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Design Analysis Cover Sheet

Complete only applicable items.

(1.) QA: L

Page: 1 Of: 38

2. DESIGN ANALYSIS TITLE	
Material Compositions and Number Densities For Neutronics Calculations (SCPB: N/A)	
3. DOCUMENT IDENTIFIER (Including Rev. No.)	4. TOTAL PAGES
BBA000000-01717-0200-00002 REV 00	38
5. TOTAL ATTACHMENTS	6. ATTACHMENT NUMBERS - NO. OF PAGES IN EACH
4	I-20, II-1, III-1, and IV-3

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12. REMARKS

This document has one TBV number controlledin accordance with NLP-3-15: TBV-220-WPD.

Design Analysis Revision Record

Complete only applicable items.

(1.)

2. DESIGN ANALYSIS TITLE

Material Compositions and Number Densities For Neutronics Calculations

3. DOCUMENT IDENTIFIER (Including Rev. No.)

BBA000000-01717-0200-00002 REV 00

4. Revision No.	5. Description of Revision
00	Issued Approved

Table of Contents:

1. Purpose -

The purpose of this analysis is to calculate the number densities and isotopic weight percentages of the standard materials to be used in the neutronics (criticality and radiation shielding) evaluations by the Waste Package Development Department. The objective of this analysis is to provide material number density information which can be referenced by future neutronics design analyses, such as for those supporting the Conceptual Design Report.

2. Quality Assurance -

The Quality Assurance (QA) program applies to this analysis (activity). The work reported in this document will support the neutronics analysis for the License Application Design phase. This activity can affect the proper functioning of the Mined Geological Disposal System (MGDS) waste package; the waste package has been identified as an MGDS Q-List item important to radiological safety (Reference 5.1). The waste package is on the Q-List by direct inclusion by the Department of Energy (DOE), without conducting a QAP-2-3 evalation. The work performed for this analysis is covered by a Waste Package Development (WPD) QAP-2-0 work control Activity Evaluation entitled "Perform Criticality, Thermal, Structural, and Shielding Analyses SCPB: N/A" (Reference 5.2). This QAP-2-0 evaluation determined such activities to be subject to *Quality Assurance Requirements and Description* (QARD) (Reference 5.3) requirements. Applicable procedural controls are listed in the evaluation.

All design inputs which are identified in this document are for pre-Title II (conceptual or preliminary) designs; some or all of these design inputs will require subsequent qualification (or superseding inputs) as the waste package design proceeds. For design documents subject to the QARD requirements, unqualified design inputs must be considered as TBV (to be verified) items subject to tracking, in accordance with applicable procedures. The design inputs identified and documented in Section 4 have been assigned the single tracking number TBV-220-WPD, to meet tracking requirements.

3. Method -

The design method used in this analysis consisted of calculating material number densities using a standard equation. Chemical (elemental/isotopic weight percentage compositions), physical (densities), and nuclear (atomic weights) data for materials were entered into a spreadsheet and number densities calculated. The number densities and isotopic compositions may be converted into the appropriate units and formats, for entry into neutronic computer codes.

The steps followed for this analysis are listed below.

A. Identify the materials,
B. Locate the material chemical composition and density information,
C. Locate the nuclear data (atomic weights) for the elements/isotopes in materials,
D. Enter the number density equation into a spreadsheet,
E. Import the material and nuclear data (atomic weights) into the spreadsheet,
F. Calculate the material number densities.

4. Design Inputs -

All design inputs are for pre-Title II designs; some or all of these design inputs will require subsequent qualification (or superseding inputs) as the waste package design proceeds. The design inputs identified and documented in Section 4 have been assigned the single tracking number TBV-220-WPD, to meet tracking requirements in accordance with applicable procedures.

4.1 Design Parameters -

The units employed in the design parameters section of this analysis are the (neutronics) industry standard units reported in the references (i.e, cm, atom/narn-cm, etc.). The units were not converted to program standard SI units (i.e., m, mm, kg, etc.). The neutronics codes have not been written to use the program standard units as inputs.

4.1.1 Material Chemical Compositions and Densities

The material chemical compositions and density information listed in this section was not developed according to the QARD. The information comes from handbooks and textbooks that are recognized and utilized industry-wide. As such, the information is to be taken as established fact that requires no additional qualification. Therefore, the range of design parameters and the values selected from the ranges will be treated as qualified data. Exceptions will be marked appropriately.

4.1.1.1 Chemical Composition of Grade 55 A 516 Carbon Steel (Weight %)
Reference 5.4, Page 36, Table 2-26

		Range:	Values Used:
C	:	0.22 (max)	0.220
Mn	:	0.60 - 1.20	0.900
P	:	0.035 (max)	0.035
S	:	0.035 (max)	0.035
Si	:	0.15 - 0.40	0.275
Fe	:	Balance	98.535

4.1.1.2 Material Density of Grade 55 A 516 Carbon Steel
Reference 5.5, Page 756, Table A.1*

Density Used*: 7.832 Mg/m^3 (0.2830 lb/in^3)

* Data was not available for Grade 55 A 516 Carbon Steel, the density of AISI 1010 carbon steel was assumed (assumption 4.3.3).

4.1.2.1 Chemical Composition of A 27 Grade 60-30 Cast Carbon Steel (Weight %)
Reference 5.4, Page 38, Table 2-32

		Range:	Values Used:
C	:	0.30 (max)	0.30
Mn	:	0.60 (max)	0.60
Si	:	0.80 (max)	0.80
S	:	0.06 (max)	0.06
P	:	0.05 (max)	0.05
Fe	:	Balance	98.19

4.1.2.2 Material Density of A 27 Grade 60-30 Cast Carbon Steel
Reference 5.5, Page 756, Table A.1*

Density Used*: 7.832 Mg/m^3 (0.2830 lb/in^3)

* Data was not available for A 27 Grade 60-30 Cast Carbon Steel, the density of AISI 1010 carbon steel was assumed (assumption 4.3.3).

4.1.3.1 Chemical Composition of A 27 Grade 70-40 Centrifugally Cast Carbon Steel (Weight %), Reference 5.4, Page 22, Table 1-6

		Range:	Values Used:
C	:	0.25 (max)	0.25
Mn	:	1.20 (max)	1.20
P	:	0.05 (max)	0.05
S	:	0.06 (max)	0.06
Si	:	0.80 (max)	0.80
Fe	:	Balance	97.64

4.1.3.2 Material Density of A 27 Grade 70-40 Centrifugally Cast Carbon Steel
Reference 5.5, Page 756, Table A.1*

Density Used*: 7.832 Mg/m^3 (0.2830 lb/in^3)

* Data was not available for A 27 Grade 70-40 Centrifugally Cast Carbon Steel, the density of AISI 1010 carbon steel was assumed (assumption 4.3.3).

4.1.4.1 Chemical Composition of A 387 Grade 22 Class 1 2-¼Cr-1Mo Low-Alloy Steel (Weight %), Reference 5.4, Page 39, Table 2-34

		Range:	Values Used:
C	:	0.05 - 0.15	0.100
Mn	:	0.30 - 0.60	0.450
P	:	0.035 (max)	0.035
S	:	0.035 (max)	0.035
Si	:	0.50 (max)	0.500
Cr	:	2.00 - 2.50	2.250
Mo	:	0.90 - 1.10	1.000
Fe	:	Balance	95.630

4.1.4.2 Material Density of A 387 Grade 22 Class 1 2-¼Cr-1Mo Low-Alloy Steel Reference 5.5, Page 756, Table A.1*

Density Used *: 7.858 Mg/m^3 (0.2840 lb/in^3)

* Data was not available for A 387 Grade 22 Class 1 2-¼Cr-1Mo Low-Alloy Steel, the density of 1Cr-½Mo low alloy steel was assumed (assumption 4.3.3).

4.1.5.1 Chemical Composition of Alloy 825 (Weight %) Reference 5.4, Page 26, Table 2-7

		Range:	Values Used:
C	:	0.05 (max)	0.05
Mn	:	1.0 (max)	1.00
S	:	0.03 (max)	0.03
Si	:	0.50 (max)	0.50
Cr	:	19.5 - 23.5	21.50
Ni	:	38.0 - 46.0	42.00
Mo	:	2.50 - 3.50	3.00
Cu	:	1.50 - 3.00	2.25
Ti	:	0.60 - 1.20	0.90
Al	:	0.20 (max)	0.20
Fe	:	22.00 (min)	28.57

4.1.5.2 Material Density of Alloy 825
Reference 5.4, Page 27, Table 2-10

Density Used: 8.14 Mg/m^3 (0.294 lb/in^3)

4.1.6.1 Chemical Composition of Alloy 825 with higher Mo (Weight %)
Reference 5.4, Page 26, Table 2-8

		Range:	Values Used:
C	:	0.025 (max)	0.025
Mn	:	1.0 (max)	1.000
S	:	0.03 (max)	0.030
Si	:	0.50 (max)	0.500
Cr	:	20.5 - 22.0	21.250
Ni	:	36.0 - 46.0	41.000
Mo	:	5.00 - 6.50	5.750
Cu	:	1.50 - 3.00	2.250
Ti	:	0.60 - 1.00	0.800
Al	:	0.20 (max)	0.200
Fe	:	22.00 (min)	27.195

4.1.6.2 Material Density of Alloy 825 with higher Mo
Reference 5.4, Page 27, Table 2-10*

Density Used*: 8.14 Mg/m^3 (0.294 lb/in^3)

* Data was not available for Alloy 825 with higher Mo, the density of Alloy 825 was assumed (assumption 4.3.3).

4.1.7.1 Chemical Composition of Alloy G-30 (Weight%)
Reference 5.6, Page 3

		Range:	Value Used:
Ni	:	Balance	37.51
Co	:	5.00 (max)	5.00
Cr	:	28.0 - 31.5	29.75
Mo	:	4.00 - 6.00	5.00
W	:	1.50 - 4.00	2.75
Fe	:	13.0 - 17.0	15.00
Si	:	0.80 (max)	0.80
Mn	:	1.50 (max)	1.50
C	:	0.03 (max)	0.03
Nb + Ta	:	0.30 - 1.50	Nb : 0.45*
			Ta : 0.45*
Cu	:	1.00 - 2.40	1.70
P	:	0.04 (max)	0.04
S	:	0.02 (max)	0.02

* See Assumption 4.3.4

4.1.7.2 Material Density of Alloy G-30
Reference 5.6, Page 10, Physical Properties Table

Density Used: 8.22 Mg/m^3 (0.297 lb/in^3)

4.1.8.1 Chemical Composition of Alloy C-4 (Weight %)
Reference 5.4, Page 30, Table 2-14

		Range:	Values Used:
C	:	0.01 (max)	0.010
Mn	:	1.00 (max)	1.000
P	:	0.025 (max)	0.025
S	:	0.010 (max)	0.010
Si	:	0.08 (max)	0.080
Cr	:	14.00 - 18.00	16.00
Mo	:	14.00 - 17.00	15.50
Co	:	2.00 (max)	2.000
Ti	:	0.70 (max)	0.700
Fe	:	3.00 (max)	3.000
Ni	:	Balance	61.675

4.1.8.2 Material Density of Alloy C-4
Reference 5.4, Page 30, Table 2-15

Density Used: 8.64 Mg/m^3 (0.312 lb/in^3)

4.1.9.1 Chemical Composition of Alloy C-22 (Weight %)
Reference 5.4, Page 32, Table 2-18

		Range:	Values Used:
C	:	0.010 (max)	0.010
Mn	:	0.50 (max)	0.500
Si	:	0.08 (max)	0.080
Cr	:	22.00	22.00
Ni	:	56.00	56.00
Mo	:	13.00	13.00
Co	:	2.50 (max)	2.060*
W	:	3.00	3.000
V	:	0.35 (max)	0.350
Fe	:	3.00	3.000

* See assumption 4.3.5

4.1.9.2 Material Density of Alloy C-22
Reference 5.4, Page 32, Table 2-19

Density Used: 8.69 Mg/m^3 (0.314 lb/in^3)

4.1.10.1 Chemical Composition of Ti Grade 12 (Weight %)
Reference 5.4, Page 34, Table 2-22

		Range:	Values Used:
N	:	0.03 (max)	0.030
C	:	0.08 (max)	0.080
H	:	0.015 (max)	0.015
Fe	:	0.30 (max)	0.300
O	:	0.25 (max)	0.250
Mo	:	0.20 - 0.40	0.300
Ni	:	0.60 - 0.90	0.750
Residuals (each)	:	0.10 (max)	*
Residuals (total)	:	0.40 (max)	*
Ti	:	Remainder	98.275*

* See assumption 4.3.6

4.1.10.2 Material Density of Ti Grade 12
Reference 5.4, Page 34, Table 2-23

Density Used: 4.51 Mg/m^3 (0.163 lb/in^3)

4.1.11.1 Chemical Composition of Ti Grade 16 (Weight %)
Reference 5.4, Page 36, Table 2-25

		Range:	Values Used:
N	:	0.03 (max)	0.0300
C	:	0.10 (max)	0.1000
H	:	0.015 (max)	0.0150
Fe	:	0.30 (max)	0.3000
O	:	0.25 (max)	0.2500
Pd	:	0.045 - 0.070	0.0575
Residuals (each)	:	0.10 (max)	*
Residuals (total)	:	0.40 (max)	*
Ti	:	Remainder	99.2475*

* See assumption 4.3.6

4.1.11.2 Material Density of Ti Grade 16
Reference 5.4, Page 34, Table 2-23*

Density Used*: 4.51 Mg/m^3 (0.163 lb/in^3)

* Data was not available for Ti Grade 16, the density of Ti Grade 12 was assumed (assumption 4.3.3).

4.1.12.1 Chemical Composition of Alloy 400 (Weight %)
Reference 5.4, Page 41, Table 2-40

		Range:	Values Used:
Ni	:	63.00 (min)	63.00
Cu	:	28.00 - 34.00	31.00
Co	:	3.00 (max)	2.476*
Fe	:	2.50 (max)	2.500
Mn	:	0.20 (max)	0.200
C	:	0.30 (max)	0.300
Si	:	0.50 (max)	0.500
S	:	0.024 (max)	0.024

* See assumption 4.3.5

4.1.12.2 Material Density of Alloy 400
Reference 5.4, Page 42, Table 2-42

Density Used: 8.83 Mg/m^3 (0.319 lb/in^3)

4.1.13.1 Chemical Composition of C71500 (CDA 715) (Weight %)
Reference 5.4, Page 43, Table 2-45

		Range:	Values Used:
Ni	:	29.00 - 33.00	31.00
Fe	:	0.40 - 1.00	0.70
Mn	:	1.00 (max)	1.00
Zn	:	1.00 (max)	1.00
Pb	:	0.05 (max)	0.05
Cu	:	Balance	66.25

4.1.13.2 Material Density of C71500 (CDA 715)
Reference 5.4, Page 43, Table 2-46

Density: 8.9375 Mg/m^3 (0.323 lb/in^3)

4.1.14.1 Chemical Composition of Type 304 Stainless Steel (Weight %),
Reference 5.7, Page 2, Table 1

		Range:	Values Used:
C	:	0.08 (max)	0.080
Mn	:	2.00 (max)	2.000
P	:	0.045 (max)	0.045
S	:	0.03 (max)	0.030
Si	:	0.75 (max)	0.750
Cr	:	18.00 - 20.00	19.00
Ni	:	8.00 - 10.50	9.250
N	:	0.10 (max)	0.100
Fe	:	Balance	68.745

4.1.14.2 Material Density of Type 304 Stainless Steel
Reference 5.5, Page 757, Table A.1

Density Used: 7.900 Mg/m^3 (0.2855 lb/in^3)

4.1.15.1 Chemical Composition of Type 304L Stainless Steel (Weight %), Reference 5.7, Page 2, Table 1

		Range:	Values Used:
C	:	0.03 (max)	0.030
Mn	:	2.00 (max)	2.000
P	:	0.045 (max)	0.045
S	:	0.03 (max)	0.030
Si	:	0.75 (max)	0.750
Cr	:	18.00 - 20.00	19.00
Ni	:	8.00 - 12.00	10.00
N	:	0.10 (max)	0.100
Fe	:	Balance	68.045

4.1.15.2 Material Density of Type 304L Stainless Steel Reference 5.5, Page 757, Table A.1*

Density Used*: 7.900 Mg/m^3 (0.2855 lb/in^3)

* Data was not available for Type 304L Stainless Steel, Type 304 was assumed (assumption 4.3.3).

4.1.16.1 Chemical Composition of Type 316L Stainless Steel (Weight %), Reference 5.4, Page 23, Table 2-1

		Range:	Values Used:
C	:	0.03 (max)	0.030
Mn	:	2.00 (max)	2.000
P	:	0.045 (max)	0.045
S	:	0.03 (max)	0.030
Si	:	0.75 (max)	0.750
Cr	:	16.00 - 18.00	17.00
Ni	:	10.00 - 14.00	12.00
Mo	:	2.00 - 3.00	2.500
N	:	0.10 (max)	0.100
Fe	:	Balance	65.545

4.1.16.2 Material Density of Type 316L Stainless Steel Reference 5.4, Page 25, Table 2-5

Density Used*: 7.9497 Mg/m^3 (0.2873 lb/in^3)

* Data was not available for Type 316L Stainless Steel, Type 316 was assumed (assumption 4.3.3).

4.1.17.1 Chemical Composition of Borated Type 304 Stainless Steels (Weight %)
Reference 5.4, Page 45, Table 2-50

		Range:	Values Used:
C	:	0.08 (max)	0.080
Mn	:	2.00 (max)	2.000
P	:	0.045 (max)	0.045
S	:	0.030 (max)	0.030
Si	:	0.75 (max)	0.750
Cr	:	18.00 - 20.00	19.00
Ni	:	12.00 - 15.00	13.50
N	:	0.10 (max)	0.100
Co	:	0.20 (max)	0.200
B	:	0.20 - 2.25	Varies by type/See below
Fe	:	Balance	Varies by type/See below

	UNS		Boron	Values Used:			
Case:	Designation	Type	Range:	B	Fe	B-10	B-11
1	S30460	304B	0.20 - 0.29	0.245	64.0500	0.0441	0.2009
2	S30461	304B1	0.30 - 0.49	0.395	63.9000	0.0711	0.3239
3	S30462	304B2	0.50 - 0.74	0.620	63.6750	0.1116	0.5084
4	S30463	304B3	0.75 - 0.99	0.870	63.4250	0.1566	0.7134
5	S30464	304B4	1.00 - 1.24	1.120	63.1750	0.2016	0.9184
6	S30465	304B5	1.25 - 1.49	1.370	62.9250	0.2466	1.1234
7	S30466	304B6	1.50 - 1.74	1.620	62.6750	0.2916	1.3284
8	S30467	304B7	1.75 - 2.25	2.000	62.2950	0.3600	1.6400

4.1.17.2 Material Density of Borated Type 304 Stainless Steel
Reference 5.8, Table VIII

	UNS		Density Used:	
Case:	Designation	Type	Mg/m^3	(lb/in^3)
1	S30460	304B	7.88	(0.2848)
2	S30461	304B1	7.88	(0.2848)
3	S30462	304B2	7.86	(0.2841)
4	S30463	304B3	7.83	(0.2830)
5	S30464	304B4	7.81	(0.2823)
6	S30465	304B5	7.79	(0.2815)
7	S30466	304B6	7.77	(0.2808)
8	S30467	304B7	7.74	(0.2797)

4.1.18.1 Chemical Composition of Borated Type 316 Stainless Steels (Weight %)
See assumptions 4.3.7, Reference 5.4, Pages 23 & 45, Table 2-1 & 2-50

		Range:	Values Used:
C	:	0.03 (max)	0.030
Mn	:	2.00 (max)	2.000
P	:	0.045 (max)	0.045
S	:	0.030 (max)	0.030
Si	:	0.75 (max)	0.750
Cr	:	18.00 - 20.00	19.00
Ni	:	12.00 - 15.00	13.50
N	:	0.10 (max)	0.100
Mo	:	2.00 - 3.00	2.500
B	:	0.20 - 2.25	Varies by type/See below
Fe	:	Balance	Varies by type/See below

		Boron	Values Used:			
Case:	Type	Range:	B	Fe	B-10	B-11
1	316B1	0.30 - 0.49	0.40	61.6450	0.0720	0.3280
2	316B2	0.50 - 0.74	0.60	61.4450	0.1200	0.4800
3	316B3	0.75 - 0.99	0.87	61.1750	0.1566	0.7134
4	316B4	1.00 - 1.24	1.00	61.0450	0.1800	0.8200
5	316B4	1.00 - 1.24	1.20	60.8450	0.2160	0.9840
6	316B5	1.25 - 1.49	1.40	60.6450	0.2800	0.9840
7	316B6	1.50 - 1.74	1.60	60.4450	0.2880	1.3120
8	316B7	1.75 - 2.25	2.00	60.0450	0.3600	1.6400

4.1.18.2 Material Density of Borated Type 316 Stainless Steel
Reference 5.8, Table VIII*

		Density Used:	
Case:	Type	Mg/m^3	(lb/in^3)
1	316B1	7.88	(0.2848)
2	316B2	7.86	(0.2830)
3	316B3	7.83	(0.2830)
4&5	316B4	7.81	(0.2823)
6	316B5	7.79	(0.2830)
7	316B6	7.77	(0.2808)
8	316B7	7.74	(0.2797)

* Data was not available for Borated Type 316 Stainless Steel, Borated Type 304 was assumed (assumption 4.3.3)

4.1.19.1 Chemical Composition of Borated Type 316 Stainless Steels (Weight %), 20% Boron Removed, See assumption 4.3.10

	SS-B1A	SS-B2A	SS-B3A	SS-B4A
B-10	0.0576	0.0865	0.1255	0.1443
B-11	0.2626	0.3941	0.5717	0.6573
C	0.0300	0.0300	0.0301	0.0301
N	0.1001	0.1001	0.1002	0.1002
Si	0.7506	0.7509	0.7513	0.7515
P	0.0450	0.0451	0.0451	0.0451
S	0.0300	0.0300	0.0301	0.0301
Cr	19.0152	19.0228	19.0331	19.0381
Mn	2.0016	2.0024	2.0035	2.0040
Fe	61.6944	61.5188	61.2816	61.1673
Ni	13.5108	13.5162	13.5235	13.5271
Mo	2.5020	2.5030	2.5044	2.5050

	SS-B4A	SS-B5A	SS-B6A	SS-B7A
B-10	0.1732	0.2022	0.2311	0.2892
B-11	0.7891	0.9210	1.0530	1.3173
C	0.0301	0.0301	0.0301	0.0301
N	0.1002	0.1003	0.1003	0.1004
Si	0.7518	0.7521	0.7524	0.7530
P	0.0451	0.0451	0.0451	0.0452
S	0.0301	0.0301	0.0301	0.0301
Cr	19.0457	19.0533	19.0610	19.0763
Mn	2.0048	2.0056	2.0064	2.0080
Fe	60.9914	60.8153	60.6390	60.2861
Ni	13.5325	13.5379	13.5433	13.5542
Mo	2.5060	2.5070	2.5080	2.5100

4.1.19.2 Material Density of Borated Type 316 Stainless Steel, 20% Boron Removed, See assumption 4.3.10

		Density Used:	
Case:	Type	Mg/m^3	(lb/in^3)
1	316B1	7.874	(0.2846)
2	316B2	7.851	(0.2837)
3	316B3	7.816	(0.2825)
4	316B4	7.794	(0.2817)
5	316B4	7.791	(0.2816)
6	316B5	7.768	(0.2807)
7	316B6	7.745	(0.2799)
8	316B7	7.709	(0.2786)

4.1.20.1 Chemical Composition of Al-Boron Alloy (Weight %)
Reference 5.4, Page 48, Table 2-54

		Range:	Value(s) Used:
B	:	0.00 - 5.00	variable (0.00 - 5.00) see below
Cu	:	0.12 (max)	0.12
Al	:	Balance	variable (99.88 - 94.88) see below

Values Used (weight %):

Case:	Al	B	B-10	B-11	
1	98.88	1.00	0.18	0.82	
2	97.88	2.00	0.36	1.64	
3	96.88	3.00	0.54	2.46	
4	95.88	4.00	0.72	3.28	
5	95.38	4.50	0.81	3.69	
6	94.88	5.00	0.90	4.10	(natural boron)
7	94.88	5.00	4.75	0.25	(enriched boron)

4.1.20.2 Material Density of Al-Boron Alloy
Reference 5.9, Page 2, Table 1

Density Values Used:

Case:	Al	B	Mg/m^3	(lb/in^3)
1	98.88	1.00	2.719	(0.0983)
2	97.88	2.00	2.728	(0.0986)
3	96.88	3.00	2.738	(0.0990)
4	95.88	4.00	2.747	(0.0993)
5	95.38	4.50	2.752	(0.0995)
6	94.88	5.00	2.757	(0.0996)
7	94.88	5.00	2.757	(0.0996)

4.1.21.1 Chemical Composition of BORAL™ (Weight %)
Reference 5.10, Page 6.6-2, Figure 6.6-1

		Range:	Value Used:
Al	:	81.005	81.005
B	:	14.869	14.869
C	:	4.126	4.126

Cases:	Values Used: B-10 (75%*)	B-11
BORAL with natural Boron	2.676 (2.007)	12.193
BORAL with B-10 enriched Boron	14.126 (10.595)	0.743

* B-10 percentages used in BORAL are 75% of expected to account for neutron streaming (Reference 5.11)

4.1.21.2 Material Density of BORAL™
Reference 5.10, Page 6.3-2

Density Used: 2.6744 Mg/m^3 (0.09665 lb/in^3)

4.1.22.1 Chemical Composition (Weight %) of B_4C
See assumption 4.3.12 for source

		Value Used:
B	:	78.57
C	:	21.43

Cases:	Values Used: B-10	B-11
B_4C with natural Boron	14.1426	64.4274
B_4C with B-10 enriched Boron	74.6415	3.9285

4.1.22.2 Material Density of B_4C
Reference 5.12, Page 6-13, Table 6-1

Theoretical Density 2.44
Percent Theoretical Density 73%
Density Used: 1.78 Mg/m^3 (0.0643 lb/in^3)

4.1.23.1 Chemical Composition of 1100 Aluminum Alloy (Weight %)
Reference 5.13, Page 65

		Range:	Value Used:
Cu	:	0.12 (max)	0.12
Al	:	Balance	99.88

4.1.23.2 Material Density of 1100 Aluminum Alloy
Reference 5.13, Page 65

Density Used: 2.71 Mg/m^3 (0.098 lb/in^3)

4.1.24.1 Chemical Composition of 6063 Aluminum Alloy (Weight %)
Reference 5.4, Page 49, Table 2-59

		Range:	Value Used:
Mn	:	0.10 (max)	0.100
Si	:	0.20 - 0.60	0.400
Cr	:	0.10 (max)	0.100
Fe	:	0.35 (max)	0.350
Cu	:	0.10 (max)	0.100
Mg	:	0.45 - 0.90	0.675
Zn	:	0.10 (max)	0.100
Ti	:	0.10 (max)	0.100
Other	:	0.15 (max)	*
Al	:	Balance	98.075

* See assumption 4.3.6

4.1.24.2 Material Density of 6063 Aluminum Alloy
Reference 5.4, Page 50, Table 2-60

Density Used: 2.69 Mg/m^3 (0.0972 lb/in^3)

4.1.25.1 Chemical Composition of Zircaloy-2 (Weight %)
Reference 5.14, Page 665, Table 3

		Range:	Value Used:
O	:	0.12 (max)	0.12
Cr	:	0.10 (max)	0.10
Fe	:	0.10 (max)	0.10
Ni	:	0.05 (max)	0.05
Sn	:	1.40 (max)	1.40
Zr	:	Balance	98.23

4.1.25.2 Material Density of Zircaloy-2
Reference 5.14, Page 666, Table 6

Density Used: 6.56 Mg/m^3 (0.2371 lb/in^3)

4.1.26.1 Chemical Composition of Zircaloy-4 (Weight %)
Reference 5.14, Page 665, Table 3

		Range:	Value Used:
O	:	0.12 (max)	0.12
Cr	:	0.10 (max)	0.10
Fe	:	0.20 (max)	0.20
Sn	:	1.40 (max)	1.40
Zr	:	Balance	98.18

4.1.26.2 Material Density of Zircaloy-4
Reference 5.14, Page 666, Table 6

Density Used: 6.56 Mg/m^3 (0.2371 lb/in^3)

4.1.27.1 Chemical Composition of Zirconium Alloy 702 (Weight %)
Reference 5.14, Page 666, Table 7

		Range:	Value Used:	
O	:	0.16 (max)		0.16
Cr + Fe	:	0.20 (max)	Cr :	0.10*
			Fe :	0.10*
Hf	:	1.00 - 4.50		4.50
Zr	:	Balance		95.14

* See asumption 4.3.4

4.1.27.2 Material Density of Zirconium Alloy 702
Reference 5.14, Page 666, Table 6

Density Used: 6.50 Mg/m^3 (0.2349 lb/in^3)

4.1.28.1 Chemical Composition of Zirconium Alloy 704 (Weight %)
Reference 5.14, Page 666, Table 7

		Range:	Value Used:	
O	:	0.18 (max)		0.18
Cr + Fe	:	0.30 (max)	Cr :	0.15*
			Fe :	0.15*
Sn	:	1.50 (max)		1.50
Hf	:	1.00 - 4.50		4.50
Zr	:	Balance		93.52

* See asumption 4.3.4

4.1.28.2 Material Density of Zirconium Alloy 704
Reference 5.14, Page 666, Table 6

Density Used: 6.56 Mg/m^3 (0.2371 lb/in^3)

4.1.29.1 Chemical Composition of Zirconium Alloy 706 (Weight %)
Reference 5.14, Page 666, Table 7

		Range:	Value Used:	
O	:	0.16 (max)		0.16
Cr + Fe	:	0.20 (max)	Cr :	0.10*
			Fe :	0.10*
Hf	:	1.00 - 4.50		4.50
Zr	:	Balance		95.14

* See asumption 4.3.4

4.1.29.2 Material Density of Zirconium Alloy 706
Reference 5.14, Page 666, Table 6

Density Used: 6.44 Mg/m^3 (0.2327 lb/in^3)

4.1.30.1 Chemical Composition of Zirconium-Hafnium Alloys (Weight %)
Reference 5.14, Page 666, Table 7

		Range:	Value Used:	
O	:	0.16 (max)		0.16
Cr + Fe	:	0.20 (max)	Cr :	0.10*
			Fe :	0.10*
Hf	:	TBD (max)		Variable
Zr	:	Balance		Variable

* See asumption 4.3.4

4.1.30.2 Material Density of Zirconium-Hafnium Alloys
Reference 5.9, Page 5, Table 2

	Density Values Used:			
Case:	Zr	Hf	Mg/m^3	(lb/in^3)
1	94.64	5.0	6.59	(0.238)
2	89.64	10.0	6.76	(0.245)
3	79.64	20.0	7.15	(0.258)
4	69.64	30.0	7.58	(0.274)
5	59.64	40.0	8.07	(0.292)
6	49.64	50.0	8.62	(0.312)
7	39.64	60.0	9.26	(0.335)
8	29.64	70.0	10.0	(0.361)
9	19.64	80.0	10.9	(0.394)
10	9.64	90.0	11.9	(0.430)

4.1.31.1 Chemical Composition of Spent Ag-In-Cd Control Rod Material (3.5×10^{21} nvt Fluence) (Weight %), Reference 5.12, Page 3-20, Figure 3-4

		Value Used:
Ag	:	77.00
Cd	:	9.00
In	:	11.00
Sn	:	3.00

4.1.31.2 Material Density of Spent Ag-In-Cd Control Rod Material
Reference 5.12, Page 6-13, Table 6-1

Density: 10.2 Mg/m^3 (0.3686 lb/in^3)

4.1.32.1 Chemical/Isotopic Composition of Depleted Uranium (Weight %)
Reference 5.15, Page 2.3-1, Section 2.3.1.d

		Range:	Value Used:
Fe	:	0.015 (max)	0.015
C	:	0.050 (max)	0.050
H	:	0.001 (max)	0.001
Mo	:	0.20 - 0.30	0.250
U-235	:	0.20 (max)	0.200
U-238	:	Balance	95.484

4.1.32.2 Material Density of Depleted Uranium
Reference 5.15, Page 2.3-1, Section 2.3.1.b

Density: 18.98 Mg/m^3 (0.686 lb/in^3)

4.1.33.1 Chemical/Isotopic Composition of Fresh Fuel (Weight %)
See assumption 4.3.12 for source

	Range:
O :	variable/see below
U-234 :	variable/see below
	(0.0056 atom % U-234, Reference 5.16, Page 975)
U-235 :	variable/see below
U-238 :	Balance

	Values Used:			
Case:	O	U-234	U-235	U-238
1.80 wt% U-235, w/ U-234	11.8487	0.00049	1.5867	86.5597
1.80 wt% U-235, w/o U-234	11.8487	0.00	1.5867	86.5646
3.00 wt% U-235, w/ U-234	11.8503	0.00048	2.6445	85.5004
3.00 wt% U-235, w/o U-234	11.8503	0.00	2.6445	85.5052
3.75 wt% U-235, w/ U-234	11.8513	0.00047	3.3056	84.8384
3.75 wt% U-235, w/o U-234	11.8513	0.00	3.3056	84.8431

4.1.33.2 Material Density of Fresh Fuel

Theoretical Density: 10.97 Mg/m^3 (Reference 5.16, Page 224, Table 5.7)
Percent of Theoretical Density: 95.90% (Reference 5.10, Page 6.3-2)

Density Used: 10.52 Mg/m^3 (0.3802 lb/in^3)

4.1.34.1 Chemical Composition of Air (Weight %)
Reference 5.17, Page F-156, See assumption 4.3.13

		Value Used:
N	:	80.0
O	:	20.0

4.1.34.2 Material Density of Air (at Sea Level)
Reference 5.17, Page F-150

Density Used: 0.001225 Mg/m^3 (0.00004427 lb/in^3)

4.1.35.1 Chemical Composition of Helium Fill Gas (Weight %)
See assumption 4.3.14 for source

		Value Used:
He	:	100.0

4.1.35.2 Material Density of Helium Fill Gas in Fuel (at 10 atmospheres)
Reference 5.17, Page B-19

Density Used: 0.01785 Mg/m^3 (0.00006451 lb/in^3)

4.1.36.1 Chemical Composition of Water (Weight %)
See assumption 4.3.12 for source

		Value Used:
H	:	11.1915
O	:	88.8085

4.1.36.2 Material Density of Water
Reference 5.17, Page B-100

Density Used: 1.00 Mg/m^3 (0.0361 lb/in^3)

4.1.37.1 Chemical Composition of Wet Crushed Tuff (Weight %)
Reference 5.18, Page 7, Table 1 (Drill Hole 61), See assumption 4.3.12

Chemical Compound Composition of Crushed Tuff (Weight %)

SiO_2	:	78.900
Al_2O_3	:	12.300
Fe_2O_3	:	0.973
CaO	:	0.451
MgO	:	0.128
TiO_2	:	0.092
Na_2O	:	3.920
K_2O	:	3.180
P_2O_5	:	0.010
MnO	:	0.046

Elemental Composition of Wet (50% water) Crushed Tuff (Weight %)

H	:	3.4756
O	:	61.9691
Na	:	2.0051
Mg	:	0.0533
Al	:	4.4887
Si	:	25.4310
P	:	0.0030
K	:	1.8201
Ca	:	0.2222
Ti	:	0.0383
Mn	:	0.0243
Fe	:	0.4692

4.1.37.2 Material Density of Wet Crushed Tuff
See assumption 4.3.15

Tuff Dry Bulk Density: 2.22 Mg/m^3 (0.0802 lb/in^3)
(Reference 5.18, Page 8, Table 3)

Water Density: 1.00 Mg/m^3 (0.0361 lb/in^3)
(Reference 5.17, Page B-100)

Mixture Density Used: 1.61 Mg/m^3 (0.0582 lb/in^3)

4.1.38.1 Chemical Composition of Borosilicate Glass (Pyrex) (Weight %)
Reference 5.12, Page 9-15, Table 9-1, See assumption 4.3.12

Chemical Compound Composition of Borosilicate Glass (Weight %)

SiO_2	:	76.315
B	:	3.900
B_2O_3	:	12.600
Na_2O	:	3.800
Al_2O_3	:	2.200
K_2O	:	0.500
LiO_2	:	0.500
Cl	:	0.070
F	:	0.005
BaO	:	0.100
H	:	0.010

Elemental Composition of Borosilicate Glass (Pyrex) (Weight %)

H	:	0.010
Li	:	0.232
B	:	7.813
O	:	51.709
F	:	0.005
Na	:	2.819
Al	:	1.164
Si	:	35.673
Cl	:	0.070
K	:	0.415
Ba	:	0.090

Case:	B-10	B-11	Li-6	Li-7
Natural Boron	1.447	6.366	0.018	0.215
Enriched Boron	7.422	0.391	0.018	0.215

4.1.38.2 Material Density of Borosilicate Glass (Pyrex)
Reference 5.5, Page 765, Table A.3

Density Used: 2.225 Mg/m^3(0.0804 lb/in^3)

4.1.2 List of Isotope Atomic Weights

Reference 5.16, Appendix C, Page 941 - 978

	Element	Symbol	Isotope	MCNP ID	Atomic Weight
1	Hydrogen	H	H-1	1001.50C	1.00782519
		D	H-2	1002.55C	2.01410222
		T	H-3	1003.50C	3.01604971
2	Helium	He	natural	2000.01C	4.0026
		He	He-4	2004.50C	4.00260312
3	Lithium	Li	Li-6	3006.50C	6.0151247
		Li	Li-7	3007.55C	7.0160039
4	Beryllium	Be	Be-9	4009.50C	9.0121855
5	Boron	B	B-10	5010.50C	10.0129388
		B	B-11	5011.56C	11.0093053
6	Carbon	C	natural	6000.50C	12.01115
		C	C-12	6012.50C	12.0000
7	Nitrogen	N	N-14	7014.50C	14.00307439
8	Oxygen	O	O-16	8016.50C	15.994915
9	Fluorine	F	F-19	9019.50C	18.9984046
11	Sodium	Na	Na-23	11023.50C	22.9897707
12	Magnesium	Mg	natural	12000.50C	24.312
13	Aluminum	Al	Al-27	13027.50C	26.9815389
14	Silicon	Si	natural	14000.50C	28.086
15	Phosphorus	P	P-31	15031.50C	30.9737647
16	Sulfur	S	S-32	16032.50C	31.9720737
17	Chlorine	Cl	natural	17000.50C	35.452
19	Potassium	K	natural	19000.50C	39.102
20	Calcium	Ca	natural	20000.50C	40.08
22	Titanium	Ti	natural	22000.50C	47.9
23	Vanadium	V	natural	23000.50C	50.942
24	Chromium	Cr	natural	24000.50C	51.996
25	Manganese	Mn	Mn-55	25055.50C	54.9380503
26	Iron	Fe	natural	26000.55C	55.847
27	Cobalt	Co	Co-59	27059.50C	58.933189
28	Nickel	Ni	natural	28000.50C	58.71
29	Copper	Cu	natural	29000.50C	63.54
30	Zinc	Zn	natural	30000.50C	65.37
33	Arsenic	As	As-75	33075.35C	74.9215964
38	Strontium	Sr	natural	38000.50C	87.62
40	Zirconium	Zr	natural	40000.50C	91.22
41	Niobium	Nb	Nb-93	41093.50C	92.906382
42	Molybdenum	Mo	natural	42000.50C	95.94
		Mo	Mo-95	42095.50C	94.905839
43	Technetium	Tc	Tc-99*	43099.50C	98.90627501*

4.1.2 List of Isotope Atomic Weights (Continued)

	Element	Symbol	Isotope	MCNP ID	Atomic Weight
44	Ruthenium	Ru	Ru-101	44101.50C	100.905576
45	Rhodium	Rh	Rh-103	45103.50C	102.905511
46	Palladium	Pd	natural	46000.50C	106.4
47	Silver	Ag	Ag-109	47109.50C	108.904756
48	Cadmium	Cd	natural	48000.50C	112.4
49	Indium	In	natural	49000.50C	114.82
50	Tin	Sn	natural	50000.35C	118.69
55	Cesium	Cs	Cs-133	55133.50C	132.905355
		Cs	Cs-135	55135.50C	134.90577
56	Barium	Ba	natural	56000.50C	137.34
57	Lanthanum	La	natural	57000.50C	138.91
58	Cerium	Ce	natural	58000.50C	140.12
60	Neodymium	Nd	Nd-143	60143.50C	142.909779
		Nd	Nd-145	60145.50C	144.912538
62	Samarium	Sm	Sm-147	62147.50C	146.914867
		Sm	Sm-149	62149.50C	148.91718
		Sm	Sm-150	62150.50C	149.917276
		Sm	Sm-151	62151.50C	150.919919
		Sm	Sm-152	62152.50C	151.919756
63	Europium	Eu	Eu-151	63151.55C	150.919838
		Eu	Eu-153	63153.55C	152.921242
		Eu	Eu-154	63154.50C	153.923053
64	Gadolinium	Gd	natural	64000.35C	157.25
		Gd	Gd-155	64155.50C	154.922664
		Gd	Gd-157	64157.50C	156.924025
72	Hafnium	Hf	natural	72000.50C	178.49
73	Tantalum	Ta	Ta-181	73181.50C	180.948007
74	Tungsten	W	natural	74000.55C	183.85
82	Lead	Pb	natural	82000.50C	207.19
92	Uranium	U	U-233	92233.50C	233.039522
		U	U-234	92234.50C	234.040904
		U	U-235	92235.50C	235.043915
		U	U-236	92236.50C	236.045637
		U	U-238	92238.50C	238.05077
93	Neptunium	Np	Np-237	93237.55C	237.048056
94	Plutonium	Pu	Pu-238	94238.50C	238.049511
		Pu	Pu-239	94239.55C	239.052146
		Pu	Pu-240	94240.50C	240.053882
		Pu	Pu-241	94241.50C	241.056737
		Pu	Pu-242	94242.50C	242.058725
		Pu	Pu-243	94243.35C	243.061972

4.1.2 List of Isotope Atomic Weights (Concluded)

	Element	Symbol	Isotope	MCNP ID	Atomic Weight
95	Americium	Am	Am-241	95241.50C	241.056714
		Am	Am-242m	95242.50C	242.059502
		Am	Am-243	95243.50C	243.061367
96	Curium	Cm	Cm-243	96243.35C	243.06137
		Cm	Cm-245	96245.35C	245.065371
		Cm	Cm-248	96248.35C	248.0722

* See assumption 4.3.16 for the source of the Atomic Weight for Tc-99

The atomic weight data listed above comes from handbooks and textbooks (References 5.16) that are utilized industry-wide. The data is taken to be established fact that requires no additional qualification.

4.1.3 Physical Constants

Avogadro's Number [N_A] = 0.602252 $(g\text{-}mol)^{-1} \times 10^{24}$, Reference 5.19. A physical constant is taken to be established fact that requires no additional qualification.

4.2 Criteria -

Not applicable.

4.3 Assumptions -

4.3.1 When a range of chemical (elemental) composition percentages are given in a data source, an average between the range's two end points is the value used for these analyses. The basis for this assumption is engineering judgement. This assumption is used is Section 4.1. (see assumption 4.3.7)

4.3.2 When a maximum elemental composition percentage is given in a data source, the maximum value is used for these analyses. The basis for this assumption is engineering judgement. This assumption is used is Section 4.1. (see assumption 4.3.5)

4.3.3 When material density information was not available for a given material, a substitute material density for a similar material is assumed as the material density. The substitute material selected is identified under the material density callouts in Section 4.1. The basis for this assumption is engineering judgement. This assumption is used in Section 4.1.

4.3.4 When a combination of trace elements are given a combined composition in a data source, the composition amount is assumed to be evenly divided upon the elements. The basis for this assumption is engineering judgement. This assumption is used in Sections 4.1.7.1, 4.1.27.1, 4.1.28.1, 4.1.29.1, and 4.1.30.1.

4.3.5 When a minimum composition weight percentage is not achieved when using assumptions 4.3.1 and 4.3.2, the quantity of a strong absorber element (like cobalt) is assumed reduced to balance the mixture. The basis for this assumption is engineering judgement (reducing the presence of a strong absorber is conservative). This assumption is used in Sections 4.1.9.1 and 4.1.12.1.

4.3.6 When undefined elemental composition impurities are specified in a material information source, the undefined composition is assumed to be made of the balancing/filling element of the material. This assumption is used is Section 4.1.

4.3.7 The elemental concentrations (composition weight %) of absorber elements (boron, hafnium) in materials selected for criticality control material (SS-B, Al-B, Zr-Hf alloys) is assumed to be selected over the listed ranges rather than set at a given concentration as per assumption 4.3.1. The basis of this assumption is past experience. This assumption is used is Sections 4.1.17, 4.1.18, 4.1.19, 4.1.20 and 4.1.30.

4.3.8 The isotopic breakdown for natural boron is assumed to be 18% B-10 and 82% B-11. The basis of this assumption is a common engineering conservatism. Current sources (Reference 5.20) indicate a slightly higher B-10 concentration. This assumption is used is Sections 4.1.17, 4.1.18, 4.1.19, 4.1.20, 4.1.21, 4.1.22, and 4.1.38.

4.3.9 The elemental composition of borated type 316L stainless steel (SS-B 316L) is assumed as similar to borated stainless steel type 304 (SS-B 304), with less carbon (0.03 wt%), no cobalt, and the addition of molybdenum (2.5 wt%). SS-B 316 has yet to be produced, but is expected to have better corrosion resistance than the SS-B 304 which is currently being produced. Elemental composition for SS-B 316 is assumed based upon the differences between the unborated type 316L and 304. This assumption is used in Sections 4.1.18.1 and 4.1.19.1.

4.3.10 The elemental composition and density for borated type 316 stainless steel with 20% boron loss (modeling long-term degradation) are assumed based upon only removing the boron from the material. The normal borated type 316 stainless steel composition and density are adjusted (as is shown in Attachment IV) by the boron mass removed. The basis for this assumption is engineering judgment and the conservation of mass. This assumption is used in Section 4.1.19.

4.3.11 The isotopic breakdown for B-10 enriched boron is assumed to be 95% B-10 and 5% B-11. The basis of this assumption is knowledge of common enrichment processes. This assumption is used in Sections 4.1.20, 4.1.21, 4.1.22, and 4.1.38.

4.3.12 The elemental composition weight percentages of materials known by their chemical formula (B_4C, UO_2, H_2O) are assumed to be the ratio of atomic weight of the atoms of a particular element over the summation of atomic weights of all atoms in the mixture. The basis for this assumption is standard chemistry. This assumption is used in Sections 4.1.22, 4.1.33, 4.1.36, 4.1.37, and 4.1.38.

4.3.13 The elemental composition weight percentages of air is assumed as 80% nitrogen and 20% oxygen only. The other elements in air were ignored. This assumption simplifies the evaluations with air. The basis for this assumption is engineering judgement that the additional isotopes have a negligible effect on neutronics calculations. This assumption is used in Section 4.1.34.

4.3.14 The helium fill gas is assumed to be 100% pure helium. This assumption simplifies the evaluations using helium. The basis for this assumption is engineering judgement that any impurities would have only a negligible effect on neutronics calculations. This assumption is used in Section 4.1.35.

4.3.15 The density of the wet tuff mixture with 50% volume fraction of water was assumed as the summation of the volume fractions (50%) times the individual densities. The basis of this assumption is standard chemistry. This assumption is used in Section 4.1.37.

4.3.16 The atomic weight for technetium (Tc) 99 was assumed as 98.90627501. The atomic weight of Tc-99 was not available in the normal reference. The basis of this assumption is the MCNP cross section library's neutron based atomic weight translated to the standard Carbon-12 based atomic weight. This assumption is used in Section 4.1.2.

4.3.17 When material densities are listed for various temperature, room temperatures densities (approximately 20°C (68°F)) are selected. The basis for this assumption is to maintain consistency between the information since the majority of the density information is given for room temperature. This assumption is used in section 4.1.

4.4 Codes and Standards -

Not applicable.

5. References -

5.1 Yucca Mountain Site Characterization Project Q-List, YMP/90-55Q REV 3, Yucca Mountain Site Characterization Project.

5.2 Activity Evaluation: Perform Criticality, Thermal, Structural, and Shielding Analyses, Document Identifier (DI) Number: B0000000-01717-2200-00025 REV 02, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

5.3 Quality Assurance Requirements and Description, DOE/RW-0333P REV 5, U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM).

5.4 Engineered Materials Characterization Report for the Yucca Mountain Site Characterization Project, Volume 2, R. A. Van Konynenburg, R. D. McCright, A. K. Roy, and D. A. Jones, UCRL-ID-119564, Vol. 2, University of California Research Laboratory, August 1995.

5.5 Fundamentals of Heat and Mass Transfer, Second Edition, F. P. Incropera and D. P. Dewitt, John Wiley and Sons Publisher.

5.6 "HASTELLOY Alloy G-30," HAYNES International Technical Information, Publication No. H - 2028C, 1989.

5.7 Standard Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels, ASTM Designation: A 240/A 240M - 94b. February 1995

5.8 Effect of Boron Content and Processing on Mechanical Properties and Microstructure of Borated Stainless Steels, R. S. Brown, CARTECH, Carpenter Technology Corporation, Reading, PA.

5.9 "Material Densities," J. K. McCoy to D. A. Thomas, Interoffice Correspondence LV.WPD.JKM.11/95.373, November 21, 1995, CRWMS M&O.

5.10 NAC-STC SAR (Safety Analysis Report), Revision 1, Nuclear Assurance Corporation, July 1992.

5.11 Safety Analysis Report for the NLI-1/2 Spent Fuel Shipping Cask, Rev. 17, Certificate of Compliance No. 9010, August 1986.

5.12 Control Rod Materials and Burnable Poisons, An Evaluation of the State of the Art and Needs for Technology Development, July 1980, EPRI NP-1974, Electric Power Research Institute, November 1981.

5.13 Metals Handbook, Ninth Edition, Volume 3, Properties and Selection: Nonferrous Alloys and Pure Metal, Americal Society for Metals Handbook Committee, Metals Park, OH, 1979.

5.14 Metals Handbook, Tenth Edition, Volume 2, Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Americal Society for Metals Handbook Committee, Metals Park, OH, 1990.

5.15 GA-9 Legal Weight Truck From-Reactor Spent Fuel Shipping Cask,Final Design Report, General Atomics, San Diego, CA, September 1993

5.16 Nuclear Chemical Engineering, 2nd Edition, Manson Benedict, Thomas H. Pigford, and Hans W. Levi, McGraw-Hill Book Company, New York, NY, 1981.

5.17 CRC Handbook of Chemistry and Physics, 66th Edition, Robert C. Weast, ed., CRC Press, Boca Raton, FL, 1985.

5.18 Preliminary Near-Field Environment Report Volume I: Technical Basis for EBS Design, Dale G. Wilder, UCRL-LR-107476, April 1993.

5.19 Introduction to Nuclear Engineering, 2nd Edition, John R. Lamarsh, Addison-Wesley Publishing Company, Reading, MA, 1983.

5.20 Nuclides and Isotopes, Fourteenth Edition, GE Nuclear Energy, 1989.

6. Use of Computer Software -

Scientific and Engineering Software:

Not applicable.

Computational Support Software:

6.1 Lotus 1-2-3 for Windows, Release 1.1, loaded on a 66MHz 486 PC, ID: 106608, Serial # 2313150

Lotus 1-2-3 for Windows is a commercial-off-the-shelf spreadsheet. The user-defined formulas used for this analysis are described in Section 7.4. The inputs and results from the spreadsheet are shown in the Attachments (I - IV).

7. Design Analysis -

The procedure followed for performing the design analysis consisted of the following:

A. Identify the materials,
B. Locate the material chemical composition and density information,
C. Locate the nuclear data (atomic weights) for the elements/isotopes in materials,
D. Enter the number density equation into a spreadsheet,
E. Import the material and nuclear data (atomic weights) into the spreadsheet,
F. Calculate the material number densities.

7.1 List of Materials

1 Grade 55 A 516 Carbon Steel
2 A 27 Grade 60-30 Cast Carbon Steel
3 A 27 Grade 70-40 Centrifugally Cast Carbon Steel
4 A 387 Grade 22 Class 1, 2-¼Cr-1Mo Low-Alloy Steel
5 Alloy 825
6 Alloy 825 with higher Mo
7 Alloy G-30
8 Alloy C-4
9 Alloy C-22
10 Ti Grade 12
11 Ti Grade 16
12 Alloy 400
13 C71500 (CDA 715)
14 Type 304 Stainless Steel
15 Type 304L Stainless Steel
16 Type 316L Stainless Steel
17 Type 304 Stainless Steel - Boron (8 cases)
18 Type 316 Stainless Steel - Boron (8 cases)
19 Type 316 Stainless Steel - 20% Boron Removed (8 cases)
21 Al-Boron Alloy (7 cases)
22 BORAL (2 cases)
23 B_4C (2 cases)
24 1100 Aluminum Alloy
25 6063 Aluminum Alloy
26 Zircaloy-2
26 Zircaloy-4
27 Zirconium Alloy 702
28 Zirconium Alloy 704
29 Zirconium Alloy 706
30 Hf-Zr Alloys (10 cases)
31 Spent Silver-Indium-Cadmium (Ag-In-Cd)

7.1 List of Materials (Continued)

32 Depleted Uranium
33 Fresh Fuel (6 cases)
34 Air
35 Helium Fill Gas
36 Water
37 Wet Crushed Tuff
38 Borosilicate Glass (Pyrex) (2 cases)

7.2 Material Chemical Composition and Density Information

The material chemical composition and density information needed for calculating number densities for the materials is listed in section 4.1.1.

7.3 Nuclear Data (Atomic Weights)

The elemental and isotopic nuclear data (atomic weights) required for calculating number densities for the materials is listed in section 4.1.2.

7.4 Number Density Equation

The equation used to calculate the material number densities is shown below. The number density equation was entered into a Lotus spreadsheet (Attachment I).

Reference 5.19, Page 35, Equation 2.55

$$N_i = \frac{\omega_i \rho N_A}{M_i}$$

where:

N_i = the number (atom) density of the ith isotope/element
ω_i = the weight percent of the ith isotope/element
ρ = the density of the material
N_A = Avogadro's number, a constant = 0.602252 $(g\text{-}mol)^{-1} \times 10^{24}$
M_i = the atomic weight of the ith isotope

7.5 Number Density Calculations

The results of the material number density calculations appear in a Lotus 1-2-3 spreadsheet shown in Attachment I. The number densities are reported in the (neutronics) industry standard units [atoms/barn-cm].

8. Conclusions -

The general purpose of this design analysis was to calculate the isotopic number densities for the materials expected to be used in the neutronics design analyses. This was accomplished; thus, no additional conclusions, decisions, or recommendations are needed.

9. Attachments -

Attachment:	Case:	Pages:
I	Number Density Worksheet {matnd00.wk3, 12-15-95}	20
II	Wet Tuff Composition Worksheet: {tuff.wk3, 12-15-95}	1
III	Borosilicate Glass Composition Worksheet {bglass.wk3, 12-15-95}	1
IV	Removed Boron Composition Worksheet: {redbcom.wk3, 12-15-95}	3

Number Density Worksheet:

Number Density = (Weight %) * (Density) * (Na) / (Aw)
Avogadro's Number [Na] = 0.602252
Atomic Weight [Aw]

Chemical Composition of Grade 55 A 516 Carbon Steel
Density = 7.832 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.2200%	8.6395E-04
Silicon	Si	28.0860	0.2750%	4.6184E-04
Phosphorus	P	30.9738	0.0350%	5.3300E-05
Sulfur	S	31.9721	0.0350%	5.1635E-05
Manganese	Mn	54.9381	0.9000%	7.7272E-04
Iron	Fe	55.8470	98.5350%	8.3223E-02
Total:			100.00%	8.5426E-02

Chemical Composition of A 27 Grade 60-30 Cast Carbon Steel
Density = 7.832 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.3000%	1.1781E-03
Silicon	Si	28.0860	0.8000%	1.3435E-03
Phosphorus	P	30.9738	0.0500%	7.6142E-05
Sulfur	S	31.9721	0.0600%	8.8518E-05
Manganese	Mn	54.9381	0.6000%	5.1514E-04
Iron	Fe	55.8470	98.1900%	8.2931E-02
Total:			100.00%	8.6133E-02

Chemical Composition of A 27 Grade 70-40 Centrifugally Cast Carbon S
Density = 7.832 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.2500%	9.8176E-04
Silicon	Si	28.0860	0.8000%	1.3435E-03
Phosphorus	P	30.9738	0.0500%	7.6142E-05
Sulfur	S	31.9721	0.0600%	8.8518E-05
Manganese	Mn	54.9381	1.2000%	1.0303E-03
Iron	Fe	55.8470	97.6400%	8.2467E-02
Total:			100.00%	8.5987E-02

Chemical Composition of A 387 Grade 22 Class 1 2-1/4Cr-1Mo Low-Alloy
Density = 7.858 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.1000%	3.9401E-04
Silicon	Si	28.0860	0.5000%	8.4250E-04
Phosphorus	P	30.9738	0.0350%	5.3477E-05
Sulfur	S	31.9721	0.0350%	5.1807E-05
Chromium	Cr	51.9960	2.2500%	2.0479E-03
Manganese	Mn	54.9381	0.4500%	3.8764E-04
Iron	Fe	55.8470	95.6300%	8.1037E-02
Molybdenum	Mo	95.9400	1.0000%	4.9328E-04
Total:			100.00%	8.5308E-02

Chemical Composition of Alloy 825
Density = 8.14 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0500%	2.0407E-04
Aluminum	Al	26.9815	0.2000%	3.6338E-04
Silicon	Si	28.0860	0.5000%	8.7274E-04
Sulfur	S	31.9721	0.0300%	4.5999E-05
Titanium	Ti	47.9000	0.9000%	9.2111E-04
Chromium	Cr	51.9960	21.5000%	2.0271E-02
Manganese	Mn	54.9381	1.0000%	8.9234E-04
Iron	Fe	55.8470	28.5700%	2.5079E-02
Nickel	Ni	58.7100	42.0000%	3.5070E-02
Copper	Cu	63.5400	2.2500%	1.7360E-03
Molybdenum	Mo	95.9400	3.0000%	1.5329E-03
Total:			100.00%	8.6989E-02

Chemical Composition of Alloy 825 with higher Mo
Density = 8.14 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0250%	1.0204E-04
Aluminum	Al	26.9815	0.2000%	3.6338E-04
Silicon	Si	28.0860	0.5000%	8.7274E-04
Sulfur	S	31.9721	0.0300%	4.5999E-05
Titanium	Ti	47.9000	0.8000%	8.1876E-04
Chromium	Cr	51.9960	21.2500%	2.0035E-02
Manganese	Mn	54.9381	1.0000%	8.9234E-04
Iron	Fe	55.8470	27.1950%	2.3872E-02
Nickel	Ni	58.7100	41.0000%	3.4235E-02
Copper	Cu	63.5400	2.2500%	1.7360E-03
Molybdenum	Mo	95.9400	5.7500%	2.9381E-03
Total:			100.00%	8.5912E-02

Chemical Composition of Alloy G-30
Density = 8.22 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0300%	1.2365E-04
Silicon	Si	28.0860	0.8000%	1.4101E-03
Phosphorus	P	30.9738	0.0400%	6.3932E-05
Sulfur	S	31.9721	0.0200%	3.0968E-05
Chromium	Cr	51.9960	29.7500%	2.8325E-02
Manganese	Mn	54.9381	1.5000%	1.3517E-03
Iron	Fe	55.8470	15.0000%	1.3297E-02
Cobal	Co	58.9332	5.0000%	4.2001E-03
Nickel	Ni	58.7100	37.5100%	3.1629E-02
Copper	Cu	63.5400	1.7000%	1.3245E-03
Niobium	Nb	92.9064	0.4500%	2.3978E-04
Molybdenum	Mo	95.9400	5.0000%	2.5800E-03
Tantalum	Ta	180.9480	0.4500%	1.2311E-04
Tungsten	W	183.8500	2.7500%	7.4049E-04
Total:			100.00%	8.5439E-02

Chemical Composition of Alloy C-4
Density = 8.64 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities	
Carbon	C	12.0112	0.0100%	4.3322E-05	
Silicon	Si	28.0860	0.0800%	1.4821E-04	
Phosphurus	P	30.9738	0.0250%	4.1999E-05	
Sulfur	S	31.9721	0.0100%	1.6275E-05	
Titanium	Ti	47.9000	0.7000%	7.6042E-04	
Chromium	Cr	51.9960	16.0000%	1.6012E-02	
Manganese	Mn	54.9381	1.0000%	9.4715E-04	
Iron	Fe	55.8470	3.0000%	2.7952E-03	
Cobal	Co	58.9332	2.0000%	1.7659E-03	
Nickel	Ni	58.7100	61.6750%	5.4662E-02	
Molybdenum	Mo	95.9400	15.5000%	8.4067E-03	
Total:			100.00%	8.5599E-02	

Chemical Composition of Alloy C-22
Density = 8.69 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities	
Carbon	C	12.0112	0.0100%	4.3573E-05	
Silicon	Si	28.0860	0.0800%	1.4907E-04	
Vanadium	V	50.9420	0.3500%	3.5958E-04	
Chromium	Cr	51.9960	22.0000%	2.2144E-02	
Manganese	Mn	54.9381	0.5000%	4.7632E-04	
Iron	Fe	55.8470	3.0000%	2.8114E-03	
Cobal	Co	58.9332	2.0600%	1.8294E-03	**
Nickel	Ni	58.7100	56.0000%	4.9920E-02	
Molybdenum	Mo	95.9400	13.0000%	7.0916E-03	
Tungsten	W	183.8500	3.0000%	8.5400E-04	
Total:			100.00%	8.5679E-02	

Chemical Composition of Titanium Grade 12
Density = 4.51 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	0.0150%	4.0426E-04
Carbon	C	12.0112	0.0800%	1.8091E-04
Nitrogen	N	14.0031	0.0300%	5.8191E-05
Oxygen	O	15.9949	0.2500%	4.2453E-04
?	?		0.0000%	
Titanium	Ti	47.9000	98.2750%	5.5727E-02
Iron	Fe	55.8470	0.3000%	1.4591E-04
Nickel	Ni	58.7100	0.7500%	3.4698E-04
Molybdenum	Mo	95.9400	0.3000%	8.4933E-05
Total:			100.00%	5.7372E-02

Chemical Composition of Titanium Grade 16
Density = 4.51 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	0.0150%	4.0426E-04
Carbon	C	12.0112	0.1000%	2.2614E-04
Nitrogen	N	14.0031	0.0300%	5.8191E-05
Oxygen	O	15.9949	0.2500%	4.2453E-04
?	?		0.0000%	
Titanium	Ti	47.9000	99.2475%	5.6278E-02
Iron	Fe	55.8470	0.3000%	1.4591E-04
Palladium	Pd	106.4000	0.0575%	1.4678E-05
Total:			100.00%	5.7552E-02

Chemical Composition of Alloy 400
Density = 8.83 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities	
Carbon	C	12.0112	0.3000%	1.3282E-03	
Silicon	Si	28.0860	0.5000%	9.4671E-04	
Sulfur	S	31.9721	0.0240%	3.9919E-05	
Manganese	Mn	54.9381	0.2000%	1.9360E-04	
Iron	Fe	55.8470	2.5000%	2.3806E-03	
Cobalt	Co	58.9332	2.4760%	2.2342E-03	**
Nickel	Ni	58.7100	63.0000%	5.7065E-02	
Copper	Cu	63.5400	31.0000%	2.5945E-02	
Total:			100.00%	9.0133E-02	

Chemical Composition of C71500 (CDA 715)
Density = 8.9375 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Manganese	Mn	54.9381	1.0000%	9.7976E-04
Iron	Fe	55.8470	0.7000%	6.7467E-04
Nickel	Ni	58.7100	31.0000%	2.8421E-02
Copper	Cu	63.5400	66.2500%	5.6122E-02
Zinc	Zn	65.3700	1.0000%	8.2341E-04
Lead	Pb	207.1900	0.0500%	1.2990E-05
Total:			100.00%	8.7034E-02

Chemical Composition of Type 304 Stainless Steel
Density = 7.9 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0800%	3.1689E-04
Nitrogen	N	14.0031	0.1000%	3.3977E-04
Silicon	Si	28.0860	0.7500%	1.2705E-03
Phosphorus	P	30.9738	0.0450%	6.9123E-05
Sulfur	S	31.9721	0.0300%	4.4643E-05
Chromium	Cr	51.9960	19.0000%	1.7386E-02
Manganese	Mn	54.9381	2.0000%	1.7321E-03
Iron	Fe	55.8470	68.7450%	5.8566E-02
Nickel	Ni	58.7100	9.2500%	7.4961E-03
Total:			100.00%	8.7221E-02

Chemical Composition of Type 304L Stainless Steel
Density = 7.9 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0300%	1.1883E-04
Nitrogen	N	14.0031	0.1000%	3.3977E-04
Silicon	Si	28.0860	0.7500%	1.2705E-03
Phosphorus	P	30.9738	0.0450%	6.9123E-05
Sulfur	S	31.9721	0.0300%	4.4643E-05
Chromium	Cr	51.9960	19.0000%	1.7386E-02
Manganese	Mn	54.9381	2.0000%	1.7321E-03
Iron	Fe	55.8470	68.0450%	5.7970E-02
Nickel	Ni	58.7100	10.0000%	8.1039E-03
Total:			100.00%	8.7034E-02

Chemical Composition of Type 316L Stainless Steel
Density = 7.9497 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Carbon	C	12.0112	0.0300%	1.1883E-04
Nitrogen	N	14.0031	0.1000%	3.3977E-04
Silicon	Si	28.0860	0.7500%	1.2705E-03
Phosphorus	P	30.9738	0.0450%	6.9123E-05
Sulfur	S	31.9721	0.0300%	4.4643E-05
Chromium	Cr	51.9960	17.0000%	1.5556E-02
Manganese	Mn	54.9381	2.0000%	1.7321E-03
Iron	Fe	55.8470	65.5450%	5.5840E-02
Nickel	Ni	58.7100	12.0000%	9.7247E-03
Molybdenum	Mo	95.9400	2.5000%	1.2398E-03
Total:			100.00%	8.5935E-02

Chemical Composition of Borated Type 304 Stainless Steel
SS304BA Density 7.88 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.0441%	2.0902E-04	Natural:	0.245%
	B-11	11.0093	0.2009%	8.6601E-04	Enriched:	0.000%
Carbon	C	12.0112	0.0800%	3.1609E-04	Total:	0.245%
Nitrogen	N	14.0031	0.1000%	3.3891E-04		
Silicon	Si	28.0860	0.7500%	1.2673E-03		
Phosphorus	P	30.9738	0.0450%	6.8948E-05		
Sulfur	S	31.9721	0.0300%	4.4530E-05		
Chromium	Cr	51.9960	19.0000%	1.7342E-02		
Manganese	Mn	54.9381	2.0000%	1.7277E-03		
Iron	Fe	55.8470	64.0500%	5.4428E-02		
Cobalt	Co	58.9332	0.2000%	1.6106E-04		
Nickel	Ni	58.7100	13.5000%	1.0913E-02		
Total:			100.00%	8.7682E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B1A Density 7.88 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.0711%	3.3699E-04	Natural:	0.395%
	B-11	11.00931	0.3239%	1.3962E-03	Enriched:	0.000%
Carbon	C	12.0112	0.0800%	3.1609E-04	Total:	0.395%
Nitrogen	N	14.0031	0.1000%	3.3891E-04		
Silicon	Si	28.0860	0.7500%	1.2673E-03		
Phosphorus	P	30.9738	0.0450%	6.8948E-05		
Sulfur	S	31.9721	0.0300%	4.4530E-05		
Chromium	Cr	51.9960	19.0000%	1.7342E-02		
Manganese	Mn	54.9381	2.0000%	1.7277E-03		
Iron	Fe	55.8470	63.9000%	5.4301E-02		
Cobalt	Co	58.9332	0.2000%	1.6106E-04		
Nickel	Ni	58.7100	13.5000%	1.0913E-02		
Total:			100.00%	8.8213E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B2A Density 7.86 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.1116%	5.2760E-04	Natural:	0.620%
	B-11	11.00931	0.5084%	2.1860E-03	Enriched:	0.000%
Carbon	C	12.0112	0.0800%	3.1529E-04	Total:	0.620%
Nitrogen	N	14.0031	0.1000%	3.3805E-04		
Silicon	Si	28.0860	0.7500%	1.2641E-03		
Phosphorus	P	30.9738	0.0450%	6.8773E-05		
Sulfur	S	31.9721	0.0300%	4.4417E-05		
Chromium	Cr	51.9960	19.0000%	1.7298E-02		
Manganese	Mn	54.9381	2.0000%	1.7233E-03		
Iron	Fe	55.8470	63.6750%	5.3972E-02		
Cobalt	Co	58.9332	0.2000%	1.6065E-04		
Nickel	Ni	58.7100	13.5000%	1.0885E-02		
Total:			100.00%	8.8783E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B3A Density 7.83 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.1566%	7.3751E-04	Natural:	0.870%
	B-11	11.00931	0.7134%	3.0557E-03	Enriched:	0.000%
Carbon	C	12.0112	0.0800%	3.1408E-04	Total:	0.870%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	63.4250%	5.3555E-02		
Cobalt	Co	58.9332	0.2000%	1.6003E-04		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Total:			100.00%	8.9323E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B4A Density 7.81 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.2016%	9.4702E-04	Natural:	1.12%
	B-11	11.00931	0.9184%	3.9237E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0800%	3.1328E-04	Total:	1.12%
Nitrogen	N	14.0031	0.1000%	3.3590E-04		
Silicon	Si	28.0860	0.7500%	1.2560E-03		
Phosphorus	P	30.9738	0.0450%	6.8336E-05		
Sulfur	S	31.9721	0.0300%	4.4135E-05		
Chromium	Cr	51.9960	19.0000%	1.7188E-02		
Manganese	Mn	54.9381	2.0000%	1.7123E-03		
Iron	Fe	55.8470	63.1750%	5.3208E-02		
Cobalt	Co	58.9332	0.2000%	1.5962E-04		
Nickel	Ni	58.7100	13.5000%	1.0816E-02		
Total:			100.00%	8.9971E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B5A Density 7.79 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.2466%	1.1554E-03	Natural:	1.37%
	B-11	11.00931	1.1234%	4.7873E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0800%	3.1248E-04	Total:	1.37%
Nitrogen	N	14.0031	0.1000%	3.3504E-04		
Silicon	Si	28.0860	0.7500%	1.2528E-03		
Phosphorus	P	30.9738	0.0450%	6.8161E-05		
Sulfur	S	31.9721	0.0300%	4.4022E-05		
Chromium	Cr	51.9960	19.0000%	1.7143E-02		
Manganese	Mn	54.9381	2.0000%	1.7079E-03		
Iron	Fe	55.8470	62.9250%	5.2861E-02		
Cobalt	Co	58.9332	0.2000%	1.5922E-04		
Nickel	Ni	58.7100	13.5000%	1.0788E-02		
Total:			100.00%	9.0615E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B6A Density 7.77 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.2916%	1.3628E-03	Natural:	1.62%
	B-11	11.00931	1.3284%	5.6464E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0800%	3.1168E-04	Total:	1.62%
Nitrogen	N	14.0031	0.1000%	3.3418E-04		
Silicon	Si	28.0860	0.7500%	1.2496E-03		
Phosphorus	P	30.9738	0.0450%	6.7986E-05		
Sulfur	S	31.9721	0.0300%	4.3909E-05		
Chromium	Cr	51.9960	19.0000%	1.7099E-02		
Manganese	Mn	54.9381	2.0000%	1.7036E-03		
Iron	Fe	55.8470	62.6750%	5.2516E-02		
Cobalt	Co	58.9332	0.2000%	1.5881E-04		
Nickel	Ni	58.7100	13.5000%	1.0760E-02		
Total:			100.00%	9.1255E-02		

Chemical Composition of Borated Type 304 Stainless Steel
SS304B7A Density 7.74 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.01294	0.3600%	1.6759E-03	Natural:	2.00%
	B-11	11.00931	1.6400%	6.9439E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0800%	3.1047E-04	Total:	2.00%
Nitrogen	N	14.0031	0.1000%	3.3289E-04		
Silicon	Si	28.0860	0.7500%	1.2448E-03		
Phosphorus	P	30.9738	0.0450%	6.7723E-05		
Sulfur	S	31.9721	0.0300%	4.3739E-05		
Chromium	Cr	51.9960	19.0000%	1.7033E-02		
Manganese	Mn	54.9381	2.0000%	1.6970E-03		
Iron	Fe	55.8470	62.2950%	5.1996E-02		
Cobalt	Co	58.9332	0.2000%	1.5819E-04		
Nickel	Ni	58.7100	13.5000%	1.0719E-02		
Total:			100.00%	9.2223E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B1A Density = 7.88 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.0720%	3.4125E-04	Natural:	0.40%
	B-11	11.0093	0.3280%	1.4139E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1853E-04	Total:	0.40%
Nitrogen	N	14.0031	0.1000%	3.3891E-04		
Silicon	Si	28.0860	0.7500%	1.2673E-03		
Phosphorus	P	30.9738	0.0450%	6.8948E-05		
Sulfur	S	31.9721	0.0300%	4.4530E-05		
Chromium	Cr	51.9960	19.0000%	1.7342E-02		
Manganese	Mn	54.9381	2.0000%	1.7277E-03		
Iron	Fe	55.8470	61.6450%	5.2384E-02		
Nickel	Ni	58.7100	13.5000%	1.0913E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2366E-03		
Total:			100.00%	8.7196E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B2A Density = 7.86 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1080%	5.1188E-04	Natural:	0.60%
	B-11	11.0093	0.4920%	2.1208E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1853E-04	Total:	0.60%
Nitrogen	N	14.0031	0.1000%	3.3891E-04		
Silicon	Si	28.0860	0.7500%	1.2673E-03		
Phosphorus	P	30.9738	0.0450%	6.8948E-05		
Sulfur	S	31.9721	0.0300%	4.4530E-05		
Chromium	Cr	51.9960	19.0000%	1.7342E-02		
Manganese	Mn	54.9381	2.0000%	1.7277E-03		
Iron	Fe	55.8470	61.4450%	5.2215E-02		
Nickel	Ni	58.7100	13.5000%	1.0913E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2366E-03		
Total:			100.00%	8.7904E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B3A Density = 7.83 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1566%	7.3751E-04	Natural:	0.87%
	B-11	11.0093	0.7134%	3.0557E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	0.87%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	61.1750%	5.1655E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	8.8295E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B4A Density = 7.81 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1800%	8.4772E-04	Natural:	1.00%
	B-11	11.0093	0.8200%	3.5123E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	1.00%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	61.0450%	5.1545E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	8.8752E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B4A Density = 7.81 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2160%	1.0173E-03	Natural:	1.20%
	B-11	11.0093	0.9840%	4.2148E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	1.20%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	60.8450%	5.1377E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	8.9455E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B5A Density = 7.79 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2520%	1.1868E-03	Natural:	1.40%
	B-11	11.0093	1.1480%	4.9172E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	1.40%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	60.6450%	5.1208E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	9.0159E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B6A Density = 7.77 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2880%	1.3563E-03	Natural:	1.60%
	B-11	11.0093	1.3120%	5.6197E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	1.60%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	60.4450%	5.1039E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	9.0862E-02		

Chemical Composition of Conceptual Borated Type 316 Stainless Steel
SS316B7A Density = 7.74 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.3600%	1.6954E-03	Natural:	2.00%
	B-11	11.0093	1.6400%	7.0246E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1778E-04	Total:	2.00%
Nitrogen	N	14.0031	0.1000%	3.3676E-04		
Silicon	Si	28.0860	0.7500%	1.2592E-03		
Phosphorus	P	30.9738	0.0450%	6.8511E-05		
Sulfur	S	31.9721	0.0300%	4.4248E-05		
Chromium	Cr	51.9960	19.0000%	1.7232E-02		
Manganese	Mn	54.9381	2.0000%	1.7167E-03		
Iron	Fe	55.8470	60.0450%	5.0701E-02		
Nickel	Ni	58.7100	13.5000%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5000%	1.2288E-03		
Total:			100.00%	9.2268E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B1A Density = 7.874 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.0576%	2.7300E-04	Natural:	0.40%
	B-11	11.0093	0.2626%	1.1311E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1853E-04	Total:	0.40%
Nitrogen	N	14.0031	0.1001%	3.3891E-04		
Silicon	Si	28.0860	0.7506%	1.2673E-03		
Phosphorus	P	30.9738	0.0450%	6.8948E-05		
Sulfur	S	31.9721	0.0300%	4.4530E-05		
Chromium	Cr	51.9960	19.0152%	1.7342E-02		
Manganese	Mn	54.9381	2.0016%	1.7277E-03		
Iron	Fe	55.8470	61.6944%	5.2384E-02		
Nickel	Ni	58.7100	13.5108%	1.0913E-02		
Molybdenum	Mo	95.9400	2.5020%	1.2366E-03		
Total:			100.00%	8.6845E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B2A Density = 7.851 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.0865%	4.0846E-04	Natural:	0.60%
	B-11	11.0093	0.3941%	1.6924E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0300%	1.1823E-04	Total:	0.60%
Nitrogen	N	14.0031	0.1001%	3.3805E-04		
Silicon	Si	28.0860	0.7509%	1.2641E-03		
Phosphorus	P	30.9738	0.0451%	6.8773E-05		
Sulfur	S	31.9721	0.0300%	4.4417E-05		
Chromium	Cr	51.9960	19.0228%	1.7298E-02		
Manganese	Mn	54.9381	2.0024%	1.7233E-03		
Iron	Fe	55.8470	61.5188%	5.2082E-02		
Nickel	Ni	58.7100	13.5162%	1.0885E-02		
Molybdenum	Mo	95.9400	2.5030%	1.2335E-03		
Total:			100.00%	8.7156E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B3A Density = 7.816 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1255%	5.9001E-04	Natural:	0.87%
	B-11	11.0093	0.5717%	2.4446E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1778E-04	Total:	0.87%
Nitrogen	N	14.0031	0.1002%	3.3676E-04		
Silicon	Si	28.0860	0.7513%	1.2592E-03		
Phosphorus	P	30.9738	0.0451%	6.8511E-05		
Sulfur	S	31.9721	0.0301%	4.4248E-05		
Chromium	Cr	51.9960	19.0331%	1.7232E-02		
Manganese	Mn	54.9381	2.0035%	1.7167E-03		
Iron	Fe	55.8470	61.2816%	5.1655E-02		
Nickel	Ni	58.7100	13.5235%	1.0843E-02		
Molybdenum	Mo	95.9400	2.5044%	1.2288E-03		
Total:			100.00%	8.7537E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B4A Density = 7.794 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1443%	6.7644E-04	Natural:	1.00%
	B-11	11.0093	0.6573%	2.8027E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1748E-04	Total:	1.00%
Nitrogen	N	14.0031	0.1002%	3.3590E-04		
Silicon	Si	28.0860	0.7515%	1.2560E-03		
Phosphorus	P	30.9738	0.0451%	6.8336E-05		
Sulfur	S	31.9721	0.0301%	4.4135E-05		
Chromium	Cr	51.9960	19.0381%	1.7188E-02		
Manganese	Mn	54.9381	2.0040%	1.7123E-03		
Iron	Fe	55.8470	61.1673%	5.1414E-02		
Nickel	Ni	58.7100	13.5271%	1.0816E-02		
Molybdenum	Mo	95.9400	2.5050%	1.2257E-03		
Total:			100.00%	8.7656E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B4A Density = 7.791 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1732%	8.1173E-04	Natural:	1.20%
	B-11	11.0093	0.7891%	3.3632E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1748E-04	Total:	1.20%
Nitrogen	N	14.0031	0.1002%	3.3590E-04		
Silicon	Si	28.0860	0.7518%	1.2560E-03		
Phosphorus	P	30.9738	0.0451%	6.8336E-05		
Sulfur	S	31.9721	0.0301%	4.4135E-05		
Chromium	Cr	51.9960	19.0457%	1.7188E-02		
Manganese	Mn	54.9381	2.0048%	1.7123E-03		
Iron	Fe	55.8470	60.9914%	5.1245E-02		
Nickel	Ni	58.7100	13.5325%	1.0816E-02		
Molybdenum	Mo	95.9400	2.5060%	1.2257E-03		
Total:			100.00%	8.8183E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B5A Density = 7.768 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2022%	9.4459E-04	Natural:	1.40%
	B-11	11.0093	0.9210%	3.9137E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1718E-04	Total:	1.40%
Nitrogen	N	14.0031	0.1003%	3.3504E-04		
Silicon	Si	28.0860	0.7521%	1.2528E-03		
Phosphorus	P	30.9738	0.0451%	6.8161E-05		
Sulfur	S	31.9721	0.0301%	4.4022E-05		
Chromium	Cr	51.9960	19.0533%	1.7143E-02		
Manganese	Mn	54.9381	2.0056%	1.7079E-03		
Iron	Fe	55.8470	60.8153%	5.0946E-02		
Nickel	Ni	58.7100	13.5379%	1.0788E-02		
Molybdenum	Mo	95.9400	2.5070%	1.2225E-03		
Total:			100.00%	8.8483E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B6A Density = 7.745 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2311%	1.0768E-03	Natural:	1.60%
	B-11	11.0093	1.0530%	4.4613E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1688E-04	Total:	1.60%
Nitrogen	N	14.0031	0.1003%	3.3418E-04		
Silicon	Si	28.0860	0.7524%	1.2496E-03		
Phosphorus	P	30.9738	0.0451%	6.7986E-05		
Sulfur	S	31.9721	0.0301%	4.3909E-05		
Chromium	Cr	51.9960	19.0610%	1.7099E-02		
Manganese	Mn	54.9381	2.0064%	1.7036E-03		
Iron	Fe	55.8470	60.6390%	5.0648E-02		
Nickel	Ni	58.7100	13.5433%	1.0760E-02		
Molybdenum	Mo	95.9400	2.5080%	1.2194E-03		
Total:			100.00%	8.8781E-02		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed
SS316B7A Density = 7.709 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.2892%	1.3408E-03	Natural:	2.00%
	B-11	11.0093	1.3173%	5.5551E-03	Enriched:	0.00%
Carbon	C	12.0112	0.0301%	1.1643E-04	Total:	2.00%
Nitrogen	N	14.0031	0.1004%	3.3289E-04		
Silicon	Si	28.0860	0.7530%	1.2448E-03		
Phosphorus	P	30.9738	0.0452%	6.7723E-05		
Sulfur	S	31.9721	0.0301%	4.3739E-05		
Chromium	Cr	51.9960	19.0763%	1.7033E-02		
Manganese	Mn	54.9381	2.0080%	1.6970E-03		
Iron	Fe	55.8470	60.2861%	5.0118E-02		
Nickel	Ni	58.7100	13.5542%	1.0719E-02		
Molybdenum	Mo	95.9400	2.5100%	1.2147E-03		
	Total:		100.00%	8.9483E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.719 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.1800%	2.9439E-04	Natural:	1.00%
	B-11	11.0093	0.8200%	1.2198E-03	Enriched:	0.00%
Aluminum	Al	26.9815	98.8800%	6.0015E-02	Total:	1.00%
Copper	Cu	63.5400	0.1200%	3.0928E-05		
	Total:		100.00%	6.1560E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.728 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.3600%	5.9079E-04	Natural:	2.00%
	B-11	11.0093	1.6400%	2.4478E-03	Enriched:	0.00%
Aluminum	Al	26.9815	97.8800%	5.9610E-02	Total:	2.00%
Copper	Cu	63.5400	0.1200%	3.1033E-05		
	Total:		100.00%	6.2680E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.738 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.5400%	8.8922E-04	Natural:	3.00%
	B-11	11.0093	2.4600%	3.6843E-03	Enriched:	0.00%
Aluminum	Al	26.9815	96.8800%	5.9203E-02	Total:	3.00%
Copper	Cu	63.5400	0.1200%	3.1139E-05		
	Total:		100.00%	6.3808E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.747 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.7200%	1.1897E-03	Natural:	4.00%
	B-11	11.0093	3.2800%	4.9292E-03	Enriched:	0.00%
Aluminum	Al	26.9815	95.8800%	5.8793E-02	Total:	4.00%
Copper	Cu	63.5400	0.1200%	3.1246E-05		
	Total:		100.00%	6.4943E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.752 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.8100%	1.3407E-03	Natural:	4.50%
	B-11	11.0093	3.6900%	5.5549E-03	Enriched:	0.00%
Aluminum	Al	26.9815	95.3800%	5.8587E-02	Total:	4.50%
Copper	Cu	63.5400	0.1200%	3.1300E-05		
	Total:		100.00%	6.5514E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.757 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	0.9000%	1.4922E-03	Natural:	5.00%
	B-11	11.0093	4.1000%	6.1827E-03	Enriched:	0.00%
Aluminum	Al	26.9815	94.8800%	5.8380E-02	Total:	5.00%
Copper	Cu	63.5400	0.1200%	3.1354E-05		
	Total:		100.00%	6.6086E-02		

Chemical Composition of Borated Aluminum Alloy (Aluminum Boron, Al-B
Density = 2.757 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities		Boron Fractions
Boron	B-10	10.0129	4.7500%	7.8757E-03	Natural:	0.00%
	B-11	11.0093	0.2500%	3.7699E-04	Enriched:	5.00%
Aluminum	Al	26.9815	94.8800%	5.8380E-02	Total:	5.00%
Copper	Cu	63.5400	0.1200%	3.1354E-05		
	Total:		100.00%	6.6664E-02		

Chemical Composition of BORAL (with Natural Boron)
Density = 2.674 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Boron	B-10	10.0129	2.6760%	4.3046E-03
	B-11	11.0093	12.1930%	1.7838E-02
Carbon	C	12.0112	4.1260%	5.5329E-03
Aluminum	Al	26.9815	81.0050%	4.8356E-02
	Total:		100.00%	7.6032E-02

Chemical Composition of BORAL (with Enriched Boron)
Density = 2.674 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Boron	B-10	10.0129	14.1260%	2.2723E-02
	B-11	11.0093	0.7430%	1.0870E-03
Carbon	C	12.0112	4.1260%	5.5329E-03
Aluminum	Al	26.9815	81.0050%	4.8356E-02
	Total:		100.00%	7.7699E-02

Chemical Composition of B4C (with Natural Boron)
Density = 1.78 g/cc

Boron Fractions		B4C Fractions
Natural: 100.00%	% B	78.57%
Enriched: 0.00%	% C	21.43%
Total: 100.00%	Total:	100.00%

Element	Symbol	Atomic Weight	Weight %	Number Densities
Boron	B-10	10.0129	14.1426%	1.5141E-02
	B-11	11.0093	64.4274%	6.2735E-02
Carbon	C	12.0112	21.4300%	1.9126E-02
	Total:		100.00%	9.7003E-02

Chemical Composition of B4C (with Enriched Boron)
Density = 1.78 g/cc

Boron Fractions		B4C Fractions
Natural: 0.00%	% B	78.57%
Enriched: 100.00%	% C	21.43%
Total: 100.00%	Total:	100.00%

Element	Symbol	Atomic Weight	Weight %	Number Densities
Boron	B-10	10.0129	74.6415%	7.9913E-02
	B-11	11.0093	3.9285%	3.8253E-03
Carbon	C	12.0112	21.4300%	1.9126E-02
	Total:		100.00%	1.0286E-01

Chemical Composition of 1100 Aluminum Alloy
Density = 2.7 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Aluminum	Al	26.9815	99.8800%	6.0194E-02
Copper	Cu	63.5400	0.1200%	3.0710E-05
	Total:		100.00%	6.0225E-02

Chemical Composition of Aluminum Alloy 6063
Density = 2.69 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities	
Magnesium	Mg	24.3120	0.6750%	4.4979E-04	
Aluminum	Al	26.9815	98.0250%	5.8857E-02	
Silicon	Si	28.0860	0.4000%	2.3073E-04	
Titanium	Ti	47.9000	0.1500%	5.0733E-05	
Chromium	Cr	51.9960	0.1000%	3.1157E-05	
Manganese	Mn	54.9381	0.1000%	2.9489E-05	
Iron	Fe	55.8470	0.3500%	1.0153E-04	
Copper	Cu	63.5400	0.1000%	2.5497E-05	
Zinc	Zn	65.3700	0.1000%	2.4783E-05	*
Other	?		0.0000%		
	Total:		100.00%	5.9801E-02	

Chemical Composition of Zircaloy - 2
Density = 6.56 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1200%	2.9640E-04
Chromium	Cr	51.9960	0.1000%	7.5982E-05
Iron	Fe	55.8470	0.1000%	7.0743E-05
Zirconium	Zr	91.2200	98.2300%	4.2544E-02
Nickel	Ni	58.7100	0.0500%	3.3647E-05
Tin	Sn	118.6900	1.4000%	4.6601E-04
Total:			100.00%	4.3487E-02

Chemical Composition of Zircaloy - 4
Density = 6.56 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1200%	2.9640E-04
Chromium	Cr	51.9960	0.1000%	7.5982E-05
Iron	Fe	55.8470	0.2000%	1.4149E-04
Zirconium	Zr	91.2200	98.1800%	4.2522E-02
Tin	Sn	118.6900	1.4000%	4.6601E-04
Total:			100.00%	4.3502E-02

Chemical Composition of Grade 702 Zirconium
Density = 6.5 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1600%	3.9159E-04
Chromium	Cr	51.9960	0.1000%	7.5287E-05
Iron	Fe	55.8470	0.1000%	7.0096E-05
Zirconium	Zr	91.2200	95.1400%	4.0829E-02
Hafnium	Hf	178.49	4.5000%	9.8694E-04
Total:			100.00%	4.2353E-02

Chemical Composition of Grade 704 Zirconium
Density = 6.56 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1800%	4.4460E-04
Chromium	Cr	51.9960	0.1500%	1.1397E-04
Iron	Fe	55.8470	0.1500%	1.0611E-04
Zirconium	Zr	91.2200	93.5200%	4.0504E-02
Tin	Sn	118.6900	1.5000%	4.9930E-04
Hafnium	Hf	178.49	4.5000%	9.9605E-04
Total:			100.00%	4.2664E-02

Chemical Composition of Grade 706 Zirconium
Density = 6.44 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1600%	3.8797E-04
Chromium	Cr	51.9960	0.1000%	7.4592E-05
Iron	Fe	55.8470	0.1000%	6.9449E-05
Zirconium	Zr	91.2200	95.1400%	4.0452E-02
Hafnium	Hf	178.49	4.5000%	9.7783E-04
Total:			100.00%	4.1962E-02

Chemical Composition of Zirconium-Hafnium 70-30 Alloy
Density = 7.58 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1600%	4.5668E-04
Chromium	Cr	51.9960	0.1000%	8.7802E-05
Iron	Fe	55.8470	0.1000%	8.1748E-05
Zirconium	Zr	91.2200	69.6400%	3.4853E-02
Hafnium	Hf	178.49	30.0000%	7.6733E-03
	Total:		100.00%	4.3153E-02

Chemical Composition of Zirconium-Hafnium 30-70 Alloy
Density = 10.0 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	0.1600%	6.0227E-04
Chromium	Cr	51.9960	0.1000%	1.1579E-04
Iron	Fe	55.8470	0.1000%	1.0781E-04
Zirconium	Zr	91.2200	29.6400%	1.9563E-02
Hafnium	Hf	178.49	70.0000%	2.3612E-02
	Total:		100.00%	4.4002E-02

Chemical Composition of Spent Silver-Indium-Cadmium Control Rod Mate
Density = 10.2 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Silver	Ag	108.9048	77.0000%	4.3433E-02
Cadmium	Cd	112.4000	9.0000%	4.9187E-03
Indium	In	114.8200	11.0000%	5.8851E-03
Tin	Sn	118.6900	3.0000%	1.5527E-03
	Total:		100.00%	5.5790E-02

Chemical Composition of Depleted Uranium
Density = 18.98 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.007825	0.0010%	1.1342E-04
Carbon	C	12.0112	0.0500%	4.7584E-04
Iron	Fe	55.8470	0.0150%	3.0702E-05
Molybdenum	Mo	95.9400	0.2500%	2.9786E-04
Uranium	U-235	235.0439	0.2000%	9.7265E-05
	U-238	238.0508	99.48%	4.7770E-02
	Total:		100.00%	4.8785E-02

Chemical Composition of Fresh Nuclear Fuel, 1.8% U-235, w/ U-234
Density = 10.52 g/cc

	U-234	0.0055%	M - U	237.9957427
a %U-234 in	U-235	1.8000%	M - O2	31.98983
0.0056%	U-238	98.1945%	M - UO2	269.9855727
	Total U:	100.00%		

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8487%	4.6941E-02
Uranium	U-234	234.0409	0.0048%	1.3124E-06
	U-235	235.0439	1.5867%	4.2777E-04
	U-238	238.0508	86.5597%	2.3041E-02
	Total:		100.00%	7.0411E-02

Chemical Composition of Fresh Nuclear Fuel, 1.8% U-235
Density = 10.52 g/cc

Uranium	U-235	1.8000%	M - U	237.9959668
	U-238	98.2000%	M - O2	31.98983
	Total U:	100.00%	M - UO2	269.9857968

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8487%	4.6941E-02
Uranium	U-235	235.0439	1.5867%	4.2777E-04
	U-238	238.0508	86.5646%	2.3043E-02
	Total:		100.00%	7.0411E-02

Chemical Composition of Fresh Nuclear Fuel, 3.0% U-235, w/ U-234
Density = 10.52 g/cc

	U-234	0.0054%	M - U	237.9592241
%U-234 in U	U-235	3.0000%	M - O2	31.98983
0.0056%	U-238	96.9946%	M - UO2	269.9490541
	Total U:	100.00%		

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8503%	4.6947E-02
Uranium	U-234	234.0409	0.0048%	1.2964E-06
	U-235	235.0439	2.6445%	7.1294E-04
	U-238	238.0508	85.5004%	2.2759E-02
	Total:		100.00%	7.0421E-02

Chemical Composition of Fresh Nuclear Fuel, 3.0% U-235
Density = 10.52 g/cc

Uranium	U-235	3.0000%	M - U	237.9594454
	U-238	97.0000%	M - O2	31.98983
	Total U:	100.00%	M - UO2	269.9492754

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8503%	4.6947E-02
Uranium	U-235	235.0439	2.6445%	7.1294E-04
	U-238	238.0508	85.5052%	2.2761E-02
	Total:		100.00%	7.0421E-02

Chemical Composition of Fresh Nuclear Fuel, 3.75% U-235, w/ U-234
Density = 10.52 g/cc

	U-234	0.0054%	M - U	237.9364056
%U-234 in U	U-235	3.7500%	M - O2	31.98983
0.0056%	U-238	96.2446%	M - UO2	269.9262356
	Total U:	100.00%		

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8513%	4.6951E-02
Uranium	U-234	234.0409	0.0048%	1.2863E-06
	U-235	235.0439	3.3056%	8.9116E-04
	U-238	238.0508	84.8384%	2.2583E-02
	Total:		100.00%	7.0427E-02

Chemical Composition of Fresh Nuclear Fuel, 3.75% U-235
Density = 10.52 g/cc

Uranium	U-235	3.7500%	M - U	237.9366252
	U-238	96.2500%	M - O2	31.98983
	Total U:	100.00%	M - UO2	269.9264552

Element	Symbol	Atomic Weight	Weight %	Number Densities
Oxygen	O	15.9949	11.8513%	4.6951E-02
Uranium	U-235	235.0439	3.3056%	8.9117E-04
	U-238	238.0508	84.8431%	2.2584E-02
	Total:		100.00%	7.0426E-02

Chemical Composition of Air
Density =0.001225 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Nitrogen	N	14.0031	80.0000%	4.2148E-05
Oxygen	O	15.9949	20.0000%	9.2249E-06
	Total:		100.00%	5.1373E-05

Chemical Composition of Helium Fill Gas
Density =0.001785 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Helium	He	4.0026	100.0000%	2.6858E-04
	Total:		100.00%	2.6858E-04

Chemical Composition of Water
Density = 1 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	11.1915%	6.6878E-02
Oxygen	O	15.9949	88.8085%	3.3439E-02
	Total:		100.00%	1.0032E-01

Chemical Composition of Wet Crushed Tuff
Density = 1.61 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	3.4756%	3.3439E-02
Oxygen	O	15.9949	61.9691%	3.7566E-02
Sodium	Na	22.9898	2.0051%	8.4568E-04
Magnesium	Mg	24.3120	0.0533%	2.1257E-05
Aluminum	Al	26.9815	4.4887%	1.6131E-03
Silicon	Si	28.0860	25.4310%	8.7797E-03
Phosphorus	P	30.9738	0.0030%	9.3914E-07
Potassium	K	39.1020	1.8201%	4.5134E-04
Calcium	Ca	40.0800	0.2222%	5.3755E-05
Titanium	Ti	47.9000	0.0383%	7.7530E-06
Manganese	Mn	54.9381	0.0243%	4.2888E-06
Iron	Fe	55.8470	0.4692%	8.1463E-05
	Total:		100.00%	8.2864E-02

Chemical Composition of Borosilicate Glass, Natural Boron
Density = 2.225 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	0.0100%	1.3296E-04
Lithium	Li-6	6.0151	0.0152%	3.3862E-05
	Li-7	7.0160	0.2171%	4.1465E-04
Boron	B-10	10.0129	1.3012%	1.7414E-03
	B-11	11.0093	6.5175%	7.9329E-03
Oxygen	O	15.9949	51.6976%	4.3311E-02
Fluorine	F	18.9984	0.0050%	3.5266E-06
Sodium	Na	22.9898	2.8193%	1.6433E-03
Aluminum	Al	26.9815	1.1645%	5.7834E-04
Silicon	Si	28.0860	35.6780%	1.7022E-02
Chlorine	Cl	35.4520	0.0700%	2.6459E-05
Potassium	K	39.1020	0.4151%	1.4225E-04
Barium	Ba	137.3400	0.0896%	8.7422E-06
Total:			100.00%	7.2991E-02

Chemical Composition of Borosilicate Glass, Enriched Boron
Density = 2.225 g/cc

Element	Symbol	Atomic Weight	Weight %	Number Densities
Hydrogen	H	1.0078	0.0100%	1.3296E-04
Lithium	Li-6	6.0151	0.0152%	3.3862E-05
	Li-7	7.0160	0.2171%	4.1465E-04
Boron	B-10	10.0129	7.4277%	9.9403E-03
	B-11	11.0093	0.3909%	4.7579E-04
Oxygen	O	15.9949	51.6976%	4.3311E-02
Fluorine	F	18.9984	0.0050%	3.5266E-06
Sodium	Na	22.9898	2.8193%	1.6433E-03
Aluminum	Al	26.9815	1.1645%	5.7834E-04
Silicon	Si	28.0860	35.6780%	1.7022E-02
Chlorine	Cl	35.4520	0.0700%	2.6459E-05
Potassium	K	39.1020	0.4151%	1.4225E-04
Barium	Ba	137.3400	0.0896%	8.7422E-06
Total:			100.00%	7.3733E-02

Source: UCRL-LR=107476 Vol.1 April 1993

Isotopes/Elements:	O-16	Si	Al-27	Fe	Ca	Mg	Ti	Na-23	K	P-31	Mn-55	H
Atomic Weights:	15.995	28.086	26.982	55.847	40.080	24.312	47.900	22.990	39.102	30.974	54.938	1.008

Tuff Drill Hole 61

Compound	Weight %	Number of Atoms per compound O	Si	Al	Fe	Ca	Mg	Ti	Na	K	P	Mn	H
SiO2	78.900%	2	1										
Al2O3	12.300%	3		2									
Fe2O3	0.973%	3			2								
CaO	0.451%	1				1							
MgO	0.128%	1					1						
TiO2	0.093%	2						1					
Na2O	3.920%	1							2				
K2O	3.180%	1								2			
P2O5	0.010%	5									2		
MnO	0.046%	1										1	
Total	100.00%												

Compound	Weight %	Number of Atoms per compound O	H
H2O	100.00%	1	2

Number of Atoms * Atomic Weight

	O-16	Si	Al-27	Fe	Ca	Mg	Ti	Na-23	K	P-31	Mn-55	H	Total
SiO2	31.9898	28.0860	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	60.0758
Al2O3	47.9847	0.0000	53.9631	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	101.9478
Fe2O3	47.9847	0.0000	0.0000	111.6940	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	159.6787
CaO	15.9949	0.0000	0.0000	0.0000	40.0800	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	56.0749
MgO	15.9949	0.0000	0.0000	0.0000	0.0000	24.3120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	40.3069
TiO2	31.9898	0.0000	0.0000	0.0000	0.0000	0.0000	47.9000	0.0000	0.0000	0.0000	0.0000	0.0000	79.8898
Na2O	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	45.9795	0.0000	0.0000	0.0000	0.0000	61.9745
K2O	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	78.2040	0.0000	0.0000	0.0000	94.1989
P2O5	79.9746	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	61.9475	0.0000	0.0000	141.9221
MnO	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	54.9381	0.0000	70.9330

Number of Atoms * Atomic Weight

	O-16	H	Total
H2O	15.9949	2.0157	18.0106

Source: UCRL-LR=107476 Vol.1 April 1993

Dry Tuff

Vol. Frac. 0.5

Density 2.22 g/cc

Source: CRC, 66 Edition, 1985

Water

Vol. Frac. 0.5

Density 1 g/cc

*Wet Tuff Mixture:

Density 1.61 g/cc

Fractional Densities Dry Tuff:
(per compound and isotope)
Compound Weight % * Volume Fraction * Density * (Number of Atoms * Atomic Weight) / (Total (Number of Atoms * Atomic Weight) per compound)

Tuff	O-16	Si	Al-27	Fe	Ca	Mg	Ti	Na-23	K	P-31	Mn-55	H	
SiO2	0.46635	0.40944	0	0	0	0	0	0	0	0	0	0	
Al2O3	0.064262	0	0.072268	0	0	0	0	0	0	0	0	0	
Fe2O3	0.003246	0	0	0.007555	0	0	0	0	0	0	0	0	
CaO	0.001428	0	0	0	0.003578	0	0	0	0	0	0	0	
MgO	0.000564	0	0	0	0	0.000858	0	0	0	0	0	0	
TiO2	0.000412	0	0	0	0	0	0.000617	0	0	0	0	0	
Na2O	0.01123	0	0	0	0	0	0	0.032282	0	0	0	0	
K2O	0.005994	0	0	0	0	0	0	0	0.029304	0	0	0	
P2O5	0.000063	0	0	0	0	0	0	0	0	0.000048	0	0	
MnO	0.000114	0	0	0	0	0	0	0	0	0	0.000391	0	Total
Total	0.553662	0.40944	0.072268	0.007555	0.003578	0.000858	0.000617	0.032282	0.029304	0.000048	0.000391	0	1.11

Fractional Densities Water:
(per compound and isotope)
Compound Weight % * Volume Fraction * Density * (Number of Atoms * Atomic Weight) / (Total (Number of Atoms * Atomic Weight) per compound)

Water	O-16	H	Total
H2O	0.444043	0.055957	0.5

1.61

Weight Fractions:	O-16	Si	Al-27	Fe	Ca	Mg	Ti	Na-23	K	P-31	Mn-55	H
	61.9691%	25.4310%	4.4887%	0.4692%	0.2222%	0.0533%	0.0383%	2.0051%	1.8201%	0.0030%	0.0243%	3.4756%

Elemental/Isotopic Weight Fractions:
Wet Crushed Tuff (50% Water by Volume)

H	3.4756%
O-16	61.9691%
Na-23	2.0051%
Mg	0.0533%
Al -27	4.4887%
Si	25.4310%
P-31	0.0030%
K	1.8201%
Ca	0.2222%
Ti	0.0383%
Mn-55	0.0243%
Fe	0.4692%
	100.00%

Source: EPRI NP-1974 November 1980

Number of Atoms per compound (Number of Atoms per compound * Isotope Fraction of Element)

Compound	Compound Weight %	O	Si	B10	B11	Na	Al	K	Li-6	Li-7	Cl	F	Ba	H
SiO2	76.315%	2	1											
B	3.900%			0.18	0.82									
B2O3	12.600%	3		0.36	1.64									
Na2O	3.800%	1				2								
Al2O3	2.200%	3					2							
K2O	0.500%	1						2						
Li2O	0.500%	1							0.2	1.8				
Cl	0.070%										1			
F	0.005%											1		
BaO	0.100%	1											1	
H	0.010%													1
Total	100.00%	(Number of Atoms per compound * Isotope Fraction of Element)												

Isotopes/Elemer	O-16	Si	B-10	B-11	Na-23	Al-27	K	Li-6	Li-7	Cl	F-19	Ba	H	
Atomic Weights:	15.995	28.086	10.013	11.009	22.990	26.982	39.102	6.015	7.016	35.452	18.998	137.340	1.008	
	Number of Atoms * Atomic Weight													
	31.9898	28.0860	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	60.0758
	0.0000	0.0000	1.8023	9.0276	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	10.8300
	47.9847	0.0000	3.6047	18.0553	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	69.6447
	15.9949	0.0000	0.0000	0.0000	45.9795	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	61.9745
	47.9847	0.0000	0.0000	0.0000	0.0000	53.9631	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	101.9478
	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	78.2040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	94.1989
	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9099	12.9707	0.0000	0.0000	0.0000	0.0000	29.8755
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	35.4520	0.0000	0.0000	0.0000	35.4520
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	18.9984	0.0000	0.0000	18.9984
	15.9949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	137.3400	0.0000	153.3349
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0078	1.0078

Source: "Fund. of Heat and Mass Transfer", 2nd Edition, 1985

Glass
Vol. Frac. 1
Density 2.225 g/cc

Source: "Nuclear Chemical Engineering", 2nd Edition, 1981

Isotope Fraction of Element

Lithium
Li-6 7.5632%
Li-7 92.4368%
100.00%

Natural Boron
B-10 18.0000%
B-11 82.0000%
100.00%

Enriched Boron
B-10 95.0000%
B-11 5.0000%
100.00%

Fractional Densities:
(per compound and isotope)
Compound Weight % * Volume Fraction * Density * (Number of Atoms * Atomic Weight) / (Total (Number of Atoms * Atomic Weight) per compound)

Glass	O-16	Si	B-10	B-11	Na-23	Al-27	K	Li-6	Li-7	Cl	F-19	Ba	H	
SiO2	0.904174	0.793835	0	0	0	0	0	0	0	0	0	0	0	
B	0	0	0.014441	0.072334	0	0	0	0	0	0	0	0	0	
B2O3	0.193159	0	0.01451	0.07268	0	0	0	0	0	0	0	0	0	
Na2O	0.021821	0	0	0	0.062729	0	0	0	0	0	0	0	0	
Al2O3	0.02304	0	0	0	0	0.02591	0	0	0	0	0	0	0	
K2O	0.001889	0	0	0	0	0	0.009236	0	0	0	0	0	0	
Li2O	0.005956	0	0	0	0	0	0	0.000339	0.00483	0	0	0	0	
Cl	0	0	0	0	0	0	0	0	0	0.001558	0	0	0	
F	0	0	0	0	0	0	0	0	0	0	0.000111	0	0	
BaO	0.000232	0	0	0	0	0	0	0	0	0	0	0.001993	0	
H	0	0	0	0	0	0	0	0	0	0	0	0	0.000223	
														Total:
Total Fractional Density per isotope:	1.150272	0.793835	0.028951	0.145014	0.062729	0.02591	0.009236	0.000339	0.00483	0.001558	0.000111	0.001993	0.000223	2.225
														0
														2.225

Fractional Density (per isotope) / Total Density

Weight Fractions:	O-16	Si	B-10	B-11	Na-23	Al-27	K	Li-6	Li-7	Cl	F-19	Ba	H	
	51.6976%	35.6780%	1.3012%	6.5175%	2.8193%	1.1645%	0.4151%	0.0152%	0.2171%	0.0700%	0.0050%	0.0896%	0.0100%	100.0000%

Elemental/Isotopic Weight Fractions:

Borosilicate Glass (natural boron)		Borosilicate Glass (enriched boron)	
H	0.0100%	H	0.0100%
Li-6	0.0152%	Li-6	0.0152%
Li-7	0.2171%	Li-7	0.2171%
B-10	1.3012%	B-10	7.4277%
B-11	6.5175%	B-11	0.3909%
O-16	51.6976%	O-16	51.6976%
F-19	0.0050%	F-19	0.0050%
Na-23	2.8193%	Na-23	2.8193%
Al-27	1.1645%	Al-27	1.1645%
Si	35.6780%	Si	35.6780%
Cl	0.0700%	Cl	0.0700%
K	0.4151%	K	0.4151%
Ba	0.0896%	Ba	0.0896%
	100.00%		100.00%

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B1A Density = 7.874 g/cc
Old density 7.88 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.0720%	0.0576%	Natural:	0.40%
	B-11	0.3280%	0.2626%	Enriched:	0.00%
Carbon	C	0.0300%	0.0300%	Total:	0.40%
Nitrogen	N	0.1000%	0.1001%		
Silicon	Si	0.7500%	0.7506%		
Phosphorus	P	0.0450%	0.0450%		
Sulfur	S	0.0300%	0.0300%		
Chromium	Cr	19.0000%	19.0152%		
Manganese	Mn	2.0000%	2.0016%		
Iron	Fe	61.6450%	61.6944%		
Nickel	Ni	13.5000%	13.5108%		
Molybdenum	Mo	2.5000%	2.5020%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B3A Density = 7.816 g/cc
Old density 7.83 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.1566%	0.1255%	Natural:	0.87%
	B-11	0.7134%	0.5717%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	0.87%
Nitrogen	N	0.1000%	0.1002%		
Silicon	Si	0.7500%	0.7513%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0331%		
Manganese	Mn	2.0000%	2.0035%		
Iron	Fe	61.1750%	61.2816%		
Nickel	Ni	13.5000%	13.5235%		
Molybdenum	Mo	2.5000%	2.5044%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B2A Density = 7.851 g/cc
Old density 7.86 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.1080%	0.0865%	Natural:	0.60%
	B-11	0.4920%	0.3941%	Enriched:	0.00%
Carbon	C	0.0300%	0.0300%	Total:	0.60%
Nitrogen	N	0.1000%	0.1001%		
Silicon	Si	0.7500%	0.7509%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0300%		
Chromium	Cr	19.0000%	19.0228%		
Manganese	Mn	2.0000%	2.0024%		
Iron	Fe	61.4450%	61.5188%		
Nickel	Ni	13.5000%	13.5162%		
Molybdenum	Mo	2.5000%	2.5030%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B4A Density = 7.794 g/cc
Old density 7.81 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.1800%	0.1443%	Natural:	1.00%
	B-11	0.8200%	0.6573%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	1.00%
Nitrogen	N	0.1000%	0.1002%		
Silicon	Si	0.7500%	0.7515%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0381%		
Manganese	Mn	2.0000%	2.0040%		
Iron	Fe	61.0450%	61.1673%		
Nickel	Ni	13.5000%	13.5271%		
Molybdenum	Mo	2.5000%	2.5050%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B4A Density = 7.791 g/cc
Old density 7.81 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.2160%	0.1732%	Natural:	1.20%
	B-11	0.9840%	0.7891%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	1.20%
Nitrogen	N	0.1000%	0.1002%		
Silicon	Si	0.7500%	0.7518%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0457%		
Manganese	Mn	2.0000%	2.0048%		
Iron	Fe	60.8450%	60.9914%		
Nickel	Ni	13.5000%	13.5325%		
Molybdenum	Mo	2.5000%	2.5060%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B5A Density = 7.768 g/cc
Old density 7.79 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.2520%	0.2022%	Natural:	1.40%
	B-11	1.1480%	0.9210%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	1.40%
Nitrogen	N	0.1000%	0.1003%		
Silicon	Si	0.7500%	0.7521%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0533%		
Manganese	Mn	2.0000%	2.0056%		
Iron	Fe	60.6450%	60.8153%		
Nickel	Ni	13.5000%	13.5379%		
Molybdenum	Mo	2.5000%	2.5070%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B6A Density = 7.745 g/cc
Old density 7.77 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.2880%	0.2311%	Natural:	1.60%
	B-11	1.3120%	1.0530%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	1.60%
Nitrogen	N	0.1000%	0.1003%		
Silicon	Si	0.7500%	0.7524%		
Phosphorus	P	0.0450%	0.0451%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0610%		
Manganese	Mn	2.0000%	2.0064%		
Iron	Fe	60.4450%	60.6390%		
Nickel	Ni	13.5000%	13.5433%		
Molybdenum	Mo	2.5000%	2.5080%		
	Total:	100.00%	100.00%		

Chemical Composition of Borated Type 316 Stainless Steel, 20% Boron Removed

SS316B7A Density = 7.709 g/cc
Old density 7.74 g/cc %B remaining 80.00%

Element	Symbol	Old wt%	Weight %		Boron Fractions
Boron	B-10	0.3600%	0.2892%	Natural:	2.00%
	B-11	1.6400%	1.3173%	Enriched:	0.00%
Carbon	C	0.0300%	0.0301%	Total:	2.00%
Nitrogen	N	0.1000%	0.1004%		
Silicon	Si	0.7500%	0.7530%		
Phosphorus	P	0.0450%	0.0452%		
Sulfur	S	0.0300%	0.0301%		
Chromium	Cr	19.0000%	19.0763%		
Manganese	Mn	2.0000%	2.0080%		
Iron	Fe	60.0450%	60.2861%		
Nickel	Ni	13.5000%	13.5542%		
Molybdenum	Mo	2.5000%	2.5100%		
	Total:	100.00%	100.00%		