

FRESH WATER FROM THE MIST LIFT CYCLE

STUART L. RIDGWAY

SEPTEMBER 1985

RDA
LOGICON

R & D ASSOCIATES, POST OFFICE BOX 9695, MARINA DEL REY, CALIFORNIA 90295

4640 ADMIRALTY WAY ■ MARINA DEL REY ■ TELEPHONE: 213 822-1715

FRESH WATER FROM THE MIST LIFT CYCLE

~~INTRODUCTION AND SUMMARY~~

The Mist Lift OTEC cycle is a low cost method of producing electricity from the temperature difference between the surface and the depths of the tropical oceans. It is an open cycle, i. e., uses water vapor as the working fluid. It differs from the Claude cycle in that the work is extracted by the vapor lifting a mist of water droplets rather than driving a turbine.

In an open cycle plant designed to produce power only a direct contact condenser is the natural choice to accept the rejected heat of the cycle at the low temperature side. It provides high effectiveness at very low cost in comparison with a surface condenser, however it does not yield desalinated water, which is desired as an OTEC product. A surface condenser will make fresh water, but is more expensive.

To determine the probable costs of a fresh water from a Mist Lift plant with surface condenser, the plant design described in the ASME Winter Annual Meeting paper, "Projected Capital Costs of Mist Lift OTEC Plant" New Orleans, December, 1984 was modified by adding a surface condenser that condensed about half of the vapor. The remaining vapor was condensed in a direct contact condenser.

The modification adds about \$600 per kilowatt to the \$2,500-per-kilowatt cost of the power only version. The fresh water production is 420,000 gallons/day per megawatt and this option looks quite attractive for those areas with need for fresh water. The cost of the fresh water feature is \$1.40 per gallon/day production capacity.

DESCRIPTION OF THE FRESH WATER OPTION

The fresh water producing version of the Mist Lift OTEC plant is quite similiar to the earlier designs that were intended to produce power only.

The fresh water adaptation consists in splitting the condensation duty between the original direct contact condenser exchanger and an added surface condenser.

The general arrangement is diagrammed in figure 1. The warm water, typically at 25 deg C, is first filtered to protect the mist generator, and then dropped through a hydraulic turbine, producing power. It is then injected into the lift duct by the mist generator as tiny droplets.

The ambient pressure at the bottom the duct corresponds to the vapor pressure of water at a lower temperature, typically 20 deg C. Some of the warm water flashes into vapor, cooling to nearly 20 deg C, and a mist is formed.

Some distance above the mist generator the vapor is condensed at lower pressure by the cold water from the depths. A pressure corresponding to saturation at 13 deg C would be typical.

The pressure difference between the mist generator and the condensing region drives a strong vapor updraft that lifts and accelerates the droplets. As the mist rises through the acceleration region, its temperature drops. The fall in temperature of the water droplets provides additional vapor to do more work, and leads to a higher efficiency of the cycle compared with the closed or the Claude cycle. An energy gain of

the droplets that correspond to a lift of 70 meters is typical for the temperature conditions chosen.

After the acceleration is complete, part of the vapor is directed sideways to a surface condenser while the water droplets and the remaining vapor proceed upwards to the direct contact condenser. A small countercurrent condenser is placed in the passage to the vacuum pump to minimize the vapor that is pumped out along with the noncondensibles.

The droplets will be moving upward at high speed. As the vapor turns to the side it will have a tendency to bend the droplet trajectories outward. To counterbalance this effect, some of the lifted water will be sprayed back into the mist at the end of the acceleration region with a inward radial velocity component. The spray will be transparent to vapor, and opaque to droplets. A chevron type mist eliminator will be placed at the entrance to the surface condenser to catch the mist droplets that escaped the mist convergence jets.

The cold water is first passed through the surface condenser, and then directed to the direct contact condenser where the remaining vapor is condensed by a converging spray, which also collapses the mist into a single phase vertical jet of water. This jet of water rises to a peak, and falls into a collector at a level above the barometric level so that it has sufficient head to drain back into the ocean.

The cold water has suffered head losses in the cold water pipe and the surface condenser and does not have enough energy to reach this level. The height of the region between the end

of the acceleration zone and the top of the plant, the coast zone, is suitably chosen so that the momentum of the accelerated mist is sufficient to carry both itself and the sprayed in cold water to above the barometric level. The accelerated mist is used as a jet pump for the cold water. No cold water pump is needed, which gives a substantial cost saving in comparison with more conventional OTEC plants.

The characteristics of a 1-MW plant are given in Table 1.

TABLE 1. CHARACTERISTICS OF A 1.0-MW MIST LIST OTEC WITH FRESH WATER CAPACITY

Nominal power output	1.0 MW
Fresh water production	420,000 gpd
Warm water temperature	25°C
Flashdown temperature	20°C
Condenser temperature	13°C
Cold water temperature	5°C
Cold/warm ratio	1.67
Cold water flow	2.72 m ³ /S
Warm water flow	1.63 ₂ m ³ /S
Mist injector area	28 m ²
Injector diameter	6.0 m
Height of acceleration zone	18 m
Maximum cross sectional duct area	64 m ²
Maximum duct diameter	9.0 m
Coast distance	64 m
Surface condenser	
Six modules	1700 tubes each
Tube length	6.1 m
Tube I.D.	0.5 in
water velocity	2.1 m/s
head loss	1.3 m
heat transfer area	2485 m ²
Cold water temp rise	4.0°C
Temp differential water to tube	2.6°C
Temp differential tube to vapor	3.2°C
Cost at \$165/m ²	\$410,000

The one megawatt plant is shown to scale in Figure 2. The lower and upper parts are shown expanded in Figures 3 and 4. The surface condenser modules are 20' x 20' in frontal area, each containing 1700 horizontal tubes. The modules are arranged in a hexagonal pattern around the rising mist column.

Unmixed cold water for mariculture is available from the duct between the two condensers.

CONCLUSION

Desalinated water production is an economically viable option for a Mist Lift OTEC power plant. The extra cost and complication for the water production is very reasonable.

SCHMATIC DIAGRAM OF MULTIPRODUCT MIST LIFT OTEC POWER PLANT

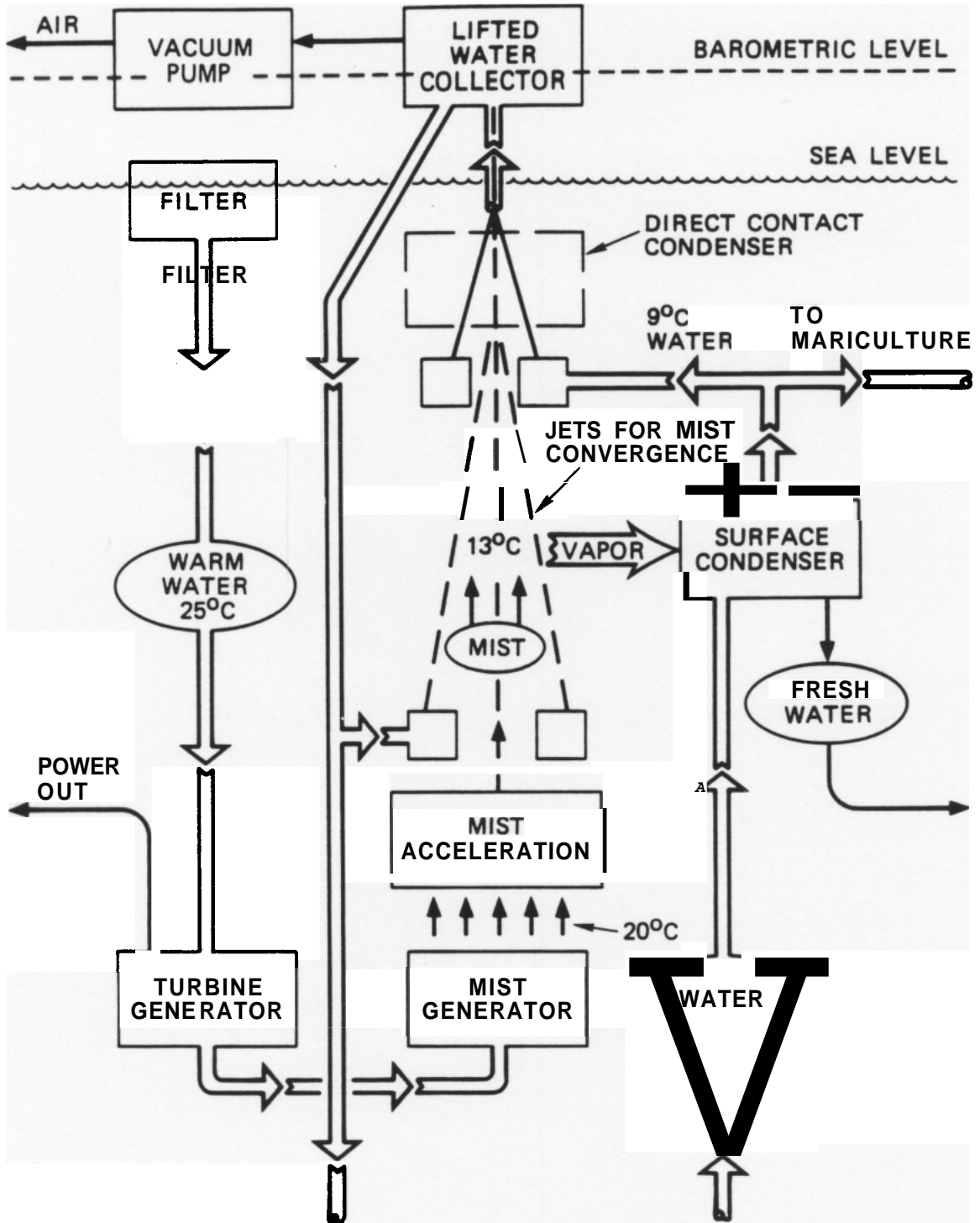


Figure 1. Schematic Diagram of Multiproduct Mist Lift OTEC Power Plant.

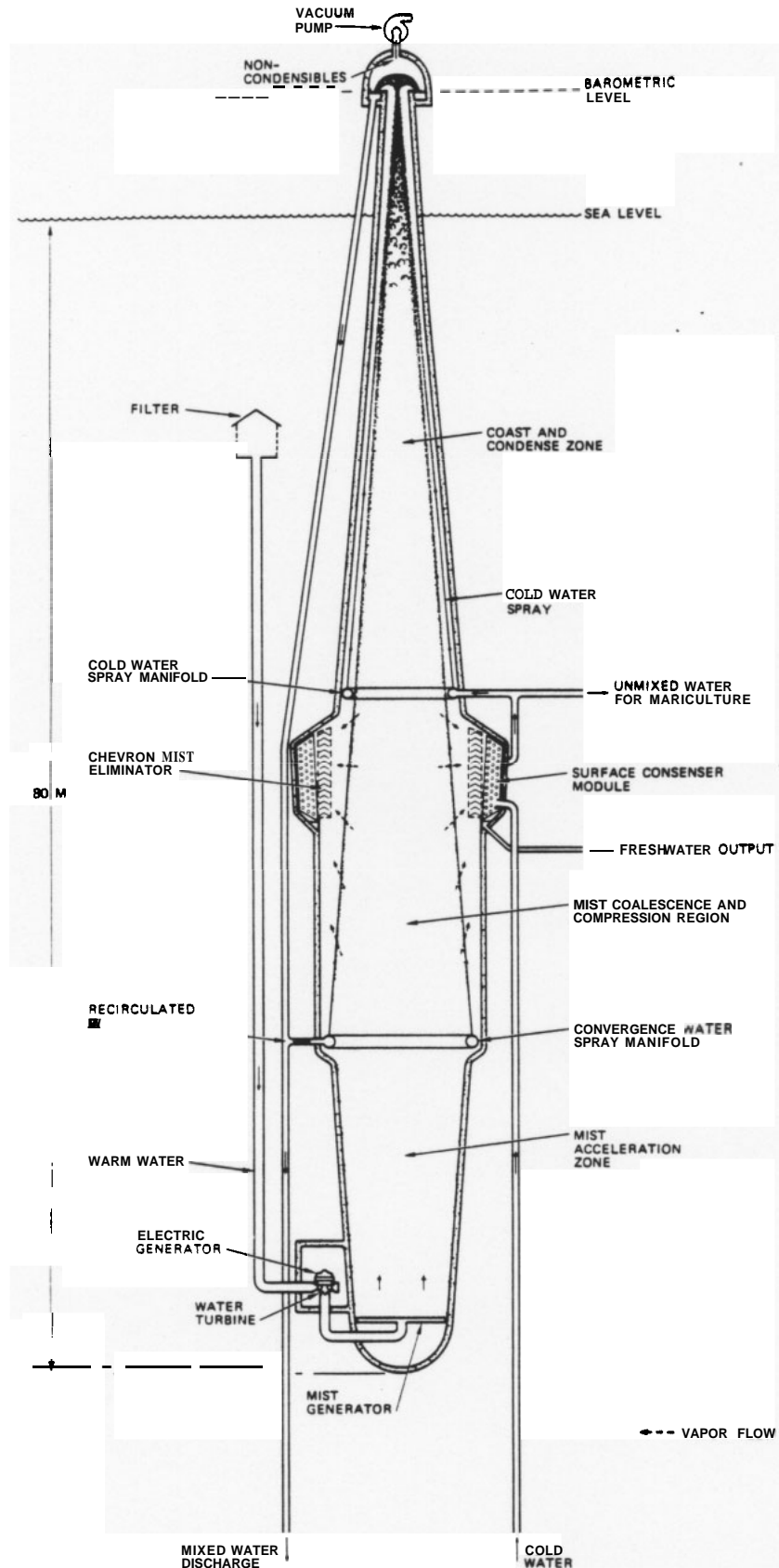


Figure 2. One megawatt 420,000 gallon/day Mist Lift OTEC.

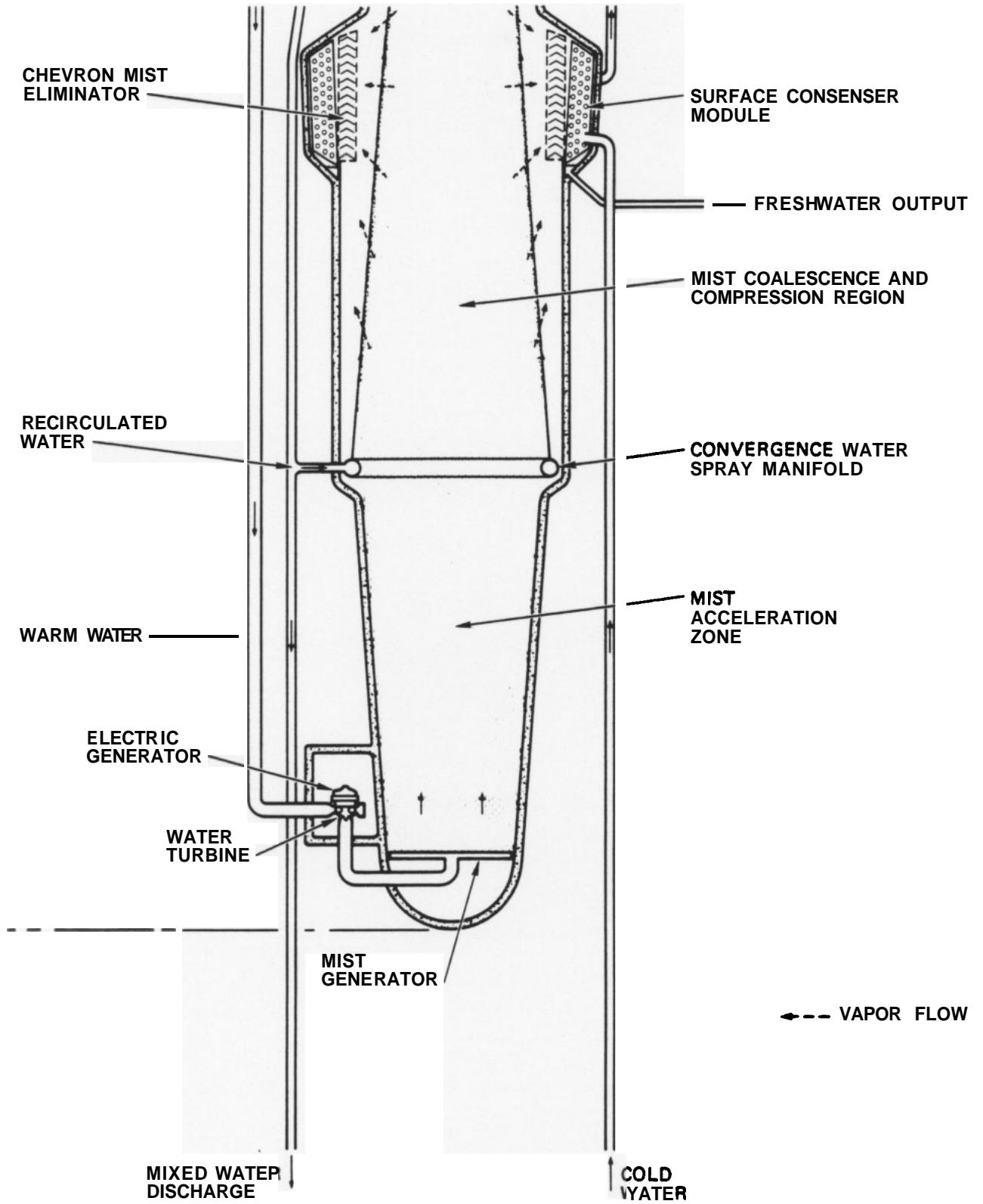


Figure 3. Lower part, one megawatt 420,000 gallon/day Mist Lift OTEC.

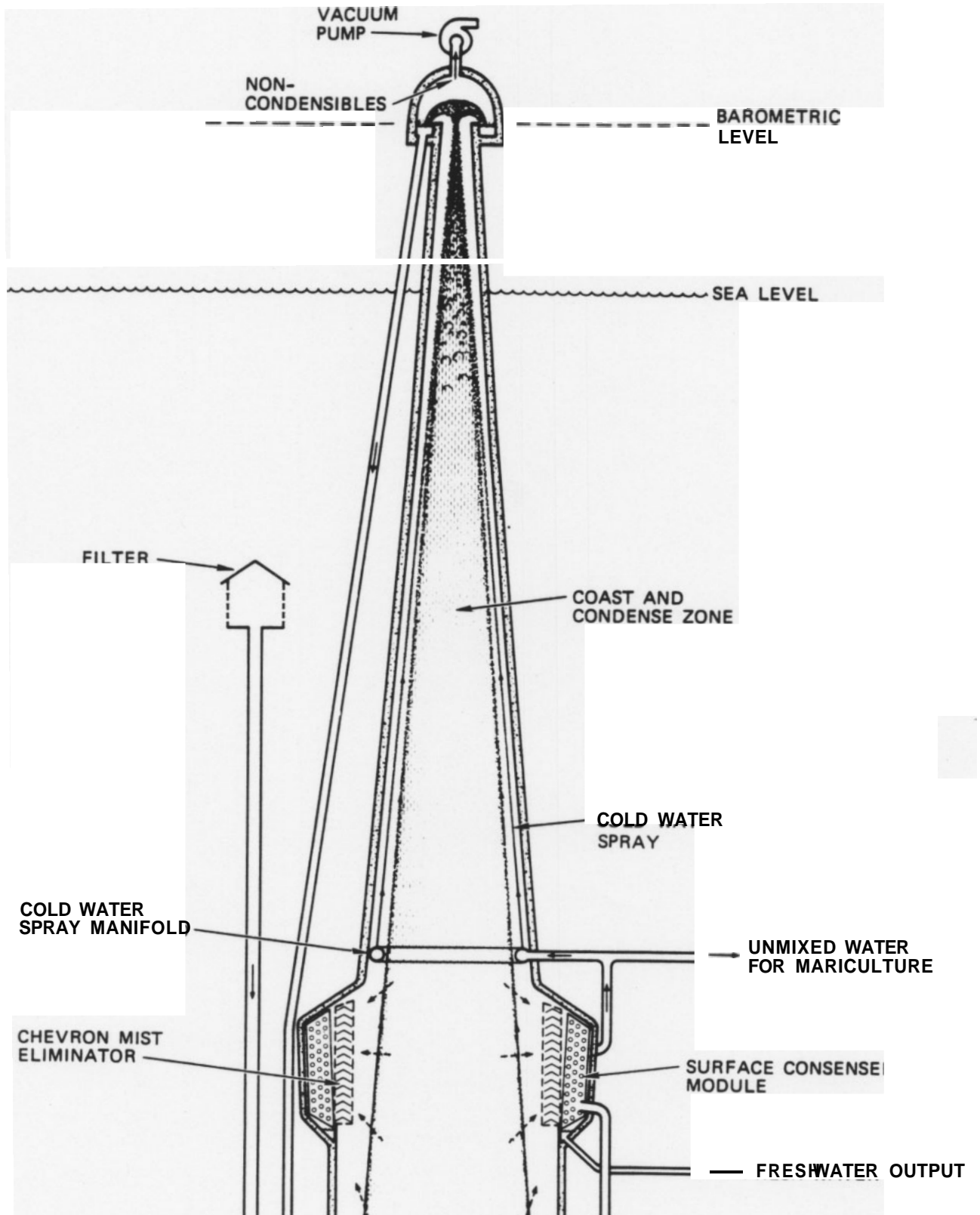


Figure 4. Top part, one megawatt 420,000 gallon/day Mist Lift OTEC.