DESIGN, DEVELOP, FABRICATE AND TEST

WET SLUG ALL-TANTALUM CAPACITORS

IN T2 CASE SIZE

FINAL REPORT

February 9, 1976 - August 9, 1976

Prepa ed By

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Prepared For

GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

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SPRAGUE ELECTRIC COMPANY
North Adams, Massachusetts 01247
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# SECTION 1

# ABSTRACT

Seven hundred fifty (750) all tantalum capacitors of the T2 case size were manufactured and tested to Group A and Group B (in part) of MIL-C-39006 as per Exhibit "A" of this contract. After testing, the capacitors, accompanied by the raw test data, were delivered to the George C. Marshall Space Flight Center.

## SECTION 2

## DISCUSSION

(1) <u>General</u>

Prior to the receipt of this contract a considerable amount of time and effort had been expended to obtain the end result, namely the all tantalum, hermetically sealed, T2 case size capacitor.

The four ratings manufactured for NASA are in the high capacitance range of the MIL-C-39006/22 specification thus indicating the high volumetric efficiency of this product.

(2) <u>Special Tooling and Equipment</u>

It should be noted that all tooling and equipment are funded solely by the Sprague Electric Co.

a. <u>Cathode Preparation</u>

Tooling was designed and fabricated for the manufacture of porous tantalum liners to extend the cathode surface area and be capable of withstanding a reverse voltage bias of 3 volts or 20% of the 85°C rated voltage whichever is less.

Liner-to-can insertion tooling was also designed and fabricated.

b. Can Beading

Special tooling for can beading was designed to seal T2 case size capacitors on the 135D sealer (i.e. the all tantalum sealing machine).

c. Hermetic Closure (Rim)

A laser welder has been purchased for welding the tantalum can and outer rim of the seal together thereby effecting a true hermetic seal.

(3) Procurement of Parts

The design and ordering of parts necessary to achieve the contract objective began prior to the receipt of the contract. These parts included the following:

a. tantalum cans

b. tantalum strip for drawing shells for the hermetic seal

c. tantalum tubulations for the hermetic seal

d. glass stock for the hermetic seal

e. special circumferential rubber gaskets

f. special teflon gaskets.

(4) Designs and Drawings

Anodes for the low voltage and high voltage groups were designed and fabricated within the Sprague Electric Company.

Complete procurement, manufacturing and assembly drawings have b en completed.

The standard teflon gasket was redesigned to accept a circumferential rubber gasket.

(5) Development Phase

a. Hermetic Seal (Shells)

The only problem area encountered in the course of this contract was in the seal area.

Several hundred tantalum shells to be used in the glass-to-tantalum seals were drawn to longer lengths than anticipated and required length modification in order to be usable. After a couple of approaches to remove several thousands from the shell length by grinding techniques a mechanical method for sizing these parts was developed and proved successful.

b. Hermetic Seal (Fusion)

The outer glass-to-tantalum seals were manufactured at the Sprague Electric Company in our hermetic seal manufacturing facility. All seals were checked for hermeticity prior to use in the capacitors.

c. Hermetic Seal (Closure)

Laser welding of the tantalum header of the glass-to-tantalum seal and the can rim was performed on dummy units to prove feasibility. This was accomplished with complete success.

d. Cathode Preparation

The fitting of cans with liners and determination of the proper liner dimensions and density were accomplished. In order to meet the reverse voltage requirements for these parts a formation equivalent to 7.0 volts at 90°C was performed and deemed acceptable.

e. Anode Preparation

Two types of pellets were designed for anodes for the low voltage and high voltage areas. Pellets were manufactured and passed all electrical quality tests.

f. Upper Gasket-Vibration Spacer Evaluation

Due to the necessity for isolating the acid electrolyte from the hermetic seal area prior to the rim and tubulation welding an evaluation of the upper gasket-vibration spacer assembly design was conducted. This study consisted of a matrix of three groups of 16 units each (rated 180μF - 10 V) with the following gasket-spacer design:

1. Teflon gasket-spacer with a circumferential rubber gasket with a seal enhancer
2. Same as 1 but without the seal enhancer
3. Standard Teflon gasket-spacer with a seal enhancer.

After aging, the units were checked for evidence of acid above the gasket-spacer. Since acid will interfere with the hermetic seal welding process it was essential at this point to keep the hermetic seal area acidfree. The results of this test were as follows:

Thymol Test For Acid
After Aging

| Group | No. of Units | Positive for Acid |
|---|---|---|
| 1 | 16 | 1 |
| 2 | 16 | 1 |
| 3 | 16 | 16 |

The units were thoroughly washed, subjected to an additional 5 temperature cycles (-55°C to +125°C) and chemically tested for acid with the following results:

Thymol Test For Acid
After Temperature Cycling

| Group | No. of Units | Positive for Acid |
|---|---|---|
| 1 | 16 | 0 |
| 2 | 16 | 1 |
| 3 | 16 | 16 |

Based on the above test results the performance of Group 3 was reviewed and it was decided to suspend this approach in light of the excellent results of the circumferential rubber gasket design.

Groups 1 and 2 continued temperature cycling for an additional 200 cycles (-55°C to +125°C) as a test for determining the effectiveness of these approaches in keeping the hermetic seal area acidfree until after hermetic closure operations.

Table I lists the electrical parameter data of capacitance, dissipation factor and room temperature DC leakage at some of the more significant readout points. Group 1 passed over 200 temperature cycles without any evidence of acid above the upper gasket-spacer assembly. Group 2 exhibited one unit with acid above the upper gasket-spacer after being subjected to 173 temperature cycles. This same unit was also positive for acid after 205 temperature cycles.

It will be noted that the electrical parameter stability of both groups over the entire test was excellent for all parameters. On the basis of these results it was

## TABLE I

### 180μF - 10 VOLT

| No. Temperature Cycles (-55°C to +125°C) | [1]Group I (16 Units) Cap (μF) | | | DF (%) | | | 25°C DCL (μA) | | | Group II (15 Units) Cap (μF) | | | DF (%) | | | 25°C DCL (μA) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Post Aging | 179 | 186 | 192 | 8.0 | 10.8 | 18.4 | 0.13 | 0.21 | 0.29 | 178 | 182 | 189 | 8.9 | 10.6 | 11.8 | 0.11 | 0.16 | 0.26 |
| 5 Cycles | 179 | 186 | 193 | 8.1 | 10.2 | 12.9 | 0.12 | 0.15 | 0.17 | 178 | 183 | 189 | 8.8 | 10.0 | 11.9 | 0.14 | 0.15 | 0.17 |
| 30 Cycles | 179 | 186 | 192 | 9.2 | 11.4 | 13.6 | 0.16 | 0.18 | 0.19 | 178 | 182 | 190 | 9.3 | 10.9 | 12.5 | 0.14 | 0.16 | 0.18 |
| 100 Cycles | 179 | 186 | 192 | 9.4 | 11.4 | 13.9 | 0.16 | 0.17 | 0.21 | 179 | 183 | 189 | 9.1 | 10.9 | 14.5 | 0.17 | 0.19 | 0.22 |
| 205 Cycles | 179 | 186 | 192 | 9.7 | 12.5 | 17.9 | 0.17 | 0.19 | 0.22 | 178 | 183 | 190 | 10.2 | 11.5 | 13.3 | 0.18 | 0.20 | 0.23 |

(1) Upper Vibration Spacer-Gasket with Circumferential Rubber Gasket and Seal Enhancer
(2) Upper Vibration Spacer-Gasket with Circumferential Rubber Gasket and No Seal Enhancer.

decided to proceed with manufacture of the Exhibit "A" units with the Group 1 design (i.e. circumferential rubber gasket and seal enhancer).

(6) Manufacture and Testing (Exhibit "A" Capacitors)

In fulfillment of the requirements of Exhibit "A" of this contract seven hundred fifty (750) capacitors in the voltage groups of 10 volts, 25 volts, 50 volts and 100 volts were manufactured, tested and delivered to the George C. Marshall Space Flight Center on August 2, 1976 (seven days prior to the termination of this contract).

Testing of these capacitors as required under Exhibit "A" of this contract included MIL-C-39006, Group A (Voltage Conditioning) on all 750 units and MIL-C-39006, Group B (Temperature Stability at Low and High Temperatures and Thermal Shock; 30 cycles) on a minimum of 10 capacitors per rating. The contract requirements were exceeded with the Group B testing in that a larger sampling (25 capacitors per rating) was tested in order to obtain more meaningful data.

All raw data accompanied the capacitors delivered to NASA however, Tables II - VI give an electrical parameter summary of these data.

## TABLE II

### EXHIBIT "A", MIL-C-39006B, GROUP A TEST
### VOLTAGE CONDITIONING, T2 CASE, 750 CAPACITORS

| Electrical Parameter | Rating (No. Units) 180µF - 10V/7V 188 Units | | | 100µF - 25V/15V 188 Units | | | 47µF - 50V/30V 187 Units | | | 22µF - 100V/65V 187 Units | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Cap (µF) | 164.7 | 176.6 | 194.0 | 93.30 | 99.58 | 105.1 | 44.08 | 48.26 | 50.66 | 20.51 | 22.97 | 26.03 |
| DF (%) | 3.4 | 10.0 | 28.9 | 3.9 | 6.0 | 11.7 | 1.0 | 2.6 | 5.7 | 0.87 | 1.96 | 3.88 |
| DCL (µA, 25°C) | 0.015 | 0.084 | 0.91 | 0.017 | 0.11 | 0.29 | 0.010 | 0.039 | 0.12 | 0.016 | 0.065 | 0.63 |

## TABLE III

**EXHIBIT "A", MIL-C-39006B, GROUP B TESTS**
**STABILITY AT LOW & HIGH TEMPERATURES**
**AND THERMAL SHOCK (30 CYCLES)**
**180µF - 10V/7V, T2 CASE (25 CAPACITORS)**

| Electrical | 25°C | | | -55°C | | | 25°C | | | 85°C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Cap (µF) | 166.3 | 177.2 | 185.9 | 125.3 | 149.6 | 171.5 | 170.1 | 177.5 | 188.1 | 179.5 | 186.0 | 195.4 |
| DF (%) | 5.4 | 12.1 | 28.1 | - | - | - | 3.6 | 8.4 | 15.7 | 7.2 | 9.8 | 11.9 |
| DCL (µA) | 0.06 | 0.10 | 0.19 | - | - | - | 0.068 | 0.092 | 0.20 | 0.34 | 0.42 | 0.52 |
| Z (Ω) | - | - | - | 10 | 14 | 21 | - | - | - | - | - | - |
| ΔCap (%) | | - | - | -4.7 | -15.6 | -30.0 | -0.17 | +0.23 | +4.6 | +2.2 | +5.0 | +11.6 |

| | 125°C | | | 25°C | | | Thermal Shock -55°C to +125°C 30 Cycles | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Cap (µF) | 185.2 | 192.6 | 202.0 | 170.0 | 176.8 | 182.5 | 171.1 | 177.[illegible] | 186.6 |
| DF (%) | 7.5 | 9.1 | 12.3 | 5.1 | 10.1 | 17.3 | 6.1 | 9.7 | 14.7 |
| DCL (µA) | 0.52 | 0.6[illegible] | 0.86 | 0.15 | 0.19 | 0.29 | 0.054 | 0.[illegible]2 | 0.21 |
| ΔCap (%) | +4.2 | +8 | 0 | +0.[illegible]3 | -0.19 | +3.8 | -0.05 | +0.29 | +[illegible].86 |
| Thymol | - | - | | - | - | - | | All Passed | |

## TABLE IV

**EXHIBIT "A", MIL-C-39006B, GROUP B TESTS
STABILITY AT LOW & HIGH TEMPERATURES
AND THERMAL SHOCK (30 CYCLES)
100µF - 25V/15V, T2 CASE (25 CAPACITORS)**

| Electrical Parameter | 25°C Low | 25°C Avg. | 25°C High | -55°C Low | -55°C Avg. | -55°C High | 25°C Low | 25°C Avg. | 25°C High | 85°C Low | 85°C Avg. | 85°C High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cap (µF) | 95.3 | 99.2 | 102.1 | 70.0 | 89.0 | 101.4 | 93.5 | 98.3 | 103.7 | 99.5 | 103.0 | 107.0 |
| DF (%) | 4.1 | 6.6 | 14.9 | - | - | - | 4.6 | 7.7 | 9.6 | 4.5 | 5.6 | 9.0 |
| DCL (µA) | 0.13 | 0.16 | 0.2 | - | - | - | 0.11 | 0.30 | 0.68 | 0.38 | 0.56 | 0.76 |
| Z (Ω) | - | - | - | 15 | 22 | 49 | - | - | - | - | - | - |
| ΔCap (%) | - | - | - | -0.8 | -10.1 | -26.9 | 0.0 | -1.1 | -3.6 | +0.6 | +3.8 | +4.6 |

| | 125°C Low | 125°C Avg. | 125°C High | 25°C Low | 25°C Avg. | 25°C High | Thermal Shock -55°C to +125°C 30 Cycles Low | Avg. | High |
|---|---|---|---|---|---|---|---|---|---|
| Cap (µF) | 101.8 | 105.4 | 109.2 | 93.5 | 97.8 | 104.5 | 95.3 | 98.6 | 102.3 |
| DF (%) | 4.5 | 5.5 | 9.7 | 2.9 | 6.5 | 8.6 | 3.3 | 5.0 | 7.3 |
| DCL (µA) | 0.50 | 0.59 | 0.73 | 0.12 | 0.14 | 0.18 | 0.084 | 0.12 | 0.16 |
| ΔCap (%) | +3.0 | +6.2 | +7.0 | 0.0 | -1.4 | -4.0 | 0.0 | +0.85 | +2.9 |
| Thymol | - | - | - | - | - | - | All Passed | | |

## TABLE V

**EXHIBIT "A", MIL-C-39006B, GROUP B TESTS**
**STABILITY AT LOW & HIGH TEMPERATURES**
**AND THERMAL SHOCK (30 CYCLES)**
**47µF - 50 V/30 V, T2 Case (25 CAPACITORS)**

| Electrical Parameter | 25°C Low | 25°C Avg. | 25°C High | -55°C Low | -55°C Avg. | -55°C High | 25°C Low | 25°C Avg. | 25°C High | 85°C Low | 85°C Avg. | 85°C High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cap (µF) | 46.92 | 48.26 | 50.33 | 43.28 | 45.81 | 47.76 | 46.93 | 48.15 | 50.17 | 48.10 | 49.20 | 51.35 |
| DF (%) | 2.1 | 2.9 | 6.0 | - | - | - | 2.1 | 2.6 | 4.6 | 2.3 | 3.4 | 15.5 |
| DCL (µA) | 0.051 | 0.062 | 0.083 | - | - | - | 0.053 | 0.093 | 0.14 | 0.31 | 0.35 | 0.42 |
| Z (Ω) | - | - | - | 28 | 30 | 37 | - | - | - | - | - | - |
| ΔCap (%) | - | - | - | -3.4 | -5.0 | -13.8 | 0.0 | -0.14 | -0.47 | +1.6 | +2.0 | +2.3 |

| Electrical Parameter | 125°C Low | 125°C Avg. | 125°C High | 25°C Low | 25°C Avg. | 25°C High | Thermal Shock -55°C to +125°C 30 Cycles Low | Avg. | High |
|---|---|---|---|---|---|---|---|---|---|
| Cap (µF) | 48.75 | 50.08 | 51.90 | 46.63 | 48.00 | 49.96 | 46.66 | 47.96 | 49.98 |
| DF (%) | 2.6 | 3.4 | 15.5 | 1.9 | 2.8 | 4.8 | 2.1 | 2.4 | 4.8 |
| DCL (µA) | 0.45 | 0.51 | 0.59 | 0.059 | 0.070 | 0.085 | 0.052 | 0.081 | 0.16 |
| ΔCap (%) | +3.5 | +3.8 | +4.2 | 0.0 | -0.53 | -0.84 | +0.04 | -0.09 | -0.31 |
| Thymol | - | - | - | - | - | - | | All Passed | |

## TABLE VI

### EXHIBIT "A", MIL-C-39006B, GROUP B TESTS
### STABILITY AT LOW & HIGH TEMPERATURES
### AND THERMAL SHOCK (30 CYCLES)
### 22µF - 100V/65V, T2 CASE (25 CAPACITORS)

| Electrical | 25°C | | | -55°C | | | 25°C | | | 85°C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Cap (µF) | 22.29 | 24.02 | 25.75 | 21.55 | 22.88 | 24.60 | 22.20 | 23.97 | 25.69 | 22.85 | 24.69 | 26.45 |
| DF (%) | 1.2 | 2.0 | 3.0 | - | - | - | 1.4 | 1.8 | 5.3 | 3.1 | 3.6 | 5.1 |
| DCL (µA) | 0.10 | 0.14 | 0.35 | - | - | - | 0.11 | 0.16 | 0.31 | 1.5 | 1.8 | 2.4 |
| Z (Ω) | - | - | - | 57 | 60 | 65 | - | - | 0 | - | - | - |
| ΔCap (%) | - | - | - | -3.3 | -4.7 | -7.9 | -0.08 | -0.19 | -0.90 | +2.2 | +2.8 | +3.3 |

| | 125°C | | | 25°C | | | Thermal Shock -55°C to +125°C 30 Cycles | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Avg. | High | Low | Avg. | High | Low | Avg. | High |
| Cap (µF) | 24.00 | 25.71 | 27.75 | 22.15 | 23.85 | 25.62 | 21.87 | 23.61 | 25.16 |
| DF (%) | 5.2 | 6.6 | 8.7 | 1.4 | 1.7 | 2.0 | 1.4 | 1.8 | 2.2 |
| DCL (µA) | 1.5 | 1.8 | 2.4 | 0.12 | 0.16 | 0.50 | 0.14 | 0.19 | 0.59 |
| ΔCap (%) | +4.6 | +7.0 | +7.9 | -0.12 | -0.71 | -1.31 | -0.17 | -1.0 | -1.6 |
| Thymol | - | - | - | - | - | - | All Passed | | |

(7) Overall Progress

All requirements of the contract were completed on schedule.

## SECTION 3

## WORK TO BE PERFORMED DURING THE NEXT REPORT PERIOD

Contract completed.

## SECTION 4

## EXPENDITURES AND FORECAST

(1) A total of $53, 700. 00 was expended in performing this contract effort.