5.1.2 Heat source

As discussed earlier in section 2.3.1, heat is produced within a nuclear reactor as a result of fission. The energy released is initialy manifest primarily as the kinetic energy of fission products, of fission neutrons and of gamma radiation. Additional energy is released as the fission products later decay as discussed in section 2.3.4. The kinetic energy is then converted to thermal energy as a result of the collisions of the fission products, fission neutrons and gamma radiation with the rest of molecules in the reactor core. The majority of this energy (about 80%) is derived from the kinetic energy of the fission products. The fission neutrons and gamma radiation contribute about another 6% of the immediate heat production. This immediate energy deposition is called the *prompt heat release* to distinguish it from the subsequent, *delayed heat release* generated by the decay of the fission products. This decay heat is significant and contributes about 14% of the energy in an operating thermal reactor. As discussed earlier in section 2.4.2, the fission product decay not only produces heat during normal reactor operation but that heat release continues for a time after reactor shutdown. Typically, after shutdown, the heat production decreases to 6.5% after one second, 3.3% after one minute, 1.4% after one hour, 0.55% after one day, and 0.023% after one year.

Most of this chapter focuses on how the heat deposited in the core is transferred out of the fuel and into the core during normal reactor operation. Since almost all of the heat deposited, whether prompt or delayed, is proportional to the neutron flux it will be assumed in the rest of this chapter that the rate of heat production is directly proportional to that neutron flux. Since the mean free path of the neutrons is large compared with the fuel rod dimensions, the neutron flux distribution is nearly uniform over the cross-section of the rod though the flux in the center is somewhat less than at larger radii (because thermal neutrons that enter the fuel from the moderator or coolant are absorbed in greater number near the surface of the fuel). For present purposes it will be assumed that flux is uniform over the cross-section of the fuel rod and therefore the rate of fission and, to a first approximation, the rate of production of heat is uniform within a fuel pellet. Thus the first component of the analysis that follows concentrates on how the heat is transferred from an individual fuel rod to the surrounding coolant.

However, the neutron flux does vary substantially from one fuel rod to another within the reactor core. Consequently, the second component of the analysis that follows focuses on how the heat transfer varies from point to point within the reactor core.