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LA-8881-PR
Progress Report

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MASTER

Milliwatt Generator Project

October 1980—March 1981

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

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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 Application by the Los Alamos National Laboratory.

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

The main tasks to be accomplished prior to the initiation of WR production at Los Alamos are shown in Figs. I-1 and I-2. This schedule has been agreed to in a series of meetings between Los Alamos personnel and representatives from DOE/ALO, Sandia National Laboratory Albuquerque (SNLA), Mound Facility (MF), and the General Electric Nuclear Division (GEND). This schedule differs somewhat from those reported previously^{1,2} because Los Alamos will be fabricating the MC 3599 heat source (4.5 watts) for the MC 3500 radioisotopic thermoelectric generator (RTG) in addition to the MC 2893A heat source (4.0 watts) for the MC 2730 RTG originally planned. The use of RTGs based on 4.5-watt heat sources necessitates additional testing, both at GEND and at Los Alamos.

During the first half of FY 1981, the primary tasks at Los Alamos were to (1) continue training of personnel, (2) ship 10 end-of-life simulant units to MF for testing, (3) ship 16 fueled heat sources to GEND for testing, (4) place 12 fueled heat sources on test for fuel-clad compatibility at 3 different tem-

MWG PROJECT SCHEDULE

DATE: April, 1981

Fig. I-1. MWG project schedule, part 1.

MWG PROJECT SCHEDULE

Fig. I-2. MWG project schedule, part 2.

peratures, (5) impact 6 fueled heat sources, and (6) begin surveillance operations. Each of these tasks has been accomplished.

II. TEST UNIT PRODUCTION

A. Fueled Test Units

1. Fabrication. As of March, 1981, 97 liners have been loaded with PuO₂ fuel and welded. To date, 62 of these liners have been encapsulated in strength members and 44 of these have been encapsulated in the outer clad assemblies. Data for the 97 liner assemblies are summarized in Tables II-1 through II-5. Data for the 62 strength members are summarized in Tables II-6 through II-9. Data for the 44 clad assemblies are summarized in Tables II-10 through II-12. These tables will be expanded and updated periodically as additional liner and strength member assemblies are encapsulated in the outer clads and as posttest data become available.

2. GEND Test Units. Ten MC 3599 heat sources have been sent to GEND for testing. The neutron emission rate and thermal power data for these heat sources, together with capsule assembly identification numbers, are summarized in Table II-13. Six MC 2893A heat sources have also been sent to GEND. Data for these units are summarized in Table II-14.

3. Compatibility Test Units. Twelve MC 2893A heat sources were encapsulated in Hastelloy X containers (to protect the clad assembly from oxidation) and placed in furnaces for compatibility tests. Data for these units are summarized in Table II-15. The compatibility test matrix is summarized in Table II-16. Five heat sources were not measured in the calorimeter prior to being put into the furnaces so that the tests could be started on time. These units will be measured when the compatibility tests are concluded.

4. Impact Test Units. Three MC 3599 and 3 MC 2893A heat sources were encapsulated for impact tests. Data for these units are summarized in Table II-17.

5. Neutron Emission Rates. The data listed in Tables II-13 through II-15 and in Table II-17 indicate that the neutron emission rate varies from feed lot to feed lot depending on light element impurity levels. However, all of the heat sources transferred for the various tests meet the specifications, 46 000 n/s for the MC 2893A heat source and 52 000 n/s for the 3599 heat source.

B. Simulant End-of-Life Test Units

1. Fabrication. Twenty liner assemblies were loaded with a 50/50 mixture (by weight) of molybdenum and tungsten powders and then welded. Each assembly had a 0.10-mm-diam hole drilled through the center of the liner caps. Data for these liner assemblies are summarized in Table II-18. All of these liner assemblies were encapsulated in strength members as summarized in Table II-19. Five of the strength members had 1.02-mm-diam holes drilled through the center of the caps; the other 15 strength members had 0.10-mm-diam holes drilled through the center of the caps. The 5 liner-strength member assemblies with 1.02-mm-diam holes in the strength member caps were pressurized to 1250 psi with helium and the liner caps were sealed with a laser welding technique. The 15 assemblies with 0.10-mm-diam holes in the strength member caps were pressurized to 1250 psi with helium, and strength member caps were sealed with a laser. These units are to be used for impact and pressure burst-tests at MF under

TABLE 11-1
FUELED LINER WELDS 1-20

Liner ID			Type	Fuel		Y (g)	Weldbox Atmosphere (ppm)			To Strength Member	Purpose	Disposition/Comments
Cap	Body	Shim		Lot	PuO ₂ (g)		O ₂	H ₂ O	N ₂			
1592	1629	1507		43 ^a	11.205	0.64	< 1	3	25	---	Test Weld	Sectioned
1593	1630	1508		43	11.205	0.64	< 1	3	25	---	Test Weld	Sectioned
1604	1631	1509		43	10.323	--	< 1	3	25	---	Test Weld	Sectioned
1609	1632	1510		43	10.323	--	< 1	3	25	1808	Test Weld	
1610	1633	1511		43	10.323	--	< 1	3	25	1809	Test Weld	
1611	1635	1512	3599	48	11.205	0.61	< 1	3	44	1812	Calorimetry Std	
1612	1636	1513	3599	48	11.205	0.61	< 1	3	44	---	Test Weld	Sectioned
1613	1638	1514	3599	48	11.205	0.61	< 1	3	44	1813	Impact Test	
1614	1639	1515	2893	48	9.960	0.54	< 1	3	44	---	Test Weld	Sectioned
1615	1640	1516	2893	48	9.960	0.54	< 1	2	44	1810	Impact Test	
1616	1641	1517	2893	48	9.960	0.54	< 1	2	44	1811	Impact Test	
1617	1642	1518	3599	48	11.205	0.61	< 1	< 1	16	---	Test Weld	Sectioned
1618	1643	1519	3599	48	11.205	0.61	< 1	< 1	16	1814	Impact Test	
1619	1644	1520	3599	48	11.205	0.61	< 1	< 1	16	1815	Shelf Life Test	
1620	1645	1521	3599	48	11.205	0.61	< 1	< 1	16	1816	Impact Test	
1621	1646	1522	3599	48	11.205	0.61	< 1	3	100	---	Test Weld	Sectioned
1622	1647	1523	3599	48	11.205	0.61	< 1	3	100	---	Test Weld	Sectioned
1623	1648	1524	3599	48	11.205	0.61	< 1	3	96	---	Test Weld	Sectioned
1624	1649	1525	3599	48	11.205	0.61	< 1	< 1	96	---	Test Weld	Sectioned
1625	1650	1526	3599	48	11.205	0.61	< 1	< 1	96	---	Test Weld	Sectioned

^aFuel lot 43 was enriched at 80 at.% ²³⁸Pu. This lot was used for practice only.

TABLE II-2
FUELED LINER WELDS 21-40

Liner ID			Type	Fuel		Y (g)	Weldbox Atmosphere (ppm)			To Strength Member	Purpose	Disposition/Comments
Cap	Body	Shim		Lot	PuO ₂ (g)		O ₂	H ₂ O	N ₂			
1626	1651	1527	3599	49	11.108	0.61	< 1	< 1	96	1778	GEND Test	
1627	1652	1528	3599	49	11.108	0.61	< 1	< 1	96	1779	GEND Test	
1628	1653	1529	3599	49	11.108	0.61	< 1	< 1	96	1780	GEND Test	
1629	1654	1530	3599	49	11.108	0.61	< 1	< 1	96	1781	GEND Test	
1630	1655	1531	3599	49	11.108	0.61	< 1	< 1	96	1782	GEND Test	
1631	1656	1532	3599	49	11.108	0.61	< 1	< 1	96	1783	GEND Test	
1651	1659	1535	2893	49	9.874	0.54	< 1	< 1	12	1710	Compatibility Test	
1652	1660	1536	2893	49	9.874	0.54	< 1	< 1	12	1711	Compatibility Test	
1653	1661	1537	2893	49	9.874	0.54	< 1	< 1	12	1712	Compatibility Test	
1694	1662	1538	2893	49	9.874	0.54	< 1	< 1	12	1713	Compatibility Test	
1695	1663	1539	2893	49	9.874	0.54	< 1	< 1	12	1714	Compatibility Test	
1654	1664	1540	2893	49	9.874	0.54	< 1	< 1	12	1715	Compatibility Test	
1658	1668	1544	2893	51	9.709	0.53	< 1	< 1	17	1786	GEND Test	
1659	1669	1545	2893	51	9.709	0.53	< 1	< 1	17	1787	GEND Test	
1660	1671	1546	2893	51	9.709	0.53	< 1	< 1	17	1788	GEND Test	
1661	1672	1547	2893	51	9.709	0.53	< 1	< 1	17	1789	GEND Test	
1662	1678	1548	2893	51	9.709	0.53	< 1	< 1	17	1790	GEND Test	
1663	1679	1549	2893	51	9.709	0.53	< 1	< 1	17	1791	GEND Test	
1664	1680	1550	2893	51	9.709	0.53	< 1	< 1	17	1792	Compatibility Test	
1665	1681	1551	2893	51	9.709	0.53	< 1	< 1	17	1801	Impact Test	

TABLE II-3
FUELED LINER WELDS 41-60

Liner ID			Type	Fuel		Y (g)	Weldbox Atmosphere (ppm)			To Strength Member	Purpose	Disposition/Comments
Cap	Body	Shim		Lot	PuO ₂ (g)		O ₂	H ₂ O	N ₂			
1667	1683	1553	2893	51	9.709	0.53	< 1	< 1	16	1802		
1670	1686	1556	2893	51	9.709	0.53	< 1	< 1	16	1793	Compatibility Test	
1671	1687	1557	2893	51	9.709	0.53	< 1	< 1	16	1794	Compatibility Test	
1672	1688	1558	2893	51	(9.709) ^a	0.53	< 1	< 1	16	1805	Calorimeter Std	Reject/Light weight ^a
1673	1690	1559	2893	51	9.709	0.53	< 1	< 1	16	1795	Compatibility Test	
1674	1691	1554	2893	51	9.709	0.53	< 1	< 1	16	1796	Compatibility Test	
1675	1692	1555	2893	51	9.709	0.53	< 1	< 1	16	1797	Compatibility Test	
1678	1698	1542	3599	51	10.922	0.60	< 1	< 1	11	1798	GENO Test	
1679	1699	1543	3599	51	10.922	0.60	< 1	< 1	11	1799	Shelf Life Test	
1680	1700	1544	3599	51	10.922	0.60	< 1	< 1	11	1800	GENO Test	
1691	1712	1568	3599	49	10.901	0.60	< 2	< 1	10	1845	GENO Test	
1692	1713	1569	3599	49/51	10.924	0.60	< 2	< 1	10	1846		
1693	1714	1570	3599	49	10.901	0.60	< 2	< 1	10	1847		
1696	1715	1571	3599	54	10.885	0.60	< 2	< 1	10	1848		
1697	1716	1572	3599	54	10.885	0.60	< 2	< 1	10	---		Defective liner weld
1698	1718	1573	3599	54	10.885	0.60	< 1	< 1	14	1849	GENO Test	
1699	1719	1574	3599	54	10.885	0.60	< 1	< 1	14	1850		SM failure ^b
1700	1720	1575	3599	54	10.885	0.60	< 1	< 1	14			Liner failed leak check
1701	1721	1576	3599	54	10.885	0.60	< 1	< 1	14	1851		SM failure
1702	1722	1577	3599	55	10.885	0.59	< 1	< 1	14			Defective liner weld

^aLiner 1672 was not fueled with full charge, and unit subsequently was used as a calorimetry standard.

^bSM = strength member.

TABLE 11-4
FUELED LINER WELDS 61-80

Liner ID				Type	Fuel		Y (g)	Weldbox Atmosphere			To Strength Member	Purpose	Disposition/Comments
Cap	Body	Shim	Lot		PuO ₂ (g)	O ₂		H ₂ O	N ₂				
1794	1827	1587	3599	55	10.860	0.60	< 1	< 1	19	2002	Shelf Life Test		
1795	1828	1588	3599	55	10.860	0.60	< 1	< 1	19	1986	Shelf Life Test		
1796	1829	1589	3599	55	10.860	0.60	< 1	< 1	19	1987	Shelf Life Test		
1797	1830	1590	3599	55	10.860	0.60	< 1	< 1	19	1988	Shelf Life Test		
1798	1831	1591	3599	55	10.860	0.60	< 1	< 1	19	1989	Shelf Life Test		
1799	1832	1592	3599	55	10.860	0.60	< 1	< 1	19	1990	Shelf Life Test		
1800	1833	1593	3599	55	10.860	0.60	< 1	< 1	19	1991	Shelf Life Test		
1801	1824	1594	3599	55	10.860	0.60	< 1	< 1	19	1992	Shelf Life Test		
1802	1835	1595	3599	55	10.860	0.60	< 1	< 1	19	1993	Shelf Life Test		
1803	1836	1596	3599	55	10.860	0.60	< 1	< 1	19	1994	Shelf Life Test		
1840	1837	1597	3599	55	10.860	0.60	< 1	< 1	19	1995	Shelf Life Test		
1841	1838	1598	3599	55	10.860	0.60	< 1	< 1	19	1996	Shelf Life Test		
1843	1840	1600	3599	55	10.860	0.60	< 1	< 1	12			Liner body was cracked	
1844	1841	1601	3599	55	10.860	0.60	< 1	< 1	12	1997	Shelf Life Test		
1845	1842	1602	3599	55	10.860	0.60	< 1	< 1	12	2003	Shelf Life Test		
1846	1843	1603	3599	55	10.860	0.60	< 1	< 1	12	1998	Shelf Life Test		
1848	1869	1604	3599	54/55	10.882	0.60	< 1	< 1	12	1999	Shelf Life Test		
1855	1884	1615	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test		
1856	1085	1616	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test		
1857	1887	1617	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test		

Liner body was cracked

TABLE 11-5
FUELED LINER WELDS 81-97

Cap	Liner ID Body	Shim	Type	Fuel wt	PuO ₂ (g)	Y (g)	Weldbox Atmosphere (ppm)			To Strength Member	Purpose	Disposition/Comments
							O ₂	H ₂ O	N ₂			
1858	1888	1618	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1859	1889	1619	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1860	1890	1620	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1861	1891	1621	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1862	1892	1622	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1863	1893	1623	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1864	1894	1624	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1865	1895	1625	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1866	1896	1626	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1867	1897	1627	2893	59	9.646	0.53	< 2	< 1	20		Shelf Life Test	
1868	1900	1629	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1869	1902	1630	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1870	1903	1631	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1871	1904	1632	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1872	1906	1633	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1873	1907	1634	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1874	1908	1635	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	
1875	1910	1636	2893	62	9.643	0.53	< 1	< 1	103		Shelf Life Test	

TABLE II-6
FUELED STRENGTH MEMBER WELDS 1-20

SM ID ^a		Liner Cap	Type	Weldbox Atmosphere (ppm)			To Clad	Purpose	Disposition/Comments
Cap	Body			O ₂	H ₂ O	N ₂			
1710	1768	1651	2893	< 1	< 1	14	1841	Compatibility Test	
1711	1769	1652	2893	< 1	< 1	14	1842	Compatibility Test	
1712	1770	1653	2993	< 1	< 1	14	1843	Compatibility Test	
1713	1771	1694	2893	< 1	< 1	14	1844	Compatibility Test	
1714	1772	1695	2893	< 1	< 1	14	1845	Compatibility Test	
1715	1773	1654	2893	< 1	< 1	14	1846	Compatibility Test	
1778	1785	1626	3599	< 1	< 1	5	1541	GENO Test	
1779	1786	1627	3599	< 1	< 1	5	1631	GENO Test	
1780	1787	1628	3599	< 1	< 1	5	1632	GENO Test	
1781	1788	1629	3599	< 1	< 1	5	1633	GENO Test	
1782	1789	1630	3599	< 1	< 1	5	1634	GENO Test	
1783	1790	1631	3599	< 1	< 1	5	1635	GENO Test	
1786	1793	1658	2893	< 1	< 1	< 5	1848	GENO Test	
1787	1794	1659	2893	< 1	< 1	< 5	1849	GENO Test	
1788	1795	1660	2893	< 1	< 1	< 5	1850	GENO Test	
1789	1796	1661	2893	< 1	< 1	< 5	1851	GENO Test	
1790	1797	1662	2893	< 1	< 1	< 5	1852	GENO Test	
1791	1798	1663	2893	< 1	< 1	< 5	1853	GENO Test	
1792	1799	1664	2893	< 1	< 1	< 5	1854	Compatibility Test	
1793	1800	1670	2893	< 1	< 1	< 5	1855	Compatibiltiy Test	

^aSM = strength member.

TABLE II-7
FUELED STRENGTH MEMBER WELDS 21-40

SM ID		Liner Cap	Type	Weldbox Atmosphere (ppm)			To Clad	Purpose	Disposition/Comments
Cap	Body			O ₂	H ₂ O	N ₂			
1794	1801	1671	2893	< 1	< 1	< 5	1856	Compatibility Test	
1795	1802	1673	2893	< 1	< 1	< 5	1857	Compatibility Test	
1796	1803	1674	2893	< 1	< 1	< 5	1858	Compatibility Test	
1797	1804	1675	2893	< 1	< 1	< 5	1859	Compatibility Test	
1798	1805	1678	2893	< 1	< 1	< 5	1665	GENO Test	
1799	1806	1679	2893	< 1	< 1	< 5	1666	Shelf Life Test	
1800	1807	1680	2893	< 1	< 1	< 5	1683	GENO Test	
1801	1817	1665	2893	< 1	< 1	< 5	1662	Impact Test	
1802	1818	1667	2893	< 1	< 1	< 5	1663		
1805	1821	1672	2893	< 1	< 1	< 5	1664	Calorimetry Std	
1808	1824	1609	2893	< 1	< 1	< 5	1860	Test Weld	
1809	1825	1610	2893	< 1	< 1	< 5	1861	Test Weld	
1810	1826	1615	2893	< 1	< 1	< 5	1862	Impact Test	
1811	1827	1616	2893	< 1	< 1	< 5	1863	Impact Test	
1812	1828	1611	3599	< 1	< 1	< 5	1647	Calorimetry Std	
1813	1829	1613	3599	< 1	< 1	< 5	1648	Impact Test	
1814	1830	1618	3599	< 1	< 1	< 5	1649	Impact Test	
1815	1831	1619	3599	< 1	< 1	< 5	1650	Shelf Life Test	
1816	1832	1620	3599	< 1	< 1	< 5	1651	Impact Test	
1845	1857	1691	3599	< 1	< 1	< 5	1735	GENO Test	

TABLE II-8
FUELED STRENGTH MEMBER WELDS 41-60

SM ID		Liner Cap	Type	Weldbox Atmosphere (ppm)			To Clad	Purpose	Disposition/Comments
Cap	Body			O ₂	H ₂ O	N ₂			
1846	1858	1692	3599	< 1	< 1	33	1736		
1847	1859	1693	3599	< 1	< 1	33	1737		
1848	1860	1696	3599	< 1	< 1	33	1738		
1849	1861	1698	3599	< 1	< 1	33	1739	GEND Test	
1850	1862	1699	3599	< 1	< 1	33			SM failed during heat treat
1851	1863	1701	3599	< 1	< 1	33			SM failed dye-pen. test
1986	1966	1795	3599	< 1	< 1	7		Shelf Life Test	
1987	1967	1796	3599	< 1	< 1	7		Shelf Life Test	
1988	1968	1797	3599	< 1	< 1	7		Shelf Life Test	
1989	1969	1798	3599	< 1	< 1	7		Shelf Life Test	
1990	1970	1799	3599	< 1	< 1	7		Shelf Life Test	
1991	1971	1800	3599	< 1	< 1	16		Shelf Life Test	
1992	1972	1801	3599	< 1	< 1	16		Shelf Life Test	
1993	1973	1802	3599	< 1	< 1	16		Shelf Life Test	
1994	1974	1803	3599	< 1	< 1	16		Shelf Life Test	
1995	1975	1840	3599	< 1	< 1	16		Shelf Life Test	
1996	1976	1841	3599	< 1	< 1	16		Shelf Life Test	
1997	1977	1844	3599	< 1	< 1	16		Shelf Life Test	
1998	1978	1846	3599	< 1	< 1	12		Shelf Life Test	
1999	1979	1848	3599	< 1	< 1	12		Shelf Life Test	

TABLE II-9
FUELED STRENGTH MEMBER WELDS 61-62

SM ID		Liner Cap	Type	Weldbox Atmosphere (ppm)			To Clad	Purpose	Disposition/Comments
Cap	Body			O ₂	H ₂ O	N ₂			
2002	1982	1794	3599	< 1	< 1	12		Shelf Life Test	
2003	1983	1845	3599	< 1	< 1	12		Shelf Life Test	

TABLE II-10
FUELED CLAD WELDS 1-20

Clad ID	Cap ID Numbers			Type	Weldbox Atmosphere (ppm)			Purpose	Disposition/Comments
	Clad	SM	Liner		O ₂	H ₂ O	N ₂		
LASL-51	1841	1710	1651	2893	< 1	< 1	12	Compatibility Test	In Test at 900°C
LASL-52	1842	1711	1652	2893	< 1	< 1	12	Compatibility Test	In Test at 600°C
LASL-53	1843	1712	1653	2893	< 1	< 1	12	Compatibility Test	In Test at 600°C
LASL-54	1844	1713	1694	2893	< 1	< 1	12	Compatibility Test	In Test at 600°C
LASL-55	1845	1714	1695	2893	< 1	< 1	12	Compatibility Test	In Test at 900°C
LASL-56	1846	1715	1654	2893	< 1	< 1	12	Compatibility Test	End test after 60 d at 600°C
UAS-003T	1632	1780	1628	3599	< 1	< 1	5	GEND Vibration Test	At GEND
UAS-004T	1633	1781	1627	3599	< 1	< 1	5	GEND Vibration Test	At GEND
UAS-005T	1634	1782	1630	3599	< 1	< 1	5	GEND Vibration Test	At GEND
UAS-006T	1635	1783	1631	3599	< 1	< 1	5	GEND Vibration Test	At GEND
UAS-007T	1641	1778	1626	3599	< 1	< 1	5	GEND Vibration Test	At GEND
UAS-008T	1631	1779	1627	3599	< 1	< 1	5	GEND Vibration Test	At GEND
LASL-57	1848	1816	1786	2893	12	3	27	GEND Vibration Test	At GEND
LASL-58	1849	1817	1787	2893	12	3	27	GEND Vibration Test	At GEND
LASL-59	1850	1818	1788	2893	12	3	27	GEND Vibration Test	At GEND
LASL-60	1851	1819	1789	2893	12	3	27	GEND Vibration Test	At GEND
LASL-61	1852	1820	1790	2893	12	3	27	GEND Vibration Test	At GEND
LASL-62	1853	1821	1791	2893	12	3	27	GEND Vibration Test	At GEND
LASL-63	1854	1822	1792	2893	12	3	27	Compatibility Test	In Test at 900°C
LASL-64	1855	1823	1793	2893	12	3	27	Compatibility Test	End test after 60 d at 900°C

TABLE II-11
FUELED CLAD WELDS 21-40

Clad ID	Cap ID Numbers			Type	Weldbox Atmosphere (ppm)			Purpose	Disposition/Comments
	Clad	SM	Liner		O ₂	H ₂ O	N ₂		
LASL-65	1856	1824	1794	2893	12	3	27	Compatibility Test	In Test at 1100°C
LASL-66	1857	1825	1795	2893	12	3	27	Compatibility Test	In Test at 1100°C
LASL-67	1858	1826	1796	2893	12	3	27	Compatibility Test	End test after 60 d at 1100°C
LASL-68	1859	1827	1797	2893	12	3	27	Compatibility Test	In Test at 1100°C
LASL-69	1860	1808	1609	2893	< 1	< 1	5	Test Weld	
LASL-70	1861	1809	1610	2893	< 1	< 1	5	Test Weld	
LASL-71	1862	1810	1615	2893	< 1	< 1	5	Impact Test	Survived 150 m/s impact at 450°C
LASL-72	1863	1811	1616	2893	< 1	< 1	5	Impact Test	Survived 150 m/s impact at 450°C
UAS-009T	1647	1812	1611	3599	< 1	< 1	5	Calorimetry Std	At MF
UAS-010T	1648	1813	1613	3599	< 1	< 1	5	Impact Test	Survived 150 m/s impact at 450°C
UAS-011T	1649	1814	1618	3599	< 1	< 1	5	Impact Test	Survived 150 m/s impact at 450°C
UAS-012T	1650	1815	1619	3599	< 1	< 1	5	Shelf Life Test	
UAS-013T	1651	1816	1620	3599	< 1	< 1	5	Impact Test	Survived 150 m/s impact at 450°C
UAS-014T	1665	1798	1678	3599	< 1	< 1	3	GEND Test	At GEND
UAS-015T	1666	1799	1679	3599	< 1	< 1	3	Shelf Life Test	
UAS-016T	1683	1800	1680	3599	< 1	< 1	3	GEND Test	At GEND
LASL-73	1662	1801	1665	2893	< 1	< 1	13	Impact Test	
LASL-74	1663	1802	1667	2893	< 1	< 1	13		
LASL-75	1664	1805	1672	2893	< 1	< 1	13	Calorimetry Std	At MF
UAS-017T	1735	1845	1691	3599	< 1	< 1	<10	GEND Test	At GEND

TABLE II-12
FUELED CLAD WELDS 41-44

Clad ID	Cap ID Numbers			Type	Weldbox Atmosphere (ppm)			Purpose	Disposition/Comments
	Clad	SM	Liner		O ₂	H ₂ O	N ₂		
UAS-018T	1736	1846	1692	3599	< 1	< 1	<10		
UAS-019T	1737	1847	1693	3599	< 1	< 1	<10		
UAS-020T	1738	1848	1696	3599	< 1	< 1	<10		
UAS-021T	1739	1849	1698	3599	< 1	< 1	<10	GEND Test	At GEND

TABLE II-13
4.5 WATT TEST UNITS FOR GEND

Clad	ID Number Strength Member	Liner	Fuel Lot	Neutron Emission (n/s)	Watts
UAS-003T	1780	1628	49	36 809	4.60
UAS-004T	1781	1629	49	36 973	4.60
UAS-005T	1782	1630	49	37 096	4.60
UAS-006T	1783	1631	49	37 019	4.60
UAS-007T	1778	1626	49	37 024	4.60
UAS-008T	1779	1627	49	37 001	4.60
				36 987	4.60
				± 96	±0.00
UAS-014T	1798	1678	51	32 984	4.50
UAS-016T	1800	1680	51	32 964	4.48
UAS-017T	1845	1691	49	37 222	4.51
UAS-021T	1849	1698	54	41 940	4.50
				36 178	4.50
				±4 274	±0.01

TABLE II-14
4.0 WATT TEST UNITS FOR GEND

Clad	ID Number		Fuel Lot	Neutron Emission (n/s)	Watts
	Strength Member	Liner			
LASL-57	1786	1658	51	29 433	3.99
LASL-58	1787	1659	51	29 543	4.00
LASL-59	1788	1660	51	29 528	4.03
LASL-60	1789	1661	51	29 238	3.98
LASL-61	1790	1662	51	29 438	4.01
LASL-62	1791	1663	51	29 551	3.99
				29 455	4.00
				± 118	±0.02

TABLE II-15
4.0 WATT COMPATIBILITY TEST UNITS

Clad	ID Number		Fuel Lot	Neutron Emission (n/s)	Watts ^a
	Strength Member	Liner			
LASL-51	1710	1651	49	32 676	4.09
LASL-52	1711	1652	49	32 500	4.09
LASL-53	1712	1653	49	32 834	4.09
LASL-54	1713	1694	49	33 339	
LASL-55	1714	1695	49	33 351	
LASL-56	1715	1654	49	33 352	
				33 009	4.09
				± 386	±0.00
LASL-63	1792	1664	51	29 542	
LASL-64	1793	1670	51	29 317	
LASL-65	1794	1671	51	29 442	3.98
LASL-66	1795	1673	51	29 358	3.98
LASL-67	1796	1674	51	29 562	4.00
LASL-68	1797	1675	51	29 617	3.87
				29 473	3.96
				± 120	±0.06

^aIn order to meet the test schedule, 5 units were not calorimeted. These will be measured after the compatibility test and before the post-mortem.

TABLE II-16
COMPATIBILITY TEST MATRIX

<u>Test Temperature</u>	<u>Number of Heat Sources Tested</u>		
	<u>60 days</u>	<u>240 days</u>	<u>2 years</u>
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.

TABLE II-17
IMPACT TEST UNITS

<u>Clad</u>	<u>ID Number</u>		<u>Fuel Lot</u>	<u>Neutron Emission (n/s)</u>	<u>Watts</u>
	<u>Strength Member</u>	<u>Liner</u>			
UAS-010T	1813	1613	48	43 888	4.61
UAS-011T	1814	1618	48	47 079	4.60
UAS-013T	1816	1620	48	46 883	4.57
LASL-71	1810	1615	48	39 610	4.10
LASL-72	1811	1616	48	39 157	4.11
LASL-73	1801	1665	51	29 041	3.98

TABLE II-18
END-OF-LIFE LINER WELDS 1-20

Liner ID			Fuel ^a		Y (g)	Weldbox Atmosphere (ppm)			To Strength Member	Disposition/Comments
Cap	Body	Shim	Lot	wt (g)		O ₂	H ₂ O	N ₂		
1681	1702	1562	OFS-3	11.251	0.60	< 1	< 1	120	1817	
1682	1703	1563	OFS-4	11.252	0.60	< 1	< 1	120	1818	
1683	1704	1564	OFS-5	11.255	0.54	< 1	< 1	120	1819	
1684	1706	1565	OFS-6	11.254	0.54	< 1	< 1	120	1820	
1685	1707	1566	OFS-7	11.250	0.54	< 1	< 1	120	1821	
1709	1709	1585	OFS-8	11.150	-	< 1	< 1	43	1822	Sealed at liner cap at 1245 psi nominal
1710	1811	1579	OFS-9	11.256	-	< 1	< 1	43	1823	Sealed at liner cap at 1245 psi nominal
1711	1812	1580	OFS-10	11.253	-	< 1	< 1	43	1827	Sealed at liner cap at 1245 psi nominal
1712	1813	1581	1	11.201	-	< 1	< 1	43	1828	Sealed at liner cap at 1245 psi nominal
1713	1814	1582	2	11.202	-	< 1	< 1	43	1829	Sealed at liner cap at 1245 psi nominal
1686	1816	1583	3	11.200	-	< 1	< 1	43	1903	
1687	1817	1584	4	11.200	-	< 1	< 1	43	1904	
1777	1874	1666	5	11.202		< 1	< 1	8	1856	
1778	1875	1607	6	11.203		< 1	< 1	8	1857	
1779	1876	1608	7	11.200		< 1	< 1	8	1858	
1780	1877	1609	8	11.201		< 1	< 1	8	1859	
1781	1878	1610	9	11.200		< 1	< 1	8	1860	
1782	1879	1611	10	11.202		< 1	< 1	8	1898	
1783	1880	1612	11	11.200		< 1	< 1	8	1899	
1784	1881	1613	12	11.200		< 1	< 1	8	1902	

^aSimulant fuel is 50/50 mixture (by weight) of molybdenum and tungsten powder.

TABLE II-19
END-OF-LIFE STRENGTH MEMBER WELDS 1-20

SM ID ^a		Liner Cap	Weldbox Atmosphere (ppm)			To Clad	Disposition/Comments
Cap	Body		O ₂	H ₂ O	N ₂		
1817	1836	1681	< 1	< 1	38	1869	Sealed at SM cap at 1250 psi nominal
1818	1837	1682	< 1	< 1	38	1870	Sealed at SM cap at 1250 psi nominal
1819	1838	1683	< 1	< 1	38	1871	Sealed at SM cap at 1250 psi nominal
1820	1839	1684	< 1	< 1	38	1872	Sealed at SM cap at 1250 psi nominal
1821	1840	1685	< 1	< 1	38	1873	Sealed at SM cap at 1250 psi nominal
1821	1866	1709	< 1	< 1	40	1745	
1823	1867	1710	< 1	< 1	40	1746	
1827	1868	1711	< 1	< 1	40	1747	
1828	1869	1712	< 1	< 1	40	1748	
1829	1870	1713	< 1	< 1	40	1751	
1856	1984	1777	< 1	< 1	6		
1857	1985	1778	< 1	< 1	6		
1858	1986	1779	< 1	< 1	6		
1859	1987	1780	< 1	< 1	6		
1860	1988	1781	< 1	< 1	6		
1898	1989	1782	< 1	< 1	6		
1899	1990	1783	< 1	< 1	6		
1902	1991	1784	< 1	< 1	6		
1903	1992	1786	< 1	< 1	6		
1904	1993	1687	< 1	< 1	6		

^aSM = strength member.

conditions simulating end-of-life helium pressures. Ten of these assemblies, 5 each sealed at the strength member and liner caps, were encapsulated in clad assemblies as summarized in Table II-20.

2. Shipment of End-of Life Units. Ten end-of-life units were sent to MF for impact tests. Data for these assemblies are summarized in Table II-21.

III. FUEL PROCESSING

A. Flow sheet

The final version of the Los Alamos fuel processing flow sheet is shown in Fig. III-1. Seven lots of feed powder, 1550 g PuO_2 , from the Savannah River Plant (SRP) were processed according to this flow sheet. The yield was 1235 g of fuel granules, or about 80% after analytical samples and processing losses were taken.

B. Fuel Characterization and Analyses

1. Neutron Emission Data. The as-received neutron emission rates for the 7 SRP feed lots mentioned above are listed in Table III-1.

2. Particle Size Data. Particle size data are listed in Table III-2 for 7 lots of as-received SRP feed powder. Data are also listed for 4 of these lots after the material was ball-milled 44 h to normalize the particle size prior to forming the <500- μm granules.

3. Spectrochemical Data. Spectrochemical data for these 7 as-received lots are listed in Table III-3. All of the cation impurity levels fall within the specification limits except for calcium and, to a lesser extent, silicon.

4. Isotopic Data. The plutonium isotopic data for these 7 feed lots are listed in Table III-4. For comparison, the Savannah River values were corrected for decay to the dates of the Los Alamos analyses.

C. Equipment

All gloveboxes and associated equipment to be used for processing PuO_2 fuel have been installed and tested. The 5 calorimeters ordered from MF were originally scheduled to be delivered to Los Alamos in January, 1981. This date has been slipped to May 1981. In the interim, MF has loaned us 2 units, similar to those ordered, thus allowing us to keep pace with project schedules. Three calorimeter standards were fabricated and encapsulated at Los Alamos and sent to MF for measurement and certification.

IV. WELDING AND NONDESTRUCTIVE TESTING

A. Flow sheets

The Los Alamos flow sheet for welding the T-111 liners is shown in Fig. IV-1. The flow sheets for welding the T-111 strength members and Hastelloy-C clad members are shown in Figs. IV-2 and IV-3, respectively. These flow sheets have been used to successfully weld the capsules summarized in Tables II-1 through II-12, and no changes in the procedures are anticipated.

TABLE II-20
END-OF-LIFE CLAD WELDS 1-10

Clad ID	Cap ID Numbers			Weldbox Atmosphere (ppm)			Disposition/Comments
	Clad	SM	Liner	O ₂	H ₂ O	N ₂	
LASL-76	1869	1817	1681	< 1	< 1	13	At Mound Facility
LASL-77	1870	1818	1682	< 1	< 1	13	At Mound Facility
LASL-78	1871	1819	1683	< 1	< 1	13	At Mound Facility
LASL-79	1872	1820	1684	< 1	< 1	13	At Mound Facility
LASL-80	1873	1821	1685	< 1	< 1	13	At Mound Facility
LASL-81	1745	1822	1709	< 1	< 1	14	At Mound Facility
LASL-82	1746	1823	1710	< 1	< 1	14	At Mound Facility
LASL-83	1747	1827	1711	< 1	< 1	14	At Mound Facility
LASL-84	1748	1828	1712	< 1	< 1	14	At Mound Facility
LASL-85	1751	1829	1713	< 1	< 1	14	At Mound Facility

TABLE II-21
END-OF-LIFE TEST UNITS

Clad	Strength ^a Member	Liner ^b	Weight Gain on Filling (g)
LASL-76	1817	1681	0.024
LASL-77	1818	1682	0.024
LASL-78	1819	1683	0.024
LASL-79	1820	1684	0.026
LASL-80	1821	1685	0.026
			0.025
			±0.001
LASL-81	1822	1709	0.025
LASL-82	1823	1710	0.025
LASL-83	1827	1711	0.023
LASL-84	1828	1712	0.021
LASL-85	1829	1713	0.023
			0.023
			±0.002

^aThe first 5 units were filled with helium at 1250 psi and sealed at the strength member cap.

^bThe second 5 units were filled with helium at 1245 psi and sealed at the liner cap.

Fig. III-1. Los Alamos MWG flow sheet - fuel processing.

TABLE III-1
NEUTRON EMISSION RATE DATA FOR FEED LOTS

ID Numbers		n/s-g ²³⁸ Pu
Los Alamos	SRP	
Lot	Lot Run	
48	438 905911	16 078
49	446 908953	18 191
51	453 910986	18 980
54	465 002006	18 388
55	475 006117	17 590
59	475 006120	17 321
62	486 009167	16 451
		17 571
		± 1 047

TABLE III-2
PARTICLE SIZE DATA FOR FEED LOTS

Lot	Mass Median Diameter (μm)	
	As Received	Ball-Milled 44 h
48	3.77	
49	4.85	
51	4.10	0.81
54	3.82	0.74
55	3.64	0.85
59	3.61	
62	3.80	0.82
	3.94	0.81
	±0.43	±0.05

TABLE III-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>	<u>Lot 54</u>	<u>Lot 55</u>	<u>Lot 59</u>	<u>Lot 62</u>	<u>Average</u>
Al	70	5	100	300	10	20	9	40	80
B	10	1	< ^a	3	<	<	5	<	1
Be	25	2	<	15	<	<	<	<	2
Bi	25	1	<	<	<	<	<	<	<
Ca	250	3	300	20	750	50	500	200	303
Cd	26	10	<	<	<	<	<	<	<
Co	50	2	<	<	<	<	5	<	1
Cr	150	5	30	100	40	30	25	30	43
Cu	50	1	15	3	<	5	5	<	5
Fe	500	5	170	490	140	120	250	110	213
Mn	50	1	15	4	3	3	10	25	10
Ni	100	5	20	60	30	30	30	20	32
Pb	50	5	15	10	50	5	5	10	17
Si	100	5	80	240	100	150	85	75	122
Sn	50	5	10	5	5	5	5	10	7
Zn	100	5	10	20	15	15	8	15	14

^aLess than sensitivity limit, not detected in sample.

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

Feed Lot	Lab	Plutonium Isotope				
		238	239	240	241	242
48	SR ^a	83.33	14.13	2.05	0.47	0.13
	Los Alamos	83.19	14.15	2.06	0.47	0.12
49	SR	83.56	13.93	1.95	0.42	0.14
	Los Alamos	83.51	13.98	1.94	0.42	0.14
51	SR	83.04	14.26	2.03	0.43	0.15
	Los Alamos	82.91	14.45	2.05	0.44	0.15
54	SR	83.26	14.13	2.03	0.44	0.14
	Los Alamos	83.20	14.18	2.05	0.43	0.14
59	SR	83.17	14.21	2.05	0.43	0.15
	Los Alamos	83.19	14.16	2.06	0.43	0.15
62	SR	83.43	14.01	2.01	0.41	0.14
	Los Alamos	83.38	14.05	2.01	0.41	0.15
Los Alamos Average		83.23	14.16	2.03	0.43	0.14
		±0.20	±0.16	±0.05	±0.02	±0.01

^aSR value corrected for decay to dates of Los Alamos measurements.

Fig. IV-1. Los Alamos MWG flow sheet - welding liners.

Fig. IV-2. Los Alamos MWG flow sheet - welding strength members.

Fig. IV-3. Los Alamos MWG flow sheet - welding clad members.

B. Equipment

1. Welding. All gloveboxes, fixtures, and power supplies to be used for welding have been installed and tested.

2. Weld Inspection. A lead-wall chamber is being built in the room located next door to the welding gloveboxes. This chamber will house the Balteau 400-kV x-ray generator used to radiograph capsule welds. All of the helium leak, ultrasonic, and dye penetrant test equipment has been installed and tested.

3. Clad 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. Successful results have been obtained by polishing the clad caps, up to 6 at a time, for 20 min with 20- μ m alumina. Thirty-two clad caps have been polished this way and then measured with a Browne and Sharpe electronic gaging system before they were shipped. Each unit met specifications with an average flatness of 0.0033 ± 0.0016 mm.

V. DESTRUCTIVE TESTING

A. Impact Tests

Seven MWG heat sources were impacted at 150 m/s and at 450°C during this report period. Two of these were surveillance WR units made at MF. The other 5 were Los Alamos test units, 2 fueled at 4.0 watts and 3 fueled at 4.5 watts. The Los Alamos test heat sources are described above in Table II-17. The impact results for all 7 of these heat sources are compared to those reported previously² for MF heat sources in Table V-1. The results have been the same for all MWG heat sources impacted at Los Alamos, that is, the clad welds breach but the strength members remain intact. The diametral strains, both height and width, are essentially the same for all of the heat sources impacted.

The 7 heat sources recently impacted will be subjected to post-mortem analyses that include metallographic, hardness and chemical analyses of the containers and chemical and fines analyses of the fuel. The fines analyses were delayed until differences in MF and Los Alamos analytical techniques were resolved, as described in Sec. C, below.

1. WR Surveillance Units. Two WR 2893 heat sources, made at MF, were impacted. The macrographs for heat source MAD-026 are shown in Figs. V-1 and V-2. Those for MAD-128 are shown in Figs. V-3 and V-4.

2. Los Alamos 4.0-Watt Units. Two Los Alamos 2893A heat sources were impacted. The macrographs for LASL-71 are shown in Figs. V-5 and V-6. Those for LASL-72 are shown in Figs. V-7 and V-8.

3. Los Alamos 4.5-Watt Units. Three Los Alamos 3599 heat sources were impacted. The macrographs for UAS-010T are shown in Figs. V-9 and V-10. The macrographs for UAS-011T are shown in Figs. V-11 and V-12, those for UAS-013T in Figs. V-13 and V-14. The 4.5-watt heat sources seem to have the same impact behavior as the 4.0-watt heat sources despite the mass increase. This is probably because the fuel absorbs most of the additional impact energy.

B. Example Weld

Clad assembly 1639 was used for an example weld. The macrographs shown in Figs. V-15 and V-16 are typical of Los Alamos clad welds and show the complete weld penetration attained.

TABLE V-1

IMPACT TEST RESULTS

ID Number	Type	Impact Velocity (m/s)	Percent Diametral Strain		Results		Comments
			Height	Width	Clad	SM ^a	
MAD-801	2893	150	25.0	17.1	Breach	Intact	Used for Los Alamos start-up test
MAD-802	2893	148	26.2	16.4	Breach	Intact	Used for Los Alamos start-up test
MAD-804	2893	150	25.6	14.0	Breach	Intact	Used for Los Alamos start-up test
WYMT-01	Simulant	149	25.0	17.1	Breach	Intact	Used for Los Alamos start-up test
MAD-026	2893	149	25.1	15.6	Breach	Intact	Surveillance test
MAD-128	2893	148	24.5	15.7	Breach	Intact	Surveillance test
LASL-71	2893A	151	23.8	15.4	Breach	Intact	Los Alamos 4.0-watt test unit
LASL-72	2893A	151	25.6	16.8	Breach	Intact	Los Alamos 4.0-watt test unit
UAS-010T	3599	150	23.8	17.4	Breach	Intact	Los Alamos 4.5-watt test unit
UAS-011T	3599	150	23.7	16.1	Breach	Intact	Los Alamos 4.5-watt test unit
UAS-013T	3599	150	27.0	18.9	Breach	Intact	Los Alamos 4.5-watt test unit

^aSM = strength member.

Fig. V-1. Impact face of MAD-026 J77 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-2. MAD-026 J77 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-3. Impact face of MAD-128 K77 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-4. MAD-128 K77 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-5. Impact face of LASL-71 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-6. LASL-71 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-7. Impact face of LASL-72 after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-8. LASL-72 after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-9. Impact face of UAS-010T after impact, 2X, simulat capsule WYMT-02 on right.

Fig. V-10. UAS-010T after impact, 90° to impact face, 2X, simulat capsule WYMT-02 on right.

Fig. V-11. Impact face of UAS-011T after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-12. UAS-011T after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-13. Impact face of UAS-013T after impact, 2X, simulant capsule WYMT-02 on right.

Fig. V-14. UAS-013T after impact, 90° to impact face, 2X, simulant capsule WYMT-02 on right.

Fig. V-15. Cross section of Los Alamos-welded clad body 1639, 4- $\frac{1}{2}$ X, AP.

Fig. V-16. Weld area for clad body 1639, 50X, AE.

C. Fines Analyses

The Los Alamos examination of 5 MC 2893 heat sources made at MF was reported previously.² Three of these units were impacted (see Table V-1) before being examined. The amount of <20- μ m PuO₂ fines recovered from these heat sources is listed in Table V-2. These values, especially those for the impacted units, are higher than those reported by MF for similar heat sources. A meeting was held between Los Alamos, MF, and SNLA personnel in order to resolve these differences. It was decided to apply both techniques to identical samples. Thus, 5 samples were analyzed at Los Alamos, 3 by using the usual Los Alamos technique and 2 by Los Alamos personnel using the MF technique and directed by MF personnel.

1. MC 2893 Samples. Two MC 2893 heat sources, believed to be identical, were supplied by MF. Heat source MAD-1471, analyzed using the MF technique, yielded 0.007 g of <20- μ m PuO₂ fines. Heat source MAD-1472, analyzed by the Los Alamos technique, yielded 0.059 g of <20- μ m PuO₂ fines.

2. Simulated Impacted Samples. Three "standards" were prepared at Los Alamos. Each contained about 10 g PuO₂ with about 3 g <20- μ m fines. These samples are described in Table V-3. Two of these samples were analyzed using the usual Los Alamos technique. The results, listed in Table V-4, show an excellent mass balance. The amounts of <20- μ m fines determined were greater than the amounts loaded by about 0.1 g. This could indicate that the Los Alamos technique biases the results toward smaller particle sizes, but it could also reflect an increase in fines content due to self-grinding when the sealed containers are handled and transported.

One sample was analyzed by Los Alamos personnel using the MF technique and directed by MF personnel. These results are also listed in Table V-4. The sample contained sufficient fines to clog the filters used in the MF technique, and the analysis could not be completed in one continuous work period as required by the MF procedure. A total of 0.64 g of <20- μ m fines was recovered using the MF technique. However, when the material remaining on the MF 20- μ m screen was reanalyzed using the Los Alamos technique, an additional 2 g of <20- μ m fines were recovered.

3. Conclusions. The results of these experiments indicate that while the Los Alamos technique yields more <20- μ m fines, the mass balance, in terms of material recovered, is excellent. It would appear that the MF method can be overwhelmed when the sample contains large amounts of fines. Thus, we have decided that the current Los Alamos technique will be used for all future fines analyses performed at Los Alamos.

D. Compatibility Tests

Three Los Alamos MC 2893A heat sources were heated for 60 days, one each at 600, 900, and 1100°C and then removed from the furnaces. These units are described in Table II-15 as LASL-56, LASL-64, and LASL-67, respectively. Each unit will be subjected to post-mortem examinations that include metallographic, hardness, and chemical analyses of the containers and chemical and fines analyses of the fuel.

E. Capsule Failures

1. Liner 1699 and Strength Member 1850. When strength member 1850, containing 4.5 watts of fuel encapsulated in liner 1699, was heat treated at 1350°C the assembly breached and a small amount of PuO₂ (~ 1 μ g) was released into the

TABLE V-2
FINES CONTENT FOR MC 2893
HEAT SOURCES

<u>ID No.</u>	<u><20-μm PuO₂ Fines (g)</u>	
	<u>Not Impacted</u>	<u>Impacted</u>
MAD-800	0.027	
MAD-801		3.56
MAD-802		3.19
MAD-804		3.81
MAD-805	0.106	

TABLE V-3
FINES CONTENT FOR SIMULATED
IMPACTED HEAT SOURCES

(g PuO₂)

<u>Size Range (μm)</u>	<u>Sample ID</u>		
	<u>TC 2003</u>	<u>TC 2201</u>	<u>TC 2302</u>
< 5	0.96	1.01	1.09
5 - 10	0.96	1.04	0.98
10 - 20	1.00	0.97	1.03
20 - 38	1.02	0.97	1.07
> 53	6.00	6.00	6.00
	9.94	9.99	10.17

TABLE V-4
FINES DETERMINATION FOR SIMULATED IMPACTED HEAT SOURCES
(g PuO₂)

Size Range (μ m)	Sample TC 2003		Sample TC 2201		Sample TC 2302			Total Found
	<u>Loaded</u>	<u>Found^a</u>	<u>Loaded</u>	<u>Found^a</u>	<u>Loaded</u>	<u>Found^b</u>	<u>Found^{a,c}</u>	
< 20	2.92	3.02	3.02	3.08	3.10	0.64	2.00	2.64
> 20	<u>7.02</u>	<u>6.89</u>	<u>6.97</u>	<u>6.87</u>	<u>7.07</u>		6.94	<u>6.94</u>
	9.94	9.91	9.99	9.95	10.17			9.58

^aLos Alamos technique used.

^bMF technique used.

^cMF technique was used and 0.64 g were found. The material was reanalyzed using the Los Alamos technique and an additional 2 g were determined.

furnace chamber. Both the liner and strength member assemblies had passed dye-penetrant and helium leak checks. Macrographs of the liner cap are shown in Figs. V-17 through V-19. The strength member cap is shown in Figs. V-20 through V-21. A complete post-mortem examination, including electron microprobe analyses, is in progress.

2. Liner 1700. Liner body 1720 was loaded with PuO_2 (4.5 watts) and cap 1700 was welded on. This assembly failed the helium leak check with a leak rate of $1 \times 10^{-7} \text{ cm}^3 \text{ atm/s}$. The macrograph in Fig. V-22 failed to show the cause of the leak, but did indicate a crack on the inside body wall approximately 0.2 mm below the weld area. This assembly is also being subjected to a complete post-mortem.

3. Impurities in Yttrium Containers. Visual analyses of several containers of yttrium chips revealed the presence of plastic and glass chips. Subsequently, all yttrium chips have been placed on an 850- μm screen in an ultrasonic cleaner and washed with ethanol prior to use. It is premature at this point, however, to attribute the failures in liners 1699 and 1700 to impurities in the yttrium chip containers.

VI. QUALITY ASSURANCE

A. Drawings

A block of Los Alamos Drawing numbers, 26Y-318000 to 26Y-318199, has been allocated for use with the MWG Project. To date, 7 drawings have been generated at Los Alamos. These are as follows.

26Y-318000, "Material Specification for Plutonium-238 Dioxide Particles, MC2893A, MC3599 Heat Sources"
26Y-318001, "Product Acceptance Specification, MC2893A"
26Y-318002, "Product Acceptance Specification, MC3599"
26Y-318020, "MC2893A Heat Source"
26Y-318021, "MC2893A Heat Source - Sub Assemblies"
26Y-318160, "MC3599 Heat Source"
26Y-318161, "MC3599 Heat Source - Sub Assemblies"

B. Documents and Procedures

To date, 62 Quality Assurance (QA) documents and procedures have been written and approved. These are summarized in the Fabrication, Inspection, and Test Plan, MWG-CMB11-PD-1, R1. Personnel are being trained and certified for the latest revisions of the processing procedures prior to the Tool Made Sample (TMS) audit to be conducted at Los Alamos by QA personnel from SNLA.

VII. MEETINGS

On October 10, 1980, R. T. Jankowski (SNLA) visited Los Alamos.

On November 9, 1980, C. Garcia (DOE/ALO) visited Los Alamos.

On November 20, 1980, R. T. Jankowski and T. J. Young (SNLA) and E. A. Mershad, D. E. Friedline, and R. L. Goss (MF) visited Los Alamos.

On December 4, 1980, R. T. Jankowski and M. Pasko (SNLA) visited Los Alamos.

On January 9, 1981, W. A. Stark, Jr. and J. A. Pattillo (Los Alamos) visited SNLA.

Fig. V-17. Cross section of liner cap 1699, liner body 1719 and shim 1574, 7X, AP.

Fig. V-18. Cross section of liner cap 1699, liner body 1719 and shim 1574, 10X, AP.

Fig. V-19. Liner cap 1699, 100X, AP.

Fig. V-20. Cross section of strength member body 1862 and cap 1850, 4- $\frac{1}{2}$ X, AP.

Fig. V-21. Strength member body 1862 and cap 1850, 10X, AP.

Fig. V-22. Liner body 1720 and cap 1700, 100X, AP.

On January 23, 1981, R. T. Jankowski and P. Syroid (SNLA) visited Los Alamos.

On February 25-26, 1981, a MWG Review Meeting was held at GEND. Los Alamos attendees were W. A. Stark, Jr., G. H. Rinehart, J. A. Pattillo, and R. A. Kent.

On March 25, 1981, R. T. Jankowski (SNLA) visited Los Alamos.

VIII. REFERENCES

1. "Milliwatt Generator Project, October 1979-April 1980," Los Alamos Scientific Laboratory Report LA-8406-PR (June 1980).
2. "Milliwatt Generator Project, April-September 1980," Los Alamos Scientific Laboratory Report LA-8673-PR (January 1981).