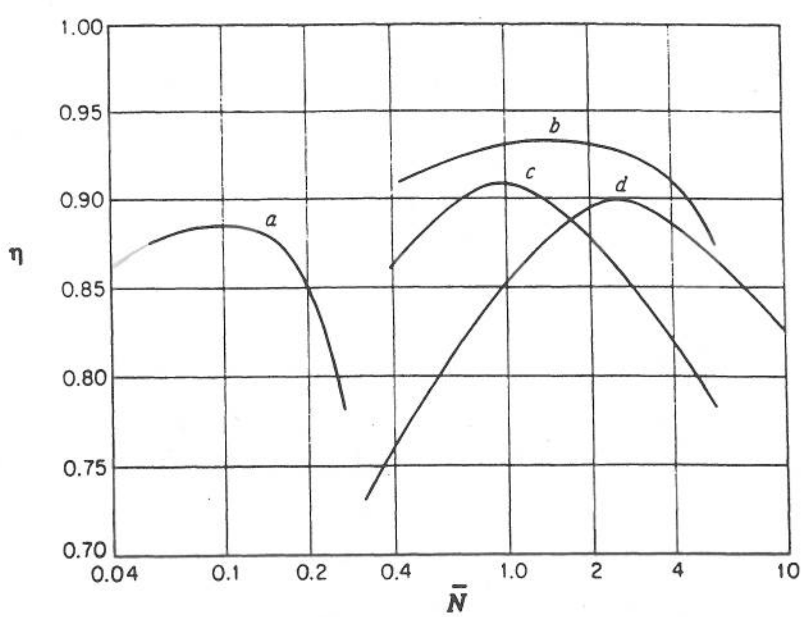

Figure 2.9 Operating range and typical efficiencies of various turbomachinery based on specific speed parameter. (a) Pelton wheel. (b) Francis propeller turbine. (c) Large single-stage centrifugal pump. (d) Axial compressors. (stage efficiency) (From Csanady, "Theory of Turbomachines," 1964; reprinted with permission from McGraw-Hill).

The usefulness of the concept of specific speed lies in deciding whether to use an axial or a centrifugal type of turbomachine for a compressor/pump or turbine. A centrifugal compressor/pump would be more suitable for low-volume flow rate with high head rise. For high volume and low head rise, an axial compressor/pump is more suitable. The peak efficiencies of each type of machine occur in different ranges of specific speed values $\bar{N}$ (see Fig. 2.9; Csanady, 1964). When we examine the cases illustrated in Fig. 2.9, we note that centrifugal compressor efficiency will peak around $\bar{N} = 1$, while the peak efficiencies of an axial flow compressor will occur at much higher values of $\bar{N}$.

2.4.4 Relationship to Cavitation in Pumps

In liquid handling machinery (hydraulic pumps, turbines, rocket pumps, etc.), a widely encountered phenomena is "cavitation." Cavitation is the formation of vapor bubbles when the static pressure is reduced locally below the fluid vapor pressure. Cavitation in turbomachinery may occur on the suction surface and near the blade tip region due to the presence of a vortex and also at other locations where the fluid pressure falls below the vapor pressure. The occurrence of cavitation is followed by a decrease in the pressure change

and a drop in efficiency. One of the most important effects is the subsequent collapse of the bubble in the region of pressure rise. This is accompanied by erosion and material damage. Further treatment of this subject will be covered later. The cavitation performance of a turbomachine can be represented by a cavitation parameter, commonly known as the *Thoma parameter*, given by

$$\tau = \frac{2(P_{o1} - p_v)}{\rho V_1^2}$$

where p_v is the vapor pressure. The other form of the Thoma parameter is the net positive suction head (NPSH)

$$\tau = \frac{H_{sv}}{H} \tag{2.33}$$

where H_{sv} is the *net positive suction head* (*NPSH*) $(= H_s - h_v)$, H_s is the total head at the inlet, which includes both the kinetic and potential energy, and h_v is the head corresponding to vapor pressure (p_v/ρ), H is the total head rise.

The suction head is one of the major parameters used in evaluating the cavitation behavior of pumps. The cavitation behavior at a given speed and volume flow is a function of H_s. By normalizing H_{sv} by the total head of the machine H (which depends on Q and N), the dependency of the speed and the volume rate can be eliminated. Therefore, τ is a similarity parameter for cavitation, and it is possible to determine experimentally the cavitation characteristics at one speed and one volume rate and scale it up to determine the cavitation characteristics at a different value of Q and N.

One other method of evaluating the cavitation performance is through the definition of a "*suction specific speed*." This was first introduced by Bergeron (1940). Wislicenus (1965) provided a more comprehensive treatment on this subject. The suction specific speed is defined as

$$SS = \frac{N\sqrt{Q}}{(H_{sv})^{3/4}} \tag{2.34}$$

This is again a dimensional number and consistent units have to be employed. Suction specific speed is clearly a grouping of operating conditions that permit similar flow conditions to exist in similar liquid handling turbomachines. Constant values of both τ and SS, or of SS alone, will result in similar inlet flow and cavitation conditions. The suction specific speed of centrifugal pumps (Wislicenus, 1965) range from 7000 to 10,000 (rpm, gpm, ft), while the low-pressure axial turbopump inducer (similar to the rocket fuel pump inducer shown in Fig. 1.7) used in the space shuttle has a specific