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**Milliwatt-Generator Heat Source
Progress Report: January-June 1983**

Emil A. Mershad

September 20, 1983

Monsanto

MOUND

Miamisburg, Ohio 45342

operated by

MONSANTO RESEARCH CORPORATION

a subsidiary of Monsanto Company

for the

U. S. DEPARTMENT OF ENERGY

Contract No. DE-AC04-76-DP00053

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Summary

The GEND IP schedule requirements for 140 fueled MC2893 heat sources were met.

A reimbursable order request from SNLA for hardware was completed as scheduled.

All LANL hardware requirements were met during the reporting period as scheduled.

Additional lots of Hastelloy-C and T-111 were qualified for use in WR production of hardware.

A rating of "Excellent" was assigned to the MWG program by DOE/DAO after they had conducted a QAS 3.0 survey of program operations.

Preliminary data from post mortem evaluation of two surveillance capsules show no anomalies, suggesting that the corresponding heat sources should be in good condition.

Testing of pressure burst capsules for the qualification of Lot 11 T-111 alloy was completed.

The hardware production period ended with an overall hardware process yield of 97.8%.

MC2893 heat source shipments

M. A. Forrest and J. N. Crawford

One hundred forty fueled MC2893 heat sources were shipped as scheduled to fulfill GEND IP requirements for the reporting period January to June 1983.

Reimbursable orders

P. E. Teaney

A reimbursable order for 22 sets of WR hardware and 2 sets of example weld hardware was fulfilled on schedule during the report period. SNLA requested this hardware to support their heat source testing requirements.

MWG hardware shipments

P. E. Teaney, M. A. Forrest, M. J. Shaffer and P. A. Parker

All hardware shipments to LANL were made ahead of the required shipping dates during the reporting period (January - June 1983). WR hardware requirements and shipments for the reporting period are summarized in Table 1. In addition, 71 pieces of example weld hardware were shipped. Hardware production for FY 83 continues to be ahead of schedule.

Raw material qualification/procurement

P. E. Teaney, E. I. Howell and M. A. Forrest

Lot #3 Hastelloy C and Lot #11 T-111 were qualified for use in WR production of hardware. Orders were placed for additional

Table 1 - MWG WR HARDWARE REQUIREMENTS AND SHIPMENTS

	<u>January</u>	<u>February</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>Example Welds</u>
Liner Shims	25	20	25	30	30	30	0
Liner Caps	25	20	25	30	30	30	1
Liner Bodies	25	20	25	30	30	30	32
Strength Member Caps	25	20	25	30	30	35	20
Strength Member Bodies	25	20	25	35	35	30	12
Clad Caps	25	20	25	30	30	30	5
Clad Bodies	35	20	24	22	22	20	11
Yttrium (g)	30		30		35		
MC2893A Pellets						7	
MC3599 Pellets			10			2	
MC2893A Pressure Burst Cap Assemblies					15		

T-111 alloy sheet material and yttrium getter material for delivery during FY 83. This will ensure that there is sufficient raw material available to meet long-term program needs.

DOE audit and MWG process review

P. E. Teaney and E. I. Howell

A QAS 3.0 Survey of the MC2893 and MC3599 process was conducted January 4 to 7 and 13 to 17. A rating of "Excellent" was assigned to the program by DOE/DAO.

Mound also conducted a DOE/AL mandated process review of the MC2893A and MC3599 program to ensure that appropriate means exist to certify that the products meet the design intent. All program manuals, drawings, and specifications were reviewed for correctness, completeness, and unification. Production and inspection dies, gauges, manuals, procedures, drawings, and personnel were all found to be adequate to produce high quality heat source components to

meet design intent and criteria. No discrepancies affecting the final product quality were found.

Surveillance capsule evaluations

P. E. Teaney and J. R. McKendree

Post mortem evaluation of two MC2893 surveillance units (PB-7-12 and PB-7-15) is nearly completed. The units were tested and are being evaluated in accordance with SNLA Document BB309768. The capsules were fabricated May 22, 1978, pressurized to a pressure corresponding to 5192.35 psia at 1010°C, and were subsequently placed on surveillance test at 410 and 210°C. Capsules PB-7-12 and PB-7-15 were aged for 1238 days at 410°C and 1147 days at 210°C, respectively.

After removal from storage, the capsules were pressure burst tested at 1010°C. PB-7-15 failed in the cap-to-body weld ramp-down zone after 333.06 hr. This mode

of failure is typical for most pressure burst tests. Testing of PB-7-12 was terminated without failure after 284.89 hr (168 hr are required). Subsequent evaluation indicated that the capsule was approaching failure in the cap-to-body weld.

Subsequent to pressure burst tests, each specimen was cross-sectioned for metallographic evaluation and oxygen and nitrogen analyses. Results to date are incomplete; however, preliminary data indicate that the microhardness and microstructure are normal for both capsules.

In summary, preliminary metallographic data for the capsules are normal, indicating that the tests were not compromised by leaks or diffusion of interstitials through the

protective clads. Pressure burst test results were also normal, suggesting that the corresponding heat source units should be in good condition. Upon completion of these evaluations, a detailed report will be sent to the SNLA Quality Assurance Engineer prior to inclusion in the next MWG status report.

Pressure burst testing of Lot 11, T-111

L. A. Gibson and J. R. McKendree

Testing of the pressure burst capsules for the qualification of Lot 11 T-111 alloy has been completed. Results are given in Table 2. Figures 1 and 2 are plots of all data from Lot 11 and the comparison of data averages between Lot 10 and Lot 11, respectively (stem failures and unusual failures were excluded from the calculations).

Table 2 - LOT 11 PRESSURE BURST TEST DATA AT 1040°C

Capsule ID	Internal Pressure (psia)	Rupture Time (hr)	Failure Location
MPT 11-01	6501	99.48	Stem - above lower crimp
MPT 11-02	7997	87.49	Small crack in stem at lower crimp
MPT 11-03	6500	1.15	Violent - 100% separation of dome from capsule
MPT 11-04	8001	77.58	Two cracks in stem at and below lower crimp
MPT 11-05	6503	40.47	Crack - radius of dome
MPT 11-06	8002	120.48	Small crack in stem near capsule
MPT 11-07	6503	103.86	Undetermined
MPT 11-08	8003	115.41	Small crack in stem near capsule
MPT 11-09	6503	92.51	Small crack C/B weld
MPT 11-10	8000	48.33	Undetermined
MPT 11-11	6501	92.69	Two small holes - C/B weld
MPT 11-12	8003	51.26	Crack in stem below lower crimp
MPT 11-13	6501	100.90	Small hole C/B weld - ramp down area
MPT 11-14	8004	94.0	Small crack C/B weld - ramp down area
MPT 11-15	6503	122.19	Undetermined
MPT 11-16	8000	118.63	Small crack in stem below lower crimp
MPT 11-17	6501	97.25	Small hole C/B weld - ramp down area
MPT 11-18	8002	38.25	Large crack radius of dome
MPT 11-19	6503	206.83	Small C/B weld - ramp down area
MPT 11-20	8001	82.34	Small crack in stem below lower crimp
MPT 11-21	6503	1.49	Violent - 100% separation of dome from capsule
MPT 11-22	8001	59.97	Undetermined
MPT 11-23	6504	120.16	Small hole in C/B weld - ramp down area
MPT 11-24	8002	44.54	Small hole in stem in lower crimp
MPT 11-25	6504	110.22	Small hole C/B weld
MPT 11-26	8001	29.41	Small crack - radius of dome
MPT 11-27	6503	144.66	Small hole C/B weld - ramp down area
MPT 11-28	8003	48.54	Small hole in stem above lower crimp
MPT 11-29	6503	122.76	Small crack in stem above lower crimp
MPT 11-30	8002	90.00	Large crack C/B weld - ramp down area

FIGURE 1 - All Lot 11 pressure burst capsule data.

FIGURE 2 - Pressure burst data, Comparison of data averages between Lot 10 and Lot 11.

Of the 30 capsules tested, 11 (36.67%) failed in the stem. These failures occurred either in the lower crimp (Figure 3), slightly above the lower crimp (Figure 4), or between the lower crimp and capsule cap (Figure 5). All stem failures occurred after more than 44 hr of test time. Previous metallographic examination of stem material revealed irregular inside surfaces of the tubing and the presence of sharp notches in the inside wall surface which could be attributed to these types of failures [1]. Of the remaining 19 capsules tested, five (16.67%) failed in the dome area (Figure 6), ten (33.3%) failed in the cap to body weld, and four (13.3%) failed in an undetermined location. Further attempts are being made to locate these very small leaks on the high pressure testing station specifically designed and constructed for this use.

FIGURE 4 - Stem failure slightly above lower crimp of capsule MPT 11-04.

FIGURE 3 - Stem failure in the lower crimp of capsule MPT 11-02.

FIGURE 5 - Stem failure between lower crimp and capsule cap of capsule MPT 11-04.

Pressure burst capsules MPT 11-03 and MPT 11-21 failed catastrophically in the dome in 1.15 and 1.49 hr of test time, respectively (Figures 7, 8, 9, and 10). SEM evaluation of the fracture surfaces indicated that the fractures were predominately brittle (intergranular in nature) with some isolated areas showing ductile dimples (Figure 11) and transgranular fractures (Figure 12). The grain facets on the fracture surfaces, especially near the inner capsule surfaces, had large numbers of Hf-rich precipitates believed to be HfO_2 (Figures 13, 14, and 15). Similar precipitates were observed in the cross sections of the dome ends, with the quantity of the precipitates decreasing from the outside edges to the center. No other foreign contaminants were found by EDX analyses.

FIGURE 7 - Catastrophic failure of capsule MPT 11-03.

FIGURE 6 - Dome failure in capsule MPT-11-18. FIGURE 8 - Failure of capsule MPT 11-03.

FIGURE 9 - Catastrophic dome failure of capsule MPT 11-21.

FIGURE 11 - Micrograph depicting both brittle and ductile areas of the fracture surface capsule MPT 11-03.

FIGURE 10 - Failure of capsule MPT 11-21.

FIGURE 12 - Intergranular and transgranular fractures on fracture surfaces of MPT 11-21.

The microhardness values appear to decrease away from the fracture surfaces. Hardness indentations traversing the cross-section show only slightly higher hardness values in the high precipitate areas (Figure 16).

These data appear to indicate that the sheet material for these two capsules was contaminated, most probably by oxygen. This contamination appears to have embrittled the material, and with the grain boundaries weakened by the presence of the precipitates, intergranular brittle fracture occurred in both MPT 1103 and MPT 11-21.

FIGURE 14 - Ductile region of fracture surface of capsule MPT 11-03.

FIGURE 13 - Micrograph of brittle fracture surface showing intergranular separation and precipitates of HfO_2 .

FIGURE 15 Hf rich precipitates on inner surface of capsule MPT 11-21.

FIGURE 16 - Cross-section of MPT 11-21 dome end.

Hardware fabrication and quality

E. I. Howell and M. D. Christolear

Hardware fabrication continued in an efficient and timely manner with losses from production errors maintained at a minimum level.

Over 1200 pieces of hardware were successfully fabricated, satisfying all programmatic needs for the period. The semiannual quality report on MC2893A/MC3599 hardware is shown in Table 3. The overall process yield for the just completed

six-month period is 97.8%; the dollar value of fabricated hardware is approximately \$219,000.

A MWG hardware reject summary for the period is shown in Table 4. Reasons for rejection are given. This information will be used to improve process yields.

The hardware quality index report shown in Table 5 lists the lot submittals by Mound to DOE/DAO and the quality index ratings for the reporting period. The monthly average was 100%.

References

Mershad, E. A., "Milliwatt Generator Heat Source Progress Report: January-June 1980, MLM-2772 (October, 1980) 26 pp.

Table 3 - QUALITY REPORT ON MC2893A/MC3599 HARDWARE

		<u>January 1 - June 30, 1983</u>	<u>To Date</u>
Liner Shim (291669-00)	Fabricated		2895
	Prime		2890
	Reject		5
	Yield		99.8%
Liner Cap (291670-00)	Fabricated		3000
	Prime		2972
	Example Weld		22
	Reject		6
	Yield		99.8%
Liner Body (291671-00)	Fabricated	378	2967
	Prime	343	2762
	Example Weld	27	169
	Reject	8	36
	Yield	97.9%	98.8%
Strength Member Cap (291672-00)	Fabricated	569	3342
	Prime	519	3209
	Example Weld	34	101
	Reject	16	32
	Yield	97.2%	99.0%
Strength Member Body (291673-00)	Fabricated	238	3071
	Prime	174	2784
	Example Weld	61	244
	Reject	3	43
	Yield	98.7%	98.6%
Clad Cap (291674-00)	Fabricated		2685
	Prime		2628
	Example Weld		43
	Reject		14
	Yield		99.5%
Clad Body (291675-00)	Fabricated	66	2757
	Prime	64	2697
	Example Weld	2	40
	Reject	0	20
	Yield	100%	99.3%
Overall Process Yield		97.8%	99.3%
Value of Fabricated Hardware		\$219,108.29	\$2,929,401.78
Cost of Defectiveness		\$4,776.41	\$26,278.53
\$ % Defectiveness		2.2%	0.9%

Table 4 - MC2893A/MC3599 HARDWARE REJECT SUMMARY
(JANUARY 1, 1983 - JUNE 30, 1983)

Type	Reject Quantity	Reject Reason
Liner Body (291671-00)	6 ^b 1 ^b 1 ^b	Dye Penetrant Void in Material Open End Bell Mouthed
Strength Member Cap (291672-00)	11 ^a 1 ^b 1 ^b 1 ^a 1 ^a 1 ^a	Dents in O.D. Pits in Material Void in Chamfer Bad Machining - Tenon Step Machining Dents and Pits Crack on Tenon Edge
Strength Member Body (291673-00)	1 ^b 1 ^b	Dye Penetrant Material Defect

^aOperated Related
^bMaterial Related

Table 5 - MC2893A/MC3599 HARDWARE QUALITY INDEX REPORT
(JANUARY 1 THROUGH JUNE 30, 1983)

C of I Number	Date Accepted	Component Description	Lot Size	Sample Size	Defective- ness	Major	Minor	Incidental	Index
88-4658	01-03-83	Liner Cap	134	6	0	0	0	0	100
88-4673	01-17-83	Clad Body	20	8	0	0	0	0	100
88-4674	01-17-83	Clad Body	15	5	0	0	0	0	100
88-4692	02-10-83	Clad Body	10	1	0	0	0	0	100
88-4693 ^a	02-10-83	Clad Body	9	N/A	N/A	N/A	N/A	N/A	N/A
88-4694	02-10-83	Clad Body	1	1	0	0	0	0	100
88-4702	02-24-83	Liner Body	84	15	0	0	0	0	100
88-4703 ^a	02-28-83	Clad Body	11	N/A	N/A	N/A	N/A	N/A	N/A
88-4709	03-09-83	Clad Body	12	7	0	0	0	0	100
88-4726 ^a	03-24-83	Clad Body	2	N/A	N/A	N/A	N/A	N/A	N/A
88-4727	03-24-83	Clad Body	2	0	0	0	0	0	100
88-4728	03-24-83	Clad Body	6	0	0	0	0	0	100
88-4744	04-12-83	Strength Member Cap	78	19	0	0	0	0	100
88-4745	04-14-83	Liner Body	78	13	0	0	0	0	100
88-4746	04-14-83	Liner Body	13	1	0	0	0	0	100
88-4751	04-15-83	Clad Body	10	3	0	0	0	0	100
88-4752	04-15-83	Clad Body	12	4	0	0	0	0	100
88-4754	04-20-83	Strength Member Body	11	0	0	0	0	0	100
88-4758	04-25-83	Strength Member Cap	24	5	0	0	0	0	100
88-4774	05-04-83	Strength Member Cap	41	7	0	0	0	0	100
88-4775	05-02-83	Strength Member Cap	43	4	0	0	0	0	100
88-4777	05-04-83	Liner Body	77	3	0	0	0	0	100
88-4786	05-13-83	Clad Body	11	1	0	0	0	0	100
88-4787	05-13-83	Clad Body	11	2	0	0	0	0	100
88-4802	05-02-83	Strength Member Cap	85	11	0	0	0	0	100
88-4817	06-15-83	Clad Body	11	0	0	0	0	0	100
88-4818	06-15-83	Clad Body	9	2	0	0	0	0	100
88-4819	06-15-83	Strength Member Body	95	6	0	0	0	0	100
88-4820	06-15-83	Strength Member Cap	170	6	0	0	0	0	100
88-4825	06-20-83	Strength Member Body	68	3	0	0	0	0	100
30 Submittals		TOTAL	1153	133	0	0	0	0	100

(average)

^aClad Bodies resubmitted because parts were returned to LANL to append new date code.

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