# Reliability of Bvgdo Degraded Power X-Band GaAs MESFET

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The purpose of this memorandum is to summarize the results of the tests performed concerning time dependent BVgdo slump on EOS-AM/Landsat-7 X-band power GaAs FETs. Manufacturer-supplied analysis stated that the slump was most likely due to unstable surface state defects generated during wafer processing and this mechanism would not lead to catastrophic failure. To support the conclusions of the manufacturer's analysis, two conditions were imposed by NASA:

1. Four post-2000 hour overdrive life test devices were to be subjected to an iterative reverse breakdown stress test. All four devices passed this test. The devices proved to be extremely robust. The test setup and data are summarized below. This test demonstrated that instantaneous failure of the devices in the application is unlikely. This testing was performed at the manufacturer's facility under supervision of H. Shaw, NASA/GSFC and H. Huang, LMMS Consultant. Vgd was applied at -15V and incremented -2V up to -25V. The dwell time at each voltage was 1 minute. The device RF performance and Bvgdo at 1mA Ig was baselined before the test. After each reverse bias voltage, the RF performance and Bvgdo were measured. In addition, the DC reverse breakdown current and Igrf were recorded. The devices survived very high breakdown currents. The results are summarized in Table A. The test circuit is shown in Figure A.

Table A
Reverse Breakdown Stress Test

| Device No. | Vg = 2.01 | | | | | |
|---|---|---|---|---|---|---|
| 4Z01-030 | | | | | | |
| Bias Point | Ig | Bvgdo | PO1 | Igrf @ PO1 | PO2 | Igrf @PO2 |
| | mA | Igd=1mA | Pin=32.5dBm | mA | Pin=22.5dBm | uA |
| Initial | | -13 | 38.03 | | 30.07 | |
| -15 | -5 | -13.35 | 38.76 | | 30.62 | |
| -17 | -23 | -13.55 | 38.66 | -0.638 | 30.51 | -19 |
| -19 | -75 | -13.7 | 38.63 | -0.545 | 30.51 | -17 |
| -21 | -272 | -13.7 | 35.52 | -0.426 | 30.53 | -16 |
| -23 | -492 | -13.7 | 38.55 | -0.571 | 30.49 | -17 |
| -25 | -758 | -13.6 | 38.59 | -0.604 | 30.5 | -19 |

| Device No. | Vg = 2.49 | | | | | |
|---|---|---|---|---|---|---|
| 4Z01-032 | | | | | | |
| Bias Point | Ig | Bvgdo | PO1 | Igrf @ PO1 | PO2 | Igrf @PO2 |
| | mA | Igd=1mA | Pin=32.5dBm | mA | Pin=22.5dBm | uA |
| Initial | | -10.95 | 39.29 | | 30.26 | |
| -15 | -28 | -11.65 | 39.19 | | 30.09 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| -17 | -90 | -11.85 | 39.26 | -7.9 | 30.26 | -54 |
| -19 | -262 | -11.9 | 39.24 | -7.9 | 30.26 | -49 |
| -21 | -513 | -11.9 | 39.17 | -7.74 | 30.17 | -48 |
| -23 | -752 | -12 | 39.19 | -7.94 | 30.19 | -52 |
| -25 | -970 | -12.15 | 39.26 | -8.1 | 30.26 | -50 |

| Device No. | Vg = 2.43 | | | | | |
|---|---|---|---|---|---|---|
| 4Z01-034 | | | | | | |
| Bias Point | Ig | Bvgdo | PO1 | Igrf @ PO1 | PO2 | Igrf @PO2 |
| | mA | Igd=1mA | Pin=32.5dBm | mA | Pin=22.5dBm | uA |
| Initial | | -11.05 | 39.11 | | 29.96 | |
| -15 | -25 | -11.7 | 39.09 | | 29.95 | |
| -17 | -76 | -11.8 | 39.06 | -6.49 | 29.99 | -45 |
| -19 | -216 | -11.9 | 39.11 | -6.43 | 30.08 | -44 |
| -21 | -446 | -11.9 | 39 | -6.34 | 30.07 | -43 |
| -23 | -642 | -11.9 | 39.07 | -6.54 | 29.95 | -50 |
| -25 | -939 | -12.05 | 39.07 | -6.89 | 29.94 | -44 |

| Device No. | Vg = 2.1 | | | | | |
|---|---|---|---|---|---|---|
| 4Z01-034 | | | | | | |
| Bias Point | Ig | Bvgdo | PO1 | Igrf @ PO1 | PO2 | Igrf @PO2 |
| | mA | Igd=1mA | Pin=32.5dBm | mA | Pin=22.5dBm | uA |
| Initial | | -15.55 | 38.36 | | 30.74 | |
| -15 | 0 | -15.65 | 38.43 | | 30.9 | |
| -17 | -2 | -15.45 | 38.36 | -0.468 | 30.72 | -15 |
| -19 | -10 | -15.75 | 38.4 | -0.253 | 30.8 | -15 |
| -21 | -31 | -15.7 | 38.37 | -0.262 | 30.8 | -14 |
| -23 | -266 | -15.9 | 38.39 | -0.37 | 30.74 | -14 |
| -25 | -595 | -16.2 | 38.42 | -0.34 | 30.78 | -14 |

Notes:
Empty cells mean data was not recorded
Pout was set with Vds=8.0V, Ids(Rf off)=1.4A, f=8.0GHz, Tc=40C

2. Eight devices from the same overdrive life test were to continue to 5000 hours with significant change in device performance. This would validate the assertion that the surface state defects annealed out of the samples early in the life test (under approximately 1000 hours) and the long term device characteristics were stable. At the time this condition was imposed the devices were between 2000 and 3000 hours. The 5000 hour test is now complete and the results are summarized below in three parts.

All of the data provided to NASA from the 5000 hour test was analyzed using Statistica and Excel. The last two digits of each heading correspond to a serial number from the test. For example: ZPO1_02 is the PO1 data for S/N 02. The Z means that S/N 02 was a device that started with BVgdo < 17 Volts.

Part I. Gm (transconductance), vp (pinch-off), idss (drain current), PO1 (Pout: Pin=+32.5dBm~$P_{-5db}$ point), PO2 (Pout:Pin=+22.5dbm), igss & igsx (gate leakage).

None of the parameters above showed a significant change.

TABLE I

gm: Vd=3V, Ids=2A. No spec limit

| HRS | ZGM_02 | GM_08 | GM_11 | GM_12 | ZGM_20 | ZGM_24 | GM_25 | ZGM_28 | GM_30 | ZGM_32 | ZGM_34 | GM_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 2.3 | 2.3 | 2.3 | 2.4 | 2.3 | 2.3 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 |
| 1000 | 2.3 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 |
| 1240 | 2.3 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 |
| 1500 | 2.3 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 |
| 2000 | 2.2 | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 |
| 3000 | 2.3 | 2.4 | 2.4 | 2.5 | 2.3 | 2.4 | 2.4 | 2.3 | | | | |
| 3780 | 2.33 | 2.4 | 2.08 | 2.44 | | 2.35 | 2.42 | 2.26 | | | | |
| 5000 | 2.32 | 2.39 | 2.43 | 2.45 | | 2.34 | 2.4 | 2.25 | | | | |

TABLE 2

-Vp: Vd=3V, Ids=20mA. Limit: -2.0V (min), -4.0V (max)

| HRS | ZVP_02 | VP_08 | VP_11 | VP_12 | ZVP_20 | ZVP_24 | VP_25 | ZVP_28 | VP_30 | ZVP_32 | ZVP_34 | VP_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 3.22 | 3.05 | 3 | 2.96 | 3.21 | 3.15 | 2.99 | 2.93 | 2.83 | 3.47 | 3.38 | 2.99 |
| 1000 | 3.25 | 3.07 | 3.03 | 2.98 | 3.22 | 3.17 | 3.01 | 2.96 | 2.85 | 3.52 | 3.43 | 2.98 |
| 1240 | 3.25 | 3.07 | 3.03 | 2.98 | 3.22 | 3.17 | 3.01 | 2.96 | 2.85 | 3.51 | 3.42 | 2.99 |
| 1500 | 3.25 | 3.07 | 3.03 | 2.97 | 3.22 | 3.17 | 3 | 2.96 | 2.86 | 3.51 | 3.42 | 2.99 |
| 2000 | 3.24 | 3.06 | 3.02 | 2.97 | 3.21 | 3.16 | 3 | 2.96 | 2.86 | 3.5 | 3.43 | 3 |
| 3000 | 3.23 | 3.05 | 3.01 | 2.97 | 3.21 | 3.16 | 3 | 2.96 | | | | |
| 3780 | 3.22 | 3.05 | 3 | 2.95 | | 3.15 | 3 | 2.94 | | | | |
| 5000 | 3.22 | 3.04 | 2.99 | 2.95 | | 3.15 | 2.99 | 2.93 | | | | |

There was virtually no change in pinch-off characteristics.

TABLE 3
-Igss: Vgs=-5V, Vds=0V. Limit: - 100uA (max)

| HRS | ZIGS_02 | IGS_08 | IGS_11 | IGS_12 | ZIGS_20 | ZIGS_24 | IGS_25 | ZIGS_28 | IGS_30 | ZIGS_32 | ZIGS_34 | IGS_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.222 | 0.255 | 0.224 | 0.24 | 0.265 | 8.49 | 0.235 | 0.232 | 0.195 | 0.223 | 0.273 | 0.173 |
| 1000 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 |
| 1240 | 0.329 | 0.351 | 0.308 | 0.315 | 0.349 | 3.08 | 0.319 | 0.297 | 0.248 | 0.278 | 0.313 | 0.198 |
| 1500 | 0.345 | 0.368 | 0.321 | 0.323 | 0.363 | 3.84 | 0.339 | 0.295 | 0.25 | 0.276 | 0.318 | 0.203 |
| 2000 | 0.389 | 0.373 | 0.331 | 0.331 | 0.416 | 10.6 | 0.345 | 0.303 | 0.262 | 0.28 | 0.33 | 0.227 |
| 3000 | 0.406 | 0.374 | 0.324 | 0.34 | 0.429 | 10.2 | 0.345 | 0.307 | | | | |
| 3780 | 0.383 | 0.353 | 0.291 | 0.315 | 0.45 | 5.28 | 0.328 | 0.284 | | | | |
| 5000 | 0.408 | 0.391 | 0.307 | 0.335 | | 4.5 | 0.332 | 0.294 | | | | |

Note that all of the 1000 hour data is 0.112uA. S/N 24 has much higher leakage under these conditions, but the level is an order of magnitude below the spec limit.

TABLE 4
-Igsx: Vds=10V, Ids=2.0A, Limit: -400uA (max)

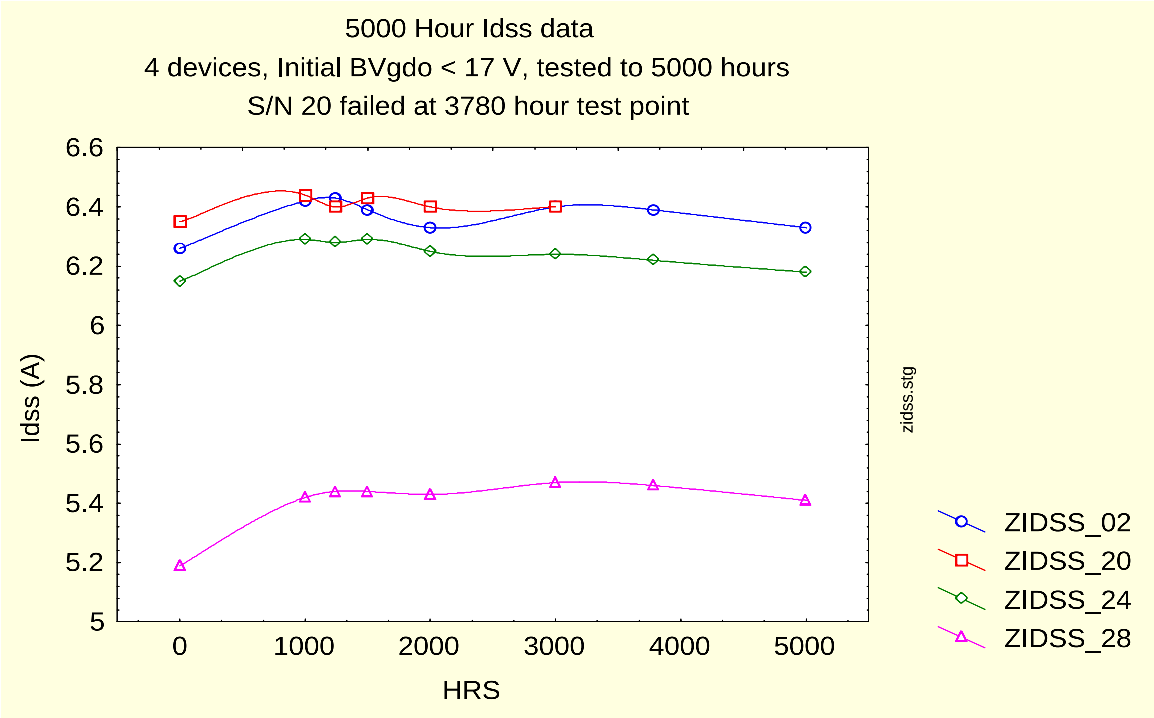
| HRS | ZIGSX_02 | IGSX_08 | IGSX_11 | IGSX_12 | ZIGSX_20 | ZIGSX_24 | IGSX_25 | ZIGSX_28 | IGSX_30 | ZIGSX_32 | ZIGSX_34 | IGSX_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 16.8 | 12.9 | 14.5 | 17.5 | 16.8 | 24.8 | 15.4 | 9.2 | 8.5 | 15.9 | 15.5 | 29 |
| 1000 | 49 | 39.1 | 37.5 | 42.6 | 49.9 | 51.9 | 38 | 26.3 | 27.3 | 52.4 | 40.2 | 44.2 |
| 1240 | 31.9 | 25.8 | 22.7 | 24.8 | 32.8 | 24 | 22.3 | 16.8 | 28.6 | 36.2 | 24.4 | 15 |
| 1500 | 48.4 | 39.7 | 43.6 | 48.3 | 50.6 | 58.7 | 41.6 | 28.3 | 29.3 | 54 | 44.1 | 48.1 |
| 2000 | 58.5 | 43.7 | 46.6 | 53.6 | 57.5 | 69 | 45.1 | 29.8 | 32 | 57.7 | 45.3 | 52.5 |
| 3000 | 50.4 | 42.3 | 38.6 | 52.6 | 50 | 62 | 40.7 | 26.7 | | | | |
| 3780 | 54.1 | 44.2 | 44.4 | 64.3 | 62.4 | 72.1 | 44.3 | 30.9 | | | | |
| 5000 | 56.4 | 48.4 | 50.8 | 72.7 | | 77.2 | 46.3 | 31.7 | | | | |

TABLE 5
Idss: Vds=3.0V, Vg=0V. Limit: 5.2A (min), 6.8A (max)

| HRS | ZIDSS_02 | IDSS_08 | IDSS_11 | IDSS_12 | ZIDSS_20 | ZIDSS_24 | IDSS_25 | ZIDSS_28 | IDSS_30 | ZIDSS_32 | ZIDSS_34 | IDSS_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 6.26 | 6.13 | 6.09 | 6.09 | 6.35 | 6.15 | 5.98 | 5.19 | 5.12 | 6.17 | 6.11 | 5.32 |
| 1000 | 6.42 | 6.21 | 6.16 | 6.11 | 6.44 | 6.29 | 6.06 | 5.42 | 5.3 | 6.38 | 6.21 | 5.27 |
| 1240 | 6.43 | 6.17 | 6.12 | 6.08 | 6.4 | 6.28 | 6.06 | 5.44 | 5.35 | 6.32 | 6.16 | 5.29 |
| 1500 | 6.39 | 6.2 | 6.14 | 6.1 | 6.43 | 6.29 | 6.07 | 5.44 | 5.37 | 6.35 | 6.22 | 5.31 |
| 2000 | 6.33 | 6.16 | 6.1 | 6.06 | 6.4 | 6.25 | 6.01 | 5.43 | 5.35 | 6.29 | 6.23 | 5.33 |
| 3000 | 6.4 | 6.13 | 6.1 | 6.03 | 6.4 | 6.24 | 6.02 | 5.47 | | | | |
| 3780 | 6.39 | 6.08 | 5.8 | 6 | | 6.22 | 6.02 | 5.46 | | | | |
| 5000 | 6.33 | 6.11 | 6.09 | 6.01 | | 6.18 | 5.98 | 5.41 | | | | |

Very stable. Little degradation except that S/N 20 failed at 3780 hours. MELCO attributed to mis-aligned test contacts. Such a failure during a high current test is very possible.TABLE 6

TABLE 6




The tables below compare the distribution of Idss, Igss and Igsx values for all 12 samples. This device provided very repeatable results. In all cases s/n 20 exhibits much the same behavior as the other devices in this test. The variability of s/n is smaller than most of the other devices in this test. There is nothing in the data to indicate imminent, catastrophic failure is about to occur on s/n 20.

TABLE 7
Idss distribution for all life test samples

| | Valid N | Mean | Std.Dev. | Standard Error |
|---|---|---|---|---|
| ZIDSS_02 | 8 | 6.368750 | .057430 | .020305 |
| IDSS_08 | 8 | 6.148750 | .044541 | .015748 |
| IDSS_11 | 8 | 6.075000 | .113892 | .040267 |
| IDSS_12 | 8 | 6.060000 | .042088 | .014880 |
| ***ZIDSS_20*** | ***6*** | ***6.403333*** | ***.031411*** | ***.012824*** |
| ZIDSS_24 | 8 | 6.237500 | .051755 | .018298 |
| IDSS_25 | 8 | 6.025000 | .035456 | .012536 |
| ZIDSS_28 | 8 | 5.407500 | .090040 | .031834 |
| IDSS_30 | 5 | 5.298000 | .102811 | .045978 |
| ZIDSS_32 | 5 | 6.302000 | .081056 | .036249 |
| ZIDSS_34 | 5 | 6.186000 | .050299 | .022494 |
| IDSS_70 | 5 | 5.304000 | .024083 | .010770 |

TABLE 8
Igss distribution for all life test samples

| | | | | Standard |
|---|---|---|---|---|
| | Valid N | Mean | Std.Dev. | Error |
| ZIGSS_02 | 8 | .324250 | .105085 | .037153 |
| IGSS_08 | 8 | .322125 | .094546 | .033427 |
| IGSS_11 | 8 | .277250 | .074787 | .026441 |
| IGSS_12 | 8 | .288875 | .078120 | .027620 |
| ***ZIGSS_20*** | ***7*** | ***.340571*** | ***.118331*** | ***.044725*** |
| ZIGSS_24 | 8 | 5.762750 | 3.687406 | 1.303695 |
| IGSS_25 | 8 | .294375 | .081989 | .028988 |
| ZIGSS_28 | 8 | .265500 | .066365 | .023463 |
| IGSS_30 | 5 | .213400 | .062288 | .027856 |
| ZIGSS_32 | 5 | .233800 | .072147 | .032265 |
| ZIGSS_34 | 5 | .269200 | .090447 | .040449 |
| IGSS_70 | 5 | .182600 | .043878 | .019623 |

TABLE 9
Igsx distribution for all life test samples

| | | | | Standard |
|---|---|---|---|---|
| | Valid N | Mean | Std.Dev. | Error |
| ZIGSX_02 | 8 | 45.68750 | 14.21673 | 5.026375 |
| IGSX_08 | 8 | 37.01250 | 11.78818 | 4.167752 |
| IGSX_11 | 8 | 37.33750 | 12.49891 | 4.419031 |
| IGSX_12 | 8 | 47.05000 | 18.58886 | 6.572154 |
| ***ZIGSX_20*** | ***7*** | ***45.71429*** | ***15.70503*** | ***5.935945*** |
| ZIGSX_24 | 8 | 54.96250 | 20.44707 | 7.229131 |
| IGSX_25 | 8 | 36.71250 | 11.48433 | 4.060324 |
| ZIGSX_28 | 8 | 24.96250 | 7.88379 | 2.787340 |
| IGSX_30 | 5 | 25.14000 | 9.45902 | 4.230201 |
| ZIGSX_32 | 5 | 43.24000 | 17.36240 | 7.764702 |
| ZIGSX_34 | 5 | 33.90000 | 13.25236 | 5.926635 |
| IGSX_70 | 5 | 37.76000 | 15.49526 | 6.929690 |

The following table presents all of the data for S/N 20. Excepting the decrease in breakdown voltage (the impetus for this investigation), the device appears to be stable. Power output is stable and there is no RF output power slump, dc parameters are stable.

## TABLE 10
## S/N 20 LIFE TEST RESULTS

| HRS | ZGM_20 | ZIGSS_20 | ZVP_20 | ZIDSS_20 | ZIGSX_20 | ZPO1_20 | ZPO2_20 | ZVGD_20 | ZVGS_20 |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 2.3 | 0.265 | 3.21 | 6.35 | 16.8 | 38.99 | 30.81 | 16.9 | 19.3 |
| 1000 | 2.3 | 0.112 | 3.22 | 6.44 | 49.9 | 38.88 | 30.88 | 12.3 | 17.7 |
| 1240 | 2.3 | 0.349 | 3.22 | 6.4 | 32.8 | 38.83 | 30.87 | 12.1 | 17.6 |
| 1500 | 2.3 | 0.363 | 3.22 | 6.43 | 50.6 | 39 | 30.84 | 12 | 17.5 |
| 2000 | 2.3 | 0.416 | 3.21 | 6.4 | 57.5 | 38.82 | 30.86 | 11.7 | 17.5 |
| 3000 | 2.3 | 0.429 | 3.21 | 6.4 | 50 | 38.97 | 30.81 | 11.3 | 17.2 |
| 3780 | | 0.45 | | | 62.4 | 38.91 | 30.63 | 11.2 | 18.3 |
| 5000 | | | | | | | | | |

S/N 20 is not distinctly different from the other devices and the failure scenario presented seems plausible. This is a very high current test; Id is set far above a normal operating point for this device. All devices show a small initial increase in Idss between the initial and 1000 hour measurement and then Idss settles. Thus, the failure of S/N 20 is discounted.

PO1 and PO2:
PO1: Vds=8.0V, Vgs (final test setting), Pin=32.5dBm, f=8Ghz. Limit: 37.8dBm (min)
PO2: Vds=8.0V, Vgs (final test setting), Pin+22.5dBm, f=8Ghz Limit: 28.8dBm (min)
Delta limit for both tests is -0.2dBm.

## TABLE 11
## PO1 and PO2

| HRS | ZPO1_02 | P01_08 | P01_11 | P01_12 | ZPO1_20 | ZPO1_24 | P01_25 | ZPO1_28 | P01_30 | ZPO1_32 | ZPO1_34 | P01_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 38.91 | 39.03 | 38.85 | 38.61 | 38.99 | 39.14 | 38.84 | 38.89 | 38.69 | 39.06 | 38.6 | 39.06 |
| 1000 | 39.07 | 39 | 38.86 | 38.61 | 38.88 | 39.08 | 38.75 | 39.19 | 38.8 | 39.48 | 39.27 | 39.48 |
| 1240 | 39 | 38.9 | 38.7 | 38.62 | 38.83 | 38.95 | 38.69 | 39.11 | 38.78 | 39.47 | 39.26 | 39.47 |
| 1500 | 39.12 | 39.12 | 38.69 | 38.65 | 39 | 39.09 | 38.77 | 39.2 | 38.9 | 39.48 | 39.36 | 39.49 |
| 2000 | 38.97 | 38.99 | 38.45 | 38.62 | 38.82 | 39.1 | 38.78 | 39.01 | 38.62 | 39.41 | 39.23 | 39.41 |
| 3000 | 38.98 | 38.89 | 38.61 | 38.62 | 38.97 | 38.97 | 38.67 | 39.02 | | | | |
| 3780 | 39.02 | 38.9 | 38.59 | 38.58 | 38.91 | 39 | 38.68 | 39.02 | | | | |
| 5000 | 38.887 | 38.87 | 38.56 | 38.57 | | 38.97 | 38.64 | 38.85 | | | | |
| HRS | ZPO2_02 | P02_08 | P02_11 | P02_12 | ZPO2_20 | ZPO2_24 | P02_25 | ZPO2_28 | P02_30 | ZPO2_32 | ZPO2_34 | P02_70 |
| 0.1 | 30.7 | 30.91 | 30.84 | 30.91 | 30.81 | 30.89 | 30.72 | 30.51 | 30.54 | 30.34 | 29.97 | 30.75 |
| 1000 | 30.76 | 31.07 | 30.85 | 30.91 | 30.88 | 31.09 | 30.86 | 30.63 | 30.65 | 30.35 | 30.12 | 30.9 |
| 1240 | 30.77 | 31 | 30.91 | 30.94 | 30.87 | 30.97 | 30.86 | 30.62 | 30.62 | 30.35 | 30.06 | 30.87 |
| 1500 | 30.79 | 31.09 | 30.85 | 30.92 | 30.84 | 30.98 | 30.8 | 30.58 | 30.58 | 30.28 | 30.03 | 30.77 |
| 2000 | 30.76 | 30.97 | 30.81 | 30.89 | 30.86 | 30.97 | 30.81 | 30.6 | 30.6 | 30.29 | 30.02 | 30.91 |
| 3000 | 30.7 | 31.03 | 30.83 | 30.92 | 30.81 | 30.93 | 30.82 | 30.52 | | | | |
| 3780 | 30.7 | 30.92 | 30.79 | 30.88 | 30.63 | 30.87 | 30.78 | 30.53 | | | | |
| 5000 | 30.67 | 30.99 | 30.75 | 30.85 | | 30.85 | 30.76 | 30.54 | | | | |

PO1 and PO2 are stable, although some devices exceeded the 0.2dBm delta limit for PO1. This out-of-spec condition had been previously noted and is not a cause for concern. S/N 12 had a decrease in Pout under 5dB overdrive of 0.24 dBm after 5000 hours. S/N 11 had a decrease of 0.3 dBm after 5000 hours under the same conditions.
The next 3 plots show PO1 for all 12 devices.

TABLE 12

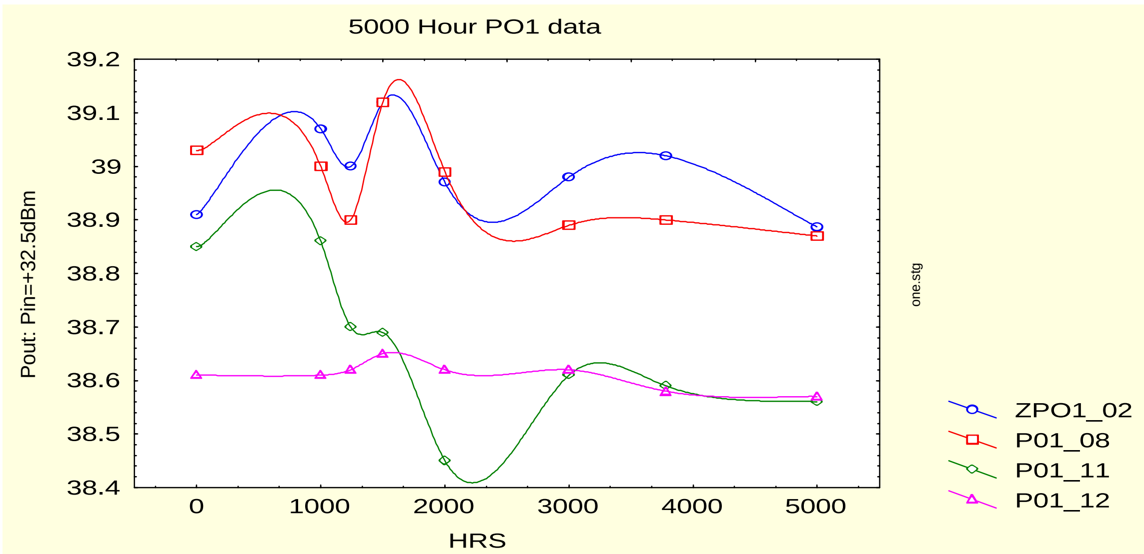



TABLE 13

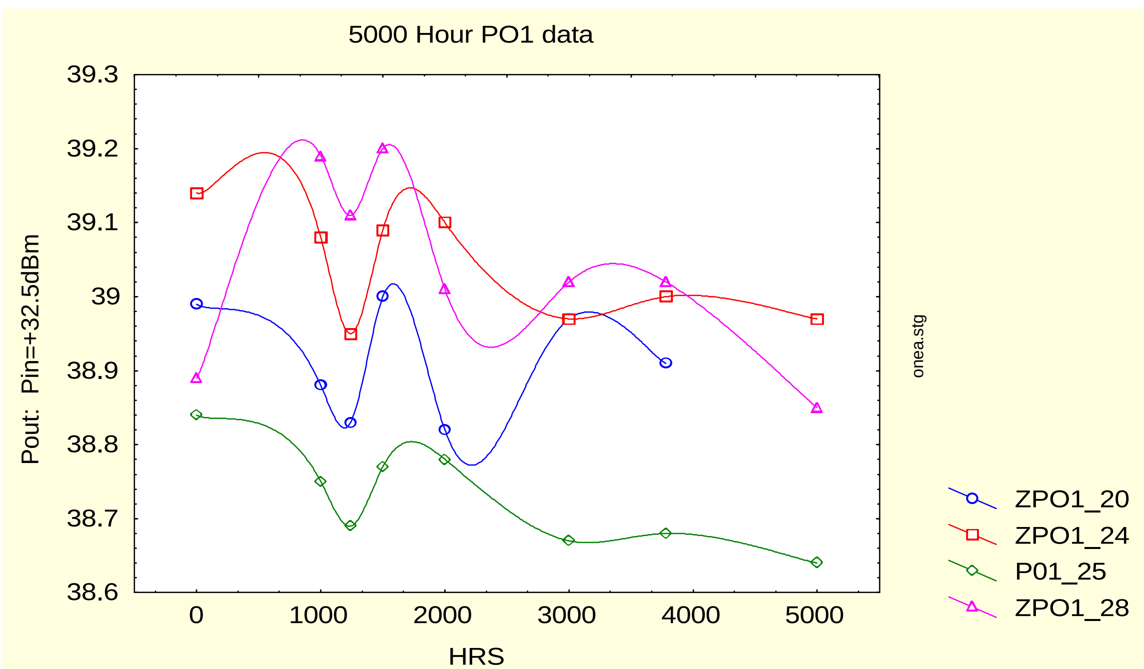
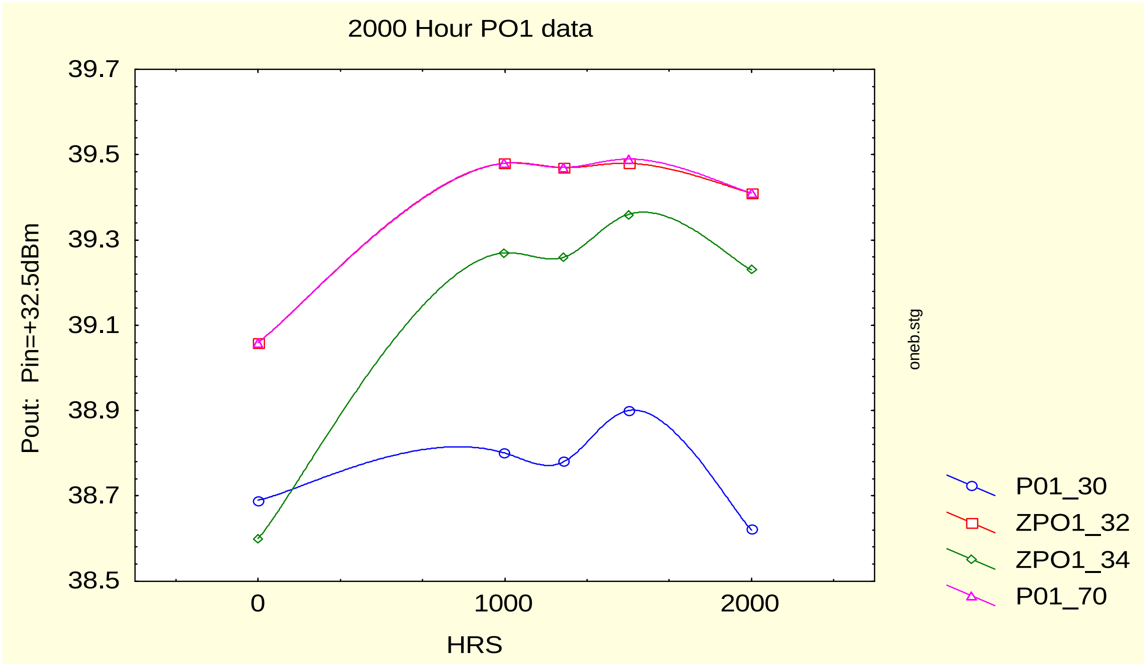


TABLE 14




The next plot shows PO2 for the same devices. These measurements were conducted in the linear drive region as opposed to the 5dB compressed condition of PO1 and show stable Pin/Pout characteristics. The application operating level of the C40 MESFETs is at $P_{-2.8dB}$ compression.

TABLE 15

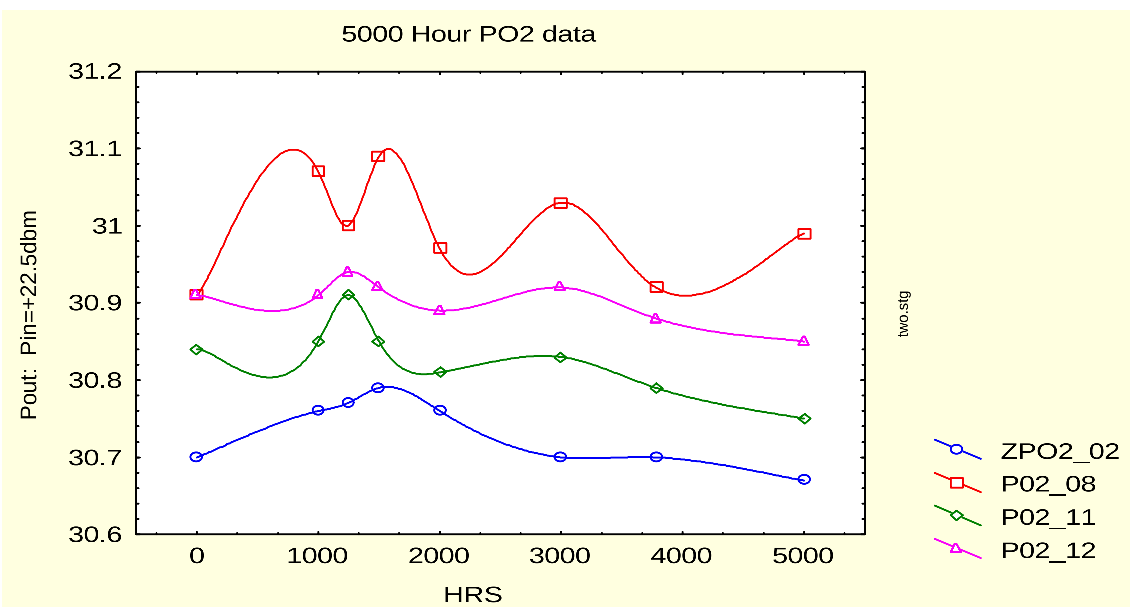


TABLE 16

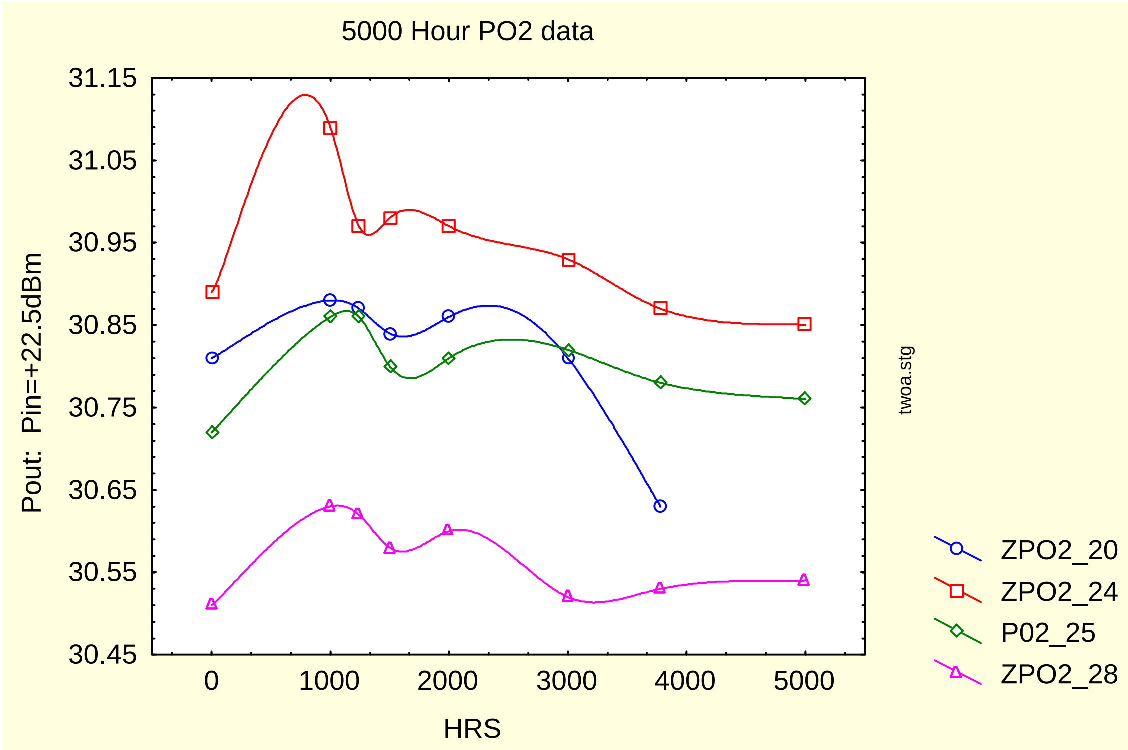
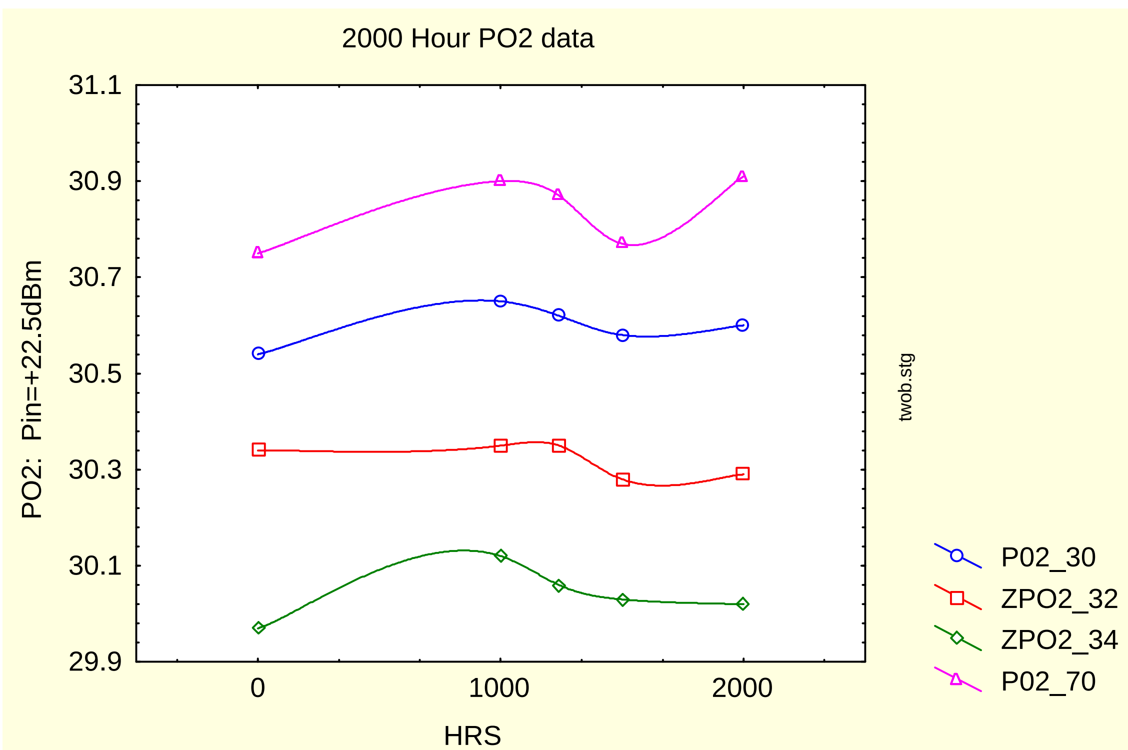



TABLE 17



The following two tables compare the PO1 and PO2 variations for all 12 samples. The only noteworthy data was that s/n 20 was close (0.18dB) to the 0.2dB Pout degradation limit at 3780 hours for PO2.

TABLE 18
PO1 distribution for all 12 samples

| | Valid N | Mean | Minimum | Maximum | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|
| ZPO1_02 | 8 | 38.99463 | 38.887 | 39.12 | 0.077125 | 0.027268 |
| P01_08 | 8 | 38.9625 | 38.87 | 39.12 | 0.087137 | 0.030808 |
| P01_11 | 8 | 38.66375 | 38.45 | 38.86 | 0.141415 | 0.049998 |
| P01_12 | 8 | 38.61 | 38.57 | 38.65 | 0.025071 | 0.008864 |
| ***ZPO1_20*** | ***7*** | ***38.91429*** | ***38.82*** | ***39*** | ***0.074578*** | ***0.028188*** |
| ZPO1_24 | 8 | 39.0375 | 38.95 | 39.14 | 0.07285 | 0.025756 |
| P01_25 | 8 | 38.7275 | 38.64 | 38.84 | 0.067981 | 0.024035 |
| ZPO1_28 | 8 | 39.03625 | 38.85 | 39.2 | 0.12716 | 0.044958 |
| P01_30 | 5 | 38.758 | 38.62 | 38.9 | 0.107331 | 0.048 |
| ZPO1_32 | 5 | 39.38 | 39.06 | 39.48 | 0.181246 | 0.081056 |
| ZPO1_34 | 5 | 39.144 | 38.6 | 39.36 | 0.307945 | 0.137717 |
| P01_70 | 5 | 39.382 | 39.06 | 39.49 | 0.182675 | 0.081695 |

TABLE 19
PO2 distribution for all 12 samples

| | Valid N | Mean | Minimum | Maximum | Std.Dev. | Standard Error |
|---|---|---|---|---|---|---|
| ZPO2_02 | 8 | 30.73125 | 30.67 | 30.79 | 0.043569 | 0.015404 |
| P02_08 | 8 | 30.9975 | 30.91 | 31.09 | 0.064752 | 0.022893 |
| P02_11 | 8 | 30.82875 | 30.75 | 30.91 | 0.04734 | 0.016737 |
| P02_12 | 8 | 30.9025 | 30.85 | 30.94 | 0.028158 | 0.009955 |
| ***ZPO2_20*** | ***7*** | ***30.81429*** | ***30.63*** | ***30.88*** | ***0.085802*** | ***0.03243*** |
| ZPO2_24 | 8 | 30.94375 | 30.85 | 31.09 | 0.076893 | 0.027186 |
| P02_25 | 8 | 30.80125 | 30.72 | 30.86 | 0.04794 | 0.016949 |
| ZPO2_28 | 8 | 30.56625 | 30.51 | 30.63 | 0.047189 | 0.016684 |
| P02_30 | 5 | 30.598 | 30.54 | 30.65 | 0.041473 | 0.018547 |
| ZPO2_32 | 5 | 30.322 | 30.28 | 30.35 | 0.034205 | 0.015297 |
| ZPO2_34 | 5 | 30.04 | 29.97 | 30.12 | 0.055227 | 0.024698 |
| P02_70 | 5 | 30.84 | 30.75 | 30.91 | 0.074833 | 0.033466 |

PART II. BVgdo (gate-drain breakdown) and BVgso (gate-source breakdown)

BVGDO: IG=-1.0mA. LIMIT: -17 V (MIN)
BVGSO: IG=-1.0mA . LIMIT: -17 V (MIN)

Both parameters have +/- 10% delta limit.

Both parameters show significant slump from their initial, pre-life test measurements. However, the slump decelerated significantly after the initial 1000 hours to the end of the test.

TABLE 20
BVgdo

| HRS | ZVGD_02 | VGD_08 | VGD_11 | VGD_12 | ZVGD_20 | ZVGD_24 | VGD_25 | ZVGD_28 | VGD_30 | ZVGD_32 | ZVGD_34 | VGD_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 16.8 | 17.2 | 17.8 | 17.6 | 16.9 | 16.3 | 17.4 | 16.6 | 17.5 | 16.1 | 16.5 | 19.1 |
| 1000 | 12 | 13.5 | 15.1 | 14.6 | 12.3 | 12.4 | 13.7 | 13 | 13.7 | 11.5 | 11.7 | 16.1 |
| 1240 | 12 | 13.3 | 14.8 | 14.4 | 12.1 | 12.2 | 13.5 | 13.1 | 13.6 | 11.5 | 11.8 | 16.1 |
| 1500 | 11.9 | 13.4 | 14.7 | 14.2 | 12 | 12.2 | 13.4 | 13 | 13.6 | 11.4 | 11.7 | 16.1 |
| 2000 | 11.6 | 13.2 | 14.6 | 14 | 11.7 | 11.9 | 13.2 | 13.1 | 13.5 | 11.4 | 11.5 | 15.8 |
| 3000 | 11.5 | 12.6 | 14.3 | 13.4 | 11.3 | 11.4 | 13.1 | 13 | | | | |
| 3780 | 11.5 | 12.5 | 14.1 | 13.1 | 11.2 | 11.3 | 13 | 12.9 | | | | |
| 5000 | 11.7 | 12.5 | 14 | 12.9 | | 11.4 | 12.7 | 13 | | | | |

TABLE 21
BVgso

| HRS | ZVGS_02 | VGS_08 | VGS_11 | VGS_12 | ZVGS_20 | ZVGS_24 | VGS_25 | ZVGS_28 | VGS_30 | ZVGS_32 | ZVGS_34 | VGS_70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 19.6 | 19.4 | 19.5 | 19.2 | 19.3 | 19.3 | 19.6 | 19.5 | 20 | 18.8 | 18.7 | 21.2 |
| 1000 | 17.9 | 18.6 | 18.6 | 18.6 | 17.7 | 18.3 | 19 | 18.2 | 18.7 | 17.5 | 17.6 | 20.1 |
| 1240 | 17.7 | 18.5 | 18.5 | 18.5 | 17.6 | 18.1 | 18.9 | 18.2 | 18.6 | 17.4 | 17.6 | 20 |
| 1500 | 17.5 | 18.3 | 18.3 | 18.4 | 17.5 | 18 | 18.7 | 18.1 | 18.5 | 17.2 | 17.4 | 19.9 |
| 2000 | 17.5 | 18.4 | 18.3 | 18.4 | 17.5 | 18 | 18.8 | 18.3 | 18.6 | 17.3 | 17.6 | 19.9 |
| 3000 | 17.2 | 18.1 | 18.1 | 18.2 | 17.2 | 17.6 | 18.6 | 17.9 | | | | |
| 3780 | 17 | 17.9 | 18 | 18 | 18.3 | 17.3 | 18.4 | 17.8 | | | | |
| 5000 | 16.9 | 17.9 | 18 | 17.9 | | 17.2 | 18.7 | 17.7 | | | | |

The next charts plot BVgdo for all 12 devices.

TABLE 22

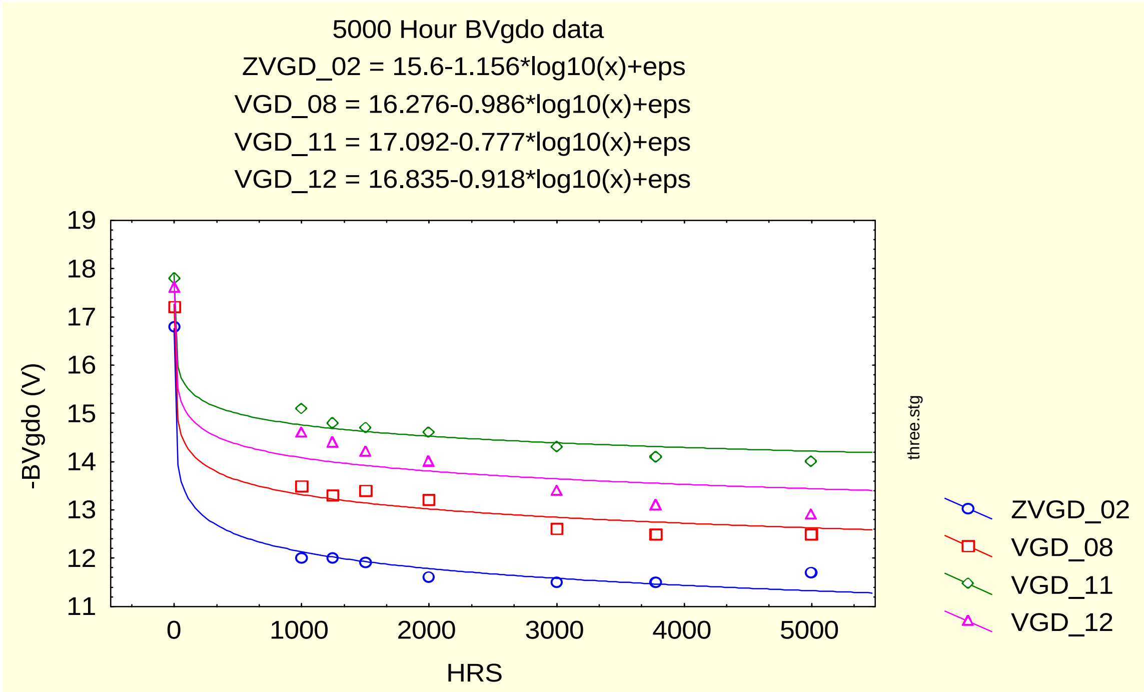



TABLE 23

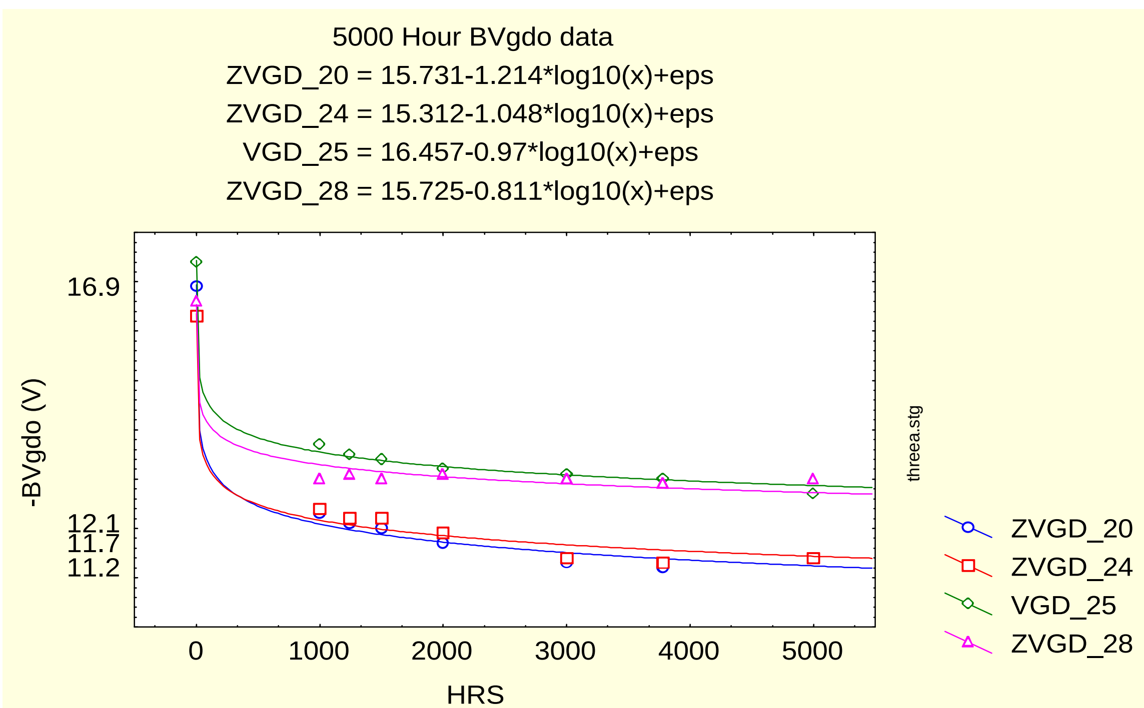
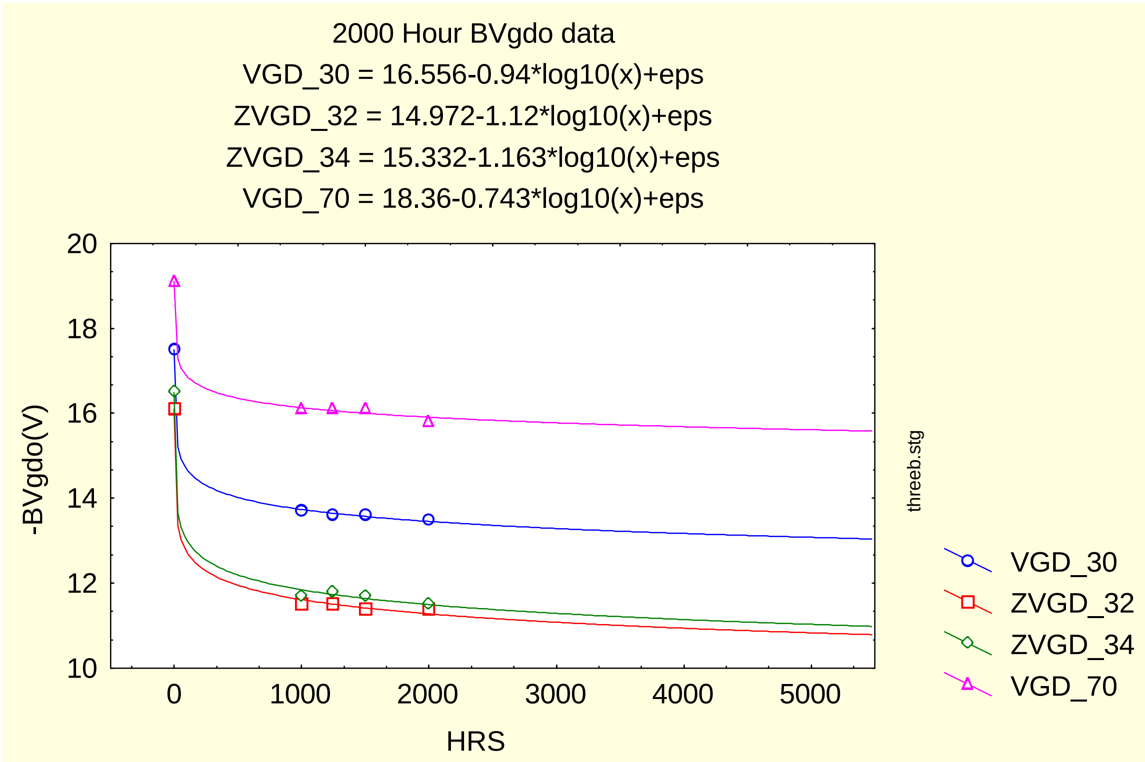


TABLE 24




The following 2 charts show the 5000 hour performance with the first 1000 hours of data removed to account for annealing of the shallow surface states suspected of causing the BVgdo slump.

TABLE 25

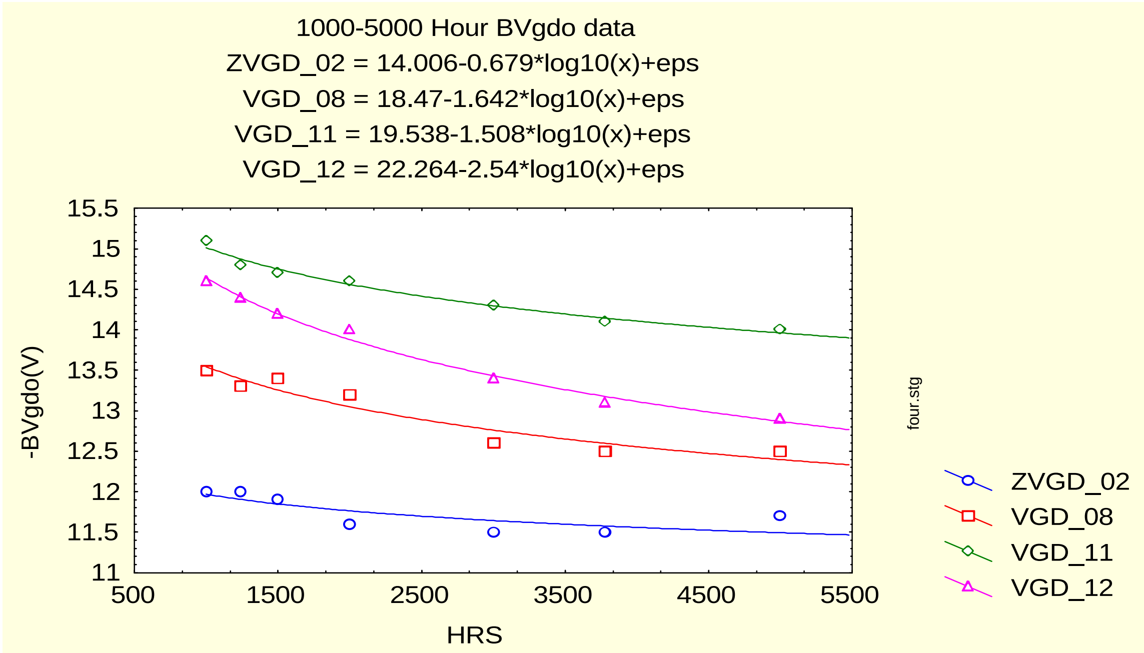
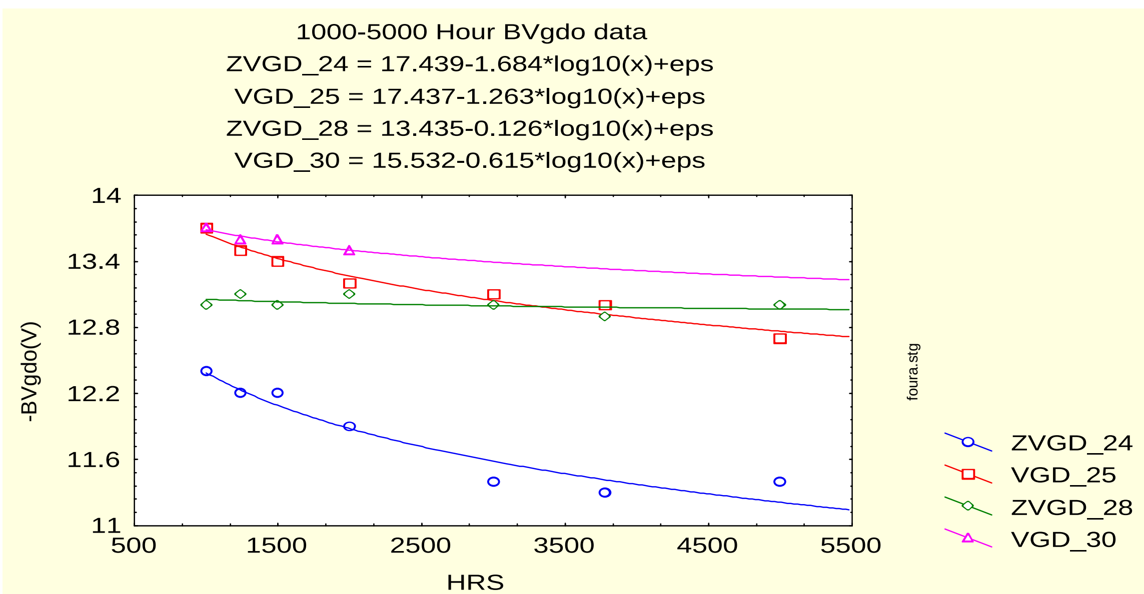



TABLE 26




PART III. Predicted performance over mission life

The next step is look at the trend in gate-source leakage (Igsx) for the 8 devices that went beyond 2000 hours.

TABLE 27

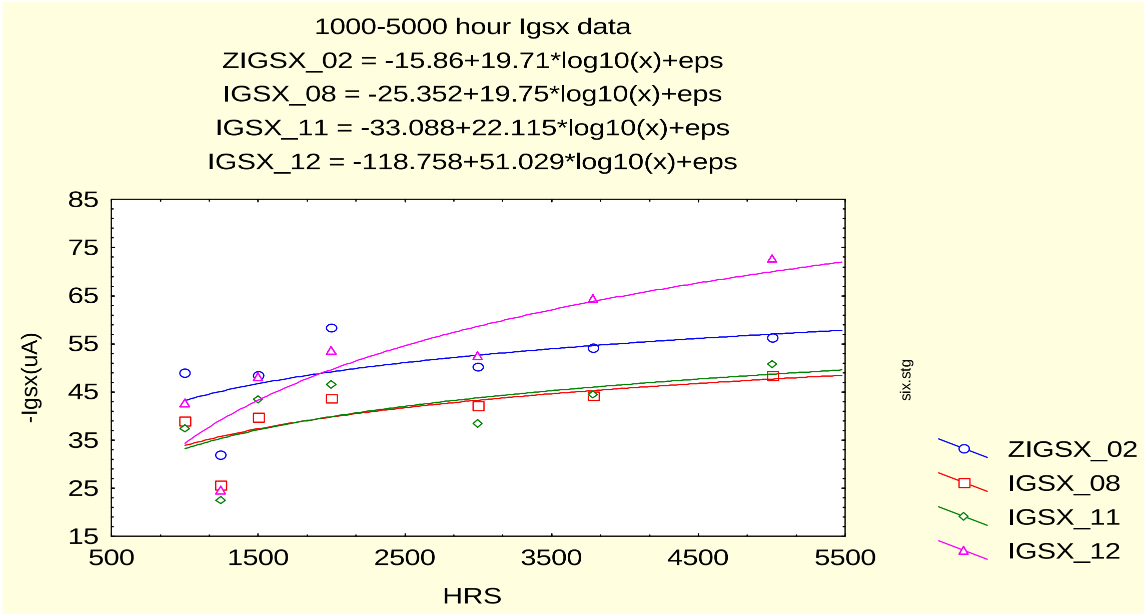
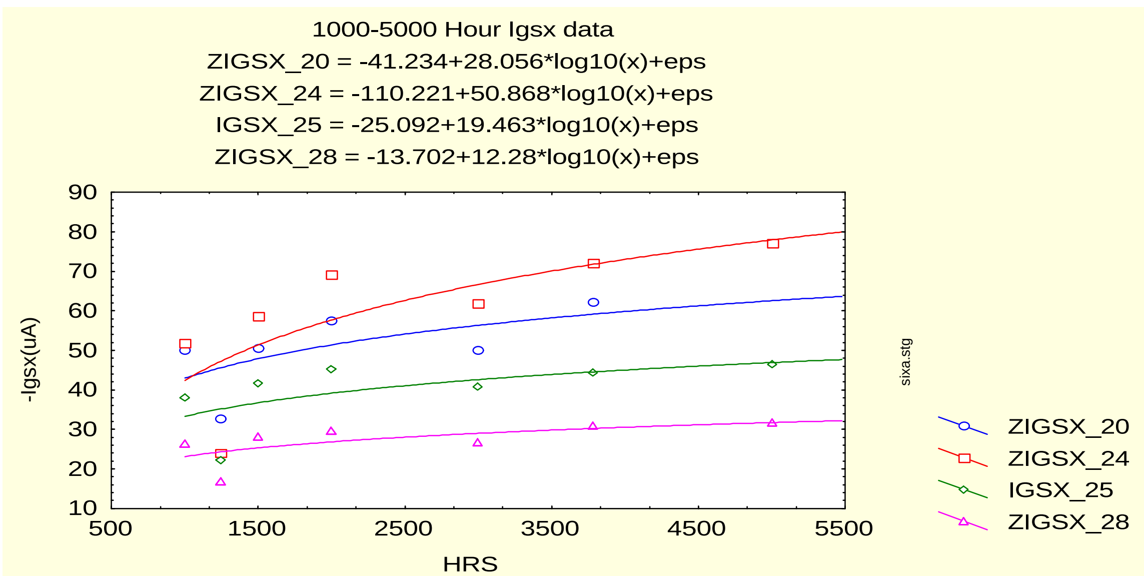
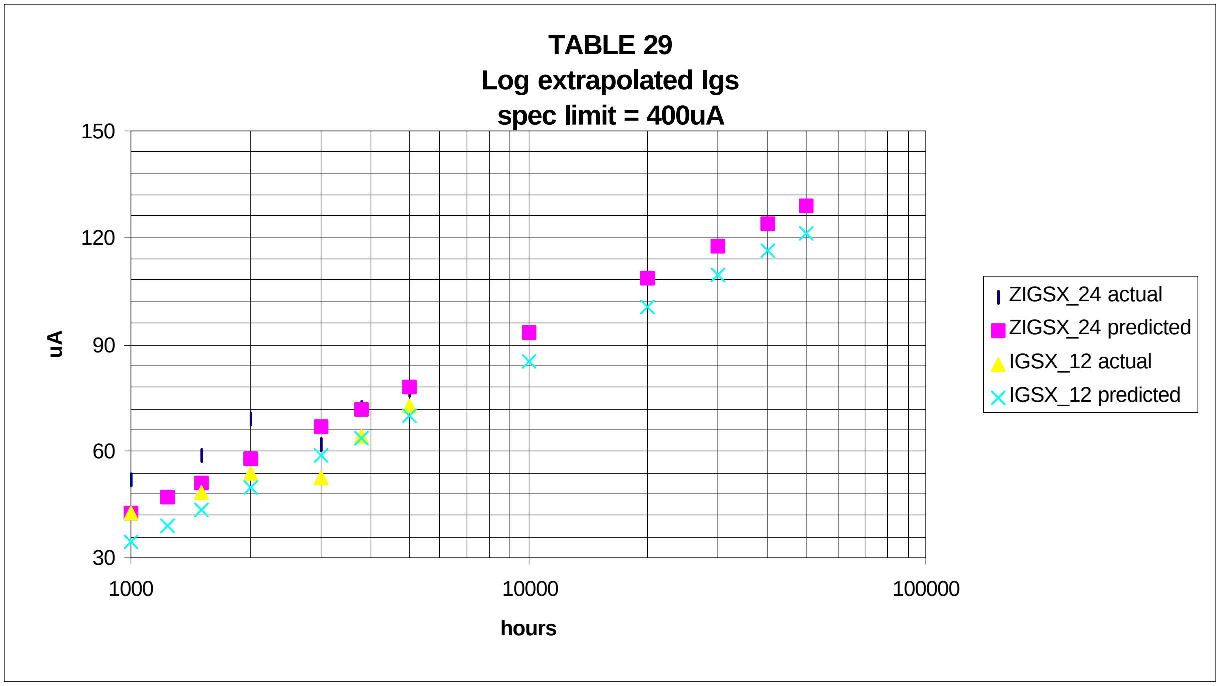



TABLE 28




These graphs show the increase in leakage as a result of the overdrive life condition. The life test at P-5dB compression provides margin over the application level at $P_{-2.8dB}$ compression. The extrapolated leakage is a good indication of the long term state of health of the devices. The spreadsheets below show the extrapolated increase if the test was continued to 50,000 hours for the two devices with the highest gate leakage, s/n 12 and 24. S/N 12 had an initial BVgdo > 17 V; S/N 24 initial BVgdo < 17V.




Testing by the manufacturer showed the MESFETs to be capable of tolerating reverse leakage as high as 970mA without failure. Long term reliability dictates that the total gate stress remain on the order of 1mA. In application the parts see a worst case gate current of 2.06mA for the Engineering Test Model (ETM). If the flight units have similar performance to the ETM, the long term degradation of the devices should not be a problem.

The next step is to compare the final degradation curves to previous projections and determine that the rate of change of breakdown voltage has not increased. The following 4 tables plot the 1000-3780 hour and 1000-5000 hour data assuming log-time degradation. Data for seven samples that completed the life test are used.

TABLE 30

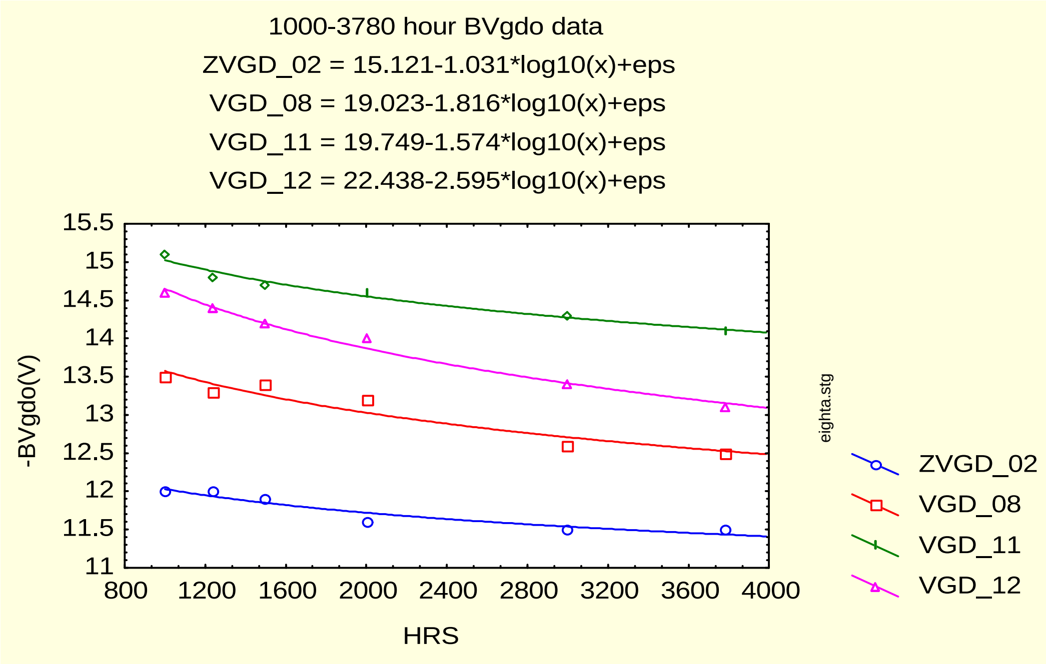



TABLE 31

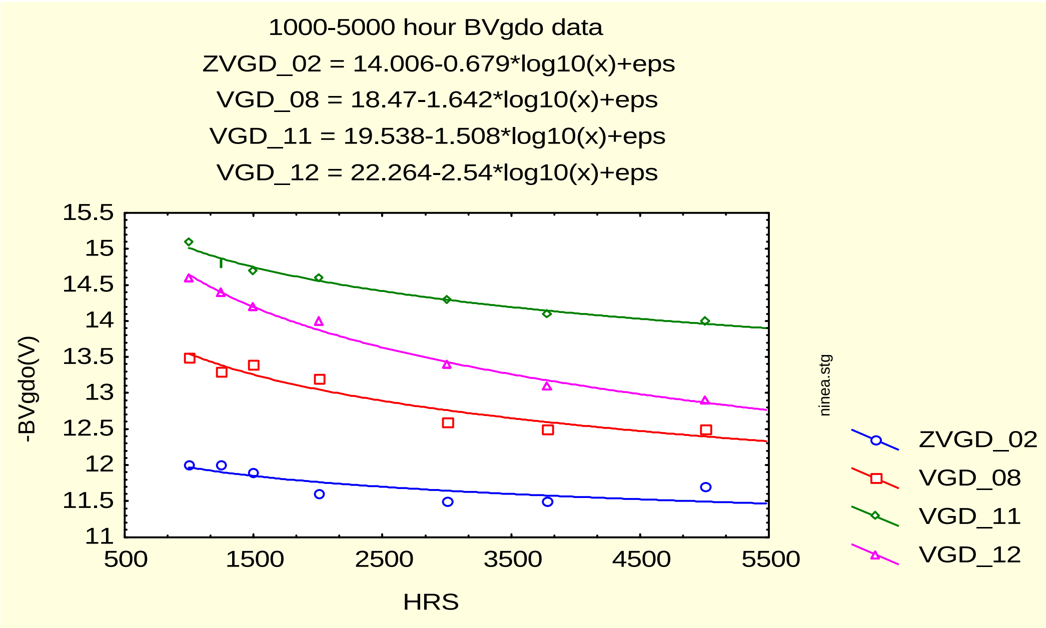


TABLE 32

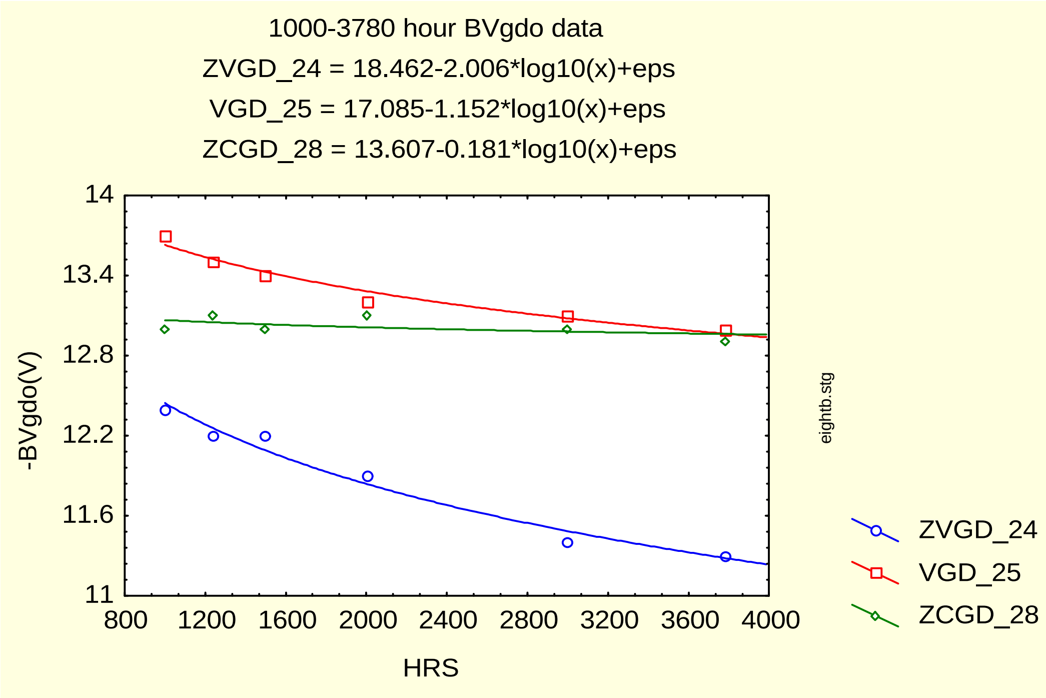
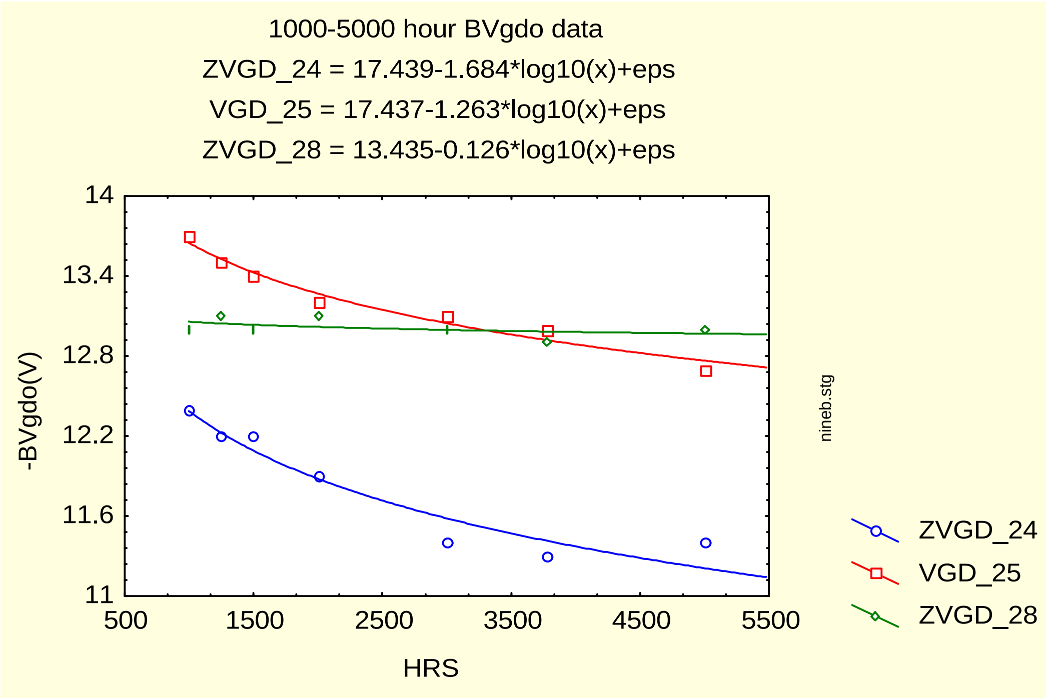



TABLE 33



There is no indication ofn any significant change in the rate of degradation between the 3780 hour data and the 5000 hour data. The slopes of the 5000 hour curves have decreased from the slopes of the 3780 hour curves for 6 of 7 samples. There is no indication that a sudden decrease in breakdown voltage or a sharp increase in gate leakage is about to occur ("Falling off the table"). Predicted and actual degradations have not diverged.

The final table shows the projected degradation to 50,000 hours using the 1000-5000 hour data for the seven surviving life test samples. There are two assumptions that accompany this data. One: Degradation will continue with time. Two: Actual flight parts will perform no worse than these devices.