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SUMMARY OF BERYLLIUM SPECIFICATIONS

Richard R. Corle

Materials Technology
GENERAL METALLURGY

Rockwell International

Atomics International Division
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

U. S. DEPARTMENT OF ENERGY
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Materials Technology
GENERAL METALLURGY

SUBJECT DESCRIPTORS

Beryllium Specifications

**ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
P. O. BOX 484
GOLDEN, COLORADO 80401**

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SUMMARY OF BERYLLIUM SPECIFICATIONS

Richard R. Corle

Abstract. This report summarizes and compares the main beryllium properties included in producer, Department of Energy (formerly ERDA) facility, and government specifications. These data are tabulated in a sequence established primarily by increasing purity and secondarily by increasing tensile properties. Comments on formability and weldability are also included.

INTRODUCTION

A multitude of beryllium specifications and grade designations has been published to control the chemical, metallurgical, mechanical, and defect limit properties. Many of these specifications (grades) describe the same or equivalent raw materials, but they have been originated and controlled by different authorities. This preponderance of specifications and grades has been a source of confusion for engineering, procurement, and production personnel associated with beryllium

products. To alleviate the problem, this report summarizes beryllium specification and grade data.

Comments on formability and weldability have also been included (see Table 1); however, these rating assessments were qualitatively determined and should not be considered irrefutable. The authority for each specification has been identified and is abbreviated as follows:

KBI -Kawecki Berylco Industries, Inc.

Brush - Brush Wellman, Inc.

RF - Rocky Flats Plant, Rockwell International

LLL - Lawrence Livermore Laboratory

DOD - Department of Defense

SAE - Society of Automotive Engineers

For additional information, a few of the more common beryllium powders commercially available have been tabulated in Table 2 of this report.

TABLE 1. Summary of Beryllium Specifications

BERYLLIUM (%)	<97	<97	<97	<97	<97
SPEC/GRADE	LS-62	LX-62	HP-40	I-400	HP-41
Revision Year	(1976)	(1970)	(1975)	(1972)	(1975)
Authority	KBI	KBI	KBI	Brush	KBI
Type of Material	Sheet	Extrusion	Rod, Bar, Blanks Instrument Grade	Block Instrument Grade	Rod, Bar, Blank Instrument Grade
Mfg./Fab.	Rolled	Extrude	Vacuum Hot Press	HPB ^a	Vacuum Hot Press
Chem. Comp. (%)					
Be (min)	(60 min-64 max)	(60 min-64 max)	94	94	94
BeO (max)	1.0 (including Al ₂ O ₃)	1.0 (including Al ₂ O ₃)	(4.25 min)	(4.25 min)	4.25 min-8.0 max
Al (max)	Balance	Balance	0.16	0.16	0.16
C (max)	0.1	0.1	0.25	0.25	0.25
Fe (max)	0.1	0.1	0.25	0.25	0.3
Mg (max)	0.05	0.05	0.08	0.08	0.08
Si (max)	---	---	0.15	0.08	0.15
As Specified (max)	---	---	---	---	---
As Specified (max)	---	---	---	---	---
As Specified (max)	---	---	---	---	---
Other (each, max)	0.04	0.04	0.1	0.1	0.1
Fe/Al Ratio	---	---	---	---	---
Mech. Prop.					(T) ^b (L) ^b
F _{tu} (ksi)	45	50	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	See Remarks
Avg Grain Size	---	---	≤ 10 microns	≤ 10 microns	≤ 12 microns
Max Grain Size	---	---	---	---	---
Density (g/cm ³)	99% Theoretical	2.07	99% Theoretical	99% Theoretical	99% Theoretical
Defect Limits	Surface Defects Controlled, Note 1 ^c	Not Controlled, Note 2 ^c	Controlled, Note 3 ^c	Controlled, Note 4 ^c	Controlled, Note 3 ^c
Weldable ^{d,e}	Yes	Yes	No	No	No
Formability ^e	Good	Good	No	No	No
Remarks	Trade Name Lockalloy	Trade Name Lockalloy	Microyield 8 ksi min	Microyield Reg-8 ksi min Select-9 ksi min	Microyield 8 ksi min

a. HPB - Hot Pressed Block

b. T - Transverse; L - Longitudinal

c. All notes are located at the end of Table 1.

d. The assessment is made for fusion welding only.

e. The rating assessment for each grade was qualitatively determined and should not be considered irrefutable.

TABLE 1. cont.

97.4	97.4	97.4	98	98	98
P10577 (1965)	P11718 (1975)	RM253335 (1975)	RM251520 (1975)	P31664-6 (1976)	MEL 71-001162A (1972)
RF	RF	LLL	LLL	RF	LLL
Not Specified	Blanks	Not Specified	Parts, Block	Block	Block
Not Specified	Deep Drawing, HPB, ^a	Hot Pressed Ingot Sheet	HPB ^a or Approv. Alternate	HPB ^a or Approv. Alternate	HPB ^a or Approv. Alternate
97.4	97.4	97.4	98	98	98
3.0	3.0	3.0	1.5	1.5	1.5
---	0.18	0.18	0.07	0.07	0.07
---	0.20	0.20	0.10	0.10	0.10
---	0.30	0.30	0.12	0.12	0.12
---	0.08	0.08	0.08	0.08	0.08
---	0.12	0.12	0.08	0.08	0.08
---	---	---	S-0.04	S-0.04	S-0.04
---	---	---	U-0.04	U-0.04	U-0.04
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	0.04	0.04	0.04
---	---	---	Controlled	Controlled	Controlled
---	---	---	(T) ^b (L) ^b	(T) ^b (L) ^b	(T) ^b (L) ^b
---	---	---	35 35	35 35	35 35
---	---	---	25-38 25-38	25-38 25-38	25-38 25-38
---	---	---	2 1	2 1	2 1
---	---	---	Controlled	Controlled	Controlled
---	---	---	F _{ty} /F _{tu} -0.9 max	F _{ty} /F _{tu} -0.9 max	F _{ty} /F _{tu} -0.9 max
---	---	---	≤ 35 microns	≤ 35 microns	≤ 35 microns
---	---	---	≤125 microns	≤125 microns	≤125 microns
1.83 - 1.87	1.84 - 1.87	1.84 - 1.87	1.84 - 1.87	1.84 - 1.87	1.84 - 1.87
Not Controlled, Negotiate	Controlled, Note 5 ^c	Controlled, Note 5 - RF Option B ^c	Controlled, Note 5 - RF Option B ^c	Controlled, Note 5 - RF Option B ^c	Controlled, Note 5 - RF Option B ^c
No	No	No	Excellent	Excellent	Excellent
No	No	No	Probable	Probable	Probable
---	---	---	Current weldable grade; scrap must be remelted if used.	Current weldable grade; scrap must be remelted if used.	Intermediate weld- able grade; weld test specimens to be provided to LLL

a. HPB - Hot Pressed Block

b. T - Transverse; L - Longitudinal

c. All notes are located at the end of Table 1.

TABLE 1. cont.

BERYLLIUM (%)	98	98	98	98	98
SPEC/GRADE	AMS 7901	MIL-B-21531A	P11512-E	P11736-4	HP-20
Revision Year	(1961)	(1969)	(1967)	(1965)	(1975)
Authority	SAE	DOD	RF	RF	KBI
Type of Material	Shapes, Bar, Rod	Shapes	Block, Shape	Block, machined shapes	Rod, Bar, Blanks
Mfg./Fab.	Hot Pressed	Vac. Hot Pressed	HPB, ^a Forged	HPB, ^a Forged	Vac. Hot Pressed
Chem. Comp. (%)					
Be (min)	98	98	98	98	98
BeO (max)	2.0	2.0	2.0	2.0	2.0
Al (max)	0.20	0.16	0.16	0.16	0.15
C (max)	0.15	0.15	0.15	0.15	0.15
Fe (max)	0.20	0.18	0.20	0.20	0.18
Mg (max)	0.08	0.08	0.08	0.08	0.08
Si (max)	0.12	0.08	0.12	0.12	0.08
As Specified (max)	----	----	N (as nitride) 0.06	N (as nitride) 0.06	----
As Specified (max)	----	----	Mn 0.05	Mn 0.05	----
As Specified (max)	----	----	Cr, Cu } 0.20 tot.	Cr, Cu } 0.20 tot.	----
As Specified (max)	----	----	Ni, Ti }	Ni, Ti }	----
As Specified (max)	----	----	----	----	----
Other (each, max)	0.04	0.04	0.05	0.05	0.04
Fe/Al Ratio	----	----	----	----	----
Mech. Prop.					
F _{tu} (ksi)	40	40	40	40	40
F _{ty} (ksi)	30	30	30	30	30
Elong. (min %)	1	1	1	1	1
Elev. Temp.	----	----	----	----	----
Other	----	Modulus	----	----	----
Avg Grain Size	----	----	----	----	≤ 25 microns
Max Grain Size	----	----	----	----	----
Density (g/cm ³)	1.84 min	1.84 min	1.84 - 1.87	1.84 - 1.86	99% Theoretical
Defect Limits	Workmanship Clause	Controlled, Note 4 ^b	Controlled, Note 5 ^b	Controlled, Note 8 ^b	Controlled, Note 3 ^b
Weldable ^{c,d}	Limited	Limited	Limited	Limited	Limited
Formability ^d	No	No	Poor	Poor	Poor
Remarks	Powder size -200 mesh	----	Type III = welded based on LLL controls (early weldable grade)	Type WLA = welded based on LASL controls (early weld- able grade)	----

a. HPB - Hot Pressed Block

b. All notes are located at the end of Table 1.

c. The assessment is made for fusion welding only.

d. The rating assessment for each grade was qualitatively determined and should not be considered irrefutable.

TABLE 1. cont.

98	98	98	98	98	98
S-200-E (1972)	SS229054 (1972)	P31351 (1973)	S-245 (1972)	HP-21 (1975)	HP-22 (1975)
Brush	LLL	RF	Brush	KBI	KBI
Parts, Shapes	Parts	Parts	Block	Rod, Bar, Billet, Blank, Structural Grade	Rod, Bar, Billet, Blank, Instrument Grade
Hot Pressed	HPB, ^a Powder, Forgings, CRS, ^b Extrusion	HPB ^a , Powder, Forgings, CRS, ^b Extrusion	HPB ^a	Vacuum Hot Pressed	Vacuum Hot Pressed
98	98	98	98	98	98
2.0	2.0	2.0	2.0	2.0	2.0
0.16	0.16	0.16	0.10	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15
0.18	0.20	0.20	0.15	0.18	0.20
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) ^c (L) ^c	(T) ^c (L) ^c	(T) ^c (L) ^c	(T) ^c (L) ^c	---
40	45 40	45 40	45 45	45 40	45
30	35 30	35 30	35 30	35 35	35
1	2 1.5	2 1.5	2 1.5	2 1.5	2
---	---	---	---	---	---
---	---	---	---	---	See Remarks
≤ 25 microns	---	---	≤ 25 microns	≤ 25 microns	≤ 25 microns
---	---	---	---	---	---
1.84 min		184 - 187	1.84 min	99% Theoretical	99% Theoretical
Controlled, Note 3 ^d		Controlled	Controlled, Note 3 ^d	Controlled, Note 3 ^d	Controlled, Note 3 ^d
Limited	Limited	Limited	Limited	Limited	Limited
Poor	Poor	Poor	Poor	Poor	Poor
---	Specified part and process control imposed	Specified part and process control imposed	---	---	Microyield 5 ksi min

a. HPB - Hot Pressed Block

b. CRS - Cross Rolled Sheet

c. T - Transverse; L - Longitudinal

d. All notes are located at the end of Table 1.

TABLE 1. cont.

BERYLLIUM (%)	98	98	98	98	98
SPEC/GRADE	I-220	PR-200-E	PR-20	XT-20	SR-200-E
Revision Year	(1974)	(1972)	(1968)	(1974)	(1974)
Authority	Brush	Brush	KBI	KBI	Brush
Type of Material	Block, Inst. Grade	Plate	Plate	Extrusion	Sheet
Mfg./Fab.	HPB ^a	Hot Roll, HPB ^a	Cross Rolling Block	Extrude	Hot Roll, HPB ^a
Chem. Comp. (%)					
Be (min)	98	98	98	98	98
BeO (max)	2.0	2.0	2.0	2.0	2.0
Al (max)	0.10	0.16	0.15	0.18	0.16
C (max)	0.15	0.15	0.15	0.15	0.15
Fe (max)	0.15	0.18	0.18	0.20	0.18
Mg (max)	0.08	0.08	0.08	0.08	0.08
Si (max)	0.08	0.08	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	0.04	0.04
Fe/Al Ratio	----	----	----	----	----
Mech. Prop.	----	(T) (L)	(T) (L)	----	----
F _{tu} (ksi)	45	65 ^b 60 ^c	65 ^b 60 ^c	70	70
F _{ty} (ksi)	35	45 40	45 40	45	50
Elong. (min %)	2	4 3	4 3	5	10
Elev. Temp.	----	----	----	----	----
Other	See Remarks	----	----	----	----
Avg Grain Size	≤ 25 microns	----	----	----	----
Max Grain Size	----	----	----	----	----
Density (g/cm ³)	1.84 min	----	1.84 min	1.84 min	----
Defect Limits	Controlled, Note 3 ^d	Controlled If Specified, Note 4 ^d	Penetrant Inspection If Required	Controlled, Note 4 ^d	----
Weldable ^{e,f}	Limited	Limited	Limited	----	Limited
Formability ^f	Poor	Poor	Poor	No	Poor
Remarks	Microyield 5 ksi min	----	----	----	----

a. HPB - Hot Pressed Block

b. Thickness of 0.250 to 0.450 inch

c. Thickness of 0.451 to 0.600 inch

d. All notes are located at the end of Table 1.

e. The assessment is made for fusion welding only.

f. The rating assessment for each grade was qualitatively determined and should not be considered irrefutable.

TABLE 1. cont.

98	98	98	98.5	98.5	98.5
PS-20	PF-20	HIP-50 (preproduction grade)	S-100-E	HP-12	HP-10
(1975)	(1975)	(1977)	(1972)	(1968)	(1971)
KBI	KBI	KBI	Brush	Brush	KBI
Sheet	Foil	Block, Bar, Rod	Parts, Shapes	Blocks	Block, Thermal Cycling
Cross Roll HPB ^a	Produced from HPB ^a	Hot Isostatic Consolidation of Electrolytic Flake Powders	Hot Pressed	Hot Pressed	HPB ^a
98	98	98	98.5	98.5	98.5
2.0	2.0	1.6	1.2	1.2	1.2
0.15	0.09	0.0075	0.14	0.09	0.08
0.15	0.12	0.003	0.15	0.12	0.10
0.18	0.15	0.005	0.16	0.04	0.15
0.08	0.08	0.003	0.08	0.06	0.08
0.08	0.08	0.0045	0.08	0.08	0.08
---	---	Cr 0.0035	---	---	---
---	---	Cu 0.0070	---	---	---
---	---	Mn 0.0025	---	---	---
---	---	Ni 0.001	---	---	---
---	---	---	---	---	---
0.04	0.04	---	0.04	0.04	0.04
---	---	---	---	---	---
---	---	---	---	---	---
70	---	80	35	35	37
50	---	60 } typical	27	27	24
10	---	4 }	1	1	1.5
---	---	---	---	---	---
---	---	---	---	---	---
---	---	---	< 25 microns	< 25 microns	< 25 microns
---	---	---	---	---	---
99% Theoretical	99% Theoretical	---	1.84 min	1.84 min	99% Theoretical
Controlled, Note 3 – Type 2 ^b	Vacuum Tight, Optically Dense	---	Controlled, Note 3 ^b	Controlled, Note 3 ^b	Controlled, Note 4 ^b
Limited	Limited	Unknown	Good	Good	Good
Poor	Moderate	Unknown	Moderate	Moderate	Moderate
---	---	Microyield 8 ksi	---	---	---

a. HPB - Hot Pressed Block

b. All notes are located at the end of Table 1.

TABLE 1. cont.

BERYLLIUM (%)	98.5	98.5	99	99	99
SPEC/GRADE	S-65	MEL 76-001319	C-50	IF-2	HP-8
Revision Year	(1973)	(1976)	(1968)	(1975)	(1968)
Authority	Brush	LLL	KBI	KBI	KBI
Type of Material	Block, Structural Grade	Parts, Shapes	Ingot	Foil	Block, Shapes
Mfg./Fab.	HPB ^a	HPB ^a HIP ^b	Vacuum Melt and Cast	Extrude and Roll Vacuum Cast Ingot	Hot Pressed
Chem. Comp. (%)					
Be (min)	98.5	98.5	99	99	99
BeO (max)	1.0	1.2	0.5	0.03	0.9
Al (max)	0.06	0.06	0.09	0.09	0.07
C (max)	0.12	0.1	0.10	0.10	0.10
Fe (max)	0.12	0.1	0.15	0.15	0.075
Mg (max)	0.08	0.08	0.08	0.02	0.06
Si (max)	0.06	0.06	0.08	0.08	0.06
Cr (max)	----	----	0.01	----	0.01
Co (max)	----	----	0.0005	----	0.0005
Cu (max)	----	----	0.015	----	0.015
Pb (max)	----	----	0.005	----	0.002
Mn (max)	----	----	0.015	----	0.012
Mo (max)	----	----	0.002	----	0.002
Ni (max)	----	----	0.03	----	0.02
B (max)	----	----	0.0002	----	0.0002
Cd (max)	----	----	0.0002	----	0.0002
Ca (max)	----	----	0.02	----	0.01
Li (max)	----	----	0.0003	----	0.0003
N (max)	----	----	0.03	----	0.02
Ag (max)	----	----	0.001	----	0.001
As Specified (max)	----	S-0.04	Zn 0.02	----	----
As Specified (max)	----	U-0.04	----	----	----
As Specified (max)	----	----	----	----	----
As Specified (max)	----	----	----	----	----
Other (each, max)	0.04	0.04	----	0.04	----
Fe/Al Ratio	----	Controlled	----	----	----
Mech. Prop.	----	(T&L) ^c	----	----	----
F _{tu} (ksi)	42	50	----	----	35
F _{ty} (ksi)	30	35-50	----	----	25
Elong (min %)	3	3	----	----	1
Elev. Temp.		Controlled			
Other	----	----	----	----	----
Avg Grain Size	≤ 15 microns	≤ 15 microns	----	----	----
Max Grain Size	----	----	----	----	----
Density (g/cm ³)	99% Theoretical	99% Theoretical	----	1.83	1.84 min
Defect Limits	Controlled Note 3 - Type 1 ^d	Controlled, Note 6 ^d	----	Vacuum Tight, Optically Dense	Controlled, Note 4 ^d
Weldable ^{e,f}	Good	Excellent	Good	Good	Good
Formability ^f	Moderate	Moderate	Good	Moderate	Moderate
Remarks	----	----	----	----	----

a. HPB - Hot Pressed Block

b. HIP - Hot Isostatically Pressed

c. T - Transverse; L - Longitudinal

d. All notes are located at the end of Table 1.

e. The assessment is made for fusion welding only.

f. The rating assessment for each grade was qualitatively determined and should not be considered irrefutable.

TABLE 1. cont.

99	99	99	99	99	99
N-50-C (1972)	HP-81 (1975)	1-70A (1973)	8115000 (1973)	CIP-HIP-1 (1975)	CD-11 (1966)
Brush	KBI	Brush	RF	KBI	KBI
Block, Billet, Shapes	Block, Optical Grade	Block, Optical Grade	Sheet	Block, Rod, Bar, Blanks	Wire
Not Specified	Vacuum Hot Pressed	Hot Pressed	Vacuum Melt, Cast and Rolled Ingot	Isostatic Consolidated	Warm Draw Rod
99	99	99	99	99	99
0.9	1.0	0.7	0.05	1.2	0.02
0.06	0.08	0.07	0.12	0.01	0.09
0.10	0.10	0.07	0.12	0.0300	0.1
0.075	0.12	0.10	0.25	0.0300	0.15
0.05	0.08	0.07	0.05	0.0060	0.08
0.06	0.08	0.07	0.12	0.0100	0.08
0.01	---	---	0.05	0.0025	---
0.0005	---	---	---	0.0005	---
0.015	---	---	0.05	0.0050	---
0.002	---	---	---	0.0005	---
0.012	---	---	---	0.0030	---
0.002	---	---	---	0.0010	---
0.02	---	---	0.05	0.0200	---
0.0002	---	---	---	---	---
0.0002	---	---	---	---	---
0.01	---	---	---	---	---
0.0003	---	---	---	---	---
0.02	---	---	0.06	---	---
0.0010	---	---	---	---	---
---	0.04	0.04	0.02	---	---
---	---	---	---	---	---
---	---	---	Ti 0.05	---	---
---	---	---	---	---	---
---	---	---	Controlled	---	---
---	---	---	(T) ^a (L) ^a	---	≤0.010-in. dia.
35	35	35	38 40	50	130
25	25	25	22 22	35	110
1	2	2	3 3	3	1
---	See Remarks	See Remarks	F _{tu} L&T within 10 ksi	---	---
---	≤ 30 microns	≤ 20 microns	---	≤ 15 microns	---
---	---	---	---	---	---
1.84 min	99% Theoretical	99% Theoretical	1.84 - 1.86	99% Theoretical	1.84
Controlled, Note 4 ^b	Controlled, Note 3 - Type 2 ^b	Controlled, Note 3 - Type 1 ^b	Controlled, Note 7 ^b	Controlled, Note 3 - Type 2 ^b	---
Good	Good	Good	Excellent	Limited	---
Moderate	Moderate	Moderate	Good	Moderate	Moderate
	Microyield Reported	Microyield Thermal Expansion Reported		Origin of Powder- Electrolytic Flake	Strength for Larger Diameter Wire Available

a. T - Transverse; L - Longitudinal

b. All notes are located at the end of Table 1.

TABLE 1. cont.

BERYLLIUM (%)	99.5	99.8	99.8	99.8
SPEC/GRADE	XT-1	C-1	1S-1	1F-1
Revision Year	(1975)	(1976)	(1975)	(1975)
Authority	KBI	KBI	KBI	KBI
Type of Material	Extrusion	Ingot	Sheet	Foil
Mfg./Fab.	Extruded Vacuum Melt and Cast Ingot	Vacuum Melt and Cast	Extruded and Cross Roll Ingots	Extruded and Hot Roll Ingots
Chem. Comp. (%)				
Be (min)	99.5	99.8	99.8	99.8
BeO (max)	0.03	0.03	0.03	0.03
Al (max)	0.01	0.01	0.01	0.01
C (max)	0.03	0.03	0.03	0.03
Fe (max)	0.03	0.03	0.03	0.03
Mg (max)	0.006	0.006	0.006	0.006
Si (max)	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.	----	----	----	----
F _{tu} (ksi)	Reported	----	(Depends on gage)	----
F _{ty} (ksi)	Reported	----	----	----
Elong. (min %)	Reported	----	Not Specified, Controlled	----
Avg Grain Size	----	----	----	----
Max Grain Size	----	----	----	----
Density (g/cm ³)	1.83 min	----	1.83 min	1.83 min
Defects	----	----	Controlled, Note 3 - Type 2 ^a	Vacuum Tight, Optically Dense
Weldable ^{b,c}	Good	----	Good	Good
Formability ^c	Good	----	Good	Good
Remarks	----	----	----	----

a. All notes are located at the end of Table 1.

b. The assessment is made for fusion welding only.

c. The rating assessment for each grade was qualitatively determined and should not be considered irrefutable.

TABLE 1. cont.

NOTES*

1. 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.

2. Penetrant and radiographic inspection will be performed when required.

3. Penetrant Inspection

The surface of the material in the machined or machined and etched condition shall be free of 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 Qualify with regard to radiographic indications (voids and/or inclusions).

Type 1 and Type 2 Qualify are defined as follows:

Maximum Dimension of Radiographic Indications

The largest dimension of an indication measured in the plane of the radiograph shall not exceed 0.030 inch (0.76 millimeter).

Maximum Average Dimension of Radiographic Indications

The arithmetic average of the maximum and the minimum dimensions of an indication

*These criteria are not necessarily exactly as stated in each individual specification; however, they are comparative.

measured in the plane of a radiograph shall not exceed 0.020 inch (0.51 millimeter).

Total Combined Value of Radiographic Indications

In any one cubic inch (1.65×10^4 cubic millimeter) of material, the total combined volume of all indications larger than 0.001 inch (0.025 millimeter) shall not exceed the volume of spheres having the following diameters:

Quality	Diameter of Sphere [in. (mm)]	Volume [cu in. $\times 10^{-6}$ (mm ³)]
Type 1	0.050 (1.27)	66 (1.07)
Type 2	0.032 (0.81)	17 (0.28)

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.

4. 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 sphere 0.050 inches in diameter.

5. Surface Defects

When examined visually, shapes shall be entirely free of detectable surface defects such as cracks, porosity, and scale.

TABLE 1. cont. Radiographic Inspection

RF Option A –

High density inclusions and/or internal or exposed cavities in each part shall be limited to the following:

<u>No. Cavities or Inclusions Allowed</u>	<u>Nominal Dimension (in.)</u>	<u>Depth (in.)</u>
Any	Any	0.003 or less
100 per 15 sq. in., randomly distributed	Less than 0.030	Greater than 0.003 to 0.017
20	0.030 to 0.050	Greater than 0.003 to 0.017

RF Option B –

Voids – There shall be no detectable voids. For limit of void detectability, see specification.

High Density Stringers – No high-density stringers with a Be equivalency greater than 0.020 inch shall be acceptable. No high-density stringers longer than 1.000 inch shall be acceptable. Not applicable to RM251520 and ME-001162.

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

- None with an effective size greater than 0.050 inch.
- One per part with an effective size in the range of 0.030 to 0.050 inch inclusive.
- In the range of 0.010 to 0.030 inch, there may be as many in any 1.0-inch-diameter

circle projected on the radiograph as tabulated below:

<u>Localized Thickness (inches)</u>	<u>Max. No. of Inclusions Per Circle</u>
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

6. Surface Quality

When examined visually, parts shall be free of detectable surface defects such as cracks, porosity, and scale.

Radiograph Inspection

Voids – There shall be no detectable voids. For limit of void detectability, see specification.

Inclusions – Inclusions with an absorption to X rays greater than that caused by a 10 percent increase in material thickness shall be limited as indicated below. Three inclusions in the range of 0.005 to less than 0.010 inch, which are included in any 0.125-inch-diameter circle, shall be treated as one 0.010-inch inclusion.

- None with an effective size greater than 0.050 inch.
- One per part with an effective size in the range of 0.030 to 0.050 inch inclusive.
- In the range of 0.010 to 0.030 inch, there may be as many in any 1.0-inch-diameter

TABLE 1. cont.

circle projected on the radiograph as tabulated below.

Local Part Thickness (Inches)	Max. No. 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

7. Surface

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

Radiographic Inspection

Voids — There shall be no detectable voids or porosity.

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

- None with an effective size greater than 0.025 inch.
- In any 1-inch-diameter circle, there shall be no more than 3 inclusions with an effective size in the range 0.010 to 0.025 inch.

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

- Length - 1 inch

b. Width — 0.015 inch

c. Radiographic density variation equivalent to 0.015-inch beryllium thickness.

8. Surface

There shall be no indication of cracks or linear discontinuities as indicated by any nondestructive testing means capable of detecting this type 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-inch-thick beryllium penetrameter shall be limited as follows:

- Any single void or inclusion greater than 0.050-inch average dimension in the part shall cause rejection of the part.
- More than 20 voids or inclusions with average dimensions between 0.030 and 0.050 inch shall be cause for rejection of the part.
- No part shall contain more than 100 detectable voids or inclusions between 0.010- and 0.030-inch average dimension, randomly distributed, per 15 square inches of surface area.
- Differences in radiographic film densities caused by nonuniformity in the part, which are not separately discernible as individual defects, shall be judged as a single defective area. Bonded areas appearing as higher density equal to or less than 0.005 equivalent radiographic absorption are acceptable.

TABLE 2. Beryllium Powder

SPEC/GRADE	SP-200-C	P-20	SP-100-C	P-10
AUTHORITY	Brush	KBI	Brush	KBI
Chem. Comp. (%)				
Be (min)	98	98	98.5	98.5
BeO (max)	2.0	2.0	1.2	1.0
Al (max)	0.16	0.15	0.14	0.08
B (max)	---	---	---	---
Cd (max)	---	---	---	---
Ca (max)	---	---	---	---
C (max)	0.15	0.15	0.15	0.10
Cr (max)	---	---	---	---
Co (max)	---	---	---	---
Cu (max)	---	---	---	---
Fe (max)	0.18	0.18	0.15	0.15
Pb (max)	---	---	---	---
Li (max)	---	---	---	---
Mg (max)	0.08	0.08	0.08	0.08
Mn (max)	---	---	---	---
Mo (max)	---	---	---	---
Ni (max)	---	---	---	---
N (max)	---	---	---	---
Si (max)	0.08	0.08	0.08	0.08
Ag (max)	---	---	---	---
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)
Fabrication	---	Impact Attrition	---	Impact Attrition
Remarks	---	---	---	---

TABLE 2. cont.

NP-50-B	P-8	P-1	EF-1
Brush	KBI	KBI	KBI
99.0	99.0	99.0	99.0
0.9	0.80	0.8	0.5
0.075	0.07	0.01	0.0075
0.00020	0.0002	----	----
0.0002	0.0002	----	----
0.01	0.01	----	----
0.10	0.10	0.03	0.0175
0.01	0.01	0.0025	0.001
0.0005	0.0005	0.0005	0.0005
0.015	0.015	0.0050	0.003
0.075	0.085	0.03	0.01
0.002	0.002	0.0005	0.0005
0.0003	0.0003	----	----
0.05	0.08	0.06	0.003
0.012	0.015	0.003	0.001
0.002	0.002	0.001	0.001
0.02	0.02	0.02	0.006
0.02	0.02	----	----
0.06	0.06	0.01	0.0075
0.0010	0.0010	----	0.0005
----	----	----	C1-0.09
			Zn-0.01
-74 microns (-200 mesh)	-74 microns (-200 mesh)	-44 microns (-325 mesh)	----
----	Impact Attrition	Impact Attrition	----
----		Electrolytic Flake Source	Electrolytic Flake Source