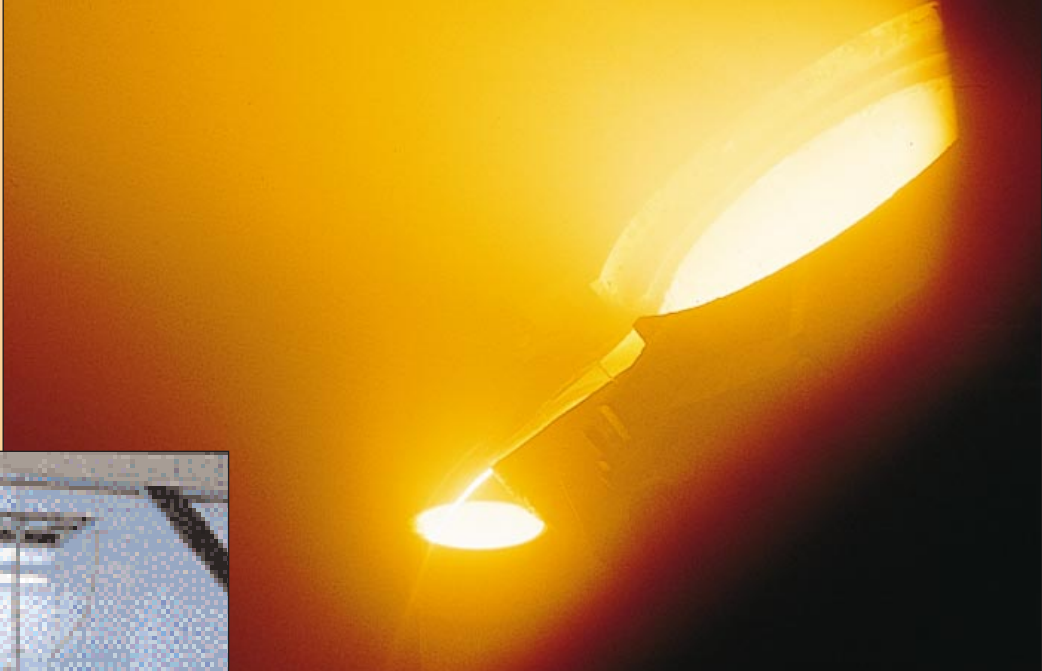


A scanning electron microscope (SEM) image showing a dense field of spherical atomized powder particles. The particles vary in size and exhibit surface features such as small protrusions and indentations, characteristic of gas-atomized metal powders. The background is dark, highlighting the metallic texture of the particles.

# *Atomized Powder Superalloys*





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# *Premium Gas Atomized Powder Metals and Alloys*



The Special Metals superalloy powder products facility at Princeton, Kentucky, was custom built for the production of high-purity superalloy and other powders. It offers a combination of production equipment and quality management unequaled in the industry. Current output reaches around a million pounds (450 tonnes) of superalloy powder a year.

The first step in the production cycle is closely related to Special Metals' world leadership in vacuum induction melting technology. The powder process begins with premium grade remelt and virgin materials vacuum melted in a 2000 lb (900 kg) capacity furnace at the top of the 30 ft (9 m) atomization tower.

The refined melt is poured through a tundish nozzle assembly at the base of the furnace, impacted by argon, and dispersed to create a fine powder collected in the lower chamber of the atomization tower for further processing.

A series of sieves are used to control the particle size distribution. Typically, coarse fractions of powder are removed. For the most specialized applications, the already fine atomized powders are screened to provide material less than 50 microns in size.

Screened powder is blended and packed into containers for consolidation by extrusion or hot isostatic pressing. After consolidation, the containers are removed by machining. The consolidated powder billets offer significantly improved ultrasonic inspection capabilities compared with conventionally processed alloy billets.

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# The Special Metals Powder Quality

Special Metals argon atomized powder is produced under extremely tight controls and supported by laboratory facilities for chemical, metallographic and physical property tests to verify conformity with the highest levels of aerospace requirements.

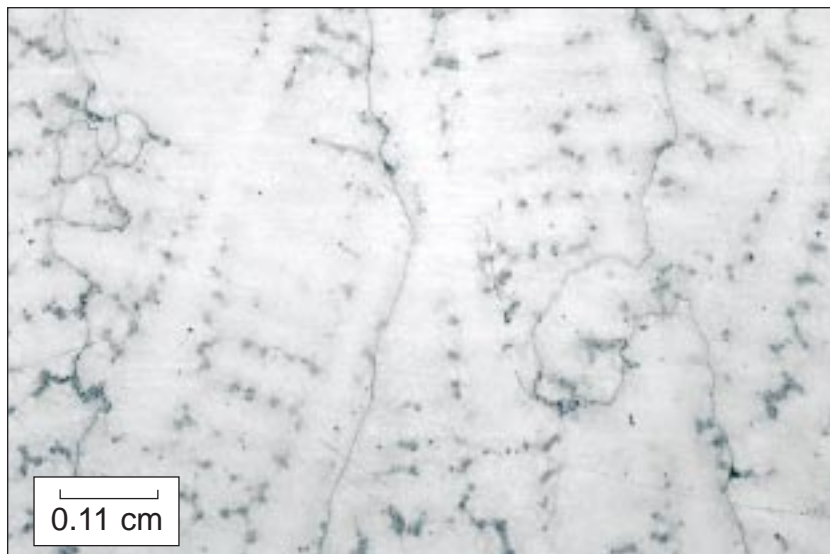
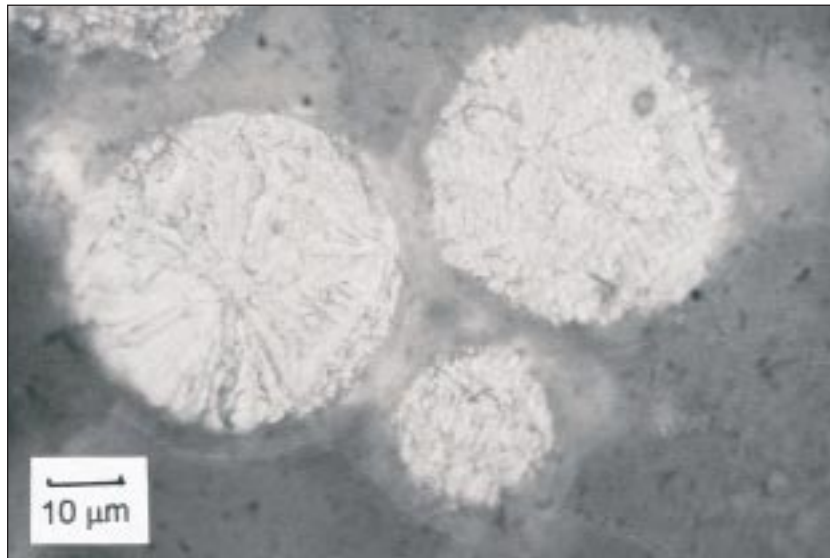
## Chemical Uniformity

To increase the temperature and stress capabilities of gas turbine engines, the aerospace industry is resorting to ever increasing levels of alloy additions. Powder processing of superalloys was developed to achieve a microscopic level

of chemical uniformity unobtainable using conventional melting techniques. Conventional melting results in slower cooling during solidification, creating large inter-dendritic regions which make homogenization difficult.

**Figure 1**

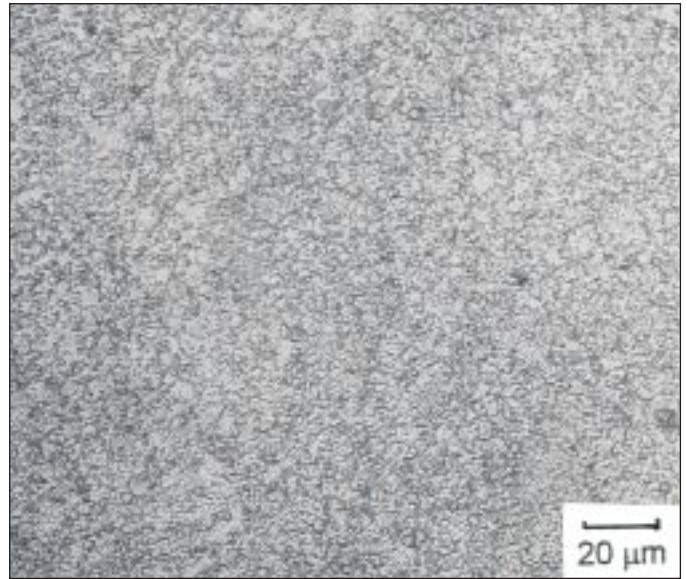
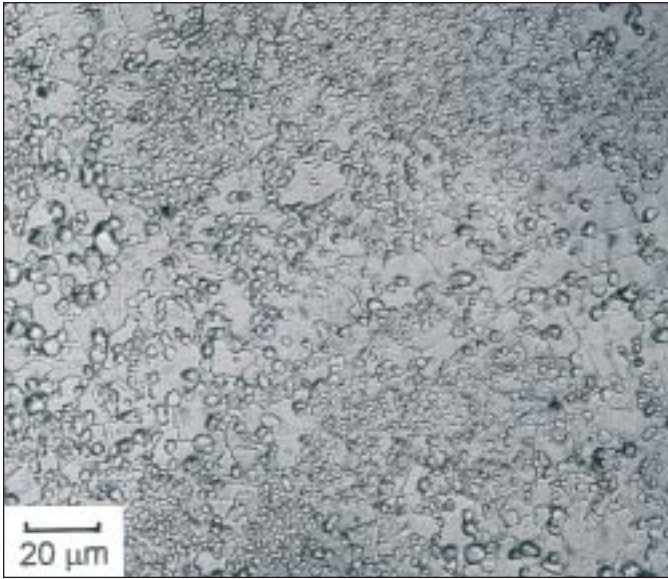
Chemical segregation in the powder material (on the right) is considerably less when compared to the conventional ingot metallurgy (below).



## Microstructural Uniformity

The high cooling rates associated with powder metallurgy provide a uniform alloy content and a fine dispersion of secondary phases such as carbides and borides.

Even with alloys having low secondary phase formation, the microstructural uniformity of powder processed alloys is unequaled.



**Figure 2**

Chemical uniformity is reflected in the final billet microstructure where improvements in grain structural uniformity are clearly evident. The picture on the left shows conventionally melted and cast UDIMET alloy 720 billet. On the right, the UDIMET alloy 720 billet is an atomized powder metallurgy product.

## Improved Workability

The microstructural control of the powder alloy permits forgers and ring rollers to use more specialized forging techniques to save on weight and work to near net shapes. Extremely fine grain sizes (ASTM 12 and finer) are possible and permit superplastic

forming. Even more advanced processing techniques are being developed including slightly sub-solidus hot isostatic pressing (SSHIP) to permit conventional forging and ring rolling of the powder metal billet materials.

**Figure 3**

SSHIP provides improved forgeability over conventional HIP consolidated billet. Severe cracking is evident in the conventional material (left) after upset forging. The SSHIP processed material (right) did not exhibit surface cracks after upsetting and punching operations.



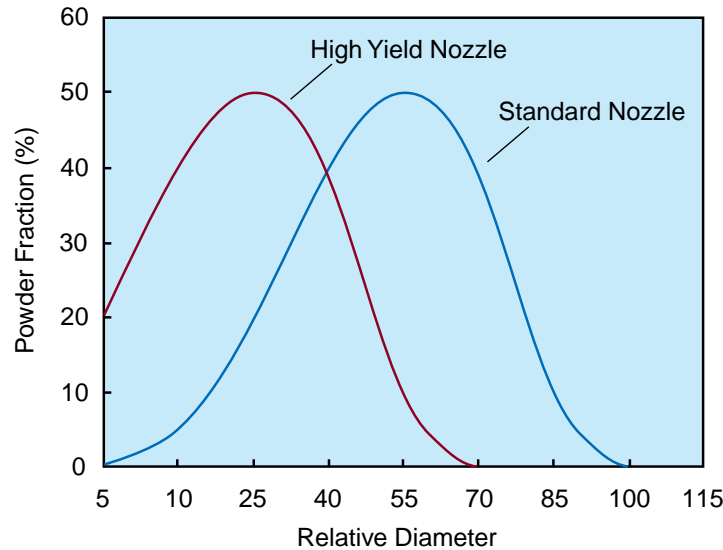
## Property Improvements

Special Metals has incorporated specialized melting and atomization processes permitting extremely fine powder distributions. As shown in figure 4, these processes represent a major improvement in the yield of fine powders. Melt related inclusions, always a possibility, are minimized during

Special Metals powder processing by fine mesh screening operations and the non-organic environment maintained during powder handling. As shown in figure 5, the fatigue life of 270 mesh superalloy powder offers major improvements in low-cycle fatigue properties.

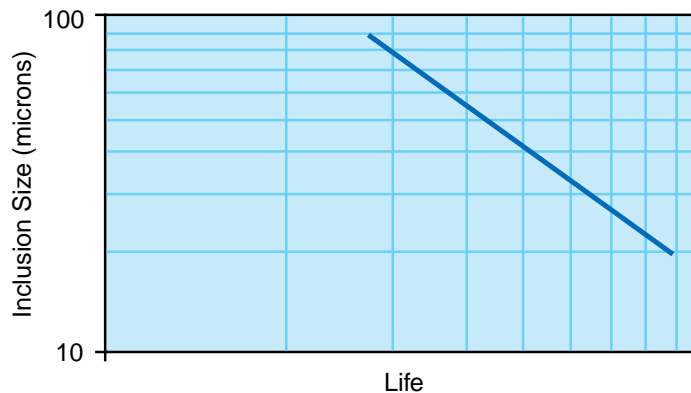
**Figure 4**

The high yield nozzle atomization process dramatically improves the yields of the powder.



**Figure 5**

Providing the basic powder route maintains the alloy integrity. The low cycle fatigue capability of the alloy is improved with finer mesh sizes.



## Processed Billet Size

For the aerospace industry, and for other developing markets, the Special Metals powder process has an almost unique capability to offer large diameter, fine

grain billets. Special Metals products have ranged from 0.5 in (13 mm) bar up to as-HIPd billet weighing as much as 10,000 lbs (4.5 tonnes).



## The Special Metals atomized powder superalloys in current production

	C	Cr	Mo	Co	Ti	Al	Nb	W	V	Ni	Additions
<b>UDIMET alloy 700</b>	0.03	14.5	5.0	17	3.5	4	—	—	—	Bal	B, Zr
<b>Alloy IN100</b>	0.07	12.4	3.4	18.5	4.2	5	—	—	0.7	Bal	B, Zr
<b>Rene 95</b>	0.08	13.0	3.5	8	2.5	3.5	3.5	3.5	—	Bal	B, Zr
<b>UDIMET alloy 720</b>	0.03	16.0	3.0	15	5	2.5	—	1.3	—	Bal	B, Zr
<b>Rene 88DT</b>	0.05	16.0	4.0	13	3.7	2	0.7	4	—	Bal	B, Zr
<b>Others</b>	On request										



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