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Progress Report

Milliwatt Generator Project

April — September 1980

MASTER

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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ABSTRACT

This formal biannual report covers the effort related to the Milliwatt Generator Project (MWG) carried out for the Department of Energy, Office of Military Applications, by the Los Alamos Scientific Laboratory (LASL).

Most of the studies discussed here are of a continuing nature. Results and conclusions may change as the work continues. Published reference to the results cited in this report should not be made without the explicit permission of the person in charge of the work.

I. SCHEDULE

A. General

The main tasks to be accomplished prior to the initiation of WR production work at LASL are shown in Fig. I-1. This schedule has been agreed to in a series of meetings between LASL personnel and representatives from DOE/ALO, Sandia National Laboratory, Albuquerque (SNLA), Mounds Facility (MF), and the General Electric Nuclear Division (GEND). The primary tasks for LASL during FY 1980 were to (1) continue staffing and the training of personnel, (2) to develop the fuel processing flowsheet and characterize the fuel, (3) to produce 30 pressure burst-test units and ship them to MF and (4) to fabricate 30 LASL fueled heat sources for testing at LASL and GEND. Each of these tasks has been accomplished. The fuel processing development is discussed below in Section II. The welding development is described below in Section III.

MWG PROJECT SCHEDULE

Fig. I-1. MWG project schedule.

B. Pressure Burst-Test Capsules

Each lot of T-III must be qualified by pressure burst testing. This test is to ensure that the strength member will be rupture-free in case of a fire (1 h at 1010°C) at the end of capsule life, or when there is a maximum internal helium pressure due to plutonium-238 alpha decay.

A pressure-burst capsule consists of a strength member cap GTA-welded to a strength member body. The capsule contains a tantalum pellet to simulate the volume of the liner capsule and fuel. The cap is provided with a tantalum tube (1.52-mm diameter, 101.6-mm long, with a 0.25-mm orifice) that is electron beam-welded through the center of the cap. This tube is used to pressurize the capsule with helium and the tube is sealed. The amount of helium introduced is such that a preset pressure (~800 psi) is attained when the capsule is heated to about 1010°C.

During 1980, LASL fabricated 50 pressure burst-test capsules. These are summarized in Tables I-1 through I-3. The capsules welded initially were used for LASL weld development efforts and 29 of those welded later were shipped to MF for testing. The results¹ for some of the LASL units tested at MF are listed in Table I-4 and compared to those obtained for similar capsules welded at MF. These results indicate that the LASL welds are essentially the same as those performed at MF.

C. Fueled Test Capsules

During FY1980, 54 liners were loaded with PuO₂ fuel and welded. To date 43 of these fueled liners have been encapsulated in strength members and 13 of these have been encapsulated in the outer clad assemblies. These units were fabricated to establish welding parameters, checkout the nondestructive test procedures and to provide 30 specimens for impact, compatibility and vibration tests. The original project plan called for LASL to fabricate the MC2893A heat source, fueled at 4.0 watts, to be used in the MC2730 Radioisotopic Thermoelectric Generator (RTG). Recently, SNLA has requested that LASL also fabricate the MC3599 heat source, fueled at 4.5 watts, to be used in the MC3500 RTG. Thus, 9 of the 30 LASL fueled test units were loaded at 4.5 watts instead of the 4.0 watts originally planned. The LASL results indicate that the heat sources can be fueled at 4.5 watts without a change in capsule dimensions. However, the void volume will be appreciably reduced and this may affect the internal helium pressure as well as the impact and vibration response.

Twelve heat sources, 6 fueled at 4.0 watts and 6 fueled at 4.5 watts, were fabricated for vibration tests at GEND. The 4.5-watt units are summarized in Table I-5. Six units, 3 fueled at 4.0 watts and 3 fueled at 4.5 watts, will be impacted at LASL. The remaining 12 units, all fueled at 4.0 watts, are for compatibility tests at LASL. The compatibility test matrix is shown in Table I-6. Post-mortem examinations of the heat sources tested for 60 or 240 d will include metallographic, hardness, and chemical analyses of the containers and chemical and fines analyses of the fuel. If the results for the 6 units tested for 60 or 240 d indicate no compatibility problems, the other 6 units will remain in test for 2 y.

D. Test Data Evaluation

The results of the pressure burst tests at MF, the vibration tests at GEND, and the impact and compatibility tests at LASL will be assembled, correlated and distributed during February 1981.

TABLE I-1
LASL PRESSURE BURST-TEST CAPSULES 1-20

Identification Numbers			Glovebox Atmosphere (ppm)			He Leak Rate (cm ³ /sx10 ⁴)	Radiograph	Status/Comments
Capsule ^a	Body	Pellet	O ₂	H ₂ O	N ₂			
LASL-01	1906	1F	1.7	2.5	155	< 1	OK	Sectioned, good weld
LASL-02	1902	8F	1.2	2.5	155	-	-	Sectioned, weld off center, reuse pellet in LASL-36
LASL-03	1903	9F	1.2	2.5	105	-	-	Sectioned, incomplete weld
LASL-04	1904	10F	1.2	2.5	105	< 1	-	Sectioned, good weld
LASL-05	1905	11F	1.1	2.5	94	< 1	OK	Body marked by collet
LASL-06	1907	12F	1.1	2.5	122	< 1	OK	Body marked by collet
LASL-07	1908	14F	1.1	2.5	104	< 1	OK	Body marked by collet
LASL-08	1909	16F	1.2	2.5	99	< 1	-	Body marked by collet
LASL-09	1910	17F	1.2	2.5	117	< 1	OK	Body marked by collet
LASL-10	1911	19F	2.0	2.5	146	< 1	OK	Body marked by collet
LASL-11	1912	20F	1.7	2.5	146	< 1	OK	Body marked by collet
LASL-12	1913	21F	1.7	2.5	146	< 1	OK	Body marked by collet
LASL-13	1914	23F	1.7	2.5	146	< 1	-	Sectioned, good weld
LASL-14	1916	25F	3.1	2.0	100	< 2	-	Sectioned, incomplete weld
LASL-15	1917	26F	9.7	2.3	144	< 10	OK	Sectioned, good weld, reuse pellet in LASL-38
LASL-16	1918	66F	0.3	2.5	18	< 1	OK	
LASL-17	1919	80F	0.3	2.0	18	< 1	OK	To MF
LASL-18	1920	81F	0.3	2.0	17	< 1	OK	To MF
LASL-19	1921	82F	0.3	2.0	16	< 1	OK	To MF
LASL-20	1922	83F	0.3	2.0	16	< 1	OK	To MF

^aCapsule number is the same as the lid number.

TABLE 1-2

LASL PRESSURE BURST-TEST CAPSULES 21-40

Identification Numbers			Glovebox Atmosphere (ppm)			He Leak Rate (cm ³ /sx10 ⁹)	Radiography	Status/Comments
Capsule ^a	Body	Pellet	O ₂	H ₂ O	N ₂			
LASL-21	1923	84F	0.3	2.0	16	< 1	OK	To MF
LASL-22	1924	85F	0.3	2.0	16	< 1	OK	To MF
LASL-23	1925	86F	0.3	2.0	16	< 1	OK	To MF
LASL-24	1926	87F	0.3	2.0	16	< 1	OK	To MF
LASL-25	1927	88F	0.2	2.0	16	< 1	OK	To MF
LASL-26	1928	002	0.2	2.0	16	< 1	OK	To MF
LASL-27	1929	003	0.2	2.0	16	< 1	OK	To MF
LASL-28	1930	006	0.2	2.0	16	< 1	OK	To MF
LASL-29	1931	007	0.2	2.0	16	< 1	OK	To MF
LASL-30	1932	008	0.2	2.0	16	< 1	OK	To MF
LASL-31	1933	009	0.6	2.0	12	< 1	OK	To MF
LASL-32	1948	082	0.9	2.0	12	< 1	OK	To MF
LASL-33	1949	081	0.9	2.0	12	< 1	OK	To MF
LASL-34	1950	083	0.9	2.0	12	< 1	OK	To MF
LASL-35	1951	084	0.9	2.0	12	< 1	OK	To MF
LASL-36	1952	8F	0.4	2.0	21	< 1	-	Sectioned, good weld
LASL-37	1953	25F	0.2	2.0	16	< 1	-	Sectioned, good weld
LASL-38	1954	26F	0.2	2.0	12	< 1	-	Sectioned, good weld
LASL-39	1947	080	0.9	2.0	12	< 1	OK	To MF
LASL-40	1934	010	1.0	2.0	12	< 1	OK	To MF

^aCapsule number is the same as the lid number.

TABLE 1-3
LASL PRESSURE BURST-TEST CAPSULES 41-50

Identification Numbers			Glovebox Atmosphere			He Leak	Radiography	Status/Comments
Capsule ^a	Body	Pellet	O ₂	H ₂ O	N ₂	Rate (cm ³ /s x 10 ⁻⁴)		
LASL-41	1935	011	1.0	2.0	12	< 1	Incomplete	Radiography questionable, sectioned, weld OK
LASL-42	1936	012	1.0	2.0	12	< 1	OK	To MF
LASL-43	1937	013	1.0	2.0	12	-	-	Lid tipped during weld, lost capsule
LASL-44	1938	014	1.0	2.0	12	< 1	OK	To MF
LASL-45	1939	015	0.9	2.0	12	< 1	OK	To MF
LASL-46	1940	016	0.9	2.0	12	< 1	OK	To MF
LASL-47	1942	076	0.9	2.0	12	< 1	OK	To MF
LASL-48	1944	077	0.9	2.0	12	< 1	OK	To MF
LASL-49	1945	078	0.9	2.0	12	< 1	OK	To MF
LASL-50	1946	079	0.9	2.0	12	< 1	OK	To MF

^aCapsule number is the same as the lid number.

TABLE I-4
 LOT 10 PRESSURE BURST-TESTS
 PERFORMED AT MF
 (at 1040°C)

LASL Capsules			MF Capsules		
Capsule Number	Internal Pressure (psia)	Rupture Time (h)	Capsule Number	Internal Pressure (psia)	Rupture Time (h)
LASL-17	8002	12.69	MPT10-10	8188	12.16
LASL-18	8002	51.82	MPT10-12	8188	33.09
LASL-20	8002	30.26	MPT10-18	8189	2.49
LASL-22	8005	2.25	MPT10-19	8187	2.93
LASL-24	8004	9.91	MPT10-21	8190	11.87
	8003	21.59	MPT10-23	8188	18.21
			MPT10-25	8190	14.00
				8188	15.38

TABLE I-5
4.5 WATT TEST UNITS FOR GEND

Identification Number			Neutron Emission (n/s)	Watts ^a
Clad	Strength Member	Liner		
003T-H80	1780	1653	36 809	4.596
004T-H80	1781	1654	36 973	4.598
005T-H80	1782	1655	37 096	4.597
006T-H80	1783	1656	37 019	4.599
007T-H80	1778	1651	37 024	4.598
008T-H80	1779	1652	37 001	4.597
			36 987	4.598
			± 96	±0.001

^aEach heat source charge was 11.108 g PuO₂, 0.61 g Y.

TABLE I-6
INITIAL LASL COMPATIBILITY
TEST MATRIX

Test Temperature	Number of Heat Sources Tested		
	60 days	240 days	2 years ^a
600°C	1	1	2
900°C	1	1	2
1100°C	1	1	2

^aAt end of test, one heat source will be sectioned, the other will be impacted and then sectioned.

II. FUEL PROCESSING

A. Flowsheet

The LASL fuel processing flowsheet is shown in Fig. II-1. Most of the QA procedures for the fuel processing have been written and approved and personnel are being trained to perform these procedures. Three lots of feed powder, 616 g of PuO_2 , from the Savannah River Plant (SRP) were processed according to this flowsheet. The yield was 530 g of fuel granules or about 86%, after analytical samples and processing losses were taken.

B. Equipment Installation and Checkout

1. Gloveboxes. Four gloveboxes dedicated to the MWG Project have been installed and brought into service. Most of these gloveboxes are provided with inert-gas recirculating systems (helium for the welding boxes, argon otherwise) that normally provide atmospheres with less than 2 ppm oxygen.

2. Glovebox Atmosphere Measurements. All gloveboxes, having inert-gas atmospheres, have been provided with analyzers to measure the oxygen and moisture contents of these atmospheres. The Teledyne Model 317X analyzers are capable of continuous trace analyses in the range 0 to 10 000 ppm oxygen. The Onkyne Model 355 units are capable of analyses in the range 0.5 to 20 000 ppm water. In addition, the welding gloveboxes have been provided with vacuum Atmospheres Model AN-1 chromatographic units capable of measuring nitrogen in the range 3 to 30 000 ppm in the presence of argon and helium. Following the initial checkout of the welding gloveboxes, the typical atmospheres have been found to contain < 1 ppm each of oxygen and water and 30 ppm nitrogen. The MWG specifications for welding atmospheres are 25 ppm oxygen, 60 ppm water and 160 ppm nitrogen.

3. Furnaces. Three modified Astro Model 1000A graphite-element furnaces have been received together with the attendant power supplies, programmers, and controllers. These units will be used for the oxygen-16 exchange of the PuO_2 feed powder, the seasoning of the feed granules at 1600°C and the drying of the granules after the final washing and screening operations. The furnaces met initial checkout specifications and they are being profiled for MWG operating temperature ranges.

In the interim, all furnaces (also Astro Model 1000As) used in the space projects have been brought under the MWG QA system to enable us to initiate the processing of MWG feed.

The Centorr tungsten-element vacuum furnace has been installed and tested to 1600°C at a vacuum of 5×10^{-7} torr. This unit has been used to simultaneously heat 4 MWG fueled strength members at $1350 \pm 5^\circ\text{C}$.

4. Calorimetry. We have ordered 5 calorimeters from MF. These will be dedicated for the MWG project and are scheduled to be delivered to LASL about February 1981. Two units will be installed in the glovebox line to measure PuO_2 feed material. The other 3 will be located outside the gloveboxes and will be used to measure the welded MWG heat sources.

At present, we are using an isothermal twin-tube calorimeter with a throughput of only 1 specimen per day. This unit will be used until the new calorimeters are delivered by MF. This calorimeter was used to measure 6 WR heat sources made at MF. The results are listed in Table II-1 and are in excellent agreement with the MF calorimetry data.

Fig. II-1. LASL MWG flowsheet - fuel processing.

5. Neutron Emission Rate Measurements. Two thermal neutron counters (TNCs), designed and built at LASL, have been installed and tested. These units were used to measure the neutron emission rates for 6 WR heat sources made at MF. The data are listed in Table II-2 and compared to those measured at MF and at the LASL analytical chemistry group, CMB-1. The agreement is excellent and indicates that the LASL counters, installed for the MWG Project, will be adequate.

6. Miscellaneous Equipment. A Carver Model C 12-ton press, provided with an automated Enerpac Model PER 2035 hydraulic power unit, has been installed and tested, as have several Ainsworth Model Gamma III analytical balances. The Micromeritics Sedigraph Model 5000 GB particle size analyzer has been installed and tested. This unit is used to determine the particle size of SRP feed powder, both as-received and after ball-milling. It is also used to analyze the fines generated in heat sources during impact tests.

TABLE II-1
LASL ANALYSES OF MF WR ASSEMBLIES
CALORIMETRY
(watts/capsule)

MWG Capsule	MF		LASL ^b
	10/4/78	1/18/80 ^a	
MAD-800-1-78	3.986	3.946	3.947 ± 0.002
MAD-801-1-78	3.984	3.944	3.945
MAD-802-1-78	3.989	3.949	3.951
MAD-803-1-78	3.988	3.948	3.948
MAD-804-1-78	3.999	3.959	3.959
MAD-805-1-78	3.992	3.952	3.952

^aCorrected for decay assuming $\lambda = 2.1617 \times 10^{-5} \text{ days}^{-1}$,
 $\Delta t = 461 \text{ days}$.

^bMeasured in January 1980.

TABLE II-2
LASL ANALYSES OF MF WR ASSEMBLIES
NEUTRON EMISSION
(n/s per g sample)

MWG Capsule	MF ^a	LASL	
		Analytical Group	MWG Unit
MAD-800-1-78	2725	2730	2740
MAD-801-1-78	2775	2740	2760
MAD-802-1-78	2765	2740	2730
MAD-803-1-78	2755	2750	2750 ^b
MAD-804-1-78	2825	2790	2785
MAD-805-1-78	2785	2780	2790

^aEach capsule contained 10.06 g PuO₂.

^bTo be used for interim as calibration standard.

C. Fuel Characterization-LASL Analyses

Three containers of SRP feed powder were recently processed at LASL. These were SRP Lot 438, Run 905911 (LASL Lot 48), SRP Lot 446, Run 908953 (LASL Lot 49), and SRP Lot 453, Run 910986 (LASL Lot 51). LASL spectrochemical data for 2 of the as-received lots are listed in Table II-3. LASL isotopic values for these lots are listed in Table II-4. The as-received neutron emission rates were 16 078 (Lot 48), 18 202 (Lot 49), and 18 980 n/s-g ²³⁸Pu (Lot 51).

III. WELDING AND NONDESTRUCTIVE TESTING

A. Flowsheets

The LASL flowsheet for welding the T-111 liners is diagrammed in Fig. III.1. The positioning, assembling, and welding sequence for the liners is shown in Fig. III-2 through Fig. III-7. The flowsheets for welding the T-111 strength members and Hastelloy-C clad members are shown in Fig. III-8 and Fig. III-9, respectively. The QA procedures for the assembly and welding of fueled heat sources have been written and approved and welding personnel are being trained.

TABLE II-3
SPECTROCHEMICAL DATA FOR FEED LOTS
(ppm by weight)

<u>Species</u>	<u>Specification</u>	<u>Sensitivity Limit</u>	<u>Lot 48</u>	<u>Lot 51</u>
Al	70	5	110	300
B	70	1	< ^a	3
Ba	25	2	<	15
Bi	25	1	<	<
Ca	250	3	300	20
Cd	25	10	<	<
Co	50	2	<	<
Cr	150	5	30	100
Cu	50	1	15	3
Fe	500	5	170	490
Mg	50	1	50	200
Mn	50	1	15	4
Ni	100	5	20	60
Pb	50	5	15	10
Si	100	5	80	240
Sn	50	5	10	5
Ta	150	100	<	<
Zn	100	5	10	20

^aLess than sensitivity limit, not detected in sample.

TABLE II-4
ISOTOPIC DATA FOR FEED LOTS
(weight percent)

<u>Pu Isotope</u>	<u>Lot 48</u>		<u>Lot 49</u>		<u>Lot 51</u>	
	<u>SR</u>	<u>LASL</u>	<u>SR</u>	<u>LASL</u>	<u>SR</u>	<u>LASL</u>
238	83.33 ^a	83.19	83.56	83.51	83.04	82.91
239	14.13	14.15	13.93	13.98	14.36	14.45
240	2.05	2.06	1.95	1.94	2.03	2.05
241	0.47	0.47	0.42	0.42	0.43	0.44
242	0.13	0.12	0.14	0.14	0.15	0.15

^aSR values were corrected for decay to date of LASL measurement.

Fig. III-1. LASL MWG flowsheet - welding liners.

Fig. III-2. MWG liner positioned for welding.

Fig. III-3. MWG liner filled with 4.5 watts PuO_2 plus yttrium.

Fig. III-4. MWG liner filled with 4.5 watts PuO_2 plus yttrium, after vibration.

Fig. III-5. MWG liner fueled at 4.5 watts, shim in place.

Fig. III-6. MWG liner fueled at 4.5 watts, cap in place.

Fig. III-7. MWG liner fueled at 4.5 watts, cap welded.

Fig. III-8. LASL MWG flowsheet - welding strength members.

Fig. III-9. LASL MWG flowsheet - welding clad members.

B. Equipment Installation and Checkout

1. Gloveboxes. Two gloveboxes, separated by a decontamination hood and dedicated to the welding of MWG capsules, have been installed. Each box is provided with an independent inert-gas (helium) recirculating atmosphere that normally contains 0.5 to 2 ppm oxygen.

2. Welding Equipment. Two welding fixtures, built at LASL from modified MF drawings, have been installed in the inert-atmosphere welding gloveboxes. One is used for "hot" welds (liners), the other for "cold" welds (strength members and clads). The fixtures incorporate 12-position turret turntables which hold 12 capsules. Each turntable is provided with 3 sets of interchangeable collets to allow welding of liners, strength members, and clads.

The Miller Analog 300 power supply with built-in current pulser and weld cycle programmer, together with the attendant controls, has been installed and tested and found to work satisfactorily.

3. Radiographic Measurements. The Balteau 400 kV x-ray generator, shown in Fig. III-10, has been received and tested. The test results indicate that, with suitable masking, 4 MWG units can be radiographed simultaneously and with adequate resolution. A series of photographs for 4 WR heat sources, made at MF, is shown in Fig. III-11. For the top row of photographs, the x-ray parameters were set to enhance resolution of the strength member welds. For the lower row of photographs, the parameters were set to enhance resolution of the clad welds. Better results have been obtained by radiographing the units after the strength member has been welded and then radiographing them again after the clad has been welded.

4. Helium Leak Detection Measurements. Two helium leak detection systems have been built and tested. Both systems incorporate Veeco MS-18 leak detectors provided with water cooling for the heat sources and with standard helium leaks calibrated at SNLA. One unit, operating in the standard dynamic mode is used to check welded liners to 5×10^{-10} cm³/s He. The other unit, shown in Fig. III-12, operates on the accumulation principle and is used to check welded strength members and clads to 1×10^{-11} cm³/s. This unit works as follows. The specimens to be tested are loaded into one side of the manifold and the helium released (if any) is collected for a given time. Similarly, the helium released in the same time period from a standard helium leak is collected in the other side of the manifold.

It is possible that either the strength member or the clad could have a leak in the weld area. However, if the fueled liner is leak-free, these leaks cannot be detected by a standard helium leak detector as no α particles will be released. Because of this, we have built a pressurization chamber capable of pressurizing a strength member or clad to 300 psi with helium over 30 min. The pressurized units can then be placed in distilled water to check for gross leaks.

5. Ultrasonic Weld Inspection. A system, based on a KF USIP-11 analyzer has been built and tested. This system is shown in Fig. III-13. A new lack-of-penetration (LOP) standard has been made from a 26-y pressure burst-test unit. The test parameters have been optimized to detect the 0.05-mm and 0.1-mm EDM notches in this standard.

6. Dye Penetrant Test. The techniques for checking welded capsules with fluorescent dye penetrant have been developed and the QA procedures have been written and approved.

Fig. III-10. Balteau 400 kV x-ray generator.

Fig. III-11. Radiography results for MF heat sources, left to right MAD-805, -804, -803, and -802. The top row emphasizes the strength member welds, the bottom row the clad welds.

Fig. III-12. Accumulation-type leak detector for testing strength member and clad welds.

Fig. III-13. Ultrasonic weld inspection system.

7. Clad Member Lapping. A Buehler Ltd. Model ECOMET III polisher/grinder has been installed for lapping the clad member caps (after welding) to a surface flatness of ± 0.01 mm. Six heat sources can be lapped at a time. Successful results have been obtained by polishing the caps for 20 min with 20- μ m alumina. A Brown and Sharpe electronic gauging system has been received and tested. This unit is capable of measuring surface flatness variations as small as 4×10^{-5} mm.

IV. DESTRUCTIVE TESTING

A. Pressure Burst Units

Four LASL pressure burst-test capsules, LASL-01, -36, -37, and -38, were sectioned and the weld areas were examined metallographically. The weld structures for these capsules are shown in Fig. IV-1 through Fig. IV-9. All welds had fully penetrated with an average thickness of 1.47 mm. No defects such as gas bubbles were observed. The average oxygen and nitrogen contents in the weld areas were 39 and 18 ppm, respectively. The average hardness for the weld areas was 244 (UHN). These values are approximately the same as those obtained for WR capsules, made at MF, listed in Table IV-1 through IV-3.

B. Impacted WR Capsules

Two WR heat sources, MAD-802-1-78 and MAD-804-1-78, were impacted at LASL at 450°C and at 148 and 150 m/s, respectively. The clad weld breached for each capsule but both strength members remained intact. The macrographs for capsule MAD-802 are shown in Fig. IV-10 through IV-15. The liner for capsule MAD-802 remained intact while necking to 0.05 mm in the dome area, Fig. IV-12 and Fig. IV-15. However, it failed intergranularly in a brittle manner in the weld, Fig. IV-13 and Fig. IV-14, at the corner of the impact face.

The macrographs for capsule MAD-804 are shown in Fig. IV-16 through Fig. IV-19. The liner for this capsule necked to 0.03 mm in the dome area but remained intact.

Analytical data for these capsules are summarized in Table IV-1 through Table IV-3. Impact results for capsules MAD-802 and MAD-804 are summarized in Table IV-4, together with data for capsule MAD-801 and simulant capsule WMYT-01, impacted at LASL and reported previously.²

C. Nonimpacted WR Capsules

Two WR heat sources made at MF, MAD-800-1-78 and MAD-805-1-78, were sectioned in the as-received condition. The macrographs are shown in Fig. IV-20 through Fig. IV-24. No flaws were detected for MAD-800. However, Fig. IV-24 indicates the possibility of a grain-boundary impurity phase at the edge of the liner weld for MAD-805. Analytical data for these capsules are listed in Table IV-1 through Table IV-3.

Fig. IV-1. Cross section of pressure burst capsule LASL-01, 4- $\frac{1}{2}$ X.

Fig. IV-2. Cross section of pressure burst capsule LASL-01, AE, 10X.

Fig. IV-3. Weld area of pressure burst capsule LASL-01, AE, 40X.

Fig. IV-4. Cross section of pressure burst capsule LASL-36, 4- $\frac{1}{2}$ X.

Fig. IV-5. Weld area of pressure burst capsule LASL-36, AE, 50X.

Fig. IV-6. Cross section of pressure burst capsule LASL-37, 4- $\frac{1}{2}$ X.

Fig. IV-7. Weld area of pressure burst capsule LASL-37, AE, 50X.

Fig. IV-8. Cross section of pressure burst capsule LASL-38, 4- $\frac{1}{2}$ X.

Fig. IV-9. Weld area of pressure burst capsule
LASL-38, AE, 50X.

Fig. IV-10. Impact face of MAD-802 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. IV-11. MAD-802 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. IV-12. Cross section of MAD-802 after impact, showing liner inside strength member, 4- $\frac{1}{2}$ X.

Fig. IV-13. Liner weld of MAD-802 after impact, 8X.

Fig. IV-14. Liner weld of MAD-802, after impact, AE, 50X.

Fig. IV-15. Dome of MAD-802 after impact, AE, 50X.

Fig. IV-16. Impact face of MAD-804 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. IV-17. MAD-804 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. IV-18. Cross section of MAD-804 after impact, showing liner inside strength member, $4\frac{1}{2}X$.

Fig. IV-19. Dome of MAD-804 after impact, AE, 50X.

Fig. IV-20. Cross section of strength member for MAD-800, 4- $\frac{1}{2}$ X.

Fig. IV-21. Cross section of liner for MAD-800, 4- $\frac{1}{2}$ X.

Fig. IV-22. Cross section of strength member for MAD-805, 4- $\frac{1}{2}$ X.

Fig. IV-23. Cross section of liner for MAD-805, 4- $\frac{1}{2}$ X.

Fig. IV-24. Liner weld area of MAD-805, AE, 100X.

TABLE IV-1
ANALYTICAL DATA FOR MWG CAPSULES
OXYGEN
(ppm by weight)

Number	Type	Liner			Strength Member		
		Body	Dome	Weld	Body	Dome	Weld
MAD-800	WR	350	180	35	35	30	35
MAD-801	WR	190	680	30	20	20	35
MAD-802	WR	120	180	40	30	25	30
MAD-804	WR	120	240	35	25	30	20
MAD-805	WR	90	190	70	35	35	40
WMYT-01	Simulant	65	190	50	50	60	45
LASL-01	Burst Test						45
LASL-36	Burst Test						50
LASL-37	Burst Test						30
LASL-38	Burst Test						30

TABLE IV-2
ANALYTICAL DATA FOR MWG CAPSULES
NITROGEN
(ppm by weight)

Number	Type	Liner			Strength Member		
		Body	Dome	Weld	Body	Dome	Weld
MAD-800	WR	130	155	105	70	65	55
MAD-801	WR	45	50	55	42	27	33
MAD-802	WR	25	20	45	25	25	25
MAD-804	WR	40	-	35	30	25	30
MAD-805	WR	30	25	20	60	45	15
WMYT-01	Simulant	< 10	15	< 10	< 10	< 10	15
LASL-01	Burst Test			15			
LASL-36	Burst Test			20			
LASL-37	Burst Test			20			
LASL-38	Burst Test			15			

TABLE IV-3
ANALYTICAL DATA FOR MWG CAPSULES
HARDNESS
(UHN)

Number	Type	Liner			Strength Member		
		Body	Dome	Weld	Body	Dome	Weld
MAD-800	WR	254	251	243	244	251	242
MAD-801	WR	263	270	259	256	262	262
MAD-802	WR	259	260	263	268	263	262
MAD-804	WR	254	264	245	256	276	255
MAD-805	WR	269	267	259	245	260	245
WMYT-01	Simulant	249	276	233	255	276	232
LASL-01	Burst Test						245
LASL-36	Burst Test						242
LASL-37	Burst Test						244
LASL-38	Burst Test						244

V. QUALITY ASSURANCE

A. Internal Documents

The planning documents written and approved for the MWG Project include (1) QA Program Plan, (2) Fabrication, Inspection, and Test Plan, (3) Personnel Qualification and Certification, (4) Procurement, (5) Specification Exception Release, (6) Change Control, (7) Document Control and (8) Submission of material to DOE. Approximately 50 processing procedures have been written for the assembly and testing of fueled heat sources. These are being tested and evaluated during the fabrication of the test units described in Section I, above. Personnel will be trained and certified for the latest revisions of these procedures prior to the LASL Tool Made Sample (TMS) audit. The identification numbers and titles for the processing procedures are summarized in the Fabrication, Inspection, and Test Plan, MWG-CMB-PD-1.

B. Interface Documents

The existing QA program drawings have been reviewed and modified by LASL and SNLA personnel. The Technical Information Exchange (TIE) Agreement has been approved and signed by the appropriate LASL and SNLA personnel.

VI. MEETINGS

On May 1, 1980, a MWG Review Meeting was held at LASL. Outside attendees were C. A. Richardson and C. Smith (DOE/ALO) and R. T. Jankowski, W. J. Kass, and N. A. Branson (SNLA). LASL attendees were C. E. Frantz and C. C. Land (CMB-5), R. R. Geoffrion (CMB-QA), and R. G. Behrens, G. H. Rinehart, W. A. Stark and R. A. Kent (CMB-11).

On June 12, 1980, R. T. Jankowski, P. Syroid and N. A. Branson (SNLA) visited LASL.

On July 23, 1980, R. T. Jankowski and T. Young (SNLA) visited LASL.

On August 22, 1980, C. Garcia (DOE/ALO) and R. T. Jankowski, T. Young, and N. A. Branson (SNLA) visited LASL.

On September 23-24, 1980, a MWG Review meeting was held at MF. LASL attendees were R. D. Strong (M-5), R. R. Geoffrion and J. H. Kottmann (CMB-QA), C. C. Land (CMB-5), and E. D. Brandon, R. G. Behrens, G. H. Rinehart, W. A. Stark, and R. A. Kent (CMB-11).

VII. REFERENCES

1. L. Prosser, Mounds Facility, Monsanto Research Corporation, unpublished data, 1980.
2. "Milliwatt Generator Project, October 1979 - April 1980," Los Alamos Scientific Laboratory Report LA-8406-PR (June 1980).

TABLE IV-4
IMPACT TEST RESULTS

Number	Type	Impact Velocity (m/s)	Percent Diametral Strain		Results		
			Height	Width	Clad	Strength Member	Liner
MAD-801	WR	150	25.0	17.1	Breach	Intact	Intact
MAD-802	WR	148	26.2	16.4	Breach	Intact	Failed at weld
MAD-804	WR	150	25.6	14.0	Breach	Intact	Intact
WMYT-01	Simulant	149	25.0	17.1	Breach	Intact	Failed at weld