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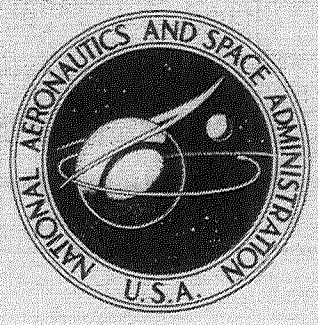

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COMPUTER-ACQUIRED PERFORMANCE DATA FROM AN ETCHED-RHENIUM, NIOBIUM THERMIONIC CONVERTER

by Richard B. Lancashire

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Cleveland, Ohio 44135

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16. Abstract

Performance data from an etched-rhenium, niobium thermionic converter are presented. The converter had a guard-ringed collector and a fixed space of 10 mils (0.254 mm). The data were obtained using a computer for data acquisition, and are presented on J, V and P, V curves. The diode was tested at emitter temperatures from 1550 K to 2010 K, collector temperatures from 850 K to 1180 K, and cesium reservoir temperatures from 525 K to 650 K.

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COMPUTER-ACQUIRED PERFORMANCE DATA FROM AN ETCHED-RHENIUM, NIOBIUM THERMIONIC CONVERTER

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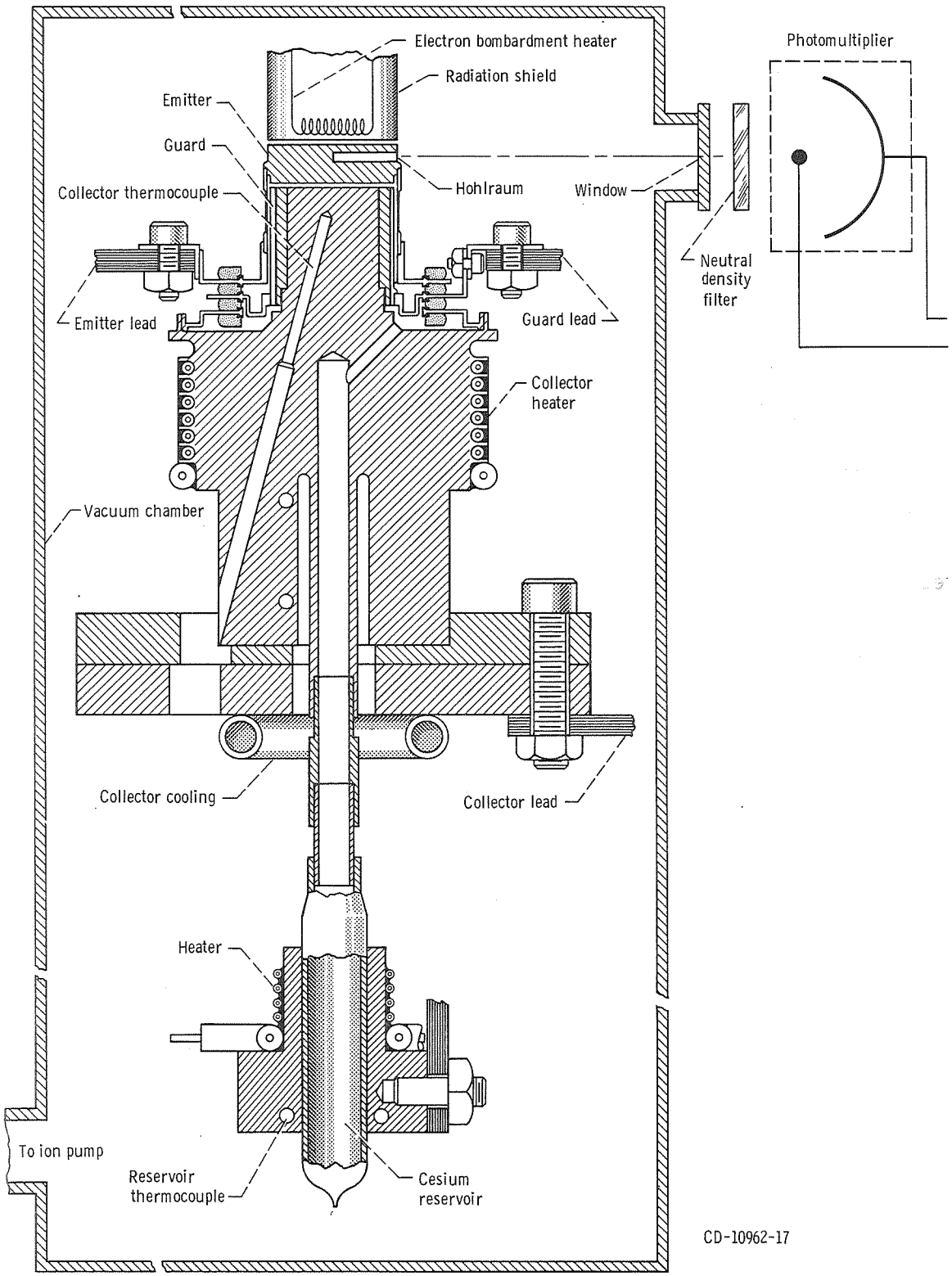
SUMMARY

The present performance data have been obtained from a thermionic converter with an etched-rhenium emitter and a niobium collector. The interelectrode spacing was 10 mils (0.254 mm) and the collector was guarded. The range of temperatures investigated was 1550 K to 2010 K for the emitter, 850 K to 1180 K for the collector, and 525 K to 650 K for the cesium reservoir. The data are presented on J, V and P, V plots in forms directly obtained from the computer.

INTRODUCTION

Lower operating temperatures associated with out-of-core thermionics allow the use of electrode materials that are prohibited by in-core operations. With this fact in mind, a program has been initiated to map the performance of six different electrode combinations using planar diodes with guarded collectors and 10-mil spacings (ref. 1). The first of these electrode combinations, reported herein, has an etched-rhenium emitter and a niobium collector.

The data are presented in J, V and P, V plots. They were gathered for emitter temperatures from 1550 K to 2010 K. Collector temperatures were varied from 850 K to 1180 K, and the cesium reservoir from 525 K to 650 K. The data were recorded using a computer-data acquisition system as described in reference 2. That system allows the rapid application of a variable transistorized load.



Converter configuration.

TEST FACILITY

Vacuum Stations

The converters were fabricated (see sketch), then filled with cesium by the contractor[1]. They may be mounted in any of six vacuum test stations which have a central instrumentation control panel. Each station has its own set of electron bombardment, collector, and cesium-reservoir heater supplies. Thermal balance of the collector and reservoir is achieved through conduction to water lines. Typical operating pressures under heat load for these systems are on the low end of the 10^{-7} torr scale after a thorough bakeout.

Instrumentation

The current developed in the converter was measured by the voltage drop across either a 0.01- or 0.1-ohm shunt. The variable transistorized load across the diode was pulsed using a triangular waveform with a period of approximately 10 milliseconds. The computer-data acquisition system (ref. 2), synchronized with this pulse, made 180 different data readings during the pulse. Sample-and-hold amplifiers were used to coordinate, in time, every three of these readings. Two of every three data observations were currents; one was amplified 10 times greater than the other. The third reading was the voltage developed between the emitter and collector. Thus, during a period of approximately 10 milliseconds, 60 synchronized current-voltage data points were obtained. The voltages were measured at the external shroud of the converter. No corrections were made for the voltage drop in the shroud since it is approximately 1.8 millivolts for 1 ampere per square centimeter. The area used in determining the current density was that of the collector, 1.55 square centimeters. The guard-ring was electrically connected to the circuit on the opposite side of the shunt from the collector.

The emitter temperature was measured by observing the total gray body radiation emitted by the edge of the emitter as viewed through a window in the vacuum chamber (see sketch). A fast-response photomultiplier was used for this measurement and was calibrated in situ using an optical pyrometer sighted on a black body cavity ($1/d = 5$) in the edge of the emitter. The pyrometer and window were calibrated using a National Bureau of Standards lamp. The maximum uncertainty associated with the observed temperature is approximately ±10 to 12 K, for an assumed black body cavity emissivity of 1.0. (Maximum uncertainty as used herein is defined to be the sum of the absolute mag-

[1]Thermo Electron Engineering Corp., Waltham, Massachusetts

nitudes of the standard deviations of the terms used in the statistical model treatment of the calibration and is considered to be a conservative estimate.) This estimate takes into account the uncertainties of the NBS calibration and of the reversal capabilities of the optical pyrometer and observer. The accuracy of the photo-tube measurement, because of its drift, changes in its sensitivity or gain, and its alinement were considered to be negligible since its calibration was checked before, during, and after each data run. The error in the total radiation measurement due to emissivity changes over the temperature range investigated was also considered to be negligible.

The observed emitter temperature was corrected for the gradient through the emitter to the active surface. The one-dimensional model used for this correction was one equating the thermal radiation across the interelectrode gap to the heat conducted through the emitter. The electron-bombardment filament used to heat the emitter was designed to nullify any heat flow through the emitter support-skirt. The model yielded the following equation

$$\Delta T_E = 1.87 \left(\frac{\epsilon}{\kappa}\right) \left(\frac{T_E}{1000}\right)^4 \left[1 - \left(\frac{T_C}{T_E}\right)^4\right]$$

where T_E is the observed emitter temperature; T_C, the collector temperature; ϵ, the effective emissivity of the active face of the emitter equal to 0.3 (ref. 3); and κ, the thermal conductivity of rhenium equal to 0.47 (ref. 4). The correction to the observed temperature amounts to -5 K at 1500 K to -18 K at 2000 K using the aforementioned values of ϵ and κ. Since few values of either ϵ or κ are presently available, there is a nondefinable uncertainty associated with the temperature correction. However, the values of the calculated corrections are believed to represent the minimum corrections to the temperature gradient. In any event, the corrections are small.

The collector and cesium reservoir temperatures were observed using chromel-alumel thermocouples embedded in the converter. Two couples were inserted at each location. The cesium reservoir couples were located in the copper block surrounding the copper tube containing the cesium (see sketch). The average of the two readings, which varied 2 to 3 K, is indicated on the data curves. The uncertainty of the indicated collector temperatures is approximately ±10 to 15 K. This uncertainty is based on an in situ calibration using a reference chromel-alumel thermocouple. All temperatures were recorded by the computer at the end of each pulse.

TEST PROCEDURE

The converter was mapped by fixing a cesium reservoir temperature and a collector temperature and ramping the emitter temperature, either upwards or downwards, by changing the input power to the emitter. Ten different emitter temperatures between 1550 K and 2000 K at approximately 50 K increments were observed in this manner. The collector temperature was then changed, and the preceding prodedure was repeated. Four different collector temperatures between 850 K and 1180 K at approximately 100 K increments were observed. The cesium reservoir temperature was then changed, and the procedure was again repeated. Six different reservoir temperatures between 525 K and 650 K at 25 K increments were established. At least one sweep or pulse of the variable electronic load was made at each one of the reservoir-, collector-, emitter-temperature combinations.

DATA PRESENTATION

The total number of J, V and P, V curves obtained from the mapping have been edited. Only those which were duplicates or indicated saturated amplifiers were eliminated from the curves presented. However, a few J, V curves are shown where the current amplifier became saturated near the end of a sweep, but the P, V curves indicated that the converter had passed its peak power output before the saturation. The curves, as presented, are the direct output from the computer. The square symbols indicate a change in voltage from right to left; the round symbols are from left to right.

The following table indicates the order of presentation of the J, V and P, V curves along with their respective operating conditions.

TABLE I. - TABULATION OF OPERATING CONDITIONS FOR J, V AND P, V CURVES

Emitter temperature, T_E, K	Collector temperature, T_C, K	Reservoir temperature, T_R, K	Sweep number
1557	854	533	125
1608	857	534	116
1591	856	576	177
1599	938	598	376
1603	938	622	388
1594	1055	599	365
1599	1036	623	400
1660	863	533	127
1654	863	576	176
1658	862	605	185
1662	857	623	197
1669	942	573	305
1667	1166	624	413
1705	866	534	117
1707	865	550	130
1704	867	576	175
1707	865	605	186
1704	879	623	207
1708	886	650	226
1694	941	528	233
1707	942	549	303
1708	942	573	306
1702	948	597	387
1707	945	622	390
1701	942	651	459
1690	1048	529	255
1709	1048	551	282
1691	1049	574	331
1715	1054	599	367
1699	1041	623	411
1698	1059	652	447
1710	1172	530	258
1710	1162	553	279
1699	1157	600	359
1703	1170	624	423
1756	869	549	131
1751	876	576	174
1761	869	605	187
1759	864	623	199
1761	864	650	215
1758	948	549	295
1768	948	573	307
1757	940	598	379
1753	942	623	391
1755	948	651	451
1761	1053	528	247
1764	1049	551	283
1758	1062	652	439
1767	1167	576	335
1764	1169	599	351
1752	1171	624	415
1757	1169	653	427
1820	874	533	118
1806	873	548	132
1807	884	576	173
1816	873	605	188
1809	894	623	206
1805	901	651	225
1806	950	549	302
1810	950	572	308
1808	945	597	386
1817	945	622	392
1800	941	650	458
1808	1055	528	254
1810	1050	550	290
1805	1056	574	330
1816	1067	599	368
1811	1056	623	410
1812	1053	652	446
1808	1181	529	266
1809	1179	552	278
1817	1167	576	336
1805	1172	600	358
1810	1156	624	422
1808	1167	653	434
1851	877	548	133
1856	882	575	168
1856	878	605	189

TABLE I. - Concluded. TABULATION OF OPERATING CONDITIONS FOR J, V AND P, V CURVES

Emitter temperature, T_E, K	Collector temperature, T_C, K	Reservoir temperature, T_R, K	Sweep number	Emitter temperature, T_E, K	Collector temperature, T_C, K	Reservoir temperature, T_R, K	Sweep number
1865	874	623	209	1953	897	605	191
1856	874	650	217	1956	888	623	211
				1959	903	650	220
1857	953	527	237				
1857	955	549	297	1960	960	548	299
1862	955	572	309	1955	960	572	311
1856	952	597	381	1963	964	597	383
1857	950	622	393	1962	968	622	395
1853	948	651	453	1956	966	650	455
1861	1060	528	249	1955	1067	574	327
1852	1064	551	285	1956	1067	599	371
1858	1063	574	325	1962	1062	623	407
1856	1070	599	369	1956	1068	652	443
1857	1062	623	405				
1855	1063	652	441	1958	1180	552	275
1857	1176	576	337	1954	1176	575	339
1858	1168	599	353	1955	1174	599	355
1859	1178	624	417	1955	1179	624	419
1854	1182	653	429	1959	1187	653	431
1904	883	531	119	2006	897	530	120
1897	883	550	141	2002	903	555	137
1904	884	576	169	2007	898	576	171
1902	883	605	190	2009	907	605	192
1897	900	623	205	2008	907	623	204
1902	880	650	219	2011	912	650	221
1904	957	549	298	2007	962	527	240
1900	957	573	310	2006	964	549	300
1899	957	597	385	2004	964	572	312
1903	961	622	394	2009	971	597	384
1905	954	650	454	2007	967	622	396
				2008	968	651	456
1904	1061	528	250	2009	1069	528	252
1901	1057	550	286	2010	1063	550	288
1902	1064	574	326	2006	1072	574	328
1899	1064	599	373	2008	1080	599	372
1904	1056	623	406	2008	1070	623	408
1903	1073	651	442	2007	1069	651	444
1903	1184	529	262	2010	1189	529	264
1901	1178	552	274	2006	1186	575	340
1902	1174	576	338	2009	1179	599	362
1902	1181	599	354	2010	1179	623	420
1904	1180	623	418	2012	1180	653	432
1901	1174	653	430				
1955	889	576	170				

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, January 25, 1971,
120-27.

REFERENCES

1. Speidel, T. O.; and Williams, R. M.: Fixed-Space Planar Thermionic Diode with Collector Guard Ring. Thermionic Conversion Specialist Conference. IEEE, 1968, pp. 113-117.

2. Breitwieser, R.; Manista, E. J.; and Smith, A. L.: Computerized Performance Mapping of a Thermionic Converter with Oriented Tungsten Electrodes. Presented at the IEEE Thermionic Conversion Specialist Conference, Carmel, Calif., Oct. 1969.

3. Kitrilakis, S.; Rufeh, F.; Lieb, D.; van Someren, L.; and Weinstein, J.: Thermionic Research Program. Vol. 1. Rep. TE-7-66, Thermo Electron Engineering Corp. (NASA CR-70467), Aug. 2, 1965.

4. Jun, C. K.; and Hoch, M.: Thermal Conductivity of Ta, W, Re from 1520° K to 2800° K. Univ. Cincinnati (AFML-TR-66-367), 1966.

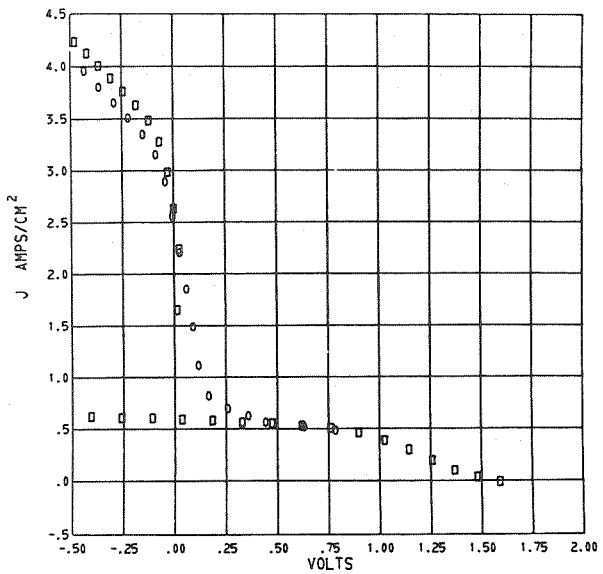


Figure 1. - Sweep 116; emitter temperature, 1608 K; collector temperature, 857 K; reservoir temperature, 534 K.

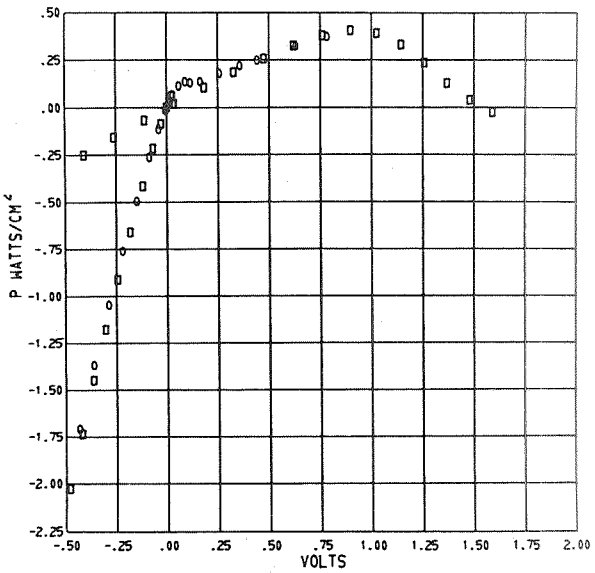


Figure 2. - Sweep 116; emitter temperature, 1608 K; collector temperature, 857 K; reservoir temperature, 534 K.

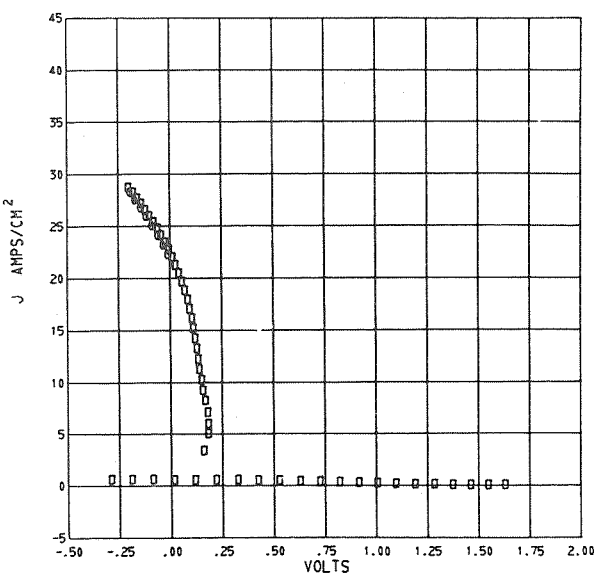


Figure 3. - Sweep 177; emitter temperature, 1591 K; collector temperature, 856 K; reservoir temperature, 576 K.

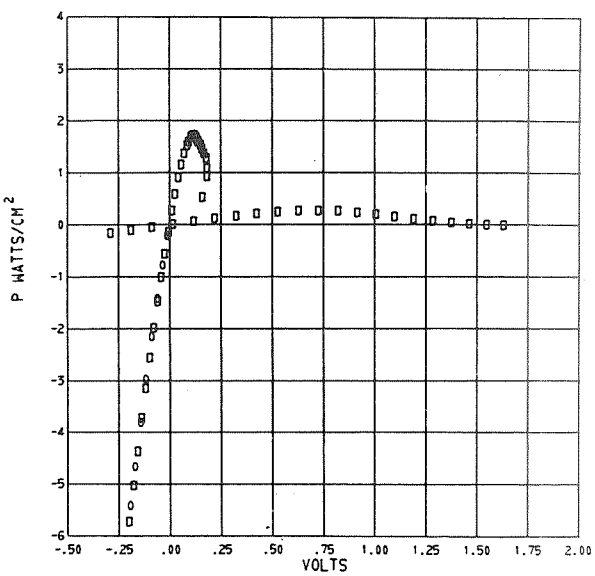


Figure 4. - Sweep 177; emitter temperature, 1591 K; collector temperature, 856 K; reservoir temperature, 576 K.

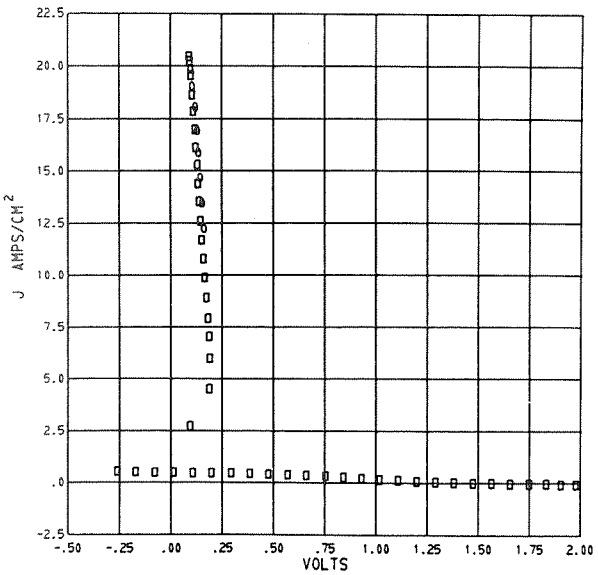


Figure 5. - Sweep 376; emitter temperature, 1599 K; collector temperature, 938 K; reservoir temperature, 598 K.

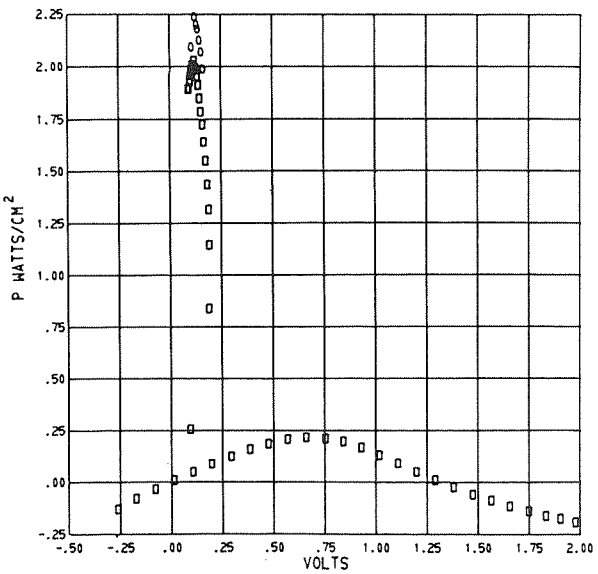


Figure 6. - Sweep 376; emitter temperature, 1599 K; collector temperature, 938 K; reservoir temperature, 598 K.

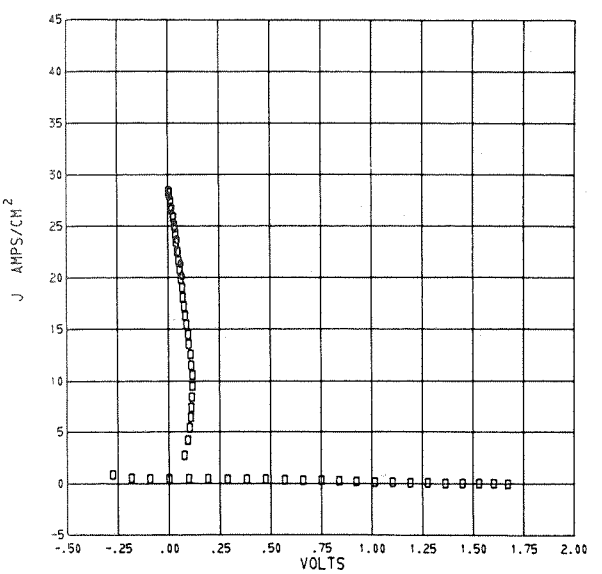


Figure 7. - Sweep 388; emitter temperature, 1603 K; collector temperature, 938 K; reservoir temperature, 622 K.

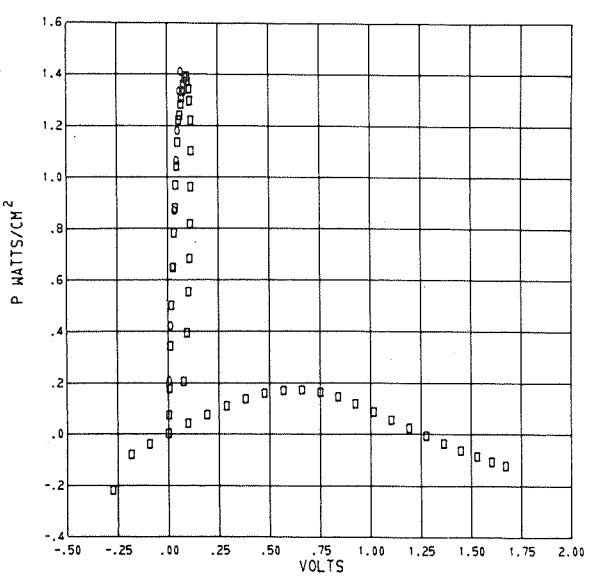


Figure 8. - Sweep 388; emitter temperature, 1603 K; collector temperature, 938 K; reservoir temperature, 622 K.

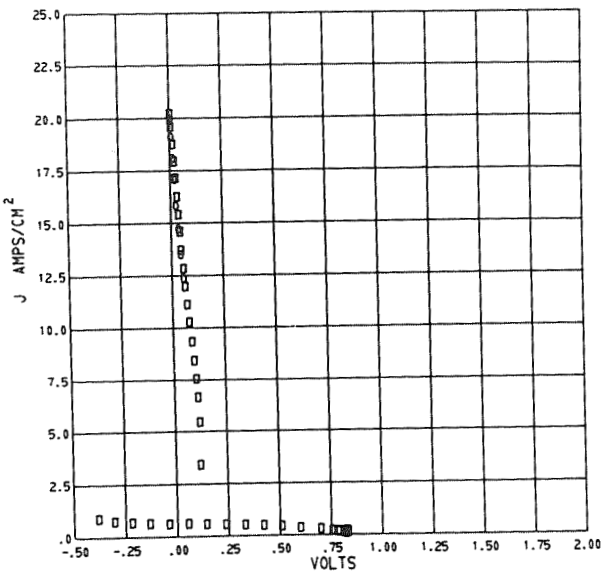


Figure 9. - Sweep 365; emitter temperature, 1954 K; collector temperature, 1055 K; reservoir temperature, 599 K.

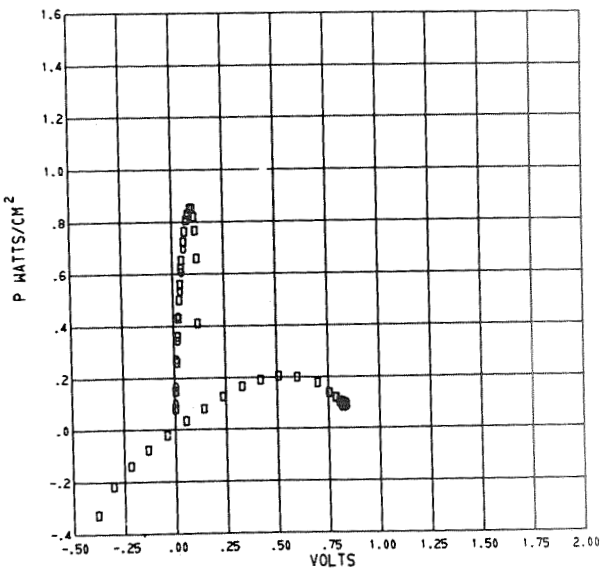


Figure 10. - Sweep 365; emitter temperature, 1594 K; collector temperature, 1055 K; reservoir temperature, 599 K.

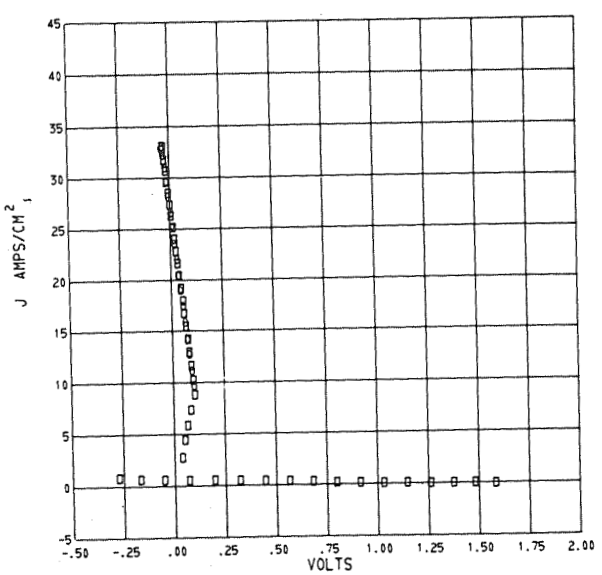


Figure 11. - Sweep 400; emitter temperature, 1599 K; collector temperature, 1036 K; reservoir temperature, 623 K.

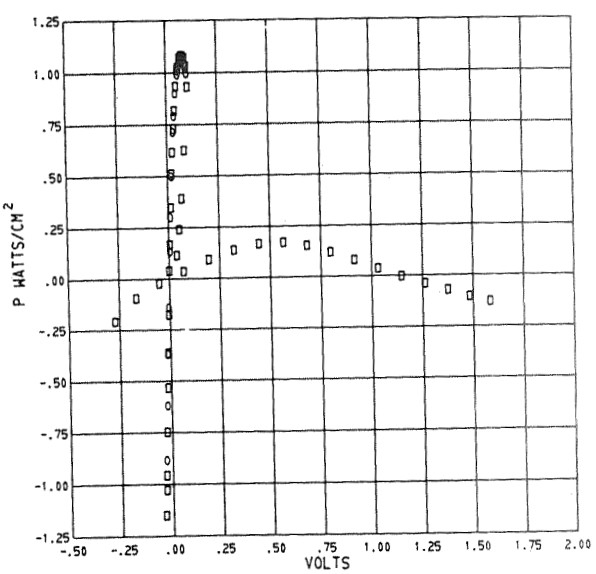


Figure 12. - Sweep 400; emitter temperature, 1599 K; collector temperature, 1036 K; reservoir temperature, 623 K.

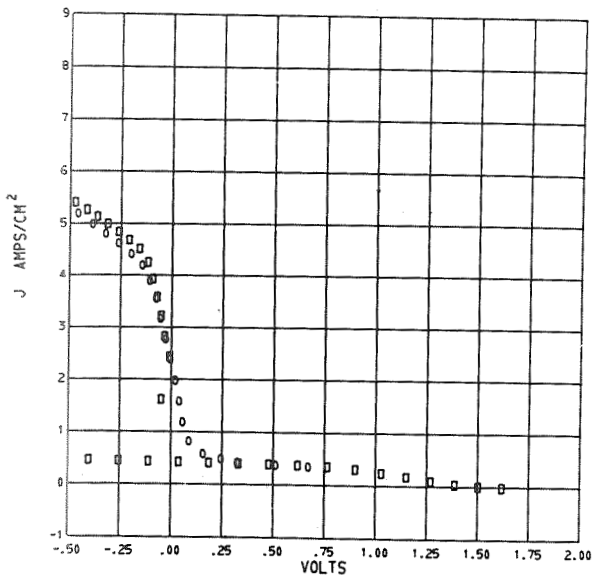


Figure 13. - Sweep 125; emitter temperature, 1557 K; collector temperature, 854 K; reservoir temperature, 533 K.

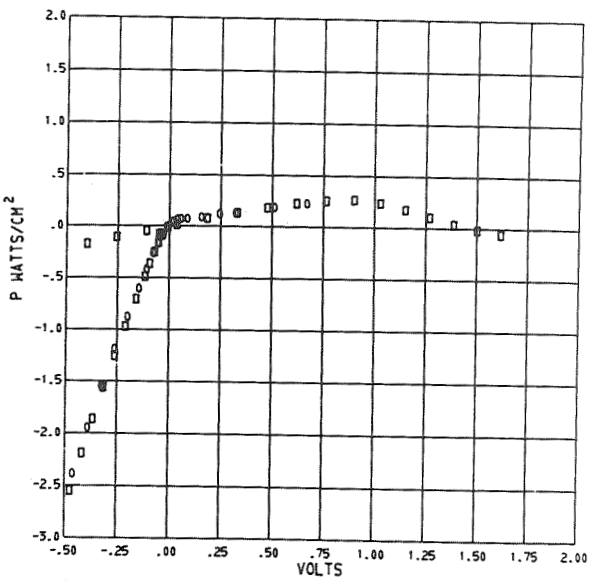


Figure 14. - Sweep 125; emitter temperature, 1557 K; collector temperature, 854 K; reservoir temperature, 533 K.

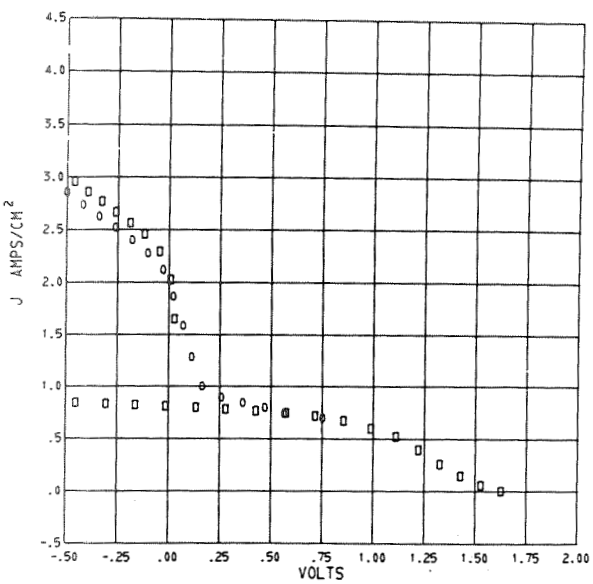


Figure 15. - Sweep 127; emitter temperature, 1660 K; collector temperature, 863 K; reservoir temperature, 533 K.

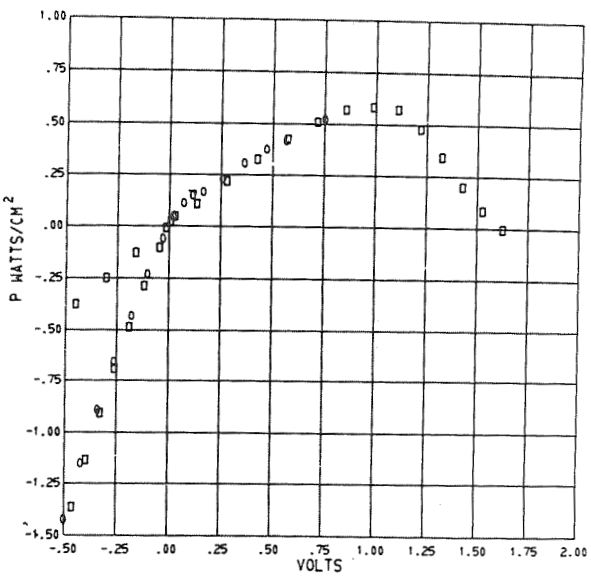


Figure 16. - Sweep 127; emitter temperature, 1660 K; collector temperature, 863 K; reservoir temperature, 533 K.

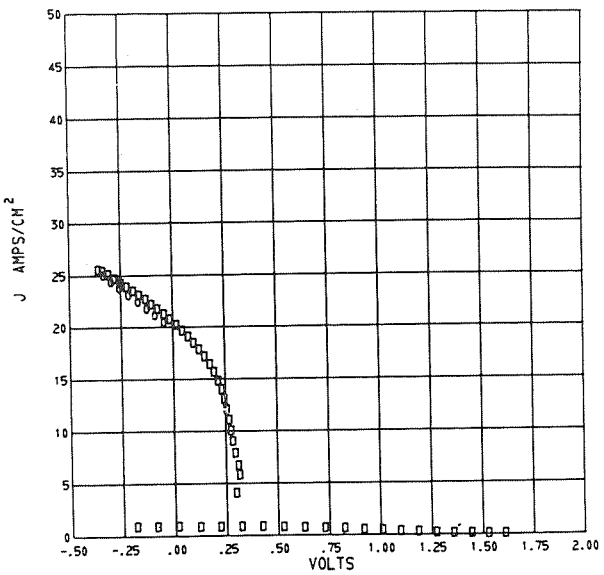


Figure 17. - Sweep 176; emitter temperature, 1654 K; collector temperature, 863 K; reservoir temperature, 576 K.

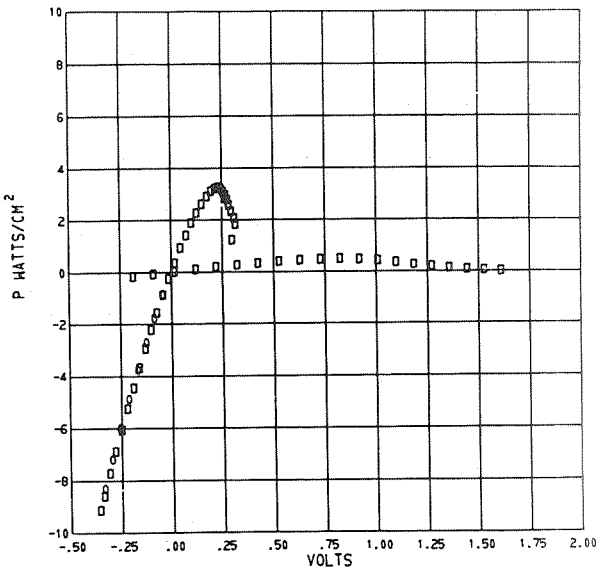


Figure 18. - Sweep 176; emitter temperature, 1654 K; collector temperature, 863 K; reservoir temperature, 576 K.

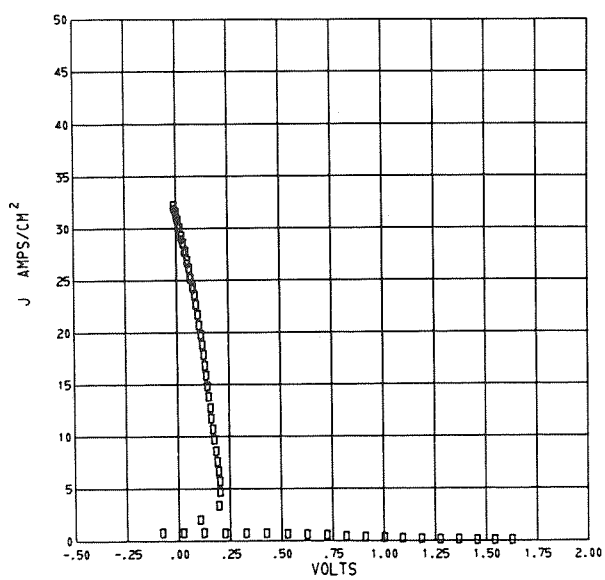


Figure 19. - Sweep 185; emitter temperature, 1658 K; collector temperature, 862 K; reservoir temperature, 605 K.

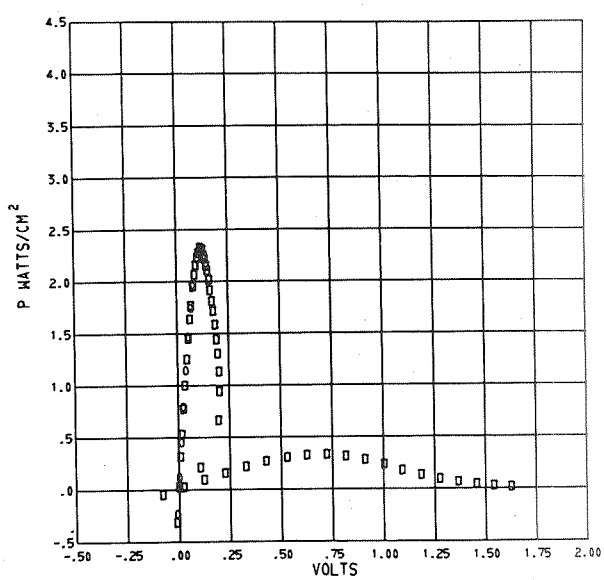


Figure 20. - Sweep 185; emitter temperature, 1658 K; collector temperature, 862 K; reservoir temperature, 605 K.

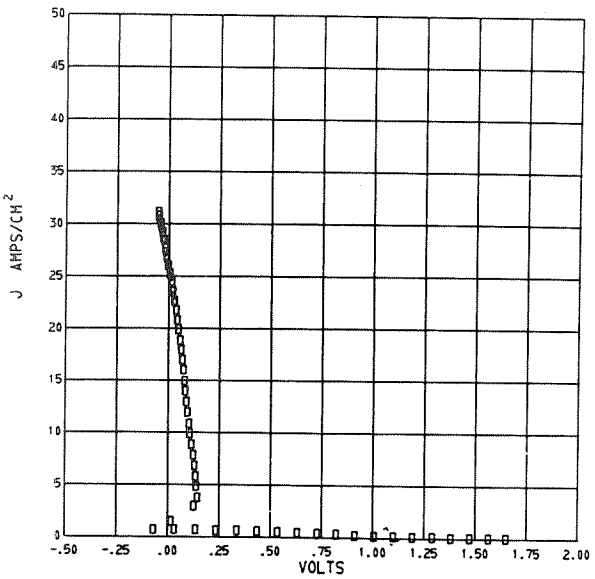


Figure 21. - Sweep 197; emitter temperature, 1662 K; collector temperature, 857 K; reservoir temperature, 623 K.

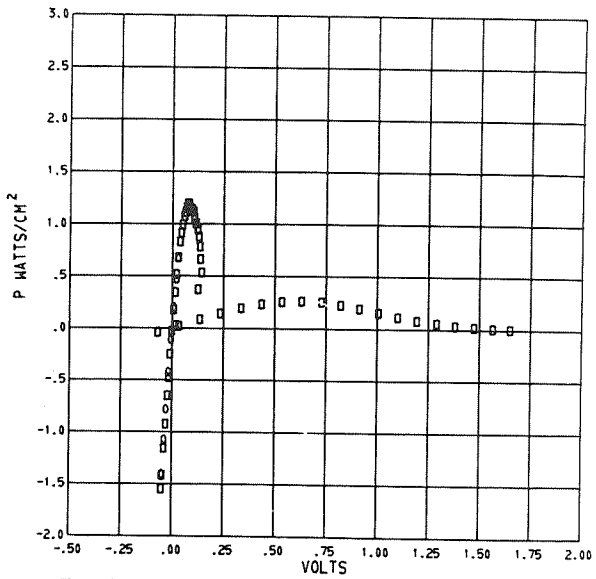


Figure 22. - Sweep 197; emitter temperature, 1662 K; collector temperature, 857 K; reservoir temperature, 623 K.

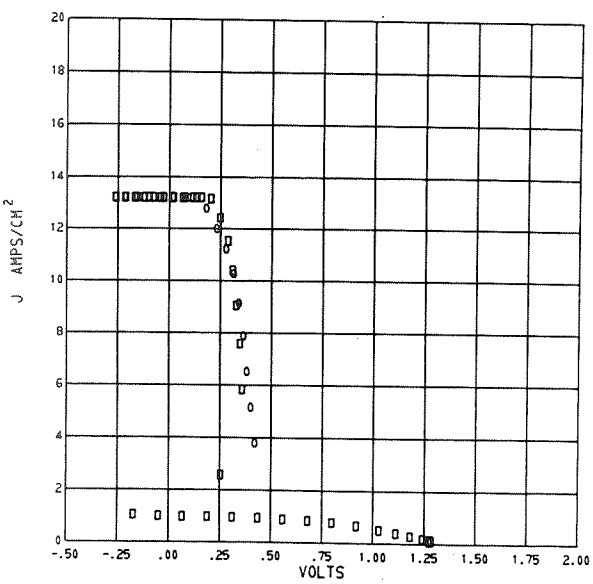


Figure 23. - Sweep 305; emitter temperature, 1669 K; collector temperature, 942 K; reservoir temperature, 573 K.

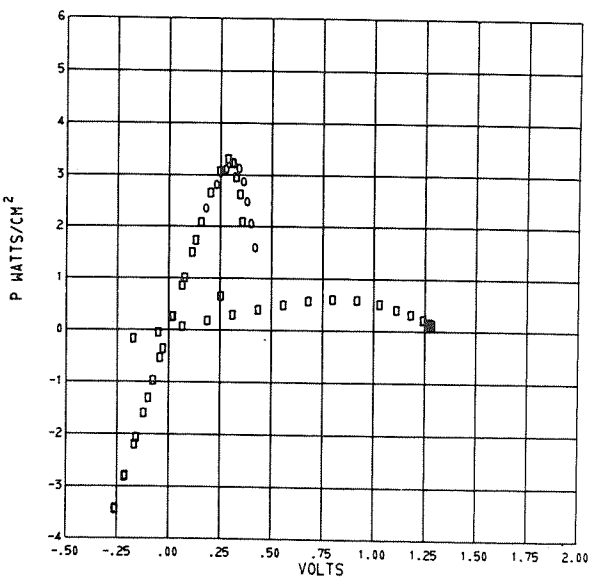


Figure 24. - Sweep 305; emitter temperature, 1669 K; collector temperature, 942 K; reservoir temperature, 573 K.

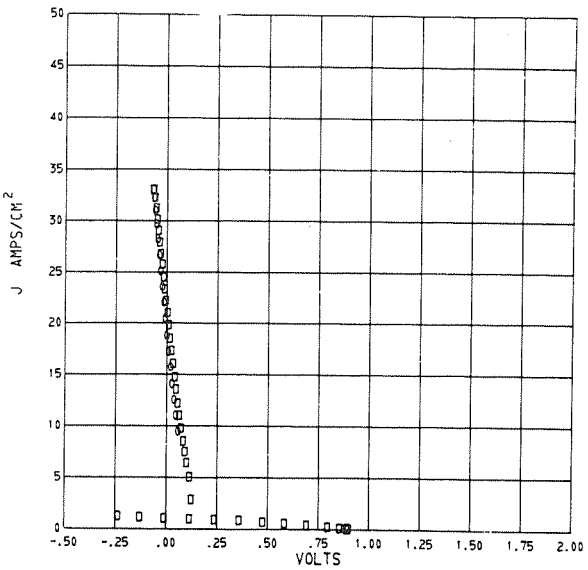


Figure 25. - Sweep 413; emitter temperature, 1667 K; collector temperature, 1166 K; reservoir temperature, 624 K.

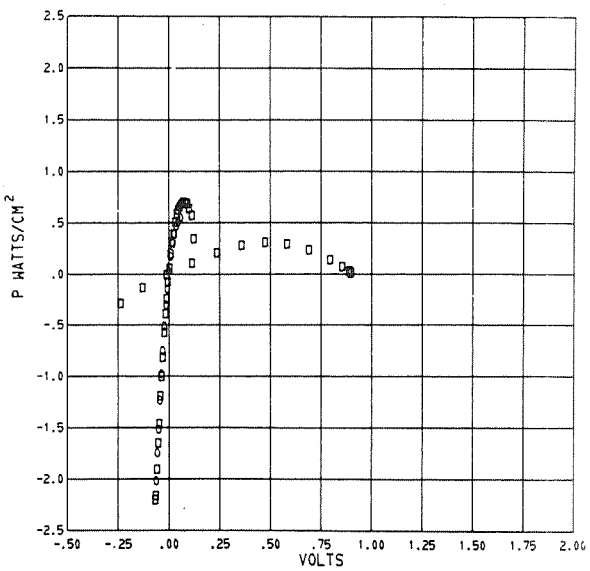


Figure 26. - Sweep 413; emitter temperature, 1667 K; collector temperature, 1166 K; reservoir temperature, 624 K.

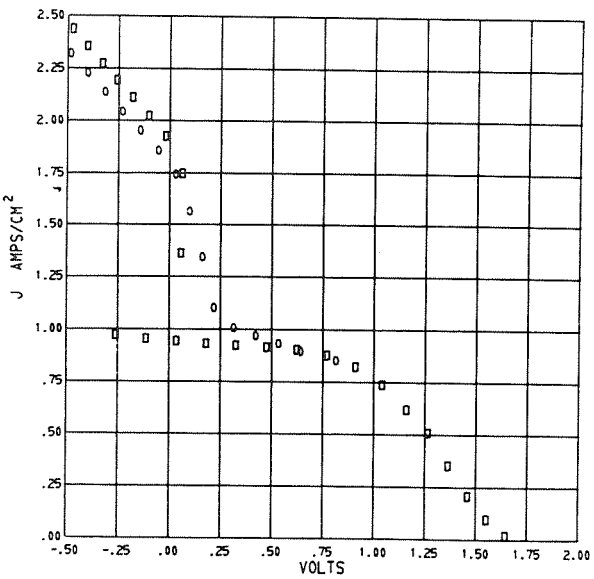


Figure 27. - Sweep 117; emitter temperature, 1705 K; collector temperature, 866 K; reservoir temperature, 534 K.

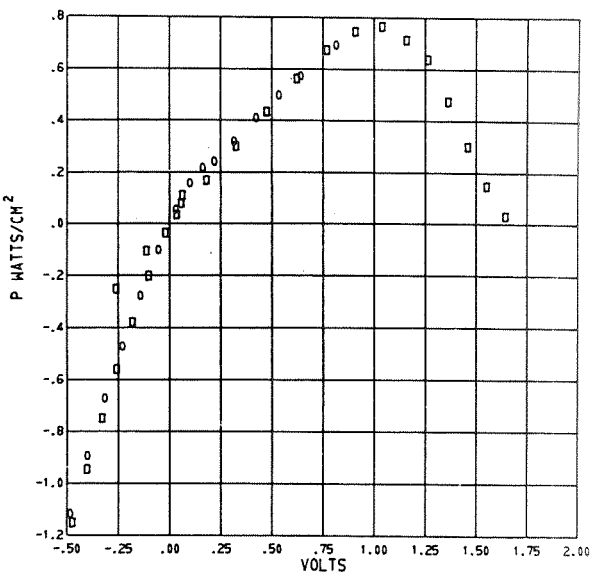


Figure 28. - Sweep 117; emitter temperature, 1705 K; collector temperature, 866 K; reservoir temperature, 534 K.

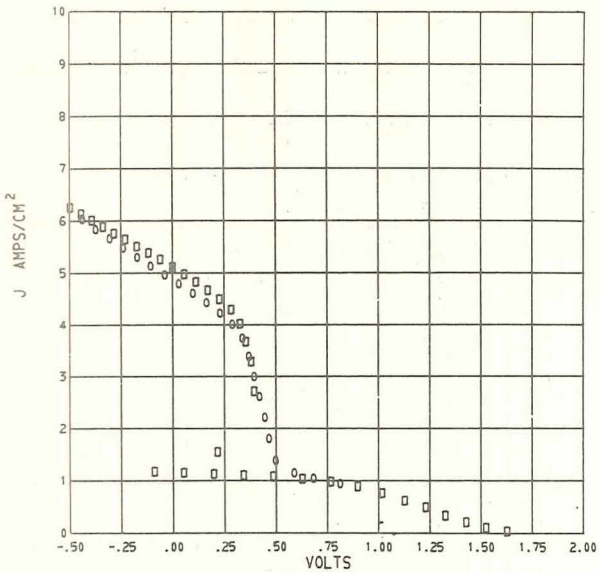


Figure 29. - Sweep 130; emitter temperature, 1707 K; collector temperature, 865 K; reservoir temperature, 550 K.

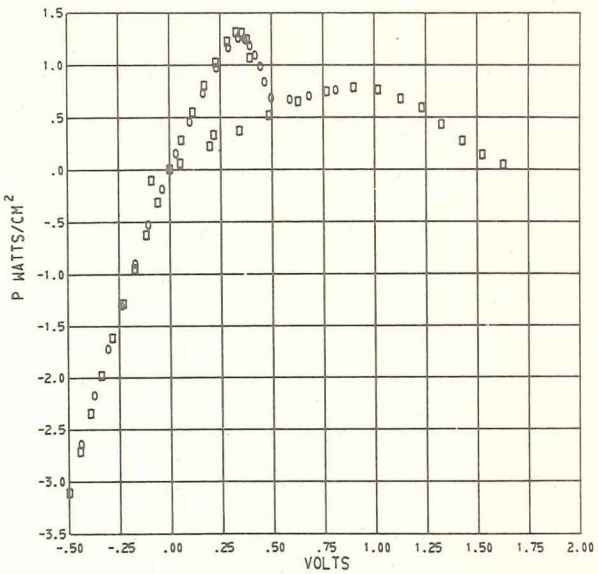


Figure 30. - Sweep 130; emitter temperature, 1707 K; collector temperature, 865 K; reservoir temperature, 550 K.

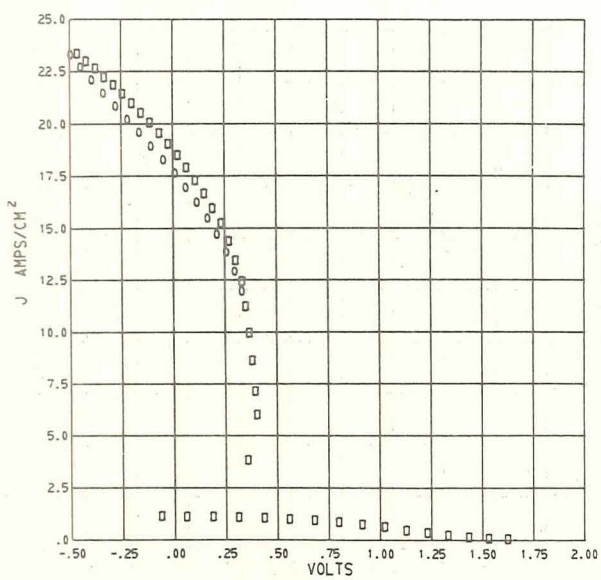


Figure 31. - Sweep 175; emitter temperature, 1704 K; collector temperature, 867 K; reservoir temperature, 576 K.

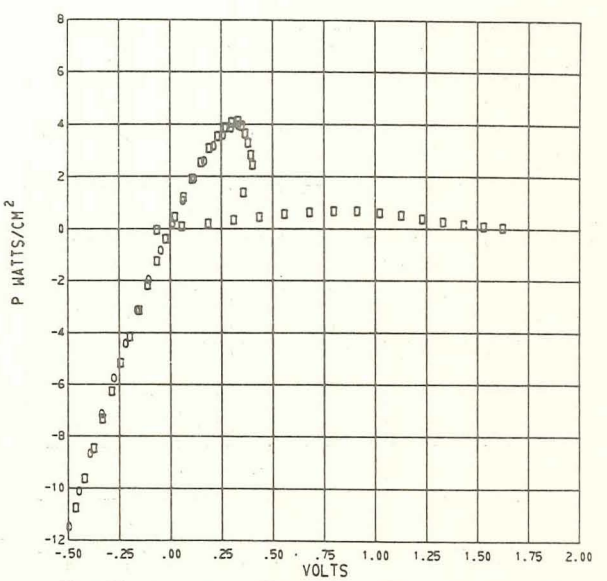


Figure 32. - Sweep 175; emitter temperature, 1704 K; collector temperature, 867 K; reservoir temperature, 576 K.

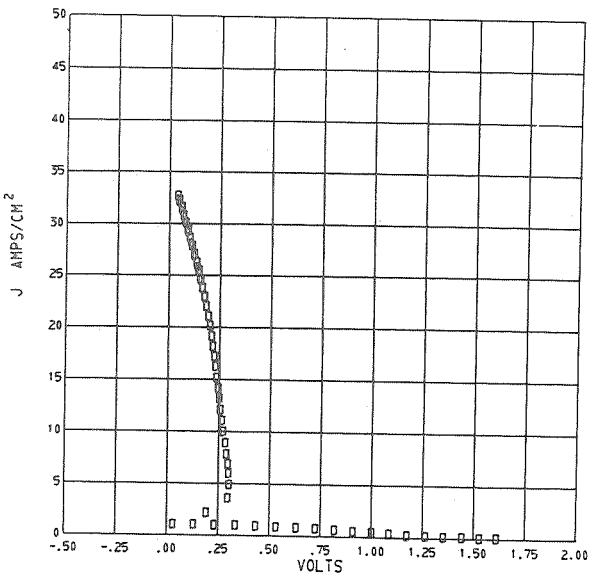


Figure 33. - Sweep 186; emitter temperature, 1707 K; collector temperature, 865 K; reservoir temperature, 605 K.

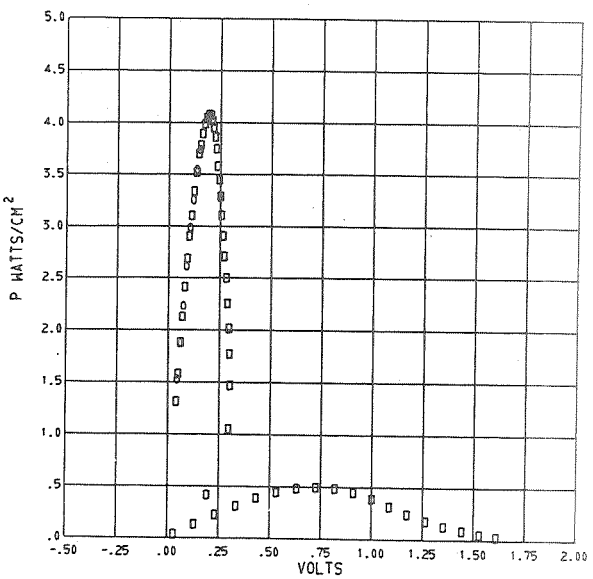


Figure 34. - Sweep 186; emitter temperature, 1707 K; collector temperature, 865 K; reservoir temperature, 605 K.

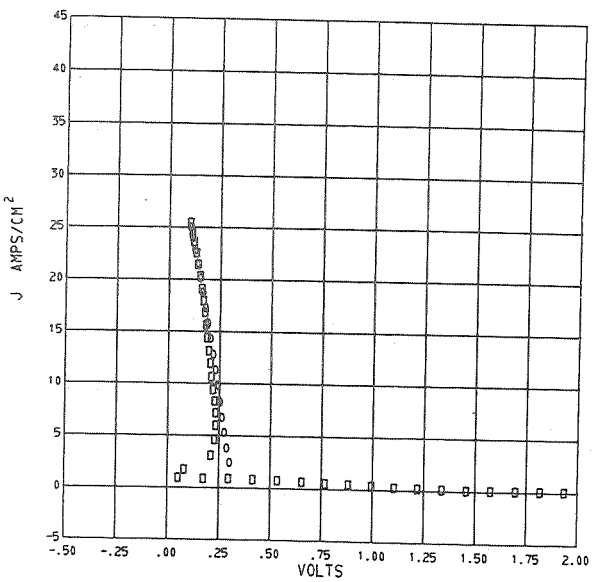


Figure 35. - Sweep 207; emitter temperature, 1704 K; collector temperature, 879 K; reservoir temperature, 623 K.

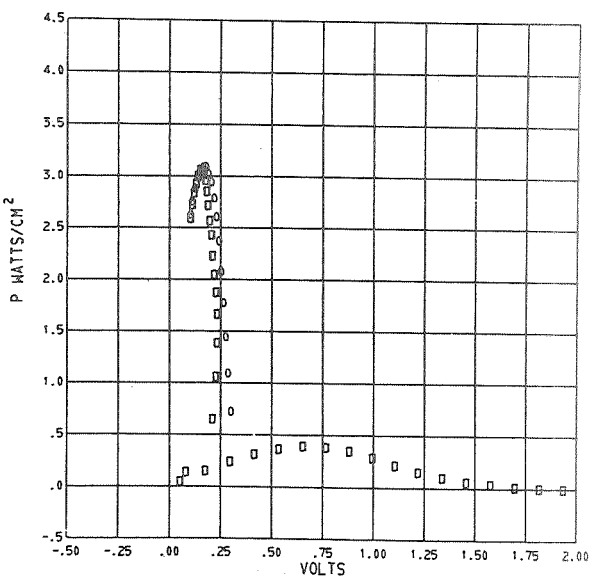


Figure 36. - Sweep 207; emitter temperature, 1704 K; collector temperature, 879 K; reservoir temperature, 623 K.

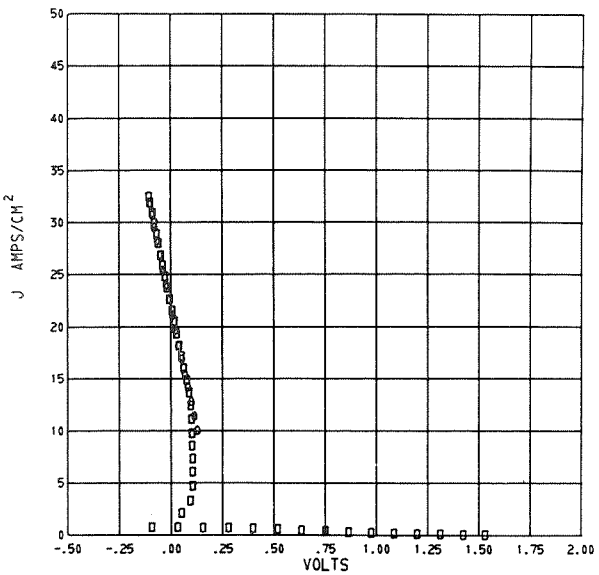


Figure 37. - Sweep 226; emitter temperature, 1708 K; collector temperature, 886 K; reservoir temperature, 650 K.

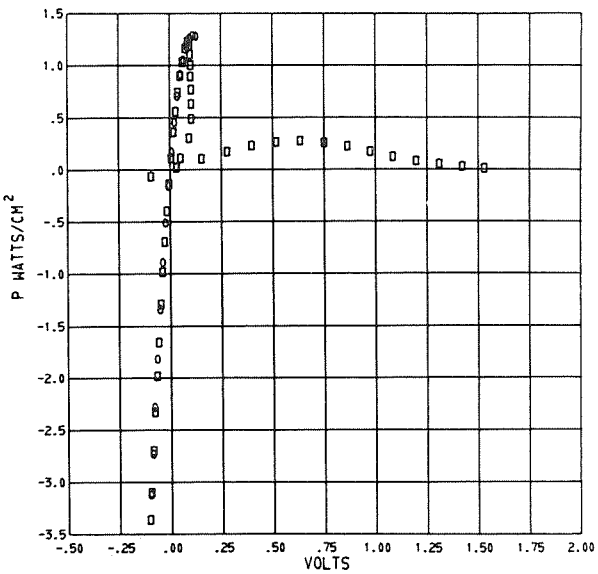


Figure 38. - Sweep 226; emitter temperature, 1708 K; collector temperature, 886 K; reservoir temperature, 650 K.

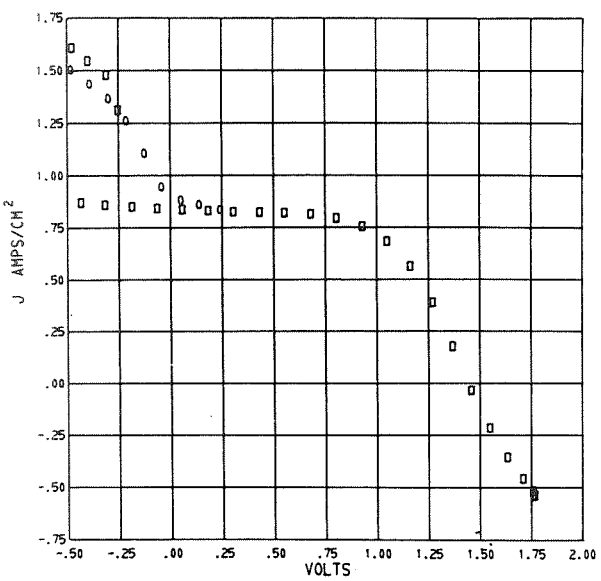


Figure 39. - Sweep 233; emitter temperature, 1694 K; collector temperature, 941 K; reservoir temperature, 528 K.

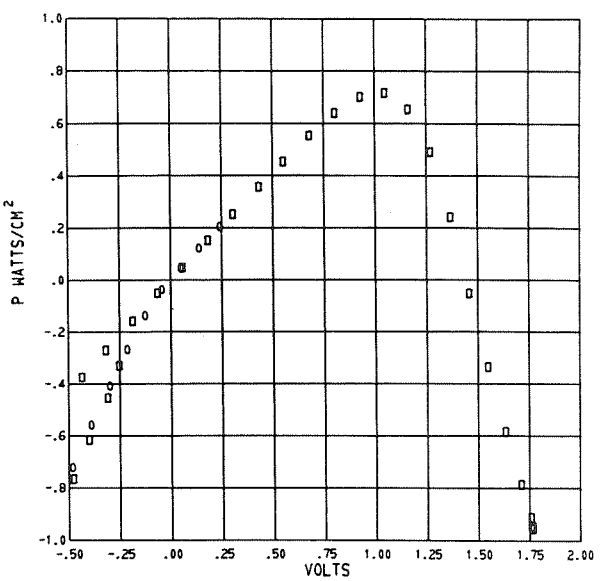


Figure 40. - Sweep 233; emitter temperature, 1694 K; collector temperature, 941 K; reservoir temperature, 528 K.

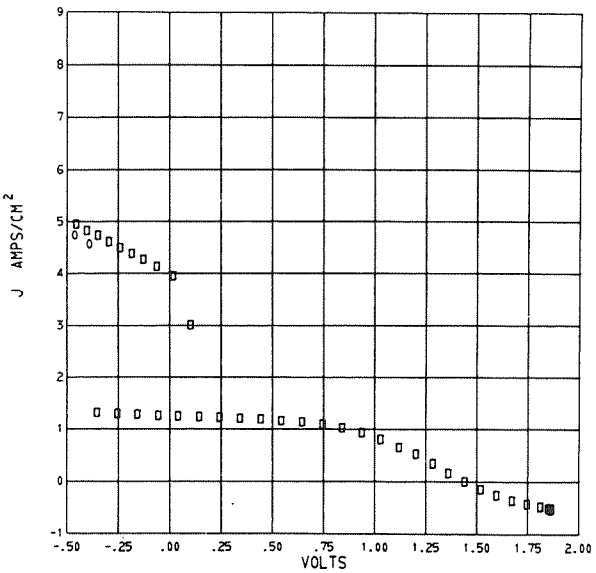


Figure 41. - Sweep 303; emitter temperature, 1707 K; collector temperature, 942 K; reservoir temperature, 549 K.

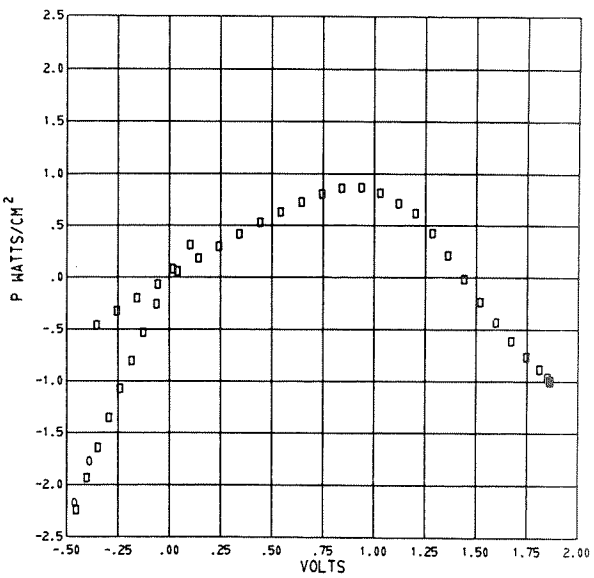


Figure 42. - Sweep 303; emitter temperature, 1707 K; collector temperature, 942 K; reservoir temperature, 549 K.

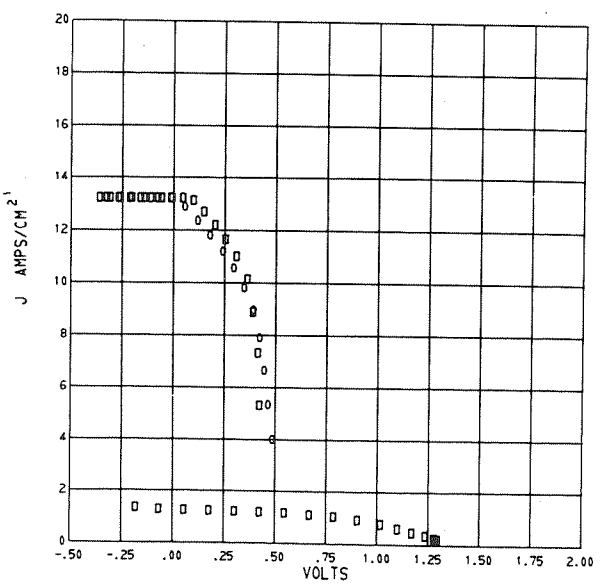


Figure 43. - Sweep 306; emitter temperature, 1708 K; collector temperature, 942 K; reservoir temperature, 573 K.

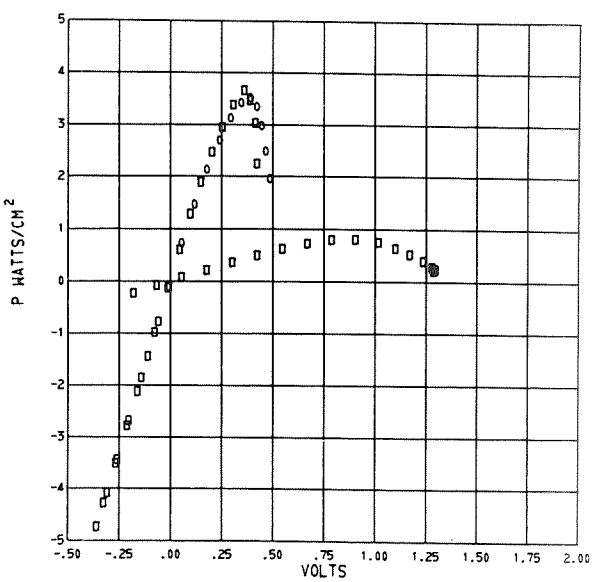


Figure 44. - Sweep 306; emitter temperature, 1708 K; collector temperature, 942 K; reservoir temperature, 573 K.

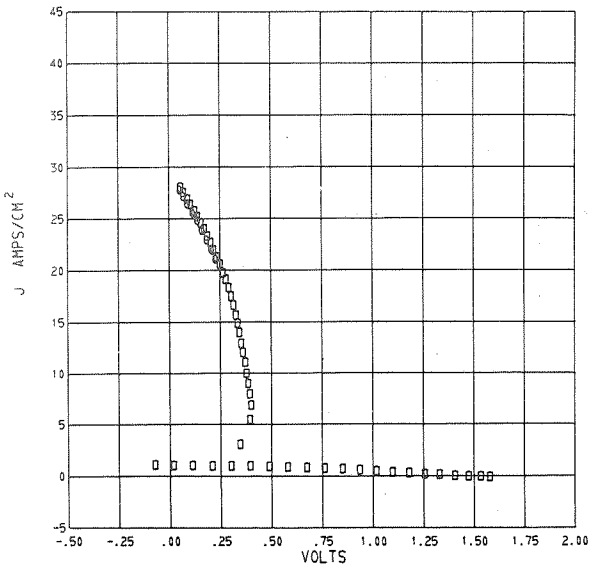


Figure 45. - Sweep 387; emitter temperature, 1702 K; collector temperature, 948 K; reservoir temperature, 597 K.

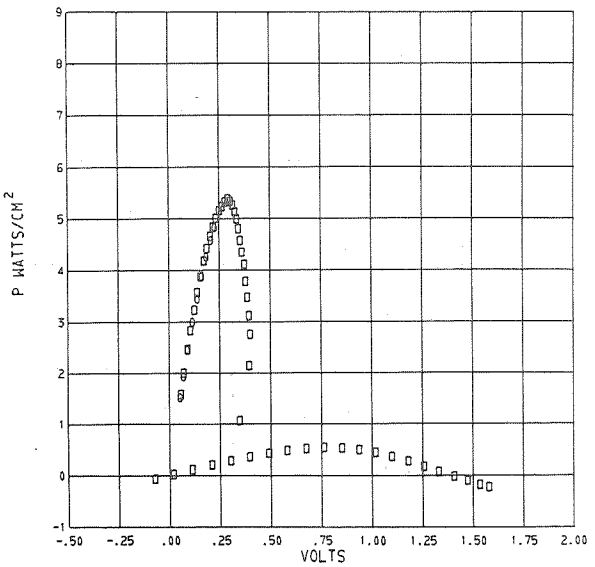


Figure 46. - Sweep 387; emitter temperature, 1702 K; collector temperature, 948 K; reservoir temperature, 597 K.

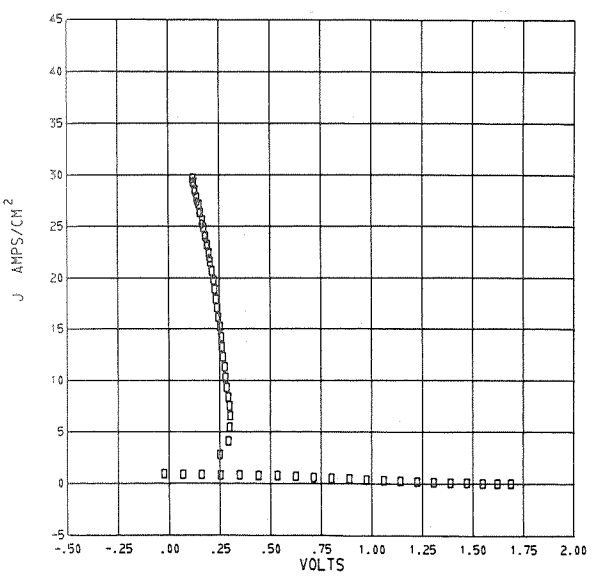


Figure 47. - Sweep 390; emitter temperature, 1707 K; collector temperature, 945 K; reservoir temperature, 622 K.

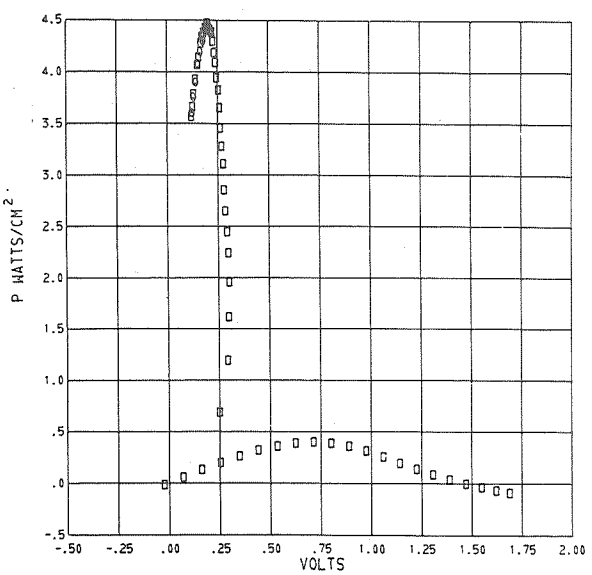


Figure 48. - Sweep 390; emitter temperature, 1707 K; collector temperature, 945 K; reservoir temperature, 622 K.

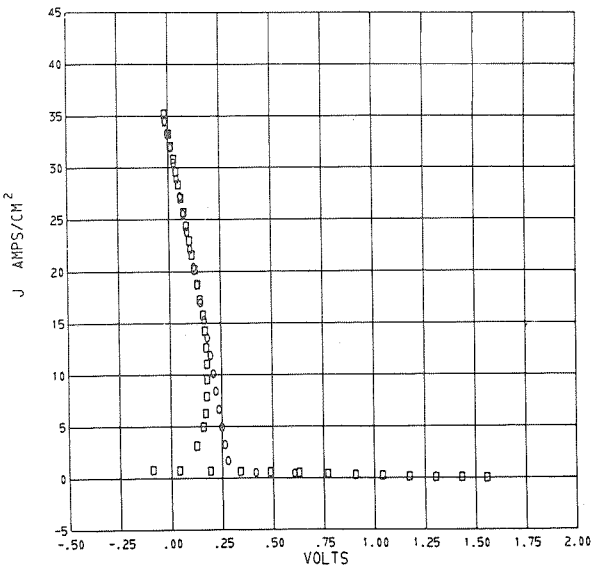


Figure 49. - Sweep 459; emitter temperature, 1700 K; collector temperature, 942 K; reservoir temperature, 651 K.

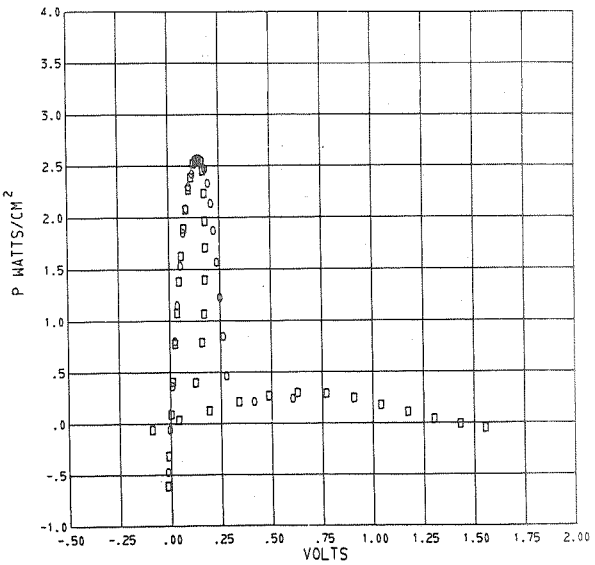


Figure 50. - Sweep 459; emitter temperature, 1700 K; collector temperature, 942 K; reservoir temperature, 651 K.

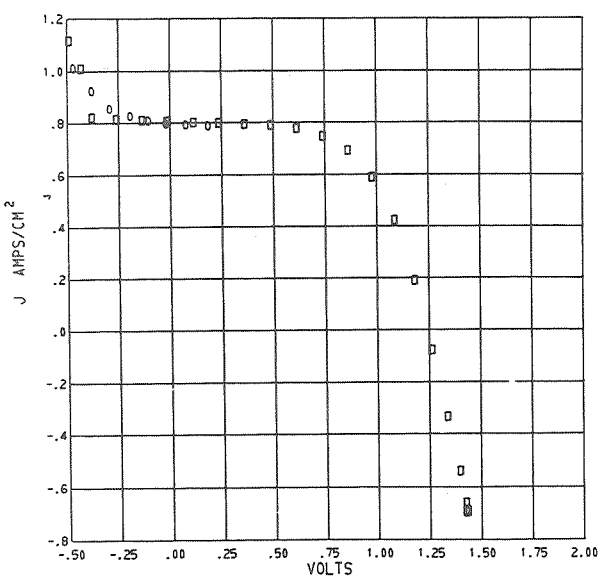


Figure 51. - Sweep 255; emitter temperature, 1690 K; collector temperature, 1048 K; reservoir temperature, 529 K.

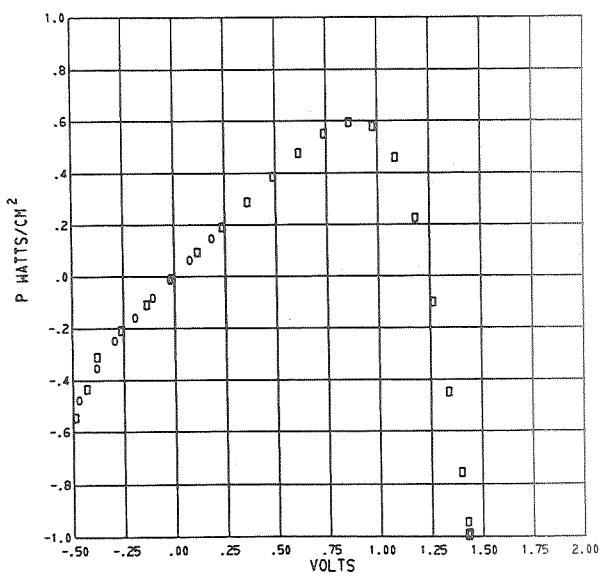


Figure 52. - Sweep 255; emitter temperature, 1690 K; collector temperature, 1048 K; reservoir temperature, 529 K.

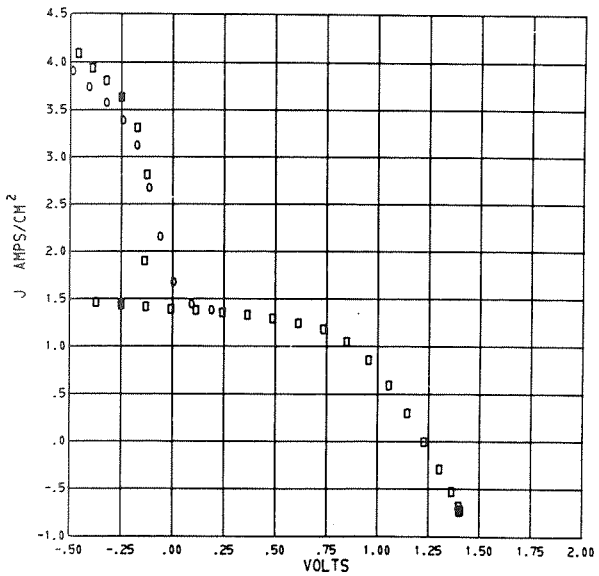


Figure 53. - Sweep 282; emitter temperature, 1709 K; collector temperature, 1048 K; reservoir temperature, 551 K.

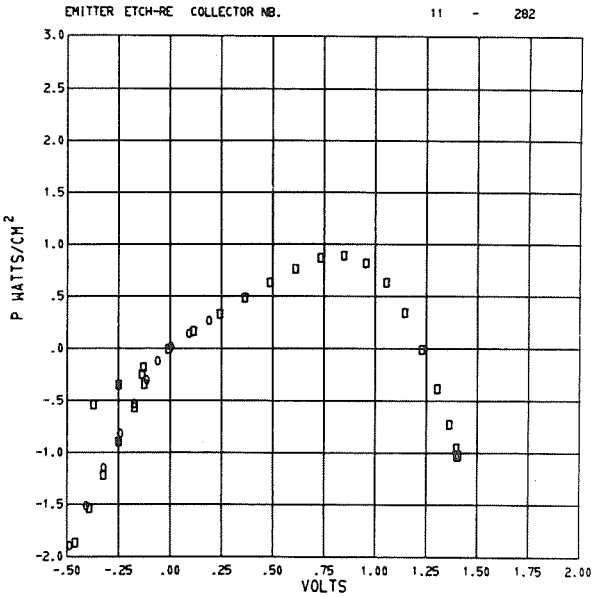


Figure 54. - Sweep 282; emitter temperature, 1709 K; collector temperature, 1048 K; reservoir temperature, 551 K.

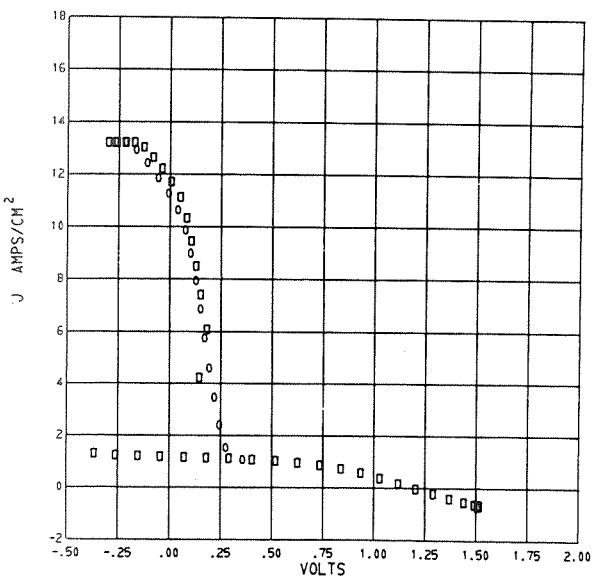


Figure 55. - Sweep 331; emitter temperature, 1691 K; collector temperature, 1049 K; reservoir temperature, 574 K.

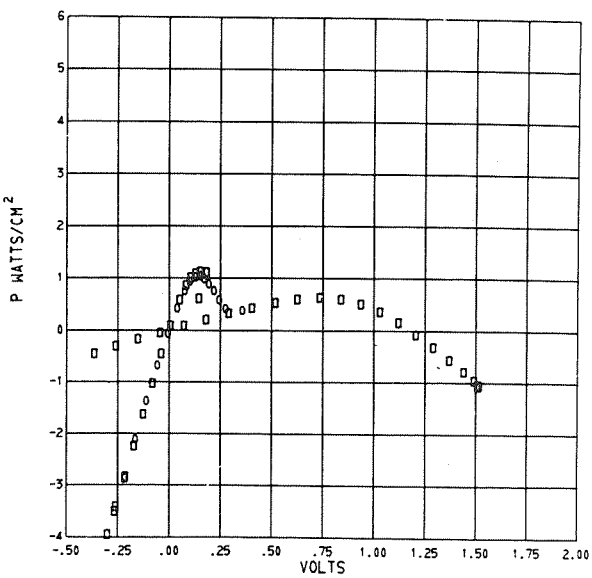


Figure 56. - Sweep 331; emitter temperature, 1691 K; collector temperature, 1049 K; reservoir temperature, 574 K.

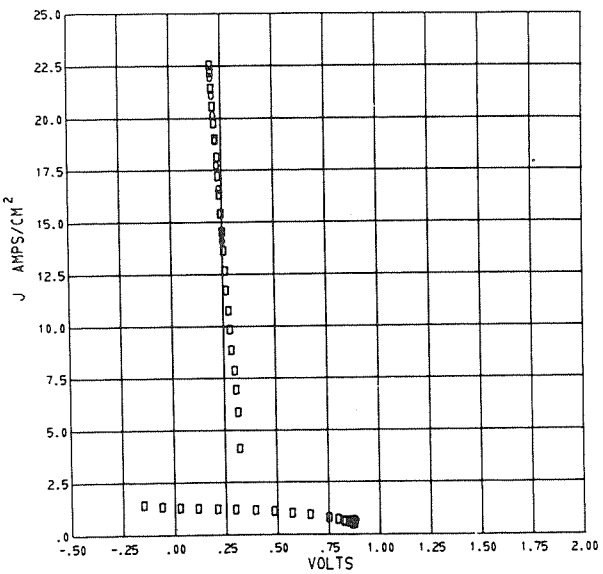


Figure 57. - Sweep 367; emitter temperature, 1715 K; collector temperature, 1054 K; reservoir temperature, 599 K.

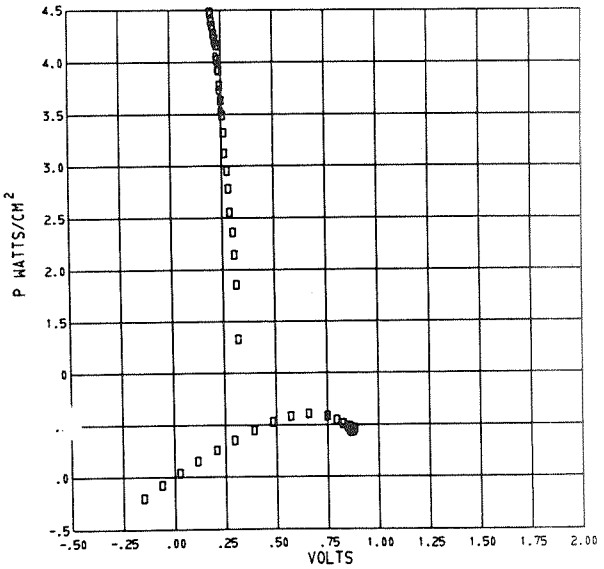


Figure 58. - Sweep 367; emitter temperature, 1715 K; collector temperature, 1054 K; reservoir temperature, 599 K.

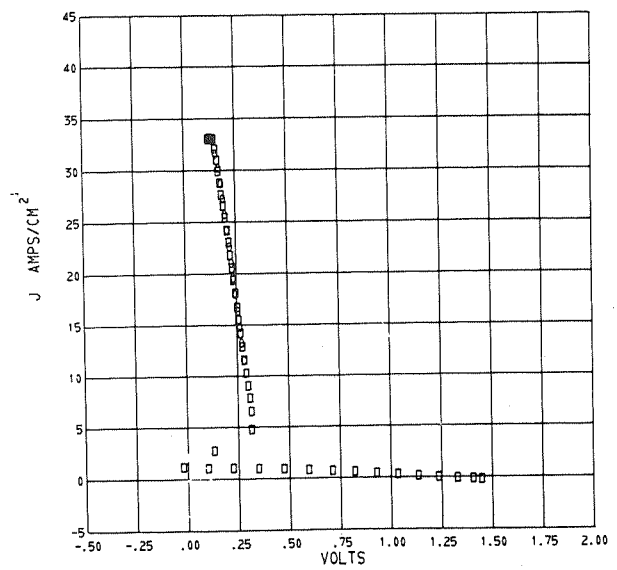


Figure 59. - Sweep 411; emitter temperature, 1699 K; collector temperature, 1041 K; reservoir temperature, 623 K.

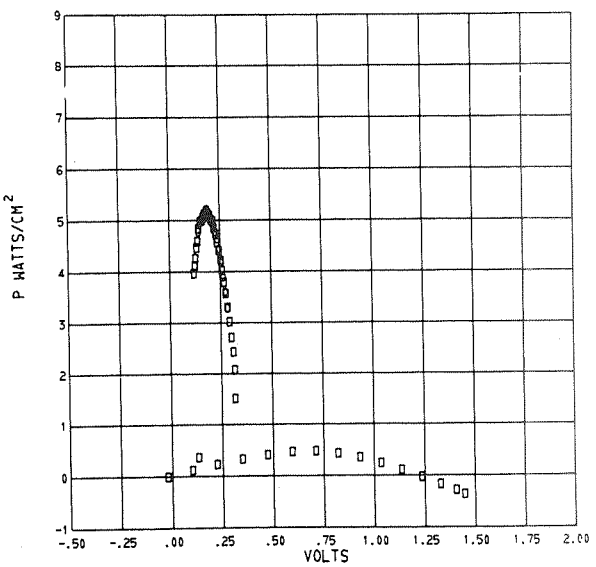


Figure 60. - Sweep 411; emitter temperature, 1699 K; collector temperature, 1041 K; reservoir temperature, 623 K.

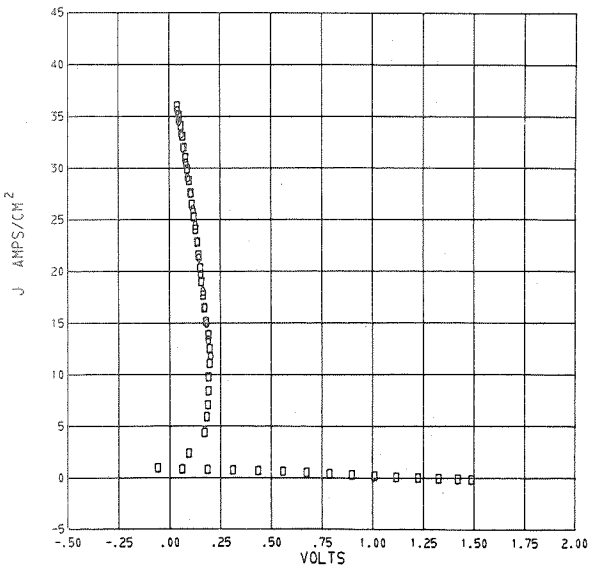


Figure 61. - Sweep 447; emitter temperature, 1698 K; collector temperature, 1059 K; reservoir temperature, 652 K.

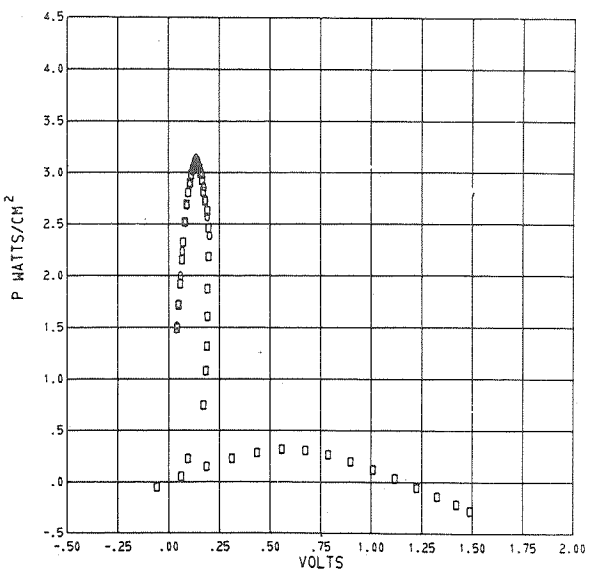


Figure 62. - Sweep 447; emitter temperature, 1698 K; collector temperature, 1059 K; reservoir temperature, 652 K.

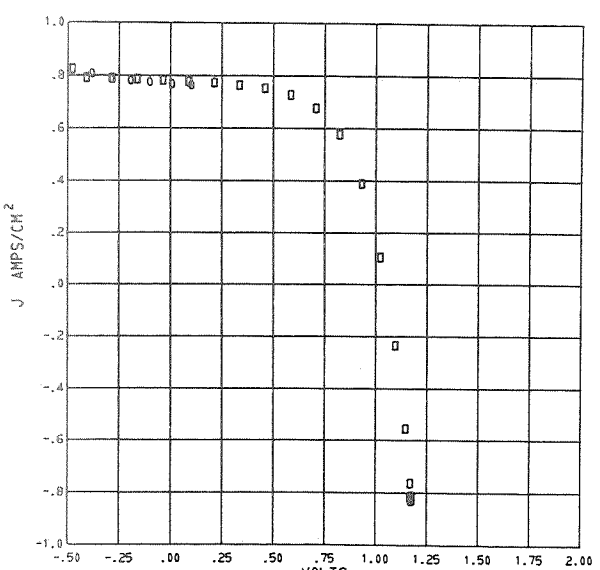


Figure 63. - Sweep 258; emitter temperature, 1710 K; collector temperature, 1172 K; reservoir temperature, 530 K.

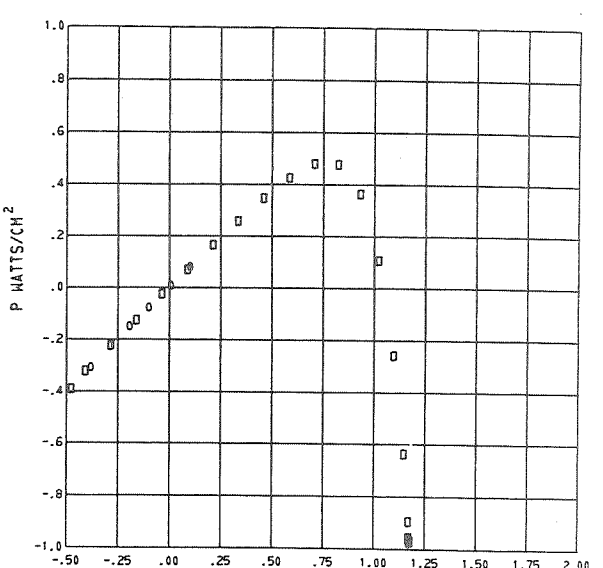


Figure 64. - Sweep 258; emitter temperature, 1710 K; collector temperature, 1172 K; reservoir temperature, 530 K.

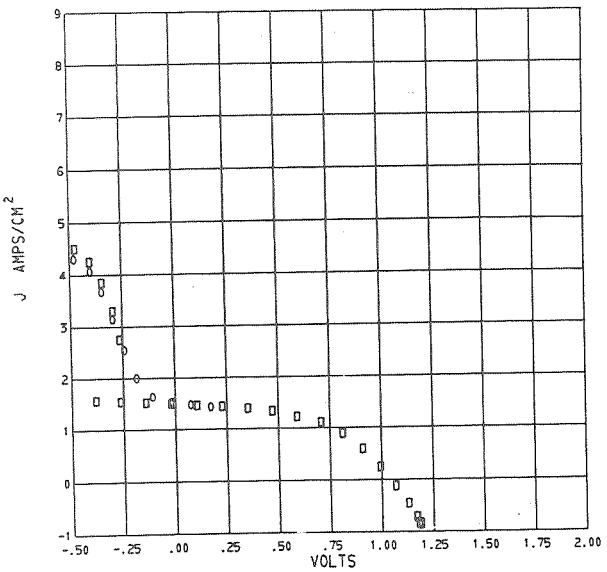


Figure 65. - Sweep 279; emitter temperature, 1701 K; collector temperature, 1162 K; reservoir temperature, 553 K.

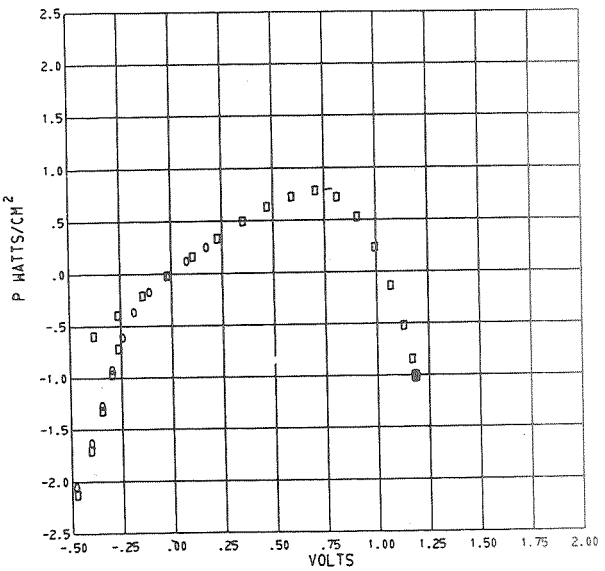


Figure 66. - Sweep 279; emitter temperature, 1701 K; collector temperature, 1162 K; reservoir temperature, 553 K.

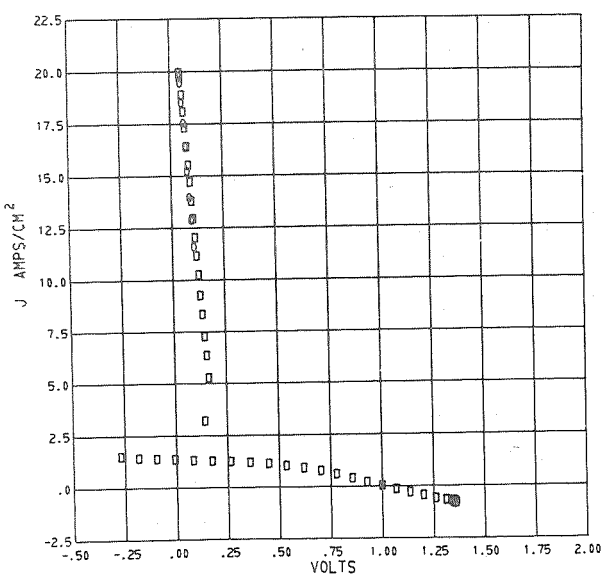


Figure 67. - Sweep 359; emitter temperature, 1699 K; collector temperature, 1157 K; reservoir temperature, 600 K.

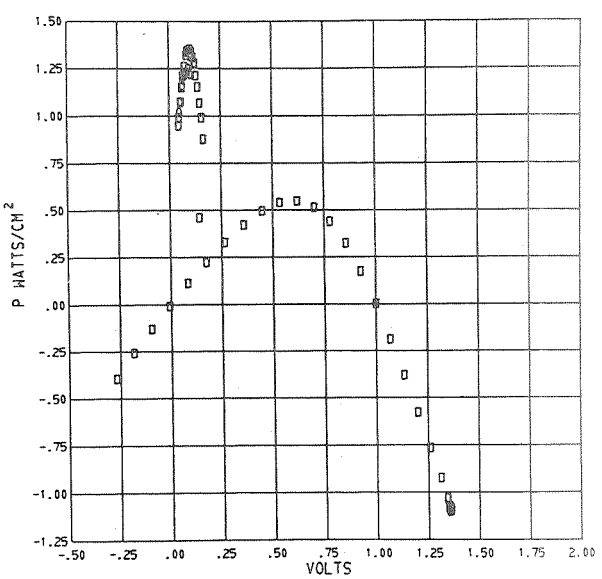


Figure 68. - Sweep 359; emitter temperature, 1699 K; collector temperature, 1157 K; reservoir temperature, 600 K.

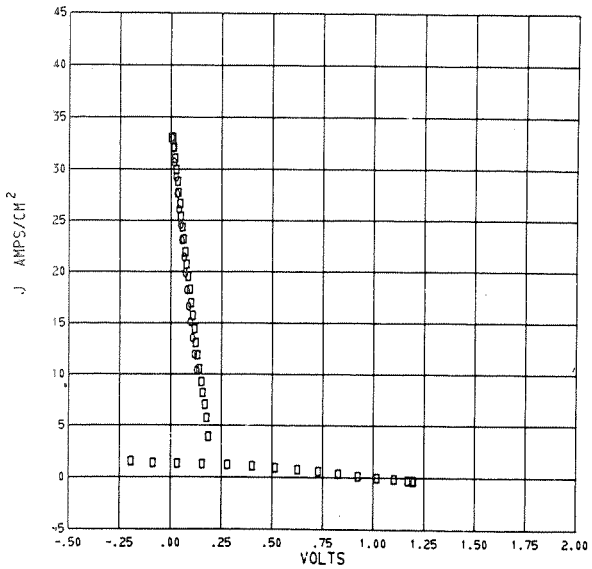


Figure 69. - Sweep 423; emitter temperature, 1703 K; collector temperature, 1170 K; reservoir temperature, 624 K.

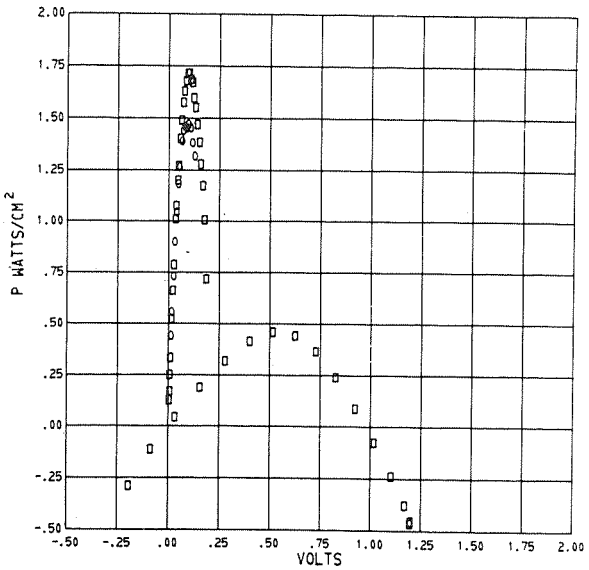


Figure 70. - Sweep 423; emitter temperature, 1703 K; collector temperature, 1170 K; reservoir temperature, 624 K.

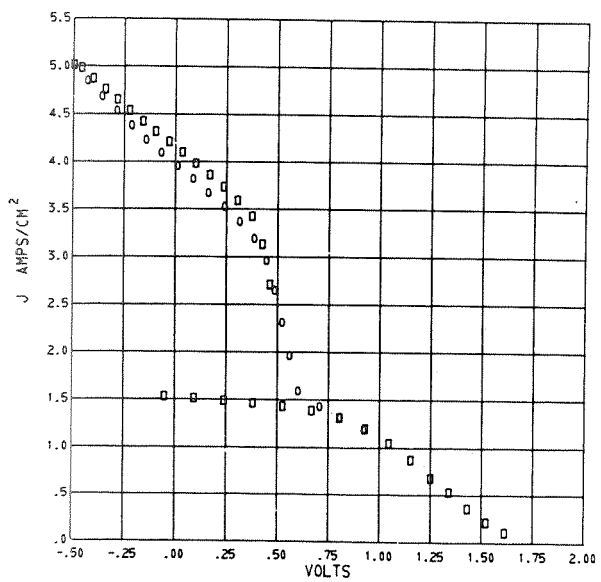


Figure 71. - Sweep 131; emitter temperature, 1756 K; collector temperature, 869 K; reservoir temperature, 549 K.

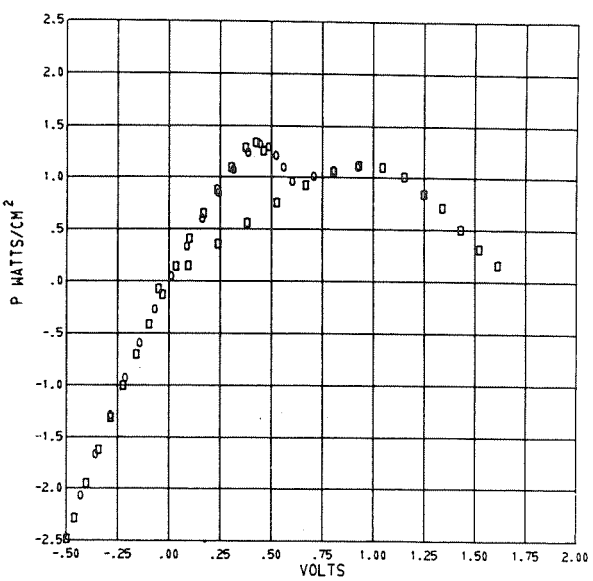


Figure 72. - Sweep 131; emitter temperature, 1756 K; collector temperature, 869 K; reservoir temperature, 549 K.

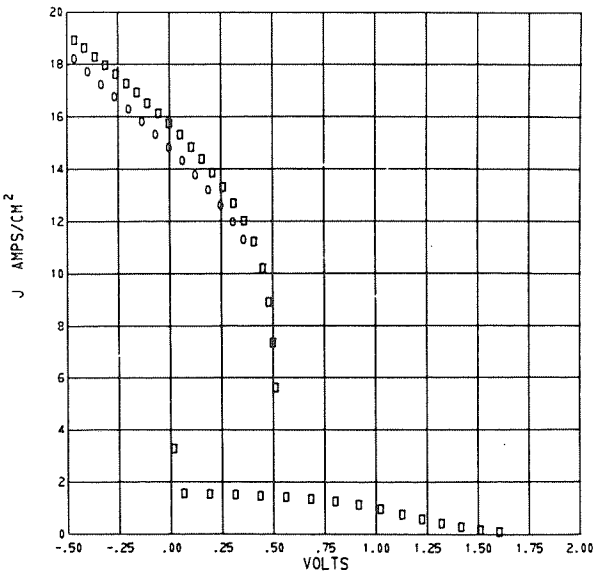


Figure 73. - Sweep 174; emitter temperature, 1751 K; collector temperature, 876 K; reservoir temperature, 576 K.

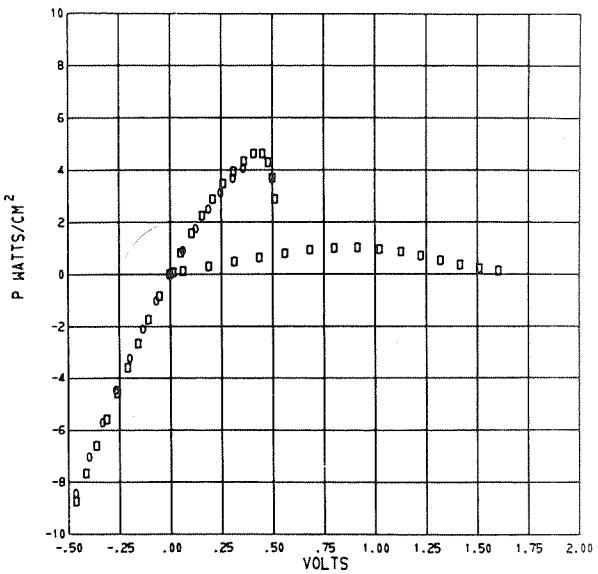


Figure 74. - Sweep 174; emitter temperature, 1751 K; collector temperature, 876 K; reservoir temperature, 576 K.

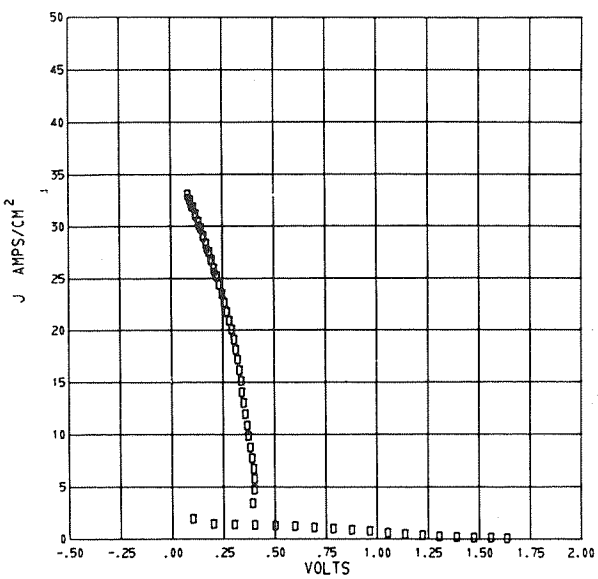


Figure 75. - Sweep 187; emitter temperature, 1761 K; collector temperature, 869 K; reservoir temperature, 605 K.

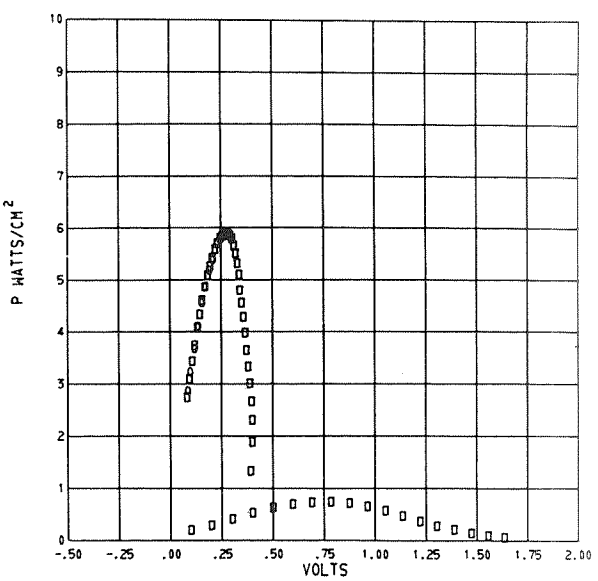


Figure 76. - Sweep 187; emitter temperature, 1761 K; collector temperature, 869 K; reservoir temperature, 605 K.

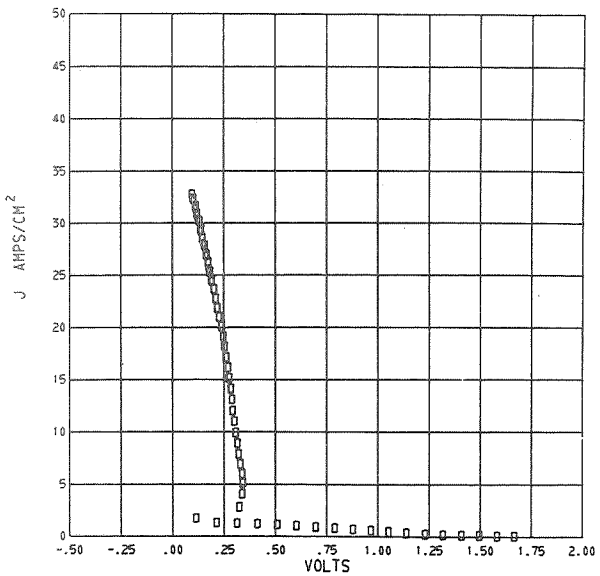


Figure 77. - Sweep 199; emitter temperature, 1759 K; collector temperature, 864 K; reservoir temperature, 623 K.

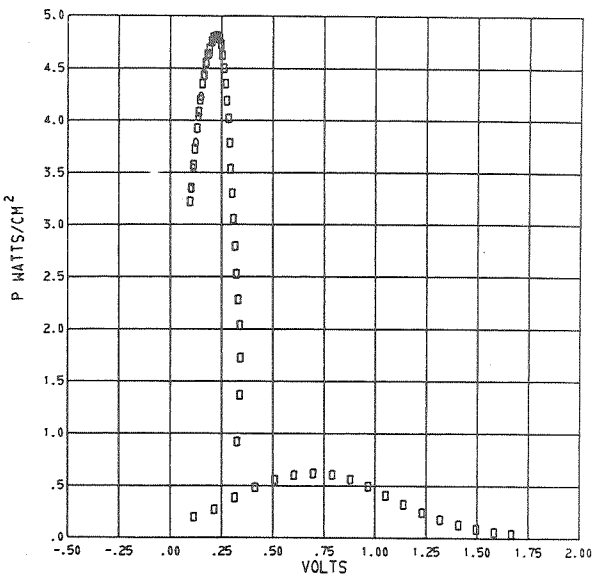


Figure 78. - Sweep 199; emitter temperature, 1759 K; collector temperature, 864 K; reservoir temperature, 623 K.

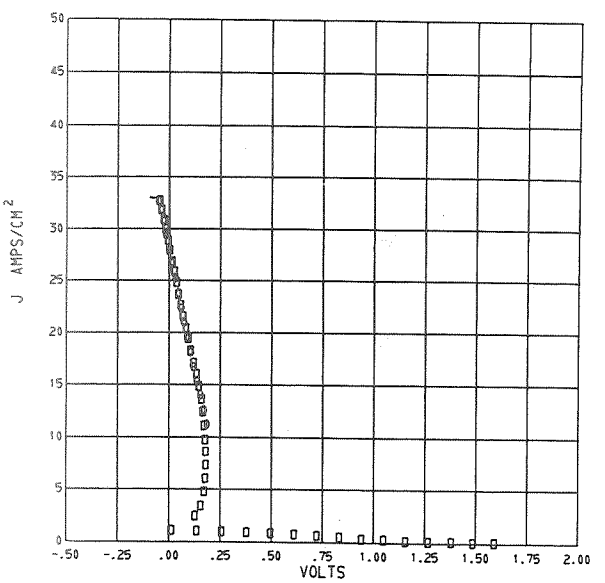


Figure 79. - Sweep 215; emitter temperature, 1761 K; collector temperature, 864 K; reservoir temperature, 650 K.

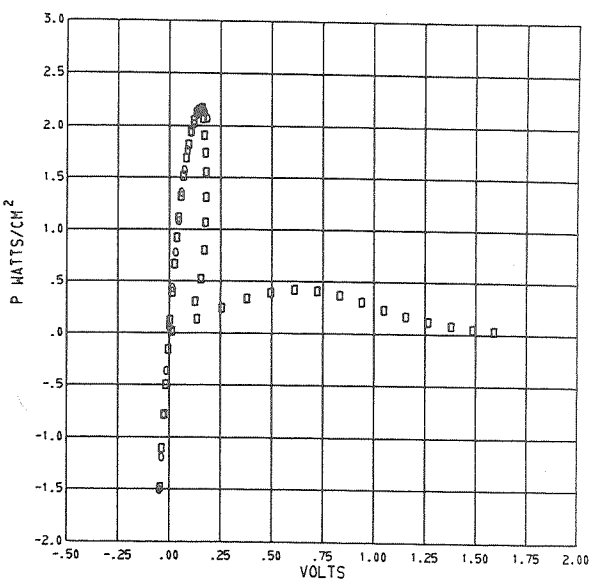


Figure 80. - Sweep 215; emitter temperature, 1761 K; collector temperature, 864 K; reservoir temperature, 650 K.

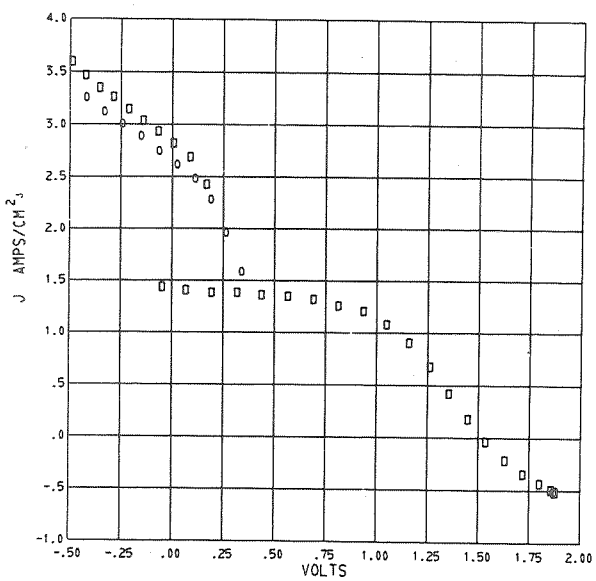


Figure 81. - Sweep 295; emitter temperature, 1758 K; collector temperature, 948 K; reservoir temperature, 549 K.

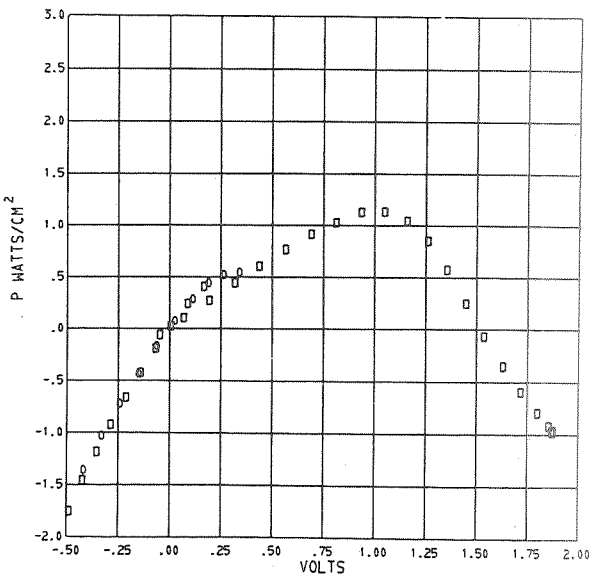


Figure 82. - Sweep 295; emitter temperature, 1758 K; collector temperature, 948 K; reservoir temperature, 549 K.

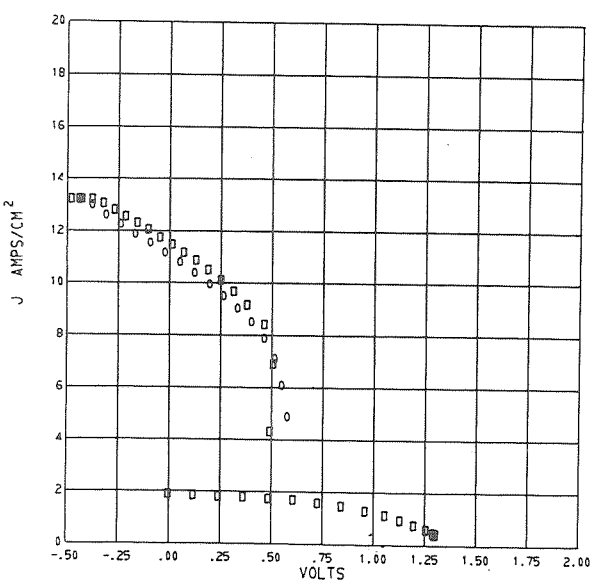


Figure 83. - Sweep 307; emitter temperature, 1768 K; collector temperature, 948 K; reservoir temperature, 573 K.

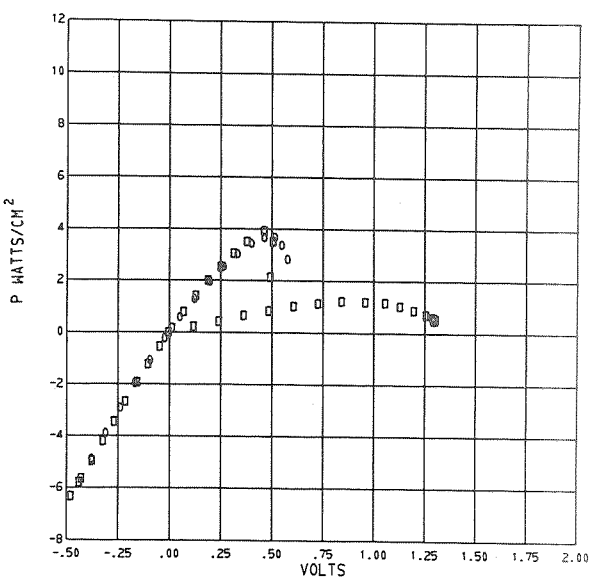


Figure 84. - Sweep 307; emitter temperature, 1768 K; collector temperature, 948 K; reservoir temperature, 573 K.

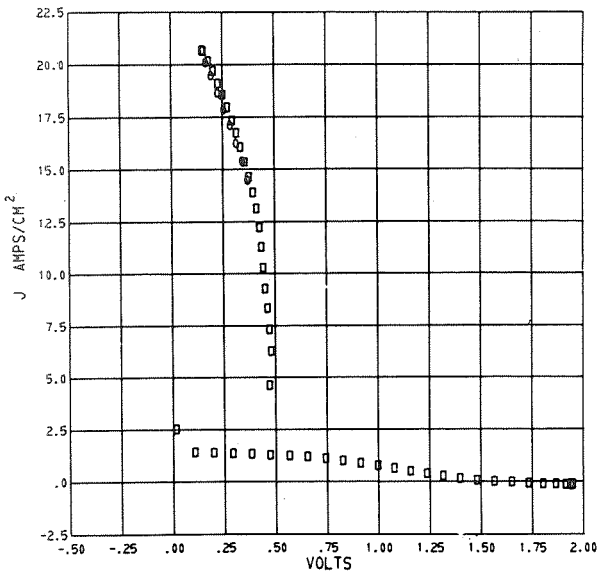


Figure 85. - Sweep 379; emitter temperature, 1757 K; collector temperature, 940 K; reservoir temperature, 598 K.

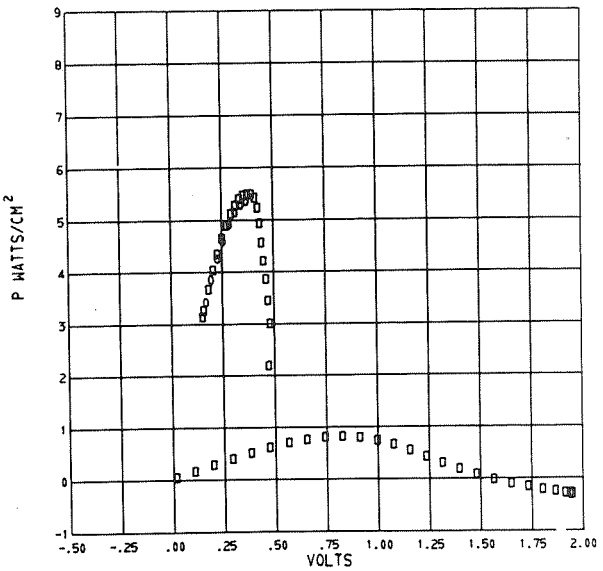


Figure 86. - Sweep 379; emitter temperature, 1757 K; collector temperature, 940 K; reservoir temperature, 598 K.

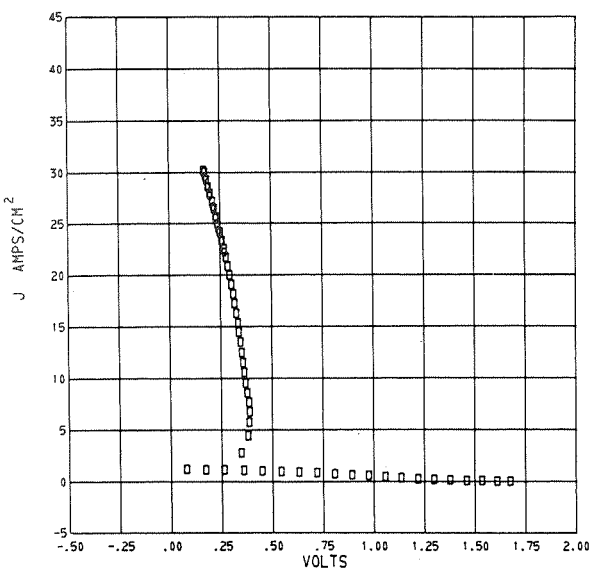


Figure 87. - Sweep 391; emitter temperature, 1753 K; collector temperature, 942 K; reservoir temperature, 623 K.

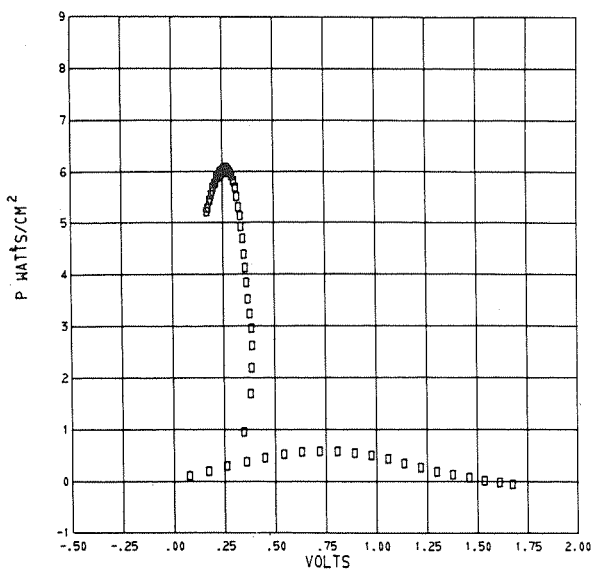


Figure 88. - Sweep 391; emitter temperature, 1753 K; collector temperature, 942 K; reservoir temperature, 623 K.

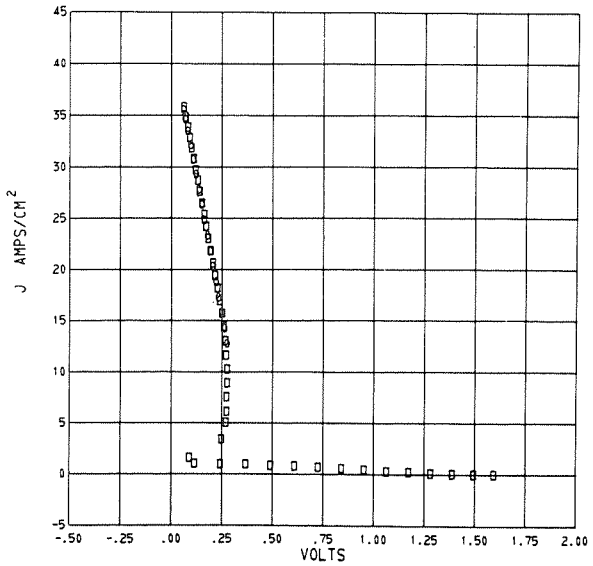


Figure 89. - Sweep 451; emitter temperature, 1755 K; collector temperature, 948 K; reservoir temperature, 651 K.

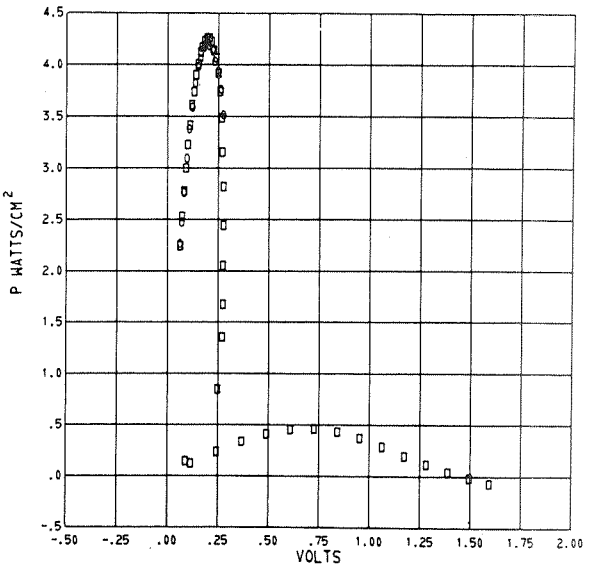


Figure 90. - Sweep 451; emitter temperature, 1755 K; collector temperature, 948 K; reservoir temperature, 651 K.

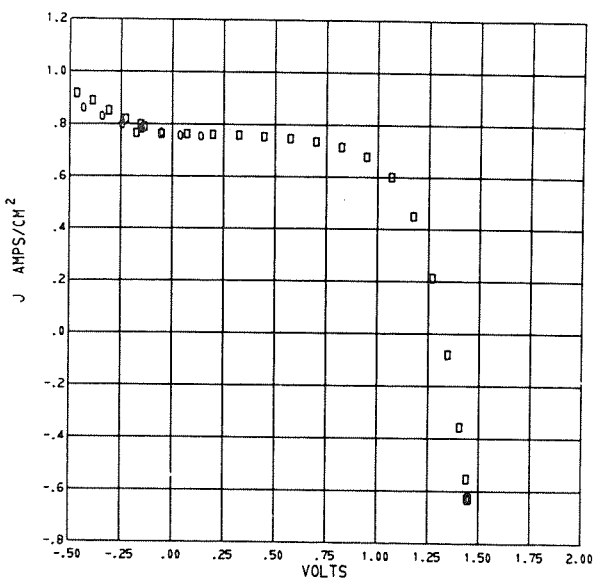


Figure 91. - Sweep 247; emitter temperature, 1761 K; collector temperature, 1053 K; reservoir temperature, 528 K.

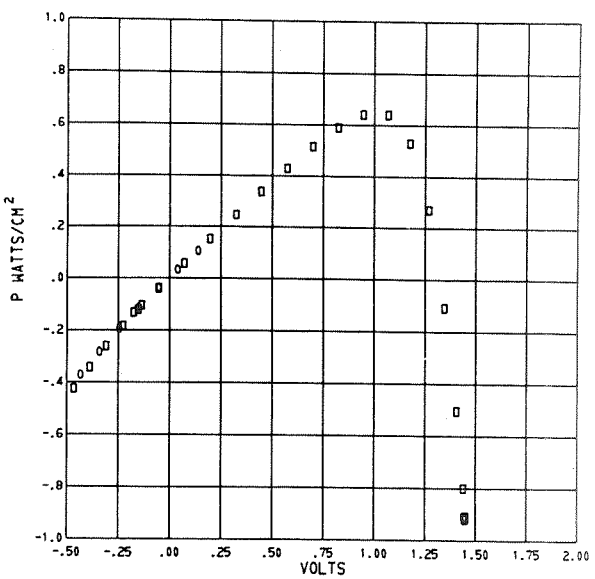


Figure 92. - Sweep 247; emitter temperature, 1761 K; collector temperature, 1053 K; reservoir temperature, 528 K.

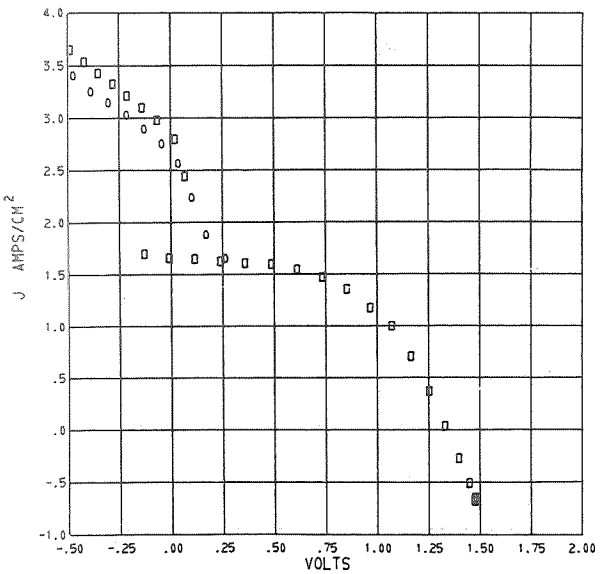


Figure 93. - Sweep 283; emitter temperature, 1764 K; collector temperature, 1049 K; reservoir temperature, 551 K.

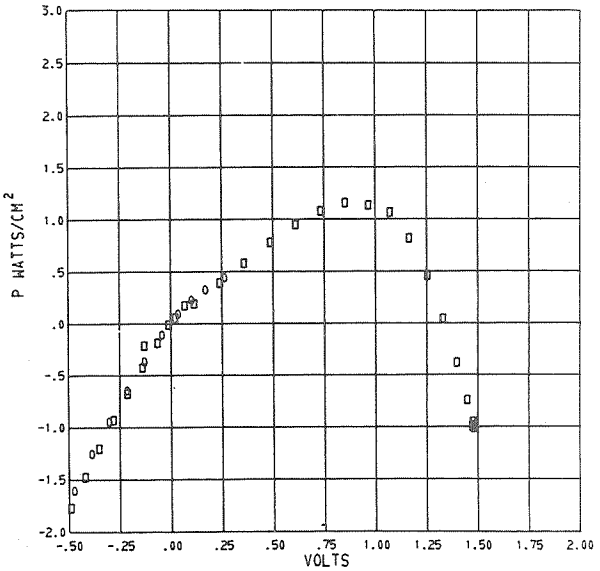


Figure 94. - Sweep 283; emitter temperature, 1764 K; collector temperature, 1049 K; reservoir temperature, 551 K.

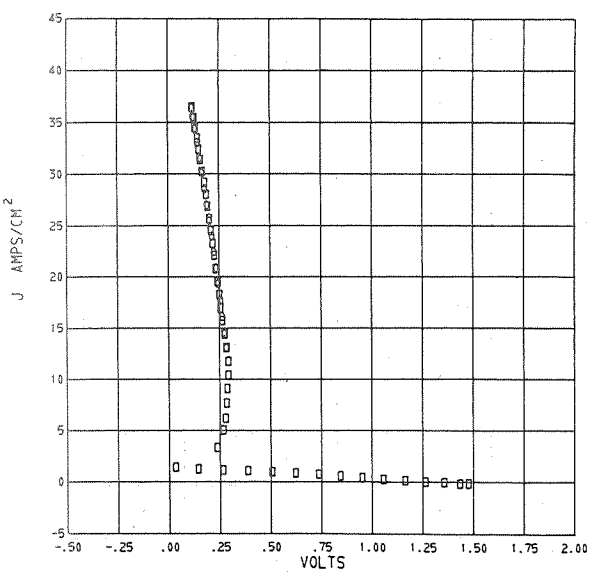


Figure 95. - Sweep 439; emitter temperature, 1758 K; collector temperature, 1062 K; reservoir temperature, 652 K.

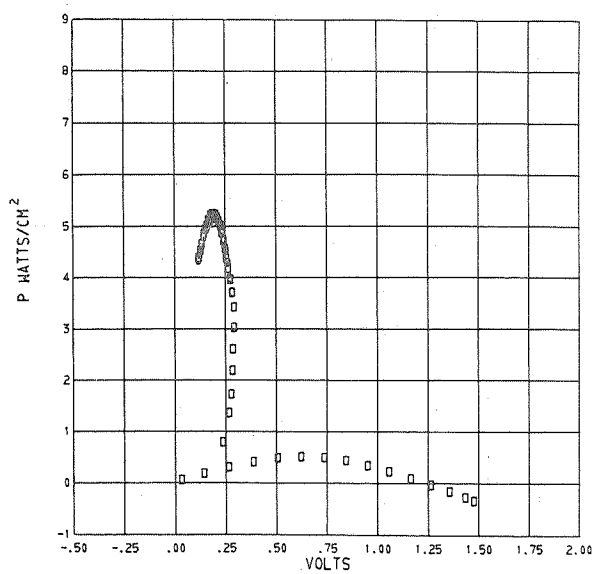


Figure 96. - Sweep 439; emitter temperature, 1758 K; collector temperature, 1062 K; reservoir temperature, 652 K.

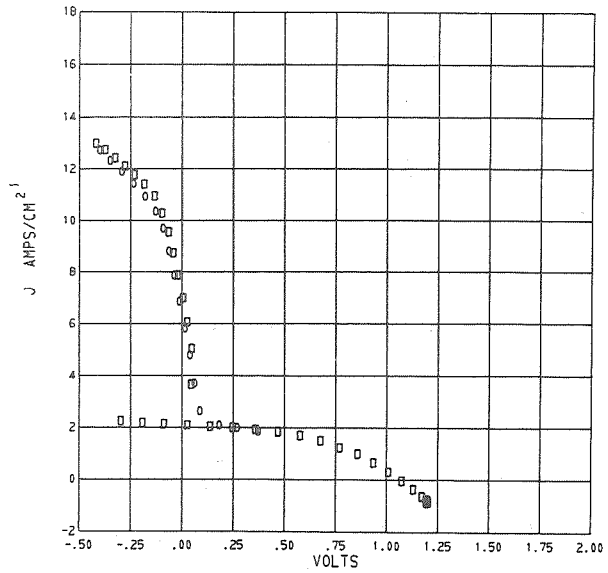


Figure 97. - Sweep 335; emitter temperature, 1767 K; collector temperature, 1167 K; reservoir temperature, 576 K.

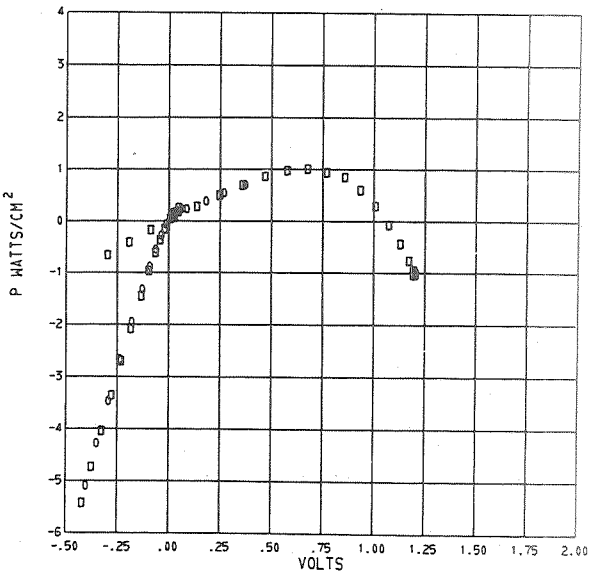


Figure 98. - Sweep 335; emitter temperature, 1767 K; collector temperature, 1167 K; reservoir temperature, 576 K.

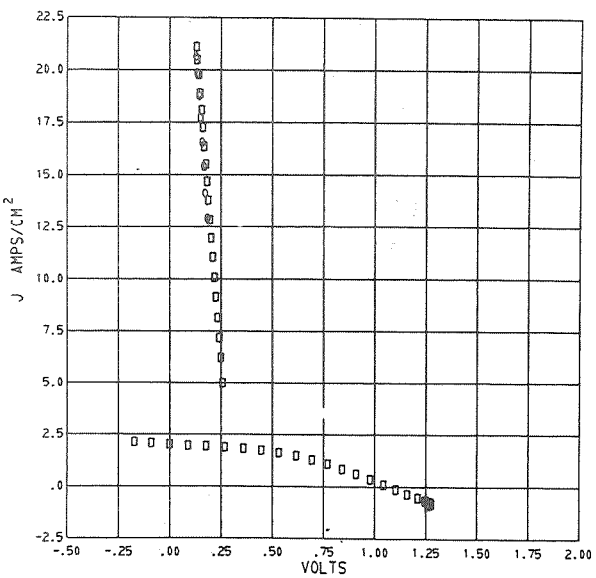


Figure 99. - Sweep 351; emitter temperature, 1764 K; collector temperature, 1169 K; reservoir temperature, 599 K.

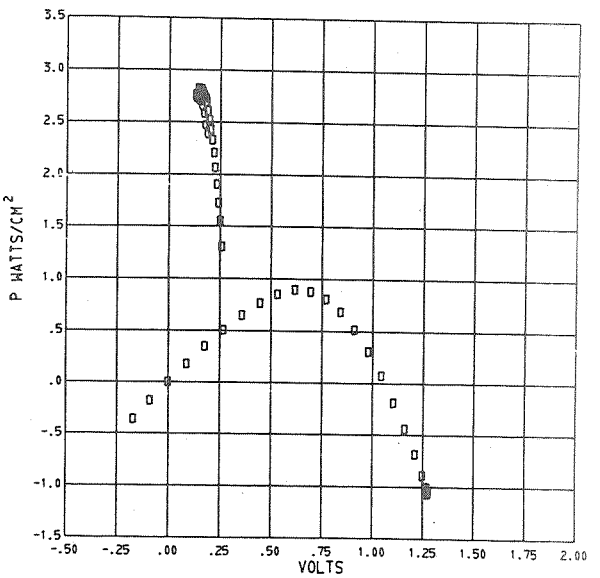


Figure 100. - Sweep 351; emitter temperature, 1764 K; collector temperature, 1169 K; reservoir temperature, 599 K.

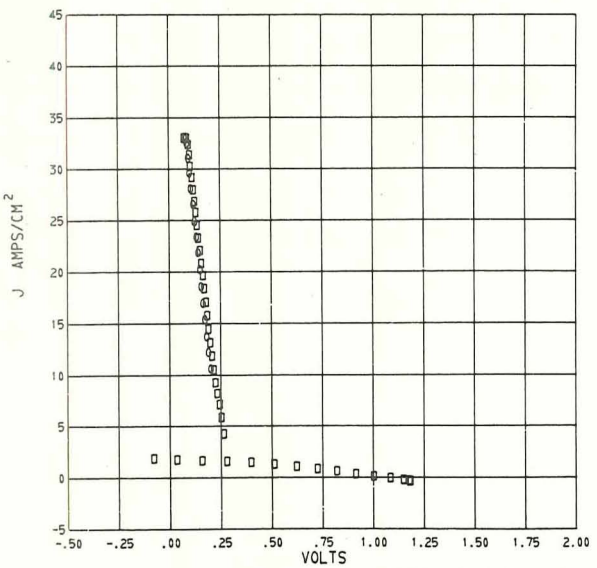


Figure 101. - Sweep 415; emitter temperature, 1752 K; collector temperature, 1170 K; reservoir temperature, 624 K.

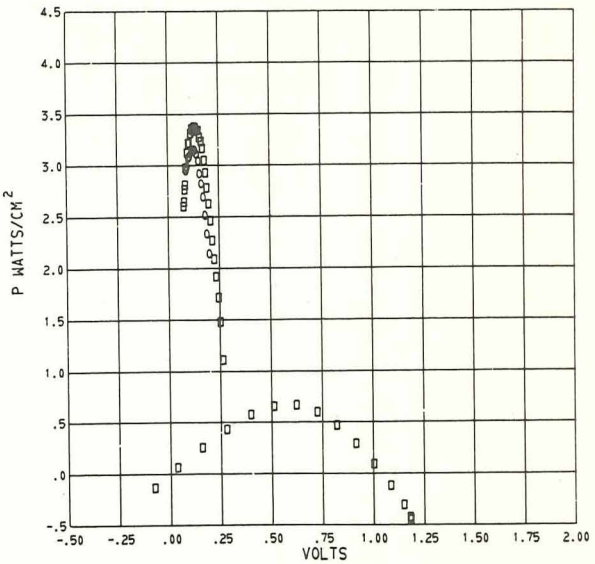


Figure 102. - Sweep 415; emitter temperature, 1752 K; collector temperature, 1170 K; reservoir temperature, 624 K.

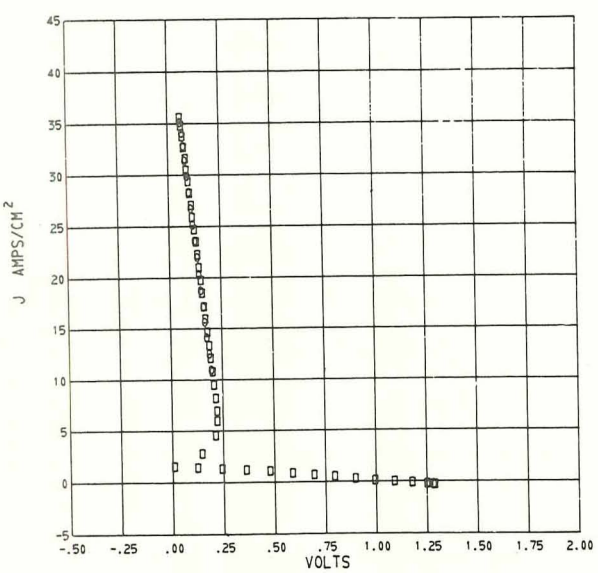


Figure 103. - Sweep 427; emitter temperature, 1757 K; collector temperature, 1169 K; reservoir temperature, 653 K.

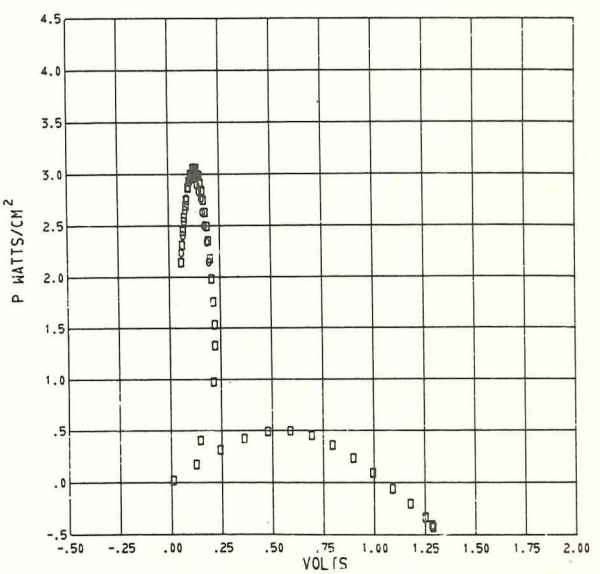


Figure 104. - Sweep 427; emitter temperature, 1757 K; collector temperature, 1169 K; reservoir temperature, 653 K.

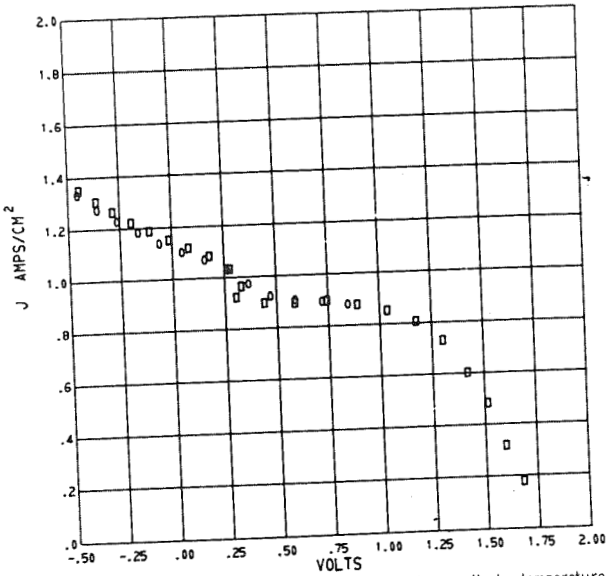


Figure 105. - Sweep 118; emitter temperature, 1820 K; collector temperature, 874 K; reservoir temperature, 533 K.

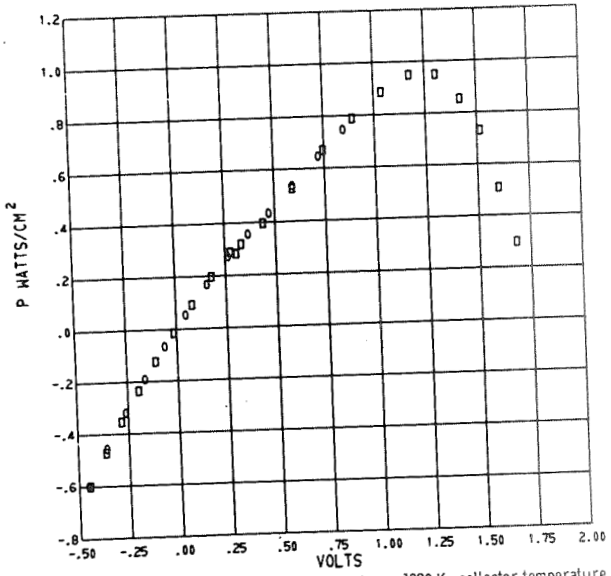


Figure 106. - Sweep 118; emitter temperature, 1820 K; collector temperature, 874 K; reservoir temperature, 533 K.

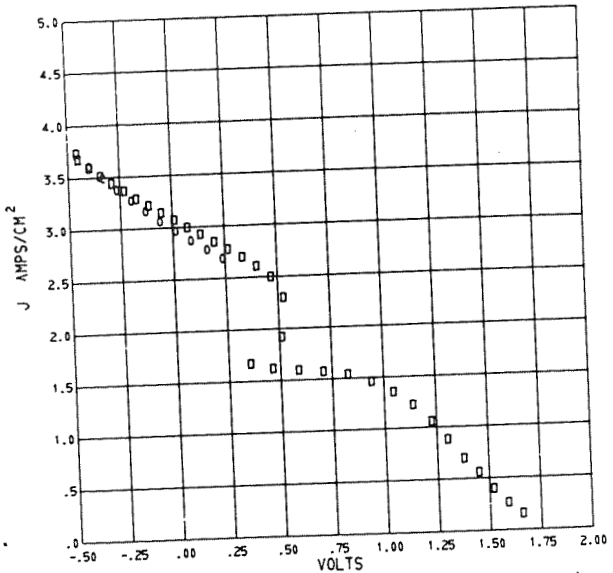


Figure 107. - Sweep 132; emitter temperature, 1806 K; collector temperature, 873 K; reservoir temperature, 548 K.

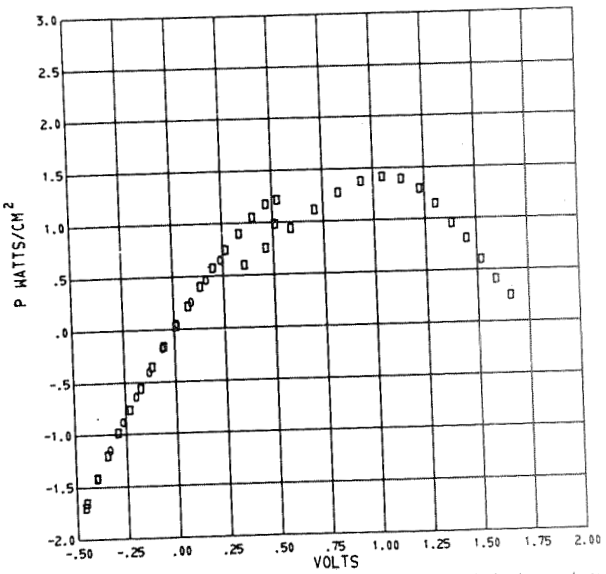


Figure 108. - Sweep 132; emitter temperature, 1806 K; collector temperature, 873 K; reservoir temperature, 548 K.

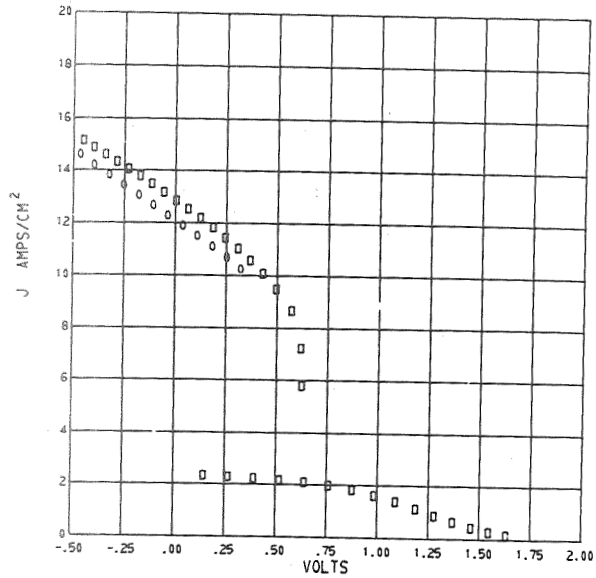


Figure 109. - Sweep 173; emitter temperature, 1807 K; collector temperature, 884 K; reservoir temperature, 576 K.

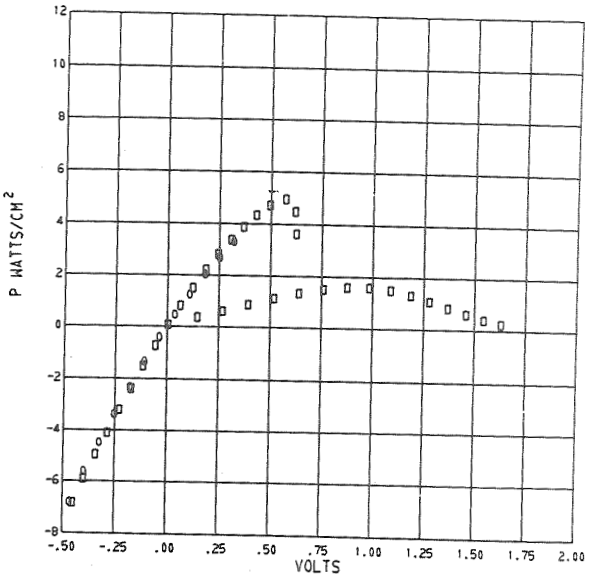


Figure 110. - Sweep 173; emitter temperature, 1807 K; collector temperature, 884 K; reservoir temperature, 576 K.

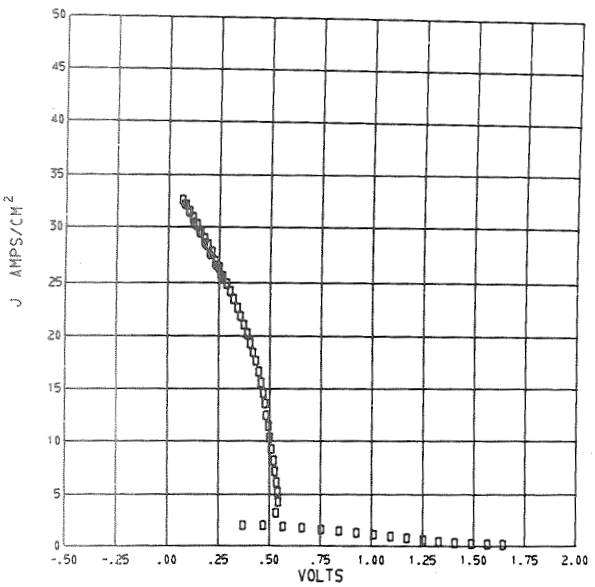


Figure 111. - Sweep 188; emitter temperature, 1816 K; collector temperature, 873 K; reservoir temperature, 605 K.

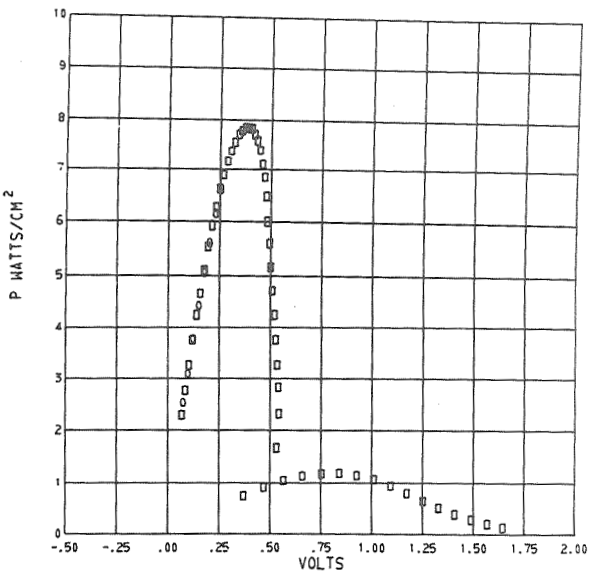


Figure 112. - Sweep 188; emitter temperature, 1816 K; collector temperature, 873 K; reservoir temperature, 605 K.

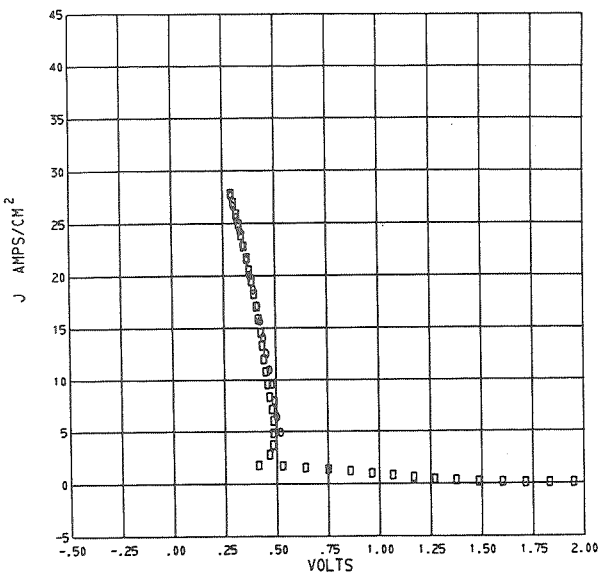


Figure 113. - Sweep 206; emitter temperature, 1809 K; collector temperature, 894 K; reservoir temperature, 623 K.

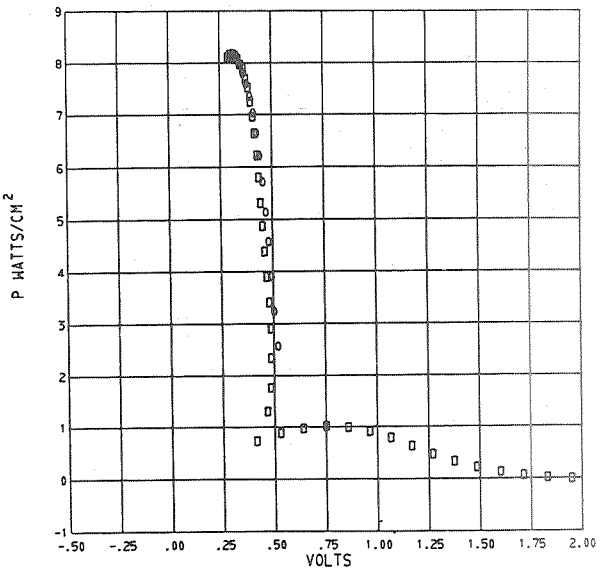


Figure 114. - Sweep 206; emitter temperature, 1809 K; collector temperature, 894 K; reservoir temperature, 623 K.

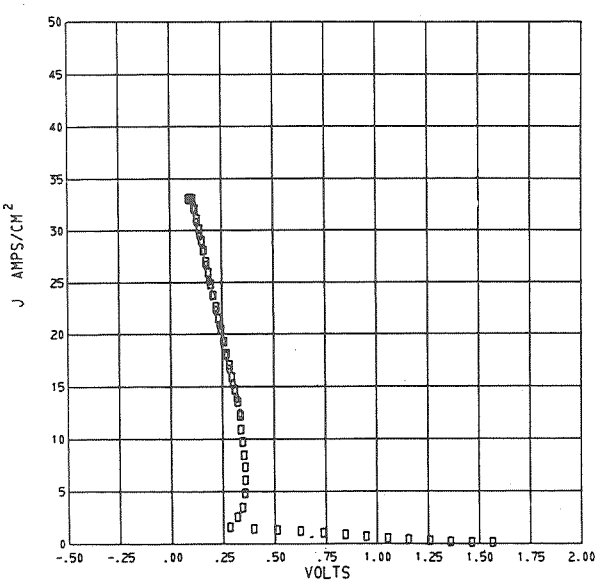


Figure 115. - Sweep 225; emitter temperature, 1805 K; collector temperature, 901 K; reservoir temperature, 651 K.

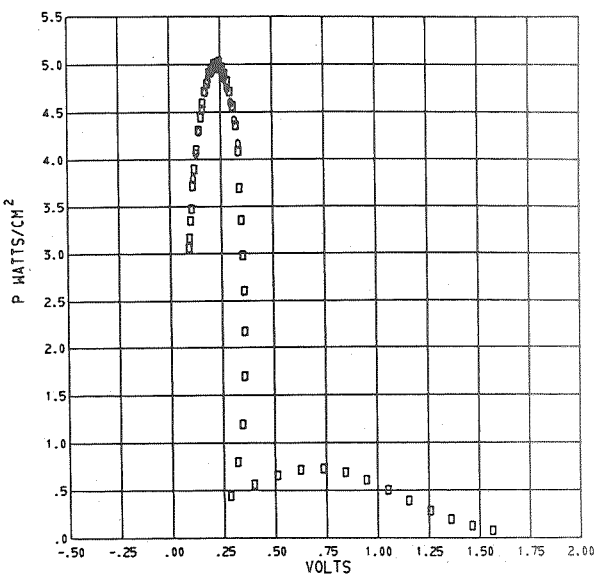


Figure 116. - Sweep 225; emitter temperature, 1805 K; collector temperature, 901 K; reservoir temperature, 651 K.

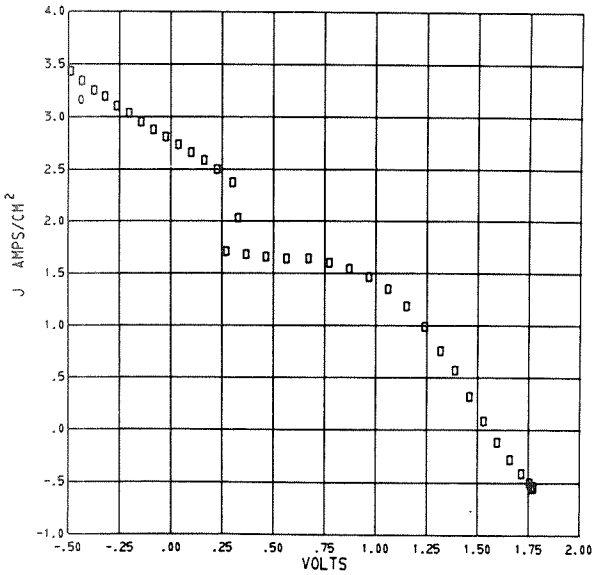


Figure 117. - Sweep 302; emitter temperature, 1806 K; collector temperature, 950 K; reservoir temperature, 549 K.

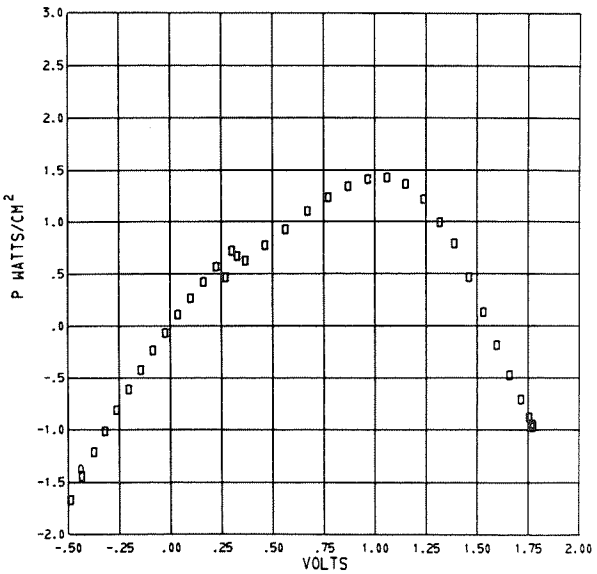


Figure 118. - Sweep 302; emitter temperature, 1806 K; collector temperature 950 K; reservoir temperature, 549 K.

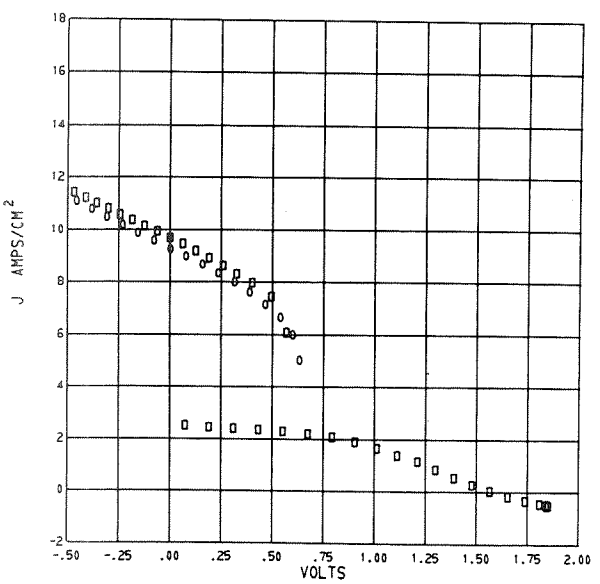


Figure 119. - Sweep 308; emitter temperature, 1810 K; collector temperature, 950 K; reservoir temperature, 572 K.

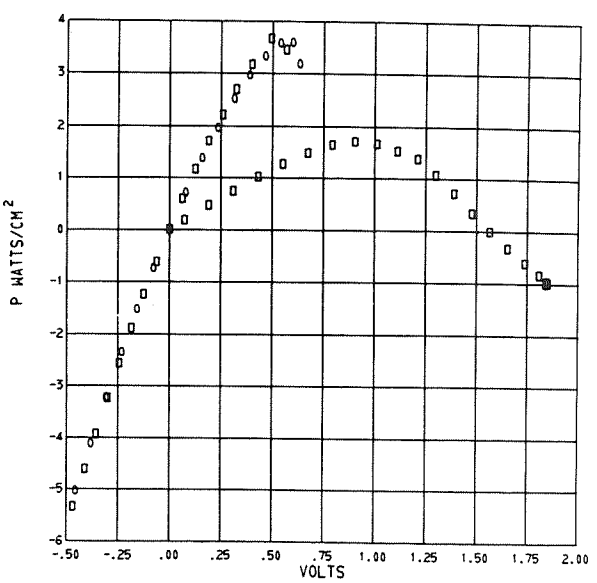


Figure 120. - Sweep 308; emitter temperature, 1810 K; collector temperature, 950 K; reservoir temperature, 572 K.

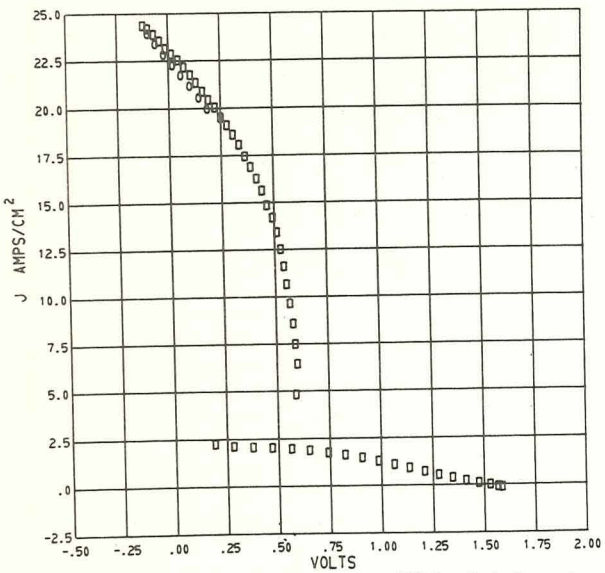


Figure 121. - Sweep 386; emitter temperature, 1808 K; collector temperature 945 K; reservoir temperature, 597 K.

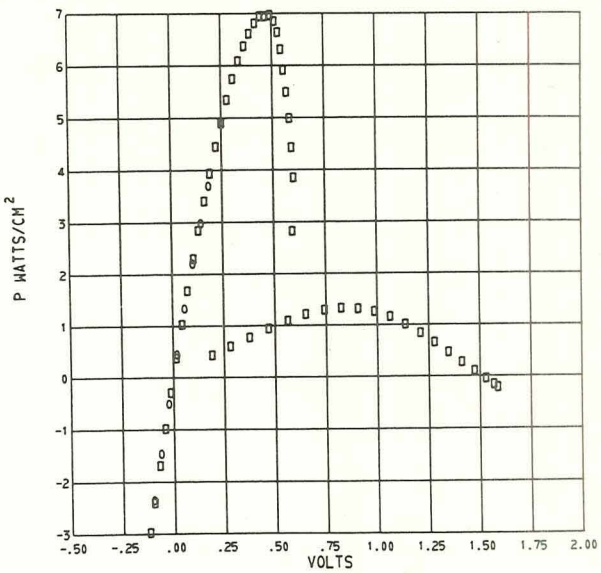


Figure 122. - Sweep 386; emitter temperature, 1808 K; collector temperature, 945 K; reservoir temperature, 597 K.

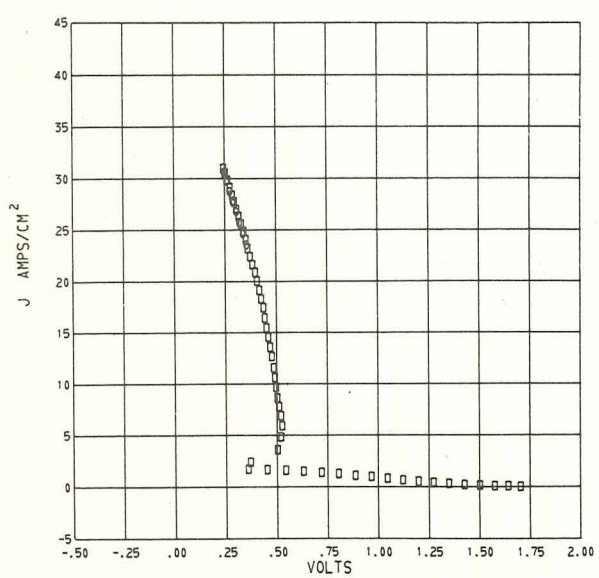


Figure 123. - Sweep 392; emitter temperature, 1817 K; collector temperature, 945 K; reservoir temperature, 622 K.

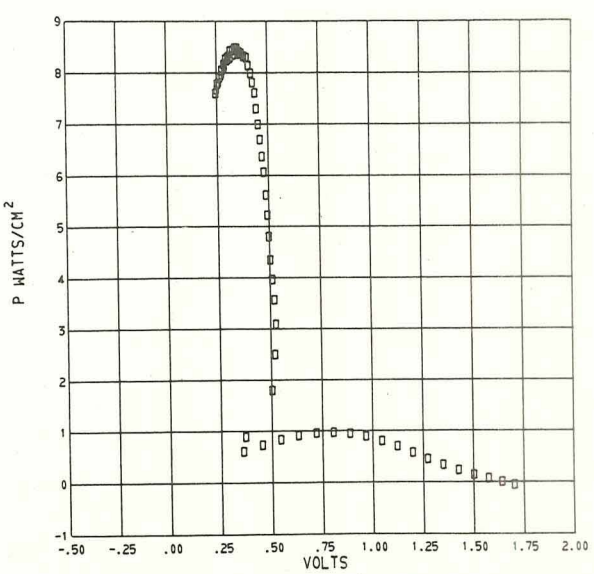


Figure 124. - Sweep 392; emitter temperature, 1817 K; collector temperature, 945 K; reservoir temperature, 622 K.

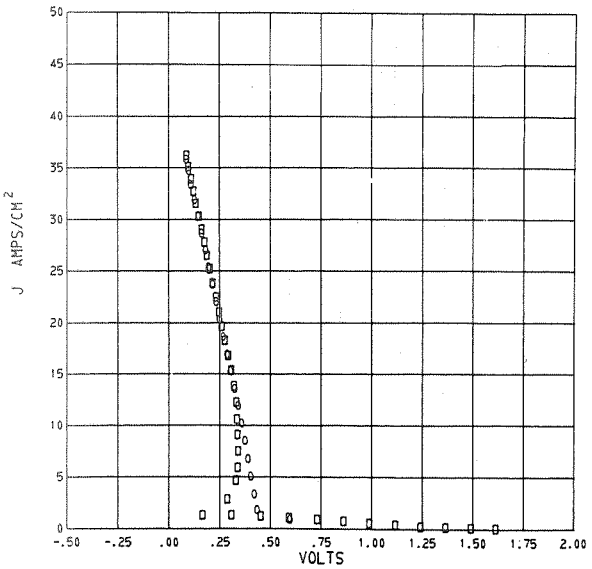


Figure 125. - Sweep 458; emitter temperature, 1800 K; collector temperature, 941 K; reservoir temperature, 650 K.

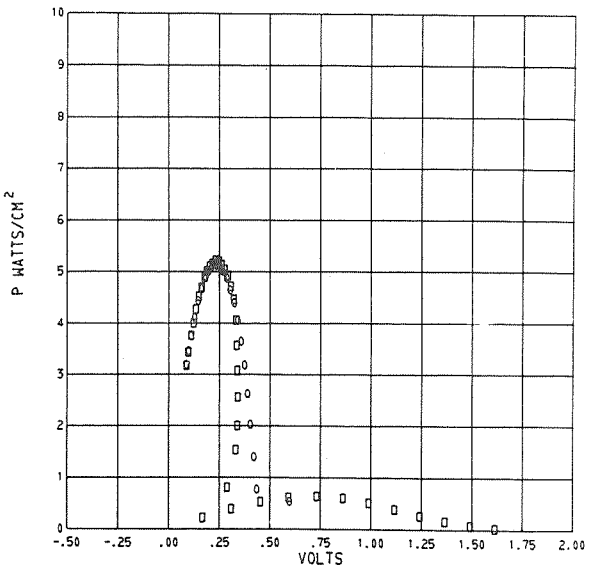


Figure 126. - Sweep 458; emitter temperature, 1800 K; collector temperature, 941 K; reservoir temperature, 650 K.

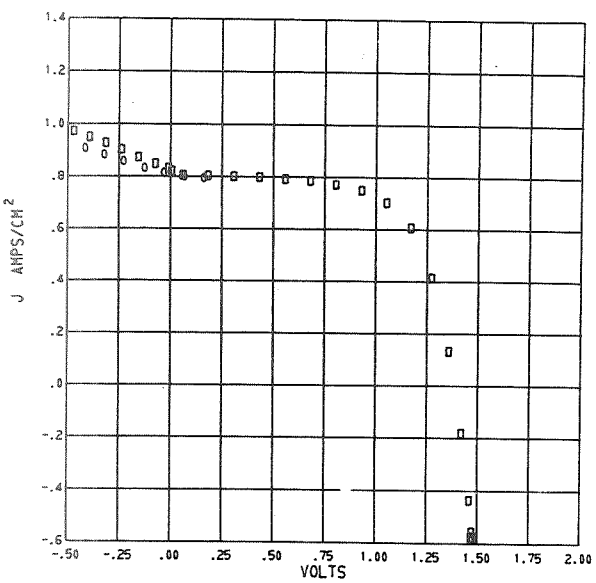


Figure 127. - Sweep 254; emitter temperature, 1808 K; collector temperature, 1055 K; reservoir temperature, 528 K.

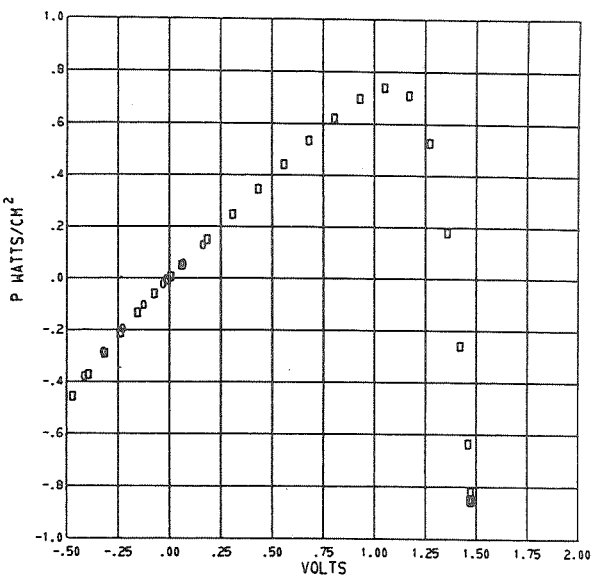


Figure 128. - Sweep 254; emitter temperature, 1808 K; collector temperature, 1055 K; reservoir temperature, 528 K.

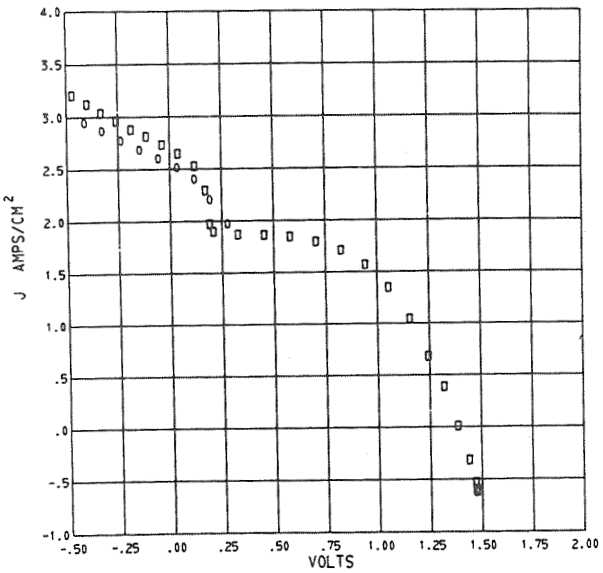


Figure 129. - Sweep 290; emitter temperature, 1810 K; collector temperature, 1050 K; reservoir temperature, 550 K.

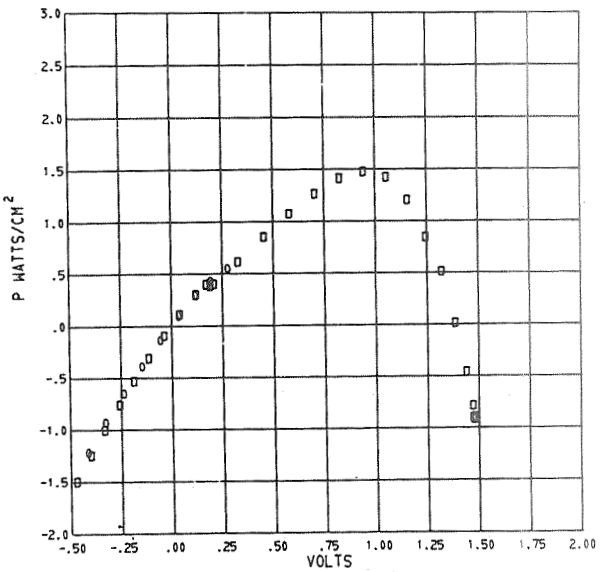


Figure 130. - Sweep 290; emitter temperature, 1810 K; collector temperature, 1050 K; reservoir temperature, 550 K.

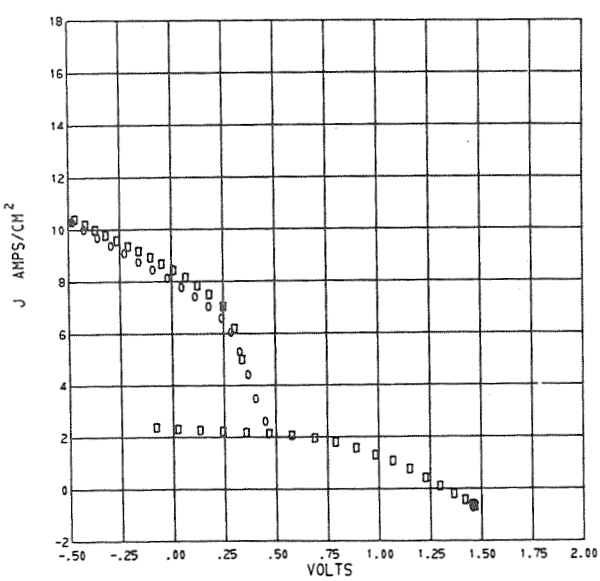


Figure 131. - Sweep 330; emitter temperature, 1805 K; collector temperature, 1056 K; reservoir temperature, 574 K.

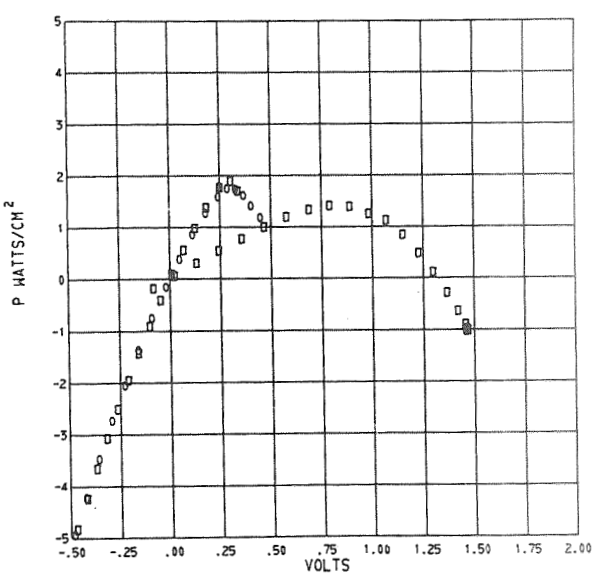


Figure 132. - Sweep 330; emitter temperature, 1805 K; collector temperature, 1056 K; reservoir temperature, 574 K.

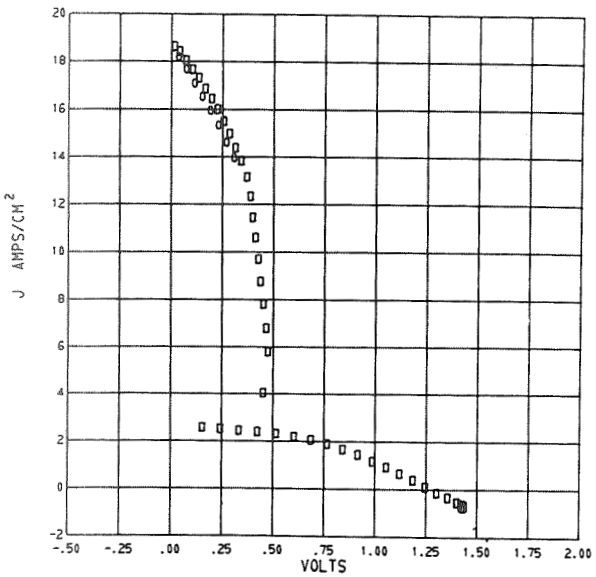


Figure 133. - Sweep 368; emitter temperature, 1816 K; collector temperature 1067 K; reservoir temperature, 599 K.

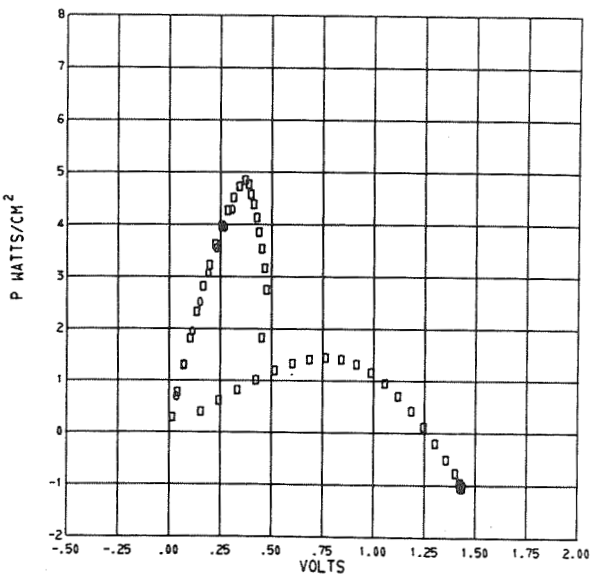


Figure 134. - Sweep 368; emitter temperature, 1816 K; collector temperature, 1067 K; reservoir temperature, 599 K.

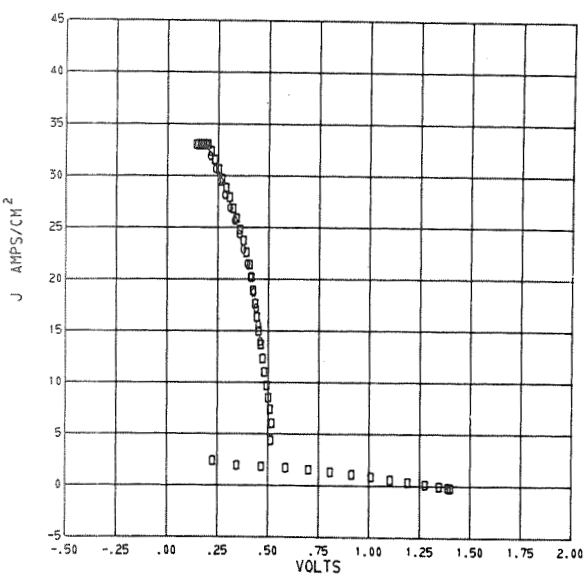


Figure 135. - Sweep 410; emitter temperature, 1811 K; collector temperature, 1056 K; reservoir temperature, 623 K.

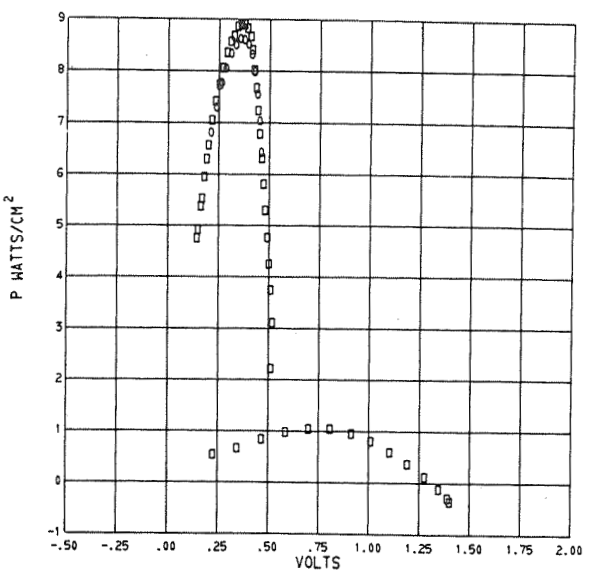


Figure 136. - Sweep 410; emitter temperature, 1811 K; collector temperature, 1056 K; reservoir temperature, 623 K.

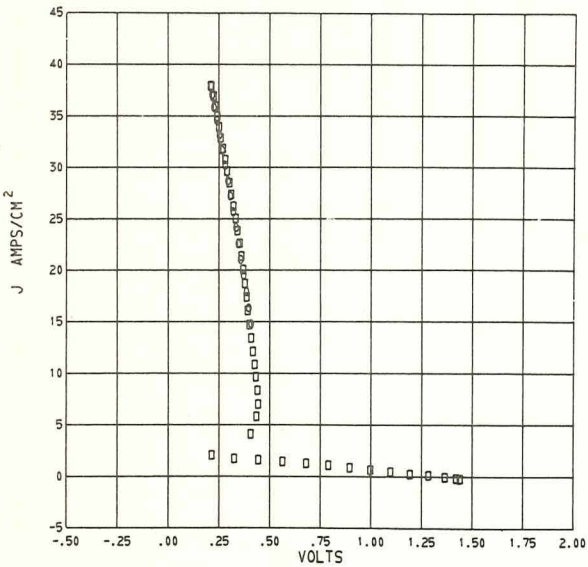


Figure 137. - Sweep 446; emitter temperature, 1812 K; collector temperature, 1053 K; reservoir temperature, 652 K.

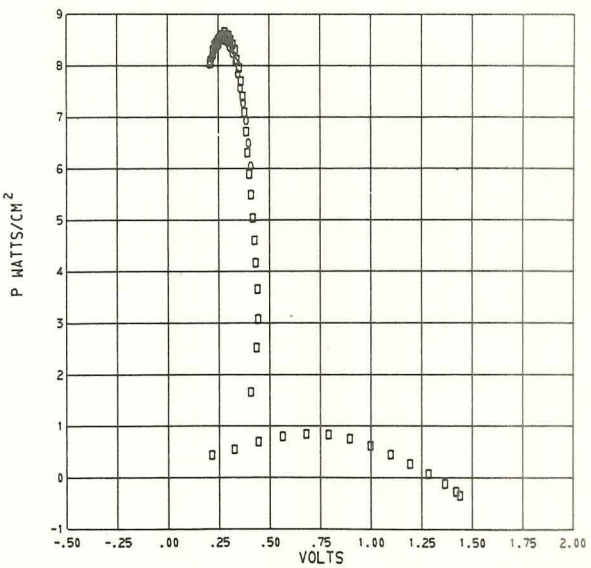


Figure 138. - Sweep 446; emitter temperature, 1812 K; collector temperature, 1053 K; reservoir temperature, 652 K.

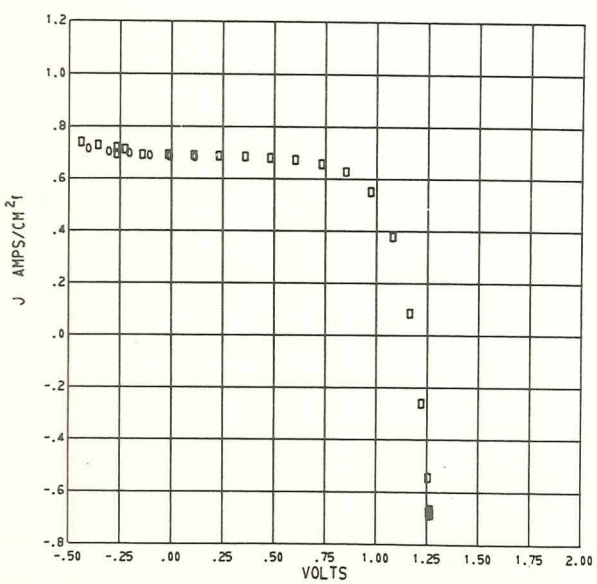


Figure 139. - Sweep 266; emitter temperature, 1808 K; collector temperature, 1181 K; reservoir temperature, 529 K.

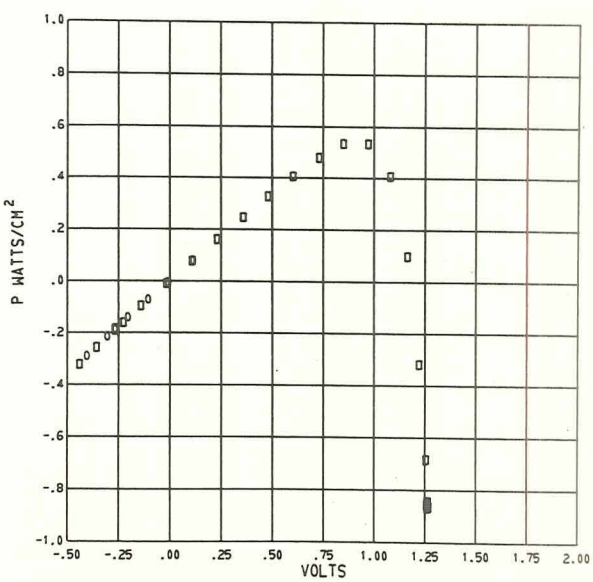


Figure 140. - Sweep 266; emitter temperature, 1808 K; collector temperature, 1181 K; reservoir temperature, 529 K.

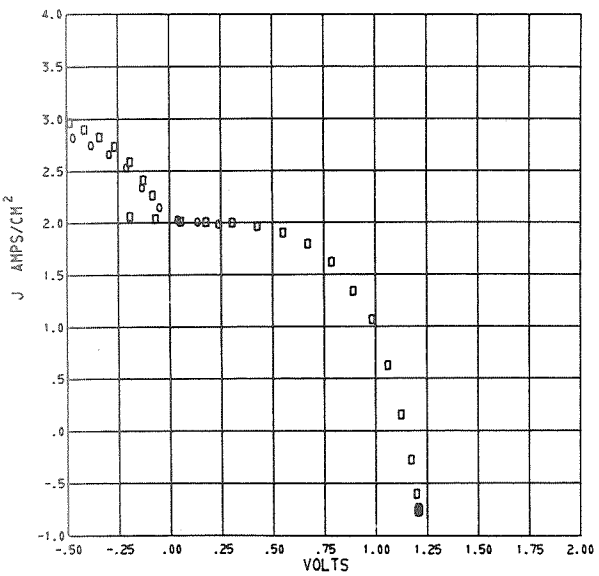


Figure 141. - Sweep 278; emitter temperature, 1809 K; collector temperature, 1179 K; reservoir temperature, 552 K.

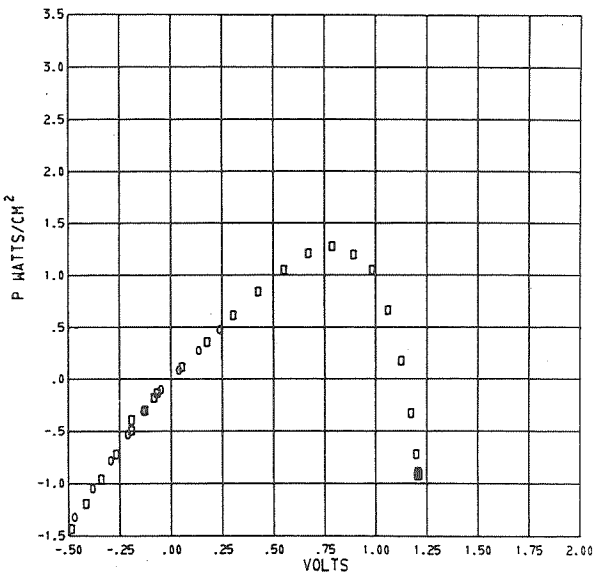


Figure 142. - Sweep 278; emitter temperature, 1809 K; collector temperature, 1179 K; reservoir temperature, 552 K.

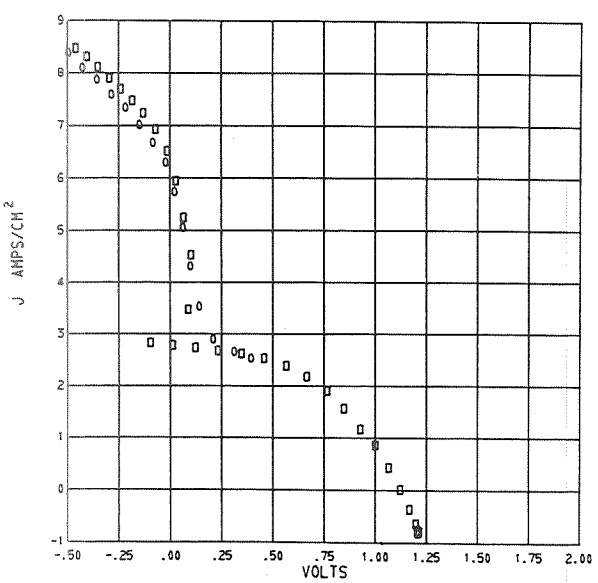


Figure 143. - Sweep 336; emitter temperature, 1817 K; collector temperature, 1167 K; reservoir temperature, 576 K.

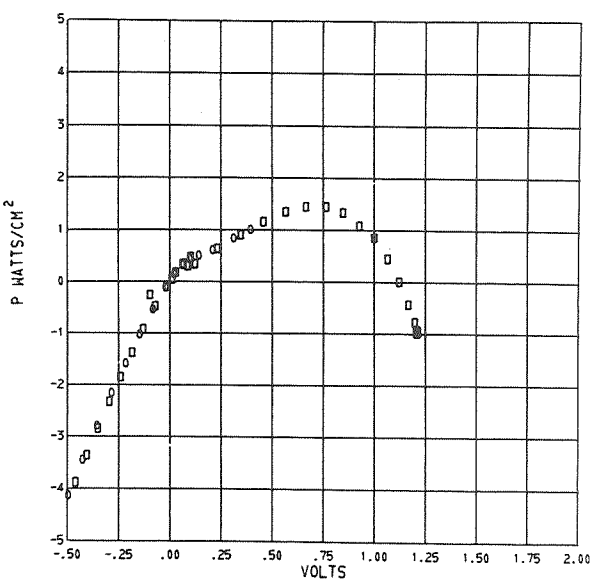


Figure 144. - Sweep 336; emitter temperature, 1817 K; collector temperature, 1167 K; reservoir temperature, 576 K.

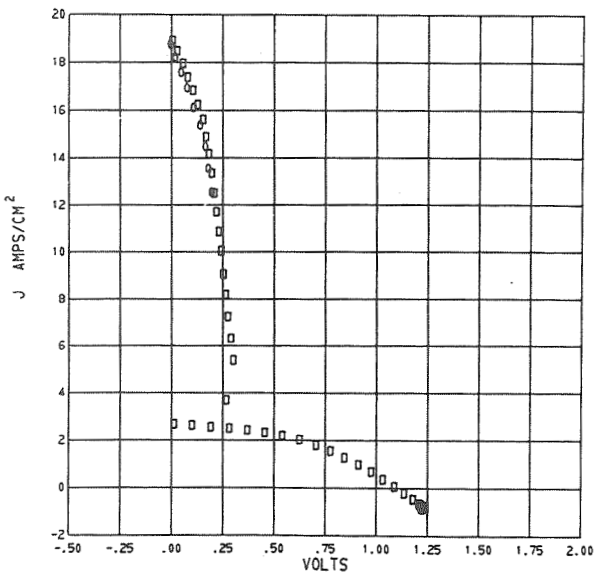


Figure 145. - Sweep 358; emitter temperature, 1805 K; collector temperature, 1172 K; reservoir temperature, 600 K.

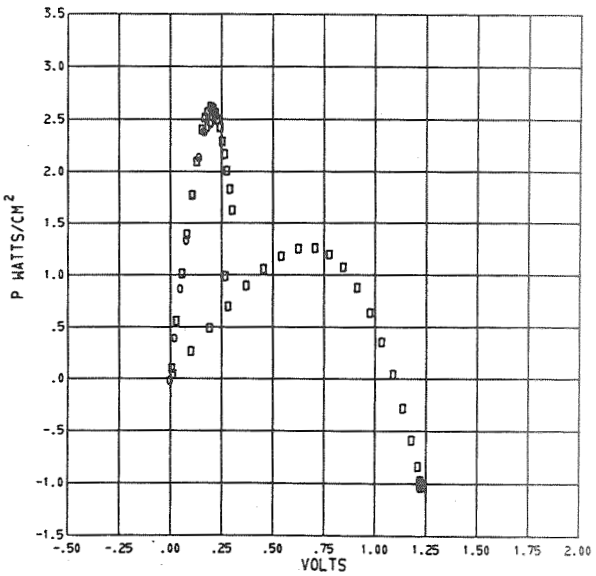


Figure 146. - Sweep 358; emitter temperature, 1805 K; collector temperature, 1172 K; reservoir temperature, 600 K.

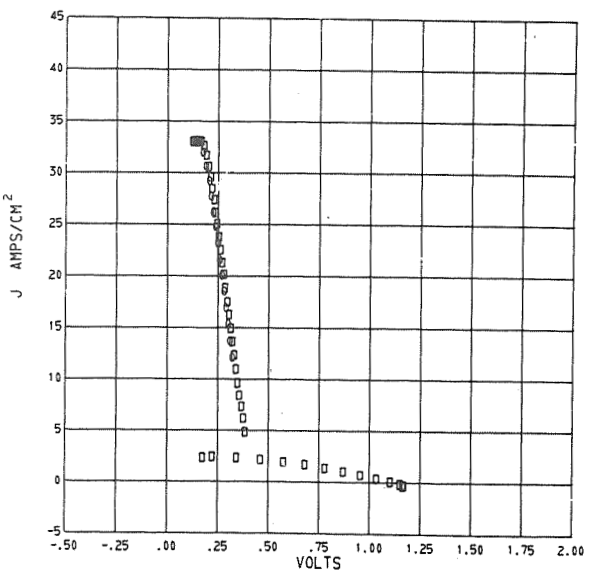


Figure 147. - Sweep 422; emitter temperature, 1810 K; collector temperature, 1156 K; reservoir temperature, 624 K.

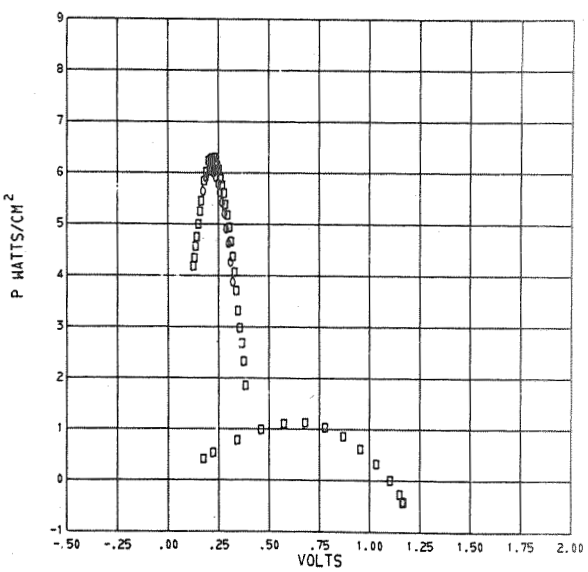


Figure 148. - Sweep 422; emitter temperature, 1810 K; collector temperature, 1156 K; reservoir temperature, 624 K.

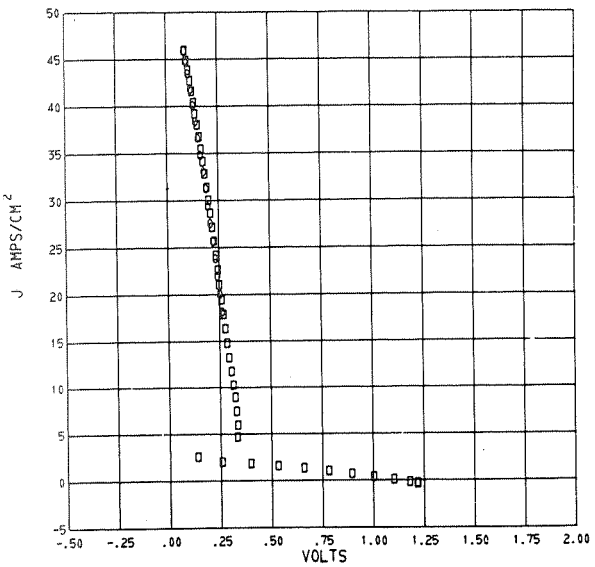


Figure 149. - Sweep 434; emitter temperature, 1808 K; collector temperature, 1167 K; reservoir temperature, 653 K.

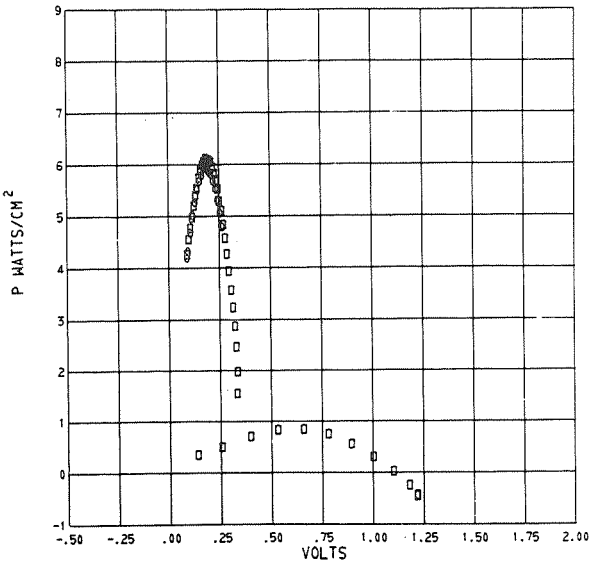


Figure 150. - Sweep 434; emitter temperature, 1808 K; collector temperature, 1167 K; reservoir temperature, 653 K.

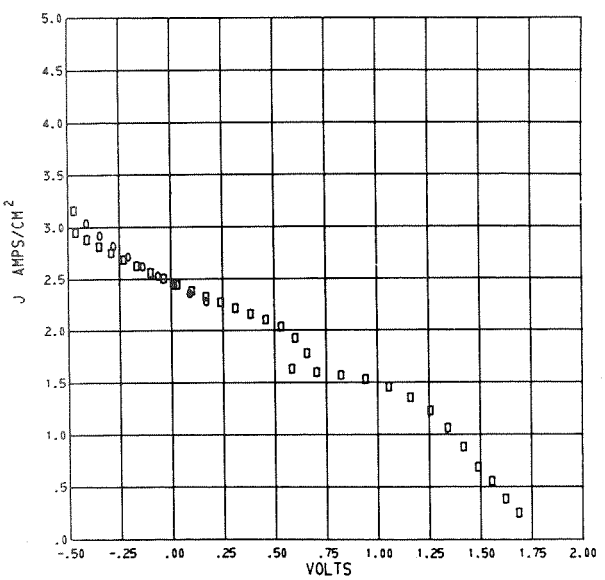


Figure 151. - Sweep 133; emitter temperature, 1851 K; collector temperature, 877 K; reservoir temperature, 548 K.

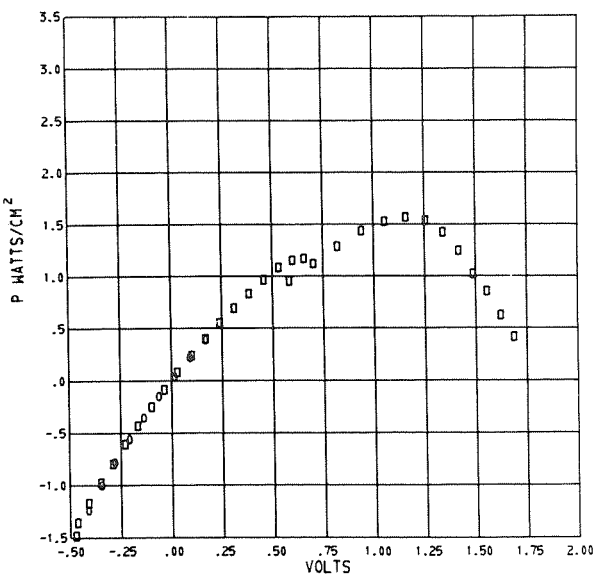


Figure 152. - Sweep 133; emitter temperature, 1851 K; collector temperature, 877 K; reservoir temperature, 548 K.

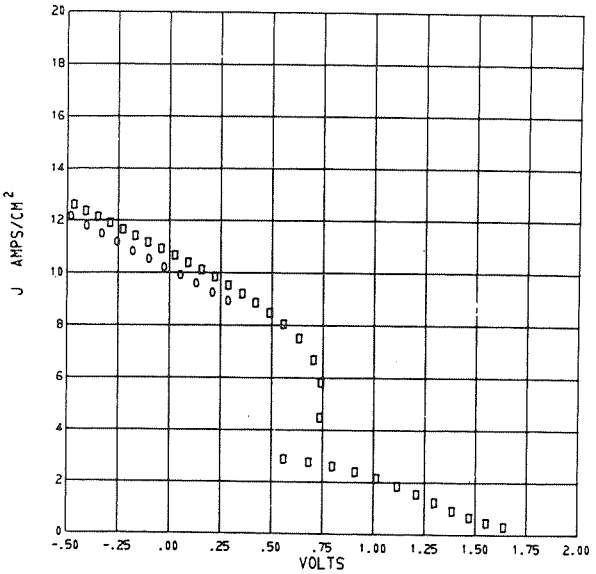


Figure 153. - Sweep 168; emitter temperature, 1856 K; collector temperature, 882 K; reservoir temperature, 575 K.

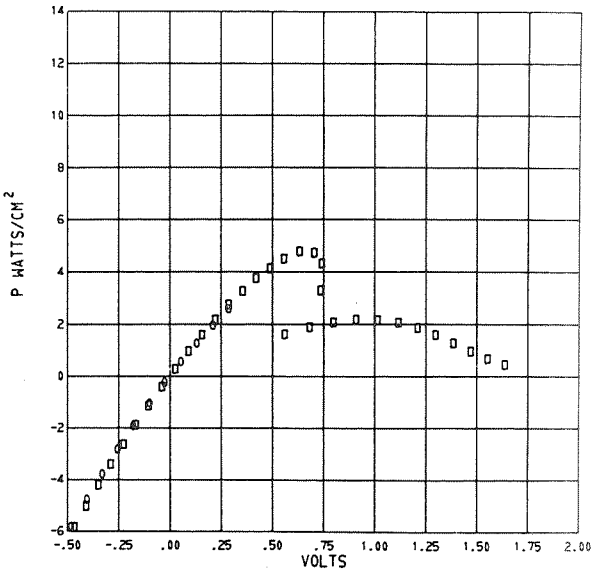


Figure 154. - Sweep 168; emitter temperature, 1856 K; collector temperature, 882 K; reservoir temperature, 575 K.

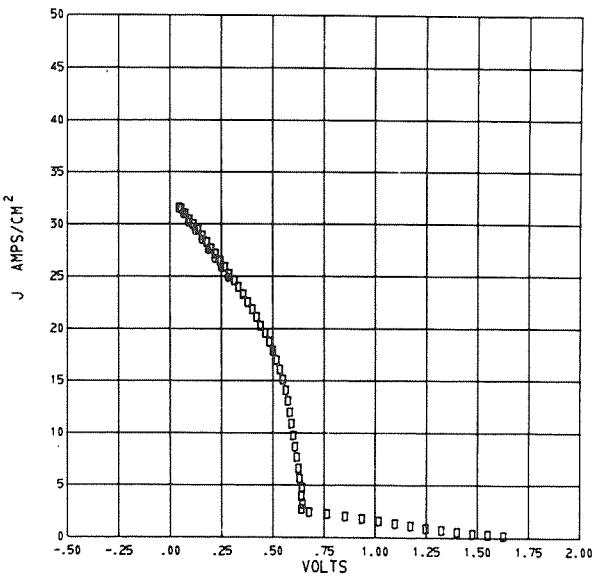


Figure 155. - Sweep 189; emitter temperature, 1856 K; collector temperature, 878 K; reservoir temperature, 605 K.

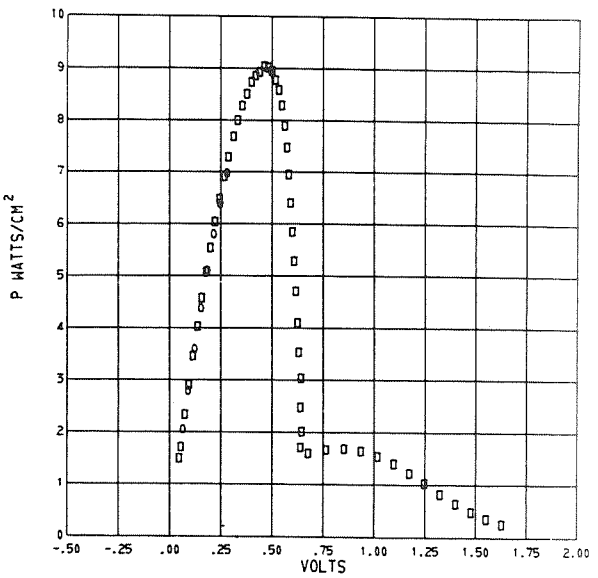


Figure 156. - Sweep 189; emitter temperature, 1856 K; collector temperature, 878 K; reservoir temperature, 605 K.

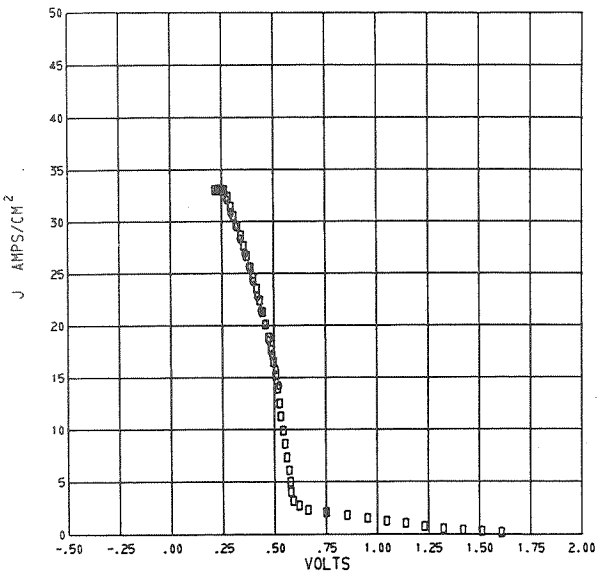


Figure 157. - Sweep 209; emitter temperature, 1865 K; collector temperature, 874 K; reservoir temperature, 623 K.

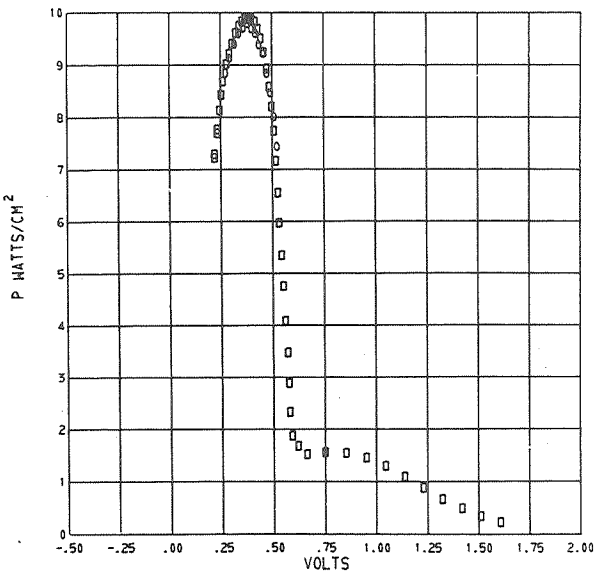


Figure 158. - Sweep 209; emitter temperature, 1865 K; collector temperature, 874 K; reservoir temperature, 623 K.

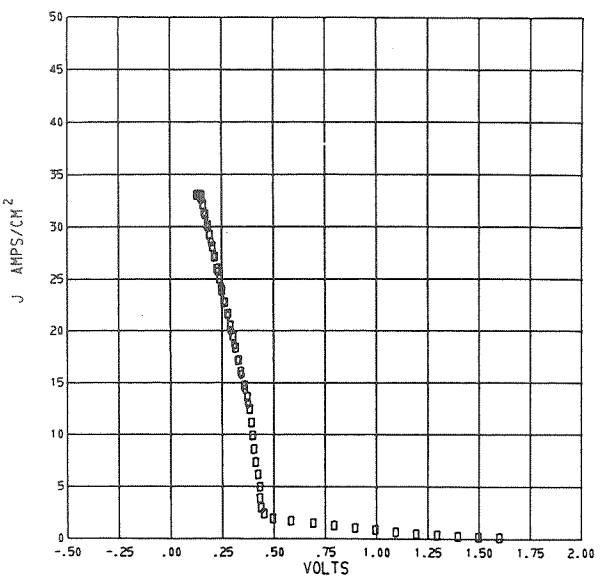


Figure 159. - Sweep 217; emitter temperature, 1856 K; collector temperature, 874 K; reservoir temperature, 650 K.

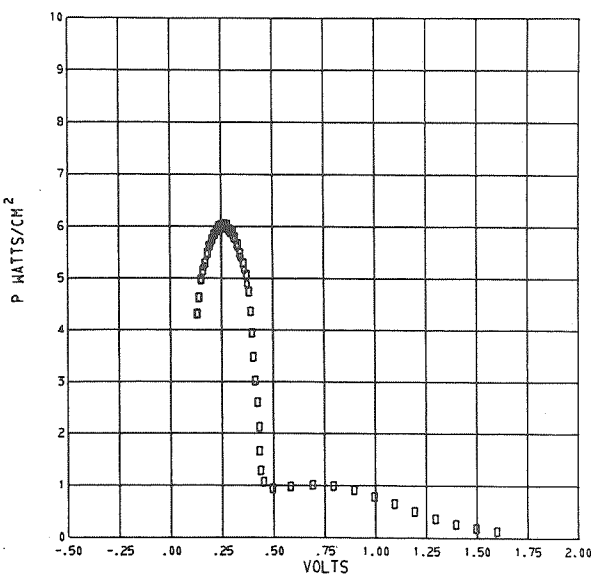


Figure 160. - Sweep 217; emitter temperature, 1856 K; collector temperature, 874 K; reservoir temperature, 650 K.

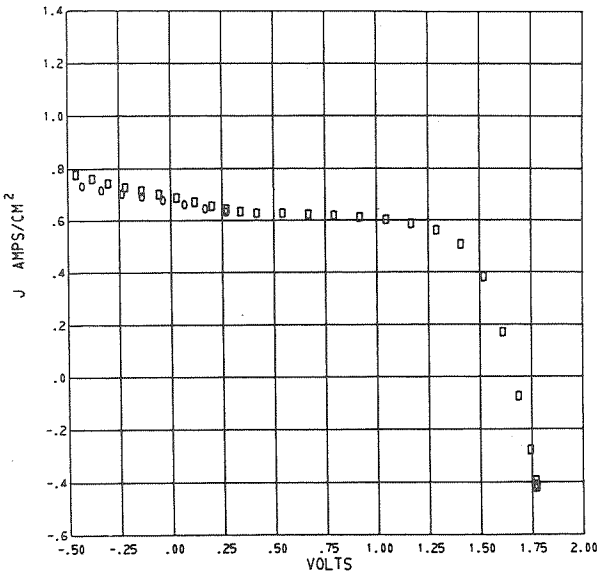


Figure 161. - Sweep 237; emitter temperature, 1857 K; collector temperature, 953 K; reservoir temperature, 527 K.

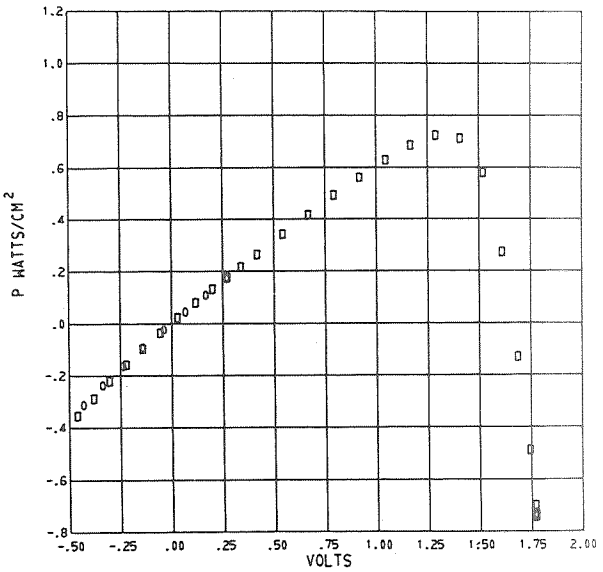


Figure 162. - Sweep 237; emitter temperature, 1857 K; collector temperature, 953 K; reservoir temperature, 527 K.

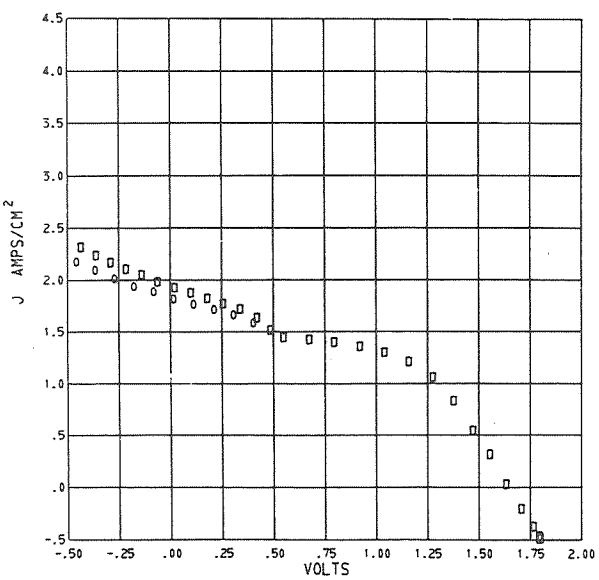


Figure 163. - Sweep 297; emitter temperature, 1857 K; collector temperature, 955 K; reservoir temperature, 549 K.

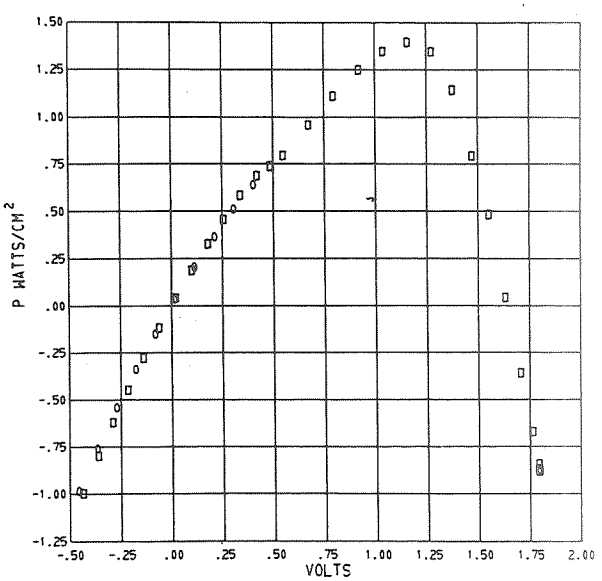


Figure 164. - Sweep 297; emitter temperature, 1857 K; collector temperature, 955 K; reservoir temperature, 549 K.

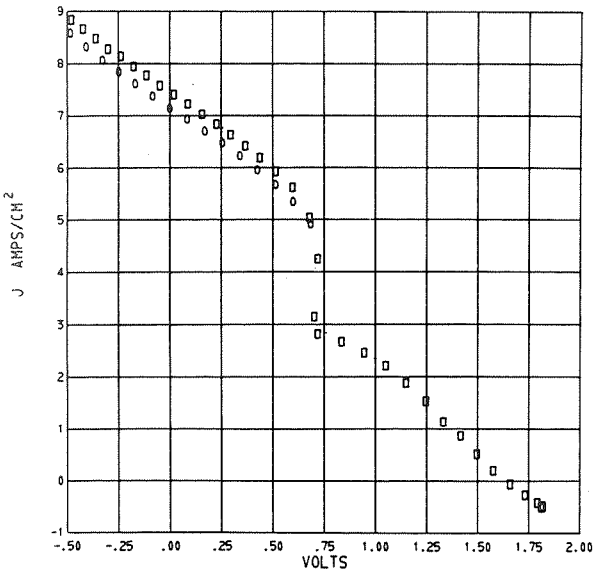


Figure 165. - Sweep 309; emitter temperature, 1862 K; collector temperature, 955 K; reservoir temperature, 572 K.

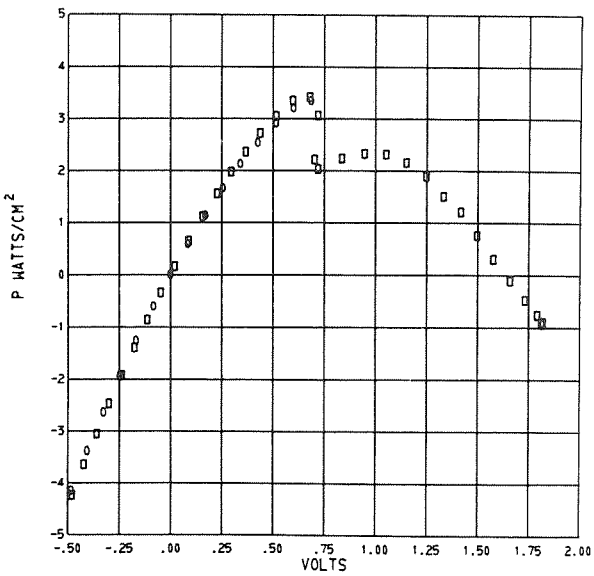


Figure 166. - Sweep 309; emitter temperature, 1862 K; collector temperature, 955 K; reservoir temperature, 572 K.

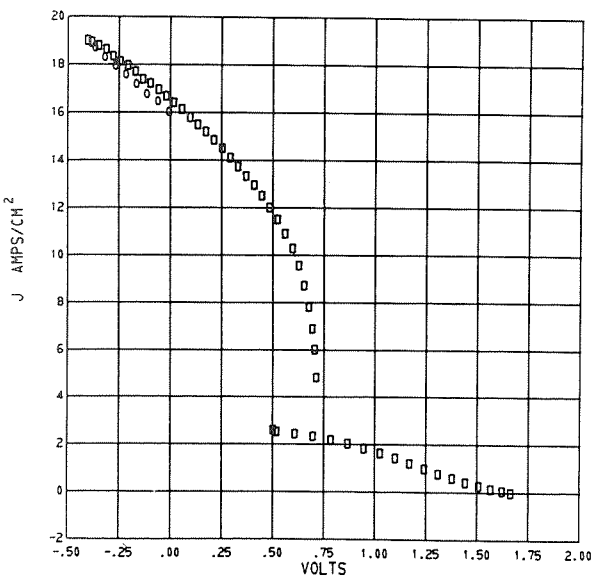


Figure 167. - Sweep 381; emitter temperature, 1856 K; collector temperature, 952 K; reservoir temperature, 597 K.

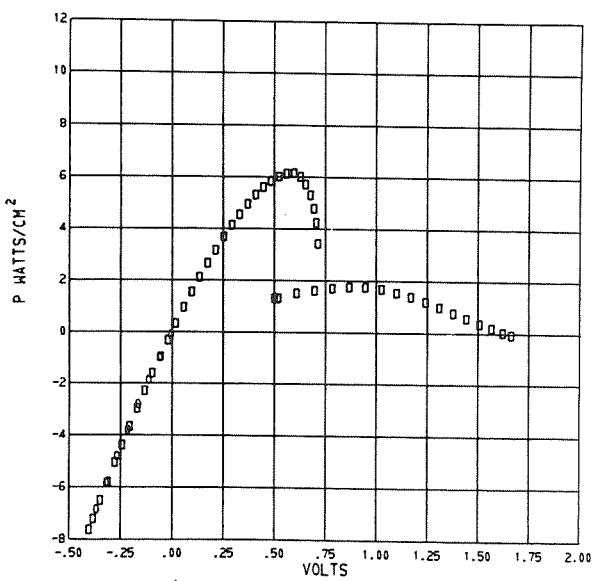


Figure 168. - Sweep 381; emitter temperature, 1856 K; collector temperature, 952 K; reservoir temperature, 597 K.

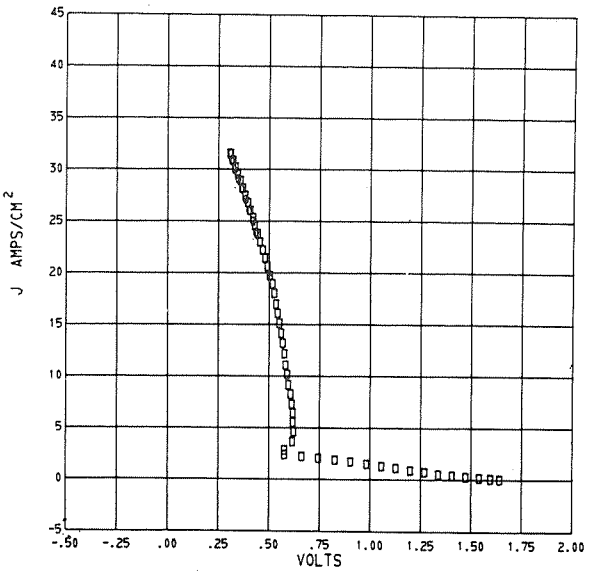


Figure 169. - Sweep 393; emitter temperature, 1857 K; collector temperature, 950 K; reservoir temperature, 622 K.

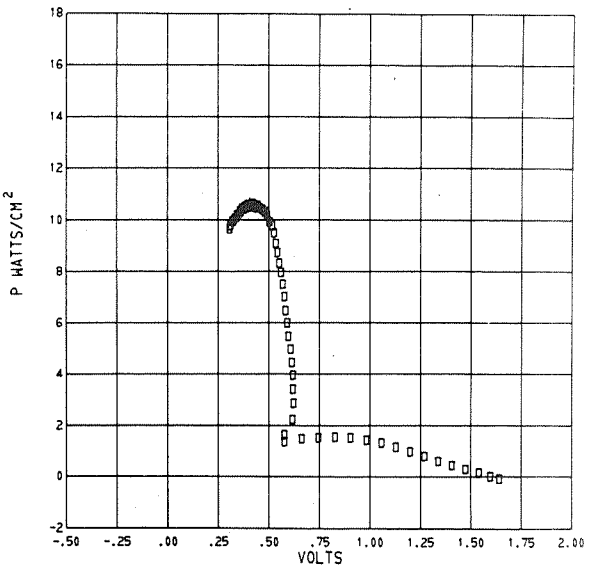


Figure 170. - Sweep 393; emitter temperature, 1857 K; collector temperature, 950 K; reservoir temperature, 622 K.

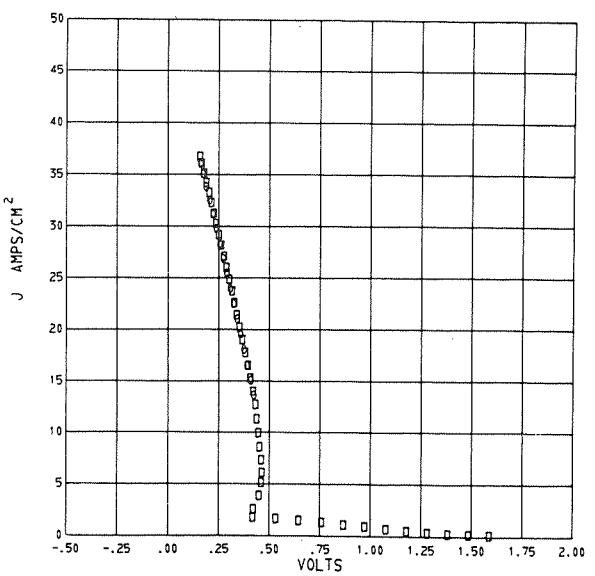


Figure 171. - Sweep 453; emitter temperature, 1853 K; collector temperature, 948 K; reservoir temperature, 651 K.

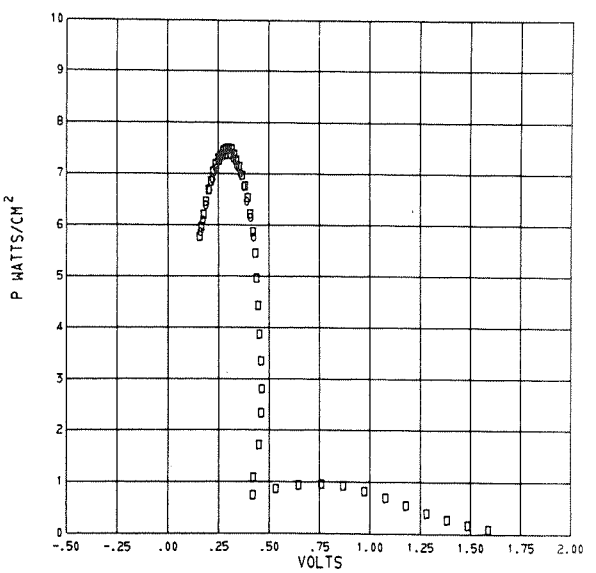


Figure 172. - Sweep 453; emitter temperature, 1853 K; collector temperature, 948 K; reservoir temperature, 651 K.

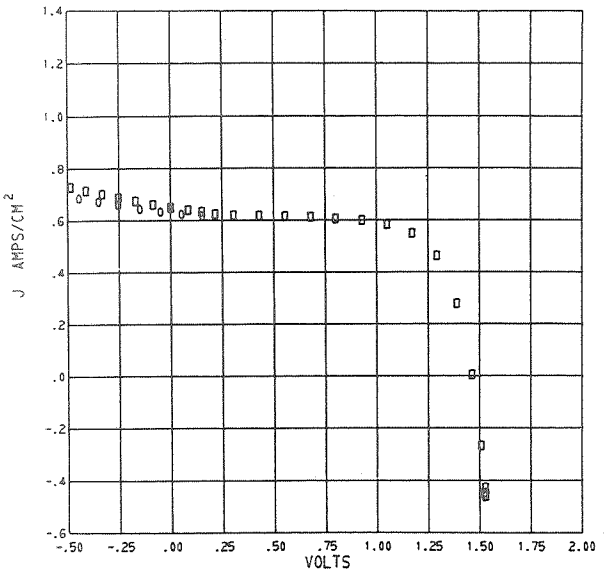


Figure 173. - Sweep 249; emitter temperature, 1861 K; collector temperature, 1060 K; reservoir temperature, 528 K.

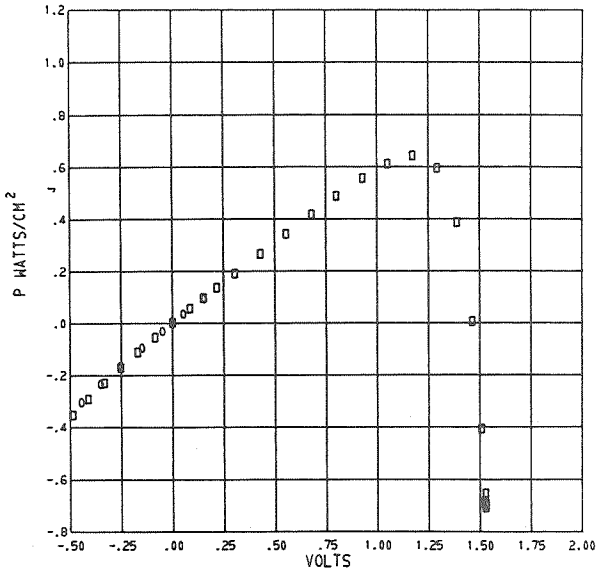


Figure 174. - Sweep 249; emitter temperature, 1861 K; collector temperature, 1060 K; reservoir temperature, 528 K.

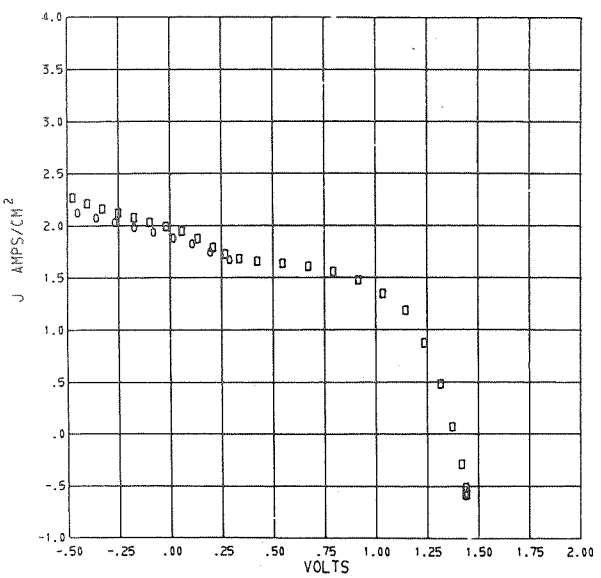


Figure 175. - Sweep 285; emitter temperature, 1852 K; collector temperature, 1064 K; reservoir temperature, 551 K.

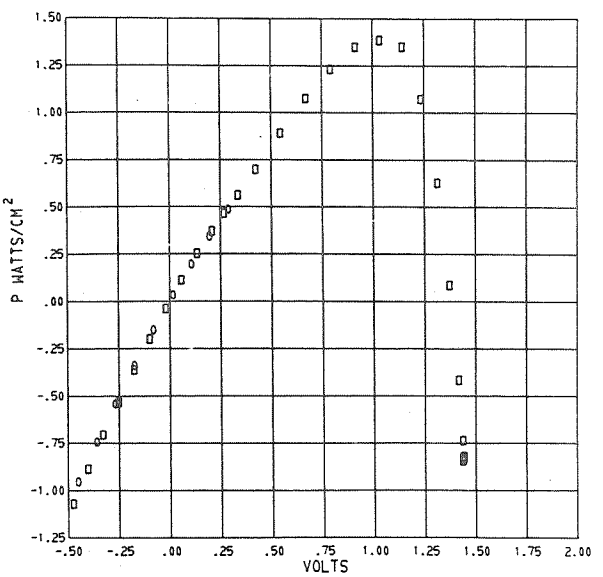


Figure 176. - Sweep 285; emitter temperature, 1852 K; collector temperature, 1064 K; reservoir temperature, 551 K.

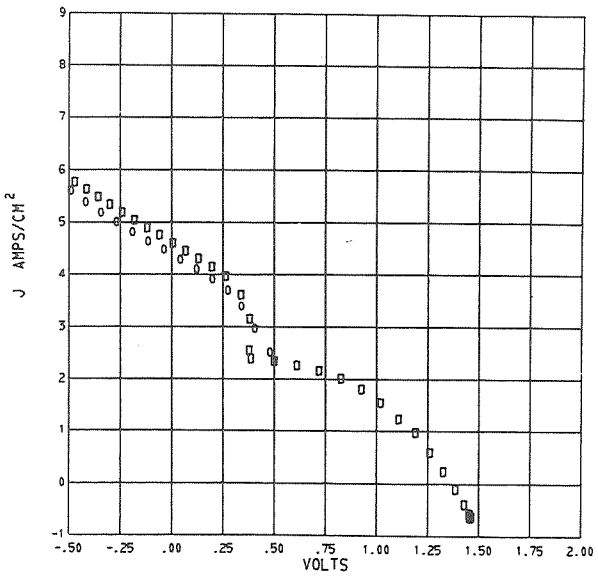


Figure 177. - Sweep 325; emitter temperature, 1858 K; collector temperature, 1063 K; reservoir temperature, 574 K.

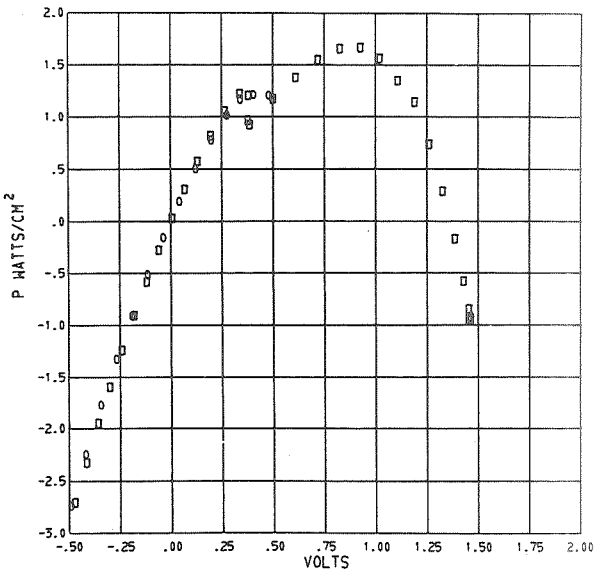


Figure 178. - Sweep 325; emitter temperature, 1858 K; collector temperature, 1063 K; reservoir temperature, 574 K.

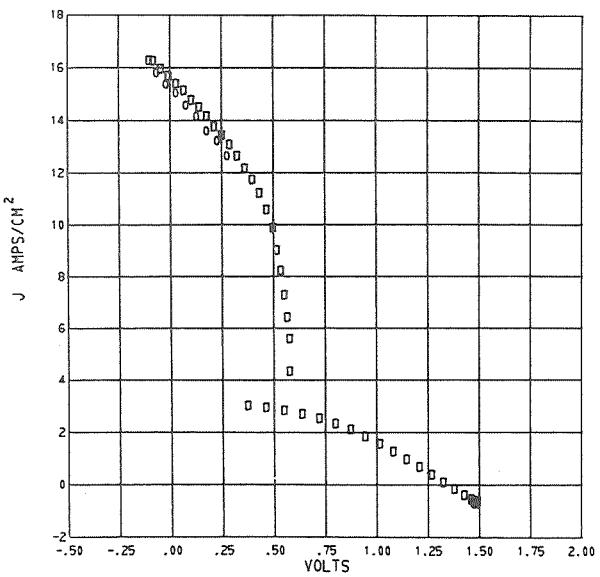


Figure 179. - Sweep 369; emitter temperature, 1856 K; collector temperature, 1070 K; reservoir temperature, 599 K.

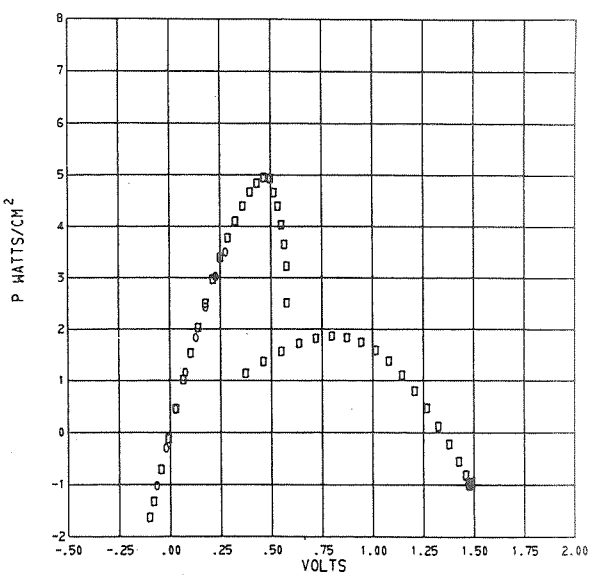


Figure 180. - Sweep 369; emitter temperature, 1856 K; collector temperature, 1070 K; reservoir temperature, 599 K.

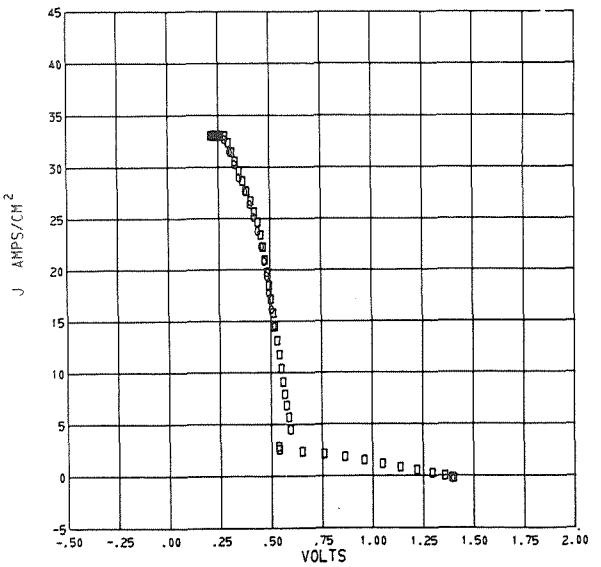


Figure 181. - Sweep 405; emitter temperature, 1857 K; collector temperature, 1062 K; reservoir temperature, 623 K.

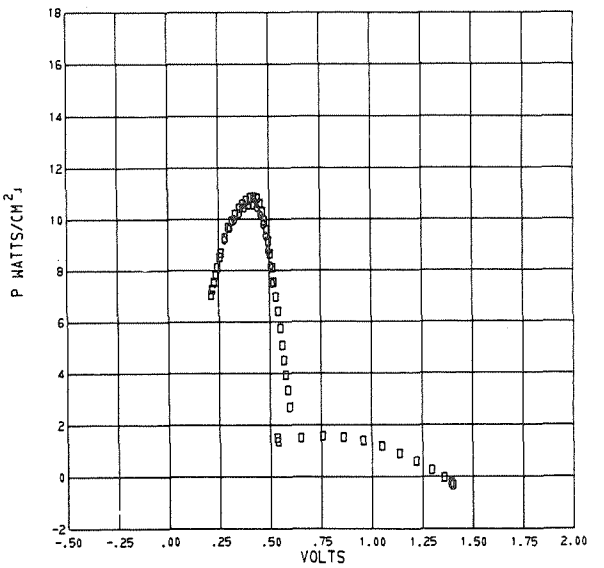


Figure 182. - Sweep 405; emitter temperature, 1857 K; collector temperature, 1062 K; reservoir temperature, 623 K.

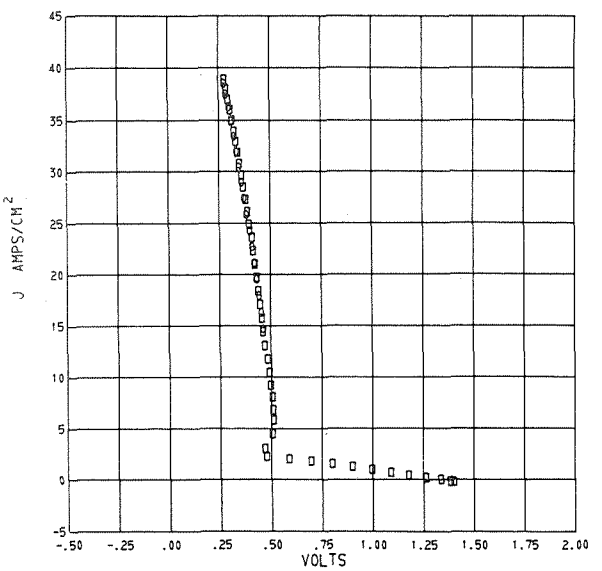


Figure 183. - Sweep 441; emitter temperature, 1855 K; collector temperature, 1063 K; reservoir temperature, 652 K.

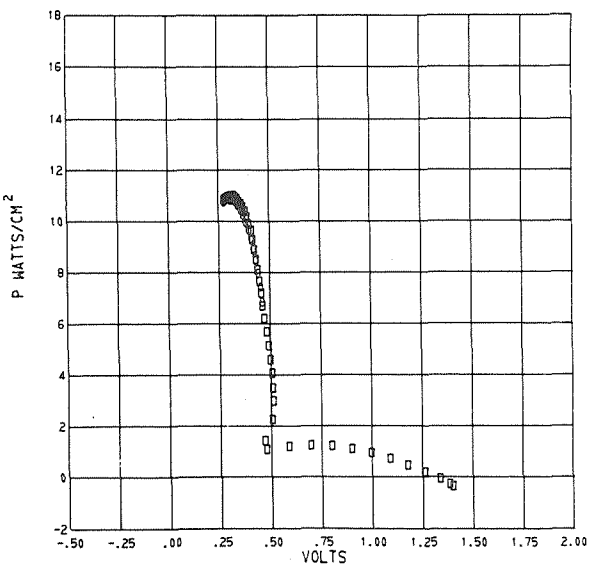


Figure 184. - Sweep 441; emitter temperature, 1855 K; collector temperature, 1063 K; reservoir temperature, 652 K.

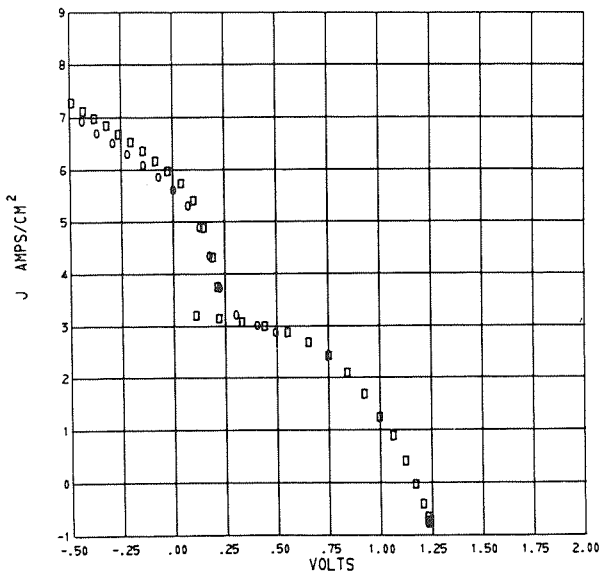


Figure 185. - Sweep 337; emitter temperature, 1857 K; collector temperature, 1176 K; reservoir temperature, 576 K.

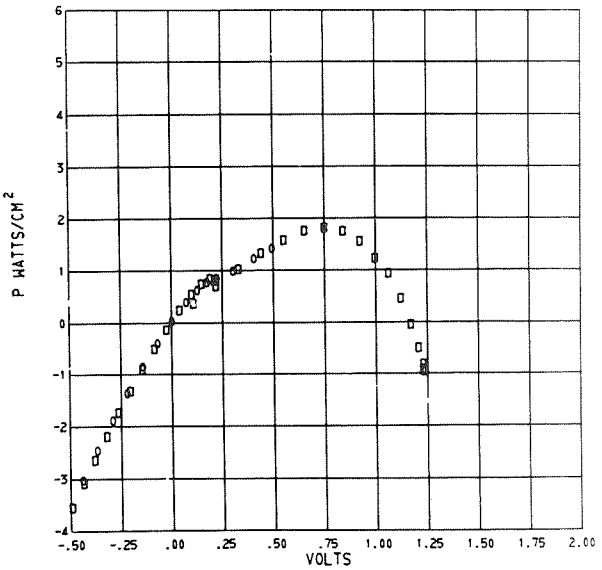


Figure 186. - Sweep 337; emitter temperature, 1857 K; collector temperature, 1176 K; reservoir temperature, 576 K.

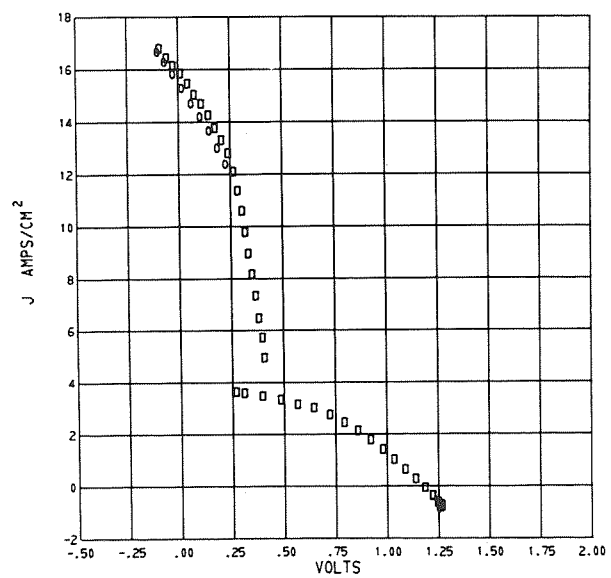


Figure 187. - Sweep 353; emitter temperature, 1858 K; collector temperature, 1168 K; reservoir temperature, 599 K.

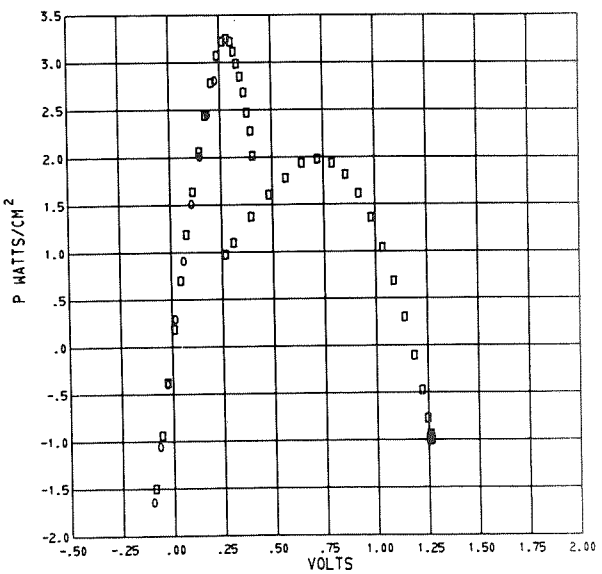


Figure 188. - Sweep 353; emitter temperature, 1858 K; collector temperature, 1168 K; reservoir temperature, 599 K.

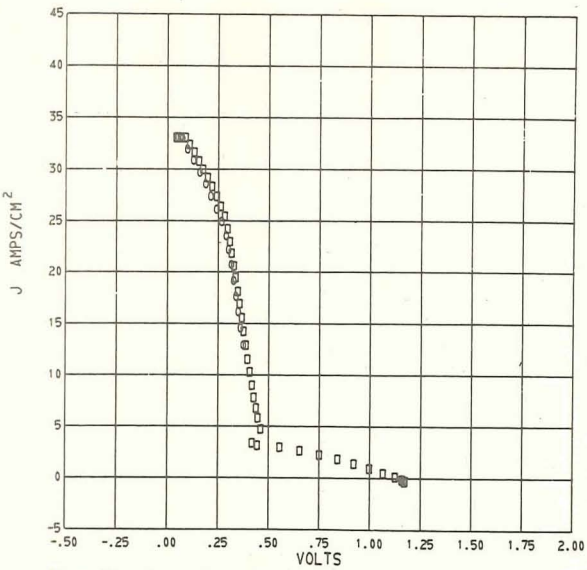


Figure 189. - Sweep 417; emitter temperature, 1859 K; collector temperature, 1178 K; reservoir temperature, 624 K.

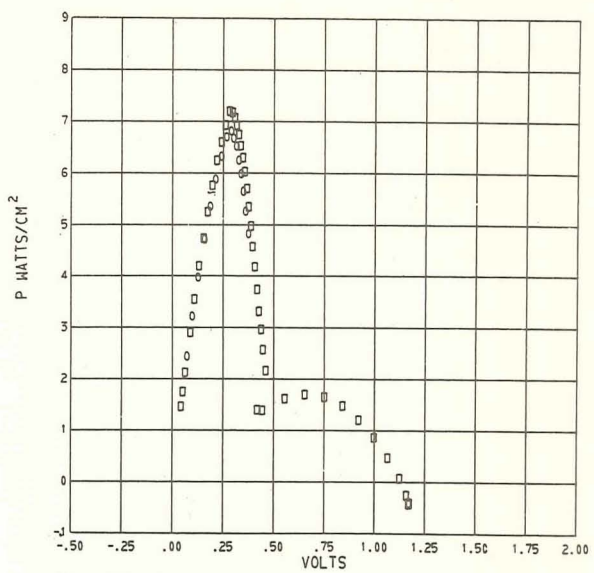


Figure 190. - Sweep 417; emitter temperature, 1859 K; collector temperature, 1178 K; reservoir temperature, 624 K.

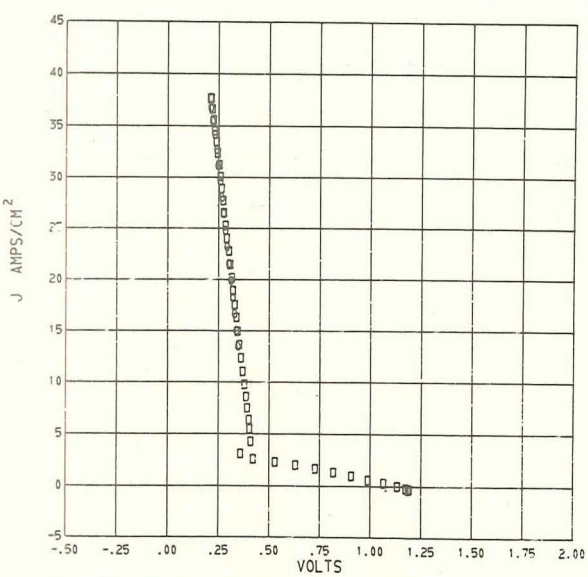


Figure 191. - Sweep 429; emitter temperature, 1854 K; collector temperature, 1182 K; reservoir temperature, 653 K.

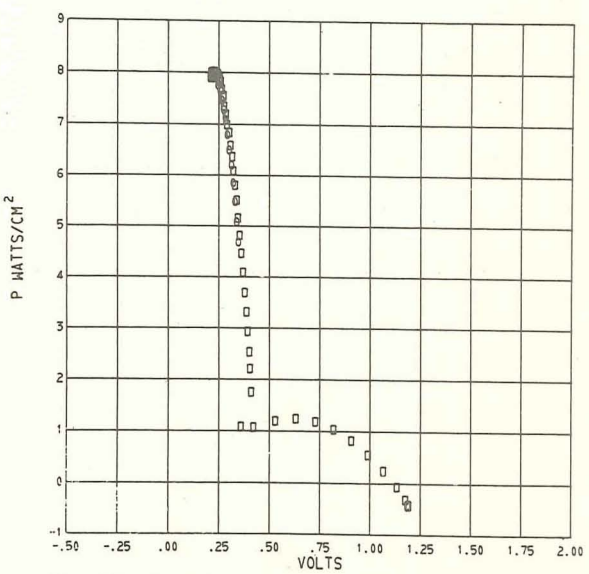


Figure 192. - Sweep 429; emitter temperature, 1854 K; collector temperature, 1182 K; reservoir temperature, 653 K.

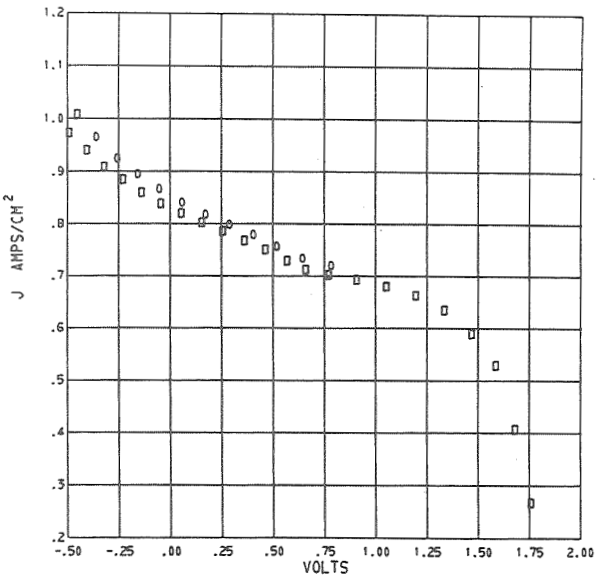


Figure 193. - Sweep 119; emitter temperature, 1904 K; collector temperature, 883 K; reservoir temperature, 531 K.

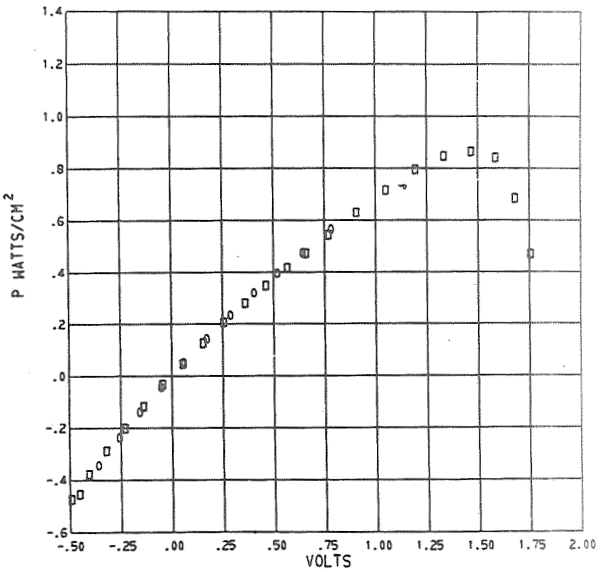


Figure 194. - Sweep 119; emitter temperature, 1904 K; collector temperature, 883 K; reservoir temperature, 531 K.

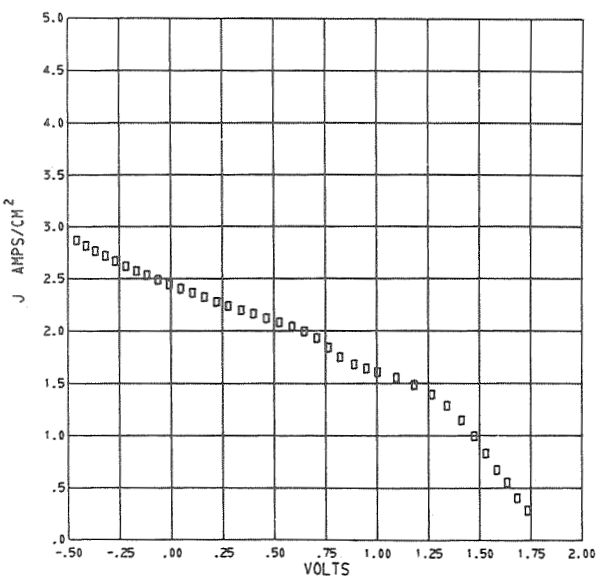


Figure 195. - Sweep 141; emitter temperature, 1897 K; collector temperature, 883 K; reservoir temperature, 550 K.

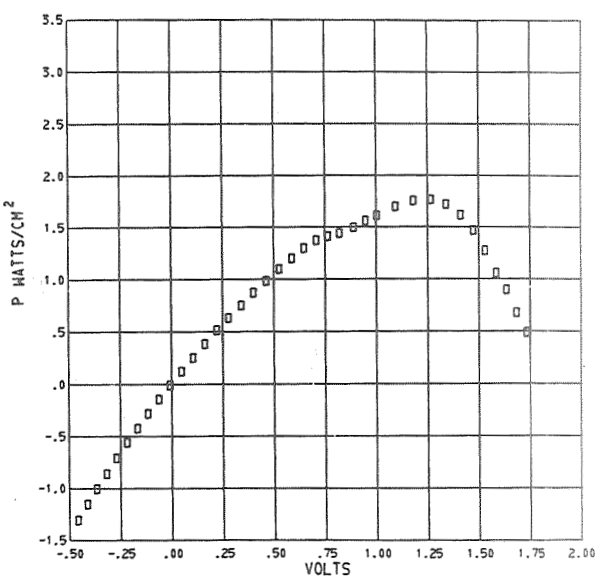


Figure 196. - Sweep 141; emitter temperature, 1897 K; collector temperature, 883 K; reservoir temperature, 550 K.

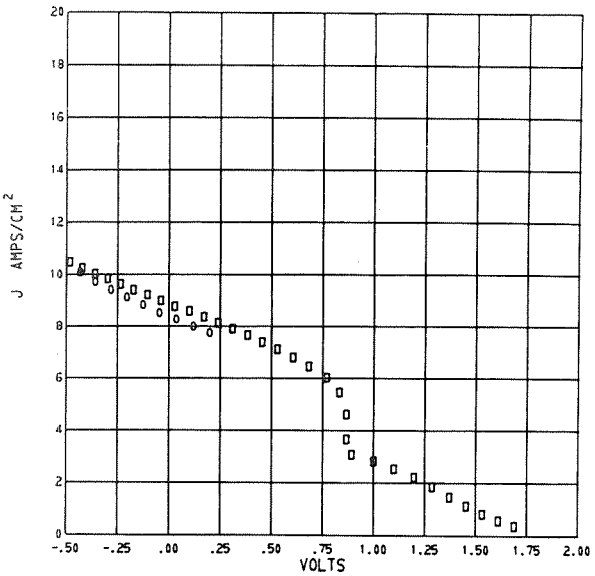


Figure 197. - Sweep 169; emitter temperature, 1904 K; collector temperature, 884 K; reservoir temperature, 576 K.

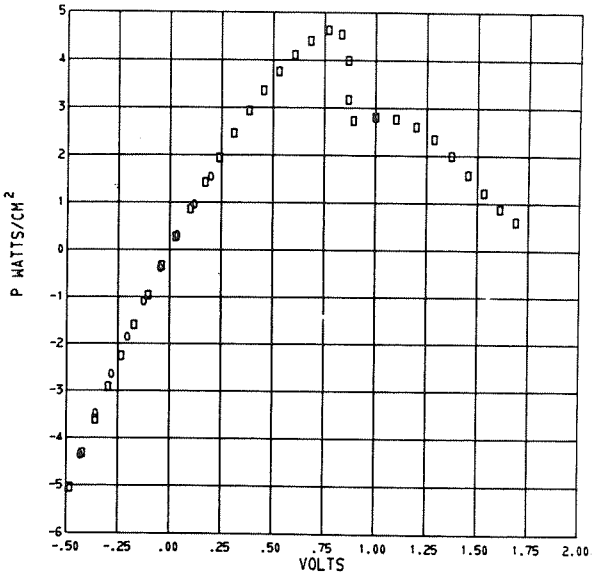


Figure 198. - Sweep 169; emitter temperature, 1904 K; collector temperature, 884 K; reservoir temperature, 576 K.

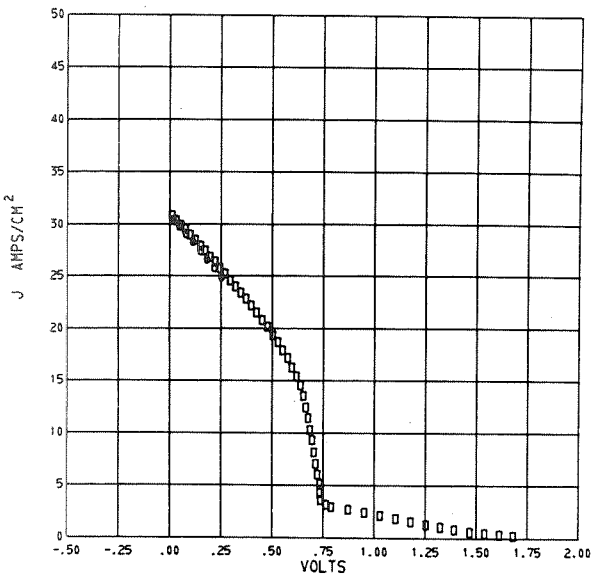


Figure 199. - Sweep 190; emitter temperature, 1902 K; collector temperature, 883 K; reservoir temperature, 605 K.

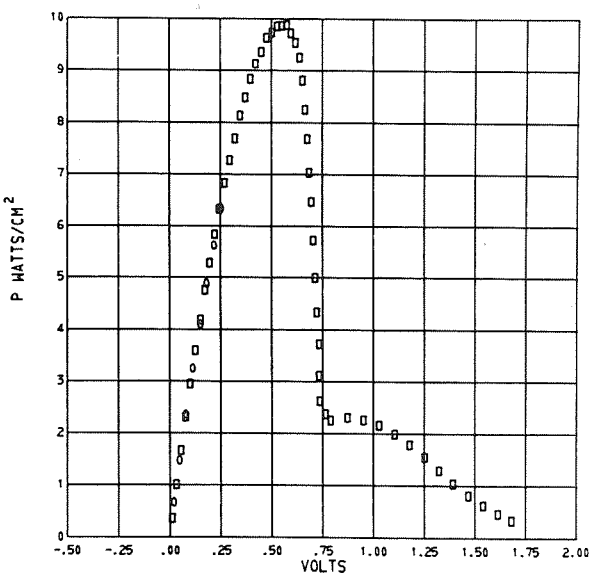


Figure 200. - Sweep 190; emitter temperature, 1902 K; collector temperature, 883 K; reservoir temperature, 605 K.

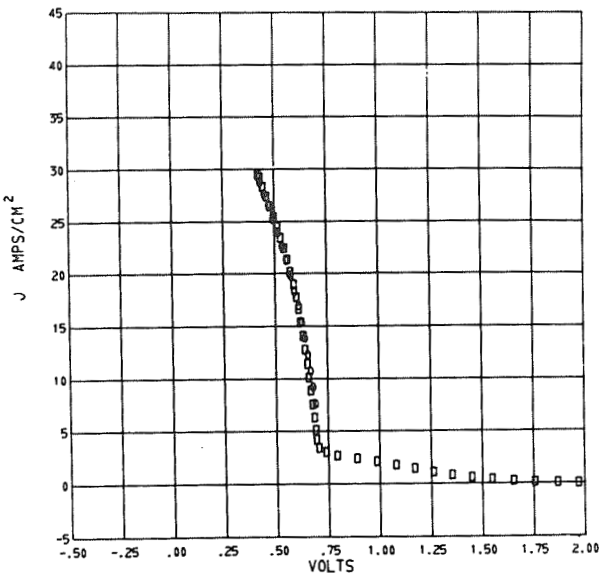


Figure 201. - Sweep 205; emitter temperature, 1897 K; collector temperature, 900 K; reservoir temperature, 623 K.

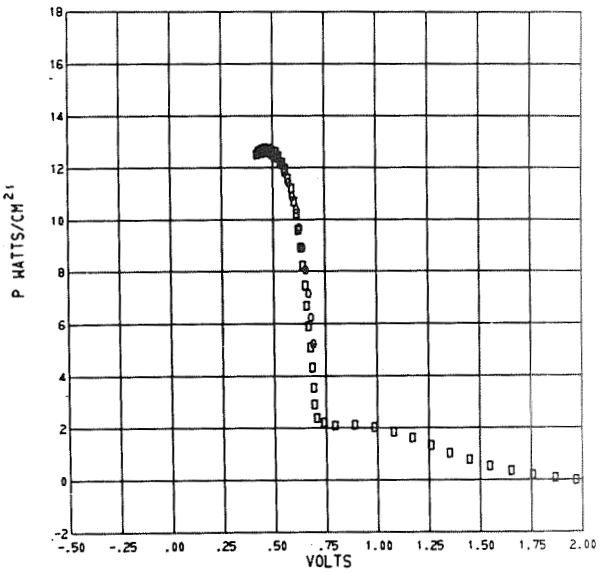


Figure 202. - Sweep 205; emitter temperature, 1897 K; collector temperature, 900 K; reservoir temperature, 623 K.

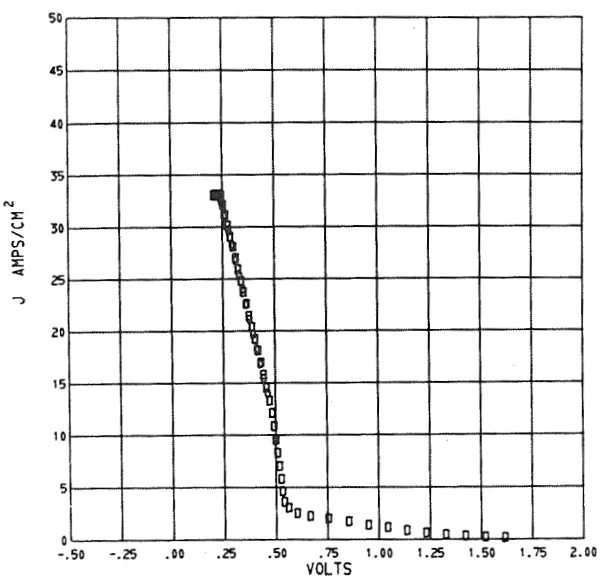


Figure 203. - Sweep 219; emitter temperature, 1902 K; collector temperature, 880 K; reservoir temperature, 650 K.

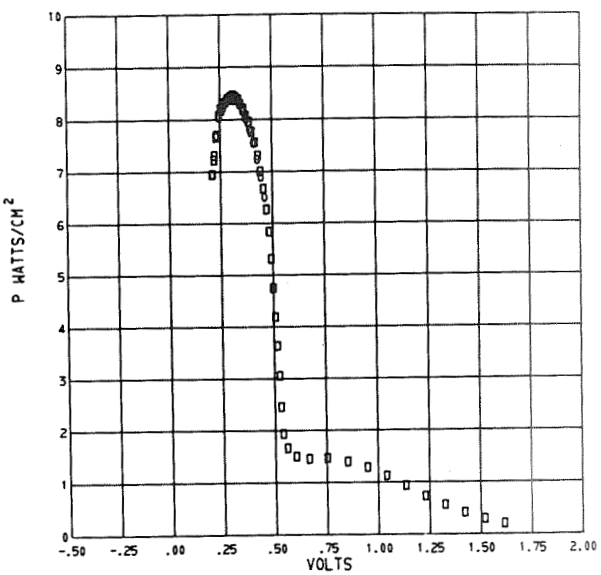


Figure 204. - Sweep 219; emitter temperature, 1902 K; collector temperature, 880 K; reservoir temperature, 650 K.

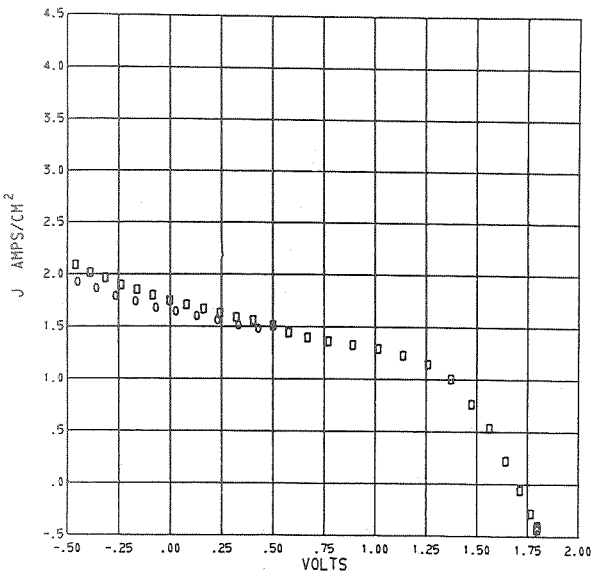


Figure 205. - Sweep 298; emitter temperature, 1904 K; collector temperature, 957 K; reservoir temperature, 549 K.

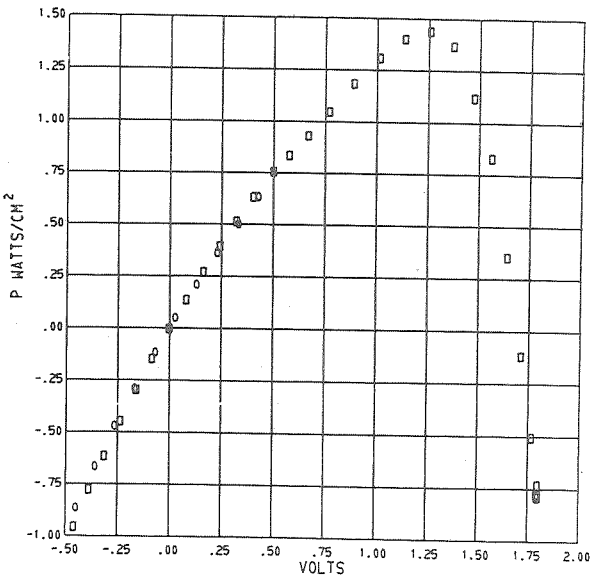


Figure 206. - Sweep 298; emitter temperature, 1904 K; collector temperature, 957 K; reservoir temperature, 549 K.

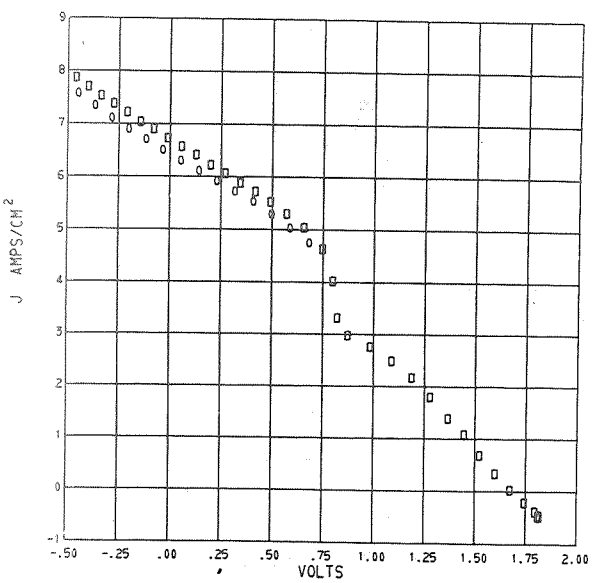


Figure 207. - Sweep 310; emitter temperature, 1900 K; collector temperature, 957 K; reservoir temperature, 573 K.

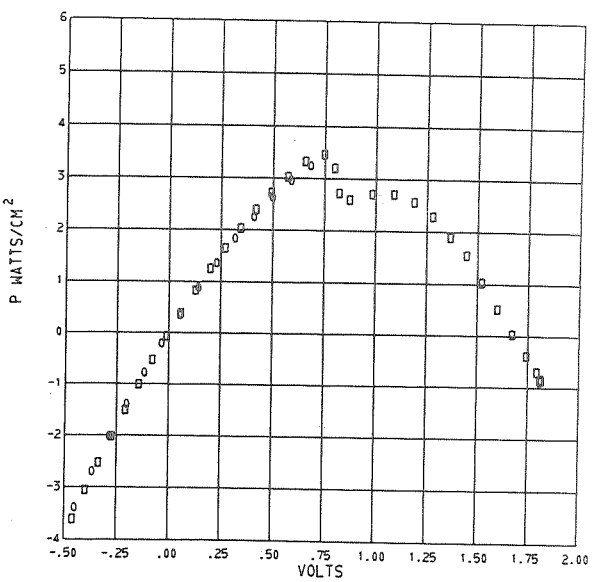


Figure 208. - Sweep 310; emitter temperature, 1900 K; collector temperature, 957 K; reservoir temperature, 573 K.

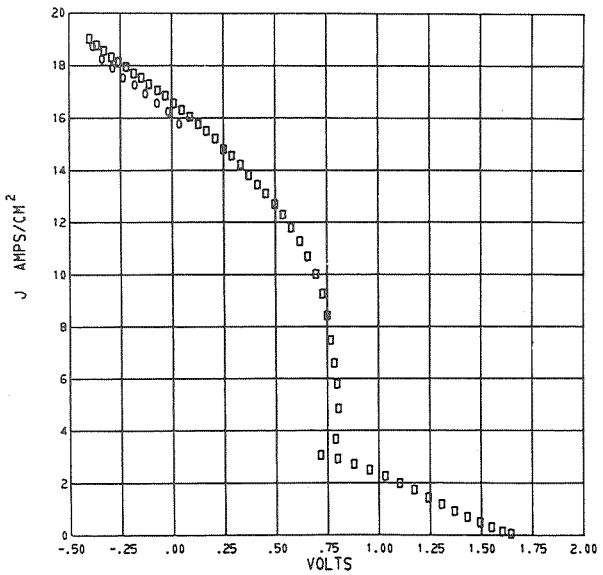


Figure 209. - Sweep 385; emitter temperature, 1899 K; collector temperature, 957 K; reservoir temperature, 597 K.

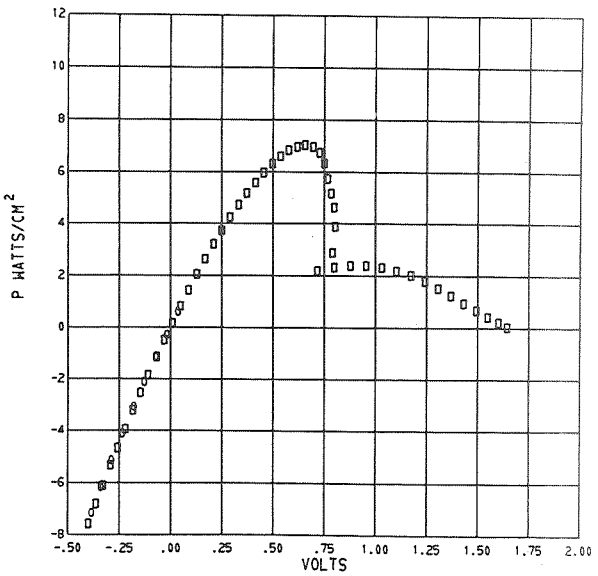


Figure 210. - Sweep 385; emitter temperature, 1899 K; collector temperature, 957 K; reservoir temperature, 597 K.

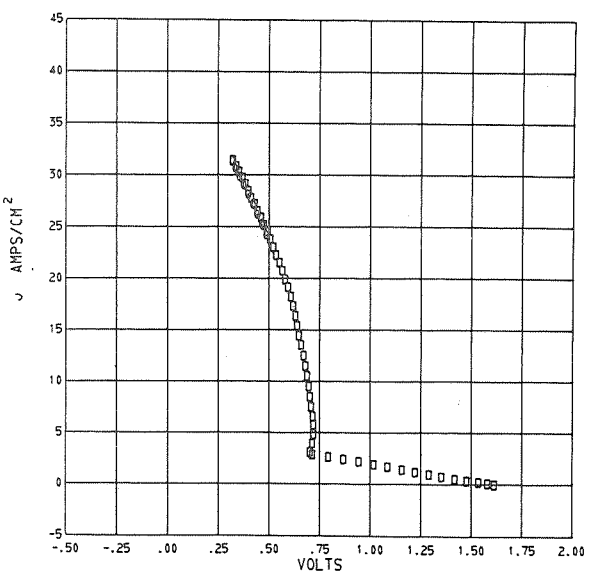


Figure 211. - Sweep 394; emitter temperature, 1903 K; collector temperature, 961 K; reservoir temperature, 622 K.

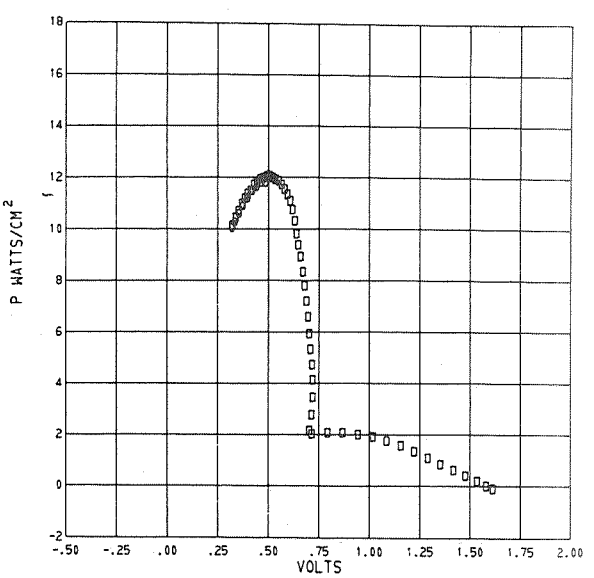


Figure 212. - Sweep 394; emitter temperature, 1903 K; collector temperature, 961 K; reservoir temperature, 622 K.

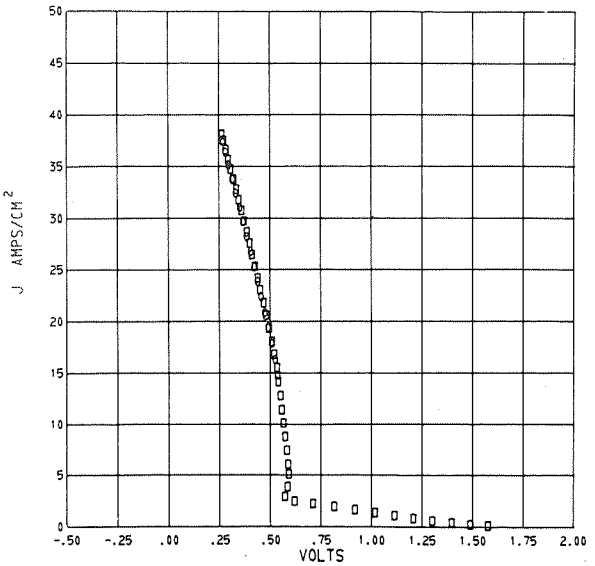


Figure 213. - Sweep 454; emitter temperature, 1905 K; collector temperature, 954 K; reservoir temperature, 650 K.

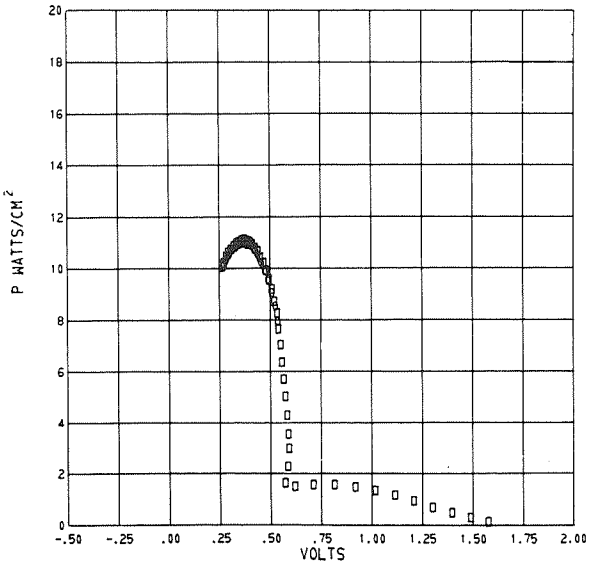


Figure 214. - Sweep 454; emitter temperature, 1905 K; collector temperature, 954 K; reservoir temperature, 650 K.

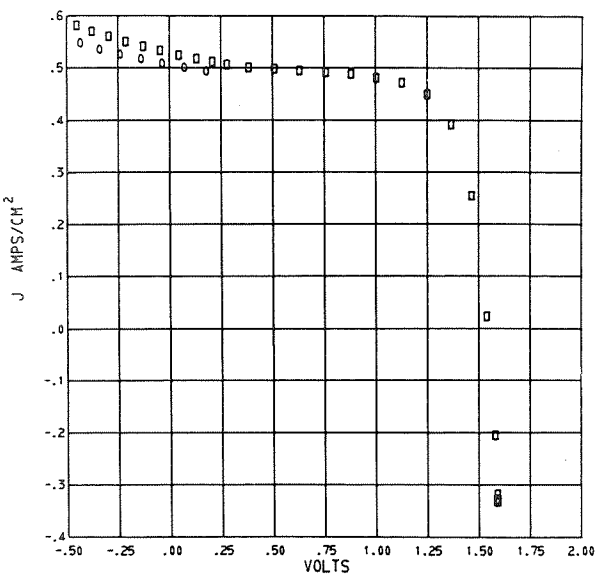


Figure 215. - Sweep 250; emitter temperature, 1904 K; collector temperature, 1061 K; reservoir temperature, 528 K.

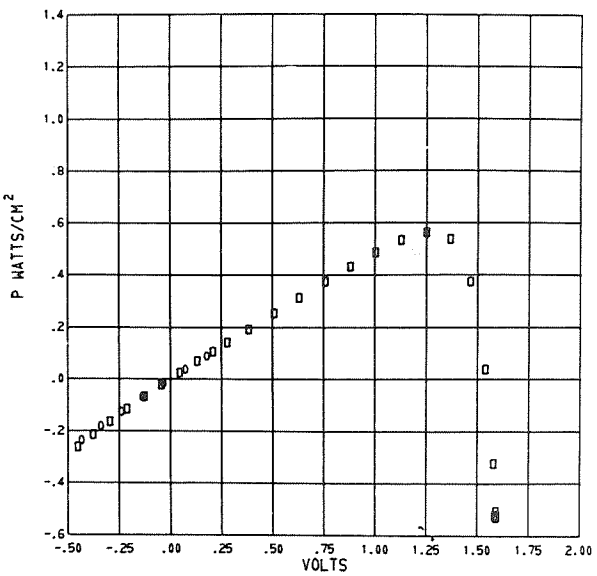


Figure 216. - Sweep 250; emitter temperature, 1904 K; collector temperature, 1061 K; reservoir temperature, 528 K.

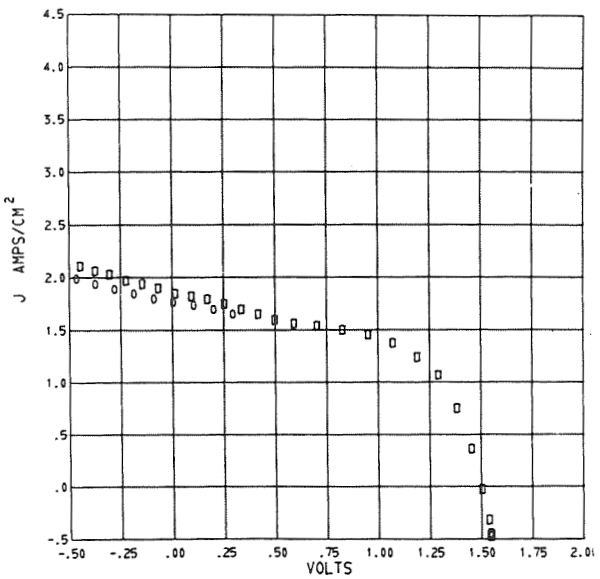


Figure 217. - Sweep 286; emitter temperature, 1901 K; collector temperature, 1057 K; reservoir temperature, 550 K.

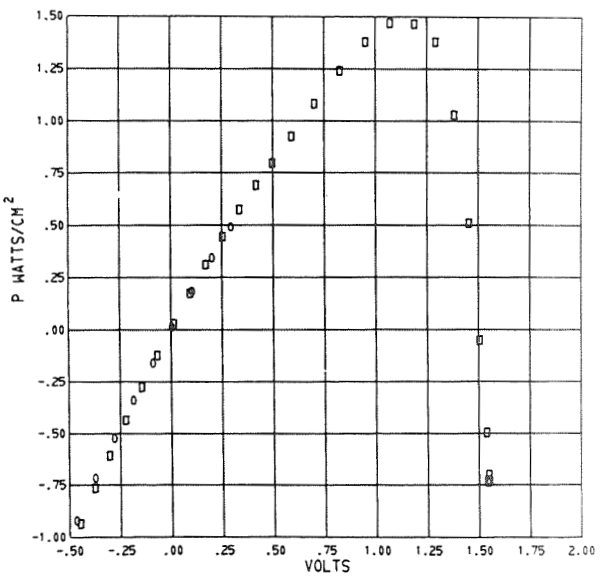


Figure 218. - Sweep 286; emitter temperature, 1901 K; collector temperature, 1057 K; reservoir temperature, 550 K.

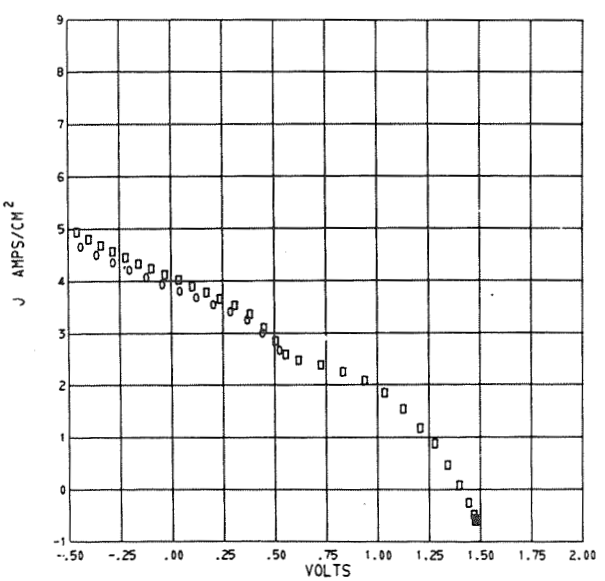


Figure 219. - Sweep 326; emitter temperature, 1902 K; collector temperature, 1064 K; reservoir temperature, 574 K.

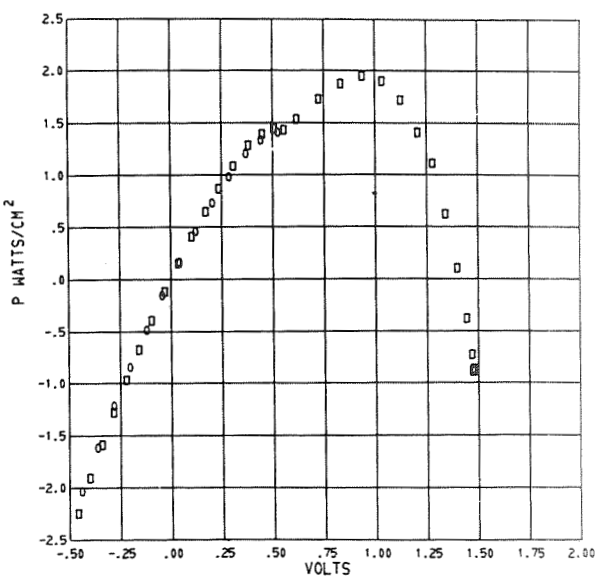


Figure 220. - Sweep 326; emitter temperature, 1902 K; collector temperature, 1064 K; reservoir temperature, 574 K.

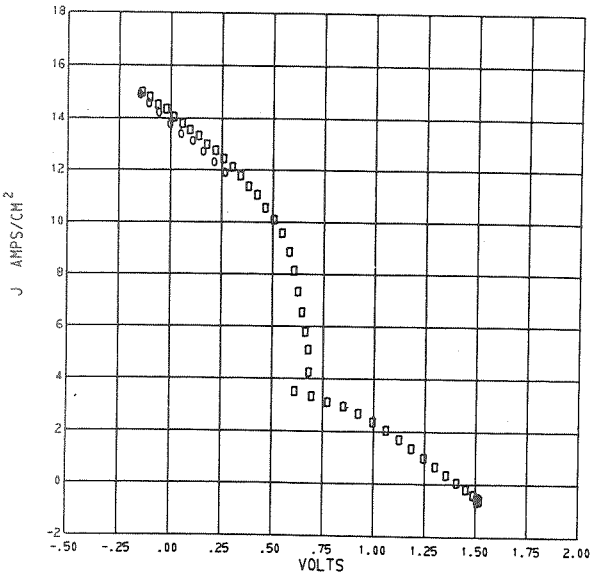


Figure 221. - Sweep 373; emitter temperature, 1899 K; collector temperature, 1064 K; reservoir temperature, 599 K.

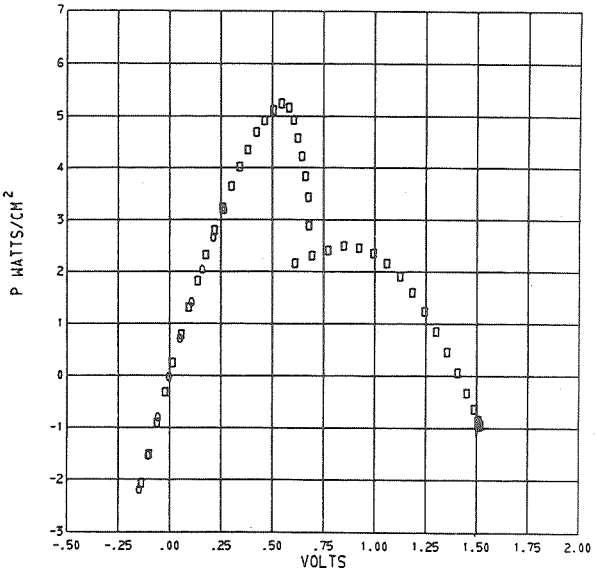


Figure 222. - Sweep 373; emitter temperature, 1899 K; collector temperature, 1064 K; reservoir temperature, 599 K.

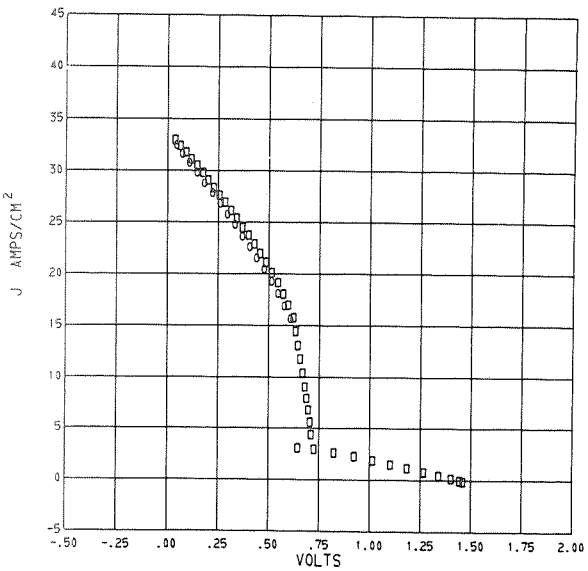


Figure 223. - Sweep 406; emitter temperature, 1904 K; collector temperature, 1056 K; reservoir temperature, 623 K.

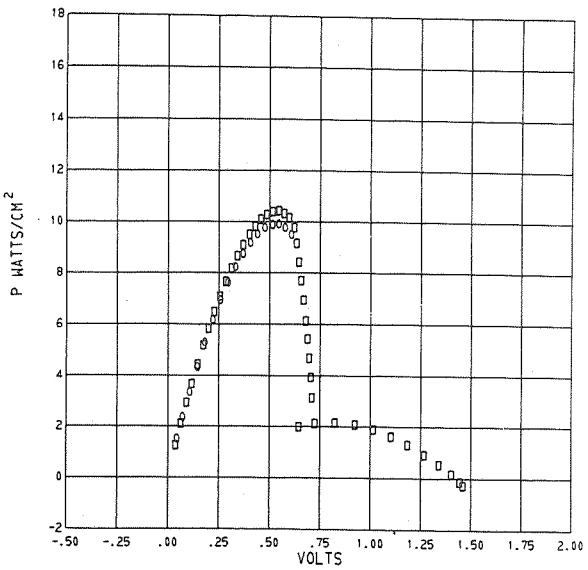


Figure 224. - Sweep 406; emitter temperature, 1904 K; collector temperature, 1056 K; reservoir temperature, 623 K.

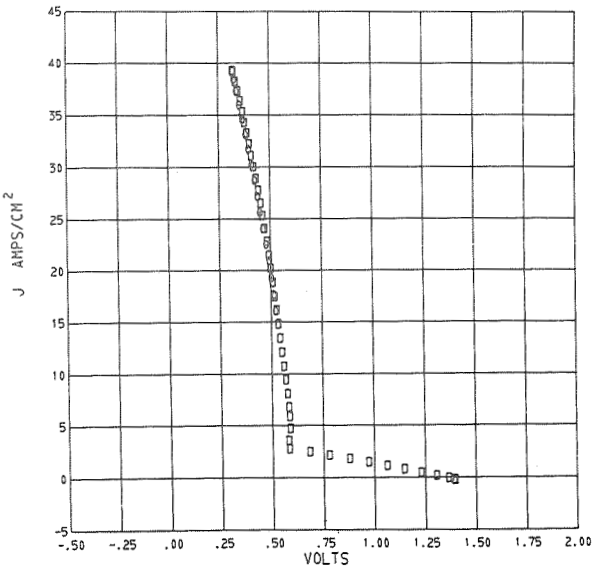


Figure 225. - Sweep 442; emitter temperature, 1903 K; collector temperature, 1073 K; reservoir temperature, 651 K.

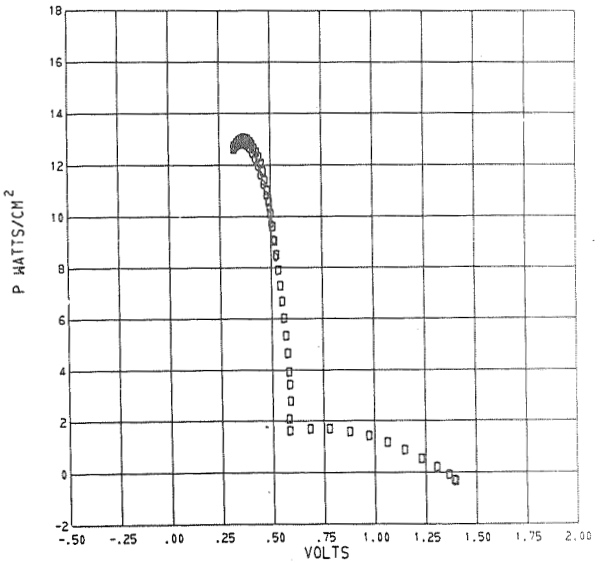


Figure 226. - Sweep 442; emitter temperature, 1903 K; collector temperature, 1073 K; reservoir temperature, 651 K.

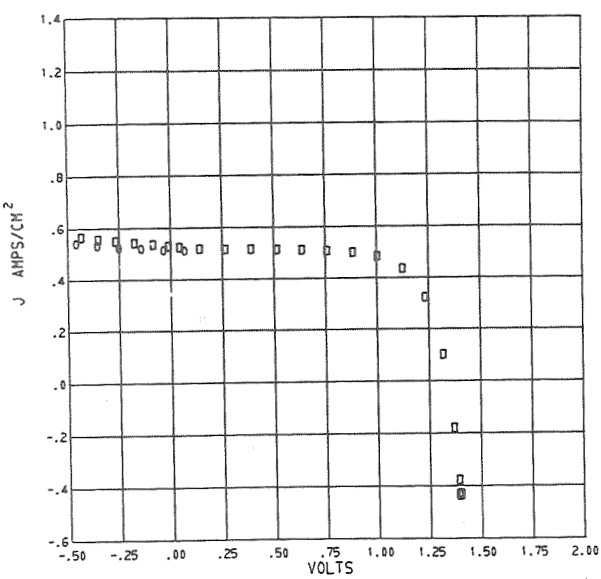


Figure 227. - Sweep 262; emitter temperature, 1903 K; collector temperature, 1184 K; reservoir temperature, 529 K.

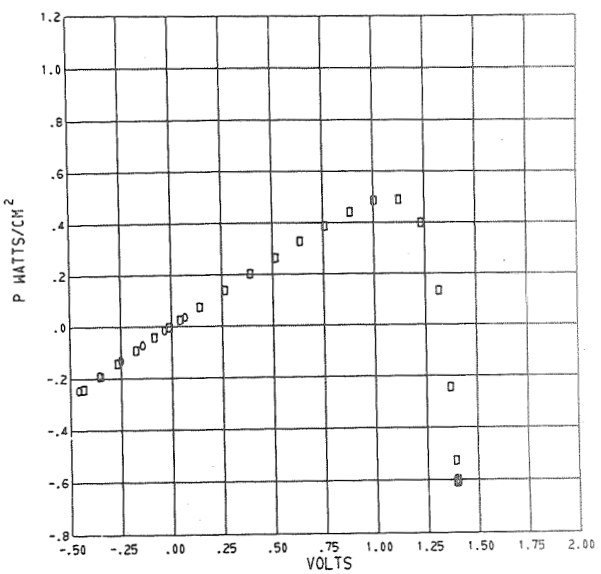


Figure 228. - Sweep 262; emitter temperature, 1093 K; collector temperature, 1184 K; reservoir temperature, 529 K.

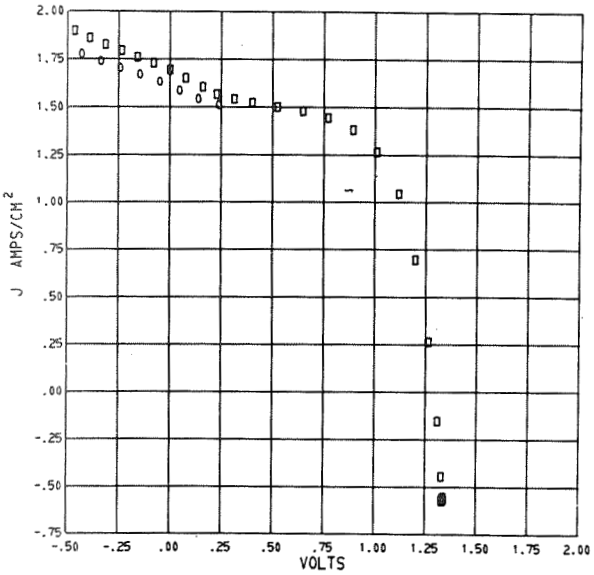


Figure 229. - Sweep 274; emitter temperature, 1901 K; collector temperature, 1178 K; reservoir temperature, 552 K.

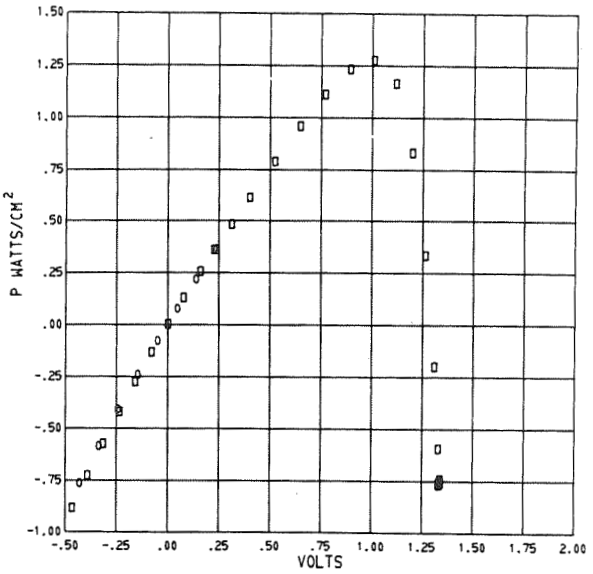


Figure 230. - Sweep 274; emitter temperature, 1901 K; collector temperature, 1178 K; reservoir temperature, 552 K.

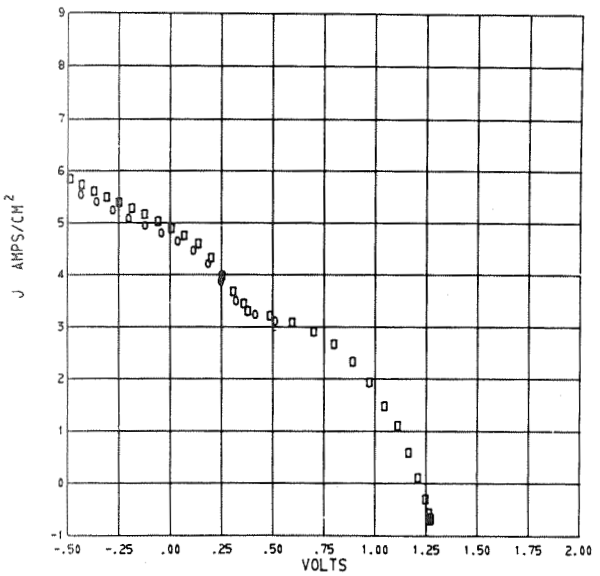


Figure 231. - Sweep 338; emitter temperature, 1902 K; collector temperature, 1174 K; reservoir temperature, 576 K.

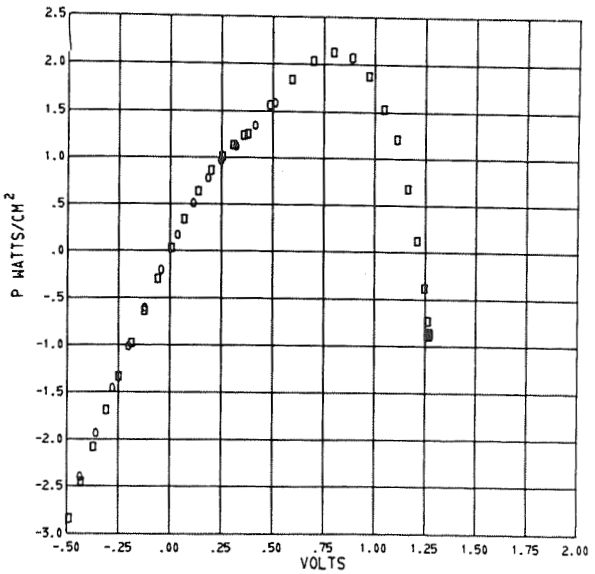


Figure 232. - Sweep 338; emitter temperature, 1902 K; collector temperature, 1174 K; reservoir temperature, 576 K.

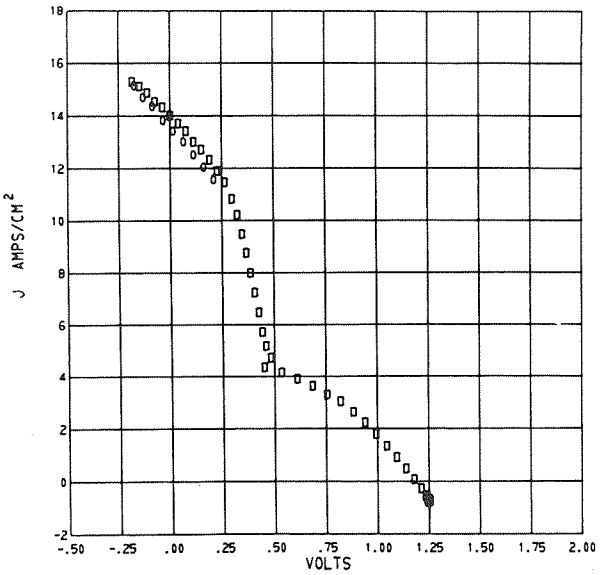


Figure 233. - Sweep 354; emitter temperature, 1902 K; collector temperature, 1181 K; reservoir temperature, 599 K.

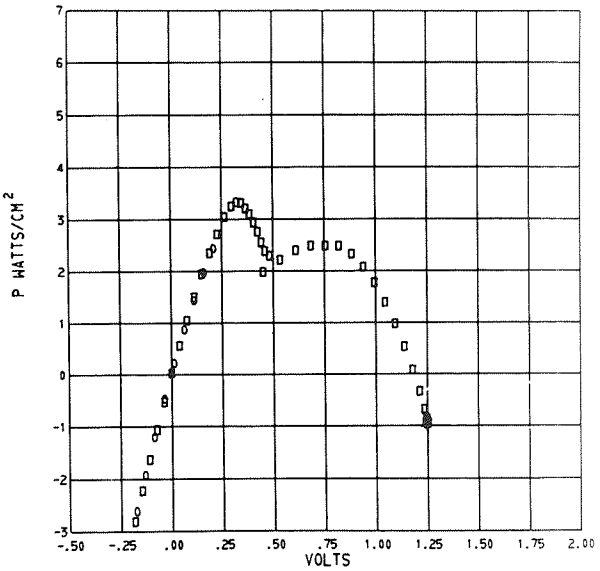


Figure 234. - Sweep 354; emitter temperature, 1902 K; collector temperature, 1181 K; reservoir temperature, 599 K.

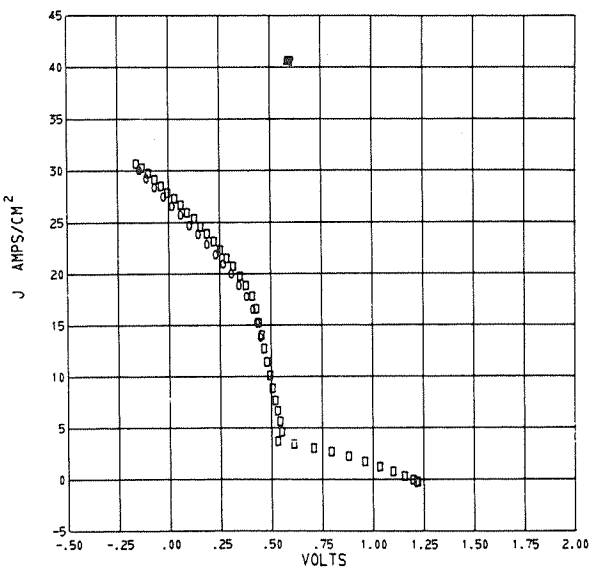


Figure 235. - Sweep 418; emitter temperature, 1904 K; collector temperature, 1180 K; reservoir temperature, 623 K.

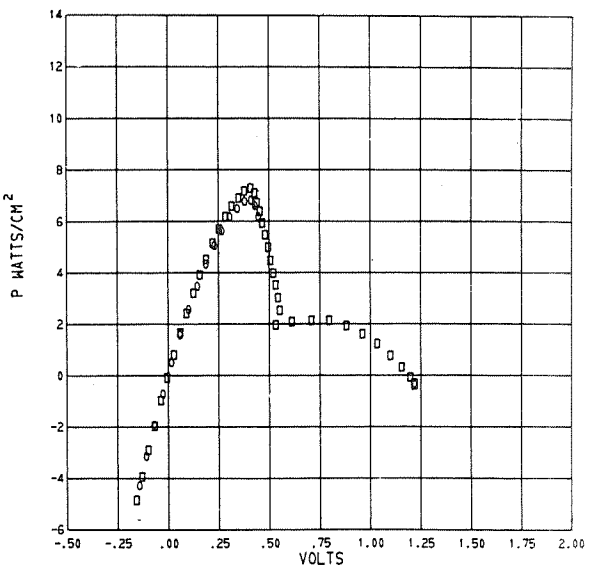


Figure 236. - Sweep 418; emitter temperature, 1904 K; collector temperature, 1180 K; reservoir temperature, 623 K.

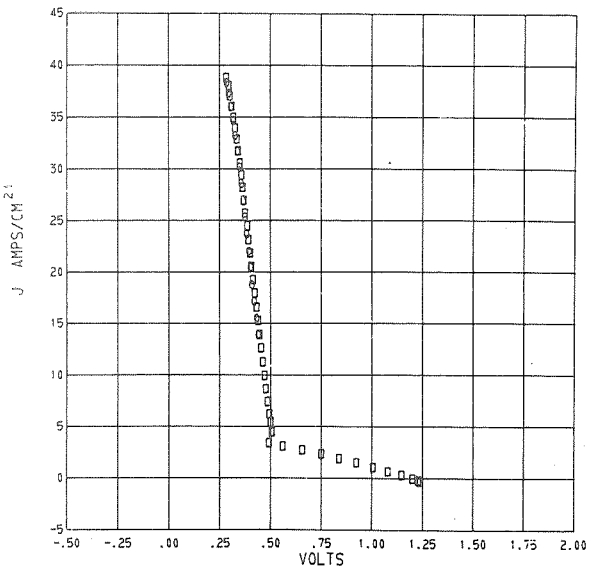


Figure 237. - Sweep 430; emitter temperature, 1901 K; collector temperature, 1174 K; reservoir temperature, 653 K.

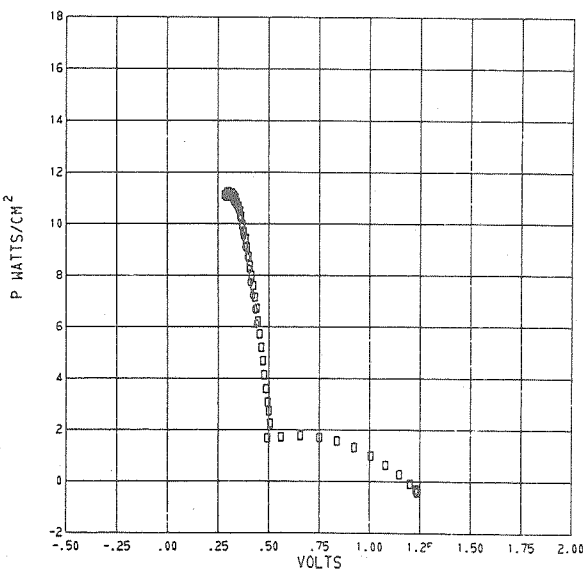


Figure 238. - Sweep 430; emitter temperature, 1901 K; collector temperature, 1174 K; reservoir temperature, 653 K.

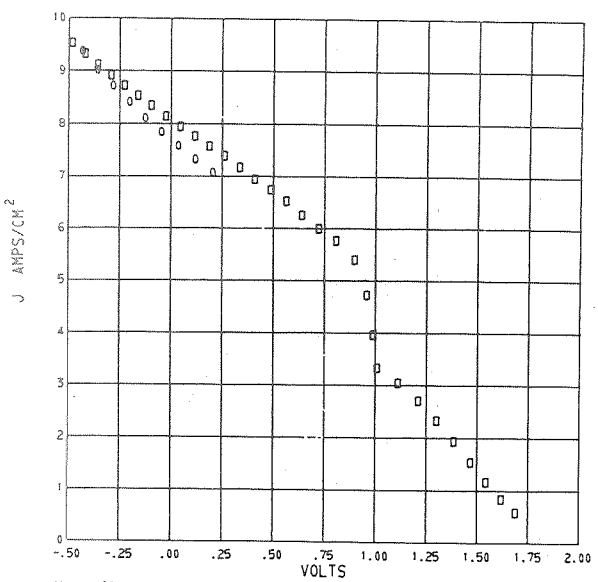


Figure 239. - Sweep 170; emitter temperature, 1955 K; collector temperature, 886 K; reservoir temperature, 576 K.

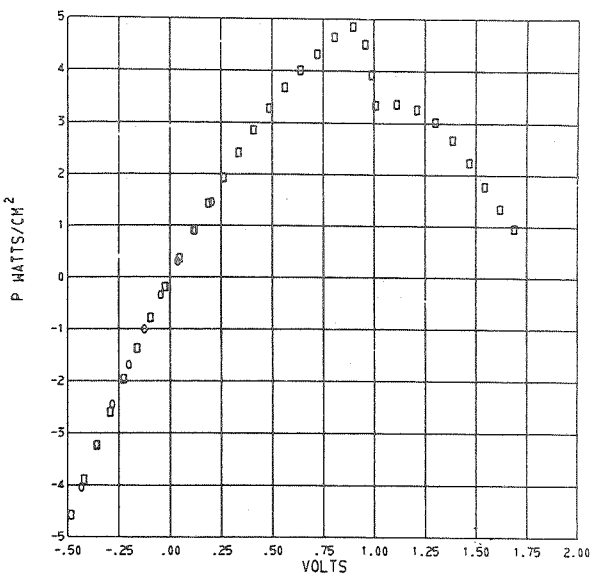


Figure 240. - Sweep 170; emitter temperature, 1955 K; collector temperature, 886 K; reservoir temperature, 576 K.

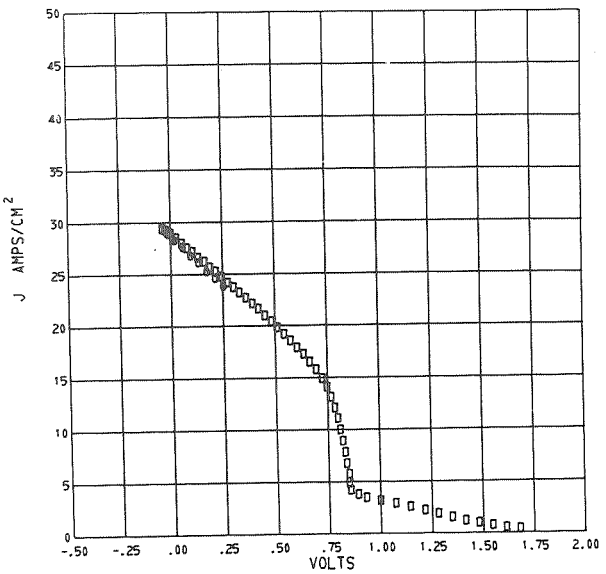


Figure 241. - Sweep 191; emitter temperature, 1953 K; collector temperature, 897 K; reservoir temperature, 605 K.

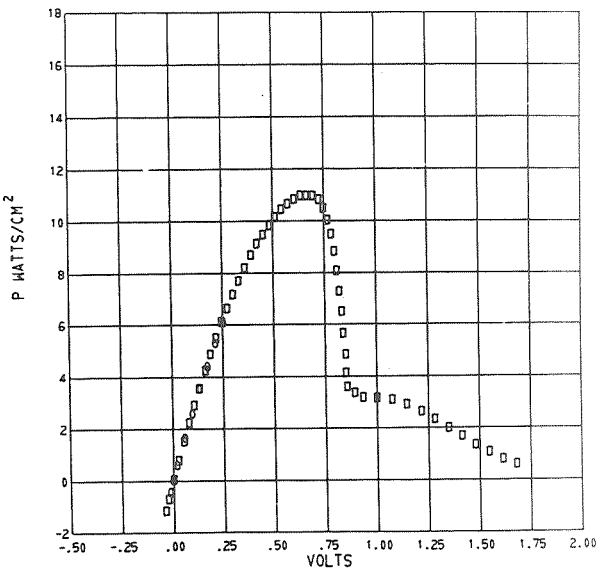


Figure 242. - Sweep 191; emitter temperature, 1953 K; collector temperature, 897 K; reservoir temperature, 605 K.

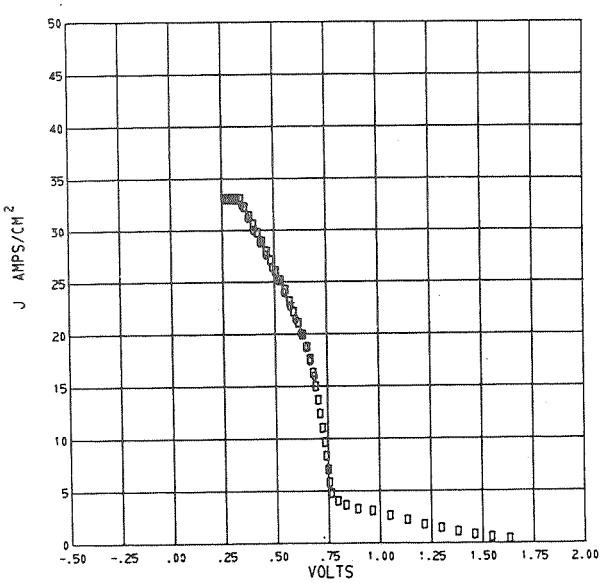


Figure 243. - Sweep 211; emitter temperature, 1956 K; collector temperature, 886 K; reservoir temperature, 623 K.

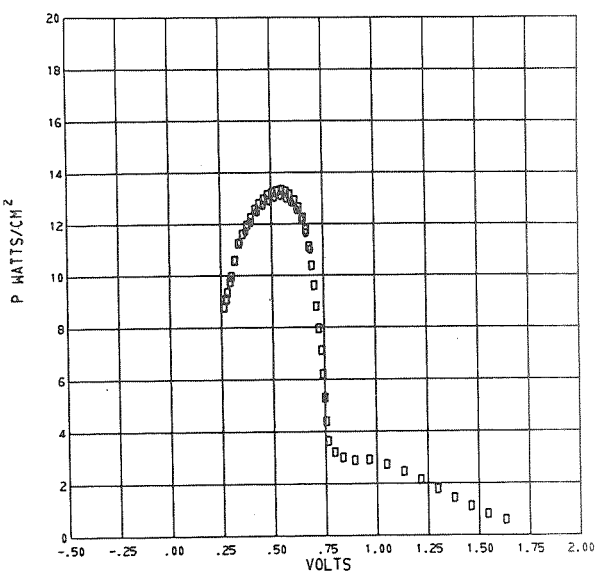


Figure 244. - Sweep 211; emitter temperature, 1956 K; collector temperature, 886 K; reservoir temperature, 623 K.

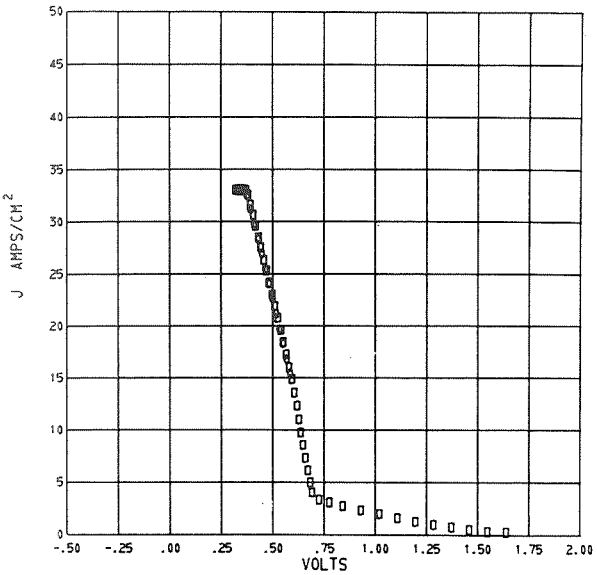


Figure 245. - Sweep 220; emitter temperature, 1959 K; collector temperature, 903 K; reservoir temperature, 650 K.

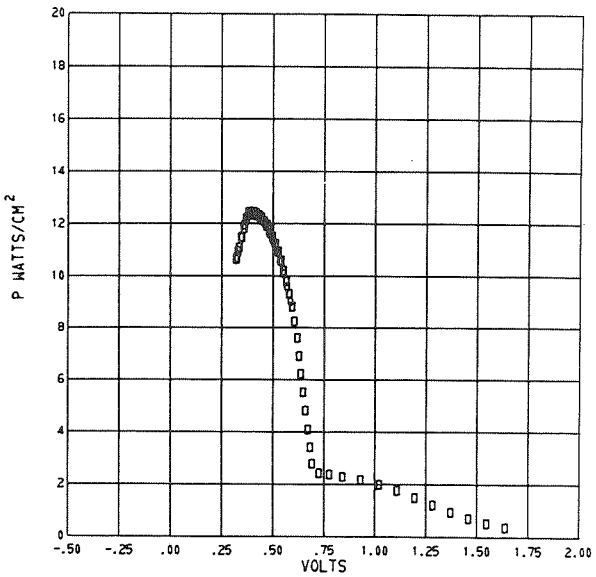


Figure 246. - Sweep 220; emitter temperature, 1959 K; collector temperature, 903 K; reservoir temperature, 650 K.

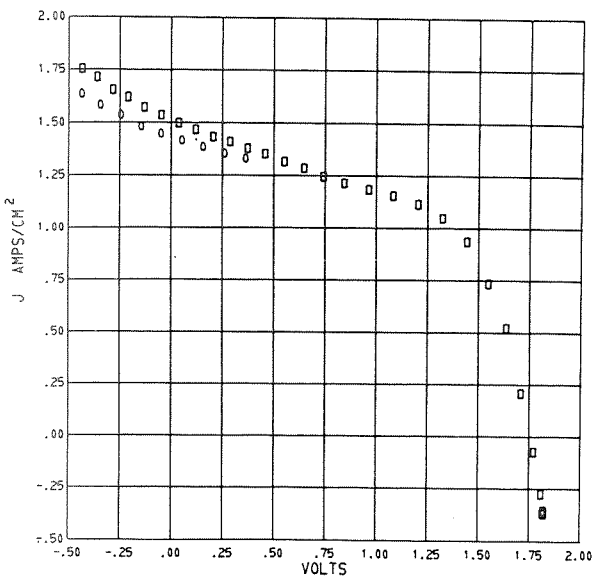


Figure 247. - Sweep 299; emitter temperature, 1960 K; collector temperature, 961 K; reservoir temperature, 548 K.

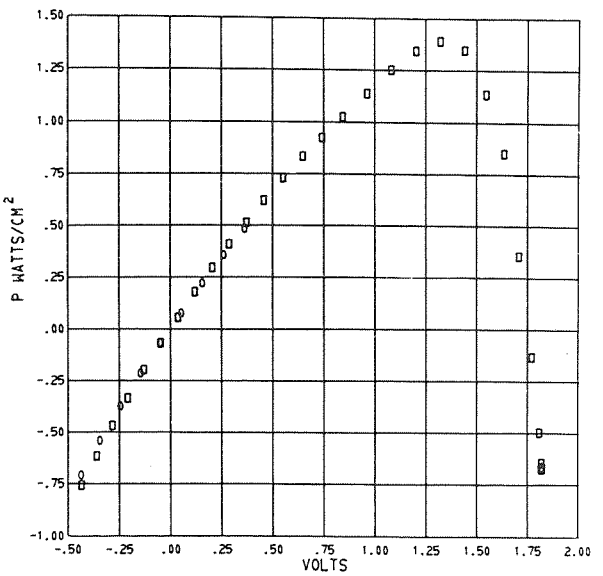


Figure 248. - Sweep 299; emitter temperature, 1960 K; collector temperature, 961 K; reservoir temperature, 548 K.

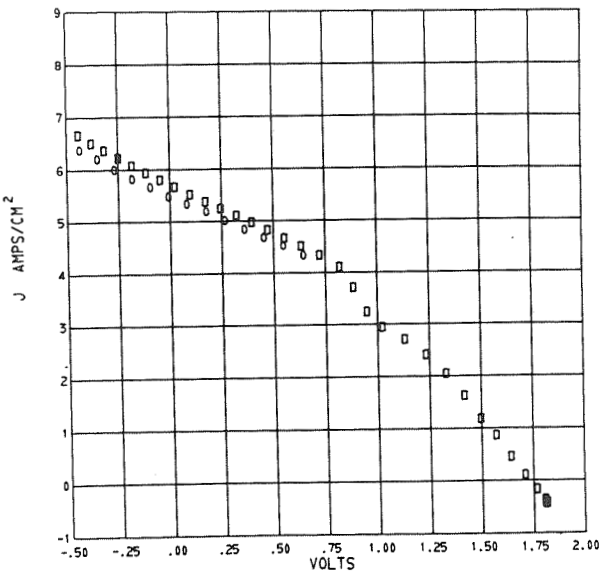


Figure 249. - Sweep 311; emitter temperature, 1955 K; collector temperature, 961 K; reservoir temperature, 572 K.

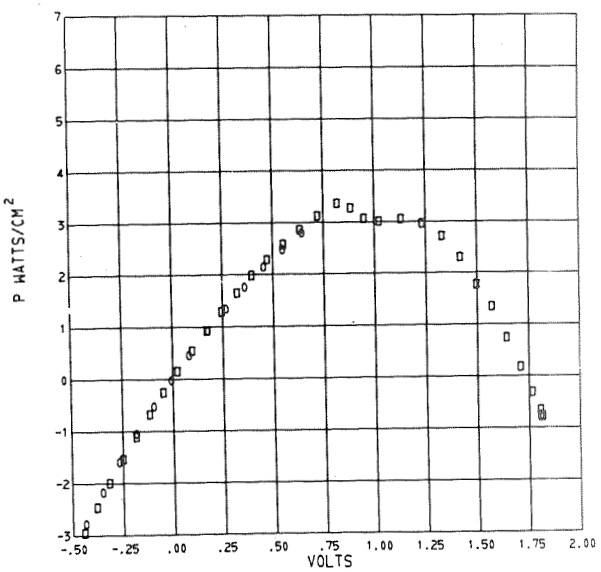


Figure 250. - Sweep 311; emitter temperature, 1955 K; collector temperature, 961 K; reservoir temperature, 572 K.

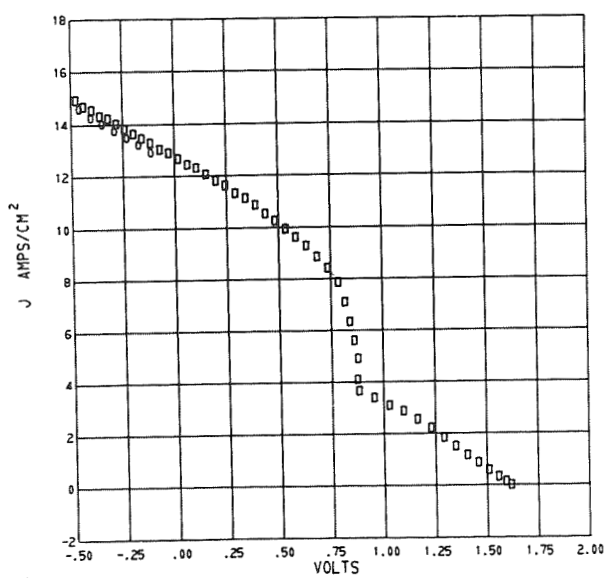


Figure 251. - Sweep 383; emitter temperature, 1963 K; collector temperature, 964 K; reservoir temperature, 597 K.

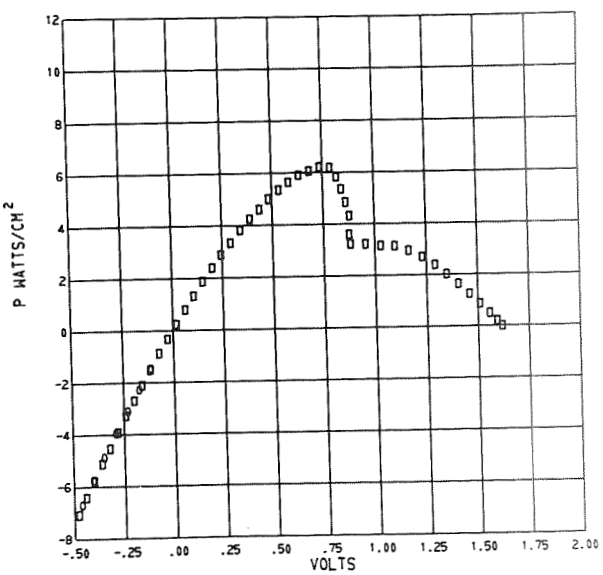


Figure 252. - Sweep 383; emitter temperature, 1963 K; collector temperature, 964 K; reservoir temperature, 597 K.

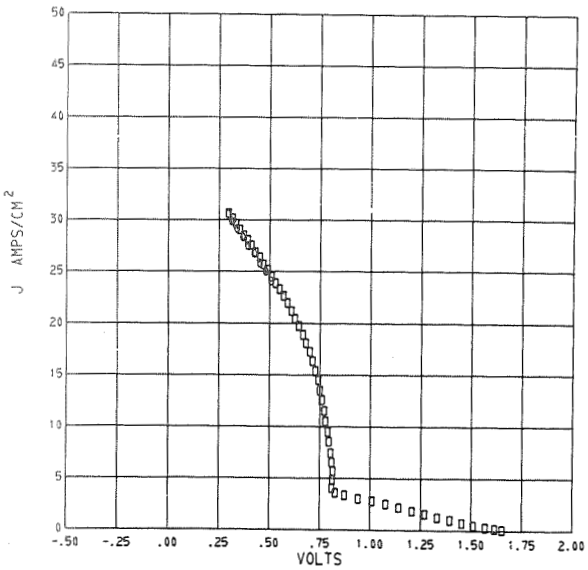


Figure 253. - Sweep 395; emitter temperature, 1962 K; collector temperature, 968 K; reservoir temperature, 622 K.

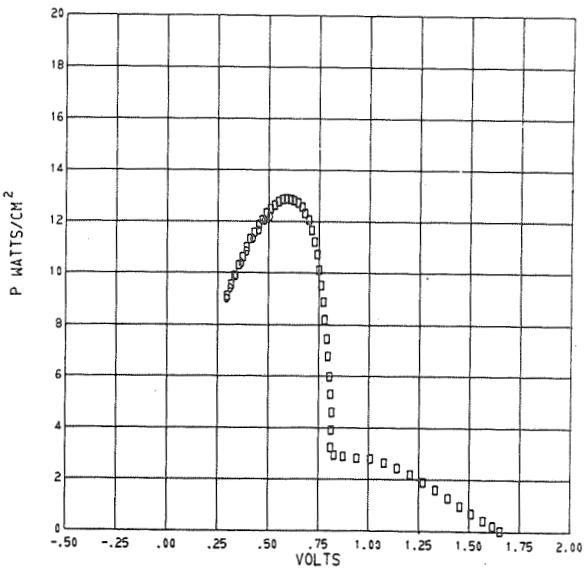


Figure 254. - Sweep 395; emitter temperature, 1962 K; collector temperature, 968 K; reservoir temperature, 622 K.

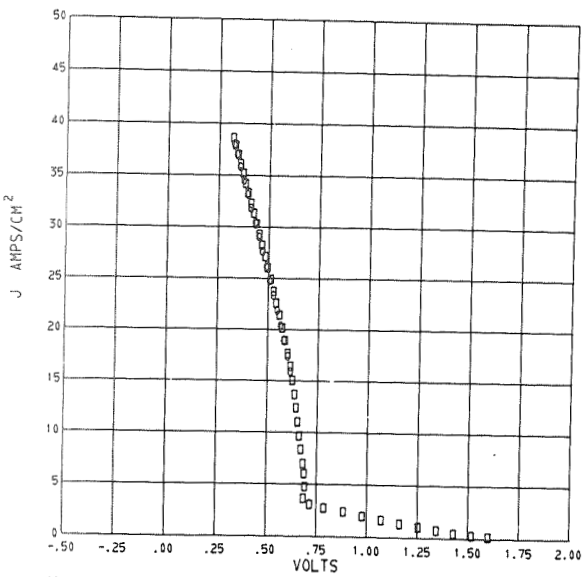


Figure 255. - Sweep 455; emitter temperature, 1956 K; collector temperature, 966 K; reservoir temperature, 650 K.

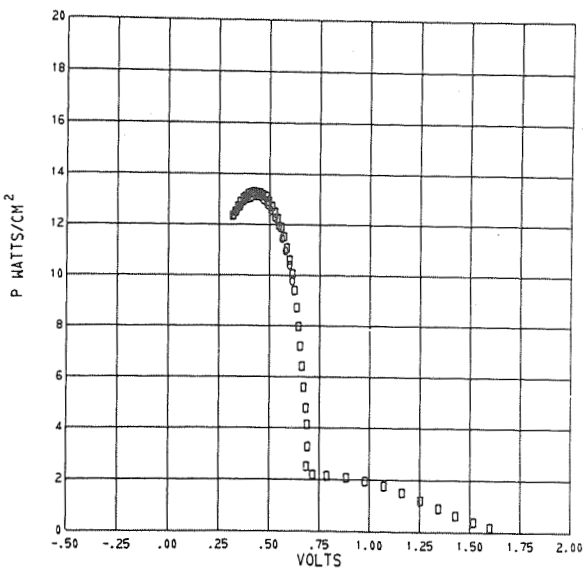


Figure 256. - Sweep 455; emitter temperature, 1956 K; collector temperature, 966 K; reservoir temperature, 650 K.

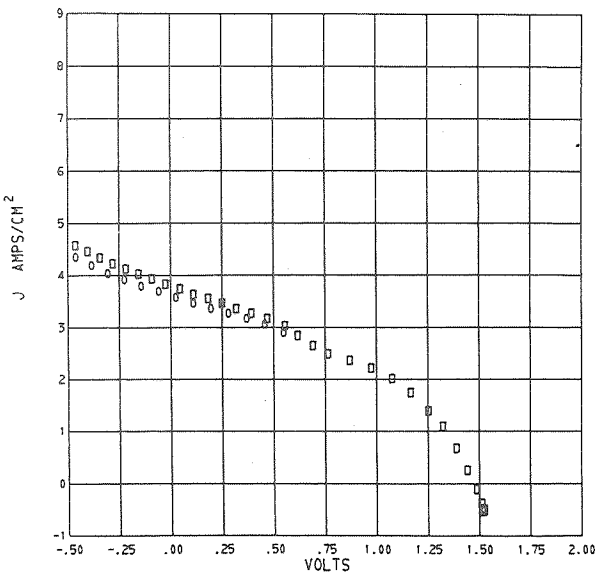


Figure 257. - Sweep 327; emitter temperature, 1955 K; collector temperature, 1067 K; reservoir temperature, 574 K.

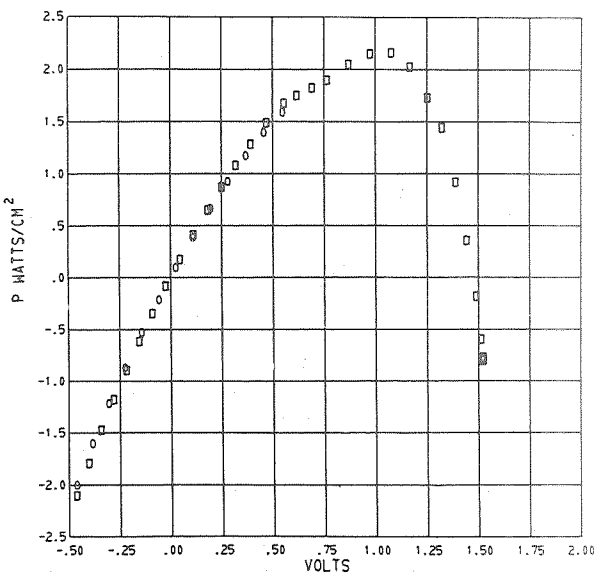


Figure 258. - Sweep 327; emitter temperature, 1955 K; collector temperature, 1067 K; reservoir temperature, 574 K.

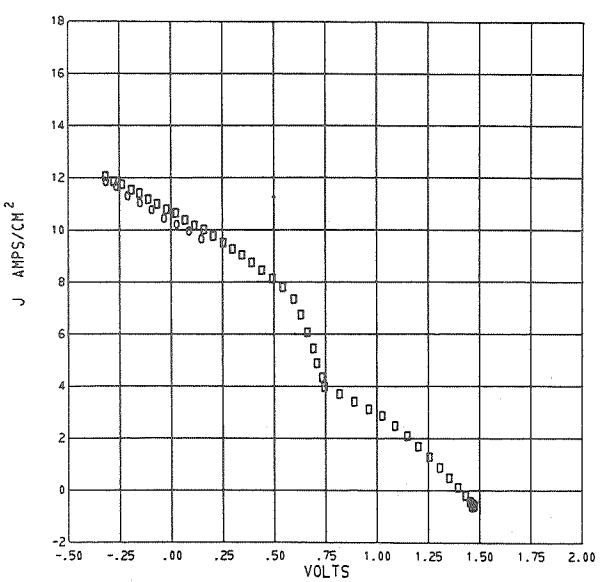


Figure 259. - Sweep 371; emitter temperature, 1956 K; collector temperature, 1067 K; reservoir temperature, 599 K.

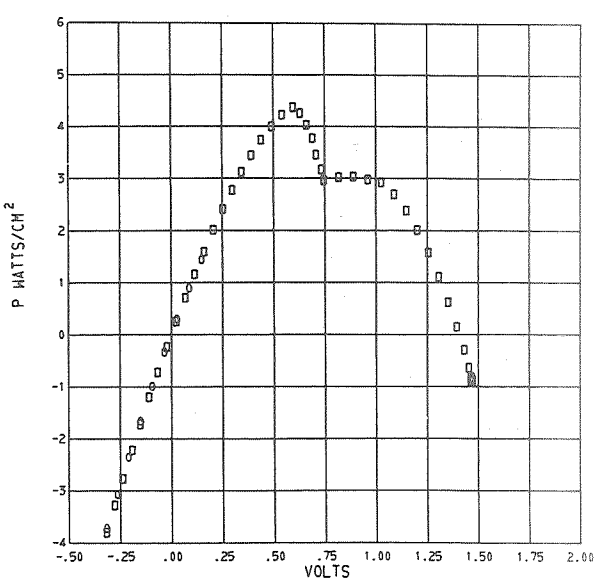


Figure 260. - Sweep 371; emitter temperature, 1956 K; collector temperature, 1067 K; reservoir temperature, 599 K.

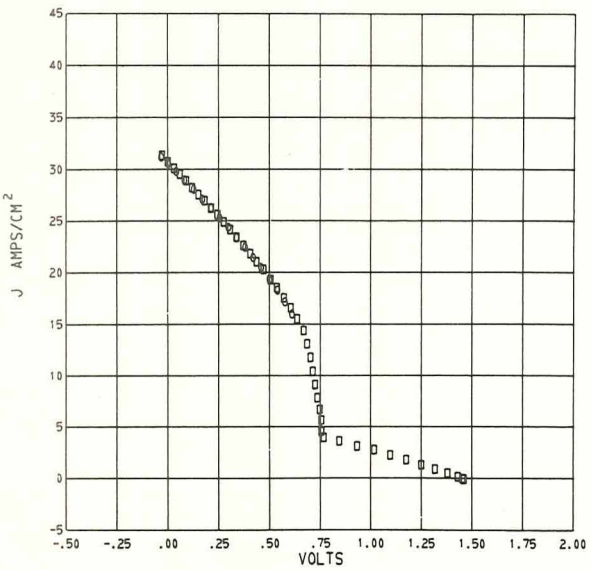


Figure 261. - Sweep 407; emitter temperature, 1962 K; collector temperature, 1062 K; reservoir temperature, 623 K.

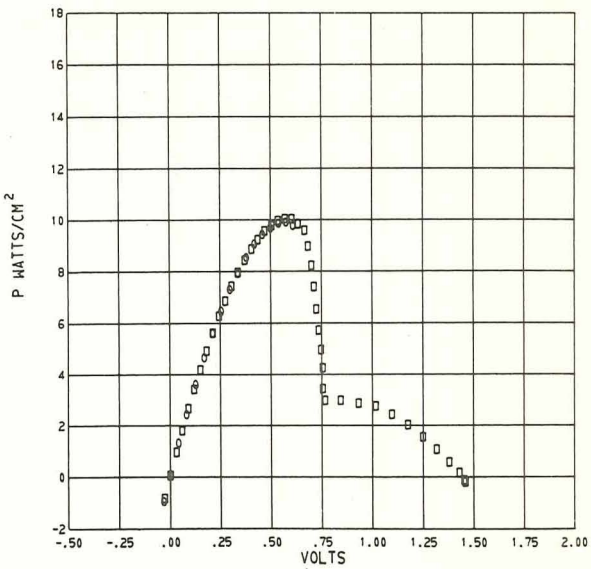


Figure 262. - Sweep 407; emitter temperature, 1962 K; collector temperature, 1062 K; reservoir temperature, 623 K.

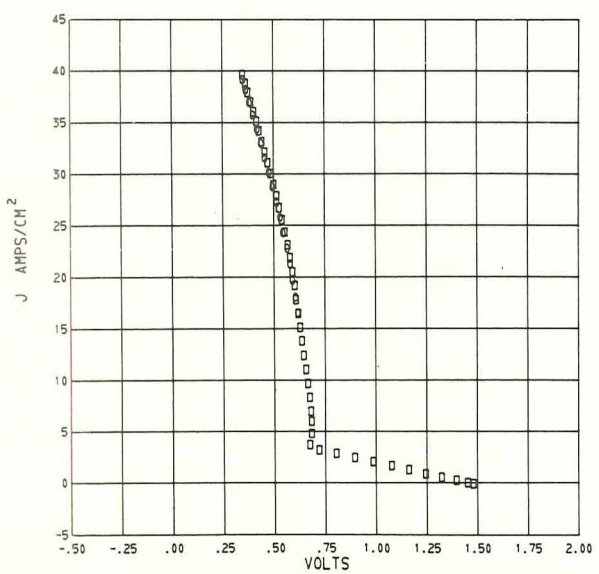


Figure 263. - Sweep 443; emitter temperature, 1956 K; collector temperature, 1068 K; reservoir temperature, 652 K.

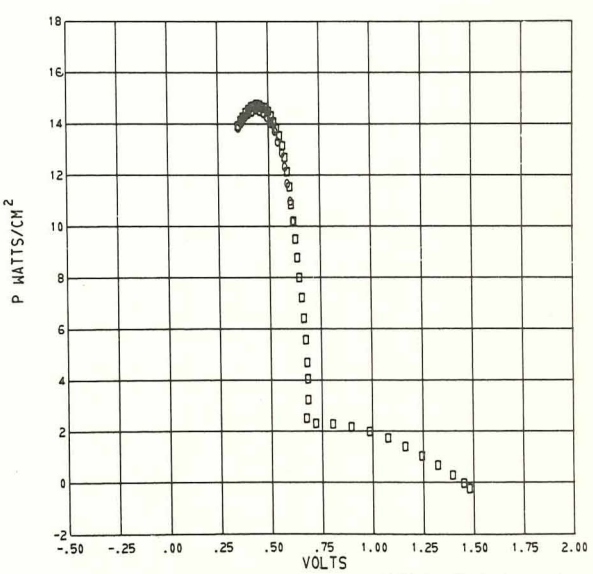


Figure 264. - Sweep 443; emitter temperature, 1956 K; collector temperature, 1068 K; reservoir temperature, 652 K.

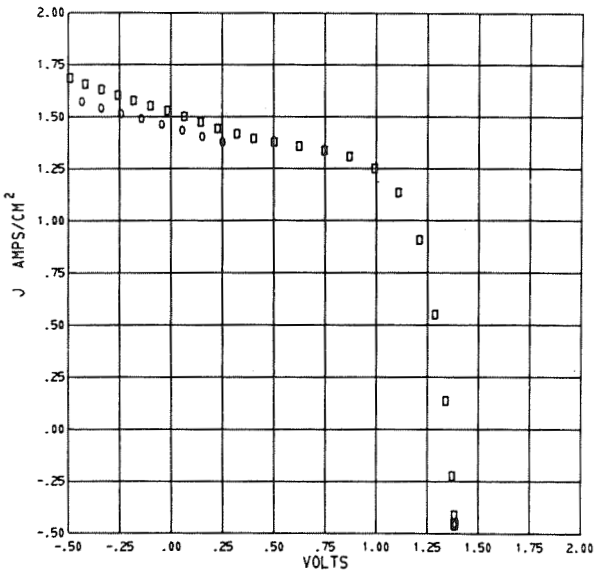


Figure 265. - Sweep 275; emitter temperature, 1958 K; collector temperature, 1180 K; reservoir temperature, 552 K.

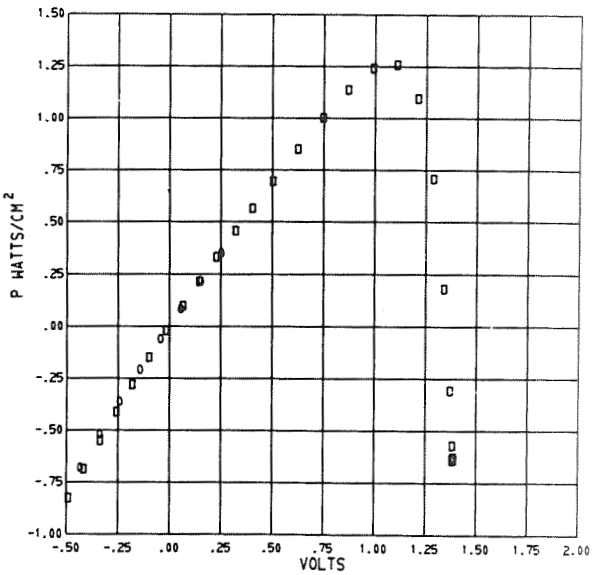


Figure 266. - Sweep 275; emitter temperature, 1958 K; collector temperature, 1180 K; reservoir temperature, 552 K.

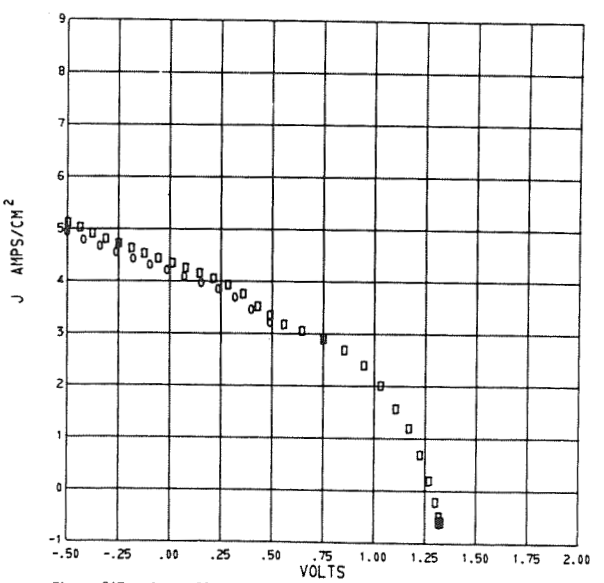


Figure 267. - Sweep 339; emitter temperature, 1954 K; collector temperature, 1176 K; reservoir temperature, 575 K.

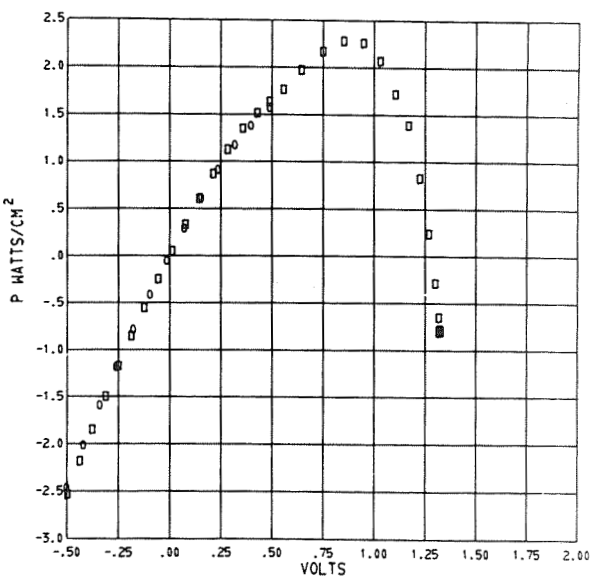


Figure 268. - Sweep 339; emitter temperature, 1954 K; collector temperature, 1176 K; reservoir temperature, 575 K.

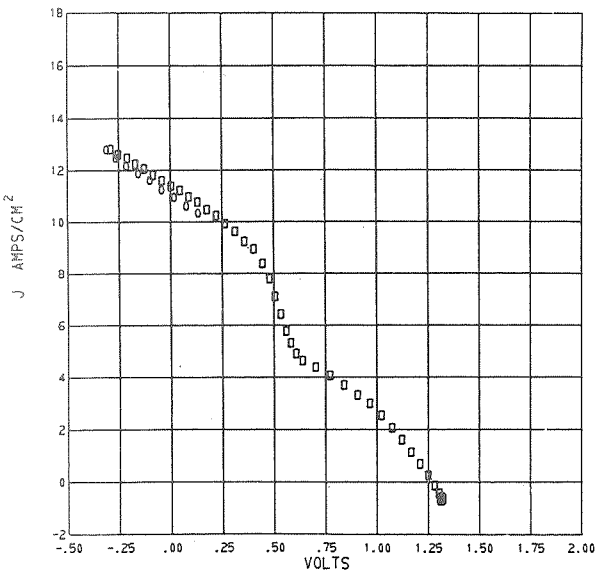


Figure 269. - Sweep 355; emitter temperature, 1955 K; collector temperature, 1174 K; reservoir temperature, 599 K.

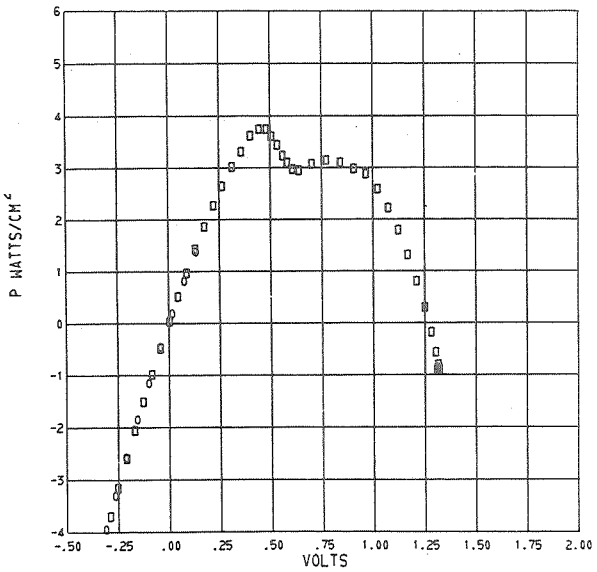


Figure 270. - Sweep 355; emitter temperature, 1955 K; collector temperature, 1174 K; reservoir temperature, 599 K.

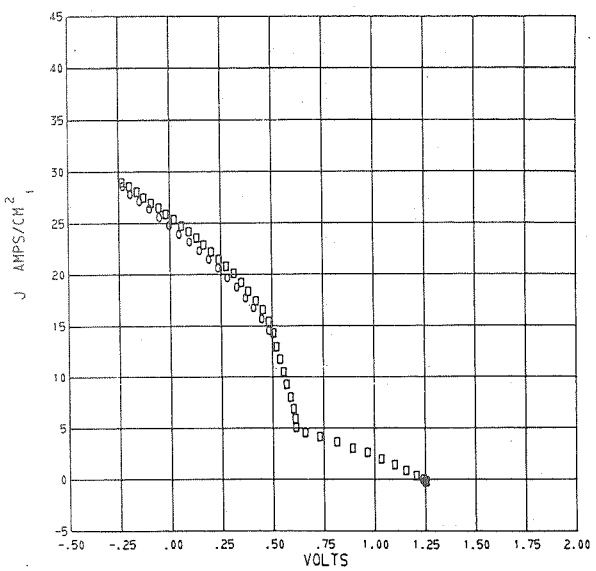


Figure 271. - Sweep 419; emitter temperature, 1955 K; collector temperature, 1179 K; reservoir temperature, 624 K.

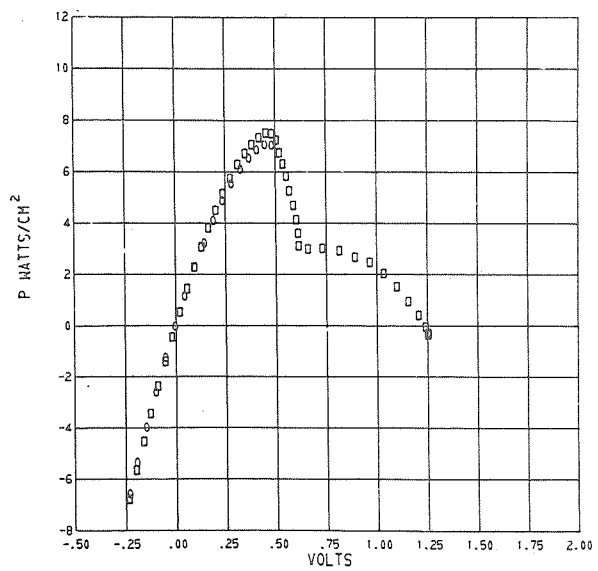


Figure 272. - Sweep 419; emitter temperature, 1955 K; collector temperature, 1179 K; reservoir temperature, 624 K.

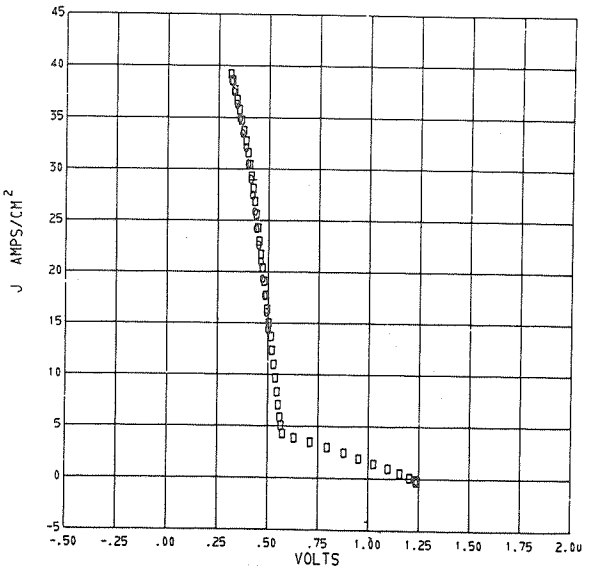


Figure 273. - Sweep 431; emitter temperature, 1959 K; collector temperature, 1187 K; reservoir temperature, 653 K.

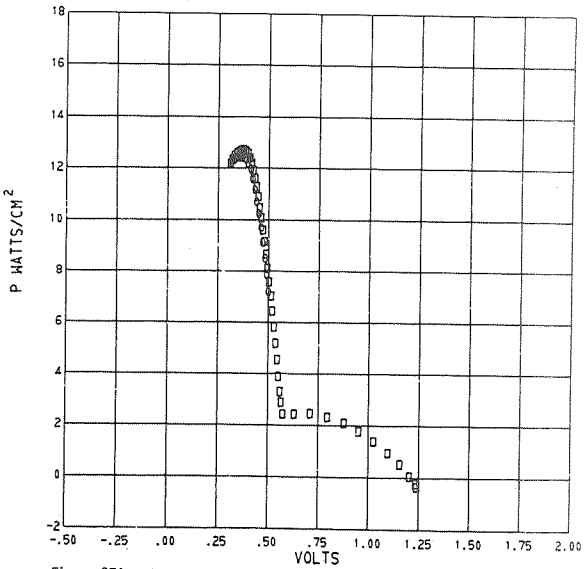


Figure 274. - Sweep 431; emitter temperature, 1959 K; collector temperature, 1187 K; reservoir temperature, 653 K.

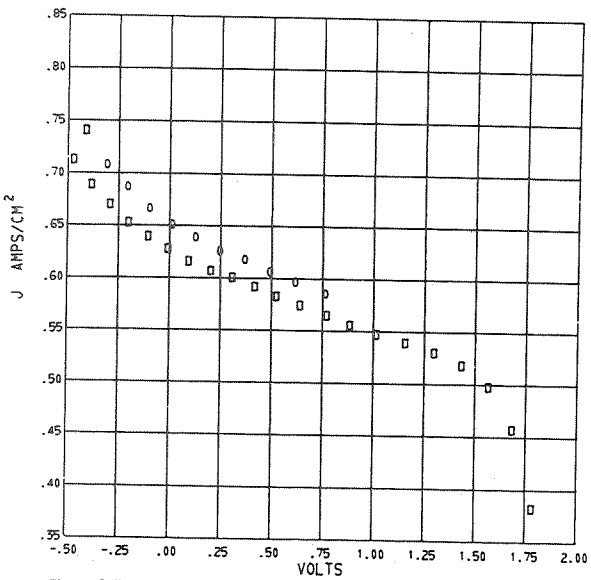


Figure 275. - Sweep 120; emitter temperature, 2006 K; collector temperature, 897 K; reservoir temperature, 530 K.

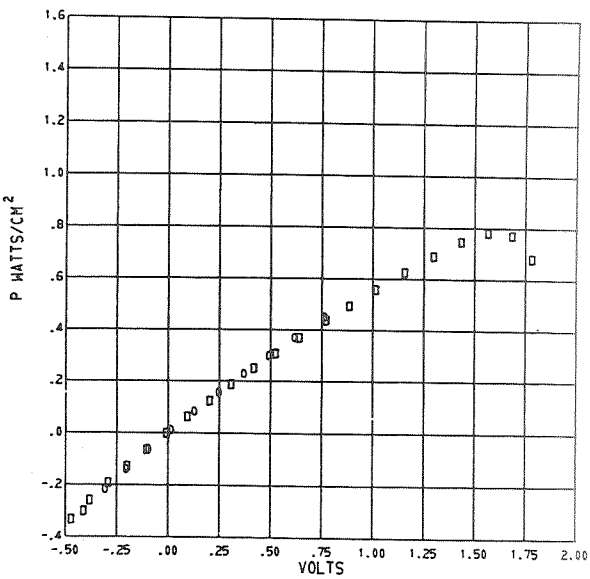


Figure 276. - Sweep 120; emitter temperature, 2006 K; collector temperature, 897 K; reservoir temperature, 530 K.

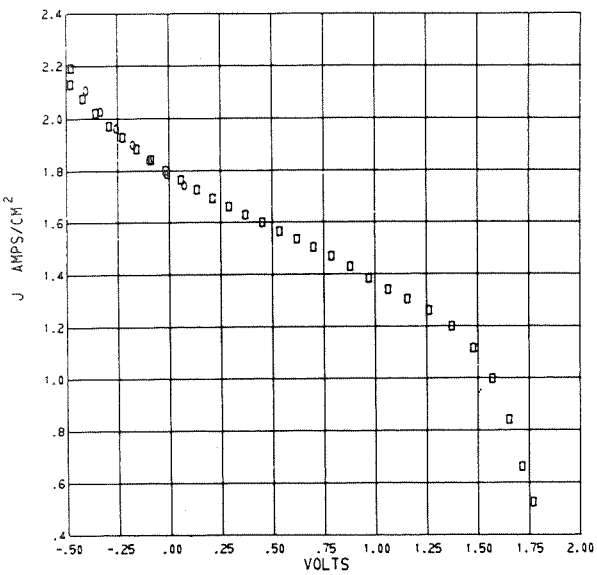


Figure 277. - Sweep 137; emitter temperature, 2002 K; collector temperature, 903 K; reservoir temperature, 550 K.

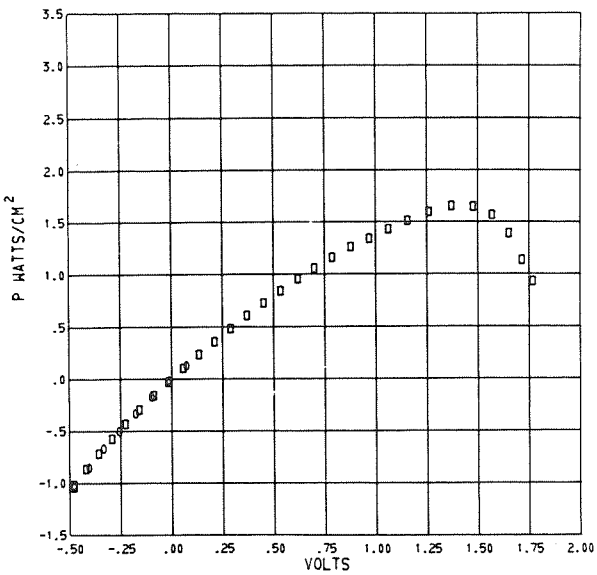


Figure 278. - Sweep 137; emitter temperature, 2002 K; collector temperature, 903 K; reservoir temperature, 550 K.

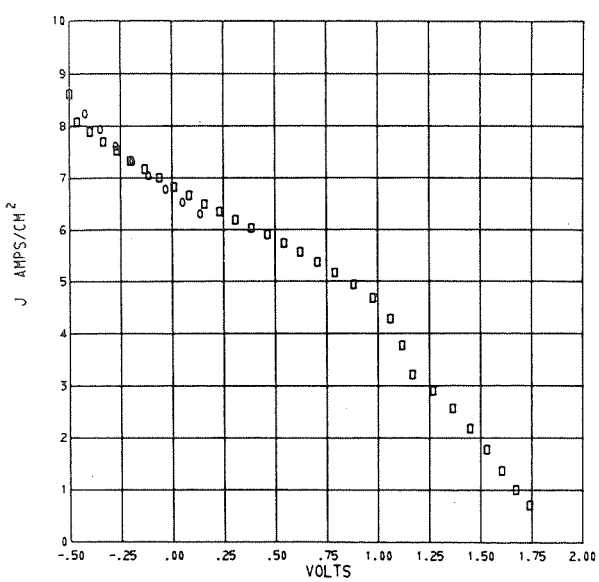


Figure 279. - Sweep 171; emitter temperature, 2007 K; collector temperature, 898 K; reservoir temperature, 576 K.

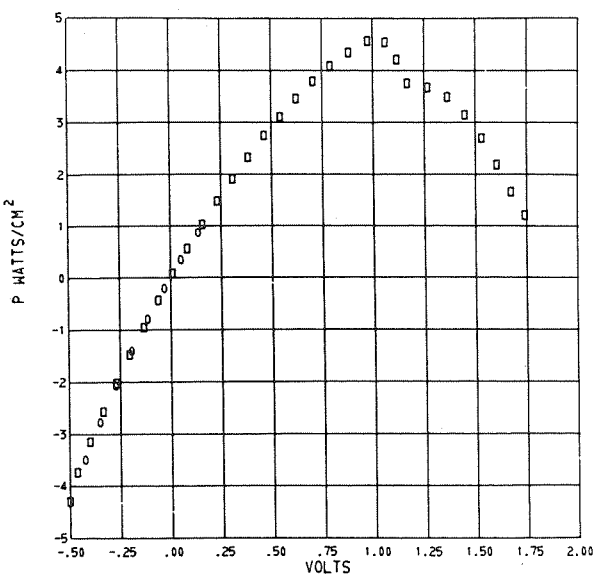


Figure 280. - Sweep 171; emitter temperature, 2007 K; collector temperature, 898 K; reservoir temperature, 576 K.

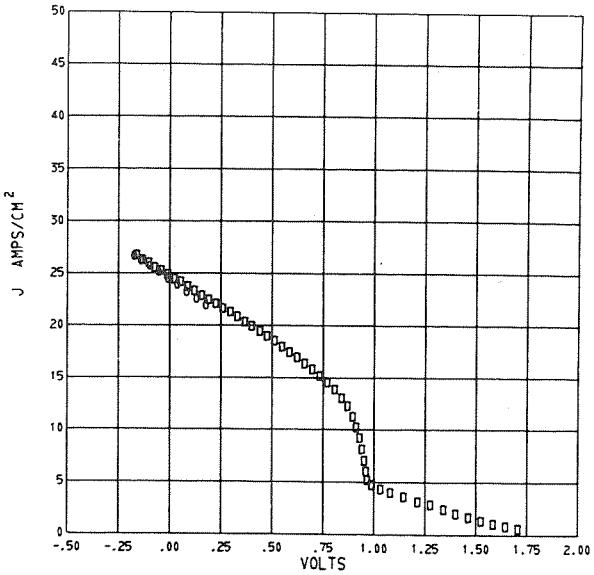


Figure 281. - Sweep 192; emitter temperature, 2009 K; collector temperature, 907 K; reservoir temperature, 605 K.

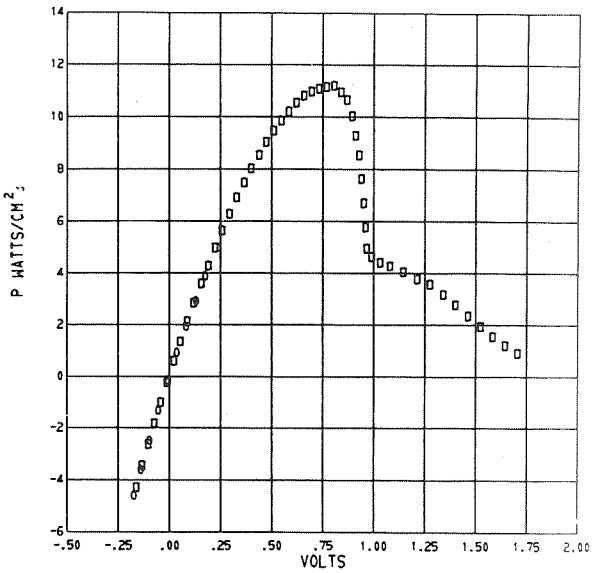


Figure 282. - Sweep 192; emitter temperature, 2009 K; collector temperature, 907 K; reservoir temperature, 605 K.

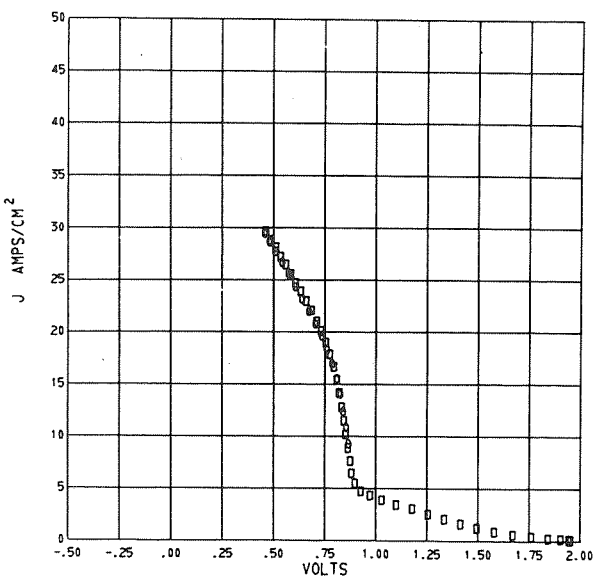


Figure 283. - Sweep 204; emitter temperature, 2008 K; collector temperature, 907 K; reservoir temperature, 623 K.

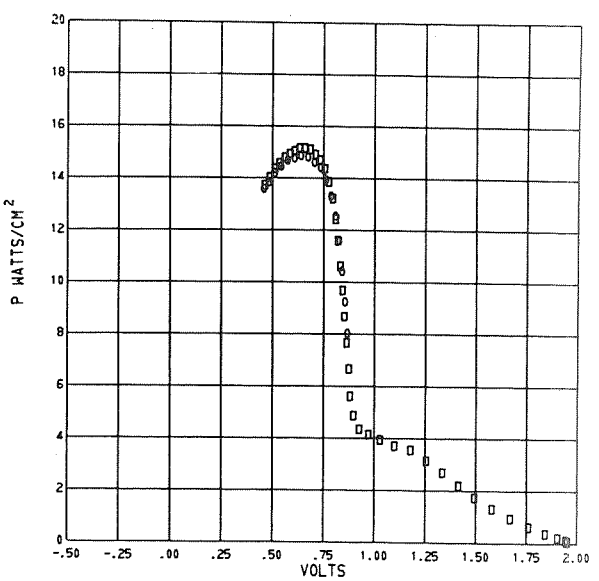


Figure 284. - Sweep 204; emitter temperature, 2008 K; collector temperature, 907 K; reservoir temperature, 623 K.

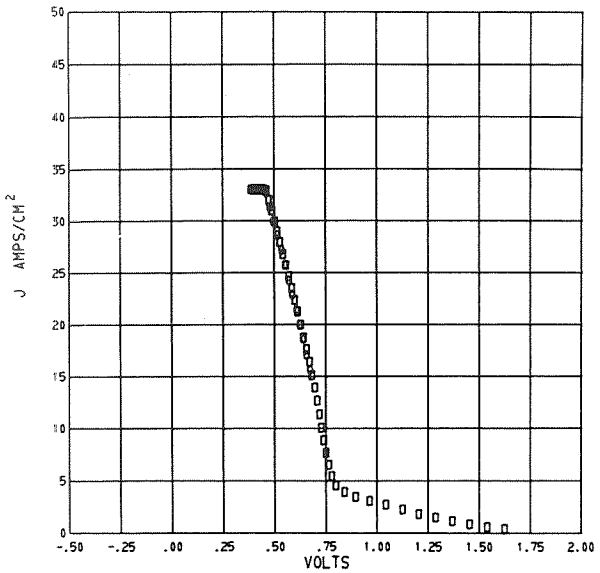


Figure 285. - Sweep 221; emitter temperature, 2011 K; collector temperature, 912 K; reservoir temperature, 650 K.

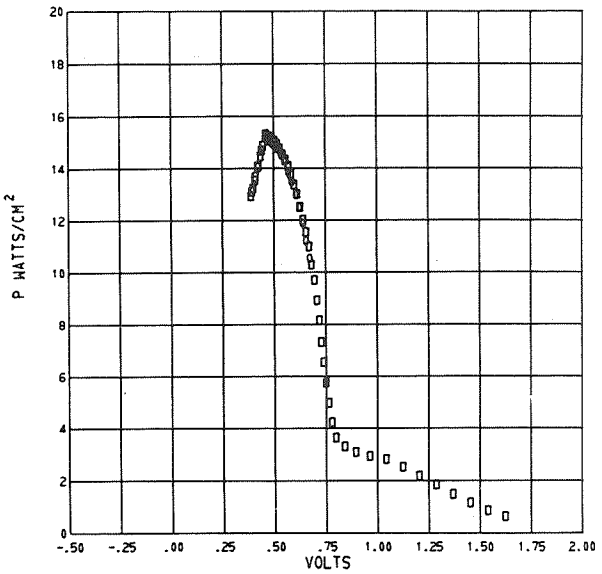


Figure 286. - Sweep 221; emitter temperature, 2011 K; collector temperature, 912 K; reservoir temperature, 650 K.

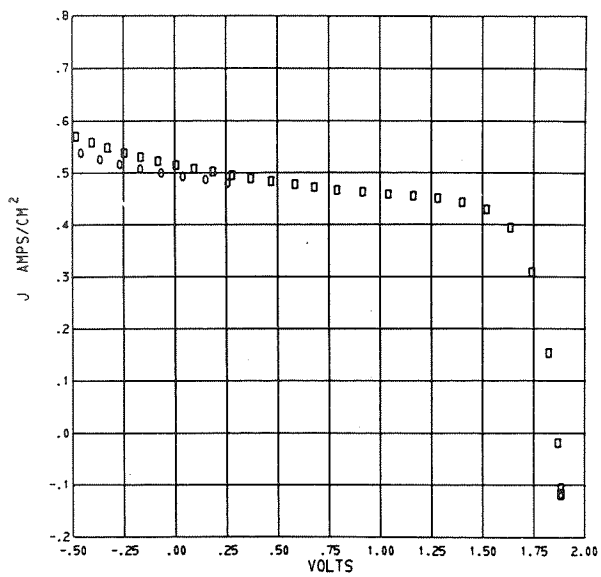


Figure 287. - Sweep 240; emitter temperature, 2007 K; collector temperature, 962 K; reservoir temperature, 527 K.

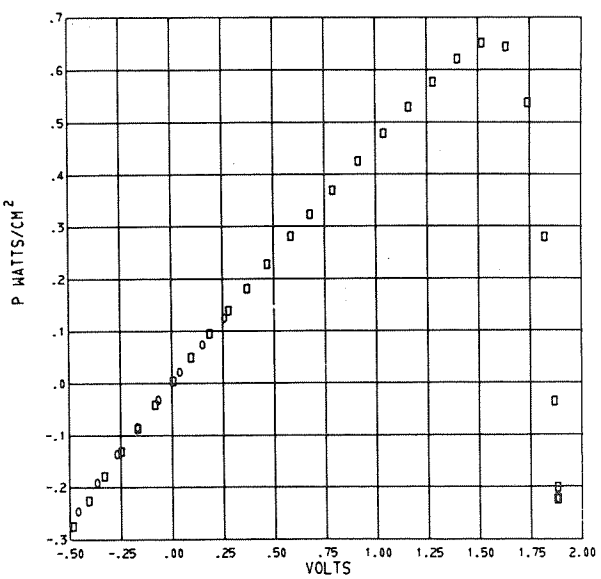


Figure 288. - Sweep 240; emitter temperature, 2007 K; collector temperature, 962 K; reservoir temperature, 527 K.

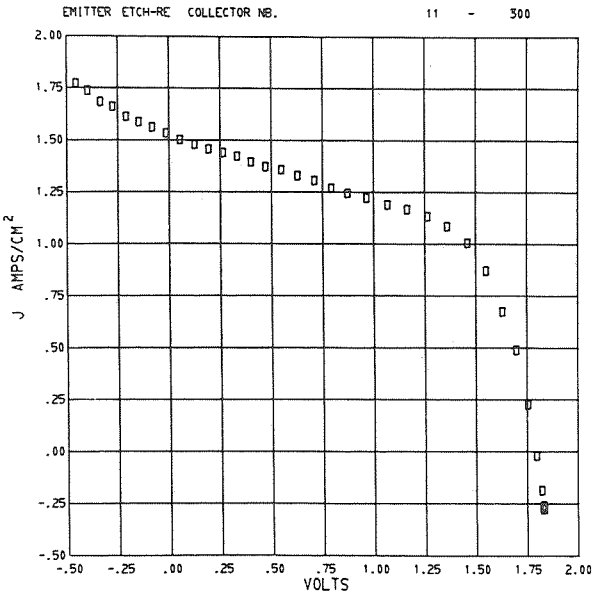


Figure 289. - Sweep 300; emitter temperature, 2006 K; collector temperature, 964 K; reservoir temperature, 549 K.

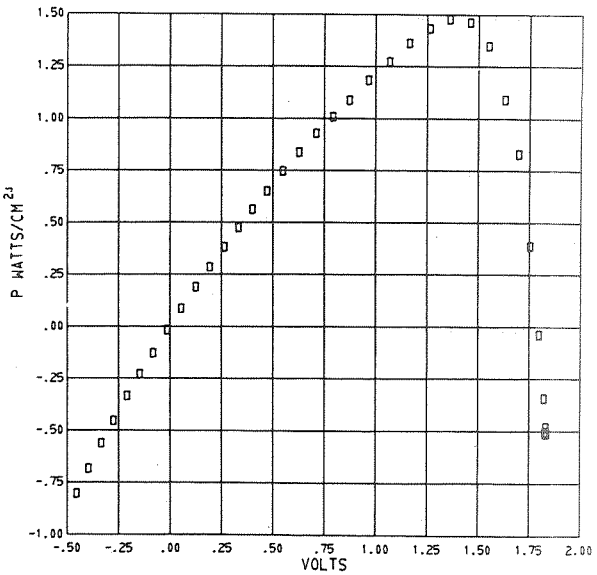


Figure 290. - Sweep 300; emitter temperature, 2006 K; collector temperature, 964 K; reservoir temperature, 549 K.

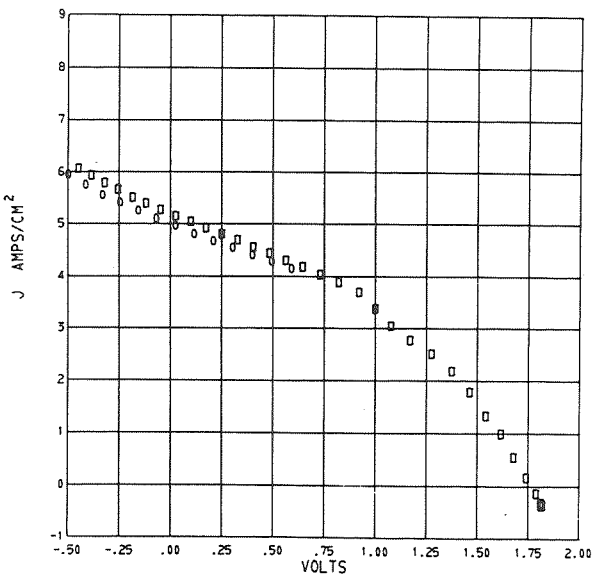


Figure 291. - Sweep 312; emitter temperature, 2004 K; collector temperature, 964 K; reservoir temperature, 572 K.

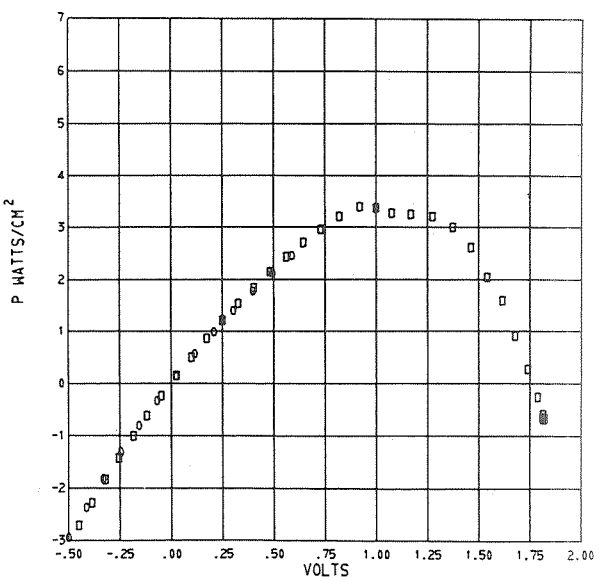


Figure 292. - Sweep 312; emitter temperature, 2004 K; collector temperature, 964 K; reservoir temperature, 572 K.

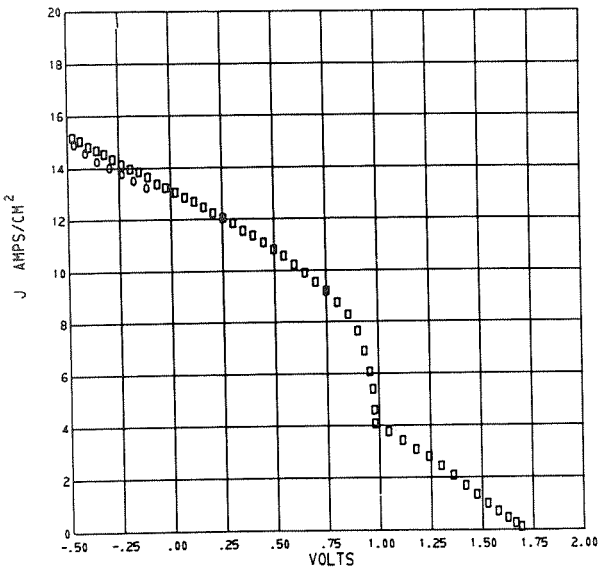


Figure 293. - Sweep 384; emitter temperature, 2009 K; collector temperature, 971 K; reservoir temperature, 597 K.

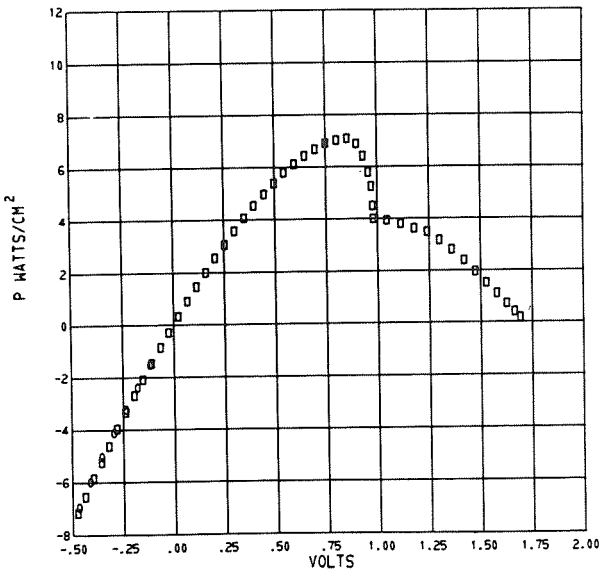


Figure 294. - Sweep 384; emitter temperature, 2009 K; collector temperature, 971 K; reservoir temperature, 597 K.

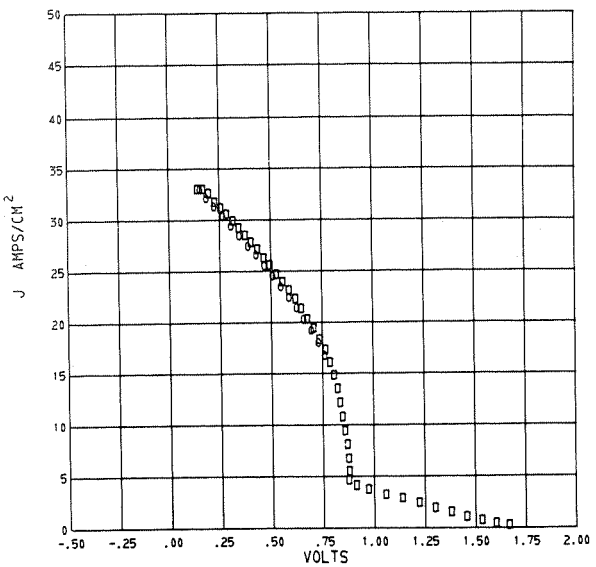


Figure 295. - Sweep 396; emitter temperature, 2007 K; collector temperature, 967 K; reservoir temperature, 622 K.

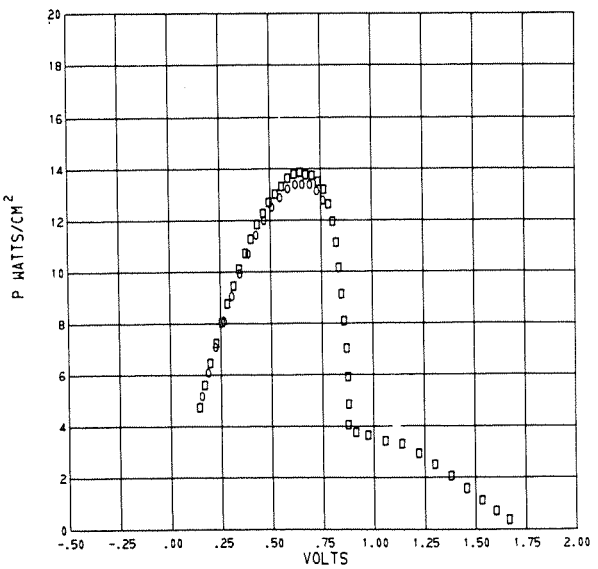


Figure 296. - Sweep 396; emitter temperature, 2007 K; collector temperature, 967 K; reservoir temperature, 622 K.

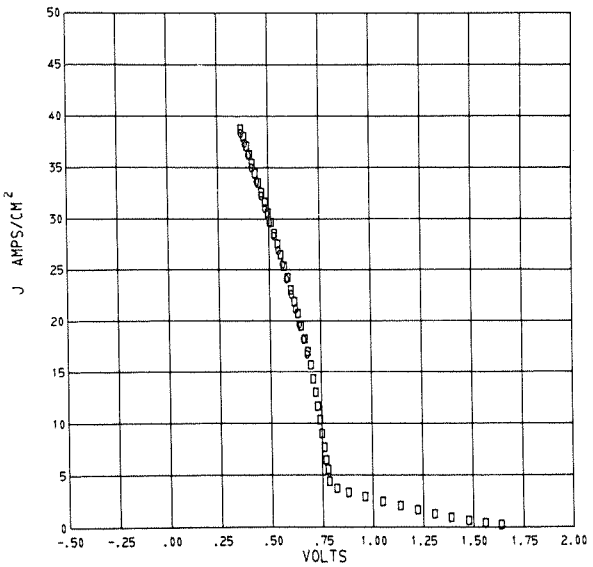


Figure 297. - Sweep 456; emitter temperature, 2008 K; collector temperature, 968 K; reservoir temperature, 651 K.

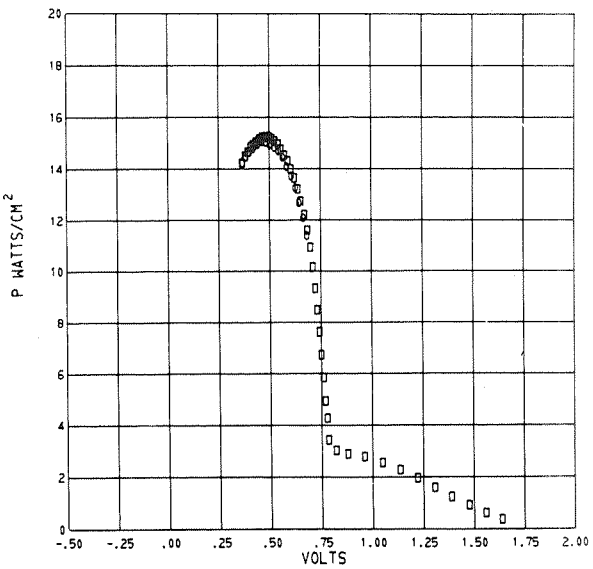


Figure 298. - Sweep 456; emitter temperature, 2008 K; collector temperature, 968 K; reservoir temperature, 651 K.

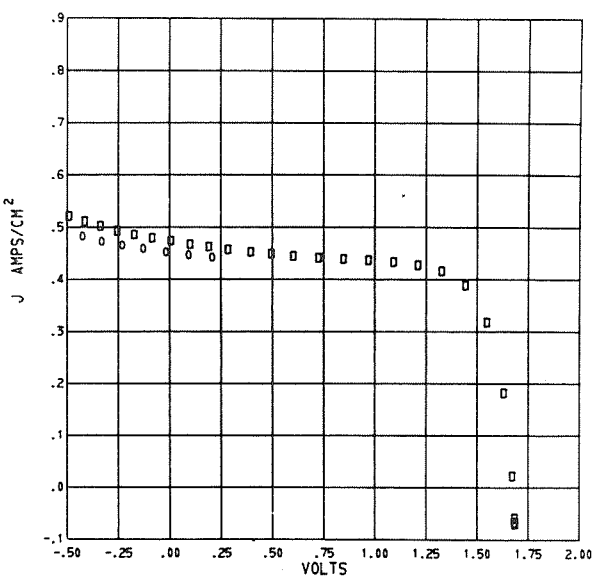


Figure 299. - Sweep 252; emitter temperature, 2009 K; collector temperature, 1069 K; reservoir temperature, 528 K.

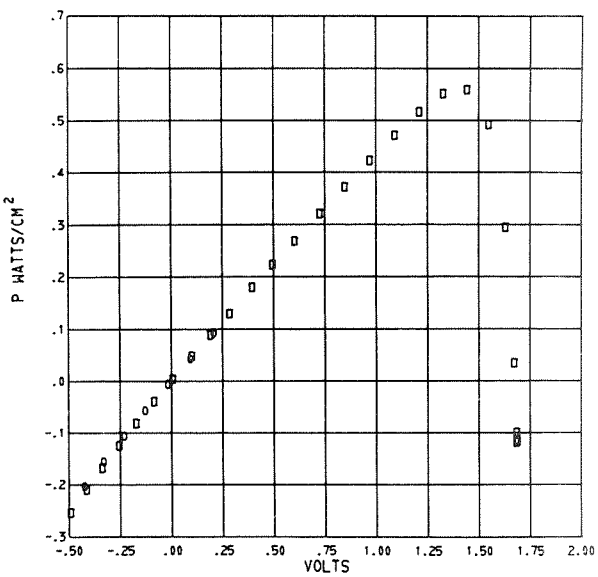


Figure 300. - Sweep 252; emitter temperature, 2009 K; collector temperature, 1069 K; reservoir temperature, 528 K.

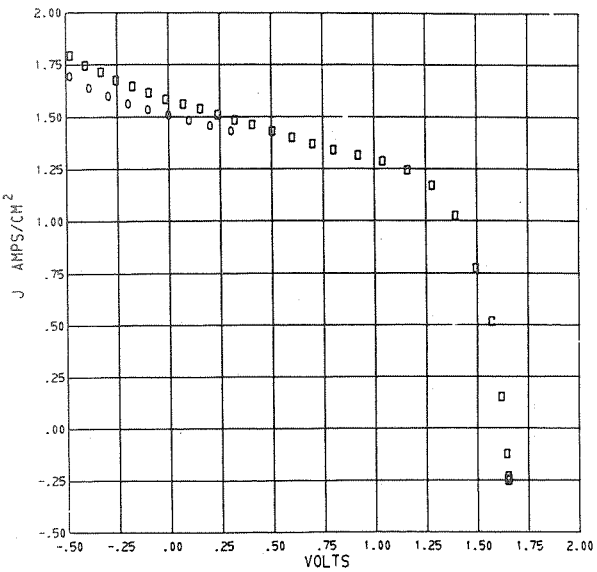


Figure 301. - Sweep 288; emitter temperature, 2010 K; collector temperature, 1063 K; reservoir temperature, 550 K.

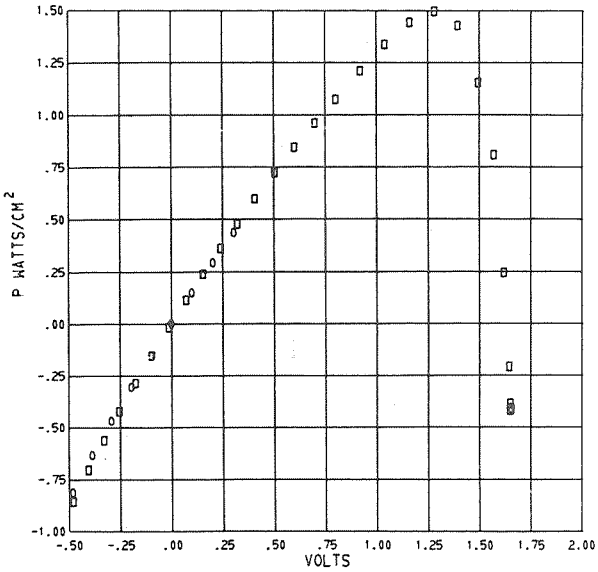


Figure 302. - Sweep 288; emitter temperature, 2010 K; collector temperature, 1063 K; reservoir temperature, 550 K.

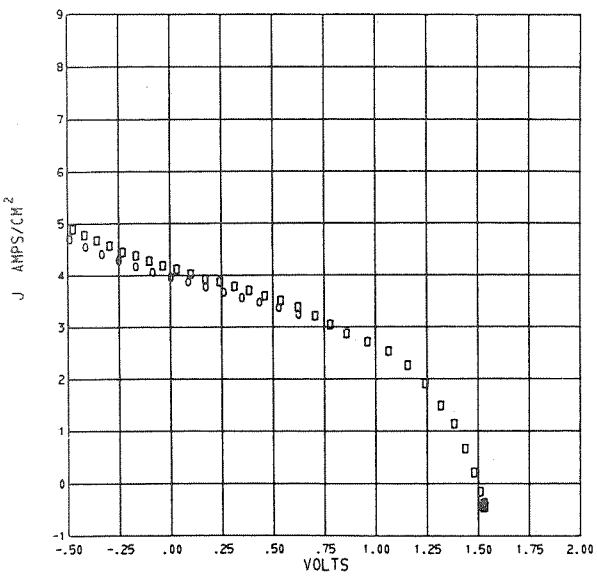


Figure 303. - Sweep 328; emitter temperature, 2006 K; collector temperature, 1072 K; reservoir temperature, 574 K.

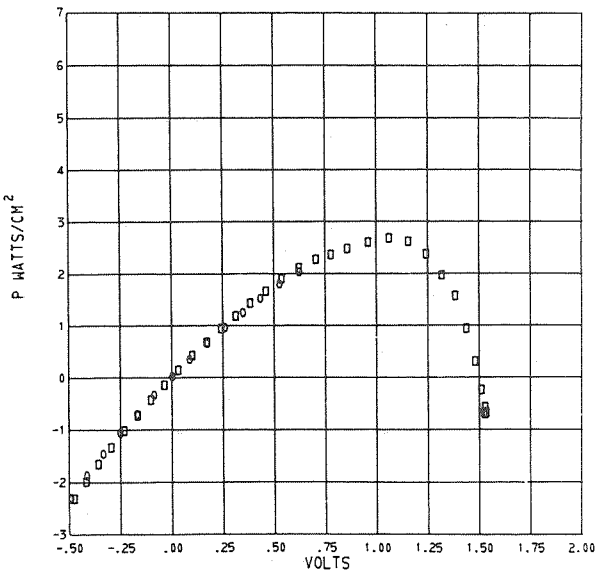


Figure 304. - Sweep 328; emitter temperature, 2006 K; collector temperature, 1072 K; reservoir temperature, 574 K.

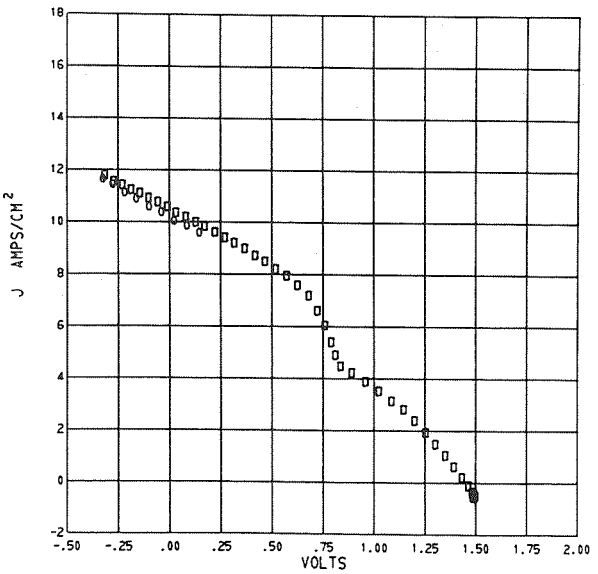


Figure 305. - Sweep 372; emitter temperature, 2008 K; collector temperature, 1080 K; reservoir temperature, 599 K.

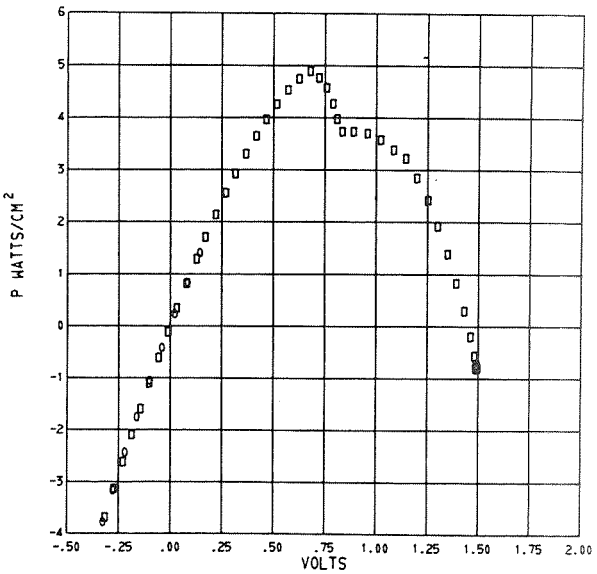


Figure 306. - Sweep 372; emitter temperature, 2008 K; collector temperature, 1080 K; reservoir temperature, 599 K.

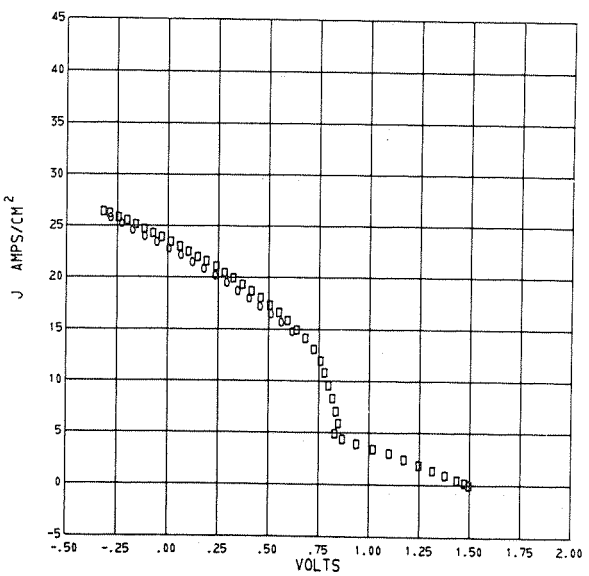


Figure 307. - Sweep 408; emitter temperature, 2008 K; collector temperature, 1070 K; reservoir temperature, 623 K.

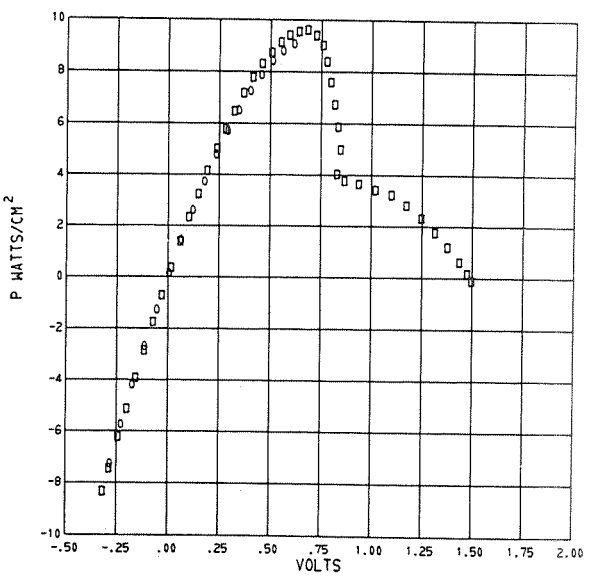


Figure 308. - Sweep 408; emitter temperature, 2008 K; collector temperature, 1070 K; reservoir temperature, 623 K.

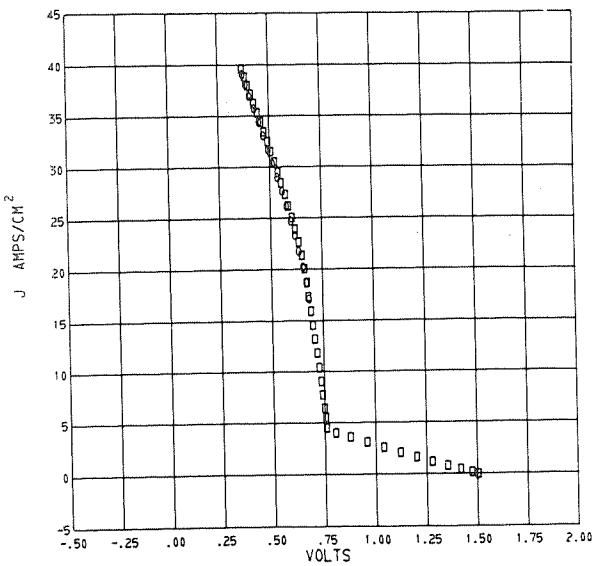


Figure 309. - Sweep 444; emitter temperature, 2007 K; collector temperature, 1069 K; reservoir temperature, 651 K.

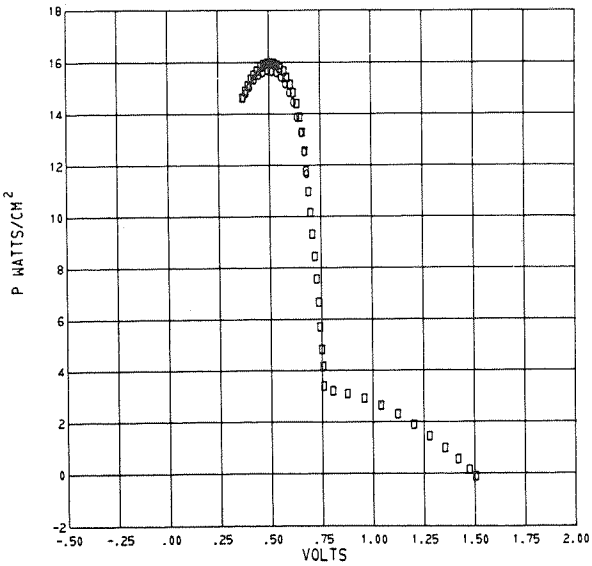


Figure 310. - Sweep 444; emitter temperature, 2007 K; collector temperature, 1069 K; reservoir temperature, 651 K.

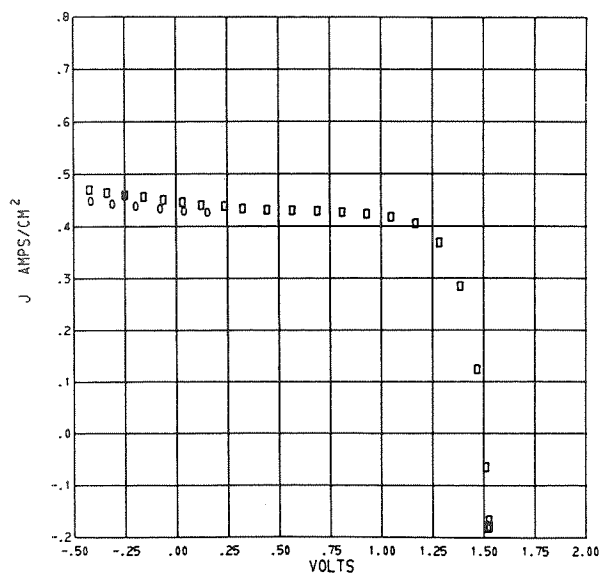


Figure 311. - Sweep 264; emitter temperature, 2010 K; collector temperature, 1189 K; reservoir temperature, 529 K.

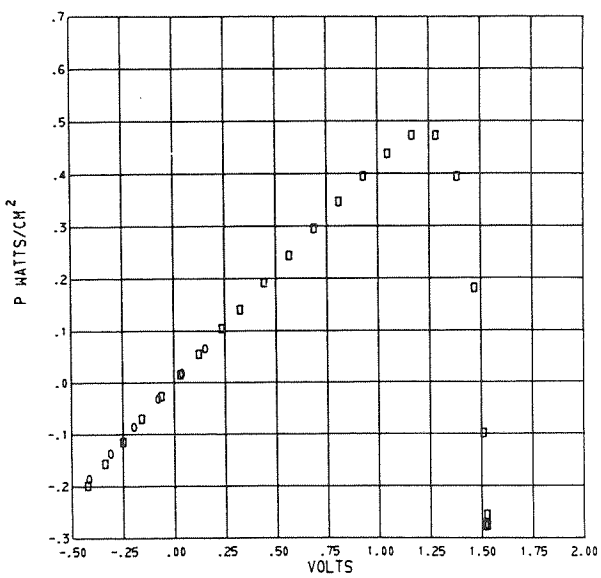


Figure 312. - Sweep 264; emitter temperature, 2010 K; collector temperature, 1189 K; reservoir temperature, 529 K.

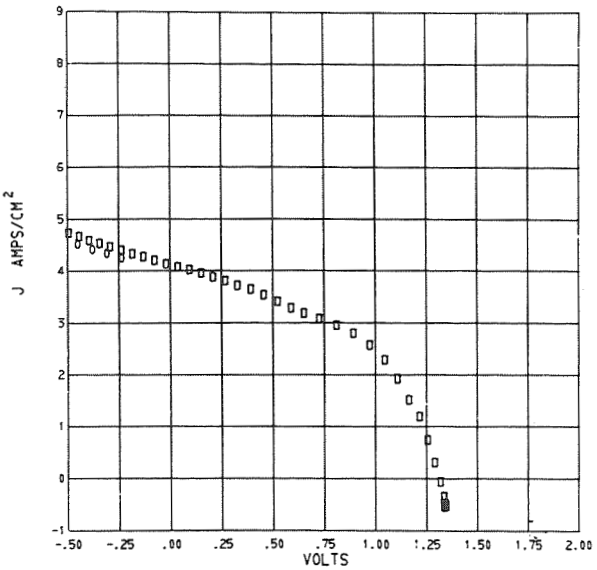


Figure 313. - Sweep 340; emitter temperature, 2006 K; collector temperature, 1186 K; reservoir temperature, 575 K.

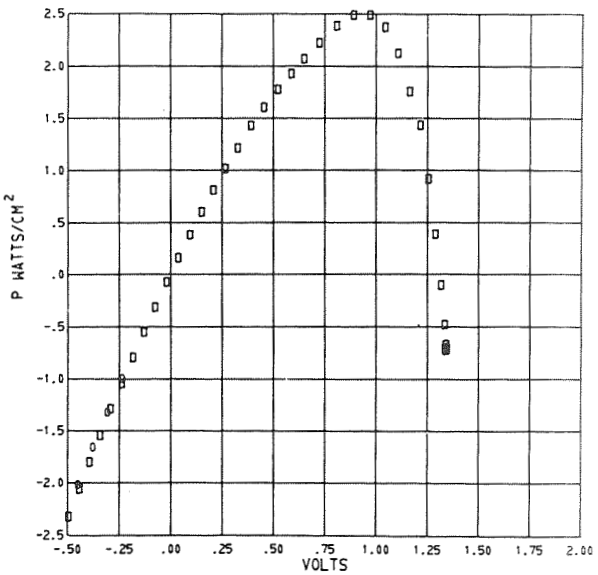


Figure 314. - Sweep 340; emitter temperature, 2006 K; collector temperature, 1186 K; reservoir temperature, 575 K.

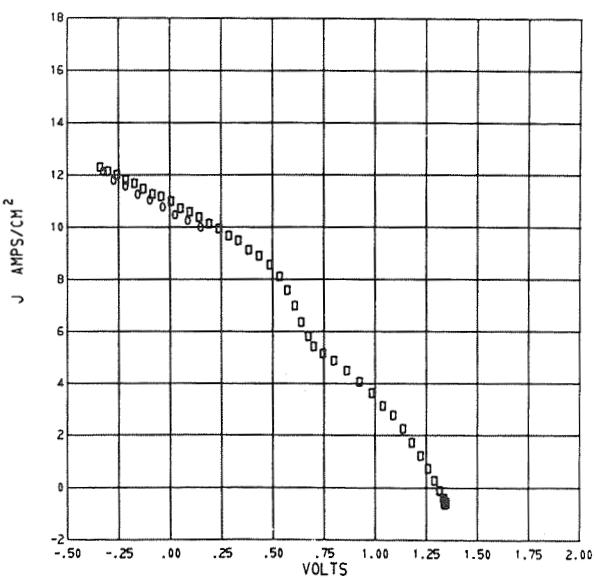


Figure 315. - Sweep 362; emitter temperature, 2009 K; collector temperature, 1179 K; reservoir temperature, 599 K.

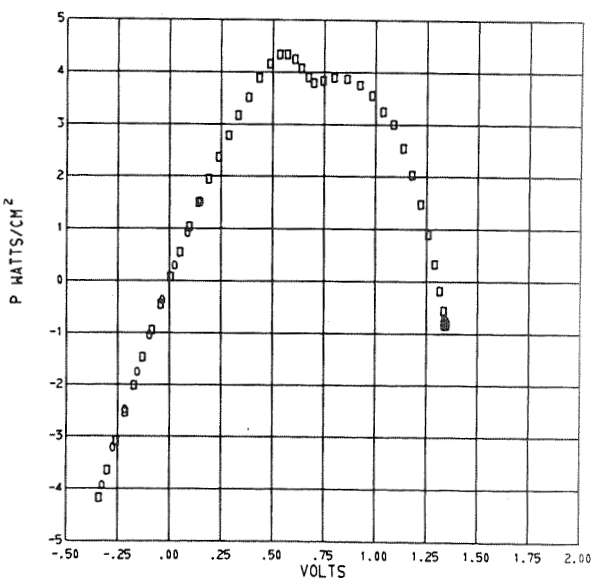


Figure 316. - Sweep 362; emitter temperature, 2009 K; collector temperature, 1179 K; reservoir temperature, 599 K.

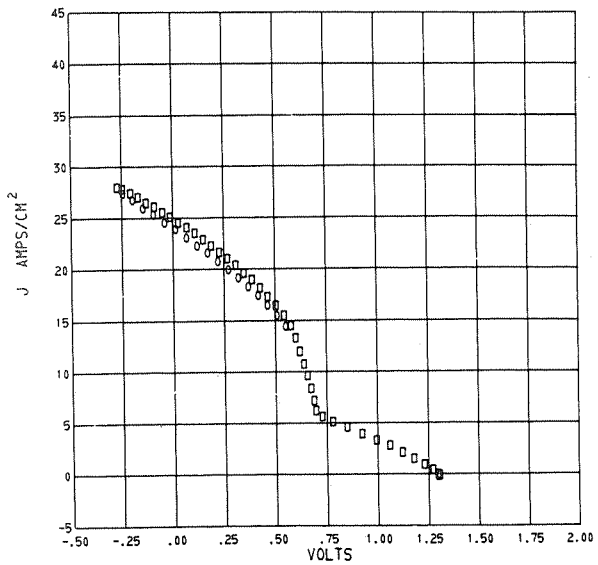


Figure 317. - Sweep 420; emitter temperature, 2010 K; collector temperature, 1179 K; reservoir temperature, 623 K.

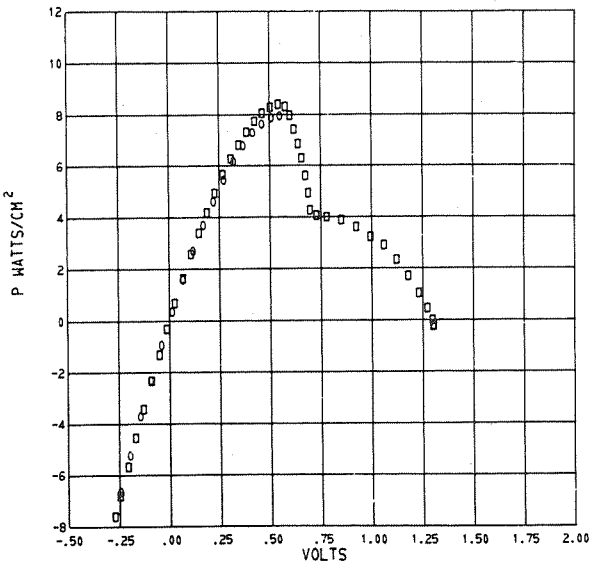


Figure 318. - Sweep 420; emitter temperature, 2010 K; collector temperature, 1179 K; reservoir temperature, 623 K.

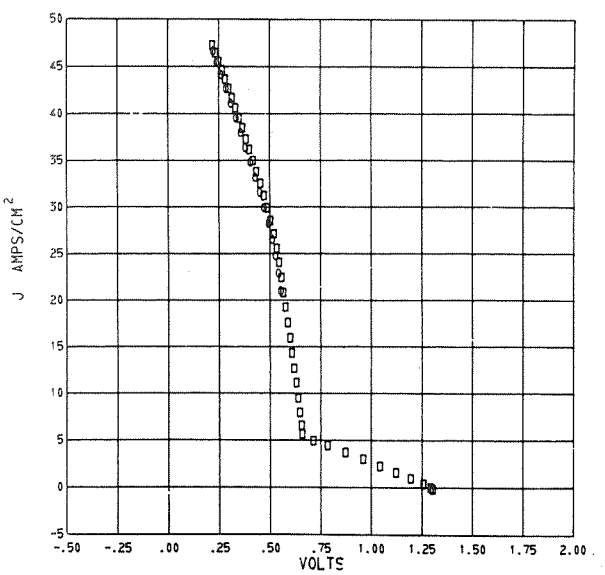


Figure 319. - Sweep 432; emitter temperature, 2012 K; collector temperature, 1180 K; reservoir temperature, 653 K.

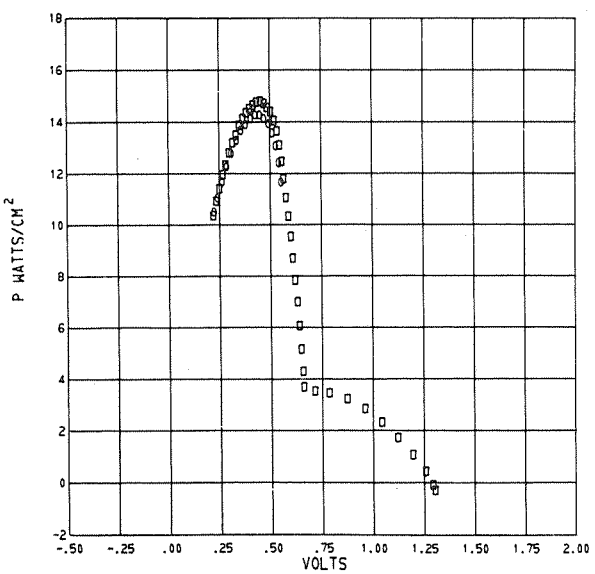


Figure 320. - Sweep 432; emitter temperature, 2012 K; collector temperature, 1180 K; reservoir temperature, 653 K.

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