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SPECIFICATION

FOR

MATERIAL SPECIFICATION

BERYLLIUM PRESSINGS AND COMPONENTS

FOR NUCLEAR REACTORS AND REACTOR SYSTEMS

PROJECT NO.

6840

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M L Nelson

Engineering Graphics
EG&G Idaho, Inc.

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APPROVAL SIGNATURE		DATE
R2 Curie for D. R. Mousseau Cognizant Engineer		4-26-78
R B Ringer R. B. Ringer Cognizant Engineer		4-26-78
D.W. Smith Quality		4-26-78
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1. SCOPE

This specification covers material requirements for reactor-grade beryllium pressings and components for use in nuclear reactors and reactor systems at the Idaho National Engineering Laboratory near Idaho Falls, Idaho.

2. APPLICABLE DOCUMENTS

The following documents, of the issue in effect on the date of invitation for bids, shall form a part of this specification to the extent specified herein.

SPECIFICATIONS

EG&G Idaho, Inc.

Company Procedures Manual Section 9.3	Liquid Penetrant Examination

American Society for Testing and Materials (ASTM)

B 214	Sieve Analysis of Granular Metal Powders
E 4	Verification of Testing Machines
E 8	Tension Testing of Metallic Materials

Brookhaven National Laboratory (BNL)

BNL 325, Second Edition, Supplement No. 2	Neutron Cross Sections; Sigma Center, Brookhaven National Laboratory. (Available from the Office of Technical Services, Department of Commerce)

Lange's

11th Edition (Mcgraw Hill)	Handbook for Chemistry

3. REQUIREMENTS

3.1 General - The subcontractor shall provide beryllium pressings or components as specified on the applicable engineering drawings and specifications.

3.2 Process Requirements - The proposed method of beryllium manufacture, powder processing, casting methods, and hot pressing procedures shall be submitted for EG&G approval prior to fabrication. When approved, these procedures shall not be changed without EG&G approval. The powder shall be of such fineness that a minimum of 98 percent (by weight) will pass through a No. 200 sieve (74 microns) when tested in accordance with ASTM B 214. A sieve analysis shall be submitted to EG&G for each lot of powder. The final form shall then be produced by hot pressing the powder from a uniform lot to form blocks with an average grain size less than 25 microns for finish machining. A uniform lot is defined as any quantity of powder which is blended to a uniform composition.

3.3 Chemical Requirements

3.3.1 Chemical Composition - Beryllium pressings and components shall have following chemical composition when analyzed in accordance with 4.4.1:

Element	Content (percent, by weight)
Beryllium	98.00 minimum
Beryllium oxide	2.00 maximum
Aluminum	0.18 maximum
Carbon	0.15 maximum
Iron	0.20 maximum
Silicon	0.12 maximum
Magnesium	0.08 maximum
Other metal impurities (each)	0.04 maximum
Any halide (each)	0.04 maximum

In addition, determine and report scandium

3.3.2 Nuclear Requirements - When analyzed in accordance with 4.4.2, the total danger sum shall not exceed 75 on a percentage basis for chemical analysis. The total danger sum (TDS) is calculated as the value which is equal to the sum of the products of the concentration of each impurity and the danger coefficient of that impurity. The danger coefficient of a substance is a measure of the ability of that substance to absorb thermal neutrons compared with the ability of some reference substance (in this case, beryllium) to absorb thermal

neutrons. The equation for determining the danger coefficient is as follows:

$$K_s(i) \quad \frac{N_o\sigma_i/A_i}{N_o\sigma_{Be}/A_{Be}}$$

where K_s (i) = the danger coefficient of impurity (i) with respect to beryllium

N_o = the number of atoms in 1 gram atom of any substance (0.603×10^{24} atoms/gram atom)

A_i = the atomic weight of the impurity

A_{Be} = the atomic weight of beryllium (9.013)

σ_i = the microscopic cross section of impurity for absorption of thermal neutrons (cm^2/atom), determined from Report BNL 325, Neutron Cross Sections and Langes "Handbook for Chemistry" 11th Edition (McGraw Hill) for cerium, terbium and thulium.

σ_{Be} = the microscopic cross section of beryllium for absorption of thermal neutrons (0.010×10^{-24} cm^2/atom)

The chemical analysis method of determining the TDS shall include iron, aluminum, boron, cadmium, lithium, copper, manganese, nickel, cerium, terbium, thulium, and other rare earths.

3.4 Physical Properties

3.4.1 Density - The minimum density of the beryllium pressings, or parts thereof, shall be no less than 1.84 grams per cubic centimeter at 70°F when measured in accordance with 4.4.4.1.

3.4.2 Soundness - The size and frequency of internal voids, cavities, and inclusions in beryllium pressings and components shall not exceed those specified in Table I. There shall be no indications of any internal cracks. Internal defects shall be determined as specified in 4.4.4.2.

3.4.2.1. Striation - Grouping of particular fines within the beryllium pressing as determined by 4.4.4.2 Radiography shall not vary in density from the surrounding material more than 15%.

Table I. Maximum Allowable Defects

Thickness of Finished Part (inches)	Maximum Dimension[1]	Maximum Average Dimension[2]	Total Combined Volume per Cubic inch[3]
0 to 9	0.030	0.020	Sphere 0.050 inch diameter

1. Maximum Dimensions of an Indication. Any dimension of any indication measured in the plane of the radiograph shall not exceed 0.030 inch.

2. Maximum Average Dimension of any Indication. The average dimensions of an indication shall not exceed 0.020 inch. The average dimension of an indication shall be the arithmetic average of the maximum and minimum dimensions measured in the plane of the radiograph.

3. Total Combined Volume Per Cubic Inch of all Indications. 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 sphere of the indicated diameter.

3.4.3 Surface Condition - The surface of beryllium pressing and components shall be free of porosity and cracks as detected when inspected in accordance with 4.4.4.3. All inclusions and spongy metal present on the surface shall be removed.

3.5 Mechanical Properties - Beryllium pressings and components shall be capable of meeting the following requirements when tested in any direction at room temperature in accordance with 4.4.3:

Ultimate Tensile Strength:	40,000 psi
Tensile Yield Strength (0.2% offset):	30,000 psi
Elongation in 1 inch (minimum):	1.0%

3.6 Identification - The identity of each beryllium pressing or portion thereof, with respect to pressing number and powder lot, shall be recorded and maintained at all stages of manufacture and reported to EG&G as specified in 4.7. Temporary markings shall be made with vegetable dyes.

3.7 Cleaning - Cleaning of beryllium pressings and components shall be in accordance with the applicable engineering drawings.

4. QUALITY ASSURANCE PROVISIONS

4.1 Subcontractor Responsibility - Unless otherwise specified by the subcontract or purchase order, the subcontractor shall be responsible for performing all tests and inspections required by this specification.

4.2 Sampling

4.2.1 Sample for Chemical Analysis - Two 50-gram samples, in the form of mechanical chips, shall be taken from each hot pressing and used for chemical analysis. One of the samples shall be analyzed as specified in 4.4.1. The other sample shall be retained by the subcontractor for check analyses at a later date.

4.2.2 Sample for Nuclear Analysis - Two 50-gram samples, in the form mechanical chips, shall be taken from each hot pressing and used for analysis of nuclear properties. One of the samples shall be analyzed as specified in 4.4.2. The other sample shall be retained by the subcontractor for check analyses at a later date.

4.2.3 Specimens for Mechanical Tests - The quantity and location of specimens shall be as specified on the engineering drawing. If the quantity is not specified on the engineering drawing, at least two specimens for mechanical tests shall be obtained from each rough shape of beryllium pressing, one in the longitudinal direction and one in the transverse direction. If cutting of test specimens from excess material is not feasible, the specimens shall be formed along with and as an integral part of each shape such that the specimens may be cut away from the shape. Specimens shall not be obtained from adjacent sections of the shape but shall be taken from different sections located throughout the shape to ensure samples which are representative of the entire quantity of material being inspected.

4.2.4 Sample for Density Test - Samples for density tests shall be the entire rough shape produced and the mechanical test specimens obtained therefrom.

4.2.5 Sample for Inclusion Volume Determination - One specimen 0.500" Dia. x 1" x 2" shall be taken from the area adjacent to the mechanical test specimens as identified in 4.2.3.

4.3 Test Equipment - Test equipment required for testing shall be verified as specified in ASTM E 4.

4.4 Inspection Methods

4.4.1 Chemical Analysis - A complete chemical analysis shall be performed on a sample chosen as specified by 4.2.1. Any chemical or

spectrochemical method approved by EG&G may be used, provided the composition of the sample can be determined to the nearest hundredth of 1 percent. The chemical composition shall conform to the requirements specified in 3.3.1.

4.4.2 Nuclear Analysis - One of the samples obtained as specified in 4.2.2 shall be analyzed for the total danger sum in conformance with the requirements of 3.3.2 by one of the following methods:

a. Chemical analysis

b. Danger coefficient in a nuclear reactor

4.4.3 Tension Tests - Specimens of beryllium pressings, prepared in accordance with 4.2.3, shall be tested for tensile strength in accordance with ASTM E8. Gripping devices shall not cause bending stress in the specimens. Tensile yield strength determinations shall be obtained from stress-strain diagrams developed from extensometer measurements. The rate of specimen straining shall be 0.005 $\pm$ 0.001 inches/inch/minute. The strain rate may be increased after determination of yield point to 0.05 x 0.01 inches/inch/minute. The reduction of area of fractured round specimens shall be reported. The tensile strengths measured shall conform to the requirements of 3.5.

4.4.4 Inclusion Volume Determination - Specimens of beryllium pressings prepared in accordance with 4.2.5 shall be radiographed in accordance with 4.4.4.2 and examined as follows.

4.4.4.1 Density Test - The density of each beryllium pressing and component shall be determined by a water-displacement method and shall be as specified in 3.4.1. Layout 1" x 2" area, count and grade inclusions as follows:

Group	Ave. Dim. of Disc., In.	Assumed Ave. Dim. for Counting Purposes	Equivalent Assumed Volume Per Discontinuity Cubic in x 10^6
A	0.001 - 0.003	0.002	0.0042
B	0.003 - 0.006	0.005	0.066
C	0.006 - 0.010	0.008	0.27
D	0.010 - 0.014	0.012	0.90
E	0.014 - 0.018	0.015	1.8
F	0.018 - 0.022	0.020	4.2

4.4.4.2 Radiographic Inspection - Each beryllium rough machined component shall be radiographically inspected for conformance with the requirements of 3.4.2. Radiographic procedures shall be in accordance with subcontractor radiographic inspection procedures which have been approved by EG&G, and shall have a quality level of 2-1T to achieve sufficient resolution to permit thorough inspection. Penetrameters corresponding to the minimum thickness of the part covered by each film exposure shall be visible on the film. Tabulate the number of discontinuities in each size group and compute equivalent volume concentration using the following formula:

$$T = (0.0042A) + (0.066B) + (0.27C) + (0.90D) + (1.8E) + (4.2F)$$

Where: T = Total combined volume of discontinuities in cubic inches x 10^{-6} per cubic inch of material.

A = number of inclusions in Group A
B = number of inclusions in Group B
C = number of inclusions in Group C
D = number of inclusions in Group D
E = number of inclusions in Group E
F = number of inclusions in Group F

V = Volume of material in cubic inches for any given area of radiograph for which A, B, C, D, E, and F are determined (V = 2).

The total combined volume of all inclusions having average dimensions larger than 0.001 inch shall not exceed the volume of an 0.050 inch sphere per cubic inch of material (this is equivalent to a volume concentration of T = 66 x 10^{-6}).

Film and report will be submitted as final vendor data to EG&G.

4.4.4.3. Liquid-Penetrant Inspection - All beryllium pressings or components shall be liquid-penetrant and visually inspected for conformance with the requirements of 3.4.3 after final machining. Inspection shall be in accordance with the EG&G company procedures manual, section 9.3, using fluorescent penetrant.

4.4.4.4. Disposition - Acceptance will be based upon criteria listed in Para. 3.4.2 and Table I.

4.5 Records - The subcontractor shall maintain a current and complete file of all records of inspections, examinations, and tests.

4.6 Access - Authorized EG&G representatives shall have access to any area where beryllium pressings or components are being fabricated and to all records pertaining to fabrication under the contract.

4.7 Test Reports - The subcontractor shall submit test reports to EG&G for each beryllium pressing or component tested. Each pressing and component shall be properly identified by its identification markings (3.6). Each report shall contain complete test results, certifying that the item tested conforms with all specification requirements. All data obtained during the tests, such as stress-strain curves, chemical and nuclear analyses, and radiographic film, shall be provided as a part of the reports.

5. PREPARATION FOR SHIPMENT

5.1 Marking - Each package shall be marked with at least the following information in water proof ink or paint and in letters at least 1/4 inch in height:

A. Name of contents

B. Quantity of items in package

C. Subcontractor's name

D. EG&G Idaho Inc. subcontract number

E. EG&G Idaho Inc.

F. Address to which package is to be shipped.

5.2 Packaging Inspection - Each package shall be inspected prior to shipping for compliance with this specification. The inspector's identification shall be affixed to each package.

5.3 Packing-Slip Container - The packing-slip container shall be waterproof and shall be affixed to the package in such a manner as to prevent loss of the packing-slip container during shipment.

6. NOTES

Intended Use - This specification is intended for use with drawings and contracts which require beryllium pressings or components from vacuum hot-pressed beryllium powder and where high strength-to-weight ratio and high modulus of elasticity are desired.