CH1002 Energy Management in Chemical Industries

Unit - VI

Ocean Energy Conversions

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Tidal Power

Introduction

- Tidal energy is generated by the relative motion of the Earth, Sun and the Moon, which interact via gravitational forces.

- Periodic changes of water levels, and associated tidal currents, are due to the gravitational attraction by the Sun and Moon.

Tidal Energy Conversion

- Recovery can be made in its various **potential forms**, these being variation in sea level and exploitation via a dam, **and kinetic forms**, these being direct exploitation of currents by turbines placed directly in the flow like submarine wind turbines, also called hydraulic turbines.

- One of the advantages of tides is their great predictability, which facilitates planning and allows better insertion of such production systems into the grids.

- There are different kinds of tides, depending on the location. The most energetic ones have about two cycles per day with a period of about 12.5 hours and amplitude that varies appreciably in a sinusoidal manner over a cycle.

Power Generation through Tidal Barrages

Tidal Power Station

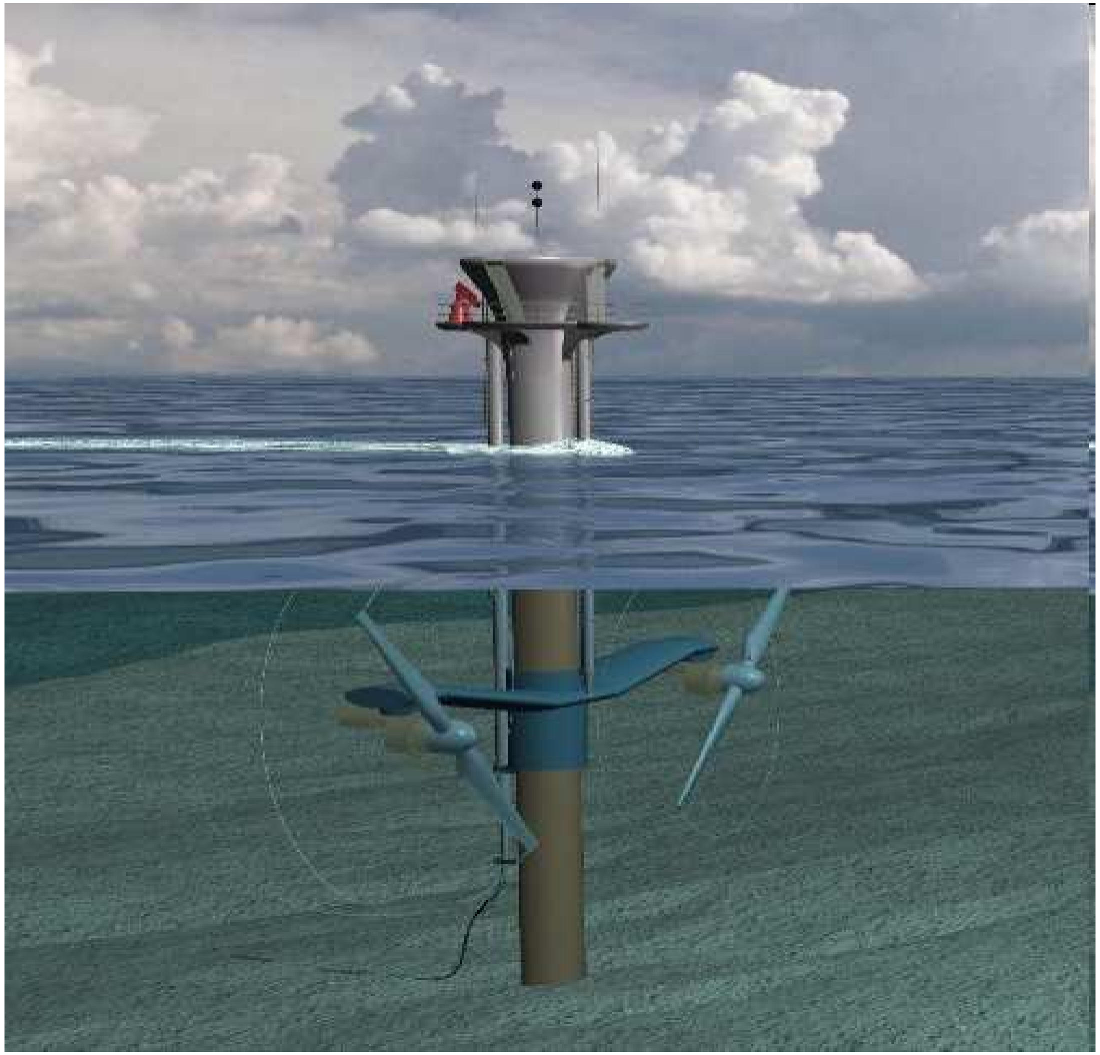
- The working of a tidal power station is similar to that of hydropower stations, since the height of the waterfall is not great, but, unlike them, two choices are available: simple or double acting.

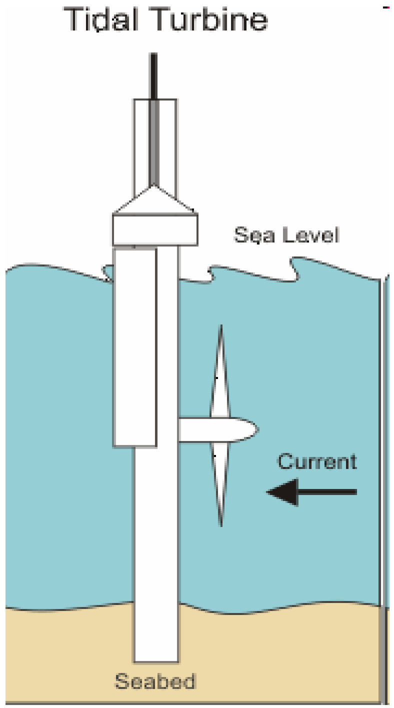
- In the **simple acting cycle**, the sluices of the dike are open during the rising tide and allow the basin to be filled. When the level of the sea has gone down enough for the height of the fall to be sufficient, the sluices are opened so the water returning to the sea drives a turbine.

- The **double acting cycle** makes it possible to use the available power equally well during rising and falling tides. Therefore reversible turbines are needed (that work in both directions of current).

Power from Marine Currents

Power from Marine Currents





Power from Marine Currents

- These currents, as distinct from tidal currents, result from a complex agitation of the ocean waters principally due to temperature and salinity gradients.

- Bearing in mind the flow rate and the global volume, we can calculate that it takes about 1,000 years for a complete mixing of the ocean waters.

- Only some currents are fast enough to be usable; this is the case with the Gulf Stream, which gives an average flow rate of 30 Mm3/s with speeds between 1.2 and 2.7 m/s, while the equatorial currents have speeds more in the range of 0.2 to 0.3 m/s.

- The global resource is hard to estimate. The Gulf Stream alone offers a kinetic power of more than 30 GW

Wave Power

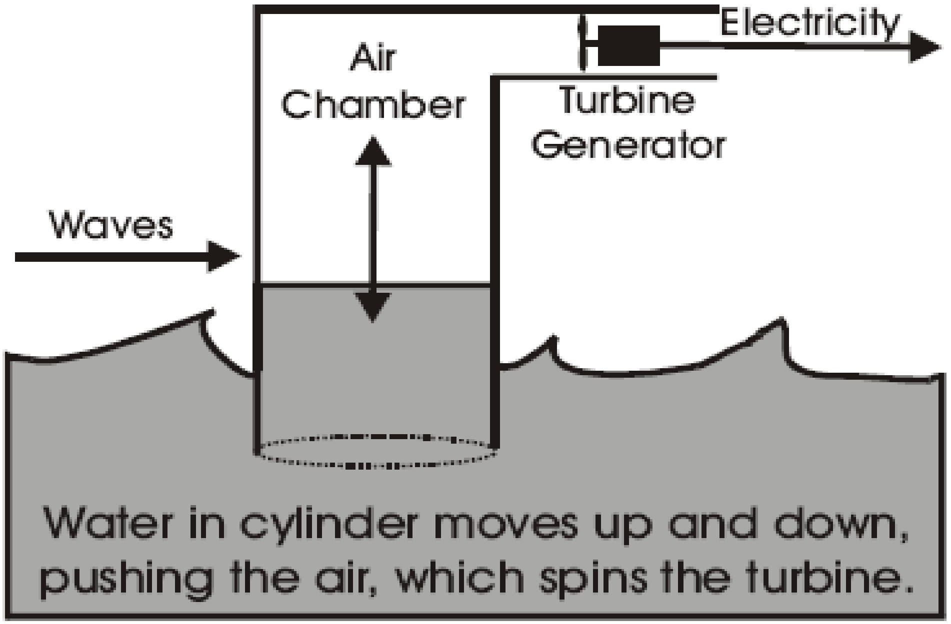
Introduction

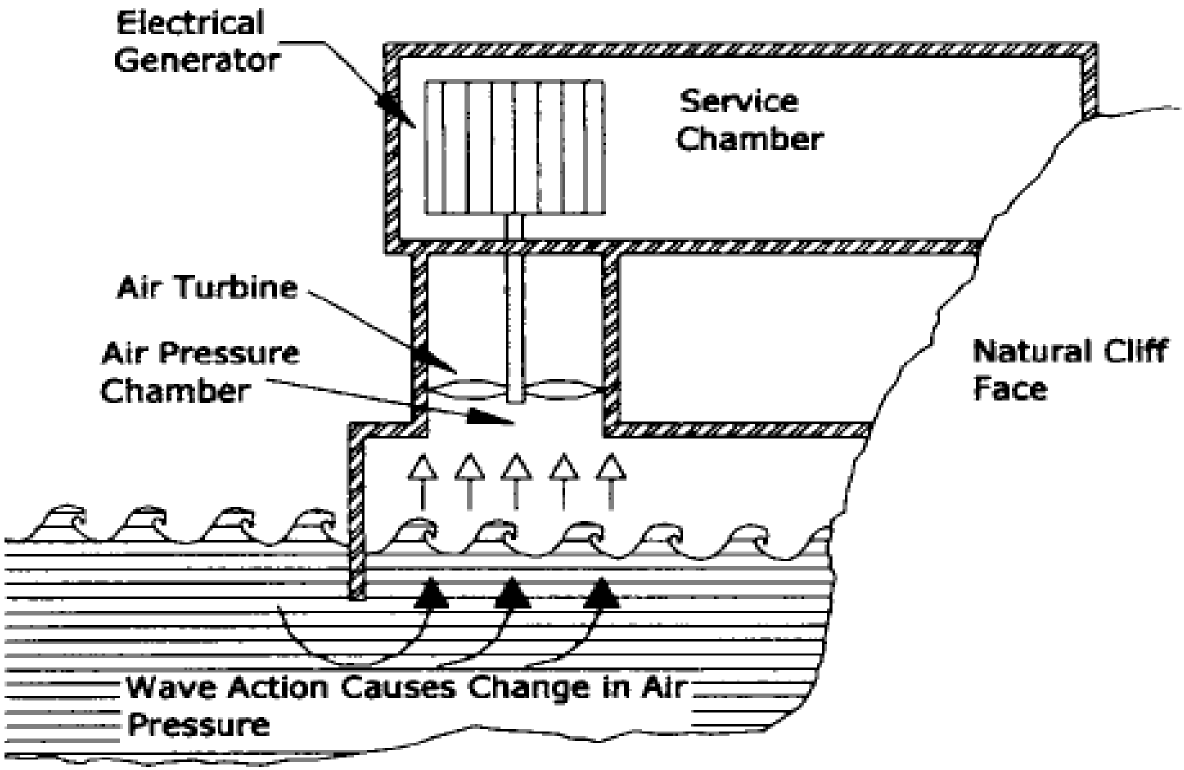
- **Wave power** is the transport of energy by ocean surface waves, and the capture of that energy to do useful work

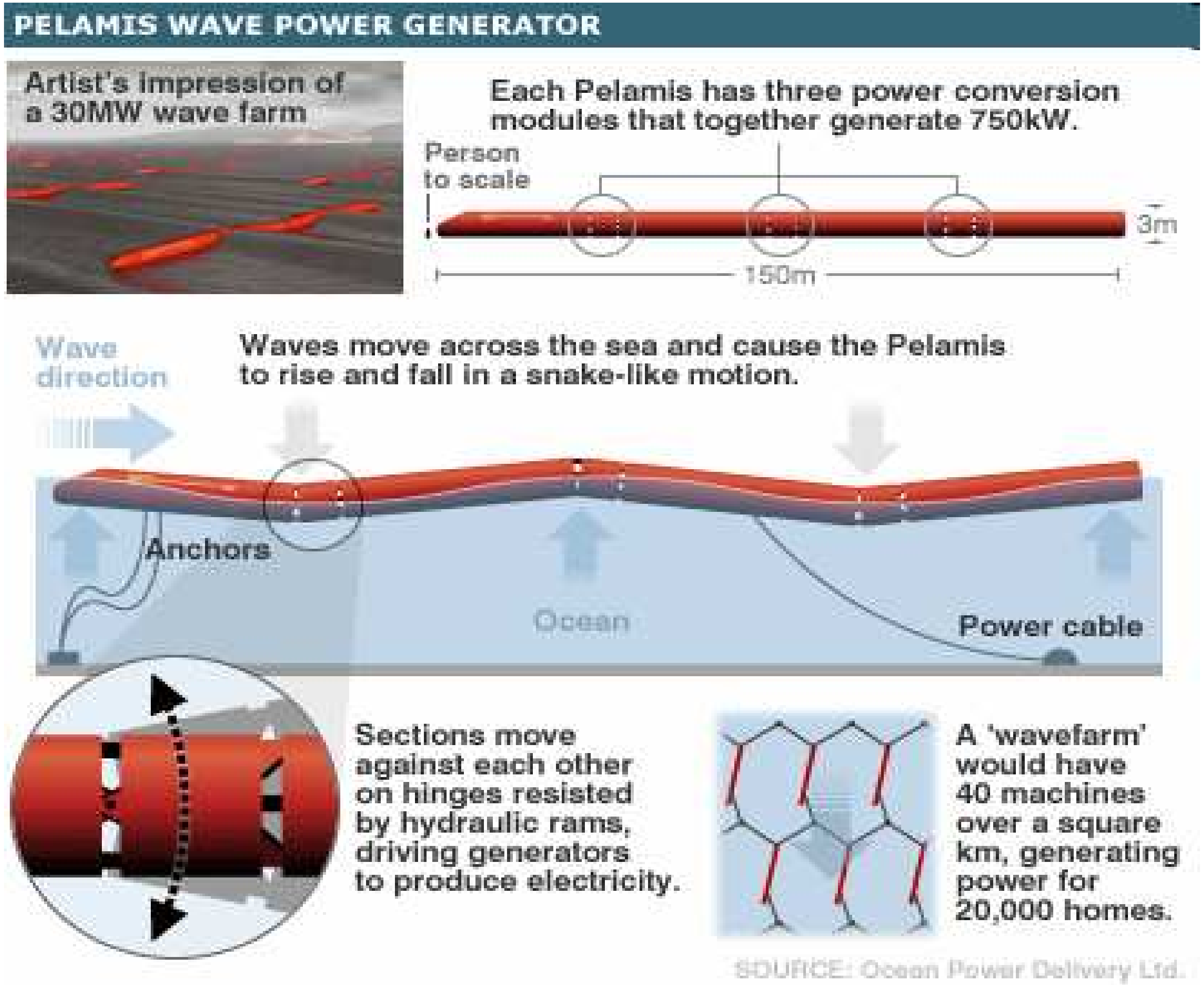
- Ocean waves are due to the action of wind on the surface of the waters.

- Wave power is distinct from the diurnal flux of tidal power

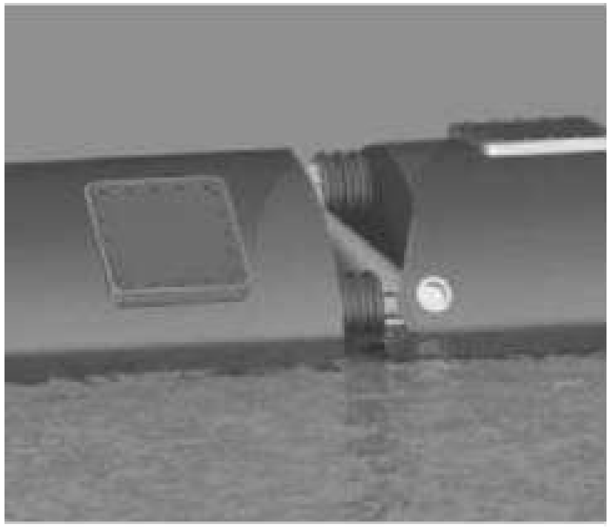
- The energy from waves represents, according to the World Energy Council (WEC), a net available quantity of 140 to 700 TWh/year (Max power of ~80 GW), or 1 to 5% of the annual world demand in electricity.


Electricity
Air
Chamber
Turbine
Generator
Waves
Water in cylinder moves up and down,
pushing the air, which spins the turbine.


Electrical Generator
Service Chamber
Air Turbine
Air Pressure Chamber
Natural Cliff Face
Wave Action Causes Change in Air Pressure


PELAMIS WAVE POWER GENERATOR
Artist's impression of a 30MW wave farm
Each Pelamis has three power conversion modules that together generate 750kW.
Person to scale
3m
150m
Wave direction
Waves move across the sea and cause the Pelamis to rise and fall in a snake-like motion.
Anchors
Ocean
Power cable
Sections move against each other on hinges resisted by hydraulic rams, driving generators to produce electricity.
A 'wavefarm' would have 40 machines over a square km, generating power for 20,000 homes.
SOURCE: Ocean Power Delivery Ltd.

Pelamis System



Pelamis System

- These consists of a group of four floating metallic cylinders linked together by three articulations of two degrees of freedom, and resembling a snake 4.6 m in diameter and a with total length of 123 m (700 tons, of which 380 tons are steel). The behavior of the system makes it follow, more or less, the distortion of the free surface, which in fact makes it a “profiler”.

- This general shape allows the system to adapt to extremely varied sea states and to make good use of their energy. In each articulation there are four hydraulic jacks, two of which use and absorb the heave (vertical) and the two others the sway (transverse). These pumps accumulate energy in the form of oil under pressure in a reservoir (100 to 350 bars). Two hydraulic motors that turn regularly each drive an asynchronous generator of 125 kW at 1,500 rpm (fixed speed).

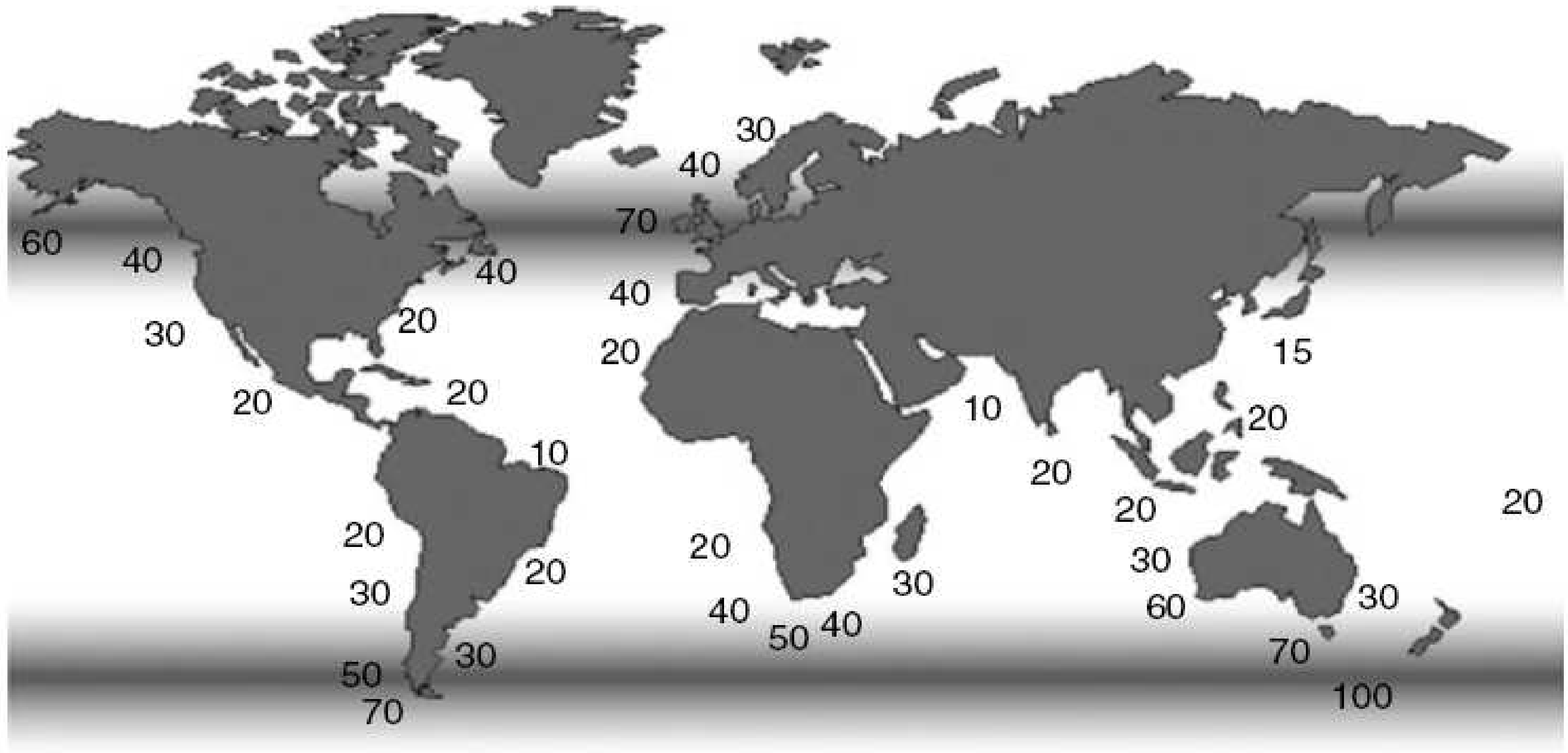


Figure 4.1 World wave power density map (figures show kW/m of wave crest length) highlighting latitudes where resource is highest. Source: CRES, 2002.

Armstrong et al., Energy beyond oil, Oxford University Press, 2007

Annual conversion efficiency of wave power to electric power is about 10%

Ocean Thermal Energy

Introduction

- Sufficient temperature gradients are found in equatorial and tropical regions. The surface temperatures there can reach values between 25 and 30ºC in a layer 100 to 200 m thick and their seasonal variations are not markedly different.
- The raw solar energy resource captured annually by the oceans is enormous, in the order of 400 x 10^{15} kWh (i.e., ~ 45,000 TW).
- Considering the global output of all the deep cold currents (30 Mm^3/s) and the fact that conceivable thermodynamic machines require a very high discharge of cold water (about 2 m^3/s per MW) and weak conversion efficiency in the order of 3% (principally due to the small difference in temperature between the hot and cold sources), we reach a maximum annual potential of 80,000 TWh, which is renewable.

Ocean Thermal Energy Conversion

- The thermodynamic converters may be of two types: open or closed cycles.

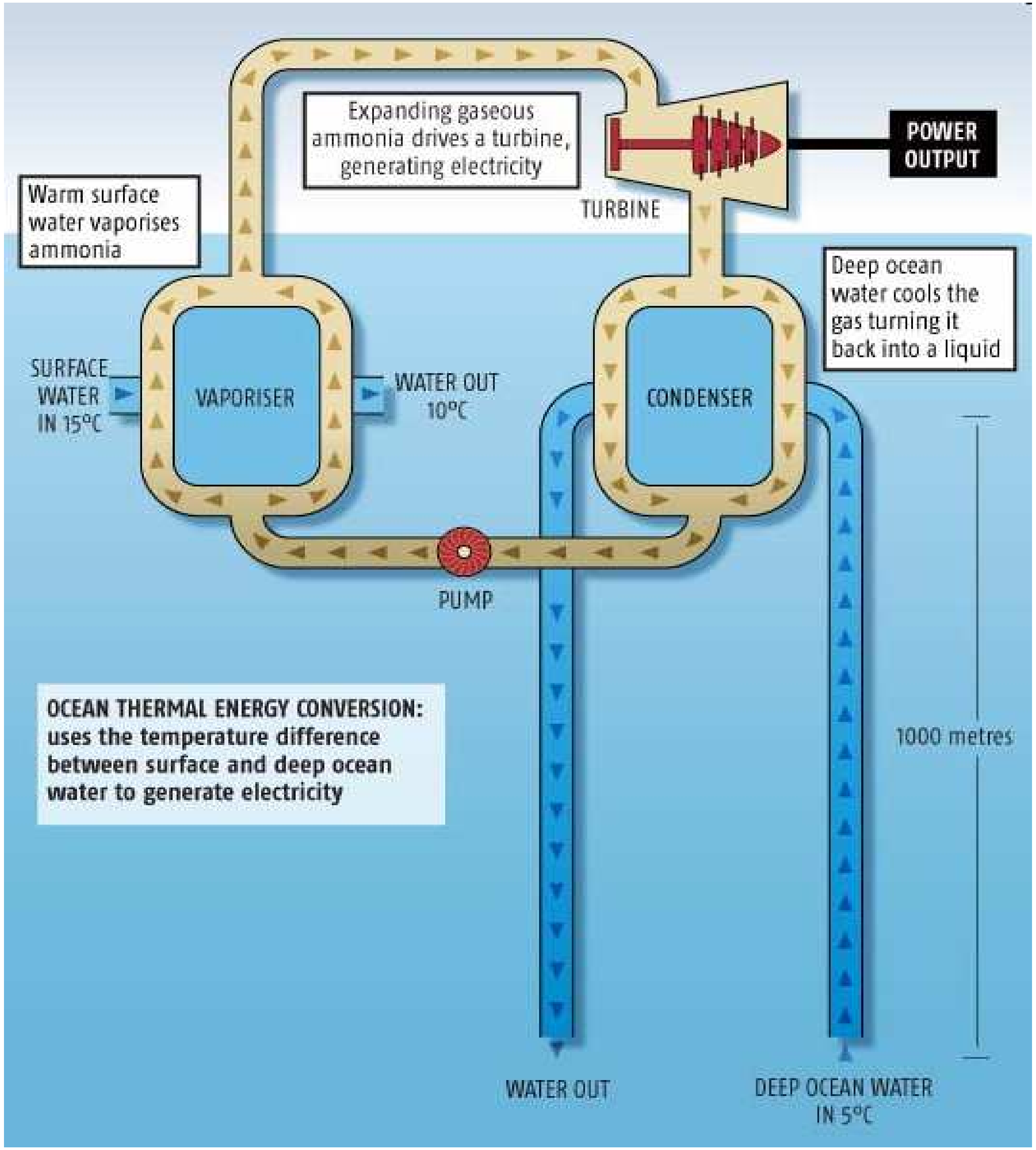
- The **open cycle** machines use seawater directly and make it possible to avoid exchangers that are very cumbersome and risk being clogged from the effect of biofouling (growth of microorganisms). The principle consists of having two turbines work in a belt of very low pressure (2 to 3 kPa or 20 to 30 mbar) created with vacuum pumps. The water from the hot source, at such pressures, vaporizes and drives the turbine, then condenses on contact with the cold source. The fresh water obtained by condensation can then be used as a value added byproduct. The major disadvantage of the open cycle resides in the large dimensions of the low pressure turbine. To produce 1 MW, a turbine diameter of 8 m is required.

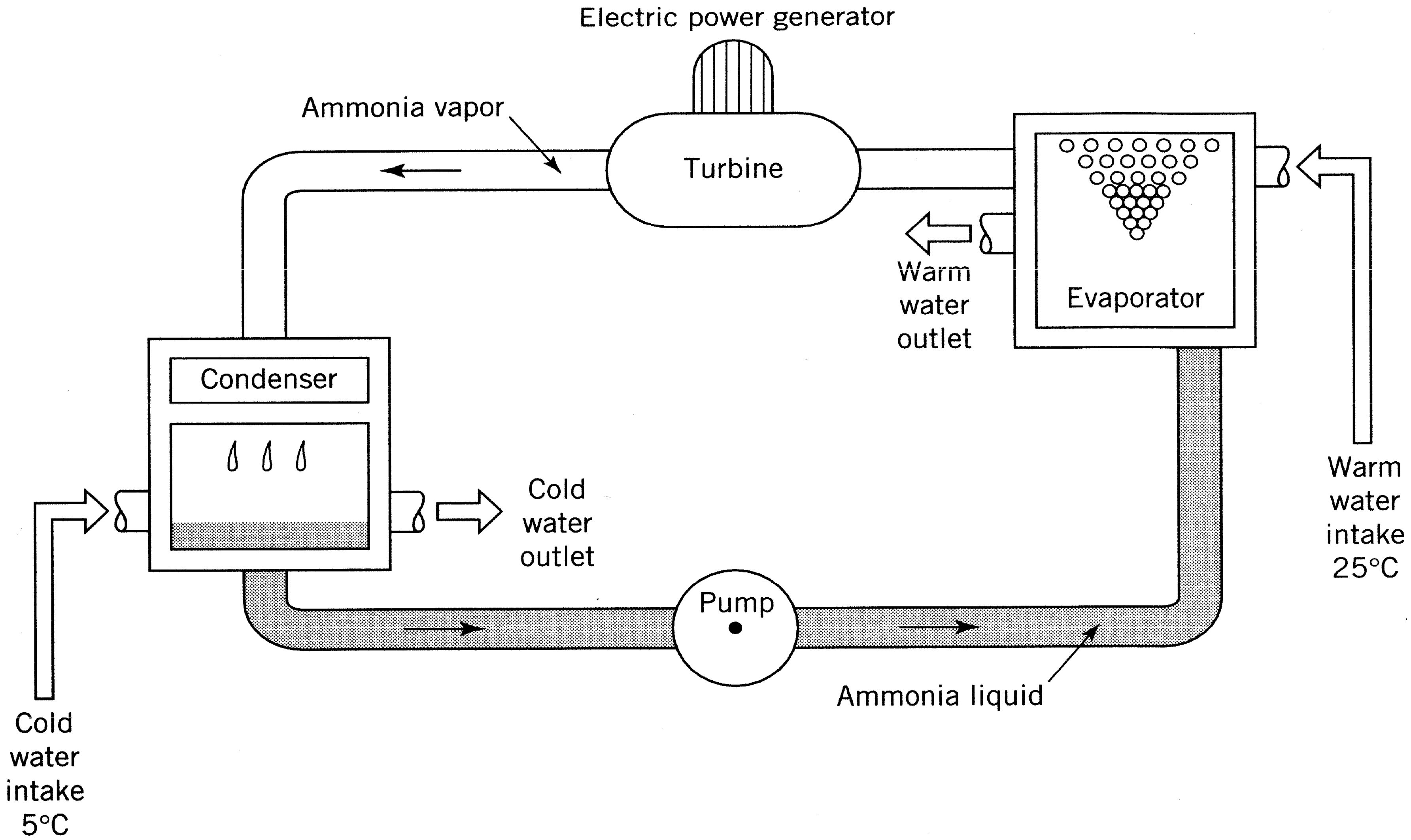
- The **closed cycle**, for its part, at the price of using a fluid of lower boilingpoint, such as ammonia, and exchangers with a large surface, allows the use of a turbine of smaller dimension (diameter 1 m for 1 MW).

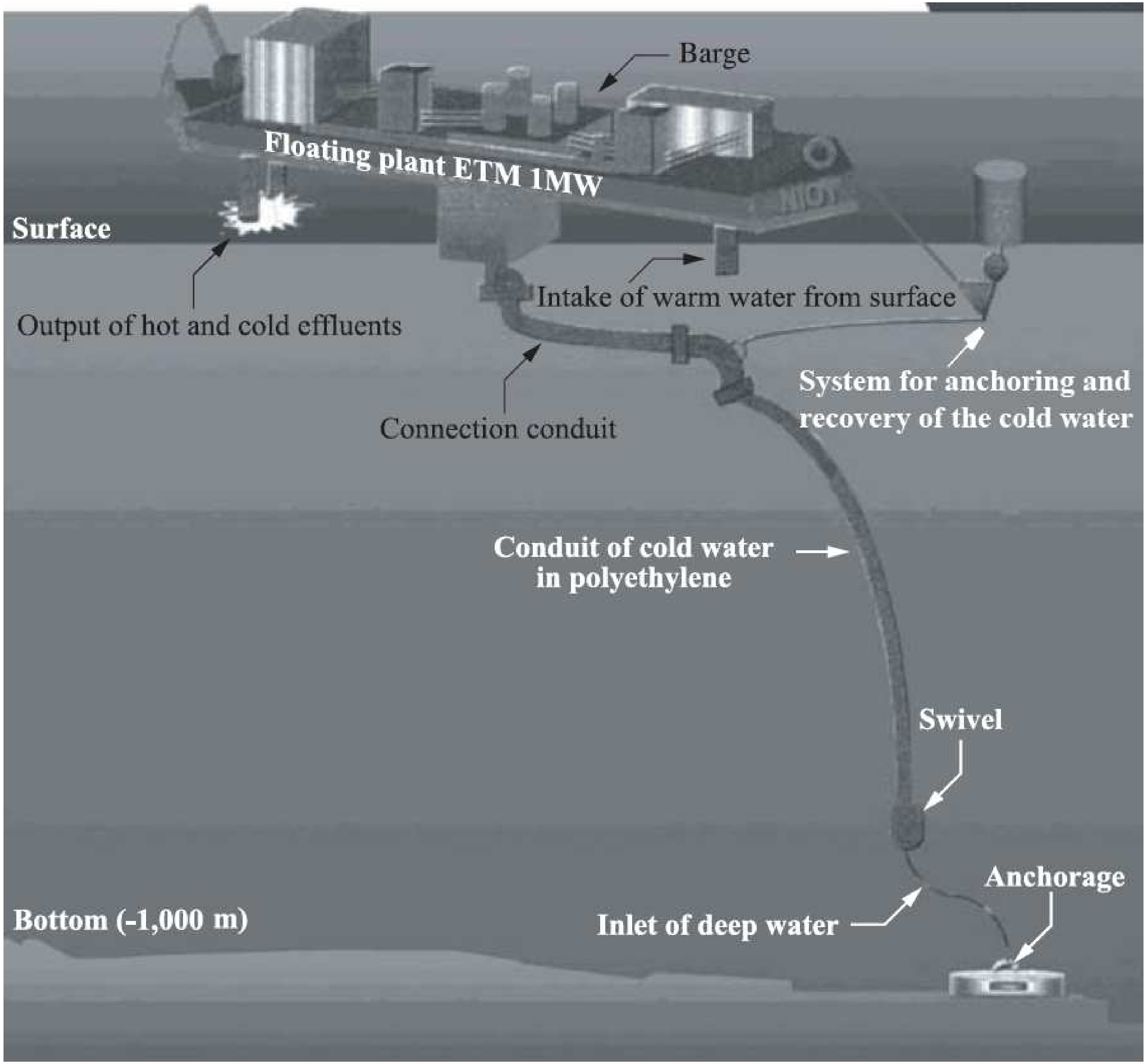
Ocean Thermal Energy Conversion (contd.)

- The exchangers should have surfaces of the order of 10,000 m^2 per MW and resist corrosion and biofouling. Materials used are titanium and aluminum. The battle against biofouling requires, if we want to avoid using chemical products (chlorine, for example), almost continuous mechanical washing.

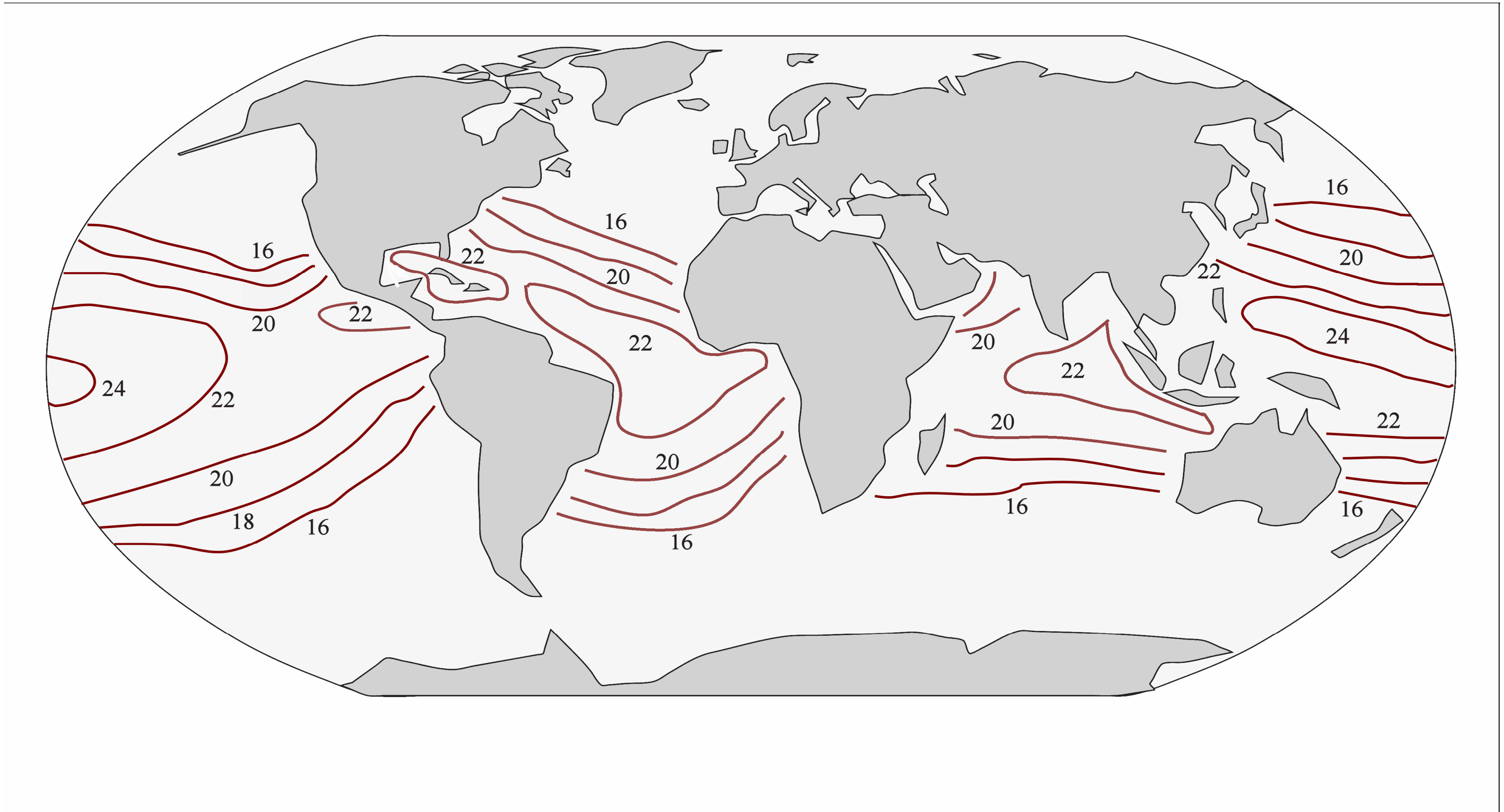
- If these methods can be put to long term use, OTEC power stations could first be used in islands in tropical and equatorial regions, where basic electricity production from fossil sources is increasingly expensive.


Expanding gaseous ammonia drives a turbine, generating electricity
POWER OUTPUT
TURBINE
Warm surface water vaporises ammonia
Deep ocean water cools the gas turning it back into a liquid
SURFACE WATER IN 15°C
VAPORISER
WATER OUT 10°C
CONDENSER
PUMP
OCEAN THERMAL ENERGY CONVERSION: uses the temperature difference between surface and deep ocean water to generate electricity
1000 metres
WATER OUT
DEEP OCEAN WATER IN 5°C


Electric power generator
Ammonia vapor
Turbine
Evaporator
Warm water outlet
Warm water intake 25°C
Condenser
Cold water outlet
Cold water intake 5°C
Pump
Ammonia liquid


Barge
Floating plant ETM 1MW
Surface
Output of hot and cold effluents
Intake of warm water from surface
Connection conduit
System for anchoring and recovery of the cold water
Conduit of cold water in polyethylene
Swivel
Anchorage
Bottom (-1,000 m)
Inlet of deep water

Global distribution of ocean thermal energy



The temperature difference (°C) shown is that between the surface and a depth of 1000 m [data from US National Renewable Energy Laboratory in RIS99]

References

- Sabonnadiere - Renewable Energy Technologies