CHAPTER 33

ELECTRON TUBES AND VACUUM EQUIPMENT

Photograph courtesy of Wesgo Metals Division, Morgan Advanced Ceramics
INTRODUCTION

The brazing of structures for vacuum tubes and other high-vacuum devices has required the development of highly refined cleaning and handling procedures, furnace equipment, and high-purity, low-vapor-pressure brazing filler metals. Vacuum tubes, of necessity, are operated at very low pressures \([10^{-6} \text{ torr to } 10^{-8} \text{ torr (}10^{-4} \text{ Pa to } 10^{-6} \text{ Pa})]\) and must maintain this very low pressure for the thousands of hours of their useful life.

High-vacuum devices and specialized equipment cannot tolerate conditions that inhibit the ability to secure and maintain extremely low pressures. As a further complication, electron tubes and other vacuum devices are heated to temperatures beyond 932°F (500°C) for extended periods during their gas evacuation cycle (bake out) to drive out the gases entrapped in their metal structures.

The operating conditions of vacuum tubes include elevated temperatures, high voltages, and/or high electrical currents. To meet the rigorous operating conditions, widely dissimilar materials must be used in construction. Thus, prior to the brazing of components for electron tubes and vacuum devices, the problems of differential thermal expansion, particulate control, and outgassing must be addressed during the design stage after a thorough analysis of the required operating environment and conditions has been completed.

BASE MATERIALS

An entire class of metal alloys has been developed to address the problem of thermal expansion mismatch, which arises when brazing ceramics to metals, a common occurrence in vacuum tube fabrication or vacuum equipment electrical feedthroughs. The majority of controlled-expansion alloys can be separated into two systems, iron- and nickel-based alloys or iron, nickel, and cobalt (fenico). Although many compositions of fenico are in use, the most common composition is Fe-29Ni-17Co.

COPPER AND NICKEL ALLOYS

Copper-based alloys containing high-vapor-pressure elements should be avoided when fabricating electron tubes and other vacuum devices. Oxygen-free high-conductivity copper (OFHC) is the preferred material in most cases when the annealed strength of pure copper is not an issue.

Although most nickel-based alloys and superalloys are vacuum compatible at elevated temperatures, high coefficients of thermal expansion often prevent their use as structural materials in electron tubes. Commercially pure nickel (UNS N02200), however, being more ductile than nickel alloys, is often used in electron tubes.\(^1\)

STAINLESS STEELS

Stainless steels are used frequently in the manufacture of vacuum equipment and hardware. For structural assemblies and vacuum chambers, low outgassing rates, high strengths, low costs, high availabilities and ease of joining make stainless steels the material of choice.