

BECHTEL BETTIS, INC.
WEST MIFFLIN, PENNSYLVANIA
MATERIALS TECHNOLOGY



- Title:** Closeout of JOYO-1 Specimen Fabrication Efforts
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- Date:** October 31, 2005
- Background:** Prior to the cancellation of the space program, efforts were in progress to fabricate large numbers of refractory metal alloy specimens for the testing of material properties. This included the fabrication of over 350 refractory metal alloy specimens for the JOYO-1 irradiation test in Japan, as well as a smaller number of specimens intended to serve as unirradiated controls. Specimen types included biaxial creep, tensile, compact tension, fracture toughness, and density specimens. The major refractory metal alloys in these test campaigns were FS-85 (Nb-11%W-27.5%Ta- 0.85%Zr), ASTAR-811C (Ta-8%W-1%Re-0.7%Hf-0.025%C), and Mo-47.5Re. Fabrication of T-111 (Ta-8%W-2%Hf) and Ta-10W was also underway to provide back-up materials.
- Summary:** Fabrication was well under way for the JOYO biaxial creep and tensile specimens when the NR Space program was cancelled. Tubes of FS-85, ASTAR-811C, and T-111 for biaxial creep specimens had been drawn at True Tube (Paso Robles, CA), while tubes of Mo-47.5Re were being drawn at Rhenium Alloys (Cleveland, OH). The Mo-47.5Re tubes are now approximately 95% complete. Their fabrication and the quantities produced will be documented at a later date. End cap material for FS-85, ASTAR-811C, and T-111 had been swaged at Pittsburgh Materials Technology, Inc. (PMTI)(Large, PA) and machined at Vangura (Clairton, PA). Cutting of tubes, pickling, annealing, and laser engraving were in process at PMTI. Several biaxial creep specimen sets of FS-85, ASTAR-811C, and T-111 had already been sent to Pacific Northwest National Laboratory (PNNL) for weld development. In addition, tensile specimens of FS-85, ASTAR-811C, T-111, and Mo-47.5Re had been machined at Kin-Tech (North Huntingdon, PA). Actual machining of the other specimen types had not been initiated.
- Flowcharts 1-3 detail the major processing steps each piece of material has experienced. A more detailed description of processing will be provided in a separate document [B-MT(SRME)-51]. Table 1 lists the in-process materials and finished specimens. Also included are current metallurgical condition of these materials and specimens. The available chemical analyses for these alloys at various points in the process are provided in Table 2.
- Future Work:** These alloys are currently located at Bettis and PMTI. However, in the immediate future these materials will be consolidated and placed in the formal Bettis storage system pending final resolution of their ownership.
- Significance to the NR Program:** The samples that resulted from these fabrication efforts were to be used in several test programs to evaluate the unirradiated and irradiated properties of refractory metal alloys. These specimens may assist future space programs that may be considering refractory metal alloys for their materials systems.

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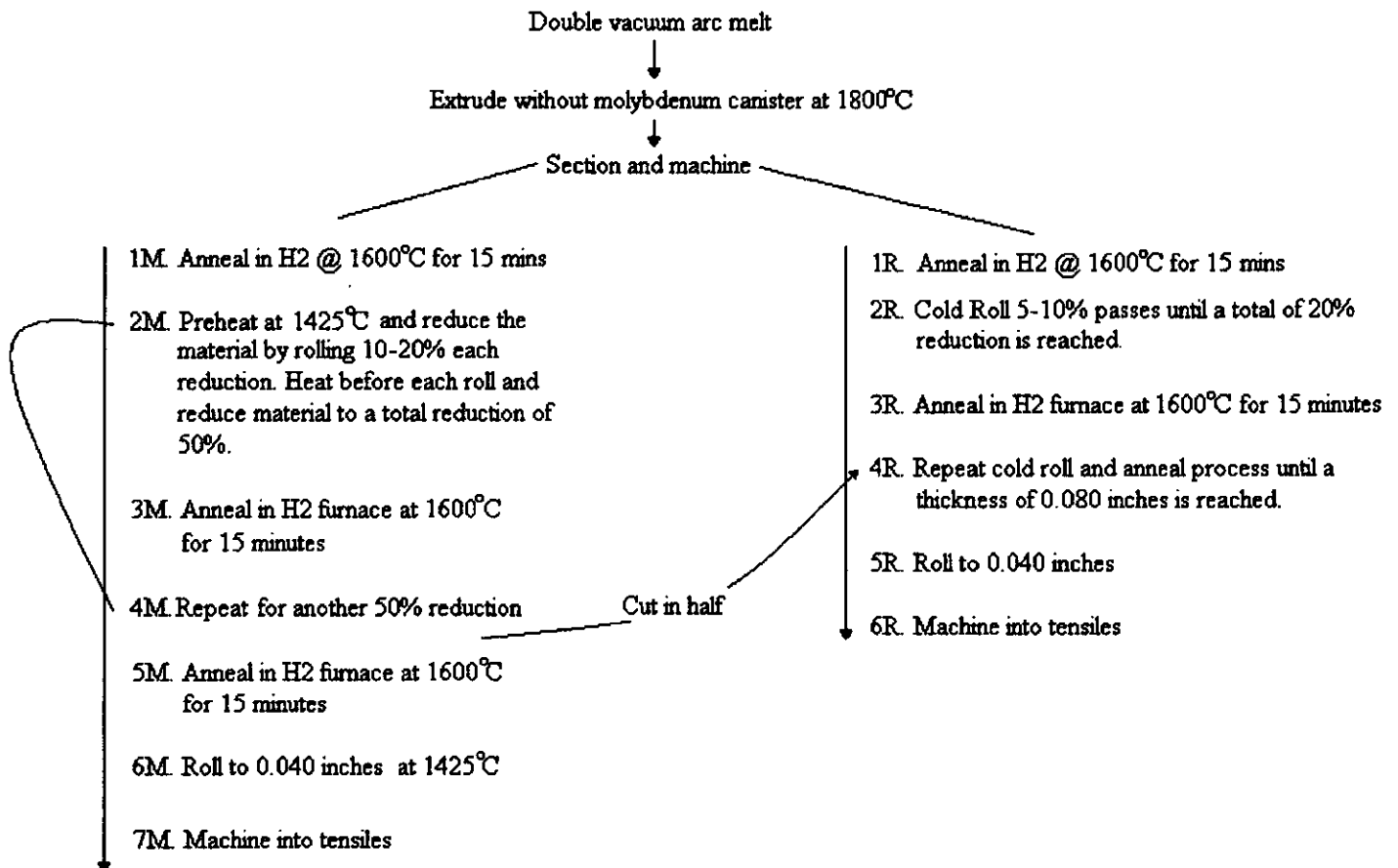
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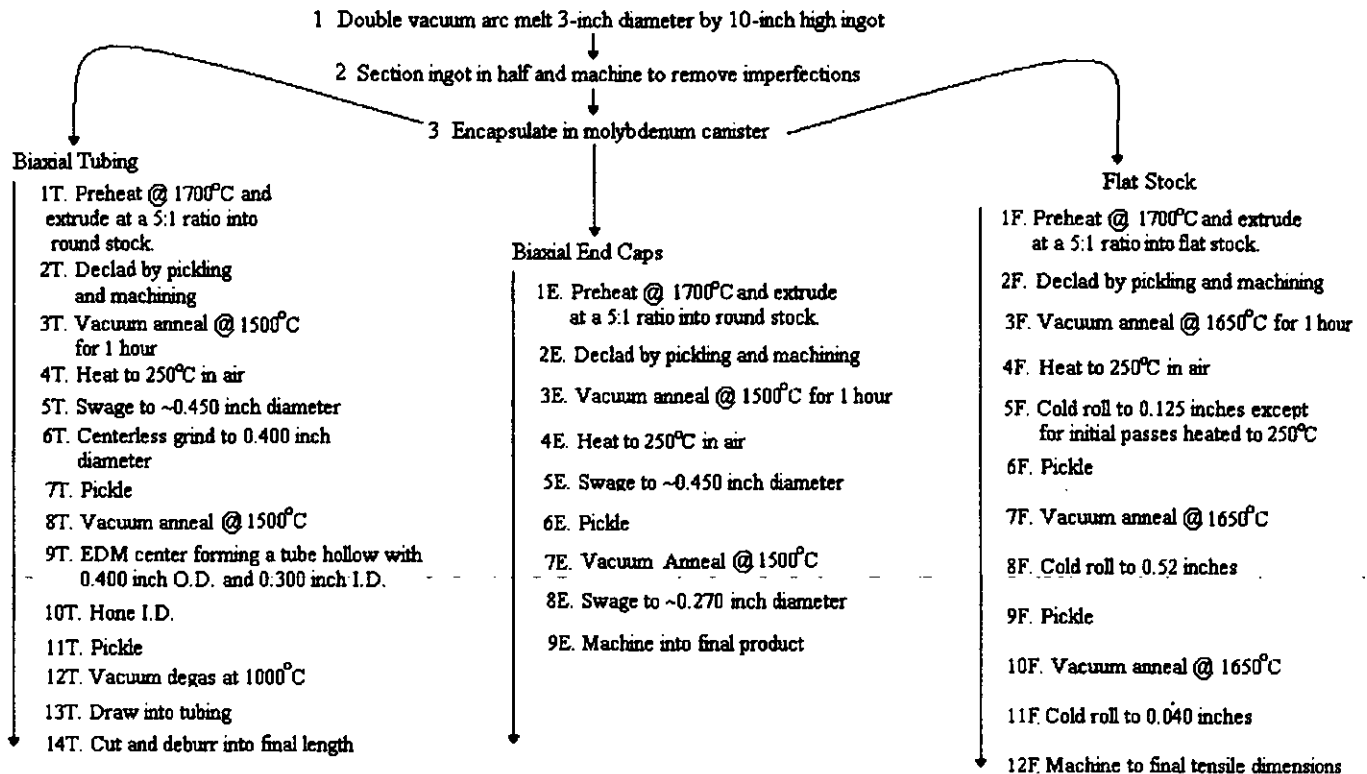
Flow Chart 1. Processing of MoRe Alloy

Processing of Mo-47.5Re Flat Stock



Flow Chart 2. Processing of Tantalum Alloys

Processing of T-111 and ASTAR-811C



Flow Chart 3. Processing of Niobium Alloy Processing of FS-85

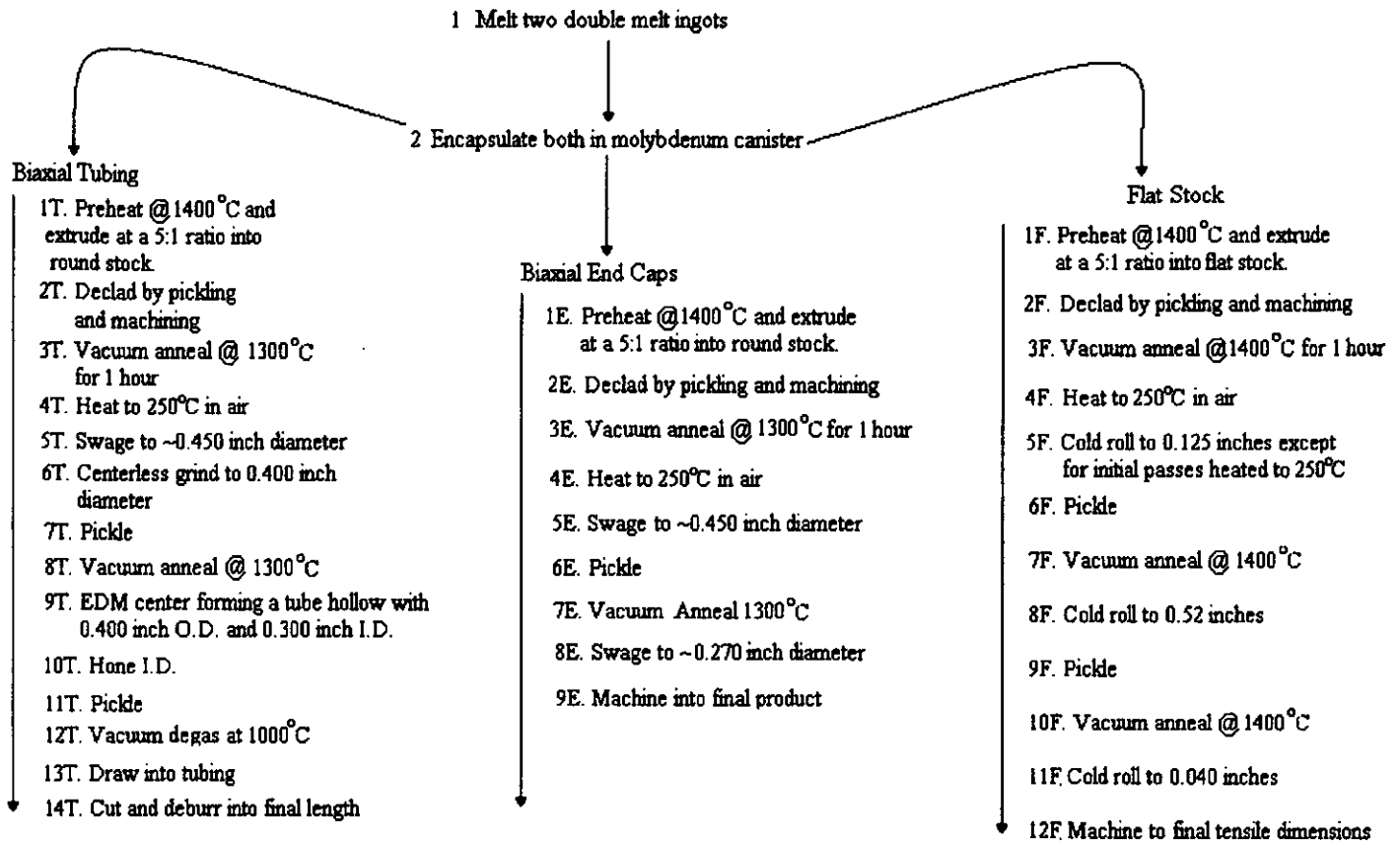


Table 1. Inventory of Materials

Material	ID	Location	Application	Last Processing Step & corresponding location in Flowcharts 1-3	Description
ASTAR-811C	X0410LR	PMTI	Biaxial creep sample tubes	Swaged	Diameter: 0.4635 in
				5T	Length: 9 5/8 in
					Rod
T-111	X0410MI	PMTI	Biaxial creep sample end caps	Swaged	Diameter: 0.2675 in
				8E	Length: 8 in
					Rod
T-111	X0410MI	PMTI	Biaxial creep sample end caps	Swaged	Diameter: 0.2655 in
				8E	Length: 3.75 in
					Rod
ASTAR-811C	X0410LR	PMTI	Biaxial creep sample end caps	Swaged	Diameter: 0.2825 in
				8E	Length: 18 in
					Rod
ASTAR-811C	X0410LR	PMTI	Biaxial creep sample end caps	Swaged	Diameter: 0.2825 in
				8E	Length: 8.25 in
					Rod
T-111	X0465	PMTI	Biaxial creep samples	Extruded	Diameter: 1.17 in
				2T	Length: 5.3 in
					Extruded Round Bar
ASTAR-811C	14077	PMTI	Biaxial creep samples	Extruded	Diameter: 1.15 in
				2T	Length: 4.63 in
					Extruded Round Bar
ASTAR-811C	X0465	PMTI	Melt sample for metallography	Melted	Diameter: 2.45 in
				1	Length: 0.1880 in
					Melt sample
ASTAR-811C	X0465	PMTI	Melt sample for metallography	Melted	Diameter: 2.45 in
				1	Length: 0.1880 in
					Melt sample
FS-85	X0563	PMTI	Tensile Samples	Rolled	Length: 7.5 in
				11F	Thickness: 0.040 in
FS-85	X0563	PMTI	Tensile Samples	Rolled	Length: 18 in

Material	ID	Location	Application	Last Processing Step & corresponding location in Flowcharts 1-3	Description
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 18 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 7.75 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 7.75 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 6 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 7.5 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 6.5 in
FS-85	X0563	PMTI	Tensile Samples	11F	Thickness: 0.040 in
	X0563	PMTI	Tensile Samples	Rolled	Length: 8.25 in
FS-85	X0410MJ	PMTI	Biaxial creep samples end caps	11F	Thickness: 0.040 in
	X0410MJ	PMTI	Biaxial creep samples end caps	Swaged	Diameter: 0.27 in
FS-85	X0410MJ	PMTI	Biaxial creep samples end caps	8E	Length: 11.25 in
	X0410MJ	PMTI	Biaxial creep samples end caps	Swaged	Diameter: 0.27 in
FS-85	X0410MJ	PMTI	Biaxial creep samples	8E	Length: 10 in
	X0410MJ	PMTI	Biaxial creep samples	Swaged	Diameter: 0.45 in
Ta-10W	X0410MJ	PMTI	Biaxial creep samples	5T	Length: 33 in
	X0410MJ	PMTI	Biaxial creep samples	Swaged	Diameter: 0.50 in
Ta-10W	X0410MJ	PMTI	Biaxial creep samples	5T	Length: 10.25 in
	X0410MJ	PMTI	Biaxial creep samples	Swaged	Diameter: 0.50 in
Ta-10W	X0410MJ	PMTI	Biaxial creep samples	5T	Length: 34 in
	X0410MJ	PMTI	Biaxial creep samples	Swaged	Diameter: 0.50 in
Ta-10W	CVAM 1679	PMTI	Biaxial creep samples	5T	Length: 34 in
	CVAM 1679	PMTI	Biaxial creep samples	Extrusion	Diameter: 1.18 in
				2T	Length: 10 in

Material	ID	Location	Application	Last Processing Step & corresponding location in Flowcharts 1-3	Description
Ta-10W	CVAM 1679	PMTI	Biaxial creep samples	Extrusion	Diameter: 1.18 in
				2T	Length: 3.5 in
T-111	N/A	Bettis	Biaxial creep specimen end caps	Machined to final dimensions	Diameter: 0.25 in
				11E	34 Top End Caps
					34 Bottom End Caps
FS-85	N/A	Bettis	Biaxial creep specimen end caps	Machined to final dimensions	Diameter: 0.25 in
				11E	70 Top End Caps
					70 Bottom End Caps
ASTAR-811C	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 1.25 in
					42 tubes
T-111	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 1.25 in
					54 tubes
FS-85	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 1.25 in
					46 tubes
T-111	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 26 in
T-111	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 27.5 in
ASTAR	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 12 in
ASTAR	N/A	PMTI	Biaxial creep specimen tubes	Tube Drawing	OD: 0.25 in, ID: 0.225 in
				13T	Length: 27 in
Ta-10W	X0410MJ	PMTI	Tensile Samples	Extruded	Thickness: 1.12 in
				1F	Length: 28 in
T-111	T-111-75	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in
				12F	Length: 1 in

Material	ID	Location	Application	Last Processing Step & corresponding location in Flowcharts 1-3	Description
Mo-47Re	T-111-30	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 30 pieces
	MoRe-C	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 70 pieces
Mo-47Re	MoRe-H	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 40 pieces
	MoRe-C	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 40 pieces
Mo-47Re	MoRe-H	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
	MoRe-H	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
FS-85	FS-85-30	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
	FS-85-75	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
ASTAR-811C	ASTAR-811C-30	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
	ASTAR-811C-75	Bettis	Tensile Samples	Machined to final dimensions	Thickness: 0.040 in Length: 1 in 6 pieces
Mo-47Re	TBD	Re. Alloys	Biaxial Creep Samples	TBD	TBD 6 pieces

Table 2. Major Alloying Ingredients and Interstitials for the Inventoried Refractory Alloys at Various Processing Steps

<i>Alloy</i>	<i>Ingot I.D.</i>	<i>Form</i>	<i>Ta w/o</i>	<i>Nb w/o</i>	<i>Mo w/o</i>	<i>W w/o</i>	<i>Hf w/o</i>	<i>Zr w/o</i>	<i>Re w/o</i>	<i>C w/o or ppm</i>	<i>N w/o or ppm</i>	<i>O w/o or ppm</i>
T-111 Target	N/A	N/A	90	-	-	8	2	-	-	0.01 max	0.005 max	0.010 max
	CVAM 1600	Ingot	90.4, 89.8	-	-	7.63, 8.16	1.87, 1.98	-	-	<0.005, <0.005	0.002, 0.0015	0.0026, 0.013
T-111	CVAM 1600	Extruded Round	90.1, 90.3	-	-	7.88, 7.75	1.87, 1.87	-	-	<0.005, 0.005	0.002, 0.0017	0.0018, 0.0015
ASTAR 811C Target	N/A		90.15	-	-	8	0.85	-	1	0.025	0.005 max	0.010 max
ASTAR 811C	CVAM 1601	Ingot	89.5, 89.7	-	-	8.19, 8.09	0.96, 0.89	-	1.33, 1.29	0.0096, 0.02	0.0021, 0.0023	0.014, 0.0032
ASTAR 811C	CVAM 1601	Extruded Round	90.6, 90.5	-	-	7.42, 7.44	0.80, 0.81	-	1.15, 1.16	0.030, 0.029	0.0036, 0.0038	<0.001, 0.0012
ASTAR 811C	CVAM 1601	0.040-inch plate	90.1	-	-	7.95	0.80	-	1.09	0.0240	<10ppm	3 ppm
ASTAR 811C	CVAM 1601	0.040-inch plate	90.2	-	-	8.00	0.83	-	0.88	0.022	<10 ppm	6 ppm
Ta-10W Target	-	-	90	-	-	10	-	-	-	0.008	0.005	0.010
Ta-10W	CVAM 1619	0.475-inch diameter rod	89.95			10.15				14 ppm	12 ppm	24 ppm
FS-85 Target	N/A	N/A	27.5	60.65	-	11	-	0.85	-	0.010	0.010	0.015
FS-85	CVAM 1602	Extruded Round	27.26, 28.23	60.7, 59.8	-	11.01, 11.00	-	0.9, 0.85	-	0.021, <0.005	0.0046, 0.005	0.0030, 0.0036

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Alloy	Ingot I.D.	Form	Ta w/o	Nb w/o	Mo w/o	W w/o	Hf w/o	Zr w/o	Re w/o	C w/o or ppm	N w/o or ppm	O w/o or ppm
FS-85	CVAM 1602	In-process tubing	27.66	60.5	-	10.99	-	0.82	-	26ppm	<10ppm	1ppm
FS-85	CVAM 1602	Final tubing	27.79	60.2	-	11.12	-	0.82	-	68ppm	<0.10 ppm	4 ppm
FS-85	CVAM 1603	Extruded Flat	27.20, 27.33	61.4, 60.3	-	10.56, 11.46	-	0.83, 0.90	-	<0.005, 0.005	0.0047, 0.0034	0.0014, 0.0018
FS-85	CVAM 1603	0.040-inch								15.7ppm, 18.9ppm	15.4ppm, 12.8ppm	65.6ppm, 71.8ppm
Moly-Rhenium Target												
Mo-Rhenium	CVAM 1613	0.040-inch hot rolled	-	-	52.5	-	-	-	47.5	50ppm	-	<20ppm
Mo-Rhenium	CVAM 1613	0.040-inch cold rolled							46.68	42.1ppm	4.2ppm	48.5ppm
Mo-Rhenium	CVAM 1613	0.040-inch cold rolled							46.17	38.2ppm	4.3ppm	52.2ppm
Mo-Rhenium	CVAM 1613	Round Extrusion							46.67, 46.36	0.002, 0.011	0.001, 0.001	0.048, 0.017
Mo-Rhenium	CVAM 1613	0.275-inch dia. rod								48.3 ppm	3.2 ppm	38.9 ppm

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