TIROS SEM-2

F5 TED/SN 0015

Calibration Report

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Prepared for

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1.0 INTRODUCTION

This is the Calibration Report for the SEM-2 F5 TED (SN 0015). It provides all the coefficients necessary to convert the TED outputs into appropriate internal voltages, temperature values, and particle energy fluxes. Section 2.0 contains the calibration data for the various monitor outputs, which provide information on internal voltages, operational status, and temperature. Particle energy flux calibration constants are given in Section 3.0, which also contains the configuration plug settings. Section 4.0 contains a description of the TED IFC operation and calibration constants. A short summary is given in Section 5.0. Appendix A contains a description of the compression counter algorithm used to convert the full TED particle counts into the compressed counts used in telemetry, and the algorithm used to invert the compressed counts back into the full counts.

In normal operation most of the TED data is obtained through the DPU, which does all of the count compressions and digital conversion of most of the TED analog monitors (Digital A TED analog monitor data). Thus some of the TED calibration constants are coupled to the DPU analog-to-digital converter calibration. These constants in Section 2.0 are provided for the SEM-2 DPU SN 0015, which is expected to be used with the TED SN 0015. Calibration constants are also provided for the direct TED analog outputs, and these data can be used to calculate the calibration constants for a different DPU.

2.0 MONITOR CALIBRATION

2.1 Analog Monitors

The TED has five (5) analog monitors which are provided directly to the spacecraft through the DPU connectors (all are on the DPU-J4 connector - see Ref. 3). Four (4) of these monitors are for voltages in the TED, and are also given in the Digital A output of the DPU. The fifth analog monitor is the isolated temperature monitor (TED THERM) which can be read by the spacecraft whenever the 28 V ATM bus to the SEM-2 is powered. There are also two temperature monitors which are used to control the TED heater, with connection directly to the TED through the heater control cable. One heater control temperature monitor is used when the TED is mounted on a NOAA spacecraft, and the other heater control temperature monitor is used when the TED is mounted on the METOP spacecraft.

The calibrations for the four TED voltage monitors are calculated from data in the appropriate F5 TED PCB test procedure, and are given in Table 2.1. The calibrations are all linear with a zero point intercept. Two calibrations are given: one is for the direct TED output line, and the second is for the output to the spacecraft after the DPU buffer. The DPU output buffers have a 0.998 gain, and the calibrations are measured in Ref. 7. Table 2.2 gives the measured HV values for the two CDEM power supplies for the eight (8) CDEM HV steps, calculated from data in Ref. 6. The TED Sweep Voltage varies from a low of 25.50 V for step 1 to a high of 490.8 V for step 64, and the actual value measured depends on where in the sweep cycle the spacecraft reading is taken (note that the value is 0 during background measurements and when the supply is off).

Table 2.1 TED Analog Voltage Monitor Calibrations

TED Monitor Description	Mnemonic	Actual Value (V)	Monitor Calibration (V/V)		Source
			Direct	F5 DPU	
TED +5 Volt	TED +5V	5.00	2.000	2.004	Ref. 4
TED Sweep Voltage	TED SWP V	(varies)	100.6	100.8	Ref. 5
TED E CDEM HV	TED E CEM HV	"	1003.0	1005.0	Ref. 6
TED P CDEM HV	TED P CEM HV	"	499.2	500.2	"

Table 2.2 TED CDEM HV Supply Values

CDEM HV Step	HV for E CDEMs (V)	HV for P CDEMs (V)
0	2510	1603
1	2600	1644
2	2660	1689
3	2730	1733
4	2810	1781
5	2880	1827
6	2940	1874
7	3010	1921

The calibration of the TED isolated temperature monitor (TED THERM) is given in Table 2.3. The polynomial fit is for the 28V ATM bus being precisely 28.0 V. For different 28V ATM bus voltages the telemetered monitor voltage value $(\text{TED THERM V})_{TM}$ must first be corrected by

$$(\text{TED THERM V})_{corr} = (\text{TED THERM V})_{TM} \times 28.0/(\text{Actual 28V ATM V}) \qquad (2.1)$$

The corrected value $(\text{TED THERM V})_{corr}$ is then used in the Table 2.3 polynomial fit with

$$\text{TED THERM Temp} = \sum_{i=0}^{8} A_i \times (\text{TED THERM V})_{corr}^{\,i} \ (^\circ\text{C}) \qquad (2.2)$$

Table 2.3 TED Isolated Temperature Monitor (TED THERM) Fit	
Polynomial Term i (Power of (TED THERM V))	Eq. (2.2) A_i Polynomial Coefficient
0	86.043939
1	-74.384817
2	26.691091
3	4.805859
4	-10.648079
5	5.130014
6	-1.236963
7	0.153214
8	-0.007788

One of the TED heater thermistors is read by the spacecraft using its own conditioning circuitry. The NOAA heater thermistors were obtained from the spacecraft manufacturer; Table 2.4 gives the specification NOAA thermistor resistance for -55°C to 70°C. The NOAA TED heater thermistor is not read out over the spacecraft telemetry, so the resistance calibration in Table 2.4 is for reference only. The second TED heater thermistor was provided by METOP, and is used for heater control when the TED is on the METOP spacecraft. The METOP TED heater control thermistor is a METOP part number S311P18-07T-30R.

2.2 Digital A Analog Monitors

The TED has thirteen (13) analog monitors in Digital A, four (4) of which are also direct analog monitors to the spacecraft. The direct voltage outputs of these monitors is calibrated in V/V (Volts input/Volts output), but this is not directly used for the Digital A outputs, since the DPU digitizes the monitor data for telemetry. The monitor calibrations for the F5 TED (SN 0015) have been converted to Digital A calibrations using the monitor digitizer calibration for the DPU SN 0015, which is 0.019950 (V input)/(count output) (the intercept is essentially 0.0V; data are obtained from Ref. 7). The DPU calibration factor is not expected to vary significantly for different units, but if the TED SN 0015 should be used with a different DPU than SN 0015 the Digital A calibration factors can be corrected, if desired. The TED Digital A monitor calibration factors are given in Table 2.5, which also lists the test procedure for the data source. The monitors are read once per major frame, or are subcommutated, as described in Ref. 1.

Table 2.4 TED Heater Thermistor Resistance Calibration - NOAA Thermistor			
Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)
-55	1296.5	10	21.134
-50	886.38	15	16.385
-45	612.31	20	12.698
-40	428.28	25	10.000
-35	304.13	30	7.9075
-30	217.89	35	6.264
-25	157.73	40	4.986
-20	115.37	45	4.039
-15	83.094	50	3.253
-10	63.329	55	2.641
-5	47.746	60	2.1525
0	36.085	65	1.7631
5	27.572	70	1.4383

Table 2.5 Digital A Analog Monitor Calibration Constants					
TED Monitor Description	Ref. 1 Mnemonic	TED Analog Line Cal (V/V)	Digital A Cal (V/cnt)	Ref. 1 Analog Subcom	Source
TED Sweep Voltage	TED SWP V	100.6	2.008	5	Ref. 5
TED E CDEM HV	TED E CEM HV	1003.0	20.01	-	Ref. 6
TED P CDEM HV	TED P CEM HV	499.2	9.96	-	"
TED IFC Ramp Voltage	TED IFC V	0.6646	0.01326	-	Ref. 5
TED Temperature	TED TEMP	1.000	0.01995	3	Ref. 4
TED +8 Volt	TED +8V	1.995	0.03980	4	"
TED +5 Volt	TED +5V	2.000	0.03990	4	"
TED -6 Volt	TED -6V	-2.000	-0.03990	4	"
TED +30 Volt	TED +30V	9.967	0.1988	4	"
TED -30 Volt	TED -30V	-10.000	-0.1995	4	"
TED +100 Volt	TED +100V	40.51	0.8082	4	Ref. 6
TED -1000 Volt	TED -1000V	-244.9	-4.885	4	"
TED IFC Ref. Voltage	TED IFC REF	1.256	0.02506	4	Ref. 4

The TED Temperature monitor in Digital A (TED TEMP) provides a measured voltage from which the temperature is then calculated. The measured voltage depends on the TED -6 volt supply value, and the measured Digital A voltage must be corrected using the measured -6 volt supply value. The corrected $(\text{TED TEMP V})_{\text{corr}}$ is obtained from the Digital A voltage $(\text{TED TEMP V})_{\text{TM}}$ by

$$(\text{TED TEMP V})_{\text{corr}} = (\text{TED TEMP V})_{\text{TM}} \times (-6.0/(\text{Actual -6V V})) \qquad (2.3)$$

The corrected value $(\text{TED TEMP V})_{\text{corr}}$ is then used in the Table 2.6 polynomial fit with

$$\text{TED TEMP Temp} = \sum_{i=0}^{8} A_i \times (\text{TED TEMP V})_{\text{corr}}^{\,i} \ (^\circ\text{C}) \qquad (2.4)$$

Observation of the TED TEMP monitor during testing shows that the temperatures calculated from the nominal response fit are within a degree C or so of the correct temperature. Thus the measured monitor voltage can be used without any additional corrections in (2.4) to calculate the TED TEMP temperature in °C.

Table 2.6 TED Digital A Temperature Monitor (TED TEMP) Fit

Polynomial Term i (Power of (TED THERM V))	Eq. (2.4) A_i Polynomial Coefficient
0	-61.163413
1	86.661572
2	-89.907755
3	69.222079
4	-34.130876
5	10.615717
6	-2.003220
7	0.208955
8	-0.009209

2.3 Bi-Level Monitors

The TED has two (2) bi-level monitor outputs which are given in Digital A, one (1) of which is also provided as a separate line for the Digital B output. All of the Digital A bi-level outputs are listed in Table 3.6 of Ref. 1; the TED bi-levels are summarized in Table 2.7 below.

Table 2.7 TED Bi-Level Monitors

Monitor Description	Mnemonic	Status Indications
TED IFC Status	TED IFC	0 = IFC off; 1 = IFC on
TED IFC Pulser Status	TED IFC PU	0 = IFC Pulser off; 1 = IFC Pulser on

The Digital B bi-level outputs are listed in Table 5.1 of Ref. 1; the only TED bi-level in Digital B is the TED IFC Status (TED IFC).

3.0 ESA CALIBRATION DATA

3.1 Electron Calibration Data

The F5 TED (SN 0015) was calibrated with electrons at the Phillips Laboratory Calibration Facility in July, 1999, following TIR-RTP-156, Rev. (-) (Ref. 8). All four (4) electron ESAs were calibrated for a number of energy channels, with the results being used to calculate the geometric factors, prescale factors, and energy flux calibration factors. As described in Ref. 2, each ESA has eight (8) main energy channels, each being the sum of eight (8) sub-channels. Each of the 64 sub-channels has a different plate voltage and resulting electron energy analysis range. For the calibrations, the sub-channel was fixed and the angular responses for several energies spanning the peak response range was measured. Normalization to the measured electron beam current then provides the absolute geometric factors.

The typical geometric factors measured for a sub-channel are illustrated in Figs. 3.1 and 3.2, which show the reduced data for the 0° LE ESA at energy sub-channel 60 (range of 0 to 63), and for the 0° HE ESA at energy sub-channel 60. The measured peak geometric factors, peak response energies, FWHM energy responses, and the resulting Gfe(E) values for all electron ESAs are listed in Table 3.1, and the Gfe(E) are plotted in Fig. 3.3. The Gfe(E) are calculated from

$$Gfe(E) = G(peak) \times \Delta E(FWHM)/E(peak) \qquad (3.1)$$

The data in Fig. 3.3 are in reasonable agreement with the theoretical values and with the other TED calibrations. The LE electron ESA shows no decrease in Gfe(E) at the lowest energy (about 60 eV). The lowest electron energies, below a few hundred eV, are the most difficult to use, since small adjustments in the calibration chamber Helmholtz coils can cause large changes in the measured G(E) values, and any localized insulator charging can also cause problems. For the present data the lowest energy LE electron

ESA calibration points are in good agreement with the higher energies, above 100 eV, and all are in good agreement with the theoretical values and with the other TED calibrations. The LE electron ESA responses have been fit to all of the calibration data. The measured Gfe(E) values in Table 3.1 are fit with a function

$$Gfe(E) = G_0 \times E^{\alpha} \tag{3.2}$$

with the fit values for G_0 and α for each electron ESA being given in Table 3.2. The fits of Table 3.2 are then used in eq. (3.2) to calculate the Prescale Factors and calibration constants in Sections 3.3 and 3.4.

Table 3.1 Measured Electron ESA Responses

ESA	Channel	Nominal Energy (eV)	Measured Values				
			Peak E (eV)	ΔE FWHM (eV)	ΔE/Peak E	G(peak) (cm^2 sr)	Gfe(E) (cm^2 sr)
0° LE	04	62.8	60.1	8.5	0.141	4.04×10^{-4}	5.706×10^{-5}
0° LE	28	193.1	188.7	26.1	0.138	5.60×10^{-4}	7.753×10^{-5}
0° LE	60	863.3	859.4	117.9	0.137	5.04×10^{-4}	6.920×10^{-5}
30° LE	04	62.8	61.2	7.8	0.127	4.90×10^{-4}	6.272×10^{-5}
30° LE	28	193.1	191.0	25.9	0.136	7.04×10^{-4}	9.538×10^{-5}
30° LE	60	863.3	864.8	117.9	0.136	7.33×10^{-4}	9.995×10^{-5}
0° HE	04	1255.	1255.	114.7	0.091	4.95×10^{-4}	4.527×10^{-5}
0° HE	28	3861.	3873.	369.	0.095	3.20×10^{-4}	3.054×10^{-5}
0° HE	60	17267.	17675.	1424.	0.081	2.01×10^{-4}	1.618×10^{-5}
30° HE	04	1255.	1241.	121.9	0.098	6.17×10^{-4}	6.061×10^{-5}
30° HE	28	3861.	3838.	386.	0.101	4.23×10^{-4}	4.256×10^{-5}
30° HE	60	17267.	17625.	1525.	0.087	2.72×10^{-4}	2.357×10^{-5}

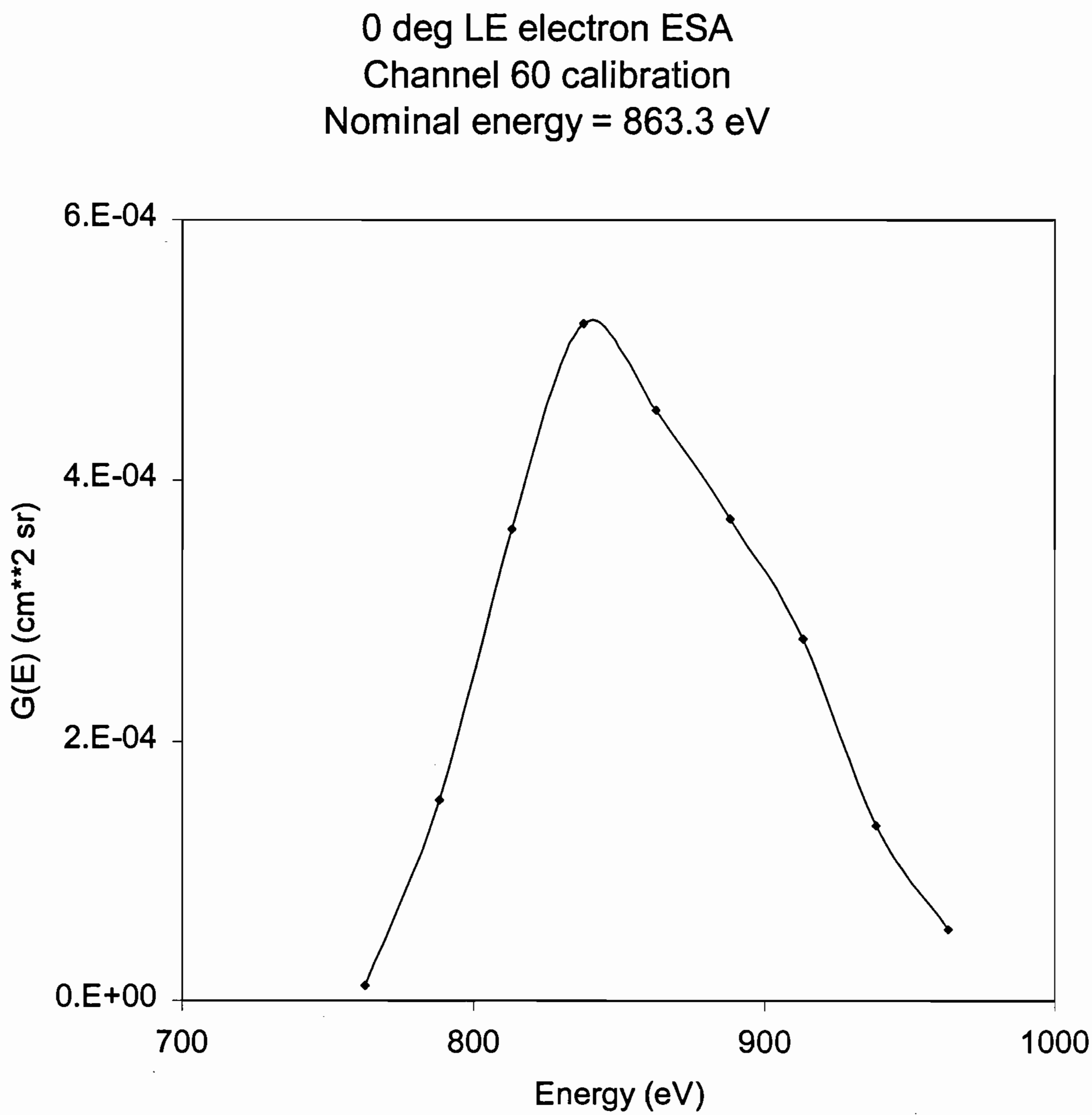

Figure 3.1 Measured 0° LE Electron ESA Response for Sub-channel 60.

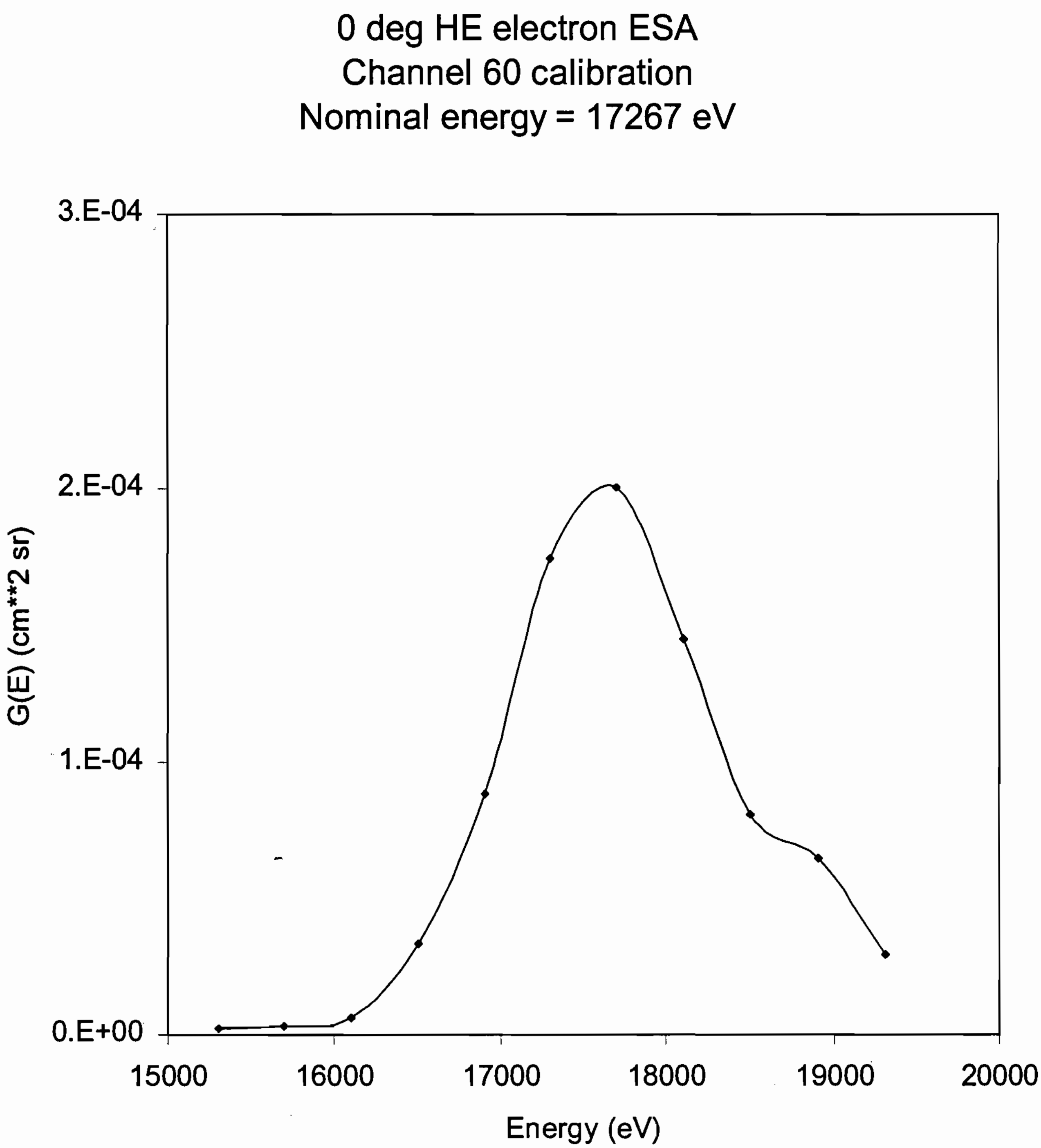

Figure 3.2 Measured 0° HE Electron ESA Response for Sub-channel 60.

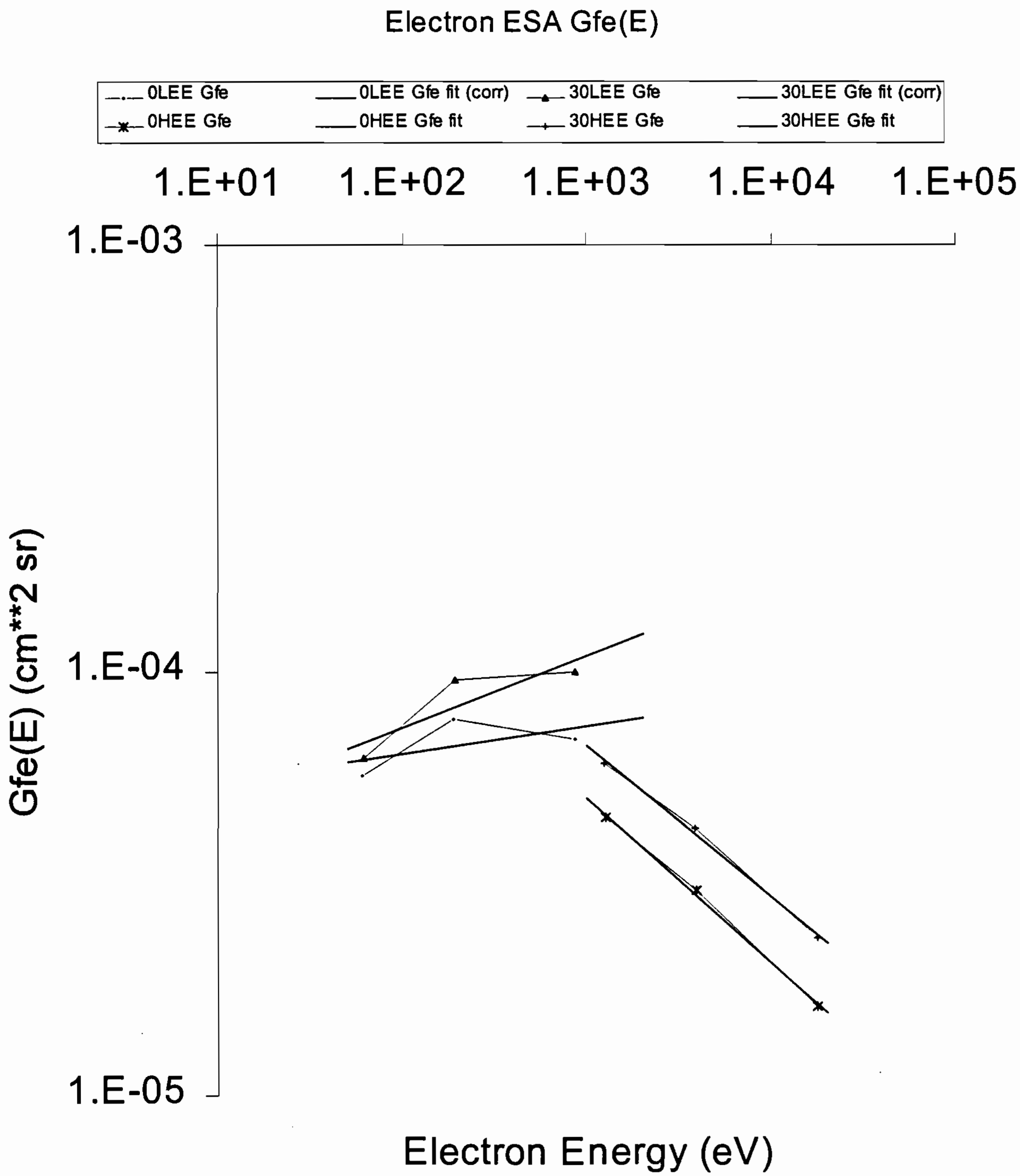

Figure 3.3 Measured Gfe(E) for the Electron ESAs.

Table 3.2 Electron ESA Gfe(E) Fits to Calibration Data		
ESA	G_o (cm^2 sr)	Exponent, α
0° LE	4.763×10^{-5}	0.06473
30° LE	3.409×10^{-5}	0.1683
0° HE	7.475×10^{-4}	-0.3906
30° HE	7.893×10^{-4}	-0.3577

3.2 Ion Calibration Data

The F5 TED (SN 0015) was calibrated with N_2^+ ions at the Phillips Laboratory Calibration Facility in July, 1999, following TIR-RTP-156, Rev. (-) (Ref. 8). All four (4) proton/ion ESAs were calibrated for a number of energy channels, with the results being used to calculate the geometric factors, prescale factors, and energy flux calibration factors. Calibrations were made for a number of sub-channels, measuring the angular responses for several energies spanning the peak response range. Normalization to the measured Faraday cup ion beam current then provides the absolute geometric factors.

The typical geometric factors measured for a sub-channel are illustrated in Figs. 3.4 and 3.5, which show the reduced data for the 0° LE ESA at energy sub-channel 60 (range of 0 to 63), and for the 0° HE ESA at energy sub-channel 60. The measured peak geometric factors, peak response energies, FWHM energy responses, and the resulting Gfe(E) values for all ion ESAs are listed in Table 3.3, and the Gfe(E), calculated from (3.1), are plotted in Fig. 3.6. For the LE ESAs the lowest energy data near 63 eV (channel 04) are not useable because of a large fractional FWHM spread of the ion beam energy. The measured values for Gfe(E) are reasonably consistent with the higher energy measurements, but they are not used because of the substantial uncertainty in the measured Gfe(E) values.

The data in Fig. 3.6 are in reasonable agreement with the theoretical values and with the other TED calibrations. The measured Gfe(E) values in Table 3.6 are fit with (3.2), with the fit values for G_o and α for each ion ESA being given in Table 3.4. The fits of Table 3.4 are used in (3.2) to calculate the Prescale Factors and calibration constants in Sections 3.3 and 3.4.

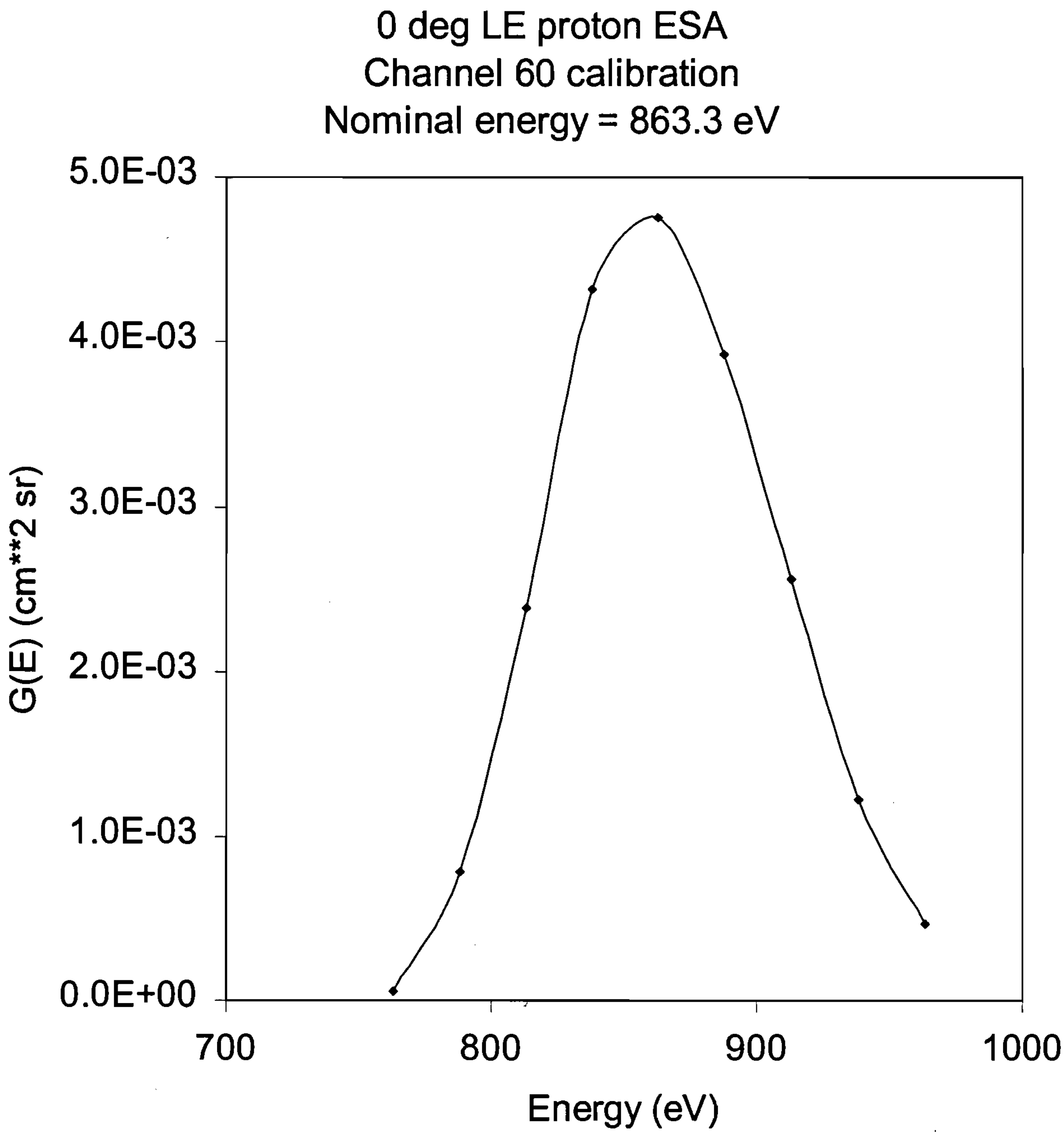

Figure 3.4 Measured 0° LE Ion ESA Response for Sub-channel 60.

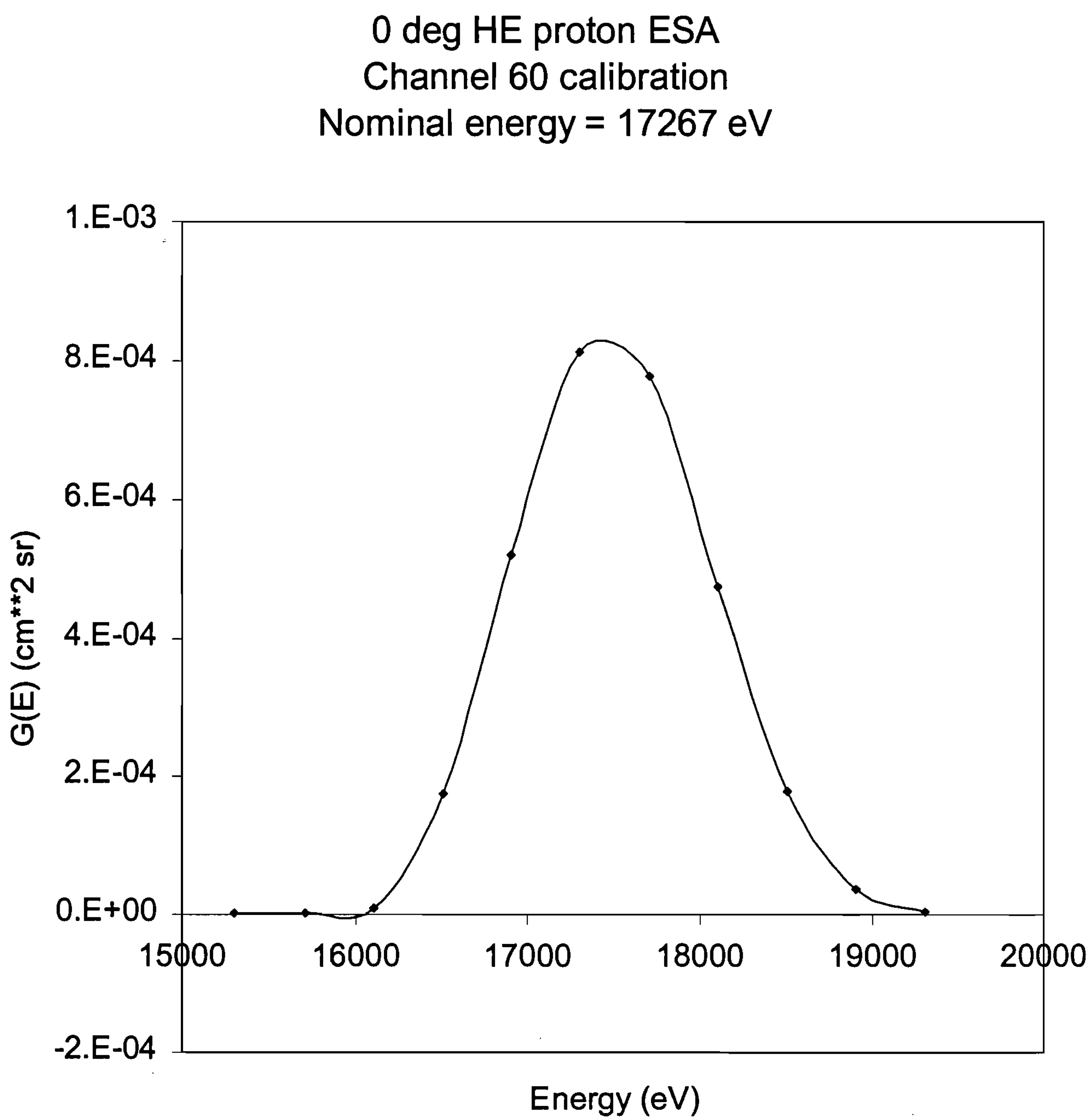

Figure 3.5 Measured 0° HE Ion ESA Response for Sub-channel 60.

Table 3.3 Measured Ion ESA Responses							
ESA	Channel	Nominal Energy (eV)	Measured Values				
			Peak E (eV)	ΔE FWHM (eV)	ΔE/Peak E	G(peak) (cm^2 sr)	Gfe(E) (cm^2 sr)
0° LE	04	62.8	(62.6)	(18.0)	(0.288)	(3.84×10^{-4})	(1.104×10^{-4})
0° LE	28	193.1	194.4	29.0	0.144	1.006×10^{-3}	1.501×10^{-4}
0° LE	60	863.3	865.4	102.9	0.119	1.680×10^{-3}	1.999×10^{-4}
30° LE	04	62.8	(62.6)	(18.0)	(0.288)	(8.12×10^{-5})	(2.335×10^{-5})
30° LE	28	193.1	195.9	32.7	0.167	4.41×10^{-4}	7.358×10^{-5}
30° LE	60	863.3	878.3	125.8	0.143	8.69×10^{-4}	1.245×10^{-4}
0° HE	04	1255.	1255.8	102.2	0.081	2.32×10^{-4}	1.892×10^{-5}
0° HE	28	3861.	3863.	304.2	0.079	4.00×10^{-4}	3.148×10^{-5}
0° HE	60	17267.	17485.	1395.	0.080	8.35×10^{-4}	6.664×10^{-5}
30° HE	04	1255.	1221.4	121.1	0.099	2.32×10^{-4}	2.303×10^{-5}
30° HE	28	3861.	3758.	360.8	0.096	4.04×10^{-4}	3.874×10^{-5}
30° HE	60	17267.	17030.	1648.	0.097	7.89×10^{-4}	7.630×10^{-5}

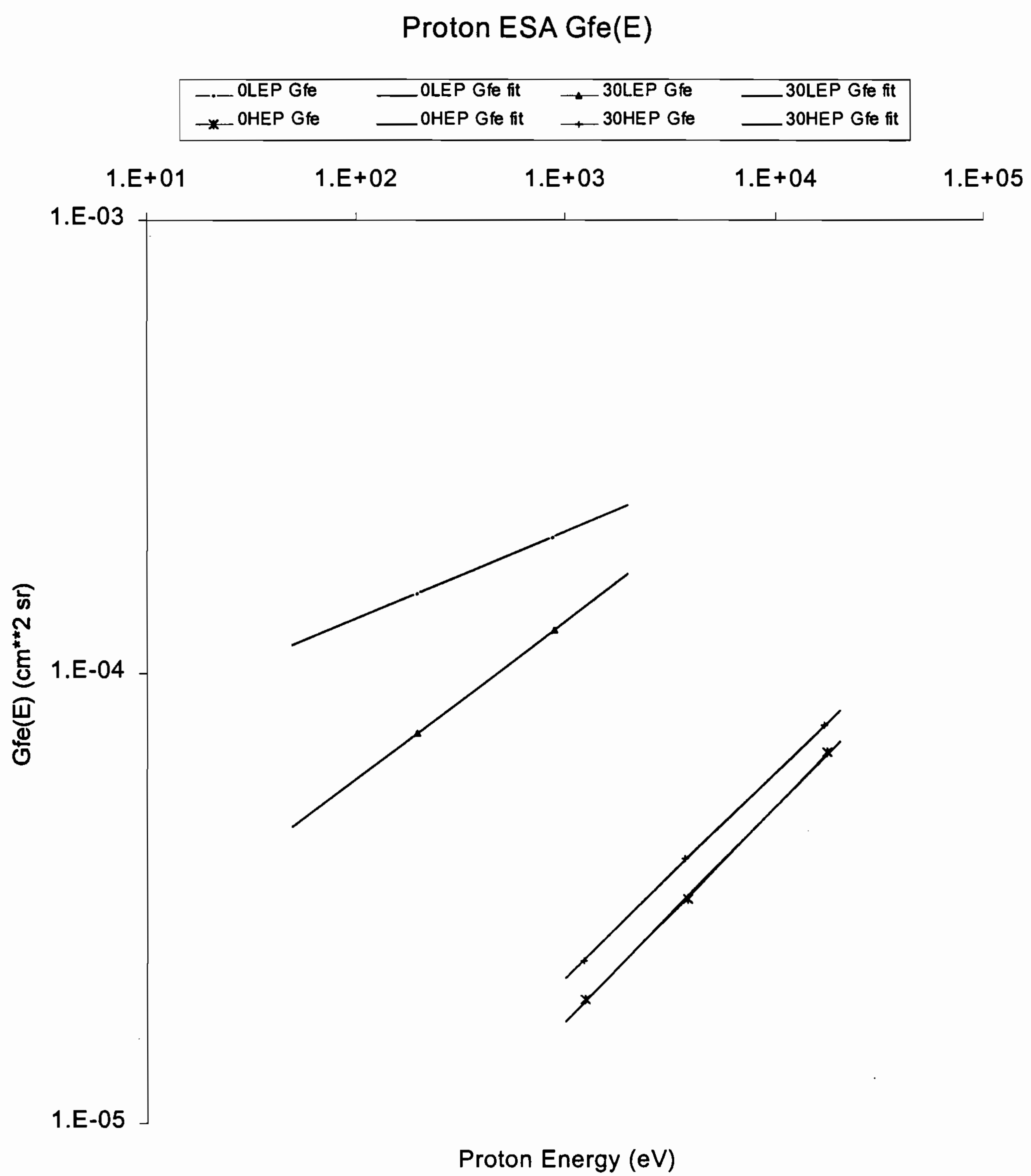

Figure 3.6 Measured Gfe(E) for the Ion ESAs.

Table 3.4 Ion ESA Gfe(E) Fits to Calibration Data		
ESA	G_o (cm^2 sr)	Exponent, α
0° LE	5.461×10^{-5}	0.1919
30° LE	1.157×10^{-5}	0.3505
0° HE	6.128×10^{-7}	0.4792
30° HE	9.153×10^{-7}	0.4543

3.3 Configuration Plug Settings

Each ESA pair for a particular particle/angle set has a total of 16 main energy channels, each of which is the sum of 8 sub-channels. The main channels are exponential in energy while the sub-channels are linear in energy. The total energy fluxes for each ESA are calculated by summing the 8 main channel counts with appropriate PROM Prescale Factors and with the Configuration Plug factors. The design values for the main channel energies, energy widths, and PROM Prescale Factors are listed in Table 3.5. The four differential channels are indicated by * in Table 3.5.

The best fit to the calibration data of Sections 3.1 and 3.2, given in Tables 3.2 and 3.4, are used to calculate the $Gfe(E_i)_{cal}$ for each of the main ESA channels, with the results being listed in Table 3.6. The $Gfe(E_i)_{cal}$ values in Table 3.6 are used to calculate the calibrated prescale factors from

$$PS(E_i)_{cal} = (DE_i/DE_1) \times (Gfe(E_1)_{cal}/Gfe(E_i)_{cal}) \quad (3.3)$$

and these are then used to calculate the adjusted prescale factors from

$$PS(E_i)_{adj} = PS(E_i)_{cal}/PS(E_i)_{PROM} \quad (3.4)$$

The values calculated from (3.3) and (3.4) are listed in Table 3.7. The Configuration Plug factors are calculated from

$$PS_{LE}(5\text{-}8)_{config} = PS(5\text{-}8\ avg)_{adj}/PS(1\text{-}4\ avg)_{adj} \quad (3.5)$$

$$PS_{HE}(13\text{-}16)_{config} = PS(13\text{-}16\ avg)_{adj}/PS(9\text{-}12\ avg)_{adj} \quad (3.6)$$

and

$$PS_{h/l,config} = PS(9\text{-}12\ avg)_{adj}/PS(1\text{-}4\ avg)_{adj} \quad (3.7)$$

where PS(1-4 avg)$_{adj}$ is the average value for main channels 1 to 4 of the PS(E_i)$_{adj}$ values in Table 3.7, and similarly for the other index values. The resulting average values and Configuration Plug factors are listed in Table 3.8. The Configuration Plug factors in Table 3.8 are used to set the F5 TED (SN 0015) Configuration Plug according to the Panametrics Drawing 6815, Configuration Plug Assembly.

Table 3.5 ESA Main Channel Design Energies and PROM Prescale Factors

ESA/Channel	Average Energy (eV)	Main Channel DE_i (eV)	Sub Channel dE_i (eV)	PS(E_i)$_{PROM}$, PROM Prescale Factors	
				Electron ESAs	Ion ESAs
LE/1	61.	22.7	2.84	1	1
LE/2	89.	33.0	4.13	1.5	1.5
LE/3	130.	48.0	6.00	2	2
LE/4*	189.	69.8	8.73	3	2
LE/5	274.	101.6	12.70	4	3
LE/6	399.	147.7	18.46	6	4
LE/7	580.	214.8	26.85	8	6
LE/8*	844.	312.3	39.04	12	8
HE/9	1227.	454.4	56.8	32	96
HE/10	1784.	660.8	82.6	48	128
HE/11*	2595.	960.8	120.1	96	128
HE/12	3774.	1396.8	174.6	128	192
HE/13	5488.	2031.2	253.9	256	256
HE/14*	7980.	2954.4	369.3	512	384
HE/15	11605.	4296.0	537.0	768	384
HE/16	16877.	6247.2	780.9	1536	512

Table 3.6 Calibrated Main Channel $Gfe(E)_{cal}$ Values

ESA/Channel	$Gfe(E)_{cal}$ Values (cm^2 sr) for ESA			
	0° Electron	30° Electron	0° Ion	30° Ion
LE/1	6.22×10^{-5}	6.81×10^{-5}	1.202×10^{-4}	4.89×10^{-5}
LE/2	6.37×10^{-5}	7.26×10^{-5}	1.292×10^{-4}	5.58×10^{-5}
LE/3	6.53×10^{-5}	7.73×10^{-5}	1.390×10^{-4}	6.37×10^{-5}
LE/4*	6.69×10^{-5}	8.24×10^{-5}	1.493×10^{-4}	7.26×10^{-5}
LE/5	6.85×10^{-5}	8.77×10^{-5}	1.604×10^{-4}	8.27×10^{-5}
LE/6	7.02×10^{-5}	9.34×10^{-5}	1.724×10^{-4}	9.44×10^{-5}
LE/7	7.19×10^{-5}	9.95×10^{-5}	1.852×10^{-4}	1.071×10^{-4}
LE/8*	7.37×10^{-5}	1.060×10^{-4}	1.990×10^{-4}	1.227×10^{-4}
HE/9	4.65×10^{-5}	6.20×10^{-5}	1.85×10^{-5}	2.32×10^{-5}
HE/10	4.01×10^{-5}	5.42×10^{-5}	2.22×10^{-5}	2.75×10^{-5}
HE/11*	3.47×10^{-5}	4.74×10^{-5}	2.65×10^{-5}	3.26×10^{-5}
HE/12	3.00×10^{-5}	4.15×10^{-5}	3.17×10^{-5}	3.86×10^{-5}
HE/13	2.59×10^{-5}	3.63×10^{-5}	3.80×10^{-5}	4.57×10^{-5}
HE/14*	2.24×10^{-5}	3.17×10^{-5}	4.54×10^{-5}	5.42×10^{-5}
HE/15	1.93×10^{-5}	2.78×10^{-5}	5.43×10^{-5}	6.43×10^{-5}
HE/16	1.67×10^{-5}	2.43×10^{-5}	6.50×10^{-5}	7.62×10^{-5}

Table 3.7 $PS(E_i)_{cal}$ and $PS(E_i)_{adj}$ Values				
ESA/Channel	$PS(E_i)_{cal}/PS(E_i)_{adj}$ Values for ESA			
	0° Electron	30° Electron	0° Ion	30° Ion
LE/1	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00
LE/2	1.42/0.95	1.36/0.91	1.35/0.90	1.27/0.85
LE/3	2.01/1.01	1.86/0.93	1.83/0.91	1.62/0.81
LE/4	2.86/0.95	2.54/0.85	2.47/1.24	2.07/1.03
LE/5	4.06/1.01	3.47/0.87	3.35/1.12	2.64/0.88
LE/6	5.76/0.96	4.74/0.79	4.53/1.13	3.37/0.84
LE/7	8.17/1.02	6.47/0.81	6.14/1.02	4.29/0.72
LE/8	11.60/0.97	8.83/0.74	8.30/1.04	5.47/0.68
HE/9	26.75/0.84	21.97/0.69	129.8/1.35	42.20/0.44
HE/10	45.03/0.94	36.52/0.76	157.8/1.23	51.77/0.40
HE/11	75.79/0.79	60.72/0.63	191.8/1.50	63.49/0.50
HE/12	127.5/1.00	100.9/0.79	233.0/1.21	77.86/0.41
HE/13	214.7/0.84	167.8/0.66	283.1/1.11	95.51/0.37
HE/14	361.4/0.71	279.0/0.55	344.2/0.90	117.2/0.31
HE/15	608.3/0.79	463.9/0.60	418.3/1.09	143.8/0.37
HE/16	1024./0.67	771.3/0.50	508.3/0.99	176.3/0.34

Table 3.8 Configuration Plug Factors				
Factor	Configuration Plug Factors for ESA			
	0° Electron	30° Electron	0° Ion	30° Ion
$PS(1\text{-}4\ avg)_{adj}$	0.976	0.922	1.013	0.923
$PS(5\text{-}8\ avg)_{adj}$	0.990	0.801	1.078	0.780
$PS(9\text{-}12\ avg)_{adj}$	0.890	0.717	1.324	0.436
$PS(13\text{-}16\ avg)_{adj}$	0.751	0.577	1.021	0.349
$PS_{LE}(5\text{-}8)_{config}$	1.015 (×1)	0.869 (×1)	1.063 (×1)	0.845 (×1)
$PS_{HE}(13\text{-}16)_{config}$	0.844 (×1)	0.804 (÷1.5)	0.771 (÷1.5)	0.800 (÷1.5)
$PS_{h/l,config}$	0.912 (×1)	0.778 (÷1.5)	1.307 (×1.5)	0.473 (÷2)

3.4 ESA Calibration Constants

Each ESA has a scale factor to convert the telemetered counts into a measured energy flux. The low energy (LE) ESA calibrated energy flux scale factors are given by

$$SF(LE)_{adj} = SF_o(LE) \times PS(1\text{-}4\ avg)_{adj}\ \text{erg/(cm}^2\text{ s sr cnt)} \qquad (3.8)$$

where

$$SF_o(LE) = (K \times DE_1/DT)/(Gfe(E_1)_{cal})\ \text{erg/(cm}^2\text{ s sr cnt)} \qquad (3.9)$$

while the high energy (HE) ESA calibrated energy flux scale factors are given by

$$SF(HE)_{adj} = SF_o(HE) \times PS(9\text{-}12\ avg)_{adj}\ \text{erg/(cm}^2\text{ s sr cnt)} \qquad (3.10)$$

where

$$SF_o(HE) = SF_o(LE) \times M_{full}\ \text{erg/(cm}^2\text{ s sr cnt)} \qquad (3.11)$$

The values of the constants in the above equations are

K = 1.60×10^{-12} erg/eV
DT = 0.2 second
DE_1 = 22.72 eV
M_{full} = 32

with the PS factors being taken from Table 3.8. The resulting calibrated energy flux scale factors for the F5 TED (SN 0015) are listed in Table 3.9.

Table 3.9 Calibrated Energy Flux Scale Factors

Scale Factor	Calibrated Energy Flux Scale Factor, erg/(cm² s sr cnt)			
	0° Electron	30° Electron	0° Ion	30° Ion
$SF(LE)_{adj}$	2.875×10^{-6}	2.460×10^{-6}	1.532×10^{-6}	3.433×10^{-6}
$SF(HE)_{adj}$	8.39×10^{-5}	6.13×10^{-5}	6.41×10^{-5}	5.19×10^{-5}

The total count values for the 4-point spectra (* channels in Tables 3.5 and 3.6) and peak energy flux channel can be converted into energy fluxes using the $Gfe(E)_{cal}$ values in Table 3.6 in

$$j_E(E) = E \times j(E) = (\text{TM counts})/(Gfe(E)_{cal} \times DT)\ \text{eV/(cm}^2\text{ s sr eV)} \qquad (3.12)$$

where DT = 0.2 s is the accumulation time for one channel. The corresponding particle fluxes can be calculated from

$$j(E) = j_E(E)/E = (\text{TM counts})/(Gfe(E)_{cal} \times DT \times E) \text{ particles}/(cm^2 \text{ s sr eV}) \quad (3.13)$$

where E is the channel average energy in eV, taken from Table 3.5.

4.0 IFC DATA PROCESSING

4.1 IFC Operation and Calibration

The TED IFC ramp and operation sequence is shown in Fig 4.1. A full IFC pulser ramp consists of 256 amplitude steps, with 64 steps in a normal 1.6 s sweep period. The pulse amplitude is constant during the sweep retrace and background count periods, when normal data accumulation does not take place; the pulse frequency is 8.32 kHz. The Sweep HV supply is turned off while IFC pulses are being generated to eliminate counts from analyzed particles. The four PHD levels (0 to 3) are each active for four complete pulser data accumulation cycles. A complete TED IFC includes the cycling of the PHD levels through all four values repeatedly for a full orbit (about 100 minutes) before termination. This follows the IFC pulser operation, and has the Sweep HV supply active to allow analysis of particles. This part of the IFC is used to verify CDEM gain saturation at the operating CDEM HV.

The four PHD level nominal values and expected total IFC counts for each IFC ramp segment are listed in Table 4.1. The normal full count for a 0.2 s accumulation period is 1663 (0.2 × 8320 = 1664; 1 count is lost because of the small dead-time between count accumulation periods and the phasing of the IFC pulser with the accumulation time periods), so a full-on data accumulation cycle count is 13304 (this is 8 less than the 13312 listed on page B.2.2.2-7 of Ref. 11). The nominal IFC ramp endpoint is 2.5 V, and the counts are calculated based on the nominal values. Table 4.1 also notes which counts are used for each PHD level calculation.

The actual measured PHD levels for all F5 TED ESAs are obtained from data in Ref. 9 (four completed test procedures, one for each of the four ESA sets), and are listed in Table 4.2. These values are used with data from the final TED CPT (Ref. 10) before integration with the F5 DPU to derive the calibration constants, which are listed in Table 4.3. The calibration constants are used to obtain the actual PHD levels from the algorithms given in Sections 4.2 and 4.3. The average value of the calibration constants for all four PHD levels is given in the last column of Table 4.3, and is valid to ±6%. The F5 TED Acceptance Test data were processed using 1.00 for the PHD level calibration constants since this provides all the data needed for stability checks. The absolute PHD firing voltage levels are not critical, since the important operating parameters are the PHD level stability and CDEM gain saturation. For normal monitoring of the TED PHD levels it is sufficient to use calibration factors of 1.00.

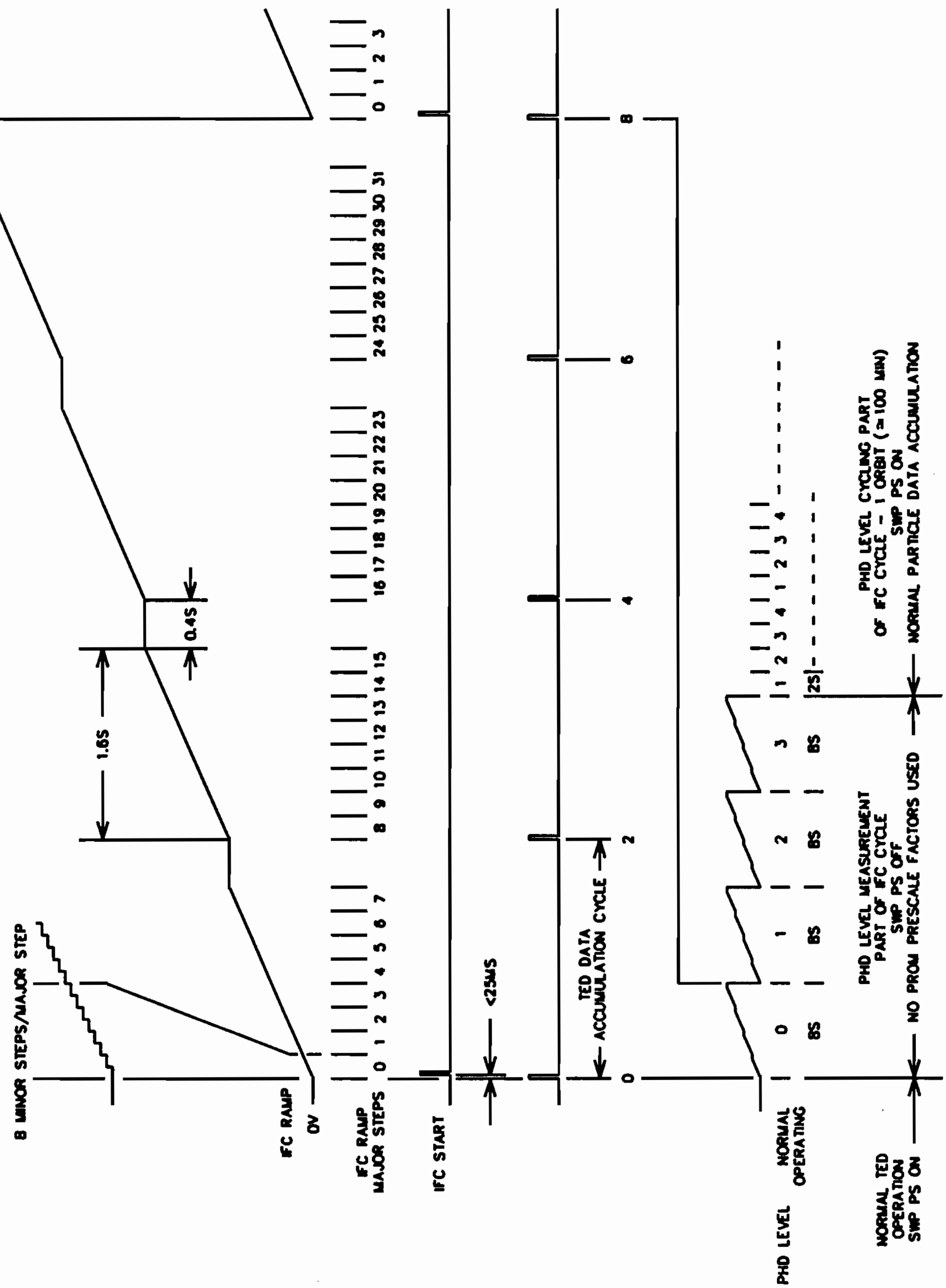

Figure 4.1 TED IFC Ramp and Operation Sequence.

Table 4.1 Nominal TED PHD Levels and Expected IFC Counts				
CDEM PHD Level		IFC Ramp Segment	Nominal IFC Count	Count Used for Level Calculation
Number	Volts			
0	0.238	1	8238	PHD 0
0	"	2	13304	
0	"	3	13304	
0	"	4	13304	
1	0.475	1	3193	PHD 1
1	"	2	13304	
1	"	3	13304	
1	"	4	13304	
2	0.950	1	0	
2	"	2	6386	PHD 2
2	"	3	13304	
2	"	4	13304	
3	1.900	1	0	
3	"	2	0	
3	"	3	0	PHD 3
3	"	4	12772	PHD 3

Table 4.2 TED Measured PHD Levels				
ESA	Measured PHD Levels (volts)			
	PHD 0	PHD 1	PHD 2	PHD 3
0° LE Electron	0.230	0.490	0.990	1.950
0° HE Electron	0.240	0.490	0.990	1.990
30° LE Electron	0.235	0.480	0.960	1.950
30° HE Electron	0.235	0.480	0.960	1.950
0° LE Proton (Ion)	0.240	0.450	0.980	1.950
0° HE Proton (Ion)	0.240	0.490	0.980	1.980
30° LE Proton (Ion)	0.235	0.490	0.990	1.950
30° HE Proton (Ion)	0.235	0.490	0.980	1.950

Table 4.3 F5 TED PHD Level Calibration Constants					
ESA	Calibration Constant for PHD Level				
	PHD 0	PHD 1	PHD 2	PHD 3	Average
0° LE Electron	0.443	0.479	0.488	0.488	0.475
0° HE Electron	0.465	0.484	0.496	0.506	0.488
30° LE Electron	0.465	0.484	0.492	0.507	0.487
30° HE Electron	0.465	0.483	0.490	0.505	0.486
0° LE Proton (Ion)	0.471	0.452	0.502	0.508	0.483
0° HE Proton (Ion)	0.468	0.485	0.492	0.505	0.488
30° LE Proton (Ion)	0.458	0.484	0.497	0.497	0.484
30° HE Proton (Ion)	0.455	0.483	0.492	0.497	0.482

The TED IFC pulser data are accumulated and stored in one of two ways. When the TED is operated separately through its BCU the individual 0.2 s counts are all stored separately in uncompressed form. This requires that the appropriate counts be summed to calculate the PHD levels. When the TED is operated through the DPU, which is the normal mode of operation, the data are summed and compressed before transmission and recording. The following Sections describe the processing of TED IFC data for these two modes of operation.

4.2 TED BCU IFC Data Processing

The TED BCU accumulates and stores all 0.2 s counts, including the sweep retrace interval. TED BCU IFC data are processed by summing the eight counts for sweep steps 0 to 7, with 8 being retrace and 9 being normal background. As shown in Table 4.1, one eight-count sum is used to calculate PHD levels 0, 1 and 2, while two eight-count sums are used for PHD level 3, since PHD level 3 is near the boundary between IFC ramp segments 3 and 4. The PHD levels are calculated from

$$PHD_i = A_i - B_i \times ((\text{Count sum})_i / C_i) \qquad (4.1)$$

The nominal values for A_i, B_i and C_i are given in Table 4.4, which is for a normalization of 5.00 V for the IFC ramp endpoint. The calibrated PHD levels are obtained by multiplying the result of (4.1) by the appropriate calibration constant from Table 4.3, if desired.

Table 4.4 PHD Level Calculation Constants for TED-BCU IFCs				
PHD Level	Count Sums from IFC Ramp Segments	Nominal Level Calculation Constants		
		A_i (V)	B_i (V)	C_i (Counts)
0	1	1.25	1.25	13304
1	1	1.25	1.25	13304
2	2	2.50	1.25	13304
3	3+4	5.00	2.50	26608

4.3 TED DPU IFC Data Processing

The DPU sums the eight energy channels for each ESA sweep into an energy flux output, which is then telemetered to ground. Normal operation uses the PROM Prescale Factors and the Configuration Plug Slope Factors for the sum. During the IFC the PROM Prescale Factors are not used, but the Configuration Plug Slope Factors are used. Processing of the IFC data requires that the TED energy flux counts be corrected for the Configuration Plug Slope Factors in order to give the proper PHD levels.

Each of the four PHD levels for a given ESA is calculated from one or two total energy flux counts, as shown in Table 4.1. The corrections must be applied to each total energy count individually before summing to calculate the PHD level (this is only necessary for PHD 3, which uses the sum of two counts). The TM counts from a given ESA are corrected using the Configuration Plug Slope Factor for that ESA, which is obtained from the appropriate two (2) bits of the Configuration Plug readout (the configuration plug is read out once per SEM-2 major frame, as four bytes). The two-bit Slope Factor for each ESA (2^1 and 2^0) give the following slope factors:

11 (also 00) : Slope Factor = ×1.0
01 : Slope Factor = ÷1.5
10 : Slope Factor = ×1.5

The decompressed IFC telemetry counts (S_{TM}) for a given ESA depend on the Slope Factor as follows:

1) Slope Factor = ×1.0; No correction required:

$$S_{TM,corr} = S_{TM}$$

2) Slope Factor = ÷1.5; Corrections as follows:
   a) If $S_{TM} \le 4437$, then $S_{TM,corr} = S_{TM} \times 1.5$
   b) If $S_{TM} > 4437$, then $S_{TM,corr} = S_{TM} + 2219$

3) Slope Factor = ×1.5; Corrections as follows:
   a) If $S_{TM} \le 9984$, then $S_{TM,corr} = S_{TM} \div 1.5$
   b) If $S_{TM} > 9984$, then $S_{TM,corr} = S_{TM} - 3328$

The corrected counts $S_{TM,corr}$ are then used to calculate the PHD level. This must be done for each of the four (4) PHD levels, for each of the eight (8) ESAs. Note that the last IFC count for the four (4) HE ESAs must be multiplied by 32 before making the above correction.

The total energy counts provided by the DPU are in compressed format, and must be decompressed before use. This leads to some quantization errors, since the decompressed counts have step sizes up to 6% of the count value (count range is ±3%; a compressed count can be decompressed by the algorithm given in Appendix A). For a full-on value of 13304 counts before compression, the decompressed count becomes 13055.5 ± 255.5, which is 1.9% low. To avoid this 1.9% PHD level shift from a full-on count, the C_i constants of (4.1) are adjusted to the values in Table 4.5, which are then used in (4.1) to obtain the nominal PHD levels.

Table 4.5 PHD Level Calculation Constants for DPU IFCs

PHD Level	Count Sums from IFC Ramp Segments	Nominal Level Calculation Constants		
		A_i (V)	B_i (V)	C_i (Counts)
0	1	1.25	1.25	13056
1	1	1.25	1.25	13056
2	2	2.50	1.25	13056
3	3+4	5.00	2.50	26112

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APPENDIX A. COMPRESSION COUNTER ALGORITHM

The compression counter algorithm used by the DPU converts input counts in the range of 0 to ≥1998848 to a compressed range of 0 to 255 (8-bit compressed counts). The algorithm for compressing an input count I_{in}(24-bits) to the compressed output count COMPR(8-bits) is as follows.

For $I_{in} \leq 32$, COMPR = I_{in}(low 8 bits)

Otherwise, shift I_{in}(24-bits) left until the first "1" is shifted out. The number of shifts used is S. Define E = 24 - S. Take the next 5 bits of I_{in} (excludes the "1" shifted out) as M1. Calculate M as follows:

If M1 ≤ 21, then M = M1/2 (truncated)
Otherwise, M = (M1 - 2)/3 + 4

Calculate the output count as

$$\text{COMPR} = M + (E - 5) \times 14 + 32$$
$$= M + (19 - S) \times 14 + 32$$

If an overflow occurs (E ≥ 21) then set COMPR = 255. This also occurs when $I_{in} \geq 1998848$.

The output count COMPR(8-bits) can be converted to a minimum input count by the following algorithm (given in Ref. 11, page D.2.2-15).

For COMPR ≤ 32, MIN = COMPR

Otherwise, calculate (use truncated integer division)

$$C1 = \text{COMPR} - 32$$

$$M1 = C1 - 14 \times (C1/14)$$

$$Em = (C1 - M1)/14 = C1/14$$

If M1 ≤ 10, then M2 = 2 × M1
If M1 > 10, then M2 = 3 × M1 - 10

$$\text{MIN} = (M2 + 32) \times 2^{Em}$$

The above gives the minimum input count, MIN, for the compressed output count COMPR. The average input count corresponding to COMPR is given by

$$\text{AVG} = [\text{MIN(COMPR)} + \text{MIN(COMPR+1)} - 1]/2$$