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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NO. NAS 5-3481

FINAL REPORT: PRECISION CURRENT LIMITERS

February, 1964

Prepared by: Microlectron, Inc.
1547 - 18th Street
Santa Monica, California

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TITLE: Final Report on the Development of a Complete Range of Current Limiters from 1/32 ampere through 5 amperes having a Slow-Blow Characteristic.

PERIOD COVERED BY REPORT: July 1963 to February 29, 1964

CONTRACT NUMBER: NAS 5-3481

ADMINISTRATION BY: National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

CONTRACTOR: Microelectron, Inc.
1547 - 16th Street
Santa Monica, California

CONTRACT OBJECTIVES:

1. To develop a complete line of special current limiters covering the range from 1/32 ampere to 5 amperes to meet a specification of one second blow time at 200% of rated current.

2. To supply twenty five working units of each of the following current limiter ratings to:

1/32 ampere	3/4 ampere
1/16 ampere	1 ampere
1/8 ampere	1½ ampere
1/4 ampere	2 ampere
3/8 ampere	3 ampere
1/2 ampere	5 ampere

3. To prepare a tentative procurement specification for these slow-blow current limiters.

Written by: D.L. Mitchelson
D. L. Mitchelson, Project Engineer

Approved by: H. C. Grant
H. C. Grant, Chief Engineer

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1.0 ABSTRACT

1.1 Summary

This report covers all the work done under NASA Contract NAS-5-3481. The objective was to develop a complete line of precision current limiters in the range 1/32 ampere to 5 amperes having a blow time of one (1) second at 200% of rated current. The work was divided into four main categories:

Preliminary study	Development
Evaluation testing	Establishment of standards

1.2 Preliminary Study

Theoretical calculations were made to determine what general modifications to current limiter types previously produced by Microlectron, Inc. would be necessary in order to produce the kind of limiter required by this contract. Particular attention was paid to an attempt to decrease the resistance of limiters in each rating category.

1.3 Development

Using the overall device designs resulting from the preliminary study, experimental work was done on each limiter rating to establish individual design requirements for that particular rating.

1.4 Evaluation Testing

The detailed characteristics of the current limiters were determined from a series of tests: Load Life; Stability; Clearing Time; Momentary Overload; Case Temperature.

1.5 Establishment of Standards 26629

The production processes determined by the development work were written into the existing Microlectron process specifications. Quality requirements for the finished product were detailed in a recommended procurement specification which is included as part of this report.

1.6 Contract Results

The contract objectives were met for all rating values with the exception of the 1/32 amp device. Although experimental quantities of 1/32 limiters were produced, the yield was low and the reliability unpredictable. For this reason work on the 1/32 limiter was discontinued. Microlectron will continue development of this device on company funds, and should production feasibility be demonstrated, test data and samples will be forwarded to NASA.

The resistance of the limiters varies from 25.0 ohms for the 1/16 ampere to 0.022 ohms for the 5 ampere. This represents a decrease in circuit resistance from values obtained on NASA Contract Number NAS 5-2780. Microlectron will proceed to manufacture stock quantities of the limiters specified and off-the-shelf deliveries will be obtainable by July, 1964. AUTHOR

2.0 Purpose

2.1 The purpose of this contract was to modify standard Microlectron current limiters to meet a 1 second time to clear at 200% of rated current. The rating categories to be modified are as follows:

1/32 amperes	3/4 amperes
1/16 amperes	1 amperes
1/8 amperes	1 ½ amperes
1/4 amperes	2 amperes
3/8 amperes	3 amperes
1/2 amperes	5 amperes

A further purpose, undertaken by Microlectron, was to write a suggested procurement specification to establish a basis for a military specification for this type of device.

3.0 Conference

3.1 On September 9, 1963, Mr. W. P. Jones of NASA Power Sources Branch, Greenbelt, Maryland, visited Microlectron in Santa Monica to review progress and discuss problems encountered on the contract. Microlectron agreed to run a series of tests to determine the effects of momentary overloads on the limiter characteristic. It was agreed that the tests would be conducted at a 60 cps rate with a 0.125 duty cycle and a peak pulse amplitude of 100% of rated current.

4.0 Narrative and Data

4.1 Design Considerations

The detailed specifications of the limiters to be developed under this contract are to be in every way the same as standard Microlectron limiters except for the one second time to clear specification. This requires the design objectives to be specified in 4.1.1 and 4.1.2.

4.1.1 Electrical Requirements

4.1.1.1 Time to clear: Between 0.4 and 4.0 seconds at 200%.

4.1.1.2 Time-Current Curves: Control points to be established at 200, 300 and 500 percent of rated current in accordance with limiters developed under NASA Contract No. NAS 5-2780.

4.1.1.3 Resistance: To be kept as low as possible.

4.1.1.4 Temperature Coefficient: 2500 parts per million per °C.

4.1.1.5 Load Life Stability: Deviation of voltage drop readings before and after 168 hours load life to be less than ± 5 percent.

4.1.1.6 Momentary Overload: An additional requirement under this contract is that limiters should remain electrically intact after momentary overload tests conducted at 60 cps with a 0.125 duty cycle and a peak pulse amplitude of 200% of rated current.

4.1.2 Mechanical Requirements

4.1.2.1 Configuration: To be as specified by Microlectron Dwg. No. A25041.

4.1.3 Fabrication

The fusible element of a current limiter is manufactured by printing a cermet conductive film on a glass substrate. Silver terminations and cermet element paths are silk screened on the substrate and securely bonded by firing at high temperatures.

4.1.3 Fabrication (Continued)

The fusible element is protected by a glass coating. Wire leads are then soldered onto the silver terminations and the body of the device is encapsulated in an epoxy molding compound. The configuration of a completed current limiter is shown in the appended procurement specification, Microlectron Drawing No. A25041.

The clearing characteristics of a current limiter are dependent on the geometry of the fusible element and its resistance. Thus it is necessary to adjust the resistance of the element to a designated value for each type of limiter before the glass insulator is printed over the element. The special problem of making the necessary resistance measurements during these operations is described in Section 4.3.1.

4.2 Technical Approach

4.2.1 General Design Modification

In the initial stages of the work on this contract, the design of Microlectron standard production current limiters was reviewed to determine what design modifications were required in order to produce a limiter that would meet the objectives of the contract. It was decided that the area of the fusible element film needed increasing slightly.

Test silk screens were made for various modified element areas, and several experimental groups of current limiters were manufactured. From the results of clearing time tests on these limiters, the correct value of element area required to produce a current limiter with the desired characteristics was determined. The particular dimensions selected for the fusible element were adopted as standard for all limiters developed under this contract.

The last stage in general design modification was to determine the resistance versus rating curve for limiters having the modified element geometry. To achieve this, several groups of limiters having element resistances spread in the range 0.020 ohms to 30 ohms were manufactured. The various current ratings of these limiters were determined by measuring their time to clear for different overload currents. A plot of resistance versus rating achieved in this way is shown in Figure 1, together with the similar graph which was projected from the resistance values of the 1/16, 1, and 3 ampere limiters previously manufactured by Microlectron. It will be seen that the resistance

4.2.1 General Design Modification (Continued)

of the newly developed limiters is little changed for limiters at the low current end of the range (1/16, 1/8, 1/4 ampere), but a reduction of up to 30% was achieved towards the higher current end of the range.

4.2.2 Individual Design Modification

Using the resistance versus rating curve described in 4.2.1, the anticipated value of the fusible element of each type of limiter categorized in 2.1 was determined. The bulk of the work performed under this contract was in modifying element material formulation and conducting tests to verify that the resulting limiters possessed the required clear time characteristic. This involved manufacturing test groups of limiters having the anticipated correct resistance and then measuring their rating from the time to clear values. Where necessary, further tests were run to establish production specifications for each device.

When the correct resistance value for each type of limiter was determined and verified, the process specifications for the 1/16 amp, 1 amp and 3 amp limiters were revised to cover the new values.

4.2.3 Development Testing Method

4.2.3.1 Determination of Rating

In order to determine the current rating of a uniform group of limiters they were evenly divided into four sub-groups. The various sub-groups were subjected to different current overloads and the time to clear for each limiter was measured as described

4.3 Problems and Solutions

4.3.1 Resistance Measurements

As the majority of the limiters have resistances under one ohm, measurements had to be made with extreme care in order to maintain measurement accuracy. After considerable experimentation with measurement techniques and devices, the Keithley Model 503, Milliohmmeter was selected as the best instrument for production use. This instrument utilizes a four-terminal measurement technique and has an overall accuracy of ± 2%.

4.3.2 The 5 Amp Limiter

This value was successfully modified with the desired characteristics but during tests made at 120% overload the termination solder melted and was forced through the encapsulant. This problem was solved by the use of a high temperature solder with a melting point in excess of that encountered when operating the device under the abnormal condition of long-term low overload.

4.3.3 The 1/32 Amp Limiter

Difficulty was encountered in modifying the element formulation for the 1/32 amp limiter. Resistance tended to be unstable with consequent low yields and poor reliability and it became apparent that an improved formulation would have to be developed to make this device a production feasibility. As this meant embarking on a more extensive program than that covered by the terms of the contract, no further work was done on this value. Microlectron plans to start this work later in the year and when production feasibility has been demonstrated, sample parts will be forwarded to NASA with supporting test data.

4.4 Description of Tests and Equipment

4.4.1 Resistance Measurements

Two resistance measurement techniques were employed: a four-terminal measurement at low current and the calculation of resistance from voltage drop measurements at rated current.

4.4.1.1 Unloaded Resistance

The instrument used in making the low current measurement was the Keithley Model 503 Milliohmeter. The maximum current applied was 5 milliamperes; maximum dissipation was 9 microwatts. Accuracy of measurement using this apparatus was better than ± 2%.

4.4.1.2 Voltage Drop

A group of limiters to receive voltage drop readings was connected in series to a current-regulated DC power supply which passed rated current through the limiters. A stabilization period of 15 minutes was allowed for the limiters to reach a state of thermal equilibrium. The voltage drop across each limiter was then measured using test probes attached to a Hewlett-Packard digital voltmeter. In making these measurements, the test probes were placed as close to the body of the limiters as possible, in order to eliminate errors due to lead resistance. Also the test probes were of low mass in order to avoid disturbing the thermal equilibrium of the limiter as the measurement was being made. Accuracy of this measurement was within ± 2%. The test circuit is shown in Figure 2.

4.4.2 Load Life

To test electrical stability all limiters were subjected to 168 hours of continuous operation at DC rated current. The limiters in each rating group were connected in series to a DC regulated power supply adjusted to supply rated current. After one hour of operation to allow the limiters to stabilize, voltage drop readings were taken. Readings were again taken at the end of the 168 hour period. Percentage deviation between these readings was less than ± 5% for all rating values. The circuit used for this test was the same as that used for voltage drop readings (See Figure 2).

4.4.3 Clearing Time

The test circuit used is shown in Figure 3 and consists essentially of a 48 volt battery power supply capable of delivering short circuit currents up to 200 amperes for short durations. The battery output was connected to the limiter under test through an ammeter, a mercury switch, and a resistance decade. The clearing time was measured by means of a Hewlett-Packard Model 523C/D Electronic Counter which was started and stopped by the current pulse applied to the limiter.

In operation, the point at which the limiter was to be inserted was first shorted out by a standard resistance equivalent in value to the limiter resistance. The current was then turned on and set to the desired overload value by adjusting the resistance decade. The current was then turned off and the limiter under test substituted for the standard resistance and

4.4.3 Clearing Time (Continued)

The counter re-set to zero. The mercury switch was closed and the current flowed in the circuit until the limiter cleared. The voltage pulse developed across the decade resistance was used as a stop and start signal for the counter so that the final reading on the counter was an exact indication of the limiter time to clear.

4.4.4 Momentary Overload

A quantity of twenty-five (25) current limiters of 1/16 ampere rating was subjected to momentary overload testing for a period of fifty (50) hours. The limiters were connected in series to a pulsed constant current generator with a square current pulse of two (2) milliseconds duration at a 60 cps repitition frequency. The amplitude of the pulse was adjusted to 200 percent of the current rating of the limiters under test.

4.4.5 Case Temperature

Three limiters having the highest voltage drop readings after load life were selected from each rating category for case temperature readings. A West Instrument Corporation Model B surface reading (low mass) thermometer was used in the test. The three limiters selected were connected in series to a power supply and their rated DC current was passed through them. The current was allowed to flow for fifteen (15) minutes to ensure that the limiters had reached their equilibrium temperature. The surface reading thermometer was then used to find and measure the maximum temperature on the case of the limiter. Care was

4.4.5 Case Temperature (Continued)

taken to ensure that the equilibrium temperature was as high as might normally occur. This was done by mounting the limiter by its leads as far from the case as possible in order to reduce heat conduction through the leads. Tests were conducted in still air at 25° C.

4.5 Evaluation of Test Data

4.5.1 Load Life and Stability

Sixty limiters from each rating category underwent load life testing for a period of 168 hours. The voltage drop readings taken before and after load life for each group of limiters are recorded in Tables 1 to 11, together with the calculated percentage deviation between the two readings. Maximum deviation was $\pm$ 5% and the average $\pm$ 2%. The average values of unloaded resistance and resistance under rated current together with calculated percent deviation are shown in Table 13.

4.5.2 Clearing Characteristics

The time-current relationship for values 1/16 ampere to 5 ampere inclusive is shown in the form of an envelope in Figure 4. This envelope shows the spread of clearing time for all ratings. The individual clear time values at each specified overload are shown in Table 12.

4.5.3 Resistance

4.5.3.1 Reduction of Resistance

A considerable reduction in nominal resistance was achieved for all rating groups of limiters other than the 1/8 and 1/16 ampere limiters. The resistance values of the limiters modified under this contract are compared in Figure 1 with the values projected from the 1/16, 1, and 3 ampere limiters developed under contract NAS 5-2780. It was not found possible to reduce the resistance of the 1/8 and 1/16 ampere devices.

4.5.4 Momentary Overload

Current limiter resistance was measured before and after the 200% momentary overload test described in paragraph 4.4.4. There was no change in resistance as a result of these tests and when fired, parts met the clearing time characteristic shown in Figure 4.

4.5.5 Case Temperature

The maximum case temperatures are recorded in Table 13. The range of temperature values was from 35° C. for the 1/16 ampere limiters to 180° C. for the 5 ampere limiters. The readings were taken at a room ambient temperature of 25° C.

4.6 Product Evaluation

4.6.1 Electrical Reliability

The tests conducted on limiters under this and previous contracts have demonstrated that:

Resistance shows no appreciable change as a result of continuous or intermittent loading with currents up to rated value.

Clearing characteristics deviate by no more than $\pm$ 10% of specified current overload for a given time to clear.

Resistance after clearing exceeds 10^5 Megohms.

4.6.2 Mechanical Reliability

Microlectron current limiters of identical physical construction have passed qualification tests to the following specifications:

Temperature range:	-55° C. to $+125^\circ$ C.
Lead strength:	Greater than 2 pounds in an axial direction.
Shock:	100 g for 11 milliseconds
Vibration:	(Operated with rated current)
	5 to 50 cps, 0.4 inch double amplitude.
	50 to 400 cps, 10 g rms
	400 to 3000 cps, 15 g rms.

Acceleration 100 g along each of the six orthogonal axes.

4.6.3 **Price and Delivery**

4.6.3.1 **Price**:

The following prices are common to all types of P300 current limiter:

Quantity:	30-49	50-99	100-499	500-999	1000-4999
Price:	$3.85	$3.81	$3.76	$3.64	$3.59

Quantity:	5000-9999
Price:	$3.55

4.6.3.2 **Delivery**:

It is planned to stock all values from 1/16 amperes to 5 amperes. This will be accomplished over a period of five months ending in July, 1964. Prior to that period, a three-week delivery will apply.

4.6.3.3 **Acceptance Testing**:

All lots will be tested according to Microlectron Specification Number A25043. If requested, two copies of the certified Acceptance Test Data will accompany each shipment of 300 parts or more.

5.0 Conclusions

The work accomplished on this contract demonstrates that a line of limiters with values from 1/16 amp to 5 amps can be manufactured with closely controlled firing characteristics, in line with the values previously developed under NASA Contract Number NAS 5-2780. These limiters are relatively immune to a wide range of environmental conditions, as detailed in the Appendix of this report.

The limiters will not open or degrade when subjected to the overload conditions covered by the area to the left of the firing time envelope shown in Figure 4, and will open for overloads within the area of the curve. In their application as protection devices for power sources, they will not open under transient overloads, but will give power source protection under longer-term overloads which would damage or drain the power sources.

The current limiter is not critical with regard to mounting, but lead length should be held as short as possible to hold circuit resistance at a minimum.

The prime objective of the contract was to modify existing limiter designs to provide a range of values from 1/32 amp to 5 amps. With the exception of the 1/32 amp limiter, this objective has been accomplished. Work on the 1/32 amp device was stopped when it became evident that the existing processes and materials were not capable of producing reasonable production yields or predictable reliability. A research program will be started later this

5.0 Conclusions (Continued)

year on Microlectron funds, and when production feasibility has been demonstrated, sample parts will be forwarded to NASA with the supporting test data.

A second objective was to reduce the overall resistance of the three values previously produced by Microlectron. The resistance of the 1 amp device was reduced by 23%, the 5 amp value by 8% and no reduction on the 1/16 amp device. Other values developed showed reductions in line with the three basic values. It should be noted that resistance reduction in the low current values is less significant than in the high current values. For example, a 23% decrease in resistance at 1 ampere represents a power reduction of 60 milliwatts, while a similar percentage reduction at 1/16 amp represents a power saving of 22 milliwatts.

Microlectron will proceed to build up a stock of all values and off-the-shelf deliveries are scheduled for July, 1964. Up to that time special orders will be supplied on a three-week delivery after receipt of order.

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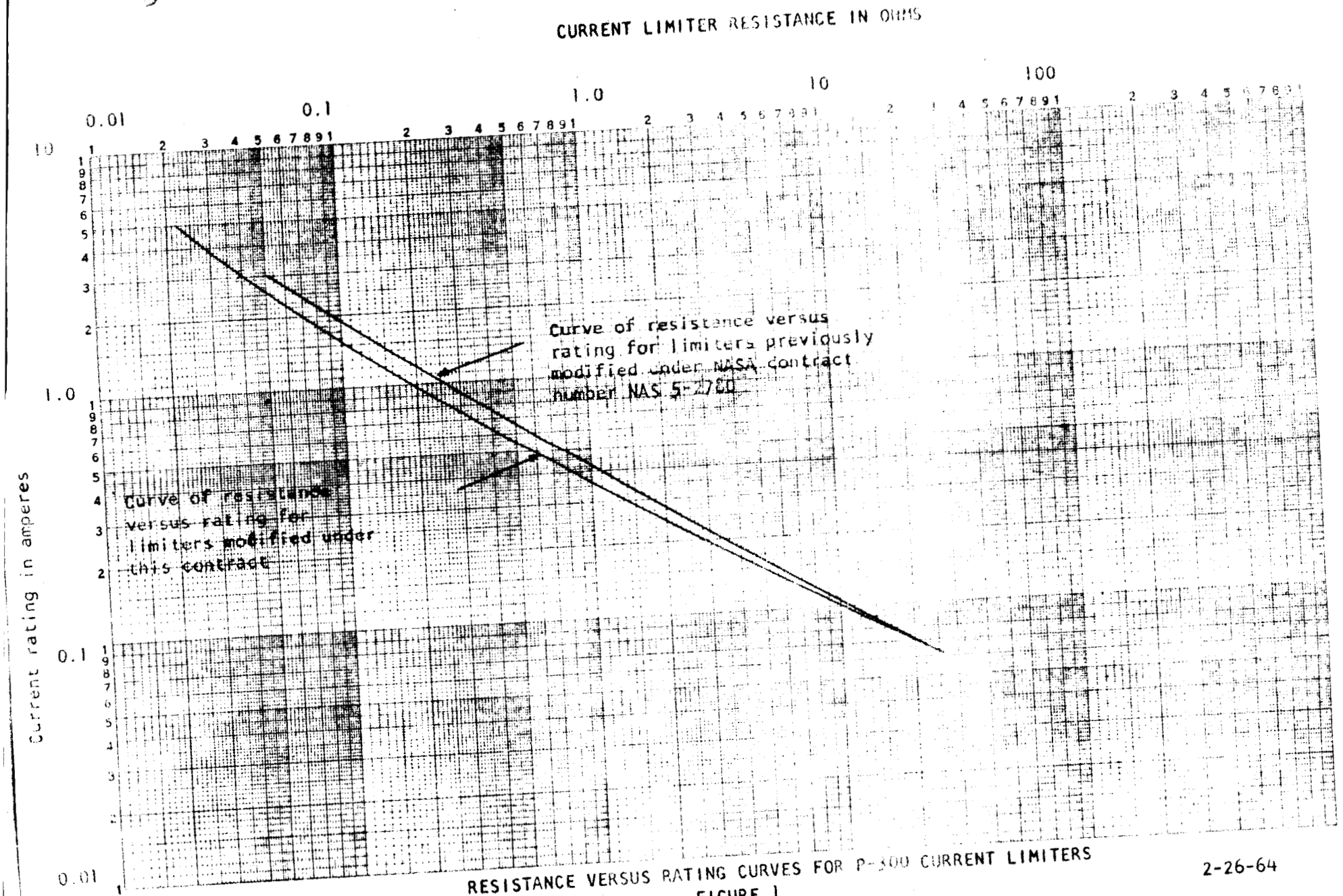

RESISTANCE VERSUS RATING CURVES FOR P-300 CURRENT LIMITERS

FIGURE 1

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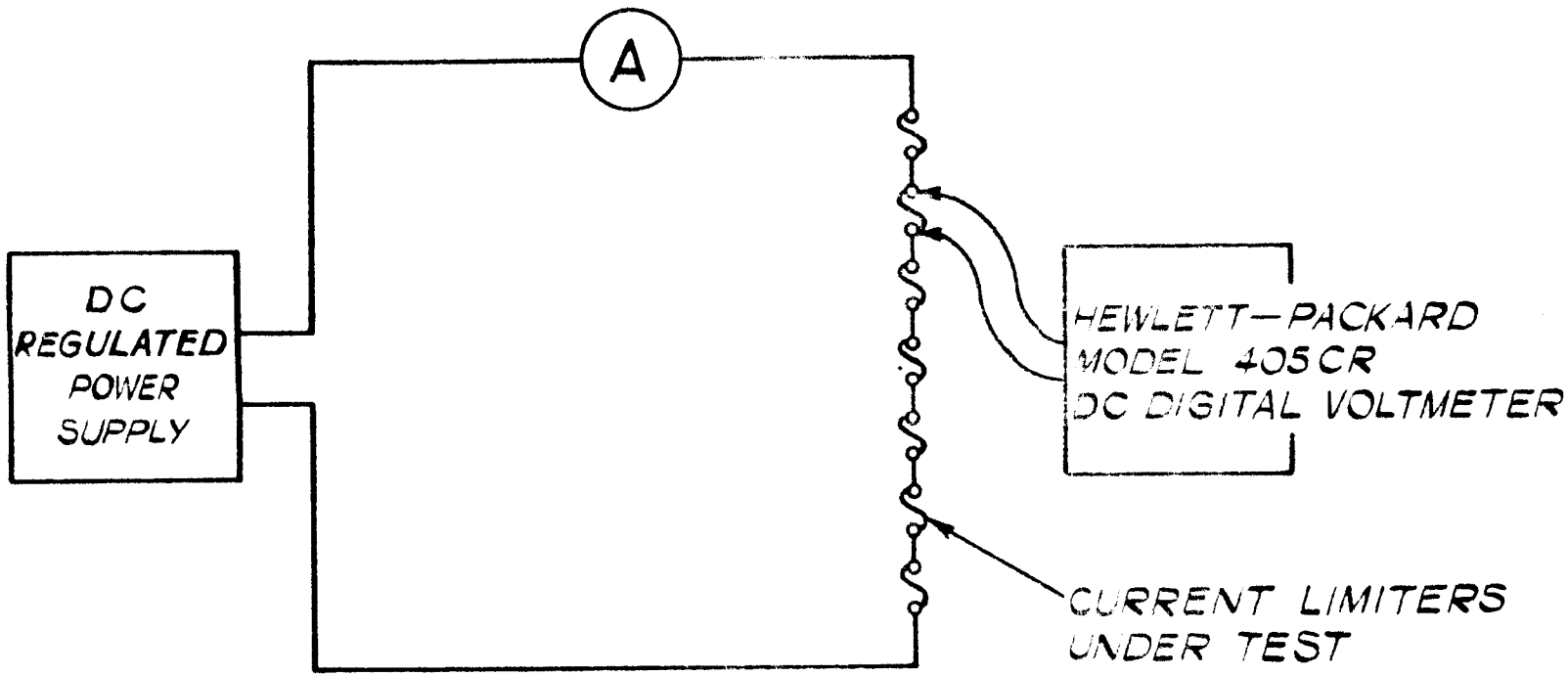

FIGURE 2

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DIMENSIONS IN INCHES

TOLERANCES UNLESS NOTED

2 PLACES	± .010
3 PLACES	± .002
FRACTIONAL	± 1/32
ANGULAR	± 0°30'

CIRCUIT FOR LOAD LIFE AND VOLTAGE DROP READINGS

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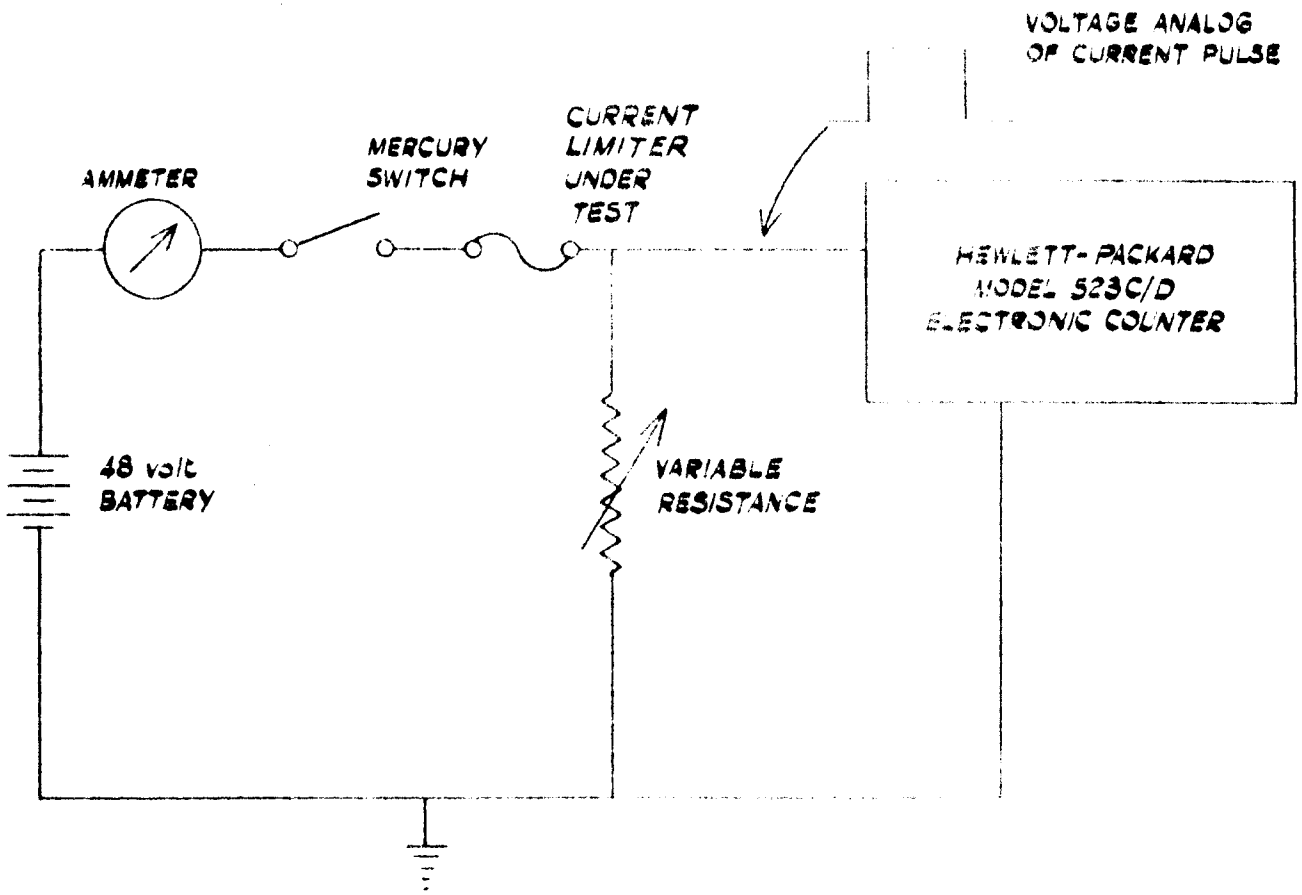

FIGURE 3

REV	DATE	DESCRIPTION	DFT.	CK.	DES.
A	2 26 64	FIRST ISSUE	LINCE		

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DIMENSIONS IN INCHES

TOLERANCES UNLESS NOTED

2 PLACES	± .010
3 PLACES	± .002
FRACTIONAL	± 1/32
ANGULAR	± 0°30'

BLOCK DIAGRAM OF EQUIPMENT USED FOR ESTABLISHING TIME-CURRENT RELATIONSHIP

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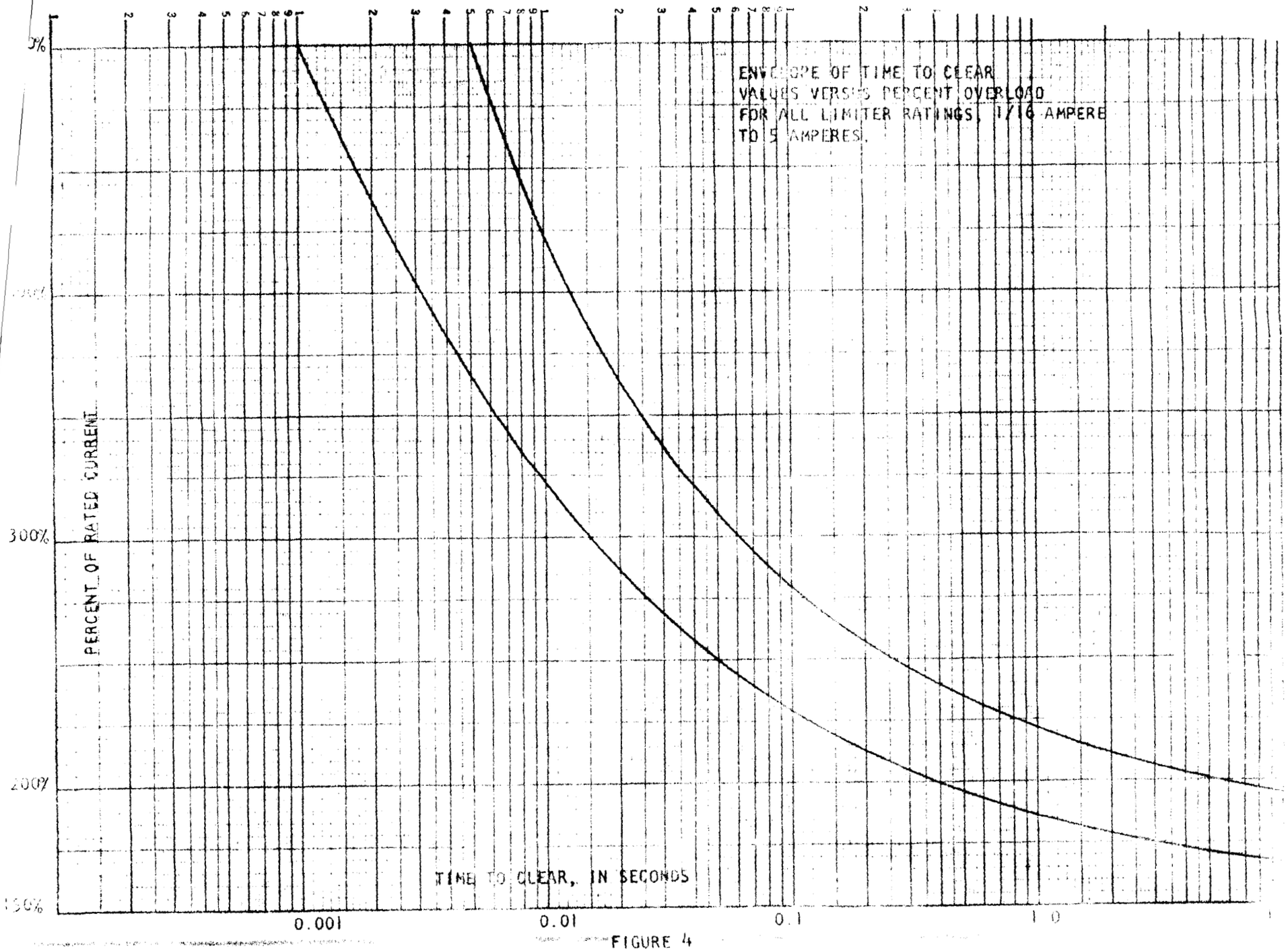
K+E KEUFFEL & ESSER CO.
8 CYCLES X 70 DIVISIONS
ENVELOPE OF TIME TO CLEAR
VALUES VERSUS PERCENT OVERLOAD
FOR ALL LIMITER RATINGS, 1/16 AMPERE
TO 5 AMPERES.
PERCENT OF RATED CURRENT
300%
200%
TIME TO CLEAR, IN SECONDS
0.001
0.01
0.1
1.0

FIGURE 4

TABLE I

Effect of Load Life

1/16 Ampere Limiter

Voltage Drop at 1/16 Ampere

Serial Number	Before Load Life	After Load Life	% Deviation
1	1.71	1.73	+1
2	1.64	1.63	-1
3	1.70	1.73	+2
4	1.64	1.67	+2
5	1.70	1.74	+2
6	1.70	1.73	+2
7	1.74	1.78	+2
8	1.70	1.73	+2
9	1.72	1.72	0
10	1.68	1.61	-4
11	1.60	1.53	-4
12	1.67	1.61	-4
13	1.65	1.59	-4
14	1.[illegible]	1.63	-4
15	1.74	1.77	+2
16	[illegible]	1.[illegible]3	+2
17	1.62	1.64	+1
18	1.77	1.79	+1
19	1.65	1.71	+4
20	1.64	1.69	+3
21	1.61	1.67	+4
22	1.63	1.70	+4
23	1.64	1.64	0
24	1.60	1.59	-1
25	1.[illegible]	1.64	0
26	1.68	1.64	-2
27	1.66	1.68	+1
28	1.55	1.56	+1
29	1.60	1.64	+3
30	1.67	1.72	+3
Averages	1.60	1.61	+1

Engineer D. L. Mitchelson

Date 2/28/64

TABLE 1

Effect of Load Life

1/16 Ampere Limiter

Voltage Drop at 1/16 Ampere

Serial Number	Before Load Life	After Load Life	% Deviation
31	1.66	1.69	±2
32	1.62	1.65	±2
33	1.76	1.73	±2
34	1.55	1.58	±2
35	1.62	1.64	±1
36	1.60	1.63	±2
37	1.54	1.57	±2
38	1.59	1.60	±1
39	1.63	1.67	±3
40	1.61	1.62	±1
41	1.59	1.62	±2
42	1.57	1.62	±1
43	1.69	1.71	±1
44	1.66	1.69	±2
45	1.61	1.61	0
46	1.67	1.66	±1
47	1.63	1.64	±1
48	1.61	1.63	±1
49	1.65	1.65	0
50	1.65	1.67	±1
51	1.78	1.79	±1
52	1.76	1.76	0
53	1.73	1.73	0
54	1.67	1.68	±1
55	1.60	1.62	±1
56	1.65	1.66	±1
57	1.68	1.70	±1
58	1.72	1.73	±1
59	1.66	1.68	±1
60	1.64	1.67	±2
Averages	1.65	1.67	±1

Average Loaded Resistance As Calculated from voltage drop after load life 26.2 ohms.

Engineer_____ Date_____

Microelectron, Inc.

TABLE 2 Sheet 1 of 2

Effect of Load Life 1/8 Ampere Limiter

Serial Number	Voltage Drop At 1/8 Ampere Before Load Life	After Load Life	% Deviation
1	1.11	1.08	-3
2	1.10	1.07	-3
3	1.13	1.10	-3
4	1.10	1.07	-3
5	1.10	1.07	-3
6	1.15	1.11	-4
7	1.14	1.12	-2
8	1.10	1.07	-3
9	1.09	1.06	-3
10	1.09	1.06	-3
11	1.13	1.10	-3
12	1.10	1.07	-3
13	1.11	1.08	-3
14	1.12	1.09	-3
15	1.09	1.08	-1
16	1.08	1.08	0
17	1.13	1.10	-3
18	1.18	1.12	-5
19	1.10	1.05	-5
20	1.10	1.05	-5
21	1.15	1.11	-4
22	1.13	1.08	-5
23	1.10	1.05	-5
24	1.12	1.07	-5
25	1.13	1.08	-5
26	1.10	1.05	-5
27	1.08	1.04	-4
28	1.11	1.09	-2
29	1.11	1.06	-5
30	1.11	1.08	-3
Averages	1.11	1.07	-4

Engineer [illegible] Date 2/27/64

Microlectron, Inc.

TABLE 2 Sheet 2 of 2

Effect of Load Life 1/8 Ampere Limiter

Serial Number	Voltage Drop At 1/8 Ampere Before Load Life	After Load Life	% Deviation
31	1.11	1.06	-5
32	1.10	1.07	-3
33	1.11	1.06	-5
34	1.12	1.11	-1
35	1.28	1.22	-5
36	1.10	1.08	-2
37	1.13	1.10	-3
38	1.14	1.11	-3
39	1.13	1.08	-5
40	1.10	1.07	-3
41	1.11	1.08	-3
42	1.11	1.08	-3
43	1.16	1.12	-4
44	1.13	1.10	-3
45	1.13	1.10	-3
46	1.16	1.12	-4
47	1.10	1.09	-1
48	1.11	1.10	-1
49	1.12	1.12	0
50	1.08	1.07	-1
51	1.11	1.10	-1
52	1.12	1.11	-1
53	1.10	1.09	-1
54	1.10	1.08	-2
55	1.13	1.11	-2
56	1.10	1.09	-1
57	1.11	1.10	-1
58	1.09	1.08	-1
59	1.09	1.09	0
60	1.11	1.09	-2
Averages	1.13	1.09	-4

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life - 8.64 Ohms

Inspector [illegible] Date [illegible]

Microelectron, Inc.

Sheet 1 of 2

TABLE 3

1/4 Ampere Resistor

Effect of Load Life

Serial Number	Voltage Drop At 1/4 Ampere Before Load Life	After Load Life	% Deviation
1	0.773	0.775	0
2	0.722	0.725	0
3	0.755	0.758	-1
4	0.757	0.764	0
5	0.764	0.771	+1
6	0.770	0.783	+2
7	0.793	0.814	+3
8	0.771	0.785	+2
9	0.772	0.783	+2
10	0.774	0.787	+3
11	0.795	0.808	+2
12	0.815	0.834	+2
13	0.766	0.770	+1
14	0.793	0.800	+1
15	0.764	0.766	0
16	0.753	0.765	+2
17	0.749	0.751	0
18	0.747	0.750	0
19	0.777	0.783	+1
20	0.774	0.781	+1
21	0.743	0.741	0
22	0.757	0.779	+3
23	0.763	0.790	+4
24	0.744	0.765	+3
25	0.762	0.768	+1
26	0.779	0.745	-4
27	0.756	0.769	+2
28	0.759	0.772	+2
29	0.762	0.792	+3
30	0.773	0.746	-3
Averages	0.741	0.748	+1

Date 2/27/69

Performer [illegible]

Microlectron, Inc.

Sheet 2 of 2

TABLE 3

1/4 Ampere Limiter

Effect of Load Life

Serial Number	Voltage Drop At 1/4 Ampere Before Load Life	After Load Life	% Deviation
31	0.754	0.761	+1
32	0.811	0.815	+1
33	0.794	0.792	0
34	0.764	0.764	0
35	0.774	0.779	+1
36	0.762	0.766	+1
37	0.765	0.767	0
38	0.777	0.777	0
39	0.793	0.789	0
40	0.758	0.779	+3
41	0.773	0.768	-1
42	0.770	0.761	-1
43	0.765	0.760	-1
44	0.759	0.752	-1
45	0.791	0.783	-1
46	0.787	0.787	+1
47	0.772	0.777	0
48	0.776	0.782	+1
49	0.765	0.775	+1
50	0.782	0.787	+1
51	0.780	0.789	+1
52	0.817	0.828	+1
53	0.786	0.832	-6
54	0.772	0.779	+1
55	0.758	0.766	+1
56	0.785	0.793	+1
57	0.794	0.792	0
58	0.765	0.767	0
59	0.782	0.786	+1
60	0.770	0.768	0
Averages	0.777	0.781	+1

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life - 3.14 Ohms

Date 2/27/64

Signature

TABLE 4 Sheet 2 of 2

Effect of Load Life 3/8 Ampere Limiter

Serial Number	Voltage Drop At 3/8 Ampere Before Load Life	After Load Life	% Deviation
31	0.505	0.509	+1
32	0.512	0.514	0
33	0.505	0.508	0
34	0.500	0.503	+1
35	0.506	0.509	+1
36	0.509	0.513	+1
37	0.497	0.500	+1
38	0.611	0.615	+1
39	0.545	0.546	0
40	0.496	0.498	0
41	0.500	0.500	0
42	0.505	0.506	0
43	0.500	0.500	0
44	0.505	0.506	0
45	0.494	0.495	0
46	0.495	0.498	+1
47	0.500	0.502	0
48	0.502	0.503	0
49	0.501	0.503	0
50	0.506	0.508	0
51	0.493	0.494	0
52	0.517	0.517	0
53	0.501	0.501	0
54	0.495	0.496	0
55	0.499	0.500	0
56	0.526	0.528	0
57	0.537	0.539	0
58	0.531	0.528	-1
59	0.509	0.519	+2
60	0.498	0.504	+1
Averages	0.510	0.512	0

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life - 1.36 Ohms

TABLE 4 Sheet 1 of 2

3/8 Ampere Limiter

Effect of Load Life

Sample Number	Voltage Drop At 3/8 Ampere Before Load Life	After Load Life	% Deviation
1	0.495	0.506	+2
2	0.503	0.514	+2
3	0.505	0.515	+2
4	0.508	0.519	+2
5	0.506	0.519	+2
6	0.511	0.517	+2
7	0.502	0.521	+2
8	0.501	0.514	+2
9	0.499	0.512	+2
10	0.501	0.510	+2
11	0.506	0.511	+2
12	0.490	0.516	+3
13	0.505	0.504	+5
14	0.488	0.530	+2
15	0.488	0.498	+2
16	0.495	0.498	+2
17	0.483	0.503	+2
18	0.489	0.492	+2
19	0.475	0.498	+2
20	0.482	0.486	+2
21	0.523	0.492	+2
22	0.490	0.534	+2
23	0.514	0.499	+2
24	0.506	0.523	+2
25	0.506	0.518	+2
26	0.482	0.516	0
27	0.512	0.484	0
28	0.526	0.515	0
29	0.504	0.529	0
30		0.506	
Average	0.500	0.507	+2

TABLE 5

Effect of Load Life

1/2 Ampere Limiter

Voltage Drop At 1/2 Ampere

Serial Number	Before Load Life	After Load Life	Δ Deviation
1	0.448	0.451	+1
2	0.407	0.409	0
3	0.413	0.413	0
4	0.433	0.416	-4
5	0.466	0.482	+3
6	0.416	0.410	-1
7	0.409	0.403	-1
8	0.410	[illegible]	0
9	[illegible]	[illegible]	0
10	0.455	[illegible]	+1
11	0.414	0.418	+1
12	0.413	0.413	0
13	0.468	0.482	+3
14	0.403	0.401	-0
15	0.410	0.405	-1
16	0.420	0.421	0
17	0.429	0.429	0
18	0.435	0.437	0
19	0.462	0.470	+3
20	0.419	0.424	+1
21	0.426	0.431	+1
22	0.413	0.415	0
23	0.419	0.423	+1
24	0.427	0.432	+1
25	0.415	0.424	+1
26	0.416	0.427	+2
27	0.408	0.409	0
28	0.413	0.417	+1
29	0.414	0.416	0
30	0.425	0.427	0
Averages	0.424	0.426	0

Engineer D. L. Mitchelson

Date 2/28/64

Table 5

1/2 Ampere Limiter

Effect of Load Life

Serial Number	Voltage Drop At 1/2 Ampere: Before Load Life	After Load Life	% Deviation
31	0.414	0.420	+1
32	0.413	0.417	+1
33	0.422	0.426	+1
34	0.416	0.420	+1
35	0.417	0.413	0
36	0.400	0.403	+1
37	0.402	0.405	+1
38	0.405	0.407	+1
39	0.412	0.414	+1
40	0.424	0.427	+1
41	0.416	[illegible]	+1
42	0.397	[illegible]	+1
43	0.395	[illegible]	+1
44	0.406	0.411	-1
45	0.410	0.412	+2
46	0.407	0.415	0
47	0.416	0.420	+2
48	0.421	0.428	+4
49	0.461	0.476	+1
50	0.423	0.427	+1
51	0.415	0.417	0
52	0.427	[illegible]	0
53	0.407	[illegible]	0
54	0.405	0.404	0
55	0.404	0.402	-0
56	0.413	0.411	-1
57	0.401	0.398	-1
58	0.401	0.399	0
59	0.404	0.402	-1
60	0.401	0.398	+1
Averages	0.412	0.414	

Average Loaded Resistance As Calculated from voltage drop after load life 0.840 ohms.

Date 2/27/64

Engineer D.L. Mitchelson

TABLE 6

Effect of Load Life

3/4 Ampere Limiter

Voltage Drop at 3/4 Ampere

Serial Number	Before Load Life	After Load Life	% Deviation
1	0.281	0.285	+2
2	0.342	0.350	+2
3	0.281	0.279	-1
4	0.269	0.266	-1
5	0.264	0.265	0
6	0.280	0.277	-1
7	0.288	0.288	0
8	0.309	0.307	-1
9	0.309	0.315	+2
10	0.281	0.283	+1
11	0.294	0.290	-2
12	0.292	0.297	+2
13	0.287	0.287	0
14	0.305	0.304	0
15	0.281	0.280	0
16	0.296	0.304	+3
17	0.319	0.353	+10
18	0.298	0.299	+1
19	0.333	0.346	+4
20	0.292	0.302	+3
21	0.284	0.284	0
22	0.334	0.337	+1
23	0.284	0.287	+1
24	0.288	0.281	-3
25	0.302	0.312	+3
26	0.290	0.294	+1
27	0.291	0.299	+3
28	0.308	0.308	0
29	0.313	0.315	+1
30	0.305	0.307	+1
Averages	0.297	0.300	+1

Engineer D.L. Mitchelson

Date 2/28/64

TABLE 6

Effect of Load Life

3/4 Ampere Limiter

Voltage Drop At 3/4 Ampere

Serial Number	Before Load Life	After Load Life	% Deviation
31	0.300	0.304	+1
32	0.290	0.287	-1
33	0.294	0.292	-1
34	0.293	0.302	+3
35	0.285	0.281	-1
36	0.299	0.311	+4
37	0.292	0.289	-1
38	0.293	0.291	-1
39	0.291	0.289	-1
40	0.310	0.316	+2
41	0.299	0.286	-4
42	0.280	0.275	-2
43	0.291	0.304	+4
44	0.311	0.319	+3
45	0.297	0.306	+4
46	0.281	0.284	+1
47	0.293	0.303	+3
48	0.281	0.285	+1
49	0.307	0.318	+4
50	0.294	0.308	+5
51	0.292	0.299	+2
52	0.287	0.294	+2
53	0.300	0.309	+3
54	0.301	0.315	+5
55	0.289	0.301	+4
56	0.291	0.294	+1
57	0.294	0.297	+1
58	0.285	0.283	-1
59	0.299	0.286	-4
60	0.293	0.302	+3
Averages	0.293	0.297	+1

Average Loaded Resistance As Calculated from voltage drop after load life 0.397 ohms.

Engineer D. L. Mitchelson

Date 2/28/64

Microelectron, Inc.

TABLE 7 Sheet 1 of 2

Effect of Load Life 1 Ampere Limiter

Voltage Drop At 1 Ampere

Serial Number	Before Load Life	After Load Life	% Deviation
1	0.287	0.282	-2
2	0.261	0.253	-3
3	0.277	0.271	-2
4	0.263	0.258	-2
5	0.281	0.275	-2
6	0.270	0.267	-3
7	0.272	0.265	-3
8	0.282	0.277	-2
9	0.268	0.262	-2
10	0.281	0.272	-3
11	0.275	0.268	-2
12	0.272	0.268	-2
13	0.279	0.270	-3
14	0.275	0.267	-3
15	0.278	0.270	-3
16	0.279	0.271	-3
17	0.274	0.265	-3
18	0.268	0.263	-2
19	0.275	0.270	-2
20	0.288	0.284	-1
21	0.282	0.274	-3
22	0.274	0.267	-3
23	0.268	0.265	-1
24	0.261	0.261	0
25	0.268	0.266	-1
26	0.274	0.262	-3
27	0.272	0.267	-2
28	0.280	0.272	-3
29	0.292	0.284	-3
30	0.283	0.277	-2
Averages	0.276	0.268	-3

Engineer DL Mitchelson Date 2/27/64

TABLE 7 Sheet 2 of 2

Effect of Load Life 1 Ampere Limiter

Serial Number	Voltage Drop At 1 Ampere Before Load Life	After Load Life	% Deviation
31	0.272	0.264	-3
32	0.280	0.272	-3
33	0.267	0.260	-3
34	0.274	0.266	-3
35	0.273	0.266	-2
36	0.287	0.279	-3
37	0.267	0.260	-2
38	0.287	0.280	-2
39	0.273	0.264	-3
40	0.270	0.262	-3
41	0.282	0.274	-2
42	0.269	0.260	-3
43	0.278	0.270	-3
44	0.305	0.295	-3
45	0.282	0.273	-3
46	0.287	0.277	-3
47	0.290	0.280	-3
48	0.298	0.299	0
49	0.289	0.294	+2
50	0.267	0.269	+1
51	0.277	0.279	+1
52	0.271	0.275	+1
53	0.270	0.272	+1
54	0.290	0.289	0
55	0.301	0.304	0
56	0.280	0.281	0
57	0.302	0.302	00
58	0.300	0.302	+1
59	0.286	0.289	+1
60	0.271	0.272	0
Averages	0.281	0.278	-1

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life - 0.27 Ohms

Engineer Date

TABLE 8 Sheet 1 of 2

Effect of Lead Life 1½ Ampere Limiter

Serial Number	Voltage Drop At 1½ Ampere Before Lead Life	After Lead Life	% Deviation
1	0.197	0.199	+1
2	0.204	0.204	0
3	0.199	0.199	0
4	0.196	0.196	0
5	0.202	0.201	-1
6	0.196	0.196	0
7	0.200	0.202	+1
8	0.191	0.191	0
9	0.199	0.199	0
10	0.193	0.192	-1
11	0.197	0.197	0
12	0.199	0.199	0
13	0.197	0.197	0
14	0.197	0.197	0
15	0.195	0.195	0
16	0.210	0.210	0
17	0.206	0.207	+1
18	0.201	0.202	+1
19	0.199	0.200	+1
20	0.193	0.193	0
21	0.197	0.197	0
22	0.198	0.197	-1
23	0.196	0.197	+1
24	0.207	0.206	-1
25	0.198	0.199	+1
26	0.195	0.195	0
27	0.196	0.196	0
28	0.192	0.192	0
29	0.203	0.202	-1
30	0.191	0.189	-1
Averages	0.198	0.198	0

Engineer [illegible] Date [illegible]

TABLE 8 Sheet 2 of 2

Effect of Load Life 1½ Ampere Limiter

Serial Number	Voltage Drop At 1½ Ampere Before Load Life	After Load Life	% Deviation
31	0.195	0.194	-1
32	0.199	0.199	0
33	0.219	0.220	+1
34	0.192	0.192	0
35	0.203	0.202	-1
36	0.203	0.202	-1
37	0.209	0.209	0
38	0.198	0.197	-1
39	0.200	0.199	-1
40	0.204	0.204	0
41	0.199	0.198	-1
42	0.199	0.196	0
43	0.219	0.220	+1
44	0.207	0.207	0
45	0.205	0.203	-1
46	0.205	0.204	-1
47	0.200	0.199	-1
48	0.189	0.192	+1
49	0.199	0.200	+1
50	0.190	0.190	0
51	0.195	0.195	0
52	0.199	0.199	0
53	0.213	0.213	0
54	0.203	0.206	+1
55	0.195	0.196	+1
56	0.200	0.202	+1
57	0.201	0.203	+1
58	0.194	0.195	+1
59	0.191	0.192	+1
60	0.211	0.213	+1
Averages	0.199	0.199	0

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life = 0.134 Ohms

Engineer Date

Microelectron, Inc.

TABLE 9 Sheet 1 of 2

Effect of Load Life 2 Ampere Limiter

Serial Number	Voltage Drop At 2 Ampere Before Load Life	After Load Life	% Deviation
1	0.192	0.185	-4
2	0.179	0.172	-4
3	0.185	0.179	-3
4	0.191	0.183	-4
5	0.196	0.188	-4
6	0.191	0.185	-3
7	0.192	0.185	-4
8	0.193	0.184	-4
9	0.192	0.186	-3
10	0.201	0.193	-4
11	0.208	0.201	-3
12	0.195	0.189	-3
13	0.199	0.194	-3
14	0.196	0.189	-3
15	0.207	0.200	-3
16	0.198	0.192	-3
17	0.199	0.194	-2
18	0.190	0.188	-1
19	0.193	0.189	-2
20	0.193	0.188	-2
21	0.206	0.201	-2
22	0.189	0.184	-2
23	0.191	0.186	-2
24	0.191	0.187	-2
25	0.193	0.189	-2
26	0.203	0.199	-2
27	0.202	0.197	-2
28	0.195	0.191	-2
29	0.207	0.201	-3
30	0.196	0.192	-2
Averages	0.196	0.190	-3

Engineer [illegible] Date 2/27/94

Microelectron, Inc.

Sheet 2 of 2

TABLE 9

2 Ampere Limiter

Effect of Load Life

Serial Number	Voltage Drop At 2 Ampere Before Load Life	After Load Life	% Deviation
31	0.196	0.191	-2
32	0.197	0.193	-2
33	0.199	0.194	-2
34	0.204	0.193	-3
35	0.202	0.196	-3
36	0.196	0.191	-3
37	0.187	0.181	-2
38	0.186	0.182	-2
39	0.185	0.180	-3
40	0.189	0.183	-2
41	0.190	0.186	-3
42	0.191	0.185	-2
43	0.193	0.188	-3
44	0.195	0.189	-3
45	0.195	0.189	-3
46	0.202	0.196	-4
47	0.203	0.195	-3
48	0.205	0.199	-3
49	0.195	0.189	-3
50	0.202	0.196	-2
51	0.206	0.201	-2
52	0.196	0.192	-3
53	0.206	0.199	-3
54	0.195	0.189	-3
55	0.205	0.199	-4
56	0.193	0.184	-3
57	0.187	0.181	-3
58	0.187	0.180	-2
59	0.188	0.184	-3
60	0.190		
Averages	0.196	0.190	-3

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life - 0.095 Ohms

Date 2/27/64

Engineer

TABLE 10 Sheet 1 of 2

Effect of Load Life 3 Ampere Limiter

Serial Number	Voltage Drop At 3 Ampere Before Load Life	After Load Life	% Deviation
1	0.182	0.180	-1
2	0.179	0.176	-2
3	0.181	0.178	-1
4	0.180	0.179	0
5	0.182	0.179	-1
6	0.178	0.177	0
7	0.183	0.181	-1
8	0.177	0.175	-1
9	0.182	0.180	-1
10	0.181	0.179	-1
11	0.180	0.176	-2
12	0.176	0.173	-2
13	0.182	0.179	-1
14	0.175	0.174	0
15	0.174	0.174	0
16	0.184	0.179	-3
17	0.177	0.177	0
18	0.184	0.182	-1
19	0.175	0.172	-2
20	0.177	0.175	-1
21	0.180	0.179	0
22	0.183	0.181	-1
23	0.175	0.175	0
24	0.179	0.177	-1
25	0.189	0.188	0
26	0.189	0.189	0
27	0.184	0.184	0
28	0.184	0.184	0
29	0.180	0.178	-1
30	0.178	0.176	-1
Averages	0.180	0.179	0

Engineer DL Mitchell Date 2/27/64

[illegible] Inc.

Sheet 2 of 2

TABLE 10

3 Ampere Limiter

Effect of Load Life

Serial Number	Voltage Drop Lt 3 Ampere: Before Load Life	After Load Life	% Deviation
31	0.177	0.177	0
32	0.178	0.176	-1
33	0.182	0.181	0
34	0.187	0.185	-1
35	0.183	0.182	0
36	0.185	0.184	0
37	0.179	0.178	0
38	0.173	0.172	0
39	0.179	0.179	0
40	0.186	0.185	0
41	0.181	0.180	0
42	0.179	0.178	-2
43	0.179	0.175	-2
44	0.180	0.177	-1
45	0.182	0.180	0
46	0.181	0.181	-1
47	0.182	0.180	0
48	0.179	0.178	-1
49	0.177	0.175	0
50	0.176	0.175	0
51	0.183	0.182	0
52	0.172	0.172	0
53	0.182	0.181	0
54	0.175	0.174	-1
55	0.179	0.177	-2
56	0.178	0.174	-2
57	0.182	0.178	-1
58	0.182	0.180	-2
59	0.179	0.176	0
60	0.171	0.171	
Averages	0.179	0.178	0

Average Loaded Resistance As Calculated from

Voltage Drop After Load Life -0.059 Ohms

[illegible] 2/22/64

TABLE II

5 Ampere Limiter

Effect of Load Life

Voltage Drop At 5 Amperes

Serial Number	Before Load Life	After Load Life	% Deviation
1	0.160	0.162	+1
2	0.156	0.160	+3
3	0.155	0.155	0
4	0.152	0.149	-2
5	0.165	0.160	-3
6	0.153	0.158	+3
7	0.154	0.162	-1
8	0.151	0.154	+2
9	0.159	0.159	0
10	0.151	0.157	+4
11	0.151	0.155	+2
12	[illegible]	0.151	+5
13	0.158	0.147	-3
14	0.146	0.153	+5
15	0.147	0.150	+2
16	0.145	0.141	-3
17	0.144	0.143	-1
18	0.153	0.154	+1
19	0.153	0.146	-5
20	0.150	0.148	-1
21	0.155	0.154	-1
22	0.147	0.145	-1
23	0.146	0.143	-2
24	0.148	0.140	-5
25	0.151	0.143	-5
26	0.146	0.146	0
27	0.145	0.147	+1
28	0.153	0.147	-4
29	0.143	0.143	0
30	0.153	0.145	-5
Averages	0.151	0.151	0

Engineer D L Mitchelson

Date 2/28/64

TABLE II

Effect Of Load Life

5 Ampere Limiter

Voltage Drop At 5 Amperes

Serial Number	Before Load Life	After Load Life	% Deviation
31	0.168	0.163	-3
32	0.153	0.150	-2
33	0.157	0.153	-3
34	0.148	0.154	+3
35	0.156	0.152	-3
36	0.147	0.155	+5
37	0.161	0.156	-3
38	0.151	0.152	+1
39	0.150	0.153	+2
40	0.155	0.161	+4
41	0.156	0.157	+1
42	0.154	0.159	+3
43	0.154	0.159	+3
44	0.155	0.161	+4
45	0.147	0.153	+4
46	0.151	0.159	+5
47	0.159	0.153	-4
48	0.149	0.146	-2
49	0.162	0.157	-3
50	0.160	0.160	0
51	0.156	0.162	+4
52	0.158	0.161	+2
53	0.160	0.156	-3
54	0.159	0.162	+2
55	0.162	0.160	-1
56	0.164	0.162	-1
57	0. 60	0.161	+1
58	0.157	0.155	-1
59	0.150	0.148	-1
60	0.153	0.154	+1
Averages	0.156	0.156	0

Average Loaded Resistance As Calculated rom voltage drop after load life 0.031 ohms.

Engineer D.L. Mitchelson

Date 2/28/64

TABLE 12

CLEARING CHARACTERISTICS FOR ALL RATINGS P-300 LIMITER

RANGE OF CLEAR TIME VALUES IN SECONDS AT

RATING AMPS	200% OVERLOAD	300% OVERLOAD	500% OVERLOAD
1/16	0.4 to 4.0	0.020 to 0.05	0.002 to 0.005
1/8	0.4 to 4.0	0.030 to 0.05	0.002 to 0.005
1/4	0.4 to 1.8	0.015 to 0.04	0.003 to 0.005
3/8	0.5 to 2.0	0.030 to 0.05	0.003 to 0.005
1/2	0.4 to 1.[illegible]	0.020 to 0.05	0.002 to 0.003
3/4	0.5 to 1.1	0.016 to 0.05	0.001 to 0.003
1	0.5 to 2.2	0.01[illegible] to 0.03	0.002 to 0.004
1-1/2	0.4 to 1.0	0.020 to 0.05	0.001 to 0.003
2	0.[illegible] to 1.8	0.020 to 0.04	0.002 to 0.005
3	0.[illegible] to 4.0	0.050 to 0.05	0.004 to 0.005
5	0.4 to 4.0	0.020 to 0.05	0.002 to 0.005

ENGINEER D.L. Robbins

DATE 2/25/64

TABLE 13

CASE TEMPERATURE AND PERCENT dR FROM UNLOADED TO LOADED RESISTANCE

RATING (AMPS)	UNLOADED RESISTANCE (OHMS)	RESISTANCE AT RATED CURRENT (OHMS)	PERCENT RESISTANCE INCREASE	MAXIMUM CASE TEMPERATURE
1/16	25.0	26.2	+5	35°C
1/8	7.50	8.64	+14	40°C
1/4	2.50	3.14	+25	42°C
3/8	1.00	1.26	+26	45°C
1/2	.650	.840	+29	47°C
3/4	.300	.397	+32	49°C
1	.200	.274	+37	52°C
1-1/2	.100	.134	+34	57°C
2	.070	.095	+36	70°C
3	.045	.059	+33	94°C
5	.022	.031	+40	180°C

ENGINEER D L Mitchelson

DATE 2/28/64

APPENDIX TO FINAL REPORT

ON NASA CONTRACT NO. NAS-53481

RECOMMENDED PROCUREMENT SPECIFICATION

FOR PRECISION CURRENT LIMITERS

MICROLECTRON SPECIFICATION NO. A 25043

Prepared By: MICROLECTRON, INC.
1547 18th Street
Santa Monica, California

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MICROLECTRON DRAWING NO. A 25041

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TABLE II	GROUP A ACCEPTANCE TESTS
TABLE III	GROUP B ACCEPTANCE TESTS
TABLE IV	SAMPLING FOR GROUP B ACCEPTANCE TESTS
TABLE V	CLEARING CHARACTERISTICS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROCUREMENT SPECIFICATION FOR CURRENT LIMITERS

1.0 SCOPE

1.1 This procurement specification covers instrument and power type current limiters designed for the protection of electrical and electronic equipment and is required for components for which no military or governmental specification has been issued.

1.2 CLASSIFICATION

1.2.1 STYLE. All current limiters furnished under this specification shall be designated by the style number P-500.

1.2.2 RATING. All current limiters furnished under this specification shall have a voltage rating of 32 volts. The current rating shall be in one of the following categories:

1/32 amp	3/4 amp
1/16 amp	1 amp
1/8 amp	1-1/2 amp
1/4 amp	2 amp
3/8 amp	3 amp
1/2 amp	5 amp

2.0 APPLICABLE DOCUMENTS

2.1 MILITARY SPECIFICATIONS

MIL-I-10	Insulating Materials, Electrical, Ceramic, Class L
MIL-3861	Wire Leads
MIL-STD-1056	AQL Sampling Plan

These documents, of the latest issue in effect, form a part of this procurement specification only to the extent specified herein. In the event of any conflict between the documents listed and this procurement specification, the latter shall govern.

3.0 REQUIREMENTS

3.1 QUALIFICATION. Current limiters furnished under this specification shall be a product which has passed the qualification tests specified in the test paragraphs listed in Table I to the satisfaction of the requirements herein.

3.2 MATERIAL. The material for each part shall be as specified herein. When a definite material is not specified, a suitable material shall be used. Acceptance or approval of any constituent material shall not be construed as a guaranty of the finished product.

3.2.1 CASE OR BODY MATERIAL. Current limiters shall have case of stycast epoxy or an equivalent material meeting the overall requirements of this specification.

3.2.2 CURRENT CARRYING PARTS. (Except current limiter element). Current carrying parts shall be of brass, copper, phosphor bronze, silver, beryllium copper, or weldable alloys.

3.2.3 NON-CURRENT CARRYING PARTS. All metal non-current carrying parts shall be of corrosion resistant material, or material adequately protected against corrosion.

3.3 DESIGN AND CONSTRUCTION. Current limiters shall be of the design, construction and physical dimensions specified in Microlectron Drawing No. A-25041.

3.3.1 FUSIBLE ELEMENTS. When more than one fusible element is used in parallel to provide required capacity, all elements shall be of the same rating, composition, and resistance.

3.3.2 LEAD WIRES. Where lead wires are used, they shall be of the length and gauge specified in Microlectron Drawing No. A-25041. Unless otherwise specified, lead wires shall be hot tin dipped.

3.4 VOLTAGE RATING. The voltage rating is the maximum nominal direct current or the peak alternating current voltage for which a current limiter is designed. The voltage rating shall be 32 volts.

3.5 CURRENT RATING. The current rating is the nominal amount of current a current limiter will carry indefinitely without blowing. The current rating shall be as specified in Microlectron Drawing No. A-25041.

3.6 RESISTANCE.

3.6.1 RESISTANCE BEFORE CLEARING. When measured as specified in 4.5.2, current limiter resistance shall be as specified in Microlectron Drawing No. A-25041.

3.6.2 RESISTANCE DEVIATION. When measured as specified in 4.5.2, the deviation between the first and last resistance measurement of all qualification tests shall not exceed ±10%.

3.6.3 RESISTANCE AFTER CLEARING. When measured as specified in 4.5.6, resistance after clearing shall be 10 megohms or greater.

3.7 TEMPERATURE COEFFICIENT OF RESISTANCE. When measured as specified in 4.5.3, temperature coefficient of resistance shall not exceed 2500 p.p.m/°C.

3.8 DIELECTRIC STRENGTH. When tested as specified in 4.5.10 and 4.5.10.1, current limiters shall not show any signs of damage, arcing, or breakdown.

3.9 CURRENT CARRYING CAPACITY

3.9.1 LOAD LIFE. Current limiters shall undergo a period of 168 hours load life testing at rated current with resistance measurements made at start and finish of test. (see 4.5.4)

3.9.2 DAMAGE. Current limiters shall show no evidence of mechanical damage or failure nor shall the case, body or terminal temperature rise more than 180°C above ambient air temperature at any time when the limiters are tested as specified in 4.5.4.

3.9.3 STABILITY. Current limiters shall show a resistance deviation of less than ± 10 percent between resistance after temperature stabilization and resistance after 168 hours load life, when measured as specified in 4.5.4 and 4.5.2.1. The repeatability of voltage drop readings taken as specified in 4.5.2.1 shall be ±1% or better.

3.10 CLEARING CHARACTERISTICS. When tested as specified in 4.5.5, current limiters shall open the circuit within the clearing times specified in Table V. Current limiters shall clear without causing plastic bodies to char, or glass or ceramic bodies to fracture. The circuit shall remain open without restrike and there shall be no mechanical failure.

3.11 SHORT CIRCUIT. When tested as specified in Paragraph 4.5.7, current limiters shall remain intact and shall open the circuit without excessive arcing. The current limiters shall remain in the energized circuit for 2 minutes with no indication of restrike. Resistance after firing shall be at least 10 megohms (see Paragraph 4.5.6). The current limiter body shall not rupture and terminals shall not be shunted. Current limiters shall not emit any flame or molten metal, and shall not rise in temperature more than 100°C above ambient temperature.

3.12 TEMPERATURE RANGE. The operating range of environmental ambient temperature for all types of current limiter herein shall be 1[illegible]°C to 40°C.

3.13 THERMAL VACUUM. When tested as specified in 4.5.8, 4.5.8.1, and 4.5.8.2, current limiters shall not fail to pass the specified tests to the requirements of 3.6.2, and 3.11 and shall not show any signs of mechanical damage.

3.14 HUMIDITY. When tested as specified in 4.5.9 current limiters shall show no evidence of corrosion or mechanical damage and shall not exhibit a resistance change greater than ± 10 percent.

3.15 MECHANICAL STRENGTH. When tested as specified in 4.5.11, 4.5.12, 4.5.13, and 4.5.14, current limiters shall show no evidence of mechanical damage and shall not change in resistance by more than ± 10 percent.

3.16 MARKING. Current limiters shall be marked with current and voltage rating and the style number P-300, as specified in 1.2.1, and 1.2.2. Marking shall remain legible after completion of all tests required by this specification.

3.17 WORKMANSHIP. Current limiters shall be processed in such a manner as to be uniform in quality and shall meet the requirements of 3.2 to 3.3.2 inclusive, 3.17.1 and 3.16 as applicable, and be free from other defects that will affect life, serviceability, or appearance.

3.18 SOLDERING. When soldering is employed, only substantially non-corrosive fluxes shall be used unless it can be shown that corrosive elements have been satisfactorily removed after soldering. All excess flux and solder shall be removed after soldering.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 CLASSIFICATION OF TESTS. The tests conducted on current limiters shall be classified as follows:

A. Qualification Tests. Qualification tests are those tests accomplished on samples submitted for qualification as a satisfactory product.

B. Acceptance Tests. Acceptance tests are accomplished on current limiters manufactured and ready for delivery.

4.2 STANDARD TEST CONDITIONS. Unless otherwise specified, all measurements and tests shall be made at 16° to 32° C. ambient atmospheric pressure, and ambient humidity.

4.2.1 TEST EQUIPMENT AND TEST FACILITIES. Test equipment and test facilities shall be of sufficient order of precision and quality to permit performance of the required tests. The supplier shall establish an adequate calibration of test equipment to the satisfaction of the customer.

4.3 QUALIFICATION TESTS.

4.3.1 SAMPLES. Samples submitted for qualification approval shall be representative of the materials and processes used in the manufacture of current limiters furnished under this specification. Unless otherwise specified, qualification samples shall consist of 60 specimens of each type and size specified.

4.3.2 TEST ROUTINE. Sample current limiters shall be subjected to the qualification tests in the order shown in Table I. After completion of the Group I tests, the specimens will be divided into the remaining groups shown in Table I, and subjected to the tests for their particular group in the sequence indicated. The remaining 20 samples shall be shipped for customer inspection.

4.3.3 TEST DATA. Each current limiter tested shall be accompanied by test data covering the tests listed in Table I which have been performed on the unit. All test data shall be provided in duplicate.

4.3.4 CERTIFICATION OF MATERIAL. When submitting samples for qualification, the supplier shall provide certification in duplicate that the materials and processes used are in accordance with the applicable specification requirements.

4.3.5 QUALIFICATION TEST FAILURE. Failure of any current limiter in any of the applicable qualification tests may be cause for refusal to grant qualification approval.

4.4 ACCEPTANCE TESTS. Acceptance tests shall be performed by the supplier and certified tests results forwarded with each shipment. Acceptance tests shall consist of the Group A and B tests listed in Tables II and III.

4.4.1 ACCEPTANCE LOT. As far as practical, an acceptance lot shall consist of units of a single type and size which have been manufactured under essentially the same conditions.

4.4.2 GROUP A TESTS. Group A tests shall consist of the tests listed in Table II. They shall be performed on the same set of samples in the order shown. No lot shall be considered acceptable if out of tolerance conditions occur on more than 5 percent of the units tested, (i.e., no less than 95 percent of a test lot will be shipped).

4.4.3 GROUP B TESTS. Group B tests shall consist of the tests listed in Table III.

4.4.3.1 SAMPLING PROCEDURE. Sampling for Group B shall be in accordance with Table IV. The specimens shall be chosen from those which have passed the Group A tests. The number of failures in all of the tests shall be combined for the purpose of comparing with acceptance and rejection numbers and determining acceptance and rejection.

4.4.3.2 DISPOSITION OF SAMPLE UNITS. Samples which have been subjected to Group B tests shall not be delivered on the contract or order.

4.5 TEST PROCEDURES.

4.5.1 VISUAL AND MECHANICAL INSPECTION. Fuses shall be examined to verify that materials, design and construction, dimensions, marking, and workmanship are in accordance with Sections 3.17 and 3.18.

4.5.2 RESISTANCE BEFORE CLEARING. Unloaded resistance measurements shall be made using a four terminal method of measurement, with a current of less than one tenth (1/10) of the rated current of the limiter. Voltage contacts shall be attached to the current limiter leads less than 0.25 inches from the limiter case. The overall measurement accuracy shall be plus/minus 2% or better.

4.5.2.1 VOLTAGE DROP. D.C. current within plus/minus 1% of the rated current shall be passed through the limiters. After a stabilization period of fifteen (15) minutes readings of voltage drop across the limiters shall be taken using a voltmeter with plus/minus 1% accuracy or better. Voltage contacts shall be attached to the current limiter leads less than 0.25 inches from the limiter case.

4.5.3 TEMPERATURE COEFFICIENT. The temperature coefficient shall be determined by measuring resistance (See 4.5.2) at -55° C, -15° C., room ambient, and plus 125° C. Temperature coefficient from room ambient to each of these three specified values shall be calculated.

4.5.4 CURRENT CARRYING CAPACITY. The current limiters shall be mounted by their leads and subjected to direct current of the rated current value. The current shall be maintained for no less than 168 hours after the temperature of each current limiter has stabilized. (It may be assumed that the temperature has stabilized when readings taken at 10 minute intervals indicate no rise within plus/minus 1° C. of the ambient air temperature). After temperature stabilization and at the end of the burn-in period (168 hours), resistance shall be determined by measuring the voltage drop across the current limiter while carrying 100 percent rated current, and recorded.

4.5.5 OVERLOAD BLOWING TEST PROCEDURE. Current limiters shall be subject to the percentage of rated current specified in Table V. The overload current shall be applied as a step function with a rise time of not greater than 0.00001 seconds. The power supply shall have an open circuit voltage within plus/minus 5 percent of the specified voltage rating of the limiter under test. The number of limiters to be tested shall be evenly divided for the various overloads when more than one overload requirement is specified. Time to clear measurements shall be measured using an electronic counter.

4.5.6 RESISTANCE AFTER CLEARING. Resistance after firing shall be measured across the current limiter terminals using a megommeter or other suitable instrument. The test voltage shall be between 45 and 50 volts.

4.5.7 SHORT CIRCUIT. Current limiters shall be subjected to a short circuit test using a 50 volt lead-acid battery. The short circuit current shall be in excess of 1000% of the rated current of the limiter and shall be calculated from a measurement of total circuit resistance.

4.5.8 THERMAL VACUUM. Current limiters shall be placed in a thermal vacuum chamber. Rated current at rated voltage shall be applied to all fuses. Total operating test time, excluding the time required to achieve stabilization, shall be at least 48 hours. This time shall be divided equally for the high temperature test (24 hours) and the low temperature test (24 hours). Stabilization shall have been achieved when the temperature registered by a reference thermocouple is maintained to with plus/minus 2° C of the high and low values specified below.

4.5.8.1 HIGH TEMPERATURE VACUUM. Chamber wall temperature shall be raised to a temperature such that the reference thermocouple attains a stabilized temperature of plus 45° C at sea level pressure. Upon achieving temperature stability, the chamber shall be evacuated to a pressure of 5 x 10 -5 mm Hg or less. During the period of evacuation, current limiters shall show no failures, malfunction or out-of-tolerance performance degradation. Stable conditions shall then be re-established at the above temperature and maintained for the balance of the test. At the end of the 24 hour period and while still at the temperature and pressure specified above, four current limiter samples shall be subjected to the short circuit test specified in Paragraph 4.6.7.

4.5.8.2 LOW TEMPERATURE VACUUM. At the conclusion of the high temperature test period, the chamber wall temperature shall be lowered to a value such that the reference thermocouple attains a stabilized temperature of -4° F. (If necessary, the chamber may be pressurized to sea level pressure during the transition from high to low temperature to reduce the time period required to effect the temperature change). When temperature stability is achieved, the chamber shall again be evacuated to 5 x 10 -5 mm Hg. or less. During the period of evacuation, the current limiter shall show no failure or malfunction. Stable conditions shall then be re-established at the above temperature, and maintained for the balance of the test. The current limiters shall show no failures, malfunction, or out-of-tolerance performance degradation. At the end of the 24 hour period and while still at the temperature and pressure specified above, four current limiter samples shall be subjected to the short circuit test specified in Paragraph 4.6.7.

4.5.9 HUMIDITY. While nonoperative, current limiters shall be subjected to a test chamber temperature of 65° C and relative humidity of 95 percent for 50 hours. The chamber temperature shall then be lowered to 27° C within one hour with the relative humidity maintained at 95 percent. At completion of the test, current limiters shall show no evidence of corrosion and shall meet specified requirements.

4.5.10 DIELECTRIC STRENGTH. SEA LEVEL. Commercial line frequency potential shall be applied for not less than one (1) minute. Potential shall be applied between one terminal and the case or mounting hardware. Test voltage shall be applied gradually at a rate not exceeding 500 volts rms per second until 1000 V.

4.5.10.1 DIELECTRIC STRENGTH, HIGH ALTITUDE. The dielectric strength test for high altitude units shall be performed in the same manner as the test specified for sea level units in Paragraph 4.5.10, except that high altitude units shall be tested as a pressure equivalent to 5 x 10 -5 mm Hg or less. The rms test voltage shall be 500 volts.

4.5.11 TERMINAL STRENGTH. Current limiter shall be firmly clamped and a force of 2 pounds shall be gradually applied to one lead at a time along the axis of the lead.

4.5.12 CENTRIFUGAL ACCELERATION. Current limiter shall be securely fastened within a centrifuge in accordance with Section 4.15.13.1 and subjected to the acceleration of 100 g. Acceleration shall be increased from zero to the specified value in approximately 2 minutes and held at the maximum for 10 minutes. During the 10 minute interval, the current limiter shall have rated current and voltage applied. This test shall be conducted with acceleration in line with all six orthogonal directions.

4.5.13 VIBRATION. Current limiters shall be subjected to the sinusoidal vibration test at 5 to 50 cps, 0.4 inch double amplitude; 50 to 400 cps, 10g RMS; 400 to 5000 cps, 15g RMS. Current limiters shall be series connected and vibrated while carrying rated current. Paragraphs 4.5.13.1 to 4.5.13.3 shall apply.

4.5.13.1 MOUNTING. The units shall be securely fastened by normal mounting means. Units which are normally supported by their wire leads shall be secured to a plane surface by clamps or conformal coatings and spaced so that the length of each lead from the unit shall be approximately 5/8 inch when measured from the edge of the terminal.

4.5.13.2 MEASUREMENTS. Performance parameters shall be measured before and after vibration.

4.5.13.3 DURATION AND DIRECTION OF MOTION. 2 hours in each of three mutually perpendicular directions (a total of 6 hours). The sweep rate shall be 1/2 octave per minute.

4.5.14 SHOCK. The current limiters shall be mounted by their normal mounting provisions in each of three mutually perpendicular planes and subjected to the transient decelerating force produced by dropping the assembly from a sufficient height that, when the assembly is decelerated by resilient impact, a deceleration of 100g is obtained for 11 milliseconds.

5.0 PREPARATION FOR DELIVERY

5.1 PRESERVATION AND PACKAGING. Current limiters shall be packaged in a manner to insure protection from one another that will prevent damage.

5.2 MARKING. In addition to any special marking required by the contract or order, unit and intermediate packages and shipping containers shall be marked to give clear shipping information and the nomenclature "Current Limiter", and the applicable Microlectron part number.

TABLE I

QUALIFICATION TESTS

Test	Requirement Paragraph	Test Paragraph
GROUP 1 (60 samples)		
Visual and mechanical inspection	3.16 thru 3.18	4.5.1
Resistance before clearing	3.6.1	4.5.2
Current carrying capacity	3.9	4.5.4
GROUP 2 (20 samples which have passed Group 1 tests)		
Thermal vacuum	3.13	4.5.8
Temperature coefficient	3.7	4.5.3
Dielectric strength	3.8	4.5.10
Terminal strength	3.16	4.5.11
Short circuit	3.11	4.5.7
Resistance after clearing	3.6.3	4.5.6
GROUP 3 (20 samples which have passed Group 1 tests)		
Humidity	3.14	4.5.9
Vibration	3.15	4.5.13
Shock	3.15	4.5.14
Centrifugal Acceleration	3.15	4.5.12
Overload blowing	3.10	4.5.5
Resistance after clearing	3.6.3	4.5.6

TABLE II

GROUP A ACCEPTANCE TESTS

	Requirement Paragraphs	Test Paragraphs	Inspection Level
Visual and Mechanical Inspection	3.2 thru 3.3.2 3.16 thru 3.18	4.5.1	100%
Resistance before clearing	3.6.1	4.5.2	100%
Current Carrying Capacity	3.9	4.5.4	100%

TABLE III

GROUP B ACCEPTANCE TESTS

	Requirement Paragraphs	Test Paragraphs	Inspection Level
Clearing Characteristics	3.10	4.5.5	According to Table IV

TABLE IV

SAMPLING FOR GROUP B ACCEPTANCE TESTS
(MIL-STD-105C AQL 0.15% Level III)

LOT	SAMPLE SIZE	ACCEPTANCE NUMBER	REJECTION NUMBER
180 and under	*	0	1
181 to 300	75	0	1
301 to 500	110	0	1
501 to 800	150	1	2
801 to 1300	200	1	2
1301 to 3200	225	1	2
Over 3200	300	2	3

*For lot sizes under 180, sample size shall be at the option of the customer and the acceptance number shall be 0.

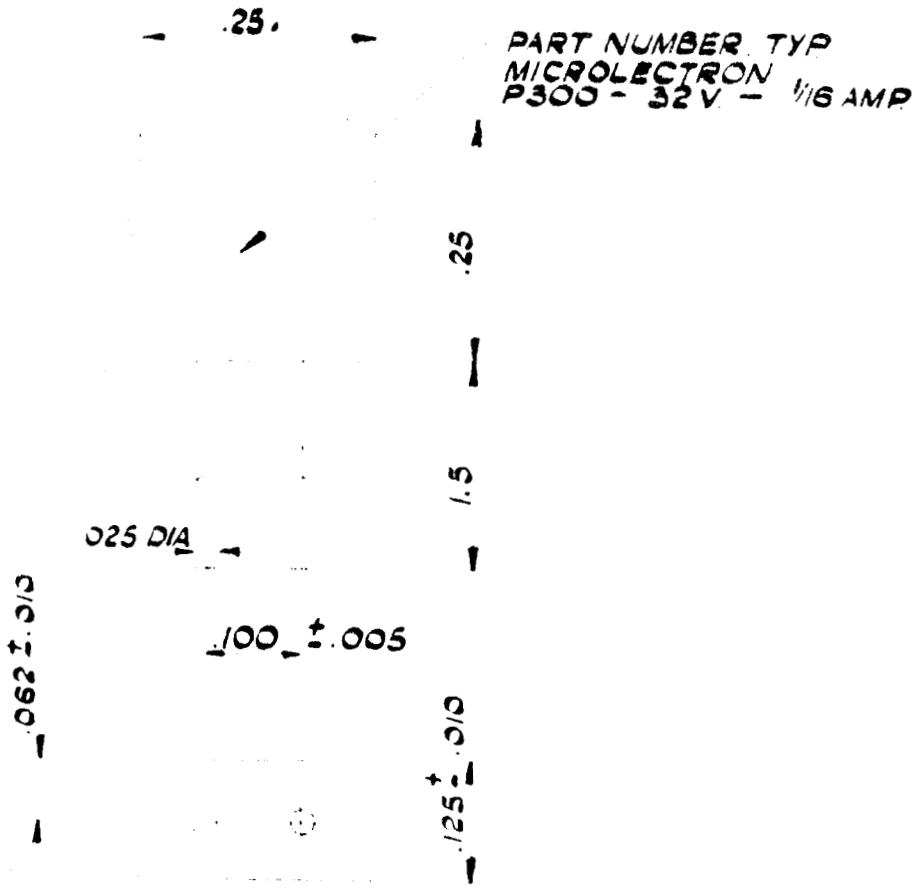
TABLE V

CLEARING CHARACTERISTICS

OVERLOAD	TIME TO CLEAR (Seconds)
200%	0.40 to 4.0
300%	0.015 to 0.50
400%	0.0030 to 0.012
500%	0.0016 to 0.0050

NOTE: Group B QUALIFICATION TESTS REQUIRE TESTING AT ALL OF THE ABOVE OVERLOAD VALUES.

GROUP B ACCEPTANCE TESTS REQUIRE TESTING AT 200% OVERLOAD ONLY.



ELECTRICAL SPECIFICATIONS COMMON TO ALL VALUES

1. OPERATING VOLTAGE: 32 Vrms maximum
2. CLEARING TIME at 200% RATED LOAD 1 second (nominal) at 25°C
3. BREAKDOWN VOLTAGE: Case to Leads — 1000 Vrms minimum
4. RESISTANCE AFTER FIRING: 10,000 megohms (nominal)
5. TEMPERATURE COEFFICIENT OF ELECTRICAL RESISTIVITY: PLUS 0.25% PER °C (nominal)
6. CLEARING CHARACTERISTICS:

OVERLOAD	TIME TO CLEAR (Seconds)		
200%	0.40	TO	4.0
300%	0.015	TO	0.050
400%	0.0030	TO	0.012
500%	0.0010	TO	0.0050

MATERIAL

1. CASE: Cast Epoxy
2. LEADS: Hot-tinned Dip Copper per MIL W3861

NOTE: Pins shall be free of epoxy coating for a distance of not less than .11" from their ends.

REV.	DATE	DESCRIPTION	DFT.	CK.	DES.
A	2 28 64	FIRST ISSUE	L INCE		

DO NOT SCALE PRINT

DIMENSIONS IN INCHES

TOLERANCES UNLESS NOTED
2 PLACES = ± .010
3 PLACES = ± .002
FRACTIONAL = ± 1/32
ANGULAR = ± 0°30'

P300 - 32 CURRENT LIMITER AERO-SPACE GRADE

DATE: 28th FEB 64 DR BY: L INCE

MICROLECTRON
INCORPORATED
SANTA MONICA CALIFORNIA

SCALE | NEXT ASSY.
SIZE A | DWG. NO. A25041

SHEET 1 OF 2

ELECTRICAL CHARACTERISTICS

RATING (AMPS)	MICROLECTRON PART NUMBER	RESISTANCE (TOLERANCE ± 20%) (OHMS)
1/6	P300-32V – 1/6 AMP	25.00
1/8	P300-32V – 1/8 AMP	7.50
1/4	P300-32V – 1/4 AMP	2.50
3/8	P300 32V – 3/8 AMP	1.00
1/2	P300-32V – 1/2 AMP	0.65
3/4	P300-32V – 3/4 AMP	0.35
1	P300-32V – 1 AMP	0.20
1 1/2	P300-32V – 1 1/2 AMP	0.10
2	P300-32V – 2 AMP	0.070
3	P300-32V – 3 AMP	0.046
5	P300-32V – 5 AMP	0.022

P300-32 CURRENT LIMITER
AERO-SPACE GRADE
DATE: 5th MARCH 64
DR BY L. ACE
MICROLECTRON
INCORPORATED
SANTA MONICA CALIFORNIA
SIZE A DWG. NO. A 25041
SHEET 2 OF 2

DO NOT SCALE PRINT
DIMENSIONS IN INCHES
TOLERANCES UNLESS NOTED
2 PLACES ± .010
3 PLACES ± .002
FRACTIONAL ± 1/32
ANGULAR ± 0°30'

DFT. CK. DES.

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