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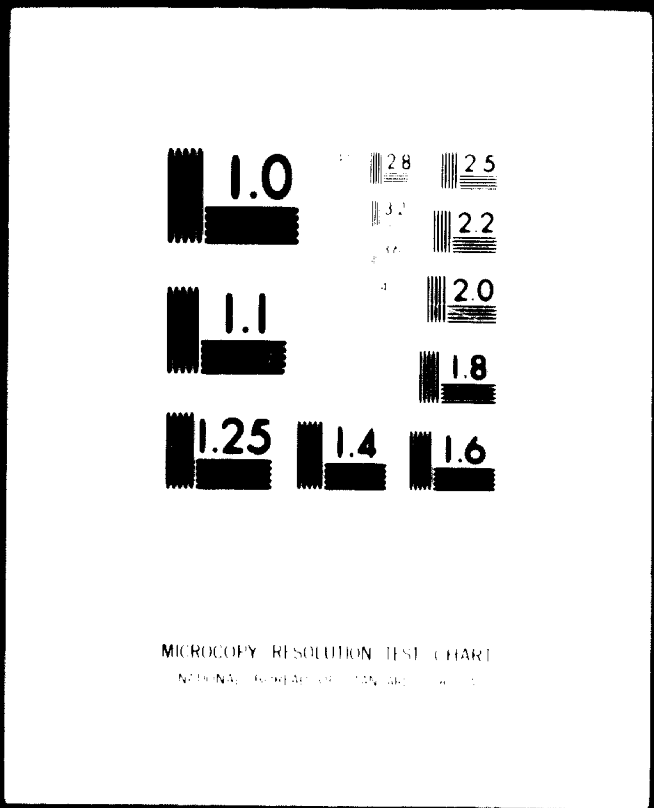

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Provision of Services relating to Assistance in Establishment of Solar Salt Production at the

"Saltworks of Togo" (Salinto) in Togo

FINAL REPORT

prepared by

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MUNICH - SELIGENSTADT

on behalf of the
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2. Introduction

Up to this day, no salt is being produced in the Republic of Togo. In other words, every single ton of salt has to be imported.

Since rock-salt deposits are unknown in the area, the Togolese government began in 1962 with German technical aid to look into the possibilities of obtaining solar salt on the coast. A report (1)* was prepared for the purpose.

The positive result of these investigations prompted a further report (2)* on the establishment of a solar-salt plant with an annual capacity of 10,000 tons or, alternativaly, 20,000 tons. The agreement of Bamako, according to which Togo was to supply Dahomey, Upper Volta, Niger and Nigeria with solar salt, resulted in an additional report (3)* regarding the possibility of producing 100,000 tons of solar salt per year.

When this agreement did not materialise, the Togolese government together with a private consortium established the Salin du Togo (Salinto) in 1969. It is the purpose of that company to assure ample domestic supplies of salt to Togo.

For this purpose, Salinto prepared another report (4)* which was essentially based on the preceding studies and investigated the economy of smaller salt production facilities. An initial annual capacity of 5,000 tons was chosen. In a second stage, production was to be increased to approx, 10,000 tons per year to satisfy actual demand.

After Salinto had started planning and building the saline early in 1971, a number of problems were encountered, which have still to be solved.

* See references

As a result, DBS was contracted by UNIDO to assist Salinto with practical advice and to prepare a report covering the following subjects:

I The present status of planning.

II The construction work performed up to date.

III A suggestion for the construction of a profitable solar plant, including the design of sea-water intake facilities and solar ponds.

IV Instructions for execution of the construction work.

V Selection of suitable machinery.

VI Instructions for the production of solar salt.

3. Findings, conclusions, recommendations

During their first visit to Salinto in Togo in the period from April 18 to 27, 1971, DBS representatives were able to make the following observations:

Salinto is hard pressed for time. The first salt harvest is scheduled to be collected in the spring of 1972, since otherwise almost one year would be lost, placing a considerable financial burden on Salinto.

Work on the construction of the saline was started by Salinto early in 1971.

The design and construction documents prepared by Salinto up to date are insufficient and have to be modified.

Salinto lacks accurate surveying data on the sea side and partly also on the land side.

Salinto has no concrete plans regarding sea-water intake. On the other hand, the intake point is fixed by construction of the pump house. The pumps are already available.

Salinto has no concrete plans concerning the size and construction of the solar ponds. According to the drawing, the crystallisers are planned in the form of concrete basins on the sandy beach.

The processing and packing of the solar salt remain to be clarified.

The capital available at present will hardly last through the first construction stage.

Based on the above observations, the investigations made on the spot and a thorough study of existing possibilities, we wish to summarise our recommendations for expansion of the saline as follows:

Surveying: up to a water depth of approx. 5 m at sea and from the pump house to the end of the pipe line on land.

Construction of the sea-water intake line on the sea bottom to allow the pumping of sea water to be started by November (Annex 18).

Installation of pumps as deep as possible, max. 3.8 m above mean sea level.

Laying of sea-water pressure line with allowance for longitudinal strain (Annex 21).

Construction of crystallization ponds in loamy soil.

Construction of solar plant according to Annex 22.

Completion of storage buildings and erection of the office building.

Erection of a weather station and an experimental pond on the premises of the saline.

Installation of washing, centrifugal and bagging facilities (Annex 25).

Training of 1 - 2 Togolese technicians in a suitable solar saline for subsequent employment as managers.

Checking of the different construction stages completed by Salinte and technical assistance up to the salt harvest.

Full payment of the company's capital stock and, if possible, procurement of a loan on favorable terms (Development Bank) to fund the first construction stage.

4. Economic aspects of salt production

The Republic of Togo, situated on the Gulf of Benin between Dahomey and Ghana, extends some 550 km to the north, while its sea coast is only about 50 km long (see Annex 1).

Rock-salt deposits have not been discovered in the country so far and there is no solar-salt plant. As a result, all of the salt consumed in the country has to be imported.

The purpose of the solar-salt plant to be erected by Salinto is gradually to meet the domestic demand for salt. In the first stage with an annual production capacity of 5,000 tons about half the present demand will be met. Complete coverage of domestic demand will be reached in the second stage with an annual capacity of 10,000 tons.

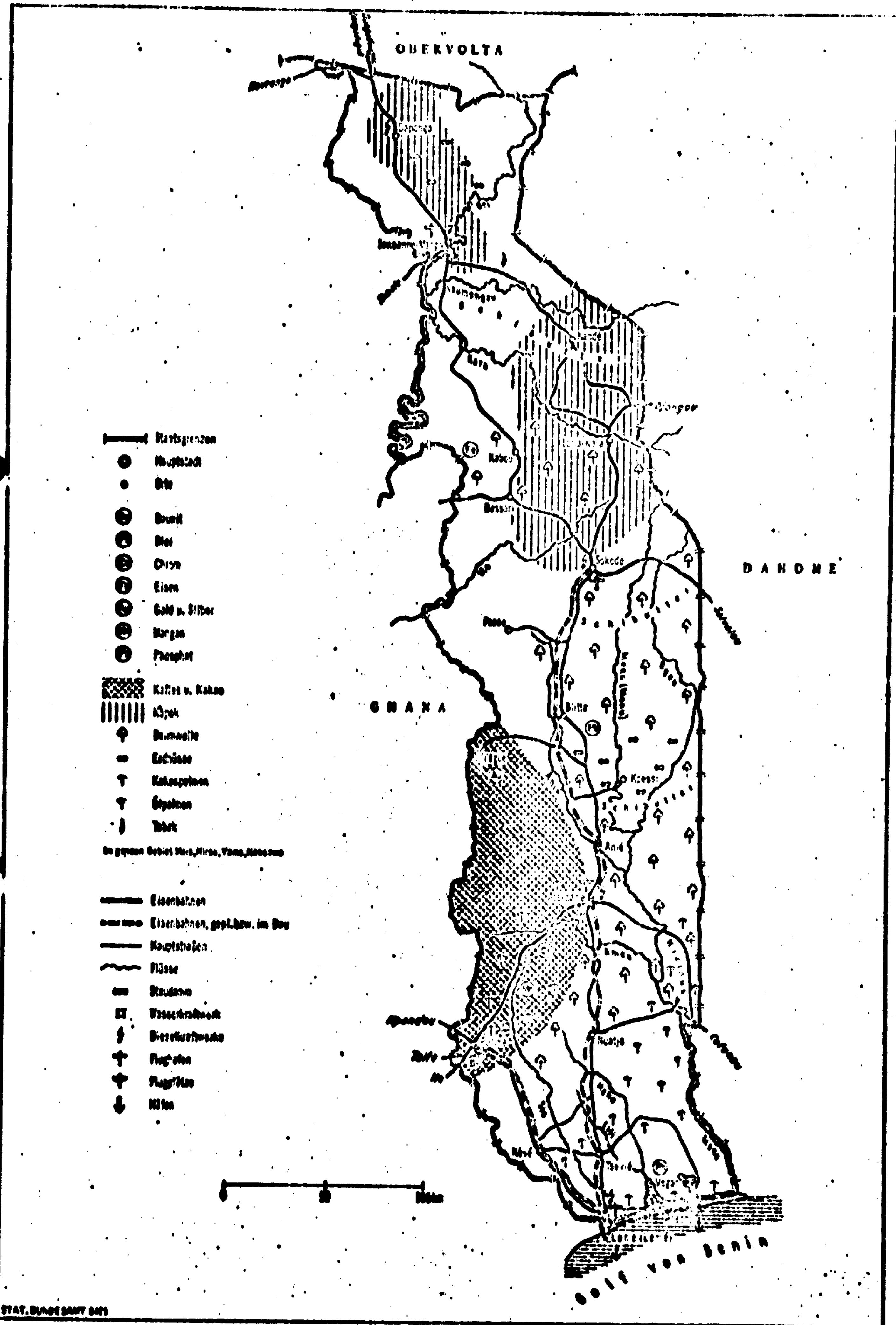
The Selinto report (4)* mentioned before assumes a net profit of about 30 % already in the first phase and one of almost 50 % in the second phase. Even if it is assumed that the capital cost used in these calculations is too low, it may be expected on account of present wholesale prices that a production facility with an annual capacity of 5,000 tons will operate profitably.

4.1 Population and salt consumption

The population of Togo increased from 1.29 million in 1956 to 1.724 million in 1967. A figure of 1.815 million is given for 1970.

Assuming an average annual consumption of approx. 6.0 kg of salt per capita, an overall consumption of approx. 11,000 tons per year has to be expected. Since imports generally remain below this figure, it may be assumed that part of the population in the extensive border areas, in which effective control is practically impossible, take advantage of illegal imports, above all from neighboring

* See references


OBERVOLTA
DANOME
GHANA
Sokode
Bassari
Kabou
Anié
Golf von Benin
Eisen
Gold u. Silber
Phosphat
Kaffee u. Kakao
Tabak
Eisenbahnen
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[illegible]

Ghana where solar salt is being produced.

Salt consumption will undoubtedly further increase as the population grows (by about 2.0 to 2.5 % annually) and as high-sea fishing is modernised.

In addition, there will be a growing demand for industrial and curing salt in the same measure as the industrialisation of the country makes progress.

4.2 Imports

4.2.1 Volume

Annex 2 summarizes salt imports for the years 1948 to 1969. It is evident that an average of approx. 7,200 tons were imported in each of the past five years.

The peak of approx. 10 - 11,000 tons in 1951, 1958 and 1962 to 1964 should be due to imports that were reexported to Upper Volta and Niger. The overall trend is towards increased salt imports.

4.2.2 Countries of origin

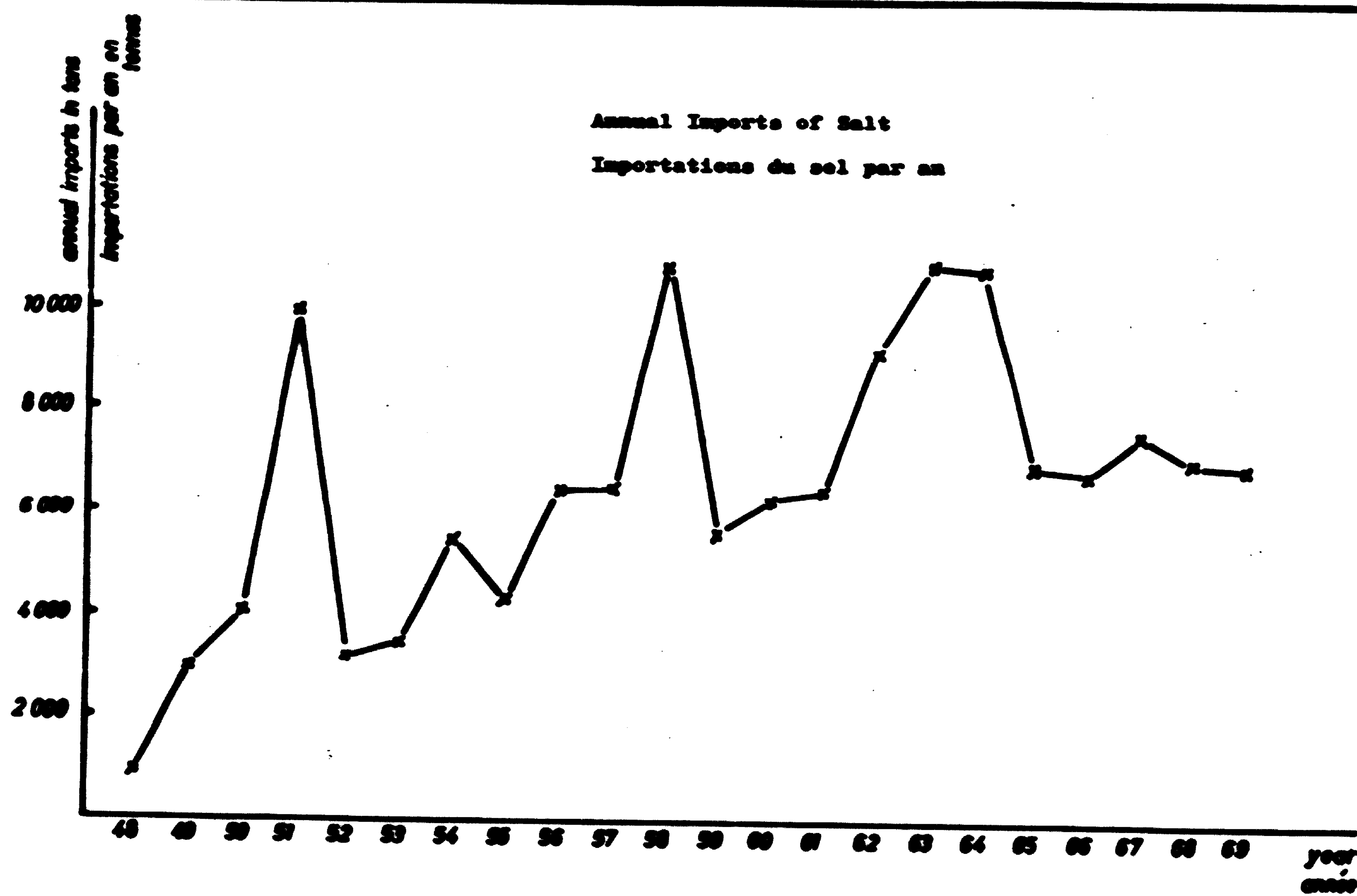
The principal supplier of salt is Spain which contributes about 50 % of the overall imports, followed by:

Senegal
Egypt
Algeria
Italy
Federal Republic of Germany
France
Great Britain
the Netherlands.

4.2.3 Prices and quality

Annex 3 lists the value of annual salt imports plus net import prices per ton for the period from 1963 to 1969. In the period from 1967 to 1969 some Fr CFA 66 million of foreign exchange were spent on salt imports every year.

Annex 2


Annual Imports of Salt
Importations du sel par an
annual imports in tons
importations par an en tonnes
10 000
8 000
6 000
4 000
2 000
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
year
année

During that period, the net import price was approx. Fr Cfa 9,000 per ton = DM 120.- per ton (1 DM = 75 Fr Cfa).

In addition, there were import duties and fees amounting to about 25 %. In 1970, the wholesale price per ton in Lomé was Fr Cfa 13,320 = DM 178.-.

By far the major portion of the imported salt is solar salt of medium to coarse grain, whitish-gray color and high moisture content. This salt from the Mediterranean countries and Senegal is generally packed in 18-kg burlap bags - recently also in plastic bags. The 18-kg bag is presently the standard sales item in Togo, since loads are carried almost exclusively on the head by women. In addition, the 25-kg bag is making slow progress, while 50-kg bags are in very low demand.

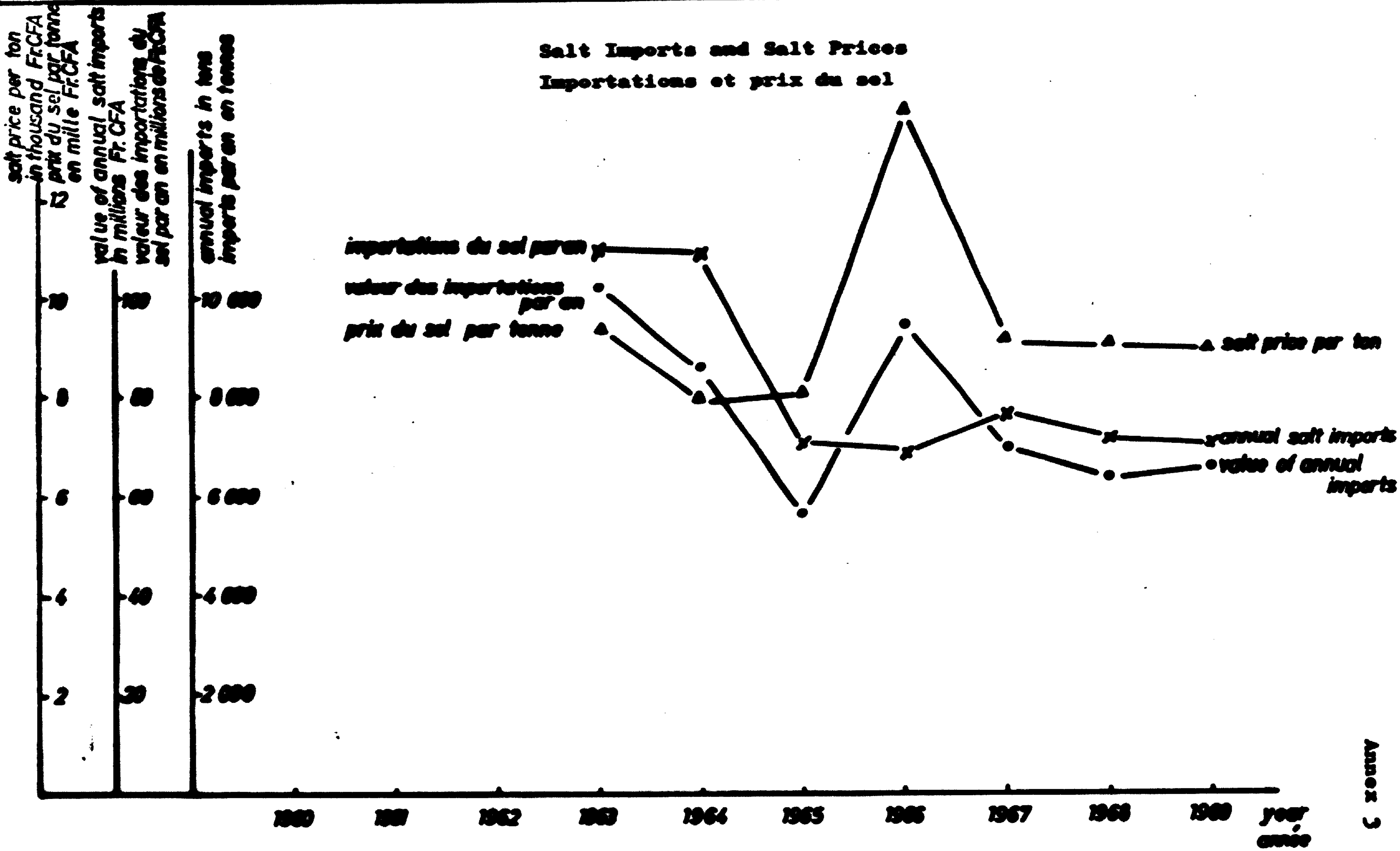
Department stores also offer medium-grain common salt in 1-kg plastic bags and fine-grain table salt in 1/2-kg bags. However, the sales volume is low since only a small portion of the urban population can afford to pay the high price of approx. Fr Cfa 75.

4.3 <u>Communications and shipping cost</u>

The road network in Togo has been considerably improved in the course of the past few years. The coastal road from the border of Ghana to the border of Dahomey has been expanded into an interregional highway and the road from Lomé to Palimé provided with an asphalt surface. In addition, improvement of the road to the north via Blitta, Socodé and Mango up to the border has been started in order to link up the north of the country with the existing communications network.

Shipment of the salt to the interior of the country is usually made by rail up to the northernmost station, which is the town of Blitta some 250 km from Lomé.

Salt Imports and Salt Prices
Importations et prix du sel



Road shipment from Blitta further to the north is still limited largely to the dry season.

According to the Salinto report (4)*, freight charges are the following:

Rail shipment (10-ton consignments):

Lomé - Paliné	Fr Cfa	775 per ton
Lomé - Atakpamé	Fr Cfa	1,050 per ton
Lomé - Blitta	Fr Cfa	1,700 per ton.

For road shipment to the north, the following additional costs are incurred:

Blitta - Socodé	90 km	Fr Cfa	1,275 per ton
Blitta - Bassari	150 km	Fr Cfa	2,250 per ton
Blitta - Lamakara	161 km	Fr Cfa	2,415 per ton
Blitta - Kandé	251 km	Fr Cfa	3,765 per ton.
Blitta - Mango	331 km	Fr Cfa	4,975 per ton
Blitta - Dapango	400 km	Fr Cfa	6,090 per ton.

These high freight charges add considerably to salt prices in the interior of the country. However, as progress is made in the extension and improvement of the road network, these costs should be reduced.

4.4 Possibilities of exportation

There should be a concrete possibility of future salt exports by Salinto to neighboring Dahomey which is part of the Cfa area. With its population of some 2.6 million, Dahomey likewise has to depend on salt imports.

The situation of the production facilities near the Dahomey border and good road connections should prove to be of particular advantage.

Possibilities of exportation to Niger will also have to be studied.

* See references

5. Site selection

A solar saline requires fairly flat, low country at sea level with a minimum of vegetation cover. The soil should be loamy, i.e. impermeable to water, to avoid costly sealing work. Moreover, the area should not be used agriculturally.

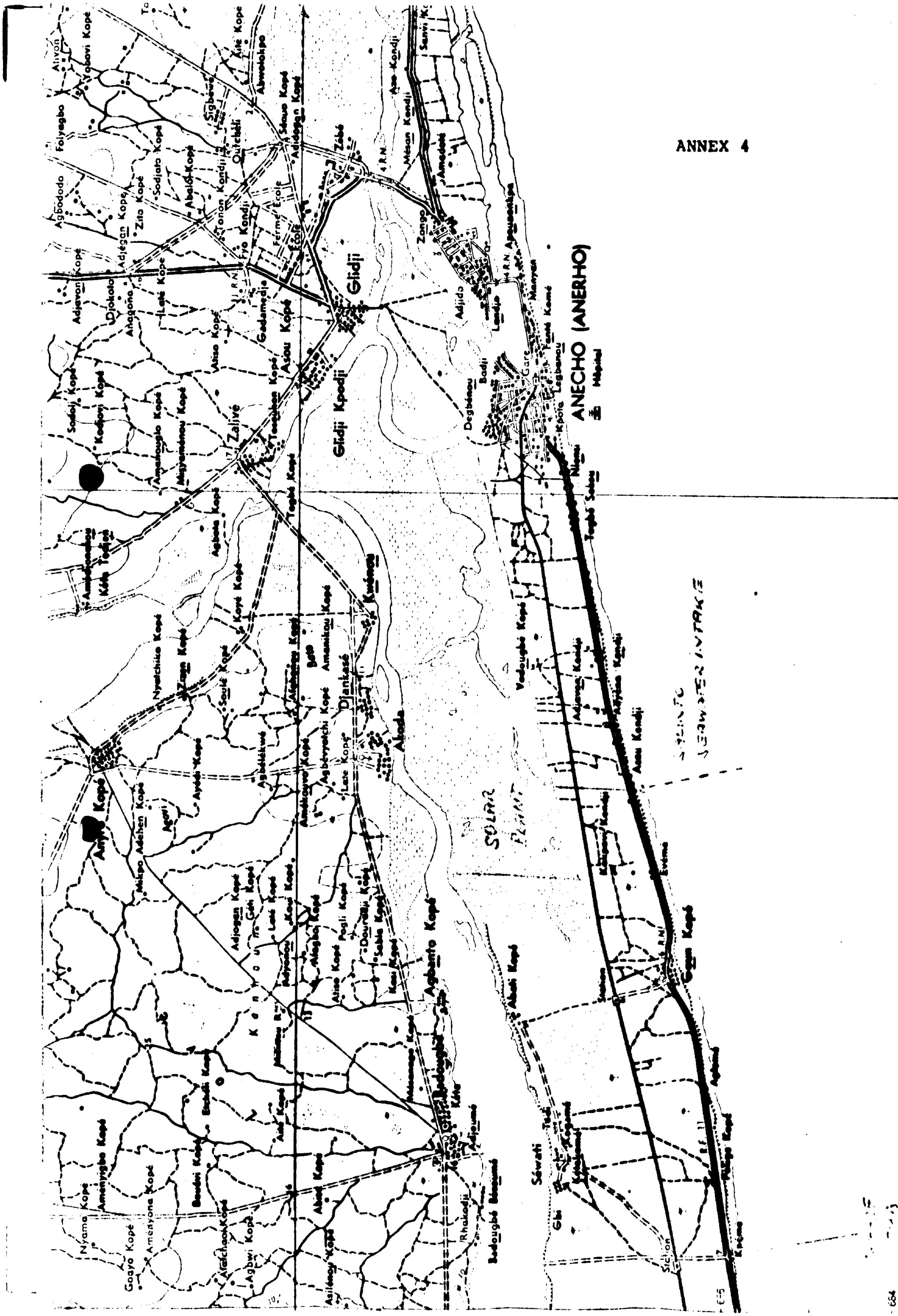
An area of this type was discovered west of Anecho by Dr. Jakubowsky together with the author of the present report and was suggested to the Togolese government as a suitable site for a solar saline. This area is about 1,000 m north of the sandy beach between Guen Kopé and Anecho. It extends about 1.2 to 1.5 km north to the lagoon and about 5 km in west-east direction (see Annex 4).

The subsoil at the site consists of firm, bluish-gray, watertight clay which during the dry season consolidates into a hard surface and is thus ideally suited for the construction of solar ponds.

The eastern part of the site was topographically surveyed in 1963 as part of the German technical assistance program. A corresponding survey of the western part was performed by the Service Topographique Togolaise in 1968. These surveys confirm that there are extremely small level differences so that the development of the required areas is considerably facilitated. Salinto is planning construction of the saline in the western part of the area described, roughly at the height of km 41 and km 42 of the railway line, as was originally proposed in the report (3)*.

* See references

ANNEX 4



ANECHO (ANERHO)
Glidji
Glidji Kpodji
Zalivé
Djankasé
Agbanto Kopé
Zongo
Adjido
Degbénou
SOLAR PLANT

As regards communications, the site of the saline is favorably located some 200 m away from the Keta-Akonda station of the Lomé-Anecho railroad and some 800 m from the newly built coastal highway. At present, a laterite-surfaced track connects the saline with the coastal highway.

For the supply of sea water, the report (3)* had provided for the installation of an additional pump on the CTMB wharf at Kpémé. The sea water was to be fed to the storage basin in the far western corner of the site through a pipe line about 1.3 km long and a canal about 3 km long, following the railroad track.

In the construction of the saline, Salinte did not follow this recommendation, but built its own pump house for sea-water collection at the beach of Keta Akonda.

For the problems involved, see Section 9.

*See references

6. Climatic aspects

The south of Togo has a typically equatorial climate with two separate rainy seasons. The annual amount of precipitation in all parts of the country is over 1,000 mm, with the exception of the 30 to 40 km wide coastal area.

Exact knowledge of climatic conditions at the proposed site is, of course, of decisive importance for solar-salt production.

The "ASECNA" Exploitation Meteorologique maintains a central station at Lomé Airport, to which another 60 meteorological stations are attached. The stations nearest the site of the saline are:

Lomé Ville
Lomé Airport
Togoville
Anecho.

Part of the data compiled by these stations cover a period of up to 30 years and thus provide good averages.

Owing to the fact, however, that greatly varying values are obtained over distances of just a few kilometers - as is evident from the following tables - it is advisable to provide the saline with a meteorological station of its own (see Section 10.3).

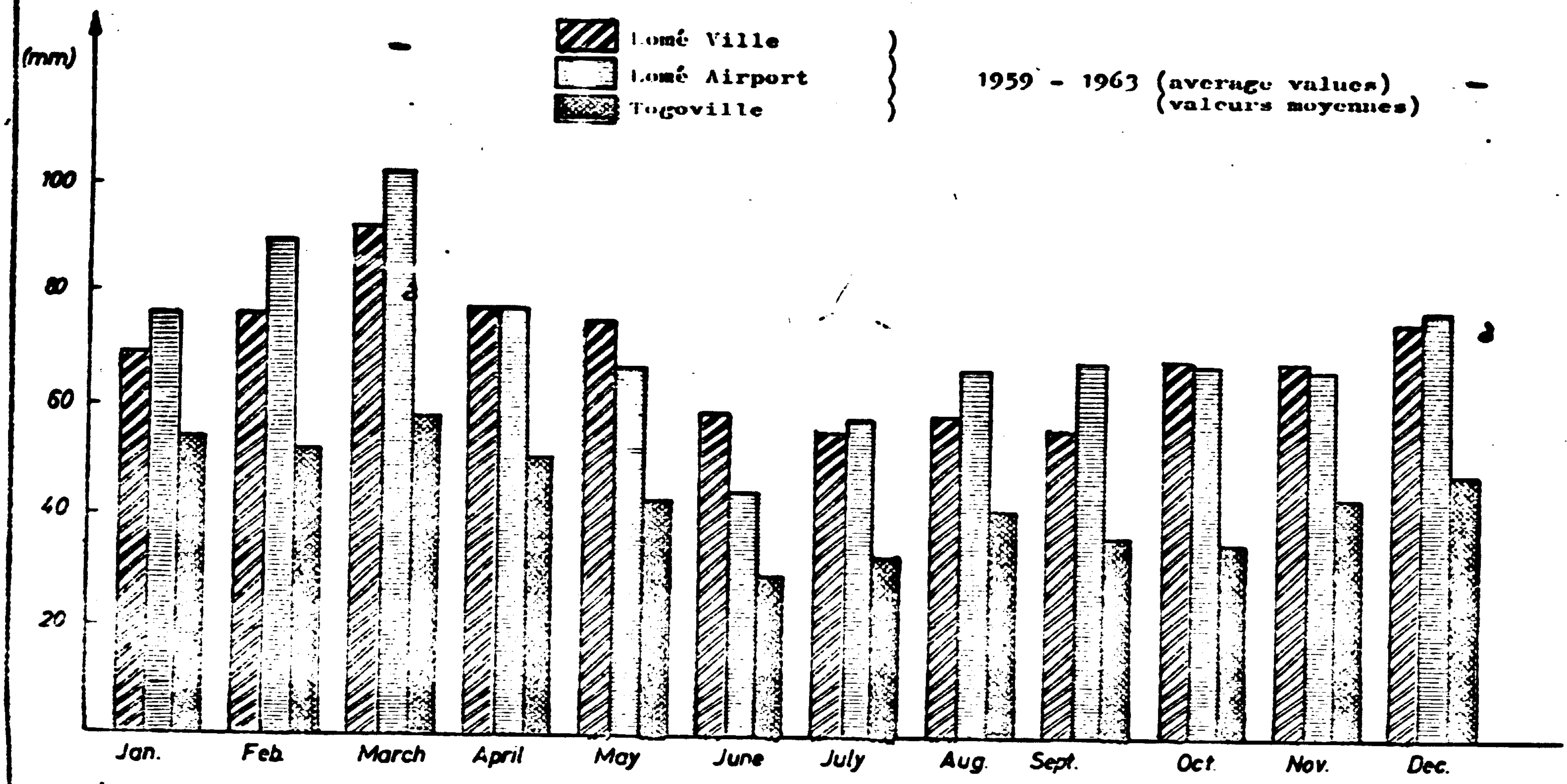
6.1 Evaporation rates

Of decisive importance for the operation of a solar saline, above all in regions with two rainy seasons, is the exact knowledge of monthly evaporation rates. In his report (1)*, Dr. Jakubowsky pointed out that the measurement data available vary greatly and therefore have to be used with caution. For the year 1961 he gave a total evaporation volume of 574.4 mm. In order to obtain more accurate information, we consulted the ASECNA at Lomé Airport and checked the

* See references

Monthly Evaporation Rates at the Togolese Coast

Taux d'évaporation mensuels sur la côte togolaise



records of the past years for those stations that are suitable for assessment and have registered the evaporation rate.

The mean values for the period from 1959 to 1963 are listed in the table (Annex 5).

From these data, the following average annual evaporation volumes are obtained:

Lomé Ville	837.7 mm
Lomé Airport	867.0 mm
Togoville	528.8 mm.

Unfortunately, evaporation is not measured at Anecho, which is nearest the site of the saline. The aforementioned figure for Lomé Ville gives an evaporation rate of approx. 2.3 mm per day.

By comparison, measurements performed by the author with the aid of a Piche Evaporimeter produced the following results:

19/4/71	4.1 mm
20/4/71	5.1 mm
21/4/71	4.1 mm
22/4/71	5.7 mm
23/4/71	4.8 mm
25/4/71	6.1 mm
26/4/71	4.8 mm
27/4/71	5.2 mm.

This gives an average evaporation rate of 5 mm per day, which is more than double the official values.

In order to clarify this discrepancy it was necessary to make a closer study of the measuring techniques employed by ASECNA. It was found that the values recorded are determined with the aid of a Piche Evaporimeter set up in a closed measuring station. This eliminates the effect of wind and insolation so that the results are not representative for solar evaporation.

On the other hand, the station also measures evaporation with an Evaporimeter according to BAC, i.e. in an open basin of 1 sq.m. This corresponds to the conditions encountered in solar evaporation so that this method can be accepted as commensurate with actual conditions.

The following annual evaporation rates according to BAC have been gathered from the unpublished records of ASECNA for Lomé Airport:

1969	1,844.5 mm
1970	1,835.2 mm.

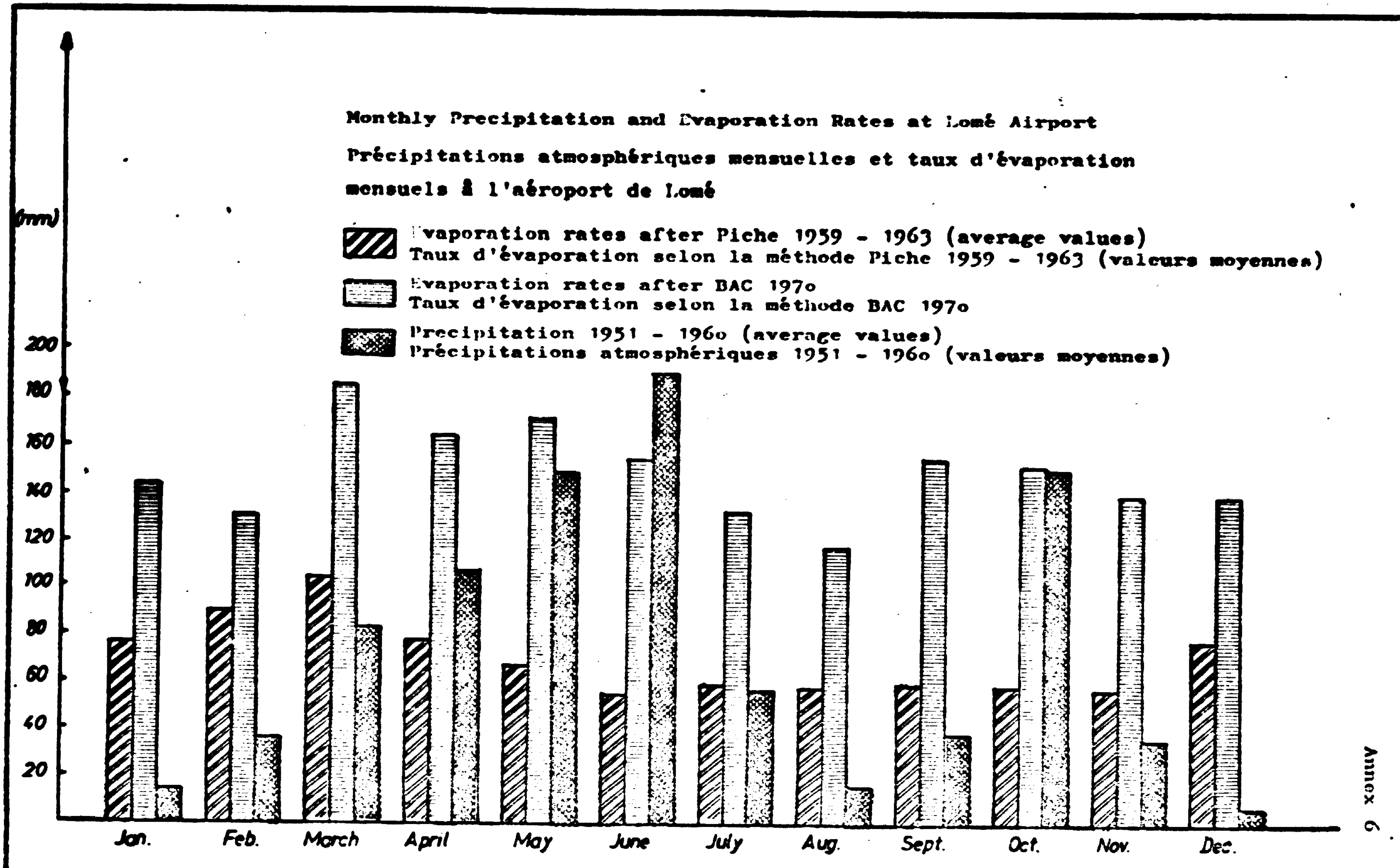
By comparison, the evaporation rates according to Piche were the following:

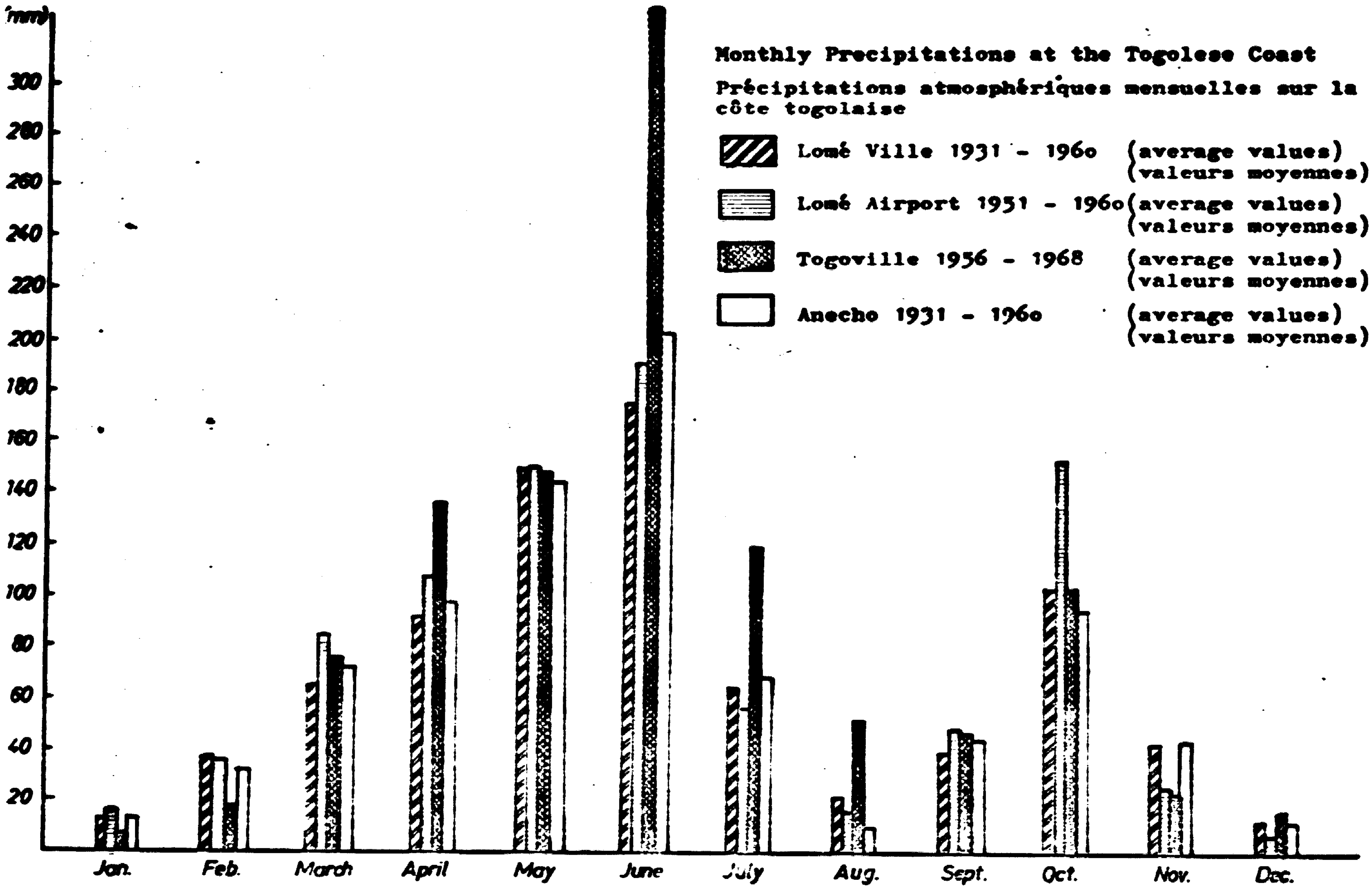
1959-63	867.0 mm
1969	783.8 mm.

The BAC values are thus very close to the values determined by the author and may be considered as a good approximation. The table (Annex 6) lists the evaporation rates according to Piche and BAC as well as the amount of precipitation in the different months.

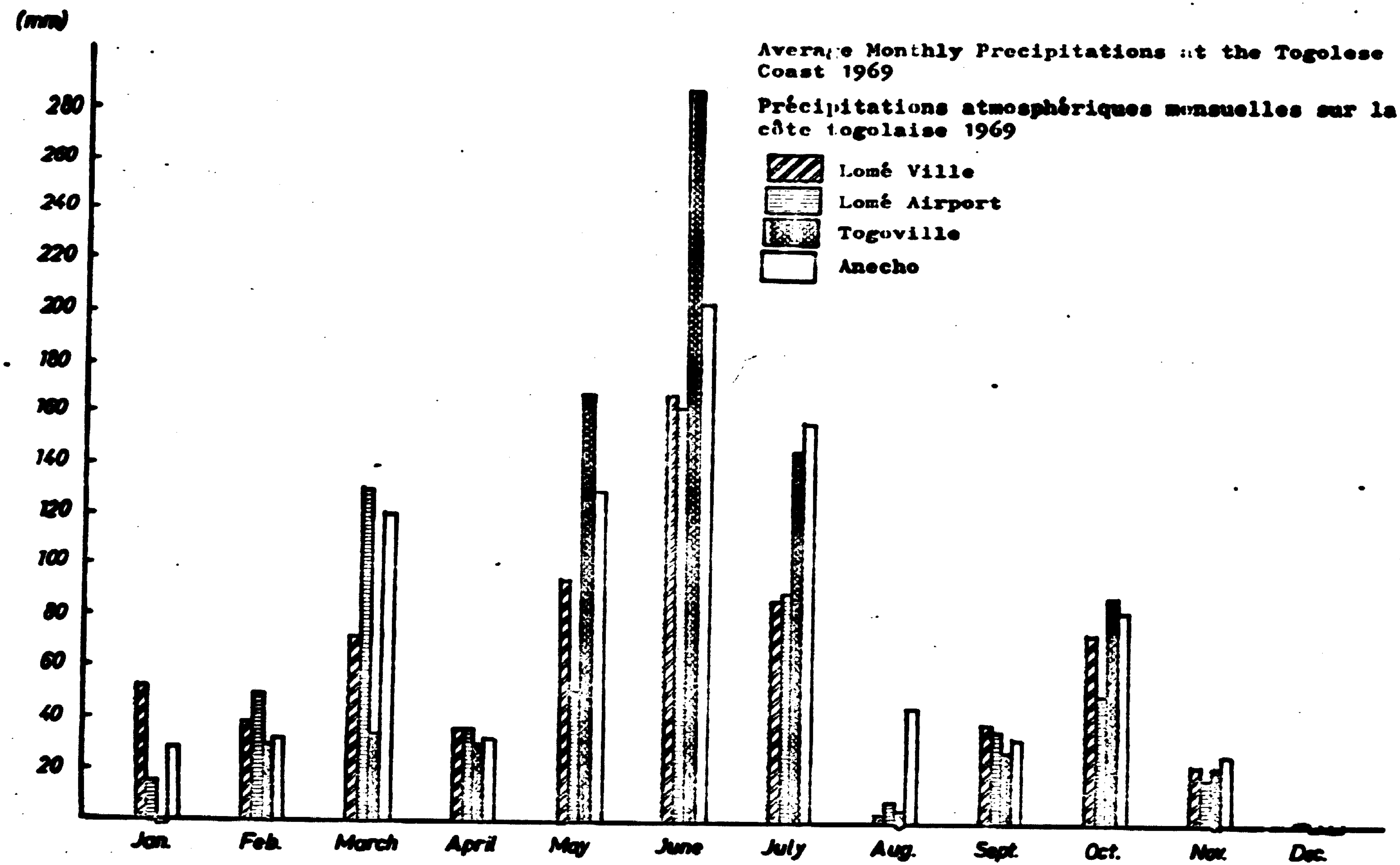
It is evident that for the Lomé Airport station the amount of precipitation exceeds the BAC evaporation rate only in the month of June. In October, the values are identical, while all other months show an excess of evaporation (according to BAC).

If we take a look at the table of precipitations (Annex 7), it becomes evident that precipitation is slightly less at Anecho than at Lomé Airport, above all in October. It may thus be assumed that net evaporation at the site of the saline will reach values at least similar to those of Lomé Airport, i.e. about 800 to 900 mm per year.


Monthly Precipitation and Evaporation Rates at Lomé Airport
Précipitations atmosphériques mensuelles et taux d'évaporation mensuels à l'aéroport de Lomé
Evaporation rates after Piche 1959 - 1963 (average values)
Taux d'évaporation selon la méthode Piche 1959 - 1963 (valeurs moyennes)
Evaporation rates after BAC 197o
Taux d'évaporation selon la méthode BAC 197o
Precipitation 1951 - 196o (average values)
Précipitations atmosphériques 1951 - 196o (valeurs moyennes)
(mm)
200
180
160
140
120
100
80
60
40
20
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.



Monthly Precipitations at the Togolese Coast
Précipitations atmosphériques mensuelles sur la côte togolaise
Lomé Ville 1931 - 1960 (average values) (valeurs moyennes)
Lomé Airport 1951 - 1960 (average values) (valeurs moyennes)
Togoville 1956 - 1968 (average values) (valeurs moyennes)
Anecho 1931 - 1960 (average values) (valeurs moyennes)
(mm)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.


Average Monthly Precipitations at the Togolese Coast 1969
Précipitations atmosphériques mensuelles sur la côte togolaise 1969
Lomé Ville
Lomé Airport
Togoville
Anecho
(mm)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Apart from this overall value, a monthly breakdown is of particular importance for brine treatment and salt harvesting in order to allow the operation of the solar installation to be optimally adapted to the climatic conditions. Further information on this subject will be found in the following Section.

6.2 Precipitation

The precipitation table (Annex 7) shows the rainfall at the coast of Togo. All the values for the Lomé Ville, Lomé Airport, Togoville and Anecho stations exhibit the same tendency. There is a major rainy season with a precipitation peak in June and a minor rainy season with lesser rainfalls in October. Although these values refer to different periods, it is evident that the basic tendency seems to hold for every year (Annex 8).

This table lists the precipitation measured at the aforementioned stations during 1969. The rainfall, above all at Anecho, is slightly higher in March and July than for the period from 1931 to 1960 (Annex 7). On the other hand, the short rainy season in October has only a minor effect. It is striking that during the major rainy season most of the rain falls at Togoville, i.e. towards the interior, This and the considerable fluctuations between the different places indicates that there are very limited local thunderstorms and rainfall which vary in size from one year to another.

A comparison of the percentage of rainfall per rainy season presents the following picture:

Lomé Ville	First rainy season approx.	54 %;
	Second rainy season approx.	17 %.
Anecho	First rainy season approx.	58 %;
	Second rainy season approx.	14 %.

In other words, about 70 % of the entire precipitation is recorded during the two rainy seasons. In spite of this, thunderstorms may produce heavy rainfall even during the so-called dry season, as is proved by the long-term records, for example for Anecho.

Although these fluctuations are not very frequent, such deviations from the rule should be taken into account when planning the solar installation in order to avoid a reduction in brine concentration.

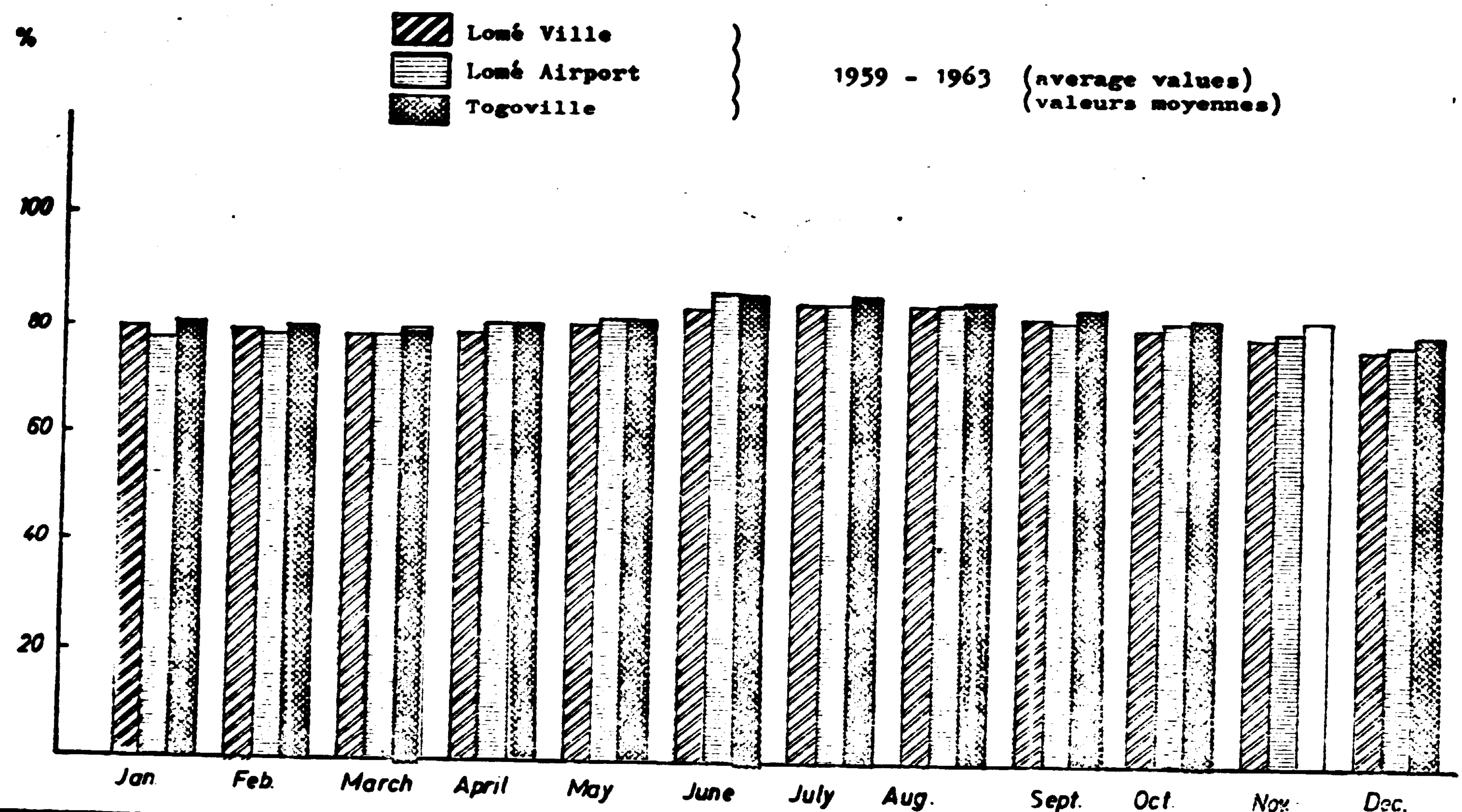
The comparison between the amount of evaporation (according to BAC) and rainfall (Annex 6) shows that the evaporation of sea water is possible in every month except June and October. If we assume, for example, that sea water reaches the preconcentrators in July ofthe first year, these ponds should be continuously operated until April to produce as much preconcentrated brine as possible. Starting in November, the brine can then be further concentrated in the subsequent stages until crystallization is achieved. Harvesting of the salt should be possible by March.

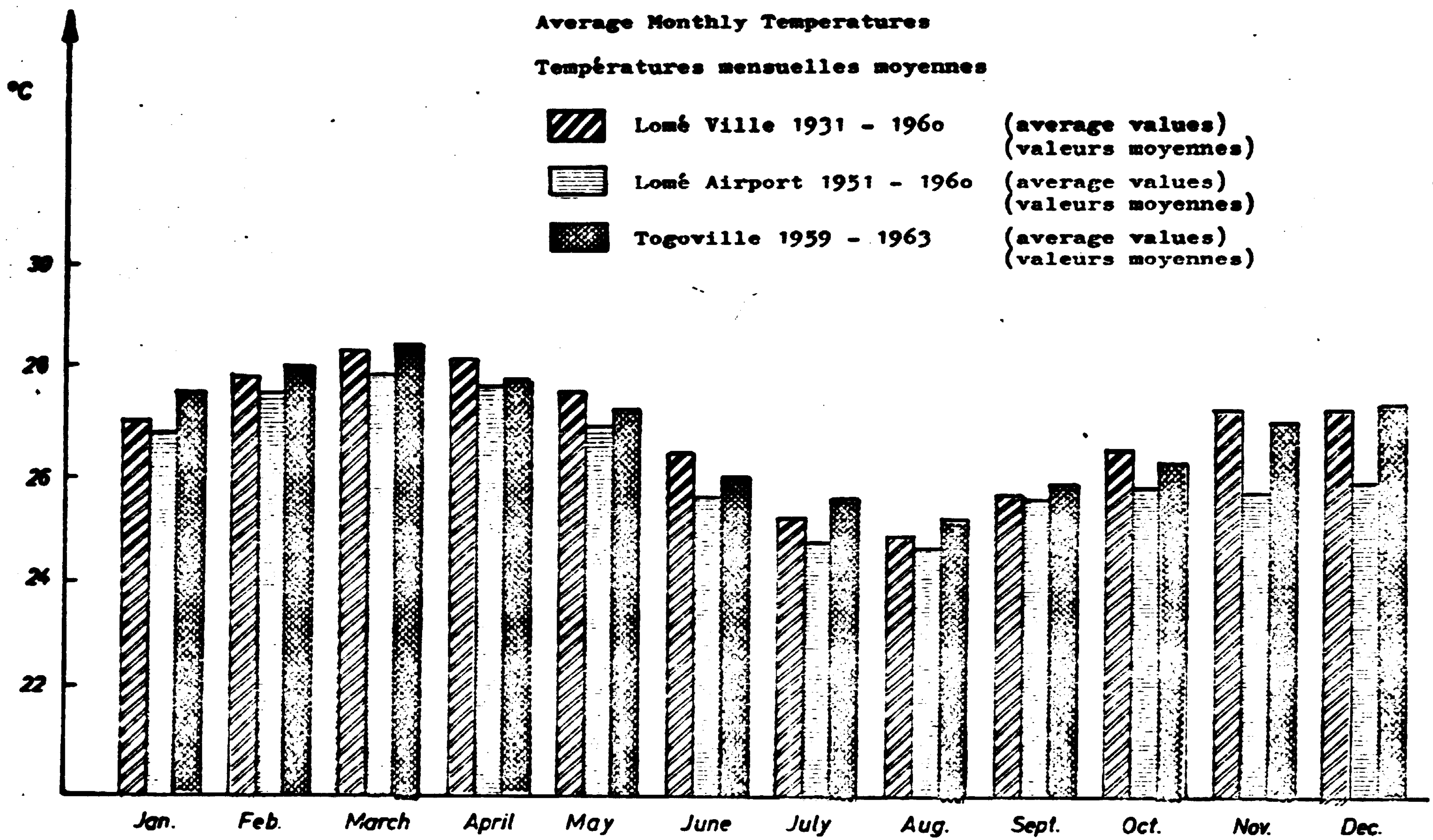
To protect the preconcentrated brine from rainfall, it is kept in deep basins with a small surface provided with a special overflow. The specifically lighter rain water will be discharged over these weirs so that the preconcentrated brine is only slightly diluted.

At the beginning of the dry season in July of the second year, this brine may be further concentrated until the salt crystallizes. Since in this case a longer crystallization time can be used, higher yields are possible.

It is thus obvious that special emphasis has to be placed on protecting the preconcentrated brine against rainfall in order to ensure a satisfactory production rate.

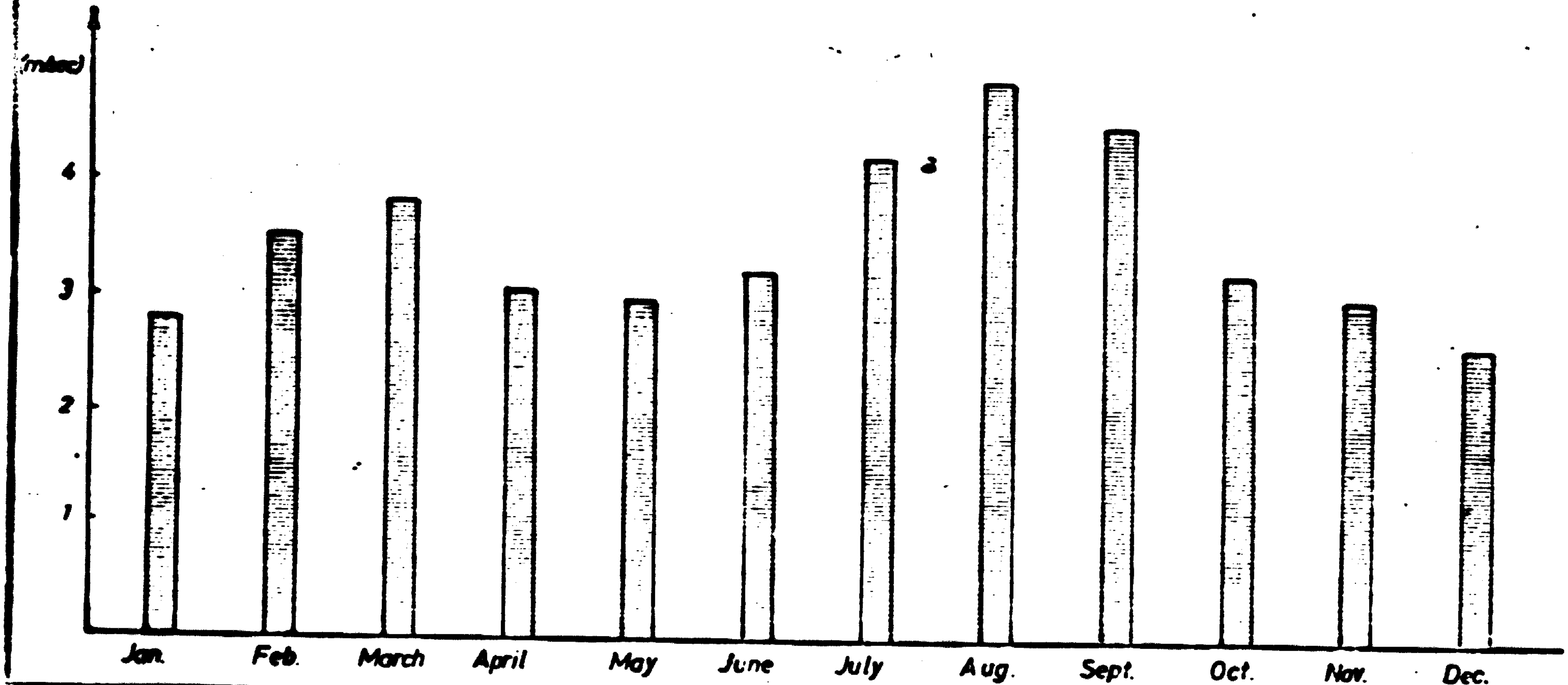
Relative Humidity at the Togolese Coast (Monthly Averages)
Humidité relative de l'air (taux mensuel) sur la côte togolaise




Average Monthly Temperatures
Températures mensuelles moyennes
Lomé Ville 1931 - 1960 (average values) (valeurs moyennes)
Lomé Airport 1951 - 1960 (average values) (valeurs moyennes)
Togoville 1959 - 1963 (average values) (valeurs moyennes)
°C
30
28
26
24
22
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Average Monthly Velocities of Winds at Lomé Airport (1955 - 1959)

Vitesses moyennes du vent à l'aéroport de Lomé (1955 - 1959)



6.3 Humidity of the air

By relative humidity of the air we understand the amount of water contained in the air at a certain temperature in relation to the degree of saturation. The lower the humidity of the air, the more water can the air absorb from evaporating bodies. As is evident from the table (Annex 9), relative humidity at the Togolese coast is fairly constant over the entire year. The average value is between 80 and 87 % with a peak during the rainy season in June and minimum values during the dry season in December.

In the course of the day, the values fluctuate between about 95 % in the morning and 60 to 70 % at noon, with an increase to over 80 % in the evening.

6.4 Temperature

Air temperature (Annex 10) in the coastal area is relatively constant. The annual average is 26.5° C with a mean maximum of 30° C and a mean minimum of 23° C. The highest temperatures are measured from December to March during the daytime (36° C), the lowest ones at nighttime (19° C).

The annual average of the sea-water temperature is 26.9° C. Between March and May it reaches values of over 30° C and drops to a monthly average of 22° C in August.

6.5 Wind velocity and direction

Wind speed at the coast of Togo is measured only by the meteorological station at Lomé Airport. The records (Annex 11) show that the wind velocity is about 2.8 to 4.9 m/sec, which is equivalent to an annual average of 3.5 m/sec. However, there are also peak velocities of up to 32 m/sec. It is therefore necessary to make the dams of the preconcentrators sufficiently high to prevent the waves from spilling into adjacent ponds of more highly concentrated brine.

For the purpose of solar evaporation, air movement is very desirable, since it will immediately carry away the moist air so that new, unsaturated air can come into contact with the water surface.

The information on wind direction is likewise very interesting. It is found that the preferred wind direction at the coast is south-southwest. The wind usually starts in the late hours of the morning and blows till the early hours of the evening. Both the wind direction and the wind speed are quite favorable for the purposes of the future saline.

7. Previous planning by Salinto

The planning data available at Salinto are insufficient. Except for the topographic map of the area north of the railway line up to the lagoon, there are no reliable topographic data. An indication of the work to be performed is given in Salinto's report (4)*. Reliable construction drawings are not available.

7.1 Production capacity and quality

The first stage of construction provides for an annual production of 5,000 tons of raw salt. The losses during harvesting and packing were assumed to be approx. 10 %, leaving an effective annual production of 4,500 tons.

In the second phase, the annual production capacity will be increased to 10,000 tons of raw salt. No information is available on the desired quality of the final product.

7.2 Sea-water line

There are no useful data on the design or constructionof the intake line.

The drawing of the concrete and earth ponds planned by Salinto only shows a side view of the suction pipe in the form of a sketch and without any dimensions (Annex 12). According to this drawing, the pipe is to be laid into the sea on a concrete structure above the water surface. At the end of this structure, the pipe runs into the water with a 90° bend.

Reliable data on the depth of the sea are not available. Nor are there reliable graphical data on the distance from the pump house to the site of the saline and pertinent spot heights.

Graphical data are likewise looking for construction of the pipe line on land and in the sea.

* See references

For the sea-water line, two diesel pumps with a capacity of 500 cu.m/h each are scheduled to be set up about 40 m from the main road towards the sea. The sea water is to be taken in by the pumps through a suction line still to be designed and pumped into the solar plant through a steel pipe line of 14" diameter with a length of approx. 1,000 m. The flanged pressure line is to be laid above ground to allow cleaning. Underpasses below the road and the railway line are provided, using concrete pipes of approx. 800 to 1,000 mm diameter.

7.3 Solar plant

Following the report (4)*, two drawings have been prepared for the construction of the solar plant, namely:

7.3.1 Implementation plan (ground plan at 1:2,000 scale)

This drawing may be considered as a layout plan for the plant from the pumping station to the ponds. However, there are no reliable data for the distance between the pump house and the railroad line, nor spot heights. According to this drawing, the solar plant is planned as follows:

At the end of the pipe line, the sea water reaches three successive reservoirs 50 m wide and 200 m long. These ponds are shown in the drawing north of the sandy palm belt, roughly in the extension of the existing road. An area of 500 m length by 1,000 m width west of the road (future phase des bassins), starting 320 m north in loamy soil, parallel to the railway line, has been earmarked for concentration of the sea water. According to the study, this area was to be subdivided into 48 ponds of 100 x 100 m. Each of these was to be subdivided another nine times. Their depth should be 30 to 40 cm. In the sandy soil between the railroad and the aforementioned area six ponds for concentrated brine (approx. 22 - 25° Bé), each measuring 30 x 100 m, and four cement ponds as crystallisers, each measur-

* See references

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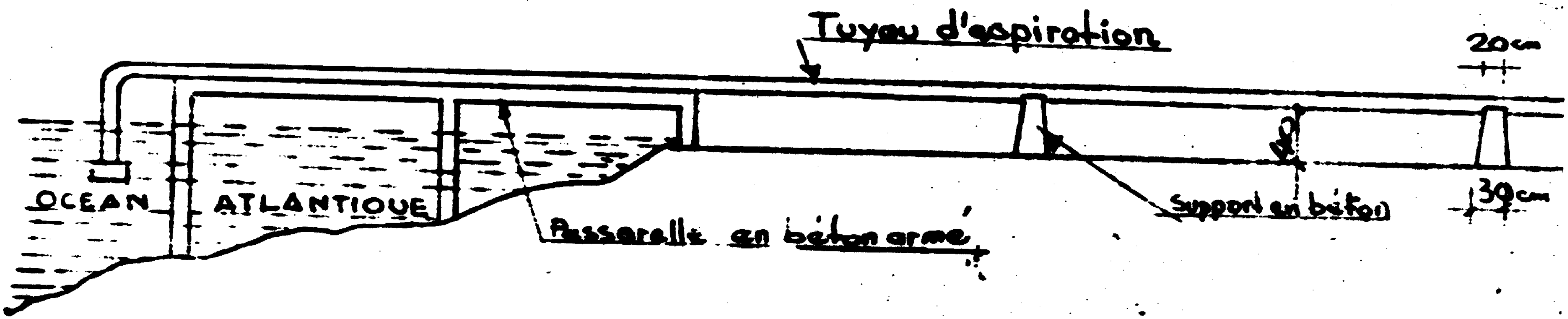


ing 80 x 125 m, are shown in the drawing. There is no further information on roads, dam widths, canals, weirs, discharge culverts for the mother liquor, etc.

According to verbal information, the sea water or brine is to be transferred from one group of ponds to another by means of mobile diesel pumps.

7.3.2 Plans - Sections of ponds - Piping (ground plans and sections at 1:20, 1:50 and 1:500 scale).

This drawing shows the ponds for concentrated brine and the concrete ponds at larger scales. It is evident from these plans that the earth ponds are to have a dam height of 0.8 to 1.0 m. The base width of the dams is 1.50 m, the crest width 1.0 m.

The bottom of the concrete ponds is shown with a thickness of 10 cm, while the lateral walls projecting 30 cm above the ground are 15 cm thick.

The following objections must be made against construction of the solar plant according to Salinto's plans:

I. In our opinion, the areas scheduled are insufficient for an annual production of 5,000 tons.

II. No allowance has been made for the second stage of construction.

III. Subdivision of the area of 300 x 1,000 m for preconcentration into 9 x 48 ponds is unnecessary and costly.

IV. Construction of the earth ponds in the sandy palm belt instead of in loamy soil increases the construction cost.

V. Instead of the expensive concrete ponds (six ponds of 80 x 125 m each cost approx. Fr Cfa 20 million), properly graded earth ponds should be constructed in loamy soil. The salt, which during harvesting may be contaminated by loam, should be processed in a washing and centrifugal plant to improve its quality (among other things, removal of part of the Epsom salt $MgCl_2$, $MgSO_4$, improved appearance, moisture suitable for bagging).

7.4 <u>Structures</u>

According to Salinto's plans, the following structures will be erected:

7.4.1 One pump house accommodating the sea-water pumps on the beach, mentioned under 7.2. In addition, the house will contain rooms for the engineer and the guard, with washing facilities. Ground area 15 x 6 m.

7.4.2 Two stores along the access road to the saline, for storing air-dried salt. Ground area 30 x 15 m, height approx. 5 m.

7.4.3 One building at the end of the present access road. This building is to serve as a materials store and workshop. In addition, it is to house a small diesel generating set providing electrical energy. Ground area 30 x 15 m.

7.4.4 One building with four offices and six rooms for the workers and the guard. Ground area approx. 17 x 18 m.

7.4.5 Two fresh-water tanks and one well.

7.4.6 One concrete slab, 30 x 50 m, for salt drying.

8. **Installations under construction and available equipment and machinery**

Up to now, all the work on the installations was performed by Salinto directly. This made it necessary to procure suitable equipment. In addition, a certain amount of material was ordered, the major part of which has already been delivered.

8.1 **Sea-water line**

For this pipe line, Salinto has already procured the following material:

8.1.1 Two Harland-Monoglide centrifugal pumps, type SNA 8, nominal capacity 500 cu.m/h, non-selfpriming, cast-iron casing, bronze runner, suction lift and pressure head according to enclosed diagram (Annex 13), driven by:

2 Skoda diesel engines, 6-cylinder in-line engines, water-cooled, 1967 models.

Output: 90 bhp

Speed: 1,500 rpm

8.1.2 Approx. 1,100 m of pipe, electro-galvanized steel, [illegible] diameter, 4 mm wall thickness, with flanges, length of sections 4.5 and 6 m.

8.1.3 The concrete pipes for underpasses below the road and the railway line.

8.2 **Structures**

The present status of the works is the following:

8.2.1 Pump house at the beach: completed up to the roof.

8.2.2 Two warehouses: foundations and partly also walls.

8.2.3 One magazine and workshop building: completed up to the roof.

8.2.4 Two fresh-water tanks: connecting pieces completed, tanks supplied.

REF. No.:

APPROVED BY:

DATE:

THE HARLAND ENGINEERING COMPANY LTD.

PUMP TYPE TEST CHARACTERISTIC

PUMP TYPE AND FRAME: MONOGLIDE SNA 8

CLIENT:

ANNEX 13

CLIENT'S DUTY

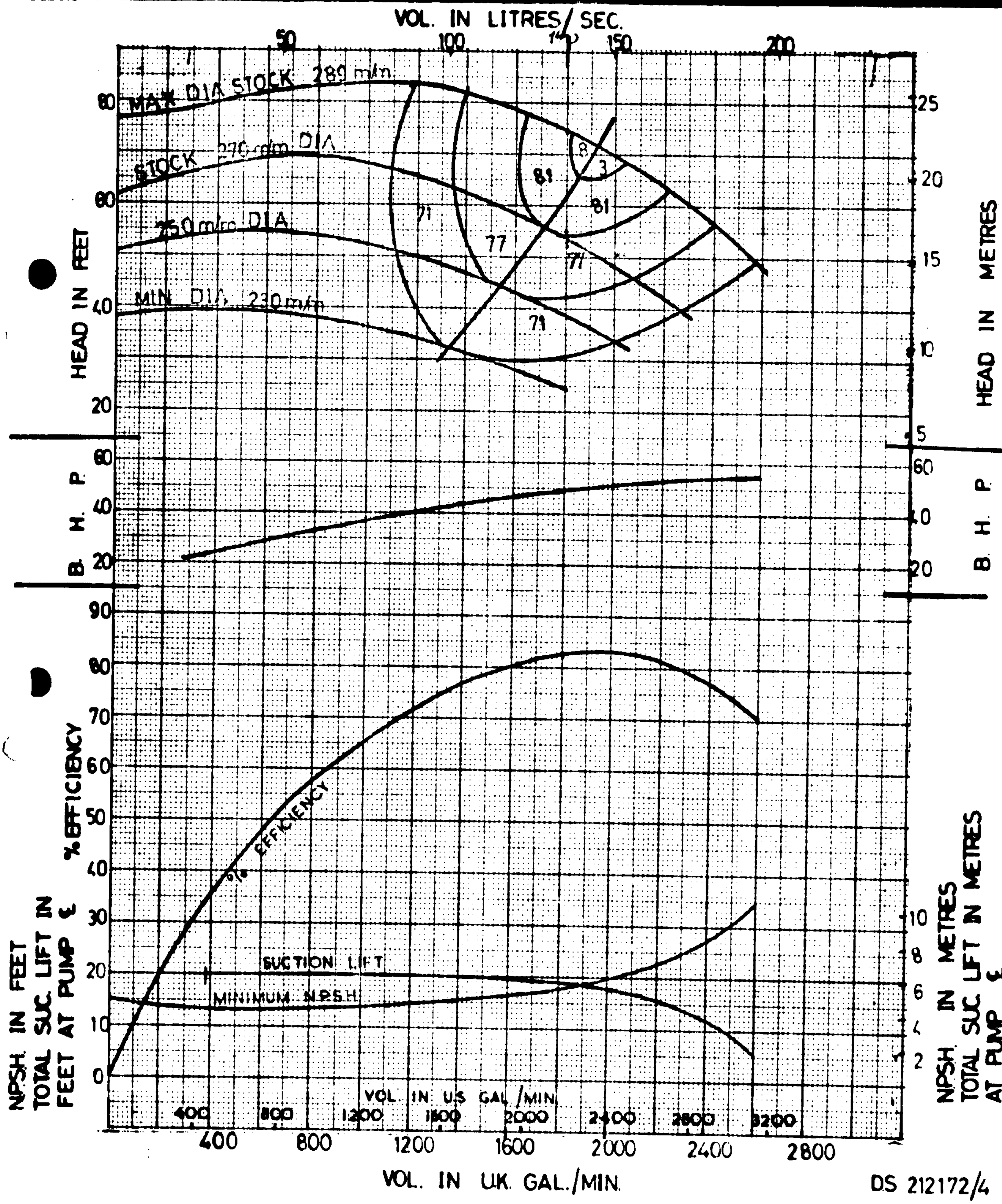
FLOW:

HEAD:

SPEED: 1460RPM.

EFFICIENCY:

This curve is based on the results of tests on at least 10% of the pumps of this frame size manufactured



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8.3 Construction equipment and machinery

8.3.1 Salinto has at its disposal the following construction equipment:

2 5-ton tipping trucks

2 dumpers

2 concrete mixers, each for 280 l

2 block making machines 1 x 1,200 stones/layer
1 x 250 stones/layer

2 theodolites

masons' and carpenters' tools.

8.3.2 The following units were purchased for the generation of electrical energy and for circulating the brine in the solar plant:

1 diesel generating set, 6 kVA (lighting current)

2 diesel generating sets, 25 kVA (are said to be on order)

3 mobile diesel pumping units, output 12 bhp

Capacity:	60 - 70 cu.m/h
Diesel engine:	manufactured by Peters
Pump:	manufactured by Sigmond

3 mobile diesel pumping units, same as above, but with 16 bhp output

Capacity:	90 - 100 cu.m/h

9. Suggestions for the construction of the sea-water line

Taking the water from the open sea is the most difficult problem encountered by Salinto in the construction of the saline. As was mentioned under 5, the intake point has been fixed by Salinto's previous work. Lagoon water cannot be used since the lagoon is of the fresh-water type.

The construction of a canal or an inlet structure at the shore is not possible, since the sandy coast would immediately fill this up with sand. For the same reason, an artificial lagoon on the beach terminating in a pump sump, as suggested in Salinto's letter of July 8, 1971, is not feasible (see letter from DBS to Salinto of August 4, 1971).

Another possibility would be the construction of a jetty through the surf and up to a suitable water depth, on which a suction line could be installed. However, a structure of this type could be built at the Togolese coast only with the aid of very heavy special-purpose equipment and considerable investment by the company, as construction of the Lomé harbor and the CTMB wharf have shown.

As a result and, above all, in view of the limited time available to Salinto, the only feasible approach is the intake of water from the open sea at Kota-Akonda (Annex 14).

For this type of water intake at the aforementioned point certain requirements have to be satisfied to ensure toublefree operation.

First of all, the intake point should be designed so that a minimum of sand is sucked in. That means that the suction head will have to be installed outside the surf zone at a sufficient height above the bottom of the sea.

Secondly, an incrustation of the pipe line, e.g. with shells, should be avoided as effectively as possible.

Outlook from the pumping station to the sea
(point of sea water intake)

Rivage (point d'aspiration de l'eau de mer)
vu de la etation de pompage

Thirdly, care should be taken not to take in argillaceous sewage discharged into the sea by the phosphate plant some 5 km west of the intake point. In other words, the intake point would have to be permanently anchored at least 150 m from the beach.

In view of the above, only the following alternatives remain for a short-term solution of the problem:

a) Construction of an intake line above the sea-water level with the aid of impact-driven piles.

b) Construction of an intake line below the sea bottom by the water jetting technique.

c) Construction of an intake line on the bottom of the sea with the aid of suitable anchorages.

We have made a close study of each of these possibilities. The equipment required for driving the necessary piles (length approx. 15 m due to the sandy subsoil) is not available in Togo or its neighboring countries. The cost of a bridge about 200 m long would therefore be further increased.

Equipment for building the intake line by the water jetting technique is likewise not available in Togo. Construction of such a plastic pipe line with the aid of special equipment, for instance from Germany, would cost over DM 600,000.- without the necessary floating units (see letter from DBS to UNIDO of August 2, 1971). As a result, this approach is likewise unfeasible.

In view of all these circumstances we therefore consider the construction of a pipe line on the bottom of the sea and the use of concrete anchorage as an appropriate and budget-priced solution. For further explanations on the subject, see Section 9.2.

An ideal solution would undoubtedly be the intake of sea water via a bridge. This solution should therefore be studied on a long-term basis. Since in the next few years the CTMB will install a new pump with a capacity of 2,000 cu.m/h, but use only 1,500 cu.m/h, it should be able to supply 500 cu.m/h of sea water.

It will be worthwhile for Salinto to study the technical and financial aspects of this alternative as a possible ultimate solution.

9.1 Installation of pumps

The pumps mentioned under 8.1.1 are available for the sea-water line. One of the pumps is earmarked for standby.

Detailed inquiries with the manufacturer of the pumps (Weir Pumps Ltd., England) have revealed that the type of pump supplied has a maximum suction lift of 6 m. This lift must not be exceeded for any prolonged period of time or cavitation will result and wear out the pumps. By suction lift we must not only understand the geodetic suction head, but should also make allowance for friction in the pipe. The geodetic suction lift is thus a value of 6 m less friction losses in the pipe. These data have to be taken into account when determining the height at which the pumps are set up, as referred to the low-water level.

The following data result for the proposed pipe line on the sea bottom:

Material:	Plastic pipe
Length:	200 m
Inside diameter:	302.4 mm
Capacity:	500 cu.m/h
Cross section:	0.072 sq.m
Flow velocity:	1.93 m/sec
Friction loss in pipe over a length of 220 m:	1.43 m
Loss through elbow and one valve:	0.25 m.

We thus obtain

$$H = 6 - 1.43 - 0.25 = 4.32 \text{ m}$$

for the height of the pump intake, as referred to the low-water level.

However, according to the information available to us (letter from Salinto dated July 8, 1971), the actual height is 4.8 m as referred to the low-water level.

It is obvious that the low water actually exists for only a limited time, and according to Weir Pumps the pumps may be briefly operated with a suction lift of about 6.4 m. However, for reasons of safety either the pump intake should be positioned 4.3 m above the low-water level or the pumps should be shut off during low water. The former of these solutions is doubtless the one to be preferred.

In view of the available pipes, the following picture results for the pressure side of the pumps:

Material of line:	electro-galvanised steel pipe
Length of line:	approx. 1,000 m
Inside diameter:	348 mm
Capacity:	500 cu.m/h
Cross section:	0.0942 sq.m
Flow velocity:	1.48 m/sec
Friction loss in pipe over a length of 1,000 m:	7.4 m
Loss through elbow and valve:	0.2 m.

Since a 5-m pipe with an inside diameter of 200 mm is to be installed directly behind the pressure outlet, a friction loss of 0.5 m has to be added. On the other hand, the level difference between the pump intake and the end of the pipe is -1.5 m so that there is a maximum total head of 6.6 m. According to the pump diagram, the type SNA-8 pump with a runner diameter of 280 mm has a head of roughly 20 m.

9.2 Construction of intake line

As was explained under 9, the best solution under the existing circumstances is, in our opinion, the laying of a pipe line on the bottom of the sea.

Since Salinto was unable to furnish information on marine conditions at the proposed intake point, we made our own investigations, first in Togo, later in the Federal Republic of Germany.

As was mentioned before, the CTMB at Guon Kopé, about 5 km west of the saltworks under construction, has been operating a pumping station on a wharf for roughly twelve years. Since annual soundings of sea depth in the proximity of the wharf were made, CTMB has its own nautical charts. From these it is evident that in the coastal strip concerned a water depth of about 5 m is found at a distance of some 150 to 200 m from the shore. CTMB's experience has shown that a water depth of about 1 to 1 1/2 wave height is necessary for taking in sea water free from sand. The propeller pumps installed on the wharf (approx. 8 m below the water surface) have to be cleaned at intervals of six months to remove shells and other deposits of a few centimeters thickness from the intake. In addition, the pumps are subject to corrosion.

Further information on the nature of the sea bottom was obtained from the consultants employed for the construction of Lomé harbor. According to this information, the surf zone in this part of the coast is about 100 to 200 m wide, depending on the type of formation encountered. The sandy strip extends about 500 m into the sea and is about 2 m thick. Below this layer of sand there are hardened sand-clay layers up to a depth of about 15 m. The coastal area of interest to us has not been investigated in the past, but we may assume roughly identical conditions.

An accurate survey of sea depth is not available, but we were able to obtain a confirmation of the information supplied by CTMB. In spite of this it will be necessary to sound the depth of the sea near the site of the saltworks (about km 42 of the railway line) at intervals of 20 m up to a distance of about 200 m from the shore (see letter by DBS to Salinto of June 24, 1971).

Exact wave data were provided by Hannover Technical University which made a basic study for the construction of Lomé harbor. The values found are listed in a table (Annex 15). They may be assumed to apply also to the project under study.

In view of the conditions described under 9 and the aforementioned data, we would suggest that the pipe line be laid from the pump house (Annex 16) into the sea as follows:

Length of line:	approx. 220 m
Height of intake above sea bottom:	approx. 2.5 m
Depth of sea at intake point:	approx. 5.0 m

Ballasting of the pipe line on the sea bottom by means of precast concrete members so that the the line sands up.

As regards the material to be used for such a pipe line, there are two possibilities, viz.:

I. Steel pipe:

<u>Advantages:</u> Can be produced in Togo.

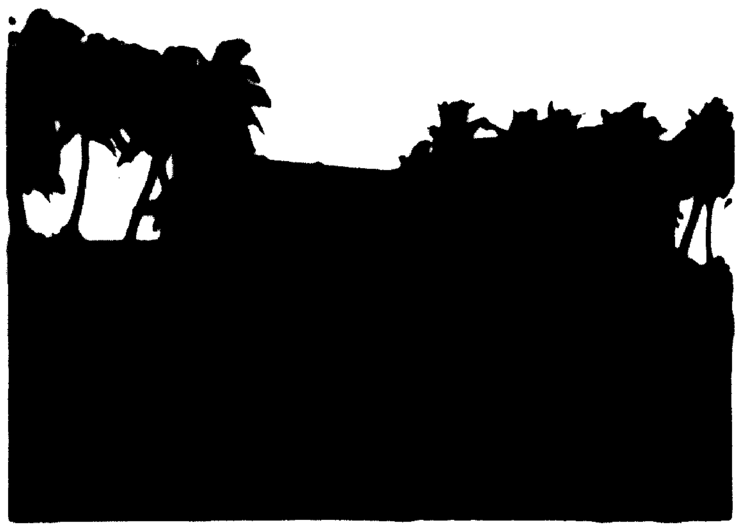
<u>Disadvantages:</u> Risk of corrosion, heavy incrustation, flange connection, rigid system, larger pipe diameter required to offset larger pipe resistance.

II. Polyethylene pipe:

<u>Advantages:</u> Corrosion-resistant, only slight incrustation, seamless welding, elastic, smaller pipe diametor owing to reduced frictional resistance, light weight, thus easy to handle.

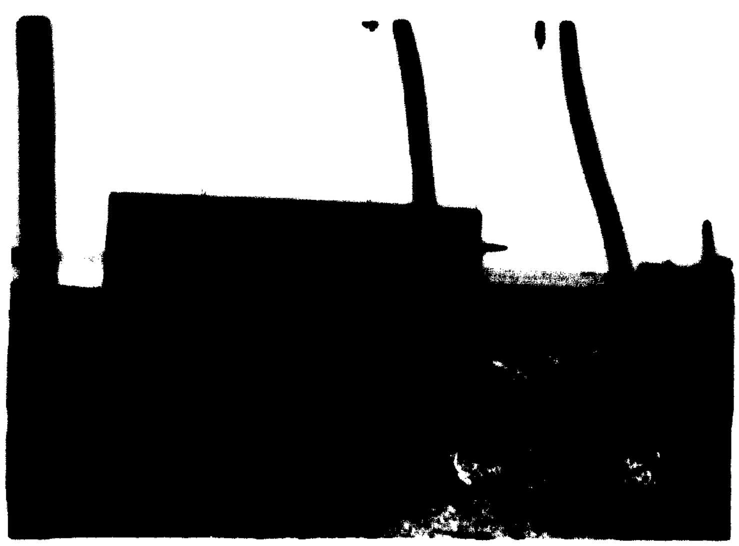
<u>Disadvantages:</u> Pipes have to be imported and welded by foreign experts with the aid of a special machine.

DEUTSCHE BERATUNGSGESELLSCHAFT FÜR SALINENTECHNIK M.B.H.



Pumping station (from the sea side)

Station de pompage (vue de la mer)



Pumping station (from the road)

Station de pompage (vue de la route)

After having studied each of these alternatives and prepared the corresponding designs (see DBS drawing 4/71 (annex 17) with description of July 6, 1971, and DBS drawing 5/71 (Annex 18) with description of August 19, 1971, sent to UNIDO), we would suggest to Salinto that a polyethylene pipe line be used.

9.2.1 Design of PE pipe line (DBS drawing 5/71, Annex 18)

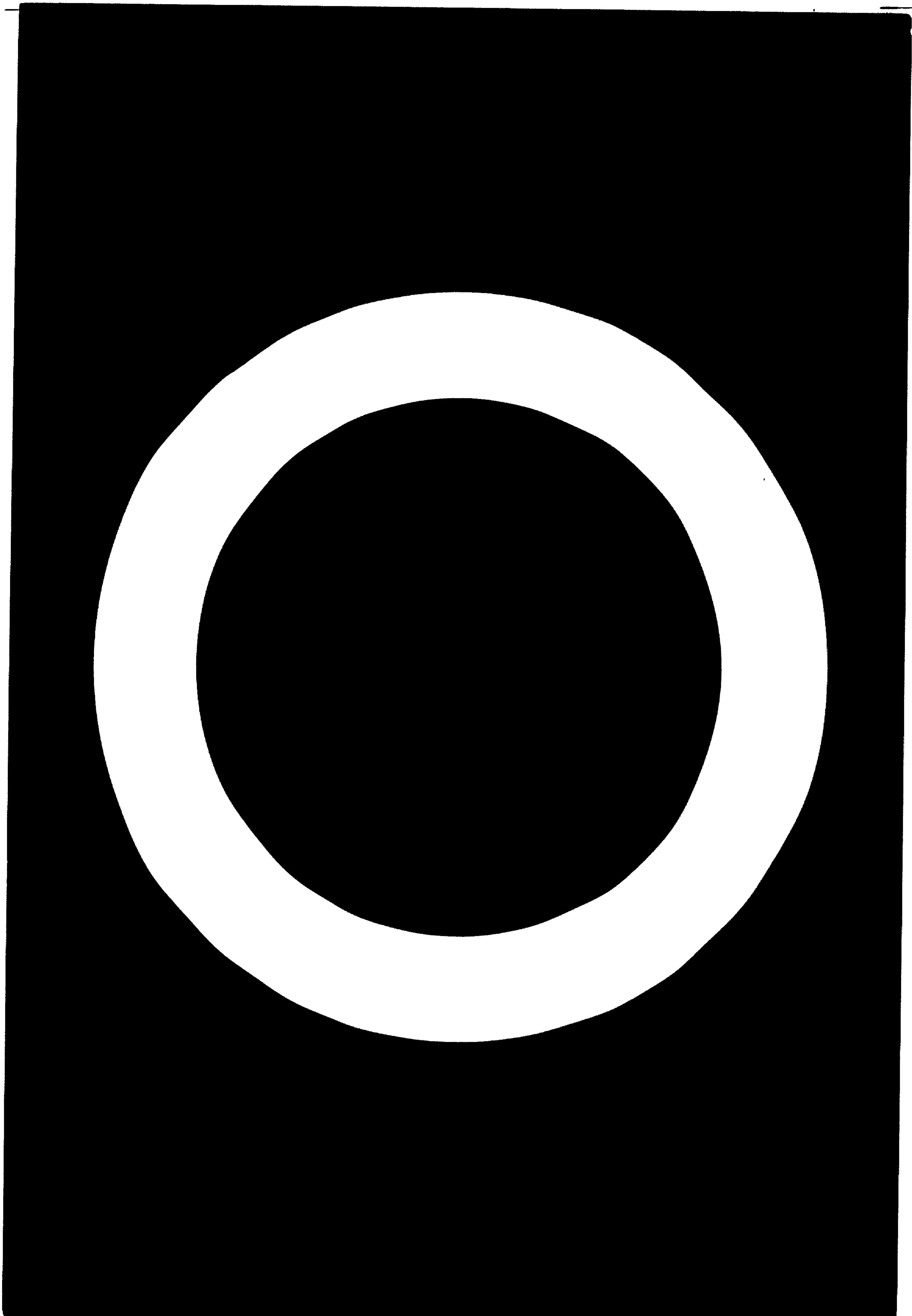
In view of the maximum pump capacity of 500 cu.m/h and the frictional resistance of the pipe (at a water temperature of 25° C), an inside diameter of about 300 mm is required. The nearest standard pipe has an inside diameter of 302.4 mm. A wall thickness of 26.3 mm has been provided to have a sufficient safety margin for mechanical stress.

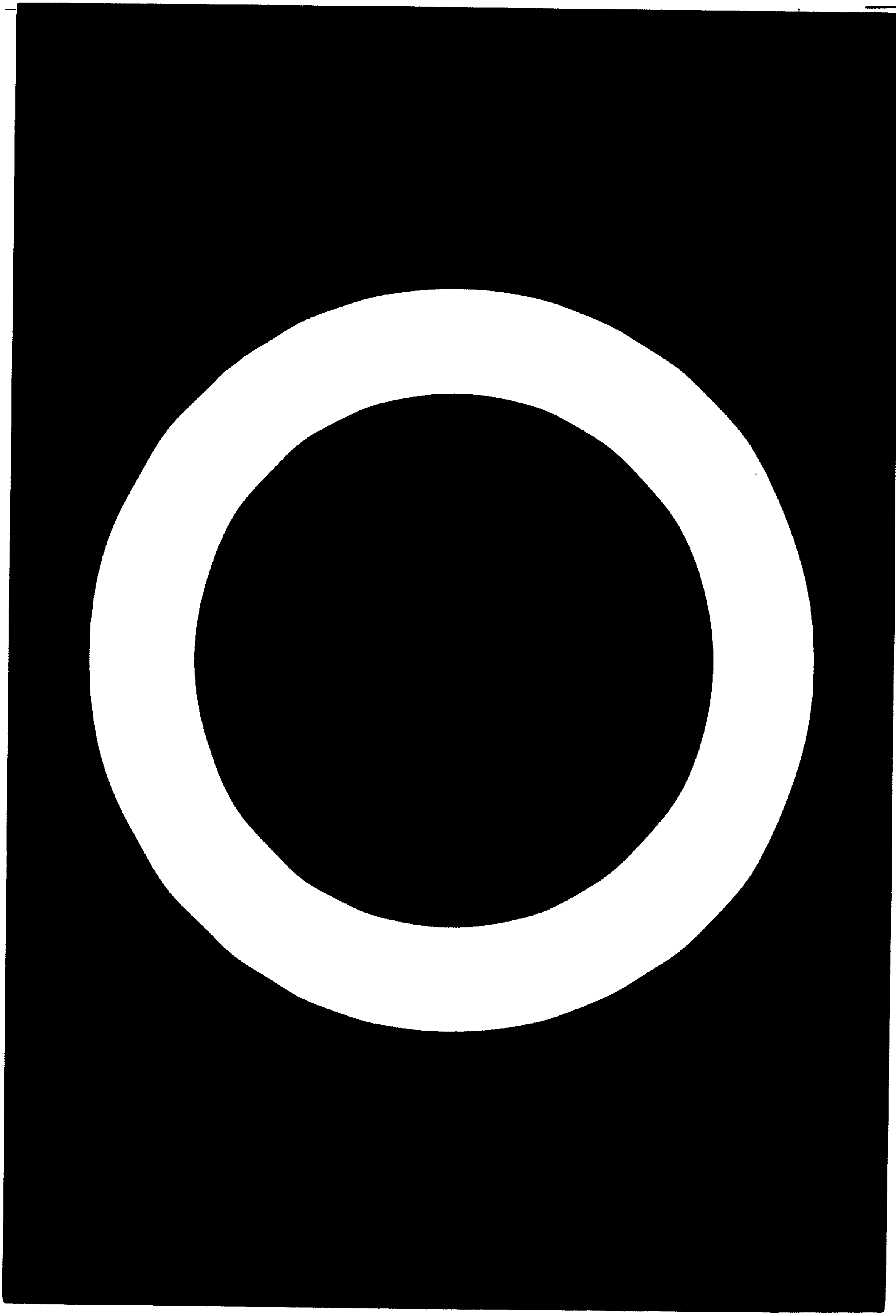
The flow velocity is far above 1.5 m/sec. This and the smooth walls of the pipe will effectively prevent deposits of shells and algae. Butt welding of the pipes (so-called hot-tool welding) with the aid of a special welder ensures smooth walls at the joints as well.

Since the pumps are not of the self-priming type, a valve must be installed in the line at the low-water level to prevent the line from running dry between the pump and the water level. This valve must be accessible by a small walkway. To take in as little sand with the water as possible, the PE line is provided with a 90° bend at the intake point, with the end of the pipe line located about 2.5 m above the sea bottom.

The suction head of the pipe should be provided with a coarse-mesh screen to prevent fish from being sucked in. The support of the vertical intake pipe should be designed so that the mechanical stress from sea motion is absorbed by this structure and not transmitted to the pipe.

Finally, the intake point should be marked by a buoy conforming to existing regulations, as a warning to navigation.





9.2.2 Laying the PE pipe line

According to information supplied by the Hannover Institute of Foundation Engineering and Civil Engineering Hydraulics, which measured wave height for the construction of Lomé harbor in Togo, the maximum wave height off Lomé is 2.50 m. However, there are also days when the waves are only 50 to 75 cm high. The pipe line should therefore be laid on a day when the wind intensity is 2 or less and there are no high waves. Every phase of the work should be properly prepared to ensure rapid laying of the pipe line.

The pipes are supplied in sections about 11 m long. The different sections aro then joined with the aid of a special welder on a suitably graded stretch of land about 35 to 40 m long parallel to tho shore, until the total length of 220 m has been assembled. The pipe may be stored on the beach until it is laid.

The precast concrete members should be suitably shaped at their top to accept the pipe line with an outside diameter of 335 mm. The members are sunk in the sea in a straight line at intervals of approx. 3 m. The dimensions of the members should be approx. 1.0 x 1.0 x 0.6 m.

Up to a water depth of 0.5 m, the lower concreto members should be placed with the aid of an excavator. A derricking boom crane mounted on two scows should be used for water depths from approx. 0.5 to 5.0 m.

After the lower concrete members have been placed, the complete pipe line is floated into position and lowered into the recesses in the concrete members with the aid of a tugboat, ballast and divers. Finally, precast concrete members of identical size, but with a recess on their underside, are lowered onto the aforementioned concrete members and secured to them.

At the end of the intake line there is a framework holding the pipe line some 2.5 m above the sea bottom. This framework should be mounted on three foundation blocks that are cast in two parts to facilitate transportation. These precast concrete members are likewise placed with the aid of the scows and the derricking boom crane. The same applies to the lowering of the supporting framework. The framework is designed so that a vertical channel section is welded into its center, which accepts and holds the vertical section of the PE pipe. This will protect the PE pipe from mechanical stress.

At the beach end, the pipe line should be laid under ground in the area not covered by water during ebb tide. From there it should be laid under ground right up to the pump house.

9.2.3 <u>Erection work</u>

In order to meet the schedule set up by Salinto, the seawater line must be completed by the end of October. We have therefore instructed the consortium Dyckerhoff & Widmann/Harmstorf, which is experienced in this type of work, to prepare a quotation with a detailed specification of services and supplies. To guarantee proper erection, experts will have to be sent over from Germany for welding the PE pipes. These experts must be experienced in the laying of PE pipes in coastal areas and surf zones.

Excavators, winches and similar equipment can be obtained from Messrs. Dywito of Lomé. The floating equipment will have to be loaned by Salinto.

We have already inquired with the harbor authority of Lomé regarding the floating rigs at their disposal and how they are equipped. Unfortunately, their answer was in the negative, but we understand that the required equipment and divers can be obtained from Messrs. COTSOM.

Provided that no further time is lost by Salinto in taking a decision, erection could start in October. Total erection time is about 4 - 5 weeks.

9.2.4 Expected service life of a plastic pipe line

As was mentioned before, a PE pipe line is not subject to corrosion. In addition, it is less subject to shell deposits than steel pipes. In spite of this, no binding prediction can be made as to possible incrustation, since this depends entirely on local conditions.

A service life of only five years should therefore be assumed until further experience is available.

Should practical operation of the pipe line show that the line will have to be shut down for removing incrustations, preparations should be made well ahead of time to guarantee the continued supply of sea water. In this connection, reference is made to our remarks regarding future possibilities with CTMB.

9.3 Construction of the sea-water pressure line (DBS drawing 6/71)

As was mentioned under 8.1, Salinto has already purchased the material required for the pressure line from the pump house to the saltworks and stored it along the road (see photos, Annexes 19 and 20).

Recalculation of the line has revealed that the available pumps are good for a capacity of 500 cu.m/h. The available head is entirely sufficient, all the more so as the ground slopes towards the saltworks. However, as was mentioned before, an accurate survey should be made for this pipe line also.

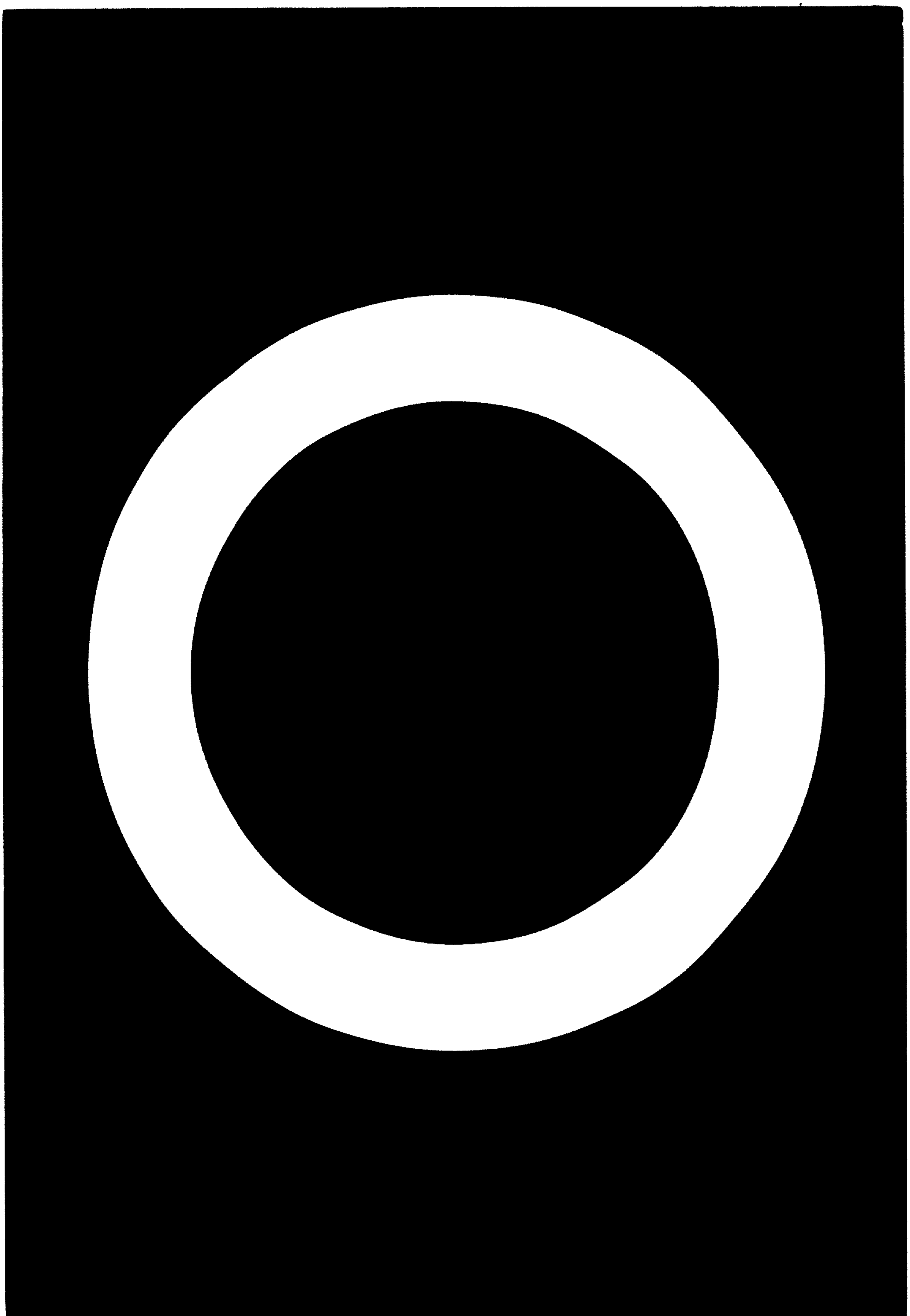
The drawing DBS 6/71 (Annex 21) shows the pressure line. The lengths and heights given are approximate and should be corrected on the basis of the survey.

Outlook from the pumping station to the road leading to the salt works (on the right hand the pipe-sections for the pressure pipe)

Route conduisant au salin, vue de la station de pompage (à droite les tuyaux pour la conduite sous pression de l'eau de mer)

Road leading to the salt works and pipe sections for the pressure pipe

Route conduisant au salin avec tuyaux pour la conduite sous pression de l'eau de mer



Railway-tracks and salt store under construction

Ligne de chemin de fer et hall de stockage en construction

Salt-store under construction

Magasin en cours de construction

The following points should be taken into consideration when designing and erecting this pipe line:

9.3.1 Laying the pipe line above ground

In order to allow cleaning of the line, if necessary, Salinto has scheduled the use of flanged steel pipe to be laid above ground.

For this purpose, the line should be erected on supports so that its average height above the ground is 40 cm. The height of the supports should be adapted to the terrain to ensure uniform level of the line.

In view of the length variations to be expected in this above-ground line, special precautions are required to avoid damage.

For a temperature difference of $\Delta T = 50°$ C (insolation and empty line), the length variation per meter of line is approx. 0.65 mm. As is evident from the DBS drawing 6/71, it is therefore necessary to divide the line into several sections and make allowance for expansion. The supports should be designed accordingly.

Between the pump house and the road underpass, the line should be laid rigidly and provided with two compensators. Beyond the road there is another rigid support, the expansion being absorbed by a compensator under the road.

For financial reasons, the use of an expansion bend with three compensators was chosen for the roughly 577 m long section of the line between the road and the railway line, all the more so as there is sufficient room. In order to absorb the entire length variation at this point, the supports will have to be designed as sliding bearings, as is shown in the drawing. For this purpose, the supports may be provided, for instance, with simple sheet-steel cups in which the pipe slides. Lubrication at these points is ensured by means of grease (eliminating noise and wear).

The same holds for the railway underpass as for the road. After the fixed support behind the railway (towards the saltworks), the remaining length of the pipe line can be laid without compensators, with sliding bearings, since the end of the line need not be fixed.

A quotation for the compensators required will be mailed to Salinto separately.

9.3.2 <u>Road and railway underpasses</u>

Salinto is contemplating the use of 800mm concrete pipes for the road and railway underpasses, on the one hand to reinforce the opening and on the other to allow the pipe line to be dismantled.

As is indicated in the drawing DBS 6/71, these pipes have to be laid at a certain depth to withstand the traffic loads. The required minimum depths as measured from the top level to the top of the concrete pipe are:

1.4 m for the road underpass,
2.0m for the railway underpass.

On either side, the concrete pipes should project at least 1.0 m from the sides of the embankment.

All embankments should be stabilised to avoid scouring. Either hand-placed riprap or concrete may be used for the purpose, depending on costs.

In both underpasses, the pipe line should be laid with bends of about 30° (as shown in the drawing) and not with 90° bends. A soakage pit may be provided for the rain water.

9.3.3 <u>Intake structure</u>

A so-called intake structure is required for admission of the sea water to the pond A1 to avoid scouring.

In planning the solar plant it was found useful to include the road for the second stage of construction in the design. The result is a crossing with the sea-water line.

It appears advisable to combine this crossing with the intake structure. As is obvious from the drawing, the pressure pipe terminates south of the road in a concrete canal about 1.0 m wide, which runs below the road to the intake structure. The canal may be covered with thick wooden beams or T-sections, since the clear span is very small.

The sea water reaches the pond A1 over tho top of the intake structure, which is roughly 4 m wide. The surroundings of the inlet point in the pond should be concreted to avoid damage to the ground.

10. Suggestions for the construction of the solar ponds

The drawing DBS 7/71 (Annex 22) shows the solar plant for an annual production of 5,000 tons with the possibility of expansion to 10,000 tons.

In planning this plant, we have assumed that the following conditions are satisfied to the greatest possible extent:

I. Adaptation of the different ponds to the elevation of the terrain (photo, Annex 23) and construction of fairly large ponds to avoid unnecessary earthworks.

II. Use of the impermeable soil also for the cystallizers to save money.

III. Construction of adequate access roads to the important points of the plant with a minimum of earthmoving.

IV. Short distances from the crystallizers to the processing plant.

V. Construction of so-called "winter ponds" for the rainy season to protect the valuable preconcentrated brine.

VI. Installation of weirs to reduce pumping to a minimum.

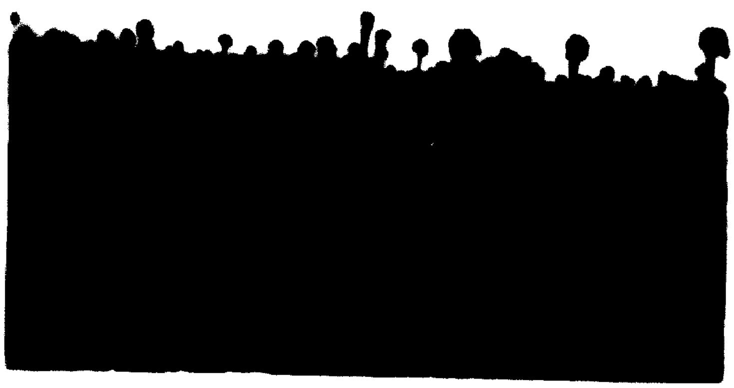
VII. Construction of a large pre-evaporation pond which need not be grade, to produce enough preconcentrated brine in the stage of 4 - 15° Bé.

VIII. Making allowance for the second stage of construction.

For the scheduled annual capacity of 5,000 tons of solar salt in the first stage of construction some 300,000 cu.m of sea water of 3.5° Bé have to be taken in and pumped into the solar plant. Up to now, the salinity of the sea water had been given as 3.5° Bé. However, measurements performed during the period from April 18 to 27 have revealed that the salinity of the water is close to 4.0° Bé if allowance is made for its temperature. As a result, we are on

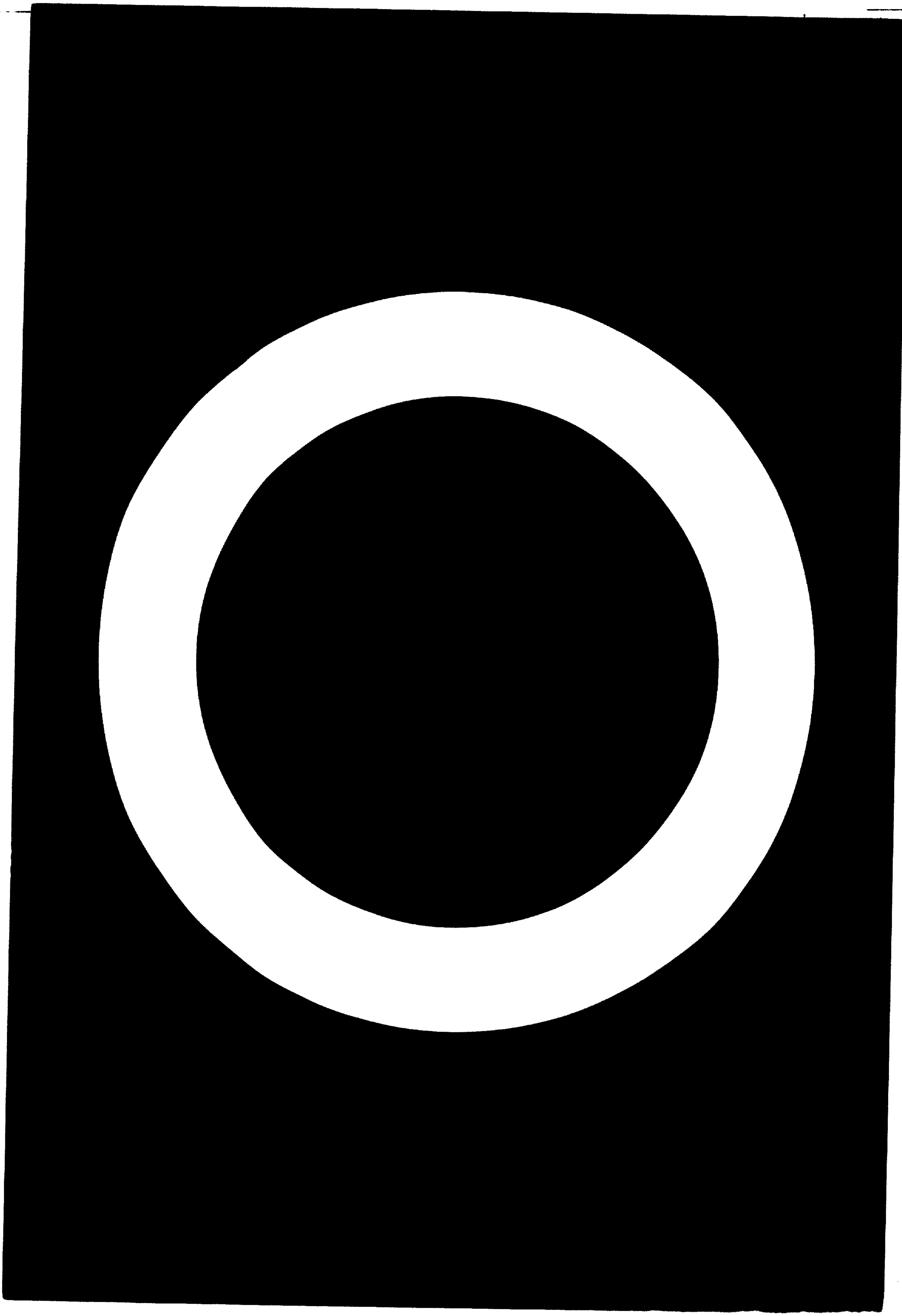
Changeover from sandy coastal strip to clayey saline area

Transition du littoral sableux au sol argileux du terrain choisi pour l'emplacement du salin



Area provided for evaporation ponds

Terrain prévu pour les cristallisoirs



the safe side with the above assumption. The 300,000 cu.m of sea water contain some 10,000 tons of salt, primarily NaCl and small quantities of $CaCO_3$, $CaSO_4$, $MgCl_2$ and $MgSO_4$.

However, since the common salt should be produced well separated from the other salts contained in the sea water, certain losses have to be expected and various stages of concentration should be provided.

It may thus be assumed that only about 5,000 tons of solar salt of good quality can be obtained from the 300,000 cu.m of sea water. The table (Annex 24) indicates the specific weight, density in degrees Bé, volume and precipitation of the different salts upon evaporation of the sea water. In view of these conditions, concentration of the sea water will be performed in steps from 4 to 15° Bé (pond B1), from 15 to 24° Bé (ponds C1 and C2), and from 24 to 28.5° Bé (ponds E1 to E4).

Crystallisation should be terminated at approx. 28.5° Bé so that the Epsom salts which will then precipitate at a higher rate can be removed together with the mother liquor.

As was explained under 6.1, we may assume an average evaporation rate of 5 mm per day for the saltworks, or a net excess of evaporation of 800 to 900 mm for the months July - March after deducting rainfall and the amount of water evaporated on rainy days.

In this connection, mention should be made of the fact that a year of exceptionally abundant precipitation may considerably alter these averages. In such a case, only a sufficient stock of preconcentrated brine and proper handling of brine supply together with the "protective ponds" A and D will help to reduce the production losses.

ANNEX 24

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

10.1 Dimensioning of ponds

The approximate areas of the different ponds result from the stepwise evaporation and the aforementioned net evaporation figures. However, it is also necessary to find a proper relationship between the areas used and the production requirements, because the larger the areas used for evaporation, the quicker the concentration of an identical volume of sea water.

10.1.1 Preconcentrators 3.5 - 15° Bé

As was mentioned above, we shall assume a value of only 3.5° Bé for the sea water to be on the safe side. To concentrate 1 cu.m of sea water from 3.5° to 7.5° Bé, about 0.5 cu.m of water have to be evaporated. Since concentrated brine evaporates more slowly than pure water, this value has to be multiplied by the factor 0.877 for the range from 3.5° to 7.5° Bé. In other words, as referred to pure water, 0.57 cu.m have to be evaporated.

For further concentration from 7.5 to 15° Bé, another 0.252 cu.m of H_2O have to be evaporated per cubic meter of brine of 7.5° Bé. In this case, the factor is 0.773, which is equivalent to a water volume of 0.326 cu.m.

For concentrating the sea water from 3.5° to 15° Bé, an equivalent volume of 0.896 cu.m of fresh water has to be evaporated.

Preconcentration of the brine practically starts as the water runs into the ponds A1 and A2. During first filling-up, a grading effect will be achieved as the water passes through these ponds into the pond B1, since a thin layer of sea water is distributed over a large area.

In order to allow the first salt harvest to be collected in the coming season, by March 1972, in spite of the short time available, it appears advisable first to concentrate

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only about half the originally scheduled volume of sea water, i.e. some 150,000 cu.m, to 15° Bé on the area of 60 ha and then to proceed with the next step. This will theoretically reduce the time required for the given evaporation volume by 50 %.

In the following year, filling of the pond B1 should start about July. According to the above remarks, the concentration of 300,000 cu.m of sea water from 3.5° Bé to 15° Bé calls for the evaporation of 300,000 cu.m x 0.896 cu.m = 267,000 cu.m of fresh water. For the area (B1) of 64 ha, this is equivalent to an evaporation volume of roughly 420 mm as referred to fresh water. In keeping with the net excess of evaporation in the different months, this volume should be reached in the period from July to December. The time remaining till March of the following year may again be used for preconcentration. By the end of the dry season, this preconcentrated brine may, for example, be pumped into the ponds C1 and C2 where it will be better protected from rainfall than in the pond B1.

The average depth of the brine in the pond B1 should be about 30 cm, or the wind may drive the waves over the dams. If necessary, filling-up should be controlled accordingly.

The brine concentrated to 15° Bé now only has about one fourth of its original volume, i.e. about 75,000 cu.m. This volume is then transferred to ponds C1 and C2 over the weirs and, if necessary, with the aid of the pumps. In addition, the ponds D1 to D4 may also be filled up.

10.1.2 Preconcentrators 15 - 24° Bé

In order to concentrate the brine from 15 to about 24 - 25° Bé, some 0.5 cu.m of water have to be evaporated per cubic meter of 15°-Bé brine. The evaporation factor for this range is 0.674 so that an equivalent volume of 0.75 cu.m as referred to fresh water has to be evaporated. Of the

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75,000 cu.m of 15°-Bé brine, 37,5000 cu.m have to be evaporated, or the equivalent water volume of 56,200 cu.m. For a total area of 20 ha, this corresponds to an evaporation volume of approx. 280 mm as referred to fresh water.

In order to attain this volume under the given conditions and to collect the harvest before the rainy season begins, it is necessary to use the preconcentrated brine of the preceding season.

10.1.3 <u>Crystallizers 24 - 28.5° Bé</u>

It is known that the limit of solubility of NaCl is around 26° Bé, i.e. NaCl begins to precipitate when this saturation is reached. This means that about 60 to 70 % of the common salt will precipitate in ths range from 26 to 28.5° Bé that has been assumed as a basis for the plant under study. Filling up the brine of 24° Bé should start as early as possible in order to obtain salt layers at least 4 to 5 cm thick. Assuming an svaporation volume of 5 mm per day we may expect an estimated salt precipitation of 1 mm per day. Accurate values can be determined only on the spot.

As soon as the ponds E1 and E2 aro ripe for harvesting, the mother liquor is drained and the salt layer lifted off with the aid of perforated stainless-steel shovels. It is advisable - above all, in tho interests of rapid harvesting - to transfer the harvested salt to mobile belt conveyors for transportation to the southern edge of the pond and into waiting trucks. The length of individual conveyors should be about 10 m so that they may be easily moved by hand. An output of 2 - 3 tons per man and eight-hour shift may be assumed. In other words, about 50 men will be able to harvest 100 to 150 tons per shift. With two-shift operation, the harvest can be collected in 18 to 25 days.

10.2 Construction of solar ponds

Our design of the solar ponds as per drawing DBS 7/71 (Annex 22) has been based on the following considerations:

Access to the saltworks is ensured by the road.

Construction of the sea-water line has been started by Salinto along this road.

The warehouses along the road, beyond the railway line, are under construction.

The ponds should be built in the loamy soil between the sandy coastal strip and the lagoon.

The ponds for the second stage of construction should be disposed symmetrically to avoid unnecessarily long distances.

The crystallizers should be as close to the warehouses and the future processing plant as possible.

The elevations of the pond surfaces should be adapted to the existing topographic map of the site so that a minimum of earthmoving is required.

The most important points of the saltworks should be easily accessible.

Construction of the solar ponds should be undertaken so that the ponds A1, A2 and B1 are completed together with the sea-water line. As a result, this phase of the work must be started right away in order to allow pumping of the sea water to begin as soon as possible.

The remaining ponds from C1 to E2 can then be built while the brine is concentrated in pond B1.

10.2.1 Ground survey and leveling

First of all, the entire site should be properly surveyed and marked by wooden pegs.

Leveling is not necessary for the first preconcentration pond B1. The palms and bushes should be grubbed; the vegetation cover might be removed by grazing animals.

It may be expected that the increasing salinity of the ground will cause the remaining vegetation to wither in the course of a few years.

In order to facilitate transfer of the brine from one pond to another, the natural ditch in the center of the pond should be deepened and extended towards the dam between ponds C1 and C2. The ditch should be deepened to about 1.5 m above mean sea level to allow the brine to be drawn off by the mobile pumps on the dam and transferred to the intermediate concentrators B1 and B2.

The sites of ponds A1, A2 and C1 to E2 will also have to be grubbed. In addition, it will here be necessary to remove the grass cover and to grade the different surfaces with the aid of a bulldozer according to the elevations given. It is important that the clay layer not be perforated in this operation to avoid seepage losses. Should the layer of clay be too thin at certain points, these would have to be specially lined with clay.

The material left over from grading can be largely used for the construction of dams. Care should be taken to store the stripped clay soil separately so that it may be used for lateral sealing of the dams against the ponds.

An additional operation is required for the crystallisation ponds E1 and E2 where the surfaces have to be fine-graded and compacted by means of rollers to allow easy harvesting of the salt.

The elevation of the different ponds as referred to mean sea level is evident from the sections in drawing No. DBS 7/71. With a value of 2.10 m above mean sea level, the ponds A1 and A2 as well as D1 to D4 are lower than the ponds B, C and E so that a large volume of brine can be stored on a minimum area surrounded by high dams.

The elevations specified are based on the assumption that the figures of the topographic map also refer to mean sea level.

10.2.2 Dams and roads

Towards the lagoon, the solar ponds must be protected against flooding, since the Mohno river frequently presses large masses of water into the lagoon during the rainy season. In order to keep the dam height within reasonable limits and also to protect the adjacent area against flooding, the lagoon should be permanently kept open to the sea east of Anecho. Should this be impossible, the sand dune at the bridge of Zébé should be opened as a precaution when the water level reaches 1.5 m above mean sea level.

For the above reasons and in view of the fact that the fill crest of ponds holding brine of low concentration should project about 30 cm above the water surface to keep waves from spilling over the dam in the case of heavy wind, we have suggested a dam height of 2.90 m above mean sea level.

Only the ponds A1, A2 and D1 to D4, which serve as a protection against rainfall and as winter ponds, will receive dams with a height of 3.10 m above mean sea level.

The width of the different fill crests varies, depending on whether the dam is used as a partition only or as an access road as well. We have therefore chosen the following dimensions:

Major roads: Dam width 7.5 m
Between the solar ponds C2 and E2 of the first stage of construction and the ponds C3 and E3 of the second stage

and on the southern edge of the ponds along E1, E2 and later E3, E4, for removal of salt and materials haulage.

Access roads: Dam width 5.0 m
Between the ponds B and C and along the eastern side of ponds C, D and E for haulage of the large mobile pumps and other materials.

Footpaths: Dam width 1.5 m
Between the ponds C1 to E1 and C2 to E2.

Ordinary dams: Width 0.5 m

As was mentioned above, the material left over from grading should be used for the construction of the dams. Should this be insufficient for the dams of the non-graded pond B1, the required material may be borrowed beside the dam, as far as the clay layer is sufficiently thick.

When building the dams, special care should be taken to cover the embankments with a layer of loam linking up with the pond bottom without any joint. Otherweise, considerable seapage losses may occur at these points.

The embankments of the dams should have a 35° slope in relation to the horizontal plane.

The fill crests, particularly those serving as roads, should receive a laterite covering layer.

The design of the weirs and the inlet from pond A2 to the ponds B1 and B2 is shown in the large-scale section of our drawing No DBS 7/71 (Annex 22).

The concreting operations should likewise be designed to avoid seapage losses. The valves should preferably be made of several boards so that various discharge heights can be obtained.

The discharge surface in the immediate proximity of the valve should be stabilized with cement to avoid scouring of the soil. The same applies to those areas in the different ponds where brine is pumped in.

10.2.3 Possibilities of brine transfer

As was mentioned under 8.3, three mobile diesel pumps with a capacity of 60 to 70 cu.m/h and another three with a capacity of 90 to 100 cu.m/h are available for repumping the brine.

The pumps with a cpacity of 90 to 100 cu.m/h are primarily used for transferring the brine from the preconcentrator B1 to the intermodiate concentrators C1 and C2. The ditch in pond B1 mentioned under 10.2.1 serves as a pump sump. Before pumping, part of the preconcentrated brine may be discharged via the weirs to speed up the transfer and save pumping time. For transferring the brine from ponds C1 and C2 to the crystallizers E1 and E2, the weirs in the supply ponds D1 and D3 should first be used until the brine level is identical. The rest of the brine can then be transferred to the cryatallization ponds with the aid of the pumps of 60 to 70 cu.m/h capacity.

Before one of the rainy seasons starts, the preconcentrated brine in the ponds E1, E2 or C1 and C2 should be transferred to the so-called "winter ponds" D1 to D4 or A1, A2. In this connection, care should be taken to fill the different ponda right up to the top so that specifically lighter rainwater may be discharged into ponds E1, E2 and B2 over the slightly opened weirs.

At the end of the rainy season, the rainwater in the E-ponds is diacharged over the weirs into the mother-liquor canal. The preconcentrated brine stored in ponds D1 to D4 is returned to the C or E-ponds in accordance with its concentration.

The pumps are transported on the access roads provided for the purpose.

A sufficiently long hose or pipe should be available for filling or draining the ponds A1 and A2 across the road.

10.2.4 Discharge of mother liquor

As soon as the brine in the crystallization ponds has reached a concentration of 28.5° Bé, the Epsom salts $MgCl_2$ and $MgSO_4$ will start to precipitate increasingly from the mother liquor. It is therefore necessary to discharge the mother liquor above the salt layer even though it still contains a certain amount of NaCl, to ensure good salt quality. We have therefore provided for a canal through which the mother liquor can be discharged into the lagoon before the salt is harvested. The canal starts at the southwestern corner of the pond E2, follows the road on the southern side of pond E1 in western direction and finally to the north. It then follows the ponds E1, D1, C1 and B1 until it reaches the lagoon.

The bottom of the canal starts at an elevation of +2.20 m above mean sea level so that the ponds E1 and E2 can be drained by gravity when the weirs are open. A gradient of approx. 0.5 % has been chosen for the canal.

The bottom of the canal is 0.5 m wide. The angle of slope should be adapted to the material available. It should likewise be around 35°.

Discharge of the mother liquor into the lagoon will increase the salinity of that water body. As a result, the lagoon will cease to be a breeding ground for Anopheles mosquitoes which transmit malaria. Since the lagoon water is not used for drinking-water purposes, there are no objections against discharging the mother liquor into the lagoon.

Since the successful operation of the solar plant depends on the exact knowledge of the processes involved in concentration and crystallization as well as on proper brine treatment, we consider it particularly important for one or two qualified Togolese to receive practical training in a suitable solar saltworks.

10.3 Meteorological station

As was mentioned under 6, it is suggested that a weather station be set up on the premises of the saltworks.

A suitable site for setting up this station is the area beside the office building or a similar place south of the solar ponds where, above all, the evaporation values will not be distorted.

The station should measure the following values, if possible three times daily (6, 12 and 18 hours):

Minimum and maximum temperatures
Relative humidity of the air
Amount of rainfall
Evaporation volume
Wind speed and direction.

It will also be of great advantage if a small experimental pond for solar evaporation is built on the same premises. For easy comparison, this should be subdivided into pre-evaporator, evaporator and crystalliser ponds like the actual plant. (Size, for instance, 30 sq.m + 10 sq.m + 5 sq.m with a depth of approx. 40 - 50 cm). To avoid seepage losses, the pond would in this case (sandy soil) have to be concreted or lined with plastic foil.

With the aid of suitable Beauméteters the degree of evaporation in every pond can be determined daily. In conjunction with the measurements of the meteorological station, this will allow certain conclusions to be drawn or trends determined.

11. **Harvesting and storing of salt**

In the first harvesting period - probably in March 1972 - it will only be possible to harvest a part of the scheduled salt volume due to the short time available. It is therefore advisable to collect this harvest exclusively by hand and to gather experience. Only then should the belt conveyors mentioned under 10.1.3 be procured.

The available tipping trucks may be used for transportation of the harvested salt from the ponds to the storage area and further to the warehouses. A vertically adjustable belt conveyor is suitable for piling up the raw salt in the two warehouses presently under construction.

As soon as a processing plant has been built, it will be necessary to find a means of transportation between the warehouses and the processing plant, which will allow handling of 40 tons of salt per eight-hour shift. A front end loader, which could also be used for further earthworks during expansion of the solar plant, would be suitable for this purpose.

12. Salt processing and packing

Processing of the harvested salt is required to remove dust particles, sand particles and the Epsom salts contained in the residual mother liquor of the salt.

In the first stage of construction it will be entirely sufficient to process the salt by washing and centrifuging to obtain a product at least equal in quality to imported solar salt.

In order to be able to adapt to changing market conditions and manufacture various grades of salt, the washing and centrifuge facilities may be supplemented by drying, grading, grinding and mixing facilities.

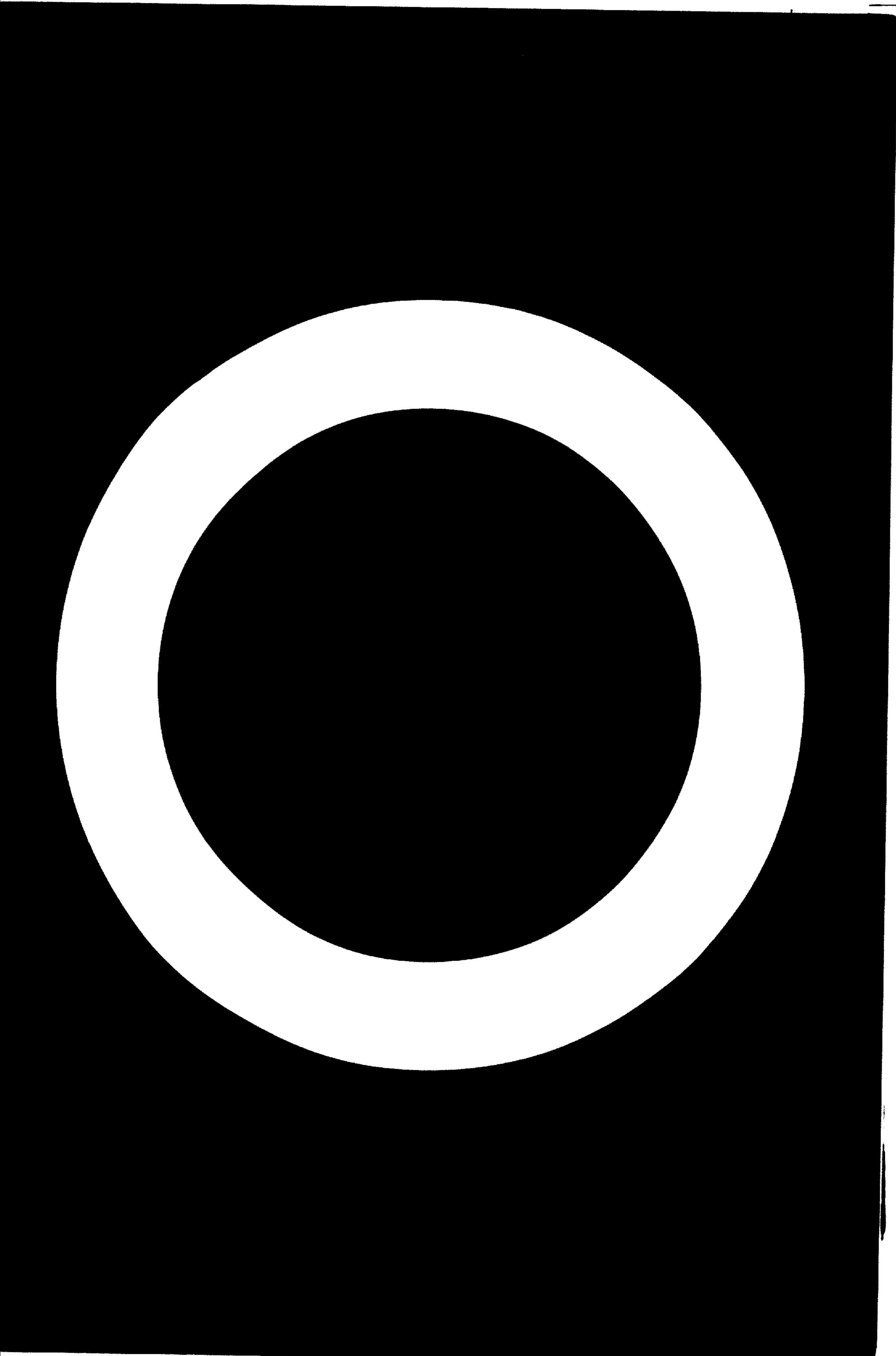
The scheduled annual output of 10,000 tons in the second stage of construction calls for a processing plant with a capacity of 5 t/h, assuming eight-hour operation. It would be uneconomical to dimension the plant for the first stage of construction only.

The drawing DBS 8/71 (Annex 25) shows a processing plant of this kind with an appropriate bagging plant for the use of plastic bags.

The salt taken from the raw salt store reaches a mixing worm via a surge bin and a batching trough conveyor. In the worm, the salt is intimately mixed with brine of approx. 20° Bé in order to dissolve mother liquor and impurities dried on the crystals.

Via a steep-incline screw conveyor the salt reaches the screening washer. The bottom of the screening washer is designed as a slotted screen so that dirt particles and dirt brine mixed with fine salt can be expelled.

The washing brine is circulated in a sedimentation tank. Fresh brine of approx. 20° Bé must be added at certain intervals, depending on the degree of contamination.



The salt washed in this manner is transmitted directly from the washing plant to an oscillating-screen centrifuge in which the adhering brine is mechanically separated. The degree of dehydration is a function of grain size and crystal structure. Centrifuges of this type generally dehydrate the solar salt to about 3 - 5 %.

Centrifuging of the salt considerably reduces the content of secondary salts so that, above all, the hygroscopic effect of $MgCl_2$ is largely eliminated; in other words, the salt remains relatively dry.

Via a conveyor belt, the centrifuged salt reaches two intermediate hoppers above the bagging system. Since above all 18 and 25-kg bags are used, two bagging scales with drawing belt conveyors and manual welders for plastic bags, all of them for a capacity of 5 t/h, have to be used.

The wall thickness of the plastic bags should be about 150 to 200 µm so that they will withstand mechanical stress during loading and in transit. If there is no suitable store available, the bags may also be stored in the open air. However, in this case they must be protected against direct sunlight.

As was mentioned at the beginning, this processing plant can easily be expanded, provided that it is suitably designed from the very beginning.

A diesel AC generating set with an output of approx. 70 kVA must be provided to supply the above plant with power.

13. Cost estimate

One of the purposes of this report is to give a cost estimate for the sea-water intake line and the processing plant.

13.1 Sea-water intake line (drawing DBS 5/71)

For the sea-bottom intake line of PE pipes suggested by us we have obtained a quotation from Messrs. Dyckerhoff & Widmann, Munich, which was sent to Salinto with our letter of August 17, 1971.

According to the quotation, the price of

Delivery of PE pipe line CIF Lomé		
Welding of pipes at the site, including personnel and equipment,		
Placing of pipe line with the aid of divers		
Supplying and placing the concrete supports and the framework at the intake point		
Laying the pipe line on land and into the sea up to about 40 m, including the necessary equipment		
is		DM 253,100.-
Plus		
Transportation of material to site		
Loan of floating rigs		
Contingencies		
	Estimate	DM 40,000.-
	Total estimate	DM 293,100.-

13.2 Processing plant (drawing DBS 8/71)

The cost of the proposed washing centrifuges and the bagging plent with a capacity of 5 t/h is estimated as follows:

Items to be manufactured in Togo:

1. Surge bin			
7. Belt conveyor	Estimate	DM	30,000.-
8. Two intermediate hoppers			
Approx. 3 tons of supporting structures		DM	12,000.-

Items to be imported:

2. Batching trough conveyor			
3. Mixing worm			
4. Steep-incline screw conveyor	Estimate	DM	225,000.-
5. Screening washer with two pumps			
6. Oscillating-screen centrifuge			
9. Two bagging scales			
10. Two drawing belt conveyors and hand welders			
Diesel AC generating set, 70 kVA		DM	40,000.-
Spare parts for two years	approx.	DM	18,000.-
CIF expenses	approx.	DM	10,000.-
		DM	335,000.-
Estimated total approx.		DM	340,000.-

Since Salinto is exempt from import duties and fees, these need not be taken into account.

14. Bibliography and references

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ASECNA, EXPLOITATION METEOROLOGIQUE

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CTMB, GUON KEOPE

DIRECTEUR DU PORT, LOME

DR. LACKNER, DR. KRANTZ + BARTH, Consulting Engineers, Offices Lomé Harbor and Bremen

Furthermore:

DYCKERHOFF & WIDMANN, MUNICH

WEIR-PUMPS, LONDON

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STENFLEX, COMPENSATORS

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BASF, LUDWIGSHAFEN

CHEM. WERKE HÜLS

MESSER-GRIESHEIM, FRANKFURT/MAIN

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