallium	0.50
HCO_3	0.13	Iron	0.06 Mx	Thorium	0.50
Bromine	0.064	Iodine	0.05	Scandium	0.40
Boron	0.015	Barium	0.05	Cerium	0.40
		Rubidium	0.02	Vanadium	0.30 Mx
		Copper	0.01 Mx	Yttrium	0.30
		Zinc	0.014 Mx	Silver	0.30 Mx
		Manganese	0.01 Mx	Lanthanum	0.30
		Lead	0.005 Mx	Mercury	0.30
				Bismuth	0.20
				Cobalt	0.10
				Gold	0.008 Mx
				Radium	0.00047 Mx

ANNEX 10

TABLE OF SPECIFIC WEIGHT, DENSITY IN DEGREE BAUMÉ AND VOLUME PRECIPITATION OF THE DIFFERENT SALTS DURING SOLAR EVAPORATION

Degree Bé	Specific Weight	Volume
3.5	1.0249	1000
4	1.0285	920
5	1.0358	774
6	1.0434	647
7	1.0509	540

Beginning of precipitation of calcium carbonate and iron oxide up to 15° Bé

8	1.0587	476
9	1.0665	422
10	1.0744	371
11	1.0825	328
12	1.0907	294
13	1.0990	266
14	1.1074	243
15	1.1160	222

Beginning of precipitation of calcium sulfate ($CaSO_4$) up to 30° Bé

16	1.1247	203
17	1.1335	186
18	1.1425	171
19	1.1516	159
20	1.1608	148
21	1.1702	139
22	1.1798	130
23	1.1896	122
24	1.1994	116
25	1.2095	112

Precipitation of sodium cloride, mainly from 25° Bé to 32° Bé mixed with different quantities of $CaSO_4$, $MgSO_4$, $MgCl_2$, KCl and Br, depending on their specific weight.

Degree Bé	Specific Weight	Volume
26	1.2198	100
27	1.2301	64
28	1.2407	44
29	1.2515	36
30	1.2624	30
31	1.2736	27
32	1.2849	24

precipitation by cooling of $MgSO_4$, impure through NaCl, $MgCl_2$, KCl; eventually extraction of bromine

33	1.2965	21
34	1.3082	19
35	1.3202	17

Precipitation of mixed salts; event. production of sodium sulfate

36	1.3324	
37	1.3447	6.3

Precipitation of potassium (potassium and magnesium salts, sodium cloride)

38	1.3574	5
39	1.3703	
40	1.3874	

Precipitation of magnesium cloride, impure through NaCO $MgSO_4$ and potassium salts

ANNEX 11

Prices for raw materials, production costs and selling prices ex CNA plant, Cabo Frio, as per December 1970.

	Cruzeiros	
Fuel oil	91.86	per ton
Seasalt	96.83	per ton
Steam at 2,5 ata.	7.30	per ton
Sweet water	0.18	per cu.m.
CaO (production cost)	30.00	per ton
Na_2CO_3 (production cost)	382.00	per ton
Brine from the solar plant at 21° Bé	5.00	cu.m.
Salt from the submerged combustion plant (production cost)	87.66	per ton
Salt from the vacuum plant (production cost)	105.39	per ton
Light soda (selling price)	623.27	per ton, fob Cabo Frio
Dense Soda (selling price)	705.00	per ton, fob Cabo Frio
Wage of attendant	7.27	per hour
Wage of repair mechanic	7.89	per hour

Cruzeiro 1 = DM 0,76

SOME FIGURES
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AND WILL NOT
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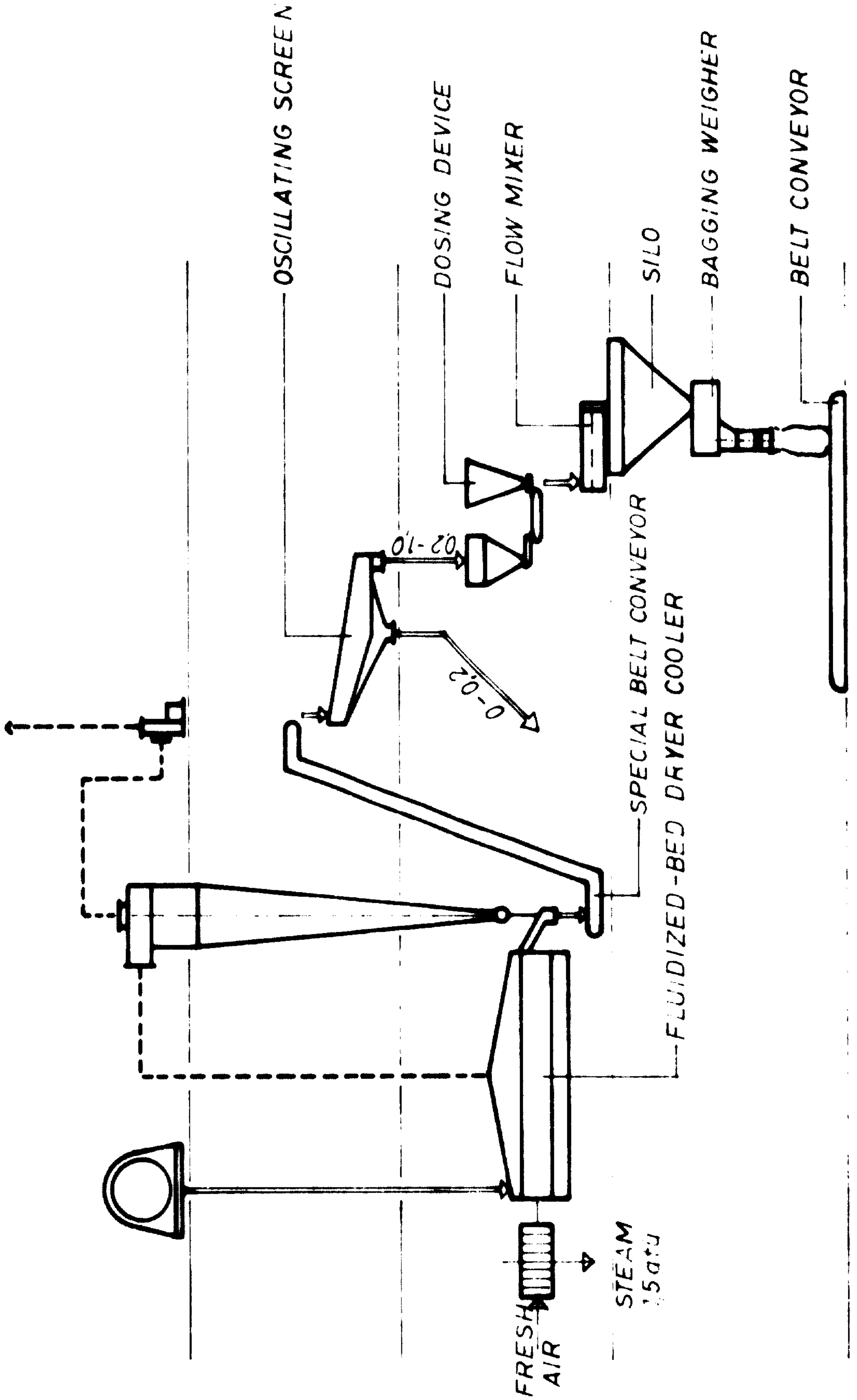
Annex 14



	Dat.	Name		**Deutsche Beratungsgesellschaft für Salinentechnik mbH**
Gez.	11.2.71	Schack		

Vacuum-Plant
Sketch
Drying, Mixing and
Bagging Section

DBS 3/71 CNA

ANNEX 15

Imports of Magnesium products to Brazil, during 1968

Store No. 51 314 hydroxydo de magnesio ($Mg(OH)_2$)
19.468 kg = \$ 11.953,-

Store No. 51 334 oxydo de magnesio (MgO)
155.556 kg = \$ 99.064,-

Store No. 51 433 sulfato de magnesio ($MgSO_4$)
439.445 kg = \$ 44.182,-

These data have been received on February 11th, 1971 from the Statistisches Bundesamt, Wiesbaden. (Federal German Bureau of Statistics, Wiesbaden, West Germany).

References and Bibliography

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Mr. Carvalho (Solar Plant)

Dr. Claudio (Soda Ash Division)

Mr. Edval, Industrial Superintendent

Mr. Jose Julio, Engineer, Assistant

Mr. Leonel, Industrial Engineer

Mr. Ignacio Paes (Engineering Department)

Dr. Pedro (Operation Department)

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Caloric, Gesellschaft für Apparatebau mbH., München

Dorr-Oliver GmbH, Wiesbaden

Deutsche Solvay AG, Theinberg

Chemische Fabrik Stockhausen & Cie., Krefeld

Statistisches Bundesamt, Wiesbaden

CNA have made the following documents available to DBS, some of which are Annexes of this report

Chart as per Annex 3	
Chart as per Annex 4	
Chart as per Annex 5	
Chart as per Annex 6	
Map of Cabo Frio 1:25.000	
Pre-concentrador da CNA	Drawing No. 3.361 al
Process Flow Diagram	Nordac Drawing No. 7654/b
Process Flow Diagram, Phase 1	Nordac Drawing No. 137504
Fluxograma da combustao submersa	CNA without number
General arrangement (layout) of evaporator	Nordac Drawing No. f 7720
Arrangement of preconcentrator	Nordac Drawing No. f 7750/c
Arrangement of decanter 1, 2 and 4	Nordac Drawing No. f 7724/b
Arrangement of decanter 3 and 5	Nordac Drawing No. f 7728/b
Arrangement and details of slurrypump drives	Nordac Drawing No. f 7739/b
Arrangement and details of scrubbertowers	Nordac Drawing No. f 7727
Tratamento da salmoura esquema	CNA Drawing No. 1612 a3
Evaporacao adaptacao para a producao de sal bruto	CNA Drawing No. 1753 a2

These sources of technical literature have been most useful in the preparation of this report

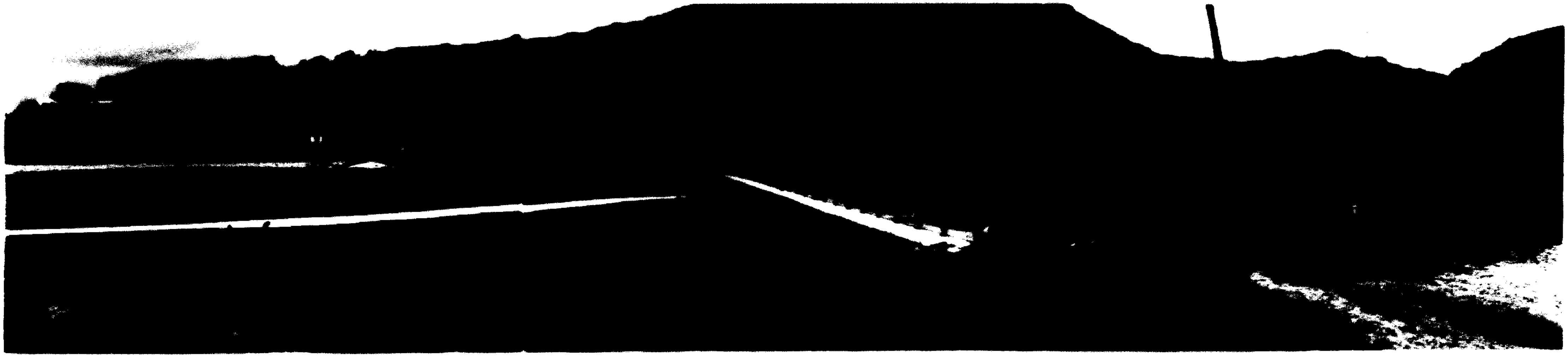
A chemical engineer's guide to seawater, chemical engineering November 1969

Sodium cloride, by D.W. Kaufmann, ACS Monography No. 145 (1960)

Erzeugung von Soda, by Prof. Dr. Z. Rant (1968)

Salzbergbau und Salinenkunde, by F.A. Führer

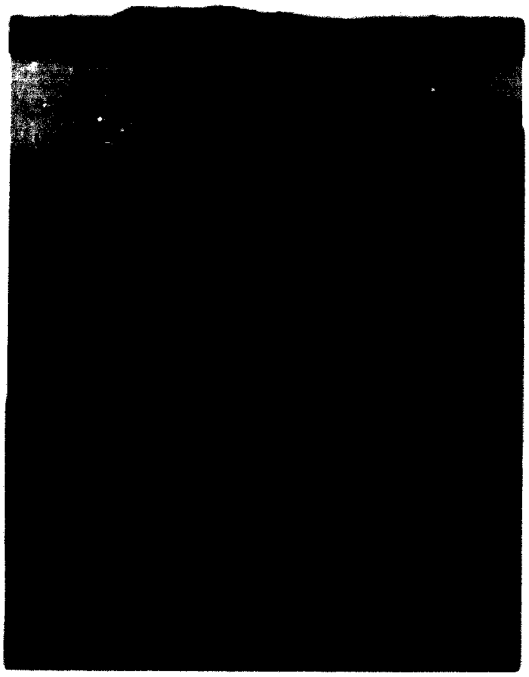
CABO FRIO PLANT



21° Bé BRINE BASIN

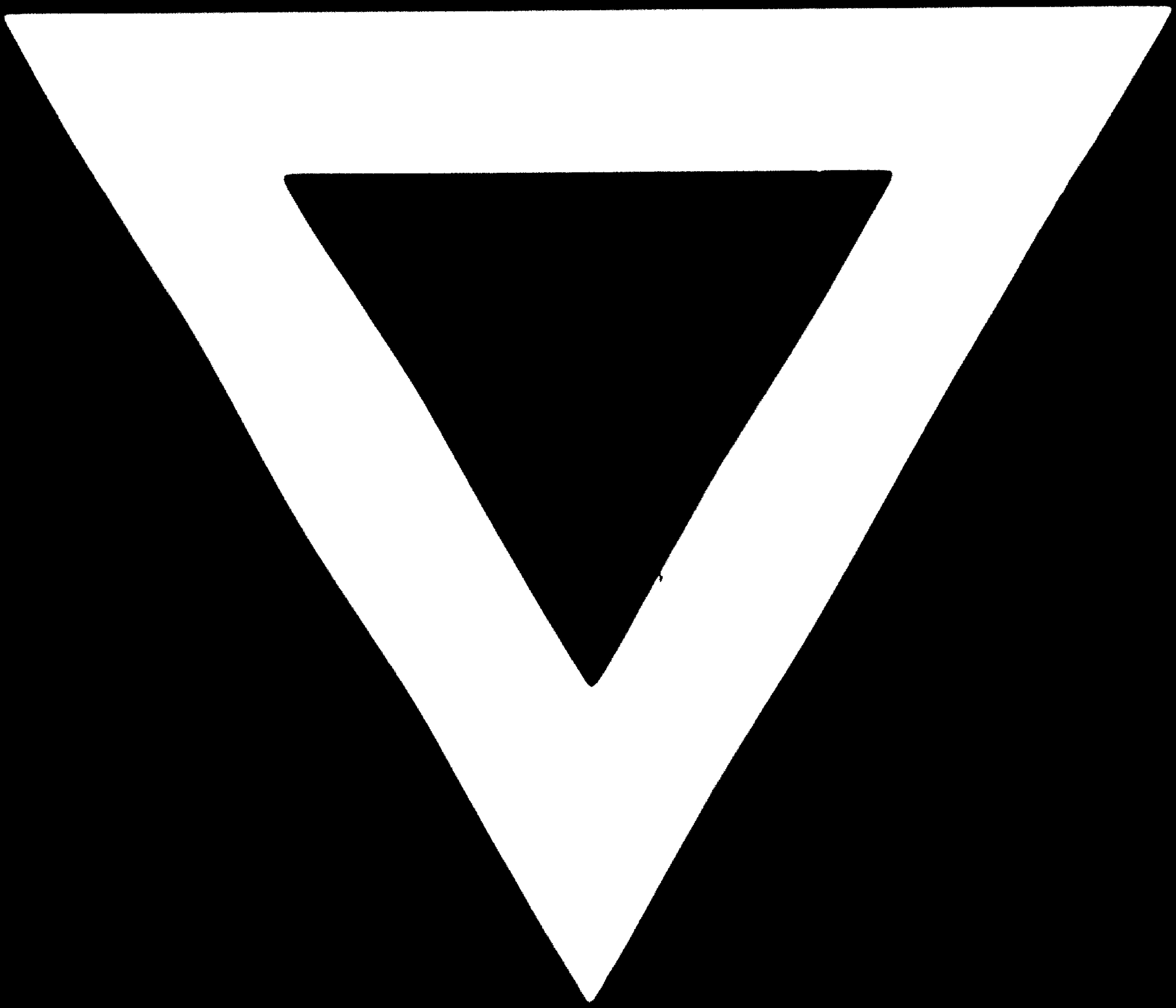
"CONCENTRADORES"

SEASHELL IN A "MARNEIS"



DRIED ALGE

C-537



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