B-TM-1639

**SPECIFICATIONS, PRE-EXPERIMENTAL PREDICITONS,
AND TEST PLATE CHARACTERIZATION INFORMATION
FOR THE PROMETHEUS CRITICAL EXPERIMENTS**

M. L. Zerkle, M. E. Meyers, S. M. Tarves, and J. J. Powers

Bettis Atomic Power Laboratory
West Mifflin, Pennsylvania 15122-0079

April 2006

Prepared for the
U.S. Department of Energy
By Bechtel Bettis, Inc.

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Acknowledgements

The authors would like to express their gratitude for the assistance provided by members of the Naval Reactors Prime Contractor Team materials community in the fabrication of the refractory metal and moderator test plates for these experiments. The assistance provided by Steve Buresh (KAPL) and Ross Luther (Bettis) during the specification, procurement, fabrication, and characterization of the test plates was invaluable. The assistance provided by Richard Dean (KAPL) in performing the high precision density measurements for the test plate specimens is gratefully acknowledged.

B-TM-1639

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Table of Contents

Table of Contents	5
List of Figures	7
List of Tables	11
1. Background	15
2. Description of Experiments	19
2.1 General Description	19
2.2 Assembly Components	20
2.2.1 Assembly Structure	20
3. Description of Materials	29
3.1 HEU Plates	29
3.2 Graphite Plates	30
3.3 Polyethylene Plates	32
3.4 Aluminum 6061-T6	33
3.5 Stainless Steel Diaphragm	35
3.6 Mo Plates	37
3.7 Nb-1Zr Plates	44
3.8 Re Plates	47
3.9 Ta-2.5W Plates	54
4. NRPCT Pre-Experimental Predictions	63
4.1 Baseline Critical Experiments	72
4.1.1 Base-1 Experiment	72
4.1.2 Base-2 Experiment	78
4.1.3 Base-3 Experiment	84
4.1.4 Base-4 Experiment	90
4.1.5 Baseline Critical Experiments Summary and Conclusions	96
4.2 Molybdenum Critical Experiments	99
4.2.1 Mo-1 Experiment	99
4.2.2 Mo-2 Experiment	106
4.2.3 Mo-3 Experiment	113
4.2.4 Mo-4 Experiment	120
4.2.5 Molybdenum Critical Experiments Summary and Conclusions	127
4.3 Niobium Critical Experiments	133
4.3.1 Nb-1Zr-2 Experiment	133
4.3.2 Nb-1Zr-3 Experiment	140
4.3.3 Niobium Critical Experiments Summary and Conclusions	147
4.4 Rhenium Critical Experiments	150
4.4.1 Re-1 Experiment	150
4.4.2 Re-2 Experiment	157
4.4.3 Re-3 Experiment	164
4.4.4 Re-4 Experiment	171
4.4.5 Rhenium Critical Experiments Summary and Conclusions	178
4.5 Tantalum Critical Experiments	180
4.5.1 Ta-2.5W-1 Experiment	180
4.5.2 Ta-2.5W-2 Experiment	187
4.5.3 Ta-2.5W-3 Experiment	194
4.5.4 Ta-2.5W-4 Experiment	201
4.5.5 Tantalum Critical Experiments Summary and Conclusions	214
5. References	219
Appendix A Specifications for the Prometheus Critical Experiments	A-1
Appendix B Specifications for the ORNL Nb-1Zr Critical Experiments	B-1

Appendix C	Definition of SPACE05A Cross Section Library	C-1
Appendix D	Material Density Measurements and Uncertainty Analysis	D-1
Appendix E	Impact of the Increased Diaphragm Thickness and Mass Loading Limit on the Predicted Critical Configuration of the Prometheus Critical Experiments	E-1
Appendix F	Mo Plate Dimension and Chemistry Reports	F-1
Appendix G	Re Plate Dimension and Chemistry Reports.....	G-1
Appendix H	Ta-2.5W Plate Dimension and Chemistry Reports	H-1
Appendix I	0.1" Thick Graphite Plate Inspection Reports	I-1
Appendix J	Polyethylene Plate Inspection Reports	J-1

List of Figures

Figure 1. Components of the first Nb-1Zr critical experiment, partially assembled split stack during approach to critical.	20
Figure 2. Schematic of the Platen.....	22
Figure 3. Schematic of the Spindle Plate.....	22
Figure 4. Expanded View of the Lower Stack.....	23
Figure 5. Schematic of the Upper Support Platform.....	24
Figure 6. Schematic of the Upper Support Plate.	25
Figure 7. Schematic of the Stainless Steel Diaphragm.	26
Figure 8. Schematic of the Cylindrical Collar Plate.....	27
Figure 9. Expanded View of the Upper Stack.....	28
Figure 10. A Nested Pair of an Inner HEU Disk and an Outer HEU Ring.....	29
Figure 11. Solid Mo Plate	38
Figure 12. Annular Mo Plate	39
Figure 13. Solid Re Plate.....	48
Figure 14. Annular Re Plate	49
Figure 15. Comparison of Measured and Inferred Re Plate Thicknesses	51
Figure 16. Solid Ta-2.5W Critical Experiment Plate	55
Figure 17. Annular Ta-2.5W Critical Experiment Plate	56
Figure 18. Overview of the Critical Experiment Configuration	66
Figure 19. Close-up View of the Critical Experiment Configuration.....	67
Figure 20. Close-up View of the Critical Experiment Configuration, without the Upper Aluminum Support Structure	68
Figure 21. Cross-sectional View of the Base-1 Assembly	73
Figure 22. Cross-sectional Close-up View of the Base-1 Assembly.....	74
Figure 23. Base-1 Assembly k_{eff} as a Function of the Number of Stacking Units.....	76
Figure 24. Base-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	76
Figure 25. Cross-sectional View of the Base-2 Assembly	79
Figure 26. Cross-sectional Close-up View of the Base-2 Assembly.....	80
Figure 27. Base-2 Assembly k_{eff} as a Function of the Number of Stacking Units	82
Figure 28. Base-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	82
Figure 29. Cross-sectional View of the Base-3 Assembly	85
Figure 30. Cross-sectional Close-up View of the Base-3 Assembly.....	86
Figure 31. Base-3 Assembly k_{eff} as a Function of the Number of Stacking Units	88
Figure 32. Base-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	88
Figure 33. Cross-sectional View of the Base-4 Assembly	91
Figure 34. Cross-sectional Close-up View of the Base-4 Assembly.....	92
Figure 35. Base-4 Assembly k_{eff} as a Function of the Number of Stacking Units	94
Figure 36. Base-4 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	94
Figure 37. Comparison of the RCP01 and MCNP5 Fission Rate Spectra for the Baseline Critical Experiments	98
Figure 38. RCP01 Fission CDFs for the Baseline Critical Experiments	98
Figure 39. Cross-sectional View of the Mo-1 Assembly	100
Figure 40. Cross-sectional Close-up View of the Mo-1 Assembly.....	101
Figure 41. Mo-1 Assembly k_{eff} as a Function of the Number of Stacking Units	104
Figure 42. Mo-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	104
Figure 43. Cross-sectional View of the Mo-2 Assembly	107
Figure 44. Cross-sectional Close-up View of the Mo-2 Assembly.....	108
Figure 45. Mo-2 Assembly k_{eff} as a Function of the Number of Stacking Units	111
Figure 46. Mo-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	111
Figure 47. Cross-sectional View of the Mo-3 Assembly	114
Figure 48. Cross-sectional Close-up View of the Mo-3 Assembly.....	115

Figure 49. Mo-3 Assembly k_{eff} as a Function of the Number of Stacking Units	118
Figure 50. Mo-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	118
Figure 51. Cross-sectional View of the Mo-4 Assembly	121
Figure 52. Cross-sectional Close-up View of the Mo-4 Assembly	122
Figure 53. Mo-4 Assembly k_{eff} as a Function of the Number of Stacking Units	125
Figure 54. Mo-4 Assembly k_{eff} as a Function of the Top Reflector Thickness	125
Figure 55: Comparison of the RCP01 and MCNP5 Fission Rate Spectra for the Mo Critical Experiments	129
Figure 56: RCP01 Fission CDFs for the Mo Critical Experiments	129
Figure 57: Comparison of the RCP01 and MCNP5 Mo Absorption Rate Spectra for the Mo Critical Experiments	130
Figure 58: Neutron Absorption Cross-Section vs. Energy for Natural Molybdenum (ENDF/BVI.0) and Isotopically-Combined Equivalent (JENDL 3.2) [20]	131
Figure 59: Comparison of RCP01 and MCNP5 Mo Absorption Rate Spectra over Ranges of Varying Cross-Section Data	132
Figure 60. Cross-sectional View of the Nb-1Zr-2 Assembly	134
Figure 61. Cross-sectional Close-up View of the Nb-1Zr-2 Assembly	135
Figure 62. Nb-1Zr-2 Assembly k_{eff} as a Function of the Number of Stacking Units	138
Figure 63. Nb-1Zr-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	138
Figure 64. Cross-sectional View of the Nb-1Zr-3 Assembly	141
Figure 65. Cross-sectional Close-up View of the Nb-1Zr-3 Assembly	142
Figure 66. Nb-1Zr-3 Assembly k_{eff} as a Function of the Number of Stacking Units	145
Figure 67. Nb-1Zr-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	145
Figure 68: Comparison of RCP01 and MCNP5 Fission Rate Spectra for Nb-1Zr Critical Experiments	148
Figure 69: RCP01 Fission CDFs for the Nb-1Zr Critical Experiments	149
Figure 70: Comparison of RCP01 and MCNP5 Nb-1Zr Absorption Rate Spectra for Nb-1Zr Critical Experiments	149
Figure 71. Cross-sectional View of the Re-1 Assembly	151
Figure 72. Cross-sectional Close-up View of the Re-1 Assembly	152
Figure 73. Re-1 Assembly k_{eff} as a Function of the Number of Stacking Units	155
Figure 74. Re-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	155
Figure 75. Cross-sectional View of the Re-2 Assembly	158
Figure 76. Cross-sectional Close-up View of the Re-2 Assembly	159
Figure 77. Re-2 Assembly k_{eff} as a Function of the Number of Stacking Units	162
Figure 78. Re-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	162
Figure 79. Cross-sectional View of the Re-3 Assembly	165
Figure 80. Cross-sectional Close-up View of the Re-3 Assembly	166
Figure 81. Re-3 Assembly k_{eff} as a Function of the Number of Stacking Units	169
Figure 82. Re-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	169
Figure 83. Cross-sectional View of the Re-4 Assembly	172
Figure 84. Cross-sectional Close-up View of the Re-4 Assembly	173
Figure 85. Re-4 Assembly k_{eff} as a Function of the Number of Stacking Units	176
Figure 86. Re-4 Assembly k_{eff} as a Function of the Top Reflector Thickness	176
Figure 87. Cross-sectional View of the Ta-2.5W-1 Assembly	181
Figure 88. Cross-sectional Close-up View of the Ta-2.5W-1 Assembly	182
Figure 89. Ta-2.5W-1 Assembly k_{eff} as a Function of the Number of Stacking Units	185
Figure 90. Ta-2.5W-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	185
Figure 91. Cross-sectional View of the Ta-2.5W-2 Assembly	188
Figure 92. Cross-sectional Close-up View of the Ta-2.5W-2 Assembly	189
Figure 93. Ta-2.5W-2 Assembly k_{eff} as a Function of the Number of Stacking Units	192
Figure 94. Ta-2.5W-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	192
Figure 95. Cross-sectional View of the Ta-2.5W-3 Assembly	195

Figure 96. Cross-sectional Close-up View of the Ta-2.5W-3 Assembly	196
Figure 97. Ta-2.5W-3 Assembly k_{eff} as a Function of the Number of Stacking Units	199
Figure 98. Ta-2.5W-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	199
Figure 99. RCP01 Cross-sectional View of the Ta-2.5W-4 Assembly	203
Figure 100. MCNP5 Cross-sectional View of the Ta-2.5W-4 Assembly	204
Figure 101. MCNP5 Cross-sectional Close-up View of the Ta-2.5W-4 Assembly	205
Figure 102. Ta-2.5W-4 Assembly k_{eff} as a Function of the Number of Stacking Units	210
Figure 103. Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness	210
Figure 104. Comparison of Predicted RCP01 and MCNP5 Ta-2.5W Absorption Rate Spectra for the Ta-2.5W-4 Critical Experiment	213
Figure 105. Comparison of RCP01 and MCNP5 Fission Rate Spectra for the Ta-2.5W Critical Experiments	216
Figure 106. Comparison of RCP01 and MCNP5 Ta-2.5W Absorption Rate Spectra for the Ta-2.5W Critical Experiments	216
Figure 107. RCP01 Fission CDFs for the Ta-2.5W Critical Experiments	217

B-TM-1639

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List of Tables

Table 1. Summary of NRPCT Designed Critical Experiments	17
Table 2. Summary of Test Plates Supplied for Prometheus Critical Experiments	18
Table 3. Jemima Plate Inventory	29
Table 4. Assembled HEU Fuel Plates	30
Table 5. Average Isotopic Composition of HEU Fuel Plates	30
Table 6. Graphite Plate Dimensions	31
Table 7. As-Built Thickness and Mass Measurements for the 0.1" Thick Graphite Plates	31
Table 8. Average Isotopic Composition of the Graphite Plates	32
Table 9. Polyethylene Plate Inventory	33
Table 10. Average Isotopic Composition of the Polyethylene Plates	33
Table 11. Chemical Composition of Aluminum 6061-T6	34
Table 12. Average Isotopic Composition of Aluminum 6061-T6	34
Table 13. Chemical Composition of Stainless Steel 301	35
Table 14. Average Elemental and Isotopic Composition of Stainless Steel 301	36
Table 15. Specifications for Mo Plates	37
Table 16. As-Built Dimensions of Mo Plates	39
Table 17. Mo Remnant Sample Density Measurements	42
Table 18. Chemical Composition Certificate for Mo Plates	43
Table 19. Chemical Analyses for the Mo Plates	43
Table 20. Average Elemental Composition of the Mo Plates	43
Table 21. Nb-1Zr Plate Inventory	44
Table 22. As-Built and Nominal Dimensions of Nb-1Zr Plates	44
Table 23. Chemical Analysis for the Nb-1Zr Plates	46
Table 24. Elemental Composition from the Top of the Ingot of the Nb-1Zr Plates	46
Table 25. Specifications for Re Plates	47
Table 26. As-Built Dimensions of Re Plates	50
Table 27. Re Remnant Sample Density Measurements	51
Table 28. Full Spectrum Chemical Analysis for Re Plates	52
Table 29. Average Isotopic Composition of the Re Plates	53
Table 30. Specifications for Ta-2.5W Plates	54
Table 31. As-Built Dimensions of the Solid Ta-2.5W Plates	57
Table 32. As-Built Dimensions of the Annular Ta-2.5W Plates	58
Table 33. As-built Thickness and Mass Measurements of the Ta-2.5W Plates, Performed by LANL	59
Table 34. Ta-2.5W Remnant Sample Density Measurements	61
Table 35. Chemical Analyses for the Ta-2.5W Plates	61
Table 36. Average Elemental Composition of the Ta-2.5W Plates	62
Table 37. Cross Section Data Sources	69
Table 38. MCNP5 with Space Cross Sections Unresolved Resonance Region Treatment	71
Table 39. MCNP5 ENDF/B-VI.8 Cross Sections Unresolved Resonance Region Treatment	71
Table 40. Predicted Critical Configuration for the Base-1 Assembly	75
Table 41. Base-1 Assembly Material Mass Distribution	75
Table 42. Base-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	77
Table 43. Predicted Critical Configuration for the Base-2 Assembly	81
Table 44. Base-2 Assembly Material Mass Distribution	81
Table 45. Base-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	83
Table 46. Predicted Critical Configuration for the Base-3 Assembly	87
Table 47. Base-3 Assembly Material Mass Distribution	87
Table 48. Base-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	89
Table 49. Predicted Critical Configuration of the Base-4 Assembly	93
Table 50. Base-4 Assembly Material Mass Distribution	93

Table 51. Base-4 Assembly k_{eff} as a Function of the Top Reflector Thickness	95
Table 52. A Summary of the Energy Spectrum Covered in the Baseline Critical Experiments	96
Table 53. A Summary of the Pre-Experimental Predictions for the Baseline Critical Experiments	97
Table 54. Predicted Critical Configuration for the Mo-1 Assembly	102
Table 55. Mo-1 Assembly Material Mass Distribution.....	103
Table 56. Mo-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	105
Table 57. Predicted Critical Configuration for the Mo-2 Assembly	109
Table 58. Mo-2 Assembly Material Mass Distribution.....	110
Table 59. Mo-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	112
Table 60. Predicted Critical Configuration for the Mo-3 Assembly.	116
Table 61. Mo-3 Assembly Material Mass Distribution.....	117
Table 62. Mo-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	119
Table 63. Predicted Critical Configuration of the Mo-4 Assembly	123
Table 64. Mo-4 Assembly Material Mass Distribution.....	124
Table 65. Mo-4 Assembly k_{eff} as a Function of the Top Reflector Thickness	126
Table 66. A Summary of the Energy Spectrum Covered in the Mo Critical Experiments.....	128
Table 67. A Summary of the Pre-Experimental Predictions for the Mo Critical Experiments	128
Table 68. Predicted Critical Configuration for the Nb-1Zr-2 Assembly	136
Table 69. Nb-1Zr-2 Assembly Material Mass Distribution	137
Table 70. Nb-1Zr-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	139
Table 71. Predicted Critical Configuration for the Nb-1Zr-3 Assembly.	143
Table 72. Nb-1Zr-3 Assembly Material Mass Distribution	144
Table 73. Nb-1Zr-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	146
Table 74. A Summary of the Energy Spectrum Covered in the Nb-1Zr Critical Experiments.....	147
Table 75. A Summary of the Pre-Experimental Predictions for the Nb-1Zr Critical Experiments	148
Table 76. Predicted Critical Configuration for the Re-1 Assembly.....	153
Table 77. Re-1 Assembly Material Mass Distribution	154
Table 78. Re-1 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	156
Table 79. Predicted Critical Configuration for the Re-2 Assembly.....	160
Table 80. Re-2 Assembly Material Mass Distribution	161
Table 81. Re-2 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	163
Table 82. Predicted Critical Configuration for the Re-3 Assembly.....	167
Table 83. Re-3 Assembly Material Mass Distribution	168
Table 84. Re-3 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	170
Table 85. Predicted Critical Configuration of the Re-4 Assembly	174
Table 86. Re-4 Assembly Material Mass Distribution	175
Table 87. Re-4 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	177
Table 88. A Summary of the Energy Spectrum Covered in the Re Critical Experiments	178
Table 89. A Summary of the Pre-Experimental Predictions for the Re Critical Experiments.....	179
Table 90. Predicted Critical Configuration for the Ta-2.5W-1 Assembly	183
Table 91. Ta-2.5W-1 Assembly Material Mass Distribution.....	184
Table 92. Ta-2.5W-1 Assembly k_{eff} as a Function of the Top Reflector Thickness	186
Table 93. Predicted Critical Configuration for the Ta-2.5W-2 Assembly	190
Table 94. Ta-2.5W-2 Assembly Material Mass Distribution.....	191
Table 95. Ta-2.5W-2 Assembly k_{eff} as a Function of the Top Reflector Thickness	193
Table 96. Predicted Critical Configuration for the Ta-2.5W-3 Assembly.	197
Table 97. Ta-2.5W-3 Assembly Material Mass Distribution.....	198
Table 98. Ta-2.5W-3 Assembly k_{eff} as a Function of the Top Reflector Thickness	200
Table 99. RCP01, MCNP5 (Space XS), and RACER Predicted Critical Configuration for the Ta-2.5W-4 Assembly	206
Table 100. MCNP5 Predicted Critical Configuration for the Ta-2.5W-4 Assembly.....	208
Table 101. Ta-2.5W-4 Assembly Material Mass Distribution.....	209

Table 102. RCP01, MCNP5 (Space XS), and RACER Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	211
Table 103. MCNP5, MCNP5 (Space XS), and RACER Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness.....	212
Table 104. A Summary of the Energy Spectrum Covered in the Ta-2.5W Critical Experiments	214
Table 105. A Summary of the Pre-Experimental Predictions for the Ta-2.5W Critical Experiments ..	215
Table D-1. Specimen Density Measurements.	D-7
Table D-2. Raw Data from the Specimen Density Measurements.	D-9
Table E-1. Sensitivity Analysis for the Rhenium Critical Experiments	E-5
Table E-2. Sensitivity Analysis for the Tantalum Critical Experiments	E-6
Table E-3. Sensitivity Analysis for the Baseline Critical Experiments.....	E-7
Table E-4. Sensitivity Analysis for the Molybdenum Critical Experiments.....	E-8

B-TM-1639

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1. Background

This report provides specifications, pre-experimental predictions, and test plate characterization information for a series of molybdenum (Mo), niobium (Nb), rhenium (Re), tantalum (Ta), and baseline critical experiments that were developed by the Naval Reactors Prime Contractor Team (NRPCT) for the Prometheus space reactor development project. In March 2004, the Naval Reactors program was assigned the responsibility to develop, design, deliver, and operationally support civilian space nuclear reactors for NASA's Project Prometheus. The NRPCT was formed to perform this work and consisted of engineers and scientists from the Naval Reactors (NR) Program prime contractors: Bettis Atomic Power Laboratory, Knolls Atomic Power Laboratory (KAPL), and Bechtel Plant Machinery Inc (BPMI). The NRPCT developed a series of clean benchmark critical experiments to address fundamental uncertainties in the neutron cross section data for Mo, Nb, Re, and Ta in fast, intermediate, and mixed neutron energy spectra. These experiments were to be performed by Los Alamos National Laboratory (LANL) using the Planet vertical lift critical assembly machine and were designed with a simple, geometrically clean, cylindrical configuration consisting of alternating layers of test, moderator/reflector, and fuel materials. Based on reprioritization of missions and funding within NASA, Naval Reactors and NASA discontinued their collaboration on Project Prometheus in September 2005. One critical experiment and eighteen subcritical handstacking experiments were completed prior to the termination of work in September 2005. Information on the Prometheus critical experiments and the test plates produced for these experiments are expected to be of value to future space reactor development programs and to integral experiments designed to address the fundamental neutron cross section uncertainties for these refractory metals. This information is being provided as an orderly closeout of NRPCT work on Project Prometheus.

Refractory metal alloys containing substantial amounts of Mo, Nb, Re, and Ta were under consideration for use in the Prometheus reactor. An outstanding issue in the nuclear design of Prometheus reactor concepts using substantial amounts of these refractory metals is the lack of prototypical critical experiment data. There are no clean benchmark quality critical experiments containing substantial amounts of Mo, Nb, Re, or Ta in prototypical neutron energy spectra in the international critical experiment handbook [1]. A series of critical experiments using each of these materials and a series of baseline experiments without refractory metal test plates were developed to resolve this issue with the following objectives in mind:

1. To assess the adequacy of existing Mo, Nb, Re, and Ta neutron cross section evaluations in neutron energy spectra characteristic of Prometheus reactor designs under normal and accident conditions.
2. To reduce the uncertainty in k_{eff} for Prometheus reactor designs containing substantial amounts of Mo, Nb, Re, and Ta by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal conditions.
3. To perform benchmark critical experiments to identify what improvements are needed in Mo, Nb, Re, and Ta neutron cross sections and to provide qualification basis for revised evaluations.

For each material (with the exception of Nb), three experiments were designed to bracket the neutron energy spectra expected in the Prometheus reactor under normal operating conditions and one experiment was designed to simulate an accident condition in which the core is flooded with water. Table 1 summarizes the NRPCT designed critical experiments. The -1 series of experiments were designed to approximate the neutron energy spectrum expected in the center of the Prometheus reactor, this series has the hardest spectrum of the four. The -2 and -3 experiments were designed to bracket the average neutron energy spectrum expected in the Prometheus reactor. The -4 experiments were designed to approximate the neutron energy spectrum for an accident condition in

which the Prometheus reactor is immersed in, and flooded with, water. The -1, -2, -3 experiments were moderated and reflected by graphite plates of increasing thickness to adjust the neutron energy spectrum in the experiments. The -4 experiments were moderated and reflected by polyethylene plates. Specifications for the NRPCT designed critical experiments are provided in Appendix A.

Oak Ridge National Laboratory (ORNL) designed a series of four critical experiments using niobium – 1 weight percent zirconium (Nb-1Zr) and furnished a series of Nb-1Zr test plates to LANL prior to the transfer of responsibility for Project Prometheus to the NR Program. The specifications for the ORNL Nb-1Zr critical experiments are provided in Appendix B for completeness. The NRPCT assumed responsibility for the Nb-1Zr experiments in March 2004 and LANL completed one polyethylene moderated and reflected critical experiment (Mexp 4U) in June 2004. An International Criticality Safety Benchmark Evaluation Project evaluation for the Mexp 4U experiment is currently under preparation [2]. Following the July 2004 security and safeguards shutdown at LANL, the NRPCT and LANL concluded that it would not be practical to complete the remaining three ORNL designed Nb-1Zr experiments (Mexp 2J, Mexp 2L, Mexp 4Y) and they were replaced by two NRPCT designed Nb-1Zr experiments (Nb-1Zr-2 and Nb-1Zr-3). No replacement for the Mexp 4Y experiment was designed.

If significant deficiencies in the Mo, Nb, Re, or Ta neutron cross section evaluations were identified by the Prometheus critical experiments, the next step would have been to perform neutron cross section measurements and develop improved cross section evaluations to resolve the experimental discrepancies. The Prometheus critical experiments would then be used to qualify the new cross section evaluations. The ultimate objective of these experiments was the reduction in the uncertainty in k_{eff} for the Prometheus reactor.

The principal test materials used in the Prometheus critical experiments include LANL supplied highly enriched uranium (HEU) plates (Jemima plates), NRPCT supplied Mo plates, ORNL supplied Nb-1Zr plates, NRPCT supplied Re plates, and NRPCT supplied tantalum – 2.5 tungsten (Ta-2.5W) plates. Table 2 summarizes the quantity and nominal dimensions of the refractory metal and moderator/reflector test plates supplied by the NRPCT and ORNL for the Prometheus critical experiments. With the termination of NR Program work on Project Prometheus the NRPCT supplied test plates have been transferred to LANL with the understanding that they would be eventually moved to DAF for use in future critical experiments. Remnant samples from the NRPCT furnished test plates are being retained by the Bettis Atomic Power Laboratory in the custody of Dr. Michael L. Zerkle.

In addition to the Prometheus critical experiments, the NRPCT supported the completion of the formal documentation for the ZPPR-16 and ZPPR-20 series of engineering mockup critical experiments that were performed in the late 1980s to validate the nuclear design of the SP-100 reactor [3, 4, 5]. The NRPCT also supported the development of three critical experiment benchmark evaluations based on the ZPPR-20 experiments that were added to the 2005 Edition of the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* [6, 7, 8].

Section 2 of this document provides a general description of the Prometheus critical experiments. Section 3 gives a detailed description of the materials and components to be used in the critical experiments. Section 4 provides the pre-experimental prediction of the critical mass and configuration for each experiment, including the results of supporting analyses. The NRPCT pre-experimental predictions are based on RCP01 [9], MCNP5 [10], MCNP5 using a collection of cross section data sets, collectively referred to as SPACE05A (will be referred to as MCNP5 with space cross sections), and RACER [11] Monte Carlo neutron transport analyses. The RCP01 and MCNP5 analyses were performed by Bettis and the MCNP5 with space cross sections and the RACER analyses were performed by KAPL. The RCP01 calculations used a preliminary version of the SPACE05A cross section set; while, MCNP5 with space cross sections and RACER calculations used the SPACE05A cross section data set (Appendix C). The MCNP5 calculations used ENDF/B-VI.8 cross sections.

The specifications for the NRPCT designed Prometheus critical experiments are provided in Appendix A and the specifications for the ORNL designed Nb-1Zr critical experiments are provided in Appendix B. Appendix C contains the definition of the SPACE05A cross section library. Appendix D provides the results of the material density measurements performed on selected remnant samples from the NRPCT supplied refractory metal test plates and provides detailed description of the uncertainty analysis used to determine the experimental uncertainty in the density measurements. Appendix E provides an analysis of the impact of increasing the thickness of the stainless steel diaphragm separating the upper and lower core assemblies and implementing a mass loading limit of 150 kg on the diaphragm of the predicted critical configuration for the Prometheus critical experiments. Vendor dimension inspection and chemistry reports for the Mo, Re, and Ta-2.5W plates are provided in Appendices F, G, and H, respectively. Finally, the vendor inspection reports for the NRPCT supplied 0.1" thick graphite plates and the polyethylene plates are found in Appendices I and J, respectively.

Additional technical work was planned to further refine the pre-experimental predictions for the Prometheus critical experiments, as well as eventual detailed post-experimental analyses; however, due to the termination of Naval Reactors Program involvement in Project Prometheus this work was reduced in scope and an orderly closeout of work was begun. This document provides the NRPCT analyses performed for this project to date, but in no way reflects the full scope that would have been undertaken had the Naval Reactors Program continued its involvement in Project Prometheus. Finally, References [12, 13, 14, 15 and 16] document the results from the 18 subcritical hand-stacking experiments performed by LANL in preparation for the Prometheus critical experiments.

Table 1. Summary of NRPCT Designed Critical Experiments

Name	Test Material	Test Spectrum
Baseline-1	N/A	Core center spectrum
Baseline-2	N/A	Harder than core average spectrum
Baseline-3	N/A	Softer than core average spectrum
Baseline-4	N/A	Flooded spectrum
Mo-1	Mo	Core center spectrum
Mo-2	Mo	Harder than core average spectrum
Mo-3	Mo	Softer than core average spectrum
Mo-4	Mo	Flooded spectrum
Nb-1Zr-2	Nb-1Zr	Harder than core average spectrum
Nb-1Zr-3	Nb-1Zr	Softer than core average spectrum
Re-1	Re	Core center spectrum
Re-2	Re	Harder than core average spectrum
Re-3	Re	Softer than core average spectrum
Re-4	Re	Flooded spectrum
Ta-2.5W-1	Ta-2.5W	Core center spectrum
Ta-2.5W-2	Ta-2.5W	Harder than core average spectrum
Ta-2.5W-3	Ta-2.5W	Softer than core average spectrum
Ta-2.5W-4	Ta-2.5W	Flooded spectrum

Table 2. Summary of Test Plates Supplied for Prometheus Critical Experiments

Material	Furnished By	Thickness (in)	Type	Outer Diameter (in)	Inner Diameter (in)	Quantity
Mo	NRPCT	0.060	Solid	21.000	-	4
			Annular	21.000	2.510	4
		0.030	Solid	21.000	-	22
			Annular	21.000	2.510	22
Nb-1Zr	ORNL	0.060	Solid	21.000	-	8
			Annular	21.000	2.500	8
		0.030	Solid	21.000	-	38
			Annular	21.000	2.500	38
		0.010	Solid	21.000	-	7
			Annular	21.000	2.500	22
			Solid Half-round Disk	10.500 (Radius)	-	29
Re	NRPCT	0.015	Solid	21.000	-	22
			Annular	21.000	2.510	22
Ta-2.5W	NRPCT	0.025	Solid	21.000	-	42
			Annular	21.000	2.510	42
Graphite	NRPCT	0.100	Solid	21.000	-	25
		0.100	Annular	21.000	2.510	25
High Density Polyethylene	NRPCT	1.000	Solid	21.000	-	2
			Annular	21.000	2.510	2
		0.500	Solid	21.000	-	2
			Annular	21.000	2.510	2
		0.080	Solid	21.000	-	20
			Annular	21.000	2.510	15

2. Description of Experiments

2.1 General Description

The Prometheus critical experiments were designed to be assembled on the Planet general-purpose vertical assembly machine at the Los Alamos Critical Experiments Facility (LACEF). The assemblies consist of a cylindrical core region containing interspersed plates of HEU, refractory metal plates, and graphite or polyethylene plates of various thicknesses. The core region is partially reflected by placing graphite or polyethylene axial reflectors on the top and bottom of the assembly. Additional detail on the components and the experimental configurations are provided in later sections.

The assembly is divided into two approximately equal portions. The upper core region and the top reflector rest on a stationary aluminum support platform attached to the Planet machine. The upper segment of the core rests on a thin, cylindrical stainless steel plate, called the diaphragm, which is retained between an aluminum support plate and cylindrical collar plate. The aluminum support plate is attached to the aluminum upper support platform. The lower core region and the bottom reflector are seated on a cylindrical aluminum spindle plate that rests on the aluminum lower platen which is connected to the vertical drive of the assembly machine. The vertical drive of the assembly machine uses a hydraulic ram for coarse positioning and a stepping motor for fine positioning. The lower core plates and bottom reflector are held in position by a central, hollow aluminum alignment tube. A neutron source is placed inside the alignment tube to ensure indication of neutron multiplication. The experiment is conducted by raising the lower portion until it fully closes to the steel diaphragm that supports the upper segment of the core. There are no control or safety rods inside the assembly.

Several neutron detectors (safety monitors) will be placed at varying distances from the assembly to monitor the neutron flux produced by the neutron source, sub-critical multiplication, and by the assembly in the final slightly delayed supercritical configuration. Any one of these monitors would initiate separation of the assembly, a SCRAM, by de-energizing the assembly machine's hydraulic system which drops the lower assembly if the measured neutron flux exceeds a preset limit. The instrumentation and control system of the assembly machine is designed to be fail safe.

A photograph of the first Nb-1Zr critical experiments is shown in Figure 1 to illustrate the various components of the assembly [2]. The bottom reflector and lower core region can be seen resting on the spindle plate. A portion of the upper core region and top reflector can be seen resting on the upper support platform. The upper support plate and collar plate are also clearly visible.

Figure 1. Components of the first Nb-1Zr critical experiment, partially assembled split stack during approach to critical.

2.2 Assembly Components

2.2.1 Assembly Structure

As illustrated in Figure 1, the experiment assemblies are split into two parts. The bottom part rests on a 1.25" thick aluminum 6061-T6 support plate called the platen. Figure 2 presents a schematic of the platen. A 3" thick aluminum 6016-T6 plate known as the spindle plate rests on top of the platen. The spindle plate has an inner diameter (ID) of 2.5" and an outer diameter (OD) of 19" and has a hollow center. Figure 3 presents a schematic of the spindle plate. The main function of the hollow spindle plate is to secure the aluminum alignment tube and to decouple the rest of the system from the platen. A threaded aluminum alignment tube screws into the spindle plate. The hollow alignment tube is made of aluminum 6061-T6 and has a 2.48" OD and a 2.0" ID. The length of the specific alignment tubes used in the critical experiments will be determined at the time of the experiment. Approximately half of the HEU, metal, and graphite or polyethylene plates rest on the spindle plate to form the lower core stack. Figure 4 provides an expanded view of the lower stack.

The top part of the experiment rests on a stationary platform. A large flat 45"x45"x1" thick aluminum 6061-T6 plate, called the upper support platform, serves as the base upon which the upper stack is placed. The upper support platform has a 29"x29" hole in the center of the plate. Figure 5 provides a schematic of the upper support platform. A 34"x34"x0.375" thick aluminum 6061-T6 support plate rests on top of the upper support platform. The upper support plate has a 22.125" ID central hole and a 0.075" deep (modeled as 0.040" deep in the baseline, Mo, Re, and Ta-2.5W critical experiments since LANL had not determined this depth at the time of the analysis, see Appendix E), 25.000" OD recess is machined into the top of the plate to accommodate the stainless steel diaphragm. Figure 6 provides a schematic of the upper support plate. A 24.80" diameter and 0.075" thick (modeled as 0.040" thick in the baseline, Mo, Re, and Ta-2.5W critical experiments since LANL had not determined this thickness at the time of the analysis) stainless steel diaphragm is placed in the center of the

recess in the upper support plate. The purpose of the diaphragm is to support the weight of the upper core assembly plates. Figure 7 provides a schematic of the stainless steel diaphragm. A 24.993" OD and 0.375" thick aluminum 6061-T6 collar rest on top of the stainless steel diaphragm. The collar plate fastens the diaphragm to the upper support plate. Figure 8 provides a schematic of the collar plate. The upper core stack is completed by placing the HEU, cladding metal, and graphite or polyethylene plates on the center of the stainless steel diaphragm. Figure 9 provides an expanded view of the upper core stack.

As mentioned above, the bottom half of the assembly rests on a 3" thick hollow aluminum spindle plate that is attached to the aluminum platen. The platen rides on a hydraulic lift system and a mechanical vertical positioning system. Criticality is achieved by decreasing the gap between the top and bottom portions of the assembly until the bottom section of the assembly barely lifts the upper section of the assembly. To disassemble the configuration, the bottom stack is dropped to its initial position. There are no control or safety rods inside the assembly. The safety features include three radiation monitors located at different distances from the assembly. If the radiation level exceeds a predetermined level, the radiation monitors will cause the hydraulic lift system to be de-energized which will return the bottom core assembly to its initial position.

Construction of the core assembly begins by placing the graphite or polyethylene reflector plate on top of the spindle plate. Next, a bottom metal reflector plate (with the exception of the baseline and Re experiments which do not include a bottom metal reflector plate) and one graphite or polyethylene plate are placed on top of the graphite or polyethylene reflector plate to approximate the reactor vessel. Then, approximately half of the stacking units required for criticality are placed on top of the bottom reflector plate. For the baseline experiments a stacking unit is defined as a set of 2 plates consisting of a HEU plate and a graphite or polyethylene plate. For the Mo, Nb-1Zr, Re, and Ta-2.5W critical experiments a stacking unit is defined as a set of 4 plates consisting of a lower metal plate, a HEU plate, an upper metal plate, and a graphite or polyethylene plate. Approximately half of the stacking units required for criticality are placed on the stainless steel diaphragm to form the upper core stack. Finally, the upper metal reflector plate (with the exception of the baseline and Re experiments which do not include a top metal reflector plate) and the graphite or polyethylene reflector plate is placed on top of the upper core stack. The upper reflector may consist of a single reflector plate or a series of thinner reflector plates to permit the fine adjustment of the upper reflector thickness to limit the excess reactivity of the critical assembly upon full closure.

Figure 2. Schematic of the Platen.

Figure 3. Schematic of the Spindle Plate.

04-GA50008-264-01

Figure 4. Expanded View of the Lower Stack.

Dimensions in inches

03-GA50005-11

Figure 5. Schematic of the Upper Support Platform.

Figure 6. Schematic of the Upper Support Plate.

Figure 7. Schematic of the Stainless Steel Diaphragm.

Figure 8. Schematic of the Cylindrical Collar Plate.

04-GA50001-263

Figure 9. Expanded View of the Upper Stack.

3. Description of Materials

3.1 HEU Plates

The HEU metal fuel plates (Jemima plates) to be used in this experiment consist of a tightly nested pair (a disk inside an annular ring, Figure 10) with a HEU1, HEU2, HEU4, or HEU5 disk on the inside and a HEU3 disk on the outside. All of the HEU fuel plates are nominally 0.118" thick. The quantity and dimensions of the HEU fuel disks and rings currently in the LANL inventory are provided in Table 3. These HEU fuel disks are assumed to be available to be assembled into a total of 28 HEU fuel plates, with the quantity and dimensions for the assembled HEU fuel plates as listed in Table 4. An average HEU fuel plate uranium density of 18.7434 g/cm³ and an average ²³⁵U enrichment of 93.219 weight percent were assumed, since these were the HEU fuel plate specifications used in the first Nb-1Zr critical experiment [2]. The average isotopic composition of the HEU fuel plates used in the pre-experimental predictions is provided in Table 5.

Figure 10. A Nested Pair of an Inner HEU Disk and an Outer HEU Ring.

Table 3. Jemima Plate Inventory

Plate Type	Quantity	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)
HEU1	6	0.118	0	15
HEU2	7	0.118	2.51	15
HEU3	25	0.118	15	21
HEU4	7	0.118	6.005	15
HEU5	8	0.118	10.005	15

Table 4. Assembled HEU Fuel Plates

Quantity	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)
6	0.118	0.0	21
7	0.118	2.51	21
7	0.118	6.005	21
5	0.118	10.005	21
3	0.118	10.005	15

Table 5. Average Isotopic Composition of HEU Fuel Plates

Isotope	Number Density (atoms/barn-cm)
²³⁴ U	4.93652×10^{-4}
²³⁵ U	4.47667×10^{-2}
²³⁶ U	1.59181×10^{-4}
²³⁸ U	2.57214×10^{-3}

3.2 Graphite Plates

Graphite plates of various thicknesses are used in the core region and reflectors for critical experiments 1, 2, and 3 of each material. The quantity and dimensions of the various graphite plates to be used in the core region of the experiments are provided in Table 6. The NRPCT has furnished to LANL 25 solid and 25 annular 0.1" thick graphite plates fabricated by UCAR Carbon Company for use in the critical experiments. The 0.1" thick graphite plates were fabricated using PGX-grade graphite with an average density of 1.732 g/cm³ and a maximum ash content of 0.07 weight percent. The vendor inspection reports for the 0.1" thick graphite plates are provided in Appendix I. LANL reports to have sufficient 0.197" and 0.394" thick graphite plates in their inventory to perform the critical experiments. Similar plates of 0.25", 0.5", and 1.0" thickness are reported to be available in the LANL inventory for use in the top and bottom reflectors. All of the graphite plates are reported to be fabricated by the same manufacturer with the same grade of graphite. The as-built thickness and mass measurements for the 0.1" thick graphite plates, as measured by LANL, are provided in Table 7. LANL had not completed a detailed inventory and as-built characterization of the other graphite plates prior to the termination of NRPCT Project Prometheus work in September. Consequently, as-built graphite plate mass and dimension information was not available for the pre-experimental predictions. The graphite plates were assumed to have an average density of 1.732 g/cm³ and negligible impurities. Table 8 provides the average isotopic composition used to model the graphite plates.

Table 6. Graphite Plate Dimensions

Quantity	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)
25	0.1	0.00	21.0
25	0.1	2.51	21.0
15 (total)	0.197 (0.5 cm)	0.00	21.0
		2.51	21.0
30 (total)	0.394 (1.0 cm)	0.00	21.0
		2.51	21.0
Not Available	0.25	0.00	21.0
		2.51	21.0
Not Available	0.5	0.00	21.0
		2.51	21.0
Not Available	1.0	0.00	21.0
		2.51	21.0

Table 7. As-Built Thickness and Mass Measurements for the 0.1" Thick Graphite Plates

Plate Identification Number	Type	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)				Mass (g)
				T1	T2	T3	Average	
G001	Solid	21	0	0.10155	0.10220	0.10200	0.1019	988.6
G002	Solid	21	0	0.10195	0.10190	0.10125	0.1017	980.3
G003	Solid	21	0	0.10275	0.10140	0.10085	0.1017	989.5
G004	Solid	21	0	0.10310	0.10515	0.10075	0.1030	986.8
G005	Solid	21	0	0.10425	0.10150	0.10135	0.1024	981.9
G006	Solid	21	0	0.10075	0.10180	0.10235	0.1016	976.9
G007	Solid	21	0	0.10010	0.10110	0.10200	0.1011	981.2
G008	Solid	21	0	0.10375	0.10320	0.10185	0.1029	981.0
G009	Solid	21	0	0.10235	0.10535	0.10080	0.1028	994.8
G010	Solid	21	0	0.10090	0.10600	0.10115	0.1027	981.5
G011	Solid	21	0	0.10510	0.10155	0.10135	0.1027	995.0
G012	Solid	21	0	0.09980	0.10250	0.10215	0.1015	993.2
G013	Solid	21	0	0.09955	0.10220	0.10815	0.1033	981.6
G014	Solid	21	0	0.10300	0.10295	0.09960	0.1019	978.3
G015	Solid	21	0	0.10070	0.10265	0.10040	0.1013	977.4
G016	Solid	21	0	0.10230	0.10055	0.10290	0.1019	990.4
G017	Solid	21	0	0.10020	0.10105	0.10265	0.1013	980.3
G018	Solid	21	0	0.10045	0.10140	0.10040	0.1008	980.5
G019	Solid	21	0	0.09960	0.10110	0.10265	0.1011	977.5
G020	Solid	21	0	0.10155	0.10050	0.10505	0.1024	986.1
G021	Solid	21	0	0.09995	0.10095	0.10255	0.1012	978.6
G022	Solid	21	0	0.10010	0.10185	0.10240	0.1015	985.5
G023	Solid	21	0	0.10050	0.10380	0.10155	0.1020	982.6
G024	Solid	21	0	0.10025	0.10500	0.10450	0.1033	991.3
G025	Solid	21	0	0.10050	0.09985	0.10305	0.1011	980.4
G100	Hole	21	2.51	0.09895	0.10160	0.10655	0.1024	970.7

Plate Identification Number	Type	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)				Mass (g)
				T1	T2	T3	Average	
G101	Hole	21	2.51	0.10160	0.10090	0.10365	0.1021	962.0
G102	Hole	21	2.51	0.10095	0.09960	0.10170	0.1008	962.1
G103	Hole	21	2.51	0.09975	0.10055	0.10210	0.1008	959.9
G104	Hole	21	2.51	0.10010	0.09960	0.10235	0.1007	966.4
G105	Hole	21	2.51	0.09935	0.10215	0.10180	0.1011	960.7
G106	Hole	21	2.51	0.10145	0.10055	0.10260	0.1015	963.5
G107	Hole	21	2.51	0.09995	0.10045	0.10440	0.1016	963.6
G108	Hole	21	2.51	0.10055	0.10520	0.10205	0.1026	976.4
G109	Hole	21	2.51	0.10025	0.10120	0.10220	0.1012	963.4
G110	Hole	21	2.51	0.10180	0.10000	0.10080	0.1009	963.8
G111	Hole	21	2.51	0.09995	0.10090	0.10145	0.1008	969.8
G112	Hole	21	2.51	0.09950	0.10220	0.10100	0.1009	967.6
G113	Hole	21	2.51	0.10140	0.10125	0.10170	0.1015	963.1
G114	Hole	21	2.51	0.10150	0.09970	0.10125	0.1008	961.8
G115	Hole	21	2.51	0.10000	0.10160	0.10215	0.1013	962.8
G116	Hole	21	2.51	0.10040	0.10120	0.10225	0.1013	961.4
G117	Hole	21	2.51	0.10045	0.10025	0.10265	0.1011	969.6
G118	Hole	21	2.51	0.10205	0.10000	0.10235	0.1015	971.6
G119	Hole	21	2.51	0.10165	0.10590	0.10720	0.1049	971.5
G120	Hole	21	2.51	0.10120	0.09500	0.10330	0.0998	963.5
G121	Hole	21	2.51	0.10595	0.10015	0.10055	0.1022	973.1
G122	Hole	21	2.51	0.10050	0.09970	0.10120	0.1005	962.5
G123	Hole	21	2.51	0.10555	0.10050	0.10230	0.1028	971.0
G124	Hole	21	2.51	0.10080	0.10295	0.09965	0.1011	961.7

Table 8. Average Isotopic Composition of the Graphite Plates

Nuclide	Number Density (atoms/b-cm)
C	8.68421×10^{-2}

3.3 Polyethylene Plates

Critical experiment 4 for each material will use 0.080" thick high density polyethylene moderator plates and a nominal 1.0" thick polyethylene reflector. There are two types of polyethylene plates, a solid plate with a 21" OD and an annular plate with a 21" OD and a 2.51" ID. The NRPCT has furnished to LANL a set of 0.080", 0.5", and 1.0" thick polyethylene plates to be used in the Prometheus critical experiments. These high density polyethylene plates were manufactured by Standard Machine Company. The inspection reports for the NRPCT furnished polyethylene plates are provided in Appendix J. The quantity and dimensions of the NRPCT furnished polyethylene plates as well as the known LANL polyethylene plate inventory are provided in Table 9. The high density polyethylene plates have an average density of 0.9573 g/cm³ and are reported to have negligible impurities [2]. The average polyethylene isotopic composition used for the pre-experimental predictions is provided in Table 10.

Table 9. Polyethylene Plate Inventory

Nominal Thickness (in)	Quantity	Inner Diameter (in)	Outer Diameter (in)
0.02	1	0.00	21.0
	1	2.51	21.0
0.04	5	0.00	21.0
	20	2.51	21.0
0.08	20	0.00	21.0
	15	2.51	21.0
0.5	2	0.00	21.0
	2	2.51	21.0
1.0	2	0.00	21.0
	2	2.51	21.0
1.125	1	0.00	21.0
	1	2.51	21.0

Table 10. Average Isotopic Composition of the Polyethylene Plates

Isotope	Number Density (atoms/b-cm)
C	4.11027E-02
H	8.22053E-02

3.4 Aluminum 6061-T6

The alignment tube, spindle plate, upper support plate, upper support platform, collar, and platen are constructed using aluminum alloy 6061-T6. The density of aluminum 6061-T6 is 2.70 g/cm³ [17]. Table 11 provides the specifications for the chemical composition of Al 6061-T6 [17] as well as the average chemical composition. The average chemical composition was used to calculate the isotopic composition of the aluminum 6061-T6 used in the model. The average isotopic composition for aluminum 6061-T6 is provided in Table 12. Note that Table 12 contains both elemental and isotopic number densities for selected elements.

LANL provided detailed dimensions for each of the aluminum pieces except for the alignment tube [2]. The alignment tube ensures proper alignment of the plates in the lower core region. The alignment tube has a 2.0" ID, 2.48" OD, and is assumed to extend from the bottom of the spindle plate to the top of the unit below the last stacking unit with a 2.51" ID HEU plate in the lower core region.

Table 11. Chemical Composition of Aluminum 6061-T6

Element	Specification (wt. %)	Average (wt. %)
Al	balance	97.305
Mg	0.8 - 1.2	1.000
Si	0.4 - 0.8	0.600
Fe	0.7 max	0.350
Cu	0.15 - 0.40	0.275
Cr	0.04 - 0.35	0.195
Zn	0.25 max	0.125
Mn	0.15 max	0.075
Ti	0.15 max	0.075

Table 12. Average Isotopic Composition of Aluminum 6061-T6

Element/Nuclide	Number Density (atoms/b-cm)
Al	5.86385E-02
Mg	6.68989E-04
Si	3.47363E-04
Fe	1.01906E-04
⁵⁴ Fe	5.95639E-06
⁵⁶ Fe	9.35026E-05
⁵⁷ Fe	2.15938E-06
⁵⁸ Fe	2.87374E-07
Cu	7.03654E-05
⁶³ Cu	4.86718E-05
⁶⁵ Cu	2.16937E-05
Cr	6.09788E-05
⁵⁰ Cr	2.64953E-06
⁵² Cr	5.10935E-05
⁵³ Cr	5.79359E-06
⁵⁴ Cr	1.44215E-06
Zn	3.10733E-05
Mn	2.21974E-05
Ti	2.54765E-05

3.5 Stainless Steel Diaphragm

The stainless steel diaphragm is constructed using stainless steel 301. The density of stainless steel 301 is 8.00 g/cm^3 [18]. Table 13 provides the specifications for the range of acceptable chemical compositions of stainless steel 301 [18] and the average chemical composition. The average weight percents were used to calculate the isotopic composition of the stainless steel 301 used in the model. The average elemental and isotopic compositions of stainless steel 301 are provided in Table 14.

The stainless steel diaphragm is designed to support the weight of the upper core region. It has a 24.8" OD and a 0.075" thickness (modeled as 0.040" thick in the baseline, Mo, Re, and Ta-2.5W critical experiments since LANL had not determined this thickness at the time of the analysis, see Appendix E). The existing 0.040" diaphragm at LANL was insufficient for safety analyses, and a thicker one (0.075") had to be procured.

Table 13. Chemical Composition of Stainless Steel 301

Element	Specification (wt. %)	Average (wt. %)
Fe	Balance	74.4625
Cr	16 - 18	17.0000
Ni	6 - 8	7.0000
C	Max 0.15	0.0750
Mn	Max 2	1.0000
N	Max 0.1	0.0500
P	Max 0.045	0.0225
S	Max 0.03	0.0150
Si	Max 0.75	0.3750

Table 14. Average Elemental and Isotopic Composition of Stainless Steel 301

Isotope	Number Density (atoms/b-cm)
Fe	6.42383E-02
⁵⁴ Fe	3.75473E-03
⁵⁶ Fe	5.89412E-02
⁵⁷ Fe	1.36121E-03
⁵⁸ Fe	1.81152E-04
Cr	1.57514E-02
⁵⁰ Cr	6.84398E-04
⁵² Cr	1.31979E-02
⁵³ Cr	1.49654E-03
⁵⁴ Cr	3.72521E-04
Ni	5.74579E-03
⁵⁸ Ni	3.91156E-03
⁶⁰ Ni	1.50672E-03
⁶¹ Ni	6.54963E-05
⁶² Ni	2.08831E-04
⁶⁴ Ni	5.31830E-05
C	3.00839E-04
Mn	8.76936E-04
N	1.71979E-04
¹⁴ N	1.71346E-04
¹⁵ N	6.32882E-07
P	3.49969E-05
S	2.25373E-05
Si	6.43265E-04

3.6 Mo Plates

The NRPCT has furnished to LANL solid and annular Mo critical experiment plates. The Mo critical experiment plates were fabricated by Schwarzkopf Technologies. The quantity and dimensional specifications for the Mo plates are provided in Table 15. Photographs of a solid and annular Mo plate are provided in Figure 11 and Figure 12. Table 16 provides the as-built dimensions of the Mo plates based on dimensional characterization measurements performed by Schwarzkopf. The outer and inner diameters reported for each plate are based on the average of two diameter measurements taken approximately 90 degrees from each other. The average outer diameter of the Mo plates is 21.000" with a standard deviation of 0.003". The average inner diameter of the annular Mo plates is 2.506" with a standard deviation of 0.004". The differences between the nominal and measured diameters are judged to be negligible. The thickness measurement for each plate is based on the average of 3 thickness measurements. The average measured thickness of the 0.060" nominal thickness Mo plates is 0.0595" with a standard deviation of 0.0007". The average measured thickness of the 0.030" nominal thickness Mo plates is 0.0301" with a standard deviation of 0.0003".

KAPL performed high-accuracy density measurements on remnant samples from the Mo plates and found the average Mo density to be 10.218 g/cm³. The results of the density measurements are provided in Table 17. Table 18 provides the guaranteed chemical analysis for the Mo plates and Table 19 provides the results of three chemical analyses using different sized samples and the average of the analyses. The nitrogen content of 0.0006% (6ppm) from the chemical analysis of the Mo plates, as shown in Table 19, is 20% higher than the nitrogen content specification of 5ppm, as set in Table 18. The effect of the nitrogen content being 20% over specification was negligible. The chemical impurities in the Mo plates are considered to be insignificant; therefore, the Mo plate material was approximated as pure Mo. The average Mo plate elemental composition used in the pre-experimental predictions is provided in Table 20 and is based on an assumed density of 10.22 g/cm³ (theoretical density) due to the lack of measured density values at that time. Refer to Appendix F for the full Mo dimension and chemistry reports, as provided by the vendors.

Table 15. Specifications for Mo Plates

Type	Quantity	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)
Solid	32	21.000 ± 0.010	-	0.0300 ± 0.0030
Annular	32	21.000 ± 0.010	2.510 ± 0.010	0.0300 ± 0.0030
Solid	4	21.000 ± 0.010	-	0.0600 ± 0.0060
Annular	4	21.000 ± 0.010	2.510 ± 0.010	0.0600 ± 0.0060

Figure 11. Solid Mo Plate

Figure 12. Annular Mo Plate

Table 16. As-Built Dimensions of Mo Plates

Serial #	Average Outer Diameter (in)	Average Inner Diameter (in)	Average Thickness (in)	Mass (g)
MO-0001	21.002	2.505	0.031	1748.0
MO-0002	21.002	2.503	0.031	1745.0
MO-0003	21.003	2.507	0.030	1726.0
MO-0004	20.997	2.504	0.031	1741.0
MO-0005	21.002	2.506	0.030	1699.0
MO-0006	21.002	2.509	0.030	1718.0
MO-0007	21.004	2.509	0.030	1706.0
MO-0008	21.000	2.499	0.030	1694.2
MO-0009	21.003	2.503	0.030	1694.2
MO-0010	21.003	2.505	0.030	1704.4
MO-0011	21.000	2.509	0.030	1712.0
MO-0012	21.001	2.501	0.030	1704.0
MO-0013	21.002	2.506	0.030	1696.0
MO-0014	21.003	2.503	0.030	1701.0

Serial #	Average Outer Diameter (in)	Average Inner Diameter (in)	Average Thickness (in)	Mass (g)
MO-0015	20.998	2.504	0.030	1731.0
MO-0016	21.001	2.502	0.030	1718.0
MO-0017	21.003	2.508	0.031	1744.0
MO-0018	21.002	2.504	0.030	1735.0
MO-0019	21.003	2.501	0.030	1712.0
MO-0020	21.003	2.503	0.030	1715.0
MO-0021	21.003	2.503	0.030	1608.0
MO-0022	21.001	2.501	0.030	1720.0
MO-0023	21.001	0.000	0.030	1742.8
MO-0024	21.002	0.000	0.030	1759.0
MO-0025	21.001	0.000	0.030	1718.8
MO-0026	21.001	0.000	0.030	1738.0
MO-0027	21.002	0.000	0.030	1724.4
MO-0028	21.001	0.000	0.030	1715.0
MO-0029	21.001	0.000	0.030	1727.4
MO-0030	21.004	0.000	0.030	1716.6
MO-0031	21.002	0.000	0.030	1723.4
MO-0032	21.003	0.000	0.030	1746.2
MO-0033	21.002	0.000	0.030	1752.2
MO-0034	21.000	0.000	0.030	1724.0
MO-0035	21.004	0.000	0.030	1740.2
MO-0036	21.002	0.000	0.030	1740.0
MO-0037	21.002	0.000	0.030	1756.2
MO-0038	21.001	0.000	0.031	1746.0
MO-0039	21.001	0.000	0.030	1762.8
MO-0040	21.000	0.000	0.030	1745.2
MO-0041	21.003	0.000	0.030	1747.0
MO-0042	21.002	0.000	0.031	1746.2
MO-0051	20.996	2.511	0.029	1685.8
MO-0052	20.988	2.512	0.030	1729.0
MO-0053	20.995	2.509	0.030	1729.4
MO-0054	20.999	2.511	0.030	1678.2
MO-0055	21.000	2.510	0.030	1690.2
MO-0056	20.996	2.514	0.030	1700.4
MO-0057	20.992	2.512	0.030	1715.4
MO-0058	20.998	2.513	0.030	1708.4
MO-0059	20.996	2.512	0.030	1703.0
MO-0060	20.997	2.513	0.030	1702.4
MO-0061	20.994	0.000	0.030	1749.0
MO-0062	20.986	0.000	0.030	1721.8
MO-0063	20.999	0.000	0.030	1709.2
MO-0064	20.997	0.000	0.030	1732.0
MO-0065	20.997	0.000	0.030	1736.0
MO-0066	20.998	0.000	0.029	1679.2
MO-0067	20.999	0.000	0.031	1752.8
MO-0068	20.998	0.000	0.029	1695.0
MO-0069	20.996	0.000	0.030	1718.2

Serial #	Average Outer Diameter (in)	Average Inner Diameter (in)	Average Thickness (in)	Mass (g)
MO-0070	20.998	0.000	0.030	1744.2
MO-0071	20.998	0.000	0.030	1715.4
MO-0072	21.000	0.000	0.029	1706.8
MO-101	21.002	0.000	0.060	3485.0
MO-102	21.001	0.000	0.060	3445.2
MO-103	20.999	0.000	0.058	3365.4
MO-104	21.000	0.000	0.059	3423.4
MO-105	21.000	2.503	0.060	3406.2
MO-106	20.999	2.510	0.060	3414.8
MO-107	20.998	2.500	0.060	3417.4
MO-108	21.000	2.501	0.060	3409.2

Table 17. Mo Remnant Sample Density Measurements

Specimen	Specimen Density (g/cm³)
Mo-105	10.218
Mo-108	10.215
Mo-107	10.217
Mo-0019	10.216
Mo-0015	10.218
Mo-0008	10.216
Mo-0007	10.219
Mo-0002	10.219
Mo-0017	10.223
Mo-0011	10.215
Mo-0012	10.213
Mo-0013	10.220
Mo-0016	10.220
Mo-0001	10.222
Mo-0021	10.220
Mo-0003	10.218
Mo-0006	10.219
Mo-0014	10.222
Mo-0009	10.217
Mo-0020	10.219
Mo-0022	10.221
Mo 2-1	10.224
Mo 2-2	10.220
Mo 2-3	10.218
Mo 2-4	10.218
Mo 2-5	10.219
Mo 2-6	10.221
Mo 2-7	10.218
Mo 2-8	10.216
Mo 2-9	10.218
Mo-051	10.220
Mo-052	10.216
Mo-053	10.215
Mo-054	10.218
Mo-055	10.214
Mo-056	10.218

Table 18. Chemical Composition Certificate for Mo Plates

Element	Content by Weight	Element	Content by Weight	Element	Content by Weight
Mo	min. 99.97 %	S	max. 10 ppm	Zn	max. 10 ppm
H	max. 10 ppm	K	max. 10 ppm	As	max. 5 ppm
C	max. 30 ppm	Ca	max. 20 ppm	Zr	max. 10 ppm
N	max. 5 ppm	Ti	max. 10 ppm	Nb	max. 10 ppm
O	max. 40 ppm	Cr	max. 20 ppm	Ag	max. 10 ppm
Na	max. 10 ppm	Mn	max. 2 ppm	Cd	max. 5 ppm
Mg	max. 10 ppm	Fe	max. 60 ppm	Ba	max. 5 ppm
Al	max. 10 ppm	Co	max. 10 ppm	Ta	max. 20 ppm
Si	max. 30 ppm	Ni	max. 10 ppm	W	max. 250 ppm
P	max. 20 ppm	Cu	max. 20 ppm	Pb	max. 10 ppm

Table 19. Chemical Analyses for the Mo Plates

Element	Mo (wt. %)			
	0.030", 2"x2"	0.030", 23"x72"	0.059"	Average
Mo	99.98305%	99.98045%	99.98270%	99.98207%
C	0.00025%	0.00025%	0.00025%	0.00025%
Fe	0.00100%	0.00110%	0.00100%	0.00103%
H	0.00005%	0.00010%	0.00005%	0.00007%
N	0.00060%	0.00050%	0.00050%	0.00053%
Nb	0.00050%	0.00050%	0.00050%	0.00050%
Ni	0.00025%	0.00025%	0.00025%	0.00025%
O	0.00150%	0.00150%	0.00070%	0.00123%
Si	0.00070%	0.00025%	0.00025%	0.00040%
Ta	0.00050%	0.00050%	0.00050%	0.00050%
Ti	0.00010%	0.00010%	0.00010%	0.00010%
W	0.01150%	0.01450%	0.01320%	0.01307%

Table 20. Average Elemental Composition of the Mo Plates

Element	Number Density (atoms/b-cm)
Mo	6.41495E-02

3.7 Nb-1Zr Plates

ORNL furnished to LANL solid and annular Nb-1Zr critical experiment plates. The Nb-1Zr critical experiment plates were fabricated from a single heat (heat number 531048) of commercial grade Nb-1Zr produced by Wah Chang in 1988. Table 21 provides the quantities, dimensions, and manufacturing tolerances of the Nb-1Zr plates furnished to LANL. Table 22 provides the nominal dimensions and as-built masses of the Nb-1Zr plates based on mass measurements performed by LANL. Nb-1Zr plate detailed as-built dimensional characterization measurements were not performed by ORNL; consequently nominal dimensions were used in this analysis. An inferred density, used to determine an inferred thickness for each plate, is calculated by dividing the mass of each plate by its nominal volume. An average density for the Nb-1Zr plates was calculated based on the weighted average of the as-built masses and nominal volume for each plate; this yielded a plate density of 8.6862 g/cm³. The as-built mass for plate 12 contained a typographical error, producing a lower than actual average plate density. With the typographical error corrected, the total density of the Nb-1Zr plates was 8.6944 g/cm³. The pre-experimental predictions use the Nb-1Zr plate density of 8.6862 g/cm³ because they were produced before the typographical error was corrected.

Table 23 provides the results of a chemical analysis performed by Wah Chang both at the top and at the bottom of the ingot used to fabricate the Nb-1Zr plates. The plate elemental composition derived from the chemical analysis at the top of the ingot and the average plate density of 8.6862 g/cm³ is used in the pre-experimental predictions and is provided in Table 24. The composition from the top of the ingot was selected for consistency with the analysis performed in HEU-MET-FAST-047 [2].

Table 21. Nb-1Zr Plate Inventory

Type	Quantity	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)
Solid	7	21.000 +0.000/-0.030	-	0.010
Annular	22	21.000 +0.000/-0.030	2.500 +0.015/-0.000	0.010
Solid Half-round disk	29	10.500 +0.000/-0.015 (Radius)	-	0.010
Solid	38	21.000 +0.000/-0.030	-	0.030
Annular	38	21.000 +0.000/-0.030	2.500 +0.015/-0.000	0.030
Solid	8	21.000 +0.000/-0.030	-	0.060
Annular	8	21.000 +0.000/-0.030	2.500 +0.015/-0.000	0.060

Table 22. As-Built and Nominal Dimensions of Nb-1Zr Plates

Plate Identification Number	Type	Nominal			Mass (g)	Inferred Density (g/cm ³)	Inferred Thickness (in)
		OD (in)	ID (in)	Thickness (in)			
1	Solid	21.00	0.00	0.010	519.5	9.153	0.0106
2	Solid	21.00	0.00	0.010	505.2	8.901	0.0103
3	Solid	21.00	0.00	0.010	505.6	8.908	0.0103
4	Solid	21.00	0.00	0.010	501.3	8.832	0.0102
5	Solid	21.00	0.00	0.010	502.2	8.848	0.0102
6	Solid	21.00	0.00	0.010	501.7	8.839	0.0102
7	Solid	21.00	0.00	0.010	474.1	8.353	0.0097
8	Hole	21.00	2.51	0.010	480.7	8.592	0.0099
9	Hole	21.00	2.51	0.010	472.3	8.442	0.0098

Plate Identification Number	Type	Nominal			Mass (g)	Inferred Density (g/cm ³)	Inferred Thickness (in)
		OD (in)	ID (in)	Thickness (in)			
10	Hole	21.00	2.51	0.010	467.0	8.347	0.0097
11	Hole	21.00	2.51	0.010	494.7	8.842	0.0102
12	Hole	21.00	2.51	0.010	493.3	8.817	0.0102
13	Hole	21.00	2.51	0.010	480.7	8.592	0.0099
14	Hole	21.00	2.51	0.010	477.3	8.531	0.0099
15	Hole	21.00	2.51	0.010	490.1	8.760	0.0101
17	Hole	21.00	2.51	0.010	494.7	8.842	0.0102
18	Hole	21.00	2.51	0.010	489.6	8.751	0.0101
19	Hole	21.00	2.51	0.010	491.6	8.787	0.0102
20	Hole	21.00	2.51	0.010	483.3	8.638	0.0100
21	Hole	21.00	2.51	0.010	511.8	9.148	0.0106
22	Hole	21.00	2.51	0.010	485.7	8.681	0.0100
23	Hole	21.00	2.51	0.010	482.3	8.621	0.0100
24	Hole	21.00	2.51	0.010	479.7	8.574	0.0099
25	Hole	21.00	2.51	0.010	482.3	8.621	0.0100
26	Hole	21.00	2.51	0.010	482.2	8.619	0.0100
27	Hole	21.00	2.51	0.010	483.4	8.640	0.0100
28	Hole	21.00	2.51	0.010	486.1	8.689	0.0101
29	Hole	21.00	2.51	0.010	477.0	8.526	0.0099
59	Solid	21.00	0.00	0.030	1493.6	8.772	0.0305
60	Solid	21.00	0.00	0.030	1484.9	8.721	0.0303
61	Solid	21.00	0.00	0.030	1473.9	8.656	0.0301
62	Solid	21.00	0.00	0.030	1469.5	8.630	0.0300
63	Solid	21.00	0.00	0.030	1460.7	8.578	0.0298
64	Solid	21.00	0.00	0.030	1468.6	8.625	0.0299
65	Solid	21.00	0.00	0.030	1503.8	8.832	0.0307
66	Solid	21.00	0.00	0.030	1486.0	8.727	0.0303
67	Solid	21.00	0.00	0.030	1434.5	8.425	0.0293
68	Solid	21.00	0.00	0.030	1479.5	8.689	0.0302
69	Solid	21.00	0.00	0.030	1482.5	8.707	0.0302
97	Hole	21.00	2.51	0.030	1472.2	8.771	0.0305
98	Hole	21.00	2.51	0.030	1491.6	8.887	0.0309
99	Hole	21.00	2.51	0.030	1461.4	8.707	0.0302
100	Hole	21.00	2.51	0.030	1417.3	8.444	0.0293
101	Hole	21.00	2.51	0.030	1440.1	8.580	0.0298
102	Hole	21.00	2.51	0.030	1443.4	8.600	0.0299
103	Hole	21.00	2.51	0.030	1510.3	8.998	0.0312
105	Hole	21.00	2.51	0.030	1460.5	8.702	0.0302
106	Hole	21.00	2.51	0.030	1450.4	8.641	0.0300
107	Hole	21.00	2.51	0.030	1441.4	8.588	0.0298
108	Hole	21.00	2.51	0.030	1462.3	8.712	0.0303
109	Hole	21.00	2.51	0.030	1499.5	8.934	0.0310
110	Hole	21.00	2.51	0.030	1447.9	8.627	0.0300
111	Hole	21.00	2.51	0.030	1436.5	8.559	0.0297
112	Hole	21.00	2.51	0.030	1424.2	8.485	0.0295
141	Solid	21.00	0.00	0.060	3023.4	8.878	0.0617
149	Hole	21.00	2.51	0.060	2907.6	8.662	0.0602

Table 23. Chemical Analysis for the Nb-1Zr Plates

Element	Nb-1Zr (wt. %)		
	Top of Ingot	Bottom of Ingot	Ingot Average
Nb	98.8565	98.8615	98.859
Zr	0.9	0.9	0.9
H	0.0005	0.0005	0.0005
C	0.003	0.003	0.003
N	0.002	0.002	0.002
O	0.011	0.005	0.008
Si	0.005	0.005	0.005
Fe	0.005	0.005	0.005
Ni	0.002	0.002	0.002
Mo	0.005	0.005	0.005
Hf	0.005	0.005	0.005
Ta	0.2	0.2	0.2
W	0.005	0.006	0.0055

Table 24. Elemental Composition from the Top of the Ingot of the Nb-1Zr Plates

Element	Number Density (atoms/b-cm)
Nb	5.56600E-02
Zr	5.16080E-04
H	2.59489E-05
C	1.30658E-05
N	7.46926E-06
O	3.59644E-05
Si	9.31260E-06
Fe	4.68348E-06
Ni	1.78248E-06
Mo	2.72617E-06
Hf	1.46534E-06
Ta	5.78176E-05
W	1.42270E-06

3.8 Re Plates

The NRPCT furnished to LANL solid and annular Re critical experiment plates. The Re critical experiment plates were fabricated by Rhenium Alloys by stitch welding together three approximately 8"x22"x0.015" Re plates using a laser welder. These stitched-together plates were then Electric Discharged Machined (EDMd) to their final dimensions. The quantity and dimensional specifications for the Re plates are provided in Table 25. Photographs of a solid and annular Re plate are provided in Figure 13 and Figure 14. Table 26 provides the as-built dimensions of the Re plates based on dimensional characterization measurements performed by Rhenium Alloys. The Re plates have been fabricated from two lots of high-purity Re powder material: R-1478 and R-1481. The outer and inner diameters reported for each plate are based on the average of two diameter measurements taken approximately 90 degrees from each other. The average outer diameter of the Re plates is 20.997" with a standard deviation of 0.002". The average inner diameter of the annular Re plates is 2.508" with a standard deviation of 0.002". The differences between the nominal and measured diameters are judged to be negligible.

The thickness measurement for each plate is based on the average of either 4 or 7 thickness measurements. The average measured thickness of the Re plates is 0.0166" with a standard deviation of 0.0003". However, the thickness measurements are believed to overestimate the average thickness of the Re plates due to the following factors: normal variation in thickness along the width of the plate due to the rolling process, stitch weld buildup, and a vendor thickness measurement procedure that emphasized characterization of the maximum thickness of the plates. Therefore, to more accurately characterize the average thickness of each Re plate an inferred thickness was determined from the outer diameter, inner diameter, mass of each plate, and the nominal Re density of 21.02 g/cm³. The average inferred thickness of the Re plates is 0.0161" with a standard deviation of 0.0004". Figure 15 provides a comparison of the measured and inferred thickness for each Re plate. The average inferred thickness is believed to more accurately reproduce the average material loading in the Re plates and is the Re plate thickness used in the pre-experimental predictions.

KAPL has performed high-accuracy density measurements using remnant samples from the Re plates and found the average Re density to be 21.001 g/cm³. The results of these density measurements are provided in Table 27. The Re plates were expected to be near theoretical density due to the amount of cold working used to fabricate the plates; therefore the average density of Re plates used to calculate the average Re isotopic composition was assumed to be 21.02 g/cm³ (theoretical density) due to the lack of as-built density measurements at the time the pre-experimental predictions were prepared. Table 28 provides the results of a full spectrum chemical analysis performed by IMR Test Labs for each lot of rhenium material used to fabricate the plates. The chemical impurities in the Re plates are considered to be insignificant, thus, the Re plate material was approximated as pure Re. The average Re plate isotopic composition used in the pre-experimental predictions is provided in Table 29. Refer to Appendix G for the full Re dimension and chemistry reports as provided by the vendors.

Table 25. Specifications for Re Plates

Type	Quantity	OD (in)	ID (in)	Thickness (in)
Solid	22	21.000 ± 0.010	-	0.0150 ± 0.0015
Annular	22	21.000 ± 0.010	2.510 ± 0.010	0.0150 ± 0.0015

Figure 13. Solid Re Plate

Figure 14. Annular Re Plate

Table 26. As-Built Dimensions of Re Plates

Plate Identification Number	Lot Number	OD (in)	ID (in)	Thickness (in)	Inferred Thickness (in)	Mass (g)
Re-01	R-1478/ R-1481	21.000	0.000	0.0164	0.0162	1929.1
Re-02	R-1478	20.999	0.000	0.0167	0.0165	1969.3
Re-03	R-1478	20.999	0.000	0.0170	0.0165	1970.9
Re-04	R-1478	20.999	0.000	0.0165	0.0166	1981.6
Re-05	R-1478	20.995	0.000	0.0166	0.0166	1976.3
Re-06	R-1478	20.998	0.000	0.0165	0.0165	1966.9
Re-07	R-1478	20.999	0.000	0.0167	0.0165	1965.7
Re-08	R-1481	20.997	0.000	0.0171	0.0165	1969.9
Re-09	R-1481	20.998	0.000	0.0170	0.0164	1953.8
Re-10	R-1481	20.997	0.000	0.0169	0.0163	1944.3
Re-11	R-1481	20.998	0.000	0.0167	0.0166	1981.6
Re-12	R-1481	20.999	0.000	0.0165	0.0167	1992.8
Re-13	R-1481	20.997	0.000	0.0161	0.0155	1851.2
Re-14	R-1481	20.999	0.000	0.0161	0.0156	1858.0
Re-15	R-1481	20.997	0.000	0.0167	0.0160	1914.1
Re-16	R-1481	20.996	0.000	0.0163	0.0154	1835.2
Re-17	R-1481	20.996	0.000	0.0167	0.0160	1911.6
Re-18	R-1481	20.999	0.000	0.0162	0.0158	1881.1
Re-19	R-1481	20.994	0.000	0.0166	0.0158	1886.9
Re-20	R-1481	20.999	0.000	0.0162	0.0154	1837.2
Re-21	R-1481	20.998	0.000	0.0172	0.0162	1929.2
Re-22	R-1481	20.998	0.000	0.0163	0.0159	1895.5
Re-23	R-1481	20.997	2.508	0.0163	0.0165	1936.7
Re-24	R-1481	20.999	2.511	0.0167	0.0166	1957.2
Re-25	R-1481	20.998	2.505	0.0165	0.0163	1917.4
Re-26	R-1481	20.998	2.509	0.0164	0.0164	1927.8
Re-27	R-1481	20.997	2.505	0.0166	0.0163	1920.2
Re-28	R-1481	20.997	2.510	0.0165	0.0162	1902.8
Re-29	R-1481	20.997	2.511	0.0163	0.0164	1926.3
Re-30	R-1481	20.997	2.510	0.0161	0.0163	1920.1
Re-31	R-1481	20.996	2.510	0.0167	0.0166	1950.5
Re-32	R-1481	20.995	2.510	0.0167	0.0163	1910.6
Re-33	R-1481	20.995	2.510	0.0168	0.0166	1945.8
Re-34	R-1481	20.998	2.510	0.0165	0.0164	1924.6
Re-35	R-1481	21.004	2.508	0.0157	0.0148	1746.3
Re-36	R-1481	20.997	2.503	0.0167	0.0161	1898.7
Re-37	R-1481	20.999	2.504	0.0163	0.0156	1832.3
Re-38	R-1481	20.995	2.510	0.0170	0.0165	1933.9
Re-39	R-1481	20.996	2.509	0.0164	0.0159	1874.5
Re-40	R-1481	21.000	2.509	0.0166	0.0158	1860.0
Re-41	R-1481	20.996	2.507	0.0168	0.0155	1827.7
Re-42	R-1481	20.998	2.510	0.0164	0.0154	1813.5
Re-43	R-1481	20.994	2.508	0.0170	0.0160	1877.3
Re-44	R-1481	21.001	2.508	0.0172	0.0162	1904.9

Figure 15. Comparison of Measured and Inferred Re Plate Thicknesses

Table 27. Re Remnant Sample Density Measurements

Specimen	Specimen Density (g/cm ³)
Re-1	20.999
Re-2	20.999
Re-3	20.979
Re-4	21.002
Re-5	21.010
Re-6	21.015
Re-7	20.999
Re-8	21.008
Re-9	21.000
Re-10	21.020
Re-11	21.014
Re-12	20.977
Re-13	20.990
Re-14	21.006

Table 28. Full Spectrum Chemical Analysis for Re Plates

Element	Rhenium Lot (ppm by weight)	
	R-1478	R-1481
H	6.6	8.3
Li	< 0.005	< 0.005
Be	< 0.005	< 0.005
B	< 0.005	< 0.005
C	19	6
N	1	2
O	28	41
F	< 0.05	< 0.05
Na	0.36	0.24
Mg	0.03	< 0.01
Al	1.2	1.1
Si	1.7	27
P	0.12	0.21
S	82	0.14
Cl	0.13	0.22
K	0.09	0.09
Ca	0.44	0.09
Sc	< 0.005	< 0.005
Ti	0.11	0.08
V	0.008	0.01
Cr	2.3	4.4
Mn	0.14	0.34
Fe	5.1	11
Co	0.01	0.04
Ni	2.2	3.5
Cu	0.07	0.12
Zn	0.09	< 0.05
Ga	< 0.05	< 0.05
Ge	< 0.05	< 0.05
As	< 0.05	< 0.05
Se	< 0.05	< 0.05
Br	< 0.05	< 0.05
Rb	< 0.01	< 0.01
Y	< 0.005	< 0.005
Zr	0.11	0.05
Nb	0.01	0.01
Mo	0.58	0.65
Ru	< 0.01	< 0.01
Rh	< 0.01	< 0.01
Pd	< 0.01	< 0.01
Ag	< 0.01	< 0.01
Cd	< 0.1	< 0.1
In	< 0.1	< 0.1
Sn	0.07	< 0.01

Element	Rhenium Lot (ppm by weight)	
	R-1478	R-1481
Sb	< 0.01	< 0.01
Te	< 0.01	< 0.01
I	< 0.01	< 0.01
Cs	< 0.5	< 0.5
Ba	< 0.01	0.02
La	< 0.01	< 0.01
Ce	< 0.01	< 0.01
Pr	< 0.01	< 0.01
Nd	< 0.01	< 0.01
Sm	< 0.01	< 0.01
Eu	< 0.01	< 0.01
Gd	< 0.01	< 0.01
Tb	< 0.01	< 0.01
Dy	< 0.01	< 0.01
Ho	< 0.01	< 0.01
Er	< 0.01	< 0.01
Tm	< 0.01	< 0.01
Yb	< 0.01	< 0.01
Lu	< 0.01	< 0.01
Hf	< 0.01	< 0.01
Ta	< 5	< 5
W	< 0.2	< 0.2
Re	Balance	Balance
Os	< 0.01	< 0.01
Ir	< 0.01	< 0.01
Pt	< 0.05	< 0.05
Au	< 0.5	< 0.5
Hg	< 0.05	< 0.05
Tl	< 0.01	< 0.01
Pb	< 0.01	0.01
Bi	< 0.01	< 0.01
Th	< 0.001	< 0.001
U	< 0.001	< 0.001

Table 29. Average Isotopic Composition of the Re Plates

Nuclide	Number Density (atoms/b-cm)
Re-185	2.54249×10^{-2}
Re-187	4.25561×10^{-2}

3.9 Ta-2.5W Plates

The NRPCT furnished to LANL solid and annular Ta-2.5W critical experiment plates. Ta-2.5W was selected as the tantalum alloy to be used in this series of experiments mainly for schedule reasons. A vendor was identified that had a sufficient quantity of Ta-2.5W sheet in inventory and could complete the fabrication of the critical experiment plates before the end of December 2004. This fabrication schedule would support the original January 2005 schedule for performing the Ta critical experiments. The 2.5 weight percent tungsten content in Ta-2.5W was judged to be acceptable for the experiments. Pure Ta was also considered for the experiment but it was found to be more expensive than Ta-2.5W and the vendor was not able to support the desired fabrication schedule. ASTAR-811C and T-111 alloys were also considered. However, it was determined that these alloys were not currently in production, the existing inventory of previously produced material was insufficient to support the critical experiments, and it would not be practical to produce a sufficient quantity of these alloys in time to support the desired critical experiment schedule.

The quantity and dimensional specifications for the Ta-2.5W plates fabricated by Allegheny Teledyne Incorporated – Wah Chang are provided in Table 30. Photographs of a solid and an annular Ta-2.5W plate are provided in Figure 16 and Figure 17. Table 31 and Table 32 provide the as-built dimensions of the solid and annular Ta-2.5W plates based on dimensional characterization measurements performed by Wah Chang. The as-built thickness and mass measurements as performed by LANL for the Ta-2.5W plates are provided in Table 33. The Ta-2.5W plates have been fabricated from two heats of Ta-2.5W material: 11-19-2 and 10-20-2. Some of the plates were selected to be reserved as spares due to fabrication irregularities. The average outer diameter, inner diameter, and thickness for the plates were calculated. The average outer diameter of the Ta-2.5W plates is 21.000" with a standard deviation of 0.002". The average inner diameter of the annular Ta-2.5W plates is 2.512" with a standard deviation of 0.001". The differences between the nominal and measured diameters are judged to be negligible. The thickness measurement for each plate is based on the average of 3 thickness measurements. The average measured thickness of the Ta-2.5W plates is 0.0246" with a standard deviation of 0.0007".

KAPL performed high accuracy density measurements using remnant samples from the Ta-2.5W plates and found the average Ta-2.5W density to be 16.726 g/cm³. The results of these density measurements are provided in Table 34. For the calculation of the average Ta-2.5W plate isotopic composition, the average density of the Ta-2.5W plates was assumed to be 16.7 g/cm³ due to the lack of density measurements at that time.

Table 35 provides specifications for the range of acceptable chemical compositions of Ta-2.5W [19] and the results of the chemical analyses performed by Wah Chang for each heat of Ta-2.5W material used to fabricate the plates. The tungsten percent abundance is the average of four measurements taken from each lot. While the as-built tungsten content for both heats is below the 2 weight percent lower limit in the Ta-2.5W specification, this is considered acceptable since it will result in a slight increase in the tantalum content of the material used in the critical experiments. The average Ta-2.5W plate elemental composition used in the pre-experimental predictions is provided in Table 36. Refer to Appendix H for the full Ta-2.5W dimension and chemistry reports, as provided by the vendors.

Table 30. Specifications for Ta-2.5W Plates

Type	Quantity	OD (in)	ID (in)	Thickness (in)
Solid	42	21.000 ± 0.005	-	0.0250 ± 0.0025
Annular	42	21.000 ± 0.005	2.510 +0.005/-0.000	0.0250 ± 0.0025

Figure 16. Solid Ta-2.5W Critical Experiment Plate

Figure 17. Annular Ta-2.5W Critical Experiment Plate

Table 31. As-Built Dimensions of the Solid Ta-2.5W Plates

Disc Number	Heat Number	Outer Diameter (in)	Inner Diameter (in)	Average Thickness (in)	Minimum Thickness (in)	Maximum Thickness (in)	Reserve as Spare
Ta2W-1	11-19-2	21.0035	0.0000	0.02460	0.02455	0.02550	No
Ta2W-2	11-19-2	21.0005	0.0000	0.02433	0.02430	0.02460	No
Ta2W-3	11-19-2	20.9995	0.0000	0.02343	0.02365	0.02505	No
Ta2W-4	11-19-2	21.0005	0.0000	0.02458	0.02470	0.02555	No
Ta2W-5	11-19-2	21.0035	0.0000	0.02372	0.02385	0.02440	No
Ta2W-6	11-19-2	21.0025	0.0000	0.02390	0.02425	0.02475	No
Ta2W-7	11-19-2	21.0035	0.0000	0.02350	0.02370	0.02400	No
Ta2W-8	11-19-2	20.9970	0.0000	0.02382	0.02360	0.02575	No
Ta2W-9	11-19-2	21.0029	0.0000	0.02468	0.02455	0.02500	No
Ta2W-10	10-20-2	20.9995	0.0000	0.02570	0.02560	0.02605	No
Ta2W-11	10-20-2	21.0025	0.0000	0.02610	0.02610	0.02615	No
Ta2W-12	10-20-2	21.0035	0.0000	0.02590	0.02595	0.02610	No
Ta2W-13	10-20-2	21.0000	0.0000	0.02583	0.02620	0.02675	No
Ta2W-14	10-20-2	20.9995	0.0000	0.02637	0.02630	0.02700	No
Ta2W-15	10-20-2	20.9985	0.0000	0.02573	0.02575	0.02610	No
Ta2W-16	10-20-2	21.0010	0.0000	0.02570	0.02610	0.02730	No
Ta2W-17	11-19-2	21.0045	0.0000	0.02482	0.02450	0.02595	No
Ta2W-18	11-19-2	21.0025	0.0000	0.02467	0.02400	0.02510	No
Ta2W-19	11-19-2	20.9970	0.0000	0.02423	0.02390	0.02590	No
Ta2W-20	11-19-2	21.0020	0.0000	0.02418	0.02400	0.02510	No
Ta2W-21	11-19-2	21.0010	0.0000	0.02457	0.02440	0.02490	No
Ta2W-22	11-19-2	21.0025	0.0000	0.02487	0.02450	0.02510	No
Ta2W-23	11-19-2	21.0025	0.0000	0.02485	0.02460	0.02590	No
Ta2W-24	11-19-2	21.0010	0.0000	0.02457	0.02410	0.02510	No
Ta2W-25	11-19-2	20.9980	0.0000	0.02398	0.02365	0.02400	No
Ta2W-26	11-19-2	21.0000	0.0000	0.02515	0.02510	0.02590	No
Ta2W-27	11-19-2	20.9990	0.0000	0.02505	0.02470	0.02510	No
Ta2W-28	11-19-2	21.0030	0.0000	0.02472	0.02430	0.02585	No
Ta2W-29	11-19-2	21.0005	0.0000	0.02458	0.02410	0.02505	No
Ta2W-30	11-19-2	21.0020	0.0000	0.02462	0.02415	0.02495	No
Ta2W-31	11-19-2	20.9990	0.0000	0.02462	0.02440	0.02490	No
Ta2W-32	11-19-2	21.0020	0.0000	0.02442	0.02430	0.02510	No
Ta2W-33	11-19-2	20.9995	0.0000	0.02483	0.02440	0.02495	No
Ta2W-34	11-19-2	20.9975	0.0000	0.02413	0.02380	0.02485	No
Ta2W-35	11-19-2	20.9980	0.0000	0.02457	0.02405	0.02550	No
Ta2W-36	11-19-2	21.0010	0.0000	0.02510	0.02440	0.02540	No
Ta2W-37	11-19-2	20.9980	0.0000	0.02457	0.02419	0.02500	No
Ta2W-38	11-19-2	21.0010	0.0000	0.02360	0.02330	0.02390	No
Ta2W-39	11-19-2	20.9980	0.0000	0.02347	0.02320	0.02410	No
Ta2W-40	11-19-2	21.0005	0.0000	0.02473	0.02410	0.02495	No
Ta2W-41	10-20-2	20.9990	0.0000	0.02477	0.02410	0.02480	Yes
Ta2W-42	10-20-2	21.0005	0.0000	0.02450	0.02400	0.02480	Yes

Table 32. As-Built Dimensions of the Annular Ta-2.5W Plates

Disc Number	Heat Number	Outer Diameter (in)	Inner Diameter (in)	Average Thickness (in)	Minimum Thickness (in)	Maximum Thickness (in)	Reserve as Spare
Ta2W-1	10-20-2	20.9995	2.5125	0.02360	0.02340	0.02425	No
Ta2W-2	10-20-2	21.0000	2.5120	0.02510	0.02480	0.02520	No
Ta2W-3	10-20-2	20.9970	2.5125	0.02330	0.02390	0.02445	No
Ta2W-4	10-20-2	20.9995	2.5110	0.02343	0.02335	0.02390	No
Ta2W-5	10-20-2	21.0000	2.5115	0.02473	0.02475	0.02490	No
Ta2W-6	10-20-2	21.0020	2.5120	0.02513	0.02485	0.02650	No
Ta2W-7	10-20-2	20.9980	2.5115	0.02475	0.02450	0.02500	No
Ta2W-8	10-20-2	20.9975	2.5120	0.02503	0.02485	0.02550	No
Ta2W-9	10-20-2	20.9980	2.5120	0.02513	0.02510	0.02525	No
Ta2W-10	10-20-2	20.9985	2.5115	0.02497	0.02485	0.02525	No
Ta2W-11	11-19-2	20.9975	2.5120	0.02493	0.02450	0.02510	No
Ta2W-12	11-19-2	20.9995	2.5105	0.02535	0.02470	0.02590	No
Ta2W-13	11-19-2	21.0015	2.5110	0.02530	0.02475	0.02560	No
Ta2W-14	11-19-2	21.0010	2.5120	0.02497	0.02474	0.02510	No
Ta2W-15	11-19-2	21.0000	2.5115	0.02405	0.02305	0.02420	No
Ta2W-16	11-19-2	21.0020	2.5120	0.02467	0.02440	0.02460	No
Ta2W-17	11-19-2	20.9980	2.5110	0.02385	0.02330	0.02430	No
Ta2W-18	11-19-2	20.9995	2.5120	0.02557	0.02495	0.02560	No
Ta2W-19	11-19-2	21.0005	2.5125	0.02502	0.02480	0.02510	No
Ta2W-20	11-19-2	20.9980	2.5120	0.02383	0.02260	0.02395	No
Ta2W-21	11-19-2	20.9985	2.5120	0.02388	0.02380	0.02460	No
Ta2W-22	11-19-2	20.9980	2.5115	0.02397	0.02375	0.02410	No
Ta2W-23	11-19-2	20.9985	2.5130	0.02462	0.02410	0.02460	No
Ta2W-24	11-19-2	21.0000	2.5110	0.02538	0.02415	0.02610	No
Ta2W-25	11-19-2	20.9990	2.5105	0.02462	0.02429	0.02500	No
Ta2W-26	11-19-2	21.0005	2.5115	0.02465	0.02465	0.02470	No
Ta2W-27	11-19-2	21.0005	2.5110	0.02298	0.02335	0.02340	Yes
Ta2W-28	11-19-2	21.0000	2.5110	0.02425	0.02350	0.02460	Yes
Ta2W-29	11-19-2	20.9995	2.5105	0.02472	0.02410	0.02465	No
Ta2W-30	11-19-2	20.9970	2.5120	0.02312	0.02290	0.02390	Yes
Ta2W-31	11-19-2	21.0000	2.5105	0.02407	0.02410	0.02440	No
Ta2W-32	11-19-2	21.0005	2.5115	0.02383	0.02385	0.02410	Yes
Ta2W-33	11-19-2	20.9995	2.5120	0.02367	0.02355	0.02400	Yes
Ta2W-34	11-19-2	20.9985	2.5115	0.02375	0.02345	0.02405	No
Ta2W-35	11-19-2	21.0000	2.5120	0.02402	0.02385	0.02415	Yes
Ta2W-36	11-19-2	20.9925	2.5110	0.02292	0.02285	0.02380	Yes
Ta2W-37	11-19-2	21.0005	2.5115	0.02400	0.02380	0.02460	Yes
Ta2W-38	11-19-2	20.9995	2.5110	0.02402	0.02395	0.02465	Yes
Ta2W-39	11-19-2	21.0000	2.5115	0.02323	0.02240	0.02425	Yes
Ta2W-40	11-19-2	20.9995	2.5120	0.02415	0.02400	0.02440	No
Ta2W-41	11-19-2	21.0005	2.5105	0.02490	0.02450	0.02500	Yes
Ta2W-42	11-19-2	20.9990	2.5145	0.02307	0.02295	0.02350	No

Table 33. As-built Thickness and Mass Measurements of the Ta-2.5W Plates, Performed by LANL

Plate Identification Number	Type	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)				Mass (g)
				T1	T2	T3	Average	
TA2W-01	Hole	21.00	2.51	0.02410	0.02390	0.02370	0.0239	2216.9
TA2W-02	Hole	21.00	2.51	0.02555	0.02575	0.02525	0.0255	2366.6
TA2W-03	Hole	21.00	2.51	0.02370	0.02330	0.02345	0.0235	2181.1
TA2W-04	Hole	21.00	2.51	0.02510	0.02405	0.02380	0.0243	2229.1
TA2W-05	Hole	21.00	2.51	0.02530	0.02525	0.02465	0.0251	2326.4
TA2W-06	Hole	21.00	2.51	0.02610	0.02575	0.02490	0.0256	2357.4
TA2W-07	Hole	21.00	2.51	0.02490	0.02500	0.02505	0.0250	2321.1
TA2W-08	Hole	21.00	2.51	0.02475	0.02495	0.02560	0.0251	2340.6
TA2W-09	Hole	21.00	2.51	0.02535	0.02540	0.02570	0.0255	2369.4
TA2W-10	Hole	21.00	2.51	0.02535	0.02560	0.02500	0.0253	2362.7
TA2W-11	Hole	21.00	2.51	0.02550	0.02540	0.02515	0.0254	2340.5
TA2W-12	Hole	21.00	2.51	0.02590	0.02505	0.02550	0.0255	2372.1
TA2W-13	Hole	21.00	2.51	0.02580	0.02550	0.02540	0.0256	2366.3
TA2W-14	Hole	21.00	2.51	0.02560	0.02505	0.02525	0.0253	2348.2
TA2W-15	Hole	21.00	2.51	0.02375	0.02430	0.02480	0.0243	2252.8
TA2W-16	Hole	21.00	2.51	0.02500	0.02525	0.02495	0.0251	2331.2
TA2W-17	Hole	21.00	2.51	0.02505	0.02380	0.02505	0.0246	2287.3
TA2W-18	Hole	21.00	2.51	0.02540	0.02545	0.02565	0.0255	2383.0
TA2W-19	Hole	21.00	2.51	0.02545	0.02520	0.02550	0.0254	2361.8
TA2W-20	Hole	21.00	2.51	0.02410	0.02395	0.02380	0.0240	2213.9
TA2W-21	Hole	21.00	2.51	0.02510	0.02480	0.02410	0.0247	2269.5
TA2W-22	Hole	21.00	2.51	0.02475	0.02450	0.02390	0.0244	2257.6
TA2W-23	Hole	21.00	2.51	0.02455	0.02470	0.02530	0.0249	2295.8
TA2W-24	Hole	21.00	2.51	0.02560	0.02475	0.02615	0.0255	2338.7
TA2W-25	Hole	21.00	2.51	0.02475	0.02480	0.02490	0.0248	2305.2
TA2W-26	Hole	21.00	2.51	0.02470	0.02505	0.02490	0.0249	2328.2
TA2W-27	Hole	21.00	2.51	0.02295	0.02330	0.02325	0.0232	2161.3
TA2W-28	Hole	21.00	2.51	0.02390	0.02480	0.02450	0.0244	2261.0
TA2W-29	Hole	21.00	2.51	0.02490	0.02495	0.02475	0.0249	2308.9
TA2W-30	Hole	21.00	2.51	0.02490	0.02380	0.02280	0.0238	2172.9
TA2W-31	Hole	21.00	2.51	0.02465	0.02420	0.02470	0.0245	2252.5
TA2W-32	Hole	21.00	2.51	0.02430	0.02415	0.02445	0.0243	2275.1
TA2W-33	Hole	21.00	2.51	0.02590	0.02400	0.02480	0.0249	2245.4
TA2W-34	Hole	21.00	2.51	0.02505	0.02460	0.02405	0.0246	2241.7
TA2W-35	Hole	21.00	2.51	0.02500	0.02465	0.02480	0.0248	2277.5
TA2W-36	Hole	21.00	2.51	0.02365	0.02335	0.02375	0.0236	2177.6
TA2W-37	Hole	21.00	2.51	0.02485	0.02510	0.02605	0.0253	2301.0
TA2W-38	Hole	21.00	2.51	0.02490	0.02495	0.02485	0.0249	2270.5
TA2W-39	Hole	21.00	2.51	0.02420	0.02280	0.02415	0.0237	2209.5
TA2W-40	Hole	21.00	2.51	0.02435	0.02450	0.02435	0.0244	2286.9
TA2W-41	Hole	21.00	2.51	0.02510	0.02500	0.02510	0.0251	2343.6
TA2W-42	Hole	21.00	2.51	0.02340	0.02330	0.02355	0.0234	2173.4
TA2W-01	Solid	21.00	0.00	0.02460	0.02540	0.02545	0.0252	2367.5
TA2W-02	Solid	21.00	0.00	0.02460	0.02495	0.02470	0.0248	2325.1
TA2W-03	Solid	21.00	0.00	0.02385	0.02455	0.02405	0.0242	2266.6

Plate Identification Number	Type	Outer Diameter (in)	Inner Diameter (in)	Thickness (in)				Mass (g)
				T1	T2	T3	Average	
TA2W-04	Solid	21.00	0.00	0.02505	0.02485	0.02475	0.0249	2341.3
TA2W-05	Solid	21.00	0.00	0.02420	0.02465	0.02430	0.0244	2291.9
TA2W-06	Solid	21.00	0.00	0.02485	0.02430	0.02500	0.0247	2318.0
TA2W-07	Solid	21.00	0.00	0.02415	0.02375	0.02395	0.0240	2258.0
TA2W-08	Solid	21.00	0.00	0.02480	0.02395	0.02375	0.0242	2289.6
TA2W-09	Solid	21.00	0.00	0.02545	0.02445	0.02415	0.0247	2359.4
TA2W-10	Solid	21.00	0.00	0.02650	0.02610	0.02630	0.0263	2457.0
TA2W-11	Solid	21.00	0.00	0.02700	0.02705	0.02675	0.0269	2554.9
TA2W-12	Solid	21.00	0.00	0.02785	0.02710	0.02695	0.0273	2507.5
TA2W-13	Solid	21.00	0.00	0.02675	0.02635	0.02715	0.0268	2500.9
TA2W-14	Solid	21.00	0.00	0.02670	0.02745	0.02700	0.0271	2540.5
TA2W-15	Solid	21.00	0.00	0.02685	0.02635	0.02715	0.0268	2482.8
TA2W-16	Solid	21.00	0.00	0.02655	0.02670	0.02625	0.0265	2509.0
TA2W-17	Solid	21.00	0.00	0.02495	0.02480	0.02595	0.0252	2385.0
TA2W-18	Solid	21.00	0.00	0.02445	0.02475	0.02460	0.0246	2337.2
TA2W-19	Solid	21.00	0.00	0.02595	0.02615	0.02595	0.0260	2397.4
TA2W-20	Solid	21.00	0.00	0.02495	0.02500	0.02465	0.0249	2346.4
TA2W-21	Solid	21.00	0.00	0.02525	0.02475	0.02455	0.0249	2329.1
TA2W-22	Solid	21.00	0.00	0.02540	0.02445	0.02470	0.0249	2351.2
TA2W-23	Solid	21.00	0.00	0.02495	0.02590	0.02575	0.0255	2415.6
TA2W-24	Solid	21.00	0.00	0.02575	0.02560	0.02505	0.0255	2409.5
TA2W-25	Solid	21.00	0.00	0.02490	0.02390	0.02410	0.0243	2274.8
TA2W-26	Solid	21.00	0.00	0.02575	0.02535	0.02625	0.0258	2432.1
TA2W-27	Solid	21.00	0.00	0.02485	0.02415	0.02485	0.0246	2357.3
TA2W-28	Solid	21.00	0.00	0.02560	0.02555	0.02445	0.0252	2371.1
TA2W-29	Solid	21.00	0.00	0.02505	0.02520	0.02415	0.0248	2317.6
TA2W-30	Solid	21.00	0.00	0.02515	0.02490	0.02560	0.0252	2388.5
TA2W-31	Solid	21.00	0.00	0.02460	0.02505	0.02525	0.0250	2341.0
TA2W-32	Solid	21.00	0.00	0.02555	0.02555	0.02485	0.0253	2393.2
TA2W-33	Solid	21.00	0.00	0.02565	0.02530	0.02485	0.0253	2362.2
TA2W-34	Solid	21.00	0.00	0.02425	0.02455	0.02420	0.0243	2297.5
TA2W-35	Solid	21.00	0.00	0.02500	0.02590	0.02465	0.0252	2325.0
TA2W-36	Solid	21.00	0.00	0.02495	0.02485	0.02515	0.0250	2380.9
TA2W-37	Solid	21.00	0.00	0.02505	0.02510	0.02500	0.0251	2348.1
TA2W-38	Solid	21.00	0.00	0.02415	0.02375	0.02435	0.0241	2256.8
TA2W-39	Solid	21.00	0.00	0.02355	0.02405	0.02355	0.0237	2236.4
TA2W-40	Solid	21.00	0.00	0.02565	0.02570	0.02470	0.0254	2353.6
TA2W-41	Solid	21.00	0.00	0.02520	0.02490	0.02495	0.0250	2360.1
TA2W-42	Solid	21.00	0.00	0.02480	0.02515	0.02500	0.0250	2388.7

Table 34. Ta-2.5W Remnant Sample Density Measurements

Specimen	Specimen Density (g/cm ³)
Ta 11-19-2 #1	16.715
Ta 11-19-2 #2	16.722
Ta 11-19-2 #3	16.724
Ta 11-19-2 #4	16.718
Ta 10-20-2 #1	16.726
Ta 10-20-2 #2	16.727
Ta 10-20-2 #3	16.740
Ta 10-20-2 #4	16.724
Ta 10-20-2 #5	16.731
Ta 10-20-2 #6	16.728
Ta 10-20-2 #7	16.734
Ta-11-19-2 #7	16.736
Ta-11-19-2 #5	16.718
Ta-11-19-2 #6	16.724

Table 35. Chemical Analyses for the Ta-2.5W Plates

Element	Ta-2.5W (wt. %)			
	Specification	Heat 11-19-2002	Heat 10-10-2002	Average
Ta	balance	balance	balance	98.061
W	2.0 – 3.5	1.825	1.975	1.900
C	max 0.010	0.003	0.003	0.003
Fe	max 0.010	<0.0050	<0.0050	0.0025
H	max 0.0015	<0.0003	<0.0003	0.00015
Mo	max 0.020	<0.0050	<0.0050	0.0025
N	max 0.010	<0.0020	<0.0020	0.0010
Nb	max 0.50	0.02	0.02	0.02
Ni	max 0.010	<0.0050	<0.0050	0.0025
O	max 0.015	<0.0050	<0.0050	0.0025
Si	max 0.005	<0.0050	<0.0050	0.0025
Ti	max 0.010	<0.0050	<0.0050	0.0025

Table 36. Average Elemental Composition of the Ta-2.5W Plates

Element	Number Density (atoms/b-cm)
Ta	5.45016E-02
W	1.03940E-03
C	2.51200E-05
Fe	4.50218E-06
H	1.49666E-05
Mo	2.62064E-06
N	7.18012E-06
Nb	2.16497E-05
Ni	4.28369E-06
O	1.57146E-05
Si	8.95211E-06
Ti	5.25256E-06

4. NRPCT Pre-Experimental Predictions

This section provides the pre-experimental predictions and supporting analysis for the Prometheus critical experiments. Three experiments have been designed to bracket the neutron energy spectra expected in Prometheus reactor designs under normal operating conditions and one experiment has been designed to simulate an accident condition in which the core is flooded with water. Experiment 1 is designed to approximate the neutron energy spectrum in the center of the core. Experiments 2 and 3 are designed to bracket the core average neutron energy spectrum. Experiment 4 is designed to simulate the average neutron energy spectrum when the core is flooded with water.

Three computer-generated 3-D images of the critical experiment, consisting of one overview and two close-up views, are presented in Figure 18, Figure 19, and Figure 20. These figures show representative pictures of what the critical experiments analyzed in this report would look like. The aluminum support structure is shown in yellow-green, the graphite/polyethylene moderator is shown in blue, the HEU is shown in red, the refractory metal test plates are shown in green, and the stainless steel diaphragm is shown in purple. The upper aluminum support structure has been removed from Figure 20 in order to illustrate the presence of the stainless steel diaphragm. The model in the images is the Ta-2.5W-4 experiment, and was modeled in RACER with 16 stacking units and a polyethylene top reflector thickness of 1.04". The images were generated by a utility that enables 3-D visualizations.

Several simplifying assumptions were made in the pre-experimental predictions. Based on the analysis of similar critical experiments, these simplifying assumptions are expected to have a worth similar to the experimental uncertainty. These assumptions include:

- The use of average plate thicknesses, masses, and number densities since the detailed as-built configuration of each experiment cannot be known until the experiment is conducted.
- The use of nominal graphite dimensions and isotopic compositions since detailed as-built information was not available at the time of the analysis.
- The use of nominal dimensions and average polyethylene number densities from similar experiments since detailed as-built information was not available at the time of the analysis.
- The collar plate (Figure 8) was approximated as an annular ring with an inner diameter of 21.4684" to preserve the collar plate volume and mass.
- A 0.040" thick stainless steel diaphragm was assumed in the baseline, Mo, Re, and Ta-2.5W experiments (the same diaphragm used in the Nb-1Zr with Polyethylene experiment [2]) since LANL had not determined the diaphragm thickness to be used in the baseline, Mo, Re, and Ta-2.5W experiments at the time of analysis (see Appendix E).
- A 0.075" thick stainless steel diaphragm was assumed in the Nb-1Zr experiments since the as-built dimensions of the diaphragm to be used in the critical experiments had not been provided by LANL at the time of the analysis, but a 0.075" thick stainless steel diaphragm had been in the qualification process.
- The Nb-1Zr assembly was split around the diaphragm to allow the mass of the top core to fall within the diaphragm mass limit of 150 kg as set by LANL.
- The baseline, Mo, Re, and Ta-2.5W assemblies were split approximately half above and half below the diaphragm since LANL had not determined the diaphragm weight limit at the time of the analysis.
- The alignment tube was assumed to extend from the bottom of the spindle plate to the bottom of the last stacking unit with a 2.51" ID since LANL had not specified the actual length of the alignment tubes to be used in the experiments.
- The presence of the neutron source was neglected.

- A target delayed critical k_{eff} between 1.0000 and 1.0020 was assumed in the RCP01 and MCNP5 analyses to determine the top reflector thickness.

RCP01 [9], MCNP5 [10], MCNP5 with space cross sections (Appendix C), and RACER [11] analyses were performed to provide additional confidence in these pre-experimental predictions through the use of multiple independent computer codes. No attempt is made within this document to provide a complete and detailed understanding of the reasons for the differences in predictions between the different computer codes, as this would have been addressed in future work. These differences may be attributed to three broad categories: modeling differences, cross section data differences, and methods differences. A general summary of the known differences between the independent analyses and the expected impact of these differences is provided below. It should also be noted that an accurate set of critical experiment measurements would have been useful in resolving these differences in predicted eigenvalues.

- The RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses were performed using equivalent geometry and material models. The only differences are related to the representation of air inside and surrounding the assemblies. The RCP01 models include an enclosing cylinder of dilute Helium with a number density of 1×10^{-20} atoms/barn-cm and the RACER models included an enclosing sphere of Helium with a number density of 1×10^{-14} atoms/barn-cm, to represent air inside and surrounding the assemblies. The MCNP5 models represent air as void. Studies done to investigate the impact of this approximation on eigenvalue calculations found the influence to be negligible.
- There are differences in the cross section data used in the RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses. The origin of the cross section data used in each independent series of analyses is summarized in Table 37. The MCNP5 analyses used ENDF/B-VI.8 cross sections. The RCP01 analyses used a preliminary version of the SPACE05A cross section set. The RCP01 and MCNP5 analyses were performed by Bettis before the final SPACE05A cross section library was available. The MCNP5 with space cross sections and RACER analyses were performed by KAPL several months after the Bettis analyses and used the SPACE05A cross section set. The SPACE05A cross section set (Appendix C) was specified by the Bettis/KAPL nuclear data communities for use in space reactor nuclear analyses and used the best neutron cross section evaluations that were available at the time. The use of different cross section data is expected to have a first order effect on the predicted eigenvalues.
- The RCP01 and MCNP5 analyses used some elemental cross section evaluations while the MCNP5 with space cross sections and RACER analyses used isotopic evaluations. In the MCNP5 analyses elemental evaluations were used when a complete set of isotopic cross section evaluations were not available. In the RCP01 analyses the elemental evaluations were used for minor alloy constituents or impurities that were not expected to have a significant neutronic impact or when a complete set of isotopic evaluations were not available. The use of selected elemental cross section instead of isotopic cross section evaluations is expected to have a second order effect on the predicted eigenvalues.
- Different unresolved resonance treatments were used by the codes systems. In the RCP01 analyses the capture, fission and elastic scattering cross sections in the unresolved resonance energy range are constructed by sampling from the Porter-Thomas distributions used to represent the unresolved resonance data sets in the cross section evaluations. The MCNP5 and RACER analyses use a probability table treatment for the unresolved resonance data. A summary of the unresolved resonance treatment ranges for the SPACE05A and the ENDF/B-VI.8 cross sections used in the MCNP5 analyses are provided in Table 38 and Table 39. These same values apply to the unresolved resonance treatment ranges used in RACER. Differences in the methods and data used to represent unresolved resonances are expected to have a first order effect on the predicted eigenvalues.

- RCP01 and RACER used a fixed energy mesh for all nuclides to represent the continuous energy cross section while MCNP5 uses a different energy mesh for each nuclide. This methods difference is expected to have a second order effect on the predicted eigenvalues.
- Both RCP01 and RACER approximate inelastic scattering using a multigroup averaged inelastic scattering cross section and energy transfer matrix truncated at 5.53 keV. (n,2n) and other high energy neutron producing reactions are added to the multigroup inelastic scattering cross section and the energy transfer matrix is adjusted to account for neutron multiplicity. MCNP5 makes not additional approximations in the treatment of inelastic scattering and other high energy neutron producing reactions. This methods difference is expected to have a second order effect on predicted eigenvalues.
- RCP01, RACER, and MCNP5 all model bound-atom thermal neutron scattering effects for graphite and polyethylene. RCP01 uses a multigroup P_3 thermal scattering kernel generated from the $S(\alpha,\beta,T)$ thermal scattering law data, while MCNP5 and RACER use a direct $S(\alpha,\beta,T)$ treatment for thermal neutron scattering. This methods difference is expected to have a second order effect on the predicted eigenvalues.
- Finally, the independent analyses each used different running strategies; however these differences are expected to have a negligible effect on predicted eigenvalues. RCP01 calculations were performed using 100 inactive iterations with 500 neutron histories per iteration followed by a 1.25 ramp-up rate, 600 active iterations with 10,000 neutron histories per iteration for a total of six million active histories. Survey calculations were performed using a single random number skip and calculations for the approach to critical were performed by statistically combining the results from 20 independent RCP01 calculations (equivalent to 120,000,000 active histories). MCNP5 calculations were performed using 100 inactive iterations with 5000 neutron histories per iteration and 1150 active iterations with 5000 neutron histories per iteration for a total of 5,750,000 active histories. MCNP5 with space cross sections calculations were performed using 175 inactive iterations with 20,000 neutron histories per iteration and 1425 active iterations with 20,000 neutron histories per iteration for a total of 28,500,000 active histories. RACER calculations were performed using 80 inactive iterations with 100,000 neutron histories per iteration and 520 active iterations with 100,000 neutron histories per iteration for a total of 52,000,000 active histories.

Figure 18. Overview of the Critical Experiment Configuration

Figure 19. Close-up View of the Critical Experiment Configuration

Figure 20. Close-up View of the Critical Experiment Configuration, without the Upper Aluminum Support Structure

Table 37. Cross Section Data Sources

Nuclides/Elements	Cross Section Evaluation Used			
	RCP01	MCNP5	MCNP5 (SPACE05A)	RACER
Al-27	ENDF/B-VI.4	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
C-nat	ENDF/B-VI.1	ENDF/B-VI.6	ENDF/B-VI.6	ENDF/B-VI.6
Cr-nat	ENDF/B-VI.5	-	-	-
Cr-50	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Cr-52	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Cr-53	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Cr-54	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Cu-nat	ENDF/B-VI.2	-	-	-
Cu-63	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Cu-65	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Fe-nat	ENDF/B-VI.5 [*]	-	-	-
Fe-54	ENDF/B-VI.5	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Fe-56	ENDF/B-VI.1	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Fe-57	ENDF/B-VI.1	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Fe-58	ENDF/B-VI.5	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
H-1	ENDF/B-VI.5	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Hf-nat	ENDF/B-VI.2	-	-	-
Hf-174	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Hf-176	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Hf-177	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Hf-178	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Hf-179	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Hf-180	-	ENDF/B-VI.2	ENDF/B-VI.2	ENDF/B-VI.2
Mg-nat	ENDF/B-VI.0	ENDF/B-VI.8	-	-
Mg-24	-	-	JENDL-3.2	JENDL-3.2
Mg-25	-	-	JENDL-3.2	JENDL-3.2
Mg-26	-	-	JENDL-3.2	JENDL-3.2
Mn-55	ENDF/B-VI.5	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Mo-nat	ENDF/B-VI.0 [†]	ENDF/B-VI.0	-	-
Mo-92	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-94	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-95	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-96	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-97	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-98	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
Mo-100	JENDL-3.1	-	JENDL-3.2	JENDL-3.2
N-nat	ENDF/B-VI.3	-	-	-
N-14	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
N-15	-	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
Nb-93	ENDF/B-VI.1	ENDF/B-VI.6	ENDF/B-VI.6	ENDF/B-VI.6
Ni-nat	ENDF/B-VI.5	-	-	-
Ni-58	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8

^{*} Fe-nat used for Fe impurity in Nb-1Zr and Fe alloy constituent in Al-6061 and SS-301 compositions.

[†] Mo-nat used for Mo impurity in Ta-2.5W compositions, isotopic cross section used for all other materials.

Nuclides/Elements	Cross Section Evaluation Used			
	RCP01	MCNP5	MCNP5 (SPACE05A)	RACER
Ni-60	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Ni-61	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Ni-62	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Ni-64	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
O-nat	ENDF/B-VI.8	-	-	-
O-16	-	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
O-17	-	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
P-31	ENDF/B-VI.0	ENDF/B-VI.6	ENDF/B-VI.6	ENDF/B-VI.6
Re-185	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
Re-187	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
S-nat	ENDF/B-VI.0	ENDF/B-VI.8	-	-
S-32	-	-	JENDL-3.2	JENDL-3.2
S-33	-	-	JENDL-3.2	JENDL-3.2
S-34	-	-	JENDL-3.2	JENDL-3.2
S-36	-	-	JENDL-3.2	JENDL-3.2
Si-nat	ENDF/B-VI.5	ENDF/B-VI.0	-	-
Si-28	-	-	ENDF/B-VI.5	ENDF/B-VI.5
Si-29	-	-	ENDF/B-VI.5	ENDF/B-VI.5
Si-30	-	-	ENDF/B-VI.5	ENDF/B-VI.5
Ta-181	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
Ti-nat	ENDF/B-VI.0	ENDF/B-VI.8	-	-
Ti-46	-	-	JENDL-3.2	JENDL-3.2
Ti-47	-	-	JENDL-3.2	JENDL-3.2
Ti-48	-	-	JENDL-3.2	JENDL-3.2
Ti-49	-	-	JENDL-3.2	JENDL-3.2
Ti-50	-	-	JENDL-3.2	JENDL-3.2
U-234	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
U-235	ENDF/B-VI.5	ENDF/B-VI.5	ENDF/B-VI.5	ENDF/B-VI.5
U-236	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0	ENDF/B-VI.0
U-238	ENDF/B-VI.5	ENDF/B-VI.5	ENDF/B-VI.5	ENDF/B-VI.5
W-nat	ENDF/B-VI.1 [‡]	-	-	-
W-182	ENDF/B-VI.0	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
W-183	ENDF/B-VI.0	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
W-184	ENDF/B-VI.0	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
W-186	ENDF/B-VI.0	ENDF/B-VI.8	ENDF/B-VI.8	ENDF/B-VI.8
Zr-nat	ENDF/B-VI.1	ENDF/B-VI.1	ENDF/B-VI.1	ENDF/B-VI.1

[‡] W-nat used for W impurity in Nb-1Zr composition, isotopic cross sections used for all other materials.

Table 38. MCNP5 with Space Cross Sections Unresolved Resonance Region Treatment

SPACE05A MCNP5 XS		
Isotope	URR start (eV)	URR end (eV)
Mo-92	5.00E+04	1.00E+05
Mo-94	2.00E+04	1.00E+05
Mo-95	2.00E+03	1.00E+05
Mo-96	1.90E+04	1.00E+05
Mo-97	1.80E+03	1.00E+05
Mo-98	3.20E+04	1.00E+05
Mo-100	2.60E+04	1.00E+05
Ta-181	3.30E+02	5.00E+03
W-182	4.50E+03	1.00E+05
W-183	7.65E+02	4.50E+04
W-184	2.65E+03	1.00E+05
W-186	3.20E+03	1.00E+05
U-234	1.50E+03	1.00E+05
U-235	2.25E+03	2.50E+04
U-236	1.50E+03	1.00E+05
U-238	1.00E+04	1.49E+05
Re-185	2.00E+03	3.50E+04
Re-187	2.00E+03	3.50E+04
Hf-174	2.30E+02	9.00E+04
Hf-176	1.08E+03	9.00E+04
Hf-177	7.00E+02	9.00E+04
Hf-178	2.10E+03	9.00E+04
Hf-179	4.50E+02	9.00E+04
Hf-180	1.00E+04	9.00E+04

Table 39. MCNP5 ENDF/B-VI.8 Cross Sections Unresolved Resonance Region Treatment

ENDF/B-VI.8 MCNP5 XS		
Isotope	URR start (eV)	URR end (eV)
W-182	4.50E+03	1.00E+05
W-183	7.65E+02	4.50E+04
W-184	2.65E+03	1.00E+05
W-186	3.20E+03	1.00E+05
U-234	1.50E+03	1.00E+05
U-235	2.25E+03	2.50E+04
U-236	1.50E+03	1.00E+05
U-238	1.00E+04	1.49E+05
Re-185	2.00E+03	3.50E+04
Re-187	2.00E+03	3.50E+04
Hf-174	2.30E+02	9.00E+04
Hf-176	1.08E+03	9.00E+04
Hf-177	7.00E+02	9.00E+04
Hf-178	2.10E+03	9.00E+04
Hf-179	4.50E+02	9.00E+04
Hf-180	1.00E+04	9.00E+04

4.1 Baseline Critical Experiments

4.1.1 Base-1 Experiment

The Base-1 experiment is designed to simulate the hardest neutron spectrum, which is in the center of the Prometheus reactor core during normal operating conditions. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 21 and Figure 22 where aluminum is yellow, graphite is blue, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The Base-1 assembly configuration, including plate layout and dimensions, is shown in Table 40. RCP01, MCNP5, MCNP5 with space cross sections, and RACER all predict an assembly height of 5.946". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 3.646" high and contains 16 stacking units consisting of a single 0.118" thick HEU plate and a 0.100" thick graphite plate and 1 stacking unit consisting of a 0.118" thick HEU plate, for a total of 17 stacking units. The assembly is reflected by a 1.0" thick graphite bottom reflector and a 1.30" thick graphite top reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Base-1 assembly has a total mass of 246.2 kg including 208.0 kg of HEU and 38.1 kg of graphite. The distribution of material in the top and bottom half of the assembly is given in Table 41.

A series of analyses have been performed to predict the k_{eff} of the Base-1 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 23 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Base-1 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 23, both the MCNP5 and RCP01 predictions are very close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0007 \pm 0.0004 \Delta k$ over the range from 8 to 28 stacking units. Figure 24 and Table 42 provide a comparison of the predicted k_{eff} of the Base-1 assembly with 17 and 18 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within Technical Safety Requirements (TSR) limits ($\rho < 0.5\%$) are highlighted in green in Table 42. The Base-1 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 87.0% fast ($E > 100 \text{ keV}$), 13.0% intermediate ($0.625 \text{ eV} < E < 100 \text{ keV}$), and 0.0% thermal ($E < 0.625 \text{ eV}$). It should be noted for all TA-18 pre-experimental predictions that there are slight differences in fission fractions between the different computer codes, but the differences are minimal and can be neglected for the purposes of classifying the experiment.

Figure 21. Cross-sectional View of the Base-1 Assembly

Figure 22. Cross-sectional Close-up View of the Base-1 Assembly

Table 40. Predicted Critical Configuration for the Base-1 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	1.00	2.51	21.0	1.000
1	HEU	0.118	2.51	21.0	1.118
	Graphite	0.100	2.51	21.0	1.218
2	HEU	0.118	2.51	21.0	1.336
	Graphite	0.100	2.51	21.0	1.436
3	HEU	0.118	2.51	21.0	1.554
	Graphite	0.100	2.51	21.0	1.654
4	HEU	0.118	2.51	21.0	1.772
	Graphite	0.100	2.51	21.0	1.872
5	HEU	0.118	2.51	21.0	1.990
	Graphite	0.100	2.51	21.0	2.090
6	HEU	0.118	2.51	21.0	2.208
	Graphite	0.100	2.51	21.0	2.308
7	HEU	0.118	2.51	21.0	2.426
	Graphite	0.100	2.51	21.0	2.526
8	HEU	0.118	0	21.0	2.644
	Graphite	0.100	0	21.0	2.744
9	HEU	0.118	0	21.0	2.862
	Graphite	0.100	0	21.0	2.962
Diaphragm	Stainless Steel	0.040	0	24.8	3.002
10	HEU	0.118	0	21.0	3.120
	Graphite	0.100	0	21.0	3.220
11	HEU	0.118	0	21.0	3.338
	Graphite	0.100	0	21.0	3.438
12	HEU	0.118	0	21.0	3.556
	Graphite	0.100	0	21.0	3.656
13	HEU	0.118	0	21.0	3.774
	Graphite	0.100	0	21.0	3.874
14	HEU	0.118	6.005	21.0	3.992
	Graphite	0.100	0	21.0	4.092
15	HEU	0.118	6.005	21.0	4.210
	Graphite	0.100	0	21.0	4.310
16	HEU	0.118	6.005	21.0	4.428
	Graphite	0.100	0	21.0	4.528
17	HEU	0.118	6.005	21.0	4.646
Top Reflector	Graphite	1.30	0	21.0	5.946

Table 41. Base-1 Assembly Material Mass Distribution

Material	Mass (kg)		
	Lower Assembly	Upper Assembly	Total
HEU	111.7	96.3	208.0
Graphite	18.4	19.7	38.1
Total	130.2	116.0	246.2

Figure 23. Base-1 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 24. Base-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 42. Base-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
17 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.00	0.98370	0.00055	-	-	0.98355	0.00015	-	-
1.10	0.99019	0.00055	-	-	0.98961	0.00013	-	-
1.15	0.99313	0.00055	-	-	0.99251	0.00038	-	-
1.20	0.99540	0.00055	0.99606	0.00026	0.99532	0.00012	0.99767	0.00021
1.25	0.99917	0.00055	0.99904	0.00026	0.99790	0.00018	1.00030	0.00019
1.30	1.00142	0.00053	1.00191	0.00024	1.00061	0.00015	1.00314	0.00021
1.35	1.00446	0.00057	-	-	1.00331	0.00018	-	-
18 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.70	0.99110	0.00055	Not investigated due to termination of project.		0.99036	0.00013	Not investigated due to termination of project.	
0.75	0.99440	0.00057			0.99367	0.00012		
0.80	0.99771	0.00053			0.99704	0.00016		
0.85	1.00069	0.00055			1.00019	0.00013		
0.90	1.00428	0.00055			1.00340	0.00020		
0.95	1.00722	0.00059			1.00652	0.00014		
1.00	1.01046	0.00057			1.00947	0.00012		

4.1.2 Base-2 Experiment

The Base-2 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be harder than the expected average neutron energy spectrum of the core but softer than the Base-1 experiment. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 25 and Figure 26 where aluminum is yellow, graphite is blue, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 43. The RCP01 analysis predicts an assembly height of 8.968" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 8.868". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 4.568" high and contains 14 stacking units consisting of a 0.118" thick HEU plate and a 0.197" thick graphite plate and 1 stacking unit consisting of a single 0.118" thick HEU plate, for a total of 15 stacking units. The bottom reflector consists of a 2.0" thick graphite reflector. The RCP01 predicted top reflector consists of a 2.40" thick graphite reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 2.30" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Base-2 assembly contains 185.0 kg of HEU. The distribution of materials in the top and bottom half of the assembly is given in Table 44 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Base-2 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 27 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Base-2 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 27, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0025 \pm 0.0005 \Delta k$ over the range from 8 to 28 stacking units. Figure 28 and Table 45 provide a comparison of the predicted k_{eff} of the Base-2 assembly with 15 and 16 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 45. The Base-2 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 79.3% fast ($E > 100$ keV), 20.7% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 25. Cross-sectional View of the Base-2 Assembly

Figure 26. Cross-sectional Close-up View of the Base-2 Assembly

Table 43. Predicted Critical Configuration for the Base-2 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	2.00	2.51	21.0	2.000
1	HEU	0.118	2.51	21.0	2.118
	Graphite	0.197	2.51	21.0	2.315
2	HEU	0.118	2.51	21.0	2.433
	Graphite	0.197	2.51	21.0	2.630
3	HEU	0.118	2.51	21.0	2.748
	Graphite	0.197	2.51	21.0	2.945
4	HEU	0.118	2.51	21.0	3.063
	Graphite	0.197	2.51	21.0	3.260
5	HEU	0.118	2.51	21.0	3.378
	Graphite	0.197	2.51	21.0	3.575
6	HEU	0.118	2.51	21.0	3.693
	Graphite	0.197	2.51	21.0	3.890
7	HEU	0.118	2.51	21.0	4.008
	Graphite	0.197	2.51	21.0	4.205
8	HEU	0.118	0	21.0	4.323
	Graphite	0.197	0	21.0	4.520
Diaphragm	Stainless Steel	0.040	0	24.8	4.560
9	HEU	0.118	0	21.0	4.678
	Graphite	0.197	0	21.0	4.875
10	HEU	0.118	0	21.0	4.993
	Graphite	0.197	0	21.0	5.190
11	HEU	0.118	0	21.0	5.308
	Graphite	0.197	0	21.0	5.505
12	HEU	0.118	0	21.0	5.623
	Graphite	0.197	0	21.0	5.820
13	HEU	0.118	0	21.0	5.938
	Graphite	0.197	0	21.0	6.135
14	HEU	0.118	6.005	21.0	6.253
	Graphite	0.197	0	21.0	6.450
15	HEU	0.118	6.005	21.0	6.568
Top Reflector	Graphite	2.40 (RCP01) 2.30 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	8.968 (RCP01) 8.868 (MCNP5, MCNP5 Space XS, RACER)

Table 44. Base-2 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	99.2	85.8	185.0	99.2	85.8	185.0
Graphite	34.7	34.2	68.9	34.7	35.2	69.9
Total	133.9	120.1	253.9	133.9	121.0	254.9

Figure 27. Base-2 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 28. Base-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 45. Base-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
15 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
2.15	0.99536	0.00059	-	-	0.99299	0.00012	-	-
2.20	0.99726	0.00059	-	-	0.99472	0.00013	-	-
2.25	0.99849	0.00057	0.99916	0.00028	0.99641	0.00018	1.00084	0.00020
2.30	1.00082	0.00059	1.00091	0.00028	0.99807	0.00012	1.00238	0.00020
2.35	1.00197	0.00061	1.00299	0.00026	0.99957	0.00015	1.00399	0.00021
2.40	1.00445	0.00059	1.00396	0.00026	1.00121	0.00013	1.00597	0.00019
2.45	1.00562	0.00057	-	-	1.00266	0.00015	-	-
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.50	0.99551	0.00057	Not investigated due to termination of project.		0.99411	0.00015	Not investigated due to termination of project.	
1.55	0.99850	0.00057			0.99595	0.00013		
1.60	1.00064	0.00059			0.99799	0.00014		
1.65	1.00261	0.00059			1.00002	0.00017		
1.70	1.00420	0.00059			1.00197	0.00015		
1.75	1.00642	0.00057			1.00395	0.00017		
1.80	1.00857	0.00057			1.00582	0.00014		

4.1.3 Base-3 Experiment

The Base-3 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be softer than the expected average neutron energy spectrum of the core. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 29 and Figure 30 where aluminum is yellow, graphite is blue, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 46. The RCP01 analysis predicts an assembly height of 16.702" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 16.152". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 6.302" high and contains 12 stacking units consisting of a 0.118" thick HEU plate and a 0.394" thick graphite plate and 1 stacking unit consisting of a single 0.118" thick HEU plate, for a total of 13 stacking units. The bottom reflector consists of a 5.0" thick graphite reflector. The RCP01 predicted top reflector consists of a 5.40" thick graphite reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 4.85" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Base-3 assembly contains 161.9 kg of HEU. The distribution of materials in the top and bottom half of the assembly is given in Table 47 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Base-3 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 31 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Base-3 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0049 \pm 0.0004 \Delta k$ over the range from 8 to 28 stacking units. Figure 32 and Table 48 provide a comparison of the predicted k_{eff} of the Base-3 assembly with 13 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 48. The Base-3 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 66.4% fast ($E > 100$ keV), 33.6% intermediate (0.625 eV $< E < 100$ keV), and 0.1% thermal ($E < 0.625$ eV).

Figure 29. Cross-sectional View of the Base-3 Assembly

Figure 30. Cross-sectional Close-up View of the Base-3 Assembly

Table 46. Predicted Critical Configuration for the Base-3 Assembly.

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	5.00	2.51	21.0	5.000
1	HEU	0.118	2.51	21.0	5.118
	Graphite	0.394	2.51	21.0	5.512
2	HEU	0.118	2.51	21.0	5.630
	Graphite	0.394	2.51	21.0	6.024
3	HEU	0.118	2.51	21.0	6.142
	Graphite	0.394	2.51	21.0	6.536
4	HEU	0.118	2.51	21.0	6.654
	Graphite	0.394	2.51	21.0	7.048
5	HEU	0.118	2.51	21.0	7.166
	Graphite	0.394	2.51	21.0	7.560
6	HEU	0.118	2.51	21.0	7.678
	Graphite	0.394	2.51	21.0	8.072
7	HEU	0.118	2.51	21.0	8.190
	Graphite	0.394	2.51	21.0	8.584
Diaphragm	Stainless Steel	0.040	0	24.8	8.624
8	HEU	0.118	0	21.0	8.742
	Graphite	0.394	0	21.0	9.136
9	HEU	0.118	0	21.0	9.254
	Graphite	0.394	0	21.0	9.648
10	HEU	0.118	0	21.0	9.766
	Graphite	0.394	0	21.0	10.160
11	HEU	0.118	0	21.0	10.278
	Graphite	0.394	0	21.0	10.672
12	HEU	0.118	0	21.0	10.790
	Graphite	0.394	0	21.0	11.184
13	HEU	0.118	0	21.0	11.302
Top Reflector	Graphite	5.40 (RCP01) 4.85 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	16.702 (RCP01) 16.152 (MCNP5, MCNP5 Space XS, RACER)

Table 47. Base-3 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	86.6	75.3	161.9	86.6	75.3	161.9
Graphite	75.2	67.0	142.2	75.2	72.5	147.6
Total	161.8	142.4	304.2	161.8	147.8	309.6

Figure 31. Base-3 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 32. Base-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 48. Base-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
13 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
4.25	0.99368	0.00061	-	-	0.98852	0.00013	-	-
4.50	0.99636	0.00061	-	-	0.99170	0.00013	-	-
4.75	0.99944	0.00063	0.99991	0.00028	0.99458	0.00020	1.00144	0.00022
4.85	1.00081	0.00061	1.00120	0.00028	0.99561	0.00014	1.00284	0.00021
5.00	1.00276	0.00061	1.00255	0.00028	0.99724	0.00015	1.00427	0.00022
5.15	1.00415	0.00059	-	-	0.99871	0.00015	-	-
5.25	1.00505	0.00061	-	-	0.99963	0.00013	-	-
5.40	1.00558	0.00063	1.00613	0.0003	1.00101	0.00020	1.00799	0.00022
5.50	1.00647	0.00061	-	-	1.00194	0.00020	-	-
5.60	1.00787	0.00061	-	-	1.00280	0.00020	-	-

4.1.4 Base-4 Experiment

The Base-4 experiment is designed to simulate the average neutron spectrum of the Prometheus reactor core when flooded with water. Polyethylene is used to simulate flooding with water. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 33 and Figure 34 where aluminum is yellow, polyethylene is blue, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 49. The RCP01 analysis predicts an assembly height of 4.078" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 4.058". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 2.138" high and contains 10 stacking units consisting of a 0.118" thick HEU plate and a 0.080" thick polyethylene plate and 1 stacking unit consisting of a single 0.118" thick HEU plate, for a total of 11 stacking units. The bottom reflector consists of a 1.0" thick polyethylene reflector. The RCP01 predicted top reflector consists of a 0.94" thick polyethylene reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 0.92" thick polyethylene reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 5th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Base-4 assembly contains 137.0 kg of HEU. The distribution of materials in the top and bottom half of the assembly is given in Table 50 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Base-4 assembly during the approach to critical as a function of both the number of stacking units and the polyethylene top reflector thickness. Figure 35 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Base-4 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 35, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0027 \pm 0.0005 \Delta k$ over the range from 8 to 28 stacking units. Figure 36 and Table 51 provide a comparison of the predicted k_{eff} of the Base-4 assembly with 11 stacking units as a function of the polyethylene top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR ($\rho > 0.5\%$) limits are highlighted in green in Table 51. The Base-4 assembly is classified as a mixed spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 44.1% fast ($E > 100$ keV), 45.2% intermediate (0.625 eV $< E < 100$ keV), and 10.7% thermal ($E < 0.625$ eV).

Figure 33. Cross-sectional View of the Base-4 Assembly

Figure 34. Cross-sectional Close-up View of the Base-4 Assembly

Table 49. Predicted Critical Configuration of the Base-4 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Poly	1.00	2.51	21.0	1.000
1	HEU	0.118	2.51	21.0	1.118
	Poly	0.080	2.51	21.0	1.198
2	HEU	0.118	2.51	21.0	1.316
	Poly	0.080	2.51	21.0	1.396
3	HEU	0.118	2.51	21.0	1.514
	Poly	0.080	2.51	21.0	1.594
4	HEU	0.118	2.51	21.0	1.712
	Poly	0.080	2.51	21.0	1.792
5	HEU	0.118	2.51	21.0	1.910
	Poly	0.080	2.51	21.0	1.990
6	HEU	0.118	2.51	21.0	2.108
	Poly	0.080	2.51	21.0	2.188
Diaphragm	Stainless Steel	0.040	0	24.8	2.228
7	HEU	0.118	0	21.0	2.346
	Poly	0.080	0	21.0	2.426
8	HEU	0.118	0	21.0	2.544
	Poly	0.080	0	21.0	2.624
9	HEU	0.118	0	21.0	2.742
	Poly	0.080	0	21.0	2.822
10	HEU	0.118	0	21.0	2.940
	Poly	0.080	0	21.0	3.020
11	HEU	0.118	0	21.0	3.138
Top Reflector	Poly	0.94 (RCP01) 0.92 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	4.078 (RCP01) 4.058 (MCNP5, MCNP5 Space XS, RACER)

Table 50. Base-4 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	74.2	62.8	137.0	74.2	62.8	137.0
Polyethylene	7.9	6.7	14.7	7.9	6.8	14.8
Total	82.2	69.5	151.7	82.2	69.6	151.8

Figure 35. Base-4 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 36. Base-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 51. Base-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
11 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.84	0.99246	0.00069	0.99249	0.00032	0.98974	0.00015	0.99357	0.00023
0.90	0.99856	0.00067	0.99925	0.00032	0.99612	0.00017	0.99975	0.00024
0.92	1.00126	0.00069	1.00120	0.00030	0.99830	0.00036	1.00191	0.00025
0.94	1.00276	0.00069	1.00293	0.00032	1.00030	0.00014	1.00409	0.00024
0.95	1.00385	0.00069	-	-	1.00132	0.00020	-	-
0.98	1.00699	0.00067	-	-	1.00431	0.00013	-	-
1.00	1.00928	0.00067	-	-	1.00639	0.00018	-	-

4.1.5 Baseline Critical Experiments Summary and Conclusions

This document provides the pre-experimental predictions for the baseline critical experiments including the effect of the Planet assembly machine structure. These critical experiments are being performed to:

1. serve as the baseline against which any biases observed in the Mo, Nb, Re, and Ta critical experiment series may be compared,
2. assess the adequacy of existing neutron cross section evaluations in neutron energy spectra expected for the Prometheus reactor under normal and accident conditions, and
3. reduce the uncertainty in k_{eff} for the Prometheus reactor by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal and accident conditions.

The first 3 experiments are designed to bracket the neutron energy spectrum expected in the Prometheus space nuclear reactor under normal operating conditions. The Base-4 experiment is designed to approximate the neutron energy spectrum expected in accident conditions in which the core is flooded by water. A summary of the fission fraction in the thermal, intermediate, and fast energy ranges for each of the baseline critical experiments is provided in Table 52. The Base-1, Base-2, and Base-3 experiments are classified as fast spectrum experiments while the Base-4 experiment is classified as a mixed spectrum experiment. A summary of the pre-experimental predictions for each of the baseline critical experiments is provided in Table 53. Predictions from RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses are reported.

A comparison of the RCP01 and MCNP5 predicted fission reaction rate spectra is provided in Figure 37. The fission reaction rate spectra predicted by both codes are quite close in the fast energy range, but differences begin to appear below about 30 keV. Note that the RCP01 fission reaction rates are plotted as a single multigroup between 5×10^{-4} eV and 0.625 eV for convenience while the MCNP5 fission reaction rates are plotted using the normal RCP01 25 thermal multigroup structure. The RCP01 predicted fission reaction rate spectra cumulative distribution functions (CDFs) for the baseline experiments are provided in Figure 38. The first three baseline experiments clearly have fast spectra while the Base-4 experiment has a mixed spectrum.

Table 52. A Summary of the Energy Spectrum Covered in the Baseline Critical Experiments

Experiment	Percent Fissions by Energy (MCNP5 Predictions)		
	<0.625eV	0.625eV - 100keV	>100keV
Base-1	0.0%	13.0%	87.0%
Base-2	0.0%	20.7%	79.3%
Base-3	0.1%	33.6%	66.4%
Base-4	10.7%	45.2%	44.1%

Table 53. A Summary of the Pre-Experimental Predictions for the Baseline Critical Experiments

Experiment	Monte Carlo Code	Stacking Units	Top Reflector Thickness (in)	k_{eff}	95% Confidence Interval	Mass of HEU (kg)	Mass of Moderator (graphite/polyethylene) (kg)
Base-1	RCP01	17	1.30	1.00061	0.00015	208.0	38.1
	MCNP5	17	1.30	1.00142	0.00053	208.0	38.1
	MCNP5 (Space XS)	17	1.30	1.00191	0.00024	208.0	38.1
	RACER	17	1.30	1.00314	0.00021	208.0	38.1
Base-2	RCP01	15	2.40	1.00121	0.00013	185.0	69.9
	MCNP5	15	2.30	1.00082	0.00059	185.0	68.9
	MCNP5 (Space XS)	15	2.30	1.00091	0.00026	185.0	68.9
	RACER	15	2.30	1.00238	0.00020	185.0	68.9
Base-3	RCP01	13	5.40	1.00101	0.00020	161.9	147.6
	MCNP5	13	4.85	1.00081	0.00061	161.9	142.2
	MCNP5 (Space XS)	13	4.85	1.00120	0.00028	161.9	142.2
	RACER	13	4.85	1.00284	0.00021	161.9	142.2
Base-4	RCP01	11	0.94	1.00030	0.00014	137.0	14.8
	MCNP5	11	0.92	1.00126	0.00069	137.0	14.7
	MCNP5 (Space XS)	11	0.92	1.00120	0.00030	137.0	14.7
	RACER	11	0.92	1.00191	0.00025	137.0	14.7

Figure 37. Comparison of the RCP01 and MCNP5 Fission Rate Spectra for the Baseline Critical Experiments

Figure 38. RCP01 Fission CDFs for the Baseline Critical Experiments

4.2 Molybdenum Critical Experiments

4.2.1 Mo-1 Experiment

The Mo-1 experiment is designed to simulate the hardest neutron spectrum, which is in the center of the Prometheus reactor core during normal operating conditions. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 39 and Figure 40 where aluminum is yellow, graphite is blue, Mo is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The Mo-1 assembly configuration, including plate layout and dimensions, is shown in Table 54. The RCP01 analysis predicts an assembly height of 7.498", the MCNP5 analysis predicts an assembly height of 7.298", and the MCNP5 with space cross sections and RACER analyses predict an assembly height of 7.348". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 4.591" high and contains one 0.100" thick graphite plate and 16 stacking units consisting of a 0.0301" thick Mo plate, a 0.118" thick HEU plate, a 0.0301" thick Mo plate, and a 0.100" thick graphite plate. The bottom reflector for the assembly consists of a 1.0" thick graphite reflector and a 0.1785" thick Mo reflector. The RCP01 predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.55" thick graphite reflector, while the MCNP5 predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.35" thick graphite reflector. The MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.40" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Mo-1 assembly contains 196.5 kg of HEU and 76.1 kg of Mo. The distribution of material in the top and bottom half of the assembly is given in Table 55 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Mo-1 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 41 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Mo-1 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0068 \pm 0.0011 \Delta k$ over the range from 8 to 28 stacking units. For an explanation of the bias, please refer to Section 4.2.5. Figure 42 and Table 56 provide a comparison of the predicted k_{eff} of the Mo-1 assembly with 16 and 17 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 56. The Mo-1 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 85.1% fast ($E > 100$ keV), 14.9% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 39. Cross-sectional View of the Mo-1 Assembly

Figure 40. Cross-sectional Close-up View of the Mo-1 Assembly

Table 54. Predicted Critical Configuration for the Mo-1 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	1.00	2.51	21.0	1.0000
	Mo	0.1785	2.51	21.0	1.1785
	Graphite	0.100	2.51	21.0	1.2785
1	Mo	0.0301	2.51	21.0	1.3086
	HEU	0.118	2.51	21.0	1.4266
	Mo	0.0301	2.51	21.0	1.4567
	Graphite	0.100	2.51	21.0	1.5567
2	Mo	0.0301	2.51	21.0	1.5868
	HEU	0.118	2.51	21.0	1.7048
	Mo	0.0301	2.51	21.0	1.7349
	Graphite	0.100	2.51	21.0	1.8349
3	Mo	0.0301	2.51	21.0	1.8650
	HEU	0.118	2.51	21.0	1.9830
	Mo	0.0301	2.51	21.0	2.0131
	Graphite	0.100	2.51	21.0	2.1131
4	Mo	0.0301	2.51	21.0	2.1432
	HEU	0.118	2.51	21.0	2.2612
	Mo	0.0301	2.51	21.0	2.2913
	Graphite	0.100	2.51	21.0	2.3913
5	Mo	0.0301	2.51	21.0	2.4214
	HEU	0.118	2.51	21.0	2.5394
	Mo	0.0301	2.51	21.0	2.5695
	Graphite	0.100	2.51	21.0	2.6695
6	Mo	0.0301	2.51	21.0	2.6996
	HEU	0.118	2.51	21.0	2.8176
	Mo	0.0301	2.51	21.0	2.8477
	Graphite	0.100	2.51	21.0	2.9477
7	Mo	0.0301	2.51	21.0	2.9778
	HEU	0.118	2.51	21.0	3.0958
	Mo	0.0301	2.51	21.0	3.1259
	Graphite	0.100	2.51	21.0	3.2259
8	Mo	0.0301	0	21.0	3.2560
	HEU	0.118	0	21.0	3.3740
	Mo	0.0301	0	21.0	3.4041
	Graphite	0.100	0	21.0	3.5041
Diaphragm	Stainless Steel	0.040	0	24.8	3.5441
9	Mo	0.0301	0	21.0	3.5742
	HEU	0.118	0	21.0	3.6922
	Mo	0.0301	0	21.0	3.7223
	Graphite	0.100	0	21.0	3.8223
10	Mo	0.0301	0	21.0	3.8524
	HEU	0.118	0	21.0	3.9704
	Mo	0.0301	0	21.0	4.0005
	Graphite	0.100	0	21.0	4.1005

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Mo	0.0301	0	21.0	4.1306
	HEU	0.118	0	21.0	4.2486
	Mo	0.0301	0	21.0	4.2787
	Graphite	0.100	0	21.0	4.3787
12	Mo	0.0301	0	21.0	4.4088
	HEU	0.118	0	21.0	4.5268
	Mo	0.0301	0	21.0	4.5569
	Graphite	0.100	0	21.0	4.6569
13	Mo	0.0301	0	21.0	4.6870
	HEU	0.118	0	21.0	4.8050
	Mo	0.0301	0	21.0	4.8351
	Graphite	0.100	0	21.0	4.9351
14	Mo	0.0301	0	21.0	4.9652
	HEU	0.118	6.005	21.0	5.0832
	Mo	0.0301	0	21.0	5.1133
	Graphite	0.100	0	21.0	5.2133
15	Mo	0.0301	0	21.0	5.2434
	HEU	0.118	6.005	21.0	5.3614
	Mo	0.0301	0	21.0	5.3915
	Graphite	0.100	0	21.0	5.4915
16	Mo	0.0301	0	21.0	5.5216
	HEU	0.118	6.005	21.0	5.6396
	Mo	0.0301	0	21.0	5.6697
	Graphite	0.100	0	21.0	5.7697
Top Reflector	Mo	0.1785	0	21.0	5.9482
	Graphite	1.55 (RCP01)	0	21.0	7.4982 (RCP01)
		1.35 (MCNP5)			7.2982 (MCNP5)
		1.40 (RACER, MCNP5 Space XS)			7.3482 (RACER, MCNP5 Space XS)

Table 55. Mo-1 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	99.2	97.3	196.5	99.2	97.3	196.5	99.2	97.3	196.5
Mo	37.8	38.3	76.1	37.8	38.3	76.1	37.8	38.3	76.1
Graphite	18.4	21.1	39.6	18.4	23.1	41.5	18.4	21.6	40.1
Total	155.4	156.8	312.2	155.4	158.7	314.1	155.4	157.3	312.7

Figure 41. Mo-1 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 42. Mo-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 56. Mo-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.20	0.99452	0.00057	-	-	0.98780	0.00014	-	-
1.25	0.99722	0.00055	-	-	0.99000	0.00011	-	-
1.30	0.99885	0.00055	-	-	0.99198	0.00015	-	-
1.35	1.00123	0.00057	0.99867	0.00028	0.99401	0.00017	1.00001	0.00030
1.40	1.00237	0.00055	1.00033	0.00026	0.99582	0.00015	1.00188	0.00019
1.45	1.00493	0.00055	1.00241	0.00026	0.99784	0.00016	1.00387	0.00019
1.50	1.00675	0.00057	1.00424	0.00026	0.99960	0.00012	1.00588	0.00021
1.55	1.00925	0.00057	1.00628	0.00026	1.00157	0.00018	1.00782	0.00028
1.60	1.01047	0.00057	-	-	1.00326	0.00015	-	-
1.70	1.01371	0.00057	-	-	1.00691	0.00015	-	-
1.75	1.01521	0.00059	-	-	1.00842	0.00020	-	-
17 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.60	0.99302	0.00057	Not investigated due to termination of project.		0.98584	0.00018	Not investigated due to termination of project.	
0.65	0.99564	0.00057			0.98838	0.00012		
0.70	0.99829	0.00057			0.99099	0.00013		
0.75	1.00026	0.00055			0.99347	0.00016		
0.80	1.00324	0.00057			0.99579	0.00016		
0.85	1.00459	0.00055			0.99815	0.00014		
0.90	1.00728	0.00057			1.00028	0.00012		
0.95	1.00913	0.00053			1.00279	0.00014		
1.00	1.01157	0.00055			1.00500	0.00013		
1.05	1.01381	0.00057			1.00694	0.00018		
1.10	1.01611	0.00055			1.00905	0.00014		

4.2.2 Mo-2 Experiment

The Mo-2 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be harder than the expected average neutron energy spectrum of the core but softer than the Mo-1 experiment. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 43 and Figure 44 where aluminum is yellow, graphite is blue, Mo is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 57. The RCP01 analysis predicts an assembly height of 10.372", the MCNP5 analysis predicts an assembly height of 10.072", and the MCNP5 with space cross sections and RACER analyses predict an assembly height of 10.122". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 5.865" high and contains one 0.197" thick graphite plate and 15 stacking units consisting of a 0.0301" thick Mo plate, a 0.118" thick HEU plate, a 0.0301" thick Mo plate, and a 0.197" thick graphite plate. The bottom reflector consists of a 2.0" thick graphite reflector and a 0.1785" thick Mo reflector. The RCP01 predicted top reflector consists of a 0.1785" thick Mo reflector and a 2.15" thick graphite reflector, while the MCNP5 predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.85" thick graphite reflector. The MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.90" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Mo-2 assembly contains 185.0 kg of HEU and 72.6 kg of Mo. The distribution of materials in the top and bottom half of the assembly is given in Table 58 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Mo-2 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 45 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Mo-2 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0071 \pm 0.0006 \Delta k$ over the range from 8 to 28 stacking units. For an explanation of the bias, please refer to Section 4.2.5. Figure 46 and Table 59 provide a comparison of the predicted k_{eff} of the Mo-2 assembly with 14 and 15 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 59. The Mo-2 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 78.1% fast ($E > 100$ keV), 21.9% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 43. Cross-sectional View of the Mo-2 Assembly

Figure 44. Cross-sectional Close-up View of the Mo-2 Assembly

Table 57. Predicted Critical Configuration for the Mo-2 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	2.00	2.51	21.0	2.0000
	Mo	0.1785	2.51	21.0	2.1785
	Graphite	0.197	2.51	21.0	2.3755
1	Mo	0.0301	2.51	21.0	2.4056
	HEU	0.118	2.51	21.0	2.5236
	Mo	0.0301	2.51	21.0	2.5537
	Graphite	0.197	2.51	21.0	2.7507
2	Mo	0.0301	2.51	21.0	2.7808
	HEU	0.118	2.51	21.0	2.8988
	Mo	0.0301	2.51	21.0	2.9289
	Graphite	0.197	2.51	21.0	3.1259
3	Mo	0.0301	2.51	21.0	3.1560
	HEU	0.118	2.51	21.0	3.2740
	Mo	0.0301	2.51	21.0	3.3041
	Graphite	0.197	2.51	21.0	3.5011
4	Mo	0.0301	2.51	21.0	3.5312
	HEU	0.118	2.51	21.0	3.6492
	Mo	0.0301	2.51	21.0	3.6793
	Graphite	0.197	2.51	21.0	3.8763
5	Mo	0.0301	2.51	21.0	3.9064
	HEU	0.118	2.51	21.0	4.0244
	Mo	0.0301	2.51	21.0	4.0545
	Graphite	0.197	2.51	21.0	4.2515
6	Mo	0.0301	2.51	21.0	4.2816
	HEU	0.118	2.51	21.0	4.3996
	Mo	0.0301	2.51	21.0	4.4297
	Graphite	0.197	2.51	21.0	4.6267
7	Mo	0.0301	2.51	21.0	4.6568
	HEU	0.118	2.51	21.0	4.7748
	Mo	0.0301	2.51	21.0	4.8049
	Graphite	0.197	2.51	21.0	5.0019
8	Mo	0.0301	0	21.0	5.0320
	HEU	0.118	0	21.0	5.1500
	Mo	0.0301	0	21.0	5.1801
	Graphite	0.197	0	21.0	5.3771
Diaphragm	Stainless Steel	0.040	0	24.8	5.4171
9	Mo	0.0301	0	21.0	5.4472
	HEU	0.118	0	21.0	5.5652
	Mo	0.0301	0	21.0	5.5953
	Graphite	0.197	0	21.0	5.7923
10	Mo	0.0301	0	21.0	5.8224
	HEU	0.118	0	21.0	5.9404
	Mo	0.0301	0	21.0	5.9705
	Graphite	0.197	0	21.0	6.1675

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Mo	0.0301	0	21.0	6.1976
	HEU	0.118	0	21.0	6.3156
	Mo	0.0301	0	21.0	6.3457
	Graphite	0.197	0	21.0	6.5427
12	Mo	0.0301	0	21.0	6.5728
	HEU	0.118	0	21.0	6.6908
	Mo	0.0301	0	21.0	6.7209
	Graphite	0.197	0	21.0	6.9179
13	Mo	0.0301	0	21.0	6.9480
	HEU	0.118	0	21.0	7.0660
	Mo	0.0301	0	21.0	7.0961
	Graphite	0.197	0	21.0	7.2931
14	Mo	0.0301	0	21.0	7.3232
	HEU	0.118	6.005	21.0	7.4412
	Mo	0.0301	0	21.0	7.4713
	Graphite	0.197	0	21.0	7.6683
15	Mo	0.0301	0	21.0	7.6984
	HEU	0.118	6.005	21.0	7.8164
	Mo	0.0301	0	21.0	7.8465
	Graphite	0.197	0	21.0	8.0435
Top Reflector	Mo	0.1785	0	21.0	8.2220
	Graphite	2.15 (RCP01)	0	21.0	10.3720 (RCP01)
		1.85 (MCNP5)			10.0720 (MCNP5)
		1.90 (RACER, MCNP5 Space XS)			10.1220 (RACER, MCNP5 Space XS)

Table 58. Mo-2 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	99.2	85.8	185.0	99.2	85.8	185.0	99.2	85.8	185.0
Mo	37.8	34.8	72.6	37.8	34.8	72.6	37.8	34.8	72.6
Graphite	36.6	31.7	68.3	36.6	34.7	71.3	36.6	32.2	68.8
Total	173.6	152.4	325.9	173.6	155.3	328.9	173.6	152.9	326.4

Figure 45. Mo-2 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 46. Mo-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 59. Mo-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
14 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
2.80	0.99790	0.00057	Not investigated due to termination of project.		0.99051	0.00017	Not investigated due to termination of project.	
2.85	0.99868	0.00057			0.99159	0.00015		
2.90	1.00039	0.00057			0.99264	0.00018		
2.95	1.00090	0.00059			0.99346	0.00013		
3.00	1.00145	0.00059			0.99453	0.00016		
3.05	1.00240	0.00059			0.99546	0.00014		
3.10	1.00341	0.00059			0.99641	0.00014		
3.20	1.00552	0.00059			0.99822	0.00018		
3.30	1.00719	0.00057			0.99982	0.00018		
3.35	1.00783	0.00057			1.00075	0.00017		
3.40	1.00901	0.00057			1.00160	0.00022		
3.50	1.01001	0.00059			1.00319	0.00022		
3.60	1.01242	0.00057	1.00464	0.00016				
15 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
1.70	0.99570	0.00057	-	-	0.98851	0.00015	-	-
1.75	0.99775	0.00055	-	-	0.99005	0.00023	-	-
1.80	0.99836	0.00057	-	-	0.99139	0.00016	-	-
1.85	1.00009	0.00055	0.99920	0.00028	0.99268	0.00018	1.00021	0.00020
1.90	1.00135	0.00057	1.00031	0.00028	0.99417	0.00017	1.00162	0.00020
1.95	1.00313	0.00057	1.00168	0.00028	0.99540	0.00018	1.00284	0.00021
2.00	1.00430	0.00057	1.00317	0.00028	0.99668	0.00014	1.00411	0.00021
2.05	1.00507	0.00057	1.00398	0.00026	0.99796	0.00013	1.00576	0.00019
2.10	1.00649	0.00057	1.00577	0.00026	0.99933	0.00011	1.00696	0.00020
2.15	1.00756	0.00055	1.00710	0.00026	1.00041	0.00013	1.00825	0.00019
2.20	1.00869	0.00059	-	-	1.00181	0.00010	-	-
2.25	1.01046	0.00055	-	-	1.00274	0.00019	-	-
2.30	1.01085	0.00057	-	-	1.00401	0.00016	-	-

4.2.3 Mo-3 Experiment

The Mo-3 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be softer than the expected average neutron energy spectrum of the core. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 47 and Figure 48 where aluminum is yellow, graphite is blue, Mo is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 60. The RCP01 and MCNP5 analyses predict an assembly height of 18.552", while the MCNP5 with space cross sections and RACER analyses predict an assembly height of 17.552". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 8.445" high and contains one 0.394" thick graphite plate and 14 stacking units consisting of a 0.0301" thick Mo plate, a 0.118" thick HEU plate, a 0.0301" thick Mo plate, and a 0.394" thick graphite plate. MCNP5 predicts a top HEU plate ID of 10.005" instead of the 6.005" ID of the top HEU plate found in the RCP01, MCNP5 with space cross sections, and RACER predictions. The bottom reflector consists of a 5.0" thick graphite reflector and a 0.1785" thick Mo reflector. The RCP01 and MCNP5 predicted top reflector consists of a 0.1785" thick Mo reflector and a 4.75" thick graphite reflector, while the MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.1785" thick Mo reflector and a 3.75" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Mo-3 assembly contains 69.1 kg of Mo. The distribution of materials in the top and bottom half of the assembly is given in Table 61 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations. It is important to note that the HEU mass in the upper assembly varies between the predicted critical configurations since MCNP5 predicted a critical configuration with a different top HEU fuel plate ID.

A series of analyses have been performed to predict the k_{eff} of the Mo-3 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 49 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Mo-3 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0072 \pm 0.0005 \Delta k$ over the range from 8 to 28 stacking units. For an explanation of the bias, please refer to Section 4.2.5. Figure 50 and Table 62 provide a comparison of the predicted k_{eff} of the Mo-3 assembly with 14 stacking units with a 6.005" ID top HEU fuel plate and 14 stacking units with a 10.005" ID top HEU fuel plate as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 62. The Mo-3 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 65.9% fast ($E > 100$ keV), 34.1% intermediate (0.625 eV $< E < 100$ keV), and 0.1% thermal ($E < 0.625$ eV).

Figure 47. Cross-sectional View of the Mo-3 Assembly

Figure 48. Cross-sectional Close-up View of the Mo-3 Assembly

Table 60. Predicted Critical Configuration for the Mo-3 Assembly.

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	5.00	2.51	21.0	5.0000
	Mo	0.1785	2.51	21.0	5.1785
	Graphite	0.394	2.51	21.0	5.5725
1	Mo	0.0301	2.51	21.0	5.6026
	HEU	0.118	2.51	21.0	5.7206
	Mo	0.0301	2.51	21.0	5.7507
	Graphite	0.394	2.51	21.0	6.1447
2	Mo	0.0301	2.51	21.0	6.1748
	HEU	0.118	2.51	21.0	6.2928
	Mo	0.0301	2.51	21.0	6.3229
	Graphite	0.394	2.51	21.0	6.7169
3	Mo	0.0301	2.51	21.0	6.7470
	HEU	0.118	2.51	21.0	6.8650
	Mo	0.0301	2.51	21.0	6.8951
	Graphite	0.394	2.51	21.0	7.2891
4	Mo	0.0301	2.51	21.0	7.3192
	HEU	0.118	2.51	21.0	7.4372
	Mo	0.0301	2.51	21.0	7.4673
	Graphite	0.394	2.51	21.0	7.8613
5	Mo	0.0301	2.51	21.0	7.8914
	HEU	0.118	2.51	21.0	8.0094
	Mo	0.0301	2.51	21.0	8.0395
	Graphite	0.394	2.51	21.0	8.4335
6	Mo	0.0301	2.51	21.0	8.4636
	HEU	0.118	2.51	21.0	8.5816
	Mo	0.0301	2.51	21.0	8.6117
	Graphite	0.394	2.51	21.0	9.0057
7	Mo	0.0301	2.51	21.0	9.0358
	HEU	0.118	2.51	21.0	9.1538
	Mo	0.0301	2.51	21.0	9.1839
	Graphite	0.394	2.51	21.0	9.5779
Diaphragm	Stainless Steel	0.040	0	24.8	9.6179
8	Mo	0.0301	0	21.0	9.6480
	HEU	0.118	0	21.0	9.7660
	Mo	0.0301	0	21.0	9.7961
	Graphite	0.394	0	21.0	10.1901
9	Mo	0.0301	0	21.0	10.2202
	HEU	0.118	0	21.0	10.3382
	Mo	0.0301	0	21.0	10.3683
	Graphite	0.394	0	21.0	10.7623
10	Mo	0.0301	0	21.0	10.7924
	HEU	0.118	0	21.0	10.9104
	Mo	0.0301	0	21.0	10.9405
	Graphite	0.394	0	21.0	11.3345

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Mo	0.0301	0	21.0	11.3646
	HEU	0.118	0	21.0	11.4826
	Mo	0.0301	0	21.0	11.5127
	Graphite	0.394	0	21.0	11.9067
12	Mo	0.0301	0	21.0	11.9368
	HEU	0.118	0	21.0	12.0548
	Mo	0.0301	0	21.0	12.0849
	Graphite	0.394	0	21.0	12.4789
13	Mo	0.0301	0	21.0	12.5090
	HEU	0.118	0	21.0	12.6270
	Mo	0.0301	0	21.0	12.6571
	Graphite	0.394	0	21.0	13.0511
14	Mo	0.0301	0	21.0	13.0812
	HEU	0.118	6.005 (RCP01, MCNP5 Space XS, RACER) 10.005 (MCNP5)	21.0	13.1992
	Mo	0.0301	0	21.0	13.2293
	Graphite	0.394	0	21.0	13.6233
Top Reflector	Mo	0.1785	0	21.0	13.8018
	Graphite	4.75 (RCP01, MCNP5) 3.75 (RACER, MCNP5 Space XS)	0	21.0	18.5518 (RCP01, MCNP5) 17.5518 (RACER, MCNP5 Space XS)

Table 61. Mo-3 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	86.6	85.0	171.6	86.6	86.8	173.5	86.6	86.8	173.5
Mo	34.3	34.8	69.1	34.3	34.8	69.1	34.3	34.8	69.1
Graphite	79.0	73.8	152.8	79.0	73.8	152.8	79.0	64.0	143.0
Total	199.9	193.6	393.5	199.9	195.5	395.4	199.9	185.6	385.5

Figure 49. Mo-3 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 50. Mo-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 62. Mo-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
14 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
3.50	0.99751	0.00059	-	-	0.98994	0.00018	-	-
3.75	0.99945	0.00057	1.00090	0.00028	0.99259	0.00010	1.00168	0.00020
3.85	1.00050	0.00059	1.00138	0.00028	0.99353	0.00016	1.00298	0.00021
3.95	1.00196	0.00059	1.00251	0.00028	0.99430	0.00016	1.00354	0.00021
4.00	1.00224	0.00061	1.00292	0.00028	0.99488	0.00015	1.00429	0.00022
4.25	1.00379	0.00061	-	-	0.99690	0.00015	-	-
4.50	1.00618	0.00059	-	-	0.99887	0.00013	-	-
4.75	1.00735	0.00059	1.00912	0.00028	1.00075	0.00015	1.01019	0.00022
5.00	1.00963	0.00057	-	-	1.00241	0.00021	-	-
14 Stacking Units with a 10.005" ID top HEU fuel plate								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
4.00	0.99526	0.00059	Not investigated due to termination of project.		0.98807	0.00017	Not investigated due to termination of project.	
4.25	0.99756	0.00059			0.99015	0.00015		
4.30	0.99808	0.00063			0.99050	0.00015		
4.35	0.99811	0.00061			0.99089	0.00015		
4.40	0.99842	0.00061			0.99137	0.00016		
4.45	0.99862	0.00059			0.99165	0.00013		
4.50	0.99882	0.00061			0.99196	0.00015		
4.75	1.00079	0.00061			0.99363	0.00014		
5.00	1.00241	0.00059			0.99516	0.00010		
5.25	1.00421	0.00059			0.99666	0.00013		
5.50	1.00455	0.00059			0.99798	0.00015		
5.75	1.00655	0.00059			0.99931	0.00010		
6.00	1.00751	0.00059			1.00028	0.00010		

4.2.4 Mo-4 Experiment

The Mo-4 experiment is designed to simulate the average neutron spectrum of the Prometheus reactor core when flooded with water. Polyethylene is used to simulate flooding with water. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 51 and Figure 52 where aluminum is yellow, polyethylene is light blue, Mo is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 63. The RCP01 analysis predicts an assembly height of 5.317", the MCNP5 analysis predicts an assembly height of 5.257", and the MCNP5 with space cross sections and RACER analyses predict an assembly height of 5.197". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 2.960" high and contains one 0.080" thick polyethylene plate and 11 stacking units consisting of a 0.0301" thick Mo plate, a 0.118" thick HEU plate, a 0.0301" thick Mo plate, and a 0.080" thick polyethylene plate. The bottom reflector consists of a 1.0" thick polyethylene reflector and a 0.1785" thick Mo reflector. The RCP01 predicted top reflector consists of a 0.1785" thick Mo reflector and a 1.00" thick polyethylene reflector, the MCNP5 predicted top reflector consists of a 0.1785" thick Mo reflector and a 0.94" thick polyethylene reflector, and the MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.1785" thick Mo reflector and a 0.88" thick polyethylene reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 5th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Mo-4 assembly contains 137.0 kg of HEU and 58.7 kg of Mo. The distribution of materials in the top and bottom half of the assembly is given in Table 64 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Mo-4 assembly during the approach to critical as a function of both the number of stacking units and the polyethylene top reflector thickness. Figure 53 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Mo-4 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0037 \pm 0.0006 \Delta k$ over the range from 8 to 28 stacking units. For an explanation of the bias, please refer to Section 4.2.5. Figure 54 and Table 65 provide a comparison of the predicted k_{eff} of the Mo-4 assembly with 10 and 11 stacking units as a function of the polyethylene top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($p < 0.5\%$) are highlighted in green in Table 65. The Mo-4 assembly is classified as a mixed spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 45.2% fast ($E > 100 \text{ keV}$), 45.3% intermediate ($0.625 \text{ eV} < E < 100 \text{ keV}$), and 9.5% thermal ($E < 0.625 \text{ eV}$).

Figure 51. Cross-sectional View of the Mo-4 Assembly

Figure 52. Cross-sectional Close-up View of the Mo-4 Assembly

Table 63. Predicted Critical Configuration of the Mo-4 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Poly	1.00	2.51	21.0	1.0000
	Mo	0.1785	2.51	21.0	1.1785
	Poly	0.080	2.51	21.0	1.2585
1	Mo	0.0301	2.51	21.0	1.2886
	HEU	0.118	2.51	21.0	1.4066
	Mo	0.0301	2.51	21.0	1.4367
	Poly	0.080	2.51	21.0	1.5167
2	Mo	0.0301	2.51	21.0	1.5468
	HEU	0.118	2.51	21.0	1.6648
	Mo	0.0301	2.51	21.0	1.6949
	Poly	0.080	2.51	21.0	1.7749
3	Mo	0.0301	2.51	21.0	1.8050
	HEU	0.118	2.51	21.0	1.9230
	Mo	0.0301	2.51	21.0	1.9531
	Poly	0.080	2.51	21.0	2.0331
4	Mo	0.0301	2.51	21.0	2.0632
	HEU	0.118	2.51	21.0	2.1812
	Mo	0.0301	2.51	21.0	2.2113
	Poly	0.080	2.51	21.0	2.2913
5	Mo	0.0301	2.51	21.0	2.3214
	HEU	0.118	2.51	21.0	2.4394
	Mo	0.0301	2.51	21.0	2.4695
	Poly	0.080	2.51	21.0	2.5495
6	Mo	0.0301	2.51	21.0	2.5796
	HEU	0.118	2.51	21.0	2.6976
	Mo	0.0301	2.51	21.0	2.7277
	Poly	0.080	2.51	21.0	2.8077
Diaphragm	Stainless Steel	0.040	0	24.8	2.8477
7	Mo	0.0301	0	21.0	2.8778
	HEU	0.118	0	21.0	2.9958
	Mo	0.0301	0	21.0	3.0259
	Poly	0.080	0	21.0	3.1059
8	Mo	0.0301	0	21.0	3.1360
	HEU	0.118	0	21.0	3.2540
	Mo	0.0301	0	21.0	3.2841
	Poly	0.080	0	21.0	3.3641
9	Mo	0.0301	0	21.0	3.3942
	HEU	0.118	0	21.0	3.5122
	Mo	0.0301	0	21.0	3.5423
	Poly	0.080	0	21.0	3.6223
10	Mo	0.0301	0	21.0	3.6524
	HEU	0.118	0	21.0	3.7704
	Mo	0.0301	0	21.0	3.8005
	Poly	0.080	0	21.0	3.8805

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Mo	0.0301	0	21.0	3.9106
	HEU	0.118	0	21.0	4.0286
	Mo	0.0301	0	21.0	4.0587
	Poly	0.080	0	21.0	4.1387
Top Reflector	Mo	0.1785	0	21.0	4.3172
	Poly	1.00 (RCP01)	0	21.0	5.3172 (RCP01)
		0.94 (MCNP5)			5.2572 (MCNP5)
		0.88 (RACER, MCNP5 Space XS)			5.1972 (RACER, MCNP5 Space XS)

Table 64. Mo-4 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	74.2	62.8	137.0	74.2	62.8	137.0	74.2	62.8	137.0
Mo	30.9	27.8	58.7	30.9	27.8	58.7	30.9	27.8	58.7
Polyethylene	8.4	7.3	15.6	8.4	7.6	16.0	8.4	7.0	15.3
Total	113.5	97.9	211.3	113.5	98.2	211.6	113.5	97.5	211.0

Figure 53. Mo-4 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 54. Mo-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 65. Mo-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
10 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
1.54	0.99708	0.00067	Not investigated due to termination of project.		0.99469	0.00015	Not investigated due to termination of project.	
1.58	0.99864	0.00065			0.99624	0.00019		
1.60	1.00003	0.00067			0.99700	0.00012		
1.64	1.00110	0.00065			0.99841	0.00018		
1.68	1.00229	0.00065			0.99978	0.00020		
1.70	1.00284	0.00065			1.00033	0.00024		
1.74	1.00491	0.00065			1.00160	0.00015		
11 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
0.80	0.99148	0.00061	-	-	0.98734	0.00018	-	-
0.84	0.99449	0.00067	0.99742	0.00030	0.99061	0.00013	0.99729	0.00023
0.88	0.99676	0.00065	1.00050	0.00030	0.99356	0.00018	1.00030	0.00023
0.90	0.99899	0.00063	1.00157	0.00030	0.99494	0.00016	1.00195	0.00024
0.94	1.00135	0.00063	1.00433	0.00030	0.99800	0.00018	1.00443	0.00023
0.98	1.00462	0.00065	-	-	1.00070	0.00015	-	-
1.00	1.00577	0.00065	1.00872	0.00030	1.00189	0.00017	1.00886	0.00024
1.04	1.00858	0.00065	-	-	1.00472	0.00013	-	-
1.08	1.01166	0.00067	-	-	1.00728	0.00016	-	-

4.2.5 Molybdenum Critical Experiments Summary and Conclusions

This document provides the pre-experimental predictions for the Mo critical experiments including the effect of the Planet assembly machine structure. These critical experiments are being performed to:

1. determine the adequacy of the existing Mo neutron cross section evaluations in neutron energy spectra characteristic of Prometheus reactor designs under normal and accident conditions,
2. reduce the uncertainty in k_{eff} for Prometheus reactor designs containing substantial amounts of Mo by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal and accident conditions, and
3. provide benchmark critical experiments needed to develop improved Mo neutron cross section evaluations if new evaluations are determined to be required.

The first 3 experiments are designed to bracket the neutron energy spectrum expected in the Prometheus space nuclear reactor under normal operating conditions. The Mo-4 experiment is designed to approximate the neutron energy spectrum expected in accident conditions in which the core is flooded with water. A summary of the fission fraction in the thermal, intermediate, and fast energy ranges for each of the Mo critical experiments is provided in Table 66. The Mo-1, Mo-2, and Mo-3 experiments are classified as fast spectrum experiments while the Mo-4 experiment is classified as a mixed spectrum experiment. A summary of the pre-experimental predictions for each of the Mo critical experiments is provided in Table 67. Predictions from RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses are reported.

Comparisons of the RCP01 and MCNP5 predicted fission reaction rate spectra and RCP01 predicted fission reaction rate spectra CDFs are provided in Figure 55 and Figure 56. Comparisons of RCP01 and MCNP5 predicted Mo absorption rate spectra are provided in Figure 57 and Figure 59. The lack of an unresolved resonance treatment in the MCNP5 nat-Mo neutron cross section data clearly results in greater absorption relative to RCP01 between 1.423 keV and 100.09 keV in all four experiments.

The four experiments also appear to be sensitive to the differences in available cross-section data. RCP01, MCNP5 with space cross sections, and RACER predictions have used the more complete JENDL 3.2 evaluation, which contains data for additional non-neutron-producing capture reactions ((n,α) , (n,γ) , (n,p) , (n,d) , and (n,t)). The MCNP5 predictions necessitate use of the ENDF/B-VI.0 dataset, which only contains data for (n,γ) neutron absorption reactions. These differences in cross-section data, as well as the afore-mentioned unresolved resonance data difference, are highlighted in Figure 58. It is important to note that the lack of unresolved resonance treatment and the incomplete neutron reaction data used in the MCNP5 analysis are competing effects. Both impact the reactivity incorrectly, but do so in an opposing manner. The ENDF/B-VI.0 dataset's lack of unresolved resonance treatment overestimates Mo absorption in the 1 keV - 100 keV range and incomplete nuclear reaction data underestimates Mo absorption in the >100 keV range. This bias in the nuclear data set highlights the need to conduct these experiments in order to reduce the reactivity error associated with incomplete nuclear data for Prometheus reactor designs that contain significant amounts of Mo.

The RCP01 analyses of all four experiments predict increased parasitic molybdenum neutron absorption in the fast neutron energy range (>100 keV, but especially >1 MeV), shown in Figure 59. The increased non-neutron-producing absorption in the fast energy range has the net effect of lowering the overall multiplication factor, resulting in the increased RCP01-predicted reflector

thicknesses for Mo-1, Mo-2, and Mo-4 and increased critical mass for Mo-3 as presented in Table 67. MCNP5 with space cross sections and RACER predictions follow this same relative trend for Mo-1 and Mo-2, yielding predicted reflector thicknesses that are larger than MCNP5 predictions. Their smaller predicted reflectors in Mo-3 and Mo-4, however, appear to predict that the drop in absorptions in the unresolved resonance region when using JENDL 3.2 evaluations will outweigh the lower fast spectrum parasitic losses of ENDF/B-VI.0 as the experiments shift to a more intermediate neutron flux.

Table 66. A Summary of the Energy Spectrum Covered in the Mo Critical Experiments

Experiment	Percent Fissions by Energy (MCNP5 Predictions)		
	<0.625eV	0.625eV - 100keV	>100keV
Mo-1	0.0%	14.9%	85.1%
Mo-2	0.0%	21.9%	78.1%
Mo-3	0.1%	34.1%	65.9%
Mo-4	9.5%	45.3%	45.2%

Table 67. A Summary of the Pre-Experimental Predictions for the Mo Critical Experiments

Experiment	Monte Carlo Code	Stacking Units	Inner Diameter of Top HEU Plate (in)	Top Reflector Thickness (in)	k_{eff}	95% Confidence Level	Mass of HEU (kg)	Mass of Mo (kg)	Mass of Moderator (graphite/polyethylene) (kg)
Mo-1	RCP01	16	6.005	1.55	1.00157	0.00018	196.5	76.1	41.5
	MCNP5	16	6.005	1.35	1.00123	0.00057	196.5	76.1	39.6
	MCNP5 (Space XS)	16	6.005	1.40	1.00033	0.00026	196.5	76.1	40.1
	RACER	16	6.005	1.40	1.00188	0.00019	196.5	76.1	40.1
Mo-2	RCP01	15	6.005	2.15	1.00041	0.00013	185.0	72.6	71.3
	MCNP5	15	6.005	1.85	1.00009	0.00055	185.0	72.6	68.3
	MCNP5 (Space XS)	15	6.005	1.90	1.00031	0.00026	185.0	72.6	68.8
	RACER	15	6.005	1.90	1.00162	0.00020	185.0	72.6	68.8
Mo-3	RCP01	14	6.005	4.75	1.00075	0.00015	173.5	69.1	152.8
	MCNP5	14	10.005	4.75	1.00079	0.00061	171.6	69.1	152.8
	MCNP5*	14	6.005	3.85	1.00050	0.00059	173.5	69.1	144.7
	MCNP5 (Space XS)	14	6.005	3.75	1.00090	0.00028	173.5	69.1	143.0
	RACER	14	6.005	3.75	1.00168	0.00020	173.5	69.1	143.0
Mo-4	RCP01	11	0	1.00	1.00189	0.00017	137.0	58.7	16.0
	MCNP5	11	0	0.94	1.00135	0.00063	137.0	58.7	15.6
	MCNP5 (Space XS)	11	0	0.88	1.00050	0.00030	137.0	58.7	15.3
	RACER	11	0	0.88	1.00030	0.00023	137.0	58.7	15.3

* NOTE: The Mo-3 configuration listed for MCNP5 with 14 stacking units, a top HEU plate inner diameter of 6.005", and top reflector thickness of 3.85" is not analyzed as a critical configuration elsewhere in this document, but is presented for comparison purposes since the other predicted critical configurations for the Mo-3 experiment all have an inner diameter of 6.005" for the top HEU plate.

Figure 55: Comparison of the RCP01 and MCNP5 Fission Rate Spectra for the Mo Critical Experiments

Figure 56: RCP01 Fission CDFs for the Mo Critical Experiments

Figure 57: Comparison of the RCP01 and MCNP5 Mo Absorption Rate Spectra for the Mo Critical Experiments

Figure 58: Neutron Absorption Cross-Section vs. Energy for Natural Molybdenum (ENDF/BVI.0) and Isotopically-Combined Equivalent (JENDL 3.2) [20]

Figure 59: Comparison of RCP01 and MCNP5 Mo Absorption Rate Spectra over Ranges of Varying Cross-Section Data

4.3 Niobium Critical Experiments

4.3.1 Nb-1Zr-2 Experiment

The Nb-1Zr-2 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be harder than the expected average neutron energy spectrum of the core. Graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 60 and Figure 61 where aluminum is yellow, graphite is blue, Nb-1Zr is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 68. The RCP01 analysis predicts an assembly height of 10.852" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 10.702". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 6.592" high and contains one 0.197" thick graphite plate and 16 stacking units consisting of 0.040" of Nb-1Zr, a 0.118" thick HEU plate, 0.040" of Nb-1Zr, and a 0.197" thick graphite plate. The bottom reflector consists of a 2.0" thick graphite reflector and a 0.180" thick Nb-1Zr reflector. The RCP01 predicted top reflector consists of a 0.180" thick Nb-1Zr reflector and a 1.90" thick graphite reflector. The MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 0.180" thick Nb-1Zr reflector and a 1.75" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Nb-1Zr-2 assembly contains 196.5 kg of HEU and 80.3 kg of Nb-1Zr. The distribution of materials in the top and bottom half of the assembly is given in Table 69 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Nb-1Zr-2 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 62 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Nb-1Zr-2 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 62, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0031 \pm 0.0004 \Delta k$ over the range from 8 to 28 stacking units. Figure 63 and Table 70 provide a comparison of the predicted k_{eff} of the Nb-1Zr-2 assembly with 16 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 70. The Nb-1Zr-2 assembly is classified as a fast spectrum assembly with the following representative fission fractions as predicted by MCNP5: 77.9% fast ($E > 100$ keV), 22.1% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 60. Cross-sectional View of the Nb-1Zr-2 Assembly

Figure 61. Cross-sectional Close-up View of the Nb-1Zr-2 Assembly

Table 68. Predicted Critical Configuration for the Nb-1Zr-2 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	2.00	2.51	21.0	2.0000
	Nb-1Zr	0.180	2.51	21.0	2.1800
	Graphite	0.197	2.51	21.0	2.3770
1	Nb-1Zr	0.040	2.51	21.0	2.4170
	HEU	0.118	2.51	21.0	2.5350
	Nb-1Zr	0.040	2.51	21.0	2.5750
	Graphite	0.197	2.51	21.0	2.7720
2	Nb-1Zr	0.040	2.51	21.0	2.8120
	HEU	0.118	2.51	21.0	2.9300
	Nb-1Zr	0.040	2.51	21.0	2.9700
	Graphite	0.197	2.51	21.0	3.1670
3	Nb-1Zr	0.040	2.51	21.0	3.2070
	HEU	0.118	2.51	21.0	3.3250
	Nb-1Zr	0.040	2.51	21.0	3.3650
	Graphite	0.197	2.51	21.0	3.5620
4	Nb-1Zr	0.040	2.51	21.0	3.6020
	HEU	0.118	2.51	21.0	3.7200
	Nb-1Zr	0.040	2.51	21.0	3.7600
	Graphite	0.197	2.51	21.0	3.9570
5	Nb-1Zr	0.040	2.51	21.0	3.9970
	HEU	0.118	2.51	21.0	4.1150
	Nb-1Zr	0.040	2.51	21.0	4.1550
	Graphite	0.197	2.51	21.0	4.3520
6	Nb-1Zr	0.040	2.51	21.0	4.3920
	HEU	0.118	2.51	21.0	4.5100
	Nb-1Zr	0.040	2.51	21.0	4.5500
	Graphite	0.197	2.51	21.0	4.7470
7	Nb-1Zr	0.040	2.51	21.0	4.7870
	HEU	0.118	2.51	21.0	4.9050
	Nb-1Zr	0.040	2.51	21.0	4.9450
	Graphite	0.197	2.51	21.0	5.1420
8	Nb-1Zr	0.040	0	21.0	5.1820
	HEU	0.118	0	21.0	5.3000
	Nb-1Zr	0.040	0	21.0	5.3400
	Graphite	0.197	0	21.0	5.5370
9	Nb-1Zr	0.040	0	21.0	5.5770
	HEU	0.118	0	21.0	5.6950
	Nb-1Zr	0.040	0	21.0	5.7350
	Graphite	0.197	0	21.0	5.9320
10	Nb-1Zr	0.040	0	21.0	5.9720
	HEU	0.118	0	21.0	6.0900
	Nb-1Zr	0.040	0	21.0	6.1300
	Graphite	0.197	0	21.0	6.3270
Diaphragm	Stainless Steel	0.075	0	24.8	6.4020

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Nb-1Zr	0.040	0	21.0	6.4420
	HEU	0.118	0	21.0	6.5600
	Nb-1Zr	0.040	0	21.0	6.6000
	Graphite	0.197	0	21.0	6.7970
12	Nb-1Zr	0.040	0	21.0	6.8370
	HEU	0.118	0	21.0	6.9550
	Nb-1Zr	0.040	0	21.0	6.9950
	Graphite	0.197	0	21.0	7.1920
13	Nb-1Zr	0.040	0	21.0	7.2320
	HEU	0.118	0	21.0	7.3500
	Nb-1Zr	0.040	0	21.0	7.3900
	Graphite	0.197	0	21.0	7.5870
14	Nb-1Zr	0.040	0	21.0	7.6270
	HEU	0.118	6.005	21.0	7.7450
	Nb-1Zr	0.040	0	21.0	7.7850
	Graphite	0.197	0	21.0	7.9820
15	Nb-1Zr	0.040	0	21.0	8.0220
	HEU	0.118	6.005	21.0	8.1400
	Nb-1Zr	0.040	0	21.0	8.1800
	Graphite	0.197	0	21.0	8.3770
16	Nb-1Zr	0.040	0	21.0	8.4170
	HEU	0.118	6.005	21.0	8.5350
	Nb-1Zr	0.040	0	21.0	8.5750
	Graphite	0.197	0	21.0	8.7720
Top Reflector	Nb-1Zr	0.180	0	21.0	8.9520
	Graphite	1.90 (RCP01) 1.75 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	10.8520 (RCP01) 10.7020 (MCNP5, MCNP5 Space XS, RACER)

Table 69. Nb-1Zr-2 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	124.3	72.2	196.5	124.3	72.2	196.5
Nb-1Zr	47.8	32.5	80.3	47.8	32.5	80.3
Graphite	40.5	28.8	69.3	40.5	30.3	70.8
Total	212.5	133.6	346.1	212.5	135.1	347.6

Figure 62. Nb-1Zr-2 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 63. Nb-1Zr-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 70. Nb-1Zr-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.60	0.99613	0.00059	-	-	0.99352	0.00013	-	-
1.70	0.99900	0.00055	0.99909	0.00026	0.99598	0.00010	1.00019	0.00020
1.75	1.00075	0.00055	1.00084	0.00026	0.99724	0.00015	1.00138	0.00020
1.80	1.00172	0.00055	1.00140	0.00026	0.99847	0.00017	1.00243	0.00020
1.85	1.00247	0.00057	-	-	0.99979	0.00014	-	-
1.90	1.00403	0.00057	1.00406	0.00026	1.00092	0.00021	1.00474	0.00020
1.95	1.00456	0.00057	-	-	1.00208	0.00017	-	-
2.00	1.00623	0.00057	-	-	1.00316	0.00011	-	-
2.05	1.00720	0.00059	-	-	1.00429	0.00012	-	-
2.10	1.00864	0.00055	-	-	1.00544	0.00015	-	-
2.15	1.00995	0.00057	-	-	1.00650	0.00014	-	-

4.3.2 Nb-1Zr-3 Experiment

The Nb-1Zr-3 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be softer than the expected average neutron energy spectrum of the core. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 64 and Figure 65 where aluminum is yellow, graphite is blue, Nb-1Zr is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 71. The RCP01 analysis predicts an assembly height of 19.709" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 18.959". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 9.349" high and contains one 0.394" thick graphite plate and 15 stacking units consisting of 0.040" of Nb-1Zr, a 0.118" thick HEU plate, 0.040" of Nb-1Zr, and a 0.394" thick graphite plate. The bottom reflector consists of a 5.0" thick graphite reflector and a 0.180" thick Nb-1Zr reflector. The RCP01 predicted top reflector consists of a 0.180" thick Nb-1Zr reflector and a 5.00" thick graphite reflector. The MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 0.180" thick Nb-1Zr reflector and a 4.25" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Nb-1Zr-3 assembly contains 185.0 kg of HEU and 76.4 kg of Nb-1Zr. The distribution of materials in the top and bottom half of the assembly is given in Table 72 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Nb-1Zr-3 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 66 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Nb-1Zr-3 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 66, the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0054 \pm 0.0007 \Delta k$ over the range from 8 to 28 stacking units. Figure 67 and Table 73 provide a comparison of the predicted k_{eff} of the Nb-1Zr-3 assembly with 15 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($p < 0.5\%$) are highlighted in green in Table 73. The Nb-1Zr-3 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 66.1% fast ($E > 100$ keV), 33.9% intermediate (0.625 eV $< E < 100$ keV), and 0.1% thermal ($E < 0.625$ eV).

Figure 64. Cross-sectional View of the Nb-1Zr-3 Assembly

Figure 65. Cross-sectional Close-up View of the Nb-1Zr-3 Assembly

Table 71. Predicted Critical Configuration for the Nb-1Zr-3 Assembly.

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	5.00	2.51	21.0	5.0000
	Nb-1Zr	0.180	2.51	21.0	5.1800
	Graphite	0.394	2.51	21.0	5.5740
1	Nb-1Zr	0.040	2.51	21.0	5.6140
	HEU	0.118	2.51	21.0	5.7320
	Nb-1Zr	0.040	2.51	21.0	5.7720
	Graphite	0.394	2.51	21.0	6.1660
2	Nb-1Zr	0.040	2.51	21.0	6.2060
	HEU	0.118	2.51	21.0	6.3240
	Nb-1Zr	0.040	2.51	21.0	6.3640
	Graphite	0.394	2.51	21.0	6.7580
3	Nb-1Zr	0.040	2.51	21.0	6.7980
	HEU	0.118	2.51	21.0	6.9160
	Nb-1Zr	0.040	2.51	21.0	6.9560
	Graphite	0.394	2.51	21.0	7.3500
4	Nb-1Zr	0.040	2.51	21.0	7.3900
	HEU	0.118	2.51	21.0	7.5080
	Nb-1Zr	0.040	2.51	21.0	7.5480
	Graphite	0.394	2.51	21.0	7.9420
5	Nb-1Zr	0.040	2.51	21.0	7.9820
	HEU	0.118	2.51	21.0	8.1000
	Nb-1Zr	0.040	2.51	21.0	8.1400
	Graphite	0.394	2.51	21.0	8.5340
6	Nb-1Zr	0.040	2.51	21.0	8.5740
	HEU	0.118	2.51	21.0	8.6920
	Nb-1Zr	0.040	2.51	21.0	8.7320
	Graphite	0.394	2.51	21.0	9.1260
7	Nb-1Zr	0.040	2.51	21.0	9.1660
	HEU	0.118	2.51	21.0	9.2840
	Nb-1Zr	0.040	2.51	21.0	9.3240
	Graphite	0.394	2.51	21.0	9.7180
8	Nb-1Zr	0.040	0	21.0	9.7580
	HEU	0.118	0	21.0	9.8760
	Nb-1Zr	0.040	0	21.0	9.9160
	Graphite	0.394	0	21.0	10.3100
9	Nb-1Zr	0.040	0	21.0	10.3500
	HEU	0.118	0	21.0	10.4680
	Nb-1Zr	0.040	0	21.0	10.5080
	Graphite	0.394	0	21.0	10.9020
10	Nb-1Zr	0.040	0	21.0	10.9420
	HEU	0.118	0	21.0	11.0600
	Nb-1Zr	0.040	0	21.0	11.1000
	Graphite	0.394	0	21.0	11.4940
11	Nb-1Zr	0.040	0	21.0	11.5340
	HEU	0.118	0	21.0	11.6520
	Nb-1Zr	0.040	0	21.0	11.6920
	Graphite	0.394	0	21.0	12.0860

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Diaphragm	Stainless Steel	0.075	0	24.8	12.1610
12	Nb-1Zr	0.040	0	21.0	12.2010
	HEU	0.118	0	21.0	12.3190
	Nb-1Zr	0.040	0	21.0	12.3590
	Graphite	0.394	0	21.0	12.7530
13	Nb-1Zr	0.040	0	21.0	12.7930
	HEU	0.118	0	21.0	12.9110
	Nb-1Zr	0.040	0	21.0	12.9510
	Graphite	0.394	0	21.0	13.3450
14	Nb-1Zr	0.040	0	21.0	13.3850
	HEU	0.118	6.005	21.0	13.5030
	Nb-1Zr	0.040	0	21.0	13.5430
	Graphite	0.394	0	21.0	13.9370
15	Nb-1Zr	0.040	0	21.0	13.9770
	HEU	0.118	6.005	21.0	14.0950
	Nb-1Zr	0.040	0	21.0	14.1350
	Graphite	0.394	0	21.0	14.5290
Top Reflector	Nb-1Zr	0.180	0	21.0	14.7090
	Graphite	5.00 (RCP01) 4.25 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	19.7090 (RCP01) 18.9590 (MCNP5, MCNP5 Space XS, RACER)

Table 72. Nb-1Zr-3 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	136.8	48.2	185.0	136.8	48.2	185.0
Nb-1Zr	51.7	24.7	76.4	51.7	24.7	76.4
Graphite	94.5	57.3	151.8	94.5	64.6	159.1
Total	283.1	130.1	413.2	283.1	137.5	420.5

Figure 66. Nb-1Zr-3 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 67. Nb-1Zr-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 73. Nb-1Zr-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
15 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
3.75	0.99736	0.00061	-	-	0.99222	0.00015	-	-
4.00	0.99968	0.00057	1.00001	0.00026	0.99411	0.00021	1.00004	0.00020
4.25	1.00169	0.00059	1.00180	0.00028	0.99589	0.00018	1.00179	0.00020
4.50	1.00264	0.00059	1.00344	0.00028	0.99763	0.00011	1.00336	0.00020
4.75	1.00448	0.00061	-	-	0.99923	0.00018	-	-
5.00	1.00581	0.00057	1.00653	0.00026	1.00052	0.00012	1.00654	0.00021
5.10	1.00712	0.00061	-	-	1.00107	0.00015	-	-
5.20	1.00691	0.00059	-	-	1.00147	0.00018	-	-
5.25	1.00748	0.00059	-	-	1.00178	0.00013	-	-
5.50	1.00848	0.00059	-	-	1.00307	0.00015	-	-
5.75	1.00929	0.00059	-	-	1.00410	0.00016	-	-

4.3.3 Niobium Critical Experiments Summary and Conclusions

This document provides the pre-experimental predictions for the Nb-1Zr critical experiments including the effect of the Planet assembly machine structure. These critical experiments are being performed to:

1. determine the adequacy of the existing Nb neutron cross section evaluations in neutron energy spectra characteristic of Prometheus reactor designs under normal and accident conditions,
2. reduce the uncertainty in k_{eff} for Prometheus reactor designs containing substantial amounts of Nb by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal and accident conditions, and
3. provide benchmark critical experiments needed to develop improved Nb neutron cross section evaluations if new evaluations are determined to be required.

Experiments 2 and 3 are designed to bracket the neutron energy spectrum expected in the Prometheus space nuclear reactor under normal operating conditions. A summary of the fission fraction in the thermal, intermediate, and fast energy ranges for each of the Nb-1Zr critical experiments is provided in Table 74. Nb-1Zr-2 and Nb-1Zr-3 are classified as fast spectrum experiments. A summary of the pre-experimental predictions for each of the Nb-1Zr critical experiments is provided in Table 75. Predictions from RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses are reported.

Comparisons of the RCP01 and MCNP5 predicted fission reaction rate spectra and RCP01 predicted fission reaction rate spectrum CDFs are provided in Figure 68 and Figure 69. Nb-1Zr experiments 2 and 3 clearly have a fast spectrum. Comparisons of the RCP01 and MCNP5 predicted Nb-1Zr absorption rate spectra are provided in Figure 70. The differences in the RCP01 and MCNP5 predicted absorption rates are believed to be primarily due to the different versions of the ^{93}Nb cross section evaluation used in the analyses. The RCP01 analyses used the ENDF/B-VI.1 ^{93}Nb evaluation while the MCNP5 analyses used the ENDF/B-VI.6. Neither ^{93}Nb cross section evaluations contained unresolved resonance data. SPACE05A used the same ENDF/B-VI.6 evaluations used in MCNP5's default cross cross sections, as evidenced by the very close agreement between the RACER and MCNP5 with space cross sections analyses and the MCNP5 with default cross sections analysis

Table 74. A Summary of the Energy Spectrum Covered in the Nb-1Zr Critical Experiments

Experiment	Percent Fissions by Energy (MCNP5 Predictions)		
	<0.625eV	0.625eV - 100keV	>100keV
Nb-1Zr-2	0.0%	22.1%	77.9%
Nb-1Zr-3	0.1%	33.9%	66.1%

Table 75. A Summary of the Pre-Experimental Predictions for the Nb-1Zr Critical Experiments

Experiment	Monte Carlo Code	Stacking Units	Top Reflector Thickness (in)	k_{eff}	95% Confidence Level	Mass of HEU (kg)	Mass of Nb-1Zr (kg)	Mass of Graphite (kg)
Nb-1Zr-2	RCP01	16	1.90	1.00092	0.00021	196.5	80.3	70.8
	MCNP5	16	1.75	1.00075	0.00055	196.5	80.3	69.3
	MCNP5 (Space XS)	16	1.75	1.00064	0.00026	196.5	80.3	69.3
	RACER	16	1.75	1.00138	0.00020	196.5	80.3	69.3
Nb-1Zr-3	RCP01	15	5.00	1.00052	0.00012	185.0	76.4	159.1
	MCNP5	15	4.25	1.00169	0.00059	185.0	76.4	151.8
	MCNP5 (Space XS)	15	4.25	1.00180	0.00028	185.0	76.4	151.8
	RACER	15	4.25	1.00179	0.00020	185.0	76.4	151.8

Figure 68: Comparison of RCP01 and MCNP5 Fission Rate Spectra for Nb-1Zr Critical Experiments

Figure 69: RCP01 Fission CDFs for the Nb-1Zr Critical Experiments

Figure 70: Comparison of RCP01 and MCNP5 Nb-1Zr Absorption Rate Spectra for Nb-1Zr Critical Experiments

4.4 Rhenium Critical Experiments

4.4.1 Re-1 Experiment

The Re-1 experiment is designed to simulate the hardest neutron spectrum, which is in the center of the Prometheus reactor core during normal operating conditions. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 71 and Figure 72 where aluminum is yellow, graphite is blue, Re is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The Re-1 assembly configuration, including plate layout and dimensions, is shown in Table 76. RCP01 and MCNP5 predict an assembly height of 6.694", while MCNP5 with space cross sections and RACER predict an assembly height of 6.644". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 4.444" high and contains 17 stacking units consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, a 0.0161" thick Re plate, and a 0.100" thick graphite plate and 1 stacking unit consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, and a 0.0161" thick Re plate, for a total of 18 stacking units. The RCP01 and MCNP5 analyses predict a 1.0" thick graphite bottom reflector and a 1.25" thick graphite top reflector. The MCNP5 with space cross sections and RACER analyses predict a 1.0" thick graphite bottom reflector and a 1.20" thick graphite top reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Re-1 assembly contains 219.6 kg of HEU and 68.8 kg of Re. The distribution of material in the top and bottom half of the assembly is given in Table 77 for RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Re-1 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 73 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Re-1 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 73, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0013 \pm 0.0006 \Delta k$ over the range from 8 to 28 stacking units. Figure 74 and Table 78 provide a comparison of the predicted k_{eff} of the Re-1 assembly with 18 and 19 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($p < 0.5\%$) are highlighted in green in Table 78. The Re-1 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 83.1% fast ($E > 100$ keV), 16.9% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 71. Cross-sectional View of the Re-1 Assembly

Figure 72. Cross-sectional Close-up View of the Re-1 Assembly

Table 76. Predicted Critical Configuration for the Re-1 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	1.00	2.51	21.0	1.0000
1	Re	0.0161	2.51	21.0	1.0161
	HEU	0.118	2.51	21.0	1.1341
	Re	0.0161	2.51	21.0	1.1502
	Graphite	0.100	2.51	21.0	1.2502
2	Re	0.0161	2.51	21.0	1.2663
	HEU	0.118	2.51	21.0	1.3843
	Re	0.0161	2.51	21.0	1.4004
	Graphite	0.100	2.51	21.0	1.5004
3	Re	0.0161	2.51	21.0	1.5165
	HEU	0.118	2.51	21.0	1.6345
	Re	0.0161	2.51	21.0	1.6506
	Graphite	0.100	2.51	21.0	1.7506
4	Re	0.0161	2.51	21.0	1.7667
	HEU	0.118	2.51	21.0	1.8847
	Re	0.0161	2.51	21.0	1.9008
	Graphite	0.100	2.51	21.0	2.0008
5	Re	0.0161	2.51	21.0	2.0169
	HEU	0.118	2.51	21.0	2.1349
	Re	0.0161	2.51	21.0	2.1510
	Graphite	0.100	2.51	21.0	2.2510
6	Re	0.0161	2.51	21.0	2.2671
	HEU	0.118	2.51	21.0	2.3851
	Re	0.0161	2.51	21.0	2.4012
	Graphite	0.100	2.51	21.0	2.5012
7	Re	0.0161	2.51	21.0	2.5173
	HEU	0.118	2.51	21.0	2.6353
	Re	0.0161	2.51	21.0	2.6514
	Graphite	0.100	2.51	21.0	2.7514
8	Re	0.0161	0	21.0	2.7675
	HEU	0.118	0	21.0	2.8855
	Re	0.0161	0	21.0	2.9016
	Graphite	0.100	0	21.0	3.0016
9	Re	0.0161	0	21.0	3.0177
	HEU	0.118	0	21.0	3.1357
	Re	0.0161	0	21.0	3.1518
	Graphite	0.100	0	21.0	3.2518
Diaphragm	Stainless Steel	0.040	0	24.8	3.2918
10	Re	0.0161	0	21.0	3.3079
	HEU	0.118	0	21.0	3.4259
	Re	0.0161	0	21.0	3.4420
	Graphite	0.100	0	21.0	3.5420

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Re	0.0161	0	21.0	3.5581
	HEU	0.118	0	21.0	3.6761
	Re	0.0161	0	21.0	3.6922
	Graphite	0.100	0	21.0	3.7922
12	Re	0.0161	0	21.0	3.8083
	HEU	0.118	0	21.0	3.9263
	Re	0.0161	0	21.0	3.9424
	Graphite	0.100	0	21.0	4.0424
13	Re	0.0161	0	21.0	4.0585
	HEU	0.118	0	21.0	4.1765
	Re	0.0161	0	21.0	4.1926
	Graphite	0.100	0	21.0	4.2926
14	Re	0.0161	0	21.0	4.3087
	HEU	0.118	6.005	21.0	4.4267
	Re	0.0161	0	21.0	4.4428
	Graphite	0.100	0	21.0	4.5428
15	Re	0.0161	0	21.0	4.5589
	HEU	0.118	6.005	21.0	4.6769
	Re	0.0161	0	21.0	4.6930
	Graphite	0.100	0	21.0	4.7930
16	Re	0.0161	0	21.0	4.8091
	HEU	0.118	6.005	21.0	4.9271
	Re	0.0161	0	21.0	4.9432
	Graphite	0.100	0	21.0	5.0432
17	Re	0.0161	0	21.0	5.0593
	HEU	0.118	6.005	21.0	5.1773
	Re	0.0161	0	21.0	5.1934
	Graphite	0.100	0	21.0	5.2934
18	Re	0.0161	0	21.0	5.3095
	HEU	0.118	6.005	21.0	5.4275
	Re	0.0161	0	21.0	5.4436
Top Reflector	Graphite	1.25 (RCP01, MCNP5) 1.20 (RACER, MCNP5 Space XS)	0	21.0	6.6936 (RCP01, MCNP5) 6.6436 (RACER, MCNP5 Space XS)

Table 77. Re-1 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	107.8	219.6	111.7	107.8	219.6
Re	34.2	34.6	68.8	34.2	34.6	68.8
Graphite	18.4	20.2	38.6	18.4	19.7	38.1
Total	164.4	162.6	326.9	164.4	162.1	326.4

Figure 73. Re-1 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 74. Re-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 78. Re-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
18 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.00	0.99096	0.00051	0.99112	0.00024	0.98972	0.00017	0.99194	0.00020
1.10	0.99598	0.00055	0.99591	0.00026	0.99441	0.00012	0.99682	0.00018
1.20	1.00022	0.00055	1.00035	0.00024	0.99888	0.00016	1.00122	0.00019
1.25	1.00179	0.00053	1.00255	0.00024	1.00113	0.00016	1.00366	0.00019
1.30	1.00467	0.00051	1.00489	0.00026	1.00328	0.00015	1.00570	0.00018
1.40	1.00882	0.00055	1.00890	0.00026	1.00739	0.00015	1.00972	0.00019
19 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.70	0.99875	0.00053	Not investigated due to termination of project.		0.99761	0.00017	Not investigated due to termination of project.	
0.74	1.00068	0.00053			0.99971	0.00017		
0.75	1.00130	0.00055			1.00019	0.00013		
0.80	1.00427	0.00053			1.00272	0.00020		
0.84	1.00575	0.00055			1.00465	0.00018		
0.85	1.00626	0.00055			1.00521	0.00009		
1.00	1.01378	0.00053			1.01238	0.00015		

4.4.2 Re-2 Experiment

The Re-2 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be harder than the expected average neutron energy spectrum of the core but softer than the Re-1 experiment. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 75 and Figure 76 where aluminum is yellow, graphite is blue, Re is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 79. The RCP01 analysis predicts an assembly height of 9.595" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 9.495". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 5.745" high and contains 16 stacking units consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, a 0.0161" thick Re plate, and a 0.197" thick graphite plate and 1 stacking unit consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, and a 0.0161" thick Re plate, for a total of 17 stacking units. The bottom reflector consists of a 2.0" thick graphite reflector. The RCP01 predicted top reflector consists of a 1.85" thick graphite reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 1.75" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Re-2 assembly contains 208.0 kg of HEU and 64.9 kg of Re. The distribution of materials in the top and bottom half of the assembly is given in Table 80 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Re-2 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 77 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Re-2 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 77, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0030 \pm 0.0006 \Delta k$ over the range from 8 to 28 stacking units. Figure 78 and Table 81 provide a comparison of the predicted k_{eff} of the Re-2 assembly with 16 and 17 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 81. The Re-2 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 76.8% fast ($E > 100$ keV), 23.2% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 75. Cross-sectional View of the Re-2 Assembly

Figure 76. Cross-sectional Close-up View of the Re-2 Assembly

Table 79. Predicted Critical Configuration for the Re-2 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	2.00	2.51	21.0	2.0000
1	Re	0.0161	2.51	21.0	2.0161
	HEU	0.118	2.51	21.0	2.1341
	Re	0.0161	2.51	21.0	2.1502
	Graphite	0.197	2.51	21.0	2.3472
2	Re	0.0161	2.51	21.0	2.3633
	HEU	0.118	2.51	21.0	2.4813
	Re	0.0161	2.51	21.0	2.4974
	Graphite	0.197	2.51	21.0	2.6944
3	Re	0.0161	2.51	21.0	2.7105
	HEU	0.118	2.51	21.0	2.8285
	Re	0.0161	2.51	21.0	2.8446
	Graphite	0.197	2.51	21.0	3.0416
4	Re	0.0161	2.51	21.0	3.0577
	HEU	0.118	2.51	21.0	3.1757
	Re	0.0161	2.51	21.0	3.1918
	Graphite	0.197	2.51	21.0	3.3888
5	Re	0.0161	2.51	21.0	3.4049
	HEU	0.118	2.51	21.0	3.5229
	Re	0.0161	2.51	21.0	3.5390
	Graphite	0.197	2.51	21.0	3.7360
6	Re	0.0161	2.51	21.0	3.7521
	HEU	0.118	2.51	21.0	3.8701
	Re	0.0161	2.51	21.0	3.8862
	Graphite	0.197	2.51	21.0	4.0832
7	Re	0.0161	2.51	21.0	4.0993
	HEU	0.118	2.51	21.0	4.2173
	Re	0.0161	2.51	21.0	4.2334
	Graphite	0.197	2.51	21.0	4.4304
8	Re	0.0161	0	21.0	4.4465
	HEU	0.118	0	21.0	4.5645
	Re	0.0161	0	21.0	4.5806
	Graphite	0.197	0	21.0	4.7776
9	Re	0.0161	0	21.0	4.7937
	HEU	0.118	0	21.0	4.9117
	Re	0.0161	0	21.0	4.9278
	Graphite	0.197	0	21.0	5.1248
Diaphragm	Stainless Steel	0.040	0	24.8	5.1648
10	Re	0.0161	0	21.0	5.1809
	HEU	0.118	0	21.0	5.2989
	Re	0.0161	0	21.0	5.3150
	Graphite	0.197	0	21.0	5.5120

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Re	0.0161	0	21.0	5.5281
	HEU	0.118	0	21.0	5.6461
	Re	0.0161	0	21.0	5.6622
	Graphite	0.197	0	21.0	5.8592
12	Re	0.0161	0	21.0	5.8753
	HEU	0.118	0	21.0	5.9933
	Re	0.0161	0	21.0	6.0094
	Graphite	0.197	0	21.0	6.2064
13	Re	0.0161	0	21.0	6.2225
	HEU	0.118	0	21.0	6.3405
	Re	0.0161	0	21.0	6.3566
	Graphite	0.197	0	21.0	6.5536
14	Re	0.0161	0	21.0	6.5697
	HEU	0.118	6.005	21.0	6.6877
	Re	0.0161	0	21.0	6.7038
	Graphite	0.197	0	21.0	6.9008
15	Re	0.0161	0	21.0	6.9169
	HEU	0.118	6.005	21.0	7.0349
	Re	0.0161	0	21.0	7.0510
	Graphite	0.197	0	21.0	7.2480
16	Re	0.0161	0	21.0	7.2641
	HEU	0.118	6.005	21.0	7.3821
	Re	0.0161	0	21.0	7.3982
	Graphite	0.197	0	21.0	7.5952
17	Re	0.0161	0	21.0	7.6113
	HEU	0.118	6.005	21.0	7.7293
	Re	0.0161	0	21.0	7.7454
Top Reflector	Graphite	1.85 (RCP01) 1.75 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	9.5954 (RCP01) 9.4954 (MCNP5, MCNP5 Space XS, RACER)

Table 80. Re-2 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	96.3	208.0	111.7	96.3	208.0
Re	34.2	30.7	64.9	34.2	30.7	64.9
Graphite	36.6	30.8	67.4	36.6	31.7	68.4
Total	182.5	157.8	340.4	182.5	158.8	341.3

Figure 77. Re-2 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 78. Re-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 81. Re-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
2.00	0.98622	0.00055	Not investigated due to termination of project.		0.98361	0.00014	Not investigated due to termination of project.	
2.50	0.99913	0.00055			0.99604	0.00013		
2.60	1.00130	0.00053			0.99819	0.00014		
2.70	1.00362	0.00055			1.00031	0.00015		
2.75	1.00434	0.00057			1.00133	0.00015		
2.80	1.00549	0.00055			1.00228	0.00022		
17 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
1.70	0.99979	0.00055	0.99980	0.00026	0.99675	0.00012	1.00034	0.00019
1.75	1.00113	0.00053	1.00116	0.00026	0.99807	0.00013	1.00204	0.00019
1.80	1.00237	0.00051	1.00262	0.00026	0.99960	0.00014	1.00348	0.00019
1.85	1.00415	0.00055	1.00416	0.00026	1.00093	0.00014	1.00500	0.00018
1.90	1.00533	0.00055	-	-	1.00227	0.00014	-	-
2.00	1.00785	0.00057	-	-	1.00495	0.00012	-	-

4.4.3 Re-3 Experiment

The Re-3 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be softer than the expected average neutron energy spectrum of the core. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 79 and Figure 80 where aluminum is yellow, graphite is blue, Re is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 82. The RCP01 analysis predicts an assembly height of 18.803" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 17.853". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 8.353" high and contains 15 stacking units consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, a 0.0161" thick Re plate, and a 0.394" thick graphite plate and 1 stacking unit consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, and a 0.0161" thick Re plate, for a total of 16 stacking units. The bottom reflector consists of a 5.0" thick graphite reflector. The RCP01 predicted top reflector consists of a 5.45" thick graphite reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 4.50" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Re-3 assembly contains 196.5 kg of HEU and 61.1 kg of Re. The distribution of materials in the top and bottom half of the assembly is given in Table 83 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Re-3 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 81 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Re-3 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0052 \pm 0.0006 \Delta k$ over the range from 8 to 28 stacking units. Figure 82 and Table 84 provide a comparison of the predicted k_{eff} of the Re-3 assembly with 16 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 84. The Re-3 assembly is classified as a fast spectrum assembly with the following representative fission fractions as predicted by MCNP5: 65.8% fast ($E > 100$ keV), 34.1% intermediate (0.625 eV $< E < 100$ keV), and 0.04% thermal ($E < 0.625$ eV).

Figure 79. Cross-sectional View of the Re-3 Assembly

Figure 80. Cross-sectional Close-up View of the Re-3 Assembly

Table 82. Predicted Critical Configuration for the Re-3 Assembly.

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	5.00	2.51	21.0	5.0000
1	Re	0.0161	2.51	21.0	5.0161
	HEU	0.118	2.51	21.0	5.1341
	Re	0.0161	2.51	21.0	5.1502
	Graphite	0.394	2.51	21.0	5.5442
2	Re	0.0161	2.51	21.0	5.5603
	HEU	0.118	2.51	21.0	5.6783
	Re	0.0161	2.51	21.0	5.6944
	Graphite	0.394	2.51	21.0	6.0884
3	Re	0.0161	2.51	21.0	6.1045
	HEU	0.118	2.51	21.0	6.2225
	Re	0.0161	2.51	21.0	6.2386
	Graphite	0.394	2.51	21.0	6.6326
4	Re	0.0161	2.51	21.0	6.6487
	HEU	0.118	2.51	21.0	6.7667
	Re	0.0161	2.51	21.0	6.7828
	Graphite	0.394	2.51	21.0	7.1768
5	Re	0.0161	2.51	21.0	7.1929
	HEU	0.118	2.51	21.0	7.3109
	Re	0.0161	2.51	21.0	7.3270
	Graphite	0.394	2.51	21.0	7.7210
6	Re	0.0161	2.51	21.0	7.7371
	HEU	0.118	2.51	21.0	7.8551
	Re	0.0161	2.51	21.0	7.8712
	Graphite	0.394	2.51	21.0	8.2652
7	Re	0.0161	2.51	21.0	8.2813
	HEU	0.118	2.51	21.0	8.3993
	Re	0.0161	2.51	21.0	8.4154
	Graphite	0.394	2.51	21.0	8.8094
8	Re	0.0161	0	21.0	8.8255
	HEU	0.118	0	21.0	8.9435
	Re	0.0161	0	21.0	8.9596
	Graphite	0.394	0	21.0	9.3536
Diaphragm	Stainless Steel	0.040	0	24.8	9.3936
9	Re	0.0161	0	21.0	9.4097
	HEU	0.118	0	21.0	9.5277
	Re	0.0161	0	21.0	9.5438
	Graphite	0.394	0	21.0	9.9378
10	Re	0.0161	0	21.0	9.9539
	HEU	0.118	0	21.0	10.0719
	Re	0.0161	0	21.0	10.0880
	Graphite	0.394	0	21.0	10.4820

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Re	0.0161	0	21.0	10.4981
	HEU	0.118	0	21.0	10.6161
	Re	0.0161	0	21.0	10.6322
	Graphite	0.394	0	21.0	11.0262
12	Re	0.0161	0	21.0	11.0423
	HEU	0.118	0	21.0	11.1603
	Re	0.0161	0	21.0	11.1764
	Graphite	0.394	0	21.0	11.5704
13	Re	0.0161	0	21.0	11.5865
	HEU	0.118	0	21.0	11.7045
	Re	0.0161	0	21.0	11.7206
	Graphite	0.394	0	21.0	12.1146
14	Re	0.0161	0	21.0	12.1307
	HEU	0.118	6.005	21.0	12.2487
	Re	0.0161	0	21.0	12.2648
	Graphite	0.394	0	21.0	12.6588
15	Re	0.0161	0	21.0	12.6749
	HEU	0.118	6.005	21.0	12.7929
	Re	0.0161	0	21.0	12.8090
	Graphite	0.394	0	21.0	13.2030
16	Re	0.0161	0	21.0	13.2191
	HEU	0.118	6.005	21.0	13.3371
	Re	0.0161	0	21.0	13.3532
Top Reflector	Graphite	5.45 (RCP01) 4.50 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	18.8032 (RCP01) 17.8532 (MCNP5, MCNP5 Space XS, RACER)

Table 83. Re-3 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	99.2	97.3	196.5	99.2	97.3	196.5
Re	30.3	30.7	61.1	30.3	30.7	61.1
Graphite	79.1	71.4	150.4	79.1	81.2	160.2
Total	208.6	199.4	408.0	208.6	209.2	417.8

Figure 81. Re-3 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 82. Re-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 84. Re-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
4.25	0.99893	0.00055	0.99978	0.00026	0.99435	0.00014	1.00052	0.00020
4.50	1.00150	0.00057	1.00161	0.00026	0.99596	0.00022	1.00216	0.00020
4.75	1.00257	0.00057	1.00316	0.00026	0.99757	0.00017	1.00386	0.00020
5.00	1.00440	0.00055	-	-	0.99887	0.00016	-	-
5.25	1.00532	0.00059	-	-	1.00015	0.00014	-	-
5.35	1.00575	0.00057	-	-	1.00074	0.00016	-	-
5.45	1.00697	0.00057	1.00648	0.00026	1.00108	0.00014	1.00737	0.00020
5.50	1.00697	0.00055	-	-	1.00133	0.00019	-	-

4.4.4 Re-4 Experiment

The Re-4 experiment is designed to simulate the average neutron spectrum of the Prometheus reactor core when flooded with water. Polyethylene is used to simulate flooding with water. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 83 and Figure 84 where aluminum is yellow, polyethylene is light blue, Re is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 85. The RCP01 analysis predicts an assembly height of 5.613" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 5.513". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 3.413" high and contains 14 stacking units consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, a 0.0161" thick Re plate, and a 0.080" thick polyethylene plate and 1 stacking unit consisting of a 0.0161" thick Re plate, a 0.118" thick HEU plate, and a 0.0161" thick Re plate, for a total of 15 stacking units. The bottom reflector consists of a 1.0" thick graphite reflector. The RCP01 predicted top reflector consists of a 1.20" thick polyethylene reflector and the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 1.10" thick polyethylene reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Re-4 assembly contains 185.0 kg of HEU and 57.2 kg of Re. The distribution of materials in the top and bottom half of the assembly is given in Table 86 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Re-4 assembly during the approach to critical as a function of both the number of stacking units and the polyethylene top reflector thickness. Figure 85 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Re-4 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 85, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0041 \pm 0.0007 \Delta k$ over the range from 8 to 28 stacking units. Figure 86 and Table 87 provide a comparison of the predicted k_{eff} of the Re-4 assembly with 15 and 16 stacking units as a function of the polyethylene top reflector thickness. It should be noted that the RACER predicted eigenvalues are below that of the MCNP5 with space cross sections, contrary to the results of other experiments. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 87. The Re-4 assembly is classified as a mixed spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 48.7% fast ($E > 100$ keV), 44.6% intermediate (0.625 eV $< E < 100$ keV), and 6.7% thermal ($E < 0.625$ eV).

Figure 83. Cross-sectional View of the Re-4 Assembly

Figure 84. Cross-sectional Close-up View of the Re-4 Assembly

Table 85. Predicted Critical Configuration of the Re-4 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Poly	1.00	2.51	21.0	1.0000
1	Re	0.0161	2.51	21.0	1.0161
	HEU	0.118	2.51	21.0	1.1341
	Re	0.0161	2.51	21.0	1.1502
	Poly	0.080	2.51	21.0	1.2302
2	Re	0.0161	2.51	21.0	1.2463
	HEU	0.118	2.51	21.0	1.3643
	Re	0.0161	2.51	21.0	1.3804
	Poly	0.080	2.51	21.0	1.4604
3	Re	0.0161	2.51	21.0	1.4765
	HEU	0.118	2.51	21.0	1.5945
	Re	0.0161	2.51	21.0	1.6106
	Poly	0.080	2.51	21.0	1.6906
4	Re	0.0161	2.51	21.0	1.7067
	HEU	0.118	2.51	21.0	1.8247
	Re	0.0161	2.51	21.0	1.8408
	Poly	0.080	2.51	21.0	1.9208
5	Re	0.0161	2.51	21.0	1.9369
	HEU	0.118	2.51	21.0	2.0549
	Re	0.0161	2.51	21.0	2.0710
	Poly	0.080	2.51	21.0	2.1510
6	Re	0.0161	2.51	21.0	2.1671
	HEU	0.118	2.51	21.0	2.2851
	Re	0.0161	2.51	21.0	2.3012
	Poly	0.080	2.51	21.0	2.3812
7	Re	0.0161	2.51	21.0	2.3973
	HEU	0.118	2.51	21.0	2.5153
	Re	0.0161	2.51	21.0	2.5314
	Poly	0.080	2.51	21.0	2.6114
8	Re	0.0161	0	21.0	2.6275
	HEU	0.118	0	21.0	2.7455
	Re	0.0161	0	21.0	2.7616
	Poly	0.080	0	21.0	2.8416
Diaphragm	Stainless Steel	0.040	0	24.8	2.8816
9	Re	0.0161	0	21.0	2.8977
	HEU	0.118	0	21.0	3.0157
	Re	0.0161	0	21.0	3.0318
	Poly	0.080	0	21.0	3.1118
10	Re	0.0161	0	21.0	3.1279
	HEU	0.118	0	21.0	3.2459
	Re	0.0161	0	21.0	3.2620
	Poly	0.080	0	21.0	3.3420

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Re	0.0161	0	21.0	3.3581
	HEU	0.118	0	21.0	3.4761
	Re	0.0161	0	21.0	3.4922
	Poly	0.080	0	21.0	3.5722
12	Re	0.0161	0	21.0	3.5883
	HEU	0.118	0	21.0	3.7063
	Re	0.0161	0	21.0	3.7224
	Poly	0.080	0	21.0	3.8024
13	Re	0.0161	0	21.0	3.8185
	HEU	0.118	0	21.0	3.9365
	Re	0.0161	0	21.0	3.9526
	Poly	0.080	0	21.0	4.0326
14	Re	0.0161	0	21.0	4.0487
	HEU	0.118	6.005	21.0	4.1667
	Re	0.0161	0	21.0	4.1828
	Poly	0.080	0	21.0	4.2628
15	Re	0.0161	0	21.0	4.2789
	HEU	0.118	6.005	21.0	4.3969
	Re	0.0161	0	21.0	4.4130
Top Reflector	Poly	1.20 (RCP01) 1.10 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	5.6130 (RCP01) 5.5130 (MCNP5, MCNP5 Space XS, RACER)

Table 86. Re-4 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	99.2	85.8	185.0	99.2	85.8	185.0
Re	30.3	26.9	57.2	30.3	26.9	57.2
Polyethylene	8.8	8.6	17.4	8.8	9.3	18.1
Total	138.3	121.3	259.6	138.3	122.0	260.4

Figure 85. Re-4 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 86. Re-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 87. Re-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
15 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.00	0.99658	0.00061	0.99697	0.00026	0.99273	0.00014	0.99540	0.00021
1.10	1.00097	0.00061	1.00117	0.00028	0.99702	0.00019	0.99969	0.00021
1.14	1.00305	0.00059	1.00296	0.00028	0.99873	0.00013	1.00118	0.00020
1.18	1.00402	0.00059	1.00475	0.00028	1.00021	0.00013	1.00281	0.00021
1.20	1.00506	0.00059	1.00520	0.00028	1.00097	0.00010	1.00343	0.00021
1.24	1.00622	0.00057	-	-	1.00242	0.00012	-	-
1.28	1.00719	0.00063	-	-	1.00387	0.00014	-	-
16 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.60	0.99804	0.00059	Not investigated due to termination of project.		0.99352	0.00017	Not investigated due to termination of project.	
0.64	1.00009	0.00057			0.99575	0.00013		
0.68	1.00174	0.00059			0.99776	0.00017		
0.70	1.00278	0.00059			0.99867	0.00011		
0.74	1.00496	0.00057			1.00077	0.00016		
0.78	1.00677	0.00059			1.00279	0.00018		
0.80	1.00780	0.00061			1.00388	0.00013		
0.84	1.01024	0.00059			1.00565	0.00016		
0.88	1.01086	0.00061			1.00751	0.00011		
0.90	1.01229	0.00061			1.00848	0.00018		
1.00	1.01671	0.00059			1.01272	0.00018		

4.4.5 Rhenium Critical Experiments Summary and Conclusions

This document provides the pre-experimental predictions for the Re critical experiments including the effect of the Planet assembly machine structure. These critical experiments are being performed to:

1. determine the adequacy of the existing ^{185}Re and ^{187}Re neutron cross section evaluations in a neutron energy spectrum characteristic of the Prometheus reactor designs under normal and accident conditions,
2. reduce the uncertainty in k_{eff} for Prometheus reactor designs containing substantial amounts of rhenium by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal and accident conditions, and
3. provide benchmark critical experiments needed to develop improved ^{185}Re and ^{187}Re neutron cross section evaluations if new evaluations are determined to be required.

The first 3 experiments are designed to bracket the neutron energy spectrum expected in the Prometheus space nuclear reactor under normal operating conditions. The Re-4 experiment is designed to approximate the neutron energy spectrum expected in accident conditions in which the core is flooded and surrounded by water or wet sand. A summary of the fission fraction in the thermal, intermediate, and fast energy ranges for each of the Re critical experiments is provided in Table 88. Re-1, Re-2, and Re-3 experiments are fast spectrum experiments while the Re-4 experiment is a mixed spectrum experiment. A summary of the pre-experimental predictions for each of the Re critical experiments is provided in Table 89. Predictions from RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses are reported.

Table 88. A Summary of the Energy Spectrum Covered in the Re Critical Experiments

Experiment	Percent Fissions by Energy (MCNP5 Predictions)		
	<0.625eV	0.625eV - 100keV	>100keV
Re-1	0.00%	16.93%	83.07%
Re-2	0.00%	23.23%	76.77%
Re-3	0.04%	34.13%	65.83%
Re-4	6.72%	44.62%	48.65%

Table 89. A Summary of the Pre-Experimental Predictions for the Re Critical Experiments

Experiment	Monte Carlo Code	Stacking Units	Top Reflector Thickness (in)	k_{eff}	95% Confidence Level	Mass of HEU (kg)	Mass of Re (kg)	Mass of Moderator (graphite/polyethylene) (kg)
Re-1	RCP01	18	1.25	1.00113	0.00016	219.6	68.8	38.6
	MCNP5	18	1.25	1.00179	0.00053	219.6	68.8	38.6
	MCNP5 (Space XS)	18	1.20	1.00035	0.00024	219.6	68.8	38.1
	RACER	18	1.20	1.00122	0.00019	219.6	68.8	38.1
Re-2	RCP01	17	1.85	1.00093	0.00014	208.0	64.9	68.4
	MCNP5	17	1.75	1.00113	0.00053	208.0	64.9	67.4
	MCNP5 (Space XS)	17	1.75	1.00116	0.00026	208.0	64.9	67.4
	RACER	17	1.75	1.00204	0.00019	208.0	64.9	67.4
Re-3	RCP01	16	5.45	1.00108	0.00014	196.5	61.1	160.2
	MCNP5	16	4.50	1.00150	0.00057	196.5	61.1	150.4
	MCNP5 (Space XS)	16	4.50	1.00161	0.00026	196.5	61.1	150.4
	RACER	16	4.50	1.00216	0.00020	196.5	61.1	150.4
Re-4	RCP01	15	1.20	1.00097	0.00010	185.0	57.2	18.1
	MCNP5	15	1.10	1.00097	0.00061	185.0	57.2	17.4
	MCNP5 (Space XS)	15	1.10	1.00117	0.00028	185.0	57.2	17.4
	RACER	15	1.10	0.99969	0.00021	185.0	57.2	17.4

4.5 Tantalum Critical Experiments

4.5.1 Ta-2.5W-1 Experiment

The Ta-2.5W-1 experiment is designed to simulate the hardest neutron spectrum, which is in the center of the Prometheus reactor core during normal operating conditions. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 87 and Figure 88 where aluminum is yellow, graphite is blue, Ta-2.5W is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The Ta-2.5W-1 assembly configuration, including plate layout and dimensions, is shown in Table 90. The RCP01 analysis predicts an assembly height of 7.350" and the MCNP5, MCNP5 with space cross sections, and RACER analyses predict an assembly height of 7.300". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 4.950" high and contains one 0.100" thick graphite plate and 18 stacking units consisting of a 0.0246" thick Ta-2.5W plate, a 0.118" thick HEU plate, a 0.0246" thick Ta-2.5W plate, and a 0.100" thick graphite plate. The bottom reflector consists of a 1.0" thick graphite reflector and a 0.15" thick Ta-2.5W reflector. The RCP01 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.10" thick graphite reflector, while the MCNP5, MCNP5 with space cross sections, and RACER predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.05" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Ta-2.5W-1 assembly contains 219.6 kg of HEU and 111.7 kg of Ta-2.5W. The distribution of material in the top and bottom half of the assembly is given in Table 91 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Ta-2.5W-1 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 89 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Ta-2.5W-1 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 89, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0025 \pm 0.0004 \Delta k$ over the range from 8 to 28 stacking units. Figure 90 and Table 92 provide a comparison of the predicted k_{eff} of the Ta-2.5W-1 assembly with 18 and 19 stacking units as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 92. The Ta-2.5W-1 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 86.0% fast ($E > 100$ keV), 14.0% intermediate (0.625 eV $< E < 100$ keV), and 0.0% thermal ($E < 0.625$ eV).

Figure 87. Cross-sectional View of the Ta-2.5W-1 Assembly

Figure 88. Cross-sectional Close-up View of the Ta-2.5W-1 Assembly

Table 90. Predicted Critical Configuration for the Ta-2.5W-1 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	1.00	2.51	21.0	1.0000
	Ta-2.5W	0.150	2.51	21.0	1.1500
	Graphite	0.100	2.51	21.0	1.2500
1	Ta-2.5W	0.0246	2.51	21.0	1.2746
	HEU	0.118	2.51	21.0	1.3926
	Ta-2.5W	0.0246	2.51	21.0	1.4172
	Graphite	0.100	2.51	21.0	1.5172
2	Ta-2.5W	0.0246	2.51	21.0	1.5418
	HEU	0.118	2.51	21.0	1.6598
	Ta-2.5W	0.0246	2.51	21.0	1.6844
	Graphite	0.100	2.51	21.0	1.7844
3	Ta-2.5W	0.0246	2.51	21.0	1.8090
	HEU	0.118	2.51	21.0	1.9270
	Ta-2.5W	0.0246	2.51	21.0	1.9516
	Graphite	0.100	2.51	21.0	2.0516
4	Ta-2.5W	0.0246	2.51	21.0	2.0762
	HEU	0.118	2.51	21.0	2.1942
	Ta-2.5W	0.0246	2.51	21.0	2.2188
	Graphite	0.100	2.51	21.0	2.3188
5	Ta-2.5W	0.0246	2.51	21.0	2.3434
	HEU	0.118	2.51	21.0	2.4614
	Ta-2.5W	0.0246	2.51	21.0	2.4860
	Graphite	0.100	2.51	21.0	2.5860
6	Ta-2.5W	0.0246	2.51	21.0	2.6106
	HEU	0.118	2.51	21.0	2.7286
	Ta-2.5W	0.0246	2.51	21.0	2.7532
	Graphite	0.100	2.51	21.0	2.8532
7	Ta-2.5W	0.0246	2.51	21.0	2.8778
	HEU	0.118	2.51	21.0	2.9958
	Ta-2.5W	0.0246	2.51	21.0	3.0204
	Graphite	0.100	2.51	21.0	3.1204
8	Ta-2.5W	0.0246	0	21.0	3.1450
	HEU	0.118	0	21.0	3.2630
	Ta-2.5W	0.0246	0	21.0	3.2876
	Graphite	0.100	0	21.0	3.3876
9	Ta-2.5W	0.0246	0	21.0	3.4122
	HEU	0.118	0	21.0	3.5302
	Ta-2.5W	0.0246	0	21.0	3.5548
	Graphite	0.100	0	21.0	3.6548
Diaphragm	Stainless Steel	0.040	0	24.8	3.6948
10	Ta-2.5W	0.0246	0	21.0	3.7194
	HEU	0.118	0	21.0	3.8374
	Ta-2.5W	0.0246	0	21.0	3.8620
	Graphite	0.100	0	21.0	3.9620

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Ta-2.5W	0.0246	0	21.0	3.9866
	HEU	0.118	0	21.0	4.1046
	Ta-2.5W	0.0246	0	21.0	4.1292
	Graphite	0.100	0	21.0	4.2292
12	Ta-2.5W	0.0246	0	21.0	4.2538
	HEU	0.118	0	21.0	4.3718
	Ta-2.5W	0.0246	0	21.0	4.3964
	Graphite	0.100	0	21.0	4.4964
13	Ta-2.5W	0.0246	0	21.0	4.5210
	HEU	0.118	0	21.0	4.6390
	Ta-2.5W	0.0246	0	21.0	4.6636
	Graphite	0.100	0	21.0	4.7636
14	Ta-2.5W	0.0246	0	21.0	4.7882
	HEU	0.118	6.005	21.0	4.9062
	Ta-2.5W	0.0246	0	21.0	4.9308
	Graphite	0.100	0	21.0	5.0308
15	Ta-2.5W	0.0246	0	21.0	5.0554
	HEU	0.118	6.005	21.0	5.1734
	Ta-2.5W	0.0246	0	21.0	5.1980
	Graphite	0.100	0	21.0	5.2980
16	Ta-2.5W	0.0246	0	21.0	5.3226
	HEU	0.118	6.005	21.0	5.4406
	Ta-2.5W	0.0246	0	21.0	5.4652
	Graphite	0.100	0	21.0	5.5652
17	Ta-2.5W	0.0246	0	21.0	5.5898
	HEU	0.118	6.005	21.0	5.7078
	Ta-2.5W	0.0246	0	21.0	5.7324
	Graphite	0.100	0	21.0	5.8324
18	Ta-2.5W	0.0246	0	21.0	5.8570
	HEU	0.118	6.005	21.0	5.9750
	Ta-2.5W	0.0246	0	21.0	5.9996
	Graphite	0.100	0	21.0	6.0996
Top Reflector	Ta-2.5W	0.150	0	21.0	6.2496
	Graphite	1.10 (RCP01) 1.05 (MCNP5, MCNP5 Space XS, RACER)	0	21.0	7.3496 (RCP01) 7.2996 (MCNP5, MCNP5 Space XS, RACER)

Table 91. Ta-2.5W-1 Assembly Material Mass Distribution

Material	Mass (kg)					
	MCNP5/MCNP5 (Space XS)/RACER			RCP01		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	107.8	219.6	111.7	107.8	219.6
Ta-2.5W	55.5	56.2	111.7	55.5	56.2	111.7
Graphite	19.4	19.2	38.6	19.4	19.7	39.1
Total	186.7	183.2	369.9	186.7	183.7	370.4

Figure 89. Ta-2.5W-1 Assembly k_{eff} as a Function of the Number of Stacking Units Figure 90. Ta-2.5W-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 92. Ta-2.5W-1 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
18 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.90	0.99471	0.00053	0.99518	0.00026	0.99243	0.00013	0.99661	0.00019
1.00	0.99930	0.00051	0.99932	0.00026	0.99654	0.00015	1.00061	0.00019
1.05	1.00077	0.00057	1.00126	0.00026	0.99849	0.00014	1.00257	0.00019
1.10	1.00299	0.00053	1.00341	0.00024	1.00048	0.00012	1.00465	0.00018
1.15	1.00473	0.00057	1.00504	0.00024	1.00240	0.00014	1.00658	0.00019
1.20	1.00688	0.00053	1.00726	0.00026	1.00418	0.00013	1.00843	0.00020
1.25	1.00836	0.00053	1.00894	0.00024	1.00611	0.00013	1.01043	0.00019
1.30	1.01024	0.00051	1.01076	0.00024	1.00780	0.00014	1.01201	0.00018
19 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
0.40	0.99335	0.00053	Not investigated due to termination of project.		0.99153	0.00011	Not investigated due to termination of project.	
0.50	0.99899	0.00055			0.99640	0.00012		
0.55	1.00177	0.00053			0.99904	0.00013		
0.60	1.00367	0.00053			1.00134	0.00015		
0.65	1.00618	0.00053			1.00364	0.00015		
0.70	1.00837	0.00055			1.00591	0.00012		
0.75	1.00986	0.00055			1.00806	0.00014		
0.80	1.01296	0.00055			1.01035	0.00017		

4.5.2 Ta-2.5W-2 Experiment

The Ta-2.5W-2 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be harder than the expected average neutron energy spectrum of the core but softer than the Ta-2.5W-1 experiment. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 91 and Figure 92 where aluminum is yellow, graphite is blue, Ta-2.5W is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 93. The RCP01 analysis predicts an assembly height of 10.678", the MCNP5 analysis predicts an assembly height of 10.478", and the MCNP5 with space cross sections and RACER analyses predict an assembly height of 10.428". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 6.428" high and contains one 0.197" thick graphite plate and 17 stacking units consisting of a 0.0246" thick Ta-2.5W plate, a 0.118" thick HEU plate, a 0.0246" thick Ta-2.5W plate, and a 0.197" thick graphite plate. The bottom reflector consists of a 2.0" thick graphite reflector and a 0.15" thick Ta-2.5W reflector. The RCP01 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.95" thick graphite reflector, the MCNP5 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.75" thick graphite reflector, and the MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.70" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Ta-2.5W-2 assembly contains 208.0 kg of HEU and 107.0 kg of Ta-2.5W. The distribution of materials in the top and bottom half of the assembly is given in Table 94 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Ta-2.5W-2 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 93 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Ta-2.5W-2 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 93, both the MCNP5 and RCP01 predictions are close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0034 \pm 0.0004 \Delta k$ over the range from 8 to 28 stacking units. Figure 94 and Table 95 provide a comparison of the predicted k_{eff} of the Ta-2.5W-2 assembly with 17 stacking units as a function of the graphite top reflector thickness. The experimental configurations predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 95. The Ta-2.5W-2 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 79.3% fast ($E > 100 \text{ keV}$), 20.7% intermediate ($0.625 \text{ eV} < E < 100 \text{ keV}$), and 0.0% thermal ($E < 0.625 \text{ eV}$).

Figure 91. Cross-sectional View of the Ta-2.5W-2 Assembly

Figure 92. Cross-sectional Close-up View of the Ta-2.5W-2 Assembly

Table 93. Predicted Critical Configuration for the Ta-2.5W-2 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	2.00	2.51	21.0	2.0000
	Ta-2.5W	0.150	2.51	21.0	2.1500
	Graphite	0.197	2.51	21.0	2.3470
1	Ta-2.5W	0.0246	2.51	21.0	2.3716
	HEU	0.118	2.51	21.0	2.4896
	Ta-2.5W	0.0246	2.51	21.0	2.5142
	Graphite	0.197	2.51	21.0	2.7112
2	Ta-2.5W	0.0246	2.51	21.0	2.7358
	HEU	0.118	2.51	21.0	2.8538
	Ta-2.5W	0.0246	2.51	21.0	2.8784
	Graphite	0.197	2.51	21.0	3.0754
3	Ta-2.5W	0.0246	2.51	21.0	3.1000
	HEU	0.118	2.51	21.0	3.2180
	Ta-2.5W	0.0246	2.51	21.0	3.2426
	Graphite	0.197	2.51	21.0	3.4396
4	Ta-2.5W	0.0246	2.51	21.0	3.4642
	HEU	0.118	2.51	21.0	3.5822
	Ta-2.5W	0.0246	2.51	21.0	3.6068
	Graphite	0.197	2.51	21.0	3.8038
5	Ta-2.5W	0.0246	2.51	21.0	3.8284
	HEU	0.118	2.51	21.0	3.9464
	Ta-2.5W	0.0246	2.51	21.0	3.9710
	Graphite	0.197	2.51	21.0	4.1680
6	Ta-2.5W	0.0246	2.51	21.0	4.1926
	HEU	0.118	2.51	21.0	4.3106
	Ta-2.5W	0.0246	2.51	21.0	4.3352
	Graphite	0.197	2.51	21.0	4.5322
7	Ta-2.5W	0.0246	2.51	21.0	4.5568
	HEU	0.118	2.51	21.0	4.6748
	Ta-2.5W	0.0246	2.51	21.0	4.6994
	Graphite	0.197	2.51	21.0	4.8964
8	Ta-2.5W	0.0246	0	21.0	4.9210
	HEU	0.118	0	21.0	5.0390
	Ta-2.5W	0.0246	0	21.0	5.0636
	Graphite	0.197	0	21.0	5.2606
9	Ta-2.5W	0.0246	0	21.0	5.2852
	HEU	0.118	0	21.0	5.4032
	Ta-2.5W	0.0246	0	21.0	5.4278
	Graphite	0.197	0	21.0	5.6248
Diaphragm	Stainless Steel	0.040	0	24.8	5.6648
10	Ta-2.5W	0.0246	0	21.0	5.6894
	HEU	0.118	0	21.0	5.8074
	Ta-2.5W	0.0246	0	21.0	5.8320
	Graphite	0.197	0	21.0	6.0290

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Ta-2.5W	0.0246	0	21.0	6.0536
	HEU	0.118	0	21.0	6.1716
	Ta-2.5W	0.0246	0	21.0	6.1962
	Graphite	0.197	0	21.0	6.3932
12	Ta-2.5W	0.0246	0	21.0	6.4178
	HEU	0.118	0	21.0	6.5358
	Ta-2.5W	0.0246	0	21.0	6.5604
	Graphite	0.197	0	21.0	6.7574
13	Ta-2.5W	0.0246	0	21.0	6.7820
	HEU	0.118	0	21.0	6.9000
	Ta-2.5W	0.0246	0	21.0	6.9246
	Graphite	0.197	0	21.0	7.1216
14	Ta-2.5W	0.0246	0	21.0	7.1462
	HEU	0.118	6.005	21.0	7.2642
	Ta-2.5W	0.0246	0	21.0	7.2888
	Graphite	0.197	0	21.0	7.4858
15	Ta-2.5W	0.0246	0	21.0	7.5104
	HEU	0.118	6.005	21.0	7.6284
	Ta-2.5W	0.0246	0	21.0	7.6530
	Graphite	0.197	0	21.0	7.8500
16	Ta-2.5W	0.0246	0	21.0	7.8746
	HEU	0.118	6.005	21.0	7.9926
	Ta-2.5W	0.0246	0	21.0	8.0172
	Graphite	0.197	0	21.0	8.2142
17	Ta-2.5W	0.0246	0	21.0	8.2388
	HEU	0.118	6.005	21.0	8.3568
	Ta-2.5W	0.0246	0	21.0	8.3814
	Graphite	0.197	0	21.0	8.5784
Top Reflector	Ta-2.5W	0.150	0	21.0	8.7284
	Graphite	1.95 (RCP01)	0	21.0	10.6784 (RCP01)
		1.75 (MCNP5)			10.4784 (MCNP5)
		1.70 (RACER, MCNP5 Space XS)			10.4284 (RACER, MCNP5 Space XS)

Table 94. Ta-2.5W-2 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	96.3	208.0	111.7	96.3	208.0	111.7	96.3	208.0
Ta-2.5W	55.5	51.5	107.0	55.5	51.5	107.0	55.5	51.5	107.0
Graphite	38.5	32.7	71.2	38.5	34.7	73.2	38.5	32.2	70.7
Total	205.8	180.5	386.3	205.8	182.5	388.3	205.8	180.1	385.8

Figure 93. Ta-2.5W-2 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 94. Ta-2.5W-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 95. Ta-2.5W-2 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
17 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI	k_{eff}	95% CI
1.65	0.99777	0.00053	0.99951	0.00026	0.99489	0.00012	1.00098	0.00019
1.70	0.99898	0.00053	1.00055	0.00026	0.99619	0.00015	1.00219	0.00019
1.75	1.00150	0.00053	1.00175	0.00024	0.99723	0.00013	1.00335	0.00019
1.80	1.00214	0.00055	1.00287	0.00026	0.99847	0.00014	1.00445	0.00019
1.85	1.00314	0.00053	1.00434	0.00026	0.99950	0.00013	1.00566	0.00019
1.90	1.00342	0.00055	1.00519	0.00026	1.00067	0.00014	1.00679	0.00019
1.95	1.00488	0.00053	1.00622	0.00026	1.00162	0.00014	1.00759	0.00020
2.00	1.00661	0.00055	1.00723	0.00026	1.00261	0.00014	1.00885	0.00019

4.5.3 Ta-2.5W-3 Experiment

The Ta-2.5W-3 experiment is designed to bracket the average neutron spectrum of the Prometheus reactor core. It is designed to be softer than the expected average neutron energy spectrum of the core. Additional graphite has been added to the assembly to simulate the effect of neutron moderation near the reflector. A cross-sectional view and close-up view of the experimental configuration are provided in Figure 95 and Figure 96 where aluminum is yellow, graphite is blue, Ta-2.5W is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). The assembly configuration, including plate layout and dimensions, is shown in Table 96. The RCP01 analysis predicts an assembly height of 20.836", the MCNP5 analysis predicts an assembly height of 20.036", and the MCNP5 with space cross sections and RACER analyses predict an assembly height of 19.086". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter. The active core region of the assembly is 10.536" high and contains one 0.394" graphite plate and 18 stacking units consisting of a 0.0246" thick Ta-2.5W plate, a 0.118" thick HEU plate, a 0.0246" thick Ta-2.5W plate, and a 0.394" thick graphite plate. The bottom reflector consists of a 5.0" thick graphite reflector and a 0.15" thick Ta-2.5W reflector. The RCP01 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 5.00" thick graphite reflector, the MCNP5 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 4.20" thick graphite reflector, and the MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 3.25" thick graphite reflector. A hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Ta-2.5W-3 assembly contains 217.8 kg of HEU and 111.7 kg of Ta-2.5W. The distribution of materials in the top and bottom half of the assembly is given in Table 97 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Ta-2.5W-3 assembly during the approach to critical as a function of both the number of stacking units and the graphite top reflector thickness. Figure 97 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Ta-2.5W-3 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. As illustrated in Figure 97, both the MCNP5 and RCP01 predictions are very close. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $0.0018 \pm 0.0010 \Delta k$ over the range from 8 to 28 stacking units. Figure 98 and Table 98 provide a comparison of the predicted k_{eff} of the Ta-2.5W-3 assembly with 17 stacking units, 18 stacking units, and 18 stacking units with a 10.005" ID top HEU fuel plate as a function of the graphite top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 98. The Ta-2.5W-3 assembly is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 68.9% fast ($E > 100$ keV), 31.0% intermediate (0.625 eV $< E < 100$ keV), and 0.03% thermal ($E < 0.625$ eV).

Figure 95. Cross-sectional View of the Ta-2.5W-3 Assembly

Figure 96. Cross-sectional Close-up View of the Ta-2.5W-3 Assembly

Table 96. Predicted Critical Configuration for the Ta-2.5W-3 Assembly.

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Graphite	5.00	2.51	21.0	5.0000
	Ta-2.5W	0.150	2.51	21.0	5.1500
	Graphite	0.394	2.51	21.0	5.5440
1	Ta-2.5W	0.0246	2.51	21.0	5.5686
	HEU	0.118	2.51	21.0	5.6866
	Ta-2.5W	0.0246	2.51	21.0	5.7112
	Graphite	0.394	2.51	21.0	6.1052
2	Ta-2.5W	0.0246	2.51	21.0	6.1298
	HEU	0.118	2.51	21.0	6.2478
	Ta-2.5W	0.0246	2.51	21.0	6.2724
	Graphite	0.394	2.51	21.0	6.6664
3	Ta-2.5W	0.0246	2.51	21.0	6.6910
	HEU	0.118	2.51	21.0	6.8090
	Ta-2.5W	0.0246	2.51	21.0	6.8336
	Graphite	0.394	2.51	21.0	7.2276
4	Ta-2.5W	0.0246	2.51	21.0	7.2522
	HEU	0.118	2.51	21.0	7.3702
	Ta-2.5W	0.0246	2.51	21.0	7.3948
	Graphite	0.394	2.51	21.0	7.7888
5	Ta-2.5W	0.0246	2.51	21.0	7.8134
	HEU	0.118	2.51	21.0	7.9314
	Ta-2.5W	0.0246	2.51	21.0	7.9560
	Graphite	0.394	2.51	21.0	8.3500
6	Ta-2.5W	0.0246	2.51	21.0	8.3746
	HEU	0.118	2.51	21.0	8.4926
	Ta-2.5W	0.0246	2.51	21.0	8.5172
	Graphite	0.394	2.51	21.0	8.9112
7	Ta-2.5W	0.0246	2.51	21.0	8.9358
	HEU	0.118	2.51	21.0	9.0538
	Ta-2.5W	0.0246	2.51	21.0	9.0784
	Graphite	0.394	2.51	21.0	9.4724
8	Ta-2.5W	0.0246	0	21.0	9.4970
	HEU	0.118	0	21.0	9.6150
	Ta-2.5W	0.0246	0	21.0	9.6396
	Graphite	0.394	0	21.0	10.0336
9	Ta-2.5W	0.0246	0	21.0	10.0582
	HEU	0.118	0	21.0	10.1762
	Ta-2.5W	0.0246	0	21.0	10.2008
	Graphite	0.394	0	21.0	10.5948
Diaphragm	Stainless Steel	0.040	0	24.8	10.6348
10	Ta-2.5W	0.0246	0	21.0	10.6594
	HEU	0.118	0	21.0	10.7774
	Ta-2.5W	0.0246	0	21.0	10.8020
	Graphite	0.394	0	21.0	11.1960

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Ta-2.5W	0.0246	0	21.0	11.2206
	HEU	0.118	0	21.0	11.3386
	Ta-2.5W	0.0246	0	21.0	11.3632
	Graphite	0.394	0	21.0	11.7572
12	Ta-2.5W	0.0246	0	21.0	11.7818
	HEU	0.118	0	21.0	11.8998
	Ta-2.5W	0.0246	0	21.0	11.9244
	Graphite	0.394	0	21.0	12.3184
13	Ta-2.5W	0.0246	0	21.0	12.3430
	HEU	0.118	0	21.0	12.4610
	Ta-2.5W	0.0246	0	21.0	12.4856
	Graphite	0.394	0	21.0	12.8796
14	Ta-2.5W	0.0246	0	21.0	12.9042
	HEU	0.118	6.005	21.0	13.0222
	Ta-2.5W	0.0246	0	21.0	13.0468
	Graphite	0.394	0	21.0	13.4408
15	Ta-2.5W	0.0246	0	21.0	13.4654
	HEU	0.118	6.005	21.0	13.5834
	Ta-2.5W	0.0246	0	21.0	13.6080
	Graphite	0.394	0	21.0	14.0020
16	Ta-2.5W	0.0246	0	21.0	14.0266
	HEU	0.118	6.005	21.0	14.1446
	Ta-2.5W	0.0246	0	21.0	14.1692
	Graphite	0.394	0	21.0	14.5632
17	Ta-2.5W	0.0246	0	21.0	14.5878
	HEU	0.118	6.005	21.0	14.7058
	Ta-2.5W	0.0246	0	21.0	14.7304
	Graphite	0.394	0	21.0	15.1244
18	Ta-2.5W	0.0246	0	21.0	15.1490
	HEU	0.118	10.005	15.0	15.2670
	Ta-2.5W	0.0246	0	21.0	15.2916
	Graphite	0.394	0	21.0	15.6856
Top Reflector	Ta-2.5W	0.150	0	21.0	15.8356
	Graphite	5.00 (RCP01)	0	21.0	20.8356 (RCP01)
		4.20 (MCNP5)			20.0356 (MCNP5)
		3.25 (RACER, MCNP5 Space XS)			19.0856 (RACER, MCNP5 Space XS)

Table 97. Ta-2.5W-3 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	106.0	217.8	111.7	106.0	217.8	111.7	106.0	217.8
Ta-2.5W	55.5	56.2	111.7	55.5	56.2	111.7	55.5	56.2	111.7
Graphite	86.7	76.2	162.9	86.7	84.0	170.8	86.7	66.8	153.6
Total	254.0	238.4	492.4	254.0	246.2	500.2	254.0	229.0	483.0

Figure 97. Ta-2.5W-3 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 98. Ta-2.5W-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 98. Ta-2.5W-3 Assembly k_{eff} as a Function of the Top Reflector Thickness

Predicted Top Reflector Thickness								
17 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
7.00	0.99999	0.00055	Not investigated due to termination of project.		0.99775	0.00011	Not investigated due to termination of project.	
7.25	0.99973	0.00057			0.99806	0.00019		
7.50	1.00018	0.00055			0.99822	0.00016		
7.75	0.99990	0.00055			0.99852	0.00013		
8.00	1.00074	0.00053			0.99879	0.00017		
8.25	1.00043	0.00055			0.99893	0.00017		
8.50	1.00102	0.00055			0.99923	0.00010		
8.75	1.00036	0.00053			0.99930	0.00019		
9.00	1.00062	0.00057			0.99942	0.00013		
18 Stacking Units								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
2.75	0.99816	0.00057	Not investigated due to termination of project.		0.99514	0.00014	Not investigated due to termination of project.	
3.00	0.99992	0.00053			0.99690	0.00011		
3.25	1.00161	0.00055			0.99843	0.00016		
3.50	1.00283	0.00055			1.00007	0.00009		
3.75	1.00379	0.00055			1.00133	0.00013		
3.85	1.00415	0.00053			1.00177	0.00011		
4.00	1.00476	0.00055			1.00240	0.00013		
4.25	1.00609	0.00055			1.00345	0.00016		
18 Stacking Units (top HEU plate ID=10.005")								
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RCP01		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
3.00	-	-	0.99933	0.00026	-	-	1.00072	0.00019
3.25	-	-	1.00073	0.00028	-	-	1.00219	0.00019
3.50	0.99807	0.00055	1.00192	0.00026	0.99540	0.00016	1.00354	0.00019
3.75	0.99965	0.00053	1.00346	0.00026	0.99663	0.00015	1.00464	0.00020
4.00	1.00005	0.00055	1.00448	0.00026	0.99770	0.00017	1.00576	0.00019
4.10	1.00086	0.00057	1.00480	0.00026	0.99803	0.00015	1.00632	0.00020
4.20	1.00099	0.00057	1.00546	0.00026	0.99844	0.00018	1.00683	0.00020
4.25	1.00059	0.00055	1.00553	0.00028	0.99866	0.00017	1.00707	0.00020
4.50	1.00286	0.00055	1.00616	0.00026	0.99951	0.00014	1.00752	0.00020
4.75	1.00297	0.00055	1.00688	0.00026	1.00037	0.00015	1.00844	0.00019
5.00	1.00338	0.00055	1.00764	0.00026	1.00100	0.00013	1.00914	0.00020
5.25	1.00409	0.00055	1.00854	0.00026	1.00161	0.00012	1.00996	0.00020
5.50	1.00452	0.00055	1.00887	0.00026	1.00207	0.00014	1.01022	0.00019

4.5.4 Ta-2.5W-4 Experiment

The Ta-2.5W-4 experiment is designed to simulate the average neutron spectrum of the Prometheus reactor core when flooded with water. Polyethylene is used to simulate flooding with water. A cross-sectional view of the RCP01 and MCNP5 experimental configurations are shown in Figure 99 and Figure 100, respectively, and a close-up view of the MCNP5 predicted experimental configuration is provided in Figure 101 where aluminum is yellow, polyethylene is light blue, Ta-2.5W is green, HEU is red, and stainless steel is purple (all dimensions in figures are in centimeters). Note that the lines cutting through the alignment tube in Figure 99 are a plotting artifact due to the detail of the geometry model; these features are not in the RCP01 model. The RCP01, MCNP5 with space cross sections, and RACER predicted assembly configurations, including plate layout and dimensions, are shown in Table 99, while the MCNP5 predicted assembly configuration is shown in Table 100. The RCP01 analysis predicts an assembly with 16 stacking units and a height of 6.415", the MCNP5 with space cross sections and RACER analyses predict an assembly with 16 stacking units and a height of 6.275, and the MCNP5 analysis predicts an assembly with 17 stacking units and a height of 6.422". The assembly rests on a 3.0" thick hollow Al 6061-T6 spindle plate that has a 19" OD and 2.50" inner diameter.

The active core region of the RCP01, MCNP5 with space cross sections, and RACER predicted assembly is 3.995" high and contains one 0.080" thick polyethylene plate and 16 stacking units consisting of a 0.0246" thick Ta-2.5W plate, a 0.118" thick HEU plate, a 0.0246" thick Ta-2.5W plate, and a 0.080" thick polyethylene plate. The bottom reflector consists of a 1.0" thick polyethylene reflector and a 0.15" thick Ta-2.5W reflector. The RCP01 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 1.04" thick polyethylene reflector, while the MCNP5 with space cross sections and RACER predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 0.90" thick polyethylene reflector.

The active core region of the MCNP5 predicted assembly is 4.322" high and contains one 0.080" thick polyethylene plate and 17 stacking units consisting of a 0.0246" thick Ta-2.5W plate, a 0.118" thick HEU plate, a 0.0246" thick Ta-2.5W plate, and a 0.080" thick polyethylene plate. The bottom reflector consists of a 1.0" thick polyethylene reflector and a 0.15" thick Ta-2.5W reflector. The MCNP5 predicted top reflector consists of a 0.15" thick Ta-2.5W reflector and a 0.80" thick polyethylene reflector.

In all Ta-2.5W-4 models, a hollow Al 6061-T6 alignment tube is assumed to extend from the bottom of the spindle plate to the top of the 6th stacking unit. All other regions are modeled as void, except as noted in Section 4.0 for the RACER models. The Ta-2.5W-4 RCP01, MCNP5 with space cross sections, and RACER predicted assembly contains 194.7 kg of HEU and 102.4 kg of Ta-2.5W, while the MCNP5 predicted assembly contains 206.2 kg of HEU and 107.0 kg of Ta-2.5W. The distribution of materials in the top and bottom half of the assembly is given in Table 101 for the RCP01, MCNP5, MCNP5 with space cross sections, and RACER predicted critical configurations.

A series of analyses have been performed to predict the k_{eff} of the Ta-2.5W-4 assembly during the approach to critical as a function of both the number of stacking units and the polyethylene top reflector thickness. Figure 102 presents the RCP01 and MCNP5 predicted k_{eff} as a function of the number of stacking units in the Ta-2.5W-4 assembly. The error bars indicate the size of the 95% confidence interval in the Monte Carlo calculations. The average difference between the MCNP5 and RCP01 predicted k_{eff} is $-0.0151 \pm 0.0013 \Delta k$ over the range from 8 to 28 stacking units. As discussed below, this relatively large, -1.51% Δk , difference between the RCP01 and MCNP5 predicted k_{eff} is attributed to the lack of an unresolved resonance treatment in the ^{181}Ta neutron cross section used in the MCNP5 calculations. Figure 103, Table 102, and Table 103 provide a comparison of the predicted

k_{eff} of the Ta-2.5W-4 assembly with 6.005" ID and 10.005" ID top HEU fuel plates for both MCNP5 and RCP01 as a function of the polyethylene top reflector thickness. The experimental configurations that were predicted to achieve delayed criticality within TSR limits ($\rho < 0.5\%$) are highlighted in green in Table 102 and Table 103. The Ta-2.5W-4 experiment is classified as a fast spectrum assembly with the following representative fission fractions, as predicted by MCNP5: 52.9% fast ($E > 100 \text{ keV}$), 43.4% intermediate ($0.625 \text{ eV} < E < 100 \text{ keV}$), and 3.7% thermal ($E < 0.625 \text{ eV}$).

The RCP01 and MCNP5 multigroup absorption rate distributions in Ta-2.5W were compared in order to understand the relatively large -1.5% Δk difference between the predicted k_{eff} for the Ta-2.5W-4 experiment. As illustrated in Figure 104, both the RCP01 and MCNP5 Ta-2.5W multigroup absorption rate distributions agree well in the fast energy range, however MCNP5 absorption rate distribution is significantly higher than RCP01 from 275 eV to 5.53 keV. One of the principle differences between the RCP01 and MCNP5 models is the lack of an unresolved resonance treatment in the ^{181}Ta neutron cross section data used in MCNP5. The RDS7 ^{181}Ta neutron cross sections used in the RCP01 analyses have an unresolved resonance treatment between MUFT groups 34 and 29 (from 275 eV to 5.53 keV). The lack of an unresolved resonance treatment in the MCNP5 ^{181}Ta cross sections is expected to result in increased Ta absorption in the unresolved resonance range and decreased assembly k_{eff} . This discrepancy between the RCP01 and MCNP5 predicted k_{eff} highlights the value of the Ta-2.5W-4 experiment in developing an improved ^{181}Ta neutron cross section evaluation.

Figure 99. RCP01 Cross-sectional View of the Ta-2.5W-4 Assembly

Figure 100. MCNP5 Cross-sectional View of the Ta-2.5W-4 Assembly

Figure 101. MCNP5 Cross-sectional Close-up View of the Ta-2.5W-4 Assembly

Table 99. RCP01, MCNP5 (Space XS), and RACER Predicted Critical Configuration for the Ta-2.5W-4 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Poly	1.00	2.51	21.0	1.0000
	Ta-2.5W	0.150	2.51	21.0	1.1500
1	Poly	0.080	2.51	21.0	1.2300
	Ta-2.5W	0.0246	2.51	21.0	1.2546
	HEU	0.118	2.51	21.0	1.3726
	Ta-2.5W	0.0246	2.51	21.0	1.3972
2	Poly	0.080	2.51	21.0	1.4772
	Ta-2.5W	0.0246	2.51	21.0	1.5018
	HEU	0.118	2.51	21.0	1.6198
	Ta-2.5W	0.0246	2.51	21.0	1.6444
3	Poly	0.080	2.51	21.0	1.7244
	Ta-2.5W	0.0246	2.51	21.0	1.7490
	HEU	0.118	2.51	21.0	1.8670
	Ta-2.5W	0.0246	2.51	21.0	1.8916
4	Poly	0.080	2.51	21.0	1.9716
	Ta-2.5W	0.0246	2.51	21.0	1.9962
	HEU	0.118	2.51	21.0	2.1142
	Ta-2.5W	0.0246	2.51	21.0	2.1388
5	Poly	0.080	2.51	21.0	2.2188
	Ta-2.5W	0.0246	2.51	21.0	2.2434
	HEU	0.118	2.51	21.0	2.3614
	Ta-2.5W	0.0246	2.51	21.0	2.3860
6	Poly	0.080	2.51	21.0	2.4660
	Ta-2.5W	0.0246	2.51	21.0	2.4906
	HEU	0.118	2.51	21.0	2.6086
	Ta-2.5W	0.0246	2.51	21.0	2.6332
7	Poly	0.080	2.51	21.0	2.7132
	Ta-2.5W	0.0246	2.51	21.0	2.7378
	HEU	0.118	2.51	21.0	2.8558
	Ta-2.5W	0.0246	2.51	21.0	2.8804
8	Poly	0.080	2.51	21.0	2.9604
	Ta-2.5W	0.0246	0	21.0	2.9850
	HEU	0.118	0	21.0	3.1030
	Ta-2.5W	0.0246	0	21.0	3.1276
Diaphragm	Stainless Steel	0.040	0	24.8	3.2076
9	Poly	0.080	0	21.0	3.4948
	Ta-2.5W	0.0246	0	21.0	3.2322
	HEU	0.118	0	21.0	3.3502
	Ta-2.5W	0.0246	0	21.0	3.3748
10	Poly	0.080	0	21.0	3.4548
	Ta-2.5W	0.0246	0	21.0	3.5194
	HEU	0.118	0	21.0	3.6374
	Ta-2.5W	0.0246	0	21.0	3.6620
	Poly	0.080	0	21.0	3.7420

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Ta-2.5W	0.0246	0	21.0	3.7666
	HEU	0.118	0	21.0	3.8846
	Ta-2.5W	0.0246	0	21.0	3.9092
	Poly	0.080	0	21.0	3.9892
12	Ta-2.5W	0.0246	0	21.0	4.0138
	HEU	0.118	0	21.0	4.1318
	Ta-2.5W	0.0246	0	21.0	4.1564
	Poly	0.080	0	21.0	4.2364
13	Ta-2.5W	0.0246	0	21.0	4.2610
	HEU	0.118	0	21.0	4.3790
	Ta-2.5W	0.0246	0	21.0	4.4036
	Poly	0.080	0	21.0	4.4836
14	Ta-2.5W	0.0246	0	21.0	4.5082
	HEU	0.118	6.005	21.0	4.6262
	Ta-2.5W	0.0246	0	21.0	4.6508
	Poly	0.080	0	21.0	4.7308
15	Ta-2.5W	0.0246	0	21.0	4.7554
	HEU	0.118	6.005	21.0	4.8734
	Ta-2.5W	0.0246	0	21.0	4.8980
	Poly	0.080	0	21.0	4.9780
16	Ta-2.5W	0.0246	0	21.0	5.0026
	HEU	0.118	10.005	21.0	5.1206
	Ta-2.5W	0.0246	0	21.0	5.1452
	Poly	0.080	0	21.0	5.2252
Top Reflector	Ta-2.5W	0.150	0	21.0	5.3752
	Poly	1.04 (RCP01) 0.90 (RACER, MCNP5 Space XS)	0	21.0	8.4152 (RCP01) 8.2752 (RACER, MCNP5 Space XS)

Table 100. MCNP5 Predicted Critical Configuration for the Ta-2.5W-4 Assembly

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
Bottom Reflector	Poly	1.00	2.51	21.0	1.0000
	Ta-2.5W	0.150	2.51	21.0	1.1500
	Poly	0.080	2.51	21.0	1.2300
1	Ta-2.5W	0.0246	2.51	21.0	1.2546
	HEU	0.118	2.51	21.0	1.3726
	Ta-2.5W	0.0246	2.51	21.0	1.3972
	Poly	0.080	2.51	21.0	1.4772
2	Ta-2.5W	0.0246	2.51	21.0	1.5018
	HEU	0.118	2.51	21.0	1.6198
	Ta-2.5W	0.0246	2.51	21.0	1.6444
	Poly	0.080	2.51	21.0	1.7244
3	Ta-2.5W	0.0246	2.51	21.0	1.7490
	HEU	0.118	2.51	21.0	1.8670
	Ta-2.5W	0.0246	2.51	21.0	1.8916
	Poly	0.080	2.51	21.0	1.9716
4	Ta-2.5W	0.0246	2.51	21.0	1.9962
	HEU	0.118	2.51	21.0	2.1142
	Ta-2.5W	0.0246	2.51	21.0	2.1388
	Poly	0.080	2.51	21.0	2.2188
5	Ta-2.5W	0.0246	2.51	21.0	2.2434
	HEU	0.118	2.51	21.0	2.3614
	Ta-2.5W	0.0246	2.51	21.0	2.3860
	Poly	0.080	2.51	21.0	2.4660
6	Ta-2.5W	0.0246	2.51	21.0	2.4906
	HEU	0.118	2.51	21.0	2.6086
	Ta-2.5W	0.0246	2.51	21.0	2.6332
	Poly	0.080	2.51	21.0	2.7132
7	Ta-2.5W	0.0246	2.51	21.0	2.7378
	HEU	0.118	2.51	21.0	2.8558
	Ta-2.5W	0.0246	2.51	21.0	2.8804
	Poly	0.080	2.51	21.0	2.9604
8	Ta-2.5W	0.0246	0	21.0	2.9850
	HEU	0.118	0	21.0	3.1030
	Ta-2.5W	0.0246	0	21.0	3.1276
	Poly	0.080	0	21.0	3.2076
9	Ta-2.5W	0.0246	0	21.0	3.2322
	HEU	0.118	0	21.0	3.3502
	Ta-2.5W	0.0246	0	21.0	3.3748
	Poly	0.080	0	21.0	3.4548
Diaphragm	Stainless Steel	0.040	0	24.8	3.4948
10	Ta-2.5W	0.0246	0	21.0	3.5194
	HEU	0.118	0	21.0	3.6374
	Ta-2.5W	0.0246	0	21.0	3.6620
	Poly	0.080	0	21.0	3.7420

Unit	Material	Thickness (in)	Inner Diameter (in)	Outer Diameter (in)	Assembly Height (in)
11	Ta-2.5W	0.0246	0	21.0	3.7666
	HEU	0.118	0	21.0	3.8846
	Ta-2.5W	0.0246	0	21.0	3.9092
	Poly	0.080	0	21.0	3.9892
12	Ta-2.5W	0.0246	0	21.0	4.0138
	HEU	0.118	0	21.0	4.1318
	Ta-2.5W	0.0246	0	21.0	4.1564
	Poly	0.080	0	21.0	4.2364
13	Ta-2.5W	0.0246	0	21.0	4.2610
	HEU	0.118	0	21.0	4.3790
	Ta-2.5W	0.0246	0	21.0	4.4036
	Poly	0.080	0	21.0	4.4836
14	Ta-2.5W	0.0246	0	21.0	4.5082
	HEU	0.118	6.005	21.0	4.6262
	Ta-2.5W	0.0246	0	21.0	4.6508
	Poly	0.080	0	21.0	4.7308
15	Ta-2.5W	0.0246	0	21.0	4.7554
	HEU	0.118	6.005	21.0	4.8734
	Ta-2.5W	0.0246	0	21.0	4.8980
	Poly	0.080	0	21.0	4.9780
16	Ta-2.5W	0.0246	0	21.0	5.0026
	HEU	0.118	6.005	21.0	5.1206
	Ta-2.5W	0.0246	0	21.0	5.1452
	Poly	0.080	0	21.0	5.2252
17	Ta-2.5W	0.0246	0	21.0	5.2498
	HEU	0.118	10.005	21.0	5.3678
	Ta-2.5W	0.0246	0	21.0	5.3924
	Poly	0.080	0	21.0	5.4724
Top Reflector	Ta-2.5W	0.150	0	21.0	5.6224
	Poly	0.80	0	21.0	6.4224

Table 101. Ta-2.5W-4 Assembly Material Mass Distribution

Material	Mass (kg)								
	MCNP5			RCP01			MCNP5 (Space XS)/RACER		
	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total	Lower Assembly	Upper Assembly	Total
HEU	111.7	94.5	206.2	111.7	83.0	194.7	111.7	83.0	194.7
Ta-2.5W	55.5	51.5	107.0	55.5	46.9	102.4	55.5	46.9	102.4
Polyethylene	9.7	7.8	17.5	9.7	8.7	18.3	9.7	7.9	17.6
Total	176.9	153.9	330.8	176.9	138.5	315.4	176.9	137.8	314.7

Figure 102. Ta-2.5W-4 Assembly k_{eff} as a Function of the Number of Stacking Units

Figure 103. Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

Table 102. RCP01, MCNP5 (Space XS), and RACER Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

16 Stacking Units (top HEU plate ID=6.005")						
Top Reflector Thickness (in)	RCP01		MCNP5 (Space XS)		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
0.65	0.99651	0.00014	Not investigated due to termination of project.		Not investigated due to termination of project.	
0.70	0.99838	0.00015				
0.75	1.00008	0.00007				
0.80	1.00181	0.00017				
0.85	1.00350	0.00013				
0.90	1.00480	0.00014				
16 Stacking Units (top HEU plate ID=10.005")						
Top Reflector Thickness (in)	RCP01		MCNP5 (Space XS)		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
0.84	0.99558	0.00009	0.99854	0.00028	0.99921	0.00020
0.88	0.99675	0.00013	0.99943	0.00026	1.00041	0.00018
0.90	0.99743	0.00014	1.00030	0.00013	1.00084	0.00020
0.94	0.99846	0.00014	1.00164	0.00028	1.00190	0.00020
0.98	0.99940	0.00014	1.00224	0.00028	1.00275	0.00020
1.00	0.99988	0.00016	1.00292	0.00028	1.00324	0.00021
1.02	1.00037	0.00014	1.00311	0.00026	1.00386	0.00020
1.04	1.00099	0.00013	1.00354	0.00028	1.00418	0.00020
1.06	1.00128	0.00013	1.00417	0.00028	1.00473	0.00020
1.08	1.00159	0.00015	1.00445	0.00028	1.00513	0.00020
1.10	1.00222	0.00013	1.00493	0.00028	1.00547	0.00021

Table 103. MCNP5, MCNP5 (Space XS), and RACER Ta-2.5W-4 Assembly k_{eff} as a Function of the Top Reflector Thickness

16 Stacking Units (top HEU plate ID=6.005")						
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
1.28	0.99892	0.00059	Not investigated due to termination of project.		Not investigated due to termination of project.	
1.30	0.99877	0.00057				
1.34	0.99930	0.00057				
1.38	1.00002	0.00057				
1.40	1.00083	0.00057				
1.44	1.00103	0.00059				
1.48	1.00203	0.00057				
1.50	1.00182	0.00057				
1.60	1.00339	0.00061				
17 Stacking Units (top HEU plate ID=6.005")						
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
0.50	0.99848	0.00057	-	-	Not investigated due to termination of project.	
0.54	0.99908	0.00057	-	-		
0.58	1.00069	0.00055	-	-		
0.60	1.00141	0.00053	-	-		
0.64	1.00287	0.00059	1.02004	0.00028		
0.68	1.00366	0.00057	1.02155	0.00028		
17 Stacking Units (top HEU plate ID=10.005")						
Top Reflector Thickness (in)	MCNP5		MCNP5 (Space XS)		RACER	
	k _{eff}	95% CI	k _{eff}	95% CI	k _{eff}	95% CI
0.64	0.99583	0.00057	1.01367	0.00028	1.01440	0.00020
0.68	0.99792	0.00055	1.01535	0.00028	1.01580	0.00020
0.70	0.99816	0.00057	1.01575	0.00026	1.01626	0.00021
0.74	0.99953	0.00057	1.01703	0.00028	1.01746	0.00019
0.78	1.00066	0.00055	1.01826	0.00028	1.01862	0.00021
0.80	1.00113	0.00059	1.01832	0.00026	1.01902	0.00019
0.84	1.00223	0.00059	1.01972	0.00028	1.02017	0.00020
0.88	1.00292	0.00057	1.02050	0.00028	1.02130	0.00021
0.90	1.00344	0.00057	1.02121	0.00028	1.02176	0.00021

Figure 104. Comparison of Predicted RCP01 and MCNP5 Ta-2.5W Absorption Rate Spectra for the Ta-2.5W-4 Critical Experiment

4.5.5 Tantalum Critical Experiments Summary and Conclusions

This document provides the pre-experimental predictions for the Ta-2.5W critical experiments including the effect of the Planet assembly machine structure. These critical experiments are being performed to:

1. determine the adequacy of the existing ^{181}Ta neutron cross section evaluations in a neutron energy spectrum characteristic of the Prometheus reactor designs under normal and accident conditions,
2. reduce the uncertainty in k_{eff} for Prometheus reactor designs by performing benchmark quality critical experiments that bracket the neutron energy spectra expected under normal and accident conditions, and
3. provide benchmark critical experiments needed to develop improved ^{181}Ta neutron cross section evaluations if new evaluations are determined to be required.

The first 3 experiments are designed to bracket the neutron energy spectrum expected in the Prometheus space nuclear reactor under normal operating conditions. The Ta-2.5W-4 experiment is designed to approximate the neutron energy spectrum expected in accident conditions in which the core is flooded and surrounded by water or wet sand. A summary of the fission fraction in the thermal, intermediate, and fast energy ranges for each of the Ta-2.5W critical experiments is provided in Table 104. All of the Ta-2.5W critical experiments are classified as fast spectrum experiments. All four experiments have a significant intermediate energy range component which increases as the spectrum softens. A summary of the pre-experimental predictions for each of the Ta-2.5W critical experiments is provided in Table 105. Predictions from the RCP01, MCNP5, MCNP5 with space cross sections, and RACER analyses are provided.

Comparisons of the RCP01 and MCNP5 predicted fission reaction rate and Ta-2.5W absorption rate spectra are provided in Figure 105 and Figure 106. The lack of an unresolved resonance treatment in the MCNP5 ^{181}Ta neutron cross section data clearly results in increased absorption in Ta-2.5W between 330 eV and 5000 eV in all four experiments. Only the Ta-2.5W-4 experiment appears to be sensitive to differences in the unresolved resonance data. As shown in Figure 105, this is because the vast majority of the fissions occur at energies greater than 10 keV for the other assemblies. The RCP01 predicted fission reaction rate spectrum CDFs for the Ta-2.5W experiments are provided in Figure 107.

Table 104. A Summary of the Energy Spectrum Covered in the Ta-2.5W Critical Experiments

Experiment	Percent Fissions by Energy (MCNP5 Predictions)		
	<0.625eV	0.625eV - 100keV	>100keV
Ta-2.5W-1	0.0%	14.1%	86.0%
Ta-2.5W-2	0.0%	20.7%	79.3%
Ta-2.5W-3	0.0%	31.0%	68.9%
Ta-2.5W-4	3.7%	43.4%	52.9%

Table 105. A Summary of the Pre-Experimental Predictions for the Ta-2.5W Critical Experiments

Experiment	Monte Carlo Code	Stacking Units	Top Reflector Thickness (in)	k_{eff}	95% Confidence Level	Mass of HEU (kg)	Mass of Ta-2.5W (kg)	Mass of Moderator (graphite/polyethylene) (kg)
Ta-2.5W-1	RCP01	18	1.10	1.00048	0.00012	219.6	111.7	39.1
	MCNP5	18	1.05	1.00077	0.00057	219.6	111.7	38.6
	MCNP5 (Space XS)	18	1.05	1.00126	0.00026	219.6	111.7	38.6
	RACER	18	1.05	1.00257	0.00019	219.6	111.7	38.6
Ta-2.5W-2	RCP01	17	1.95	1.00162	0.00014	208.0	107.0	73.2
	MCNP5	17	1.75	1.00150	0.00053	208.0	107.0	71.2
	MCNP5 (Space XS)	17	1.70	1.00055	0.00026	208.0	107.0	70.7
	RACER	17	1.70	1.00219	0.00019	208.0	107.0	70.7
Ta-2.5W-3	RCP01	18	5.00	1.00098	0.00019	217.8	111.7	170.8
	MCNP5	18	4.20	1.00099	0.00057	217.8	111.7	162.9
	MCNP5 (Space XS)	18	3.25	1.00073	0.00026	217.8	111.7	153.6
	RACER	18	3.25	1.00219	0.00019	217.8	111.7	153.6
Ta-2.5W-4	RCP01	16	1.04	1.00099	0.00013	194.7	102.4	18.3
	MCNP5	17	0.80	1.00113	0.00059	206.2	107.0	17.5
	MCNP5 (Space XS)	16	0.90	1.00030	0.00013	194.7	102.4	17.6
	RACER	16	0.90	1.00084	0.00020	194.7	102.4	17.6

Figure 105. Comparison of RCP01 and MCNP5 Fission Rate Spectra for the Ta-2.5W Critical Experiments

Figure 106. Comparison of RCP01 and MCNP5 Ta-2.5W Absorption Rate Spectra for the Ta-2.5W Critical Experiments

Figure 107. RCP01 Fission CDFs for the Ta-2.5W Critical Experiments

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Appendix A

Specifications for the Prometheus Critical Experiments

B-TM-1639

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Specifications for the Base-1 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" graphite (reflector)
- 17 stacking units consisting of [0.118" HEU, 0.100" graphite]
- 1 stacking unit consisting of [0.118" HEU]
- 1.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.50 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The nominal thickness of the graphite plates used in the central assembly is 0.100 inches.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.5 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Base-2 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 2.0" graphite (reflector)
- 15 stacking units consisting of [0.118" HEU, 0.197" graphite]
- 1 stacking unit consisting of [0.118" HEU]
- 2.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.50 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The nominal thickness of the graphite plates used in the central assembly is 0.197 inches.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be +/- 0.5 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Base-3 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 5.0" graphite (reflector)
- 12 stacking units consisting of [0.118" HEU, 0.394" graphite]
- 1 stacking unit consisting of [0.118" HEU]
- 5.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.50 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The nominal thickness of the graphite plates used in the central assembly is 0.394 inches.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be +/- 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Base-4 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" polyethylene (reflector)
- 10 stacking units consisting of [0.118" HEU, 0.080" polyethylene]
- 1 stacking unit consisting of [0.118" HEU]
- 1.0" polyethylene (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.50 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 6th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 5th unit.
3. The nominal thickness of the high density polyethylene plates used in the central assembly is 0.080 inches.
4. The thickness of the upper polyethylene reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be +/- 0.50 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Mo-1 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" graphite (reflector)
- 0.180" (3 @ 0.060") Mo (reflector)
- 0.100" graphite
- 17 stacking units consisting of [0.030" Mo, 0.118" HEU, 0.030" Mo, 0.100" graphite]
- 0.180" (3 @ 0.060") Mo (reflector)
- 1.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.100 ± 0.005 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.5 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Mo-2 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 2.0" graphite (reflector)
- 0.180" (3 @ 0.060") Mo (reflector)
- 0.197" graphite
- 15 stacking units consisting of [0.030" Mo, 0.118" HEU, 0.030" Mo, 0.197" graphite]
- 0.180" (3 @ 0.060") Mo (reflector)
- 2.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.197 ± 0.005 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Mo-3 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

1.25" Al 6061-T6 (platen)
3.0" Al 6061-T6 (spindle plate)
5.0" graphite (reflector)
0.180" (3 @ 0.060") Mo (reflector)
0.394" graphite
14 stacking units consisting of [0.030" Mo, 0.118" HEU, 0.030" Mo, 0.394" graphite]
0.180" (3 @ 0.060") Mo (reflector)
5.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.394 ± 0.006 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Mo-4 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" polyethylene (reflector)
- 0.180" (3 @ 0.060 in) Mo (reflector)
- 0.080" polyethylene
- 11 stacking units consisting of [0.030" Mo, 0.118" HEU, 0.030" Mo, 0.080" polyethylene]
- 0.180" (3 @ 0.060") Mo (reflector)
- 1.0" polyethylene (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 6th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 5th unit.
3. The thickness of the high density polyethylene plates used in the central assembly shall be 0.080 ± 0.004 inch.
4. The thickness of the upper polyethylene reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.50 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Nb-1Zr-2 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 2.0" graphite (reflector)
- 0.180" Nb-1Zr (reflector)
- 0.197" graphite
- 16 stacking units consisting of [0.040" Nb-1Zr, 0.118" HEU, 0.040" Nb-1Zr, 0.197" graphite]
- 0.180" Nb-1Zr (reflector)
- 2.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.197 ± 0.005 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Nb-1Zr-3 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 5.0" graphite (reflector)
- 0.180" Nb-1Zr (reflector)
- 0.394" graphite
- 15 stacking units consisting of [0.040" Nb-1Zr, 0.118" HEU, 0.040" Nb-1Zr, 0.394" graphite]
- 0.180" Nb-1Zr (reflector)
- 5.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.394 ± 0.006 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Re-1 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" graphite (reflector)
- 18 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re, 0.100" graphite]
- 1 stacking unit consisting of [0.015" Re, 0.118" HEU, 0.015" Re]
- 1.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.100 ± 0.005 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.5 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Re-2 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 2.0" graphite (reflector)
- 16 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re, 0.197" graphite]
- 1 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re]
- 2.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.197 ± 0.005 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Re-3 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 5.0" graphite (reflector)
- 15 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re, 0.394" graphite]
- 1 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re]
- 5.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the graphite plates used in the central assembly shall be 0.394 ± 0.006 inch.
4. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Re-4 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 1.0" polyethylene (reflector)
- 14 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re, 0.080" polyethylene]
- 1 stacking units consisting of [0.015" Re, 0.118" HEU, 0.015" Re]
- 1.0" polyethylene (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the high density polyethylene plates used in the central assembly shall be 0.080 ± 0.004 inch.
4. The thickness of the upper polyethylene reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.50 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Ta-2.5W-1 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

1.25" Al 6061-T6 (platen)
 3.0" Al 6061-T6 (spindle plate)
 1.0" graphite (reflector)
 0.150" (6 @ 0.025") Ta-2.5W (reflector)
 0.100" graphite
 19 stacking units consisting of [0.025" Ta-2.5W, 0.118" HEU, 0.025" Ta-2.5W, 0.100" graphite]
 0.150" (6 @ 0.025") Ta-2.5W (reflector)
 1.0" graphite (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The Ta-2.5W plates from heat 11-19-2 shall be used to construct the bottom and center of the assembly until they are expended, then Ta-2.5W plates from heat 10-20-2 shall be used to complete the top of the assembly. Ta-2.5W plates from different heats shall not be mixed in a unit or in the top and bottom reflector. Ta-2.5W plates from heat 10-20-2 should be used to construct the top and bottom reflectors.
4. The thickness of the graphite plates used in the central assembly shall be 0.100 ± 0.005 inch.
5. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.4 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last unit may be adjusted.

Specifications for the Ta-2.5W-2 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

- 1.25" Al 6061-T6 (platen)
- 3.0" Al 6061-T6 (spindle plate)
- 2.0" graphite (reflector)
- 0.150" (6 @ 0.025") Ta-2.5W (reflector)
- 0.200" graphite
- 17 stacking units consisting of [0.025" Ta-2.5W, 0.118" HEU, 0.025" Ta-2.5W, 0.200" graphite]
- 0.150" (6 @ 0.025") Ta-2.5W (reflector)
- 2.0" graphite (reflector)

In addition:

5. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
6. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
7. The thickness of the graphite plates used in the central assembly shall be 0.200 ± 0.005 inch.
8. The Ta-2.5W plates from heat 11-19-2 shall be used to construct the bottom and center of the assembly until they are expended, then Ta-2.5W plates from heat 10-20-2 shall be used to complete the top of the assembly. Ta-2.5W plates from different heats shall not be mixed in a unit or in the top and bottom reflector. Ta-2.5W plates from heat 10-20-2 should be used to construct the top and bottom reflectors.
9. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Ta-2.5W-3 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

1.25" Al 6061-T6 (platen)
 3.0" Al 6061-T6 (spindle plate)
 5.0" graphite (reflector)
 0.150" (6 @ 0.025") Ta-2.5W (reflector)
 0.394" graphite
 18 stacking units consisting of [0.025" Ta-2.5W, 0.118" HEU, 0.025" Ta-2.5W, 0.394" graphite]
 0.150" (6 @ 0.025") Ta-2.5W (reflector)
 5.0" graphite (reflector)

In addition:

5. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
6. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
7. The thickness of the graphite plates used in the central assembly shall be 0.394 ± 0.006 inch.
8. The Ta-2.5W plates from heat 11-19-2 shall be used to construct the bottom and center of the assembly until they are expended, then Ta-2.5W plates from heat 10-20-2 shall be used to complete the top of the assembly. Ta-2.5W plates from different heats shall not be mixed in a unit or in the top and bottom reflector. Ta-2.5W plates from heat 10-20-2 should be used to construct the top and bottom reflectors.
9. The thickness of the upper graphite reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 1.0 inches. If the upper reflector thickness is outside this tolerance band, another stacking unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Specifications for the Ta-2.5W-4 Experiment

Starting at the bottom of the assembly ($z = 0.0$ "), the experimental stack up is:

1.25" Al 6061-T6 (platen)
3.0" Al 6061-T6 (spindle plate)
1.0" polyethylene (reflector)
0.150" (6 @ 0.025 in) Ta-2.5W (reflector)
0.080" polyethylene
16 stacking units consisting of [0.025" Ta-2.5W, 0.118" HEU, 0.025" Ta-2.5W, 0.080" polyethylene]
0.150" (6 @ 0.025") Ta-2.5W (reflector)
1.0" polyethylene (reflector)

In addition:

1. All of the above cylindrical plates have a 21.0 inch outer diameter. Void extends both axially and radially beyond the assembly.
2. A 2.5 inch diameter hole extends through the center of the Al spindle plate, while a 2.51 inch diameter hole extends through the center of the assembly up to the top of the 7th unit to accommodate an empty Al 6061-T6 alignment tube (2.0 inch inner diameter, 2.48 inch outer diameter). The alignment tube extends from the bottom of the assembly ($z = 0.0$ ") to the top of the 6th unit.
3. The thickness of the high density polyethylene plates used in the central assembly shall be 0.080 ± 0.005 inch.
4. The Ta-2.5W plates from heat 11-19-2 shall be used to construct the bottom and center of the assembly until they are expended, then Ta-2.5W plates from heat 10-20-2 shall be used to complete the top of the assembly. Ta-2.5W plates from different heats shall not be mixed in a unit or in the top and bottom reflector. Ta-2.5W plates from heat 10-20-2 should be used to construct the top and bottom reflectors.
5. The thickness of the upper polyethylene reflector may be adjusted to ensure that the excess reactivity of the assembly is less than \$0.50 at full closure. The tolerance on the upper reflector thickness shall be ± 0.40 inches. If the upper reflector thickness is outside this tolerance band, another unit should be added or subtracted from the assembly or the mass of the HEU fuel plate in the last stacking unit may be adjusted.

Appendix B

Specifications for the ORNL Nb-1Zr Critical Experiments

B-TM-1639

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THE NIOBIUM EXPERIMENTS

Description of the experimental configuration in Mexp 2J ($k_{\text{eff}} = 0.99754 \pm 0.00048$)

Starting at bottom ($y=0.0$), one has:

6.0372 cm of void, 3.81 cm of aluminum (the platen), 14.4274 cm of Cu, 1.007872 cm of gr,
[8 cells of (0.299720 cm of HEU, 1.007872 cm of gr, 0.076200 cm of Nb-1Zr, 1.007872 cm of gr)],
0.299720 cm of HEU, 1.007872 cm of gr, 14.4272 cm of Cu

In addition:

1. All of the above cylindrical plates extend out to a radius of 26.67 cm, and are surrounded by a 0.127-cm annular void, followed by a copper reflector out to $X=Z = \pm 44.152$ cm. This copper reflector goes from the bottom at $Y=0.0$ to the top at $Y=60.150376$ cm.
2. A hole of radius 4.7625 cm extends up thru the center of the aluminum platen, while a smaller hole of radius 3.175 cm continues up to the top of the 5th HEU plate to accommodate an empty aluminum support tube ($r_{\text{min}}=2.54$ cm, $r_{\text{max}}=3.1496$ cm), which extends from the bottom of the configuration at $Y=0.0$, up to the top of the 5th HEU plate at $Y=35.148648$ cm.

Description of the experimental configuration in Mexp 2L ($k_{\text{eff}} = 1.00454 \pm 0.00051$)

Starting at bottom ($y=0.0$), one has:

6.0372 cm of void, 3.81 cm of aluminum (the platen), 14.4274 cm of Cu, 0.503936 cm of gr,
[8 cells of (0.299720 cm of HEU, 0.503936 cm of gr, 0.076200 cm of Nb-1Zr, 0.503936 cm of gr)],
0.299720 cm of HEU, 0.503936 cm of gr, 14.4272 cm of Cu

In addition:

1. All of the above cylindrical plates extend out to a radius of 26.67 cm, and are surrounded by a 0.127-cm annular void, followed by a copper reflector out to $X=Z = \pm 44.152$ cm. This copper reflector goes from the bottom at $Y=0.0$ to the top at $Y=60.150376$ cm.
2. A hole of radius 4.7625 cm extends up thru the center of the aluminum platen, while a smaller hole of radius 3.175 cm continues up to the top of the 5th HEU plate to accommodate an empty aluminum support tube ($r_{\text{min}}=2.54$ cm, $r_{\text{max}}=3.1496$ cm), which extends from the bottom of the configuration at $Y=0.0$, up to the top of the 5th HEU plate at $Y=30.613224$ cm.

Description of the experimental configuration in Mexp 4U ($k_{\text{eff}} = 1.01212 \pm 0.00054$)

Starting at bottom ($y = -0.0001$ cm), one has:

0.0001 cm of void, 3.81 cm of aluminum (the platen), 2.8575 cm Poly (refl), 0.279 cm Nb1Zr (refl), 0.0508 cm Poly, 0.1016 cm Nb1Zr, 0.29972 cm HEU, 0.1016 cm Nb1Zr, [12 cells of (0.1016 cm Poly, 0.1016 cm Nb1Zr, 0.29972 cm HEU, 0.1016 cm Nb1Zr)], 0.0508 cm Poly, 0.279 cm Nb1Zr (refl), 2.8575 cm Poly (refl), 0.0001 cm void

In addition:

1. All of the above cylindrical plates extend out to a radius of 26.67 cm. Beyond that radially, there is nothing but void (ie, no copper reflector).
2. A hole of radius 4.7625 cm extends up thru the center of the aluminum platen, while a smaller hole of radius 3.175 cm continues up to the top of the 5th HEU plate to accommodate an empty aluminum support tube ($r_{\text{min}} = 2.54$ cm, $r_{\text{max}} = 3.1496$ cm), which extends from the bottom of the configuration at $Y = -0.0001$, up to the top of the 5th HEU plate at $Y = 9.8167$ cm.
3. Note that this bare configuration has 13 HEU plates, 26 of the 0.1016-cm Nb-1Zr plates, 12 of the 0.1016-cm-thk (and 2 of the 0.0508-cm-thk) polyethylene moderator sheets, two 2.8575-cm poly (refl) plates, and two 0.279-cm-thk Nb-1Zr reflector plates. There is no copper reflector axially or radially.
4. The two innermost Nb-1Zr reflector plates have the same thickness (0.279 cm) as the space reactor vessel while the 2 outermost Poly reflector plates simulate the reactor reflector. These Poly reflector plates had to be somewhat thicker than in the previous cases in order to attain criticality. Above configuration extends from $Y = -0.0001$ to $Y = 17.94186$ cm.

Description of the experimental configuration in Mexp 4Y ($k_{\text{eff}} = 1.01665 \pm 0.00051$)

Starting at bottom ($y = -0.0001$ cm), one has:

0.0001 cm of void, 3.81 cm of aluminum (the platen), 0.0001 cm Poly, 0.279 cm Nb-1Zr (refl),
0.003810 cm Poly, 0.1016 cm Nb-1Zr, 0.29972 cm HEU, 0.1016 cm Nb-1Zr,
[20 cells of (0.00762 cm Poly, 0.1016 cm Nb-1Zr, 0.29972 cm HEU, 0.1016 cm Nb-1Zr)],
0.00381 cm Poly, 0.279 cm Nb-1Zr (refl), 0.0001 cm Poly, 0.0001 cm void

In addition:

1. All of the above cylindrical plates extend out to a radius of 26.67 cm. Beyond that radially, there is nothing but void (ie, no copper reflector).
2. A hole of radius 4.7625 cm extends up thru the center of the aluminum platen, while a smaller hole of radius 3.175 cm continues up to the top of the 5th HEU plate to accommodate an empty aluminum support tube ($r_{\text{min}} = 2.54$ cm, $r_{\text{max}} = 3.1496$ cm), which extends from the bottom of the configuration at $Y = -0.0001$, up to the top of the 5th HEU plate at $Y = 6.53639$ cm.
3. Note that this bare configuration has 21 HEU plates, 42 of the 0.1016-cm Nb-1Zr plates, 20 of the 0.00762-cm-thk (and 2 of the 0.00381-cm-thk) polyethylene moderator sheets, two 0.279-cm-thk Nb-1Zr reflector plates. (The two 0.0001-cm-thk polyethylene regions may be ignored.) There is no copper reflector axially or radially.
4. The two Nb-1Zr reflector plates have the same thickness (0.279 cm) as the space reactor vessel. Note that there is essentially no polyethylene reflector beyond the Nb-1Zr. Criticality is achieved thru the use of a large number of HEU plates. The above configuration extends from $Y = -0.0001$ to $Y = 15.08954$ cm.

Appendix C

Definition of SPACE05A Cross Section Library

Nuclide	Data Source
AC225	JENDL-3.3
AC226	JENDL-3.3
AC227	JENDL-3.3
AG107	ENDF\B-VI.0
AG109	ENDF\B-VI.0
AG110M	JENDL-3.2
AG111	ENDF\B-VI.0
AL27	ENDF\B-VI.8
AM241	ENDF\B-VI.3
AM242	ENDF\B-VI.1
AM242M	ENDF\B-VI.1
AM243	ENDF\B-VI.5
AM244	JENDL-3.2
AR36	JEF-2.2
AR38	JEF-2.2
AR40	JEF-2.2
AS75	JENDL-3.2
AU197	ENDF\B-VI.1
B10	ENDF\B-VI.1
B11	ENDF\B-VI.0
BA130	JENDL-3.2
BA132	JENDL-3.2
BA134	JENDL-3.2
BA135	JENDL-3.2
BA136	JENDL-3.2
BA137	JENDL-3.2
BA138	JENDL-3.2
BA140	JENDL-3.2
BE-BEO	ENDF\B-VI.0
BE-METAL	ENDF\B-VI.0
BE9	ENDF\B-VI.8
BI209	ENDF\B-VI.7
BK249	ENDF\B-VI.0
BK250	JENDL-3.2
BR79	JENDL-3.2
BR81	JENDL-3.2
C	ENDF\B-VI.6
C-GRAPH	ENDF\B-VI.6
CA40	JENDL-3.2
CA42	JENDL-3.2
CA43	JENDL-3.2
CA44	JENDL-3.2
CA46	JENDL-3.2
CA48	JENDL-3.2
CD106	ENDF\B-VI.4

Nuclide	Data Source
CD108	ENDF\B-VI.4
CD110	ENDF\B-VI.4
CD111	ENDF\B-VI.3
CD112	ENDF\B-VI.4
CD113	ENDF\B-VI.0
CD114	ENDF\B-VI.4
CD115M	ENDF\B-VI.0
CD116	ENDF\B-VI.4
CE140	JENDL-3.2
CE141	ENDF\B-VI.0
CE142	JENDL-3.2
CE143	JEF-2.2
CE144	ENDF\B-VI.0
CF249	ENDF\B-VI.0
CF250	ENDF\B-VI.2
CF251	ENDF\B-VI.2
CF252	ENDF\B-VI.2
CF253	ENDF\B-VI.2
CF254	JENDL-3.2
CL35	JENDL-3.2
CL37	JENDL-3.2
CM241	ENDF\B-VI.0
CM242	ENDF\B-VI.0
CM243	ENDF\B-VI.0
CM244	ENDF\B-VI.0
CM245	ENDF\B-VI.7
CM246	ENDF\B-VI.7
CM247	JENDL-3.2
CM248	JENDL-3.2
CM249	JENDL-3.2
CM250	JENDL-3.2
CO58	JEF-2.2
CO58M	JEF-2.2
CO59	ENDF\B-VI.2
CR50	ENDF\B-VI.8
CR52	ENDF\B-VI.8
CR53	ENDF\B-VI.8
CR54	ENDF\B-VI.8
CS133	ENDF\B-VI.0
CS134	ENDF\B-VI.0
CS135	JEF-2.2
CS136	ENDF\B-VI.0
CS137	JENDL-3.2
CU63	ENDF\B-VI.8
CU65	ENDF\B-VI.8
DY160	ENDF\B-VI.7
DY161	ENDF\B-VI.7
DY162	ENDF\B-VI.7
DY163	ENDF\B-VI.7
DY164	ENDF\B-VI.7
ER162	JENDL3.3
ER164	JENDL3.3

Nuclide	Data Source
ER166	JENDL3.3
ER167	JENDL3.3
ER168	JENDL3.3
ER170	JENDL3.3
ES253	ENDF\B-VI.0
EU151	ENDF\B-VI.0
EU152	ENDF\B-VI.0
EU153	ENDF\B-VI.0
EU154	ENDF\B-VI.7
EU155	ENDF\B-VI.7
EU156	ENDF\B-VI.0
EU157	ENDF\B-VI.0
F19	ENDF\B-VI.8
FE54	ENDF\B-VI.8
FE56	ENDF\B-VI.8
FE57	ENDF\B-VI.8
FE58	ENDF\B-VI.8
GA69	JENDL-3.2
GA71	JENDL-3.2
GD152	ENDF\B-VI.4
GD154	ENDF\B-VI.4
GD155	ENDF\B-VI.0
GD156	ENDF\B-VI.0
GD157	ENDF\B-VI.0
GD158	ENDF\B-VI.0
GD160	ENDF\B-VI.0
GE70	JENDL-3.2
GE72	JENDL-3.2
GE73	JENDL-3.2
GE74	JENDL-3.2
GE76	JENDL-3.2
H-H2O	ENDF\B-VI.8
H-POLY	ENDF\B-VI.8
H-ZRH	ENDF\B-VI.8
H1	ENDF\B-VI.8
H2	ENDF\B-VI.6
H2-D2O	ENDF\B-VI.6
H3	ENDF\B-VI.0
HE3	ENDF\B-VI.1
HE4	ENDF\B-VI.0
HF174	ENDF\B-VI.2
HF176	ENDF\B-VI.2
HF177	ENDF\B-VI.2
HF178	ENDF\B-VI.2
HF179	ENDF\B-VI.2
HF180	ENDF\B-VI.2
HG196	JENDL-3.3
HG198	JENDL-3.3
HG199	JENDL-3.3
HG	JENDL-3.3
HG201	JENDL-3.3
HG202	JENDL-3.3

Nuclide	Data Source
HG204	JENDL-3.3
HO165	ENDF\B-VI.5
I127	JENDL-3.2
I129	JENDL-3.2
I130	JEF-2.2
I131	ENDF\B-VI.0
I135	ENDF\B-VI.0
IN113	JENDL-3.2
IN115	JENDL-3.2
IR191	ENDF\B-VI.4
IR193	ENDF\B-VI.4
K39	JENDL-3.2
K40	JENDL-3.2
K41	JENDL-3.2
KR78	JENDL-3.2
KR80	JENDL-3.2
KR82	JENDL-3.2
KR83	ENDF\B-VI.0
KR84	JENDL-3.2
KR85	JENDL-3.2
KR86	JENDL-3.2
LA138	JENDL-3.2
LA139	ENDF\B-VI.1
LA140	JEF-2.2
LI6	ENDF\B-VI.1
LI7	ENDF\B-VI.0
LU175	ENDF\B-VI.7
LU176	ENDF\B-VI.7
MG24	JENDL-3.2
MG25	JENDL-3.2
MG26	JENDL-3.2
MN55	ENDF\B-VI.8
MO100	JENDL-3.2
MO92	JENDL-3.2
MO94	JENDL-3.2
MO95	JENDL-3.2
MO96	JENDL-3.2
MO97	JENDL-3.2
MO98	JENDL-3.2
MO99	JENDL-3.2
N14	ENDF\B-VI.8
N15	ENDF\B-VI.0
NA22	JEF-2.2
NA23	ENDF\B-VI.8
NB93	ENDF\B-VI.6
NB94	JENDL-3.2
NB95	ENDF\B-VI.0
ND142	JENDL-3.2
ND143	ENDF\B-VI.2
ND144	JENDL-3.2
ND145	ENDF\B-VI.2
ND146	JENDL-3.2

Nuclide	Data Source
ND147	JENDL-3.2
ND148	JENDL-3.2
ND150	JENDL-3.2
NI58	ENDF\B-VI.8
NI59	JEF-2.2
NI60	ENDF\B-VI.8
NI61	ENDF\B-VI.8
NI62	ENDF\B-VI.8
NI64	ENDF\B-VI.8
NP236	JENDL-3.2
NP237	ENDF\B-VI.1
NP238	ENDF\B-VI.2
NP239	ENDF\B-VI.0
O-BEO	ENDF\B-VI.8
O16	ENDF\B-VI.8
O17	ENDF\B-VI.0
OS	JEF3.0
P31	ENDF\B-VI.6
PA231	JENDL-3.2
PA232	ENDF\B-VI.8
PA233	ENDF\B-VI.0
PB204	JENDL3.2
PB206	ENDF\B-VI.0
PB207	ENDF\B-VI.1
PB208	ENDF\B-VI.5
PD102	ENDF\B-VI.5
PD104	ENDF\B-VI.5
PD105	ENDF\B-VI.5
PD106	ENDF\B-VI.5
PD107	ENDF\B-VI.0
PD108	ENDF\B-VI.5
PD110	ENDF\B-VI.5
PM147	ENDF\B-VI.1
PM148	ENDF\B-VI.0
PM148M	ENDF\B-VI.0
PM149	ENDF\B-VI.0
PM151	ENDF\B-VI.0
PR141	ENDF\B-VI.0
PR142	JEF-2.2
PR143	ENDF\B-VI.0
PU236	ENDF\B-VI.4
PU237	ENDF\B-VI.0
PU238	ENDF\B-VI.0
PU239	ENDF\B-VI.5
PU240	ENDF\B-VI.2
PU241	ENDF\B-VI.3
PU242	ENDF\B-VI.0
PU243	ENDF\B-VI.2
PU244	ENDF\B-VI.0
RA224	JENDL-3.2
RA226	JENDL-3.2
RB85	ENDF\B-VI.0

Nuclide	Data Source
RB86	ENDF\B-VI.0
RB87	ENDF\B-VI.0
RE185	ENDF\B-VI.0
RE187	ENDF\B-VI.0
RH103	ENDF\B-VI.0
RH105	ENDF\B-VI.0
RU100	JENDL-3.2
RU101	ENDF\B-VI.2
RU102	ENDF\B-VI.2
RU103	ENDF\B-VI.0
RU104	JENDL-3.2
RU105	ENDF\B-VI.0
RU106	ENDF\B-VI.0
RU96	ENDF\B-VI.0
RU98	ENDF\B-VI.0
RU99	JENDL-3.2
S32	JENDL-3.2
S33	JENDL-3.2
S34	JENDL-3.2
S36	JENDL-3.2
SB121	ENDF\B-VI.0
SB123	ENDF\B-VI.0
SB124	ENDF\B-VI.0
SB125	ENDF\B-VI.0
SB126	ENDF\B-VI.0
SC45	ENDF\B-VI.8
SE74	JENDL-3.2
SE76	JENDL-3.2
SE77	JENDL-3.2
SE78	JENDL-3.2
SE79	JENDL-3.2
SE80	JENDL-3.2
SE82	JENDL-3.2
SI28	ENDF\B-VI.5
SI29	ENDF\B-VI.5
SI30	ENDF\B-VI.5
SM144	ENDF\B-VI.3
SM147	ENDF\B-VI.0
SM148	JENDL-3.2
SM149	ENDF\B-VI.0
SM150	ENDF\B-VI.2
SM151	ENDF\B-VI.1
SM152	ENDF\B-VI.2
SM153	ENDF\B-VI.0
SM154	ENDF\B-VI.0
SN112	JENDL-3.2
SN114	JENDL-3.2
SN115	JENDL-3.2
SN116	JENDL-3.2
SN117	JENDL-3.2
SN118	JENDL-3.2
SN119	JENDL-3.2

Nuclide	Data Source
SN120	JENDL-3.2
SN122	JENDL-3.2
SN123	ENDF\B-VI.0
SN124	JENDL-3.2
SN125	ENDF\B-VI.0
SN126	ENDF\B-VI.0
SR86	JENDL-3.2
SR87	JENDL-3.2
SR88	JENDL-3.2
SR89	ENDF\B-VI.0
SR90	JENDL-3.2
TA181	ENDF\B-VI.0
TA182	ENDF\B-VI.0
TB159	JENDL-3.2
TB160	ENDF\B-VI.0
TC99	JENDL-3.2
TE120	ENDF\B-VI.0
TE122	JENDL-3.2
TE123	JENDL-3.2
TE124	JENDL-3.2
TE125	JENDL-3.2
TE126	JENDL-3.2
TE127M	ENDF\B-VI.0
TE128	JENDL-3.2
TE129M	ENDF\B-VI.0
TE130	JENDL-3.2
TE132	ENDF\B-VI.0
TH228	JENDL-3.2
TH229	JENDL-3.2
TH230	JENDL-3.2
TH232	ENDF\B-VI.0
TH233	JENDL-3.2
TI	JENDL-3.2
TI46	JENDL-3.2
TI47	JENDL-3.2
TI48	JENDL-3.2
TI49	JENDL-3.2
TI50	JENDL-3.2
U232	JEF-2.2
U233	JENDL-3.2
U234	ENDF\B-VI.0
U235	ENDF\B-VI.5
U236	ENDF\B-VI.0
U237	ENDF\B-VI.2
U238	ENDF\B-VI.5
V	ENDF\B-VI.8
W	ENDF\B-VI.1
W182	ENDF\B-VI.8
W183	ENDF\B-VI.8
W184	ENDF\B-VI.8
W186	ENDF\B-VI.8
XE124	JENDL-3.2

Nuclide	Data Source
XE126	JENDL-3.2
XE128	JENDL-3.2
XE129	JENDL-3.2
XE130	JENDL-3.2
XE131	ENDF\B-VI.0
XE132	JENDL-3.2
XE133	ENDF\B-VI.0
XE134	JENDL-3.2
XE135	ENDF\B-VI.0
XE136	JENDL-3.2
Y89	JENDL-3.2
Y90	ENDF\B-VI.0
Y91	ENDF\B-VI.0
ZN	JEF-3.0
ZR	ENDF\B-VI.1
ZR-ZRH	ENDF\B-VI.1
ZR90	ENDF\B-VI.8
ZR91	ENDF\B-VI.8
ZR92	ENDF\B-VI.8
ZR93	JENDL-3.2
ZR94	ENDF\B-VI.8
ZR95	ENDF\B-VI.0
ZR96	ENDF\B-VI.8

Appendix D

Material Density Measurements and Uncertainty Analysis

B-TM-1639

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Introduction

Density measurements of the Ta, Mo, and Re samples were performed by Knolls Atomic Power Laboratory using the submersion method. While this method is known to be accurate, potential sources of measurement error are the laboratory equipment, the sensitivity to water purity and quantity, and specimen handling. The following equipment was used in this series of measurements:

- Mettler AT261 calibrated balance (± 0.00002 g)
- Hart Scientific 1521 Thermometer with 5627-9 probe (± 0.001 °C)
- Omega 450 ATH Thermocouple Thermometer (± 0.1 °C)
- Cole Palmer Oakton 03316-72 calibrated barometer ($\pm 3\%$)
- Waltrous & Company, Inc. Lufft 5033-32W calibrated hygrometer (± 1 mmHg)

Density Analysis

The density of the samples is calculated from measurements as shown in Equation 1:

$$\rho_{\text{specimen}} = \frac{\bar{W}_{\text{specimen dry}} \rho_{\text{water}} - \bar{W}_{\text{specimen wet}} \rho_{\text{air}}}{\bar{W}_{\text{specimen dry}} - \bar{W}_{\text{specimen wet}}} \quad (1)$$

where: ρ_{specimen} = density of specimen (g/cm^3)
 ρ_{water} = density of water (g/cm^3)
 ρ_{air} = density of air (g/cm^3)
 $\bar{W}_{\text{specimen dry}}$ = weight of specimen dry (g) [see Equation 2]
 $\bar{W}_{\text{specimen wet}}$ = weight of specimen wet (g) [see Equation 3]

Three separate measurements of wet and dry weight were averaged according to Equations 2 and 3:

$$\bar{W}_{\text{specimen dry}} = \frac{\left(W_{\text{specimen dry}}\right)_1 + \left(W_{\text{specimen dry}}\right)_2 + \left(W_{\text{specimen dry}}\right)_3}{3} \quad (2)$$

$$\bar{W}_{\text{specimen wet}} = \frac{\left(W_{\text{specimen / saddle wet}} - W_{\text{saddle wet}}\right)_1 + \left(W_{\text{specimen / saddle wet}} - W_{\text{saddle wet}}\right)_2 + \left(W_{\text{specimen / saddle wet}} - W_{\text{saddle wet}}\right)_3}{3} \quad (3)$$

where: $W_{\text{specimen / saddle wet}}$ = combined weight of saddle & specimen wet (g)
 $W_{\text{saddle wet}}$ = weight of saddle wet (g)

The density of water is calculated as shown in Equation 4:

$$\rho_{\text{water}} = (3.42935528E-8)\bar{T}_{\text{water}}^3 + (-7.34259259E-6)\bar{T}_{\text{water}}^2 + (4.62032628E-5)\bar{T}_{\text{water}} + (9.99942302E-1) \quad (4)$$

where: $\bar{T}_{water}$ = water temperature (°C) [see Equation 5]

Three separate measurements of water temperature were averaged according to Equation 5:

$$\bar{T}_{water} = \frac{(T_{water})_1 + (T_{water})_2 + (T_{water})_3}{3} \quad (5)$$

The density of air is calculated as shown in Equation 6:

$$\rho_{air} = \frac{(0.4645540)(P_{bar} - 0.0037802 \cdot H_{rel} P_{vapor})}{(\bar{T}_{air} + 273.15)(1000.027)} \quad (6)$$

where: P_{bar} = barometric pressure (mmHg)
 H_{rel} = relative humidity (%)
 P_{vapor} = vapor pressure (mmHg) [see Equation 7]
 $\bar{T}_{air}$ = air temperature (°C) [see Equation 8]

Vapor pressure has been correlated to a function of air temperature as shown in Equation 7:

$$P_{vapor} = (4.9500000E - 4)\bar{T}_{air}^3 + (1.5080000E - 4)\bar{T}_{air}^2 + (4.8269330E - 1)\bar{T}_{air} + (3.8535478) \quad (7)$$

Three separate measurements of water temperature were averaged according to Equation 8:

$$\bar{T}_{air} = \frac{(T_{air})_1 + (T_{air})_2 + (T_{air})_3}{3} \quad (8)$$

Error Analysis

The error associated with the submersion method of density measurement has been calculated using an RMS (root-mean squared) approach. The governing equations follow.

The RMS error associated with the specimen density equation [Equation 1] is shown below in Equation 9:

$$RMS_{\rho_{specimen}} = \sqrt{\left(\frac{\partial \rho_{specimen}}{\partial \bar{W}_{specimen dry}} \frac{\partial \bar{W}_{specimen dry}}{\partial \bar{W}_{specimen dry}} \right)^2 + \left(\frac{\partial \rho_{specimen}}{\partial \bar{W}_{specimen wet}} \frac{\partial \bar{W}_{specimen wet}}{\partial \bar{W}_{specimen wet}} \right)^2 + \left(\frac{\partial \rho_{specimen}}{\partial \rho_{water}} \frac{\partial \rho_{water}}{\partial \rho_{water}} \right)^2 + \left(\frac{\partial \rho_{specimen}}{\partial \rho_{air}} \frac{\partial \rho_{air}}{\partial \rho_{air}} \right)^2} \quad (9)$$

where: $\frac{\partial \rho_{specimen}}{\partial \bar{W}_{specimen dry}} = \frac{\rho_{water}}{\bar{W}_{specimen dry} - \bar{W}_{specimen wet}} - \frac{\bar{W}_{specimen dry} \rho_{water} - \bar{W}_{specimen wet} \rho_{air}}{(\bar{W}_{specimen dry} - \bar{W}_{specimen wet})^2}$

$\frac{\partial \bar{W}_{specimen dry}}{\partial \bar{W}_{specimen dry}}$ = error associated with specimen dry weight [see Equation 10]

$$\frac{\partial \rho_{\text{specimen}}}{\partial \bar{W}_{\text{specimen wet}}} = \frac{-\rho_{\text{air}}}{\bar{W}_{\text{specimen dry}} - \bar{W}_{\text{specimen wet}}} + \frac{\bar{W}_{\text{specimen dry}} \rho_{\text{water}} - \bar{W}_{\text{specimen wet}} \rho_{\text{air}}}{\left(\bar{W}_{\text{specimen dry}} - \bar{W}_{\text{specimen wet}} \right)^2}$$

$\partial \bar{W}_{\text{specimen wet}}$ = error associated with specimen wet weight [see Equation 11]

$$\frac{\partial \rho_{\text{specimen}}}{\partial \rho_{\text{water}}} = \frac{-\bar{W}_{\text{specimen wet}}}{\bar{W}_{\text{specimen dry}} - \bar{W}_{\text{specimen wet}}}$$

$\partial \rho_{\text{water}}$ = error associated with water density [see Equation 12]

$$\frac{\partial \rho_{\text{specimen}}}{\partial \rho_{\text{air}}} = \frac{\bar{W}_{\text{specimen dry}}}{\bar{W}_{\text{specimen dry}} - \bar{W}_{\text{specimen wet}}}$$

$\partial \rho_{\text{air}}$ = error associated with air density [see Equation 13]

The error associated with specimen dry weight is calculated from the averaging equation on an RMS basis as shown in Equation 10:

$$\partial \bar{W}_{\text{specimen dry}} = RMS_{\bar{W}_{\text{specimen dry}}} = \sqrt{\sum_{n=1}^3 \left(\frac{\partial \bar{W}_{\text{specimen dry}}}{\partial \left(W_{\text{specimen dry}} \right)_n} \partial \left(W_{\text{specimen dry}} \right)_n \right)^2} \quad (10)$$

where: $\partial \bar{W}_{\text{specimen dry}} = \delta_{\text{balance}} = 0.00002 (g)$

The error associated with specimen wet weight is calculated from the averaging equation on an RMS basis as shown in Equation 11:

$$\partial \bar{W}_{\text{specimen wet}} = RMS_{\bar{W}_{\text{specimen wet}}} = \sqrt{\sum_{n=1}^3 \left(\frac{\partial \bar{W}_{\text{specimen wet}}}{\partial \left(W_{\text{specimen wet}} \right)_n} \partial \left(W_{\text{specimen wet}} \right)_n \right)^2} \quad (11)$$

where: $\partial \bar{W}_{\text{specimen wet}} = \delta_{\text{balance}} = 0.00002 (g)$

The error associated with the water density is calculated from the averaging equation on an RMS basis as shown in Equation 12:

$$\partial \rho_{\text{water}} = RMS_{\rho_{\text{water}}} = \sqrt{\left(\frac{\partial \rho_{\text{water}}}{\partial \bar{T}_{\text{water}}} \partial \bar{T}_{\text{water}} \right)^2} \quad (12)$$

$$\text{where: } \partial \bar{T}_{\text{water}} = RMS_{\bar{T}_{\text{water}}} = \sqrt{\sum_{n=1}^3 \left(\frac{\partial \bar{T}_{\text{water}}}{\partial (T_{\text{water}})_n} \partial (T_{\text{water}})_n \right)^2}$$

$$\text{where: } \partial T_{\text{water}} = \delta_{\text{water probe}} = 0.001(^{\circ}\text{C})$$

The error associated with the air density is calculated from the averaging equation on an RMS basis as shown in Equation 13:

$$\partial \rho_{\text{air}} = RMS_{\rho_{\text{air}}} = \sqrt{\left(\frac{\partial \rho_{\text{air}}}{\partial P_{\text{bar}}} \partial P_{\text{bar}} \right)^2 + \left(\frac{\partial \rho_{\text{air}}}{\partial H_{\text{rel}}} \partial H_{\text{rel}} \right)^2 + \left(\frac{\partial \rho_{\text{air}}}{\partial \bar{T}_{\text{air}}} \partial \bar{T}_{\text{air}} \right)^2} \quad [\text{See Note 1}] \quad (13)$$

NOTE 1: P_{vapor} is solely a function of $\bar{T}_{\text{air}}$

$$\text{where: } \frac{\partial \rho_{\text{air}}}{\partial P_{\text{bar}}} = \left(\frac{0.464554}{1000.027} \right) \left(\frac{1}{\bar{T}_{\text{air}} + 273.15} \right)$$

$$\partial P_{\text{bar}} = \delta_{\text{barometer}} = 1(\text{mmHg})$$

$$\frac{\partial \rho_{\text{air}}}{\partial H_{\text{rel}}} = \left(\frac{0.464554}{1000.027} \right) \left(\frac{-0.0037802 P_{\text{vap}}}{\bar{T}_{\text{air}} + 273.15} \right)$$

$$\partial H_{\text{rel}} = \delta_{\text{hygrometer}} = 3\%$$

$$\frac{\partial \rho_{\text{air}}}{\partial \bar{T}_{\text{air}}} = \left(\frac{-C_1}{C_3} \right) \left\{ \left[\frac{C_2 H_{\text{rel}} (C_6 + 2C_7 \bar{T}_{\text{air}} + 3C_8 \bar{T}_{\text{air}}^2)}{(\bar{T}_{\text{air}} + C_4)} \right] + \left[\frac{P_{\text{bar}} - C_2 H_{\text{rel}} (C_5 + C_6 \bar{T}_{\text{air}} + C_7 \bar{T}_{\text{air}}^2 + C_8 \bar{T}_{\text{air}}^3)}{(\bar{T}_{\text{air}} + C_4)^2} \right] \right\}$$

where: $C_1 = 0.464554$

$C_2 = 0.0037802$

$C_3 = 1000.027$

$C_4 = 273.15$

$C_5 = 3.8535478$

$C_6 = 0.4826933$

$C_7 = 0.0001508$

$C_8 = 0.000495$

$$\partial \bar{T}_{\text{air}} = RMS_{\bar{T}_{\text{air}}} = \sqrt{\sum_{n=1}^3 \left(\frac{\partial \bar{T}_{\text{air}}}{\partial (T_{\text{air}})_n} \partial (T_{\text{air}})_n \right)^2}$$

$$\text{where: } \partial T_{\text{air}} = \delta_{\text{air probe}} = 0.1(^{\circ}\text{C})$$

Results

Table D-1 lists the specimen densities and their measurement uncertainties as determined using the above-mentioned methods. Table D-2 provides the raw data from the specimen density measurements.

Table D-1. Specimen Density Measurements.

Specimen ID	Specimen Density (g/cm ³)	Specimen Density Uncertainty (g/cm ³)	Operator	Dry Weight Date
Molybdenum				
Mo-105	10.21828	0.00004	R.Dean	07/20/05
Mo-108	10.21465	0.00004	R.Dean	07/20/05
Mo-107	10.21725	0.00004	R.Dean	07/20/05
Mo-0019	10.21588	0.00008	R.Dean	07/18/05
Mo-0015	10.21813	0.00008	R.Dean	07/18/05
Mo-0008	10.21569	0.00009	R.Dean	07/18/05
Mo-0007	10.21907	0.00008	R.Dean	07/18/05
Mo-0002	10.21903	0.00008	R.Dean	07/18/05
Mo-0017	10.22282	0.00008	R.Dean	07/18/05
Mo-0011	10.21461	0.00008	R.Dean	07/21/05
Mo-0012	10.21295	0.00009	R.Dean	07/21/05
Mo-0013	10.22007	0.00008	R.Dean	07/22/05
Mo-0016	10.21976	0.00008	R.Dean	07/22/05
Mo-0001	10.22213	0.00008	R.Dean	07/22/05
Mo-0021	10.21975	0.00009	R.Dean	07/22/05
Mo-0003	10.21777	0.00008	R.Dean	07/22/05
Mo-0006	10.21853	0.00008	R.Dean	07/22/05
Mo-0014	10.22151	0.00008	R.Dean	07/25/05
Mo-0009	10.21651	0.00009	R.Dean	07/25/05
Mo-0020	10.21867	0.00008	R.Dean	07/25/05
Mo-0022	10.22055	0.00008	R.Dean	07/25/05
Mo 2-1	10.22437	0.00015	R.Dean	08/09/05
Mo 2-2	10.21992	0.00016	R.Dean	08/09/05
Mo 2-3	10.21806	0.00014	R.Dean	08/09/05
Mo 2-4	10.21778	0.00011	R.Dean	08/09/05
Mo 2-5	10.21872	0.00008	R.Dean	08/10/05
Mo 2-6	10.22120	0.00013	R.Dean	08/10/05
Mo 2-7	10.21821	0.00012	R.Dean	08/10/05
Mo 2-8	10.21554	0.00011	R.Dean	08/10/05
Mo 2-9	10.21783	0.00006	R.Dean	08/10/05
Mo-051	10.21968	0.00009	R.Dean	09/08/05
Mo-052	10.21635	0.00008	R.Dean	09/08/05
Mo-053	10.21481	0.00008	R.Dean	09/08/05
Mo-054	10.21790	0.00009	R.Dean	09/08/05
Mo-055	10.21398	0.00009	R.Dean	09/08/05
Mo-056	10.21848	0.00009	R.Dean	09/08/05
Rhenium				
Re-8	21.00769	0.00076	R.Dean	07/25/05
Re-9	21.00022	0.00070	R.Dean	07/25/05
Re-10	21.01982	0.00080	R.Dean	07/25/05
Re-11	21.01377	0.00075	R.Dean	07/25/05
Re-12	20.97726	0.00071	R.Dean	07/26/05
Re-13	20.98962	0.00073	R.Dean	07/26/05

Specimen ID	Specimen Density (g/cm ³)	Specimen Density Uncertainty (g/cm ³)	Operator	Dry Weight Date
Re-14	21.00555	0.00069	R.Dean	07/26/05
Re-1	20.99868	0.00073	R.Dean	07/26/05
Re-2	20.99861	0.00078	R.Dean	07/26/05
Re-3	20.97916	0.00072	R.Dean	07/26/05
Re-4	21.00247	0.00073	R.Dean	07/27/05
Re-5	21.01046	0.00075	R.Dean	07/27/05
Re-6	21.01502	0.00073	R.Dean	07/27/05
Re-7	20.99941	0.00077	R.Dean	07/27/05
Tantalum-2.5Tungsten				
Ta 11-19-2 #1	16.71548	0.00017	R.Dean	07/27/05
Ta 11-19-2 #2	16.72158	0.00018	R.Dean	07/27/05
Ta 11-19-2 #3	16.72443	0.00018	R.Dean	07/27/05
Ta 11-19-2 #4	16.71798	0.00016	R.Dean	07/27/05
Ta 10-20-2 #1	16.72615	0.00017	R.Dean	07/28/05
Ta 10-20-2 #2	16.72737	0.00021	R.Dean	07/28/05
Ta 10-20-2 #3	16.74034	0.00017	R.Dean	07/29/05
Ta 10-20-2 #4	16.72384	0.00017	R.Dean	07/29/05
Ta 10-20-2 #5	16.73094	0.00017	R.Dean	07/29/05
Ta 10-20-2 #6	16.72821	0.00017	R.Dean	07/29/05
Ta 10-20-2 #7	16.73395	0.00017	R.Dean	08/01/05
Ta-11-19-2 #7	16.73555	0.00018	R.Dean	08/01/05
Ta-11-19-2 #5	16.71812	0.00017	R.Dean	08/01/05
Ta-11-19-2 #6	16.72362	0.00021	R.Dean	08/01/05

Table D-2. Raw Data from the Specimen Density Measurements.

Density Measurements of Physics Test Plates																						
Dry Weight Date	Operator	Specimen ID	Specimen Dry Weight (g)	Saddle Wet Weight (g)			Avg	Wet Weight (g)	Delta	Water Temp. (C)			Avg	Rel. Hum. (%)	Vapor Press. (mmHg)	Density (g/cm³)	Specimen ID	Operator	Dry Weight Date			
				1	2	3				1	2	3								1	2	3
R.Dean	07/20/05	07/20/05	48.3719	48.3719	0.3875	0.3874	0.3876	0.3875	44.0196	44.0194	44.0196	44.0196	44.0196	44.0196	44.0196	44.0196	07/20/05	R.Dean	07/20/05	07/20/05		
R.Dean	07/20/05	07/20/05	48.3440	48.3440	0.3875	0.3874	0.3876	0.3875	44.0196	44.0194	44.0196	44.0196	44.0196	44.0196	44.0196	44.0196	07/20/05	R.Dean	07/20/05	07/20/05		
R.Dean	07/20/05	07/20/05	48.8296	48.8296	0.3882	0.3881	0.3882	0.3882	44.4521	44.4523	44.4523	44.4523	44.4523	44.4523	44.4523	44.4523	07/20/05	R.Dean	07/20/05	07/20/05		
R.Dean	07/20/05	07/20/05	48.5848	48.5848	0.3882	0.3881	0.3882	0.3882	44.2422	44.2426	44.2426	44.2426	44.2426	44.2426	44.2426	44.2426	07/20/05	R.Dean	07/20/05	07/20/05		
R.Dean	07/16/05	07/16/05	24.9007	24.9006	0.3868	0.3869	0.3869	0.3868	22.5291	22.5292	22.5292	22.5292	22.5292	22.5292	22.5292	22.5292	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.6537	24.6537	0.3871	0.3871	0.3872	0.3871	22.6463	22.6463	22.6463	22.6463	22.6463	22.6463	22.6463	22.6463	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.3602	24.3602	0.3872	0.3872	0.3873	0.3872	22.7619	22.7619	22.7619	22.7619	22.7619	22.7619	22.7619	22.7619	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.4382	24.4382	0.3871	0.3871	0.3870	0.3871	22.4433	22.4433	22.4433	22.4433	22.4433	22.4433	22.4433	22.4433	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.8171	24.8171	0.3876	0.3876	0.3875	0.3876	22.8369	22.8369	22.8369	22.8369	22.8369	22.8369	22.8369	22.8369	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.8171	24.8171	0.3876	0.3877	0.3876	0.3876	22.6220	22.6222	22.6222	22.6222	22.6222	22.6222	22.6222	22.6222	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/16/05	07/16/05	24.6165	24.6166	0.3865	0.3864	0.3865	0.3864	22.1974	22.1972	22.1972	22.1972	22.1972	22.1972	22.1972	22.1972	07/16/05	R.Dean	07/16/05	07/16/05		
R.Dean	07/22/05	07/22/05	24.3606	24.3606	0.3863	0.3863	0.3864	0.3863	22.3234	22.3234	22.3234	22.3234	22.3234	22.3234	22.3234	22.3234	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.4411	24.4411	0.3867	0.3865	0.3867	0.3865	22.5352	22.5352	22.5352	22.5352	22.5352	22.5352	22.5352	22.5352	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.5011	24.5011	0.3862	0.3862	0.3863	0.3862	22.6827	22.6827	22.6827	22.6827	22.6827	22.6827	22.6827	22.6827	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	23.8671	23.8672	0.3873	0.3873	0.3873	0.3873	22.0181	22.0177	22.0177	22.0177	22.0177	22.0177	22.0177	22.0177	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/22/05	07/22/05	24.8649	24.8649	0.3860	0.3860	0.3860	0.3860	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	22.8463	07/22/05	R.Dean	07/22/05	07/22/05		
R.Dean	07/																					

D-9

Appendix E

Impact of the Increased Diaphragm Thickness and Mass Loading Limit on the Predicted Critical Configuration of the Prometheus Critical Experiments

B-TM-1639

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Abstract

Critical experiments were to be performed by Los Alamos National Laboratory (LANL) at the Los Alamos Critical Experiments Facility (LACEF) in Technical Area 18 (TA-18) in support of Project Prometheus. This letter provides an analysis of the impact of increasing the diaphragm thickness from 0.040" to 0.075" and implementing a 150 kg diaphragm mass loading limit upon the predicted critical configuration for the Re, Ta-2.5W, Baseline, and Mo critical experiments. These experiments were cancelled following the termination of the Naval Reactor Program work on Project Prometheus.

Background

The critical experiments were to be assembled on the Planet general-purpose split vertical assembly machine at LACEF. The assemblies were to consist of a cylindrical core region containing interspersed plates of highly enriched uranium (HEU) metal, various refractory metals, and graphite or polyethylene of various thicknesses. These experiments were designed to assess the adequacy of the existing neutron cross sections used in physics models for neutron energy spectra characteristic of Prometheus reactor designs under normal and accident conditions.

Three experiments were designed to bracket the neutron energy spectra expected in Prometheus reactor designs under normal operating conditions, and one experiment was designed to simulate an accident condition in which the core is flooded with water. Experiment 1 was designed to approximate the neutron energy spectrum in the center of the core. Experiments 2 and 3 were designed to bracket the upper and lower range, respectively, of the core average neutron energy spectrum. Experiment 4 was designed to simulate the average neutron energy spectrum when the core is flooded with water.

The assembly machine support structure uses a stainless steel diaphragm to support the upper core region of the critical assembly. LANL provided revised specifications for the diaphragm thickness and mass loading limit after the NRPCT pre-experimental predictions for the Re, Ta-2.5W, Baseline, and Mo critical experiments were issued. In these revised specifications the thickness of the stainless steel diaphragm used to support the upper core region of the experimental assemblies was increased from 0.040" to 0.075" and a 150 kg mass loading limit was placed on the diaphragm. This mass limit places a bound on the number of stacking units that can be in the upper core region of the assembly. The pre-experimental predictions for the Re, Ta-2.5W, Baseline, and Mo critical experiments were based on a 0.040" thick stainless steel diaphragm, the same diaphragm thickness used in the Nb-1Zr 4U [2] critical experiment, and did not include a mass limit on the upper core region of the experimental assembly.

In addition, the metal reflector thickness used in the pre-experimental predictions for the Ta-2.5W critical experiments used the nominal design value of 0.150". A thickness based on the average as-built Ta-2.5W plate thickness was not used due to the lack of as-built Ta-2.5W thicknesses at the time of analysis. The average as-built thickness for the individual Ta-2.5W plates was 0.0246", leading to a predicted metal reflector thickness of 0.1476" (6 @ 0.0246"). A series of analyses were performed to assess the impact of the increased, 0.075", diaphragm thickness, the 150 kg diaphragm mass loading limit, and the 0.1476" Ta-2.5W metal reflector thickness on the pre-experimental predictions for the Re, Ta-2.5W, Baseline, and Mo critical experiments.

Summary and Conclusions

A maximum of four different analyses were run for a given experiment and these analyses are described as cases. Case (a) is the 0.040" thick diaphragm, the original number of stacking units in the upper core region, and the 0.150" thick Ta-2.5W metal reflector (for the Ta-2.5W critical experiments only). Case (b) is the 0.075" thick diaphragm, the original number of stacking units in the

upper core region, and the 0.150" thick Ta-2.5W metal reflector (for the Ta-2.5W critical experiments only). Case (c) is for the Ta-2.5W critical experiments only and includes the 0.075" thick diaphragm, the original number of stacking units in the upper core region, and the 0.1476" thick Ta-2.5W metal reflector. Case (d) is the updated critical configuration with the 0.075" thick diaphragm, the 150 kg mass limit put into place by adjusting the number of stacking units in the upper core region, and the 0.1476" thick Ta-2.5W metal reflector (for the Ta-2.5W critical experiments only). These results are provided in Tables E-1 through E-4.

Note that the case (d) final predicted critical configuration is either unchanged from the original [case (a)] or has a slightly different top reflector thickness. Also note that the change in the multiplication factor (Δk) due to the variations in the experimental configuration is calculated relative to case (a), the originally predicted critical configuration.

The k_{eff} sensitivities to the changes in the experimental configuration were analyzed using both RCP01 and MCNP5. The average changes in the multiplication factor (between the two codes) due to the change in the diaphragm thickness and the number of stacking units in the upper core region of the assembly are: -0.00064 for the Re critical experiments, -0.00133 for the baseline critical experiments, and -0.00048 for the Mo critical experiments. The average change in the multiplication factor due to the change in diaphragm thickness, the number of stacking units in the upper core region of the assembly, and the change in the Ta-2.5W metal reflector thickness for the Ta-2.5W critical experiments is -0.00034. These results indicate that the critical configuration for each of the TA-18 critical experiments is affected only slightly above the 95% confidence interval of each of the originally predicted nominal experimental configuration [case (a)] multiplication factors. The combined effect of these changes is well within the 0.40-0.50% Δk experimental uncertainty expected for the TA-18 critical experiments. Therefore, the 0.075" diaphragm thickness, the 150 kg diaphragm mass loading limit, and the change in the Ta-2.5W metal reflector thickness (for the Ta-2.5W critical experiments only) are concluded to have no significant impact on the predicted critical configuration for the TA-18 critical experiments.

Table E-1. Sensitivity Analysis for the Rhenium Critical Experiments

Re Experiment	Case	MCNP5					RCP01						
		Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk	Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk
1	a ¹	18	9	1.25	1.00179	0.00053	-	18	9	1.25	1.00113	0.00016	-
	b ²	18	9	1.25	1.00067	0.00053	-0.00112	18	9	1.25	0.99979	0.00016	-0.00135
	d ³	18	7	1.25	1.00154	0.00053	-0.00025	18	7	1.25	1.00045	0.00020	-0.00068
2	a	17	8	1.75	1.00113	0.00053	-	17	8	1.85	1.00093	0.00014	-
	b	17	8	1.75	0.99971	0.00051	-0.00142	17	8	1.85	0.99979	0.00014	-0.00113
	d	17	6	1.75	1.00054	0.00057	-0.00059	17	6	1.85	1.00049	0.00012	-0.00043
3	a	16	8	4.50	1.00150	0.00057	-	16	8	5.45	1.00108	0.00014	-
	b	16	8	4.50	0.99997	0.00055	-0.00153	16	8	5.45	1.00025	0.00018	-0.00083
	d	16	4	4.50	1.00082	0.00057	-0.00068	16	4	5.45	1.00096	0.00017	-0.00012
4	a	15	7	1.10	1.00097	0.00061	-	15	7	1.20	1.00097	0.00010	-
	b	15	7	1.10	0.99964	0.00059	-0.00133	15	7	1.20	0.99995	0.00018	-0.00101
	d	15	7	1.15	1.00225	0.00061	-	15	7	1.24	1.00145	0.00013	-

¹ A 0.040" thick diaphragm and no mass limit on the upper core region² A 0.075" thick diaphragm and no mass limit on the upper core region³ A 0.075" thick diaphragm and a 150 kg mass limit on the upper core region

Table E-2. Sensitivity Analysis for the Tantalum Critical Experiments

Ta-2.5W Experiment	Case	MCNP5					RCP01						
		Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk	Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk
1	a ¹	18	9	1.05	1.00077	0.00057	-	18	9	1.10	1.00048	0.00012	-
	b ²	18	9	1.05	0.99883	0.00053	-0.00094	18	9	1.10	0.99928	0.00010	-0.00119
	c ³	18	9	1.05	0.99953	0.00055	-0.00124	18	9	1.10	0.99899	0.00016	-0.00149
	d ⁴	18	6	1.05	1.00052	0.00053	-0.00025	18	6	1.10	1.00036	0.00018	-0.00011
2	a	17	8	1.75	1.00150	0.00053	-	17	8	1.95	1.00162	0.00014	-
	b	17	8	1.75	0.99978	0.00055	-0.00172	17	8	1.95	1.00049	0.00013	-0.00113
	c	17	8	1.75	1.00000	0.00057	-0.00150	17	8	1.95	1.00042	0.00015	-0.00120
	d	17	5	1.75	1.00069	0.00053	-0.00081	17	5	1.95	1.00155	0.00011	-0.00008
3	a	18	9	4.20	1.00099	0.00057	-	18	9	5.00	1.00100	0.00013	-
	b	18	9	4.20	1.00053	0.00055	-0.00046	18	9	5.00	1.00004	0.00014	-0.00095
	c	18	9	4.20	0.99624	0.00057	-0.00475	18	9	5.00	1.00024	0.00016	-0.00076
	d	18	3	4.20	1.00097	0.00057	-0.00002	18	3	5.00	1.00109	0.00015	+0.00009
4	a	17	8	0.80	1.00113	0.00059	-	16	8	1.04	1.00099	0.00013	-
	b	17	8	0.80	1.00014	0.00055	-0.00099	16	8	1.04	0.99973	0.00011	-0.00126
	c	17	8	0.80	1.00007	0.00057	-0.00106	16	8	1.04	0.99993	0.00010	-0.00106
	d	17	7	0.80	1.00038	0.00055	-0.00075	16	7	1.04	1.00021	0.00011	-0.00078

¹ A 0.040" thick diaphragm, no mass limit on the upper core region, and a 0.150" thick Ta-2.5W metal reflector² A 0.075" thick diaphragm, no mass limit on the upper core region, and a 0.150" thick Ta-2.5W metal reflector³ A 0.075" thick diaphragm, no mass limit on the upper core region, and a 0.1476" thick Ta-2.5W metal reflector⁴ A 0.075" thick diaphragm, a 150 kg mass limit on the upper core region, and a 0.1476" thick Ta-2.5W metal reflector

Table E-3. Sensitivity Analysis for the Baseline Critical Experiments

Baseline Experiment	Case	MCNP5					RCP01						
		Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk	Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk
1	a ¹	17	8	1.30	1.00142	0.00053	-	17	8	1.30	1.00061	0.00015	-
	b ²	17	8	1.30	0.99988	0.00055	-0.00154	17	8	1.30	0.99915	0.00016	-0.00146
	d ³	17	8	1.35	1.00293	0.00057	-	17	8	1.35	1.00184	0.00016	-
2	a	15	7	2.30	1.00082	0.00059	-	15	7	2.40	1.00121	0.00013	-
	b	15	7	2.30	0.99905	0.00059	-0.00177	15	7	2.40	0.99997	0.00009	-0.00124
	d	15	7	2.35	1.00124	0.00059	-	15	7	2.45	1.00168	0.00026	-
3	a	13	6	4.85	1.00081	0.00061	-	13	6	5.40	1.00101	0.00020	-
	b	13	6	4.85	1.00014	0.00061	-0.00067	13	6	5.40	1.00021	0.00016	-0.00081
	d	13	4	4.85	0.99976	0.00061	-0.00105	13	4	5.40	1.00039	0.00017	-0.00063
4	a	11	5	0.92	1.00126	0.00069	-	11	5	0.94	1.00030	0.00014	-
	b	11	5	0.92	0.99936	0.00069	-0.00190	11	5	0.94	0.99923	0.00012	-0.00107
	d	11	5	0.94	1.00209	0.00069	-	11	5	0.96	1.00136	0.00015	-

¹ A 0.040" thick diaphragm and no mass limit on the upper core region² A 0.075" thick diaphragm and no mass limit on the upper core region³ A 0.075" thick diaphragm and a 150 kg mass limit on the upper core region

Table E-4. Sensitivity Analysis for the Molybdenum Critical Experiments

Mo Experiment	Case	MCNP5					RCP01						
		Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk	Number of Units	Number of Top Units	Top Reflector Thickness (in)	Multiplication Factor	95% Confidence Level	Δk
1	a ¹	16	8	1.35	1.00123	0.00057	-	16	8	1.55	1.00157	0.00018	-
	b ²	16	8	1.35	0.99933	0.00055	-0.00190	16	8	1.55	1.00015	0.00015	-0.00142
	d ³	16	6	1.35	1.00067	0.00055	-0.00056	16	6	1.55	1.00096	0.00011	-0.00061
2	a	15	7	1.85	1.00009	0.00055	-	15	7	2.15	1.00041	0.00013	-
	b	15	7	1.85	0.99867	0.00055	-0.00142	15	7	2.15	0.99933	0.00012	-0.00108
	d	15	5	1.85	0.99927	0.00059	-0.00082	15	5	2.15	1.00002	0.00015	-0.00039
3	a	15	5	1.90	1.00104	0.00057	-	-	-	-	-	-	-
	b	14	7	4.75	1.00079	0.00061	-	14	7	4.75	1.00075	0.00015	-
	d	14	7	4.75	0.99935	0.00059	-0.00144	14	7	4.75	0.99976	0.00012	-0.00099
4	a	14	3	4.75	1.00118	0.00057	+0.00039	14	3	4.75	1.00049	0.00014	-0.00025
	b	14	3	4.70	1.00028	0.00061	-	-	-	-	-	-	-
	a	11	5	0.94	1.00135	0.00063	-	11	5	1.00	1.00189	0.00017	-
	b	11	5	0.94	1.00058	0.00063	-0.00077	11	5	1.00	1.00104	0.00015	-0.00085

¹ A 0.040" thick diaphragm and no mass limit on the upper core region² A 0.075" thick diaphragm and no mass limit on the upper core region³ A 0.075" thick diaphragm and a 150 kg mass limit on the upper core region

Appendix F

Mo Plate Dimension and Chemistry Reports

B-TM-1639

(Intentionally Blank)

SCHWARZKOPF
A PLANSEE Affiliated Company

Customer Name	KNOLLS	Purchase Order #	6001187	Drawing/Part #	SKMGP2177	Revision	
Sales Order #	29530	Production Order #	50280	Inspector	MARK GODDARD	Date	3/23/05

Dimension	Equipment Used	Serial #	Weight	Thickness	Actual Dimension	Thickness
059 Thick	Digital Thermometer	M0-105	3406 G	.0601	.0599	.0598
		M0-106	3415 G	.0592	.0607	.0590
		M0-107	3417 G	.0605	.0545	.0593
		M0-108	3410 G	.0595	.0596	.0598

SCHWARZKOPF A PLANSEE Affiliated Company

First Article Inspection Report

Customer Name	Knolls Atomic	Part Name	SK-MPG2177	Rev.	None
Sales Order #	29530	Part Number	50103, 50104, 50280, 50281	Inspected	4/28/05

SK-MPG2177-H01 (.030 thick with hole)

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-0001	1748.0	0.0303	21.001	21.003	2.507
MO-0002	1745.0	0.0306	20.998	21.006	2.503
MO-0003	1726.0	0.0298	21.001	21.004	2.508
MO-0004	1741.0	0.0305	20.997	20.997	2.500
MO-0005	1699.0	0.0300	20.998	21.006	2.504
MO-0006	1718.0	0.0304	21.000	21.003	2.511
MO-0007	1706.0	0.0297	21.003	21.004	2.507
MO-0008	1694.2	0.0300	21.002	21.000	2.510
MO-0009	1694.2	0.0298	21.002	21.003	2.492
MO-0010	1704.4	0.0299	21.002	21.003	2.502
MO-0011	1712.0	0.0301	21.000	21.002	2.506
MO-0012	1704.0	0.0297	21.000	21.002	2.510
MO-0013	1696.0	0.0297	21.000	21.004	2.505
MO-0014	1701.0	0.0300	21.000	21.005	2.506
MO-0015	1731.0	0.0303	20.999	21.002	2.506
MO-0016	1718.0	0.0301	20.999	21.002	2.505
MO-0017	1744.0	0.0308	20.999	21.002	2.508
MO-0018	1735.0	0.0304	21.000	21.003	2.503
MO-0019	1712.0	0.0306	21.002	21.004	2.503
MO-0020	1715.0	0.0300	21.004	21.002	2.502
MO-0021	1608.0	0.0292	21.001	21.005	2.504
MO-0022	1720.0	0.0303	20.999	21.003	2.504

SK-MPG2177-H02 (.030 thick without hole)

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-0023	1742.8	0.0302	21.000	21.002	N/A

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-0021	1759.1	0.0312	21.001	21.002	N/A
MO-0025	1718.3	0.0299	20.999	21.000	N/A
MO-0026	1718.9	0.0298	21.002	21.001	N/A
MO-0027	1723.4	0.0297	21.000	21.000	N/A
MO-0028	1715.6	0.0301	21.003	21.002	N/A
MO-0029	1727.4	0.0300	20.999	21.002	N/A
MO-0030	1716.0	0.0297	21.002	21.005	N/A
MO-0031	1723.3	0.0303	21.000	21.003	N/A
MO-0032	1746.2	0.0305	21.001	21.004	N/A
MO-0033	1752.2	0.0307	21.003	21.001	N/A
MO-0034	1724.0	0.0303	21.000	21.000	N/A
MO-0035	1740.2	0.0300	21.003	21.004	N/A
MO-0036	1740.0	0.0301	21.002	21.007	N/A
MO-0037	1756.2	0.0303	21.001	21.003	N/A
MO-0038	1746.0	0.0307	21.000	21.002	N/A
MO-0039	1762.8	0.0307	21.000	21.002	N/A
MO-0040	1745.2	0.0305	20.999	21.000	N/A
MO-0041	1747.0	0.0302	21.002	21.004	N/A
MO-0042	1746.2	0.0307	21.002	21.002	N/A

SK-MPG2177-H01 (.059 thick with hole)

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-105	3406.2	0.0591	21.000	21.000	2.503
MO-106	3414.8	0.0592	21.000	21.000	2.510
MO-107	3417.4	0.0595	21.000	21.000	2.506
MO-108	3409.2	0.0596	21.000	21.000	2.510

SK-MPG2177-H02 (.059 thick without hole)

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-101	3485.0	0.0601	21.003	21.000	N/A
MO-102	3445.2	0.0595	21.002	21.000	N/A
MO-103	3465.4	0.0576	20.998	21.000	N/A
MO-104	3423.4	0.0586	20.998	21.002	N/A

NOTE: The recording of false, fictitious, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute

Inspector

Date

QC Supervisor

Date

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First Article Inspection Report

Customer Name	Knolls Atomic	Product Order #	6001187	Drawing Title	SK-MPG2177	Rev	None
Series Order #	29530	Production Order #	51218	Inspector	G. Dosjars	Date	6/3/05

SK-MPG2177-H01 (.030 thick with hole)

SN	Weight (g)	Thickness	O.D.	I.D.	Yield Pcs
MO-051	1685.8	0.0289	20.996	25.10	2512
MO-052	1729.0	0.0305	20.986	25.11	2512
MO-053	1779.4	0.0303	20.991	25.11	2507
MO-054	1678.2	0.0296	20.998	25.11	2511
MO-055	1690.2	0.0294	20.996	25.03	2511
MO-056	1700.4	0.0302	20.994	25.15	2512
MO-057	1715.4	0.0301	20.992	25.11	2513
MO-058	1708.4	0.0289	20.997	25.13	2512
MO-059	1703.0	0.0300	20.997	25.12	2511
MO-060	1702.4	0.0300	21.003	25.11	2514

NOTE: The recording of false fictitious, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute

Inspector: John J. Dosjars Date: 6/3/05
QC Subject: SK-MPG2177

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First Article Inspection Report

Customer Name Knolls Atomic	Part Number 6001187	Part # (Rev) SK-MPG2177	Rev Ncno
Order # 29530	Production Order # 51219	QC Dept G. Desjardins	Date 6/3/05

SK-MPG2177-H02 (.030 thick without hole)

S/N	Weight (g)	Thickness	O.D.	I.D.	True Pos
MO-061	1719.0	0.0300	20.990	N/A	N/A
MO-062	1721.8	0.0298	20.988	N/A	N/A
MO-063	1709.2	0.0295	21.000	N/A	N/A
MO-064	1732.0	0.0311	20.997	N/A	N/A
MO-065	1736.0	0.0301	20.999	N/A	N/A
MO-066	1678.2	0.0280	20.996	N/A	N/A
MO-067	1752.8	0.0309	20.997	N/A	N/A
MO-068	1695.0	0.0288	20.996	N/A	N/A
MO-069	1718.2	0.0288	20.995	N/A	N/A
MO-070	1744.2	0.0302	21.000	N/A	N/A
MO-071	1715.4	0.0294	21.000	N/A	N/A
MO-072	1706.8	0.0293	20.999	N/A	N/A

NOTE: The recording of false thickness or fraudulent statements or entries on this document may be just cause for termination of Federal Supply.

Inspector: John Desjardins Date: 6/3/05
QC Supervisor: John Desjardins Date: 6/3/05

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SCHWARZKOPF TECHNOLOGIES CORPORATION
115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H02
STC Job No: 50104 Lot: 1 Of: 1 Quantity Inspected: 20
Quantity Shipped: 20

Remarks: Stc Art No 50025138

Material report: 81839875000010

Batch #: 0090232160

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Ocker Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation

115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

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A PLANSEE Affiliated Company

SCHWARZKOPF TECHNOLOGIES CORPORATION
115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H02
STC Job No: 51219 Lot: 1 Of: 1 Quantity Inspected: 12
Quantity Shipped: 12

Remarks: Stc Art No 50025136

Material report: 82493034000010

Batch #: 0090273793

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Oaker Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation
115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

PLANSEE Aktiengesellschaft
 Postfach 10 15 0
 85748 Plansee
 Tel. 089 35700-0
 Fax 089 35700-100
 E-Mail: info@plansee.de

PLANSEE **INSPECTION CERTIFICATE**

acc. to DIN EN 10204 - 3.1B

Report No.: **81839875000010**
 Date: **02.09.2004**
 Customer: **Schwarzkopf Technologies / US**
 PAG-Order No./Pos.No.: **1038545 / 70**
 PAG-Material-No.: **88149**
 PAG-Segment / PoC.: **/ Kerber / 2952**
 Customer Order No.: **4500018902** dated **11.05.2004**
 Specification No.:

Material / Product: **MO / MOLY SHEET .030" x 24" x 72"**
 Condition of material / Quality: **cut with scissors / normal quality**

Quantity / Weight: **104,320 KG / KG**
 Batch(es): **0090232160 104,320 KG**

GUARANTEED CHEMICAL ANALYSIS: acc. to PAG-Spec. A001

Mo	min. 99,97 %*				
Ag	max. 10 µg/g	Al	max. 10 µg/g	As	max. 5 µg/g
Ba	max. 5 µg/g	Ca	max. 20 µg/g	Cd	max. 5 µg/g
Co	max. 10 µg/g	Cr	max. 20 µg/g	Cu	max. 20 µg/g
Fe	max. 80 µg/g	K	max. 10 µg/g	Mg	max. 10 µg/g
Mn	max. 2 µg/g	Na	max. 10 µg/g	Nb	max. 10 µg/g
Ni	max. 10 µg/g	Pb	max. 10 µg/g	Ta	max. 20 µg/g
Ti	max. 10 µg/g	Zn	max. 10 µg/g	Zr	max. 10 µg/g
W	max. 250 µg/g				
C	max. 30 µg/g	H	max. 10 µg/g	N	max. 5 µg/g
O	max. 40 µg/g	P	max. 20 µg/g	S	max. 10 µg/g
Si	max. 30 µg/g	* metallic purity without W			

Hardness HV: **EN ISO 6607-1 250**

Certified that the supplies services detailed hereon have been inspected and tested in accordance with the conditions and requirements of the contract or purchase order and unless otherwise noted below, conform in all respects to the specification(s), drawings relevant thereto.

This certificate has been generated by computer and need not to be signed for validity according to EN 10204

Works Inspector:

(Dr. Thurner)

PLANSEE Aktiengesellschaft
 High Performance Materials
 Inspection Department QMS2

(Partner) (Kerber)

SCHWARZKOPF
A *PLANSEE* Affiliated Company

SCHWARZKOPF TECHNOLOGIES CORPORATION

115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H01
STC Job No: 50103 Lot: 1 Of: 1 Quantity Inspected: 22
Quantity Shipped: 22

Remarks: Ste Art No 50025136
Material report: 81839875000010
Batch #: 0090232160

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Ochoa Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation
115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

SCHWARZKOPF
A PLANSEE Affiliated Company

SCHWARZKOPF TECHNOLOGIES CORPORATION
115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H01
STC Job No: 51218 Lot: 1 Of: 1 Quantity Inspected: 10
Quantity Shipped: 10

Remarks: Stc Art No 50025136
Material report: 82493034000010
Batch #: 0090273793

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Oake Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation
115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

PLANSEE Aktiengesellschaft
 A - 6600 Reutte
 Tel.: +43/5672/600-0
 Fax: +43/5672/600-500
 http://www.plansee.com

PLANSEE

TEST-REPORT

acc. to EN 10204 - 2.2

Report No.: 82493034000010
 Date: 07/19/2005
 Customer: Schwarzkopf Technologies LLC / US
 PAG-Order No./Pos.No.: 1421823 / 10
 PAG-Material-No.: 88149
 PAG-Segment / PoC. / 7F / Schonger / 2956
 Customer Order No.: 4500020898 dated 03/07/2005
 Specification No.:

Material / Product: MO / MOLY SHEET .030" x 24" x 72"
 Condition of material / Quality: cut with scissors / normal quality

Dimensions:
 Customer-Material-No.:
 Customer-Drawing: / /
 PAG-Drawing: / /
 Quantity / Weight: 43.010 KG / KG
 Batch(es): 0080273793 43.010 KG

GUARANTEED CHEMICAL ANALYSIS: acc. to PAG-Spec. A001

Mo min. 99.97 %*

Ag max. 10 µg/g	Al max. 10 µg/g	As max. 5 µg/g
Ba max. 5 µg/g	Ca max. 20 µg/g	Cd max. 5 µg/g
Co max. 10 µg/g	Cr max. 20 µg/g	Cu max. 20 µg/g
Fe max. 60 µg/g	K max. 10 µg/g	Mg max. 10 µg/g
Mn max. 2 µg/g	Na max. 10 µg/g	Nb max. 10 µg/g
Ni max. 10 µg/g	Pb max. 10 µg/g	Ta max. 20 µg/g
Ti max. 10 µg/g	Zn max. 10 µg/g	Zr max. 10 µg/g
W max. 250 µg/g		
C max. 30 µg/g	H max. 10 µg/g	N max. 5 µg/g
O max. 40 µg/g	P max. 20 µg/g	S max. 10 µg/g
Si max. 30 µg/g	* metallic purity without W	

Certified that the supplies/services detailed hereon have been inspected and tested in accordance with the conditions and requirements of the contract or purchase order and unless otherwise noted below, conform in all respects to the specification(s), drawing(s) relevant thereto.

This certificate has been generated by computer and need not to be signed for validity according to EN 10204.

PLANSEE Aktiengesellschaft -
 High Performance Materials
 QMSZ - Certificates

SCHWARZKOPF
A PLAINSEE Affiliated Company

SCHWARZKOPF TECHNOLOGIES CORPORATION
115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H01
(0.059" thick)
STC Job No: 50280 Lot: 1 Of: 1 Quantity Inspected: 4
Quantity Shipped: 4

Remarks: Stc Art No 50025306
Material report: 82052337000010
Batch #: 0090242449

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Oake Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation
115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

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A PLANSEE Affiliated Company

SCHWARZKOPF TECHNOLOGIES CORPORATION

115 Constitution Blvd./Franklin, MA 02038

CERTIFICATE OF CONFORMANCE

Customer: Knolls Atomic Power Laboratory Date: September 7th, 2005
P.O. No: 6001187 Material: Moly Dwg. No: SK-MPG2177-H02
(0.059" thick)
STC Job No: 50281 Lot: 1 Of: 1 Quantity Inspected: 4
Quantity Shipped: 4

Remarks: Stc Art No 50025307
Material report: 82052337000010
Batch #: 0090242449

This is to certify that this shipment is in conformance with the Drawings and/or Specifications listed on this order, and that we have performed the required physical tests and inspections on the materials.

The liability of Schwarzkopf Technologies hereunder is limited to the cost of the materials in question.

Certified Tom Coker Title _____
Certified _____ Title _____
Certified _____ Title _____
Certified _____ Title _____

2120 Rev. E

Schwarzkopf Technologies Corporation
115 Constitution Blvd. Franklin, MA 02038 Phone 508.553.3800 Fax 508.553.3823

PLANSEE Aktiengesellschaft
 40000 Reutlingen
 Tel. +49 7141 123-0
 Fax +49 7141 123-110
 E-Mail: info@plansee.de

PLANSEE

INSPECTION CERTIFICATE

acc. to DIN EN 10204 - 3.1B

Report No.: 82052337000010
 Date: 09.12.2004
 Customer: Schwarzkopf Technologies / US
 PAG Order No./Pos.No.: 1261929 / 60
 PAG-Material-No.: 257308
 PAG-Segment / PoC. / 7F / Kerber / 2952
 Customer Order No.: 4500020152 dated 04.11.2004
 Specification No.

Material / Product: MO / MOLY SHEET .059" x 23.6" x 78.7"
 Condition of material / Quality: cut with scissors / normal quality

Quantity / Weight: 147,650 KG / KG
 Batch(es): 0090242409 147,650 KG

GUARANTEED CHEMICAL ANALYSIS: acc. to PAG-Spec. A001

Mo	min. 99.97 %				
Ag	max. 10 µg/g	Al	max. 10 µg/g	As	max. 5 µg/g
Ba	max. 5 µg/g	Ca	max. 20 µg/g	Cd	max. 5 µg/g
Co	max. 10 µg/g	Cr	max. 20 µg/g	Cu	max. 20 µg/g
Fe	max. 60 µg/g	K	max. 10 µg/g	Mg	max. 10 µg/g
Min	max. 2 µg/g	Na	max. 10 µg/g	Nb	max. 10 µg/g
Mn	max. 10 µg/g	Pb	max. 10 µg/g	Te	max. 20 µg/g
Ti	max. 10 µg/g	Zn	max. 10 µg/g	Zr	max. 10 µg/g
W	max. 250 µg/g				
C	max. 30 µg/g	H	max. 10 µg/g	N	max. 5 µg/g
O	max. 40 µg/g	P	max. 20 µg/g	S	max. 10 µg/g
Si	max. 30 µg/g	* metallic purity without W			

Hardness HV: EN ISO 6507-1 250 - 254

Certified that the supplies/services detailed hereon have been inspected and tested in accordance with the conditions and requirements of the contract or purchase order and unless otherwise noted below, conform in all respects to the specifications, drawing(s) relevant thereto.

This certificate has been generated by computer and need not to be signed for validity according to EN 10204.

Works Inspection

(Dr. Thurner)

PLANSEE Aktiengesellschaft
 High Performance Materials
 Inspection Department QMS2

(Partner)

(Kerber)

14/07 '05 17:22 FAX -43 5672 600 514

PLANSEE/TZ

12001

PLANSEE

Plansee Aktiengesellschaft
A-6630 Riedle/Tirol
Tel: ++43(5672)500-2282 bzw. 2079
Fax: ++43(5672)600-514

Prüfprotokoll TZPA

Problemlösung
MO-20808

07. Juli 2005

Abteilung: Schwarzkopf Techn.

Antraggeber: Jett Hicks

Kontierung: 0000

Probenbezeichnung: Mo-Sheet

0,030 2"x2"

C:	<5 µg/g	Fe:	10 µg/g
H:	<1 µg/g	N:	6 µg/g
Nb:	<10 µg/g	Ni:	<5 µg/g
O:	15 µg/g	Si:	7 µg/g
Ta:	<10 µg/g	Ti:	<2 µg/g
W:	115 µg/g		

Batch: 0090273793 Report No. 82493034000010

0,030 24"x72"

C:	<5 µg/g	Fe:	11 µg/g
H:	1 µg/g	N:	5 µg/g
Nb:	<10 µg/g	Ni:	<5 µg/g
O:	15 µg/g	Si:	<5 µg/g
Te:	<10 µg/g	Ti:	<2 µg/g
W:	145 µg/g		

Batch: 0090232160 Report No. 81839875000010

0,059 Fl x Rw

C:	<5 µg/g	Fe:	10 µg/g
H:	<1 µg/g	N:	5 µg/g
Nb:	<10 µg/g	Ni:	<5 µg/g
O:	7 µg/g	Si:	<5 µg/g
Ta:	<10 µg/g	Ti:	<2 µg/g
W:	132 µg/g		

Batch: 0090242449 Report No. 82053370000010

Ausgangsdatum: 14. Jul. 05

Überprüft:

PLANSEE

Bitte vorabige Bestätigung des Prüfsystems nicht unterschreiben und bestätigen.
Das Prüfsystem ist nur zur Verfügung gestellt. Bitte.

Date 1 von 1 (Seite 1)

Amended September 19th, 2005

f u

SECRET

EN 10234 22

Material: Product	MO / MOLY SHEET .030" x 24" x 72"
Condition of material: Quality	cut with scissors / normal quality

Dimensions		
Customer Material No		
Customer Drawing	/ /	
PAG Drawing	/ /	
Quantity	Weight	95.000 KG / KG
Batch/lot	0090266485	85 000 KG

Mo	min	99.97 %*									
Ag	max	10	$\mu\text{g/g}$	A	max	10	$\mu\text{g/g}$	As	max	5	$\mu\text{g/g}$
Ba	max	5	$\mu\text{g/g}$	Ca	max	20	$\mu\text{g/g}$	Cd	max	5	$\mu\text{g/g}$
Co	max	10	$\mu\text{g/g}$	Cr	max	20	$\mu\text{g/g}$	Cu	max	20	$\mu\text{g/g}$
Fe	max	60	$\mu\text{g/g}$	K	max	10	$\mu\text{g/g}$	Mn	max	10	$\mu\text{g/g}$
Mg	max	2	$\mu\text{g/g}$	Na	max	10	$\mu\text{g/g}$	Nb	max	10	$\mu\text{g/g}$
Ni	max	10	$\mu\text{g/g}$	Pb	max	10	$\mu\text{g/g}$	Ta	max	20	$\mu\text{g/g}$
Ti	max	10	$\mu\text{g/g}$	Zn	max	10	$\mu\text{g/g}$	Zr	max	10	$\mu\text{g/g}$
W	max	250	$\mu\text{g/g}$								
C	max	30	$\mu\text{g/g}$	H	max	10	$\mu\text{g/g}$	N	max	5	$\mu\text{g/g}$
O	max	40	$\mu\text{g/g}$	P	max	20	$\mu\text{g/g}$	S	max	10	$\mu\text{g/g}$
Si	max	30	$\mu\text{g/g}$								

* metallic purity without W

Noted that the supplies identified herein have been staged and tested in accordance with the contract and that the results of the sample production order and unless otherwise noted below, confirm that the supplies are of acceptable quality and quantity.

*This certificate is a non-confidential document. It is not to be used for any purpose other than to verify the information contained herein. It is not to be used for any other purpose.

PLANSI Abtengeselektion
High Performance Materials
QMGZ Certifikat

B-TM-1639

(Intentionally Blank)

Appendix G

Re Plate Dimension and Chemistry Reports

B-TM-1639

(Intentionally Blank)

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 - Re-22)

Part number: _Re-01_ Lot Number: R-1478/1481_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1929.1g_

Temperature of disk at time of measurement: _22.78°C_

Thickness measurements (.015±.0015)

#1 _0.0165"__ #2 _0.0160"__ #3 _0.0155"__

Outside diameter ($\varnothing 21.000 \pm 0.010$)

#1 _21.000"__ #2 _21.000"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 – Re-22)

Part number: _Re-02_ Lot Number: R-1478_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1969.3g_

Temperature of disk at time of measurement: _22.22°C_

Thickness measurements (.015±.0015)

#1 _0.0165" _ #2 _0.0168" _ #3 _0.0170" _

Outside diameter ($\varnothing$ 21.000±0.010)

#1 _20.997" _ #2 _21.000" _

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

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Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 - Re-22)

Part number: _Re-03_ Lot Number: R-1478_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1970.9g_

Temperature of disk at time of measurement: _21.94°C_

Thickness measurements (.015±.0015)

#1 _0.0170"__ #2 _0.0168"__ #3 _0.0170"__

Outside diameter (Ø21.000±0.010)

#1 _20.998"__ #2 _20.999"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
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Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Solid Disk
(Re-01 – Re-22)

Part number: _Re-04_ Lot Number: R-1478_____

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_____

Weight of disk: _1981.6g_____

Temperature of disk at time of measurement: _22.22°C_____

Thickness measurements (.015±.0015)

#1 _0.0160"__ #2 _0.0168"__ #3 _0.0150"__

Outside diameter (Ø21.000±0.010)

#1 _21.000"__ #2 _20.998"_____

Cliff Guthman
Quality Control Engineer

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B-TM-1639

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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 - Re-22)

Part number: _Re-05_ Lot Number: R-1478_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1976.3g_

Temperature of disk at time of measurement: _22.5°C_

Thickness measurements (.015±.0015)

#1 _0.0165" _ #2 _0.0165" _ #3 _0.0164" _

Outside diameter ($\varnothing 21.000 \pm 0.010$)

#1 _20.996" _ #2 _20.994" _

Cliff Guthman
Quality Control Engineer

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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 – Re-22)

Part number: _Re-06_ Lot Number: R-1478_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1966.9g_

Temperature of disk at time of measurement: _21.94°C_

Thickness measurements (.015±.0015)

#1 _0.0164" _ #2 _0.0158" _ #3 _0.0163" _

Outside diameter ($\varnothing 21.000 \pm 0.010$)

#1 _20.999" _ #2 _20.997" _

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
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Web site: <http://www.rhenium.com>

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Elyria, Oh 44036-0245
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Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 - Re-22)

Part number: _Re-07_ Lot Number: R-1478_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1965.7g_

Temperature of disk at time of measurement: _22.5°C_

Thickness measurements (.015±.0015)

#1 _0.0165" _ #2 _0.0161" _ #3 _0.0163" _

Outside diameter (Ø21.000±0.010)

#1 _20.998" _ #2 _20.999" _

Cliff Guthman
Quality Control Engineer

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Web site: <http://www.rhenium.com>

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P.O. Box 245
Elyria, Oh 44036-0245
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Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Solid Disk
(Re-01 – Re-22)

Part number: _Re-08_ Lot Number: R-1481_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1969.9g_

Temperature of disk at time of measurement: _22.5°C_

Thickness measurements (.015±.0015)

#1 _0.0170" _ #2 _0.0165" _ #3 _0.0165" _

Outside diameter ($\varnothing$ 21.000±0.010)

#1 _20.997" _ #2 _20.996" _

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
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Web site: <http://www.rhenium.com>

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Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Solid Disk
(Re-01 – Re-22)

Part number: _Re-09_ Lot Number: R-1481_

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_

Weight of disk: _1953.8g_

Temperature of disk at time of measurement: _22.5°C_

Thickness measurements (.015±.0015)

#1 _0.0170" _ #2 _0.0160" _ #3 _0.0162" _

Outside diameter ($\varnothing 21.000 \pm 0.010$)

#1 _21.000" _ #2 _20.995" _

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
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Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Solid Disk
(Re-01 – Re-22)

Part number: _Re-10_ Lot Number: R-1481_____

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_____

Weight of disk: _1944.3g_____

Temperature of disk at time of measurement: _22.22°C_____

Thickness measurements (.015±.0015)

#1 _0.0165"__ #2 _0.0163"__ #3 _0.0164"_____

Outside diameter (Ø21.000±0.010)

#1 _20.999"__ #2 _20.995"_____

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

B-TM-1639

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P.O. Box 245
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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Solid Disk
(Re-01 – Re-22)

Part number: _Re-11____ Lot Number: R-1481____

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343____

Weight of disk: _1981.6g____

Temperature of disk at time of measurement: _22.5°C____

Thickness measurements (.015±.0015)

#1 _0.0163"__ #2 _0.0165"__ #3 _0.0158"____

Outside diameter (Ø21.000±0.010)

#1 _20.999"__ #2 _20.997"____

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

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P.O. Box 245
Elyria, Oh 44036-0245
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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Solid Disk
(Re-01 – Re-22)

Part number: _Re-12_ Lot Number: R-1481_____

Gage serial numbers:

24" Caliper: 06749_ 1" Micrometer: _9052740_ Scale: _1343_____

Weight of disk: _1992.8g_____

Temperature of disk at time of measurement: _22.78°C_____

Thickness measurements (.015±.0015)

#1 _0.0161"__ #2 _0.0164"__ #3 _0.0159"_____

Outside diameter ($\varnothing$ 21.000±0.010)

#1 _20.999"__ #2 _20.998"_____

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-23__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1936.7g__

Temperature of disk at time of measurement: __21.94°C__

Thickness measurements (.015±.0015)

#1 __.0158"__ #2 __.0160"__ #3 __.0156"__

Outside diameter (Ø21.000±0.010)

#1 __20.997"__ #2 __20.997"__

Inside diameter (Ø2.510±0.010)

#1 __2.508"__ #2 __2.507"__

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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-24__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1957.2g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0161"__ #2 __.0165"__ #3 __.0160"__

Outside diameter (Ø21.000±0.010)

#1 __20.998"__ #2 __20.999"__

Inside diameter (Ø2.510±0.010)

#1 __2.511"__ #2 __2.511"__

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Quality Control Engineer

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1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
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Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. --

Annular Disk
(Re-23 -- Re-44)

Part number: __Re-25__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1917.4g__

Temperature of disk at time of measurement: __22.22°C__

Thickness measurements (.015 $\pm$.0015)

#1 __.0157"__ #2 __.0153"__ #3 __.0163"__

Outside diameter ($\varnothing$ 21.000 $\pm$ 0.010)

#1 __20.999"__ #2 __20.997"__

Inside diameter ($\varnothing$ 2.510 $\pm$ 0.010)

#1 __2.509"__ #2 __2.501"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
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KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-26__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1927.8g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0157"__ #2 __.0151"__ #3 __.0156"__

Outside diameter (Ø21.000±0.010)

#1 __20.998"__ #2 __20.997"__

Inside diameter (Ø2.510±0.010)

#1 __2.509"__ #2 __2.508"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
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Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-27__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1920.2g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0161"__ #2 __.0158"__ #3 __.0157"__

Outside diameter (Ø21.000±0.010)

#1 __20.995"__ #2 __20.998"__

Inside diameter (Ø2.510±0.010)

#1 __2.508"__ #2 __2.502"__

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Quality Control Engineer

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Web site: <http://www.rhenium.com>

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P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-28__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1902.8g__

Temperature of disk at time of measurement: __22.78°C__

Thickness measurements (.015±.0015)

#1 __.0163"__ #2 __.0162"__ #3 __.0159"__

Outside diameter (Ø21.000±0.010)

#1 __20.996"__ #2 __20.998"__

Inside diameter (Ø2.510±0.010)

#1 __2.509"__ #2 __2.511"__

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Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-29__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1926.3g__

Temperature of disk at time of measurement: __21.94°C__

Thickness measurements (.015±.0015)

#1 __.0150"__ #2 __.0164"__ #3 __.0162"__

Outside diameter (Ø21.000±0.010)

#1 __20.999"__ #2 __20.994"__

Inside diameter (Ø2.510±0.010)

#1 __2.510"__ #2 __2.511"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-30__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__
Scale: 1343__

1" Micrometer: __9052740__
6" Caliper: __Rec-005

Weight of disk: __1920.1g__

Temperature of disk at time of measurement: __22.22°C__

Thickness measurements (.015±.0015)

#1 __.0151"__ #2 __.0150"__ #3 __.0154"__

Outside diameter (Ø21.000±0.010)

#1 __20.999"__ #2 __20.995"__

Inside diameter (Ø2.510±0.010)

#1 __2.511"__ #2 __2.509"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
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Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-31__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1950.5g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0162"__ #2 __.0160"__ #3 __.0158"__

Outside diameter (Ø21.000±0.010)

#1 __20.995"__ #2 __20.997"__

Inside diameter (Ø2.510±0.010)

#1 __2.510"__ #2 __2.510"__

Cliff Guthman
Quality Control Engineer

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Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. –

Annular Disk
(Re-23 – Re-44)

Part number: __Re-32__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1910.6g__

Temperature of disk at time of measurement: __22.22°C__

Thickness measurements (.015±.0015)

#1 __.0164"__ #2 __.0165"__ #3 __.0165"__

Outside diameter (Ø21.000±0.010)

#1 __20.995"__ #2 __20.994"__

Inside diameter (Ø2.510±0.010)

#1 __2.509"__ #2 __2.510"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
Per Bechtel Bettis Inc.
Drawing #SK-MGP2177 Rev. -

Annular Disk
(Re-23 - Re-44)

Part number: __Re-33__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1945.8g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0163"__ #2 __.0164"__ #3 __.0164"__

Outside diameter (Ø21.000±0.010)

#1 __20.997"__ #2 __20.992"__

Inside diameter (Ø2.510±0.010)

#1 __2.510"__ #2 __2.509"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

1329 Taylor St.
P.O. Box 245
Elyria, Oh 44036-0245
Voice (440) 365-7388
Fax (440) 366-9831

KAPL Inspection Sheet
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Drawing #SK-MGP2177 Rev. –

Annular Disk
(Re-23 – Re-44)

Part number: __Re-34__ Lot Number: R-1481__

Gage serial numbers:

24" Caliper: __06749__ 1" Micrometer: __9052740__
Scale: 1343__ 6" Caliper: __Rec-005__

Weight of disk: __1924.6g__

Temperature of disk at time of measurement: __22.5°C__

Thickness measurements (.015±.0015)

#1 __.0164"__ #2 __.0163"__ #3 __.0161"__

Outside diameter (Ø21.000±0.010)

#1 __20.999"__ #2 __20.996"__

Inside diameter (Ø2.510±0.010)

#1 __2.510"__ #2 __2.509"__

Cliff Guthman
Quality Control Engineer

Rhenium Alloys, Inc
Email: rhenium@rhenium.com
Web site: <http://www.rhenium.com>

Thickness measurements (taken 3 3/4" in from O.D.) A) .0167 B) .0165 C) .0164 D) .0174	
TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.030 .XXX±.010 BREAK ALL SHARP EDGES		RHENIUM
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DATE 5/31/05		PART NO. Re-01	
DR. BY CLG		SCALE NTS	
APP. BY		REV DESCRIPTION KAPL inspection sheets	
DATE		DATE	

<p>Re-XX Lot # R-400X</p>		<p>1320 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7358 (FAX) (440) 366-9831</p>		<p>REV</p>	<p>DESCRIPTION</p>	<p>DATE</p>	
		<p>KAPL inspection sheets</p>			<p>SCALE</p>	<p>NTS</p>	<p>APP. BY</p>
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.030 .XX±.010 BREAK ALL SHARP EDGES</p>		<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>		<p>DATE</p>	<p>5/31/05</p>	<p>DR. BY</p>	<p>CLG</p>
<p>Re-XX Lot # R-400X</p>		<p>1320 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7358 (FAX) (440) 366-9831</p>		<p>REV</p>	<p>DESCRIPTION</p>	<p>DATE</p>	<p>Re-02</p>
<p>Thickness measurements (taken 3 3/4" in from O.D.) A) .0166 B) .0163 C) .0168 D) .0168</p>		<p>1320 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7358 (FAX) (440) 366-9831</p>		<p>SCALE</p>	<p>NTS</p>	<p>APP. BY</p>	<p>Re-02</p>

<p>Re-XX Lot # R-XXX</p>		<p>Thickness measurements (taken 3/4" in from O.D.)</p> <p>A) .0170 B) .0175 C) .0175 D) .0164</p>	
		<p>Re-XX Lot # R-XXX</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX-.000 XXX-.010 BREAK ALL SHARP EDGES</p>		<p>RENIUM 1328 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7388 (FAX) (440) 366-9831</p>	
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<p>SCALE</p>		<p>DATE</p>	
<p>APP BY</p>		<p>NTS</p>	
<p>REV</p>		<p>DESCRIPTION</p>	
<p>DATE</p>		<p>PART NO.</p>	
<p>KAPL inspection sheets</p>			
<p>Re-03</p>

Thickness measurements (taken 3 3/4" in from O.D.) A) .0171 B) .0165 C) .0172 D) .0167	
TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.000 .XXX±.010 BREAK ALL SHARP EDGES		Rc RHENIUM	
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REV		DESCRIPTION	
DATE		PART NO.	
SCALE		NTS	
APP BY		CLG	
DATE		5/31/05	
DR BY		CLG	
KAPL inspection sheets			
Re-04			

<p>Thickness measurements (taken 3/4" in from O.D.)</p> <p>A) .0166 B) .0165 C) .0167 D) .0167</p>		REV		DESCRIPTION	DATE
		KAPL inspection sheets		PART NO.	
<p>Re-XX Lot # R-XXX</p>		SCALE	NTS	Re-05	
		APP BY	CLG		
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX=.XX0 .XXX=.XXX0 BREAK ALL SHARP EDGES</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 385-7388 (FAX) (440) 388-9831</p>		<p>DATE 5/31/05</p>	
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<p>Re-XX Lot # R-4XX</p>		<p>Thickness measurements (taken 3/4" in from O.D.)</p> <p>A) .0174 B) .0170 C) .0164 D) .0163</p>	
		<p>Re-XX Lot # R-4XX</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX±.000 XXX±.010 BREAK ALL SHARP EDGES</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7388 (FAX) (440) 360-8831</p>	
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<p>REVISIONS</p>		<p>DATE</p>	
<p>DESCRIPTION</p>		<p>DATE</p>	
<p>REV</p>		<p>DATE</p>	
<p>KAPL inspection sheets</p>		<p>SCALE</p>	
<p>PART NO.</p>		<p>NTS</p>	
<p>APP. BY</p>		<p>Re-06</p>	

Re-XX
Lot # R-4XX

A

B

C

D

Thickness measurements (taken 3 3/4" in from O.D.)
A) .0171
B) .0172
C) .0170
D) .0168

TOLERANCES UNLESS OTHERWISE SPECIFIED
XX=±.030
XXX=±.010
BREAK ALL SHARP EDGES

Re

RHENIUM

1329 TAYLOR STREET
ELYRIA, OHIO 44036
(440) 365-7388
(FAX) (440) 368-9831

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REV

DESCRIPTION

DATE

KAPL inspection sheets

SCALE

NTS

PART NO.

APP. BY

DR. BY

DATE

CLG

Re-07

<p>Re-XX Lot # R-4XX</p>		<p>1328 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7388 (FAX) (440) 368-9831</p>		<p>REV</p>	<p>DESCRIPTION</p>	<p>DATE</p>
		<p>KAPL inspection sheets</p>			<p>SCALE</p>	<p>PART NO.</p>
<p>Thickness measurements (taken 3 3/4" in from O.D.)</p> <p>A) .0181 B) .0158 C) .0178 D) .0178</p>		<p>DATE 5/31/05</p>		<p>NTS</p>	<p>Re-08</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX=±.000 .XXX=±.010 BREAK ALL SHARP EDGES</p>		<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>		<p>DR. BY</p>	<p>CLG</p>	<p>APP. BY</p>

<p>Thickness measurements (taken 3 3/4" in from O.D.)</p> <p>A) .0178 B) .0168 C) .0177 D) .0174</p>				<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7388 (FAX) (440) 368-8631</p>		<p>REV DESCRIPTION DATE</p>	
<p>Re-XX Lot # R-4XX</p>		<p>RHENIUM</p>		<p>SCALE PART NO.</p>		<p>KAPL inspection sheets</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX=±.030 .XXX=±.010 BREAK ALL SHARP EDGES</p>		<p>DATE 5/31/05</p>		<p>SCALE NTS</p>		<p>Re-09</p>	
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<p>Re-XX Lot # R-100X</p>		<p>Thickness measurements (taken 3/4" in from O.D.) A) .0175 B) .0176 C) .0174 D) .0169</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.030 XXX±.010 BREAK ALL SHARP EDGES</p>		<p>RHENIUM 1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 388-7388 (FAX) (440) 388-9831</p>	
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<p>REV</p>		<p>DESCRIPTION</p>	
<p>DATE</p>		<p>SCALE</p>	
<p>KAPL inspection sheets</p>		<p>PART NO.</p>	
<p>NTS</p>		<p>APP. BY</p>	
<p>Re-10</p>		<p>CLG</p>

<p>Thickness measurements (taken 3 3/4" in from O.D.)</p> <p>A) .0171 B) .0168 C) .0169 D) .0165</p>				<p>REV</p>		<p>DESCRIPTION</p>		<p>DATE</p>	
				<p>KAPL inspection sheets</p>		<p>Re-12</p>			
<p>Re-XX Lot # R-140X</p>		<p>1320 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7366 (FAX) (440) 366-9831</p>		<p>SCALE</p>		<p>PART NO.</p>		<p>DATE</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX=±.030 XXX=±.010 BREAK ALL SHARP EDGES</p>		<p>Rc RHENIUM</p>		<p>DATE</p>		<p>NTS</p>		<p>APP BY</p>	
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Lot Number: R-1481
 Temperature of disk at time of inspection: 21.8°C
 Weight of disk: 1351.2g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0165 C) .0144
 B) .0164 D) .0172
 Outside diameter:
 A) 20.999
 B) 20.995
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

REV	DESCRIPTION	DATE
	KAPL inspection sheets	
SCALE	PART NO	
NTS		
APP BY		

Re-13

1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 383-7386 (FAX) (440) 368-9831	DATE 5/6/05	CLO
DR BY		
TOLERANCES UNLESS OTHERWISE SPECIFIED .XX = ±.030 .XXX = ±.010 BREAK ALL SHARP EDGES THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.		

<p>Lot Number: R-1481 Temperature of disk at time of inspection: 21.2°C Weight of disk: 1858.0g Thickness measurement taken 3 3/4" in from outside diameter: A) .0159 C) .0155 B) .0164 D) .0164 Outside diameter: A) 20.995 B) 21.002 Gage serial numbers: 24" Caliper: 06749 .5" dial indicator: 15903 Scale: 1343</p>		REV		DESCRIPTION	DATE
		KAPL Inspection sheets		PART NO.
SCALE	NTS	Re-14	
		APP BY	CLG		
TO: FRANCES UNLESS OTHERWISE SPECIFIED .XX" ± 0.30 .XXX" ± 0.10 BREAK ALL SHARP EDGES		1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7308 (FAX) (440) 366-9831		DATE 6/6/05	
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Lot Number: R-1481
 Temperature of disk at time of inspection: 21.8°C
 Weight of disk: 1914.1g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0172 C) .0168
 B) .0160 D) .0167
 Outside diameter:
 A) 20.997
 B) 20.997
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOI FRANCES UNIT PWS OTHERWISE SPECIFIED XXX-036 -XXX-010 REFRAX ALL SHARP EYES				1320 TAYLOR STREET ELYRIA, OHIO 44036 (440) 393-7388 (FAX) (440) 366-9831	
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REV	DESCRIPTION	SCALE		PART NO.	
	KAPL inspection sheets	NTS		APP BY	
<div style="text-align: right; font-size: 2em; font-weight: bold;">Re-15</div>					

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.4°C
 Weight of disk: 1835.2g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0157 C) .0154
 B) .0173 D) .0166
 Outside diameter:
 A) 20.995
 B) 20.996
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOLERANCES UNLESS
OTHERWISE SPECIFIED
XX=±.030
XXX=±.010
BREAK ALL SHARP EDGES

1320 TAYLOR STREET
 ELYRIA, OHIO 44036
 (440) 363-7288
 (FAX) (440) 366-9831

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DATE 6/6/95
 DR BY CLG

SCALE NTS
 APP BY

REV DESCRIPTION

KAPL inspection sheets

PART NO.

Re-16

Re-XX
Lot # R-14XX

A

B

C

D

Lot Number: R-1481
Temperature of disk at time of inspection: 21.6°C
Weight of disk: 1911.6g
Thickness measurement taken 3 3/4" in from outside diameter:
A) .0163 C) .0174
B) .0160 D) .0171
Outside diameter:
A) 20.096
B) 20.997
Gage serial numbers:
24" Caliper: 06749 .5" dial indicator: 15903
Scale: 1343

TOLERANCES UNLESS OTHERWISE SPECIFIED
XX±.030
XXX±.010
BREAK ALL SHARP EDGES

Rc

RHENIUM

3003 SL

1339 TAYLOR STREET
ELYRIA, OHIO 44036
(440) 355-7358
(FAX) (440) 366-9831

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DATE
6/6/05

DR BY
CLG

REV

DESCRIPTION

DATE

KAPL inspection sheets

PART NO

SCALE

NTS

APP BY

Re-17

G-43

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.6°C
 Weight of disk: 1881.1g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0148 C) .0164
 B) .0166 D) .0169
 Outside diameter:
 A) 20.999
 B) 20.998
 Gage serial numbers:
 24" Caliper: 06743 .5" dial indicator: 15903
 Scale: 1343

**CAUTION !!
 Broken Welds**

TOLERANCES UNLESS OTHERWISE SPECIFIED XX±.030 XXX±.010 BREAK ALL SHARP EDGES		1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7306 (FAX) (440) 366-9831		REV	DESCRIPTION	DATE
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		DR. BY		SCALE	PART NO.	
		CLG		NTS		
				APP. BY		
				Re-18		

Lot Number: R-1481
 Temperature of disk at time of inspection: 22.2°C
 Weight of disk: 1886.9g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0168 C) .0163
 B) .0165 D) .0107
 Outside diameter:
 A) 20.990
 B) 20.998
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOLERANCES UNLESS
 OTHERWISE SPECIFIED
 .XX" ± 0.30
 .XXX" ± 0.10
 BREAK ALL SHARP EDGES

1329 TAYLOR STREET
 ELYRIA, OHIO 44036
 (440) 395-7398
 (FAX) (440) 366-9831

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REV DESCRIPTION DATE

KAPL inspection sheets

SCALE NTS PART NO

Re-19

APP BY

DR BY

CLG

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.6°C
 Weight of disk: 1837.2g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0157 C) .0170
 B) .0157 D) .0165
 Outside diameter:
 A) 21.001
 B) 20.997
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOLERANCES UNLESS OTHERWISE SPECIFIED XX=1/32 XXX=1/16 BREAK ALL SHARP EDGES		RHENIUM 2000-35		1329 TAYLOR STREET ELYRIA, OHIO 44016 (440) 365-7368 (FAX) (440) 366-9831		REV	DESCRIPTION	DATE
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DATE		DR BY		CLG		SCALE	PART NO.	
6/6/05						NTS		
						APP BY		
						Re-20		

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.6°C
 Weight of disk: 1529.2g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0177 C) .0165
 B) .0172 D) .0175
 Outside diameter:
 A) 20.007
 B) 20.998
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOLERANCES UNLESS
 OTHERWISE SPECIFIED
 XX±.030
 XXX±.010
 BREAK ALL SHARP EDGES

1339 TAYLOR STREET
 ELYRIA, OHIO 44036
 (440) 395-7368
 (FAX) (440) 366-9831

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 RHENIUM ALLOYS INC.

REV	DESCRIPTION	DATE
	KAPL inspection sheets	
SCALE	PART NO.	
NTS		
APP BY		

Re-21

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.8°C
 Weight of disk: 1895.5g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0164 C) .0167
 B) .0164 D) .0158
 Outside diameter:
 A) 20.997
 B) 20.998
 Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15903
 Scale: 1343

TOLERANCE UNLESS OTHERWISE SPECIFIED XXX±.030 XXX±.010 BREAK ALL SHARP EDGES				1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7388 (FAX) (440) 366-9831	
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DR-BY		DATE 6/6/05		CLG	
SCALE		NTS		PART NO.	
APP BY		NTS		PART NO.	
REV		DESCRIPTION		DATE	
		KAPL inspection sheets			

Re-22

<p>Re-XX Lot # R-400X</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 368-7388 (FAX) (440) 368-9031</p>		<p>REVENUE DATE</p>	
		<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .004±.003 .001±.010 BREAK ALL SHARP EDGES</p>		<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING DESIGN, PROCUREMENT OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>	
<p>Thickness measurements (taken 3 3/4" in from O.D.) A) .0161 B) .0170 C) .0166 D) .0171</p>		<p>Width measurements taken from O.D. to edge of I.D. 1) 9.245 2) 9.247 3) 9.245 4) 9.252</p>		<p>SCALE NTS APP BY</p>	
<p>REV DESCRIPTION</p>		<p>DATE</p>		<p>PART NO.</p>	
<p>KAPL inspection sheets</p>		<p>Re-23</p>		<p>CLG</p>

<p>Re-XX Lot # R-4XX</p>		REV		DESCRIPTION		DATE	
		KAPL inspection sheets		KAPL inspection sheets		KAPL inspection sheets	
<p>Thickness measurements (taken 3/4" in from O.D.)</p> <p>A) .0175 B) .0169 C) .0166 D) .0173</p> <p>Width measurements taken from O.D. to edge of I.D.</p> <p>1) 9.246 2) 9.248 3) 9.248 4) 9.250</p>		SCALE		PART NO.		Re-27	
		DATE		NTS		APP BY	
<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7388 (FAX) (440) 368-8831</p>		DATE		5/31/05		DR BY	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX±.030 XXX±.010 BREAK ALL SHARP EDGES</p>		DATE		5/31/05		CLG	
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<p>Re-XX Lot # R-100X</p>		<p>Thickness measurements (taken 3 3/4" In from O.D.)</p> <p>A) .0164 B) .0175 C) .0168 D) .0162</p>	
		<p>Width measurements taken from O.D. to edge of I.D.</p> <p>1) 9.249 2) 9.248 3) 9.247 4) 9.246</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX = ±.000 .XXX = ±.010 BREAK ALL SHARP EDGES</p>		<p>1328 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7388 (FAX) (440) 368-9831</p>	
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<p>REVISION</p>		<p>DATE</p>	
<p>DESCRIPTION</p>		<p>PART NO.</p>	
<p>REV</p>		<p>SCALE</p>	
<p>KAPL inspection sheets</p>		<p>NTS</p>	
<p>APP BY</p>		<p>Re-28</p>	

<p>Re-XX Lot 8 R-AXX</p>		REV		DESCRIPTION		DATE	
		KAPL		Inspection sheets		PART NO.	
<p>Thickness measurements (taken 3 3/4" in from O.D.)</p> <p>A) .0188 B) .0170 C) .0164 D) .0161</p> <p>Width measurements taken from O.D. to edge of I.D.</p> <p>1) 9.249 2) 9.249 3) 9.248 4) 9.249</p>		SCALE		NTS		APP BY	
		DATE		5/31/05		DR BY	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED</p> <p>.XX-.X.00 .XXX-.X.010 BREAK ALL SHARP EDGES</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7388 (FAX) (440) 366-8831</p>		<p>RENUM</p>		<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>	
						<p>Re-29</p>

<p>Re-XX Lot # R-XXX</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7355 (FAX) (440) 366-8831</p>		<p>REVENUE DATE 5/31/05</p>	
		<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX ± 0.030 XXX ± 0.010 BREAK ALL SHARP EDGES</p>		<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHEINUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING DESIGN, PROCUREMENT OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHEINUM ALLOYS INC.</p>	
<p>Thickness measurements (taken 3 3/4" in from O.D.) A) .0182 B) .0161 C) .0180 D) .0168</p>		<p>Width measurements taken from O.D. to edge of I.D. 1) 9.248 2) 9.247 3) 9.246 4) 9.249</p>		<p>DATE</p>	
<p>REV</p>		<p>DESCRIPTION</p>		<p>DATE</p>	
<p>KAPL inspection sheets</p>		<p>SCALE</p>		<p>PART NO.</p>	
<p>APP BY</p>		<p>NTS</p>		<p>Re-31</p>	
<p>CLG</p>		<p>DR BY</p>		<p>DATE</p>	

<p>Re-XX Lot 8 R-4XX</p>		REV		DESCRIPTION		DATE	
		KAPL inspection sheets		KAPL inspection sheets		KAPL inspection sheets	
<p>Thickness measurements (taken 3 3/4" in from O.D.)</p> <p>A) .0162 B) .0171 C) .0168 D) .0175</p> <p>Width measurements taken from O.D. to edge of I.D.</p> <p>1) 9.246 2) 9.248 3) 9.249 4) 9.250</p>		SCALE		PART NO.		Re-32	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX-2.030 XXX-2.010 BREAK ALL SHARP EDGES</p>		DATE		DR. BY		CLG	
<p>1325 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7388 (FAX) (440) 366-8831</p>		DATE		5/31/05		DR. BY	
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<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>		DATE		5/31/05		DR. BY

<p>Re-XX Lot # R-100X</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44038 (440) 365-7388 (FAX) (440) 368-9831</p>		<p>REHENIUM</p>		<p>TOLERANCES UNLESS OTHERWISE SPECIFIED XX=±.005 XXX=±.010 BREAK ALL SHARP EDGES</p>	
		<p>REV DESCRIPTION DATE</p>		<p>SCALE NTS</p>		<p>DATE 5/31/05</p>	
<p>Thickness measurements (taken 3 3/4" In from O.D.) A) .0170 B) .0162 C) .0165 D) .0167</p>		<p>Width measurements taken from O.D. to edge of I.D. 1) 9.250 2) 9.247 3) 9.246 4) 9.248</p>		<p>KAPL inspection sheets</p>		<p>DR BY CLG</p>	
				<p>Re-34</p>			

Lot Number: R-1481
 Temperature of disk at time of inspection: 23.2°C
 Weight of disk: 1746.3g
 Thickness measurement taken 3 3/4" in from
 outside diameter:
 A) .0157 C) .0161
 B) .0156 D) .0153
 Inside diameter:
 A) 2.508
 B) 2.507
 Outside diameter:
 A) 21.007
 B) 21.000
 Width measurement taken from O.D. to edge
 of I.D.:
 A) 9.248 C) 9.248
 B) 9.247 D) 9.244

Gage serial numbers:
 24" Caliper: 06749 .5" dial indicator: 15003
 12" Caliper: REC-002 Scale: 1343
 6" Caliper: REC-005

TOLERANCES UNLESS OTHERWISE SPECIFIED XXX±.030 XXX±.010 BREAK ALL SHARP EDGES		 1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 355-7388 (FAX) (440) 366-9831		REV	DESCRIPTION	DATE
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		DR BY		SCALE	PART NO.	
		CLG		NTS		
				APP BY		
						Re-35

Lot Number: R-1481

Temperature of disk at time of inspection: 23.1°C

Weight of disk: 1898.7g

Thickness measurement taken 3 3/4" in from outside diameter:

A) .0168 C) .0166

B) .0169 D) .0165

Inside diameter:

A) 2.502

B) 2.503

Outside diameter:

A) 20.996

B) 20.998

Width measurement taken from O.D. to edge of I.D.:

A) 9.246 C) 9.245

B) 9.248 D) 9.248

Gage serial numbers:

24" Caliper: 06749 .5" dial indicator: 15903

12" Caliper: REC-002 Scale: 1343

6" Caliper: REC-005

1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7389 (FAX) (440) 366-9831	
TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.030 .XXX±.010 BREAK ALL SHARP EDGES		THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING, DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.	
REV DESCRIPTION DATE		SCALE PART NO.	
KAPL inspection sheets		DATE 6/6/05	
DR BY		CLG	

Re-36

Lot Number: R-1481
 Temperature of disk at time of inspection: 22.4°C
 Weight of disk: 1832.3g
 Thickness measurement taken 3 3/4" in from
 outside diameter:

A) .0157 C) .0157
 B) .0156 D) .0167

Inside diameter:

A) 2.506
 B) 2.501

Outside diameter:

A) 21.000
 B) 20.998

Width measurement taken from O.D. to edge
 of I.D.:

A) 9.250 C) 9.250
 B) 9.248 D) 9.244

Gage serial numbers:

2.4" Caliper: 06749 .5" dial indicator: 15903
 12" Caliper: REC-002 Scale: 1343
 6" Caliper: REC-005

TOLERANCES UNLESS
 OTHERWISE SPECIFIED
 XX±.030
 XXX±.010
 BREAK ALL SHARP EDGES

1329 TAYLOR STREET
 ELYRIA, OHIO 44036
 (440) 365-7386
 (FAX) (440) 366-9631

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 RHENIUM ALLOYS INC.

DATE 6/6/05
 DR BY CLG

REV DESCRIPTION DATE
 KAPL inspection sheets

SCALE PART NO.

APP BY NTS

Re-37

<p>Lot Number: R-1481 Temperature of disk at time of inspection: 23.6°C Weight of disk: 1933.9g Thickness measurement taken 3 3/4" in from outside diameter: A) .0168 C) .0172 B) .0170 D) .0171 Inside diameter: A) 2.509 B) 2.510 Outside diameter: A) 20.992 B) 20.998 Width measurement taken from O.D. to edge of I.D.: A) 9.248 C) 9.246 B) 9.250 D) 9.246</p>		<p>Gage serial numbers: 24" Caliper: 06740 .5" dial indicator: 15903 12" Caliper: REC-002 Scale: 1343 6" Caliper: REC-005</p>	
		<p>1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 385-7388 (FAX) (440) 386-9831</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX = ±.030 .XXX = ±.010 BREAK ALL SHARP EDGES</p>		<p>RHENIUM 100% NiTi</p>	
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<p>REV DESCRIPTION DATE</p>		<p>KAPL inspection sheets</p>	
<p>SCALE NTS</p>		<p>PART NO.</p>	
<p>APP BY</p>		<p>Re-38</p>	

Lot Number: R-1481
 Temperature of disk at time of inspection: 21.2°C
 Weight of disk: 1874.5g
 Thickness measurement taken 3 3/4" in from
 outside diameter:

A) .0157 C) .0162
 B) .0165 D) .0172

Inside diameter:

A) 2.510
 B) 2.508

Outside diameter:

A) 20.993
 B) 20.999

Width measurement taken from O.D. to edge
 of I.D.:

A) 9.243 C) 9.246
 B) 9.248 D) 9.247

Gage serial numbers:

24" Caliper: 06749 .5" dial Indicator: 15903
 12" Caliper: REC-002 Scale: 1343
 6" Caliper: REC-005

TOLERANCES UNLESS
 OTHERWISE SPECIFIED
 XX=±.030
 XXX=±.010
 BREAK ALL SHARP EDGES

1379 TAYLOR STREET
 ELYRIA, OHIO 44036
 (440) 365-7368
 (FAX) (440) 366-9831

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 IN WHOLE OR IN PART WITHOUT CONSENT OF
 RHENIUM ALLOYS INC.

DATE

6/6/05

DR. BY

CLG

REV DESCRIPTION

DATE

KAPL inspection sheets

PART NO.

SCALE NTS

APP. BY

Re-39

Lot Number: R-1481
Temperature of disk at time of inspection: 22.4°C
Weight of disk: 1613.5g
Thickness measurement taken 3 3/4" in from outside diameter:
A) .0171 C) .0160
B) .0165 D) .0158
Inside diameter:
A) 2.509 B) 2.510
Outside diameter:
A) 20.997 B) 20.998
Width measurement taken from O.D. to edge of I.D.:
A) 9.248 C) 9.250
B) 9.248 D) 9.246

Gage serial numbers:
24" Caliper: 06749 .5" dial indicator: 15903
12" Caliper: REC-002 Scale: 1343
6" Caliper: REC-005

REV	DESCRIPTION	DATE				
KAPL inspection sheets		PART NO.				
SCALE	NTS	DATE	DR BY	CLG		
APP BY		6/6/05				

TOLERANCES UNLESS OTHERWISE SPECIFIED
XXX±.030
XXX±.010
BREAK ALL SHARP EDGES

1329 TAYLOR STREET
ELYRIA, OHIO 44036
(440) 345-7368
(FAX) (440) 366-9831

THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.

Lot Number: R-1481
 Temperature of disk at time of inspection: 22.8°C
 Weight of disk: 1877.3g
 Thickness measurement taken 3 3/4" in from
 outside diameter:

A) .0170 C) .0166
 B) .0169 D) .0173

Inside diameter:

A) 2.509
 B) 2.506

Outside diameter:

A) 20.990
 B) 20.997

Width measurement taken from O.D. to edge
 of I.D.:

A) 9.245 C) 9.247
 B) 9.246 D) 9.245

Gage serial numbers:

24" Caliper: 06749 .5" dial indicator: 15903
 12" Caliper: REC-002 Scale: 1343
 6" Caliper: REC-005

TOLERANCES UNLESS OTHERWISE SPECIFIED XX+1.00 XXX+2.010 BREAK ALL SHARP EDGES		1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 365-7356 (FAX) (440) 366-9831		REV	DESCRIPTION	DATE
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				PART NO. Re-43		

<p>Lot Number: R-1481 Temperature of disk at time of inspection: 21.8°C Weight of disk: 1904.9g Thickness measurement taken 3 3/4" in from outside diameter: A) .0172 C) .0170 B) .0172 D) .0174 Inside diameter: A) 2.508 B) 2.508 Outside diameter: A) 21.003 B) 20.998 Width measurement taken from O.D. to edge of I.D.: A) 9.248 C) 9.245 B) 9.246 D) 9.245</p>		<p>Gage serial numbers: 24" Caliper: 06749 .5" dial indicator: 15003 12" Caliper: REC-002 Scale: 1343 6" Caliper: REC-005</p>	
<p>TOLERANCES UNLESS OTHERWISE SPECIFIED .XX±.030 .XXX±.010 BREAK ALL SHARP EDGES</p>		<p>1329 TAYLOR STREET ELYRIA, OHIO 44036 (440) 385-7308 (FAX) (440) 368-9831</p>	
<p>THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO RHENIUM ALLOYS INC. AND SHALL NOT BE USED FOR ENGINEERING DESIGN, PROCUREMENT, OR MANUFACTURE IN WHOLE OR IN PART WITHOUT CONSENT OF RHENIUM ALLOYS INC.</p>		<p>DATE 5/6/05 DR BY CLG</p>	
<p>REV DESCRIPTION DATE</p>		<p>KAPL inspection sheets</p>	
<p>SCALE NTS</p>		<p>PART NO.</p>	
<p>APP BY</p>		<p>Re-44</p>

131 Woodedge Drive
Lansing Business & Technology Park
Lansing, NY 14082

Phone: 607.333.7000 • Fax: 607.531.3210
www.imrtest.com • E-mail: imr@imrtest.com
Toll Free: 800.464.8422

Original Date
May 9, 2005
Revised Date
May 10, 2005

CERTIFIED MATERIAL ANALYSIS

Cliff Guthman
Rhenium Alloys Inc.
1329 Taylor Street
PO Box 245
Elyria, OH 44036-0245
USA

IMR Report Number 200504066-Revision 1 (corrected sample # on chemistry table per customer request)

PO Number
12176

SUMMARY

The sample was received for chemical analysis. The GDMS portion of the analysis was outsourced by IMR to a qualified outside facility (non-A2LA accredited). Per customer request the sample was analyzed by combustion for hydrogen, oxygen, nitrogen and carbon. Note that the combustion methods used for hydrogen, oxygen, nitrogen and carbon are the referee methods of analysis.

Date Received
May 3, 2005

Sample #
R-1478

The results are given on the following page.

Material
Rhenium Strips

Reviewed by

Hank Balduzzi
Chemist

Reviewed by

Peter Damian
Chemistry Dept. Manager

All procedures were performed in accordance with the IMR Quality Manual, current revisions, and related procedures, and the PMA-MCL Manual F-20 and related procedures. The information contained in this test report represents only the material tested and may not be reproduced, except in full, without the written approval of IMR, Inc. IMR, Inc. maintains a quality system in compliance with the PMA-MCL 13025 (2000) and is accredited by the American Association for Laboratory Accreditation (A2LA), certification #1140101 and #1140102. IMR, Inc.'s liability to the customer or any third party is limited to the amount charged for services provided. All samples will be retained for a minimum of 6 months and may be destroyed thereafter unless otherwise specified by the customer. The recording of data, retention, or immediate destruction or return on this document may be purchased as a service under federal statute. Trovato testing was not performed in accordance with NADCAP requirements (including theoretical rate used), but does adhere to A2LA and ASTM B requirements.

CHEMISTRY

Element	R-1478
H ¹	6.6
Li	< 0.005
Be	< 0.005
B	< 0.005
C ²	19
N ¹	1
O ²	28
F	< 0.05
Na	0.36
Mg	0.03
Al	1.2
Si	1.7
P	0.12
S ²	82
Cl	0.13
K	0.09
Ca	0.44
Sc	< 0.005
Ti	0.11
V	0.008
Cr	2.3
Mn	0.14
Fe	5.1
Co	0.01
Ni	2.2
Cu	0.07
Zn	0.09
Ga	< 0.05
Ge	< 0.05
As	< 0.05
Se	< 0.05
Br	< 0.05
Rb	< 0.01
Sr	< 0.01
Y	< 0.005
Zr	0.11
Nb	0.01
Mo	0.58
Ru	< 0.01
Rh	< 0.01
Pd	< 0.01
Ag	< 0.01
Cd	< 0.1

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In	< 0.1
Sn	0.07
Sb	< 0.01
Te	< 0.01
I	< 0.01
Cs	< 0.5
Ba	< 0.01
La	< 0.01
Ce	< 0.01
Pr	< 0.01
Nd	< 0.01
Sm	< 0.01
Eu	< 0.01
Gd	< 0.01
Tb	< 0.01
Dy	< 0.01
Ho	< 0.01
Er	< 0.01
Tm	< 0.01
Yb	< 0.01
Lu	< 0.01
Hf	< 0.01
Ta	< 5
W	< 0.2
Re	Matrix
Os	< 0.01
Ir	< 0.01
Pt	< 0.05
Au	< 0.5
Hg	< 0.05
Tl	< 0.01
Pb	< 0.01
Bi	< 0.01
Th	< 0.001
U	< 0.001

¹Determined by inert gas fusion-thermal conductivity.²Determined by combustion-infrared absorbance.

Unless otherwise indicated, elements were analyzed by GDMS.

Results in ppm (ppm = parts per million = mg/Kg); 0.1000% by wt = 1000 ppm unless otherwise indicated.

Methods: ASTM E 1019-03, CAP-032A (Hydrogen), and GDMS.

131 Woodside Drive
Lansing Business & Technology Park
Lansing, NY 14082

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Toll free: 800.464.0422

May 10, 2005

CERTIFIED MATERIAL ANALYSIS

Cliff Guthman
Rhenium Alloys Inc.
1329 Taylor Street
PO Box 245
Elyria, OH 44036-0245
USA

IMR Report Number 200504068

PO Number
12175

SUMMARY

The sample was received for chemical analysis. The GDMS portion of the analysis was outsourced by IMR to a qualified outside facility (non-A2LA accredited). Per customer request the sample was analyzed by combustion for hydrogen, oxygen, nitrogen and carbon. Note that the combustion methods used for hydrogen, oxygen, nitrogen and carbon are the referee methods of analysis.

Date Received
May 3, 2005

Sample #
R-1481

Material
Rhenium Rectangles

The results are given on the following page.

Reviewed by

Hank Balduzzi
Chemist

Reviewed by

Peter Damian
Chemistry Dept. Manager

All procedures were performed in accordance with the IMR Quality Manual, current revision, and related procedures, and the PRA-MC's Manual 9-23 and related procedures. The information contained in this test report represents only the material tested and, may not be reproduced, except in full, without the written approval of IMR, Inc. IMR, Inc. maintains a quality system in compliance with the ISO/IEC 17025:1999 and is accredited by the American Association for Laboratory Accreditation (A2LA) certificate #104001 and #104002. IMR, Inc.'s liability to the customer or any third party is limited to the amount charged for services provided. All samples will be retained for a minimum of 6 months and may be destroyed thereafter unless otherwise specified by the customer. The recording of false, fictitious, or fraudulent statements or entries on this document may be punished as a felony under federal statute. Unless testing was not performed in accordance with NADCAP requirements (including their own rule book), but does conform to A2LA and ASTM B requirements.

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CHEMISTRY

Element	R-1481
H ¹	8.3
Li	< 0.005
Be	< 0.005
B	< 0.005
C ²	6
N ³	2
O ²	41
F	< 0.05
Na	0.24
Mg	< 0.01
Al	1.1
Si	27
P	0.21
S	0.14
Cl	0.22
K	0.09
Ca	0.09
Sc	< 0.005
Ti	0.08
V	0.01
Cr	4.4
Mn	0.34
Fe	11
Co	0.04
Ni	3.5
Cu	0.12
Zn	< 0.05
Ga	< 0.05
Ge	< 0.05
As	< 0.05
Se	< 0.05
Br	< 0.05
Rb	< 0.01
Sr	< 0.01
Y	< 0.005
Zr	0.05
Nb	0.01
Mo	0.65
Ru	< 0.01
Rh	< 0.01
Pd	< 0.01
Ag	< 0.01
Cd	< 0.1

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In	< 0.1
Sn	< 0.01
Sb	< 0.01
Te	< 0.01
I	< 0.01
Cs	< 0.5
Ba	0.02
La	< 0.01
Ce	< 0.01
Pr	< 0.01
Nd	< 0.01
Sm	< 0.01
Eu	< 0.01
Gd	< 0.01
Tb	< 0.01
Dy	< 0.01
Ho	< 0.01
Er	< 0.01
Tm	< 0.01
Yb	< 0.01
Lu	< 0.01
Hf	< 0.01
Ta	< 5
W	< 0.2
Re	Matrix
Os	< 0.01
Ir	< 0.01
Pt	< 0.05
Au	< 0.5
Hg	< 0.05
Tl	< 0.01
Pb	0.01
Bi	< 0.01
Th	< 0.001
U	< 0.001

¹Determined by inert gas fusion-thermal conductivity.²Determined by combustion-infrared absorbance.

Unless otherwise indicated, elements were analyzed by GDMS.

Results in ppm (ppm = parts per million = mg/Kg); 0.1000% by wt = 1000 ppm unless otherwise indicated.

Methods: ASTM E 1019-03, CAP-032A (Hydrogen), and GDMS.

Appendix H

Ta-2.5W Plate Dimension and Chemistry Reports

B-TM-1639

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PLD3 1-10

WAIH CHIANG QUALITY INSPECTION REPORT

INSPECTOR STEVE ROEMER SIGNATURE SR DATE 1-26-05
 S/D 124912 ITEM 2 P.O. KN600216 DWG# SK-MGP2174 REV. D
 HEAT NO. 1020-2 ALLOY T2LSW SFC 1283696
 DISC NO. T2W-1 - T2W-4 ROOM TEMPERATURE 67.6° - 68° DISC TEMPERATURE 68° - 70°
 EQUIPMENT NO. WC 623A, 425A, WC 2307 (TEMP) WC 2370, WC 2119 INSPECTED PER WI-QI-1

DISC NUMBER	+0.005" 21.0" O.D.	+0.005" -0.000" 2.510" I.D.	+0.025" 0.025" LENGTH	6% FLAT	SURFACE PER Q.P.	HOLE LOC.
T2W-1	20.9995	2.5125	.02370 - .02425	OK	None	OK
T2W-2	21.0000	2.5120	.02480 - .02520	OK	OK	OK
T2W-3	20.9970	2.5125	.02390 - .02445	OK	OK	OK
T2W-4	20.9995	2.5110	.02335 - .02390	OK	OK	OK
T2W-5	21.0000	2.5115	.02475 - .02490	OK	OK	OK
T2W-6	21.0020	2.5120	.02485 - .02620	OK	OK	OK
T2W-7	20.9980	2.5115	.02450 - .02520	OK	OK	OK
T2W-8	20.9975	2.5120	.02485 - .02530	OK	OK	OK
T2W-9	20.9980	2.5120	.02570 - .02525	OK	OK	OK
T2W-10	20.9985	2.5115	.02485 - .02525	OK	None	OK
T2W-11						
T2W-12						
T2W-13						
T2W-14						
T2W-15						
T2W-16						
T2W-17						
T2W-18						

NOTE: The recording of test results, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute.

WAH CHANG QUALITY INSPECTION REPORT

SUPPLEMENT TO SFC 1283696

PAGE 2 OF 3

DISC NUMBER	.025" ± .0025"	.025" ± .0025"	.025" ± .0025"
Ta2W-1	.02350	.02370	.02360
Ta2W-2	.02500	.02510	.02500
Ta2W-3	.02330	.02380	.02380
Ta2W-4	.02330	.02350	.02350
Ta2W-5	.02460	.02475	.02485
Ta2W-6	.02500	.02450	.02500 (02500 NEMA 10 HANA)
Ta2W-7	.02460	.02475	.02490
Ta2W-8	.02490	.02500	.02520
Ta2W-9	.02500	.02570	.02530
Ta2W-10	.02520	.02490	.02480
Ta2W-11			
Ta2W-12			
Ta2W-13			
Ta2W-14			
Ta2W-15			
Ta2W-16			
Ta2W-17			
Ta2W-18			
Ta2W-19			

NOTE: The recording of false, fictitious, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute."

15 10 11-10
 Ball 11-25
 242 26-40

WALL CHANG QUALITY INSPECTION REPORT

INSPECTOR STEVE ROEMER SIGNATURE Steve Roemer DATE 3-2-05
 S# 124912 ITEM 2 P.O. #N6000216 DWG# SK-MGP2174 REV. B
 HEAT NO. 11-49-2 ALLOY Ta2.5W SFC 1283700
 DISC NO. Ta2W-1-Ta2W-43 ROOM TEMPERATURE 64.1°-69.3° DISC TEMPERATURE 65°-68°-72°
 EQUIPMENT NO. 4C 423A, 405F (TERM) 4C2307, 4C2119, 4C2270 INSPECTED PER WI-Q1-1
Box 1 of 2 THAW 11-25 Box 2 of 2 26-40

DISC NUMBER	±.005" 21.0" O.D.	±.005" .000" 2.510" I.D.	±.0025" .025" LENGTH	6% FLAT	SURFACE PER Q.P.	HOLE LOC.
Ta2W-1						
Ta2W-2						
Ta2W-3						
Ta2W-4						
Ta2W-5						
Ta2W-6						
Ta2W-7						
Ta2W-8						
Ta2W-9						
Ta2W-10						
Ta2W-11	20.9975	2.5120	.02450 - .02610	OK	OK	OK
Ta2W-12	20.9995	2.5705	.02470 - .02590	OK	OK	OK
Ta2W-13	21.0015	2.5110	.02475 - .02560	OK	OK	OK
Ta2W-14	21.0010	2.5125	.02474 - .02510	OK	OK	OK
Ta2W-15	21.0000	2.5115	.02305 - .02420	OK	OK	OK
Ta2W-16	21.0020	2.5720	.02440 - .02460	OK	OK	OK
Ta2W-17	20.9980	2.5710	.02330 - .02430	OK	OK	OK
Ta2W-18	20.9995	2.5720	.02495 - .02560	OK	OK	OK

[illegible]

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MAR-01-2005 17:17

DREMET-WAH CHANG

541 917 6797 P.06

WAH CHANG QUALITY INSPECTION REPORT

SUPPLEMENT TO SFC 12-83700 PAGE 3 OF 4
Box 142 11-25

DISC NUMBER	.025" +-.0025"	.025" +-.0025"	.025" +-.0025"
Ta2W-1			
Ta2W-2			
Ta2W-3			
Ta2W-4			
Ta2W-5			
Ta2W-6			
Ta2W-7			
Ta2W-8			
Ta2W-9			
Ta2W-10			
Ta2W-11	.02570	.02480	.02490
Ta2W-12	.02570	.02575	.02490
Ta2W-13	.02490	.02530	.02570
Ta2W-14	.02570	.02480	.02550
Ta2W-15	.02390	.02405	.02420
Ta2W-16	.02450	.02490	.02460
Ta2W-17	.02360	.02375	.02420
Ta2W-18	.02520	.02510	.02600
Ta2W-19	.02495	.02500	.02570

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SFC 1283700

[illegible]

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B-TM-1639

(Intentionally Blank)

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08148 MR-02-2335

PG 1 of 1

QUALITY INSPECTION REPORT

INSPECTOR STEVE ROEMER SIGNATURE [Signature] DATE 1-24-05
 S/O 124912 ITEM 1 P.O. KN6000216 DWG# SK-MGP1174 REV. B
 HEAT NO. 11-19-2 ALLOY Ta2SW SFC 1283681
 DISC NO. Ta2W-1 - Ta2W-19 ROOM TEMPERATURE 67.2° - 70.0° DISC TEMPERATURE 66° - 68°
 EQUIPMENT NO. WC 6723A, 425F (TEMPERATURE) WC 2307 (AM TEND) WC 2370 INSPECTED PER WI-Q1-1

DISC NUMBER	+0.005" 21.0" O.D.	N/A I.D.	+0.0025" .015" LENGTH	6% FLATNESS	SURFACE PER QUALITY PLAN
Ta2W-1	21.0035		.02455 - .02550	OK	OK
Ta2W-2	21.0005		.02430 - .02460	OK	OK
Ta2W-3	20.9995		.02465 - .02505	OK	OK
Ta2W-4	21.0005		.02470 - .02555	OK	OK
Ta2W-5	21.0035		.02385 - .02440	OK	OK
Ta2W-6	21.0025		.02425 - .02475	OK	OK
Ta2W-7	21.0035		.02370 - .02400	OK	OK
Ta2W-8	20.9970		.02360 - .02575	OK	OK
Ta2W-9	21.0029		.02455 - .02600	OK	OK
Ta2W-10					
Ta2W-11					
Ta2W-12					
Ta2W-13					
Ta2W-14					
Ta2W-15					
Ta2W-16					
Ta2W-17					
Ta2W-18					
Ta2W-19					

NOTE: The accuracy of these dimensions, or frequent statements of effort, or under Federal Specification.

88 P. 08

WAH CIANG QUALITY INSPECTION REPORT

SUPPLEMENT TO SEC 1283681

PAGE 2 OF 3

DISC NUMBER	.025" $\pm .0025"$	.025" $\pm .0025"$	.025" $\pm .0025"$
Ta2W-1	.02450	.02470	.02460
Ta2W-2	.02410	.02440	.02450
Ta2W-3	.02320	.02350	.02360
Ta2W-4	.02400	.02455	.02370
Ta2W-5	.02380	.02395	.02390
Ta2W-6	.02380	.02340	.02350
Ta2W-7	.02345	.02340	.02365
Ta2W-8	.02360	.02385	.02400
Ta2W-9	.02410	.02470	.02495
Ta2W-10			
Ta2W-11			
Ta2W-12			
Ta2W-13			
Ta2W-14			
Ta2W-15			
Ta2W-16			
Ta2W-17			
Ta2W-18			
Ta2W-19			

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PC 143 10-16

WAH CHANG QUALITY INSPECTION REPORT

INSPECTOR ROEMER, STEVE SIGNATURE [Signature] DATE 1-26-05
 S/O 124912 ITEM 1 P.O. KN600216 DWG# SK-MCP2174 REV. B
 HEAT NO. 10-20-2 ALLOY Ta2W SFC 12-83691
 DISC NO. Ta2W-1-Ta2W-4 ROOM TEMPERATURE 66°-69.5° DISC TEMPERATURE 66°-68°
 EQUIPMENT NO. WC 6-12-3A, 425F, WC 2-307(TEN) WC 2-270 INSPECTED PER WI-Q1-1

DISC NUMBER	+0.005" ±1.0" O.D.	N/A I.D.	+0.025" ±.025" LENGTH	6% FLATNESS	SURFACE PER QUALITY PLAN
Ta2W-1					
Ta2W-2					
Ta2W-3					
Ta2W-4					
Ta2W-5					
Ta2W-6					
Ta2W-7					
Ta2W-8					
Ta2W-9					
Ta2W-10	20.9995		.02560 - .02605	OK	OK
Ta2W-11	21.0025		.02610 - .02615	OK	OK
Ta2W-12	21.0035		.02595 - .02610	OK	OK
Ta2W-13	21.0000		.02630 - .02675	OK	OK
Ta2W-14	20.9995		.02630 - .02700	OK	OK
Ta2W-15	20.9985		.02575 - .02610	OK	OK
Ta2W-16	21.0010		.02610 - .02730	OK	OK
Ta2W-17					
Ta2W-18					
Ta2W-19					

NOTE: The recording of data, location, or description of defects or anomalies on this document may be punishable as a felony under Federal Statute.

TOTAL P.05

WAH CHANG	QUALITY INSPECTION REPORT
SUPPLEMENT TO SRC <u>1283691</u>	
PAGE <u>2</u> OF <u>3</u>	

541 917 6797 P.05

DISC NUMBER	.025" + .0025"	.025" + .0025"	.025" + .0025"
Ta2W-1			
Ta2W-2			
Ta2W-3			
Ta2W-4			
Ta2W-5			
Ta2W-6			
Ta2W-7			
Ta2W-8			
Ta2W-9			
Ta2W-10	.02550	.02560	.02600
Ta2W-11	.02550	.02610	.02670
Ta2W-12	.02570	.02590	.02630
Ta2W-13	.02540	.02610	.02680
Ta2W-14	.02570	.02660	.02680
Ta2W-15	.02560	.02570	.02570
Ta2W-16	.02610	.02540	.02560
Ta2W-17			
Ta2W-18			
Ta2W-19			

0267-14M CHANG

08:27 08-02-2005

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101817-40

WAH CHANG QUALITY INSPECTION REPORT

INSPECTOR STEVE ROEMER SIGNATURE [Signature] DATE 1-27-05
 S/O 124912 ITEM 1 P.O. KN6000216 DWG# SK-MGP2174 REV. B
 HEAT NO. 1179-2 ALLOY Ta25W SFC 1283692
Ta2W17-Ta2W40
 DISC NO. Ta2W17-Ta2W40 ROOM TEMPERATURE 63.6°-68° DISC TEMPERATURE 64°-68°
3A-12-25
 EQUIPMENT NO. WC-2270, 42-SP (BMA) WC1992, PHOTOMETRICS INSPECTED PER WI-QI-1

DISC NUMBER	+ .005" 21.0" O.D.	N/A I.D.	+ .0025" .025" LENGTH	6% FLATNESS	SURFACE PER QUALITY PLAN
Ta2W-1					
Ta2W-2					
Ta2W-3					
Ta2W-4					
Ta2W-5					
Ta2W-6					
Ta2W-7					
Ta2W-8					
Ta2W-9					
Ta2W-10					
Ta2W-11					
Ta2W-12					
Ta2W-13					
Ta2W-14					
Ta2W-15					
Ta2W-16					
Ta2W-17	<u>21.0045</u>			<u>OK</u>	<u>OK</u>
Ta2W-18	<u>21.0025</u>			<u>OK</u>	<u>OK</u>
Ta2W-19	<u>20.9970</u>			<u>OK</u>	<u>OK</u>

NOTE: The recording of data, drawings, or documents shall be performed in accordance with the requirements of the applicable standards.

WAH CHANG QUALITY INSPECTION REPORT

SUPPLEMENT TO SPC

1283692

PAGE 3 OF 4

DISC NUMBER	.025" + .0025"	.025" + .0025"	.025" + .0025"
Ta2W-1			
Ta2W-2			
Ta2W-3			
Ta2W-4			
Ta2W-5			
Ta2W-6			
Ta2W-7			
Ta2W-8			
Ta2W-9			
Ta2W-10			
Ta2W-11			
Ta2W-12			
Ta2W-13			
Ta2W-14			
Ta2W-15			
Ta2W-16	.02460	.02370	.02475
Ta2W-17	.02460	.02560	.02490
Ta2W-18	.02470	.02460	.02470
Ta2W-19	.02400		

"NOTE: The recording of false, fictitious, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute."

"NOTE: The recording of false, fictitious, or fraudulent statements or entries on this document may be punishable as a felony under Federal Statute."

To: KNOLLS ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210510 ver. 2 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 15, 2005
 Quantity: 9 pcs.
 Weight: 46.8 lbs.
 Heat No.: 11-19-2
 SFC No.: 1283681
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6	7	8
W	2.0% NOMINAL	DCP	2.10	1.94	1.98	1.84	2.02	1.98	1.93	2.10
Ta		BALANCE								

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6	7	8
C	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	0.003	0.003	0.003	<0.0020
Fe	0.010	DCP	<0.0050							<0.0050
H	0.0015	LECO	<0.0003							<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Nb	0.50	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.02	0.02	0.006
Ni	0.010	DCP	<0.0050							<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050							<0.0050

Certified By: R Louie, QA Supervisor Iss 02/15/05

Wah Chang Is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 11-19-2
SFC No.: 1283681

Doc. 210510 ver. 2 APPROVED, Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.84	1.77	1.79 1.90
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

"Knowingly or willfully recording of false, fictitious or fraudulent statements or entries on this document may be punished as a felony under Federal Statutes including Federal Law, Title 18, Chapter 47."

To: KNOLLS ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210504 ver. 2 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 15, 2005
 Quantity: 7 pcs.
 Weight: 38.5 lbs.
 Heat No.: 10-20-2
 SFC No.: 1283691
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6
W	2.0% NOMINAL	DCP	2.21	2.20	2.24	2.01	2.40	2.09
Ta	BALANCE							

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6
C	0.010	LECO	<0.0020	<0.0020	<0.0020	0.003	0.003	0.002
Fe	0.010	DCP	<0.0050					0.007
H	0.0015	LECO	<0.0003					<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Nb	0.50	DCP	<0.0050	0.01	0.01	0.01	0.02	0.01
Ni	0.010	DCP	0.03*					<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050					<0.0050

*Acceptable result per paragraph 3.1.1.1 of Workscope.

Certified By: R Louie, QA Supervisor 02/15/05

Wah Chang Is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 10-20-2
SFC No.: 1283691

Doc. 210504 ver. 2 APPROVED, Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.75	1.89	2.16 2.10
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

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To: KNOX ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210557 ver. 3 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 16, 2005
 Quantity: 24 pcs.
 Weight: 124.8 lbs.
 Heat No.: 11-19-2
 SFC No.: 1283692
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6	7	8
W	2.0% NOMINAL	DCP	2.10	1.94	1.98	1.84	2.02	1.98	1.93	2.10
Ta		BALANCE								

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6	7	8
C	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	0.003	0.003	0.003	<0.0020
Fe	0.010	DCP	<0.0050							<0.0050
H	0.0015	LECO	<0.0003							<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Nb	0.50	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.02	0.02	0.006
Ni	0.010	DCP	<0.0050							<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050							<0.0050

Certified By: R. Louie, QA Supervisor Feb 02/16/05

Wah Chang Is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 11-19-2
SFC No.: 1283692

Doc. 210557 ver. 3 APPROVED, Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.84	1.77	1.79 1.90
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

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To: KNOLLS ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210477 ver. 2 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 15, 2005
 Quantity: 10 pcs.
 Weight: 52 lbs.
 Heat No.: 10-20-2
 SFC No.: 1283896
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6
W	2.0% NOMINAL	DCP	2.21	2.20	2.24	2.01	2.40	2.09
Ta		BALANCE						

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6
C	0.010	LECO	<0.0020	<0.0020	<0.0020	0.003	0.003	0.002
Fe	0.010	DCP	<0.0050					0.007
H	0.0015	LECO	<0.0003					<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Nb	0.50	DCP	<0.0050	0.01	0.01	0.01	0.02	0.01
Ni	0.010	DCP	0.03*					<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050					<0.0050

*Acceptable result per paragraph 3.1.1.1 of Worksopce.

Certified By: R Louie, QA Supervisor 02/15/05

Wah Chang Is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 10-20-2
SFC No.: 1283696

Doc. 210477 ver. 2 APPROVED. Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.75	1.89	2.16 2.10
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

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To: KNOX ATOMIC POWER LAB
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 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210544 ver. 3 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 16, 2005
 Quantity: 30 pcs.
 Weight: 155 lbs.
 Heat No.: 11-19-2
 SFC No.: 1283700
 Mett Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6	7	8
W	2.0% NOMINAL	DCP	2.10	1.94	1.98	1.84	2.02	1.98	1.93	2.10
Ta	BALANCE									

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6	7	8
C	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	0.003	0.003	0.003	<0.0020
Fe	0.010	DCP	<0.0050							<0.0050
H	0.0015	LECO	<0.0003							<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Nb	0.50	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.02	0.02	0.006
Ni	0.010	DCP	<0.0050							<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050							<0.0050

Certified By: R Louie, QA Supervisor 02/16/05

Wah Chang is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 11-19-2
SFC No.: 1283700

Doc. 210544 ver. 3 APPROVED, Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.84	1.77	1.79 1.90
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

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To: KNOLLS ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210505 ver. 2 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 15, 2005
 Quantity: 2 pcs.
 Weight: 10.1 lbs.
 Heat No.: 10-20-2
 SFC No.: 1286781
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6
W	2.0% NOMINAL	DCP	2.21	2.20	2.24	2.01	2.40	2.09
Ta	BALANCE							

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6
C	0.010	LECO	<0.0020	<0.0020	<0.0020	0.003	0.003	0.002
Fe	0.010	DCP	<0.0050					0.007
H	0.0015	LECO	<0.0003					<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Nb	0.50	DCP	<0.0050	0.01	0.01	0.01	0.02	0.01
Ni	0.010	DCP	0.03*					<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050					<0.0050

*Acceptable result per paragraph 3.1.1.1 of Workscope.

Certified By: R Louie, QA Supervisor 02/15/05

Wah Chang is A Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 10-20-2
SFC No.: 1265761

Doc. 210505 ver. 2 APPROVED. Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.75	1.69	2.16 2.10
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

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To: KNOLLS ATOMIC POWER LAB
 Address: PO Box 1072
 Schenectady, NY 12301
 Attention Of: Accounts Payable

Doc. 210503 ver. 2 APPROVED, Page 1 of 2

PRODUCT CERTIFICATION

IN REGARD TO YOUR

Purchase Order No.: KN6000216
 Sales Order No.: 124912
 Item No.: 1
 Description: Ta2.5W Disc
 Dimensions: 21" Dia. x 0.025" L
 Specifications: SK-MGP2174 Rev. B (Gr R05252), and P.O.
 Date: February 15, 2005
 Quantity: 2 pcs.
 Weight: 10.6 lbs.
 Heat No.: 10-20-2
 SFC No.: 1286782
 Melt Source: ULBA METALLURGICAL PLANT

INGOT CHEMISTRY IN PERCENT

Element	Alpha Spec.	Method	1	2	3	4	5	6
W	2.0% NOMINAL	DCP	2.21	2.20	2.24	2.01	2.40	2.09
Ta			BALANCE					

INGOT IMPURITIES IN PERCENT

Element	Spec. Max.	Method	1	2	3	4	5	6
C	0.010	LECO	<0.0020	<0.0020	<0.0020	0.003	0.003	0.002
Fe	0.010	DCP	<0.0050					0.007
H	0.0015	LECO	<0.0003					<0.0003
Mo	0.020	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
N	0.010	LECO	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.002
Nb	0.50	DCP	<0.0050	0.01	0.01	0.01	0.02	0.01
Ni	0.010	DCP	0.03*					<0.0050
O	0.015	LECO	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Si	0.005	DCP	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Ti	0.010	DCP	<0.0050					<0.0050

*Acceptable result per paragraph 3.1.1.1 of Workscope.

Certified By: R. Louise, QA Supervisor 02/15/05

Wah Chang is a Registered / Certified ISO 9001:2000 Company.

B-TM-1639

Purchase Order No.: KN6000216
Sales Order No.: 124912
Item No.: 1
Heat No.: 10-20-2
SFC No.: 1285782

Doc. 210503 ver. 2 APPROVED, Page 2 of 2

PRODUCT CHEMISTRY IN PERCENT

Element	Alpha Spec	Top	Top Middle	Bottom
W	2.0% NOMINAL	1.75	1.89	2.16 2.10
Ta	BALANCE			

PRODUCT IMPURITIES IN PERCENT

Element	Spec. Max.	Top
C	0.010	0.003
Fe	0.010	<0.0050
H	0.0015	<0.0003
Mo	0.020	<0.0050
N	0.010	<0.0020
Nb	0.50	0.02
Ni	0.010	<0.0050
O	0.015	<0.0050
Si	0.005	<0.0050
Ti	0.010	<0.0050

METALLOGRAPHY TEST (FOR INFO ONLY)

Test	Units	Results
Recrystallization:	%	100

MERCURY FREE STATEMENT

Wah Chang certifies that the product associated with this certification did not come in direct contact with mercury or any of its compounds during manufacturing, testing, inspection, and packaging.

"Knowingly or willfully recording of false, fictitious or fraudulent statements or entries on this document may be punished as a felony under Federal Statutes including Federal Law, Title 18, Chapter 47."

Appendix I

0.1" Thick Graphite Plate Inspection Reports

B-TM-1639

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2-Feb-05

CERTIFICATE OF QUALITY CONFORMITY

SalesOrder: B0004 A 1

ShipTo: LOS ALAMOS NATIONAL LABORATORY CustomerPO: 3004768
 DROP POINT BLDG. 28 01S ShipDate: 2/2/2005
 LOS ALAMOS NM 875440000
 Size: 21.000 X 00.000 X 000.100 Qty: 25 Ross Luther

This is to certify that the material shipped on the above numbered order
is UCAR graphite grade PGX

BD: Bulk density (G/CC)

SR: Specific Resistance (Micro-OHM-Meters)

FO	BD	SR	Furnace	Run
TRS17H4001	1.732	11.172	55	274

FO	Thickness	Width	Length
TRS17H4001	38.870	0	78.268

CC: W/Shipment

Kathy Amodio, ATG Group

~~CONFIDENTIAL~~
 UCAR Carbon Co., Inc. PO Box 2170, Clarksburg, WV 26302
 Tel. 304-624-7651 Fax 304-624-1269

B-TM-1639

2-Feb-05

CERTIFICATE OF QUALITY CONFORMITY

SalesOrder: B0004 A 2

ShipTo: LOS ALAMOS NATIONAL LABORATORY

CustomerPO: 3004768

DROP POINT BLDG. 28 01S

ShipDate: 2/2/2005

LOS ALAMOS

NM 875440000

Size: 21.000 X 02.510 X 000.100

Qty: 25

Ross Luther

This is to certify that the material shipped on the above numbered order
is UCAR graphite grade PGX

BD: Bulk density (G/CC)

SR: Specific Resistance (Micro-OHM-Meters)

FO	BD	SR	Furnace	Run
TRS17H4001	1.732	11.172	55	274

FO	Thickness	Width	Length
TRS17H4001	38.870	0	78.268

CC: W/Shipment

Kathy Amodio, ATG Group

~~THIS DOCUMENT IS UNCLASSIFIED~~

UCAR Carbon Co., Inc, PO Box 2170, Clarksburg, WV 26302
Tel. 304-624-7651 Fax 304-624-1289

Appendix J
Polyethylene Plate Inspection Reports

B-TM-1639

(Intentionally Blank)

plastic
supply inc.

3448 Grand NE
Albuquerque, NM 87107
505-884-0637
FAX 505-884-0525

CERTIFICATE OF CONFORMITY

Customer Name STANDARD MACH

Address 7933 Ranchitos Loop N.E

Customer P.O.# 15867

Material HD Poly

Specifications HDPE POLYETHYLENE NATURAL SHEET

Manufacturer Poly-Hi

Description 1 1/2 THICK - 3/4 THICK - 1/8 THICK

15376/15379, 15377/15380, 15378/15381

Supplied on Invoice # 106188

Date 8-17-05

Signed

Plastic Supply Inc.

Aret

Form # SMC1012

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH: (505) 890-1124
 Fax (505) 890-1126
 e-mail kba11@stdmachine.com

INSPECTION REPORT

Page 1 of 1

CUSTOMER Knolls Atomic Power B/P or Part: Rev.
 Part Name: 1" HD Poly W/Hole Lot # Lot Qty: 2
 JOB # 15376 P.O.# 6003191 MIL SPEC
 Date 9/22/05 INSPECTOR: John Adams 105 X Level JL 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	Ø 21.00	± .010	Calipers	21.00		
2	Ø 2.510	± .005	Calipers	2.51		
3	1.00	± .010	Calipers	1.00		
				FIRST	SMC A-1	FINAL
						SMC A-1

Form # SMC1012

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH: (505) 890-1124
 FAX (505) 890-1126
 e-mail kball@stdmachine.com

INSPECTION REPORT

Page 1 of 1

CUSTOMER: Knolls Atomic Power B/P or Part: Rev.
 Part Name: .50" HD Poly W/Hole Lot # Lot Qty. 2
 JOB # 15377 P.O.# 6003191 MIL SPEC
 Date 9/22/05 INSPECTOR: John Adams 105 X Level II 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	Ø 21.00	± .010	Calipers	21.00		
2	Ø 2.510	± .005	Calipers	2.51		
3	.50	± .010	Calipers	.50		
				FIRST	FINAL

Form # SMC1012

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH: (505) 890-1124
 Fax (505) 890-1126
 e-mail kball@stdmachine.com

INSPECTION REPORT

Page 1 of 1

CUSTOMER: Knolls Atomic Power B/P or Part Rev.
 Part Name: .08" HD Poly W/Hole Lot # Lot Qty. 15
 JOB # 15378 P.O# 6003191 MIL SPEC
 Date 9/22/05 INSPECTOR John Adams 105 X Level II 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	Ø 21.00	± .010	Calipers	21.008	21.008	21.00
2	Ø 2.510	± .005	Calipers	2.510	2.51	
3	.08	± .005	Calipers	.08	.08	
				FIRST	SMC A-1	FINAL
						SMC A-1

Form # **SMC1012**

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH: (505) 890-1124
 Fax (505) 890-1126
 e-mail kball@stdmachine.com

INSPECTION REPORTPage 1 of 1

CUSTOMER: **Knolls Atomic Power** B/P or Part: Rev.
 Part Name: **1" HD Poly** Lot # Lot Qty **2**
 JOB # **15379** P.O.# **6003191** MIL SPEC
 Date **9 / 22 / 05** INSPECTOR: **John Adams** 105 ☒ Level **II** 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	Ø 21.00	± .010	Calipers	21.00		
2	1.00	± .010	Calipers	1.00		
				FIRST	SMC A-1	FINAL
					SMC A-1

Form # SMC1012

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH: (505) 890-1124
 Fax (505) 890-1126
 e-mail kball@stdmachine.com

INSPECTION REPORT

Page 1 of 1

CUSTOMER: Knolls Atomic Power C/P or Part: Rev.
 Part Name: .50" HD Poly Lot # Lot Qty. 2
 JOB # 15380 P.O. # 6003191 MIL SPEC
 Date 9/22/05 INSPECTOR: John Adams 105 X Level II 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	21.00	± .010	Calipers	21.0	21.00	
2	.50	± .010	Calipers	.50	.50	
FIRST				SMC A-1	FINAL	SMC A-1

Form # SMC1012

7933 Ranchitos Loop NE
 Albuquerque, NM 87113
 PH. (505) 890-1124
 Fax (505) 890-1126
 e-mail kball@stdmachine.com

INSPECTION REPORT

Page 1 of 1
 CUSTOMER: Knolls Atomic Power B/P or Part: Rev.

 Part Name: .08" HD Poly Lot # Lot Qty: 20

 JOB # 15381 P.O# 6003191 MIL SPEC

 Date 9/22/05 INSPECTOR John Adams 105 X Level II 414

NO.	B/P DIMENSION	TOL	METHOD OF INSPECTION	FIRST ARTICLE	HIGH READING	LOW READING
1	Ø 21.00	± .010	Calipers	2.00	21.00	
2	.08	± .005	Calipers	.08	.08	
				FIRST	SMC A-1	FINAL SMC A-1

B-TM-1639

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