AD-A092 903 VARIAN ASSOCIATES INC PALO ALTO CA F/G 9/1
HIGH POWER KLYSTRONS FOR EFFICIENT RELIABLE HIGH POWER AMPLIFIE--ETC(U)
NOV 80 M LEVIN DAAB07-76-C-8072
UNCLASSIFIED CSA-76-8072-F NL

1 OF 2
AD
A092903

Report No. CSA-76-8072-F

Contract No. DAAB07-76-C-8072

HIGH POWER KLYSTRONS FOR EFFICIENT RELIABLE HIGH POWER AMPLIFIERS

LEVEL II

M. Levin

VARIAN ASSOCIATES, Inc.
611 Hansen Way
Palo Alto, CA 94303

AD A092903

DTIC ELECTE DEC 16 1980 S D E

FINAL
TECHNICAL REPORT

November 1980

U.S. ARMY
COMMUNICATIONS SYSTEMS AGENCY
FORT MONMOUTH, NEW JERSEY

DDC FILE COPY

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

MONITORING OFFICE
U.S. ARMY
COMMUNICATIONS R&D COMMAND
Fort Monmouth, NJ

THE VIEWS, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR(S), AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

80 12 15 050

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as offical Government endorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CSA-76-8072-F	2. GOVT ACCESSION NO. AD-A092 903	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) High Power Klystrons for Efficient Reliable High Power Amplifiers		5. TYPE OF REPORT & PERIOD COVERED 16 June 1976 – 31 July 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. Levin		8. CONTRACT OR GRANT NUMBER(s) DAAB07-76-C-8072
9. PERFORMING ORGANIZATION NAME AND ADDRESS Varian Associates, Inc 611 Hansen Way Palo Alto, CA 94303		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1X763707D245/1 702
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Communications Systems Agency ATTN: CCM-RD-T Fort Monmouth, NJ 07703		12. REPORT DATE November 1980
		13. NUMBER OF PAGES 153
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U.S. Army Electronics Technology and Device Laboratory (ERADCOM) ATTN: DELET-BM Fort Monmouth, NJ 07703		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release – Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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

High Power Broadband Klystrons, Troposcatter Tubes, High Efficiency Microwave Tubes, High Power Klystron, Vapor/Liquid Phase Cooling Systems

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

This report covers the design of reliable high efficiency, high power klystrons which may be used in both existing and proposed troposcatter radio systems. High Power (10 kW) klystron designs were generated in C-band (4.4 GHz to 5.0 GHz), S-band (2.5 GHz to 2.7 GHz), and L-band or UHF frequencies (755 MHz to 985 MHz). The tubes were designed for power supply compatibility and use with a vapor/liquid phase heat exchanger. Four (4) S-band tubes were developed in the course of this program along with two (2) matching focusing solenoids and two (2) heat exchangers. These tubes use five (5) tuners with counters which are attached to the focusing solenoids. A reliability mathematical model of the tube and heat exchanger system was also generated.

UNCLASSIFIED

DD FORM 1 JAN 73 1473

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF ILLUSTRATIONS

Accession For
NTIS GRA&I ☒
DDC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist. | Avail and/or special
A | 23 C.F

1. INTRODUCTION

1.1 SUMMARY

This report covers the design of reliable high efficiency, high power klystrons which may be used in both existing (lower efficiency and limited bandwidth) and proposed troposcatter radio systems. High power (10 kW) klystron designs were generated in C-Band (4.4 GHz to 5.0 GHz), S-Band (2.5 GHz to 2.7 GHz), and L-Band or UHF frequencies (755 MHz to 985 MHz). The tubes were designed for power supply compatibility and use with a vapor/liquid phase heat exchanger. Four S-Band tubes were developed in the course of this program along with two matching focusing solenoids and two heat exchangers. These tubes employ five tuners with counters which are attached to the focusing solenoids. A reliability mathematical model of the tube and heat exchanger system was also produced.

1.2 KLYSTRON TYPES

The newer Varian klystrons discussed or mentioned in this report are (in cronological sequence of design or development) as follows:

VKC-7790: The six cavity VKC-7790 C-band klystron with a "single-knob" tuner mechanism and VYW-7800 yoke electromagnet were developed under ECOM contract DAAB07-70-C-0228. See these contract reports for more complete details. This klystron utilizes a long penultimate and extra long prepenultimate drift length to produce second harmonic enhancement and thereby achieve 56% minimum beam efficiency, 12 MHz 1 dB bandwidth and 50 dB minimum gain.

VKC-7790AP: The VKC-7790AP C-band klystron was designed (but not built) and the VYW-7800AP yoke electromagnet was designed and built under this contract. The sixth cavity and the extra long 7790 drift length were eliminated and the electronic design was scaled from the existing high-efficiency 5K70SG/SK (Apollo). The rationale was that the reduced magnet power resulting from the shorter length would compensate for the lower beam efficiency. Furthermore, it would provide compat ible system efficiency with lower weight and improve the small-signal bandwidth performance.

VA-908R: The VA-908R C-band klystron and VA-1908R yoke electromagnet were developed and produced by Varian Associates, Inc., for Raytheon/USAF, TRC-170. For this application the tube typically provides 16 MHz minimum 3 dB bandwidth at 48% efficiency with 52 dB gain. The tube is capable of about 22 MHz bandwidths with the gain reduced to the order of 48 dB.

VKS-7830: The VKS-7830 S-band klystron and VYW-7830 solenoid electromagnet and companion heat exchanger were developed under this contract. This tube provides 50% beam efficiency at 18 MHz bandwidth with 51 dB gain.

UHF-Tropo: A preliminary design(s) for a UHF-Tropo (L-band) klystron and solenoid electromagnet have been generated under this contract.

1.3 KLYSTRON FEATURES

All of the above types, with the exception of the six cavity 7790, utilize the second harmonic current component (five cavity Apollo version) in the bunched beam to further enhance the bunching process and incorporate digital tuning mechanisms for rapid precise frequency changes without accessory equipment.

These are all high efficiency klystron amplifiers for troposcatter and for other applications requiring power outputs in the order of 10 kW. They are either capable of, or can be adapted to, applications requiring high level multiple signal inputs (Section 3.4). The same beam power supply and cooling system may be used for all types; other power supply requirements are similar, but vary somewhat due to frequency (and therefore, size) as tabulated on the following page:

	VKC 7790	VKC 7790AP Proposed	VA 908R	VKS 7830	UHF Tropo Proposed	
Beam Voltage	14	14	14	14	14.5	kVdc
Beam Current	1.4	1.4	1.4	1.4	1.5	Adc
Beam Power	20	20	20	20	22	kW
Heater Voltage	6	6	6	8	16 max	Vac
Heater Current	6.5	6.5	6.5	9	TBS	Aac
Heater Power	40	40	40	70	120 max	W
Magnet Voltage	120	100	80	75	TBS	Vdc
Magnet Current	16.5	14	12.5	13.5	15 max	Adc
Magnet Power	2	1.4	1	1	1 max	kW

The above values are approximate nominals. VKC-7790 produced well over 10 kW at this operating level. VA-908R data has been adjusted for 10 kW operation; they are tested for 8 kW minimum power output for TRC-170.

1.4 S-BAND DEVELOPMENT

This report emphasizes the highlights of the S-band development effort and provides selected coverage of the test results obtained.

The VKS-7830 klystron amplifier assembly, consisting of the klystron, its focusing electromagnet and heat exchanger, was developed under U.S. Army Contract DAAB07-76-C-8072 and Development Specification CSA-76-001A.

The primary objectives are to provide a high efficiency klystron amplifier for troposcatter applications producing 10 kW of output power tunable over the 2.5 to 2.7 GHz frequency range. The klystron body and electromagnet are liquid cooled and the collector is ebulliently cooled. (i.e., cooled using the latent heat of vaporization of a boiling liquid which offers improved heat exchanger efficiency - see Appendix G). The cooling system is compatible with azeotropic (i.e., a liquid mixture in which the component parts boil off at the same temperature, in this case 209°F) Dowtherm 209 and water coolant. (See Appendix G and report

ECOM-0228-2 for details on the advantages and properties of this cooling technique.) Power supply requirements are compatible with the VKC-7790, the VKC-7790AP, etc. Digital tuning mechanisms are provided for rapid, precise frequency changes without accessory equipment.

The development was performed by the High Power Klystron Development Group at Varian Associates, Inc.

This klystron amplifier assembly successfully meets the contract objectives.

2. DESIGN, C-BAND (4.4 to 5.0 GHz)

2.1 VKC-7790

The C-band tropo klystron, type VKC-7790, resulted from a previous development (see Reports ECOM-0228 series). This tube and auxiliary equipment use a combination of techniques to obtain high overall efficiency. One is second harmonic space charge bunching. This is a process whereby the fundamental and second harmonic components of the space charge waves in the electron beam of a microwave tube are combined to produce more highly concentrated electron bunches raising the tube's efficiency. This can be done by utilizing resonators tuned to the 2nd harmonic of the operating frequency or alternatively, properly extending the drift lengths to enhance the 2nd harmonic component in the space charge waves. The latter method was utilized in the VKC-7790. Computer simulation was used to optimize the extended drift lengths for maximum efficiency. The overall system efficiency is further improved by using a combination vapor/liquid phase cooling system rather than a liquid only system (see Appendix G). The combined cooling system saves about 2 kilowatts of prime power as a comparison to earlier liquid only cooling systems. See reports ECOM-0228 series for details of other developments incorporated in the VKC-7790 such as sliding short tuners, improved beam coupling, single knob tuner, etc.

One disadvantage associated with the design used in the VKC-7790 is that it must be operated at, or close to, the optimum operating voltage to maintain the maximum efficiency. If the beam voltage is reduced appreciably, the efficiency is also reduced. Other disadvantages include loss of bandwidth at small signal (below saturated output power) and increased magnet weight and power consumption resulting from the appreciably extended drift lengths.

2.2 VKC-7790AP

As a result of the deficiencies discussed above, a comparative analysis was made of the various design approaches available. It was decided to modify the design to obtain the desired bandwidth both at full (saturated) and reduced (small-signal) power output. By eliminating the sixth cavity (no longer needed for gain or bandwidth), shortening the prepenultimate extra long drift length and scaling the electronic design from the existing high efficiency 5K70SG/SK (Apollo), the VKC-7790 was simplified and evolved as the VKC-7790AP. This design still employs second harmonic bunching, but to an extent less than the optimum and some electronic efficiency is therefore sacrificed. However, elimination of the sixth cavity and the extra long prepenultimate drift length shortens the tube significantly and therefore allows the magnet weight and power consumption to be reduced appreciably. Consequently, the reduced magnet power consumption would partially compensate for the reduced electronic efficiency. The overall system efficiency would be somewhat less, but comparable, to the VKC-7790. The design parameters for the VKC-7790AP are summarized in Section 3.3 and the outline drawing (143316) may be seen in Appendix C.

2.3 VA-908R

While the design evolution described above was in progress, the VA-908R klystron was selected for the Raytheon/USAF TRC-170 high power amplifiers.

The VA-908R is essentially a shortened (the first two drift lengths are shorter) version of the VKC-7790AP. This further shortening reduces the gain-bandwidth of the tube. However, only 50 dB and 12 MHz were required and the even lower magnet weight and power were desirable for this system. The output cavity Qe was also reduced somewhat from the more optimum value planned for the VKC-7790AP; this allows the tube to be more forgiving of misapplication in the field at some sacrifice in efficiency. The VA-908R should not be confused with the older VA-908C; the VA-908R employs the type of refinements discussed here-in and yields substantially improved performance in comparison to the earlier predecessor.

The VKC-7790AP and the VA-908R are so similar that there would have been little benefit from continuing the VKC-7790AP development effort. Two electromagnets were fabricated, but the tube fabrication was terminated before building any tubes and the emphasis of this program was shifted to the VKS-7830 at S-band.

3. DESIGN, S-BAND (2.5 to 2.7 GHz)

3.1 S-BAND PROGRAM

The original objectives of this contract were to continue the development of the C-band klystron, electromagnet and heat exchanger, and to develop paper designs for similar high-efficiency tropo klystrons and magnets at S-band and UHF (L-band).

As discussed in the previous section (2.3), the emphasis of the program was shifted to S-band, i.e., paper designs were completed for the VKC-7790AP, etc. at C-band and for a UHF klystron, etc. (see Section 4) and development and fabrication work were carried out at S-band.

Four klystrons (VKS-7830), two electromagnets (VYW-7830), and two heat exchangers were built and evaluated.

The heat exchangers are more compact versions (tube and magnet are now external), of the VKC-7790 units. Heat exchanger photographs, operating/maintanance instructions, layout drawings/schematics and the purchase specification are included, in the above order, in Appendix E. The heat exchanger was used during all klystron testing. The test data pertinent to this unit only appears on sheet A-3. This heat exchanger exploits the efficiency enhancing techniques discussed in Appendix G.

The VYW-7830 electromagnets (see photograph, Figure 4, page D-4) and digital tuner were of course used in testing all the klystrons; specific electromagnet test data may be seen on page A-59.

The reliability analysis for the S-band assemblies is contained in Appendix F.

The design objectives for the VKS-7830 klystron amplifier, the VYW-7830 electromagnet and the companion heat exchanger are summarized as follows:

Parameter	Symbol	Max	Min	Units
Frequency	F	2.7	2.5	GHz
Beam Voltage	E_b	15.0		kV
Beam Current	I_b	2.0		A
Beam Power	P_{dc}	30.0		kW
Power Output	Po		10.0	kW
RF Drive	Pd	100.0		mW
Gain	Gain		40.0	dB
1 dB Bandwidth	BW		12.0	MHz
Heater Voltage	E_f	8.0		V
Heater Current	I_f	15.0		A
System Efficiency	S_{eff}		45.0	%
Signal to Noise	Sn		-60.0	dB
Input VSWR	VSWR	1.3		VSWR
Load VSWR	VSWR	1.2		VSWR

These objectives have been achieved.

3.2 DESIGN CONCEPT

For the reasons discussed in the previous section (see 2.1) super-high efficiency techniques were not appropriate or feasible for the VKS-7830. This klystron, therefore, is patterned after the several Varian klystrons achieving higher efficiency with straightforward, but optimum, 5 cavity design.

3.3 TROPO KLYSTRON DESIGN PARAMETERS SUMMARY

The tabulation on the following page summarizes the principal design parameters of the VKC-7790AP, the VKS-7830, and the projected UHF tropo klystron.

Symbol	Parameter	VKC-7790AP	VKS-7830	UHF Tropo	Units
Po	Power Output	10	10	10	kW
F_c	Center Frequency	4.7	2.6	0.86	GHz
E_b	Beam Voltage	14	14	14.5	kV
I_b	Beam Current	1.4	1.4	1.5	A
μk	Microperveance	0.86	0.86	0.86	$\mu A/V^{3/2}$
b/a	Filling Factor	0.6	0.65	0.67	---
2a	Tunnel Diameter	0.13	0.23	0.69	inch
2b	Beam Diameter	0.08	0.15	0.46	inch
γa	Normalized Beam	0.66	0.69	0.66	rad
γb	and Tunnel Radius	0.4	0.45	0.44	rad
d1	1st gap length	0.09	0.25	0.38	inch
d2	2nd gap length	0.09	0.25	0.38	inch
d3	3rd gap length	0.09	0.25	0.38	inch
d4	4th gap length	0.09	0.17	0.38	inch
d5	5th gap length	0.06	0.12	0.38	inch
$\beta ed1$		0.95	1.2	0.74	rad
$\beta ed2$	Normalized	0.95	1.2	0.74	rad
$\beta ed3$	Gap	0.95	1.2	0.74	rad
$\beta ed4$	Lengths	0.95	1.0	0.74	rad
$\beta ed5$		0.95	0.7	0.74	rad
$\ell 1\text{-}2$	Drift	1.22	2.31	3.75	inch
$\ell 2\text{-}3$	Tube	1.07	2.03	3.75	inch
$\ell 3\text{-}4$	Lengths	1.07	2.03	6.25	inch
$\ell 4\text{-}5$	Gap to Gap	0.63	1.17	3.75	inch
$\beta q\ \ell 1\text{-}2$	Normalized	71	71	37	degrees
$\beta q\ \ell 2\text{-}3$	Drift	63	62	37	degrees
$\beta q\ \ell 3\text{-}4$	Lengths	63	62	62	degrees
$\beta q\ \ell 4\text{-}5$		37	36	37	degrees
B_{br}	Brillouin Field	950	465	160	Gauss

3.4 DESIGN EVOLUTION

VKS-7830, S/N 101, was basically scaled from the VKC-7790AP. Some small adjustments were made because all the dimensions did not scale to convenient standard sizes. The cavity configurations were trimmed to obtain the desired tuning range and rate with the best R/Q compatible with minimum drift tube offset. Large signal computations were performed to determine the optimum output cavity Q_{e5} for best efficiency. The external and internal Q's of the input cavity were adjusted for the best achievable operating match. The results of this design phase are summarized below.

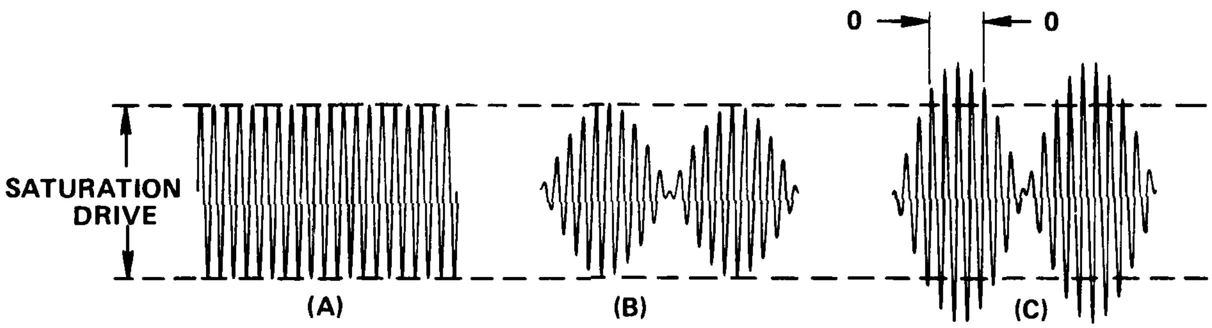
Frequency	2.5 - 2.7	GHz
[1] R/Q (1, 2, & 3)	125	ohms
R/Q (4th)	120	ohms
R/Q (5th)	120	ohms
[2] Tune Rate (1, 2, & 3)	4.0	MHz/mil
Tune Rate (4th)	3.8	MHz/mil
Tune Rate (5th)	3.6	MHz/mil
[3] Q_{e1} (external Q)	400	---
Q_{01} (internal Q)	1100	---
Q_{L1} (loaded Q)	290	---
[4] Q_{e5} (S/N 102-104)	61 - 72	---

[1] R/Q is equivalent to the L to C ratio of the resonant circuit; these high values enhance gain and bandwidth. [2] These values of tuning rate allow the frequency range to be covered with reasonable tuner movement without mechanical instabilities. [3] The external Q in parallel with the internal Q $(1/Q_{e1}) + (1/Q_{o1}) = (1/400) + (1/1100) = 293$ approximately equals the loaded Q (290) for low input VSWR at the input cavity resonant frequency. [4] These values of output cavity Q_{e5} were determined for good intermodulation distortion performance near saturation.

VKS-7830, S/N 101, performed well and met all specification requirements. Measurements, with an adjustable output matching device, confirmed the output Q_{e5} was optimum for the maximum possible efficiency. However, during the performance of additional tests beyond the scope of the specification, behavior was observed which might cause difficulties in some applications. For instance, executing two-tone intermodulation measurements on S/N 101, the presence of additional products were noted at power levels near saturation. These were attributed to some form of feedback; the most probable being electrons returning from the region of the output gap. This can occur in an otherwise perfectly normal and usable klystron when subjected to appreciable overdrive (i.e., drive power in excess of that required for saturation output).

Further computations and analysis enhanced our understanding of the phenomenon occurring at power levels near saturation when two drive signals are applied to the klystron input and/or the more general effect resulting from excessive rf drive power.

Referring to the drive signals illustrated below:



The vertical direction represents drive level and the horizontal represents time. The parallel dashed lines represent the drive level which produces saturation power output with a single CW, swept or FM drive signal. (A) depicts such a driving signal.

(B) represents the composite drive signal resulting from two carriers of equal amplitude but slightly different frequency, at a level where the peak amplitude of the driving signal just produces saturated power output (represented again by the dashed lines). Under condition (B), the average power output (the sum of both carriers) would be a little more than one-half (calculations indicate about -2 dB) of the saturated power output from only one carrier. As the rf drive is increased beyond (B), the condition shown in (C) is approached. The device is overdriven during the time interval represented by 0-0. That is, the drive is greater than that required for a single tone saturated power output during this time. The _instantaneous_ power output during this time interval will either be equal to the saturation power or somewhat less, depending on the amount of overdrive.

As the drive level is increased from (B) towards (C), the total average power output during the interval 0-0 will be greater than for the corresponding interval at drive (B), until there is sufficient overdrive that the power falls. However, during the rest of the time period, the power output in (C) will be greater than it was during the comparable interval in (B). The result is that the _total average_ power increases as the drive is increased to some point beyond (B), and the maximum average power output does not occur with condition (B), but rather at some higher level. Typically, two-tone saturation occurs where the average two-tone power output is 1 to 1.2 dB less than the single-tone power output. Note that this occurs at a drive level greater than (B) and therefore an overdrive condition exists during part of the time (the interval 0-0, which calculates to be approximately 50% of the time at two-tone saturation).

Any "velocity modulated" amplifying device produces output power by converting the kinetic energy of the electron beam into that output power. To achieve this, the average velocity of the beam must be reduced. In practice, some electrons are slowed more than others; these slow electrons may be turned around and returned towards the input which may produce regenerative effects. Our large signal computer computations indicate that an overdriven condition can drastically lower the velocity of the slower electrons compared to that velocity at saturation. This can materially increase the likelihood of regenerative effects.

Therefore, it can be seen that: (1) a two-tone signal at a total power output level greater than approximately 2 to 3 dB below the saturated single-tone power will produce an overdrive condition part of the time, (2) overdrive produces slower slow electrons; therefore, (3) two-tone operation near two-tone saturation substantially increases the likelihood of regenerative effects compared to single-tone operation. However, it should be noted that multiple signal inputs are usually applied at substantially reduced power levels where this type of problem does not occur.

The number of electrons returning from the output gap can be minimized by reducing the output cavity gap voltage (which returns and/or modulates the electrons) by reducing the output cavity Q_{e5} below the optimum coupling value. This procedure has the disadvantage of lowering the klystron efficiency.

The detrimental effects of the return current can, on the other hand, be lessened by reducing the overall loop (forward and/or backward) gain of the electronic circuit. This can be accomplished in several ways: (1) Increasing the bandwidth (this tube is capable of approximately 25 MHz at -1 dB). However, it is understood that this extra "bonus" bandwidth would be undesirable. (2) Shorten the tube (this was not practical at the time). (3) Add additional cavity loading (internal in cavities 2 and/or 3). (4) Increase the drift tube gaps, thereby reducing the gap coupling coefficients, in cavities 1 and/or 2 and/or 3.

For the reasons discussed in the following paragraphs, alternatives 3 and 4 plus reducing Q_{e5} were pursued; tube S/N 102, 103 and 104 were modified accordingly. The first, second and third cavity drift tube gaps were increased to 0.250 inch ($B_e d$ = 1.5 radians) from 0.200 inch ($B_e d$ = 1.2 radians) and the drift tube tip angle was adjusted to restore the original tuning range and rate and cavity R/Q. Calculations indicated this revision would reduce the gain by approximately 2 to 3 dB. Additional cavity loading produces about another 1 dB gain reduction.

Experiments with S/N 101 and a sliding hemisphere tuner (to effectively reduce the output cavity Q_{e5} by introducing a VSWR of the correct amplitude and phase) provided data to determine the value of Q_{e5} for good intermodulation performance near saturation. These results are summarized on the following page:

Frequency GHz	Q_{e5} S/N 101	VSWR Intermod	Q_{e5}' Intermod	Q_{e5}' + 15%
2.5	100	1.9	53	61
2.6	104	1.8	58	66
2.7	101	1.6	63	72

The Q_{e5} (S/N 101) is the value for maximum efficiency, but only reduced level (below saturation) multiple input signals can be satisfactorily applied.

The Q_{e5}' (intermod) would be the value for good saturation level intermod if nothing else were done to alleviate regenerative effects. However, the experiments with S/N 101 indicated that an output Q of 53 (at 2.5 GHz) would reduce the klystron efficiency enough that the objective system efficiency of 45% could no longer be achieved. Therefore, the gain reducing steps described previously were implemented allowing the output Q's to be increased by approximately 15% above Q_{e5}' (intermod). These higher Q values are indicated in the last column above.

This combination of reducing gain and output Q to Q_{e5}' (intermod) + 15% yielded the best likelihood of both good saturation level intermodulation performance and the desired system efficiency and were implemented in S/N 102, 103, and 104. A version of this klystron with higher efficiency than the current model might then be appropriate for application which do not require overdriven operation such as produced by multiple signal inputs at levels near single-tone saturation. However, a shorter low-gain version might be more appropriate for applications requiring multiple signal inputs and operation at power levels near single-tone saturation.

The tabulation in Section 3.3 represents the design as revised for S/N 102, 103, and 104. These can be compared with VKC-7790AP design (comparison is only meaningful among the "normalized" parameters). The projected UHF-tropo design is also included thereon for reference.

3.5 FINAL DESIGN

The final design parameters are summarized, as mentioned, in Section 3.3; the performance is summarized in Section 5, and the test results are presented in Section 6.

The VKS-7830 employs a dispenser type cathode with very low cathode loading of approximately 1/3 A/cm^2.

The rf input is type-N coaxial and is loop coupled to the first cavity through an alumina ceramic window.

Rectangular rf cavities with liquid cooling are utilized with sliding-short tuner (see reports ECOM-0228 series).

Power output is iris coupled to the output waveguide and coupled through an alumina ceramic disk, pillbox-type rf window.

The collector is vapor phase-cooled and provided with a boiler and weir similar to the 7790 type.

The electromagnet is a liquid cooled aluminum foil solenoid which also mounts the external digital tuner mechanisms.

Drawings of the VKS-7830 et al are provided in Appendix C.

4. DESIGN, UHF (755 to 985 MHz)

4.1 CURRENT PERFORMANCE

UHF troposcatter transmitters currently deployed primarily employ either the 4KM50LR or the VA-917 Varian amplifier klystrons. The approximate typical performance currently available from those existing UHF (L-band) tropo amplifiers is summarized below:

Power Output:	10 kW
Frequency:	755-985 MHz
1 dB Bandwidth:	5 MHz
3 dB Bandwidth:	6.5 MHz
Beam Efficiency:	30%
Gain:	38 dB

Slightly more bandwidth may be obtained with a reduction of gain and efficiency, or more efficiency and gain is achievable at lesser bandwidths. Better performance is realized towards the high end of the band where the percentage bandwidth is lower.

4.2 IMPROVED PERFORMANCE

One objective of this program was to evolve a paper design for a new klystron amplifier for UHF (L-band) troposcatter service. The new improved design discussed herein will be able to provide the following approximate typical performance:

Power Output:	10 kW
Frequency:	755-985 MHz
1 dB Bandwidth:	7.0 MHz min
3 dB Bandwidth:	8.5 MHz*
Beam Efficiency:	45%
Gain:	43 dB*

*Approximate, depends on design.

The principal improvements in electrical performance are substantially increased bandwidth and efficiency. However, this design also offers beam supply and cooling system compatibility with the VKC-7790, VKC-7790AP, VA-908R, and VKS-7830. Furthermore, it will be a clean, functional design including klystron improvements evolved over the past 20 years.

4.3 ELECTRONIC DESIGN

Super-high efficiency techniques (such as employed in the VKC-7790) were not appropriate or feasible here. This new improved UHF tropo klystron amplifier will, therefore, be patterned after the several Varian klystrons achieving high efficiency with straightforward, but optimum, five-cavity design such as used in the VKC-7790AP, the VA-908R, the VKS-7830, et al. See Section 3.3 for summary of parameters and Appendix C for the preliminary outline drawing. The efficiency will be somewhat reduced due to the deterioration from optimum resulting from the wider tuning range (30% here as compared to 14% for the first two types above and 8% for the latter).

Both of the older existing types of UHF tropo tubes are appreciably non-optimum by current standards in several respects (as one might deduce from the substantially lower efficiency - see 4.1).

4.4 RF DESIGN

Whereas the selection of the electronic interaction design is reasonably clear-cut, the rf design is not. There are several approaches, each of which have advantages and disadvantages. The difficulty arises due to the requirement of simultaneously achieving high efficiency and wide bandwidth. The former dictates a suitably high interaction load impedance over the bandpass; the latter tends to necessitate a lower impedance.

Most integral cavity klystrons operating below a frequency of about 2000 MHz utilize capacitive tuners. The R/Q of a cavity resonator is proportional to the square root of the inductance divided by the capacitance. The frequency of a capacitively tuned cavity is inversely proportional to the square root of the capacitance. With a capacitive tuner, the capacitance is increased to lower the frequency. Therefore, the capacitance is highest at the lowest frequency. The R/Q of the cavity, then, is lowest at the lowest frequency when a capacitive tuner is used.

For a fixed bandwidth over the tuning range, the percentage bandwidth is the greatest at the lowest frequency. However, as shown above, when a capacitive tuner is used, the R/Q is lowest at this frequency. The impedance times bandwidth product of a cavity is proportional to the R/Q.

Therein lies the problem. To use the commonly used capacitive tuner for this tube would require an unattainable high R/Q. Therefore, a normal capacitive tuner arrangement cannot be used. Another approach is needed.

Three other possible approaches are discussed in the following paragraphs. They are presented in reverse order of what currently appears to be overall feasibility.

4.5 SLIDING SHORT DESIGN

From S-band to Ku-band, the integral cavity, sliding-short-tuner klystron design has been proven a very effective device in a diversity of applications. There is no known theoretical reason why this type of design cannot be scaled down to UHF. It has not yet been done at Varian, however; there are some possible potential problems.

The normally used rectangular cavity geometry is not any particular difficulty at the higher frequencies where the sizes are relatively small. The accuracy, rigidity, and alignment required for good tuner contact across the tuning range can be achieved in a reasonable manner.

A cavity for these UHF frequencies would, however, be approximately 4 inches x 8 inches x 4 inches. Since there is atmospheric pressure outside and vacuum inside, a substantial force would be applied to the outer cavity walls. This force would tend to distort these flat walls and cause tuner misalignment and/or intermittent contact. Most metals suitable for vacuum devices, or mechanical combinations of these metals, tend to distort when subjected to the temperature cycling typically encountered in vacuum tube processing. Copper is among the better metals in this regard partially because the high temperature operations anneal the copper. However, this same softness makes copper a weak vacuum wall. Overall, then, copper is most likely the best cavity material, but very thick vacuum walls would be required to minimize distortion and very close parts and assembly tolerances for these sizes would be required.

Also, since the tuner contact area at these lower frequencies would be very large, the force required to move the tuners may be beyond the manageable limit.

This design approach, then, entails the most unknowns and, therefore, the greatest risk. If these possible problems can be overcome, the sliding short design would most likely yield the best operating performance. Of these three options, it would certainly be the heaviest, and the most expensive to develop and to manufacture.

4.6 FILTER LOADED OUTPUT CIRCUIT (FLC)

The inadequate output cavity R/Q of the capacitively tuned cavity (see rf design) can be overcome by utilizing a filter loaded output circuit. This type of design yields an impedance times bandwidth product that is enhanced by about 50% over a single output resonator. This much improvement is sufficient to meet the requirements for this UHF tropo tube.

Instead of coupling the output cavity directly to the output transmission line, the output cavity is coupled to a filter cavity, which in turn, is coupled to the output line. When properly designed, the resulting response is similar to that of an IF transformer near critical coupling. FLC type output circuits are being successfully used on a variety of higher frequency Varian klystrons.

Capacitively tuned cavities are usually cylindrical and, by definition, the tuners are non-contacting. The possible problems discussed in the "sliding short" section are thereby avoided. The filter cavity would also be capacitively tuned and would be similar in size and shape to the output cavity.

The driver and output cavities would be coaxial to the electron beam. The filter cavity is coupled to the output cavity and not to the beam; it, therefore, would be situated as an eccentric protuberance. It is believed that this cavity can be accomodated within the electromagnet without undue tumult, but a certain degree of mechanical distention is inevitable. As a result, the tube would be somewhat awkward to process, to package for shipping, to handle, and to install.

For the given 1 dB bandwidth, this design would produce the smallest 3 dB bandwidth (an advantage or a disadvantage?) and the lowest gain. The development costs would be comparable to the external cavity approach and manufacturing costs would be intermediate. One more tuning counter must be adjusted (6) than with the other approaches. This represents a minor inconvenience for the user, but does increase Varian test costs noticeably. There is the possibility of multipactor problems in the filter cavity tuner.

4.7 EXTERNAL CAVITIES

The 10 kW power level at frequencies below 1000 MHz is well within the domain of the external cavity klystron. Thousands of these tubes are providing yeoman service around the world.

The external cavity design is essentially the "sliding short tuner" with the moveable elements outside the vacuum. The vacuum envelope is completed with a cylindrical ceramic window within each cavity assembly. The flat rectangular parts of the cavity, then, have atmospheric pressure inside and out and are not subjected to vacuum tube processing. The distortion problems discussed in the "sliding-short" section, therefore, do not occur. The tuner is primarily inductive and the inverse of a capacitive tuner. The R/Q, then, tends to be a maximum near the low end of the tuning range where the percentage bandwidth is the greatest. High efficiency with wide bandwidth is therefore achievable.

Older external cavity designs required appreciable adjustment in the field. This is the result of the era during which they were designed and is not a fundamental requirement. The same more sophisticated techniques currently employed in the design of integral cavity tubes can now be used to design external cavity tubes optimized across the tuning range. Improved beam optics and modern electromagnets can eliminate complex field adjustments in this area.

Development costs, and initial costs for the complete tube and magnet, would be comparable to the FLC approach. Replacement costs for the tube only would be substantially less since the tuning cavities need not be replaced. Additional labor, of course, is required on site to install the cavities on the tube.

External cavity tubes can be provided completely prepackaged (with the cavities, etc. factory installed) as has been done with the VA-958. This provides increased convenience, but the replacement cost advantage is reduced.

4.8 DESIGN SELECTION

Klystrons based on any of the preceeding options can be developed. The electron gun, electromagnet, collector, etc. would be the same or similar in any case. The last option discussed, the external cavity tube, overall seems to have the most advantages and the least unknowns. It, therefore, appears to be the best choice. This analysis is about as complete as possible based on paper, pencil, and computer.

The following experimental program, therefore, is suggested to clarify the remaining unknowns and permit a more rational and logical selection:

4.8.1 Fabricate an external cavity(ies) mock-up configured for this design. Optimize and measure tuning range and rate and R/Q.

Determine and/or verify with cold test measurements that suitable characteristics (primarily sufficiently high R/Q) can, in fact, be obtained.

4.8.2 Design and fabricate a suitable output cavity(ies), filter cavity(ies) and output circuit(s) mock-up. Optimize and measure tuning range and rate and the real part of gap impedance. Determine and/or verify with cold test measurements that suitable characteristics (primarily sufficiently high gap impedance) can, in fact, be obtained.

4.8.3 Investigate potential modern-day techniques for interfacing the external cavity tube with its external cavities. Determine whether or not the time-proven standard method can be improved upon from the standpoint of user convenience and simplicity.

4.8.4 Adapt the FLC output cavity (2 above) into a single resonator driver cavity(ies) and verify characteristics.

4.8.5 Design and fabricate mock-ups of promising versions of a sliding short cavity design. After a preliminary selection, bake out and evacuate the mock-up cavity. Measure characteristics before and after tuner cycling.

4.9 OTHER UHF APPLICATIONS

The types of klystrons used in other UHF applications may be useful data in selecting the type of device for this service. Several of these are itemized below; it should be noted, however, that the choice has been sometimes based on non-technical considerations.

1. U.S. UHF TV: About 2/3 internal and 1/3 external.
2. European TV: About 95% external at 10 kW. About 75% external and 25% integral at the higher power levels.
3. UHF Tropo: About 95% external.
4. TACAN: Essentially all integral.

4.10 UHF DESIGN CONCLUSIONS

A new improved UHF troposcatter klystron amplifier with the characteristics summarized in the "Improved Performance" section can be designed and built. Selection among the three alternative rf designs would best be made after an experimental investigation.

4.11 DESIGN OPTION SUMMARY

IMPROVED UHF TROPOSCATTER
10 kW KLYSTRON AMPLIFIER

RF Design Option Summary

	Sliding Short Internal Cavity	Filter Loaded Internal Cavity	External Cavity
Development Cost	highest	--- same ---	--- same ---
Initial Cost	highest	--- same ---	--- same ---
Replacement Cost	highest	mid	lowest*
Power Output	------ same ----------	------ same ----------	------ same ----------
1 dB BW	------ same ----------	------ same ----------	------ same ----------
3 dB BW	best	least	mid
Gain	best	least	mid
Size	------ same -----------	------ same -----------	------ same -----------
Weight	heaviest	mid	lightest
User Convenience	best	mid	least
Reliability		essentially	
Life		identical	

*replace tube only

5. PERFORMANCE (S-BAND)

This section summarizes the typical performance achieved with the VKS-7830 klystron, VYW-7830 electromagnet and companion heat exchanger. For detailed individual test results see Section 6 and Appendix A.

Parameter	Results	Units
Frequency (Tuning Range)	2.5 to 2.7	GHz
Beam Voltage	13.5 to 14.5	kV
Beam Current	1.38 to 1.53	A
Beam Power	18.6 to 21.8	kW
Power Output	10.2 to 11.3	kW
RF Drive	40 to 100	mW
Beam Efficiency	49.9 to 54.8	%
Saturated Gain	50.4 to 54.0	dB
Body Current	3.5 to 5.0	mA
1 dB Bandwidth	17 to 19	MHz
Heater Voltage	8.0	V
Heater Current	8.7 to 9.2	A
Magnet Voltage	75 to 85	V
Magnet Current	12.5 to 14.5	A
Magnet Power	1.01 to 1.23	kW
Heat Exchanger Power	0.86 to 1.21	kW
System Efficiency	40.6 to 48.4	%
Second Harmonic Power	-33 to -56	dB
Third Harmonic Power	-33 to -50	dB
Signal to Noise	-60 to >-60	dB
Input VSWR*	1.12 to 1.26	VSWR
Spurious Output	None observed	dB
P_o min (1.2 Load VSWR)	9.2 to 10.5	kW
15^o Tilt Angle	OK	---
AM to PM Conversion	< 2^o/dB	^{o}/dB
IM Products Max	-14 to -16	dB

*with isolator

6. TEST RESULTS, S-BAND

Appendix A contains selected original test data arranged in order of tube serial numbers. For each serial number the data are presented in the ATP sequence with extra tests following (see Appendix A Index). The Acceptance Test Procedure (ATP) should be referred to for details on testing methods, equipment, etc. The following paragraphs discuss the results included in Appendix A:

6.1 PERFORMANCE DATA

See pages A2, A4, A60 and A62.

These Test Performance Data Sheets summarize the principal performance characteristics of the VKS-7830 klystrons.

6.2 BANDPASS CURVES

See pages A5-7.

These chart recordings depict the saturated power output bandpass (power output versus frequency) and the small signal bandpass (power output 10 dB below saturation). Reference power output, the -1 dB level, the frequency (relative to center frequency) at which the saturated power is -1 dB, and the 1 dB bandwidth are indicated. The operating conditions are also shown.

6.3 INPUT VSWR

See page A8.

These data are the VSWR present on the klystron drive line looking into the input isolator and the input cavity at three (2.5, 2.6, and 2.7 GHz) center frequencies.

6.4 SPURIOUS OUTPUT

See page A8.

No spurious outputs were observed.

6.5 LOAD VSWR

See page A9.

These data present the effects of a load VSWR of 1.2:1 at the phase producing the lowest power output. See Para. 6.11.

6.6 MOUNTING

See page A9.

There were no deliterious effects observed when the klystron, magnet, weir, heat exchanger, etc. were tilted at an angle of 15°.

6.7 TUNING CHARTS

See pages A10 and 11.

This is the computer derived (see Para. 6.10, "Tune Chart Bandpass") tuning chart for the individual VKS-7830. Counter settings are provided for tuning the klystron in 2 MHz increments.

6.8 BANDPASS vs DRIVE POWER

See page A12.

This chart recording is similar to those discussed in Para. 6.2, but include several drive power levels.

6.9 BANDPASS vs BEAM VOLTAGE

See pages A13-18.

These are again similar to Para. 6.2, but beam voltage is also a variable. In one set (A13, 15, and 17) the drive power is fixed at the 14 kV saturation level. In the others (A14, 16 and 18) the drive power is readjusted for saturation at each beam voltage.

6.10 TUNE CHART BANDPASS

See pages A19-31.

The tuning charts (Para. 6.7) are derived by tuning the klystron at selected frequencies, recording the counter settings, and computer interpolating the counter readings for other frequencies. The bandpass curves were chart recorded and provide a good presentation of performance over the tuning range.

6.11 LOAD VSWR BANDPASS

Pages A33-43 depict the effect on the bandpass at 2.6 GHz of a 1.2:1 VSWR of variable phase. A hemisphere producing a 1.2:1 VSWR was repositioned along the waveguide in half-inch steps without any klystron adjustment. Pages A32 and 44 show the bandpass at 2.5 and 2.7 GHz respectively at the hemisphere position (phase) producing the lowest power output.

6.12 AM TO PM CONVERSION

See pages A45-48.

Phase shift versus drive power has been chart recorded at 2.5, 2.6 and 2.7 GHz. The graphical differentiation to produce AM to PM conversion (^{o}/dB) has been performend at 2.6 GHz on page A-48. The value is below 2^{o}/dB.

6.13 INTERMODULATION DISTORTION

See pages A49 - 58.

Two equal carriers of varying levels, separated by 2 MHz, were applied to the klystron input. Third and fifth order products, with the levels of each plus all the higher order products, are shown in the spectrum analyzer photographs. The VKS-7830 intermodulation characteristic as well as the single carrier and two equal carrier transfer characteristics have been overplotted (dashed lines) on the curves for a typical Varian klystron on page A58.

6.14 BODY COOLANT FLOW vs PRESSURE DROP

A typical curve of pressure drop across the klystron body versus the coolant flow through it is shown on page A61.

6.15 VYW-7830 ELECTROMAGNET

Electromagnet test results are presented in page A59.

6.16 HEAT EXCHANGER

Test results are shown in page A3.

7. CONCLUSIONS

The VKS-7830 klystron with the VYW-7830 electromagnet and companion heat exchanger perform to specification with performance to spare in most areas. Operation is compatible with the VKC-7790, the VKC-7790AP, the VA-908R, and the projected new improved UHF-tropo klystron. The VKS-7830 is not only suitable for its intended tropo service, but also, most other applications requiring high quality rf power in the neighborhood of the 10 kW level over its frequency range. A reliability analysis for this tube, electromagnet and heat exchanger has been performed; See Appendix F.

The design and drawings for the VKC-7790AP klystron and the VYW-7800AP electromagnet were accomplished during the course of this program. This high efficiency klystron is capable of broadbandwidth, high-gain operation. The gain bandwidth product is greater than that available from the VA-908R.

The basic design concepts for an improved UHF (L-band) tropo klystron have evolved. This device would offer substantially greater efficiency and bandwidth than is currently available. Further development effort would be required to define the optimum design and proceed with fabrication of this device.

8. RECOMMENDATIONS, S-BAND

The basic design of the VKS-7830 is quite flexible and can be adapted to suit specific requirements. Several options are suggested below:

Wider Bandwidth: The present design is capable of, and most suitable for, wider bandwidth (with resulting reduced gain) applications; 20 to 25 MHz, 1 dB bandwidth is reasonable.

Reduced Gain-Bandwidth: A shorter version of the tube, and magnet, would be most suitable for applications requiring less than 20 to 25 MHz of bandwidth. This version would weigh a little less and consume a little less magnet power.

Higher Efficiency: Somewhat higher efficiency could be obtained for applications not requiring the tube be subjected to serious overdrive conditions. A shorter version, as discussed above, would be most suitable here as well.

APPENDIX A

VKS-7830 KLYSTRON, VYW-7830 ELECTROMAGNET

AND

HEAT EXCHANGER TEST DATA

APPENDIX A INDEX

See Section 6 for explanation and details of tests and test conditions.

S/N 101

VKS-7830
VF 7830
Serial No. 101

PARAMETER	SYMBOL	MIN	MAX				UNITS
Frequency	F:	----	----	2.5	2.6	2.7	GHz
Beam Voltage	Eb:	----	15.0	13.5	13.5	13.5	kVdc
Beam Current	Ib:	----	2.0	1.38	1.38	1.38	Adc
Beam Power	Pdc:	----	30.0	18.63	18.63	18.63	kW
Power Output	Po:	10.0	----	10.2	10.2	10.2	kW
R.F. Drive	Pd:	----	100	40	40	50	mW
Efficiency	Eff:	----	----	54.8	54.8	54.8	%
Gain	Gain:	40	----	54.0	54.0	53.1	dB
Body Current	Iby:	----	----	3.5	5	4	mAdc
Bandwidth	-1dB Bw:	12	----	18	18	18	MHz
Heater Voltage	Ef:	----	8.0	8.0	8.0	8.0	Vac
Heater Current	If:	----	15.0	9.0	9.0	9.0	Aac
Magnet Voltage	Em:	----	----	85	85	85	Vdc
Magnet Current	Im:	----	----	14.5	14.5	14.5	Adc
Magnet Power	Pm:	----	----	1.23	1.23	1.23	kW
System Efficiency	Seff:	45	----	48.4	48.4	48.4	%
Second Harmonic	Ph:	----	----	-56	-44	-47	dB
Third Harmonic	Ph:	----	----	-50	-37	-40	dB
Signal to Noise	Sn:	-60	----	-64	-65	-64	dB
Heat Exchanger Power	Ph:	----	----	Low Fan:	.864	kW	
				High Fan:	1.207	kW	

TESTED BY: REID ISAKSEN DATE: May 18, 1978

Moc No. 25 DA 85

Serial No. 76262-2

HEAT EXCHANGER SYSTEM
(C. H. BULL CO.)

TEST	TEST CONDITION	SYSTEM PERFORMANCE
BODY/MAGNET COOLANT FLOW RATE	LOW FLOW INTERLOCK TRIP POINT	0.5 GPM
VAPOR RETURN PRESSURE	OVER PRESSURE INTERLOCK TRIP POINT	23 Inches of H_2O
COOLANT TEMPERATURE	OVER TEMPERATURE INTERLOCK TRIP POINT	172 ^oF
COOLANT TEMPERATURE	FAST FAN STARTING POINT (adjustable)	104 ^oF

TESTED BY PEID ISAKSEN DATE June 2, 1978

VARIAN QA ______ DATE ______

S/N 102

VKS 830

Serial No. 102

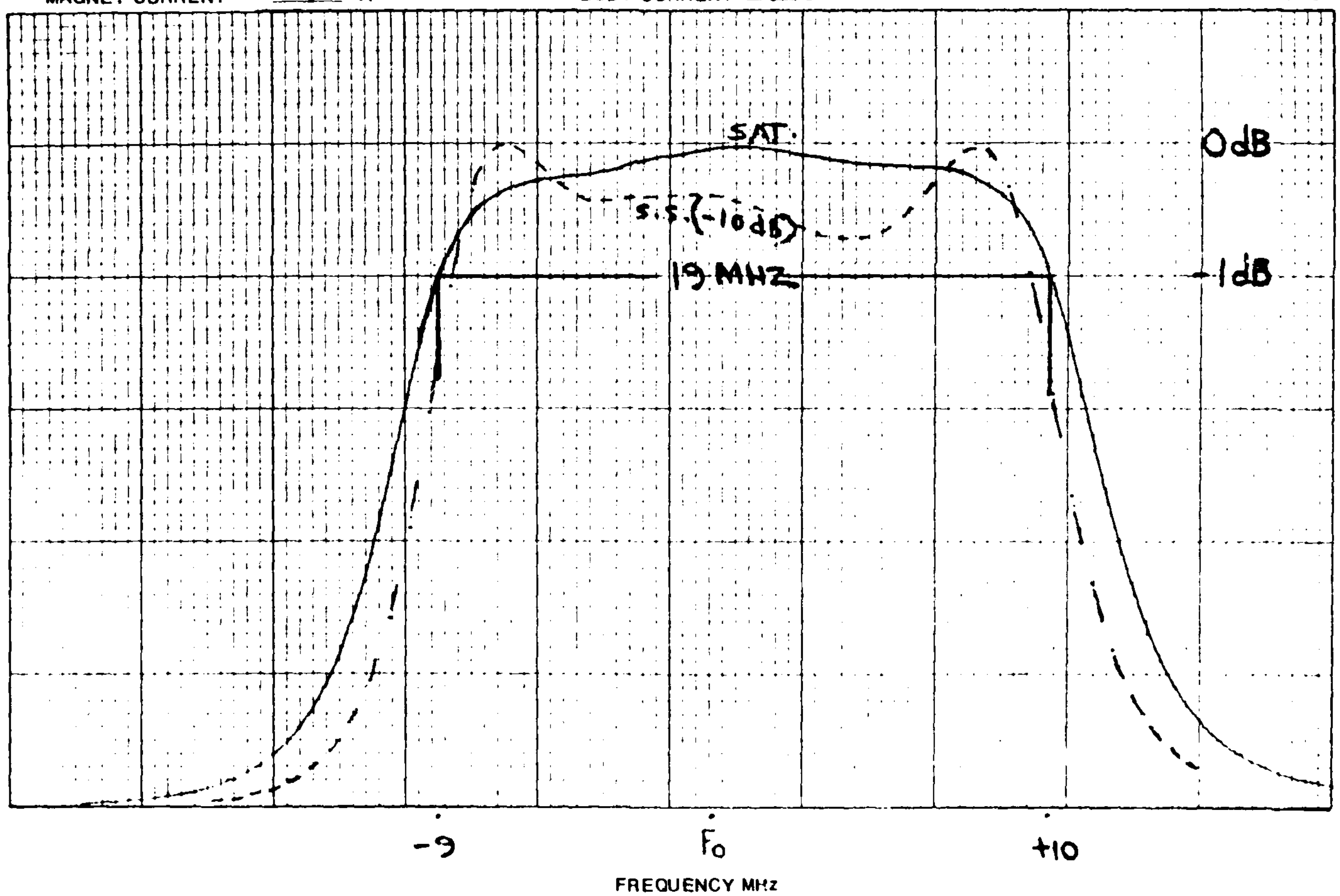
PARAMETER	SYMBOL	MIN	MAX				UNITS
Frequency	F:	----	----	2.5	2.6	2.7	GHz
Beam Voltage	Eb:	----	15.0	14.0	14.0	14.0	kVdc
Beam Current	Ib:	----	2.0	1.46	1.46	1.46	Adc
Beam Power	Pdc:	----	30.0	20.44	20.44	20.44	kW
Power Output	Po:	10.0	----	10.3	10.2	10.2	kW
R.F. Drive	Pd:	----	100	80	60	70	mW
Efficiency	Eff:	----	----	50.4	49.9	49.9	%
Gain	Gain:	40	----	51.1	52.3	51.6	dB
Body Current	Iby:	----	----	4.5	4.5	4.5	mAdc
Bandwidth	-1dB Bw:	12	----	19	17	17	MHz
Heater Voltage	Ef:	----	8.0	8.0	8.0	8.0	Vac
Heater Current	If:	----	15.0	9.0	9.0	9.0	Aac
Magnet Voltage	Em:	----	----	75	75	75	Vdc
Magnet Current	Im:	----	----	13.5	13.5	13.5	Adc
Magnet Power	Pm:	----	----	1.013	1.013	1.013	kW
System Efficiency	Seff:	45	----	45.4	45.0	45.0	%
Second Harmonic	Ph:	----	----	-43.6	-33.3	-52.6	dB
Third Harmonic	Ph:	----	----	-37.8	-33.6	-41.0	dB
Signal to Noise	Sn:	-60	----	-60	-60	-60	dB
Heat Exchanger Power	Ph:	----	----	Low Fan:	0.864	kW	
				High Fan:	1.207	kW	

TESTED BY: Reid Isaksen DATE: September 12, 1978

4740-10-25 R10/73
TEST DATA SHEET

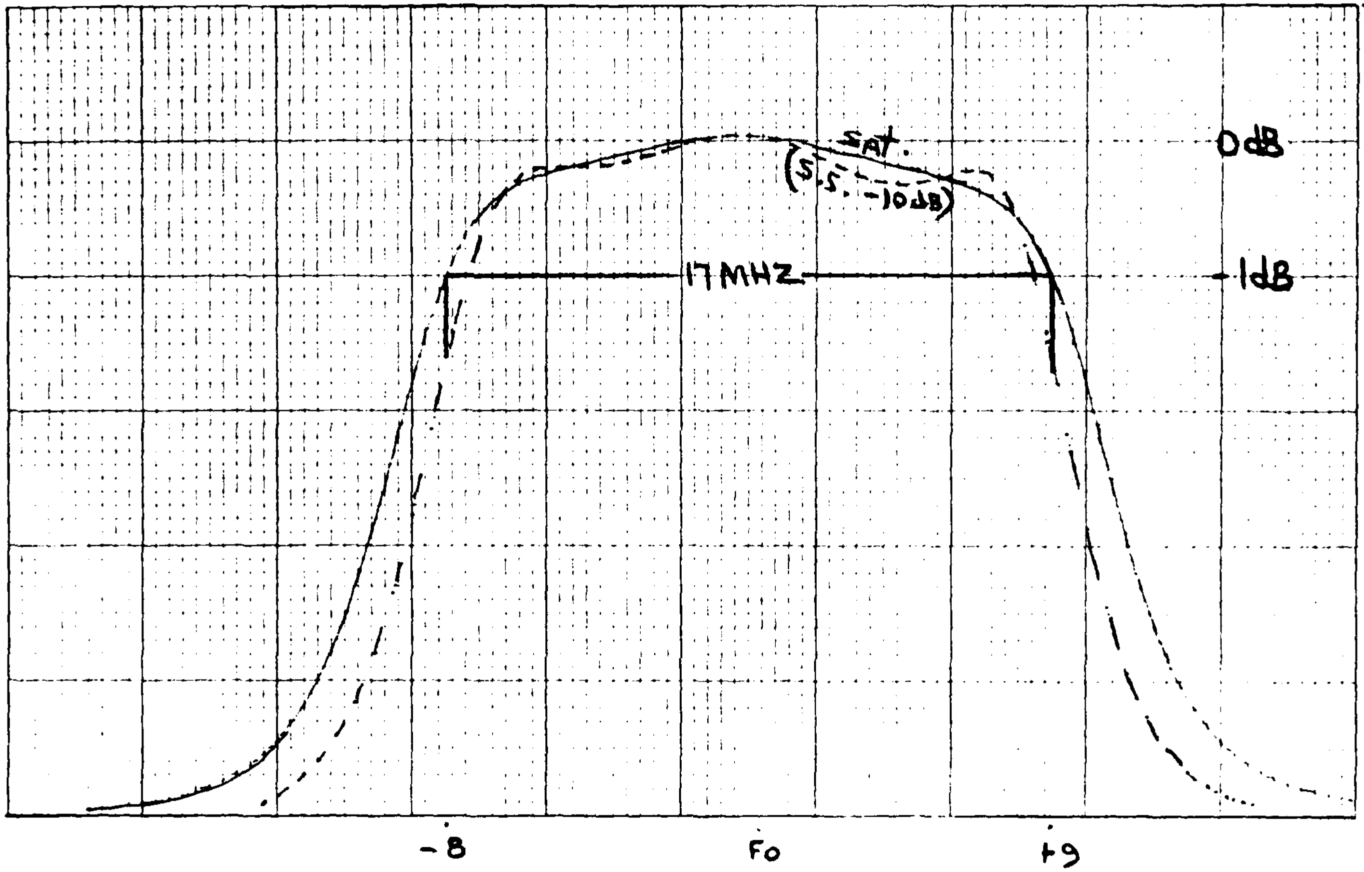
VKS7830 SERIAL NO. 102 | CHANNEL 2500 MHZ | DATE 9-12-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.3 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	80 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	51.1 dB



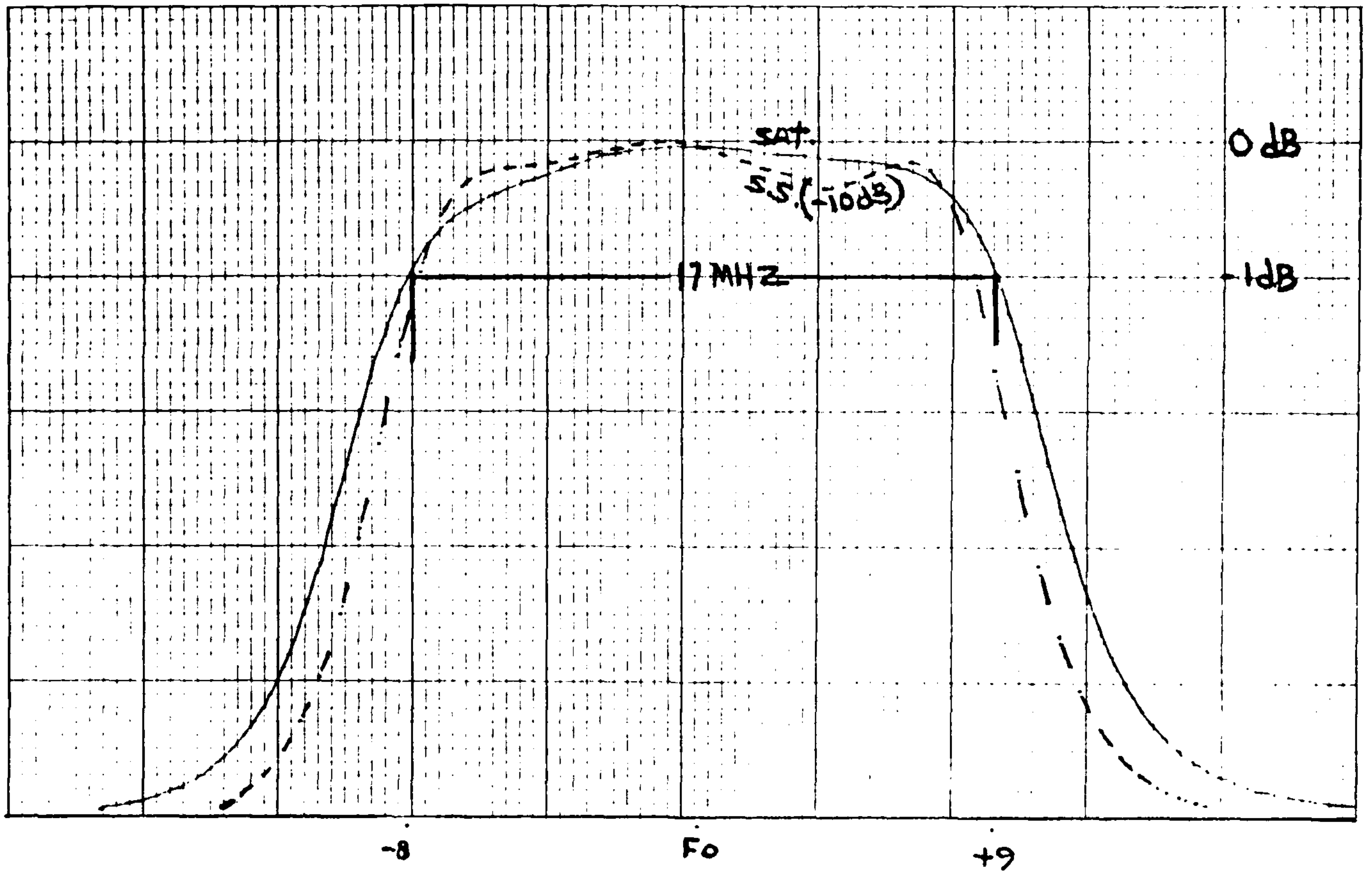
4/40-10-25 R10/75
TEST DATA SHEET

VKS 7830 SERIAL NO.	102	CHANNEL	2.00 MHz	DATE 9-12-78 BY:	REID
FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	.0 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	52.3 dB



4740-10-25 R10/73
TEST DATA SHEET

VKS7930 SERIAL NO.	102	CHANNEL	2700 MHZ	DATE: 9-12-78	BY: REID
FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	70 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	51.6 dB



INPUT VSWR TEST

PARAMETER	SYMBOL				MIN	MAX	UNITS
Frequency	F:	2.5	2.6	2.7	---	---	GHz
Input VSWR	VSWR:	1.13	1.25	1.17	---	1.3	VSWR

SPURIOUS OUTPUT TEST

PARAMETER	SYMBOL				MIN	MAX	UNITS
Frequency	F:	2.5	2.6	2.7	---	---	GHz
Spurious Output	Ns:	NONE	NONE	NONE	---	---	dB

TESTED BY: Reid Isaksen

DATE: September 12, 1978

LOAD VSWR TEST

PARAMETER	SYMBOL				MIN	MAX	UNITS
Frequency	F:	2.5	2.6	2.7	---	---	GHz
Load VSWR	VSWR:	1.2	1.2	1.2	1.2	---	VSWR
Power Output	Po:	9.6	9.2	9.5	10.0	---	kW
Bandwidth	Bw:	18	17	18	8	---	MHz
Gain	Gain:	50.8	51.8	51.3	40	---	dB
System Efficiency	Seff:	42.3	40.6	41.9	45	---	%

TESTED BY: Reid Isaksen

DATE: September 14, 1978

MOUNTING TEST

PARAMETER	SYMBOL		MIN	MAX	UNITS
Frequency	F:	2.6	---	---	GHz
Power Output	Po:	10.2	10.0	---	kW
Bandwidth	Bw:	17	12.0	---	MHz
Gain	Gain:	52.3	40	---	dB
System Efficiency	Seff:	45.0	45	---	%

TESTED BY: Reid Isaksen

DATE: September 12, 1978

VKS-7830 KLYSTRON AMPLIFIER, S/N 102
TUNING CHART: APPROACH SETTING FROM COUNTERCLOCKWISE DIRECTION

FREQ MHZ	CAV 1	CAV 2	CAV 3	CAV 4	CAV 5
2500	127	113	112	190	193
2502	138+	126	121	202	207
2504	149+	139-	130+	214	220-
2506	160+	151+	140	225+	231+
2508	171+	163+	150	236+	242
2510	182	175+	160+	247+	252-
2512	193-	187	171-	258	261
2514	203+	199-	181+	268	270-
2516	214	210	192+	278+	278
2518	224+	221	203	288	286-
2520	235-	232	214	298-	293+
2522	245	243	225	307	301
2524	255+	254-	236	316+	308+
2526	265+	264+	247-	325+	316
2528	275+	275	258-	334+	323+
2530	285+	285+	268+	343	331-
2532	295+	296-	279-	352-	338+
2534	305+	306-	289+	360+	346
2536	315	316-	300-	369-	354-
2538	325	326-	310-	377	362-
2540	335-	335+	320	385+	370
2542	344	345	330-	394-	378
2544	354-	355-	339+	402	387-
2546	363	364	349	410	395
2548	372+	373+	358+	418	404-
2550	381+	383-	368-	426	412
2552	391-	392	377-	434	421-
2554	399+	401	386-	442-	429+
2556	408+	410	394+	450-	438
2558	417	419	403	457+	446+
2560	426-	428-	411+	465	455
2562	434+	436+	420-	473-	464-
2564	443-	445	428	480+	472+
2566	451	453+	436	488-	480+
2568	459+	462-	444	495+	488+
2570	467+	470	452	503-	495+
2572	475	478	460	510	502
2574	483-	486	468	517+	507
2576	490	494-	476	524+	512-
2578	497	501+	484-	531+	516-
2580	504	509	492-	538+	519+
2582	511	516+	499+	545+	523
2584	518	524-	507+	552+	526+
2586	525	531	515	559	530
2588	532	538+	523-	566	534+
2590	539	545+	530+	573-	539+
2592	546	553-	538-	579+	544+
2594	553	560-	545+	586	550-
2596	560	567	553-	593	556-
2598	567	574	560-	599+	562-

12 SEP 78

FREQ MHZ	CAV 1	CAV 2	CAV 3	CAV 4	CAV 5
2600	574	581	567	606	568
2602	581+	588	574	612+	575-
2604	588+	595	581	619	582-
2606	595+	602+	588	625+	589-
2608	603-	609+	595	631+	596-
2610	609+	616	602-	638-	602+
2612	616+	623	608+	644	609+
2614	623	630	615	650	616
2616	629+	637	622-	656	622
2618	636-	644-	628+	662+	628
2620	642-	650+	635-	668+	634
2622	648-	657+	641+	674+	640-
2624	654-	664	648-	680+	645
2626	659+	670+	654+	686	651-
2628	665	677	661	692	656
2630	671-	683+	668-	698-	662-
2632	676+	690	674+	703+	667+
2634	682	696+	681	709	673-
2636	688	703-	688-	715-	678+
2638	694	709-	694+	720+	684-
2640	700	715	701	726	689
2642	707-	721+	707+	732-	694
2644	713+	727+	714-	737+	699-
2646	720+	733+	720	743	704-
2648	727	739+	726	749-	709-
2650	734-	745+	732+	754	714-
2652	740	751+	738	760-	719-
2654	746	757	744	765	724
2656	751+	763-	750-	770+	730
2658	756+	768+	755+	776-	736
2660	761+	774-	761	781-	742
2662	766	779+	766+	786	748-
2664	770+	785-	772-	791	754-
2666	775	790	777	796	759
2668	780-	795+	782	801	764
2670	784+	800+	787	806	769
2672	789	806-	792	811	773
2674	794+	811-	797-	816	777
2676	799+	816	801+	821	780+
2678	805	821	806	826	783
2680	811-	826	811-	831	785+
2682	817-	831	815	836-	787+
2684	823	836+	820-	841-	789+
2686	829	841+	824+	845+	791+
2688	835	846+	829	850	793+
2690	841	851+	834	855-	796
2692	846+	856+	839	859	799+
2694	851-	862-	844+	863	804
2696	854+	867-	850	867-	811-
2698	857-	872	856+	870	819+
2700	857	877	863	873	831

TUNING INSTRUCTIONS:

DEACTIVATE THE KLYSTRON. CALIBRATE IF NECESSARY, SEE BELOW. SET COUNTERS TO THE DIGITS SHOWN ON CHART. THE NUMBER OF THE CAVITY WITH THE CORRESPONDING DRIVE AND COUNTER IS INDICATED IN THE DIAMONDS LOCATED ON THE TUNER FACE. DO NOT DISENGAGE TUNERS, SEE NOTE BELOW.

ALWAYS APPROACH SETTING FROM COUNTERCLOCKWISE DIRECTION. IF THE DRIVE MUST BE TURNED CLOCKWISE, GO PAST THE DESIRED SETTING BY ONE FULL TURN OF THE DRIVE AND MAKE FINAL SETTING BY TURNING DRIVE COUNTERCLOCKWISE.

IF THE TUNING CHART INDICATES A COUNTER SETTING WITHOUT A + OR -, TURN THE DRIVE COUNTERCLOCKWISE UNTIL EXACT DIGITS APPEAR ON THE COUNTER. IF TUNING CHART INDICATES A COUNTER SETTING WITH A -, TURN THE DRIVE COUNTERCLOCKWISE AND STOP A LITTLE SHORT OF ALIGNING LAST DIGIT (ABOUT 1/3 OF A COUNT). IF THE TUNING CHART INDICATES A COUNTER SETTING WITH A +, TURN THE DRIVE COUNTERCLOCKWISE AND GO A LITTLE PAST ALIGNING THE LAST DIGIT, (ABOUT 1/3 OF A COUNT).

NOTE: FINAL SETTING MUST BE MADE BY TURNING DRIVE COUNTERCLOCKWISE.

INITIAL CALIBRATION:

BE SURE THE TUNER DRIVES & TUBE LOCK ARE COMPLETELY DISENGAGED.

SET EACH OF THE TUNER COUNTER DIALS TO EXACTLY "010" BY ROTATING THE KNOB COUNTER-CLOCKWISE.

FULLY ENGAGE THE TUBE-LOCK BY COMPLETELY ROTATING THE LOCK-UNLOCK KNOB AS INDICATED ON THE FACE OF THE TUNER MECHANISM.

CAREFULLY INSERT (SLIDE TOWARDS THE TUBE AXIS) AND ENGAGE EACH OF THE TUNER SHAFTS INTO TUNER SOCKETS ON THE TUBE. WHILE ENGAGING, ROTATE (ROCK) SLIGHTLY TO ALIGN. WHEN FULLY ENGAGED THE COUNTER SHOULD READ BETWEEN 008 AND 012. DO NOT TURN KLYSTRON TUNER DRIVE WHILE FOLLOWING THE ABOVE PROCEDURE.

NOTE AND RECORD EACH OF THE ABOVE TUNER SETTINGS AND RETURN TO THOSE SETTINGS BEFORE DISENGAGING TUNERS AND/OR REMOVING TUBE.

TUNER MISALIGNMENT:

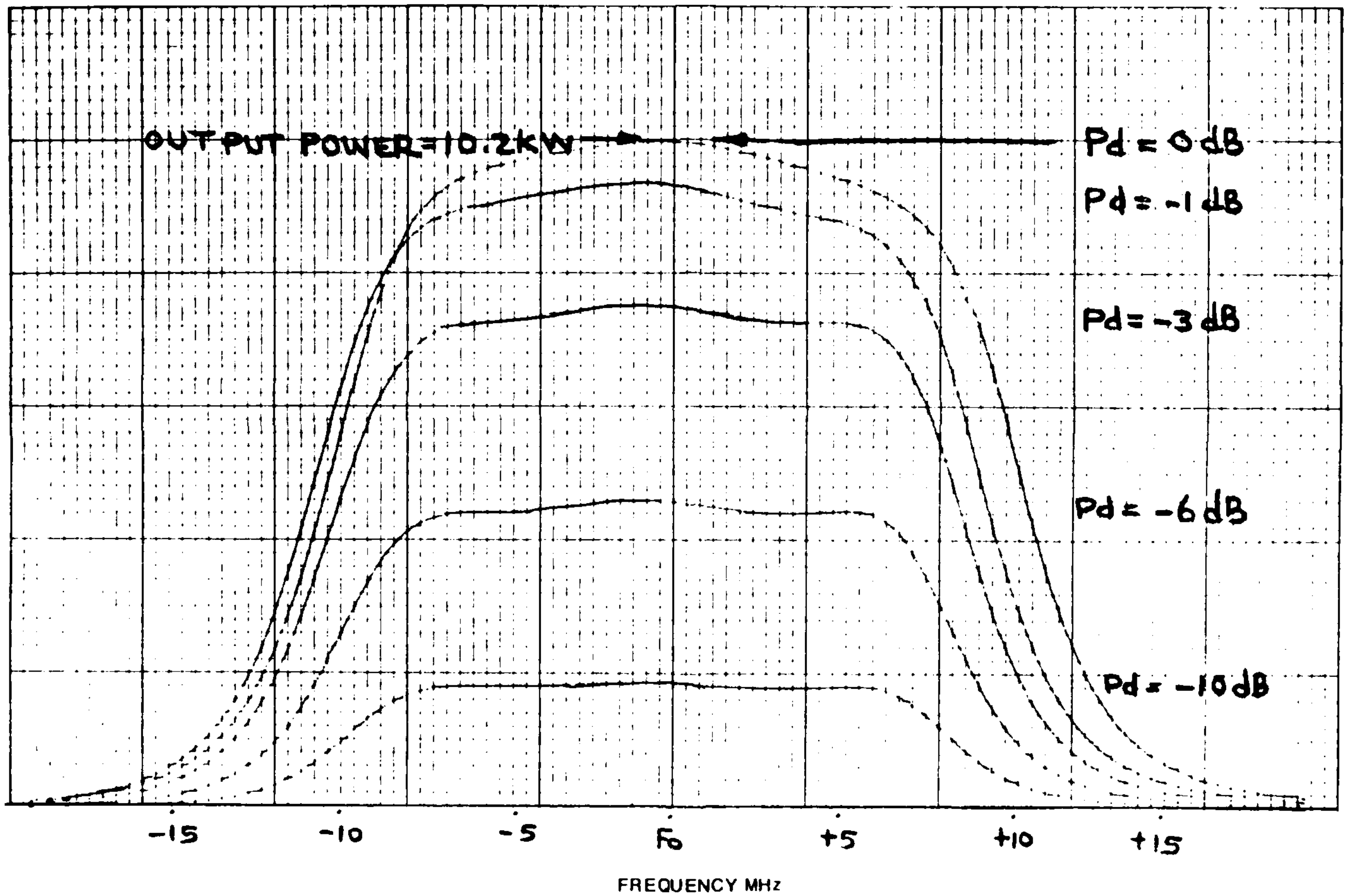
IF THE TUBE TUNERS ARE ACCIDENTALLY MISALIGNED, REMOVE THE TUBE, TURN EACH OF THE TUBE TUNER DRIVES (WITH A 3/16 HEX KEY) AS FAR AS THEY WILL GO IN A CLOCKWISE DIRECTION (APPLY 100 IN-OZ TORQUE, DO NOT FORCE), THEN BACK-OFF JUST UNTIL THE TOP AND BOTTOM FLATS ON THE HEX ARE HORIZONTAL (PERPENDICULAR TO THE TUBE AXIS). PROCEED AS FOR THE INITIAL CALIBRATION.

NOTE: DISENGAGING THE TUNER DRIVE AFTER CALIBRATION MAY INVALIDATE THE CALIBRATION.

4-40-10-25 R10/73
TEST DATA SHEET

VKS7830 SERIAL NO. 102 | CHANNEL 2600 MHZ | DATE: 9-12-78 BY: REID

FILAMENT VOLTAGE 8.0 V | BEAM VOLTAGE 14.0 kV | POWER OUTPUT VARIOUS kW
FILAMENT CURRENT 9.0 A | BEAM CURRENT 1.46 A | DRIVE POWER ___ mW
MAGNET CURRENT 13.5 A | BODY CURRENT ___ mA | GAIN ___ dB



VKS7830 SERIAL NO. 102

CHANNEL 2500 MHZ

DATE 9-12-78 BY: REID

FILAMENT VOLTAGE 8.0 V

FILAMENT CURRENT 9.0 A

MAGNET CURRENT 13.5 A

BEAM VOLTAGE VARIOUS kV

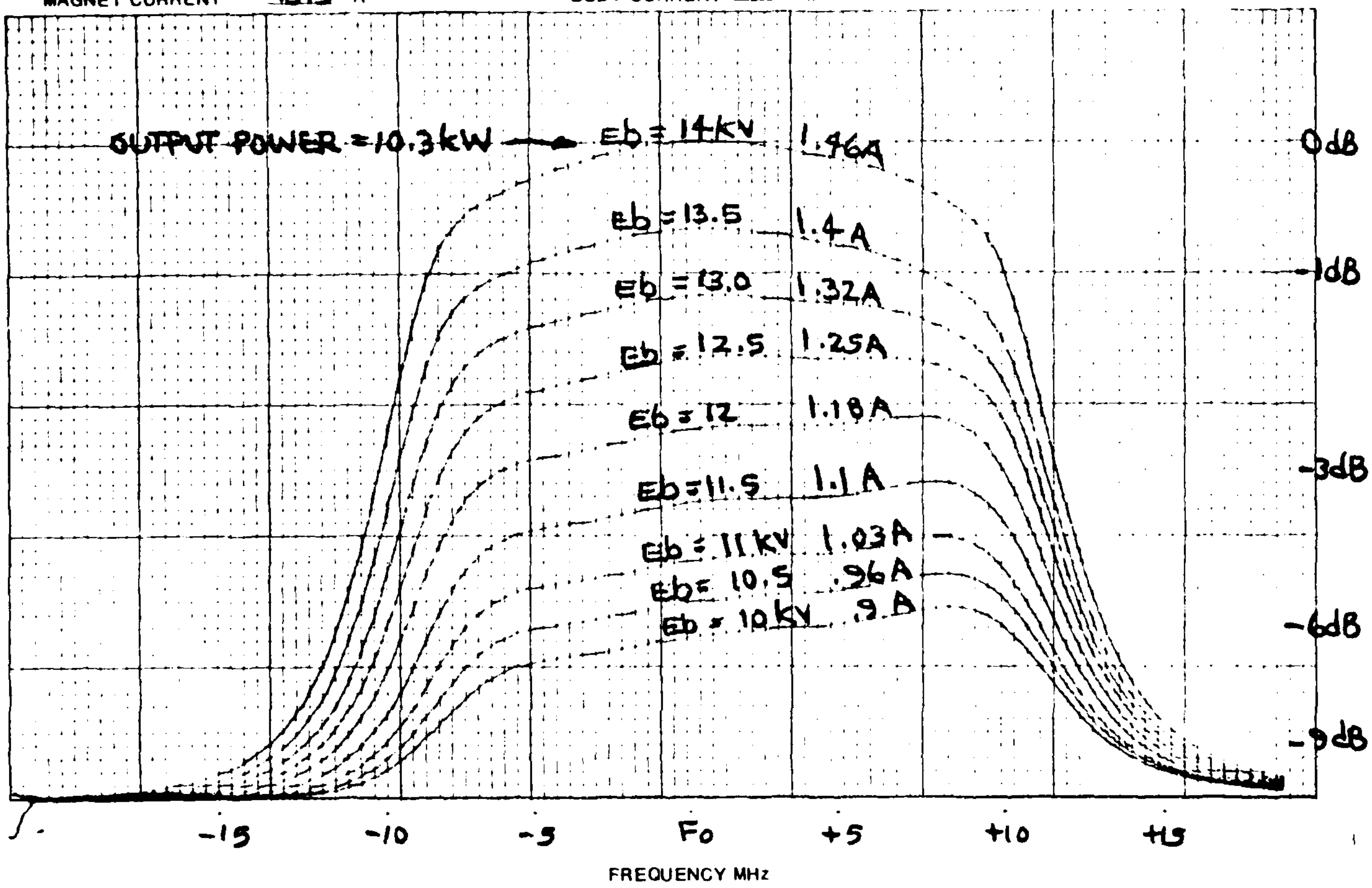
BEAM CURRENT ___ A

BODY CURRENT ___ mA

POWER OUTPUT VARIOUS kW

DRIVE POWER 80 mW

GAIN ___ dB



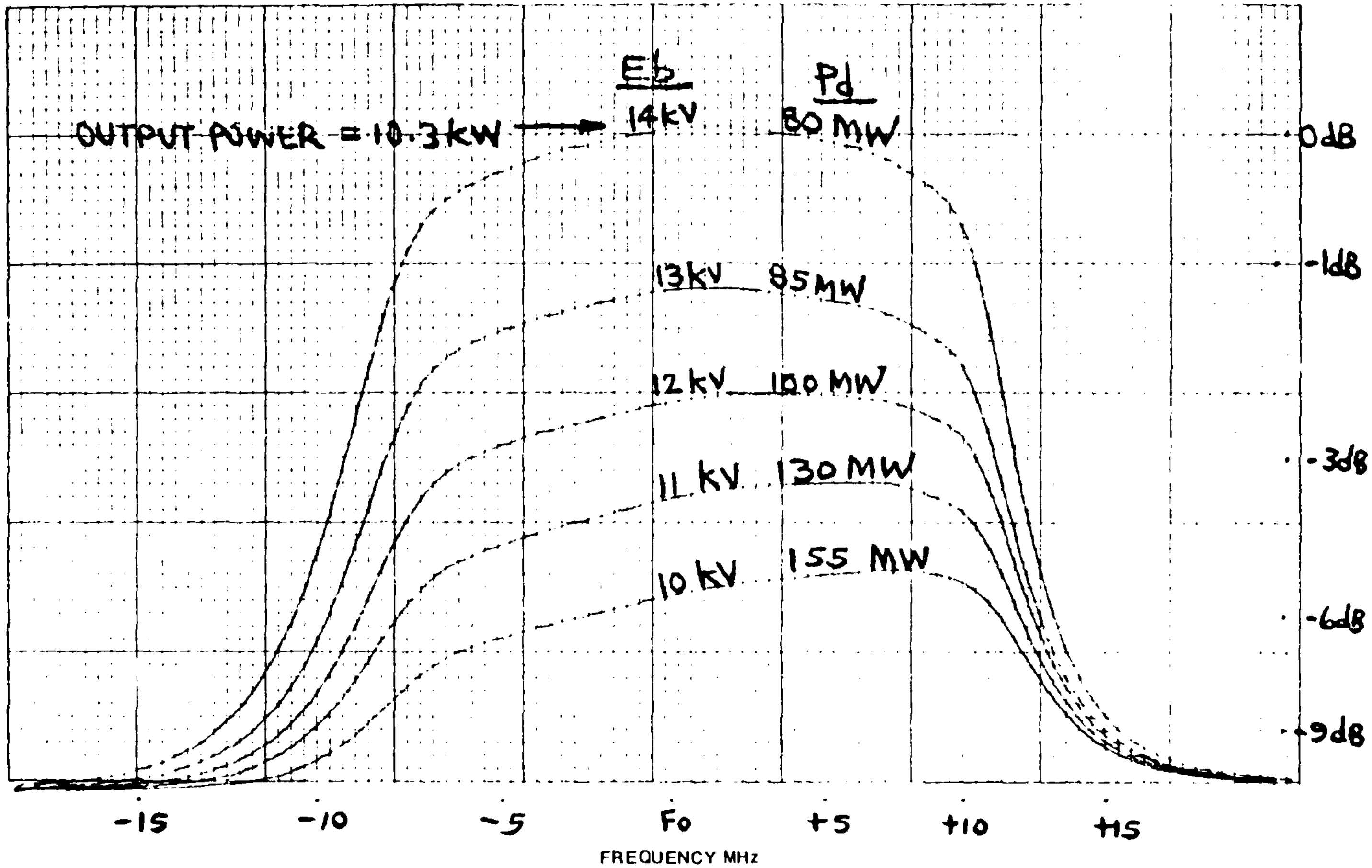
TEST DATA SHEET

VKS 7830 SERIAL NO. 102 | CHANNEL 2500 MHz | DATE 9-14-78 BY: RLD

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE VARIOUS kV
BEAM CURRENT A
BODY CURRENT mA

POWER OUTPUT VARIOUS kW
DRIVE POWER mW
GAIN dB



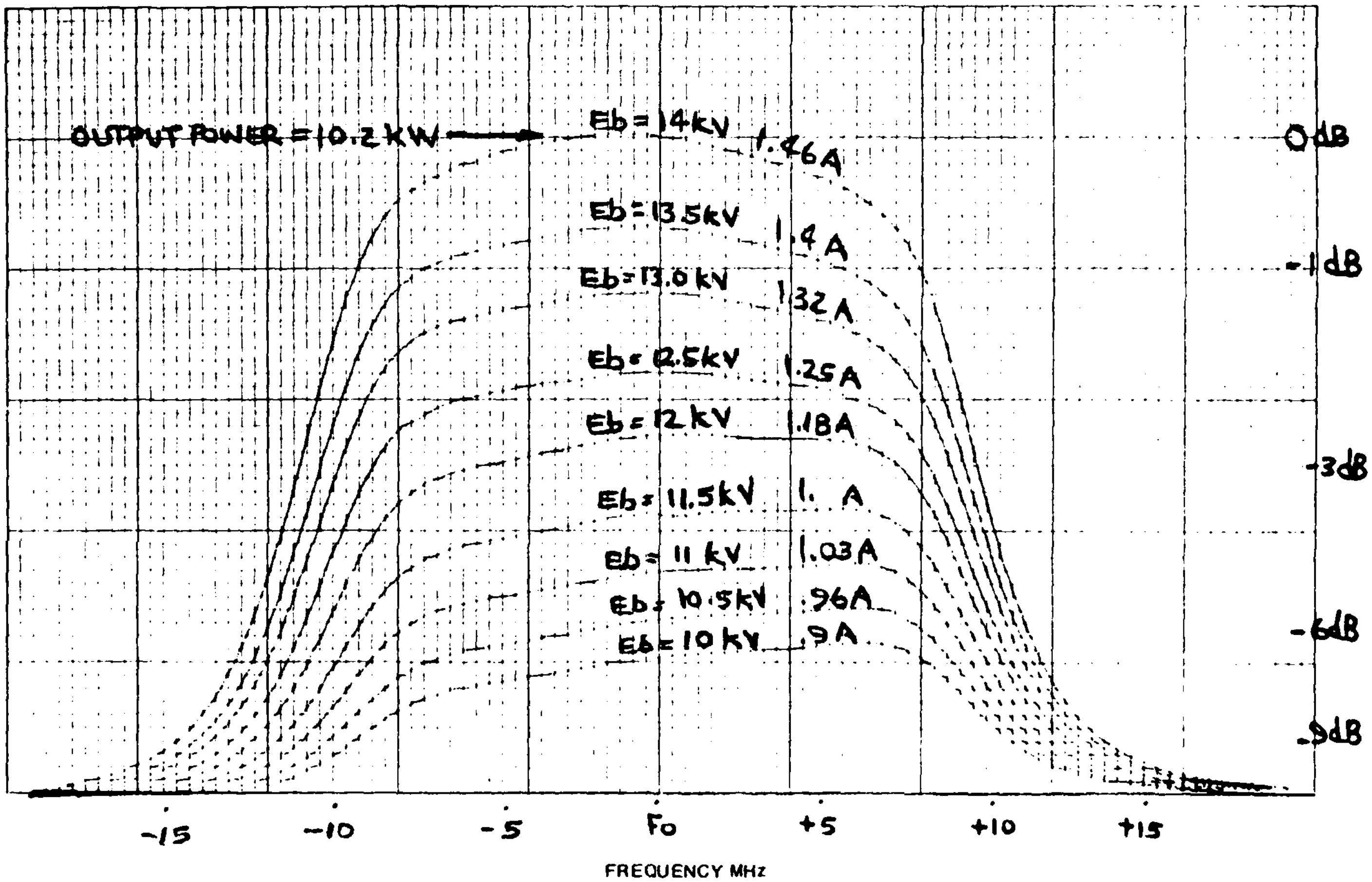
4740-10-25 R 10/73
TEST DATA SHEET

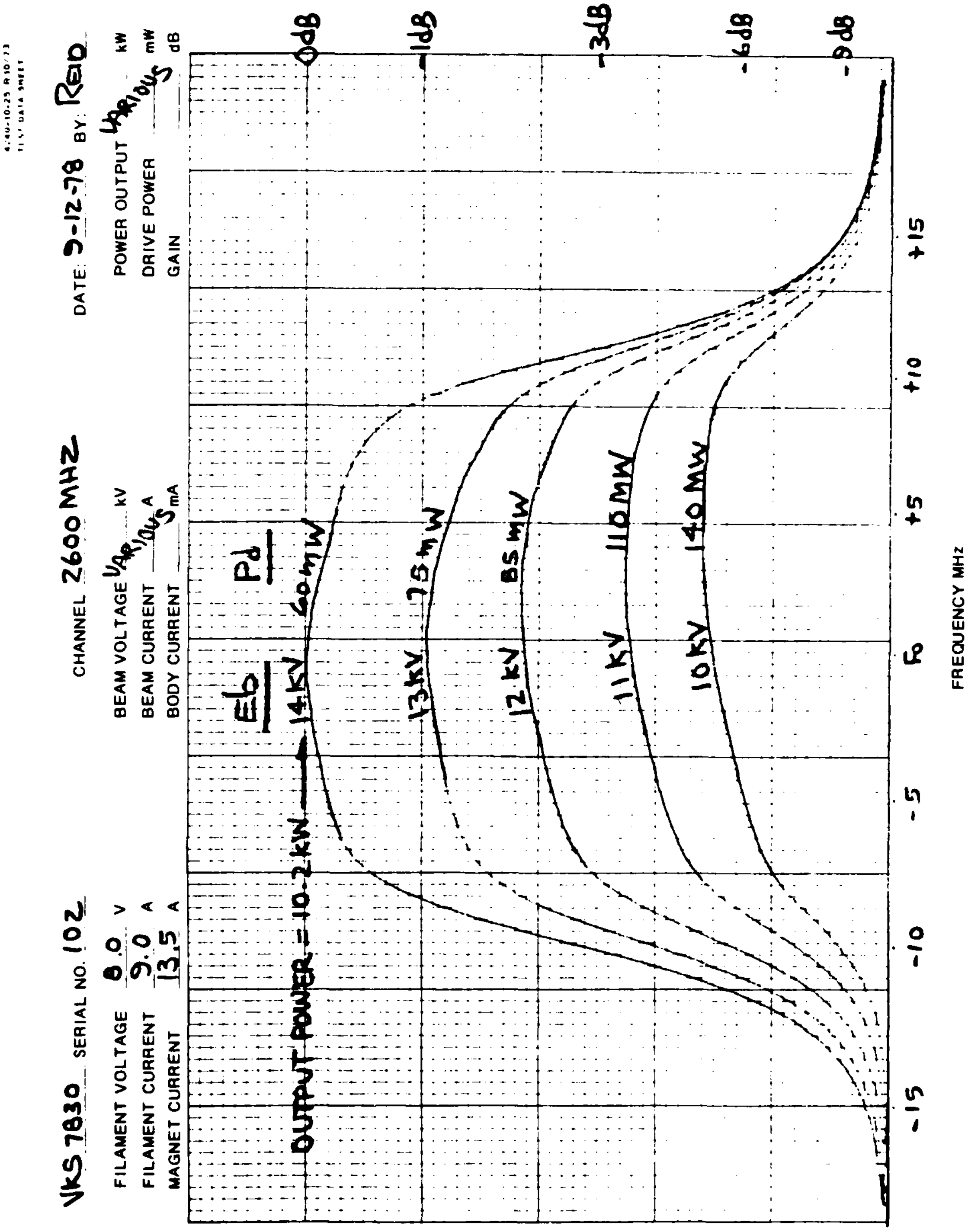
VKS 7830 SERIAL NO. 102 | CHANNEL 2600 MHZ | DATE 9-12-79 BY: REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE VARIOUS kV
BEAM CURRENT VARIOUS A
BODY CURRENT ____ mA

POWER OUTPUT VARIOUS kW
DRIVE POWER 60 mW
GAIN ____ dB



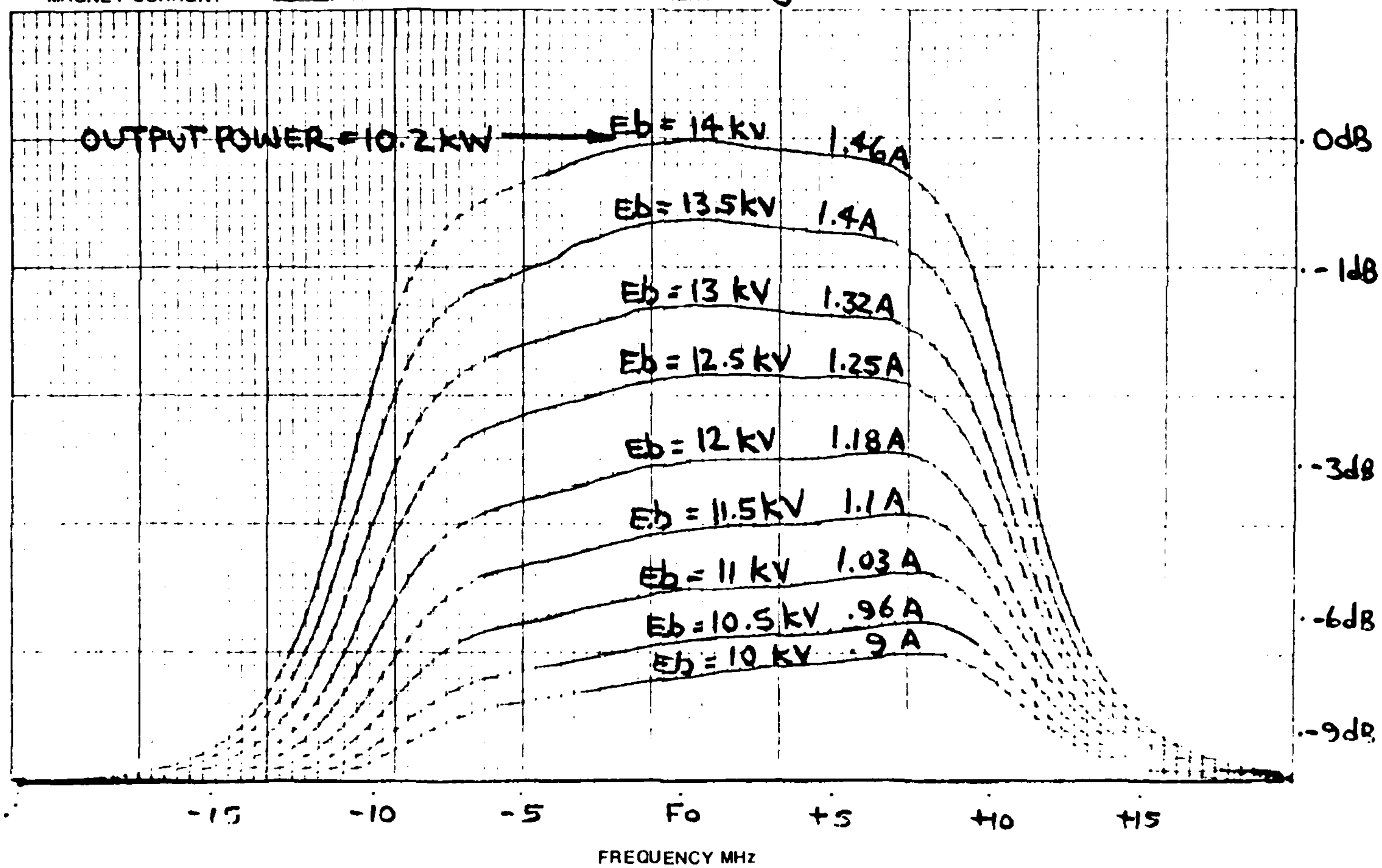


VKS 7830 SERIAL NO. 102
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A
CHANNEL 2600 MHZ
BEAM VOLTAGE kV
BEAM CURRENT A
BODY CURRENT mA
DATE: 9-12-78 BY: REID
POWER OUTPUT kW
DRIVE POWER mW
GAIN dB
Eb
Pd
14KV
60mW
13KV
75mW
12KV
85mW
11KV
110MW
10KV
140MW
OUTPUT POWER = 10.2KW
0dB
-1dB
-3dB
-6dB
-9dB
-15
-10
-5
F0
+5
+10
+15
FREQUENCY MHz

4240-10-25 R10 73
TEST DATA SHEET

VKS7830 SERIAL NO. 102 | CHANNEL 2700 MHZ | DATE: 9-14-78 BY Reid

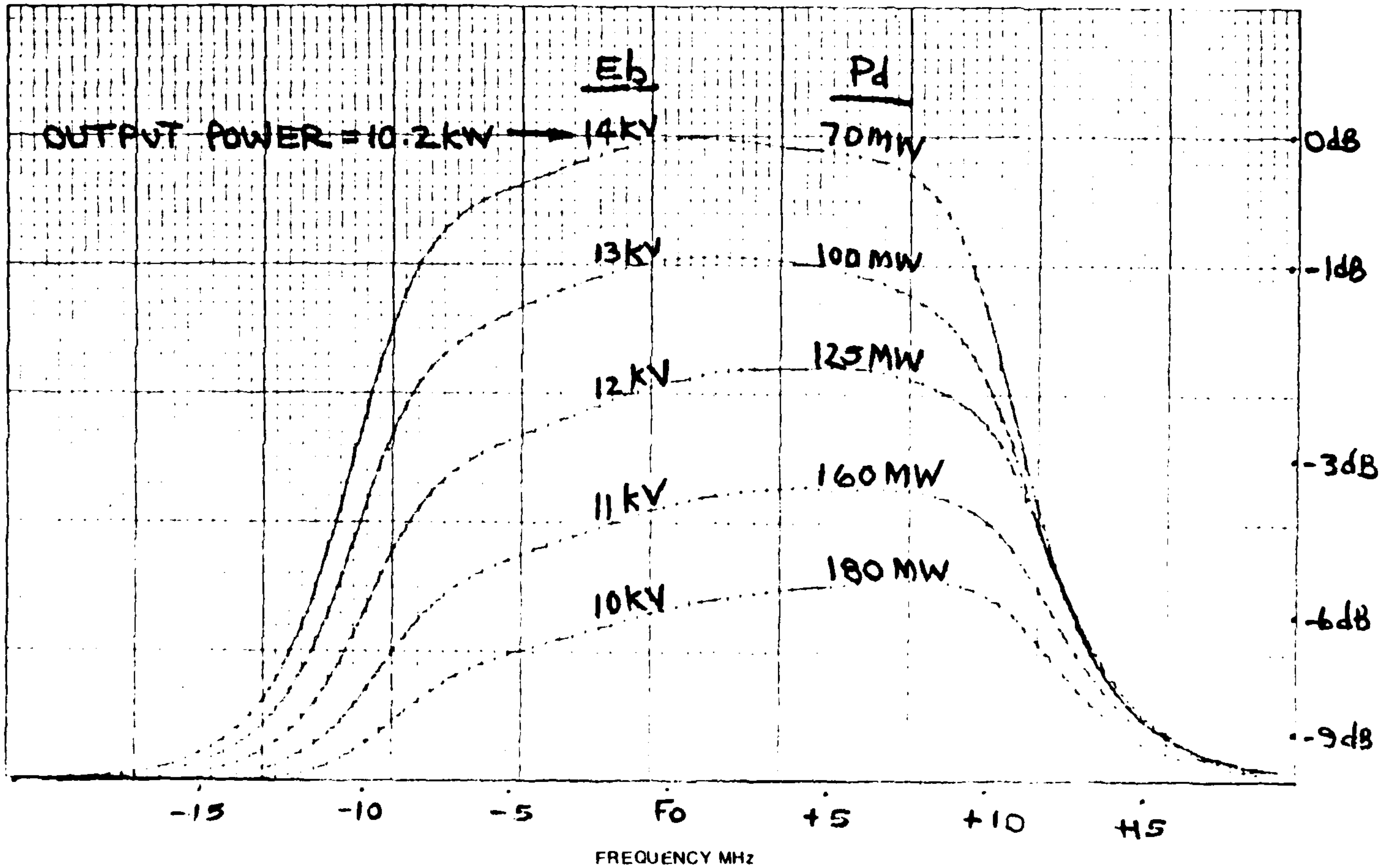
FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	VARIOUS kV	POWER OUTPUT	VARIOUS kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	A	DRIVE POWER	70 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	mA	GAIN	dB



4240-10-25 R10/73
TEST DATA SHEET

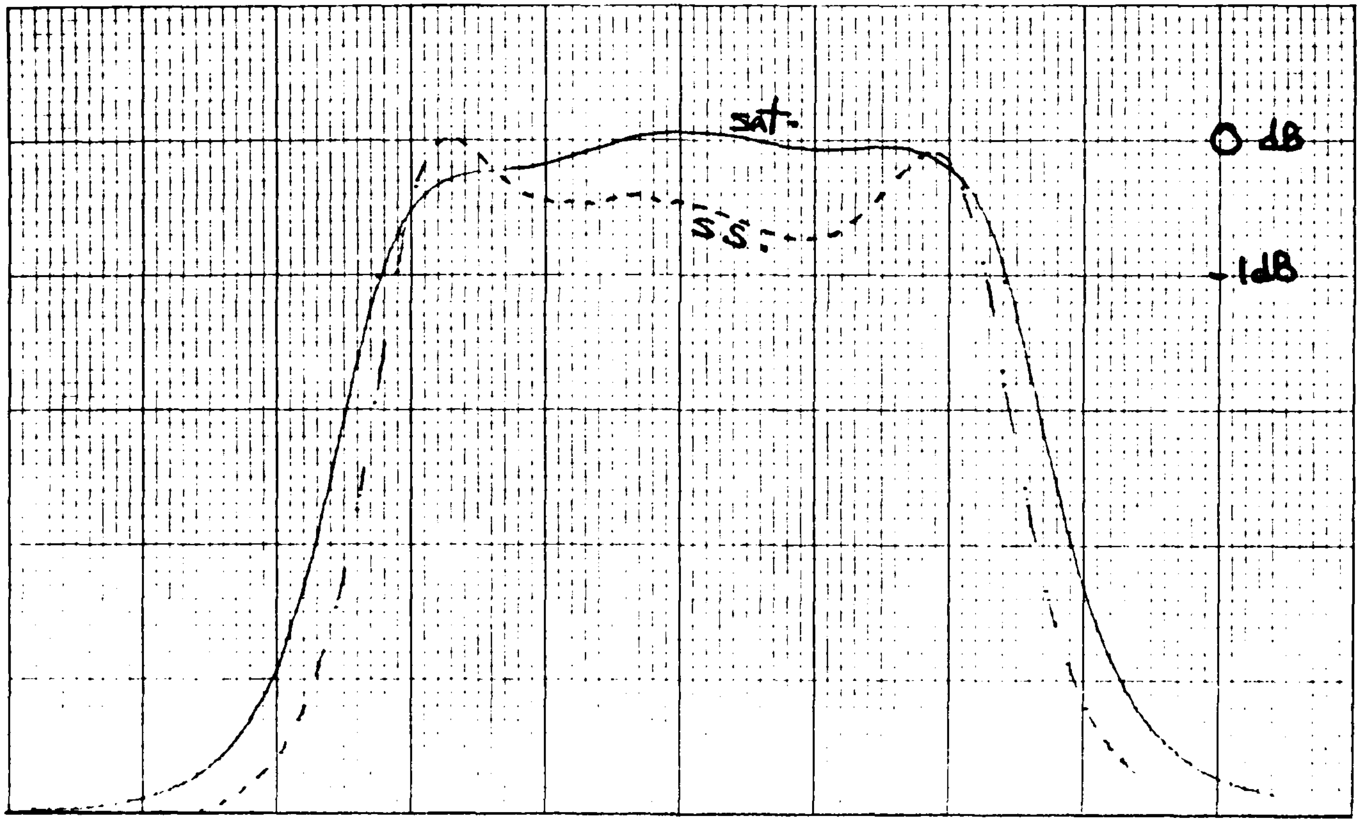
VKS7830 SERIAL NO. 102 | CHANNEL 2700 MHZ | DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE 8.0 V | BEAM VOLTAGE VARIOUS kV | POWER OUTPUT VARIOUS kW
FILAMENT CURRENT 9.0 A | BEAM CURRENT ___ A | DRIVE POWER ___ mW
MAGNET CURRENT 13.5 A | BODY CURRENT ___ mA | GAIN ___ dB



4240-10-25 R 10/73
TEST DATA SHEET

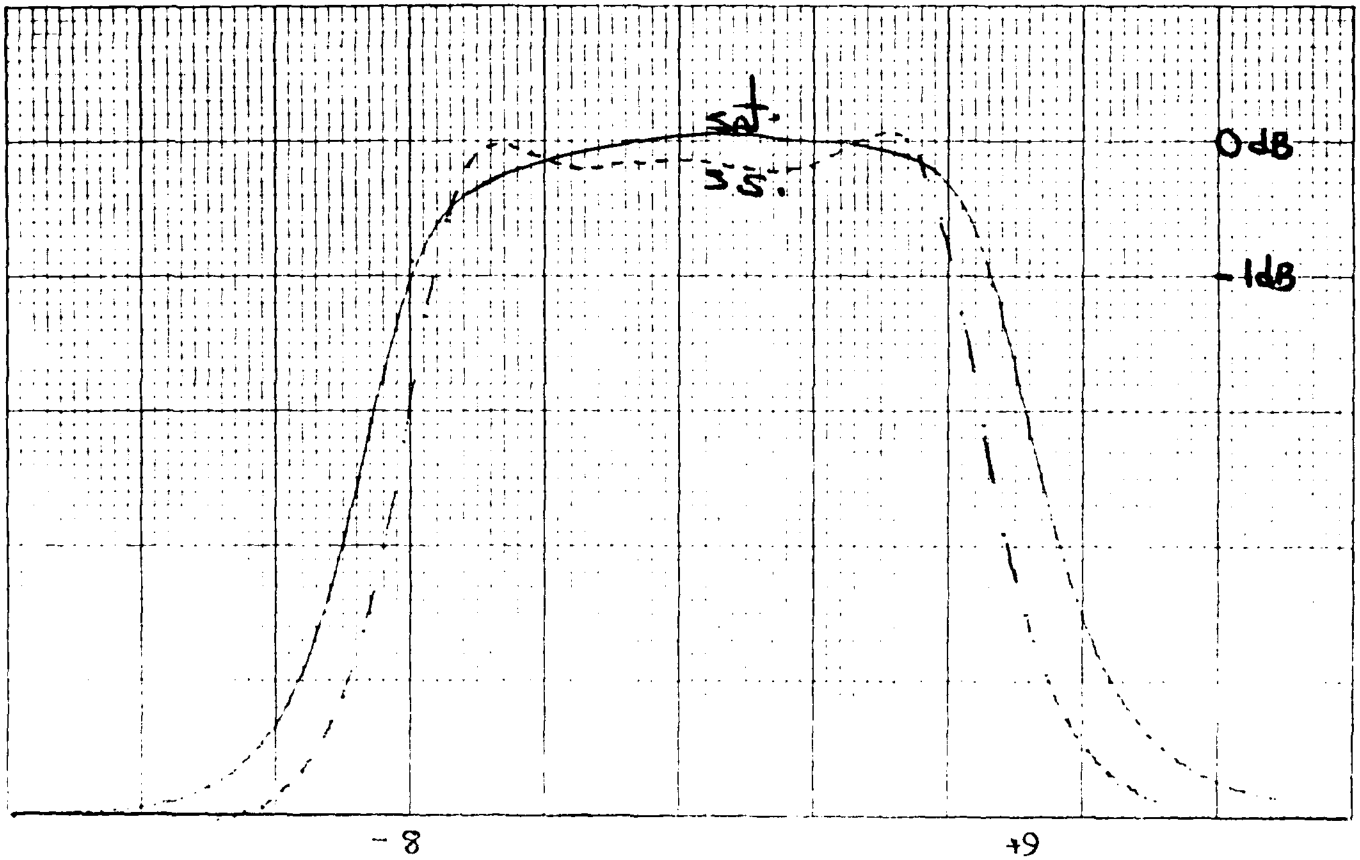
1830 SERIAL NO. 102	CHANNEL 2500 MHz	DATE: 9-11-78 BY: Keil
FILAMENT VOLTAGE 8.0 V	BEAM VOLTAGE 14.0 kV	POWER OUTPUT 10.3 kW
FILAMENT CURRENT 9.0 A	BEAM CURRENT 1.46 A	DRIVE POWER 80 mW
MAGNET CURRENT 13.5 A	BODY CURRENT 4.5 mA	GAIN ___ dB



4240-10-25 R 10/73
TEST DATA SHEET

X630 SERIAL NO. 102 CHANNEL 2522 MHz DATE: 9-11-78 BY: Feld

FILAMENT VOLTAGE 8.0 V BEAM VOLTAGE 14.0 kV POWER OUTPUT 10.3 kW
FILAMENT CURRENT 9.0 A BEAM CURRENT 1.46 A DRIVE POWER 60 mW
MAGNET CURRENT 13.5 A BODY CURRENT 4.5 mA GAIN ____ dB



FREQUENCY MHz

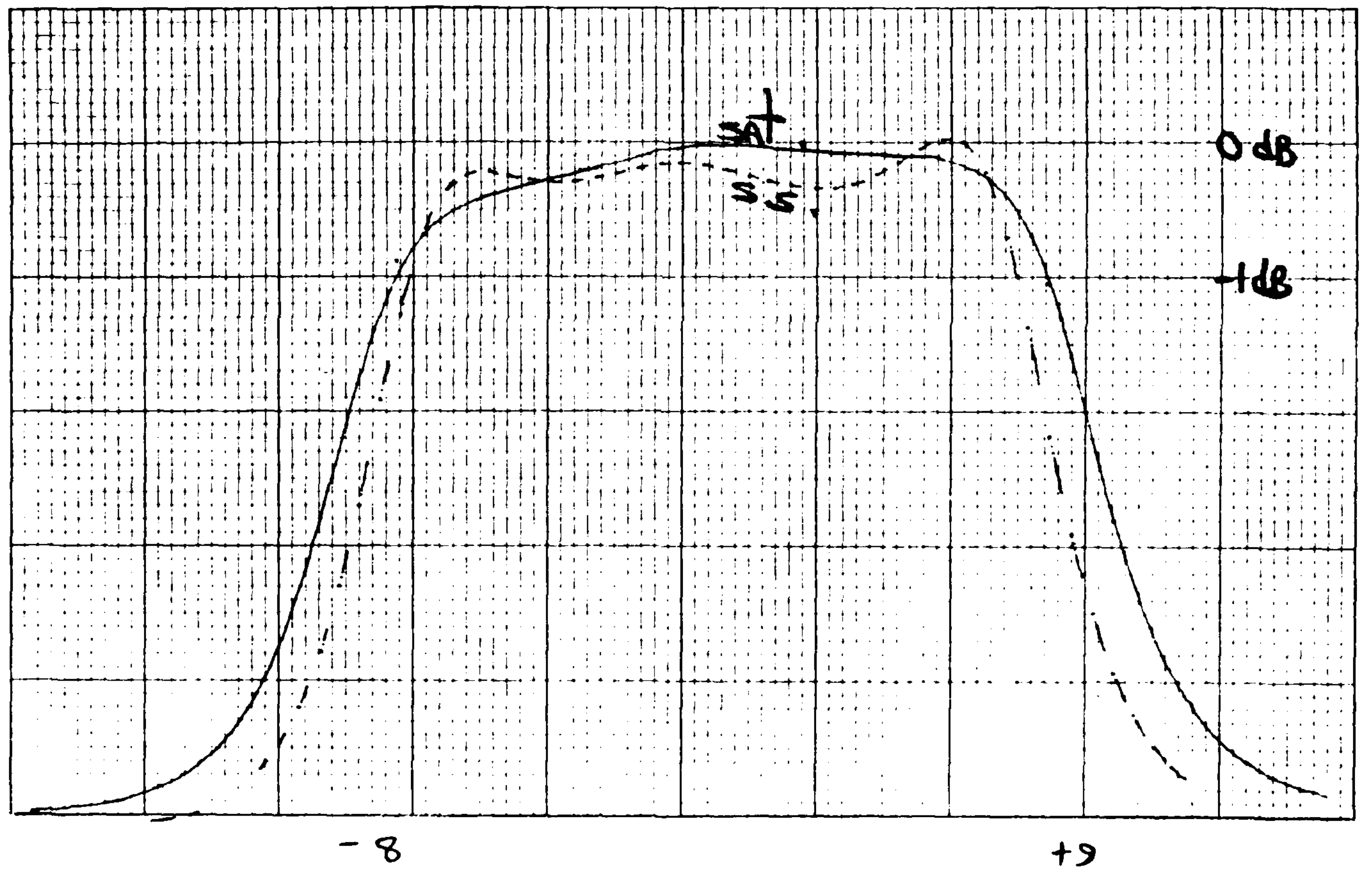
4240-10-25 R 10/73
TEST DATA SHEET

7830 SERIAL NO. 102 CHANNEL 2546 MHZ DATE: 9-11-76 BY: REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

POWER OUTPUT 10.2 kW
DRIVE POWER 60 mW
GAIN ____ dB



FREQUENCY MHz

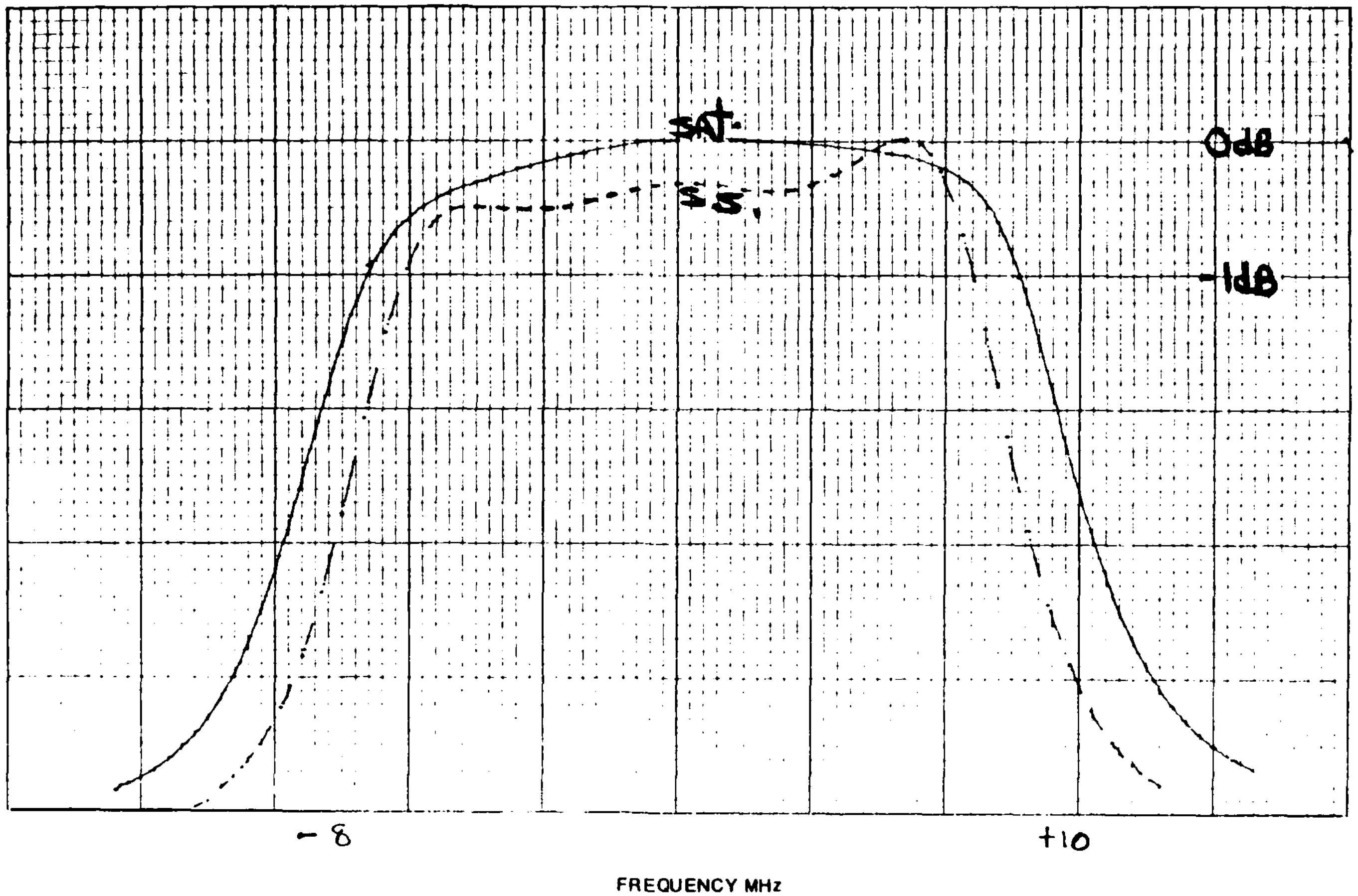
4240-10-25 R10/73
TEST DATA SHEET

7830 SERIAL NO. 102 CHANNEL 2572 MHz DATE 9-11-78 BY: REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

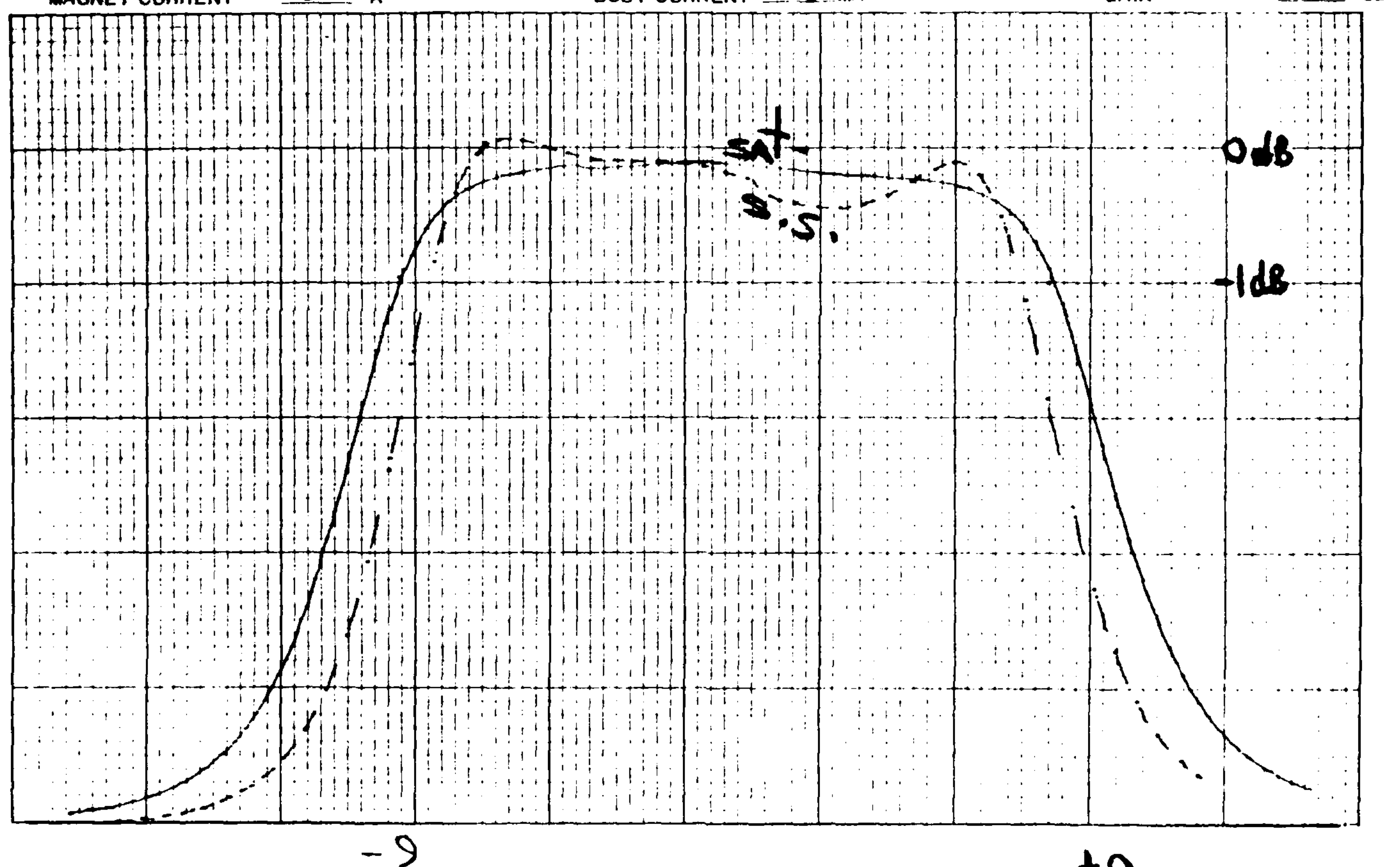
POWER OUTPUT 10.2 kW
DRIVE POWER 65 mW
GAIN ____ dB



4.40-10-25 R10/73
TEST DATA SHEET

7830 SERIAL NO. 102 | CHANNEL 2586 MHz | DATE 9-11-78 BY: REID

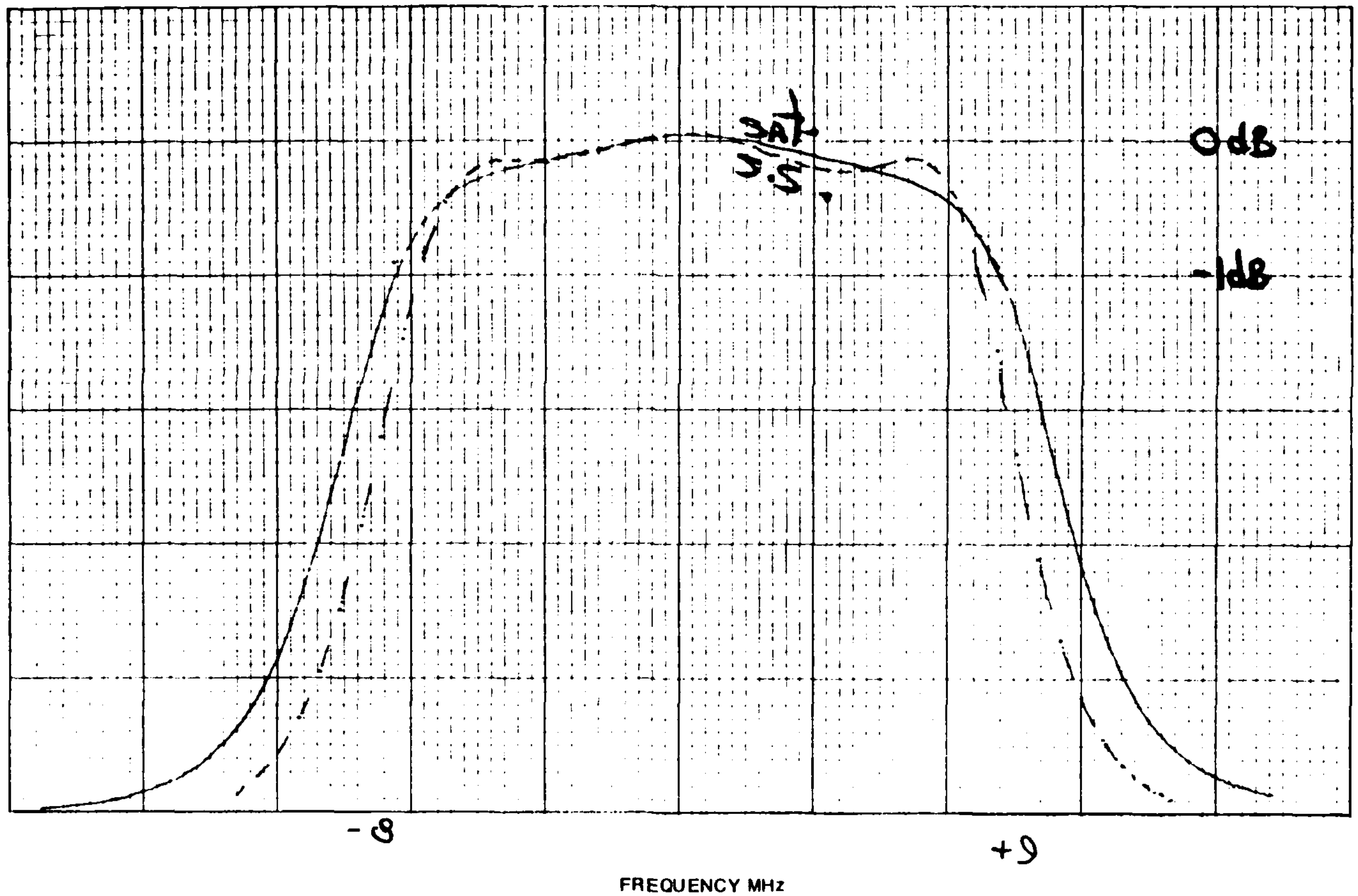
FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.0 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	65 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB



4240-10-25 R10-73
TEST DATA SHEET

7736 SERIAL NO. 102 | CHANNEL 2600 MHz | DATE: 5-11-75 BY: REW

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB



4240-10-25 R 10/73
TEST DATA SHEET

7830 SERIAL NO. 102

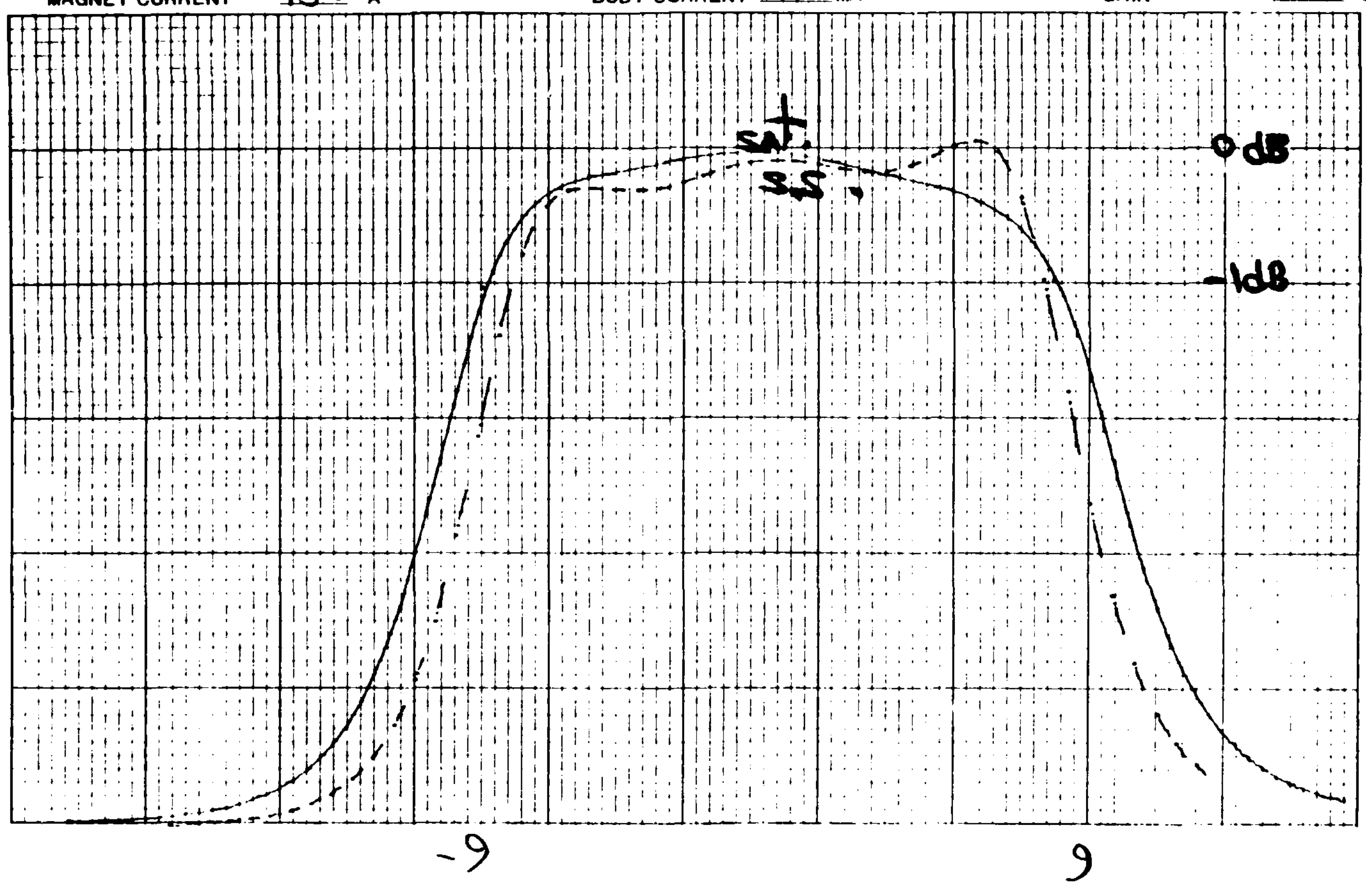
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

CHANNEL 2614 MHz

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

DATE: 9-11-78 BY: REID

POWER OUTPUT 10.0 kW
DRIVE POWER 60 mW
GAIN ____ dB



FREQUENCY MHz

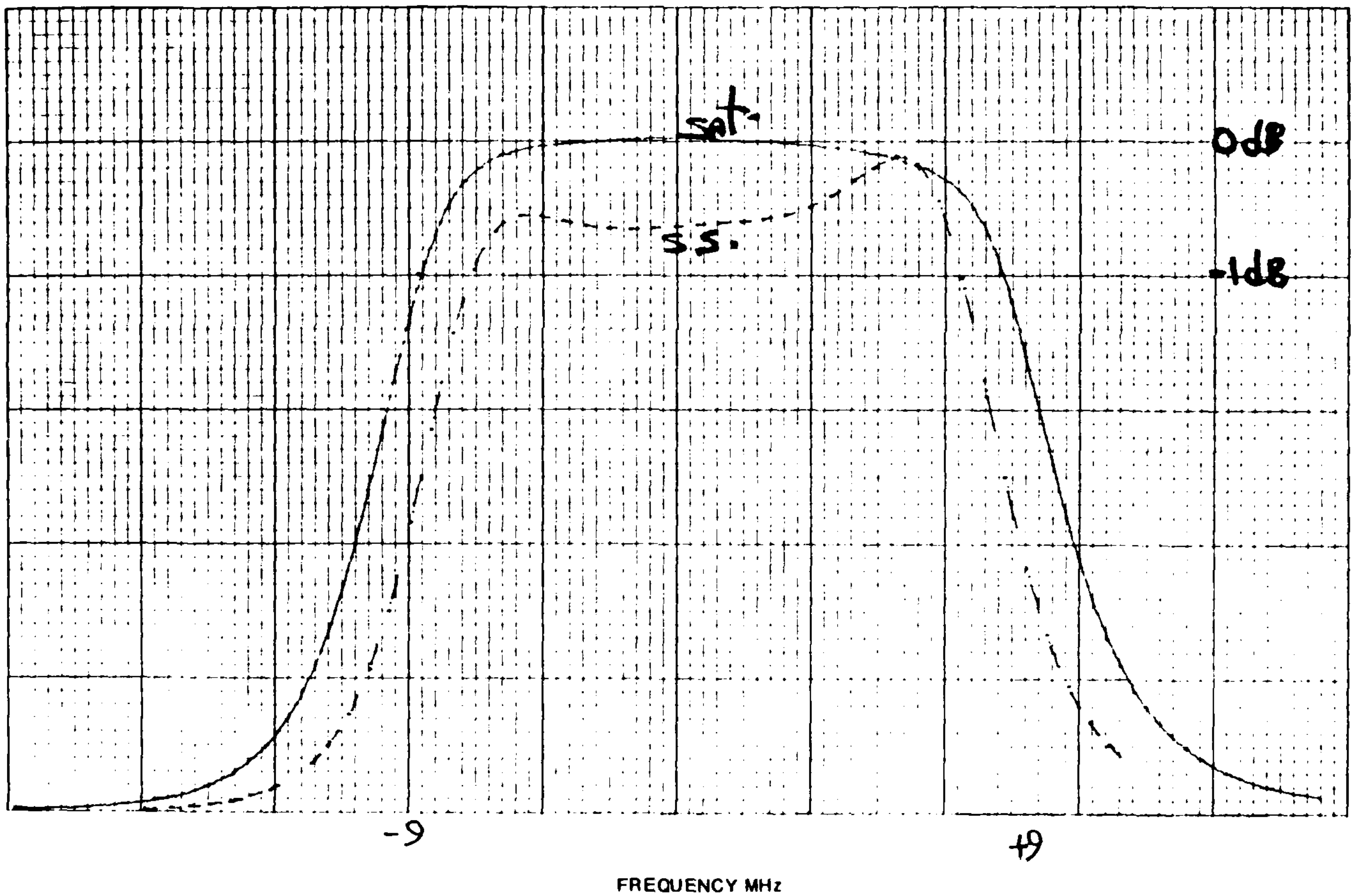
4240-10-25 R 10/73
TEST DATA SHEET

7 830 SERIAL NO. 102 CHANNEL 2628 MHz DATE: 9-11-76 BY: T.E.

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

POWER OUTPUT 10.1 kW
DRIVE POWER 60 mW
GAIN ____ dB



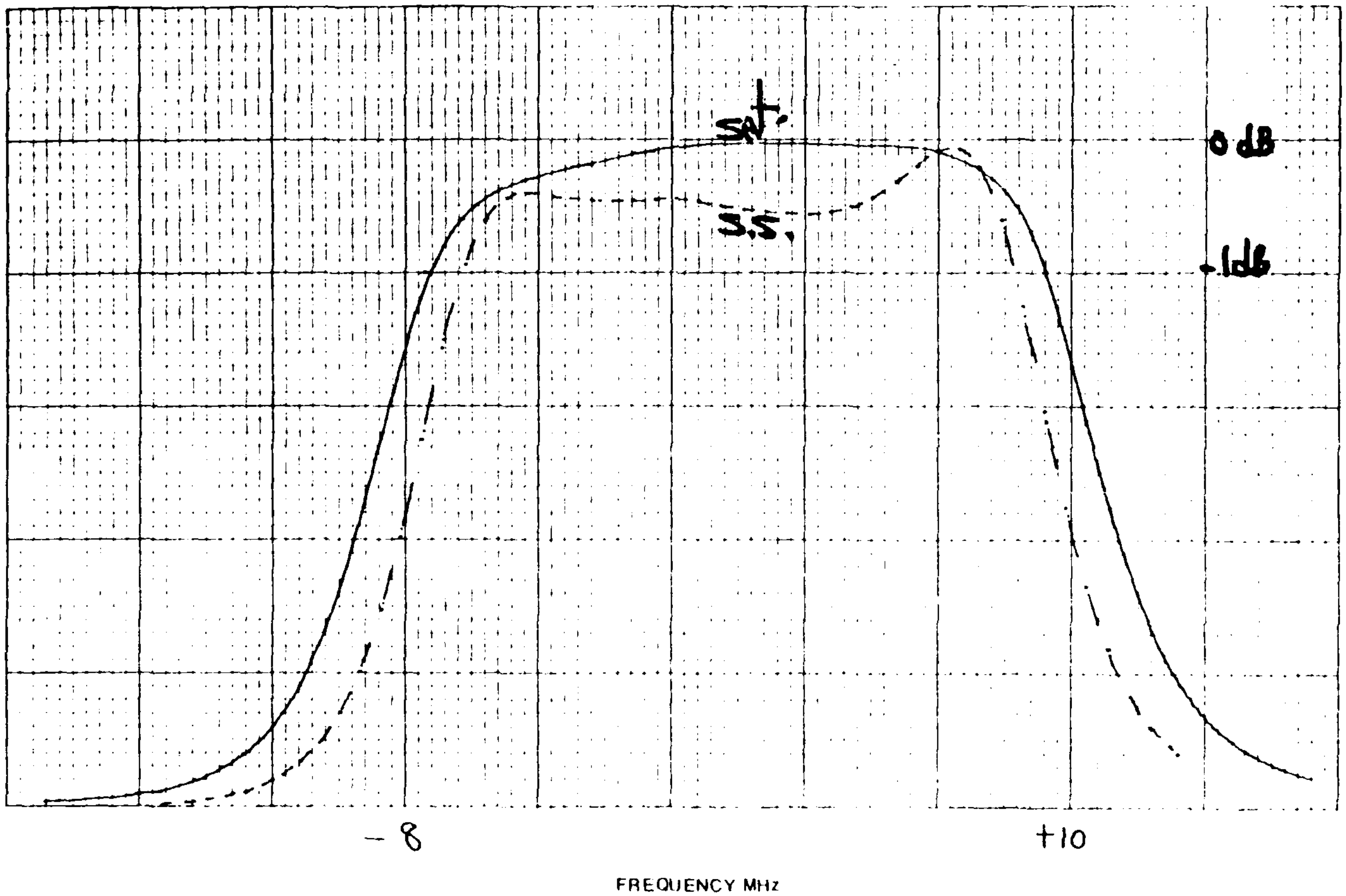
TEST DATA SHEET

7830 SERIAL NO. 102 CHANNEL 640 MHz DATE: 9-11-76 BY: Keu

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 7.5 mA

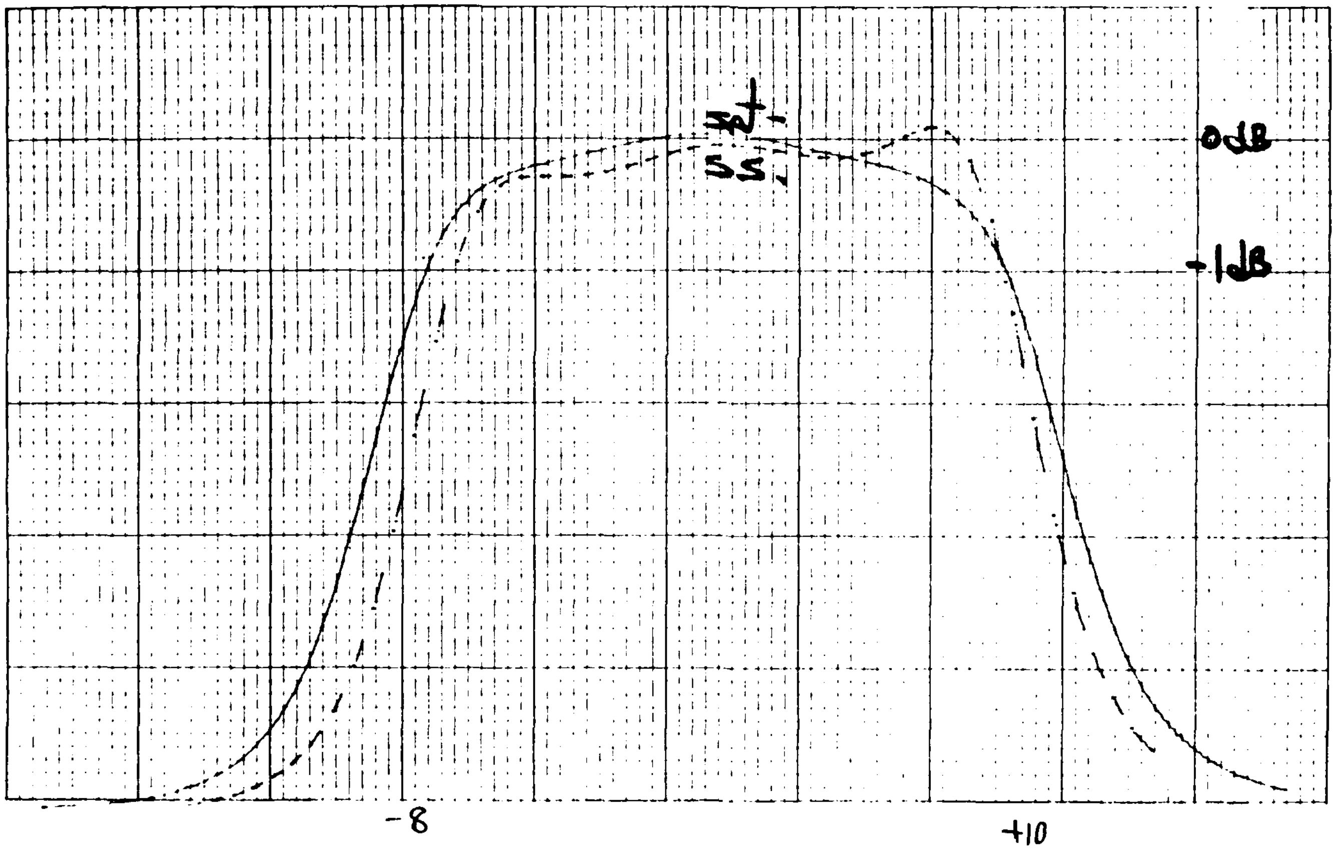
POWER OUTPUT 10.0 kW
DRIVE POWER 70 mW
GAIN ___ dB



TEST DATA SHEET

7830 SERIAL NO. 102 | CHANNEL 2654 MHz | DATE 9-11-78 BY: [illegible]

FILAMENT VOLTAGE	8.0 V		BEAM VOLTAGE	14.0 kV		POWER OUTPUT	10.1 kW
FILAMENT CURRENT	9.0 A		BEAM CURRENT	1.46 A		DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A		BODY CURRENT	4.5 mA		GAIN	dB

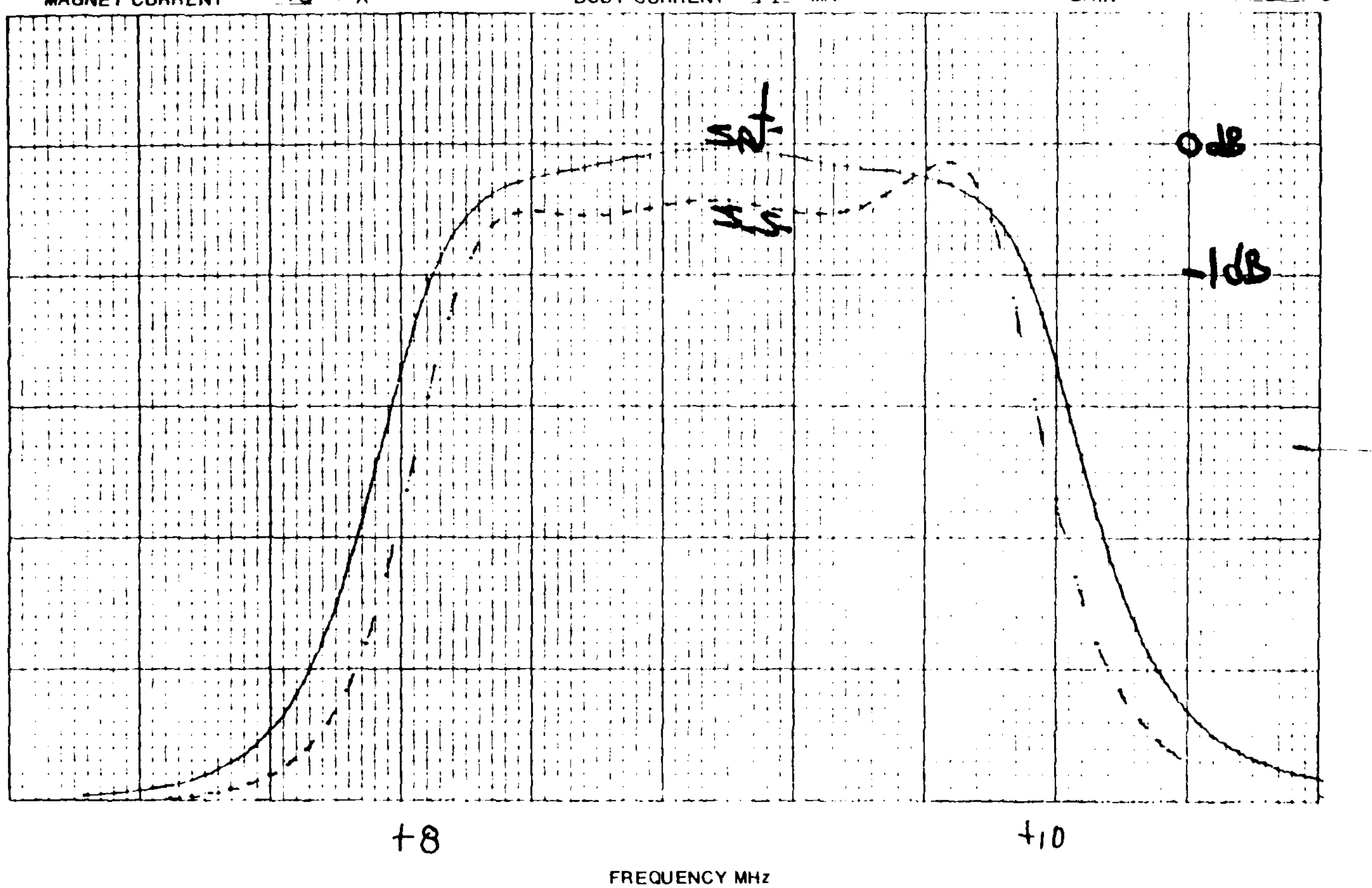


FREQUENCY MHz

TEST DATA SHEET

7830 SERIAL NO. 102 CHANNEL 2666 MHz DATE 9-11-72 BY R.E.L

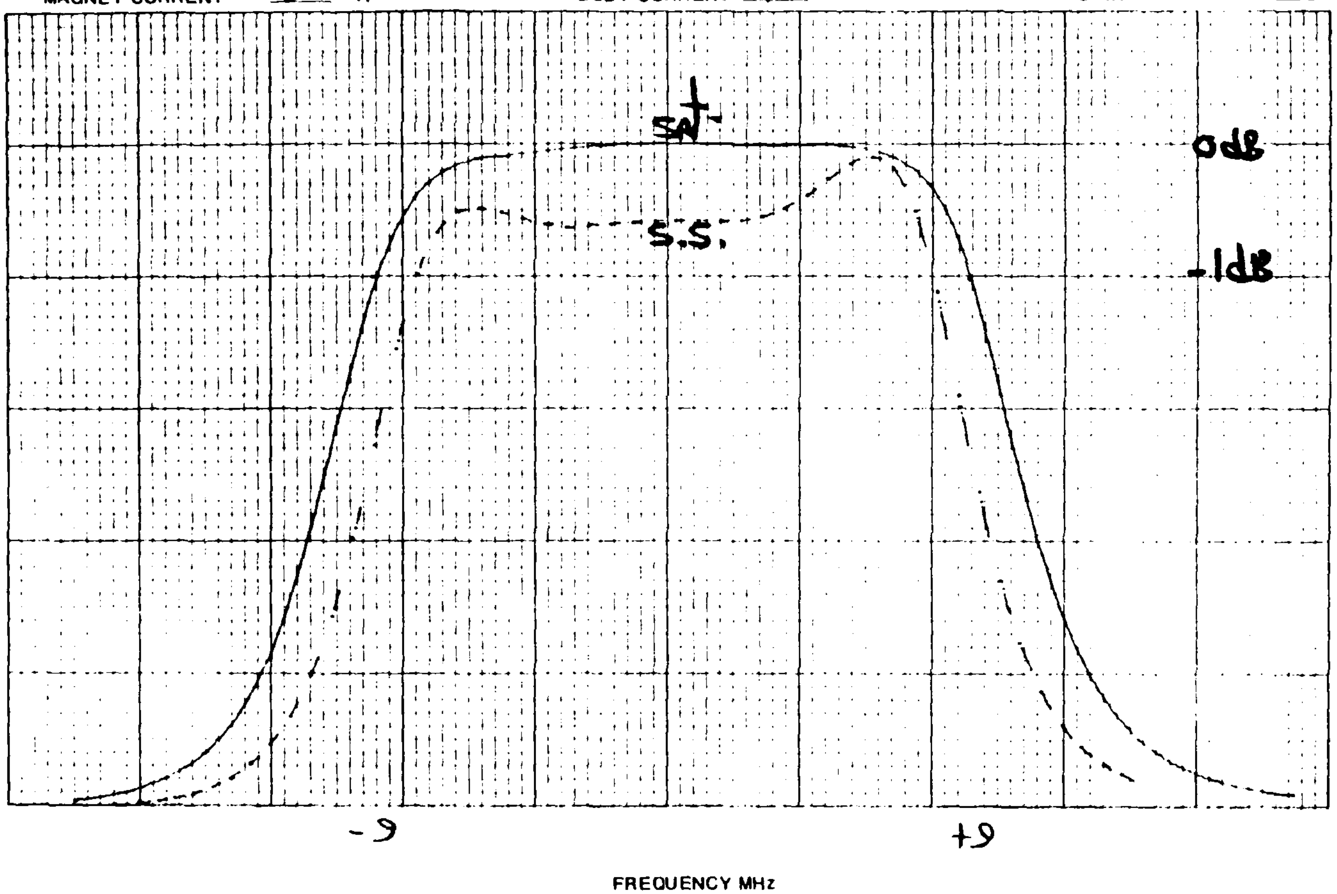
FILAMENT VOLTAGE 8.0 V	BEAM VOLTAGE 14.0 kV	POWER OUTPUT 10.0 kW
FILAMENT CURRENT 9.0 A	BEAM CURRENT 1.46 A	DRIVE POWER 70 mW
MAGNET CURRENT 13.5 A	BODY CURRENT 7.5 mA	GAIN ____ dB

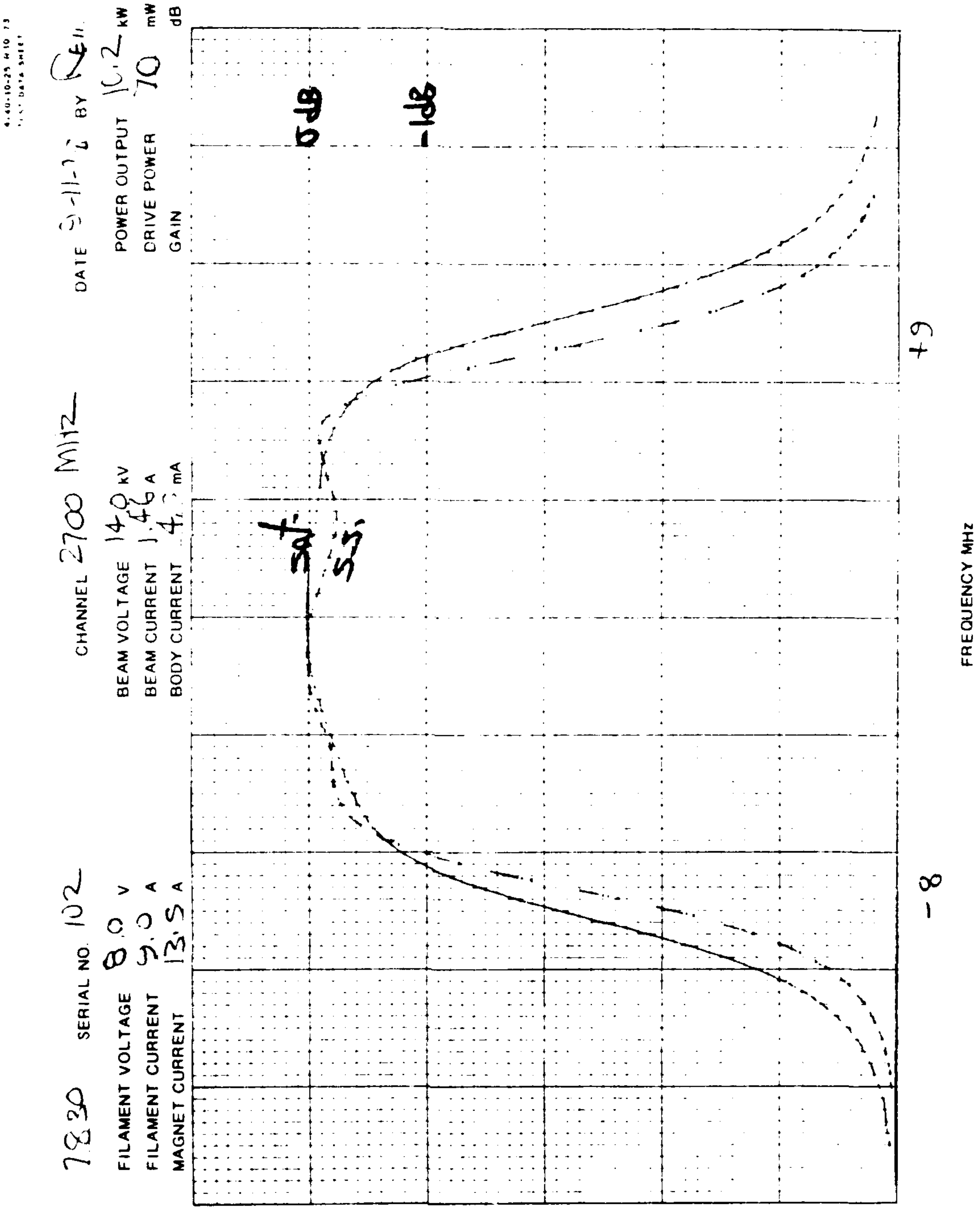


TEST DATA SHEET

7830 SERIAL NO. 102 CHANNEL 2628 MHz DATE: 9-11-79 BY: [illegible]

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	17.0 kV	POWER OUTPUT	10.1 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	70 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB



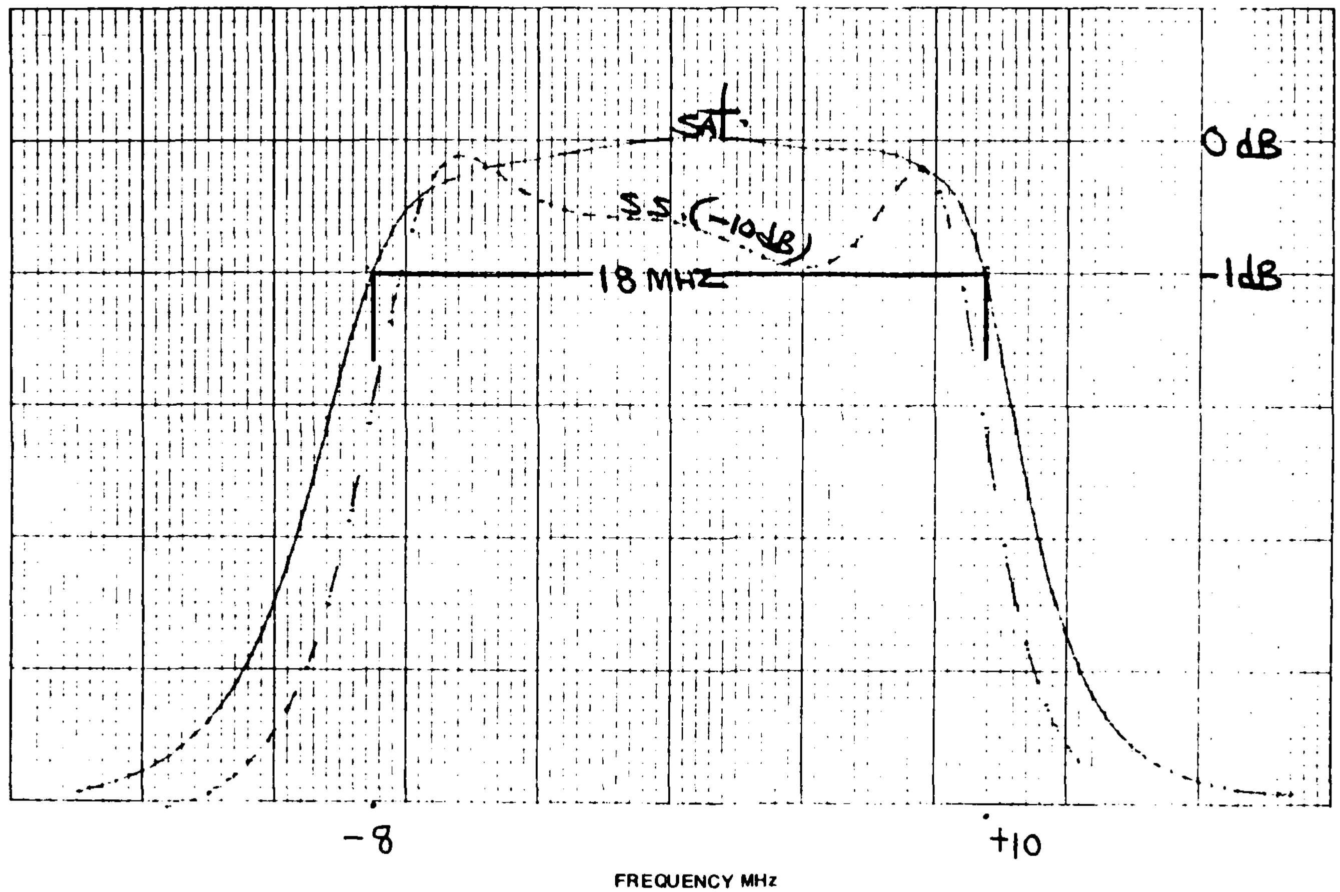

7830
SERIAL NO. 102
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A
CHANNEL 2700 MHz
BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT mA
DATE BY
POWER OUTPUT 10.2 kW
DRIVE POWER 70 mW
GAIN dB
0 dB
-1 dB
sat
S.S.
-8
+9
FREQUENCY MHz

4240-10-25 R10/73
TEST DATA SHEET

(1/2" DIA. BALL) OUTPUT LOAD MISMATCH = 1.2:1

VKS7830 SERIAL NO. 102 CHANNEL 2500 MHZ DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE 8.0 V BEAM VOLTAGE 14.0 kV POWER OUTPUT 9.6 kW
FILAMENT CURRENT 9.0 A BEAM CURRENT 1.46 A DRIVE POWER 80 mW
MAGNET CURRENT 13.5 A BODY CURRENT .5 mA GAIN __ dB



4:40-10-25 R10/73
TEST DATA SHEET

VKS7830 SERIAL NO. 102 -1.5

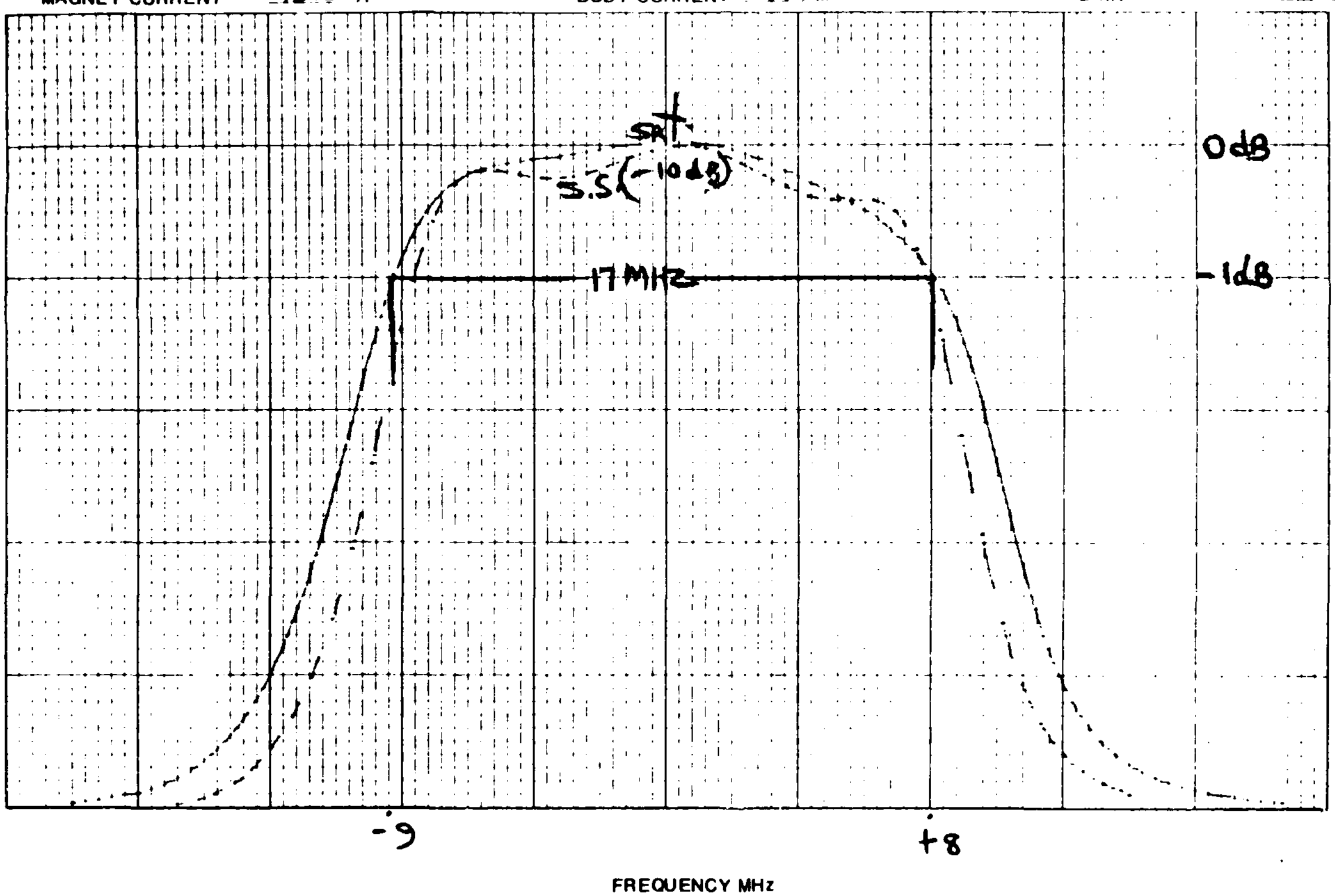
CHANNEL 2600MHz

DATE 9-14-78 BY REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

POWER OUTPUT 10.4 kW
DRIVE POWER 60 mW
GAIN ___ dB



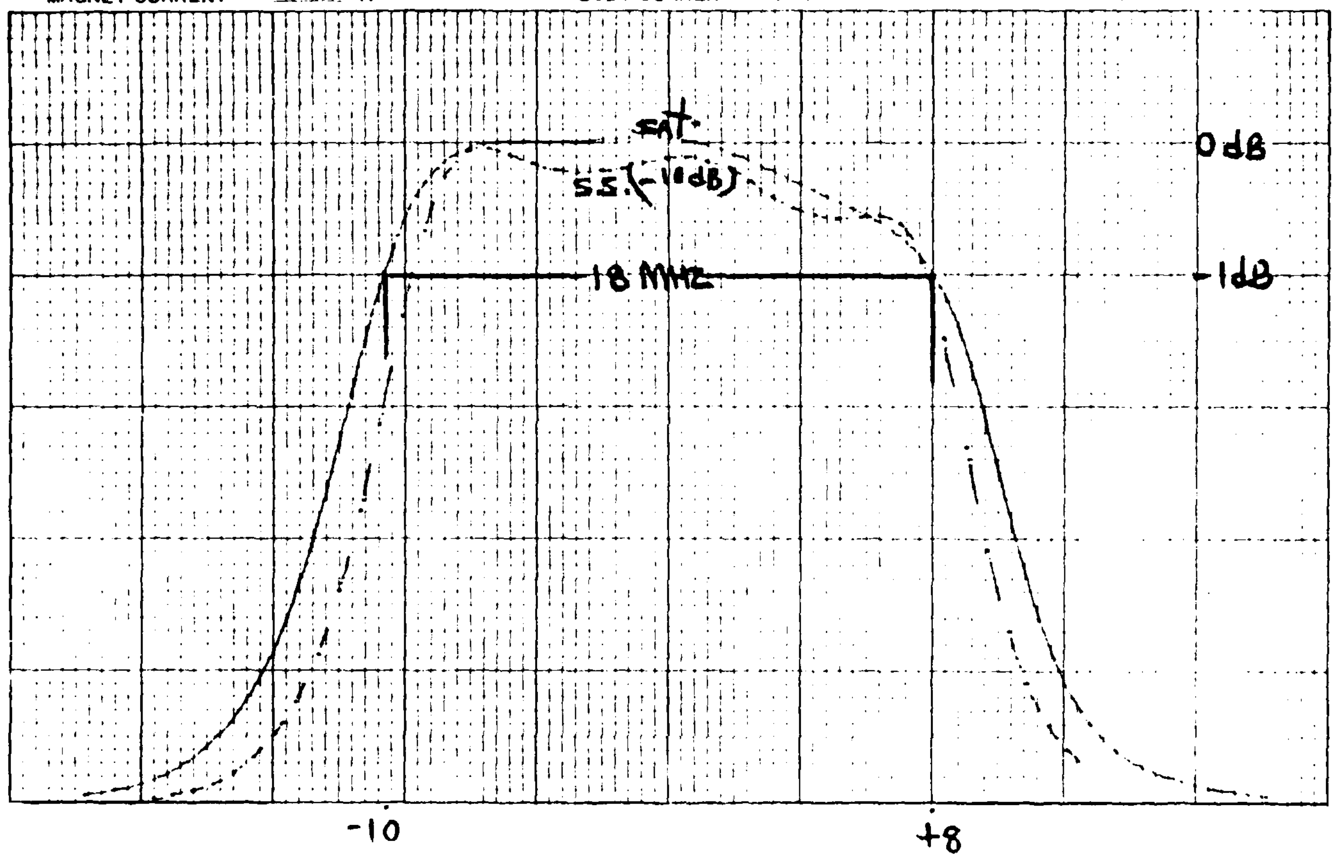
4240-10-25 R10/73
TEST DATA SHEET

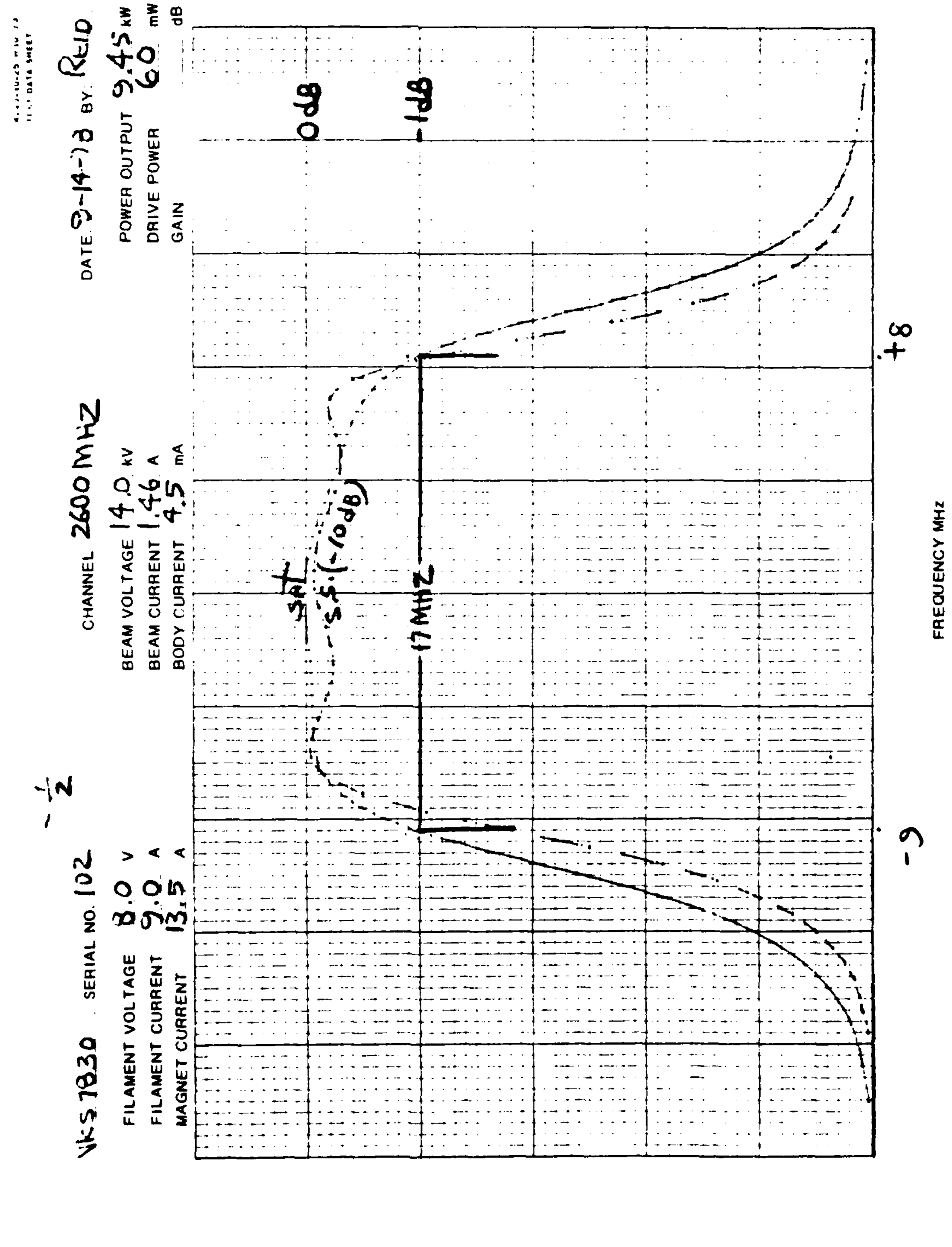
VKS 7830 SERIAL NO. 102 -1.0

CHANNEL 2600 MHZ

DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.0 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB



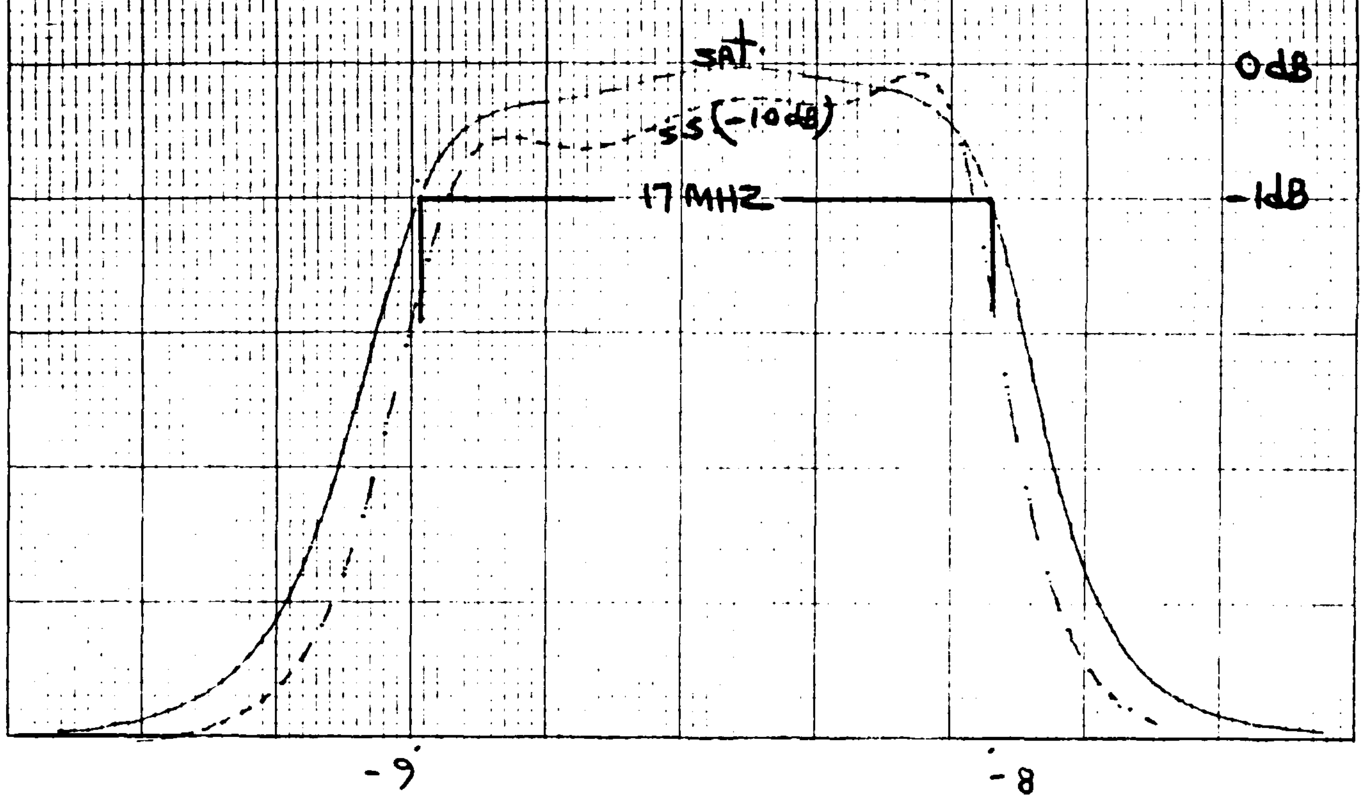


VKS 7830 SERIAL NO. 102
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A
CHANNEL 2600 MHz
BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA
DATE 9-14-78 BY: REID
POWER OUTPUT 9.45 kW
DRIVE POWER 6.0 mW
GAIN dB
TEST DATA SHEET
-½
0dB
-1dB
SAT
5.5 (-10dB)
17MHz
-9
+8
FREQUENCY MHz

(½" DIA. BALL) OUTPUT LOAD MISMATCH = 1.2:1

VKS7830 SERIAL NO. 102 ϕ CHANNEL 2600 MHZ DATE: 9-14-79 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	9.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	___ dB



TEST DATA SHEET

VKS7830 SERIAL NO. 102 + 1/2

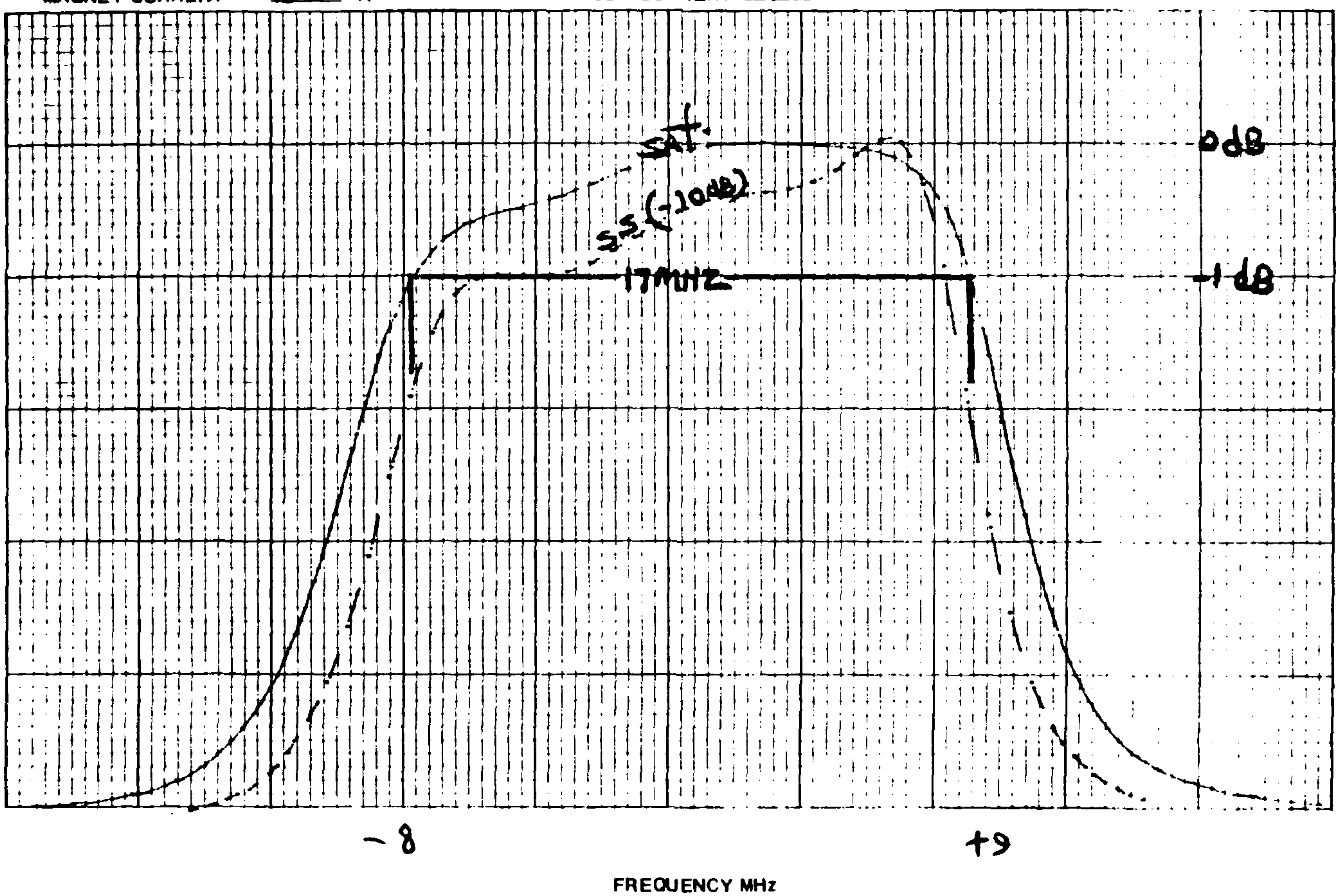
CHANNEL 2600 MHz

DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

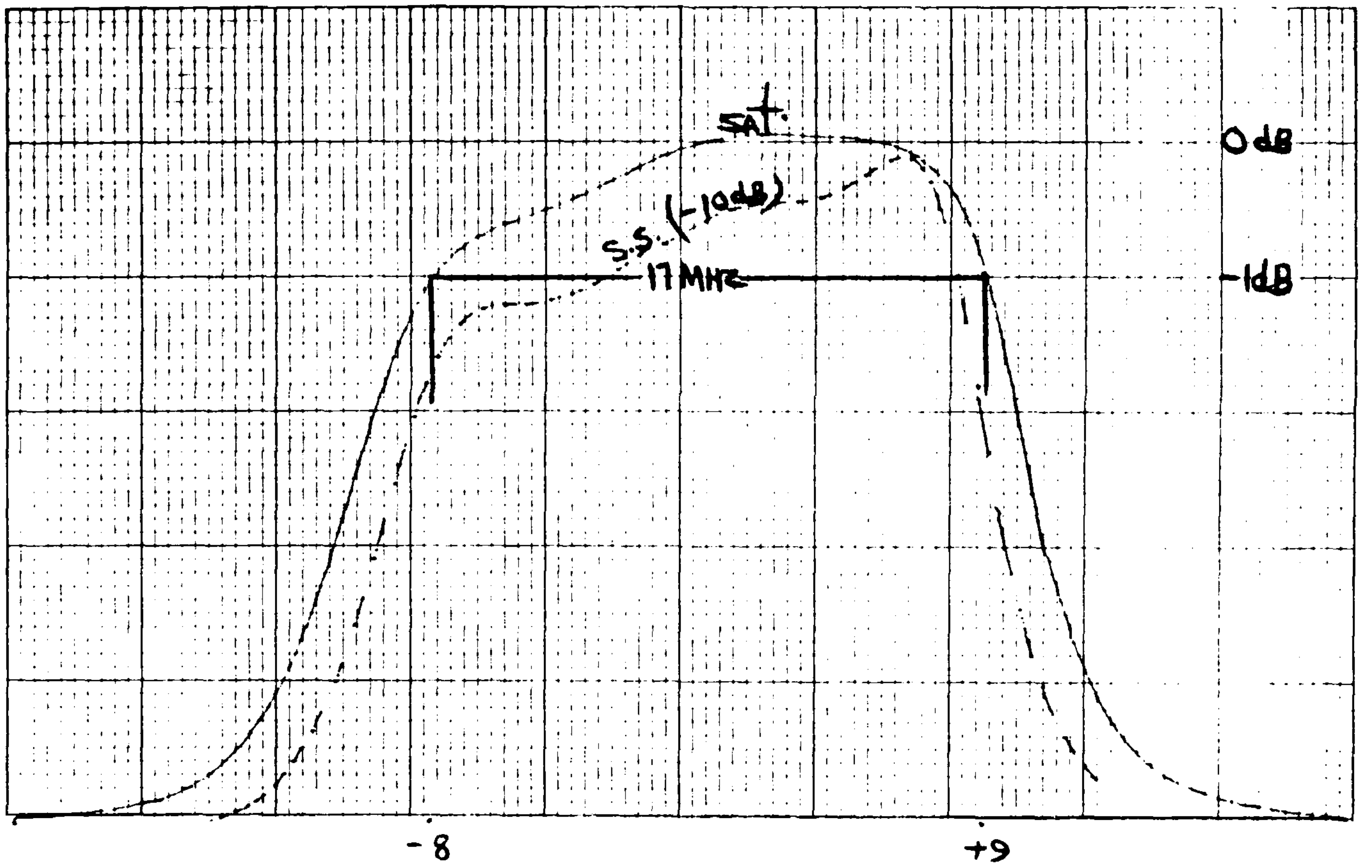
POWER OUTPUT 9.3 kW
DRIVE POWER 60 mW
GAIN ____ dB



TEST DATA SHEET

VKS7830 SERIAL NO. 102 +1.0 CHANNEL 2600 MHZ DATE: 9-11-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	9.9 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.6 mA	GAIN	dB



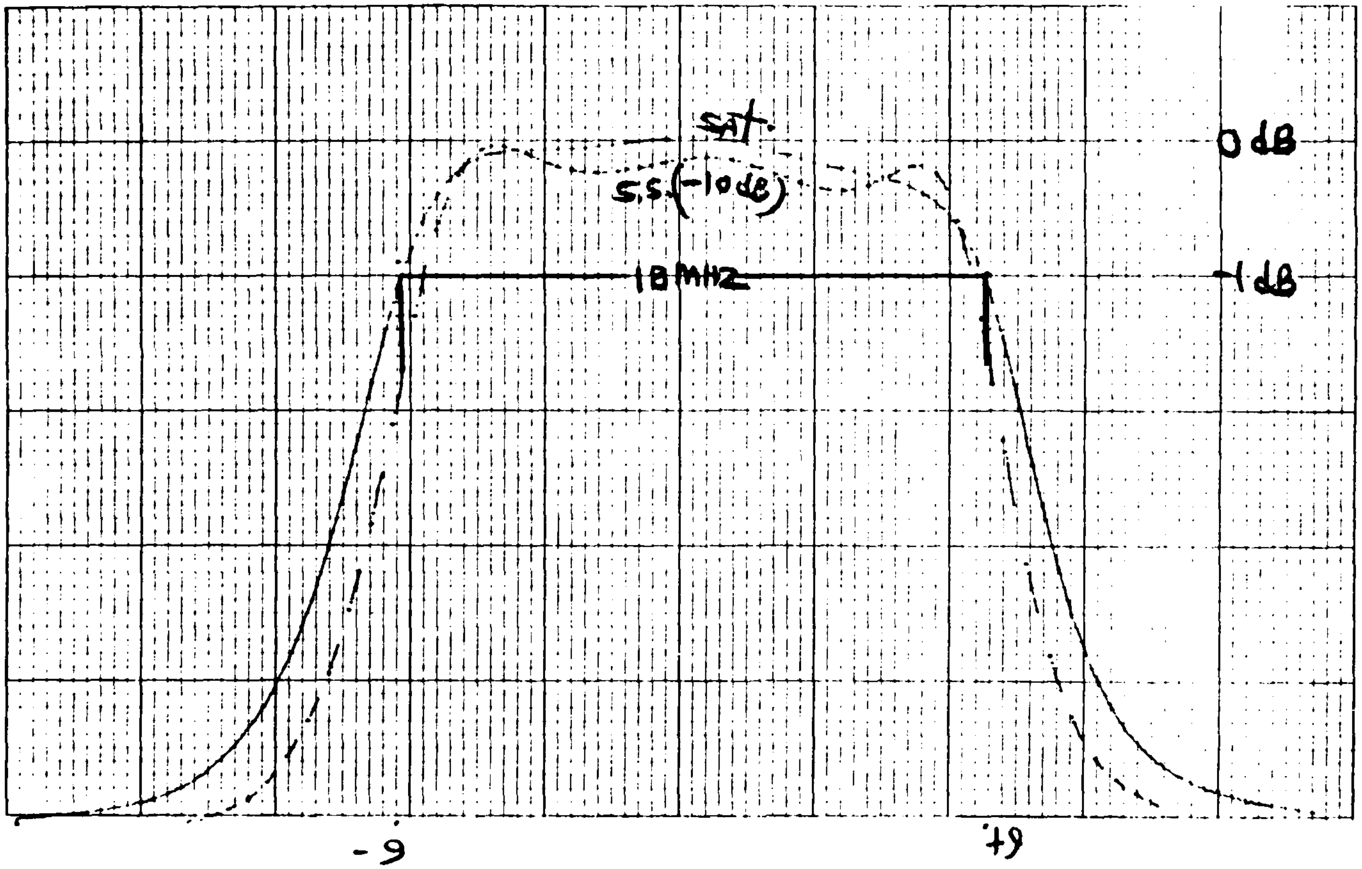
TEST DATA SHEET

VKS7830 SERIAL NO. 102 +1.5 CHANNEL 2600 MHZ DATE: 9-14-78 BY: REID

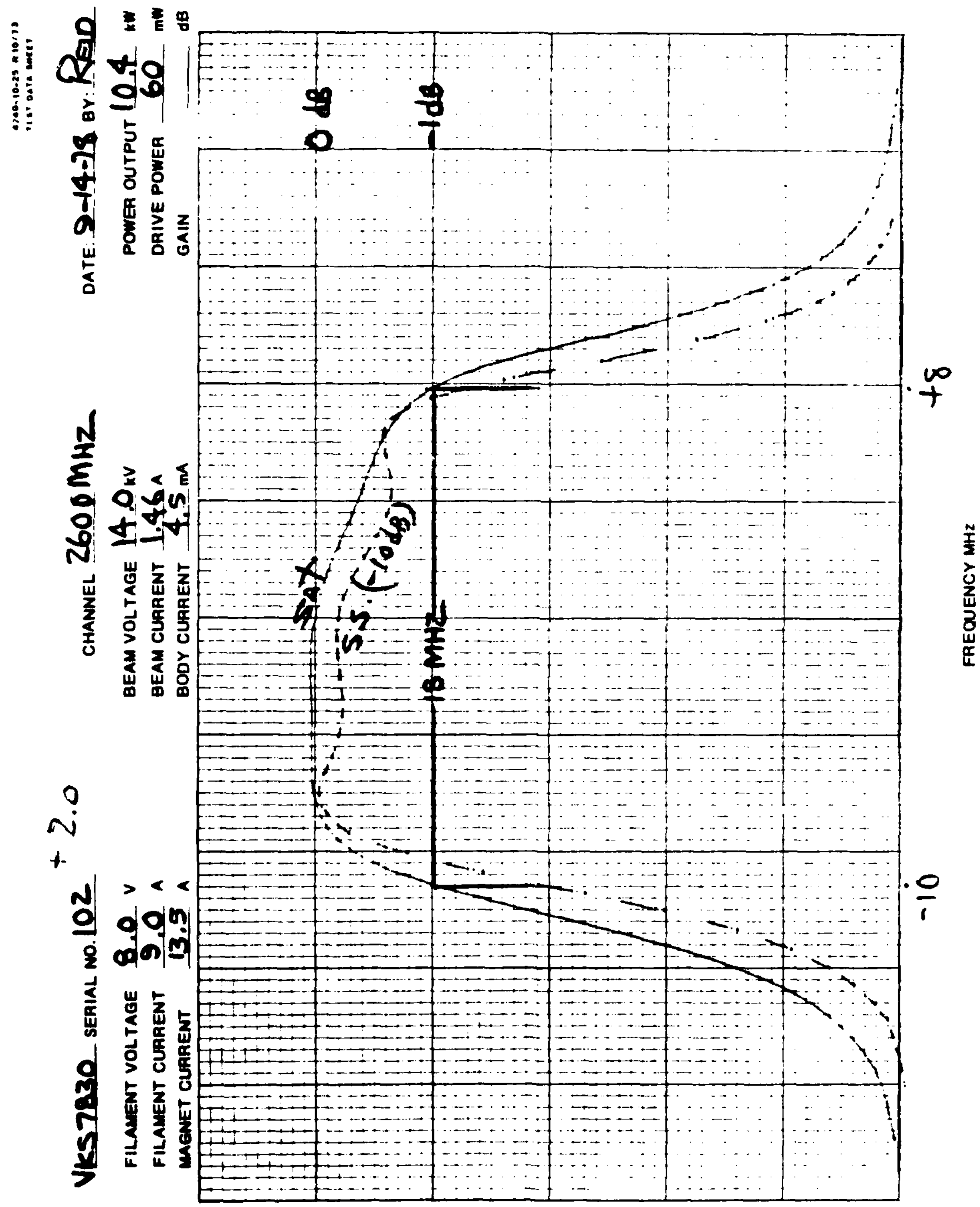
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

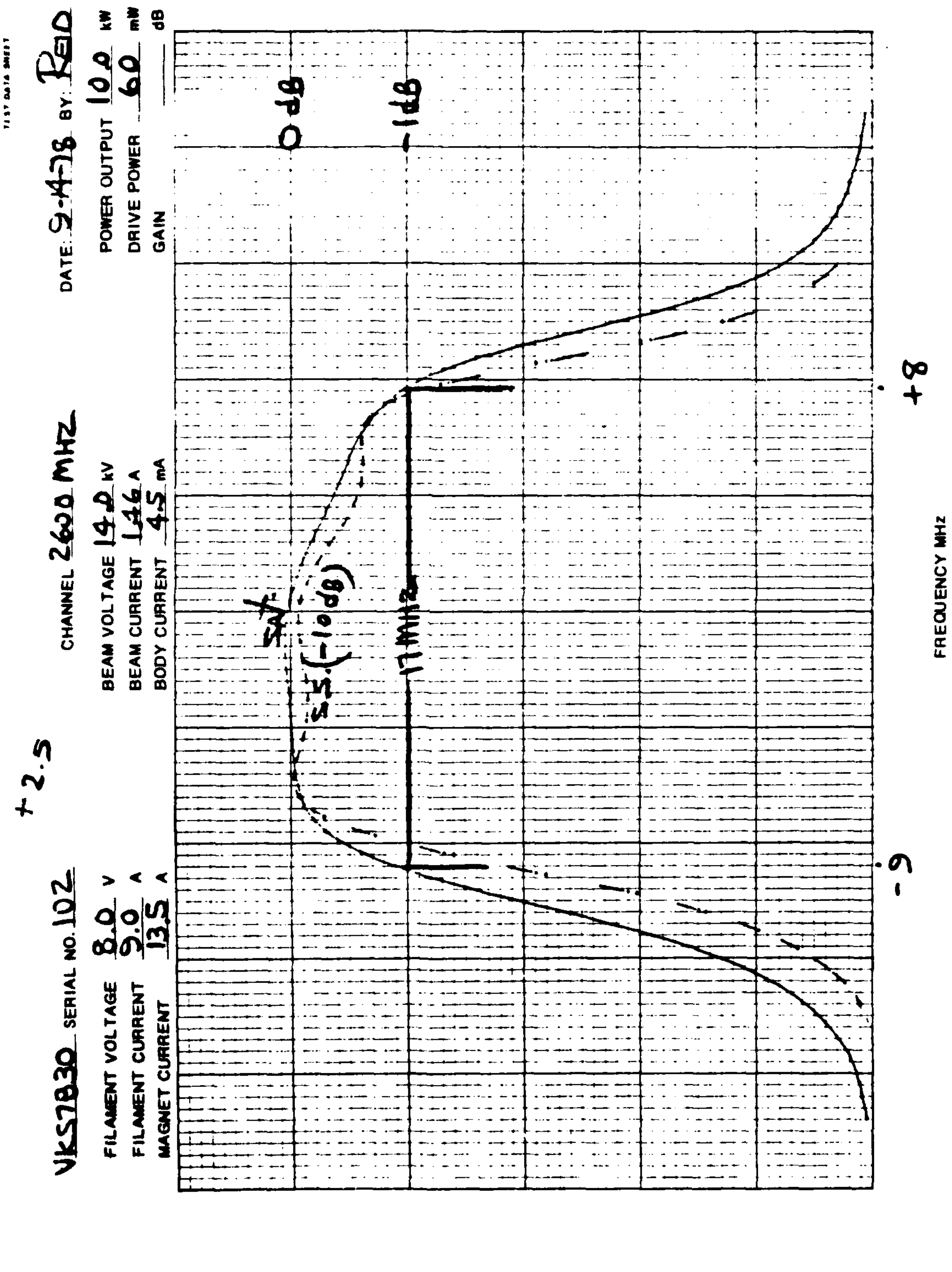
POWER OUTPUT 10.4 kW
DRIVE POWER 6.0 mW
GAIN ____ dB



FREQUENCY MHz



4700-10-25 R10/73
TEST DATA SHEET
VKS7830
SERIAL NO. 102
+2.0
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A
CHANNEL 2600 MHz
BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA
DATE: 9-14-78 BY: Reid
POWER OUTPUT 10.4 kW
DRIVE POWER 60 mW
GAIN dB
0 dB
-1 dB
SAT
S.S. (-10 dB)
18 MHz
-10
+8
FREQUENCY MHz

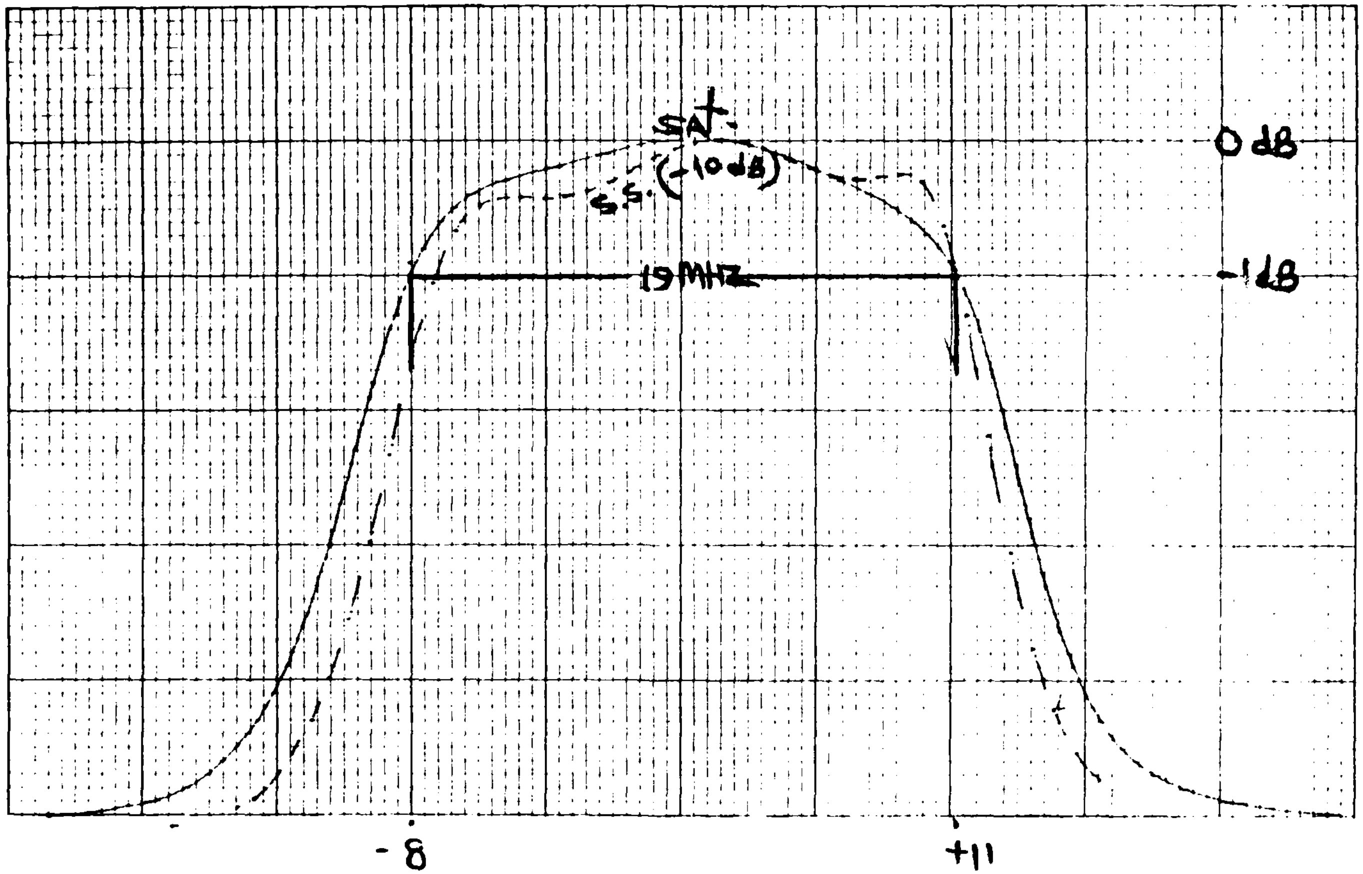

TEST DATA SHEET
VKS7830 SERIAL NO. 102
FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A
CHANNEL 2600 MHz
BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA
DATE: 9-14-78 BY: REID
POWER OUTPUT 10.0 kW
DRIVE POWER 60 mW
GAIN dB
+2.5
0 dB
-1dB
SAT
5.5 (-10dB)
17 MHz
-9
+8
FREQUENCY MHz

4240-10-25 R10/73
TEST DATA SHEET

+3.0

VKS7830 SERIAL NO. 102 — CHANNEL 2600 MHZ — DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE 8.0 V — BEAM VOLTAGE 14.0 kV — POWER OUTPUT 9.4 kW
FILAMENT CURRENT 9.0 A — BEAM CURRENT 1.46 A — DRIVE POWER 60 mW
MAGNET CURRENT 13.5 A — BODY CURRENT 4.5 mA — GAIN ____ dB

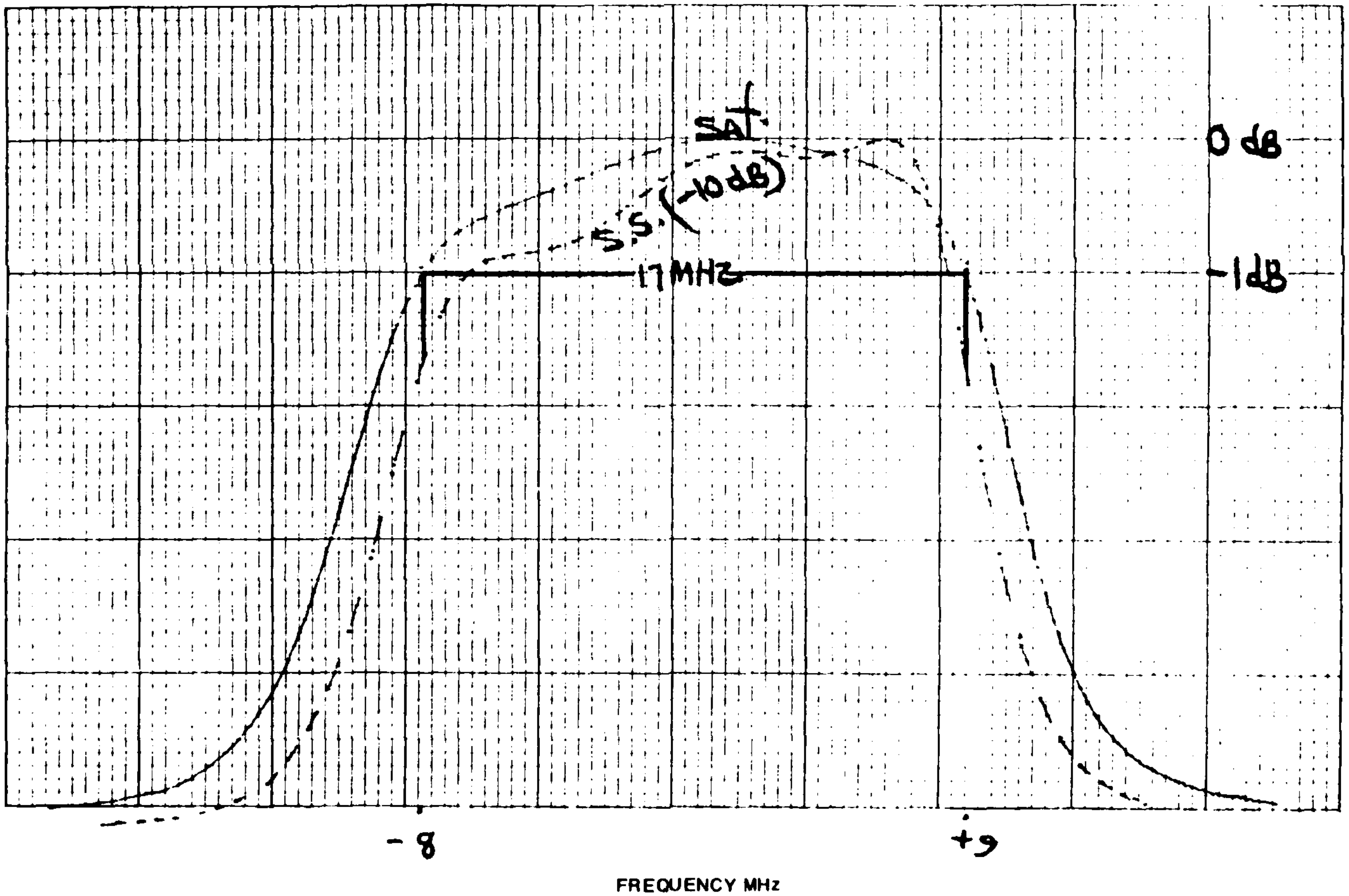


4/40-10-25 R10/73
TEST DATA SHEET

+3.5

VKS7830 SERIAL NO. 102 | CHANNEL 2600 MHz | DATE: 9-14-79 BY: REID

FILAMENT VOLTAGE 8.0 V	BEAM VOLTAGE 14.0 kV	POWER OUTPUT 9.1 kW
FILAMENT CURRENT 9.0 A	BEAM CURRENT 1.46 A	DRIVE POWER 60 mW
MAGNET CURRENT 13.5 A	BODY CURRENT 4.5 mA	GAIN ___ dB

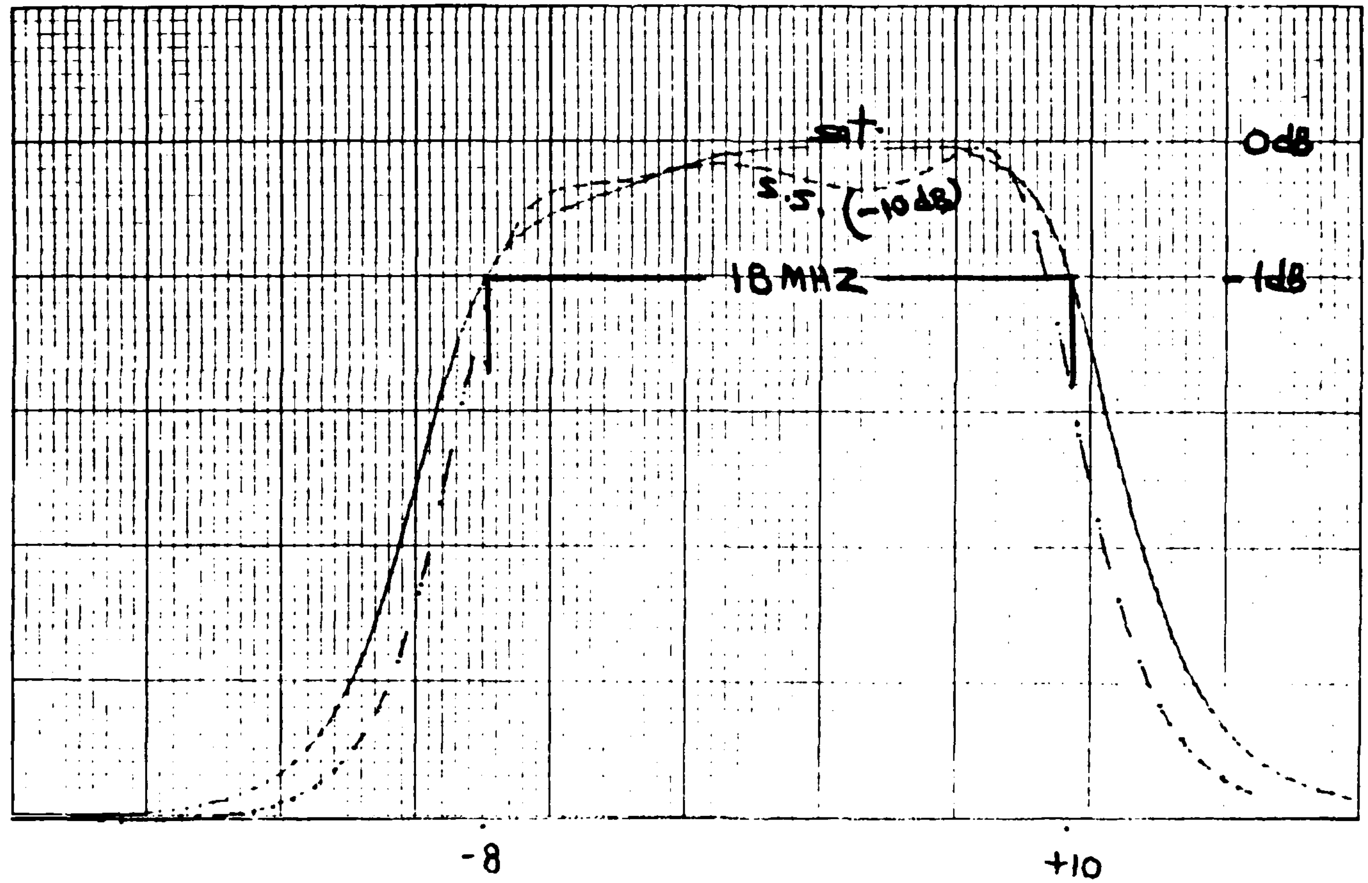


(½" DIA. BALL) 1.2:1 OUTPUT LOAD MISMATCH

4740-10-25 R10/73
TEST DATA SHEET

VKS7830 SERIAL NO. 102 CHANNEL 2700MHZ DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	9.5 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	70 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB

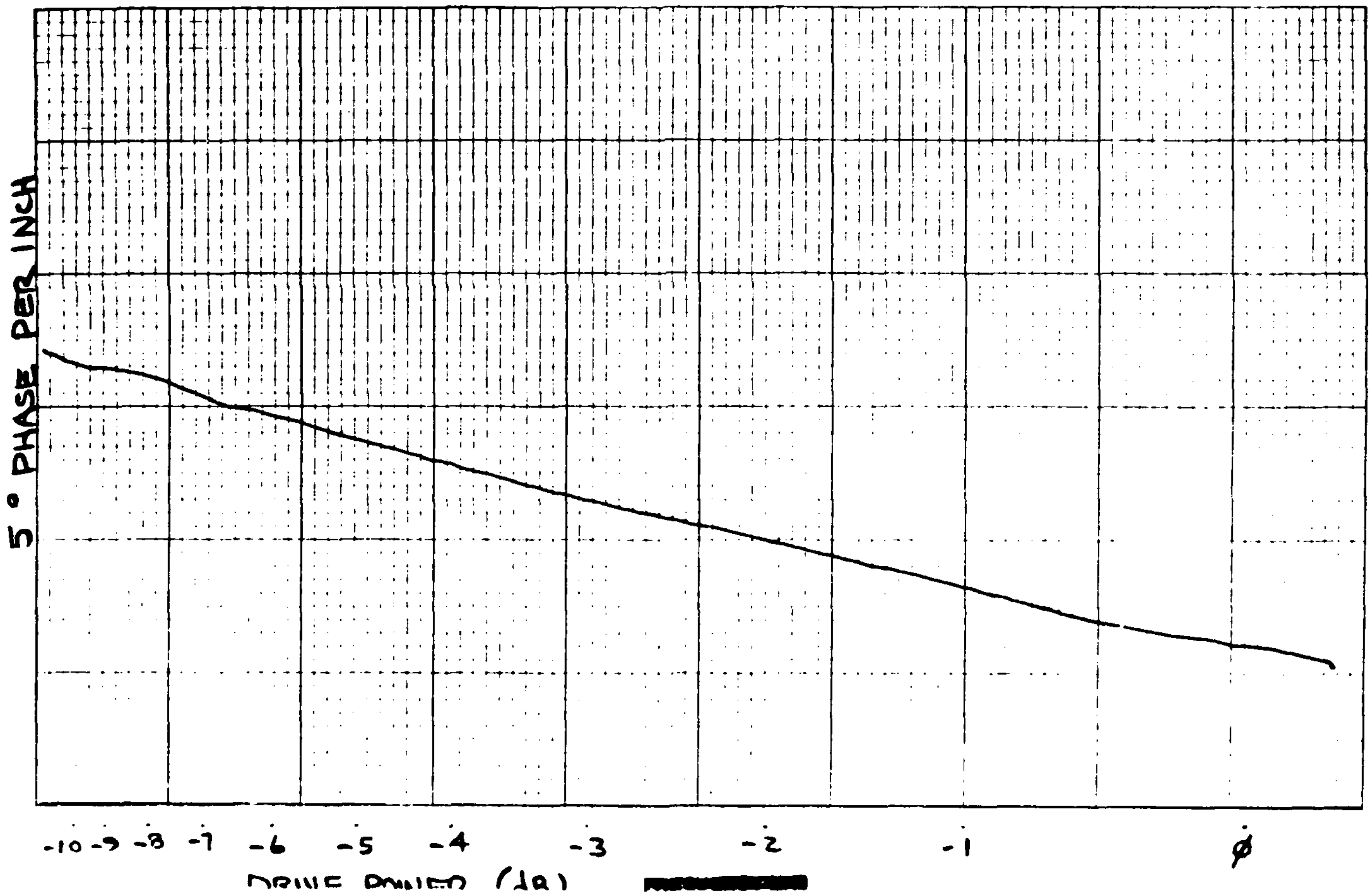


AM/PM CONVERSION

4240-10-25 R10/73
TEST DATA SHEET

VKS7830 SERIAL NO. 102 | CHANNEL 2500 MHZ | DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	(@ ϕdB pd) → POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	80 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	dB



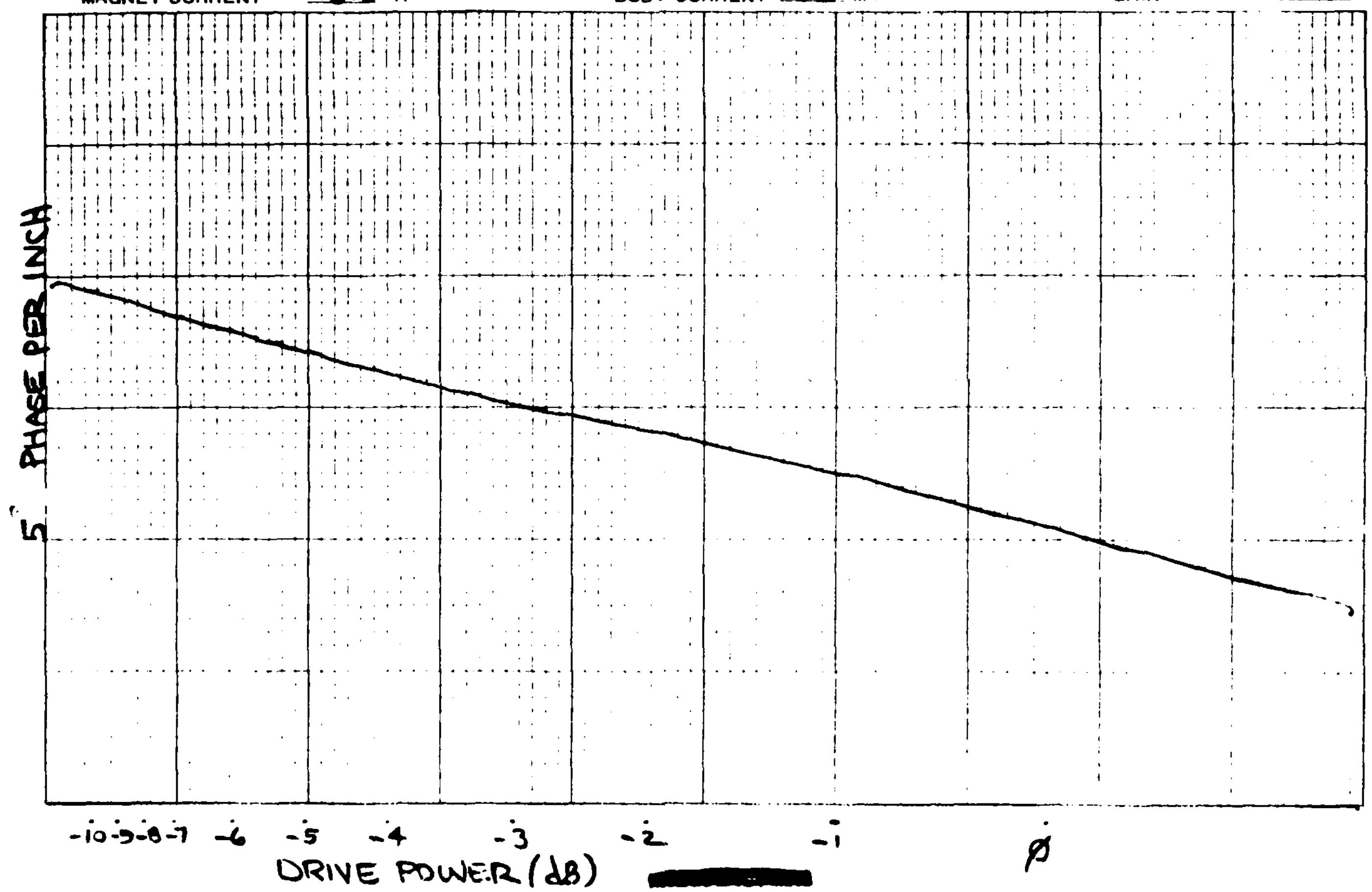
4740-10-25 R 10/73
TEST DATA SHEET

AM/PM CONVERSION

VKS 7830 SERIAL NO. 102 CHANNEL 2600 MHZ DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV	POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	dB

(@ ø dB Pd)



4240-10-29 R 10/73
TEST DATA SHEET

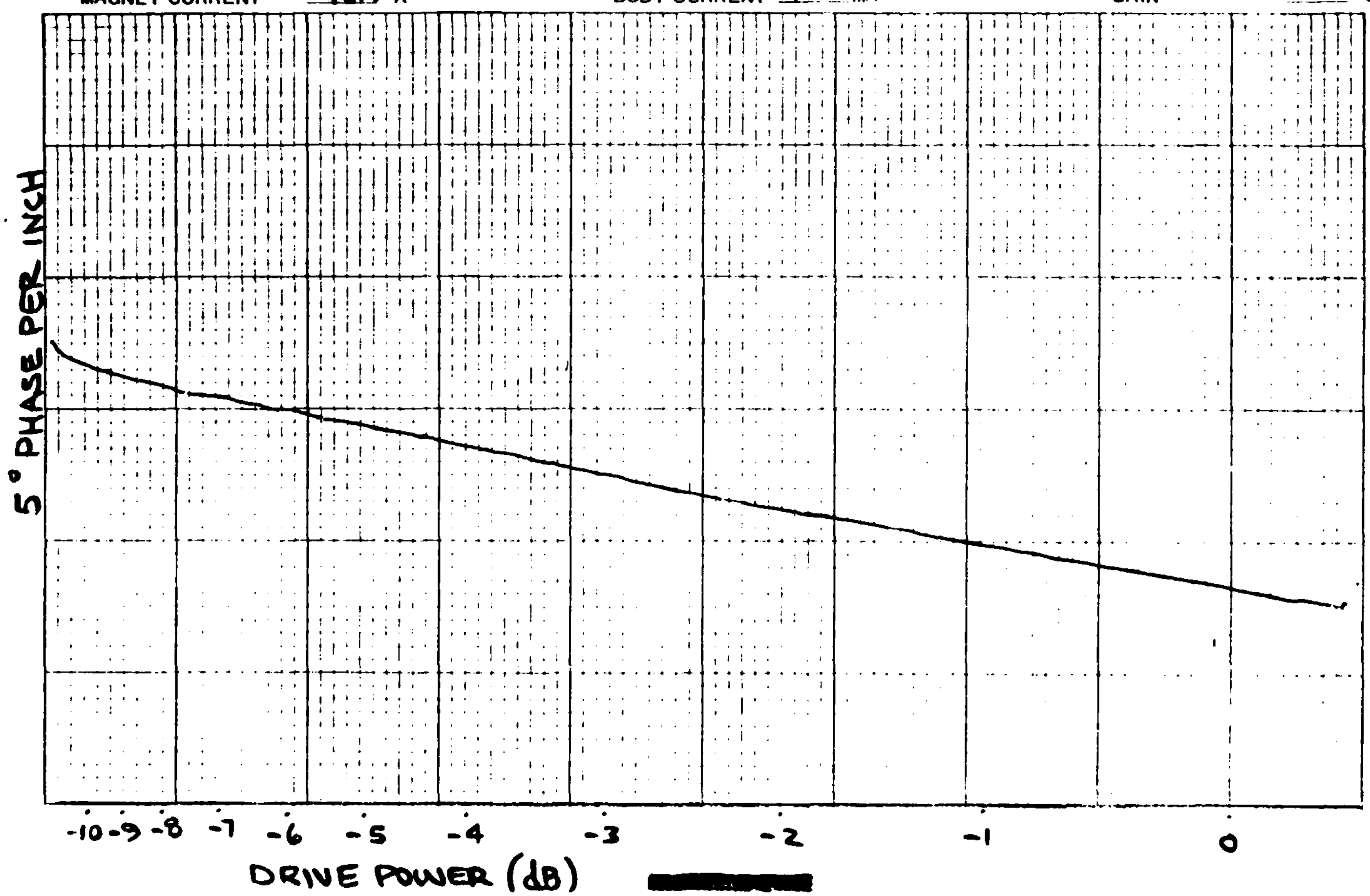
AM/PM CONVERSION

VKS7830 SERIAL NO. 102 | CHANNEL 2700 MHZ | DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE 8.0 V
FILAMENT CURRENT 9.0 A
MAGNET CURRENT 13.5 A

BEAM VOLTAGE 14.0 kV
BEAM CURRENT 1.46 A
BODY CURRENT 4.5 mA

(@ ϕdB Pd) POWER OUTPUT 10.2 kW
DRIVE POWER 70 mW
GAIN ____ dB



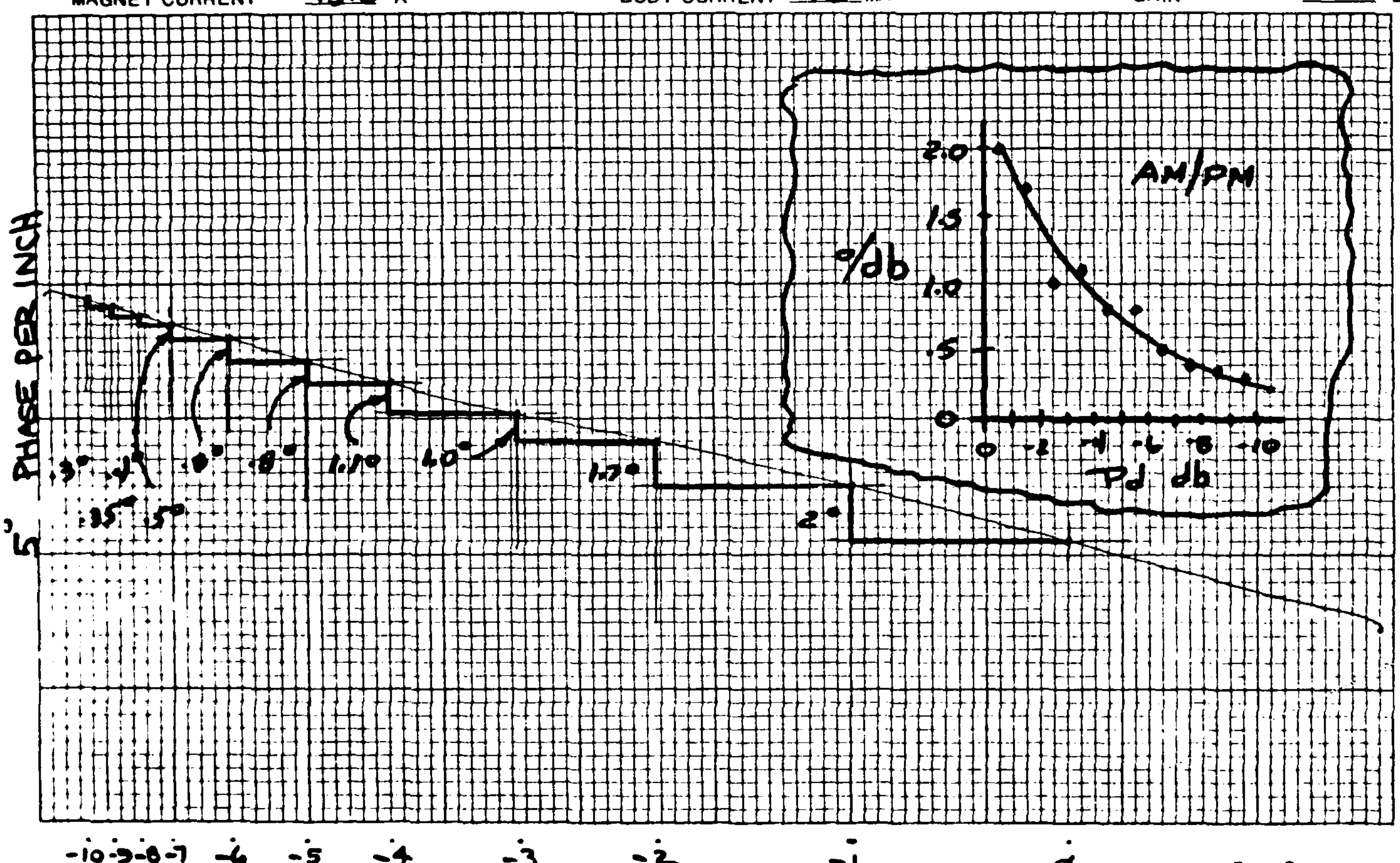
[redacted]

AM/PM CONVERSION

TEST DATA SHEET

VKS 7830 SERIAL NO. 102 | CHANNEL 2600 MHZ | DATE: 9-14-78 BY: REID

FILAMENT VOLTAGE	8.0 V	BEAM VOLTAGE	14.0 kV (@ ø dB Pd)	POWER OUTPUT	10.2 kW
FILAMENT CURRENT	9.0 A	BEAM CURRENT	1.46 A	DRIVE POWER	60 mW
MAGNET CURRENT	13.5 A	BODY CURRENT	4.5 mA	GAIN	____ dB

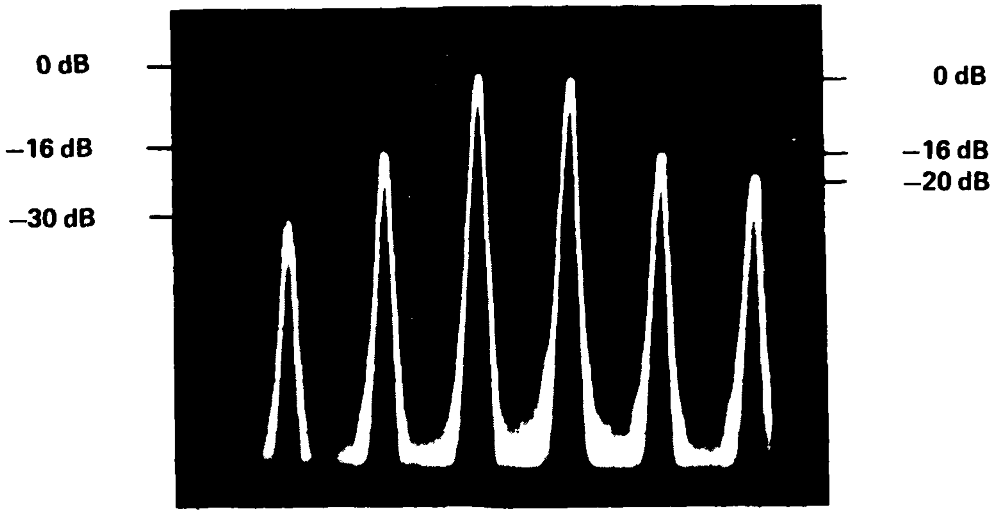


DRIVE POWER (dB) [redacted]

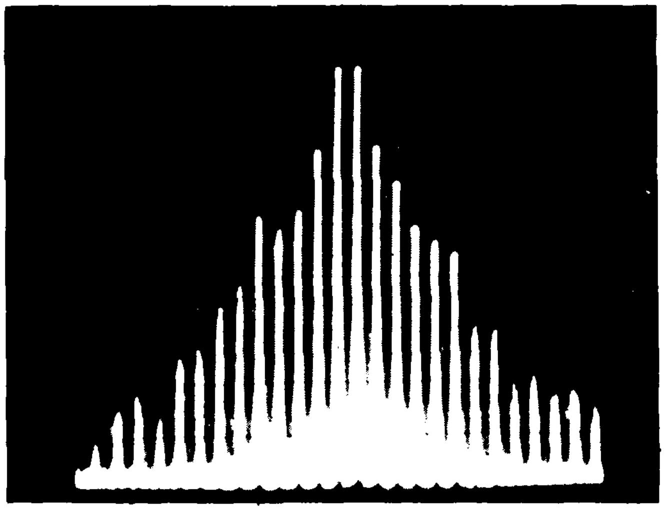
23 Sep 78

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M - 13.5A
F_o = 2.6 GHz, P_o = 8.0 kW, Pd = 60 mW



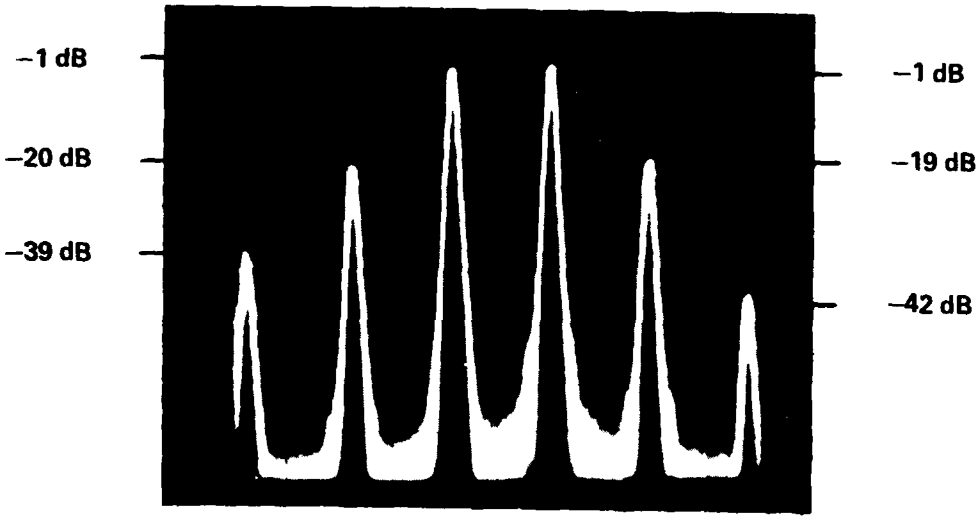
3rd & 5th ORDER PRODUCTS



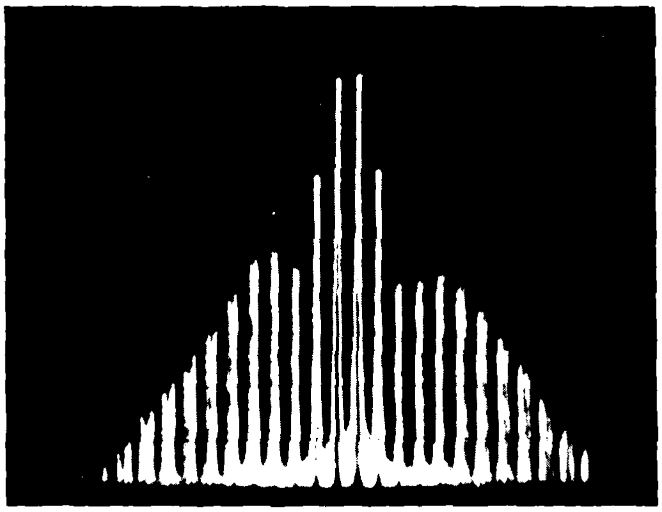
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5A
F_o = 2.6 GHz, Po = 6.4 kW, Pd = 32 mW



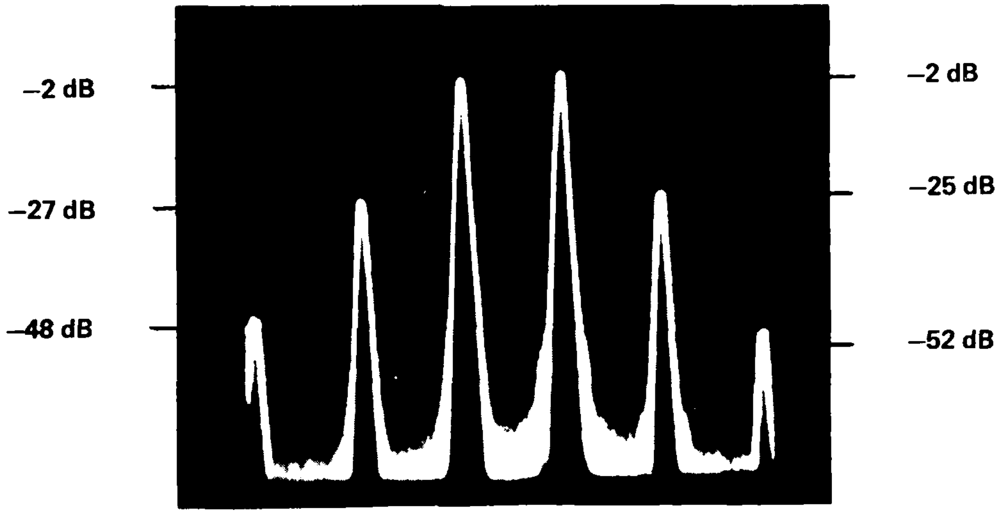
3rd & 5th ORDER PRODUCTS



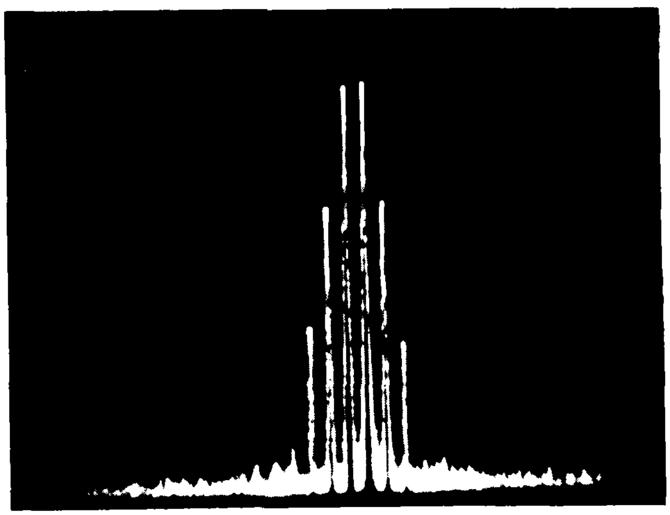
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

$E_b = 14.0$ kV, $I_b = 1.46$A, $E_M = 80$ V, $I_M = 13.5$A
$F_o = 2.6$ GHz, Po = 4.9 kW, Pd = 21 mW



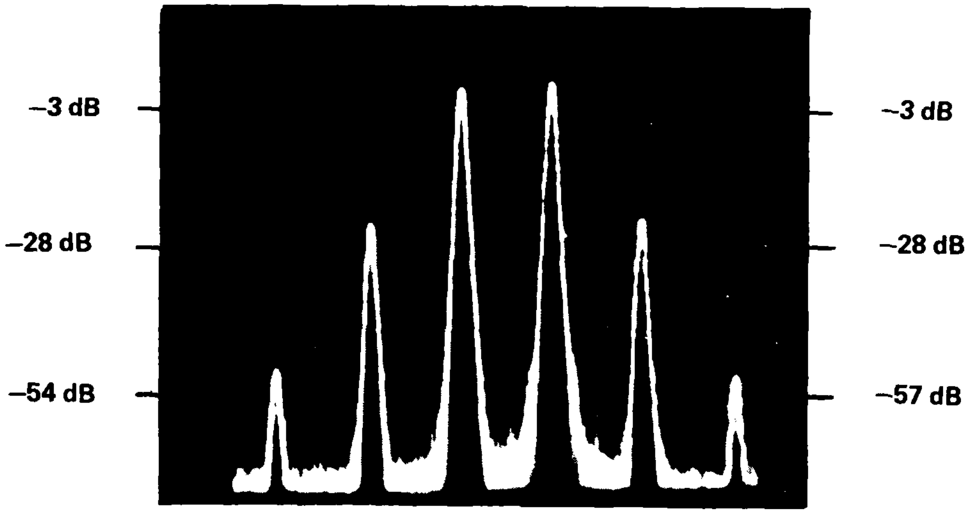
3rd & 5th ORDER PRODUCTS



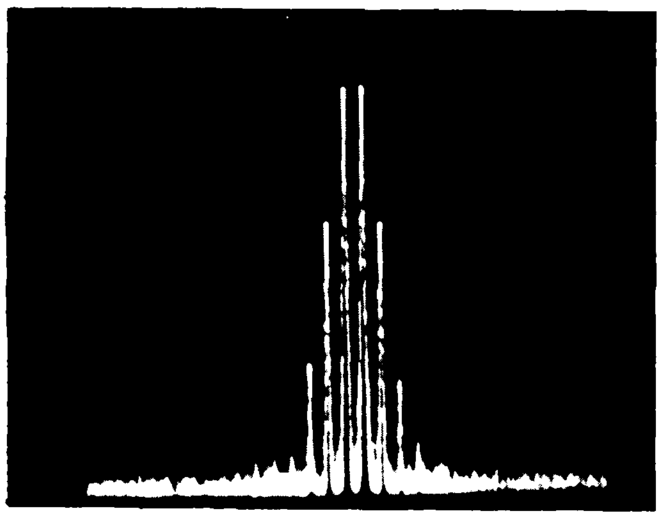
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

$E_b = 14.0$ kV, $I_b = 1.46$A, $E_M = 80$ V, $I_M = 13.5$A
$F_o = 2.6$ GHz, Po = 4.0 kW, Pd = 15 mW



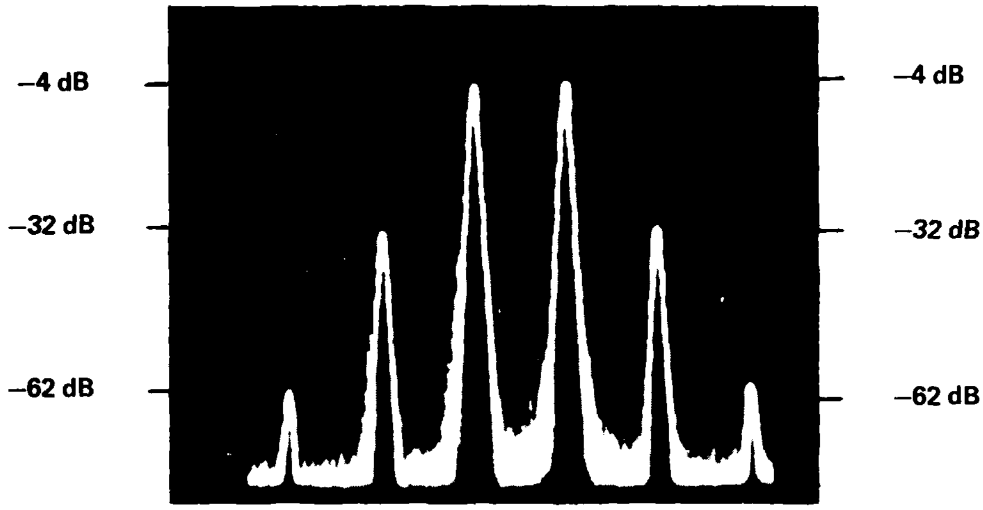
3rd & 5th ORDER PRODUCTS



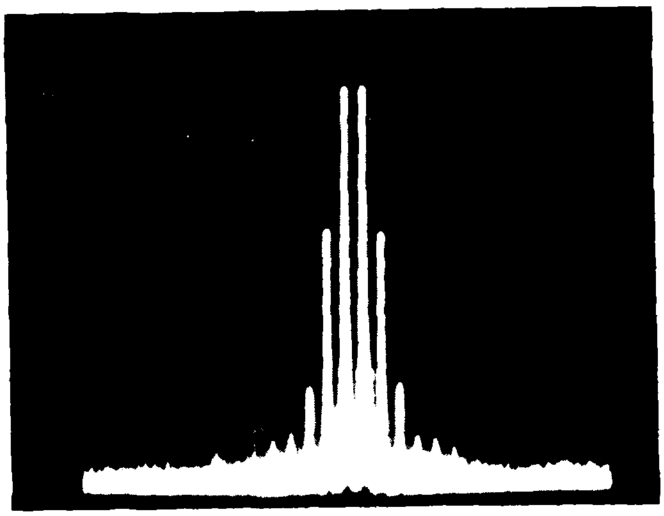
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5A
F_o = 2.6 GHz, Po = 3.2 kW, Pd = 10 mW



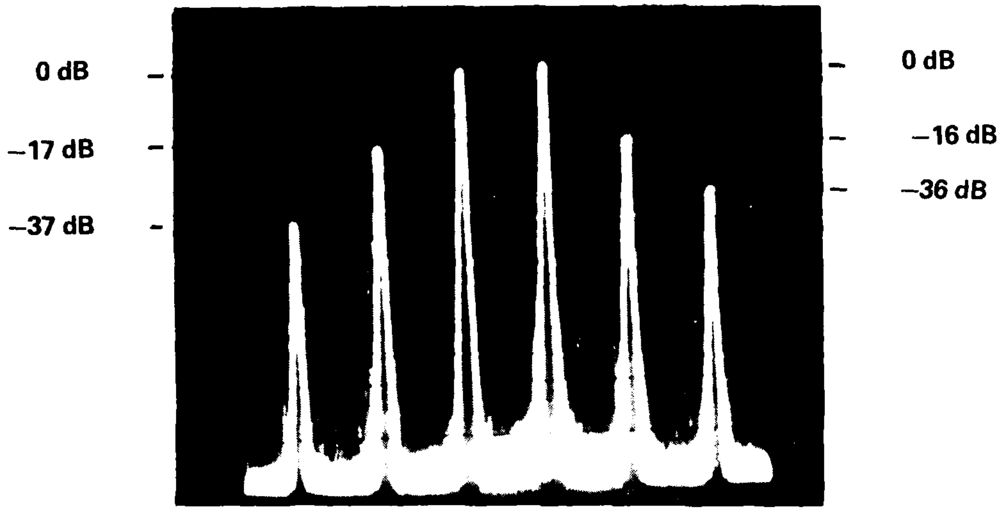
3rd & 5th ORDER PRODUCTS



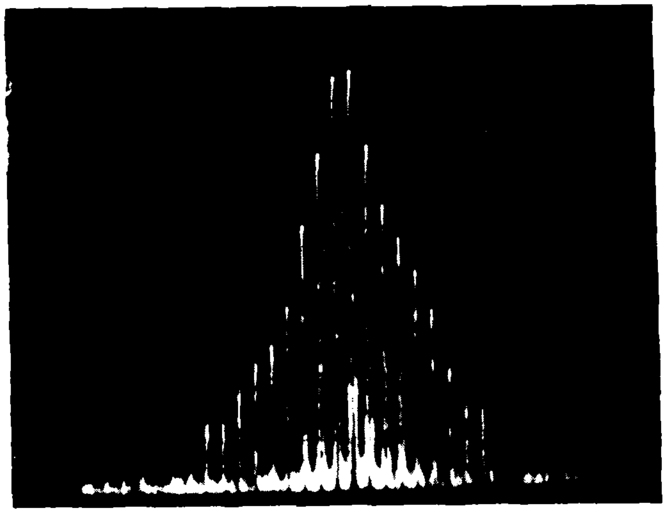
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5A
F_o = 2.7 GHz, Po = 8.0 kW, Pd = 50 mW



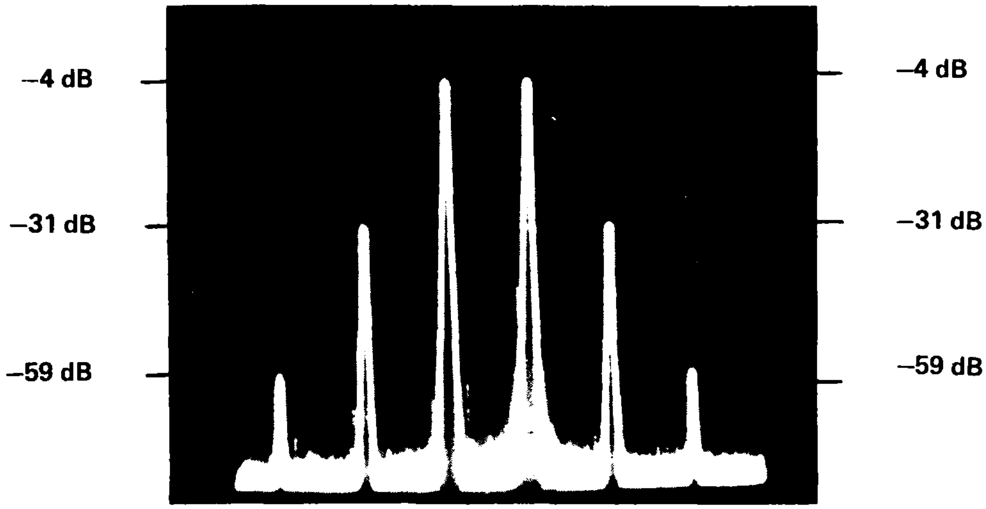
3rd & 5th ORDER PRODUCTS



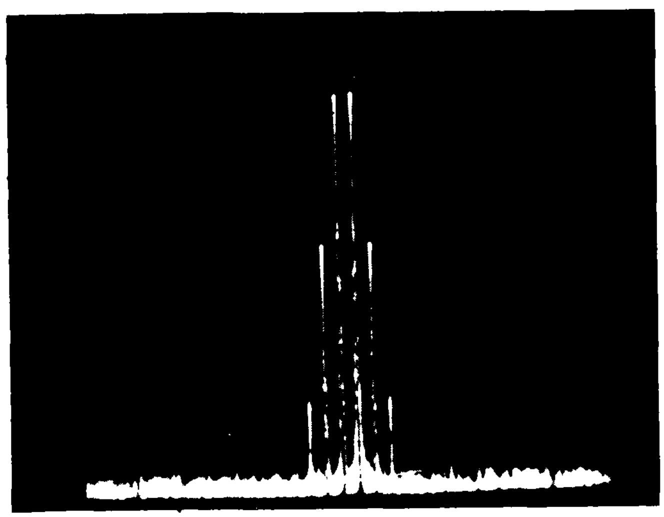
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5 A
F_o = 2.7 GHz, Po = 3.2 kW, Pd = 10 mW



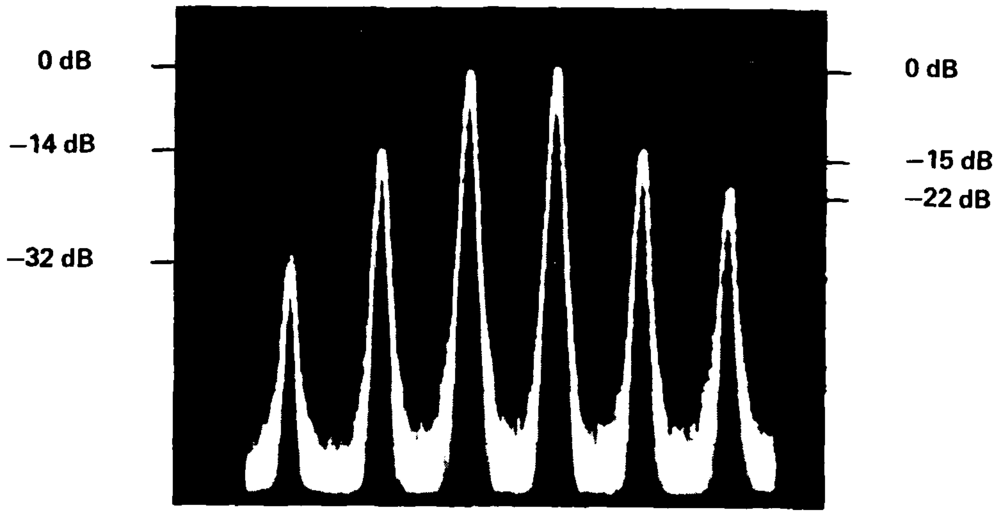
3rd & 5th ORDER PRODUCTS



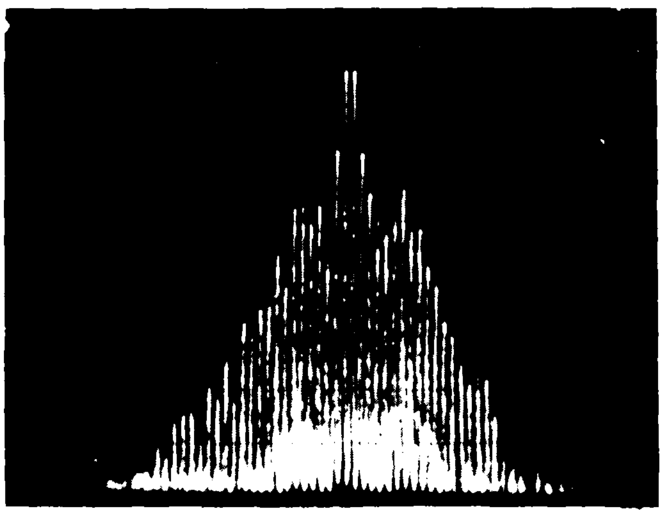
HIGHER ORDER PRODUCTS

VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5A
F_o = 2.5 GHz, Po = 8.0 kW, Pd = 80 mW

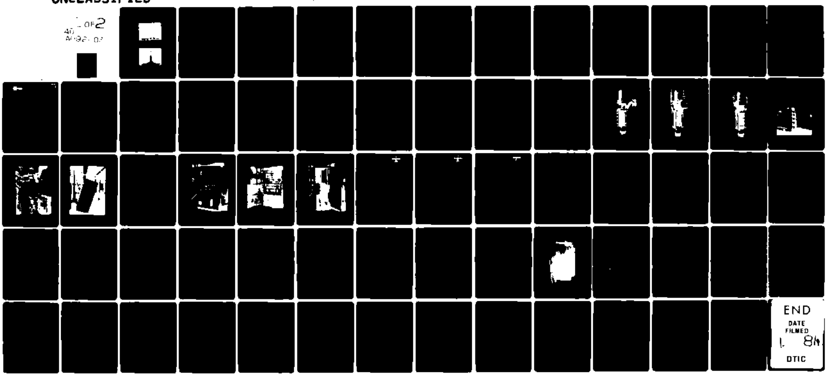


3rd & 5th ORDER PRODUCTS



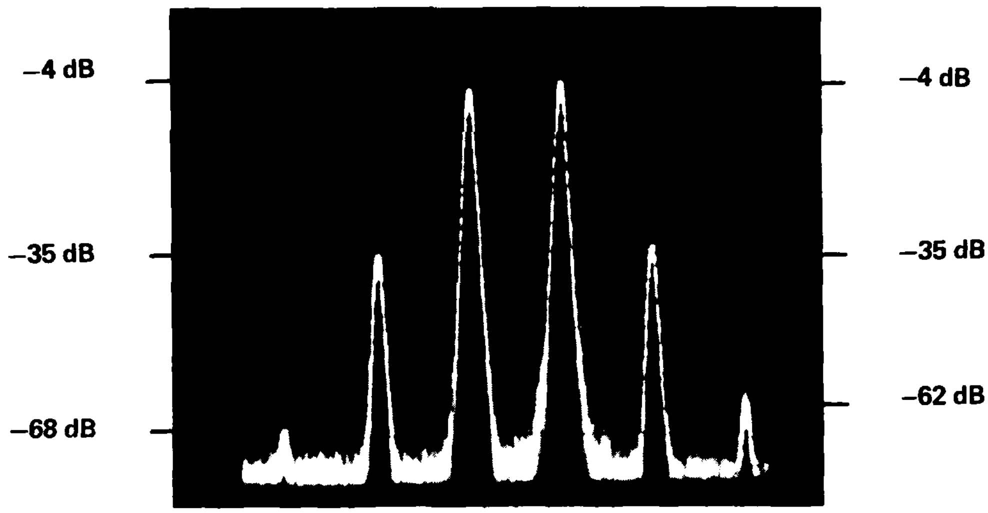
HIGHER ORDER PRODUCTS

AD-A092 903 VARIAN ASSOCIATES INC PALO ALTO CA F/G 9/1
HIGH POWER KLYSTRONS FOR EFFICIENT RELIABLE HIGH POWER AMPLIFIE--ETC(U)
NOV 80 M LEVIN DAAB07-76-C-8072
UNCLASSIFIED CSA-76-8072-F NL

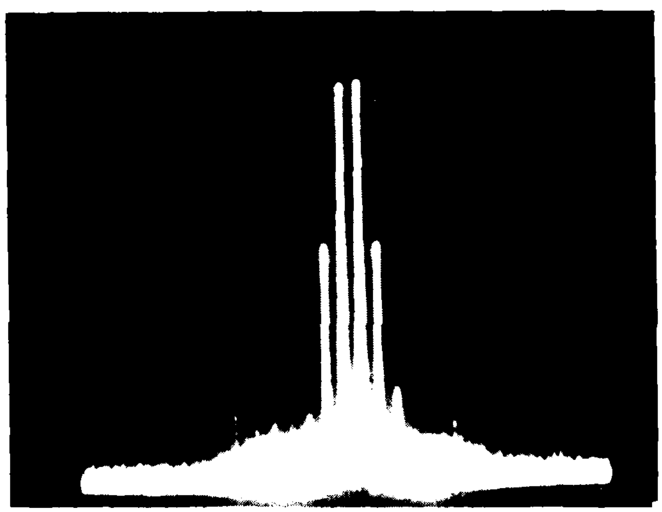


VKS-7830, S/N 102
TWO TONE INTERMODULATION TEST
13 SEPTEMBER 78

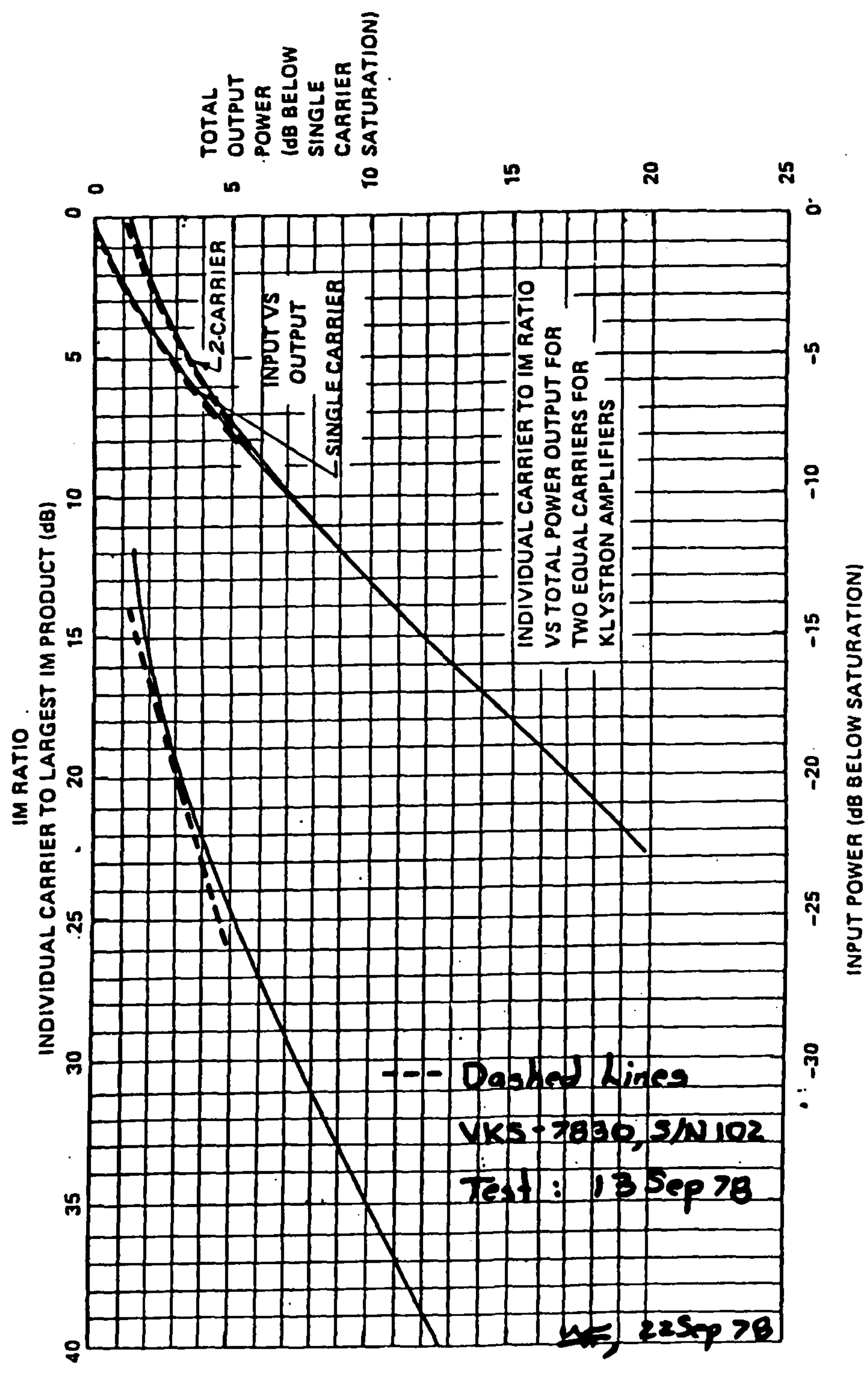
E_b = 14.0 kV, I_b = 1.46A, E_M = 80 V, I_M = 13.5A
F_o = 2.5 GHz, Po = 2.8 kW, Pd = 10 mW



3rd & 5th ORDER PRODUCTS



HIGHER ORDER PRODUCTS



IM RATIO
INDIVIDUAL CARRIER TO LARGEST IM PRODUCT (dB)
0
5
10
15
20
25
30
35
40
TOTAL OUTPUT POWER (dB BELOW SINGLE CARRIER SATURATION)
0
5
10
15
20
25
INPUT POWER (dB BELOW SATURATION)
0
-5
-10
-15
-20
-25
-30
2-CARRIER
INPUT VS OUTPUT
SINGLE CARRIER
INDIVIDUAL CARRIER TO IM RATIO VS TOTAL POWER OUTPUT FOR TWO EQUAL CARRIERS FOR KLYSTRON AMPLIFIERS
--- Dashed Lines
VKS-7830, S/N 102
Test: 13 Sep 78
22 Sep 78

I 'CTRO MAGNET

VYW-7830

Varian Serial No. 102

Vendor Serial No. 20097

NO.	TEST	SYMBOL	RESULTS	LIMITS MIN.	MAX.	UNITS
1.	Insulation Resistance ambient temp, 500 Vdc	R	>100	100	---	megohms
2.	Resistance @ 20°C waterflow = 1.0 gpm	R	4.93	4.7	5.2	ohms
3.	Voltage at 11.7A waterflow = 1.0 gpm	E	58	---	60	Vdc
	& ambient temp.	T	21°C	---	---	°C
4.	Coolant -ressure Drop waterflow = 1.0 gpm	ΔP	8	5.0	12.5	psi
5.	Magnetic Field Current @ 11.7A		1,100	1,050	---	guass
6.	Hydrostatic Hold water Pressure @ 150 psi for 5 minures	ok	OK	No Leakage		---

7. Wiring & Polarity per Varian Dwg. D144193.

Checked by Sal Manoguerra Date September 12, 1978

Comments

8. Outline Dimensions per Varian Dwg. D144193.

Checked by Date

Comments

Tested by Date QA Date

Customer Source

S/N 103

VKS-7830

Serial No. 103

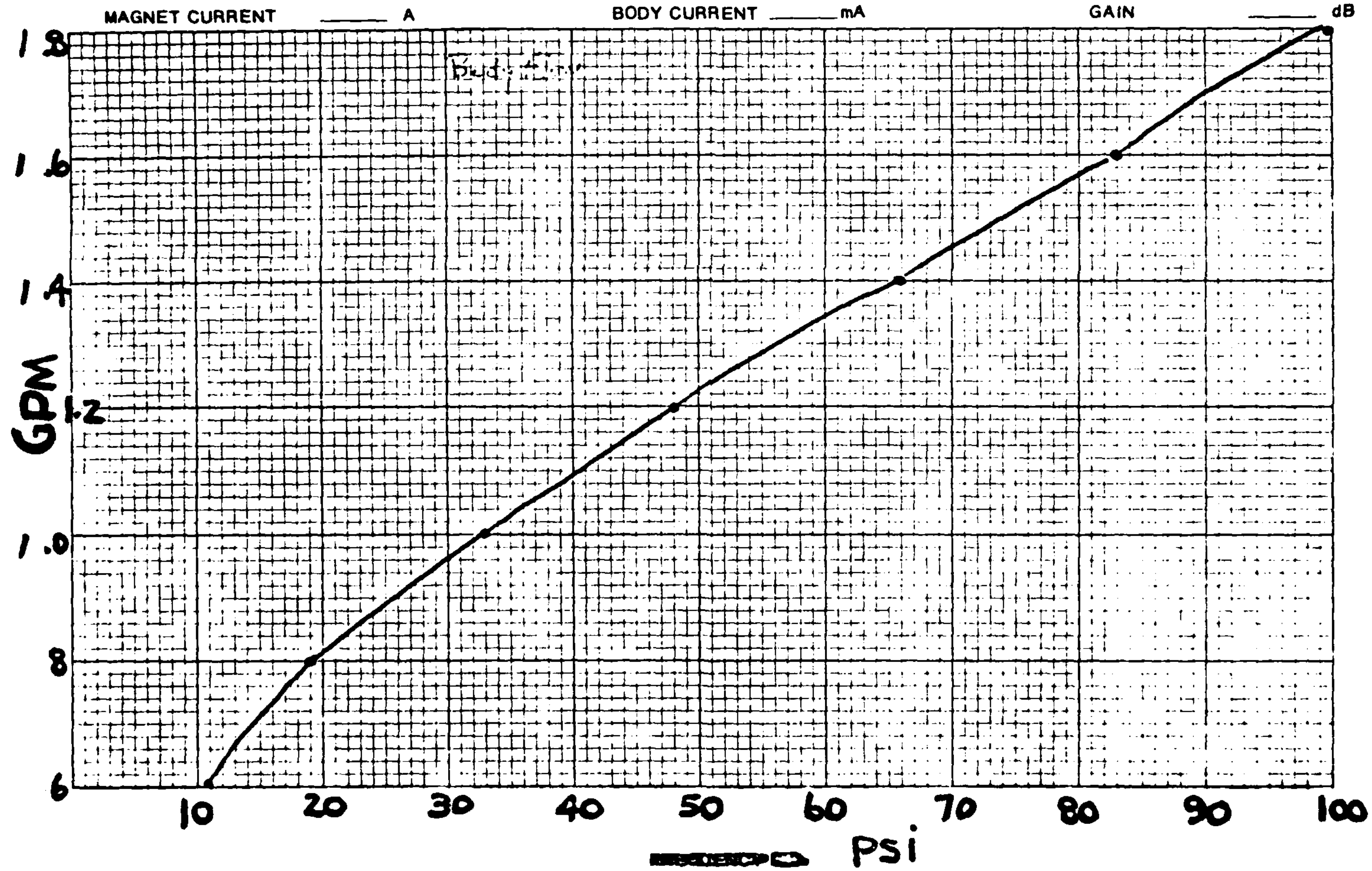
PARAMETER	SYMBOL	MIN	MAX				UNITS
Frequency	F:	----	----	2.5	2.6	2.7	GHz
Beam Voltage	Eb:	----	15.0	14.25	14.25	14.25	kVdc
Beam Current	Ib:	----	2.0	1.53	1.53	1.53	Adc
Beam Power	Pdc:	----	30.0	21.8	21.8	21.8	kW
Power Output	Po:	10.0	----	11.35	11.10	11.0	kW
R.F. Drive	Pd:	----	100	100	100	100	mW
Efficiency	Eff:	----	----	52.0	50.9	50.5	%
Gain	Gain:	40	----	50.4	50.5	50.4	dB
Body Current	Iby:	----	----	5	5	5	mAdc
Bandwidth	-1dB Bw:	12	----	19	18	19	MHz
Heater Voltage	Ef:	----	8.0	8.0	8.0	8.0	Vac
Heater Current	If:	----	15.0	9.2	9.2	9.2	Aac
Magnet Voltage	Em:	----	----	77	77	77	Vdc
Magnet Current	Im:	----	----	13.5	13.5	13.5	Adc
Magnet Power	Pm:	----	----	1.04	1.04	1.04	kW
System Efficiency	Seff:	45	----	47.2	46.1	45.7	%
Second Harmonic	Ph:	----	----	48.5	43.2	44.0	dB
Third Harmonic	Ph:	----	----	44.7	49.7	39.4	dB
Signal to Noise	Sn:	-60	----	>-60	>-60	>-60	dB
Heat Exchanger Power	Ph:	----	----	Low Fan:	0.864	kW	
				High Fan:	1.207	kW	

TESTED BY: Reid Isaksen DATE: March 8, 1979

VKS-7830 S/N 103

______ SERIAL NO. ______ CHANNEL ______ DATE: 2-14-79 BY: REID

FILAMENT VOLTAGE	______ V	BEAM VOLTAGE	______ kV	POWER OUTPUT	______ kW
FILAMENT CURRENT	______ A	BEAM CURRENT	______ A	DRIVE POWER	______ mW
MAGNET CURRENT	______ A	BODY CURRENT	______ mA	GAIN	______ dB



S/N 104

VKS 7930

Serial No. 104

PARAMETER	SYMBOL	MIN	MAX				UNITS
Frequency	F:	----	----	2.5	2.6	2.7	GHz
Beam Voltage	Eb:	----	15.0	14.5	14.5	14.5	kVdc
Beam Current	Ib:	----	2.0	1.50	1.50	1.50	Adc
Beam Power	Pdc:	----	30.0	21.75	21.75	21.75	kW
Power Output	Po:	10.0	----	11.0	11.25	11.4	kW
R.F. Drive	Pd:	----	100	100	100	100	mW
Efficiency	Eff:	----	----	50.5	52.2	52.4	%
Gain	Gain:	40	----	50.4	50.5	50.5	dB
Body Current	Iby:	----	----	5	5	5	mAdc
Bandwidth	-1dB Bw:	12	----	18	19	18	MHz
Heater Voltage	Ef:	----	8.0	8.0	8.0	8.0	Vac
Heater Current	If:	----	15.0	8.7	8.7	8.7	Aac
Magnet Voltage	Em:	----	----	77	77	77	Vdc
Magnet Current	Im:	----	----	12.5	13.5	13.5	Adc
Magnet Power	Pm:	----	----	1.04	1.04	1.04	kW
System Efficiency	Seff:	45	----	45.8	47.3	47.5	%
Second Harmonic	Ph:	----	----	40.1	43.5	47.1	dB
Third Harmonic	Ph:	----	----	35.4	50.8	40.2	dB
Signal to Noise	Sn:	-60	----	>-60	>-60	>-60	dB
Heat Exchanger Power	Ph:	----	----	Low Fan:	0.864	kW	
				High Fan:	1.207	kW	

TESTED BY: Reid Isaksen DATE: March 7, 1979

APPENDIX B

VKS-7830 OPERATING INSTRUCTIONS

CW KLYSTRON AMPLIFIER

VKS-7830

2.5-2.7 GHz

10 kW CW

OPERATING INSTRUCTIONS

INTRODUCTION

These Operating Instructions provide basic information for installing and operating the VKS-7830 CW klystron amplifier. Additional information is given in the Test Performance Sheet. The Test Performance Sheet contains test results at specific frequencies for the individual tube. Requests for copies of this publication or additional information should be addressed to:

Manager, Tube Sales
Varian Associates, Inc.
Palo Alto Microwave Tube Division
611 Hansen Way
Palo Alto, California 94303
(415) 493-4000
TWX: 910-373-1731

For more detailed tube operating procedures in specific equipments, consult the applicable equipment manuals and equipment performance standards. In case of conflict, equipment manuals and performance standards shall govern, except for the absolute maximum ratings on the tube. Additional information may be obtained from the equipment manufacturer.

WARNING

SERIOUS HAZARDS EXIST IN THE OPERATION OF MICROWAVE TUBES. BEFORE ATTEMPTING ANY TUBE OPERATIONS, CAREFULLY READ THE "OPERATING HAZARDS SHEET" SHIPPED WITH EACH TUBE IN ADDITION TO READING THESE INSTALLATION AND OPERATING INSTRUCTIONS.

OPERATING HAZARDS

This tube should be used in equipment which provides protection as described below. Installation and operating precautions should be observed, and ratings given in the Test Performance Sheet must not be exceeded.

High Voltage – Voltages required for operation of this tube are extremely dangerous to life; equipment should have protective interlocks to make physical contact with these voltages impossible.

Radio Frequency Radiation – Precautions should be taken to prevent exposure of personnel to the strong microwave fields generated by this tube. Microwave radiation due to leakage at the waveguide flange should be prevented by making tight rf input and output connections. Exposure of the human body to microwave radiation in excess of 10 milliwatts per square centimeter may be harmful.

If voltages are to be applied when the tube is not connected into a waveguide system, the rf input and the output flange should be closed tightly with shielded terminations.

Elevated Temperature – Portions of this tube will attain elevated temperatures during operation. Avoid physical contact for a sufficient period after operation is terminated to permit adequate cooling.

Coolant Hazards – The following precautions apply when aqueous Dowtherm 209 is utilized as a coolant: Eye protection should be worn when handling. Minimize skin contact. Breathing of the vapors should be avoided. Under certain conditions ignition or explosion of the vapor can occur. Avoid leaks or spillage, follow normal safety precautions and provide adequate ventilation when handling.

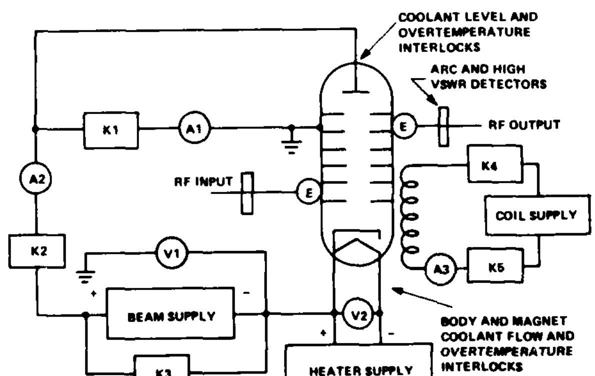
WARNING

DO NOT ATTEMPT TO OPERATE THIS TUBE UNTIL IT HAS BEEN DETERMINED THAT ALL PRECAUTIONS HAVE BEEN TAKEN TO PROTECT PERSONNEL FROM ALL HAZARDS. PROTECTIVE DEVICES SUCH AS SHIELDS AND INTERLOCKING SWITCH CIRCUITS MUST BE IN OPERATION.

PROTECTIVE MEASURES

Heater Voltage – Heater voltage should be applied for at least 5 minutes before applying beam voltage. Heater surge current should be limited to 20 amperes.

Beam Voltage – An overvoltage relay, K3 in Figure 1, should be provided to limit the beam voltage to 16 kVdc. Interlocks should prevent the application of beam voltage before the heater has warmed up, coolants are flowing and the focusing-coil currents are applied. Beam voltage must be removed immediately if the focusing field fails.



A1 – BODY CURRENT METER
A2 – BEAM CURRENT METER
A3 – MAGNET CURRENT METER
K1 – BODY OVERCURRENT RELAY
K2 – BEAM OVERCURRENT RELAY
K3 – BEAM OVERVOLTAGE RELAY
K4 – COIL UNDERCURRENT RELAY
K5 – COIL OVERCURRENT RELAY
V1 – BEAM VOLTAGE METER
V2 – HEATER VOLTAGE METER

FIGURE 1
SUGGESTED KLYSTRON METERING AND PROTECTION

Beam Current – An optional overcurrent relay, K2, may be provided to remove the beam voltage if the beam current exceeds 1.6 amperes.

Body Current – An overcurrent relay, K1, should be provided to remove the beam voltage if the tube body current

Pub. 3796 4/78

Printed In U. S. A.

exceeds 50 mAdc.

Focusing-Field Protection – To prevent tube damage and maintain proper operation, rapid-acting undercurrent and overcurrent relays, K4 and K5, should be used in the focusing coil circuit. They should remove the beam voltage if the coil current either falls below 10 amperes or rises above 15 amperes. If the focusing field fails, causing a large portion of the beam energy to be dissipated in a small area, tube failure can result within a few milliseconds.

Cooling – The tube should be used with a properly designed and operated cooling system. Scaling and corrosion should be minimized to realize optimum tube performance and life. Metals used in the cooling system should be close to copper in the galvanic series. Adequate cooling is provided by a coolant comprised of 53% by weight of Dowtherm 209 and 47% distilled water; however, distilled water cools more efficiently.

The tube collector is cooled by coolant vaporization. A circulating system with a vapor-air or vapor-water condenser should be used. The vapor path should be as direct as is practical and should be sloped to prevent possible back pressure build-up. All low spots should be drained back to the inlet water-line.

It is important to maintain the collector coolant level above the top surface of the cylindrical finned heat dissipator. To insure this, one recommended means is to use a weir system. The weir system should include a protective coolant level interlock.

If the coolant is to be subjected to sub-freezing (for the coolant used) environments, steps must be taken to prevent its freezing in the tube. The use of coolant heaters is recommended under such conditions. Glycol antifreeze mixtures must not be used. Other contaminants such as soaps, foaming detergents and water soluble oils as well as particulate matters must be kept to a minimum. Exposure of the coolant to air should be minimized. A coolant purification loop and/or coolant filtering may be desirable adjuncts. Freedom from contamination in the cooling system is an important consideration in obtaining maximum life. Only pure fluids should be used. The system should be drained, cleaned, and refilled with fresh fluids at least annually. All possible sources of oils or greases should be eliminated.

The tube body and magnet inlet coolant temperatures must not exceed 70°C. Interlocks should remove the beam and magnet voltages if the inlet coolant temperature exceeds this limit or if the collector temperature exceeds 145°C. The collector temperature is monitored by a chromel-alumel thermocouple attached to the tube collector. The connections to this thermocouple are made through the Cannon receptacle mounted on the tube. The thermocouple resistance (pins H and J) is approximately 10 ohms.

The following tabulation is based on liquid and vapor cooling in a system at atmospheric pressure and sea level with 20 kW of collector dissipation. Interlocks should be provided to remove the beam and magnet voltages if the coolant flow falls below any of the following values:

	Distilled Water	53%/47% Dowtherm 209/Water	
Tube Body	0.6	1.0	gpm min
Collector	0.25	0.35	gpm min
Electromagnet	0.6	1.0	gpm min

The maximum static pressure should not exceed 125 psig in the tube body or in the electromagnet, nor ± 0.5 psig in the collector system. In addition, about 20 cfm of forced air should be directed at the cathode end of the tube.

If at any time coolant is allowed to drip down the tube and over the surface of the cathode ceramic, the resulting arcing with H.V. on is capable of destroying the tube by inducing a ceramic puncture. Furthermore, if aqueous Dowtherm 209 is used as the coolant, ignition or explosion may occur.

Reflected Power and RF Arcing – The tube should not be used with loads which produce a VSWR of greater than 1.5:1. Higher values of reflected power or arcs may damage the tube. Protection should be provided between the tube and any transmission line component. A sample of reflected power obtained from a directional coupler and/or the signal from the arc detector sensor should operate a circuit to remove rf drive within 10 microseconds if the VSWR exceeds 1.5:1 or if arcing occurs. It is not necessary to remove beam voltage. Operation of the protective circuit should be checked regularly. Specification performance cannot be necessarily expected if the VSWR exceeds 1.1:1.

Arcs (In the Tube) – The power supply should have sufficient impedance in series with the klystron to prevent arc damage. The maximum current in the event of a tube arc should be limited to 750 amperes with a total energy of 40 joules maximum.

RF Leakage – External leakage should be prevented by making tight rf input and output connections. Under certain tuning conditions, regeneration or oscillation can occur if rf energy from the output line, or radiation from the antenna reaches the input cavity because of faulty rf connections or inadequate shielding.

Cathode – Periodically when the voltages are turned off, foreign particles should be wiped away from the areas of the tube body near the cathode seal to prevent possible arc-overs.

INSTALLATION

Tube Inspection – Check the rf output window and cathode H.V. insulator. No foreign particles of any kind should be between the flange and the output window.

Both of these ceramic surfaces must be perfectly clean. If necessary, clean using acetone and a camel's-hair brush.

Mounting –

1. Mount the VYW-7830 electromagnet, with its major axis vertical, using the mounting holes on the bottom of the magnet structure.
2. Be sure the tuner drives and tube-lock are completely disengaged.
3. Carefully and gently lower the klystron into the electromagnet.

CAUTION

AVOID TOUCHING THE CERAMICS OR STRIKING THE CATHODE OR OUTPUT WAVEGUIDE ASSEMBLIES WHILE INSERTING THE TUBE.

The output waveguide must be located opposite (180°) the tuner mechanism on the magnet!

4. As the collector polepiece enters the magnet top plate,

the tube must be aligned rotationally so that the guide pins on the cathode polepiece engage the mating receptacles in the magnet base plate. When correctly and completely seated, the collector polepiece should be flush with or up to 1/8 inch above the magnet top plate.

5. Set each of the tuner counter dials to exactly "010" by rotating the knob counter-clockwise.
6. Fully engage the tube-lock by completely rotating the lock-unlock knob as indicated on the face of the tuner mechanism.
7. Carefully insert (slide towards the tube axis) and engage each of the tuner shafts into the tuner sockets on the tube. While engaging, rotate (rock) slightly to align. When fully engaged the counter should read between 008 and 012. Do not turn the klystron tuner drive while following the above procedure.
8. Note and record each of the above tuner settings and return to those settings before disengaging tuners and/or removing tube.

Demounting – Be sure that the lock-unlock knob is rotated completely in the unlock direction before attempting to remove the tube. This will automatically disengage the tuners.

Tuner Misalignment – If the tube tuners are accidentally misaligned, remove the tube, turn each of the tube tuner drives (with a 3/16 hex key) as far as they will go in a clockwise direction (do not force), then back-off just until the top and bottom flats on the hex are horizontal (perpendicular to the tube axis). Proceed, then, to step 2.

Coolant Connections – *Mating* coolant fittings for the coolant connectors on the tube and electromagnet are as follows:

Collector	Inlet	LL2-H16-192SS Hansen Fitting
	Outlet	Aeroquip No. 66196-350-S flange
		Aeroquip No. 55000-350-S coupling
Body		LL2-H16-192SS, Hansen Fittings
Electromagnet		LL2-H16-192SS Hansen Fittings

The collector inlet hose or steam outlet should not apply stress to the collector, which is attached to the tube by a ceramic insulator. The hoses should be of insulating material to isolate the collector from ground electrically. Ethylene-Propylene-Dienne-Poly-Methylene-lined hoses are recommended to minimize coolant contamination.

1. Attach a coolant jumper between the magnet outlet and the body inlet.
2. Attach the coolant inlet to the magnet inlet. The system should be designed to gravity/syphon drain from this inlet. Attach the coolant outlet to the body outlet.
3. Attach the collector cooler inlet to the collector boiler. Attach the in-line weir or steam line to the boiler steam outlet. Attach the overflow line to the weir outlet.

NOTE

Avoid stressing the tube during installation and removal of the coolant connections. Be sure that the quick connect fittings have been locked into place. Avoid spilling the coolant.

4. Place the cathode cooling blower into position so that at least 20 cfm of air is directed at the cathode end of the tube.

Electrical Connections – Figure 1 shows the most usual operating arrangement, i.e., with the tube body at ground potential. The heater is connected to the cathode internally to make sure the heater and cathode operate at the same dc potential thereby minimizing noise. If a dc heater supply is used to minimize heater hum, connect the common heater-cathode lead to the positive side of the supply. The heater-cathode lead is white and the heater lead is yellow. The heater supply should be insulated to withstand the full beam voltage. The output connector mates with standard CPR-284 flange, or equivalent. The input coaxial connector is a Type N jack, which mates with UG-21D/U, or equivalent.

1. Be sure waveguide flange and tube window are perfectly clean before attaching waveguide to the tube.
2. Attach the waveguide to the tube. Align the mating flange very carefully to avoid stress on the output window flange. Tighten the screws evenly to prevent fracture of the ceramic window.
3. Make electrical connections as shown in Figure 1. Connect the collector lead through appropriate relays and meters to the tube body and positive side of the power supply. The collector, body (ground) and collector thermocouple are connected through the receptacle mounted on the tube body. The mating plug is Cannon No. CA-06AQ24-205(A105). The connections are as follows:

Pin	A, B	Interlock
	C, D	Not Used
	E	Body Ground
	F, G	Collector
Pin	H, J	Thermocouple
	K, L	Do Not Use

4. Connect electromagnet to the power supply. The coil connector on the electromagnet mates with Amphenol MS3 106B-18-11S plug or equivalent. Coil connections and polarity are as follows:

Pin A	Positive
Pin B	Negative
Pins C and D	Interlock Jumper
Pin E	Magnet Ground

OPERATION

Preliminary Check – Check the following conditions before applying voltages to the tube.

1. Heater and cathode leads are connected correctly.
2. Collector is connected to supply correctly.
3. Tube body and magnet are grounded.

OPERATING HAZARDS

READ THIS SHEET AND TAKE ALL SAFETY PRECAUTIONS

PROPER USE AND SAFE OPERATING PRACTICES WITH RESPECT TO MICROWAVE TUBES ARE THE RESPONSIBILITY OF EQUIPMENT MANUFACTURERS AND USERS OF SUCH TUBES. VARIAN PROVIDES INFORMATION ON ITS PRODUCTS AND ASSOCIATED HAZARDS, BUT IT ASSUMES NO RESPONSIBILITY FOR AFTER-SALE OPERATING AND SAFETY PRACTICES. LIMITED LIFE AND RANDOM FAILURES ARE INHERENT CHARACTERISTICS OF ELECTRON TUBES. TAKE APPROPRIATE ACTION THROUGH REDUNDANCY OR OTHER SAFEGUARDS TO PROTECT PERSONNEL AND PROPERTY FROM TUBE FAILURE.

ALL PERSONS WHO WORK WITH OR ARE EXPOSED TO MICROWAVE TUBES OR EQUIPMENT WHICH UTILIZES SUCH TUBES MUST TAKE PRECAUTIONS TO PROTECT THEMSELVES AGAINST POSSIBLE SERIOUS BODILY INJURY. DO NOT BE CARELESS AROUND SUCH PRODUCTS.

OPERATING INSTRUCTIONS

This sheet, the Test Performance Sheet and the Operating Instructions can help you to operate this tube safely and efficiently. READ THEM. The Test Performance Sheet is a record of individual product test conditions and test results at the factory. Special operating considerations and precautions will be found in the Operating Instructions. Uninformed or careless operation of this tube can result in poor performance, damage to the tube or other property, serious bodily injury and, possibly death.

Address written questions regarding tube operation to the Manager, Tube Sales, at the address at the bottom of this sheet.

WARNING — SERIOUS HAZARDS EXIST IN THE OPERATION OF MICROWAVE TUBES

The operation of microwave tubes involves one or more of the following hazards, any one of which, in the absence of safe operating practices and precautions, could result in serious harm to personnel:

a. HIGH VOLTAGE – Normal operating voltages can be deadly.
b. RF RADIATION – Exposure to rf radiation may cause serious bodily injury possibly resulting in blindness or death. **Cardiac pacemakers may be affected.**
c. X-RAY RADIATION – High voltage tubes can produce dangerous, possibly fatal, x-rays.
d. BERYLLIUM OXIDE POISONING – The dust or fumes from beryllium oxide (BeO_2) ceramics used in microwave tubes are highly toxic and can cause serious injury or death.
e. CORROSIVE AND POISONOUS COMPOUNDS – If a dielectric gas is used in the external waveguide or around the high voltage bushing portions of microwave tubes, highly toxic or corrosive compounds may be produced by microwave or high voltage breakdown.
f. IMPLOSION HAZARD – Ceramic windows in microwave tubes can shatter on impact or crack in use, possibly resulting in injury from flying particles or from beryllium oxide (BeO_2) dust or fumes.
g. HOT WATER – The electron collector and water used to cool it reach scalding temperatures. Touching or rupture of the cooling system can cause serious burns.
h. HOT SURFACES – Surfaces of air-cooled collectors and other parts of tubes can reach temperatures of several hundred degrees centigrade and cause serious burns if touched.

Additional specific information about microwave tube hazards:

HIGH VOLTAGE

Many microwave tubes operate at voltages high enough to kill through electrical shock. Design equipment utilizing these tubes to prevent personnel contact with high voltages. Securely attach prominent hazard warnings. Personnel should always break the primary circuits of the power supply and discharge high voltage condensers when direct access to the tube is required.

RADIO FREQUENCY RADIATION

EXPOSURE OF PERSONNEL TO RF RADIATION SHOULD BE MINIMIZED. PERSONNEL SHOULD NOT BE PERMITTED IN THE VICINITY OF OPEN ENERGIZED WAVEGUIDES OR ENERGIZED ANTENNAS. It is generally accepted that exposure to "high levels" of rf radiation can result in severe bodily injury including blindness. **Cardiac pacemakers may be affected.**

The effect of prolonged exposure to "low-level" rf radiation continues to be a subject of investigation and controversy. While there continues to be support for lower limits, it is generally agreed among official standard-setting groups in the U.S. that prolonged exposure of personnel to rf radiation at frequencies of 10 MHz – 100 GHz should be limited to average power densities of ten milliwatts per square centimeter (10 mW/cm^2) or lower, using any possible one tenth of an hour (.1 hour) as the averaging period. It is also generally agreed that exposure should be reduced in working areas where temperatures are above normal. The 10 mW/cm^2 average level has been adopted by several U.S. Government agencies including the Occupational Safety and Health Administration (OSHA) as the standard or protection guide for employee work places.

ALL INPUT AND OUTPUT RF CONNECTIONS, WAVEGUIDES, FLANGES AND GASKETS MUST BE RF LEAKPROOF. NEVER OPERATE A MICROWAVE TUBE WITHOUT A PROPERLY MATCHED RF ENERGY ABSORBING LOAD ATTACHED. NEVER LOOK INTO OR EXPOSE ANY PART OF THE BODY TO AN ANTENNA OR OPEN WAVEGUIDE WHILE THE TUBE IS ENERGIZED. MONITOR THE TUBE AND RF SYSTEM FOR RF RADIATION LEAKAGE AT REGULAR INTERVALS AND AFTER SERVICING.

X RAY RADIATION

As voltages increase beyond 15 kilovolts metal-body tubes are capable of producing progressively more dangerous X-ray radiaiton. Provide adequate X-ray shielding on all sides of these tubes, particularly the cathode and collector ends, as well as the modulator and pulse transformer tanks. Check X-ray levels. NEVER OPERATE HIGH VOLTAGE TUBES WITHOUT ADEQUATE X-RAY SHIELDING IN PLACE. MONITOR THE TUBE AFTER SERVICING AND AT REGULAR INTERVALS FOR POSSIBLE CHANGES IN X-RAY LEVELS DUE TO AGING.

DANGER — BERYLLIUM OXIDE CERAMICS (BeO_2) — AVOID BREATHING DUST OR FUMES

Some microwave tubes contain beryllium oxide (BeO_2) ceramics; usually the output waveguide window or around the cathode. Do not perform any operations on BeO_2 ceramics which produce dust or fumes; for example, grinding, grit blasting, and acid cleaning. BERYLLIUM OXIDE DUST AND FUMES ARE HIGHLY TOXIC AND BREATHING THEM CAN RESULT IN SERIOUS PERSONAL INJURY OR DEATH. If a broken window is suspected, carefully remove the tube from its waveguide and seal the output flange of the tube with tape. Because BeO_2 warning labels may be obliterated or removed, we urge you to contact Varian before performing any work on ceramics in any Varian microwave tube.

Take precautions to protect personnel working in the disposal or salvage of tubes containing BeO_2. All such personnel should be made aware of the deadly hazards involved and the necessity for great care and attention to safety precautions. Varian will dispose of tubes without charge provided they are returned to Varian freight prepaid, with a written request for disposal by Varian.

CORROSIVE AND POISONOUS COMPOUNDS

External output waveguides and cathode high voltage bushings of microwave tubes are sometimes operated in systems that use a dielectric gas to impede microwave or high voltage breakdown. If breakdown does occur, the gas may decompose and combine with impurities, such as air or water vapor, to form highly toxic and corrosive compounds. Examples are Freon gas which may form LETHAL PHOSGENE, and sulfur hexafluoride (SF_6) gas which may form highly toxic and corrosive sulfur or fluorine compounds such as BERYLLIUM FLUORIDE. When breakdown does occur in the presence of these gases, VENTILATE THE AREA, AVOID BREATHING ANY FUMES OR TOUCHING ANY LIQUIDS WHICH DEVELOP, TAKE PRECAUTIONS APPROPRIATE FOR BERYLLIUM COMPOUNDS AND FOR OTHER HIGHLY TOXIC AND CORROSIVE SUBSTANCES, before permitting personnel to perform any work on or near the tube.

IMPLOSION HAZARD

Due to the internal vacuum in microwave tubes the glass or ceramic output window can shatter inward (implode) if struck with a hard object or subjected to mechanical shock. Flying debris could result in bodily injury, including cuts and puncture wounds and, if made of BERYLLIUM OXIDE ceramic, produce highly toxic dust or fumes. DO NOT BREATHE SUCH DUST OR FUMES.

HOT WATER

EXTREME HEAT occurs in the electron collector portion of microwave tubes during operation. Water channels used for cooling also reach high temperatures (as high as boiling, 100°C or above), and the hot water is under pressure (typically as high as 100 psi). A rupture of the water channel or other contact with hot portions of this tube could scald or burn. Take precautions to prevent and avoid such rupture or contact.

HOT SURFACES

The electron collector portion of microwave tubes is often air-cooled or conduction-cooled. The air-cooled external surface normally operates at a high temperature (typically 200° to 300°C). Other portions of the tube may also reach high temperatures, especially the cathode insulator and the cathode/heater surfaces. All hot surfaces may remain hot for an extended time after the tube is shut off. To prevent serious burns, take care to prevent and avoid any bodily contact with these surfaces both during and for a reasonable cool-down period after tube operation.

4. RF input and output waveguide are connected into system.
5. Collector, body, and electromagnet coolants are flowing.
6. Cathode cooling blower is turned on.
7. RF drive is at correct frequency.

Application of Voltages – Recommended operating voltages and currents are shown on the Test Performance Sheet which accompanies each tube.

1. Turn on the electromagnet power supply and set the focusing current to the value shown on the Test Performance Sheet. Never allow the focusing current to drop below 10 amperes.
2. Apply reduced heater voltage if possible. Increase the voltage slowly to the value specified on the Test Performance Sheet. The heater current should be approximately the value specified on the Test Performance Sheet. Surge current should never exceed 20 amperes. Allow at least 5 minutes for the cathode to warm up.
3. Starting at zero, or the lowest voltage available, increase the beam voltage to the value specified on the Test Performance Sheet. Body current should be less than 50 milliamperes.
4. Apply rf drive, adjust the drive level and trim magnet current for minimum body current.

Removal of Voltages –

CAUTION

FOR NORMAL SHUTDOWN AND/OR IN THE EVENT OF A POWER INTERRUPTION, THE POWER SUPPLY DESIGN MUST INSURE THAT ADEQUATE ELECTROMAGNET CURRENT IS MAINTAINED (APPROXIMATELY 75 WATTS MINIMUM OF MAGNET POWER FOR EACH kV OF BEAM VOLTAGE) UNTIL BEAM VOLTAGE IS SUBSTANTIALLY ZERO.

TUNING PROCEDURE

1. Deactivate the tube by removing rf drive and/or beam voltage.
2. Locate the desired frequency on the tuning chart found in the Test Data Booklet. The tuner counter settings are listed alongside the frequency values in the chart.
3. Rotate tuner drive 1 to the desired counter position. The number of the klystron cavity with the corresponding drive and counter is indicated in the diamonds located on the tuner face. If this setting was made by turning the drive *clockwise*, then overshoot the desired value by one turn and make the final setting by turning the drive *counterclockwise.*

NOTE

The final tuner setting must be made by turning the drive counterclockwise *in order to eliminate backlash.*

If the tuning chart indicates a counter setting without a + (plus) or – (minus), turn the drive counterclockwise until the exact digits appear on the counter.

If the tuning chart indicates a counter setting with a – (minus), turn the drive counterclockwise and stop a little short of aligning the last digit (about 1/3 count).

If the tuning chart indicates a counter setting with a + (plus), turn the drive counterclockwise and go a little past aligning the last digit.

4. Repeat Step 3 above for tuner drives 2, 3, 4, and 5.
5. Set rf input drive frequency to the new channel/frequency.
6. Reactivate the tube.

TRANSPORTATION AND STORAGE

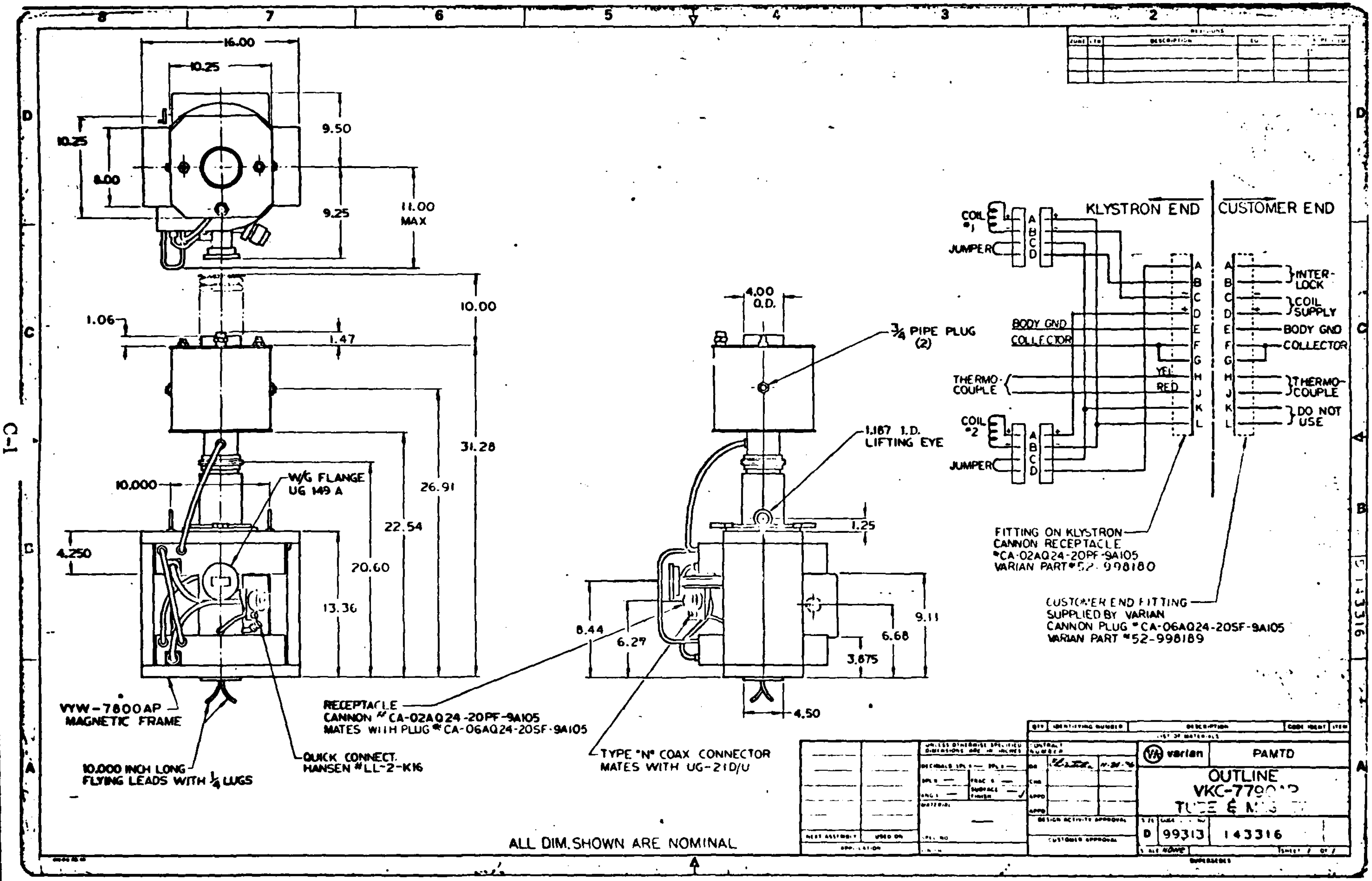
Use the original packing case for both transporting and storing the tube. The tube should be stored in the packing case when not in service. Before placing in the packing case, drain the tube and blow out the remaining coolant with warm dry air.

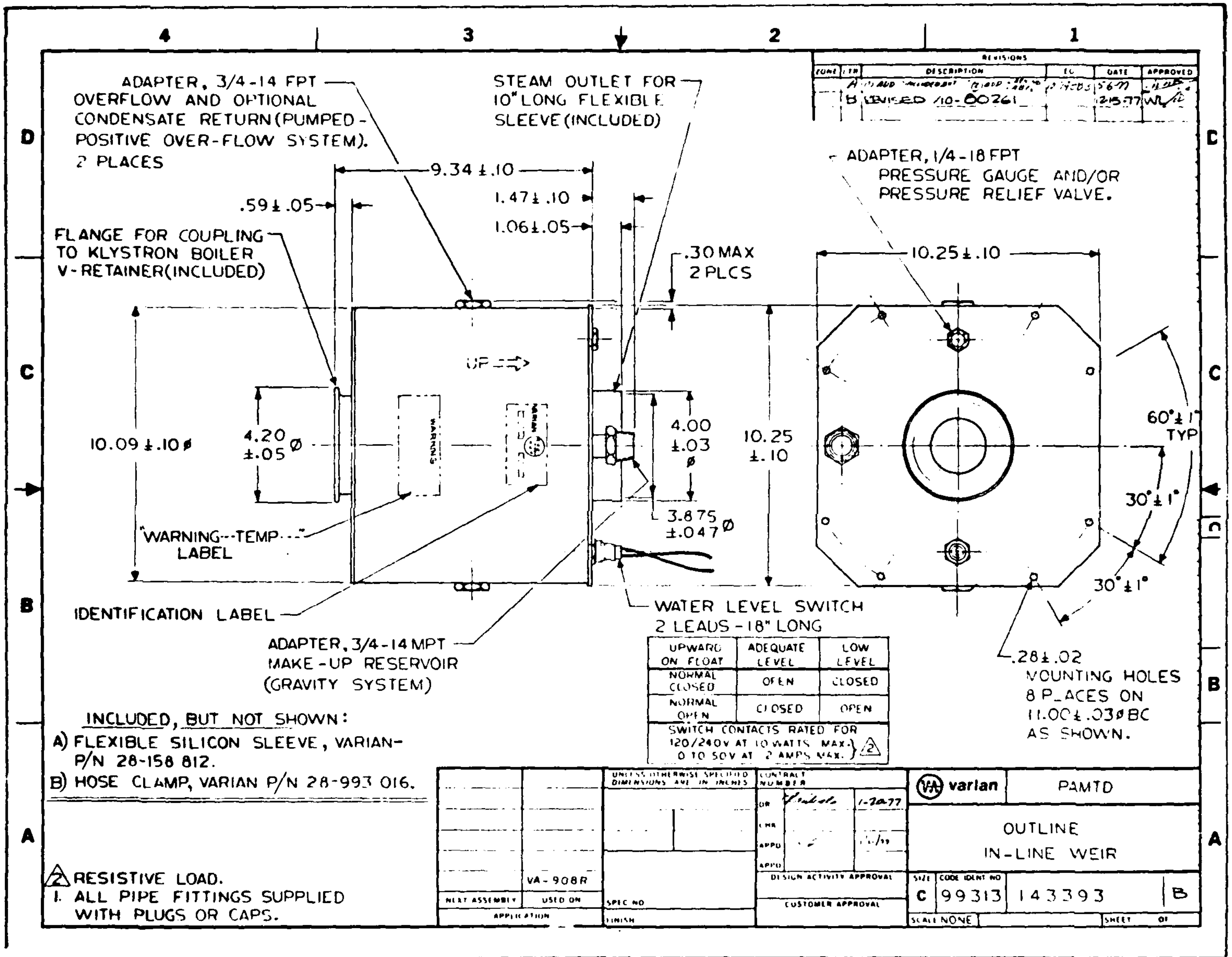
The protective covers for the input connector and output flange should be in place whenever the tube is not installed.

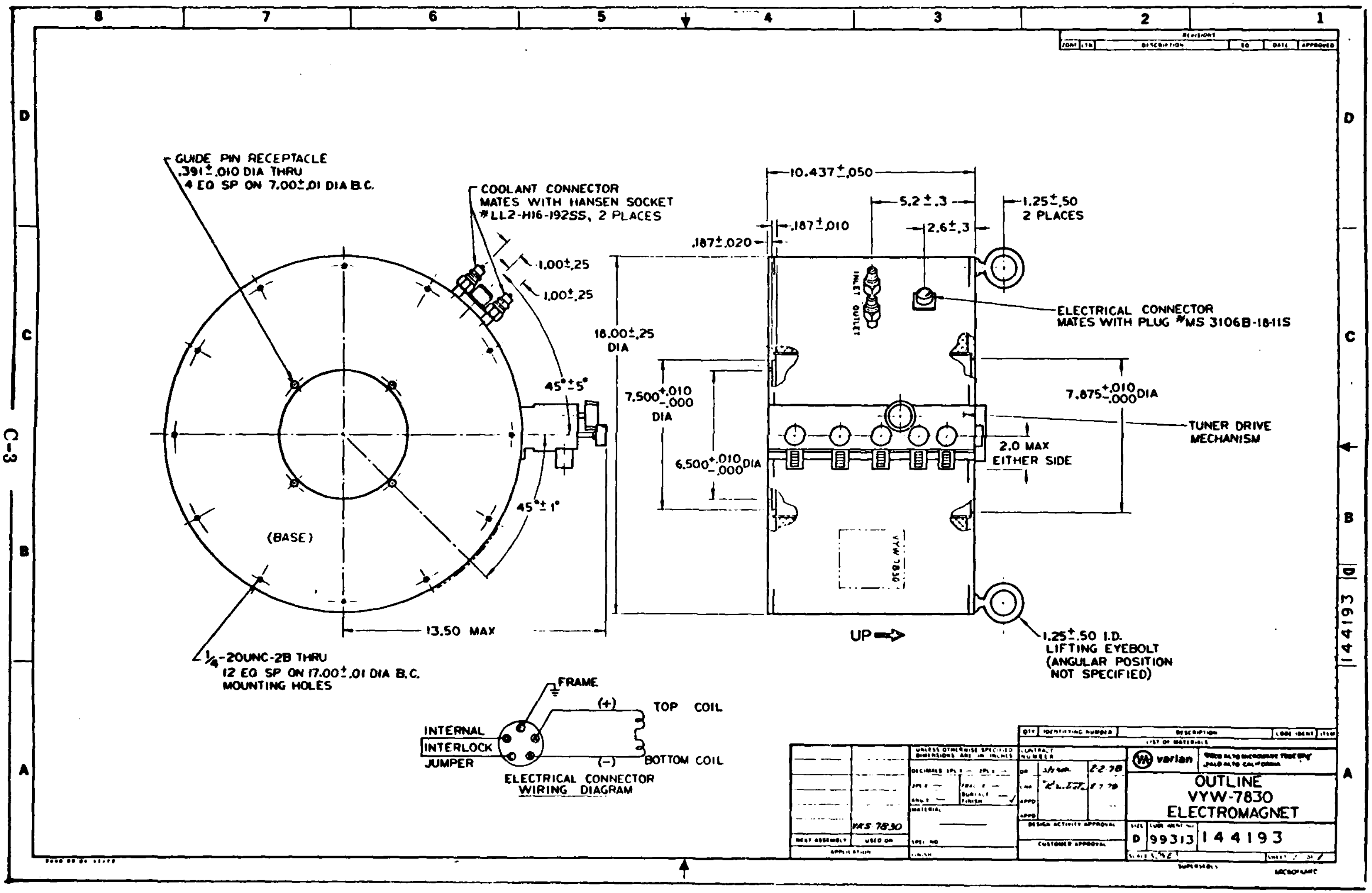
The condition of the klystron may be determined during storage with the Varian VPW-6700P1 klystron test set. Connect the klystron to the test set. Adjust and maintain the heater voltage to the value specified in the Test Performance Sheet. Allow at least 5 minutes for warm-up. The heater current should be within ± 10% of the Test Performance Sheet value. Apply 1000 volts dc. The beam current should be between 25 and 40 mAdc.

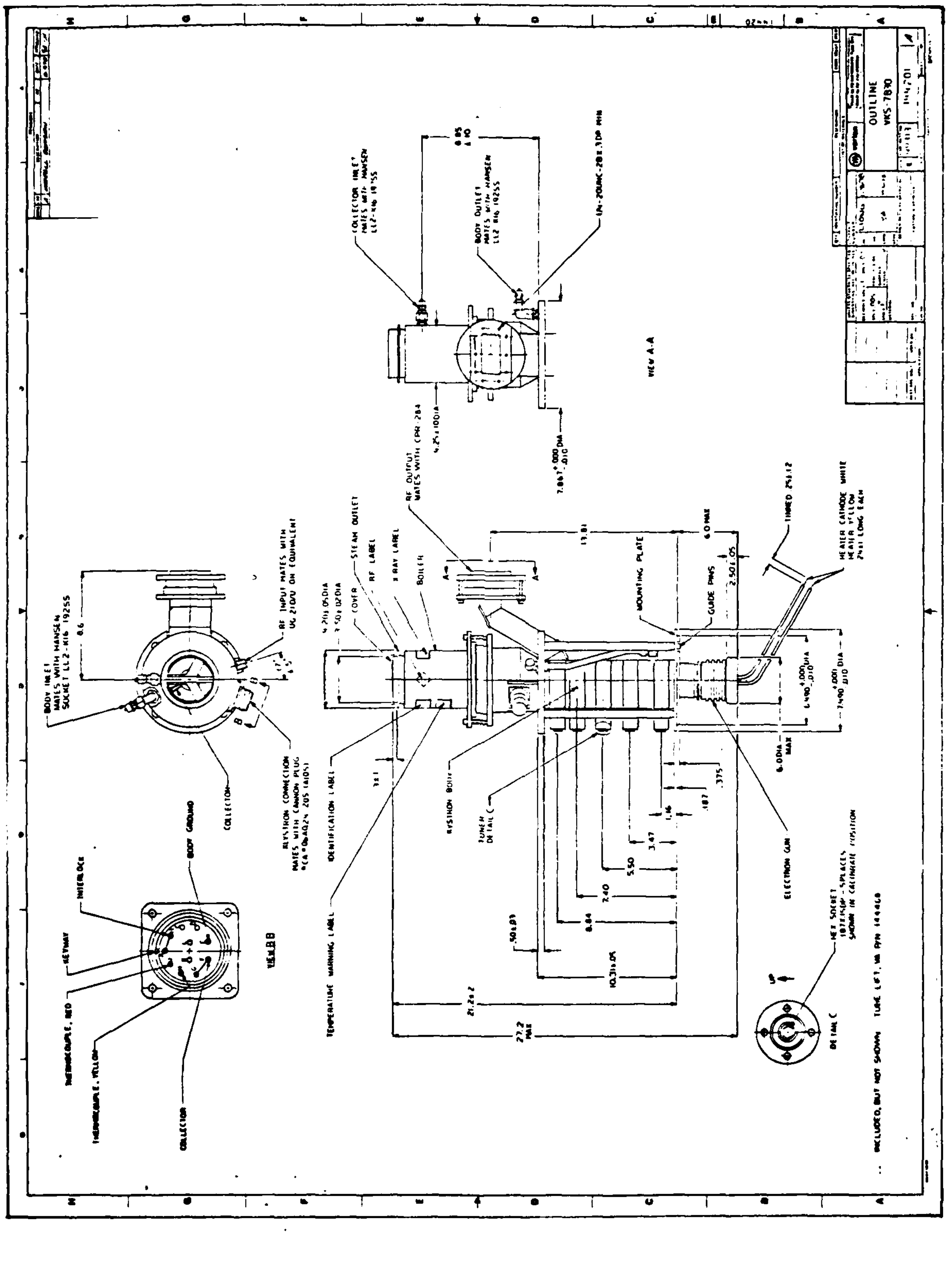
APPENDIX C

DRAWINGS

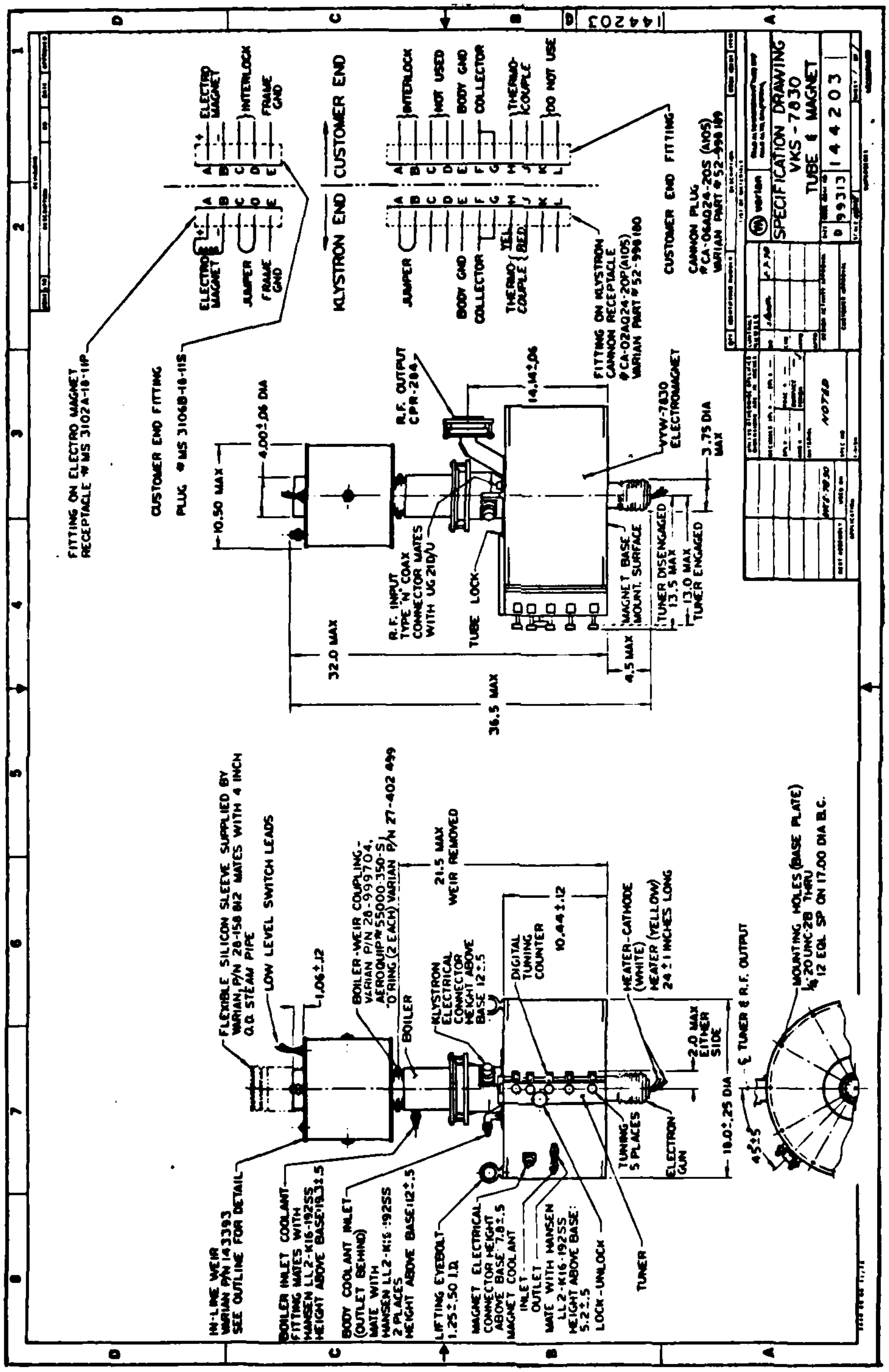

16.00
10.25
10.25
8.00
9.50
9.25
11.00 MAX
10.00
1.06
1.47
31.28
26.91
22.54
20.60
13.36
10.000
4.250
W/G FLANGE UG 149 A
VYW-7800AP MAGNETIC FRAME
10.000 INCH LONG FLYING LEADS WITH 1/4 LUGS
QUICK CONNECT. HANSEN #LL-2-K16
RECEPTACLE CANNON # CA-02AQ24-20PF-9A105 MATES WITH PLUG # CA-06AQ24-20SF-9A105
4.00 O.D.
3/4 PIPE PLUG (2)
1.187 I.D. LIFTING EYE
1.25
8.44
6.29
9.11
6.68
3.875
4.50
TYPE "N" COAX CONNECTOR MATES WITH UG-21D/U
KLYSTRON END
CUSTOMER END
COIL #1
JUMPER
COIL #2
JUMPER
BODY GND
COLLECTOR
THERMO-COUPLE
YEL
RED
INTER-LOCK
COIL SUPPLY
BODY GND
COLLECTOR
THERMO-COUPLE
DO NOT USE
FITTING ON KLYSTRON CANNON RECEPTACLE #CA-02AQ24-20PF-9A105 VARIAN PART #52-998180
CUSTOMER END FITTING SUPPLIED BY VARIAN CANNON PLUG #CA-06AQ24-20SF-9A105 VARIAN PART #52-998189
ALL DIM. SHOWN ARE NOMINAL
varian
PAMTD
OUTLINE
D
99313
143316

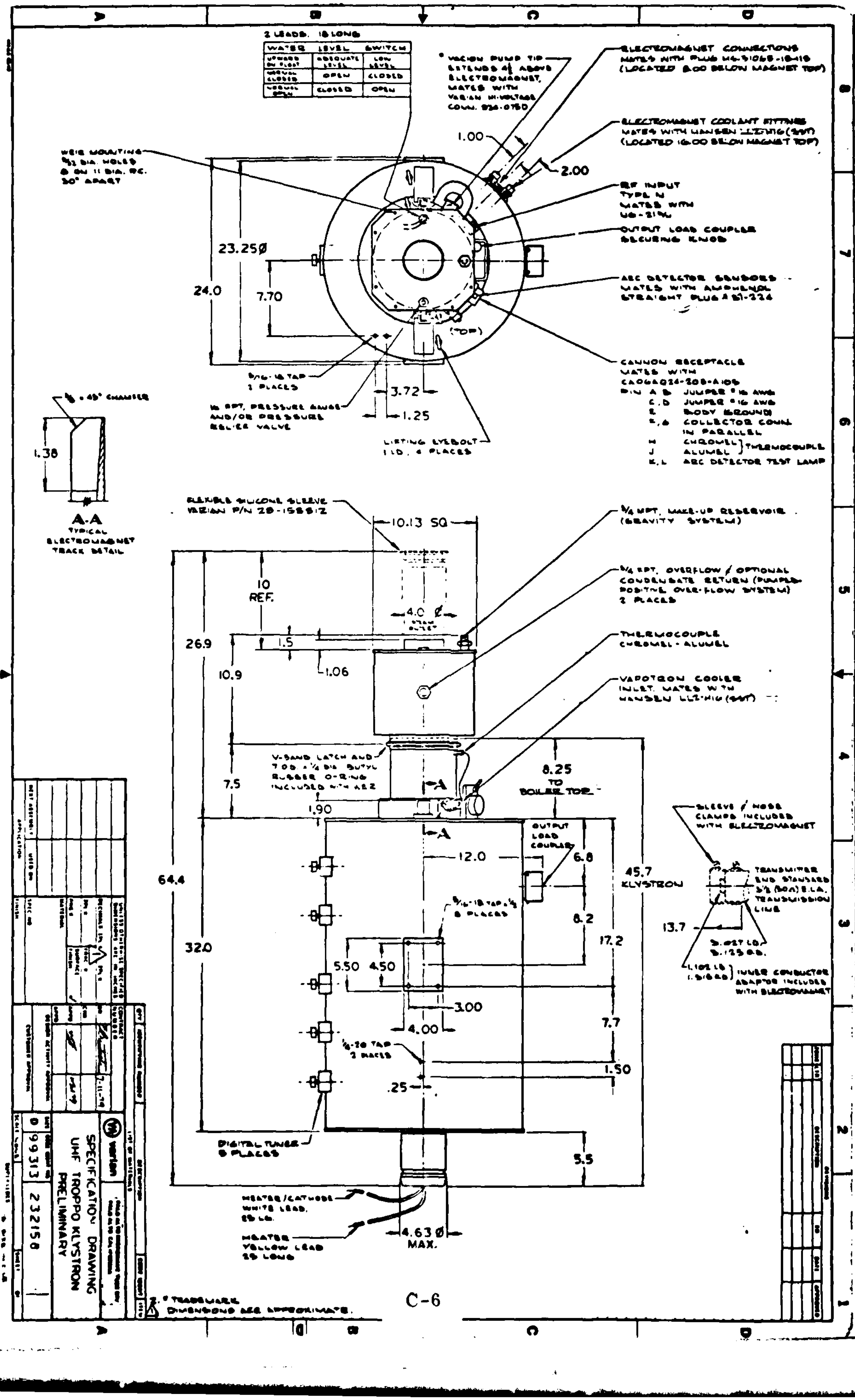

ADAPTER, 3/4-14 FPT
OVERFLOW AND OPTIONAL
CONDENSATE RETURN (PUMPED-
POSITIVE OVER-FLOW SYSTEM).
2 PLACES
STEAM OUTLET FOR
10" LONG FLEXIBLE
SLEEVE (INCLUDED)
ADAPTER, 1/4-18 FPT
PRESSURE GAUGE AND/OR
PRESSURE RELIEF VALVE.
9.34 ±.10
1.47 ±.10
1.06 ±.05
.59 ±.05
FLANGE FOR COUPLING
TO KLYSTRON BOILER
V-RETAINER (INCLUDED)
.30 MAX
2 PLCS
10.25 ±.10
UP
WARNING
10.09 ±.10 ø
4.20 ø
±.05
4.00
±.03
ø
10.25
±.10
60° ±1°
TYP
30° ±1°
30° ±1°
3.875 ø
±.047
"WARNING---TEMP---"
LABEL
IDENTIFICATION LABEL
WATER LEVEL SWITCH
2 LEADS - 18" LONG
ADAPTER, 3/4-14 MPT
MAKE-UP RESERVOIR
(GRAVITY SYSTEM)
UPWARD ON FLOAT | ADEQUATE LEVEL | LOW LEVEL
NORMAL CLOSED | OPEN | CLOSED
NORMAL OPEN | CLOSED | OPEN
SWITCH CONTACTS RATED FOR
120/240V AT 10 WATTS MAX.
0 TO 50V AT 2 AMPS MAX. 2
.28 ±.02
MOUNTING HOLES
8 PLACES ON
11.00 ±.03 ø BC
AS SHOWN.
INCLUDED, BUT NOT SHOWN:
A) FLEXIBLE SILICON SLEEVE, VARIAN-
P/N 28-158 812.
B) HOSE CLAMP, VARIAN P/N 28-993 016.
2 RESISTIVE LOAD.
1. ALL PIPE FITTINGS SUPPLIED
WITH PLUGS OR CAPS.
REVISIONS
B REVISED 10-00261
VA-908R
NEXT ASSEMBLY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
CONTRACT NUMBER
1-20-77
DESIGN ACTIVITY APPROVAL
CUSTOMER APPROVAL
SPEC NO
FINISH
varian
PAMTD
OUTLINE
IN-LINE WEIR
C
99313
143393
B
SCALE NONE
SHEET OF


GUIDE PIN RECEPTACLE
.391±.010 DIA THRU
4 EQ SP ON 7.00±.01 DIA B.C.
COOLANT CONNECTOR
MATES WITH HANSEN SOCKET
#LL2-H16-192SS, 2 PLACES
1.00±.25
1.00±.25
18.00±.25
DIA
45°±5°
45°±1°
(BASE)
13.50 MAX
1/4-20UNC-2B THRU
12 EQ SP ON 17.00±.01 DIA B.C.
MOUNTING HOLES
10.437±.050
5.2±.3
2.6±.3
1.25±.50
2 PLACES
.187±.010
.187±.020
INLET
OUTLET
ELECTRICAL CONNECTOR
MATES WITH PLUG #MS 3106B-18-11S
7.500+.010 -.000
DIA
6.500+.010 -.000 DIA
7.875+.010 -.000 DIA
TUNER DRIVE
MECHANISM
2.0 MAX
EITHER SIDE
VYW 7830
UP
1.25±.50 I.D.
LIFTING EYEBOLT
(ANGULAR POSITION
NOT SPECIFIED)
FRAME
(+)
TOP COIL
INTERNAL
INTERLOCK
JUMPER
(−)
BOTTOM COIL
ELECTRICAL CONNECTOR
WIRING DIAGRAM
varian
OUTLINE
VYW-7830
ELECTROMAGNET
D
99313
144193
VKS 7830
NEXT ASSEMBLY
USED ON
APPLICATION
REVISIONS
LIST OF MATERIALS
DESIGN ACTIVITY APPROVAL
CUSTOMER APPROVAL
144193



OUTLINE
VKS-7830
VIEW A-A
VIEW B-B
COLLECTOR INLET MATES WITH HANSEN LL2-K16 1925S
BODY OUTLET MATES WITH HANSEN LL2 K16 1925S
RF OUTPUT MATES WITH CPR-284
BODY INLET MATES WITH HANSEN SOCKET LL2-K16 1925S
RF INPUT MATES WITH UG 2107U OR EQUIVALENT
KLYSTRON CONNECTION MATES WITH CANNON PLUG
COLLECTOR
STEAM OUTLET
COVER
RF LABEL
X RAY LABEL
BOILER
MOUNTING PLATE
GUIDE PINS
THREAD
HEATER CATHODE WHITE
HEATER YELLOW
IDENTIFICATION LABEL
TEMPERATURE WARNING LABEL
KLYSTRON BODY
TUNER DETAIL C
ELECTRON GUN
DETAIL C
INTERLOCK
BODY GROUND
KEYWAY
THERMOCOUPLE, RED
THERMOCOUPLE, YELLOW
COLLECTOR
INCLUDED, BUT NOT SHOWN


SPECIFICATION DRAWING
VKS-7830
TUBE & MAGNET
144203
KLYSTRON END
CUSTOMER END



2 LEADS, 18 LONG
WATER LEVEL SWITCH
UPWARD ON FLOAT | ADEQUATE LEVEL | LOW LEVEL
NORMAL CLOSED | OPEN | CLOSED
NORMAL OPEN | CLOSED | OPEN
* VACION PUMP TIP EXTENDS 4½ ABOVE ELECTROMAGNET, MATES WITH VARIAN HI-VOLTAGE CONN. 924-0750
ELECTROMAGNET CONNECTIONS MATES WITH PLUG MS-3106E-18-1S (LOCATED 8.00 BELOW MAGNET TOP)
ELECTROMAGNET COOLANT FITTINGS MATES WITH HANSEN LL2-H16 (SST) (LOCATED 16.00 BELOW MAGNET TOP)
1.00
2.00
RF INPUT TYPE N MATES WITH UG-21%
OUTPUT LOAD COUPLER SECURING KNOB
ARC DETECTOR SENSORS MATES WITH AMPHENOL STRAIGHT PLUG # 57-224
CANNON RECEPTACLE MATES WITH CA06A024-20S-A106
PIN A,B JUMPER #16 AWG
C,D JUMPER #16 AWG
E BODY GROUND
F,G COLLECTOR CONN. IN PARALLEL
H CHROMEL } THERMOCOUPLE
J ALUMEL
K,L ARC DETECTOR TEST LAMP
WEIS MOUNTING 9/32 DIA. HOLES 8 ON 11 DIA. B.C. 30° APART
23.250
24.0
7.70
(TOP)
5/16-18 TAP 2 PLACES
¼ NPT, PRESSURE GAUGE AND/OR PRESSURE RELIEF VALVE
3.72
1.25
LIFTING EYEBOLT 1 I.D., 4 PLACES
1/16 x 45° CHAMFER
1.38
A-A TYPICAL ELECTROMAGNET TRACK DETAIL
FLEXIBLE SILICONE SLEEVE VARIAN P/N 28-155512
10.13 SQ
10 REF.
4.0 Ø
¾ NPT, MAKE-UP RESERVOIR (GRAVITY SYSTEM)
¾ NPT, OVERFLOW / OPTIONAL CONDENSATE RETURN (PUMPED-POSITIVE OVER-FLOW SYSTEM) 2 PLACES
THERMOCOUPLE CHROMEL - ALUMEL
VAPOTRON COOLER INLET, MATES WITH HANSEN LL2-H16 (SST)
26.9
1.5
10.9
1.06
V-BAND LATCH AND 7.05 x ¼ DIA. BUTYL RUBBER O-RING INCLUDED WITH ASSY
7.5
8.25 TO BOILER TOP
1.90
A
OUTPUT LOAD COUPLER
12.0
6.8
45.7 KLYSTRON
64.4
8.2
5/16-18 TAP x ½ 8 PLACES
32.0
17.2
5.50
4.50
3.00
4.00
7.7
¼-20 TAP 2 PLACES
1.50
.25
DIGITAL TUNER 8 PLACES
5.5
HEATER/CATHODE WHITE LEAD, 25 LG.
HEATER YELLOW LEAD 25 LONG
4.63 Ø MAX.
SLEEVE / HOSE CLAMPS INCLUDED WITH ELECTROMAGNET
TRANSMITTER END STANDARD 3⅛ (50Ω) E.I.A. TRANSMISSION LINE
13.7
INNER CONDUCTOR ADAPTOR INCLUDED WITH ELECTROMAGNET
2. * TRADEMARK
1. DIMENSIONS ARE APPROXIMATE.
varian
SPECIFICATION DRAWING
UHF TROPPO KLYSTRON
PRELIMINARY
D 99313 232158
A B C D
1 2 3 4 5 6 7 8

APPENDIX D

PHOTOGRAPHS

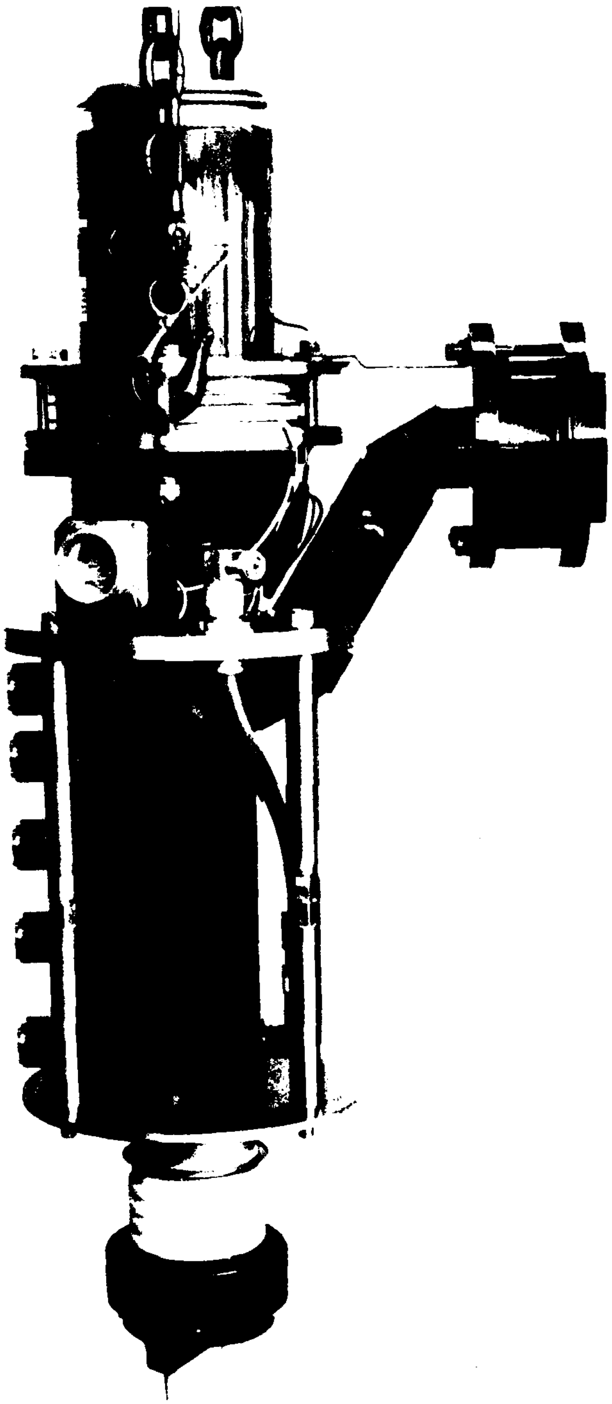


Figure 1. VKS 7830 KLYSTRON

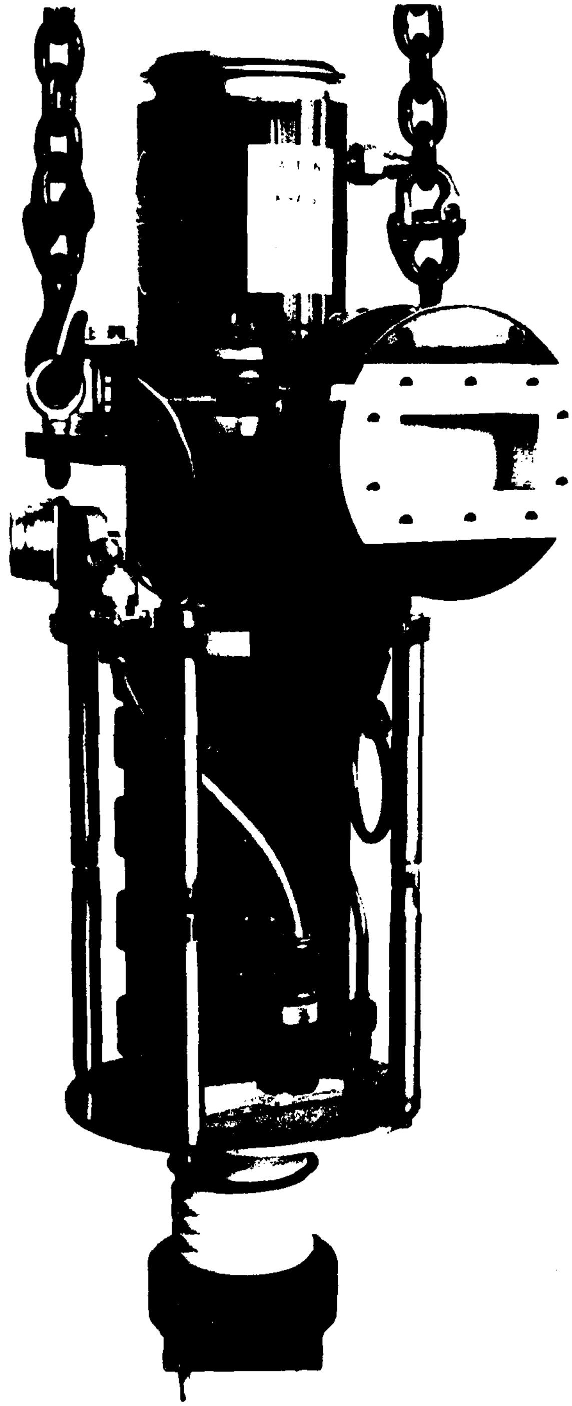


Figure 2. VKS 7830 KLYSTRON

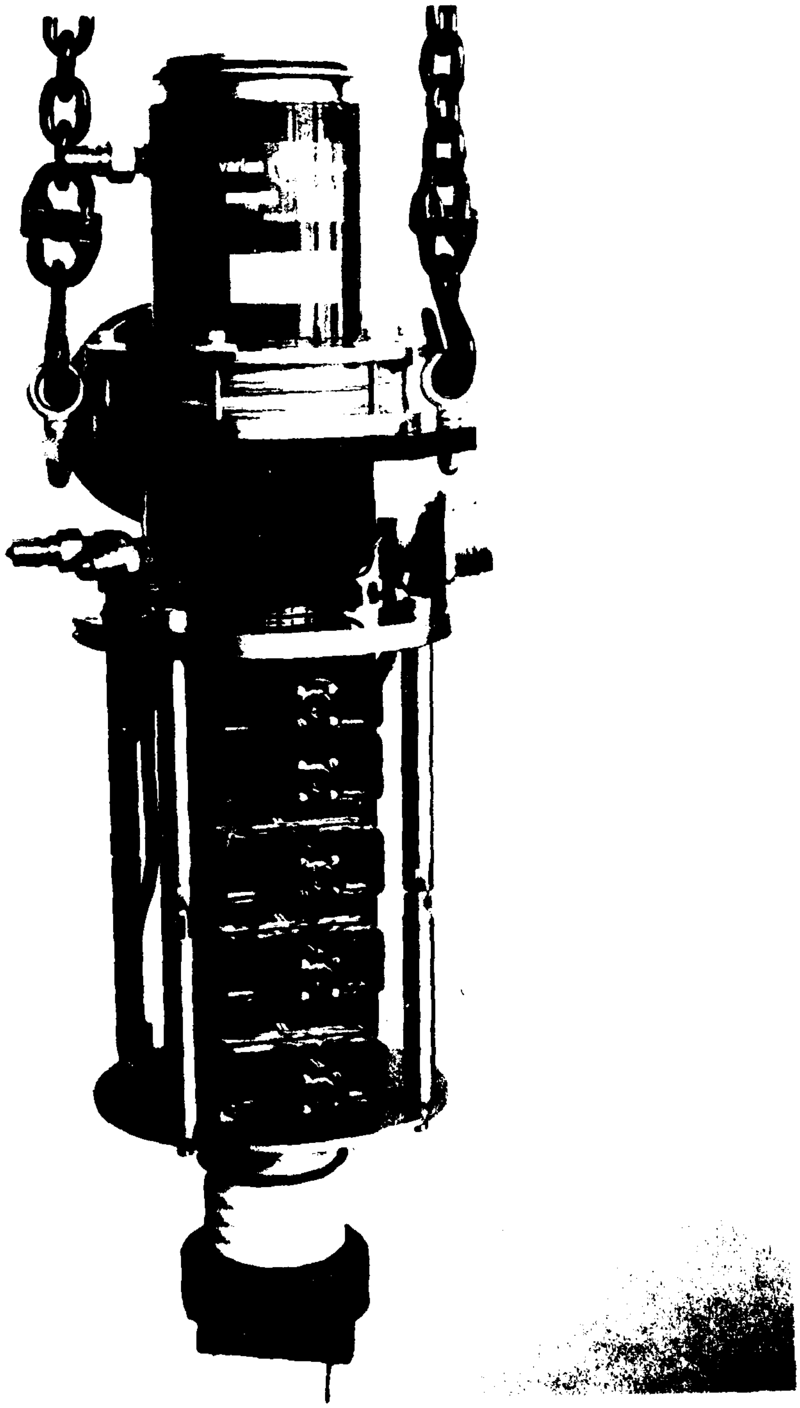


Figure 3. VKS 7830 KLYSTRON

Figure 4. VYW 7830 ELECTROMAGNET

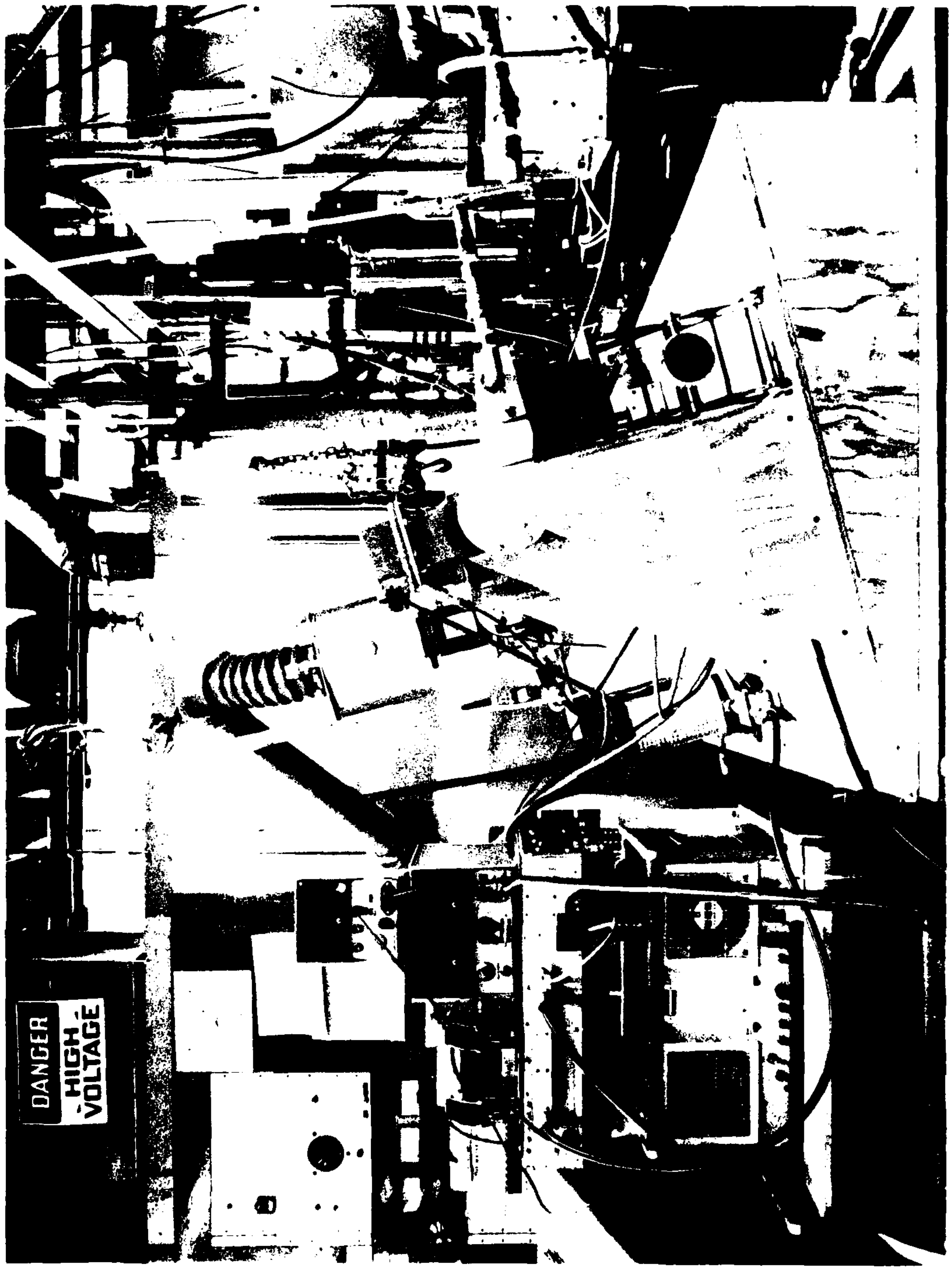


Figure 5. 15° TILT TEST, KLYSTRON & TEST EQUIPMENT

Figure 6. 15° TILT TEST, HEAT EXCHANGER

APPENDIX E

HEAT EXCHANGER

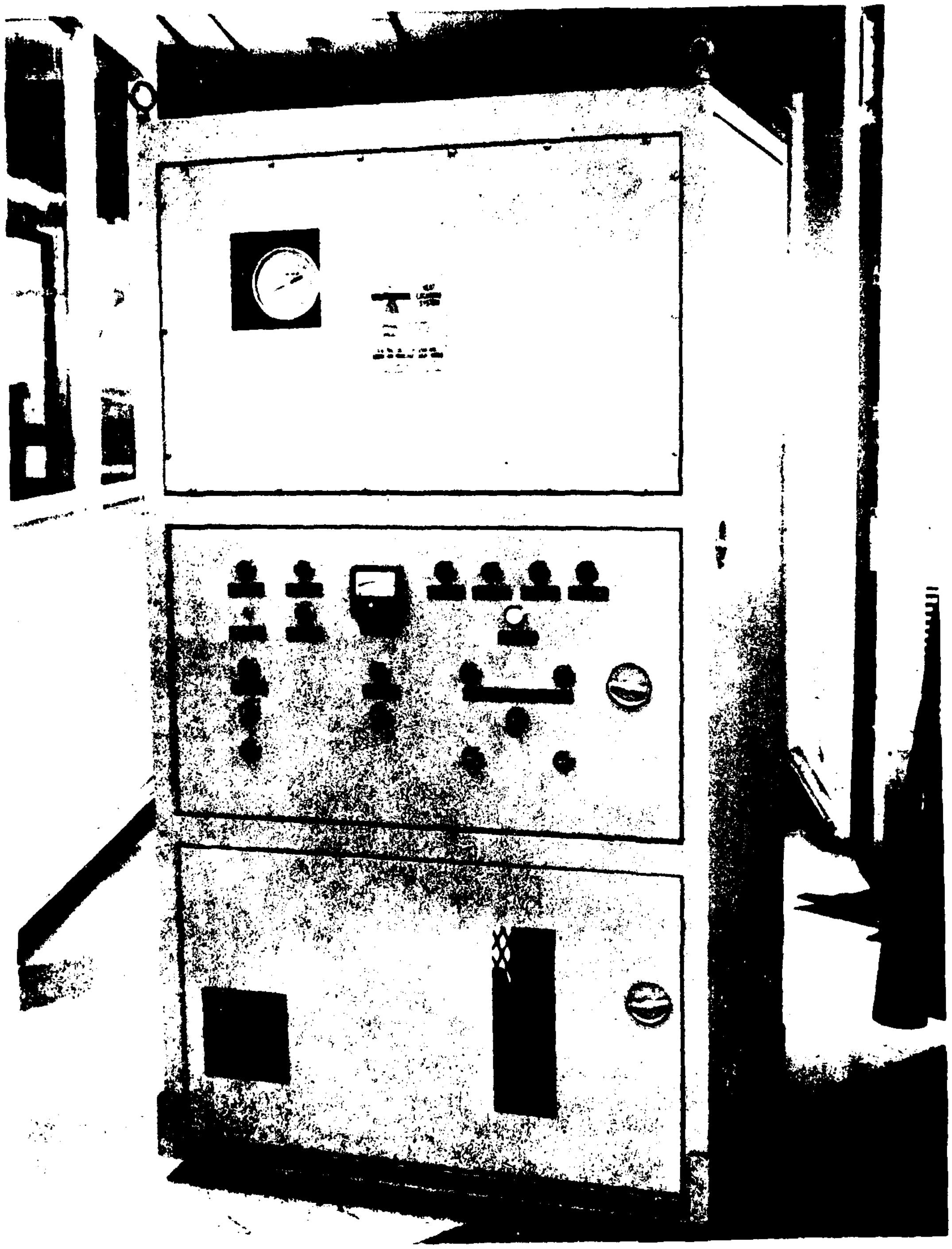


Figure 7. HEAT EXCHANGER FRONT PANEL

Figure 8. HEAT EXCHANGER CONTROL PANEL

Figure 9. HEAT EXCHANGER INTERIOR (SIDE VIEW)

OPERATING AND MAINTENANCE INSTRUCTIONS
MODEL 25DA85 HEAT EXCHANGER
SERIAL NOS. 76262-1 and 76262-2
VARIAN PAMTD P.O. 10ABB-815035

C. H. BULL CO.

229 UTAH AVENUE
SOUTH SAN FRANCISCO, CALIF. 94080
(415) 871-8440

DESCRIPTION:

Heat exchanger is self-contained air cooled two phase system, designed for condensing vapor from the collector of a Varian VKC-7790 Klystron and sub-cooling the condensate to 70°C in ambient temperatures from 0 to 50°C from sea level to 10,000 feet above sea level. System is designed for operation with 60/40 solution of Dowtherm 209. Coolant shall be delivered in two separate flows, 1 GPM to the Klystron and .75 GPM to the auxiliary circuit. Complete exchanger and controls are described on C. H. Bull Company Drawing 76262, sheets 1, 2, 3, and with electrical schematic and control panel layout per Drawing D-70331-1; field wiring diagram is D-70331-2.

PRIOR TO OPERATION:

A. Connect 3 phase 60 Hz 208 volt power supply to L-1, L-2, and L-3 on TB 2.

B. Connect single phase 120 volt power leads to L-1 and L-2 on TB 1.

C. Connect leads from low weir level, remote alarm, and collector thermocouple as indicated.

D. Connect coolant supply and return lines to klystron.

E. Connect auxiliary coolant supply and return lines.

F. Connect vapor inlet line, 4", from klystron to vapor inlet at upper rear corner of enclosure.

G. Open gate valves on either side of strainer located on pump suction line; close coolant by-pass valve located near top of reservoir. Momentarily jog fan by placing selector switch in "hand" position. If air is discharged from upper rear opening, fan is turning in proper rotation and pump will also be turning in proper rotation.

H. Operate pump with selector switch in "hand" position until coolant level is 1" from the bottom of the sight glass. Re-fill reservoir and operate pump again to completely fill system piping.

PREPARED BY: Charles E. Bull **REF. NO:** Job 262

DATE: December 18, 1978 **SHEET** 1 **OF** 3

C. H. BULL CO.
229 UTAH AVENUE
SOUTH SAN FRANCISCO, CALIF. 94080
(415) 871-8440

I. Turn on interlock system and continue operating pump until all interlocks are satisfied and level in sight glass is up to operating mark.

OPERATION:

A. Heat exchanger is now ready to be placed in automatic mode. Place fan, pump, and heater selector switches in automatic position and re-set interlocks. System will shut-down for low flow, low reservoir fluid level, low weir level, collector over-temperature, fluid over-temperature, and high vapor pressure.

B. In automatic mode, fan will be started at low speed when coolant supply temperature reaches 140°F. Fan will switch to high speed when coolant supply temperature rises to 165°F. Adequate cooling will be accomplished with the fan on low speed under most normal operating ambient conditions.

C. Air passages into the exchanger and discharging from the exchanger should not be obstructed, to avoid heated discharge air being returned to the inlet.

D. Flow being delivered by the pump can be read during operation on the meter at the lower right-hand corner of the unit. Temperature of flow being delivered to the klystron and auxiliary supply connections can be read on the temperature gauge at the upper right-hand corner of the unit. Liquid level can be observed through the sight glass at the lower right-hand corner of the unit.

E. All panels and doors should remain tightly closed during operation as there is possibility of an explosion of the Dowtherm 209 vapors in the event of a leak. Every effort has been made to provide explosion-proof or vapor tight wiring and switch components in the exchanger area. The electrical control panel has been sealed to prevent penetration of any vapor or liquid leakage into this area.

MAINTENANCE:

A. Both fan motor and pump motor have sealed bearings and require no lubrication.

C. H. BULL CO.
229 UTAH AVENUE
SOUTH SAN FRANCISCO, CALIF. 94080
(415) 871-8440

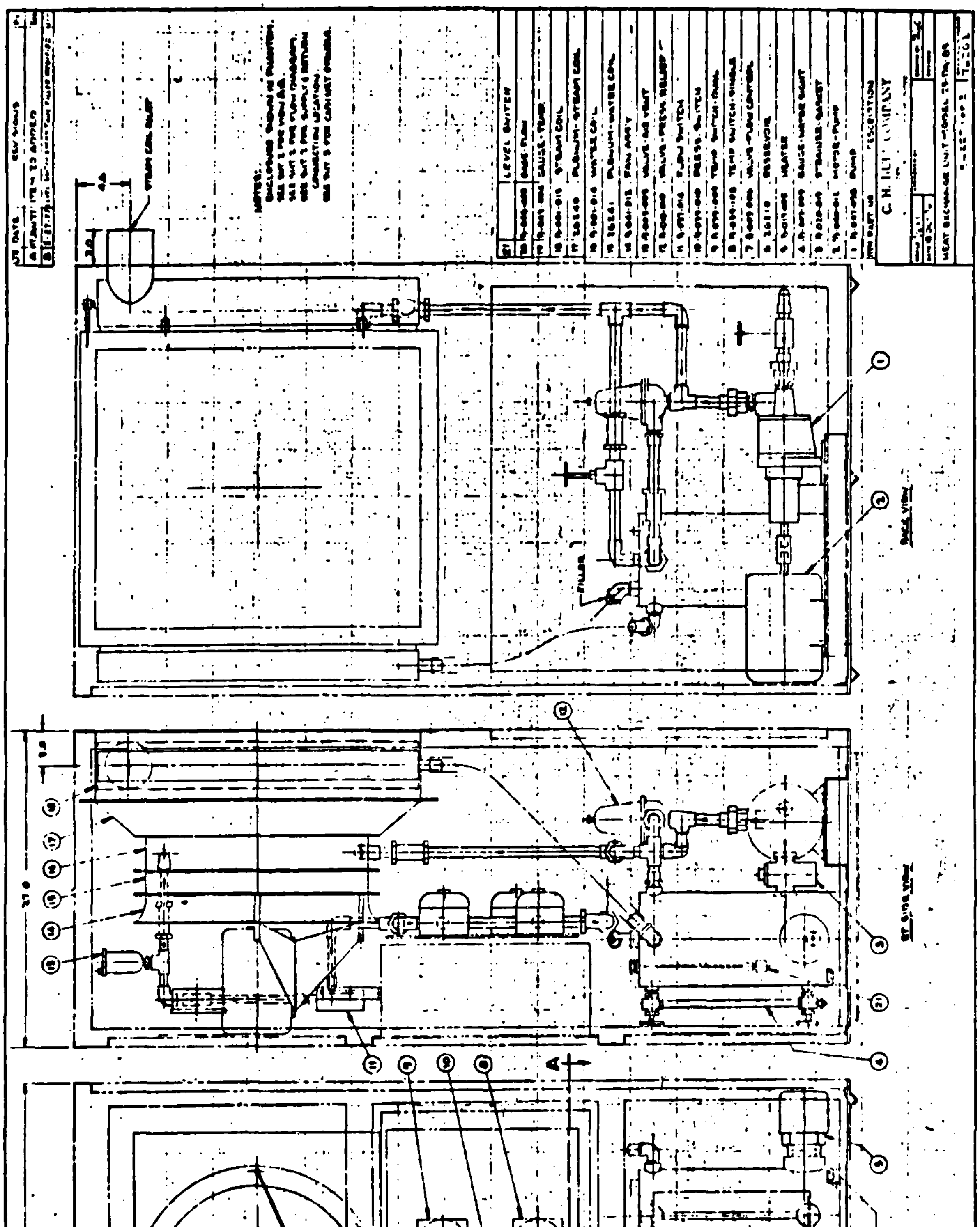
B. Strainer basket should be removed and cleaned annually. Insure that valves on either side of strainer are closed before opening strainer cap and re-opened after cap is replaced.

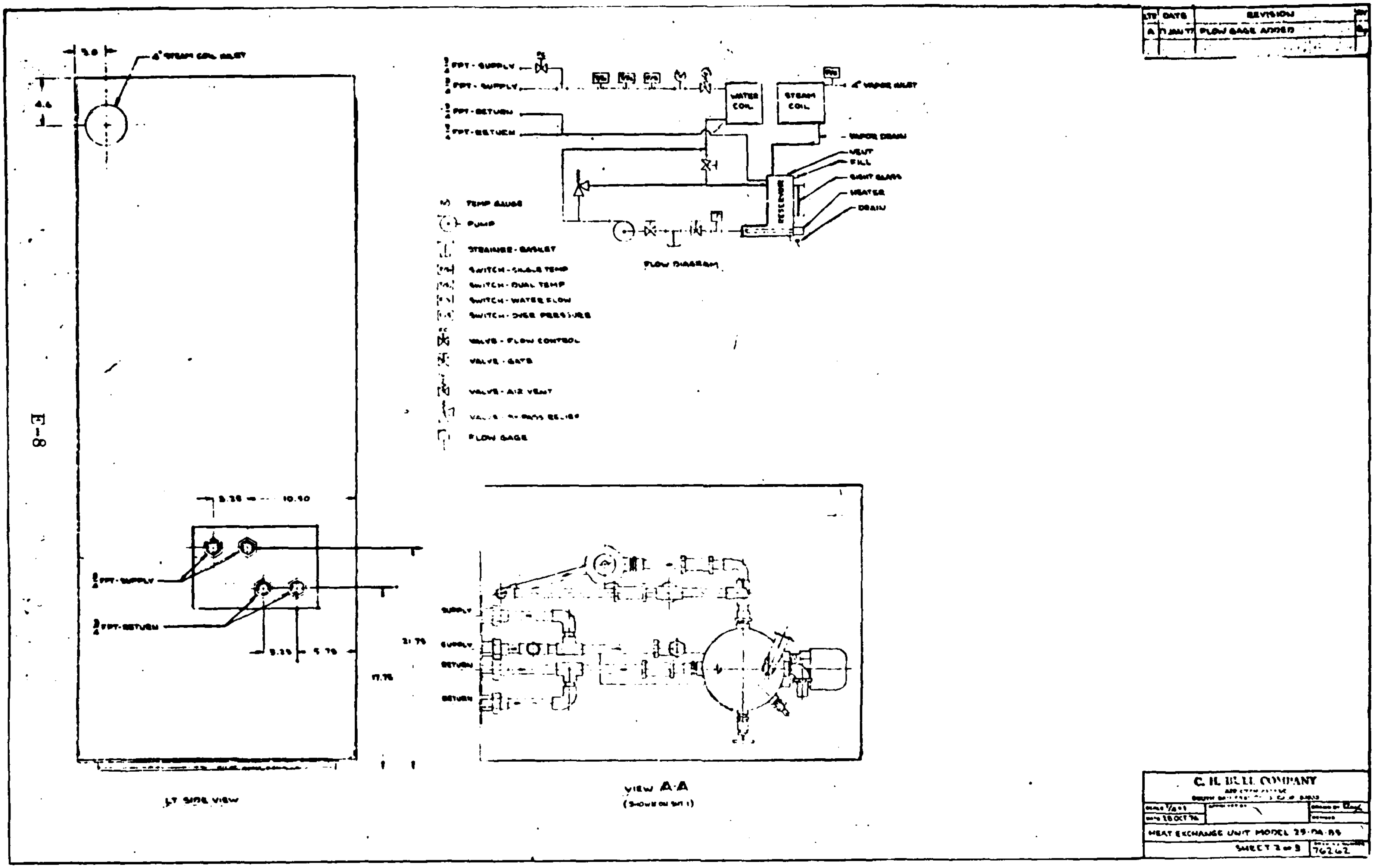
C. Heat exchanger will operate equally well with water or an Azeotropic solution of water and 53-60% Dowtherm 209. No other fluids should be used. If it is necessary to drain the unit for shipment, storage, or other reason, proceed as follows:

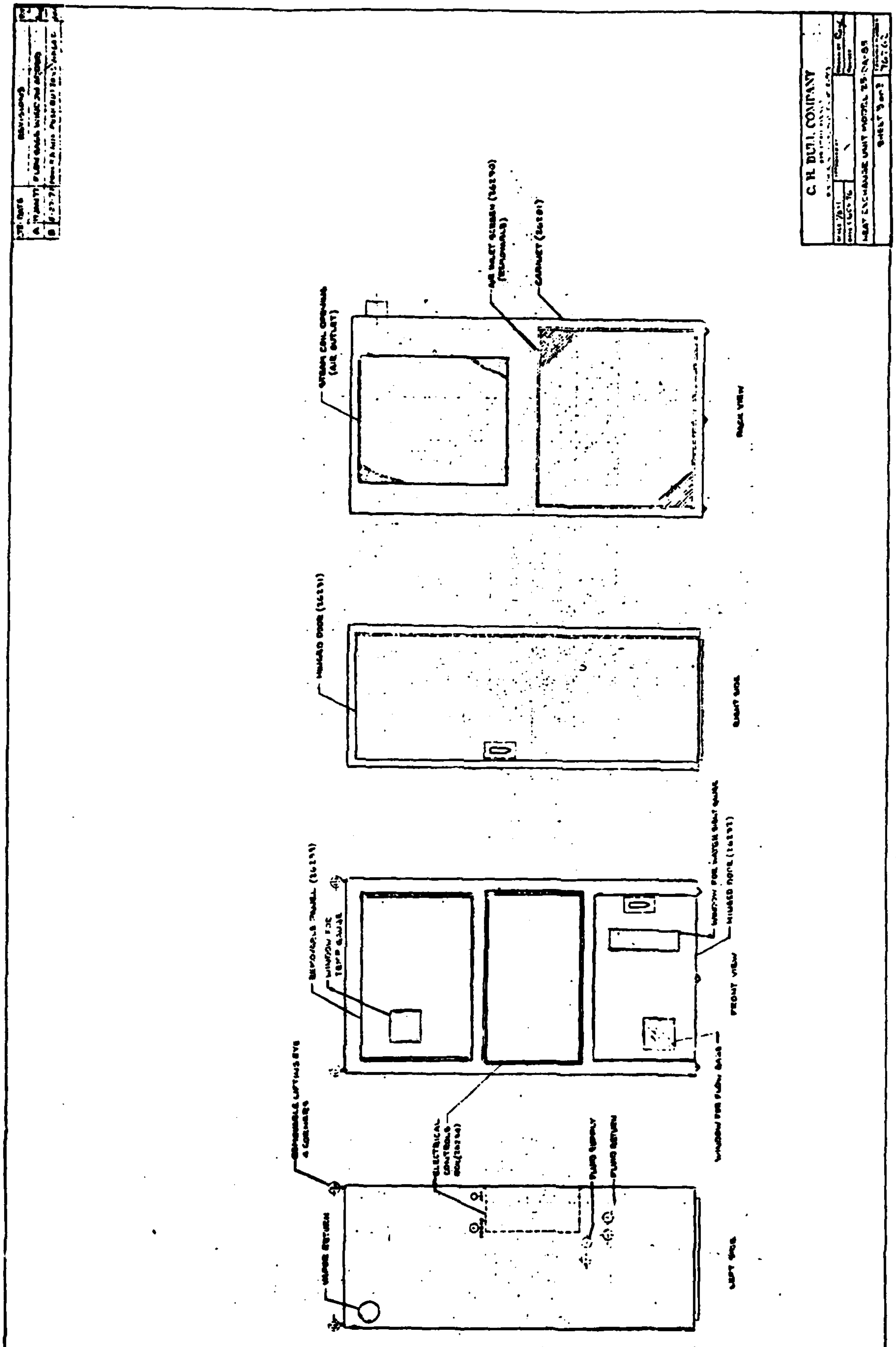
1. Connect hose to drain cock located near bottom of reservoir and left-hand side of unit.

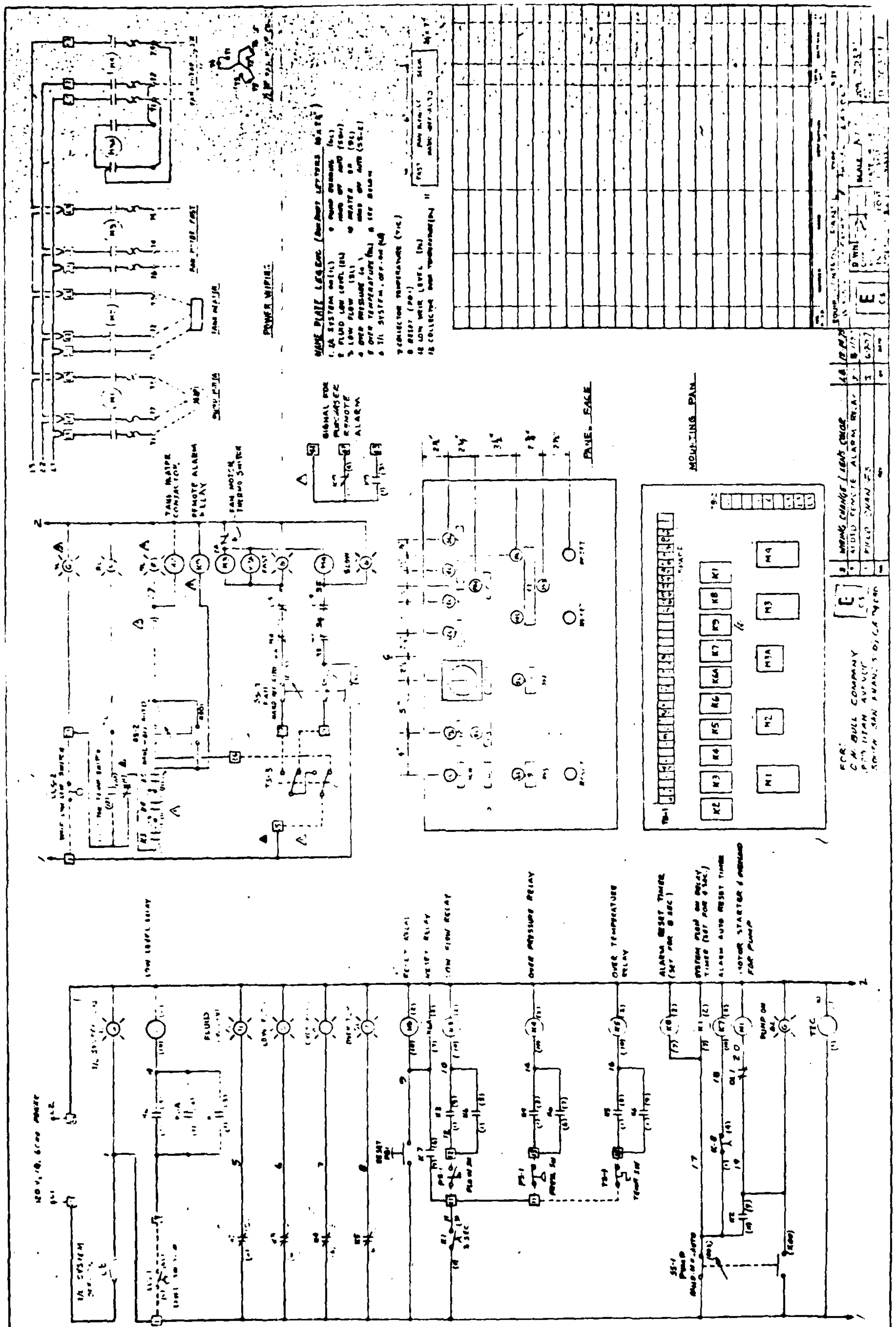
2. Open by-pass gate valve near top of reservoir. This in conjunction with automatic air vent at top of unit will permit drainage of liquid cooling coil. Drainage of discharge line from coil outlet to klystron and auxiliary load supply connections must be made externally.

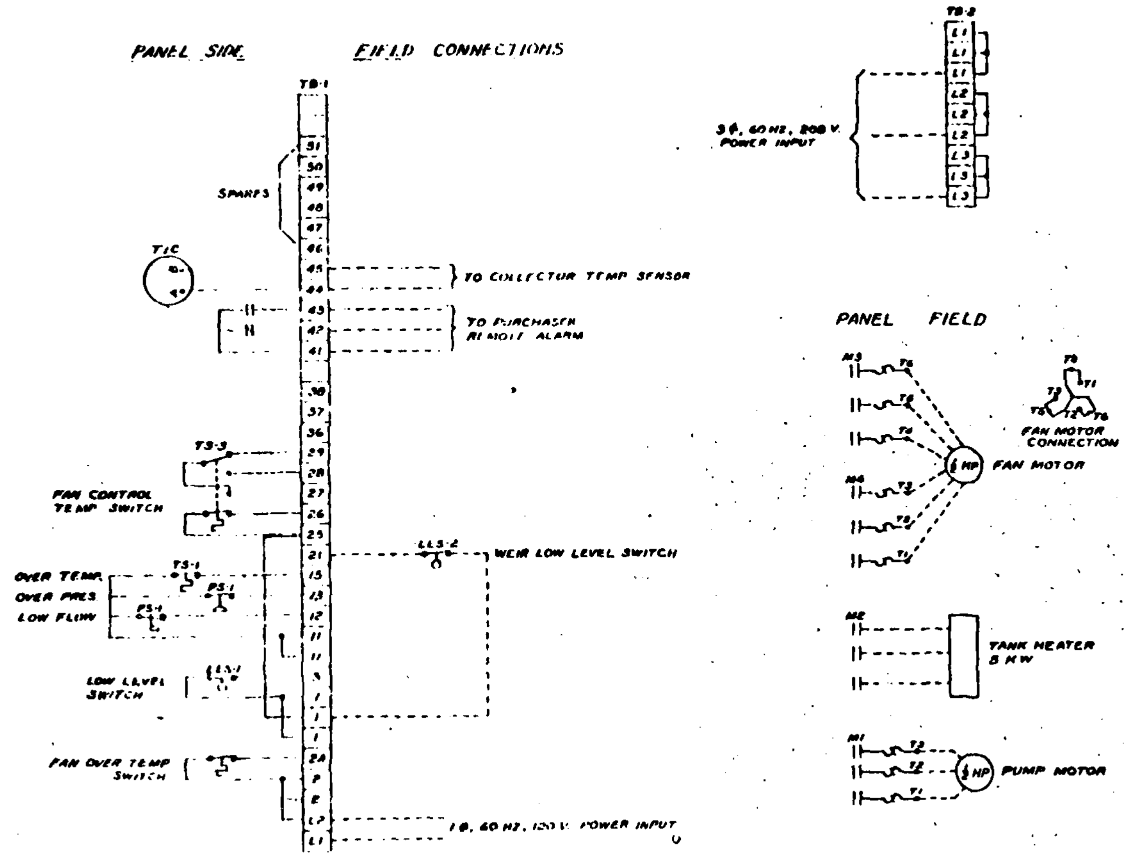
3. If system has been used with water instead of Dowtherm 209, it is strongly suggested that all piping be blown out prior to exposure to freezing conditions. Disconnect vapor hose connection to reservoir and cap nipple then plug return connections from klystron and auxiliary load. Pressurize through fill connection and collect discharges coolant at the two supply connections and the reservoir drain.




STEAM COIL INLET
FPT - SUPPLY
FPT - RETURN
WATER COIL
STEAM COIL
VAPOR INLET
VAPOR DRAIN
VENT
FILL
SIGHT GLASS
HEATER
DRAIN
FLOW DIAGRAM
TEMP GAUGE
PUMP
STRAINER - BASKET
SWITCH - SINGLE TEMP
SWITCH - DUAL TEMP
SWITCH - WATER FLOW
SWITCH - DIFF PRESSURE
VALVE - FLOW CONTROL
VALVE - GATE
VALVE - AIR VENT
FLOW GAGE
SUPPLY
RETURN
VIEW A-A
LT SIDE VIEW
REVISION
FLOW GAGE ADDED
C. H. BULL COMPANY
HEAT EXCHANGE UNIT MODEL
SHEET 2 of 3
76262


STEAM COIL OPENING
(AIR OUTLET)
CABINET
BACK VIEW
HINGED DOOR
RIGHT SIDE
REMOVABLE PANEL
WINDOW FOR
TEMP GAUGE
HINGED DOOR
FRONT VIEW
WINDOW FOR FLOW GAGE
ELECTRICAL
CONTROLS
BOX
FLUID SUPPLY
FLUID RETURN
LEFT SIDE




PANEL SIDE
FIELD CONNECTIONS
TB-1
SPARES
T/C
TO COLLECTOR TEMP SENSOR
TO PURCHASER REMOTE ALARM
TS-3
FAN CONTROL TEMP SWITCH
LLS-2
WEIR LOW LEVEL SWITCH
OVER TEMP.
OVER PRES
LOW FLOW
TS-1
PS-1
LOW LEVEL SWITCH
FAN OVER TEMP SWITCH
1Φ, 60 HZ, 120 V. POWER INPUT
TB-2
3Φ, 60 HZ, 208 V. POWER INPUT
PANEL FIELD
FAN MOTOR CONNECTION
FAN MOTOR
TANK HEATER
5 KW
PUMP MOTOR

VKC-7790 HEAT EXCHANGER

SPECIFICATION HE-1

The purpose of the specification is to outline the requirements of a heat exchanger to be used with and provide adequate cooling for the Varian VKC-7790 amplifier klystron. The unit shall be designed so as to use an absolute minimum of input power. Except for minor modifications, the heat exchanger design and operation shall be the same as the C.H.Bull Model No. 25DAK84. One notable difference, however, is that no space need be provided for mounting or housing of the VKC-7790 klystron and magnet.

A. MECHANICAL

1. The heat exchanger shall not exceed 68" in height, 37" in width, or 27" in depth. One protrusion is permissible beyond the 37" width dimension. The protrusion shall be limited to a 4" steam inlet duct. The protrusion is limited to 3" in length. The steam inlet shall be as high as possible.

2. External fluid flow (4 connections) shall be supplied from 3/4" female pipe connections, either flush mounted or recessed. These connections shall be adequately supported so that pipe nipples may be securely engaged without requiring access to the inside of the cabinet for wrench "back-up".

3. The air flow pattern shall be arranged so that both the air intake and air exhaust are at the rear of the cabinet.

4. The control panel and interlock sequence lights shall be the front of the heat exchanger and the control panel should be recessed and hermetically isolated from areas subject to fluid or vapor leakage. The control panel shall be as high as possible.

5. A sight glass shall be provided for fluid level observation and shall be easily visible from the front of the cabinet.

6. If possible, the filler pipe and drain shall be accessible at the front of the cabinet. The filler pipe shall be arranged so that the heat exchanger is easily filled. The drain shall be arranged so that the heat exchanger is easily and completely drained.

7. A prime consideration of the design shall be easy accessibility to all components with regard to maintenance and repair.

8. A mechanical layout drawing shall be submitted at the earliest possible date and must be approved by technical representatives of Varian Associates and the U.S. Army Electronics Command before construction of the heat exchanger can begin.

9. The heat exchanger, when packed for shipment, shall withstand transport by common carrier (truck, rail, aircraft or ship) and military cargo truck.

B. ELECTRICAL

1. All electrical circuits and components within the vapor or fluid areas shall be of explosion proof design.

2. Interlock protection and indicator lights shall include at least the following functions:

   a. Low flow
   b. Fluid over-temperature
   c. Fluid level
   d. Vapor over-pressure
   e. Collector over-temperature
   f. Low weir level
   g. Interlock closure

3. A recessed, hermetically isolated terminal board shall be provided for the following input and output functions.

Input:

a. 3Ø 208 plus neutral and ground.

b. Input for collector over-temperature meter relay

c. Low weir level input (to complete heat exchanger inter-lock chain)

Output:

a. External inter-lock closure (to provide closure for transmitter inter-lock chain, when all heat exchanger functions are operational).

4. A 4.5 to 5.0 kW heater shall be provided in the reservoir. The purpose of the heater is to reduce the time required for the heat exchanger to become operational after storage at low temperatures.

5. With the exception of the 5.0 kW heater used only under low temperature conditions, the input power requirements for the operation of the heat exchanger shall not exceed 0.8 kW.

C. <u>THERMAL</u>

1. The heat exchanger shall provide adequate cooling for the VKC-7790 klystron with an input of 25 kilowatts from the klystron, magnet and ancillary transmitter equipment. The unit must achieve the 25 kW exchange at 10,000 feet and 50°C ambient temperatures. The unit shall also be operational at 0°C ambient.

2. The heat exchanger shall be a combined vapor phase and liquid phase exchanger using 60% Dowtherm 209 and 40% water as the coolant medium.

3. Gasket material shall be either Butyl rubber or natural rubber.

4. The heat exchanger unit shall provide for two independent external fluid circuits. The first circuit shall provide 1 gpm flow at 70 psig to the klystron body and magnet. The second circuit shall provide 0.75 gpm flow at 70 psig.

5. Power inputs from the klystron and magnet will be approximately as follows:

   Power input from collector: 20 kW
   Power input from magnet and body: 2.8 kW

6. Maximum inlet temperature of fluid to the klystron body and magnet shall be 70°C.

APPENDIX F

RELIABILITY ANALYSIS

VKS-7830 KLYSTRON / COOLING SYSTEM

RELIABILITY MATHEMATICAL MODEL

SEQUENCE R001

CONTRACT NO. DAAB07-76-C-8072

PREPARED BY
VARIAN ASSOCIATES, INC.

RELIABILITY MATHEMATICAL MODEL FOR SYSTEM

Block Diagram and Mathematical Model

The reliabiilty block diagram consists of two components; the KLystron Amplifier and the Heat Exchanger.

Heat Exchanger	—	Klystron Amplifier	=	Mission Success

The mathematical modele for the successful operation (R_s) of the VKS-7830 system is $R_s = e^{-(59.428/10^6} t$

$R_s = R_H \times R_K$, or

$e^{-\lambda_s t} = (e^{-\lambda_H t})\ (e^{-\lambda_K t})$ and

$\lambda_s = \lambda_H + \lambda_K$

$\lambda_s = 34.899/10^6$ hours + $24.529/10^6$ hours

$\lambda_s = 59.428/10^6$ hours

The system MTBF = $^1/\lambda_s$ = 16,827 hours.

R_s = System Reliability R_H = Heat Exchanger Reliability

R_H = Heat Exchanger Reliability λ_H = Heat Exchanger Failure Rate

R_K = Klystron Reliability

λ_s = System Failure Rate

λ_H = Heat Exchanger Failure Rate

λ_K = Klystron Failure Rate

t = mission time

RELIABILITY ANALYSIS OF THE KLYSTRON AMPLIFIER VKS-7830

1.0 DESCRIPTION

The VKS-7830 is a 10 kilowatt klystron amplifier operating over the frequency band 2500 MHz to 2700 MHz. The tube is liquid, vapor and air cooled and is electromagnetically focused. The cathode is of the dispenser type with an expected life in excess of 100,000 hours.

The VKS-7830 is similar to the 5K70SG/5K70SK klystrons. The tube is scaled version of the 5K70SG except for the tuning mechanism. The tuner, which consists of a vacuum bellows and sliding short tuner (refer to Figure 1) is scaled from the 5K70SK. Therefore, the expected life of the VKS-7830 can be reasonably predicted from the 5K70SG/5K70SK.

2.0 MTBF PREDICTION BY SIMILARITY

The 5K70SG was designed and built for the NASA Apollo Space program. Forty-one tubes have been shipped from 1965 through 1976 with eleven tube failures occurring during this period (refer to Figure 3). The MTBF for the 5K70SG has been estimated at 40,768 hours. (MTBF based on 11-year operation at fourteen sites; seven-day, eight-hour, fifty-two week operation was assumed.) A Weibull Hazard graph estimating tube performance is shown in Figure 2.

The predicted failure rate by sub-assembly for the VKS-7830 is shown in the Tube Failure Tree (Figure 4).

3.0 CAVITY TUNER RELIABILITY

The tuner mechanism for the 5K70SK was subjected to life cycle tests to determine the reliability of the design. During the tests, critical performance characteristics were monitored to determine if changes were occurring during the cycling period. The first indication of vacuum pressure rise was to be considered end of life for the vacuum bellows and any erratic behavior in the frequency repeatability of the tuner was to be

FIGURE 1. SLIDING CONTACT MECHANISM FOR THE 5K70SK

varian

WEIBULL HAZARD
x 3 LOGARITHMIC CYCLES

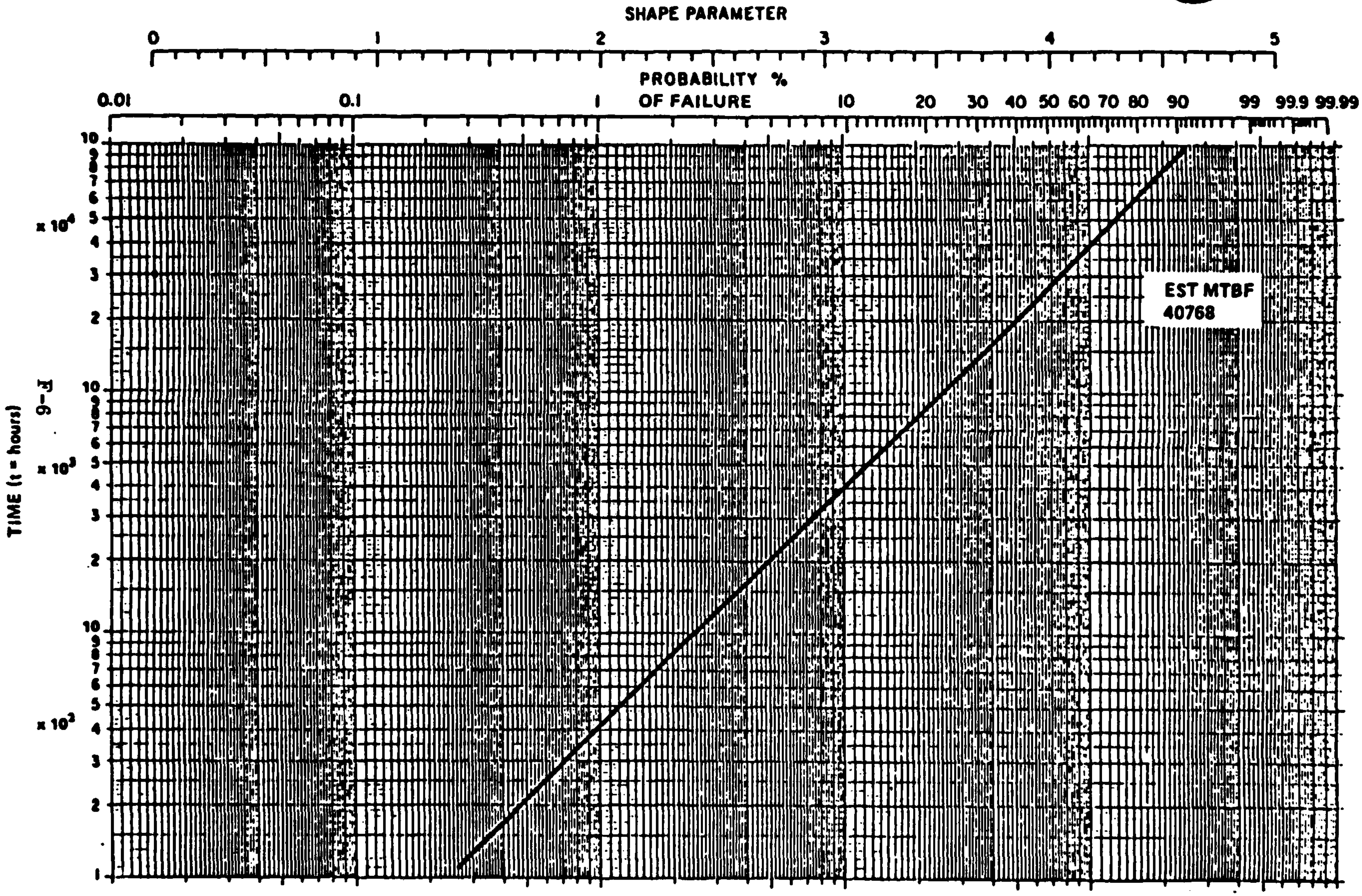


FIGURE 2. 5K70SG ESTIMATED TUBE PERFORMANCE

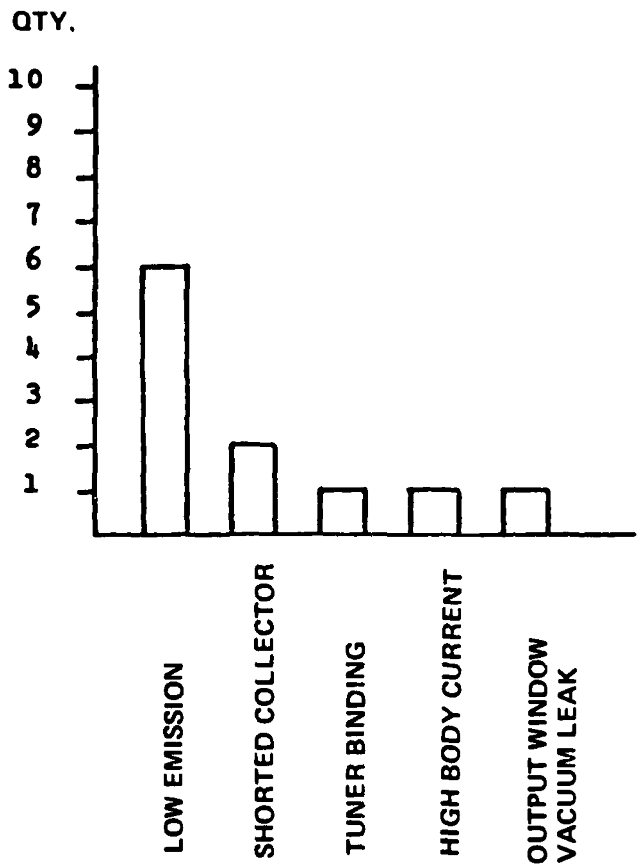
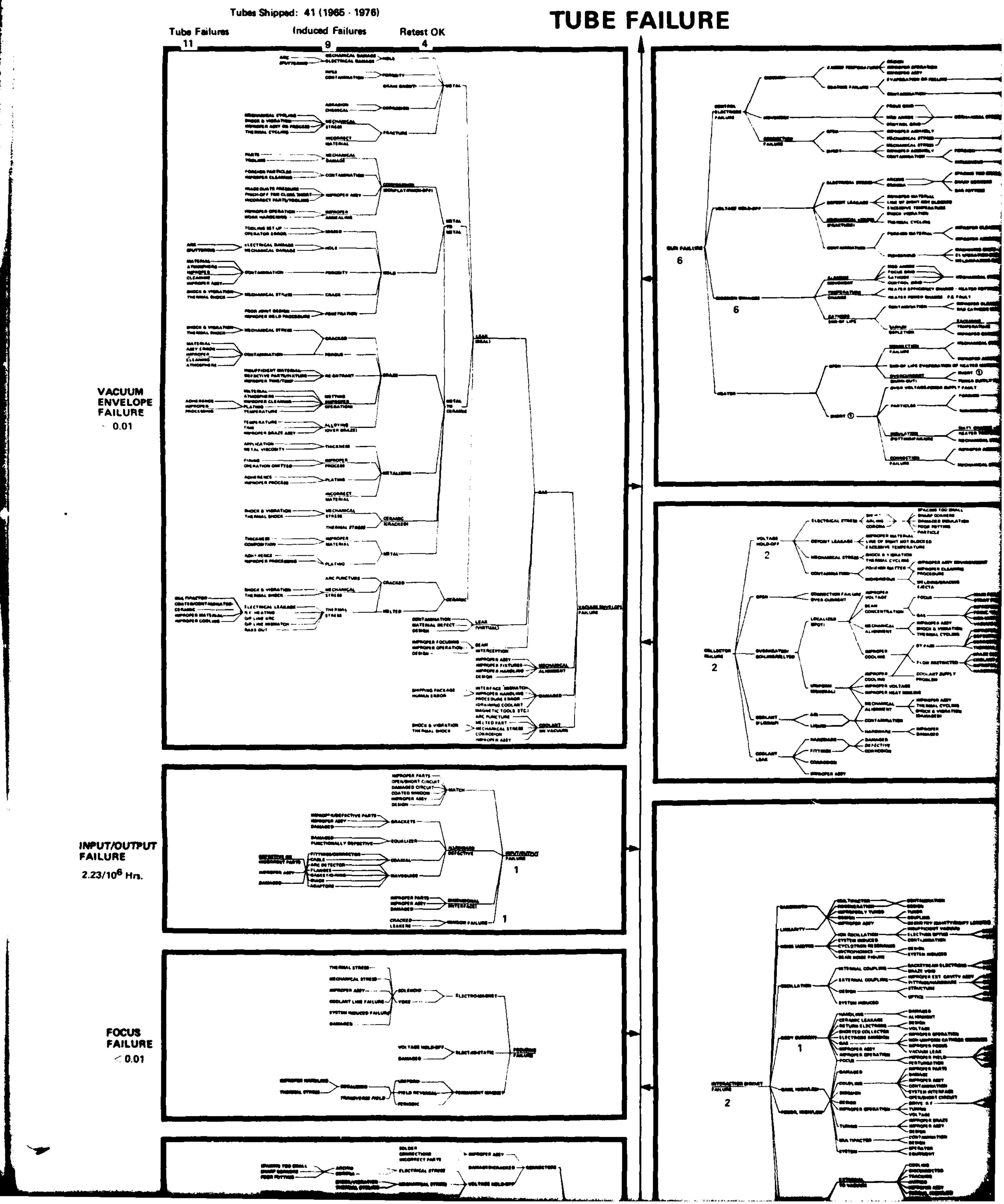
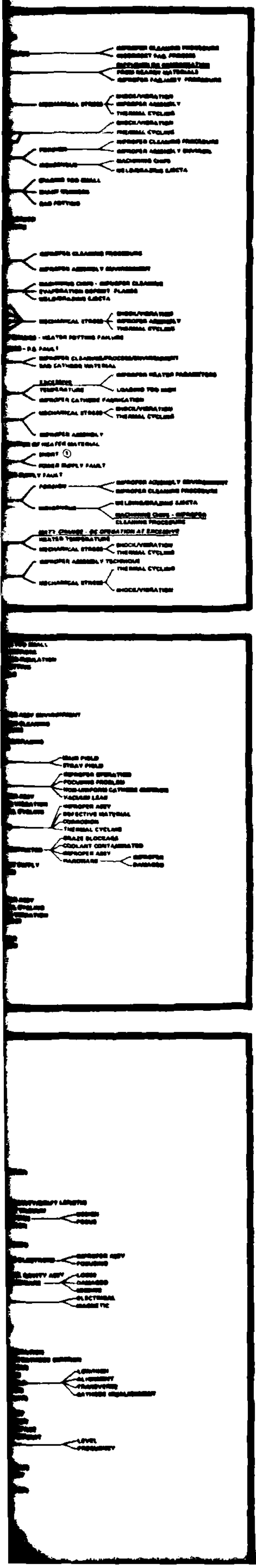


FIGURE 3. 5K70SG FAILURE MODES



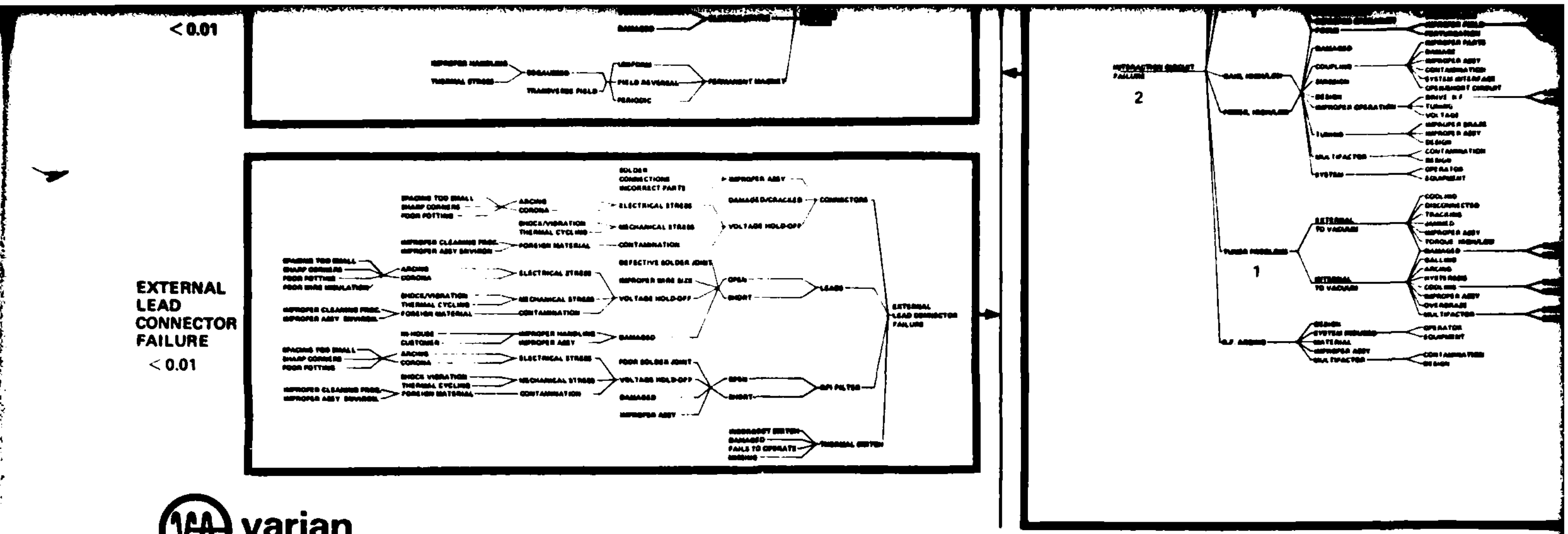
Tubes Shipped: 41 (1965 - 1976)
TUBE FAILURE
Tube Failures
11
Induced Failures
9
Retest OK
4
VACUUM ENVELOPE FAILURE
0.01
INPUT/OUTPUT FAILURE
2.23/10^6 Hrs.
FOCUS FAILURE
< 0.01
6
6
2
2
1
1
1
2



GUN
FAILURE
13.38/10^6 Hrs.

COLLECTOR
FAILURE
4.46/10^6 Hrs.

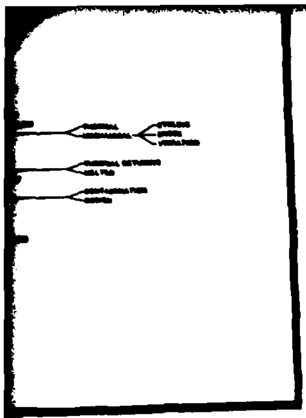
INTERACTION
CIRCUIT
FAILURE
4.46/10^6 Hrs.



varian

HYBRID or CAVITY AMPLIFIER FAILURE TREE

3



3/20/78

considered end of life for the sliding contact within the cavity. The goal was 10,000 cycles. Three separate tests were conducted. The variable for each test was the total travel of the sliding contact tuner. The following is the results of the three tests:

Travel Length	Cycles	Failure Mode
0.500 in	2,549	Bellows failure due to metal fatigue
0.350 in	3,183	Bellows failure due to metal fatigue
0.175 in	10,710	Bellows failure due to metal fatigue.

An estimate of the 5K70SK tuner life is graphically presented in Figure 5. Since the tests were a "sample of one" at each travel length, the probability of attaining 10,000 cycles for a travel length of 0.175 inches is 0.72. The mathematical model for the life of 5K70SK tuner is (f(Y) = $2.55 \times 10^4 - 1.06 \times 10^5 (X) + 1.19 \times 10^5 (X^2)$ where $0.175 \leq X \leq 0.500$.

The life of the VKS-7830 is dependent on cathode life and tuner life. Cathode wear-out is measured by the depletion of the cathode emitting material which results in the loss of output power. The rate of depletion is based on the loading of the cathode (A/cm^2). The loading of the VKS-7830 cathode is 0.3 A/cm^2 which corresponds to an expected life in excess of 100,000 hours (refer to Figure 6).

The end of life mechanism for the tuner assembly is mechanical failure of the tuner bellows which result in vacuum leaks. The life of the tuner is measured in cycles and is related to the travel of the sliding contact mechanism. The probability of failure is an extreme value distribution; as the travel length increases the probability of failure increases exponentially. The mathematical model for tuner life in cycles is f(y) = $2.55 \times 10^4 - 1.06 \times 10^5 (X) + 1.19 \times 10^5 (X^2)$ where $0.175 \leq x \leq 0.500$.

Thus the life of the tuner in hours is dependent on how often the freauency is adjusted and the average travel length per adjustment. The average travel length for the 5K70SK tuner is 0.175 inches which corresponds to a 10,000 cycle bellow life. The total active length of the bellows

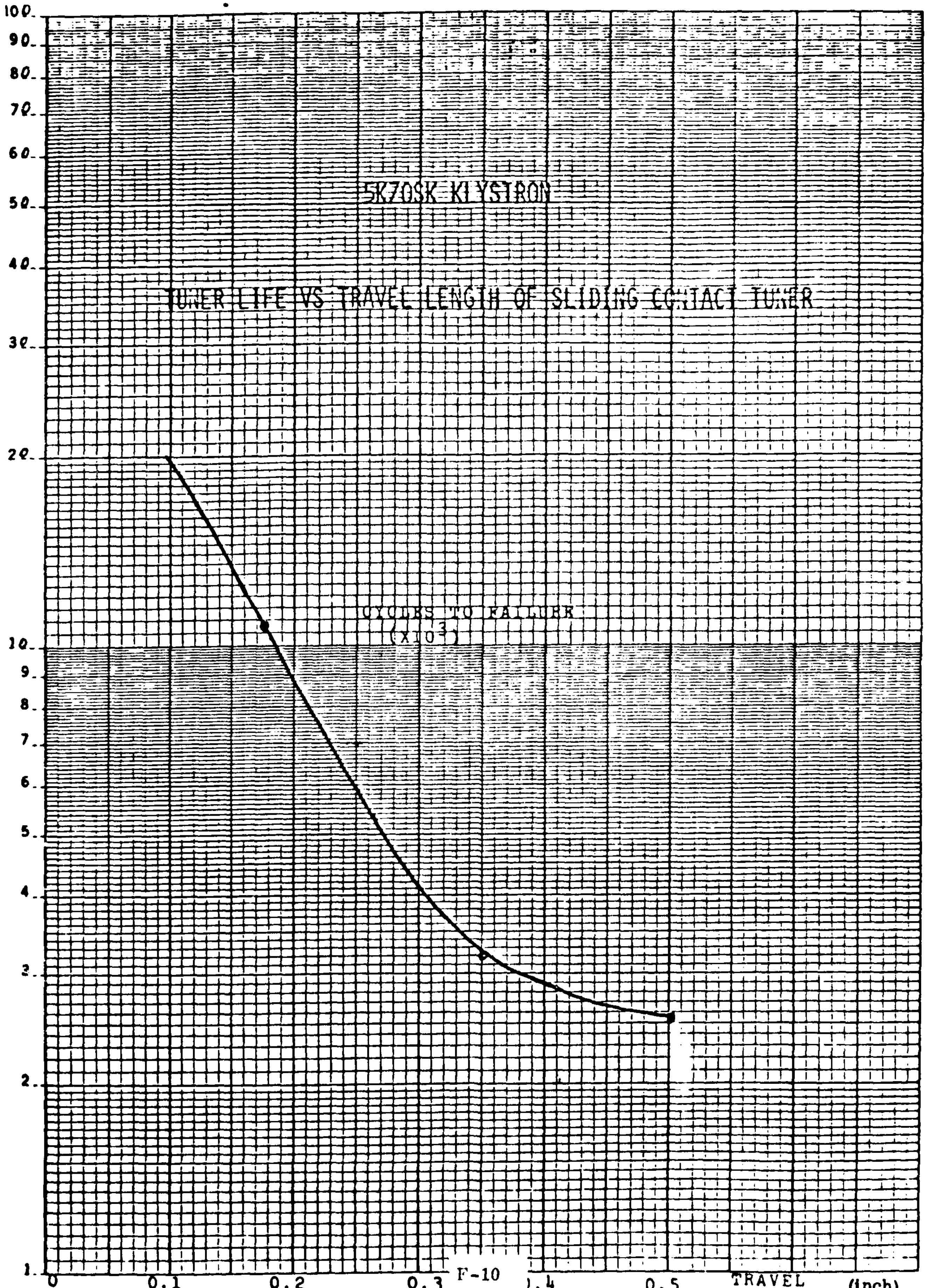


FIGURE 5. 5K70SK TUNER LIFE VS TRAVEL LENGTH OF SLIDING CONTACT TUNER

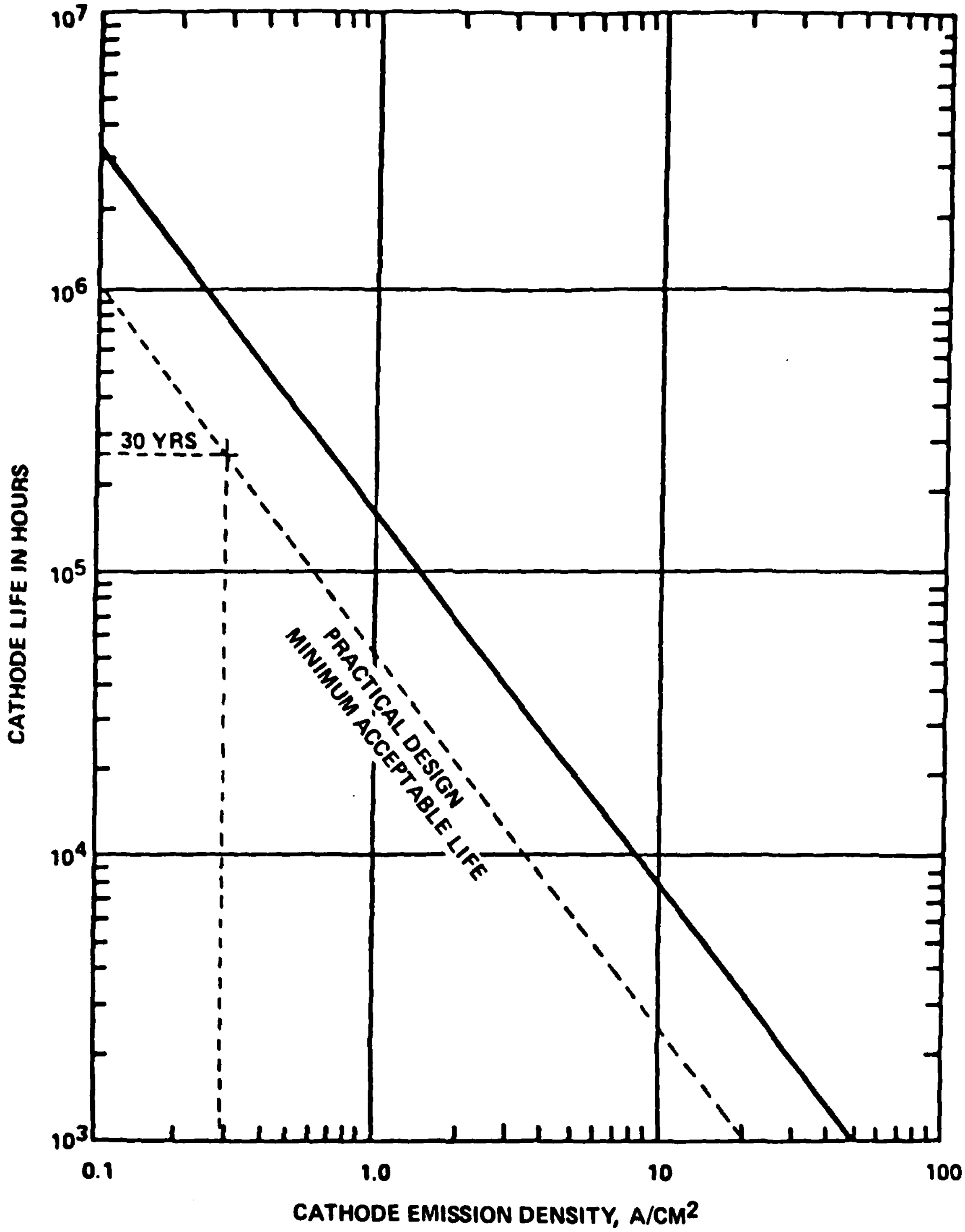


FIGURE 6. LIFE OF BARIUM-ALUMINATE IMPREGNATED CATHODES VS EMISSION LOADING

COMPONENT PARTS

Failure Rate Data

Unit Heat Exchanger

Date 11 May 1979

Type/Model 25DA-85

Operating and Environmental Conditions Ground Fixed

Item	Part Identification No.	Description	Manufacturer	Failure Rate $/10^6$ Hrs.	Qty	Failure Rate $/10^6$ Hrs.	Note
1	B-040-012	1/3 HP Motor		1.235	1	1.235	1
2	B-047-038	Pump	Decatur	0.342	1	0.342	2
3	B-013-005	Heater	Chromalox	0.268	1	0.268	3
4	B-039-108	Temp. Switch	United Electric	2.462	1	2.462	4
5	B-039-009	Temp. Switch	United Electric	2.462	1	2.462	4
6	B-039-010	Press. Switch	United Electric	0.976	1	0.976	5
7	B-037-014	Flow Switch	Gem	4.823	1	4.823	6
8	B-001-014	Water Coil	Anderson Heat Exchanger Coils	0.904	1	0.904	7
9	B-001-015	Steam Coil	Anderson Heat Exchanger Coils	—			7
10	B-041-012	Fan Ass'y	Aerovent	2.339	1	2.339	8
11	—	Relays	Potter Brumfield	1.909	8	15.272	[illegible]
12	—	Time Delay Relays	Omnetrics	1.908	2	3.816	10
					Total:	34.899	

Component Failure Rates from RAC "Non Electronic Parts Reliability Date", 1978. (NPRD-1)

Heat Exchanger Model #25DA-85

Component Parts Failure Rate Data Notes

All failure rate data taken from "Nonelectronic Parts Reliability Data" (NPRD-1) published by the Reliability Analysis Center at the Rome Air Development Center, Griffiss AFB, New York, 1978.

Note	Item	Nonelectronic Parts Reliability Data		
		Category	Page	Failure Rate
1	1	General A/C Motor	63	1.235
2	2	Turbine Driven Pump	72	0.342
3	3	Heater, General	54	0.268
4	4, 5	Thermostat	95	2.462
5	6	Pressure Switch	91	0.976
6	7	Flow Switch	88	4.823
7	8, 9	Heat Exchanger	55	0.904
8	10	Axial Fan	44	1.104
		General A/C Motor	63	1.235
9	11	Relays, General	78	1.909
10	12	Relays, Time Delay	81	1.908

convolutions used in the VKS-7830 is essentially identical to that used in the 5K70SK, and therefore the expected life should be identical to the 5K70SK.

4.0 SHELF LIFE

Tube life due to storage has been found to be insignificant. The Federal Aviation Administration has stated in their "High Power Microwave Tube Reliability Study" (Report #FAA-RD-76-172, Section V, para. C).

C. Shelf Life Factors

Data were available to measure trends of shelf life effects on tube life. It was determined, however, that no such trends existed in the data. Discussions with various tube manufacturers and users agree with the results from the data analysis. That is, if tubes are properly stored, their operating life should not be significantly reduced.

5.0 BLOCK DIAGRAM AND MATHEMATICAL MODEL

For system reliability purposes, the klystron amplifier can be considered as a single component. Thus, the reliability block diagram consists of one only block.

Klystron Amplifier

Therefore, based on the proceeding, the mathematical model for the successful operation (R) of the VKS-7830 klystron amplifier is:

$R = e^{-t/40,768}$, where t is the mission time in hours.

APPENDIX G

COMMENTS ON THE PRINCIPLES AND ADVANTAGES OF VAPOR PHASE COOLING

This Appendix is a reprint of Appendix C, R & DTR ECOM-0228-2, July 1971, A. Goldfinger and M. Levin.

APPENDIX G

COMMENTS ON THE PRINCIPLES AND ADVANTAGES OF VAPOR PHASE COOLING

Vapor phase cooling systems eliminate some of the disadvantages of water-cooling systems by exploiting the latent heat of vaporization of water. Raising the temperature of one gram of water from 40°C to 70°C (as in a water system) requires 30 calories of energy. Transforming one gram of water at 100°C to steam vapor requires 540 calories. In a vapor-cooling system, then, a given quantity of water will remove nearly twenty times as much energy as in a water-cooling system. Power densities as high as 200 watts per square centimeter at atmospheric pressure have been attained through vapor-phase cooling. A typical vapor-phase cooling installation consists of a tube with a specially designed anode immersed in a "boiler" filled with distilled water. When power is applied to the tube, anode dissipation heats the water to 100°C; further applied energy causes the water to boil and be converted into steam vapor. The vapor is passed through a condenser where it gives up its energy and is converted back to the liquid state. This condensate is then returned to the boiler, completing the cycle. The result is a system that reduces the water flow requirement nearly twenty times and in many applications eliminates the pump required in a circulating water system. A bonus is almost complete silence during operation.

A dramatic improvement over water-cooling systems is the reduction in the size of the heat exchanger required. A heat exchanger of any given thermal capacity can be reduced in size if the mean temperature gradient (ΔTm) between the cooled liquid and the secondary coolant can be increased. In a typical water-cooled system, water enters the heat exchanger at 70°C and leaves at 40°C, the mean temperature being 55°C. With air as a secondary coolant (or heat sink) at about 30°C, there is a mean temperature differential, ΔTm of 25°C. In a typical vapor-cooling system, vapor enters the condenser at 100°C, water leaves at about 100°C resulting in a mean temperature of 100°C. The mean temperature differential ΔTm then between the steam and the air is now 100°C - 30°C = 70°C, or nearly three times that of the water-cooled system. Tests have confirmed that steam-to-water heat exchanger equipment for a vapor-cooled system will require only one-third to one-quarter the area of flow associated with water-cooled systems.

Where air-cooled exchangers are preferred, this higher thermal gradient can be exploited in reducing the size of the heat exchanger equipment or in lowering the blower horsepower requirement. In some instances where sufficient area is available, natural convection alone is used to cool the steam condensers, resulting in complete elimination of the condenser blower.

Where water is preferred as a secondary coolant, similar ratios apply and water consumption is drastically reduced.

ELECTRONICS TECHNOLOGY AND DEVICES LABORATORY
DISTRIBUTION LIST

101 Defense Technical Information Center
ATTN: DTIC-TCA
Cameron Station (Bldg 5)
012 Alexandria, VA 22314

203 GIDEP Engineering & Support Dept
TE Section
P.O. Box 398
001 NORCO, CA 91760

205 Director
Naval Research Laboratory
ATTN: CODE 2627
001 Washington, DC 20375

301 Rome Air Development Center
ATTN: Documents Library (TILD)
001 Griffiss AFB, NY 13441

437 Deputy for Science & Technology
Office, Asst Sec Army (R&D)
001 Washington, DC 20310

438 HQDA (DAMA-ARZ-D/Dr. F.D. Verderame)
001 Washington, DC 20310

482 Director
US Army Materiel Systems Analysis Actv
ATTN: DRXSY-T
001 Aberdeen Proving Ground, MD 21005

563 Commander, DARCOM
ATTN: DRCDE
5001 Eisenhower Avenue
001 Alexandria, VA 22333

564 Cdr, US Army Signals Warfare Lab
ATTN: DELSW-OS
Vint Hill Farms Station
001 Warrenton, VA 22186

Commander
US Army Communications Systems Agency
ATTN: CCM-RD
006 Fort Monmouth, NJ 07703

579 Cdr, PM Concept Analysis Centers
ATTN: DRCPM-CAC
Arlington Hall Station
001 Arlington, VA 22212

602 Cdr, Night Vision & Electro-Optics
ERADCOM
ATTN: DELNV-D
001 Fort Belvoir, VA 22060

603 Cdr. Atmospheric Sciences Lab
ERADCOM
ATTN: DELAS-SY-S
001 White Sands Missle Range, NM

607 Cdr, Harry Diamond Laboratories
ATTN: DELHD-CO, DC (In Turn)
2800 Powder Mill Road
001 Adelphi, MD 20783

609 Cdr, ERADCOM
ATTN: DRDEL-CG, CD, CS (In Turn)
2800 Powder Mill Road
001 Adelphi, MD 20783

612 Cdr, ERADCOM
ATTN: DRDEL-CT
2800 Powder Mill Road
001 Adelphi, MD 20783

680 Commander
US Army Electronics R&D Command
000 Fort Monmouth, NJ 07703

1 DELEW-D
1 DELET-DD
1 DELSD-L (Tech Library)
2 DELSD-L-S (STINFO)
6 Originating Office
015 4 DELET-BM

681 Commander
US Army Communications R&D Command
ATTN: USMC-LNO
001 Fort Monmouth, NJ 07703
001 DRDCO-COM-RM-3

103 Code R123, Tech Library
DCA Defense Comm Engrg Ctr
1800 Wiehle Ave.
001 Reston, VA 22090

104 Defense Communications Agency
Technical Library Center
Code 205 (P.A. Tolovi)
001 Washington, DC 20305

314 Hq, Air Force Systems Command
ATTN: DLCA
Andrews Air Force Base
001 Washington, DC 20331

418 Commander
HQ, Fort Huachuca
ATTN: Technical Reference Div
001 Fort Huachuca, AZ 85613

518 TRI-TAC Office
ATTN: TT-DA
001 Fort Monmoth, NJ 07703

FAILURE
4.46/10^6 Hrs.

END

DATE FILMED

1 81

DTIC