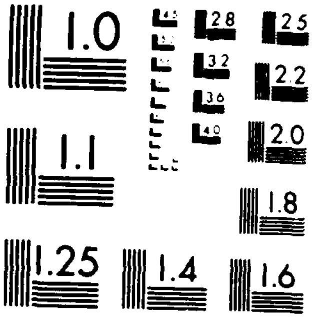
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AFWAL-TR-83-2070

SOLID STATE POWER CONTROLLER FUSE DEVELOPMENT PROGRAM

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OCTOBER 1983

FINAL REPORT FOR PERIOD AUGUST 1981 - JULY 1983

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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The purpose of this development program is to design a family of fail-safe fuses (2-30A, 28VDC, 115/230V-400 Hz) for applications in aircraft electrical systems solid state power controllers (SSPCs). The SSPC functions as a circuit interrupter and a load controller, and when operating properly should protect the aircraft wiring between itself and the load. However, if the SSPC fails to open during a short or overload condition, excessive current can flow, resulting in serious damage to aircraft wiring. The purpose of the SSPC fuse is to prevent wire damage in this double fault condition.

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Foreword

This document is the Final Technical Report for the Solid State Power Controller Fuse Development Program. The work was performed by Bussmann Division, McGraw-Edison Corporation, St. Louis, Missouri, under Air Force Contract Number F33615-81-C-2052. Project, Task and Work Unit numbers are 3145, 314529 and 31452964.

The work was administered under the direction of the Power Systems Branch, Aerospace Power Division, Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio, by Mr. Duane Fox, Project Engineer and Mr. Joe Weimer, Electrical Engineer.

Martin R. Smith of the Bussmann Division was technically responsible. The report was prepared by Vernon R. Spaunhorst, with significant contributions by Walter H. Curtis and Varinder Kalra.

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Summary

This report documents the fuse development program for aircraft electrical systems utilizing Solid State Power Controllers (SSPC), performed by Bussmann Division, McGraw-Edison. Aspects of the development covered by this report are theoretical analysis, prototype and final fuse design, and fabrication and testing of fuses.

The development program consisted of four phases, which were: Phase I, the theoretical analysis and preliminary design of fuses; Phase II, the development of prototype fuse hardware; Phase III, the development of final design specifications plus fuse fabrication and Phase IV, qualification testing and analysis

Phase I activities included numerous studies to verify and to determine the effects of the various contract requirements. Also included in Phase I was the preliminary design of the fuses which included the study of present designs.

Phase II consisted of refining the most promising designs of Phase I and to fabricate and test prototype fuses with ratings from 2 to 30 amperes. Also included was the development of a Fuse Design Specification.

Phase III objectives were to incorporate any changes in the Design Specification and to fabricate fuses in all ampere ratings (2, 5, 7.5, 10, 15, 20 and 30A) for the qualification testing of Phase IV.

Phase IV activities included the qualification testing and evaluation of Phase III fuses, the fabrication of contract fuses (220 of each ampere rating) and finally the preparation of this report.

1.0 Introduction

1.1 Background

Past efforts by the Air Force have developed Solid State Power Controllers (SSPCs) for aircraft electrical power loads. These controllers have been developed for operation at 28 volt D.C., 115 volt 400 Hz, and 230 volt 400 Hz with current ratings varying from 1.5 ampere to 400 amperes.

The power controller functions as a circuit breaker and as a load controller and is usually used in conjunction with a computerized load management system. This total system can provide automatic load management and control with minimum crew action.

The SSPC, when functioning properly, will protect the aircraft wire between the power controller and the load. The SSPC will normally trip when the load circuit is either overloaded or shorted. However, if the power controller fails to trip, excessive current can flow in the load wiring due to the short or overload condition. This possibility of failure has dictated that a fuse be used in conjunction with the SSPC to prevent serious damage to the aircraft wiring in the double fault condition.

1.2 Objective

The objective of this program was to develop a family of fail-safe fuses for application in aircraft electrical system SSPCs. The fuses were designed for use at 28 volt D.C., 115 volt 400 Hz and 230 volt 400 Hz controllers with nominal operating currents from 2 to 30 amperes. The program concentrated on developing the detailed performance and design specifications for the fuses and on demonstrating acceptable fuse performance through extensive testing.

1.3 Approach

This program which covered all aspects of the development of SSPC fuses varying from theoretical analysis and design through extensive test validation, was conducted in four primary phases:

- Phase I - Theoretical analysis and preliminary design of fuses.
- Phase II - Prototype fuse hardware development and testing.
- Phase III - Final design specification and fuse fabrication.
- Phase IV - Evaluation testing and analysis.

2.0 Phase I - Theoretical Analysis and Preliminary Design of Fuses

2.1 Phase I - Objectives

The primary objectives of Phase I were to conduct a theoretical analysis and develop a preliminary design of the fuse element and housing. The fuse performance was the most critical factor: however, the factors affecting fuse performance were traded off with respect to cost, reliability and simplicity of design.

2.2 Phase I - Theoretical Analysis

In addition to a paper search to verify the requirements of the contract, the theoretical analysis included several studies to determine the factors affecting the performance of the SSPC fuse and the factors affecting the number of required fuse designs.

2.2.1 Factors Affecting the SSPC Fuse Performance

The following contract requirements had a significant effect on the size, construction and performance of the SSPC fuse.

2.2.1.1 The SSPC Envelope Curve

The time current characteristic of the SSPC family of fuses were required to fit within the SSPC envelope curve shown in Figure 1.

2.2.1.2 The Fuse Mounting Characteristics

The fuse mounting characteristics were discussed with Mr. Duane Fox at a preliminary project review meeting held at Wright Patterson Air Force Base on September 3, 1981. At the meeting it was agreed the fuseclip and panel mounted methods of mounting were not practical. A lead-in (radial lead) mounting would be the preferred type.

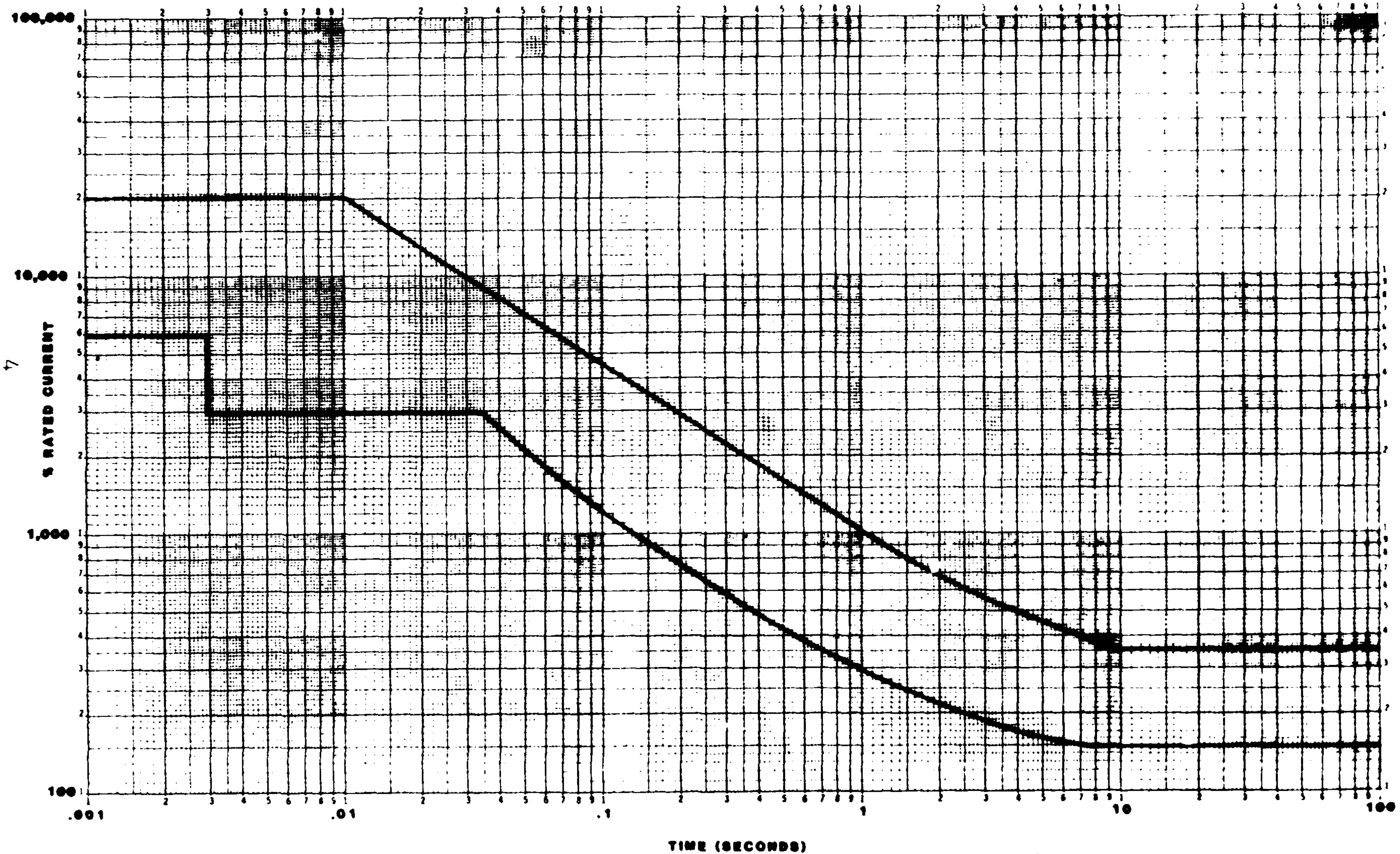


Figure 1
SSPC Envelope Curve

2.2.1.3 Conformance To Applicable Military Requirements

The applicable requirements of MIL-F-5372, MIL-F-15160 and MIL-F-23419 are as follows:

a) Moisture Resistance: MIL-STD-202, Method 106
b) Random Drop: MIL-STD-202, Method 203
c) Salt Spray: MIL-STD-202, Method 101-Condition B
d) Shock (Mechanical): MIL-STD-202, Method 213-Condition I or MIL-F-5372, Paragraph 4.6.19
e) Shock (Thermal): MIL-STD-202, Method 107-Condition A or B
f) Terminal Strength: MIL-STD-202, Method 211-Condition A or E or MIL-F-5372, Paragraph 4.6.9
g) Vibration: MIL-STD-202, Method 204-Condition C or MIL-F-5372, Paragraph 4.6.12

2.2.2 The Factors Affecting The Number Of Fuse Designs

The following factors had a significant effect on the necessary number of fuse designs:

a) Voltage/Current Rating: 28V D.C., 115-230V, 400 Hertz/ 2-30A
b) Usage (Electrical Ratings Vs Fuses Used)
c) Maximum Fault Current: 8,000A, 400 Hertz at rated voltage
d) 400 Hertz Frequency and D.C.
e) Operating Temperature: -55°C to +85°C
f) Storage Temperature: -65°C to +150°C
g) Altitude Range: 0 - 80,000 ft.
h) Reliability

2.2.3 Paper Search

An SSPC Fuse Paper Search was conducted and a final report issued on February 28, 1982. A copy of this report is included as Appendix A. This report set out to verify the SSPC envelope curve, search the SSPC designs, determine the usage for SSPC fuses and verify other contract requirements.

No data was found which disputed the upper (wire damage) curve. However, it was assumed no tests were proposed above 20,000% of rating and hence the curve is horizontal. If tests were made above 20,000% of rating, the curve would continue upward at a slope similar to that shown for values below 20,000%.

Available printed data on the lower limit curve (SSPC trip characteristic), did not agree entirely with the contract requirements. This data, plus actual tests on a SSPC unit, indicate a lower "current limiting point" of 1,500% or less. Data on SSPC testing is shown in Figure 2.

Research of the SSPC designs, gave a better understanding of the SSPC operation. In addition, tests on an SSPC showed the device to have a trip characteristic very similar to the contract requirements in the range up to 1,000% of rating and these trip characteristics were repeatable.

Research on the usage of the SSPC fuses has shown that approximately 350 - 400 SSPCs could be applied on single engine aircraft and approximately 1,000 could be applied on multi-engine aircraft. The major voltages are 28V D.C., 115V A.C. and 230V A.C. The majority of current ratings are 5 amperes and less, with the 2 ampere rating representing approximately 68.5% of the total volume.

The operating temperature (-55^oC to $+85^oC$), storage temperature (-65^oC to $+150^oC$) and altitude range (0 - 80,000 feet) requirements were all verified by the Paper Search.

2.3 Phase I - Preliminary Design Of The Fuses

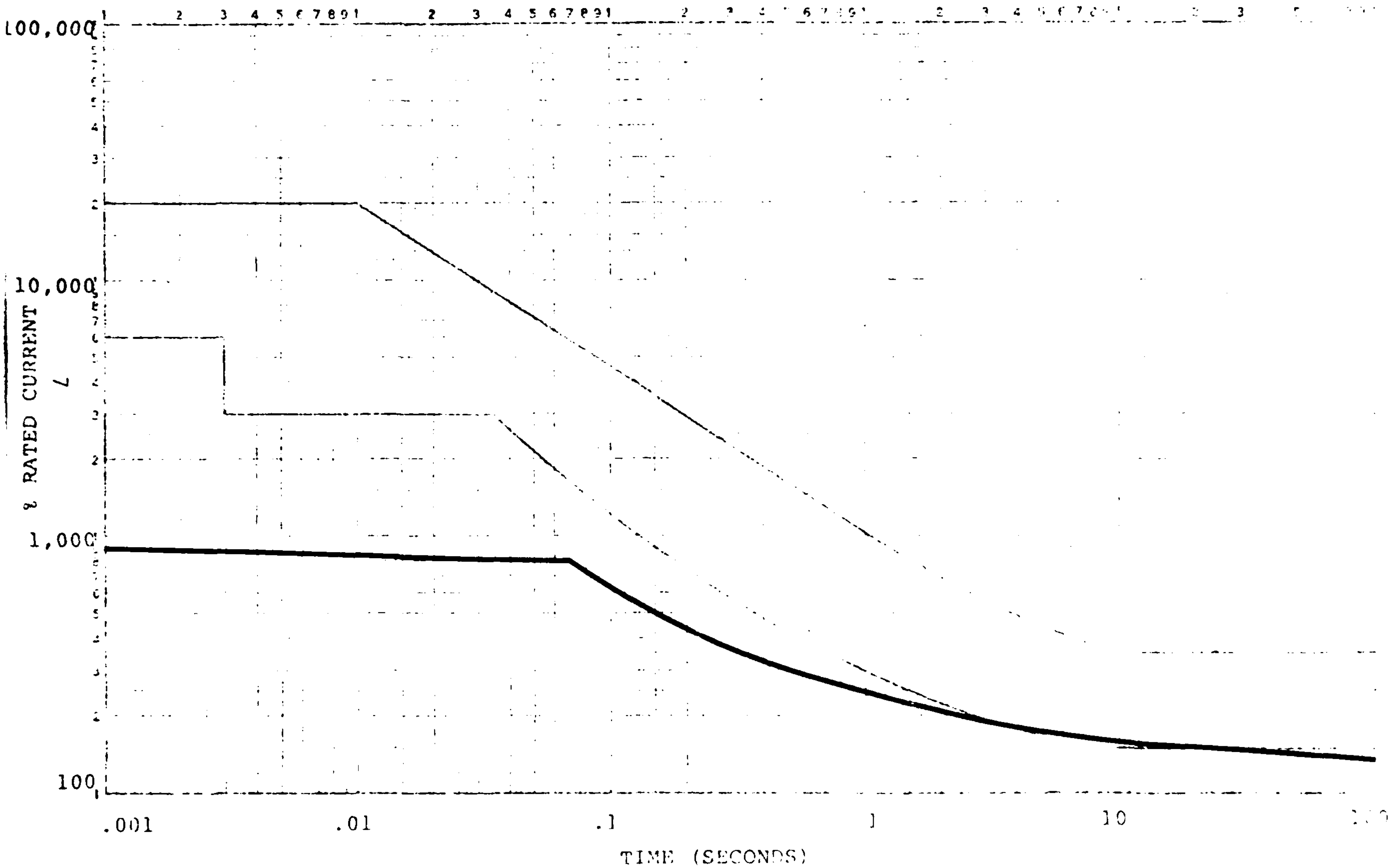
The second portion of Phase I which was the development of preliminary designs, involved a variety of projects. These included a) a comparison of existing fuse time current characteristics against the contract envelope curve, b) a major effort to locate a 400 Hz high current testing source, c) a comparison test of both 60 Hz vs 400 Hz and sea level vs 80,000 feet and finally d) the development of various preliminary designs.

2.3.1 Comparison Of Existing Fuse Characteristics

Initial work on the SSPC contract began with a comparison of existing fuse time current characteristics against the SSPC envelope curve. Attached as Appendix B, are fuse characteristic curves plotted on the SSPC envelope curve. Fuses selected were those considered the best candidates for fitting within the SSPC envelope and those exhibiting basic fuse characteristics. This comparison revealed several fuse designs which approached the SSPC envelope curve, however, later testing eliminated all present product designs.

Figure 2

SSPC Sample 1.6A



Tested at Room Ambient Figure 2 1.6 AMPERE SSPC CHARACTERISTIC CURVE

2.3.2 400 Hertz Search

Since the SSPC fuse was to be designed for aircraft, a major effort was made to locate a 400 Hertz testing source. Contacts were made with the following companies:

Guardian Electric, Chicago, Illinois

Eaton Corporation, Milwaukee, Wisconsin

McDonnell Douglas Corporation, St. Louis, Missouri

Autonetics Division, Anaheim, California

Boeing Corporation, Wichita, Kansas

Detailed discussions with Guardian Electric lead to the conclusion that they are unable to provide the circuit calibration and documentation required for our test program.

Eaton Corp. was found to have a suitable 400 Hz facility and 400 Hz tests were performed in January 1982. In addition, a second series of tests were completed in April. The only drawbacks with the Eaton facility were a 3,000 ampere maximum short circuit capacity and a problem in sustaining the voltage during the short circuit test.

McDonnell Douglas Corp. was found to have a 400 Hz, 115 volt, low ampere source. This equipment was used in February 1982, to examine the performance of an SSPC device.

It is our understanding that Autonetics Div., Rockwell International Corp., has a suitable testing source, but due to stringent scheduling requirements for the B-1 bomber program, this facility was not available for other tests.

The Boeing Company had also been contacted and they have a 400 Hz capability up to 6,000 amperes. However, they also have a problem in sustaining the voltage during the short circuit test.

The search for a 400 Hz testing source also included an effort to purchase a large motor generator set or solid state frequency converter. The search was discontinued due to availability, cost and excessive size.

A small 400 Hz, low voltage current supply was leased for current carry tests.

2.3.3 60 Hertz Vs 400 Hertz and Sea Level Vs 80,000 Feet

A number of tests were made to compare both 60 Hz vs 400 Hz and sea level vs 80,000 ft. Tests were performed at both Bussmann and the Eaton Corp. in Milwaukee, Wisconsin. The final results showed little difference in both tests (see Appendix C). Based on these results, all future tests were performed on 60 Hz at normal atmospheric pressure.

2.3.4 Development of Preliminary Design

A large number of preliminary design concepts were investigated with regard to the required contract envelope and short circuit capabilities. These designs were segregated into the following seven categories. Outline drawings and time current characteristic curves for these designs are included in Appendix D.

2.3.4.1 The Pleated Link Design _ (Buss GDR 3)

This design is described in technical report "Solid State Power Controller Verification Studies Final Technical Report". (Report Number AFAPL-TR-79-2029 January 1979, Reference Data Item 3.)

This design met the contract time current requirements, but was only tested on short circuit up to 1,000 amps. Improvement would be required to meet the 8,000 amp. requirements of the contract. In addition, the original design had a complicated construction using a second tube inside the outer steatite tube. This inner tube, which contained filler, was sealed on one end with a washer. If, due to shock and vibration of the airplane, the joint between the glass tube and washer opens, releasing filler, the fuse will lose its short circuit capability. Also, the filler will get into the pleated section, which will make the fuse slower at low overloads, thus reducing the protection in that area.

Another area of concern was the small gap between the pleats in an assembled fuse. When the fuse opens to interrupt a fault condition, the opened segment of the strip is likely to close on itself under the effect of gravity depending upon the position of the airplane.

At this point in the contract, the plan was to modify the design to interrupt the higher fault current of 8,000 amps., by adding more weak spots. Also, the pleated legs would be separated and the inside glass tube and washer would not be used, which would make the construction simpler and less expensive. Initial tests on the samples using a filler on the short circuit section of the strip and keeping the pleated section in air, looked encouraging.

2.3.4.2 The Dual Element (MDL Modified) Design

This construction was considered because its original performance curve came close to the SSPC envelope. However, the latest modification which came very close to the envelope might be limited to 2 amp. only. Beyond that size, a filler appeared to be necessary to meet the short circuit requirements. It was feared that under some conditions this filler might leak into the heater section altering its performance. Up to 2 amp., a sleeving on the short circuit strip, a pyrex tube instead of regular glass, and even a heat shrink sleeve on the entire length of the tube, was tested to achieve the desired short circuit performance.

2.3.4.3 Bi-Metal Element Design

a) This construction used a combination of zinc and silver/copper links. The center section of this bi-metal strip was zinc, which was riveted and soldered at each end with one short silver/copper link having a weak spot. The theory was that at low values of current, zinc would melt open and at higher currents, silver/copper links would open in their weak spots. Both zinc and silver/copper varied in thickness.

b) Another attempt at a bi-metal element design incorporated a modified version of an FNQ 25 fuse. This design retained the original shape of the FNQ 25 strip, however, the strip was made of two different metals. The first half was blanked from the original copper, while the second half was blanked from a high resistance material. The pieces were connected in series at the center by a rivet and the normal amount of fusing alloy. The purpose was to generate extra heat in the high resistance half, which would transfer to the copper strip, causing it to open quicker at low currents. The end result was a 12A fuse. The experiment failed because the high resistance end would open before the copper. At this point of the contract, more testing was planned using much thinner metal in the copper section of the element.

2.3.4.4 Folded Element Design

This element was made with the idea of getting a longer length without pleating. The element looked similar to the letter N with the legs stretched out for soldering to the end caps. The problem encountered was that the legs had to be separated by a sleeve which restricted the space available for filling the fuse. The performance was unsatisfactory since the sleeves would retain heat. This restricted dissipation of heat and made the device operate out of the time current envelope.

2.3.4.5 Loaded Link (FNQ Modified) Design

Because the performance of the FNQ 30 fuse appeared close to the requirements of the contract, a number of attempts were made to modify the FNQ enabling it to fit within the required envelope.

a) The first attempt was to change the filler in a standard FNQ 30 from sand to powder. Since powder does not conduct heat as readily as sand, we had hoped the fuse would open faster at low currents. Because the fuse must carry continuously at 125%, the 30A fuse was derated to 24A. The FNQ 24A fit within the required envelope, however, more time delay was required in the range of 2 000 - 3,000% of rated current.

b) As mentioned in Section 2.3.4.3, an attempt was made to use a bi-metal strip in the FNQ design. Even though the initial tests failed, the Phase I plan was to try to improve this design.

During the testing of this fuse, we also tested a standard FNQ 25. The FNQ 25 which was derated to an FNQ 20, performed fairly well, however, it did fall from the envelope in the 1,000 to 3,000% range.

c) Another modification of the FNQ, was the narrowing of the wide sections of the strip. The purpose of narrowing the wide sections, was to eliminate some of the heat sink, thereby decreasing the opening time at low currents. This design appeared to fit in the envelope, however, it also required additional time delay in the upper range.

2.3.4.6 Coil Wire Design

At this point in the contract, the coil wire design was in its initial stages and little was known about the construction. We felt the construction would have a center core of suitable insulating material and a suitable size of wire, as determined by the amp rating of the fuse, wound around the core. Initial tests on a 2 amp fuse showed a lot of promise. At this point, no short circuit tests had been performed.

2.3.4.7 Saw Tooth

Due to the complexity of the pleated strip design plus the possibility of restriking due to the springing action of the pleats, another attempt was made to increase the length of the strip without pleating. This increase in length was accomplished by blanking the strip in a "saw tooth" configuration. This "saw tooth" configuration provides a more rigid strip, which is easier to manufacture and reduces the possibility of recontacting after the fuse has opened. The disadvantage is that even though the length of the strip can be increased by approximately 100%, it is not possible to achieve the length obtained by pleating. At this point, tests were required to determine the amount of additional length needed to achieve the requirements of the curve.

2.4 Preliminary Reliability and Maintenance Analysis

As required by the contract, an SSPC Fuse Reliability Program report was issued by Q.R.C., Inc., on November 18, 1981.

3.0 Phase II - Prototype Fuse
Hardware Development and Testing

3.1 Phase II - Objectives

The primary objectives of Phase II were to first, further develop the most promising preliminary designs and second, to fabricate and test prototype fuses.

3.2 Phase II - Preliminary Design Concepts

3.2.1 Preliminary Design Review Meeting (Phase I Agreements)

At the conclusion of Phase I, a Preliminary Design Review Meeting was held at Bussmann Manufacturing on April 14, 1982, at which time the following items were discussed.

3.2.1.1 The Contract Envelope Curve

At the Preliminary Design Review Meeting, discussions concerning the shape of the SSPC envelope curve resulted in two agreements.

The first concerned the upper limit or wire damage curve. This agreement assumed no tests are proposed above 20,000% of rating and hence the curve is horizontal. If tests were made above 20,000% of rating, the curve would continue upward at a slope similar to that shown for values below 20,000%.

The second concerned the lower limit or SSPC trip curve. This agreement pointed out that the trip point at 3,000% of rating could be an extremely difficult design point for the fuse to meet. Relaxation of this requirement might be necessary in order to achieve the other contract considerations for cost, reliability and simplicity of design.

3.2.1.2 The Contract Short Circuit Requirements

3.2.1.3 Environmental Test Requirements

A review of the environmental tests specified in the military standards referenced by the contract, resulted in the following agreements.

The random drop test (MIL-STD-202, Method 106) was removed. This test, which evaluates the effect of component parts due to handling and shipping, is only referenced in the older standard MIL-F-5372 (April 1965). The newer standard MIL-F-23419 (August 1977) which contains fuses more closely associated with the SSPC fuse designs, does not include a random drop test.

The mechanical shock test (MIL-F-5372, Paragraph 4.6.19) was dropped in favor of the MIL-F-23419 test (MIL-STD-202, Method 213, Condition I). The MIL-STD-202 test is more common. It is referenced in a standard test specification as opposed to a unique fuse specification and it is a more severe test.

The terminal strength test (MIL-F-5372, Paragraph 4.6.9) was dropped in favor of the MIL-F-23419 test (MIL-STD-202, Method 211, Condition A). The test called for in MIL-F-5372 is for fuses with knife blade terminals. Test Condition A of Method 211, MIL-STD-202 applies directly to radial lead-ins.

The vibration test (MIL-F-5372, Paragraph 4.6.12) was dropped in favor of the MIL-F-23419 test (MIL-STD-202, Method 204, Test Condition C). The MIL-STD-202 test is more common. It is referenced in a standard test specification as opposed to a unique fuse specification and it is a more severe test.

3.2.2 Preliminary Design Concepts Eliminated

Additional evaluation of the seven preliminary design concepts lead to the elimination of four concepts.

3.2.2.1 Dual Element (MDL Modified) Design

This design, which is similar to the standard MDL construction, was intended for the lower ampere (2A and 5A) contract sizes. However, in order to meet the stringent contract short circuit requirements, an arc quenching filler material needed to be added. Although adding a filler material was possible, we felt the result would be a design with higher construction costs than other alternatives. Therefore, no additional efforts were expended.

3.2.2.2 Bi-Metal Element Design

Two versions of the bi-metal element were investigated.

a) The first design incorporated a zinc center element riveted and soldered on each end to silver elements. Although a number of versions were examined, the design did not fit the lower time current requirements of the SSPC envelope curve.

b) The second version contained one high resistance copper alloy element riveted and soldered in series with a copper element. The intent was to generate extra heat in the high resistance material, which would be transferred to the copper element, causing it to open faster on low currents. Again, a number of versions were tried, but none fit within the SSPC envelope curve in the low time current region.

Both design concepts were eliminated due to the poor time current characteristics.

3.2.2.3 Folded Element Design

This design used an insulating sleeve in order to separate the folded portions of the fuse element. The insulating sleeve restricted the space available for filling the fuse with an arc quenching filler and caused the fuse to retain heat, making the device operate outside the SSPC envelope curve. Due to unsatisfactory performance, the folded element design was dropped.

3.2.2.4 Loaded Link (FNQ Modified) Design

Three design concepts were pursued using the basic FNQ loaded link design. Although initial tests showed these designs were close to the contract requirements, no completely acceptable results were achieved and the design concept was eliminated.

3.3 Phase II (Prototype Fabrication and Testing)

Additional testing of the preliminary coil wire and pleated link designs, led to the conclusion that both designs, in an expanded form, would be suitable. Also, the saw tooth design was still being considered for the 20 and 30 ampere sizes.

3.3.1 Coiled Wire Design (Figures 3 & 4)

3.3.1.1 Design Concept and Range

This design used as a fuse element, a fusible wire (copper wire, tin plated) which was wound on a soft ceramic core material. It was intended for the smaller ampere (2A and 5A) high volume fuses and would work in a standard 1/4 x 1-1/4 inch fuse package.

Coiling the wire on a core, allowed for a very long, high resistance, large diameter wire to be assembled into the fuse package. This combination of resistance and thermal mass was necessary to meet the SSPC envelope curve requirements.

3.3.1.2 Fabrication Techniques

Fabrication of the fuse element was fast and simple with the proper equipment. Coil winding machinery, such as the machine purchased from the George Stevens Co., greatly increased our ability to produce high quality fuse elements. This machine could wind fuse elements for 1-1/4 inch long fuses, at a rate of 30 elements per minute for the 2A fuse and 50 elements per minute for the 5A fuse. Core material was purchased in reels and coiled with fusible wire. These reels could be used in conjunction with automated fuse assembly equipment, which cut each fuse element from the reel and placed it into a fuse package.

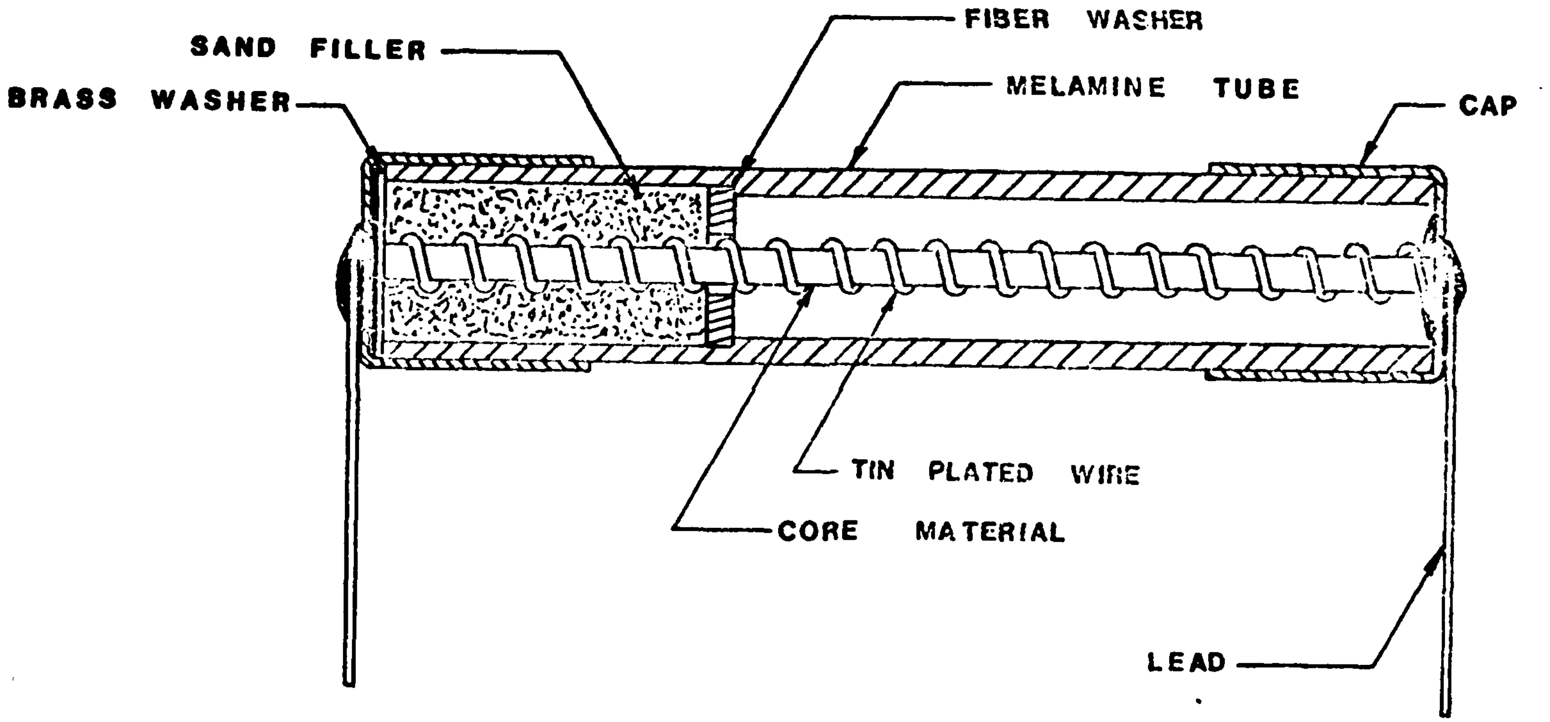


Figure 3 PRELIMINARY COIL WIRE DESIGN FOR 2–5A

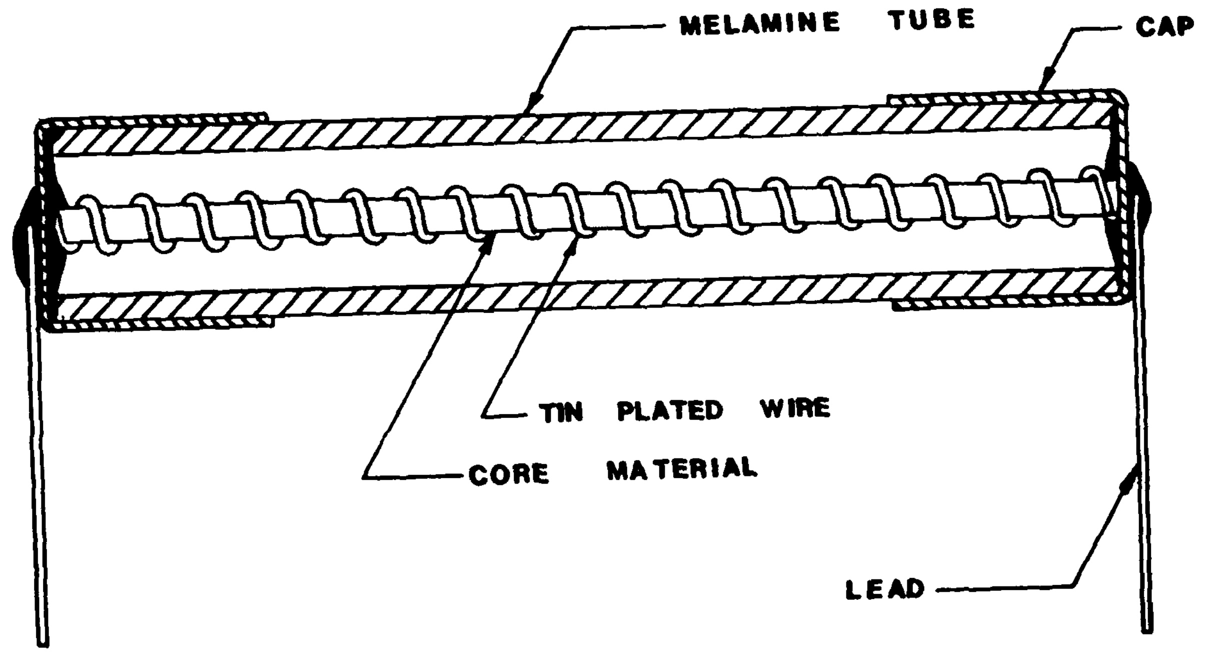


Figure 4 COIL WIRE DESIGN FOR 2A

At this point of Phase II, the one restriction of this construction was the necessity of adding an arc quenching filler material. It was felt this operation would probably be done separately, unless the fuse volumes justified more sophisticated equipment.

Figure 4 was added because it was felt that the 2 amp design might pass short circuit without filler. However, testing would be required.

3.3.1.3 Testing and Evaluation

Phase II testing of the coiled wire design verified its ability to meet the SSPC envelope curve in the 2 and 5 ampere sizes. These tests were performed at +25°C with some preliminary testing at -55°C and +85°C. Short circuit tests at 250V, 10,000A, 60 Hz were also acceptable when an arc quenching sand filler material was used. The unfilled version had not been tested.

3.3.2 Pleated Link Design

3.3.2.1 Design Concept and Range (Figure 5)

The Phase II version of this design used a copper alloy strip which was pleated to fit into a shorter package. It was capable of covering the entire 2 through 30 ampere range, but due to consideration for cost, reliability, and simplicity of design, it was planned for the 7-1/2A through 30A ratings only. The physical size recommended was the standard 13/32 x 1-1/2 inch fuse package, but additional work was planned towards reducing this size for the 7-1/2 and 10A ratings.

The strip material rather than a coiled wire, was necessary for the higher ampere ratings. Pleating the strip allowed for a very long, high resistance material to be assembled into the fuse package. This combination of resistance and thermal mass, was necessary to meet the SSPC envelope curve requirements.

3.3.2.2 Fabrication Techniques

Strips were blanked out to length on a standard type die. A narrow necked down section or weak spot was also punched out for operation on short circuits. The pleats were added in a separate forming die. This die had to be constructed so that the strip material was not stretched during the pleating operation. Stretching would change the electrical and thermal characteristics of the strip material.

Like the coiled wire design, this construction had a section containing an arc quenching filler material and another section in air.

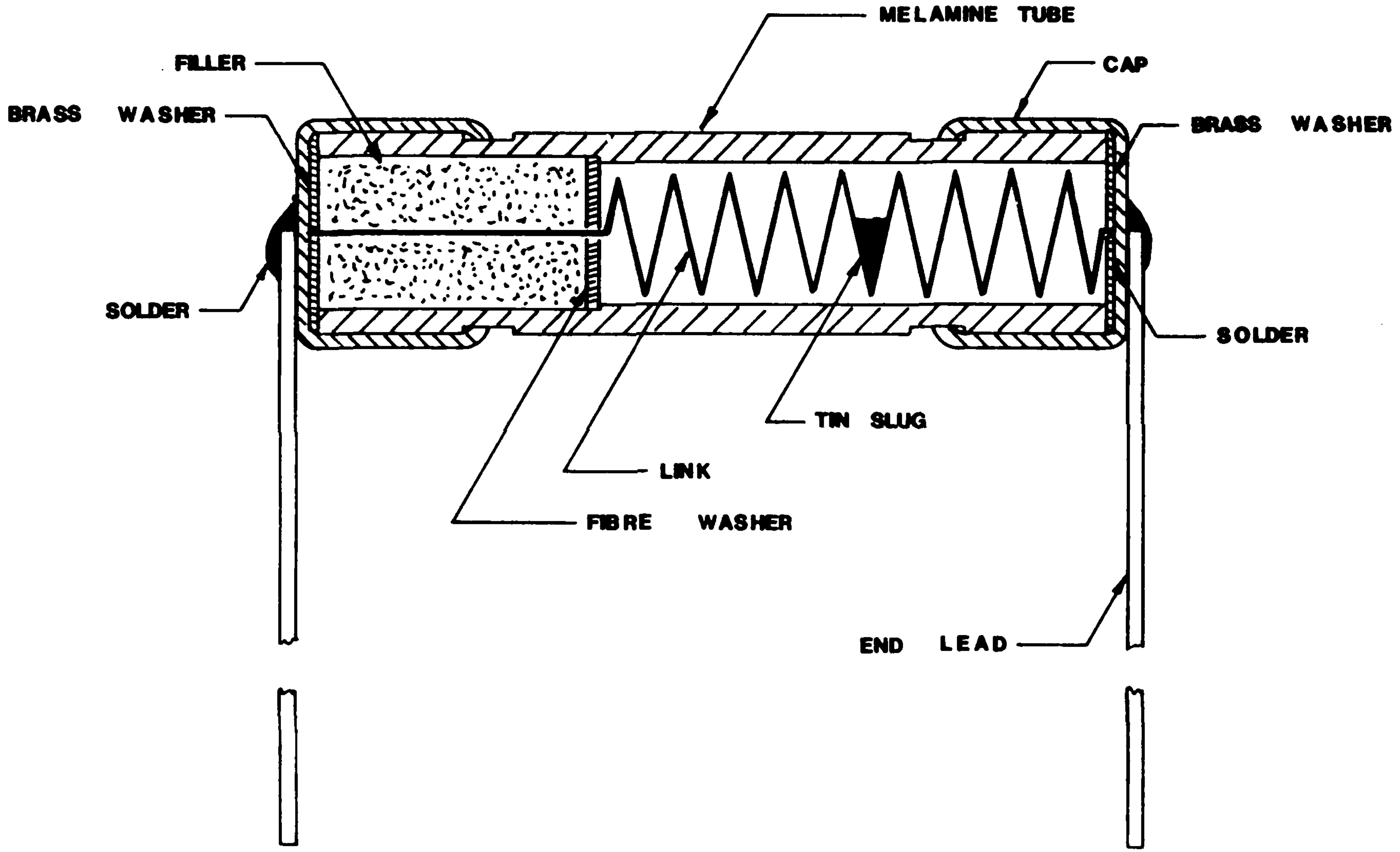


Figure 5 PRELIMINARY PLEATED LINK DESIGN

3.3.2.3 Testing Results

Test results on the 7-1/2 and 10 ampere pleated link design verified these ratings met the SSPC envelope curve at +25°C. Additional tests on these ampere ratings at -55°C and +85°C were planned. Short circuit tests at 250V, 10,000A, 60 Hz had also been successfully completed.

3.3.3 Saw Tooth Link Design (Figure 6)

The saw tooth link gave the increased strip length necessary for an SSPC fuse, but was not as complex as the pleated link. It was intended only for the larger 20 and 30 ampere rating and offered advantages in cost, reliability and simplicity of design.

Preliminary tests on a 20 ampere fuse had given encouraging results, but additional testing was required.

3.4 Preliminary SSPC Fuse Design Specification

The visual and mechanical examination, cold resistance, current carrying capacity, overload interrupt and short circuit interrupt tests were performed in accordance with the Phase II test plan. This plan is enclosed as Appendix F. Environmental tests and fuse standard sheets have been added to the Phase II test plan and this new document "Proposed SSPC Fuse Design Specification" is enclosed as Appendix G.

SAW-TOOTH DESIGN FOR 20 & 30A

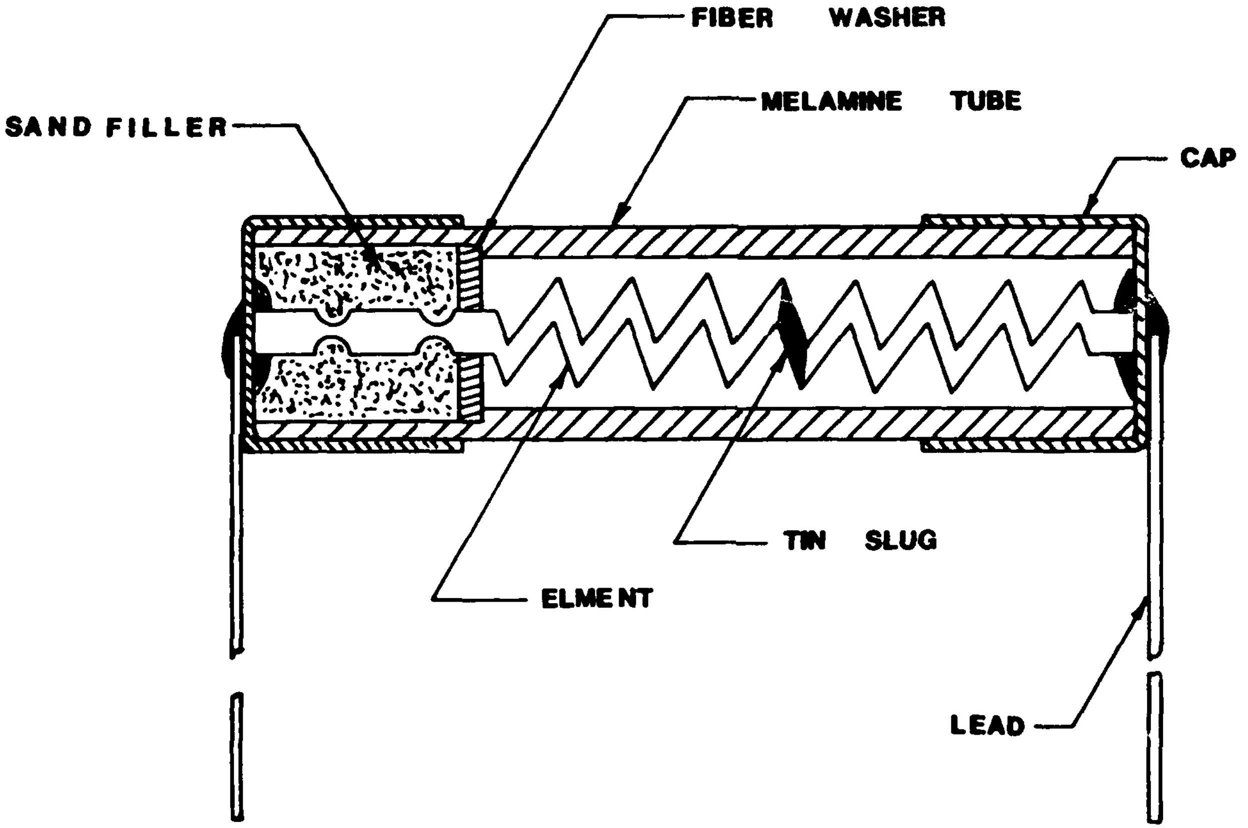


Figure 6 PRELIMINARY SAW-TOOTH DESIGN FOR 20 & 30A

3.5 SSPC Fuse Materials and Equipment List

Phase II of the SSPC contract required the following fuse material and equipment list.

3.5.1 Construction Materials

3.5.1.1 Fusible Element

a) Tin plated copper wire

Copper wire will be tin plated and coiled onto core by Bussmann.

b) Pleated copper strip

Strip will be blanked, tinned and pleated by Bussmann.

c) Saw tooth copper strip

Strip will be blanked and tinned by Bussmann.

3.5.1.2 Core Material

Nextel 312 ply-twisted yarn by 3M
Supplier - "Ceramic Fiber Products/3M"

3.5.1.3 Arc Quenching Filler

#7113 sand
Supplier - Bussmann

3.5.1.4 Tube

a) #8999 melamine tube with modification
Supplier - Bussmann

b) #7540 melamine tube with modification
Supplier - Bussmann

3.5.1.5 Ferrules

a) #9318 albaloy plated cap
Supplier - Bussmann

b) #7552 albaloy plated cap
Supplier - Bussmann

3.5.1.6 Solder

40 - 60 tin lead
Supplier - Bussmann

3.5.1.7 Fusing Alloy

100% tin

a) Tin slug at center of element
Supplier - Bussmann

3.5.1.8 Washers

a) Fiber washer separating filled end from unfilled end.
Supplier - Bussmann

b) Brass washer for end of fuse
Supplier - Bussmann

3.5.1.9 Leads

14-22 gauge tin plated copper
Supplier - Bussmann

3.5.2 Construction Equipment

3.5.2.1 Coil winding machine - Model 409 Continuous Resistance Winder
Machine Manufacturer - George Stevens Mfg. Co., Inc.
Coiling will be performed by Bussmann.

3.5.2.2 Plating facility for tin plating copper wire.
Includes equipment for measuring tin thickness.
Plating will be performed by Bussmann.

3.5.2.3 Blanking die for pleated link.
Supplier - Bussmann

3.5.2.4 Pleating die for pleated link.
Supplier - Bussmann

3.5.2.5 Blanking die for saw tooth link.
Supplier - Bussmann

3.5.2.6 Stamping die for marking caps.
Supplier - Bussmann

3.5.2.7 Work Benches

3.5.2.8 Soldering irons and hot plates.

3.5.3 Test Equipment

3.5.3.1 400 Hertz, Low Voltage Current Source: 0 - 200A

Model 300 - 200 Invertron AC current source
Model 850T-1 SC variable frequency oscillator
Manufacturer - California Instruments

3.5.3.2 Cold Chamber

3.5.3.4 Resistance Meter

Model 4201 Digital Micro - ohmmeter
Manufacturer - Valhalla Scientific, Inc.

3.5.3.5 Visual and Mechanical Examination Equipment

a) Terminal Strength
Chatillon gauge DPP-5, DPP-10, C6202

b) Visual Examination

c) Dimensional Inspection

1. Length

2. Diameter

3. Lead Length

Vernier Caliper - Helios 52-1019

3.5.3.6 Short Circuit Test Equipment

a) Bussmann

0-600V; 0-200,000A; 60 Hertz

b) Eaton Corp.

0-230V; 0-2,900A; 400 Hertz

3.5.3.7 Environmental Equipment

a) Moisture Resistance

b) Salt Spray

c) Shock (Mechanical)

Performed at Environ Laboratories, Inc.
Minneapolis, Minnesota

3.6 Critical Design Review Meeting

At the conclusion of Phase II, a Critical Design Review Meeting was held at Bussmann Manufacturing on September 9, 1982 to review all aspects of Phase II. This included all materials, equipment, and component parts required in the manufacture and testing of future fuses plus a review of the draft set of Design Specifications.

4.0 Phase III - Final Design Specification And Fuse Fabrication

4.1 Phase III - Objectives

Phase III of the SSPC contract consisted of the following primary objectives:

a) Final design hardware test plan
b) Final design concepts
c) Final design specification
d) Fuse fabrication, testing and evaluation

4.2 Final Design Hardware Test Plan

Phase III of the SSPC contract required the preparation of a Final Design Hardware Test Plan. The purpose of the plan was to verify the design, construction and performance of SSPC fuses. In addition, it was also intended to develop a basis for production screening to assume a high level of quality. This plan, which was completed and submitted during Phase III, is included in Appendix H. It should be noted that a portion of the short circuit requirements contained in this Final Plan have been changed from 10,000A, 250V, to 7,500A, 250V. This change applies to the 7.5 to 30A range only. The 2 and 5 amp specification remains at 10,000A.

4.3 Final Design Concepts

The final 0 - 30A fuse package was eventually reduced to two designs, the coiled wire design for the 2 and 5A sizes and the pleated link design for the 7-1/2, 10, 15, 20 and 30A sizes.

Both designs employ the same principal, increased element length, to obtain the required time delay characteristics. In the 2 and 5A package, the increased length is obtained by winding the wire onto a center core while in the 7-1/2 to 30A package the element is folded (pleated) to the required length. In both designs, the increased element length requires an increase in element thickness to carry the rated current. This increased thickness or mass results in the required time delay at the upper overload condition.

4.3.1 Coil Wire Design

As stated above, this design employs tin plated copper wire coiled onto a flexible ceramic core packaged in a 1/4 x 1-1/4 inch melamine tube. See Figures 7 through 10. Preliminary testing of this design ruled out the use of a fiberglass core which melted during low overloads, glass tubes which ruptured during short circuit and 100% filler which resulted in arcing problems on low overloads.

4.3.1.1 2A Coil Design

As can be seen in Figures 7, 9 and 10, the final design of the 2A fuse employed the coil wire element described in 4.3.1, packaged in a 1/4 x 1-1/4 inch melamine tube with standard caps and no filler. .025 inch diameter leads were soldered to the caps. As can be seen in the qualification test, this design required no filler, notching or other modifications to pass short circuit requirements. The 2A design also fit within the required overload envelope.

4.3.1.2 5A Coiled Design

As shown in Figures 8, 9 and 10, the final design of the 5A fuse was very similar to the 2A design in that it also used the coil wire design packaged in a 1/4 x 1-1/4 inch melamine tube. The major differences were the addition of longer notched caps to help meet the short circuit requirements and larger .050 inch diameter leads to bleed away excess heat during current carry tests.

Initial samples employed various fillers in an effort to meet the short circuit requirement. However, the filler, which was tested in both the entire tube and in different sections of the tube, not only failed to satisfy short circuit requirements, but also caused problems with the fuse rating and restriking during low overload tests. It was eventually determined that the best short circuit results were obtained with the longer, heavy walled, notched caps and no filler.

SCALE

UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE
DECIMAL ± .005"
FRACTIONAL ± 1/64"
ANGULAR ± 2°

DATE 6-7-83
NO EXP 65C56 SPC-2
TITLE TIME-DELAY FUSE
SUP NO
DATED
DWG
CK
CHANGE
ENG WC
MFG
SALES

Bussmann Division
McGraw-Edison Company
St. Louis, MO 63178

DISTRIBUTION

ELECTRICAL REQUIRMENTS:
CARRY 125% OF RATING FOR 4 HOURS
OPEN AT 200% OF RATING 2.70 SEC. MIN.
OPEN AT 400% OF RATING .550 TO 6.90 SEC.
OPEN AT 1000% OF RATING .130 TO 1.05 SEC
OPEN AT 3000% OF RATING .035 TO .19 SEC.

TEMP. REQUIREMENTS:
ALL RATING TEST TO BE PERFORMED AT +85°C, 25°C AND -55°C

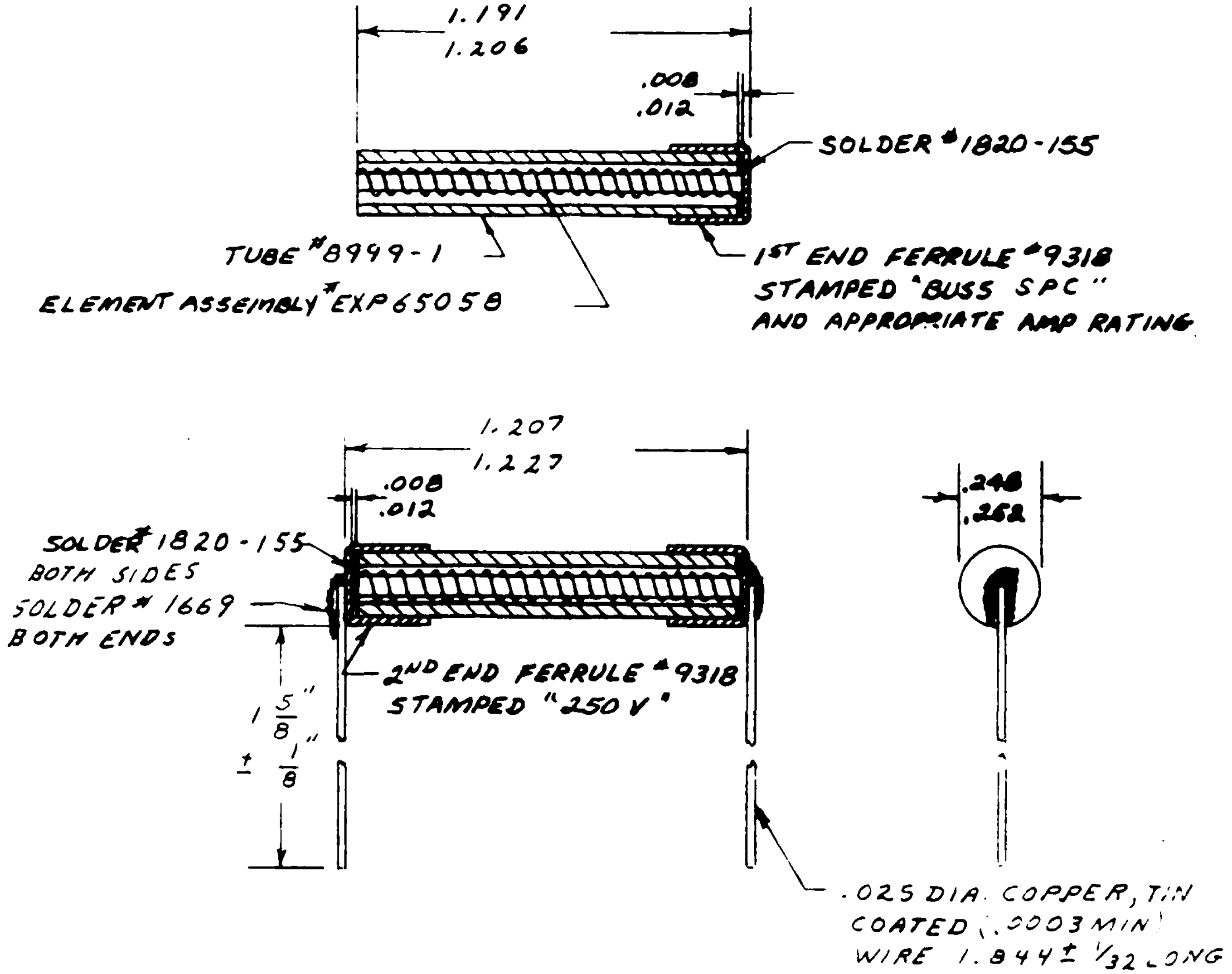


Figure 7 **SPC-2A**

SCALE

UNLESS OTHERWISE SPECIFIED
TOLERANCES TO BE
DECIMAL ± .005"
FRACTIONAL ± 1/64"
ANGULAR ± 2°

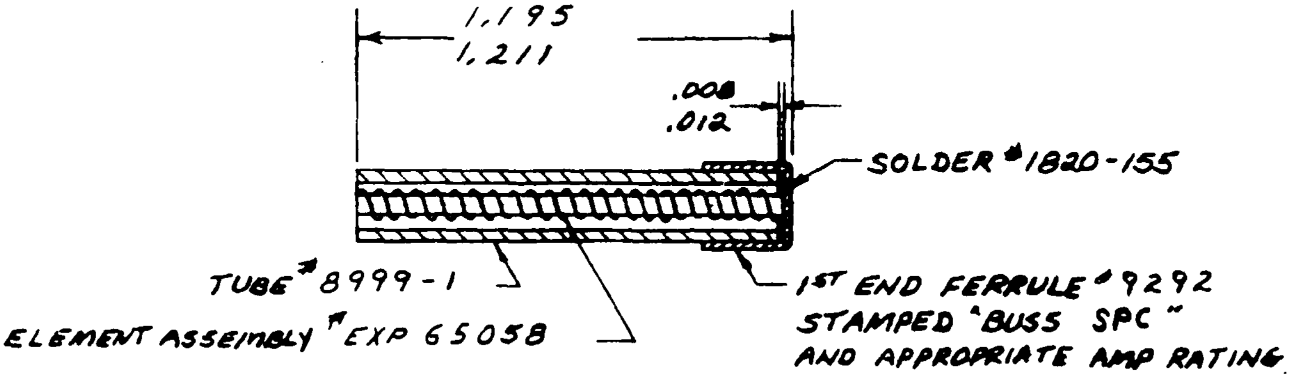
DATE 6-7-83
NO EXP 65057 SPC-5
TITLE TIME-DELAY FUSE
SUP NO
DATED
DWG GM
CK
CHANGE
ENG WC
MFG
SALES

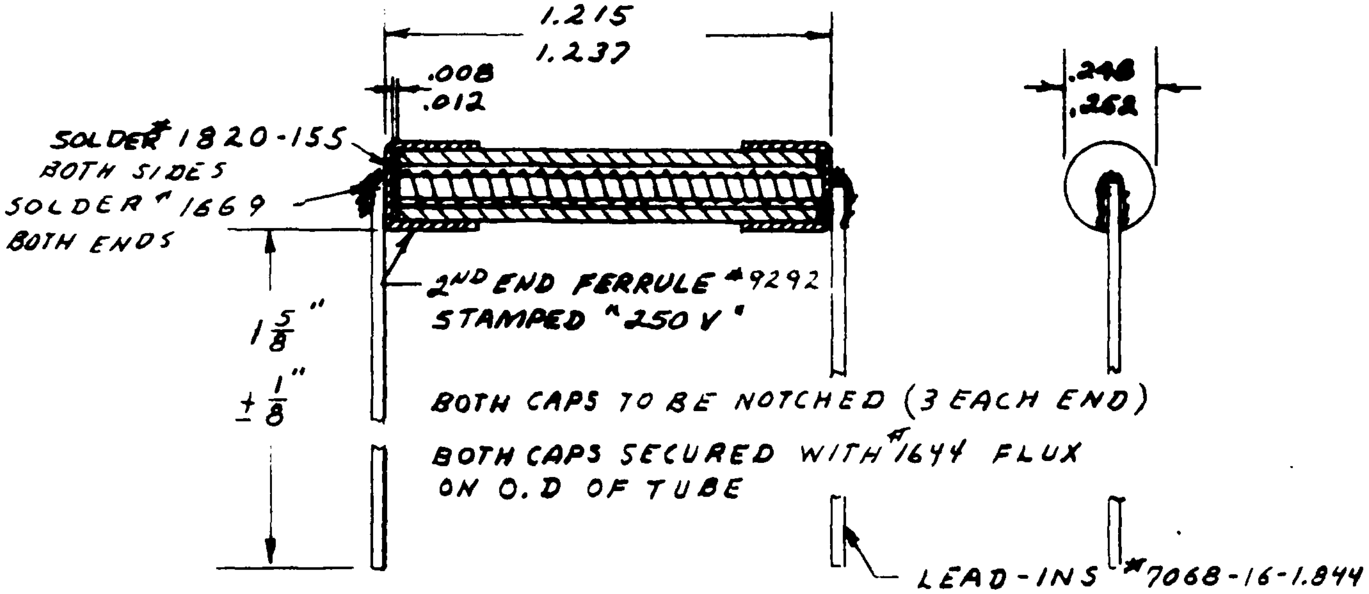
Bussmann Division
McGraw-Edison Company
St. Louis, MO 63178

DISTRIBUTION

ELECTRICAL REQUIREMENTS:
CARRY 125 % OF RATING FOR 4 HOURS
OPEN AT 200 % OF RATING 2.70 SEC. MIN.
OPEN AT 400 % OF RATING .550 TO 6.90 SEC.
OPEN AT 1000 % OF RATING .130 TO 1.05 SEC.
OPEN AT 3000 % OF RATING .035 TO .19 SEC.

TEMP REQUIREMENT:
ALL RATING TEST TO BE PERFORMED AT
+85°C, 25°C AND -55°C





BOTH CAPS TO BE NOTCHED (3 EACH END)

BOTH CAPS SECURED WITH #1644 FLUX
ON O.D OF TUBE

Figure 8 **SPC-5A**

SCALE

UNLESS OTHERWISE SPECIFIED
TOLERANCES TO BE
DECIMAL ± .005"
FRACTIONAL ± 1/64"
ANGULAR ± 2°

DATE 6-7-83
NO EXP65058
TITLE ELEMENT ASSY
SUP NO
DATED
DWG DM
CK
CHANGE
ENG WC VS
MFG
SALES

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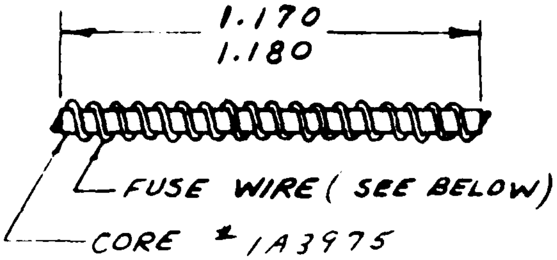
St. Louis, MO 63178

DISTRIBUTION

FOR SPC 2-5



AMP	ELEMENT ASSEMBLY NUMBER	FUSE WIRE NUMBER	TURNS PER INCH
2	EXP 65058-2	EXP 65059-2	40
5	EXP 65058-5	EXP 65059-5	20

Figure 9

AMP	NUMBER OF PART	MATERIAL	DIA BEFORE PLATING	PLATING	PLATING THICKNESS (TIN)	DIA AFTER PLATING
2	EXP65059 -2	#33 COPPER	.0071	SILVER PLATED TO .190 O/F (WITH FINAL PLATING OF TIN)	.0005- .0008 (INCH)	.0081- .0087
5	EXP65059-5	#28 COPPER	.0126	TIN	.0005- .0008 (INCH)	.0136- .0142

BASE WIRE DIA. TOL. ±.001

LENGTH TO BE DETERMINED BY NUMBER OF TURNS PER INCH AT COILING

USED ON ELEMENT ASSEMBLY
EXP 65058

FOR EXP 65056/SPC 2
EXP 65057/SPC 5

SCALE

UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE
DECIMAL ± .005
FRACTIONAL ± 1/64
ANGULAR ± 2°

DATE 6-7-83	NO EXP65059
TITLE FUSE WIRE	
SUP NO	DATED
DWG GM	CK
ENG WC	MFG
SALES	

RELEASED ____ PER ____

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McGraw-Edison Company
St. Louis, MO 63178

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Figure 10

As can be seen in the Qualification Testing, the overload performance of the final design is marginal at 3,000% of rating. The ability of the 5A design to better meet the contract envelope can be improved by using a longer wire at more "turns per inch". However, this improvement results in failure to meet the 10,000A, 250V short circuit requirements.

4.3.2 Pleated Link Design

The pleated link design, which is used on the 7-1/2 through 30A sizes, contains a copper strip pleated on the overload end to a specific length. (See Figures 11 through 16.) The pleated overload section contains a tin slug and contains no filler. The short circuit section is notched and is surrounded by sand to improve the short circuit performance. The major differences in the 5 ampere sizes is the number and size of weak spots, the thickness of the strip and the number of the pleats. As the ampere ratings and therefore the pleats decreased, all ratings, 7-1/2 amp and larger, were encased in a 13/32 x 1-1/2 inch package consisting of a melamine tube and standard caps.

4.3.2.1 7-1/2, 10 and 15 Ampere Pleated Design

The 7-1/2, 10 and 15 amp fuses are identical in construction except for the thickness of the strip and the number of pleats. All three use a lead diameter of .051 inch.

4.3.2.2 20 Ampere Pleated Design

In addition to a thicker strip, fewer pleats, and notched caps, the 20 amp design contained narrower weak sections and larger diameter leads (.064) than the 7-1/2 - 15A range. The narrower weak sections and notched caps were necessary to improve short circuit performance and the large diameter leads were required to dissipate heat during current carry tests.

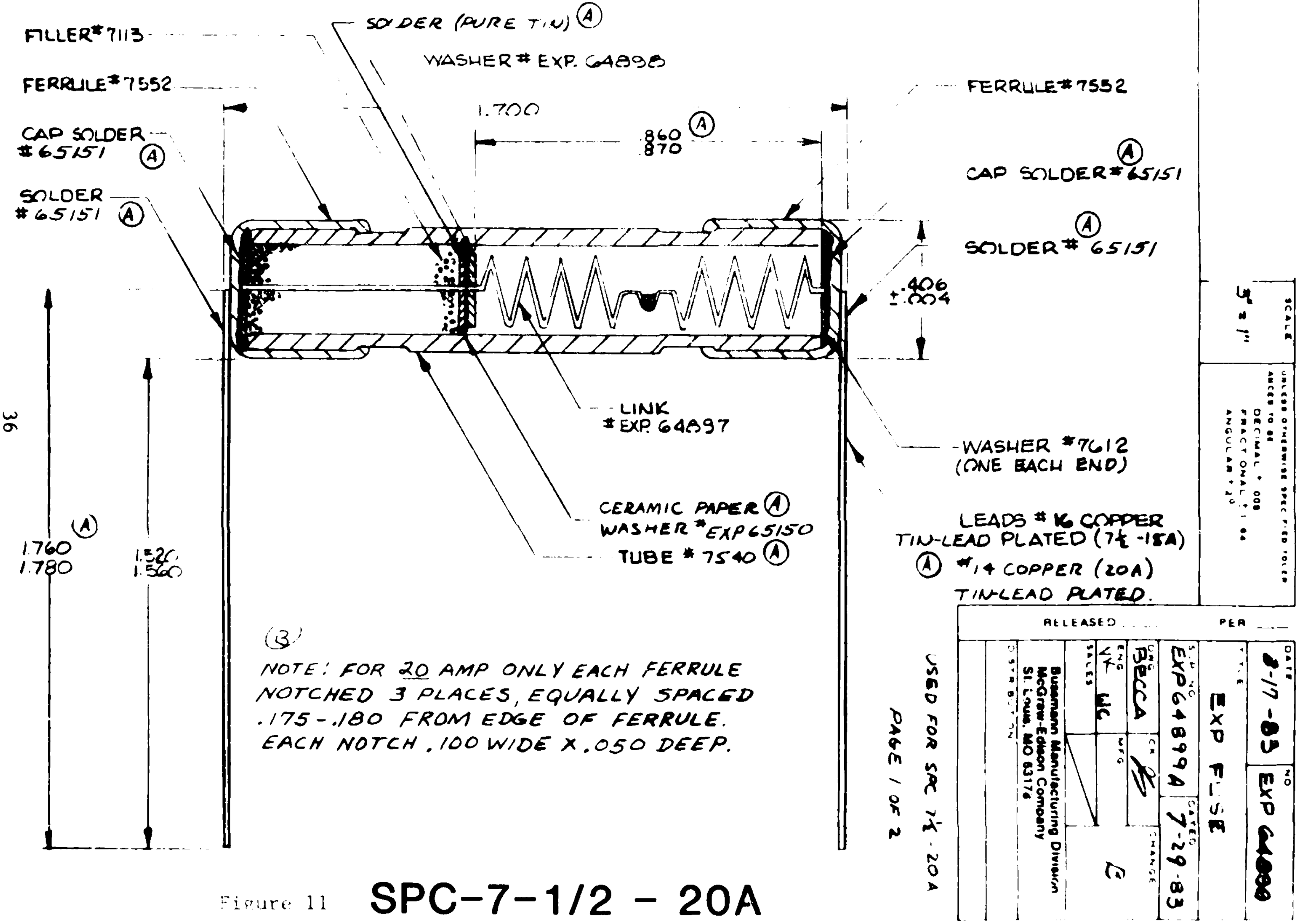
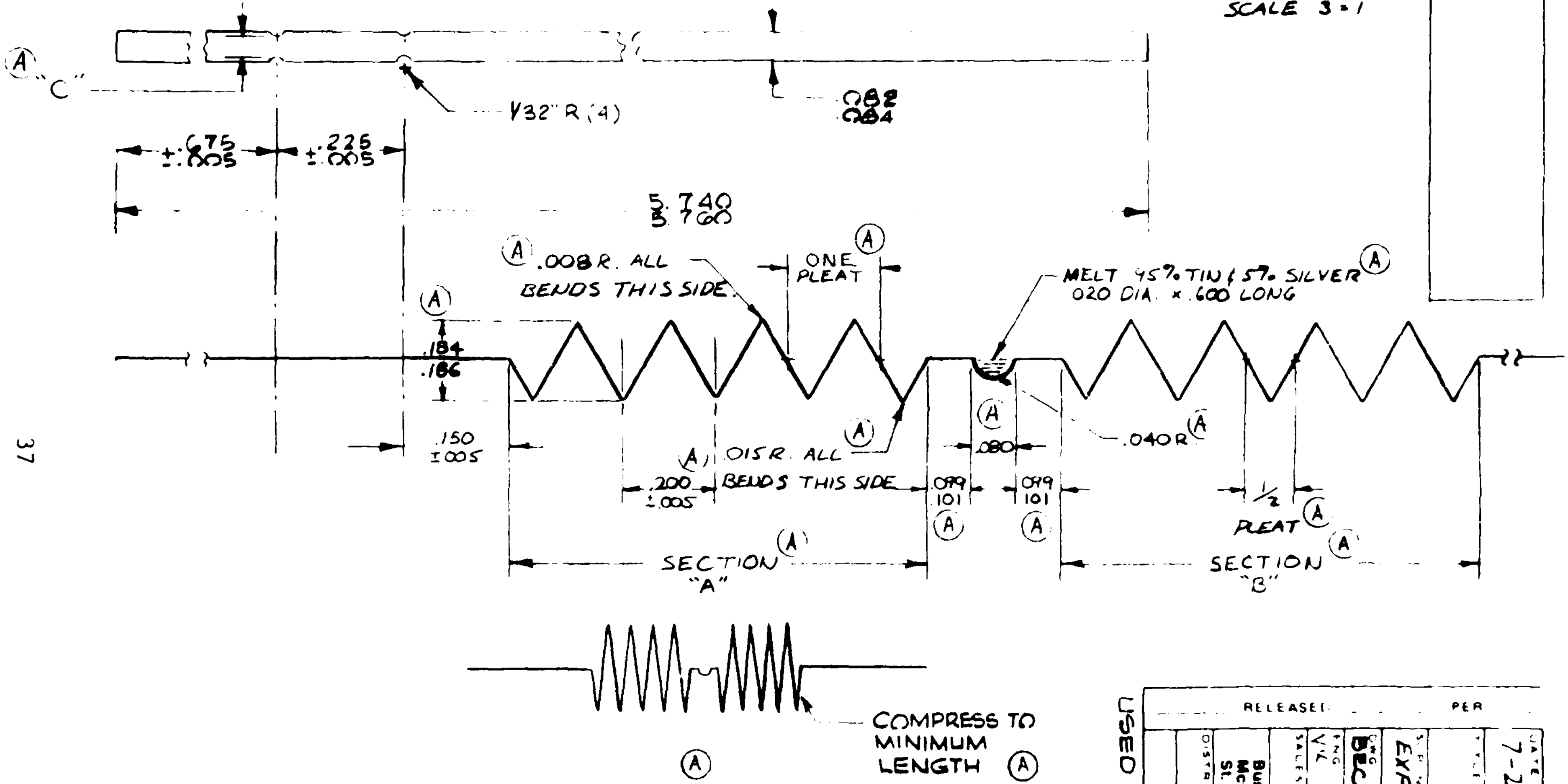


Figure 11 SPC-7-1/2 - 20A

UNLESS OTHERWISE SPECIFIED
TOLERANCES TO BE:
DECIMAL ±.005"
FRACTIONAL ±1/64"
ANGULAR ±2°

SCALE 3 = 1



DATE 7-29-83
NO. EXP 64897
TITLE LINK
S.P. NO. EXP 64897
DATED 10-22-82
DWG BECCA
CK.
CHANGE A
ENG VK WC
MFG
SALES
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PER

USED IN FUSE EXP 64899
PAGE 1 OF 2

Ⓐ

AMP RATING	MATERIAL	THICKNESS	NUMBER OF PLEATS		WEAK SPOT WIDTH "C"
			SECTION "A"	SECTION "B"	
7½	COPPER	.0028-.0030	4½	4½	.069 ±.001
10	COPPER	.0042-.0044	4½	4½	.069 ±.001
15	COPPER	.0066-.0068	3½	4½	.069 ±.001
20	COPPER	.0093-.0095	3½	3½	.051 ±.001

Figure 12

	SCALE 6" = 1"	UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE DECIMAL ± .005 FRACTIONAL ± 1/64 ANGULAR ± 2°

RE'	CHANGE DESCRIPTION	DATE	ECN #
A	.232-.236 was .260-.262	7-29-83	

DATE 7-29-83	NO. EXP 64898	
TITLE WASHER		
SUP. NO. EXP 64898	DATED 10-22-82	
DWG. BECCA	CK.	CHANGE A
ENG. WC	MFG.	
SALES		

PER

RELEASED

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USED IN FUSE EXP. 64899
65148

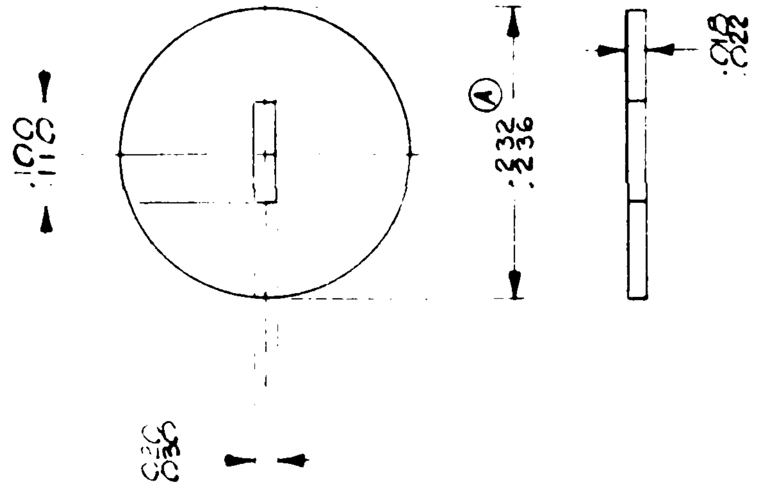

Figure 13

MATERIAL: BRASS

NUMBER OF PART		64898
PCS PER LB		
THICKNESS		.018 .022
STOCK	WIDTH	
	TOLERANCE	
	LBS PER M	
SCRAP	LBS PER M	

SCALE 3X

UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE
DECIMAL ± .005
FRACTIONAL ± 1/64
ANGULAR ± 2°

DATE 8-17-83
NO EXP65148
TITLE EXP FUSE
SUP NO EXP65148
DATED 7-29-83
DWG TCB
CK
CHANGE A
ENG WC
MFG
SALES

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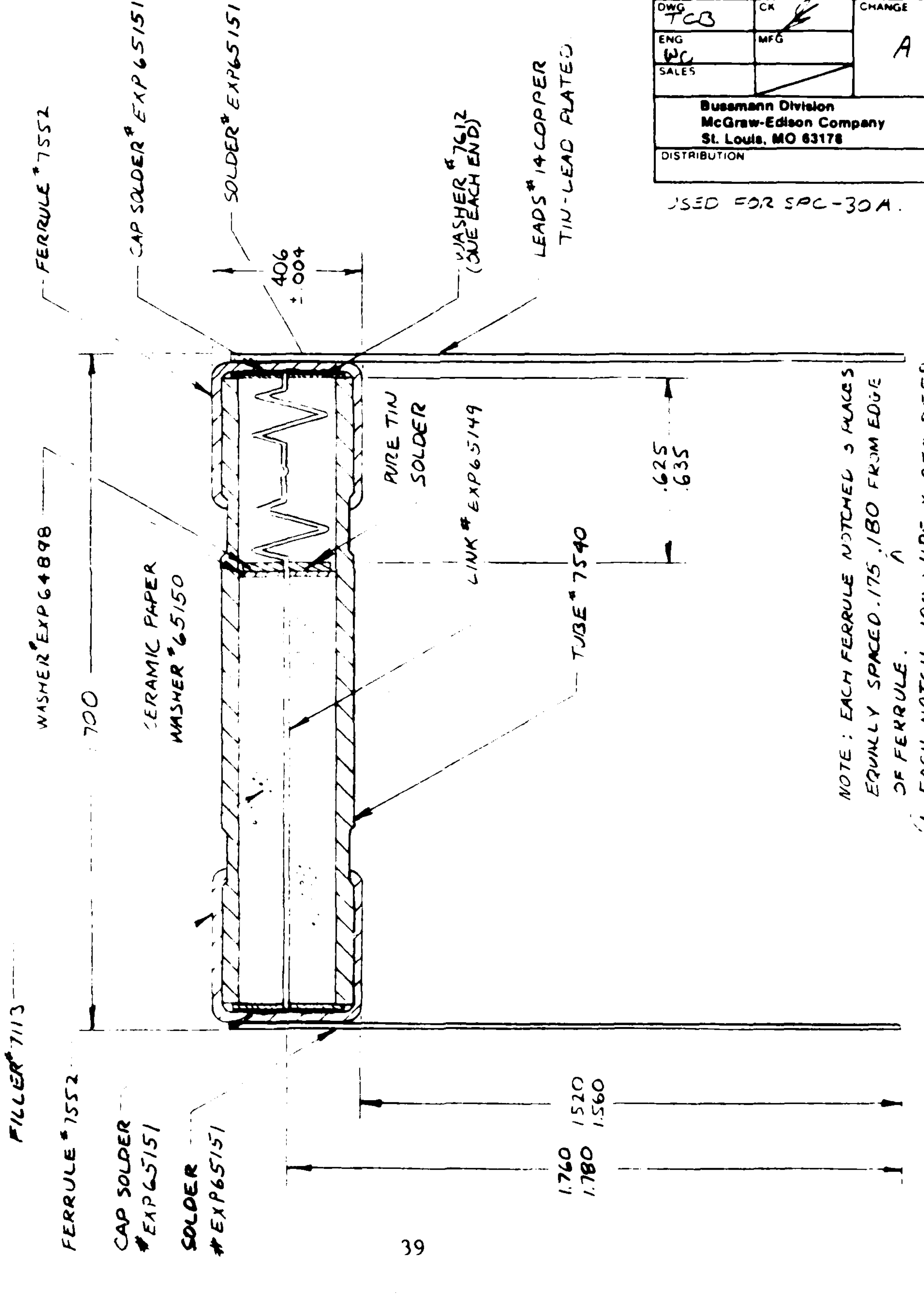
St. Louis, MO 63178

DISTRIBUTION

USED FOR SPC-30A.



NOTE: EACH FERRULE NOTCHED 3 PLACES EQUALLY SPACED .175 .180 FROM EDGE OF FERRULE. A

A EACH NOTCH .100 WIDE X .050 DEEP

SPC-30A

Figure 14

SCALE

UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE
DECIMAL ± .005"
FRACTIONAL ± 1/64"
ANGULAR ± 2°

DATE 8-17-83
NO EXP 65149
TITLE LINK
SUP NO EXP 65149
DATED 7-29-83
DWG TCB
CK B
CHANGE A
ENG WC
MFG
SALES

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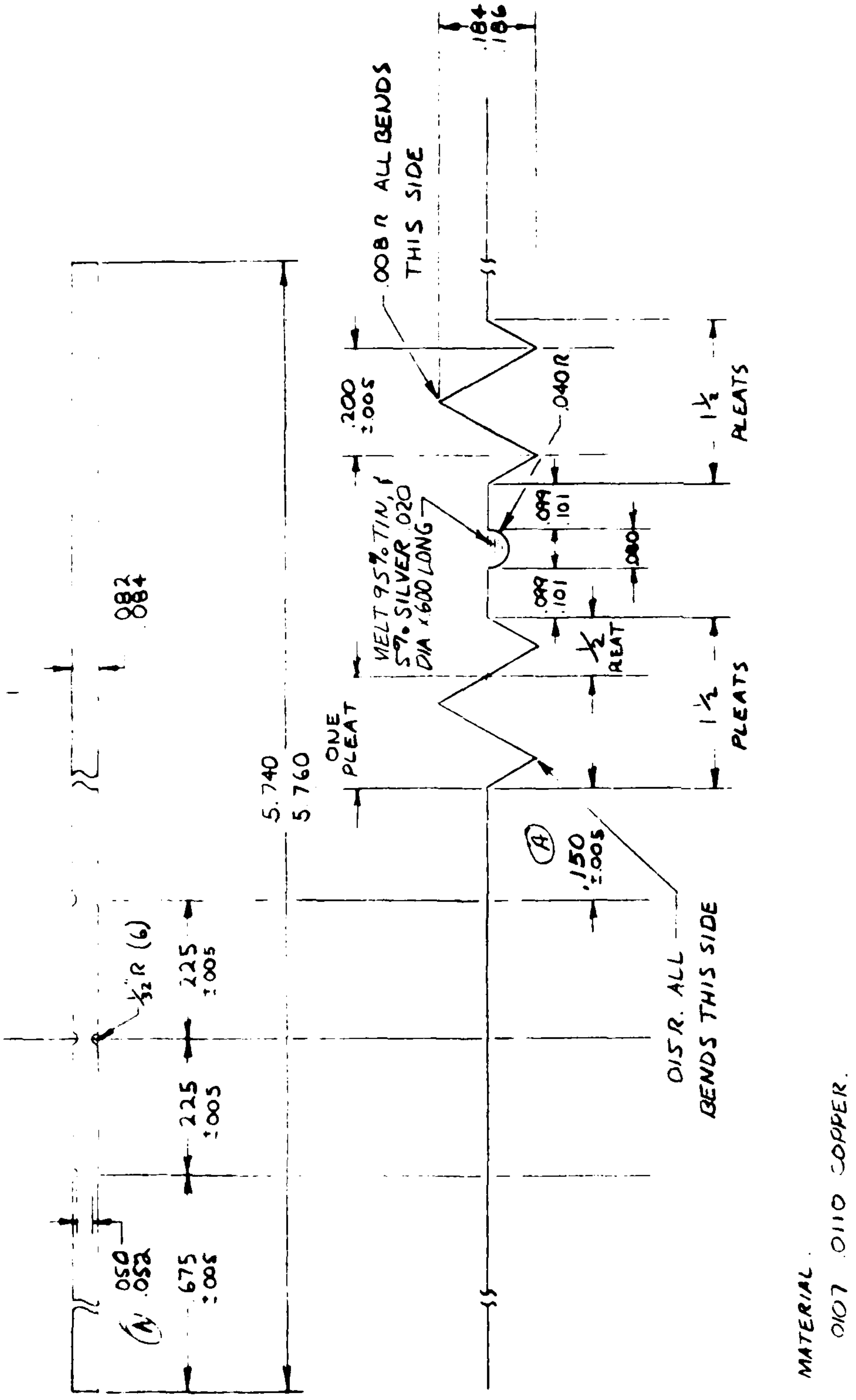
USED ON SPC-30A.



MATERIAL
.0107 .0110 COPPER

Figure 15

	SCALE 6X	UNLESS OTHERWISE SPECIFIED TOLERANCES TO BE DECIMAL ± .005" FRACTIONAL ± 1/64" ANGULAR ± 2°	DATE 7-29-83

DATE 7-29-83	NO EXP 65150	
TITLE WASHER		
SUP NO	DATED	
DWG TCB	CK	CHANGE
ENG WC	MFG	
SALES		

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St. Louis, MO 63178

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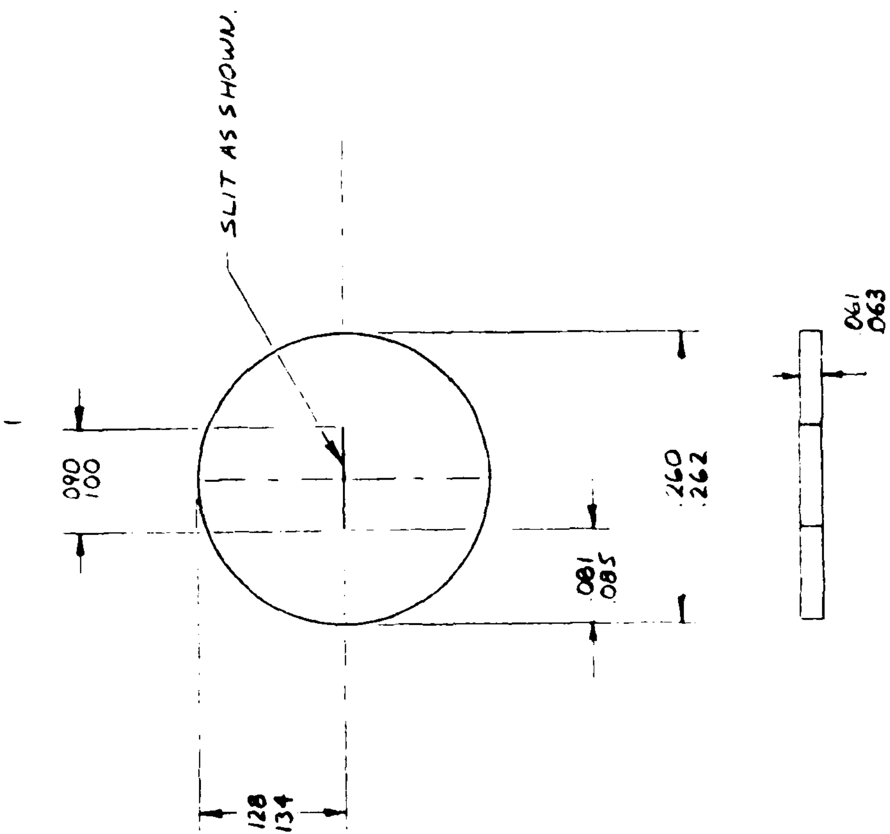
USED IN FUSE EXP 64899
65148



MATERIAL : CERAMIC PAPER
PURCHASED FROM, COTRONICS
3379 SHORE PARKWAY, BROOKLYN, N.Y. 11235

NUMBER OF PART	
PCS PER LB	
THICKNESS	.061 .063
STOCK WIDTH	
STOCK TOLERANCE	
STOCK LBS PER M	
SCRAP LBS PER M	

Figure 16

4.3.2.3 30 Ampere Pleated Design

As with the 20 ampere design, the 30 amp fuse required notched caps plus a still thicker strip with even fewer pleats. In addition, the 30A size required three weak sections to pass short circuit requirements. The lead diameter was the same as the 20 amp design, however, a high temperature solder was required to prevent lead melt off during low overloads. This solder is now used on the entire 7-1/2 - 30 amp range.

4.4 Final Design Specifications

Phase III of the SSPC contract required the preparation of a Final SSPC Fuse Design Specification.

The purpose of this document was to detail the final fuse specifications, including materials of construction and all necessary testing. This specification, which was completed and submitted during Phase III, is included in Appendix I.

4.5 Fuse Fabrication, Testing and Evaluation

The final requirement of Phase III was the assembly, testing and evaluation of the qualification test samples. It should be noted that the testing and evaluation portion of Phase III was preliminary only and the actual qualification testing took place in Phase IV.

As shown in Paragraph 4.5.1 of the "Final SSPC Fuse Design Specification" (Appendix I), the number of samples required for qualification was 44 each of the maximum and minimum current rating of each size shown in the specification sheet for which qualification is desired and 24 each of all other current ratings which fall between the maximum and minimum current ratings.

Ampere	No. of Samples
2	44
5	44
7½	44
10	24
15	24
20	24
30	44

The actual number of fuses fabricated was greater to allow for preliminary, in-house testing by Bussmann. This preliminary testing by Bussmann included all the required tests that were to follow in the qualification testing of Phase IV.

5.0 Phase IV - Evaluation Testing And Analysis

5.1 Phase IV - Objective

Phase IV of the SSPC contract consisted of the following primary objectives:

a) Qualification Testing and evaluation
b) Fabrication of contract fuses
c) Preparation of final technical report
d) Final design review meeting

5.2 Qualification Testing

The first objective of Phase IV was the testing and evaluation of the qualification samples fabricated in Phase III. The fuses were tested in accordance with the "Final SSPC Fuse Design Specification" written during Phase III (see Appendix I).

As shown in the fuse design specification, the test program consisted of six phases or groups of testing. The minimum and maximum current rating of each fuse size (2, 5, 7-1/2 and 30A) were exposed to all six groups of testing while all other current ratings which fall between the minimum and maximum current ratings (10, 15 and 20A) were exposed only to Group I and II testing. The results of the qualification testing is contained in Appendix J.

5.2.1 Group I - 2, 5, 7-1/2 and 30A - 44 Fuses
10, 15 and 20A - 24 Fuses

All fuses of every ampere rating were exposed to Group I testing which consisted of the following:

a) Burn-in
b) Voltage drop
c) Resistance
d) Visual and mechanical examination
e) Current carry capacity

5.2.1.1 Burn-In

All fuses were subjected to a 60 Hz, A.C. current on low voltage (10-20V) at 100% of rated current for 1 hour (minimum) at room ambient temperature. (See paragraph 4.7.4 of the Fuse Design Specification for additional mounting and testing details.) The tests were performed by Bussmann. Any suspicious fuses were discarded.

5.2.1.2 Voltage Drop

During the above burn-in, the voltage drop of the fuses was measured and recorded using a D.C. voltmeter having a minimum input impedance of [illegible] megohms. (See paragraph 4.7.5 of the Fuse Design Spec. for additional details.)

5.2.1.3 Fuse Resistance Check

At the conclusion of the above burn-in (5.2.1.1), the resistance of each fuse was measured with a Wheatstone bridge or equivalent sensitive instrument. (See paragraph 4.7.3 of the Fuse Design Spec. for additional details.) Any suspicious fuses were discarded.

5.2.1.4 Visual and Mechanical Examination

Following the above resistance check, each fuse was examined to verify that the materials, design, construction, physical dimensions, marking and workmanship are in accordance with the applicable requirements (see Paragraph 4.7.1 of Fuse Design Spec.)

5.2.1.5 Current Carry Capacity

At the conclusion of the above four tests, each fuse was subjected to a current carry capacity test using a 400 Hz, low voltage source at 125% of rated current. The fuses were apportioned and submitted to test temperatures of -55°C, +25°C and +85°C. Of those fuse ratings containing 44 samples each, (2, 5, 7-1/2 and 30A) 14 fuses were tested at -55°C, 16 at +25°C and 14 at +85°C.

Of those fuse amperes containing 24 samples each, (10, 15 and 20A) eight fuses were tested at -55°C, eight at +25°C and eight at +85°C. (See paragraph 4.7.6 of the Fuse Design Spec. for additional details.) The current carry tests were performed by Bussmann.

5.2.2 Group II - (2, 5, 7-1/2, 10, 15, 20 and 30A - 24 Fuses)

At the conclusion of Group I testing, 24 fuses of every ampere rating were exposed to Group II testing which consisted of the following:

a) Terminal strength
b) Overload interrupt
c) Insulation resistance

At the conclusion of these tests, only the maximum and minimum ampere ratings (2, 5, 7-1/2 and 30A) had fuses remaining for Group III - VI testing.

5.2.2.1 Terminal Strength

Twenty-four fuses of each ampere rating were tested for terminal strength by applying a three pound force to the lead assemblies, first, perpendicular to the terminal axis and second, along the terminal axis. (See paragraph 4.7.7 of the Fuse Design Spec. for further details.)

5.2.2.2 Overload Interrupt

Following the above Terminal Strength Test, the 24 fuses of each ampere rating were subjected to an overload interrupt test using a 60 Hz, 250V source. Of each group of 24 fuses, eight were tested at -55°C, eight at +25°C and eight at +85°C. The temperature at which each fuse was blown corresponds to the temperature of its current carry test. Each group of eight fuses was tested at four different current levels including two fuses at 200% of rating, two at 400%, two at 1,000% and two at 3,000%. (See paragraph 4.7.8 of the Fuse Design Spec. for additional details.) The overload interrupt tests were performed at Bussmann's test facility in Sauget, Ill.

Time current curves comparing overload interrupt data to the contract envelope are contained in Figures 17 - 37.

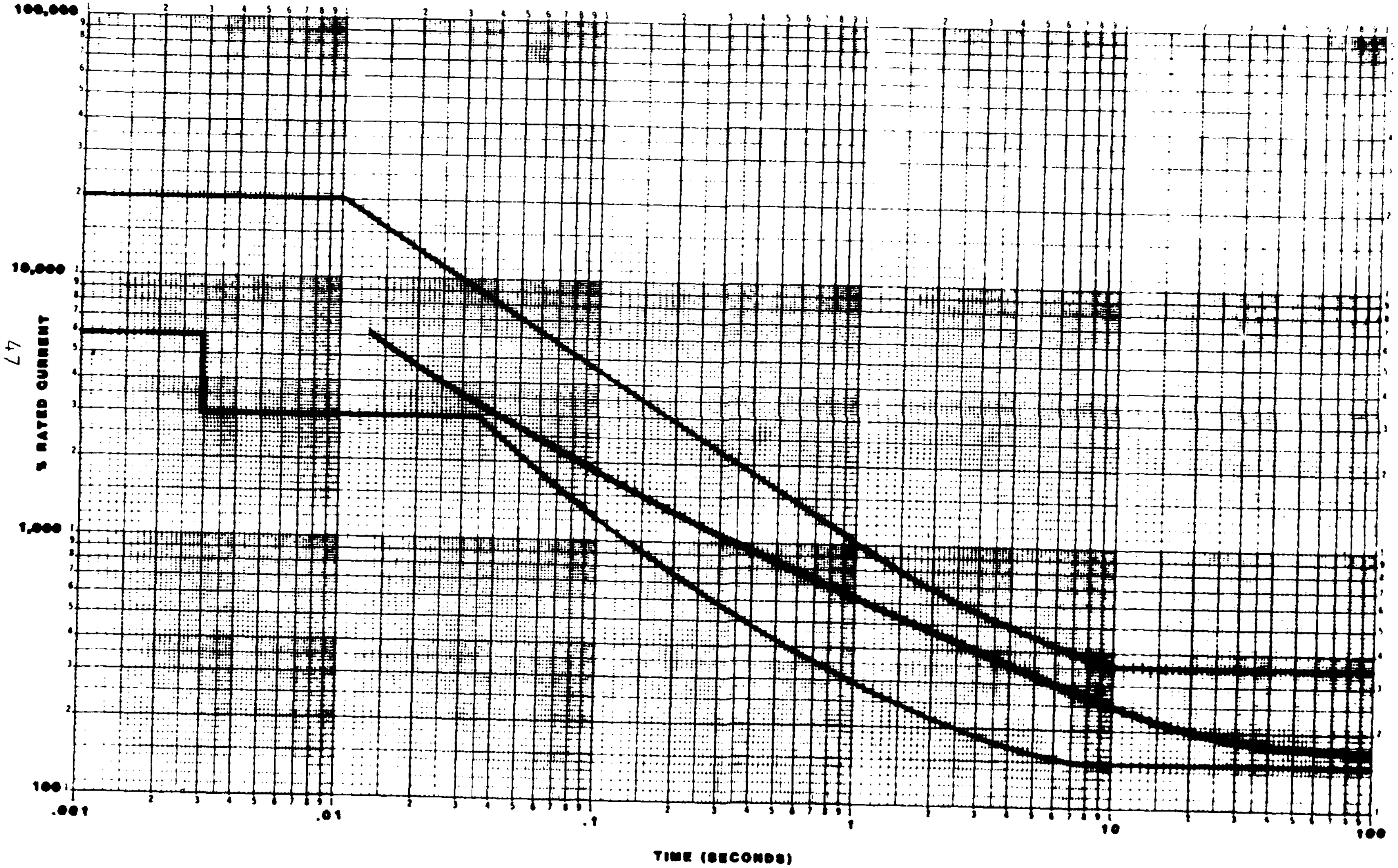


Figure 17
2A Overload Interrupt
+85°

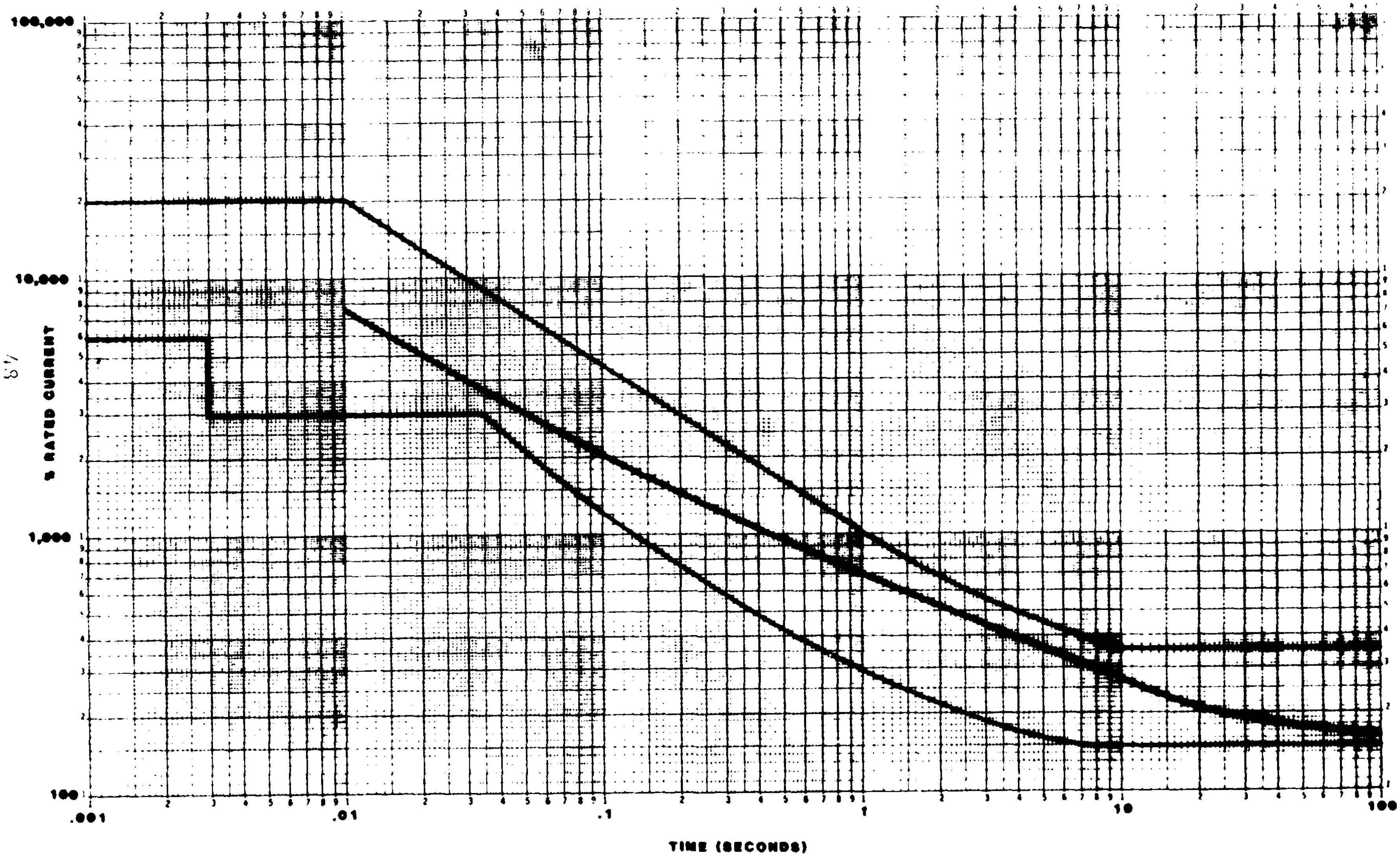


Figure 16
2A Overload Interrupt
+25°C

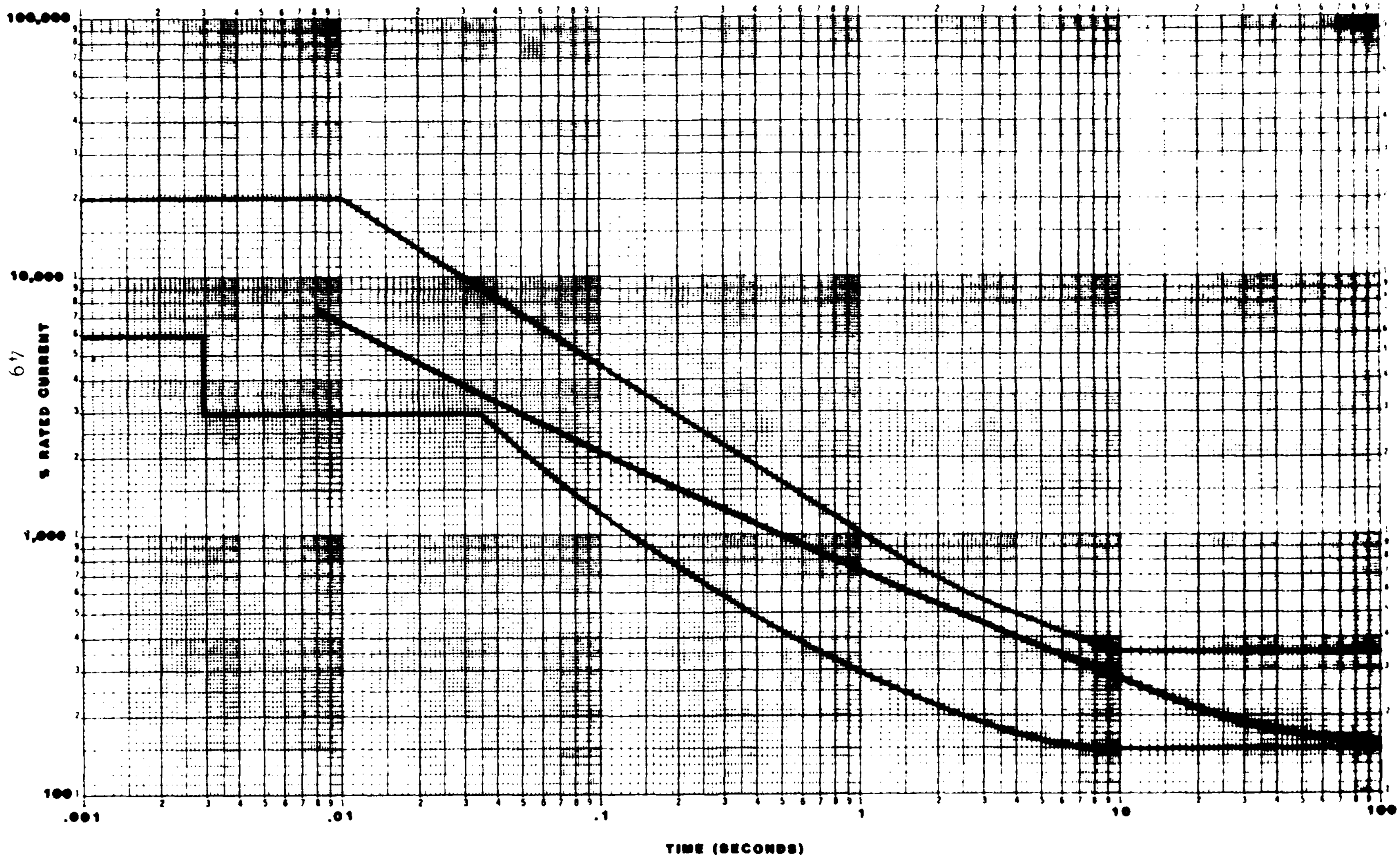


Figure 14
2A Overload Interrupt
-55°C

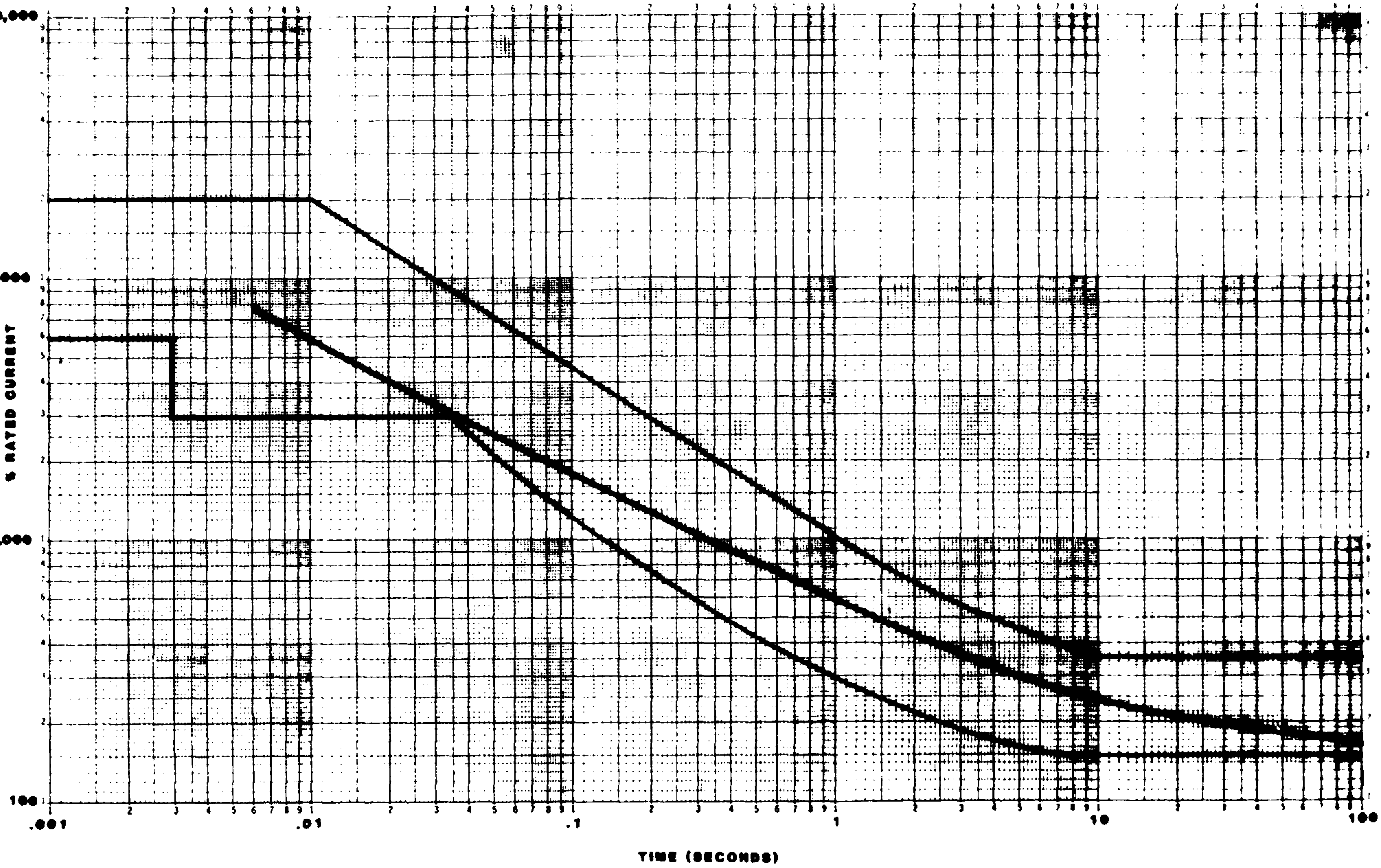


Figure 20
5A Overload Interr
+35°C

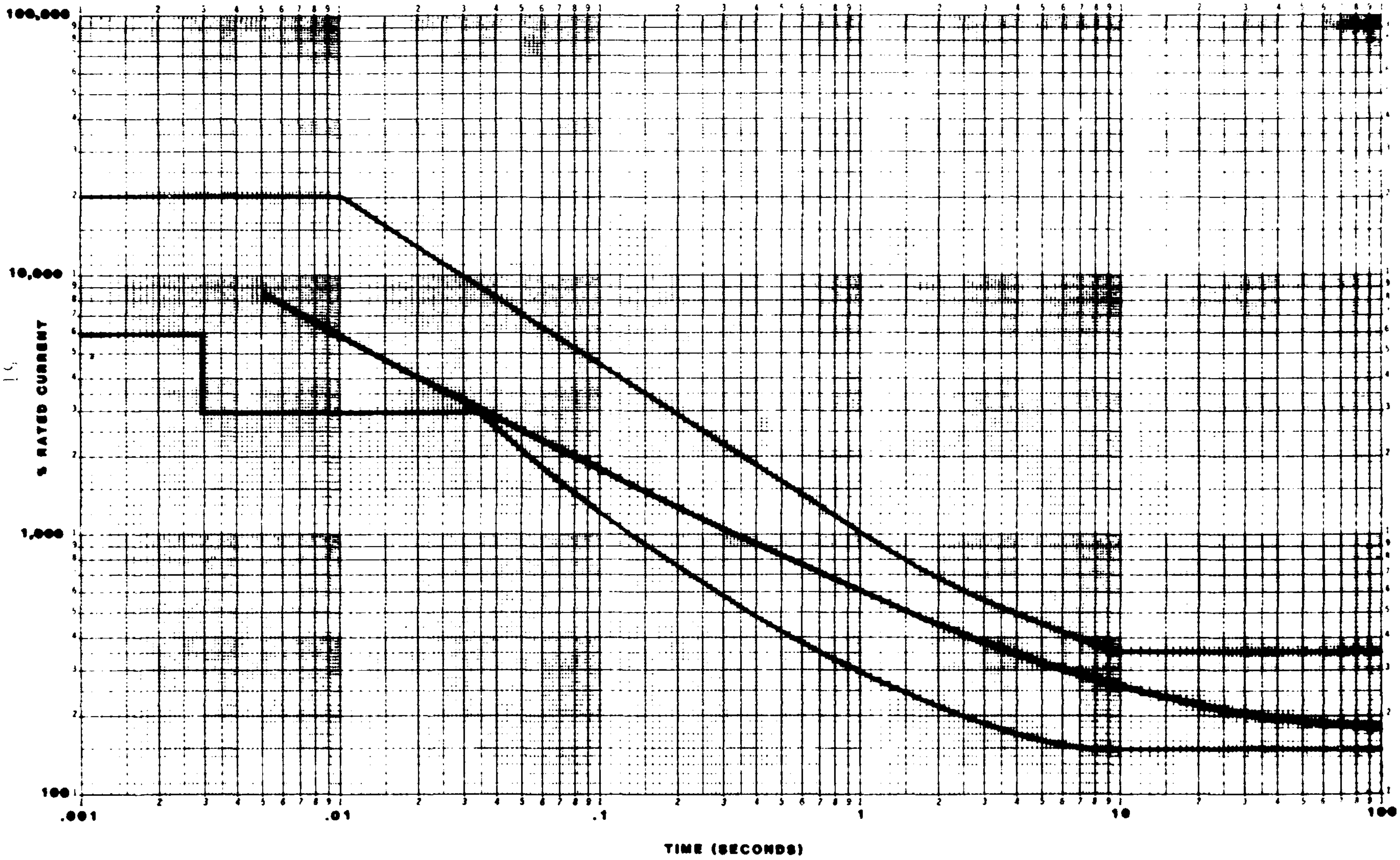


Figure 21
5A Overload Interrupt
+25°C

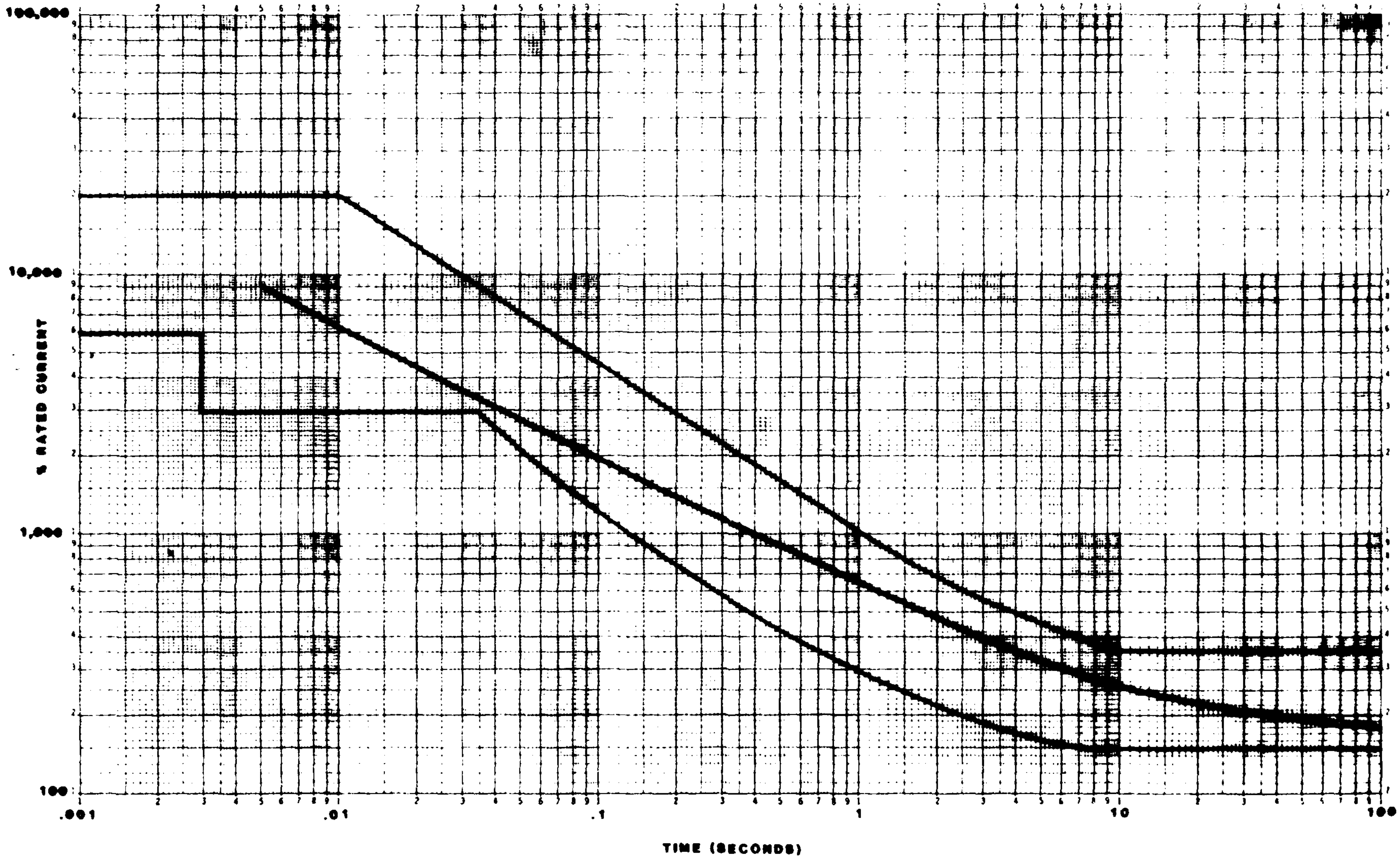


Figure [illegible]
5A Overload Interrupt[illegible]
[illegible]

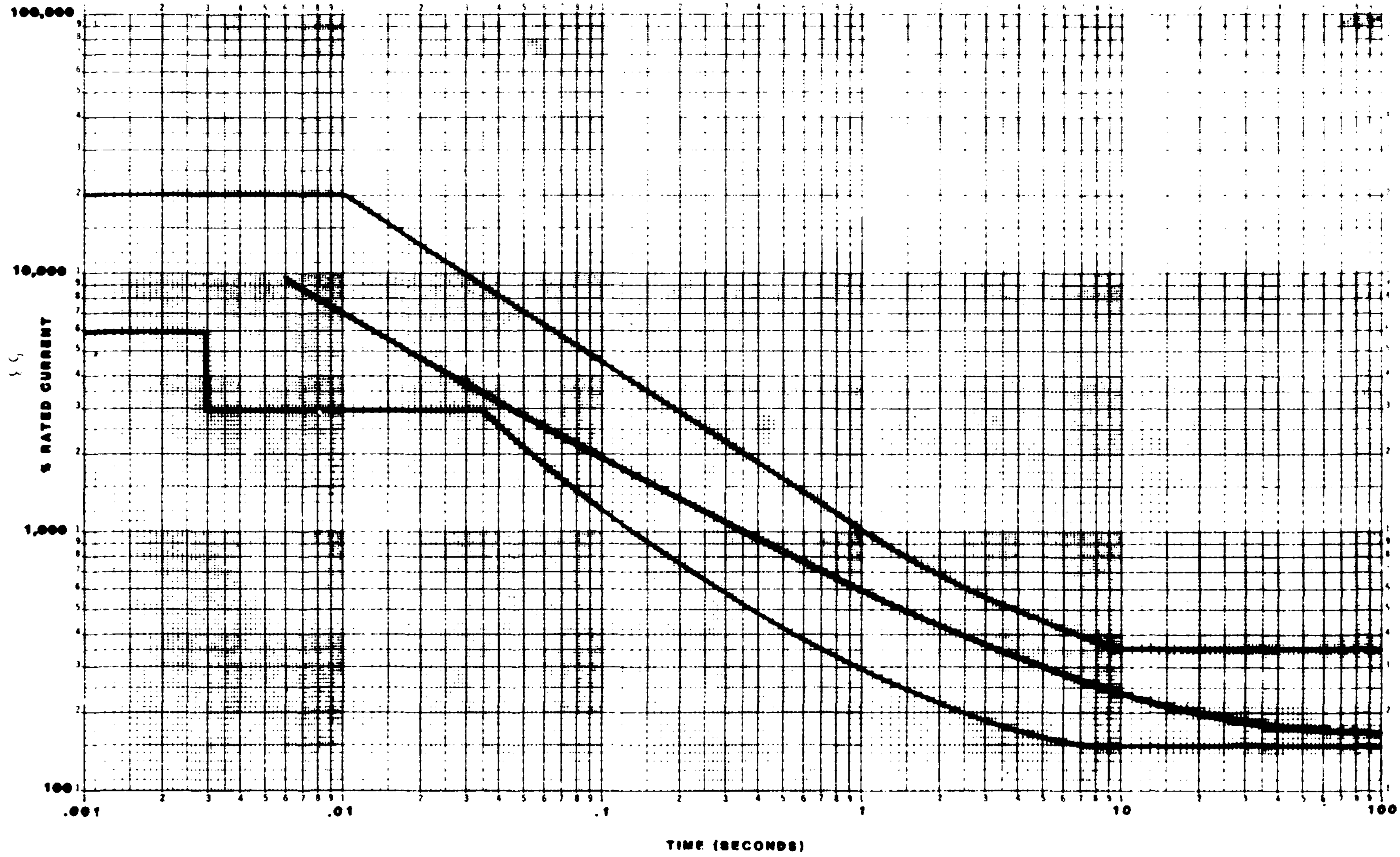


Figure 23
7.5A Overload Interrupt
+35°C

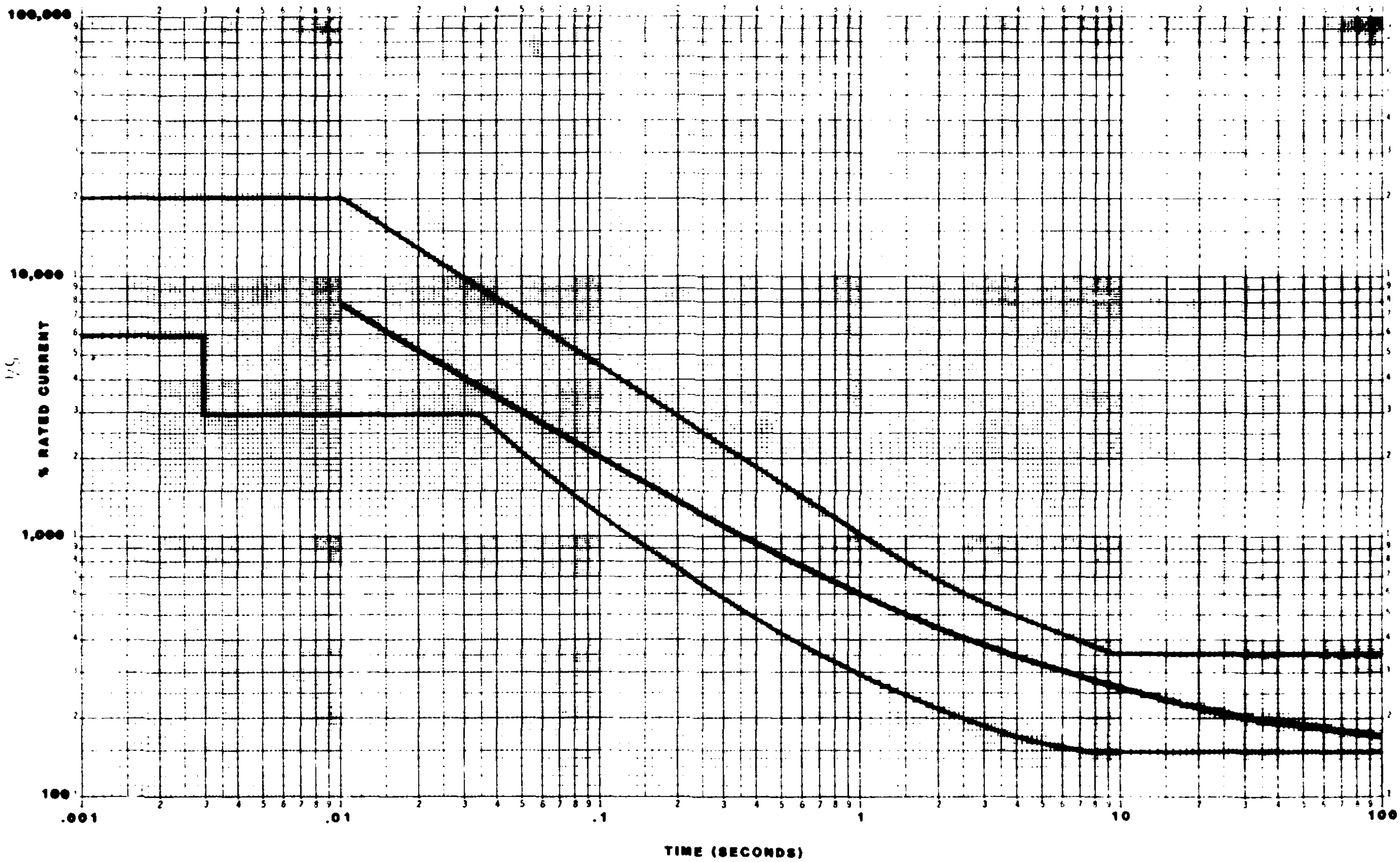


Figure 24
7.5A Overload Interrupt
125°C

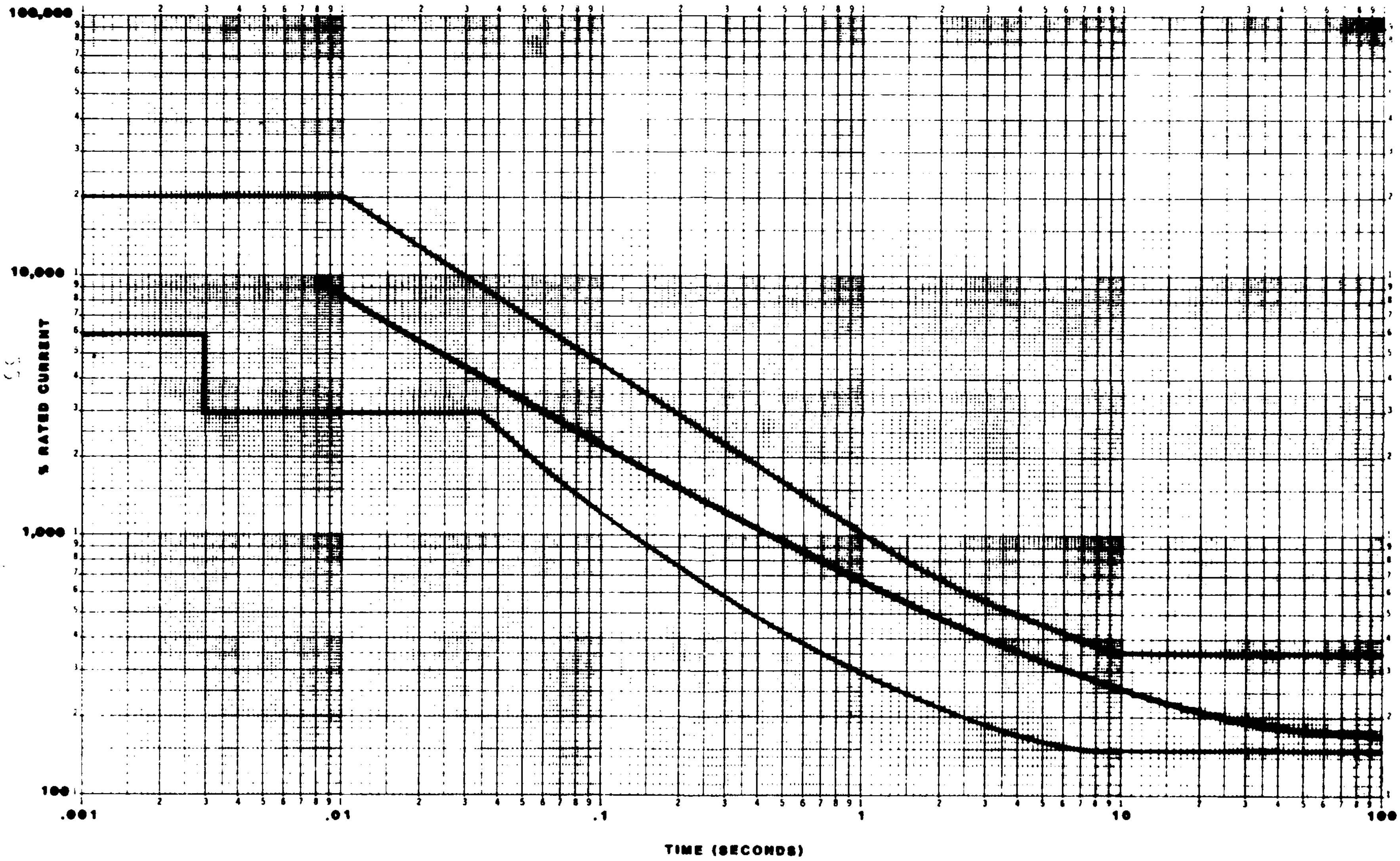


Figure 25
7.5A Overload Interrupt
-55°C

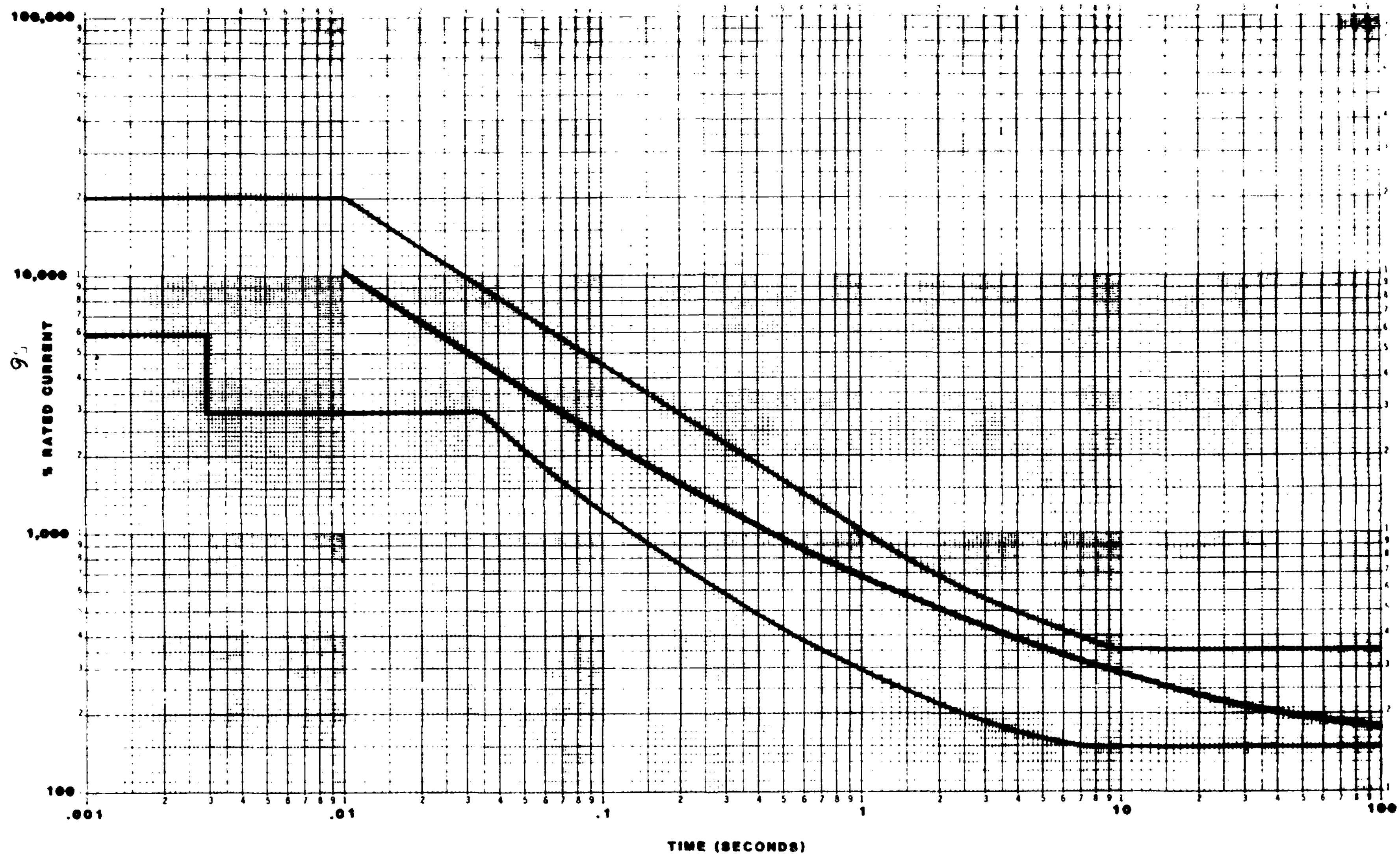


Figure 26
10A Overload Interrupt
+85°C

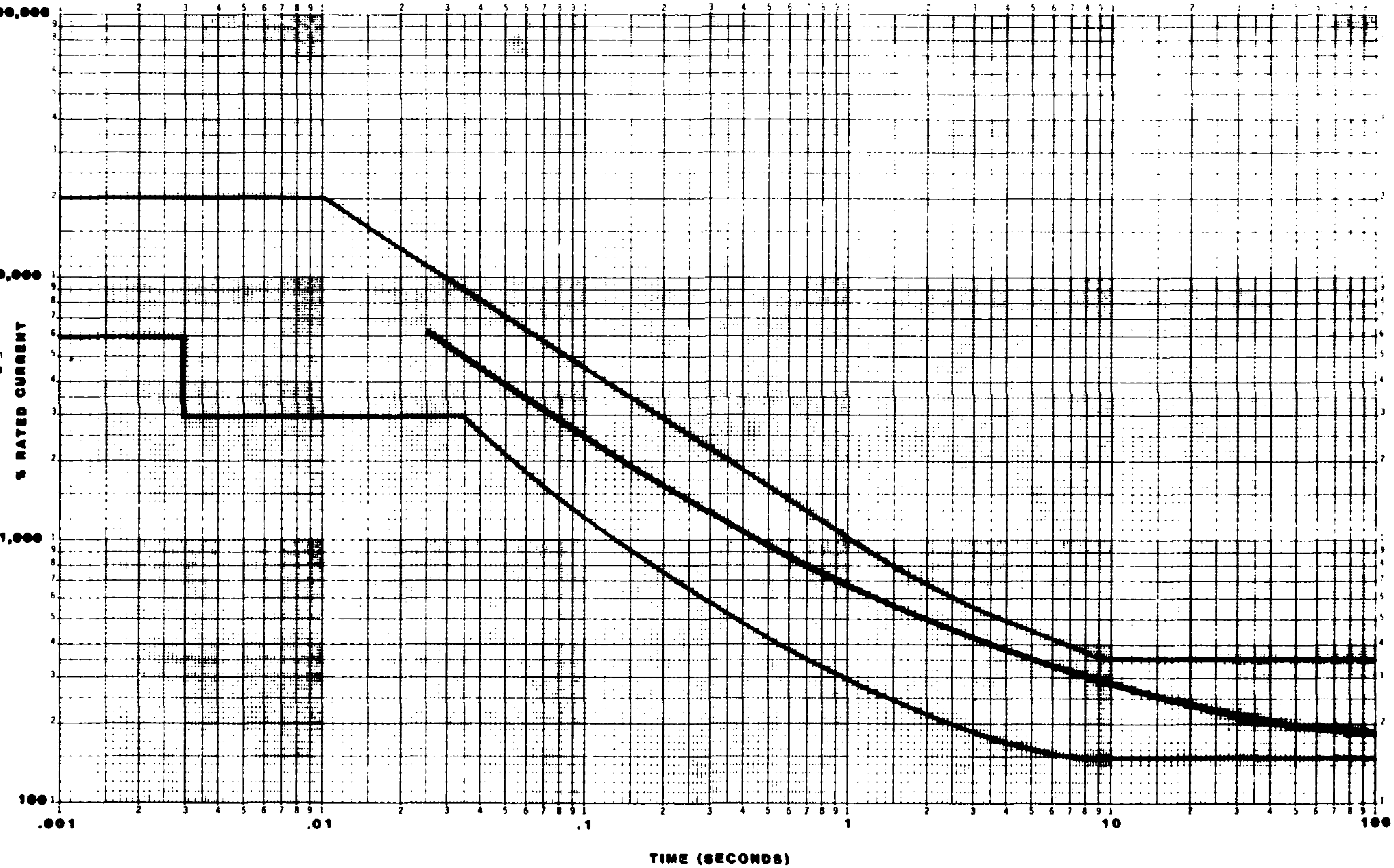


Figure 27
10A Overload Interrupt
+25oC

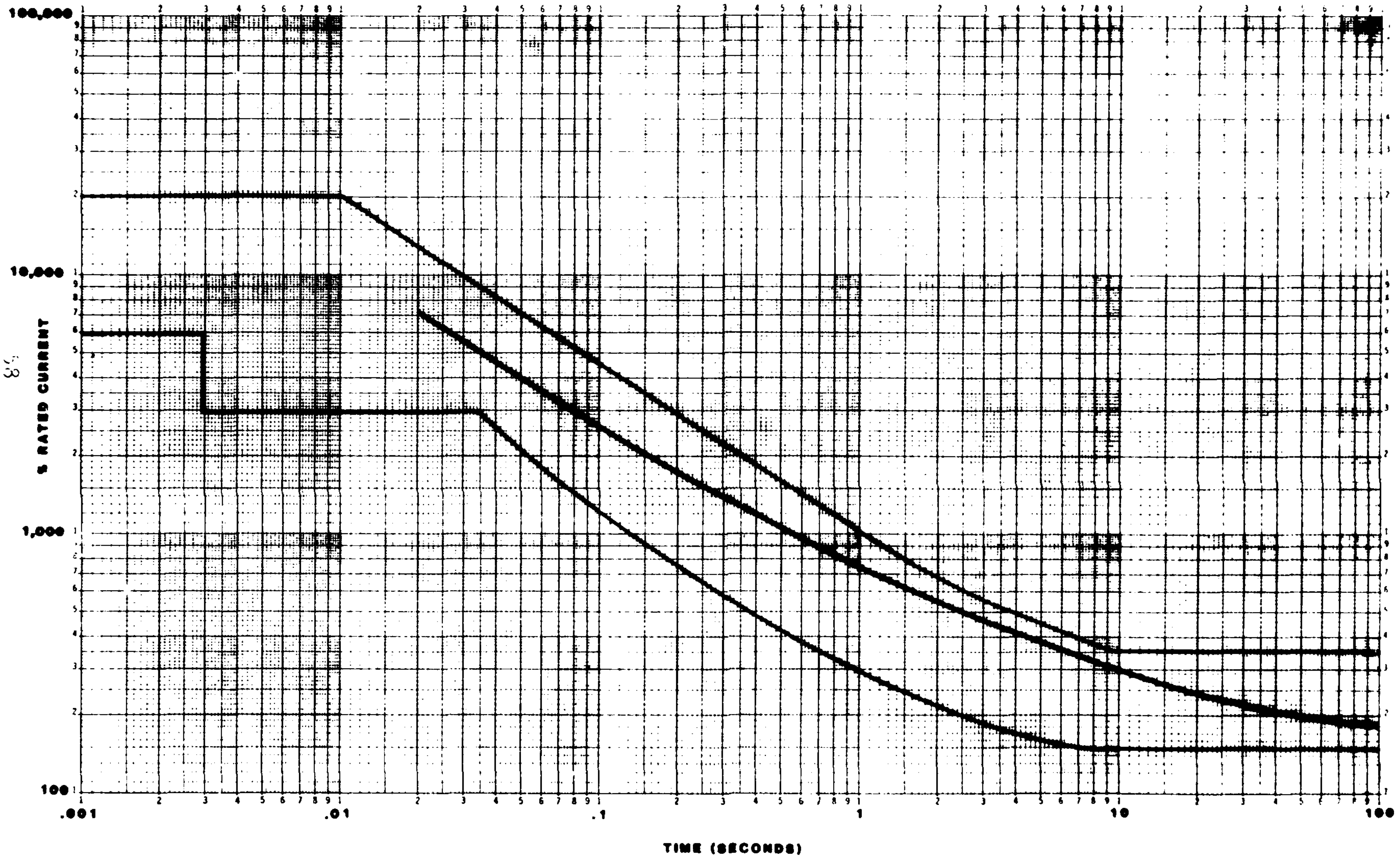


Figure 28
10A Overload Interrupt
-55°C

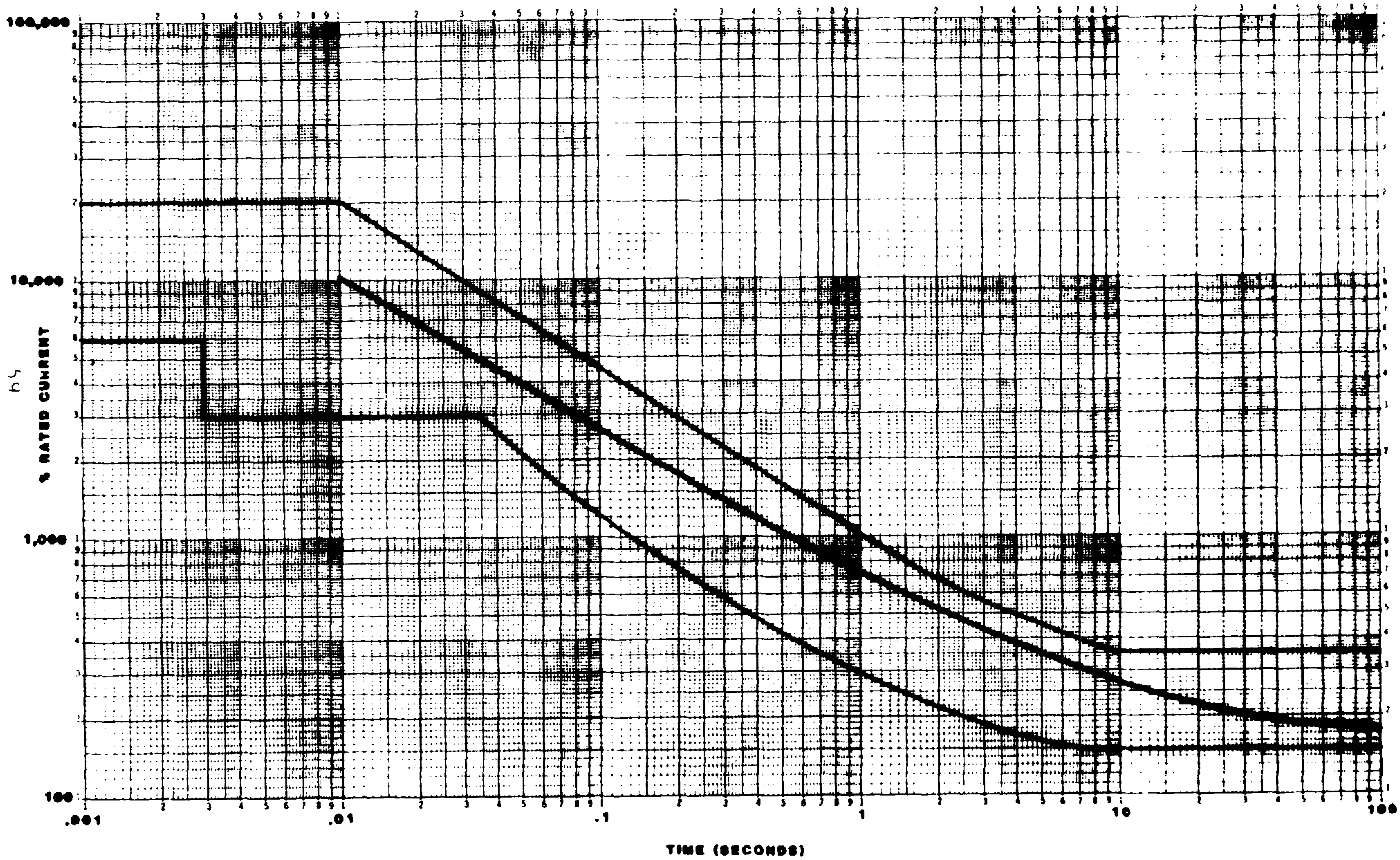


Figure [illegible]
15A Overload Interrupt
+85°C

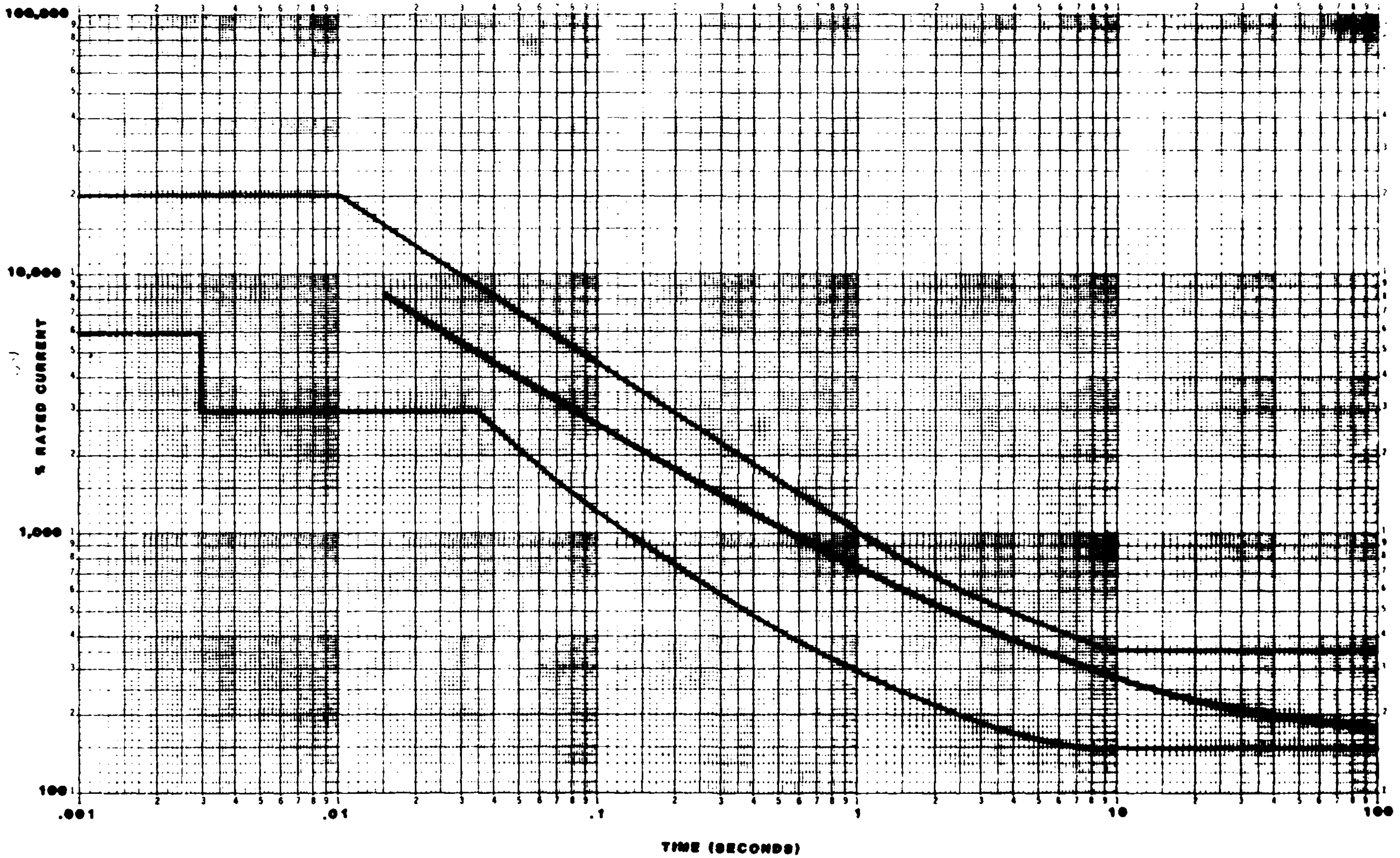


Figure 30
15A Overload Interrupt
4250[illegible]

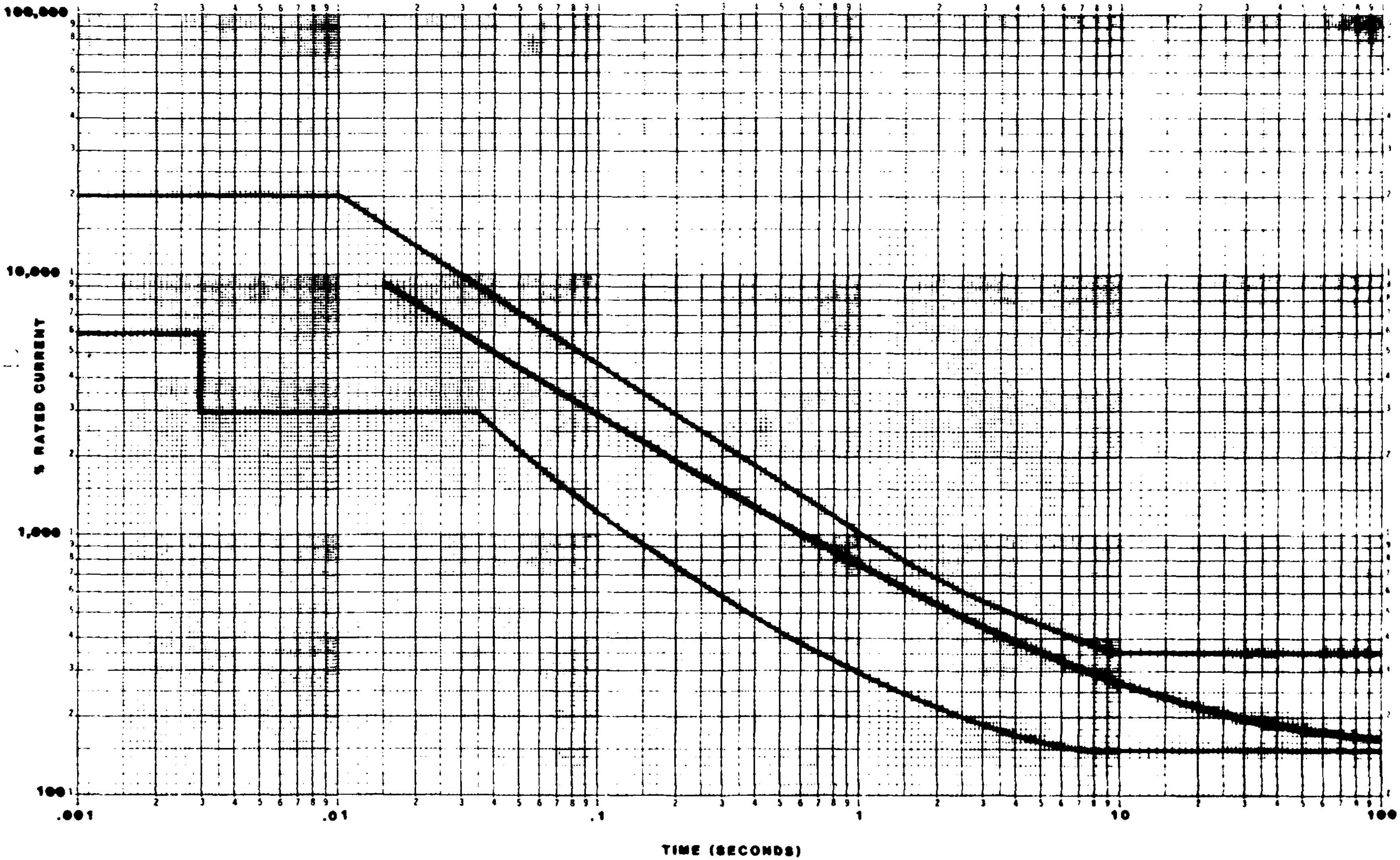


Figure 31
15A Overload Interrupt
-55°C

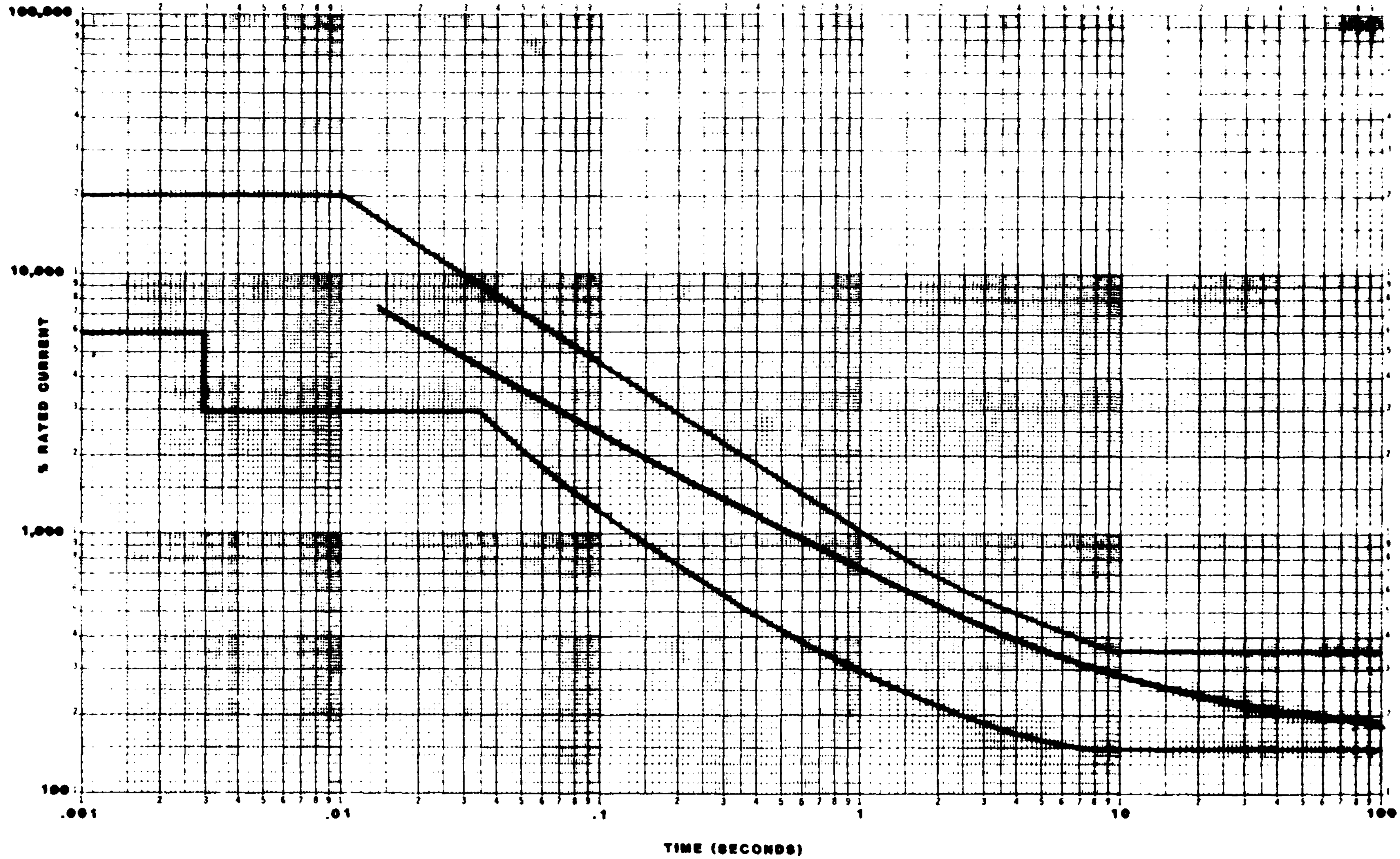


Figure 32
20A Overload Interrupt
+85°C

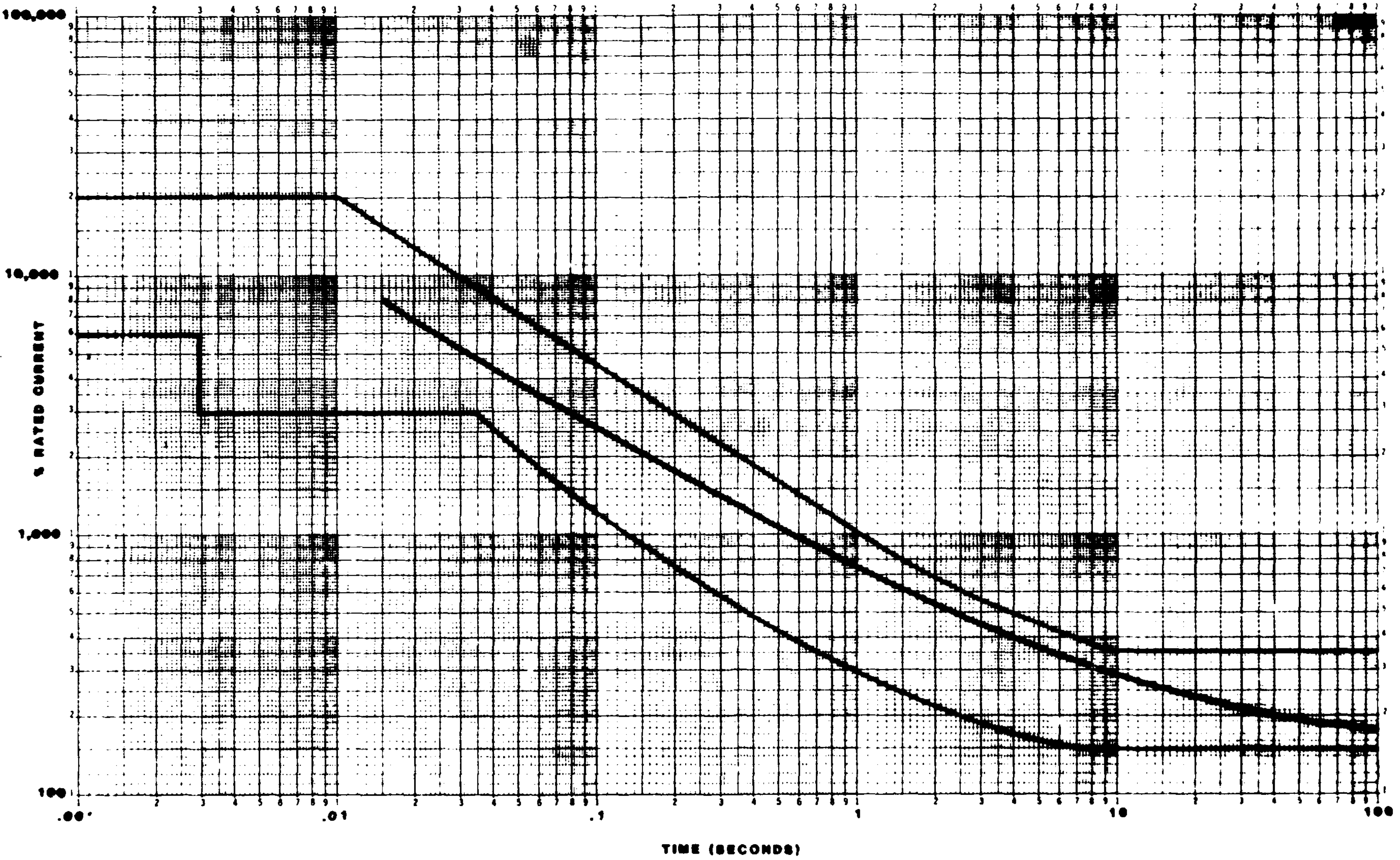


Figure 33
20A Overload Interrupt
+25°C

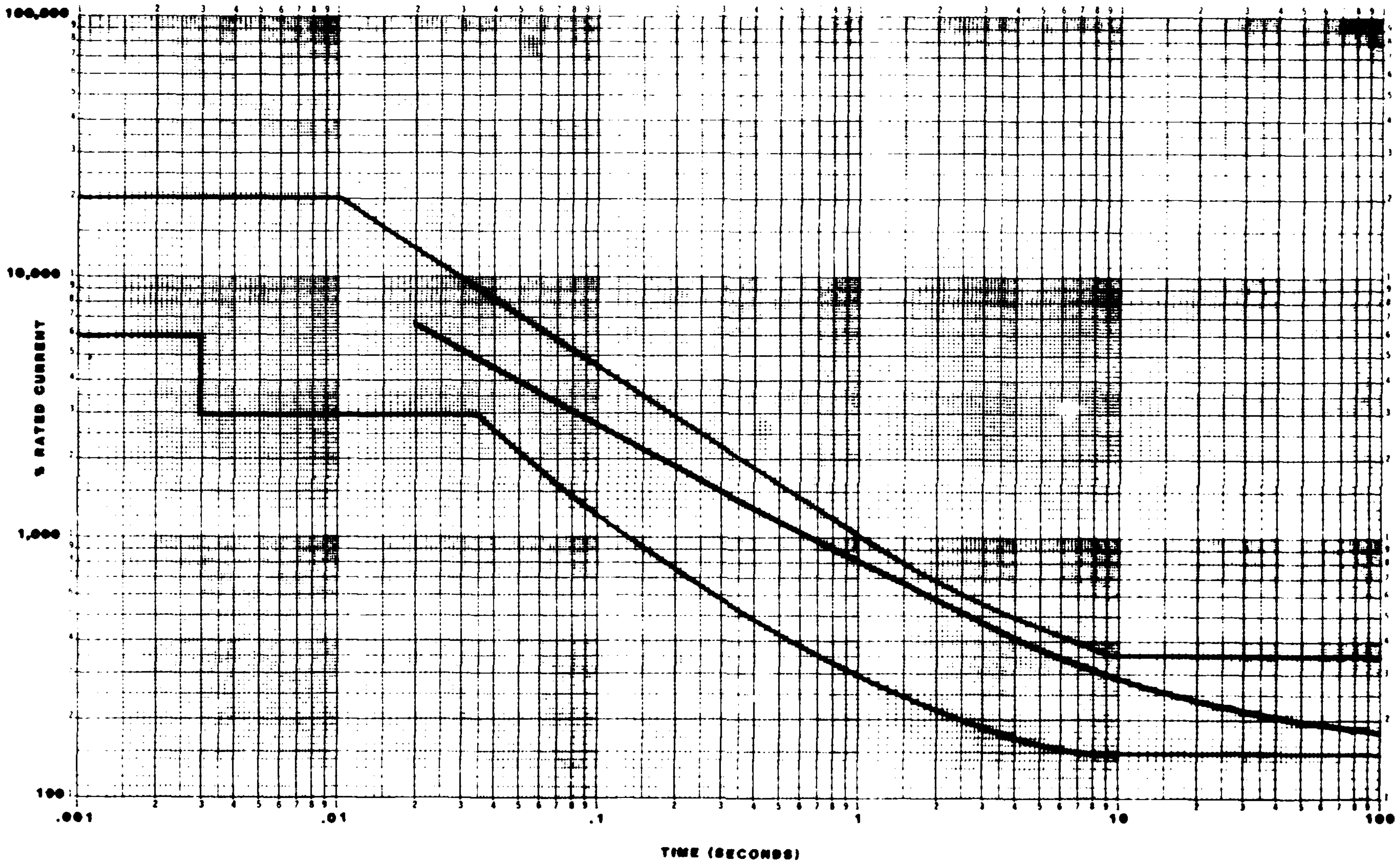


Figure 34
20A Overload Interrupt
-55°C

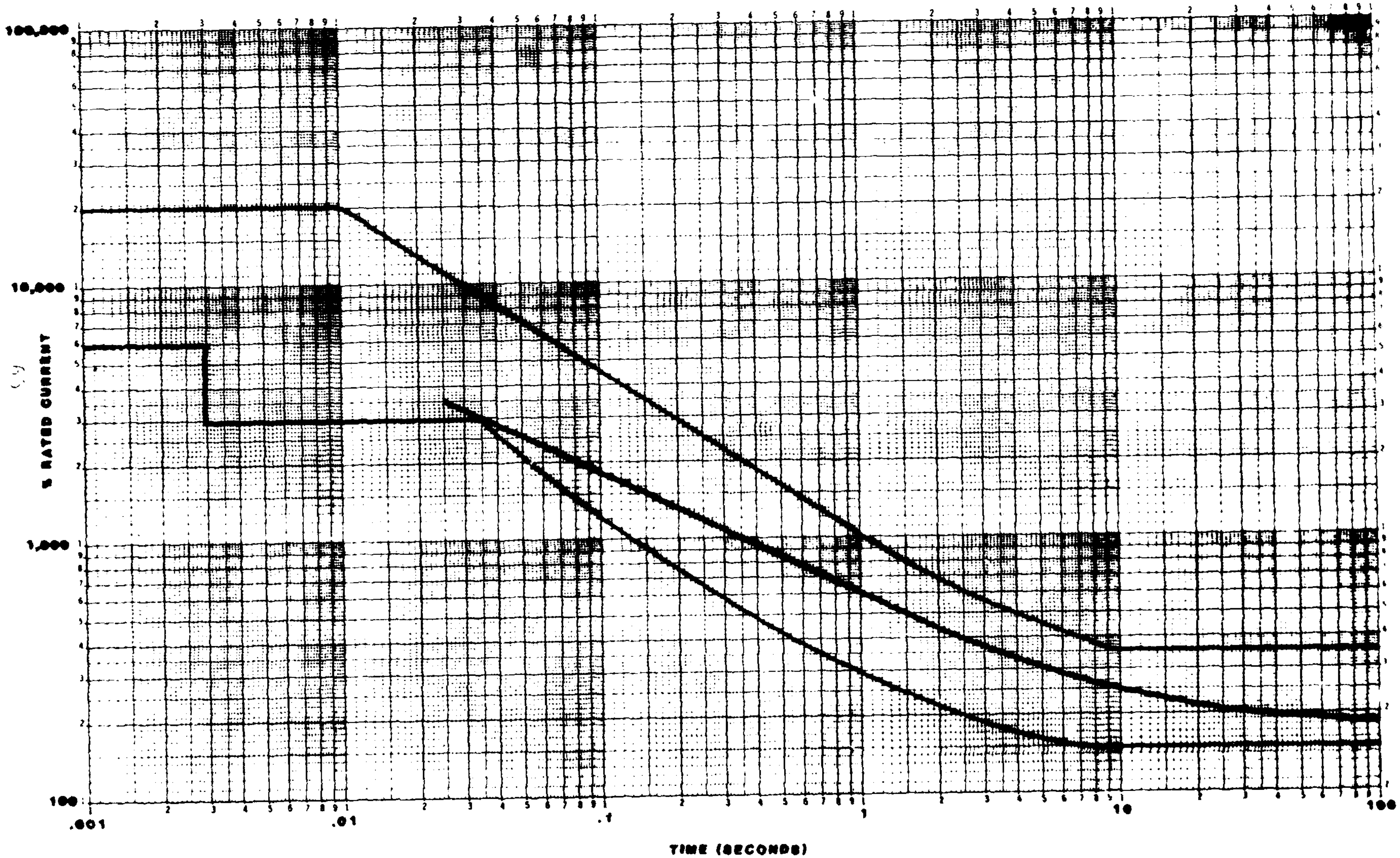


Figure 35
30A Overload Interru
+85°C

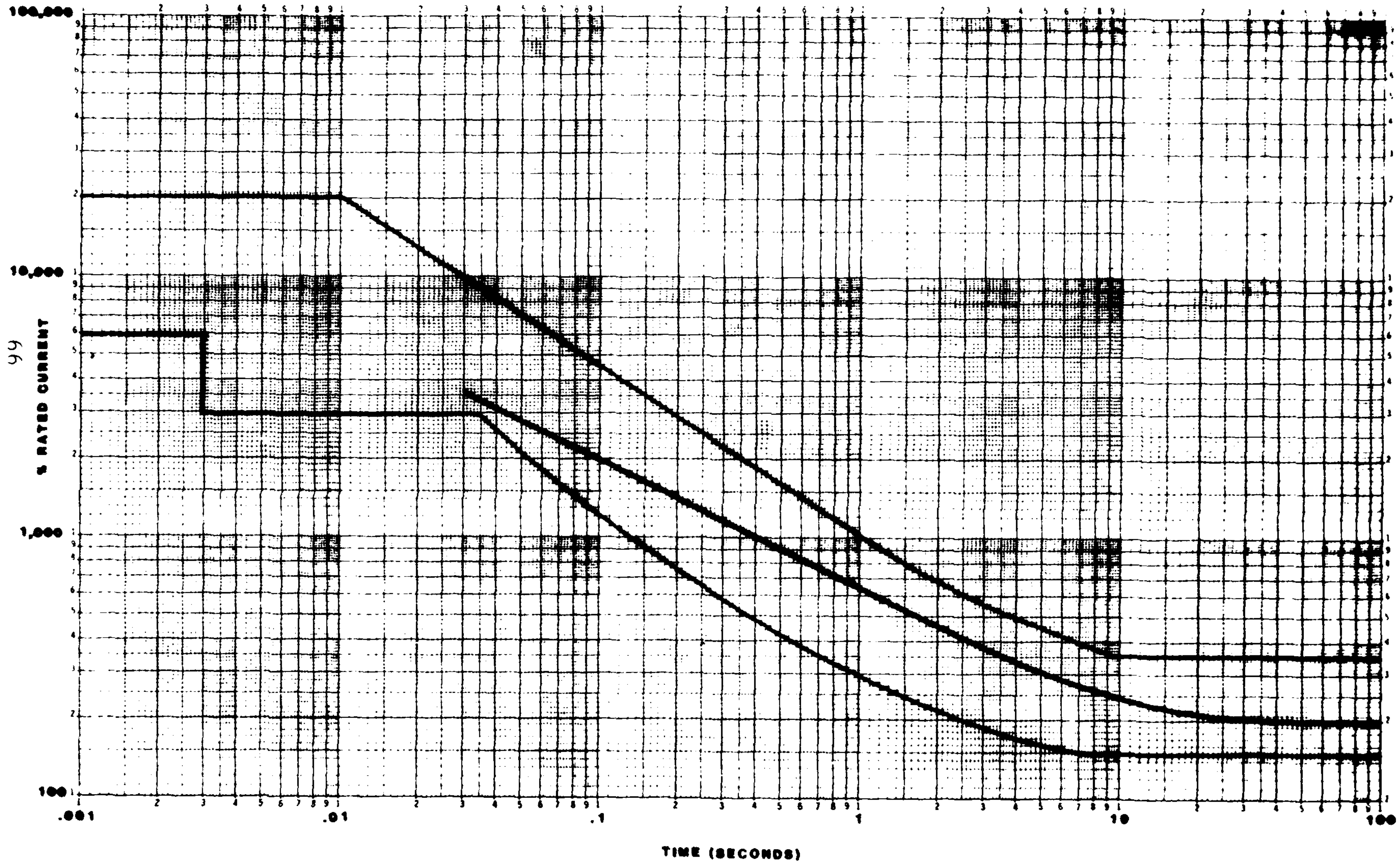


Figure 36
30A Overload Interrupt
+25°C

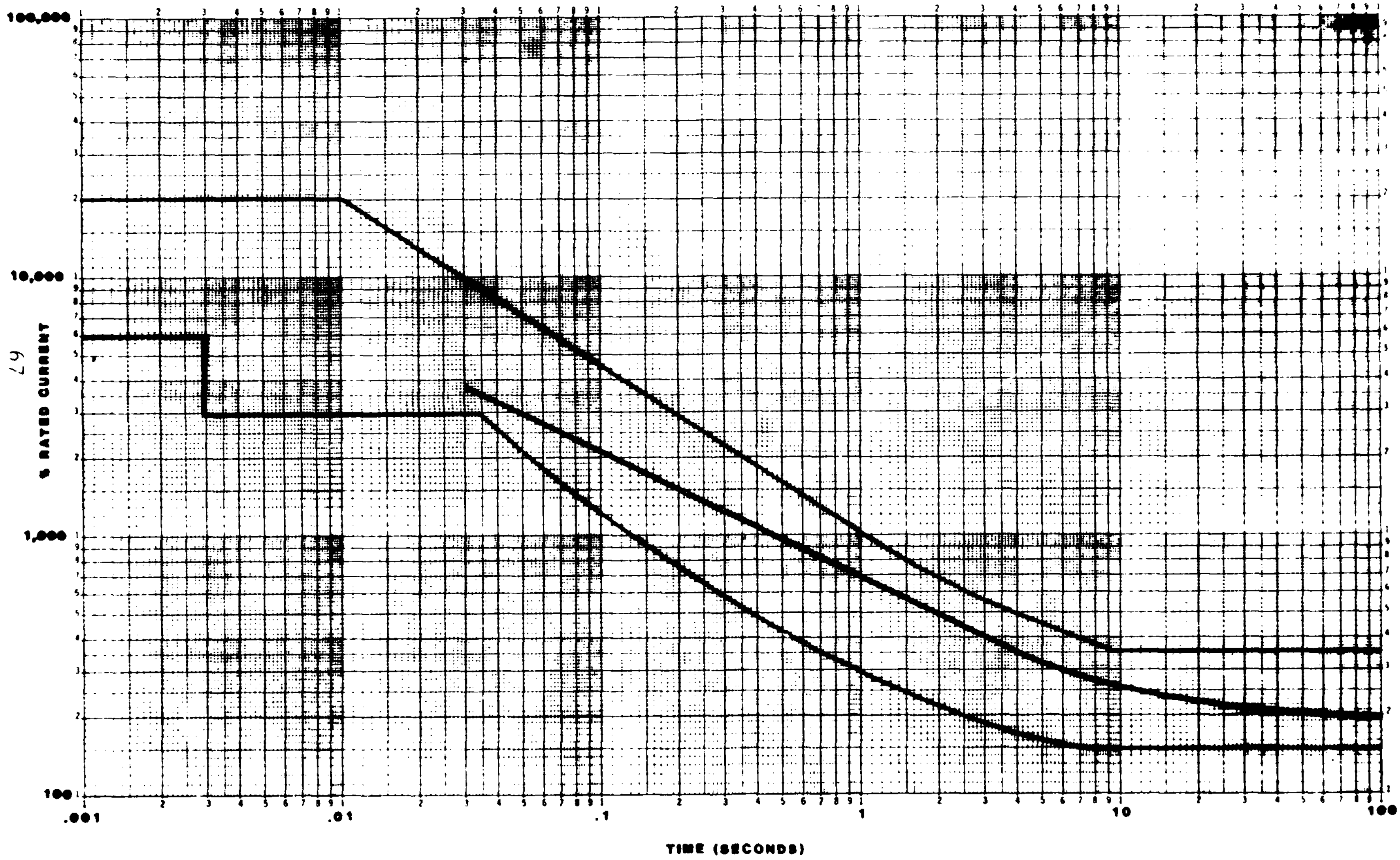


Figure 37
30A Overload Interrupt
-55°C

5.2.2.3 Insulation Resistance

Those fuses exposed to overload interrupt were tested for insulation resistance per paragraph 4.7.9 of the Fuse Design Spec.

5.2.3 Group III

At the conclusion of Group II testing, only the minimum and maximum ampere ratings of each fuse size remained (2, 5, 7-1/2 and 30A - 20 fuses each). Eight fuses of each ampere rating were exposed to Group III testing which consisted of the following:

a) Short circuit
b) Insulation resistance

5.2.3.1 Short Circuit

Following exposure to Group I testing, eight fuses of each remaining ampere rating (2, 5, 7-1/2 and 30A) were subjected to short circuit tests consisting of 10,000 amps at 250V on the 2 and 5 ampere ratings, and 7,500A at 250V on the 7.5 through 30 amp rating. The tests were performed at a power factor of .85 - .95 with a random closing point. All short circuit tests were performed at room ambient temperature. Of the eight fuses of each ampere rating, two had previously been exposed to a -55°C carry, four to a +25°C carry and two to a +85°C carry. Oscillograms and computer printouts were recorded on each fuse. (See paragraph 4.7.10 of the Fuse Design Spec. for additional details.) The short circuit tests were performed at Bussmann's test facility in Sauget, Ill.

Additional fuses were also subjected to D.C. short circuit tests consisting of 200A at 60V. These tests were performed by Bussmann at room ambient temperature.

5.2.3.2 Insulation Resistance

Those fuses exposed to short circuit currents were later tested for insulation resistance per paragraph 4.7.9 of the Fuse Design Spec.

5.2.4 Group IV

At the conclusion of Group III testing, 12 fuses each of the minimum and maximum ampere ratings (2, 5, 7-1/2 and 30A) remained. Of these 12 fuses, four fuses of each ampere rating were exposed to Group IV testing. Group IV testing consisted of the following:

a) Vibration
b) Continuity
c) Shock
d) Continuity

5.2.4.1 Vibration

Four fuses of each remaining ampere rating (2, 5, 7-1/2 and 30A) were exposed to high frequency vibration tests per paragraph 4.7.11 of the Final Fuse Design Spec.

Vibration tests were performed by Bussmann.

5.2.4.2 Continuity

Those fuses exposed to vibration testing were later checked for continuity using a low voltage ohmmeter per paragraph 4.7.2 of the Final Fuse Design Spec.

5.2.4.3 Shock

The same fuses exposed to vibration were later exposed to shock tests per paragraph 4.7.12 of the Final Fuse Design Spec. Shock tests were performed at Environ Laboratories in Minneapolis, MN.

5.2.4.4 Continuity

Those fuses exposed to shock testing were later checked for continuity using a low voltage ohmmeter per paragraph 4.7.2 of the Final Design Spec.

5.2.5 Group V

Following Group IV testing, eight fuses each of the minimum and maximum ampere ratings (2, 5, 7-1/2 and 30A) remained. Of the eight fuses, four fuses of each ampere rating were exposed to Group V testing, consisting of the following:

a) Salt spray
b) Overload interrupt
c) Insulation resistance

5.2.5.1 Salt Spray

Four fuses of each remaining ampere rating (2, 5, 7-1/2 and 30A) were exposed to salt spray (corrosion) tests per paragraph 4.7.13 of the Final Fuse Design Spec. The salt spray tests were performed at Environ Laboratories in Minneapolis, MN.

5.2.5.2 Overload Interrupt

Those fuses exposed to salt spray tests were later exposed to overload interrupt tests at room ambient temperature, 60 Hz, and 250 Volts.

Each group of four fuses was tested at four different current levels including one fuse at 200% of rating, one at 400%, one at 1,000% and one at 3,000%. Depending on the length of the blow, opening times were measured either with a stop watch, cycle counter or oscillogram. (See paragraph 4.7.8 of the Final Fuse Design Spec. for additional details). The overload interrupt tests were performed at Bussmann's test facility in Sauget, Ill.

5.2.5.3 Insulation Resistance

Those fuses exposed to overload interrupt tests were later tested for insulation resistance per paragraph 4.7.9 of the Final Fuse Design Spec.

5.2.6 Group VI

Following Group V testing, four fuses each of the minimum and maximum ampere ratings (2, 5, 7-1/2 and 30A) remained. The final four fuses of each ampere rating were exposed to Group VI testing which consisted of the following:

a) Moisture resistance
b) Thermal shock
c) Current carry capacity
d) Overload interrupt
e) Insulation resistance

5.2.6.1 Moisture Resistance

The four remaining fuses of each ampere rating (2, 5, 7-1/2 and 30A) were exposed to a moisture resistance test per paragraph 4.7.14 of the Final Fuse Design Spec. The moisture resistance tests were performed at Environ Laboratories.

5.2.6.2 Thermal Shock

The same fuses exposed to the moisture resistance check were later exposed to thermal shock per paragraph 4.7.15 of the Final Fuse Design Spec. The thermal shock tests were performed by Bussmann.

5.2.6.3 Current Carry Capacity

The same fuses exposed to moisture and thermal shock were later exposed to current carry tests using a 400 Hz, low voltage source at 125% of rated current. The test was performed at room ambient temperature. (See paragraph 4.7.6 of the Fuse Design Spec. for additional details.) The current carry tests were performed by Bussmann.

5.2.6.4 Overload Interrupt

The same fuses exposed to moisture, thermal shock and current carry were later subjected to overload interrupt tests at room ambient temperature, 60 Hz and 250 volts.

Each group of four fuses was tested at four different current levels including one fuse at 200% of rating, one at 400%, one at 1,000% and one at 3,000%. Depending on the length of the blow, opening times were measured either with a stop watch, cycle counter or oscillogram. (See paragraph 4.7.8 of the Final Fuse Design Spec. for additional details.) The overload interrupt tests were performed at Bussmann's test facility in Sauget, Ill.

5.2.6.5 Insulation Resistance

Those fuses exposed to the above four tests were later tested for insulation resistance per paragraph 4.7.9 of the Final Fuse Design Spec.

5.3 Qualification Test Results

The results of the qualification testing program are included as Appendix J. With the exception of the following minor variations, all fuses of each ampere rating satisfied the requirements of the Final SSPC Fuse Design Specification (Appendix I).

5.3.1 Group I Testing - Visual and Mechanical Examination

Under Visual and Mechanical examination, two variations were noted.

a) On the 7.5 - 30 amp range both caps were stamped with "Buss" and the ampere rating. The second cap should have been stamped "250V".

b) On the 7.5 and 10 amp fuses, the lead length ran slightly less than the specified 1.50" minimum. This is a minor variation since leads are usually cut shorter during application.

5.3.2 Group III Testing - Short Circuit Tests

Since DC short circuit tests were originally overlooked, no fuses were saved for this purpose. We therefore used the fuses that had been previously exposed to shock and vibration. Several fresh fuses were also tested in the 5A and 30 amp sizes. All fuses proved acceptable.

5.4 Fabrication of Contract Fuses

Phase IV of the SSPC contract required the fabrication of 220 fuses of each ampere rating for Air Force evaluation. The fuses were delivered to the Air Force with the original draft of this report.

5.5 Final Technical Report

Phase IV of the SSPC contract required the preparation of a final technical report covering all of the technical development and testing conducted in this program. The draft version was submitted to the Air Force for review in September of 1983. This final version contains all of the appropriate changes, additions and deletions suggested by the Air Force.

5.6 Final Design Review Meeting

The Final Design Review Design Meeting of Phase IV was eventually concelled by the Air Force, however, all preparations by Bussmann had been completed.

SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX A

SSPC FUSE PAPER SEARCH

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

Appendix A

SSPC Fuse Paper Search

Bussmann Division
McGraw-Edison Corporation
P.O. Box 14460
St. Louis, MO 63178

Final Report

February 28, 1982

Vernon Spaunhorst
Design Engineer

Martin Smith
Martin R. Smith
Chief Engineer

Dean Klohr
Project Manager

FOREWORD

This document is a final report for the SSPC Fuse Paper Search. The work was performed by Bussmann Division, McGraw-Edison Company, St.Louis, Missouri under Air Force Contract No. F33615-81-C-2052.

Martin R. Smith of the Bussmann Division, was technically responsible. The report was prepared by Vernon Spaunhorst, also of Bussmann, with significant contribution by:

Mr. Robert Yount
Q.R.C., Inc.
8905 Fairview Road
Silver Spring, MD 20910

Mr. Varinder Kalra	Bussmann
Mr. Earle Long	Bussmann
Mr. Walter Curtis	Bussmann

TABLE OF CONTENTS

LISTS OF ILLUSTRATIONS AND TABLES

SECTION I

INTRODUCTION AND SUMMARY

1.1 Introduction

The SSPC "Paper Search" was conducted in an effort to verify a number of unique requirements associated with the SSPC and the fuse devlopment contract. These requirements include time-current characteristics, usage, (voltage/current ratings vs. units used), maximum fault current, operating and storage temperature and altitude range.

In addition, Bussmann felt the Paper Search was necessary to provide the personnel involved in the fuse development program with a better understanding of the SSPC and its requirements.

The Search concentrated primarily on Air Force technical reports plus documents provided by QRC Incorporated, who obtained the material from a search of the Defense Technical Information Center (DTIC). It should be noted that most of these reports are fairly old, dating back to the early and mid 70's.

1.2 Summary

The SSPC Paper Search consisted of a review of the papers listed below and interviews with representatives of the aircraft industry, SSPC manufactures and Military specialists.

Bussmann Data Ascention

Item No.	Title
1	Development of Transistorized Solid State Power Controllers for B-1 Flight Tests (Nov. 1977)
2	Advanced Solid State Power Controller Development Phase I Study Report (Sept. 15, 1978)
3	Solid State Power Controller Verification Studies, Final Technical Report (Jan. 1979)
4	Power System Control Study Phase I - Integrated Control Techniques (Oct. 1979)
5	MIL-P-81653B Power Controller, General Specification For (Feb. 1980)
6	Power System Control Study, Phase I - Integrated Control Techniques, Phase II - System Modeling (March 1981)
7	High Current Power Controller (April 1981)
8	Advanced Aircraft Electrical System Control Technology Demonstrator Phase I: Requirements Analysis and Conceptual Design (July 1981)
20	AD-A003834 "Influences of Solid State Electrical Distribution on Aircraft Power Generation Solid-Power Controller Compatibility"
21	AD-A008595 "Power Controller Breadboard and Development Requirements"
22	AD-A014366 "Further Evaluation of the Solid State Simulator for the A-7B Aircraft Electrical System"
23	AD-A022616 "AC Power Controllers for B-1 Flight Tests. Part I: Final Technical Report Design, Development Fabrication and Testing of Hybrid Power Controllers"

Item No.	Title
24	AD-A056256 "Development of Transistorized Solid State Power Controllers for B-1 Flight Tests"
25	AD-A063405 "Advanced Solid State Power Controller Development. Phase I Study Report"
26	AD-A047859 "Advanced Aircraft Electrical Systems (AAES). Definition and Prototype Design for F-14 Aircraft. Volume 1: Technical"
27	AD-A086994 "AC Controller Feasibility Study (RCA)
28	AD-A082759 "Power Controller 28V DC Load Switching (N.O. SPST)
29	AD-A08166 "Feasibility Study B-1 Power Controller"
30	AD-B039643 "Study of Solid State Remote Control Techniques as Applied to the Redesign of the Electrical System in a Large Civil Aircraft"
31	WAED73.01E "Design Development, Fabrication and Evaluation of a Three-Phase Ten Ampere Solid State Power Controlled Breadboard
32	Bibliography of Wire Damage Data
33	MIL-W-5088H "Military Specification Wiring, Aerospace Vehicle"
37	Final Report #058-AER.01 on Performance of a 52-79721-422 Circuit Breaker
38	U.S. Government Memorandum. Mechanical Fracture of Filamentary Fuses
39	Failure Mechanisms Report #FMR 04-003. The Mechanisms of Degradation and Failure in a Filamentary Fuse Wire
40	Failure Mechanisms Report #FMR 04-002. Effect of a Thermal-Vacuum Environment on the Electric Characteristics of Buss GLX Fuses

Item No.	Title
41	Report of Fuse Performance and Its Relationship to Initial Parameter Measurements
42	Report on the Use of Hot Wire Resistance Measurements to Select Homogeneous Fuses

Of the 28 documents listed above, the 1979 report entitled "Solid State Power Controller Verification Studies, Final Technical Report" (Item #3), was by far, the most comprehensive and informative source found. In addition, it appeared to contain the most recent information on the development of the SSPC.

The main objectives of the search, which were to verify certain contract requirements plus develop a better understanding of the SSPC, have, for the most part, been completed. As can be seen in the following sections, most requirements of the contract have been verified. There are, however, several specifications which remain uncertain.

The first of these is the slope of the lower curve as explained in Section 2.2. Another area of concern is the SSPC usage. The search indicates 65% of the SSPCs to be less than 2.0 amps while the contract calls for fuses of 2 to 30 amps. A third important specification is the 8,000A interrupting capacity. As of this date, no available test facility, capable of providing 8,000A at 400 Hz, has been located.

Section II

Verification of the SSPC Envelope Characteristic Curve

2.1 The Upper Limit (Wire Damage Characteristics)

Information on aircraft wiring and wire damage is not easily obtainable and the information that is available is complicated and difficult to apply.

Available information idicates that wire damage is influenced by a number of conditions including ambient temperature, altitude, wiring insulation and packaging (bundles or free air).

Mr. Ron Solomon of the McDonnell Douglas Corporation recommended obtaining MIL-W-5088H (Item #33) which covers the selection and installation of wiring and wiring devices used in aerospace vehicles. This document gives a substantial amount of information including the effects of bundles, ambient temperature, altitude, etc. However, there was no apparent method of applying this information to Bussmann's "upper limit" curve.

Additional wire damage information was found in the following documents:

1) Solid State Power Controller Certification Studies, Final Technical Report (Item #3)

2) Power Controller Breadboard and Development Requirements (Item #21)

3) Feasibility Study, B-1 Power Controller (Item #29)

The information contained in these reports does not pertain specifically to wire damage, but is included as a part of the requirements for SSPCs and related fuses. Figure 1 compares the information of these reports with the requirements contained in Bussmann's contract #F33615-81-C-2052.

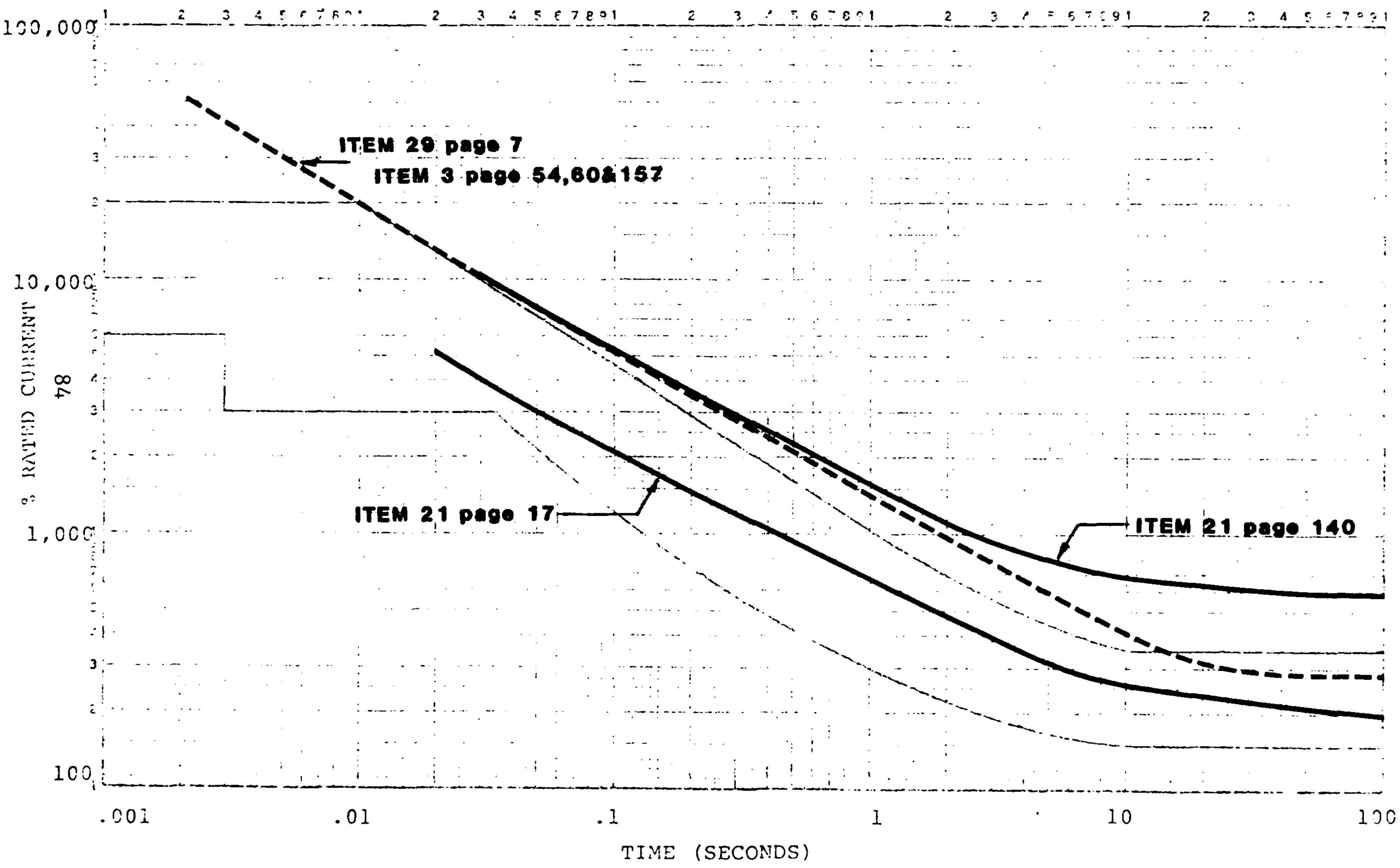

100,000
10,000
1,000
100
% RATED CURRENT
.001
.01
.1
1
10
100
TIME (SECONDS)
ITEM 29 page 7
ITEM 3 page 54,60&157
ITEM 21 page 17
ITEM 21 page 140

Figure 1

Items #3 and #29 compares time vs. load in amps for 2A SSPCs only, while Item #21 compares time vs. percent of rated load current. As can be seen in Figure 1, except for the low end, these curves are almost identical. Even more important is the fact that these curves are very similar to the curve in Bussmann's contract.

Bussmann was hoping to receive additional documents on wire damage from QRC, Incorporated. However, it now appears that all available material has been received. Based on present data, it appears the "upper limit" curves specified in Bussmann's contract are valid.

2.2 The Lower Limit (SSPC Trip Characteristic)

Information on the "lower limit", was, for the most part, obtained from the same documents used for the "upper limit" verification. The data, which was available primarily in curve form, was found in the following documents:

1) Solid State Power Controller Verification Studies, Final Technical Report (Item #3)

2) Power Controller Breadboard and Development Requirements (Item #21)

3) Feasibility Study, B-1 Power Controller (Item #29)

Figure 2 compares the information of these reports with the requirements contained in Bussmann's contract.

Even though some curves were given in time vs. load in amps for 2A SSPCs while others were shown in time vs. percent of rated load current, they appeared, for the most part, very similar. As can be seen in Fig. 2, the curve in Bussmann's contract could almost be interpreted as an average of the other curves. However, one source of information, not included in Fig. 2, which does not coincide with these curves is the data resulting from tests performed on a sample SSPC by McDonnell Douglas for Bussmann. Results of this testing is included in Section III. A lower curve incorporating this data is significantly closer to the performance curve of fuses.

Data from this test also supports some concern regarding the current limiting portion of the curve. As shown in Fig. 2, the current limiting point of the contract is 3000% compared to the 1500% of Item 3, page 54. Actual test data indicates a current limiting point of approximately 900%. The difference in both the slope and the current limiting point could significantly alter the fuse design.

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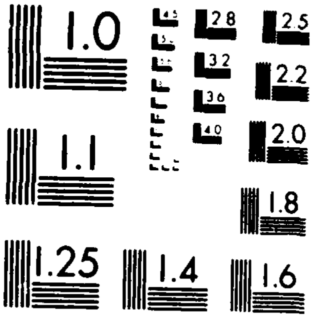


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

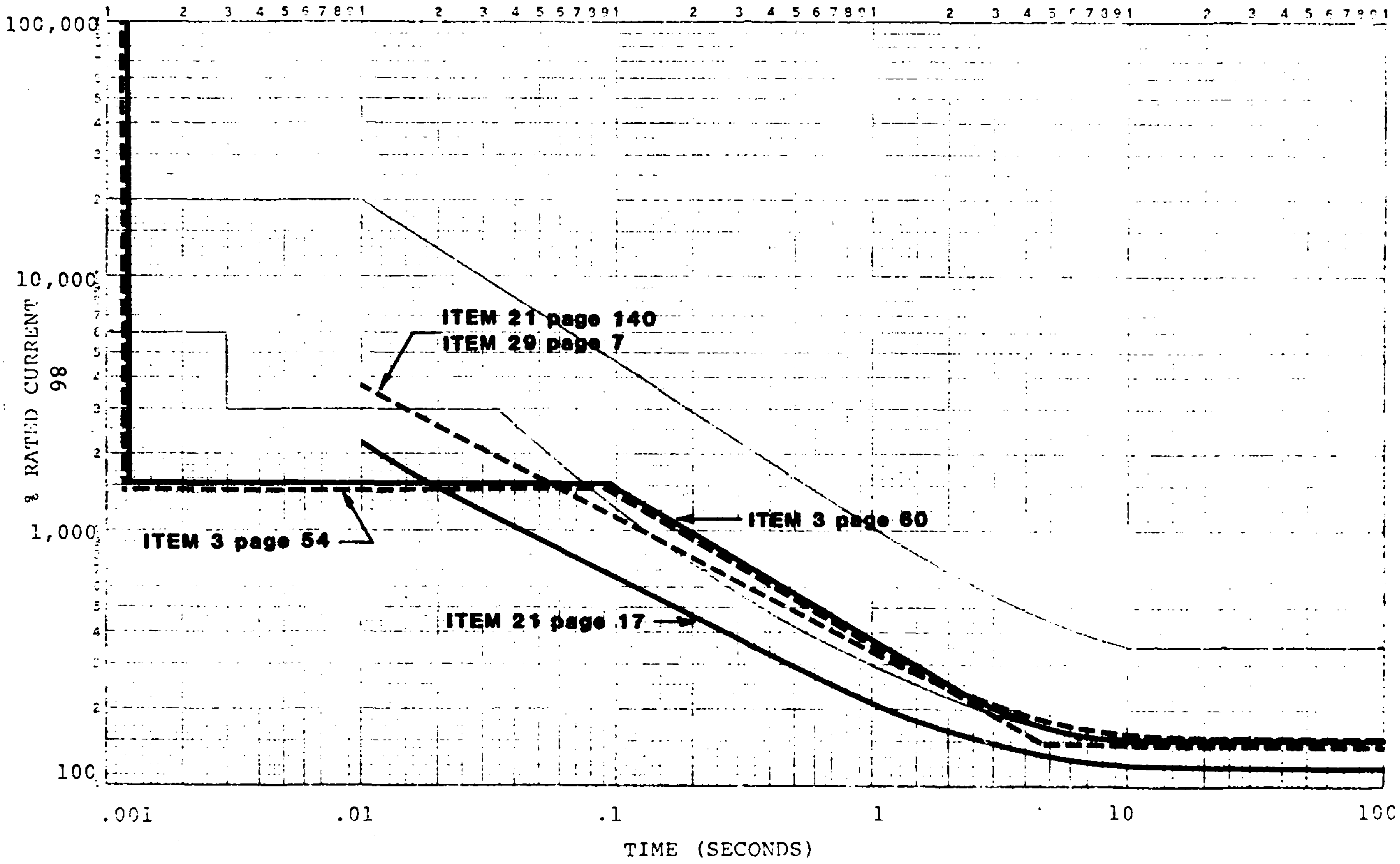

100,000
10,000
1,000
100
% RATED CURRENT
.001
.01
.1
1
10
100
TIME (SECONDS)
ITEM 21 page 140
ITEM 29 page 7
ITEM 3 page 60
ITEM 3 page 54
ITEM 21 page 17

Figure 2

Section III

Research of the SSPC Design

Research of the SSPC design was included in the original concept of this contract because Bussmann felt a better understanding of the electrical operation of the SSPC would be beneficial in the development of a related fuse. This research was to include both an analysis of available samples and electrical schematics plus actual testing of sample SSPCs.

Contact was made with the technical services division of Washington University, St. Louis, Missouri (WUTA, Washington University Technology Association, Inc.) in regard to analyzing the SSPC samples in our possession. A preliminary review by WUTA of the samples and pertinent Paper Search data confirmed our conclusions. That is, SSPCs contain hybrid custom circuits between the main pass elements and the control circuitry. Also, from the Paper Search data available, it is apparent that later versions are microprocessor controlled.

Based on this information, it is now apparent that the planned analysis of the SSPC is beyond the scope of the fuse development program.

On 2/24/82, actual testing of a sample SSPC was conducted at the McDonnell-Douglas Corporation. As stated in Section 2.2, the data from this test (Appendix B) was significantly different from the contract requirements. A comparison of this data to the contract requirement is contained in Fig. 3.

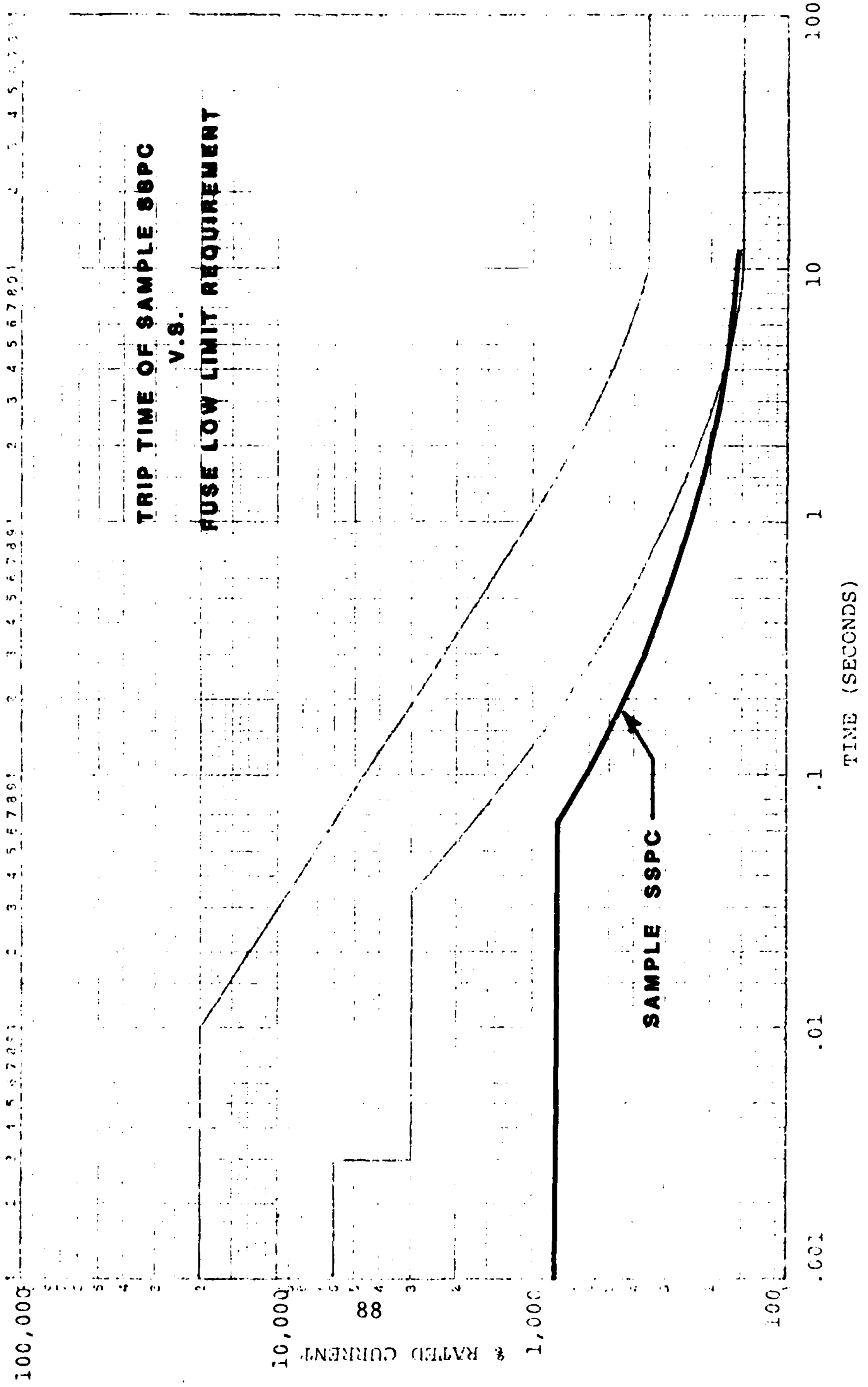

TRIP TIME OF SAMPLE SSPC
V.S.
FUSE LOW LIMIT REQUIREMENT
SAMPLE SSPC
% RATED CURRENT
100,000
10,000
1,000
100
TIME (SECONDS)
.001
.01
.1
1
10
100

Figure 3

Section IV

SSPC Usage

Section IV on SSPC Usage is divided into three main areas of interest:

1) Current ratings of SSPCs
2) Voltage rating of SSPCs
3) Volume of Units Required

Information on these subjects can be found in a number of documents; however, the data collected fails to coincide in some areas.

1) Current rating is one area of concern in which all collected data appears fairly consistent. Most documents indicate the majority of SSPCs will be 5 amps or below. Page 26 of Item #3 contains a pie chart on the B-1 bomber usage, which gives a good representation of the majority of data collected. (Figure 4) This information, however, does not coincide with the contract. As can be seen in the pie chart, 65% of the required SSPCs are 1.6 amp or less. Bussmann's contract covers fuses from 2-30 amps.

   Information on current ratings can be found in the following documents:

   Item #3, page 26
   Item #4, page 25
   Item #6, page 101
   Item #20, page 13
   Item #24, page 1
   Item #25, page 121
   Item #26, pages 3-14, 3-17

2) Information on voltage ratings is not as clear cut as that on current. It appears the voltage ratings are divided into two main groups--115/200V. AC and 230/400 V. AC. A third smaller group also included is 28V DC.

   The 230V rating appears primarily in the B-1 bomber. Again, the pie chart on page 26 of Item #3 is a good example, showing 79% of the SSPCs with a 230V rating. Other documents confirming this fact are:

   Item #3, page 10
   Item #20, page 4
   Item #24, page 1

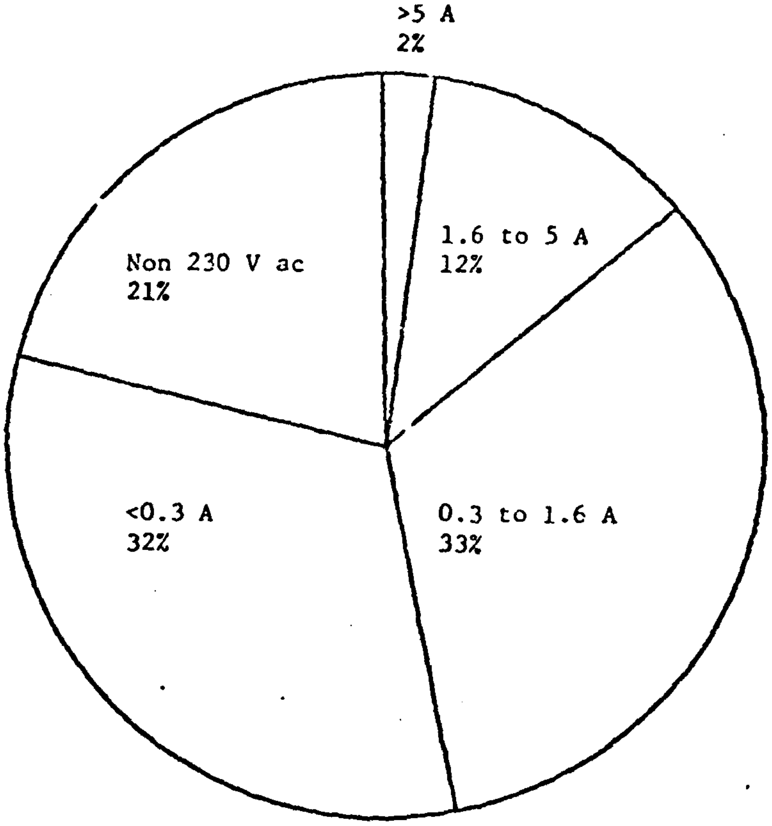


Figure 4 Distribution of Power Controller Loads

2) Continued

The 115/200V ratings seem to appear in most aircraft other than the B-1. Documents including this information are:

Item #6, page 101
Item #25, page 139
Item #26, pages 3-1 and 3-17

3) Volumes of SSPCs appear to be divided into two groups; 1) single engine aircraft and; 2) multi-engine aircraft.

Item #4, page 23 and Item #6, page 64 indicate a usage of approximately 350-400 SSPCs on a single engine aircraft.

Item #6, page 101 shows a usage of approximately 1000 SSPCs on multi-engine aircraft. This value is confirmed by studies on the B-1 bomber included in Item #3, page 10 and Item #20, page 4.

Section V

Verification of Additional Contract Requirements

5.1 Maximum Fault Current

The maximum fault current of 8,000 amps specified in Bussmann's contract was cause for some concern, primarily because of the relatively few test facilities capable of providing 8,000 amps at 400 Hz. Mr. Frank Chacon of the Eaton Corporation recommended checking whether the 8,000 amp figure was a "Peak" or a "RMS" value. During the 400 Hz testing performed at the Eaton test facility, the maximum current obtainable was 3200A RMS at 250 Volts.

A number of documents contain information on maximum fault current. However, except for Item #6, none of the sources indicate values approaching the 8,000A requirement. Item #6, however, includes information on a study conducted on contending advanced technology generating concepts. Included in this study is a Permanent Magnet Rotor Generator (PMG) which offers the advantage of size and weight reductions, but on the other hand, includes the drawback of severe fault currents as high as 15 PU rating or approximately 4,000A per generator. If the PMG system is not the reason for the 8,000A requirement, the validity of this specification remains questionable.

5.2 Operating Temperature

Numerous documents contain information on the operating temperature of the SSPC, resulting in a wide range of specifications. However, the requirement of -55°C to +85°C contained in the contract appears similar to the majority of data collected.

5.3 Storage Temperature

As with the operating temperature, numerous documents contain information on the storage temperature of SSPCs. This information shows clearly, that the -65°C to 150°C temperature is correct.

5.4 Altitude Range

Available documents indicate maximum altitudes ranging from 42,000 feet to 100,000 feet. However, the majority of information is very close to the contract specification of 0-80,000 feet.

APPENDIX A

LISTING OF DATA SOURCES

Verify SSPC Envelope Characteristic Shape

Item #7

Page 43, 44	HCPC 10A, 1 phase, 3 phase trip characteristics
Page A-16	HCPC 10A fail-safe fuse 40A---2-20 sec. 250A---.1-1 sec.

Item #21

Page 14	Information on wire protection with 5A, D.C. controller
Page 16	Information on fusible link
Page 17	Curve-percent of rated load vs. time
Page 18	Recommends fuse link per MIL-P-81653
Page 30	Curve-load current vs. time - 5A, D.C.
Page 37	Curve-load current vs. time - actual test
Page 59	Wire protection - 2A, AC
Page 60	Fuse - 2A, AC
Page 61	Curve-percent of rated load vs. time 2A, AC
Page 66	Curve, load current vs. time
Page 75	Curve, load current vs. time
Page 135	End Curves - % of rated load vs. time
Page 161	Table of trip times vs. current

Item #22

Page 36	Chart of test data - blow time vs. current

Item #29

Page 6	Fuse designed to protect #26 gauge wire and Rockwell 2A-SSPC. New fuse required for SSPCs greater than 3A.
Page 7	SSPC (2A) switch trip and fuse clearing time
Page 8	SSPC - Fuse
Page 17	Figure 8 - recommended trip characteristics for modified SSPC

Item #29 (cont.)

Page 35	SSPC specification comparisons (26, 115, and 230V-AC)
A9	SSPC trip and fuse clearing time requirement
App. B-3	SSPC curve - rated current vs. trip time

Item #30

Page 5	#26 gauge for low power circuits
	#24 gauge for high power circuits
App. B	26, 24 and 22 gauge wires

Item #31

Page 5	Trip characteristics for AC load
Page 13-18	Trip time data (-55°C, 25°C and 120°C)
Page 25	Trip time data (-55°C, 25°C and 100°C)
App. B Page 7	Trip values for 10A-115V, 400 Hz SSPC

Item #33

Page 11	#24 gauge is minimum wire size
Page 42	Wire temperature rating chart
Page 46	Operating temperature of single wire in air
Page 48	Derating factor for wire vs. altitude

Appendix A

Research SSPC Design

Item #3

Detailed explanation - especially page 40

Item #26

Page 4-377 RCA power controller

Item #31

Page 2	General requirements
Page 8	Function
Page 9	Schematic diagram of 3 phase, 10A SSPC
App. A Page 9	Parts legend for schematic

Item #29

App. A	Describes Rockwell SSPC
App. B	Rockwell Solid State Power Controller Chip
App. B-2	Power Controller Functions
App. B-6	Block diagram of SSPC

Appendix A

SSPC Usage

Item #3

Page 10	900 SSPCs on 1
Page 26	Pie Chart showing size and voltage

Item #4

Page 23	400 SSPCs on single engine aircraft
Page 25	Data showing % of various amps on single engine aircraft

Item #6

Page 101	Usage table - 1000 SSPCs, 1 phase, 115 volt

1/2A - 484
2A - 291
5A - 110
10A - 93
20A - 22

Item #20

Page 4	839 SSPCs on B-1 - 1.5 + 1.6A
Page 13	B-1 - 80% are less than 1.6 or 1.5 amps
Page 132	Data showing amp and voltage of B-1 SSPCs.

Item #24

Page 1	On B-1s, 50% of SSPCs are 1/2A and less

Item #25

Page 329	Shows SSPC current ratings
Page 121	Shows SSPC current ratings
Page 139	Shows SSPC current ratings

Item #25

Page 329	SSPC ratings of 10, 8, 5, 3, 2, 1 and 1/2A

Item #26

Page 1-3	270V, D.C., 28V, D.C. and 400 Hz
Page 3-1	115/200V AC
Page 3-14	SSPC Used - 2A - 28V DC 5A - 28V DC 10A- 28V DC 2A - 115V AC 5A - 115V AC
Page 3-17	70% of SSPCs are 2A at 115V AC and 28V DC
Page 3-26	SSPCs 28V DC - 2A, 5A and 10A 115V AC- 2A, %A and 10A 270V DC - 2A
Page 328	Recommended mixture of loads
Page 4-1	Tolerance on DC voltage - ± 10 volts
Page 4-3	300V DC output
Page 4-280	Load power controller summary
Page 4-340	SSPC types 28V DC - 2, 5 and 10A 115V AC - 2, 5, 10 and 50A

Item #27

Page 1	115V, 5A, 400 Hz Controller 26V, 1A, 400 Hz Controller

Item #29

Page 33	Study covering SSPCs with ratings of 1/2A, 2A and 5A at 115V, AC and 1A at 26V
Page 44	Mentioned 28V DC and 270V DC SSPCs Standard voltages - 28V DC, 270V DC, 115V AC and 26V AC.

Item #31

Page ii	10A - 200/115V, 400 Hz SSPC

Appendix A

Additional Contract Requirements

A. Maximum Fault Current

Item #4	
Page 31	4-90KVA generator on B-1 or B-52
Item #6	
Page 116	Permanent magnet generator (PMG): Cannot control feed current; therefore, severe fault currents, as high as 15 PU can be generated.
Item #20	
Page 144	Shows worst condition on B-1 bomber to be 230 KVA at P.F. of .85.
Item #24	
Page 3	Fault current up to 1000% of rated current
Item #25	
Page 5	Fault current of 1600A for 3 phase and 1200A for 1 phase for the first quarter cycle
Page 163	3763A Peak and 2,304A RMS
Page 156-180	Fault current analysis
Item #31	
Page 13-18	S/C current 400 amperes
Page 25	S/C current 400 amperes

B & C - Operating Temperature and Storage Temperature

Item #3

Page 91	+85°C normal operating temperature +122°C - max. design temperature for SSPC
Page 53	-55°C to +100°C (for fuse)
Page 87	-65°F to 160°F

Item #7

Page C-7 & 3-13	Case temperature - -40°C to +75°C Case storage temperature -65°C to 100°C

Item #21

Pages 135 to end	Ambient temperature -54°C to 95°C with a case temperature of 120°C Storage -65°C to 150°C

Item #24

Page 19	Test temperature -55°C, +25°C and +75°C
Page 58	Operating temperature - -54°C to +75°C Storage Temperature - -65°C to +95°C Emergency Temperature - -54°C to +95°C

Item 25

Page 5	Ambient temperature of -55°C to +125°C
Page 147	-49°C to +49°C

Item 25

Page 5	-55°C to 125°C for fighters
Page 11	Case temperature of -55°C to 120°C

Item #26

Page D-4	Storage temperature -65°C to 150°C

Item #26

Page 4-9	Maximum output temperature - 149°C
Page 4-22	Operating temperature
Page 4-335	Component case temperature
Page 4-346	SSPC case temperature

Item #28

Page D-4	Storage temperature of -65°C to 150°C

Item #29

Page 30	Maximum ambient temperature - 96.9°C
Page A 6	Environmental Characteristics Operating - 55°C to +71°C Storage - -65°C to +150°C

Item #31

Page 11	Operating temperature -55°C to +120°C

Item #33

Page 34	Heat shrinkable sleeving MIL-I-23053
Page 38	Wire -200°C

D. Altitude

Item #3	
Page 87	0-70,000 ft.
Item #21	
Page 135 to end	100,000 ft.
Item #25	
Page 147	0-42,000 ft.
Item #29	
Page A6	0-70,000 ft.
Item #33	
Page 38	60,000 ft.

Technical Memorandum

ENGINEERING LABORATORIES

Appendix B

NO. 257-290

DATE 25 February 1982

REV.

SUBJECT TEST OF SOLID STATE POWER CONTACTOR FOR BUSSMAN MFG CO.

T/WR NO. 027776.16

MODEL NO. N/A

TEST DEPT 257A

TEST STARTED 2/24/82

TEST COMPLETED 2/24/82

☐ PRIME DEPARTMENT FINAL REPORT

☐ SUPPORT DEPARTMENT REPORT

☒ LIMITED TR REPORT

☐ INTERIM TEST REPORT NO.

PREPARED BY
E. A. Sandoval, Technical Specialist
Electrical Laboratory

APPROVED BY 2/25/82
P. M. Fleetwood, Section Chief
Instrumentation & Standards Labs

DISTRIBUTION:

NAME	DEPT
J. C. Bass	250
P. M. Fleetwood	257
C. F. Kuhn - File	257
J. G. Shipley	257

1. A Solid State Power Contactor (SSPC) part number 459C300 S/N 066 manufactured by Telephonics of Huntington, N.Y., and rated at 1.6 amperes RMS at 230V AC RMS 400 Hz was tested to determine the time it takes for the SSPC to open after overload currents are applied.

2. The tests were conducted in the Electrical Generator Test Facility of MCAIR St. Louis, Mo. and the tests were witnessed by Engineers V. Spaunhorst and E. Long of Bussmann Manufacturing Company of St. Louis, Mo.

3. The test results during the overload tests are listed in Table 1. These test results were within the limits expected by the witnesses.

TABLE 1 - FAULT CURRENT TRIP TIMES

Fault Amps			AC Volts	Seconds	Remarks
1.	1.6	100%	234.0	417.0	Did Not Open (Normal)
2.	2.56	160%	231.34	11.5	
3.	3.2	200%	231.0	2.125	
4.	4.8	300%	229.75	0.525	
5.	6.4	400%	229.7	0.225	1st run
			231.0	0.245	2nd run
6.	9.6	600%	228.30	0.105	1st run
			230.0	0.1075	2nd run
7.	12.8	800%	227.0	0.0675	1st run
			226.0	0.0625	2nd run
8.	14.4	900%	233.0	Instant Trip	Tripped on 1st cycle
			232.0	"	"
9.	16.0	1000%	235.0	"	"

SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052

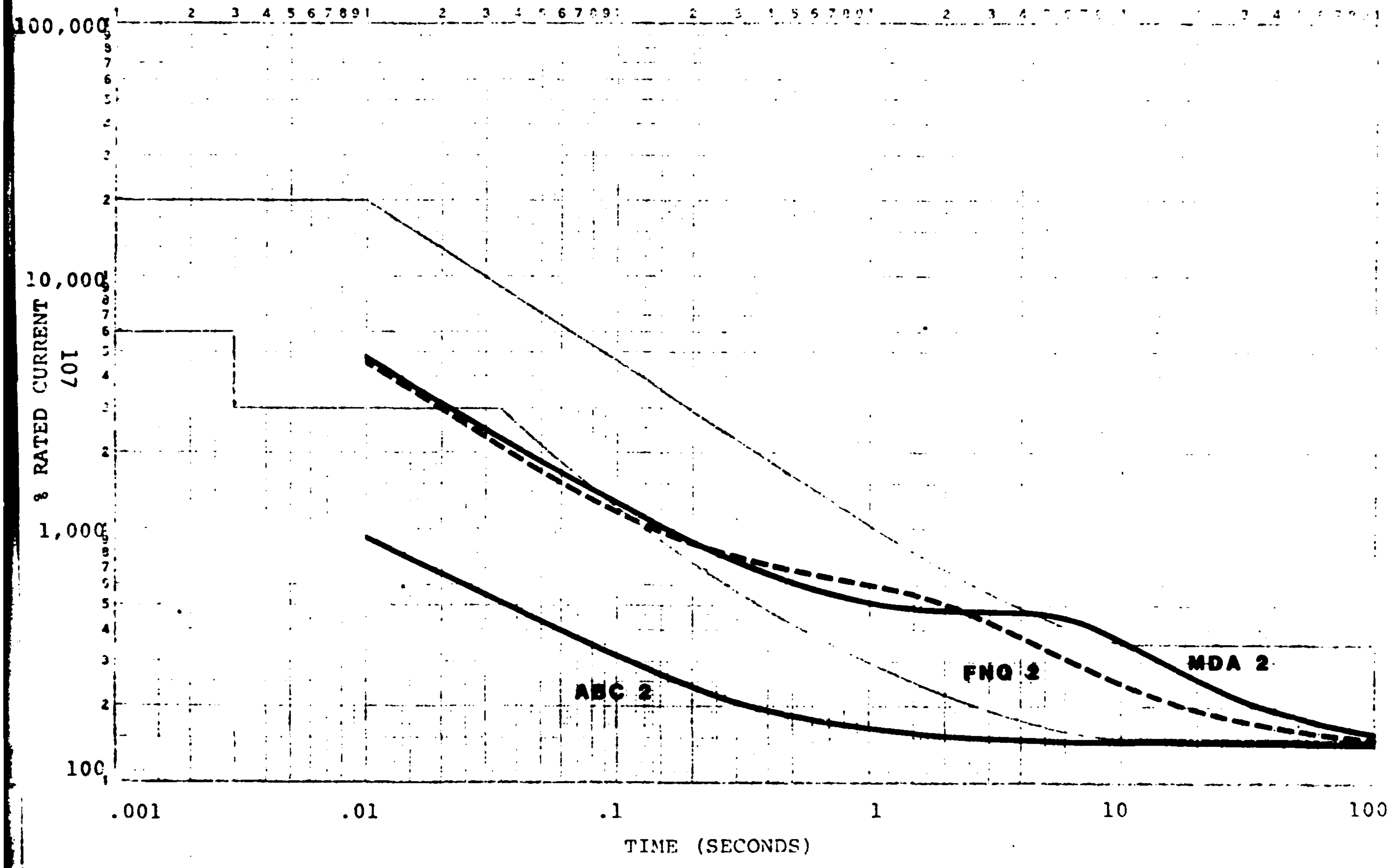
PROJECT NUMBER 3145-2964

APPENDIX B

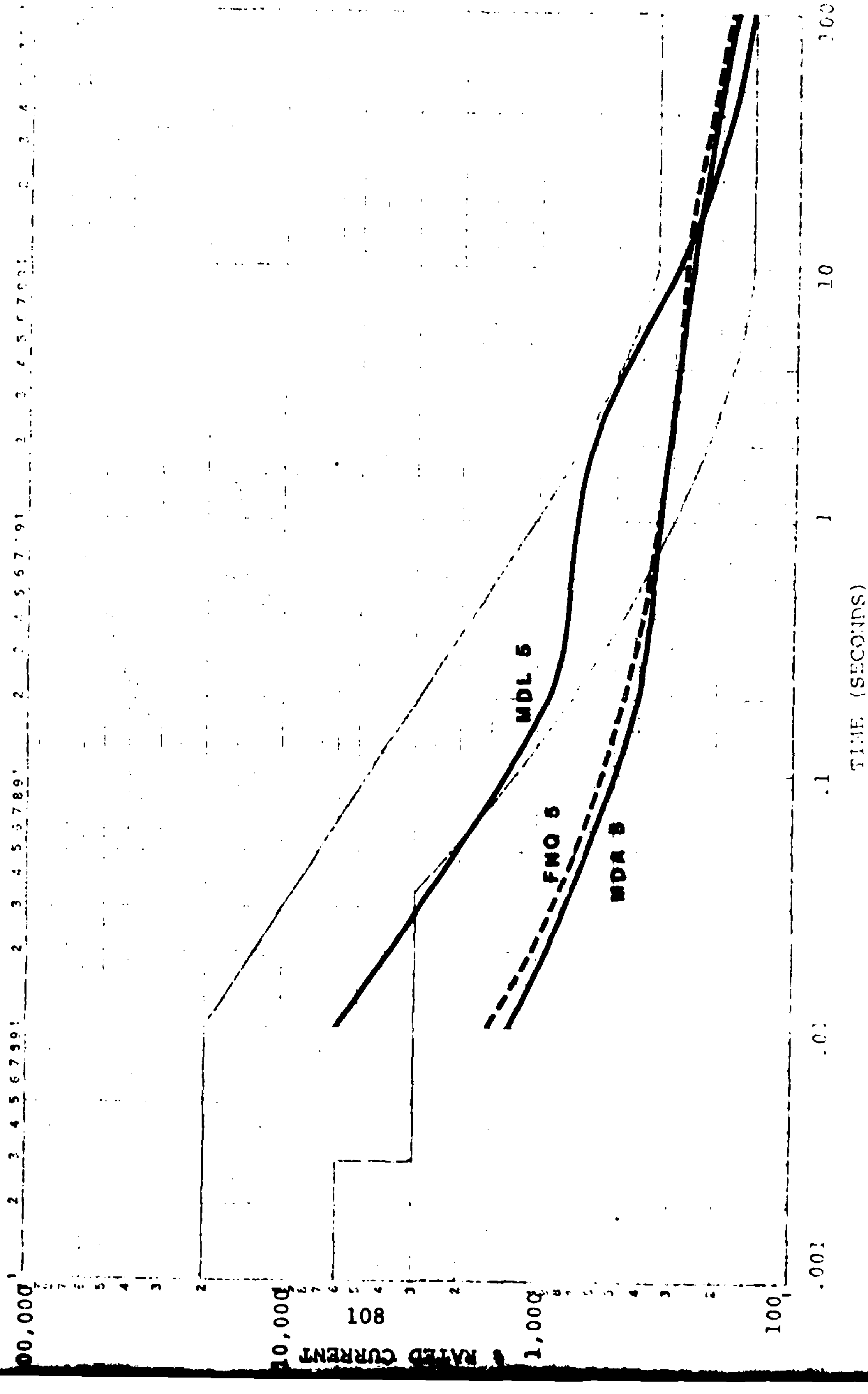
COMPARISON OF EXISTING FUSE TIME CURRENT CHARACTERISTICS TO THE SSPC ENVELOPE CURVE

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

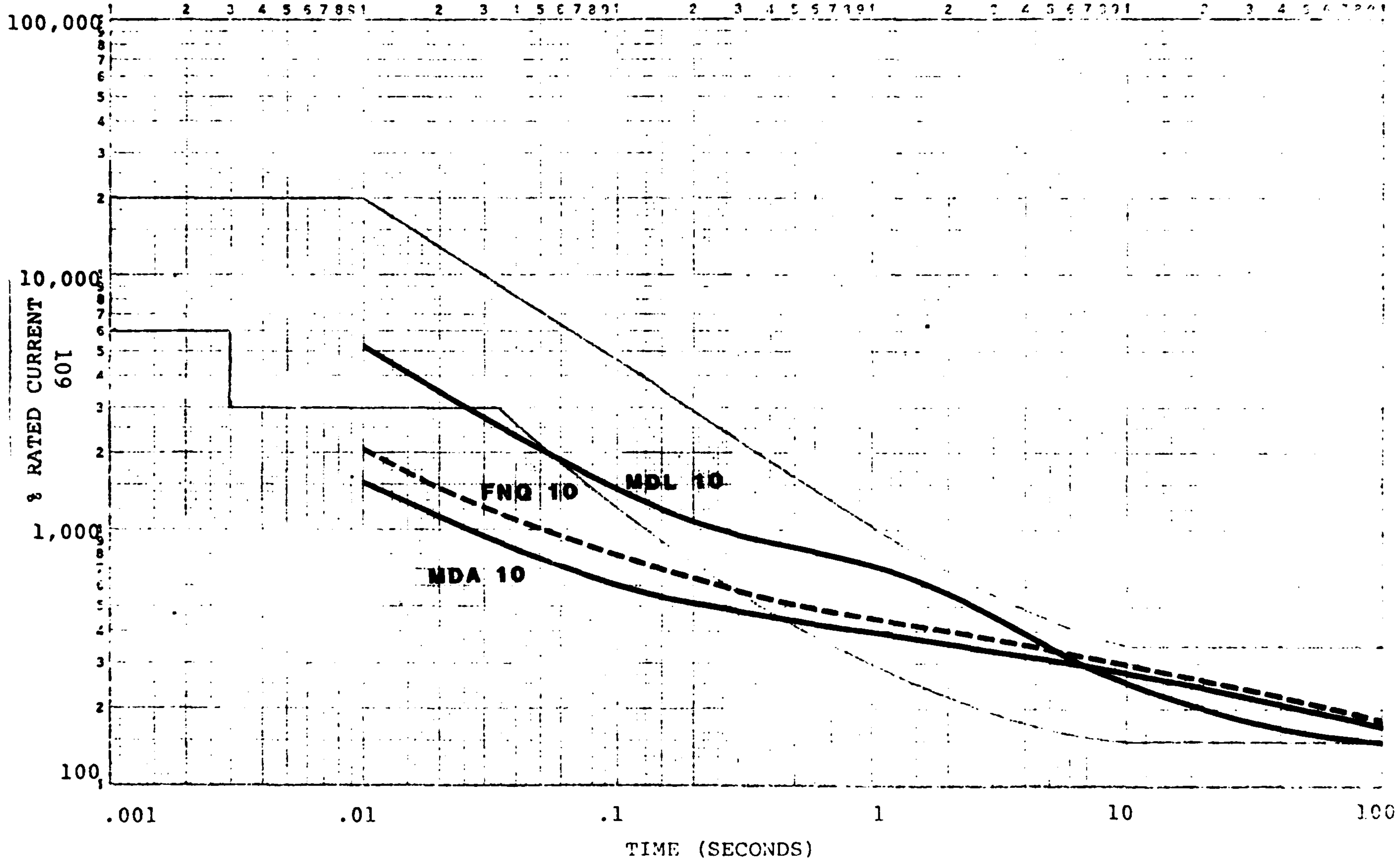
Item 9
Released 9-24-81



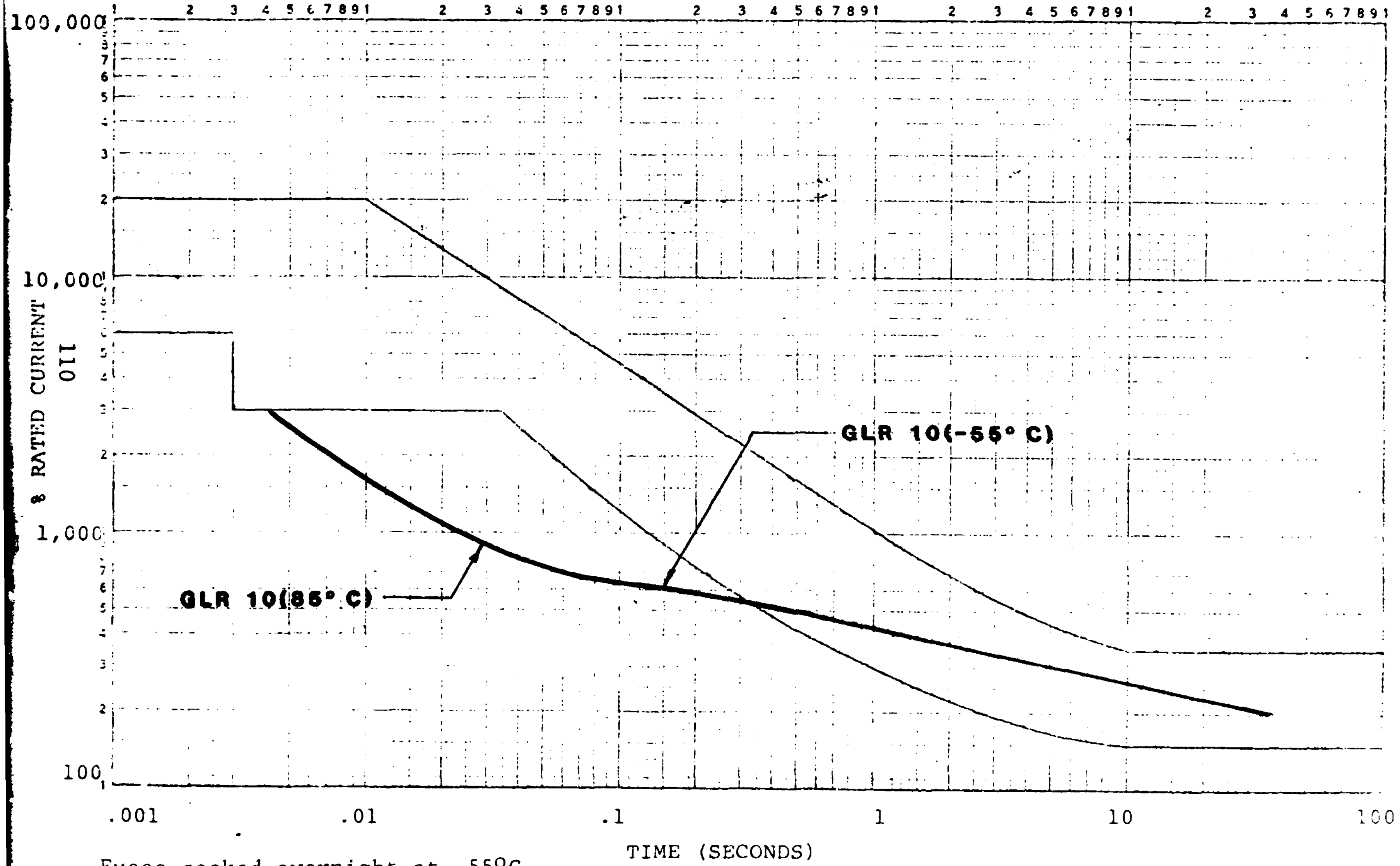
Item 10
Released 9-24-



Item 11
Released 9-24-81



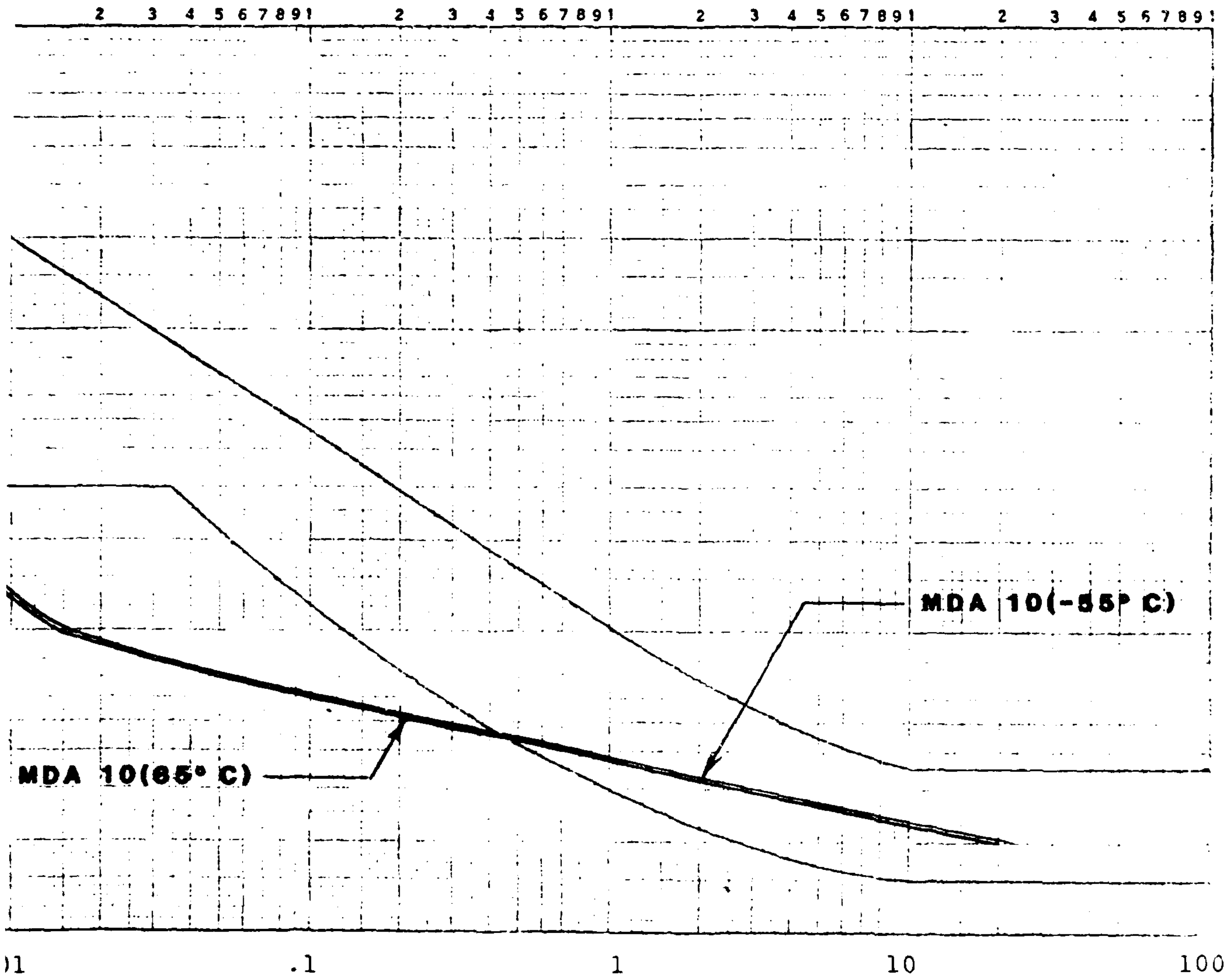
Tests Performed at 125 v. D.C. up to 3000% Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

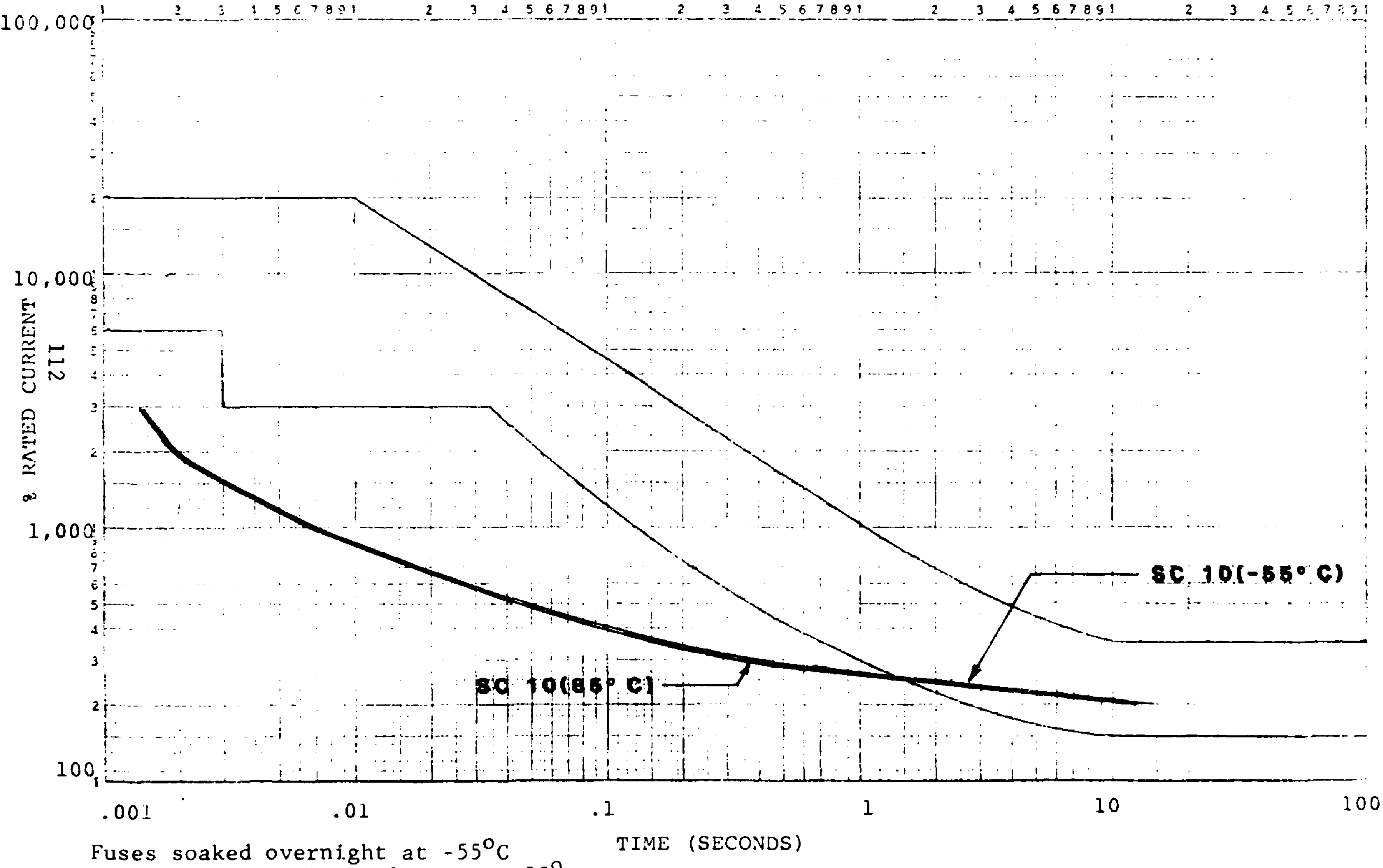
Item 12B
Released 9-30-81

25 v. D.C. up to 3000% Rated Current



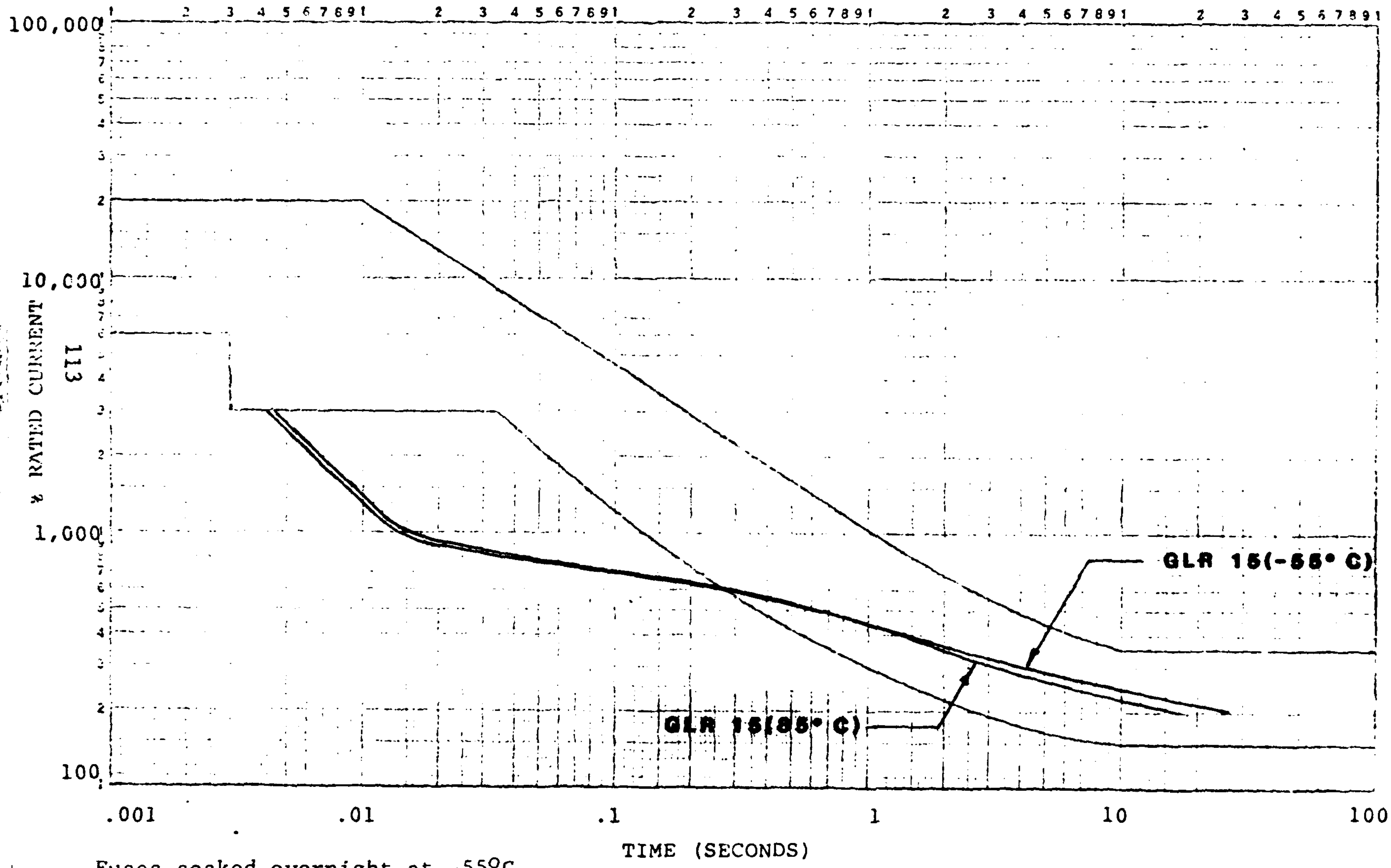
ght at -55°C
st 1 hour at 85°C

Tests Performed at 125 v. D.C. up to 3000% Rated Current



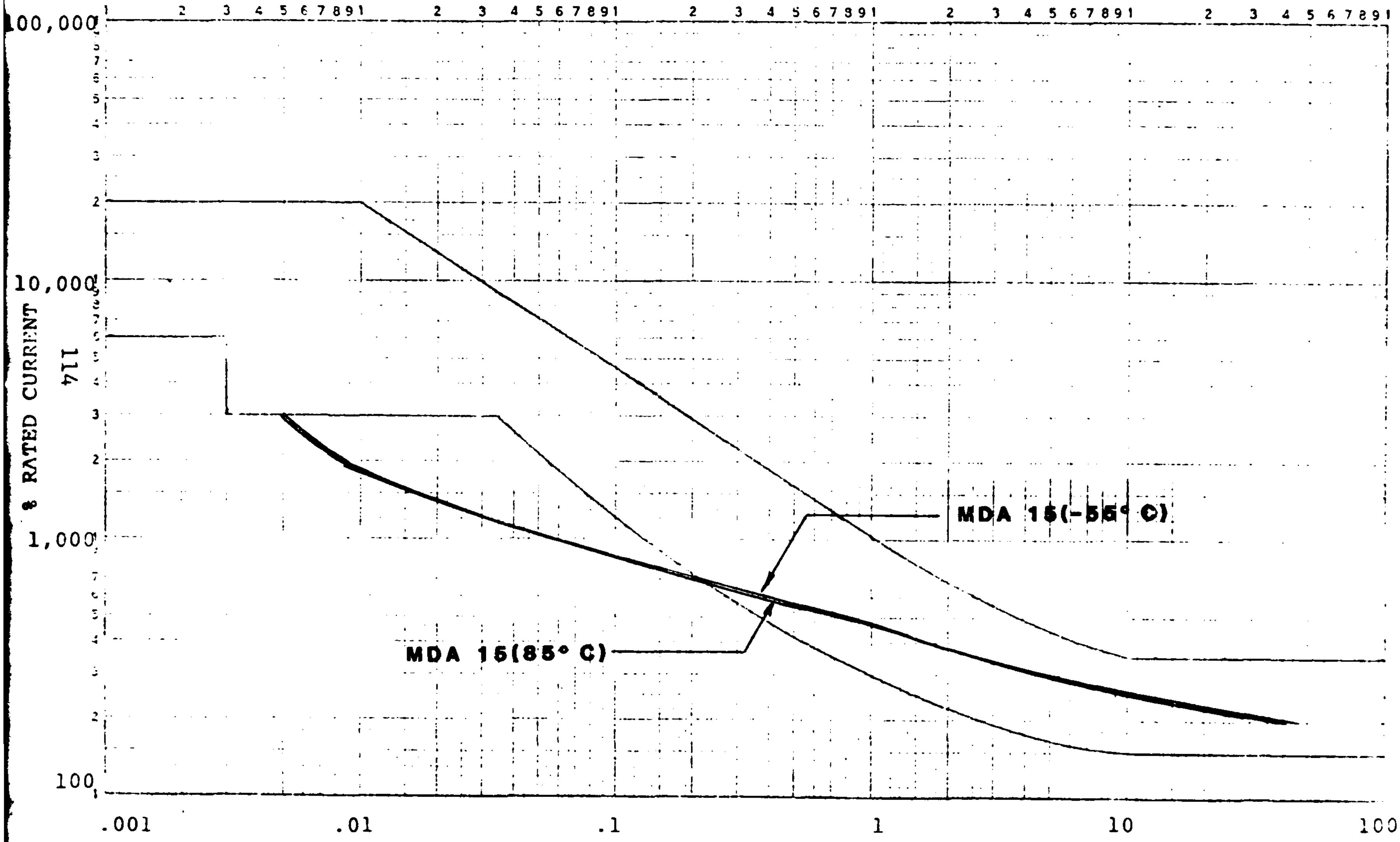
Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

Tests Performed at 125 v. D.C. up to 3000% Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

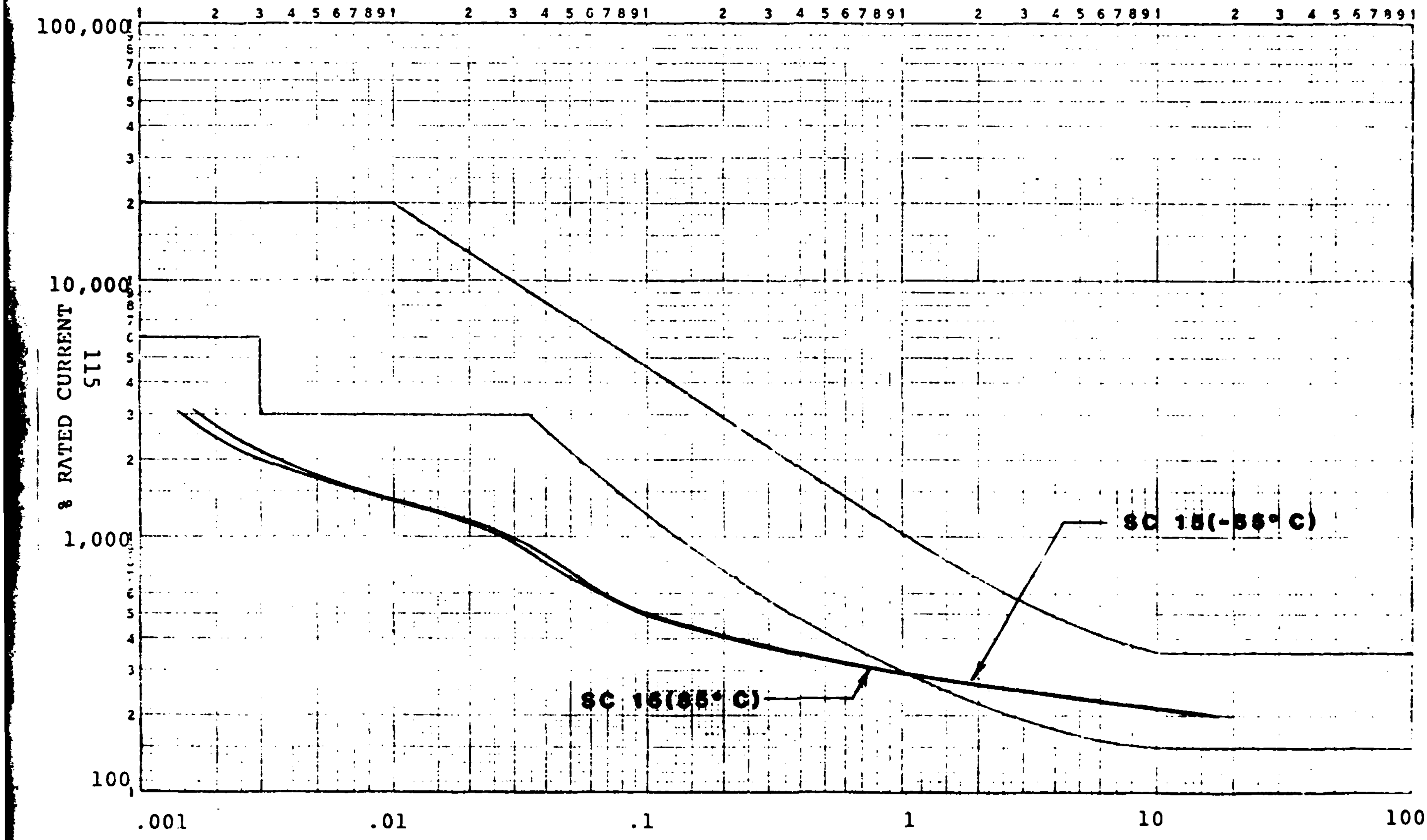
Tests Performed at 125 v. D.C. up to 3000% Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

Item 13
Releasec ,-30-81

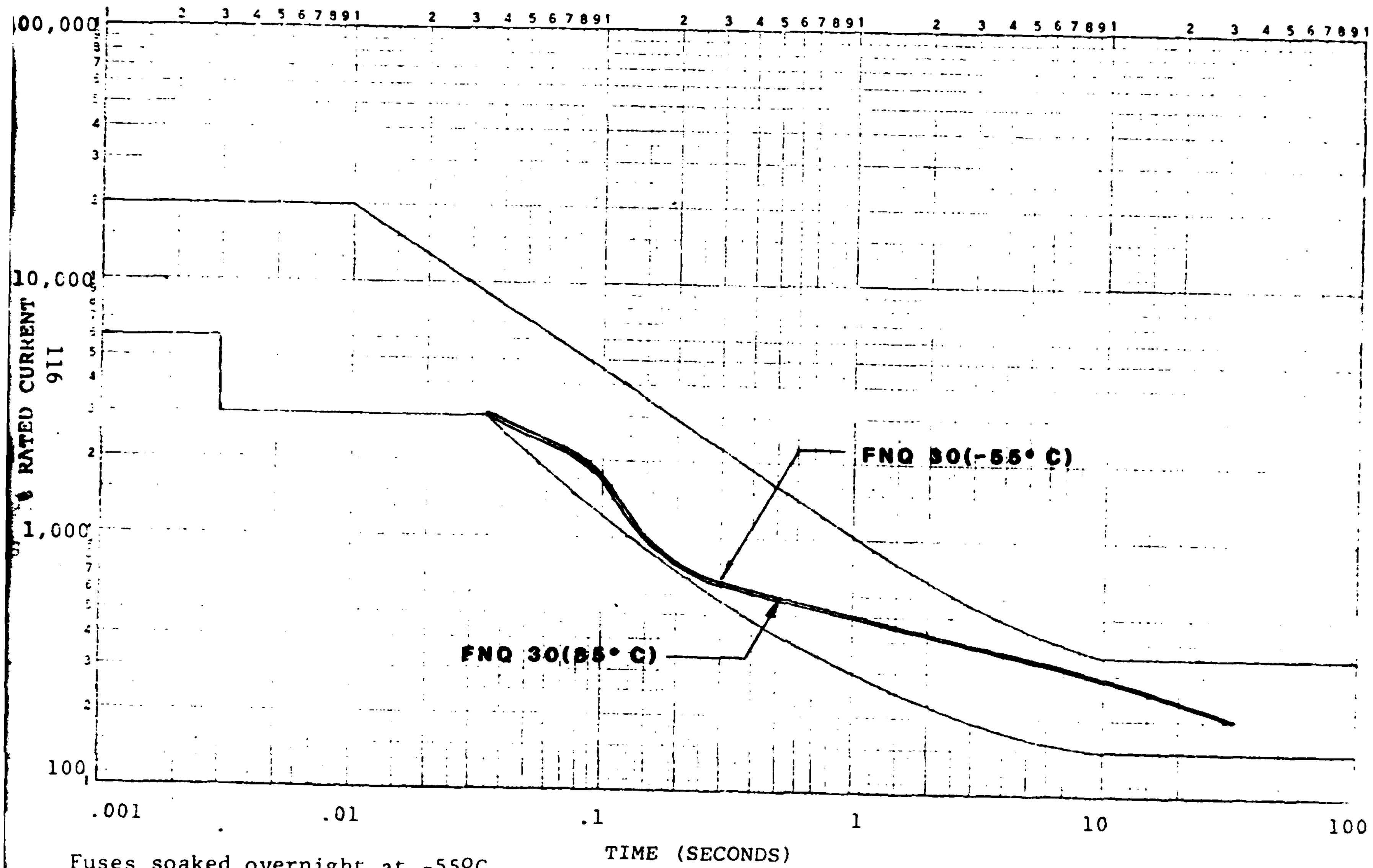
Tests Performed at 125 v. D.C. up to 3000% Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

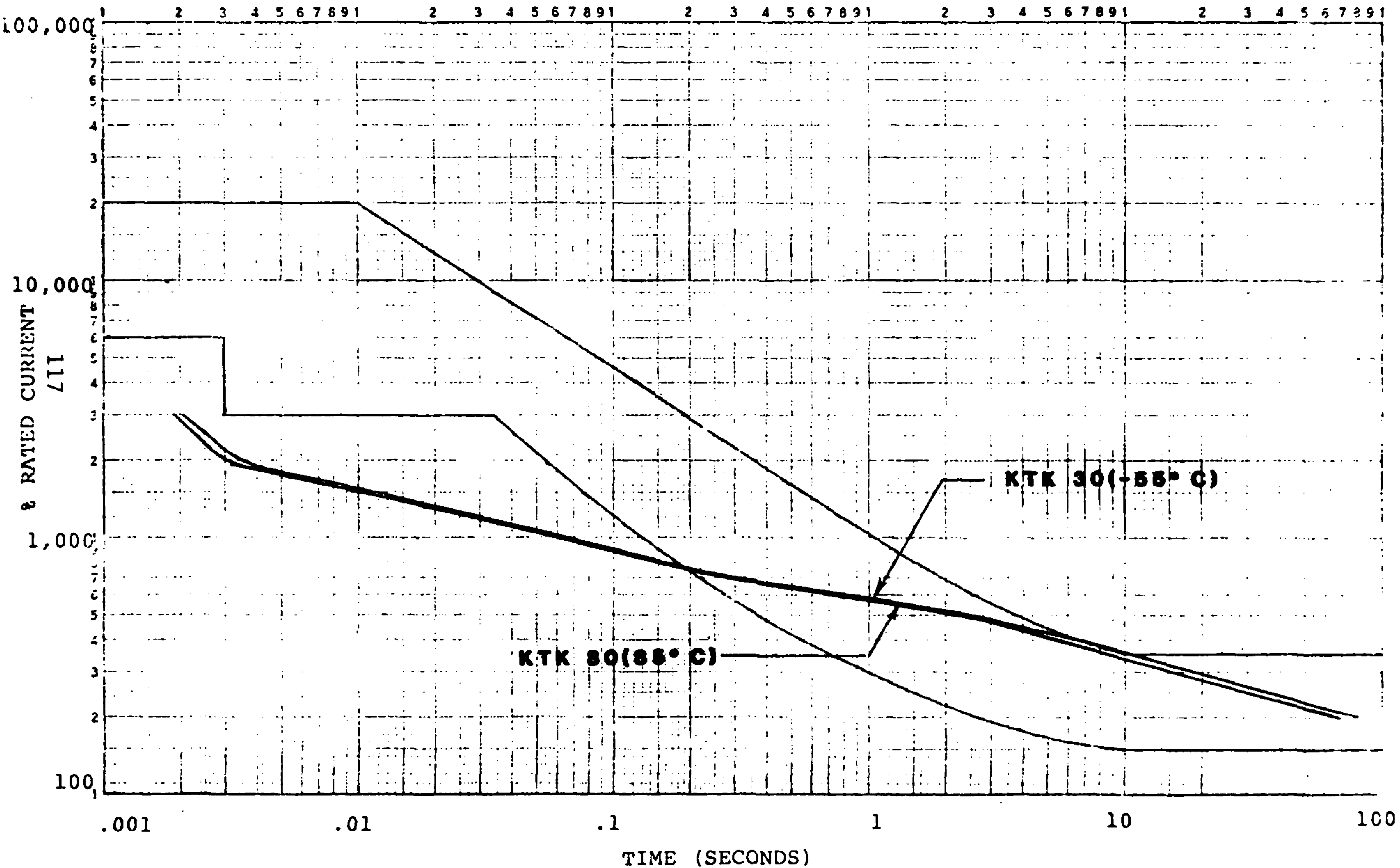
Tests r.rformed at 125 v. D.C. up to 3000%
Rated Current

Item 14A
Released .-30-81



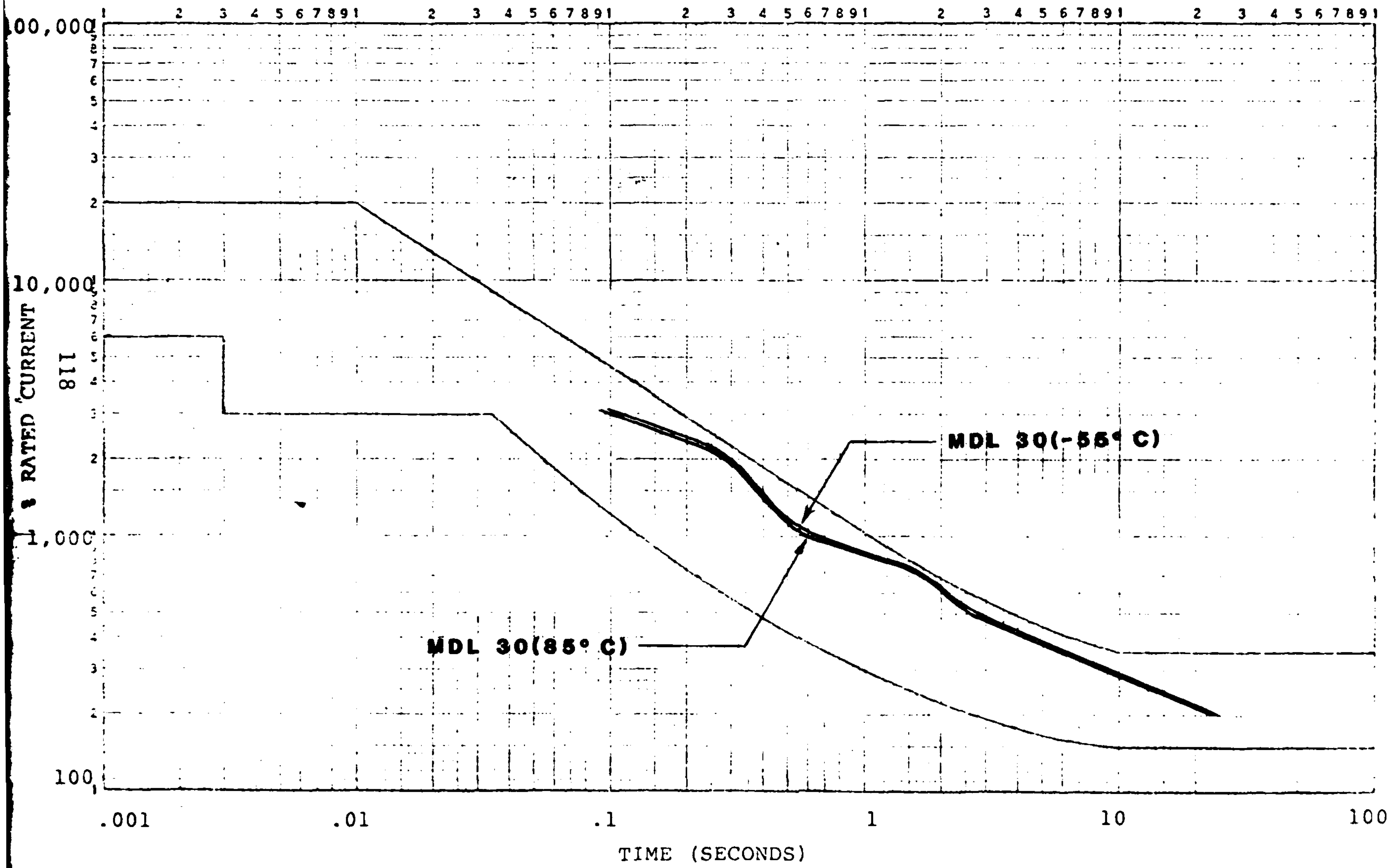
Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

Tests Performed at 125 v. D.C. up to 3000%
Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C

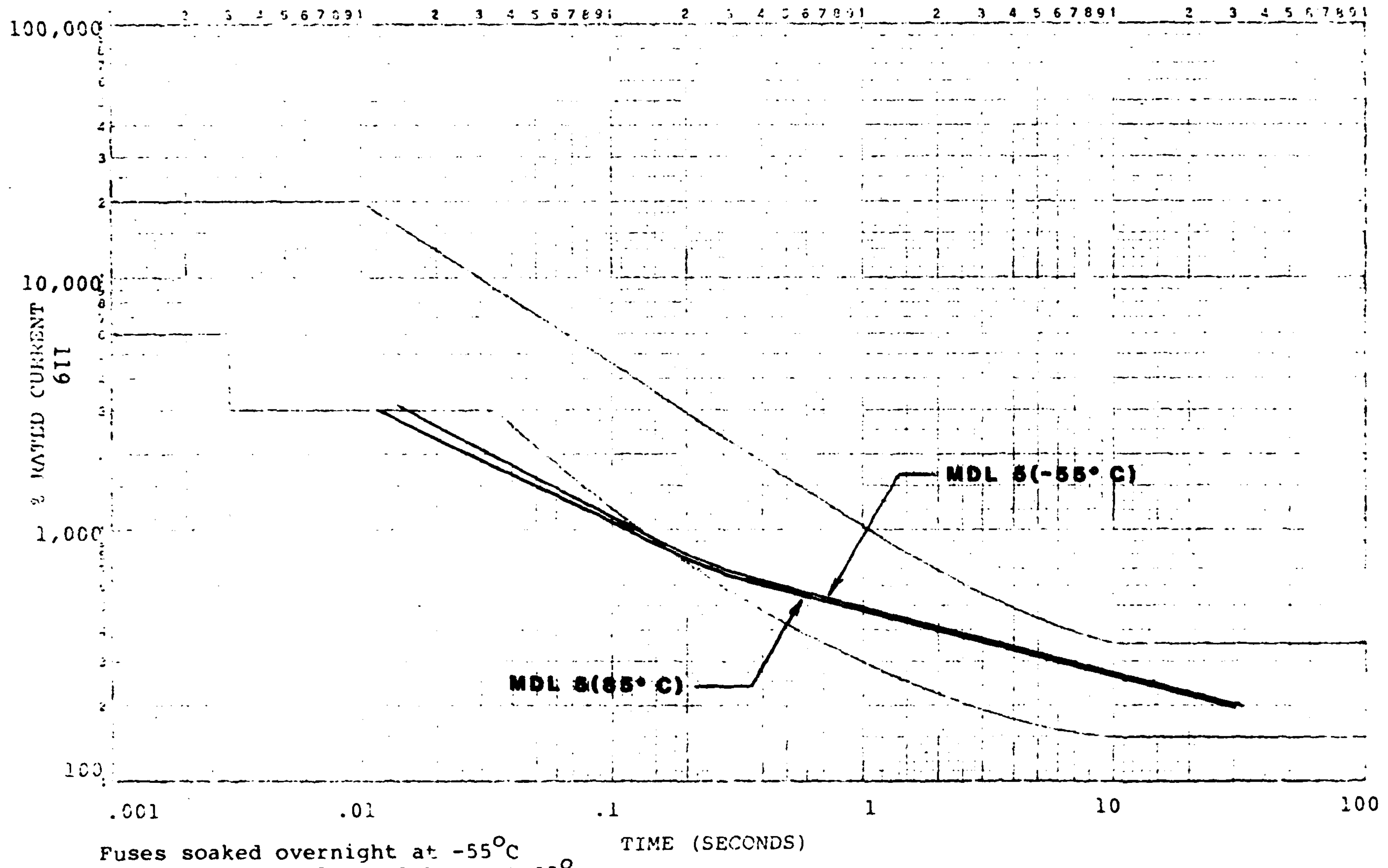
Tests Performed at 125 v. D.C. up to 3000%
Rated Current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C
MDL-30, Ruptured Glass Tubes at Overloads 300% and above.

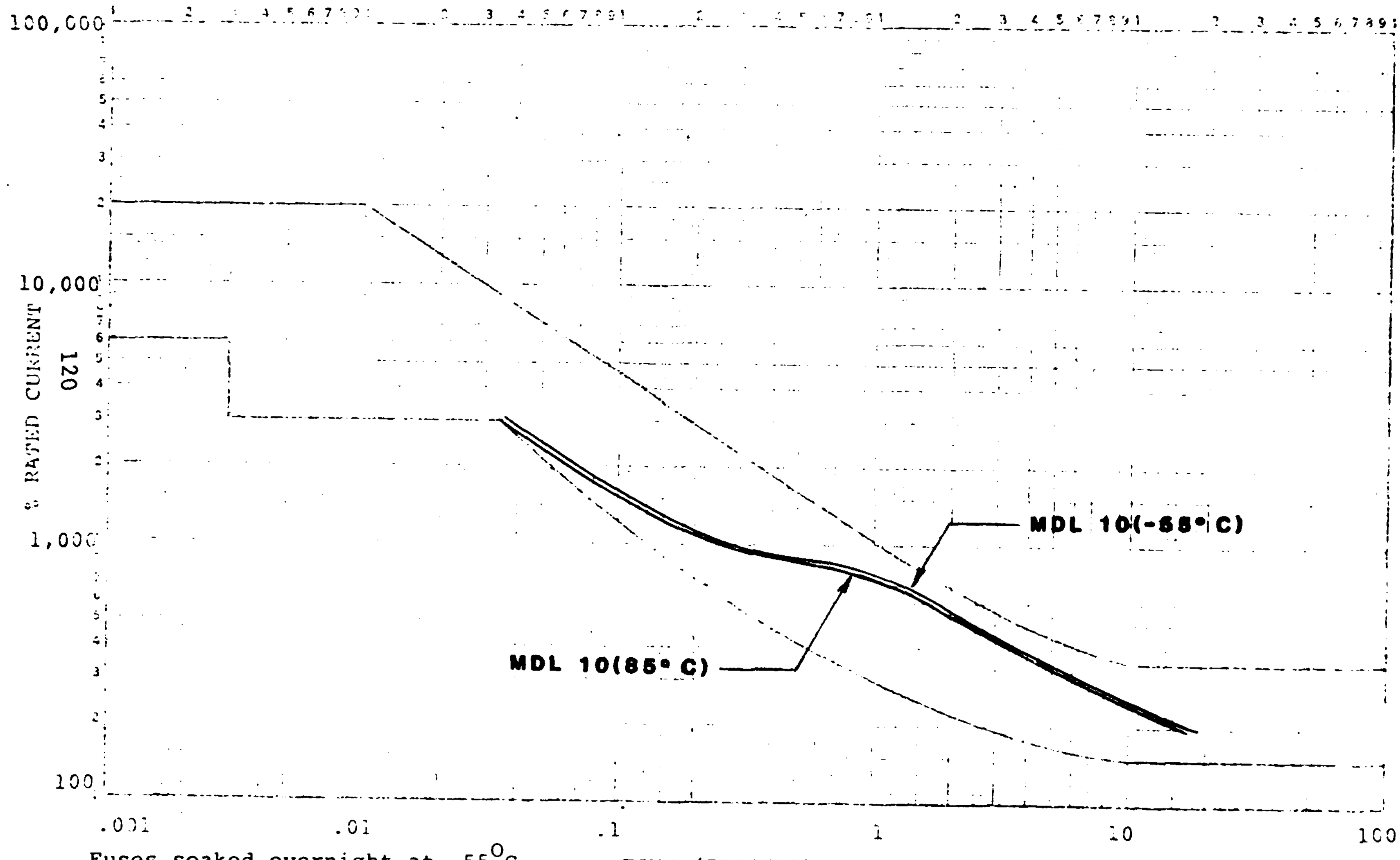
Item 15
Released ʼ30/81

Tests performed at 125V D.C. up to
3,000% rated current



Fuses soaked overnight at -55°C
Fuses soaked at least 1 hour at 85°C
MDL -5, ruptured glass tubes at overloads 200% and above

Tests performed at 125V D.C. up to
3,000% rated current



Fuses soaked overnight at -55^{O}C
Fuses soaked at least 1 hour at 85^{O}C
MDL - 10, Ruptured glass tubes at overloads 200% and above

SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052

PROJECT NUMBER 3145 -2964

APPENDIX C

COMPARISON TESTS OF 60 HZ VERSUS 400 HZ OPERATION AND SEA LEVEL VERSUS 80,000 FEET PERFORMANCE

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

Data Item 34
Released Date 12/30/81

Appendix C
page 1

COMMERCIAL FUSE PERFORMANCE

Freq. - 60 Hz
Volts - 125V
Power Factor-.73-.80

FUSE	CURRENT LEVEL	FUSE PERFORMANCE		I^2t		
		OPEN AIR	80,000 ft.	OPEN AIR	80,000 ft.	
ABC-2	200%	OK	OK	.39 sec.	.50 sec.	(Clearing Time)
	500%	OK	OK	.05 sec.	.37 sec.	(Clearing Time)
	2,500A	OK	OK	5.2	5.3	
	5,000A	OK	OK	5.7	4.3	
	8,000A	OK	OK	6.2	6.0	
ABC-15	200%	OK	OK	9.0 sec.	19 sec.	(Clearing Time)
	500%	OK	OK	.2 sec.	.7 sec.	(Clearing Time)
	2,500A	OK	OK	343	345	
	5,000A	OK	OK	379	343	
	8,000A	OK	OK	378	394	
ABC-30	200%	OK	OK	6.6 sec.	5.5 sec.	(Clearing Time)
	500%	OK	OK	.37 sec.	.53 sec.	(Clearing Time)
	2,500A	OK	OK	1,647	1,650	
	5,000A	OK	OK	1,636	1,618	
	8,000A	OK	OK	1,769	1,838	
MDL-2	200%	OK	OK	41 sec.	31 sec.	(Clearing Time)
	500%	OK	OK	1.2 sec	1.3 sec.	(Clearing Time)
	2,500A	OK	OK	121	128	
	5,000A	OK	OK	121	122	
	8,000A	OK	OK	133	130	
MDL-7	200%	(1)Cracked Tube	OK	18 sec.	16 sec.	(Clearing Time)
	500%	OK	OK	1.8 sec.	3.4 sec.	(Clearing Time)
	2,500A	OK	(1)Burst Tube	731	767	
	5,000A	OK	OK	744	729	
	8,000A	(1)Cracked Tube	OK	789	788	

* The term OK in regard to fuse performance means the fuse remained intact and cleared the circuit while containing all fragments (tube, end, caps, fuse element, etc.) of the fuse construction.

COMMERCIAL FUSE PERFORMANCE

Freq. - 60 Hz
Volts - 250V
Power Factor-.79-.85

FUSE	CURRENT LEVEL	FUSE PERFORMANCE		I^2t		
		OPEN AIR	80,000 ft.	OPEN AIR	80,000 ft.	
SC-4	200%	OK	OK	-	-	
	500%	OK	OK	5.54	5.55	
	2,500A	OK	OK	6.50	6.52	
	5,000A	OK	OK	6.99	7.07	
	8,000A	OK	OK	8.79	8.89	
SC-20	200%	OK	OK	21 sec.	13 sec.	(Clearing Time)
	500%	OK	OK	1243	1162	
	2,500A	OK	OK	768	745	
	5,000A	OK	OK	899	777	
	8,000A	OK	OK	945	921	
SC-30	200%	OK	OK	25 sec.	27 sec.	(Clearing Time)
	500%	OK	OK	10,704	9,912	
	2,500%	OK	OK	2,699	2,688	
	5,000A	OK	OK	3,115	3,156	
	8,000A	OK	OK	3,211	3,103	
GLR-15	200%	OK	OK	31 sec.	30 sec.	(Clearing Time)
	500%	OK	OK	1,646	1,642	
	2,500A	OK	OK	267	309	
	5,000A	OK	OK	358	354	
	8,000A	OK	OK	353	372	
FNQ-30	200%	OK	OK	31 sec.	16 sec.	(Clearing Time)
	500%	OK	OK	10,955	10,667	
	2,500A	OK	OK	2,891	2,917	
	5,000A	OK	OK	3,067	3,067	
	8,000A	OK	OK	3,173	3,136	

* The term OK in regard to fuse performance means the fuse remained intact and cleared the circuit while containing all fragments (tube, end, caps, fuse element, etc.) of the fuse construction.

COMMERCIAL FUSE PERFORMANCE

60 Hz vs 400 Hz

Current Level - 3200A @ 115V
2900A @ 230V

FUSE	VOLTAGE	CLOSING PT. (RANDOM	I^2t 60 Hz SEA LEVEL	400 Hz SEA LEVEL	400 Hz 80,000 FT.
ABC-30	115V	30°	1536	-	499
		60°	1683	399	-
		70°	1613	307	382
		90°	1594	362	-
		150°	1690	445	480
MDL-7	115V	70°	866	186	195
		70°	736	136	-
		80°	683	168	162
		90°	720	192	137
		90°	728	121	-
GLR-15	230V	0°	269	100	*
		0°	314	68	*
		0°	312	65	*
		20°	285	86	*
		58°	338	86	*
SC-15	230V	50°	354	72	*
		60°	400	60	*
		82°	346	35	*
		80°	344	57	*
		90°	278	46	*
FNQ-30	230V	90°	-	659	*
		90°	2822	889	*
		50°	2880	871	*
		100°	2816	784	*
		72°	2848	908	*

* Altitude tests on 230V fuses were deleted because of time restriction plus no apparent difference on 115 fuses.

SSPC FUSE DEVELOPMENT PROGRAM

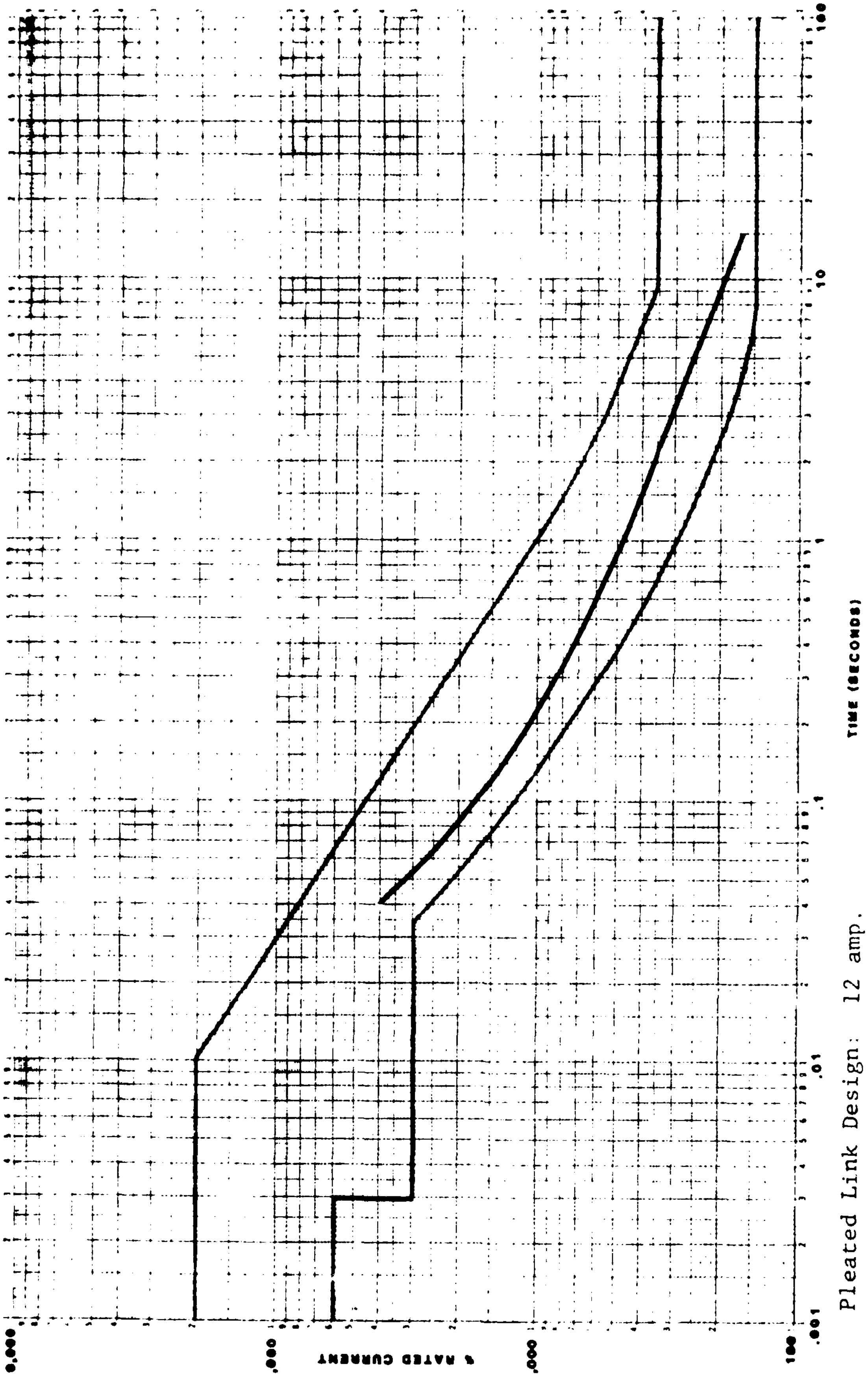
FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX D

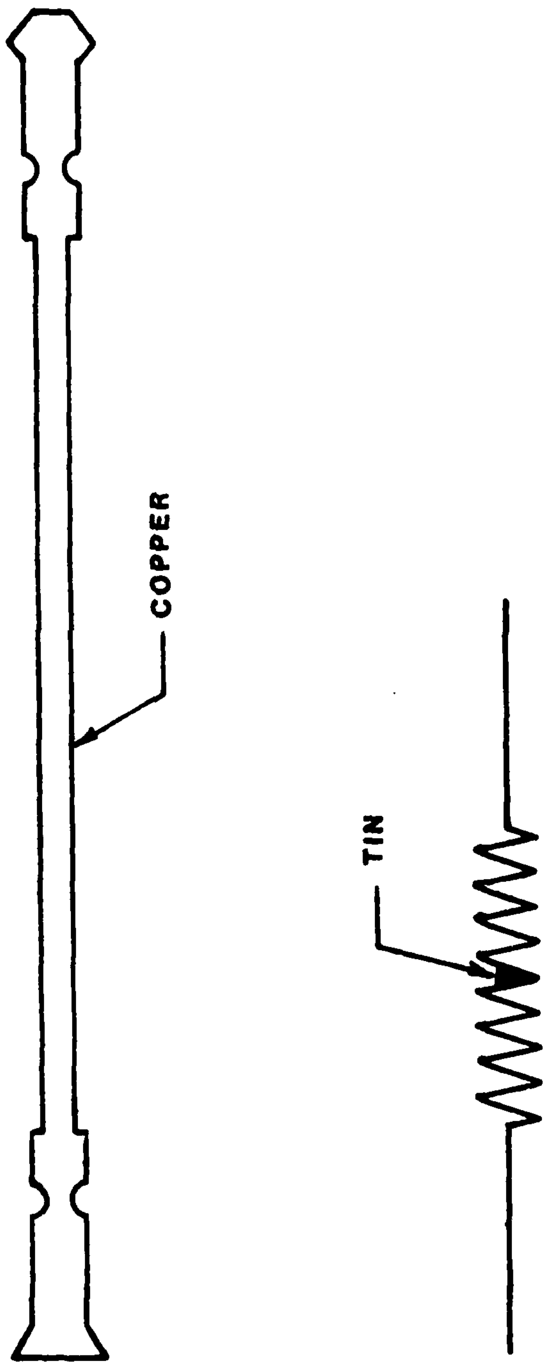
PRELIMINARY DESIGN CONCEPTS

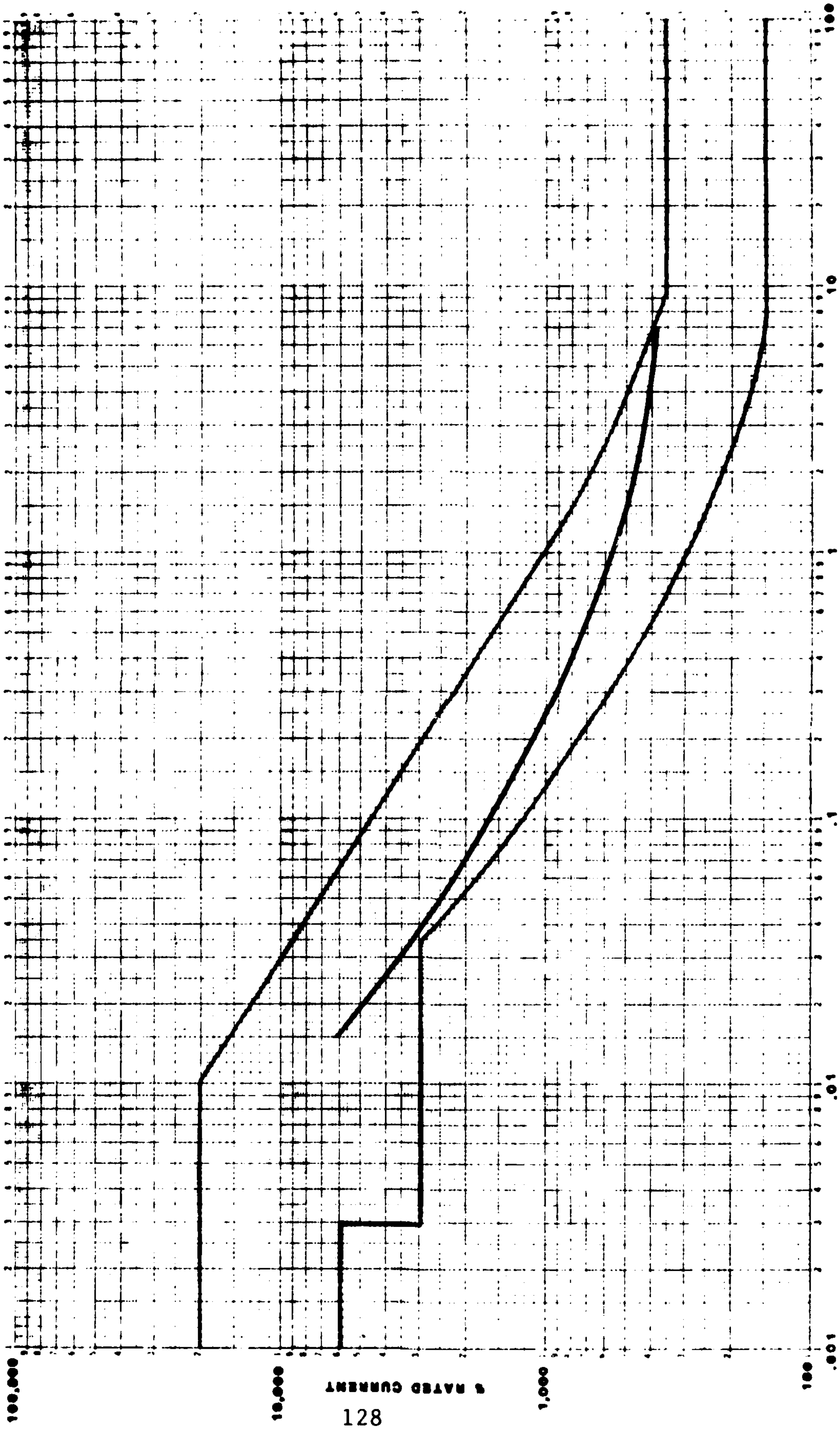
BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178



Pleated Link Design: 12 amp.
Fuses tested at room ambient.

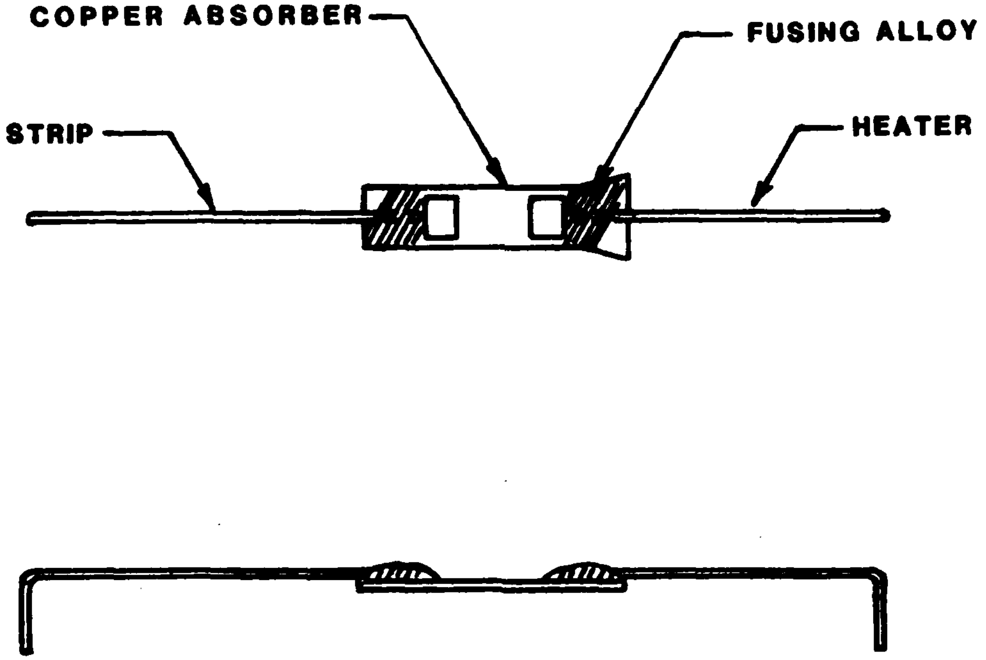
PLEATED LINK for SSPC FUSE

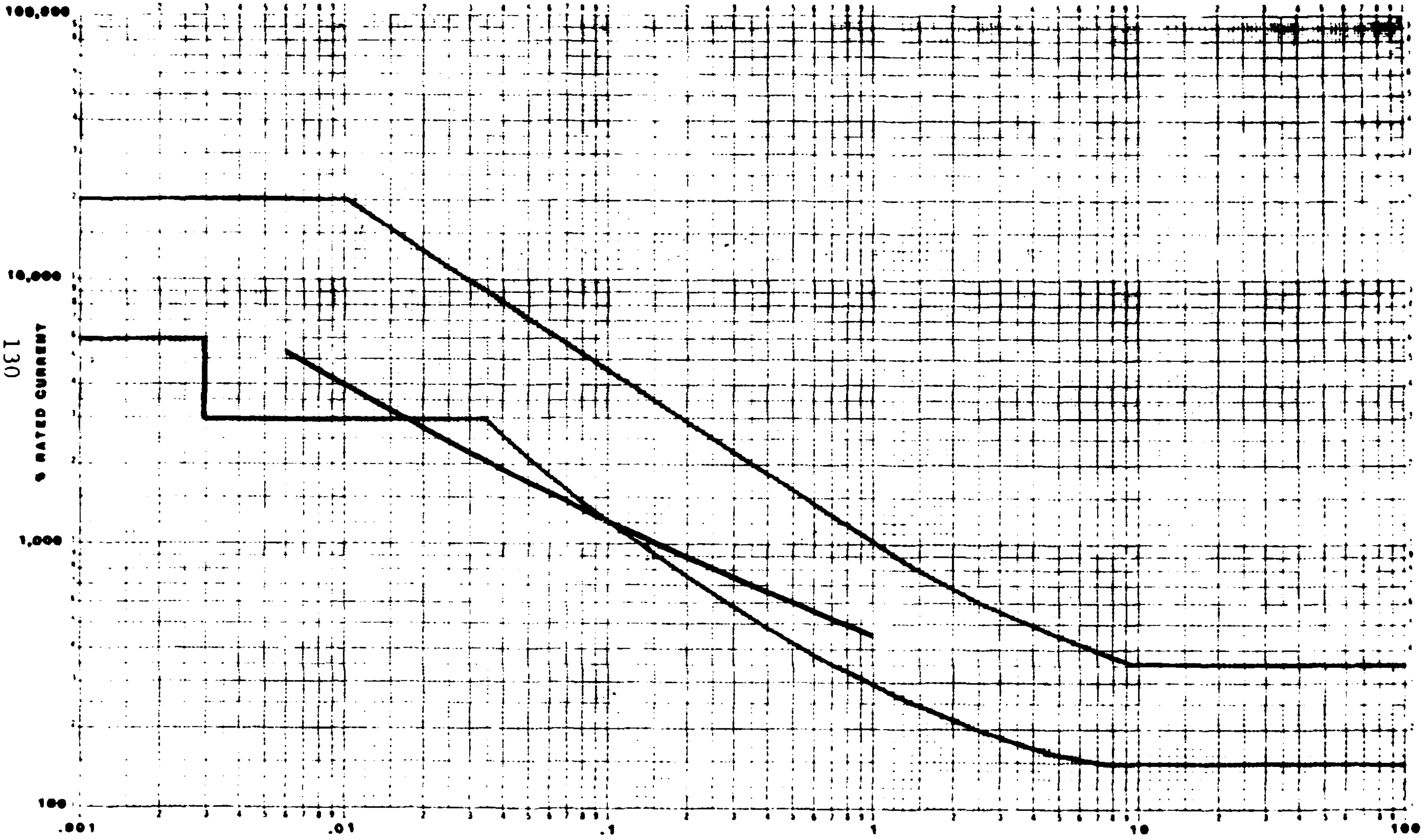




Dual Element Design: 1.6 amp.
Fuses tested at room ambient.

DUAL-ELEMENT DESIGN for SSPC FUSE

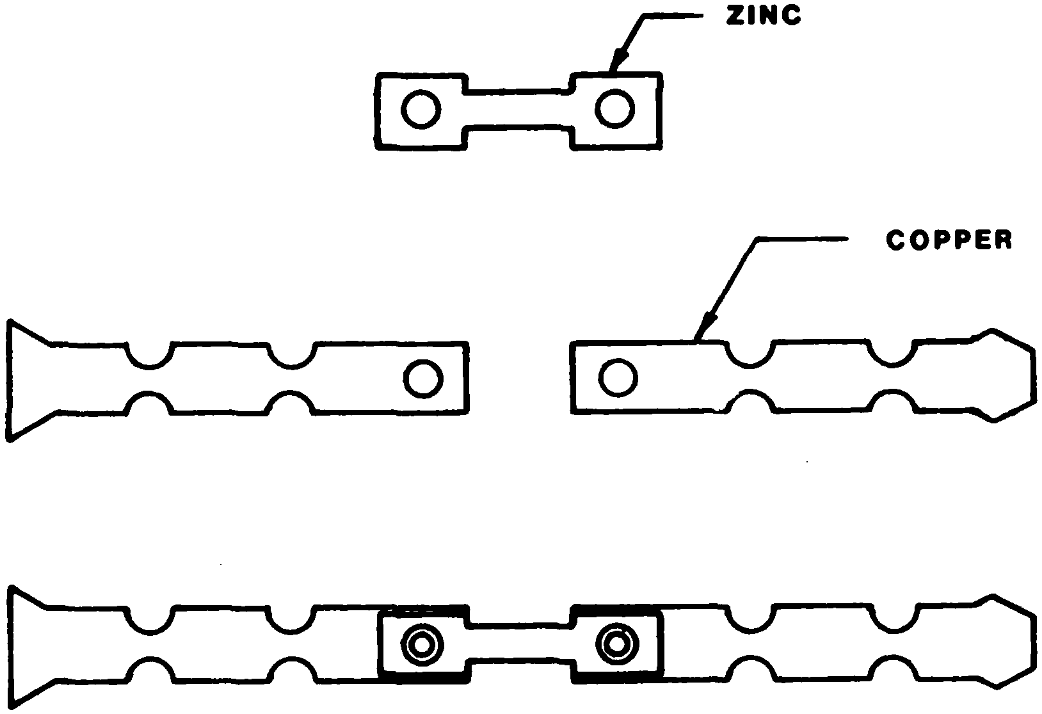


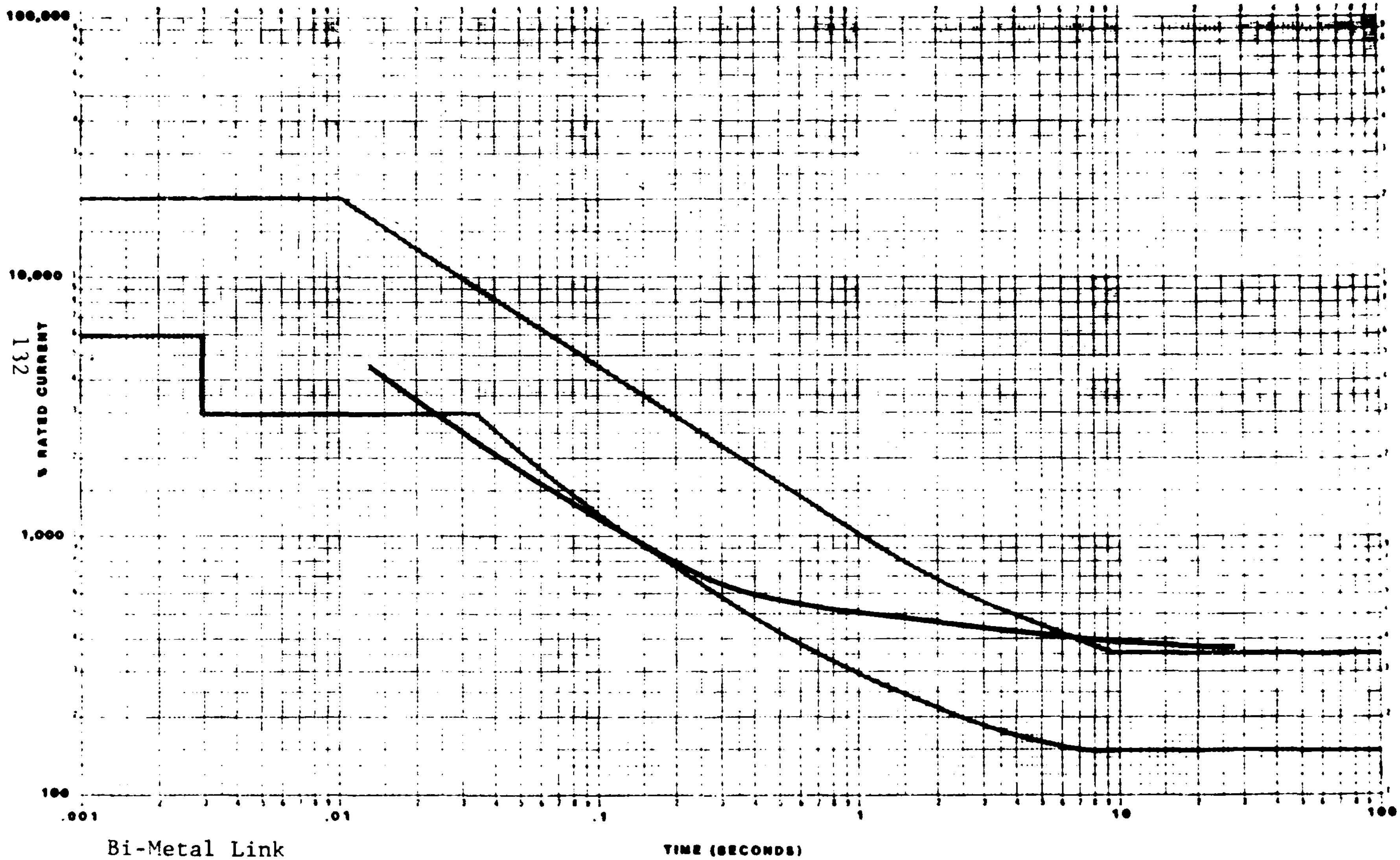


Bi-Metal Design: 6.75 amp.
Center Strip: Zinc
Side Strip: Silver/Copper

Fuses tested at room ambient.

BI-METAL LINK for SSPC FUSE

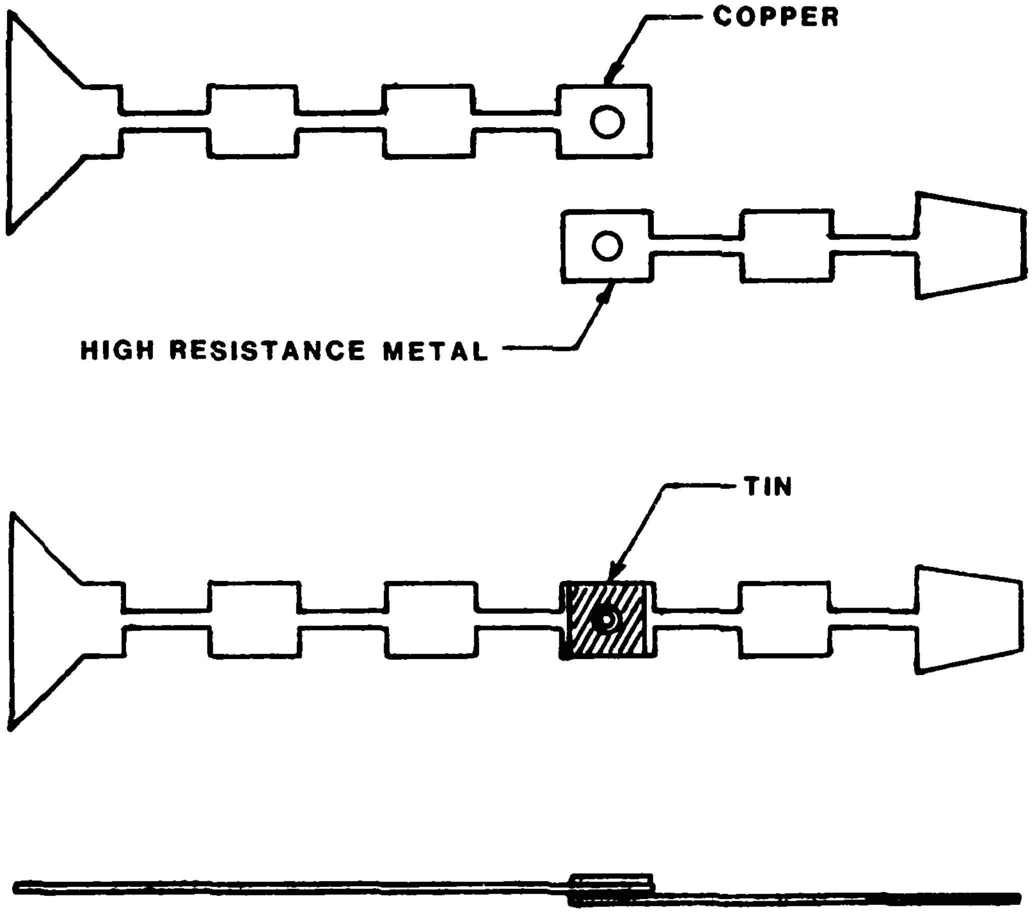


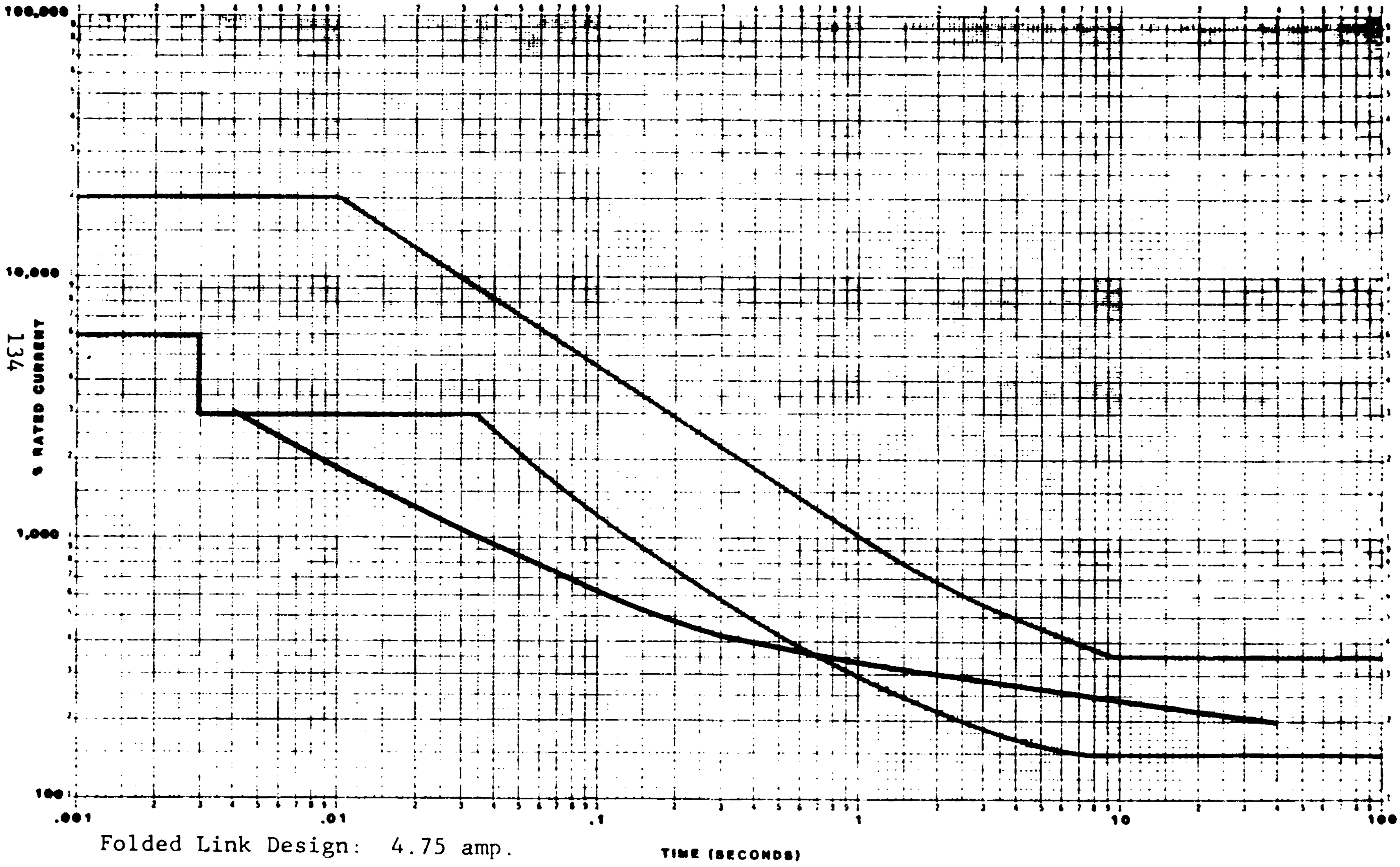


Bi-Metal Link
FNQ Design 12A

Fuses tested at room ambient.

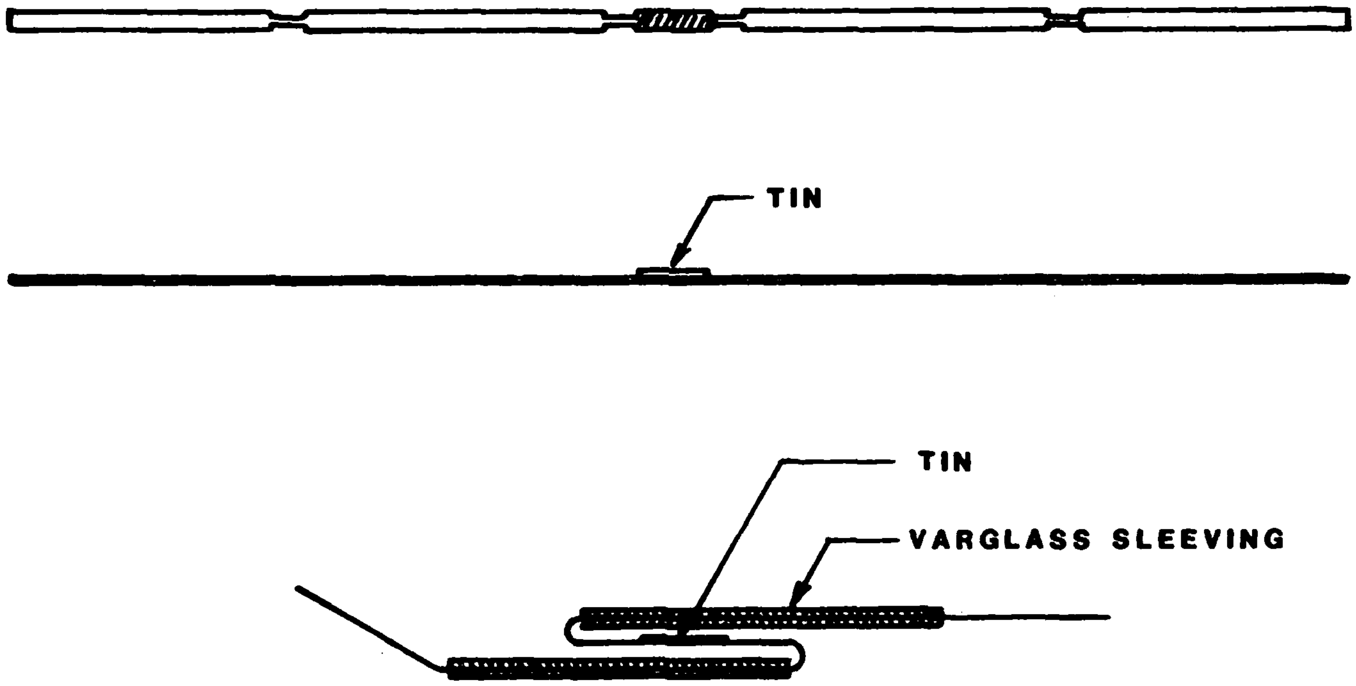
Bi-METAL LINK for SSPC FUSE FNQ DESIGN

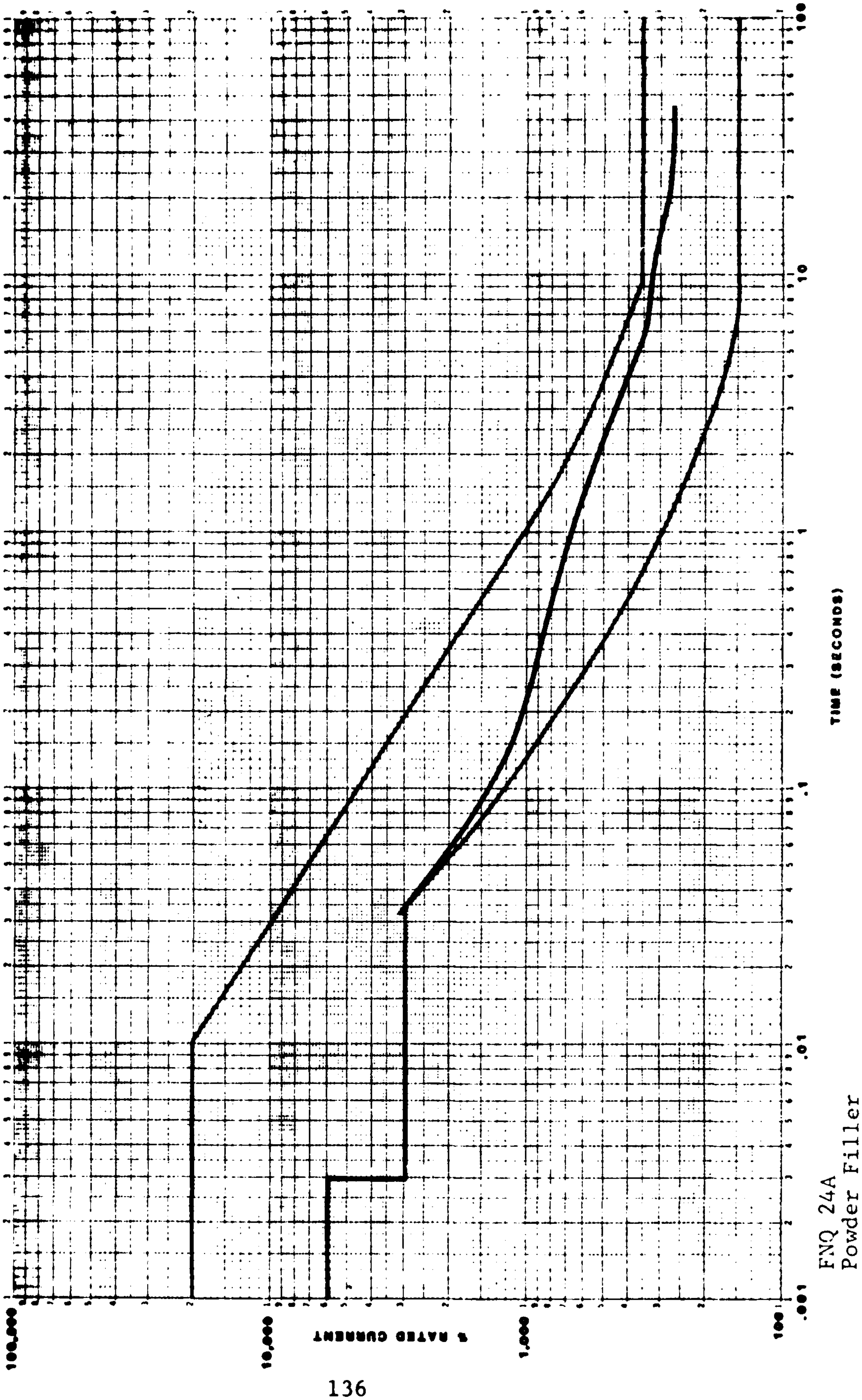




Folded Link Design: 4.75 amp.
Fuses tested at room ambient.

FOLDED LINK FOR SSPC FUSE

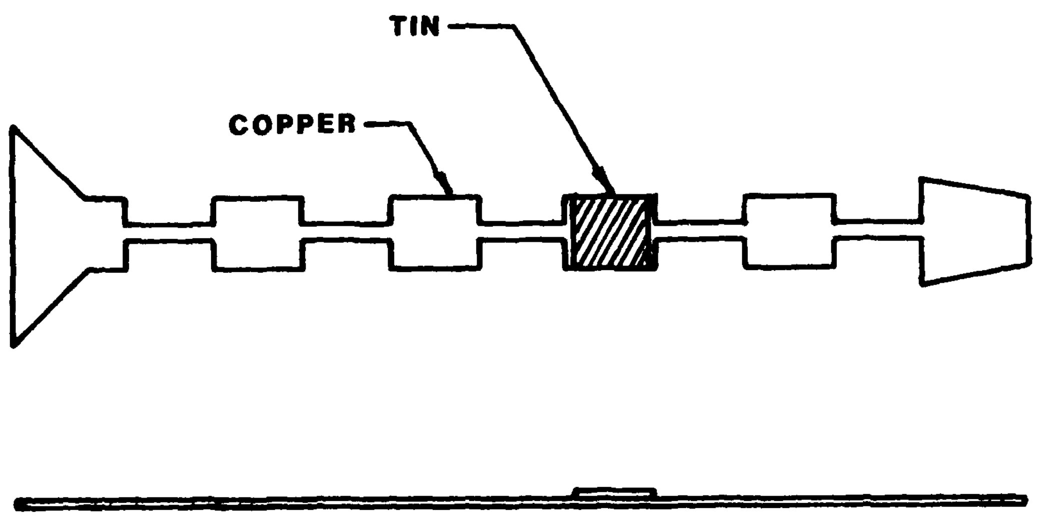


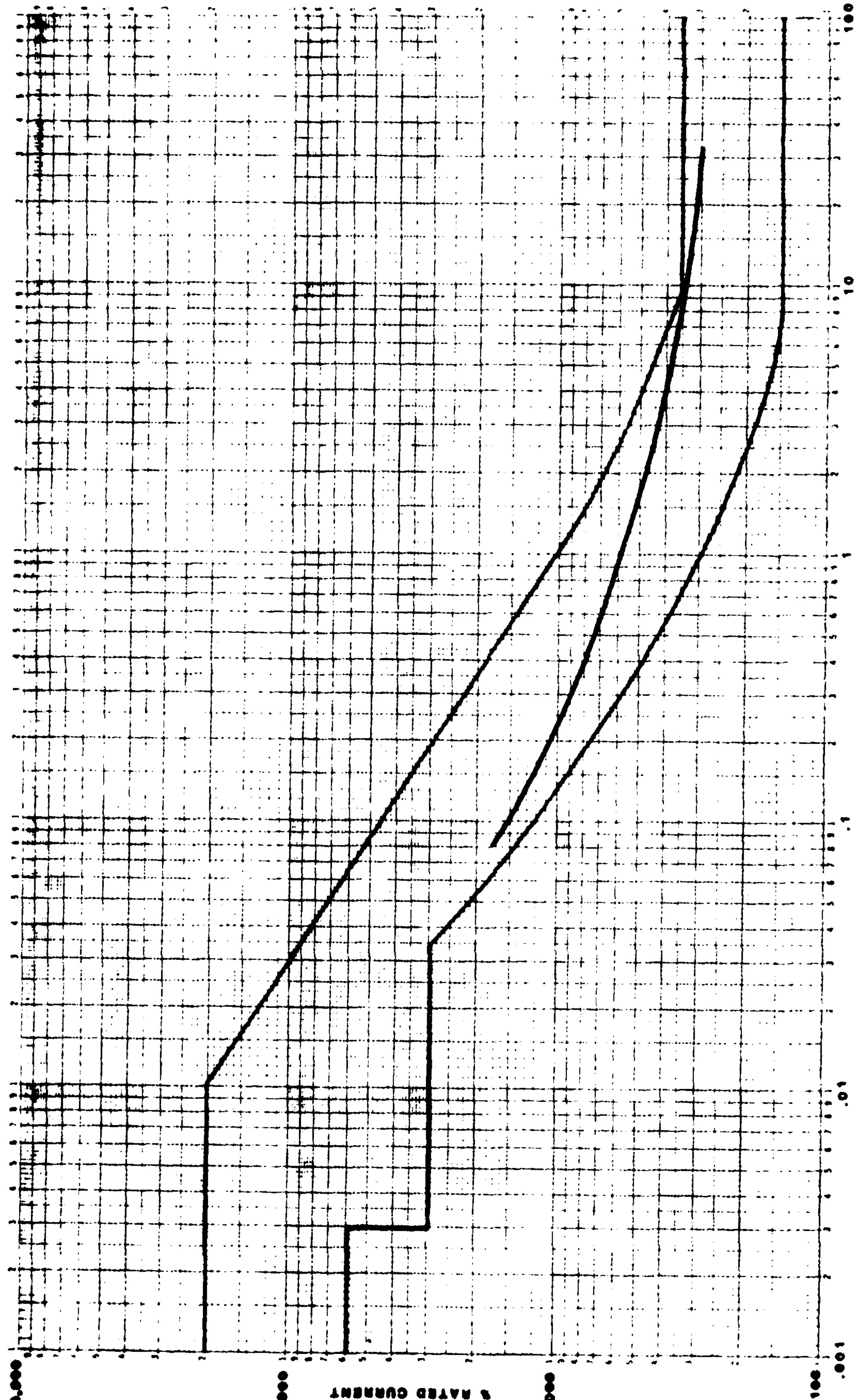


FNQ 24A
Powder Filler

Fuses tested at room ambient.

LOADED LINK for SSPC FUSE
FNQ Design



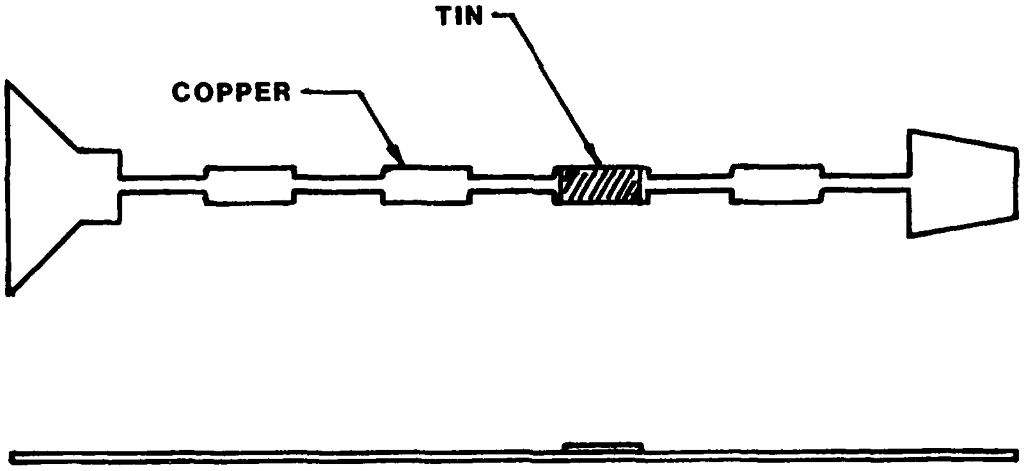


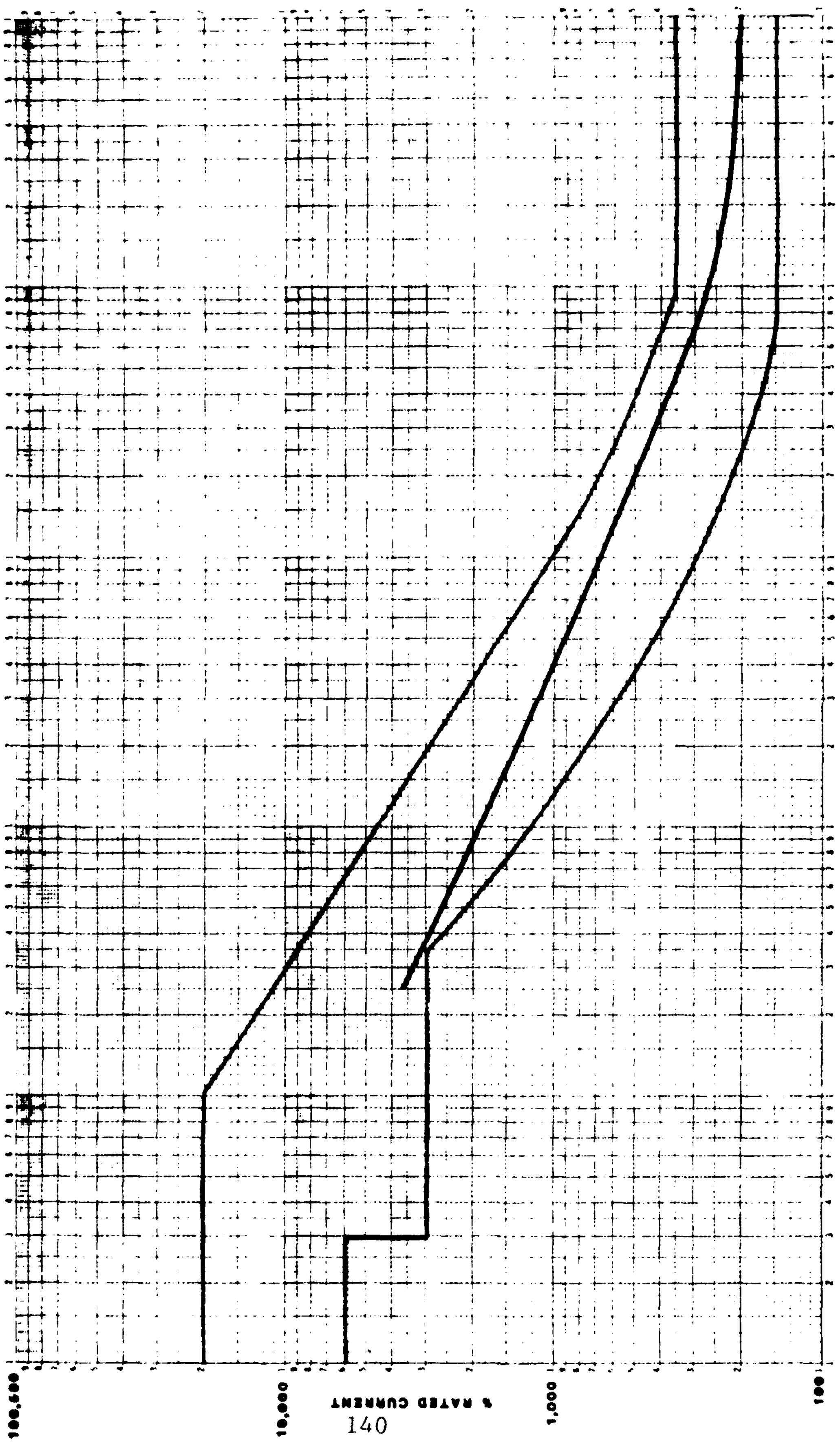
FNQ Design
Narrow Strip 20A

Fuses tested at room ambient.

LOADED LINK for SSPC FUSE

Narrowed FNQ Design

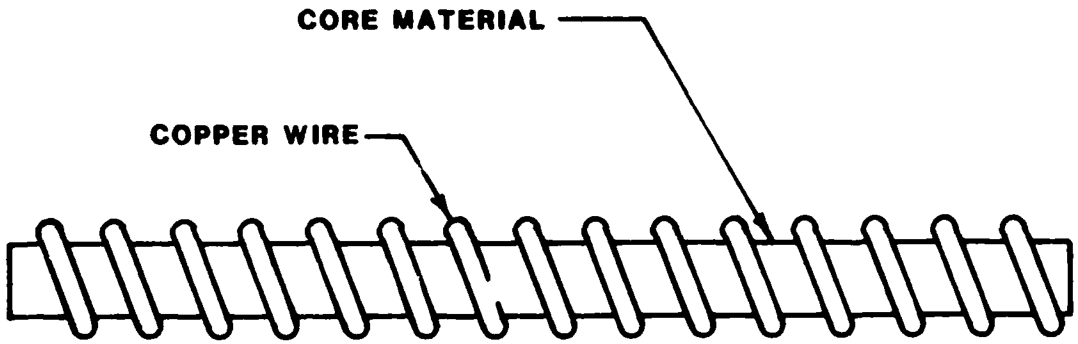




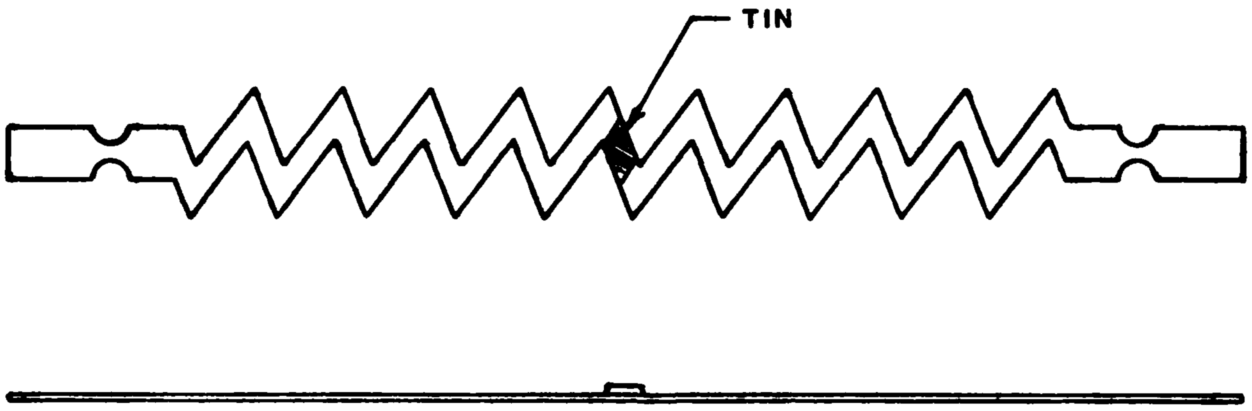
Coil Wire Design
2A

Fuses tested at room ambient.

COIL WIRE DESIGN for SSPC FUSE



SAWTOOTH LINK for SSPC FUSE



SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX E

SSPC FUSE RELIABILITY PROGRAM

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
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Appendix

ITEM NO. 17
RELEASED 11-18-81

QRC
INCORPORATED

SSPC FUSE RELIABILITY PROGRAM

Report 1
Summary

An investigation of the reliability of fuses indicates that the inherent high reliability of fuses is not always achieved due to degradation of the product in the manufacturing process. The investigation also establishes the need for additional information on the value of screening procedures for fuses.

18 November 1981

1.0 BACKGROUND

Under contract F33615-81-C-2052 the Bussmann Division of McGraw-Edison Company is to develop a fuse for use with the Solid State Power Controller (SSPC). The SSPC is used in aircraft to control power to various devices such as flap motors, landing lights and other electrical loads. The SSPC is designed to interrupt the power to its controlled device in the event of an overload condition. The purpose of the SSPC fuse is to protect the aircraft wiring and buss if the SSPC fails to "switch-off" an overload. When used in this type of application, fuses are also called current limiters.

1.1 Reliability requirements.

The specification for the SSPC fuse requires a failure rate of 0.1 failures per million hours of operation, which translates to a 10 million hour mean time between failures (MTBF). This value is the same as that given in MIL-HDBK-217, (Table 2.14-1) Reliability Prediction of Electronic Equipment.

1.2 Failure definition.

No definition of failure was provided, therefore, one must be developed to provide a basis for discussion or evaluation of reliability.

2.0 FUSE RELIABILITY CONSIDERATION

Given the construction and application of fuses, certain characteristics that relate to reliability are well known.

2.1 Failure modes.

Assuming a fuse design has been proven, that is it doesn't have a short between terminals and it does open within some specified performance band, there are two possible failure modes. A fuse may open when it should not, or it may fail to open when it should.

The causes of premature opening are an improperly fabricated fuse element, poor solder connections, improper fill or other fabrication errors. Failure to open properly is caused by improper fabrication of the fuse element and other manufacturing errors.

2.2 Failure definitions.

Failure of a fuse may be defined as failure to open when it should, opening when it should not or both. In most applications fuses are easily replaceable and an occasional open fuse would be replaced without being reported as a failure. Failure of a fuse to open, however, is likely to cause some form of damage and, therefore, more likely to be reported as a failure.

2.3 Reliability characteristics.

A properly designed and constructed fuse has an almost infinite life. That is, the fuse will carry a certain current indefinitely but still open on prescribed overload conditions.

3.0 FUSE RELIABILITY DATA

Initially it was assumed that data existed which substantiated the 0.1 failures per million hours given in MIL-HDBK-217. Such data has not been located. Also, while manufacturers of fuses and various users have conducted fuse testing, the test data available is of limited value. The purposes and procedures of the tests vary and in all cases the total accumulated test hours is small compared to the 23 million hours (with no failures) required to demonstrate the 0.1 figure at a 90% confidence level.

3.1 Data sources.

In an effort to obtain reliability data on fuses, the following sources were utilized:

GIDEP
RADC
NASA
BUSSMANN
DTIC
NTIS

3.2 Summary of findings.

No data was found which indicates a general failure rate for fuses of 0.1 failures per million hours. RADC has data showing failure rates approaching this value, but no failure definition is provided. NASA has done considerable testing of miniature fuses to establish derating curves for their unique applications and to establish screening criteria. Available manufacturers' test data is based on short time spans, mostly 1 to 24 hours.

3.2.1 RADC.

Based on a total of 529 million part hours and 72 failures, a failure rate of 0.136 X 10^{-6} hours was determined for a ground fixed environment. A shipboard sheltered failure rate of 0.124 X 10^{-6} hours is based on 48.6 million operating hours with 6 failures. This data must be viewed with some skepticism since a failure definition is lacking and because the performance of every fuse was not tested. Also, this is field data which leaves questions on the quality of reporting.

3.2.2 NASA.

For space applications it is of utmost importance that fuses do not open unless there is a dangerous overload. With this requirement in view, NASA has conducted testing to establish the current carrying capacity of fuses and develop derating criteria. NASA has recently conducted testing to evaluate the merits of different screening criteria.

3.2.3 Bussmann.

Bussmann regularly conducts burn-in and screening tests on their fuses. The predominantly used predictor of fuse quality used by Bussmann and other manufacturers is cold resistance. In a recent test, 2675 acceptable fuses were subjected to a 1 hour burn-in. Following burn-in, 42 fuses had unacceptable cold resistance values and were culled from the shipment.

3.2.4 GIDEP.

The GIDEP data is essentially the same as the RADC data. This is not surprising since both utilize the FARADA data.

4.0 CONCLUSIONS

The existing reliability data on fuses can be very misleading depending on the objectives of the test, the method of the test, and the failure definition applied. A definition of failure for the SSPC fuse is required. Fuses are inherently reliable, but screening procedures are necessary to eliminate fuses which have been degraded in the manufacturing process.

4.1 Failure definitions.

Given the application and the performance requirements of the SSPC fuse, the following failure definition is proposed.

> Failure is defined as the inability to meet the performance requirements for the SSPC fuse.

In other words, opening when it should not or failing to open when it should is defined as a failure.

4.2 Reliability.

To conduct reliability testing that would demonstrate, at a 90% confidence, a failure rate of 0.1 X 10^{-6} hours would require the following test times depending on the number of failures:

Failures	Time (millions of hours)
0	23
1	38
2	51
3	62
4	76
5	87

Testing of this magnitude is not only beyond the scope of the contract, it exceeds the realm of the practical. It is, therefore, apparent that methods must be devised which will screen out potential failures and result in delivery of SSPC fuses which are of high quality.

4.3 Screening.

While cold resistance values of fuses are used industry wide as a screening procedure, there is some indication that hot resistance may be a better criteria. Burn-in times are usually 1 hour although occasionally 24 hours or more of burn-in has been used. To date no information has been developed which indicates what an optimum burn-in time might be. Radiographic inspection is a possible screening method, but there is a serious question of its benefit when applied to fuses.

5.0 FUTURE RELIABILITY EFFORT

Additional failure rate and failure mode data is being collected and will be analyzed as acquired. Emphasis is being placed on acquisition of data on various screening procedures. A review of Bussmann test data files will be made in a effort to determine the merit, if any, of longer burn-in times.

After this additional data has been evaluated, a screening procedure for the SSPC fuse will be proposed.

SSPC FUSE DEVELOPMENT PROGRAM
FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX F
PROPOSED TEST PLAN FOR SSPC FUSES (PHASE II)
PROTOTYPE FUSE HARDWARE DEVELOPMENT

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14450
ST. LOUIS, MO 63178

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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7. AUTHOR(s) Walter H. Curtis Lead Design Engineer	8. CONTRACT OR GRANT NUMBER(s) F33615-81-C-2052
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bussmann Division P.O. Box 14460 St. Louis, Mo. 63178	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 3145 29 64
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Solid State power controller
SSPC
Fuse
Fail safe fuse

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This test plan is intended to verify the design, construction and performance of SSPC fuses. It also is intended to develop a basis for production screening to assure a high level of quality.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SSPC FUSE DEVELOPMENT
GENERAL TEST PLAN/PROCEDURES
BREADBOARD FUSE EVALUATION (PHASE II)

1.0 SCOPE

1.1 Scope. This test plan is intended to verify the design, construction, and performance of SSPC fuses. It also is intended to develop a basis for production screening to assure a high level of quality.

2.0 APPLICABLE DOCUMENTS

Contract F33615-81-C-2052

3.0 TEST PROGRAM

3.1 Development. The SSPC fuse is being developed using a phased approach which insures certain bench marks are met before further work is performed. In consonance with this approach, the test plan shall be implemented in accordance with the phased approach established by the contract.

3.1.1 Phase II. Testing in Phase II shall consist of the Group I and Group II tests of this specification.

4.0 TEST PROGRAM

4.1 Test sequence. The sequence of tests shall be in accordance with Table I.

4.2 Test samples. The number of sample fuses to be subjected to each test shall be in accordance with Table I.

4.3 Test facilities. The tests shall be performed at facilities capable of conducting the prescribed tests and measurements in a manner satisfactory to the government.

4.4 Test equipment. Test equipment calibration shall be documented. Test data accuracy shall be recorded and shall be consistent with the equipment and calibration accuracy required for the specific test.

TABLE 1

Test Sequence and Sample Quantities

Inspection	Sample Qty.	Test Para.	Notes
Group I		4.6	
Visual & mechanical examination	ALL	4.6.1	
Cold resistance	ALL	4.6.2	
Group II		4.7	
Current carrying	5	4.7.1	1
Overload interrupt	37	4.7.2	1
Short circuit interrupt	8	4.7.3	1

NOTE: 1. Quantity shown is for each rating.

4.5 Test data. Pertinent data will be recorded for all tests conducted. The data shall be retained for the duration of the development program plus a minimum of one year.

4.6 Group I tests.

4.6.1 Visual and mechanical examination. All samples submitted for testing shall be examined to verify that material, design, construction, physical dimensions, marking and workmanship comply with the applicable requirements. All samples shall be numbered or otherwise individually identified.

4.6.2 Cold resistance. The resistance of all sample fuses shall be measured at room ambient temperature. The measurement shall be taken with a Wheatstone bridge, Kelvin bridge or equivalent sensitive instrument.

4.7 Group II tests.

4.7.1 Current carrying capacity. Five samples of each fuse rating shall be subjected to a 400 Hz or 60 Hz alternating voltage at 125% (+10% -0%) of rated current. The power supply may be of any value which is not less than 6 volts. The current shall be maintained for a period of not less than 3 hours at room ambient temperature. The test shall be repeated using the same samples at -55°C and at +85°C following a 30 minute soak at each temperature.

4.7.2 Overload interrupt. A sample quantity of 37 fuses of each current rating shall be subjected to the percentage of rated current shown in Table 2. The test samples shall be distributed in accordance with the temperatures shown in the Table. The samples shall soak at the stated temperatures for 30 minutes prior to the application of electrical current. The 400 Hz or 60 Hz power supply may be of any value which is not less than 6 volts.

TABLE 2

Overload Interrupt Test

Sample Qty. & Temperature			% of Rated Current	Clearing Time (Seconds)	
				Min.	Max.
Room	-55°C	+85°C	+3%		
5	2	2	200	2.70	>100
5	2	2	300	1.0	>100
5	2	2	500	.370	3.80
5	0	0	1,000	.130	1.05
5	0	0	3,000	.035	.190

4.7.3 Short circuit interrupt capacity. Eight sample fuses of each rating shall be subjected to a 6,000 ampere short circuit test in accordance with Table 3. The test shall be conducted using a 400 Hz or 60 Hz power source having an open circuit voltage equal to the fuse voltage rating. Fuses shall open the circuit and remain in tact. The voltage should be held for 30 seconds after interruption. Any rupture of the fuse shall constitute a failure.

TABLE 3

Short Circuit Interrupt Capacity

Test Qty.	Altitude
8	Sea Level

SSPC FUSE DEVELOPMENT PROGRAM
FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX G
PRELIMINARY SSPC FUSE DESIGN SPECIFICATION

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

PRELIMINARY SSPC FUSE DESIGN SPECIFICATION

FUSES, AIRCRAFT TYPE,
GENERAL SPECIFICATION FOR

1. SCOPE

1.1 Scope. This specification covers aircraft type fuses designed for the protection of aircraft wiring associated with solid state power controllers (SSPCs) on direct current (DC) and alternating current (AC) (up to 400 Hertz (Hz)) circuits.

2. APPLICABLE DOCUMENTS

Contract F33615-81-C-2052

3. REQUIREMENTS

3.1 Specification Sheets. The individual item shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between requirements of this specification and the specification sheet, the latter shall govern.

3.2 Material. The material for each part shall be as specified herein. However, when a definite material is not specified, a material shall be used which will enable the fuses to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guarantee of the acceptance of the finished product.

3.2.1 Restricted Material. Flammable or explosive material, or material which can produce toxic or suffocating fumes when the fuses are in service shall not be used in the construction of the fuses.

3.2.2 Case or Body.

3.2.2.1 Glass. When glass is used, it shall be of high quality, free from strain, and sufficiently clear to permit the enclosed fuse element to be readily seen.

3.2.2.2 Plastic. Unless otherwise specified (see 3.1), any plastic insulation may be used, except that cotton base or cotton or cellulose filled molding material shall not be used.

3.2.2.3 Ceramic. Ceramic insulation shall be grade L.311 or higher grade, in accordance with MIL-I-10.

3.2.2.4 Epoxy. Epoxy encapsulant compound shall conform to type B of MIL-I-16923.

3.2.3 Current Carrying Parts (except fuse element). Current carrying parts shall be of brass, copper, or phosphor bronze conforming to QQ-B-613 or QQ-B-626, QQ-C-576, QQ-B-750 and MIL-C-21768, respectively.

3.2.4 Non-Current Carrying Parts. All metal non-current carrying parts shall be of corrosion resistant material or of material adequately protected against corrosion in accordance with MIL-F-14072.

3.3 Design and Construction. Fuses shall be of a design, construction and physical dimensions as specified (see 3.1).

3.3.1 Mounting. Unless otherwise specified (see 3.1) the fuse shall be designed with lead type terminals.

3.3.2 Terminal Mounting. Terminals shall be secured to the fuse body so that they shall not loosen. The fuse wire shall be so attached that there shall be no danger of breaking the fuse wire or connections when installing the fuse. Terminals other than the ends to which the fusible elements are attached and the leads shall be free from solder.

3.3.3 Terminal Finish or Plating. Ferrules shall be plated as specified (see 3.1). Leads shall be tin-lead plated or coated as specified (see 3.1).

3.3.3.1 Bright Alloy Plating. Minimum plating of bright alloy shall be 0.00008 inch thick. The plating shall be of the following composition:

Copper - 50 to 60 percent
Tin - 25 to 28 percent
Zinc - 14 to 18 percent

3.3.3.2 Tin-Lead Plating or Coating. Tin-lead plating or coating shall conform to MIL-P-81728.

3.4 Continuity. Fuses shall have electrical continuity (see 4.8.2).

3.5 Resistance. Fuses shall have electrical resistance as specified (see 3.1 and 4.8.3).

3.6 Current-Carrying Capacity. Fuses shall show no evidence of mechanical damage and shall carry 125% of rated current without opening. The temperature of the case, body or terminals shall not rise more than 90°C above room ambient temperature (see 3.1 and 4.8.4).

3.7 Terminal Strength. Fuse terminals shall not become damaged when subjected to the specified force (see 3.1 and 4.8.5).

3.8 Overload Interrupt. Fuses shall open the circuit within the time limits specified in Table I without causing the case or body to char or fracture. The circuit shall remain open without the circuit closing again during the 1-minute period after interrup. Immediately after removal of the fuse, and in no case not more than 1 minute after removal of the fuse, the insulation resistance shall be as specified in 3.9 (see 4.8.6).

3.9 Insulation Resistance. The insulation resistance after overload interrupt (see 3.8) and short circuit (see 3.10) shall be at least 1/2 megohm (see 4.8.7).

TABLE I OVERLOAD INTERRUPT TEST

Percent of Rated Current (+3% - 0%)	Clearing Time (Seconds) Minimum	Maximum
200	2.70	>100.0
500	.370	3.80
1000	.130	1.05
3000	.035	.19

3.10 Short Circuit. Fuses shall remain intact and shall open the circuit. The fuses shall remain in the energized circuit 1 minute without any indication of the circuit closing again. Immediately after removal of the fuse, and in no case not more than 1 minute after removal of the fuse, the insulation resistance shall be as specified in 3.9 (see 4.8.8).

3.11 Vibration, High Frequency. There shall be no electrical or mechanical damage to the fuse (see 4.8.9).

3.12 Shock. There shall be no electrical or mechanical damage to the fuse (see 4.8.10).

3.13 Salt Spray (corrosion). There shall be no evidence of excessive corrosion. Excessive corrosion is defined as that which interferes with the electrical or mechanical performance, or in the case of plated metals, corrosion which has passed through the plating and attacked the base metal. There shall be no warping, cracking, or other electrical or mechanical damage to the fuse (see 4.8.11).

3.14 Moisture Resistance. There shall be no cracking, peeling, loosening of terminals or evidence of electrolytic corrosion.

3.15 Thermal Shock. The fuses shall show no mechanical or electrical damage and there shall be no loosening of the terminals or other parts (see 4.8.13).

3.16 Marking. Unless otherwise specified (see 3.1), each fuse shall be marked in accordance with method I of MIL-STD-1285.

3.16.1 Ferrule and End Cap Marking. The fuse ferrules shall be marked with the following:

a. Type designation
b. Manufacturer's name, trademark or code symbol.

TABLE II. INSPECTION SEQUENCE

Inspection	Requirement Paragraph	Test Method Paragraph
Group I (all samples)		
Visual and mechanical examination----	3.3, 3.16	4.8.1
Resistance--------------------------	3.5	4.8.3
Current-carrying capacity------------	3.6	4.8.4
Group II (see 3.1) (24 sample units/current rating)		
Terminal strength--------------------	3.7	4.8.5
Overload interrupt-------------------	3.8	4.8.6
Insulation resistance--------------	3.9	4.8.7
Group III (see 3.1) (4 sample units/current rating)		
Short circuit------------------------	3.10	4.8.8
Insulation resistance--------------	3.9	4.8.7
Group IV (4 sample units/current rating)		
Vibration, high frequency------------	3.11	4.8.9
Continuity-------------------------	3.4	4.8.2
Shock--------------------------------	3.12	4.8.10
Continuity-------------------------	3.4	4.8.2
Group V (4 sample units/current rating)		
Salt spray (corrosion)---------------	3.13	4.8.11
Overload interrupt (at room ambient temperature and maximum voltage rating)-------------------------	3.8	4.8.6
Insulation resistance--------------	3.9	4.8.7
Group VI (4 sample units/current carrying)		
Moisture resistance------------------	3.14	4.8.12
Thermal Shock------------------------	3.15	4.8.13
Current carrying capacity (at room ambient temperature)---------------	3.6	4.8.4
Overload interrupt (at room ambient temperature and maximum voltage rating)-------------------------	3.8	4.8.6
Insulation resistance--------------	3.9	4.8.7

4. QUALITY ASSURANCE PROVISIONS

Paragraphs 4.1 through 4.7 dealing with Responsibility for Inspection and Quality Conformance Inspection will be included in the final specification.

4.8 Method of Examination and Test.

4.8.1 Visual and Mechanical Examination. Fuses shall be examined to verify that the materials, design, and construction, physical dimensions, marking and workmanship are in accordance with the applicable requirements (see 3.1 through 3.3 and 3.16).

4.8.2 Continuity (see 3.4). Continuity of each fuse shall be determined by use of a low voltage ohmmeter or other suitable method.

4.8.3 Resistance (see 3.5). Resistance shall be measured with a Wheatstone bridge, Kelvin bridge, or equivalent sensitive instrument. Measurements shall be taken at room ambient temperature and as close to the fuse element as practicable.

4.8.4 Current-carrying Capacity (see 3.6). Fuses shall be subjected to an AC current (400 Hz) at 125 percent of rated current. The samples shall be apportioned and submitted to the test at:

1) $-55^{\circ}C \; {}^{+0^{\circ}}_{-3}{}^{\circ}C$

2) $+25^{\circ}C \; {}^{+5^{\circ}}_{-5}{}^{\circ}C$ (Room ambient temperature)

3) $+85^{\circ}C \; {}^{+3^{\circ}}_{-0}{}^{\circ}C$

The current shall be maintained for 30 minutes after the temperature of each fuse has stabilized, but shall be applied for not less than 1-1/2 hours. It may be assumed that the temperature has stabilized when three consecutive temperature readings taken at 10 minute intervals show no rise in temperature. Fuses shall be mounted in a fuseholder as specified (see 3.1). When two or more fuses are tested in series, the fuseholders shall be located so that there will be a spacing of not less than 6 inches between any two fuses under test. The wire connecting the fuseholders together and connecting the fuseholders to the ammeter and the source of supply shall be size 8 and shall be in accordance with J-C-30. The length of wire between fuseholders shall be 2 feet. The temperature of the fuse case or body and of the terminals shall be measured by thermocouples (wire size 28 to 32 AWG).

4.8.5 Terminal Strength (see 3.7). Unless otherwise specified, terminals shall be tested in accordance with method 211, test condition A of MIL-STD-202. Forces shall be applied to the lead type terminals as follows:

1. Along terminal axis. (3 pound force)
2. Perpendicular to terminal axis. (3 pound force)

4.8.6 Overload Interrupt (see 3.8). Fuses shall be subjected to the percentage of rated current shown in Table I. The sample fuses shall be apportioned and submitted to the tests at:

1) $-55^{\circ}\mathrm{C}\ ^{+0^{\circ}}_{-3^{\circ}}\mathrm{C}$

2) $+25^{\circ}\mathrm{C}\ ^{+5^{\circ}}_{-5^{\circ}}\mathrm{C}$ (Room ambient temperature)

3) $+85^{\circ}\mathrm{C}\ ^{+3^{\circ}}_{-0^{\circ}}\mathrm{C}$

The fuses shall be maintained at the test temperature for a minimum of 30 minutes, prior to the actual application of the test current. The power supply shall be an AC source 60 Hz or 400 Hz and have an open circuit voltage of not less than that of the specified voltage rating of the fuse under test. The fuses shall be left in the circuit for 1 minute after blowing without any indication of the circuit reclosing, and insulation resistance readings shall be taken within 1 minute following the removal of the test voltage. Opening time measurements shall be made with an oscillograph for periods shorter than 1 second; a synchronous timer may be used for measurements longer than 1 second; a stop watch is suitable for measurements of longer than 10 seconds. Following the test, insulation resistance shall be measured as specified in 4.8.7.

4.8.7 Insulation Resistance (see 3.9). Fuses shall be tested after overload interrupt (see 3.8) and short circuit (see 3.10) in accordance with method 302 of MIL-STD-202. The following details shall apply:

a. Test condition - A.
b. Points of measurement - Between terminals.
c. Following the test, fuses shall be examined for compliance with 3.9.

4.8.8 Short Circuit (see 3.10). Fuses shall be subjected to the tests at the current, frequency and voltage specified (see 3.1). The direct current tests shall be made using appropriate generating equipment for a source of power and with the rate of current rise for the test circuit adjusted for at least 3.25 x 10^6 amperes per seconds. The alternating current tests shall be applied within $\pm 10^o$ of zero point of the voltage wave and the circuit power factor shall be 0.85 to 0.95. Short circuit currents shall be determined by means of an oscillograph. Test circuits shall be calibrated for the specified current with the applicable fuseholder (see 3.1) short-circuited. Following the test, insulation resistance shall be measured as specified in 4.8.7.

4.8.9 Vibration, High Frequency (see 3.11). The fuses shall be subjected to vibration tests in accordance with method 204 of MIL-STD-202. The following details shall apply:

a. Mounting - In applicable fuseholder (see 3.1).
b. Test condition - C.
c. One-half of the sample units shall be tested while carrying 100 percent of rated current at any convenient voltage and frequency and the balance tested with no current. All sample units shall be tested for continuity as specified in 4.8.2 at the end of the test.

4.8.10 Shock (see 3.12). Fuses shall be tested in accordance with method 213 of MIL-STD-202. The following details and exceptions shall apply:

a. Mounting method and accessories - Fuses shall be mounted in or on applicable fuseholders (see 3.1).
b. Test condition - I, unless otherwise specified (see 3.1).
c. Measurements before and after test - One-half of the sample units shall be tested while carrying 100 percent of rated current at any convenient voltage and frequency (see 3.1), and the remainder with no current. All fuses shall be tested before and after test for continuity as specified in 4.8.2.

4.8.11 Salt Spray (corrosion) (see 3.13). Fuses shall be tested in accordance with method 101 of MIL-STD-202. The following details shall apply:

a. 5-percent salt solution.
b. Test condition - B.
c. Following the drying period, the fuses shall be subjected to 100 percent of rated current for 1 hour.
d. Following the test, fuses shall be examined for compliance with 3.13.

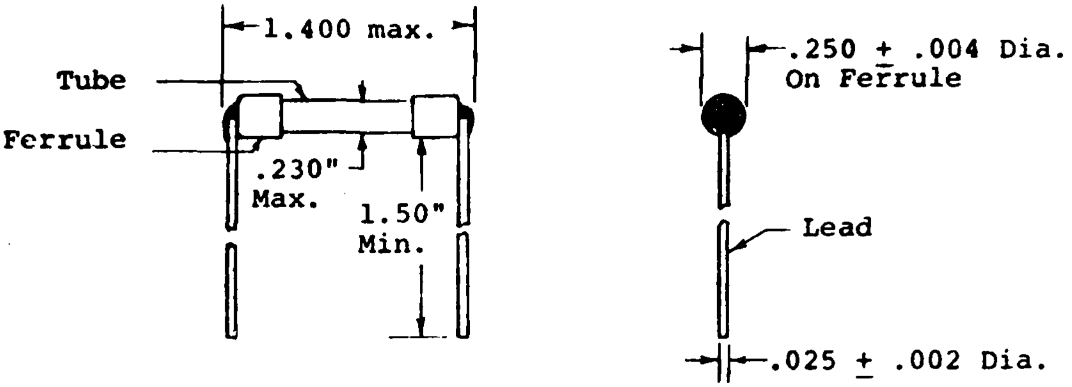
4.8.12 Moisture Resistance (see 3.14). Fuses shall be tested in accordance with method 106 of MIL-STD-202. The following details and exceptions shall apply:

a. Mounting - Normal mounting means on a noncorrosive metal panel positioned 15 degrees from the vertical with the terminal down.
b. Polarized voltage shall be 100 volts dc.
c. Steps 7A and 7B are not applicable.
d. Following the test, the fuses shall be examined for compliance with 3.14.

4.8.13 Thermal Shock see (3.15). The fuses shall be subjected to thermal shock tests in accordance with method 107 of MIL-STD-202. The following details shall apply:

a. Test condition - A.
b. Examination after test - Fuses shall be examined for compliance with 3.15.

SOLID STATE POWER CONTROLLER (SSPC) FUSE



NOTE:

Dimensions are in inches.

REQUIREMENTS:

Applicable Fuseholders: MIL-F-21346/2, Style FH22A, fuseholders shall be used for all testing. The fuses shall be attached to the fuseholder screw terminals with the leads.

Terminals:

Material - Fuse ferrules - brass

- Leads - copper

Finish - Fuse Ferrules - Bright Alloy Plating

- Leads - Tin-Lead Plating or Coating

Body:

Plastic or ceramic tube.

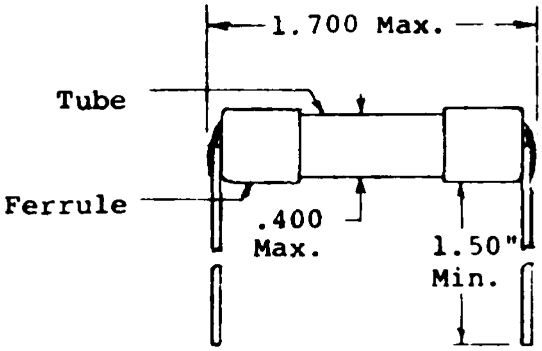
TABLE I ELECTRICAL RATINGS

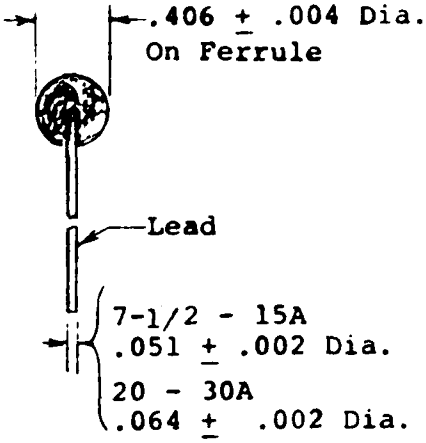
Current Rating (Amperes)	Short Circuit Interrupt		Resistance (Ohms)
	28V DC	*250V AC 60 Hz	
2		10,000A	
5		10,000A	

NOTE:

The AC short circuit interrupt test is performed at 60 Hz, since no 400 Hz source of adequate capacity is available.

SOLID STATE POWER CONTROLLER (SSPC) FUSE





NOTE:

Dimensions are in inches.

REQUIREMENTS:

Applicable Fuseholders: MIL-F-21346/3, Style FH25AM fuseholders shall be used for all testing. The fuses shall be attached to the fuseholder screw terminals with the leads.

Terminals:

Material - Fuse Ferrules - Brass
- Leads - Copper

Finish - Fuse Ferrules - Bright Alloy Plating
- Leads - Tin-Lead Plating or Coating

Body:

Plastic or ceramic tube.

TABLE I ELECTRICAL RATINGS

Current Rating (Amperes)	Short Circuit Interrupt		Resistance (Ohms)
	28V DC	*250V AC 60 Hz	
7-1/2		10,000A	
10		10,000A	
15		10,000A	
20		10,000A	
30		10,000A	

NOTE:

The AC short circuit interrupt test is performed at 60 Hz, since no 400 Hz source of adequate capacity is available.

SSPC FUSE DEVELOPMENT PROGRAM
FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX H
FINAL DESIGN HARDWARE TEST PLAN

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

Appendix H

SSPC FUSE DEVELOPMENT PROGRAM

FINAL DESIGN HARDWARE TEST PLAN

Bussmann Division
McGraw-Edison Corporation
P.O. Box 14460
St.Louis, Mo. 63178

1.0 SCOPE

1.1 Scope. This test plan is intended to verify the design, construction, and performance of SSPC fuses. It also is intended to develop a basis for production screening to assure a high level of quality.

2.0 APPLICABLE DOCUMENTS

Contract F33615-81-C-2052

3.0 PROGRAM REQUIREMENTS

3.1 Development. The SSPC fuse is being developed using a phased approach which insures certain bench marks are met before further work is performed. Consistent with this approach, the test plan shall be implemented in accordance with the phased approach established by the contract.

3.1.1 Testing. Testing shall consist of the Group I and Group II tests of this specification.

4.0 TEST PROGRAM

4.1 Test sequence. The sequence of tests shall be in accordance with Table I.

4.2 Test samples. The number of sample fuses to be subjected to each test shall be in accordance with Table I.

4.3 Test facilities. The tests shall be performed at facilities capable of conducting the prescribed tests and measurements in a manner satisfactory to the government.

TABLE I

Test Sequence and Sample Quantities

Inspection	Sample Qty.	Test Para.	Notes
Group I		4.5	
Visual & mechanical examination	ALL	4.5.1	
Cold resistance	ALL	4.5.2	
Group II		4.6	
Current carrying	15	4.6.1	1
Overload interrupt	37	4.6.2	1
Short circuit interrupt	8	4.6.3	1

NOTE: 1. Quantity shown is for each rating.

4.4 Test data. Pertinent data will be recorded for all tests conducted. The data shall be retained for the duration of the development program plus a minimum of one year.

4.5 Group I tests.

4.5.1 Visual and mechanical examination. All samples submitted for testing shall be examined to verify that material, design, construction, physical dimensions, marking and workmanship comply with the applicable requirements. All samples shall be numbered or otherwise individually identified.

4.5.2 Cold resistance. The resistance of all sample fuses shall be measured at room ambient temperature. The measurement shall be taken with a Wheatstone bridge, Kelvin bridge or equivalent sensitive instrument.

4.6 Group II tests.

4.6.1 Current carrying capacity. Fifteen samples of each fuse rating shall be apportioned and subjected to a 400 Hz or 60 Hz alternating voltage (see note) at 125% (+10% -0%) of rated current at $-55^\circ\text{C}\,^{+0^\circ}_{-3^\circ}\text{C}$, $+25^\circ\text{C}\,^{+5^\circ}_{-5^\circ}\text{C}$ and $+85^\circ\text{C}\,^{+3^\circ}_{-0^\circ}\text{C}$ temperature. The current shall be maintained for a period of not less than 3 hours following a 30 minute soak at each temperature.

4.6.2 Overload interrupt. A sample quantity of 37 fuses of each current rating shall be subjected to a 400 Hz or 60 Hz alternating voltage (see note) at the percentage of rated current shown in Table 2. The test samples shall be distributed in accordance with the temperatures shown in the Table. The samples shall soak at the stated temperatures for 30 minutes prior to the application of electrical current.

Note: The power supply may be of any value which is not less than 6 volts.

TABLE 2

Overload Interrupt Test

Sample Qty. & Temperature			% of Rated Current	Clearing Time Min. (Seconds)	Max.
$+25^\circ\text{C}\,^{+5^\circ}_{-5^\circ}\text{C}$	$-55^\circ\text{C}\,^{+0^\circ}_{-3^\circ}\text{C}$	$+85^\circ\text{C}\,^{+3^\circ}_{-0^\circ}\text{C}$	+3%		
5	2	2	200	2.70	>100
5	2	2	300	1.00	>100
5	2	2	400	.550	6.90
5	0	0	1,000	.130	1.05
5	0	0	3,000	.035	.190

4.6.3 Short circuit interrupt capacity. Eight sample fuses of each rating shall be subjected to a short circuit test in accordance with Table 3. The test shall be conducted at the rated voltage of the fuse using a 60 Hz power source. Fuses shall open the circuit and remain in tact. The voltage should be held for 30 seconds after interruption. Any rupture of the fuse shall constitute a failure.

TABLE 3

Short Circuit Interrupt Capacity

		Test Current	
Test Qty.	Altitude	2 & 5A	7-1/2 & 30A
8	Sea Level	10,000A	7,500A

SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052
PROJECT NUMBER 3145-2964

APPENDIX I

FINAL SSPC FUSE DESIGN SPECIFICATION

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MO 63178

Appendix I

FINAL SSPC FUSE DESIGN SPECIFICATION
CONTRACT NUMBER F33615-81-C-2052, PROJECT NUMBER 3145-2964
FUSES, AIRCRAFT TYPE, GENERAL SPECIFICATION FOR

1. SCOPE

1.1 Scope. This specification covers aircraft type fuses designed for the protection of aircraft wiring associated with solid state power controllers (SSPCs) on direct current (DC) and alternating current (AC) (up to 400 Hz) circuits.

1.2 Classification.

1.2.1 Part Number. The part numbers of the fuses shall be in the following form and as specified (see 3.1).

M XXXXX/1 2A
Specification Sheet
Current Rating
This Specification
For Military Part Number

2. APPLICABLE DOCUMENTS

2.1 Issues of Documents. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

J-C-30	- Cable and Wire, Electrical (Power, Fixed Installation).
QQ-B-613	- Brass, Leaded and Nonleaded: Flat Products (Plate, Bar, Sheet, and Strip).
QQ-B-626	- Brass, Leaded and Nonleaded: Rod, Shapes, Forgings, and Flat Products with Finished Edges (Bar and Strip).
QQ-B-750	- Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections.
QQ-C-576	- Copper Flat Products with Slit, Slit and Edge-Rolled, Sheared, Sawed or Machined Edges, (Plate, Bar, Sheet and Strip).

MILITARY

MIL-I-10 - Insulating Materials, Electrical, Ceramic, Class L.
MIL-I-16923 - Insulating Compound, Electrical, Embedding.
MIL-C-21768 - Copper Alloy Numbers 210 (Gliding, 95%) and 220 (Commercial Bronze, 90%) Sheet and Strip.
MIL-C-45662 - Calibration System Requirements.
MIL-F-14072 - Finished for Ground Electronic Equipment.
MIL-P-81728 - Tin-Lead Plating.

STANDARDS (MILITARY)

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts.
MIL-STD-1285 - Marking of Electrical and Electronic Parts.

3. REQUIREMENTS

3.1 Specification Sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between requirements of this specification and the specification sheet, the latter shall govern.

3.1.1 Fuses with ratings not covered by specification sheets. This specification shall be applicable to fuses with other fuse ratings provided the desired ratings fall within the maximum and minimum current and voltage ratings specified by the applicable specification sheet. The qualified products list shall be applicable to these fuses.

3.2 Qualification. Fuses furnished under this specification shall be products which are qualified for listing on the applicable qualified products list at the time set for opening of bids (see 4.5 and 6.3).

3.3 Material. The material for each part shall be as specified herein. However, when a definite material is not specified, a material shall be used which will enable the fuses to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guarantee of the acceptance of the finished product.

3.3.1 Restricted Material. Flammable or explosive material, or material which can produce toxic or suffocating fumes when the fuses are in service, shall not be used in the construction of the fuses.

3.3.2 Case or Body.

3.3.2.1 Glass. When glass is used, it shall be of high quality, free from strain, and sufficiently clear to permit the enclosed fuse element to be readily seen.

3.3.2.2 Plastic. Unless otherwise specified (see 3.1), any plastic insulation may be used, except that cotton base or cotton or cellulose filled molding material shall not be used.

3.3.2.3 Ceramic. Ceramic insulation shall be grade L311 or higher grade, in accordance with MIL-I-10.

3.3.2.4 Epoxy. Epoxy encapsulant compound shall conform to type B of MIL-I-16923.

3.3.3 Current Carrying Parts (except fuse element). Current carrying parts shall be of brass, copper, or phosphor bronze conforming to QQ-B-613, or QQ-B-626, QQ-C-576, QQ-B-750 and MIL-C-21768, respectively.

3.3.4 Non-Current Carrying Parts. All metal non-current carrying parts shall be of corrosion resistant material or of material adequately protected against corrosion in accordance with MIL-F-14072.

3.4 Design and Construction. Fuses shall be of a design, construction and physical dimensions as specified (see 3.1).

3.4.1 Mounting. Unless otherwise specified (see 3.1) the fuse shall be designed with lead type terminals.

3.4.2 Terminal Mounting. Terminals shall be secured to the fuse body so that they shall not loosen. The fuse wire shall be so attached that there shall be no danger of breaking the fuse wire or connections when installing the fuse. Terminals, other than the ends to which the fusible elements are attached and the leads, shall be free from solder.

3.4.3 Terminal Finish or Plating. Ferrules shall be plated as specified (see 3.1). Leads shall be tin-lead plated or coated as specified (3.1).

3.4.3.1 Bright Alloy Plating. Minimum plating of bright alloy shall be 0.00008 inch thick. The plating shall be of the following composition:

Copper - 50 to 60 percent
Tin - 25 to 28 percent
Zinc - 14 to 18 percent

3.4.3.2 Tin-Lead Plating or Coating. Tin-lead plating or coating shall conform to MIL-P-81728.

3.5 Continuity. Fuses shall have electrical continuity (see 4.7.2).

3.6 Burn-In. All fuses of a qualification or production lot shall be subjected to the burn-in test. Any fuses which open during the burn-in test shall be discarded (see 3.1 and 4.7.4).

3.7 Resistance. All fuses of a qualification or production lot shall be subjected to the resistance test. Any fuses which do not meet the electrical resistance specified shall be discarded (see 3.1 and 4.7.3).

3.8 Voltage Drop. Fuses shall have the voltage drop specified (see 3.1 and 4.7.5).

3.9 Current-Carrying Capacity. Fuses shall show no evidence of mechanical damage and shall carry 125% of rated current without opening. The temperature of the case, body or terminals shall not rise more than 90^{o}C above room ambient temperature (see 3.1 and 4.7.6).

3.10 Terminal Strength. Fuse terminals shall not become damaged when subjected to the specified force (see 3.1 and 4.7.7).

3.11 Overload Interrupt. Fuses shall open the circuit within the time limits specified (see 3.1) without causing the case or body to char or fracture. The circuit shall remain open without the circuit closing again during the 1 minute period after interrupt. Immediately after removal of the fuse, and in no case not more than 1 minute after removal of the fuse, the insulation resistance shall be as specified in 3.12 (see 4.7.8).

3.12 Insulation Resistance. The insulation resistance after overload interrupt (see 3.11) and short circuit (see 3.13) shall be at least 1/2 megohm (see 4.7.9).

3.13 Short Circuit. Fuses shall remain intact and shall open the circuit. The fuses shall remain in the energized circuit 1 minute without any indication of the circuit closing again. Immediately after removal of the fuse, and in no case not more than 1 minute after removal of the fuse, the insulation resistance shall be as specified in 3.12 (see 4.7.10).

3.14 Vibration, High Frequency. There shall be no electrical or mechanical damage to the fuse (see 4.7.11).

3.15 Shock. There shall be no electrical or mechanical damage to the fuse (see 4.7.12).

3.16 Salt Spray (corrosion). There shall be no evidence of excessive corrosion. Excessive corrosion is defined as that which interferes with the electrical or mechanical performance, or in the case of plated metals, corrosion which has passed through the plating and attacked the base metal. There shall be no warping, cracking, or other electrical or mechanical damage to the fuse (see 4.7.13).

3.17 Moisture Resistance. There shall be no cracking, peeling, loosening of terminals or evidence of electrolytic corrosion (see 4.7.14).

3.18 Thermal Shock. The fuses shall show no mechanical or electrical damage and there shall be no loosening of the terminals or other parts (see 4.7.15).

3.19 Marking. Unless otherwise specified (see 3.1), each fuse shall be marked in accordance with Method I of MIL-STD-1285.

3.19.1 Ferrule and End Cap Marking. The fuse ferrules shall be marked with the following:

a. Part number
b. Manufacturer's name, trademark or code symbol.

3.20 Workmanship. Fuses shall be manufactured and processed in such a manner as to be uniform in quality and shall be free from loose terminals, cracked, or displaced parts, sharp edges, burrs and other defects that will affect life, serviceability or appearance.

3.20.1 Soldering. Soldering shall be such as to minimize the spattering of solder and flux onto surrounding surfaces. Only noncorrosive fluxes shall be used, unless it can be shown that all corrosive products have been satisfactorily removed or neutralized after soldering. All soldered connections shall be of such character and quality that the bonding between the soldered items may be determined by visual examination. There shall be no evidence of "cold soldering", and the use of excessive amounts of solder will not be permitted.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Test equipment and inspection facilities. Test and measuring equipment and inspection facilities of sufficient accuracy, quality and quantity to permit performance of the required inspection shall be established and maintained by the contractor. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with MIL-C-45662.

4.2 Classification of inspection. The inspections specified herein are classified as follows:

a. Materials inspection (see 4.3).
b. Qualification inspection (see 4.5).
c. Quality conformance inspection (see 4.6).

4.3 Materials inspection. Materials inspection shall consist of certification supported by verifying data that the materials listed in Table I, used in fabricating the fuses, are in accordance with the applicable referenced specifications or requirements prior to such fabrication.

4.4 Inspection conditions. Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in the "GENERAL REQUIREMENTS" of MIL-STD-202.

TABLE I

MATERIALS INSPECTION

Material	Requirement Paragraph	Applicable Specification
Plastic	3.3.2.2	--
Epoxy	3.3.2.3	MIL-I-16923
Brass	3.3.3	QQ-B-613 QQ-B-626
Copper	3.3.3	QQ-C-576
Copper Alloy	3.3.3	MIL-C-21768
Phosphor Bronze	3.3.3	QQ-B-750
Bright Alloy Plating	3.4.3.1	--
Tin-Lead Plating	3.4.3.2	MIL-P-81728

4.5 Qualification inspection. Qualification inspection shall be performed at a laboratory acceptable to the Government (see 6.3) on sample units produced with equipment and procedures normally used in production.

4.5.1 Sample size. Unless otherwise specified (see 3.1), the number of samples submitted for qualification shall be 44 each of the maximum and minimum current rating of each size shown in the specification sheet for which qualification is desired and 24 each of all other current ratings which fall between the maximum and minimum ratings. All the maximum and minimum ratings shall be subjected to the tests of Group I, Table II and then apportioned as indicated for the remaining test groups. The other ratings shall be subjected to Group I and Group II of Table II.

F/G 10/2

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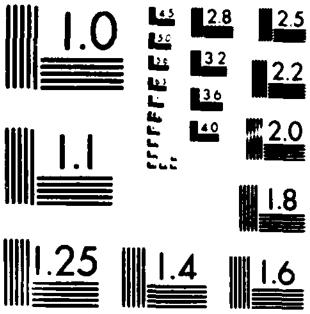

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4.5.2 Inspection routine. The sample shall be subjected to the qualification inspection shown in Table II, in the order shown. All sample units shall be subjected to the inspection of Group I. The sample shall then be divided as specified in Table II for Groups II to VI inclusive.

4.5.3 Failures. One or more failures shall be cause for refusal to grant qualification approval.

4.5.4 Retention of qualification. To retain qualification, the manufacturer shall forward a report at 12-month intervals to the qualifying activity. The qualifying activity shall establish the initial reporting date. The report shall consist of:

a. A summary of the results of the tests performed for inspection of product for delivery, (Groups A and B), indicating as a minimum the number of lots that have passed and the number that have failed. The results of tests of all reworked lots shall be identified and accounted for.

TABLE II
QUALIFICATION INSPECTION SEQUENCE

Inspection	Requirement Paragraph	Test Method Paragraph
Group I (all samples)		
Burn-in	3.6	4.7.4
Resistance	3.7	4.7.3
Visual and mechanical examination	3.4, 3.19, 3.20	4.7.1
Voltage drop	3.8	4.7.5
Current-carrying capacity	3.9	4.7.6
Group II (see 3.1) (24 sample units/current rating at maximum voltage rating)		
Terminal strength	3.10	4.7.7
Overload interrupt	3.11	4.7.8
Insulation resistance	3.12	4.7.9
Group III (see 3.1) (8 sample units/current rating)		
Short circuit	3.13	4.7.10
Insulation resistance	3.12	4.7.9
Group IV (4 sample units/current rating)		
Vibration, high frequency	3.14	4.7.11
Continuity	3.5	4.7.2
Shock	3.15	4.7.12
Continuity	3.5	4.7.2
Group V (4 sample units/current rating)		
Salt spray (corrosion)	3.16	4.7.13
Overload interrupt (at room ambient temperature and maximum voltage rating)	3.11	4.7.8
Insulation resistance	3.12	4.7.9
Group VI (4 sample units/current rating)		
Moisture resistance	3.17	4.7.14
Thermal shock	3.18	4.7.15
Current carrying capacity (at room ambient temperature)	3.9	4.7.6
Overload interrupt (at room ambient temperature and maximum voltage rating)	3.11	4.7.8
Insulation resistance	3.12	4.7.9

b. A summary of the results of tests performed for periodic inspection, (Group C), including the number and mode of failures. The summary shall include results of all periodic inspection tests performed and completed during the 12-month period. If the summary of the test results indicates nonconformance with specification requirements, and corrective action acceptable to the qualifying activity has not been taken, action may be taken to remove the failing product from the qualified products list.

Failure to submit the report within 30 days after the end of each 24-month period may result in loss of qualification for the product. In addition to the periodic submission of inspection data, the contractor shall immediately notify the qualifying activity at any time during the 12-month period that the inspection data indicates failure of the qualified product to meet the requirements of this specification.

In the event that no production occurred during the reporting period, a report shall be submitted certifying that the company still has the capabilities and facilities necessary to produce the item. If during two consecutive reporting periods there has been no production, the manufacturer may be required, at the discretion of the qualifying activity, to submit a representative product of each style, voltage rating, and current rating to testing in accordance with the qualification inspection requirements.

4.6 Quality conformance inspection.

4.6.1 Inspection of product for delivery. Inspection of product for delivery shall consist of Groups A and B.

4.6.1.1 Inspection lot. An inspection lot shall consist of all fuses of the same style and current rating produced under essentially the same conditions, and offered for inspection at one time.

4.6.1.2 Group A inspection. Group A inspection shall consist of the inspections specified in Table III.

4.6.1.2.1 Sampling plan. Statistical sampling and inspection shall be in accordance with MIL-STD-105 for general inspection level II, except the burn-in test and resistance test shall be performed on 100% of the production lot. The acceptable quality level (AQL) shall be as shown in Table III. Major and minor defects shall be as defined in Table IV.

4.6.1.2.2 Rejected lots. If an inspection lot is rejected, the contractor may rework it to correct the defects, or screen out the defective units, and resubmit for reinspection. Resubmitted lots shall be inspected using tightened inspection. Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots.

TABLE III

GROUP A INSPECTION

Inspection	Requirement Paragraph	Test Method Paragraph	AQL (percent-defective) Major	Minor
Burn-in	3.6	4.7.4	--	--
Resistance	3.7	4.7.3	--	--
Visual and mechanical examination	3.4, 3.19.3, 3.20	4.7.1	2.5	4

TABLE IV

MAJOR AND MINOR DEFECTS

Categories

Major
1 Material not as specified (see Table I).
2 Ferrule and terminal mounting not as specified (see 3.4.2).
3 Terminal finish not as specified (see 3.4.3).
4 Fuse does not have continuity (see 3.5).
5 Broken glass or insulating material (see 3.11 and 3.13 through 3.18).
6 Marking - Incorrect part number (see 3.19).
7 Dimensions out of tolerance.

Minor
10 Illegible or improperly located markings (see 3.19).
11 Minor cuts, scratches, burrs and nicks not impairing function.
12 Incomplete removal of soldering flux residue.
13 Other evidence of poor workmanship not affecting the function of the fuse.

4.6.1.3 Group B inspection. Group B inspection shall consist of the inspections specified in Table V, in the order shown, and the sample shall be selected from inspection lots that have passed the Group A inspection.

4.6.1.3.1 Sampling plan. The sampling plan shall be in accordance with MIL-STD-105 for special inspection level S-4. The sample size shall be based on the inspection lot size from which the sample was selected for Group A inspection. The AQL shall be 2.5 percent defective.

4.6.1.3.2 Rejected lots. If an inspection lot is rejected, the contractor may rework it to correct the defects, or screen out the defective units, and resubmit for reinspection. Resubmitted lots shall be inspected using tightened inspection. Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots.

4.6.1.3.3 Disposition of sample units. Sample units which have been subjected to Group B inspection shall not be delivered on the contract.

TABLE V

GROUP B INSPECTION

Inspection	Requirement Paragraph	Test Method Paragraph
Current-carrying capacity (at room ambient temperature)-------------------------------	3.9	4.7.6
Terminal strength------------------------------	3.10	4.7.7
Overload interrupt (at room ambient temperature)-	3.11	4.7.8
Insulation resistance-------------------------	3.12	4.7.9

4.6.2 Periodic inspection. Periodic inspection shall consist of Group C. Except where the results of these inspections show noncompliance with the applicable requirements (see 4.6.2.1.4), delivery of products which have passed Group A and B shall not be delayed pending the results of these periodic inspections.

4.6.2.1 Group C inspection. Group C inspection shall consist of the inspections specified in Table VI, in the order shown for each subgroup. Group C inspection shall be made on sample units selected from inspection lots which have passed the Groups A and B inspection, unless the Government considers it more practical to select a sample from current production. A manufacturer's normal quality control tests, production tests, environmental tests, and so forth, may be used to fulfill all or part of Group C inspection; however, all of Group C inspection shall be completed as specified.

4.6.2.1.1 Sampling plan. Unless otherwise specified (see 3.1) the number of samples submitted for Group C inspection shall be 44 each of the maximum and minimum current rating of each size shown in the specification sheet, and 24 each of all other current ratings which fall between the maximum and minimum ratings. The in between rating shall be subjected to Subgroup 2, Table VI. Sample units shall be selected 24 months after the date of notification of qualification and after each subsequent 48 month period. The sample units shall be subdivided into subgroups shown in Table VI. When production of a particular type of fuse has been suspended for 24 months or more, sample units shall be selected from the first lot of the new production presented for acceptance, and after each subsequent 24-month period.

4.6.2.1.2 Failures. If one or more sample units fail to pass Group C inspection, the sample shall be considered to have failed.

4.6.2.1.3 Disposition of sample units. Sample units which have been subjected to Group C inspection shall not be delivered on the contract.

4.6.2.1.4 Noncompliance. If a sample fails to pass Group C inspection, the manufacturer shall notify the qualifying activity and the cognizant inspection activity of such failure and take corrective action on the materials or processes, or both, as warranted, and on all units of product which can be corrected and which were manufactured under essentially the same conditions with essentially the same materials, processes, etc., and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action, acceptable to the qualifying activity, has been taken. After the corrective action has been taken, Group C inspection shall be repeated on additional sample units (all inspection, or the inspection which the original sample failed, at the option of the qualifying activity). Group A and B inspection may be reinstituted; however, final acceptance and shipment shall be withheld until the Group C inspection has shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure shall be furnished to the cognizant inspection activity and the qualifying activity.

TABLE VI

GROUP C INSPECTION

Inspection	Requirement Paragraph	Test Method Paragraph
Subgroup 1 (8 sample units/current rating at maximum voltage rating)		
Short circuit	3.13	4.7.10
Insulation resistance	3.12	4.7.9
Subgroup 2 (24 sample units/current rating at maximum voltage rating)		
Terminal strength	3.10	4.7.7
Overload interrupt	3.11	4.7.8
Insulation resistance	3.12	4.7.9
Subgroup 3 (4 sample units/current rating)		
Vibration, high frequency	3.14	4.7.11
Continuity	3.5	4.7.2
Shock	3.15	4.7.12
Continuity	3.5	4.7.2
Subgroup 4 (4 sample units/current rating)		
Salt spray (corrosion)	3.16	4.7.13
Overload interrupt (at room ambient temperature and maximum voltage rating)	3.11	4.7.8
Insulation resistance	3.12	4.7.9
Subgroup 5 (4 sample units/current rating)		
Moisture resistance	3.17	4.7.14
Thermal shock	3.18	4.7.15
Current-carrying capacity (at room ambient temperature)	3.9	4.7.6

4.7 Method of Examination and Test.

4.7.1 Visual and Mechanical Examination. Fuses shall be examined to verify that the materials, design, and construction, physical dimensions, marking and workmanship are in accordance with the applicable requirements (see 3.1 through 3.4, 3.19 and 3.20).

4.7.2 Continuity (see 3.5). Continuity of each fuse shall be determined by use of a low voltage ohmmeter or other suitable method.

4.7.3 Resistance (see 3.7). Resistance shall be measured with a Wheatstone bridge, Kelvin bridge, or equivalent sensitive instrument. Measurements shall be taken at room ambient temperature and as close to the fuse element as practicable. The bridge current shall not exceed 10 percent of rated fuse current.

4.7.4 Burn-In (see 3.6). Fuses shall be subjected to an AC current at any convenient voltage or frequency at 100% of rated current for 1 hour (minimum) at room ambient $(25^{\circ}\ ^{+5^{\circ}}_{-5}\ ^{\circ}C)$ temperature. Fuses shall be mounted in a fuseholder as specified (see 3.1). When two or more fuses are tested in series, the fuseholders shall be located so that there will be a spacing of not less than 6 inches between any two fuses under test. The wire connecting the fuseholders together, and connecting the fuseholders to the ammeter and the source of supply, shall be size 8 and shall be in accordance with J-C-30. The length of wire between fuseholders shall be 2 feet ±1 inch.

4.7.5 Voltage Drop (see 3.8). Voltage drop shall be measured using a DC voltmeter having a minimum input impedance of 11 megohms with measurements taken at room ambient temperature and as close to the fuse element as practicable. The voltage drop shall be measured after the fuse has been subjected to rated current for not less than 5 minutes.

4.7.6 <u>Current-Carrying Capacity (see 3.9)</u>. Fuses shall be subjected to an AC current (400 Hz) and any convenient voltage at 125 percent of rated current. The samples shall be apportioned and submitted to the test temperatures shown, except the qualification (Group VI). Group B and Group C (subgroup 5) tests shall be run at room ambient.

1) $-55^{o}C\ ^{+0^{o}}_{-3}oC$

2) $+25^{o}C\ ^{+5^{o}}_{-5}oC$ (Room ambient temperature)

3) $+85^{o}C\ ^{+3^{o}}_{-0}oC$

The current shall be maintained for 30 minutes after the temperature of each fuse has stabilized, but shall be applied for not less than 1-1/2 hours. It may be assumed that the temperature has stabilized when three consecutive temperature readings taken at 10 minute intervals show no rise in temperature. Fuses shall be mounted in a fuseholder as specified (see 3.1). When two or more fuses are tested in series, the fuseholders shall be located so that there will be a spacing of not less than 6 inches between any two fuses under test. The wire connecting the fuseholders together and connecting the fuseholders to the ammeter and the source of supply, shall be size 8 and shall be in accordance with J-C-30. The length of wire between fuseholders shall be 2 feet, ± 1 inch. The temperature of the fuse case or body and of the terminals shall be measured by thermocouples (wire size 28 to 32 AWG).

4.7.7 <u>Terminal Strength (see 3.10)</u>. Unless otherwise specified, terminals shall be tested in accordance with method 211, test condition A of MIL-STD-202. Forces shall be applied to the lead type terminals as follows:

1. Along terminal axis. (3 pound force)
2. Perpendicular to terminal axis. (3 pound force).

4.7.8 Overload Interrupt (see 3.11). Fuses shall be subjected to the percentage of rated current and voltage specified (see 3.1). The sample fuses shall be apportioned and submitted to the test temperatures shown, except the qualification (Groups V and VI), Group B and Group C (Subgroup 4) tests shall be run at room ambient.

1) $-55^{o}C \ ^{+0^{o}}_{-3}oC$

2) $+25^{o}C \ ^{+5^{o}}_{-5}oC$ (Room ambient temperature)

3) $+85^{o}C \ ^{+3^{o}}_{-0}oC$

The fuses shall be maintained at the test temperature for a minimum of 30 minutes, prior to the actual application of the test current. The power supply shall be an AC source 60 Hz or 400 Hz and have an open circuit R.M.S. voltage of not less than that of the specified voltage rating of the fuse under test, except for Group B test, the power supply may be of any value which is not less than 6 volts. The fuses shall be left in the circuit for 1 minute after blowing without any indication of the circuit reclosing, and insulation resistance readings shall be taken within 1 minute following the removal of the test voltage. Opening time measurements shall be made with an oscillograph for periods shorter than 1 second; a synchronous timer may be used for measurements longer than 1 second; a stop watch is suitable for measurements of longer than 10 seconds. Following the test, insulation resistance shall be measured as specified in 4.7.9.

4.7.9 Insulation Resistance (see 3.12). Fuses shall be tested after overload interrupt (see 3.11) and short circuit (see 3.13) in accordance with method 302 of MIL-STD-202. The following details shall apply:

a. Test condition - A.
b. Points of measurement - Between terminals.
c. Following the test, fuses shall be examined

4.7.10 Short Circuit (see 3.13). Fuses shall be apportioned and subjected to the tests at the current, frequency and voltage specified (see 3.1). The direct current tests shall be made using appropriate generating equipment for a source of power and with the rate of current rise for the test circuit adjusted for at least 3.25 x 10^6 amperes per seconds. The alternatin current tests shall be applied within + 10° of zero point of the voltage wave and the circuit power factor shall be 0.85 to 0.95. Short circuit currents shall be determined by means of an oscillograph. Test circuits shall be calibrated for the specified current with the applicable fuseholder (see 3.1) short-circuited. Following the test, insulation resistance shall be measured as specified in 4.7.9.

4.7.11 Vibration, High Frequency (see 3.14). The fuses shall be subjected to vibration tests in accordance with method 204 of MIL-STD-202. The following details shall apply:

a. Mounting - In applicable fuseholder (see 3 1).
b. Test condition - C.
c. One-half of the sample units shall be tested while carrying 100 percent of rated current at any convenient voltage and frequency and the balance tested with no current. All sample units shall be tested for continuity as specified in 4.7.2 at the end of the test

4.7.12 Shock (see 3.15). Fuses shall be tested in accordance with method 213 of MIL-STD-202. The following details and exceptions shall apply:

a. Mounting method and accessories - Fuses shall be mounted in or on applicable fuseholders (see 3.1).
b. Test condition - I, unless otherwise specified (see 3.1).
c. Measurements before and after test - One-half of the sample units shall be tested while carrying 100 percent of rated current at any convenient voltage and frequency (see 3.1), and the remainder with no current All fuses

4.7.13 Salt Spray (corrosion) (see 3.16) Fuses sha be tested in accordance with method 101 of MIL-STD-202. The following details shall app

a. 5-percent salt solution.
b. Test condition - B.
c. Following the drying period, the fuses shall be subjected to 100 percent of rated current for 1 hour.
d. Following the test, fuses shall be examined for compliance with 3.16.

4.7.14 Moisture Resistance (see 3.17). Fuses shall tested in accordance with method 106 of MIL-S The following details and exceptions shall ap

a. Mounting - Normal mounting means on a noncorrosive metal panel positioned 15 degrees from the vertical with the terminal down.
b. Polarized voltage shall be 100 volts D
c. Steps 7A and 7B are not applicable.
d. Following the test, the fuses shall be examined for compliance with 3.17.

4.7.15 Thermal Shock (see 3.18). The fuses shall be subjected to thermal shock tests in accordanc with method 107 of MIL-STD-202. The followin details shall apply:

a. Test condition - A.
b. Examination after test - Fuses shall b examined for compliance with 3.18.

5. PACKAGING (To Be Determined)

6. NOTES

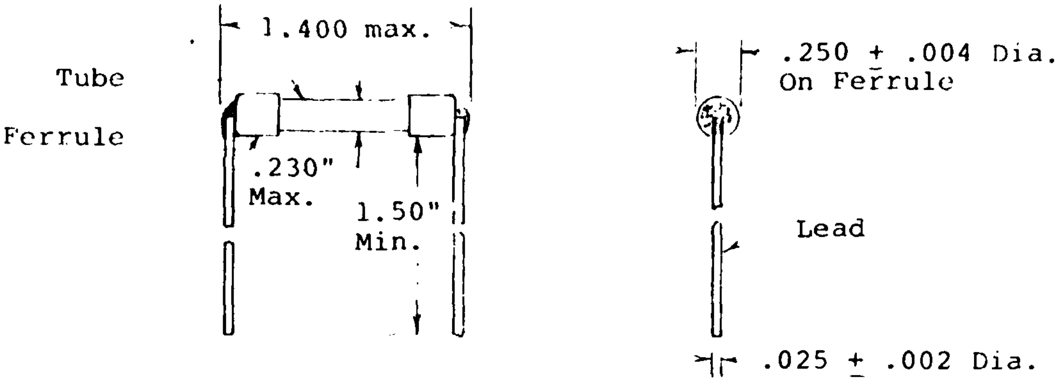
6.1 Intended Use. The primary applications for these aircraft fuses are AC (400 Hz) circuits up to 240 R.M.S. volts, and 28VDC circuits. Most test requirements in this specification specify 400 Hz sources in order to simulate actual applications However, the overload interrupt test offers the option of a 60 or 400 Hz source, and the AC short circuit test is performed at 60 Hz. Testing at 60 Hz is included for overload interrupt tests due to the limited availability of full voltage 400 Hz test sources with steady state current capabilities above 200 amperes. Short circuit tests are specified at 60 Hz since no 240V, 400 Hz source is available which is capable of sustaininɡ full voltage during the test. Additional informat on this subject is contained in the reports of Air Force Contract F33615-81-C-2052, Project 3145-

6.2 Ordering Data. To be determined.

6.3 Qualification. To be determined.

Appendix I
STANDARD SHEET I
Page 1 of 2

SOLID STATE POWER CONTROLLER (SSPC) FUSE



NOTE:

Dimensions are in inches.

REQUIREMENTS:

Applicable Fuseholders: Grayhill screw type binding post #29-3 (or equivalent) 2 per fuse required.

Terminals:

Material - Fuse ferrules - brass

- Leads - copper

Finish - Fuse Ferrules - Bright Alloy Plating

- Leads - Tin-Lead Plating

Body:

Plastic, or ceramic tube.

TABLE I ELECTRICAL RATINGS

Part No.	Current Rating (Amperes)	Short Circuit Interrupt		Cold Resistance (Ohms)		Voltage Drop (Volts)	
		28V DC	*250V AC 60 Hz	Min.	Max.	Min.	Max.
MXXXXX/1-2A	2	200A	10,000A	.0750	.0350	.150	.250
MXXXXX/1-5A	5	200A	10,000A	.0175	.0250	.110	.160

* AC short circuit tests are performed at 60 Hz (see 6.1).

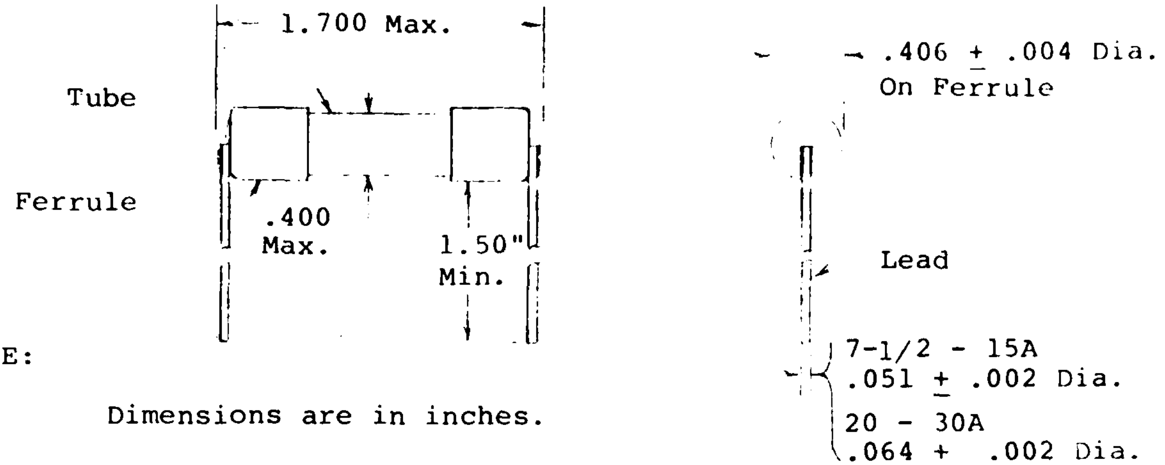
OVERLOAD INTERRUPT TIME

Percent of Rated Current (+3% - 0%)	Clearing Time (Seconds)	
	Minimum	Maximum
200	2.70	>100.0
400	.550	6.90
1000	.130	1.05
3000	.035	.19

Samples for qualification and Group C testing:

44 each (2A and 5A ratings)

SOLID STATE POWER CONTROLLER (SSPC) FUSE



NOTE:

Dimensions are in inches.

REQUIREMENTS:

Applicable Fuseholders: Grayhill screw type binding post #29-3 (or equivalent) 2 per fuse required.

Terminals:

Material - Fuse Ferrules - Brass

- Leads - Copper

Finish - Fuse Ferrules - Bright Alloy Plating

- Leads - Tin-Lead Plating

Body:

Plastic, or ceramic tube.

TABLE I ELECTRICAL RATINGS

Part No.	Current Rating (Amperes)	Short Circuit Interrupt		Cold Resistance (Ohms)		Voltage Drop (Volts)	
		28V DC	* 250V AC 60 Hz	Min.	Max.	Min.	Max.
MXXXXX/2-7½A	7-1/2	200A	7,500A	0110	.0160	.100	.160
MXXXXX/2-10A	10	200A	7,500A	.00800	.00980	.090	.140
MXXXXX/2-15A	15	200A	7,500A	.00450	.00570	.080	.130
MXXXXX/2-20A	20	200A	7,500A	.00300	.00400	.060	.110
MXXXXX/2-30A	30	200A	7,500A	.00160	.00220	.050	.100

* AC short circuit tests are performed at 60 Hz (see 6.1).

OVERLOAD INTERRUPT TIME

Percent of Rated Current (+3% - 0%)	Clearing Time (Seconds)	
	Minimum	Maximum
200	2.70	>100.0
400	.550	6.90
1000	.130	1.05
3000	.035	.19

Samples for qualification and Group C testing:

44 each (7-1/2A and 30A ratings)

24 each (10A, 15A and 20A ratings)

SSPC FUSE DEVELOPMENT PROGRAM

FINAL TECHNICAL REPORT

CONTRACT NUMBER F33615-81-C-2052

PROJECT NUMBER 3145-2964

APPENDIX J

QUALIFICATION TEST DATA

BUSSMANN DIVISION
MCGRAW-EDISON CORPORATION
P.O. BOX 14460
ST. LOUIS, MC. 63178

QUALIFICATION TESTS

SSPC FUSE

BUSS SPC FUSES

Appendix J

QUALIFICATION TESTS

BUSS SPC FUSES

FINAL SSPC FUSE DESIGN SPECIFICATION (12-31-82)

DATE: FEBRUARY 28, 1983

MANUFACTURER:
BUSSMANN DIVISION
MCGRAW-EDISON COMPANY
P.O. BOX 14460
ST. LOUIS, MO. 63178

AUTHORIZATION:
CONTRACT NO. F33615-81-C-2052

PROJECT NO. 3145-2964

LETTER - AFWAL/POOS-2 (J. WEIMER/56241)
01-07-83

TESTING LABORATORIES:
BUSSMANN DIVISION
MCGRAW-EDISON COMPANY
P.O. BOX 14460
ST. LOUIS, MO. 63178

APPROVAL INFORMATION

SUBMITTED BY:	APPROVED BY:
VERNON SPAUNHORST DESIGN ENGINEER	WALTER CURTIS ENGINEERING MANAGER, SMALL DIMENSION

QUALIFICATION TESTS

SPECIFICATION PARAGRAPHS AND TEST PARAGRAPHS

Inspection	Requirement Paragraph	Test Method Paragraph
Group I		
Burn-in-------------------------	3.6	4.7.4
Resistance----------------------	3.7	4.7.3
Visual and mechanical examination	3.4, 3.19, 3.20	4.7.1
Voltage drop--------------------	3.8	4.7.5
Current-carrying capacity--------	3.9	4.7.6
Group II		
Terminal strength----------------	3.10	4.7.7
Overload interrupt---------------	3.11	4.7.8
Insulation resistance----------	3.12	4.7.9
Group III		
Short circuit--------------------	3.13	4.7.10
Insulation resistance----------	3.12	4.7.9
Group IV		
Vibration, high frequency--------	3.14	4.7.11
Continuity--------------------	3.5	4.7.2
Shock----------------------------	3.15	4.7.12
Continuity--------------------	3.5	4.7.2
Group V		
Salt spray (corrosion)-----------	3.16	4.7.13
Overload interrupt (at room ambient temperature and maximum voltage rating)-----------------------	3.11	4.7.8
Insulation resistance----------	3.12	4.7.9
Group VI		
Moisture resistance--------------	3.17	4.7.14
Thermal shock--------------------	3.18	4.7.15
Current carrying capacity (at room ambient temperature)-----------	3.9	4.7.6
Overload interrupt (at room ambient temperature and maximum voltage rating)-----------------------	3.11	4.7.8
Insulation resistance----------	3.12	4.7.9

SUMMARY OF QUALIFICATION TEST RESULTS

Tests performed per "Final SSPC Fuse Design Specification" dated 12-31-82.

Group I (44 samples each 2A, 5A, 7-1/2A & 30A/24 samples each 10A, 15A & 20A)

		2A	5A	7-1/2A	10A	15A	20A	30A
Burn-In	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Resistance	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Visual And Mechanical Examination	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Voltage Drop	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Current Carrying Capacity	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							

Group II (24 samples of each ampere rating)

		2A	5A	7-1/2A	10A	15A	20A	30A
Terminal Strength	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Overload Interrupt	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							
Insulation Resistance	Accept	✓	✓	✓	✓	✓	✓	✓
	Reject							

Group III (8 samples of each ampere rating)

		2A	5A	7-1/2A	30A
Short Circuit	Accept	✓	✓	✓	✓
	Reject				
Insulation Resistance	Accept	✓	✓	✓	✓
	Reject				

Group IV (4 samples of each ampere rating)

		2A	5A	7-1/2A	30A
Vibration	Accept	✓	✓	✓	✓
	Reject				
Continuity	Accept	✓	✓	✓	✓
	Reject				
Shock	Accept	✓	✓	✓	✓
	Reject				
Continuity	Accept	✓	✓	✓	✓
	Reject				

Group V (4 samples of each ampere rating)

		2A	5A	7-1/2A	30A
Salt Spray	Accept	✓	✓	✓	✓
	Reject				
Overload Interrupt	Accept	✓	✓	✓	✓
	Reject				
Insulation Resistance	Accept	✓	✓	✓	✓
	Reject				

Group VI (4 samples of each ampere rating)

		2A	5A	7-1/2A	30A
Moisture Resistance	Accept	✓	✓	✓	✓
	Reject				
Thermal Shock	Accept	✓	✓	✓	✓
	Reject				
Current Carrying Capacity	Accept	✓	✓	✓	✓
	Reject				
Overload Interrupt	Accept	✓	✓	✓	✓
	Reject				
Insulation Resistance	Accept	✓	✓	✓	✓
	Reject				

REPORT OF QUALIFICATION TESTS

SSPC FUSE

Submitted by:

Bussmann Division
McGraw-Edison Company
P.O. Box 14460
St.Louis, Mo. 63178

Reference: (a) Contract No. F33615-81-C-2052
Project No. 3145-2964

(b) Authorization Letter - AFWAL/POOS-2 (J.Weimer/56241) 01-07-83

(c) Final SSPC Fuse Design Specification dated 12-31-82.

(d) Military Standard 202F of 29 January 1981.

Enclosure: (1) Tabulated test results of tests run at Bussmann Division.

(2) Test results of tests run at Environ Laboratories, Minneapolis, Minn.

1. Authority: Reference (a) and (b).

2. Purpose: The purpose of this investigation was to run qualification tests on Buss SPC fuses.

3. Description of material:

Buss SPC 2A	44 Samples	No. 1 - 44
Buss SPC 5A	44 Samples	No. 1 - 44
Buss SPC 7½A	44 Samples	No. 1 - 44
Buss SPC 10A	24 Samples	No. 1 - 24
Buss SPC 15A	24 Samples	No. 1 - 24
Buss SPC 20A	24 Samples	No. 1 - 24
Buss SPC 30A	44 Samples	No. 1 - 44

4. Method of tests:

All qualification tests were run in accordance with the "Final SSPC Fuse Design Specification" dated 12-31-82.

NUMBER OF TEST SAMPLES REQUIRED

Test Group	2A	5A	7-1/2A	10A	15A	20A	30A
I	44	44	44	24	24	24	44
II	24	24	24	24	24	24	24
III	8	8	8	0	0	0	8
IV	4	4	4	0	0	0	4
V	4	4	4	0	0	0	4
VI	4	4	4	0	0	0	4

5. Results: The following tests were conducted at the Bussmann Division:

Group I - Burn-In
Resistance
Visual and Mechanical Examination
Voltage Drop
Current-Carrying Capacity

Group II - Terminal Strength
Overload Interrupt
Insulation Resistance

Group III - Short Circuit
Insulation Resistance

Group V - Overload Interrupt
Insulation Resistance

Group VI - Current Carrying Capacity
Overload Interrupt
Insulation Resistance

The following tests were conducted at Environ Laboratories, Minneapolis, Minn.

Group IV - Vibration
Continuity
Shock
Continuity

Group V - Salt Spray

Group VI - Moisture Resistance
Thermal Shock

Enclosure (1)

SSPC FUSE QUALIFICATION TESTS

BUSS SPC FUSES

Final SSPC Fuse Design Specification (12-31-83)

Group I

1. Burn-In

Requirement Paragraph 3.6, Test Paragraph 4.7.4.

No. of Fuses	Fuse Type	Results		Comme
		Accept	Reject	
44	Buss SPC 2A	✓		
44	Buss SPC 5A	✓		
44	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
44	Buss SPC 30A	✓		

2. Resistance

Requirement Paragraph 3.7, Test Paragraph 4.7.3.

Group I

3. Visual and Mechanical Examination

Requirement Paragraph 3.4, 3.19, 3.20, Test Paragraph 4.

No. Of Fuses	Fuse Type	Results		Comment
		Accept	Reject	
44	Buss SPC 2A	✓		ON THE 7½-30 2ND END CAP BLANK. SHOULD BEEN STAMPE
44	Buss SPC 5A	✓		
44	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
44	Buss SPC 30A	✓		

4. Voltage Drop

Requirement Paragraph 3.8, Test Paragraph 4.7.5.

No. Of Fuses	Fuse Type	Results		Comment
		Accept	Reject	
44	Buss SPC 2A	✓		
44	Buss SPC 5A	✓		
44	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
44	Buss SPC 30A	✓		

Group I

5. Current Carrying Capacity

Requirement Paragraph 3.9, Test Paragraph 4.7.6.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
44	Buss SPC 2A	✓		
44	Buss SPC 5A	✓		
44	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
44	Buss SPC 30A	✓		

Group II

1. Terminal Strength

Requirement Paragraph 3.10, Test Paragraph 4.7.7.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
24	Buss SPC 2A	✓		
24	Buss SPC 5A	✓		
24	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
24	Buss SPC 30A	✓		

Group II

2. Overload Interrupt

Requirement Paragraph 3.11, Test Paragraph 4.7.8.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
24	Buss SPC 2A	✓		
24	Buss SPC 5A	✓		
24	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
24	Buss SPC 30A	✓		

3. Insulation Resistance

Requirement Paragraph 3.12, Test Paragraph 4.7.9.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
24	Buss SPC 2A	✓		
24	Buss SPC 5A	✓		
24	Buss SPC 7½A	✓		
24	Buss SPC 10A	✓		
24	Buss SPC 15A	✓		
24	Buss SPC 20A	✓		
24	Buss SPC 30A	✓		

Group III

1. Short Circuit Test

Requirement Paragraph 3.13, Test Paragraph 4.7.10.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
8	Buss SPC 2A	✓		7½ - 30 A SAMPLES WERE TESTED AT 7,500 A - 250 V.
8	Buss SPC 5A	✓		
8	Buss SPC 7½A	✓		
8	Buss SPC 30A	✓		

FUSES THAT HAD BEEN EXPOSED TO VIBRATION + SHOCK TESTS WERE ALSO EXPOSED TO DC SHORT CIRCUIT TESTS, CONSISTING OF 200A AT 60V.

ALL FUSES PROVED ACCEPTABLE.

2. Insulation Resistance

Requirement Paragraph 3.12, Test Paragraph 4.7.9.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
8	Buss SPC 2A	✓		
8	Buss SPC 5A	✓		
8	Buss SPC 7½A	✓		
8	Buss SPC 30A	✓		

Group V

1. Overload Interrupt

Requirement Paragraph 3.11, Test Paragraph 4.7.8.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
4	Buss SPC 2A	✓		
4	Buss SPC 5A	✓		
4	Buss SPC 7½A	✓		
4	Buss SPC 30A	✓		

2. Insulation Resistance

Requirement Paragraph 3.12, Test Paragraph 4.7.9.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
4	Buss SPC 2A	✓		
4	Buss SPC 5A	✓		
4	Buss SPC 7½A	✓		
4	Buss SPC 30A	✓		

Group VI

1. Current Carrying Capacity

Requirement Paragraph 3.9, Test Paragraph 4.7.6.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
4	Buss SPC 2A	✓		
4	Buss SPC 5A	✓		
4	Buss SPC 7½A	✓		
4	Buss SPC 30A	✓		

2. Overload Interrupt

Requirement Paragraph 3.11, Test Paragraph 4.7.8.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
4	Buss SPC 2A	✓		
4	Buss SPC 5A	✓		
4	Buss SPC 7½A	✓		
4	Buss SPC 30A	✓		

Group VI

3. Insulation Resistance

Requirement Paragraph 3.12, Test Paragraph 4.7.9.

No. Of Fuses	Fuse Type	Results		Comments
		Accept	Reject	
4	Buss SPC 2A	✓		
4	Buss SPC 5A	✓		
4	Buss SPC 7½A	✓		
4	Buss SPC 30A	✓		

EQUIPMENT LIST

Specification Paragraph	Equipment Name	Manufacturer	Model No.	Serial No.	Calibration Date
3.6 4.7.4	Power Source	Yokogawa G.E.	--	--	1-83
3.7 4.7.3	Digital Micro-Ohmmeter	Valhalla Scientific, Inc.	4201	33-132	3-9-83
3.8 4.7.5	Digital Multimeter	John Fluke Mfg. Co.	8010A	3060034	12-82
3.9 4.7.6	A.C. Current Source	California Instruments	Model 10-10 Model 300-200	90280	
	Precision Oscillator 0-400 Hz	California Instruments	Series 850-T	CS90106	
	Current Meter	John Fluke Mfg. Co.	8010A	3060034	12/82
	Oven	Standard Environmental Systems, Inc.	Model RK/108	79024	N/A
	Thermal Couple Digital Readout	Leeds and Northrup	--	395005-E	
	Freezer	Rheem Mfg. Co.	ULT 775C-L-I	RR87197	N/A
3.9 4.7.6	24 Pt. Recorder	Esterline Angus Inst. Co.	--	937052	
3.10 4.7.7	Pull Tester	John Chattilon and Sons	--	--	1-83
3.11 4.7.8	B.R.A.I.N. II Computer	Bussmann	--	--	

EQUIPMENT LIST

Specification Paragraph	Equipment Name	Manufacturer	Model No.	Serial No.	Calibration Date
3.11 4.7.8	Cycle Counter	Comuter Measurements Co.	313A		
	Current Transformer	Weston Instruments, Inc.	461	--	N/A
	Oscillograph	Hathaway Instrument Co.	S14-E	9941-1	Continuous
	A.C. Ammeter	Weston Instruments, Inc.	433	154742	2/83
	Wattmeter	Weston Instruments, Inc.	432	--	9/28/82
	A.C. Voltmeter	Weston Instruments, Inc.	433	125156	3/17/83
	Transformer	Pensylvania Transformer	7057A		N/A
	Thermal Couple Digital Readout	Leeds and Northrup	933NUM	94234	6/83
	Thermal Couple Readout	West Instr.Corp.	IN-23	67070431	
	Oven	Bussmann	--	--	N/A
	Ice Chest	--	--	--	N/A
3.12 4.7.9	500V Meggar	Biddle	--	BS1111494	3/17/83
3.13 4.7.10	Transformer	Westinghouse	Style 24 3A 923 G03	69F18137	N/A

Remainder of equipment is a repeat of above equipment.

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)

Fuse Type - Buss SPC 2

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	ok	.0796	.186
2	OK	.0798	.186
3	OK	.0802	.185
4	OK	.0799	.187
5	OK	.0789	.183
6	OK	.0792	.183
7	OK	.0783	.181
8	OK	.0803	.187
9	OK	.0785	.181
10	OK	.0794	.201
11	OK	.0799	.202
12	OK	.0805	.205
13	OK	.0786	.197
14	Ok	.0795	.204
15	Ok	.0796	.204
16	OK	.0802	.205
17	OK	.0797	.202
18	OK	.0799	.203
19	Ok	.0791	.207
20	ok	.0802	.212
21	ok	.0804	.212
22	OK	.0799	.208

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 2

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
23	OK	.0784	.207
24	OK	.0782	.205
25	OK	.0803	.212
26	OK	.0796	.209
27	OK	.0809	.215
28	OK	.0796	.202
29	OK	.0809	.207
30	OK	.0812	.215
31	OK	.0790	.202
32	OK	.0812	.204
33	OK	.0807	.208
34	OK	.0797	.206
35	OK	.0811	.208
36	OK	.0812	.208
37	OK	.0804	.206
38	OK	.0794	.203
39	OK	.0794	.201
40	OK	.0818	.207
41	OK	.0785	.198
42	OK	.0812	.205
43	OK	.0780	.198
44	OK	.0785	.198

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 5

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	.0211	.136
2	OK	.0217	.142
3	OK	.0208	.135
4	OK	.0214	.140
5	OK	.0210	.135
6	OK	.0211	.137
7	OK	.0214	.141
8	OK	.0212	.139
9	OK	.0211	.141
10	OK	.0208	.135
11	OK	.0210	.136
12	OK	.0212	.136
13	OK	.0209	.137
14	OK	.0211	.138
15	OK	.0213	.138
16	OK	.0209	.135
17	OK	.0207	.143
18	OK	.0217	.136
19	OK	.0208	.136
20	OK	.0217	.143
21	OK	.0213	.136
22	OK	.0209	.135

LABORATORY REPORT

Appendix J

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 5

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
23	OK	.0208	.136
24	OK	.0206	.131
25	OK	.0211	.137
26	OK	.0209	.135
27	OK	.0209	.138
28	OK	.0209	.136
29	OK	.0208	.136
30	OK	.0210	.136
31	OK	.0214	.139
32	OK	.0217	.142
33	OK	.0213	.138
34	OK	.0212	.135
35	OK	.0215	.139
		0212	.138

Appendix J

LABORATORY REPORT

No.__________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 7-1/2

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	0132	.130
2	OK	0134	.130
3	OK	0136	.134
4	OK	0132	.129
5	OK	0134	.132
6	OK	0132	.127
7	OK	0130	.127
8	OK	0134	.133
9	OK	0135	.134
10	OK	0131	.128
11	OK	0132	.130
12	OK	0131	.128
13	OK	0127	.123
14	OK	0130	.127
15	OK	0134	.133
16	OK	0134	.131
17	OK	0133	.130
18	OK	0136	.136
19	OK	0130	.125
20	OK	0130	.126
21	OK	0133	.131

LABORATORY REPORT

Append

No. ____

Bussmann Division - McGraw-Edison Company
St. Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 7-1/2

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Vol
23	OK	0130	.127
24	OK	0134	.133
25	OK	0128	.125
26	OK	0132	.128
27	OK	0134	.133
28	OK	0130	.127
29	OK	0130	.125
30	OK	0137	.133
31	OK	0135	.133
32	OK	0135	.133
33	OK	0132	.129
34	OK	0131	.128
35	OK	0129	.126
36	OK	0130	.127
37	OK	0129	.125
38	OK	0133	.129
39	OK	0137	.136
40	OK	0140	.141
41	OK	0131	.128
42	OK	0134	.133
43	OK	0137	.130

Appendix J

LABORATORY REPORT

No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 10

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	00870	.108
2	OK	00873	.110
3	OK	00890	.113
4	OK	00887	.114
5	OK	00892	.112
6	OK	00885	.113
7	OK	00880	.111
8	OK	00881	.110
9	OK	00880	.112
10	OK	00892	.113
11	OK	00887	.119
12	OK	00893	.119
13	OK	00886	.114
14	OK	00883	.117
15	OK	00876	.112
16	OK	00878	.111
17	OK	00881	.113
18	OK	00882	.116
19	OK	00883	.116
20	OK	00886	.113
21	OK	00879	.115
22	OK	00880	.119
23	OK	00891	.118
24	OK	00884	.118

LABORATORY REPORT

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No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group 1 (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 15

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	00514	.111
2	OK	00504	.104
3	OK	00504	.104
4	OK	00509	.108
5	OK	00508	.106
6	OK	00510	.107
7	OK	00505	.104
8	OK	00498	.104
9	OK	00508	.104
10	OK	00510	.105
11	OK	00504	.103
12	OK	00518	.110
13	OK	00520	.111
14	OK	00513	.102
15	OK	00518	.106
16	OK	00510	.103
17	OK	00519	.104
18	OK	00512	.105
19	OK	00522	.109
20	OK	00510	.106
21	OK	00511	.102
22	OK	00510	.104
23	OK	00511	.105
		00505	.107

LABORATORY REPORT

Appendix J

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)

Fuse Type - Buss SPC 20

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	00340	.084
2	OK	00339	.087
3	OK	00334	.083
4	OK	00344	.086
5	OK	00336	.085
6	OK	00340	.084
7	OK	00333	.083
8	OK	00342	.085
9	OK	00338	.085
10	OK	00338	.085
11	OK	00335	.084
12	OK	00338	.085
13	OK	00345	.092
14	OK	00349	.089
15	OK	00336	.085
16	OK	00333	.083
17	OK	00340	.085
18	OK	00345	.090
19	OK	00344	.090
20	OK	00340	.088
21	OK	00336	.086
22	OK	00339	.086
23	OK	00337	.087
24	OK	00353	.093

Appendix I

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 30

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
1	OK	.00187	.070
2	OK	.00194	.074
3	OK	.00191	.072
4	OK	.00191	.072
5	OK	.00189	.069
6	OK	.00196	.074
7	OK	.00190	.072
8	OK	.00191	.070
9	OK	.00193	.070
10	OK	.00194	.071
11	OK	.00196	.070
12	OK	.00196	.071
13	OK	.00197	.061
14	OK	.00194	.071
15	OK	.00198	.072
16	OK	.00199	.073
17	OK	.00194	.073
18	OK	.00194	.072
19	OK	.00195	.073
20	OK	.00193	.074
21	OK	.00194	.073
22	OK	.00196	.074

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Burn-In/Resistance/Voltage Drop)
Fuse Type - Buss SPC 30

No.	Burn-In	Resistance (OHMS)	Voltage Drop (Volts)
23	OK	.00197	.074
24	OK	.00196	.074
25	OK	.00194	.070
26	OK	.00196	.074
27	OK	.00197	.071
28	OK	.00198	.072
29	OK	.00195	.072
30	OK	.00199	.072
31	OK	.00198	.073
32	OK	.00198	.072
33	OK	.00194	.072
34	OK	.00195	.074
35	OK	.00194	.072
36	OK	.00195	.076
37	OK	.00196	.075
38	OK	.00196	.079
39	OK	.00197	.074
40	OK	.00199	.074
41	OK	.00200	.074
42	OK	.00197	.073
43	OK	.00201	.074
44	OK	.00196	.076

Appendix I

LABORATORY REPORT

No. ___

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 2

DIM.	A	B	C	D			A	B	C	D	
NO.	1.400 MAX	.230 MAX	.246 .254	1.50 MIN		NO.	1.400 MAX	.230 MAX	.246 .254	1.50 MIN	
1	1.305	.223	.252	1.526	1.622	23	1.310	.223	.250	1.554	1.531
2	1.308	.223	.251	1.544	1.536	24	1.305	.223	.250	1.552	1.506
3	1.310	.224	.251	1.520	1.538	25	1.314	.223	.250	1.540	1.546
4	1.304	.223	.250	1.515	1.555	26	1.304	.223	.249	1.505	1.542
5	1.305	.223	.251	1.515	1.598	27	1.309	.223	.253	1.521	1.540
6	1.325	.225	.251	1.540	1.520	28	1.306	.222	.251	1.544	1.531
7	1.309	.223	.251	1.534	1.538	29	1.308	.222	.249	1.510	1.521
8	1.313	.224	.251	1.516	1.550	30	1.312	.222	.251	1.548	1.524
9	1.296	.223	.249	1.545	1.515	31	1.305	.223	.250	1.594	1.535
10	1.301	.223	.250	1.546	1.526	32	1.310	.223	.251	1.545	1.524
11	1.306	.223	.250	1.542	1.507	33	1.316	.223	.251	1.509	1.521
12	1.315	.223	.250	1.501	1.548	34	1.315	.223	.249	1.534	1.530
13	1.305	.223	.250	1.521	1.540	35	1.307	.223	.250	1.520	1.536
14	1.308	.223	.251	1.543	1.530	36	1.316	.223	.250	1.547	1.540
15	1.310	.223	.250	1.552	1.532	37	1.311	.223	.250	1.541	1.516
16	1.315	.223	.250	1.526	1.562	38	1.310	.223	.250	1.521	1.548
17	1.315	.224	.250	1.516	1.542	39	1.314	.223	.249	1.534	1.519
18	1.316	.223	.250	1.523	1.550	40	1.320	.223	.250	1.530	1.505
19	1.309	.223	.251	1.524	1.515	41	1.300	.223	.251	1.527	1.507
20	1.320	.223	.250	1.553	1.528	42	1.316	.222	.250	1.544	1.523
21	1.316	.223	.251	1.531	1.522	43	1.301	.223	.249	1.520	1.543
22	1.314	.223	.249	1.554	1.520	44	1.309	.223	.249	1.529	1.516

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 5

DIM. →		A		B		C		D				A		B		C		D			
NO.		1.400 MAX		.230 MAX		.246 .254		1.50 MIN		NO.		1.400 MAX		.230 MAX		.246 .254		1.50 MIN			
1		1.327		.223		.250		1.565	1.554	23		1.332		.222		.251		1.525	1.546		
2		1.348		.223		.250		1.546	1.555	24		1.328		.222		.250		1.555	1.564		
3		1.338		.223		.250		1.551	1.565	25		1.330		.222		.251		1.551	1.565		
4		1.340		.222		.251		1.560	1.562	26		1.327		.222		.251		1.555	1.553		
5		1.332		.222		.251		1.554	1.564	27		1.332		.222		.251		1.556	1.562		
6		1.339		.223		.251		1.564	1.555	28		1.326		.223		.250		1.557	1.550		
7		1.338		.223		.251		1.551	1.558	29		1.328		.222		.250		1.552	1.525		
8		1.335		.223		.251		1.543	1.547	30		1.332		.223		.250		1.537	1.558		
9		1.330		.223		.251		1.544	1.557	31		1.333		.222		.251		1.546	1.559		
10		1.330		.223		.251		1.532	1.555	32		1.354		.222		.251		1.555	1.554		
11		1.325		.222		.252		1.544	1.565	33		1.338		.222		.251		1.560	1.559		
12		1.329		.221		.251		1.556	1.556	34		1.325		.222		.251		1.548	1.565		
13		1.339		.222		.251		1.567	1.564	35		1.343		.222		.251		1.557	1.561		
14		1.330		.222		.250		1.543	1.552	36		1.336		.222		.251		1.547	1.557		
15		1.334		.222		.251		1.534	1.563	37		1.331		.222		.252		1.572	1.541		
16		1.338		.222		.250		1.556	1.555	38		1.338		.223		.251		1.556	1.555		
17		1.332		.222		.250		1.556	1.545	39		1.337		.223		.251		1.532	1.550		
18		1.335		.222		.251		1.522	1.549	40		1.328		.223		.251		1.562	1.555		
19		1.340		.222		.250		1.551	1.551	41		1.337		.223		.251		1.551	1.557		
20		1.341		.223		.250		1.562	1.532	42		1.342		.222		.250		1.550	1.560		
21		1.326		.223		.250		1.556	1.546	43		1.336		.222		.250		1.543	1.562		
22		1.331		.223		.251		1.545	1.565	44		1.323		.223		.251		1.561	1.555		

LABORATORY REPORT

No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 7-1/2

DIM →		A	B	C	D				A	B	C	D			
NO.		1.700 MAX	.400 MAX	.402 .410	1.50 MIN		NO.		1700 MAX	.400 MAX	.402 .410	1.50 MIN			
1		1.587	.352	.409	1.425	1.468	23		1.590	.352	.410	1.484	1.430		
2		1.600	.351	.410	1.360	1.470	24		1.595	.352	.409	1.416	1.510		
3		1.593	.350	.408	1.449	1.476	25		1.594	.352	.410	1.410	1.499		
4		1.590	.345	.409	1.489	1.400	26		1.590	.351	.410	1.432	1.494		
5		1.582	.351	.409	1.493	1.435	27		1.582	.352	.410	1.484	1.415		
6		1.585	.351	.410	1.425	1.482	28		1.590	.351	.410	1.442	1.444		
7		1.589	.353	.410	1.388	1.515	29		1.581	.352	.410	1.421	1.480		
8		1.587	.352	.410	1.498	1.392	30		1.587	.351	.410	1.399	1.500		
9		1.587	.353	.410	1.420	1.512	31		1.590	.351	.410	1.439	1.499		
10		1.598	.351	.409	1.494	1.499	32		1.586	.352	.409	1.496	1.439		
11		1.595	.353	.409	1.437	1.500	33		1.583	.352	.410	1.497	1.402		
12		1.599	.352	.409	1.408	1.497	34		1.612	.352	.410	1.469	1.420		
13		1.590	.352	.409	1.440	1.494	35		1.592	.352	.410	1.400	1.502		
14		1.590	.351	.409	1.438	1.490	36		1.580	.352	.410	1.424	1.478		
15		1.590	.352	.410	1.425	1.489	37		1.589	.352	.410	1.501	1.432		
16		1.586	.351	.410	1.398	1.514	38		1.590	.351	.410	1.430	1.485		
17		1.590	.352	.410	1.489	1.410	39		1.580	.352	.409	1.414	1.501		
18		1.588	.352	.409	1.434	1.480	40		1.592	.353	.410	1.494	1.392		
19		1.585	.353	.410	1.398	1.505	41		1.586	.352	.410	1.491	1.404		
20		1.586	.353	.409	1.440	1.500	42		1.594	.353	.410	1.424	1.508		
21		1.588	.352	.409	1.511	1.445	43		1.590	.352	.410	1.411	1.505		
22		1.591	.352	.410	1.424	1.500	44		1.594	.353	.410	1.378	1.486		

Appendix J

LABORATORY REPORT

No.__________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group 1 (Visual and Mechanical Examination)
Fuse Type - Buss SPC 10

DIM	A	B	C	D			A	B	C	D	
NO.	1.700 MAX	.400 MAX	.402 .410	1.50 MIN		NO.	1700 MAX	.400 MAX	.402 .410	1.50 MIN	
1	1.593	.351	.409	1.518	1.440	23	1.591	.352	.410	1.418	1.480
2	1.585	.351	.409	1.514	1.432	24	1.586	.353	.409	1.426	1.504
3	1.590	.351	.409	1.482	1.456	25					
4	1.587	.351	.409	1.446	1.508	26					
5	1.585	.351	.409	1.441	1.502	27					
6	1.590	.351	.410	1.445	1.501	28					
7	1.576	.351	.410	1.415	1.482	29					
8	1.586	.351	.409	1.414	1.510	30					
9	1.582	.351	.410	1.492	1.452	31					
10	1.590	.351	.410	1.425	1.502	32					
11	1.582	.352	.410	1.501	1.423	33					
12	1.585	.354	.408	1.510	1.420	34					
13	1.595	.351	.409	1.501	1.432	35					
14	1.585	.354	.410	1.508	1.447	36					
15	1.585	.351	.409	1.436	1.502	37					
16	1.590	.352	.410	1.425	1.500	38					
17	1.590	.352	.409	1.442	1.502	39					
18	1.587	.345	.409	1.415	1.483	40					
19	1.594	.354	.410	1.498	1.428	41					
20	1.585	.352	.409	1.502	1.430	42					
21	1.590	.351	.408	1.505	1.426	43					
22	1.585	.353	.409	1.505	1.420	44					

LABORATORY REPORT

No. ______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 15

DIM		A		B		C		D				A		B		C		D	
NO.		1.700 MAX		.400 MAX		.402 .410		1.50 MIN		NO.		1700 MAX		.400 MAX		.402 .410		1.50 MIN	
1		1.597		.352		.410		1.518	1.510	23		1.588		.352		.410		1.540	1.501
2		1.595		.352		.410		1.538	1.509	24		1.598		.352		.410		1.535	1.502
3		1.595		.352		.410		1.531	1.510	25									
4		1.595		.353		.409		1.524	1.524	26									
5		1.596		.352		.410		1.516	1.528	27									
6		1.588		.352		.409		1.525	1.512	28									
7		1.598		.352		.410		1.516	1.505	29									
8		1.595		.352		.410		1.542	1.503	30									
9		1.595		.351		.410		1.510	1.530	31									
10		1.586		.352		.410		1.538	1.518	32									
11		1.585		.352		.413		1.532	1.515	33									
12		1.590		.352		.410		1.519	1.531	34									
13		1.590		.352		.411		1.551	1.511	35									
14		1.599		.352		.410		1.526	1.516	36									
15		1.595		.352		.414		1.539	1.510	37									
16		1.596		.352		.410		1.525	1.518	38									
17		1.590		.344		.409		1.530	1.530	39									
18		1.585		.351		.410		1.535	1.522	40									
19		1.594		.352		.412		1511	1538	41									
20		1.596		.352		.410		1.528	1.506	42									
21		1.596		.352		.409		1.528	1.528	43									
22		1.589		.352		.408		1.535	1.502	44									

LABORATORY REPORT

No. ____ ___ __ __

Bussmann Division - McGraw-Edison Company
St. Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 20

DIM	A	B	C	D			A	B	C	D	
NO.	1.700 MAX	.400 MAX	.402 .410	1.50 MIN		NO.	1700 MAX	.400 MAX	.402 .410	1.50 MIN	
1	1.636	.354	.409	1.534	1.526	23	1.636	.352	.408	1.534	1.539
2	1.629	.345	.407	1.520	1.545	24	1.627	.352	.409	1.530	1.534
3	1.631	.351	.408	1.522	1.538	25					
4	1.630	.352	.408	1.542	1.541	26					
5	1.632	.352	.409	1.525	1.524	27					
6	1.641	.352	.409	1.530	1.522	28					
7	1.632	.339	.409	1.537	1.538	29					
8	1.647	.352	.408	1.520	1.534	30					
9	1.622	.345	.408	1.530	1.528	31					
10	1.630	.352	.408	1.520	1.528	32					
11	1.634	.352	.408	1.520	1.536	33					
12	1.634	.351	.409	1.525	1.545	34					
13	1.634	.352	.408	1.538	1.531	35					
14	1.641	.351	.408	1.550	1.536	36					
15	1.636	.351	.408	1.529	1.539	37					
16	1.628	.351	.407	1.525	1.555	38					
17	1.629	.352	.408	1.526	1.540	39					
18	1.632	.353	.408	1.528	1.547	40					
19	1.654	.352	.409	1.547	1.530	41					
20	1.640	.352	.408	1.520	1.540	42					
	[illegible]	.352	.408	1.525	1.554						

Appendix J

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Visual and Mechanical Examination)
Fuse Type - Buss SPC 30

DIM		A		B		C		D				A		B		C		D	
NO.		1.700 MAX		.400 MAX		.402 .410		1.50 MIN		NO.		1700 MAX		.400 MAX		.402 .410		1.50 MIN	
1		1.648		.352		.410		1.555	1.515	23		1.636		.352		.410		1.557	1.515
2		1.641		.352		.409		1.528	1.530	24		1.647		.351		.410		1.558	1.512
3		1.644		.352		.407		1.516	1.542	25		1.631		.352		.410		1.555	1.512
4		1.640		.352		.409		1.522	1.544	26		1.652		.352		.410		1.509	1.552
5		1.642		.352		.410		1.537	1.540	27		1.634		.352		.409		1.534	1.543
6		1.643		.353		.409		1.520	1.526	28		1.634		.352		.409		1.536	1.515
7		1.636		.353		.409		1.550	1.518	29		1.634		.352		.410		1.550	1.523
8		1.625		.346		.409		1.549	1.520	30		1.642		.353		.410		1.554	1.528
9		1.632		.352		.410		1.544	1.552	31		1.635		.352		.409		1.527	1.527
10		1.635		.352		.408		1.520	1.544	32		1.642		.352		.410		1.525	1.538
11		1.634		.352		.407		1.526	1.514	33		1.638		.352		.410		1.559	1.539
12		1.633		.352		.410		1.516	1.545	34		1.639		.352		.410		1.540	1.551
13		1.641		.352		.408		1.520	1.565	35		1.635		.353		.410		1.549	1.509

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 2

Test Temperature (See Below)

NO.	START			T				T				T				T				T	
1				104				104				104				104				103	
2				113				113				113				113				113	
3				114				114				114				114				114	
4				110				110				110				111				111	
5				104				104				104				104				104	
6				102				102				102				102				102	
7				106				106				106				106				106	
8				110				110				110				110				110	
9				110				110				110				109				110	
10				110				110				110				110				110	
11				103				103				103				103				103	
12				100				100				100				100				100	
13				100				100				100				100				100	
14				103				103				103				103				103	
15				37				38				40				39				40	
16				40				40				41				41				42	
17				39				39				41				40				42	
18				38				38				39				38				40	
19				40				40				41				42				42	
20				40				40				41				41				42	

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LABORATORY REPORT

No. ____

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 2

Test Temperature (See Below)

	NO.	START			T				T				T				T		
+25°C	23				40				39				40				41		
	24				37				37				36				37		
	25				42				41				42				43		
	26				38				37				38				39		
	27				40				40				42				43		
	28				41				40				41				43		
	29				40				38				38				41		
	30				39				37				39				40		
-55°C	31				-18				-18				-18				-19		
	32				-20				-19				-19				-20		
	33				-11				-16				-17				-18		
	34				-20				-19				-19				-20		
	35				-16				-16				-17				-17		
	36				-22				-21				-23				-24		
	37				-20				-19				-20				-21		
	38				-20				-19				-19				-20		
	39				-22				-21				-22				-24		
	40				-19				-11				-18				-20		
	41				-20				-19				-20				-23		
	42				-56				-55				-55				-56		

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 5

Test Temperature (See Below)

	NO.	START			T				T				T				T				T
+85°C	1				107				109				109				109				109
	2				112				112				112				112				111
	3				118				118				118				118				118
	4				117				118				118				118				118
	5				117				117				117				117				117
	6				114				114				114				114				114
	7				114				114				114				114				114
	8				110				110				110				110				110
	9				123				123				123				124				124
	10				114				114				114				114				114
	11				110				110				110				110				110
	12				107				108				108				108				108
	13				104				104				104				104				104
	14				110				110				110				110				110
+25°C	15				48				48				48				48				48
	16				46				47				46				46				46
	17				47				47				47				47				47
	18				47				48				48				48				48
	19				42				43				43				43				43
	20				46				46				46				46				46
	21				44				45				45				44				44
	22				45				46				46				46				46

Appendix

LABORATORY REPORT

No.______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 5

Test Temperature (See Below)

	NO.	START			T				T				T				T				
+25°C	23				46				47				46				46				46
	24				42				43				42				42				42
	25				42				43				43				43				43
	26				45				45				45				45				45
	27				44				45				45				45				45
	28				37				38				37				37				37
	29				44				44				44				44				44
	30				45				46				45				45				45
-55°C	31				-15				-16				-15				-16				-16
	32				-12				-14				-11				-12				-13
	33				-20				-21				-18				-20				-20
	34				-19				-20				-17				-19				-19
	35				-15				-17				-14				-15				-16
	36				-18				-19				-18				-19				-19
	37				-14				-15				-13				-14				-14
	38				-23				-24				-23				-24				-24
	39				-19				-20				-18				-20				-20
	40				–				–				–				–				–
	41				-20				-22				-20				-22				-21
	42				-15				-17				-15				-16				-17
	43				-18				-23				-18				-19				-20
	44				–				–				–				–				–

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 7½

Test Temperature (See Below)

+85°C

+25°C

NO.	START			T				T				T				T				T	
1				105				105				105				105				105	
2				103				103				103				103				103	
3				113				113				113				113				113	
4				112				111				112				112				112	
5				119				119				119				120				119	
6				109				109				109				109				108	
7				102				102				103				103				103	
8				105				105				106				106				105	
9				112				112				112				112				111	
10				117				116				116				116				117	
11				114				115				115				115				115	
12				109				109				109				108				109	
13				106				106				106				106				106	
14				105				104				105				105				105	
15				46				44				41				45				44	
16				42				42				39				42				42	
17				48				48				46				43				46	
18				46				46				45				46				45	
19				47				47				47				48				46	
20				45				45				45				46				45	
21				46				46				45				46				45	
22				46				47				42				46				47	

Appendix J

LABORATORY REPORT

No. ______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 7½

Test Temperature (See Below)

	NO.	START			T				T				T				T				T
+25°C	23				43				45				42				43				42
	24				45				45				42				45				44
	25				46				46				43				45				44
	26				44				45				42				45				45
	27				46				47				41				46				45
	28				46				45				41				45				45
	29				46				46				41				45				45
	30				46				46				42				47				48
-55°C	31				0				-4				-3				-5				-3
	32				-4				-7				-7				-8				-7
	33				-19				-23				-23				-24				-23
	34				-3				-6				-6				-8				-7
	35				-10				-13				-13				-14				-13
	36				-11				-15				-14				-15				-15
	37				-10				-13				-12				-14				-13
	38				-11				-14				-13				-15				-14
	39				-8				-10				-10				-11				-10
	40				-9				-10				-8				-10				-10
	41				-16				-17				-16				-18				-16
	42				-19				-22				-20				-22				-20
	43				-13				-15				-14				-15				13
	44				-9				-13				-10				-12				-10

Appendix

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 10

Test Temperature (See Below)

	NO.	START			T				T				T				T				T	
+85°C	1				110				110				111				110				110	
	2				106				106				106				106				106	
	3				114				114				114				114				114	
	4				124				124				124				124				124	
	5				120				120				121				120				120	
	6				110				110				110				110				110	
	7				106				106				106				106				106	
	8				115				115				115				115				115	
+25°C	9				49				50				49				49				49	
	10				51				51				51				51				51	
	11				51				51				51				51				51	
	12				51				51				51				51				51	
	13				49				49				49				49				49	
	14				46				47				46				46				46	
	15				49				49				49				49				49	
	16				47				47				47				47				47	
-55°C	17				-9				-9				-9				-8				-9	
	18				-14				-15				-15				-14				-15	
	19				-14				-15				-15				-14				-15	
	20				-20				-22				-22				-20				-22	
	21				-16				-17				-17				-16				-17	
	22				-12				-12				-13				-12				-12	
	23				-21				-22				-22				-21				-22	
	24				-22				-24				-22				-22				-24	

Appendix

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 15

Test Temperature (See Below)

	NO.	START			T				T				T				T				T
+85°C	1				119				119				119				119				119
	2				122				122				122				122				122
	3				123				123				123				123				123
	4				124				125				125				125				125
	5				134				133				134				134				134
	6				118				118				118				118				118
	7				114				114				114				114				114
	8				116				116				116				116				116
+25°C	9				57				55				55				55				56
	10				58				57				58				58				58
	11				56				55				55				55				55
	12				57				56				56				57				57
	13				64				62				63				63				63
	14				57				55				56				57				57
	15				47				47				45				47				59
	16				50				50				50				50				50
-55 C	17				-5				+2				0				-5				-4
	18				+5				+8				+9				+9				+6
	19				+5				+9				+9				+9				+7
	20				-3				+1				+1				+1				-2
	21				-2				+1				+2				+2				0
	22				+4				+8				+9				+6				+5
	23				-8				-4				-5				-7				-7
	24				+11				+13				+14				+13				+12

LABORATORY REPORT

Appendix J

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 20

Test Temperature (See Below)

	NO.	START	T	T	T	T	T
+85°C	1		116	116	117	117	117
	2		115	115	115	115	116
	3		117	117	117	117	117
	4		124	124	124	124	125
	5		118	118	118	118	118
	6		114	114	114	114	115
	7		117	117	117	117	118
	8		108	108	108	109	108
+25°C	9		89	83	93	81	82
	10		92	88	94	89	90
	11		87	81	90	82	84
	12		76	72	80	72	74
	13		84	78	89	80	79
	14		89	88	94	87	88
	15		86	81	89	81	78
	16		88	82	90	84	81
-55 C	17		-8	-8	-9	-9	-11
	18		-7	-8	-9	-10	-11
	19		+3	+3	+1	+1	-1
	20		-7	-8	-8	-9	-11
	21		-8	-10	-11	-12	-14
	22		-2	-4	-5	-6	-8
	23		+3	+3	+2	+1	0
	24		+1	0	-2	-2	-5

Appendix

LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 30 .

Test Temperature (See Below)

+85°C

+25°C

NO.	START			T				T				T				T				T	
1				119				119				119				119					
2				110				110				110				110					
3				120				120				120				120					
4				123				123				123				123					
5				119				119				120				120					
6				127				127				128				128					
7				124				124				124				125					
8				119				119				119				119					
9				124				125				125				125				126	
10				126				127				127				128				128	
11				116				118				118				119				119	
12				130				131				131				131				132	
13				115				116				116				117				117	
14				123				123				123				123				124	
15				84				87				87				88				88	
16				126				129				129				132				131	
17				98				100				100				102				102	
18				103				105				105				105				105	
19				95				95				96				96				96	
20				102				105				105				106				107	
21				108				110				110				111				112	
22				114				117				117				118				117	

LABORATORY REPORT

No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group I (Current Carry Test)

Fuse Type - Buss SPC 30

Test Temperature (See Below)

NO.	START			T				T				T				T				T
23				92				94				96				96				97
24				102				104				105				105				105
25				97				98				102				101				100
26				89				90				92				91				91
27				81				80				80				80				80
28				97				95				95				95				94
29				99				97				97				97				97
30				97				97				97				98				97
31				28				30				32				34				35
32				41				–				–				–				–
33				36				39				41				42				43
34				53				56				58				59				60
35				18				20				22				23				23
36				21				25				26				27				28
37				17				19				20				22				23
38				37				39				40				42				43
39				–				–				–				–				–
40				18				20				21				22				18
41				37				40				41				42				43
42				34				37				38				39				39
43				28				31				33				34				34
44				36				39				40				42				42

+25°C

~~-55°C~~ -38°C

LABORATORY REPORT

No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)
Fuse Type - Buss SPC 2

NO.	ALONG TERMINAL AXIS	PERPENDICULAR TO TERMINAL AXIS
1	OK	OK
2		
3		
4		
5		
6		
7		
8		
15		
16		
17		
18		
19		
20		
21		
22		
31		
32		
33		
34		
35		
36		
37		
38	OK	OK

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)

Fuse Type - Buss SPC 5

NO.	ALONG TERMINAL AXIS									PERPENDICULAR TO TERMINAL AXIS											
1					OK										OK						
2																					
3																					
4																					
5																					
6																					
7																					
8																					
15																					
16																					
17																					
18																					
19																					
20																					
21																					
22																					
31																					
32																					
33																					
34																					
35																					

Appendix J

LABORATORY REPORT

No.____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)
Fuse Type - Buss SPC 7-1/2

NO.		ALONG TERMINAL AXIS								PERPENDICULAR TO TERMINAL AXIS											
1				OK										OK							
2																					
3																					
4																					
5																					
6																					
7																					
8																					
15																					
16																					
17																					
18																					
19																					
20																					
21																					
22																					
31																					
32																					
33																					
34																					
35																					

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)

Fuse Type - Buss SPC 10

NO.	ALONG TERMINAL AXIS	PERPENDICULAR TO TERMINAL AXIS
1	OK	OK
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24	OK	OK

Appendix J

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)
Fuse Type - Buss SPC 15

NO.	ALONG TERMINAL AXIS	PERPENDICULAR TO TERMINAL AXIS
1	OK	OK
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24	OK	OK

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LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)
Fuse Type - Buss SPC 20

NO.		ALONG TERMINAL AXIS								PERPENDICULAR TO TERMINAL AXIS											
1				ok											ok						
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					
13																					
14																					
15																					
16																					
17																					
18																					
19																					
20																					
21																					
22																					
23																					
24				ok											ok						

Appendix

LABORATORY REPORT

No. ______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Terminal Strength)
Fuse Type - Buss SPC 30

NO.	ALONG TERMINAL AXIS	PERPENDICULAR TO TERMINAL AXIS
1	OK	OK
2		
3		
4		
5		
6		
7		
8		
15		
16		
17		
18		
19		
20		
21		
22		
31		
32		
33		
34		
35		
36		
37		
38	OK	OK

LABORATORY REPORT

Appendix

No. ______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 2

Test Temperature (see below)

	NO.	200%	(450% ACT) 400%	(950% ACT) 1000%	3000%	INSULATION RESISTANCE MEG OHMS
+85°C	1	17.4 Sec				1000 +
	2	18				1000 +
	3		2.50 Sec			1000 +
	4		2.48			1000 +
	5			.40 Sec.		1000 +
	6			.34		1000 +
	7				.041 Sec.	1000 +
	8				.041	1000 +
+25°C	15	22 Sec				1000 +
	16	22				1000 +
	17		3.28 Sec			1000 +
	18		3.27			1000 +
	19			.50 Sec.		1000 +
	20			.50		1000 +
	21				.050 Sec	1000 +
	22				.053	1000 +
-55°C (-60°C Act)	31	23 Sec				1000 +
	32	23				1000 +
	33		3.66 Sec			1000 +
	34		3.65			6
	35			.55 Sec		1000 +
	36			.58		1000 +
	37				.048 Sec.	1000 +
	38				.052	1000 +

LABORATORY REPORT

Appendix I

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 5

Test Temperature (see below)

	NO.	(180% ACT) 200%	(380% ACT) 400%	(840% ACT) 1000%	(2920% ACT) 3000%	INSULATION RESISTANCE MEG OHMS
+85°C	1	54 SEC				1000 +
	2	59 SEC				1000 +
	3		2.64 SEC			1000 +
	4		2.65			1000 +
	5			.466 SEC		1000 +
	6			.471		1000 +
	7				.036 SEC	1000 +
	8				.033	1000 +
+25°C	15	80 SEC				60
	16	25				1000 +
	17		3.06 SEC			1000 +
	18		3.00			1000 +
	19			.487 SEC		1000 +
	20			.467		1000 +
	21				.033 SEC	1000 +
	22				.039	1000 +
-55°C (-60°C ACT)	31	73 SEC				1000 +
	32	90				1000 +
	33		3.23 SEC			1000 +
	34		3.39			1000 +
	35			.679 SEC		1000 +
	36			.667		1000 +
	37				.042 SEC	1000 +
	38				.042	600

LABORATORY REPORT

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No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 7½

Test Temperature (see below)

	NO.	200%	400%	(1027 % ACT) 1000%	(2773 % ACT) 3000%	INSULATION RESISTANCE MEG OHMS
+85°C	1	18.5 SEC				1000 +
	2	24				1000 +
	3		2.68 SEC			1000 +
	4		2.73			1000 +
	5			.333 SEC		1000 +
	6			.357		1000 +
	7				.048 SEC	1000 +
	8				.054	1000 +
+25°C	15	36 SEC				1000 +
	16	37				1000 +
	17		2.94 SEC			1000 +
	18		2.69			1000 +
	19			.372 SEC		4
	20			.350		300
	21				.057 SEC	1000 +
	22				.057	160
-55°C (-60°C ACT)	31	21 SEC				1000 +
	32	34				1000 +
	33		3.44 SEC			150
	34		3.38			400
	35			.433 SEC		40
	36			.420		40
	37				.067 SEC	1000 +
	38				.069	1000 +

LABORATORY REPORT

Appendix I

No. __________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)
Fuse Type - Buss SPC 10
Test Temperature (see below)

	NO.	200% (190% ACT)	400% (420% ACT)	1000% (1200% ACT)	3000% (2900% ACT)	INSULATION RESISTANCE MEG OHMS
+85°C	1	54 SEC				1000 +
	2	59				1000 +
	3		3.67 SEC			1000 +
	4		3.49			1000 +
	5			.322 SEC		1000 +
	6			.316		1000 +
	7				.073 SEC	60
	8				.069	1000 +
+25°C	9	84 SEC				1000 +
	10	58				1000 +
	11		3.35 SEC			1000 +
	12		3.28			1000 +
	13			MISSED OSCILLOGRAM		1000 +
	14			.326 SEC		1000 +
	15				.074 SEC	28
	16				.078	40
-55°C (-60°C ACT)	17	64 SEC				1000 +
	18	71				1000 +
	19		4.52 SEC			1000 +
	20		4.52 SEC			1000 +
	21			.404 SEC		400
	22			.435		700
	23				.082 SEC	90
	24				.091 SEC	90

LABORATORY REPORT

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No. ____________

Bussmann Division - McGraw-Edison Company
St. Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 15

Test Temperature (see below)

	NO.	200%	400%	1000% (973% ACT)	3000%	INSULATION RESISTANCE MEG OHMS
+85°C	1	31 SEC				1000 +
	2	25				1000 +
	3		3.77 SEC			1000 +
	4		3.87			1000 +
	5			.602 SEC		1000 +
	6			.598		1000 +
	7				.078 SEC	1000 +
	8				.076	350
+25°C	9	39 SEC				1000 +
	10	40				1000 +
	11		4.13 SEC			1000 +
	12		4.08			1000 +
	13			.614 SEC		1000 +
	14			.642		1000 +
	15				.076 SEC	100
	16				.082	275
-55°C (-60° ACT)	17	30 SEC				1000 +
	18	29				1000 +
	19		4.10 SEC			1000 +
	20		4.26			1000 +
	21			.733 SEC		1000 +
	22			.728		1000 +
	23				.096 SEC	40
	24				.090	15

LABORATORY REPORT

No. ____________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 20

Test Temperature (see below)

	NO.	(210% Act)	(385% Act)	(1040% Act)	(3060% Act)	INSULATION RESISTANCE
		200%	400%	1000%	3000%	MEG OHMS
+85°C	1	46 Sec				1000 +
	2	41				1000 +
	3		4.05 Sec			1000 +
	4		3.82 Sec			1000 +
	5			.542 Sec		1000 +
	6			.537		1000 +
	7				MISSED OSCILLOGRAM	1000 +
	8				.065 Sec	1000 +
+25°C	9	38 Sec				1000 +
	10	30				1000 +
	11		4.26 Sec			1000 +
	12		4.33			1000 +
	13			.572 Sec		1000 +
	14			.557		1000 +
	15				.090 Sec	1000 +
	16				.073	1000 +
-55°C (-60°C Act)	17	43 Sec				1000 +
	18	53				1000 +
	19		4.70			500
	20		4.63			1000 +
	21			.676 Sec		1000 +
	22			.709		1000 +
	23				.080 Sec	1000 +
	24				.082	400

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LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group II (Overload Interrupt/Insulation Resistance)

Fuse Type - Buss SPC 30

Test Temperature (see below)

	NO.	200%	400%	966% ~~1000%~~	3166% ~~3000%~~	INSULATION RESISTANCE MEGOHMS
+25°C ~~+85°C~~	1	79 SEC				1000 +
	2	45				1000 +
	3		2.76 SEC			1000 +
	4		2.84			1000 +
	5			.454 SEC		1000 +
	6			.439		1000 +
	7				.040 SEC	1000 +
	8				.041	1000 +
+85°C ~~+25°C~~	15	45.5 SEC				1000 +
	16	28.5				1000 +
	17		2.45 SEC			60
	18		2.42			1000 +
	19			.406 SEC		1000 +
	20			.416		20
	21				.031 SEC	1000 +
	22				.038	1000 +
-55°C	31	61 SEC				400
	32	61.5				1000 +
	33		3.2 SEC			400
	34		3.23			500
	35			.542 SEC		14
	36			.549		1000 +
	37				.052 SEC	1000 +
	38				.040	1000 +

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LABORATORY REPORT

No. _____

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group III (Short Circuit Test/Insulation Resistance)
Fuse Type - Buss SPC (Ampere Rating - See Below)

	NO.	A.C. TEST		D.C. TEST			AC INSULATION	DC RESISTANCE	MEG (OHMS)
2A	9	OK		#41	OK		1000 +	1000 +	
	10	OK	Group IV SAMPLES	#42	OK	60 Volts	1000 +	1000 +	
	23	OK		#43	OK		1000 +	1000 +	
	24	OK		#44	OK		1000 +	1000 +	
	25	OK					1000 +		
	26	OK					1000 +		
	39	OK					1000 +		
	40	OK					1000 +		
5A	9	OK	FRESH FUSE		OK		1000 +	1000 +	
	10	OK	FRESH FUSE		OK		1000 +	1000 +	
	23	OK		#41	OK	60 Volts	1060 +	1000 +	
	24	OK	Group IV SAMPLES	#42	OK		1000 +	1000 +	
	25	OK		#43	OK		1000 +	1000 +	
	26	OK		#44	OK		1000 +	1000 +	
	39	OK					1000 +		
	40	OK					1000 +		

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LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group III (Short Circuit Test/Insulation Resistance)
Fuse Type - Buss SPC (Ampere Rating - See Below)

	NO.	A.C. TEST			D.C. TEST	INSULATION RESISTANCE (MEG OHMS)	
						AC	DC
7-1/2A	9	OK		#41	OK	1000 +	1000 +
	11	OK	GROUP IV	#42	OK	1000 +	1000 +
	23	OK	SAMPLES	#43	OK	1000 +	500
	24	OK		#44	OK	1000 +	1000 +
	25	OK				1000 +	
	26	OK				1000 +	
	39	OK				1000 +	
	40	OK				1000 +	
30A	9	OK		FRESH FUSE	OK	1000 +	1000 +
	11	OK		FRESH FUSE	OK	1000 +	1000 +
	23	OK		#41		1000 +	1000 +
	24	OK	GROUP IV	#42		1000 +	1000 +
	25	OK	SAMPLES	#43		1000 +	1000 +
	26	OK		#44		1000 +	1000 +
	39	OK				1000 +	
	40	OK				1000 +	

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LABORATORY REPORT

No. ________

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group V (Overload Interrupt/Insulation Resistance)
Fuse Type - Buss SPC (Ampere Rating - See Below)
Test Temperature +25°C

	NO.	200%	400%	1000%	3000%	INSULATION RESISTANCE MEG OHMS
2A	27	40 Secs.				400
	28		5.12 Secs.			1000+
	29			.52 Secs.		1000+
	30				.053 Secs	1000+
5A	27	43 Secs.				1000+
	28		3.25 Secs.			1000+
	29			.35 Secs.	(2920%)	1000+
	30				.033 Secs.	1000+
7½A	27	63 Secs.				1000+
	28		3.42 Secs.			1000+
	29			.40 Secs	(2933% ACT)	1000+
	30				.048 Secs.	3
30A	27	66 Secs.				1000+
	28		2.82 Secs	(966% ACT)		750
	29			.50 Secs.	(3166% ACT)	60
	30				.052	

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LABORATORY REPORT

No.

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group VI (Current Carrying Capacity)
Fuse Type - Buss SPC (Ampere Rating - See Below)
Test Temperature +25°C

	NO.	START			T				T				T				T	
2A	11				57				61				60				61	
	12				59				64				64				65	
	13				62				65				65				66	
	14				56				62				63				63	
5A	11				61				65				63				63	
	12				68				73				70				70	
	13				66				70				68				69	
	14				61				64				62				63	
7½A	10				56				56				57				56	
	12				72				70				71				70	
	13				68				67				68				67	
	14				69				66				68				66	
30A	10				83				86				89				89	
	12				103				108				108				112	
	13				97				99				102				102	
	14				105				109				109				109	

LABORATORY REPORT

No. ______

Bussmann Division - McGraw-Edison Company
St.Louis, Mo. 63178

Subject Group VI (Overload Interrupt/Insulation Resistance)
Fuse Type - Buss SPC (Ampere Rating - See Below)
Test Temperature +25°C

	NO.	200%	400%	1000%	3000%	INSULATION RESISTANCE MEG OHMS
2A	11	43 Secs.				1000+
	12		2.41 Secs.			1000+
	13			.48 Secs.		1000+
	14				.066 Secs	1000+
5A	11	46.5 Secs.				1000+
	12		3.31 Secs.			1000+
	13			.31 Secs.	(2920% ACT)	1000+
	14				.036 Secs.	1000+
7½A	10	43 Secs.				1000+
	12		3.64 Secs			1000+
	13			.41 Secs	(2933% ACT)	1000+
	14				.046	
30A	10		2.71 Secs			1000+
	12	32.5 Secs		(966% ACT)		1000+
	13			.47 Secs.	(3166% ACT)	200
	14				.039 Secs.	1000+

environ
LABORATORIES, INC.
9725 Girard Avenue South
Minneapolis Minnesota

ENGINEERING REPORT NO. 12649

"SHOCK TEST"

4 August 1983

for

BUSSMANN DIVISION
McGraw Edison Company
P.O. Box 14460
St. Louis, Missouri 63178

Prepared by: Bradley C. Czech
Bradley C. Czech
Staff Scientist

Harley M. Sutton
Harley M. Sutton
Vice President

ENVIRON LABORATORIES, INC.
4 August 1983

ENGINEERING REPORT NO. 12649
Page 1

Prepared for: BUSSMANN DIVISION

McGraw Edison Company

P.O. Box 14460

St. Louis, Missouri 63178

Subject: SHOCK TEST

1. ABSTRACT

1.1 Object

Subject Bussmann Division fuses to a Shock Test as requested in Bussmann Division Purchase Order No. E47270.

1.2 Conclusions

The test units remained intact and appeared to have suffered no damage as a result of the Shock Test. Electrical continuity was retained in all units following the Shock Test.

2. UNITS TESTED

Four of each of the following fuses: SPC-2A, SPC-5A, SPC-7½A, and SPC-30A. The units of each model type were assigned serial numbers 41 through 44.

3. TEST REQUESTED

Fuses shall be subjected to a Shock Test in accordance with MIL-STD-202, Method 213, Condition I. The test units were to be subjected to 3 shocks in each direction of three orthogonal axes of the units (for a total of 18 shocks). Shock waveforms were to be 100 g in amplitude, 6 milliseconds in duration, and of terminal-peak sawtooth configuration.

3. TEST REQUESTED (Cont'd)

The units were to be checked for electrical continuity before and after testing. Half of the test units were to be tested while carrying 100 percent of rated current at any convenient voltage and frequency, and the remainder with no current.

4. INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

L.A.B. Corporation Shock Machine, Type 24-400
Endevco Amplifier, Model 2614B, Environ No. 350-020, Last calibration date: 31 January 1983
Endevco Accelerometer, Model 2272, S/N NA53, Last calibration date: 9 March 1983
Tektronix Type 564B Oscilloscope, S/N B060494, Last calibration date: 30 June 1983
Hewlett Packard Oscilloscope Camera, Model 196A
Endevco Power Supply, Model 2621, Environ No. 380-518, Last calibration date: 31 January 1983
Krohn Hite Band Pass Filter, Model 330M, Environ No. 440-001, Last calibration date: 8 December 1982
Weston AC Ammeter (used for SPC-2A's and SPC-7½A's), 5/10 amps. full scale, Model 433, S/N 118763, Environ No. 230-003, Last calibration date: 2 June 1983
Weston AC Ammeter (used for SPC-5A's and SPC-30A's), 10/50 amps. full scale used, Model 904, S/N 20021,Environ No. 230-050, Last calibration date: 12 July 1983
Biddle Power Rheostat, 1000 W, Cat. No. 20

4.2 Procedure

Testing was accomplished in two lots, one consisting of the SPC-2A and SPC-5A units, the other comprised of the SPC-7½A and SPC-30A units. For a given test lot, two of one fuse type were wired in parallel with two of the other, utilizing an adjustable power rheostat and a step-down transformer to achieve the necessary rated currents of each type as monitored with separate ammeters.

4. *INSTRUMENTATION, PROCEDURE AND RESULTS* (Cont'd)

4.2 Procedure (Cont'd)

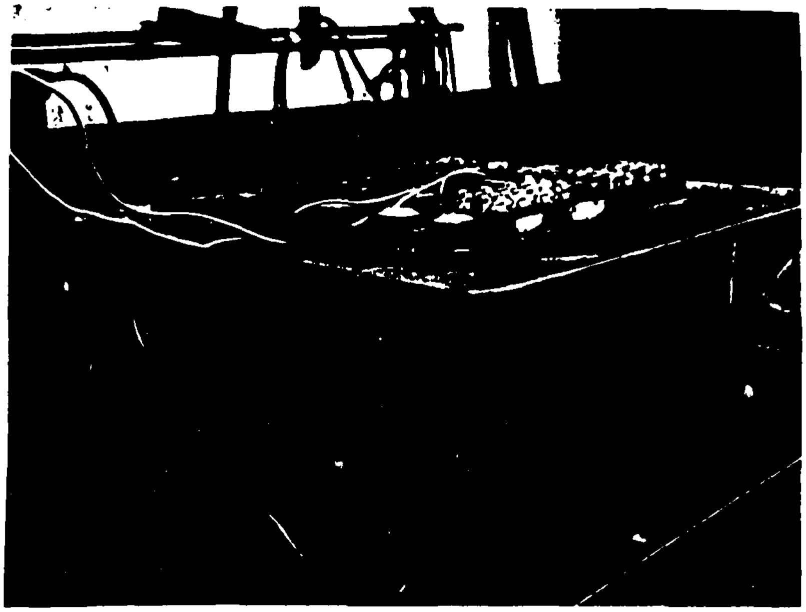
The shock machine was calibrated to obtain the desired waveform, then the test fixture was mounted in the various test orientations atop the shock machine carriage. Shock waveforms were nominally 100 g in amplitude, 6 milliseconds in duration, and were of terminal-peak sawtooth configuration. All units were subjected to 18 shocks, comprised of 3 pulses in each direction of 3 orthogonal axes, with half of each type unit carrying 100 percent of rated current during testing.

4.3 Results

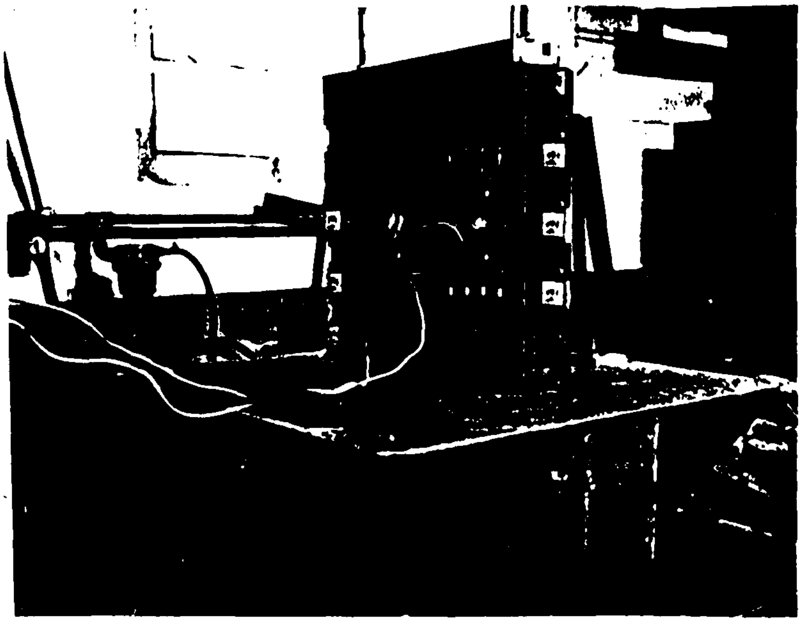
Upon completion of the test, the test units remained intact and exhibited no signs of damage as a result of the Shock Test. Electrical continuity was maintained by all units.

Photographs of the Shock Test set-up and shock waveforms follow. A bandpass of 0.2 to 3000 hz was utilized for the waveform displays to reduce high frequency noise.

Photographs of Test Set-up



Photograph No. 1 - Photograph of Shock Test set-up, showing test fixture mounted atop shock machine carriage for testing in the "leads up" orientation. Current-carrying wires lead off to left.



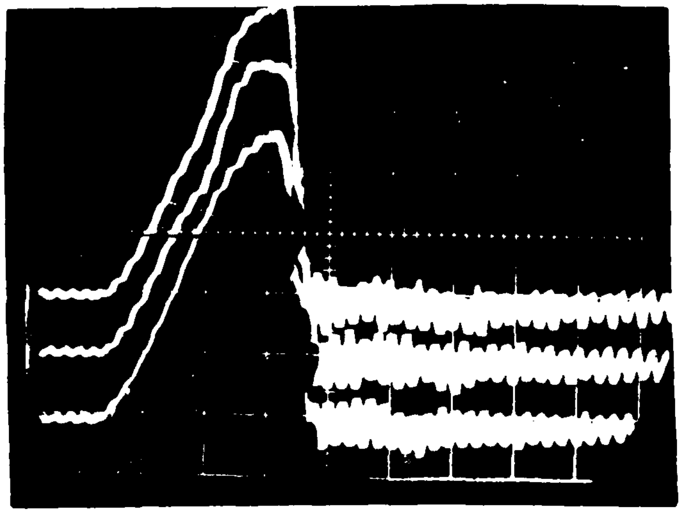
Photograph No. 2 - Photograph of Shock Test set-up, showing the fixture oriented for testing in one of four axes utilizing the metal bar tie-down shown. Accelerometer is visible beyond right edge of fixture plate, atop small metal block fastened to shock machine carriage.

Index to Photographs of Shock Waveforms

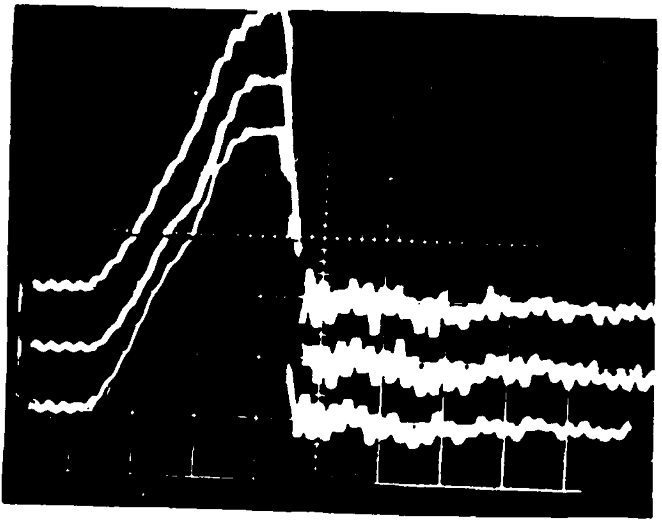
Vertical: 20 g/division
Horizontal: 2 ms/division

Units	Photograph No.	Orientation
SPC-2A and SPC-5A	1	Leads up
	2	Leads down
	3	Longitudinal, S/N's read down
	4	Longitudinal, S/N's read up
	5	Lateral, S/N's right side up
	6	Lateral, S/N's upside down
SPC-7½A and SPC-30A	7	Longitudinal, 7½: S/N's read up 30: S/N's right side up
	8	Longitudinal, (opposite of #7)
	9	Lateral, 7½: S/N's upside down 30: S/N's read up
	10	Lateral, (opposite of #9)
	11	Leads up
	12	Leads down

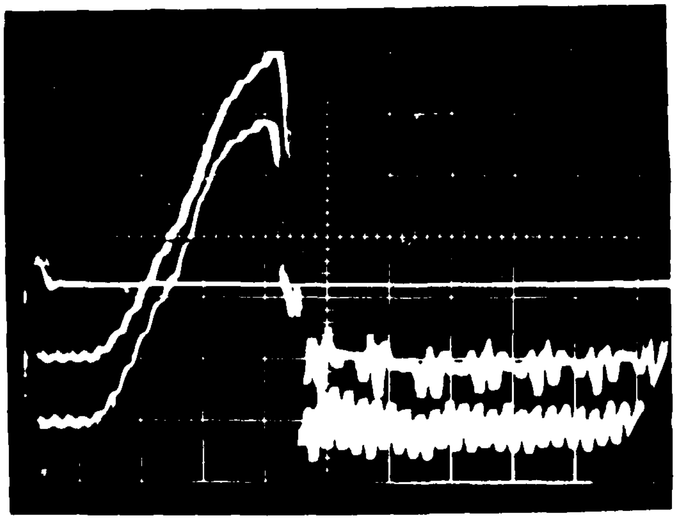
Photographs of Test Set-up



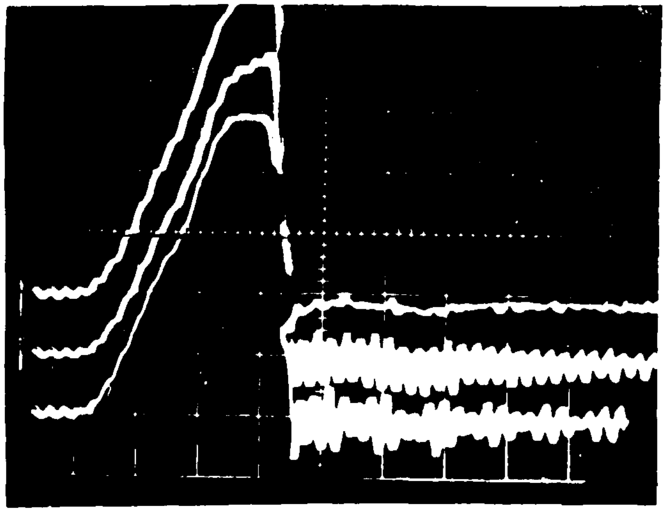
Photograph No. 1



Photograph No. 2

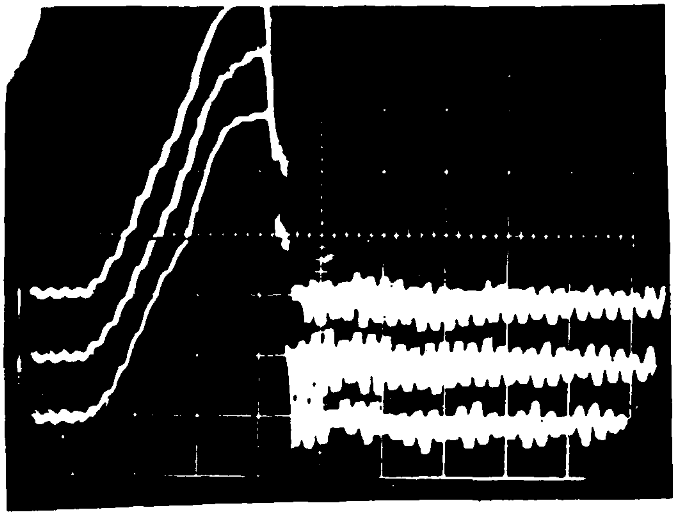


Photograph No. 3
(3 drops executed, only 2 recorded due to oscilloscope triggering difficulties)

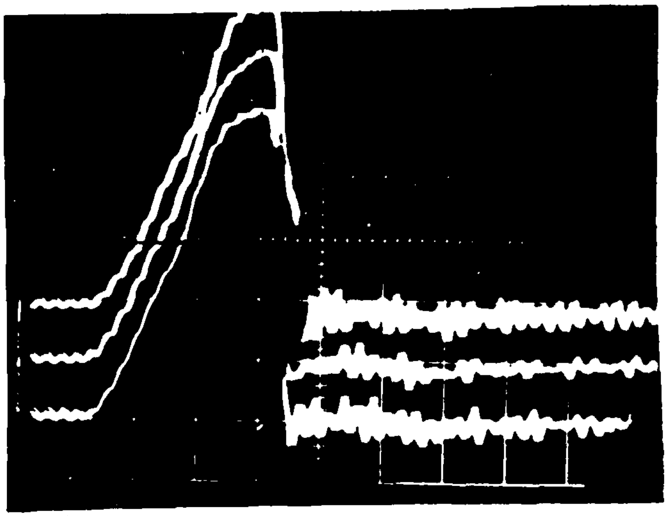


Photograph No. 4

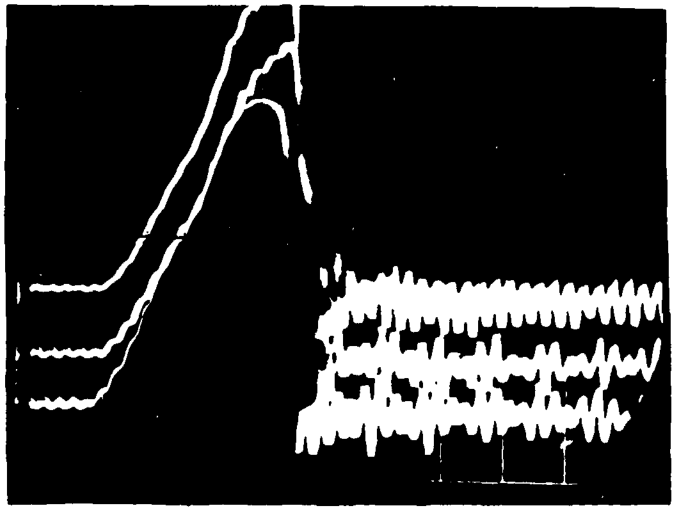
Photographs of Test Set-up



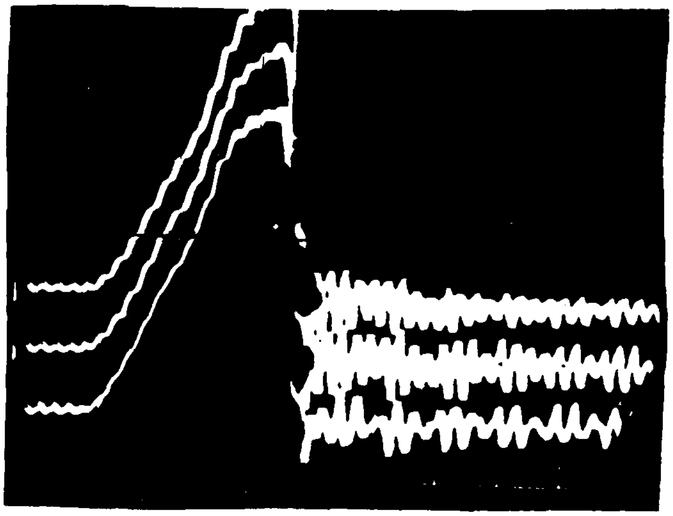
Photograph No. 5



Photograph No. 6

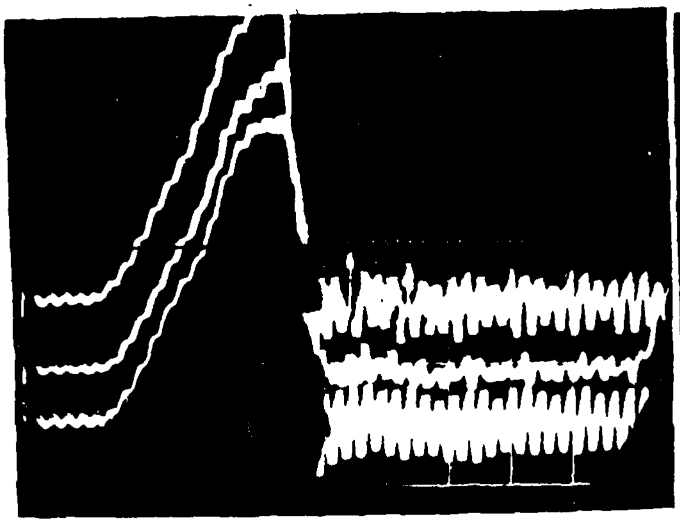


Photograph No. 7

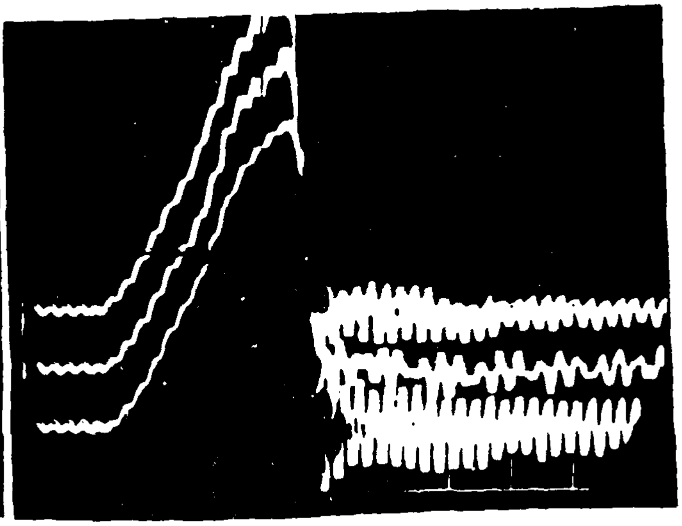


Photograph No. 8

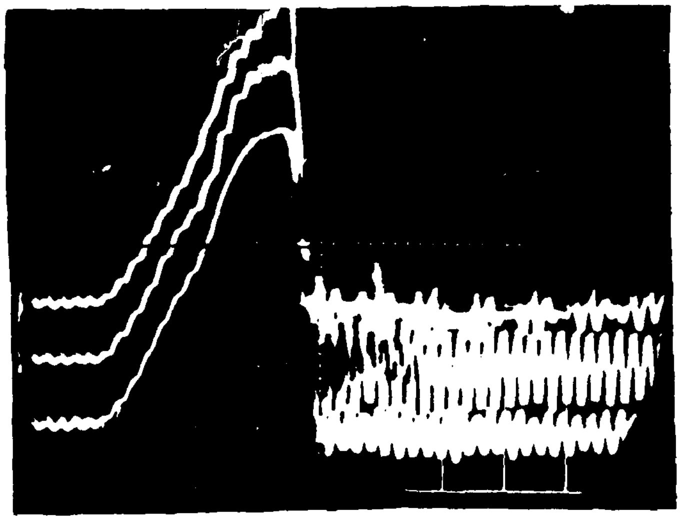
Photographs of Test Set-up



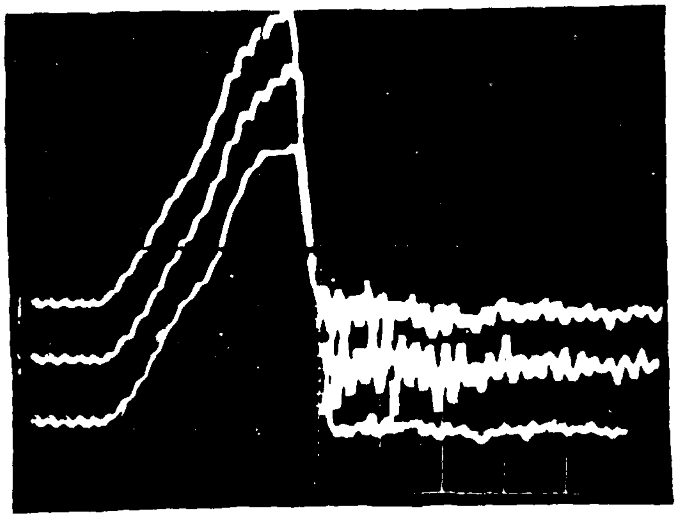
Photograph No. 9



Photograph No. 10



Photograph No. 1 1



Photograph No. 12

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LABORATORIES, INC.
9725 Girard Avenue South
Minneapolis Minnesota

ENGINEERING REPORT NO. 12649-2

"SALT SPRAY TEST"

28 July 1983

for

BUSSMANN DIVISION
McGraw Edison Company
P.O. Box 14460
St. Louis, Missouri 63178

Prepared by: Nola J. Carlson
Nola J. Carlson
Staff Scientist

Harley M. Sutton
Vice President

Prepared for:

BUSSMAN DIVISION

McGraw Edison Company

P.O. Box 14460

St. Louis, Missouri 63178

Subject: SALT SPRAY TEST

1. ABSTRACT

1.1 Object

Sixteen fuses were subjected to a Salt Spray Test per MIL-STD-202, Method 101, as requested by Bussmann Division in their Purchase Order No.E47270. The test units were returned to Bussman Division for further post-test evaluation.

1.2 Conclusions

All units exhibited some tarnishing of the metal and a small amount of whitish corrosion on the metal portions. The 30A and 7½A fuses were subjected to 100 percent of their rated current for one hour with no apparent damage to the units.

2. UNITS TESTED

The Bussmann Division of McGraw Edison Company submitted four SPC-2A fuses (#27, #28, #29, #30), four SPC-5A fuses (#27, #28, #29, #30), four SPC-7½A fuses (#27, #28, #29, #30), and four SPC-30A fuses (#27, #28, #29, #30) for a Salt Spray Test per MIL-STD-202, Method 101.

3. TEST REQUESTED

Subject the 16 fuses to a Salt Spray Test in accordance with Method 101D of MIL-STD-202F. The length of the test shall be 48 hours. Following the drying period, the fuses shall be subjected to 100 percent of the rated current for one hour.

4. INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

Salt Spray Chamber, Associated Environmental Systems Model MX9208, Environ No. 504-012
Digital Thermometer, Doric Model 410A, Environ No. 430-004, Last calibration date: 26 May 1983
pH Meter, Corning Model 125, Environ No. 491-001
AC Ammeter, Weston Model 433, Range: 0-10A, Environ No. 230-003, Last calibration date: 2 June 1983
AC Ammeter, Weston Model 904, Range: 0-50A, Environ No. 230-050, Last calibration date: 12 July 1983
Biddle 1000W Power Rheostat, Cat. No. 20
Variac, Environ No. 380-503

4.2 Procedure

The test specimens were suspended in the salt spray chamber using waxed string, and were positioned so that they were approximately 15° from the vertical. The 5% salt solution was mixed and its specific gravity and pH were checked and adjusted to conform with the requirements of MIL-STD-202F. The chamber was then closed and the heat and salt spray turned on. The temperature in the chamber was maintained at 95 +2 -3°F, while the salt spray was adjusted so that for each 80 square centimeters of horizontal collecting area, there was 0.5 to 3.0 ml of salt solution collected per hour (based on an average run of at least 16 hours). This exposure was continuous for 48 hours.

Immediately following the salt spray exposure, the fuses were rinsed in running tap water not warmer than 100°F. Each fuse was examined for corrosion, warping, cracking or other electrical or mechanical damage.

Following a 24 hour drying period at room ambient conditions, the 7½A and 30A test units were subjected to 100 percent of their rated current for one hour.

4.3 Results

All of the test units exhibited some discoloration of the metal portions, and a small amount of whitish corrosion

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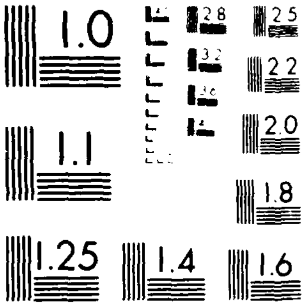


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4. INSTRUMENTATION, PROCEDURE AND RESULTS (Cont'd)

4.3 Results (Cont'd)

was evident on the test units. There was no apparent warping, cracking or other electrical or mechanical damage on the fuses tested.

The 7½A and 30A fuses showed no evidence of damage following the exposure to 100 percent of their rated current.

NOTE: Bussmann Division personnel agreed to perform the post-salt spray performance tests on the 2A and 5A fuses.

Appendix J

environ
LABORATORIES, INC.
9725 Girard Avenue South
Minneapolis Minnesota

ENGINEERING REPORT NO. 12649-3

"MOISTURE RESISTANCE TEST"

1 August 1983

for

BUSSMANN DIVISION
McGraw Edison Company
P.O. Box 14460
St. Louis, Missouri 63178

Prepared by: Nola J. Carlson
Nola J. Carlson
Staff Scientist

Harley M. Sutton
Vice President

ENVIRON LABORATORIES, INC. ENGINEERING REPORT NO. 12649-3
1 August 1983 Page 1

Prepared for: BUSSMANN DIVISION

McGraw Edison Company

P.O. Box 14460

St. Louis, MIssouri 63178

Subject: MOISTURE RESISTANCE TEST

1. ABSTRACT

1.1 Object

To subject 16 fuses to a Moisture Resistance Test in accordance with MIL-STD-202, Method 106, as requested by Bussmann Division in their Purchase Order No. 47270.

1.2 Conclusions

The test units exhibited various degrees of rust and corrosion on or near the terminal ends following the moisture resistance exposure. There was no evidence of cracking, peeling, or loosening of the terminals.

The test units were returned to Bussmann Division for further post-test evaluation.

2. UNITS TESTED

The Bussmann Division of McGraw Edison Company submitted four SPC-2A fuses (#11, #12, #13, #14), four SPC-5A fuses (#11, #12, #13, #14), four SPC-7½A fuses (#10, #12, #13, #14), and four SPC-30A fuses (#10, #12, #13, #14) for a Moisture Resistance Test per MIL-STD-202, Method 106.

3. TEST REQUESTED

Subject 16 fuses submitted by Bussmann Division of the McGraw Edison Company to a Moisture Resistance Test per MIL-STD-202, Method 106, excluding steps 7A and 7B. Polarizing voltage shall be 100 volts DC.

4. INSTRUMENTATION, PROCEDURE AND RESULTS

4.1 Instrumentation

Drying Oven, Environ Model T1-3, Environ No. 500-003
Humidity Chamber, Blue M. Model FR-366PC-1, Environ No. 501-014
Dry Bulb/Wet Bulb Temperature Recorder, Ametek Controls Division Model TRX12M/M-78, Environ No. 200-061, Last calibration date: 20 July 1983
Digital Multimeter, Keithley Model 160B, Range Used: 0-1000 VDC, Environ No. 215-001, Last calibration date: 17 March 1983
DC Power Supply, manufactured by Environ Labs
Temperature Recorder/Controller, Honeywell-Brown Model 15301336-01-01-0-024-002-01, Range: -100 to 250°F, Environ No. 200-056, Last calibration date: 28 April 1983

4.2 Procedure

The sixteen fuses were mounted on a noncorrosive panel positioned 15 degrees from the vertical with the terminal down. The fuses were wired so that the polarizing voltage would be applied between the fuse insulation material and the terminal ends.

Before placing the test units in the humidity chamber, they were conditioned in a drying oven at temperature of 50±2°C (122±3.6°F) for a period of 24 hours. The test units were then placed in the humidity chamber and the cycling was commenced by first raising the temperature to 65±2°C (149±3.6°F) in 2½ hours (Step 1), with the relative humidity maintained at 90-98%. The chamber was kept at these conditions for 3 hours (Step 2); then, the temperature was lowered to 25 +10, -2°C (77°F +18, -3.6°F) within 2½ hours and immediately raised to 65±2°C with a relative humidity of 90-98% (Steps 3 and 4). During the lowering and raising of dry bulb temperature, the relative humidity was between 80 and 98%. The high temperature and humidity was held for 3 hours (Step 5), and then dropped down to 25±2°C within 2½ hours (Step 6). The 25°C, 90-98% relative humidity was maintained for the remainder of the 24-hour cycle (see representative dry bulb/wet bulb temperature chart on page 4 of this report). The 24-hour cycle was repeated for a total of 10 cycles, except that at the end of Step 6 of the 10th cycle, after

4. INSTRUMENTATION, PROCEDURE AND RESULTS (Con'td)

4.2 Procedure (Cont'd)

1 hour at 25°C, the units were removed from the chamber. Throughout the humidity exposure, a polarizing voltage of 100 VDC was applied between the metallic parts and the insulating parts of the fuses. One amp fuses were wired into the circuit so that any leakage current greater than 1 amp would be detected.

Following the humidity exposure, the units were inspected for cracking, peeling, loosening of terminals and evidence of electrolytic corrosion.

4.3 Results

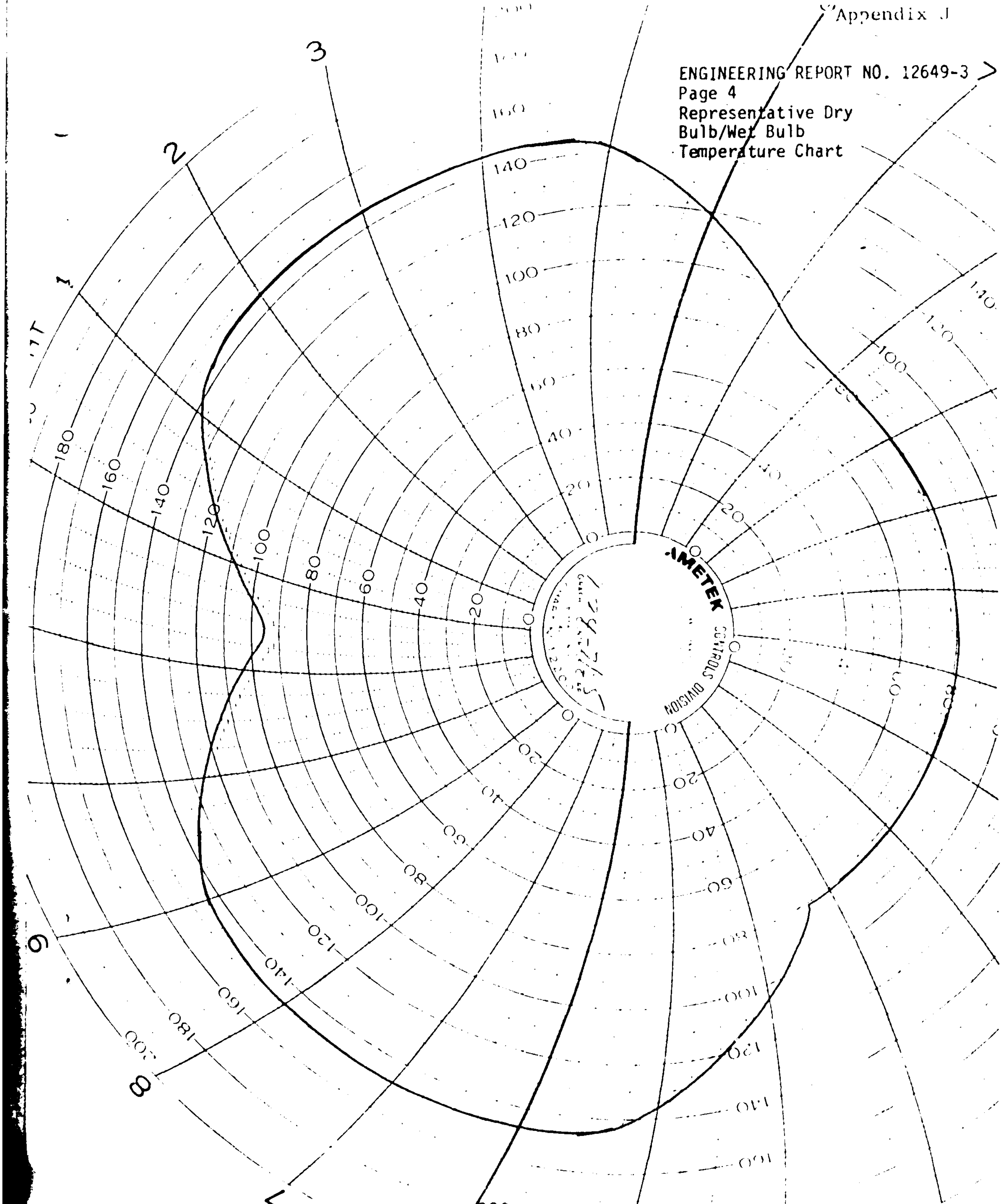
At no time during the moisture resistance exposure did the leakage current exceed 1 ampere.

Post-exposure inspection of the test units revealed no evidence of cracking, peeling, or loosening of the terminals. The various degrees of corrosion found on the fuses is listed below for each fuse type tested.

Fuse Type	Results of Visual Examination
SPC-30A	Very slight discoloration of terminal ends.
SPC-7½A	Moderate to severe rust, corrosion and tarnishing on terminal ends.
SPC-SA	Small amount of corrosion on only 3 units, near terminal ends.
SPC-2A	Small amount of corrosion on 2 units, near terminal end.

Appendix J

ENGINEERING REPORT NO. 12649-3
Page 4
Representative Dry
Bulb/Wet Bulb
Temperature Chart



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