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MANUFACTURING METHODS AND TECHNOLOGY (MM AND T) MEASURE FOR FAB--ETC(U)
APR 78 B B ADAMS, S W KESSLER, R E REED DAAB07-76-C-8120

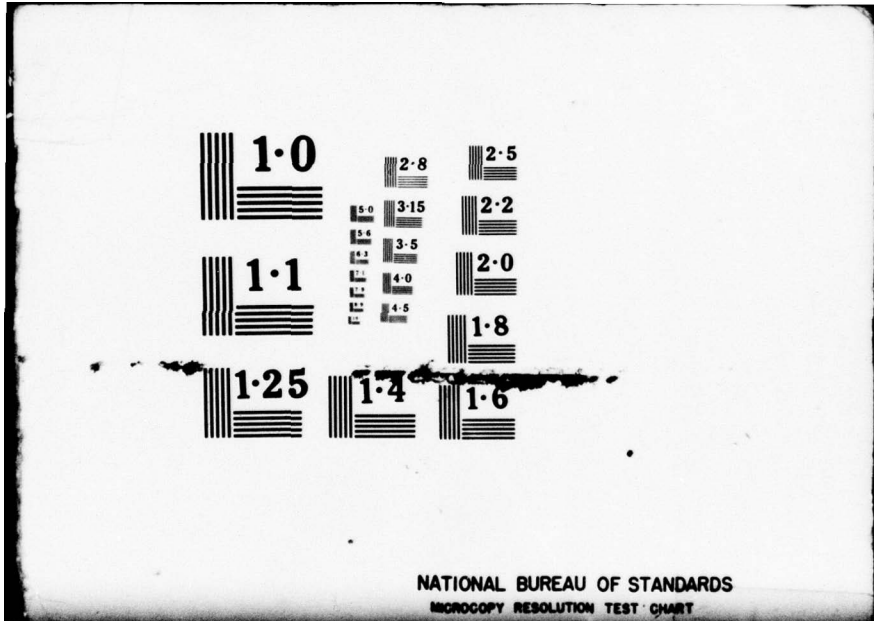
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This project has been accomplished as part of the U.S. Army (Manufacturing and Technology) Program, which has as its objective the timely establishment of manufacturing processes, techniques or equipment to insure the efficient production of current or future defense programs.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This Sixth Quarterly Report describes the progress on the MM&T program for Transcendent (Heat-Pipe cooled) thyristors. Production engineering measures for the device and the pertinent state-of-the-art on the sample devices are included. Test results on all the confirmatory samples are listed.		

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20. (Continued)

The present status includes the submission of the confirmatory samples, the fabrication of the confirmatory sample devices, the engineering analyses of the final test results on these devices, and the equipment refinements being procured for this program.

Plans for the next Quarter are the preparations and fabrication of devices for the pilot run phase.

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SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

**MANUFACTURING METHODS AND TECHNOLOGY (MM&T)
MEASURE FOR FABRICATION OF SILICON TRANSCALENT THYRISTOR**

Sixth Quarterly Progress Report

Period Covered: 1 January 1978 to 31 March 1978

Object of Study: The objective of this manufacturing methods and technology measure is to establish the technology and capability to fabricate Silicon Transcalent Thyristors.

Contract No. DAAB07-76-C-8120

Approved for public release; distribution unlimited

**Prepared by:
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ABSTRACT

This sixth quarterly technical report on the MM&TE Contract DAAK07-76-C-8120 for Transcalent (Heat-Pipe cooled) SCR Thyristors describes the completion of device refinements for the Confirmatory Samples. Also described are the problems encountered and the results achieved in the testing of the numerous characteristics, including the measurement of some new parameters, not previously required by the contract.

Actual test results for the five confirmatory samples are included to verify that the device design conforms to the electrical, mechanical and thermal specification, SCS-477.

Additional preparations for production are described as well as some vendor selection information. The revision to the PERT Chart, prepared and submitted on 29 August 1977, is still applicable.

Plans for the next quarter include preparation of a Preliminary Pilot Run Report, demonstration of the pilot line and production of the pilot run sample devices.

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PURPOSE

The purpose of this production engineering contract is to establish the technology and capability to fabricate heat-pipe cooled semiconductor power devices, silicon Transcendent Thyristors, Type J-15371. The subsequent pilot production of these devices is a part of the contract. This report covers the efforts performed by the contractor in the sixth quarterly period to modify the engineering sample device for production, use the established process and fabrication methods to construct the confirmatory samples and adequately characterize and deliver these sample thyristors. Plans for future work are also presented, corrective action is delineated for problems that have been encountered and other information is discussed to help assure that the purpose of the contract is accomplished.

This contractual MM&TE program is being used to establish the production techniques, establish quality control procedures and verify a pilot production capability for the J-15371 thyristor, conforming to the drawing attached to AMENDMENT 1 of SCS-477. Electrical, mechanical, thermal and environmental inspections are a part of the program as well as extensive documentation requirements, per DD 1423.

No high volume production facilities existed at the start of this contract for the Transcendent type of solid-state power device. However, production planning constitutes Step II of the contract. Thus, the time required to produce future large quantities of the J-15371 will be reduced for either current military requirements or future emergency requirements. Reduction of the reproductive costs for production quantities is also an important objective.

The J-15371 thyristor is a 400 amperes RMS, 800 volts, forced air cooled solid-state power control device, utilizing integral heat-pipes for improved cooling efficiency, lighter weight and smaller size than the conventional devices with their externally attached heat-sinks. Improved reliability results from these innovations. A blocking voltage capability of 800 volts minimum at 125° Celsius is a requirement. Original R&D efforts were conducted successfully by RCA under Contract No. DAAK02-69-C-0609, for MERADCOM, Ft. Belvoir, VA. Potential applications include power conditioning, power switching, phase control, voltage variable power supply and motor speed control equipments.

GLOSSARY

All abbreviations, symbols and terms used in this report are consistent with the Electronics Command Technical Requirements SCS-477, dated 5 December, 1974. This Technical Requirements document, in turn, references MIL-S-19500 for the abbreviations and symbols used therein except, as follows:

VGR = Reverse Gate Voltage

IGR = Reverse Gate Current

The format used for this report is that specified in the DD 1423, namely, ECIPPR No. 15, Appendix C, augmented by MIL-STD-847A. Sub-section numbering is based on Appendix C and the applicable test methods are those referenced in the following military standards:

MIL-STD-750B
MIL-Std-202E

Detail, individual item requirements shall be in accordance with MIL-S-19500.

NARRATIVE AND DATA

1. Device

- a. Description of the Structure - Refer to pages 9-13 of the First Quarterly Report for a description of the Transcendent thyristor device, the applicable reports, and the applicable patents as well as the advantages of this heat-pipe cooled technical approach. Refer to Figure 1 in the Second Quarterly Report for the cross-section drawing of the J-15371 with the external dimensions added.
- b,c. Defining the Problem Areas and Work Performed to Resolve the Problem

(1) Conversion of Design for Production

The Transcendent Thyristor design achieved under R&D Contract No. DAAK02-69-C-0609 was described in the FTR, October, 1972. Subsequent refinements have been incorporated under Contract N62269-73-C-0635 and by RCA-funded engineering projects. Additional engineering is being applied under the MM&TE program to convert the design to one more suitable for production, as described in prior Quarterly Reports covering the period 27 September 1976 to 31 December, 1977 and below for the most recent quarterly period.

(a) Item No. 0001AB Confirmatory Sample Phase

i. Device Fabrication

Nine more confirmatory samples were fabricated during the last quarterly report period. Five of the thyristors were shipped to MERADCOM, attention of Dr. R. Eaton in fulfillment of the second phase of the MM&TE Contract. All five confirmatory sample devices passed Specification No. SCS-477 which lists over 50 separate inspections for electrical, mechanical, thermal and environmental characteristics. Final measurements were also made which confirmed that each unit did not degrade during the tests. The serial numbers of the devices shipped are: F20, F23, F26, F29, and F31.

Two of the thyristors fabricated, F22 and F24, were tested at a constant acceleration of 500 Gs for one minute along three axes of the device. This test was for engineering information only.

One of the devices, F22, failed the test because its electrical characteristics indicated a short circuit at final measurement. There was no external physical damage to the device. F24 showed no change from its initial electrical characteristics.

The results of this constant acceleration test are consistent with those of an earlier test reported on page 54 of the 4th Quarterly Report of this contract. A 50% survival rate for this stringent test seems the norm.

Device F27 which was fabricated during this report period failed the dv/dt test. At 125°C, F27 dv/dt was 90 v/μs compared to a specification of 100 v/μs. Another device which was fabricated, F30, degraded following cycling to -25°C. The devices remain in the residual inventory of the contract.

ii. Silicon Wafer Processing

The redundant photoresist process described in the last quarterly report has been successful in controlling the electrical characteristics of the thyristor. The two-step process reduces the probability of pin holes in the resist from forming extraneous shunt paths for the gate current.

In diffusing the silicon wafers, a shunting current, I_s , is measured to control the emitter diffusion. The reciprocal of shunt current is a measure of the resistance of the p base. In Figure 1 is plotted the shunt current versus the gate trigger current for a number of devices. The scatter about the line drawn through the data is believed to be due to difficulty in making a low voltage ohmic contact to the unmetallized silicon. The data shows the gate current increases with the shunting current.

In Figure 2 is shown the dependency of dv/dt upon the shunting current. The scatter about the line is similar to that displayed when gate current was the dependent parameter. This data also shows the dv/dt increases with the shunting current.

In Figure 3 is plotted the dv/dt versus the gate current. Most of the data points nest very close to the trend line except for N18. N18 was processed prior to the introduction of redundant processing.

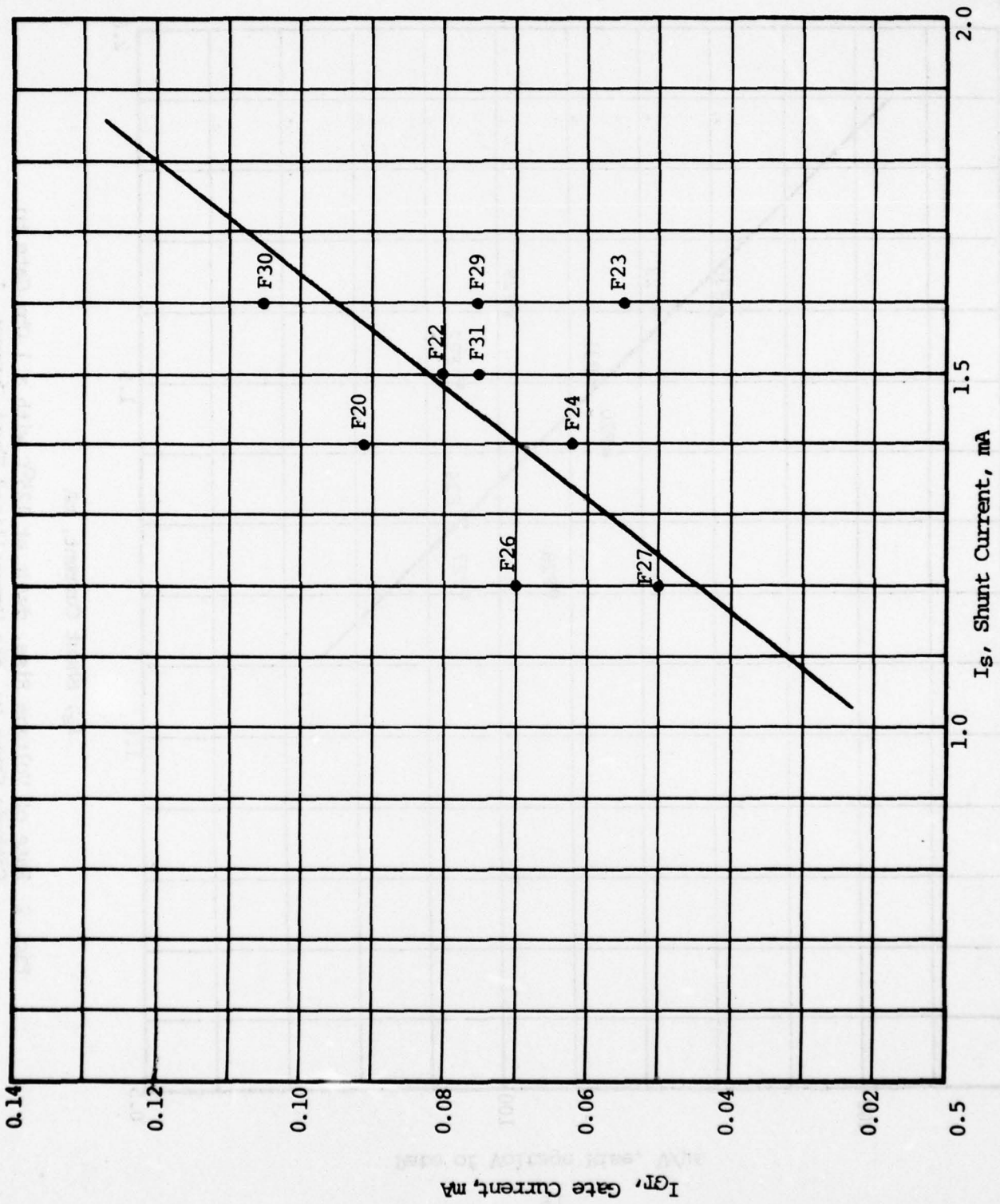


Fig. 1 Room Temperature Gate Current, I_{GT} , vs. Unmetallized Shunt Current, I_s , for the Confirmatory Sample Devices

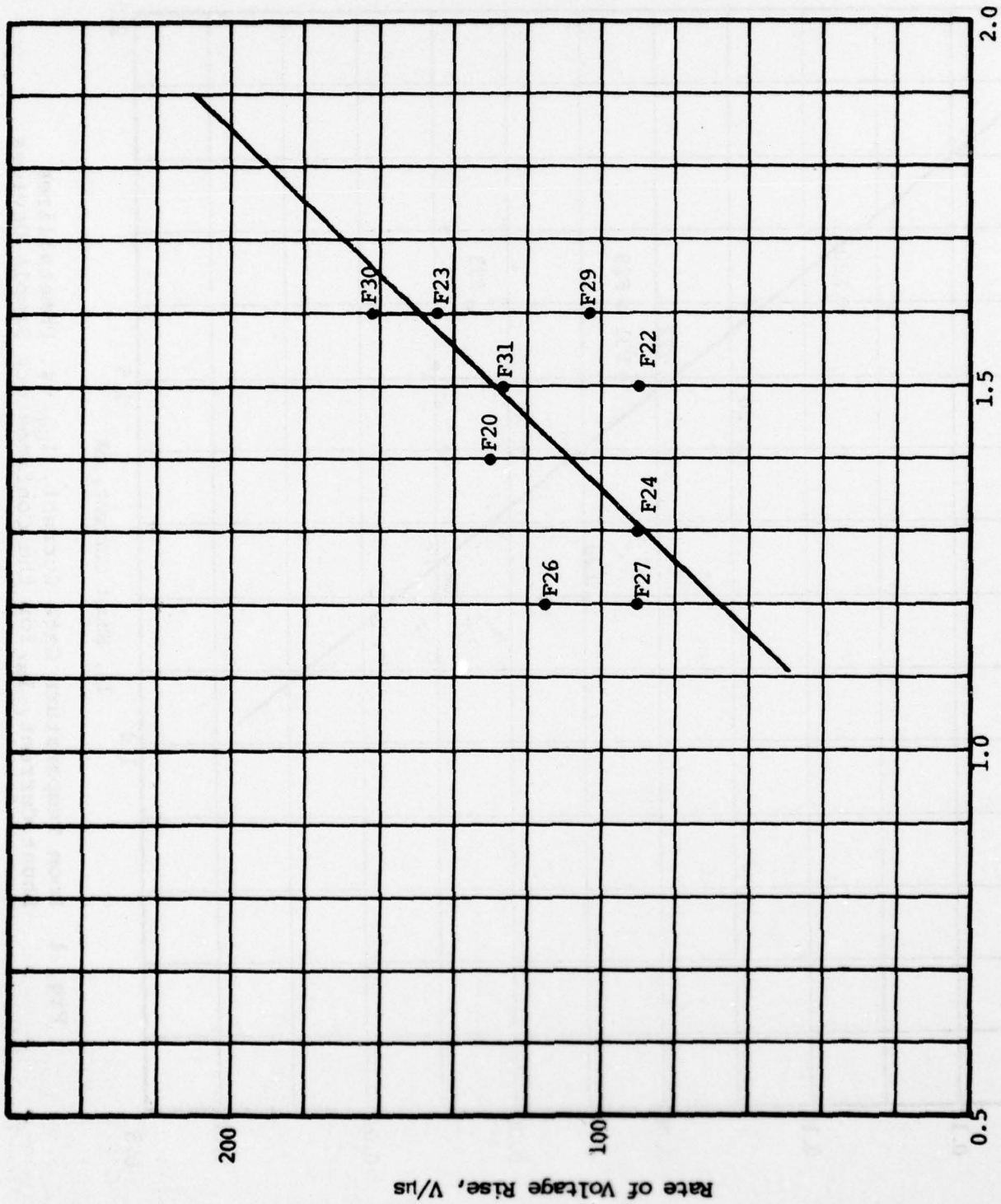


Fig. 2 Rate of Voltage Rise, dv/dt , at 125°C with a 1 Ohm Gate to Cathode Shunt vs. the Unmetallized Shunt Current, I_s , for the Confirmatory Sample Devices

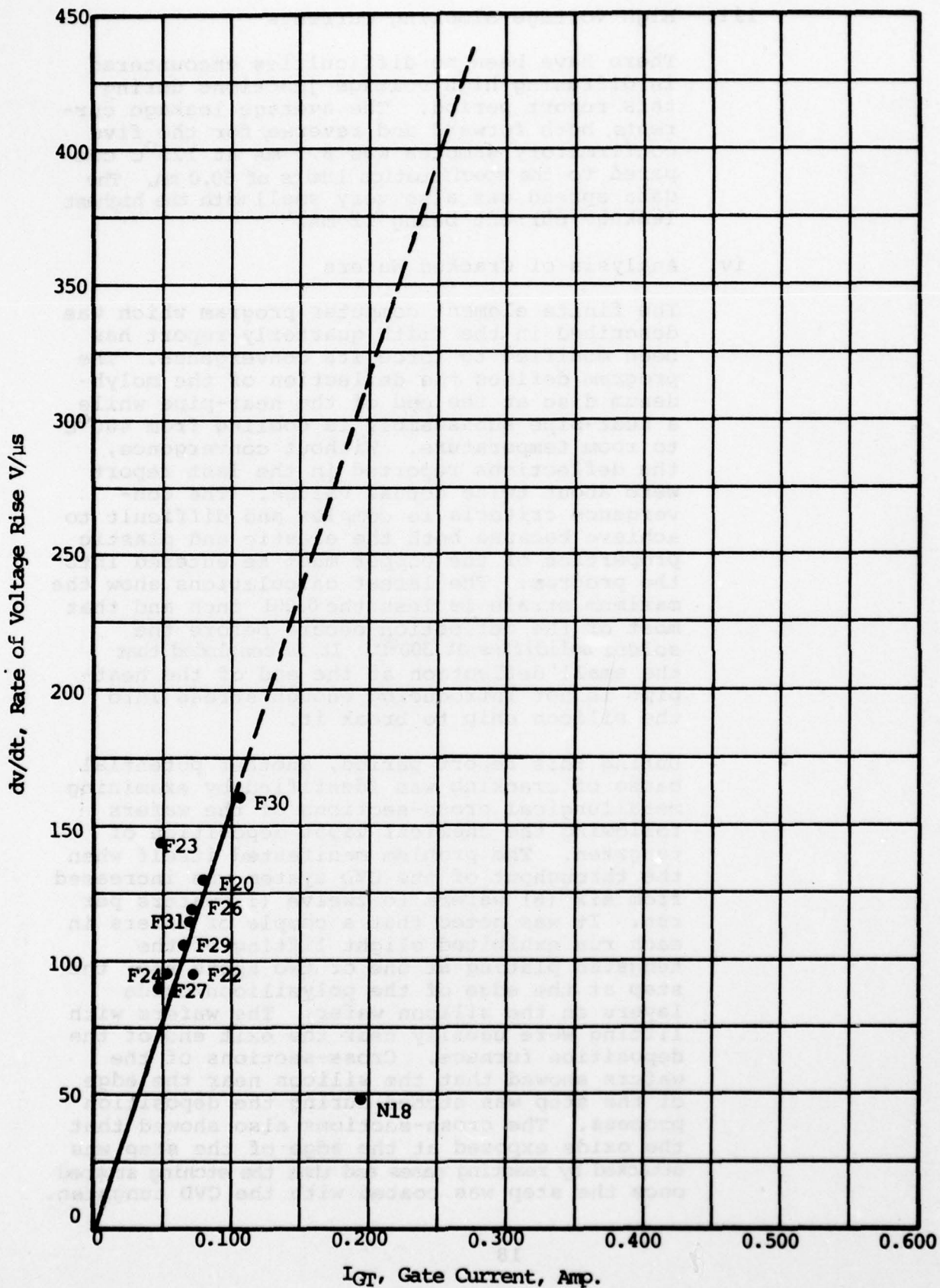


Fig. 3 Rate of Voltage Rise, dv/dt , at 125°C with a 1 Ohm Gate to Cathode Shunt vs. Room Temperature Gate Current for Confirmatory Sample Devices

iii. High Voltage Blocking Currents

There have been no difficulties encountered in diffusing high voltage junctions during this report period. The average leakage currents, both forward and reverse, for the five confirmatory samples was 8.7 mA at 125°C compared to the specification limits of 60.0 mA. The data spread was also very small with the highest leakage current being 12 mA.

iv. Analysis of Cracked Wafers

The finite element computer program which was described in the fifth quarterly report has been modified to force its convergence. The program defines the deflection of the molybdenum disc at the end of the heat-pipe while a heat-pipe subassembly is cooling from 400°C to room temperature. Without convergence, the deflections reported in the last report were about twice actual values. The convergence criteria is complex and difficult to achieve because both the elastic and plastic properties of the copper must be entered into the program. The latest calculations show the maximum strain is less than 0.001 inch and that most of the deflection occurs before the solder solidifies at 300°C. It is concluded that the small deflection at the end of the heat-pipe is not introducing enough stress into the silicon chip to break it.

During this report period, another potential cause of cracking was identified by examining metallurgical cross-sections of the wafers following the chemical vapor deposition of tungsten. The problem manifested itself when the throughput of the CVD system was increased from six (6) wafers to twelve (12) wafers per run. It was noted that a couple of wafers in each run exhibited slight lifting of the tungsten plating at one or two spots near the step at the edge of the polysilicon/oxide layers on the silicon wafer. The wafers with lifting were usually near the exit end of the deposition furnace. Cross-sections of the wafers showed that the silicon near the edge of the step was etched during the deposition process. The cross-sections also showed that the oxide exposed at the edge of the step was attacked by reacting gases and that the etching stopped once the step was coated with the CVD tungsten.

The etching must therefore occur only during the first few seconds of the process. Since hydrofluoric acid vapor, a by-product of the reaction, will attack silicon dioxide; it was reasoned that a concentration of another by-product, tungsten oxytetrafluoride is formed at the site of the lifting and that it is this compound which etches the silicon. To minimize the presence of oxygen, on which the formation of the compound WOF_4 in the system is dependent, the entire CVD system was helium leak checked for air leaks.

Repairs were made to a leaking valve, the cold traps were cleaned of excess deposits to increase the pumping speed, and an outgassing rate was established which is reconfirmed before each CVD run. The outgassing of the system is measured by closing the valve between the pump and the system after the system is evacuated and noting the rate at which the pressure rises in five minutes. Any leaks will increase the observed rate of outgassing and the run is then aborted. Since the valve was repaired, the traps cleaned and the outgassing rate observed, there has been no lifting of the tungsten plating.

Considering the nature of the problem, in that a crater will act as a notch in the brittle silicon and that the crater can be covered with CVD tungsten, it is conceivable that some wafers with hidden defects were mounted into devices. The craters are not always evident to the unaided eye but yet, they would provide a notch from which a crack could propagate and degrade the forward blocking junction. In the worst case, the crack could cause delamination during stress testing, such as thermal cycling to $-25^{\circ}C$, thus destroying the device.

In an effort to insure that the problem will not recur, steps have been taken to insure better coverage of the edge of the polysilicon/oxide layers. The first step mentioned in the last quarterly report is the ordering of the new evaporating fixtures which is capable of rotating the wafers in the vacuum bell jar while the palladium is being evaporated. This new fixture will provide better edge coverage as well as increase the capacity of the system. This fixture has not yet been delivered by the vendor.

The second effort will provide a more permanent solution to cratering, in that exposure of the oxide to the hydrofluoric acid vapors will be prevented. An experimental lot of wafers is now being processed. If successful, the process will be used for the pilot run.

v. Wick

Another bar of wick was made for tensile testing. The bar was made by sintering the copper powder at the same temperature as the wick in a heat-pipe is sintered and had the dimensions of 0.535 inch in diameter by 8 inches long. The tensile curve is shown in Figure 4. At a load of 390 pounds, the bar broke in a brittle fashion at a stress of 1700 psi. The voids in the sintered powder, which are necessary for capillary action, notch the sample so that the bar breaks at the weakest sintered link between particles. A strength of 1700 psi is sufficient strength for any material which does not bear a load.

vi. Ceramic Seal

The metallizing ink was changed on the ceramic in a continuing effort to upgrade the integrity of the ceramic-to-metal seal. This change was made so that the ink would be the same as now used on other devices of the RCA power tube product line.

The high strength of RCA's proprietary metallizing was confirmed by brazing cathode and anode flanges to the metallized ceramic and pulling the flanges off of the ceramic in the tensile machine. The first assembly which had cathode flanges brazed to both ends of the ceramic broke at 673 pounds. The fracture was in the ceramic, midway between the flanges. The second seal assembly which employed anode flanges broke at 373 pounds. The fracture was again in the ceramic but was closer to one of the flanges. The anode flange is twice as thick as the cathode flange and the added rigidity introduced some residual stresses into the ceramic. These tests verify that the flange-to-ceramic joints are stronger than the ceramic and that the metallizing process is thus under control. A strength of 373 pounds is a much greater load than a device would be subjected to in service.

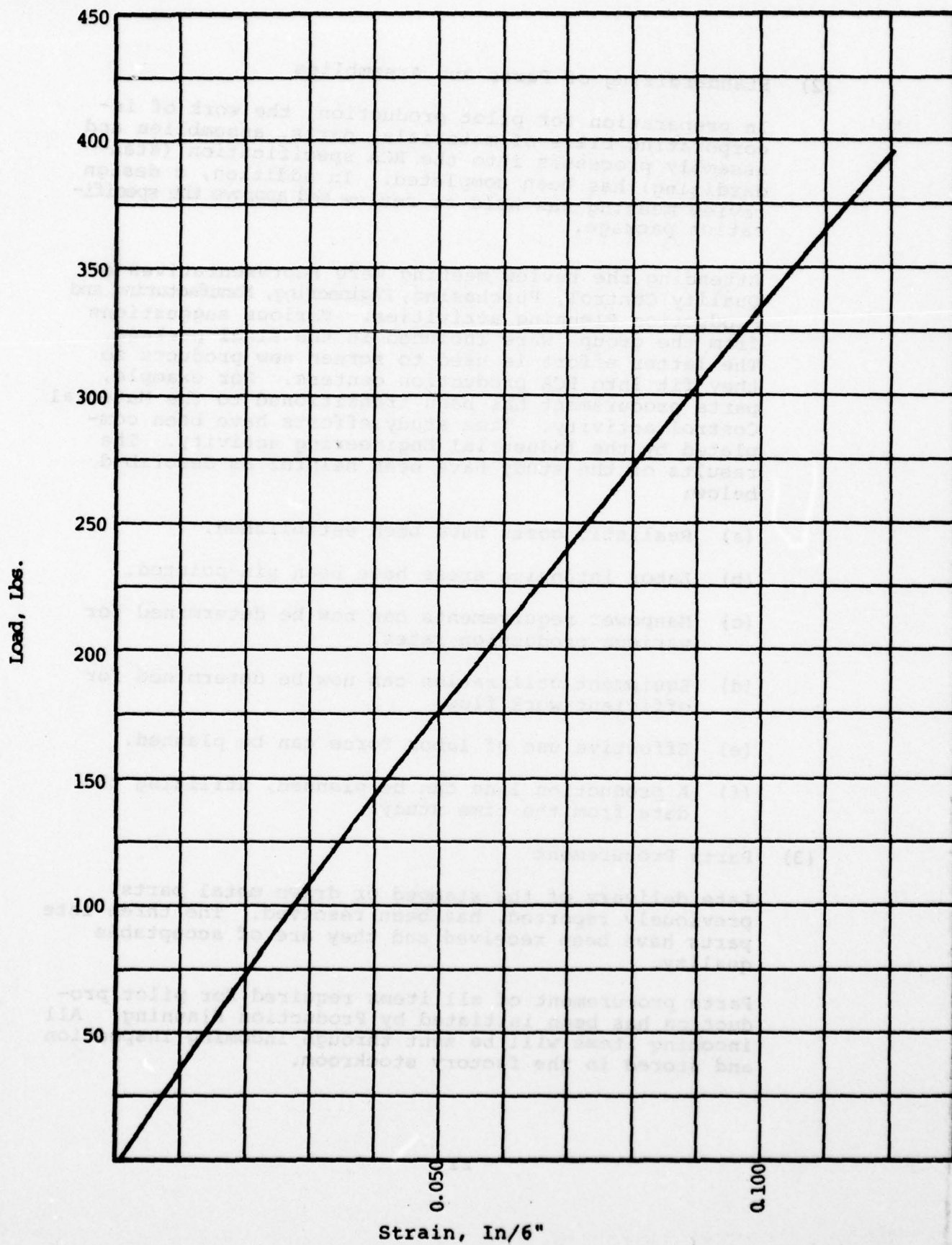


Fig. 4 Stress-Strain Curve of a Bar of Sintered Wick

(2) Standardizing of Parts and Assemblies

In preparation for pilot production, the work of incorporating bills of materials, parts, assemblies and assembly processes into the RCA specification (standardizing) has been completed. In addition, a design review meeting was held to review and approve the specification package.

Attending the review meeting were representatives of Quality Control, Purchasing, Engineering, Manufacturing and Production Planning activities. Various suggestions from the group were included in the final package. The latter effort is used to screen new products so they fit into RCA production centers. For example, parts procurement has been transitioned to the Material Control activity. Time study efforts have been completed by the Industrial Engineering activity. The results of the study have been helpful as described below:

- (a) Realistic costs have been established.
- (b) Labor intensive areas have been pin-pointed.
- (c) Manpower requirements can now be determined for various production rates.
- (d) Equipment utilization can now be determined for efficient work flow.
- (e) Effective use of labor force can be planned.
- (f) A production line can be planned, utilizing the data from the time study.

(3) Parts Procurement

Late delivery of the stamped or drawn metal parts, previously reported, has been resolved. The three late parts have been received and they are of acceptable quality.

Parts procurement of all items required for pilot production has been initiated by Production Planning. All incoming items will be sent through Incoming Inspection and stored in the factory stockroom.

(4) Test Report

The test report on "Silicon Transcendent Thyristor Confirmatory Samples, RCA Development Type J-15371, Tested to ECOM Spec. No. SCS-477" was completed and submitted 23 March 1978. This completes item No. 0003AB of the contract.

d. Conclusions

The confirmatory sample phase of the contract is complete and RCA is awaiting acceptance of the samples to proceed with the pilot run phase of the contract. Preparations for the pilot production phase are continuing.

e. Drawings

Drawings of the piece parts and sub-assemblies of the device were included in the first Quarterly Report with revisions to these engineering drawings subsequently included in the Second Quarterly Report. Any subsequent revisions will be noted as they occur.

2. Process, Equipment and Tooling

a. Purpose of Each Step

(1) Device Processing and Tooling

Figure 4, Engineering Drawing No. 3025577, in the First Quarterly Report, showed the flow of parts through the various assembly steps and a descriptive title was listed for each operation. Also shown were the sub-assembly drawings and fixture drawing numbers for each operation. In both the First and Second Quarterly Reports, the procedures for using the fixtures were included with a photograph of each fixture. This information continues to be used for the device fabrication and processing.

(2) Electrical and Environmental Test Equipment

The flow chart of the electrical and environmental testing sequence was given in Figure 7, Drawing No. 3025578, of the First Report. The name of the test was given as well as the special conditions and the MIL-STD-750B method number. Long-time tests had the time interval indicated in the figure. This chart remains valid for the program.

b,c. Problem Areas and Work to Resolve Problems

(1) Device Processing and Tooling

Fabrication processes that are known to limit the production quantities are being improved by improving the yields, by increasing the quantity per operation, by reducing the labor required and by more complete documentation of the processes.

(a) Edge Contouring Process Refinement

The wafers from lot #17 were contoured by a vendor selling contouring equipment. The contoured edge was etched and the wafers tested for their blocking voltage capability. None of the wafers were capable of blocking more than a few hundred volts because of excessive chipping along the knife edge of the contour. The vendor was also not able to cut the 5 degrees angle as specified.

For these reasons, the same contouring procedure will be used in the pilot run as was used for contouring the engineering and confirmatory samples.

(b) Tungsten Chemical Vapor Deposition System

The throughput of the tungsten CVD system was upgraded from six wafers to twelve wafers at a time. Problems and their solutions which arose in increasing the capacity of the system were discussed in an earlier section of this report, under "1. "Device", b,c,(1),(a), iv, "Analysis of Cracked Wafers."

(c) Diffusion Process Refinement

A "Ramp-up", "hold", and "ramp-down" controller was purchased for the diffusion furnaces. Having "ramp-up" available in the furnace controller frees an operator for other tasks when wafers are inserted in a furnace. Formerly an operator had to be in constant attendance of the furnace while the furnace was being ramped-up to the diffusion temperature. A timer had previously been installed on the furnaces to start the slow cool or ramp-down.

(d) Vacuum Evaporator Improvements

The delivery of the fixture for the vacuum evaporator has been delayed because the vendor cannot make its height adjustable. RCA has been working with the supplier to correct this deficiency in design by making the height of the evaporant source adjustable. The design is to be finalized during the next month.

(2) Electrical, Thermal and Environmental Test Equip.

(a) Status

All test equipments continued to operate satisfactorily for the evaluation of the confirmatory samples. All of the electrical test equipments were listed in Table 1 of the Second Quarterly Report. In the same report, the tests performed in each equipment were listed in Table 2. Actual test results are listed in Section 5, "Data and Analysis" of this report. Test procedures were included in the Appendices of the Second and Third Quarterly Reports.

Functional block diagrams for each of the test sets were included in Appendix C of the First Quarterly Report. Photographs of the electrical test equipments were included in Figures 3 through 12 of the Third Quarterly Report.

Layouts of the various test equipments were included in the Appendix of the "Report of Test on Silicon Transcendent Thyristor Engineering Samples", dated 15 July 1977 and issued separately.

(b) Test Equipment Calibration Schedules

Electrical test equipment calibration dates were listed in Table 4 of the Fourth Quarterly Report. The schedule established for the recalibration of these equipments on a regular basis was used to recalibrate each equipment in this report period. This call-out occurs automatically at four to six months intervals. The calibration was carried out by the RCA Meter Laboratory Calibration and Standards Department.

Environmental test equipment calibrations in the RCA-Lancaster environmental laboratory are also performed at four to six months intervals. The calibration schedule was listed in Table 5 of the Fourth Quarterly Report.

d. Conclusion

The process, equipment and tooling designed, fabricated and used to fabricate and evaluate the engineering and confirmatory sample devices is now ready for fabricating the pilot production. No process, equipment or tooling limitations are apparent for the pilot production phase.

e. Drawings and Photographs of Tooling and Equipment

Copies of the drawings of the special tools and fixtures were included in the First Quarterly Report along with Block Diagrams of the test equipment. Tools and fixtures that were revised were included in the Second Quarterly Report. Photographs of these items were included in both reports.

Photographs of the electrical test equipment were included in the Third Quarterly Report with text references that described each equipment item. Testing procedures for the electrical test equipment were included in Appendix C of the Second Quarterly Report and in the Appendix of the Third Quarterly Report.

3. Flow Chart of Manufacturing Process Yield

Manufacturing process yields are to be determined during the Pilot Run.

4. Equipment and Tooling Costs

This information will not be included since such a data requirement is generally not applicable to a Firm Fixed Price Contract on equipment and tooling that is purchased and furnished by the contractor for unrestricted use in fabricating the devices required by the contract.

5. Data and Analysis

a. Inspections

(1) Confirmatory Sample Devices

The confirmatory devices were inspected in accordance with paragraph 4.4, using the sampling plan included in this paragraph of SCS-477. The requirements of paragraphs F.48 of the contract and 1.2.6 and 3.1.8 of ECIPPR No. 15 were observed.

The test results on the five confirmatory devices reveal an obvious consistency and reproducibility of most of the electrical and thermal characteristics. The basic device design is thus judged to be adequate. Specific comments, analyses and discussion of the test results are listed below by inspection sub-groups in SCS-477. Refer to Table 1a, b, c and d for both the specification (spec.) and the actual measured values.

b. Discussion of Inspection Results

(1) Forward and Reverse Blocking Currents

Figure 5 illustrates the plot of Forward Blocking Current vs. Case Temperature for the Engineering Samples and the Confirmatory Samples. It should be noted that the confirmatory grouping is tighter than that of the Engineering Samples. Figure 6 further emphasizes this aspect for the Reverse Blocking Current.

(2) Gate Characteristics

Figures 7 and 8 show the superimposed Gate Trigger Current and Voltage for the Engineering and Confirmatory Samples. It should be noted that the five Confirmatory Samples were taken from three different diffusion lots and this should be considered as an increase in the confidence level for production control and reproducibility. The recent gate characteristics data reflects lesser excursions than the earlier data.

(3) Holding Currents at 25°C

This Confirmatory Sample parameter plotted in the bar graphs of Figure 9 averages about 5.5 mA_{dc} with little spread as compared to the Engineering Samples and is well under the 500 mA_{dc} limit for the specification. For some applications of the thyristor, it is desirable to have higher holding currents to minimize the external circuitry used to shut the device off. The limits, therefore, should be maintained so that this value may be increased if desired.

ITEM: SILICON TRANSCALANT THYRISTOR, J15371

CONTRACT: DAA 807-76-C-8120

SPEC: SCS-477 5 DECEMBER 1974 & AMENDMENT - 1 31 AUGUST 1976

MFR: RCA (EO&D) LANCASTER, PA.

BUYER: COMM.SYS.PROCUREMENT BRANCH (USAECOM), FT. MONMOUTH, N.J.

GROUP	A		2		4		3		4			
SUBGROUP	1	2	2	4	4	4	3	3	4	4		
NO. UNITS TESTED	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%		
TEST	Visual & Mech.	Reverse Current	Forward Blocking	Gate Trig. V	Gate Trig. I	Holding Current	Reverse Current	Forward Block'g	Gate Trig. V	Exp. Rate		
MYL-STD-750 METHOD	2071	4211	4206	4221	4221	4201	4211	4206	4221	4231		
TEST CONDITION	Visual	25°C					125°C			25°C		
SYMBOL												
MAX.	-	15mA	15mA	5Vdc	1000mAdc	500mAdc	60mA	60mA	5.0Vdc	100V/μs		
MIN.	-	15mA	15mA	5Vdc	1000mAdc	500mAdc	60mA	60mA	5.0Vdc	100V/μs		
UNIT NO.	A R											
	C E											
	C J											
	1978											
	Date											
	Tested											
F20	✓	0.3mA	0.6mA	0.7V	81mA	5mA	7mA	20mA	0.4Vdc	130V/μs	60μs	1.2 V
F23	✓	0.4	0.5	0.7	65	5	7	9	0.3	145	150	1.2
F26	✓	0.3	0.5	0.7	60	6	4	9	0.4	117	50	1.2
F29	✓	0.4	0.4	0.8	65	6	5	12	0.4	103	80	1.3
F31	✓	0.3	0.4	0.8	65	6	5	9	0.4	115	75	1.2

TABLE 1a Test Data - Confirmatory Samples

Note: Details of test conditions are given in spec.

CONTR'S. TYPE: J15371

DATE TEST COMPLETED:

MFR'S. TYPE: J15371

DATE TEST BEGUN:

FR. TO

1	1. Final Measurements			2			3. Final Meas.			4. Final Measurements			Unit No.
	10%	10%	10%	100%	100%	100%	10%	10%	10%	10%	10%	10%	
Surge Current	Reverse Current	Forward Block'g	Rev. Gate Current	Gate Trig. V	Gate Trig. I	On-state Volt.	Temp. Moist	Cycle & Resist	Blocking per para.	Voltage 4.6.1	Life	Test	
4066.2	4211	4206	4219	4221	4221	4226	1051	1021	4211	4206	4211	4206	(case temp, Tc
> 250C	250C						4211	4206	250C		1250C		
IFM	iRBOM 15mA	iFBOM 15mA	IGR 7.0Adc (pulsed)	VGT 10Vdc	IGT 1500 mAdc	VFM 2.3V	iRBOM 15mA	iFBOM 15mA	iRBOM 15mA	iFBOM 15mA	iRBOM 60mA	iFBOM 60mA	
10 Surges													
Δ	Δ	Δ	Δ	1.0Vdc	160mAdc	0.9V	Δ	Δ	Δ	Δ	Δ	Δ	F20
Δ	Δ	Δ	Δ	0.9	82	0.9	Δ	Δ	0.2mA	0.4mA	5mA	1.2mA	F23
>4,000A	0.4mA	0.5mA	0.5Adc	0.9	120	0.8	0.2mA	0.3mA	Δ	Δ	Δ	Δ	F26
Δ	Δ	Δ	Δ	1.0	125	0.8	Δ	Δ	Δ	Δ	Δ	Δ	F29
Δ	Δ	Δ	Δ	1.1	130	1.2	Δ	Δ	Δ	Δ	Δ	Δ	F31

TABLE 1b - Test Data - Confirmatory Samples

Δ Conformance Verified by 20% Sample.

UNIT NO.	3. Final Measurements			4. Final Measurements			5	Prior Grp, B, SG2	Heat-Pipe Isothermal	
	10% Reduced Barometric Pressure	10% Salt Atmosphere	10% Thermal Fatig.	10% Salt Atmosphere	10% Thermal Fatig.	10% Thermal Resistance				100% Thermal Resistance
	1001			1041 para. 4.6.2			3151	100% 3151	100% ---	
	4211	4206 4221 4221	4226 4221 4221	4206 4221 4221	4221 4221 4221	4226 4221 4221	4226	100% 3151	100% ---	
	1RBOM 20mA	1FBOM 20mA 5Vdc 1000mAdc	VFM 2.5V 1000mAdc	1RBOM 20mA 5Vdc 1000mAdc	IGT 1000mAdc	VFM 2.5V 1000mAdc	VFM 2.5V 1000mAdc	0J-C 0.15°C/Matt	AT	
								(FINAL)	(INITIAL)	
F20	Δ	Δ	Δ	0.5mA	0.6mA 0.7Vdc 90mAdc	1.1V	1.1V	0.07°C/Matt	0.10°C/Matt	30C
F23	Δ	Δ	Δ	(Salt Atmosphere Test)		Δ	Δ	0.12	0.14	5
F26	Δ	Δ	Δ			Δ	Δ	0.10	0.10	3
F29	0.4mA	0.4mA 0.8Vdc 68mAdc	1.3V	0.2	0.2 0.7 75	1.2	1.2	0.11	0.07	3
F31	Δ	Δ	Δ	(Thermal Fatigue Test)		Δ	Δ	0.10	0.14	4

Conformance Verified by 20% Sample TABLE 1d - Test Data - Confirmatory Samples

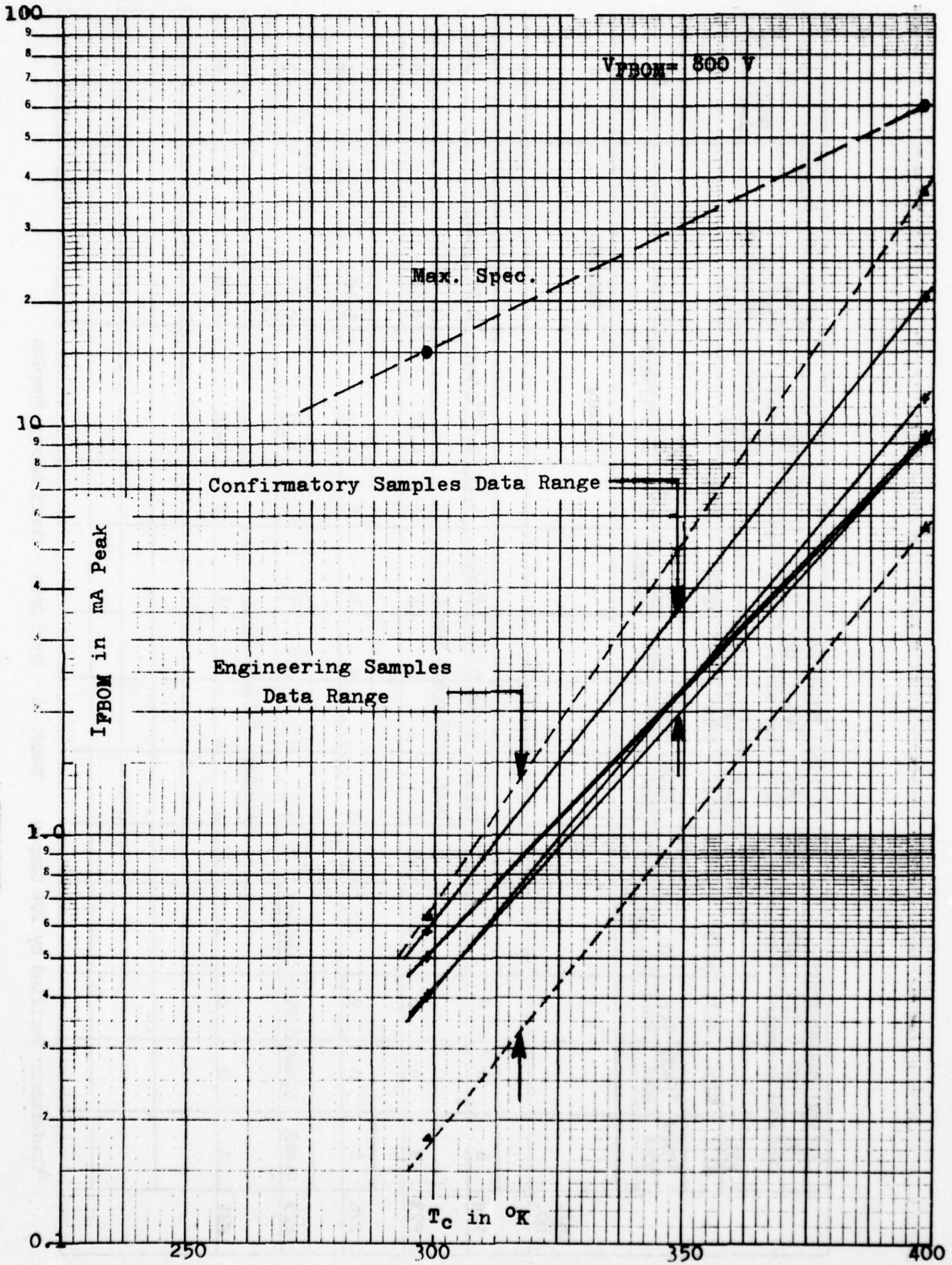


Fig. 5 Forward Blocking Current vs. Case Temperature

KOE
1-LOK HMIC 165
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

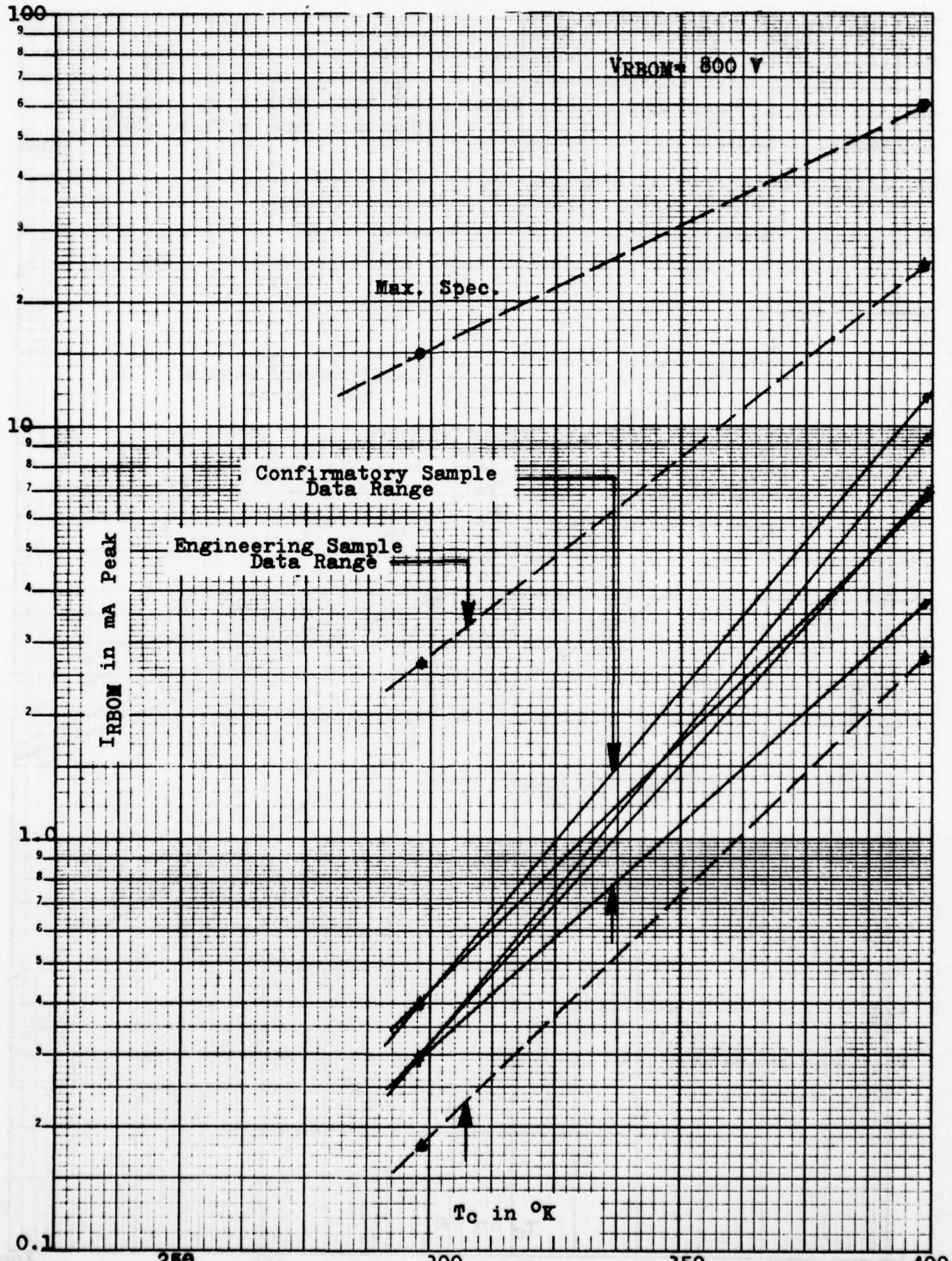


Fig. 6 Reverse Blocking Current vs. Case Temperature

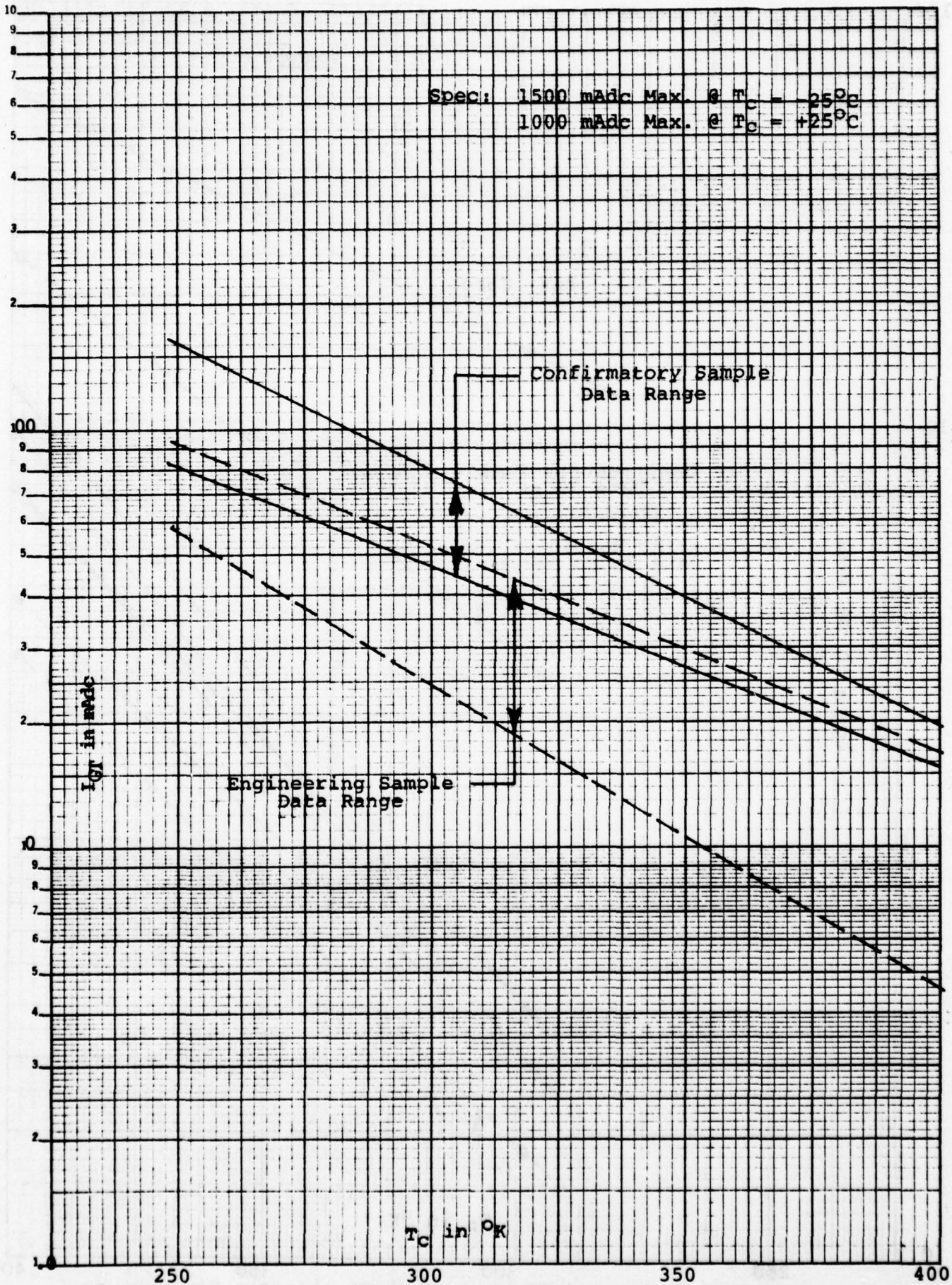


Fig. 7 Gate Trigger Current vs. Case Temperature
 36

K_oZ SEMI-CONDUCTORS 351 ST. NEUFEL & ESSER CO. VALLEY, PA. 2 CYCLES TO DIVISIONS

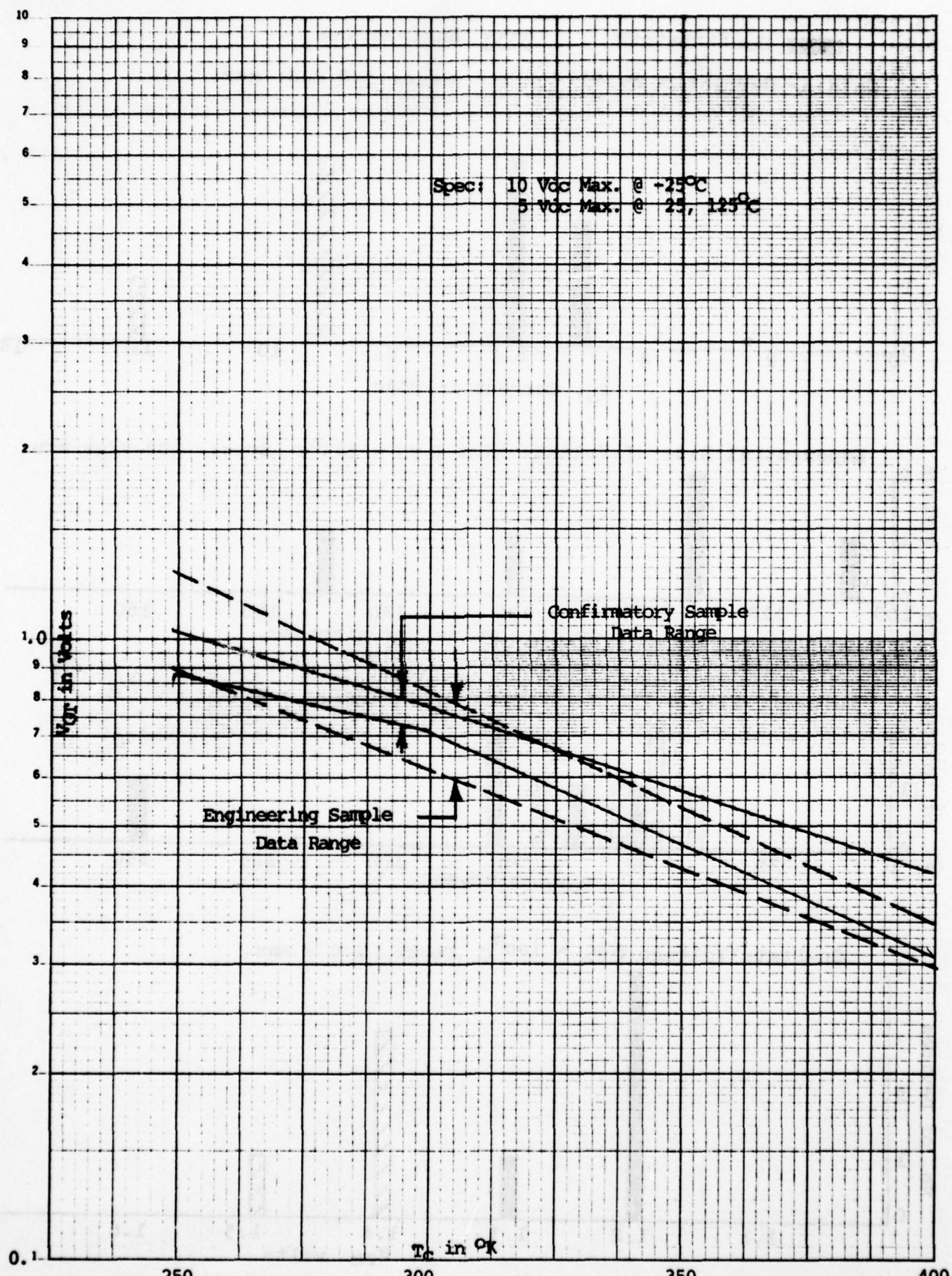


Fig. 8 Gate Trigger Voltage vs. Case Temperature

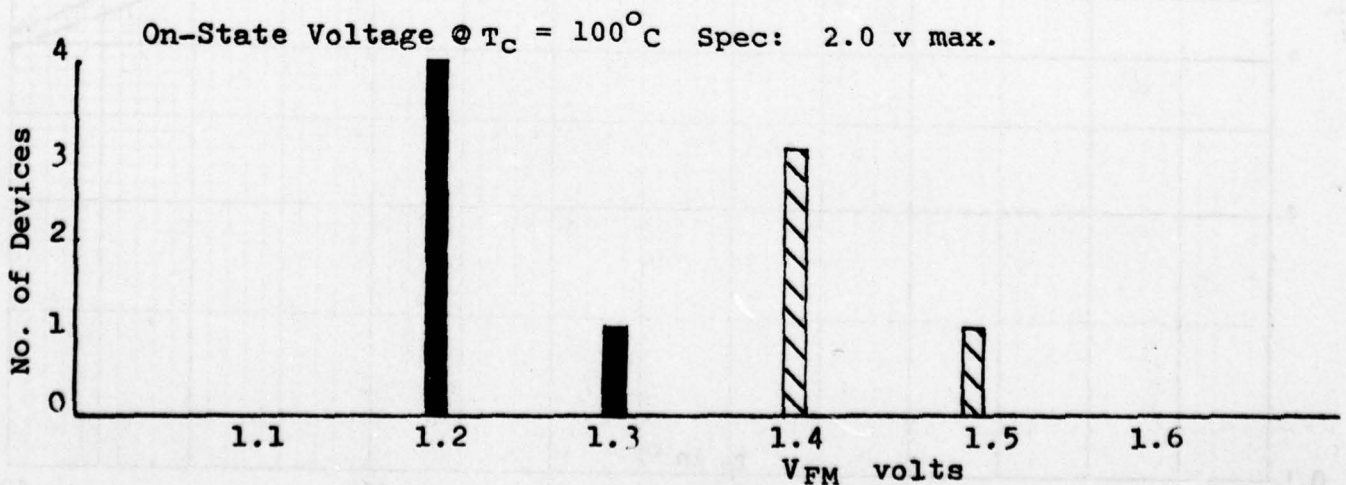
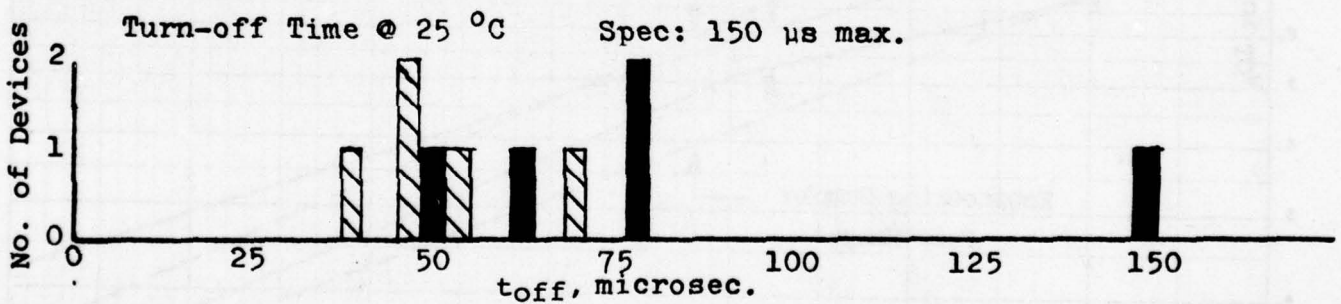
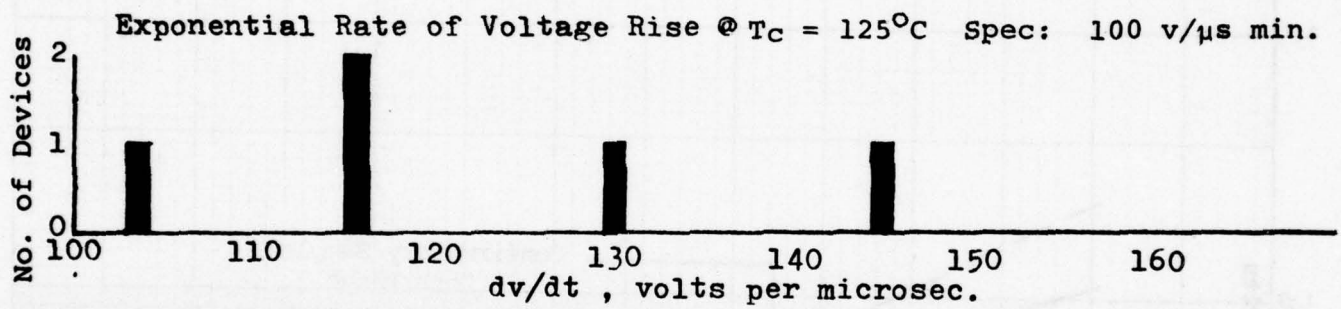
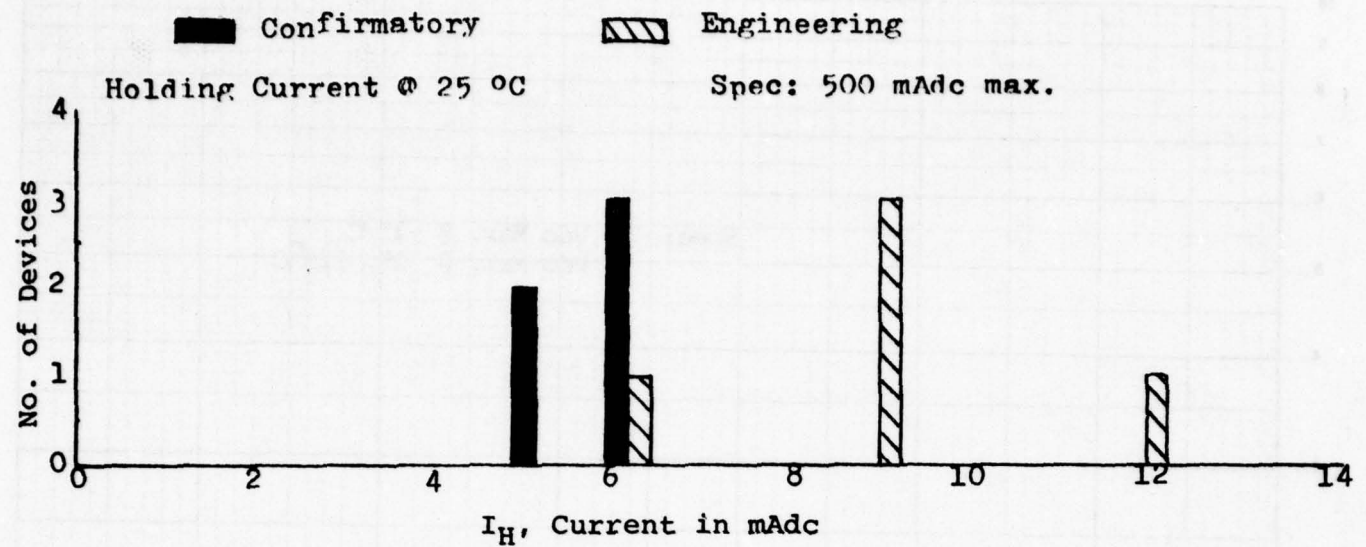


Fig. 9 Confirmatory/Engineering Tests

(4) Dynamic Tests

The bar graphs of Figure 9 also show the test results of the Exponential Rate of Voltage Rise, Turn-Off Time and the On-State Voltage Measurements. The conditions imposed on the device for the Exponential Rate of Voltage Rise were derived from Modification P00003 or Specification SCS-477. With these more realistic conditions, the results were above the required 100 volts per microsecond. The distributions might be explained by the high rate of change of this parameter at elevated temperatures as well as by the variations in I_{GT} . The stability and the measurement of temperature become critical if data is to be repeated with high precision.

The Turn-Off Time, Fig. 9, of the Confirmatory Sample devices was nearly the same as that of the Engineering Samples with the exception of one data point. In training personnel to use this complex equipment, a test limit was imposed and the test conditions were adjusted to this to determine if a device was acceptable. It is felt that no attempt was made to evaluate the minimum Turn-Off Time for this one device and, hence, resulted in a maximum limit reading. Since the data point was within limits, it was not questioned when reviewed initially.

The On-State Voltage average at 100°C case temperature has decreased as shown in the final bar graph of Figure 9. This is desirable from the standpoint of a lower operating junction temperature and the ability to withstand surge currents.

(5) Surge Current

Thyristor No. F26 was the sample subjected to the Surge Current Test consisting of a one-half sine-wave forward current surge at 4000 to 4200 amperes peak. On the next one-half cycle (the negative half or reverse voltage cycle), an 800 volts peak one-half sine wave is applied to the device being tested to confirm that it is capable of blocking the reverse voltage immediately following a surge of current. This was repeated at one minute intervals for ten surges. At the time of test, a time constant adjustment was required since instead of one voltage pulse, two were actually applied to the device after each surge. This represented only a slight increase in the severity of the test. However, this malfunction of the equipment will be corrected for the devices of the Pilot Run. Final measurements show the F26 characteristics were unchanged by the more severe test. Included in the final measurements is a pulsed reverse gate current measurement of 0.5 peak amperes at 5.0 volts.

(6) Reduced Temperature Tests

All devices were tested for gate trigger characteristics and on-state voltage at a case temperature of 25°C below zero (248°K). The gate trigger characteristics are shown in the graphs of Figures 7 and 8.

Thermal impedance measurements were recorded prior to this test and then immediately after or after the major sampling tests where applicable. Figure 10 illustrates these results in bar graph form, again showing the Engineering Sample data and the Confirmatory Sample results both before and after the reduced temperature tests. Thermal resistance showed only a slight shift downward after the 25°C below zero test.

(7) Heat-Pipe Isothermal Tests

During the on-state voltage test at 250 amps average, both heat-pipes were checked for isothermal characteristics. The measurement was taken on the downstream side of the air flow between the fins. If the heat-pipes are functioning, the maximum temperature differential across the pipe should be no more than 8°C for the operating conditions specified. The average excursion for the cathode heat-pipe was 2°C and for the anode was 4°C. The latter, higher figure was used in the final column of the data sheet.

(8) Physical Dimensions

Figures 11 and 12 show the results of physical dimensions of the Confirmatory Samples along with the Engineering Samples for statistical purposes. Dimensions A, B, C and D form a distribution that appears to be within a manufacturing control tolerance. Dimension E is the lead length and is specified over 6.00 inches. This is a non-critical dimension and is included in the data sheet for reference only.

(9) Temperature Cycle and Moisture Resistance

Thyristor No. F26 began the moisture resistance test on 3 March 1978, according to MIL-Std-202, Method 106. The test was completed ten days later with little effect on the exterior appearance of the device. Temperature cycling began at that point according to MIL-Std-202, Method 107C except that the low extreme was 25°C below zero. The device was subjected to five cycles of one hour at 25°C below zero, five minutes at room temperature, one hour at 150°C and finally, five minutes at room temperature. Final measurements were satisfactory including a thermal resistance measurement which remained unchanged from the initial measurement.

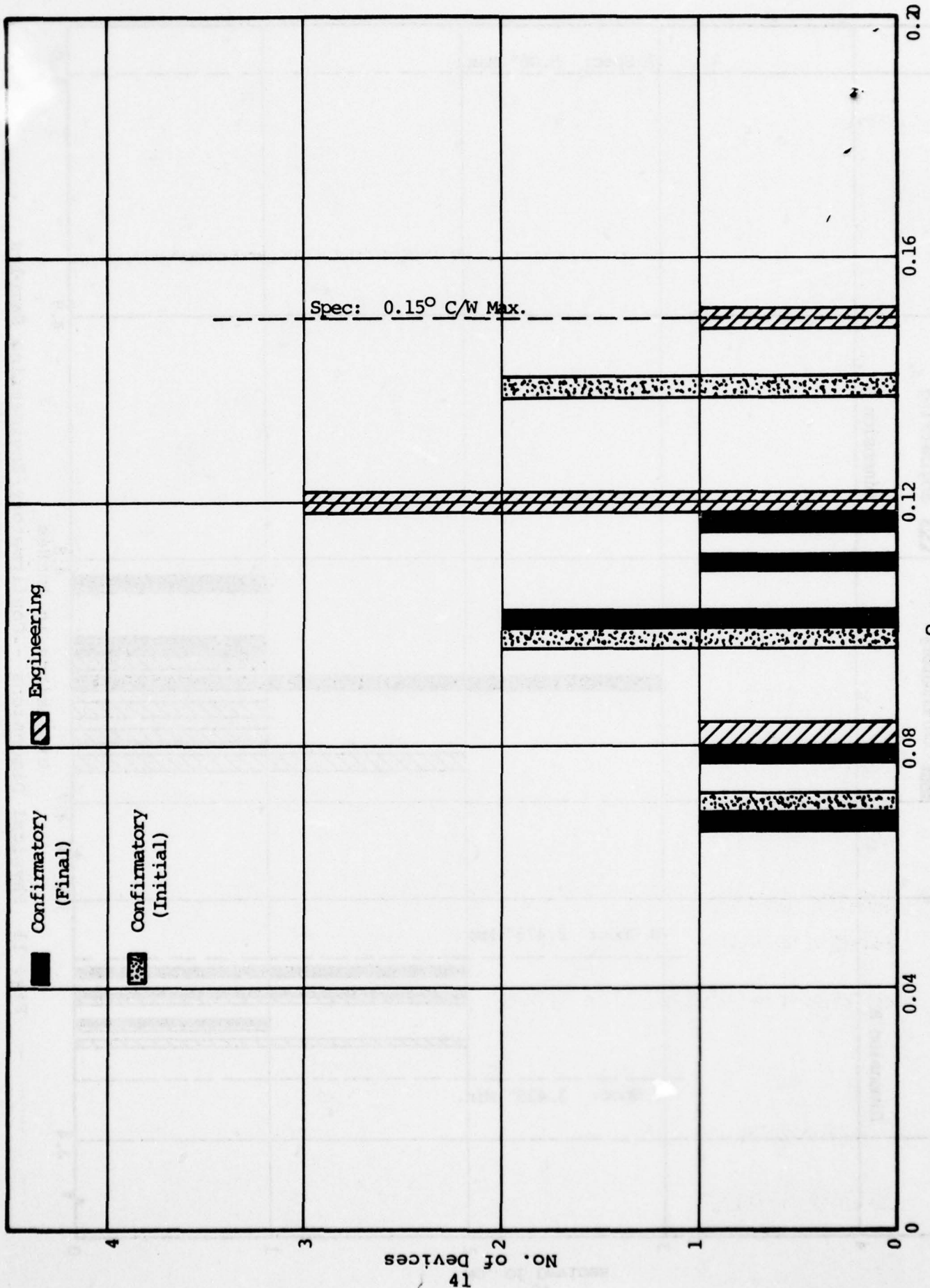


Fig. 10 Thermal Resistance @ $I_F = 250$ Adc

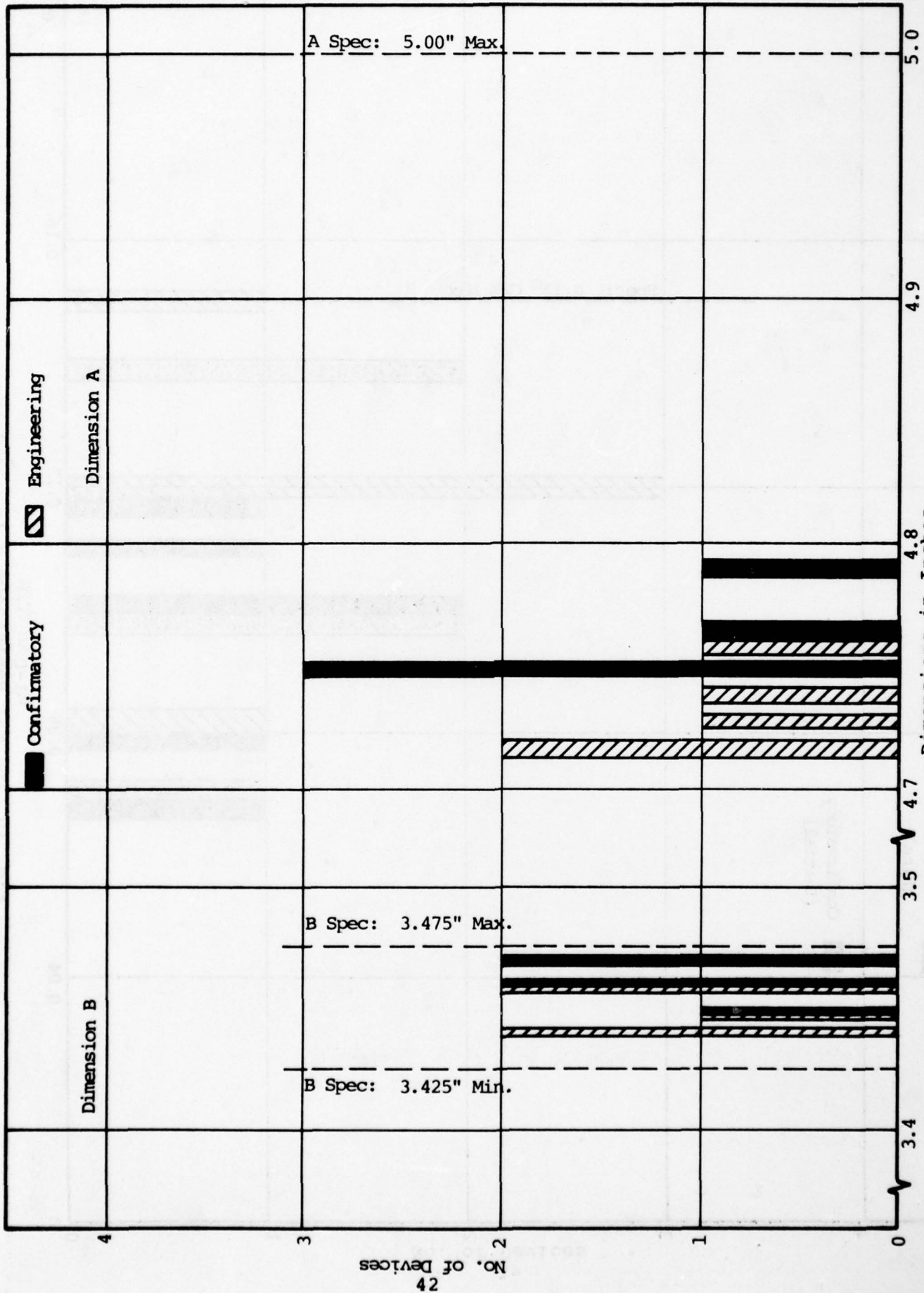


Fig. 11 Physical Dimensions - Confirmatory/Engineering Samples

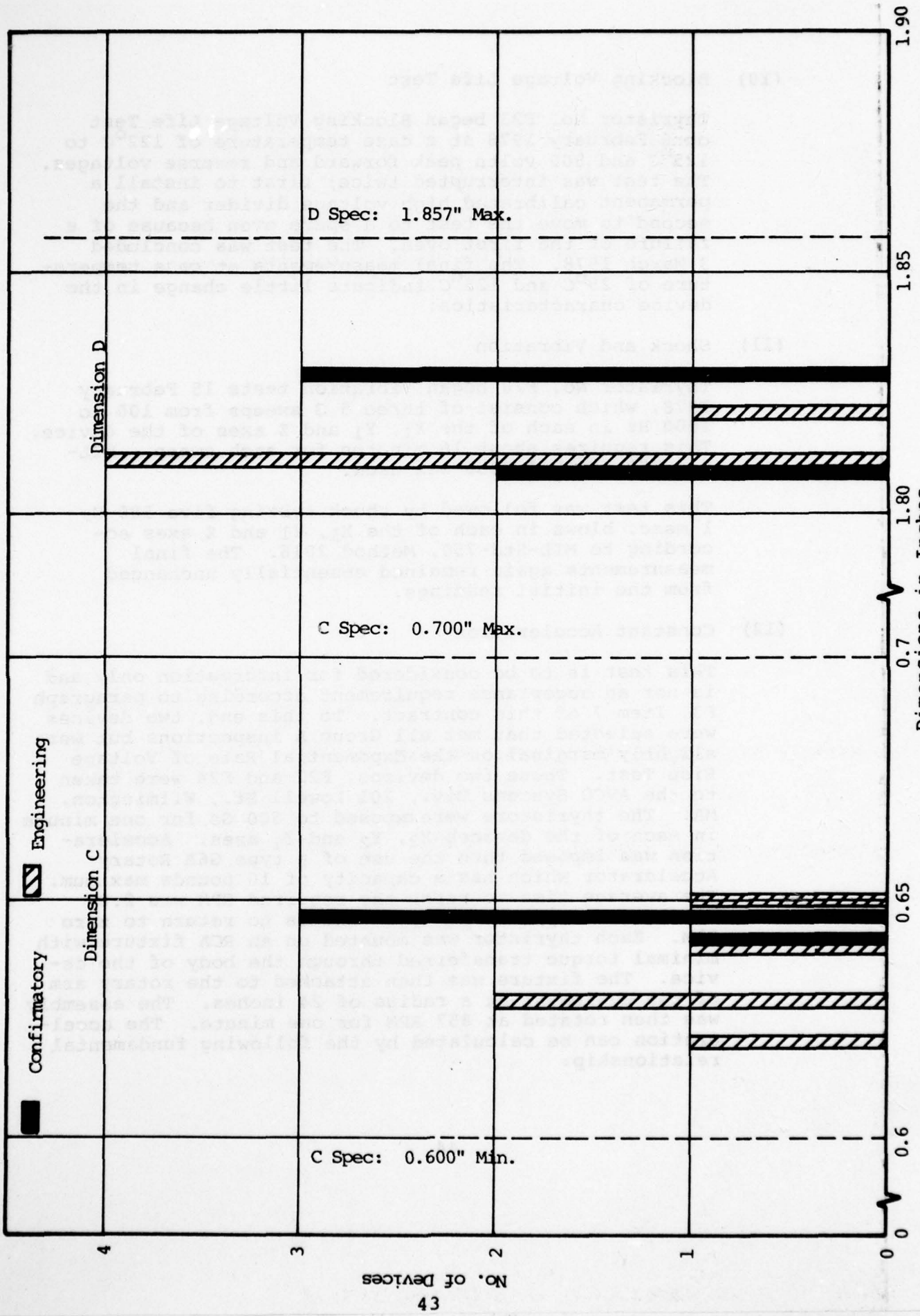


Fig. 12 Physical Dimensions - Confirmatory/Engineering Samples

(10) Blocking Voltage Life Test

Thyristor No. F23 began Blocking Voltage Life Test on 8 February 1978 at a case temperature of 122°C to 125°C and 800 volts peak forward and reverse voltages. The test was interrupted twice; first to install a permanent calibrated high voltage divider and the second to move the test to a spare oven because of a failure of the first oven. The test was concluded 3 March 1978. The final measurements at case temperature of 25°C and 125°C indicate little change in the device characteristics.

(11) Shock and Vibration

Thyristor No. F20 began vibration tests 15 February 1978, which consist of three 5 G sweeps from 100 to 1000 Hz in each of the X₁, Y₁ and Z axes of the device. This requires about 16 minutes for each sweep. MIL-Std-750, Method 2056 was used.

This test was followed by shock testing five 500 G, 1 msec. blows in each of the X₁, Y₁ and Z axes according to MIL-Std-750, Method 2016. The final measurements again remained essentially unchanged from the initial readings.

(12) Constant Acceleration

This test is to be considered for information only and is not an acceptance requirement according to paragraph F3, Item 7 of this contract. To this end, two devices were selected that met all Group A inspections but were slightly marginal on the Exponential Rate of Voltage Rise Test. These two devices, F22 and F24 were taken to the AVCO Systems Div., 201 Lowell St., Wilmington, MA. The thyristors were exposed to 500 Gs for one minute in each of the device's X₂, Y₂ and Z₁ axes. Acceleration was imposed thru the use of a type G6A Rotary Accelerator which has a capacity of 10 pounds maximum. The average time to reach the required RPM was 2.8 minutes and approximately 2 minutes to return to zero RPM. Each thyristor was mounted on an RCA fixture with minimal torque transferred through the body of the device. The fixture was then attached to the rotary arm of the equipment at a radius of 24 inches. The assembly was then rotated at 857 RPM for one minute. The acceleration can be calculated by the following fundamental relationship:

$a = rW^2$
 where a = the normal component of radial acceleration, ft./sec.²
 r = the radius of mass, in ft.
 W = radial velocity, Rad/sec.

$$a = (2 \text{ ft.}) \frac{857 \text{ Rev.}}{\text{Min.}} \cdot \frac{\text{min.}}{60 \text{ sec}} \cdot \frac{2\pi \text{ Rad.}}{\text{Rev.}}^2$$

$$a = 16108 \text{ ft/sec.}^2$$

or $G_{\text{Force}} = \frac{16108 \text{ ft/sec.}^2}{32.2 \text{ ft/sec.}^2} = 500.3 \text{ Gs}$

The test was repeated for each of the other two axes. Visual inspection after the test did not reveal any physical damage, however, electrical tests disclosed that F22 had shorted and, therefore, failed the test. On the other hand, F24 showed no change from its initial electrical characteristic.

The results of this test are consistent with those of an earlier test reported on page 54 of the Fourth Quarterly Report of this contract. A 50% survival rate for this stringent test seems the norm.

(13) Reduced Barometric Pressure Test

Thyristor No. F29 was mounted in a vacuum bell jar for the Reduced Barometric Pressure Test. After correcting some insulation problems associated with the high-voltage feed-through connectors, the device operated for one minute at 15 mm of Hg with 800 peak volts forward and reverse. The bell was shielded from ambient light and no corona was visible. An oscilloscope was used to further verify the absence of corona. The initial and final measurements were similar. No changes occurred to the external surfaces of the device.

(14) Salt Atmosphere Test

The Salt Atmosphere Test was performed on thyristor No. F20 at the RCA facility located in Camden, NJ. The length of the test was 24 hours as per MIL-Std-750, Method 1041.1. At the conclusion of the test, the device was washed in the manner allowed. Careful examination disclosed a minor white corrosion product on the axially aligned studs. Additionally, a brown corrosive residue appeared on the Kovar and cold rolled steel stamped parts surrounding the wafer. The steel part covered with the conformal coating showed no corrosive products at all. These corrosive products are

of a minor nature and did not affect performance by evidence of the final measurements. This thyristor was not further cleaned and was immediately packed, as is, for shipment.

It should be noted also that thyristor F26 was not cleaned for cosmetic purposes after the moisture resistance test and was also packed for shipment after final testing.

(15) Thermal Fatigue Test

Thyristor No. F29 was installed in this test equipment on March 7, 1978. The test equipment is designed to automatically turn the device off and on according to the requirements of paragraph 4.6.2 of SCS-477. A strip-chart temperature measuring recorder was used to verify the temperature excursions and the number of cycles. After 208 cycles, only the gate trigger current showed a slight increase. All other final measurements remained essentially the same.

c. Corrective Action

The corrective actions taken during the last month of the fifth quarter and the first month of this sixth quarter has made it possible to produce the confirmatory device samples according to the PERT schedule. It is now felt that of all actions taken, improvements at metallizing reduced the wafer cracking and voltage degradation that occurred during the initial testing of the confirmatory samples.

Control was gained over the dv/dt and gate characteristics of the thyristor by adjusting the cathode diffusion depth and by eliminating pin holes in the oxide layer. With these parameters under control and by eliminating furnace cross-contamination, yields of wafers into devices have been markedly improved. RCA feels confident in starting the pilot phase of the contract.

6. Specification

There are no further modifications of the specifications of SCS-477. RCA feels confident that the Transcendent thyristors fabricated during the pilot run phase of the contract will meet all of the requirements of the specification.

7. Requirement for Pilot Run

With the shipment of the confirmatory samples, a request was made to start the pilot run phase of the contract. Parts are on hand to start the pilot run when the approval is received.

8. Total Cost for Pilot Run

Data not available until the pilot run is completed.

9. Program Review

The PERT Chart revision submitted 29 August 1977 remains in effect showing the pilot run to start mid-April.

CONCLUSIONS

Effort expended in the sixth contract quarter was successful in completing the five Confirmatory Samples. Verification that the design meets all of the specifications adds assurance that the Pilot Run phase should also be successful. All of the problems identified in this report responded to the corrective action taken. RCA is thus confident of meeting the full MM&TE specification requirements for the Pilot Run devices. The improved wafers and packaging which was demonstrated in fabricating the Confirmatory Samples will be continued for the Pilot Run phase of the contract.

The program is proceeding in accordance with the revised PERT Chart, dated 29 August 1977.

PROGRAM FOR THE NEXT QUARTER

1. Issue the monthly reports, as required by DD 1423.
2. Prepare and issue the Preliminary Pilot Run Report.
3. Prepare for the Demonstration of Pilot Line production rate.
4. Fabricate the Pilot Run devices following government authorization.

IDENTIFICATION OF PERSONNEL

The professional and skilled technical personnel who actually worked on the MM&TE project during the first six quarters of the contract had varied backgrounds, as listed in the biographical resumes included in the previous Quarterly Reports. Two additional resumes are included in this report for added personnel assigned to the project in the sixth quarter.

In addition to the major responsibilities, above, numerous supporting personnel including managers, secretaries, purchasing agents, environmental technicians, machinists, electricians, experimental tube builders, etc., have contributed to the progress made in the first eighteen months of the contract.

R. C. Bauder - Member, Technical Staff, Environmental Laboratory

Mr. Bauder received the B.S. in Physics from Muhlenberg College in 1961. He then attended Franklin and Marshall College and received M.S. in Engineering and Science from Penn State University in 1969. Mr. Bauder joined the Special Equipment Design group at RCA Lancaster in 1962 and worked on the design of microwave test equipment for small and medium power tubes. From 1965 to 1968, he worked in Color Tube production. The major assignments were the development of automated phosphor screening processes and the reclamation of phosphors from waste water. Since 1968, he has worked in Environmental Engineering where his primary responsibilities have been in stress analysis and the development of computer-aided structural design programs. He has published several reports on the NMODES method of predicting the dynamic behavior of structures.

Lloyd B. Denlinger, Laboratory Technician, Developmental Processes

Mr. Denlinger started working at RCA in 1950 as a luminescent technician, in the manufacture of black and white kinescope phosphors. This assignment was followed by one for the manufacture of the color picture tube phosphors: red, blue and green.

In 1958 he was transferred to the Chemical and Physical Laboratory where he worked on Electro-Luminescent phosphors. In 1963, there was a reassignment in the same lab after which Mr. Denlinger worked with the chemical cleaning of metals and also with the electroplating of various metals.

He successfully completed a correspondence course in electroplating from the Joseph B. Kushner electroplating school and has had many years of experience under the direction of engineers and scientific specialists in the power products finishing operations. His latest assignment involves the chemical processing of silicon wafers for Transcalent devices.

DISTRIBUTION LIST

The following pages include the distribution list supplied by the contracting officer with the approval letter for the First Quarterly Report as well as the additions authorized subsequently.

This list was utilized also for the distribution of the Second, Third, Fourth and Fifth Quarterly Reports.

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