treatment includes the machining operations, secondary finishing operations such as grinding, polishing, etc., chemical treatment, thermal treatments, and cleaning operations. The importance of surface preparation in gas-pressure bonding cannot be overemphasized. The presence of contamination in the form of dirt, oxide films, etc., can prevent diffusion across the interfaces and result in poor bonding. Since only microdeformation occurs in gas-pressure bonding, there is no opportunity to break-up and disperse the contamination during the bonding process. It therefore must be removed prior to assembly of the components for bonding. The optimum surface preparation varies with different materials and few generalizations can be made regarding the best techniques. It is safe to say, however, that all possible steps must be taken to provide the cleanest surface for bonding. Surface roughness is also important since the rougher the surface, the more difficult it is to move the surfaces into complete intimate contact. This means that attention must be given to the type of machining operation used to finish the geometries to final dimensions. Naturally, grinding operations produce smoother surfaces than other machining operations; however, grinding grit tends to be embedded in the surface and sometimes interfers with bonding if not removed by a subsequent etching operation. Hence, it is apparent that all surface-finishing operations must be carefully evaluated and integrated to insure a surface suitable for diffusion bonding.

The actual bonding parameters of temperature, pressure, and time are all interrelated. Since diffusion phenomena are controlled by both time and temperature, this importance is rather obvious. Also, as in any heat treatment, they control the final grain size, base-metal properties, and potential contamination from the surrounding environment. Sufficient pressure must be available to move the surfaces into intimate contact. The higher the temperature or the longer the time, the lower the pressure which must be applied since creep is the primary method of macrovoid closure. Lower pressures are more economically achieved and therefore pressure should be minimized where possible. Therefore, one must establish the correct combination of these parameters which will yield the best bonding with a minimum of grain growth and base-metal property change.

Refractory Metal Bonds

Numerous refractory metal combinations have been successfully joined by gas-pressure bonding. However, all systems and combinations have not been optimized. Detailed discussions of experiments conducted on each system would yield a manuscript far too large to be useful to most readers. For this reason, the discussions which follow will concentrate on satisfactory bonding procedures and the resulting microstructures.

Columbium to Columbium

Bonding parameters of 1150° to 1325° C. and 10,000 psi for 3 hrs. yield high-integrity solid-phase bonds with columbium. Etching in a nitric-hydro-