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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

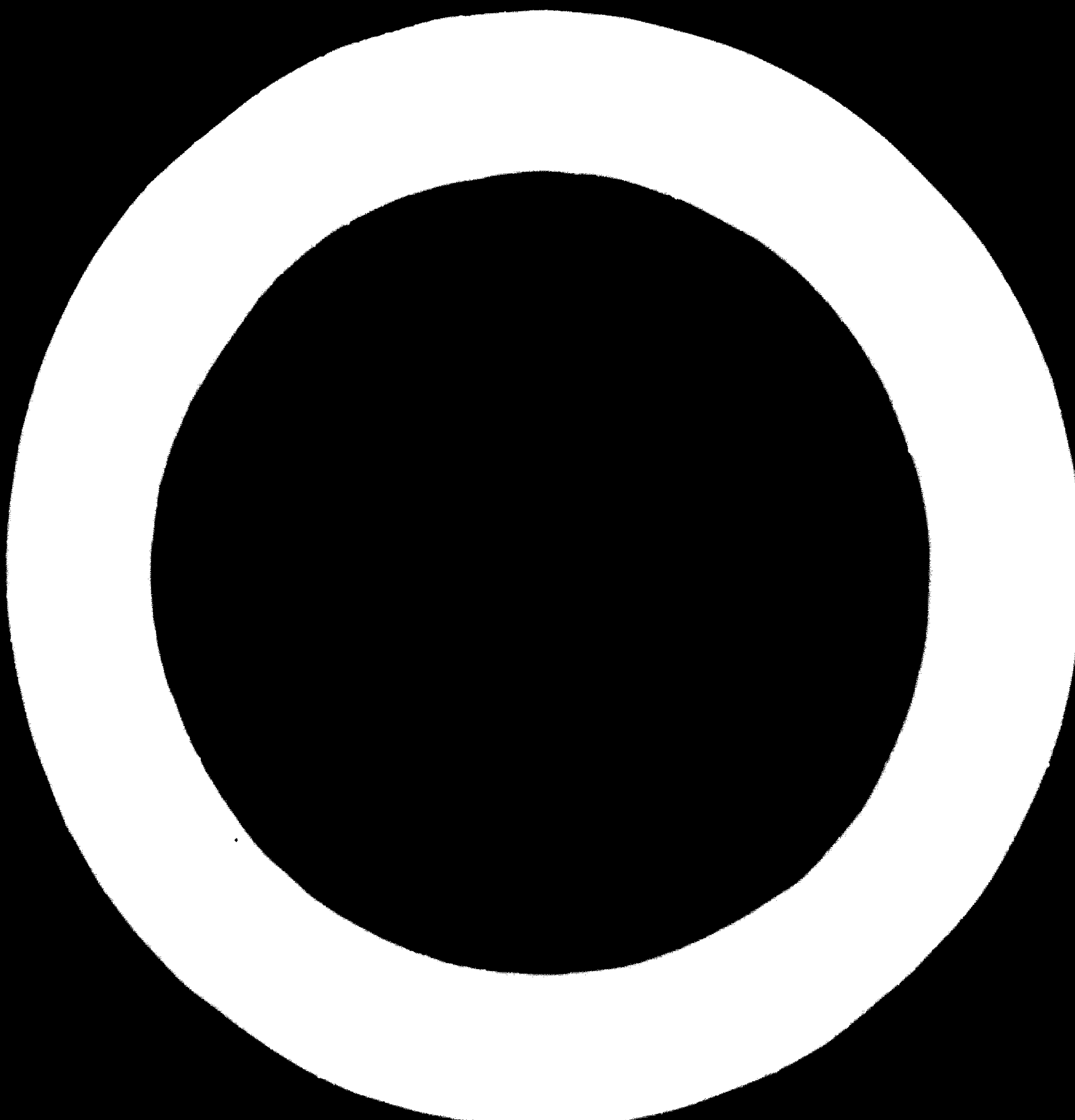
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

MODERNIZATION AND MECHANIZATION OF SALT INDUSTRIES BASED ON SEAWATER IN DEVELOPING COUNTRIES

Report of Expert Group Meeting on Modernization and Mechanization of Salt Industries

Rome, 25 - 29 September 1968

UNITED NATIONS



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Vienna, Austria

Explanatory notes

The following symbols, abbreviations and terms have been used throughout the paper:

A full stop (.) is used to indicate decimals

A comma (,) is used to distinguish thousands and millions

A slash (/) is used to represent the word "per"

1 acre = 0.405 hectares, 4,047 square metres

1 foot = 0.3048 metres

1 imperial gallon = 4.545 litres

1 in (inch) = 2.540 centimetres

1 kg = 1 kilogram

1 kVA = 1 kilovolt

1 kWh = 1 kilowatt hour

1 lb (pound) - 0.453 kilograms

1 long (English) ton = 1.016 metric tons

1 mile = 1.6093 kilometres

ppm = parts per million

1 US gallon = 3.785 litres

1 yd = 1 yard

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Contents (continued)

Letter of transmittal to the Executive Director of UNIDO

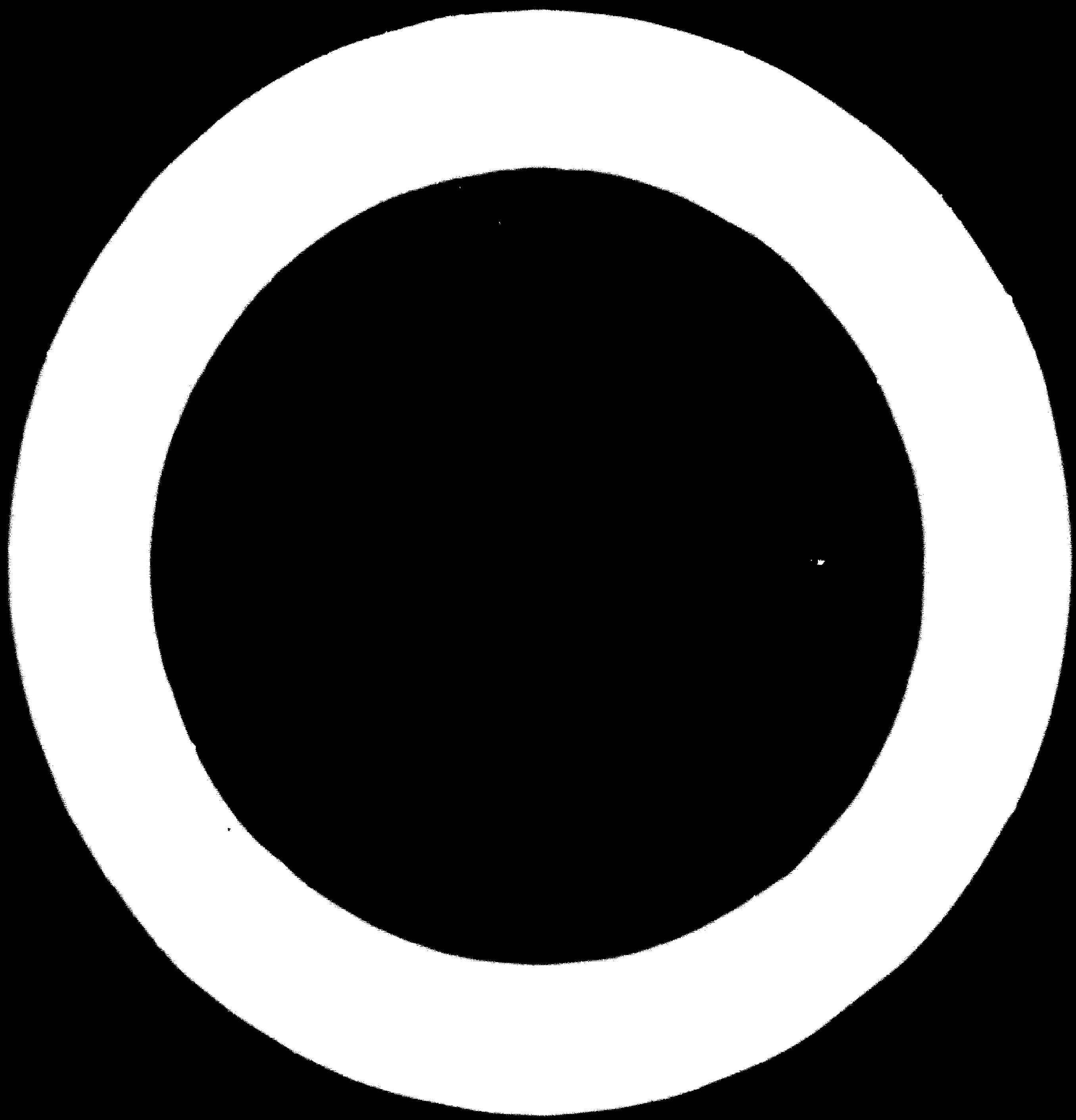
We have the honour to submit herewith the Report of the Group of Experts on the Modernization and Mechanization of Salt Industries based on Seawater in Developing Countries. This report was prepared following the meeting held from 25-27 September 1968 at the headquarters of the Amministrazione dei Monopoli di Stato in Rome, and a visit to its solar salt-works at Barletta, 28-29 September 1968.

The General Chairman of the group was Mr. W. A. Caldwell, Chief, Basic Chemicals, Pharmaceuticals and Building Materials Section, Industrial Technology Division, UNIDO, and the Meeting Co-ordinator was Mr. P. M. Terlizzi of the same section. The other members of the group are listed in annex II to the report.

The terms of reference for the Expert Working Group Meeting were to present selected papers on salt industries based on seawater, to discuss these papers and to suggest recommendations that would be of value to developing countries concerned with the installation, modernization, or mechanization of sea-salt industries.

Facilities for the meeting were provided by the Italian Government through the Amministrazione dei Monopoli di Stato, which also arranged a visit to its largest solar-salt plant, located at Barletta, Province of Foggia. Thanks are due to these groups and to those individuals therein (in particular to Dr. Giuseppe Gualdi), whose assistance contributed greatly to the success of the Meeting.

Signed by the Members
of the Expert Working
Group



Preface

1. The Expert Group Meeting on the Modernization and Mechanization of Salt Industries Based on Seawater in Developing Countries was held in Rome, Italy from 25-27 September 1968, followed by a visit to the salt works at Barletta, which provided the participants with detailed information on modernization and mechanization of a solar sea-salt plant. Facilities for the meeting and arrangements for the visit were provided by the Italian Amministrazione dei Monopoli di Stato.

2. The purpose of the meeting was to collect and analyse information that would be of value to developing countries wishing to develop sea-salt industries.

3. The meeting was opened by W. A. Caldwell of the Industrial Technology Division of UNIDO, who welcomed the participants in the name of UNIDO and outlined the general scope and aims of the meeting. In turn, Dr. Giuseppe Gualdi, Central Director of the Salt Services of the Amministrazione dei Monopoli di Stato, welcomed the participants to Rome and outlined the progress Italy had made in the sea-salt industry, the assistance it had provided to developing countries, and the importance of mechanizing and modernizing solar-salt plants.

4. Apart from Mr. W. A. Caldwell of UNIDO, who served as General Chairman and Mr. P. M. Terlizzi of UNIDO, who served as Meeting Co-ordinator, ten experts participated in the meeting - one each from France, Kuwait, India, Japan, Portugal and Venezuela; and two each from Italy and the United States. There were five observers - three from the Federal Republic of Germany and two from Turkey. The participants are listed in Annex II.

5. The agenda of the meeting is given in Annex I. Presentation of the expert papers was followed by discussion of the paper and a summary of the results of the discussion by a moderator. After consideration of government and regional papers and a general discussion, the participants joined in formulating technical recommendations and recommendations for specific UNIDO action to be taken in order to implement the conclusions arrived at during the meeting.

6. The present publication includes the report and conclusions of the Group resulting from the meeting (Part I) and summaries of expert and government and regional papers, discussed or considered during the meeting (Part II). Papers were presented by experts from: France, Italy, Kuwait, India, Japan, Portugal, United States and Venezuela. Government papers were available from: Algeria, Argentina, Brazil, Bulgaria, Chile, China, Cuba, Haiti, Malta, Nicaragua, Peru, Sudan, Turkey, Union of Soviet Socialist Republics and Uruguay. The

United Nations Economic Commission for Africa presented a paper on production and consumption of salt in Africa. In addition, UNIDO presented an introductory paper. The introduction to the report contains a description of the solar-salt process.

7. The views expressed in the government, regional and expert papers are those of the authors and do not necessarily represent the views of the secretariat of UNIDO.

Introduction

Modernization and mechanization of salt industries

8. In introducing the discussion, a representative of the Industrial Technology Division of UNIDO pointed out the importance of mechanization and modernization of salt industries based on seawater in developing countries. Many salt plants today still use much manual labour or simple machines in the harvesting of sea-salt. The equipment may be, for example, a handcart moved on a track, a portable conveyor belt that must be guided constantly or lifting devices using pulleys for handling bagged salt. Mechanization, in these cases, could cover the use of motorized vehicles, fork-lift trucks for storage, improved scraper accessories and the like.

9. Modernization is the next step to be considered. Machines based on old principles, although usable, can perhaps be replaced by others that are more advanced, in terms of efficiency, and that can be adopted with a minimum of cost and within the existing technical framework of a country. For example, modern harvesting machines can be used, the salt can be conveyed from salt fields directly to the processing facilities by long conveyor belts. Salt can be graded for physical quality and subjected to simple control tests and specifications. It can be weighed and bagged automatically. Concentrating and crystallizing ponds can be made more leak-proof, thereby saving material, and new techniques can increase their capacity and improve their functioning. Chemical quality-control procedures can reduce the production of low-quality salt and increase the varieties of salt that can be made. More corrosion-resistant construction materials can reduce replacements. All of these may be considered as "modernization".

10. Each recommended change should be considered in the light of the cost of labour as compared with the cost of mechanization or modernization in the particular country.

11. In addition to the production of crude salt, some developing countries require assistance in the production of salt products useful for the cheese-, canning-, baking- and other food-processing industries. These countries may also wish to develop their salt-producing capabilities to a point where they can provide suitable material for use in such industries as pulp and paper, ceramics, rubber, oil and soap, textile dyeing, ice manufacture, water conditioning and the manufacture of caustic soda and chlorine.

12. Some countries have marginally economic salt fields operated mostly by family units, others import significant quantities rather than use their own resources, still others have found that their rock salt deposits are easier to work, while some have never seriously considered developing salt industries, either because of lack of domestic industrial uses for the salt, or because their climates are unsuitable for salt production.

The role of UNIDO

13. One of the functions of UNIDO is to provide such developing countries, at their request, with assistance in the formulation of plans to assess the economic merits and technological requirements for establishing a salt industry. Another concern of UNIDO is to assist developing countries in modernizing or mechanizing their present solar-salt production facilities and production techniques.

14. The UNIDO budget for 1969 and 1970 includes plans for providing funds for salt-industry developments in Africa, Asia and the Far East, Europe and the Middle East, and the Americas. It is hoped that countries in all of these regions will request UNIDO to send experts to survey their present facilities and make recommendations as to how to improve their productivity.

15. UNIDO hopes to call upon members of this Working Group to assist these countries as experts when such requirements arise. Collectively, the results of this Expert Working Group Meeting should go far towards opening up new opportunities technically, industrially and economically for those developing countries where salt production can be vitally important for their industrialization.

16. UNIDO, in planning for this Expert Working Group Meeting, requested all countries having access to seawater to provide information on the status of their salt industries. In addition to the expert papers that were presented, the Working Group reviewed summaries of papers prepared and submitted by the Governments of Algeria, Argentina, Brazil, Bulgaria, Chile, China, Cuba, Haiti, Malta, Peru, Sudan, Turkey, the Union of Soviet Socialist Republics and Uruguay, as well as from the United Nations Economic Commission for Africa. These summaries are presented below in Part II.

Description of the solar-salt process

17. In order to assist in the appreciation of the papers summarized and the technical recommendations proposed in this report, the following brief description of the solar-salt process is given.

18. Saline water from the sea or elsewhere is pumped or allowed to flow into reservoirs and thence into a system of shallow concentrating ponds, which often cover a considerable area. The ponds are generally interconnected by channels and are so arranged that the saline water can flow, by gravity or pumping, as required, from one pond to another in a designed sequence. In these concentrating ponds the brine is exposed to the evaporation action of sun and wind, and its salt concentration rises from an initial 3^{o} Baumé to 22^{o} and 24^{o} Baumé in the final concentrating pond. An important aspect of the management of the process is the control of the flow of water through successive ponds so that the salt concentration rises in stages. At about 14^{o} to 20^{o} Baumé calcium sulphate crystallizes and settles to the bottom of the pond. The brine mother liquor is then allowed to flow into crystallizing ponds. These basins are smaller in area than the concentrating ponds and have flat, well-prepared bottoms so that the crystallized salt can settle in a uniform layer at the bottom. The concentrated mother liquor above the salt, called bittern, is then run off either to waste or to a system for recovery of the chemicals that it contains.

19. The salt remaining on the bottom of the crystallizing ponds (basically 97 to 99 per cent sodium chloride) is then harvested by a variety of processes ranging from simple hand labour to the use of highly mechanized equipment that scrapes up the salt and automatically transfers it onto conveyors for piling, storage and eventual transport.

20. Before shipment the salt is usually washed to remove sand, earth and other impurities. Finally, depending upon the type of operation involved, the salt is graded, crushed, treated with additives, packaged in a variety of forms from bulk to table packets and prepared for shipment.

PART I

CONCLUSIONS AND RECOMMENDATIONS

21. Consideration of expert and government papers presented at the Meeting led to a number of conclusions and recommendations. Some of these are of technical nature, and some relate to points that should be considered by UNIDO. Technical conclusions and recommendations are listed below and then explained in detail.

Technical conclusions and recommendations

(a) Factors affecting a decision to construct or improve a solar-salt plant

(b) Location of a solar-salt plant

(c) Construction of water intake and storage facilities

(d) Concentrating ponds

(e) Crystallizing ponds

(f) Harvesting of salt

(g) Handling of salt

(h) By-products and derivatives

(i) Other processes

Factors affecting a decision to construct or improve a solar-salt plant

22. Apart from the usual techno-commercial considerations such as markets or costs, common to most processes and plants, a number of special factors have to be taken into account in considering a solar-salt plant. These include:

(a) Availability of water of sufficient salinity. Seawater near coastal areas varies in its salt content particularly in the neighbourhood of large estuaries where it may be diluted with fresh river water to such an extent as to make solar evaporation inefficient. It is desirable therefore to have chemical analyses made over a period of time on samples from the area from which water intake is proposed.

(b) Suitable weather conditions. The ideal conditions are long periods without rain and a hot dry wind to help evaporation. Measurements must include temperature, rainfall, humidity, wind velocity and effective evaporation rate. With this in mind, periods of the year suitable for solar-salt production can be properly planned.

(c) Suitable site conditions. A solar-salt complex will require a large area of flat land, generally of low value for other purposes, close to the source of saline water. It should be accessible to deep water for sea loading of bulk salt and near existing railroads or highways and public utilities.

(d) Effect on the economy. In considering markets and economies it should be borne in mind that in addition to providing a country's requirements of salt for such internal or export uses as food seasoning, hide and skin treatment and fish preservation, the output of a solar-salt plant has the potential of providing a developing country with a source of raw materials (should it at a later stage need to establish a basic chemical industry producing for example, soda ash, caustic soda and chlorine, all of which require salt).

An existing solar-salt industry can frequently be made more productive by the application of new methods of evaporation control and harvesting. This normally requires advice from experts familiar with solar-salt manufacture. These considerations, among others, will be detailed later. For example in the harvesting of salt there is a range of improvement from partial mechanization such as introduction of trucks and dumpers to a fully mechanized plant with elaborate harvesters and salt-handling and conveyor equipment. The selection from this range must be carefully considered not only from the financial but also from the employment viewpoint. In many developing countries the solar-salt industry is a traditional family affair and mechanization is likely to raise both social and economic problems. Again, the question of year-round continuity of employment must be given attention.

Location of a solar-salt plant

23. Once a general region has been selected as being the best compromise of several ideal conditions (i.e. near to the sea and to a harbour, having good roads, power lines etc.), the exact site of the solar-salt plant must be chosen with care. This selection should be preceded by a survey, which will include an analysis of the salt water and an assessment of the presence of marine life, such as algae, plankton, shellfish and seaweed, which have a deleterious effect on salt production. The survey should also include the drilling of test holes in the area to determine sedimentary deposits, seepage rates and the presence of sweet or brackish water. The elevation and natural slopes of land should be observed and considered in relation to mean sea level. Soil tests should be made to determine the characteristics of surfaces for building the crystallizing ponds and whether they are firm enough to carry cultivating and harvesting equipment. Information should be obtained on the availability of land for future plant expansion, and the nearness and depth of nearby water to accommodate sea-going vessels for salt loading. Other weather and water conditions should also be checked, such as the possibility of excessive amounts of blown sand, which would contaminate the finished product and excessive rise and fall of tides, which would affect pumping conditions.

Construction of water intake and storage facilities

24. Solar-salt production requires the constant availability of seawater of as high a salt content as possible. A relatively constant salt content is also desirable to reduce the probability of poor production. While the use of the action of tides to obtain water is usually practicable, the use of a canal connected to the sea might be necessary. A steady supply such as can be provided by a pumping station is normally recommended. Usually the pumping station should be at the outer point of the pipeline projecting into the sea. Sometimes a pier may be needed to permit the pumping point to be located where tidal changes would not seriously affect the performance of the pumps. Furthermore the location should have a minimum of sand, marine life and other contamminants. Water from the pumping station can be conveyed to a holding reservoir either by pipeline or by means of open earth sluice-ways in which partial evaporation can take place during pumping. Holding reservoirs are necessary to provide water in case of pump breakdown or other problems affecting the supply of seawater to the ponds. In rainy seasons in some areas, sluice-ways are frequently covered. Concrete sluice-ways are usually desirable as the rapid flow of water can erode earthen banks, although these can be made to work if they are protected by rip-rap or if the flow of water is reduced. Stone walls and wooden planks can also be used to build sluice-ways. Surfaces in contact with salt water should be clean so as to reduce the ammount of impurities in the final salt production. Gates for controlling the passage of seawater can be either manually operated wooden gates or, in more advanced systems, electrically operated concrete gates. The capacity required for the pumping station will depend upon the production schedule, salt concentration of the water and losses due to production faults. An idea of the capacity of pumps required may be obtained from the following: Expected output of solar salt per year should be, let us take, 100,000 short tons. Since 1 US gallon of seawater contains approximately 0.203 lbs of recoverable salt, therefore seawater required would be 9.8 million gal per day. It should be assumed that the plant may operate for only 100 days and that the required water must be taken in during this period. This would mean a pump with a capacity of approximately 7,000 gal per minute allowing for seepage. Preferably two pumps of 3,500 may be used to allow for maintenance. A wide range of suitable centrifugal cast-iron pumps are commercially available.

25. Although provision is usually made for intake of seawater over a comparatively short season, it is recommended that reservoirs be installed to provide

a constant source of seawater to the solar-salt field in the event of pump failure or difficulties due to bad weather. Their size will depend upon such factors as availability of land, the production of the plant and whether there is a rainy season. Reservoirs need not be shallow as no great evaporation effect is expected in them.

Concentrating ponds

26. The layout of concentrating ponds is a very important part of the design of a solar salt-works. They should, in general, be sited so that a smooth and controllable flow of gradually more concentrated brine can take place from one pond to another in the series. The actual area required will depend on the rate of evaporation achieved, and this in turn depends on weather conditions, such as wind velocity, humidity, sunshine, absence of rain. Typical figures, however, would be 1,500 to 2,000 acres for 100,000 short tons per annum of salt, although this will be influenced by local conditions, ground characteristics and degree of seepage. The area could conveniently be divided into, say, eight ponds. The preparation of the concentrating ponds is important. It is desirable that there should be very little seepage of liquor through the bottom; otherwise the partly concentrated brine will be lost to the underlying water table or, alternatively, unconcentrated seawater will soak through to the concentrated liquor. Either interferes with production. The factors affecting seepage are very complex and depend on the tidal range, the height above or below mean sea level of the concentrating ponds and their relative height to each other, the distance from the sea and the nature of the soil. Much can be learned from drilling and seepage tests. When the amount of seepage is too great, the situation can sometimes be improved by lining part or all of the ponds with a suitable clay. The dikes forming the border of the ponds should be carefully built and should have sides at an angle of 10^{o} or more. Some pond dikes are inclined up to 45^{o}. Reinforcement with concrete or with crushed stone at the base of the dikes may in some cases be necessary depending on climatic conditions in the area, e.g. in very high winds the waves developed in a big pond may damage the sides if they are not properly constructed.

27. The pond should also be arranged so that the prevailing winds blow across them to augment evaporation.

28. Concentrating ponds in which the seawater density has reached approximately 14 to 20^{o} Baumé will precipitate out calcium sulphate as gypsum. When the ponds are emptied of mother liquor the gypsum formed is in some cases rolled or tamped

to permit a smooth hard floor. After 3 to 5 years accumulation the gypsum is sometimes removed and sold.

29. There are a number of other considerations that should be taken into account in the operation of concentrating ponds.

30. For example, in some countries the presence of plankton in and on the surface of evaporating seawater causes problems, including reduction of evaporation rate and discolouration of salt. Methods of dealing with this problem include physically skimming off the top layer. This is usually effective but requires considerable labour. Alternatively, the addition of two parts per million of chlorine is a deterrent to plankton formation, but care has to be taken as excessive chlorination will cause precipitation of some salts and the risk of clogging of pipes.

31. As the seawater become more concentrated, plankton tends to disappear, but frequently another marine growth is formed. This imparts a reddish tinge to the brine, which usually does not persist in the final salt. Mention should also be made of the addition of dyes to the brine. A suitable dye increases the absorption of the sun's rays by the brine and consequently increases the evaporation rate. In most cases, however, the benefits obtained barely counterbalance the cost of the dye. Since the same effect can be obtained by increasing the area of the concentrating ponds, the use of dyes is a balance between the cost of the dye and that of additional land and is frequently not worth while.

32. Marsh lands are excellent sea salt plant site sites. Their real estate value is poor, large areas are generally available, and their height above sea level is at a minimum, allowing for easy flow of seawater over its areas.

Crystallizing ponds

33. This is a section of the plant where good design is particularly important for obtaining good yields of high purity salt.

34. The area required for crystallizing ponds varies from one fifth to one tenth of the area required for concentration ponds, depending on evaporative conditions and the concentration of seawater. The ponds should be situated so that dry air blows across them but if there is a prevailing off-shore wind from a sandy soil, some concentrating ponds should be put on the windward side to trap the dust carried by the wind; otherwise excessive contamination of the salt may occur. Individual crystallizing ponds should be rectangular and of a size that

will suit the method of harvesting employed. They can be for example 100 to 150 yd wide by 300 to 500 yd long. In too large ponds, wavelets will form in high winds and this tends to give a deposit of undesirably fine salt. They should have firm, well built edges, which can be protected if necessary by crushed stone reefs. The bottom should be smooth and compact with a gentle gradient so that pools of mother liquor are not left behind. The bottom should be of a material that is impervious to brine and strong enough to bear the weight of the harvesting equipment. The choice of harvesting equipment is frequently dictated by the nature of the crystallizing pond bottom. In countries with low rainfall and prolonged dry spells it is possible to build up a floor of salt and keep it there from one year to another, scraping off only the top layers when harvesting. This allows the use of heavy, robust harvesters of a comparatively simple type and gives a very pure salt since no earth is disturbed. It is, however, obviously not practical in countries with a wet season when the rain would dissolve away the salt floor. In such conditions a puddled clay floor is sometimes used and a harvesting arrangement with a low ratio of weight to supporting area has to be used.

35. The crystallizing ponds may be operated in a number of ways. A typical method is to run in 3 to 4 inches of concentrated brine, and allow it to concentrate to the desired extent while depositing salt. Density measurements are important to control this stage of the process. The mother liquor or bittern is run off when the density has reached the correct level. This is usually 26 to 28^{o} Baumé but may be as high as 30^{o}. A fresh supply of concentrated brine is then admitted to maintain the desired range of density. The process is repeated until a cake of salt 6 to 8 inches thick is built up. This is then harvested.

Harvesting of salt

36. Harvesting is the term used for collecting the salt from the crystallizing ponds. A wide range of techniques are used and it is in this area that there is great scope for modernization and mechanization.

37. At one end of the scale, hand labour is used and the salt is removed from the beds with picks and shovels. It is then put into small piles and removed by hand in sacks, buckets etc. Considerable skill is required in the actual removal of the salt from the bed so that dirt is not mixed with the salt. Although the work is hard and unpleasant, in some countries it provides a source of employment, which should not be disrupted. In time, however, such hand labour will give way to the next method - machine handling.

38. This can be carried out by a variety of techniques, some comparatively simple, others requiring considerable capital expenditure. There is a great need for partial mechanization where, for example, the salt may be scooped up by a tractor. In some cases the salt bed may be hard enough to allow a scraper to travel across it scooping up the salt into a conveyor. In other cases, as at Barletta, the scraper mechanism is mounted on two long, wide-diameter pipes that run right across the crystallizer pond and can be rolled along the pond gradually so that the scraper can attack a fresh surface. The pipes have the function of spreading the weight of the scraping gear, allowing it to move, and consolidating the salt as they roll over it. (Expert advice is desirable before a developing country embarks on a programme of mechanization, and specialists in this subject should be employed.)

39. The salt, after harvesting, is conveyed either by travelling belts or a series of trucks to a central stock pile of crude salt. It is important that the area between the crystallizer ponds be in good condition to cope with the weight and action of salt harvesting equipment. The proper design and layout of the crystallizer pond section will contribute considerably to the efficient harvesting of salt.

Handling of salt

40. Once the crude salt has reached the stock pile a wide variety of treatments can be used. In some cases stockpiles are very large and material is removed from them as required by mechanical means. For some applications the salt has to be crushed just before shipment. Salt washing is important in that it improves the colour of the salt, and removes some impurities, both soluble and insoluble. The salt-washing can take many forms. When wet salt from the crystallizing ponds is piled in mounds, the mother liquor containing impurities drains to the bottom. Rain showers can be beneficial by causing a further washing effect although if the rain is excessive it may be necessary to protect the salt with plastic film covers, or to store it in wooden shelters.

41. More elaborate methods of washing consist of stirring in brine (e.g. in screw classifiers) and filtering off the liquor. Alternatively, the salt may be treated on inclined travelling belts where clean brine or fresh water is allowed to run counter-current to the salt. The salt is then piled and allowed to drain.

42. The salt has then to be prepared for shipment and this process takes many forms, depending on the final market. In some cases it is carried in bulk in

trucks or in hoppers to ships, in others it is bagged. Machines are available for packaging salt in 1 kg or smaller packs. The degree of analytical control depends upon the specifications under which the salt is to be sold.

43. For some uses it is desirable that the salt be treated with anti-caking or free-flowing agents. Ferrocyanides can be used for anti-caking. In salt for foodstuffs a level of 5 ppm of ferrocyanide is acceptable but only in some countries. Magnesium carbonate is also used and is suitable for foodstuffs. Potassium iodide is sometimes incorporated for health reasons. These materials can be sprayed on to the salt before packaging.

44. For export sales of salt in bulk it is desirable to have good port facilities preferably with a deep water channel. The use of barges or lighters entails much double handling and with a low-cost product like salt adds appreciably to the cost. High loading convevors, bucket transport direct from the salt piles and similar mechanical methods should all be considered.

<u>By-products and derivatives</u>

45. A solar-salt process, if operated on a large scale with scientific and mechanical control, can be the source of a number of products other than salt (sodium chloride). Mention has already been made of the recovery of gypsum at an early stage of the concentration. Magnesium chloride can also be recovered by seeding the partially concentrated brine with crystals. Removal of part of the magnesium chloride at this stage not only provides a supply of this material but makes the remaining brine easier to evaporate.

46. The main source of by-products is, however, the so-called bittern or mother liquor from the crystallizing ponds. A developing country should consider the recovery of these products, which include magnesium sulphate, magnesium chloride, potassium chloride and bromides. However, unless a fairly large scale of operations is undertaken, say 100,000 t <u>per annum</u> of salt, it may be found that by-product recovery from the bittern is not economical.

47. In addition to these by-products, a developing country should consider the economics of proceeding to the next stage of a chemical complex based on salt. This will usually take the form of electrolysis of the salt to produce chlorine and caustic soda or the use of the Solvay process to produce sodium carbonate. In some cases a modified Solvay process giving sodium carbonate and ammonium chloride suits the economy of a country. Caustic soda and soda ash are basic

raw materials for a variety of products like rayon, soap and glass, while chlorine is used for some pesticides and plastics. A great deal of data is available on the economics and technologies of these processes.

Other processes

48. The production of salt from seawater is not limited to solar evaporation. In areas where solar energy is limited, and the need for salt is great, methods are employed to produce salt, utilizing a combination of processes. For example:

49. Salt field system. In Japan a method is used whereby the sun partially evaporates the brine. The brine so treated is then delivered to a plant for crystallization in a multiple-effect vacuum evaporator. From the evaporator the salt is washed, dried and packaged.

50. Boiling of seawater. This system, also used in Japan, Kuwait and the United States, is divided into two systems. One is mechanical thermo-compression evaporation system and is adopted principally where electrical power is used. A steam compressor operates on power from a motor to produce compressed steam to be fed as evaporating energy to the evaporator. The other system is a thermo-compression evaporation and vacuum system. Where a low-cost fuel is available, this is the most economical system. In this system a high-temperature and high-pressure boiler is used with a compressor directly coupled to the back-pressure turbine. The thermo-compression evaporation system is adopted for the evaporation of seawater. This is followed by the vacuum system, using turbine exhaust gas as the source of heat for evaporating the concentrated brine.

51. Ion-exchange membranes. By this method a number of cation- and anion-exchange membranes are arranged alternately. Cation and anions passing through these membranes in the presence of an electric current concentrate the salt in alternate passages and a brine more highly concentrated than seawater is obtained. This brine is then led to an evaporator where salt is crystallized. New developments in this technique have resulted in membranes that do not permit the passage of unwanted seawater components such as magnesium, calcium, sulphate etc. The first product, sodium chloride is thus of higher quality.

52. Triple-effect forced circulation evaporation. In this method, which is employed in Kuwait, concentrated seawater from a desalination plant is fed to the first-effect evaporator and heated by live steam. The brine discharged

from the first evaporator is fed into a second and similar evaporator, which is heated by the vapour resulting from the brine in the first effect. At this stage the least soluble and most troublesome of the constituents, calcium sulphate, precipitates. The discharge is led to a cone-bottomed settler or gypsum separator, from which the calcium sulphate slurry is withdrawn. The overflow is passed to the third and last effect where crystallization of salt takes place. The salt crystals collect at the bottom. The salt slurry is centrifuged, dried, cooled, screened and packaged.

53. Additional considerations. It was recommended that washing equipment be installed and that high-purity salt production be considered for both edible and industrial use as this should lead to increased consumption and industrial utilization. Since seawater desalting and solar salt production may be compatible operations at some future date, it is expected that they will become more generally used. This will provide opportunities for the solar salt producers to obtain concentrated brine as feed to the solar evaporators. Developing countries should be alert to such opportunities.

Conclusions and recommendations for consideration by UNIDO

(1) The use of fellowships for training of personnel for solar-salt plants was not recommended by the Group. It was felt that in order to obtain worthwhile benefits a fellow would have to observe the whole-year cycle of a solar-salt plant and this would be too time consuming. Moreover, it was felt that many of the solar-salt plants would be hesitant about accepting representatives of potentially competitive enterprises.

(2) The promotion of demonstration plants was also not recommended since conditions and procedures for manufacturing solar salt vary so greatly from one country to another. To be of value, a demonstration plant would have to include techniques to cover a variety of conditions.

(3) It was recommended that UNIDO establish a roster of consultants and experts in the solar-salt industries. Such experts, who should be well versed in the erection, planning, modification and operation of solar-salt plants, could quickly evaluate the condition of existing solar-salt plants and recommend, where necessary, remedial action. They would also be capable of offering advice on the design and construction of new plants.

(4) It was recommended that UNIDO consider the status of the solar-salt plants in various developing countries as outlined in the government papers summarized in this report. Discussion should be held with those countries where there was felt to be scope for beneficial action.

(5) It was recommended that UNIDO draw to the attention of developing countries not possessing solar-salt plants, but with suitable climates and physical resources, the possibilities of development, but emphasize the need for carrying out careful economic and physical studies before undertaking production. In this connexion, due weight should be given to the use, in the longer term, of salt as a raw material for a chemical industry.

PART II

PROCEEDINGS OF THE EXPERT GROUP MEETING

The papers prepared for the meeting included:

Expert papers, dealing with experiences in the modernisation and mechanization of salt industries based on seawater in France, India, Italy, Japan, Kuwait, Portugal, United States and Venezuela.

Government papers, dealing with the present state of production, present and estimated future consumption and plans for improvement of the industry in Algeria, Argentina, Brasil, Bulgaria, Chile, China, Cuba, Haiti, Malta, Nicaragua, Peru, Sudan, Turkey, Union of Soviet Socialist Republics, Uruguay.

A regional paper, submitted by the United Nations Economic Commission for Africa, on production, consumption and future plans of the four subregions of Africa.

These papers, as listed in Annex III, are summarised in the following pages.

SUMMARIES OF EXPERT PAPERS

French experience in the modernization and mechanization of salt industries based on seawater

by Philippe R. de Flers

There have been considerable changes over the last twenty years in France in solar-salt requirements as regards both quantity and quality of the product. Consequently France has directed her researches towards improving production per unit of area, output per man-shift and quality.

A study was made of the reactions of seawater exposed to solar evaporation, and new methods of analysis were devised. The soil forming the salt-pans was examined for plasticity, permeability and the like. Surveys were also made of the composition of seawater, evaporation rates, crystallization and of the density and purity standards for the finished salt.

Modernization was effected chiefly by dealing with the reduction or suppression of factors that restricted production or increased its cost, such as reduced or irregular concentration of seawater, excessive intermediate pumping and poor control of flow to crystallizing ponds. Attention was also paid to the increase of output per unit of surface in the crystallizing ponds, to the improvement of their beds, (in some cases by the use of salt floors), and to close control of the magnesium salt content, which affects crystallization. Harvesting is also a delicate operation, and suitable machinery has been installed to scrape up the salt and transfer it by conveyor belts to the stock-piles and washing plants. Different types of washing plants were used, depending to some extent on the earlier treatment of the salt. All depend on washing with an artificially saturated brine.

A wide variety of grades and purities of salts and of packaging are now required, which necessitates the use of special equipment. Anti-caking and other modifying agents may be added or, on occasion, the salt may be incorporated in cattle food. Water transport is preferred for bulk shipments.

In addition to improving its own production on the lines indicated above, France has been able to advise a number of other countries. France is also examining the possibility of combining desalination methods used in the production of fresh water with conventional salt production.

Indian experience in the modernization and mechanization of salt industries based on seawater

by P. K. Seshan

Production. Of the 5,076 salt-plants registered with the Salt Commissioner of India, 5,022 are small, producing less than 10,000 long tons of salt/year. These plants are located on the East and West Coast of India in the States of Andhra Pradesh, Madras and Maharashtra. Of 4,270,000 tons of salt produced in India yearly, 76 per cent is from seawater. The acreage licensed in India for salt-producing could have an output of 8.5 million tons/year if fully worked.

Consumption. In India the pattern of salt consumption is approximately 60 per cent for food, 30 per cent for industry and 10 per cent for export.

Salt produced in the Gujerat region from seawater is exported to Japan, East Africa and South-east Asia, while that produced on the south-east coast near Tuticorin, Madras, is exported to Ceylon.

Licensing. India requires that all manufactures of salt, regardless of the area worked, come under a licensing system. Those operating an area of ten acres or less are not required to take out a licence, provided the produced salt is destined for domestic or local use and not for regular trading purposes.

Process. The salt process in India follows traditional patterns. Seawater is admitted by sluice-gates at high tides through creeks or dug-out canals to low-level reservoirs. From the reservoir the brine is led to concentrating ponds, where it is allowed to settle, the solids separating out in the form of a slushy slime. When the salt concentration of the brine reaches 10° to 14° Baumé to permit crystallization of gypsum, the gypsum is recovered. With a view to accelerating evaporation, the brine in the concentrating ponds is made to circulate in a zig-zag manner by provision of embankments, barriers and sluices. Collection of salt from crystallizing ponds involves several steps. Once the bittern has been drained from the pan, labourers use metal hoes to break up the salt layer and shovel it into piles 4 feet high. After washing with fresh brine, the salt is carried away in baskets and stacked before being transported to a central storage point. At present no mechanical equipment is used for salt collection. For export, tugs and flat-bottomed barges are used extensively for loading ocean-going vessels berthed nearly eight miles off shore. They are loaded at a loading rate of 2,000 tons/day.

In India there has been little large-scale mechanization of salt-works, mainly because of the high cost of the equipment, which must be imported, [illegible] maintenance costs and the necessity to provide power and fuel to operate such plants in remote coastal areas. Furthermore, mechanization would disrupt an important labour market.

By-products are important. India can find markets for about 15,000 to 20,000 tons of marine gypsum and about 4,500 tons/year of magnesium chloride and 850 tons of calcium chloride are also sold annually. In India, salt is marketed as vacuum salt, refined salt, free-flowing table salt, iodized salt, medicated salt and salt-licks for animals.

<u>Allied products</u>. Salt is used in India to produce soda ash, caustic soda and chlorine. The estimated pattern of consumption of soda ash in India is expected to be about 470,000 tons in 1969. There are several industrial complexes based on salt, each of which accounts for large capital investments and employs hundreds of skilled and semi-skilled personnel. Furthermore, they save India substantial amounts of foreign exchange.

Industries based on salt can be conveniently added to existing complexes. For example, a pulp and paper mill with a capacity of 200 to 300 tons/day has a caustic soda plant of 30 tons/day output located near it. A rayon tire-cord factory has an 80 tons/day caustic soda plant, the chlorine output of which (100 tons/day) is utilized by a paper mill. A textile mill has a caustic soda plant of 100 tons/day output which is utilized by a petrochemical complex producing polyvinyl chloride from ethylene. Another caustic soda plant, of 50 tons/day capacity, owned by a textile mill, feeds a soap factory. The formation of industries and complexes based on salt has also contributed to increased production of high-quality salt in India.

Italian experience in the modernization and mechanization of salt industries based on seawater

by Silvio Galimberti

This paper reviews the development of the Italian salt industry since 1946, when over 1 million tons/year of salt were being produced in three main plants (Bari, Sardinia and Sicily). These salt-works, which were of ancient origin, relied heavily on manual labour in their operations, and only a very limited range of implements such as picks, shovels, wheelbarrows and handcarts were used. The quality of the salt was good because of the skill of the operators, and there was little or no washing machinery.

However, as industry generally expanded in Italy after the Second World War, the salt industry was also affected. Whereas previously the use of manual methods had provided useful employment for many people, it now became necessary, in order to reduce labour costs, to mechanize the industry. It proved not too difficult to mechanize the operations for which machines were available, such as pumps, conveyor belts and motor trucks, but harvesting proved more difficult to mechanize. The problem depended greatly on the load-bearing qualities of the bottoms of the ponds on which the harvesters operated. It proved necessary to devise two quite different methods of harvesting for ponds with soft or hard bottoms. The development of these methods took place over several years, as it was possible to introduce only a few improvements each year. It was also necessary to modify the shape of the crystallizing ponds so that they were suitable for mechanical harvesting. This involved a considerable amount of excavation and building of embankments. The work had to be done during the winter months. These changes considerably reduced the cost of production, but it was also necessary to improve the quality of the product to meet modern needs. This involved the installation of plants for washing and purifying the salt after harvesting.

The mechanization programme resulted in a number of problems such as the maintenance of machines exposed to highly corrosive conditions during the summer and their storage during the winter months. Moreover, amortization charges were high on equipment used for only a few months each year. Nevertheless, on balance, the Italian salt industry, highly mechanized as it now is, has become a much more efficient and more economical producer than in the past and is capable of improving still further.

The possibilities of initiating sea-salt production in areas in early stages of industrial development

by Guiseppe Gualdi

The world salt problems. Until the recent tremendous expansion of the chemical industry, world annual *per capita* consumption of common salt was from 10 to 15 kg, of which about 7 kg was used for human nutrition, most of the rest being used for cattle-feed and the preservation of hides. This demand was supplied from rock-salt mines and solar salt-works. Most of these installations were primitive and small, since suitable machinery for them was not available. Since the price of salt is low, solar salt-works were usually located in coastal areas of little or no other economic value.

Today, however, the demand of the chemical industry for sodium chloride for the production of sodium salts and chloride derivatives is increasing rapidly and steadily. In most of the developed countries the yearly *per capita* consumption of salt is now between 100 and 200 kg and will probably increase further. Developing countries must therefore plan for salt production for both dietary and industrial purposes.

Standards for selecting sites for solar salt-works. A solar salt-works extracts salt from saline water (usually seawater) by the action of solar and wind energy. About 50 m^3 of seawater are needed to produce a ton of salt. Certain economic, climatic and topographical factors must be considered in selecting the site for a solar salt-works.

Although salt is essential to human nutrition and is in great demand for industrial purposes, it is of low commercial value. Consequently, initial capital outlay for producing it should be as small as possible, and operating costs should be low enough to permit its sale at competitive prices. Plant capacity should be high so as to minimise overhead costs. The land for the plant should have little or no other commercial value. Natural ponds or marshy areas near the sea are very suitable. In temperate climates, solar salt-works may yield yearly from 50 to 150 tons of salt per hectare of salt-pan, so a very large area must be used if annual outputs measurable in tens or hundreds of thousands of tons are to be obtained.

The optimal climatic factors include long periods of clear weather and high temperatures, low atmospheric humidity, strong and dry prevailing winds and high water salinity. A wide plain adjacent to the sea is needed for the main works, damming and canalization, so as to minimize excavation and filling, the cost of which would not be justified by the low price of the product.

Impermeable clay soils are required so as to limit losses caused by infiltration of fresh water into the ponds or by leakage of the concentrated brine. The difference in level between the surfaces of the ponds and that of the water-table must not be great. This factor is more important than the permeability of the soil. In temperate zones the ground-water near the sea, where salt-works are usually built, usually consists of fresh water. Even in sandy areas no variation of the ground-water level is caused by tidal movements.

Whenever possible, the site of a solar-salt plant should be somewhat below the mean sea level. Any peripheral high areas should be used for the evaporating ponds so that drainage of brine away from the salt-works into the sea would be a sustainable loss to the economy of the plant. Finally, the site should be served by roads and railroads or be near a ship-loading point so as to minimize transportation costs.

Planning production. The planning of a salt-works is quite different from the planning of an ordinary industrial plant. Whereas a plant of the latter kind can usually be designed for gradual development, sites suitable for solar salt-works are found in nature and do not permit of much alteration. Once such a site has been developed to yield the maximum production, no further increases can be expected.

Since climatic conditions can vary widely from year to year, the productive capacity of a solar salt-works should be 25 to 30 per cent greater than the anticipated demand. Unfortunately, the plant designer is often handicapped by a lack of the information needed to ensure that the production realized will be as great as has been anticipated.

For example, the designer must have reliable information on monthly rainfall and on the average rate of evaporation, so as to determine the best seasons for salt production, but meteorological offices show little interest in corporation rates and data obtained with evaporimeters are unreliable. However, special instruments have been devised that, with the use of certain correction factors, are quire accurate. The importance of accurate data on evaporation rates cannot be overstated.

If a country requires solar-salt plants, its entire coastline should be surveyed, taking transportation costs into consideration. If yearly production is to be on the scale of hundreds of thousands of tons, the feasibility of establishing the plants near existing seaports should be investigated. The construction of new ports solely for salt traffic is rarely economical.

Once a suitable low-lying area near the sea has been found, it should be surveyed accurately, since the position of the ground in relation to the mean sea level is of critical importance. The nature of the soil should also be determined. When the site of the plant has been selected, the first problem is to provide an inlet for the raw brine. Works of this kind are usually difficult, since such areas are seldom protected by rocky formations that permit the excavation of channels that would not be subject to obstruction by sand. However, bold new solutions have been found that have simplified this problem.

Usually, the less levelled areas can be used for concentrating ponds, which can be relatively deep in the earlier stages. The incoming brine can be admitted into this area, which generally occupies about eight ninths of the plant site. The more level areas should be reserved for the crystallizing ponds. Canals and pumping stations should be provided to connect these different ponds. The stockpiles, salt-processing facilities and the like should be grouped at the point best served with transportation facilities. The details of these specialized components will vary according to local conditions and requirements.

In establishing a solar salt-works, it must be recognized that construction and starting up will require considerable time. Also, the initial product will be of poor quality, although it will improve fairly rapidly. In temperate climates a minimum of four or five years from the start of construction will be required before plant operation is fully efficient. It is thus evident that a developing country must act promptly to determine its probably salt requirements and plan realistically to meet them if it is to be prepared adequately for the successive stages of its development.

Systems used in Japan for the production of salt from seawater

by Koichiro Suwa

In Japan, the three following systems are used to extract salt from seawater:

The salt-field system. At flood tide, seawater is allowed to flow into sandy fields, where it is evaporated by solar heat. Sand on which salt has been deposited is then collected and put into seawater to separate the salt from the sand. The concentrated brine is filtered and fed into multiple-effect vacuum evaporators to concentrate the brine further and to crystallize the salt.

The direct-evaporation system. This method begins with the pumping of seawater to a series of slopes down which it flows and is partially evaporated. The brine is then pumped to a raised tank from which it drips down along bamboo poles, evaporating still further. When the required concentration has been attained, the brine is fed into thermo-compression evaporators or multiple-effect vacuum evaporators. The salt thus obtained is in the form of a slurry, from which the impurities are removed, first in a salt-washing machine and then in a centrifugal separator. The salt is then sent for packaging either in a moist state or after passage through a dryer.

The ion-exchange membrane system. Seawater, introduced into an ion-exchange membrane system, is selectively concentrated. It is then introduced into a thermo-compression evaporator or vacuum evaporator where the salt is crystallized.

Japan produces two grades of salt: dietary salt and coarse salt, the sodium chloride concentrations of which are, respectively, at least 99 per cent and at least 95 per cent. The salt-field, direct-evaporation ion-exchange membrane systems account, respectively, for 74 per cent, 12 per cent and 14 per cent of the 1,006,015 tons of salt produced annually in Japan.

Japan utilizes the bittern from sea-salt production to obtain chemicals such as bromine, magnesium sulphate, gypsum, potassium chloride, magnesium hydroxide and magnesium chloride. Three different processes for their recovery have been developed and are currently in use.

Kuwaiti experience in the modernization and mechanization of salt industries based on seawater

by Mahmud A. Mardi

The process employed in the salt plant of Kuwait is triple-effect, forced-circulation evaporation. Concentrated seawater from a distillation plant that operates on the flash principle is fed into a storage tank, whence it is pumped to the first-effect evaporator. The feed-brine composition, as compared with Kuwait Bay seawater composition, is shown in the table below.

Table

Composition of feed brine as compared with Kuwait Bay seawater

Chemical	Kuwait Bay seawater (per cent by weight)	Concentrated feed brine (per cent by weight)
NaCl	3.165	8.157
$MgCl_2$	0.490	1.149
$MgSO_4$	0.244	0.555
$CaSO_4$	0.183	0.465
KCl	0.081	0.205
$Ca(HCO_3)_2$	0.023	-
$MgBr_2$	0.009	0.023

In the first-effect evaporator, brine is heated by low-pressure live steam, which is piped from adjacent power station boilers. The brine discharged from this first-effect evaporator is fed into a similar second-effect evaporator, which is heated by the vapour from the brine in the first effect. At this stage, the least soluble and most troublesom of the constituents, calcium sulphate, is precipitated. Therefore, the discharge from the second-effect evaporator is led to a cone-bottomed settler or gypsum separator from the bottom of which calcium sulphate slurry can be withdrawn. The overflow is passed to a third and final effect.

The salt crystallises in the third effect, whence the slurry is pumped to a stirred slurry tank or thickener in which salt crystals settle to the bottom, and a solution of the more soluble impurities collects at the top of the thickener, from which it is withdrawn. The salt slurry is led to a centrifuge capable of reducing the moisture content to less than 3 per cent. The wet salt is then dried, cooled, screened and conveyed in part to a sacking machine and in part to a polythene packaging machine. Magnesium carbonate is added to the packaged salt to act as a free-flowing agent.

The Kuwait salt plant started production early in 1963 and now has a daily capacity of 20 tons. Over half this quantity is used for the production of chlorine, and the other half is saleable as table salt or as industrial salt. The product is of fine grain size.

Since the process is one of evaporation, distilled water is also produced at a rate of about 62,000 imperial gallons/day. This water is returned to the main product line of the nearby seawater distillation plants that supply the feed brine to the salt plant.

Portuguese experience in the modernization and mechanization of salt industries based on seawater

by M. Pereira da Rocha

One of the conditions for survival of small sea-salt producers in Portugal is co-operative effort. A group of about 300 small producers in the Aveiro area and a similar group in the Figueira da Foz area have formed associations. Later, with the formation of a co-operative movement in Portugal, these salt-producing groups were incorporated into agricultural guilds as separate salt sections.

These salt sections have advanced the principles of production, sales control, statistics and the like in sea-salt manufacturing. An important task being undertaken is the creation of infrastructures for marketing, product improvement, transportation (both land and water), salt-washing equipment and co-operative storage.

Although the small salt systems are operating quite efficiently, Portugal would like to see an integration of small plants into larger ones so as to permit greater productivity. One problem associated with small salt-works in Portugal is that some of them are located on small islands, crossed by channels, and affected by tides, which often necessitate costly engineering works and cause many technical difficulties.

Since there is available land in southern Portugal, this region would be well suited for a large industrial sea-salt operation that would be competitive with foreign sources for the export market.

A study of potential new facilities indicated that the following conditions be met:

(a) Sites with areas from 500 to 700 hectares. Two suitable places were found on the coast of Algarve.

(b) Each plant should produce about 50,000 tons of salt yearly and should incorporate plants for the extraction of magnesium and potassium salts for chemical industries.

To prepare the basic data for such a large complex, a pilot salt plant with an area of approximately 50 hectares will be built.

In Portugal the quality of salt is low because of its high content of magnesium, moisture and other impurities. In order to improve quality, Portugal will attempt to regulate salt prices on the basis of purity and quality. At present, the price of all salt is the same, regardless of quality.

An interesting salt-producing technique used in Portugal is dissolving rock-salt in seawater and then recrystallizing it to remove impurities.

Energy requirements of selected desalination processes and related costs in the United States

by Donat B. Brice

About 85 per cent of the salt produced in California is obtained by solar evaporation. The largest production is in the San Francisco area; the second area is near San Diego. The area ratio of concentrating ponds is about 15 to 1. The Western Salt Company has 567 hectares of concentrating ponds and 41 hectares of crystallizing ponds. For some months the salt-plant of this company has been receiving brine from the Clair Engle desalination plant. This brine, which is the effluent from the plant, has almost twice the salinity of normal seawater. Although it is too early to predict the results, the chief advantages is expected to be a reduction in evaporation time.

If a water desalination plant were to be integrated with a solar salt-plant, the area of concentrating ponds would be reduced roughly in proportion to the increase in salinity. For a brine of three times the salinity of seawater, the area of concentrating ponds would be reduced to one third the area needed with seawater.

Of great importance in combining desalination with solar salt production is balancing the outputs of desalted water and of salt. If it is assumed that a desalination plant has a fresh-water output of 4,000 m^3/day and discharges brine at a concentration of 7° Baumé, the volume of brine discharged will also be 4,000 m^3/day. If the *per capita* consumption of fresh water is 0.25 m^3/day and that of salt for edible purposes 3 kg/year, a population of 16,000 would consume all of the water but only 48,000 kg of salt yearly.

The 4,000 m^3 daily output of concentrated brine would contain 205,000 kg of salt. Since the solar salt process normally recovers 70 per cent of the salt in the brine, daily salt production would amount to about 144,000 kg. Clearly, there would have to be intensive industrial exploitation of the salt for the production of caustic soda, chlorine and the like if real advantage is to be taken of the concentrated brine from a desalination plant.

In connexion with a solar-salt industry, the economics and prospects of seawater desalination are of interest. The very conditions that make for a favourable location of a solar-salt plant, such as a high and consistent annual evaporation rate, low precipitation, and high insolation, also make for an arid, water-short area. For this reason the desalination of seawater at solar-salt plant locations can be expected in the future.

Every brine desalination process requires a considerable input of energy to separate the water from the salt. The vapour pressure of seawater at any given temperature is less than the pressure necessary to recondense the vapour into liquid. The paper presents a detailed analysis of the energy required to desalt water by various techniques.

Machinery, equipment and components utilized in the solar-salt industry in the United States

by Frank Osborne Wood

The various elements of the entire solar-evaporation process for the production of salt are considered, and the different types of machines suitable for them are described. A plant with an annual output of 500,000 tons of salt is used as an example.

Condensing and crystallizing ponds. American practice in the selection of a site for a solar salt-works is to make an initial survey, usually by drilling test holes, half a mile apart, over the proposed site to determine whether it contains sedimentary clay deposits within 10 ft of the surface. If such a deposit is found but shows breaks caused by ancient channels or the like, additional test holes must be drilled on quarter-mile centres to define the area of the break so that it can be avoided.

The area required for the concentrating and crystallizing ponds for a plant of this size will depend largely upon the net evaporation rate. While the ratio between the areas of the concentrating ponds will be affected by seepage, a ratio of 15 to 1 has been selected as typical. In the present example, 500 acres of crystallizing ponds would be required if a yield of 1,000 tons per acre is assumed. At the given ratio, the area of the concentrating ponds would be 7,500 acres, the total pond area being 8,000 acres.

The gates required for the ponds and canals can be constructed of wood or of wood and concrete. Winged concrete sluice-ways can also be used.

Pumps. Pumps will be required at each point where a pond or other body of water is not at a higher elevation than the pond that it is to feed. In American practice, turbine pumps are normally used. Cast-iron pumps with open cupro-nickel impellers are used in some plants. However, any parts that come into contact with the brine should be coated with bitumastic material wherever possible.

Salt harvesters. In a plant such as that used as an example here, producing 500,000 tons of salt yearly, and with harvesting being done during 7 months of the year for 45 hours per week, the harvesting rate would be 370 tons/hour. Harvesting equipment is available with a wide range of loading rates.

Transfer equipment. Narrow-gauge railways with diesel locomotives and bottom-dumping mine cars for transporting the salt from the harvesters to the plant are used in the United States. Motor trucks that can carry 35 tons while drawing 20-ton trailers are also used. The truck bodies are fabricated from aluminium.

Washing equipment. In the United States, the usual washing device is a dewatering drag conveyor, which is essentially an open rectangular box approximately 100 ft long and 6 ft wide, within which moves a stainless steel belt. Salt carried by the belt is sprayed first with concentrated brine and then with fresh water. The salt is then passed to a second belt and is discharged onto a storage pile.

Additional equipment. Other machinery used in salt production in the United States includes classifiers, centrifuges and screening and packaging equipment. While much of this equipment is standard in the United States, it can be modified for use with existing equipment, or other devices of radically new design can be made available.

Venezuelan experience in the modernization and mechanization of salt industries based on seawater

by Carlos Olmos Pérez

All of the salt produced in Venezuela is obtained from seawater. The existing installations for sea-salt production are located in the Araya Peninsula. This area is a complete industrial centre for marine salt exploitation. It is adapted to the shape of the available land and is located so that temperature and prevailing wind offer maximum guarantees for good production. The bulk transportation of the salt from the site of production to storage, grinding, washing and packaging is done with narrow-gauge railroads with mechanized facilities for loading and unloading the wagons. The processing area has the necessary equipment for the washing, milling, drying, classifying and packaging of fine salt with additives. A special plant for the preparation of salt with mineral additives for veterinary use is also equipped with the necessary washing, milling, drying and classifying units as well as with equipment to manufacture compressed salt blocks.

The facility also includes a bulk storage silo with a capacity of 10,000 tons of salt. Another silo can accommodate 6,000 tons in boxes or bags. There is also a long pier that permits ships up to 10 metres in draught to be loaded mechanically. The equipment allows simultaneous loading of two ships.

The facility contains a complete mechanical shop, electrical and woodworking shops, machine tools and facilities and equipment to maintain the entire installation at the salt complex. An emergency, 240-kVA auxiliary electrical generating plant is available for emergency use. The salt lake at Araya is a natural pond. One of the shorter sides of which is formed by a sand-bar where the seawater inlet is located. The two longer sides are hills between 100 and 200 metres high. The salt water from the pond is pumped to the condensing ponds. After crystallization, a salt cake, approximately 15 to 18 cm thick is formed. The main equipment for harvesting salt is a machine, moved by a tractor, that has a toothed shovel of adjustable height. This shovel extracts the salt cake from the pond bottom. The salt is then put on a steel pan conveyor, which carries it to a belt conveyor, which in turn feeds it into a hopper for loading boats. This mechanized harvesting system gathers approximately 150 tons of salt per hour.

The transportation of the salt to the washing plant is by means of small wooden boats hauled by a flat-bottomed tug-boat. Each tug-boat hauls about ten boats holding approximately three tons each. Upon arrival at the processing plant the boats are placed by hand on a steel frame, overturned, and the salt is poured into a concrete hopper. Once the boats are unloaded they are pushed by hand to the end of a canal where the tug is waiting to tow them back to the harvesting area.

The salt is first washed with concentrated brine and then with a counter-current flow of clean brine and transported by belt conveyor to the drying and storage area. The washing equipment has a production rate of 150 tons/hour.

The annual production of bulk salt in Venezuela is approximately 90,000 tons.

SUMMARIES OF GOVERNMENT PAPERS

Algeria

The principal sources of salt in Algeria are deposits of rock-salt in the so-called rochers and in salt lakes. A minor amount is also available from salty rivers and from the sea. Of the deposits of rock-salt, the two most important are de Djelfa and d'El Ontaia. Thus far, the exploitation of these deposits has been rather primitive.

Salt is principally obtained from the salt lakes situated throughout Algeria. These evaporate naturally and leave large deposits of salt, which are harvested. Production from these sources in 1966 was about 120,000 tons.

Domestic consumption of salt was only about 71,000 tons in that year, the remainder being exported. In general, there does not seem to be much need for solar-salt plants using seawater; the salt lakes provide ample sources which are more easily worked. Moreover, the salt lakes are very conveniently situated to the seaports for transport purposes.

Argentina

Argentina produces no significant amounts of sea-salt, since most of its salt comes from brine wells. Attempts have been made to establish solar salt-works near Mar Chiquita, in Mar de la Plata and in Patagonia, but none were successful, first because of the irregular rainfall and secondly because these operations were combined with a petrochemical industry that failed to establish itself.

Brine is pumped from wells and is either put into ponds for solar evaporation or processed in controlled or forced evaporation systems. The ranges of purity of the salt produced by these three processes are, respectively, 91 to 98.5 per cent, 92 to 98.5 per cent and 99 to 99.5 per cent. Before treatment, the brine is sometimes treated chemically to remove iron, calcium and sulphates.

These plants are of two types. Most numerous are small-scale plants in which all workings and extractions are performed by hand. In plants of the other type, the work is mechanized by tractors, graders, rotary cutters, scrapers, mechanical shovels and the like.

Large salt-plants use single- or double-bladed graders drawn by diesel tractors with caterpillar tracks or rubber tires. The salt is scraped to the sides of the ponds and is loaded by mechanical shovels into trucks that run on tracks laid during the harvesting period. Trains of these trucks, drawn by a small locomotive, take the salt to the storage area. From 10,000 to 60,000 tons of salt are collected in heaps and are left to dry in the open for periods varying from 10 months to a full year.

Salt intended for human consumption is crushed into various grain sizes, washed, centrifuged, dried, screened etc. and packed in 50-kg sacks or, when intended for household use, into 1-kg or 0.5-kg paper or plastic packets. Two firms prepare salt-licks for the cattle-raising industry. These blocks, which may or may not contain other minerals, are compacted by a 600-ton hydraulic press. Salt intended for industrial purposes, such as for the chemical industry, meat-packing, fish-preservation, food processing and hide preservation is shipped in 50-kg sacks.

Salt is produced in nine main regions, the most important of which are the Provinces of La Pampa, Buenos Aires, Cordoba and San Luis. La Pampa has been the chief producer of common salt, its yearly output exceeding 150,000 tons.

Like other mining enterprises, salt producers receive preferential treatment as regards the importation of equipment, machinery and spare parts that are not produced domestically, provided that such equipment is intended for direct and exclusive use in extracting the resources of the subsoil. A 10 per cent exemption from import duties is now being granted.

In 1966, 853,000 tons of salt were produced, of which 500,000 tons were consumed domestically. Of this amount, 18 per cent was used for human consumption and the rest for industrial purposes.

Brazil

The Salt Executive Committee is responsible for economic policy regarding salt and is under the jurisdiction of the Ministry of Industry and Commerce, the Minister being its president. The Executive Committee has been in existence for nearly 30 years. Its objectives are the planning of the best possible exploitation of potential salt-production capacity and support of projects for its future development.

Production is centred in five regions: Ararnama, Areia Branca, Fortaleza, Macau and Tutoia. The present output is about 1 million tons yearly, of which 26 per cent is for human consumption, 29 per cent for animal feeding, and 35 per cent for industrial purposes, the remainder being exported.

In projecting future demand for salt, Brazil assumes that this demand is a function of a number of variables, mainly the increases in industrial production and in population. There is also an important relation between the purchasing power of individual consumers and industrial production. Accordingly, estimated demand is based on the rate of growth of industrial production volume as related to that of population increase. The report includes a comprehensive economic survey of this matter.

The core of the report is concerned with the possibilities of increasing salt production in Brazil to 8 to 9 million tons yearly. The prospects for this plan are excellent, provided that modern and mechanized techniques can be used. One important consideration is that the Salt Executive Committee must be given the necessary directives to carry out a technical and economic programme. For example, it will be necessary to establish meteorological stations with adequate staff and instrumental equipment. The development of pilot salt-plants to evaluate economies of scale is suggested.

Bulgaria

Production. Salt is produced in Bulgaria by solar evaporation of seawater. The system used, a series of concentrating and crystallizing ponds, with close control of brine density, is orthodox. There is one crystallizing season: June through August. The actual harvesting of the salt is done by relatively primitive means. Facilities exist for washing the salt. Thanks to improved organization and salt-production methods, the annual output of sea-salt has risen from around 20,000 tons in 1947 to 60,000 tons in recent years.

Part of the sea-salt is delivered in the form of crystals for the milk-processing industry, and the remainder is ground for domestic and industrial use.

The salt-harvesting systems used are considered obsolete, since the salt is processed by machines and other equipment of low productivity, and the level of development of the production and handling operations is low.

In addition, a large part of the bittern that remains after the common salt has been extracted from it and which is rich in other salts is discharged into the sea. The production of magnesium chloride is quite small and is done with obsolete technical processes and equipment.

A number of proposals have accordingly been prepared to improve matters. One envisages complete production of salt by solar methods but with improved and modernized equipment. Another begins with solar evaporation, but the process is completed by concentration in a multi-effect evaporator. A third proposal is the production of table salt by means of an evaporative system operating on the thermo-compression principle. Various combinations of these proposals are being considered with a view to bringing yearly salt production to 100,000 tons.

Chile

Chile does not have a sea-salt industry; its salt is obtained from mines. In one great salt-field of the Province of Tarapaca alone there are 24,000 million tons of sodium chloride of 99.66 per cent purity. The salt deposits are worked mechanically.

During 1967 production reached 443,000 tons, 97 per cent of which came from the working of natural deposits and the remainder from artificial brine salt fields. In 1968 production reached 1,150,000 tons.

During 1967 exports reached 290,000 tons, all of which went to Japan and the United States in equal shares. In 1968 1 million tons were shipped, and double this figure is planned for 1969.

China

Taiwan produces from 400,000 to 500,000 tons of solar salt per year. Its sodium chloride content is set above 90 per cent for the first grade and 85 per cent for the second grade. One quarter of the salt produced was consumed domestically and the balance exported. At present, because of increased domestic demand, salt is no longer exported.

In Taiwan, because of climatic conditions, there are three salt-producing periods: the brisk season (June through September), the rainy season (March through May) and the common season (October through February). The production of salt during these three periods is, respectively, 45 per cent, 11 per cent and 44 per cent of the total.

Taiwan requires additional solar-salt production and has need of assistance in salt-storage techniques, the preparation and maintenance of concentrating ponds, seawater pumping equipment and in the mechanisation of harvesting and stockpiling. Furthermore, to meet increasing demand, Taiwan requires assistance in the development of new salt-fields.

Cuba

Production. Salt is produced in Cuba almost entirely by solar evaporation of seawater. Two main areas are in operation, one in the west of the country in the Province of Matanzas (Bidos) and the other in the east in Oriente Province (Caimanera). Because of the climate, production in the east is triple that of the west. Since the western area is in greater proximity to the markets and freight rates are lower, competition among the individual producers is keen.

The system of production is well standardized. Salt water is introduced into the concentrating ponds and moves in six stages from Baumé values of 3.5°, 5°, 10°, 15°, 20° and 25°. It is then introduced to a seventh stage, the crystallizing pond, where the salt crystallizes out at from 25.5° to 28° Baumé. This system is designed to ensure the gradual precipitation of undesirable salts until a brine concentration of 25.5° Baumé is reached, with subsequent extraction of the purest possible sodium chloride.

To assist in production Cuba utilizes simple meteorological equipment, such as rain gauges, evaporimeters and thermometers in all salt plants. The larger installations also have equipment such as barographs and hydrometers.

Cuba produces seven types of salt ranging from common salt "extra-course" with specified grain size, used as a feed mix and having a minimum sodium chloride content of 93 per cent to a common salt "extra-fine" with a minimum sodium chloride content of 99.9 per cent.

The enterprise operating the fourteen salt-production units in Cuba is the Empresa Consolida de La Mineria, which produces approximately 150,000 tons of granular salt yearly. There are seven salt-processing plants and one small brine plant that uses the thermo-compression system of evaporation and that has a capacity of 0.9 tons/hour. The processing plants are equipped for washing, drying, crushing, screening and grading.

The processing of salt from the crystallizing bed, that is, excavation, piling and conveyance to storage points, is done manually. A few salt plants have facilities for mechanized haulage and piling where transport is provided by narrow-gauge locomotives and pneumatic-tired tractors, while belt conveyors and cranes are used for piling.

Cuba has two new quality-control laboratories and has set technical standards for quality as well as taking measures to improve quality without additional investment. These measures have helped to realize a 10 per cent increase in production per unit area and in quality.

Cuba is well situated for salt production because of its favourable climate resulting from high annual evaporation rate, with long dry spells, low rainfall and a pattern of almost constant favourable winds throughout the year, in addition to such topographical characteristics as a long, irregular coastline and firm ground capable of bearing heavy loads.

Future plans. Cuba needs assistance in the modernization and mechanization of the salt-extraction processes and in the utilization of bittern to obtain by-products such as magnesium salts, bromine and potassium chloride. Assistance is also needed in the areas of utilization of wind energy, process automation and the design of new salt plants.

Haiti

There is no rationally operated enterprise in Haiti for the production of salt from seawater. The salt presently produced in this way is of poor quality and contains, on the average, 20 per cent of impurities. Its low quality renders it generally unfit for industrial use or for human consumption. At present salt is produced in about 1,400 basins, called "salt holes", by about 500 producers working in family units. After the various production operations, such as concentrating the brine, the salt produced is put in piles and hauled to markets. Annual production from these family enterprises is estimated at about 40,000 tons/year. The selling price varies from US$4 to US$7 per ton in the salt fields.

Malta

Solar-salt production in Malta is primitive; the largest salt-works there produces only 1,500 to 2,000 tons yearly. The large salt-works normally introduces seawater into concentrating ponds, and the crystallized salt is harvested manually. The minor salt plants, which are normally hewn from rock, are usually operated by one or two persons who actually hand-carry the brine and harvest the salt by hand. Because of the intense heat in the summer, salt is harvested at night.

Malta has natural facilities for good solar-salt production. However, assistance is needed to conduct feasibility studies on the location of such plants, the techniques to be used in building ponds and the like, and a study of the type of mechanization to be considered.

A problem not uncommon to small islands with tourist attractions is the fact that real estate is costly near the coastlines, and salt-production facilities must thus compete for land at abnormally high prices. This makes salt production an activity of marginal profit.

Malta has a desalination plant that produces 1 million imperial gallons of fresh water daily and the effluent from this plant, 1 million gallons of hot brine of twice the salinity of the original seawater, is discharged into the sea. Part of this concentrated brine might be used to produce salt if economic considerations justified it. This possibility should be investigated.

Nicaragua

Production. Salt production in Nicaragua is designed almost entirely to meet the domestic consumption. In 1960 the industry produced 18,924 tons of salt of 95 per cent purity. Salt-manufacturing methods are primitive and traditional and result in a low output of a poor-quality high-cost product. The cost per ton is US$50 at the distributor and US$77 at the retail level.

Consumption. Although the total salt consumption of Nicaragua may be the third largest in Central America, its *per capita* consumption is the highest in this region: 11.67 kg. This is attributable to the high meat diet of the population. Salt was not used on a large scale industrially until a soda and chlorine plant went into operation at the end of 1967. The demand for salt (20,000 to 25,000 tons/yearly) for this purpose is supplied at present by imports from Mexico, since there are no salt plants in Nicaragua or elsewhere in Central America that can produce salt in the quantities and of the quality required for the soda-chlorine plant.

Plants. Nicaragua has 51 salt plants in operation of which 46 utilise solar evaporation and five employ the boiling method. Most of these plants are situated in the Pacific Coast area in the Departments of Léon and Managua, with only a small number in the rest of the country. These plants provide employment for more than 500 persons.

Future plans. Nicaragua is now pursuing a project to design and install a solar-salt plant to produce from 20,000 to 25,000 tons of granular salt per year exclusively for the production of soda and chlorine. There are opportunities for larger-scale operations with a view to remedying current shortages of high-quality salt in Central America under the terms of the agreement on the economic integration of this region.

It is considered that mechanisation of salt production would be economically advisable in Nicaragua at yearly production levels of 35,000 tons or more.

Peru

The salt presently produced in Peru is of poor quality, meeting neither the standards of refined salt for human consumption nor those for the various types of salt used by the chemical industry. This industrial demand has increased so rapidly that its proportion of total salt consumption has risen from 10 per cent to 38 per cent. As matters stand, future salt production will probably be insufficient to meet this demand.

Of the salt consumed in Peru, 90 per cent is produced from seaside salt-fields and some "brine springs". Peru also has rock-salt deposits, situated chiefly in forest and mountain areas. Owing to their remoteness from large population centres, the lack of adequate means of communications and transport, and the steadily rising cost of extraction, rock-salt mines are not economical to work at present.

The outlook for the expansion of the salt industry on the Peruvian coast is a different matter, however. The existence of large deposits in natural conditions that favour salt extraction by the solar process, the proximity of large urban centres, and the existence of transport and communications networks which ensure low freight rates, together with governmental planning to improve port facilities, indicate that this sector will be able to provide reliable sources of salt when modern facilities are installed. This would provide Peru with salt, not only to meet its domestic requirements, but also for export.

The Peruvian salt industry is administered by a state monopoly. The Government controls prices, purchases all salt produced and is responsible for its marketing. Nevertheless, realizing the need to promote industrial development, being aware of the growing demand for chemical products and derivatives based on salt and anxious to promote the growth of the industry in general, in 1952 the Peruvian Government enacted Law 12712, authorizing industrialists to obtain concessions for salt deposits when the salt is to be used in basic industries considered to be of national importance. Two concessions are being worked so far, one by Alcalis Peruanos S.A. and the other by Quimica del Pacifica S.A. in connexion with the manufacture of caustic soda. About 40,000 tons of salt are produced annually by these firms for their own use.

The four following types of salt are sold: granular (solar), crushed (granular), improved (iodized) and refined (table salt). Salt consumption has risen from 87,806 tons in 1957 to 108,708 tons in 1966. The projected domestic salt demand for 1972 is as follows:

Dietary salt	124,800 tons
Industrial salt (monopoly)	40,200 tons
Industrial salt (concessions)	58,000 tons
Total	223,000 tons

However, projects now under consideration for the flotation processing of minerals and the production of sodium carbonate will increase the 1972 demand by 180,000 tons, for a total projected demand of 403,000 tons for that year. There is thus a clear necessity to expand the salt production of Peru rapidly.

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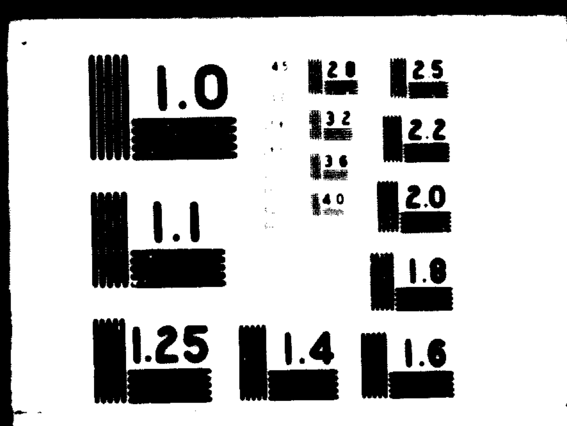

Sudan

Production. The Sudan has seven or eight salt-works, the principal one being near Port Sudan. This installation has a yearly output of about 60,000 tons. The works are laid out in orthodox fashion with concentrating and crystallizing ponds. There are three salt crops each year. Some gypsum is produced. There is no mechanization, and quality control of the salt is limited.

There is a smaller installation at the prison at Suakin. Two companies near Port Sudan have concessions for salt production, and plans for construction have been drawn up. There are also two natural salt lagoons that are no longer exploited. Applications have been received for concessions to work them again.

Consumption. The average annual *per capita* human consumption of salt is 7 kg, giving a total consumption of 84,000 tons for this purpose. Salt for animal feed may raise the total to 100,000 tons. Very little salt is exported.

Turkey

Production. Solar salt production is performed by traditional primitive methods. Water is brought from the sea to the pumping station through a canal and pumped to the concentrating ponds. The brine is stirred by wooden water-wheels to increase the evaporation rate. When the brine concentration reaches 25° to 27° Baumé, it is transferred to the cyrstallizing ponds, again with the use of wooden water-wheels. When the crystallization process is completed, the salt is levelled, first with motor rollers and then with stone rollers. The motor rollers are guided by operators who walk beside them.

Salt-scraping machines were formerly provided for the mechanization of the salt-collecting process, but this equipment was found to be unsuitable because the poor weight-carrying characteristics of the salt-beds did not permit efficient operation. The beds were damaged, and considerable amounts of salt were lost.

Salt is now mechanically loaded from piles stacked by hand labour, but the loading machines are not considered efficient. Wood is the basic construction material. For example, pond gates are wooden and are filled with a clay slurry.

Ship loading is performed automatically by an electrically driven conveyor belt, and in this system the salt is also automatically weighed.

The power requirements of the plant are supplied by motor-generator sets. These sets and the locomotives now use diesel fuel.

Consumption. Salt in Turkey is utilized in the canning, petrochemical, textile and leather, and chlorine industries.

Future plans. Future plans include the mechanization of salt-collecting procedures by utilizing techniques and equipment now being used by some Mediterranean salt-works, by increasing the rolling areas of motor rollers, and by replacing the present diesel-fueled power systems by electrical power to be obtained by extending high-voltage lines to the salt fields.

Union of Soviet Socialist Republics

Solar salt is produced in the USSR from the waters of the Black Sea and the Sea of Azov. The water is evaporated in concentrating and crystallizing ponds, and harvesting equipment having a capacity of up to 90 tons of salt per harvesting hour is utilized. This equipment removes the salt from the crystallizing beds, crushes the salt and loads it onto conveyors that bring it to stockpiles that hold from 1,000 to 5,000 tons. After storage for about six months the salt is cleaned, ground and packaged. Present solar-salt production is estimated at 65 kg per square metre of surface. New techniques suggest that this figure can be raised to 300 kg/m^2. The cost of production at present is estimated at 1.7 to 2.8 rubles per ton. Research into improvements of the process is continuing.

Uruguay

Attempts have been made to establish a solar sea-salt industry in Uruguay, but this project was abandoned completely in about ten years. At present, the demand for salt is met by production from salt-mines.

A solar salt-works was installed near the spa of La Coronilla and the swamps of San Miguel, in the Department of Rocha, which is in the south-east part of the country, near the Brazilian frontier.

In this operation, seawater was pumped into salt fields with an area of about 4,000 hectares, about 1,500 hectares of which were divided into sections through which the brine circulated, its concentration gradually increasing as it evaporated. The primary external factors involved in this process were, of course, insolation and rainfall. At each stage of concentration, the appropriate mineral element settled out, the final element being the bittern, which was rich in sulphates of magnesium and other valuable compounds. Although the basic product was sea-salt, which was originally produced in amounts from 2,000 to 5,000 tons yearly, finally reaching 20,000 tons yearly, the possibility of obtaining by-products such as gypsum, for which there was a ready market, was considered.

The complete installation was constructed, including pumping facilities, crystallizing ponds, dikes, perimeters, divisions, piping and electrical power plants. The first concession for this industry was granted in February 1942, the time-limit for the establishment of the enterprise being extended to March 1947 - without success. A second concession was granted in June 1948, with the possibility of establishment by January 1951 - again without success. Further efforts led to the granting of a third concession in 1954, and a plant was established in 1957. However, this plant never achieved industrial production and was completely abandoned as a salt producer several years later.

It is the opinion of a hydraulic engineer that one of the principal problems was insufficient pumping capacity resulting from the repeated occurrence of faults, caused by tidal action, in the water-intake structure.

Summary of paper submitted by the United Nations Economic Commission for Africa

Production and consumption of salt in Africa

Production. Salt production in Africa in 1965 amounted to approximately 1,048,000 tons in North Africa, 9,000 tons in West Africa, virtually none in Central Africa and 296,000 tons in East Africa. Production is almost entirely by solar evaporation, and there was little mechanization. Detailed figures for individual countries, together with a forecast of future production, are given in the attached table.

Consumption. Consumption at present is almost entirely for dietary purposes, and the average annual *per capita* consumption for each of the subregions is below the 4.5 to 6.8 kg level considered necessary for adequate nutrition. There is therefore a strong potential demand even if no great use is made of salt in the chemical industries. Nevertheless, Africa is a net exporter of salt, principally from North Africa.

Future plans. The expected increases in output and consumption are also shown in the attached table. Considering the subregions industrially, it may be said, first, that there is a need to establish salt production in Central Africa. With the coming into operation of the Congo (Brazzaville) potash installation, it is possible that this subregion will become more than self-sufficient, provided that all Member States of the region avail themselves of the opportunity to satisfy their needs from this source.

In much of West Africa conditions are unsatisfactory for solar-salt production because of the moist climate and the low salt concentration of the sea, owing to dilution by large rivers. However, in certain countries such as Ghana, Guinea, Senegal and Togo there are possibilities for salt production. Improvements could be made, not only in the mechanization of the salt-works but also in transport and port facilities. In Nigeria there is a possibility of expanding salt production by the use of vacuum evaporation. In East Africa, although salt production must be increased if exports to Japan are to be maintained and expanded, there are few regions in which conditions are very favourable for the installation of new solar-salt plants. This is particularly true of Ethiopia. Here, too, transport and port facilities are important.

Generally speaking, North Africa, which is already the greatest producer of salt, has by far the most favourable operating conditions. The most important salt-producing countries are Algeria, Tunisia and the United Arab Republic. Expansion in North Africa is expected to be less difficult than in the other subregions. The Red Sea area, from the point of view of salinity of the water, climate and general topography, is particularly suited to solar-salt production and deserves special investigation with a view to expanding its solar-salt facilities.

Table

Forecast of production and consumption of salt in the four subregions of Africa

	Production (1000 tons)				Consumption (1000 tons)				Net exports or imports (-) (1000 tons)			
	1965	1970	1975	1980	1965	1970	1975	1980	1965	1970	1975	1980
NORTH AFRICA	1,048	1,430	1,942	2,519	488	653	835	1,062	560	777	1,107	1,457
Algeria	135	180	240	320	75	103	137	183	60	77	103	137
Libya	6	8	11	16	-	8	11	16	6	-	-	-
Morocco	38	52	71	98	34	52	71	98	4	-	-	-
Sudan	60	90	110	135	60	73	89	108	-	17	21	27
Tunisia	315	400	510	650	32	84	107	137	283	316	403	513
United Arab Republic	494	700	1,080	1,300	287	333	420	520	207	367	580	780
WEST AFRICA	90	415	675	900	324	448	669	916	-234	-33	6	-16
Ghana	31	100	150	200	35	48	66	91	-4	52	84	109
Guinea	3	15	25	50	16	21	76	85	-13	-6	-51	-35
Nigeria	-	200	300	400	145	213	312	459	-145	-13	-12	-59
Senegal	56	100	150	150	35	42	51	62	21	58	99	88
Togo	-	-	50	100	11	15	19	24	-11	-15	31	76
CENTRAL AFRICA	-	-	-	-	59	82	111	146	-59	-82	-111	-146
EAST AFRICA	296	360	496	582	262	361	502	670	34	-1	-6	-88
Ethiopia	236	250	350	400	81	95	140	175	129	155	210	225
Kenya	31	40	60	80	37	52	77	103	-6	-12	-17	-23
Madagascar	15	50	60	70	15	25	31	54	-	25	29	16
Mauritius	4	5	6	7	4	5	6	7	-	-	-	-
United Republic of Tanzania	10	15	20	25	26	49	64	85	-16	-34	-44	-60
SUBREGIONS (Total)	1,434	2,205	3,113	4,001	1,093	1,544	2,117	2,794	341	661	996	1,207
SUBREGIONS (Total) (on the basis of a 5 kg *per capita* requirement for dietary purposes)					1,360	1,550	1,770	2,020				

ANNEX I

AGENDA

Welcome and introduction by
W. A. Caldwell - General Chairman

Introductory Statement of UNIDO secretariat
P. M. Terlizzi - Meeting Co-ordinator

First meeting

Venezuelan experience in the modernization and mechanization of salt industries based on seawater - Carlos Olmos Pérez

Discussion and summary of Venezuelan paper
Moderator - Mahmud Ahmed Mardi (Kuwait)

Italian experience in the mechanization and modernisation of salt industries based on seawater - Silvio Galimberti

Discussion and summary of Italian paper
Moderator - P. K. Seshan (India)

Second meeting

Kuwaiti experience in the modernization and mechanisation of salt industries based on seawater - Mahmud Ahmed Mardi

Discussion and summary of Kuwaiti paper
Moderator - Giuseppe Gualdi (Italy)

Portuguese experience in the modernization and mechanization of salt industries based on seawater - M. Pereira da Rocha

Discussion and summary of Portuguese paper
Moderator - Donat B. Brice (USA)

Third meeting

French experience in the modernisation and mechanisation of salt industries based on seawater - Philippe R. de Flers

Discussion and summary of French paper
Moderator - Koichiro Suwa (Japan)

Indian experience in the modernization and mechanization of salt industries based on seawater - P. K. Seshan

Discussion and summary of Indian paper
Moderator - Carlos Olmos Pérez (Venezuela)

Fourth meeting

Energy requirements of selected desalination processes and related costs in the United States - Donat B. Brice

Discussion and summary of United States paper
Moderator - M. Pereira da Rocha (Portugal)

Systems used in Japan for the production of salt from seawater - Koichiro Suwa

Discussion and summary of Japanese paper
Moderator - Philippe R. de Flers (France)

Fifth meeting

Machinery, equipment and components utilized in the solar-salt industry in the United States - Frank Osborne Wood

Discussion and summary of the United States paper
Moderator - Paul M. Terlizzi

The possibilities of initiating sea-salt production in areas in the early stages of industrial development - Giuseppe Gualdi

Sixth meeting

Formulation of specific technological recommendations for specific UNIDO action to be taken by developing countries in order to implement the results obtained during the Meeting of the Expert Working Group for the modernisation and mechanization of various sectors of the solar-salt industries.

Visit to the Italian Government's largest sea-salt plant, La Salina di Margherita di Savoia, Barletta.

Viewing of complete solar sea-salt process from pumping of seawater to packaging of the salt.

ANNEX II

LIST OF PARTICIPANTS

BRICE, Donat B.	Staff Chemical Engineer Department of Water Resources State of California P. O. Box 388 Sacramento, California United States of America
DE FLERS, Philippe R.	Cie Salins d'Anjou 51 rue Leconte de Lisle Paris 16e France
GALIMBERTI, Silvio	Salt Industry Consultant Casale Postale 268 Cagliari, Sardinia Italy
GUALDI, Giuseppe	Central Director of the Salt Services Amministrazione dei Monopoli di Stato Piazza Mastai, Rome Italy
MARDI, Mahmud Ahmed	Plants Director Ministry of Electricity and Salt P. O. Boxes 12 and 54, Kuwait Kuwait
OLMOS PÉREZ, Carlos	Technical Assessor Administration of the Salt Industry Edificio Norte, Centro Simón Bolivar Sebucán, Caracas Venezuela
ROCHA, M. Pereira da	Salt Technologist Regulatory Commission for the Production of Chemicals and Pharmaceuticals C. Carmo 43, Lisbon Portugal
SHESHAN, P. K.	Industrial Adviser Directorate General of Technical Development Ministry of Industrial Development and Company Affairs, Government of India, New Delhi India
SUWA, Koichiro	Director of the Technical Research Department The Japan Monopoly Corporation 2 Akasaka-Aoicho, Minato-ku, Tokyo No. 623-3 Kase, Kamakura City, Kanagawa Japan

WOOD, Frank Osborne	Technical Director Salt Institute, United States Trade Association 206 North Washington St. Alexandria, Virginia - 22314 United States of America

Observers

CARL, H. Egon	Escher Wyss GmbH 798 Ravensburg Germany (Federal Republic of)
LEUNER, Walter	6453 Seligenstadt Südring 64 Germany (Federal Republic of)
RICHTER-BERNBURG, G.	Vice-President of Geological Survey Bundesanstalt für Bodenforschung Hannover-Buchholz Germany (Federal Republic of)
OKAR, Cahit	Turkish Salt Works Calmati Turkey
SULTAN, Sevket	Turkish Salt Works Calmati Turkey

UNIDO staff members

Mr. W. A. CALDWELL, Chief, Basic Chemicals, Pharmaceuticals and Building Materials Section, served as General Chairman of the Meeting.

Mr. Paul M. TERLIZZI, Industrial Development Officer, Basic Chemicals, Pharmaceuticals and Building Materials Section, served as Meeting Co-ordinator.

ANNEX III

LIST OF PAPERS PREPARED FOR THE MEETING

Expert papers

1.	Philippe R. de Flers	French experience in the modernization and mechanization of salt industries based on seawater
2.	P. K. Sheshan	Indian experience in the modernization and mechanization of salt industries based on seawater
3.	Silvio Galimberti	Italian experience in the modernization and mechanization of salt industries based on seawater
4.	Giuseppe Gualdi	The possibilities of initiating sea-salt production in areas in early stages of industrial development
5.	Koichiro Suwa	Systems used in Japan for the production of salt from seawater
6.	Mahmud A. Mardi	Kuwaiti experience in the modernization and mechanization of salt industries based on seawater
7.	M. Pereira da Rocha	Portuguese experience in the modernisation and mechanization of salt industries based on seawater
8.	Donat B. Brice	Energy requirements of selected desalination processes and related costs in the United States of America
9.	Frank Osborne Wood	Machinery, equipment and components utilised in the solar-salt industry in the United States of America
10.	Carlos Olmos Pérez	Venezuelan experience in the modernization and mechanization of salt industries based on seawater

Government papers

1. Algeria
2. Argentina
3. Brazil
4. Bulgaria
5. Chile
6. China
7. Cuba
8. Haiti
9. Malta

10. Nicaragua
11. Peru
12. Sudan
13. Turkey
14. Union of Soviet Socialist Republics
15. Uruguay

Regional paper

Production and consumption of salt in Africa by the United Nations Economic Commission for Africa

ANNEX IV

NOTE ON THE VISIT TO THE SEA-SALT PLANT LA SALINA DI MARGHERITA DI SAVOIA

Barletta, Italy, 28 - 29 September 1968

As part of the Expert Working Group Meeting, the Italian Government arranged for the participants to visit its largest and most modern sea-salt plant. Upon arrival, Giuseppe Gualdi, Central Director of the Salt Services of the Amministrazione dei Monopoli di Stato, introduced the members to the technical staff of the salt-plant and outlined, with the aid of a chart, the facilities to be seen and the arrangement of the ponds, collection centres and processing facilities.

The tour began with a visit to the pumping station, several miles from the main plant. The pumps, at the end of a concrete pier, have a capacity of 20,000 US gallons per minute. The seawater is admitted through a large pipe located about 30 feet from the pier's end and approximately 25 feet under water, screened to filter out large marine life. The depth was selected on the basis of studies of wave action, sand accumulation and the like. It is desirable to obtain the cleanest seawater possible.

From the pumping station, which operates 24 hours daily, water is carried under the pier in a concrete channel to the concentrating ponds. The salt-plant has a raw-water reservoir large enough to provide the water supply for a complete salt harvest, should unusual conditions halt the intake of fresh seawater.

As the water floods into the concentrating ponds, their levels are controlled automatically by gates and auxiliary pumping between ponds. When its density reaches a set figure, the brine is drained off to ponds farther downstream until the density of the concentrated brine reaches a point at which it is ready for the crystallising ponds, the last step before the removal of salt. During the concentrating steps, liquid levels are often varied, depending upon environmental conditions, removal of impurities and the like.

In the crystallising ponds, when the density has reached a predetermined level and salt has begun to crystallize, the mother liquor (bittern) which contains salts other than sodium chloride, is drained off and, as solar energy evaporates the water, a hard salt floor about 6 inches thick is formed.

After complete draining of the bittern, a mechanical harvester is used to gather the salt.

Since this sea-salt factory was built by utilizing an old lake-bed, the soil representing the bed consists partially of soft slime. Consequently, heavy machines that exert a high pressure on the ground cannot be used because of its poor bearing capacity. Equipment had to be designed that is sufficiently large and powerful to provide efficient harvesting and yet exert a ground pressure less than 200 - 300 g/cm^2. Based on the experience gained in this installation, salt-harvesting equipment has been standardized and introduced to other salt-works in the monopoly.

These machines were closely inspected and viewed in operation by the expert group. Basically, they consist of a segmented steel-pipe roller that occupies the width of the crystallising pond. This roller is moved lengthwise down the pond and acts as a roller and guide for a cutter-scraper arrangement that rides above it on a track. An operator follows the path of the roller, adjusting the scraper blades so that the maximum amount of salt is scraped up without damage to the bed. This scraped-up salt is automatically put on a conveyor belt and moves down the roller to the pond edge, where it automatically falls into car hoppers. These hoppers move on a track, and the salt is carried to an assembly point whence it is again carried by conveyors to a storage point where it is piled to a height of over 200 feet.

Upon demand, large drag-lines top off the salt piles with rotary scoops and the salt again moves down conveyors to a salt-washing cycle. From this point the salt moves to drying furnaces, treatment with anti-caking additives, classification for sise, packaging and shipment.

Bulk shipment to sea transport is handled by a seven-mile overhead ropeway along which buckets travel that hold more than a ton of salt. These buckets ride the ropeway across the brine ponds and open water to a pier-end where the salt is automatically loaded into ships' holds.

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