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SUMMARY OF BERYLLIUM SPECIFICATIONS CURRENT AND HISTORICAL

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SUBJECT DESCRIPTOR

Beryllium Specifications

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SUMMARY OF BERYLLIUM SPECIFICTIONS CURRENT AND HISTORICAL

S. P. Abeln and P. Kyed

ABSTRACT

This report summarizes beryllium properties included in producer, Department of Energy, and government specifications. The specifications are divided into two major categories: current and historical. Within each category the data are arranged primarily according to increasing purity and secondarily by increasing tensile properties. Qualitative comments on formability and weldability are included. Also, short summaries of powder production and consolidation techniques are provided.

INTRODUCTION

In 1978, Richard R. Corle compiled the first Summary of Beryllium Specifications[1] as a means of alleviating the confusion surrounding beryllium specifications and their different authorities. The summary proved very useful to production, procurement, and research at Rocky Flats and other facilities.

Since 1978, the array of available specifications has changed considerably. Kawecki Berylco Industries, once a major producer of beryllium parts, is no longer in existence. Many specifications have been created, updated, or cancelled since 1978.

This report provides an updated beryllium specification summary. The purpose is to alleviate the confusion associated with beryllium specifications. The specification data in this report are compiled as quick and easy-to-use references so that the similarities and differences are evident.

Beryllium is made to two basic grades: structural/nuclear and instrumentation. Structural/nuclear grades are characterized as having moderate strength and ductility. The strength/ductility combinations are controlled by judicious selection of input powder, consolidation technique, and heat treatment. The higher strength/ductility grades have higher purity and finer grain size. Instrumentation grades are characterized by high microyield strength and excellent dimensional stability. Grain size is significantly finer and tramp elements significantly higher for instrument grades.

The specifications are divided into two major categories: current and historical. Historical specifications are no longer in use but are included for reference purposes. Each major category has two subcategories: powders and consolidated block. Within each subcategory, the specifications are arranged primarily in order of increasing purity and secondarily in order of increasing tensile properties. Comments on formability and weldability are also included. However, these assessments were determined qualitatively, and should not be considered irrefutable.

In addition to the summary of specifications, short discussions of beryllium powder production and consolidation techniques are included to explain terms such as hot isostatic pressing and impact grinding.

BERYLLIUM POWDER PRODUCTION PROCESSES

The three beryllium powder production processes currently being used are Braun-type attrition, impact grinding, and ball milling. Each of these processes has a common first step: the conversion of vacuum-cast ingots into machining swarf by multiple-point lathes. Beyond this first step, the processes vary considerably.

In Braun-type attrition (Figure 1), the swarf is fed into a mill via a hopper. The mechanical attritioning occurs between two opposed beryllium

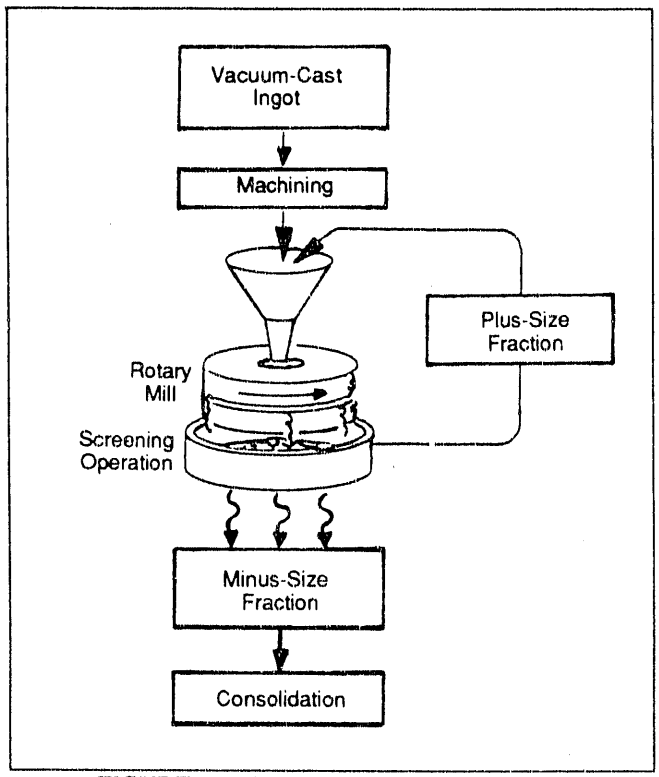

FIGURE 1. Braun-Type Attrition Process

grinding disks with radial grooves. One of the disks is stationary while the other is rotated by a fixed-speed motor. Because of the heat buildup from grinding, the disks must be water cooled. If proper operation and cooling procedures are not followed, heat buildup causes substantial oxide formation, adversely affecting the final product.

After the swarf is ground, it is exposed to a magnetic field to remove any magnetic impurities and sized on a 325-mesh (-44-micron) vibrating screen. This screen is in a closed circuit with the attritioning mill, meaning that all particles coarser than 325 mesh (about 90%) are returned to the mill for regrind while the finer material is the final product. The closed circuit ensures that the final product is essentially finer than 325 mesh.

Braun-type attritioning is the oldest beryllium powder production process. The powder morphology is flat and pancake-like, aligning itself upon vibration packing (Figure 2). The

FIGURE 2. Scanning Electron Micrograph of Beryllium Powder Produced by Braun-Type Attrition (Top), Impact Grinding (Middle), and Ball Milling (Bottom). Courtesy of Brush Wellman, Inc.

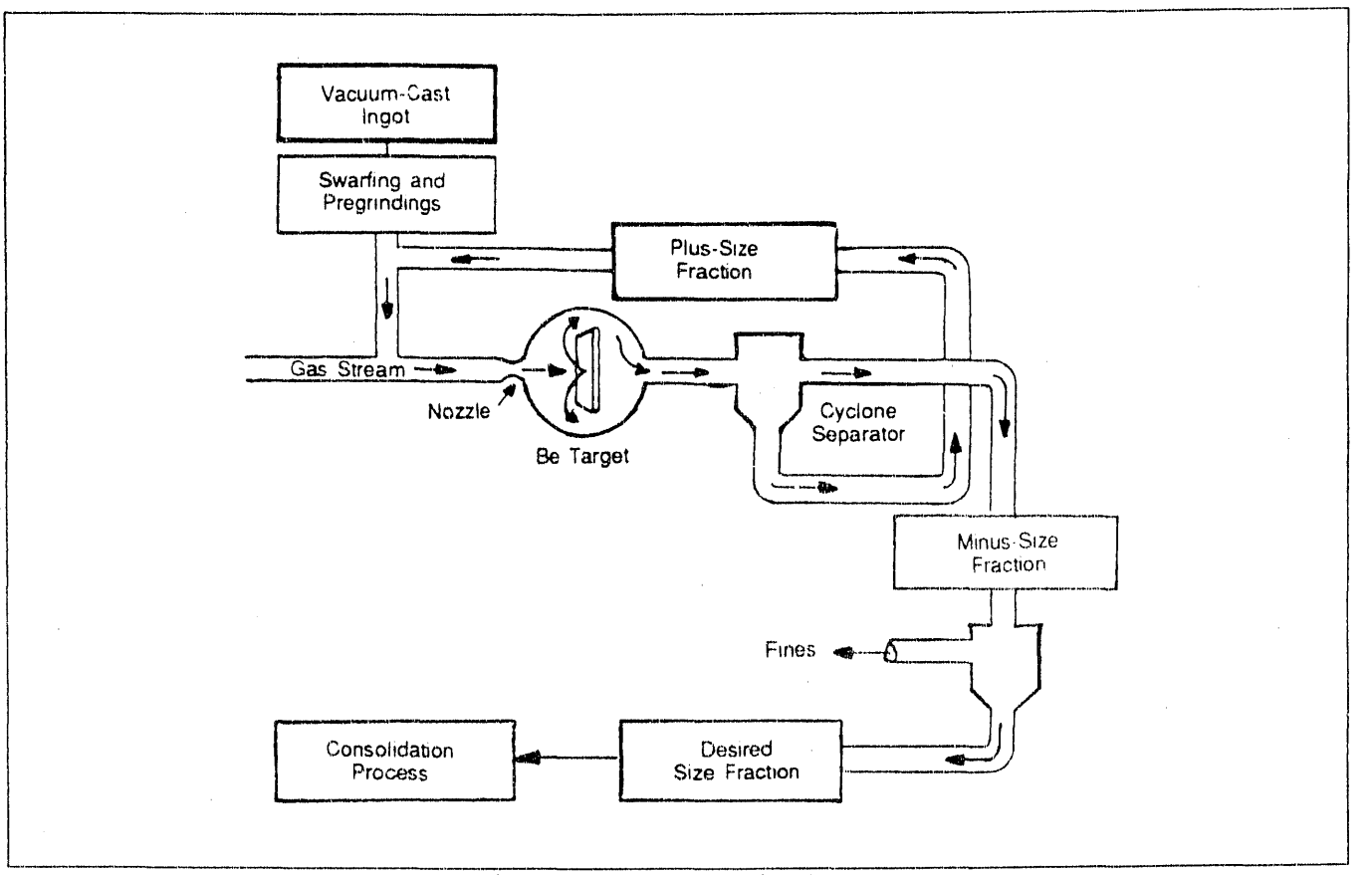

FIGURE 3. Impact Grinding Process

result is a slightly textured billet after consolidation. Braun-type attritioning produces structural/nuclear-grade beryllium.

Braun-type attritioning is gradually being replaced by impact grinding (Figure 3). Impact grinding increases the quality of hot-pressed beryllium parts by reducing non-metallic inclusions, reducing oxide content, and producing a more blocky morphology, which increases isotropy of mechanical properties (smaller difference in longitudinal and transverse properties). See Figure 2.

In impact grinding, the feed must be finer than the machining swarf, so a pregrind operation is necessary. The most common pregrind is pin milling, although other processes are used. After the pregrind, the particles are placed in a gas stream and impacted against a beryllium target. The impacted particles are sized with an air classifier and separated into coarse and -44-micron particles. Coarse particles are impacted again (closed circuit) while the -44-micron particles go into a product drum. Impact grinding currently produces most structural-grade beryllium.

Ball milling, unlike Braun-type attritioning and impact grinding, produces an ultra-fine powder with high oxide content. These two characteristics combine to produce a high microyield strength product ideal for instrument applications.

Ball milling is a simple operation. The machining swarf is placed inside a cylindrical drum filled with carbide balls. When turned on, the mill rotates, producing a tumbling action. This

tumbling reduces the swarf to an ultra-fine powder less than 10 microns (Figure 3). There are no subsequent screening or separation processes.

Contamination occurs during ball milling. Iron, carbon, and other elements are picked up from the grinding equipment, causing instrument-grade beryllium to be much higher in tramp elements than structural grades.

BERYLLIUM POWDER CONSOLIDATION PROCESSES

The two basic types of beryllium powder consolidation techniques currently being used are vacuum hot pressing and hot isostatic pressing. Hot pressed block is a generic term describing either of these techniques.

Historically, vacuum hot pressing has been the most cost-effective method for producing a variety of billet sizes from 7 to 72 inches in diameter. Two grades of beryllium powder can be vacuum hot pressed: nuclear grade (also known as structural grade) and instrument grade. Nuclear grades are vacuum hot pressed from -44-micron powder, and contamination is controlled to maximize ductility. Instrument grade, on the other hand, uses much finer powders higher in oxides and contaminants to increase microyield strength and isotropy. Instrument grades and nuclear grades require different pressing parameters for consolidation because of differences in their chemistry.

Process parameters for vacuum hot pressing are limited because of microstructural requirements and equipment limitations. The fine-grained requirement limits the temperature to a range of 1000 to 1100 °C, which is slightly below the temperature at which extensive grain growth occurs. In this temperature range, the resulting average grain size is approximately the same as the average powder size. The pressure achieved is limited by the die materials used. Graphite dies have safe loads up to about 1 ksi while nickel-based superalloy dies are used up to 4 ksi.

Vacuum hot pressing of beryllium is a low-pressure sintering process; densification depends upon evaporation-condensation, surface diffusion, volume diffusion, and creep mechanisms. Each of these mechanisms is time and temperature dependent, showing increased rates at higher temperatures. Pressings often take more than 20 hours to complete.

Hot isostatic pressing is significantly more versatile than vacuum hot pressing because the compaction processes are not limited by graphite dies. Hence, compaction can occur at high pressures (15 ksi) and a variety of temperatures, allowing better control of properties.

The hot isostatic pressing process is as follows:

1. Manufacturing (from welded sheet metal) a vacuum-tight sealable container.

2. Filling the container with beryllium powder.

3. Evacuating all adsorbed gasses from the container by heating the filled container while pulling a vacuum.

4. Sealing the gas-evacuated container while maintaining the internal vacuum.

5. Applying simultaneous temperature and isostatic gas pressure for consolidation. The most important step is the removal of all adsorbed gases; otherwise, subsequent heating can result in undesirable thermally induced porosity.

CURRENT SPECIFICATIONS - CONSOLIDATED BERYLLIUM

Explanations of terms used in these specifications are listed below.

Authority

Brush - Brush Wellman, Inc.
DOD - Department of Defense
KBI - Kawecki Berylco Industries, Inc.
Los Alamos - Los Alamos National Laboratory
LLNL - Lawrence Livermore National Laboratory
RF - Rocky Flats
SAE - Society of Automotive Engineers
SNLL - Sandia National Laboratory, Livermore

Manufacturing/Fabrication

CRS - Cross Rolled Sheet
HIP - Hot Isostatic Pressed
HPB - Hot Pressed Block
VHP - Vacuum Hot Pressed
VHPB - Vacuum Hot Pressed Block

Mechanical Properties

L - Longitudinal
T - Transverse

NOTE: Specification Notes are listed at the end of this report.

Current Specifications - Consolidated Beryllium →

Spec/Grade Revised	I-400 7/1/87	RM 255166 6/6/83				RM 251520 6/6/83	
Authority	Brush	LLNL				LLNL	
Material	Block-Instrument Grade (regular & select)	Block-Structural/Nuclear				Block-Structural/Nuclear	
Mfg./Fab.	HPB	HPB or App. Alt.				HPB or App. Alt.	
Chem. Comp. (wt%)		Weldable Grade A		Standard Grade B			
Be (min)	94.0	98.0		98.0		98.0	
BeO (max)	(4.25 min)	0.9		2.00		1.5	
Al (max)	0.16	0.07		0.16		0.07	
C (max)	0.25	0.10		0.15		0.10	
Fe (max)	0.25	0.12		0.18		0.12	
Mg (max)	0.08	0.08		0.08		0.08	
Si (max)	0.08	0.08		0.08		0.08	
As Specified (max)	---	N 0.10		N 0.15		S 0.04	
As Specified (max)	---	U 0.03		U 0.03		U 0.04	
As Specified (max)	---	----		----		----	
As Specified (max)	---	----		----		----	
As Specified (max)	---	----		----		----	
Other (each max)	0.1	0.04		0.04		0.04	
Fe/Al Ratio	---	Controlled		----		Controlled	
Mech. Prop.		(T)	(L)	(T)	(L)	(T)	(L)
F_{tu} (ksi)	50	35	35	35	35	35	35
F_{ty} (ksi)	---	25-38	25-38	25	25	25-38	25-38
Elong. (min %)	---	2.0	1.0	1.0	1.0	2	1
Elev. Temp.	---	8% at 650 °C (T)				8% at 650 °C (T)	
Other	See Remarks	F_{ty}/F_{tu} = 0.9 max				F_{ty}/F_{tu} = 0.9 max	
Avg Grain Size	≤10 Microns	≤35 Microns				≤35 Microns	
Max Grain Size	---	≤125 Microns				≤125 Microns	
Density (g/cm³)	99.0% Theoretical	99% Theoretical				1.84 - 1.87	
Defect Limits	Controlled, Note 1	Controlled, Note 2				Controlled, Note 3	
Weldable	No	----				RF Option B	
Formability	No	----				Excellent	
Remarks	Microyield Regular - 9.0 ksi min Select - 10 ksi min	No recycle of machine chips or scrap block without remelting.				Probable Weldable grade, scrap must be remelted if used.	

P31664 7/7/83	S-200-E 2/20/84	P14765 4/17/85	P11512 7/1/86	I-220 7/1/87
RF	Brush	Los Alamos	RF	Brush
Block-Structural/Nuclear	Block-Structural/Nuclear	Block-Structural/Nuclear	Block-Structural/Nuclear	Block-Structural/Nuclear
HPB or App. Alt.	HPB	Not Specified	HPB, Forged	HPB
98.0	98.0	98.0	98.0	98.0
1.5	2.0	2.0	2.0	2.2
0.07	0.16	0.16	0.16	0.10
0.10	0.15	0.15	0.15	0.15
0.12	0.18	0.20	0.20	0.15
0.08	0.08	0.08	0.08	0.08
0.08	0.08	0.12	0.12	0.08
S 0.04	----	N (as nitride) 0.06	N (as nitride) 0.06	---
U 0.04	----	Mn 0.05	Mn 0.05	---
----	----	Cr, Cu, Ni, Ti } 0.20 Total	Cr, Cu, Ni, Ti } 0.20 Total	---
----	----	----	----	---
----	----	----	----	---
0.04	0.04	0.05	0.05	0.04
Controlled	----	----	----	---
(T) (L)				
35 35	40	40	40	55
25-38 25-38	30	30	30	40
2 1	1	1	1	2
8% at 650 °C (T)	----	----	----	---
F_{ty}/F_{tu} = 0.90 max	----	----	----	See Remarks
≤35 Microns	≤25 Microns	----	----	≤20 Microns
≤125 Microns	----	----	----	---
1.84 - 1.87	99% Theoretical	1.84 - 1.87	1.84 - 1.87	99.0% Throretical
Controlled, Note 3, RF Option B	Controlled, Note 4	Controlled, Note 3	Controlled, Note 3	Controlled, Note 4
Excellent	Limited	No	Limited	Limited
Probable	Poor	----	Poor	Poor
Weldable grade, scrap must be remelted if used.	----	----	----	Microyield Regular Grade: 5.0 ksi min Select Grade: 6.0 ksi min

Current Specifications - Consolidated Beryllium (continued) →

Spec/Grade Revision Date	SR-200-E 5/1/74	RM 253939 6/6/83	SS451522 2/23/88	S-200-F 4/1/87
Authority	Brush	LLNL	SNLL	Brush
Type of Material	Sheet	Block-Structural/Nuclear	Block-Structural/Nuclear	Block-Structural/Nuclear
Mfg./Fab.	Hot Rolled VHPB	VHP/HIP	VHP/HIP	VHP
Chem. Comp. (wt%)				
Be (min)	98.0	98.5	98.5	98.5
BeO (max)	2.0	1.2	1.2	1.5
Al (max)	0.16	0.06	0.06	0.10
C (max)	0.15	0.10	0.10	0.15
Fe (max)	0.18	0.10	0.10	0.13
Mg (max)	0.08	0.08	0.08	0.08
Si (max)	0.08	0.06	0.06	0.06
As Specified (max)	---	S 0.04	U 0.04	----
As Specified (max)	---	U 0.04	S 0.04	----
As Specified (max)	---	----	----	----
As Specified (max)	---	----	----	----
As Specified (max)	---	----	---	----
Other (each max)	0.04	0.04	0.04	0.04
Fe/Al Ratio	---	Controlled	Controlled	----
Mech. Prop.		(T) (L)	(T) (L)	
F_{tu} (ksi)	70	50 50	50 50	47
F_{ty} (ksi)	50	35-50 35-50	35-50 35-50	35
Elong. (min %)	10	3.0 3.0	3.0 3.0	2
Elev. Temp.	---	6% Elong. at 650 °C (T)	----	----
Other	---	----	Yield Strength variation shall not exceed 6000 psi	----
Avg. Grain Size	---	≤15 Microns	≤15 Microns	≤20 Microns
Max Grain Size	---	≤50 Microns	≤50 Microns	----
Density (g/cm^3)	---	99.3% Theoretical	99.3% Theoretical	99.0% Theoretical
Defect Limits	---	Controlled, Note 5	Controlled, Note 5	Controlled, Note 4
Weldable	Limited	Excellent	Excellent	----
Formability	Poor	Limited	Limited	----
Remarks	---	No recycle of machine chips or scrap blocks without remelting.	No recycle of machine chips or scarp block without remelting.	----

B-26-D 11/15/82						PF-10 12/20/80						PF-60 12/17/79					
Brush						Brush						Brush					
Vacuum Casting, Crushed Lump, Machine Chips						Foil						Foil					
Vacuum Melted and Cast						Hot Rolled HPB						Hot Rolled HPB					
99.0						99.4						99.0					
0.50						0.6						0.8					
0.09						0.01						0.05					
0.10						0.03						0.07					
0.10						0.03						0.07					
0.08						0.006						0.05					
0.06						0.02						0.04					
B	0.0002	Cu	0.01	Ni	0.03	Ni	0.02	Cr	0.0025	Ag	0.0005	B	0.0003	Cu	0.01	Ni	0.02
Cd	0.0002	Pb	0.002	N	0.03	Ca	0.02	Mo	0.001	B	0.0003	Cd	0.0002	Pb	0.002	N	0.04
Ca	0.02	Li	0.0003	Ag	0.0005	Zn	0.01	Ti	0.001	Cd	0.0002	Ca	0.01	Li	0.0003	Ag	0.001
Cr	0.01	Mn	0.015	Zn	0.02	Cu	0.005	Co	0.0005			Cr	0.01	Mn	0.012		
Co	0.0010	Mo	0.002			Mn	0.003	Pb	0.0005			Co	0.001	Mo	0.002		
---						----						0.04					
---						----						----					
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---						----						----					
---						----						----					
---						----						----					
---						----						1.84 min.					
---						Controlled, Note 6						Controlled, Note 6					
---						----						----					
---						----						----					
---						Tentative Specification						Tentative Specification					

Current Specifications - Consolidated Beryllium (concluded)

Spec/Grade Revision Date	I-70 7/1/87	S-65 7/1/87
Authority	Brush	Brush
Type of Material	Block-Optical Grade	Block-Structural Grade
Mfg./Fab.	HPB	HPB
Chem. Comp. (wt%)		
Be (min)	99.0	99.0
BeO (max)	0.7	1.0
Al (max)	0.07	0.06
C (max)	0.07	0.10
Fe (max)	0.10	0.08
Mg (max)	0.07	0.06
Si (max)	0.07	0.06
As Specified (max)	----	----
As Specified (max)	----	----
As Specified (max)	----	----
As Specified (max)	----	----
As Specified (max)	----	----
Other (each max)	0.04	0.04
Fe/Al Ratio	----	----
Mech. Prop.		
F_{tu}	35	42
F_{ty}	25	30
Elong. (min %)	2	3
Elev. Temp.	----	----
Other	See Remarks	----
Avg Grain Size	≤20 Microns	≤20 Microns
Max Grain Size	----	----
Density (g/cm^3)	99.3% Theoretical	99.0% Theoretical
Defect Limits	Controlled, Note 4, Type 1	Controlled, Note 4, Type 1
Weldable	Good	Good
Formability	Moderate	Moderate
Remarks	Microyield Thermal Expansion Reported	----

CURRENT SPECIFICATIONS - POWDERED BERYLLIUM

Explanations of terms used in these specifications are listed below.

Authority

Brush - Brush Wellman, Inc.
DOD - Department of Defense
KBI - Kawecki Berylco Industries, Inc.
Los Alamos - Los Alamos National Laboratory
LLNL - Lawrence Livermore National Laboratory
RF - Rocky Flats
SAE - Society of Automotive Engineers
SNLL - Sandia National Laboratory, Livermore

Manufacturing/Fabrication

CRS - Cross Rolled Sheet
HIP - Hot Isostatic Pressed
HPB - Hot Pressed Block
VHP - Vacuum Hot Pressed
VHPB - Vacuum Hot Pressed Block

Mechanical Properties

L - Longitudinal
T - Transverse

NOTE: Specification Notes are listed at the end of this report.

Current Specifications - Powdered Beryllium

Spec/Grade Revised	IP-70 7/1/87	SP-200-F 6/1/87	SP-65 7/1/87
Authority	Brush	Brush	Brush
Chem. Comp. (wt%)			
Be (min)	98.0	98.5	99.0
BeO (max)	0.7	1.5	1.0
Al (max)	0.07	0.10	0.06
B (max)	0.04	0.04	0.0002
Cd (max)	0.04	0.04	0.0002
Ca (max)	0.04	0.04	0.01
C (max)	0.07	0.15	0.10
Cr (max)	0.04	0.04	0.01
Co (max)	0.04	0.04	0.001
Cu (max)	0.04	0.04	0.015
Fe (max)	0.10	0.13	0.08
Pb (max)	0.04	0.04	0.002
Li (max)	0.04	0.04	0.0003
Mg (max)	0.07	0.08	0.06
Mn (max)	0.04	0.04	0.012
Mo (max)	0.04	0.04	0.002
Ni (max)	0.04	0.04	0.03
N (max)	0.04	0.04	0.03
Si (max)	0.07	0.06	0.06
Ag (max)	0.04	0.04	0.0010
Other	0.04	0.04	0.04
Partial	95% -325 mesh	95% -325 mesh	95% -325 mesh
Fabrication	Impact grinding	Impact grinding	Impact grinding
Remarks	Note 7	Note 7	Note 7

HISTORICAL SPECIFICATIONS - CONSOLIDATED BERYLLIUM

Explanations of terms used in these specifications are listed below.

Authority

Brush	-	Brush Wellman, Inc.
DOD	-	Department of Defense
KBI	-	Kawecki Berylco Industries, Inc.
Los Alamos	-	Los Alamos National Laboratory
LLNL	-	Lawrence Livermore National Laboratory
RF	-	Rocky Flats
SAE	-	Society of Automotive Engineers
SNLL	-	Sandia National Laboratory, Livermore

Manufacturing/Fabrication

HIP	-	Hot Isostatic Pressed
HPB	-	Hot Pressed Block
CRS	-	Cross-Rolled Sheet
VHP	-	Vacuum Not Pressed
VHPB	-	Vacuum Hot Pressed Block

Mechanical Properties

L	-	Longitudinal
T	-	Transverse

NOTE: Specification notes are listed at the end of this report.

Historical Specifications - Consolidated Beryllium →

Spec/Grade Revision Date	LS-62 (Lockalloy Sheet) 1976	LX-62 (Lockalloy Extrusions) 1970	HP-40 1975	HP-41 1975
Authority	KBI	KBI	KBI	KBI
Type of Material	Sheet	Extrusion	Rod, Bar, Blanks Instrument Grade	Rod, Bar, Blanks Instrument Grade
Mfg./Fab.	Rolled	Extruded	VHP	VHP
Chem. Comp. (wt%)				
Be (min)	(60 min-64 max)	(60 min-64 max)	94	94
BeO (max)	1.0 (including Al_2O_3)	1.0 (including Al_2O_3)	(4.25 min)	4.25 min-8.0 max
Al (max)	Balance	Balance	0.16	0.16
C (max)	0.1	0.1	0.25	0.25
Fe (max)	0.1	0.1	0.25	0.3
Mg (max)	0.05	0.05	0.08	0.08
Si (max)	0.1	0.1	0.15	0.15
As Specified (max)	----	----	----	----
As Specified (max)	----	----	----	----
As Specified (max)	----	----	----	----
As Specified (max)	----	----	----	----
As Specified (max)	----	----	----	----
Other (each max)	0.04	0.04	0.1	0.1
Fe/Al Ratio	----	----	----	----
Mech. Prop.				(T) (L)
F_{tu} (ksi)	45	50	50	60 60
F_{ty} (ksi)	30	35	----	45 45
Elong. (min %)	7	7	----	1.5 1
Elev. Temp.	----	----	----	----
Other	----	----	See Remarks	See Remarks
Avg Grain Size	----	----	≤10 Microns	≤12 Microns
Max Grain Size	----	----	----	----
Density (g/cm³)	99% Theoretical	0.075 (lb/in.³)	99% Theoretical	99% Theoretical
Defect Limits	Surface Defects Controlled, Note 8	Not Controlled, Note 9	Controlled, Note 4	Controlled, Note 4
Weldable	Yes	Yes	No	No
Formability	Good	Good	No	No
Remarks	Trade Name - Lockalloy	Trade Name - Lockalloy	Microyield Strength - 8 ksi min	Microyield Strength - 8 ksi min

P10577 8/13/75	P11718 8/18/75	RM 253335 5/1/75	MEL-71-001162A 8/3/72	AMS 7901 10/1/86
RF	Brush	LLNL	LLNL	SAE
Not Specified	Blanks	Not Specified	Block	Bars, Rod, Shapes
Not Specified	Deep Drawn HPB	Hot Pressed Ingot Sheet	HPB or Approved Alternative	HPB
97.4	97.4	97.4	98.0	98.00
----	3.0	3.0	1.5	2.00
----	0.18	0.18	0.07	0.20
----	0.20	0.20	0.10	0.15
----	0.30	0.30	0.12	0.20
----	0.08	0.08	0.08	0.08
----	0.12	0.12	0.08	0.12
----	----	----	S 0.04	---
----	----	----	U 0.04	---
----	----	----	----	---
----	----	----	----	---
----	----	----	----	---
----	----	----	0.04	0.04
----	----	----	Controlled	---
----	----	----	(T) (L)	---
----	----	----	35 35	40
----	----	----	25-38 25-38	30
----	----	----	2 1	1
----	----	----	Controlled	---
----	----	----	F_{tu}/F_{ty} = 0.9	---
----	----	----	≤35 Microns	---
----	----	----	≤125 Microns	---
1.83-1.87	1.84-1.87	1.84-1.87	1.84-1.87	1.84 min.
Not Controlled, Negotiable	Controlled, Note 3,	Controlled, Note 3, RF Option B	Controlled, Note 3, RF Option B	Note 10
No	No	No	Excellent	Limited
No	No	No	Probable	No
----	----	----	Intermediate weldable grade; weld test specimens to be provided to LLNL	Specification declared non-current by SAE 4/11/86. Not recommended for new designs. Powder size -200 mesh. For parts requiring high strength/weight ratio and high modulus of elasticity.

Historical Specifications - Consolidated Beryllium (continued)

Spec/Grade Revision Date	MIL-B-21531A 11/10/69	P11736 3/30/65	HP-20 1975	HP-20-SNG 1977	SS229054 8/17/72
Authority	DOD	RF	KBI	KBI	LLNL
Type of Material	Shapes	Block, Machined Shapes	Rods, Bars, Blanks	Rods, Bars, Blanks	Parts
Mfg./Fab	VHP	HPB, Forged	VHP	VHP	HPB, Powder, Forgings, CRS, Extruded
Chem. Comp. (wt%)					
Be (min)	98.00	98.0	98.0	98	98.0
BeO (max)	2.00	2.0	2.0	2.0	2.0
Al (max)	0.16	0.16	0.15	0.15	0.16
C (max)	0.15	0.15	0.15	0.15	0.15
Fe (max)	0.18	0.20	0.18	0.15	0.20
Mg (max)	0.08	0.08	0.08	0.15	0.08
Si (max)	0.08	0.12	0.08	0.15	0.08
Cr (max)	----	----	----	0.15	----
Co (max)	----	----	----	0.15	----
Cu (max)	----	----	----	0.15	----
Pb (max)	----	----	----	0.15	----
Mn (max)	----	----	----	0.15	----
Mo (max)	----	----	----	0.15	----
Ni (max)	----	----	----	0.15	----
As Specified (max)	----	N (as nitride) 0.06	----	----	----
As Specified (max)	----	Mn 0.05	----	----	----
As Specified (max)	----	Cr, Cu, Ni, Ti } 0.20 Total	----	----	----
As Specified (max)	----	----	----	----	----
As Specified (max)	----	----	----	----	----
Other (each max)	0.04	0.05	0.04	----	0.04
Fe/Al Ratio	----	----	----	----	----
Mech. Prop.					T / L
F_{tu} (ksi)	40	40	40	40	45 / 40
F_{ty} (ksi)	30	30	30	30	35 / 30
Elong. (min %)	1	1	1	1	2 / 1.5
Elev. Temp.	----	----	----	----	----
Other	Young's Modulus (lb/in^3) = 42 x 10^6	----	----	----	----
Avg Grain Size	----	----	≤25 Microns	≤25 Microns	----
Max Grain Size	----	----	----	----	----
Density (g/cm^3)	1.84 min	1.84-1.86	99% Theoretical	99% Theoretical	----
Defect Limits	Controlled, Note 11	Controlled, Note 12	Controlled, Note 4	Controlled	----
Weldable	Limited	Limited	Limited	Unknown	Limited
Formability	No	Poor	Poor	Unknown	Poor
Remarks	Powder Size -200 mesh	Type WLA = welded based on Los Alamos control (early weldable grade)	----	----	Specified part and process control imposed.

P31351 2/26/73	S-245 1972	HP-21 1975	HP-22 1975	PR-200-E 1972	PR-20 1968
RF	Brush	KBI	KBI	Brush	KBI
Parts	Block	Rod, Bar, Billet, Blank, Structural Grade	Rod, Bar, Billet, Blank, Instrument Grade	Plate	Plate
HP-B, Powder Forgings, CRS, Extruded	HPB	VHP	VHP	Hot Rolled HPB	Cross Rolled Block
98.0	98	98	98	98	98
2.0	2.0	2.0	2.0	2.0	2.0
0.16	0.10	0.15	0.15	0.16	0.15
0.15	0.15	0.15	0.15	0.15	0.15
0.20	0.15	0.18	0.20	0.18	0.18
0.08	0.08	0.08	0.08	0.08	0.08
0.08	0.08	0.08	0.08	0.08	0.08
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
----	----	----	----	----	----
0.04	0.04	0.04	0.04	0.04	0.04
----	----	----	----	----	----
T L	T L	T L		T L	0.25-0.45 0.451-0.60
45 40	45 45	45 45	45	65 60	65 60
35 30	35 30	35 35	35	45 40	45 40
2 1.5	2 1.5	2 1.5	2	4 3	4 3
----	----	----	----	----	----
----	----	----	See Remarks	----	----
----	≤25 Microns	≤25 Microns	≤25 Microns	----	----
----	----	----	----	----	----
1.84-1.87	1.84 min	99% Theoretical	99% Theoretical	----	1.84 min
Controlled	Controlled, Note 4	Controlled, Note 4	Controlled, Note 4	Controlled If Specified, Note 11	Penetrant Insp. If Required
Limited	Limited	Limited	Limited	Limited	Limited
Poor	Poor	Poor	Poor	Poor	Poor
Specified part and process control imposed.	----	----	Microyield Strength 5 ksi min	----	----

Historical Specifications - Consolidated Beryllium (continued)

Spec/Grade	XT-20	MIL-B-8964			AMS 7902A		
Revision Date	1974	1/17/69			10/1/86		
Authority	KBI	DOD			SAE		
Type of Material	Extrusion	Sheet, Plate			Sheet, Plate		
Mfg./Fab	Extruded	Cross Rolled HPB			Hot Rolled		
Chem. Comp. (wt%)							
Be (min)	98	98 (See Remarks)			98.0		
BeO (max)	2.0	2.0			2.0		
Al (max)	0.18	0.16			0.16		
C (max)	0.15	0.15			0.15		
Fe (max)	0.20	0.16			0.18		
Mg (max)	0.08	0.08			0.08		
Si (max)	0.08	0.08			0.08		
As Specified (max)	----	----			----		
As Specified (max)	----	----			----		
As Specified (max)	----	----			----		
As Specified (max)	----	----			----		
As Specified (max)	----	----			----		
Other (each max)	0.04	0.04			0.04		
Fe/Al Ratio	----	----			----		
Mech. Prop. [Thick (in.)]	----	0.20-0.249	0.250-0.450	0.0451-0.6000	0.20-0.250	0.250-0.451	0.541-0.6000
F_{tu} (ksi)	70	70	65	60	70	65	60
F_{ty} (ksi)	45	50	45	40	50	45	40
Elong. (min %)	5	5	4	3	5	4	3
Elev. Temp.	----	----	----	----	----	----	----
Other	----	----	----	----	----	----	----
Avg Grain Size	----	----			----		
Max Grain Size	----	----			----		
Density (g/cm³)	1.84 min	Not Specified			1.84 min		
Defect Limits	Controlled, Note 11	Controlled, Note 4 Type 1			Note 10		
Weldable	----	----			----		
Formability	No	----			----		
Remarks	----	Be content is listed as "Remainder" but is probably 98% max.			Specification declared non-current by SAE 4/11/86. Not recommended for new designs.		

PS-20 1975	PF-20 1975	HIP-50 (preproduction grade 1977)	AMS 7900 10/1/86	S-100-E 1972
KBI	KBI	KBI	SAE	Brush
Sheet	Foil	Block, Bar, Rod	Bars, Rods, Shapes	Parts, Shapes
Cross Rolled HPB	HPB	HIP Electrolytic Flake Powders	HPB	HPB
98	98	98	98.20	98.5
2.0	2.0	1.6	1.50	1.2
0.15	0.09	0.0075	0.18	0.14
0.15	0.12	0.03	0.15	0.15
0.18	0.15	0.05	0.20	0.16
0.08	0.08	0.003	0.08	0.08
0.08	0.08	0.0045	0.10	0.08
----	----	Cr 0.0035	----	----
----	----	Cu 0.0070	----	----
----	----	Mn 0.0025	----	----
----	----	Ni 0.01	----	----
----	----	----	----	----
0.04	0.04	----	0.04	0.04
----	----	----	----	----
----	----	----	----	----
70	----	80	35	35
50	----	60 (typical)	27	27
10	----	4	1	1
----	----	----	----	----
----	----	----	----	----
----	----	----	----	≤25 Microns
----	----	----	----	----
99% Theoretical	99% Theoretical	----	1.84 min	1.84 min
Controlled, Note 4, Type II	Note 6	----	Note 10	Controlled, Note 4
Limited	Limited	Unknown	----	Good
Poor	Moderate	Unknown	----	Moderate
----	----	Microyield Strength - 8 ksi	Specification declared non-current by SAE 4/11/86. Not recommended for new designs. Powder size -200 mesh. For parts requiring high strength/weight ratio and high modulus elasticity.	----

Historical Specifications - Consolidated Beryllium (continued)

Spec/Grade	HP-12	HP-10	MEL-76-001319	C-50	IF-2
Revision Date	1968	1971	7/15/76	1968	1975
Authority	Brush	KBI	LLNL	KBI	KBI
Type of Material	Blocks	Block, Thermalcycling	Parts, Shapes	Ingot	Foil
Mfg./Fab	HPB	HPB	VHP/HIP	Vacuum Melted and Cast	Extruded Rolled Ingot
Chem. Comp. (wt%)					
Be (min)	98.0	98.5	98.5	99	99
BeO (max)	1.2	1.2	1.2	0.3	0.03
Al (max)	0.09	0.08	0.06	0.09	0.09
C (max)	0.12	0.10	0.1	0.10	0.10
Fe (max)	0.04	0.15	0.1	0.15	0.15
Mg (max)	0.06	0.08	0.08	0.08	0.02
Si (max)	0.08	0.08	0.06	0.08	0.08
Cr (max)	----	----	----	0.01	----
Co (max)	----	----	----	0.0005	----
Cu (max)	----	----	----	0.015	----
Pb (max)	----	----	----	0.002	----
Mn (max)	----	----	----	0.015	----
Mo (max)	----	----	----	0.002	----
Ni (max)	----	----	----	0.03	----
B (max)	----	----	----	0.0002	----
Cd (max)	----	----	----	0.0002	----
Ca (max)	----	----	----	0.02	----
Li (max)	----	----	----	0.0003	----
N (max)	----	----	----	0.03	----
Ag (max)	----	----	----	0.001	----
As Specified (max)	----	----	S 0.04	Zn 0.02	----
As Specified (max)	----	----	U 0.04	----	----
As Specified (max)	----	----	----	----	----
As Specified (max)	----	----	----	----	----
As Specified (max)	----	----	----	----	----
Other (each max)	0.04	0.04	0.04	----	0.04
Fe/Al Ratio	----	----	Controlled	----	----
Mech. Prop.	----	----	T L	----	----
F_{tu} (ksi)	35	37	50 50	----	----
F_{ty} (ksi)	27	24	35-50 35-50	----	----
Elong. (min %)	1	1.5	3 3	----	----
Elev. Temp.	----	----	Controlled	----	----
Other	----	----	----	----	----
Avg Grain Size	≤25 Microns	≤25 Microns	≤15 Microns	----	----
Max Grain Size	----	----	≤50 Microns	----	----
Density (g/cm³)	1.84 min	99% Theoretical	99% Theoretical	----	1.83
Defect Limits	Controlled, Note 4	Controlled, Note 11	Controlled, Note 5	----	Note 6
Weldable	Good	Good	Excellent	Good	Good
Formability	Moderate	Moderate	Moderate	Good	Moderate
Remarks	----	----	----	----	----

HP-8 1968	N-50-C 1972	HP-81 1975	8115000 10/11/73	CIP-HIP-1 1975
KBI	Brush	KBI	RF	KBI
Block, Shapes	Block, Billet, Shapes	Block, Optical Grade	Sheet	Block, Rod, Bar, Blanks
HPB	Not Specified	VHP	Vacuum Melted, Cast and Rolled Ingot	Isostatic Consolidated
99	99	99	99.0	99
0.9	0.9	1.0	0.05	1.2
0.07	0.06	0.08	0.12	0.01
0.10	0.10	0.10	0.12	0.0300
0.075	0.075	0.12	0.25	0.0300
0.06	0.05	0.08	0.05	0.0060
0.06	0.06	0.08	0.12	0.0100
0.01	0.01	----	0.05	0.0025
0.0005	0.0005	----	----	0.0005
0.015	0.002	----	0.05	0.0050
0.002	----	----	----	0.0005
0.012	0.012	----	----	0.0030
0.002	0.002	----	----	0.0010
0.02	0.02	----	0.05	0.0200
0.0002	0.0002	----	----	----
0.0002	0.0002	----	----	----
0.01	0.01	----	----	----
0.0003	0.0003	----	----	----
0.02	0.02	----	0.06	----
0.001	0.0010	----	----	----
----	----	U 0.04	Ti 0.05	----
----	----	----	----	----
----	----	----	----	----
----	----	----	----	----
----	----	----	----	----
----	----	----	0.02	----
----	----	----	Controlled	----
----	----	----	T L	50
35	35	35	38 40	35
25	25	25	22 22	3
1	1	2	3 3	----
----	----	----	----	----
----	----	See Remarks	F_{tu} L and T within 10 ksi	----
----	----	≤30 Microns	----	≤15 Microns
----	----	----	----	----
184 min	1.84 min	99% Theoretical	1.84-1.87	99% Theoretical
Controlled, Note 11	Controlled, Note 11	Controlled, Note 4, Type 2	Controlled, Note 13	Note 4, Type 2
Good	Good	Good	Excellent	Limited
Moderate	Moderate	Moderate	Good	Moderate
----	----	Microyield Strength Reported	----	Origin of Powder Electrolytic Flake

Historical Specifications - Consolidated Beryllium (concluded)

Spec/Grade	CD-11	XT-1	C-1	1S-1	1F-1
Revision Date	1966	1975	1976	1975	1975
Authority	KBI	KBI	KBI	KBI	KBI
Type of Material	Wire	Extrusion	Ingot	Sheet	Foil
Mfg./Fab	Warm Drawn Rod	Extruded Vacuum Melted and Cast Ingot	Vacuum Melted and Cast	Extruded and Cross Rolled Ingots	Extruded and Hot Rolled Ingots
Chem. Comp. (wt%)					
Be (min)	99	99.5	99.8	99.8	99.8
BeO (max)	0.02	0.03	0.03	0.03	0.03
Al (max)	0.09	0.01	0.01	0.01	0.01
C (max)	0.1	0.03	0.03	0.03	0.03
Fe (max)	0.15	0.03	0.03	0.03	0.03
Mg (max)	0.08	0.006	0.006	0.006	0.006
Si (max)	0.08	0.010	0.01	0.01	0.01
Cr (max)	----	0.0025	0.0025	0.0025	0.0025
Co (max)	----	0.0005	0.0005	0.0005	0.0005
Cu (max)	----	0.005	0.005	0.005	0.005
Pb (max)	----	0.0005	0.0005	0.0005	0.0005
Mn (max)	----	0.003	0.003	0.003	0.003
Mo (max)	----	0.001	0.001	0.001	0.001
Ni (max)	----	0.02	0.02	0.02	0.02
B (max)	----	----	----	----	----
Cd (max)	----	----	----	----	----
Ca (max)	----	----	0.02	0.02	0.02
Li (max)	----	----	----	----	----
N (max)	----	----	----	----	----
Ag (max)	----	----	0.0005	0.0005	0.0005
As Specified (max)	----	----	Zn 0.01	Zn 0.01	Zn 0.01
As Specified (max)	----	----	Ti 0.001	Ti 0.001	Ti 0.001
Other (each max)	----	----	----	----	----
Fe/Al Ratio	----	----	----	----	----
Mech. Prop.	≤0.010 in. dia.	----	----	----	----
F_{tu} (ksi)	130	Reported	----	(Depends on gage)	----
F_{ty} (ksi)	110	Reported	----	----	----
Elong. (min %)	1	Reported	----	Not Specified, Controlled	----
Elev. Temp.	----	----	----	----	----
Other	----	----	----	----	----
Avg Grain Size	----	----	----	----	----
Max Grain Size	----	----	----	----	----
Density (g/cm³)	1.84	1.83 min	----	1.83 min	1.83 min
Defect Limits	----	----	----	Controlled, Note 4, Type 2	Note 6
Weldable	----	Good	----	Good	Good
Formability	Moderate	Good	----	Good	Good
Remarks	Strength for larger diameter wire available	----	----	----	----

HISTORICAL SPECIFICATIONS - POWDERED BERYLLIUM

Explanations of terms used in these specifications are listed below.

Authority

Brush	-	Brush Wellman, Inc.
DOD	-	Department of Defense
KBI	-	Kawecki Berylco Industries, Inc.
Los Alamos	-	Los Alamos National Laboratory
LLNL	-	Lawrence Livermore National Laboratory
RF	-	Rocky Flats
SAE	-	Society of Automotive Engineers
SNLL	-	Sandia National Laboratory, Livermore

Manufacturing/Fabrication

HIP	-	Hot Isostatic Pressed
HPB	-	Hot Pressed Block
CRS	-	Cross-Rolled Sheet
VHP	-	Vacuum Hot Pressed
VHPB	-	Vacuum Hot Pressed Block

Mechanical Properties

L	-	Longitudinal
T	-	Transverse

NOTE: Specification notes are listed at the end of this report.

Historical Specifications - Powdered Beryllium ——————————>

Spec/Grade	SP-200-C	P-20	SP-100-C	P-10	NP-50-B	P-8
Authority	Brush	KBI	Brush	. BI	Brush	KBI
Chem. Comp. (wt%)						
Be (min)	98	98	98.5	98.5	99.0	99.0
BeO (max)	2.0	2.0	1.2	1.0	0.9	0.80
Al (max)	0.16	0.15	0.14	0.08	0.075	0.07
B (max)	----	----	----	----	0.00020	0.0002
Cd (max)	----	----	----	----	0.0002	0.0002
Ca (max)	----	----	----	----	0.01	0.01
C (max)	0.15	0.15	0.15	0.10	0.10	0.10
Cr (max)	----	----	----	----	0.01	0.01
Co (max)	----	----	----	----	0.0005	0.0005
Cu (max)	----	----	----	----	0.015	0.015
Fe (max)	0.18	0.18	0.15	0.15	0.075	0.085
Pb (max)	----	----	----	----	0.002	0.002
Li (max)	----	----	----	----	0.0003	0.0003
Mg (max)	0.08	0.08	0.08	0.08	0.05	0.08
Mn (max)	----	----	----	----	0.012	0.015
Mo (max)	----	----	----	----	0.002	0.002
Ni (max)	----	----	----	----	0.02	0.02
N (max)	----	----	----	----	0.02	0.02
Si (max)	0.08	0.08	0.08	0.08	0.06	0.06
Ag (max)	----	----	----	----	0.0010	0.0010
Other	0.04	0.04	0.04	0.04	----	----
Partial	-200 mesh 75% -100 mesh 98%	-74 Micron (-200 mesh)	-200 mesh 98%	-74 Microns (-200 mesh)	-74 Microns (-200 mesh)	-74 Microns (-200 mesh)
Fabrication	----	Impact Grinding	----	Impact Grinding	----	Impact Grinding
Remarks	----	----	----	----	----	----

Spec/Grade	P-1	EF-1
Authority	KBI	KBI
Chem. Comp. (wt%)		
Be (min)	99.0	99.0
BeO (max)	0.8	0.5
Al (max)	0.01	0.01
B (max)	----	----
Cd (max)	----	----
Ca (max)	----	----
C (max)	0.03	0.03
Cr (max)	0.0025	0.0025
Co (max)	0.0005	0.0005
Cu (max)	0.0050	0.005
Fe (max)	0.03	0.03
Pb (max)	0.0005	0.0005
Li (max)	----	----
Mg (max)	0.006	0.006
Mn (max)	0.003	0.003
Mo (max)	0.001	0.001
Ni (max)	0.02	0.02
N (max)	----	----
Si (max)	0.01	0.010
Ag (max)	----	0.0005
Other	----	Cl 0.09 Zn 0.01
Partial	-44 Microns (-325 mesh)	----
Fabrication	Impact Grinding	----
Remarks	Electrolytic Flake Source	Electrolytic Flake Source

SPECIFICATION NOTES

These criteria may not be exactly as stated in each individual specification; however, they are comparable.

Note 1

Penetrant Inspection - Cracks are not permissible, while pores (as determined by penetrant) are limited to the following:

A. The size of an individual pore on the surface may not exceed 0.050 in.

B. A maximum of three pores (0.003 to 0.050 in.) per inch on the surface is acceptable.

C. No restrictions to size or number if they do not hold Zyglo.

Radiographic Inspection - The total combined volume per cubic inch of all indications with an average dimension larger than 0.001 inch shall not exceed the volume of a 0.50-in.-dia. sphere. The variable density areas, bending, or restrictions shall not vary in radiographic density more than 5% compared to the surrounding area of similar thickness. Light high-density indications or areas in material 1.000 in. thick or less that are 5% or less in radiographic density compared to the surrounding material are radiographically acceptable.

Note 2

Radiographic requirements for defects and inclusions shall be specified on the drawings for each finished part. Buyer may specify radiographic acceptance requirements for part blanks to screen unacceptable material prior to final fabrication.

Note 3

Surface Defects - When examined visually, shapes shall be entirely free from detectable surface defects such as cracks, porosity, and scale.

Radiographic Inspection (Option A) - High-density inclusions and/or internal or exposed cavities in each part shall be limited to the following:

Number of Cavities or Inclusions Allowed	Nominal Dimension (in.)	Depth (in.)
None	None	0.003 or less
100 per 15 sq. in. randomly distributed	Less than 0.030	Greater than 0.003 to 0.017

Radiographic Inspection (Option B) - There shall be no detectable voids. For limit of void detectability, see specification.

No high-density stringers with a beryllium equivalency greater than 0.020 in. shall be acceptable. No high-density stringers longer than 1.000 in. shall be acceptable. Not applicable to RM 251520 and ME-001162.

Inclusions with an absorption to X rays greater than that caused by a 10% increase in material thickness shall be limited as follows:

A. None with an effective size greater than 0.050 in.

B. One per part with an effective size in the range of 0.030 to 0.050 in. inclusive.

C. In the range of 0.010 to 0.030 in., inclusions in any 1.0-in.-dia. circle projected in the radiograph are limited as follows:

Localized Thickness (in.)	Maximum Number of Inclusions per Circle
0 to 0.4	3
0.4 to 0.8	8
0.8 to 1.5	12
1.5 to 2.0	23
2.0 to 2.5	30
2.5 to 3.0	37
3.0 to 4.0	47
4.0 to 5.0	60
5.0 to 6.0	73

NOTE 4

Penetrant Inspection - The surface of the material in the machined or machined-and-etched

condition shall be free from porosity or cracks as determined by liquid penetrant inspection.

Radiographic Inspection - The material shall be radiographically inspected for conformance to Type 1 or Type 2 quality with regard to radiographic indications (void and/or inclusions).

Type 1 and Type 2 qualities are defined as follows: the largest dimension of an indication measured in the plane of the radiograph shall not exceed 0.030 in.

The arithmetic average of the maximum and the minimum dimensions of an indication measured in the plane of the radiograph shall not exceed 0.020 in.

In any one cubic inch of material, the total combined volume of all indications larger than 0.001 in. shall not exceed the volume of spheres having the following diameters:

Quality	Diameter of Sphere (in.)	Volume ($in.^3 \times 10^6$)
Type 1	0.050	66
Type 2	0.032	17

The volume of the indications shall be calculated on the basis of an assumed sphere, the diameter of which is equal to the maximum average dimension of the indication.

Note 5

Surface Quality - When examined visually, parts shall be free from detectable surface defects such as cracks, porosity, and scale.

Radiographic Inspection - There shall be no detectable voids for limits on void detectability. See specification.

Inclusions with an absorption to X rays greater than that caused by a 10% increase in material thickness shall be limited as indicated below.

Three inclusions in the range of 0.005 to less than 0.010 in., which are included in any 0.125-in.-dia. circle, shall be treated as one 0.010-in. inclusion.

A. None with an effective size greater than 0.050 in.

B. One per part with an effective size in the range of 0.030 to 0.050 in. inclusive.

C. In the range of 0.010 to 0.030 in., inclusions in any 1.0-in.-dia. circle projected on the radiograph are limited as follows:

Localized Thickness (in.)	Maximum Number of Inclusions per Circle
0 to 0.4	3
0.4 to 0.8	6
0.8 to 1.5	11
1.5 to 2.0	15
2.0 to 2.5	18
2.5 to 3.0	22
3.0 to 4.0	30
4.0 to 5.0	37
5.0 to 6.0	45

Note 6

Foil Integrity - Foil is generally available in three classifications of integrity, as defined below:

A. Vacuum Tight: There shall be no detectable leakage through the foil when tested with a helium mass spectrometer leak detector with a sensitivity of 2×10^{-8} atm cm^3/sec.

B. Optically Dense: The foil shall not be penetrated by light when illuminating one side of the foil over a restricted area with a high-intensity light source and viewing from the opposite side in a darkened room.

C. As Rolled: Supplied in as-produced condition, neither inspected nor guaranteed for vacuum tightness or optical density.

Surface Quality - The surface of the foil shall be free from cuts, scratches, laps, splits, creases, or rolled-in inclusions. Surface pits, if present, shall not exceed 15% of the sheet thickness as measured by optical methods.

Note 7

Radiographic Inspection - When inspected radiographically, the combined volume of all inclusions in a standard sample having an average dimension larger than 0.001 in. shall not exceed the volume of a 0.050-in. sphere of material, based on a solid block.

Note 8

Penetrant Inspection - The surface of the sheet in the finished condition prior to shipment shall be free from cracks and other defects as determined by liquid penetrant inspection.

Note 9

Penetrant and radiographic inspection will be performed when required.

Note 10

Quality - Material shall be uniform in quality and condition; it shall be clean, sound, and free from foreign materials and from internal and external imperfections detrimental to fabrication or to performance of parts.

Note 11

Penetrant Inspection - Liquid penetrant inspection of machined surfaces shall reveal no porosity or cracks.

Radiographic Inspection - The combined volume per cubic inch of voids and inclusions shall not exceed the volume of a 0.050-in.-dia. sphere.

Note 12

Surface - There shall be no indication of cracks or linear discontinuities as indicated by any non-destructive testing means capable of detecting this type of defect.

Radiographic Inspection - Any defect that penetrates the entire wall thickness shall be cause for rejection of the part.

High-density inclusions having an absorption to X rays greater than that caused by a 0.005-in.-thick beryllium penetrator shall be limited as follows:

A. Any single void or inclusion greater than 0.050 in. average dimension in the part shall cause rejection of the part.

B. More than 20 voids or inclusions with average dimensions between 0.030 and 0.050 in. shall be cause for rejection of the part.

C. No part shall contain more than 100 detectable voids or inclusions between 0.010 and 0.030 in. average dimension, randomly distributed, per 15 square inches of surface area.

D. Differences in radiographic film densities caused by non-uniformity in the part, which are not separately discernable as individual defects, shall be judged as a single defective area. Bonded areas appearing as higher density equal to or less than 0.005 in. equivalent radiographic absorption are acceptable.

Note 13

Surface - When examined by dye penetrant methods, finished parts shall be entirely free from cracks or linear discontinuities.

Radiographic Inspection - There shall be no detectable voids or porosity.

Inclusions with an absorption to X rays greater than that caused by a 0.010-in. beryllium equivalency shall be limited as follows:

A. None with an effective size greater than 0.025 in.

B. In any 1-in.-dia. circle, there shall be no more than three inclusions with an effective size in the range of 0.010 to 0.025 in.

High-density stringers are unacceptable if they exceed any of the following:

A. Length of 1 in.

B. Width of 0.015 in.

C. Radiographic density variation equivalent to 0.015-in. beryllium thickness.

REFERENCE

1. R. R. Corle, *Summary of Beryllium Specifications*, RFP-2664, Rockwell International, Rocky Flats Plant, Golden, CO, February 17, 1978.

END

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