4.4.3 FULL WELL CAPACITY

Reference 4.4.3-1 - CAS-4-2036,"Cassini Orbiter Functional Requirements Book, Imaging Science Subsystem (ISS)", Rev. C

Reference 4.4.3-2 - "Galileo Solid-State Imaging Subsystem Calibration Report : Part 1", H. Breneman and K. Klaasen, November 1, 1988

Reference 4.4.3-3 - CCD #220 (NAC FM) Notebook

Reference 4.4.3-4 - CCD # 361 (WAC FM) Notebook

Reference 4.4.3-5 - Section 5.1.4 - System Gain

Reference 4.4.3-6 - Section 5.1.11 - Linearity

The full well capacity of the CCD is defined as the amount of signal electrons that can be properly collected and transferred by each pixel of the CCD. Reference 4.4.3-1 requires that the ISS CCD full well capacity be greater than or equal to 50,000 electrons (e^-), with a goal of 100,000 electrons (e^-). Additionally, an on-chip processing requirement for pixel summation of up to 800,000 (e^-) is also listed.

The average full well capacities of the NAC and WAC FM CCDs were measured at the component level (CCD Screening), and at the subsystem level (Subsystem Calibration Tests). The method used to determine full well capacity utilized the Square of Noise versus Mean Signal (DN) plots taken from flat field images of increasing exposure levels. (The slope of these plots is the gain (e^- / DN) of the system.) The signal level, at which there is a break point in the plot, indicates where the noise begins to decrease, and is defined as the full well capacity off the CCD. Above this break point signal level, the charge begins to spill from one pixel to another during CCD *readout* (this should not be confused with "blooming" where electrons spill from one pixel to another during signal *integration* - Reference 4.4.3-2).

The component level tests measured both the NAC and WAC FM CCDs as having full well capacities greater than 100,000 electrons (refer to Figure 4.4.3-1 and Figure 4.4.3-2). As can be seen from the referenced plots, the full well capacity was approximated at 110,000 electrons for the NAC FM CCD, and 105,000 electrons for the WAC FM CCD.

For the subsystem level full well capacity measurements, shown in Table 4.4.3-1, data was taken from the System Gain (Reference 4.4.3-5) and Light Transfer Curve/ Blemish /Gain calibration data sets. The System Gain data set provided the calculated gain for the different gain states. The Light Transfer Curve/ Blemish /Gain data set was used to obtain the (somewhat subjective) full well capacity values. Due the limited amount of data points provided in the data sets, values for "minimum full well capacity" and "first data point beyond full well" are given.

As can be seen from the Table 4.4.3-1, the 1x1 / Gain State 2 imaging mode exceeds the minimum 50,000 electrons full well capacity requirement for both the NAC and WAC FM CCDs. The NAC CCD also appears to exceed the 100,000 electron full well goal for this mode, whereas the WAC CCD closely approaches the goal for this mode.

The table also shows that the full well capacity of the summed images do not follow the simple algorithm of being 4X that of the 1x1/GS2 mode for 2x2 summation, and 16X that of the 1x1/GS2 mode for 4x4 summation. As discussed in Reference 4.4.3-5 and Reference 4.4.3-6, the 4x4 summation mode was discovered to have a linearity problem where the linearity breaks down at approximately the 1000 DN signal level. Accordingly, the minimum full well capacity that was determined for this summation mode falls significantly below the expected level.

Another data set, the Parallel Clock (PC) Voltage calibration data set (not shown here), was used in order to determine the effects of PC Voltage on full well capacity. The data set consisted of "light transfer curve" data taken with various PC Voltage values (from 2 to 14) . The plots of this data showed that the full well capacity does not vary significantly between PC Voltage settings of 4 and 12, but decreases at PC Voltage settings of 2 and 14. (Note : The recommended PC Voltage setting is 9, which was the value used for subsystem calibration tests.)

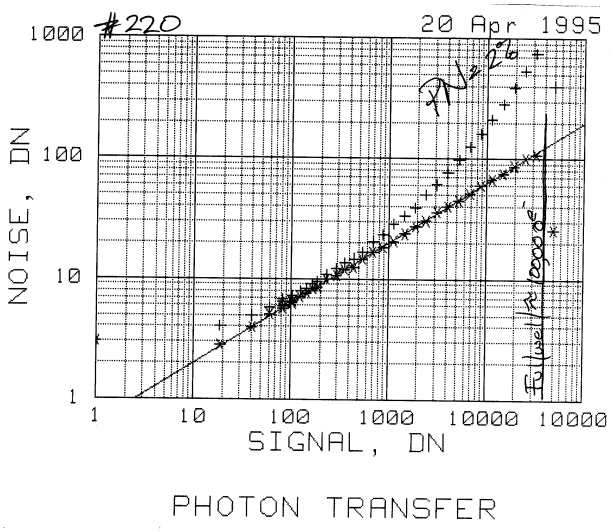

Figure 4.4.3-1 - NAC FM CCD Component Level Full Well Plot

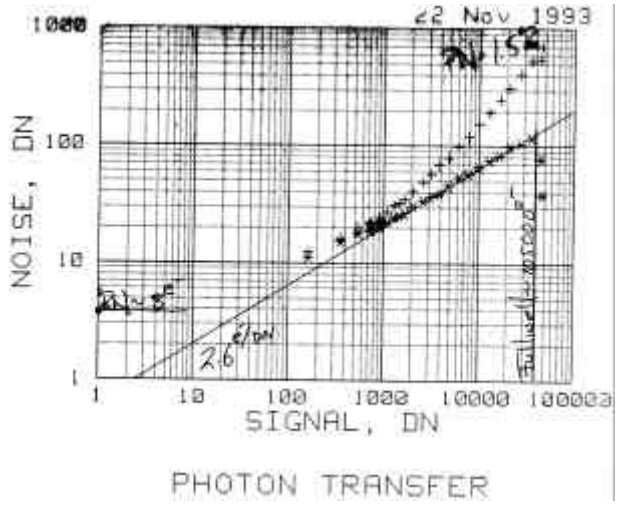

Figure 4.4.3-2 - WAC FM CCD Component Level Full Well Plot

CAMERA	SUM / GAIN STATE	FIGURE	e^-/DN (Reference 4.4.3-5)	MINIMUM FULLWELL CAPACITY		FIRST DATA POINT BEYOND FULLWELL	
				DN	e^-	DN	e^-
NAC /1, /6	1X1 / 3	Figure 4.4.3-3	12.88	3583	46,453	-	-
/1, /6	1X1 / 2 - AB Off	Figure 4.4.3-4	29.21	3708	108,320	-	-
/1, /6	1X1 / 2 - AB On	Figure 4.4.3-5	29.09	3750	109,088	-	-
/1, /6	2X2 / 1	Figure 4.4.3-6	94.47	3583	338,486	-	-
/1, /2, /6	4X4 / 0	Figure 4.4.3-7	205.804	843	173,493	-	-
WAC /3	1X1 / 3	Figure 4.4.3-8	11.54	3725	42,987	-	-
/4	1X1 / 2 - AB Off	Figure 4.4.3-13	28.07	3275	91,929	3562	99,985
/3, /5	1X1 / 2 - AB Off	Figure 4.4.3-9	27.55	3188	87,829	3813	105,048
/3, /5	1X1 / 2 - AB On	Figure 4.4.3-10	27.76	3188	88,499	3844	106,709
/3	2X2 / 1	Figure 4.4.3-11	90.69	3667	332,560	-	-
/2, /3	4X4 / 0	Figure 4.4.3-12	204.92	719	147,337	-	-

Notes :
/1 Figures are from data set discussed in Section 5.1.4.1 - NAC FM System Gain Calibration Results.
/2 The 4x4/GS0 mode is non-linear above 1000 DN.
/3 Figures are from data set discussed in Section 5.1.4.2 - WAC FM System Gain Calibration Results.
/4 Full well values taken from Parallel Clock Voltage (PCV) data set, where additional data points were taken at the higher signal levels.
/5 Shown to demonstrate full well values are not significantly effected by utilizing the antiblooming mode. Use data from /4 note for full well value.
/6 No data showing full well break point.

Table 4.4.3-1 - NAC and WAC FM Full Well Capacity

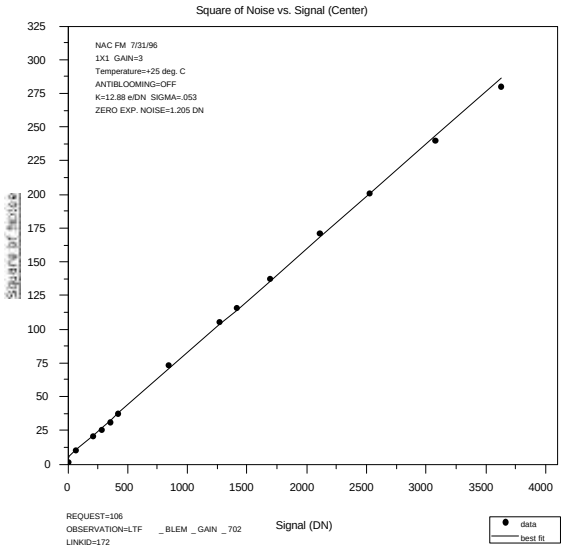

Figure 4.4.3-3 - NAC FM 1X1/GS3 (Noise)^2 vs. Signal (DN)

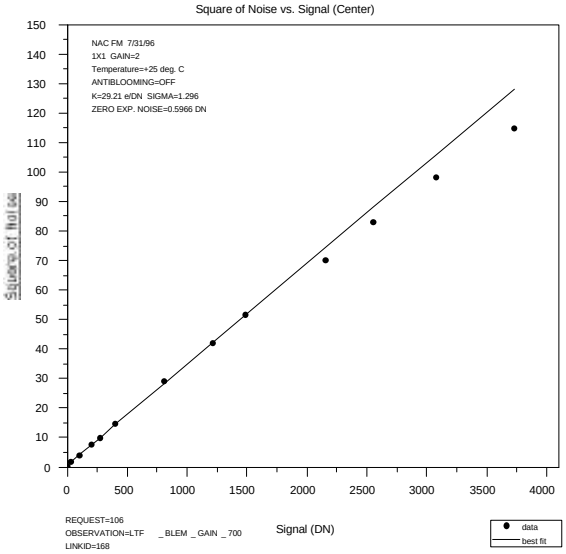

Figure 4.4.3-4 - NAC FM 1X1/GS2 (AB Off) (Noise)^2 vs. Signal (DN)

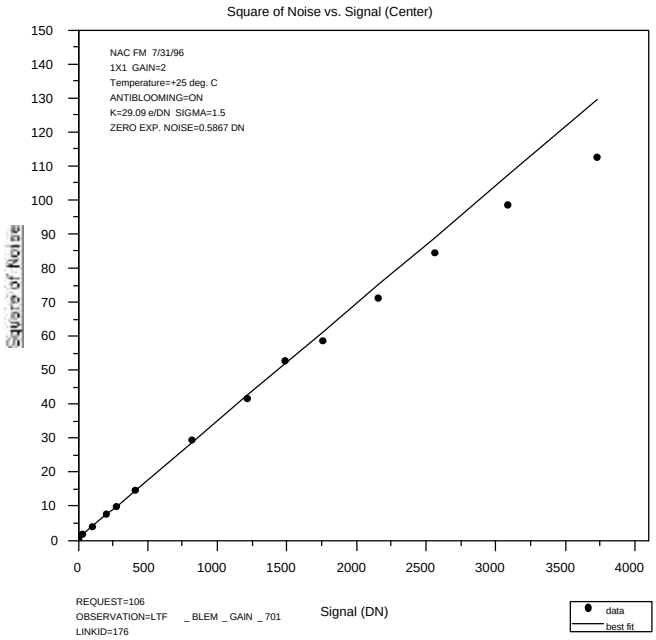

Figure 4.4.3-5 - NAC FM 1X1/GS2 (AB On) $(Noise)^2$ vs. Signal (DN)

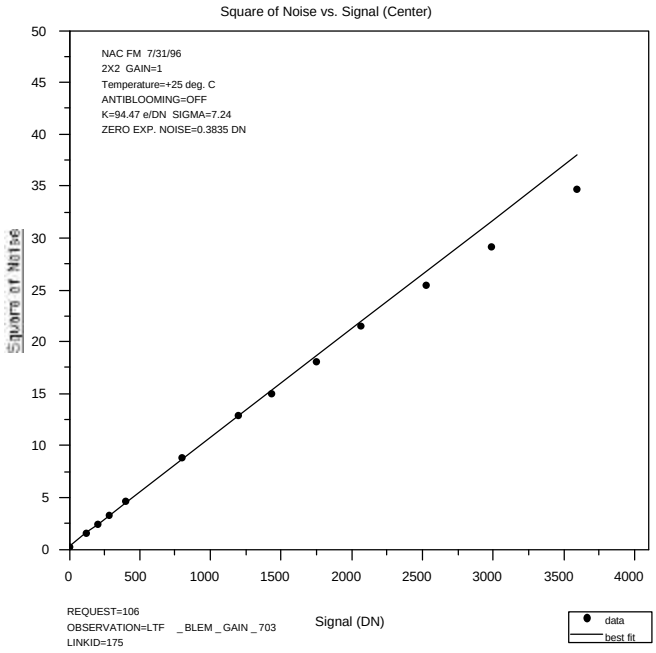

Figure 4.4.3-6 - NAC FM 2X2/GS1 $(Noise)^2$ vs. Signal (DN)

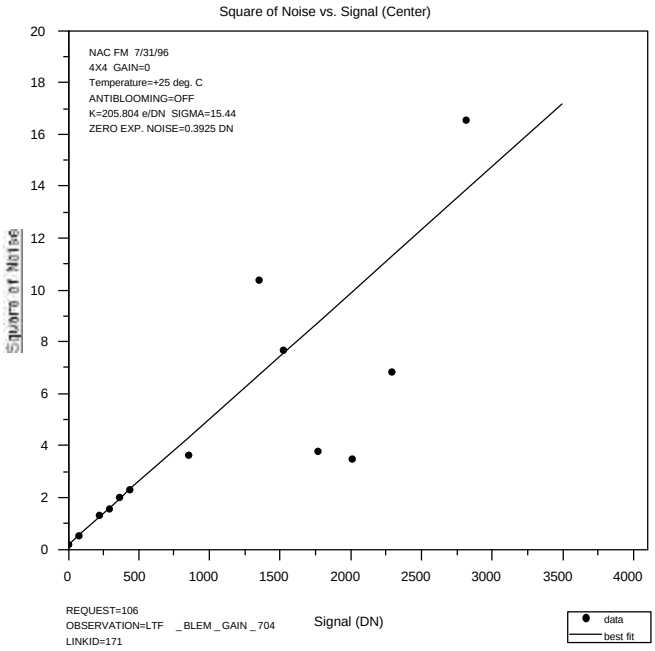

Figure 4.4.3-7 - NAC FM 4X4/GS0 (Noise)^2 vs. Signal (DN)

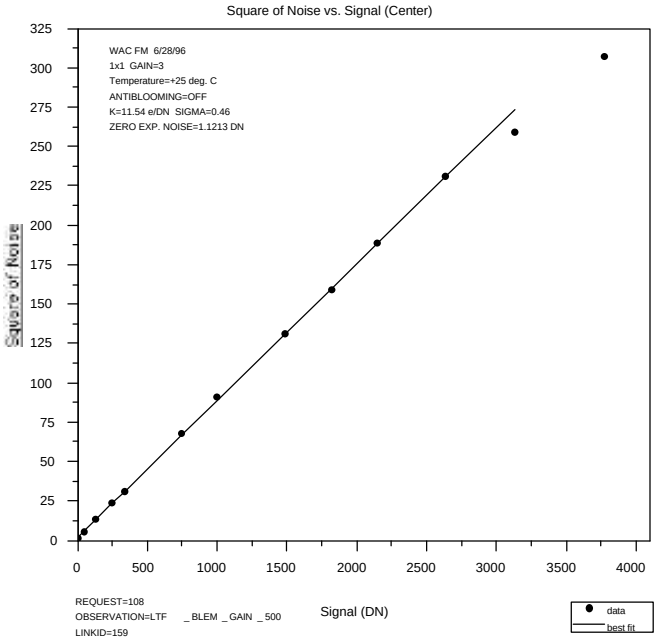

Figure 4.4.3-8 - WAC FM 1X1/GS3 $(Noise)^2$ vs. Signal (DN)

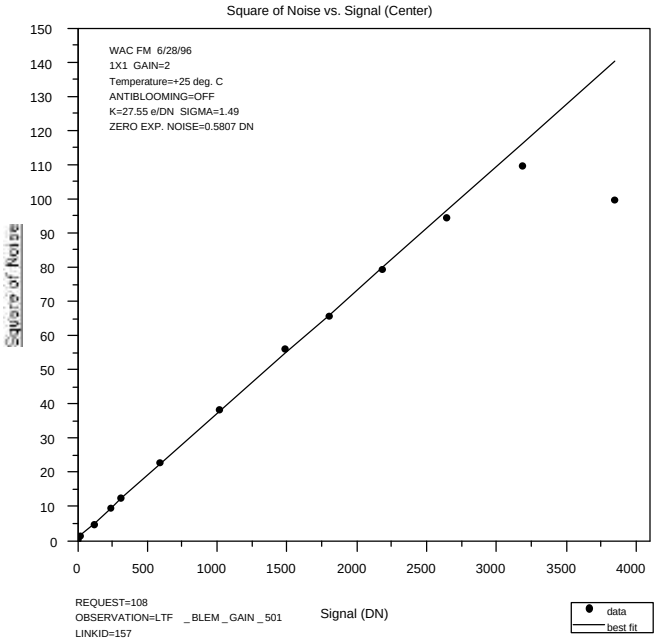

Figure 4.4.3-9 - WAC FM 1X1/GS2, AB Off, $(Noise)^2$ vs. Signal (DN)

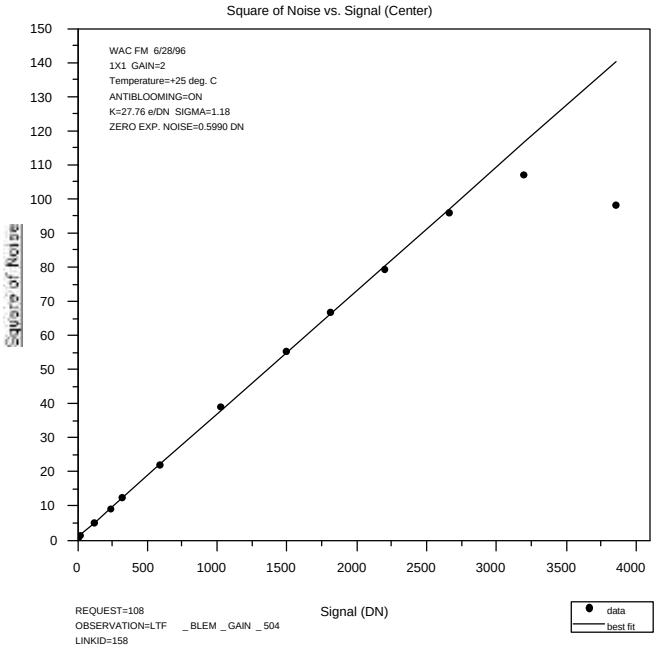

Figure 4.4.3-10 - WAC FM 1X1/GS2, AB On, $(Noise)^2$ vs. Signal (DN)

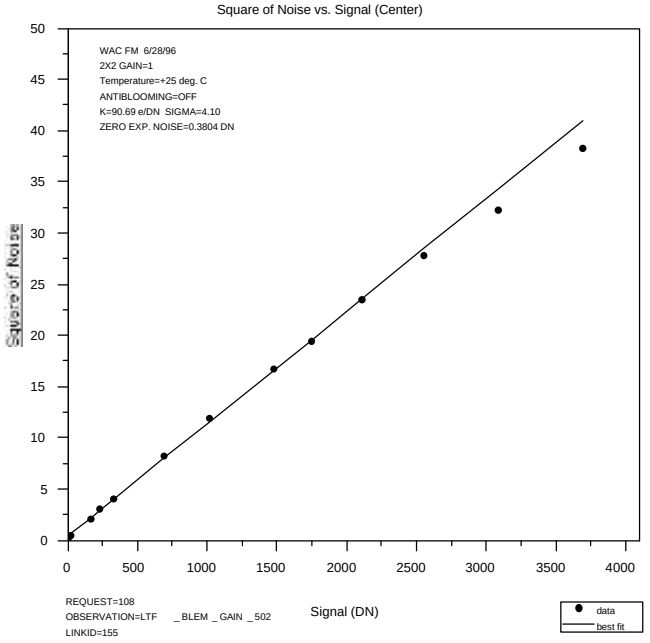

Figure 4.4.3-11 - WAC FM 2X2/GS1 $(Noise)^2$ vs. Signal (DN)

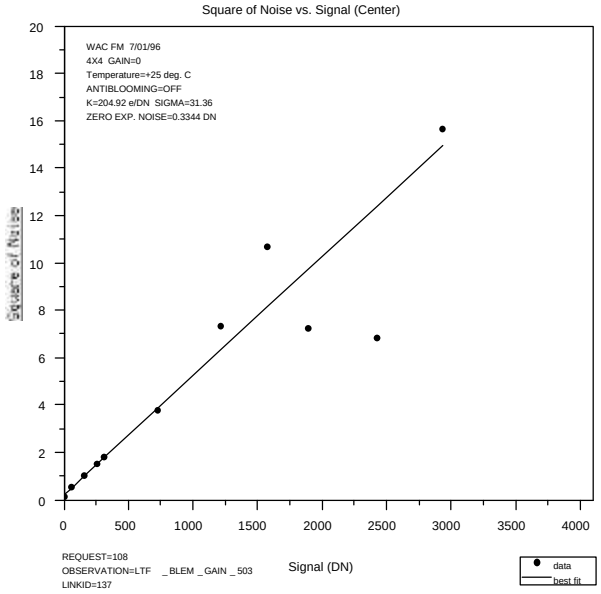

Figure 4.4.3-12 - WAC FM 4X4/GS0 $(Noise)^2$ vs. Signal (DN)

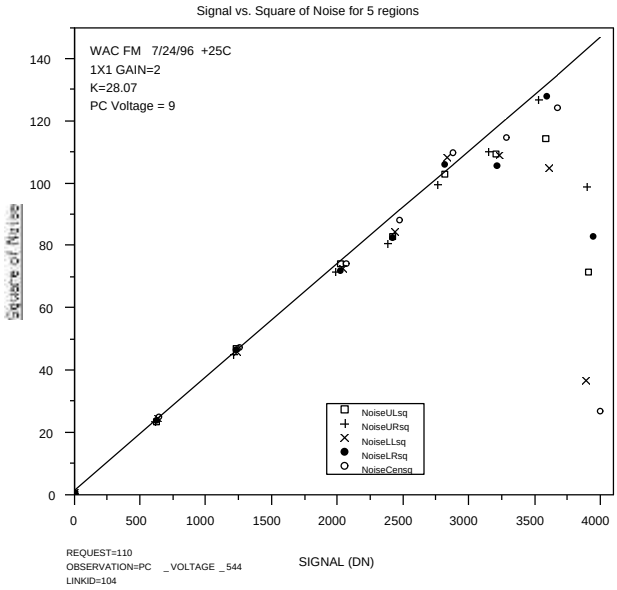

Figure 4.4.3-13 - WAC FM 1X1/GS2, PCV Test Data, AB Off, (Noise)2 vs. Signal (DN)