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MASTER

THE HOT ISOSTATIC PRESSING EXPERIENCE
OF THE OAK RIDGE Y-12 PLANT

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UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** under **U. S. GOVERNMENT** Contract W-7405 eng 26

**UNION
CARBIDE**

OAK RIDGE Y-12 PLANT
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UNION CARBIDE CORPORATION
Nuclear Division

Y-12 PLANT

Contract W-7405-eng-26
With the US Atomic Energy Commission

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ABSTRACT

Approved designs of hot-gas autoclaves in 1963 used the principle of minimizing gas convection currents. The hot isostatic pressing facility at the Oak Ridge Y-12 Plant is designed so that convection currents are maximized in the contained vessel. Argon is used to enhance this effect.

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SUMMARY

Industrial design of hot-gas autoclaves in 1963 used the principle of minimizing helium gas convection currents. The design of the facility at the Oak Ridge Y-12 Plant^(a) was directly opposite in that the convection currents were maximized in a contained vessel. Argon was used to enhance this effect.

One of the major problems in successfully operating a hot isostatic pressing facility is the construction of pressure transfer cannisters which will not rupture during compaction. Y-12 controlled this problem by designing cannisters in which the welds in tension were minimized or protected by frictionally loaded surfaces.

To compensate for differences in the thermal coefficients of the tooling and compacted parts, directional cooling was used.

(a) Operated for the US Atomic Energy Commission by the Union Carbide Corporation - Nuclear Division.

INTRODUCTION

The Y-12 Plant has been actively engaged in the development of hot isostatic pressing since 1963. This report presents, in a condensed form, the experience gained in both the design and operation of the Y-12 hot isostatic pressing facility.

REVIEW OF THE HOT ISOSTATIC PRESSING EXPERIENCE

CONVENTIONAL DESIGN

In the past, the Y-12 Plant has given considerable thought to the problem of maintaining uniform hot zones under hot isostatic pressing conditions. Since, at high pressures (15,000 psi) and temperatures (1,000° C), the density of the gaseous medium can approach that of water, the problem appeared to resolve itself into a need for controlling the resultant convection currents. General practice by industry in the United States, at the time of the initial study in 1963, was to minimize convection currents by packing the part to be compacted in some refractory (such as aluminum oxide). Helium was used as the pressure fluid, again to minimize convection currents. Some minor efforts, such as the use of a ceramic lid, were made to contain the currents in the furnace hot zone. This arrangement resulted in a hot zone with extreme temperature variations which were generally unpredictable when a new part geometry was introduced into the hot zone. Further, only a small portion (perhaps 40%) of the total hot zone was usable. The furnace design generally used consisted of stacked cylinders wrapped with heating coils with lengthwise multizone control.

Y-12 DESIGN

The approach to the design of the Y-12 Plant facility was diametrically opposite. Instead of minimizing convection currents, the design attempted to maximize them. Further, care was taken to contain the currents virtually totally within the hot zone. The Y-12 furnace design (shown in Figure 1) consisted, essentially, of an insulated metal bell jar which sat over a bottom heating coil. Two types of bell jars have been used: one type was a simple bell jar with no provision for separating the hot and cold gas currents; the other included a double inner wall. The space between these walls was open to the top of the hot zone and below the heating coil. This second design provided physical separation of some convection currents as well as a cold-gas return and appeared to function better, but both were satisfactory. In both cases, care was taken to provide a minimum annulus between the wall and part equal to about 25 to 30 percent of the hot-zone cross-sectional area. Failure to do this inhibited the convection currents, resulting in a sizable temperature differential, and, in some cases, overheating the elements. An initial pressure of 1,000 psi was required in order to obtain sufficient gaseous density to dissipate, by convection, the heat generated by the heating elements. When all these considerations were carried out properly, there was no detectable temperature difference in the hot zone (17 1/2" D x 50" L), the heating response was fast, and the desired temperature could be virtually "dialed into" the hot zone. The part to be compacted was transported to the autoclave inside the bell jar; and, at temperature, was supported by columns rising above the heating coil. Small parts were packed in a granular refractory bed contained inside a perforated metal can.

Figure 1. DESIGN OF THE Y-12 HOT ISOSTATIC FURNACE.

SPECIAL TECHNIQUES

A special problem was to find a way to can the part in a material which would be ductile enough at temperature to transfer the compacting pressure without rupturing the can. Another part of this problem was to choose a material that would not react with the part at the operating temperature. The solution to this problem may require the use of two cans: a nonreactive can around the part (not necessarily leak proof) and an essentially leak-proof pressure transfer can. Y-12 has significantly reduced the

problems of pressure cannister leakage by isolating cannister construction welds that would be under tension at the operating temperature, and by providing a high-pressure bleed-off tube. These features are shown schematically in Figure 2 and by the photograph of Figure 3.

Figure 2. DESIGN OF THE PRESSURE-PROTECTED WELD JOINT.

As seen in Figure 2, the vessel pressure exerts forces upon annulus lips which result in frictional forces. If the annulus lip is long enough, these frictional forces are great enough to isolate the construction welds from tensional forces resulting from cannister deformation during compaction. Consequently, the deformational forces are compensated by flexure of the annulus lip.

The bleed-off tube serves several purposes. If a small leak is present or if one develops during the initial stages of compaction, the tube allows the pressure to

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Figure 3. HOT ISOSTATIC PRESSED PART. (Showing the Outgassing Stubs, Vented Cannister, and Pressure-Protected Weld Joint)

escape from the cannister, thus avoiding equalization of pressures both inside and outside the cannister. Obviously, if the pressures are equal, no compaction will occur. As compaction and consequent cannister deformation continue, the gaseous escape paths are sealed off and, in practice, some material usually extrudes into the bleed-off tube.

It has been Y-12's practice to outgas the part at sufficient temperature to drive off all the absorbed water and oxygen. This step can be a time-consuming process and the required temperature has been as high as 800° C. The presence of additional bleed-off tubes materially speeds up this cycle. These additional bleed-off tubes are usually sealed off after the outgassing step and therefore need not be high-pressure tubing.

To minimize strains induced into the cannister during compaction, a close-fitting, prepressed (at ambient temperatures), and premachined compact is desired. This need is especially evident for large parts. However, parts have been made using loosely filled powder compacted only by vibration. Fabrication of hollow shapes usually involves the use of a mandrel. As such, the comparative thermal properties become important. Unless corrective steps are taken, the usual heat flow is through the outer surface allowing the part to shrink upon the mandrel and to develop hoop stresses, sometimes sufficient to crack the part. Providing means to cool the inner surface of the mandrel with the bell jar acting as an insulator, as shown in Figure 4, reverses the direction of the heat flow. This procedure, when coupled with materials having the proper thermal coefficients, maximizes the probability of success.

Figure 4. DESIGN OF THE INTERNAL COOLING ARRANGEMENT.