AD-A167 757 VERTICAL JUNCTION SOLAR CELLS(U) SOLAREX CORP GAITHERSBURG MD AEROSPACE DIV 20 DEC 85 N00014-83-C-2340 1/1

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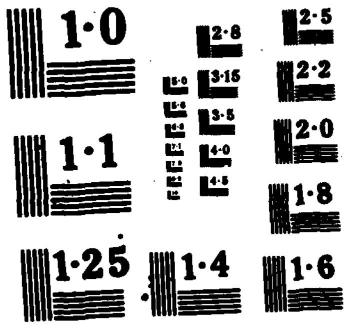
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FINAL REPORT

TASK 2

VERTICAL JUNCTION SOLAR CELLS

NRL NO. N00014-83-C-2340

TO

NAVAL RESEARCH LABORATORY

DECEMBER 20, 1985

BY

SOLAREX AEROSPACE DIVISION
201 PERRY PARKWAY
GAITHERSBURG, MD 20877
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Scope:

The goal of this program was to develop and evaluate an acceptable coversliding technology for vertical junction solar cells.

The technical program was divided into the following sub-tasks:

1.0 to fabricate 80 vertical junction cells of most recent configuration for evaluation as individual samples and for test module assembly,

2.1 to develop a satisfactory method for coversliding V.J. cells to withstand deep thermal cycle in space, Both a conventional adhesive such as DC 93-500 and new adhesives such as phenyl methyl silicon polymer would be used. Covered cells will be cycled a minimum of 50 cycles (-115°C to +125°C) as an evaluation.

2.2 to establish welding parameters for V.J. cells and evaluate their weldability,

3.0 Using techniques from 2.1 and 2.2 four modules (4 cell each) to be fabricated and thermal cycled in dry nitrogen (-115°C to +125°C 25 cycles) and thermal vacuum tested at 135°C. Two of the modules to have soldered interconnects and to have welded interconnects.

4.0 Based on results of Tasks 2 and 3, two six cell modules to be designed: 1 soldered, 1 welded, Design to be discussed with COTR prior to finalization.

5.0 Final design to be fabricated subjected to a thermal vacuum test at +135°C, thermal cycled -115°C to +125°C, and characterized by I-V measurements and delivered to NRL for testing and evaluation. One soldered and one welded.

Cell Fabrication

Cell fabrication was started after an initial delay of approximately 3 months due to the silicon suppliers' schedules. Once started, the cell fabrication effort experienced only one setback: defective photoresist caused a loss of resolution and a consequent loss of control over the wall/groove geometry. This was easily corrected with a new batch of resist and the cells were completed without any further problems.

Twenty of the cells produced were set aside for delivery. Their I-V characteristics are presented in Appendix A.

Coversliding

Technologies:

After initial trials, three methods were chosen for this study:

All cells and coverslides are cleaned with Acetone and Isopropanol before encapsulating.

1. Place cell at 45° angle and apply encapsulant to top of cell.

   Allow encapsulant to cover cell naturally, place coverslide on cell from bottom to top.

   Place in vacuum chamber for 4 minutes at 28 in. Hg.

   Remove bubbles and align coverslide using microscope.

   Place on hotplate at 150°C for 5 min.

   Place in oven at 130°C for 25 min.

2. Place coverslide at 45° angle and apply encapsulant to top of coverslide.

   Allow encapsulant to cover coverslide naturally.

   Place in vacuum chamber for 2 minutes at 28 in. Hg.

   Place on hotplate at 150°C for 1-2 minutes until tacky.

   With coverslide at 45° angle place cell over coverglass from bottom to top.

   Remove any bubbles and align coverslide under scope.

   Place on hotplate for 5 minutes at 150°C.

   Place in oven at 130°C for 25 minutes.

3. Place coverslide in encapsulant jig, apply a thin layer of encapsulant using a squeegee.

   Place in vacuum chamber for 2 minutes at 28 in. Hg.

With coverslide at 45° angle apply cell from bottom to top.

Place in vacuum chamber for 2 minutes.

Align coverslide and remove bubbles under scope.

Place on hotplate at 150°C for 5 minutes.

Place in oven at 130°C for 25 minutes.

*After encapsulating all cells are cleaned with Isopropanol and any excess encapsulant is removed.

After evaluating the results, method three seemed to work the best. In this method a thin layer of encapsulant is spread onto a coverslide which is then placed on the cell. Few bubbles remain after curing and the electrical properties remained unchanged. However, after extensive thermal cycling, cells covered using method three showed a large amount of delamination. Method two worked the worst, with the major difficulty being the removal of bubbles. With method one bubbles were easily removed, however, the thicker layer of encapsulant appears to cause some damage to the electrical properties of the cell.

No electrical degradation occured using method one for the final two encapsulants selected. Therefore, method one was used for test and final panel assembly.

<u>Encapsulants</u>:

The five encapsulants initially tested were:

Dow Corning	3-6527
Dow Corning	93-500
McGhan NuSil	CV-2500
McGhan NuSil	CV-2501
McGhan NuSil	CV-2567

Of the five encapsulants tested DC 3-6527 and MN CV-2567 worked the best. However, MN CV-2567 has a one hour cure time at room temperature, and has a workable time of 15 minutes or less. Also, due to the viscosity of the prepared encapsulant, bubbles cannot be removed in the vacuum chamber. DC 3-6527, which worked the best, had none of these problems and is easily applied. The three remaining encapsulants, DC 93-500, MN CV-2500 and MN CV-2501, fared poorly after thermal cycling. However, all three have acceptable working times and bubbles were removed without much trouble.

The manufacturers data sheets are included as Appendix B.

Thermal Cycling:

A thermal cycling apparatus was constructed to meet the requirements of this study. It is composed of 2 chambers: one cooled by hollow walls filled with liquid nitrogen and another heated by resistance heated panels. The samples are moved between these two chambers by a chain and pulley arrangement. The actual sample temperature measurements and the transport motor control is performed by an Apple II and computer with an Omega White-Box Data Acquisition unit.

The V.J. cells were cycled 50 times with a temperature range of 125°C to -115°C. Electrical tests were conducted after one, five, and fifty cycles. Few cells showed adverse effects after one cycle. After five cycles electrical properties began to drop, with most degradation occuring in cells with DC 93-500, MN CV-2500, and MN CV-2501 encapsulants.

A preliminary evaluation of the data indicated that DC 3-6527 was the probable choice. At this time the Sales representaive for Dow Corning was consulted to determine the suitability of the material for the space environment. After further consultation on his part, he recommended that we include DC-Q3-6575 in the experiment. The basis for this recommendation is the better environmental suitability of this particular formulation. Dow Corning has submitted samples to NASA-Goddard for further evaluation on this issue. A group of V.J.'s was encapsulated with this material and thermal cycled under identical conditions as the previous groups.

Planar cells were included along with V.J.'s in the last set of encapsulant evaluations to demonstrate that the observed electrical failure occurs only in V.J.'s due to breakage of their fragile walls and not by a degradation of the optical properties of the encapsulant. No changes were observed in the covered planar cells.

The encapsulants chosen for the experimental panels were DC-3-6527 and DC-Q3-6575 based upon their ease of application and minimal degradation upon thermal cycling.

Panel Fabrication

Weld Schedule Development:

Nineteen voltage/duration combinations were used on the Hughes welder to develop the final combination. Planar cells were used initially to avoid wasting the finished V.J. cells.

A voltage range of 55 to 70 welds with duration ranging from 70 to 220 milliseconds were used. I-V curves were drawn before and after welding. Welds were pulled using a Unitek tab pull tester to determine the weld strength. Results indicated that 70 volts and a duration of 80 ms. produced the strongest welds with the least cell degradation.

The completion of this phase was delayed approximately 8 weeks while the welder was returned to the manufacturer for repairs to its power supply.

The Panel Assembly

The 4 test panels were assembled using 3"x4"x1/2" substrates supplied by NRL. The dielectric layer was already laminated to the front surface and the substrates were ready for the laying down of the cell strings.

The cells were assembled into 4 modules of 4 cells each. Of the 4 modules 2 used the DC-3-6527 coverslide adhesive and 2 used the DC-Q3-6575 adhesive. In the 2 groups of 2 modules, one of each was a soldered module and one of each was welded.

Welding to the backs of the VJ cells proved to be nearly impossible because the amount of electrode pressure needed to produce a good welded joint was more than sufficient pressure to cause the breakage of the groove walls on the front side of the cell. The modules with the welded fronts were assembled with soldered back contacts. This was not considered to be of major importance because in our experience the main failure point for thermal cycled interconnects is on the front contact.

Solder was used to connect the mesh to the panel busses and the panel busses to their leads.

The cell string was attached to its substrate using DC 93-500. A thin layer of the adhesive was used to prevent any excess adhesive from adhering to and interfering with the mesh interconnect. The module was then placed inside a vacuum bag at 150°C for 15 minutes to cure the DC 93-500.

Test Panel Thermal Cycling

The test panels were cycled for 25 cycles using the same test parameters as the covered cells. No electrical degradation was observed (see Data Appendix D). No visible changes occured other than a yellowing of the dielectric layer on the panel substrates.

Final Panel Assembly

After consultation with COTR, the decision was made to produce both the final panels with DC-Q3-6575 one welded and one soldered.

The final panels received the same thermal cycling regimen as the test panels with 2 exceptions: during one cycle the low temperature dropped to approximately -160°C and the maximum temperature rose to approximately +150°C. This was due to a controller problem and was corrected immediately.

The final panels also received a 4 hour thermal vacuum soak at $\leq 1 \times 10^{-5}$ torr and 135°C +5°C, -0°C. This was performed in a diffusion pumped vacuum chamber with the pressure monitored by an ionization gauge. The heating was supplied by tungsten halogen lamps and measured by a thermocouple in contact with one of the panels. The heat was controlled by switching the lamps to maintain the temperature between 135°C and 140°C.

After these tests no visible degradation was seen with the exception of some discoloration of the panels' dielectric material after heating. There were no observable changes of the covered cells or the interconnections.

Both panels exhibited an approximate 4% decrease in peak power after thermal cycling with no further degradation from the thermal vacuum test (see data in Appendix E).

Conclusions:

The data presented in this report shows an alternate coversliding technique now exists which does not cause drastic mechanical and electrical damage to the cell when thermal cycled between -115°C and +125°C.

This alternate technique utilizes a new unqualified material which will require additional testing and qualification before it can be considered flight-ready. But the evidence remains that the Vertical Junction cell can be coverslid and it can survive a good, representational thermal cycling regimen.

Summary

Previous programs have shown the Vertical Junction cell to have increased radiation resistance over planar silicon cell technologies. Until the present, however, this radiation resistance could not be utilized because of the difficulties incurred when conventional coversliding technologies were applied. Their testing in a simulated space environment invariably resulted in major mechanical damage to the delicate wall structure of these devices. This damage was caused at low temperatures by the encapsulation material in the grooves between the walls - a problem severe enough to preclude their consideration for any flight use.

The present program has evaluated several encapsulant materials, identified three as potential candidates, and verified that two of these are capable of performing well under conditions simulating actual mission parameters. The data obtained from environmental testing indicates that the Vertical Junction cell can withstand these extreme temperature cycles when the proper encapsulant is used.

In short, the Vertical Junction cell has been proven to have excellent electrical performance with exceptional radiation resistance. Now, it can also be encapsulated and survive environmental testing.

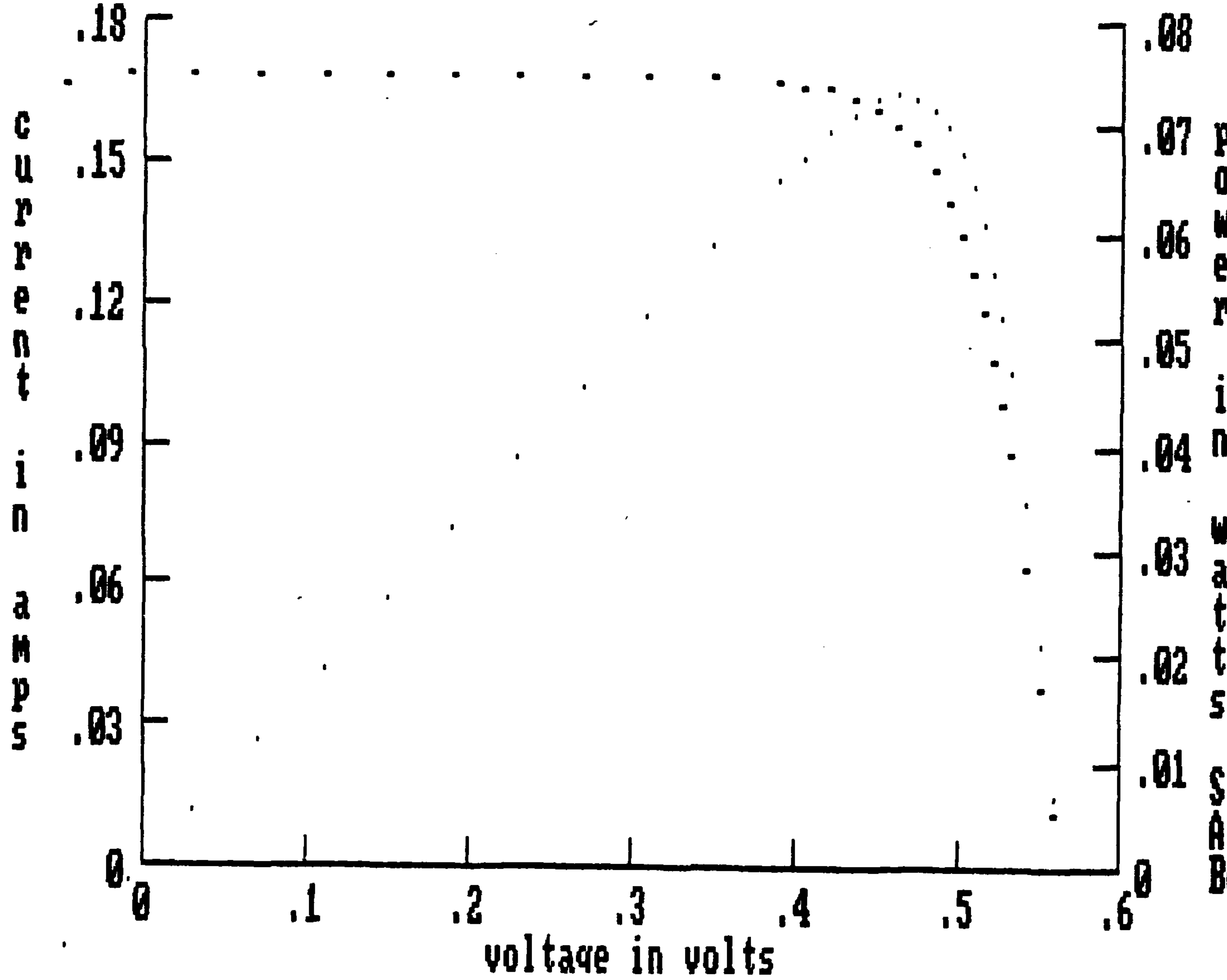
Future research programs on Vertical Junction cells should include actual flight testing of the covered cell under typical orbital conditions. Ideally, such a program would be large enough to do under actual manufacturing conditions. This would permit process optimization and result in increases in cell performance, uniformity and yield - very important considerations in a process which has, in the past, only been done in a laboratory setting.

Additional work will be required to qualify DC 93 6575 for space flight use and the development of cell interconnect welding techniques will be necessary for missions involving particularly harsh environments.

APPENDIX A

DELIVERY CELL I-V DATA

VJ 3



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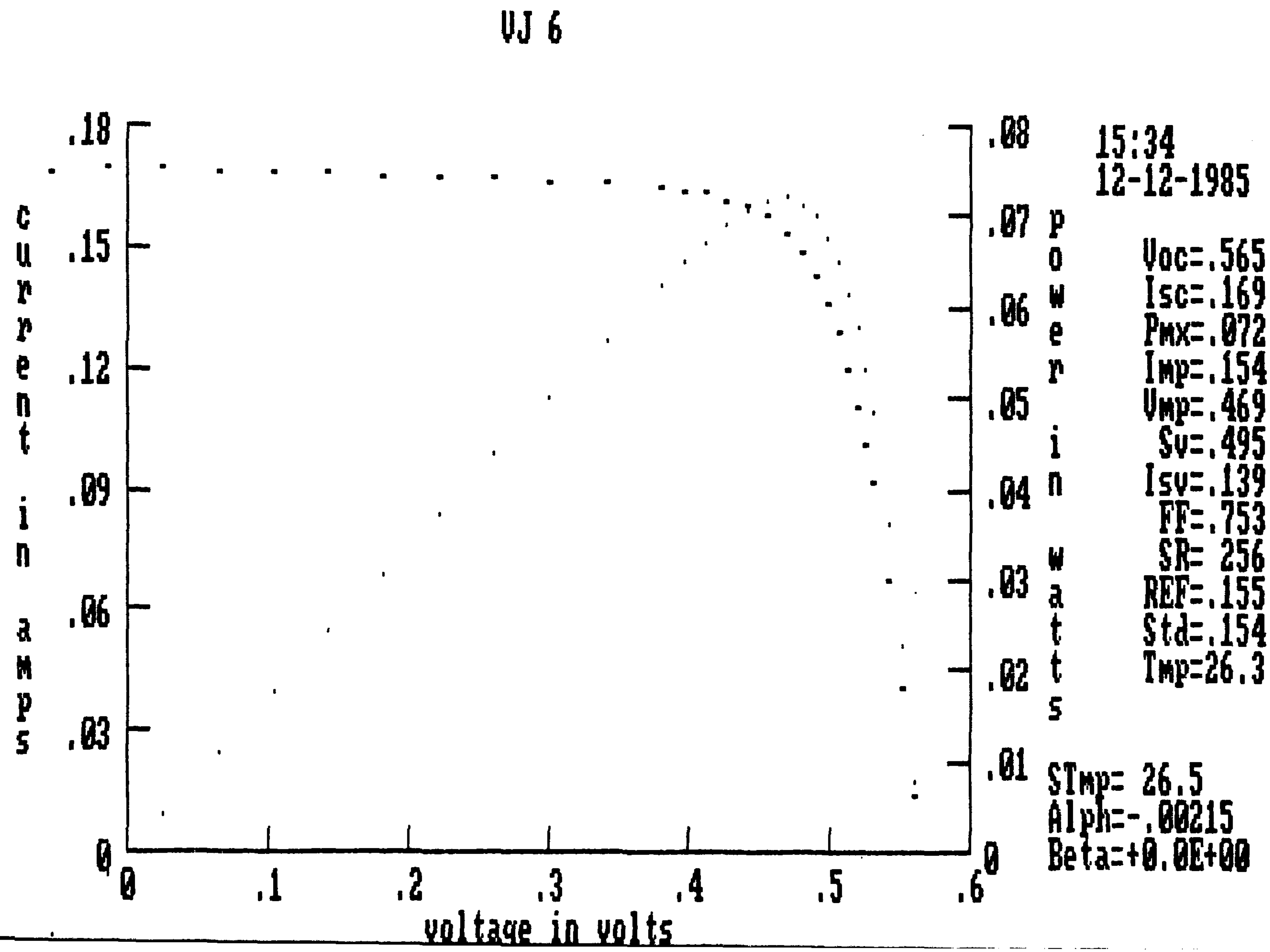
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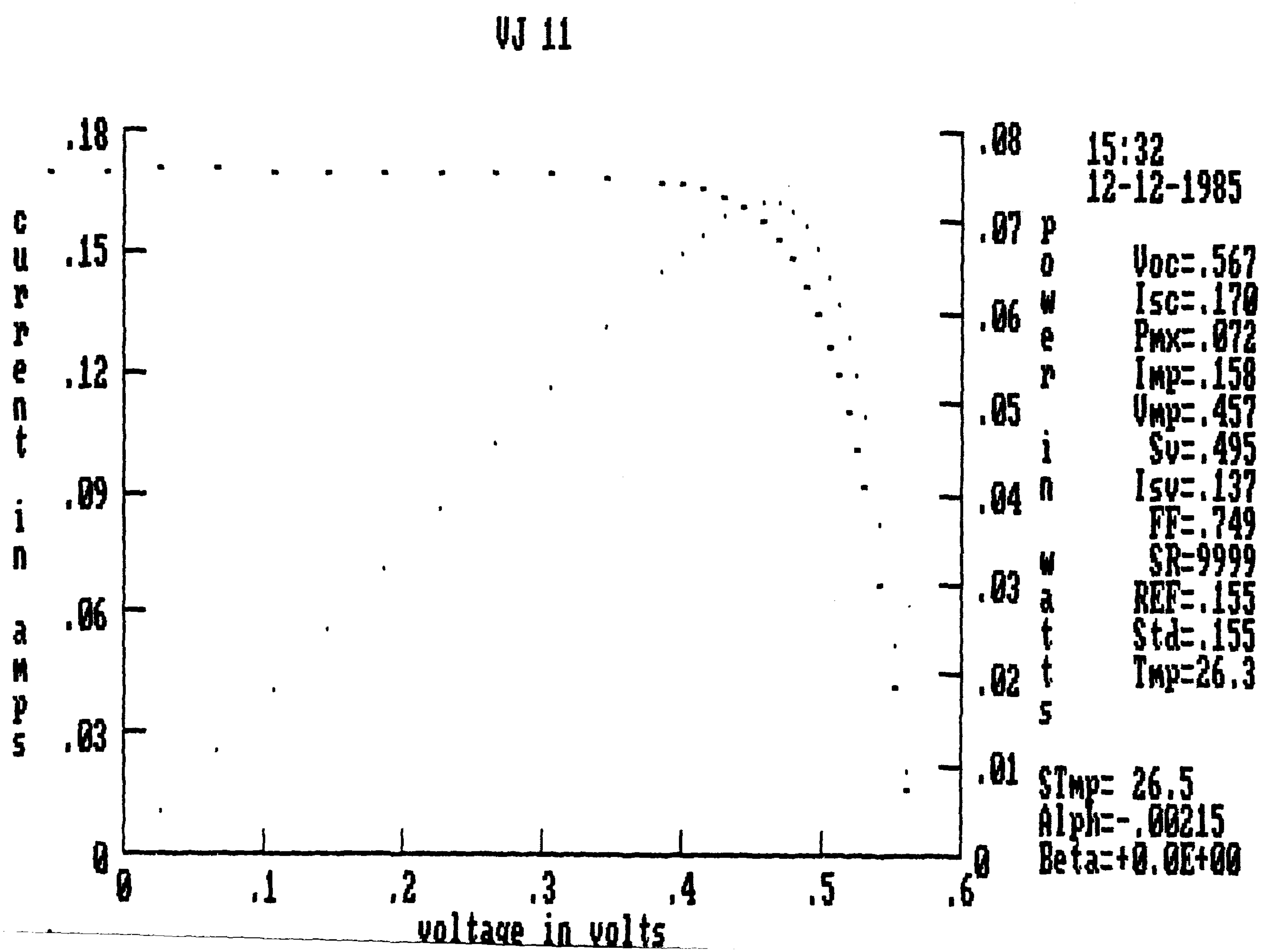
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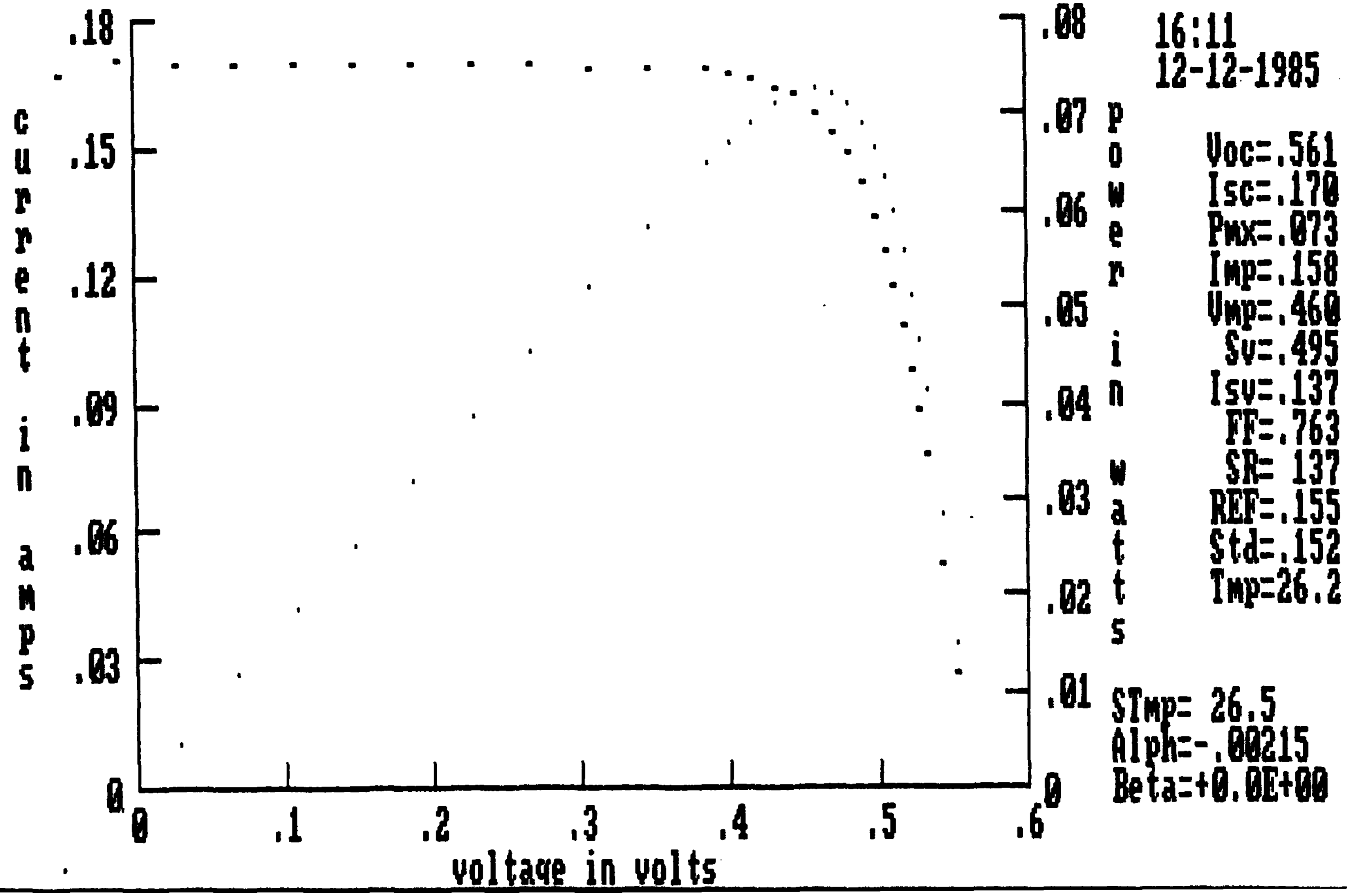

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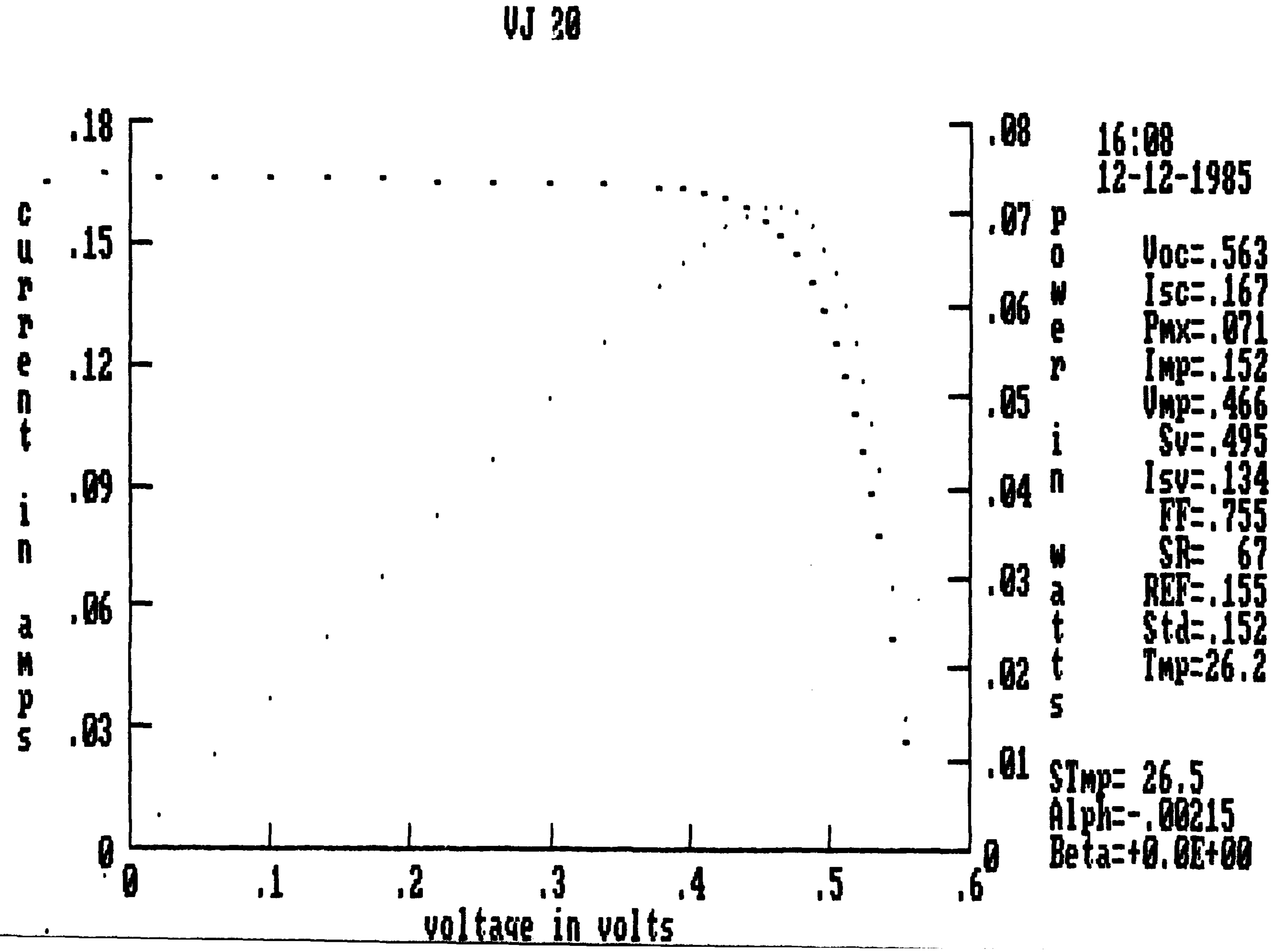

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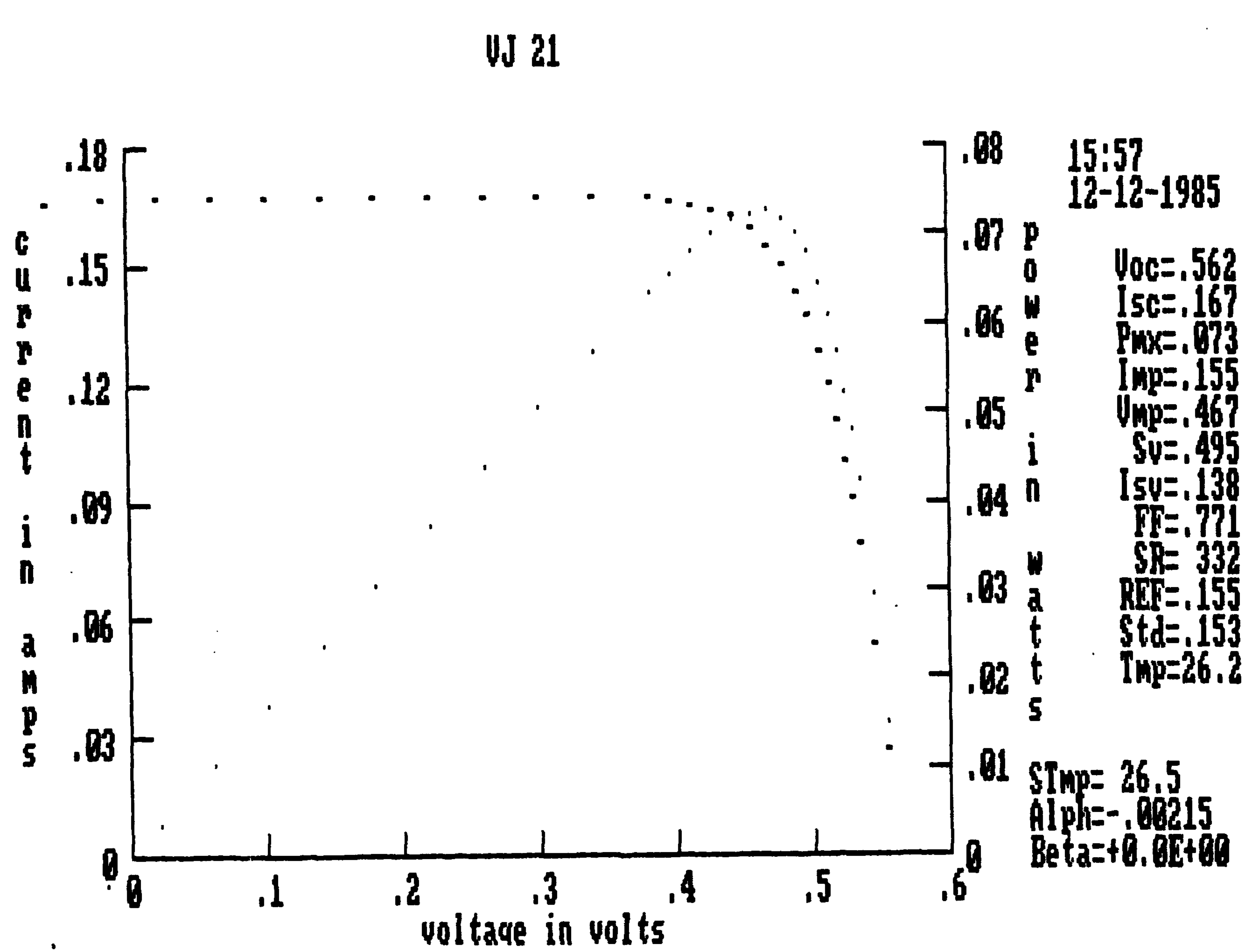
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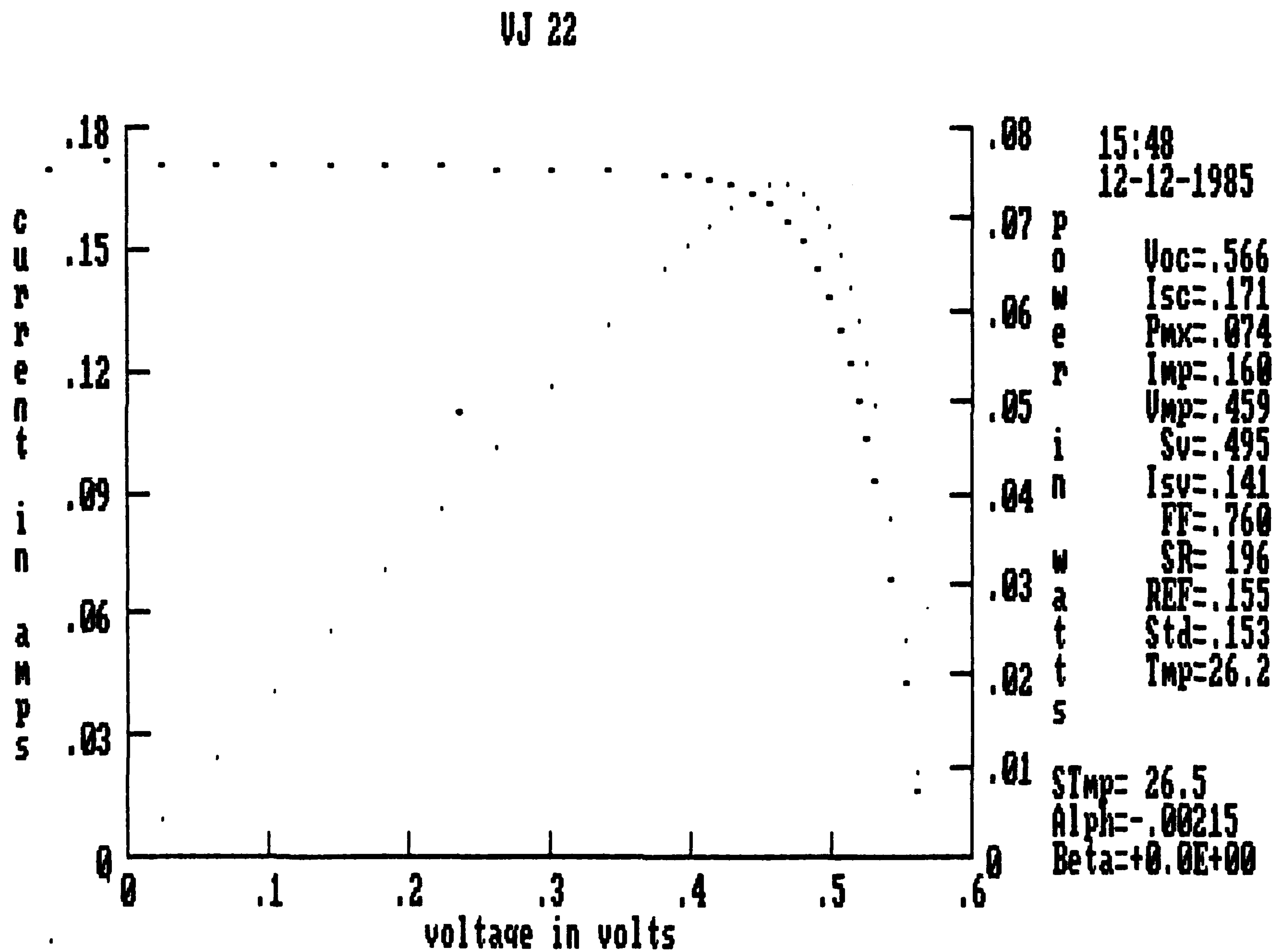
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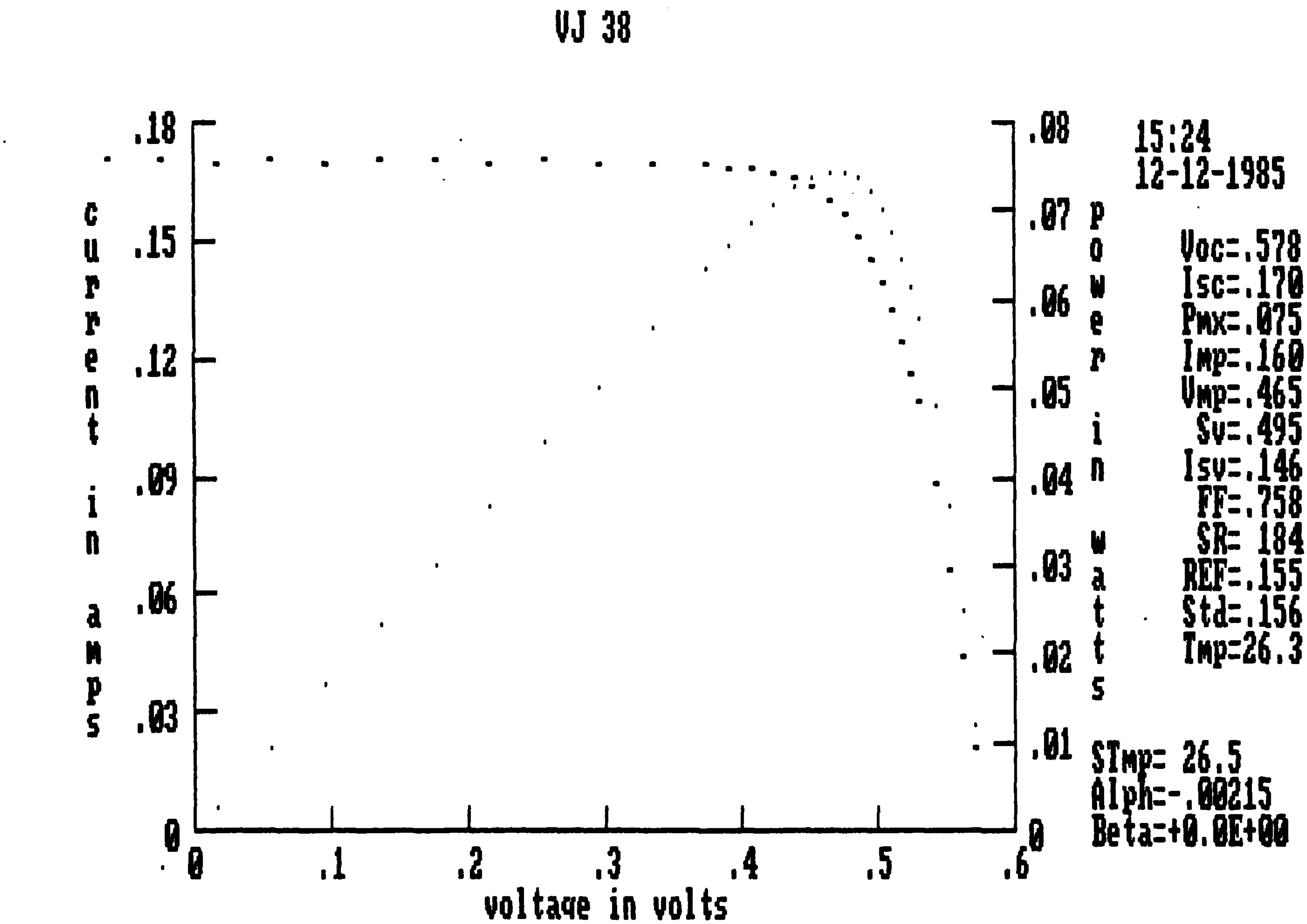

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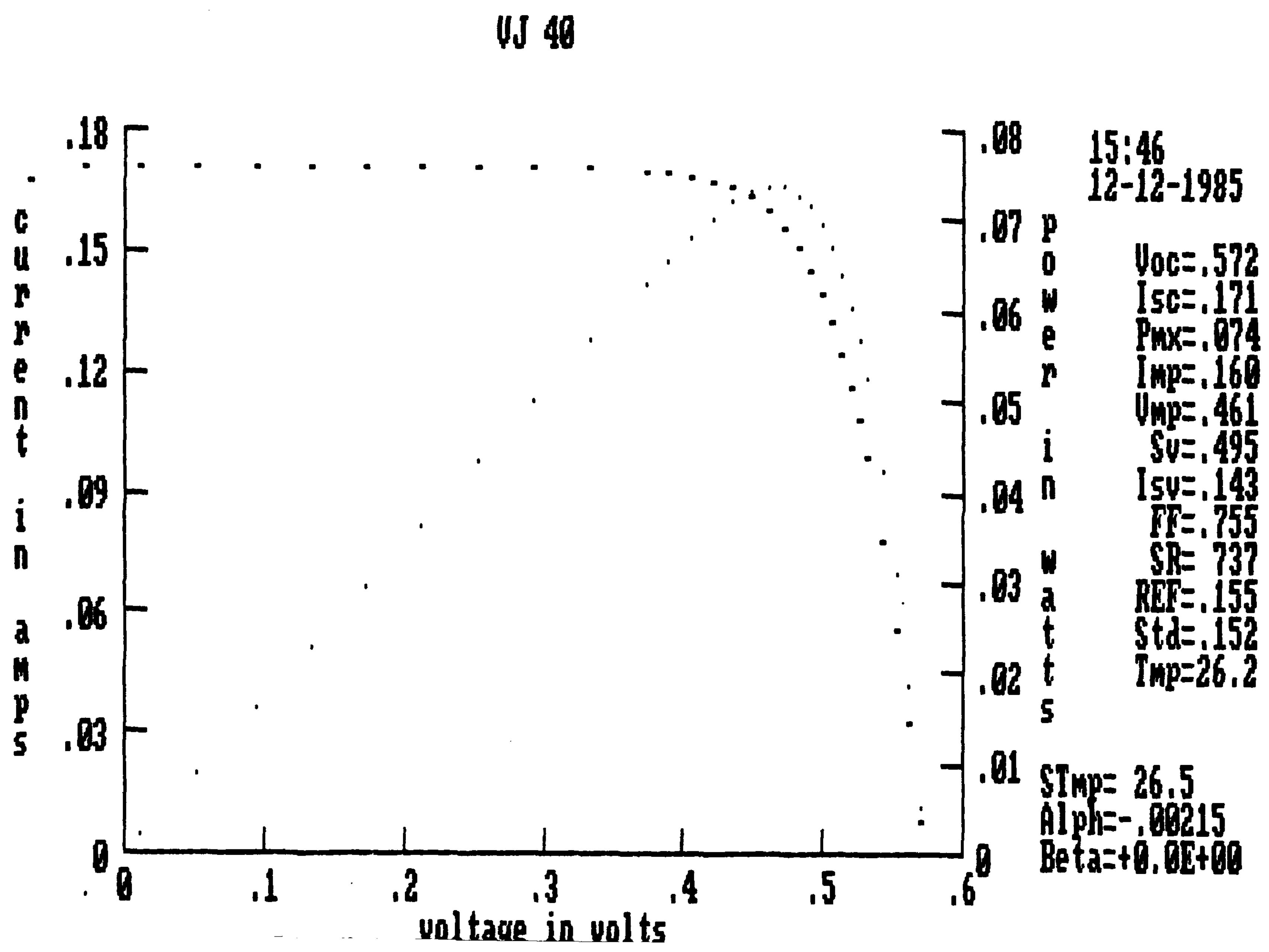
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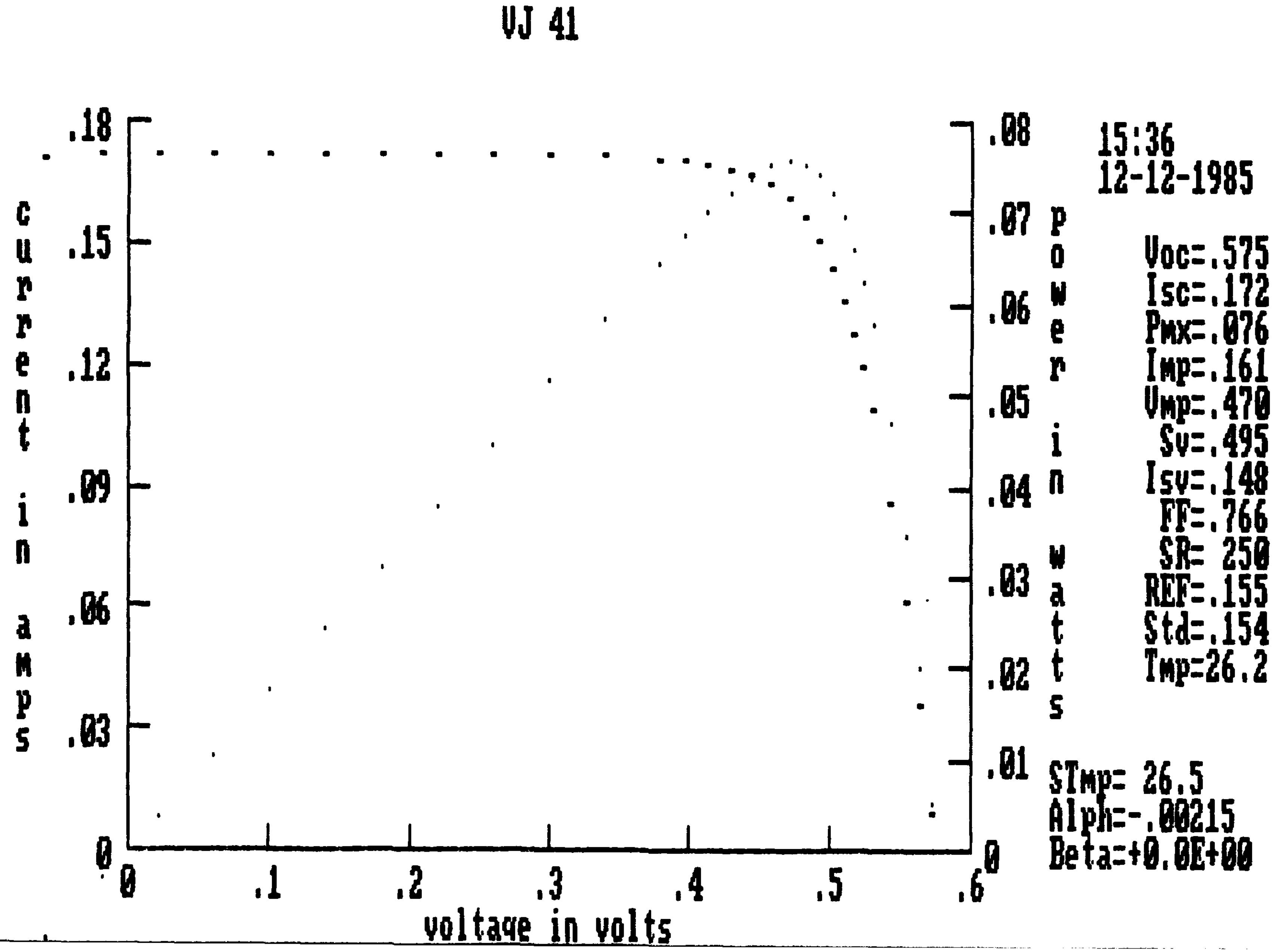
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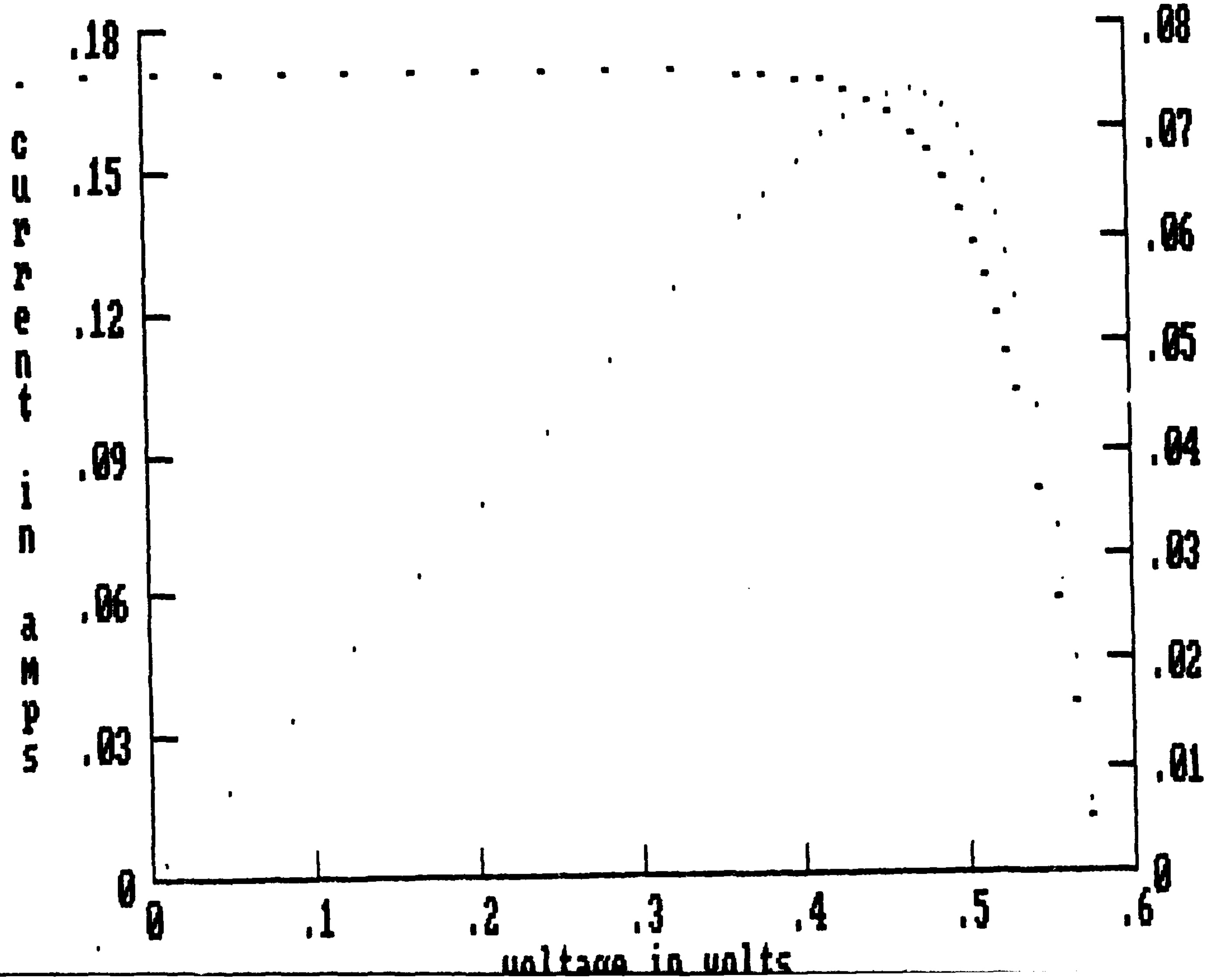

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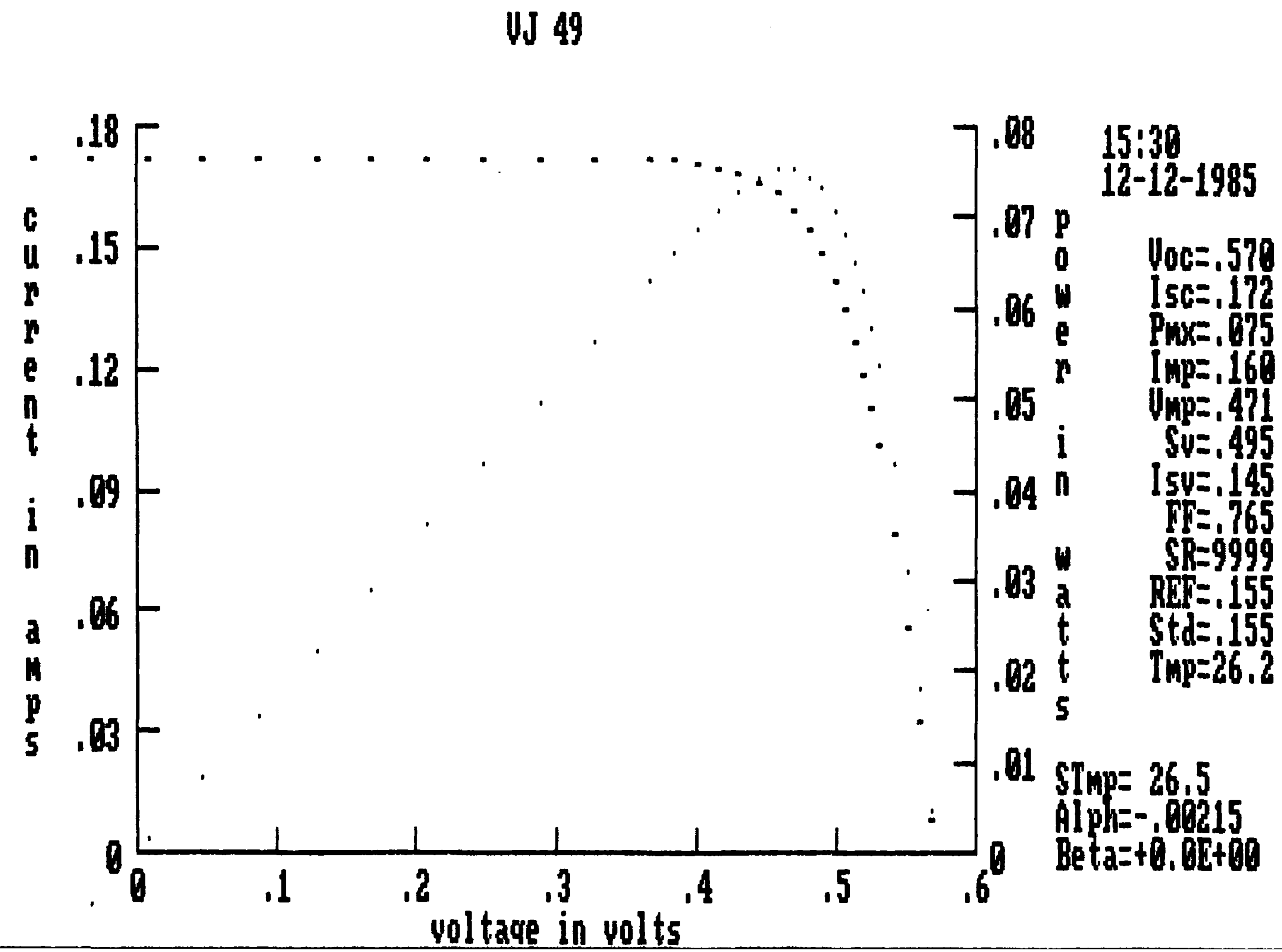

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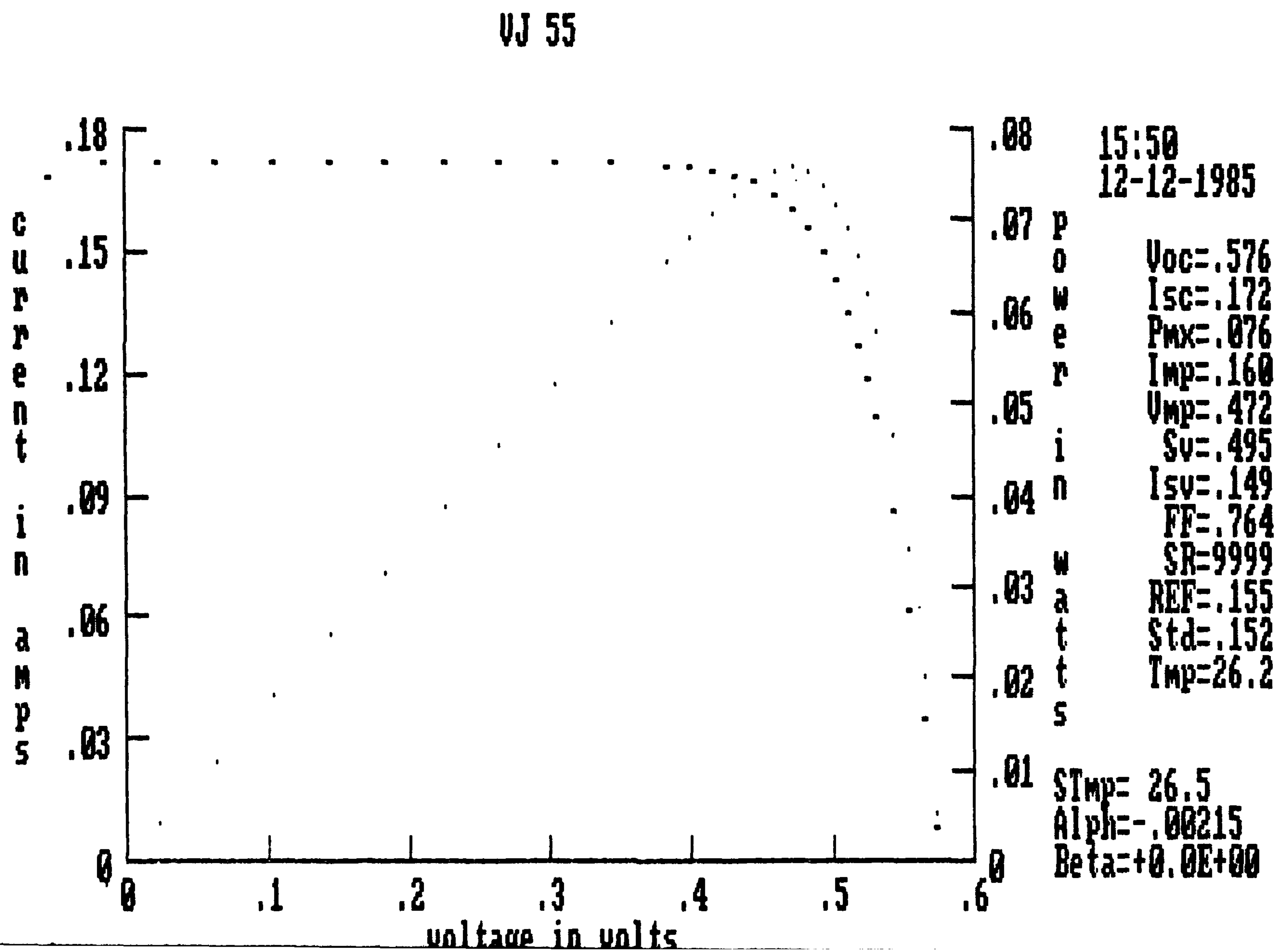
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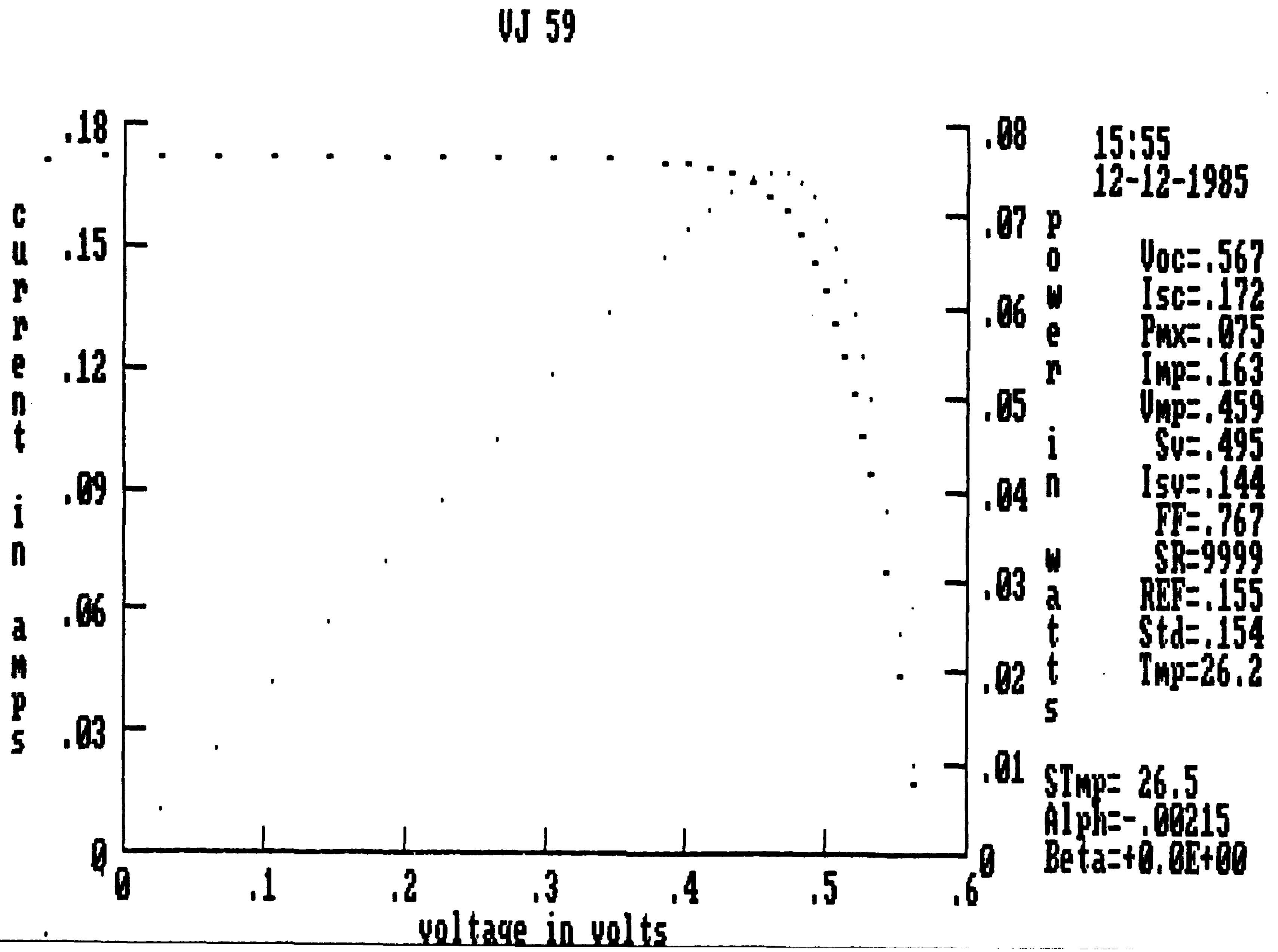

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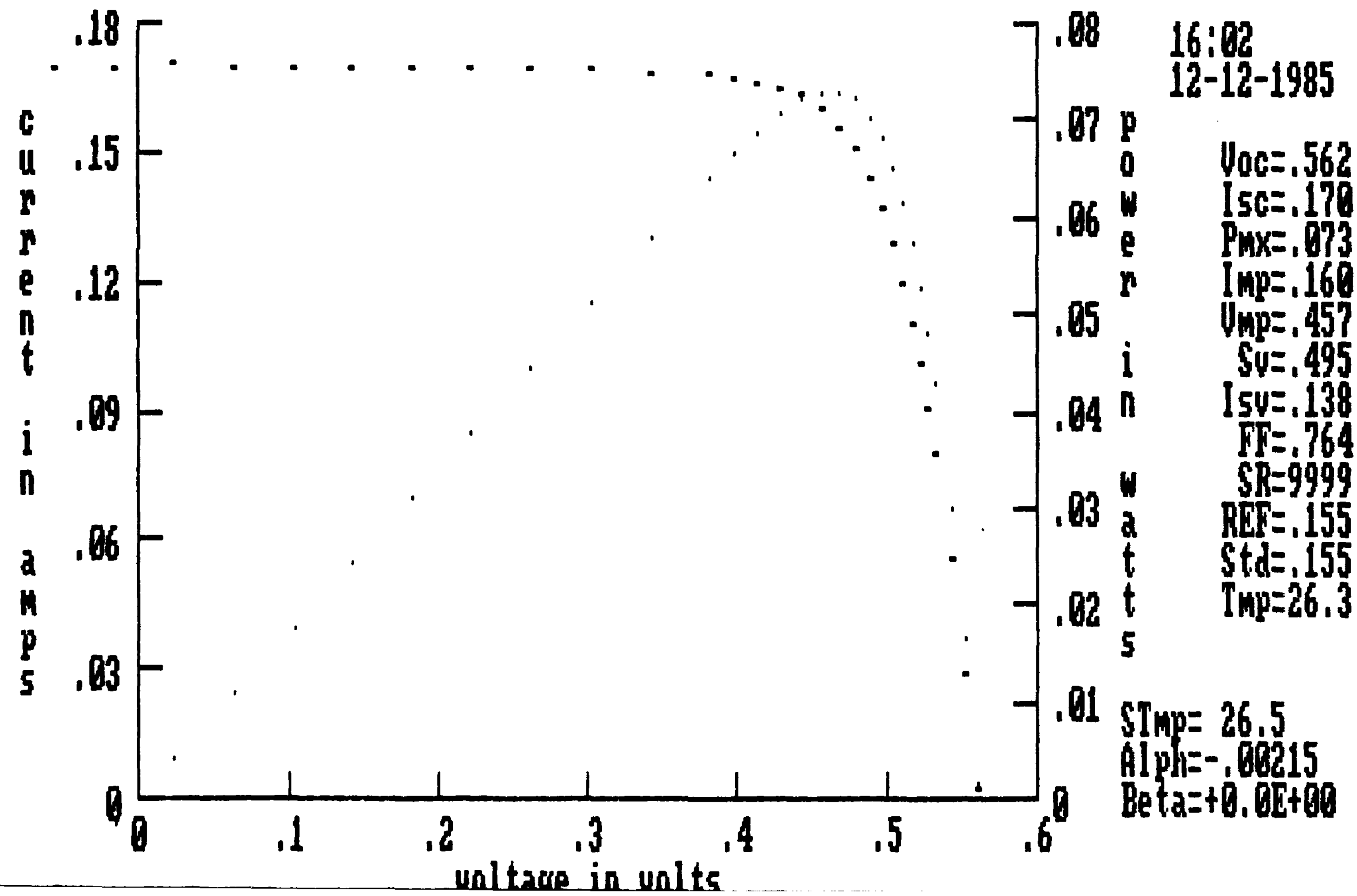
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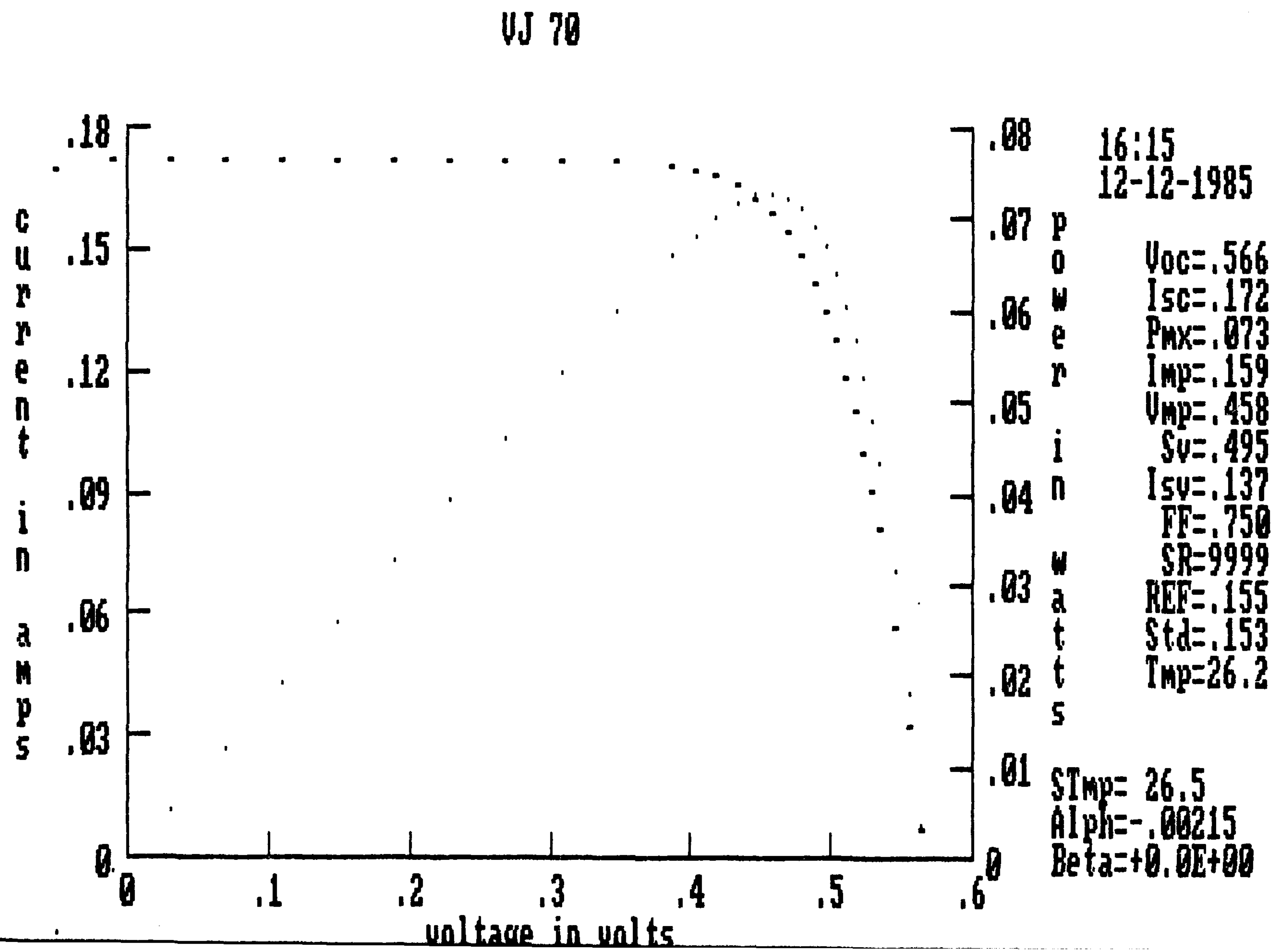
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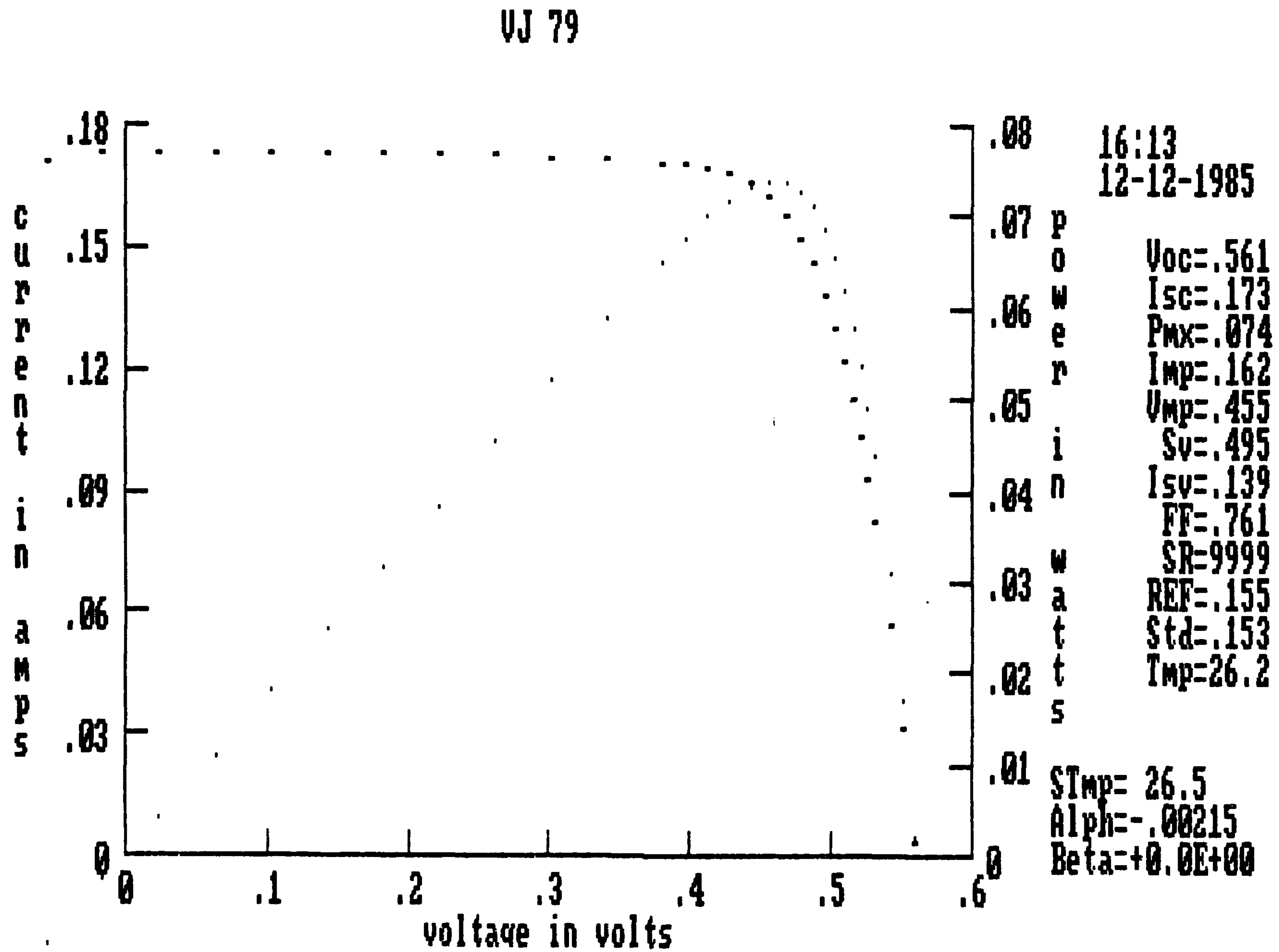
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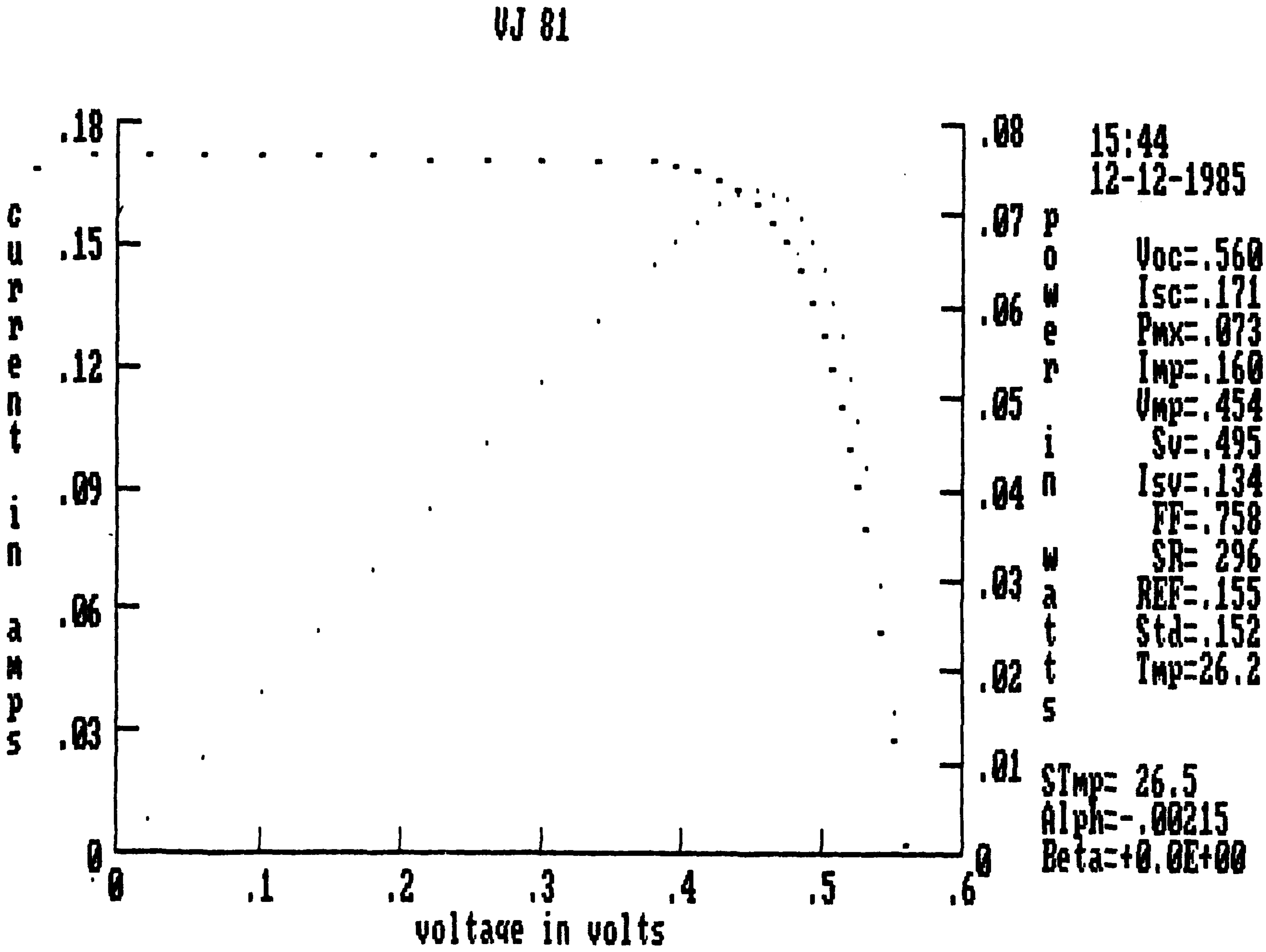
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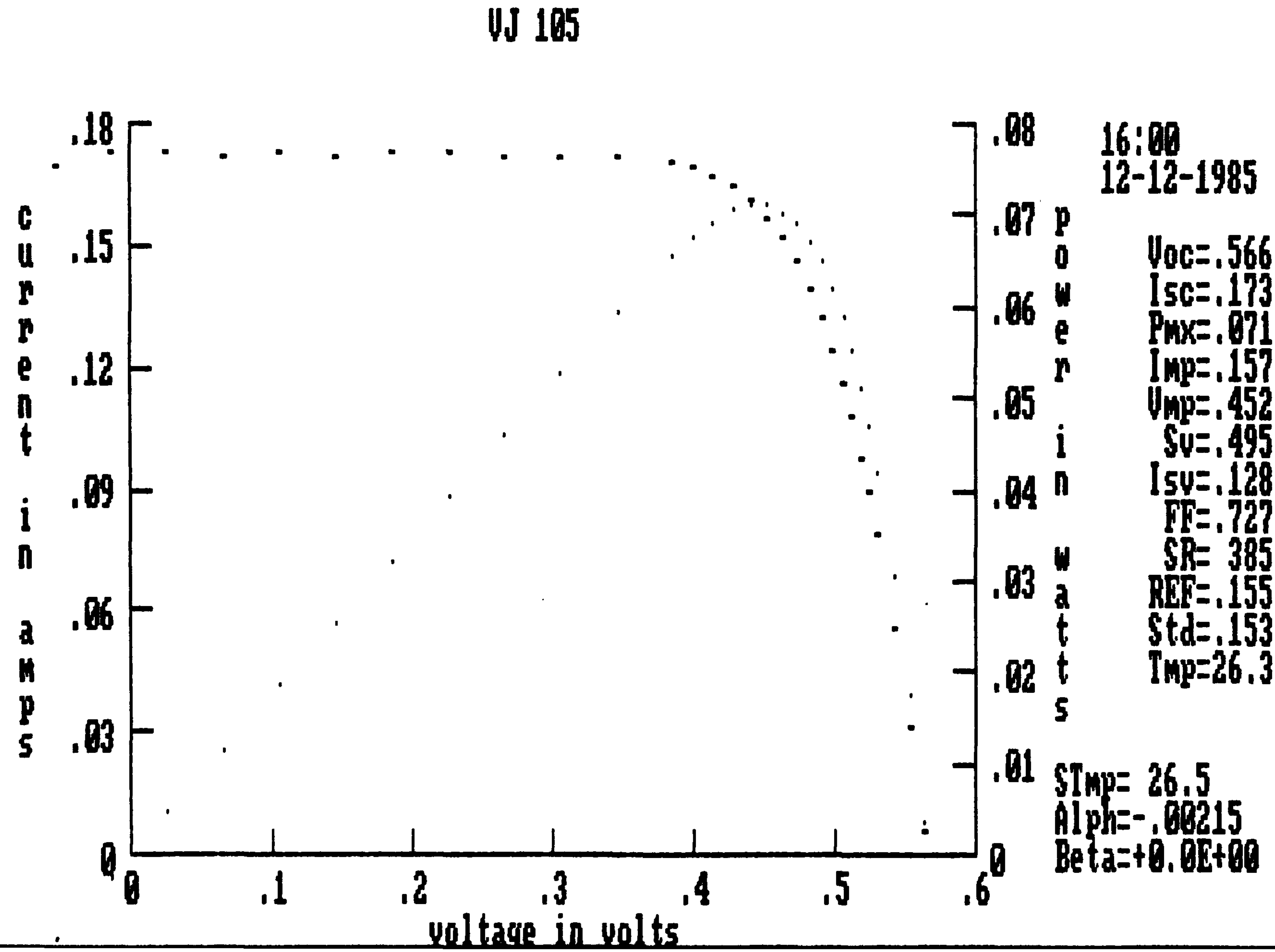
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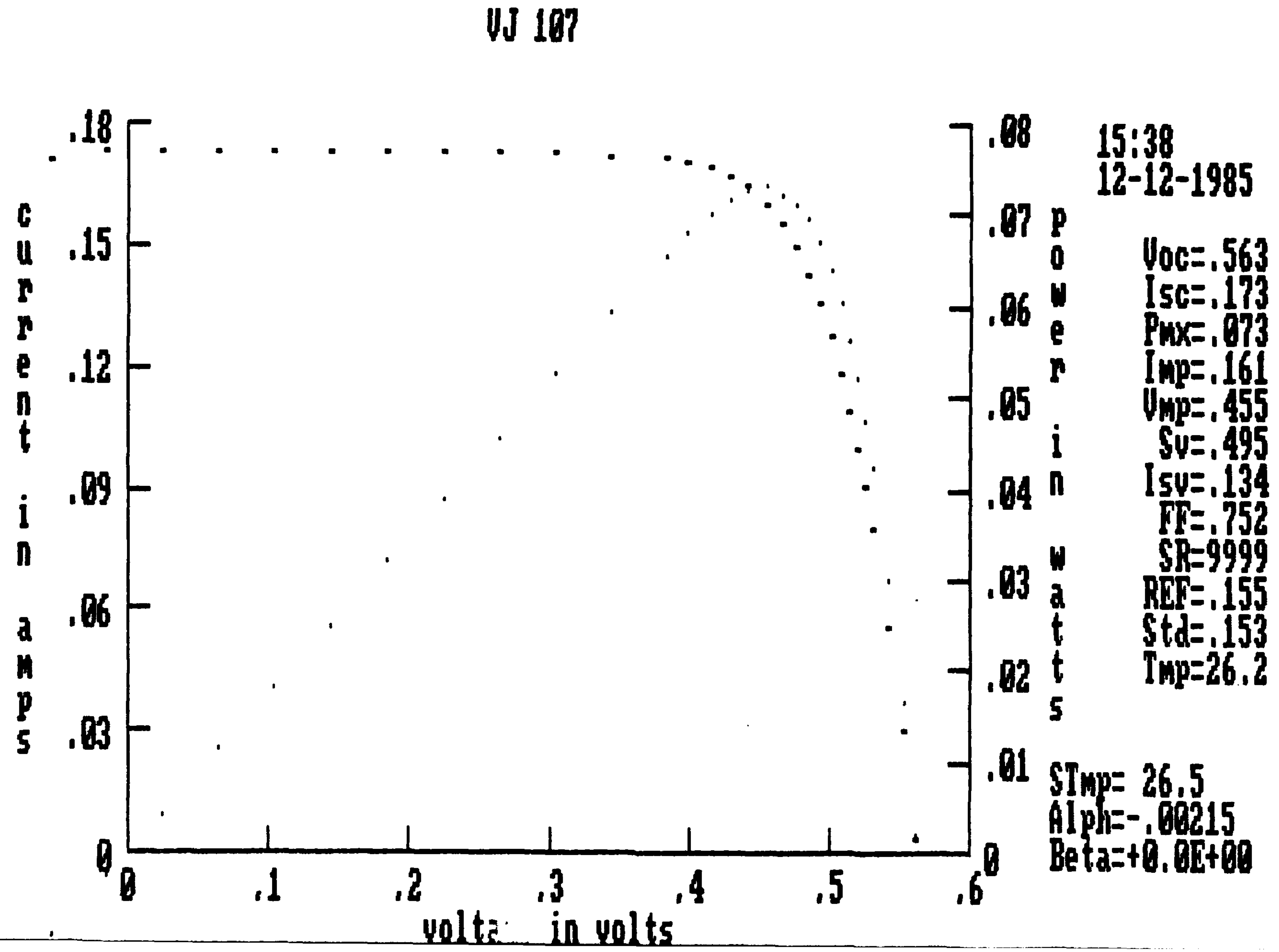
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APPENDIX B

ENCAPSULANT MATERIAL DATA SHEETS

McGHAN
NuSIL
CORPORATION

1150 Mark Avenue
Carpinteria, CA 93013
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TECHNICAL PROFILE

CV-2500
CONTROLLED VOLATILITY RTV SILICONES

Description:

McGHAN NuSIL CV-2500 is a two-part, clear RTV silicone specially processed for applications requiring low outgassing and minimal volatile condensibles under extreme operating conditions.

Applications:

McGHAN NuSIL CV-2500 may be used as embedding and potting compounds for environmental protection of electronic assemblies and components in industrial and space applications where minimal outgassing is essential to avoid condensation in sensitive devices. In addition to providing protection from extremes in temperature, humidity, radiation, thermal and mechanical stresses, CV-2500 is suitable as an adhesive in low-strength applications such as solar cell arrays where clarity and low volatility are of particular importance.

Mixing:

McGHAN NuSIL CV-2500 is mixed just prior to use in a ratio of 10 parts base to 1 part curing agent. Air entrapped during mixing should be evacuated prior to use. Lowering the curing agent concentration of more than 10 percent may result in a softer, weaker material which could have higher vacuum weight loss. Increasing the concentration more than 10 percent may degrade the physical and thermal properties of the material.

Curing and Pot Life:

McGHAN NuSIL CV-2500 is designed to cure at room temperature as well as elevated temperatures. The following table illustrates the effects of temperature on cure time:

Temperature °C (°F)	Cure Time
25C (77F)	24 hours
65C (149F)	2 hours
100C (212F)	30 minutes
150C (302F)	10 minutes

Pot life of catalyzed material may be extended by freezing.

NOTE: A PRIMER MAY BE REQUIRED IN SOME BONDING APPLICATIONS. McGHAN NuSIL SP-135 SILICONE PRIMER IS RECOMMENDED.

Storage and Shelf Life:

McGHAN NuSIL CV-2500 has a shelf life of six months from date of shipment when stored at room temperature, 25C (77F) in the original unopened container.

NOTE: REFREIGERATION STORAGE IS NOT ESSENTIAL BUT MAY EXTEND THE USEFUL SHELF LIFE OF THESE MATERIALS.

Typical shelf life vs. storage temperature of unmixed material is as follows:

Temperature	Expected Shelf Life
25C (77F)	6 months
10C (50F)	12 months
4C (40F)	18 months

Typical Properties as Supplied:

Chemical Classification	VMQ
Color	Clear
Pot Life @ 25C (77F)	2 hours
Viscosity, cps @ 25C (77F)	8000 ± 2000
Mix Ratio, by weight	10:1

Typical Cured Properties: Cured 15 minutes @ 150C (302F)

Specific Gravity	1.04
Color	Clear
Durometer, Shore A	50
Tensile Strength, psi	900
Elongation, %	100
Brittle Point	-65C (-85F)
Refractive Index @ 25C (77F)	1.412
Dielectric Strength, volts/mil	550
Volume Resistivity, ohm-cm	1×10^{14}
CMCM, %	<0.1
Total Mass Loss, %	<1.0
Spectral Transmittance (350 - 1100 Nanometers), % minimum	90

Total Mass Loss (TML) and Collected Volatile Condensible Materials (CVCM) are tested in accordance with ASTM E-595-83 and NASA SP-R-0022A, cured per McGHAN NuSIL Test Method #TM-012A.

Packaging:

50 gram kit
100 gram kit
500 gram kit

Specifications:

The typical properties shown in this technical profile should not be used as a basis for preparing specifications. Please contact McGhan NuSil Corporation for assistance and recommendations on specification limits.

CAUTION:

IT IS RECOMMENDED THAT THE PURCHASER THOROUGHLY TEST PERFORMANCE AND SAFETY OF ANY APPLICATION PRIOR TO FULL SCALE PRODUCTION OR COMMERCIALIZATION. TYPICAL APPLICATIONS LISTED IN THIS TECHNICAL PROFILE SHOULD NOT BE TAKEN AS INDUCEMENTS TO INFRINGE ANY PATENT. McGHAN NuSIL WARRANTS ONLY THAT ITS PRODUCTS MEET ITS SPECIFICATIONS. THERE IS NO WARRANTY OF MERCHANTABILITY OF FITNESS FOR USE OR ANY OTHER EXPRESS OR IMPLIED WARRANTIES. McGHAN NuSIL CORPORATION MAKES NO GUARANTEE OF SATISFACTORY RESULTS FROM RELIANCE UPON INFORMATION, STATEMENTS OR RECOMMENDATIONS CONTAINED HEREIN AND DISCLAIMS ALL LIABILITY FROM ANY RESULTING LOSS OR DAMAGE.

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TECHNICAL PROFILE

CV-2501
CONTROLLED VOLATILITY RTV SILICONES

Description:

McGHAN NuSIL CV-2501 is a two-part, clear RTV silicone specially processed for applications requiring low outgassing and minimal volatile condensibles under extreme operating conditions. CV-2501 has an extended (8 hour) pot life for applications that require more working time.

Applications:

McGHAN NuSIL CV-2501 may be used as embedding and potting compounds for environmental protection of electronic assemblies and components in industrial and space applications where minimal outgassing is essential to avoid condensation in sensitive devices. In addition to providing protection from extremes in temperature, humidity, radiation, thermal and mechanical stresses, CV-2501 is suitable as an adhesive in low-strength applications such as solar cell arrays where clarity and low volatility are of particular importance.

Mixing:

McGHAN NuSIL CV-2501 is mixed just prior to use in a ratio of 10 parts base to 1 part curing agent. Air entrapped during mixing should be evacuated prior to use. Lowering the curing agent concentration of more than 10 percent may result in a softer, weaker material which could have higher vacuum weight loss. Increasing the concentration more than 10 percent may degrade the physical and thermal properties of the material.

Curing and Pot Life:

McGHAN NuSIL CV-2501 is designed to cure at room temperature as well as elevated temperatures. The following table illustrates the effects of temperature on cure time:

Temperature °C (°F)	Cure Time
25C (77F)	Not Recommended
65C (149F)	4 hours
100C (212F)	1 hour
150C (302F)	15 minutes

Pot life of catalyzed material may be extended by freezing.

NOTE: A PRIMER MAY BE REQUIRED IN SOME BONDING APPLICATIONS. McGHAN NuSIL SP-135 SILICONE PRIMER IS RECOMMENDED.

Storage and Shelf Life:

McGHAN NuSIL CV-2501 has a shelf life of six months from date of shipment when stored at room temperature, 25C (77F) in the original unopened container.

NOTE: REFREIGERATION STORAGE IS NOT ESSENTIAL BUT MAY EXTEND THE USEFUL SHELF LIFE OF THESE MATERIALS.

Typical shelf life vs. storage temperature of unmixed material is as follows:

Temperature	Expected Shelf Life
25C (77F)	6 months
10C (50F)	12 months
4C (40F)	18 months

Typical Properties as Supplied:

Chemical Classification	VMQ
Color	Clear
Pot Life @ 25C (77F)	8 hours
Viscosity, cps @ 25C (77F)	8000 ± 2000
Mix Ratio, by weight	10:1

Typical Cured Properties: Cured 15 minutes @ 150C (302F)

Specific Gravity	1.04
Color	Clear
Durometer, Shore A	50
Tensile Strength, psi	900
Elongation, %	100
Brittle Point	-65C (-85F)
Refractive Index @ 25C (77F)	1.412
Dielectric Strength, volts/mil	550
Volume Resistivity, ohm-cm	1×10^{14}
CMCM, %	<0.1
Total Mass Loss, %	<1.0
Spectral Transmittance (350 - 1100 Nanometers), % minimum	90

Total Mass Loss (TML) and Collected Volatile Condensible Materials (CVCM) are tested in accordance with ASTM E-595-83 and NASA SP-R-0022A, cured per McGHAN NuSIL Test Method #TM-012A.

Packaging:

50 gram kit
100 gram kit
500 gram kit

Specifications:

The typical properties shown in this technical profile should not be used as a basis for preparing specifications. Please contact McGhan NuSil Corporation for assistance and recommendations on specification limits.

CAUTION:

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2/85, rev. C

McGHAN
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TECHNICAL PROFILE

CV-2567
CONTROLLED VOLATILITY RTV SILICONE

Description:

McGHAN NuSIL CV-2567 is a two-part, clear, easily pourable liquid silicone RTV specially processed for applications requiring extreme low temperature, low outgassing and minimal volatile condensibles under extreme operating conditions. CV-2567 is based on a phenyl silicone polymer with good radiation resistance and a service temperature range of -115C to 240C (-178F to 400F).

Applications:

CV-2567 may be used for environmental protection in potting, encapsulating and coating applications where minimal outgassing is essential to avoid condensation in sensitive devices. Because of its low viscosity, CV-2567 can also be used as a diluent for reducing the viscosity of McGHAN NuSIL CV-2566 Controlled Volatility RTV Silicone.

Mixing:

McGHAN NuSIL CV-2567 is mixed just prior to use by the addition of 0.5% by weight of CV-2567 curing agent to CV-2567 base. Use of a micro-syringe is recommended for dispensing small amounts of curing agent. Base and curing agent should be thoroughly mixed and vacuum deaired at 28 inches Hg prior to use. To obtain optimum cure in thin section applications (under 0.125 inches), CV-2567 should be covered during the cure cycle.

CAUTION: CV-2567 CURING AGENT MAY CAUSE SKIN AND EYE IRRITATION. IN CASE OF EYE CONTACT, IRRIGATE WITH WATER IMMEDIATELY AND GET MEDICAL ATTENTION.*

Working Time:

Working time is approximately one hour at 25C (77F) and 50% relative humidity. Cure time is approximately 24 hours at 25C (77F) and 50% relative humidity. Optimum properties are achieved after seven days at 25C (77F) and 50% relative humidity.

NOTE: A PRIMER MAY BE REQUIRED IN SOME BONDING APPLICATIONS. McGHAN NuSIL SP-120 SILICONE PRIMER IS RECOMMENDED.

Typical Properties as Supplied:

Chemical Classification	PMQ
Color	Clear
Viscosity, cps 25C (77F)	5,000
Pot Life @ 25C (77F), hours	1
Cure Time @ 25C (77F), 50% R.H.	
Set Up (thin section), hrs.	24
Full Cure, days	7

* Standard curing agent is DBTDL (Dibutyl Tin Dilaurate) 0.5% by weight.

Typical Properties: Cured 7 days @ 25C (77F), 50% R.H.

Specific Gravity @ 25C (77F)	1.00
Durometer, Shore A	20
Tensile Strength, psi	100
Elongation, %	120
Lap Shear, psi	60
Brittle Point, °C (°F)	-115 (-178)
Linear Shrinkage, %	0.1
Refractive Index @ 25C (77F)	1.4279
Dielectric Strength, volts/mil	500
Volume Resistivity, ohm-cm	1.5×10^{15}
Collected Volatile Condensible Materials, % (CVCM)	<0.1
Total Mass Loss, % (TML)	<1.0

TOTAL MASS LOSS AND COLLECTED VOLATILE CONDENSIBLE MATERIALS ARE TESTED IN ACCORDANCE WITH ASTM E-595-77 AND NASA SP-R-0022A. CURED PER McGHAN NuSIL TEST METHOD #TM-012A.

Storage and Shelf Life:

McGHAN NuSIL CV-2567 has a shelf life of six months from date of shipment when stored in original unopened containers at room temperature, 25C (77F).

NOTE: REFRIGERATION STORAGE IS NOT ESSENTIAL BUT MAY EXTEND THE USEFUL SHELF LIFE OF THIS MATERIAL.

Typical shelf life vs. storage temperature of unmixed material is as follows:

Temperature	Expected Shelf Life
25C (77F)	6 months
10C (50F)	12 months
4C (40F)	18 months

Packaging:

50 gram kit
100 gram kit
500 gram kit

Specifications:

The typical properties shown in this technical profile should not be used as a basis for preparing specifications. Please contact McGhan NuSil Corporation for assistance and recommendations on specification limits.

CAUTION:

IT IS RECOMMENDED THAT THE PURCHASER THOROUGHLY TEST PERFORMANCE AND SAFETY OF ANY APPLICATION PRIOR TO FULL SCALE PRODUCTION OR COMMERCIALIZATION. TYPICAL APPLICATIONS LISTED IN THIS TECHNICAL PROFILE SHOULD NOT BE TAKEN AS INDUCEMENTS TO INFRINGE ANY PATENT. McGHAN NuSIL WARRANTS ONLY THAT ITS PRODUCTS MEET ITS SPECIFICATIONS. THERE IS NO WARRANTY OF MERCHANTABILITY OF FITNESS FOR USE OR ANY OTHER EXPRESS OR IMPLIED WARRANTIES. McGHAN NuSIL CORPORATION MAKES NO GUARANTEE OF SATISFACTORY RESULTS FROM RELIANCE UPON INFORMATION, STATEMENTS OR RECOMMENDATIONS CONTAINED HEREIN AND DISCLAIMS ALL LIABILITY FROM ANY RESULTING LOSS OR DAMAGE.

6/84, rev. A

Information about Controlled Volatility Materials

DOW CORNING

DESCRIPTION

Dow Corning 93-500 space-grade encapsulant is a transparent, room-temperature-curing, solventless silicone material designed for potting, filling, embedding and encapsulating electronic and other equipment for use in the space environment. It is supplied as a nearly colorless, free flowing, low viscosity fluid.

Features of the uncured encapsulant

Dow Corning 93-500 space-grade encapsulant and its curing agent blend readily, and the low viscosity of the catalyzed material (under 80 poises) aids in the potting and filling of deep, intricately shaped components. After addition of the curing agent, Dow Corning 93-500 space-grade encapsulant remains workable for about 1 hour at 24 C (75.2 F). The encapsulant cures in unlimited thickness in 24 hours at 25 C (77 F) ...even in confined areas... without exotherm. This material is not recommended for use in thin coatings of less than 0.010 inch unless confined or covered.

Features of the cured encapsulant

Dow Corning 93-500 space-grade encapsulant has been specially prepared for use in systems that will operate in hard vacuum, but where a high temperature post cure is not feasible. When used as supplied, the encapsulant exhibits extremely low weight loss. It has a total mass loss of less than 0.35% and less than 0.1% collected volatile condensable materials (condensed on a 25 C [77 F] collector plate) when exposed for 24 hours at 125 C (275 F) and less than 10^{-6} torr vacuum. Thus, chances of contamination of critical surfaces, such as optical systems and exposed electrical contacts, are greatly reduced. Dow Corning 93-500 space-grade encapsulant can be placed in service immediately following the completion of its room temperature curing schedule. Other features of the cured encapsulant include:

- Transparency—embedded parts can be visually inspected.
- Wide operating temperature— -65 to 200 C (-85 to 392 F).
- Easy repairability—sections of the encapsulant can be cut out for replacement of components; new encapsulant can be poured in place and cured to re-form a tight seal.
- Good physical and electrical stability—retains properties from -65 to 200 C (-85 to 392 F), over a wide range of frequency and humidity.
- Good firmness and flexibility—Shore A scale hardness of approximately 45; elongation of about 100 percent.
- Good damping qualities—low transmission of vibration and shock.
- Good environmental protection—low water absorption (less than 0.10% after 7 days immersion at 25 C [77 F]); high resistance to radiation (useable after exposure to 200 megarads).
- Low shrinkage during cure—does not exert pressure on encapsulated or embedded components.

DOW CORNING® 93-500 SPACE-GRADE ENCAPSULANT

Type	Silicone rubber
Physical Form	
as supplied	Clear, pourable fluid
as cured	Firm, flexible rubber
Cure	Room-temperature curing in approximately 24 hours
Primary Uses	Potting, filling, embedding, and encapsulating electronic equipment used in space environment

USES

Dow Corning 93-500 space-grade encapsulant is used as an embedding and potting compound to provide resilient environmental protection for modules, relays, power supplies, delay lines, cable connectors or complete electronic assemblies. It can also be used as an encapsulant for electronic components, circuit boards, and as a solar cell adhesive.

In use, the encapsulant assures the protection of electronic circuits and components from temperature extremes, high humidity, radiation, thermal shock and mechanical vibration. In addition, its inherent physical and electrical properties make it ideally suited for the harsh environment of space.

ENGINEERING DATA

Operating Temperature Range

Cured sections of Dow Corning 93-500 space-grade encapsulant are useable over a wide temperature

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

As Supplied	
Color	Light straw
Specific Gravity at 25 C (77 F)	1.08
Viscosity at 25 C (77 F), poises	80
Pot Life at 25 C (77 F), with curing agent added, hours	1
Silicone Resin Content, percent	100
As Cured — 7 days at 25 C (77 F)*	
Color	Transparent; colorless to light straw
Refractive Index	1.4124
Durometer Hardness, Shore A, points	46
Total Mass Loss, % after 24 hrs at 125 C (275 F) and $\leq 10^{-6}$ torr	0.25
Collected Volatile Condensable Materials at 25 C (77 F), percent	0.05
Tack-Free Time at 25 C (77 F), hours	24
Specific Gravity at 25 C (77 F)	1.08
Thermal Conductivity, cal per [(cm) (degree C) (sec)]	3.5×10^{-4}
Linear Coefficient of Expansion, in/in°C-min	300×10^{-6}
Thermal Shock Resistance, from -55 to 155 C (-67 to 312 F), MIL-I-16923C	Pass 10 cycles
Water Absorption, after 7 days immersion at 25 C (77 F), percent	Less than 0.10
Brittle Point, degrees	-65 C (84 F)
Radiation Resistance, Cobalt 60 source	Still usable after exposure to 200 megarads; hard and brittle after 500 megarads
ASTM D 149 Dielectric Strength,† volts/mil	570
ASTM D 150 Dielectric Constant, at 100 Hz	2.75
at 100 KHz	2.73
ASTM D 150 Dissipation Factor, at 100 Hz	0.0011
at 100 KHz	0.0013
ASTM D 257 Volume Resistivity, ohm-cm	6.9×10^{13}
ASTM D 412 Tensile Strength, die C, psi	790
ASTM D 412 Elongation, die C, percent	110

* 1 part by weight of curing agent to 10 parts by weight of base encapsulant.

†Tested on specimen 0.062-inch thick using ¼-inch standard ASTM electrodes; 500 volts per second rate of rise.

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

range of -65 to 200 C (-85 to 392 F). Short time exposure (less than two hours) at temperatures as high as 300 C (572 F) will not degrade the encapsulant. However, generation of volatile species increases as the temperature is elevated.

When parts are embedded in Dow Corning 93-500 space-grade encapsulant, differences in thermal expansion values between the encapsulant and the embedded parts—and the shape of these parts—may influence temperature limits at which such systems may be used. For this reason, thermal operating limits for embedded components should be accurately determined by laboratory tests before large scale use.

Compatibility

Materials which have been found to inhibit the cure of Dow Corning 93-500 space-grade encapsulant include:

Polyvinylchloride, plasticized
Epoxy — amine cured
Dow Corning® 630 protective coating
Dow Corning® 3110, 3112, and 3120 RTV silicone rubber cured with Dow Corning RTV catalysts S or F; cured 7 days at room temperature (Dow Corning 3110, 3112, and 3120 RTV silicone rubbers cured with Dow Corning RTV catalyst S and F at room temperature plus 4 hours at 150 C do not inhibit cure.)
Polysulfide MIL-S-8516
Humiseal® 1B-27 coating
Mystik® 6207 tape
Mystik® 6215 tape
Scotch® cellophane tape

Scotch® 360 tape
Permacel® masking tape
Vinyl electric tape
Pliobond® adhesive
Latex vacuum tubing
Neoprene rubber
Buna N rubber
GRS rubber
Natural rubber
Viton® A rubber
Acid core solder flux
Rosin core solder flux
Sulphur Compounds,
- Thiols
- Sulphides
- Sulphates
- Silphites
- Thioureas

Nitrogen Compounds,
- Amines
- Amides
- Imides
- Azides

Each application should be pretested with the product in question.

Corrosion

No corrosion has been observed on common metals—notably copper—when used with Dow Corning 93-500 space-grade encapsulant.

Mixing

Dow Corning® 93-500 curing agent is supplied with the encapsulant. Just prior to use, the two are blended in the ratio of 10 parts of encapsulant to 1 part of the curing agent, by weight. Thorough mixing is easy, since both encapsulant and curing agent are supplied as low viscosity fluids. During mixing, care should be taken to minimize entrapment of air. Any entrapped air should be removed before the encapsulant is poured.

If the encapsulant is cured in sections less than 1 inch deep, all entrapped air should escape before the cure is complete. For thick sections and quick de-airing, the use of a vacuum is required. The vacuum should be applied slowly; otherwise, the material may foam and overflow the container. As a rule, containers should be no more than half full. Vacuum should be held for 3 to 5 minutes after all bubbles have collapsed.

The encapsulant and the curing agent present no handling problems in normal industrial practice, either from the standpoint of skin irritation or accidental ingestion. Eye contact produces a slight temporary discomfort and essentially no irritation.

Varying Curing Agent Concentration

Variations of up to 10 percent in the concentration of curing agent in Dow Corning 93-500 space-grade encapsulant have little effect upon set-up time or on the properties of the final cured part. Lowering the curing agent concentration by more than 10 percent will result in a softer, weaker material which could have higher vacuum weight loss characteristics; increasing the percent will result in an overhardening of cured encapsulant and will tend to degrade physical and thermal-vacuum properties.

Preparing Containers and Components

Containers, molds or components which come into contact with Dow Corning 93-500 space-grade encapsulant should be clean and dry. Containers or molds which have been used to handle room temperature vulcanizing silicone rubber, organic rubber, or plastics should not be used, since traces of these materials may inhibit the cure or contaminate the encapsulant. Inhibition of cure which results from an incompatible component or substrate can usually be prevented by one of the following methods.

1. Wash the contaminants off with solvent; ultrasonic cleaning has also been found to be effective.

2. Volatilize the contaminants by heating prior to applying the encapsulant.

Applying and Curing

When pouring Dow Corning 93-500 space-grade encapsulant into the unit in which it is to be cured, care should be taken to minimize air entrapment within the system. Where practical, it is suggested that pouring be done under vacuum, particularly if the component being cast has many fine voids. When this technique cannot be used the unit should be evacuated after the encapsulant has been poured.

Dow Corning 93-500 space-grade encapsulant can be satisfactorily cured either exposed to air or completely sealed, and at temperatures ranging from 25 to 150 C (77 to 302 F).

After 24 hours at 25 C (77 F), Dow Corning 93-500 space-grade encapsulant will have cured sufficiently to allow handling. Full mechanical and electrical strength, and optimum weight loss properties, however, will not be achieved for 7 days. Curing time can be appreciably decreased by heating the compound. Suggested quick curing cycles are as follows: 65 C (149 F) for 4 hours or 100 C (212 F) for 1 hour or 150 C (302 F) for 15 minutes. Relatively massive parts will require additional time in the oven to bring them up to the required temperature.

SHIPPING LIMITATIONS

None.

STORAGE AND SHELF LIFE

When stored in original unopened containers at or below 32 C (77 F), Dow Corning 93-500 space-grade encapsulant has a shelf life of 6 months from date of shipment.

PACKAGING

Dow Corning 93-500 space-grade encapsulant is supplied in packages that contain the encapsulant and its curing agent in separate containers. Net weights for complete packages —encapsulant and curing agent—are:

3.9-oz (110-gm) kit
1.1-lb (.5-kg) kit

USERS PLEASE READ

The information and data contained herein are believed to be accurate and reliable; however, it is the user's responsibility to determine suitability of use. Since Dow Corning cannot know all of the uses to which its products may be put or the conditions of use, it makes no warranties concerning the fitness or suitability of its products for a particular use or purpose.

You should thoroughly test any proposed use of our products and independently conclude satisfactory performance in your application. Likewise, if the manner in which our products are used requires governmental approval or clearance, you must obtain it.

Dow Corning warrants only that its products will meet its specifications. *There is no warranty of merchantability of fitness for use, nor any other express or implied warranties.* The user's exclusive remedy and Dow Corning's sole liability is limited to refund of the purchase price or replacement of any product shown to be otherwise than as warranted. Dow Corning will not be liable for consequential damages of any kind.

Suggestions of uses should not be taken as inducements to infringe any patents.

DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48640

Printed in U.S.A. Form No. 61-257-77

DOW CORNING

Information about Materials for High Technology Applications

DOW CORNING

DESCRIPTION

Dow Corning® 3-6527 A & B silicone dielectric gel is a unique, two-component, transparent silicone encapsulant specially designed to seal, protect and preserve the electrical characteristics of delicate electronic circuits and hybrid devices in severe environments.

When the two components are thoroughly mixed in a 1:1 ratio by either weight or volume, the product cures in place to form a cushioning, self-healing, resilient gel-like mass. The cured gel retains much of the stress relief and self-healing qualities of a liquid, while developing much of the dimensional stability and non-flow characteristics of a solid elastomer. These unique properties are maintained at both high and low temperature extremes and are not lost even when aged continuously at high temperatures.

Dow Corning 3-6527 A & B silicone dielectric gel also exhibits a permanent, reformable, pressure sensitive adhesive bond to many substrates that are compatible with the cure of this product (see Compatibility). This adhesive quality, together with its highly hydrophobic properties, make this product ideally suited for applications that require long-term sealing against moisture and other atmospheric contaminants. These properties are particularly desirable where both high and low temperature cycling is involved.

In general, Dow Corning 3-6527 A & B silicone dielectric gel is ideally suited for applications that encompass any of the following requirements:

DOW CORNING® 3-6527 A & B SILICONE DIELECTRIC GEL

Type	Two-component silicone
Physical Form	Silicone liquid
Special Properties	Non-corrosive; reversion resistant; resistant to atmospheric contamination, mechanical shock and vibration; good adhesion and dielectric properties; high temperature stability
Primary Use	Seal, protect and preserve electrical characteristics of delicate electronic circuits and hybrid devices

- Protection from mechanical stress and strain
- Permanent, pressure sensitive *adhesion — priming* is not required
- Protection from moisture, dirt and other atmospheric contaminants
- Physical and electrical stability over a wide temperature range from -58 to 392 F (-50 to 200 C)
- Physical and electrical stability during continuous aging at temperatures as high as 392 F (200 C).
- Protection from thermo-mechanical shock
- Protection from mechanical shock and vibration
- Good dielectric properties, even at high frequencies.

Mixing and Processing

To properly catalyze Dow Corning 3-6527 A & B silicone dielectric gel, thoroughly mix Part A with Part B in a 1:1 ratio by either weight or volume. A somewhat softer gel (higher penetration value) can be obtained by increasing the ratio of Part A to Part B in the initial mix. Likewise, a somewhat firmer gel (lower penetration value) can be obtained by increasing the ratio of Part B to Part A in the initial mix. Changes in cure rate can result when deviations from the 1:1 mix ratio are used.

If air bubbles are introduced during the mixing or handling process, they can be removed by vacuum deairing at 28-29 inches of mercury for 5-10 minutes. The deairing container should have at least four times the liquid volume to allow for expansion as the air bubbles expand and break. Airless mixing, metering, and dispensing equipment is recommended for production processing.

Pot Life and Cure Rate

After the two components are thoroughly mixed in a 1:1 ratio, Dow Corning 3-6527 A & B silicone dielectric gel will have a working life of about 16 hours and a gel (cure) time of about 24 hours at room temperature. The viscosity of the initial mix will double (pot life) in about 9 hours at room temperature.

Typical schedules for heat curing 100 grams of 1:1 catalyzed product in an 8-ounce glass jar are as follows:

4 hrs at 150 F (65 C)
1 hr at 212 F (100 C)
15 min at 302 F (150 C)

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

As Supplied — Part A		
CTM 0005	Color, APHA	5
CTM 0044	Specific Gravity at 77 F (25 C)	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	380
CTM 0208	Non-Volatile Content, 2g/2 hrs/302 F (150 C), percent	98.0
As Supplied — Part B		
CTM 0005	Color, APHA	5
CTM 0044	Specific Gravity at 77 F (25 C), cp*	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	320
CTM 0208	Non-Volatile Content, 2g/2 hrs/302 F (150 C), percent	97.0
As Catayzed — 1:1 ratio by weight or volume		
CTM 0005	Color, APHA	15
CTM 0044	Specific Gravity at 77 F (25 C)	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	330
CTM 0208	Non-Volatile Content, 2g/2 hrs/302 F (150 C), percent	98.0
CTM 0055	Pot Life, hours	2
CTM 0674A	Gel Time,	
	at room temperature, plunger A, hrs	24
	at 185 F (85 C), plunger A, min	15.6
	at 275 F (135 C), plunger A, min	7.4
As Cured — Physical†		
CTM 0002	Refractive Index at 77 F (25 C)	1.4074
CTM 0155	Penetration, x 10^{-1} mm,	
	initial, measured at 77 F (25 C)	57
	initial, measured at 302 F (150 C)	55
	initial, measured at 392 F (200 C)	34
	initial, measured at -40 F (-40 C)	54
	initial, measured at -58 F (-50 C)	35
	after aging 2 wks at 302 F (150 C)	37
	after aging 2 wks at 392 F (200 C)	35
CTM 0653	Volume of Cubical Expansion,	
	-0°C — 150°C, cc/cc/°C	9.9×10^{-4}
	-25°C — 150°C, cc/cc/°C	9.89×10^{-4}
As Cured — Electrical†		
CTM 0114	Dielectric Strength, volts/mil	440
CTM 0112	Dielectric Constant,	
	at 100 Hz	2.95
	at 100 KHz	2.95
CTM 0112	Dissipation Factor,	
	at 100 Hz	0.0025
	at 100 KHz	0.00015
CTM 0272	Volume Resistivity, ohm-cm	2.33×10^{15}
CTM 0171	Arc Resistance, seconds	182
CTM 0114	Dielectric Strength,	
	initial, measured at 77 F (25 C), volts/mil	385
	initial, measured at 302 F (150 C), volts/mil	390
	initial, measured at 392 F (200 C), volts/mil	398
	initial, measured at -40 F (-40 C), volts/mil	495
	initial, measured at -58 F (-50 C), volts/mil	525
	after aging 2 wks at 302 F (150 C)	515
	after aging 2 wks at 392 F (200 C)	500

*Brookfield LVT #3 at 60 rpm

†Cured 1 hour at 302 F (150 C). Depending upon the time and temperature of heat exposure, the color of the cured gel will vary from water clear to a tinted dark amber. Even with this color change the material remains sufficiently clear to visually inspect encapsulated assemblies. The color change is attributed to the formation of a very small concentration of chromophores that do not degrade the electrical, physical, or non-corrosive properties of the gel.

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

Relatively massive parts will require additional cure time to bring the material up to the desired temperature. Considerably shorter cure times can result when the part is preheated prior to adding the product or when the product is applied in relatively thin sections.

Repairability

Once cured in place, Dow Corning 3-6527 A & B silicone dielectric gel can be removed with relative ease, repairs or changes made, and the repaired area re-gelled in place with additional product. Since this gel develops good adhesion to itself, the repaired region will become an integral part of the original material.

Compatibility

Certain materials, chemicals, curing agents, and plasticizers can inhibit the cure of Dow Corning 3-6527 A & B silicone dielectric gel. Most notable of these are:

- Organo-tin and other organo-metallic compounds
- Silicone rubber containing organo-tin catalyst
- Sulfur, polysulfides, polysulfones or other sulfur-containing materials
- Amines, urethanes, or amine-containing materials
- Unsaturated hydrocarbon plasticizers.

If a substrate or material is questionable with respect to potentially causing inhibition of cure, it is recommended that a small scale compatibility test be run to ascertain suitability in a given application. The presence of liquid or uncured product at the interface between the questionable substrate and the cured Dow Corning 3-6527 A & B silicone dielectric gel would indicate incompatibility and inhibition of cure.

SHIPPING LIMITATIONS

None.

STORAGE AND SHELF LIFE

When stored in closed containers at or below 90 F (32 C), Dow Corning 3-6527 A & B silicone dielectric gel, before mixing, has a shelf life of 6 months from date of shipment.

PACKAGING

Dow Corning 3-6527 A & B silicone dielectric gel is supplied in the following kit sizes:

2-lb (0.9-kg)
18-lb (8.1-kg)
80-lb (36-kg)
800-lb (360-kg)

All weights, net.

New Product Information

DOW CORNING

DOW CORNING® Q3-6575 SILICONE DIELECTRIC GEL

Type	Two-component encapsulant
Physical Form	Gel
Special Properties	Stability at extremely low temperature
Primary Uses	Sealing, protecting and preserving many types of microelectronic devices

DESCRIPTION

DOW CORNING® Q3-6575 silicone dielectric gel is a two-component, transparent silicone encapsulant which provides good dielectric properties in severe environments, particularly at extremely low temperatures. Working range is -112 F to 392 F (-80 C to 200 C).

When the two components, A and B, of DOW CORNING Q3-6575 silicone dielectric gel are thoroughly mixed in a 1:1 ratio by either weight or volume, a cushioning, self-healing gel is formed. The cured gel retains the stress relief of a liquid while developing much of the dimensional stability and the nonflow characteristics of an elastomer. These unique properties are maintained at both the low and high temperature extremes, even with aging.

Special features of DOW CORNING Q3-6575 silicone dielectric gel include:

- Physical and electrical stability over a wide temperature range from -112 F to 392 F (-80 C to 200 C)
- Protection from mechanical stress and strain caused by thermomechanical shock and vibration
- Good dielectric properties, even at high frequencies
- No solvents or cure by-products

USES

DOW CORNING Q3-6575 silicone dielectric gel forms a permanent, pressure-sensitive, adhesive bond to many substrates. The adhesive quality and a silicone's highly hydrophobic property make it suitable for long-term sealing against moisture and other atmospheric contaminants. It is especially useful for sealing, protecting and preserving the electrical characteristics of many types of microelectronic devices, including hybrid circuits.

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

As Supplied – Part A		
CTM 0044	Specific Gravity at 77 F (25 C)	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	700
CTM 0208	Nonvolatile Content, 2 g/2 hrs/302 F (150 C), percent	96.0
As Supplied – Part B		
CTM 0044	Specific Gravity at 77 F (25 C)	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	650
CTM 0208	Nonvolatile Content, 2 g/2 hrs/302 F (150 C), percent	96.0
As Catalyzed – 1:1 Ratio By Weight or Volume		
CTM 0044	Specific Gravity (uncured) at 77 F (25 C)	0.97
CTM 0050	Viscosity at 77 F (25 C), cp*	675
CTM 0208	Nonvolatile Content, 2 g/2 hrs/302 F (150 C), percent	96.0
CTM 0055	Pot Life, hours	1/2
CTM 0674A	Gel Time, at 275 F (135 C), plunger A, minutes	5.9
As Cured – Physical		
CTM 0155A	Penetration, X 10^{-1}mm, measured at 77 F (25 C)	50
As Cured – Electrical		
CTM 0114A	Dielectric Strength, volts/mil	350
CTM 0249A	Volume Resistivity, ohm-cm	1×10^{14}

*Brookfield RVF #1 at 10 rpm

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

HOW TO USE

Mixing and Processing

DOW CORNING Q3-6575 silicone dielectric gel is properly catalyzed by thoroughly mixing Part A with Part B in a 1:1 ratio by either weight or volume.

If air bubbles are entrapped during mixing or handling they may be deaired with a vacuum of 28 to 29 inches of mercury for 5 to 10 minutes. Deair in a container at least four times the liquid volume to allow for expansion and breaking of the air bubbles. Airless mixing, metering and dispensing equipment is recommended for production processing.

Pot Life and Cure Rate

When the A and B components of DOW CORNING Q3-6575 silicone dielectric gel are thoroughly mixed in a 1:1 ratio, the working time is one hour. The viscosity of the initial mixture will double in 30 minutes at room temperature.

Typical schedules for heat curing 100 grams of catalyzed product in a 4-ounce glass jar are as follows:

4 hours at 150 F (65 C)
1 hour at 212 F (100 C)
15 minutes at 302 F (150 C)

Repairability

Once cured in place, DOW CORNING Q3-6575 silicone dielectric gel can be removed so that repairs or changes can be made. The repaired area can be regelled in place. The product adheres well to itself.

Compatibility

Certain materials, chemicals, curing agents and plasticizers can inhibit the cure of DOW CORNING Q3-6575 silicone dielectric gel. Most notable of these are:

- Organo-tin and other organo-metallic compounds
- Silicone rubber containing organo-tin catalyst
- Sulfur, polysulfides, polysulfones or other sulfur-containing materials
- Amines, urethanes or amine-containing materials
- Unsaturated hydrocarbon plasticizers

If a substrate or material is questionable with respect to potentially causing inhibition of cure, it is recommended that a small scale compatibility test be run to ascertain suitability in a given application. The presence of liquid or uncured product at the interface between the questionable substrate and the cured DOW CORNING Q3-6575 silicone dielectric gel indicates incompatibility and inhibition of cure.

IMPORTANT INFORMATION ON STORAGE AND HANDLING

When stored at room temperature, DOW CORNING Q3-6575 silicone dielectric gel has a shelf life of 6 months from date of shipment.

Materials Safety Data Sheet

A Materials Safety Data Sheet (Department of Labor, Form No. LSB-OOS-4), which gives OSHA data for this product may be obtained by writing Dow Corning Corporation, Mail No. 140, Miidland, Michigan, 48640.

SHIPPING LIMITATIONS

None.

PACKAGING

DOW CORNING Q3-6575 silicone dielectric gel is available in 800-, 100-, 22- and 2-lb. (363-, 45-, 10- and 0.9-kg) kits.

USERS PLEASE READ

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DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48640

Printed in U.S.A. Form No. 10-114-84

DOW CORNING

APPENDIX C

CELL THERMAL CYCLING RESULTS

DC 3-6527

a. Initial
b. 1 Cycle
c. 5 Cycle
d. 50 Cycles

	Isc mA	Voc mV	Pmax mW
Cell #5			
a.	165	562	67
b.	166	561	67
c.	165	559	61
d.	166	559	66
Cell #24			
a.	169	564	71
b.	168	566	65
c.	167	565	65
d.	167	562	69
Cell #32			
a.	167	560	70
b.	167	559	70
c.	165	556	68
d.	167	558	70
Cell #34			
a.	172	556	71
b.	171	556	70
c.	171	553	70
d.	171	555	70
Cell #10			
a.	167	557	65
b.	167	559	66
c.	166	558	65
d.	166	557	65
Cell #26			
a.	167	558	68
b.	165	558	66
c.	170	557	66
d.	165	557	66

DC-93-500

a. Initial
b. 1 Cycle
c. 5 Cycle
d. 50 Cycles

	Isc mA	Voc mV	Pmax mW
Cell #92			
a.	171	559	71
b.	169	558	71
c.	167	558	70
d.	157	454	40
Cell #15			
a.	170	565	69
b.	170	564	69
c.	169	542	59
d.	145	435	32
Cell #73			
a.	170	561	70
b.	168	547	62
c.	160	500	48
d.	140	442	35
Cell #80			
a.	166	[illegible]	60
b.	166	[illegible]	61
c.	165	550	59
d.	163	527	49
Cell #84			
a.	171	555	69
b.	170	548	65
c.	166	530	57
d.	146	450	38
Cell #25			
a.	168	562	72
b.	169	562	72
c.	171	558	71
d.	158	480	43

MN-CV 2500

a. Initial
b. 1 Cycle
c. 5 Cycle
d. 50 Cycles

	Isc mA	Voc mV	Pmax mW
Cell #42			
a.	171	554	71
b.	170	549	68
c.	169	509	53
d.	142	419	30
Cell #90			
a.	171	554	72
b.	166	509	52
c.	146	431	34
d.	119	394	23
Cell #33			
a.	166	554	67
b.	165	554	63
c.	155	484	43
d.	115	389	23
Cell #27			
a.	170	561	66
b.	167	532	55
c.	152	437	35
d.	129	410	25
Cell #95			
a.	169	559	72
b.	167	531	57
c.	147	420	28
d.	126	393	26
Cell #97			
a.	170	563	70
b.	169	555	65
c.	162	465	41
d.	150	447	36

MN-CV 2501

a. Initial
b. 1 Cycle
c. 5 Cycle
d. 50 Cycles

	Isc mA	Voc mV	Pmax mW
Cell #57			
a.	170	559	70
b.	165	513	52
c.	153	430	35
d.	128	404	27
Cell #17			
a.	169	556	57
b.	159	473	36
c.	125	398	21
d.	94	385	?
Cell #47			
a.	170	568	67
b.	168	567	65
c.	169	557	59
d.	161	486	41
Cell #88			
a.	168	561	70
b.	166	539	58
c.	142	426	34
d.	127	388	25
Cell #29			
a.	170	562	68
b.	170	562	68
c.	168	536	56
d.	153	448	37
Cell #7			
a.	167	561	68
b.	165	543	55
c.	153	479	41
d.	131	413	28

MN-CV 2567

a. Initial
b. 1 Cycle
c. 5 Cycle
d. 50 Cycles

	Isc mA	Voc mV	Pmax mW
Cell #96			
a.	169	553	68
b.	169	553	68
c.	169	553	68
d.	169	553	67
Cell #111			
a.	171	559	67
b.	171	559	67
c.	170	559	66
d.	170	552	63

Dow Corning Q3-6575

	Isc mA	Voc mV	Pmax mV
Cell #19			
a	169	563	70
b	169	563	70
c	169	563	70
d	167	547	62
Cell #1			
a	164	562	72
b	163	563	72
c	164	562	72
d	163	561	70
Cell #4			
a	163	562	69
b	163	563	70
c	162	563	70
d	162	564	70
Cell #174 (Planar Control)			
a	161	607	76
b	161	606	76
c	161	607	76
d	161	608	76

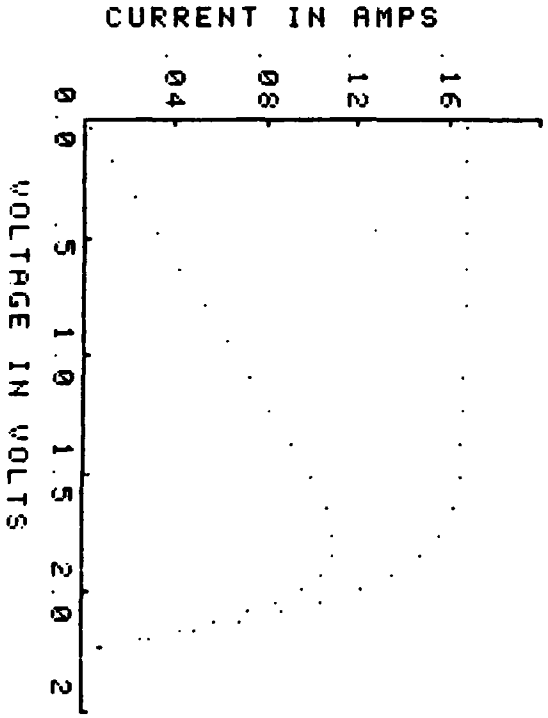
Cell #	Encapsulant	Coversliding Method
5	DC3-6527	1
7	MNCV-2501	3
24	DC3-6527	1
34	DC3-6527	2
10	DC3-6527	3
26	DC3-6527	3
27	MNCV-2500	2
29	MNCV-2501	3
32	DC3-6527	2
33	MNCV-2500	2
42	MNCV-2500	1
47	MNCV-2500	2
53	MNCV-2567	1
57	MNCV-2501	1
66	DC93-500	1
73	DC93-500	2
80	DC93-500	2
84	DC93-500	3
88	MNCV-2501	2
90	MNCV-2500	1
92	DC93-500	1
15	DC93-500	1
95	MNCV-2500	3
96	MNCV-2567	3
97	MNCV-2500	3
25	DC93-500	3
17	MNCV-2501	1
111	MNCV-2567	3

APPENDIX D

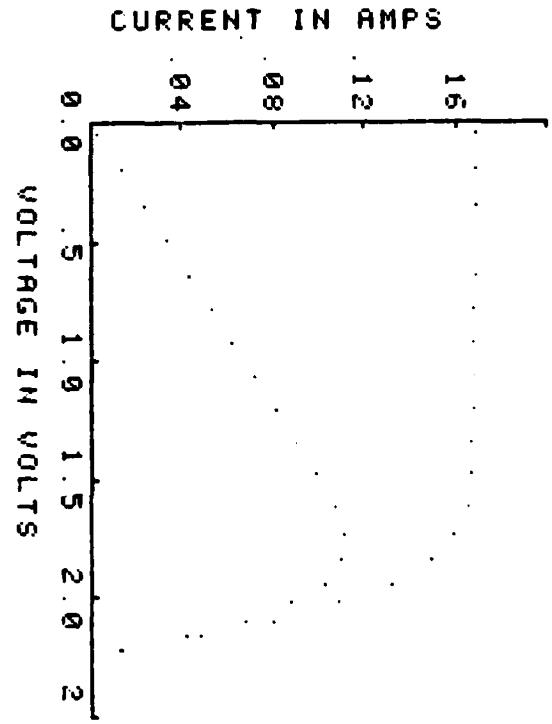
TEST PANEL

THERMAL CYCLING DATA

OPERATOR E. GADDY
DATE: 11/14/85 TIME 10:01
TEST ARTICLE VJ 1
PEAK POWER .276
OPN CKT VOLTAGE= 2.241
SHT CKT CURRENT= .168
FILL FACTOR .728
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 23
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .08731
STANDARD CELL OUTPUT .087



OPERATOR GJK
DATE: 11/19/85 TIME 11:51
TEST ARTICLE VJ 1
PEAK POWER .277
OPN CKT VOLTAGE= 2.246
SHT CKT CURRENT= .169
FILL FACTOR .728
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 26
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

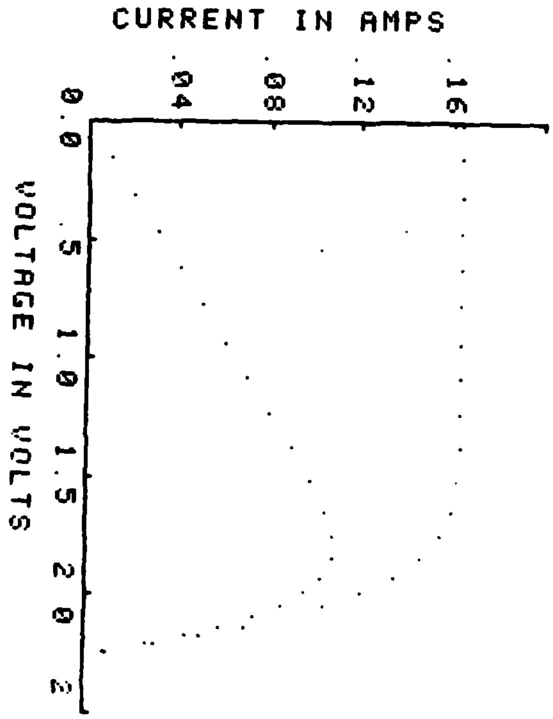


SOLDERED DC3-6527

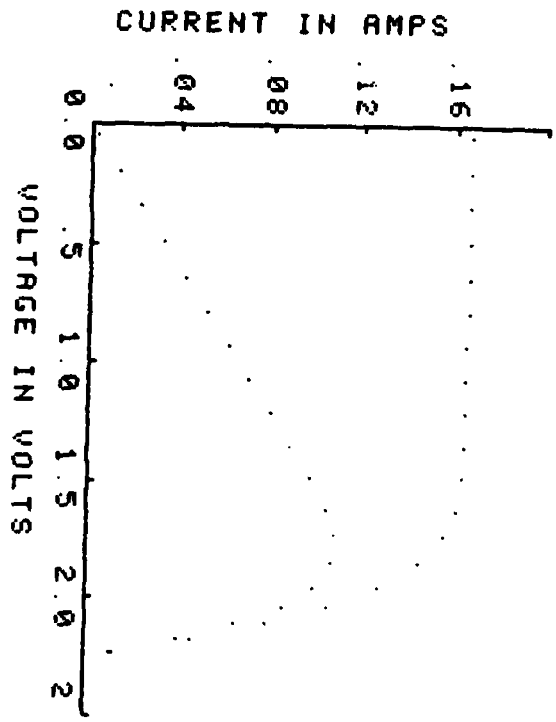
BEFORE

AFTER

OPERATOR E. GADDY
DATE: 11/14/85 TIME 10:08
TEST ARTICLE VJ 2
PEAK POWER .272
OPN CKT VOLTAGE= 2.256
SHT CKT CURRENT= .165
FILL FACTOR .726
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 23
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .08731
STANDARD CELL OUTPUT .088



OPERATOR GJK
DATE: 11/19/85 TIME 11:54
TEST ARTICLE VJ 2
PEAK POWER .271
OPN CKT VOLTAGE= 2.257
SHT CKT CURRENT= .166
FILL FACTOR .719
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 26
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

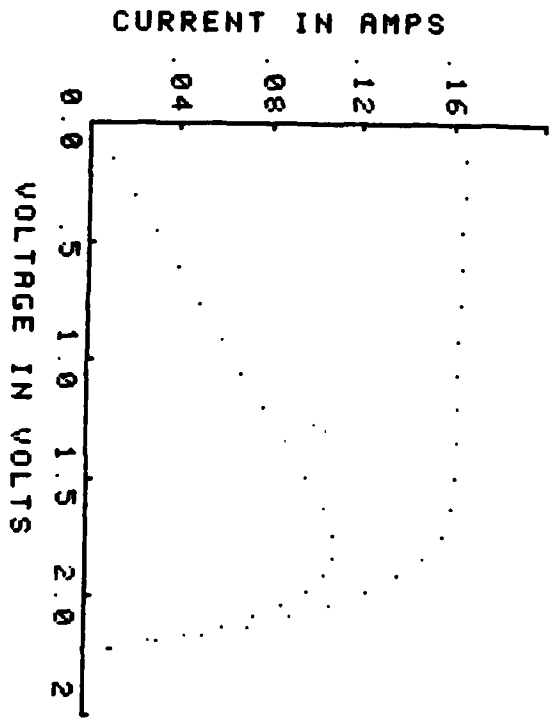


SOLDERED DC-Q3-6575

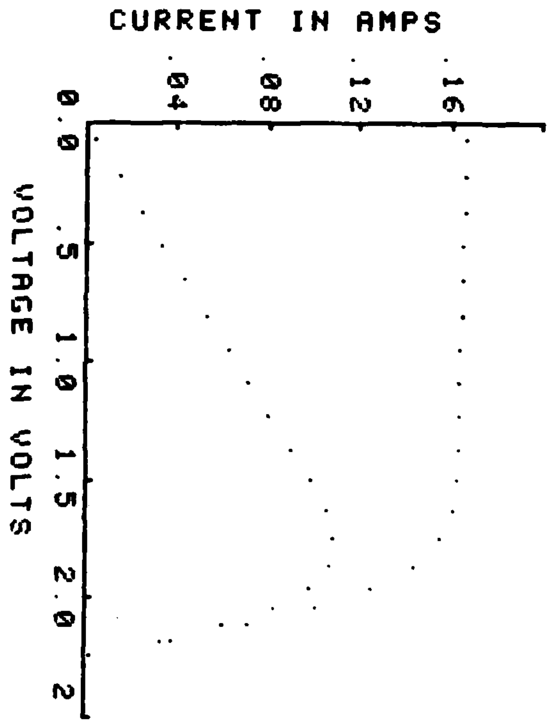
BEFORE

AFTER

OPERATOR E. GADDY
DATE: 11/14/85 TIME 10:12
TEST ARTICLE VJ 3
PEAK POWER .272
OPN CKT VOLTAGE= 2.241
SHT CKT CURRENT= .166
FILL FACTOR .726
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 23
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .08731
STANDARD CELL OUTPUT .088



OPERATOR GJK
DATE: 11/19/85 TIME 11:58
TEST ARTICLE VJ 3
PEAK POWER .273
OPN CKT VOLTAGE= 2.246
SHT CKT CURRENT= .167
FILL FACTOR .729
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 26
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

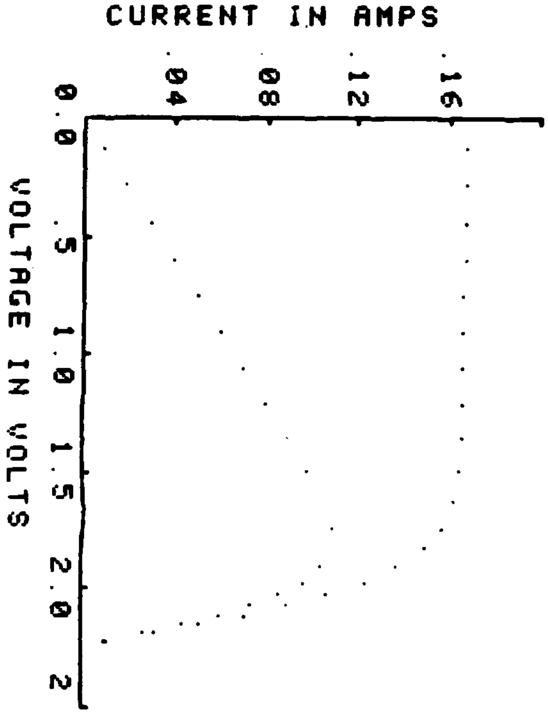


WELDED DC 3-6527

BEFORE

AFTER

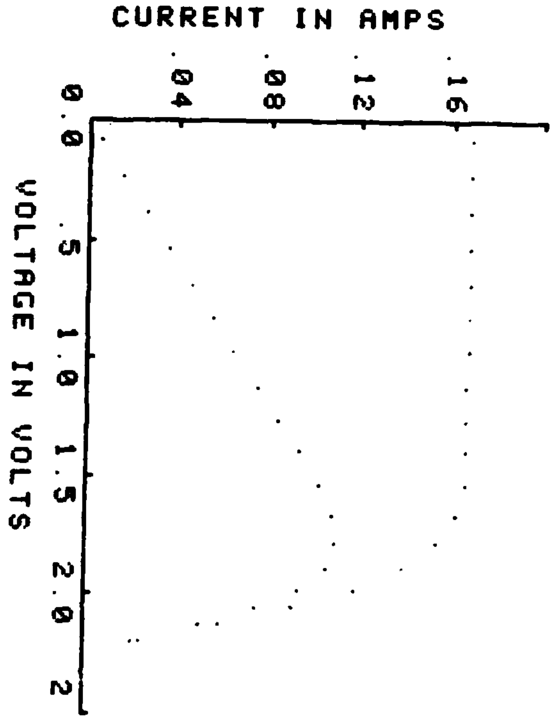
OPERATOR E. GADDY
DATE: 11/14/85 TIME 10:16
TEST ARTICLE VJ 4
PEAK POWER .275
OPN CKT VOLTAGE= 2.233
SHT CKT CURRENT= .168
FILL FACTOR .727
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 23
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .08731
STANDARD CELL OUTPUT .088



WELDED DC-83-6575

BEFORE

OPERATOR GJK
DATE: 11/19/85 TIME 12:06
TEST ARTICLE VJ 4
PEAK POWER .276
OPN CKT VOLTAGE= 2.228
SHT CKT CURRENT= .169
FILL FACTOR .734
ALPHA (VOLTS/(CELL*DEG C))=
-.0022
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 4
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 26
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089



AFTER

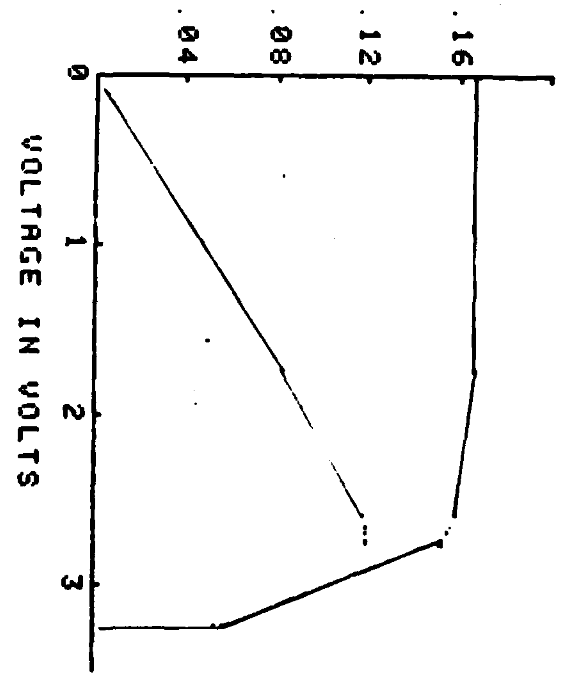
APPENDIX E

FINAL PANEL

TEST DATA

OPERATOR GJK
DATE: 12/9/85 TIME 07:21
TEST ARTICLE VJ 6-S
PEAK POWER .420
OPN CKT VOLTAGE= 3.383
SHT CKT CURRENT= .167
FILL FACTOR .744
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 24
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .088

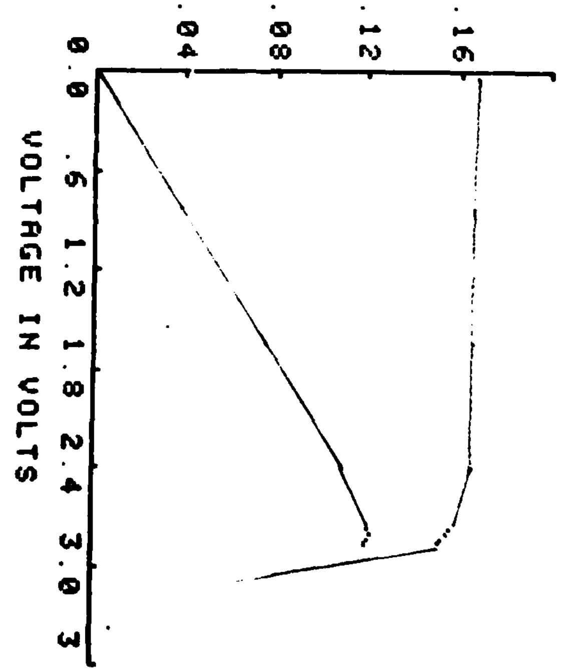
#	VOLTAGE	CURRENT	POWER
1	.014	.1669	.0023
2	.111	.1667	.0185
3	1.747	.1662	.2904
4	2.602	.1594	.4147
5	2.661	.1574	.4188
6	2.690	.1560	.4196
7	2.737	.1534	.4198
8	2.765	.1516	.4192
9	3.251	.0568	.1846
10	3.382	.0002	.0008



FINAL PANEL SOLDERED
AFTER THERMAL CYCLES

OPERATOR GJK
DATE: 11/29/85 TIME 07:11
TEST ARTICLE VJ-6(SOLDER)
PEAK POWER .439
OPN CKT VOLTAGE= 3.421
SHT CKT CURRENT= .168
FILL FACTOR .765
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 21
STANDARD TEMPERATURE= 29
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .085

#	VOLTAGE	CURRENT	POWER
1	.049	.1675	.0082
2	.829	.1668	.1383
3	1.631	.1670	.2724
4	2.393	.1663	.3980
5	2.810	.1561	.4387
6	2.776	.1571	.4361
7	2.840	.1530	.4344
8	2.855	.1514	.4321
9	2.735	.1594	.4360
10	3.382	.0090	.0306

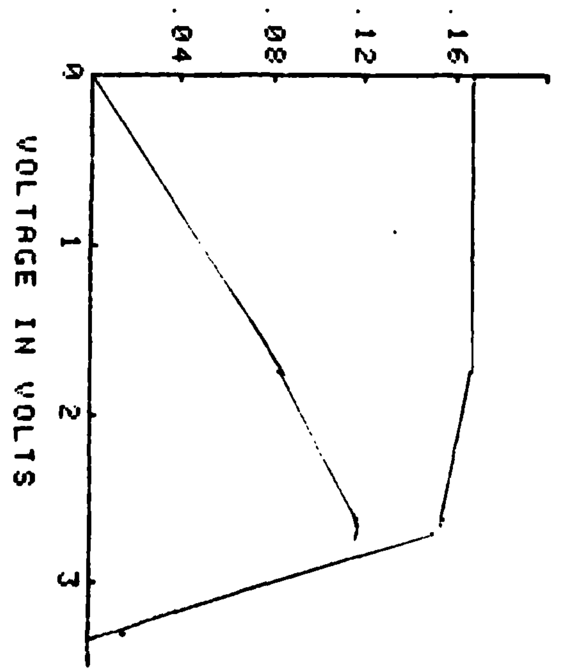


FINAL PANEL
SOLDERED INITIAL

OPERATOR GJK
DATE: 12/9/85 TIME 07:15
TEST ARTICLE VJ 6-W
PEAK POWER .410
OPN CKT VOLTAGE= 3.359
SHT CKT CURRENT= .168
FILL FACTOR .725
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 24
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

#	VOLTAGE	CURRENT	POWER
1	.020	.1684	.0034
2	.051	.1684	.0085
3	1.746	.1674	.2923
4	2.663	.1539	.4097
5	2.707	.1510	.4089
6	2.658	.1544	.4103
7	2.631	.1558	.4099
8	3.322	.0159	.0528
9	3.358	.0004	.0012

CURRENT IN AMPS

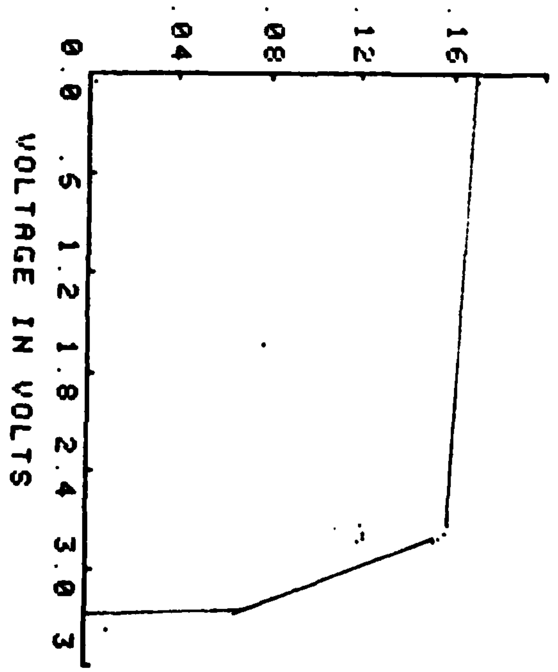


FINAL PANEL WELDED
AFTER THERMAL CYCLE

OPERATOR GJK
DATE: 11/29/85 TIME 07:19
TEST ARTICLE VJ-6(WELDED)
PEAK POWER .441
OPN CKT VOLTAGE= 3.411
SHT CKT CURRENT= .171
FILL FACTOR .757
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 21
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .084

#	VOLTAGE	CURRENT	POWER
1	.047	.1708	.0081
2	1.647	.1692	.2786
3	2.743	.1597	.4381
4	2.781	.1586	.4411
5	2.816	.1558	.4388
6	2.839	.1527	.4336
7	3.258	.0642	.2092
8	3.386	.0107	.0361

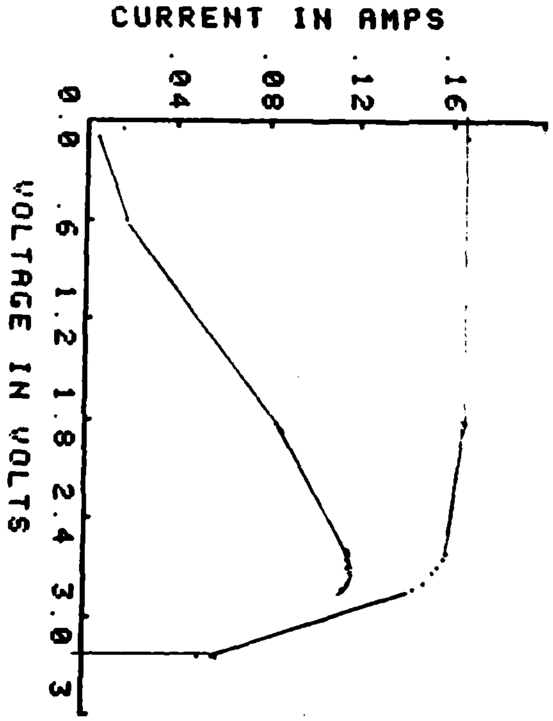
CURRENT IN AMPS



FINAL PANEL WELDED
INITIAL

OPERATOR GJK
DATE: 12/19/85 TIME 05:39
TEST ARTICLE VJ-6(SOLDERED)
PEAK POWER .421
OPN CKT VOLTAGE= 3.382
SHT CKT CURRENT= .167
FILL FACTOR .744
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 22
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

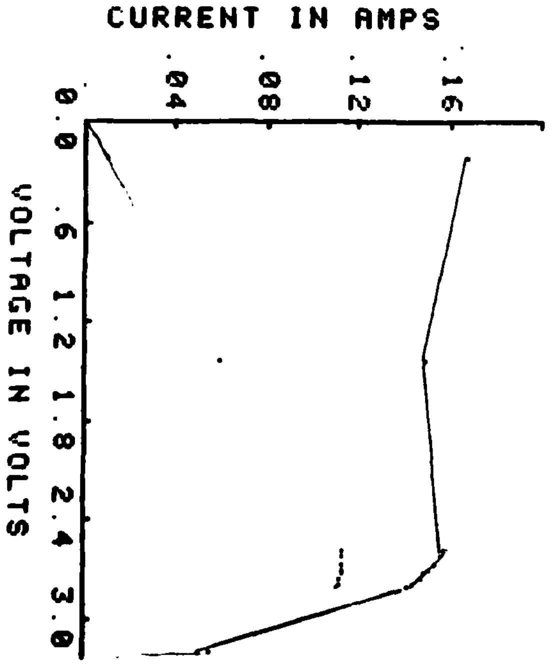
#	VOLTAGE	CURRENT	POWER
1	.104	.1672	.0174
2	1.824	.1665	.3038
3	2.626	.1592	.4180
4	2.661	.1576	.4192
5	2.705	.1552	.4200
6	2.742	.1534	.4206
7	2.836	.1450	.4113
8	2.801	.1491	.4177
9	3.253	.0566	.1842
10	3.380	.0008	.0027



FINAL PANEL SOLDERED
AFTER THERMAL VACUUM
(FINAL)

OPERATOR GJK
DATE: 12/19/85 TIME 05:35
TEST ARTICLE VJ-6(WELDED)
PEAK POWER .410
OPN CKT VOLTAGE= 3.362
SHT CKT CURRENT= .168
FILL FACTOR .726
ALPHA (VOLTS/(CELL*DEG C))=
-.00215
BETA (AMPS/(CELL*DEG C))=
.00008
NUMBER OF SERIES CELLS= 6
NUMBER OF PARALLEL CELLS= 1
AMBIENT TEMPERATURE= 22
STANDARD TEMPERATURE= 28
STD CELL SHOULD READ .0884
STANDARD CELL OUTPUT .089

#	VOLTAGE	CURRENT	POWER
1	.000	.1681	.0000
2	.217	.1673	.0362
3	1.434	.1496	.2146
4	2.750	.1476	.4059
5	2.781	.1450	.4032
6	2.808	.1426	.4003
7	2.725	.1494	.4072
8	3.212	.0564	.1811
9	2.698	.1513	.4082
10	2.663	.1538	.4094
11	2.623	.1565	.4104
12	2.580	.1581	.4079
13	3.355	.0014	.0048



FINAL PANEL WELDED
AFTER THERMAL VACUUM (FINAL)

END

DTIC

6-86