Figure 10.29 The distribution of wave energy with wave period.

Figure 10.29 shows the relationship between the distribution of total oceanic wave energy and wave period. The energy of ordinary wind waves is high because these waves are always present and well distributed throughout all the oceans. Storm waves are larger and carry more energy, but they do not occur as frequently and are present over much less of the ocean area. Therefore, storm waves have less total energy than ordinary wind waves. Tsunami-type waves contain a large amount of energy, but they are infrequent and confined to fewer areas of the oceans. The tides, when considered as waves, concentrate their energy in two narrow bands centered on the twice-daily and once-daily tidal periods. Tide wave forms are discussed in chapter 11.

10.12 Practical Considerations: Energy from Waves

A tremendous amount of energy exists in ocean waves. The power of all waves is estimated at $2.7 \times 10^{12}$ watts, which is about equal to 3000 times the power-generating capacity of Hoover Dam. Unfortunately for human needs, this energy is widely dispersed and not constant at any given location or time. It is, therefore, difficult to tap this supply to produce power, except in small quantities.

Wave energy can be harnessed in three basic ways: (1) using the changing level of the water to lift an object, which can then do useful work because of its potential energy; (2) using the orbital motion of the water particles or the changing tilt of the sea surface to rock an object to and fro; and (3) using rising water to compress air or water in a chamber. A combination of these may also be used. If the wave motion is used directly or indirectly to turn a generator, electrical energy may be produced.

Consider a large, surface float with a hollow cylinder extending down into the sea (fig. 10.30). Inside the cylinder is a piston, and the up-and-down motion of the surface float causes the cylinder to move up and down over the piston, while the large drag plate restricts the motion of the piston. The system takes in water as the surface buoy rises on the crest of the waves and squirts water out as the surface buoy drops with the passing of the trough. The pumped water can be used to turn a turbine, but because wave energy is distributed over a volume of water, this mechanism does not withdraw much of the passing wave’s energy. This system could be adapted to pump air rather than water.

Another system constructs a tapered channel perpendicular to the shore. Incoming waves force the water up 2–3 m (6–10 ft) in the narrow end of the channel, where it spills into an elevated storage tank, then down through a turbine. This system is used to generate power by a 75-kilowatt plant on Scotland’s Isle of Islay, a 350-kilowatt plant at Tofestalen, Norway, and two 1500-kilowatt plants, one in Java and the other in Australia. Both the surface float and the tapered channel are examples of changing the level of an object or the water itself to create potential energy.

Wave power systems that use the orbital or rocking motion of the waves are under study in Great Britain. Long strings of
Figure 10.31 Each rise and fall of the waves pumps pulses of compressed air into a storage tank. A smooth flow of compressed air from the storage tank turns a turbine that generates electricity.

Figure 10.32 Japan’s “Mighty Whale” was launched in March 1998 and has been undergoing trials as a wave absorber and energy source.

mechanical power units are moored in water where waves are abundant. Each passing wave makes the power units move relative to each other, causing pumps to move oil that passes through a turbine in a closed system.

In Western Australia, the Azores, and Japan, other systems using wave energy to compress air are being developed (fig. 10.31). Air traps can be installed along a wave-exposed coast so that the crest of a wave moving into the trap compresses air forcing it through a one-way valve; the air traps can also be constructed to pass air in either direction. This compressed air powers a turbine. The trough of the wave allows more air to enter the trap, readying it for compression by the following wave crest.

Japan launched a prototype unit, the “Mighty Whale,” in 1998 (fig. 10.32). The unit is 50 m (164 ft) long, 30 m (98 ft) wide, and 12 m (39 ft) in depth. The Mighty Whale faces the waves, allowing the water level to rise and fall in three internal air chambers. The oscillating water forces air past turbines that function in two directions. The power capacity of each unit is set at 110 kilowatts. A series of these units linked side by side is expected to act as a breakwater and furnish energy, aeration, and purification of seawater at fish farms.

Shores that are continually pounded by large-amplitude waves are most likely to be developed for wave power. Great Britain has a coastline with frequent high-energy waves and an average wave power of about $5.5 \times 10^4$ watts (or 55 kilowatts) per meter of coastline. If the wave energy could be completely harnessed along 1000 km (620 mi) of coast, it would generate enough power to supply 50% of Great Britain’s present power needs. Along the northern California coast, waves are estimated to expend $23 \times 10^6$ kilowatts of power annually; it is thought that $4.6 \times 10^6$ kilowatts, or 20%, could be harvested to generate electrical power. The Pacific Gas & Electric Company, a northern California utility, has considered installing a generating device in a breakwater planned for Fort Bragg, California.

When we think about wave energy systems, thoughtful consideration needs to be given to items other than cost. If all the energy were extracted from the waves in a coastal area, what effect would this action have on the shore area? If the nearshore areas are covered with wave energy absorbers 5–10 m (15–33 ft) apart, what will the effect be on other ocean uses? Since the individual units collect energy at a slow rate, can they collect enough energy over their projected life span to exceed the energy used to fabricate and maintain them? Answers to these questions will help us understand that the harvesting of wave energy is not without an effect on the environment, that it may not be either cost-or energy-effective, and that its location may present enormous problems for installation, maintenance, and transport of energy to sites of energy use.