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MCDONNELL DOUGLAS TECHNICAL SERVICES CO.

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

1.3-DN-C0504-036.

ORBITER TO SPACELAB ELECTRICAL POWER INTERFACE

AVIONICS SYSTEM ENGINEERING

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1.0 SUMMARY

This report presents the results of an investigation of the factors which affect the determination of Spacelab (S/L) minimum interface Main DC voltage and available power from the Orbiter. This study addresses the dedicated fuel cell mode of powering the S/L and identifies the minimum S/L interface voltage and available power using the predicted fuel cell power plant performance curves. The values obtained are slightly lower than current estimates and represent a more marginal operating condition than previously estimated.

2.0 DISCUSSION

Figure 1 is a simplified diagram of the Orbiter to Spacelab Main DC power feeder depicting the dedicated fuel cell configuration for the S/L Large Module (LM). In this mode the S/L receives its power from fuel cell No. 3 via Orbiter Main DC bus C. The resistances shown represents Rockwell furnished data and are for 1/0 gauge wire at 68 °F.

The key factors affecting the voltage and power available to the S/L are fuel cell performance and feeder line resistance. The following discussion deals with those variables affecting fuel cell performance and feeder line resistance and their affect on determination of minimum S/L voltage and available power.

2.1 Fuel Cell Performance

One of the prime concerns of this study is to identify worst-case or marginal performance aspects. For this reason the fuel cell performance characteristics for a 5000 hour fuel cell are used. Figure 2 depicts the performance curves for both steady state and transient conditions. The transient curves shown depict the predicted minimum fuel cell output voltage for step load changes. Figure 3 is a plot of step load changes to 12KW versus minimum transient voltage. The maximum step load change is 10KW and would represent a change in load demand from the steady state operating point of 2KW to 12KW. This curve was constructed

by plotting additional transient curves for steady state operating points to 12KW. An example is shown in Figure 2 for a step load change of 5KW from 7KW to 12KW. No data exists which describes transient to steady recovery time. It is the opinion of R/SD and NASA engineers that recovery to steady state occurs within 5 to 7 minutes. For purposes of this study it is assumed that recovery to steady state occurs in 7 minutes and is linear.

2.2 Feeder Resistance

Figure 1 indicates the S/L Main feeder line resistance for 1/0 gauge wire at 68°F and the longest feeder line (25 ft. for the S/L, L/M configuration). Factors affecting line resistance which must be considered in a worst case analysis are ambient wire temperature and increases in wire temperature due to I^2R heat build up.

2.2.1 Ambient Temperature

The payload bay wire tray ambient temperature will vary due to vehicle orientation as defined in Shuttle Vehicle to S/L ECLSS/Thermal Interfaces, ICD-2-05201. This temperature can range from -280°F to +200°F in orbit. For purposes of this study the resistance of the components and wire in the Main Power Distrubution Assembly was considered to remain at ambient temperature. This unit is mounted on a cold plate.

2.2.2 Line Loss Heating

Figure 4 is a curve showing steady state temperature versus current for a I/O gauge wire of the type used in the S/L feeder circuit. This data is from the R/SD laboratory test report LTR 1706-7801 dated October 27, 1975, "Space Shuttle Temperature/Current Characteristics of Connectors - Evaluation Test." Laboratory test conditions simulated those which the feeder line will encounter in space. Of more significance to this evaluation is the rate of wire temperature increase, since the fuel cell performance requirements limits the maximum time at 12KW to 15 minutes every three hours; the maximum temperature the wire will reach will be

limited by this time factor. Figure 5 is a curve extrapolated from the R/SD test report which shows rate of temperature increase of a 1/0 gauge wire carrying 200 amps. During the first 15 minutes the temperature increases at a rate of approximately 6.5 degrees per minute. This test was performed at 250°F. Each conductor in circuit segment 1 in Figure 1 will carry slightly over 200 amps at 12KW. Therefore the 6.5 degree rate of temperature increase is applied for Segment 1. In Circuit Segment 2 each conductor will carry half the current of segment 1 or one forth the power; therefore the temperature of this segment will increase at approximately one forth of the rate of Segment 1, or 1.625 degrees per minute.

In summary the feeder line resistance will vary as a function of ambient temperature and wire temperature due to feeder line current. Wiring heating due to line current is a function of time with the maximum temperature for this analysis occurring 15 minutes after initiation of a step load change. This is an important factor to consider in determining maximum available power to the spacelab.

2.3 Results

Appendix 1 presents an explanation of the calculations performed in this study and includes calculated data for various values of step load change (Δ P) and ambient temperature. Figures 6, 7, and 8 are plots of data contained in Appendix 1 which represent selected operating conditions which are intended to provide performance references and indicate worst case performance.

Figure 6 is a plot of step load change vs minimum S/L interface voltage for an ambient temperature of 68°F. Minimum interface voltage occurs for a ΔP of 10KW at an ambient wire temperature of 200°F. The minimum voltage under these conditions is 25.6 volts.

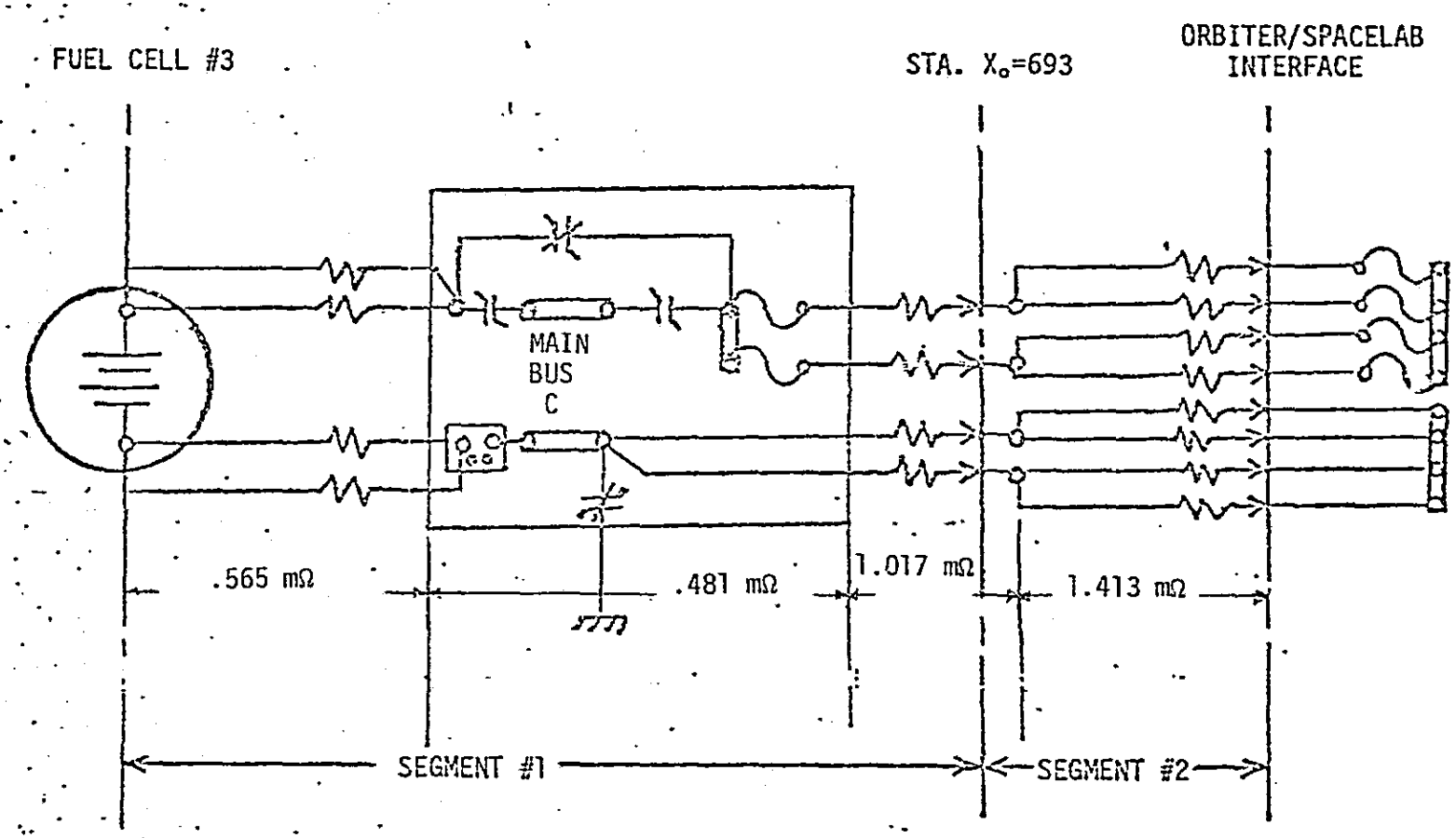
Figure 7 is a plot of minimum interface voltage vs ambient temperature for ΔP of 5KW and 10KW. The ΔP = 5KW curve represents performance for step load change from fuel cell maximum continuous output (7KW) to fuel cell peak output (12KW). From 70° to 200°F the interface voltage decreases approximately 0.35 volts.

Figure 8 is a plot of available interface power vs wire tray temperature. This curve is the minimum power available to the S/L during the 15 minute peak load period for a ΔP of 10KW and varies from 11.33 KW to 11.19 KW over the full range of ambient temperatures.

3.0 CONCLUSION AND RECOMMENDATIONS

It is the conclusion of this study that in using the predicted fuel cell performance curves for a 5000 hour fuel cell the minimum S/L interface voltage is 25.6 volts. This will occur at an ambient temperature of 200°F for a step load change from 2KW to 12KW. The minimum peak power available will be 11,150 watts. These "predicted" levels are somewhat lower than previous estimates and represent more marginal operating conditions than previously anticipated. The present values in ICD-2-C5301, Shuttle Vehicle/Spacelab Avionics Interfaces are "26.4" volts and "12 KW peak minus losses". As fuel cell development tests are completed the data will be reflected in updated performance curves. It is expected that this data will be available in September or October of this year. Unless development testing indicates fuel cell performance to be considerably better than predicted, some operational constraints may have to be employed. These could range from supporting Spacelab flights with "new" fuel cells only, to restricting step load changes when using "old" fuel cells. As more accurate fuel cell performance data becomes available it is recommended than in in-depth study be performed to determine the minimum voltage and peak power available to the Spacelab and if required identify the action necessary to being these parameters within an acceptable operating range.

DEDICATED FUEL CELL MODE



NOTE: ALL WIRE IS #0 GAGE

FIGURE 1: ORBITER TO SPACELAB MAIN POWER FEEDER

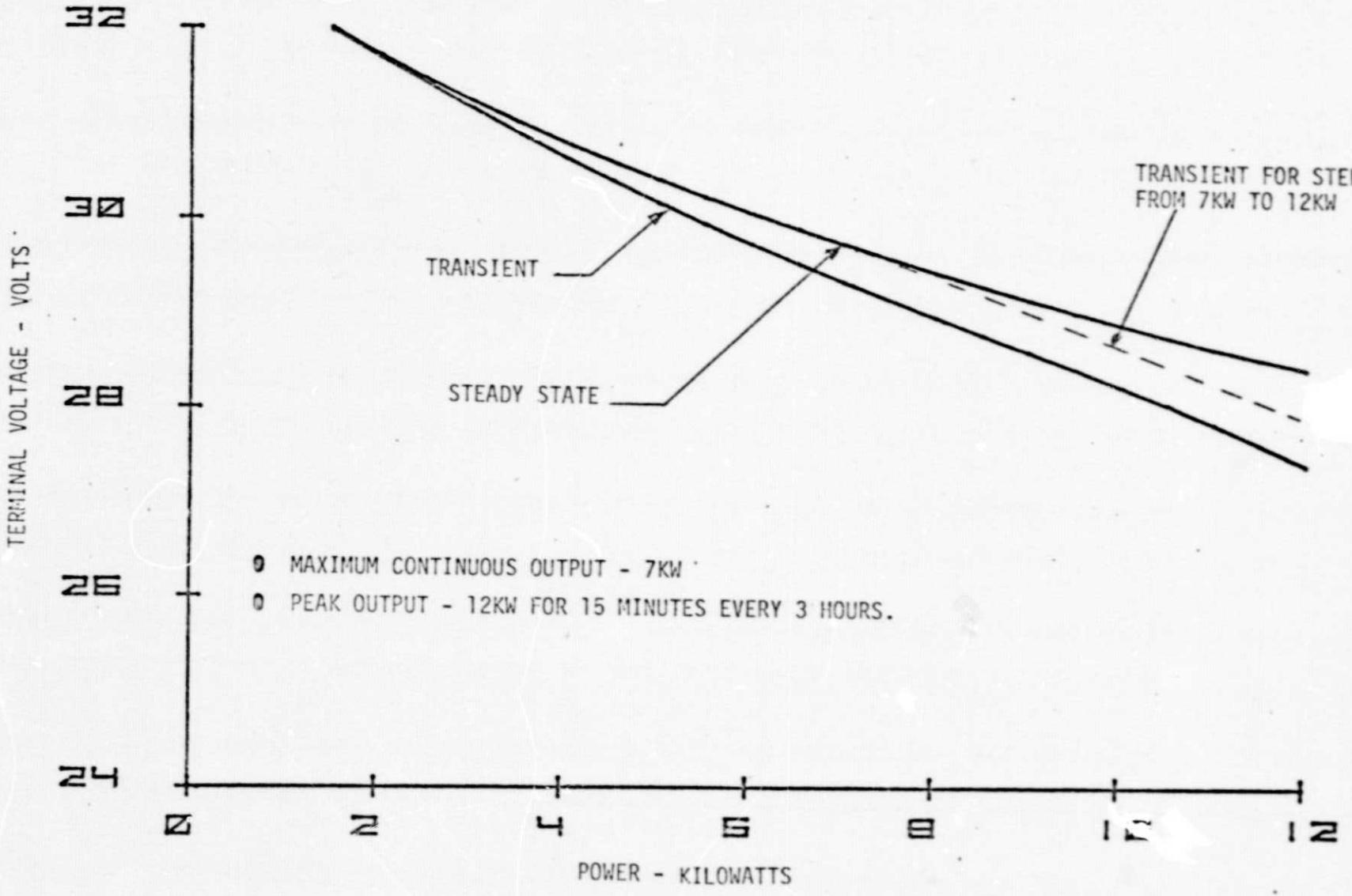


FIGURE 2: PREDICTED FUEL CELL POWER PLANT PERFORMANCE

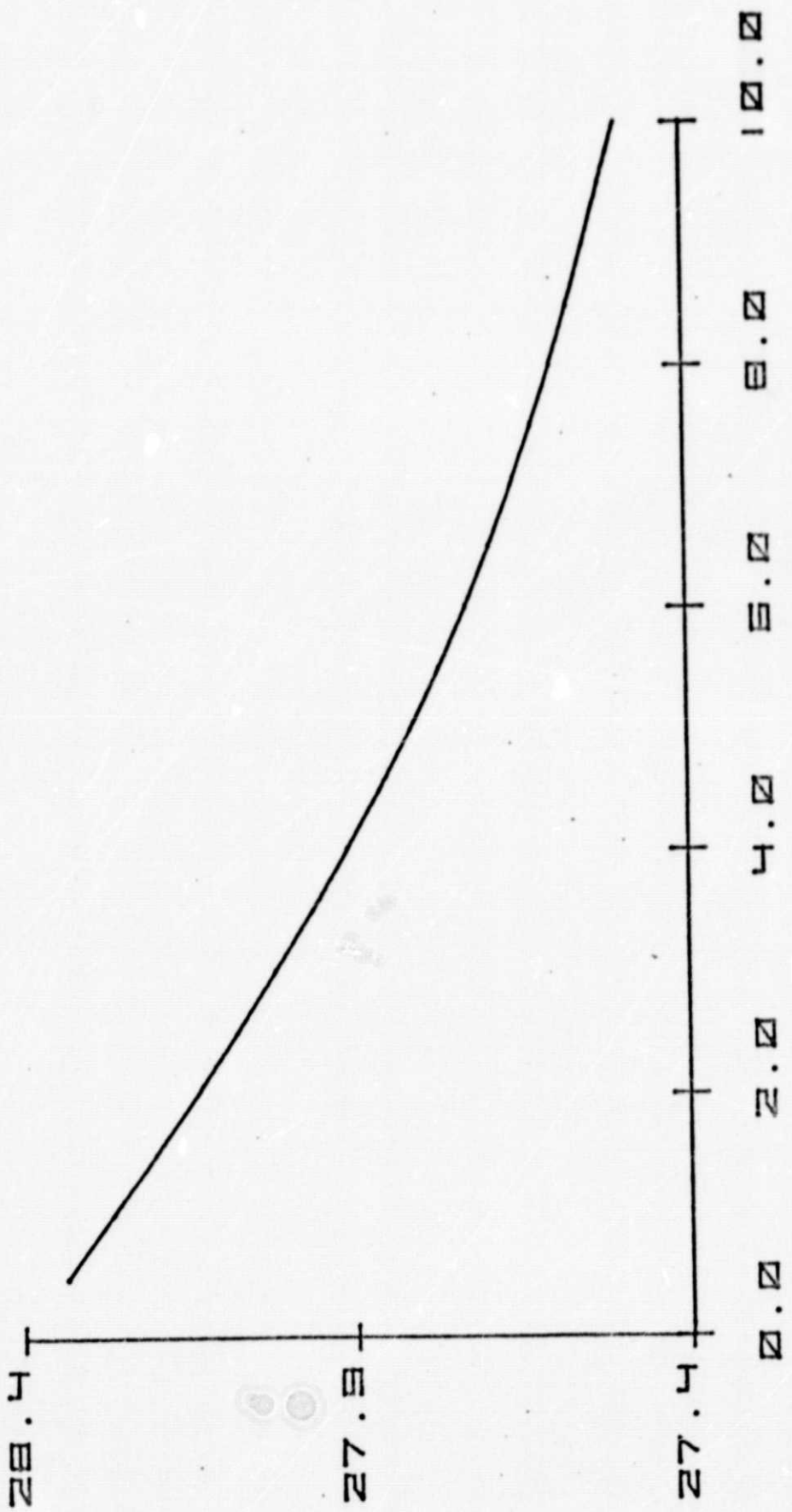


FIGURE 3: MINIMUM FUEL CELL VOLTAGE VS STEP LOAD CHANGE TO 12KW

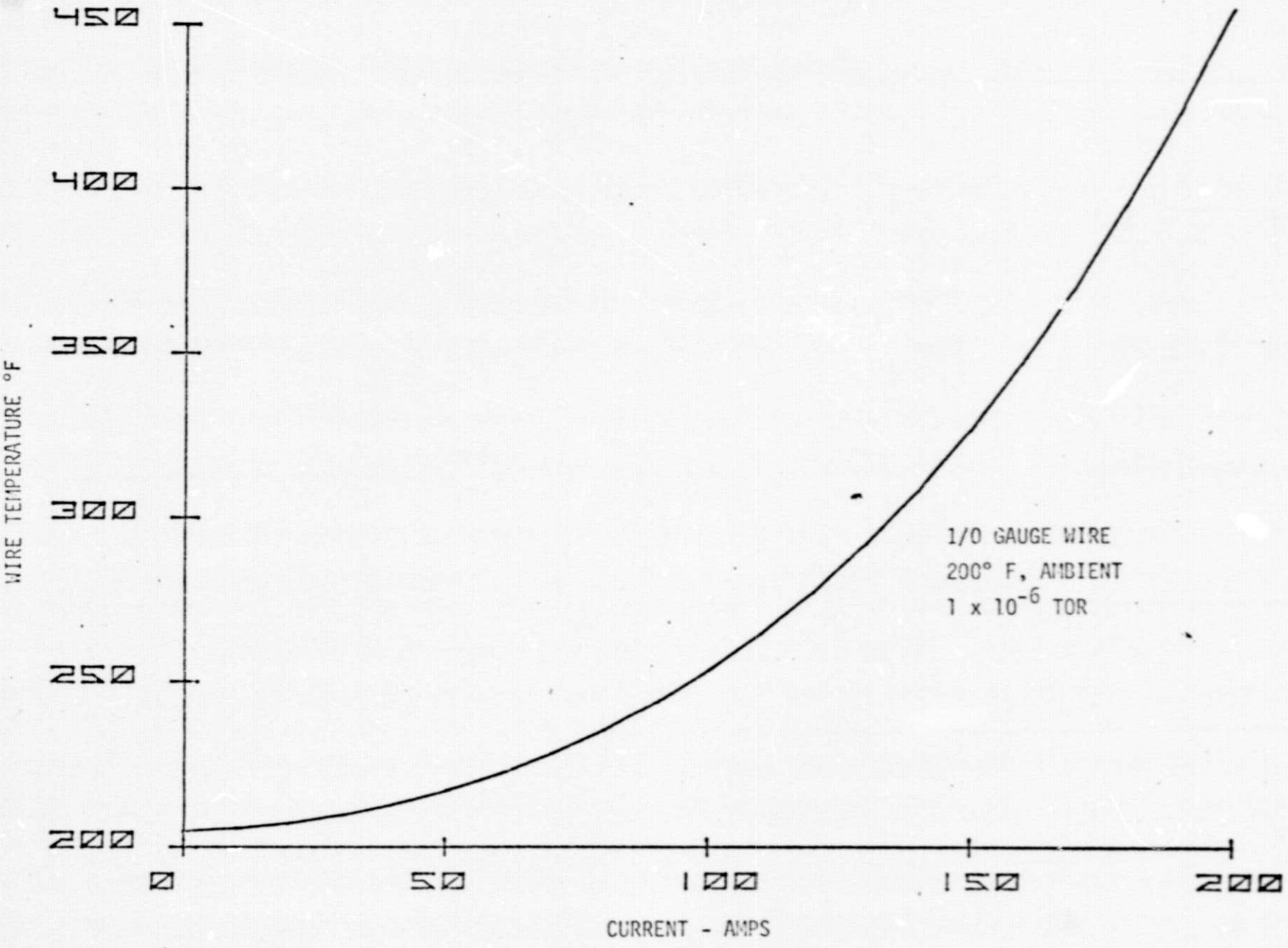


FIGURE 4: CURRENT VS STEADY TEMPERATURE

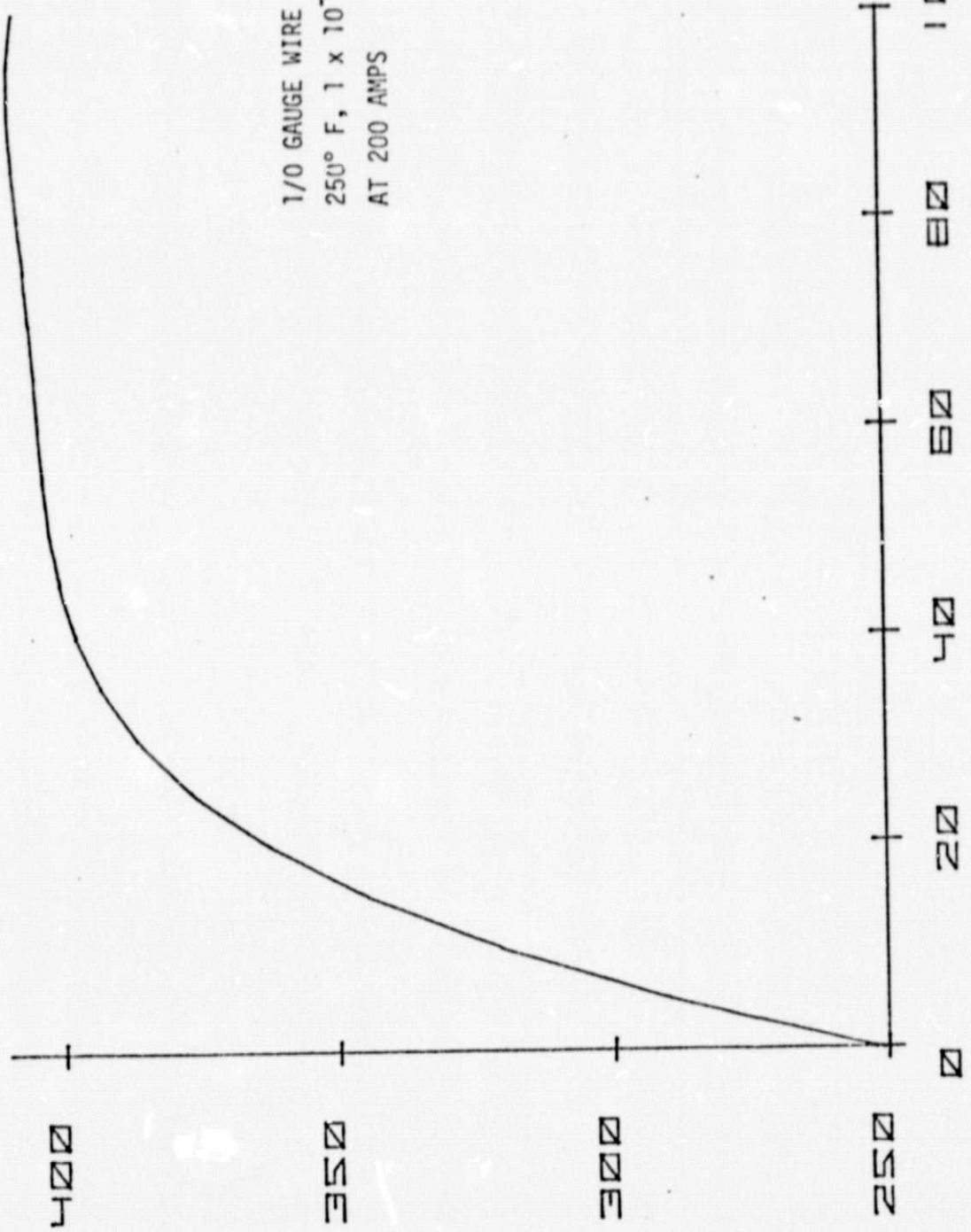


FIGURE 5: TEMPERATURE RISE TIME FOR 1/0 GAUGE WIRE CARRYING 200 AMPS

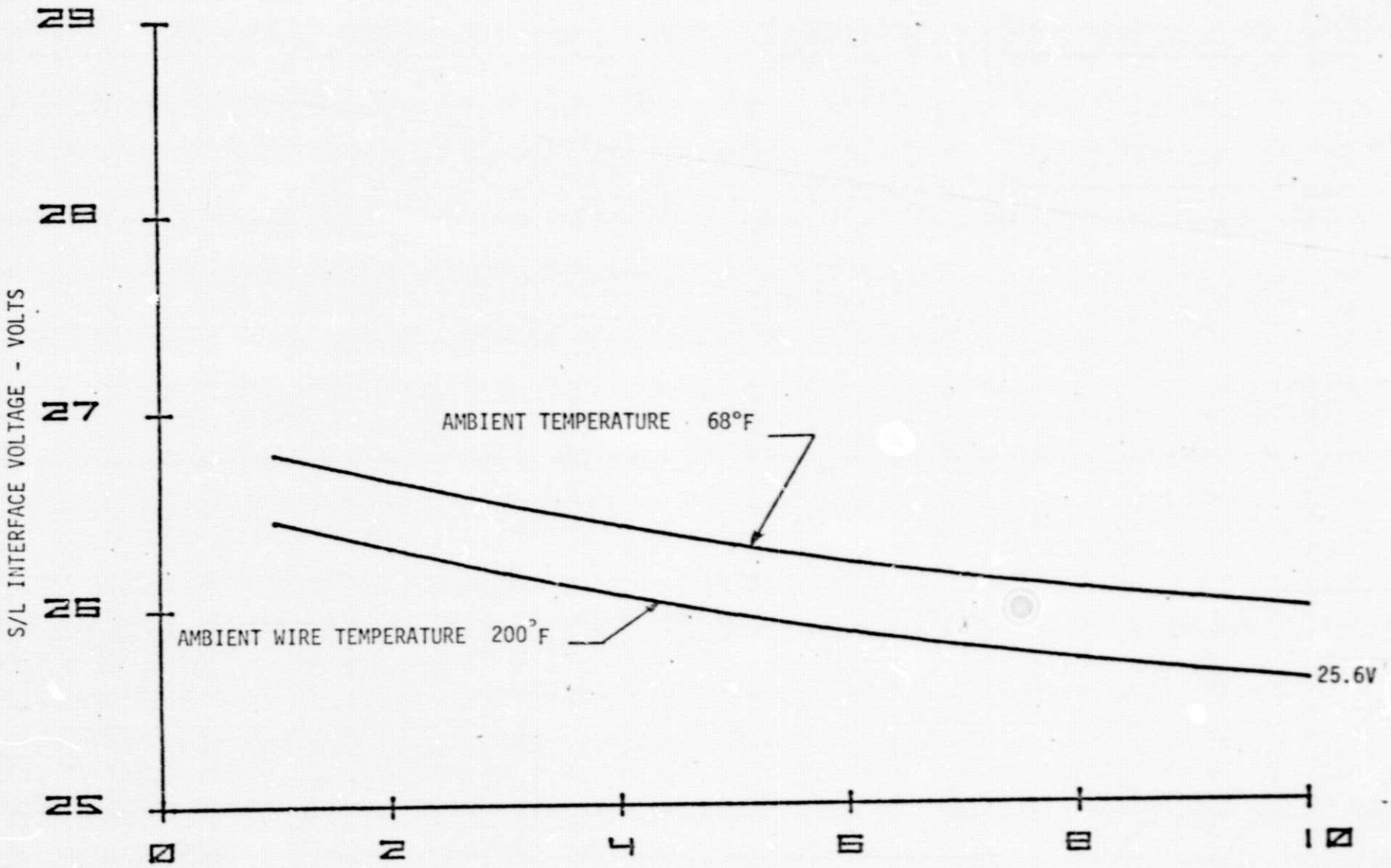


FIGURE 6: MINIMUM S/L INTERFACE VOLTAGE

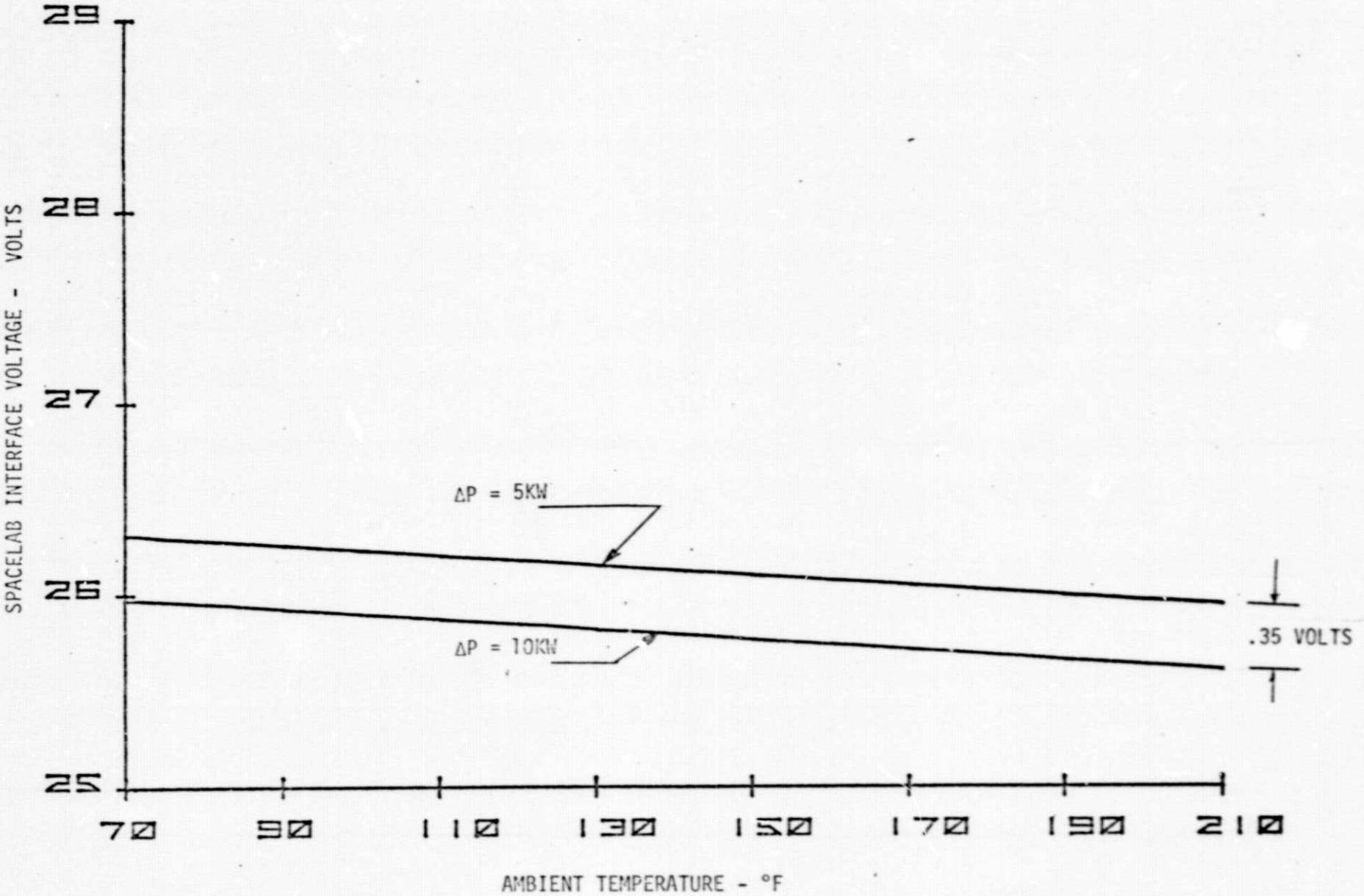


FIGURE 7: MINIMUM S/L INTERFACE VOLTAGE VS AMBIENT TEMPERATURE

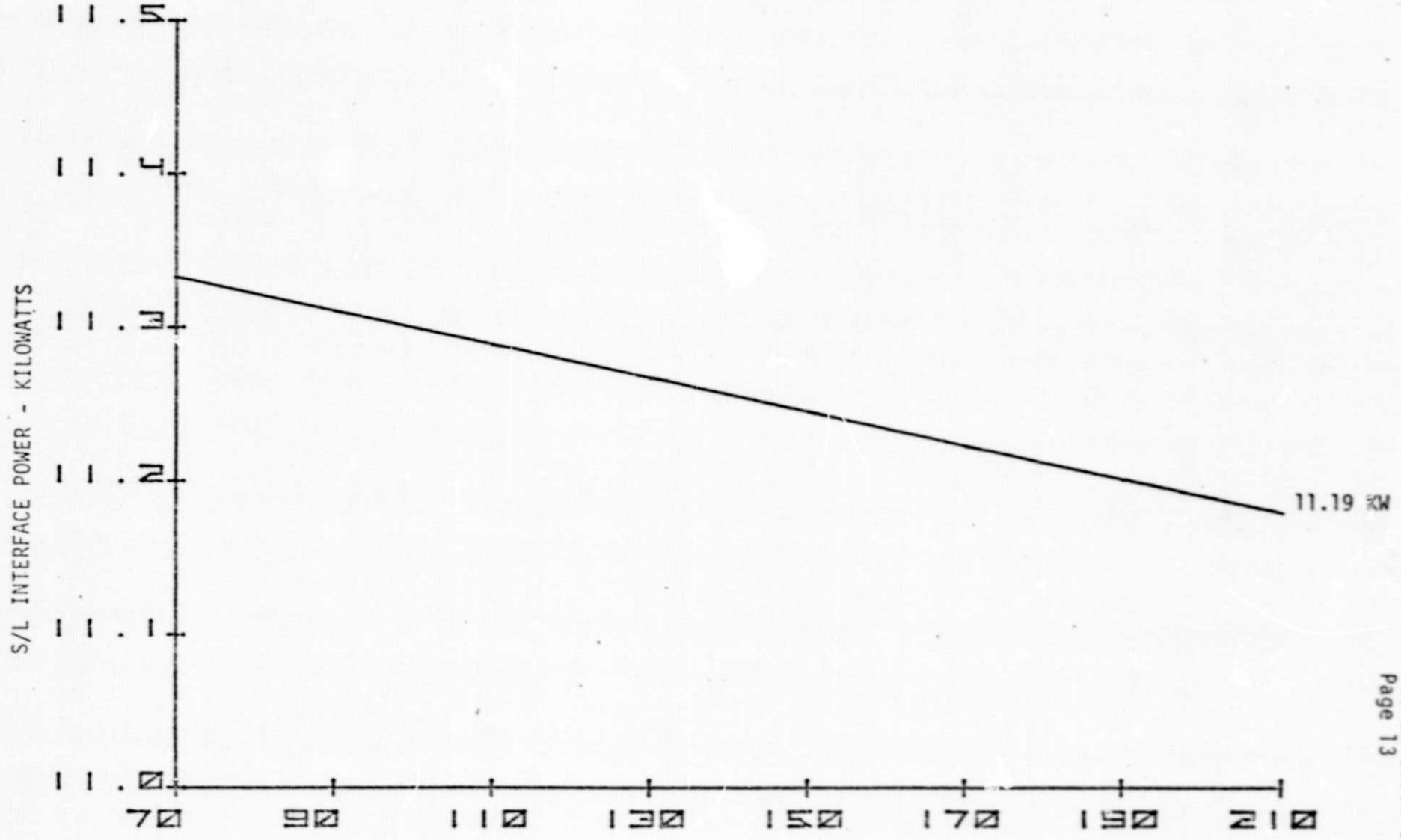


FIGURE 8: MAXIMUM USEFUL POWER TO S/L AT PEAK FUEL CELL OUTPUT

APPENDIX I

ORBITER TO SPACELAB ELECTRICAL POWER INTERFACE CALCULATIONS AND DATA

OBJECTIVES

- To define S/L interface voltage as a function of a change in load demand. This takes into account the effects of the fuel cell thermal transient characteristic.

- To determine the minimum useful power at the Orbiter/Spacelab interface.

Fuel Cell Terminal Voltage

- The following expression is obtained from construction and "curve fit" from the predicted Fuel Cell performance curves:

$$V_{FCmin} = 28.4 - .1307\ \Delta P + .00107\ \Delta P^2 + .001029\ \Delta P^3 - .0000516\ \Delta P^4$$

V_{FCmin} - Minimum fuel cell transient voltage at 12KW

ΔP - Step load change to 12KW

- The following expression defines the fuel cell terminal voltage as a function of time (thermal recovery to steady state in 7 min):

$$V_{FC} = V_{FC\ min} + \frac{(28.4 - V_{FC\ min})}{7}\ t$$

V_{FC} - Fuel cell terminal voltage

$V_{FC\ min}$ - Minimum fuel cell transient voltage at 12KW

t - Time in minutes (Limited to 7 minutes)

Fuel Cell Current

$$I_{FC} = 12000/V_{FC}$$

I_{FC} = Fuel Cell output current at 12KW

V_{FC} - Fuel Cell terminal voltage

Wire Resistance (From Figure 1)

R_T = Resistance of Thermally controlled segment, + resistance of 2 wire segment as a function of ambient temperature and temperature increase due to line current, + resistance of 4 wire segment as a function of ambient temperature and temperature increase due to line current.

$$R_T = [.481 + (.565 + 1.017)[1 + K (T_A + 6.5t - 68)] + 1.413 [1 + K(T_A = 3.25t - 68)]] \times 10^{-3}$$

R_T - Feeder Resistance

T_A - Ambient Temperature

t - Time in minutes (limited to 15 minutes at 12KW)

K - Temperature coefficient of resistance. (.002055 mΩ/°F)

This reduces to:

$$R_T = (3.058 + .00615\ T_A + .0164t)\ 10^{-3}$$

S/L Interface Voltage

$$V_{IF} = V_{FC} - I_{FC}\ R_T$$

V_{IF} - Spacelab Interface Voltage

V_{FC} - Fuel Cell terminal voltage

I_{FC} - Fuel Cell current

R_T - Feeder resistance

Interface Power

$$P_{IF} = 12000 - I_{FC}^{\ 2}\ R_T$$

P_{IF} - Power avaialble to Spacelab

I_{FC} - Fuel Cell current

R_T - Feeder resistance

Procedure

Given the step load change (Δ P) the above equations are solved for P_{IF} and V_{IF} for various values of ambient temperature. The resulting data is enclosed.

DELTA P 1, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.793	424.51	11374
1	26.805	424.22	11371
2	26.818	423.94	11369
3	26.831	423.66	11367
4	26.844	423.38	11365
5	26.857	423.10	11363
6	26.870	422.82	11361
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 2, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.658	426.43	11368
1	26.690	425.87	11367
2	26.722	425.31	11365
3	26.754	424.75	11364
4	26.786	424.19	11363
5	26.819	423.64	11361
6	26.851	423.09	11360
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 3, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.532	428.25	11362
1	26.582	427.43	11362
2	26.632	426.60	11361
3	26.682	425.78	11361
4	26.732	424.97	11360
5	26.782	424.15	11360
6	26.833	423.34	11359
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 4, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.417	429.93	11357
1	26.484	428.86	11358
2	26.550	427.79	11358
3	26.617	426.73	11358
4	26.683	425.67	11358
5	26.750	424.62	11358
6	26.816	423.58	11359
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 5, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.315	431.42	11353
1	26.396	430.13	11354
2	26.477	428.84	11355
3	26.558	427.57	11356
4	26.639	426.30	11356
5	26.721	425.04	11357
6	26.802	423.78	11358
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 6, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.227	432.72	11349
1	26.321	431.23	11351
2	26.415	429.76	11352
3	26.508	428.29	11353
4	26.602	426.84	11355
5	26.695	425.40	11356
6	26.789	423.96	11357
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 7, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.153	433.83	11346
1	26.257	432.18	11348
2	26.361	430.54	11350
3	26.465	428.92	11351
4	26.570	427.30	11353
5	26.674	425.70	11355
6	26.778	424.11	11357
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 8, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.089	434.78	11343
1	26.202	432.98	11345
2	26.316	431.21	11348
3	26.429	429.44	11350
4	26.542	427.70	11352
5	26.656	425.96	11354
6	26.769	424.24	11357
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 9, AMBIENT TEMPERATURE 68

TIME	VIF	IFC	PIF
0	26.033	435.61	11340
1	26.155	433.69	11343
2	26.276	431.79	11346
3	26.397	429.91	11348
4	26.519	428.04	11351
5	26.640	426.19	11354
6	26.761	424.35	11356
7	26.883	422.54	11359
8	26.876	422.54	11356
9	26.869	422.54	11353
10	26.862	422.54	11350
11	26.855	422.54	11347
12	26.848	422.54	11344
13	26.841	422.54	11341
14	26.834	422.54	11338
15	26.827	422.54	11335

DELTA P 1, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	26.448	424.51	11227
1	26.461	424.22	11225
2	26.474	423.94	11223
3	26.487	423.66	11222
4	26.500	423.38	11220
5	26.513	423.10	11218
6	26.527	422.82	11216
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 2, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	26.312	426.43	11220
1	26.345	425.87	11219
2	26.377	425.31	11218
3	26.410	424.75	11218
4	26.442	424.19	11217
5	26.475	423.64	11216
6	26.507	423.09	11215
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 3, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	26.185	428.25	11214
1	26.235	427.43	11214
2	26.286	426.60	11214
3	26.337	425.78	11214
4	26.387	424.97	11214
5	26.438	424.15	11214
6	26.489	423.34	11214
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 4, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	26.068	429.93	11207
1	26.136	428.86	11208
2	26.203	427.79	11209
3	26.270	426.73	11210
4	26.338	425.67	11211
5	26.405	424.62	11212
6	26.472	423.58	11213
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 5, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.965	431.42	11202
1	26.047	430.13	11204
2	26.129	428.84	11205
3	26.211	427.57	11207
4	26.293	426.30	11209
5	26.375	425.04	11211
6	26.458	423.78	11212
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 6, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.876	432.72	11197
1	25.971	431.23	11200
2	26.066	429.76	11202
3	26.160	428.29	11204
4	26.255	426.84	11207
5	26.350	425.40	11209
6	26.445	423.96	11212
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 7, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.800	433.83	11193
1	25.906	432.18	11196
2	26.012	430.54	11199
3	26.117	428.92	11202
4	26.223	427.30	11205
5	26.328	425.70	11208
6	26.434	424.11	11211
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 8, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.736	434.78	11189
1	25.851	432.98	11193
2	25.966	431.21	11197
3	26.080	429.44	11200
4	26.195	427.70	11204
5	26.310	425.96	11207
6	26.425	424.24	11211
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 9, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.680	435.61	11186
1	25.803	433.69	11190
2	25.925	431.79	11194
3	26.048	429.91	11198
4	26.171	428.04	11202
5	26.294	426.19	11206
6	26.417	424.35	11210
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 10, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.627	436.40	11183
1	25.757	434.36	11188
2	25.888	432.34	11192
3	26.018	430.35	11197
4	26.148	428.37	11201
5	26.279	426.40	11205
6	26.409	424.46	11210
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 5, AMBIENT TEMPERATURE 70

TIME	VIF	IFC	PIF
0	26.310	431.42	11351
1	26.391	430.13	11352
2	26.472	428.84	11352
3	26.553	427.57	11353
4	26.634	426.30	11354
5	26.715	425.04	11355
6	26.796	423.78	11356
7	26.877	422.54	11357
8	26.871	422.54	11354
9	26.864	422.54	11351
10	26.857	422.54	11348
11	26.850	422.54	11345
12	26.843	422.54	11342
13	26.836	422.54	11339
14	26.829	422.54	11336
15	26.822	422.54	11333

DELTA P 5, AMBIENT TEMPERATURE 80

TIME	VIF	IFC	PIF
0	26.284	431.42	11339
1	26.365	430.13	11340
2	26.446	428.84	11341
3	26.527	427.57	11342
4	26.608	426.30	11343
5	26.689	425.04	11344
6	26.770	423.78	11345
7	26.851	422.54	11346
8	26.845	422.54	11343
9	26.838	422.54	11340
10	26.831	422.54	11337
11	26.824	422.54	11334
12	26.817	422.54	11331
13	26.810	422.54	11328
14	26.802	422.54	11325
15	26.796	422.54	11322

DELTA P 5, AMBIENT TEMPERATURE 100

TIME	VIF	IFC	PIF
0	26.231	431.42	11316
1	26.312	430.13	11317
2	26.393	428.84	11318
3	26.474	427.57	11320
4	26.556	426.30	11321
5	26.637	425.04	11322
6	26.718	423.78	11323
7	26.799	422.54	11324
8	26.793	422.54	11321
9	26.786	422.54	11318
10	26.779	422.54	11315
11	26.772	422.54	11312
12	26.765	422.54	11309
13	26.758	422.54	11306
14	26.751	422.54	11303
15	26.744	422.54	11300

DELTA P 5, AMBIENT TEMPERATURE 120

TIME	VIF	IFC	PIF
0	26.177	431.42	11293
1	26.259	430.13	11295
2	26.340	428.84	11296
3	26.422	427.57	11297
4	26.503	426.30	11298
5	26.585	425.04	11299
6	26.666	423.78	11301
7	26.748	422.54	11302
8	26.741	422.54	11299
9	26.734	422.54	11296
10	26.727	422.54	11293
11	26.720	422.54	11290
12	26.713	422.54	11287
13	26.706	422.54	11284
14	26.699	422.54	11281
15	26.692	422.54	11278

DELTA P 5, AMBIENT TEMPERATURE 140

TIME	VIF	IFC	PIF
0	26.124	431.42	11271
1	26.206	430.13	11272
2	26.288	428.84	11273
3	26.369	427.57	11275
4	26.451	426.30	11276
5	26.532	425.04	11277
6	26.614	423.78	11278
7	26.696	422.54	11280
8	26.689	422.54	11277
9	26.682	422.54	11274
10	26.675	422.54	11271
11	26.668	422.54	11268
12	26.661	422.54	11265
13	26.654	422.54	11262
14	26.647	422.54	11259
15	26.640	422.54	11256

DELTA P 5, AMBIENT TEMPERATURE 160

TIME	VIF	IFC	PIF
0	26.071	431.42	11248
1	26.153	430.13	11249
2	26.235	428.84	11251
3	26.317	427.57	11252
4	26.398	426.30	11254
5	26.480	425.04	11255
6	26.562	423.78	11256
7	26.644	422.54	11258
8	26.637	422.54	11255
9	26.630	422.54	11252
10	26.623	422.54	11249
11	26.616	422.54	11246
12	26.609	422.54	11243
13	26.602	422.54	11240
14	26.595	422.54	11237
15	26.588	422.54	11234

DELTA P 5, AMBIENT TEMPERATURE 180

TIME	VIF	IFC	PIF
0	26.018	431.42	11225
1	26.100	430.13	11226
2	26.182	428.84	11228
3	26.264	427.57	11230
4	26.346	426.30	11231
5	26.428	425.04	11233
6	26.510	423.78	11234
7	26.592	422.54	11236
8	26.585	422.54	11233
9	26.578	422.54	11230
10	26.571	422.54	11227
11	26.564	422.54	11224
12	26.557	422.54	11221
13	26.550	422.54	11218
14	26.543	422.54	11215
15	26.536	422.54	11212

DELTA P 5, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.965	431.42	11202
1	26.047	430.13	11204
2	26.129	428.84	11205
3	26.211	427.57	11207
4	26.293	426.30	11209
5	26.375	425.04	11211
6	26.458	423.78	11212
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 10, AMBIENT TEMPERATURE 180

TIME	VIF	IFC	PIF
0	25.680	436.40	11207
1	25.811	434.36	11211
2	25.941	432.34	11215
3	26.071	430.35	11220
4	26.201	428.37	11224
5	26.331	426.40	11228
6	26.461	424.46	11232
7	26.592	422.54	11236
8	26.585	422.54	11233
9	26.578	422.54	11230
10	26.571	422.54	11227
11	26.564	422.54	11224
12	26.557	422.54	11221
13	26.550	422.54	11218
14	26.543	422.54	11215
15	26.536	422.54	11212

DELTA P 10, AMBIENT TEMPERATURE 200

TIME	VIF	IFC	PIF
0	25.627	436.40	11183
1	25.757	434.36	11188
2	25.888	432.34	11192
3	26.018	430.35	11197
4	26.148	428.37	11201
5	26.279	426.40	11205
6	26.409	424.46	11210
7	26.540	422.54	11214
8	26.533	422.54	11211
9	26.526	422.54	11208
10	26.519	422.54	11205
11	26.512	422.54	11202
12	26.505	422.54	11199
13	26.498	422.54	11196
14	26.491	422.54	11193
15	26.484	422.54	11190

DELTA P 10, AMBIENT TEMPERATURE 120

TIME	VIF	IFC	PIF
0	25.841	436.40	11277
1	25.971	434.36	11281
2	26.100	432.34	11284
3	26.230	430.35	11288
4	26.359	428.37	11291
5	26.489	426.40	11295
6	26.618	424.46	11298
7	26.748	422.54	11302
8	26.741	422.54	11299
9	26.734	422.54	11296
10	26.727	422.54	11293
11	26.720	422.54	11290
12	26.713	422.54	11287
13	26.706	422.54	11284
14	26.699	422.54	11281
15	26.692	422.54	11278

DELTA P 10, AMBIENT TEMPERATURE 140

TIME	VIF	IFC	PIF
0	25.788	436.40	11254
1	25.917	434.36	11258
2	26.047	432.34	11261
3	26.177	430.35	11265
4	26.307	428.37	11269
5	26.436	426.40	11273
6	26.566	424.46	11276
7	26.696	422.54	11280
8	26.689	422.54	11277
9	26.682	422.54	11274
10	26.675	422.54	11271
11	26.668	422.54	11268
12	26.661	422.54	11265
13	26.654	422.54	11262
14	26.647	422.54	11259
15	26.640	422.54	11256

DELTA P 10, AMBIENT TEMPERATURE 160

TIME	VIF	IFC	PIF
0	25.734	436.40	11230
1	25.864	434.36	11234
2	25.994	432.34	11239
3	26.124	430.35	11242
4	26.254	428.37	11246
5	26.384	426.40	11250
6	26.514	424.46	11254
7	26.644	422.54	11258
8	26.637	422.54	11255
9	26.630	422.54	11252
10	26.623	422.54	11249
11	26.616	422.54	11246
12	26.609	422.54	11243
13	26.602	422.54	11240
14	26.595	422.54	11237
15	26.588	422.54	11234

DELTA P 10, AMBIENT TEMPERATURE 70

TIME	VIF	IFC	PIF
0	25.976	436.40	11336
1	26.104	434.36	11339
2	26.233	432.34	11342
3	26.362	430.35	11345
4	26.491	428.37	11348
5	26.620	426.40	11351
6	26.749	424.46	11354
7	26.877	422.54	11357
8	26.871	422.54	11354
9	26.864	422.54	11351
10	26.857	422.54	11348
11	26.850	422.54	11345
12	26.843	422.54	11342
13	26.836	422.54	11339
14	26.829	422.54	11336
15	26.822	422.54	11333

DELTA P 10, AMBIENT TEMPERATURE 80

TIME	VIF	IFC	PIF
0	25.949	436.40	11324
1	26.078	434.36	11327
2	26.207	432.34	11330
3	26.336	430.35	11333
4	26.465	428.37	11337
5	26.594	426.40	11340
6	26.723	424.46	11343
7	26.851	422.54	11346
8	26.845	422.54	11343
9	26.838	422.54	11340
10	26.831	422.54	11337
11	26.824	422.54	11334
12	26.817	422.54	11331
13	26.810	422.54	11328
14	26.803	422.54	11325
15	26.796	422.54	11322

DELTA P 10, AMBIENT TEMPERATURE 100

TIME	VIF	IFC	PIF
0	25.895	436.40	11301
1	26.024	434.36	11304
2	26.154	432.34	11307
3	26.283	430.35	11311
4	26.412	428.37	11314
5	26.541	426.40	11317
6	26.670	424.46	11321
7	26.799	422.54	11324
8	26.793	422.54	11321
9	26.786	422.54	11318
10	26.779	422.54	11315
11	26.772	422.54	11312
12	26.765	422.54	11309
13	26.758	422.54	11306
14	26.751	422.54	11303
15	26.744	422.54	11300