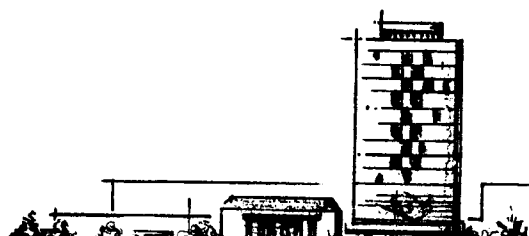
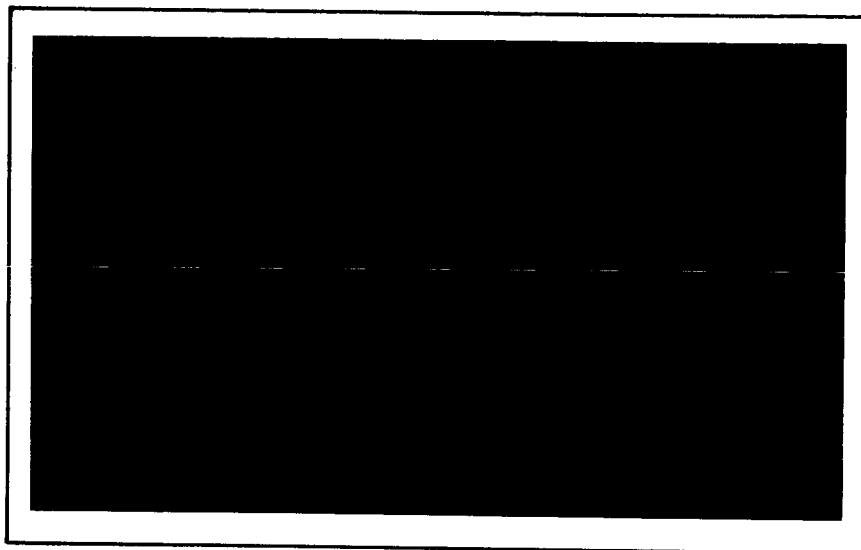


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TWELFTH QUARTERLY REPORT

on

A STUDY OF THE RELIABILITY OF  
ELECTRONIC COMPONENTS IN A NUCLEAR-  
RADIATION ENVIRONMENT

to

JET PROPULSION LABORATORY

January 13, 1966

by

C. L. Hanks and D. J. Hamman

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, pursuant to a sub-contract issued under Prime Contract NAS7-100 between the California Institute of Technology and the United States of America represented by the National Aeronautics and Space Administration.

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A STUDY OF THE RELIABILITY OF  
ELECTRONIC COMPONENTS IN A NUCLEAR-  
RADIATION ENVIRONMENT

by

C. L. Hanks and D. J. Hamman

INTRODUCTION

This is the Twelfth Quarterly Report and the Thirty-Seventh Monthly Progress Report on Contract No. 950458 (File 2998) entitled "A Study of the Reliability of Electronic Components in a Nuclear-Radiation Environment". This report summarizes the project activity from October 1 to December 31, 1965, which has included approximately 1900 hours of additional radiation exposure for the electronic parts in Test Groups III, V, and VI. This makes a total of approximately 9150 hours of exposure since the radiation exposure was initiated. The parameter measurements after 8000 hours of exposure were completed during this period, and those following the completion of 9000 hours of exposure were started at the close of this report period.

PROGRESS SUMMARY

Progress during this report interval has included the following project activities:

1. Completion of the 8000-hour measurements on all component parts in the seven test groups. This is in addition to 100 hours of high-flux radiation for the parts in Test Group IV.

2. Completion of approximately 60 per cent of the 9000-hour measurements of the component parts in the seven test groups.
3. Conversion of the 7000- and 8000-hour data cards as generated by the automatic data-recording system to the requirements of JPL Specification No. ZPP-2090-GEN. Data cards obtained from this conversion were shipped to the sponsor.

#### TECHNICAL DETAILS

Project effort during this report interim was directed toward the continuation of the life tests that include nuclear radiation as an environmental condition and those that serve as control tests and exclude radiation as one of the environments. As a part of this effort, parameter measurements were performed on all test parts when those in the radiation environment had completed 8000 and 9000 hours of radiation exposure. The latter measurements were started at the close of this interim and are incomplete. In addition, computed statistic sheets covering test results through 7000 hours were received from the sponsor.

This section presents various details concerning these activities and the progress that has been made.

#### Measurement Status

Parameter measurements were completed according to schedule on all test groups when the parts in Test Groups III, V, and VI had accumulated 8000 hours of radiation exposure during this report interval. In addition, the measurements after 9000 hours of accumulated radiation exposure were initiated as scheduled during the last week of this report interim but are incomplete at this time.

The data cards generated in the performance of the 8000-hour measurements by the automatic data-recording system were processed with a computer program to obtain data cards in accordance with the format requirements of JPL Specification No. ZPP-2090-GEN. The output cards from this program were shipped to the sponsor.

The conversion of the data cards from the 7000-hour measurements, which were completed at the close of the previous (eleventh) quarterly report period, was also completed during this interim with the output cards being shipped to the sponsor.

### Results

Progress during this report interval has included the completion of 2208 additional hours of operational load for an accumulated total of approximately 11,000 operational hours for all test groups. The component parts in Test Groups III, V, and VI have accumulated a total of 9150 hours of radiation exposure. The 11,000 hours of operational load are in addition to 100 hours of operation and high-flux radiation exposure of the electronic parts in Test Group IV.

Table 1 is a listing of the additional component parts that have indicated failure during this report period. The environmental conditions for the various test groups listed in Table 1 are as follows:

Table 1

Group	Test Conditions
I	100 C, 760 torr, operational
II	100 C, $10^{-5}$ torr, operational
III	100 C, $10^{-5}$ torr, operational <sup>(a)</sup>
IV	100 C, $10^{-5}$ torr, operational <sup>(b)</sup>
V	50 C, $10^{-5}$ torr, operational <sup>(a)</sup>
VI	100 C, $10^{-5}$ torr, static <sup>(a)</sup>
VII	100 C, 760 torr, static

(a) 10,000 hours at  $3 \times 10^5$  n cm<sup>-2</sup> sec<sup>-1</sup>  
and  $1 \times 10^5$  ergs g<sup>-1</sup> (C) hr<sup>-1</sup>

(b) 100 hours at  $3 \times 10^7$  n cm<sup>-2</sup> sec<sup>-1</sup>  
and  $1 \times 10^7$  ergs g<sup>-1</sup> (C) hr<sup>-1</sup>

The following table summarizes the radiation exposure of Test Groups III, V, and VI through 8079.3 hours of exposure. The exposure values listed are averages over the volumes of the capsules occupied by the test specimens. Neutron exposures listed are for fast neutrons only (i.e.,  $E > 0.1$  MeV). These values are based on neutron distributions measured in mockups of the radiation capsules (see the Neutron Dosimetry Section of the Supplement to the First Quarterly Report, May 15, 1963, or the Revised Test Procedure for JPL Test No. 617, Phase II, January 25, 1965) and do not include perturbations due to test components or assembly or time-dependent distribution changes. Postirradiation analysis of in-pile neutron dosimeters will provide more accurate determinations of actual doses received by individual components or groups of components.



Table 2. Approximate Neutron and Gamma Exposures

Irradiation Period, hours	Neutrons (n/cm <sup>2</sup> )		Gamma [ergs/g(c)]	
	Test Group V	Test Groups III and VI	Test Group V	Test Groups III and VI
0 - 250	2.4 x 10 <sup>11</sup>	2.8 x 10 <sup>11</sup>	2.64 x 10 <sup>7</sup>	2.62 x 10 <sup>7</sup>
250 - 500	2.6 x 10 <sup>11</sup>	3.0 x 10 <sup>11</sup>	2.60 x 10 <sup>7</sup>	2.57 x 10 <sup>7</sup>
500 - 1000	3.9 x 10 <sup>11</sup>	4.6 x 10 <sup>11</sup>	5.31 x 10 <sup>7</sup>	5.29 x 10 <sup>7</sup>
1000 - 2000	7.4 x 10 <sup>11</sup>	9.3 x 10 <sup>11</sup>	1.04 x 10 <sup>8</sup>	1.04 x 10 <sup>8</sup>
2000 - 3000	7.5 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	1.12 x 10 <sup>8</sup>	1.12 x 10 <sup>8</sup>
3000 - 4000	7.4 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	1.03 x 10 <sup>8</sup>	1.02 x 10 <sup>8</sup>
4000 - 5000	7.5 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	9.81 x 10 <sup>7</sup>	9.76 x 10 <sup>7</sup>
5000 - 6000	7.4 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	1.06 x 10 <sup>8</sup>	1.05 x 10 <sup>8</sup>
6000 - 7000	7.5 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	1.02 x 10 <sup>8</sup>	1.02 x 10 <sup>8</sup>
7000 - 8000	7.4 x 10 <sup>11</sup>	8.8 x 10 <sup>11</sup>	9.94 x 10 <sup>7</sup>	9.90 x 10 <sup>7</sup>
Total In-Pile*	6.2 x 10 <sup>12</sup>	7.3 x 10 <sup>12</sup>	8.34 x 10 <sup>8</sup>	8.30 x 10 <sup>8</sup>

\*Estimated integrated exposures from experimental startup through BRR (Battelle Research Reactor) Cycle 194, 8079.3 hours of accumulated radiation.

Computed Statistic Sheets

The first results of the computed statistic effort associated with this program were received from the sponsor during the latter part of this program. These results included computed statistics through the 7000-hour measurements such as the minimum, mean, maximum, and standard deviation of each measured parameter for the various part types being tested. The F and T values and the minimum, mean, maximum, and standard deviation of the deviation between measurements of a particular parameter were also included. These data have been scanned briefly, but

insufficient time was available between the receipt of the computed statistics sheets and the end of this report period to process any of these data for this report.

#### FUTURE PLANS

The radiation exposure and operational life tests will be terminated during the next quarterly report interval. The radiation exposure will be discontinued after approximately 9800 hours of total exposure. Data cards from the 9000-hour measurement interval and final measurements will be shipped to the Jet Propulsion Laboratory within one week following the completion of each set of measurements. Work will also be started on the final report during the next quarterly report interval.

Table 3. Identification of Additional Catastrophic Failures

Type of Component	Manufacturer's Part Number	Test Group	Specimen Number	Hours at Failure	Remarks
Capacitor	P323ZN2	III	16	7000	Capacitance and D.F.
"	"	II	58	"	Capacitance and D.F.
Capacitor	683G	III	16	7000	Short
Capacitor	HP56C50D1	I	20	7000	Capacitance and D.F.
"	"	I	33	"	Capacitance and D.F.
Transistor	2N911	IV	62	7000	$h_{FE}$
Transistor	2N914	VI	112	7000	$h_{FE}$
Transistor	2N915	III	01	7000	$h_{FE}$
"	"	III	13	"	$h_{FE}$
Transistor	2N1050	V	81	7000	
"	"	V	83	"	
Transistor	2N861	III	03	7000	$h_{FE}$
"	"	III	08	"	$h_{FE}$
"	"	III	12	"	"
"	"	I	20	"	"
"	"	VI	105	"	"
"	"	VI	108	"	"
"	"	VI	109	"	"
"	"	VII	123	"	"
"	"	VII	133	"	"
Capacitor	P323ZN	III	03	8000	Capacitance and D.F.
"	"	III	11	"	Ditto
"	"	IV	64	"	"
"	"	IV	67	"	"
"	"	VI	102	"	"
"	"	VI	110	"	"
"	"	VI	117	"	"

Table 3. Continued

Type of Component	Manufacturer's Part Number	Test Group	Specimen Number	Hours at Failure	Remarks
Capacitor	HP	I	22	8000	Capacitance and D.F.
"	"	I	35	"	Capacitance and D.F.
Diode	FD1184	IV	63	8000	Leakage
Diode	FD643	I	29	8000	Leakage
"	"	IV	73	"	"
"	"	IV	74	"	"
Diode	1N916	I	32-39	8000	V <sub>F</sub>
"	"	II	41-49	"	"
"	"	II	51-59	"	"
"	"	IV	74	"	"
Transistor	2N914	I	24	8000	H <sub>FE</sub>
"	"	IV	67	"	"
Transistor	2N915	II	51	8000	H <sub>FE</sub>
Transistor	2N1050	I	29	8000	H <sub>FE</sub>
"	"	V	82	"	"
"	"	V	84	"	"
"	"	V	85	"	"
"	"	V	95	"	"
"	"	VI	103	"	"
Transistor	2N2412	III	17	8000	H <sub>FE</sub>
"	"	II	45	"	"
Transistor	2N861	I	37	8000	H <sub>FE</sub>
"	"	I	38	"	"
"	"	II	53	"	"
"	"	VII	137	"	"