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POST FLIGHT EVALUATION OF ELECTRONIC CIRCUITRY PERFORMANCE

William B. Huber

TRI-CON ASSOCIATES, INC.
765 Concord Avenue
Cambridge, Massachusetts 02138

June 30, 1976

Final Report
Period covered 1 October 1975 to 30 June 1976

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Hot Filament Gauge Satellite Density Payloads

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

To provide support service as required at the prelaunch, launch, assembly or operational area in support of satellite density payloads and provide post flight diagnostic and evaluation of electronic circuit performance.

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1. OBJECTIVE OF CONTRACT

The objective of this contract was to provide support service as required at the prelaunch, launch, assembly or operational area in support of satellite density payloads and provide post flight diagnostic and evaluation of electronic circuit performance.

2. DESCRIPTION OF WORK PERFORMED

There was no required support service during the prelaunch, launch, assembly or operational area for the density payloads. However, when an anomaly in flight data for the hot filament ionization gauge on the S3-2 satellite appeared, the contract monitor requested a detailed analysis of data printouts in order to diagnose the anomaly and evaluate the electronic circuit performance.

2.1 Anomaly in Flight Data

Review of early flight data indicated the following:

(1) Prior to revolution Number 25 the hot filament ionization gauge appeared to be working satisfactorily. The probe emission monitor indicated that the filament emission regulator loop bias controlling the emission to 1.1×10^{-7} amperes. There was correlation between pressure data measured in both the hot filament and the cold cathode ionization gauges.

(2) By revolution Number 52 the emission regulator of the hot filament ionization gauge was out of regulation as evidenced by low and varying probe current value as well as by a low pressure measurement compared to that measured by the cold cathode ionization gauge.

2.2 Analysis of Design of Hot Filament Ionization Gauge Circuits.

The filament emission control loop and monitor circuit was analyzed to determine operation limits and failure modes. The following was determined from the analysis:

(1) The probe electrometer which sampled approximately ten percent of the filament emission was operated at +49.5 volts with respect to ground and the gain to its output was $-3X10^{7}$ volts/ ampere.

(2) The telemetry emission current monitor amplifier offset the electrometer amplifier to ground level and had a gain of -1.0 volts/volt. The transfer characteristic of the probe current input to telemetry amplifier output was:

$$E_{TLM} = -3.0X10^{7}\ I_p + 5.3 \text{ volts}$$

or

$$I_p = \frac{(5.3 - E_{TLM})X10^{-7}}{3} \text{ amps.}$$

The monitor output at zero probe current input was +5.3 volts or 0.3 volts above the PCM encoder limit. At $-1.1X10^{-7}$ amperes of probe current the monitor output was at +2.0 volts.

(3) The gain from the electrometer output to the filament regulator output amplifier was -6.8 volts/volt.

(4) Review of development test data showed that nominal filament voltage for a probe current of $1.1X10^{-7}$ amperes was 3.0 volts. Maximum filament circuit voltage available was set at approximately 3.7 volts in order to prevent burn-out. The filament power source contained no active current limiter. In order to drive the filament regulator output 0.7 to limit from nominal, it would require but 0.1 volts at the output of the electrometer or about four percent of the nominal probe current of $1.1X10^{-7}$ amperes.

(5) The electrometer amplifier contained a thirty second time constant in its feedback element in order to stablize the control loop which contained the long thermal time constant of the filament. Unfortunately this time constant, therefore, appeared in the probe current monitor.

(6) The filament voltage was reduced to zero for five seconds out of approximately every 320 seconds by means of an electronic timer. This function was

accomplished after the long time constant of the electrometer. Therefore, the filament shut-down was instantaneous with only the thermal time constant of the filament assembly. The turn on time constant should have been faster in that the voltage applied to the filament was 3.7 volts until the loop started to control, at which point the filament voltage went to a nominal 3.0 volts.

2.3 Analysis of Flight Data

Printouts were made available for data analysis from launch to revolution Number 52. Early data (up to and including revolution Number 24) indicated that the emission regulator was working normally. The telemetry monitor was constant at 1.9 to 2.0 volts (about $1.1X10^{-7}$ amperes). During this early period the data was scanned to find a filament off mode of operation. One was discovered in the data for revolution Number 24. Unfortunately, this data was real time data and the emission monitor was read out only once per eight seconds. For three successive readouts the monitor read 2.0, 2.4, and 2.0 volts. This is reasonable because of the thirty second time constant.

Figure 1 is a plot of expected waveforms in the filament circuit. Waveform **A** shows that during the filament off interval the power is removed from the filament for five seconds.

When turned back on the voltage goes to the limit level of 3.7 volts until the control loop settles out. This is estimated to be about two seconds since the filament is not completely cold.

Waveform B shows the probable probe current. Even though the filament power is removed the probe current does not drop to zero immediately because of the thermal time constant of the filament assembly. The response of the probe is much faster when the filament is turned on because of the saturated heater voltage of 3.7 volts until the control loop stabilizes. Waveform C shows the probable resulting telemetry monitor signal for probe current. During the filament off interval the monitor signal can rise to the zero probe current level of 5.3 volts only at a rate determined by the thirty second time constant in the electrometer and the thermal time constant of the filament.

Assuming that the thermal time constant of the filament is insignificant compared to thirty seconds, in five seconds the monitor will rise to 2.51 volts from 2.0 volts on its way to 5.3 volts. ($E_{TLM} = 5.3 - 3.3\ E^{-t/30}$). When the filament off signal is removed the signal returns to the control loop value of 2.0 volts rapidly due to the saturated heater voltage of 3.7 volts.

Between revolution Number 24 and revolution Number 52 there was no data for analysis. During revolution Number 52 the filament control circuit was malfunctioning. The emission monitor voltage varied from about 4.1 volts to about 3.2 volts, indicating emission current values of $4X10^{-8}$ amps to $7X10^{-8}$ amps. At no time during the twenty-four minutes of data reviewed did the emission monitor reach the control value of $1.1X10^{-7}$ ampere or 2.0 volts output. The heater voltage at the output of the regulator circuit should have been at saturation at these low emission current levels.

On revolution Number 57, at spacecraft time 70760, there was a filament turn off as indicated by the filament flag monitor. The probe emission monitor did not change significantly indicating no change in filament emission. The emission monitor at this time read 3.6 volts or $5.8X10^{-8}$ amperes. This seems to indicate that the filament regulator or the filament itself was open and somehow the cold filament emitted at the levels 4 to $7X10^{-8}$ amperes.

There were no other filament off indications in subsequent data reviewed out to revolution Number 500.

A review of the hot filament ionization gauge data during revolution Number 52 was made in detail in order to determine whether or

not there was correlation between probe emission current readings and pressure readings from the automatic range switching gauge electrometer.

The gauge electrometer on range one had a full scale input value of $5X10^{-10}$ amperes. Thus, the gain in range one was $1X10^{10}$ volts/ampere. There were four ranges with automatic range switching with adjacent range gain ratios of ten. The thresholds for range change were set at full scale (+5 volts at the telemetry output) and 6 percent full scale (0.3 volts at the telemetry output). The electrometer employed low power electrometer tubes rather than semiconductors in the input stage in order to protect against high voltage discharges in the density gauge. Because the drift of tubes is one to two orders of magnitude greater than semiconductors, an automatic zero adjust was incorporated in the electrometer. This adjustment was commanded by a timer within the instrument such that it occurred approximately once per minute with a duration of 100 milliseconds. The telemetry indication of zero adjustment was: the range information staircase went to zero volts, and the gauge electrometer output went to near zero volts (equivalent zero drift of the electrometer referred to the input). No positive zero adjustment indication was found in the twenty-four minutes of data for revolution Number 52.

Table 1 lists emission peak monitor output versus spacecraft time with notes on gauge electrometer output. During the first half of the data run there are electrometer peak currents which occur at the same rate as the vehicle spin rate (about one every twenty seconds. This peak is approximately 1.1 volts output on range 2 of the electrometer (equivalent to $1.1X10^{-9}$ amperes at the gauge output). The width of the peak is about two seconds (as measured at $1.0X10^{-10}$ amperes).

The emission monitor during this time averaged 3.8 volts or $5X10^{-7}$ amperes.

A second broad peak appears at 635 seconds after turn on. This peak is approximately midway in time between the original narrow peak. The broad peak averages about six seconds as measured at $1X10^{-10}$ amperes, but its amplitude starts at $1.4X10^{-10}$ amperes and goes to a maximum of $8.4X10^{-10}$ amperes at 937 seconds after turn on. During the second half of the twenty four minute data interval, the narrow peak decreased to a minimum of $4.9X10^{-10}$ amperes at 1112 seconds after turn on and then abruptly disappears.

The emission current monitor apparently fluctuates with the wide gauge electrometer peak. Emission monitor levels are maximum (minimum emission) at the broad peaks and minimum half-way between broad peaks.

2.4 Evaluation of Circuit Performance From Data Review

Sometime between revolution Number 24 and revolution Number 52 the filament assembly or power supply failed such that the filament emission dropped in amplitude and the control loop opened up. The gauge still responded with much decreased sensitivity as evidenced by the variation in gauge electrometer output with vehicle spin rate.

It is doubtful that an open filament circuit or cold filament would produce sufficient emission to account for a probe current approximately one-half that of a hot filament. It is more probable that the emission voltage regulator failed in a peculiar mode that produced something less than nominal filament voltage of 3.0 volts, or the filament surface became poisoned in the presence of some material outgassed by the space vehicle. The filament turn off in revolution Number 57 showed no change in emission current. This indicated that either the filament is open and emitting in the region of $5X10^{-8}$ amperes or the electronic malfunction includes the filament off circuit.

TABLE I

Revolution #52 Emission versus Time and Notes on Gauge Electrometer Current

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
38843.423	0 Seconds	5.1 V	Turn On
54.423	11 "	5.0 V	
	14 "	4.9	
58.423	15 "	4.86	
63.423	20 "	4.72	
68.424	25 "	4.60	
73.424	30 "	4.50	
78.424	35 "	4.40	
79.924			Peak Pressure 1.1 V-Range 2 ($1.1X10^{-9}$ amp)
83.424	40 "	4.32	
88.424	45 "	4.28	
93.424	50 "	4.22	
98.424	55 "	4.14	
99.674			Peak Pressure 1.1V-Range 2
38903.424	60 "	4.10	
08.424	65 "	4.08	
13.424	70 "	4.06	
18.424	75 "	4.00	
19.174			Peak Pressure 1.1V-Range 2
23.424	80 "	3.93	
28.425	85 "	3.98	
33.425	90 "	3.98	
38.425	95 "	3.92	
38.675			Peak Pressure 1.1V-Range 2

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
43.425	100 Seconds	3.92	
48.425	105 "	3.92	
53.425	110 "	3.90	
58.425	115 "	3.88	Peak Pressure 1.1V-Range 2
63.425	120 "	3.88	
68	125 "	3.88	
73	130 "	3.88	
77.925			Peak Pressure 1.1V-Range 2
78.425	135 "	3.84	
83.425	140 "	3.86	
88	145 "	3.86	
93	150 "	3.84	
38997.676			Peak Pressure 1.1V-Range 2
98.426	155 "	3.82	
39003.426	160 "	3.84	
8	165 "	3.84	
13	170 "	3.82	
17.176			Peak Pressure 1.1V-Range 2
18.426	175 "	3.80	
23	180 "	3.82	
28	185 "	3.84	
33	190 "	3.80	
35.576			Peak Pressure 1.1V-Range 2
38	195 "	3.80	
43	200 "	3.82	
48	205 "	3.82	
53.427	210 "	3.80	
56.427			Peak Pressure 1.08V-Range 2
58	215 "	3.80	
63.427	220 "	3.82	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
68	225 Seconds	3.82	
73	230 "	3.78	
76.177			Peak Pressure 1.16V-Range 2
78	235 "	3.78	
83	240 "	3.80	
88	245 "	3.82	
93	250 "	3.78	
95.677			Peak Pressure 1.08V-Range 2
98.427	255 "	3.78	
103	260 "	3.80	
108.428	265 "	3.80	
113	270 "	3.76	
115.178			Peak Pressure 1.1V-Range 2
118	275 "	3.78	
123	280 "	3.80	
128	285 "	3.80	
133	290 "	3.76	
134.678			Peak Pressure 1.08V-Range 2
138	295 "	3.78	
143	300 "	3.80	
148.428	305 "	3.78	
150.488		3.80	
151		3.82	
152		3.86	
153	310 "	3.88	
154		3.92	Peak Pressure 1.1V-Range 2
155		3.94	
156		3.94	
157		3.94	
158	315 "	3.94	
159		3.94	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
163.428	320 Seconds	3.94	
168	325 "	3.92	
173.429	330 "	3.88	
173.929			Peak Pressure 1.08V-Range 2
178	335 "	3.88	
183	340 "	3.88	
188		3.84	
193	350 "	3.82	Peak Pressure 1.08V-Range 2
198	355 "	3.82	
203	360 "	3.84	
208	365 "	3.82	
213.179			Peak Pressure 1.08V-Range 2
213.429	370 "	3.80	
218	375 "	3.80	
39223.429	380 "	3.82	
228	385 "	3.80	
232.580			Peak Pressure 1.08V-Range 2
39233.430	390 "	3.78	
238	395 "	3.80	
243	400 "	3.82	
248	405 "	3.78	
252.430		3.76	Peak Pressure 1.08V-Range 2
253	410 "	3.76	
258	415 "	3.80	
263	420 "	3.80	
268	425 "	3.76	
271.930		3.76	Peak Pressure 1.08V-Range 2
273	430 "	3.76	
278	435 "	3.78	
283	440 "	3.80	
288.430	445 "	3.76	
291.581		3.76	Peak Pressure 1.08V-Range 2
293	450 "	3.76	
298	455 "	3.78	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
303	460 Seconds	3.80	
308.431	465 "	3.76	
311.181		3.74	Peak Pressure 1.08V-Range 2
313	470 "	3.76	
318	475 "	3.78	
323	480 "	3.78	
328	485 "	3.74	
330.931			Peak Pressure 1.08V-Range 2
333.431	490 "	3.76	
338	455 "	3.78	
343.431	500 "	3.78	
348.431	505 "	3.74	
350.431		3.74	Peak Pressure 1.08V-Range 2
353.432	510 "	3.78	
358	515 "	3.78	
363	520 "	3.76	
368.432	525 "	3.74	
369.932			Peak Pressure 1.08V-Range 2
373	530 "	3.76	
378	535 "	3.80	
383	540 "	3.76	
388	545 "	3.74	
389.682		3.74	Peak Pressure 1.08V-Range 2
393	550 "	3.76	
398	555 "	3.80	
403	560 "	3.78	
408	565 "	3.76	
409.182		3.76	Peak Pressure 1.08V-Range 2
413.433	570 "	3.80	
418	575 "	3.80	
423	580 "	3.78	
428.433	585 "	3.78	
428.933			Peak Pressure 1.08V-Range 2

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
433	590 Seconds	3.80	
39438	595 "	3.84	
443	600 "	3.78	
448.433	605 "	3.78	Peak Pressure 1.08V-Range 2
453	610 "	3.82	
458	615 "	3.88	
39463.433	620 "	3.96	
467.183		3.94	Peak Pressure 1.06V-Range 2
468	625 "	3.94	
473	630 "	3.96	
478	635 "	3.96	
478.584			Broad Peak 1.38V-Range 1
483	640 "	3.90	
487.584		3.90	Peak Pressure 1.06V-Range 2
488.434	645 "	3.90	
493	650 "	3.92	
498	655 "	3.92	
503	660 "	3.86	
507.434			Peak Pressure 1.06V-Range 2
508	665 "	3.86	
513	670 "	3.88	
518	675 "	3.88	
523	680 "	3.82	
526.934		3.82	Peak Pressure 1.06V-Range 2
528	685 "	3.84	
533.435	690 "	3.88	
537.185			Broad Peak 2.36V-Range 1
538	695 "	3.86	
543	700 "	3.78	
546.435			Peak Pressure 1.06V-Range 2
548	705 "	3.80	
553	710 "	3.84	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
556.685		3.84	Broad Peak 2.82V-Range 1
558	715 Seconds	3.82	
39563.435	720 "	3.80	
39566.185		3.80	Peak Pressure 1.04V-Range 2
568	725 "	3.82	
573	730 "	3.84	
575.185		3.86	Broad Peak 3.18V-Range 1
578	735 "	3.84	
583	740 "	3.80	
585.585		3.82	Peak Pressure 1.04V-Range 2
588.435	745 "	3.86	
593	750 "	3.86	
595.686		3.86	Broad Peak 3.76V-Range 1
598.436	755 "	3.84	
603	760 "	3.82	
605.436		3.82	Peak Pressure 1.04V-Range 2
608	765 "	3.84	
613	770 "	3.86	
615.186		3.86	Broad Peak 4.46V-Range 1
618	775 "	3.84	
623	780 "	3.80	
624.936		3.80	Peak Pressure 1.04V-Range 2
628	785 "	3.84	
633	790 "	3.86	
39634.686		3.84	Broad Peak .52V-Range 2
638	795 "	3.80	
643	800 "	3.78	
644.686		3.80	Peak Pressure 1.02V-Range 2
648	805 "	3.82	
653	810 "	3.84	
654.187		3.84	Broad Peak .58V-Range 2

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
39658.437	815 Seconds	3.78	
663	820 "	3.78	
664.187		3.78	Peak Pressure 1.02V-Range 2
668	825 "	3.80	
673	830 "	3.82	
39674.687		3.82	Broad Peak .56V-Range 2
678	835 "	3.76	
683	840 "	3.78	
683.687		3.78	Peak Pressure 1.00V-Range 2
688	845 "	3.80	
694.187	850 "	3.84	Broad Peak .60V-Range 2
698.437	855 "	3.74	
39703	860 "	3.76	Peak Pressure .98V-Range 2
708	865 "	3.78	
712.937		3.80	Broad Peak .74V-Range 2
713	870 "	3.82	
718	875 "	3.72	
723.188		3.74	Peak Pressure .96V-Range 2
723.438	880 "	3.76	
728	885 "	3.78	
732.438		3.78	Broad Peak .78V-Range 2
733	890 "	3.78	
738.438	895 "	3.64	
742.588		3.66	Peak Pressure .94V-Range 2
743	900 "	3.68	
748	905 "	3.70	
751.938		3.68	Broad Peak .86V-Range 2
39753.438	910 "	3.62	
758	915 "	3.52	
762.188		3.66	Peak Pressure .92V-Range 2 (Peak Getting Broader(2 Sec. wide)

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
763	920 Seconds	3.58	
768	925 "	3.70	
771.688		3.80	Broad Peak .72V-Range 2 (3 Sec. Wide)
773	930 "	3.74	
778.439	935 "	3.68	
781.939		3.72	Peak Pressure .90V-Range 2 (2 Sec. Wide)
783	940 "	3.74	
788	945 "	3.76	
790.931		3.76	Broad Peak .84V-Range 2 (6 Sec. Wide)
793	950 "	3.72	
798	955 "	3.70	
39801.439		3.72	Peak Pressure .86V-Range 2
803	960 "	3.74	
808	965 "	3.76	
810.689		3.78	Broad Peak .80V-Range 2 (7 Sec. Wide)
813	970 "	3.72	
818	975 "	3.72	
821.939		3.74	Peak Pressure .82V-Range 2 (3 Sec. Wide)
823	980 "	3.76	2 Seconds of Data Missing
828.689	985 +	3.76	
830.939		3.80	Broad Peak .68V-Range 2
833	990	3.74	
828.689	985 +	3.76	2 Seconds of Data Missing
830.939		3.80	Broad Peak .68V-Range 2
833	990 "	3.74	
838.440	995 "	3.76	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
39843.440	1000 Seconds	3.80	
848	1005 "	3.82	
849.690		3.82	Broad Peak .74V-Range 2 (6 Sec. Wide)
853	1010 "	3.72	
858	1015 "	3.74	
860.190		3.76	Peak Pressure .72V-Range 2 (2 Sec. Wide)
863	1020 "	3.76	
868	1025 "	3.80	
869.190		3.80	Broad Peak .66V-Range 2 (7 Sec. Wide)
873	1030 "	3.72	
878	1035 "	3.76	
879.940		3.78	Peak Pressure .68V-Range 2 (2 Sec. Wide)
883	1040 "	3.78	
888.440	1045 "	3.82	
888.690		3.82	Broad Peak .70V-Range 2 (6 Sec. Wide)
893	1050 "	3.78	
898.441	1055 "	3.82	
899.441	1056 "	3.82	Peak Pressure .64V-Range 2 (2 Sec. Wide)
903	1060 "	3.84	
908.191		3.86	Broad Peak .72V-Range 2 (6 Sec. Wide)
908.441	1065 "	3.86	
913.441	1070 "	3.84	
918	1075 "	3.86	
918.941		3.88	Peak Pressure .62V-Range 2 (2.5 Sec Wide)
923	1080 "	3.88	
927.691		3.92	Broad Peak .72V-Range 2 (6 Sec. Wide)
928	1085 "	3.92	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
39933.441	1090 Seconds	3.88	
938	1095 "	3.92	Peak Pressure .58V-Range 2 (2 Sec. Wide)
943	1100 "	3.94	
947.191		3.94	Broad Peak .74V-Range 2 (6.5 Sec. Wide)
948	1105 "	3.94	
953	1110 "	3.92	
958.192		3.96	Peak Pressure 4.90V-Range 1 (2 Sec. Wide)
958.442	1115 "	3.96	
963	1120 "	3.96	
966.942		3.98	Broad Peak .74V-Range 2 (6 Sec. Wide)
968	1125 "	3.98	
973	1130 "	3.96	Peak Missing
978	1135 "	3.98	
983	1140 "	4.00	
986.442		4.00	Broad Peak .72V-Range 2 (6.5 Sec. Wide)
988	1145 "	3.98	
993	1150 "	3.96	
998	1155 "	3.98	
40003.442	1160 "	3.98	
005.942		3.98	Broad Peak .78V-Range 2 (6 Sec. Wide)
008	1165 "	3.98	
013	1170 "	3.98	
018	1175 "	4.00	
023	1180 "	4.00	
025.193		4.00	Broad Peak .66V-Range 2 (6 Sec. Wide)
028	1185 "	3.94	
033	1190 "	3.98	
40038.443	1195 "	3.98	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
40043	1200 Seconds	3.98	
44.943		3.94	Broad Peak .60V-Range 2 (6.5 Sec. Wide)
48	1205 "	3.92	
53	1210 "	3.96	
58	1215 "	3.96	
63	1220 "	3.96	
64.443		3.94	Broad Peak .56V-Range 2 (6 Sec. Wide)
68	1225 "	3.92	
73	1230 "	3.94	
78.444	1235 "	4.08	
83.444	1240 "	4.08	
83.944		4.08	Broad Peak 4.44V-Range 1 (6 Sec. Wide)
88	1245 "	4.04	
93	1250 "	4.06	
98	1255 "	4.04	
40103.444	1260 "	4.00	Broad Peak 4.00V-Range 1 (5 Sec. Wide)
108	1265 "	3.98	
113	1270 "	4.00	
118	1275 "	3.98	
122.944		3.90	Broad Peak 3.54V-Range 1 (5 Sec. Wide)
123.444	1280 "	3.88	
128	1285 "	3.90	
133	1290 "	3.92	
138	1295 "	3.90	
142.445			Broad Peak 3.12V-Range 1 (5 Sec. Wide)
40143 .445	1300 "	3.78	
148	1305 "	3.78	
153	1310 "	3.82	

Spacecraft Time	Time From Turn On	Emission Monitor (Volts)	Notes
40158	1315 Seconds	3.80	
163.195		3.58	Broad Peak 2.34V-Range 1 (4 Sec. Wide)
168	1325 "	3.64	
173	1330 "	3.70	
178	1335 "	3.68	
181.445		3.48	Broad Peak 2.36V-Range 1 (3 Sec. Wide)
183	1340 "	3.46	
188	1345 "	3.54	
193	1350 "	3.60	
198	1355 "	3.56	
201.196		3.26	Broad Peak 2.24V-Range 1 (3 Sec. Wide)
203	1360 "	3.30	
208.446	1365 "	3.36	
213	1370 "	3.44	
218	1375 "	3.40	
220.696		3.24	Broad Peak 2.00V-Range 1 (3 Sec. Wide)
223	1380 "	3.30	
228	1385 "	3.40	
40233	1390 "	3.48	
238	1395 "	3.34	
240.196		3.24	Broad Peak 1.68V-Range 1 (2.5 Sec. Wide)
243	1400 "	3.32	
248	1405 "	3.40	
253	1410 "	3.44	
258	1415 "	3.28	
259.697		3.20	Broad Peak 1.42V-Range 1 (2 Sec. Wide)
263	1420 "	3.24	
40268.447	1425 "	3.34	
273	1430 "	3.40	

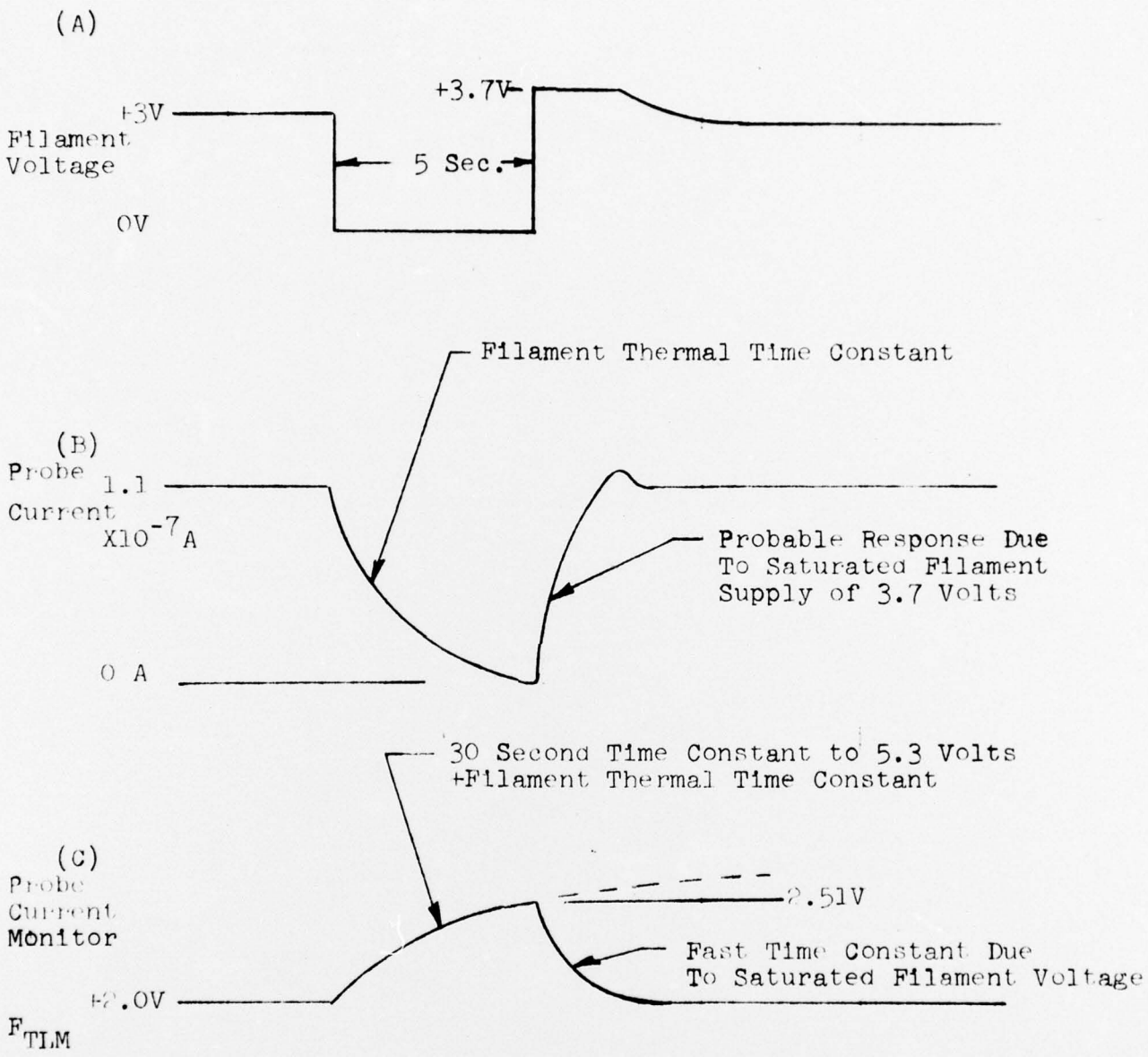

Figure 1

Filament Emission Circuit Waveforms

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