Copy.

THE STRUCTURAL INTEGRITY OF INJECTION MOLDED F-15 ALLOY

Abstract

Microelectronic packages are now being produced in commercial volumes using injection molded F-15 Alloy. Section thicknesses as low as 0.010 inch thick are being utilized in injection molded packages that are leak tested to a limit of 2 X 10^{-10} CC of He/sec. and guaranteed to 1 X 10^{-9} CC of He/sec. This paper explores microporosity normal to metal injection molded parts and examines the mechanisms that insure high reliability in regard to hermeticity.

The Authors are:

Dr. John E. Ahearn, P.E. Materials Technologist of Isotronics

Dr. Ian S.R. Clark, Materials Technologist of Fine Particle Technology Corporation.

ISOTRONICS

ISOTRONICS, INC., Industrial Park, New Bedford, Massachusetts 02745-1283 (508) 998-2000 FAX (508) 998-2835

The hybrid packaging industry is the beneficial recipient of injection molded, glass-to-metal sealed packages of F-15 Alloy (Kovar TM Carpenter Steel), sealed, plated, and shipped to the most stringent standards. Finished packages, prior to plating, after plating, and following environmental tests required to meet government specifications, have been leak tested after each step to 2 X 10^{-10} CC of He/sec. using the new 947 Varian leak tester. These packages are guaranteed to a hermeticity of 1 X 10^{-9} CC He/sec.

An outline of the injection molding process used to fabricate these microelectronic packages is shown in Figure 1.

A. Pure Co, Ni and Fe powders such as those shown in Fig. 2 and having diameters $<$ 10 μm are blended to the appropriate F-15 composition.

B. These powders are combined with a proprietary multicomponent binder system to provide a uniform plasticised mix at the injection molding temperature. Feedstock for injection molding, as shown in Fig. 3, is created by granulating the mix.

C. The granulated feedstock is fed into an injection molding machine in the same manner as for plastic parts. The product is a "green" part, Fig. 4, with suitable shape but oversized to accommodate the shrinkage which occurs during the subsequent sintering.

D. Removal of the gate and runner system occurs in the "green" state by trimming. No sand, grit, or glass blasting is used.

E. The multicomponent binder system is removed by a thermal debinding procedure which is controlled to produce residual carbon in the part at levels of $<$ 0.01%. Parts at this stage retain their shape either from residual amounts of binder or from the onset of sintering and are called "brown" parts based on their color. Fig. 5, shows a SEM photomicrograph of the surface of a brown part.

F. Sintering under controlled conditions of time (several hours), temperature (over 1200^{o}C), and atmosphere (reducing) produces a tough, ductible, and easily welded structure that readily accepts glassing and plating. Sintering also causes the injection molded parts to shrink from the mold size by a nominal 14 percent. However, the shrink is very predictable and reproducible and tolerances of less than 0.003 in/in can be maintained. See Fig. 6

A practical shift of grain size from ASTM #9 or finer to larger sizes, up to about ASTM #4, was inherent under the manufacturing conditions necessary for injection molding of F-15 Alloy, as shown in Fig. 7. The main concern during the injection molding of F-15 Alloy is that decarburization be continued to such a degree that the temperature for spontaneous grain transformation to matensite is suppressed well below -100^{o}C. With freedom from partial transformation in our injection molded F-15 Alloy, glass cracking is no more of a problem than is incurred with wrought F-15 composition.

A second consideration is that of microstructural porosity. In the past, F-15 Alloys made with conventional powder metallurgical techinques exhibited microporosity that did not permit the easy manufacture of hermetic packages. We are not finding such structural deficiencies with injection molded packages and have repeatedly tested 750 parts to better than 1 X 10^{-9} CC of He/sec. The microstructural porosity in these highly hermetic molded packages in non interconnected and thus does not provide a leak path. Fig. 8a shows the typical microporosity in the center of a cross-section while Fig. 8b shows the typical lower level of porosity near the surface of the cross-section.

Our explanation for this blessing from the bountiful hand of Mother Nature is as follows: The very fine metal powders ($<$ 10 um dia.) have high specific surface energies compared to the much coarser powders used in conventional powder metallurgy. These high specific surface energies are the sole driving force for consolidation of the parts during sintering. No pressing, rolling or other consolidation techniques are necessary. So great is this driving force, that the densities of the sintered parts are $\approx$ 95% of full density.

To demonstrate that the non-interconnected porosity provides high hermeticity, a package with bottom thickness of only 0.010 inch thick was chosen first. Fig. 9 shows the dimensional information. The hermeticity of $>$ 2 X 10^{-10} CC of He/sec. was measured as stated earlier. Fig. 10 shows the finished package with leads glassed in position.

In the development area, we are examining three prospects that could be available by June 1988, God-willing and Mother Nature being of good disposition. These are:

1. 304-L Stainless Steel

2. 316-L Stainless Steel

3. Molybdenum

Molybdenum is a most exciting prospect in that direct sealing using a modified 7059 Type (Corning™) Glass is feasible. The oxide interface is very thin to colorless. It is anticipated that this material sealed to Mag-5 Glass, in development, will find suitability in applications involving the low temperatured associated with superconductivity and also in areas where freedom from magnetic influence is desirable.

Our present experience concerning the injection molding of microelectronic packages has been obtained via exposure to the following materials. These are:

1. F-15 or Kovar Alloy (Carpenter Technology, Reading, PA.™). This material is being used to fabricate a wide variety of package geometries glass-metal sealed with MAG-1 Glass (Military Armor Glass™, Isotronics Patent)

2. Invar - an alloy of about 36% Ni with the balance Fe composition, that has a CTE (Coefficient of Thermal Expansion) of about 2×10^{-6} in/in/^{o}C. Since this CTE matches that of Fiber Optic Glass, microelectronic packages designed for fiber optic applications manufactured from invar provide those properties necessary to enhance fiber optic coupling efficiency. Invars offer great advantages for such application.

3. Another useful material in the Ni-Fe family is that of 99% Fe - 1% Ni. This alloy approximates and betters many properties associated with low carbon, cold rolled steel. The powder metallurgy equivalent of CRSteel is far cleaner and uniform than the normal cold rolled steel available from third world countries at present.

4. Tungsten-Copper (W-Cu) alloys are most useful for high power devices in that their heat dissipation capability is highly desirable. The common 25%C-75%W injection molded material is about 12-13% more efficient in heat extraction capacity than Beryllium Oxide ceramic. This material is being widely accepted.

Conclusions:

1. Interconnected microporosity through the structure of parts made by injection molding F-15 Alloy does not occur or it would be impossible to obtain leak rates less than 1×10^{-9} CC of He/sec.

2. Photomicrographic studies indicating that microporosity is not interconnected, support the hypothesis of leak path incontinuity.

3. A 0.010 inch thick section is the thinnest member that we anticipate molding. Therefore, having encountered no leaking or detrimental porosity in the microstructure after hundreds of tests, we are confident that injection molding has successfully overcome this limiting design factor.

4. Applications, most complicated from a geometric standpoint, and in volumes exceeding 1,000 to 10,000 pieces are often more cost effective when fabricated by injection molding techniques than by any more traditional manner.

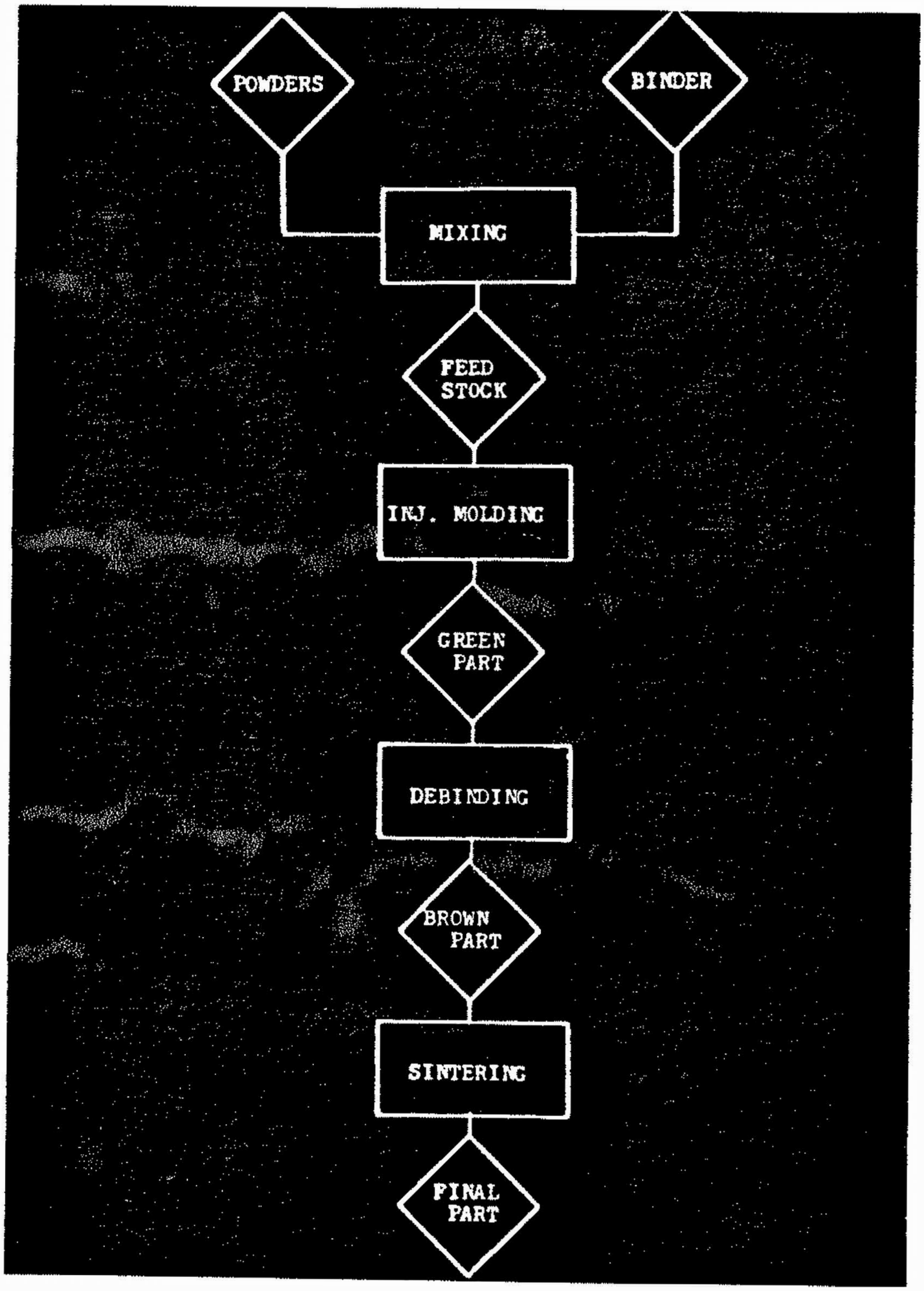
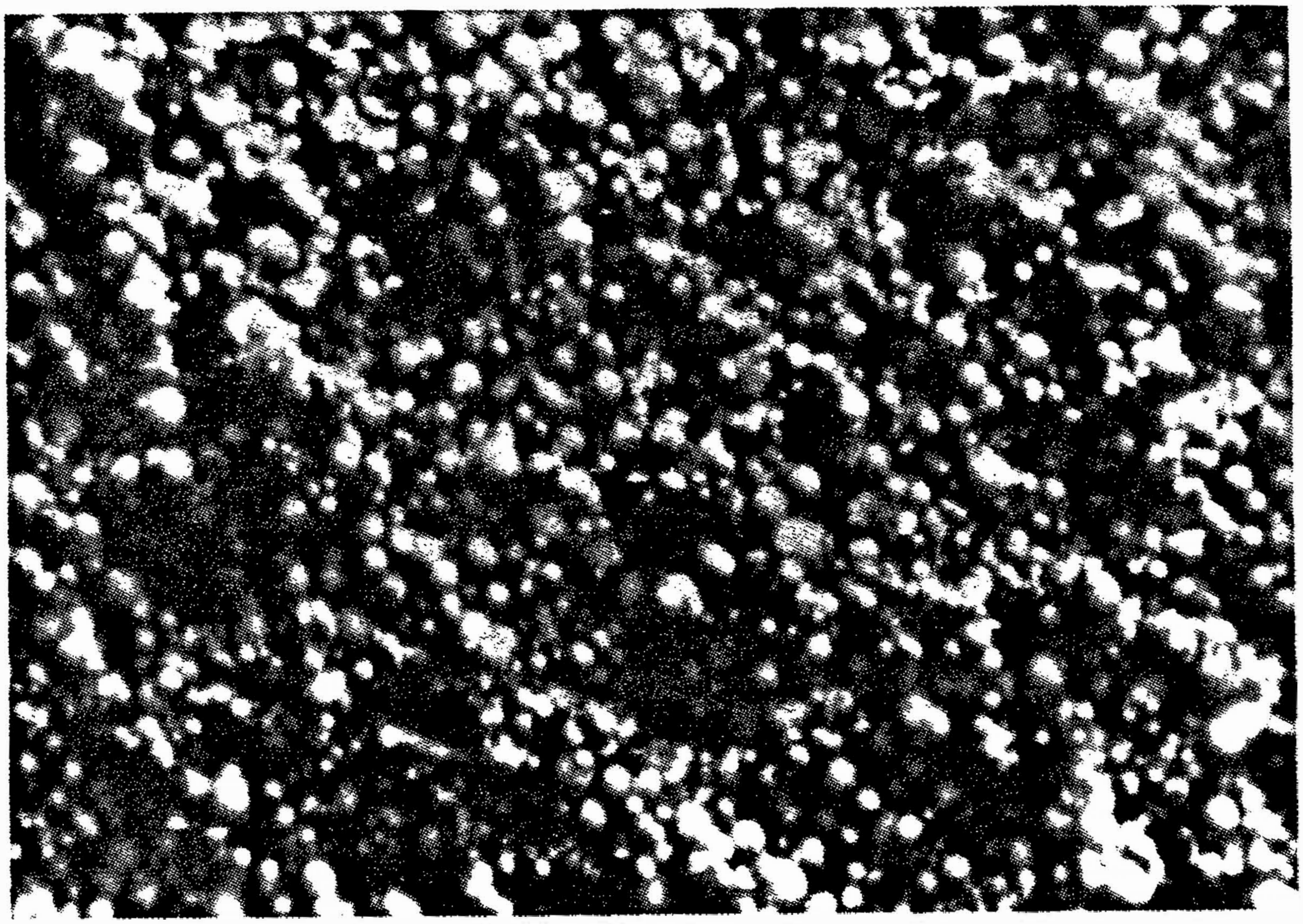
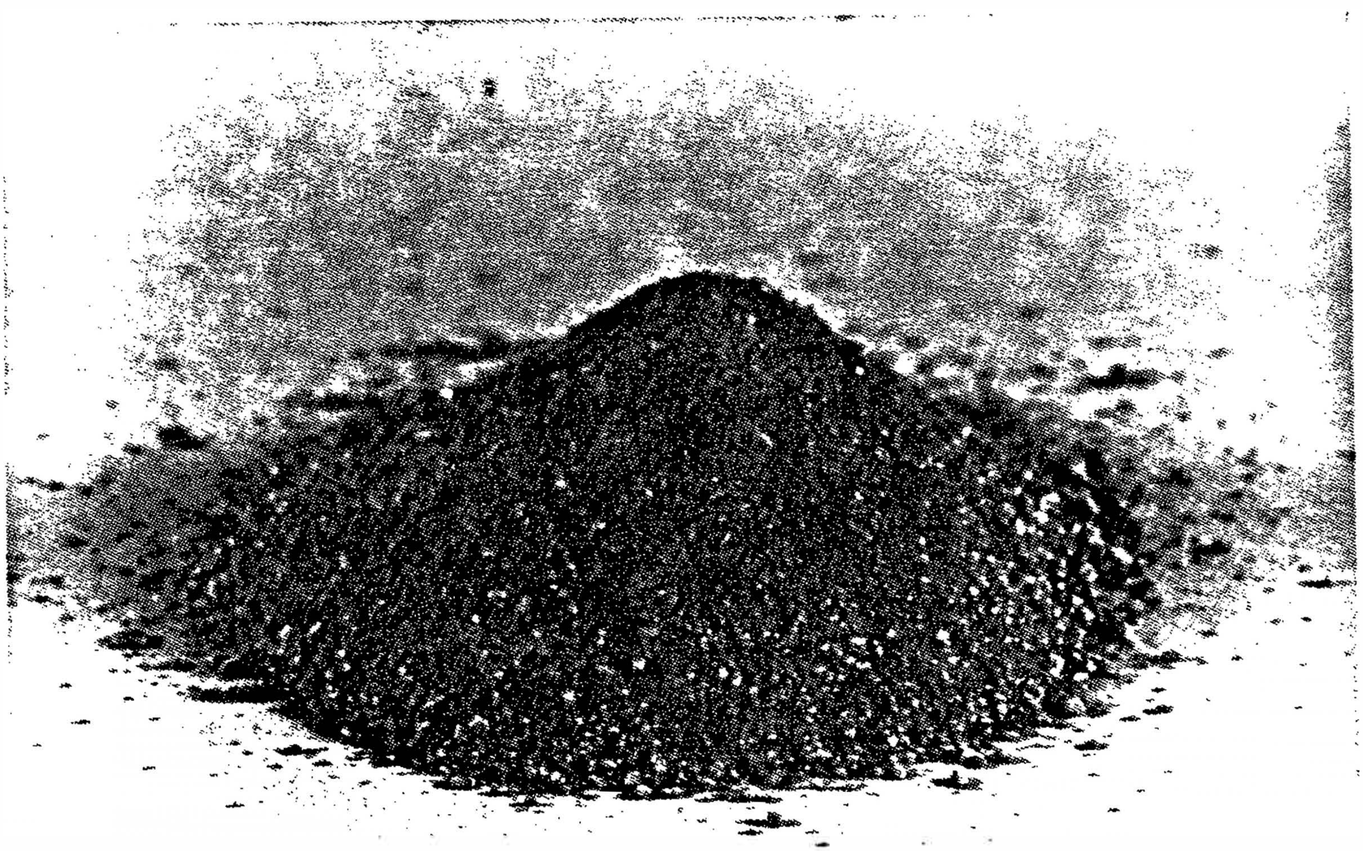


Figure 1: Schematic process flow sheet for the FPTC metal injection molding process.



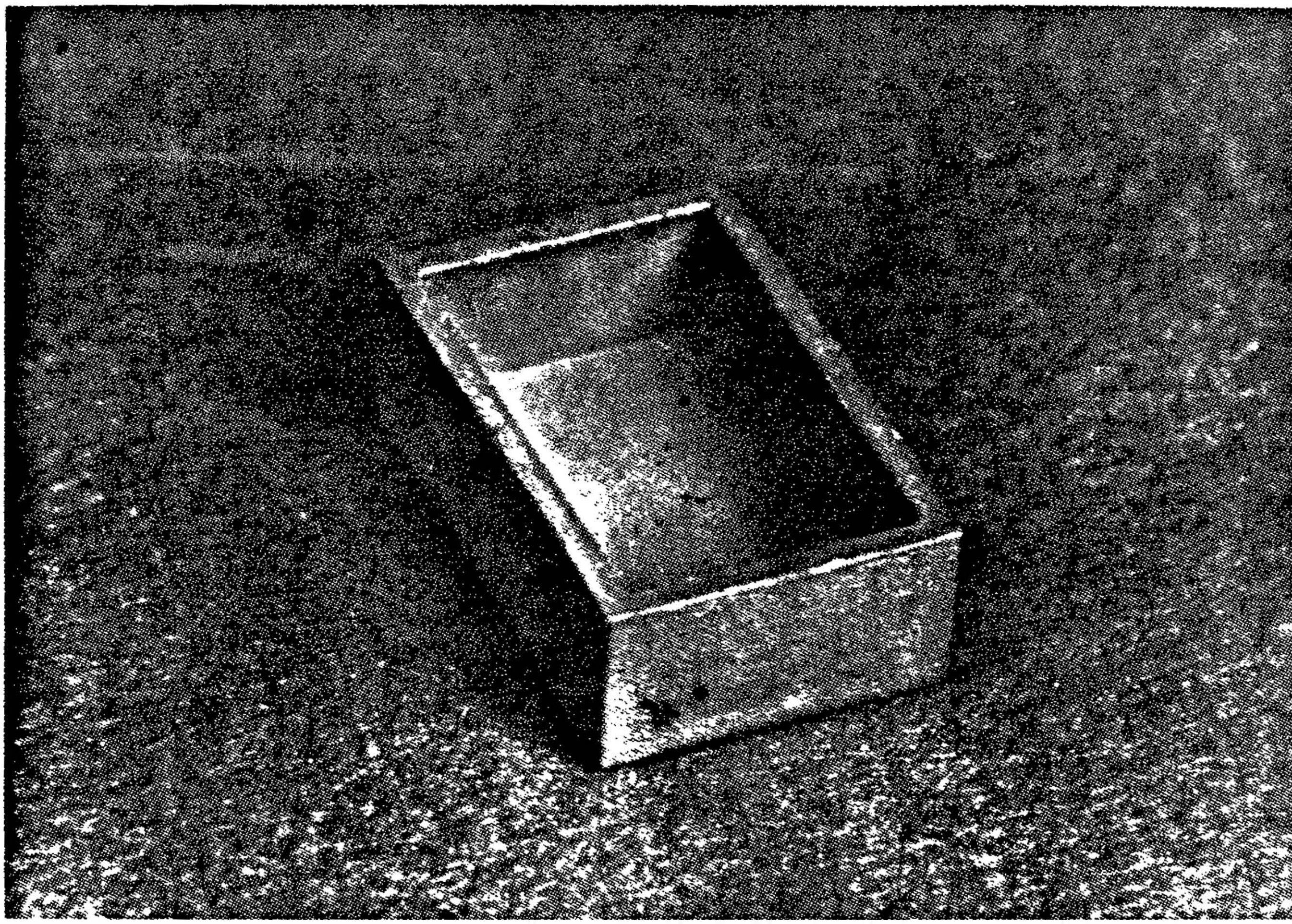
1000X

Figure 2: SEM photomicrograph of carbonyl iron powder showing the rounded particles which are desirable in metal injection molding.



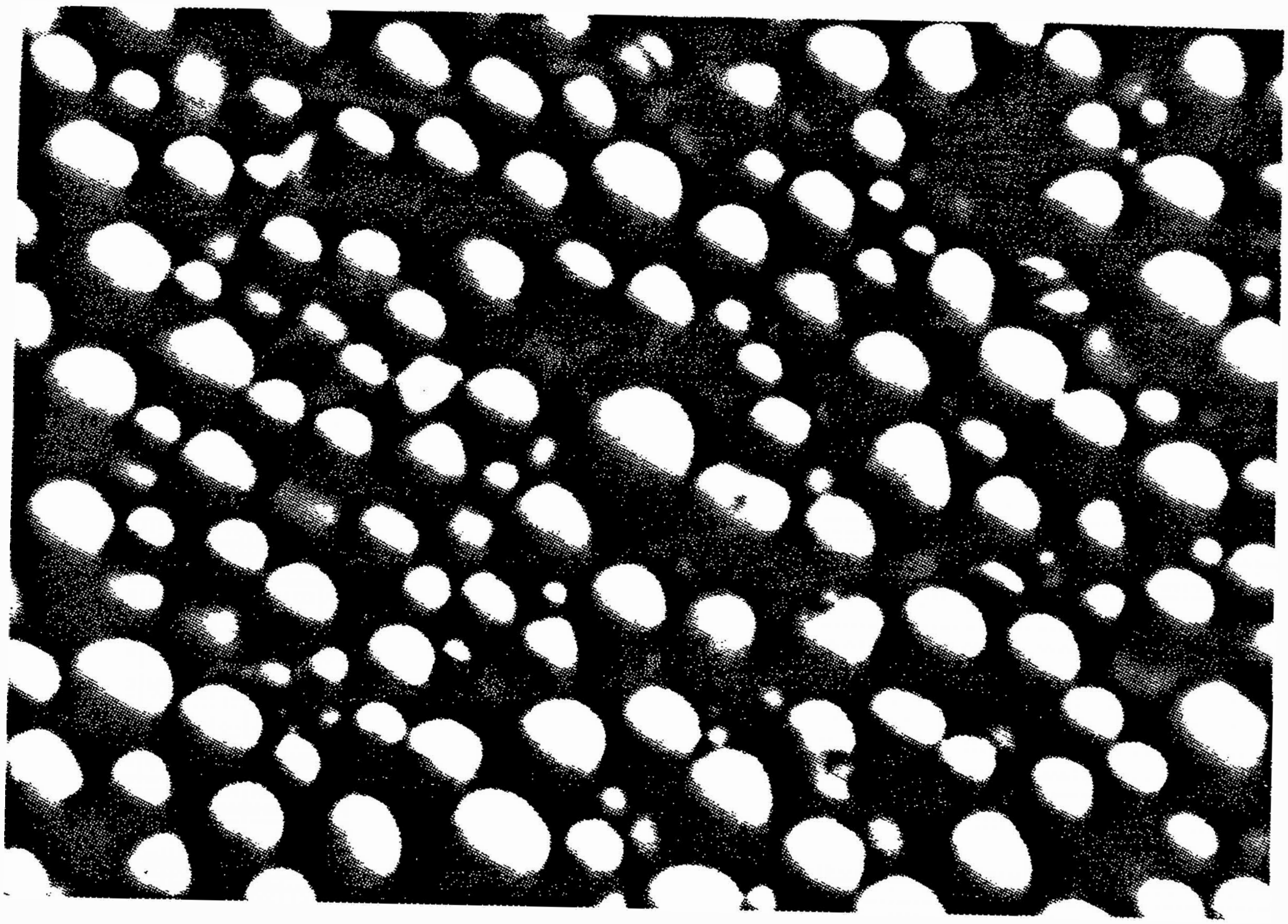
Actual Size

Figure 3: Photo showing the granulated feed stock comprising metal powders and binders.



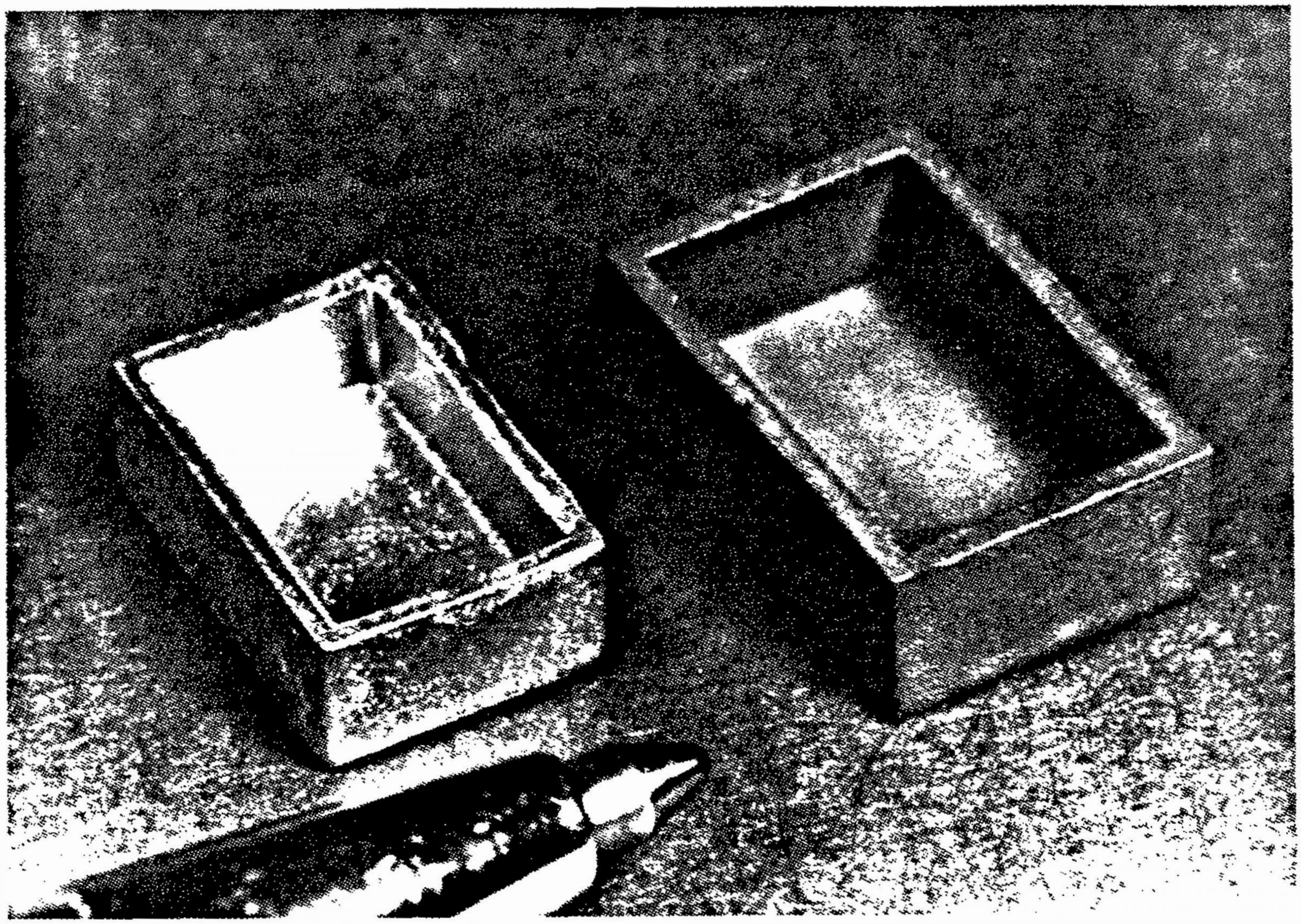
6.25X

Figure 4: Photo of a "green" part in the as-molded condition.



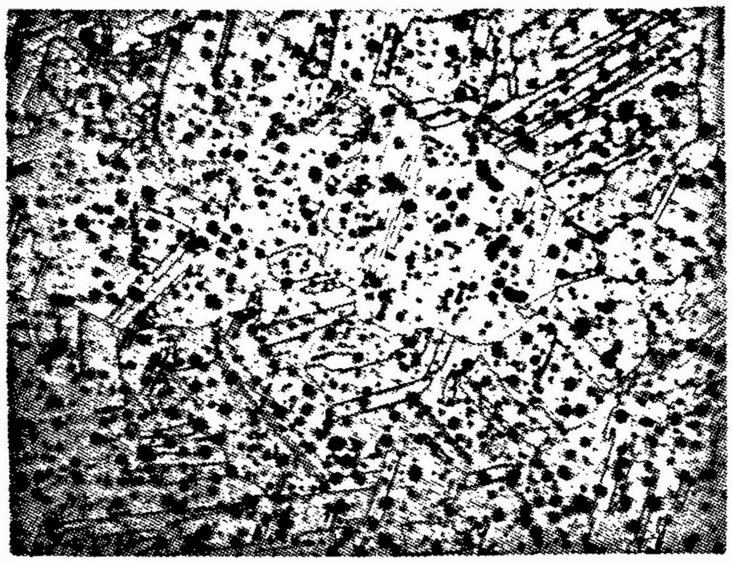
1000X

Figure 5: SEM photomicrograph of the surface of a "brown" part after the binders are removed but before sintering.



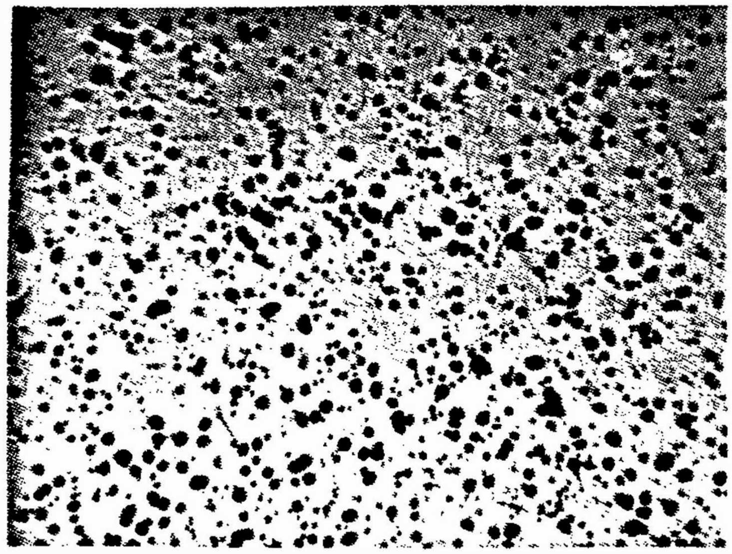
6X

Figure 6: Photo showing the "green" part on the right and the sintered part on the left. Note that the sintered part has shrunk by about 14 percent from the green size.

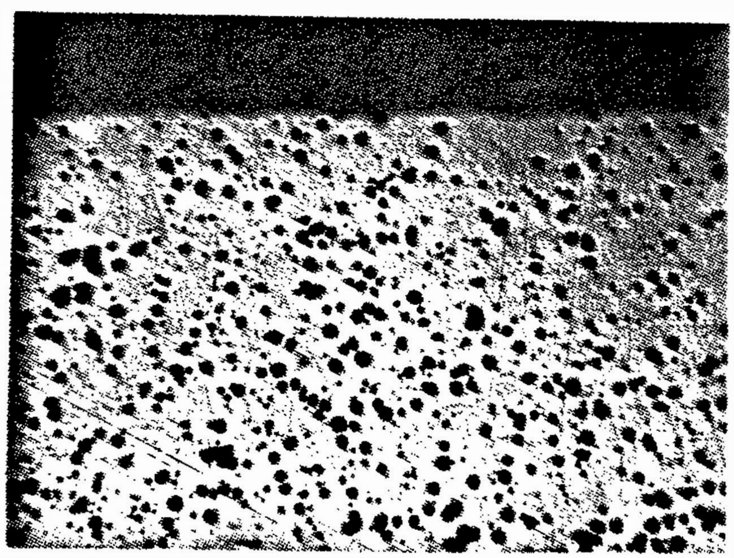


100X

Figure 7: Photomicrograph showing the structure of the F-15 alloy at the bottom of the sintered part. Etch: 50 vol.% HCl, 16.7 vol.% HNO_3, 33.3 vol.% glycerine.



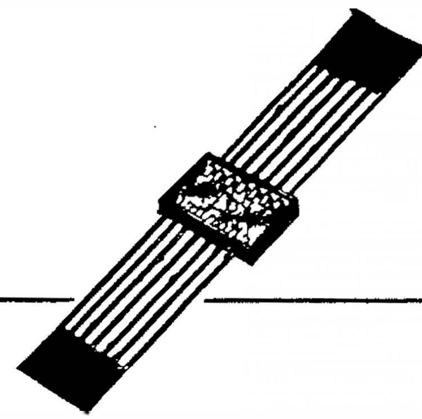
100X (a)

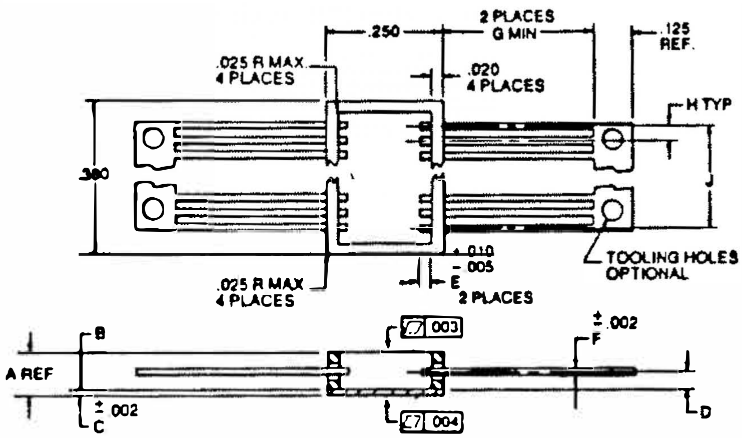


100X (b)

Figure 8: Photomicrographs showing porosity in the cross-section of the bottom of the F-15 alloy part.
(a) center of the cross-section
(b) surface of the cross-section

IP-1005 .250 × .380





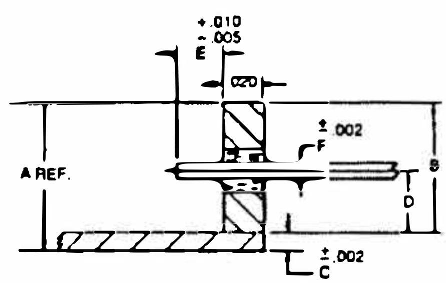
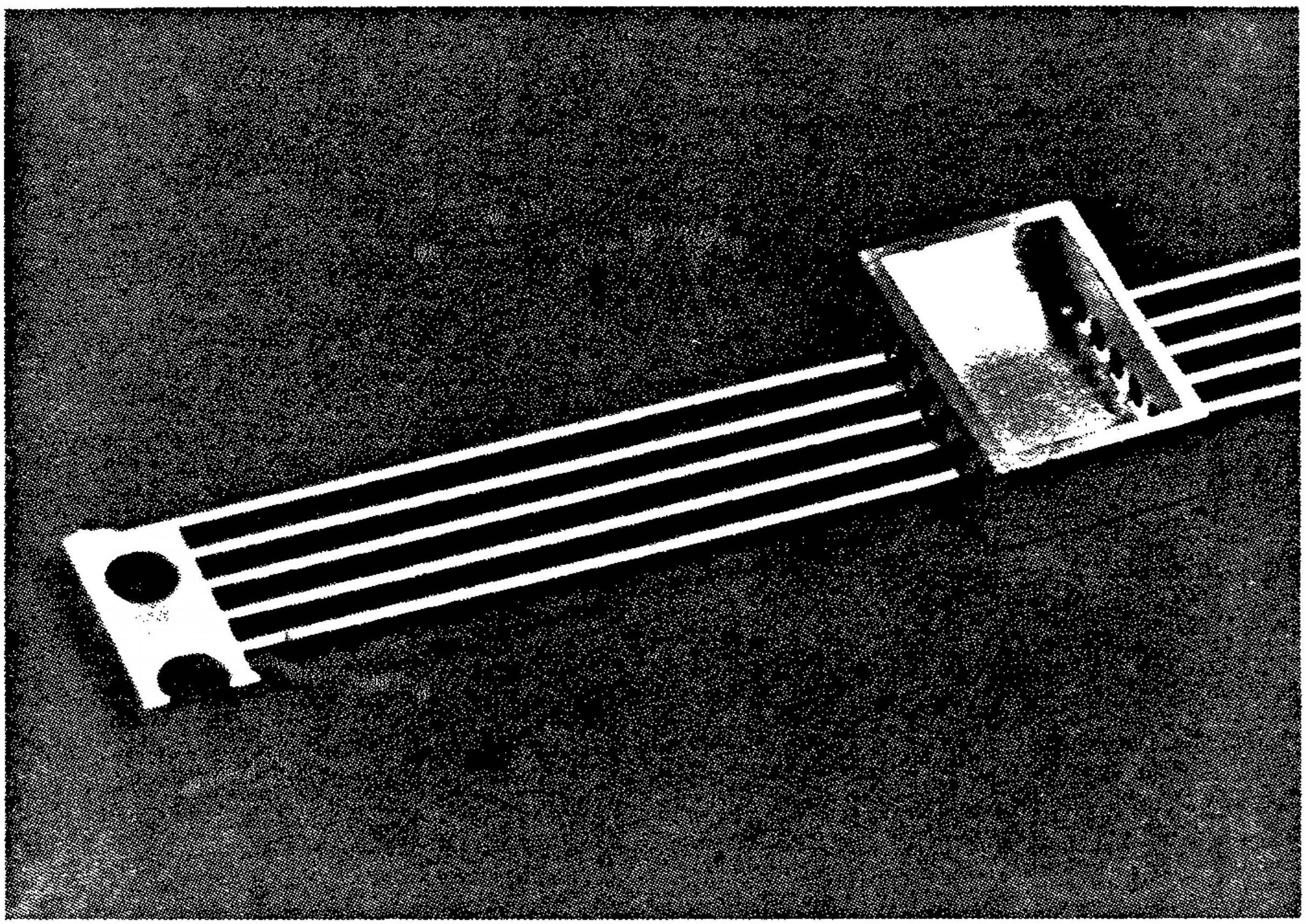


TABLE OF DIMENSIONS												
PART NO. IP-1005-	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**NO. OF LEADS**	**WELDABLE**	**NOTES**
17	.115	.105	.010	.030	.030	.018	.075	—	—	4	*No	4,6,7

Figure 9: Dimensions of the part.



4.6X

Figure 10: Photo showing the finished package with leads glassed in position.