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294 926

Final Development Report

for

The Design and Development

of

A One-Half Watt Heater Power Reduced Size Nuvistor Triode

THIS REPORT COVERS THE PERIOD

27 JUNE 1960 TO 15 NOVEMBER 1962

RADIO CORPORATION of AMERICA

ELECTRON TUBE DIVISION

HARRISON, NEW JERSEY

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NAVY DEPARTMENT BUREAU of SHIPS ELECTRONICS DIVISION

Contract No. NObsr 81478

Index No. SR0080302 ST-140

RADIO CORPORATION OF AMERICA
ELECTRON TUBE DIVISION
HARRISON, NEW JERSEY

January 7, 1963

Department of the Navy
Bureau of Ships
Washington 25, D. C.

Attention: Chief, Bureau of Ships - Code 691A3

Subject: Contract No. NObsr 81478
Index No. SR0080302 ST-140

Dear Sir:

Enclosed herewith are nine (9) copies of the Final Development Report for the period 27 June 1960 to 15 November 1962 and two (2) copies of Developmental Manufacturing Information under subject contract.

If additional copies of the enclosed report are required or further information is desired, it is requested that inquiries be directed to:

Mr. R. T. Jeffery
Contract Administration
Radio Corporation of America
415 South 5th Street
Harrison, New Jersey

Very truly yours,

Jim Rose

G. M. Rose, Manager
Special Development Activity

GMR:md

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Contract No. NObsr 81478

Index No. SR0080302 ST-140

Prepared: R.K. Reusch, W.J. Helwig

Approved: G.M. Rose, Jr.

Engineering Data Requirements - Military Specification MIL-R-978 (SHIPS), 1 December 1949

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ABSTRACT

This report covers the design and development of two reduced size nuvistors having one half watt heaters. One is a sharp cut-off medium mu triode similar in characteristics to the RCA 7586 Industrial Nuvistor Triode. Its RCA developmental number is A15274. The other is a remote cutoff version of the A15274, and its RCA developmental number is A15330. Both types were designed with the aid of a computer.

The A15274 has a transconductance of 12.0 millimhos at 7 milliamperes of plate current. It operates as a grounded grid amplifier at 500 Mc/s with a noise factor of 5.9 db. and can sustain oscillation at frequencies up to at least 2 Gc/s.

The A15330 has a transconductance of 10.0 millimhos at 7.9 milliamperes of plate current and it can tolerate about 130 millivolts of undesired signal at its grid before 4% cross modulation is exceeded. At 500 Mc/s the noise factor in grounded grid configuration is about 6.0 db.

Fifty samples of the A15274 and twenty samples of the A15330 have been delivered to the contracting agency.

It is believed that both types, the A15274 and the A15330 have met the objective specifications of the contract.

PART I

PURPOSE

GENERAL FACTUAL DATA

DETAIL FACTUAL DATA

CONCLUSIONS

PURPOSE

The original objective of this program was the design and development of a small size ceramic-metal envelope medium mu triode, of concentric cylindrical cantilever electrode construction, having a maximum heater power of one-half watt and other electrical characteristics approximating those of the RCA nuvistor general purpose triode, type 7586. This developmental tube was to be suitable for general purpose RF amplifier applications. Fifty (50) developmental samples of this design were to be furnished the contracting agency.

Later the scope of the contract was modified to include a second objective which was the modification of the above described design to produce a mechanically similar triode with a remote cutoff characteristic. This second developmental tube was to be of the same basic construction and maintain the low heater power requirements. Twenty (20) developmental samples of this second design were to be furnished the contracting agency.

GENERAL FACTUAL DATA

IDENTIFICATION OF PERSONNEL

Herbert J. Ackerman - Engineering Leader, Techniques Engineering Group, Methods and Process Laboratory. Mr. Ackerman received his Bachelor of Science degree in Mechanical Engineering from the College of the City of New York in 1951 after serving with the Army Air Force during the war and is currently working towards his MS in Management Engineering at Newark College of Engineering. He has been with RCA since 1951 working in the field of tool design, equipment design, and methods development for the production of developmental electron device components. Mr. Ackerman is a member of Pi Tau Sigma and Tau Beta Pi.

Harold J. Albrecht - Technician, Advanced Development Group. Mr. Albrecht received his training as a toolmaker in the Essex County Vocational and Technical High School in Newark, N.J. He worked for Breeze Corporation, Inc. in their Airplace Cartridge Starter department as a toolmaker and assembler, and later was foreman of the department for four years until 1945. He then started in the Model Shop of National Union Electric Research Laboratory as a technician. In 1950 he was made a working foreman of the department. His duties consisted of developing both the tools, dies and fixtures to manufacture all the parts of developmental vacuum tubes, and spinning techniques for economical small-lot production. In 1956 he joined the Electron Tube Division of RCA as an engineering technician and has been engaged in the development of vacuum tube parts, tools, dies and fixtures. Mr. Albrecht is credited with the production of the first wire guides for the nuvistor grid machines, including the wire guides for the grids of the tubes covered in this report.

John J. Carrona - Engineering Leader, Chemical & Physical Laboratory. Mr. Carrona received the degree of Bachelor of Science in Mechanical Engineering from the Newark College of Engineering in 1950 and the degree of Master of Science in Metallurgy from the Stevens Institute of Technology in 1958. He joined RCA in 1954 and has been engaged in the metallurgical problems associated with tube structures.
Mr. Carrona served with the U.S. Army Air Force during the war and from 1950 to 1954 was Plant Manager for the North American Research Laboratory.

Hugh Cort, Jr. - Analyst Programmer, Technical Systems Planning Group. Mr. Cort is a graduate of the University of Missouri with additional work at Pomona College and Cornell University. After serving ten years as an officer in the U.S. Army he became an equipment engineer with the Western Electric Co. He then served as an analyst and programmer for engineering data systems. In 1958 he became the EDPM Program Coordinator for Western Electric Company Engineering Coordination Project 216L-SAGE. Mr. Cort joined RCA in 1960 and has worked extensively on the application of computers to tube design.

Margaret Deevy - Technician, Advanced Development Group. Miss Deevy joined RCA in 1940 as a glass tube mounter. She was transferred to the Advanced Development Group in 1942 and since that time has assisted in most of the developmental work of this laboratory including the V.T. fuse tube, fine wire diamond drawing dies, the transducer tube, transistors, the pencil tube including the ceramic pencil tube, and nuvistors. Miss Deevy fabricated many of the critical parts for, and mounted and processed, the tubes covered in this report.

Andrew G.F. Dingwall - Senior Engineer, Chemical & Physical Laboratory. Dr. Dingwall received the degree of Bachelor of Science in Mechanical Engineering from Princeton University in 1949 and the degree of Master of Science in Mechanical Engineering from Columbia University in 1950. He was a Fulbright Exchange Scholar at the University of Sheffield, England in 1951 with a renewal in 1952. He received his PhD in Glass Technology at Sheffield in 1953. He also received the degree of Master of Science in Mathematics at the Polytechnic Institute of Brooklyn in 1956. He is currently working toward a doctorate in mathematics at the Polytechnic Institute of Brooklyn. Dr. Dingwall has been with RCA since 1953 and for the last several years has been engaged in the application of reaction-rate theory to studies of the mechanism of deterioration of electron tubes on life. Dr. Dingwall is a member of the American Ceramic Society, Society of Glass Technology and a past-chairman of the New York Metropolitan Section of the American Ceramic Society.

Alfred O. Farrar - Associate Engineer, Techniques Engineering Group, Methods and Process Laboratory. Mr. Farrar received a diploma in Tool Design from the Industries Training School of Stevens Institute of Technology in 1956 and is currently working toward a Bachelor of Science degree in Mechanical Engineering. In 1956 he joined the Baker Contact Division of Engelhard Industries as a Tool Engineer. Prior to that he had been with Wright Aeronautical Division as a Process Engineer. He joined RCA in 1958 as an associate engineer in the Product Development Activity engaged in engineering tooling systems and designing tools for developmental production of metal parts. Mr. Farrar is a Senior Member of the American Society of Tool and Manufacturing Engineers.

Lawrence P. Garvey - Engineer, Chemical and Physical Laboratory. Mr. Garvey received his Bachelor of Science Degree in Ceramic Engineering from Alfred University in 1948 after having served with the U.S. Army in the Manhattan Project during 1944-1946. He joined Babcock and Wilcox in 1948 as a ceramics engineer where he was engaged in development work on high temperature refractory materials. He joined RCA in 1953 as an engineer in the ceramics group, and has been engaged in developmental work on ceramic structures and parts for electron devices. Mr. Garvey is a member of the American Ceramic Society and of the National Institute of Ceramic Engineers.

George V. Gerber - Engineer, Nuvistor Techniques Group. Mr. Gerber received the degree of Bachelor of Science in Mechanical Engineering from Bucknell University in 1949 and the Master of Science degree in Mechanical Engineering from Clarkson College of Technology in 1951. He joined the Hyatt Bearings Division of General Motors in 1951 where he was engaged in the design of parts and fixtures for use with roller bearings until 1953 when he transferred to the Aircraft Engineering Section of Hyatt as a project engineer. He has been associated with RCA since 1956 where he was employed as an engineer in the Methods and Processes Laboratory and has been engaged in development work on ceramic pencil tubes and nuvistors. Mr. Gerber is a member of the Institute of Radio Engineers and the American Ceramic Society.

William J. Helwig - Engineer, Advanced Development Group. Mr. Helwig received his Bachelor of Science degree in Electrical Engineering from Newark College of Engineering in 1948 after having served with the U.S. Navy during the war. He has done graduate work in Electrical Engineering at Stevens Institute of Technology and the University of Pittsburgh. He was with the Westinghouse Electric Corporation where he worked on the development of X-Ray Image Intensifier Tubes until his recall to the Navy in 1951. He joined RCA in 1953 where he worked on projects such as ceramic pencil tubes and nuvistors. He is a member of Tau Beta Pi and a senior member of the Institute of Radio Engineers and is Past Chairman of the New York Chapter of the IRE Professional Group on the Electron Devices. Mr. Helwig is project engineer of this contract.

<u>Albert P. Kauzmann</u> - Engineer, Advanced Development Group. Mr. Kauzmann received his Bachelor of Science degree in Electrical Engineering from the Massachusetts Institute of Technology in 1927. He joined the Champion Radio Works in 1927 where he worked as a receiving tube design engineer. In 1929 Mr. Kauzmann did graduate work in physics at the University of Munich. He has been with RCA since 1931 as a design engineer. He is responsible for the development of the early wide-band amplifier tubes such as the type 6AC7 and rectifiers such as the 5Z4. Mr. Kauzmann is a Senior Member of the Institute of Radio Engineers.

<u>Roy H. Kirkland, Jr.</u> - Engineer, Test Engineering Group. Mr. Kirkland received the degree of Bachelor of Science in Mechanical Engineering from the University of Tennessee in 1951, and is taking post-graduate work toward his Master of Science degree at Newark College of Engineering. He was employed by Wright Aero Division of the Curtiss-Wright Corporation working in the Vibration and Stress Analysis Division of the Research Department until 1955. He joined the Walter Kidde Co. in that year as supervisor of the Environmental Testing Group engaged in development of the Auxiliary Power Unit for the North American Navaho missile. He became associated with RCA in 1957 as an Environmental and Mechanical Engineer for the Electron Tube Division and has been concerned with the development of mechanical testing techniques on receiving tubes, including nuvistor types. Mr. Kirkland is a member of the Institute of Environmental Sciences.

<u>M. Berwyn Knight</u> - Engineering Leader, Advanced Development Group. Mr. Knight received his Bachelor of Science degree in Electrical Engineering from the University of Wisconsin in 1948, after having served with the U.S. Army during World War II. He joined RCA in 1948 in the Receiving Tube Application Laboratory where he worked on circuit applications for tubes. In 1954 he transferred to Receiving Tube Advanced Development where he worked on the development of special tubes for color television receivers. He was responsible for the design of the commercially available type 7630, a beam deflection tube used in single sideband communication circuits. Mr. Knight has had 25 papers published on electron tubes and tube applications and is a Senior Member of the Institute of Radio Engineers.

<u>Roger A. Krey</u> - Engineer, Advanced Development Group. Mr. Krey graduated from M.I.T. in 1936 with a degree in General Engineering. Employed at the Electron Tube Division of RCA since 1955, he has worked on the application of ceramic-metal construction to receiving tubes and related electrical devices. One of his accomplishments is the soluble compound used to metalize ceramics for the nuvistor receiving tube. Mr. Krey's experience, prior to joining RCA, included service as technical instructor and aircraft pilot in the Army, and five years as an instructor in mechanical engineering at Worcester Polytechnical Institute and Clarkson College.

Edward Lee - Engineer, Chemical and Physical Laboratory. Mr. Lee received the degree of Bachelor of Science in Metallurgical Engineering from the University of Pennsylvania in 1949. He was then employed by the Frankford Arsenal as a research and development engineer. From 1950 to 1958 he was with the Wright Aeronautical Division where he was engaged in the development of high temperature alloys. Mr. Lee has been with RCA since 1958 as an engineer working on metallurgical problems associated with materials for electron tubes.

Norman L. Lindburg - Engineer, Advanced Development Group. Mr. Lindburg received the B.S. degree in Physics from Oregon State College in 1952. He then served two years in the U.S. Navy as a commissioned officer in the Special Weapons Project, including a year's training at Sandia Base. In 1954, Mr. Lindburg joined the Radio Corporation of America and was assigned to the Receiving Tube Advanced Development Department of the Electron Tube Division in Harrison. He worked on the early development of designs and processing techniques for various types of electron tubes including pencil tubes, high-gm triodes, secondary-emission amplifier tubes, and nuvistor power pentodes. He is presently engaged in the early design and fabrication techniques on new electron devices.

Robert D. McLaughlin - Engineer, Test Engineering Group. Mr. McLaughlin received the degree of Bachelor of Science in Electrical Engineering from Cornell University in 1952, and received the degree of Master of Management Engineering from the Newark College of Engineering in 1959. He was an Engineering Officer in the U.S. Navy from 1953 to 1955. He has been with RCA in the Test Engineering Group since 1955 where he has been engaged in the development of specialized test equipment for both regular and unconventional receiving tubes.

Robert S. Nelson - Engineer, Nuvistor Design Group. Mr. Nelson received the Bachelor of Science degree in Electrical Engineering from Massachusetts Institute of Technology in 1956. He joined RCA at that time as a member of the Advanced Development Group where he was engaged in the development of beam-deflection tubes, UHF oscillator tubes, and nuvistor types. He is presently with the Nuvistor Design Group. Mr. Nelson is a member of the Institute of Radio Engineers.

Charles J. Pearce - Senior Engineer, Methods and Process Laboratory. Mr. Pearce attended Case Institute of Technology and Polytechnic Institute of Brooklyn. Prior to 1930 he was employed by General Electric where he was engaged in the development of mercury-filled devices, and gas or mercury-vapor filled electron tubes. Since his transfer to RCA in 1930 he has been associated with the development and processing of glass, metal, miniature and subminiature classes of receiving tubes, and the equipment for evacuating them or rare-gas filling. From early 1959 he has been working on developmental nuvistor exhaust equipment and processing techniques.

Donnel W. Power - Engineering Leader, Advanced Development Group. Mr. Power received his Bachelor of Science degree in Electric Engineering from Purdue University in 1929. He joined the General Electric Company in 1929 and transferred to the newly formed RCA Tube Division in 1930. He has been engaged in Advanced Development Activities since joining RCA including projects such as the first metal kinescopes, pencil tubes, and nuvistors. Mr. Power is a Senior Member of the Institute of Radio Engineers.

Nicholas E. Pryslak - Engineering Leader, Methods and Processes Laboratory. Mr. Pryslak was graduated from the RCA Institutes with a diploma in Communications Engineering in 1940 and has studied Electrical Engineering at the Newark College of Engineering and Stevens Institute of Technology. He joined RCA in 1936 as a technician and in 1943 was assigned as an engineer in the Tube Development Shop. He has worked on such projects as the development of a K-band klystron in conjunction with the MIT Radiation Laboratory, K-band and S-band magnetrons in cooperation with the Columbia University Radiation Laboratory, pencil tube development and more recently nuvistors. Mr. Pryslak is a Senior Member of the Institute of Radio Engineers.

Raymond K. Reusch - Engineer, Advanced Development Group. Mr. Reusch received his Bachelor of Science degree in Electrical Engineering from the University of Illinois in 1952. After joining RCA in 1952 he served as a Lieutenant and Radio Officer in the U.S. Army from 1952 to 1954. Since his return to RCA he completed the Specialized Trainee Program and was assigned to the Advanced Development Activity of the Electron Tube Division. He has been engaged in UHF noise studies of developmental pencil triodes, the development under a Signal Corps contract of an S-Band Triode Transmitter Unit, and performance studies of developmental nuvistors for RF applications.

Otto H. Schade, Sr. Staff Engineer, Advanced Development Group. Dr. Schade studied at the Technische Hochschule at Berlin-Carlottenberg and was invested with the honorary degree of Doctor of Engineering by Rensselaer Polytechnic Institute in 1953. He has been with RCA since 1931 where he has been engaged in work such as the original development of beam power tubes. He has received the Modern Pioneers Award of the National Association of Manufacturers, the Morris Liebmann Memorial Prize of the Institute of Radio Engineers, the Fellowship Award of the Society of Motion Picture and Television Engineers and the David Sarnoff Gold Medal Award of the SMPTE. Doctor Schade is a Fellow of the Institute of Radio Engineers

Otto H. Schade, Jr. - Engineer, Advanced Development Group. Mr. Schade received the degree of Bachelor of Electrical Engineering from Rensselaer Polytechnic Institute in 1953 and joined the Receiving Tube Design Group of RCA in that year. He was responsible for the design and development of beam power receiving tubes and damper diodes. The 6DQ5 and 6DE4 were among his developments. After transfer to the Advanced Development Group in 1959 Mr. Schade has been engaged in design and development work on nuvistors. Mr. Schade is a member of Eta Kappa Nu and a member of the Institute of Radio Engineers.

Harry F. Schellack - Engineer, Methods and Processes Laboratory. Mr. Schellack received the degree of Bachelor of Science in Mechanical Engineering from the Newark College of Engineering in 1955 and is currently completing graduate work in Electrical Engineering at the same college. He has been with RCA since 1955 as an engineer in the Methods and Processes Laboratory engaged in parts and developmental equipment design as well as tool design for the making of electron tube parts. Mr. Schellack is a member of Pi Tau Sigma and a member of the American Society of Mechanical Engineers.

Hamilton D. Woodland - Associate Engineer, Techniques Engineering Group, Methods and Process Laboratory. Mr. Woodland received his Bachelor of Science degree in Mechanical Engineering from Newark College of Engineering in 1952. He is currently working toward his MS in Mechanical Engineering at Newark College of Engineering. He was with Harris Structural Steel Company as a supervisor of a structural design department. He has been with RCA in the Method and Process Laboratory since 1956 as an engineer working on tooling methods and techniques for the development of new electron device components.

INDIVIDUAL MAN HOURS EXPENDED

27 June 1960 to 30 November 1962

Engineers:	R. K. Reusch	3037
	W. J. Helwig	2837
	R. H. Kirkland	607
	R. D. McLaughlin	478
	A. G. F. Dingwall	432
	A. O. Farrar	429
	O. H. Schade, Sr.	389
	D. W. Power	407
	M. B. Knight	340
	C. J. Pearce	319
	F. J. Feyder	236
	S. Y. Husni	216
	G. V. Gerber	142
	A. P. Kauzmann	104
	O. H. Schade, Jr.	102
	N. E. Pryslak	99
	W. J. Bachman	91
	W. A. Harris	88
	R. A. Krey	78
	H. Cort	67
	L. P. Garvey	67
	N. L. Lindburg	58
	T. F. Berry	57
	T. J. Henry	50
	E. Lee	40
	J. J. Carrona	34
	H. D. Woodland	32
	L. H. Gnau	31
	H. J. Ackerman	29
	E. P. Bertin	22
	R. T. Hansen	19
	H. F. Schellack	13
	R. S. Nelson	10
	J. A. Forman	9
	R. Longobucco	6
	C. W. Horsting	4
	H. Blust	2
	C. L. Raynor	2
	R. E. Brown	1
	A. Liebman	1
	R. J. McGovern	1
	C. Meltzer	1
	H. Wittlinger	1

Total Engineering 10,988

Individual Man Hours Expended (Cont.)

Semi-Technical:	M. M. Deevy	880
	H. J. Albrecht	793
	G. Stone	598
	F. Kolandra	204
	J. Filipczak	97
	F. Kot	81
	D. Doerner	63
	C. Seylaz	56
	D. Pidgeon	44
	E. Gioia	31
	R. Henry	28
	D. Parris	26
	H. Skurnik	26
	W. Lipke	12
	E. J. Clifford	9
	N. Gebrian	7
	W. S. Hutchison	7
	E. Mercer	6
	O. Marcin	2
	L. Tissot	2
	J. Zuber	2
	C. Berman	1
	W. Czander	1
	Total Semi-Tech.	2,976

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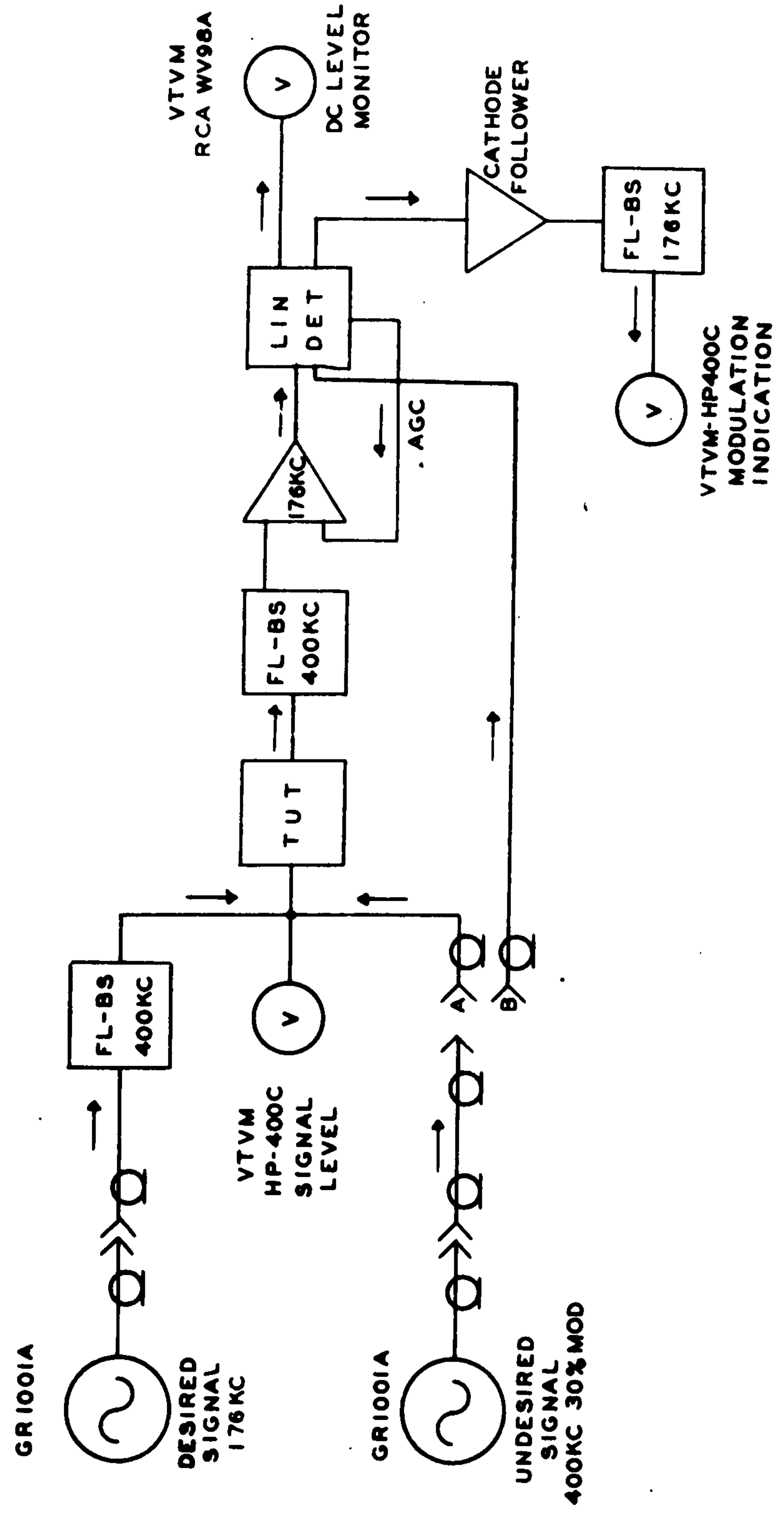
MEASUREMENT PROCEDURES

Cross Modulation Testing Procedure

The circuit arrangement used in making cross modulation measurements described elsewhere in this report is shown in Fig. 1. The desired frequency used is, of itself, unimportant. Too low a frequency would make the filters unwieldy, too high a frequency would make voltage measurements difficult. The suitable frequency of 176 kc/s was chosen because of the commercial availability of components for this frequency. The undesired frequency of 400 kc/s was arbitrarily chosen. It is, however, one that presents no spurious response with the desired signal. Suitable band supression filters are inserted at points in the measurement chain to preclude measurement error. In operation the desired signal is applied to the apparatus at sufficient level to cause operation of the automatic gain control system of the 176 kc/s amplifier and the detector dc level is noted. The desired 176 kc/s signal is not modulated at any time during the tests. The 176 kc/s signal is then removed and the 400 kc/s undesired signal is applied to the detector input (connection B of Fig. 1) and its level is adjusted to give the same detector dc level as produced previously by the 176 kc/s signal. The 400 kc/s signal is modulated at an arbitrary 30% during the tests, this value being sufficiently high for measurement purposes but low enough to produce distortion-free modulation from the signal source. With this 400 kc/s 30% modulated signal applied to the detector input the reading of the modulation level vacuum tube voltmeter is noted. The 400 kc/s signal is removed from the detector input and applied to the tube under test (connection A, Fig. 1). The 176 kc/s desired signal input is also reapplied to the tube under test. This level is not critical if sufficient 176 kc/s signal level is applied since the automatic gain control circuit will hold the detector level constant. The operating point of the tube under test is adjusted to any desired set of values and the level of the undesired 400 kc/s signal is increased from zero until the modulation indicator VTVM reads the desired value. This value has been chosen as 4% of the level indicated when the 400 kc/s undesired signal was applied directly to the detector input. Although, for comparison purposes, any percentage could be used, it is customary to choose a perfect square, such as 1%, 4% or 9%, because the percentage of cross modulation is related to the square of undesired signal voltage. Choosing a perfect square facilitates the mental transposition to different percentages of cross modulation. Values lower than 4% are subject to error in this particular equipment because of hum and other noise. A measurement of the signal level at the input of the tube under test then gives the value of RMS voltage of modulated undesired signal which causes 4% of the modulation of this undesired signal to be impressed on the desired 176 kc/s carrier. Because the level of the undesired 400 kc/s signal is very much greater than the desired 176 kc/s signal, it



CROSS MODULATION
MEASUREMENT
CIRCUIT DIAGRAM

Fig. 1

is not normally necessary to remove the 176 kc/s signal during this measurement. Since the desired 176 kc/s signal is unmodulated during the test all of the modulation which is measured in the detector output is due to cross modulation produced in the tube under test from the modulated undesired signal. The procedure may be repeated at various operating points of the tube under test to give a point by point cross modulation characteristic of the tube under test.

Equivalent Noise Resistance Testing

Johnson[5] first equated the shot noise produced in an electron tube with the noise produced in a resistance connected across the input of a theoretically noise free tube and Pearson[8] described apparatus for determining the value of this equivalent resistance. The equipment used for determination of equivalent-noise-resistance values quoted in this report follows the method of Pearson in that a value of resistance is inserted in the grid circuit of the tube under test and this resistance is adjusted to double the noise power output produced by the tube under test with no resistance in the grid circuit. A diagram of the equipment used is shown in Fig. 2. The apparatus basically consists of a four stage band pass amplifier with a center frequency of 450 kcs and a square-law detector which operates an indicating device. The actual bandwidth of the amplifier is unimportant. Although the total noise power produced by either the tube under test or the substituted resistance is a function of bandwidth, this factor is a common denominator in both measurements made and is effectively cancelled out. A center frequency of 450 kcs was chosen because of the availability of commercial components and because this frequency is high enough to eliminate the effects of "flicker noise" yet low enough to eliminate the effects of induced grid noise. The values of equivalent resistance as measured are therefore a measure of shot-noise in the tube under test and should not be confused with equivalent noise resistances quoted by other authors[6,10] wherein the values are determined by different methods and at much higher frequencies.

In operation the tube to be tested is incorporated in the amplifier input circuit as shown in Fig. 2. The grid of the tube under test is connected directly to a bias supply (switch in Cal position) and the operating point of the tube is determined by adjusting the bias and plate supplies. With the tube operating, the gain of the amplifier is adjusted to give a convenient deflection on the output indicator of the square-law detector. A variable resistance (R_{eq}--Fig. 2) is then inserted in the grid circuit of the tube under test (switch in test position). This variable resistance is then adjusted to produce an additional noise output equal to that produced by the tube without the added resistance in the grid circuit. This additional but equal amount of noise may be determined in two ways. In one method the reading of

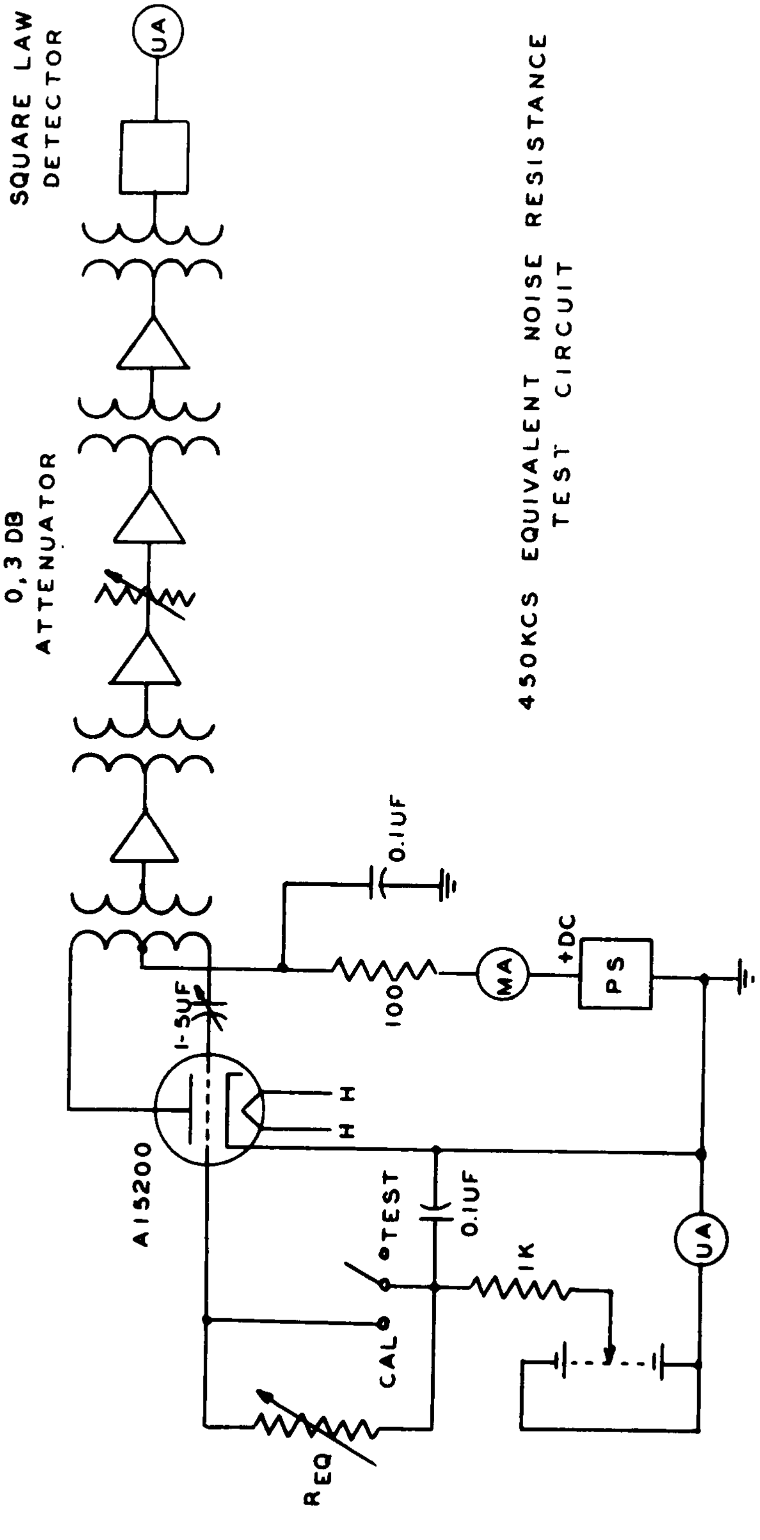

SQUARE LAW DETECTOR
UA
0,3 DB ATTENUATOR
450KCS EQUIVALENT NOISE RESISTANCE TEST CIRCUIT
0.1UF
1-5UF
100
MA
+DC
PS
H
H
A15200
TEST
0.1UF
1K
UA
CAL
REQ

Fig. 2

noise output of the square law detector with the tube alone being operated is noted with the 0-3 db attenuator depicted in Fig. 2 in the 0 db position. This switch is then put in the 3 db position, the variable resistance is inserted in the grid circuit and then adjusted to give the same reading as previously obtained. In the other method the attenuator may be left in the 0 db position and the variable resistance adjusted to give a reading on the output indicator which is just twice that obtained without the resistance in the circuit. Ordinarily, in operation both methods are used as a check on readings. The value of the substituted R_{eq} (a decade box is used) is the value of equivalent noise resistance value which produces an amount of thermal agitation noise equal to the shot noise of the tube under test.

Mechanical Resonance Testing

Comparative measurements of cathode support stiffness were made by determining the resonant frequency of the cathode structure. Subassemblies for test were made by brazing cathode flanges to the cathode support members in the normal manner. These assemblies were attached to a vibration test plate with organic cement at the base of the flange and coated cathode cups were subsequently slipped on the support tubings. The vibration test plate was 1/16th inch thick aluminum attached at two points to the frame of a small loudspeaker. This mounting has been found to produce components of vibratory motion adequate for excitation of the transverse vibration resonances of electrode structures. Resonance was determined by observation of motion at the top of the cathode with the aid of a microscope. Although this method departs in some respects from actual conditions in an operating tube, the differences can be of some advantage for comparison tests. The absence of the heater is one advantage. The heater introduces a minor uncontrolled variable to the structure because its mass is only slightly coupled to the cathode structure through the relatively compliant heater wire at a few points of contact which are not easily controlled in assembly and which are subject to change even during vibration tests. The resonant frequency in an operating tube will be roughly 10 per cent lower than under the test condition because the high operating temperature of the cathode and support reduces the elastic moduli. Finally, there is a slight effect from the compliance of the cathode flange as mounted on three wires in a tube compared to the mounting on the test plate.

Noise Factor Measurements

The noise factor values quoted in this report have been determined using the apparatus described in Fig. 3. The test amplifier is operated under grounded grid conditions with a shorted quarter wave line for anode circuit tuning. The line is a rectangular section of unplated brass approximately 1-1/4 inches on a side with a circular center conductor 1/4 inch in diameter. The RF output is taken from a movable probe capacitively coupled to the center conductor.

The input to the amplifier is tuned by a pair of movable shorted stubs. The output is tuned by adjusting the movable short on the plate line to give maximum power into a 50 ohm termination. The plate loading is adjusted by varying the position of the capacitive probe. The cathode circuit contains a variable cathode resistor (R_k - Fig. 3) for adjusting the bias of the tube under test. RF is blocked from this cathode resistor by an RF choke. A second stage RF amplifier is located between the test amplifier and the mixer to reduce the magnitude of the correction for the second and succeeding stages contribution to the noise factor and to eliminate the correction for noise power input at the image frequency. This second stage is of the same type construction as the test amplifier stage but uses another nuvistor type. The other components of the measuring apparatus are commercially available items. The noise generator is of the gas discharge type and is used in conjunction with an Airborne Instruments Laboratories 72A automatic noise factor indicator. For gain measurements a Hewlett Packard calibrated signal generator is used as the signal source.

In operation the "A" connection of Fig. 3 is made with the RF signal generator set to the test frequency and the local oscillator is adjusted to give the proper IF frequency (30 Mcs). The two RF amplifier stages are then tuned for maximum response along with the two sets of tuning stubs at the outputs of the amplifier stages. The set of tuning stubs at the input of the test RF amplifier stage are adjusted for minimum VSWR. The output of the RF signal generator is then noted for a given reading of the detector output meter which is included in the General Radio Model 1216A IF amplifier unit. The "A" connection of Fig. 3 is then removed and the "B" connection substituted. The overall noise factor of the system is read on the AIL Model 72A automatic noise factor measuring equipment. These two measurements are repeated after removing the test RF amplifier and its associated input tuning stubs from the system. A comparison of the signal generator outputs in the "A" connection of Fig. 3 will determine the gain of the test amplifier stage and the noise factor determined in the "B" connection is used as the second stage noise factor in the computation of the first stage noise factor. The noise factor of the first stage is calculated from the usual formula [4]

$$F = F_1 + \frac{F_2 - 1}{G_1}$$

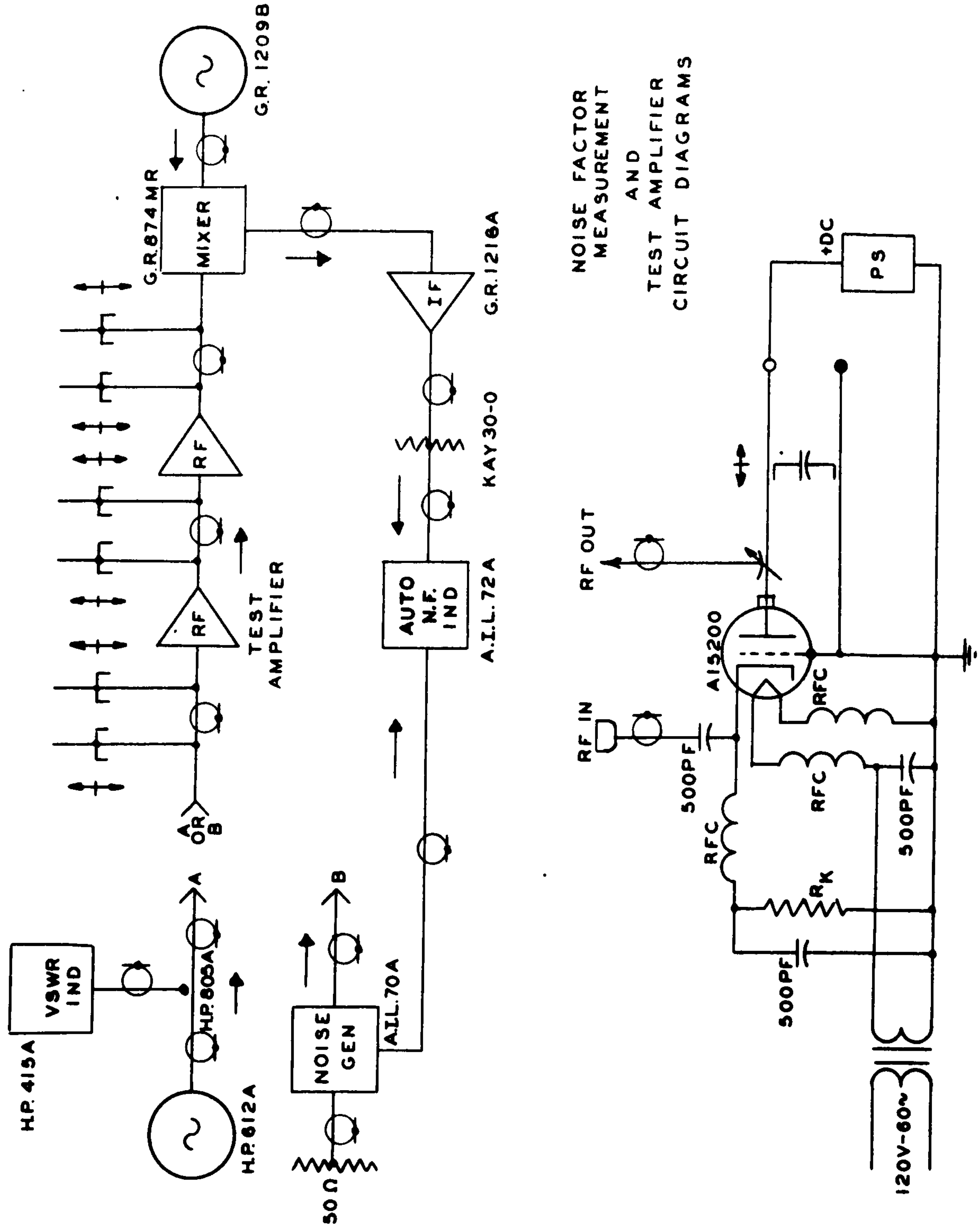

NOISE FACTOR MEASUREMENT AND TEST AMPLIFIER CIRCUIT DIAGRAMS
G.R. 1209B
G.R. 874 MR
MIXER
IF
G.R. 1216A
KAY 30-0
AUTO N.F. IND
A.I.L. 72A
RF
RF
TEST AMPLIFIER
A OR B
A
B
VSWR IND
H.P. 415A
H.P. 805A
H.P. 612A
NOISE GEN
A.I.L. 70A
50 Ω
PS
+DC
RF OUT
RF IN
A15200
RFC
RFC
RFC
500PF
500PF
500PF
R_K
120V-60~

Fig. 3

where F is the overall noise factor, F_1 is the noise factor of the first stage, F_2 is the noise factor of the second stage and G_1 is the gain of the first stage. It is the value of F_1 which is quoted elsewhere in this report as the tube noise factor. As described above, the input to the test RF amplifier stage was tuned by means of the input stubs for minimum VSWR. Values of F_1 derived in this manner are referred to herein as the matched noise factors. Measurements of F_1 made by adjusting the input stubs not for minimum VSWR but for minimum overall noise factor as indicated on the A.I.L. Model 72A indicating equipment are referred to herein as optimum noise factors.

Transconductance Measurements

In general, all measurements of tube parameters were made on a General Radio Vacuum Tube Bridge Type No. 561-D. Some of the measurements of transconductance which are shown later in this report are made in a special manner in that the grid is operated at approximately space potential. The circuit being used to measure transconductance is shown in Fig. 4. It will be noted that the grid is returned to a positive ten volt supply through a 20 megohm resistance. This will assure a constant value of one-half microampere of grid current. The plate of the tube under test is returned to a variable positive voltage supply so that plate current may be adjusted to a predetermined fixed value. Fixing both the plate and grid currents assures that the field distribution in the area of the grid is constant from test-to-test and that values of transconductance measured are not affected by extraneous potentials. During a test the plate current is adjusted by adjusting the plate voltage supply and the grid potential is measured by means of an electrometer connected to the grid through a decoupling network consisting of the 100,000 ohm resistance and the 0.02 microfarad capacitor shown in Fig. 4. The value of voltage read at the grid is an indirect measurement of the contact difference of potential between the emitting surface of the cathode and the grid. Although the voltages measured are not an absolute value of contact potential a change in this value from test-to-test is an absolute measure of the actual change in contact potential.

By using a measurement system such as this it is possible to discriminate among some of the causes of change of transconductance with life of a tube. Change in contact potential of the grid is directly separable and may be eliminated as a reason for transconductance change but at the same time the measurements yield data on the time variations in contact potential. While such data may not directly interest the circuit designer it is invaluable in the actual development of tube designs and processing schedules.

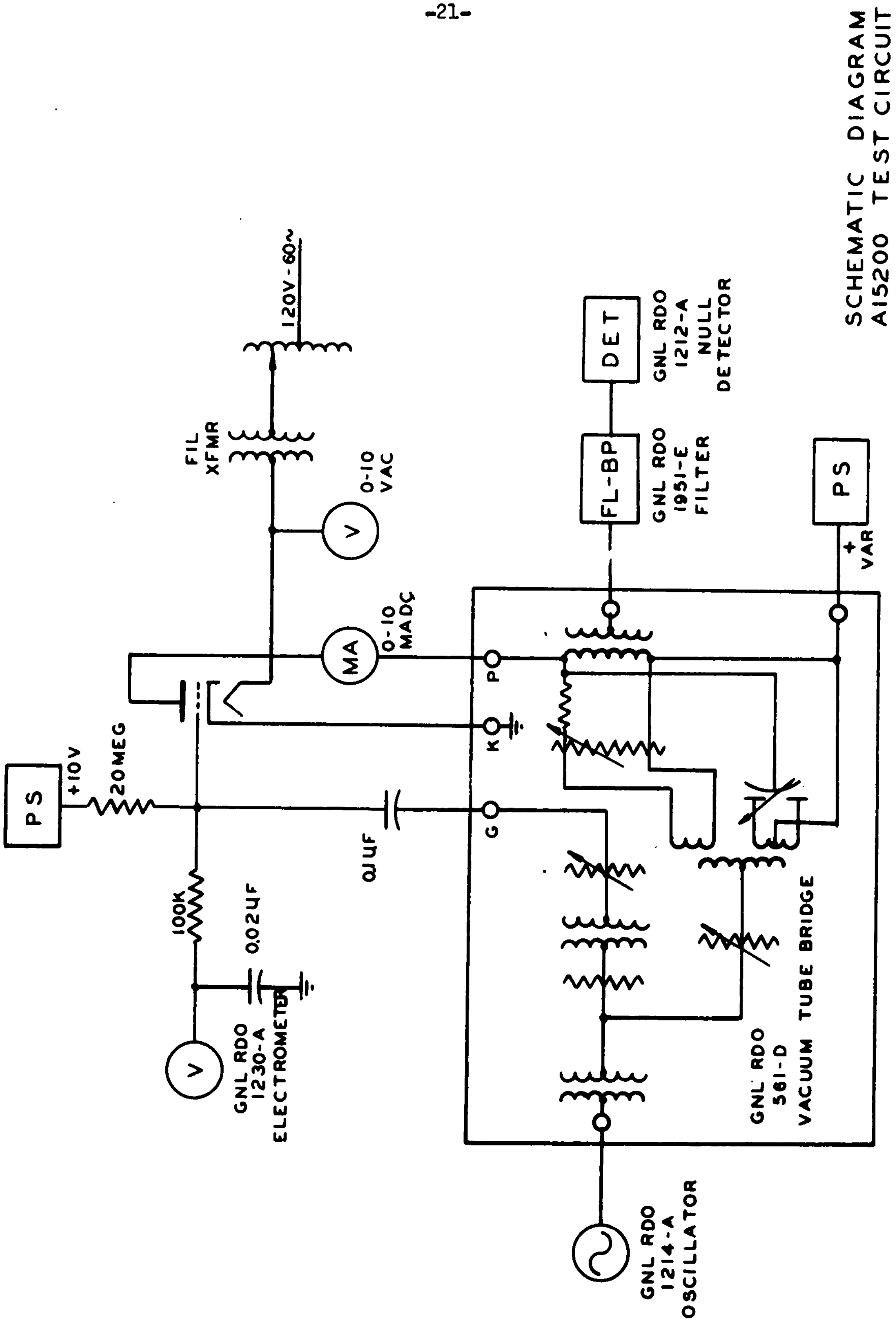

SCHEMATIC DIAGRAM
A15200 TEST CIRCUIT
120V-60~
FIL
XFMR
0-10
VAC
V
MA
0-10
MADC
P
K
G
PS
+10V
20MEG
0.1UF
100K
0.02UF
V
GNL RDO
1230-A
ELECTROMETER
FL-BP
GNL RDO
1951-E
FILTER
DET
GNL RDO
1212-A
NULL
DETECTOR
PS
+
VAR
GNL RDO
561-D
VACUUM TUBE BRIDGE
GNL RDO
1214-A
OSCILLATOR

Fig. 4

Two Terminal-Pair Parameter Measurements

Measurements from which the two terminal-pair parameters of developmental type A15274 have been determined were made with the circuit shown in Fig. 5. A General Radio Function and Immittance Bridge is used as the basic measuring device with an AN/APR-4 receiver as the detector. A test fixture is connected directly to the measurement terminals of the bridge by coaxial connectors. This test fixture is designed to allow the measurement of an RCA developmental type A15274 in the grounded-grid type of operation. The effective input and output terminals of the device which are being measured are the plate cap and the socketed cathode terminal. The grid is grounded in the test fixture by means of a ring of spring fingers contacting the shell ring of the tube. The measurements made in this manner are therefore not of the tube elements alone but actually of the tube and its associated socketing. The test fixture is designed so that the fixture can be attached to the bridge in either electrical directions (AA-BB or AB-BA in Fig. 5). This allows both forward and reverse admittances to be measured. Proper voltage polarities must be applied to the input and output bias terminals of the bridge depending on the connection of the test fixture.

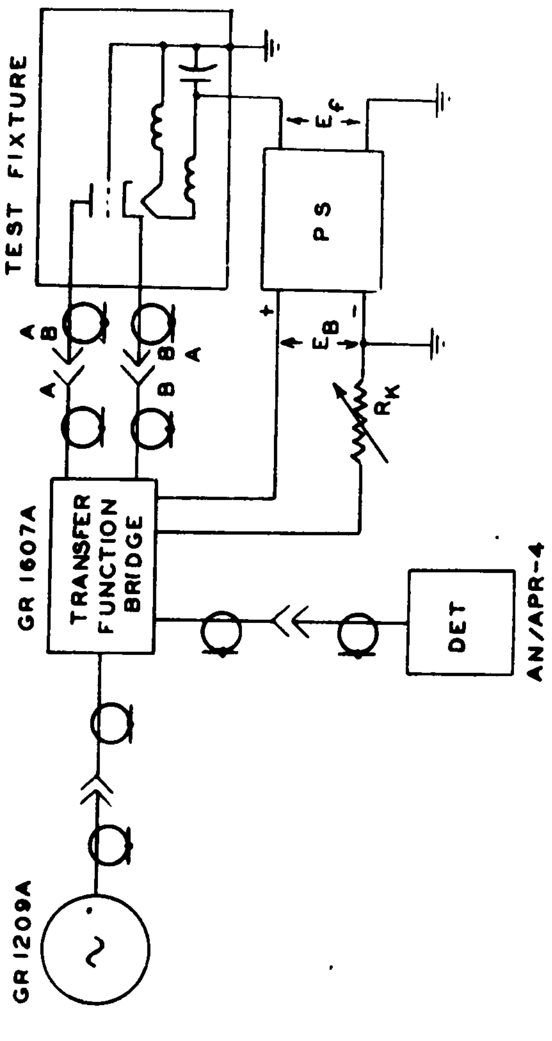
Y_{11} (short circuit input admittance) is measured by arranging the bridge to measure admittance. An rf short circuit is presented to the tube plate terminals (the bridge is equipped to do this) and the admittance of the socket cathode terminal is measured.

Y_{21}, the forward transfer admittance, is measured with the bridge arranged to measure transfer admittance. The transfer admittance between the socket cathode terminal and the plate top cap is measured.

Y_{12}, the feedback transadmittance, and Y_{22}, the short circuit output admittance, must be measured indirectly due to the small magnitude of some of the components, i.e. g_{22}, the short circuit output conductance. The values of Y_{12} and Y_{22} are derived by means of a method presented by W. A. Harris.[2] The locus of Y_1, the input admittance, is found for the condition of g_3 (the output termination conductance) held constant and b_3 (output termination susceptance) varied from minus infinity to plus infinity. This is done for two suitable known values of g_3. The locus of Y_1, when plotted against an admittance plane, will always be a circle provided the network under test is linear. Circles obtained from different values of g_3 will be tangent to each other at Y_{11}. Y_{12} and Y_{22} are then derived from the characteristics of the circles.

Miscellaneous Measurements

A number of additional measurements are described on the Tentative Military Specification Sheets. Also, a few measurements of a minor nature are described in the text of the report.



TWO TERMINAL-PAIR PARAMETER MEASUREMENT CIRCUIT DIAGRAM

Fig. 5

DETAIL FACTUAL DATA

DEVELOPMENTAL TUBE TYPE IDENTIFICATION

Under this contract, a number of tube types were developed in the course of the design that led to the final types delivered. Some of these types led toward further development and others were made to investigate feasibility of design variations but no further work followed. These various tubes are identified by developmental type numbers assigned by RCA and are here briefly described.

RCA Developmental Type A15200

This is the initial design model developed under this contract. It is a double-ended tube with four-pin linotetrar basing and a plate cap. The heater power is 450 mw. and typical operation gives a transconductance of 9.0 mmho at 7 ma plate current.

RCA Developmental Type A15258

This is an envelope variation using the electrode structure of the A15200. The envelope is reduced in size and all electrode terminals, with the exception of the heater leads, are coaxial. The electrical characteristics of the A15258 are identical to those of the A15200. Only a few samples were made for exploration and to demonstrate feasibility.

RCA Developmental Type A15261

This is a basing variation of the A15200. Instead of the linotetrar base, this type has a coaxial cathode terminal. Only a few samples were made to demonstrate feasibility.

RCA Developmental Type A15274

This is the final design of the sharp cut-off version and is the type that was delivered. The external envelope configuration and basing are the same as for the type A15200. Heater power is 430 mw. and typical operation gives a transconductance of 12.0 mmho at 7 ma of plate current.

RCA Developmental Type A15286

This is a coaxial version of the A15274. The envelope and basing are identical to the A15261 and the electrical characteristics are identical to those of the A15274. Only a few samples were made to demonstrate feasibility.

RCA Developmental Type A15287

This is an early remote cut-off design. It is similar in all respects to the A15274 except that 5 siderods, at uniform intervals, have been removed from the grid. Only a few samples were made for evaluation.

RCA Developmental Type A15330

This is the final design of the remote cut-off version. The basing and envelope configuration are identical to the A15200. Heater power is 430 mw and typical operation gives a transconductance of 10.0 mmho at 7.9 ma of plate current.

MECHANICAL DESIGN DEVELOPMENT

Envelope

The envelope used for the tube types developed under this contract is about 1/2 the size of the standard nuvistor envelope. A comparison is shown in Fig. 6. Maximum use was made of the construction techniques developed for the nuvistor line of tube types. Some envelope variations were made that are discussed in a later section of this report, but most of the tubes constructed had the envelope that is described in this paragraph. The outline dimensions are shown in Fig. 7. The bulb has a nominal maximum diameter of 1/4 inch at the ceramic insulator. The bulb terminates at one end in the metallic anode terminal and at the other end in the metallic grid terminal cylinder. A ceramic stem wafer is sealed within the extremity of the grid terminal cylinder and three leads are sealed through this stem. The two central leads are heater terminals and the third is the cathode lead. These leads are all 0.017 inches in diameter and extend 3/16 inch beyond the envelope. A fourth lead of the same length and diameter is welded to the grid cylinder to provide a grid lead which may be inserted in a socket together with the heater and cathode leads. A basing diagram is shown in Fig. 8. This base has been designed to fit the standard linotetrar four-pin transistor socket (Elco No. 803 BC or equiv.). The anode connection may be made with a flexible connector. A low inductance connection to the grid may also be made by using a clip or finger connection to the grid cylinder.

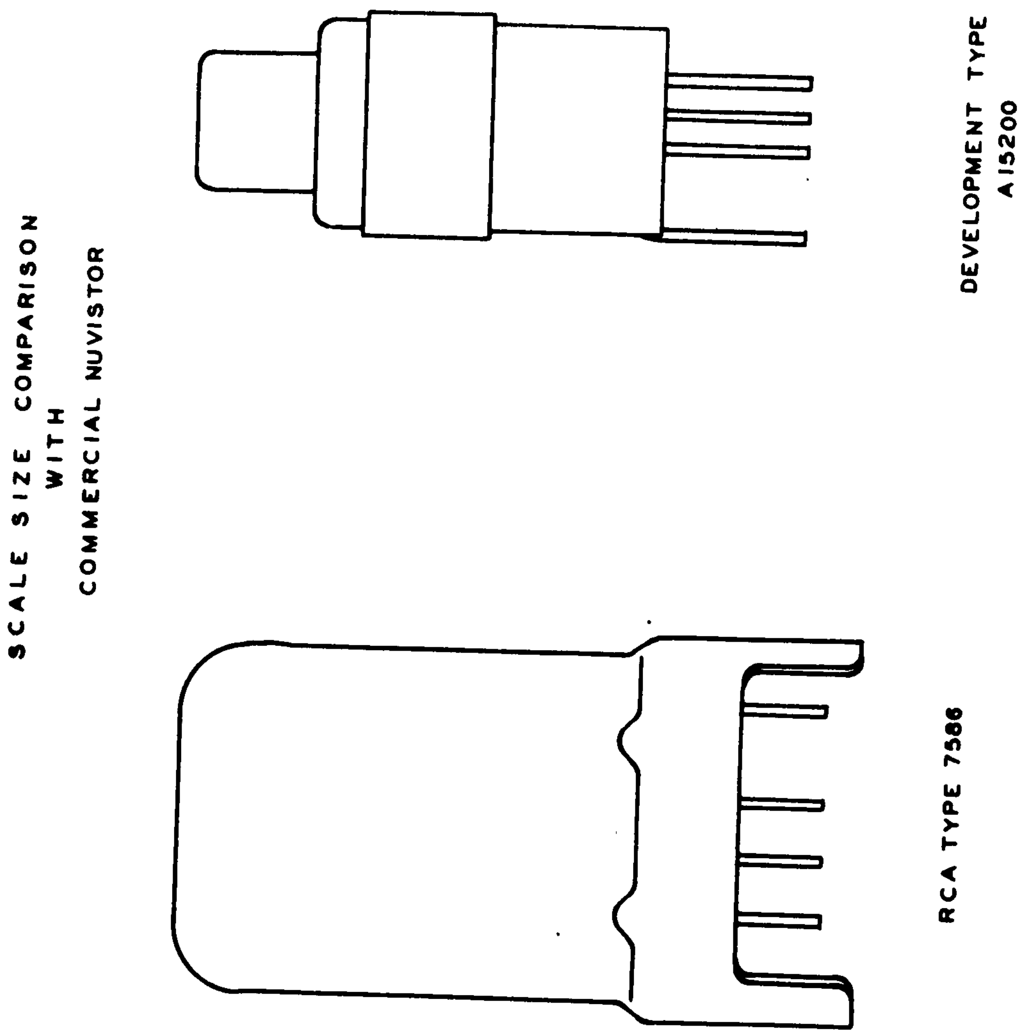

SCALE SIZE COMPARISON
WITH
COMMERCIAL NUVISTOR
DEVELOPMENT TYPE
A15200
RCA TYPE 7586

Fig. 6

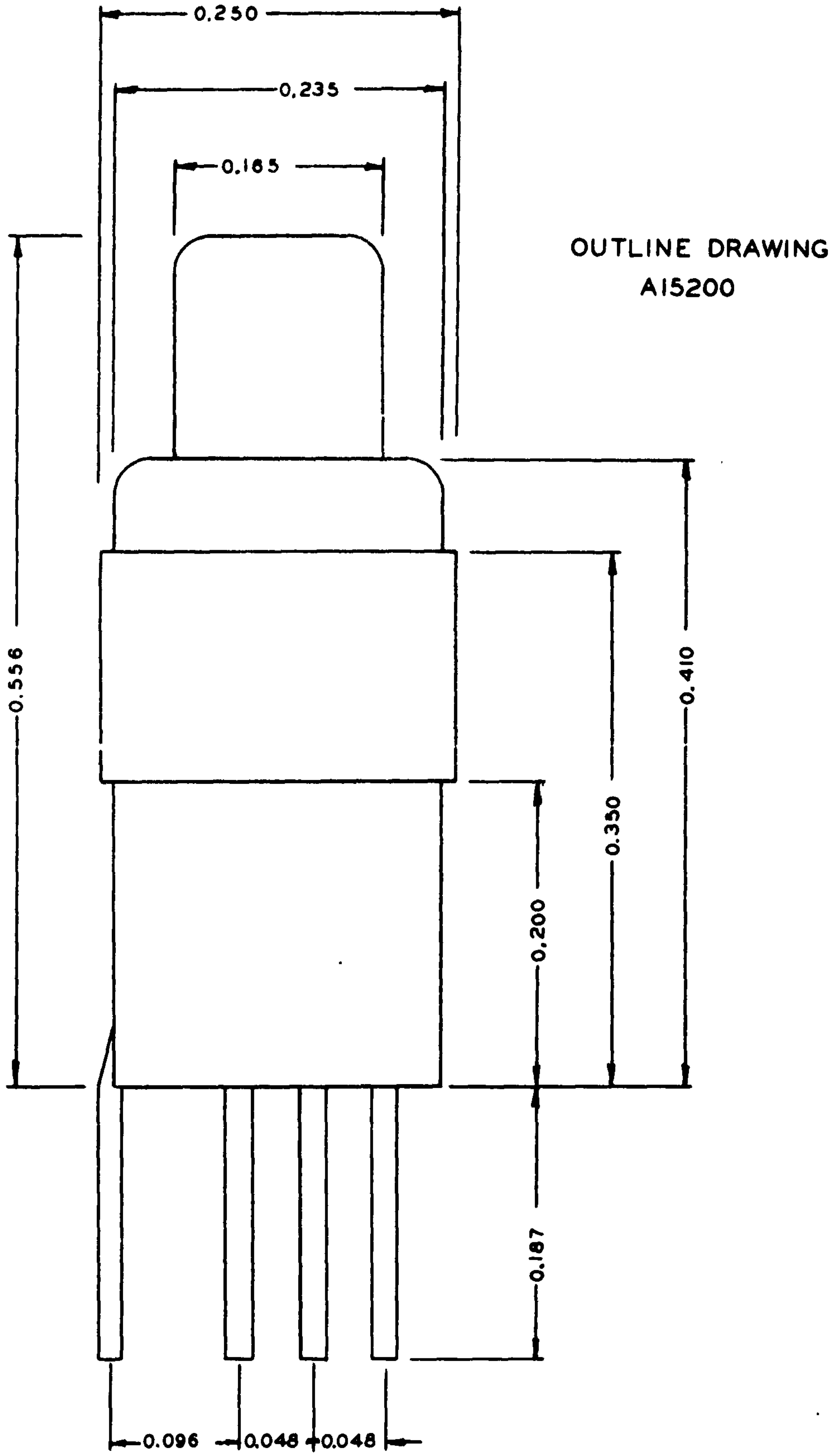
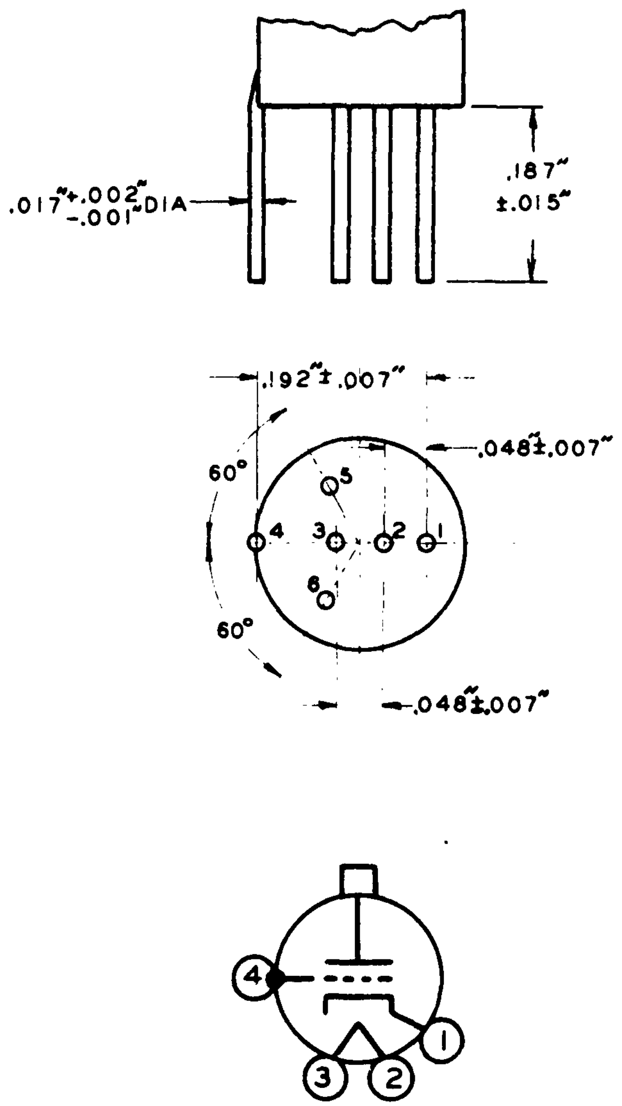

0.250
0.235
0.165
OUTLINE DRAWING
A15200
0.556
0.410
0.350
0.200
0.187
0.096
0.048
0.048

Fig. 7

BASING DIAGRAM - A15200

FOUR PIN LINOTETRAR BASE



PIN 1: CATHODE
PIN 2: HEATER
PIN 3: HEATER
PIN 4: GRID
PIN 5: SEE NOTE 1
PIN 6: SEE NOTE 1
TOP CAP: PLATE

NOTE 1: PIN HAS INTERNAL CONNECTION AND IS CUT OFF CLOSE TO CERAMIC WAFER. DO NOT USE.

Fig. 8

The internal structure is of the cylindrical cantilever type, similar in many respects to the regular nuvistor. A cutaway view showing the cylindrical geometry of the tube is shown in Fig. 9. The individual components are identified in the sectional view of Fig. 10.

Heater Cathode Structure

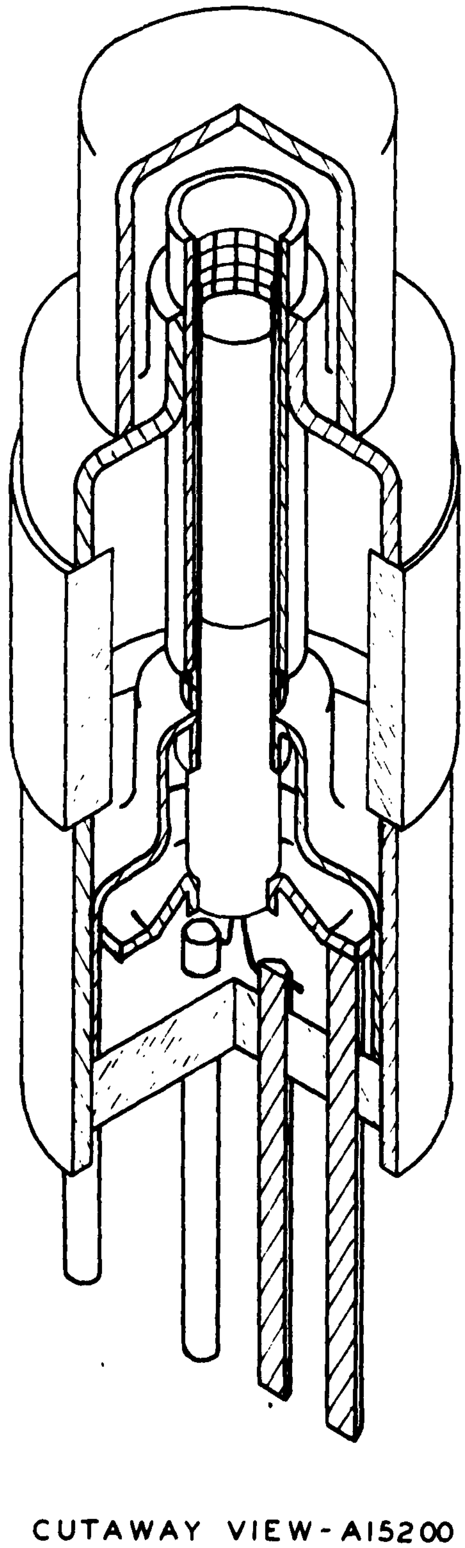
The cathode used for the A15200 and all succeeding types is a nickel cup closed at the upper end to conserve heater power. It has an outer diameter of 0.045" and is 4 mm long. It is made from seamless nickel tubing (P50 alloy) with one end closed by rolling it over a fixture. This cup slides over a cylindrical support which is brazed at the other end to a cathode flange which is in turn brazed to three supports passing through the stem.

The cathode support originally developed and used in all types except the A15330 was made from rolled and welded 0.00025" thick vacuum melted alloy of nickel and chromium. This thickness, which is half that of the standard nuvistor, was chosen, along with the smaller diameter (0.045" vs. 0.060"), to conserve heat. This part was a very difficult part to make and, for the A15330, a cathode support of different construction was developed. This new support was made by spirally wrapping with 1/3 overlap a 0.00016" thick ribbon of nickel chromium alloy onto a mandrel of the proper diameter and material. The resulting assembly is nickel flashed and then fired to sinter the over-lapping faces together. The supports are then cut to length.

The heaters used in all but the very first samples are 'dark' heaters, a development which permits the heater to operate at a much lower temperature for the same cathode temperature and heater power input. As a result, some problems such as heater life trouble are minimized.

Fig. 11 shows an average temperature characteristic for the A15200 and, as can be seen, a cathode temperature of about 1050°K brightness temperature is produced with a heater input of 500 mw. These data were obtained by operating complete tube mounts in a bell jar and measuring the temperature at the top of the cathode with an optical pyrometer through the anode opening. The size of the tube precludes the possibility of introducing a thermocouple measuring device into the mount for direct temperature readings. This type of measurement was repeated for comparison purposes when the spiral cathode support was developed for the A15330 and showed the spiral support to be thermally identical to the rolled type.

As a result of analysis of the A15200 operation, it was concluded that the cathode would operate properly with a heater input as low as 400 mw. The final design of the heater, the one used in the A15274 and the A15330 operates at 430 mw.



CUTAWAY VIEW - A15200
SHOWING CYLINDRICAL GEOMETRY

Fig. 9

SECTIONAL VIEW
A 15200

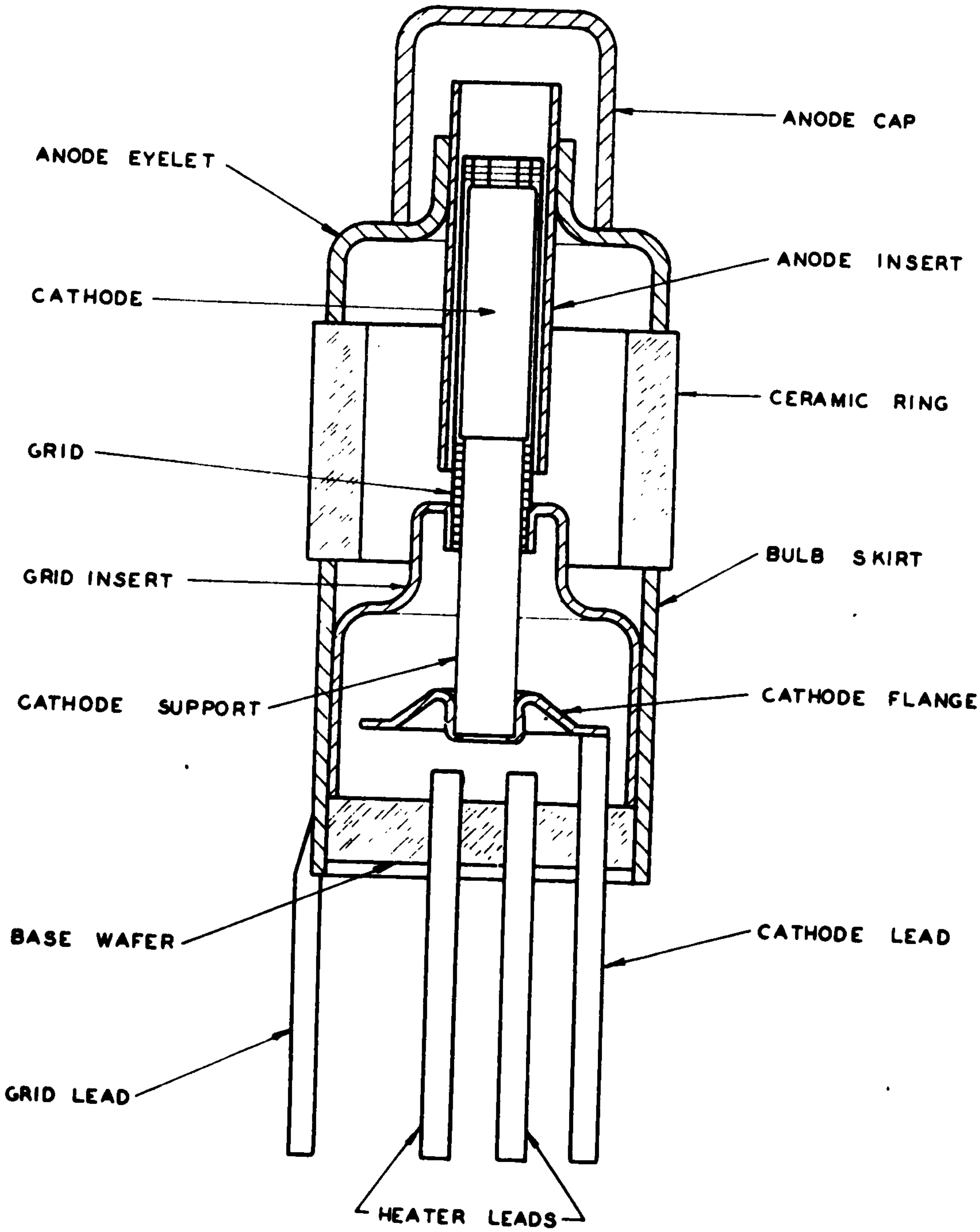
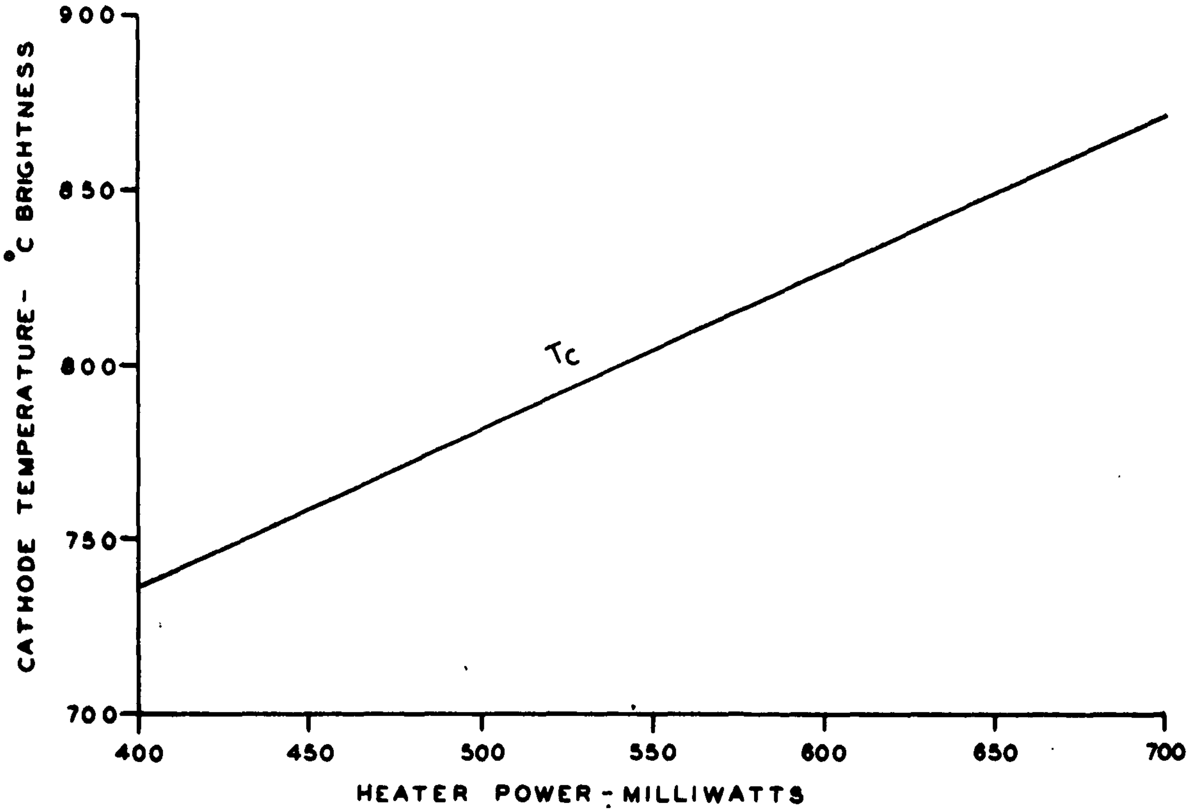


Fig. 10



AVERAGE CATHODE CHARACTERISTICS
DEVELOPMENTAL TYPE A15200

Fig. 11

Grid Structure

The grids used are of the nuvistor type in which the siderods provide most of the control, and the wrapping wire provides the structural strength and only a minor part of the control. The dimensions of the grid varied from type to type and will be discussed fully in the section covering the electrical design. In general, the siderods were nickel plated tungsten and the wrapping wire copper plated tungsten. Some grids were made of molybdenum rather than tungsten but tubes made with these grids tended to have grid emission. Both the thermal conductivity and the resultant work function of molybdenum are somewhat lower than for tungsten. The evaporation products from the cathode which deposit on the grid are appraently "poisoned" more readily on the tungsten grids. Confirmation of this is found in both contact potential measurements and in observations made during the aging process. In addition, tungsten is considerably stronger and somewhat stiffer than molybdenum. For these reasons, the A15274 and the A15330 were made with tungsten grids.

Anode Structure

The anode is a piece of seamless nickel tubing press-fitted into the anode eyelet that forms a portion of the envelope. The anode ID was 0.075" in the A15200 and was reduced to 0.062" in the A15274 and the A15330.

Assembly

The basic elements of the internal structure have already been described. Fig. 12 shows the actual parts and is reproduced in approximately 1:1 scale.

All metal parts of the envelope are of number 52-alloy 0.010 inches thick. This alloy has been chosen because of its reasonable match in coefficient of thermal expansion with the forsterite ceramic used in the sleeve and base wafer. The ceramic bulb sleeve is metallized by printing molybdenum ink on the ends of the sleeve and firing. This is a well known process. A plating of nickel about one mil thick is then applied over the molybdenum as is customary with this method of metallizing. Copper is then plated on the nickel to a thickness of about two mils. This copper is the brazing material which flows during the assembly and seals the anode eyelet and bulb skirt to the ceramic. Some minor difficulties have been experienced when an insufficient amount of nickel underplate is used as this results in a "mushy" seal. This is apparently due to the loss of nickel into solution in the molten copper leaving a molybdenum surface which the copper does not wet readily.

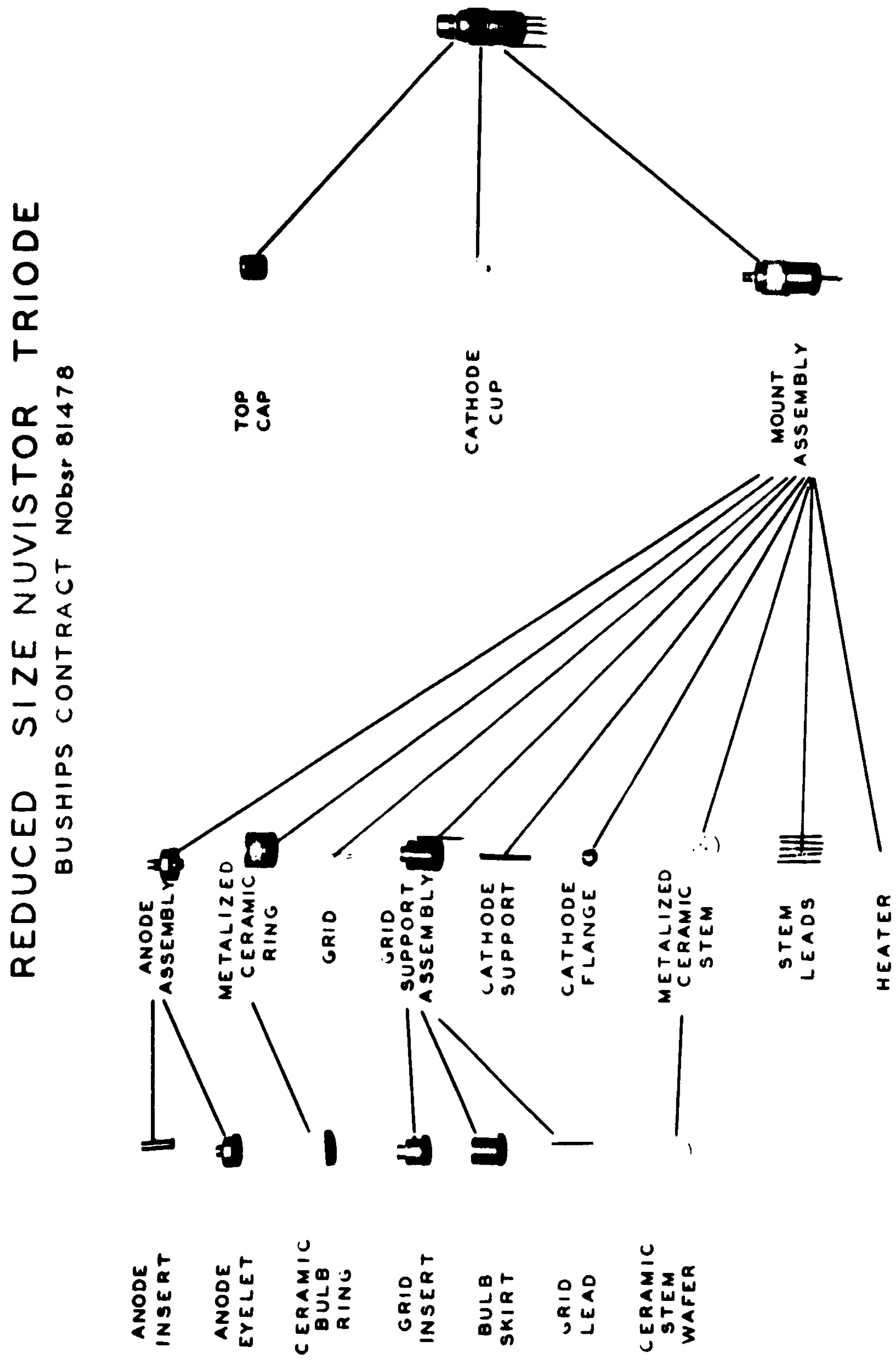

A15200
REDUCED SIZE NUVISTOR TRIODE
BUSHIPS CONTRACT NObsr 81478
TOP CAP
CATHODE CUP
MOUNT ASSEMBLY
ANODE ASSEMBLY
METALIZED CERAMIC RING
GRID
GRID SUPPORT ASSEMBLY
CATHODE SUPPORT
CATHODE FLANGE
METALIZED CERAMIC STEM
STEM LEADS
HEATER
ANODE INSERT
ANODE EYELET
CERAMIC BULB RING
GRID INSERT
BULB SKIRT
GRID LEAD
CERAMIC STEM WAFER

Fig. 12

The ceramic base wafer is metallized by dipping the ceramic in a molybdate-salt solution and then firing in hydrogen to reduce the salt to molybdenum metal. This technique permits metalizing of the inside surfaces of the lead holes which could not be otherwise accomplished. After firing, the flat surfaces of the wafer are ground to remove the metallizing from these surfaces.

Molybdenum leads are used because the metal's low coefficient of expansion insures compression seals where the leads pass through the base wafer. The grid lead is also molybdenum but only because of convenience and not because of mechanical properties. This lead is tack-welded to the bulb skirt before assembly and a small copper ring is placed around the lead. During the brazing process a firm mechanical and electrical joint is produced.

The cathode flange is made of 0.004 inch thick cold-rolled steel which has been etched in nitric acid to give it a roughened surface. In assembly (the tube mount being upside down) a copper brazing ring is located in the depression of this flange and the ring melts during the brazing process and flows over the entire surface area of the flange, effecting a braze joint to the cathode support sleeve.

The grid insert is similarly made of steel etched after forming and a grid-to-support braze is made in the same manner as just described. In the first A15200 mounts this grid insert was made of number 52-alloy and a high percentage of grids did not braze to the support. This was due to the high solubility of copper in the nickel which constitutes the major part of 52-metal. This prevented free flow of the copper brazing material. The change of material to steel has alleviated this condition since the solubility of copper in iron is very low.

The anode insert is press-fitted into the anode eyelet before mount assembly but a copper brazing ring is added during assembly so that the press fit is not relied upon in the completed mount.

Small copper brazing rings are added on the stem leads after they are positioned during mounting.

All parts are assembled on an oxidized Nichrome assembly jig and the entire tube, less cathode cup and anode cap, is passed through a hydrogen furnace which maintains the assembly at the 1100°C zone for about one minute. The assembly is withdrawn slowly to prevent excessive thermal shock. A drawing of the brazing jig and a description of the braze cycle appear in Part III, Manufacturing Information.

After brazing, the cathode cup is added to the mount by insertion through the open anode end. A flattened ring of Nioro brazing material is placed on the anode eyelet, the centering ring pressed over the anode, and the anode cap positioned on top of the brazing ring. The tube is ready for exhaust and sealing at this point.

Exhaust

The tubes are exhausted and sealed, one at a time in a bell jar exhaust system by radiant heat from a muffle which is in turn heated by R.F. power. Equipment is available in this laboratory capable of exhausting in excess of one thousand tubes of this type at one time, but the convenience of observing a single tube during exhaust makes the bell jar system more desirable at present.

Fig. 13 is a view of the arrangement used for holding an A15200 during exhaust. The shoulder of the ceramic bulb ring is supported by means of a split Nichrome ring which is suspended from the upper rim of a molybdenum muffle by three Nichrome hanger wires spot welded to the split ring. The exhaust schedule initially used is six minutes of heating in three steps. The first minute is essentially a preheat with the muffle about 600°C. The muffle temperature is then raised to about 800°C for two minutes for outgassing of the tube elements. A two minute step of about 900°C muffle temperature follows during which time the cathode coating breaks down due to the radiant heat alone. No heater lighting is used. Breakdown occurs over a period of about 45 to 60 seconds at the start of this two minute step. The muffle temperature is then raised to slightly over 1000°C and the Nioro brazing ring melts sealing the anode cap to the anode eyelet. The heating power is removed and the tube is cool enough to be removed in 9 minutes. The whole cycle occupies just over 15 minutes.

With the development of the A15274, the exhaust procedure was refined. Only minor changes were found necessary and these consist of slightly higher temperatures during the processing steps. These higher temperature requirements are probably due to the increased thermal mass and inertia of the type A15274 compared with the type A15200. Using the same temperatures for the A15274 as used for the type A15200 did not give complete cathode breakdown and resulted in gassy and hard to activate tubes. The temperatures and pressures during processing are shown in Fig. 14. Curves of both muffle temperature and tube temperatures are shown as measured with an optical pyrometer.

The muffle construction is shown in Fig. 13. The muffle itself is of seamless molybdenum tubing 5/8 inches in diameter by 2 inches long and having an 0.020 inch wall. It is supported by three Nichrome wire legs in the center of a 2-1/2 inch diameter Vycor bell jar. The muffle is heated by an RF coil consisting of seven close wound turns of 1/4 inch diameter copper tubing with the coil I.D. just sufficient to clear the bell jar. The bell jar is seated on a neoprene gasket on a flange of a VEECO model VS-9 pumping station. The pressure curves of

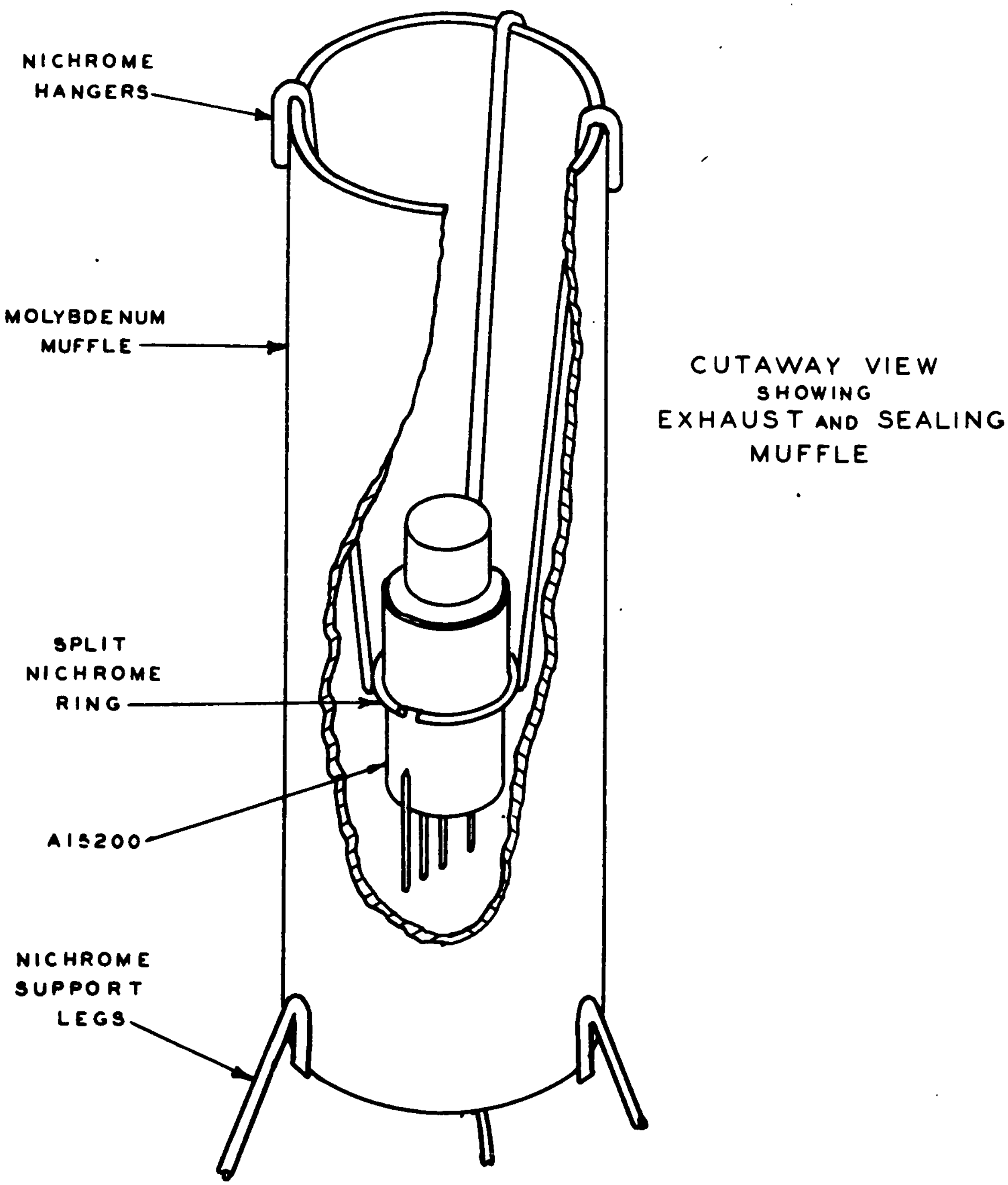

NICHROME
HANGERS
MOLYBDENUM
MUFFLE
SPLIT
NICHROME
RING
A15200
NICHROME
SUPPORT
LEGS
CUTAWAY VIEW
SHOWING
EXHAUST AND SEALING
MUFFLE

Fig. 13

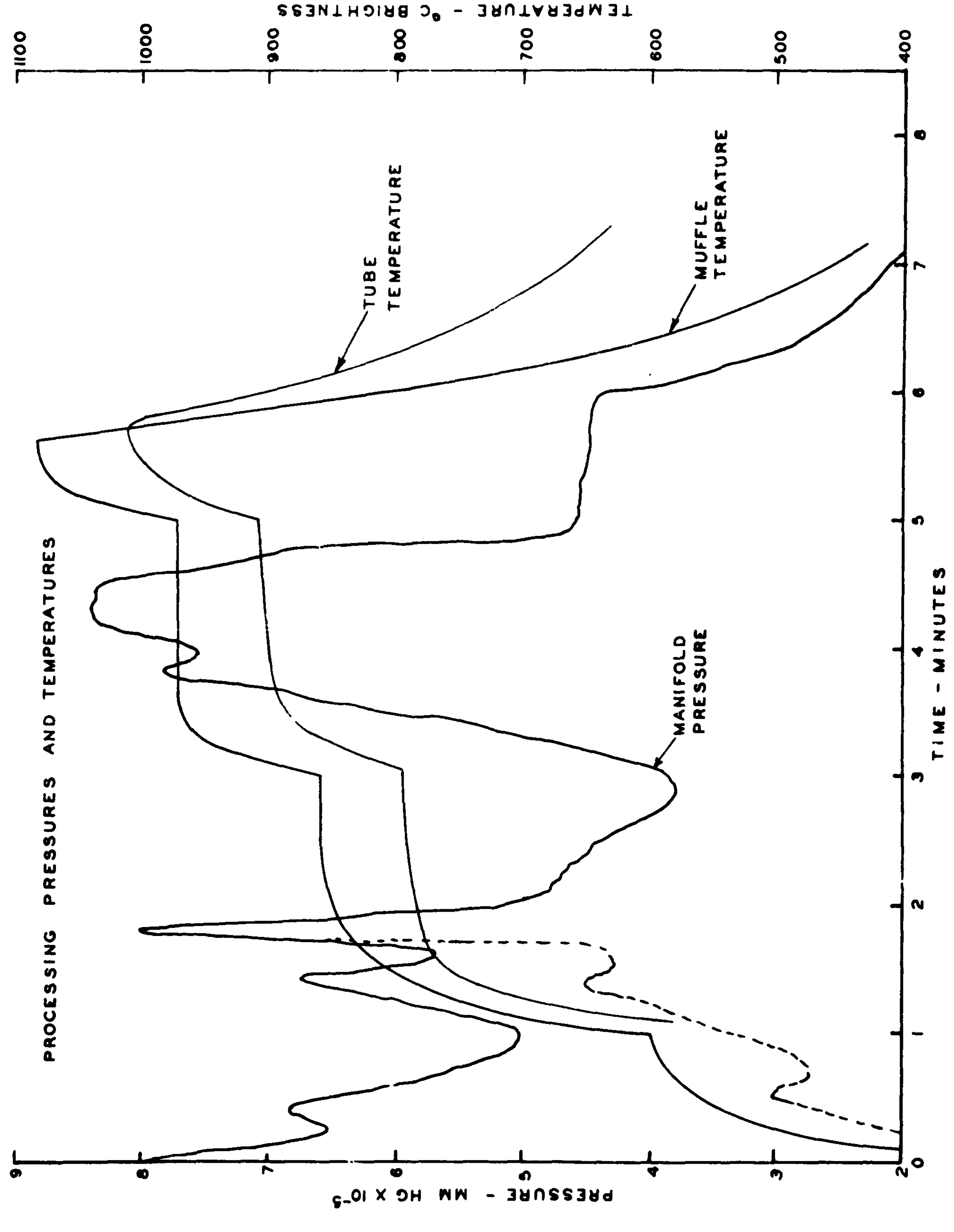

PROCESSING PRESSURES AND TEMPERATURES
TEMPERATURE - °C BRIGHTNESS
1100
1000
900
800
700
600
500
400
TUBE TEMPERATURE
MUFFLE TEMPERATURE
MANIFOLD PRESSURE
PRESSURE - MM HG X 10⁻⁵
9
8
7
6
5
4
3
2
0
1
2
3
4
5
6
7
8
TIME - MINUTES

Fig. 14

Fig. 14 are the values as measured by the ion gauge in the vacuum system manifold. Previous measurements have shown measurements at this gauge position do not vary appreciably from those in the bell jar itself at these pressures. RF heating current is normally applied as soon as the system has pumped down to 8×10^{-5}mm Hg which occurs at less than one minute after sealing off of the system. Pumping before application of RF heating has been allowed to continue to pressures in the region of 10^{-6}mm Hg and this condition is shown as the dashed curve of Fig. 14. As can be seen, less than two minutes after the start of heating there is no difference in system pressure regardless of the starting point. Fig. 14 shows the processing to be in four heating steps; a preheat, bakeout, cathode breakdown, and seal-off being of one, two, two, and approximately three-quarter minutes duration respectively. After the first minute of the bakeout step (total elapsed heating time--2 minutes) outgassing of the tube structure is essentially complete and the residual pressure is mostly due to outgassing of the hot muffle and other portions of the apparatus. This is substantiated by running through the exhaust schedule without a tube in position. Cathode breakdown begins almost as soon as the temperature is again raised at an elapsed heating time of 3 minutes. As can be seen in Fig. 14, two distinct pressure peaks are produced, the first representing the decomposition of the strontium and/or calcium carbonates and the second from the barium carbonate. The evolved gas during this portion of the schedule is due almost entirely to the breakdown of the emission coating and this may be demonstrated by processing a tube mount without a cathode. When breakdown is completed the temperature is again raised and the brazing ring of Nioro alloy is melted to form the final seal. The RF heating current is turned off after 0.85 minutes of this step and the tube is allowed to cool at its natural rate with no attempt to limit the thermal shock by slow cooling. The initial cooling rate is seen to be in excess of 200°C per minute, but no trouble has been experienced due to this. After an elapsed time of 15 minutes (approximately 9 minutes of cooling) the tube is cool enough to be removed with bare fingers.

The exhaust procedure for the A15274 was used also for the A15330.

Aging

Although aging might be thought of as essentially electrical in nature, it is included here because it logically follows the description of exhaust procedure and because it is actually a further conditioning or preparation of the active elements.

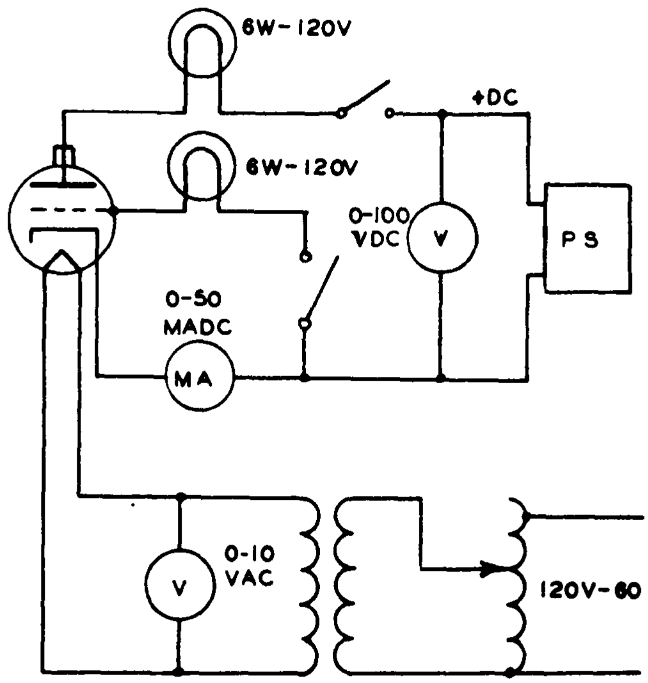
Initially, aging was done on a Tektronix Curve Tracer while observing the plate characteristics. After a period of experimentation with this type of aging on both A15200's and A15274's, a schedule using D.C. voltages was developed for the A15274.

Aging of the type A15274 is done under DC conditions as shown in Fig. 15. A six watt incandescent bulb is in series with the plate circuit as a limiting device. Fig. 15 also shows a lamp in series with the grid. This lamp performs no useful function but is already present in the aging rack being used. At the start of the aging schedule both plate and grid circuit switches are in the open position and the heater is given a "hot shot" of 10 volts AC for 30 seconds. The heater voltage is then reduced to 8.5 volts and the plate circuit switch is closed applying plus 75 volts DC to the tube and lamp series combination. About 50% of final current is available immediately upon applying plate voltage. The grid is left floating at this time because at the start of aging its work function is very much negative with respect to the cathode and if it were connected to the cathode electrically the tube would be effectively biased almost to or even beyond cutoff. This would greatly reduce the plate current and limit the electrolytic activation process. If one switches the grid in and out of the circuit during this part of the aging process (and this is not normally done), he will note that early in the step the plate current will be decreased or even cut off by electrically connecting the grid to the cathode. As the step continues the reduction in current becomes less, passes through a period when no change in plate current is effected, and then finally the plate current increases as expected when the grid is connected to the cathode. This open-grid step is five minutes. At the start of this step the grids have a high value of work function making them very negative with respect to the cathode. It is assumed that at this time the surface of the grid is very clean. As the step continues, evaporation products from the hot cathode are deposited on the grid lowering its work function and making it less negative with respect to the cathode. At the end of the five minutes the grid work function may have changed as much as several volts. The heater voltage is then reduced to 7.5 volts and the grid switch is closed connecting it electrically to the cathode. The majority of type A15274 tubes exhibit acceptable rated conditions characteristics at the start of this step although the low heater voltage transconductance may be somewhat deficient. This step is maintained for forty-five minutes. The average cathode current during this step is 18 to 20 milliamperes and the actual voltage at the plate is 40 to 50 volts. The tubes are considered fully activated at the end of this forty-five minute step, but in order to minimize grid contact potential variation they are stabilized under rated voltage conditions and cathode bias for a period of forty-eight hours.

The aging schedule for the type A15274 was found to be suitable for the type A15330 also.

Mechanical Testing

The main purpose of mechanical testing is to place a control on the ruggedness of the device in question. In the case of this family of tubes,



SCHEMATIC DIAGRAM
A15274 AGEING CIRCUIT

Fig. 15

the least rugged parts are the grid and the cathode assembly. Very early in the development some tests were made to ascertain the mechanical resonance of the cathode assembly and the grid. These preliminary tests were not made on enough samples to obtain complete data, however, they were adequate to indicate that the mechanical strength was reasonably good and that development of this design could continue.

After sufficiently large numbers of the A15200 became available, more complete tests were made. Samples of the developmental type A15200 were operated in vibration test equipment in which they were subjected to 5 g acceleration from 50 cps to 15,000 cps at a sweep rate of 30 seconds per octave. Measurements were made with a 68 ohm cathode resistor, a plate voltage supply of 55 volts and a 2000 ohm load resistance. Below 2000 cps noise output occurs due to randomized motion of the heater within the cathode support sleeve. The maximum noise output from this source is about 100 millivolts and averages about 30 millivolts. A broad resonance of the cathode structure occurs between 3000 and 4000 cps with a maximum output of 300 millivolts and an average of about 100 millivolts. A rather sharp grid resonance is found at about 7 kcs. The maximum noise output for this resonance is about 150 millivolts with an average of about 70 millivolts. Data showing the distribution for a lot of 23 type A15200's is shown in Fig. 16. Four points are shown for each tube tested; the output at 100 cps which is typical for the range from 50 to 300 cps; the maximum output and corresponding frequency for the range of 50 to 1500 cps which is due to heater bounce; the maximum output and corresponding frequency for the range of 1500 to 5000 cps which is due to cathode structure resonance; and the maximum output and corresponding frequency for the range of from 5000 to 15,000 cps which is due to grid resonance. The frequency scale in Fig. 16 is not carried beyond 10,000 cps (although all measurements were taken to 15,000 cps) because in no case has there been any output greater than 1 millivolt at frequencies above the fundamental grid resonant frequency.

Five developmental type A15200 tubes were subjected to an impact test consisting of twenty 1,000 g blows of approximately one millisecond duration in two directions along the axis of the tube and two directions mutually perpendicular with the axis of the tube. Post- impact measurements showed some performance degradation but no change of as much as 10% in any characteristic (Ib, gm, μ). X ray photographs showed no evidence of any mechanical deformation of the tube elements. Operating these tubes overnight under normal conditions completely restored their pre-impact characteristics. A second group of A15200's was then run on the same test but plate currents were monitored during the impact blows and the tubes were measured between changes of axes. No evidence of any interelectrode shorts during the impact blows were observed and it was found that the characteristics changes occurred during the initial blows. It is presumed that a very minute amount of occluded gas is released from

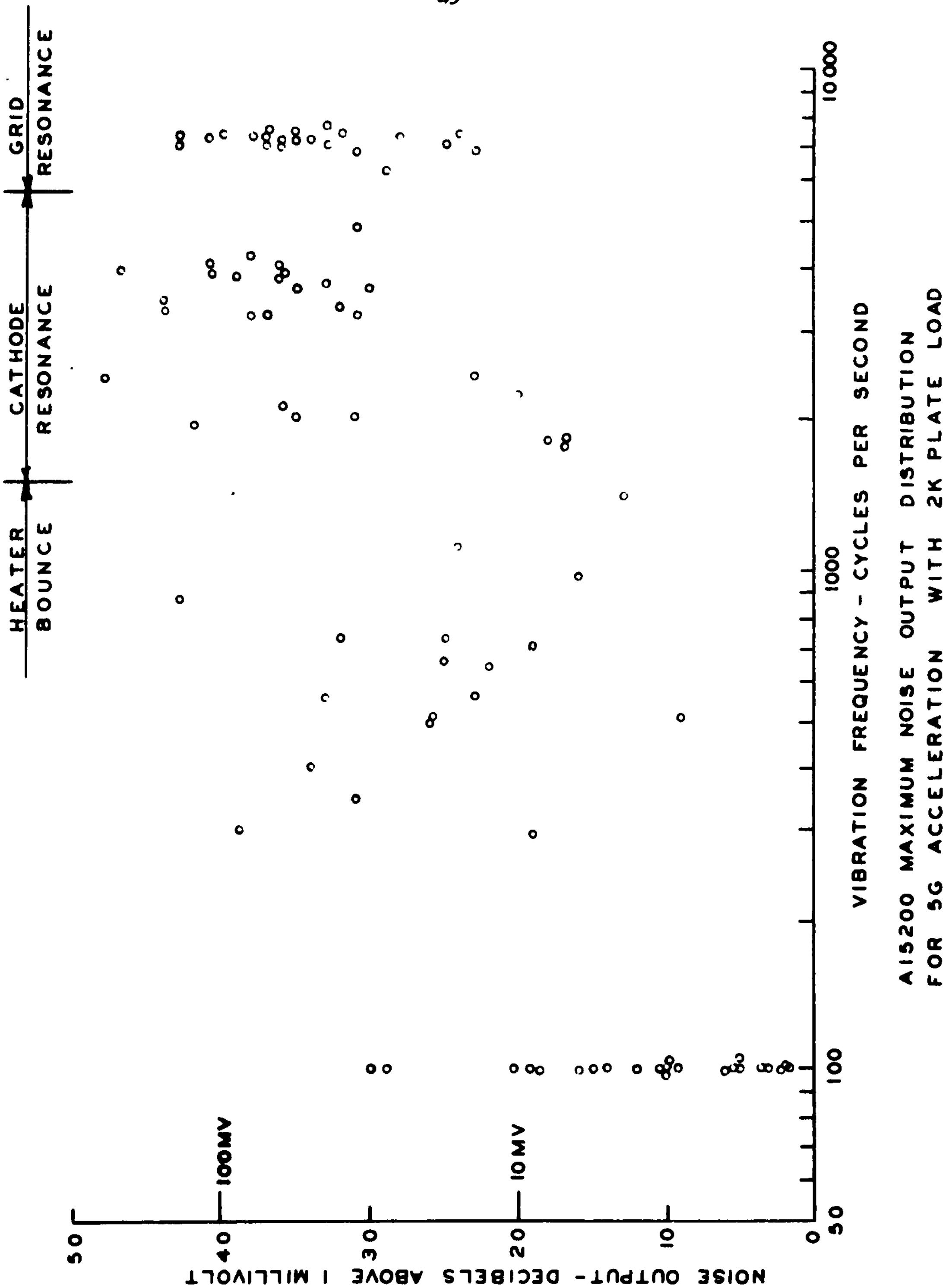

HEATER BOUNCE
CATHODE RESONANCE
GRID RESONANCE
100MV
10MV
50
40
30
20
10
0
NOISE OUTPUT- DECIBELS ABOVE 1 MILLIVOLT
50
100
1000
10000
VIBRATION FREQUENCY - CYCLES PER SECOND
A15200 MAXIMUM NOISE OUTPUT DISTRIBUTION
FOR 5G ACCELERATION WITH 2K PLATE LOAD

Fig. 16

somewhere in the envelope resulting in a minor and temporary poisoning of the cathode which becomes fully reactivated on further operation.

When samples of the A15274 became available, the vibration and impact tests were repeated. Samples of the developmental type A15274 were operated in vibration test equipment and also subjected to 5 g acceleration from 50 to 15,000 cps at a sweep rate of 30 seconds per octave. Measurements were made under the same operating conditions as described for the A15200 and the A15200 data is typical of the results obtained with the A15274. "Heater Bounce" noise and cathode resonance noise remain the same in frequency and magnitude as is to be expected since these components are essentially the same in both the type A15274 and the type A15200. The grid resonance which occurred at about 7 kcs in the type A15200 has decreased in frequency to about 6.5 kcs in the type A15274, due to the difference in grid geometry. Samples of the A15274 with grids of tungsten siderods and molybdenum siderods have shown no significant difference in resonant frequency, although one would expect the molybdenum grid to have a slightly higher resonant frequency. While the grid winding machine was set up with tungsten siderod wire, a few grids were run off with 150 tpi on the helix wrapping wire instead of the normal 100 tpi. Vibration tests on tubes with these grids showed no significant variation in grid resonant frequency.

A group of five A15274's with tungsten siderod grids was subjected to an impact test of 5 one-millisecond duration blows at 1000 g in each of four directions. One of these tubes was known to have one cathode support lead not brazed to the cathode flange giving only two point assymmetrical support instead of three point symmetrical support. All tubes are normally checked by a continuity test to insure that all three points of cathode support are brazed. The four good tubes successfully completed the test while the known bad tube suffered almost complete loss of plate current. It would appear that the lack of symmetrical support had allowed the cathode to momentarily touch the grid resulting in temporary cathode poisoning. This tube was restored to normal characteristics by two hours of operation. Tubes not having all three brazes are satisfactory in operation from an electrical standpoint, but obviously must be weeded out because of mechanical considerations.

This impact test was repeated with A15274's having molybdenum siderod grids. The results of the test at the 1000 g impact level were not considered satisfactory since rather large changes in amplification factor occurred probably due to permanent displacement of the grid position. This may be due to the fact that the molybdenum siderod grids are much softer than the tungsten siderod grids as fabricated for the A15274. In addition, there was much erratic grid emission present after the impact test in the molybdenum siderod grid A15274's.

A group of five A15330's were subjected to the same vibration test as described above for the A15274. Plate supply voltage was 60v., the cathode resistor was 100 ohms and the plate load resistor was 2000 ohms. The cathode resonance effects appeared to be quite similar to those of the A15274 indicating that the spiral cathode support was mechanically similar to the wrapped support. Grid resonance occurred at about 6.0 kc which is somewhat lower than for either the A15274 or the A15200. The magnitude is about the same among the 3 types for both the cathode and the grid resonance. The A15330, however, exhibits a number of lesser resonances above the main grid resonance. The peak voltage is about 12 mv. and averages much lower. These resonances are probably higher order modes caused by the non-homogenity of the 'variable pitch' grid.

Another group of five type A15330's was impact tested in the manner described above. After the test, one tube had 'gone air' although this may have been due to undue stress applied when it was clamped into the test fixture. The other four showed an increase in transconductance of about 3% which is almost insignificant. However, the value of cut-off plate current changed considerably which would have a serious effect upon the cross-modulation characteristics. This appears to be caused by a deformation of the spiral cathode support. Because of the heat treatment that the support receives during its fabrication, the support is softer than the rolled type. No further impact testing was performed but it is felt that a reduction of the stringency of the test from 1000 g's to 750 g's would alleviate the problem. It is also felt that with further development, a spiral support could be produced which is equally as strong as the rolled type. Also, there is no reason why the A15330 could not be made with the rolled cathode support except difficulty of fabrication of the support.

A group of developmental type A15200 tubes were subjected to a low frequency fatigue vibration test. Four tubes were subjected to 48 hours vibration at 60 cps and 2.5 g as per paragraph 4.9.19.1 of MIL-E-1D and one tube was run at 5 g for the 48-hour period. All five tubes were run with heater voltage only applied during the test. Post fatigue tests showed no significant changes in characteristics. All of these five tubes were from the groups which had previously been subjected to the 20 blows of 1000 g at 1 millisecond impact tests mentioned previously. It was felt that using these tubes also for the fatigue vibration test would tend to accentuate any structural faults. The 48-hour fatigue vibration test was performed on a group of four A15274's which had not had any previous mechanical testing. There was an average change in transconductance of about 8%, which is not believed to be of significance.

Temperature Measurements

Measurements have been made on socketed A15200's to determine what temperatures may be encountered in operation. Tests were made with a standard four-pin linotetrar transistor socket mounted in a 1/16 inch aluminum chassis and with the anode connected to its supply by means of a long and fine wire. These conditions would probably present the most severe thermal conditions when a socketed mounting is used. Flying lead mounting would be more severe thermally but no serious thought has been given to this type mounting for the developmental type A15200. Temperature measurements were made with an extremely fine thermocouple at various points on the tube and the results are shown in Fig. 17. Heater power was maintained at 450 milliwatts and anode dissipations were regulated by adjustment of plate voltage and grid bias. The higher values of anode dissipation are the result of high plate voltages rather than high current to prevent damage to the cathode. Calculations were made for all temperatures actually measured and excellent correlation between the results were obtained. The maximum internal temperatures of both the grid and anode were calculated and these are also shown in Fig. 17. From these calculations it is assumed that no difficulties from grid emission should be encountered under normal operating conditions. Two watts anode dissipation would be considered far in excess of normal operating limits for the A15200 but even at this high value temperature limitations should be relatively unimportant.

Because it is highly probable that many applications for the final design model of the A15200 would be in high-frequency amplifier stages where "plumbing" circuitry would be used, additional measurements were conducted with an anode heat sink. These results are shown in Fig. 18. All temperatures for this method of mounting are substantially lower and the anode dissipation may be increased beyond 3 watts before the same temperatures are reached as with 2 watts anode dissipation without heat-sinking the anode.

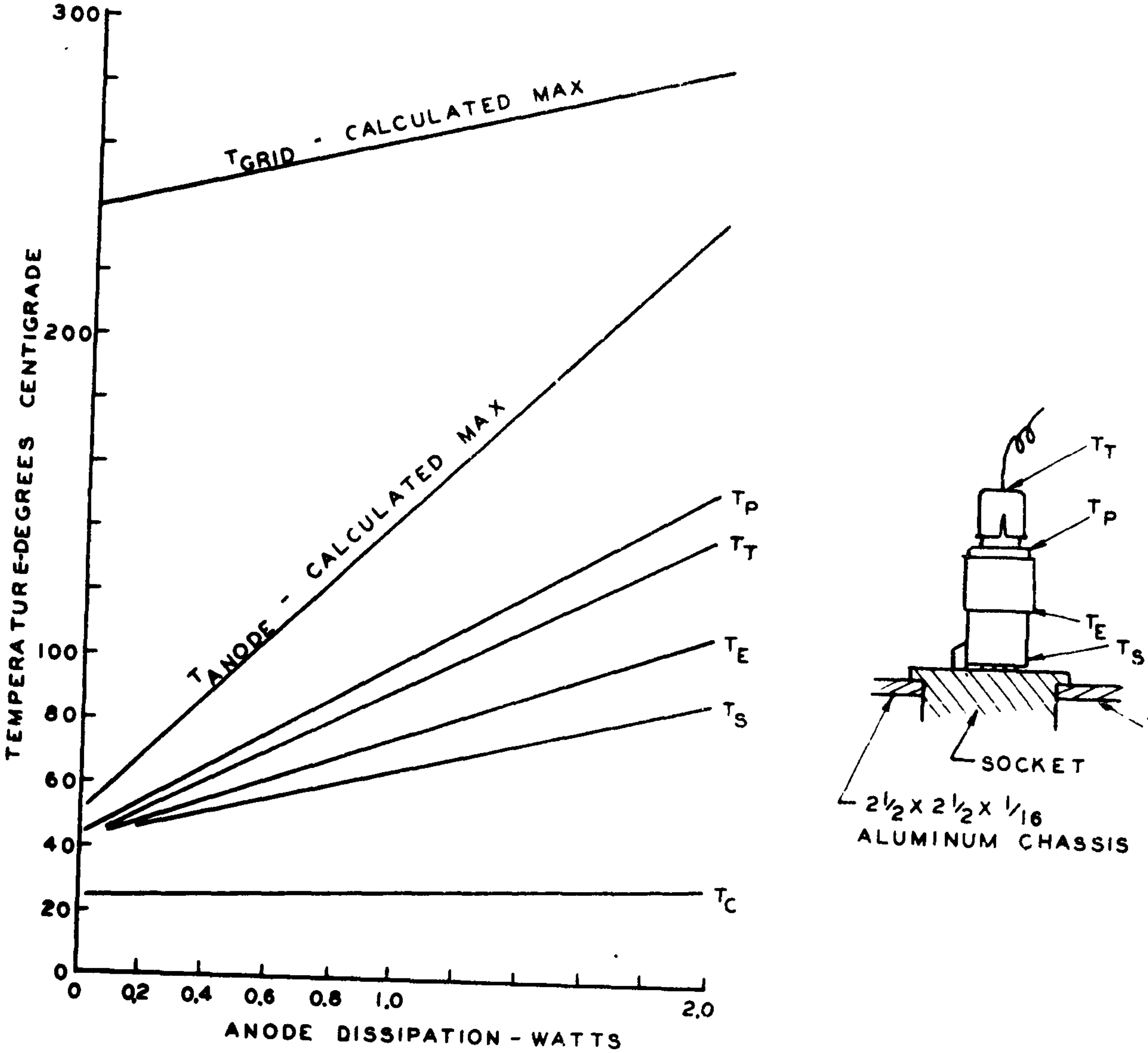
Although the maximum internal anode and grid temperatures in the A15274 and A15330 will probably be slightly higher than those temperatures shown in Figs. 17 and 18, it is felt that no problems will be involved.

ELECTRICAL DESIGN

Initial Design

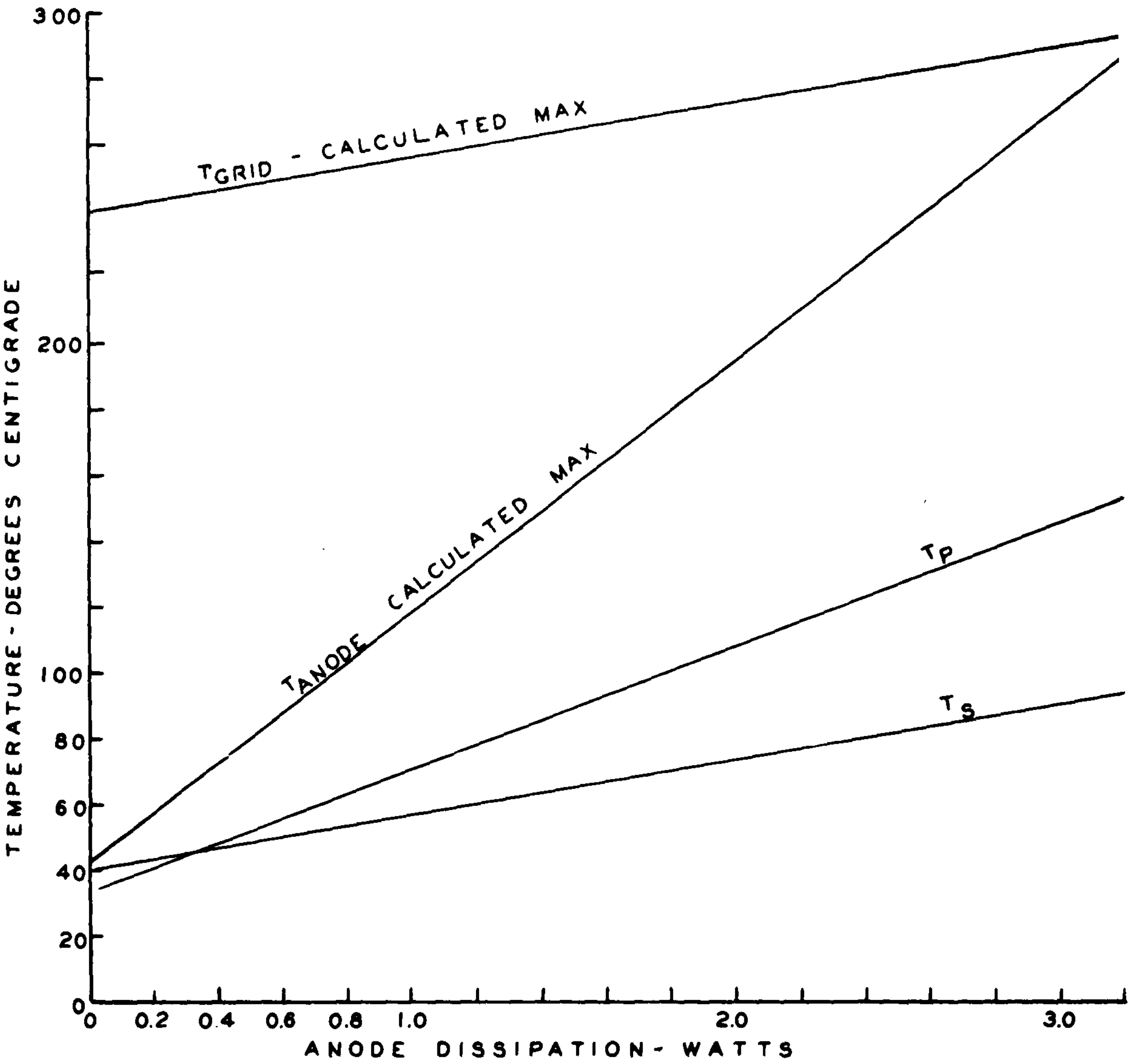
The contract called for the development of a tube having a maximum heater power of 1/2 watt and other electrical characteristics approximating those of the RCA nuvistor general purpose triode, type 7586.

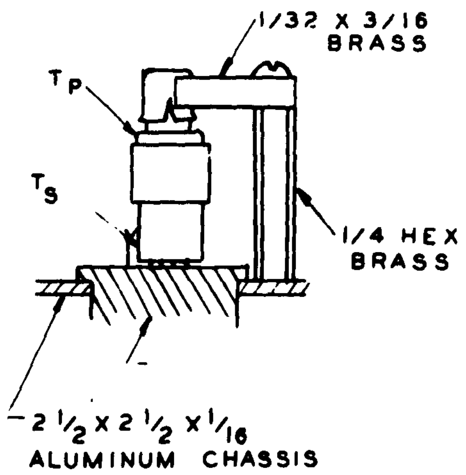
The design of the initial developmental type, the A15200, was arrived at by conventional design methods and by drawing on a rather extensive experience in designing and making close spaced tubes.



OPERATING TEMPERATURES
OF A15200
WITHOUT ADDITIONAL HEAT SINK

Fig. 17





OPERATING TEMPERATURES
OF A15200
WITH ANODE HEAT SINK

Fig. 18

The cathode diameter was 0.045", and its coated length was about 0.160", and the coated diameter 0.0455 to 0.0460". The coating was a conventional triple-carbonate type.

The grid was a cylindrical electrode with 45 siderods of 0.0008" diameter wire. The siderods are the control elements. A 144 TPI helix of 0.0008" diameter was wound over the siderods for mechanical support. The grid ID was 0.0505".

The anode ID was 0.075".

The average plate characteristics for the A15200 is shown in Fig. 19. This family of curves was taken with a heater power of 450 mw. These tubes average about 9 mmho transconductance at a plate current of 7 ma.

Redesign

The usual mathematical formulae for electrical characteristics of electron tubes do not give results of the required engineering accuracy for cases where fine wire grids and very close grid-cathode spacings are used such as in the A15200. The design of tubes of this class quite often becomes a case of cut-and-try. A refined method of calculating the space-current distribution and the current-voltage characteristics of such tubes has been developed independently of this contract by Dr. O. H. Schade, Sr. and this procedure has been adapted for solution on Electronic Data Processing Equipment.

The assumptions of uniform potential fields and current densities in the grid-cathode space are invalid for the general class of tubes we are dealing with. The principal difficulty of the analytic approach is the problem of introducing the space charge to correct electrostatic charges and potentials for calculating the current when the magnitude and distribution of the space charge is not defined until the current distribution is known. In order to circumvent this difficulty the newly developed method divides the non-uniform electrostatic potential field in the cathode-grid space into sections parallel to a laminar current flow. These sections are then replaced by "equivalent" sections having linear electrostatic fields for which the space current solution is known. The principal problem in this approach is to derive the equivalent electrostatic parallel plane fields from the distorted electrostatic potential fields. Once these equivalent sections are determined, their individual characteristics may be found and combined to give the performance of the complete tube.

This is but a sketch outline of the basic procedure involved and further amplification of the process is beyond the limit of this report. For a detailed description of this method, see Reference 13.

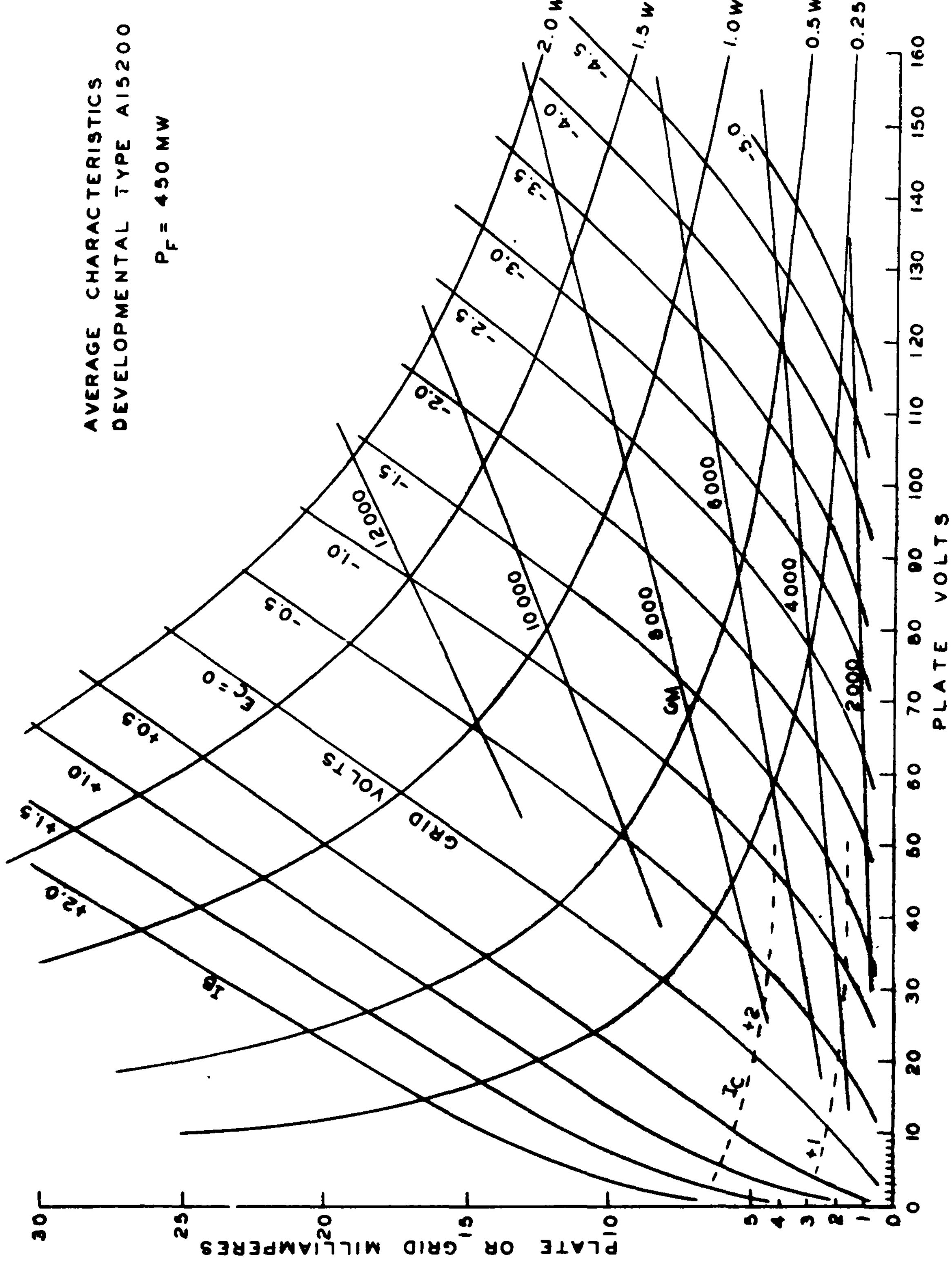

AVERAGE CHARACTERISTICS
DEVELOPMENTAL TYPE A15200
P_F = 450 MW
PLATE VOLTS
PLATE OR GRID MILLIAMPERES
GRID VOLTS
Ec = 0
GM
IB
IC
2.0 W
1.5 W
1.0 W
0.5 W
0.25 W

Fig. 19

Figs. 20 through 23 are demonstrative of a hypothetical tube designed by means of this computer program. Fig. 20 shows the dimensional information required for computer input. The values of mu-zero are those calculated by the computer for the electrostatic mu or amplification factor of the hypothetical tube. This is designated mu-zero because it is the mu value of the electrostatic model alone and does not include space-current effects. In Figs. 21 through 23 it will be noted that the vertical column headings range from 0 to 2.2 in 0.2 increments. The units of these column headings are mu-zero volts or in other words they are plate voltages normalized in terms of mu-zero. This coordinate choice is made partly because it allows the same computer solutions to be used for different grid-anode spacings if other inputs remain constant. All that is necessary in this case is to recalculate the new mu-zero for the changed grid-anode spacing.

The coordinates for the horizontal rows are grid bias values in true volts and no multiplication factors are necessary although some correction for contact potential may need to be made.

Fig. 23 shows the correction factors to determine the actual amplification factor under operating conditions in terms of mu-zero.

Figs. 21 and 22 show computed cathode currents and corresponding computed transconductances for the hypothetical tube defined in Fig. 20. These values are total values although outputs may be printed in terms of current and transconductance per unit area if so desired.

Also available in the same form as Figs. 21 and 22 are the plate resistance characteristics of the tube although this data is not shown herein.

The computer output data may also be transferred directly to an analog computer, and plate or transfer characteristic may be plotted in curve form if so desired.

Computer results have been checked against a variety of existing tubes and results are in excellent agreement. It is felt that the greatest difficulty probably lies in physically making the tubes to dimensionally agree with the computer inputs. Computer data has indicated the necessity for extremely close control of physical dimensions if uniformity of electrical characteristics is to result.

A number of hypothetical tubes have been "built" using the computer, utilizing a range of grid pitch, grid-wire size, and grid-cathode spacing. The characteristics of these models were evaluated to determine the parameters of the final electrical design tube made under this contract. It appears that the design limitations of this tube are those imposed by mechanical feasibility. The final design has a grid of smaller pitch, finer wire and closer grid-cathode spacing than the developmental type

```
                    2-K62A60G0.6
     THE INPUTS ARE AS FOLLOWS
GRID-CATHODE SPACE = 0.002000 IN.   GRID-PLATE SPACE = 0.005750 IN.

PITCH = 0.002420 IN.    WIRE DIAMETER = 0.000600 IN.

THE CATHODE AREA =   0.1400  SQ CM.     CATHODE TEMPERATURE  =    1000  K

THE CATHODE WORK FUNCTION =  1.60


     THE COMPUTED VALUES ARE AS FOLLOWS
I-S =     1.01754     I-INFINITY =    0.009494     I-ZERO =    0.008552

V-ZERO =     2.01198       MU-ZERO FOR D/D IS 1.5 =  37.334       MU-ZERO FOR D/D IS 1.8 =  37.538
```

Fig. 20

2-K62A60G0.6

CURRENT IS GIVEN HERE IN MILLI-AMPS

BEGINNING PLATE = -0.

BIAS	-0.	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200
-0.	1.197	4.293	8.059	12.323	16.987	22.001	27.328	32.935	38.796	44.883	51.175	57.649
-0.20	0.141	1.535	4.508	8.247	12.561	17.244	22.290	27.650	33.281	39.151	45.243	51.537
-0.40	0.	0.377	2.225	5.168	8.822	12.977	17.584	22.648	28.012	33.657	39.551	45.657
-0.60	0.	0.051	0.857	3.020	6.042	9.658	13.760	18.259	23.182	28.463	34.070	39.976
-0.80	0.	0.	0.259	1.532	3.896	6.980	10.609	14.716	19.226	24.070	29.285	34.744
-1.00	0.	0.	0.030	0.591	2.286	4.829	7.994	11.666	15.778	20.266	25.133	30.277
-1.20	0.	0.	0.	0.210	1.149	3.106	5.801	9.052	12.762	16.893	21.423	26.241
-1.40	0.	0.	0.	0.	0.442	1.813	3.995	6.616	10.151	13.676	18.062	22.575
-1.60	0.	0.	0.	0.	0.178	0.905	2.552	4.931	7.861	11.255	15.077	19.312
-1.80	0.	0.	0.	0.	0.	0.342	1.470	3.386	5.906	8.934	12.414	[illegible]
-2.00	0.	0.	0.	0.	0.	0.156	0.720	2.149	4.255	6.916	10.037	[illegible]
-2.20	0.	0.	0.	0.	0.	0.	0.276	1.230	2.875	5.160	7.958	[illegible]
-2.40	0.	0.	0.	0.	0.	0.	0.139	0.583	1.796	3.695	6.126	9.027
-2.60	0.	0.	0.	0.	0.	0.	0.	0.251	1.031	2.511	4.573	7.122
-2.80	0.	0.	0.	0.	0.	0.	0.	0.125	0.501	1.552	3.240	5.501
-3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.242	0.862	2.144	4.037
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	0.111	0.404	1.351	2.866
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.218	0.736	1.888
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.101	0.329	1.147
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.161	0.641
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.292
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.172
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. 21

2-K62A60G0.6

GM IS GIVEN HERE IN MICRO-MHOS

BEGINNING PLATE = -0.

BIAS	-0.	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200
-0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-0.20	0.	9791.0	14585.3	17888.3	20411.0	22560.7	24360.3	25717.7	26960.4	28065.8	29060.1	29975.1
-0.40	0.	3709.7	9127.8	13067.3	16297.2	18963.0	21324.6	23477.5	25245.6	26719.8	27934.1	28904.0
-0.60	0.	0.	4914.8	9088.4	12315.9	14991.7	17437.0	19830.4	21964.4	23966.5	25664.2	27288.5
-0.80	0.	0.	2066.6	6071.2	9390.0	12074.5	14414.5	16480.5	18511.5	20492.0	22342.1	24247.0
-1.00	0.	0.	0.	3306.6	6868.1	9679.7	12019.9	14159.2	16160.8	17943.8	19650.8	21257.4
-1.20	0.	0.	0.	0.	4611.6	7538.9	9998.3	12126.7	14116.4	15969.9	17627.2	19254.6
-1.40	0.	0.	0.	0.	2425.8	5508.0	8123.7	10303.1	12250.7	14094.3	15870.7	17320.6
-1.60	0.	0.	0.	0.	0.	3678.6	6313.7	8573.0	10563.3	12360.2	14171.4	15706.0
-1.80	0.	0.	0.	0.	0.	1872.7	4578.0	6953.9	9015.7	10848.5	12598.6	14277.3
-2.00	0.	0.	0.	0.	0.	0.	2983.5	5392.1	7576.9	9435.2	11138.5	12805.9
-2.20	0.	0.	0.	0.	0.	0.	1452.9	3915.6	6148.6	8050.4	9777.7	11437.5
-2.40	0.	0.	0.	0.	0.	0.	0.	2447.1	4610.2	6622.1	8461.8	10120.4
-2.60	0.	0.	0.	0.	0.	0.	0.	1146.0	3237.5	5359.4	7195.8	8813.8
-2.80	0.	0.	0.	0.	0.	0.	0.	0.	1972.9	4122.9	6072.6	7712.1
-3.00	0.	0.	0.	0.	0.	0.	0.	0.	972.9	2867.9	4740.5	6538.1
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	1611.0	3519.8	5374.2
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	758.3	2556.5	4348.0
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1387.5	3117.3
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2137.5
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1170.8
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. 22

2-K62A60G0.6

AMPLIFICATION FACTOR OR MU

BEGINNING PLATE = -0.

BIAS	-0.	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200
-0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-0.20	0.	0.897	0.869	0.889	0.907	0.928	0.936	0.936	0.938	0.938	0.938	0.
-0.40	0.	0.	0.762	0.792	0.835	0.866	0.882	0.901	0.917	0.926	0.931	0.
-0.60	0.	0.	0.662	0.701	0.742	0.777	0.811	0.842	0.861	0.881	0.892	0.
-0.80	0.	0.	0.	0.668	0.689	0.719	0.745	0.765	0.792	0.815	0.837	0.
-1.00	0.	0.	0.	0.586	0.648	0.678	0.703	0.728	0.752	0.767	0.785	0.
-1.20	0.	0.	0.	0.	0.636	0.648	0.673	0.697	0.720	0.737	0.754	0.
-1.40	0.	0.	0.	0.	0.	0.620	0.650	0.672	0.694	0.709	0.730	0.
-1.60	0.	0.	0.	0.	0.	0.620	0.627	0.646	0.668	0.685	0.704	0.
-1.80	0.	0.	0.	0.	0.	0.	0.601	0.627	0.650	0.667	0.685	0.
-2.00	0.	0.	0.	0.	0.	0.	0.599	0.610	0.636	0.653	0.666	0.
-2.20	0.	0.	0.	0.	0.	0.	0.	0.603	0.626	0.634	0.651	0.
-2.40	0.	0.	0.	0.	0.	0.	0.	0.591	0.592	0.612	0.635	0.
-2.60	0.	0.	0.	0.	0.	0.	0.	0.	0.573	0.605	0.624	0.
-2.80	0.	0.	0.	0.	0.	0.	0.	0.	0.553	0.600	0.615	0.
-3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.603	0.597	0.
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.520	0.567	0.
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.612	0.
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.531	0.
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. 23

A15200 whose characteristics have been described earlier in this report. Although the hypothetical tube described in Figs. 20 through 23 is not the final design, the characteristics may be compared with the characteristics of the developmental type A15200 in Fig. 19 as an indication of the increased performance which was expected of the final design model.

Design of the Developmental Type A15274

The RCA Developmental Type No. A15274 has been assigned to the final design version of sharp cutoff nuvistor developed under the terms of this contract. The external appearance, dimensions, and basing of the type A15274 are the same as those of the type A15200. The main purpose in the design of the type A15200 was to determine the suitability of its mechanical configuration. It is believed that the constructional features of the type A15200 have proven to be satisfactory and they have therefore been used as the basis for the design of the type A15274. The principal difference between the A15274 and the A15200 is in the active electrode geometries. All electrode spacings in the A15274 are smaller than the corresponding spacings of the type A15200 and the type A15274 incorporates a grid of finer effective pitch and smaller diameter wire. These dimensional changes result in a tube having the electrical characteristics meeting the contract requirements. These requirements were stated as "electrical characteristics equal or superior to those of the present nuvistor prototype triode."

The requirement of "a maximum heater dissipation of 1/2 watt" is also specified. The type A15200 was designed with a 450 milliwatt input heater which is 10 per cent under the specified maximum. All characteristics data of the type A15200 shown in other sections of this report were measured with this 450 milliwatt heater input. A series of life tests have also been run operating type A15200 tubes with various values of heater input power. Fig. 24 shows graphically the results of these tests. Each curve represents the average of 5 tubes and all curves are normalized to zero hour transconductance averages for each test. Naturally, the tubes having lower heater inputs have a lower absolute value of transconductance but using absolute values might tend to cloud the picture. Each group of tubes was read at down periods using the same value of heater input power for measurement as was used for operation. No criteria of selection of tubes for these tests were imposed other than that they were operable samples. All were randomly selected from the existing stock of samples and as a result all had previously been stabilized for 48 hours at 6.3 volts or 450 milliwatts. This may partially account for the tests with the lower heater inputs actually "aging in" to a higher than zero hour value during early life. The curves of Fig. 24 represent down period testing conditions of a fixed grid bias of -1.5 volts and a plate voltage of 75 volts. Although not depicted here graphically, additional measurements were made during down

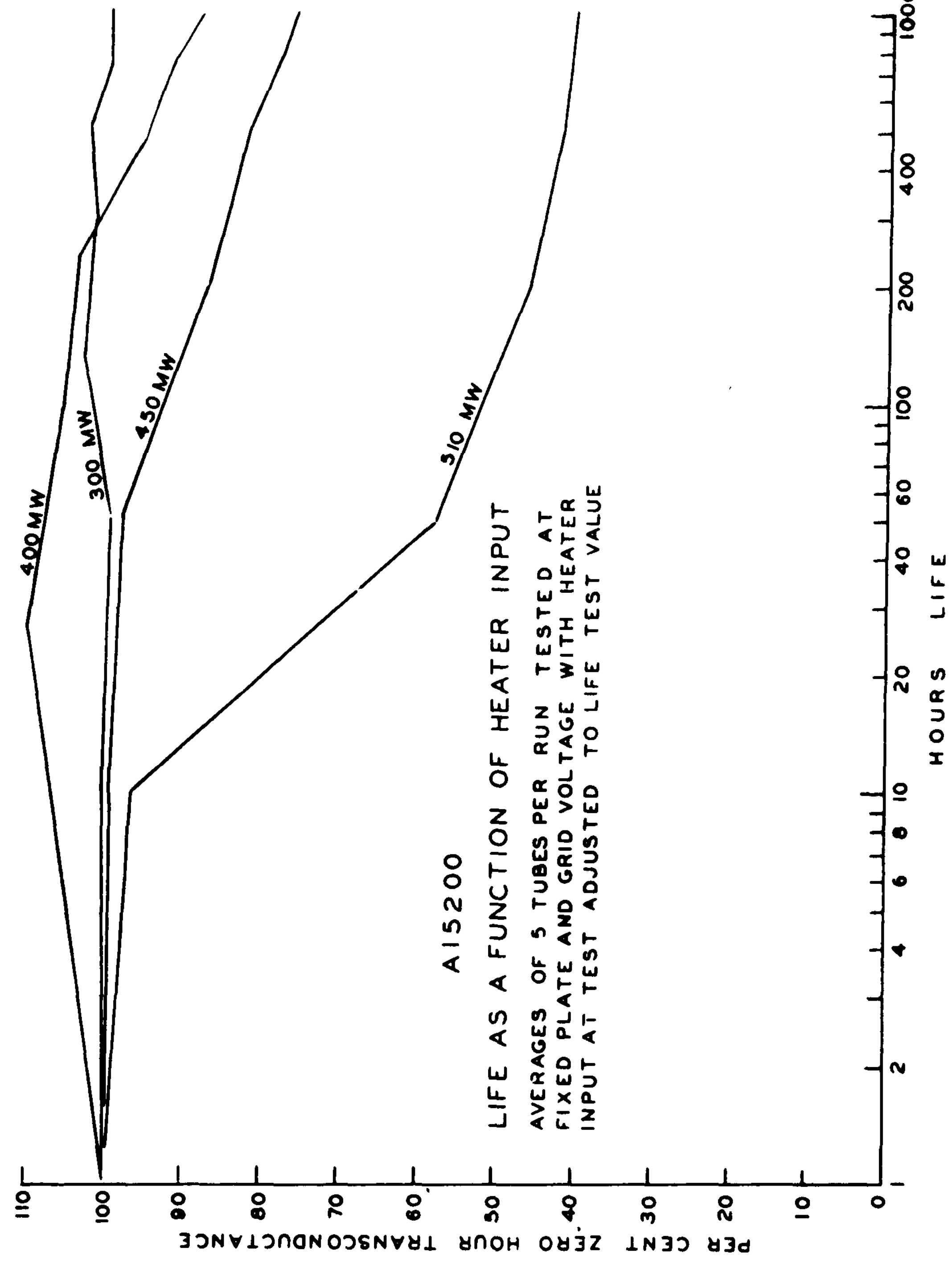

A15200
LIFE AS A FUNCTION OF HEATER INPUT
AVERAGES OF 5 TUBES PER RUN TESTED AT
FIXED PLATE AND GRID VOLTAGE WITH HEATER
INPUT AT TEST ADJUSTED TO LIFE TEST VALUE
400MW
300 MW
450 MW
510 MW
PER CENT ZERO HOUR TRANSCONDUCTANCE
110
100
90
80
70
60
50
40
30
20
10
0
HOURS LIFE
2
4
6
8
10
20
40
60
100
200
400
1000

Fig. 24

periods under conditions of both fixed grid and plate current and also with cathode bias. Of the three conditions the fixed grid bias probably represents the most severe characteristics test and, as expected, the other test conditions show less transconductance loss. The lowest heater power input used in the course of these tests was 300 milliwatts and although the life curves appear attractive there are some reasons against using such a low heater power in this tube. Since the curves of Fig. 24 are normalized it is not immediately apparent that the lower heater input results in reduced characteristics and a subsequent loss of performance. In addition, the 300 milliwatt input may be considered as on the "ragged edge" of operation and if this value were used as the design center, poor heater voltage regulation would possibly be disastrous when low voltage conditions were encountered.

A heater input power of 400 milliwatts has been chosen for the developmental type A15274 chiefly on the strength of these test results. This value would seem to be a good compromise between life and operational characteristics. A heater design has been completed for the desired 400 milliwatts input at 6.3 volts. Some of these heaters have been tested in A15200 mounts and the tubes perform satisfactorily. A previous attempt to make a 400 milliwatt heater design resulted in a heater with 4 milliamperes too low current and while this may seem insignificant when dealing with the general entertainment type electron tube, it represents some 25 milliwatt loss of power in the A15274 type, or the equivalent of more than 0.5 volt under rated heater voltage.

While these life tests were performed using type A15200 nuvistor triodes, it is believed that the results should be directly applicable to the type A15274. The actual cathode in the A15274 will be that of the A15200 and all materials and processing should be the same, only the anode and grid dimensions being different.

As previously described, a number of hypothetical tubes were "built" utilizing an electronic computer program. These "paper tubes" covered a range of grid pitches, grid wire sizes, and grid cathode spacings. A comparison evaluation was made of these data to determine the mechanical dimensions which would give the desired electrical performance. As one would expect, the data showed that increased performance as measured by the transconductance to plate-current ratio is achieved by increasingly finer pitches, grid wire sizes and reduced grid-cathode distances. The decrease in all of these dimensions results in increasingly higher amplification factors unless the grid-anode distance is also decreased. Because the contract requirements are for a medium-mu triode, the final choice of geometry was based on practical considerations of dimensions of electrode and fixture parts. The dimensions chosen by no means represent the ultimate, but are a compromise between good performance and feasibility of fabrication.

Having thus interpolated the desired tube geometry from computer data other runs were made using the actual desired dimensions to obtain the characteristics of the proposed developmental type A15274. Figs. 25 through 29 show the computer data for the tube as calculated. The input data are shown in Fig. 25. The grid chosen for the A15274 consists of 65 siderods of 0.6 mil wire with a 100 TPI helix of 0.7 mil wrapping wire. If one is curious enough to do a little arithmetic, he will find that these grid dimensions do not directly agree with the computer input data as shown in Fig. 25. This is in part due to the fact that cylindrical electrode geometry is employed in the type A15274 and that the computer program is based on the conversion from the actual distorted electrostatic potential fields to the equivalent electrostatic parallel plane fields because the space-current solutions are known for the cases of linear electrostatic fields. In the mathematical conversion of cylindrical geometry to equivalent parallel-plane geometry for the electrostatic case, it is generally true that all dimensions became smaller.[1] It is the results of these and other conversions which appear in Fig. 25.

Fig. 26 shows the cathode current characteristics as derived from the computer. Column headings are given directly in plate volts and the horizontal rows are for grid bias values in volts. An upper and a lower current limit have been programmed into the computer and where the computed currents exceed these limits zeros are printed in the output. Also, values for higher values of plate voltage and/or greater values of grid bias can be computed if desired, but these will be printed on separate sheets since only a given amount of output data can be recorded on an individual sheet.

Transconductances as determined by the computer are shown in Fig. 27 with coordinates corresponding to those of the current characteristics of Fig. 26. In the same manner, plate resistances are shown in Fig. 28 and amplification factors in Fig. 29.

The cathode for the A15274 is the same as for the A15200. The grid ID is the same as for the A15200. However, as the grid wire diameter is smaller the effective grid diameter is smaller. This grid has 65 siderods 0.0006 in. in diameter. The lateral wire is 0.0007 in. in diameter wound in a helix of 100 TPI. A complete description of the grid is given in Part III, Manufacturing Information. The anode ID is 0.062 inch.

A great deal of trouble was encountered in winding the grids for the A15274. It was necessary to obtain 3 different lots of wire before wire that was satisfactory was obtained. The first lot could be wound into grids successfully but, when the grids were brazed, the tungsten became so brittle that the grids could not be handled. Variations in brazing schedules were not fruitful in producing acceptable grids from this lot of wire. The second lot also proved unsuccessful due to poor

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THE INPUTS ARE AS FOLLOWS

HOT CATHODE DIAMETER = 0.04600 IN., GRID DIAMETER = 0.05100 IN., PLATE DIAMETER = 0.06150 IN.

PITCH = 0.00249 IN., WIRE DIAMTER = 0.00060 IN.

THE CATHODE AREA = 0.1550 SQ CM, CATHODE TEMPER ATURE = 1000 K

THE CATHODE WORK FUNCTION = 1.60

THE COMPUTED VALUES ARE AS FOLLOWS

EMISSION CURRENT (I-S) = 1.054 AMPS/SQ CM.

I-INFINITY = 6.294 MILLI-AMPS/SQ CM., I-ZERO = 5.787 MILLI-AMPS/SQ CM.

V-ZERO = 2.04865 MU-ZERO FOR D/D IS 1.5 = 28.429 MU-ZERO FOR D/D IS 1.0 = 28.470

THE CORRECTED MU = 36.925

FIG. 2

Fig. 25

45K62A6500.6

CURRENT IS GIVEN HERE IN MILLI-AMPS

BIAS	BEGINNING PLATE = -0. -0.	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000
0.20	3.162	6.967	11.397	16.319	21.679	27.419	33.497	0.	0.	0.	0.	0.
0.	0.897	4.117	8.142	12.734	17.793	23.272	29.116	0.	0.	0.	0.	0.
-0.20	0.105	1.733	5.192	9.398	14.138	19.331	24.920	30.862	0.	0.	0.	0.
-0.40	0.	0.465	2.818	6.351	10.728	15.607	20.932	26.622	0.	0.	0.	0.
-0.60	0.	0.073	1.327	4.059	7.716	12.092	17.138	22.580	28.375	34.491	0.	0.
-0.80	0.	0.	0.444	2.391	5.413	9.212	13.631	18.732	24.271	30.176	0.	0.
-1.00	0.	0.	0.102	1.221	3.613	6.862	10.762	15.321	20.383	26.012	32.002	0.
-1.20	0.	0.	0.	0.468	2.204	4.936	8.361	12.443	17.153	22.132	27.756	0.
-1.40	0.	0.	0.	0.161	1.180	3.356	6.348	9.977	14.200	18.934	24.104	29.[illegible]
-1.60	0.	0.	0.	0.	0.502	2.104	4.627	7.333	11.650	16.005	20.835	26.0[illegible]
-1.80	0.	0.	0.	0.	0.187	1.182	3.199	5.987	9.392	13.335	17.873	22.7[illegible]
-2.00	0.	0.	0.	0.	0.	0.540	2.054	4.417	7.446	11.069	15.175	19.7[illegible]
-2.20	0.	0.	0.	0.	0.	0.200	1.188	3.092	5.741	8.977	12.776	17.0[illegible]
-2.40	0.	0.	0.	0.	0.	0.	0.580	2.014	4.269	7.139	10.587	14.551
-2.60	0.	0.	0.	0.	0.	0.	0.217	1.190	3.038	5.545	8.623	12.265
-2.80	0.	0.	0.	0.	0.	0.	0.	0.618	2.009	4.155	6.900	10.190
-3.00	0.	0.	0.	0.	0.	0.	0.	0.249	1.213	2.984	5.389	8.353
-3.20	0.	0.	0.	0.	0.	0.	0.	0.132	0.658	2.019	4.076	6.715
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.291	1.242	2.944	5.234
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.145	0.696	2.034	4.031
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.343	1.275	2.916
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.179	0.733	2.041
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.331	1.311
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.183	0.759
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.418
-4.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.189

FIG. 3

Fig. 26

45K52A55G0.6

GM IS GIVEN HERE IN MICRO-MHOS

THE BEGINNING PLATE WAS -0.

BIAS	-0.	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000
0.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	7642.5	13085.9	15510.2	17302.5	18851.1	20220.3	21442.7	0.	0.	0.	0.	0.
-0.20	0.	9128.7	13309.5	15957.9	17660.3	19161.7	20461.5	0.	0.	0.	0.	0.
-0.40	0.	4143.1	9662.7	13348.7	16055.0	18097.3	19454.4	20706.0	0.	0.	0.	0.
-0.60	0.	0.	5936.4	9899.7	13288.5	15986.9	18252.5	19725.1	0.	0.	0.	0.
-0.80	0.	0.	3062.7	7093.4	10259.5	13074.7	15939.7	18145.6	19980.7	21198.8	0.	0.
-1.00	0.	0.	0.	4807.8	8022.3	10691.6	13123.2	15708.9	18918.1	19984.6	0.	0.
-1.20	0.	0.	0.	2651.2	6081.3	8765.3	11036.3	13360.5	15456.2	17719.9	19745.5	0.
-1.40	0.	0.	0.	0.	4255.8	7079.3	9386.5	11539.2	13533.4	15441.6	17303.5	0.
-1.60	0.	0.	0.	0.	2483.1	5434.7	7873.4	9975.3	12019.5	13840.2	15576.7	17279.6
-1.80	0.	0.	0.	0.	0.	3910.4	6430.9	8533.2	10510.2	12361.8	14149.9	15577.7
-2.00	0.	0.	0.	0.	0.	2456.3	5026.9	7237.3	9123.7	11028.0	12743.7	14410.3
-2.20	0.	0.	0.	0.	0.	0.	3687.1	6006.9	7942.4	9803.3	11468.7	13104.5
-2.40	0.	0.	0.	0.	0.	0.	2428.1	4754.9	6758.3	8579.8	10382.5	11909.6
-2.60	0.	0.	0.	0.	0.	0.	0.	3489.3	5650.5	7459.5	9217.6	10904.7
-2.80	0.	0.	0.	0.	0.	0.	0.	2352.8	4560.9	6402.9	8085.0	9780.7
-3.00	0.	0.	0.	0.	0.	0.	0.	1216.0	3377.9	5342.7	7059.5	8687.4
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	2306.8	4353.3	6112.1	7722.1
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	1231.5	3306.0	5106.1	6709.8
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	2248.0	4173.8	5869.2
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	1291.0	3252.4	4974.1
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2234.2	4012.5
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1374.3	3179.3
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2233.4
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1451.1
-4.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

FIG 4

Fig. 27

45K62A65G0.6

RP IS GIVEN HERE IN OHMS

THE BEGINNING PLATE WAS -0.

BIAS	-0.	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000
0.20	0.	2428.7	2138.6	1945.1	1801.8	1692.3	0.	0.	0.	0.	0.	0.
0.	0.	2760.6	2321.0	2072.4	1897.9	1766.2	0.	0.	0.	0.	0.	0.
-0.20	0.	3931.0	2609.1	2235.7	2013.5	1855.0	1734.5	0.	0.	0.	0.	0.
-0.40	0.	0.	3393.3	2523.3	2160.6	1960.2	1815.7	0.	0.	0.	0.	0.
-0.60	0.	0.	5018.5	3130.4	2489.6	2122.7	1907.0	1779.9	1[illegible]79.0	0.	0.	0.
-0.80	0.	0.	0.	4024.6	2931.9	2433.8	2100.9	1879.7	1747.7	0.	0.	0.
-1.00	0.	0.	0.	5697.5	3545.5	2797.3	2364.3	2076.9	1[illegible]76.3	1721.2	0.	0.
-1.20	0.	0.	0.	0.	4476.2	3237.7	2662.1	2303.6	2054.8	1[illegible]70.4	0.	0.
-1.40	0.	0.	0.	0.	6259.1	3970.1	3020.7	2547.0	2[illegible]35.5	2019.4	1355.1	0.
-1.60	0.	0.	0.	0.	0.	4848.5	3491.1	2847.7	2447.3	2177.6	1996.2	0.
-1.80	0.	0.	0.	0.	0.	6640.6	4162.5	3229.0	2702.[illegible]	2358.2	2126.4	0.
-2.00	0.	0.	0.	0.	0.	0.	5157.7	3709.6	3010.7	2587.7	2290.2	0.
-2.20	0.	0.	0.	0.	0.	0.	6914.6	4392.6	3396.8	2642.9	2433.7	0.
-2.40	0.	0.	0.	0.	0.	0.	0.	5421.0	3902.3	3163.4	2698.2	0.
-2.60	0.	0.	0.	0.	0.	0.	0.	7089.5	4593.0	3550.8	2976.0	0.
-2.80	0.	0.	0.	0.	0.	0.	0.	0.	5654.3	4088.8	3314.4	0.
-3.00	0.	0.	0.	0.	0.	0.	0.	0.	7514.2	4789.6	3724.9	0.
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	10602.0	5550.1	4255.6	0.
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	7536.9	4972.9	0.
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	10588.1	5997.3	0.
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7771.9	0.
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10743.4	0.
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

FIG.5

Fig. 28

45K62A65G0.6

AMPLIFICATION FACTOR OR MU

BEGINNING PLATE = -0.

BIAS	-0.	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000
0.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	36.1	36.0	35.9	35.8	35.7	0.	0.	0.	0.	0.	0.
-0.20	0.	35.9	34.7	35.7	35.6	35.5	35.5	0.	0.	0.	0.	0.
-0.40	0.	0.	32.8	33.7	34.7	35.5	35.3	0.	0.	0.	0.	0.
-0.60	0.	0.	29.8	31.0	33.1	33.9	34.8	35.1	0.	0.	0.	0.
-0.80	0.	0.	0.	28.5	30.1	31.8	33.5	34.1	34.9	0.	0.	0.
-1.00	0.	0.	0.	27.4	28.4	29.9	31.0	32.7	33.7	34.4	0.	0.
-1.20	0.	0.	0.	0.	27.2	28.4	29.4	30.8	31.8	33.1	0.	0.
-1.40	0.	0.	0.	0.	26.6	27.4	28.4	29.4	30.3	31.2	32.1	0.
-1.60	0.	0.	0.	0.	0.	26.4	27.5	28.4	29.4	30.1	31.1	0.
-1.80	0.	0.	0.	0.	0.	26.0	26.8	27.5	28.4	29.2	30.1	0.
-2.00	0.	0.	0.	0.	0.	0.	25.9	26.8	27.5	28.5	29.2	0.
-2.20	0.	0.	0.	0.	0.	0.	25.5	26.4	27.0	27.9	28.5	0.
-2.40	0.	0.	0.	0.	0.	0.	0.	25.8	26.4	27.2	28.0	0.
-2.60	0.	0.	0.	0.	0.	0.	0.	24.7	26.0	26.7	27.4	0.
-2.80	0.	0.	0.	0.	0.	0.	0.	0.	25.8	26.2	26.8	0.
-3.00	0.	0.	0.	0.	0.	0.	0.	0.	24.7	25.6	26.3	0.
-3.20	0.	0.	0.	0.	0.	0.	0.	0.	24.5	25.5	26.0	0.
-3.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.9	25.4	0.
-3.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	23.8	25.0	0.
-3.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	25.3	0.
-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.0	0.
-4.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-4.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

FIG. 6

Fig. 29

adherence of the nickel plate to the tungsten base wire. As the siderod wire passed through the slots of the grid wind machine wire guide, the plating peeled off and clogged the grooves causing wire breakage. As the slots are only slightly larger than the wire (approx. 0.001 in. wide) only a small amount of flaking would result in a stoppage. The third lot of wire proved satisfactory and all subsequent wire has been purchased from this supplier.

During this period of grid wire trouble, some grids were made from molybdenum wire. It was from the use of these grids that the difficulty with grid emission discussed earlier was encountered.

Characteristics of the Type A15274

A measured plate characteristic of the A15274 is shown as Fig. 30. Also included in this figure are contours of constant transconductance. Comparison of these characteristics with the corresponding characteristics of the A15200, Fig. 19 shows an average increase in transconductance at a given operating point of about 30%. The actual increase in performance due to the design geometry of the A15274 is really more than this but a small amount has been sacrificed because of the reduced heater input power of the A15274 compared to that of the A15200. The data of Fig. 30 are again obtained under steady state DC operating conditions and allowance for decreased cathode temperature due to emission cooling is not necessary. The curves of Fig. 30 may be compared with the computer output data of Fig. 26. Some points of apparent discrepancy may be noted but are accountable. The bias lines will not agree because of a difference in contact potential and the computer data currents may be higher because emission cooling of the cathode is not taken into account as is done in the measurement methods for the curves of Fig. 30. In addition, the plate voltages of the computer data are derived from amplification factors and minor variations in geometry on the actual tube will cause the amplification factor to be slightly different resulting in an expanded or contracted plate voltage scale. If the computer data is plotted on the graticule of a tube characteristics curve tracer and the plate family of the tube in question is displayed under this graticule, many of these minor correction factors may easily be determined.

The transfer characteristics of the type A15274 are presented as Fig. 37 with transconductance contours included. Figs. 30 and 37 may be compared with published characteristics of the commercial RCA type 7586 nuvistor triode.

Perhaps a better picture of the type A15274 performance is given in the transconductance characteristics shown in Fig. 38. Because one of the targets of this contract is "electrical characteristics equal to

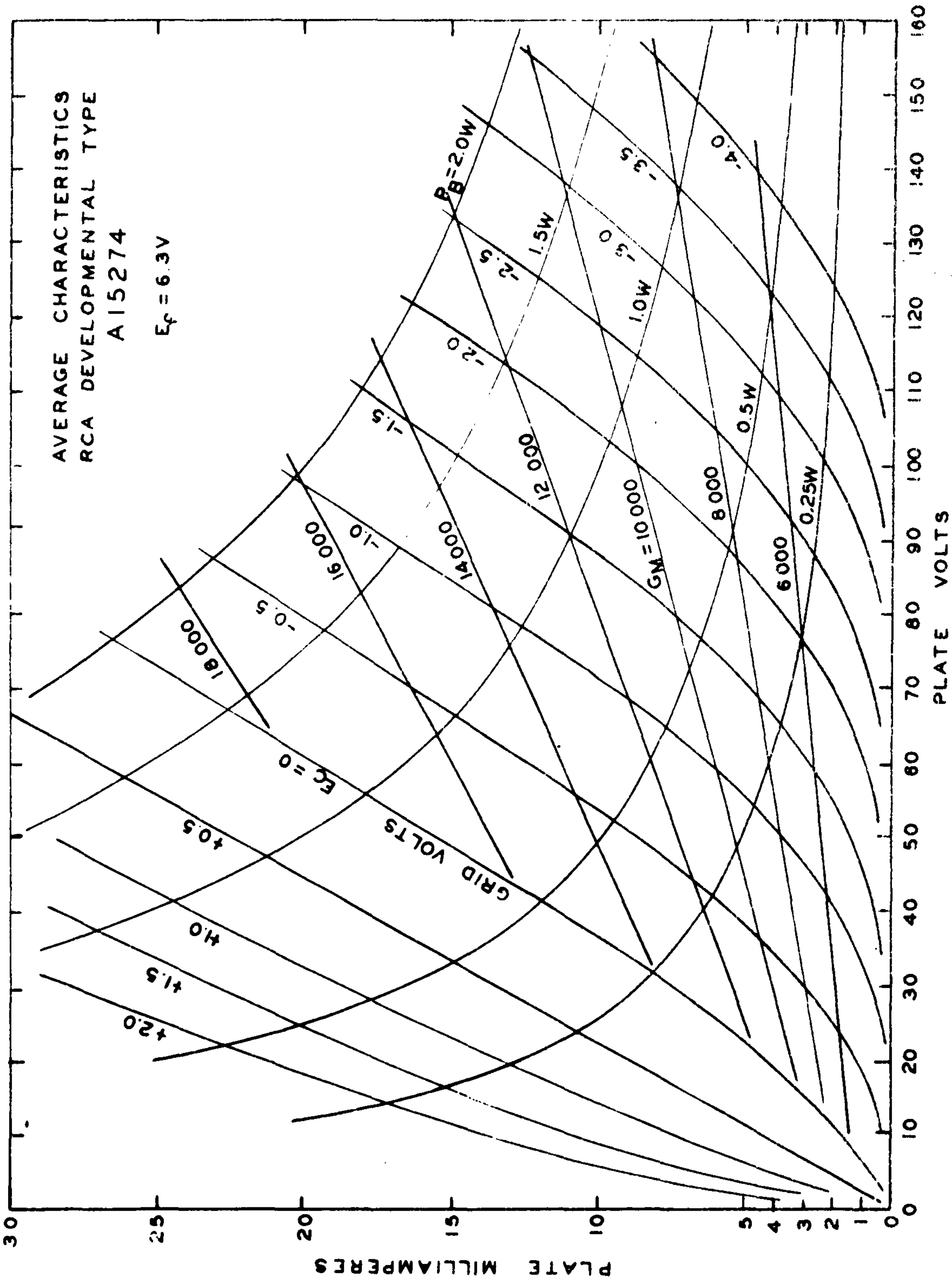

AVERAGE CHARACTERISTICS
RCA DEVELOPMENTAL TYPE
A15274
$E_f = 6.3V$
PLATE VOLTS
PLATE MILLIAMPERES
GRID VOLTS
$E_C = 0$
$P_B = 2.0W$
1.5W
1.0W
0.5W
0.25W
$G_M = 10000$
18000
16000
14000
12 000
8000
6000

Fig. 30

or superior to those of the present nuvistor prototype triode" comparable data are shown in Fig. 39 for the commercially available RCA type 7586 nuvistor triode. A comparison of the corresponding data of Figs. 38 and 39 shows that the type A15274 has significantly better transconductance for a given plate voltage and current than the RCA type 7586 for plate currents below twelve milliamperes and transconductances lower than 14,000 micromhos. If one were to extend the data beyond the limits of both Figs. 38 and 39, one would find that the characteristics of the type A15274 would depress until they were no longer superior to those of the RCA type 7586. This is due to the smaller cathode area of the type A15274 which results in a tendency to saturate at lower currents than the RCA type 7586. However, at any point one would consider as a normal operating point for the type A15274, its characteristics are definitely superior to those of the RCA type 7586 and this is accomplished with much less than 50 per cent of the heater input.

Design of Developmental Type A15287

Some early work on a remote cutoff tube is represented by the A15287. While the grid machine was set up with molybdenum siderod wire for the type A15274 grids, it was decided that it would be a fairly simple matter to make a few remote-cutoff grids by merely removing a few of the siderod wires. A computer program run was made using a double-pitch grid and the results of this run were combined in various proportions with a standard type A15274 single-pitch grid. The best result was indicated for the removal of 5 equally spaced siderods. The grid produced in this manner is obviously much less than ideal since the μ of the gapped sections is much too low. It was, however, of some interest and a few tubes were processed using these remote-cutoff grids. These tubes were assigned the RCA Development type number A15287. The plate characteristic of the type A15287 is shown in Fig. 31 and the extreme remoteness of the characteristic is quite obvious. The derivative characteristics are shown in Fig. 32 and for comparison a representative characteristic of the type A15274 is shown in dashed lines. The transconductance characteristics are shown in Fig. 33 with the A15274 curves included for comparison. Some comparison tests of the type A15287 were made and the cross-modulation characteristics are shown in Fig. 55. Noise factor and gain tests made at 700 Mcs. indicate that gain is about comparable with the type A15274 and the noise factor is probably about one-half db worse than the type A15274. Close comparison for RF performance is really not possible because of the marked variation in characteristics between the types which in turn is due to the manner in which the A15287 was made. It does indicate, however, the feasibility of a remote cutoff tube with the good characteristics of the type A15274.

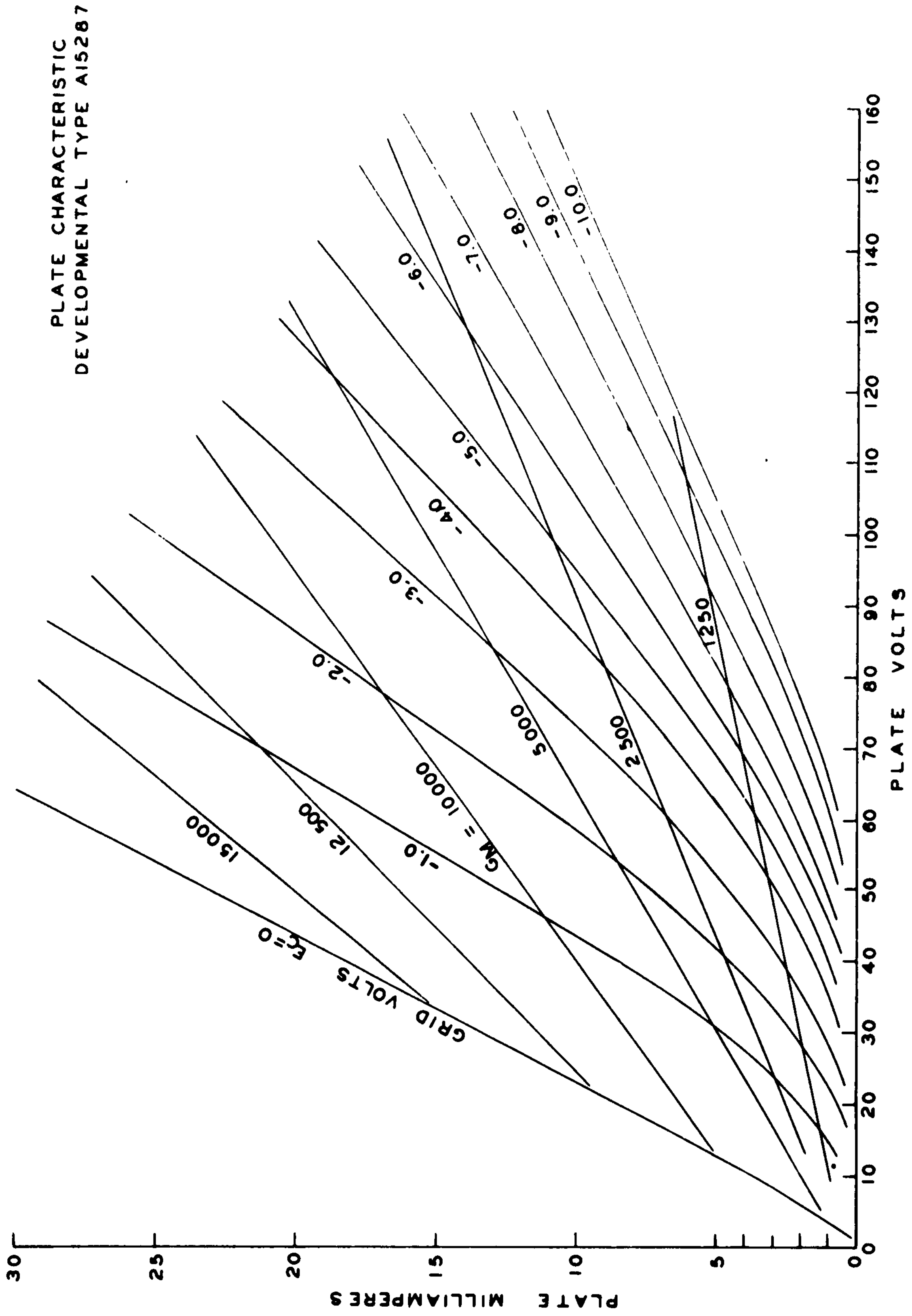


PLATE CHARACTERISTIC
DEVELOPMENTAL TYPE A15287
PLATE MILLIAMPERES
PLATE VOLTS
GRID VOLTS E_C=0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
GM = 10000
15000
12 500
5000
2500
1250
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

Fig. 31

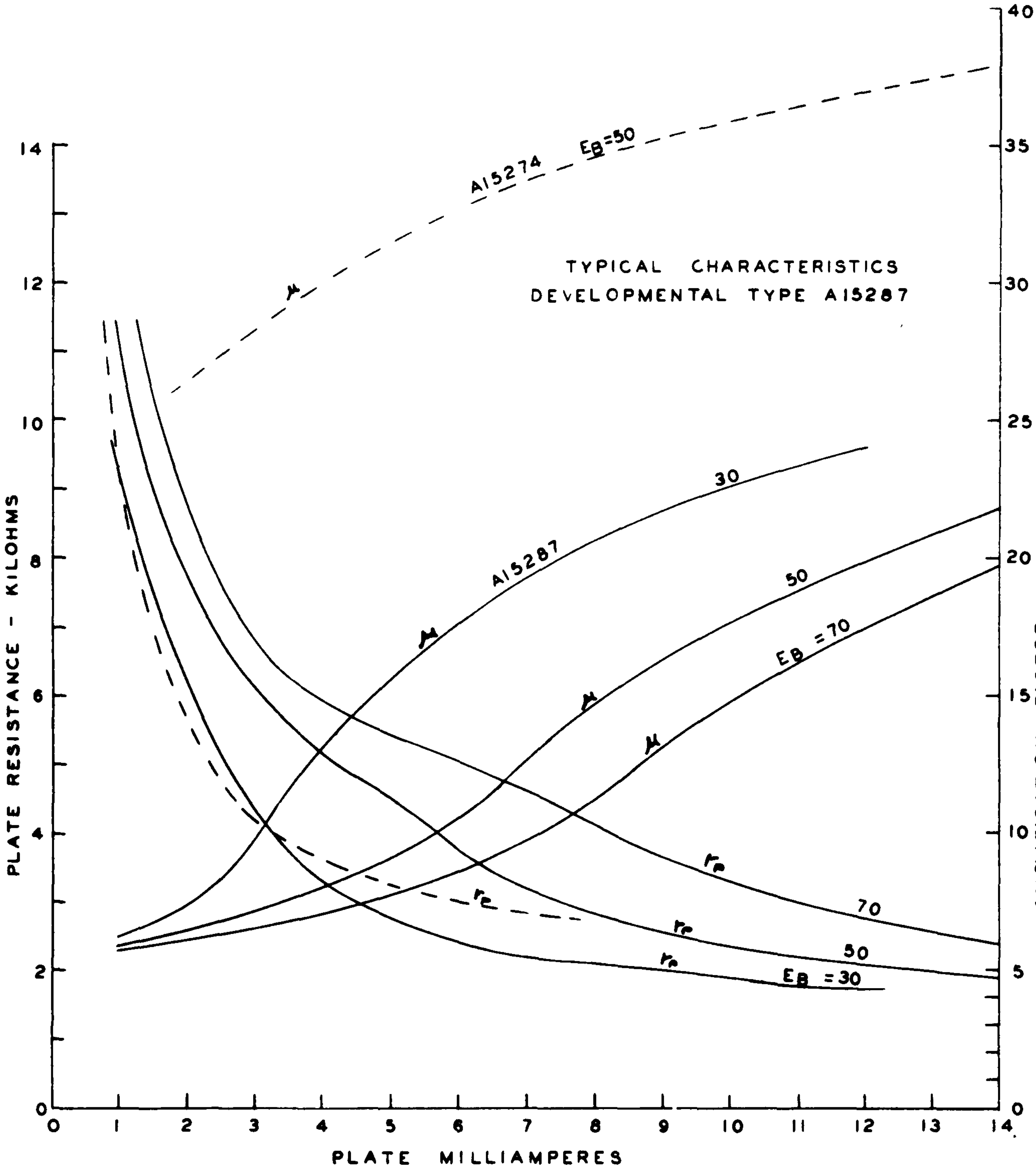

TYPICAL CHARACTERISTICS
DEVELOPMENTAL TYPE A15287
A15274 E_B=50
μ
A15287
30
50
E_B =70
μ
μ
μ
r_p
70
r_p
50
r_p
E_B =30
r_p
PLATE RESISTANCE - KILOHMS
AMPLIFICATION FACTOR
PLATE MILLIAMPERES
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40

Fig. 32

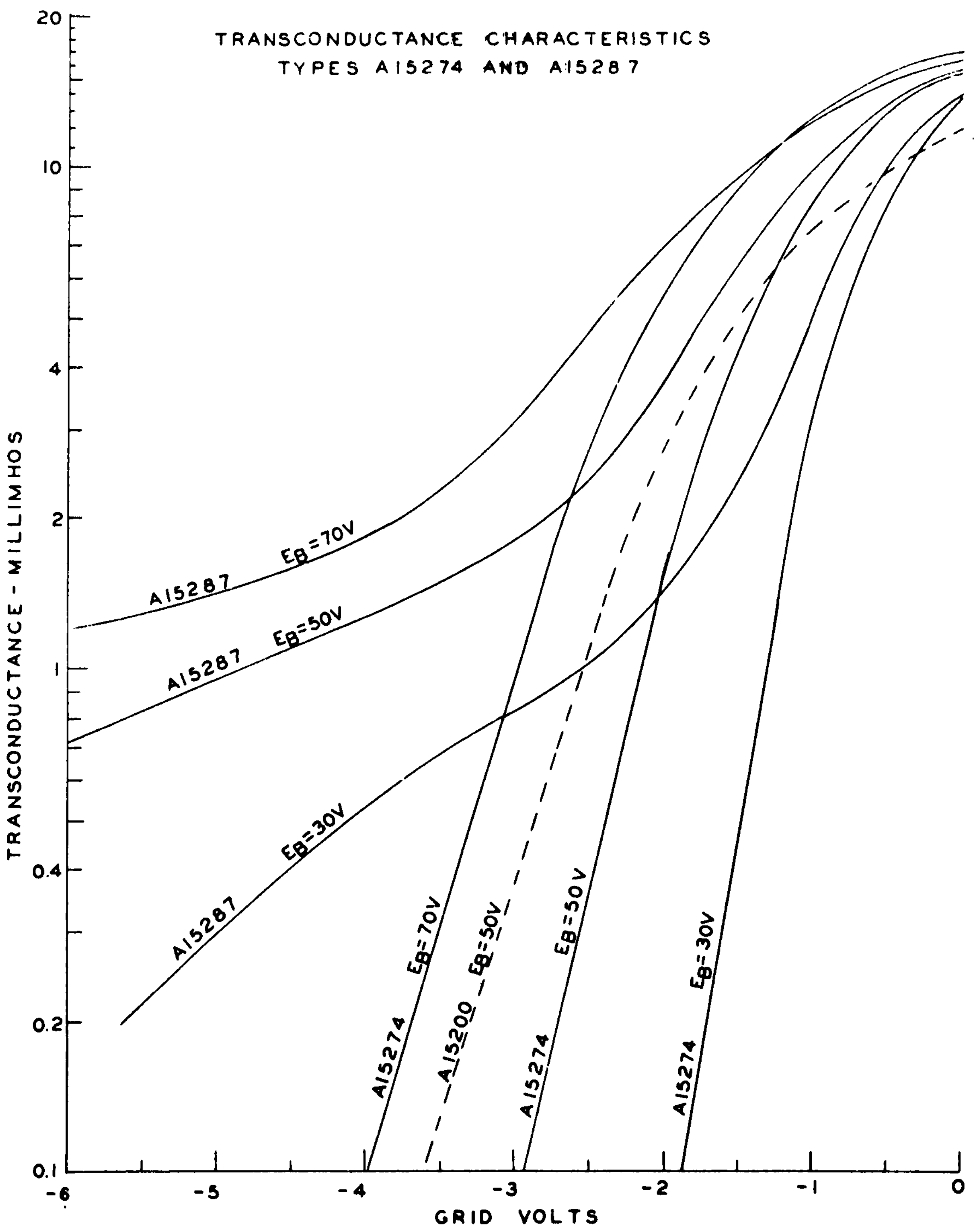

TRANSCONDUCTANCE CHARACTERISTICS
TYPES A15274 AND A15287
TRANSCONDUCTANCE - MILLIMHOS
20
10
4
2
1
0.4
0.2
0.1
A15287 EB=70V
A15287 EB=50V
A15287 EB=30V
A15274 EB=70V
A15200 EB=50V
A15274 EB=50V
A15274 EB=30V
-6
-5
-4
-3
-2
-1
0
GRID VOLTS

Fig. 33

Design of Developmental Type A15330

The second part of the contract was to develope a remote cutoff version of the 1/2 watt heater power reduced size nuvistor triode. The developmental type No. A15330 was assigned to this tube. Because of the availability of parts tooling, it was decided to keep the parts diameters the same and change only the grid wire spacing, if possible. In the design of this tube, maximum use was made of machine calculation of tube characteristics. The diameters of the elements and the cathode area were taken to be the same as the A15274. Runs were made for both 0.0006 in. diameter and 0.0007 in. diameter grid siderods and for various numbers of siderods. The exact number of siderods chosen is governed by the divisions available on a dividing plate for the milling machine used to make the grid wire guides. The following tabulation gives the specifications for the various machine runs.

Hot Cathode Diameter	0.0469 in.
Grid "	0.0510 in.
Anode "	0.0615 in.
Cathode Area	0.1550 sq. cm.

Grid Wire Diameter	0.00073 in.	0.00063 in.
Number of Siderods	34	40
	40	45
	60	48
		51
		60
		72

The computed data were then pieced together to form "likely looking" composite characteristics. Again the requirement of constructability, set by the miller dividing head, must be met. The aim is to evolve a linear or nearly linear "log gm" curve. Two composites were made, each using 3 different TPI sections of 0.0006 in. diameter grid wire. The grid composites consisted of sections as follows:

	Siderods per 2 π radians			
Grid	72	60	51	45
A	75%	13.35%	11.65%	
B		65%	19.45%	15.55%

Tubes with these grids were then machine computed. Curves of gm, rp, and μ for the two grids were plotted from the computed data and the cross-modulation characteristics were calculated by the second derivative of gm with e_c method. On the basis of the calculated cross-modulation curves, a tube with grid B would seem to be superior; however, it was thought that grid A would give better noise performance. Because of the better compromise, grid A was chosen for the A15330. A complete description of the grid may be found in Part III under manufacturing information.

The spiral cathode support was developed for this type. In early samples, trouble with excessive grid contact potential was encountered. This was believed to be caused by high manganese content in the available Nichrome ribbon that was used to make the initial samples of the support. When Nichrome ribbon became available which was inside the manganese specification for this application, no more contact potential trouble was experienced.

The plate characteristic family is shown in Fig. 40. The transconductance, plate resistance, and amplification factor for a typical tube is shown in Fig. 42.

This tube was made to have good cross-modulation characteristics and still retain good noise performance. In both respects it is quite good. Complete data on these characteristics will be given in a later section under Application Data. The cross-modulation performance is superior to that of the remote cutoff nuvistor triode, type 6DS4. Noise performance is only about 0.3 to 0.5 db inferior to the A15274.

Life Tests

In earlier parts of this report, life tests were described. However, these were designed to aid in arriving at the best value for heater power. The life tests considered here are tests run on the final designs, the A15274 and the A15330. Fig. 34 shows the results of a test of a group of five A15274's operated at 6.3 volts heater, E_b = 75v., R_g = 0.5 meg., E_{hk} = + 100 v., E_c = -1.3v., R_L = R_k = 0. The tubes were operated in an oven to hold the temperature of the shell at 150°C. The change in transconductance at 1000 hours was about 28%. Fig. 35 shows the life test results of a group of five A15330's operated at E_h = 6.3v., E_b = 67.5v., E_{hk} = + 100v., E_c = -1.3v., and R_k = R_L = 0. The change in transconductance at 1000 hours is about 38%.

Heater only life tests have been run in which the heater only is cycled 1 minute on and two minutes off at elevated voltage. The cathode is made positive with respect to the heater. The purpose of this test is to induce heater failure, either open heater or heater-to-cathode shorts. As the test is quite abusive to the tube, the electrical characteristics are not measured. The heater voltage is 7.5 volts and the heater-to-

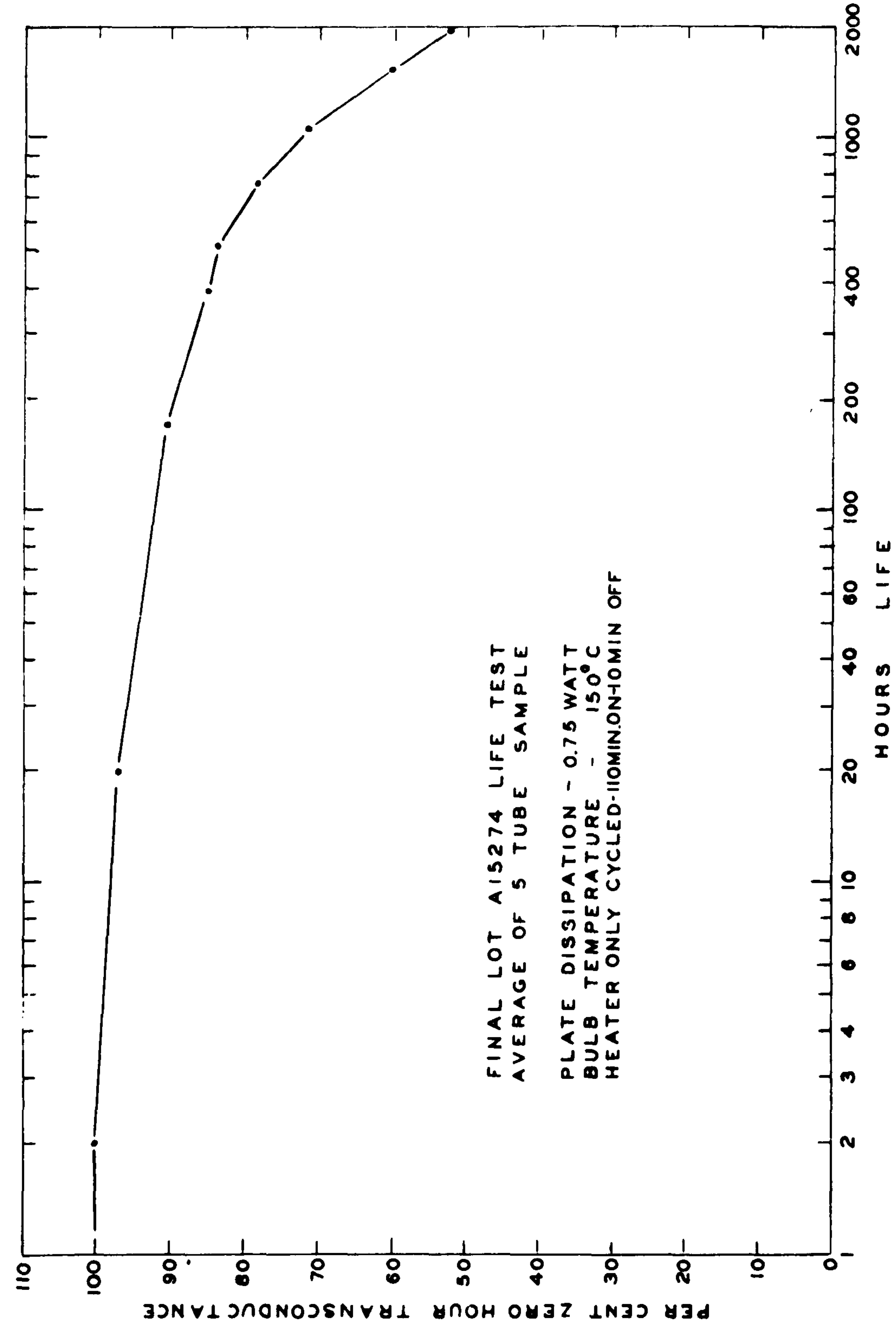
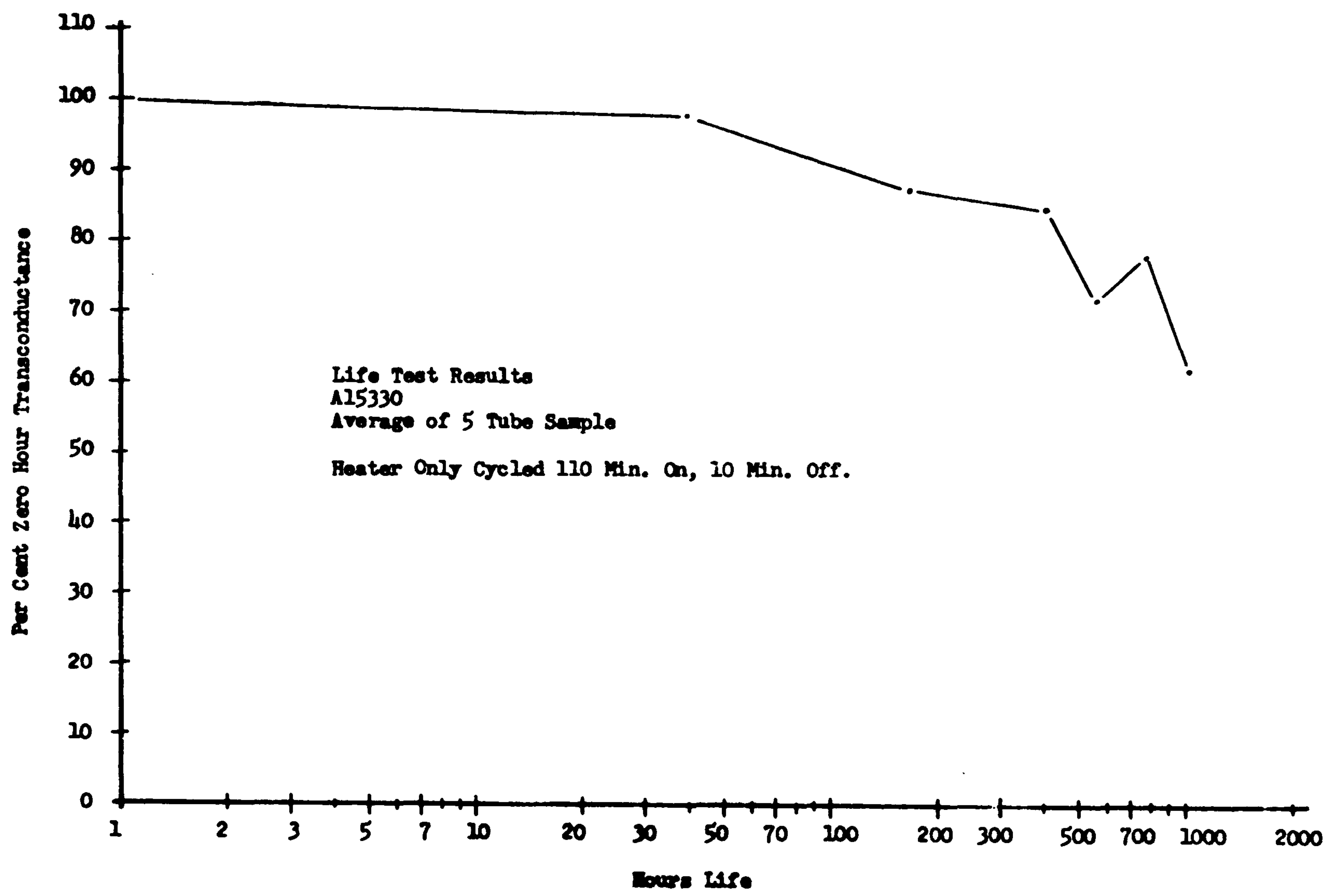

FINAL LOT A15274 LIFE TEST
AVERAGE OF 5 TUBE SAMPLE
PLATE DISSIPATION - 0.75 WATT
BULB TEMPERATURE - 150°C
HEATER ONLY CYCLED-110MIN.ON-10MIN OFF
PER CENT ZERO HOUR TRANSCONDUCTANCE
HOURS LIFE
0
10
20
30
40
50
60
70
80
90
100
110
2
3
4
6
8
10
20
40
60
100
200
400
1000
2000

Fig. 34



Life Test Results
A15330
Average of 5 Tube Sample
Heater Only Cycled 110 Min. On, 10 Min. Off.
Per Cent Zero Hour Transconductance
0
10
20
30
40
50
60
70
80
90
100
110
1
2
3
5
7
10
20
30
50
70
100
200
300
500
700
1000
2000
Hours Life

Fig. 35

cathode voltage is 100 volts. This test is run for 100 hours. If no heater failures occur and heater cathode leakage remain below 10 μamp with E_{hk} both + 100 and -100v. dc, the test is considered successful. Five A15274's were subjected to this test and met the requirements even though the heater voltage was 9.0v. instead of 7.5v. Five A15330's also were tested and successfully passed the test. However, three of these tubes developed grid-to-cathode shorts. A second group of five were x rayed and put on the same life test. After 28 hours of life they were again x rayed. Deformation of the cathode support could be detected. However, A15330's on regular life test have not shown any indication of cathode support deformation and it is believed to be caused by abnormally severe thermal cycling. One-hundred hours of cycling is 2000 times on and off, or more than 5 on periods per day for one year. Although it represents a short-coming, it is considered relatively insignificant and it is believed that further development would overcome the problem. An earlier test substantiates this opinion. A single tube with an early sample of the spiral support was cycled at the same rate with $E_h = 8.0$ volts for 600 hours with no apparent indication of deformation.

CHARACTERISTICS OF THE DELIVERY SAMPLES

In previous portions of this report a few curves of characteristics have been given. In this portion, collected in one place, are the principle characteristics of both the A15274 and the A15330. Also given in this section are the acceptance inspection results for both types, based on the Tentative MIL-E-1 Specifications which are included under Manufacturing Information.

No tubes were delivered that were used in any degradation test. The tubes were serially numbered during manufacture, but these markings were removed prior to delivery.

Further specialized data is given in the following section on Application Information.

APPLICATION INFORMATION

General

The information given in this section is information that would be useful to anyone contemplating the use of the A15274 or the A15330. Although the work was distributed throughout the contract period and in many cases was either a by-product of development work or a check on design, it is collected in one section for convenience to the reader. The measurement procedures are covered in general under the section of this report by that name. In general, the tests were performed on A15274's and A15330's; however, in some cases tests are reported that were made on

(text continued on page 91)

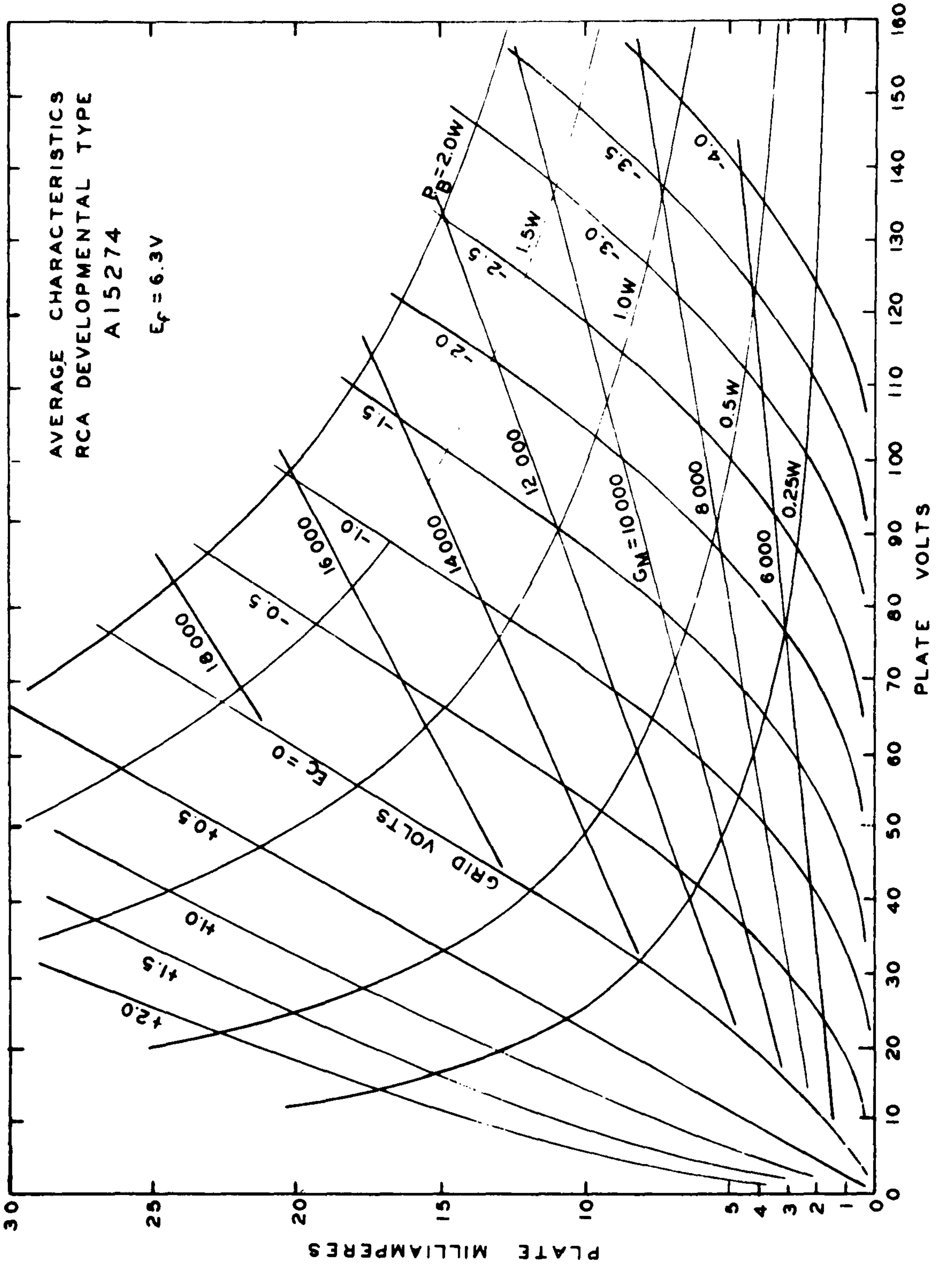

AVERAGE CHARACTERISTICS
RCA DEVELOPMENTAL TYPE
A15274
$E_f = 6.3V$
GRID VOLTS
PLATE VOLTS
PLATE MILLIAMPERES

Fig. 36

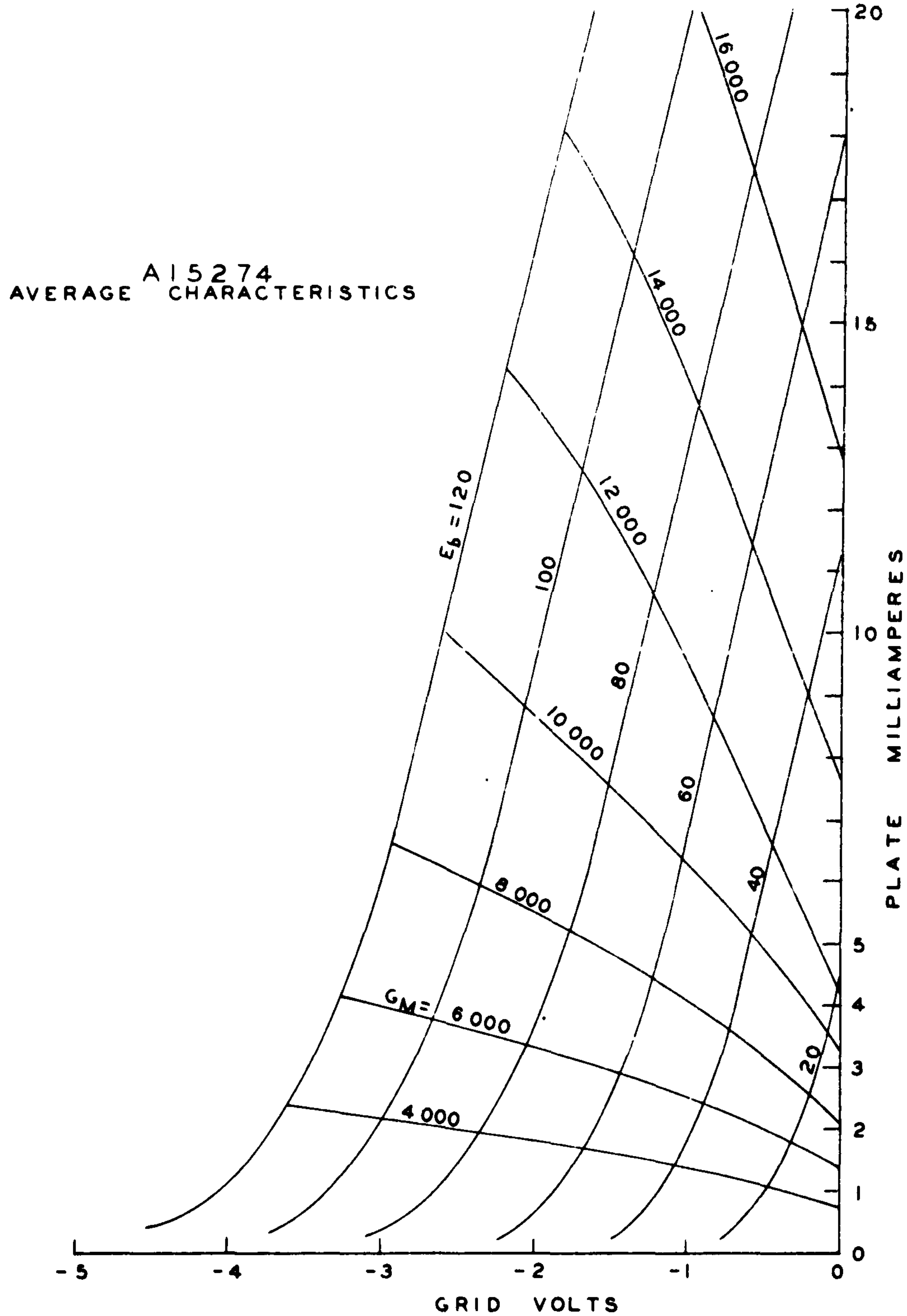

A15274
AVERAGE CHARACTERISTICS
E_b = 120
100
80
60
40
20
G_M = 6 000
4 000
8 000
10 000
12 000
14 000
16 000
PLATE MILLIAMPERES
GRID VOLTS
-5
-4
-3
-2
-1
0
1
2
3
4
5
10
15
20

Fig. 37

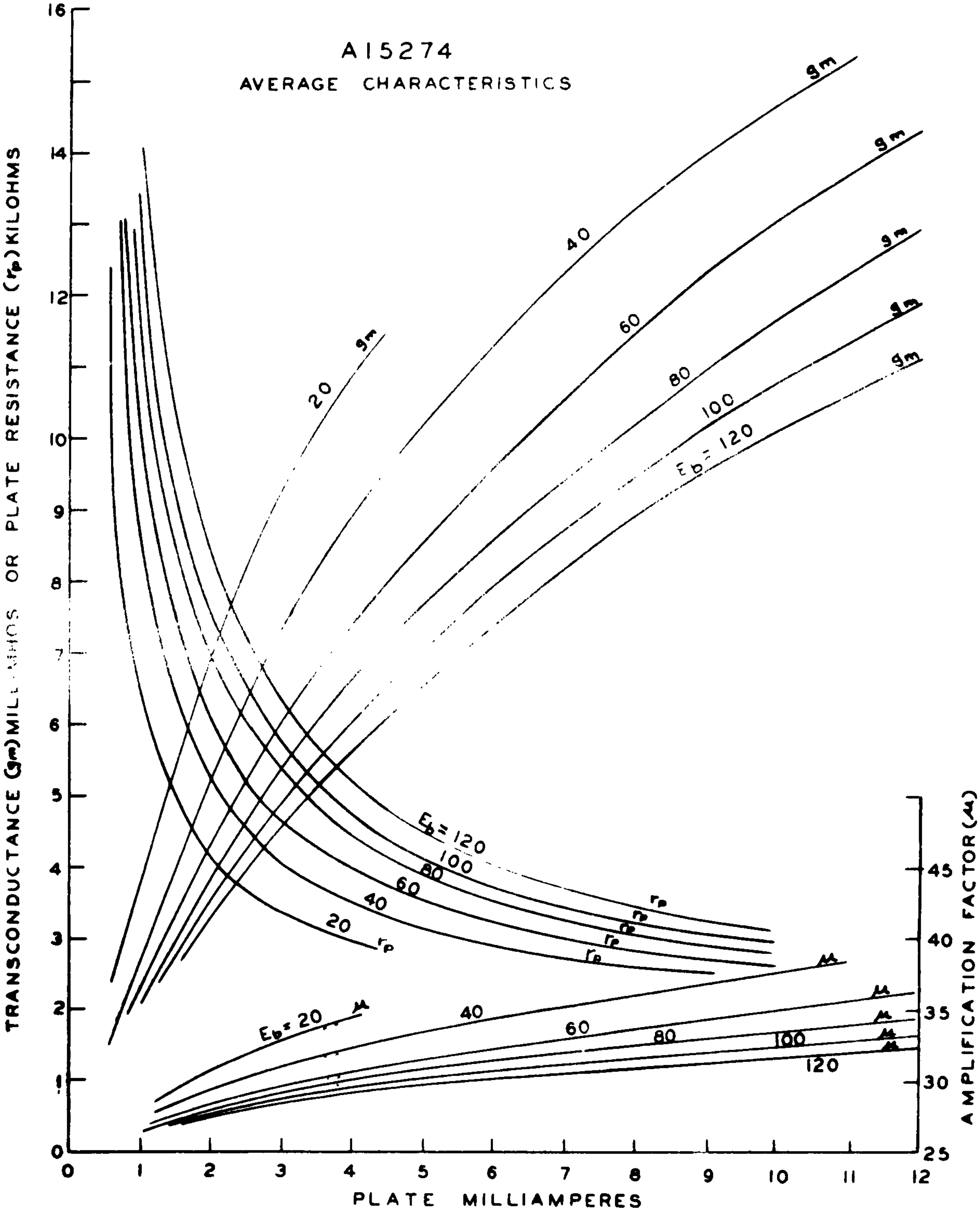

A15274
AVERAGE CHARACTERISTICS
TRANSCONDUCTANCE (gm) MILLIMHOS OR PLATE RESISTANCE (rp) KILOHMS
AMPLIFICATION FACTOR (μ)
PLATE MILLIAMPERES
gm
20
40
60
80
100
Eb = 120
rp
Eb = 20
μ
120
0
1
2
3
4
5
6
7
8
9
10
11
12
14
16
25
30
35
40
45

Fig. 38

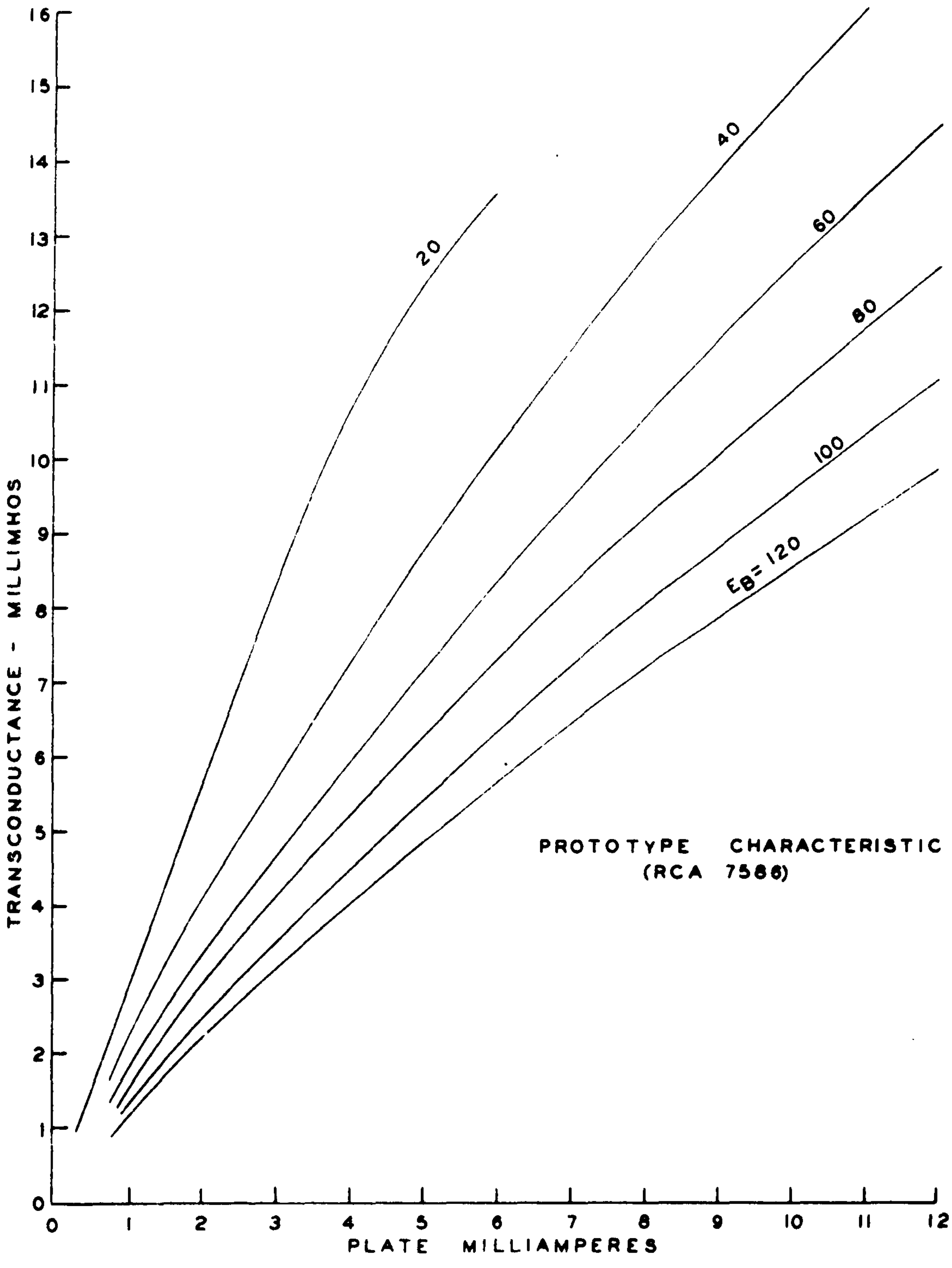

16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
TRANSCONDUCTANCE - MILLIMHOS
0
1
2
3
4
5
6
7
8
9
10
11
12
PLATE MILLIAMPERES
20
40
60
80
100
E_B= 120
PROTOTYPE CHARACTERISTIC
(RCA 7586)

Fig. 39

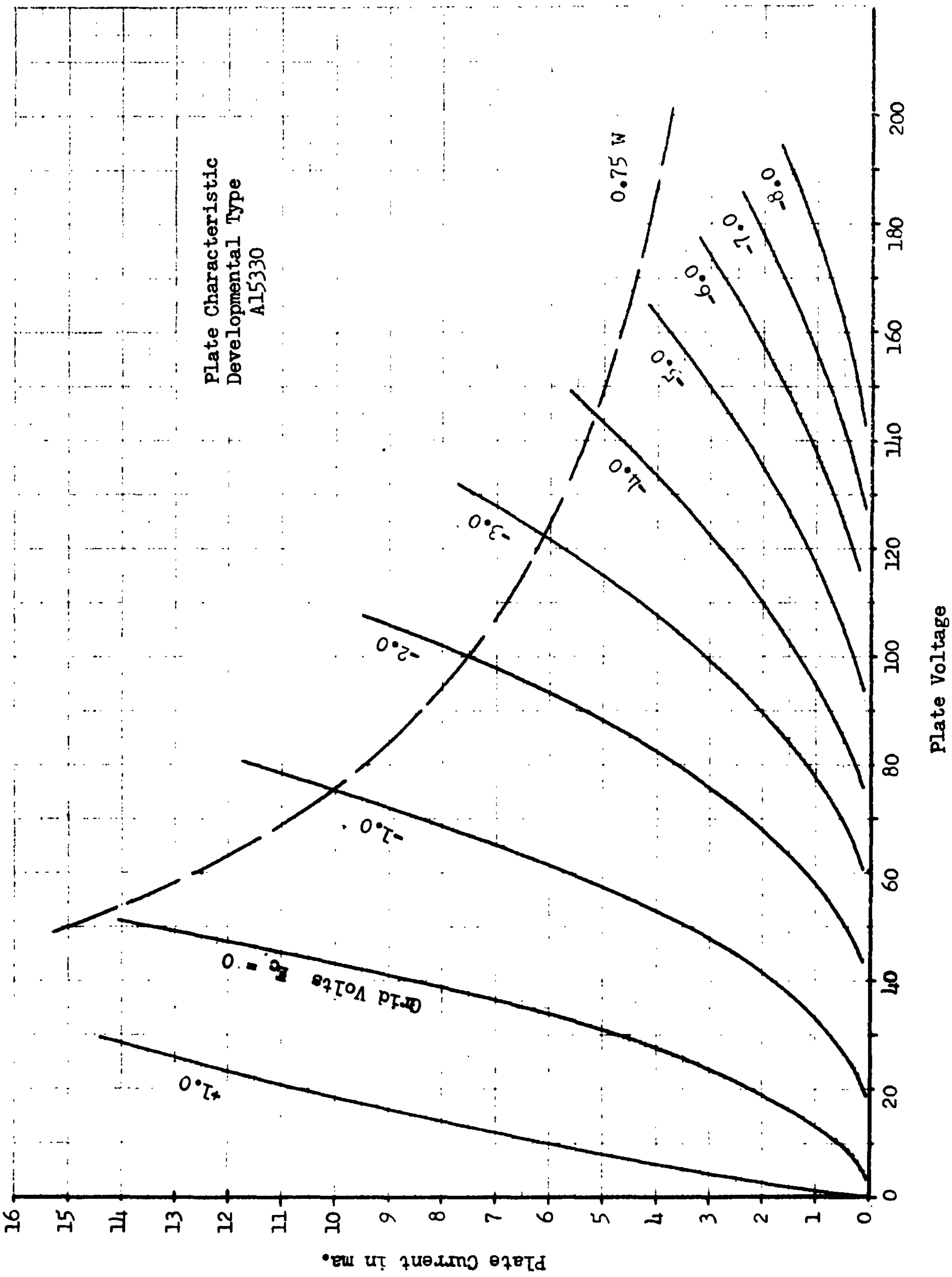


Plate Characteristic
Developmental Type
A15330
0.75 W
Grid Volts E_c = 0
+1.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
Plate Voltage
Plate Current in ma.
0
20
40
60
80
100
120
140
160
180
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Fig. 40

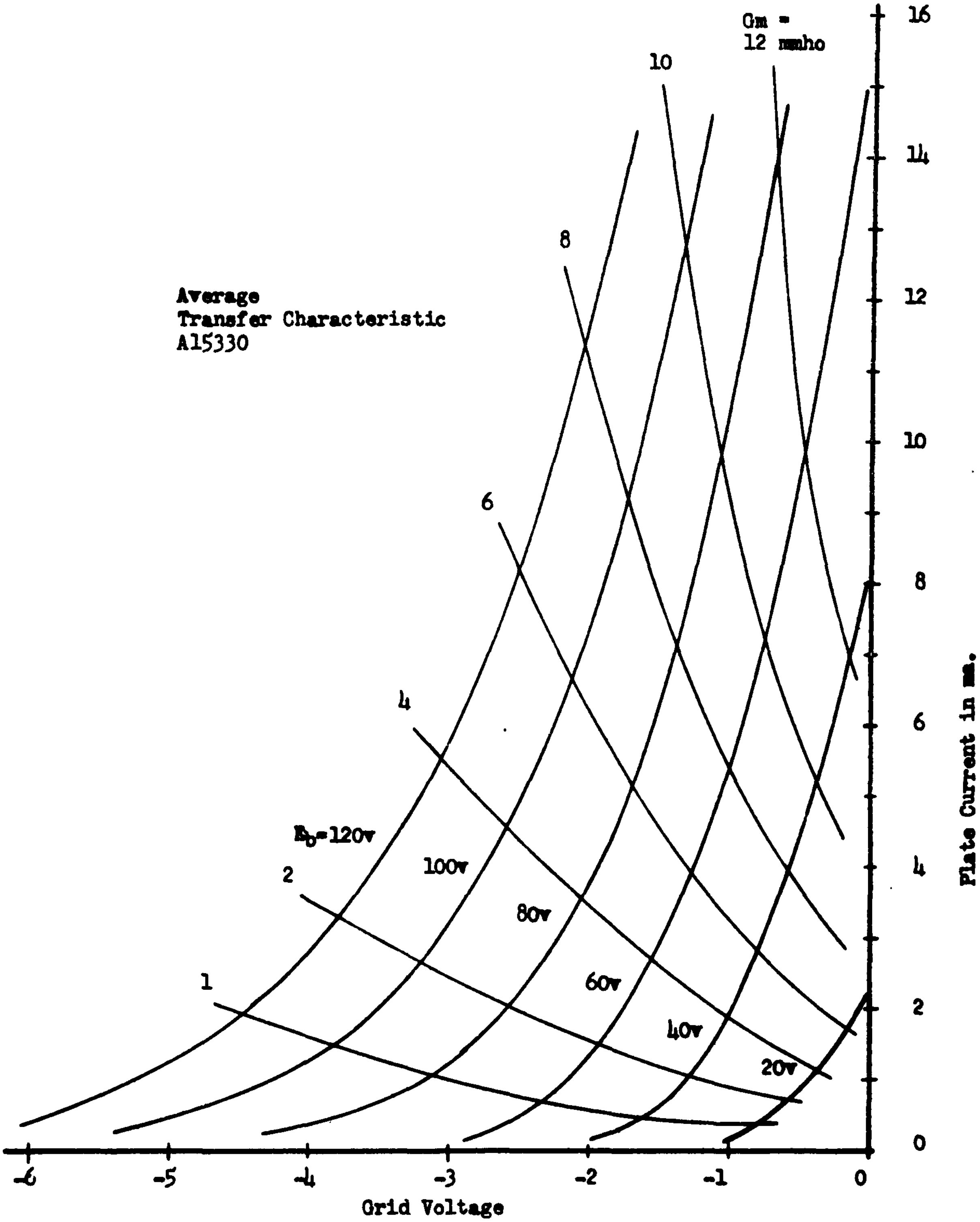

Gm =
12 mmho
10
8
6
4
2
1
Average
Transfer Characteristic
A15330
E_b=120v
100v
80v
60v
40v
20v
16
14
12
10
8
6
4
2
0
-6
-5
-4
-3
-2
-1
0
Grid Voltage
Plate Current in ma.

Fig. 41

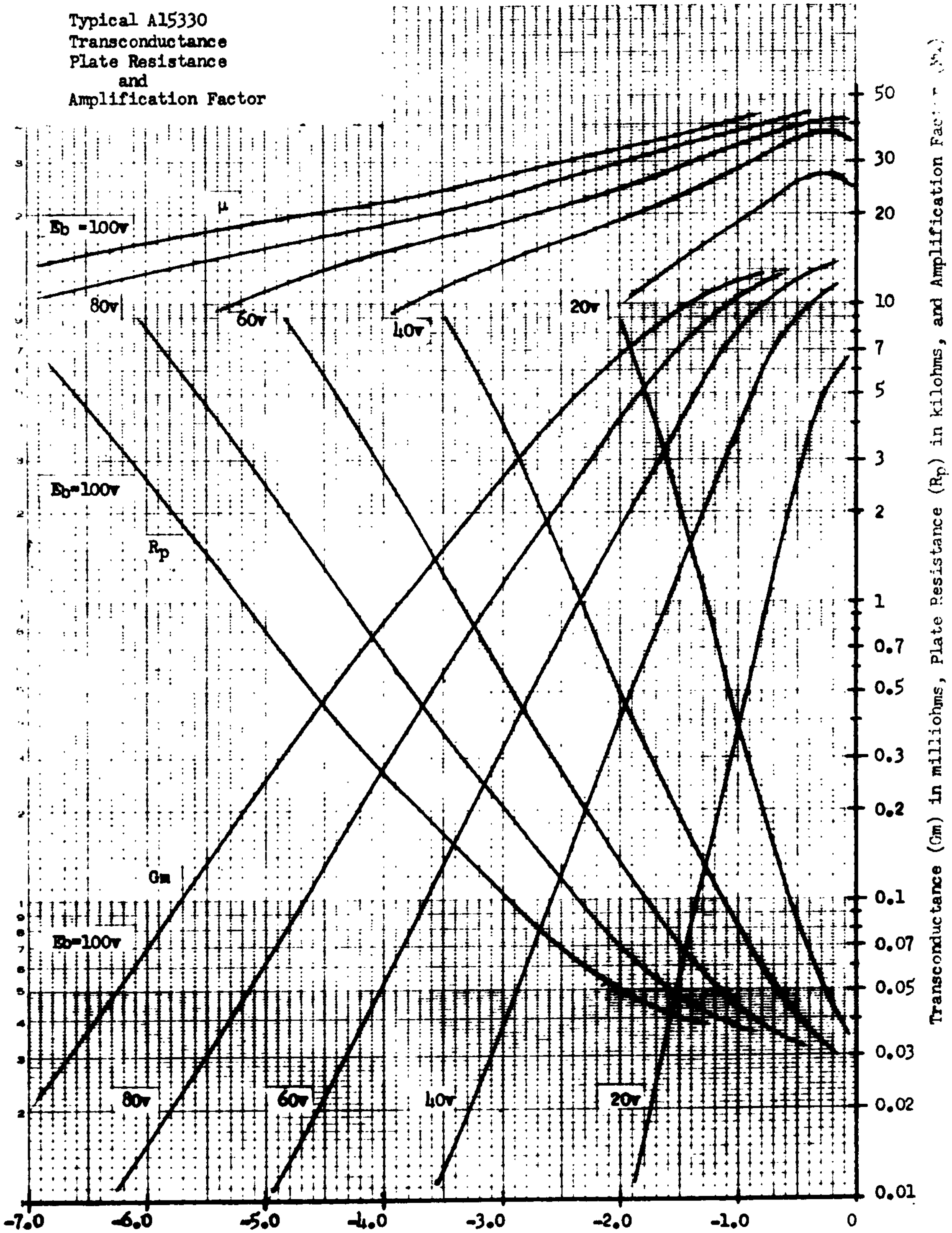

Typical A15330
Transconductance
Plate Resistance
and
Amplification Factor
μ
Eb = 100v
80v
60v
40v
20v
Eb=100v
Rp
Gm
Eb=100v
80v
60v
40v
20v
50
30
20
10
7
5
3
2
1
0.7
0.5
0.3
0.2
0.1
0.07
0.05
0.03
0.02
0.01
-7.0
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0
Transconductance (Gm) in millimhos, Plate Resistance (Rp) in kilohms, and Amplification Factor (μ)
Grid Voltage

Fig. 42

TEST RESULTS
DELIVERY LOT
RCA DEVELOPMENTAL TYPE A15274

Test	Plate Current (1)	Transconductance (1)	Amplification Factor	Heater Current	Plate Current (2)	Transconductance (2)	Transconductance (3)
Para. No.	4.10.4.1	4.10.9	4.10.11.1	4.10.8	4.10.4.1	4.10.9	4.10.9
Symbol	Ib	Sm	Mu	If	Ib	Sm/Δ Ef	Δ SmEf
Units	mAdc	μmhos	--	mA	μAdc	μmhos	%
Max. Limit	8.0	12400	40	70	30	--	15
Min. Limit	6.0	9600	30	65	--	9000	--
	6.9	11800	36.8	68	9	11100	5.9
	6.3	10900	32.1	68	14	9860	9.5
	6.5	10700	36.1	67	6	9600	10.2
	7.1	11000	34.8	69	1	10100	8.1
	6.7	11000	36.7	67	2	10100	8.1
	6.9	11200	35.7	67	7	10300	8.0
	7.0	11400	33.1	68	11	10600	7.0
	7.2	11200	34.8	68	4	10200	8.9
	6.9	11000	35.3	67	4	10300	6.3
	6.7	11200	36.2	67	8	10700	4.4
	6.8	10600	35.2	68	1	9910	6.5
	7.3	11500	34.4	68	1	10800	6.0
	6.6	11200	35.8	68	10	10300	8.0
	6.9	11200	35.6	68	11	10500	6.2
	6.9	11800	34.7	68	7	11000	6.7
	6.5	11400	36.2	68	12	10200	10.5
	7.6	11600	33.3	69	8	10900	6.0
	6.9	11100	34.0	67	28	10300	4.5
	7.3	11500	32.7	67	5	10600	10.4
	6.7	11300	35.9	67	9	10600	6.1
	6.6	10600	35.3	68	1	9880	6.7
	6.1	10700	35.3	66	17	9680	9.5
	6.6	10800	36.9	67	4	9770	9.5
	6.6	11400	34.2	68	30	10400	8.7
	7.6	10700	32.4	68	6	10400	2.8
	6.1	10500	36.1	68	15	9430	10.1
	6.6	11700	34.4	67	12	10700	8.5
	6.7	11400	35.6	67	13	10200	10.5
	7.0	11600	35.3	69	18	10900	6.0
	7.1	11300	34.2	68	5	10500	7.0
	7.2	11600	33.6	68	7	10800	6.8
	6.9	11400	34.9	68	15	10700	6.1
	7.1	11400	33.6	67	19	10400	8.7
	7.2	11100	34.0	68	6	9960	10.2
	7.1	11700	34.2	68	5	10700	8.5
	6.7	11200	33.4	68	15	10400	7.1
	7.3	11600	32.7	68	22	10500	9.4
	6.7	11300	35.7	67	27	10300	8.8
	7.0	11200	33.1	68	9	10100	9.8
	6.9	11400	36.0	68	9	10300	9.6
	7.2	11600	34.0	68	4	10800	6.8
	7.1	11300	32.8	67	30	10500	7.0
	6.7	11400	34.3	68	3	10500	7.8
	7.0	11500	35.4	68	4	10700	6.9
	6.6	11500	33.8	66	3	10400	9.5
	6.7	11000	36.2	68	2	10200	7.1
	6.9	11200	33.9	68	4	10400	7.1
Average	6.87	11249	34.7	67.7	9.9	10372	7.74

NOTE: For test conditions see RCA Tentative Military Specification Sheet---Electron Tube, RCA Developmental Type A15274 of 22 December 1961

Fig. 43

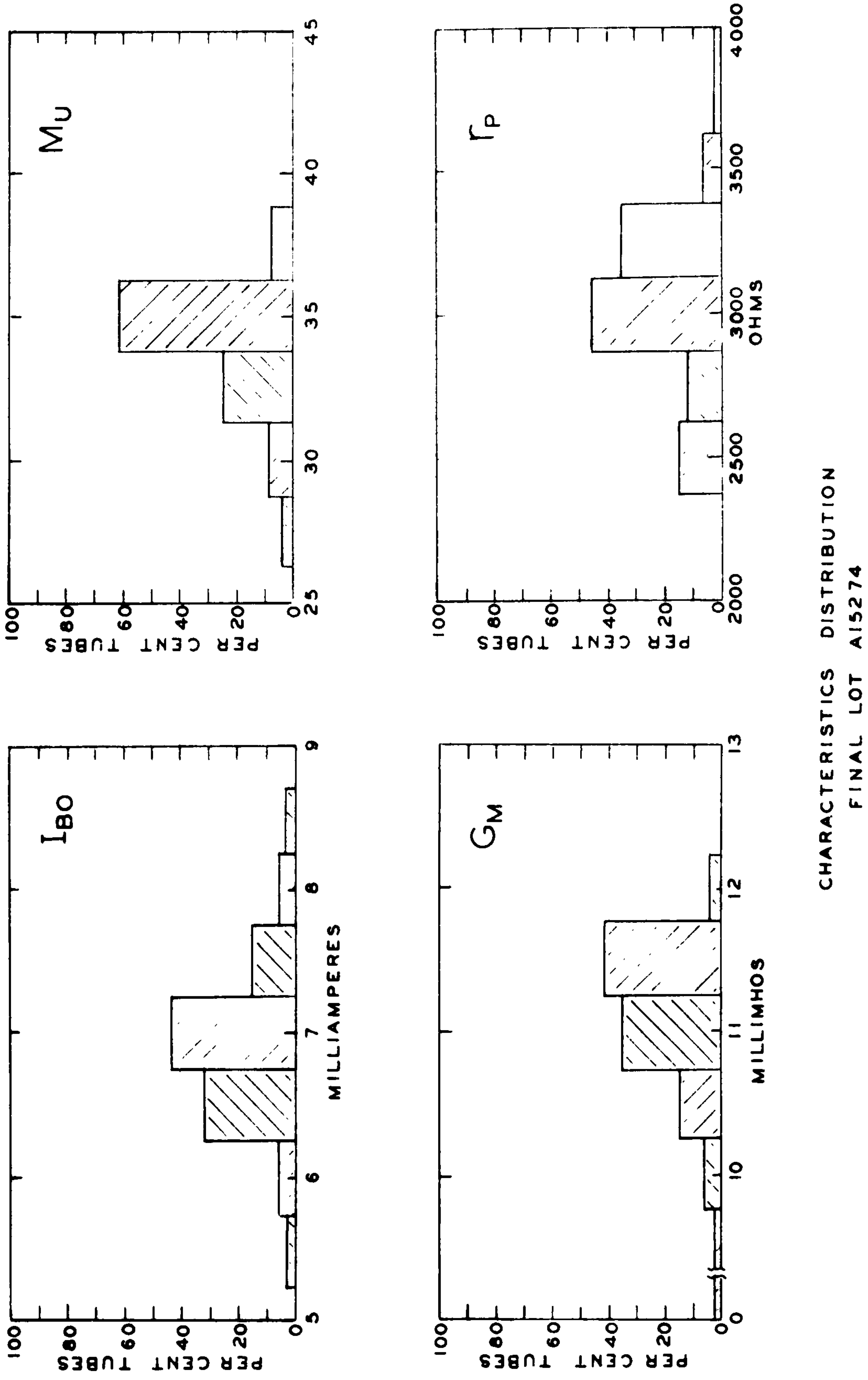

I_BO
MILLIAMPERES
G_M
MILLIMHOS
M_U
r_P
OHMS
PER CENT TUBES
CHARACTERISTICS DISTRIBUTION
FINAL LOT A15274

Fig. 44

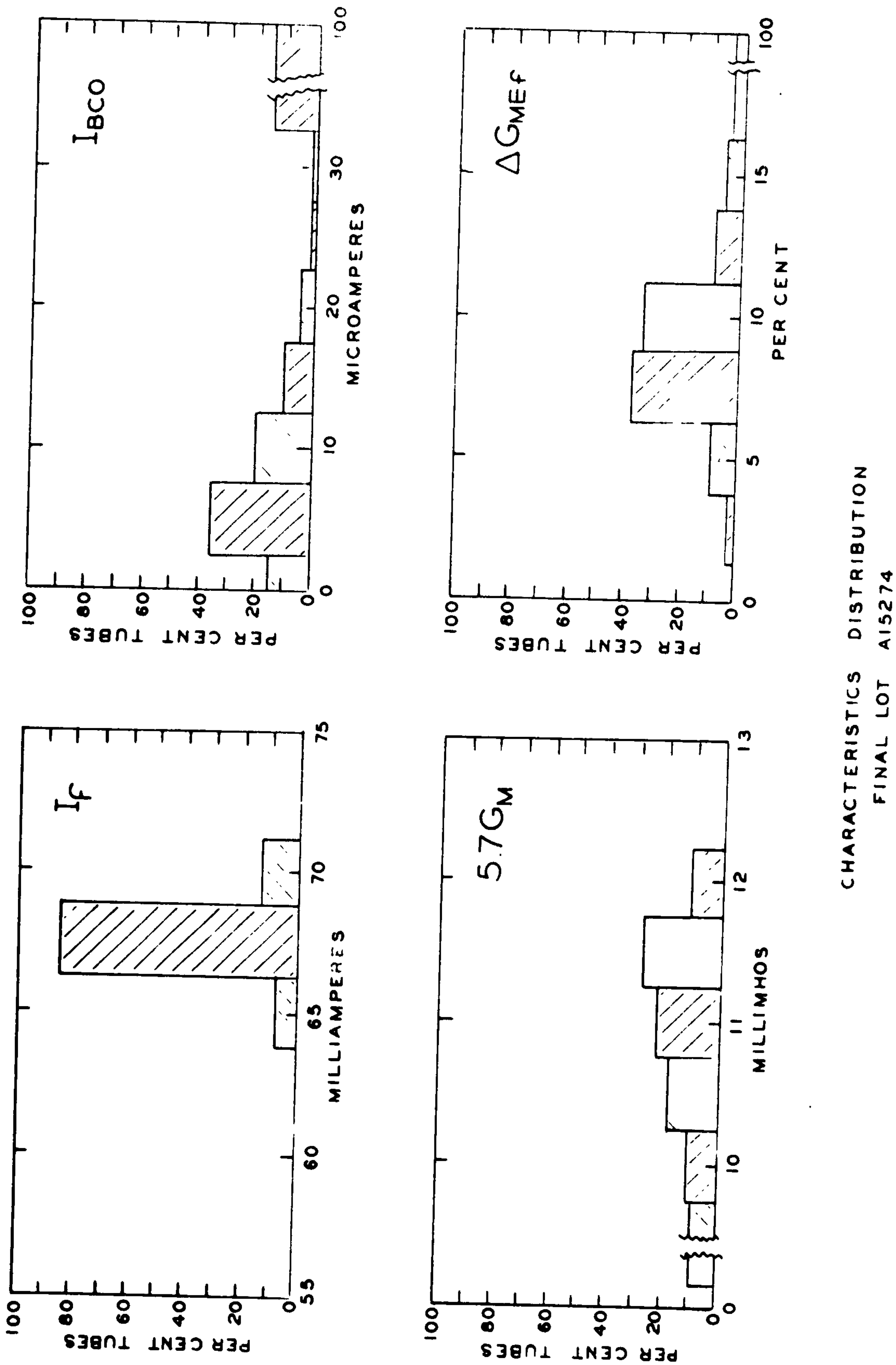

I_BCO
PER CENT TUBES
MICROAMPERES
ΔG_MEf
PER CENT TUBES
PER CENT
I_f
PER CENT TUBES
MILLIAMPERES
5.7G_M
PER CENT TUBES
MILLIMHOS
CHARACTERISTICS DISTRIBUTION
FINAL LOT A15274

Fig. 45

	Plate Current (1)		Transconductance (1)		Amplification Factor	
	I_b mAdc		Sm µmhos		Mu --	
	Pretest	Post Test	Pretest	Post Test	Pretest	Post Test
Para 4.9.20.5 Shock (1) 1000g, 1 ms: E_b = 75 Vdc, E_c = - 1.3 Vdc, E_{hk} = + 100 Vdc						
1	7.7	7.6	10900	11000	30.5	32.7
2	5.6	6.2	10100	10400	34.5	32.8
3	6.8	7.0	10200	10800	35.5	36.4
4	7.0	6.2	10600	9420	32.3	32.1
Para 4.9.20.5 Shock (2) 50g, 11 ms: E_b = 75 Vdc, E_c = - 1.3 Vdc, E_{hk} = + 100 Vdc						
1	7.5	7.5	11100	11000	31.5	31.7
2	6.6	6.6	10800	10700	33.0	33.6
3	6.5	6.6	10400	10400	36.6	36.6
4	6.7	6.7	10300	10300	31.9	31.8
Para 4.9.20.6 Fatigue 5g, 60 cps, 48 hour: E_f = 6.3v E_b = 0						
1	7.8	6.7	11800	10200	30.1	31.6
2	6.5	6.1	10300	9370	37.2	37.2
3	7.3	7.1	11100	10400	34.1	33.7
4	6.6	6.7	11100	10600	34.9	35.6

ACCEPTANCE INSPECTION (DEGRADATION) RESULTS
RCA DEVELOPMENTAL TYPE A15274

TABLE 1

	Heater-Current		Heater-Cathode Leakage		Heater-Cathode Leakage	
	I_f		$+I_{hk}$ µAdc		$-I_{hk}$ µAdc	
	Pretest	Post Test	Pretest	Post Test	Pretest	Post Test
Para 4.11.7 Heater Cycling Life Test E_f = 9.0v; E_{hk} = - 100 Vdc E_b = 0 1 min. on/2 min. off 2000 cycles						
1	65	67	.1	.05	.02	.1
2	67	67	.05	.05	.02	.05
3	65	65	.15	.1	.02	.0
4	66	67	.15	.1	.25	.1
5	65	68	.1	.05	.02	.07

ACCEPTANCE INSPECTION (LIFE) RESULTS
RCA DEVELOPMENTAL TYPE A15274

TABLE 2

TEST RESULTS
DELIVERY LOT
RCA DEVELOPMENTAL TYPE A15330

Test	Plate Current (1)	Transconductance	Amplification Factor	Heater Current	Plate Current (2)	Grid Current
Para. No.	4.10.4.1	4.10.9	4.10.11.1	4.10.8	4.10.4.1	4.10.6.1
Symbol	Ib	Sm	Mu	I_f	I_b	I_c
Units	mAdc	µmhos	--	mA	µAdc	µAdc
Max.Limit	9.0	11,500	37	70	60	0.1
Min.Limit	7.0	9,000	30	65	10	--
	8.2	10,000	32.9	67	24	0
	7.8	9,700	34.1	68	28	0
	8.3	10,100	32.5	67	38	0
	8.0	9,900	32.8	67	28	0
	7.9	9,800	34.2	68	24	0
	8.2	10,700	32.6	67	49	0
	8.2	10,400	32.6	67	23	0
	7.3	9,600	35.9	67	27	0
	7.2	10,000	36.5	67	29	0
	8.1	10,500	32.5	67	17	0
	8.3	11,000	33.8	66	27	0
	7.9	10,800	34.3	67	45	0
	7.8	10,400	34.4	67	20	0
	8.1	10,500	33.6	67	42	0
	7.7	10,000	30.3	67	14	0
	7.8	10,400	33.3	67	17	0
	7.7	9,600	33.4	67	20	0
	8.2	10,400	32.8	68	30	0
	8.2	10,800	33.2	67	46	0
	7.7	10,000	33.8	67	14	0
Average	7.9	10,200	33.5	67	28	0

TABLE 3

Acceptance Inspection Results
Degradation and Life Test
RCA Developmental Type A15330

Plate Current (1) Ib mAdc Pretest	Post Test	Trans-conductance Sm µmhos Pretest	Post Test	Plate Current (2) Ib µAdc Pretest	Post Test
Para. 4.9.20.5 Shock (1) 1000g, 1ms, Eb=75Vdc, Ec=-1.3Vdc, Ehk=+100Vdc					
7.7	7.9	9700	10000	21	49
7.5	7.6	9800	10000	15	7
8.0	8.8	10000	10100	57	249
8.2	9.4	9900	10100	75	425
Para. 4.19.19.9 Sweep Frequency Vibration 5g, 50c/s to 15kc/s, Ebb=70Vdc, Rp=2000, Ck=1000µf., Rk=100ohm					
7.6	7.8	9300	9400	21	21
7.6	7.6	10000	10000	25	24
7.9	7.5	9900	9700	17	14
7.3	8.00	10100	9900	60	31

Heater Current If mA Pretest	Post-Test	Heater Cathode Leakage +Ihk µAdc Pretest	Post-Test	Heater Cathode Leakage -Ihk µAdc Pretest	Post-Test
Para. 4.11.4, Heater Cycling Life Test Ef=7.5V, Ehk=-100Vdc, Eb=0, Rk=0 1 Min. On/2 Min. Off, 2000 Cycles					
65	65	0.15	0.05	0.50	0.20
67	67	0.10	0.10	0.45	0.20
68	68	0.20	0.05	0.65	0.30
65	66	0.20	0.05	0.75	0.25
67	67	0.15	0.05	0.55	0.20

TABLE 4

DISPOSITION OF SAMPLES NObsr 81478

No.	Type	Date	Destination	Authorization
3	A15200	9 June 1961	USASRDL Evans	NObsr 81478 30A-627 Ser.691A1B1-946 1 Jun 61
4	A15274	16 Nov 1961	NADC Johnsville	NObsr 81478 30A-627 Ser.691A1B1-1666 2 Nov 61
6	A15274	19 Dec.1961	NADC Johnsville	NObsr 81478 30A-627 Ser.691A1B1-1374 12 Dec 61
2	A15274	29 Dec 1961	APL Johns Hopkins	NObsr 81478 30A-627 Ser.691A1B1-1374 14 Dec 61
31	A15274	27 Dec 1961	BuShips	Contract NObsr 81478
4	A15274	29 Dec 1961	BuShips	Contract NObsr 81478
50	Subtotal			
20	A15330	1 Oct 1962	BuShips	Contract NObsr 81478
70	Total			

TABLE 5

A15200's. In the latter case, similar tests performed on the A15274 or A15330 would yield similar or identical results; for an example, cathode warm-up time.

Plate Connector

The size of the top cap of this envelope precludes the use of any standard connector. Therefore, a new one has been designed. The dimensions of this plate connector are shown in Fig. 46. Although the material of which this connector is made is of relatively little consequence, those made for use in this laboratory were made from a silver, magnesium, nickel alloy manufactured by Handy & Harmon. This material is sufficiently ductile to be easily formable and may be hardened after forming. Because of its high silver content, it has excellent corrosion resistance and high thermal and electrical conductivity. A number of these connectors were supplied with the delivery samples.

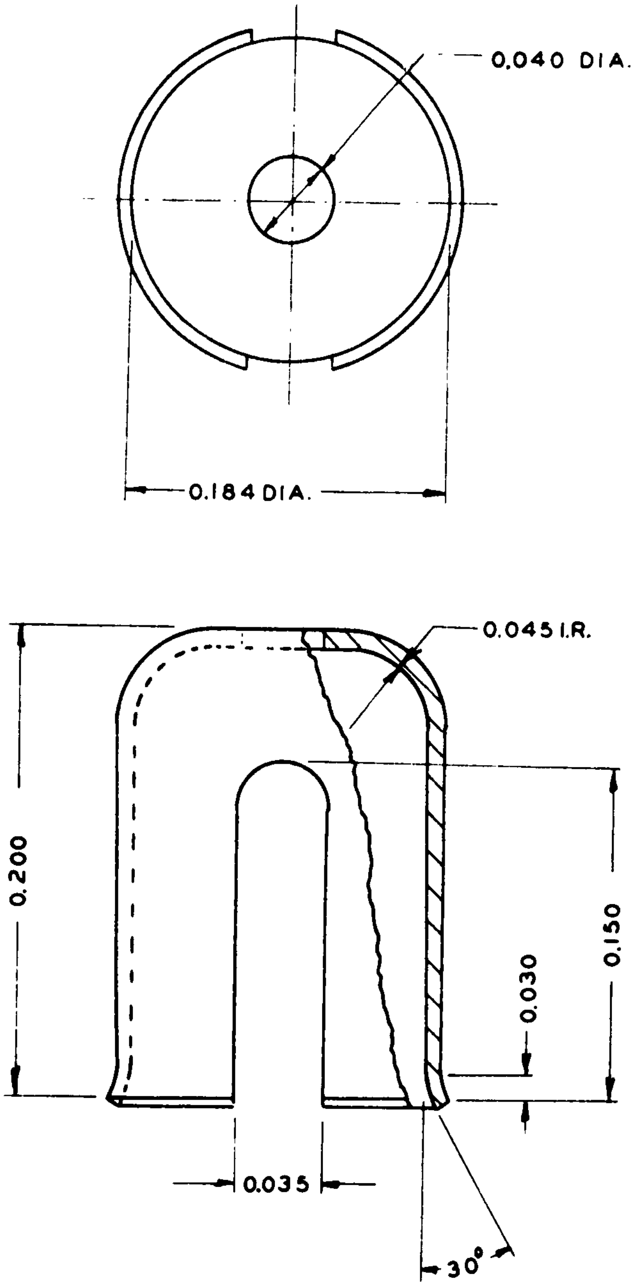
Interelectrode Capacitance

It is of considerable interest for circuit design purposes to determine the effective capacitances of a tube as it would be used in a practical chassis mounted socket. For this purpose an adaptor was constructed in which a standard four pin linotetrar socket was mounted in a 1/16 inch thick aluminum plate. Connections were arranged so that the aluminum plate "chassis" could be used as a tube shield in three-terminal bridge measurements and connected to whichever tube electrode might be grounded in a particular circuit arrangement. Two anode cap connectors were provided; one shielded completely and the other with only the connecting lead shielded. The complete shielding had relatively small effect on most of the readings and values with the shielded lead only are considered most practical for application purposes. The following table, Table 6, gives representative values obtained from the measurement of a number of developmental type A15274 and A15330 tubes.

TABLE 6

Interelectrode Capacitances of the A15274 and A15330

	A15274	A15330
C_{gk}	3.33 pf	3.42 pf
C_{gp}	1.97 pf	2.05
C_{pk}	0.060	0.051
C_{in}	3.47	3.56
C_{out}	0.061	0.051
C_{hk}	1.35	1.28



A15200 PLATE CONNECTOR

Fig. 46

In addition, by use of this adaptor and partial tube assemblies, it has been possible to differentiate between the effects of the envelope and the active electrodes in their contributions to the interelectrode capacitances. The results of these measurements are shown schematically in Fig. 47. It can be seen that with the exception of the heater-cathode capacitance the active elements contribute the major portion of the capacitances. Fig. 47 represents an A15200. The A15274 and A15330 have higher grid-cathode and grid-plate capacitance due to closer spacing of the active elements. The corresponding envelope contributions are not effected. This substantially reduces the percentage contribution of the envelope to the total of these two capacitances.

Amplifier Performance

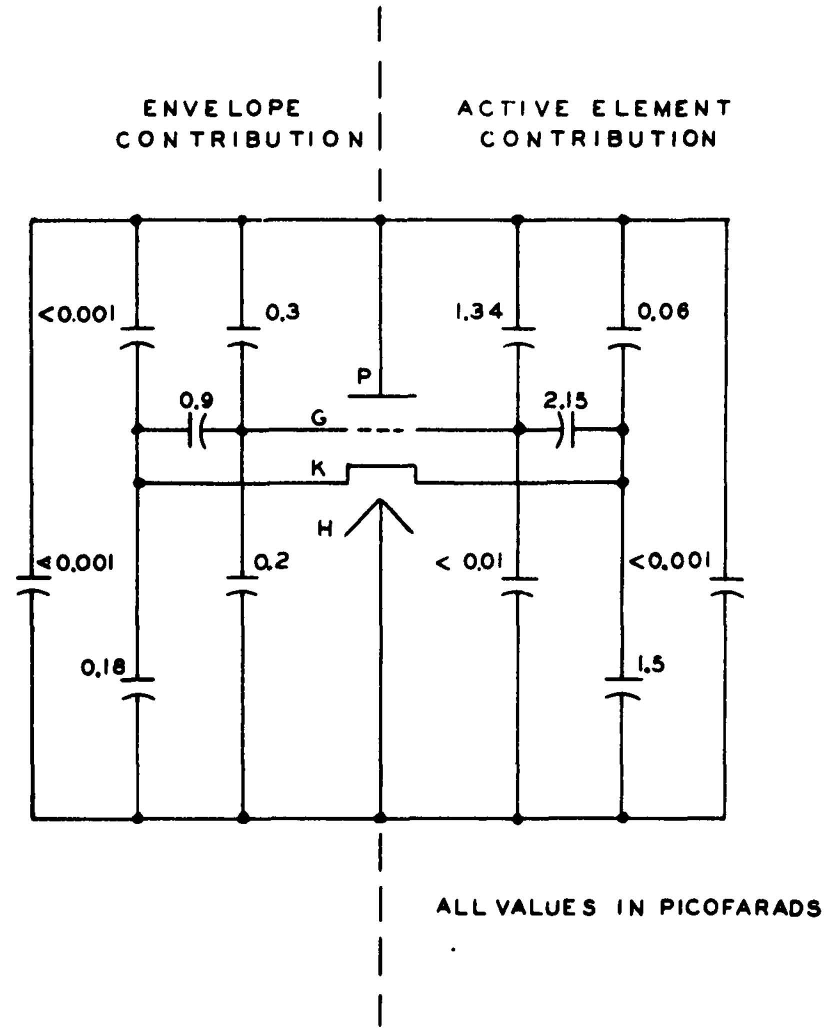
Noise Factor and Gain: Ultra-high-frequency amplifier performance measurements were made with the circuit shown in Fig. 3. Early work on using this tube as a UHF amplifier pointed out the necessity for a low inductance connection to the grid as the grid lead and socket inductance created instability in the region of 700 Mcs. To overcome this effect, an additional grid grounding contact was used which consisted of a length of ordinary spring finger stock formed in a circle and attached to the chassis around the socket. The entire periphery of the grid terminal is then well grounded. Two-terminal pair measurements (described later) of the A15274 indicate that it is reasonably safe to say that the tube, in such a grounded grid stage, will present no oscillation problems with any practical output termination.

Developmental type A15274's were measured with a plate supply voltage of 50 volts and a cathode resistance of 100 ohms giving a plate current of about 7 ma. These conditions give a nominal 3/4 watt total power input to the tube. The noise factor and gain measurements are shown in Table 7.

TABLE 7

Average Noise Factor and Gain Measurements
A15274

Freq.	Matched Input		Optimum Input	
	NF	G	NF	G
500	6.2 db	14.1 db	5.9 db	13.6 db
700	7.6	13.0	7.5	12.0
900	11.4	10.5	9.7	10.0



DISTRIBUTION OF A15200
DIRECT INTERELECTRODE CAPACITANCES

Fig. 47

Although gain-bandwidth measurements were made on the A15200, they were not repeated for the A15274. The A15200 figures shown in Table 8, give a good indication of what might be expected from the A15274 although the A15274 may give somewhat higher gain. It should be pointed out that these are measurements of a complete amplifier and not of the tube alone. The gain is power gain. The product of gain and bandwidth is not expected to be a constant.

TABLE 8

Average Gain and Bandwidth Measurements
A15200

Freq.	Gain	Bandwidth
500 Mcs.	12.3 db	11.6 Mcs.
700	10.5	22
900	7.9	36

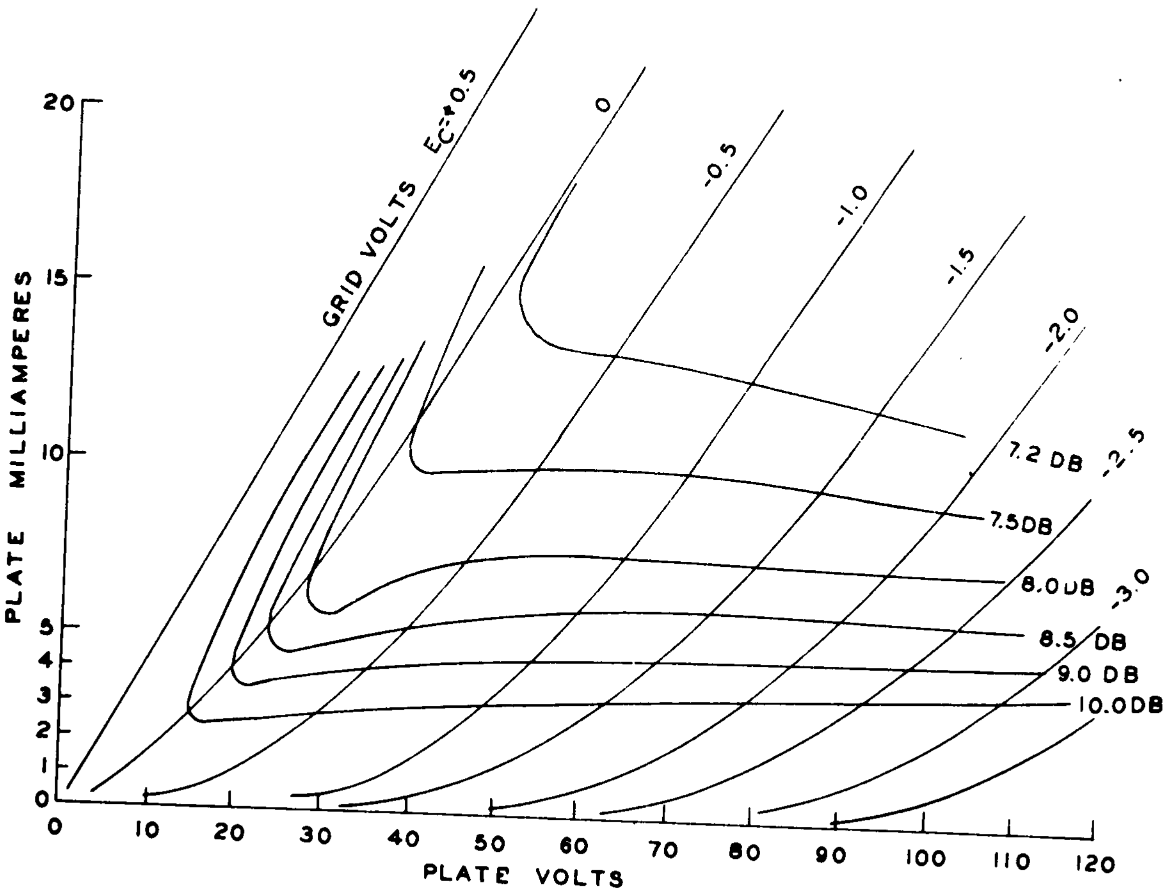
A typical A15274 was measured for noise factor and available gain at 700 Mcs. at a large number of operating points and this data plotted against the plate family. These gain data were not taken at constant bandwidth but rather at whatever bandwidth the operating conditions produced. The minimum bandwidth was approximately 2 Mcs. at about Eb = 50, Ib = 3 ma. The maximum bandwidth is in excess of 10 Mcs. at about Eb = 60v, Ib = 10 ma. These gain and noise factor contours are shown in Fig. 48 and Fig. 49.

Similar noise factor, gain and bandwidth measurements were made for the A15330 with a plate supply voltage of 60v., a cathode resistor of 100 ohms, giving a plate current of about 7.9 ma. The results are shown in the following table.

TABLE 9

Noise Factor, Gain, and Bandwidth
A15330

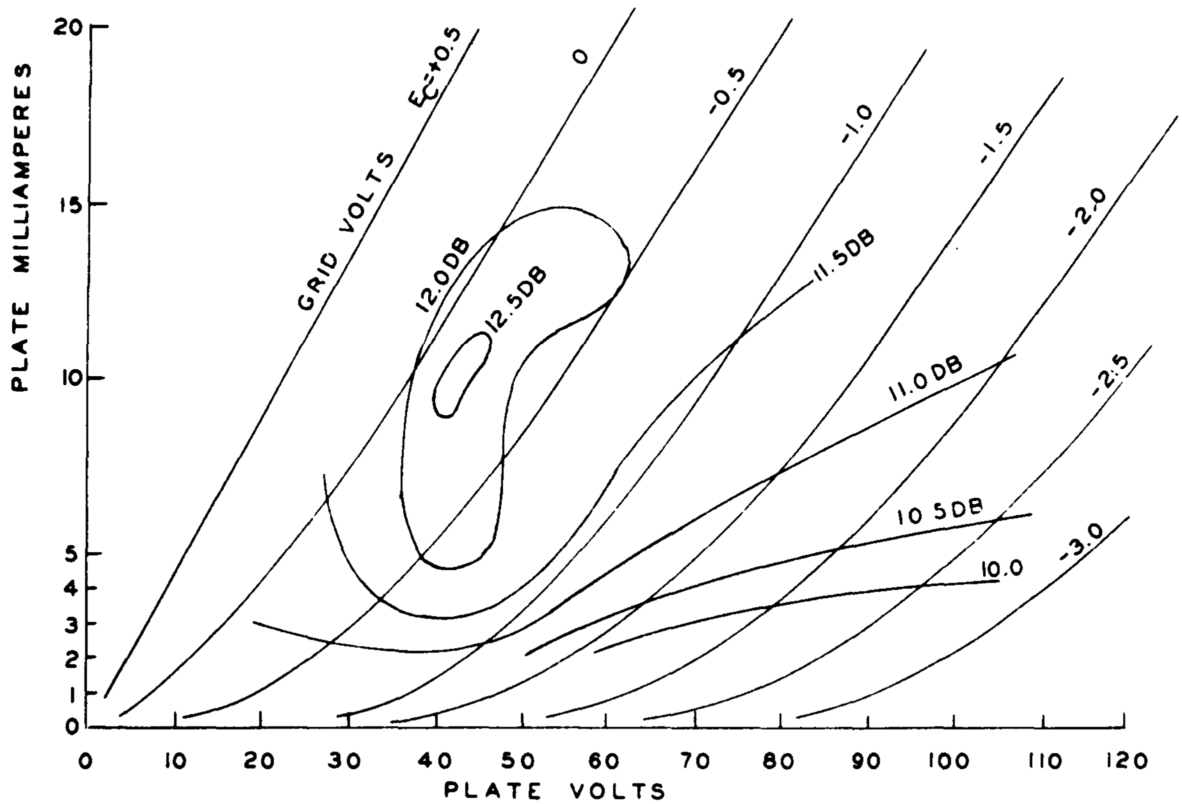
Freq.	Optimum Input NF	Optimum Input G	Approx. Bandwidth	Matched Input NF	Matched Input G
500 Mcs.	5.8 db	12.8 db	12 Mcs.	6.0 db	12.9
700	7.4	10.8	25	7.8	10.9
900	9.3	9.9	25	9.6	10.1



A15274

TYPICAL TUBE NOISE FACTOR CONTOURS
OPTIMUM VALUES IN 700 MCS AMPLIFIER STAGE

Fig. 48



A15274

MAXIMUM AVAILABLE GAIN CONTOURS
OPERATED IN 700MCS AMPLIFIER STAGE

Fig. 49

Measurements of noise factor at various operating conditions were also made for the A15330. These are shown in Fig. 50 plotted against a plate family. It will be noted that, at the same operating conditions, the A15330 is only a few tenths of a db inferior to the A15274. This is considered quite good for a remote cutoff tube.

Equivalent Noise Resistance and Flicker Noise: Extensive measurements of equivalent noise resistance were made for the A15274. These measurements are reported later under the section covering low voltage operation, as they were used mainly in the study of low voltage operation.

Three samples of the RCA developmental type A15200 were forwarded via USASRDL Evans to the University of Minnesota for flicker noise measurements. These measurements were made under Contract DA36-039sc-85289 and involved no direct expense to Contract NObsr 81478. The input noise resistance of these three tubes at various plate currents is shown in Figs. 51, 52, and 53, for frequencies from 10 c/s to 100 kc/s. Tubes number 2 and 3 display quite similar characteristics while tube number 1 has somewhat higher noise resistance. One of the three tubes supplied for these tests had a slightly lower amplification factor and a lower transconductance to plate current ratio than the other two. It is assumed that this is the tube identified as number 1 in the data supplied. The data for tubes number 2 and 3 at 100 kc/s is in good agreement with the data shown in Fig. 79 taken at 450 kc/s.

Fig. 54 shows the input noise at a fixed frequency of 30 c/s as a function of plate current for the three measured tubes. It may be seen from this figure that the input noise resistance increases as the plate current is increased. This is true for frequencies below about 1000 c/s but for frequencies above about 10 kc/s the reverse is true when the noise becomes predominantly shot noise instead of flicker noise.

These data taken on the RCA developmental type A15200 may be compared with that shown by van der Ziel[14] for the standard size nuvistor which is described as "better than average." The A15200 data show it to be as good, if not better than the standard nuvistor for low frequency noise resistance.

Because of the timing factor these flicker noise measurements were made on the developmental type A15200 and not on the type A15274 which is the final design. However, since the same cathode is employed in both types, one would expect the type A15274 to also display excellent flicker noise properties.

In a later report,[15] van der Ziel makes the statement, "The Low-frequency equivalent noise resistance of these tubes is very good."

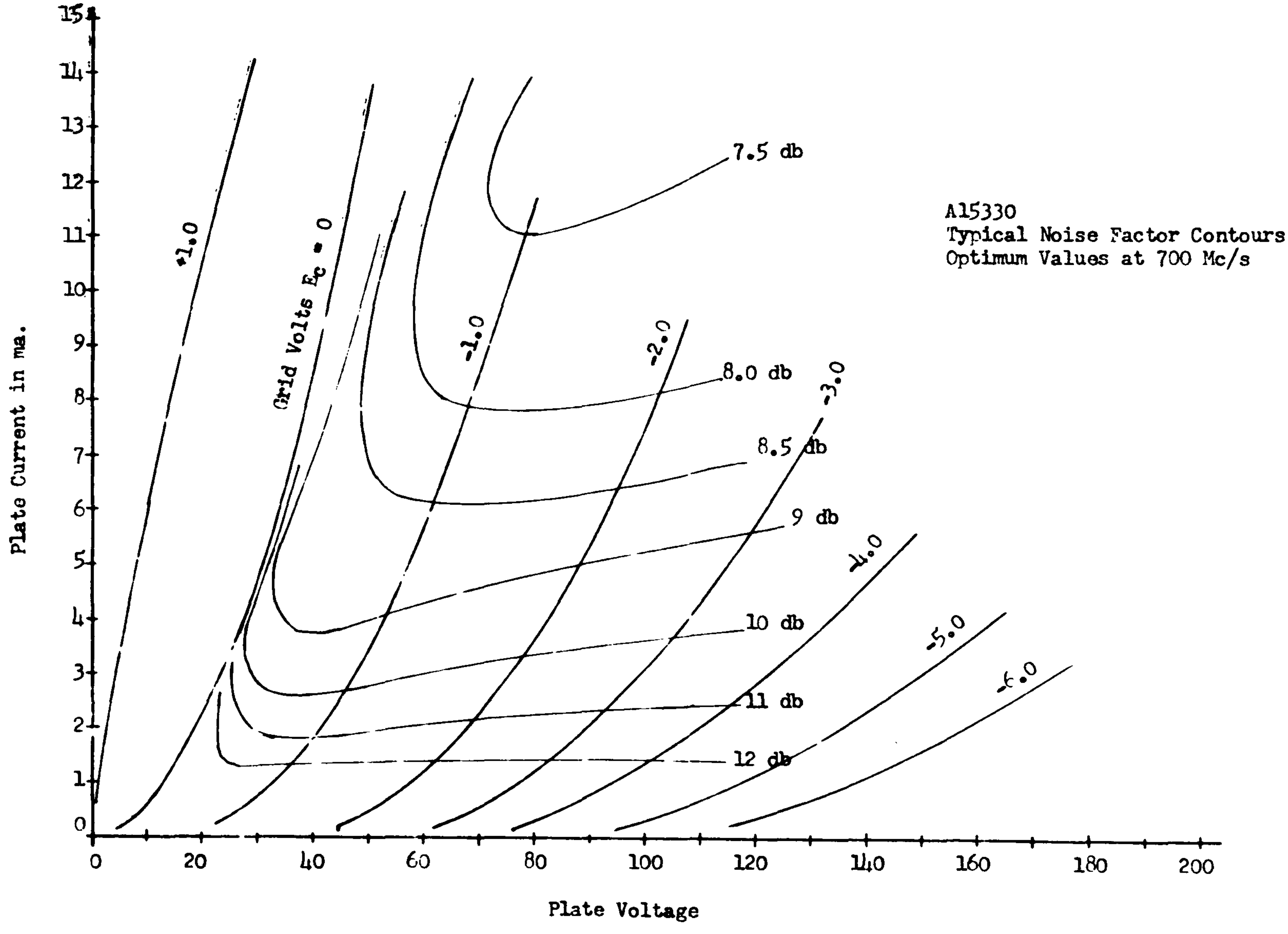

A15330
Typical Noise Factor Contours
Optimum Values at 700 Mc/s
7.5 db
8.0 db
8.5 db
9 db
10 db
11 db
12 db
+1.0
Grid Volts E_c = 0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
Plate Current in ma.
Plate Voltage
0
20
40
60
80
100
120
140
160
180
200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Fig. 50

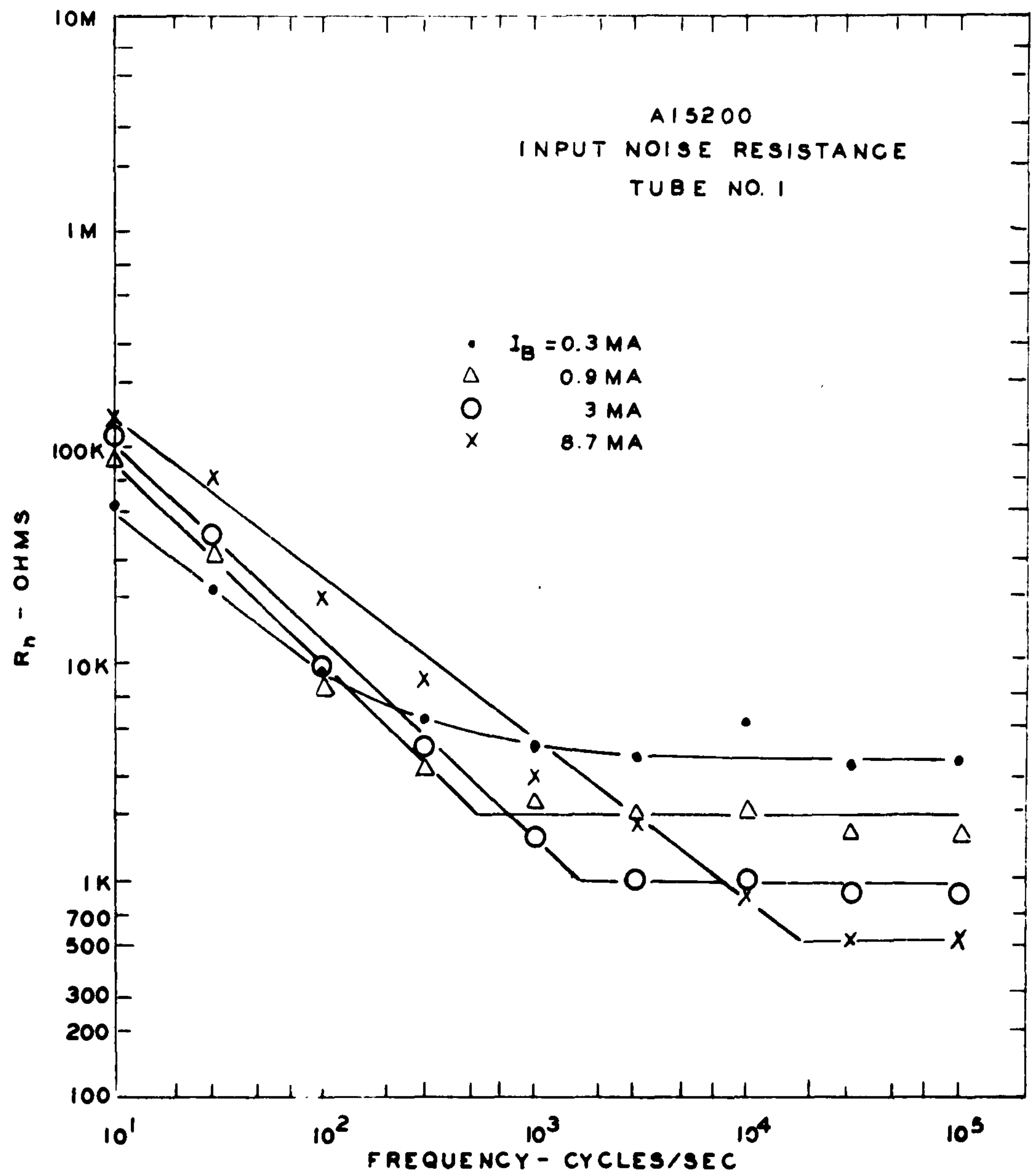

A15200
INPUT NOISE RESISTANCE
TUBE NO. 1
• I_B = 0.3 MA
△ 0.9 MA
○ 3 MA
X 8.7 MA
10M
1M
100K
10K
1K
700
500
300
200
100
R_n - OHMS
10^1
10^2
10^3
10^4
10^5
FREQUENCY - CYCLES/SEC

Fig. 51

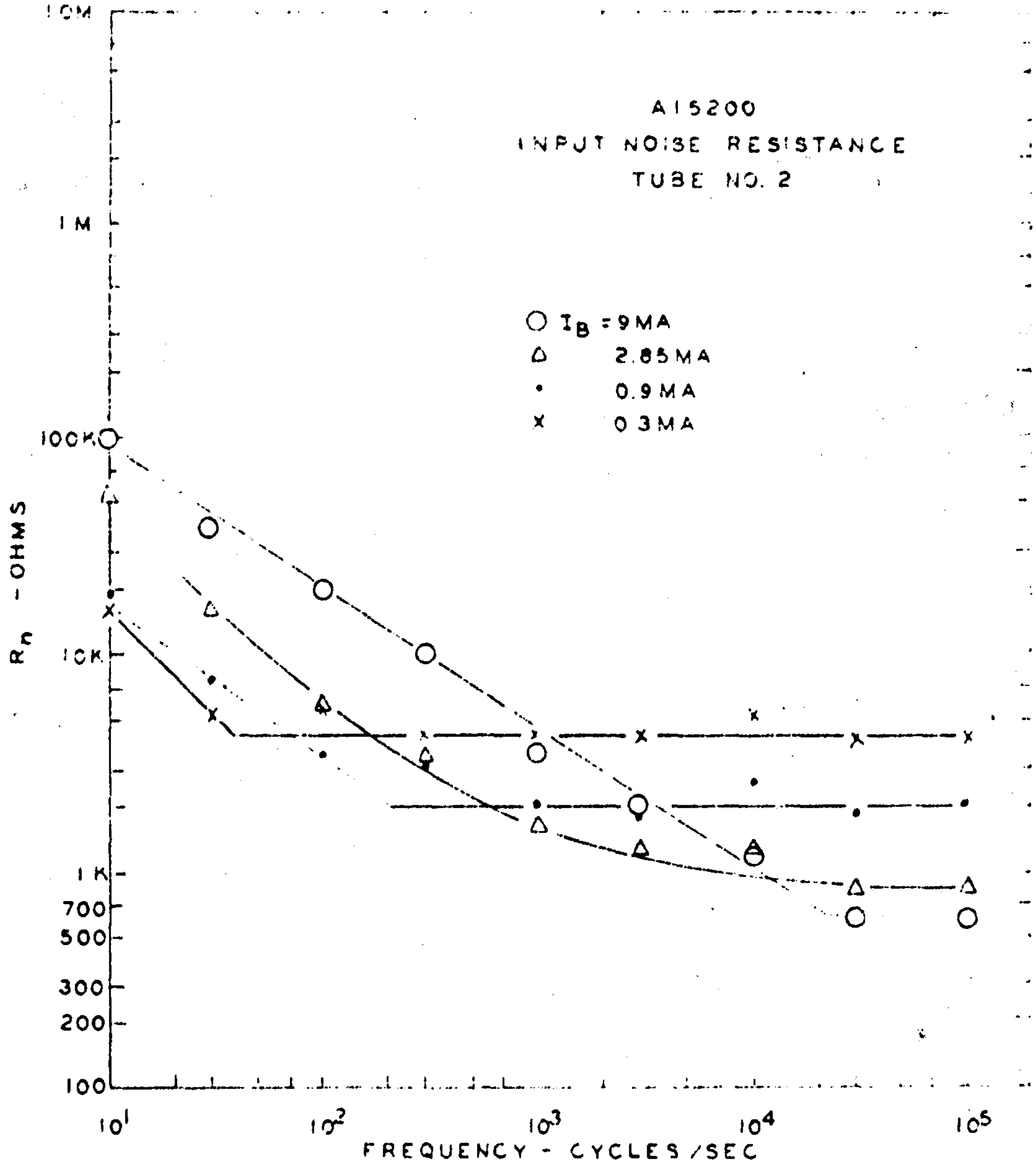

A15200
INPUT NOISE RESISTANCE
TUBE NO. 2
○ I_B = 9 MA
△ 2.85 MA
• 0.9 MA
x 0.3 MA
10M
1M
100K
10K
1K
700
500
300
200
100
R_n - OHMS
10^1
10^2
10^3
10^4
10^5
FREQUENCY - CYCLES/SEC

Fig. 52

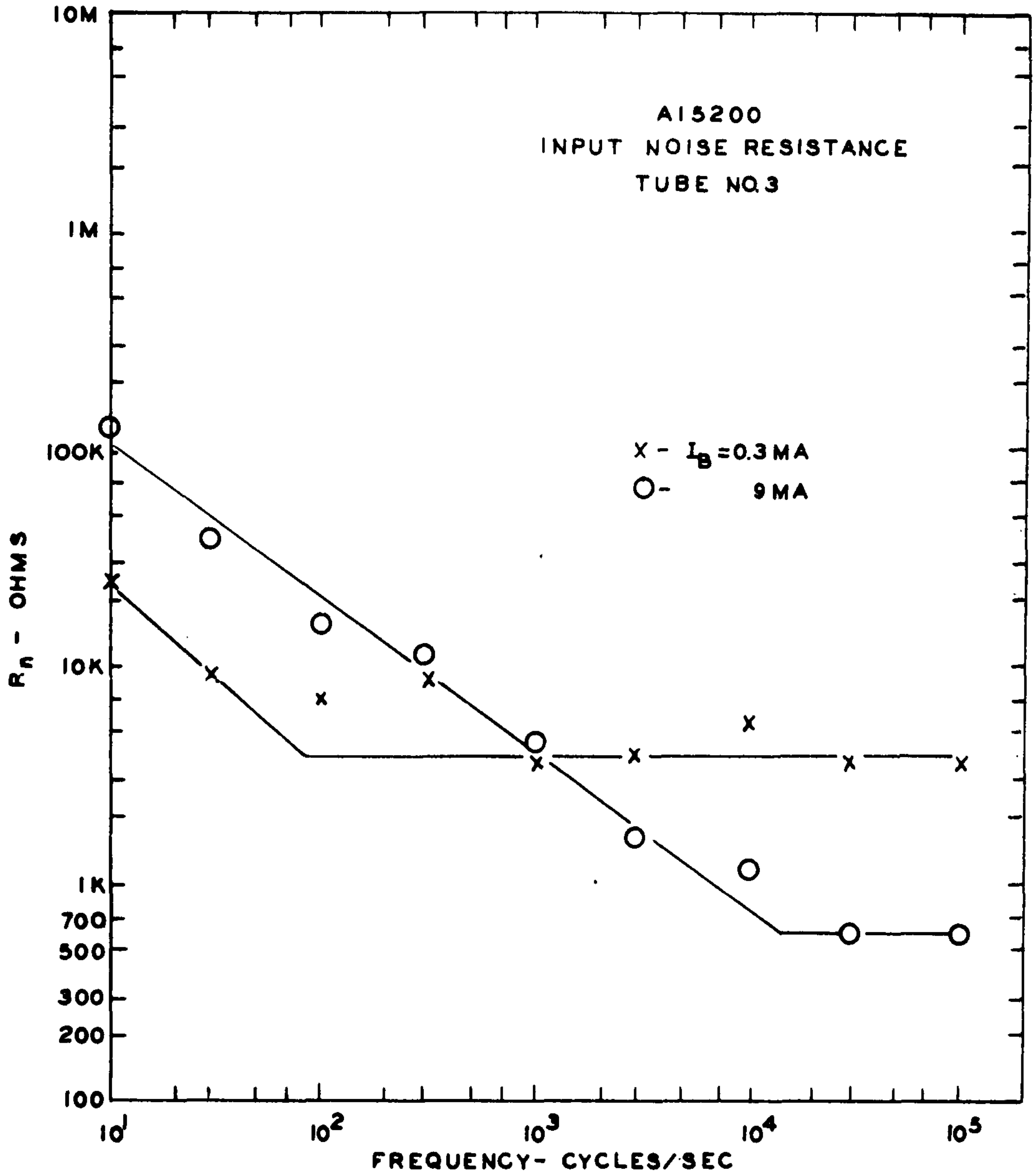

A15200
INPUT NOISE RESISTANCE
TUBE NO.3
X - I_B=0.3 MA
O - 9 MA
10M
1M
100K
10K
1K
700
500
300
200
100
R_n - OHMS
10^1
10^2
10^3
10^4
10^5
FREQUENCY- CYCLES/SEC

Fig. 53

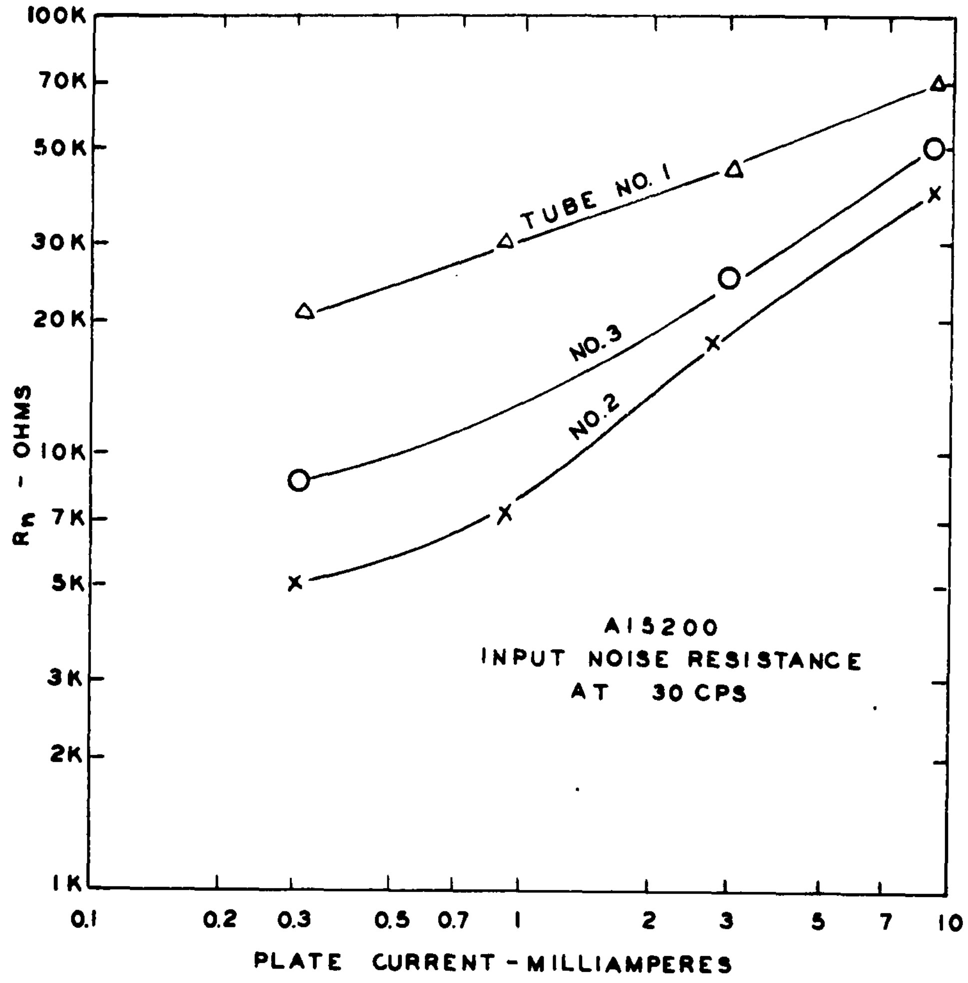

100K
70K
50K
30K
20K
10K
7K
5K
3K
2K
1K
0.1
0.2
0.3
0.5
0.7
1
2
3
5
7
10
R_n - OHMS
PLATE CURRENT - MILLIAMPERES
TUBE NO. 1
NO. 3
NO. 2
A15200
INPUT NOISE RESISTANCE
AT 30 CPS

Fig. 54

Cross Modulation Performance: Cross modulation tests were conducted on type A15274 and the results are depicted graphically as Fig. 55. The ordinate in Fig. 55 is the level in volts RMS of an interfering signal required to produce 4% cross modulation of the desired signal. This means that 4% of the modulation of the undesired signal will be impressed on the desired signal. If, for example, the undesired signal were modulated at a 30% level, 0.04 x 0.30 or 1.2% extraneous modulation would be produced on the desired signal. The two lower curves of Fig. 55 show the characteristics of the type A15274 when operated with a fixed plate voltage and the transconductance varied by adjusting grid bias as would be the case with an AGC controlled amplifier. The curves are not significantly different in shape or value from other sharp cutoff triodes such as the prototype 7586 nuvistor. Another curve shows the characteristic of the type A15274 when operated with a "sliding" plate supply. The supply voltage and load resistance are merely arbitrarily chosen values but show that cross modulation characteristics can be improved at the expense of power drain. Also shown in Fig. 55 is the characteristic of the developmental type A15287, a remote cutoff variation of the A15274, showing the improvement in cross modulation characteristics that may be obtained without increased power drain.

The A15330 was developed specifically to have a good cross modulation performance commensurate with good noise performance. Tests were made under conditions shown on the curves, Fig. 56. Also shown, for comparison purposes, is the performance of the RCA Nuvistor, 6DR4, which is designed for use in TV rf amplifiers. It is to be noted that the curve for the A15330 is much flatter and has a higher minimum value than that for the 6DR4. The 6DR4 is usually operated with a sliding plate.

Fig. 56 also shows the performance of the A15330 with a 'sliding plate'. The plate supply is 125v through an 8.2 k dropping resistor. This results in even better performance and, although not shown on the curve, it is superior to the sliding plate 6DR4. The disadvantage of this type operation is that it is wasteful of plate supply power and is hard to cut off. Almost 10 volts E_c is required to reduce gm to 1%.

Fig. 57 shows the noise performance at 700 Mc/s of a typical tube plotted along with the cross modulation curve. The circuit was tuned for maximum power gain and optimum noise factor at 10,000 gm and then the bias increased in steps to reduce gain.

Two Terminal-Pair Parameters: Two terminal-pair parameters completely describe at any one frequency a network with two pairs of terminals. Particularly useful in the UHF range are the admittance parameters because they express 'shunt' rather than 'series' circuit values. The circuit designer building a UHF amplifier would very much like to have the parameters for the active element. Without them, he must guess and make his

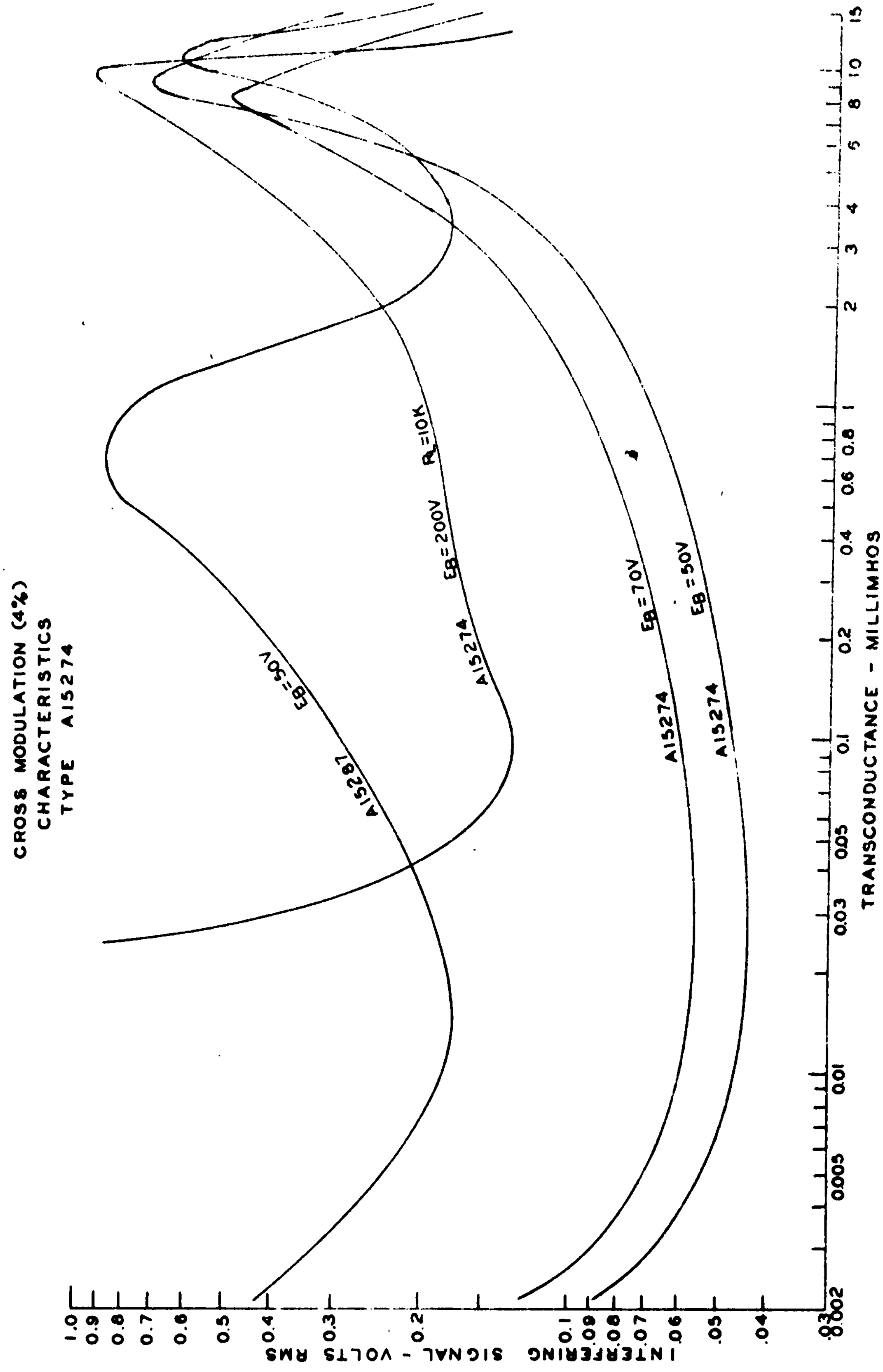

CROSS MODULATION (4%)
CHARACTERISTICS
TYPE A15274
$E_B = 50V$
A15287
$E_B = 200V$
$R_L = 10K$
A15274
$E_B = 70V$
A15274
$E_B = 50V$
A15274
INTERFERING SIGNAL - VOLTS RMS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
.09
.08
.07
.06
.05
.04
.03
TRANSCONDUCTANCE - MILLIMHOS
0.002
0.005
0.01
0.03
0.05
0.1
0.2
0.4
0.6
0.8
1
2
3
4
6
8
10
15

Fig. 55

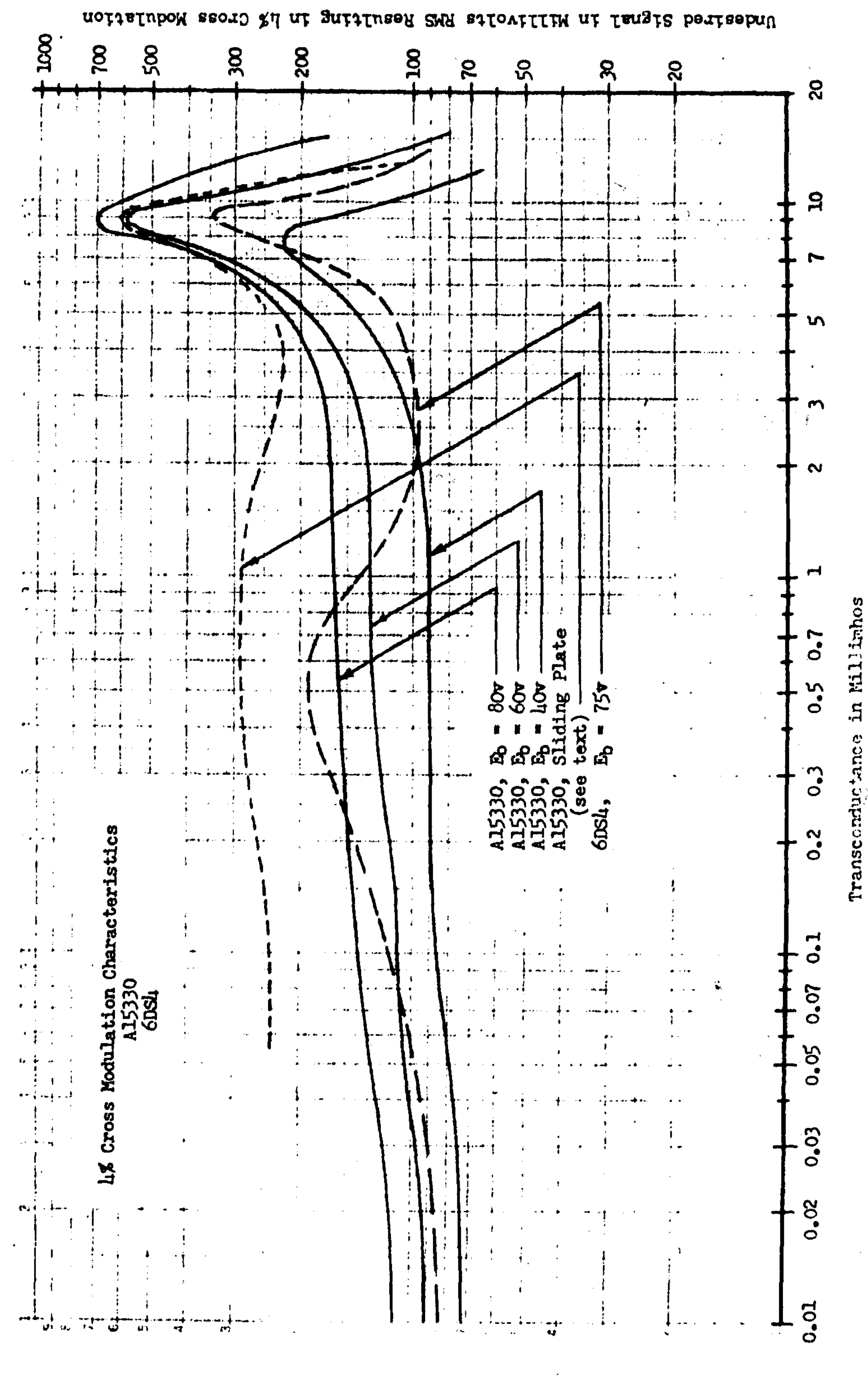

4% Cross Modulation Characteristics
A15330
6DS4
A15330, E_b = 80v
A15330, E_b = 60v
A15330, E_b = 40v
A15330, Sliding Plate (see text)
6DS4, E_b = 75v
Undesired Signal in Millivolts RMS Resulting in 4% Cross Modulation
Transconductance in Millimhos
1000
700
500
300
200
100
70
50
30
20
0.01
0.02
0.03
0.05
0.07
0.1
0.2
0.3
0.5
0.7
1
2
3
5
7
10
20

Fig. 56

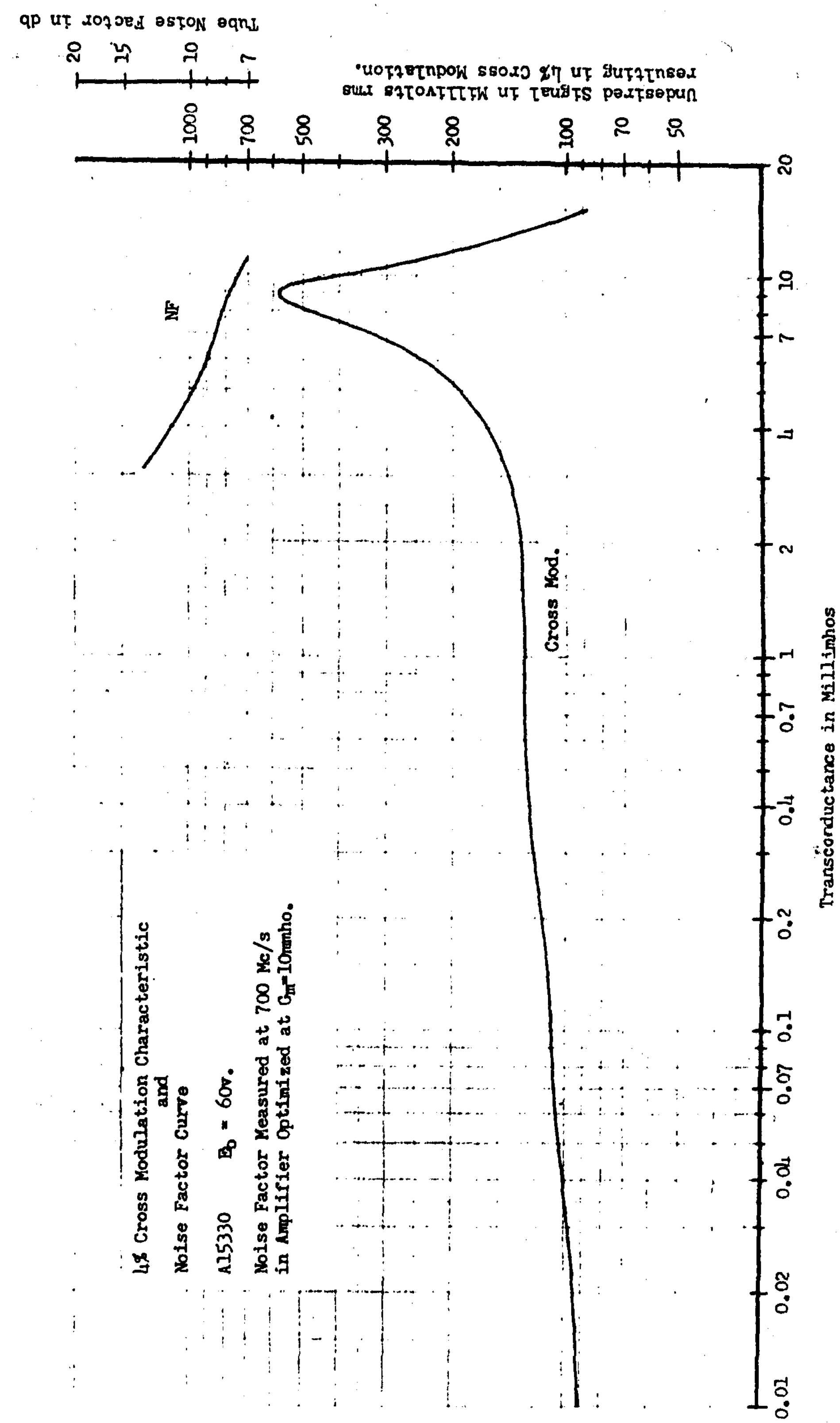

Tube Noise Factor in db
20 15 10 7
Undesired Signal in Millivolts rms resulting in 4% Cross Modulation.
1000 700 500 300 200 100 70 50
NF
Cross Mod.
4% Cross Modulation Characteristic and Noise Factor Curve
A15330 E_b = 60v.
Noise Factor Measured at 700 Mc/s in Amplifier Optimized at G_m=10mmho.
0.01 0.02 0.04 0.07 0.1 0.2 0.4 0.7 1 2 4 7 10 20
Transconductance in Millimhos

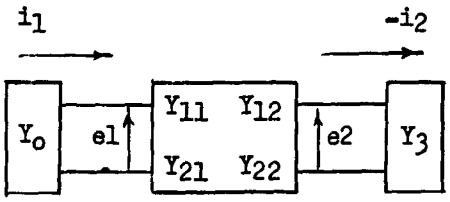
Fig. 57

amplifiers with a considerable tuning range in order to compensate for errors. The matrix equations are the familiar ones:

$$i_1 = e_1Y_{11} + e_2Y_{12}$$

$$i_2 = e_1Y_{21} + e_2Y_{22}$$

which represent the network



Some work that greatly aids the application of these parameters to circuit design has been done by W. A. Harris and appears in the 1955 IRE Convention Record under the title "Corrections to the theory of the Grounded-Grid Triode." His equations make use of the quantity ϕ which is the phase angle of the product of the short-circuit forward admittance, Y_{21}, and the short-circuit feedback admittance, Y_{12}, and the quantity R_o which is described by the relation

$$R_o = \frac{1}{2} \frac{|Y_{12} \quad Y_{21}|}{g_{11} \quad g_{22}}$$

R_o is not a resistance but rather is a dimensionless scalar quantity.

The power gain of the network when the input termination admittance, Y_o, is the conjugate match with the circuit input admittance, Y_{11} is

$$G = \frac{|Y_{21}|^2}{g_{11}\, g_{22}} \; \frac{\frac{g_3}{g_{22}}}{\left(\frac{g_3}{g_{22}} + 1 - R_o \cos\phi - R_o\right)\left(\frac{g_3}{g_{22}} + 1 - R_o \cos\phi + R_o\right)}$$

where g_3 is the output termination conductance and the output termination susceptance, b_3, is adjusted for maximum gain.

The value of g_3 for the maximum available gain is given by

$$\frac{g_3}{g_{22}} = \sqrt{(1 - R_o \cos \phi - R_o)\ (1 - R_o \cos \phi + R_o)}$$

unless the right hand member becomes imaginary which indicates instability.

If this criterion for stability is met, the maximum available gain is given by

$$G_{max} = \frac{1}{2}\ \frac{|Y_{21}|^2}{g_{11}\ g_{22}}\ \frac{1}{1 - R_o \cos \phi + \sqrt{(1 - R_o \cos \phi)^2 - R_o^2}}$$

Another important amplifier quantity is bandwidth which is almost always determined by the high-Q output circuit. In order to calculate the bandwidth, the circuit conductance must be known. With b_3 adjusted for maximum gain and Y_o matched to Y_1, the output conductance, g_2 is given by the relation

$$g_2 + g_3 = g_{22}\ \frac{\left(\frac{g_3}{g_{22}} + 1 - R_o\ \cos \phi\right)^2 - R_o^2}{\frac{g_3}{g_{22}} + 1 - R_o \cos \phi}$$

The output susceptance, b_2 is: $b_2 = b_{22} - g_{22} R_o \sin \phi$.

The input admittance, Y_1, may be found by the usual equation,

$$Y_1 = Y_{11} - \frac{Y_{22}\ Y_{21}}{Y_{22} + Y_3} \quad ,$$

or by the relationship

$$\frac{Y_1}{g_{11}} = 1 + j\,\frac{b_{11}}{g_{11}} + \frac{R_o}{1 + \frac{g_3}{g_{22}}}\ e^{\,j\phi}\,(1 + e^{-j2\theta})$$

where: $\tan \theta = \frac{R_o}{1 + \frac{g_3}{g_{22}}}\ \sin \phi$.

For the derivations of these formulae, the reader is directed to the aforementioned article by Harris.

Graphs showing the values for Y_{11}, Y_{12}, Y_{21}, Y_{22}, R_o, and ϕ are included and appear as Figs. 58 through 72. The terminals at which measurements are given are the socket cathode lead and the plate cap. The grid is grounded by a ring of spring fingers contacting the shell ring. Measurements are not for the tube by itself, but are for the socketed condition as would be normal in use and include the effects of the socketing. The frequency range covered is 0 to 900 Mc/s. The curves shown are for a typical tube. Y_{11} is a function mainly of gm, C_{gk}, and frequency; other effects are second order. The other curves are more complex. Families are given for various operating conditions and the values for other operating conditions may be interpolated from the curves.

Micro-Strip Amplifier: An experimental 500 Mcs. microstrip amplifier was constructed to determine the feasibility of using the type A15200 in such an application. An epoxy filled fiberglass laminate was used as the base but the efficiency of the anode transformer was calculated to be only about 20% because of the high loss factor of the base material. The measured amplifier gain was only about 3.5 db at 500 Mcs. This microstrip amplifier was duplicated on a teflon-based laminate for use with the type A15274. Calculations indicated that an anode transformer efficiency of about 85% is attainable with this lower-loss material and that a stage gain of about 11 db should be achievable at 500 Mcs. Although the amplifier on the teflon base material was constructed, stage gain figures were disappointing. It is thought that this was caused by lossy bypassing capacitors used to short-circuit the anode line to ground. As it was felt that further work would do little toward development of the tube, further work was discontinued.

Oscillator Performance

In order to evaluate some of the high-frequency performance characteristics of the A15200, tests were performed using the A15200 as an oscillator in a lumped-constant Colpitts-type circuit. RF connections were made directly to the anode cap and bulb skirt. A schematic of this circuit appears as Fig. 73.

As an unloaded oscillator simulating, for example, receiver local oscillator service, an oscillator grid signal of 2 volts peak is readily developed across a 10,000 ohm grid resistor. Below 400 Mcs. this signal level can be generated with less than one-tenth watt plate input. As the operating frequency is raised above 400 Mcs. the required input for this signal level increases, reaching approximately one-half watt at 1000 Mcs.

RCA DEVELOPMENTAL TYPE A15274

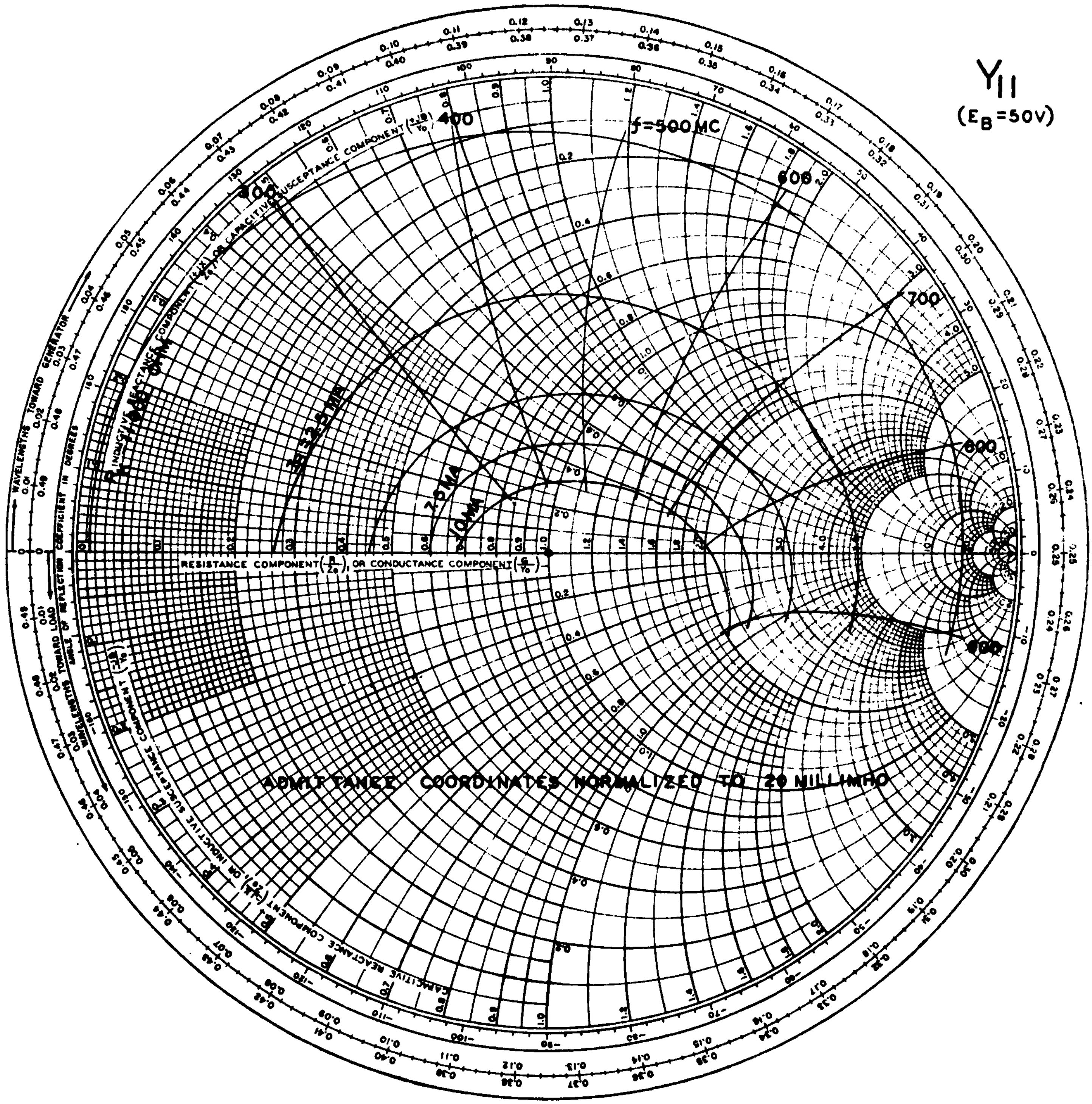


Fig. 58

RCA DEVELOPMENTAL TYPE A15274

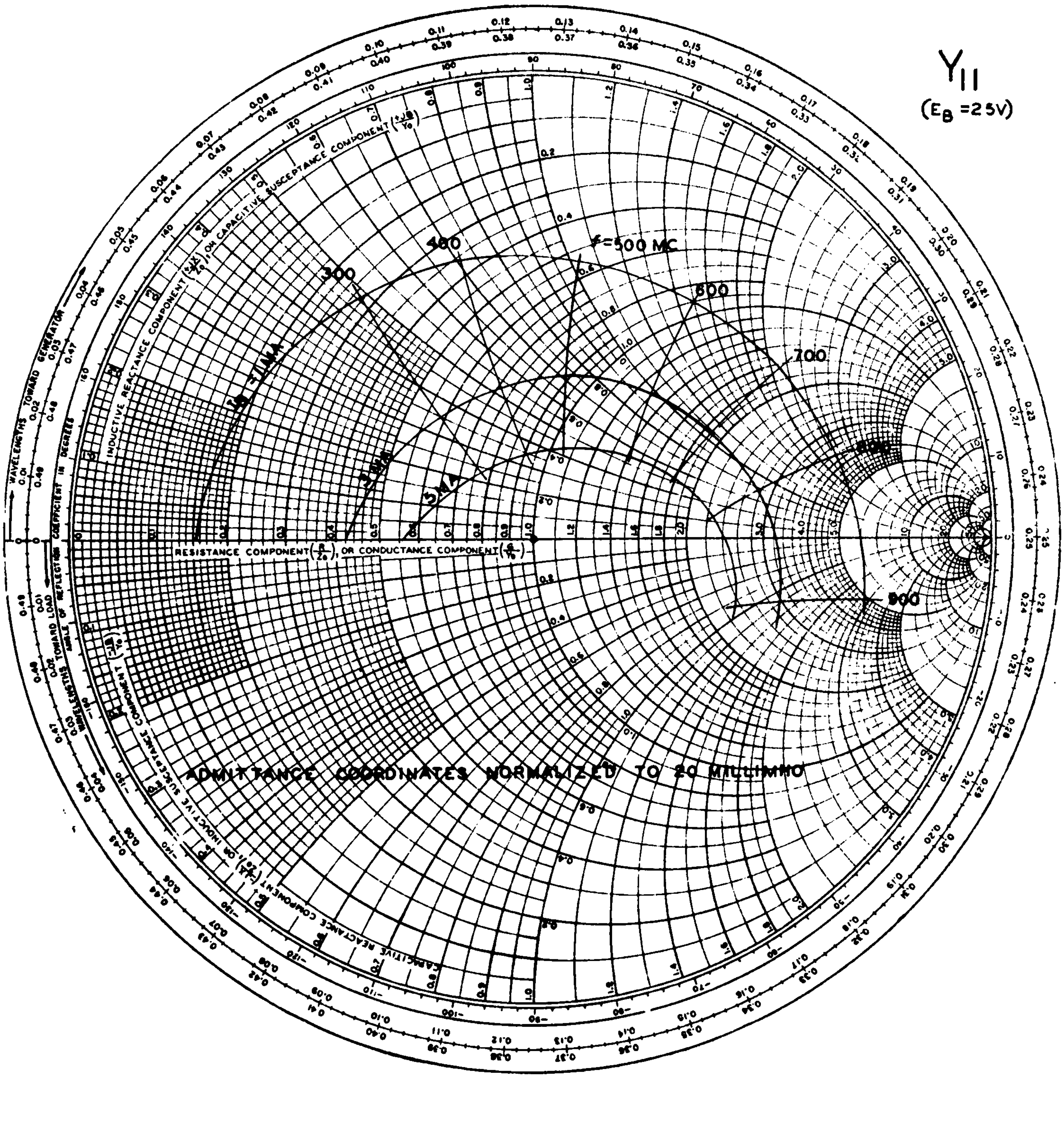


Fig. 59

RCA DEVELOPMENTAL TYPE A15274

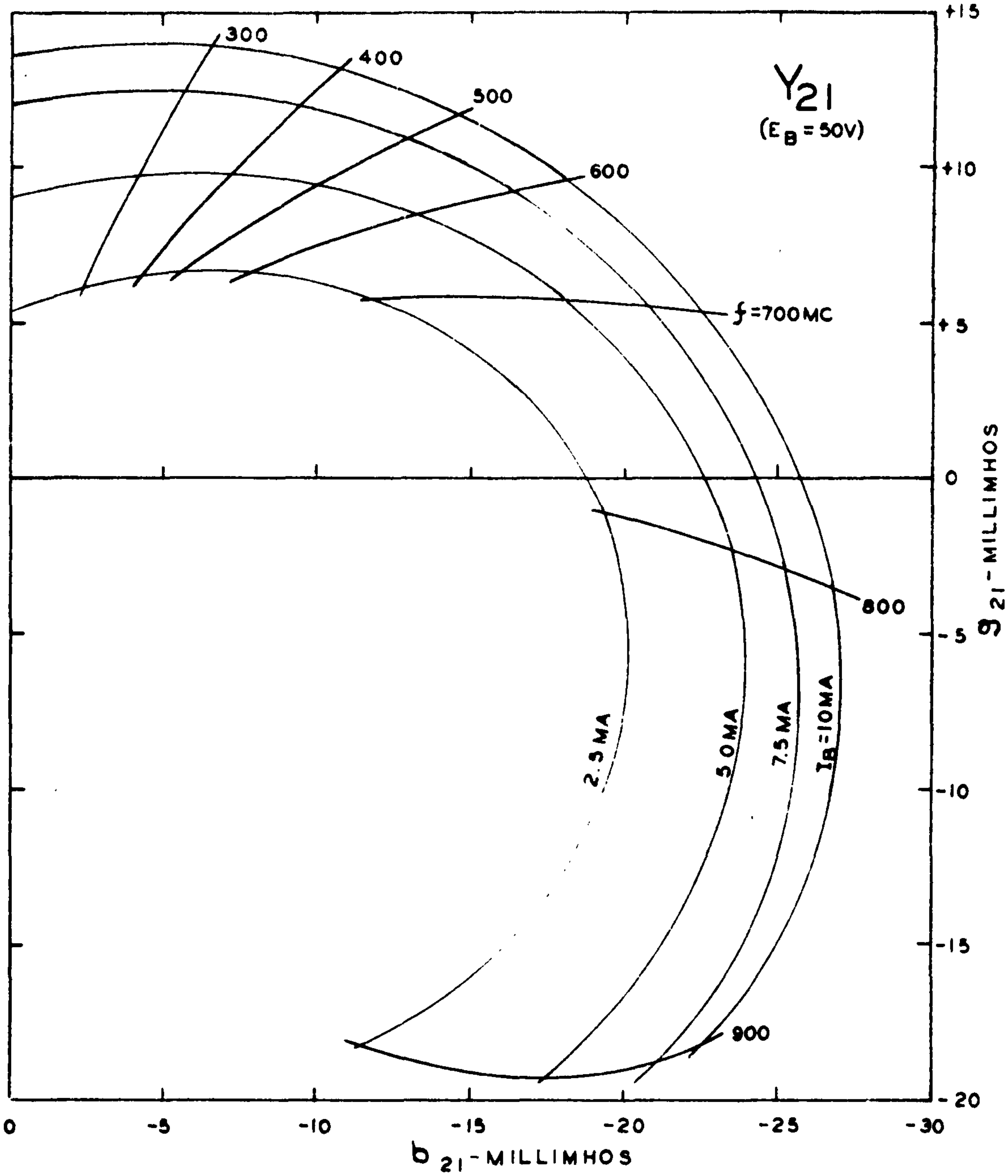


Fig. 60

RCA DEVELOPMENTAL TYPE A15274

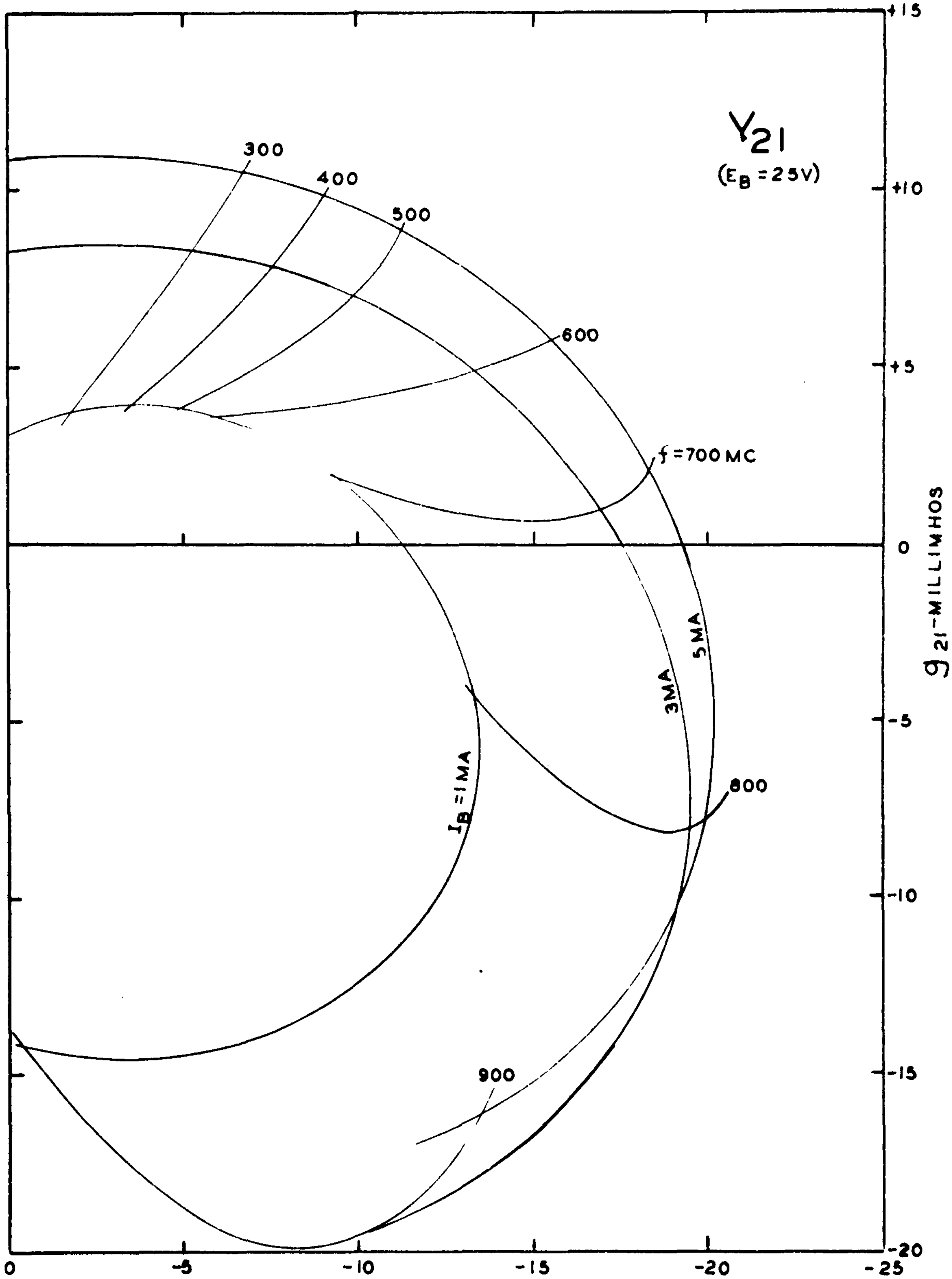


Fig. 61

RCA DEVELOPMENTAL TYPE A15274

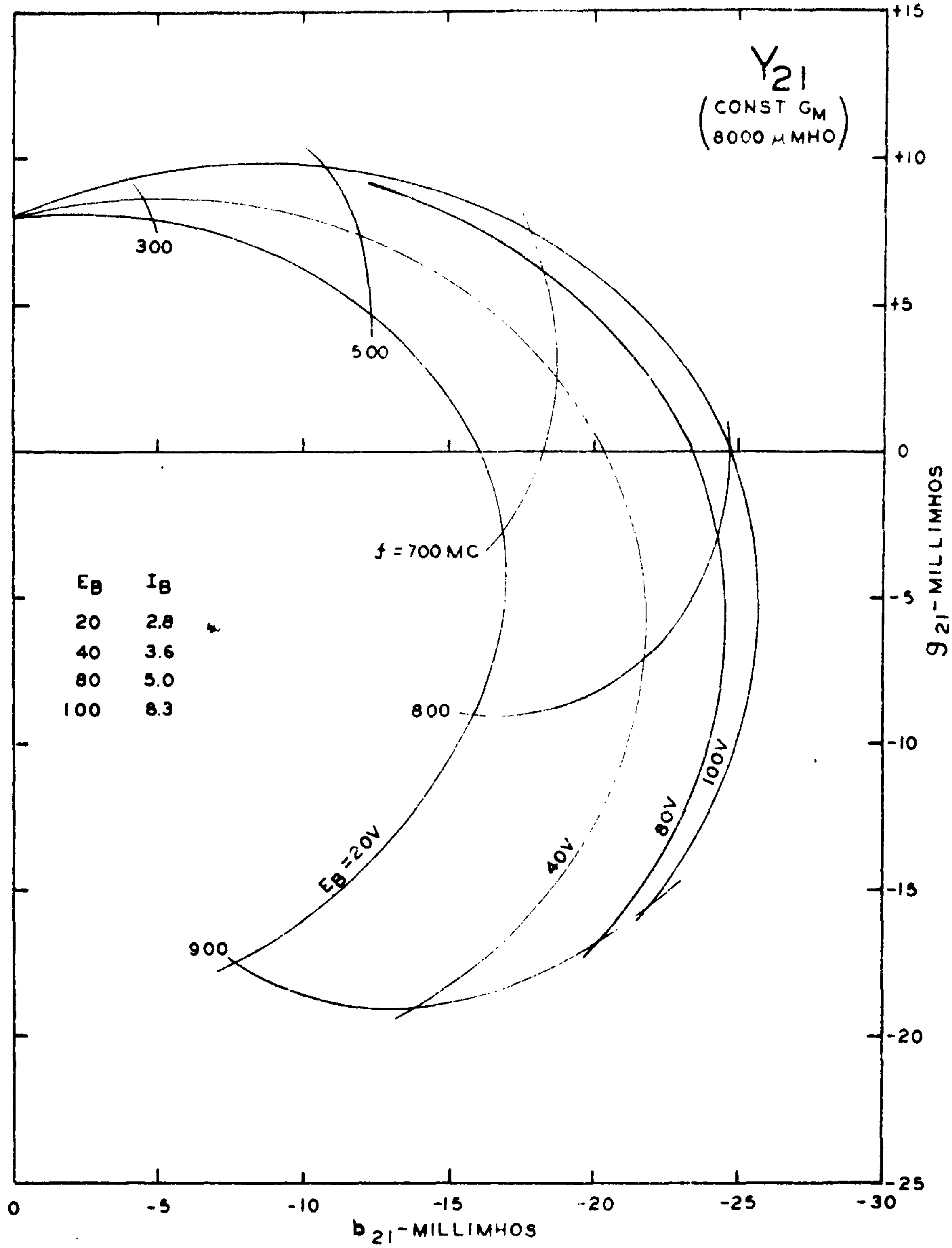


Fig. 62

RCA DEVELOPMENTAL TYPE A15274

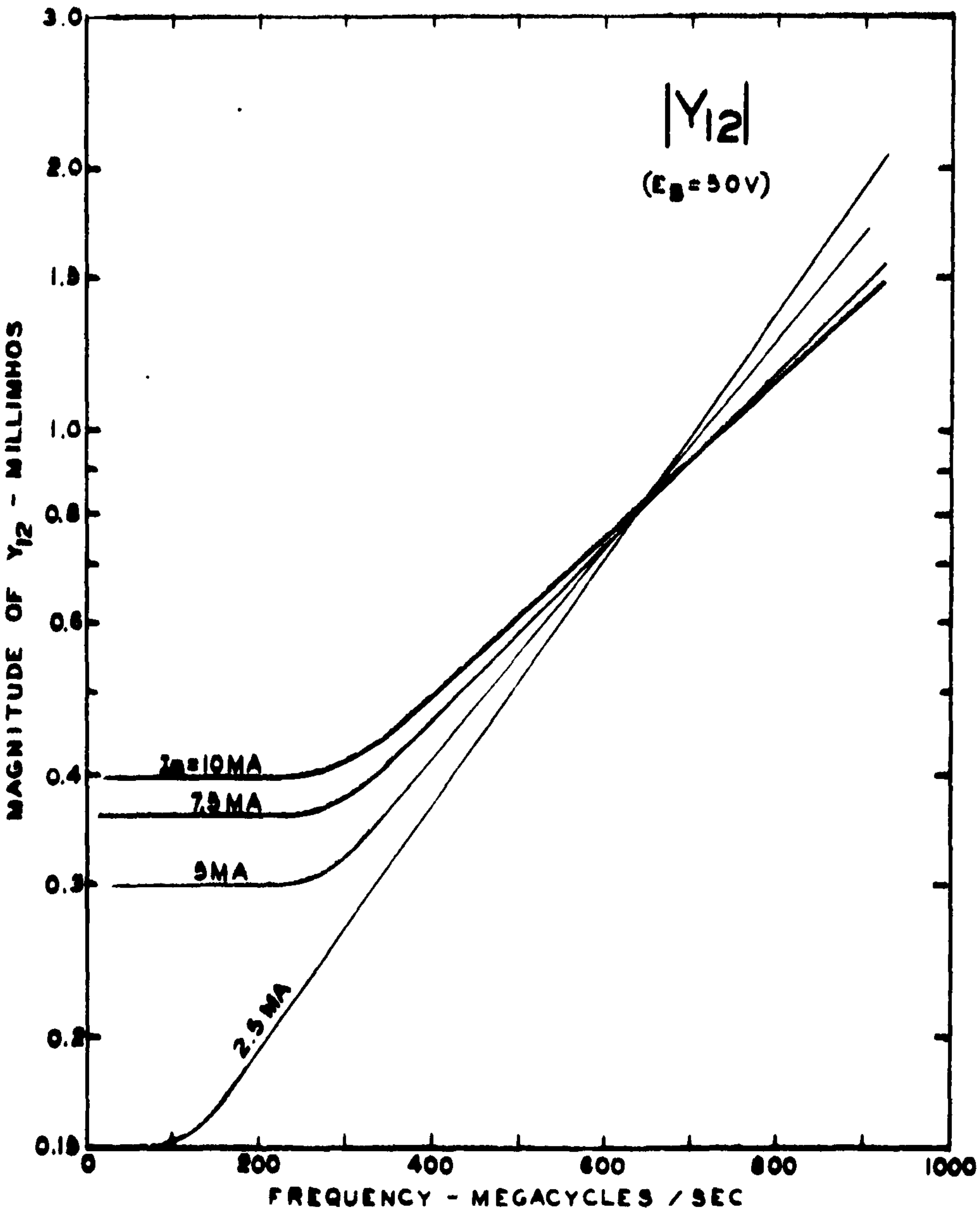


Fig. 63

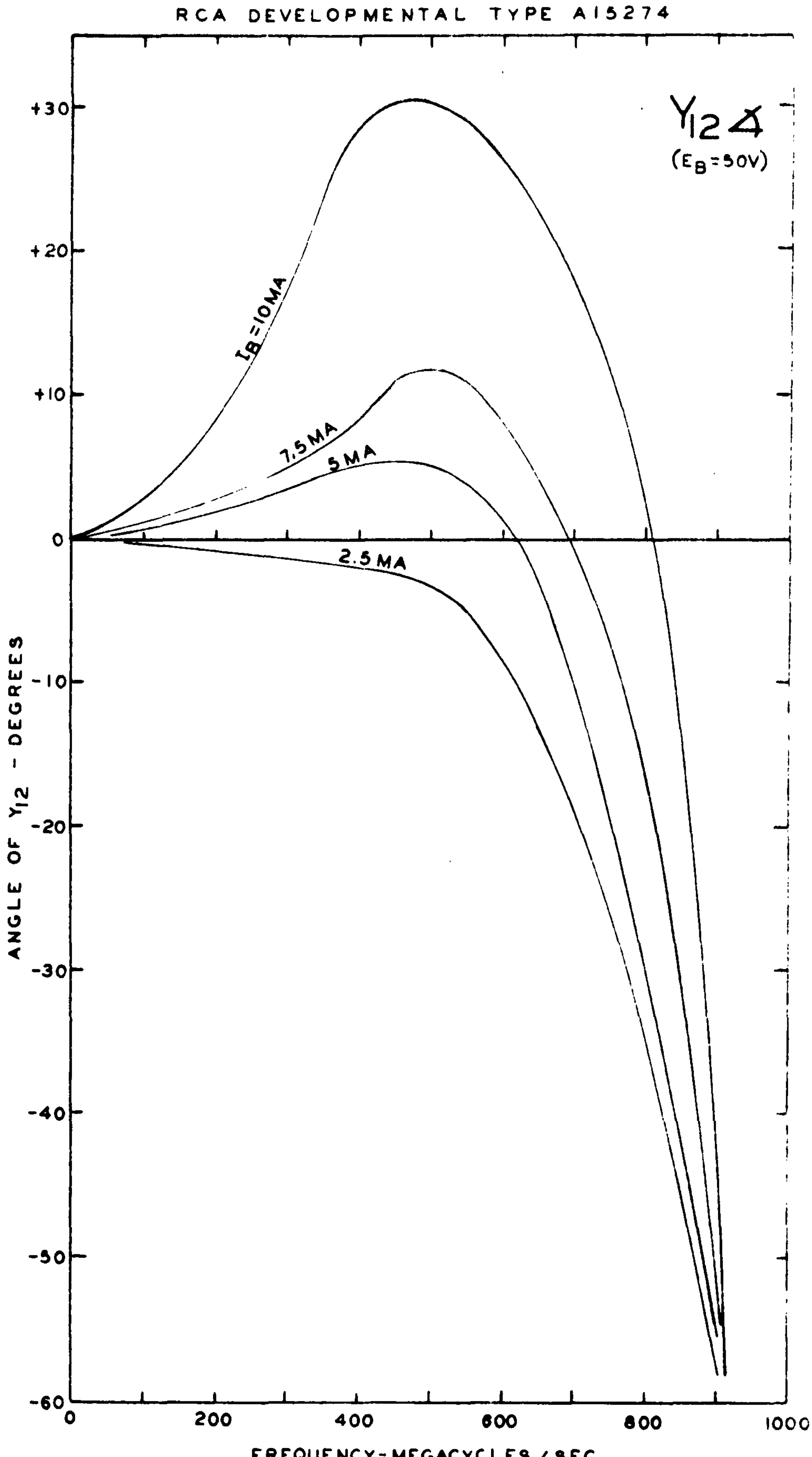

RCA DEVELOPMENTAL TYPE A15274
$Y_{12}\angle$
(E_B=50V)
I_B=10MA
7.5MA
5MA
2.5MA
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
ANGLE OF Y_{12} - DEGREES
0
200
400
600
800
1000
FREQUENCY-MEGACYCLES / SEC

Fig. 64

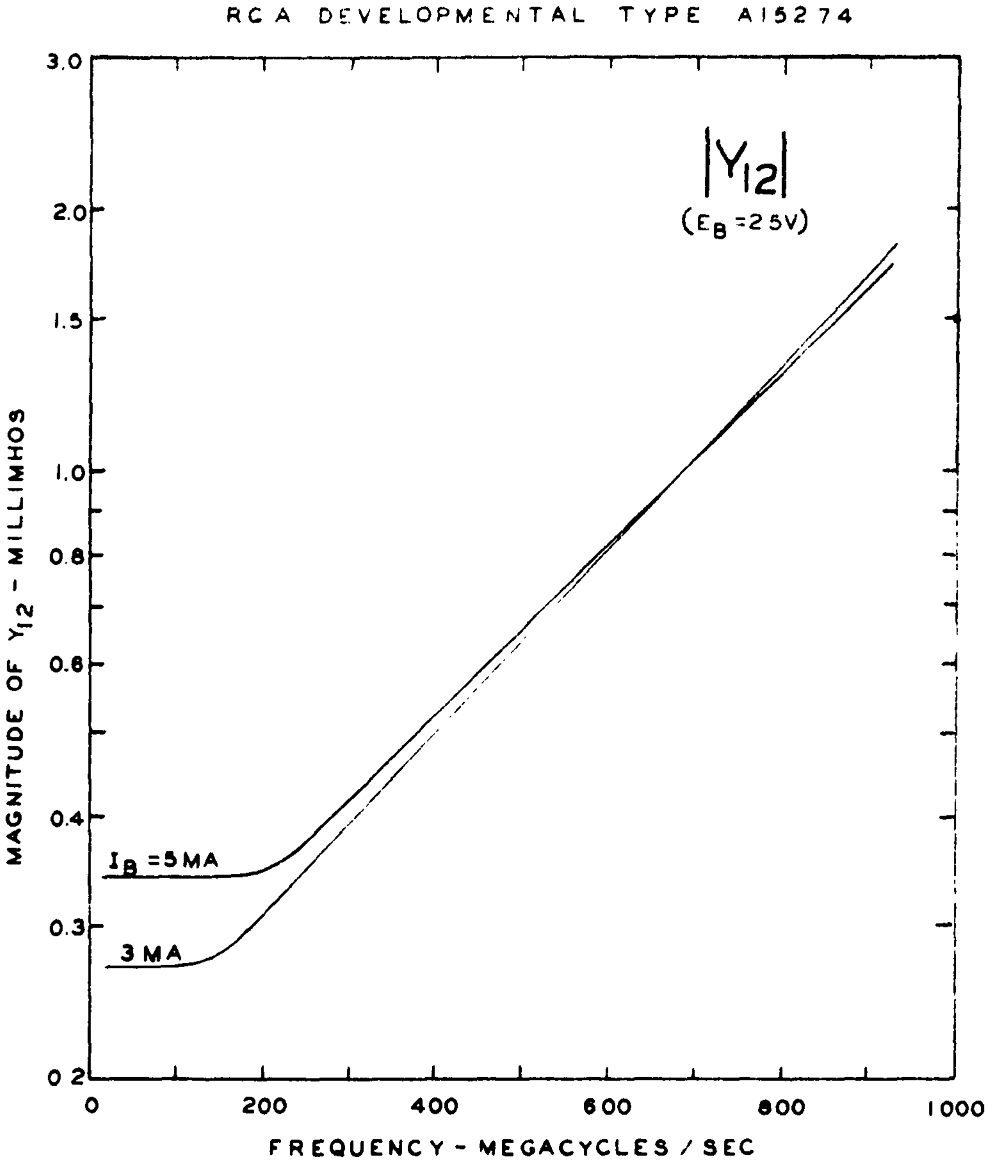

RCA DEVELOPMENTAL TYPE A15274
|Y12|
(E_B = 25V)
I_B = 5 MA
3 MA
3.0
2.0
1.5
1.0
0.8
0.6
0.4
0.3
0.2
0
200
400
600
800
1000
MAGNITUDE OF Y_{12} - MILLIMHOS
FREQUENCY - MEGACYCLES / SEC

Fig. 65

RCA DEVELOPMENTAL TYPE A15274

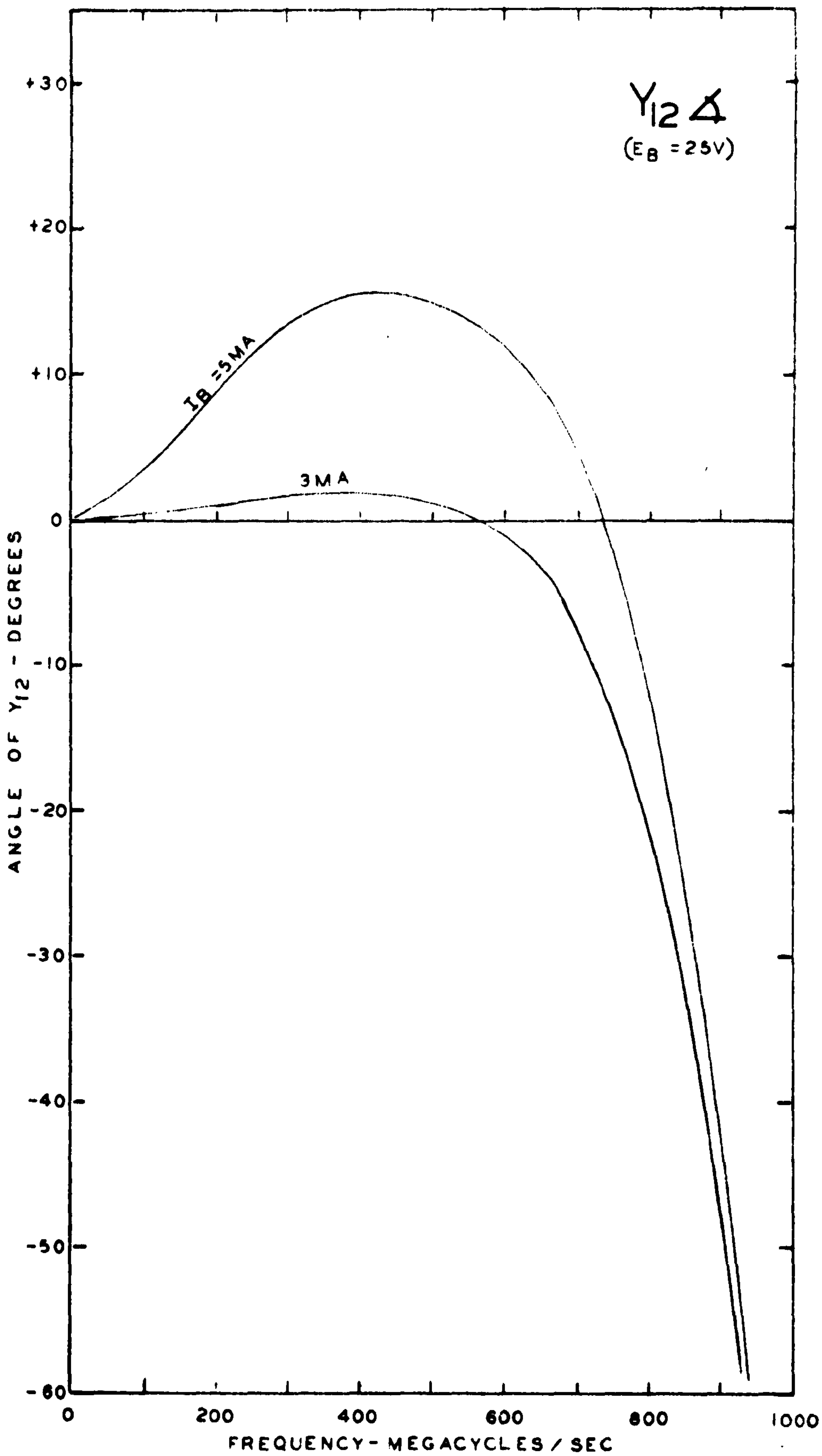


Fig. 66

RCA DEVELOPMENTAL TYPE A15274

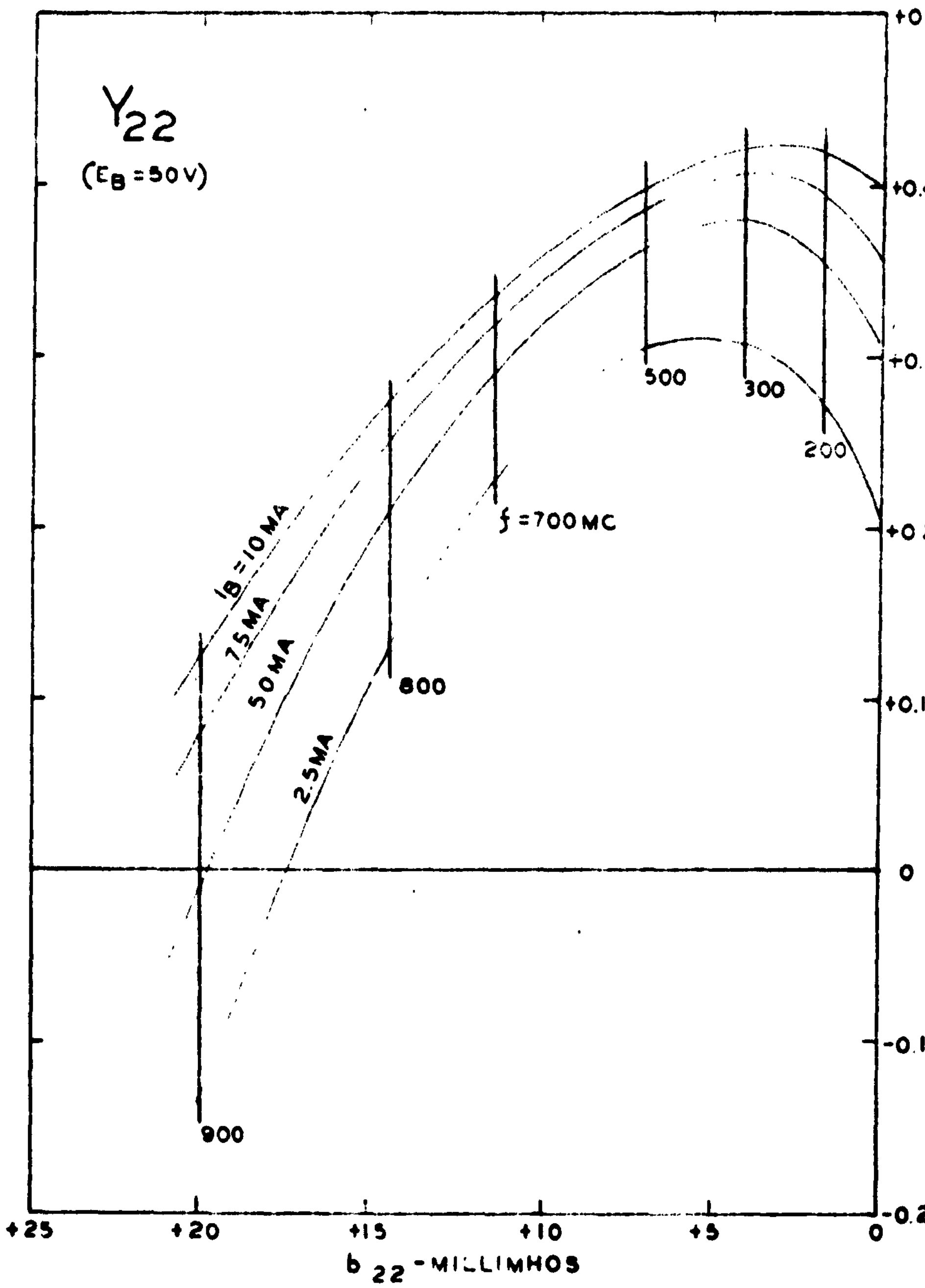


Fig. 67

RCA DEVELOPMENTAL TYPE A15274

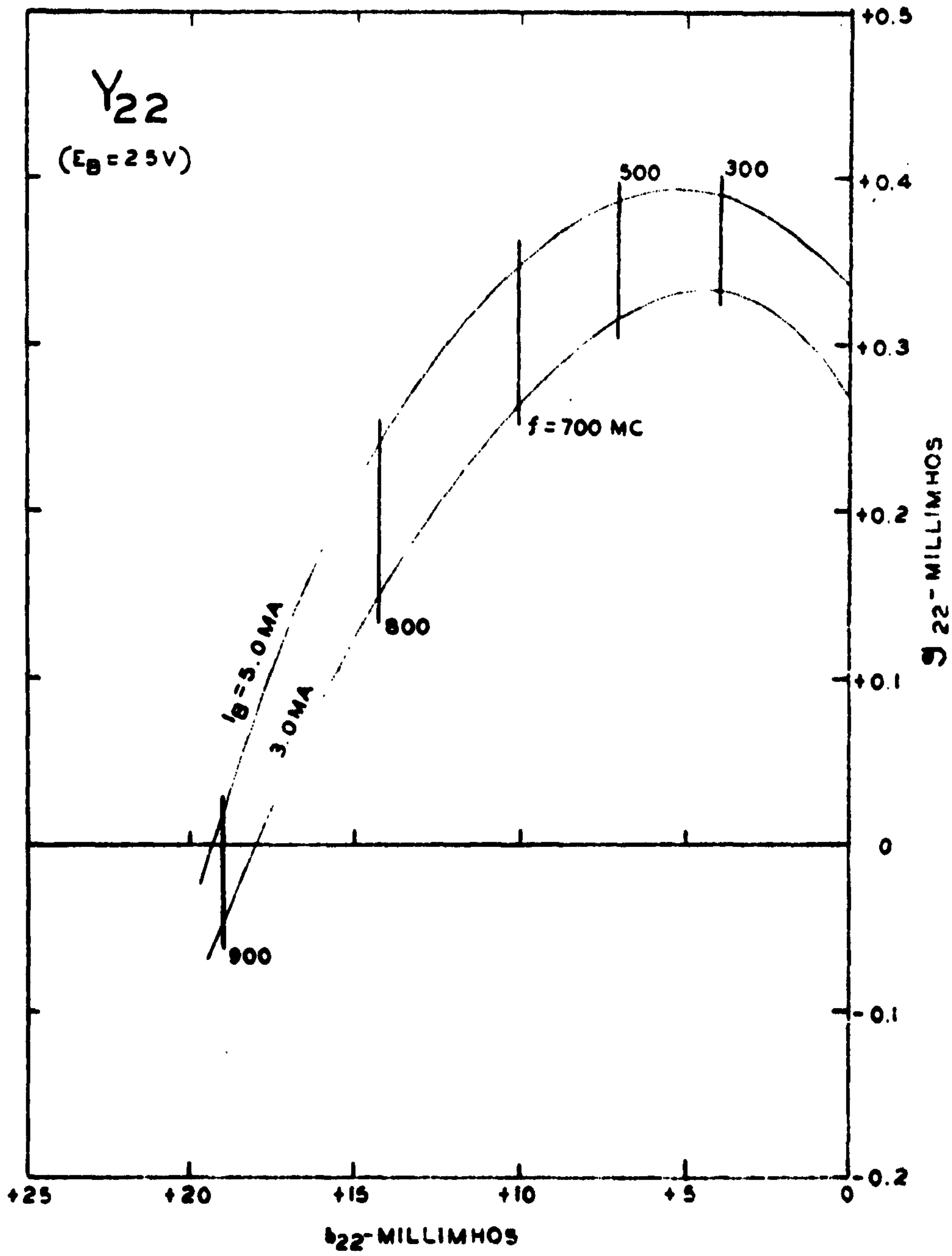


Fig. 68

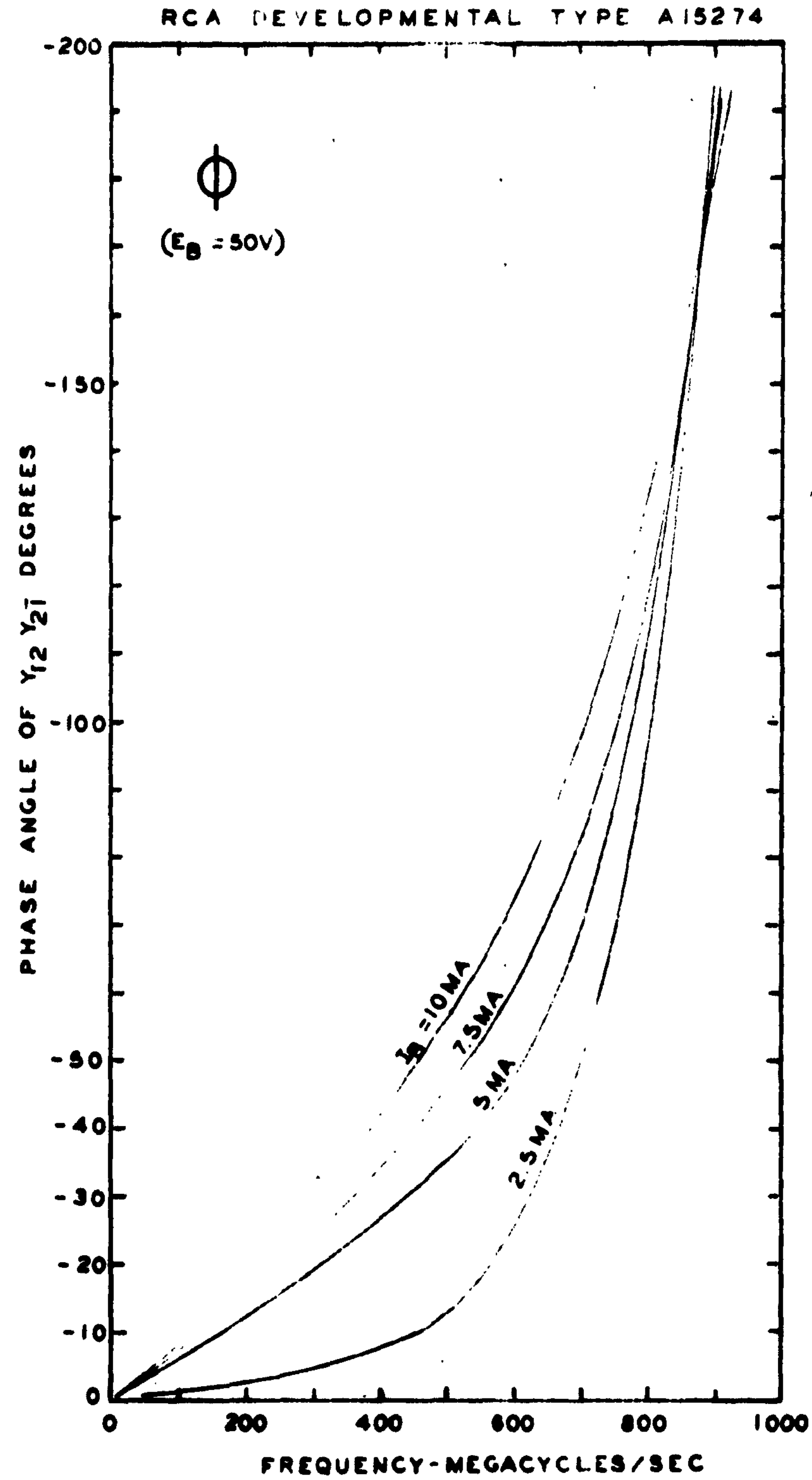

RCA DEVELOPMENTAL TYPE A15274
Φ
(E_B = 50V)
PHASE ANGLE OF Y_{12} Y_{21} DEGREES
-200
-150
-100
-50
-40
-30
-20
-10
0
I_B = 10MA
7.5MA
5MA
2.5MA
0
200
400
600
800
1000
FREQUENCY-MEGACYCLES/SEC

Fig. 69

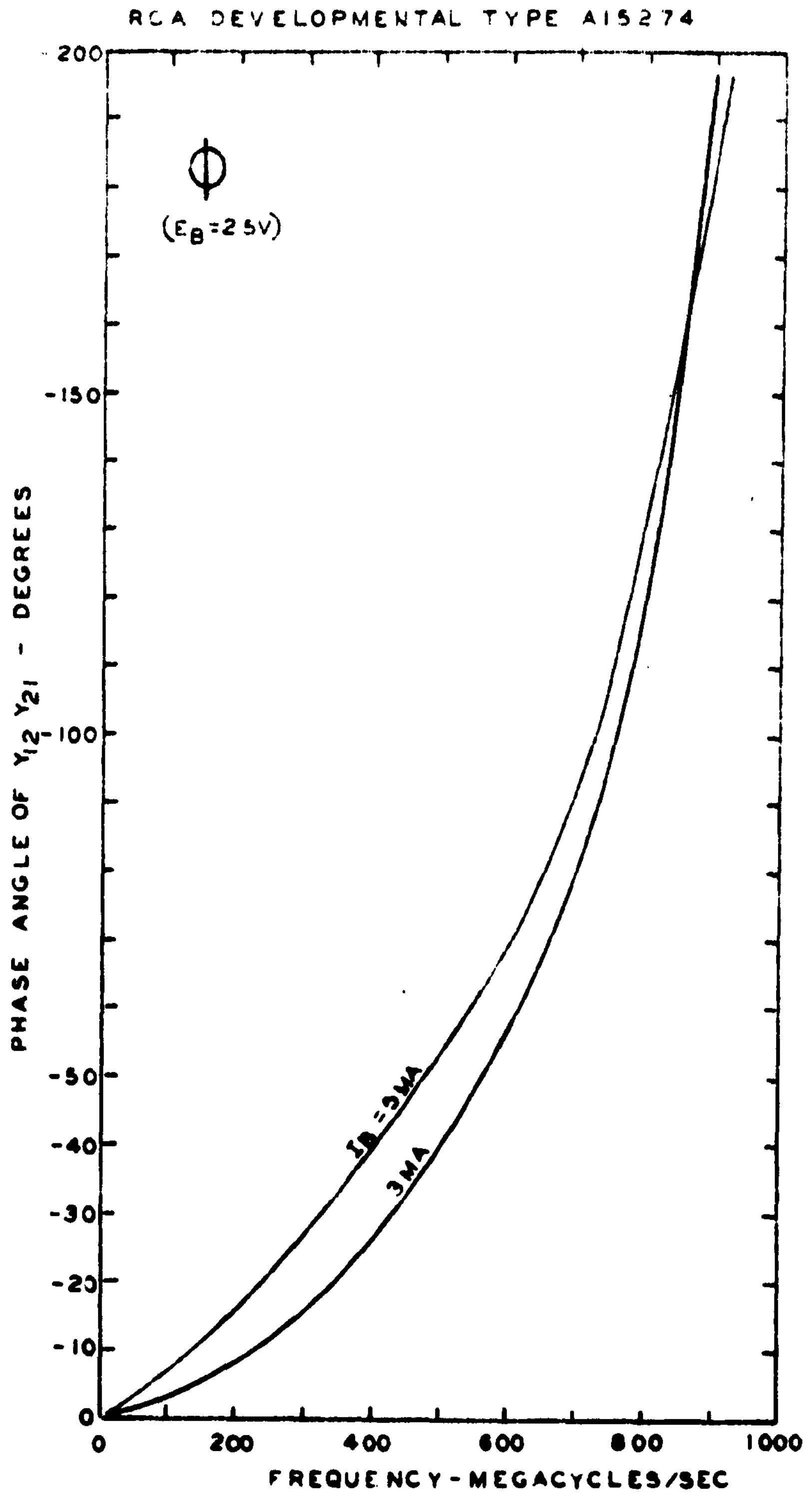

RCA DEVELOPMENTAL TYPE A15274
Φ
(E_B=25V)
PHASE ANGLE OF Y_{12} Y_{21} - DEGREES
200
-150
-100
-50
-40
-30
-20
-10
0
I_B=3MA
3MA
0
200
400
600
800
1000
FREQUENCY-MEGACYCLES/SEC

Fig. 70

RCA DEVELOPMENTAL TYPE A15274

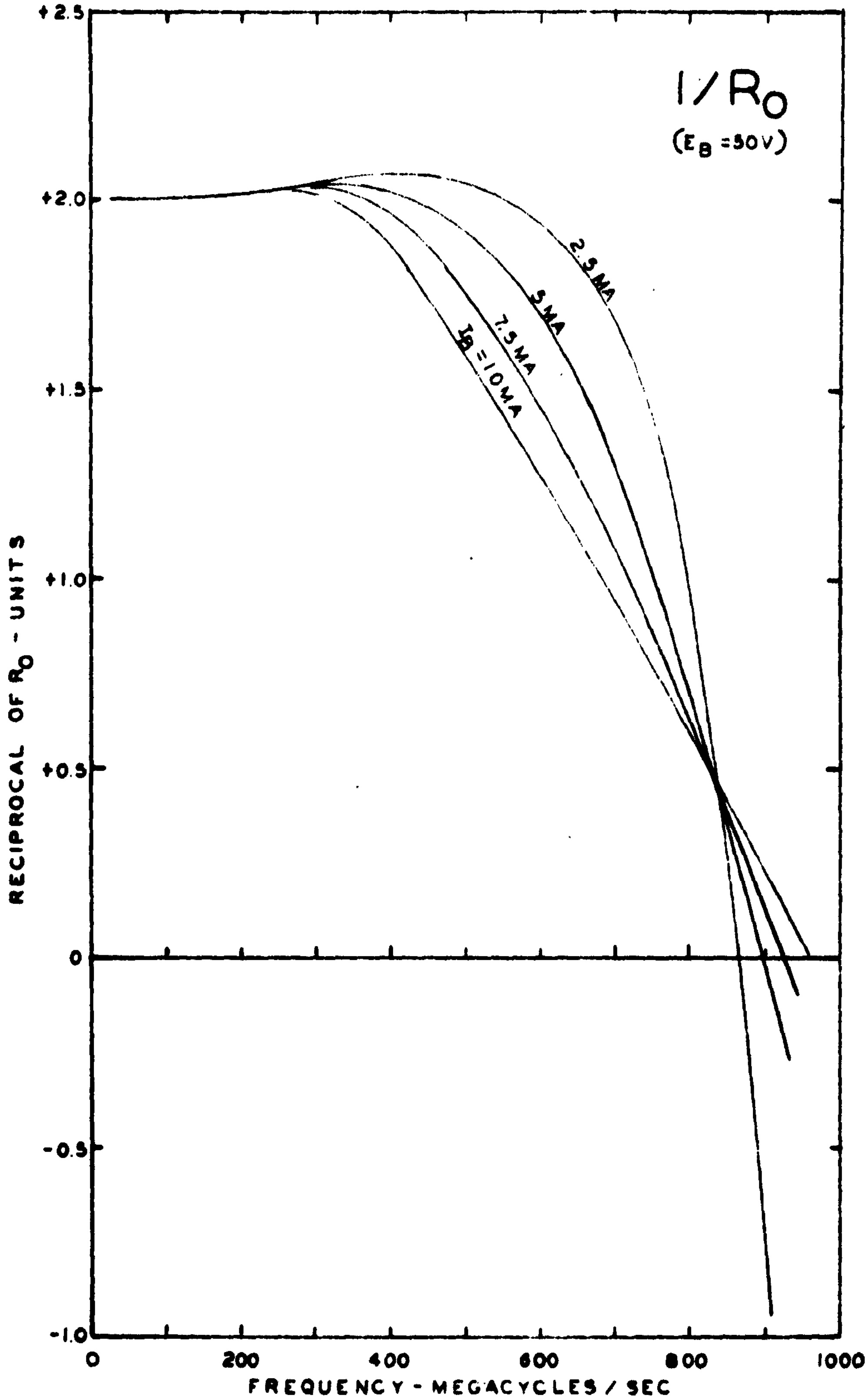


Fig. 71

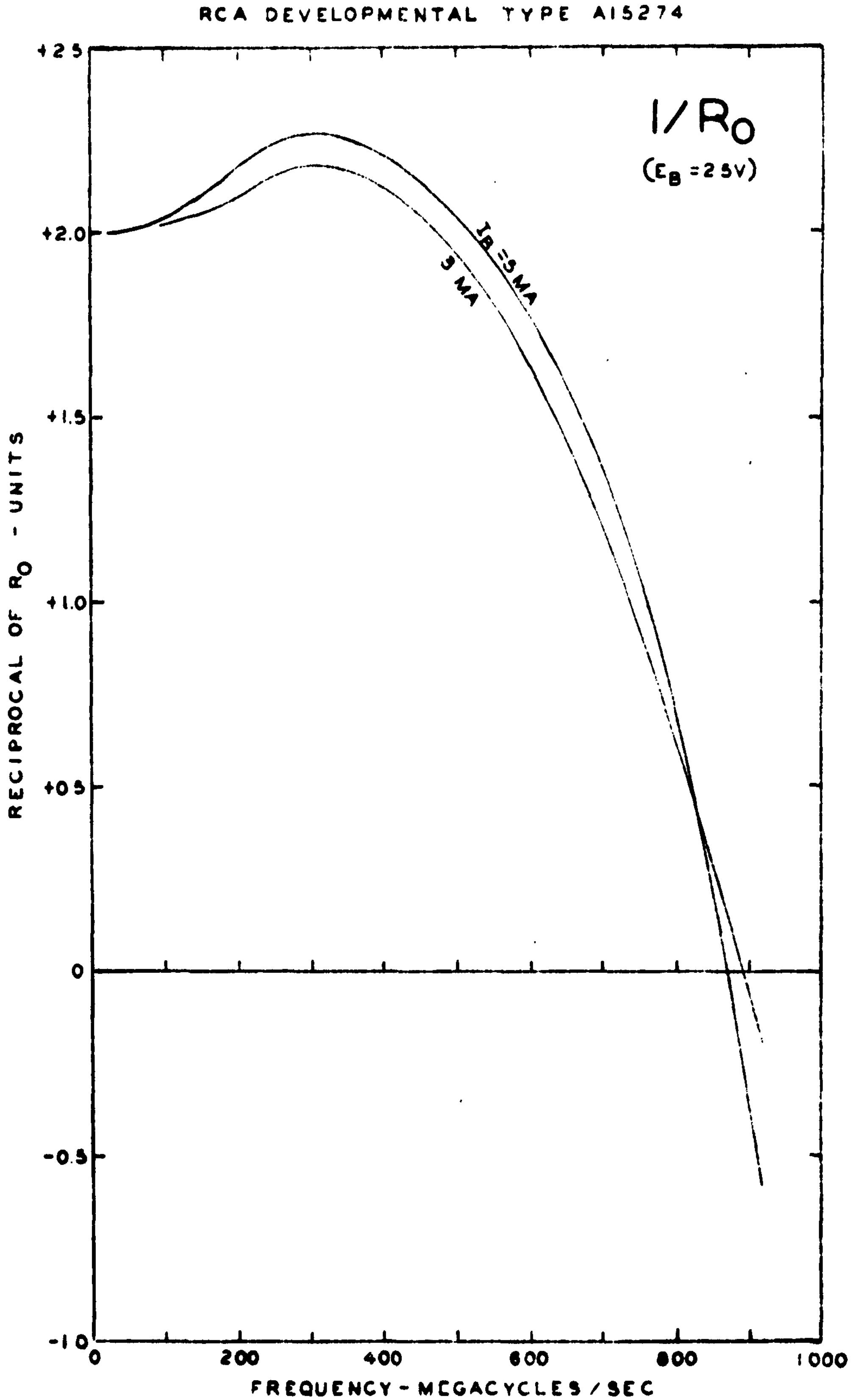
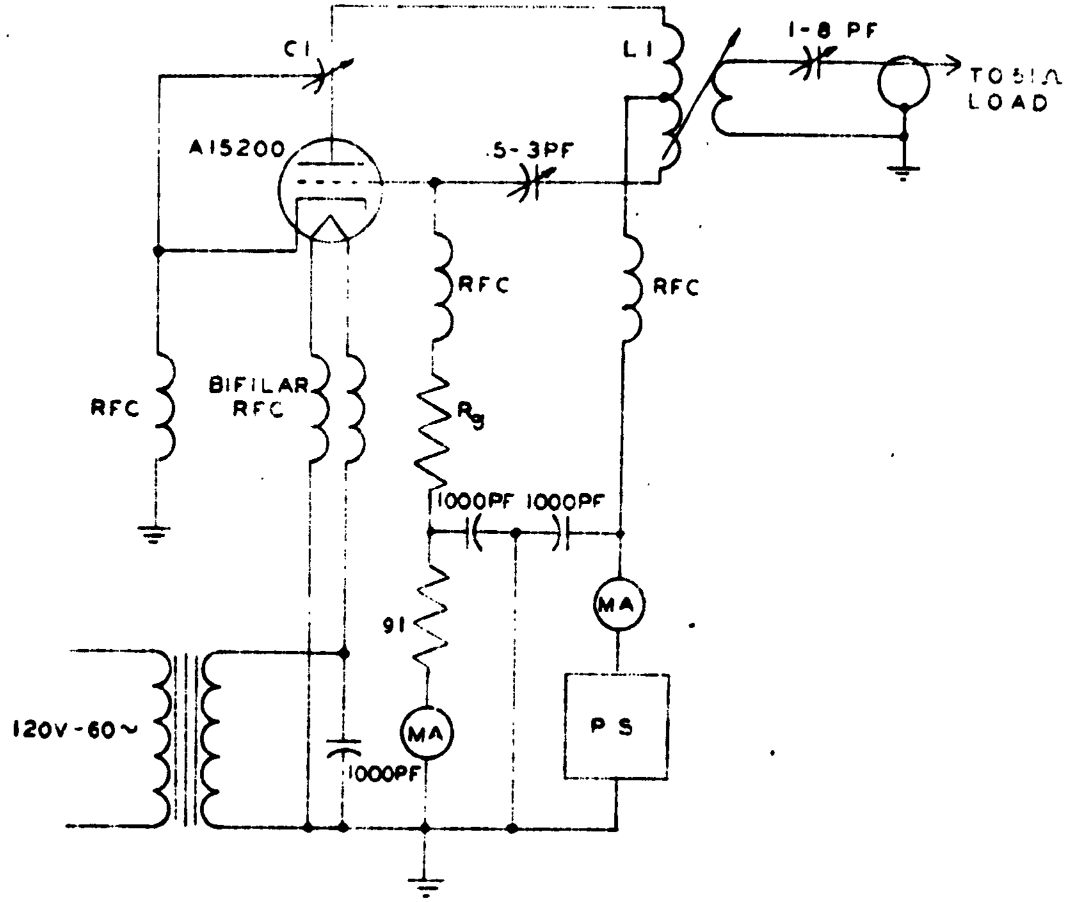

RCA DEVELOPMENTAL TYPE A15274
1/RO
(EB =25V)
IB =5MA
3 MA
RECIPROCAL OF RO - UNITS
FREQUENCY - MEGACYCLES / SEC
+2.5
+2.0
+1.5
+1.0
+0.5
0
-0.5
-1.0
0
200
400
600
800
1000

Fig. 72



A15200 UHF OSCILLATOR CIRCUIT

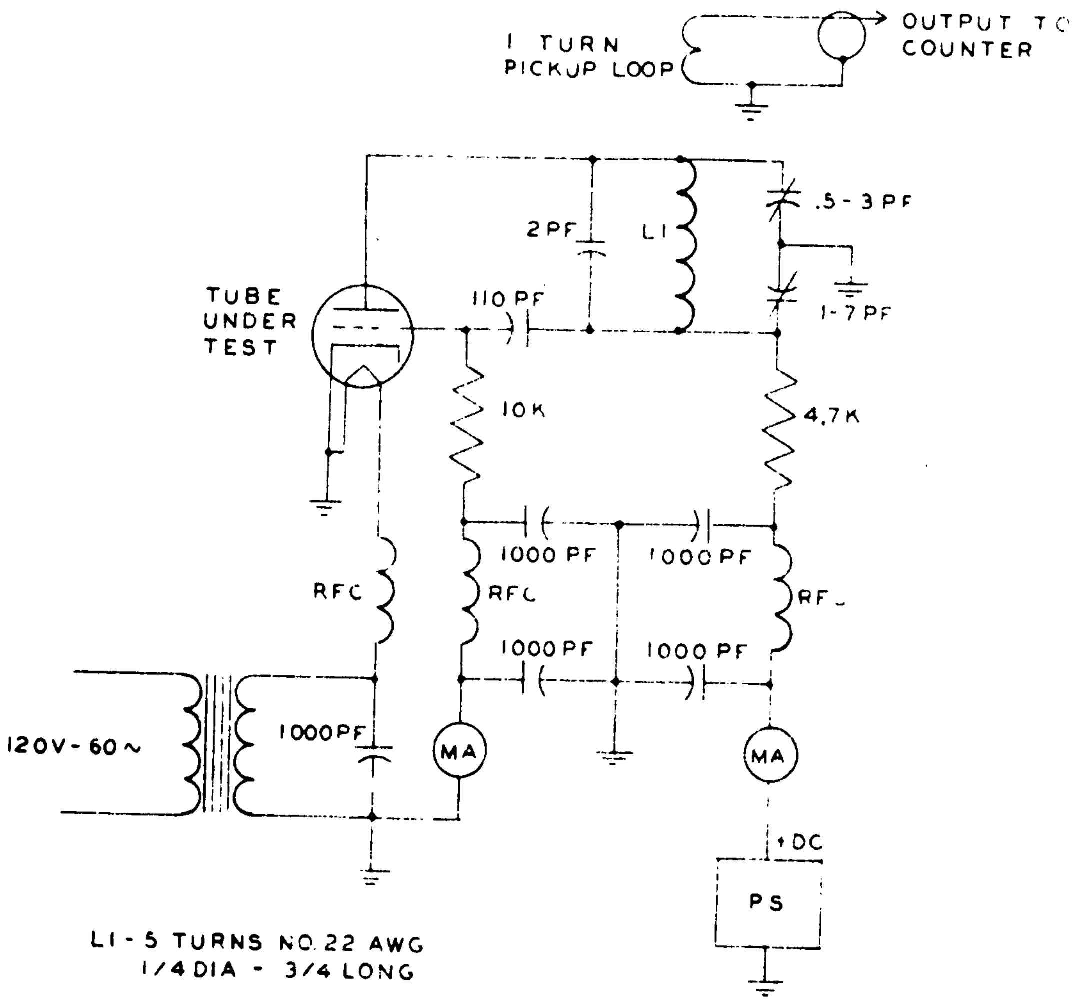
Fig. 73

With this same circuit sufficient power to light a lamp load could be delivered up to 700 Mcs. Measurements were made with a wattmeter load at frequencies up to 400 Mcs. At 400 Mcs. a plate efficiency (useful power output/plate power input) of slightly better than 50% can be obtained with the circuit of Fig. 73. A typical operating condition of 150 volts plate supply and 8 milliamperes of plate current will deliver 0.65 watts to the wattmeter load at 400 Mcs. At 250 Mcs. with a plate supply of 200 volts and a plate current of 10 milliamperes 1.3 watts are delivered to the load in this circuit. This represents a plate efficiency of 65 per cent as normally computed. However, even if we add the heater power of 450 milliwatts in figuring the input the overall efficiency is still much better than 50 per cent.

The circuit in which these tests were made was not necessarily of optimum construction for ultra-high-frequency purposes and it is presumed that improved efficiency could easily be achieved by methods such as using the distributed-constant circuits normally employed at these frequencies.

Temperature stability of interelectrode capacitances is often an important tube characteristic, especially when the tube is employed in oscillator circuits. The oscillator circuit is probably the most sensitive method of obtaining measurements related to capacitance changes. Samples of the developmental type A15200 were tested in an oscillator circuit which had been previously used for testing of other tube types so that comparative data were already available. This test chassis has provisions for interchanging various type sockets without disturbing the main tuning inductance. The circuit is of the Colpitts' type and is shown in Fig. 74. It is tuned to about 200 Mcs. primarily with tube capacitances but has trimmers to allow operation at constant frequency under similar feedback conditions with a variety of tube types. In this manner comparisons with other tube types may be made under nearly identical conditions. The circuit is physically arranged so that heat generated by the tube under test has a minimal effect on the circuit components. This is partially accomplished by connecting the chassis thermally to a water bath in order to maintain it at a constant temperature.

The output from this oscillator is taken from a pickup loop very loosely coupled to a buffer amplifier which raises the signal level to 0.2 volt. This signal level is required to operate a Hewlett-Packard type 524C electronic counter. The signal from the test oscillator is beat against a standard 200 Mcs. signal in the counter and the test frequency may be very accurately determined. Values of capacitance change are derived from differences in measured frequency. The tank coil of the test oscillator circuit tunes to 200 Mcs with 5.8 picofarads, so that a frequency change of 100 kilocycles is equivalent to a net capacitance change of 5.8×10^{-3} picofarads. For purposes of consistency in comparison, feedback in the test circuit is adjusted so that the grid-cathode capacitance appears across approximately 20 per cent of the



"STANDARD" OSCILLATOR DRIFT
TEST CIRCUIT

Fig. 74

tank inductance reducing the effect of grid-cathode capacitance in terms of the whole inductance.

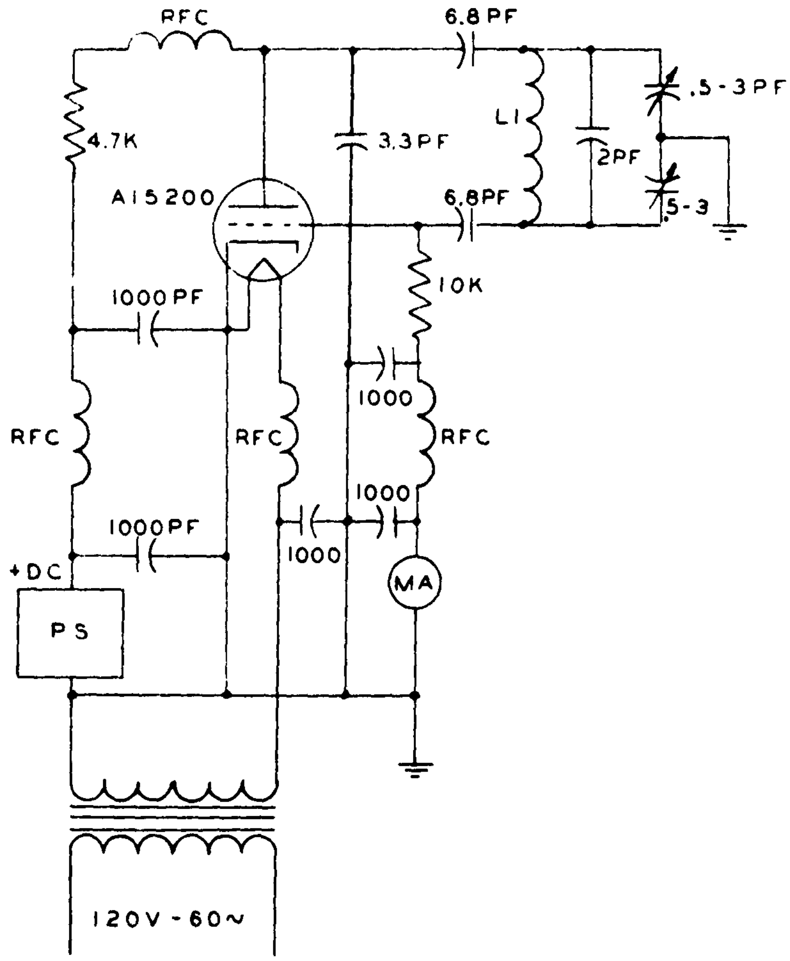
Table 10 presents comparative measurements for some tube types in popular use as local oscillators and representing varied types of construction. The operating conditions indicate the power input required to develop approximately the same signal level for each tube type. Under the headings of 10 per cent E_{bb} change and 10 per cent E_f change, the signs associated with frequency shift indicate the direction of frequency change compared with direction of applied voltage change. Because the frequency change is essentially linear within the limits of either raising or lowering the applied voltages by 10 per cent the tabulated values hold for either increasing or decreasing supply voltages. A negative sign in front of a value indicates a lowered frequency with a voltage increase or correspondingly an increased frequency with a voltage decrease. The first column under plate voltage change indicates the instantaneous frequency shift as the voltage is changed while the second column shows the subsequent shift in reaching thermal equilibrium. The total frequency shift from the original operating frequency is the algebraic sum of these two values. The numbers under heater voltage change represent total frequency shift after thermal equilibrium has been reached. For warm-up drift the instantaneous frequency was measured at intervals after application of all voltages to a cold tube. The deviations from the stable frequency (reached five to ten minutes after switch-on) are tabulated for one-half, one and two minutes after application of voltages. A positive value indicates deviation above the final frequency. All of the tube types of Table 10 were measured under as near identical condition as possible to show their relative stability. The last line in Table 10 is included for the developmental type A15200 operated in the modified circuit depicted in Fig. 75 and is to illustrate that the "standard" test circuit of Fig. 74 is not necessarily representative of circuits designed for high stability. The data in Table 10 indicate the exceptional frequency stability where the type A15200 is used. The frequency changes are in fact generally smaller than those due to tube-to-tube variations when different samples of conventional tubes are plugged into the same socket. Table 11 demonstrates that in addition to stability the construction of the developmental type A15200 also offers the advantage of uniformity. Data for seven tubes made at different times are included. The tubes were plugged into the "standard" test oscillator circuit of Fig. 74 without making any circuit adjustments. The information in Table 11 is comparable to that in Table 10 and in addition the final stable frequency measurements are included for the warm-up deviation tests. It can be seen that for the A15200 tubes measured in the same socket without any circuit adjustments a total spread of 0.89 Mcs or less than one-half per cent in final frequency was produced.

Some further data on the stability of the developmental type A15200 over greater changes in applied voltages are shown in Fig. 76.

TABLE 10

Frequency Changes in 200 Mcs Oscillator Circuit

Tube Type	Operating Conditions			10% E_{bb} Change			10% E_f Change	Warm Up Deviation		
	Ebb Volts	I_b ma	I_c ma	Inst. kc	Thermal kc	Total kc	kc	1/2 Min kc	1 Min kc	2 Min kc
6EA8 Triode Section	80	3.5	0.76	75	-3	72	-70	210	154	90
6CG8A Triode Section	80	3.2	0.70	45	-10	35	-40	253	87	30
6AF4A	50	2.6	0.74	35	-5	30	-20	255	175	95
7586	40	2.4	0.85	35	0	35	-100	45	25	10
A15200	55	2.5	0.87	16	-1.5	14.5	-42	36	19	6.5
A15200 Modified Circuit	75	4.8	0.47	7.5	-1	6.5	-1	-2	-6	-6



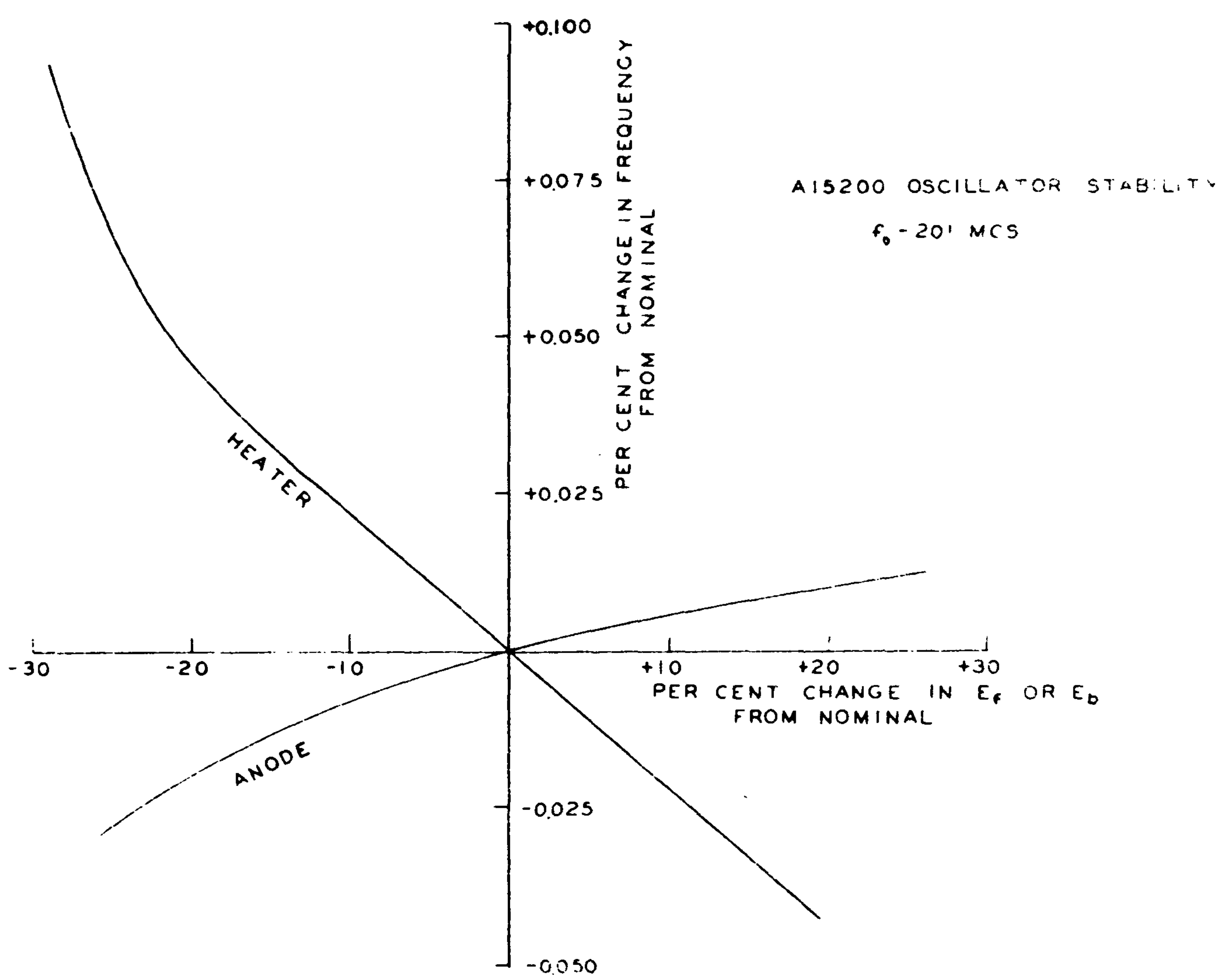
A15200 LOW DRIFT OSCILLATOR CIRCUIT

Fig. 75

TABLE 11

Type A15200 Oscillator Uniformity at 200 Mcs

Tube No.			B3	G21	E4	E1	G18	G7	G10
+10% Ebb	Instantaneous	kc	13	16	12	10	10	15	16
	Thermal	kc	-1	-3	-3	-3	-1	-2	-1
	Total	kc	12	13	9	7	9	13	15
-10% Ebb	Instantaneous	kc	-17	-23	-16	-15	-18	-17	-21
	Thermal	kc	1	1	1	1	1	2	1
	Total	kc	-16	-22	-15	-14	-17	-15	-20
+10% E_f	Total	kc	-42	-43	-46	-49	-42	-41	-43
-10% E_f	Total	kc	41	40	71	45	41	38	39
Warm Up Deviation	1/2 Min	kc	33	31	36	37	41	32	40
	1 Min	kc	18	18	19	20	22	16	20
	2 Min	kc	7	6.5	8	7	6.5	3.5	8
	Stable Freq.	Mc	201.50	201.59	201.73	200.91	201.70	201.80	201.74


A15200 OSCILLATOR STABILITY
f_0 - 201 MCS
PER CENT CHANGE IN FREQUENCY FROM NOMINAL
+0.100
+0.075
+0.050
+0.025
-0.025
-0.050
-30
-20
-10
+10
+20
+30
PER CENT CHANGE IN E_f OR E_b FROM NOMINAL
HEATER
ANODE

F . 7

The oscillator tests just discussed have shown the type A15200 to have rather good characteristics in this service. Because the developmental type A15274 does not differ basically from the type A15200 one would expect the same good performance. It is, however, reasonable to expect slightly higher maximum frequency of operation of the type A15274 because of its increased transconductance.

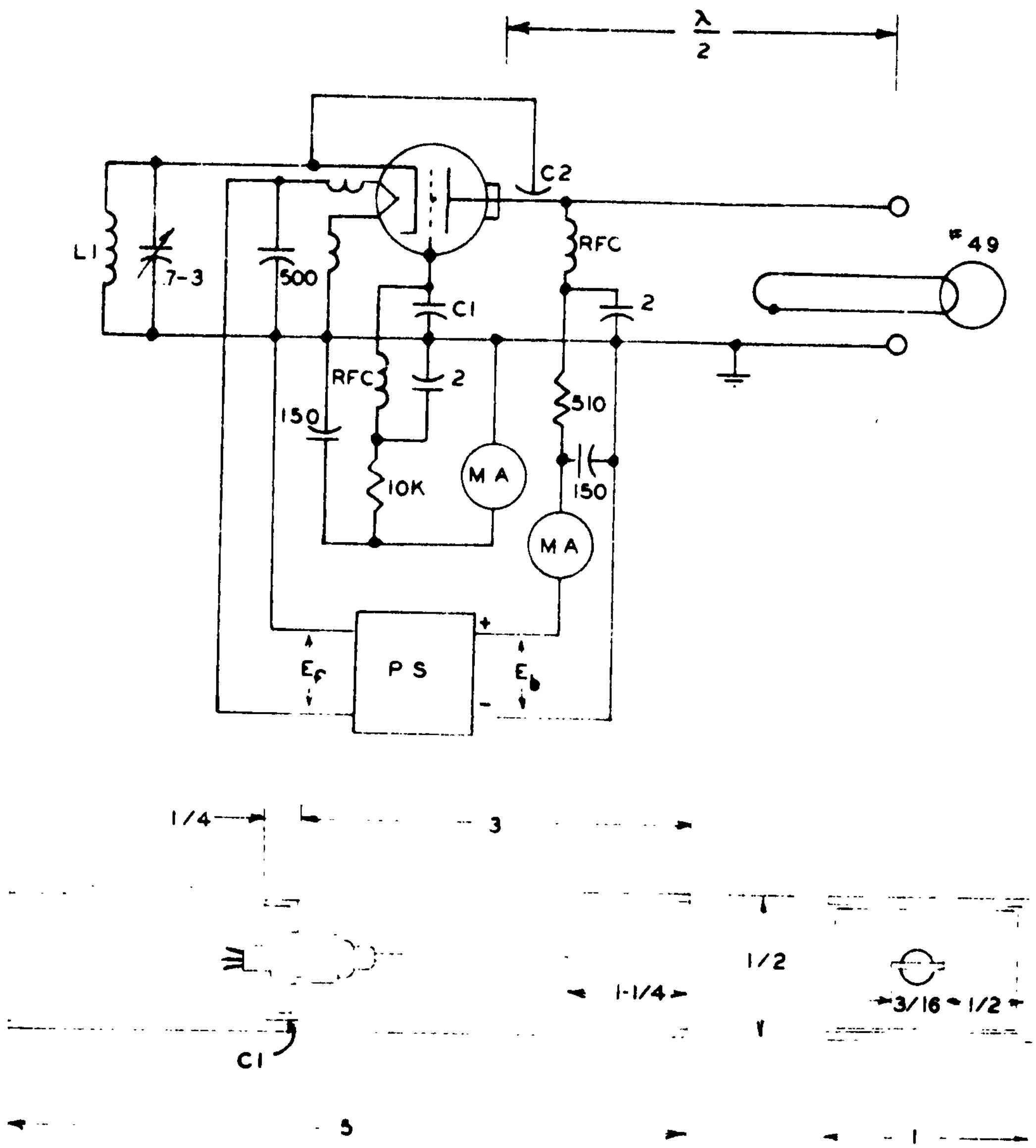
Fig. 77 shows the circuit diagram and partial layout of an oscillator using the type A15274. The "chassis" for this oscillator is a "U" shaped channel with a partition serving as the grid plane. A clip is soldered to this partition and grid connection is made to the type A15274 by inserting the shell ring of the tube in the clip and allowing the plate end of the tube to project through a hole in the partition. This partition is insulated from the "U" channel by Teflon sheet which serves as the dielectric for C1 of Fig. 77. A standard linotetrar socket is used to provide electrical connections to the heater and cathode. A piece of insulated wire is run from the socket cathode lead, alongside the tube, to near the plate cap of the tube. This serves as the feedback capacitor shown as C2 in Fig. 77. The adjustment of this feedback capacitor is rather critical at a given frequency but no "holes" in frequency occur. The anode line is a strip .020" by 3/16" and cut in length for frequency adjustment.

This oscillator circuit has operated satisfactorily to above 2.1 Gc/s and oscillation is obtained at this frequency with less than 0.3 watt plate input. Using a lamp load, a power output of about 40 milliwatts as observed with three-quarters watt plate input at 1.68 Gc/s.

In conformance with BuShips direction, three operable samples of the developmental type A15200 were delivered to the Evans Signal Laboratories USASRDL for their transfer to MELABS, Palo Alto, California, where the tubes were to be evaluated for use in the R903 receiver being developed under contract DA-36-039 SC-78354. The intended use was as a very low power drain local oscillator operating from 460 to 1060 Mcs. in a butterfly circuit. Informal reports indicate that very satisfactory operation was obtained with a total of one and one-half watts input. While this seems to be somewhat more power than we would expect, it is not known if the circuit was optimized for the type A15200. Even so, these power requirements for the type A15200 are only about half those of any other available tube. It is highly unlikely that any serious attempt will be made to design a tube of the type A15200 design into the receiver because of the timing factors involved.

Pulse Operation

Measurements have been made under pulse conditions on the type A15200. A pulsed supply of two microseconds pulse width with a repetition frequency of about 500 cps was used. A 125 volt peak positive pulse is applied to the grid and plate which are tied together. All samples of the type A15200 are capable of peak emission in excess of one-half ampere under these conditions and most are capable of about



CIRCUIT DIAGRAM AND LAYOUT

2 GC OSCILLATOR

Fig. 77

one ampere peak. Since the cathode area is about one-seventh of a square centimeter the half-ampere peak figure represents approximately 3.5 amperes per square centimeter. One tube was operated in excess of one hundred hours under these pulse conditions and although there was an initial decrease in pulse emission from 0.9 amperes peak to 0.5 amperes in the first few hours of operation, the peak emission stabilized at 0.5 amperes for the rest of the time of operation. Transconductance measurements have been made at times during the operation and at one hundred hours of pulse operation the sample still has in excess of 90% of its zero hour transconductance.

Peak Cathode Current Density

It is generally known that for all types of tubes the cathode current density varies over the surface of the cathode being a minimum directly under the grid wire and a maximum at a point midway between the wires. In the case of a remote cutoff tube, this condition is accentuated due to the difference of pitch between the "close-wound" and "open-wound" portions of the grid. Although a knowledge of the values of these current densities would be valuable in determining a recommended operating point and in setting up life test conditions, they are not often available due to the complex and laborious computations required to obtain them.

However, because the A15330 was designed using a computer, this information was readily obtained by making a minor alteration in the machine program and rerunning the original design information. These data have been overplotted on a plate family for the A15330 and are shown in Fig. 78. These peak current densities occur in the spaced sections of the grid.

Cathode Warm-Up Time

The time required for a cold tube to reach 90 per cent of stable plate current after the application of all voltages has been measured for the type A15200. The average time is fifteen seconds for a stable plate current of ten milliamperes and the maximum time has not exceeded seventeen seconds for any tube measured. This performance will be almost identical to that of the A15274 and A15330 because of the similarity of the heater-cathode assembly.

Low Voltage Operation

Rather extensive measurements of equivalent noise resistance of the A15200 have been made. The equivalent noise resistance can be used as a measure of cathode activation in a tube[1] and can also be used to some extent to evaluate the comparative performance of a given tube with a theoretically ideal tube. Fig. 79 shows the variations in both transconductance and equivalent noise resistance (R_{eq}) as a function of heater voltage for several values of plate current. It will be noted

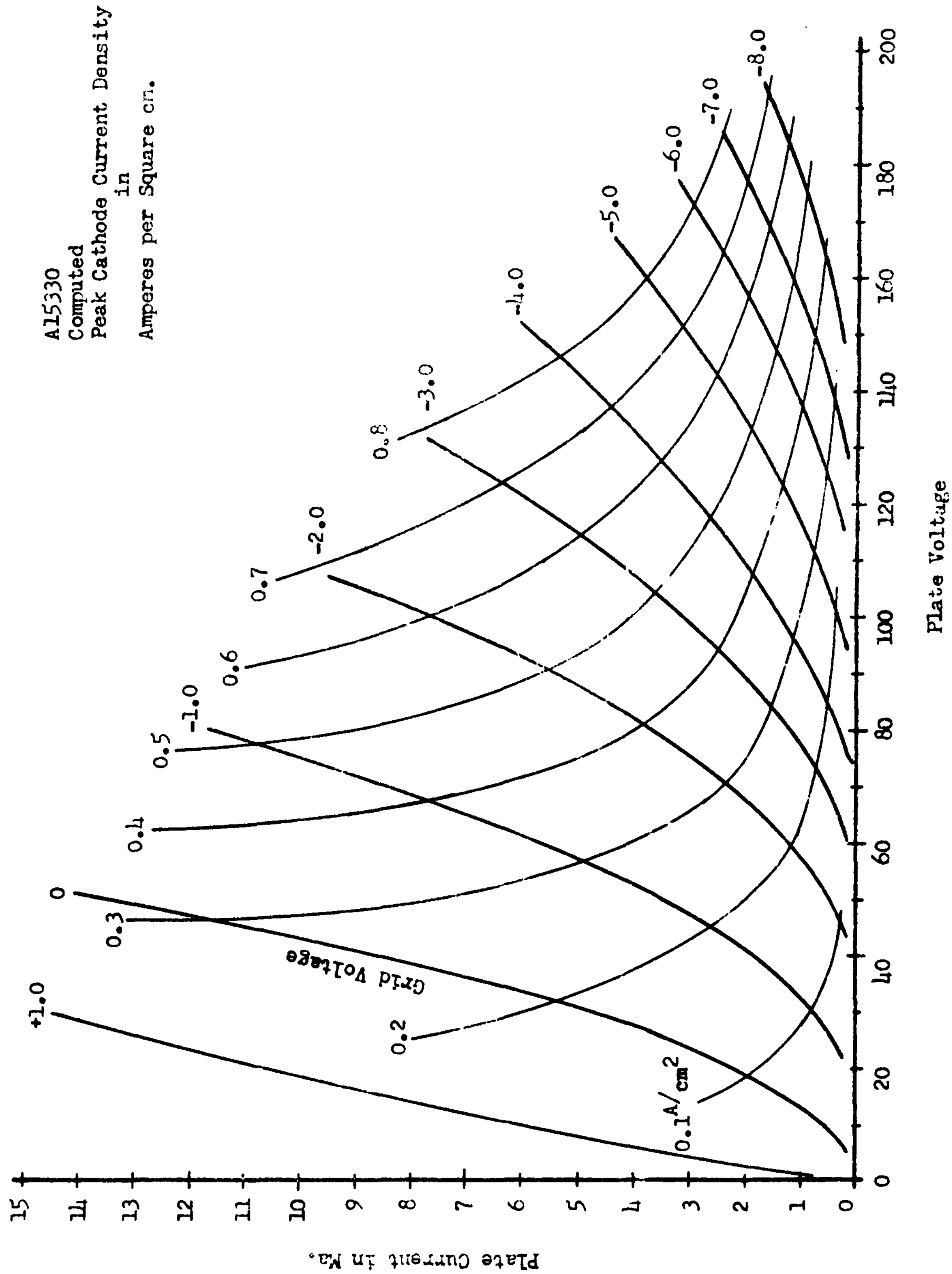
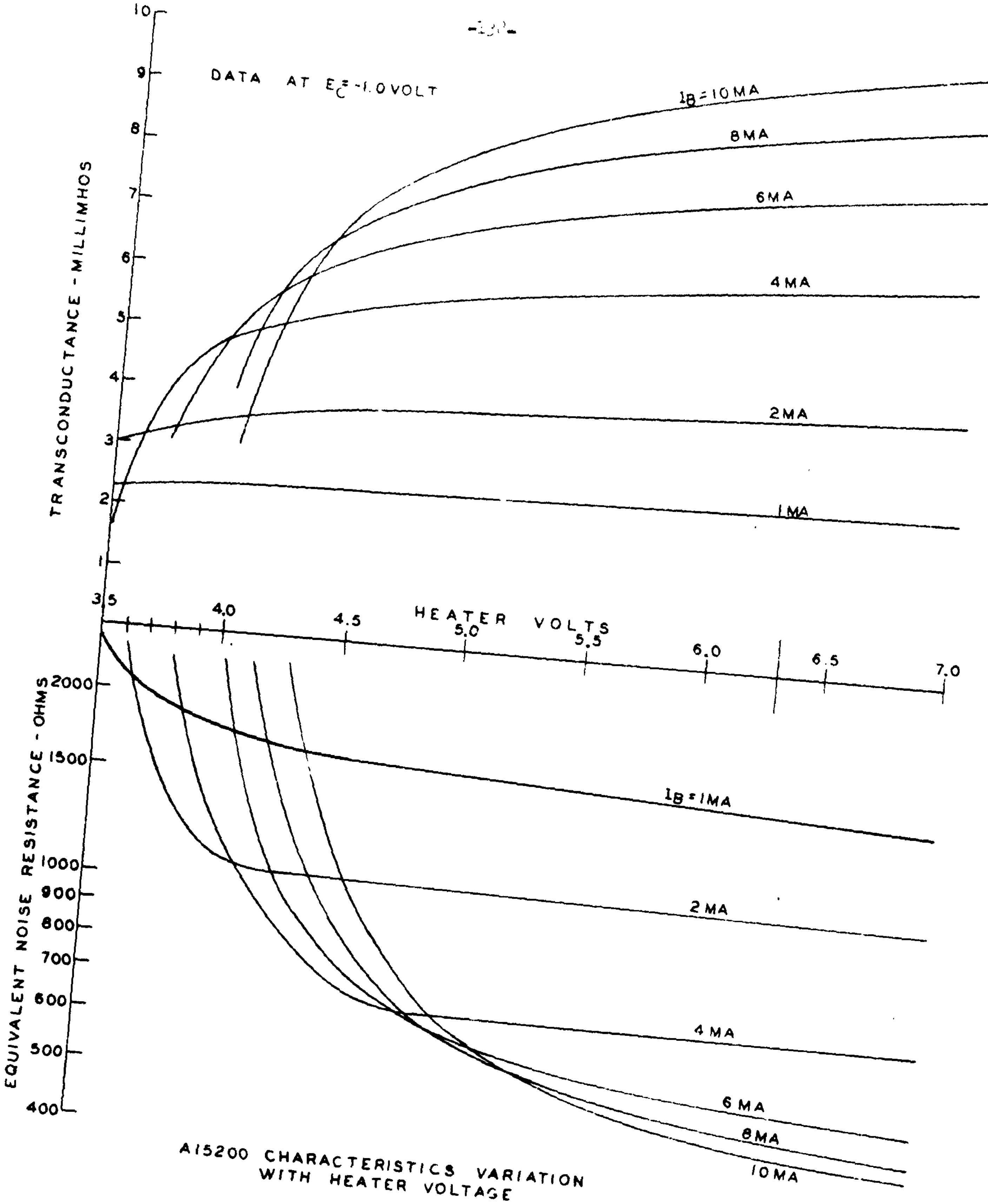

A15330
Computed
Peak Cathode Current Density
in
Amperes per Square cm.
Plate Current in Ma.
Plate Voltage
Grid Voltage
+1.0
0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
0.1 A/cm²
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0 20 40 60 80 100 120 140 160 180 200
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Fig. 78



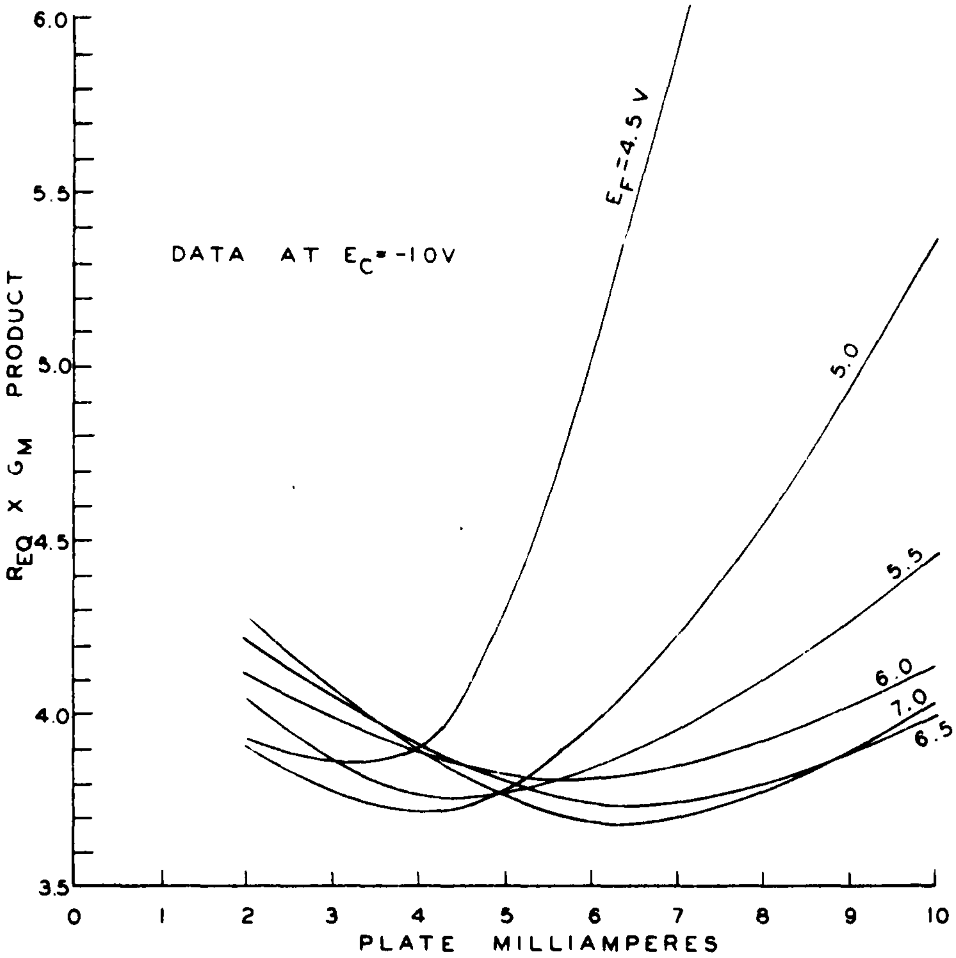
A15200 CHARACTERISTICS VARIATION WITH HEATER VOLTAGE

Fig. 79

from this figure that the transconductance at one milliampere can be maintained with as low as 3.5 volts on the heater. This represents a heater power input of 175 milliwatts. For a plate current of 8 milliamperes no serious loss of transconductance is experienced until the heater voltage is reduced to below 4.5 volts which is the equivalent of approximately 260 milliwatts power input to the heater. Examination of the equivalent noise resistance curves of Fig. 79 shows about the same degree of dependance on heater voltage as the transconductance curves. As indicated, these data were measured with a fixed grid bias of -1.0 volt. Similar measurements have been made under other conditions such as a fixed grid current of 0.5 microampere and while, as might be expected, some differences in the absolute values of transconductance or R_{eq} are obtained, the shapes of the curves with respect to heater voltage are not substantially altered.

Harris[3] has shown that the product of the transconductance (gm) and the equivalent noise resistance (R_{eq}) should be equal to approximately 2.5 for a triode amplifier. Fig. 80 shows a plot of this R_{eq} x gm product for the developmental type A15200 as a function of plate current with heater voltages as the parameter. It may be seen from the curves that in this case the R_{eq} x gm product never has a value less than 3.7 under the conditions of measurement. These data as indicated are for a fixed grid bias of -1.0 volts. Once again, these computations have been made for other operating conditions and while the R_{eq} x gm product may be lower it never decreases to a value as low as 3.0. The value of 2.5 (or sometimes as high as 3.0[7]) has been derived from theoretical considerations and is readily achievable with the relatively wide spacings used in most tubes. However, as has been stated previously the usual mathematical formulae for electrical characteristics of electron tubes do not give results of the required engineering accuracy for cases where very close grid cathode spacings are used. This is predominantly due to the effect of "Inselbildung" wherein marked variations in current density are produced along the cathode surface. The portions of the cathode between grid wires are producing emission which is a source of shot noise but contributing very little of the transconductance. The curves of Fig. 80 show, however, that at normal operating conditions marked variations in the R_{eq} gm product are not produced and that the A15200 can even be operated at very low heater voltages without detrimental effect on this product if the plate current is decreased.

Noise factor measurements on the developmental type A15200 at 700 Mcs were also made under conditions of varying heater voltage, plate voltage and plate current. Grid bias was held to -0.5 volt by adjustment of the cathode resistance. These tests showed the noise factor and gain to be relatively independent of heater voltage as long as plate current is maintained at a constant value. An average noise factor of 12 db was measured at 2 milliamperes plate current. The noise factor decreases with



PRODUCT OF TRANSCONDUCTANCE AND EQUIVALENT NOISE RESISTANCE AS A FUNCTION OF PLATE CURRENT FOR TYPICAL A15200

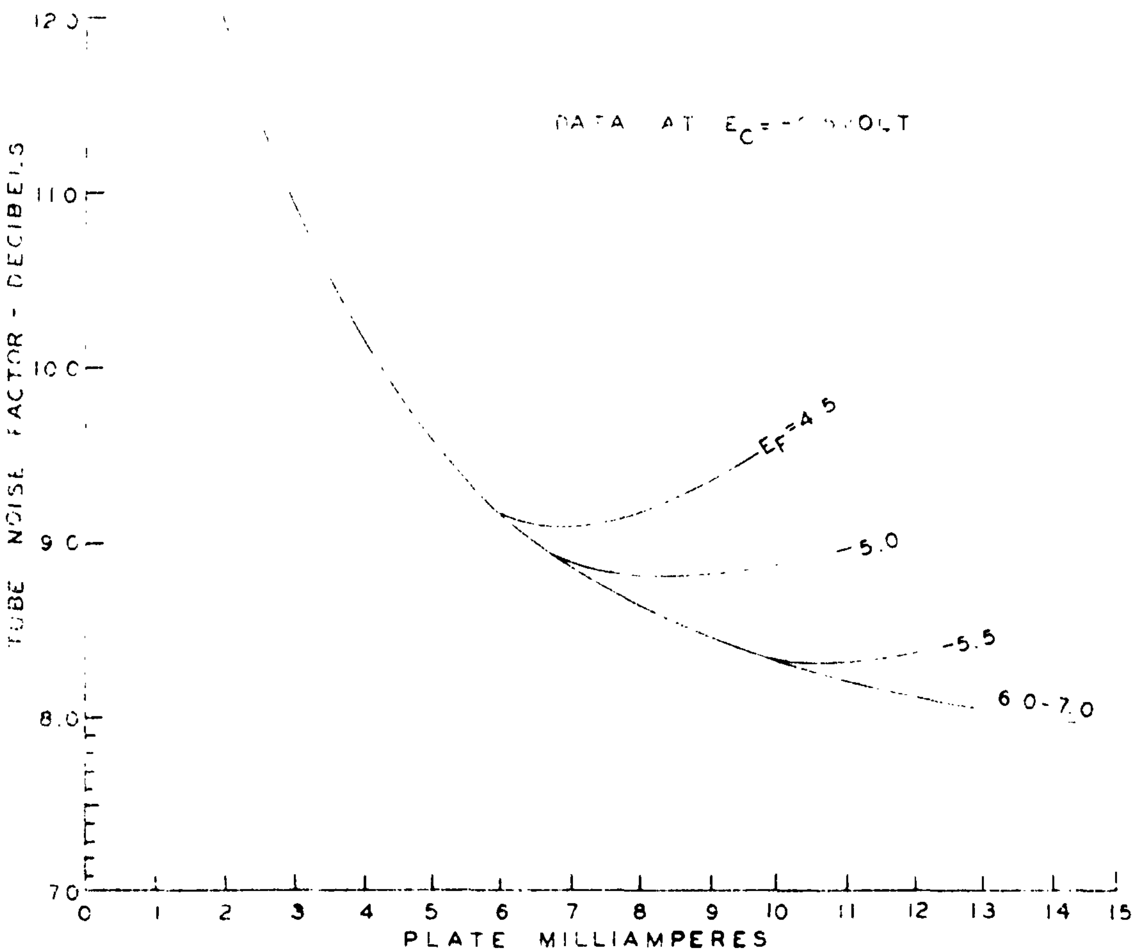
Fig. 80

increasing plate current until it is below 9 db at 8 milliamperes but improvement is slight beyond this point. The curves obtained are shown in Fig. 81 and it may be of interest to compare Fig. 81 with the curves of Fig. 80. The deviations of the curves for given heater voltages are comparable, but the noise factor values seem to be less sensitive than the gm R_{eq} product.

Some very low voltage measurements were also made on a typical sample of the A15200 at 500 Mcs. With a plate supply of twenty volts and a cathode resistor of 25 ohms noise factor and gain measurements, 7.0 db and 11.2 db, respectively, were obtained at 3.4 milliamperes plate current. A decrease in the plate supply to 10 volts with zero bias gave corresponding measurements of 8.7 and 10.4 db at 1.7 milliampere plate current.

As just mentioned the developmental type A15200 shows usable characteristics at plate voltages below twenty volts. Although the noise performance at high frequencies is somewhat degraded, it may be advantageous to consider low voltage application for the type A15200 at audio or video frequencies. Fig. 82 shows average plate characteristics for the developmental type A15200 at very low plate supply voltages. Once again these are measured data. A hypothetical audio-frequency amplifier employing the type A15200 with the following circuit constants: R_L = 1800 ohms, R_K = 82 ohms, R_g = 100k ohms, might be conveniently operated from a supply voltage of 25 volts. This would give a voltage at the plate of the A15200 of just under 20 volts with a plate current of about 3 milliamperes. The transconductance at this operating point is about 7,000 micromhos and a stage gain of about 19.5 db is attainable. If we further consider cascading four such stages we may operate the heaters of the A15200's in series and use the 25 volt plate supply also for the heater supply. Some 78 db of amplification may be had for a total current drain of less than 95 milliamperes at 25 volts or less than two and one-half watts total input and in addition the low value of plate load resistance would extend the frequency response into the video range. Only a very simple and physically-small power supply would be required since small-size low-voltage filter condensers could be used along with solid-state rectifier and a small low-voltage, low-current power transformer.

As with the type A15200, equivalent-noise-resistance measurements have been made on a typical A15274 at 450 kcs. Fig. 83 shows the transconductance variations for constant plate current as a function of heater input power while Fig. 84 shows the variation in equivalent noise resistance under the same conditions. Comparable curves for the type A15200 are shown as Fig. 79. The abscissae of the A15200 curves are in heater volts while those of Figs. 83 and 84 are in heater watts. As mentioned earlier, the type A15274's from which these measurements were derived were made with the 450 milliwatt heaters originally used in the type A15200. Because a 400 milliwatt heater at 6.3 volts is currently available and will be used in subsequent samples of the type A15274 the abscissae in milliwatts is more meaningful.



VARIATION OF 700 MCS NOISE FACTOR
WITH PLATE CURRENT

Fig. 81

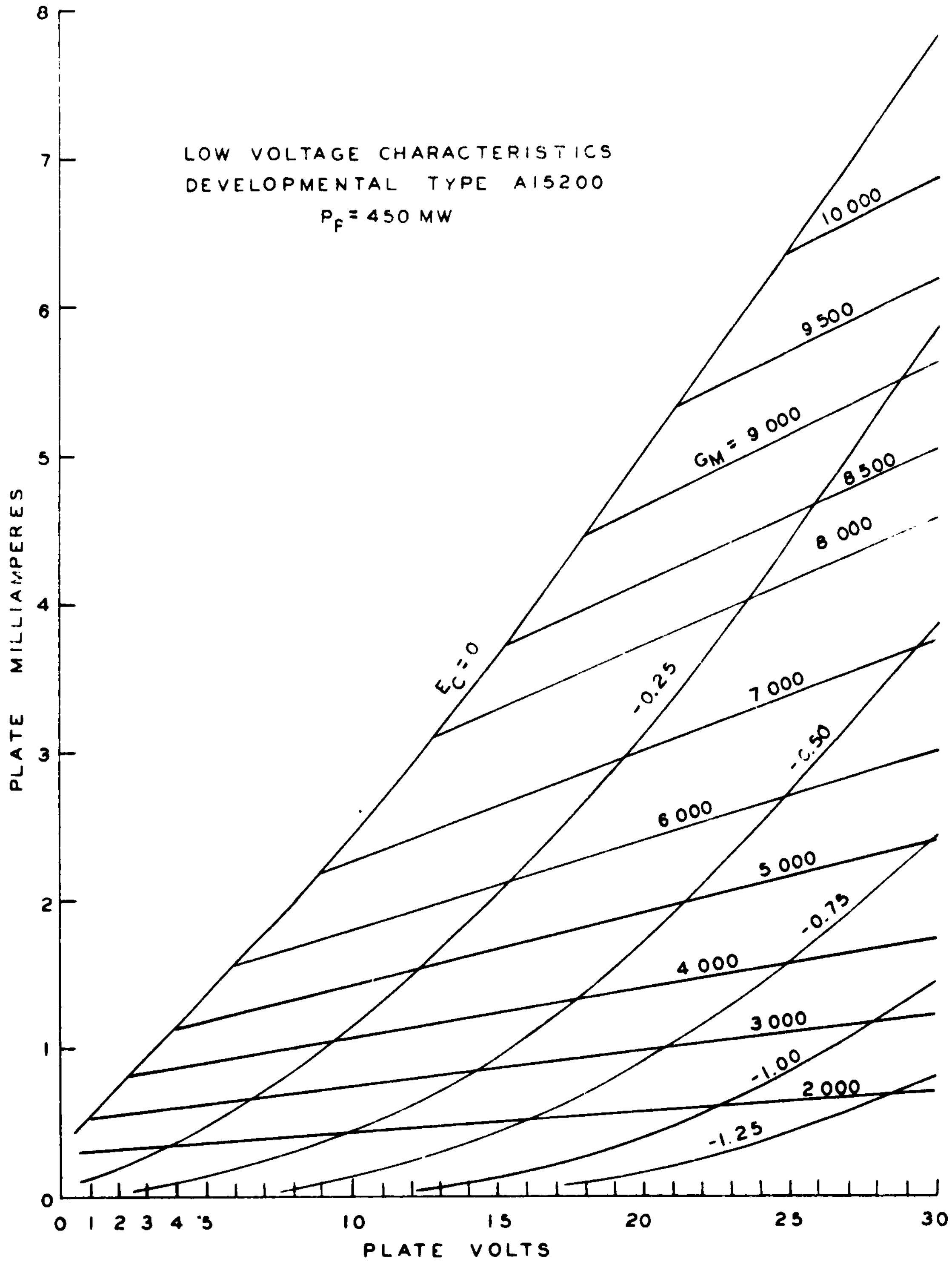
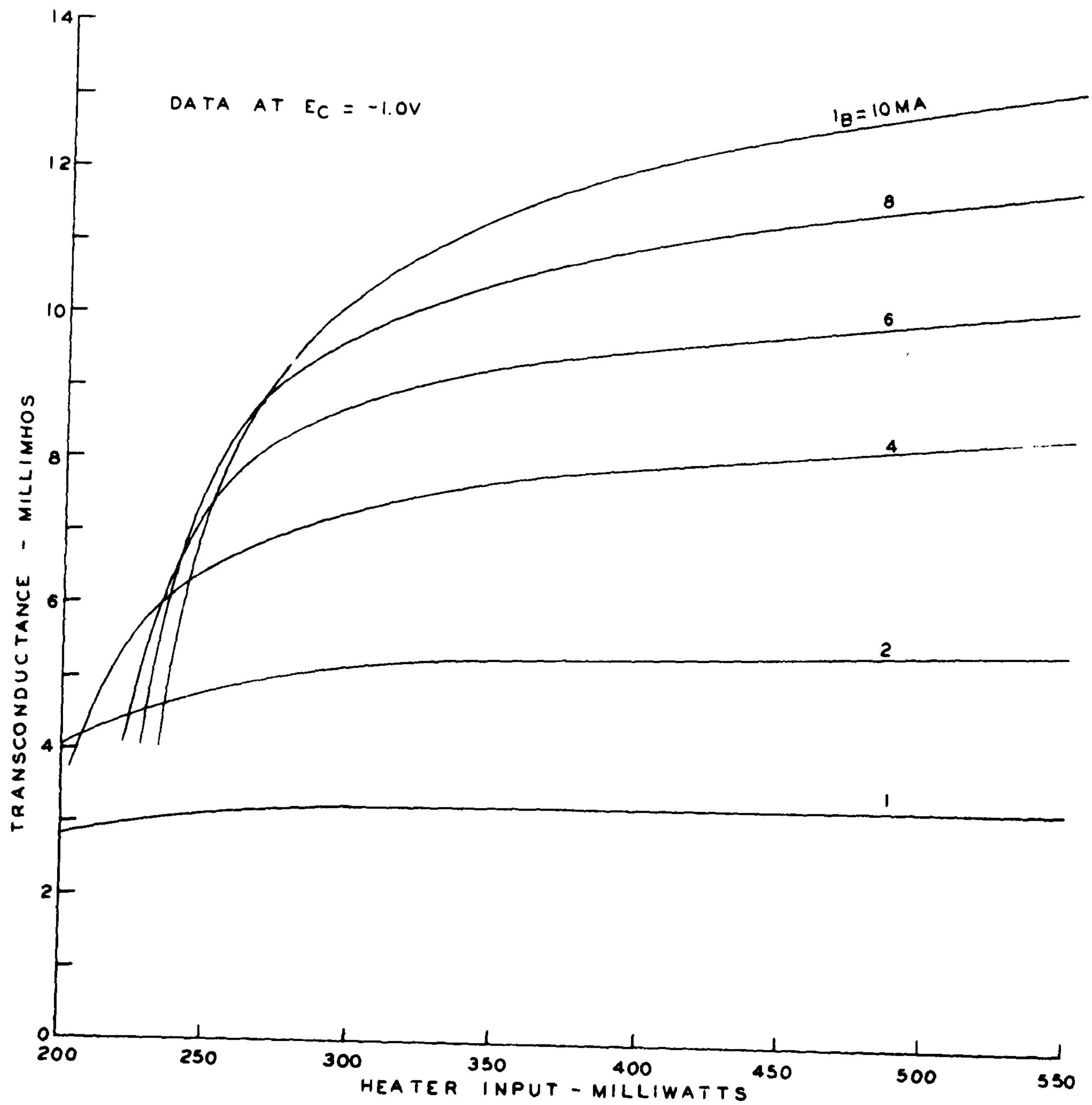
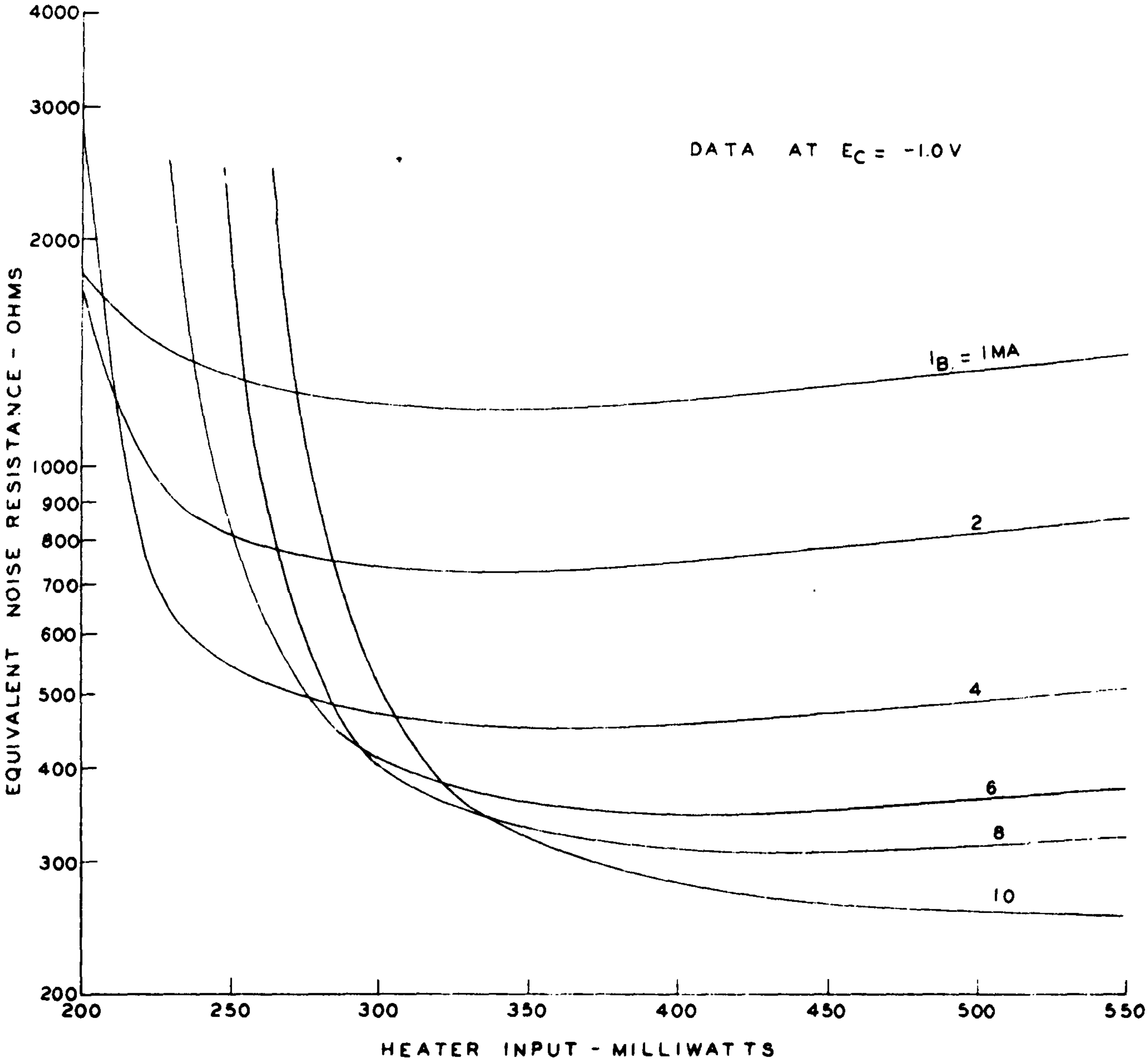

LOW VOLTAGE CHARACTERISTICS
DEVELOPMENTAL TYPE A15200
P_F = 450 MW
PLATE MILLIAMPERES
PLATE VOLTS
E_C = 0
-0.25
-0.50
-0.75
-1.00
-1.25
G_M = 9 000
10 000
9 500
8 500
8 000
7 000
6 000
5 000
4 000
3 000
2 000
0
1
2
3
4
5
6
7
8
10
15
20
25
30

Fig. 82



A15274
TRANSCONDUCTANCE VARIATION WITH HEATER POWER

Fig. 83



A15274

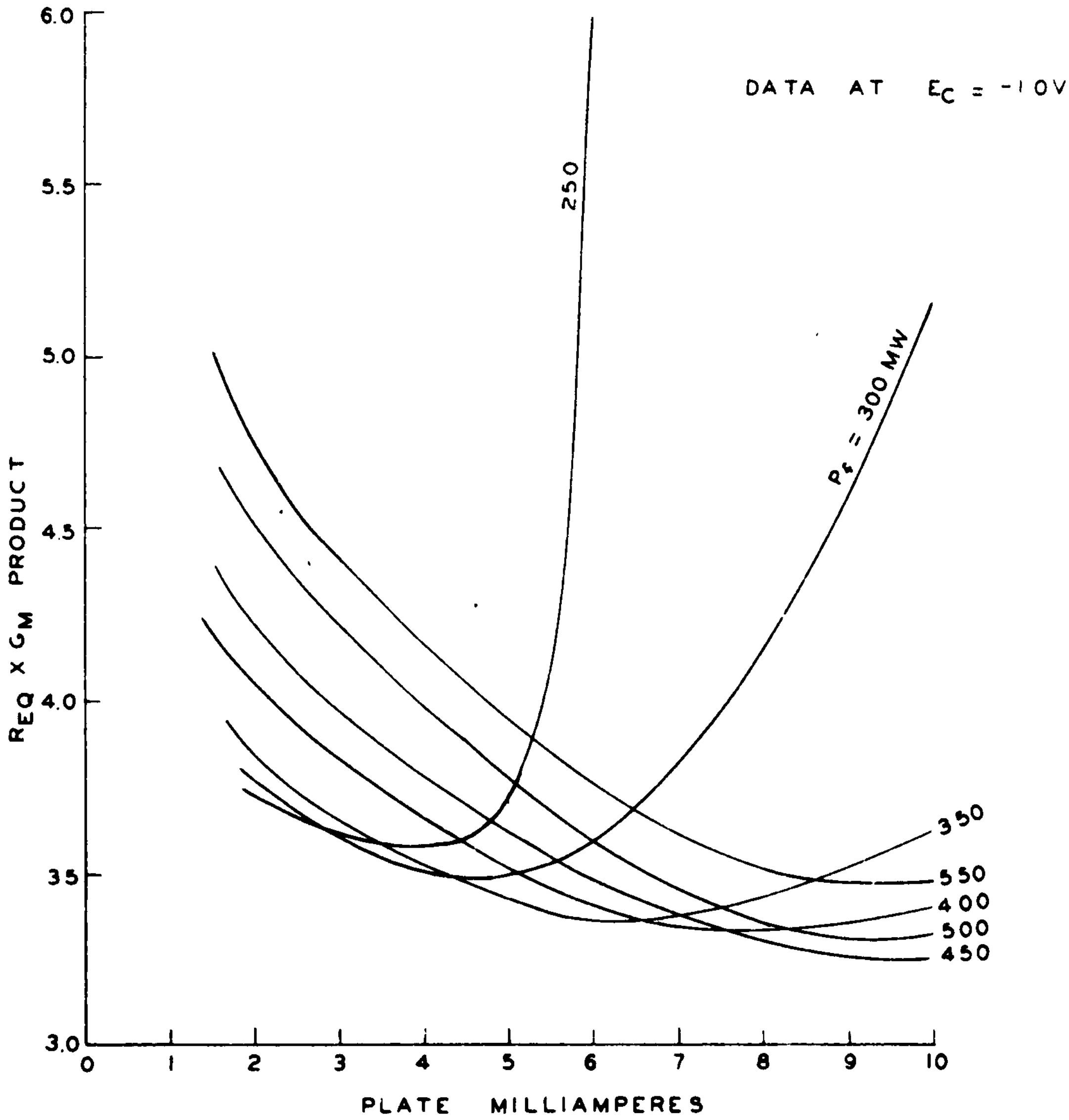
NOISE RESISTANCE VARIATION WITH HEATER POWER

Fig. 84

The product of these transconductances and equivalent noise resistances is shown in Fig. 85. No marked variation in the product is produced with a 350 milliwatt heater input and this will be the equivalent of about a 10 per cent under-voltage in the heater to be used. Fig. 85 also shows a lower value of the product R_{eq} X G_m for the same operating conditions than the type A15200. This is an indication of better field conditions at the cathode than are present in the type A15200. Although not shown in this report, contours of R_{eq} X G_m have been over-plotted on a type A15274 plate characteristic and the theoretical figure of 2.5 is obtained at low plate voltages (circa 25v.)

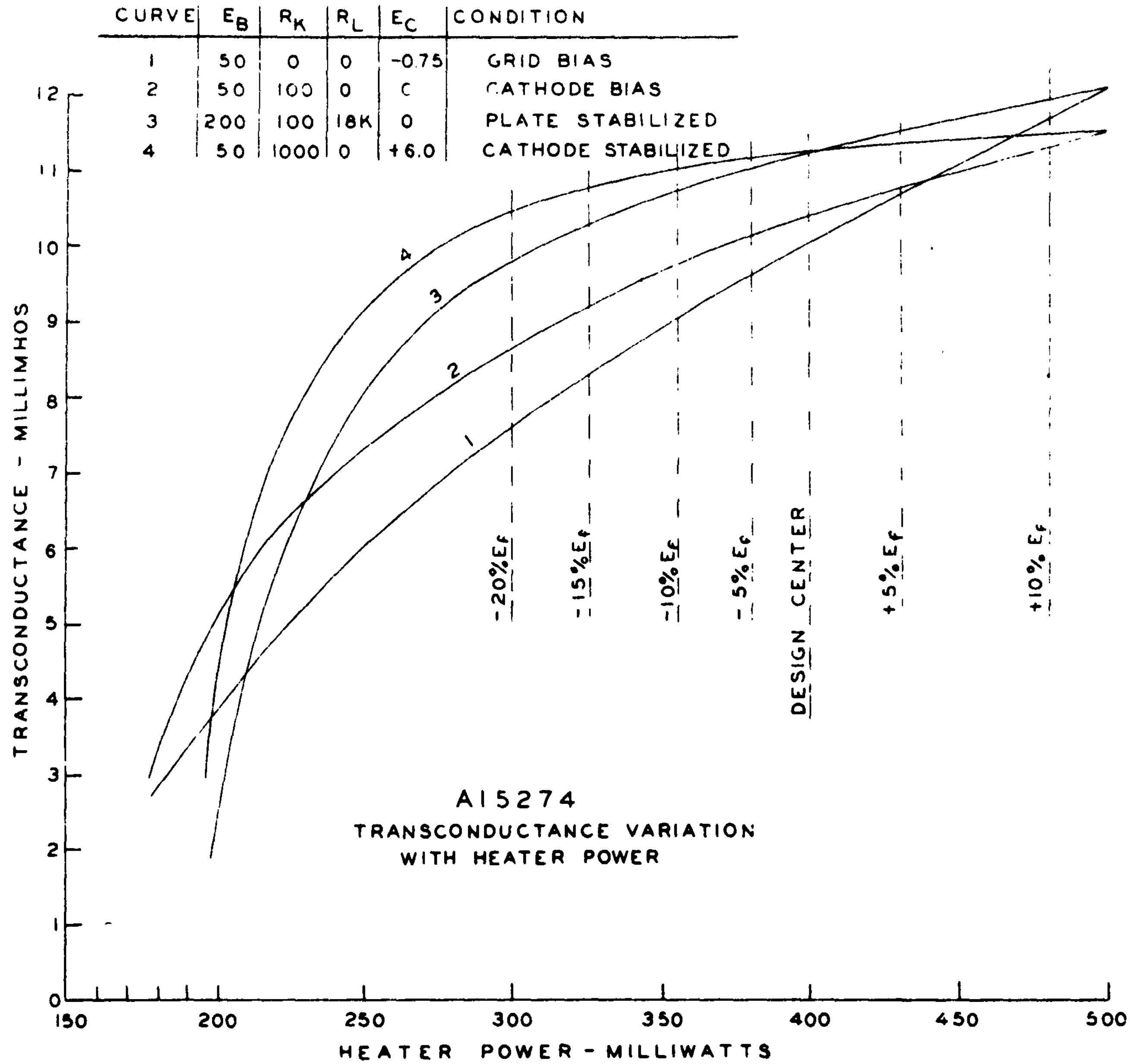
Because of the relatively close grid-cathode spacing in the type A15274, plate current and transconductance will be affected by cathode temperature change due to shifting of the potential minimum. The curves of Fig. 83 were measured holding the plate current constant by raising the plate voltage while the heater input was being lowered. This is not a common condition in normal operation. The curves of Fig. 86 show the changes in transconductance encountered when the heater input is changed while other operating voltages remain fixed. Curve 1 of Fig. 86 shows the marked effect on transconductance of lowering heater input when operating at fixed grid and plate voltages. Again, as these measurements were made on A15274 samples with the 450 milliwatt heater, the abscissa is given in heater input power instead of volts. The vertical lines representing changes in heater voltage, however, are derived from the 400 milliwatt heater intended for use in the final design samples and may be taken as a measure of heater voltage regulation required for desired operational stability. Curves 2, 3 and 4 of Fig. 86 represent the results of some degenerative circuit methods which may be used if stability is required and close heater-voltage regulation is not possible.

As has been mentioned, low voltage operation of the tubes developed under this contract appears promising. A very low voltage plate characteristic of the type A15274 is shown as Fig. 87. It can be seen that with a plate voltage of 12 volts and a plate current of approximately 2 milliamperes, a transconductance of 8,000 micromhos is obtainable. This represents a total power input to the tube of under 450 milliwatts. Grid loading at these low voltages would appear to be somewhat of a problem. Because of the close grid-to-cathode spacing of the type A15274, a considerable amount of electron current flows to the grid due to the initial velocities of emitted electrons. Approximately 0.6 volts of negative grid bias is required to reduce this current to one-half microampere. The effect of slightly positive grid operation on transconductance may also be seen in Fig. 87. The transconductance per unit plate current decreases sharply as the grid is run positive. This is due to the fact that the transconductance is measured in the plate circuit and the grid is effectively "robbing" current from the plate. If the transconductance is measured in the cathode circuit the ratio of transconductance perunit cathode current does not decrease in this positive grid region. As a normal amplifier, the type A15274 would be limited to very small signals in order to use as little negative bias as possible



PRODUCT OF TRANSCONDUCTANCE AND EQUIVALENT NOISE RESISTANCE AS A FUNCTION OF PLATE CURRENT FOR A15274

Fig. 85



CURVE | E_B | R_K | R_L | E_C | CONDITION
1 | 50 | 0 | 0 | -0.75 | GRID BIAS
2 | 50 | 100 | 0 | 0 | CATHODE BIAS
3 | 200 | 100 | 18K | 0 | PLATE STABILIZED
4 | 50 | 1000 | 0 | +6.0 | CATHODE STABILIZED
-20% E_f
-15% E_f
-10% E_f
-5% E_f
DESIGN CENTER
+5% E_f
+10% E_f
A15274
TRANSCONDUCTANCE VARIATION
WITH HEATER POWER
TRANSCONDUCTANCE - MILLIMHOS
HEATER POWER - MILLIWATTS

Fig. 86

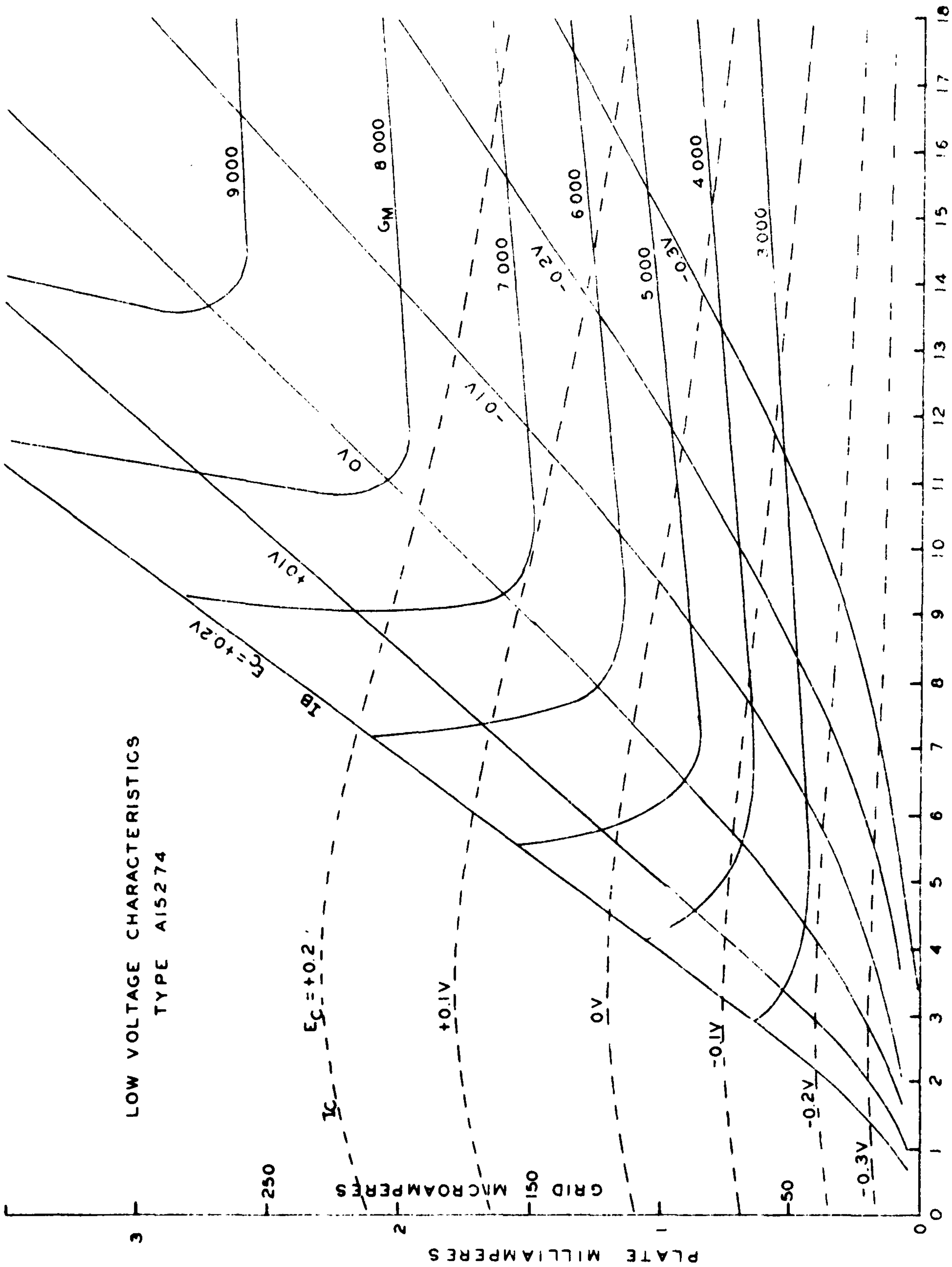

LOW VOLTAGE CHARACTERISTICS
TYPE A15274
PLATE VOLTS
PLATE MILLIAMPERES
GRID MICROAMPERES
$E_C = +0.2$
+0.1V
0V
-0.1V
-0.2V
-0.3V
I_C
I_B
$E_C = +0.2V$
+0.1V
0V
-0.1V
-0.2V
-0.3V
G_M
9000
8000
7000
6000
5000
4000
3000

Fig. 87

to achieve maximum transconductance and yet keep the signal from driving the grid positive. An experimental RF amplifier using two type A15274's in a cascode circuit operated from a single 12.6 volt source for both heaters and plate supply has given 20 db gain at 27 Mc/s with a bandwidth of 1.7 Mc/s. Again, high input impedances are not possible at these low operating voltages but in applications where this is not of great importance, advantage may be taken of the good performance of the type A15274 at very low total power inputs.

Similar measurements for the A15330 were not made. One would expect that the low heater voltage would have the same effects as reported for the A15200 and A15274. However, low plate voltage would seriously degrade the cross modulation performance, and it is for its cross-modulation performance that one would use the A15330.

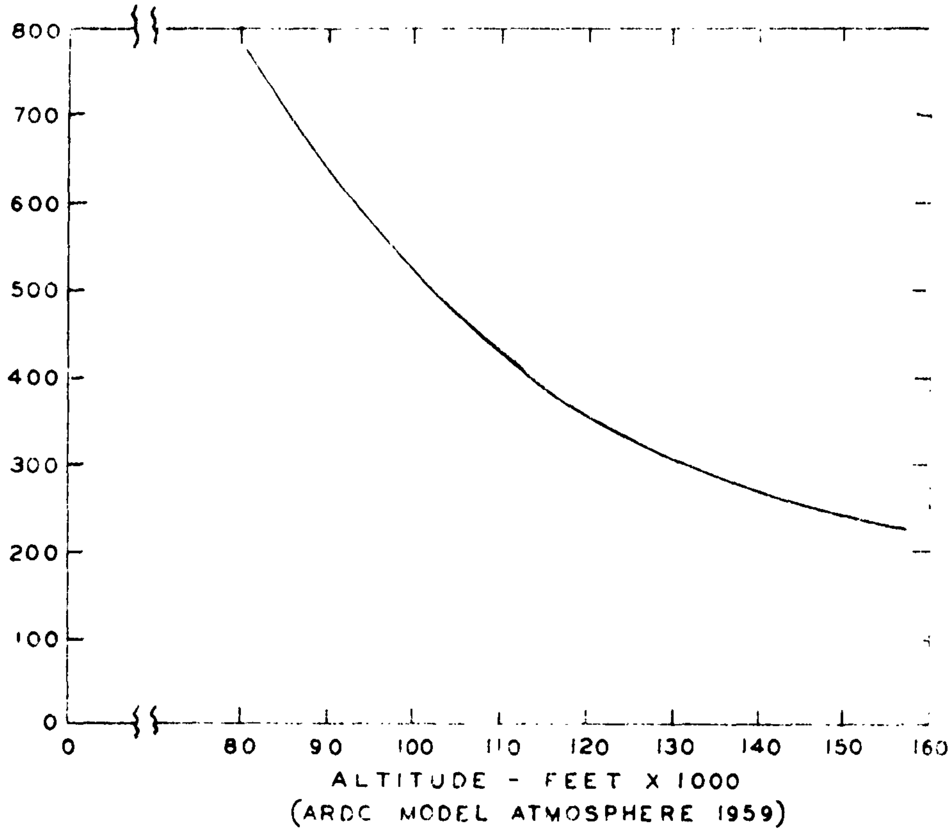
Low Pressure Breakdown

Developmental type A15274's have been tested for low-pressure voltage breakdown in accordance with paragraph 4.9.12.1 of MIL-E-1D. At an altitude equivalent of 85,000 ft. a voltage of more than 700 rms VAC may be impressed across the envelope and at altitude equivalents in excess of 150,000 ft., 250 rms VAC may be applied without corona or arcing. Fig. 88 shows the results of the test. The tubes tested were not cleaned in any manner for the test and had been subjected to normal handling. In addition, identification marks in graphite were present on the outer surface of the ceramic bulb insulator..

Because of its similarity to the A15274, one would expect equivalent performance from the A15330.

Radiation Tests

Two shrinkage A15200's were exposed to a neutron radiation field of the 5 megawatt swimming pool reactor at the Industrial Reactor Laboratories at Plainsboro, New Jersey. These were complete tubes but had leaks causing them to be air tubes and the test was conducted merely to determine residual radioactivity. The Industrial Reactor Laboratories is jointly operated by ten industrial companies including RCA. This facility is part of general RCA overhead and so no direct billing to this contract was incurred by the testing. The tubes were exposed for a total dosage of approximately 3×10^{15} neutron/cm^2-sec. (fast). This is the same total radiation as that specified in MIL-STD-446 Environmental Requirements Guide for Electronic Component Parts for Reactor Radiation requirements for Environmental Groups VI and VIII, although due to the higher neutron flux level available at the Plainsboro Laboratories the exposure time was 5 minutes instead of the 1000 hours specified in MIL-STD-446. The A15200's tested were not examined for damage or deterioration since this test was performed only to measure residual radio-activity as previously



A15274
LOW PRESSURE VOLTAGE BREAKDOWN

Fig. 88

mentioned. The tubes when first withdrawn from the reactor had a radioactivity level of about 10 microcuries and a decay rate corresponding to a half-life on the order of a day. After two weeks, however, the decay rate had decreased to an indicated half life of one month with a radioactive level of 68 microcuries. The staff at Plainsboro attribute most of this remaining radioactivity to the iron present in some parts of the tube. At 1200 hours the radioactivity level had decreased to less than 10 microcuries. This level is not low enough for safe indiscriminate handling but is sufficiently low for handling by trained personnel or for safe operation in enclosed equipment.

It is calculated that of the 950 milligrams total weight of a finished tube, about 275 milligrams or 29 per cent consists of iron. This is mostly contained in the number 52-alloy envelope parts.

These tests were made on inoperative tubes and are not considered as part of the scope of the contract but the data is provided for information purposes.

Two operable samples of the type A15274 were exposed to a neutron radiation field in the 5 megawatt swimming-pool reactor at the Industrial Reactor Laboratories. The exposure dosage was 10^{17} neutrons/cm^2-sec. or about three times that specified in MIL-STD-446. Attempts were made to measure these two tubes immediately after exposure but due to the necessity of radiation protection they were subjected to several mechanical mishaps. One tube was found to have gone air and it is thought that this is probably due to having been excessively pinched in the remote control manipulators while attempting to socket it in test equipment in the "hot room." The other tube showed no transconductance but test equipment limitations prevented further analysis. Both of these tubes were engineering samples which had gone through a previous 20 blow 1000 g impact test and this coupled with the above mentioned mishaps may have been the actual cause of failure. The tubes will remain too "hot" for a long time before close examination is possible. The two type A15274's which had been held aside as the control tubes for this test were measured again and then left at the reactor for a 1000 hour exposure at about 10^{10} neutron/cm^2. Unfortunately, due to circumstances beyond the control of RCA, these tubes were never measured following irradiation. However, tests performed on conventional nuvistors of similar construction show excellent immunity to fluxes and dose rates of the magnitudes mentioned here.

DESIGN VARIATIONS

General

In the course of development, several variations in envelope design were made to investigate desirability or feasibility. These variations were not adopted but their design is of interest and could possibly lead to further development. They are discussed in chronological order of production.

Developmental Type A15261

In general, it was desirable to have tubes which fit the linotetrar base. However, it was thought that a coaxial version would be desirable at higher frequencies. Fig. 89 shows this type of construction. The tube was assigned the developmental No. A15261. It is identical to the A15200 except for basing. In the A15261 the grid lead has been omitted and the shell is used for the grid connection. The cathode lead pin has been replaced by a cylindrical connection which is joined to the normal pin 1 of the base and also to pins 5 and 6 (see Fig. 8). The heater leads are brought through the center of the cathode terminal and potted with a compound such as an epoxy resin. With the A15261 configuration, the tube is suitable for applications where coaxial mounting is desired. The inductance of the grid lead in the A15200 is almost entirely eliminated and by the use of the three cathode leads (1, 5, and 6) passing through the base, cathode lead inductance has been considerably decreased. The remaining cathode inductance can be tuned out in grounded-grid amplifier circuits where the A15261 would normally be used. Further work on this type was dropped when the A15274 was developed.

Developmental Type A15258

A few operating samples of the type A15258 were made to investigate the possible effects of envelope capacitance and inductance on high frequency operation of the type A15200 electrode structure. These tubes (A15258) employed the active electrodes of the A15200 but had full coaxial electrode leads. R.F. amplifier tests showed no difference in performance from the type A15200 and it was concluded that the envelope structure of the type A15200 is completely satisfactory as to lead inductance effects. The type A15258 was intended only as a laboratory test for the electrical effects of envelope configuration and no further effort on this type is planned.

This is an interesting envelope configuration from the standpoint of minimum size. Fig. 90 shows an outline drawing of the type and Fig. 91 a sectional view. This is perhaps one of the smallest indirectly heated cathode tubes ever made, if not the smallest.

Developmental Type A15286

A few samples using the electrode geometry of the A15274 were made

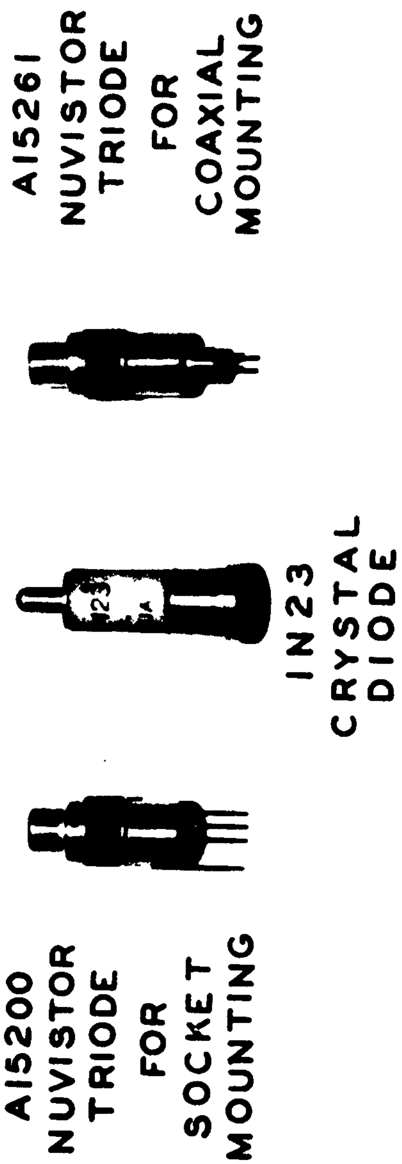

A15200 NUVISTOR TRIODE FOR SOCKET MOUNTING
1N23 CRYSTAL DIODE
A15261 NUVISTOR TRIODE FOR COAXIAL MOUNTING

Fig. 89

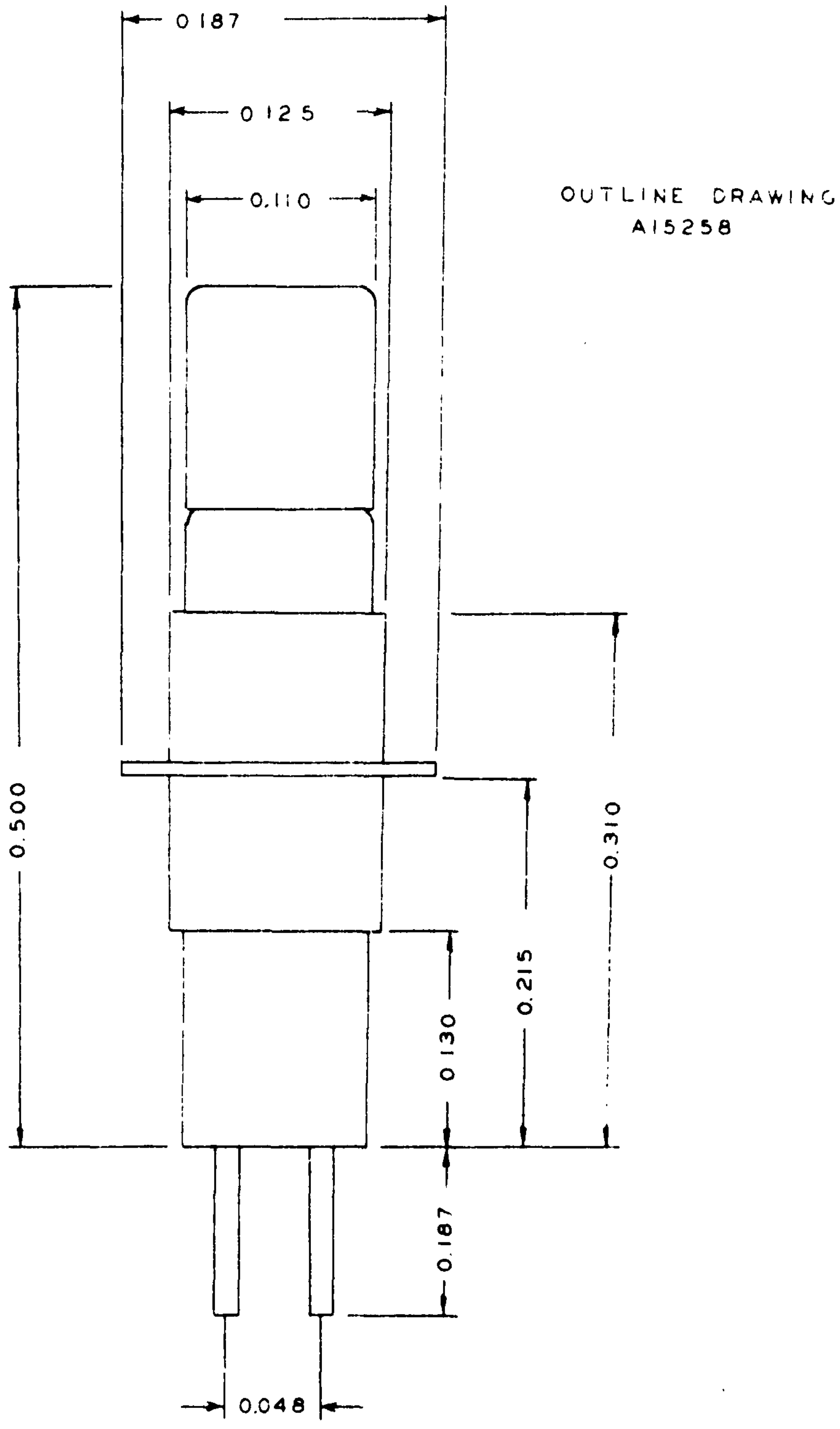

0.187
0.125
0.110
OUTLINE DRAWING
A15258
0.500
0.310
0.215
0.130
0.187
0.048

Fig. 90

SECTIONAL VIEW
A15258

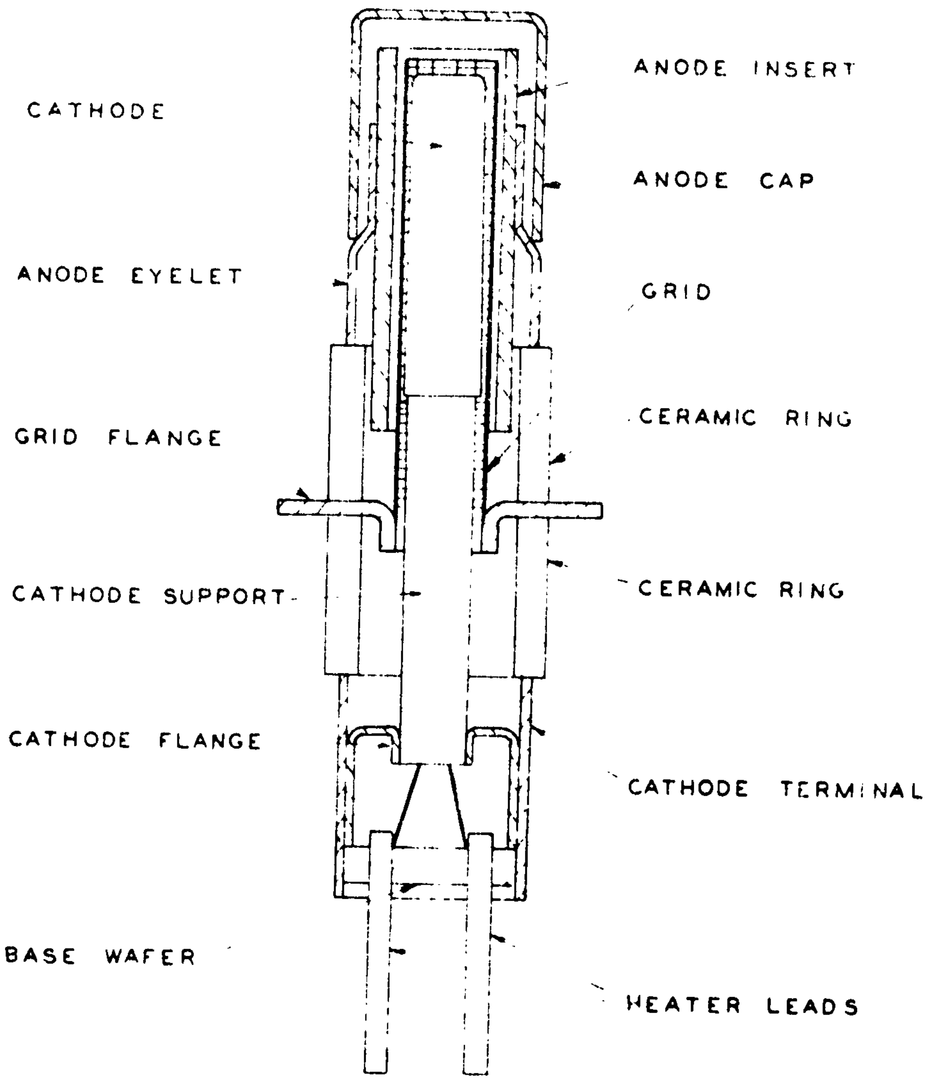


Fig. 91

u ing this envelope design and these tubes were assigned the RCA developmental type number A15286. All of the parts of the type A15286 are the same as those of the type A15274. The only difference lies in the way the cathode lead is brought out. In the type A15274 the cathode is brought out as one long lead which fits into the standard four-pin linotetrar socket, while the other two leads which support the cathode flange are cut off close to the base wafer. In the type A15286 all three leads are cut off close to the base wafer and they are each brazed to a concentric terminal cylinder. This cylinder may be filled internally with some potting compound to provide heater lead insulation. This basing is the same as that of the A15261. Testing of these type A15286 tubes has shown that the thermal connection of these two extra cathode leads introduces an additional thermal loss of about 40 milliwatts. Tubes made with the normal 400 milliwatt heater of the type A15274 required about 10% excess heater voltage to reproduce the type A15274 characteristics. Using the normal 440 milliwatt heater of the type A15200 in the type A15286 gave the corresponding characteristics of the type A15274 when operating the A15286 at rated heater voltage.

PROJECT PERFORMANCE AND SCHEDULE

In general, the original schedule was adhered to quite well. Fig. 92 shows the initial schedule. Because of problems involved with delivery of materials, an extension of time without additional funds was requested and granted. Under this extension, delivery of the 50 samples was to be made 31 Dec. 1961 rather than 20 Aug. 1961. Fig. 93 indicates the schedule on which this portion of the contract was conducted. In January, 1962, RCA proposed a contract extension without additional funds to design a remote cutoff version of the A15274 and to deliver 20 samples on 30 Sept. 1962. This extension was granted and Fig. 94 shows the schedule for the design of this tube.

RADIO CORPORATION OF AMERICA

ELECTRON TUBE DIVISION

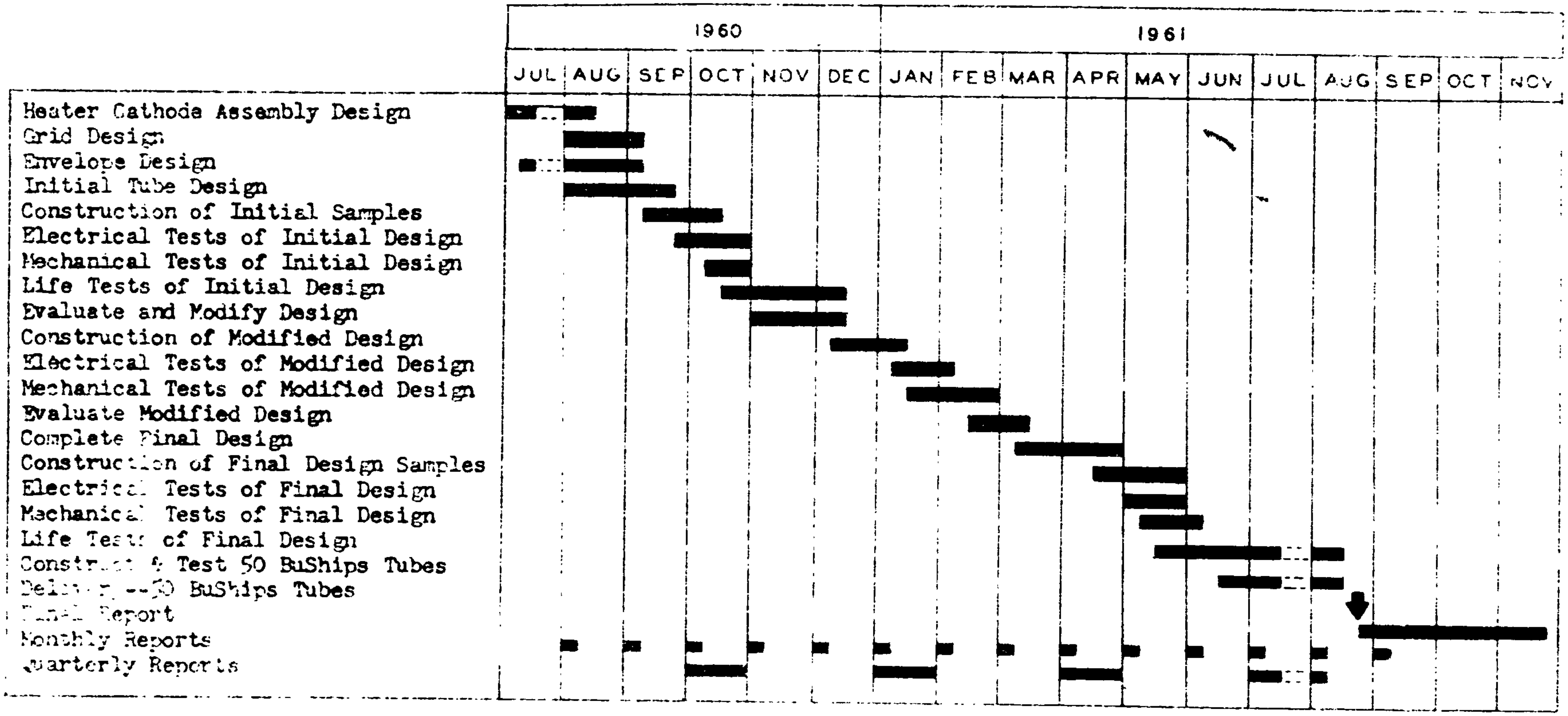
WORK PROGRAM AND SCHEDULE

INDEX NO SR0080302 ST-140

CONTRACT NO NObsr81478

REPORT DATE

PERIOD COVERED



RADIO CORPORATION OF AMERICA

ELECTRON TUBE DIVISION

WORK PROGRAM AND SCHEDULE

INDEX NO. SR0080302 ST-140

CONTRACT NO. NObsr 81478

REPORT DATE

PERIOD COVERED

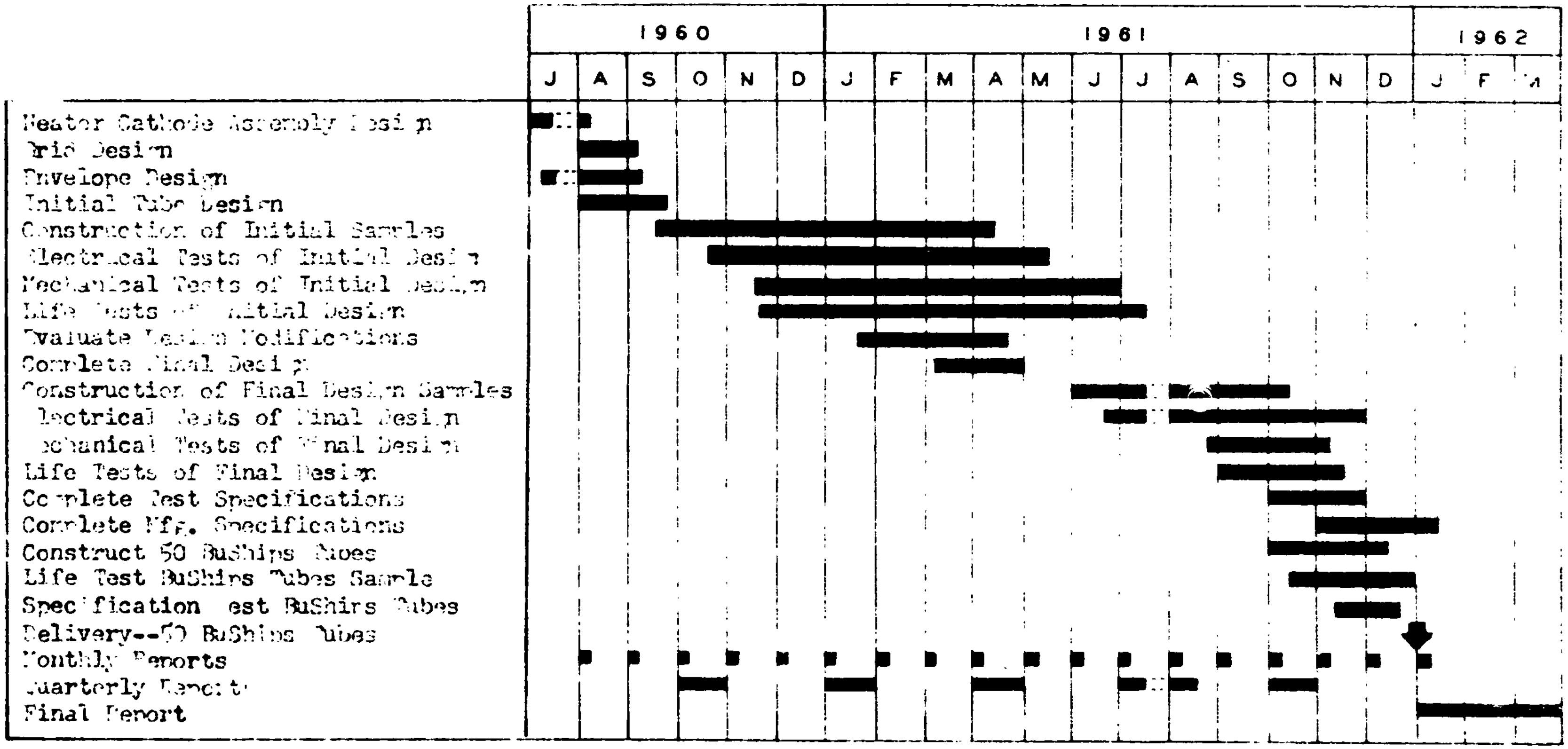


Fig. 93

RADIO CORPORATION OF AMERICA
ELECTRON TUBE DIVISION

ADDENDUM TO
WORK PROGRAM AND SCHEDULE

Index No. SR0080302 ST-140

Contract No. NObsr 81478

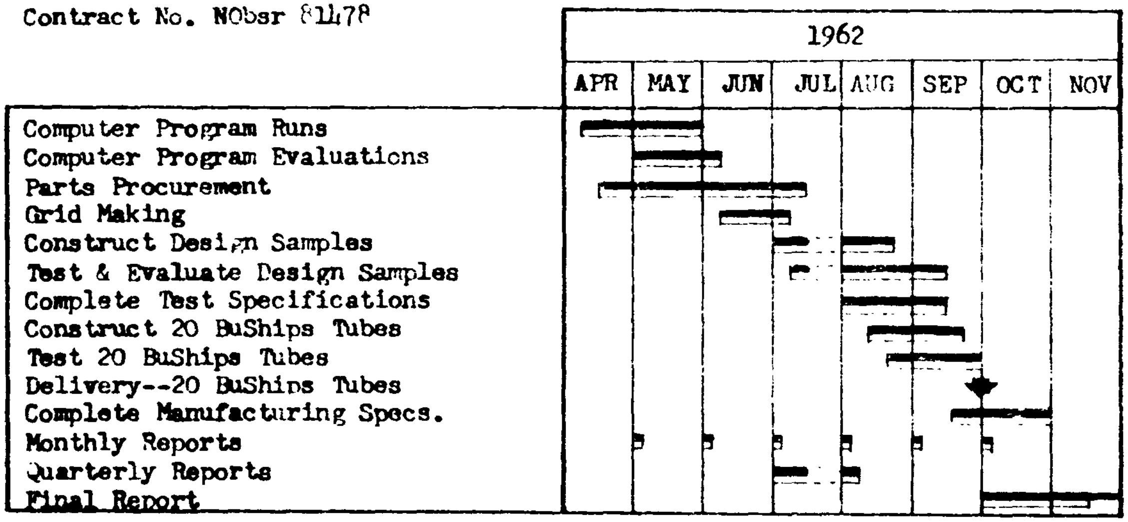


Fig. 9[illegible]

RKR

CONCLUSIONS

It is believed that the contract requirements have been met and exceeded. These were to produce a triode of nuvistor type construction with electrical characteristics similar to the RCA 7586 but requiring only one half watt of heater power, and also to produce a similar but remote cutoff triode. The tubes produced are believed to be superior to their prototypes in some respects. The ceramic-to-metal joint techniques make possible the fabrication of tubes of this extremely small size. They are relatively easy to manufacture, due to the cylindrical cantilever construction used and are readily adaptable to manufacture on nuvistor type production facilities. Their electrical characteristics are obtained with about twice the grid wire diameter, grid pitch, and interelectrode spacings of planor tubes of equivalent or inferior performance. In addition, the tubes are quite rugged and tolerant of vibration.

The A15274 promises to be an excellent tube for low level, low noise applications from very low to very high frequencies, as well as an excellent low power, stable oscillator at frequencies up to 2.0 Gc/s.

The A15330 promises to be an excellent tube for a gain controlled rf amplifier required to operate in the presence of interfering signals and also display excellent noise performance at frequencies up to 900 Mc/s.

Both tubes, due to their ceramic-metal construction, should be even less susceptible to damage and deterioration due to high intensity radiation than are conventional glass envelope types.

PART II

RECOMMENDATIONS

RECOMMENDATIONS

The recommendations presented here fall into two categories: further development of the final design types, and further development of related or second generation types.

It is believed that the final designs of the two tube types supplied are essentially complete, with one possible exception. This is the helical wound cathode support. This part has a tendency to deform under extensive thermal cycling and appears to have a somewhat lower yield strength than the rolled type support. It is believed that this could be corrected with further development. In addition, although the designs are readily adaptable for production on conventional nuvistor type manufacturing facilities, some further development would be required to actually mass produce the types. For instance, the parts tooling used was designed for small lot production and would probably require some modification if parts were required in large numbers.

Further development of related or second generation types could proceed in the following directions. One would be development of alternate basing configurations, in particular coaxial basing. The A15258 presents another interesting development possibility for an extremely small sized triode. Still another possibility is a low power, low heater power, power amplifier with the A15274 envelope configuration.

PART III

MANUFACTURING INFORMATION (DEVELOPMENTAL)

Assembly Drawing

Bills of Materials A15274

Bills of Materials A15330

Parts Details

Brazing Jig

Assembly Procedure

Brazing Schedule

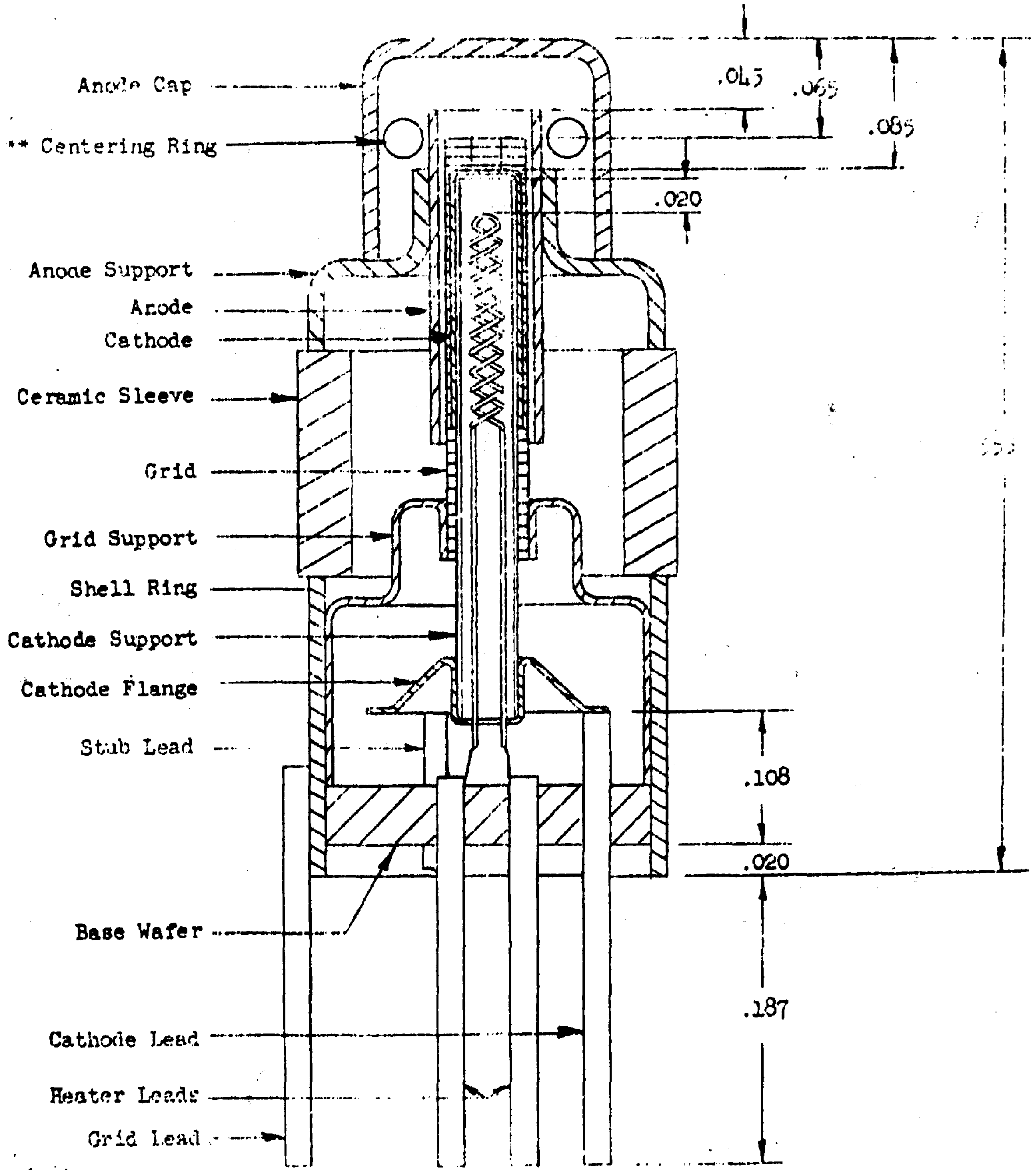
Exhaust Schedule

Aging Schedule

MIL-E-1 Specifications

[illegible]

(1) Developmental Type [illegible]
(2) Developmental Type [illegible]17330



SCALE— 10:1
DIMENSIONS IN Inches UNLESS OTHERWISE SHOWN   DIMENSIONS SHOWN WITHOUT TOLERANCES ARE DESIGN CENTERS

BILL OF MATERIALS

RCA DEVELOPMENTAL TYPE A15274

Part Description	No. Per Tube	No. Per Assembly
Anode Assembly	1	
Anode		1
Anode Support		1
Braze Ring A	2	
Ceramic Sleeve Assembly	1	
Ceramic Sleeve		1
Cathode Assembly	1	
Cathode Cup		1
Cathode Support A	1	
Flange, Cathode Support	1	
Braze Ring B	1	
Grid A	1	
Grid Support Assembly	1	
Grid Support		1
Shell Ring		1
Lead, Grid		1
Heater Assembly	1	
Wafer Base Assembly	1	
Wafer Base		1
Braze Ring C	1	
Leads		
Heater Lead	2	
Cathode Lead	1	
Stub Lead	2	
Braze Ring D	6	
Washer, Maing Braze	1	
Ring, Centering	1	
Top Cap	1	

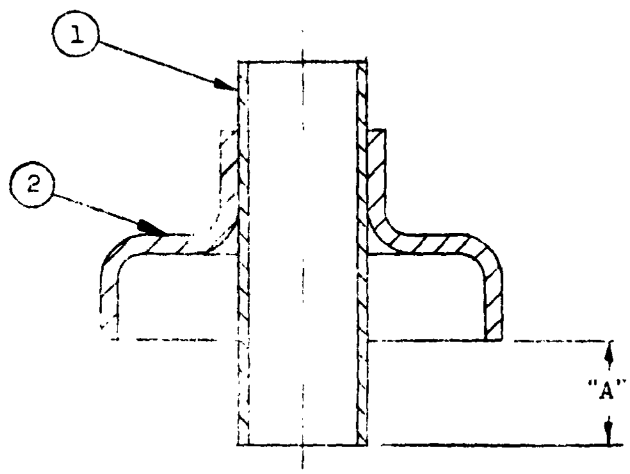
BILL OF MATERIALS

RCA DEVELOPMENTAL TYPE A15330

Part Description	No. Per Tube	No. Per Assembly
Anode Assembly	1	
Anode		1
Anode Support		1
Braze Ring A	2	
Ceramic Sleeve Assembly	1	
Ceramic Sleeve		1
Cathode Assembly	1	
Cathode Cup		1
Cathode Support B	1	
Flange, Cathode Support	1	
Braze Ring B	1	
Grid B	1	
Grid Support Assembly	1	
Grid Support		1
Shell Ring		1
Lead Grid		1
Heater Assembly	1	
Wafer Base Assembly	1	
Wafer Base		1
Braze Ring C	1	
Leads		
Heater Lead	2	
Cathode Lead	1	
Stub Lead	2	
Braze Ring D	6	
Washer, Main Braze	1	
Ring, Centering	1	
Top Cap	1	

A15274 - A15330

Anode Assembly



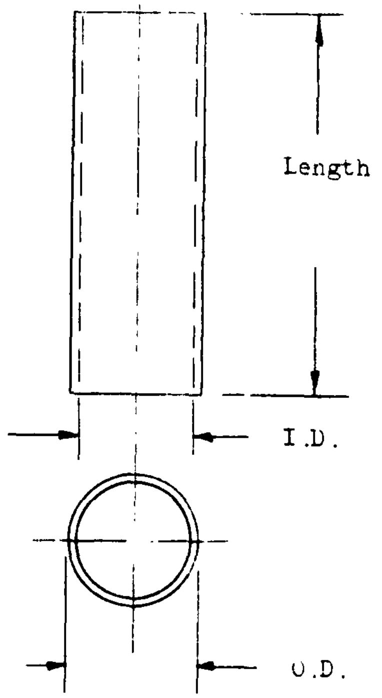
Components		Dimension	Notes
(1) Anode	**(2) Support**	**A**	
		.060±.002	-

Treatment: Washin hot Blacosolv, then in hot water.
Rinse in Methanol and dry.

Scale: 15:5
Dimensions in Inches

A15274 - A15330

Anode



Material: Seamless Tubing, Electronic Grade A Nickel

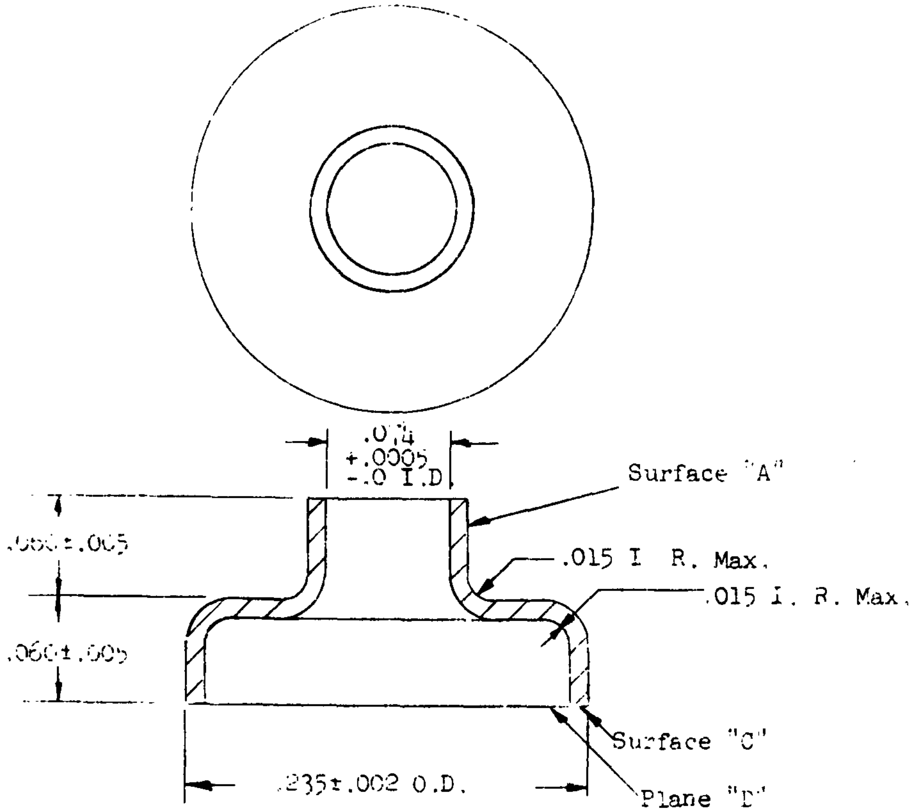
Dimensions:	O.D.	I.D.	Length
	$0.075 \pm {}^{.0005}_{.0000}$	$0.062 \pm {}^{.0005}_{.0000}$	0.22[illegible] ± .005

Treatment: Wash in hot Blacosolv, then in hot deionized water.
Rinse in Methanol and dry.
Fire in line hydrogen at 800°C for 10 min.

Not to Scale
Dimensions in inches.

A1[illegible]7L - A1[illegible]30

Anode Support



Tolerances - Include out-of-round
Burr Max. = .00[illegible]

NOTES:

1. The axis of the cylinder formed by surface "A" shall be considered the axis of the part.
2. The plane "D" defined by the trimmed end of the cap must be (⊥) perpendicular to the axis of the part within .002" full indicator reading.
3. All points on the surface "C" of the trimmed end of the part must fall on plane "D" within ±.002".
4. Camber - .005" max.

MATERIAL: .010±.001 gas free 52-Alloy

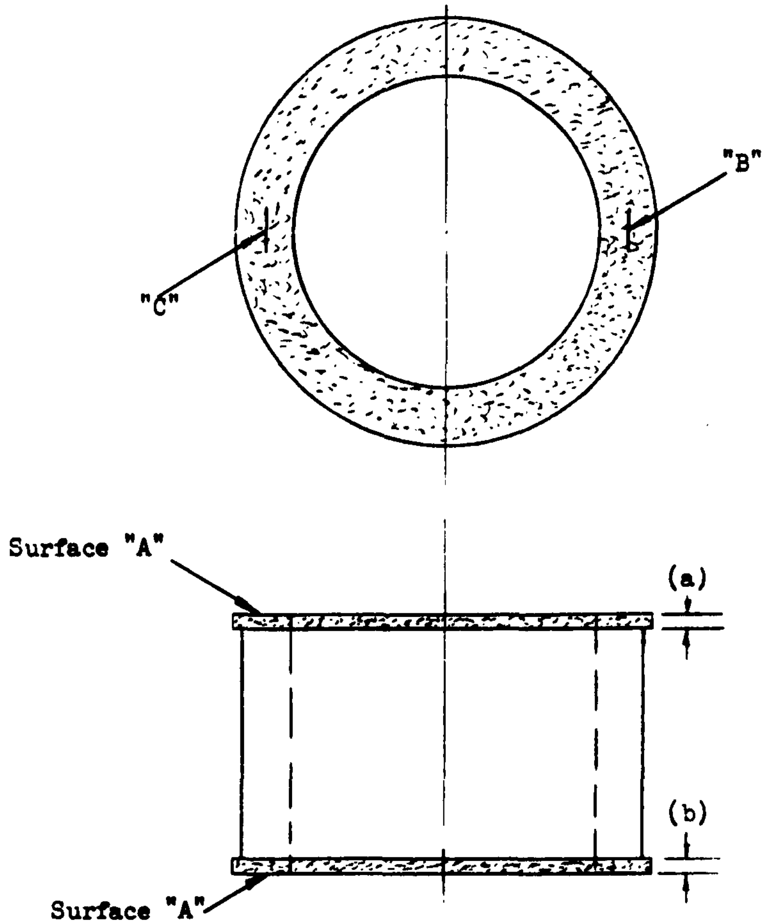
Treatment: Wash in hot Blacosolv, then in hot deionized water. Rinse in Methanol and dry. Fire in line hydrogen at 800° for 10 min.

Scale: 10:1

Dimensions in Inches

A15274 - A15330

Ceramic Sleeve Assembly



Dimensions:	(a) .010 max.	(b) .010 max.

Metalizing: Molybdenum metalized

Plating: Plate 1.5 to 2.0 mils of copper over nickel.

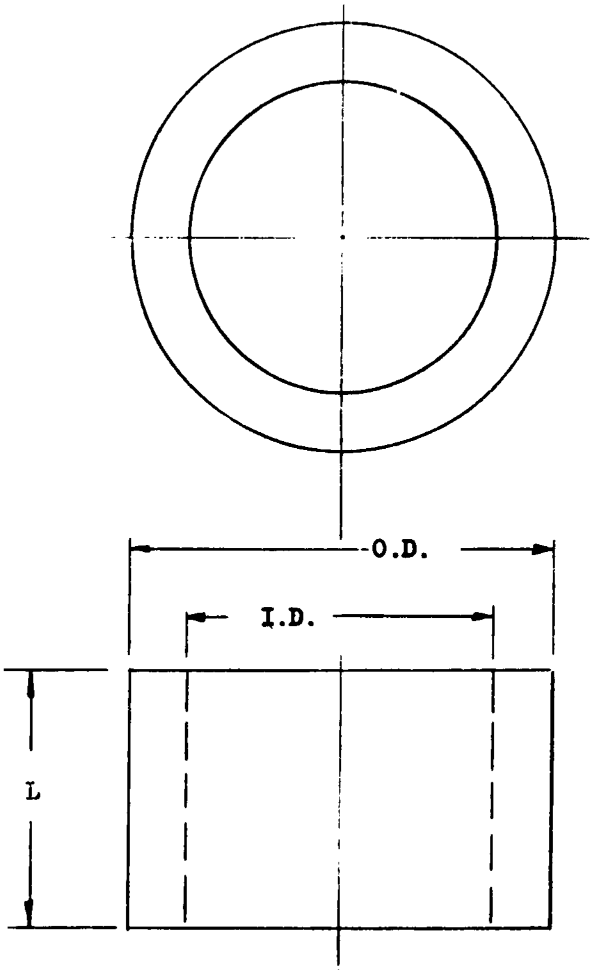
Treatment: Rinse in tap water and methanol and dry.

Not to scale

Dimensions in inches

A15274 - A15330

Ceramic Sleeve



Dimension

I.D.	O.D.	L	NOTES
.180±.003	$.250^{+.005}_{-.000}$	.150±.003	1 - 10 see page 171

Material: Forsterite

Scale: 10:1

Dimensions in Inches

A15274 - A15330

Ceramic Sleeve Notes

1. The axis of the part shall be considered the axis of the cylinder generated by the inside surface "ID" of the part.

2. Concentricity of I.D. and O.D. - .005" - TIR.

3. Adhered particles on either top or bottom surface of part are cause for rejection.

4. Flash and Burr not to exceed .002" high.

5. No spots, discolorations or foreign material larger in major dimension than .015". Minimum distance between impurities .020".

6. Maximum number of impurities on ends, five per end; maximum of 10 impurities on either O.D. or I.D. circumferences.

7. Major dimension of any chip must not exceed .010".

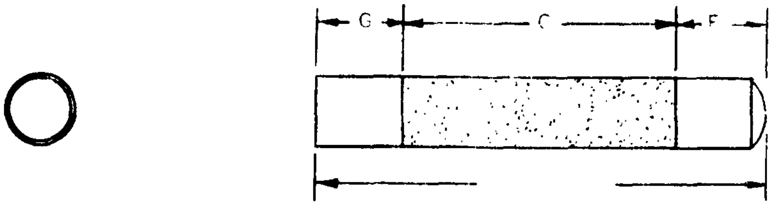
8. No more than 5 chips permitted on either top or bottom surfaces.

9. Maximum radius on all edges = .010".

10. All points in each end surface of the cylinder must lie in their respective planes within ± .002. The planes formed by the end surfaces must be perpendicular to the axis of the part within ± .002" and parallel || to each other with ± .001".

A15274 - A15330

Cathode Assembly



COATING

TOLERANCE ± - DIMENSIONS (mm) T	G	C	F	PREP.	WEIGHT (mg)	APPARENT DENSITY mg/mm 3	COATED O.D. (in.)
-	.004-.010	.150 +.010 -.000	.008 ±.004	see notes	0.5	1.9	.0455-.046

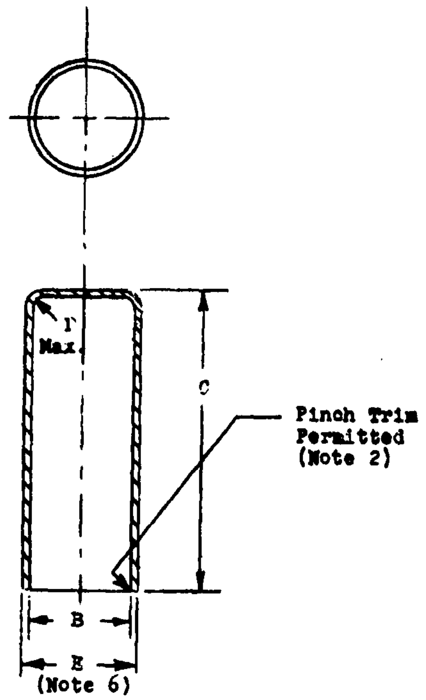
Notes: Cathode Coating: Standard triple-carbonate receiving tube cathode coating.

Not to scale.

Dimensions in Inches.

A15274 - A15330

Cathode Cup



	B	C	D
Dimensions:	$0.041 \pm {}^{.0005}_{.0000}$	$0.170 \pm .005$	0.002

Notes: 1. Surface must be free of scratches with a finish of ASA $\sqrt{16}$

2. No burr I.D. - 0.001 max. burr on O.D.

6. Out-of-Round included in E dimension.

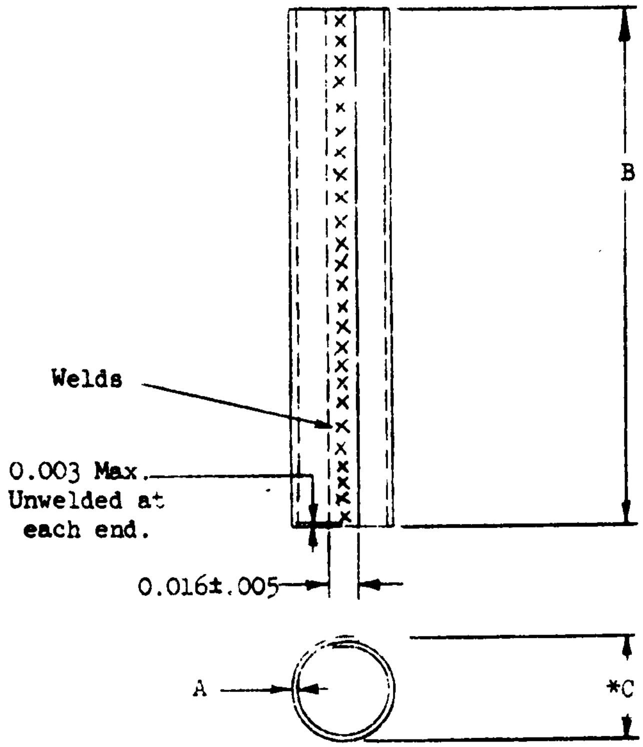
Treatment: Wash in hot Blackasolv, then in hot deionized water. Rinse in Methanol and dry.

Not to Scale.

Dimensions in Inches.

A15271

Cathode Support A



Dimensions:	A	B	C
	0.00025	0.360 ± .003	0.040 ± $^{.0005}_{.0000}$

Material: Low Manganese Nichrome

Notes: 1. Welds must be uniformly spaced (approx. 20-25 welds).

Treatment: Wash in hot Blacosolv, then in hot deionized water. Rinse in methonal and dry. Fire in dry hydrogen at 1000° for 16 min.

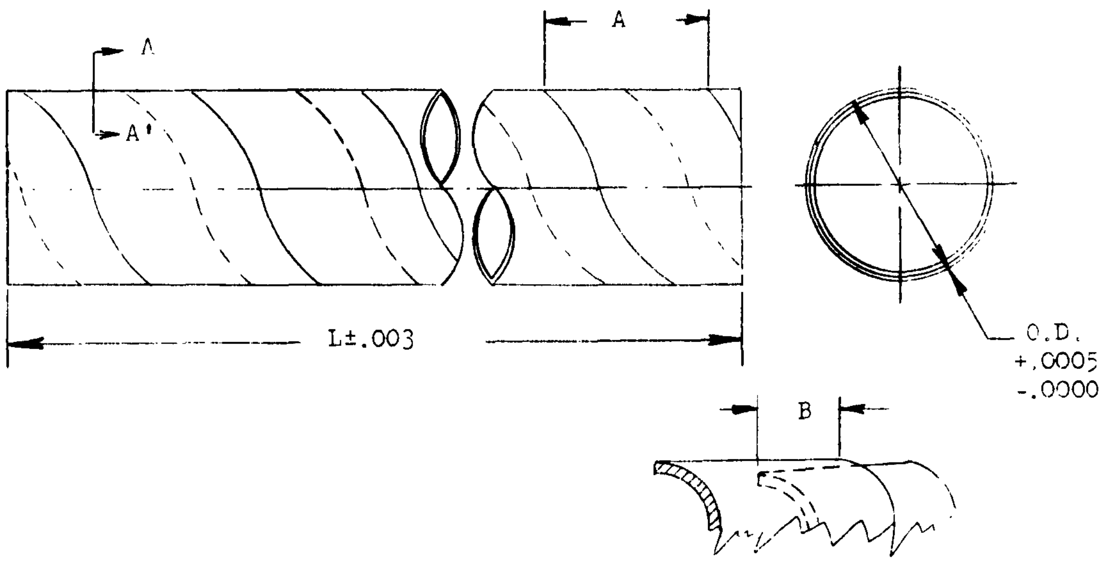
Not to Scale.

Dimensions in Inches.

Dimensions shown without tolerances are design centers.

A15330

Cathode Support 3, Helical Wound



Detail of Lap
Section A-A'

Material	Pitch	T.P.I.	O.D.	Dimensions A	B	L
.000162x.125x-Low Manganese Nichrome.	.125	8	.040	.125	.050	.360

Treatment: Nickel Plate 0.0001 plating thickness.
Fire in dry hydrogen at 1130°C for 30 min.

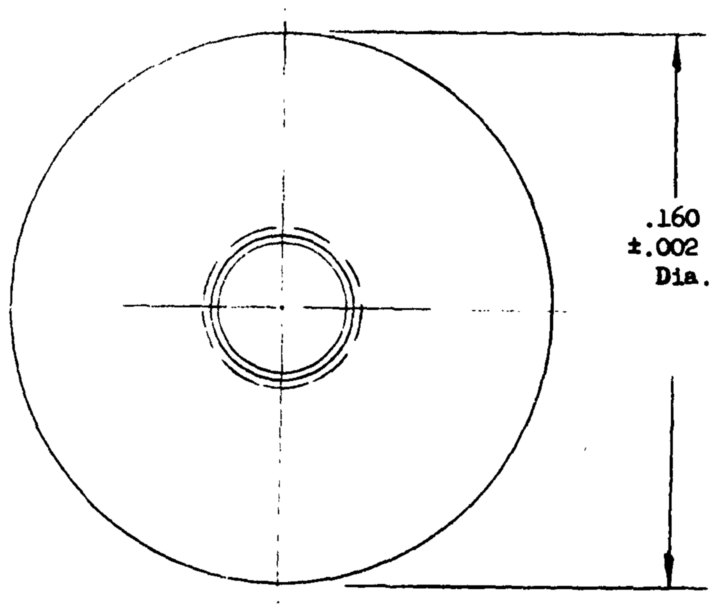
Not to Scale.

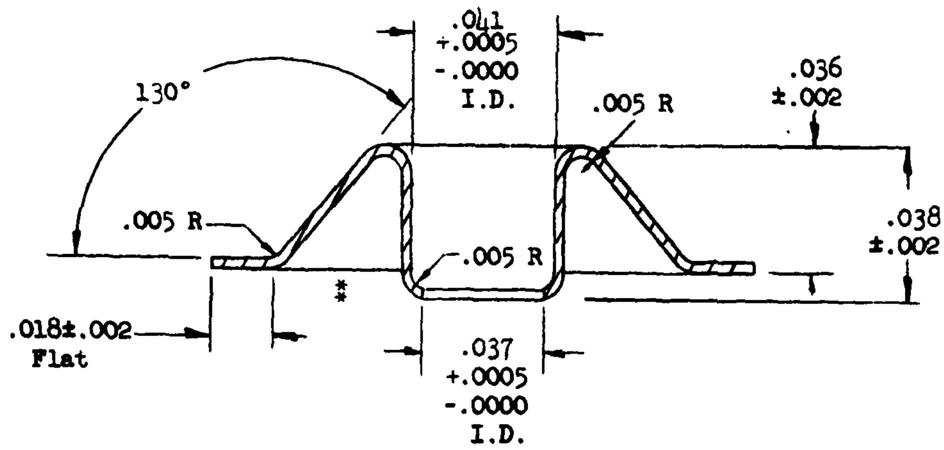
Dimensions in Inches

Dimensions shown without tolerances are design centers.

A15274 - A15330

Flange, Cathode Support





MATERIAL: .004 1010 cold rolled steel

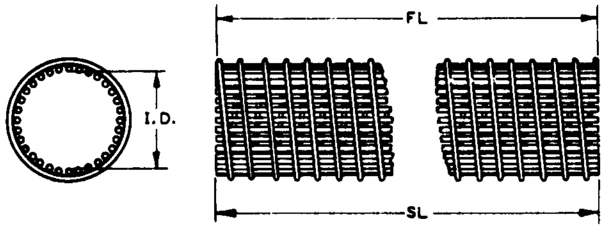
Treatment: Wash in hot Blacosolv and dry. Five in line hydrogen at 800°C for 10 min. Etch in 5% nitric acid at room temp. for 1 min. Wash in tap water and then ultrasonically wash in methanol and dry. Fire in line hydrogen at 800°C for 10 min.

Scale: 20:1

Dimensions in Inches
Dimensions shown without tolerances are design centers.

A15274 - Grid A

FINISHED NUVISTOR GRID SPECIFICATION



NOMINAL INSIDE DIAMETER .051

WOUND	Right	HAND	FINISHED TURNS	41	
T.P.I.	see table		FINISHED LENGTH (FL)	.290	INCHES
PITCH	see table		UNFINISHED TURNS	-	
NUMBER AXIAL WIRES	65		UNFINISHED LENGTH	-	INCHES
AXIAL WIRE SPACING	5.54	DEGREES	LATERAL WIRE LENGTH/TURN	.160	INCHES
LEG LENGTH (TOP)	-	INCHES	LATERAL WIRE LENGTH/1000 GRIDS	165	METERS
LEGS TRIM (TOP)	-		AXIAL WIRE LENGTH (SL)	.290	INCHES
LEG LENGTH (BOT.)	-	INCHES	AXIAL WIRE LENGTH/1000 GRIDS	479	METERS
LEGS TRIM (BOT.)	-				

GRID DIAMETER TOLERANCE +0.0005 -0.0000

MANDREL DIAMETER TOLERANCE +0.0002 -0.0000

MATERIAL AND TREATMENT SPECIFICATIONS

		MANDREL		LATERAL WIRE			AXIAL WIRES			
SUFFIX DESIG.	GRID INSIDE DIA.	DIA.	MATERIAL	MATERIAL	DIA. (mil)	WT. mg /1000mm	MATERIAL	DIA. (mil)	WT. mg /200 mm	NOTES
-1	.0505	.0500	Nichrome	Copper Plated Tungsten	.7	4.270-4.615	Nickel Plated Tungsten	.6	3.240-3.505	-

TABLE FOR VARIABLE PITCH TYPE ONLY:

PITCH (INCHES)	TURNS	LENGTH (INCHES)
.0045	2-3	0.010
.010	19	0.190
.0045	19-20	0.090
	41	0.290

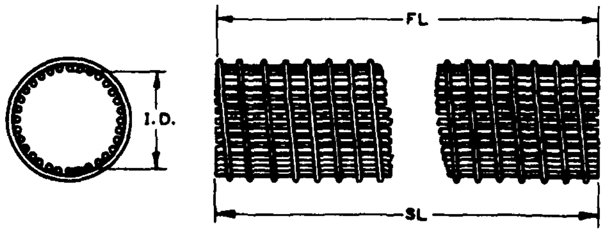
See notes page 180.

Dimensions in Inches

Dimensions shown without tolerances are design centers.

A15330 - Grid B

VARAXIAL FINISHED NUVISTOR GRID SPECIFICATION



NOMINAL INSIDE DIAMETER .051"

WOUND	Right HAND		FINISHED TURNS	35	
T.P.I.	See table		FINISHED LENGTH (FL)	.290	INCHES
PITCH	See table		UNFINISHED TURNS	-	
NUMBER AXIAL WIRES	68		UNFINISHED LENGTH	-	INCHES
AXIAL WIRE SPACING	See chart page 179		LATERAL WIRE LENGTH/TURN	.159	INCHES
LEG LENGTH (TOP)	-	INCHES	LATERAL WIRE LENGTH/1000 GRIDS	141	METERS
LEGS TRIM (TOP)	-		AXIAL WIRE LENGTH (SL)	.290	INCHES
LEG LENGTH (BOT.)	-	INCHES	AXIAL WIRE LENGTH/1000 GRIDS	498	METERS
LEGS TRIM (BOT.)	-				

GRID DIAMETER TOLERANCE $^{+0.0005}_{-0.0000}$ MANDREL DIAMETER TOLERANCE $^{+0.0002}_{-0.0000}$

MATERIAL AND TREATMENT SPECIFICATIONS

SUFFIX DESIG.	GRID INSIDE DIA.	MANDREL DIA.	MANDREL MATERIAL	LATERAL WIRE MATERIAL	LATERAL WIRE DIA. (mil)	LATERAL WIRE WT. mg/200 mm	AXIAL WIRES MATERIAL	AXIAL WIRES DIA. (mil)	AXIAL WIRES WT. mg/200 mm	NOTES
-1	.0505	.0500	Nichrom	Copper Plated Tungsten	0.7	4.270-4.615	Nickel Plated Tungsten	0.6	3.240-3.[illegible]5	1

See Pages 179 and 180 for Axial Wire Spacing and notes.

Dimensions in Inches unless otherwise shown.

Dimensions without tolerances are design centers.

TABLE FOR VARIABLE PITCH TYPE ONLY:

PITCH (INCHES)	TURNS	LENGTH (INCHES)
.0045	2-3	0.010
.010	19	0.190
.0045	19-20	0.090
	41	0.290

A15330 - Grid B

Axial Wire Spacing

Arc Segment	No. of Wires	Degrees Spacing
0-20°	4	5°
20-26°	1	6°
26-46°	4	5°
46-53°	1	7°
53-73°	4	5°
73-79°	1	6°
79-99°	4	5°
99-106°	1	7°
106-126°	4	5°
126-132°	1	6°
132-152°	4	5°
152-159°	1	7°
159-174°	3	5°
174-180°	1	6°
180-200°	4	5°
200-206°	1	6°
206-226°	4	5°
226-233°	1	7°
233-253°	4	5°
253-259°	1	6°
259-279°	4	5°
279-286°	1	7°
286-306°	4	5°
306-312°	1	6°
312-332°	4	5°
332-339°	1	7°
339-354°	3	5°
354-360°	1	6°

A15274 - A15330

Grid Notes

1. Post-Brazing Operations

   a. Remove entire grid strip from winding mandrel.

   b. Insert cutting mandrel into grid strip.

   c. Cut grids to specified length.

   d. Slide each finished grid to end of mandrel and inspect for missed brazes, pushed turns, loose end wires, etc. Inspection is to be performed under 10X magnification.

   e. Place acceptable grids in individual compartments in plastic trays (or metal trays with plastic inserts), and cover with glassine bags for storage.

   f. If grids are to be stored for more than 48 hours before use, they should be stored as in (e) above. Within 48 hours of the time they are to be consumed in manufacturing grids should be treated as follows:

	Bath #1	Bath #2
Ultrasonic Cold Blacosolv	One Minute	One Minute
Ultrasonic 90°C Deionized H_2O	Two Minutes	Two Minutes
Ultrasonic Methanol	One Minute	One Minute

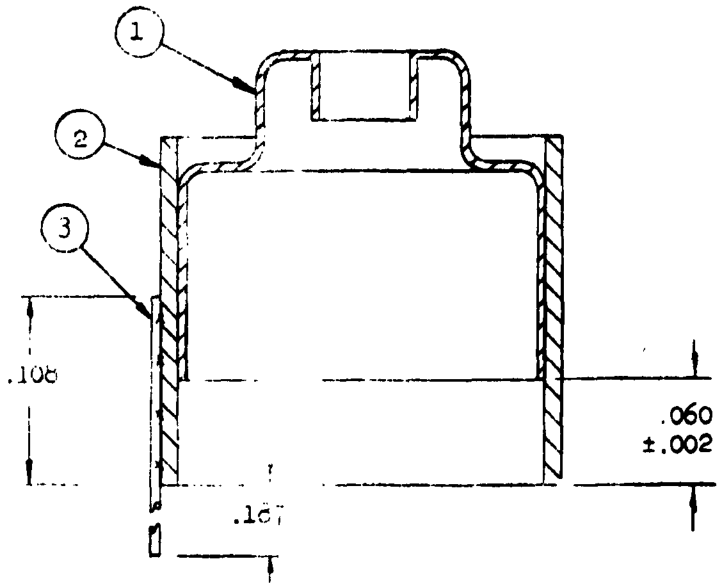
   Forced Hot Air Dry

   All washes will be conducted with two containers of solvent (Bath #1, and Bath #2). After ten washing cycles, the solvents in the Bath #1 containers are to be discarded, and the solvents which were used in Bath #2 containers are to replace them. Clean solvents will then be used for the new Bath #2.

   g. After the grids have been treated as per (f) above, they are not to be handled with bare hands.

A15274 - A15330

Grid Support Assembly



Components: 1. Grid Support
2. Shell Ring
3. Grid Lead

Notes: Spot weld as shown.

Treatment: Ultrasonically wash in methanol and dry. Fire in line hydrogen at 800°C for 10 min.

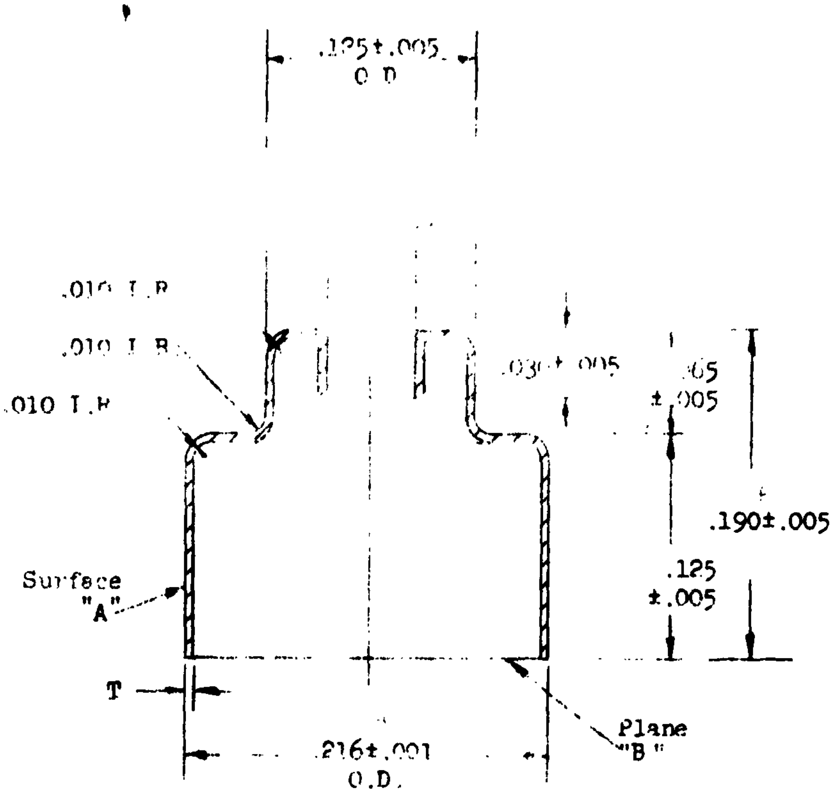
Scale: 10:1

Dimensions in Inches

Dimensions shown without tolerances are design centers.

A15274 - A15330

Grid Support



Material: 1010 cold rolled steel

Dimensions:

T	C
0.005	0.0540
	0.0544

Notes: 1. Centerline of part is defined as the centerline of the cylinder generated by Surface "A".

2. Plane "B" of edge to be perpendicular to centerline of part ± .003".

Treatment: Wash in hot Blacosolv and dry. Etch in 5% Nitric Acid at room temp. for one min. Wash in tap water, then ultrasonically wash in methanol and dry.

Scale - 10:1

Dimensions in inches

Dimensions shown without tolerances are design centers.

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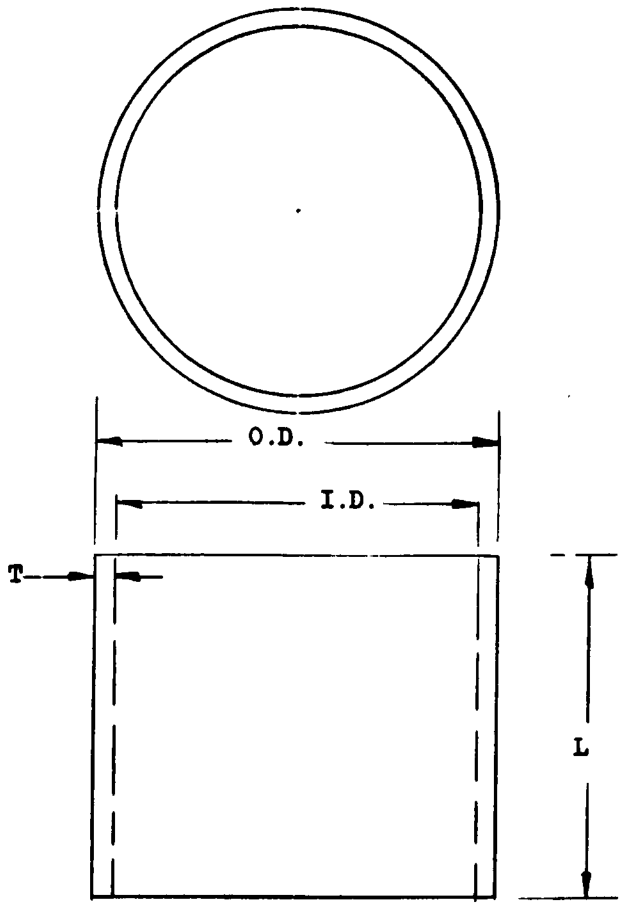
Shell Ring



Dimension				
T	**I.D.**	**O.D.**	**L**	**Notes**
.010	.215±.001	-	.200±.005	-

Material: Gas free 52-Alloy

Treatment: Wash in hot Blacosolv, then in hot deionized water. Rinse in methanol and dry. Fire in line hydrogen at 800°C for 10 min.

Not to Scale.

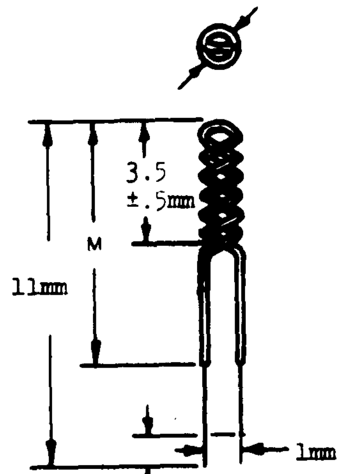
Dimensions in Inches.

Dimensions shown without tolerances are design centers.

A15274 - A15330

Heater Assembly

HEATER RATING
VOLTS 6.3
AMPS. .064

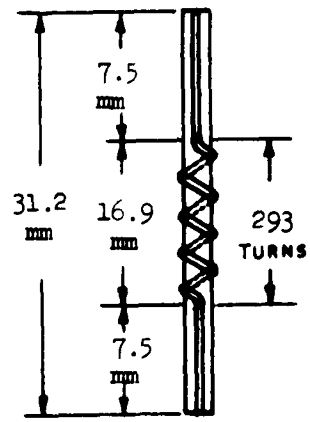


MATERIAL SPECIFICATIONS

1. HEATER WIRE..................	Non-Sag Tungsten	
A. WIRE WEIGHT..............	1.893	mg/200 mm (2)%
B. EQUIV. DIA..............	0.99	mils
C. CUT LENGTH..............	133	mm
2. SINGLE HELICAL MANDREL......	Molybdenum	
A. WIRE WEIGHT..............	16.45±.15	mg/200 mm
B. EQUIV. DIA..............	4.0	mils

MANUFACTURING SPECIFICATIONS

1. SINGLE HELICAL		
A. TPI THEORETICAL..........	440	TPI
B. GEAR DATA................		
C. WINDING SPEED............	3.83	RPM
D. WEIGHT OF CUT COIL....... (WITH MANDREL)		mg
2. DOUBLE HELICAL		
A. MANDREL DIA..............	17	mils
B. TPI THEORETICAL..........	30	TPI
C. WINDING SPEED............		RPM
D. FINISHED COIL WEIGHT..... (MANDREL DISSOLVED)	1.259	mg



PROCESS SPECIFICATIONS

1. WIND SINGLE HELICAL COIL....
2. HEAT SET ON MANDREL.........
3. CUT TO LENGTH...............
4. WIND DOUBLE HELICAL COIL....
5. PROCESS AS (A) BELOW
   - A.1. COAT AND FIRE..........
   - 2. DISSOLVE MANDREL.......
   - B.1. HEAT SET...............
   - 2. DISSOLVE MANDREL.......
   - 3. COAT AND FIRE..........
6. INSPECTION..................
7. PACKING.....................

COATING SPECIFICATIONS

Coating Material	COATING WEIGHT mg	COATED COIL OD. IN	M mm	COATED COIL WEIGHT mg	NOTES
"Dark" aluminum oxide.	2.5-3.2	.037 Max.	9.5 Min.	3.6-4.3	-

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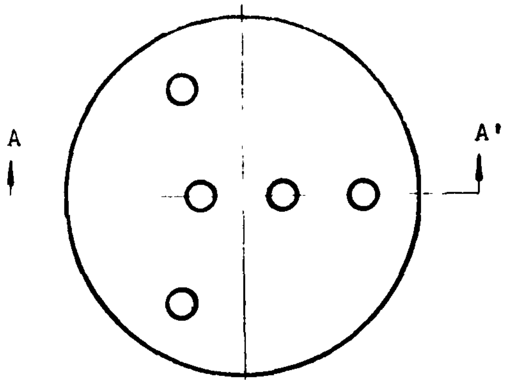
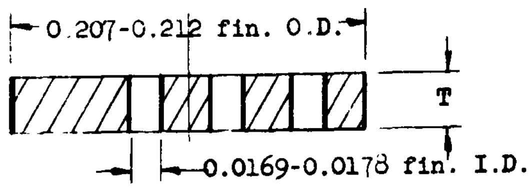
Wafer Base Assembly





Section A-A'

Dimensions: T .030-.035

Metalizing: Molybdenum metalized.

Plating: Nickel Plated

Treatment: Wash in tap water then in methanol and dry. Fire in line hydrogen at 800°C for 15 min.

Notes: 1. By visual observation all metalizing material must be removed from both flat surfaces.

2. Radii of approximately .010-.013 is accomplished during tumbling, but during the grinding operation a portion of the arc is removed so that a full 1/4 arc does not appear on the finished part.

Not to Scale.

Dimensions in Inches.

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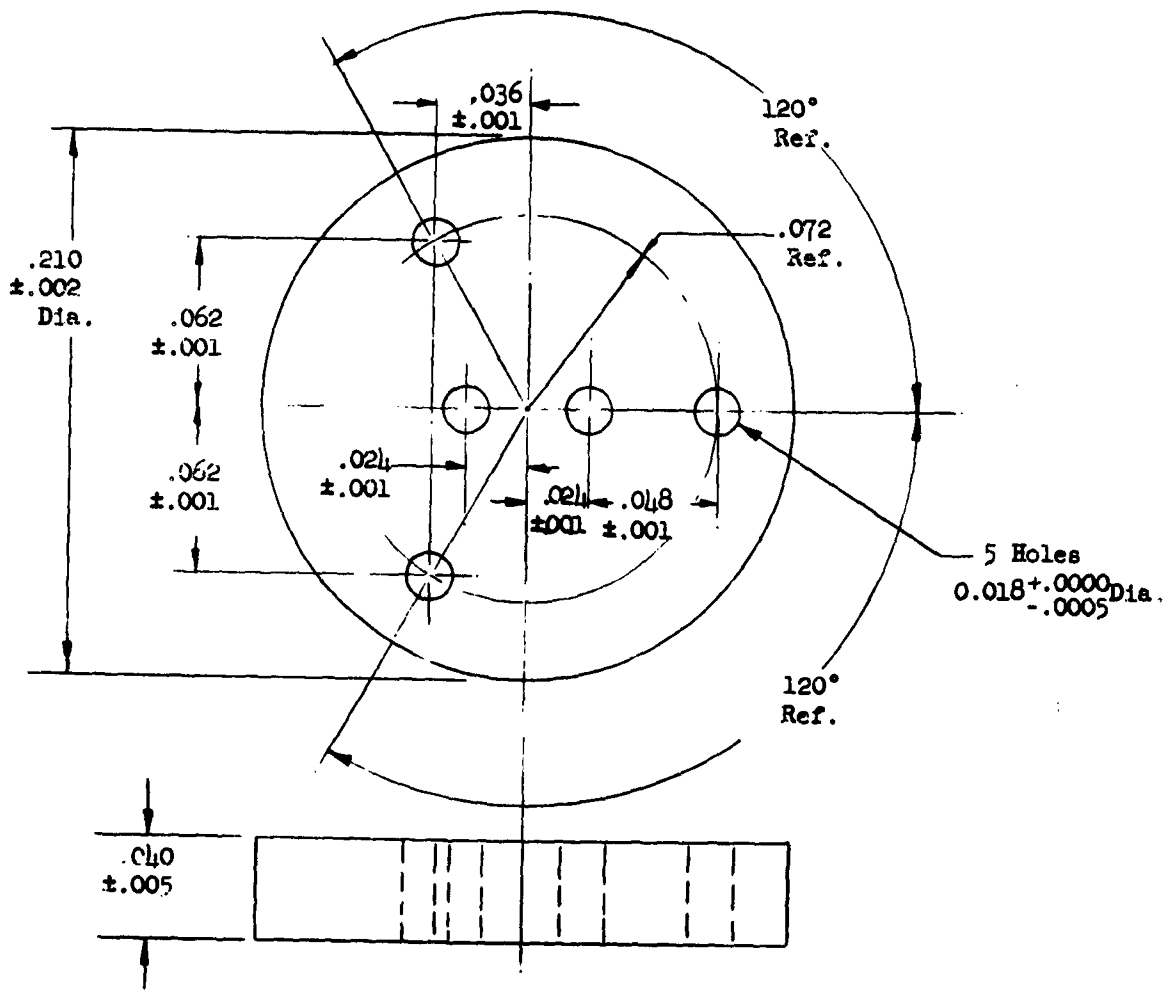
Wafer Base



Material: Forsterite

Notes: See following page.

Scale: 15:1

Dimensions in Inches unless otherwise shown

Dimensions without tolerances are design centers.

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Wafer Base Notes

1. Diameter tolerances include out-of-round tolerances.

2. Inspect for hole location with template using optical comparator at 31.25X magnification when available.

3. Wafer is manufactured using normal Forsterite techniques.

4. Radius on edges - Maximum 0.010".

5. Radius on holes - Maximum 0.005".

6. Holes must be perpendicular to top & bottom surfaces within $\pm 5^{\circ}$.

7. Method of gaging holes. Pins 0.0175" as go gage, class X tolerance, should drop thru freely. Pins of 0.018" as No go-Class X tolerance should not go. Hole location and oval holes to be checked on comparator using template.

8. Flash and burr not to exceed 0.002" high.

9. Chips around hole not to exceed 0.010" in greatest dimension. No more than 5 holes per side to show chips.

10. Chips should have a minimum distance of 0.030" between them or between a chip and impurity.

11. No spots, discolorations or foreign material larger in major dimension than 0.015".

12. Foreign material: five allowed per side, minimum spacing 0.030" between any two impurities or impurity and chip.

13. Adhered particles on edge or in holes are cause for rejection.

14. Thickness .040" ± .005" as measured with micrometer with anvil points have flats of 1/64".

15. Lead holes to be perpendicular to face within .001" measured at a point .058 out from face. Inspect part on a 1% spot check basis - all holes in sample part to be checked.

    Recommended Method of Inspection: for note 15.

    Use optical comparator with reference axes along face and up lead. Rotating assembly while maintaining face registry will demonstrate perpendicularity. A point on lead .580" above face should be within .010" of vertical reference axis at all times during rotation for part to be considered acceptable.

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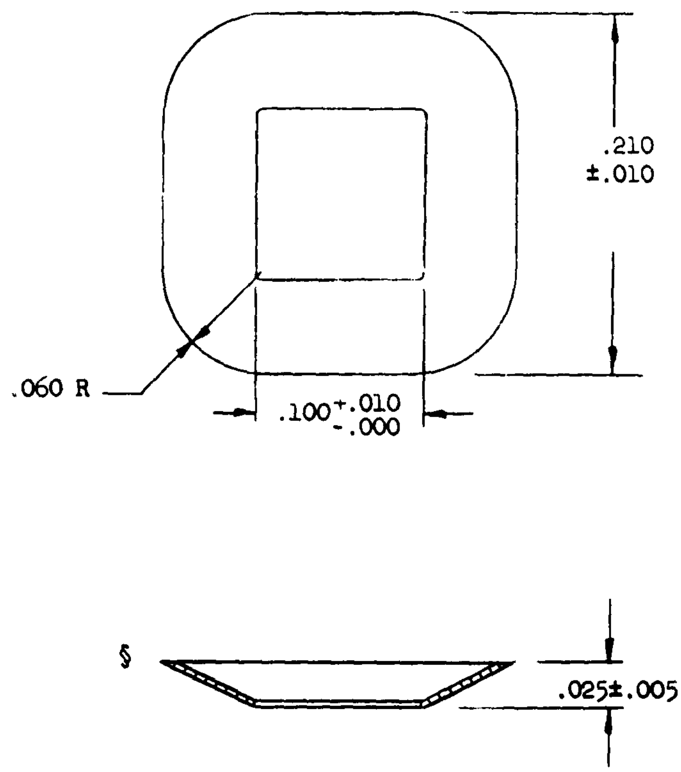
Washer, Main Braze



MATERIAL - .006±.001 Nioro

Treatment: Ultrasonically wash in methanol for two min.

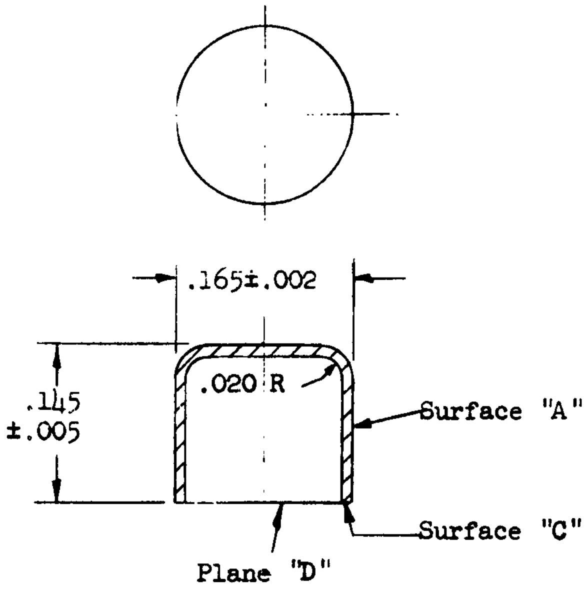
Scale: 10:1

Dimensions in Inches

Dimensions shown without tolerances are design centers.

A15274 - A15330

Top Cap



Tolerances - Include out-of-round

Burr Max. = .002

NOTES:
1. The axis of the cylinder formed by surface "A" shall be considered the axis of the part.
2. Surface "A" shall be concentric with the axis of the part to within .005" full indicator reading.
3. The plane "D" defined by the trimmed end of the cap must be ($\perp$) perpendicular to the axis of the part within .004" full indicator reading.
4. All points on the surface "C" of the trimmed end of the part must fall on plane "D" within ±.002".
5. Camber - .005" max.

MATERIAL: .010±.001 gas free 52-alloy.

Treatment: Wash in hot Blacosolv, then in hot deionized water. Rinse in methanol and dry. Fire in line hydrogen at 800°C for 10 min.

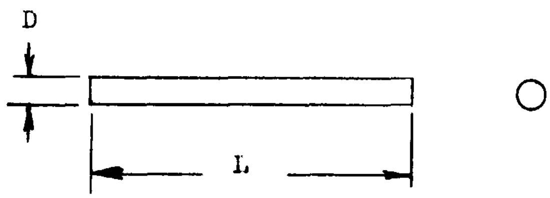
Scale: 6:1

Dimensions in Inches

Dimensions shown without tolerances are design centers.

A15274 - A15330

Leads



Manufacturing Specifications

Part Description	Wire Diam. D(mils)	Length L(inches)±.010	Max. Allowable Camber	Burr
Cathode Lead	15.6	0.295	.005	.0005
Grid Lead	15.6	0.295	.005	.0005
Heater Lead	16.1	0.252	.005	.0005
Stub Lead	15.6	0.177	.005	.0005

Material: Heater Leads - iron plated molybdenum
Cathode, grid, & stub leads - copper plated molybdenum

Treatment: Wash in hot Blacosolv then hot deionized water. Rinse in methanol and dry.

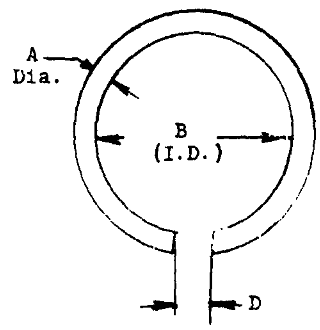
Notes: The pieces shall have an adherent, uniform plating free of flakes, peel, wrinkles, and scratches through the plating. Examination shall be made under 10X magnification.

Dimensions are in inches unless otherwise shown.

Dimensions shown without tolerances are design centers.

A15274 - A15330

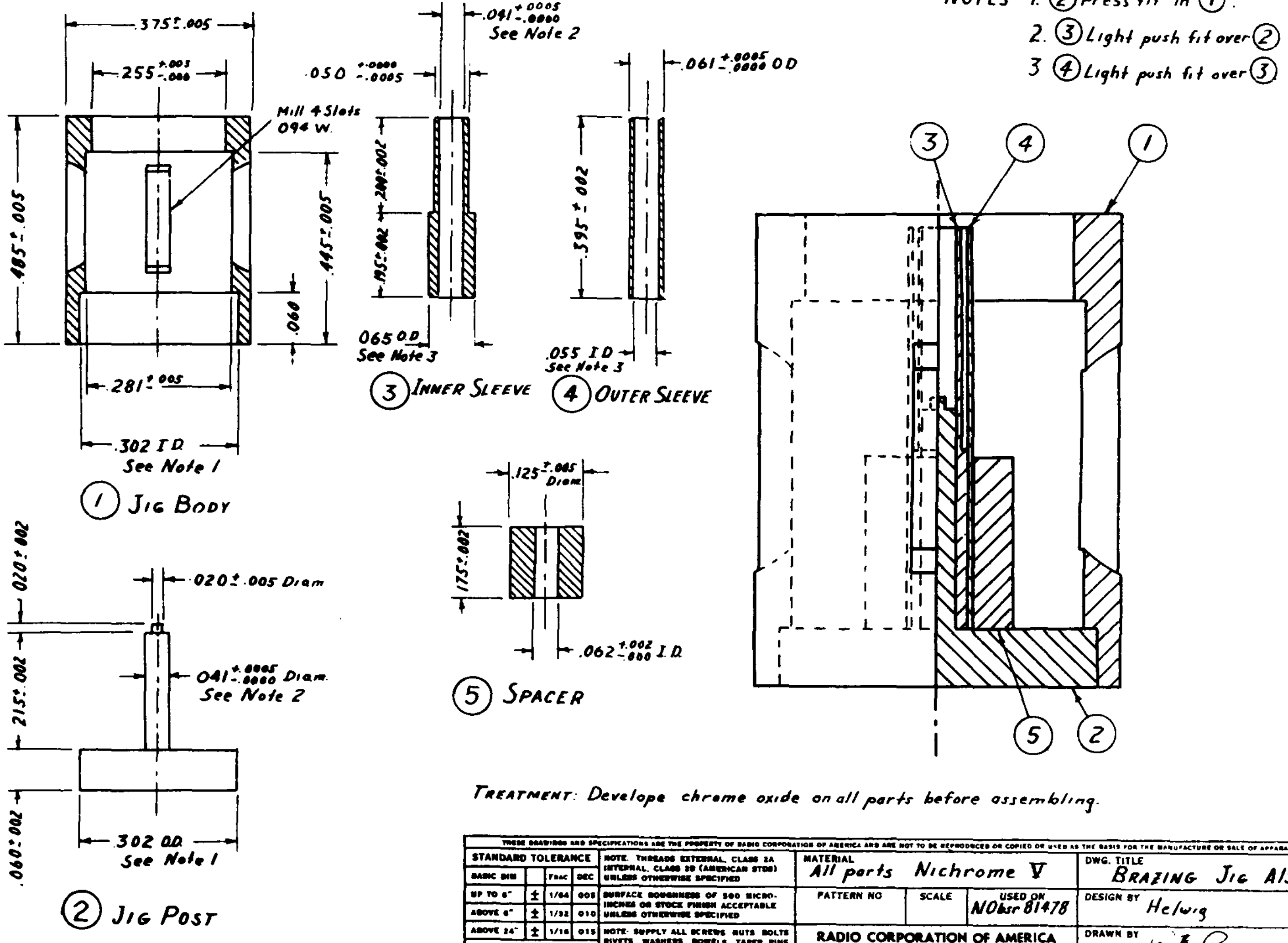
Wire Rings



Manufacturing Specifications

Part Description	Wire Diam."A" (Mils)	Inside Diam. "B" (inches) Includes Out-of-Round	"D" (mils)	Under Length (mm)	Material
Braze Ring A	15	0.095	0-5	8.8	OFHC Copper
Braze Ring B	20	0.075	0-5	7.6	"
Braze Ring C	20	0.195	0-5	25.6	"
Braze Ring D	10	$0.016^{+.001}_{-.000}$	0-5		"
Centering Ring	30	$0.074^{+.0005}_{-.0000}$	10-30		Nickel

Treatment: Wash in hot Blacosolv, then in hot deionized water. Rinse in Methanol and dry.



NOTES: 1. (2) Press fit in (1).
2. (3) Light push fit over (2)
3 (4) Light push fit over (3)

TREATMENT: Develope chrome oxide on all parts before assembling.

REVISIONS

CHECKED BY

APPROVED BY

O

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STANDARD TOLERANCE			
BASIC DIM		FRAC	DEC
UP TO 6"	±	1/64	.005
ABOVE 6"	±	1/32	.010
ABOVE 24"	±	1/16	.015
ANGULAR DIM	± 1/2°		

NOTE: THREADS EXTERNAL, CLASS 2A INTERNAL, CLASS 2B (AMERICAN STD) UNLESS OTHERWISE SPECIFIED

SURFACE ROUGHNESS OF 500 MICRO-INCHES OR STOCK FINISH ACCEPTABLE UNLESS OTHERWISE SPECIFIED

NOTE: SUPPLY ALL SCREWS NUTS BOLTS RIVETS WASHERS, DOWELS TAPER PINS COTTER PINS & WOODRUFF KEYS WITH PART

MATERIAL: All parts Nichrome V

PATTERN NO

SCALE

USED ON: NObsr 81478

RADIO CORPORATION OF AMERICA
EQUIPMENT DEVELOPMENT

DWG. TITLE: BRAZING JIG A15274 & A15330

DESIGN BY: Helwig

DRAWN BY: W. K. R.

MODEL NO

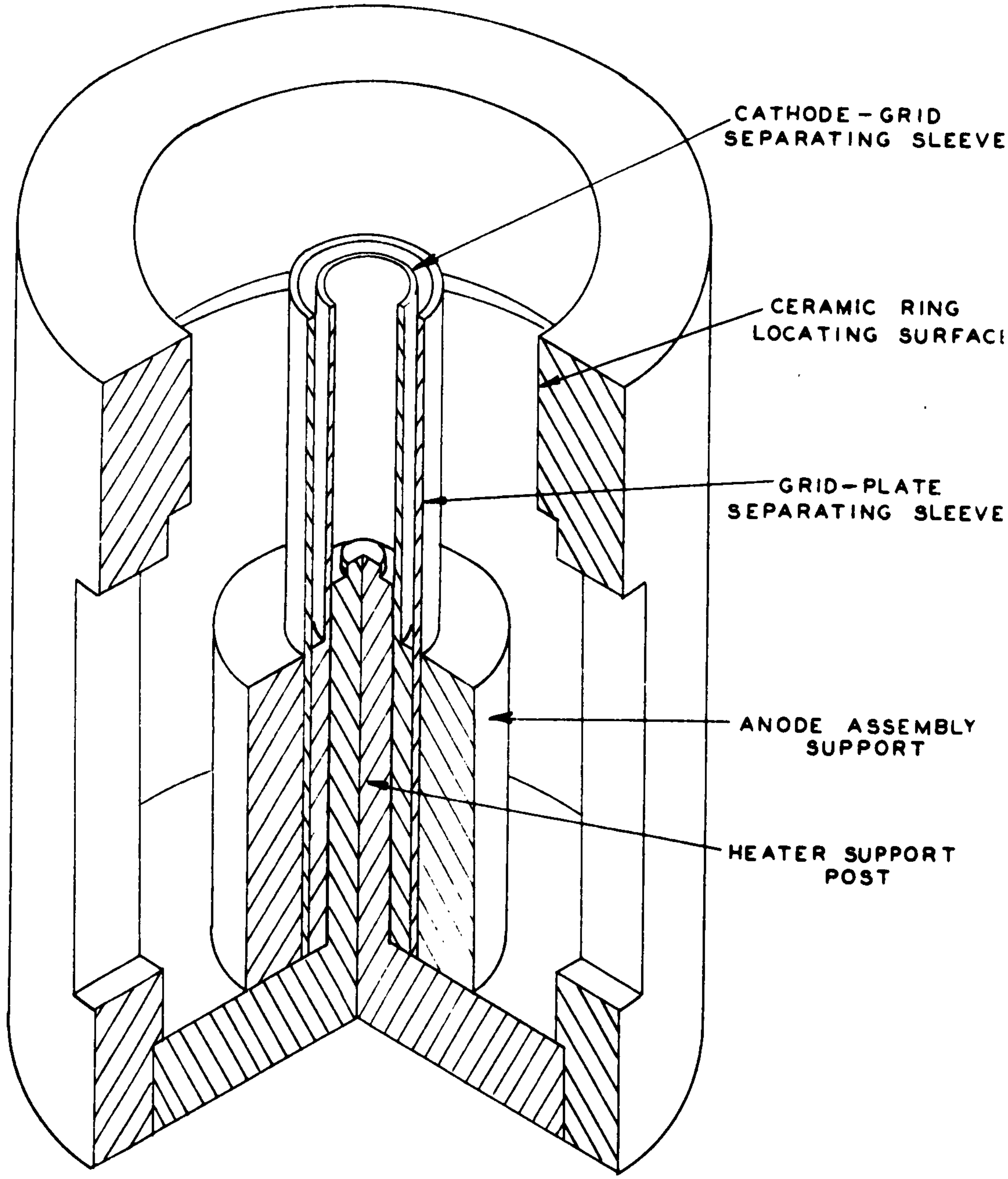
B
SIZE

DWG. NO.

T 660 12/56

DEFIANCE NO 1020F-B

ASSEMBLY JIG



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Assembly Procedure

1. Insert anode assembly into brazing jig.
2. Place braze ring A around anode cylinder.
3. Insert cathode support into jig.
4. Insert grid into jig.
5. Drop ceramic sleeve assembly into place.
6. Insert grid support assembly into jig.
7. Place braze ring A on grid support.
8. Place cathode support flange onto cathode support.
9. Place braze ring B on cathode support flange.
10. Insert heater leads through proper holes in wafer base assembly and spot weld heater assembly legs to heater leads.
11. Insert wafer base assembly - heater assembly into mount and seat heater assembly and wafer base assembly.
12. Place braze ring C on wafer base assembly.
13. Insert cathode lead and stub leads into proper holes in wafer base assembly.
14. Place braze ring D on all leads including grid lead.
15. Braze mount. (See Brazing Schedule, page 195).
16. Remove mount from jig and trim leads to specified length.
17. Place cathode assembly onto cathode support.
18. Drop main braze washer over anode support.
19. Place centering ring on anode.
20. Place top cap on mount.
21. Exhaust and seal. (See Exhaust Schedule, page 196).
22. Age and stabilize. (See Aging Schedule, page 197).

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Brazing Schedule

Time	Operation	Temp.
0	Transition to preheat	
2 min. 30 sec.	Preheat	1070°C
5 min.	Transition to braze zone	
5 min. 30 sec.	Braze	1125°C
6 min. 45 sec.	Transition to cool down zone	
9 min. 15 sec.	Cool down	250°C
15 min. 15 sec.	Transition out of furnace	
16 min.	End of cycle	

Braze in line hydrogen

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Exhaust Schedule

Time	Operation
	Close system. Begin time at system pressure of 8×10^{-5} min. Hg.
0	Preheat: Apply RF Heating to raise muffle temperature to 600°C at time-1 min.
1 Min.	Bakeout: Increase RF heating to raise muffle to 850°C
3 Min.	Cathode Breakdown: Increase RF Heating to raise muffle to 970°C.
5 Min.	Seal: Increase RF heating to melt Main Braze Washer at about 5.85 Min.
5.85 Min.	Cooldown: Shutdown RF heating.
15 Min.	Open System and remove tube.

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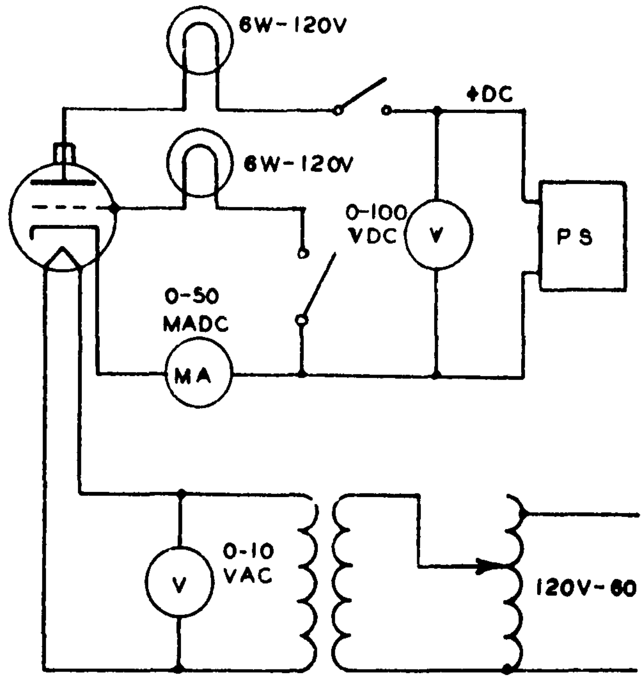
Aging Schedule

Time	Condition		
	E_H	E_{bb}	E_{cc}
0	10v.	-	-
0.5 min.	8.5v.	75v.	-
5.5 Min.	7.5v.	75v.	0v.
45 Min.	0	0	0

Stabilization

48 hours

	E_b	R_K	E_{cc}
A15274	50v.	100 Ω	0
A15330	60	100 Ω	0



SCHEMATIC DIAGRAM
A15274 & A15330
Aging Circuit

BUSHIPS CONTRACT NObsr 81478
Index No. SR0080302 ST-140

MIL-E-1/

22 December 1961

RCA TENTATIVE
MILITARY SPECIFICATION SHEET
ELECTRON TUBE, RCA DEVELOPMENTAL TYPE A15274

The requirements and tests of the latest issue of Specification MIL-E-1 shall apply, except as otherwise required herein.

DESCRIPTION: Receiving, Triode, Medium Mu, Amplifier, Miniature Ceramic-Metal Shell

RATINGS: Absolute Maximum

Parameter:	Ef V	Ebb Vdc	Eb Vdc	Ec Vdc	Ehk V	Rk ohm	Rg meg	Ik mAdc	Ic mAdc	Pp W	T (shell) °C	Alt. Ft.
Maximum:	6.9	330	110	+4	+100	-	(Note 1)	15	2.0	0.75	150	100,000
Minimum:	5.7	-	-	-20	-100	-	-	-	-	-	-	-
TEST CONDITIONS:	6.3	50	-	0	(Note 2)	100	-	-	-	-	-	-

OUTLINE: See Note 28

CATHODE: Coated Unipotential

BASE: Linotetrar - 4 Pin (JEDEC E4-24)

DIAMETER: 0.260" max.

HEIGHT: 0.750" max.

ENVELOPE: See Note 28

PIN NO.:	1	2	3	4	TC
ELEMENT:	K	H	H	G	P

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	LIMITS Max.	Unit
	GENERAL							
3.1	Qualification	Required; (Note 3)	-	-	-	-	-	-
3.7	Identification Marking	(Note 4)	-	-	-	-	-	-
3.6	Performance		-	-	-	-	-	-
4.9.2	Dimensions	- - -	(Note 5)	-	-	-	-	-
	QUALIFICATION INSPECTION (NOTE 6)							
	Cathode	Coated Unipotential	-	-	-	-	-	-
3.4.3	Base Connections		-	-	-	-	-	-
	ACCEPTANCE INSPECTION, PART 1, (PRODUCTION), (NOTE 7)							
4.10.6.1	Total Grid Current	Eb = 75, Rg = 0.5 meg, Ec = -1.3, Rk = 0	1.0 (Note 8)	II	Ic	-	-0.1	µAdc
4.10.4.1	Plate Current (1)		1.0 (Note 8)	II	Ib	6.0	8.0	mAdc

ACCEPTANCE INSPECTION, PART 1, (PRODUCTION), (NOTE 7) (Cont'd.)

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	LIMITS Max.	Unit
4.10.9	Transconductance (1)	Ck = 1000 µf	1.0 (Note 8)	II	Sm	9600	12400	µmhos
4.10.4.1	Plate Current (2)	Ecc = -4.0 Vdc; Rk = 0	[illegible] (Note 8)	II	Ib	-	30	µAdc
4.7.5	Continuity and Short Test (Inoperatives) (Note 9)		0.4	II	-	-	-	-
4.10.8	Heater Current		1.0	II	If	65	70	mA

ACCEPTANCE INSPECTION, (DESIGN), PART 2

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	LIMITS Max.	Unit
4.9.1	Mechanical		-	-	-	-	-	-
4.10.15	Heater-Cathode Leakage	Ehk = +100 Vdc; Ehk = -100 Vdc	4.0	II	Ihk Ihk	- -	5 5	µAdc µAdc
4.10.9	Transconductance (2)	Ef = 5.7 V; Ck = 1000 µf	1.0	II	Sm/ΔEf	9000	-	µmhos
4.8	Insulation of Electrodes	g-all = -100 Vdc p-all = -300 Vdc	2.5	II	R R	1000 1000	- -	Meg Meg
- - -	Cathode Warm-Up Time	Rk = 100 ohms; (Note 23)	6.5	L6	KWT	-	15	sec
4.10.9	Transconductance (3)	Ef = 5.7 V	6.5	Code E	ΔSm_{Ef}	-	15	%
4.10.11.1	Amplification Factor		6.5	Code E	Mu	30	40	-
4.10.1.1.1	AC Emission	Ef = 5.5 V; Ebb = 45 Vdc Ec = 2.8 Vac; (Note 11)	6.5	Code E	Is	20	-	ma
4.10.14	Direct Interelectrode Capacitance		6.5	Code E	Cin Cout Chk Cg-p Cp-k	3.2 .050 1.05 1.8 .050	4.0 .065 1.65 2.2 .065	µµf µµf µµf µµf µµf
- - -	Noise Factor	Test Freq. 450 Mc	-	-	-	-	6.6	db
4.9.12.1	Low Pressure Voltage Breakdown	Pressure = 8.0±0.5 mm Hg Voltage = 250 Vac	6.5	Code E (Note 12)	-	-	-	-
4.9.19.9	Sweep Frequency Vibration (1)	Ebb = 65 Vdc; Rp = 2000; Ck = 1000 µf; G = 5; (Notes 13, 15)	6.5	Code E	Ep	-	(Note 15)	-
4.9.19.9	Sweep Frequency Vibration (2)	Ebb = 65 Vdc; Rp = 2000; Ck = 1000 µf; G = 5	6.5	Code E (Note 12)	[illegible]	-	(Note 16)	-

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	Max.	Unit
	ACCEPTANCE INSPECTION, PART 2 (DEGRADATION) (NOTE 14)							
4.9.20.5	Shock (1)	Ehk = +100 V; 1000G; 1 millisec; (Note 17); Eb = 75 Vdc; Ec = -1.3 Vdc	-	-	-	-	-	-
4.9.20.5	Shock (2)	Note 10	-	-	-	-	-	-
4.9.20.6	Fatigue	Ebb = Ecc = 0; Rk = 0; G = 5.0 (Note 18)	6.5	Code E (Note 19)	-	-	-	-
- - -	Post Shock (1) & (2), and Fatigue Test Endpoints	Plate Current (1)	-	-	ΔIb	-	±10	%
		Transconductance (1)	-	-	Δ_tSm	-	±15	%
		Grid Current	-	-	Ic	-	-0.15	µAdc
		Heater-Cathode Leakage						
		Ehk = +100 Vdc	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	Ihk	-	10	µAdc
		Sweep Frequency Vibration (1)	-	-	ep	-	(Note 20)	mVac
		Plate Current (2)	-	-	Ib	-	40	µAdc

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	ALLOWABLE DEFECTIVES PER CHARACTERISTIC 1st Sample	Combined Sample	Sym.	LIMITS Min.	Max.	Unit
	ACCEPTANCE INSPECTION, PART 3 (LIFE) (NOTE 14)									
4.11.7	Heater Cycling Life Test	Ef = 7.5V; Ehk = -100 Vdc; Eb = 0; Rk = 0; 1 min. on, 2 min. off (Note 21)	-	-	-	-		-	-	-
4.11.4	Heater Cycling Life Test End Points	Heater-Cathode Leakage								
		Ehk = +100 Vdc	-	-	-	-	hk	-	10	µAdc
		Ehk = -100 Vdc	-	-	-	-	hk	-	10	µAdc
4.11.5	Intermittent Life Test	Group A Ebb = 75 Vdc, Rg = 0.5 meg, Ehk = +100 V, Ec = -1.3, RL = Rk = 0 T(shell) = +150°C min. (Notes 24, 25)	-	-	-	-	-	-	-	-
4.11.4	Intermittent Life Test End Points (500 hours)	(Note 26) Inoperatives, Note 27	-	-	-	-	-	-	-	-
		Grid Current	-	-	-	-	Ic	-	-0.2	µAdc
		Change in Transconductance (1) of individual tubes	-	-	-	-	Δ_tSm	-	20	%
		Heater-Cathode Leakage								
		Ehk = +100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc		-	-	-	Ihk	-	10	µAdc

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	ALLOWABLE DEFECTIVES PER CHARACTERISTICS 1st Sample	Combined Sample	Sym.	LIMITS Min.	Max.	Unit
	ACCEPTANCE INSPECTION, PART 3 (LIFE) (NOTE 14) (Cont'd.)									
4.11.4	Intermittent Life Test End Points (500 hours) (Cont'd.)	Insulation of electrodes								
		E(g-all) = -100 Vdc	-	-	-	-	R	500	-	meg
		E(p-all) = -300 Vdc	-	-	-	-	R	500	-	meg
		Total Defectives	-	-	1	3	-	-	-	-
4.11.4	Intermittent Life Test End Points (1000 hours)	(Note 26) Inoperatives, Note 27	-	-	-	-	-	-	-	-
		Grid Current	-	-	-	-	Ic	-	-0.3	µAdc
		Change in Transconductance (1) of individual tubes	-	-	-	-	$\Delta_t Sm$	-	25	%
		Heater-cathode leakage								
		Ehk = +100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Insulation of electrodes								
		E(g-all) = -100 Vdc	-	-	-	-	R	500	-	meg
		E(p-all) = -300 Vdc	-	-	-	-	R	500	-	meg
		Total Defectives	-	-	1	3	-	-	-	-

NOTES:

1. Maximum Grid Circuit Resistance for operation at Metal-Shell Temperatures up to 150°C:

   For fixed bias operation: 0.5 meg
   For cathode bias operation: 1.0 meg

2. The reference point for heater-cathode potential shall be the positive terminal of the cathode resistor.

3. With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in Qualified Products List (QPL-1) Supplement (Army), whether or not such products have actually been so listed by that date. Information pertaining to qualification of products covered by this specification should be requested from the Standardization Division, U. S. Army Signal Material Support Agency, Fort Monmouth, New Jersey, Attention: SIGMS-PSM-3.

4. Type-designation marking of electron tubes procured on Department of Army contracts, and which have passed Government inspection and comply with all requirements of this specification sheet, shall consist of "USA-manufacturer's qualification code letters-tube designation." The letters "JAN" or any abbreviation thereof shall not be used. If any specification waiver has been granted, the combination "USA-manufacturer's qualification code letters" shall not be used to complete the type-designation marking.

5. Overall Height and Diameter shall be design tests (6.5% AQL, Code Letter E). All other dimensions shall be Qualification Tests.

6. All tests applicable herein shall be performed during qualification; however, these two tests are normally performed during qualification inspection only.

7. Tests in this group shall be performed after the holding period conforming to requirements in paragraph 4.5, MIL-E-1D.

8. The indicated AQL is applicable to all of the particular tests, combined, within the test group where this note is referenced.

9. Test in accordance with paragraphs 4.7.5 and 4.7.7 of MIL-E-1, except that the tube shall be tapped 3 times in each of 2 planes 90° to 120° apart, using a hand tapper consisting of a bakelite rod 1/8" diameter and 7" long with a rubber tip one (1) inch long. The rubber tip consists of gum tubing 1/8" I.D. and 3/32" wall thickness with an average Durometer rating of 35±5 Shore A or equal.

NOTES:

10. Test per Shock (1) conditions, except Impact shall be 50 g, 11 milliseconds.

11. The DC resistance in the grid circuit shall not exceed 2.0 ohms. Measure AC emission as the DC component of current in the plate circuit.

12. This test shall be conducted on the initial lot and thereafter on a lot approximately every 30 days. When one lot has passed. the 30 day rule shall apply. In the event of lot failure, the lot shall be rejected and succeeding lots shall be subjected to this test until a lot passes.

13. Sweep Frequency Vibration (1) Test: Tube under test shall be vibrated in the X plane through a frequency range of 3000 to 15000 cps. Sweep time shall be approximately 7.0 seconds, and the rate of change of frequency shall be approximately linear. Each tube shall be rotated to find the direction of vibration in the X plane which gives the highest output reading.

14. Destructive Tests: Tubes subjected to the following destructive tests are not to be delivered under this specification:

Shock Test
Fatigue Test
Heater Cycling Life Test
Intermittent Life Test Operation
Interface Life Test

15. Tubes shall be rejected for Sweep Frequency Vibration (1) if they have an output exceeding the following limits:

200 mv Peak - 3 to 6 KC
20 mv Peak - 6 to 15 KC

16. Sweep Frequency Vibration (2) Test: Tube under test shall be vibrated in the X plane through a frequency range of 50 to 3000 cps. Sweep time shall be 30 seconds per octave. Tubes shall be rejected if they have an output exceeding the following limits:

100 mv RMS - .05 to 3 KC

17. A grid resistor of 0.5 megohm shall be added; however, this resistor shall not be used when a thyratron-type short indicator is employed.

18. Fatigue Vibration Test: Tubes under test shall be vibrated in the X plane at 60 cps for 48 hours.

19. This test shall be conducted on the initial lot and thereafter on a lot approximately every 6 months. When one lot has passed, the 6 month rule shall apply. In the event of lot failure, the lot shall be rejected and succeeding lots shall be subjected to this test until a lot passes.

20. For post Shock and Fatigue tests, tubes shall be considered failures if they have an output exceeding:

250 mv Peak - 3 to 6 KC
25 mv Peak - 6 to 15 KC

21. The no-load to steady state full load regulation of the heater-voltage supply shall be not more than 3.0 percent.

22. See paragraph 20.2.5.1 of Appendix C, MIL-E-1D.

23. Cathode warm-up time is that time for cathode current to reach 90% of the value obtained 3 minutes after the heater is turned on.

24. The life test shall be read at the following down periods: 0, 500, and 1000 hours. The pre-release criteria of paragraph 4.11.3.5, MIL-E-1D, shall not apply; however, the following shall be applicable:

For 500 hour shipment:

<u>Eligibility:</u> No lot failure in the preceding three (3) consecutive lots.

<u>Loss of Eligibility:</u> Two (2) or more lot failures in the last three consecutive lots.

All life tests shall be continued to 1000 hours.

25. Shell temperature is defined as the highest temperature indicated when using a thermocouple of No. 40 B&S or smaller diameter elements welded to a ring of 0.025 inch diameter phosphor bronze in contact with the shell. The shell temperature requirement will be satisfied if a tube having bogie plate current (±5 percent) under normal test conditions is determined to operate at or above the minimum specified temperature in any socket of the life test rack.

NOTES:

26. Order for evaluation of life test defects: see paragraph 4.11.3.1.2 in MIL-E-1D.

27. An inoperative, as referenced in life test, is defined as a tube having a discontinuity, permanent short, or air leak. Tubes are not to be tapped.

28. Basing, outline, and dimensions: see diagram on next page.

BUSHIPS CONTRACT NObsr 81478
Index No. SR0080302 ST-140

MIL-E-1/.

13 November 1962

RCA TENTATIVE
MILITARY SPECIFICATION SHEET
ELECTRON TUBE, RCA DEVELOPMENTAL TYPE A15330

The requirements and tests of the latest issue of Specification MIL-E-1 shall apply, except as otherwise required herein.

DESCRIPTION: Receiving, Triode, Medium Mu, Amplifier, Miniature Ceramic-Metal Shell

RATINGS: Absolute Maximum

Parameter:	Ef V	Ebb Vdc	Eb Vdc	Ec Vdc	Ehk V	Rk ohm	Rg meg	Ik mAdc	Ic mAdc	Pp W	T (shell) °C	Alt. Ft.
Maximum:	6.9	330	110	+4	+100	-	(Note 1)	12	2.0	0.75	150	100,000
Minimum:	5.7	-	-	-20	-100	-	-	-	-	-	-	-
TEST CONDITIONS:	6.3	60	-	0	(Note 2)	100	-	-	-	-	-	-

OUTLINE: See Note 28

CATHODE: Coated Unipotential

BASE: Linotetrar - 4 Pin (JEDEC E4-24)

DIAMETER: 0.260" max.

HEIGHT: 0.750" max.

ENVELOPE: See Note 28

PIN NO.:	1	2	3	4	TC
ELEMENT:	K	H	H	G	P

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	LIMITS Max.	Unit
	GENERAL							
3.1	Qualification	Required: (Note 3)	-	-	-	-	-	-
3.7	Identification Marking	(Note 4)	-	-	-	-	-	-
3.6	Performance		-	-	-	-	-	-
4.9.2	Dimensions	- - -	(Note 5)	-	-	-	-	-
	QUALIFICATION INSPECTION (NOTE 6)							
	Cathode	Coated Unipotential	-	-	-	-	-	-
3.4.3	Base Connections		-	-	-	-	-	-
	ACCEPTANCE INSPECTION, PART 1, (PRODUCTION), (NOTE 7)							
4.10.6.1	Total Grid Current	Eb = 75, Rg = 0.5 meg, Ec = -1.3, Rk = 0	1.0 (Note 8)	II	Ic	-	-0.1	µAdc
4.10.4.1	Plate Current (1)		1.0 (Note 8)	II	Ib	7.0	9.0	mAdc

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	Max.	Unit
	ACCEPTANCE INSPECTION, PART 1, (PRODUCTION), (NOTE 7) (Cont'd.)							
4.10.9	Transconductance (1)	Ck = 1000 µf	1.0 (Note 8)	II	Sm	9000	11500	µmhos
4.10.4.1	Plate Current (2)	Ec c = -5.0 Vdc; Rk = 0	1.0 (Note 8)	II	Ib	10	60	µAdc
4.7.5	Continuity and Short Test (Inoperatives) (Note 9)		0.4	II	-	-	-	-
4.10.8	Heater Current		1.0	II	If	65	70	mA
	ACCEPTANCE INSPECTION, (DESIGN), PART 2							
4.9.1	Mechanical		-	-	-	-	-	-
4.10.15	Heater-Cathode Leakage	Ehk = +100 Vdc; Ehk = -100 Vdc	4.0	II	Ihk Ihk	- -	5 5	µAdc µAdc
4.10.9	Transconductance (2)	Ef = 5.7 V; Ck = 1000 µf	1.0	II	Sm/ΔEf	8400	-	µmhos
4.8	Insulation of Electrodes	g-all = -100 Vdc p-all = -300 Vdc	2.5	II	R R	1000 1000	- -	Meg Meg
- - -	Cathode Warm-Up Time	Rc = 100 ohms; (Note 23)	6.5	L6	KWT	-	15	sec
4.10.9	Transconductance (3)	Ef = 5.7 V	6.5	Code E	ΔSm_{Ef}	-	15	%
4.10.1.1	Amplification Factor		6.5	Code E	Mu	30	37	-
4.10.1.1.1	AC Emission	Ef = 5.5 V; Ebb = 45 Vdc Ec = 2.8 Vac; (Note 11)	6.5	Code E	Is	20	-	ma
4.10.14	Direct Interelectrode Capacitance		6.5	Code E	Cin Cout Chk Cg-p Cp-k	3.2 .046 1.05 1.8 .046	4.0 .060 1.65 2.2 .060	µµf µµf µµf µµf µµf
- - -	Noise Factor	Test Freq. 450 Mc	-	-	-	-	6.6	db
4.9.12.1	Low Pressure Voltage Breakdown	Pressure = 8.0±0.5 mm Hg Voltage = 250 Vac	6.5	Code E (Note 12)	-	-	-	-
4.9.19.9	Sweep Frequency Vibration (1)	Ebb = 70 Vdc; Rp = 2000; Ck = 1000 µf; G = 5; (Notes 13, 15)	6.5	Code E	Ep	-	(Note 15)	-
4.9.19.9	Sweep Frequency Vibration (2)	Ebb = 70 Vdc; Rp = 2000; Ck = 1000 µf; G = 5	6.5	Code E (Note 12)	Ep	-	(Note 16)	-

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Sym.	LIMITS Min.	LIMITS Max.	Unit
	ACCEPTANCE INSPECTION, PART 2 (DEGRADATION) (NOTE 14)							
4.9.20.5	Shock (1)	Ehk = +100 V; 750G; 1 millisec; (Note 17); Eb = 75 Vdc; Ec = -1.3 Vdc	-	-	-	-	-	-
4.9.20.5	Shock (2)	Note 10	-	-	-	-	-	-
4.9.20.6	Fatigue	Ebb = Ecc = 0; Rk = 0; G = 5.0 (Note 18)	6.5	Code E (Note 19)	-	-	-	-
- - -	Post Shock (1) & (2), and Fatigue Test Endpoints	Plate Current (1)	-	-	ΔIb	-	±10	%
		Transconductance (1)	-	-	Δ_tSm	-	±15	%
		Grid Current	-	-	Ic	-	-0.15	µAdc
		Heater-Cathode Leakage						
		Ehk = +100 Vdc	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	Ihk	-	10	µAdc
		Sweep Frequency Vibration (1)	-	-	ep	-	(Note 20)	mVac
		Plate Current (2)	-	-	Ib	10	75	µAdc

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	ALLOWABLE DEFECTIVES PER CHARACTERISTICS 1st Sample	ALLOWABLE DEFECTIVES PER CHARACTERISTICS Combined Sample	Sym.	LIMITS Min.	LIMITS Max.	Unit
	ACCEPTANCE INSPECTION, PART 3 (LIFE) (NOTE 14)									
4.11.7	Heater Cycling Life Test	Ef = 7.5V; Ehk = -100 Vdc; Eb = 0; Rk = 0; 1 min. on, 2 min. off (Note 21)	-	-	-	-	-	-	-	-
4.11.4	Heater Cycling Life Test End Points	Heater-Cathode Leakage								
		Ehk = +100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	-	-	Ihk	-	10	µAdc
4.11.5	Intermittent Life Test	Group A Ebb = 75 Vdc, Rg = 0.5 meg, Ehk = +100 V, Ec = -1.3, RL = Rk = 0 T(shell) = +150°C min. (Notes 24, 25)	-	-	-	-	-	-	-	
4.11.4	Intermittent Life Test End Points (500 hours)	(Note 26) Inoperatives, Note 27	-	-	-	-	-	-	-	-
		Grid Current	-	-	-	-	Ic	-	-0.2	µAdc
		Change in Transconductance (1) of individual tubes	-	-	-	-	Δ_tSm	-	30	%
		Heater-Cathode Leakage								
		Ehk = +100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	-	-	Ihk	-	10	µAdc

Par. No.	Test	Conditions	AQL (Percent Defective)	Insp. Level Or Code	Allowable Defectives per Characteristics: 1st Sample	Allowable Defectives per Characteristics: Combined Sample	Sym.	Limits: Min.	Limits: Max.	Unit
	ACCEPTANCE INSPECTION, PART 3 (LIFE) (NOTE 14) (Cont'd.)									
4.11.4	Intermittent Life Test End Points (500 hours) (Cont'd.)	Insulation of electrodes								
		E(g-all) = -100 Vdc	-	-	-	-	R	500	-	meg
		E(p-all) = -300 Vdc	-	-	-	-	R	500	-	meg
		Total Defectives	-	-	1	3	-	-	-	-
4.11.4	Intermittent Life Test End Points (1000 hours)	(Note 26) Inoperatives, Note 27	-	-	-	-	-	-	-	-
		Grid Current	-	-	-	-	Ic	-	-0.3	µAdc
		Change in Transconductance (1) of individual tubes	-	-	-	-	$\Delta_t Sm$	-	40	%
		Heater-cathode leakage								
		Ehk = +100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Ehk = -100 Vdc	-	-	-	-	Ihk	-	10	µAdc
		Insulation of electrodes								
		E(g-all) = -100 Vdc	-	-	-	-	R	500	-	meg
		E(p-all) = -300 Vdc	-	-	-	-	R	500	-	meg
		Total Defectives	-	-	1	3	-	-	-	-

NOTES:

1. Maximum Grid Circuit Resistance for operation at Metal-Shell Temperatures up to 150°C:

   For fixed bias operation: 0.5 meg
   For cathode bias operation: 1.0 meg

2. The reference point for heater-cathode potential shall be the positive terminal of the cathode resistor.

3. With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in Qualified Products List (QPL-1) Supplement (Army), whether or not such products have actually been so listed by that date. Information pertaining to qualification of products covered by this specification should be requested from the Standardization Division, U. S. Army Signal Material Support Agency, Fort Monmouth, New Jersey, Attention: SIGMS-PSM-3.

4. Type-designation marking of electron tubes procured on Department of Army contracts, and which have passed Government inspection and comply with all requirements of this specification sheet, shall consist of "USA-manufacturer's qualification code letters-tube designation." The letters "JAN" or any abbreviation thereof shall not be used. If any specification waiver has been granted, the combination "USA-manufacturer's qualification code letters" shall not be used to complete the type-designation marking.

5. Overall Height and Diameter shall be design tests (6.5% AQL, Code Letter E). All other dimensions shall be Qualification Tests.

6. All tests applicable herein shall be performed during qualification; however, these two tests are normally performed during qualification inspection only.

7. Tests in this group shall be performed after the holding period conforming to requirements in paragraph 4.5, MIL-E-1D.

8. The indicated AQL is applicable to all of the particular tests, combined, within the test group where this note is referenced.

9. Test in accordance with paragraphs 4.7.5 and 4.7.7 of MIL-E-1, except that the tube shall be tapped 3 times in each of 2 planes 90° to 120° apart, using a hand tapper consisting of a bakelite rod 1/8" diameter and 7" long with a rubber tip one (1) inch long. The rubber tip consists of gum tubing 1/8" I.D. and 3/32" wall thickness with an average Durometer rating of 35±5 Shore A or equal.

NOTES:

10. Test per Shock (1) conditions, except Impact shall be 50 g, 11 milliseconds.

11. The DC resistance in the grid circuit shall not exceed 2.0 ohms. Measure AC emission as the DC component of current in the plate circuit.

12. This test shall be conducted on the initial lot and thereafter on a lot approximately every 30 days. When one lot has passed, the 30 day rule shall apply. In the event of lot failure, the lot shall be rejected and succeeding lots shall be subjected to this test until a lot passes.

13. Sweep Frequency Vibration (1) Test: Tube under test shall be vibrated in the X plane through a frequency range of 3000 to 15000 cps. Sweep time shall be approximately 7.0 seconds, and the rate of change of frequency shall be approximately linear. Each tube shall be rotated to find the direction of vibration in the X plane which gives the highest output reading.

14. Destructive Tests: Tubes subjected to the following destructive tests are not to be delivered under this specification:

    Shock Test
    Fatigue Test
    Heater Cycling Life Test
    Intermittent Life Test Operation
    Interface Life Test

15. Tubes shall be rejected for Sweep Frequency Vibration (1) if they have an output exceeding the following limits:

    200 mv Peak - 3 to 7 KC
    20 mv Peak - 7 to 15 KC

16. Sweep Frequency Vibration (2) Test: Tube under test shall be vibrated in the X plane through a frequency range of 50 to 3000 cps. Sweep time shall be 30 seconds per octave. Tubes shall be rejected if they have an output exceeding the following limits:

    100 mv RMS - .05 to 3 KC

17. A grid resistor of 0.5 megohm shall be added; however, this resistor shall not be used when a thyratron-type short indicator is employed.

18. Fatigue Vibration Test: Tubes under test shall be vibrated in the X plane at 60 cps for 48 hours.

19. This test shall be conducted on the initial lot and thereafter on a lot approximately every 6 months. When one lot has passed, the 6 month rule shall apply. In the event of lot failure, the lot shall be rejected and succeeding lots shall be subjected to this test until a lot passes.

20. For post Shock and Fatigue tests, tubes shall be considered failures if they have an output exceeding:

    250 mv Peak - 3 to 7 KC
    25 mv Peak - 7 to 15 KC

21. The no-load to steady state full load regulation of the heater-voltage supply shall be not more than 3.0 percent.

22. See paragraph 20.2.5.1 of Appendix C, MIL-E-1D.

23. Cathode warm-up time is that time for cathode current to reach 90% of the value obtained 3 minutes after the heater is turned on.

24. The life test shall be read at the following down periods: 0, 500, and 1000 hours. The pre-release criteria of paragraph 4.11.3.5, MIL-E-1D, shall not apply; however, the following shall be applicable:

    For 500 hour shipment:

    <u>Eligibility:</u> No lot failure in the preceding three (3) consecutive lots.

    <u>Loss of Eligibility:</u> Two (2) or more lot failures in the last three consecutive lots.

    All life tests shall be continued to 1000 hours.

25. Shell temperature is defined as the highest temperature indicated when using a thermocouple of No. 40 B&S or smaller diameter elements welded to a ring of 0.025 inch diameter phosphor bronze in contact with the shell. The shell temperature requirement will be satisfied if a tube having bogie plate current (±5 percent) under normal test conditions is determined to operate at or above the minimum specified temperature in any socket of the life test rack.

NOTES:

26. Order for evaluation of life test defects: see paragraph 4.11.3.1.2 in MIL-E-1D.

27. An inoperative, as referenced in life test, is defined as a tube having a discontinuity, permanent short, or air leak. Tubes are not to be tapped.

28. Basing, outline, and dimensions: see diagram on next page.

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