Adipic Acid (92-4)

Without exception, currently operating commercial production processes for adipic acid depend on the production or purchase of KA Oil (a mixture of cyclohexanone, the ketone or K component, and cyclohexanol, the alcohol or A component) or of pure cyclohexanol and its subsequent oxidation in solution to adipic acid using an excess of strong nitric acid. BASF had announced its intention to produce 50,000 metric tons per year adipic acid by C_4 carbonylation at Ludwigshafen, Germany, which would have been an exception, but this project has been postponed.

By far the most common route to the KA Oil needed for adipic acid production is the air oxidation of cyclohexane. Most commercial routes combine hydroperoxide formation and decomposition in the presence of a catalyst, most commonly low concentrations of cobalt salts, sometimes combined with other metals. An alternative commercially established route uses substantial quantities of recycled boric acid as a catalyst, which also forms an ester with the cyclohexanol as it is formed. Phenol hydrogenation is an alternative route used commercially to produce KA Oil for adipic acid.

Yet another route has very recently been commercialized on a smaller scale by Asahi Chemical Company. This involves partial hydrogenation of benzene over a complex ruthenium catalyst under high pressure to form predominantly cyclohexene. The cyclohexene is subsequently hydrated under moderate conditions in the presence of a slurry catalyst, consisting mainly of zeolites, to give cyclohexanol. Cyclohexane, which is a by-product of the benzene hydrogenation, is assumed to be separated by an extractive distillation process and sold as a by-product.

These four routes have very different characteristics and cost distributions, ranging from the high raw material costs but comparatively low capital costs for the phenol-based route to the reverse situation for the Asahi route, assuming all are operated on the same large scale of about 220,000 metric tons per year. Production costs for each of these routes have been developed and are given in the report.

Nitric acid oxidation produces both nitrous oxide, N_2O, and NO_x (NO, NO_2, and higher oxides). Generally speaking, nitrous oxide discharge has not been controlled but NO_x effluent has been regulated for many years. There is one established (but expensive) process for N_2O removal in use, namely noncatalytic incineration of tail-gas with added fuel under reducing conditions, which decomposes nitrous oxide to nitrogen and oxygen. The heat generated can be recovered as steam, which can be credited, thus reducing running costs, but the equipment requires substantial capital investment. Very limited

information has been released on selective catalytic methods for decomposing nitrous oxide. DuPont itself, as well as several catalyst manufacturers, has developed processes to decompose nitrous oxide into nitrogen and oxygen at 600-700^{o}C.

Adipic acid is produced at the rate of somewhat over 1.5 million metric tons per year world wide. The major use of adipic acid is to produce nylon 6/6. The market for nylon 6/6 is predominantly in fibers, while high-specification nylon 6/6 resin, with or without fillers or modifiers, provides the other substantial outlet for nylon 6/6.

Adipic acid and nylon 6/6 supply in North America, Western Europe, and Japan is dominated by its major primary producers, their subsidiaries, and associated companies: DuPont, BASF, Monsanto, Rhone-Poulenc, Asahi Chemical, Bayer, and AlliedSignal. The technologies for adipic acid and nylon 6/6 production are closely held by these companies.

Demand for adipic acid is expected to grow modestly in the United States and Japan, but demand in Western Europe has declined partly because of closure of adipic-based adiponitrile capacity and will recover only to about 1992 demand levels by 2000. Imports of nylon chip will further limit domestic market growth in Western Europe and Japan, based on Eastern Europe and Far East sources, respectively. The United States and Japan will remain net importers of adipic acid but Western Europe will probably expand as a net exporter in view of its excess capacity.