STATES OF GUERNSEY
WATER BOARD

Official Opening

of the

Sea Water Distillation Plant

by

THE RIGHT HONOURABLE R. A. BUTLER, C.H., M.P.,
Her Majesty's Secretary of State for the Home Department.

SATURDAY, the 22nd of OCTOBER, 1960.

STATES WATER BOARD

1960

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WALTER H. MORGAN, B.Sc., A.M.I.C.E., A.M.I.W.E.

Foreword

by

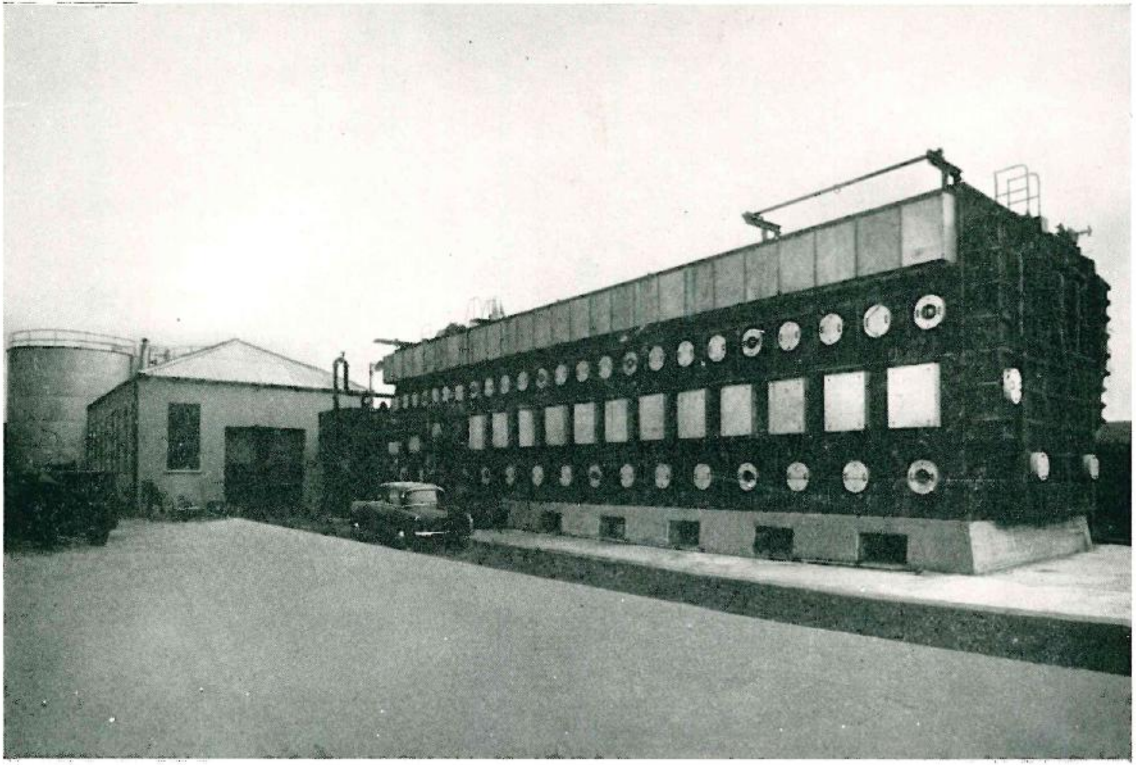
The President of the States Water Board

The primary object of the distribution of this brochure, both to those of our guests who will be with us on the afternoon of October 22nd and also to those who have been prevented from joining us, is that there shall be a real understanding of the part which the Sea Water Distillation Plant is designed to play in our Island life.

The whole project is radical in its conception and as such, the fullest knowledge is imperative.

Recently our Engineer and Manager, Mr. W. H. Morgan, B.Sc., A.M.I.C.E., A.M.I.W.E., presented a paper to the Annual Conference of the British Waterworks Association in Edinburgh, and this we have reproduced in full, in the knowledge that it will receive your study and that thereby a complete understanding will be achieved.

ALAN M. MACKAY.



General view of Sea Water Distillation Plant.

SEA WATER DISTILLATION IN GUERNSEY

Only in arid lands is fresh water valued as a necessity, the one vital element without which life is impossible and for which there is no substitute. In temperate lands, with abundant rainfall, water is used freely and without thought by the great majority of people.

Until recent years this lavish use and sometimes waste of water has been encouraged by the very low cost of production. Unfortunately the provision of a water supply becomes progressively more expensive as the demand increases, the cheaper sources having been used to capacity it becomes necessary to bring into the system less economic impounding sites, to lay longer pipelines, use more elaborate treatment and pumping machinery, so inevitably the costs rise.

A stage must ultimately be reached when new thinking and a new approach to water supply problems are required.

In Guernsey, when investigations of traditional methods failed to give reasonable results, it became obvious that a new line must be taken. This led eventually to the works described in this paper. They constitute a radical change from the orthodox works employed in the British Isles for providing a supply of water. A few years ago such a scheme would not have been contemplated seriously and it will be appreciated that the project was not embarked upon without an exhaustive examination of all possible alternatives.

The States of Guernsey Water Board has the duty of providing a supply of water, not only for domestic consumers, but also for the needs of an extensive horticultural industry primarily engaged in the growing of tomatoes under glass. A shortage of water on a domestic system, apart from a complete breakdown of supply, is unpleasant and very undesirable though not disastrous. On the other hand shortage in the supply to the glasshouse industry early in the season could be financially catastrophic as crops are not amenable to rationing. It is therefore necessary to take every reasonable precaution to ensure that even under drought conditions there is no serious shortage of water.

In an island of some 24 square miles, with a population of 45,000 and over 1,100 acres of glasshouses, the gathering grounds available for water supply are severely limited. The average rainfall is approximately 35 inches but almost two-thirds of this is lost by evaporation due to the configuration of the ground coupled with the prevalence of strong winds and sunshine. The porous layer overlying the general granitic rock of the Island is in many places only a few feet thick and in the deepest parts about 50 feet so that the underground storage is incapable of providing a reliable long-term supply under drought conditions.

Winter rainfall is vital and it is a shortage of rain in winter which causes difficulty, not a dry summer. Summer rainfall, unless excessive, produces little water for supply purposes. It is fortunate that there have been rainfall records in Guernsey for more than 100 years and it is possible, with the information obtained during recent droughts, to assess the amount of water likely to be available for supply under any conditions of weather experienced during this period.

The total available storage is about 500 million gallons, a little over 6 months supply. With this full to capacity in the spring it is possible to meet the demand throughout the year, but a failure of autumn and winter rain jeopardises the supply for the next season. For the purpose of assessing the position it is necessary to take an 18-month period from April in one year to September of the year next following, the calendar year being of little significance.

The Table below shows the effect of dry winters on stream yield and the deficiency in supply which would result. The rainfall is the total for the months of October to March plus 50% of that for the previous September and the following April.

Available storage is shown as 450 million gallons, allowing 50 million gallons as a minimum reserve at the end of September to maintain essential services.

YEARS OF LOW WINTER RAINFALL

Resources and Demand referred to present Consumption

Years	Effective Rainfall Inches	Stream Yield Million Gallons	Available Storage Million Gallons	Total Water for Supply Million Gallons	Demand Million Gallons	Deficiency Million Gallons
1853/4	14.16	750	450	1,200	1,400	200
1879/80	13.57	700	450	1,150	1,400	250
1897/8	14.92	800	450	1,250	1,400	150
1920/1	15.78	900	450	1,350	1,400	50
1948/9	13.38	650	450	1,100	1,400	300
1953/4	15.84	950	450	1,400	1,400	—

The above figures cover, in each case, an 18-month period from April to the September in the year next following.

It will be seen from the Table that additional storage of 200 million gallons would reduce the potential losses in the horticultural industry to a very low level. The demand for water for industry is unlikely to expand materially and possible increases in domestic consumption are restricted by the size of the Island and by economic factors. While some increase in supply is probable there is no question of a significant rise in the foreseeable future and this factor had some bearing on the decisions which were taken.

Untapped sources of fresh water were non-existent. Those few small streams not already used for supply dry up completely under drought conditions.

Additional storage, the next thought of the water engineer, was considered very carefully. It was clear that there was no suitable valley on the Island which would provide a site for a dam and the only possible place where storage of 200 million gallons could be provided would have entailed an expenditure approaching £1,000,000 for the reservoir and ancillary works. This cost was so high for the storage provided that it was decided to investigate less orthodox means of safeguarding the supply and thoughts were turned to the conversion of sea water.

Electrodialysis has been publicised considerably of recent years, but enquiries indicated that it would not be a practical proposition for sea water conversion, at least for some years to come, as the power costs were prohibitive and the life of membranes still problematical.

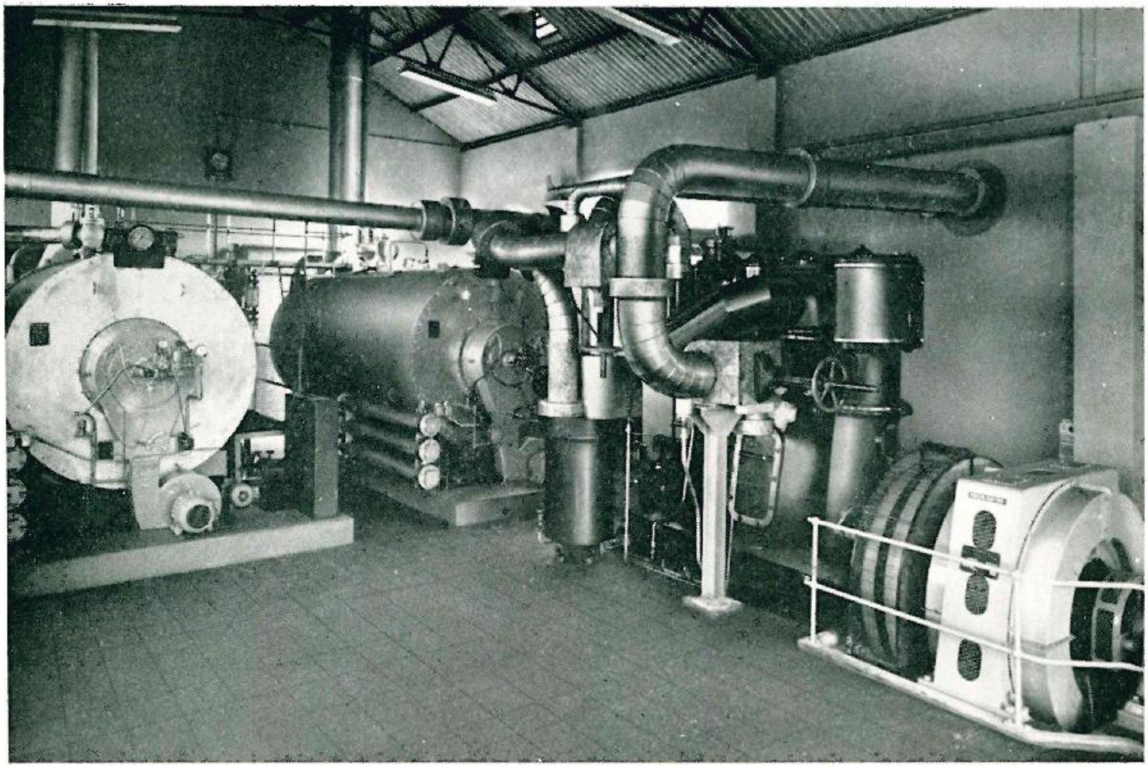
The next possibility was distillation which, due to recent technical advances, had become much less expensive in capital cost and more efficient in operation. There is a widespread but mistaken idea that a distillation process is essentially expensive on fuel because of the high latent heat of vapourisation of water. It is forgotten that in condensing into liquid, the form in which the distillate is required, this same latent heat is made available again. Its useful recovery affects the capital cost of the plant, the higher the efficiency the higher the cost. In practice a very high proportion of the latent heat can be recovered.

Preliminary enquiries sent to firms specialising in this field brought forth proposals which indicated that equipment could be provided which would meet the requirements of the Board at a cost which merited consideration.

The indications were that the low temperature flash evaporation process was the most satisfactory, particularly if waste heat could be used to reduce running costs. The Guernsey electricity supply is provided by diesel engine driven plant and waste heat boilers on the exhausts would have made a useful contribution had the electrical load been constant. In fact the minimum night load is so low as to be of no practical value for this purpose. This same factor was the main reason why a turbo-alternator set providing pass-out or back-pressure steam for evaporator heating could not be used. Undoubtedly, if conditions permit, the most economical operation can be achieved by combining the generation of electricity with the distillation of water. In Guernsey conditions were not favourable for a combined plant and it was decided that a simple self-contained sea-water distillation plant would be the most economical proposition.

A detailed specification which had to be sufficiently elastic to enable the manufacturer to put forward his particular design of plant was sent to those firms capable of submitting a competitive tender.

As mentioned earlier, capital cost in this type of plant rises fairly steeply with the lowering of fuel consumption, that is, the higher the net gained output ratio the higher the capital cost. In order that tenders could be compared on a fair basis, a formula was evolved which included fuel and other running costs on an assumed average usage of 2,000 hours per annum, depreciation over a 20-year period and interest on money



View inside Boiler House.

borrowed to cover capital expenditure. This formula was given to the firms tendering in order that they should be in a position to balance capital cost with operating efficiency and so produce the best possible overall plant for the job, and was as follows:—

$$\text{Total Annual Charges} = £.08c + \frac{15 \times 10^7}{c} + ha - 1000$$

where c = Total Capital Cost.

h = Hours run per annum.

a = Fuel cost/hour.

In the event of the total of annual charges under this formula being equal in two tenders, a remote possibility, the tender showing the lower fuel consumption was to have been accepted. Messrs. G. & J. Weir Ltd., whose tender was successful, put forward a scheme which, on the above formula with 2,000 hours running, gave an annual cost of approximately £32,000 with fuel oil at £9 per ton. The total capital cost including local works amounted to £257,000.

In comparison the estimated capital cost of storage would have resulted in loan charges of over £60,000 per annum, to which would have been added the usual maintenance expenditure, making the annual charges approximately double those for the distillation plant.

A reservoir would be preferred by a water engineer if costs allowed. It has little mechanical equipment to be maintained, is simple to incorporate in the system and it relieves him of the responsibility of deciding if and when it is necessary to bring it into use to ensure the maintenance of supply. This last point is important so far as distillation is concerned, the quantity of water available depending upon the time during which the plant is run. Unnecessary running must be avoided to economise on fuel but should the starting up be left too late then there could still be a shortage of water.

In spite of these disadvantages the difference in cost was such that there could be no question of providing additional storage in Guernsey, especially as demand is unlikely to rise steeply and during years of average rainfall there is ample water available to meet a 25% increase in consumption.

With an increase in the estimated use of the distillation plant of 100% the annual cost would still be only £44,000 and the cost of using it continuously as a source of supply would be little more than the cost of financing the provision of storage which under those conditions would be providing no safeguard for drought years.

In July 1958 the States Water Board made to the States of Guernsey their recommendations regarding the installation of a distillation plant and it was agreed that the scheme should go forward.

The siting of the plant required careful consideration for a variety of reasons, land is scarce, the site had to be close to a harbour for the economical supply of oil by tanker, the sea water supply had to be arranged to suit local tidal conditions and storage in close proximity was desirable, in order that the distilled water could be mixed with the normal supply. The fact that the plant could be accommodated on a very small site eased the position somewhat.

The ideal site did not, of course, exist and there had to be some measure of compromise. The site eventually purchased, rather less than ½ acre in extent, is 1,100 yards from the sea intake, 350 yards from the quay and 400 yards from Juas quarry, a storage reservoir of 120 million gallons capacity. It will be seen therefore that a reasonable measure of success was achieved in meeting the necessary requirements.

The following brief description of the main items of plant and of their installation gives some impression of the work involved in the project.

The sea water supply is pumped to the plant by a Hayward Tyler submersible pump running at 1,450 R.P.M. and delivering 90,000 gallons per hour through a 12 inch diameter main. The pump is suspended from a small gantry on the rock foreshore, the suction strainer being 5 feet below low water mark to ensure continuity of supply. The 30 foot tidal range in Guernsey posed a number of problems in the siting and installation of this pump. The final position was chosen to ensure that it would, as far as possible, be free from the impact of heavy seas. At low water it is protected by outlying reefs which provide shelter in rough weather and at high tide the pump is more than 30 feet below the surface and consequently not subjected to breaking waves. There is, however, a current of up to 5 knots at high and low water which had to be considered in the design of the gantry. This was constructed of standard joists anchored in concrete and protected from corrosion by sacrificial anode.

Three hundred yards of concrete lined spun iron pipe were laid across the beach supported on concrete piers and the electric cable to the pump laid in a 3 inch asbestos cement pipe follows the same route. Between the beach and the site, a distance of 800 yards, the sea water main is laid in asbestos cement pressure pipes. A 12 inch asbestos cement waste brine line follows the same route as the pumping main but discharges into a culvert which empties well clear of the pump intake to avoid any risk of short circuiting. The whole of the concreting and pipelaying work on the beach was carried out at low water during spring tides, which restricted working time to about 6 days per month. These days, needless to say, were usually stormy, to the discomfiture of all concerned.

The electric cable follows the pumping line to the site and the starter is in the main control room. A step-up auto-transformer installed above high water mark reduces the starting current and compensates for the voltage drop in the supply cable.

Steam which supplies the power for operating the plant is generated in two Spencer-Bonecourt Steambloc packaged type oil fired boilers, each with a rating of 13,000 lbs. per hour having a working pressure of 245 lbs./ sq. in. gauge. These are fully automatic and complete with feed pumps, forced draught fans, fuel pumps and heaters. The burners give a modulated flame control down to approximately ⅓ load beyond which the regulation is by cut off. Under normal conditions the boilers will be working continuously at about 80% load so that the modulation will take care of minor fluctuations. Ignition of the oil is by butane pilot flame electrically ignited and flame failure automatically shuts down the boiler and sounds an alarm bell. The starting or restarting sequence is fully automatic and labour is reduced to a minimum.

Fuel oil storage on site is provided by two tanks each of 500 tons capacity fitted with main steam heating coils and also steam outflow heaters. This storage is sufficient to run the plant for about two months at full load. An 8 inch diameter welded steel pipeline was laid underground from the harbour to the tanks and through this the oil is pumped direct by coastal tankers. Provision has been made for steam heating this line, also for emptying it after each consignment, to avoid clogging with cold thick oil. In practice the steam heating does not appear necessary provided that the oil in the ships tanks is kept at a temperature of 110°F.- 120°F. Sufficient heat is then carried throughout the line to enable the oil to be pumped easily and cleared by a stripper pump on completion of unloading. The oil being use is Shell K.G. heavy fuel oil 950 second.

A service tank holding 5,000 gallons receives the oil from the main storage through an oil filter. This tank has both steam and electric heating, the latter for starting the plant from cold. Once steam is raised it can be used for heating the main tanks and the service tank.

Feed water for the boiler is normally obtained from the distillate which is of a high degree of purity and needs little treatment, a subsidiary supply of mains water is, however, provided for times when the evaporator is not in operation.

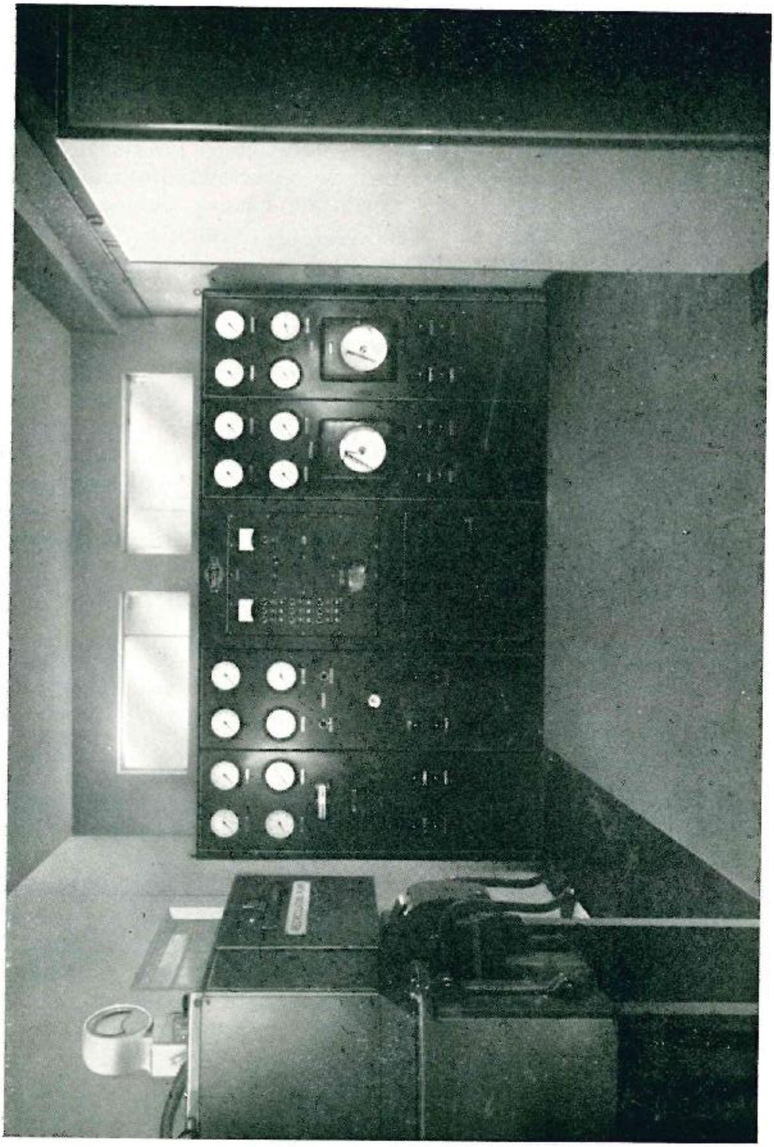
A Belliss and Morcom compound steam engine driving an English Electric alternator provides electric power for the plant. This set is of 750 H.P. running at 375 R.P.M. and producing 550 K.W. at 0.8 power factor on a 400 volt 3 phase 50 cycle supply. The steam pressure at the engine stopvalve is 240 lbs./ sq. in. gauge and the exhaust pressure is 15 lbs./ sq. in. gauge.

It may appear at first sight that a steam turbine could have been used with advantage but the choice was governed by the steam requirements of the evaporator. For the power required, a turbine under the necessary conditions of back pressure would have been less economical on steam and consequently would have adversely affected the fuel consumption of the whole plant.

The power generated by the alternator is used for operating the following units, sea water pump, evaporator feed pump, recirculating pump, brine and distillate pumps and the boiler auxiliaries. These provide a load of about 500 K.W. under full load working conditions.

A standby power supply of 100 K.W. is available from the States Electricity Department. This is adequate for the running of individual pumps, except the recirculating pump which is of 450 H.P., and as a matter of convenience this supply is also used for all instrumentation.

The evaporator is a mild steel shell 69 feet long, 19 feet wide and 18 feet high containing 40 evaporating compartments, or stages, in two decks, 16 in the bottom deck and 24 in the upper deck. This structure, weighing over 300 tons, was delivered to site in prefabricated sections



Main Instrument Panel.

the largest of which was over 16 tons. After assembly they were electrically welded on site and water tested on completion.

The evaporator shell stands on a concrete grillage 2 feet 9 inches above ground level, so providing access to the underside.

Each stage has a heat exchanger consisting of aluminium brass tubes expanded into nickel plated mild steel tubeplates which are welded into and form part of the evaporator shell. Also in each stage is a mild steel brine weir connected to the preceding stage by holes in the division plates. Each heat exchanger has a distillate tray below the tubes and these are also connected from stage to stage by trunking in which is fitted an orifice for each stage.

The whole evaporator shell is covered with insulating material to prevent leakage of heat and so maintain the temperature gradient through the various stages, which is vital to the proper operation of the plant, the temperature difference between stages being only $2\frac{1}{2}$°F.

Connected to the evaporator are four pumps, the feed pump with a duty of 764 G.P.M. against 270 feet head, the recirculating pump delivering 3,050 G.P.M. with a discharge head of 285 feet and a suction of 28 inch Hg, the brine pump 573 G.P.M. and the distillate pump 382 G.P.M.

Two air ejectors produce the necessary vacuum in the evaporator shell.

The control equipment and switchgear for the whole plant is housed in the control room adjacent to the boiler house. This equipment includes the alternator control panel, distribution switchgear, motor starters and indicating and recording instruments necessary for control of the evaporator. These latter include temperature, vacuum and pressure gauges, flow meters and salinometers connected to different stages in the system, provided with both audible and visual alarms to indicate faults in the plant especially in respect of quality of distillate. In the event of salinity rising above 100 p.p.m the distillate is automatically discharged to waste until the fault is rectified.

The operation of the plant is briefly as follows. The major part of the sea water supply from the submersible pump passes through the distillate cooler into the first stage of the evaporator but a small proportion is used as a cooling medium for the engine lubricating oil cooler, the condensate cooler and the air ejectors. In all rather more than 80,000 gallons per hour are taken into the plant and 20,000 gallons per hour produced as distillate. The remaining brine is rejected at various stages and led to a sea water discharge tank from which is flows back to the sea.

Steam from the boilers is fed through the steam engine driven alternator set and the exhaust is led to the exhaust steam heater, a conventional heat exchanger in which it heats the recirculating water from the evaporator. The condensed exhaust steam then flows through the condensate cooler to the condensate tank and so back to the boilers.

High pressure steam from the boilers is also supplied direct to the air ejectors and to the oil heaters on the boilers. Steam passing through a pressure reducing valve is available for heating the fuel oil in the main storage and service tanks.

The sea water fed into the three primary stage tube banks is heated by steam flashing in these compartments and reaches a temperature of 97°F. The quantity of sea water required in the remaining 37 stages is not so great as in the primary stages so, between stages 3 and 4 surplus sea water feed is rejected to waste and the balance is drawn off by the feed pump for circulation through the top sections of the heat exchangers. Chemical treatment for the prevention of scale can be applied at this point.

The sea water, after passing through the heat exchangers and devapourisers, enters the deaerator through spray nozzles and mixes with the recirculating brine. The mixture of recirculating brine and feed at a temperature of 200°F. is allowed to flow into stage 40 and then through the remaining stages at progressively decreasing temperatures and pressures until it reaches stage 1 at 100°F. with a 28 inch vacuum. In each stage vapour flashes from the brine and in condensing contributes its share of the total distillate. From stage 1 a quantity of brine equal to the distillate is discharged to waste to maintain the brine concentration at 2. The remainder of the brine is recirculated through the lower part of the heat exchangers, at a rate of 3,000 gallons per minute, and hence to the exhaust steam heater where the temperature is raised to 202.5°F. It is then passed into the deaerator to mix with the feed from the deaerator sprays, the mixture flashing through successive stages as already described. The distillate condensed on the tubes of the heat exchangers is passed from stage to stage until it reaches the 1st stage where it is drawn off by the distillate pump and pumped through the distillate cooler to storage.

Due to the weather conditions experienced over the past months it has not been necessary to operate the plant in earnest, but extensive test runs have been made to ensure that the guaranteed performance can be obtained. The essential factors are output, quality of distillate and efficiency.

The specified output of 500,000 gallons per day has been achieved with a purity of approximately 50 parts per million total dissolved solids. This figure is approximate because there is some variation from time to time depending upon running conditions.

The designed net gained output ratio, that is the ratio between distillate made and steam used, was 10.6 and this figure also has been achieved.

Heat exchangers and other units subjected to contact with heated brine have been examined and show no signs of build up of scale which is very gratifying, particularly as no chemical treatment has so far been applied to the sea water for scale prevention.

It must be said that the opinions formed during the running of this evaporator have been very favourable both as to stability when on load and to general performance.

It would seem that a plant of this type has a future in the water industry which is not confined entirely to arid zones. In coastal areas where there are difficulties in obtaining adequate supplies of fresh water from natural sources the cost of demineralising sea water may well be competitive, high though it is.

List of Main Contractors

DISTILLATION PLANT

G. & J. Weir Ltd.

Sub-Contractors

Boilers	Spencer-Bonecourt-Clarkson Ltd.
Steam Engine	Belliss & Morcom Ltd.
Electrical Equipment	The English Electric Co., Ltd.
	Allen West & Co., Ltd.
Pumps	Drysdale & Co., Ltd.
Steelwork Fabrication	Wm. Simons & Co., Ltd.
	John Upham Ltd.
Metering	Geo. Kent Ltd.
Lagging	Cape Asbestos Co., Ltd.

OIL STORAGE TANKS

Samuel Cutler & Sons Ltd.

BOILER HOUSE	E. Littlewood & Co., Ltd.
PIPES	The Stanton Ironworks Co., Ltd.
	Stewarts & Lloyds Ltd.
	G. R. Speaker & Co., Ltd.

SEA WATER PUMP

Hayward Tyler & Co., Ltd.

ELECTRICAL INSTALLATION

Guernsey States Electricity Board.

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