14.5 DISPLACED ENHANCEMENT DEVICES

14.5.1 Single-Phase Flow

The use of several different types of inserts, which are categorized as displaced enhancement devices, is documented in the literature (Bergles et al., 1995; and Bergles 1998). They include static mixer elements (e.g., Kenics, Sulzer), metallic mesh, disks, rings, or balls, which tend to "displace" the fluid from the core of the channel to its heated or cooled wall, and vice versa; the heat transfer surface itself remains unaltered. The earliest set of data on displaced enhancement devices was perhaps reported by Koch (1958), who tested two such devices: suspended rings and disks as inserts, and tubes packed with Raschig rings and round balls. The disks were found to promote higher heat transfer with rather moderate increases in the friction factor penalty. In the case of rings and round balls, although the heat transfer improvements were comparable to that with disks, the friction factors were exorbitantly high (more than 1600%). Several studies (Van Der Meer and Hoogenedoorn, 1978; Marner and Bergles, 1978; Lin et al., 1978; Pahl and Muschelknautz, 1979) have reported the performance of different types of static mixers, and a comprehensive review of their characteristic features is given by Pahl and Muschelknautz (1979). Most of these devices are, however, effective only in laminar flows, as in turbulent flows, the pressure-drop penalties are extremely high (Bergles, 1998). The application of static mixers is generally restricted to chemical processing with heat transfer, where fluid mixing is the primary need.

One of the newer displaced enhancement devices commercially available at the present time is the wire matrix insert shown in Fig. 14.28. A coiled-wire matrix, shaped in assorted size cloverleaf patterns, is metallurgically attached to a core rod, and this assembly, with different coil-matrix densities, is used as a tube insert. The wires tend to disrupt the core as well as boundary layer flows, thereby promoting better mixing and enhanced heat transfer. Oliver and Aldington (1986) have reported limited data for laminar flows of viscous liquids.

For high-temperature gas applications, classical examples that continue to be employed are bent tab, bent strip, punched-tab strip, and other types of inserts placed in

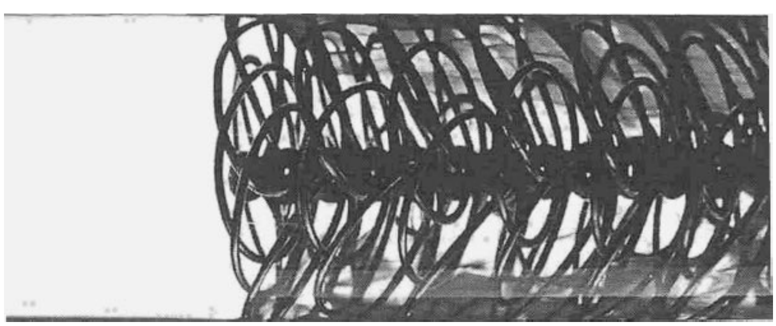

Figure 14.28 Heatex wire matrix tube inserts. (Courtesy of Cal Gavin Ltd.)

the flue tubes of fire-tube boilers and hot-water heaters. Although often referred to as baffles or retarders or turbulators, these inserts are basically mixing devices that increase the convective heat transfer coefficient in turbulent flows (Koch, 1958; Evans and Churchill, 1963; Nirmalan et al., 1986; Junkhan et al., 1988). Similarly, spiral brush inserts in short channels with turbulent flows and high wall heat flux have been tested by Megerlin et al. (1974). Although the heat transfer coefficients improved by as much as 8.5 times that in a smooth tube, the pressure drop was exorbitantly high. The latter aspect of displaced enhancement devices in general has restricted their use in practical applications.

14.5.2 Boiling

A limited number of studies have reported the use of displaced enhancement devices in boiling applications to increase CHF (Bergles, 1998). These have included rings, spacers, inserts (mesh or brush type), and so on, for both bulk and subcooled boiling conditions (Megerlin et al., 1974; Ryabov et al., 1977; Bergles, 1998). Much of this work was carried out in the late 1960s and early 1970s, driven primarily by the needs to address ways to increase CHF in nuclear power plants, and such devices have not received attention recently.

14.5.3 Condensing

As in the case of boiling, displaced enhancement devices have not found much use in condensation applications. Only two rather dated studies (Azer et al., 1976; Fan et al., 1978) appear to have considered the use of Kenics static mixer inserts experimentally. The improvements in heat transfer coefficients, however, were once again accompanied by a very high pressure-drop penalty.

14.6 SWIRL FLOW DEVICES

Swirl flow devices generally consist of a variety of tube inserts, geometrically varied flow arrangements, and duct geometry modifications that produce secondary flows. Typical examples of each of these techniques include twisted-tape inserts, periodic tangential fluid injection, and helically twisted tubes, shown schematically in Fig. 14.29. Of these, twisted-tape inserts have received considerable attention in the literature, and their thermal–hydraulic performance in single-phase, boiling, and condensation forced convection, as well as design and application issues, have been discussed in great detail (Manglik and Bergles, 2002a).

14.6.1 Single-Phase Flow

Perhaps the most effective and widely used swirl flow device for single-phase flows is the twisted-tape insert, which has design and application literature dating back more than a century (Whitham, 1986). It has been shown to increase significantly

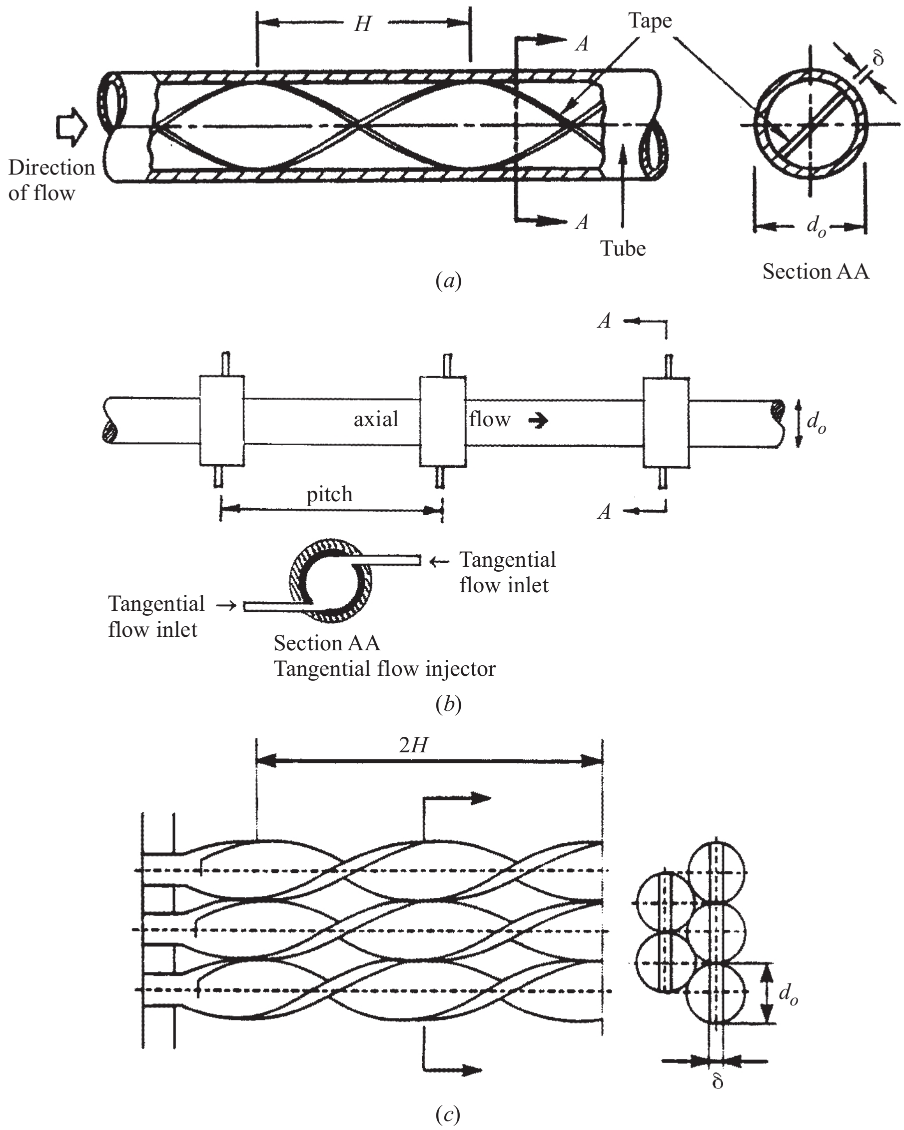

Figure 14.29 Typical examples of swirl flow devices: (*a*) twisted-tape insert; (*b*) altered tube flow arrangement; (*c*) twisted duct. (From Manglik and Bergles, 2002a.)

the heat transfer coefficient with a relatively small pressure-drop penalty (Smithberg and Landis, 1964; Lopina and Bergles, 1969; Date and Singham, 1972; Hong and Bergles, 1976; Marner and Bergles, 1989; Manglik and Bergles, 1991; 1992; Manglik and Yera, 2002). Frequent use of twisted tapes is in retrofit of existing shell-and-tube heat exchangers to upgrade their heat duties. Also, when employed in a new