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LABORATORY IMAGING PERFORMANCE COMPARISON BETWEEN THE THERMOVISION 900LW AND THE INFRAMETRICS 760

BRIAN YASUDA

AUGUST 1994

FINAL REPORT FOR 06/06/94-06/16/94

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This technical report has been reviewed and is approved for publication.

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THIS REPORT COMPARES THE SQUARE WAVE RESPONSE, MODULATION TRANSFER FUNCTION, NOISE EQUIVALENT, DELTA TEMPERATURE, SPATIAL UNIFORMITY, AND BLOOMING BETWEEN THE AGEMA THERMOVISION 900LW AND THE INFRAMETRICS 760 RADIOMETERS.

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FOREWORD

This technical memorandum was prepared by the EO Evaluation/Analyses Group, Mission Avionics Division, Avionics Directorate, Wright Labs, Wright-Patterson AFB OH.

The following personnel contributed to the design, implementation, and analysis of this test:

1. Brian Yasuda, WL/AARI-3
2. Lt. Suzanne Corej, NAIC
3. Ernest Armstrong, T/SSI (Contractor)
4. John Bognar, T/SSI (Contractor)

This technical memorandum was submitted by Mr. Yasuda in August 1994.

INTRODUCTION

Between 6 and 16 June 1994, WL/AARI conducted laboratory performance measurements on an AGEMA Thermovision 900LW and Inframetrics 760 imaging radiometer systems. The purpose of these tests was to determine which of the two radiometers had better imaging performance. Radiometric accuracy was not a part of this test. The imaging performance data would be used in addition to other characteristics to help determine which of the two systems would be purchased for NAIC applications. These tests were performed at the WL/AARI, Bldg. 622 IR Lab Facility at WPAFB under in-house project 2004-05-72, EO Sensor/Image Analysis.

The following tests were conducted on the sensors; Square Wave Response (SWR), Modulation Transfer Function (MTF), Noise Equivalent Delta Temperature (NEDT), Spatial Uniformity, and Blooming.

The AGEMA Thermovision 900LW uses a cryogenically cooled Mercury Cadmium Telluride (MCT) detector with a spectral bandpass of 8-12 micrometers. The frame (field) rate is selectable between 15 and 30 Hz noninterlaced, however, at 30 Hz the scan lines/frame drops by 50% resulting a proportional drop in the vertical FOV. During these tests the sensor was operated at 15 Hz which is considered normal operation. The digital video output frame was 272 samples per horizontal line and 136 lines vertical with a 12-bit dynamic range. This system is capable of making measurements between -30 and +1500 degrees Celsius normally and from -30 to +2000 degrees Celsius with the extended range option. The -30 to +80 degree Celsius window was used for all the tests in this effort. Lens options allow the following FOVs: 2.5X1.25 degrees (8X), 10X5 degrees (2X), 20X10 degrees (1X), and 40X20 degrees (.5X). The 2X lens was the only lens used for these tests. During data acquisition a built-in 100 Mbyte Winchester disk was used to store the images which were later transferred to a laboratory Sun workstation via the Thermovision's ethernet output port. An analog video output was also available for a VCR or TV monitor, however, only the digital data was acquired. Software operates under OS9 and is supported by X Windows

The Inframetrics 760 uses a cryogenically cooled Mercury Cadmium Telluride detector with a normal (filtered) bandpass of 8-12 micrometers. The digital video had a frame rate of 30 Hz, 2:1 interlacing, 256 samples per horizontal line and 1[illegible] lines vertical with an 8-bit dynamic range. This system is capable of making measurements between -20 to +400 degrees Celsius normally and from +20 to +1500 degrees Celsius with the extended range option. The 2, 50 and 100 degree Celsius windows were used for all the tests in this effort. Lens options allow the following FOVs: 2X1.5 degrees (10X), 6.67X5 degrees (3X), 20X15 degrees (1X) and 40X30 degrees (.5X). The 3X lens was the only lens used for these tests. During acquisition the D*STAR computer system was used to store the images which were later transferred to a laboratory Sun workstation via Bernoulli Disks. The D*STAR system is capable of storing up to 20 minutes of video data. There was no capability for an ethernet output, thus removable Bernoulli disks (not part of the D*STAR system) were used to transfer the data. Without D*STAR storage is limited to 25 frames

on a 3.5 inch floppy disk. RS-170 analog video is also available for VCR or TV monitors, but was not used for data analysis. Software is compatible with Windows and images are stored in the TIFF file format.
There were no problems encountered with the AGEMA Thermovision testing.
During the tests a couple of problems were experienced with the Inframetrics 760. The D*STAR computer system did not work during the initial checkout and it was sent back to the factory for repairs. After repairs the radiometer was again setup for tests, however, it would not work in the normal 8-12 micrometer mode. Another radiometer receiver head was substituted which solved the normal 8-12 micrometer mode problem but created a calibration mismatch with the electronics unit. A second matching electronics unit was not available for these measurements. The mismatched units were used for this test since calibration checks were not a part of this effort. The calibration problem resulted in some lost data due to saturation of signal but in general did not affect the results for these types of tests. Some information was also lost because of data storage problems. Some stored files contained duplicate data thus losing the expected results. The duplication may have resulted from operator or computer error.

SUMMARY

1. Square Wave Response - The Inframetrics is better than the Thermovision as expected with a cutoff horizontal and vertical resolution between .75 and 1.0 cycle/mr vs a cutoff between .5 and .75 cycles/mr. The advantage of the Inframetrics for the horizontal SWR is due primarily to the difference in horizontal FOV (6.67 vs 10 degrees), while the vertical SWR difference is due primarily to the higher number of scan lines for the Inframetrics (192 vs 136).

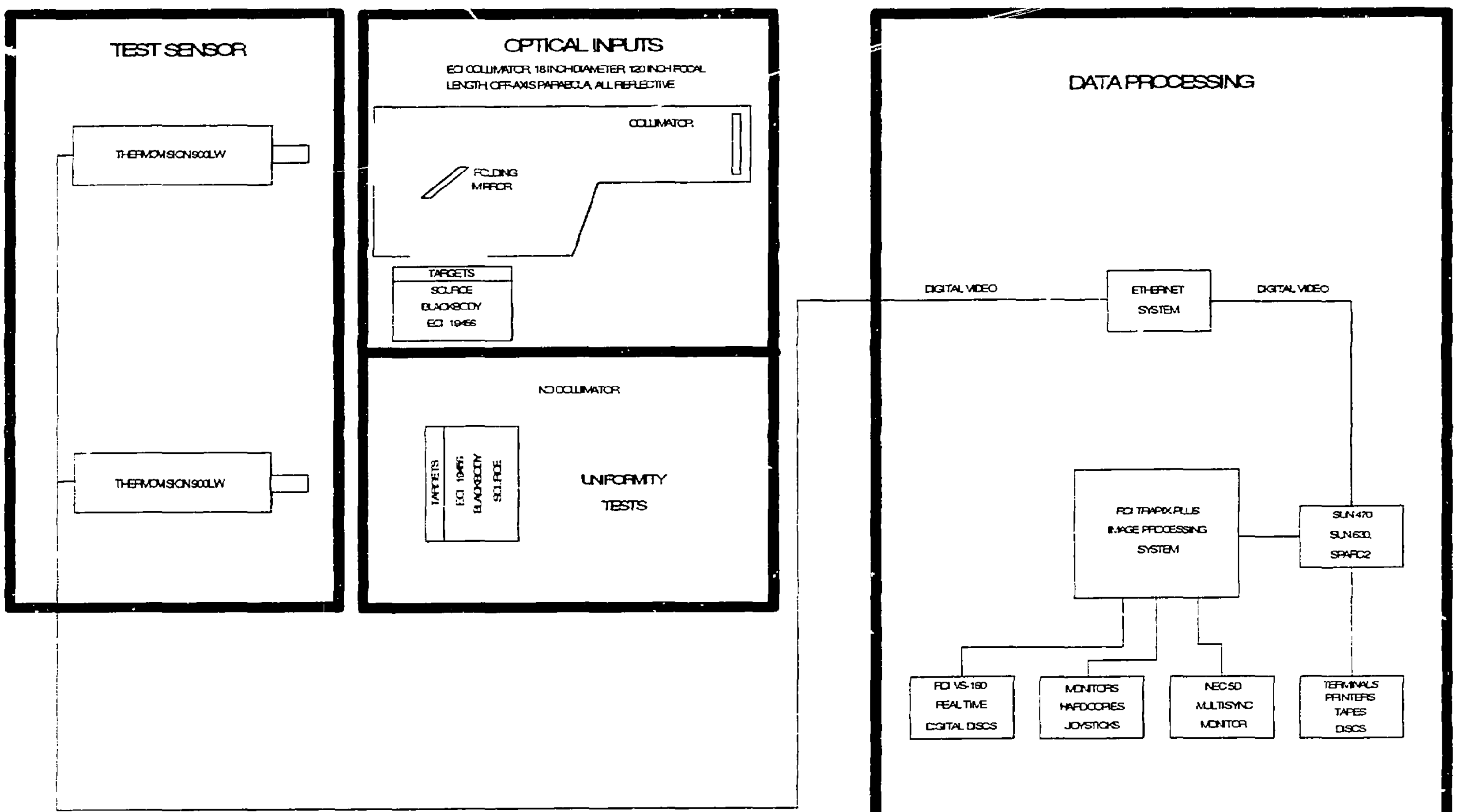
2. Modulation Transfer Function - Supports the SWR data in showing that the horizontal resolution is better with the Inframetrics than the Thermovision.

3. Signal and Noise - The temporal NEDT data clearly shows that the Thermovision has higher sensitivity than the Inframetrics. For comparable temperature windows the Thermovision has an TNEDT of .14 degree C around zero delta temperature vs the Inframetrics TNEDT of .24 degree C.

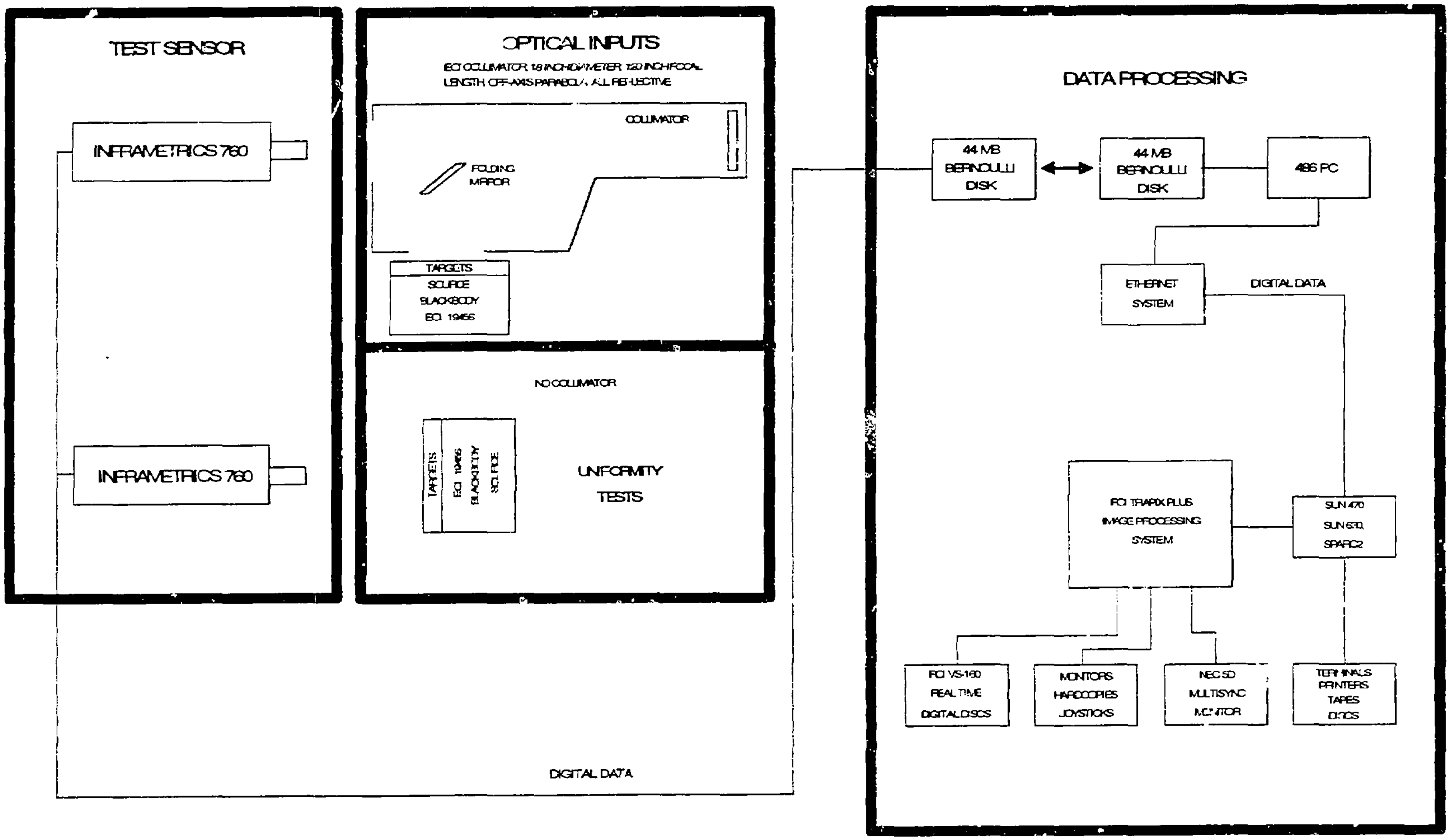
4. Spatial and Temporal Noise - The spatial NEDT data indicates that the Thermovision has better uniformity than the Inframetrics at background temperatures below 30 degrees C. Above 30 degrees C the SNEDTs are about equal.
The temporal NEDT data is essentially the same as that of the signal and noise results above except that the whole frame is evaluated. As with the previous result, the TNEDT data shows the Thermovision to have better sensitivity (.16 degrees C at background temperature of 22 degrees C) than the Inframetrics (.27 degrees C) for similar temperature window modes.
The combined NEDT data is a combination of SNEDT and TNEDT. The CNEDT for the Thermovision is about .17 degrees C at 22 degrees C background temperature and .29 degrees C for the Inframetrics.

5. Blooming - The data shows that image spread was greater for the Inframetrics than for the Thermovision for all three target sizes and at all target temperatures over 100 degrees C.

AGEMA THERMOVISION TEST CONFIGURATIONS



INFRAMETRICS 760 TEST CONFIGURATIONS



SQUARE WAVE RESPONSE

TEST METHODOLOGY AND PROCEDURES -

Measurements were made for the horizontal and vertical SWR, on-axis. A series of 7:1 aspect ratio (bar height to bar width), four-bar patterns were used as targets for these SWR tests. A low resolution pattern was inserted at the collimator focal plane and the delta temperature set so that a strong nonsaturated delta signal could be observed. This delta temperature was fixed throughout this test. The sensor was set up in a fixed window and auto level mode of operation and left in that mode until the SWR set was completed. Fifty digital frames were acquired and stored on the radiometer's disk system for each frequency pattern. This data was later transferred to the laboratory Sun workstation via ethernet (Thermovision) or Bernoulli Disk (Inframetrics) for post processing. The zero frequency pattern modulation was obtained from the signal and noise data which used a low frequency square pattern. This pattern was used as the 100% reference modulation. All the four-bar patterns average peak to peak signals were normalized with respect to this 100% square aperture pattern. Average peak to peak signals was determined by calculating the peak bar signal of each of the four bars and the peak space signal for each of the three spaces between the bars. Bar to adjacent space delta signal was calculated for each of the six edges and averaged to obtain one peak to peak delta signal for each pattern. These measurements were accomplished on a 50 frame average image. The process was repeated for higher and higher resolution patterns until the sensor could no longer resolve the bars.

The AGEMA Thermovision was operated at 15 Hz frame rate, -30 to +80 degree window, and 10X5 degree FOV. The Inframetrics 760 was operated at 30 Hz frame rate, 50 degree differential window, auto level, 8-12 micrometer normal filter, and 6.67X5 degree FOV.

RESULTS -

Plot #1 indicates that the horizontal square wave responses of the Thermovision is not as good as the Inframetrics. The Thermovision could resolve the .5 cycle/mr target but not the .75 cycle/mr target. According to AGEMA's specs the sensor has a spatial resolution of 230 elements per line (50% modulation) and a 174.5 mr horizontal FOV with the 3X lens which translates to .66 element pairs (cycles)/mr. This agrees with the measured cutoff resolution. The Inframetrics could resolve the .75 cycle/mr target but not the 1.0 cycle/mr target. According to Inframetrics specs the sensor has a spatial resolution of 194 elements per line (50% modulation) and a 116.4 mr horizontal FOV with the 2X lens which translates to .83 element pairs (cycles)/mr. This also agrees with measured cutoff resolution. The .25 cycle/mr data point for the Inframetrics is a linear interpolated result rather than measured data. A measurement was made at this resolution, however, the data was saturated and considered invalid. This saturation occurred because of the previously discussed mismatch between radiometer head and electronics.

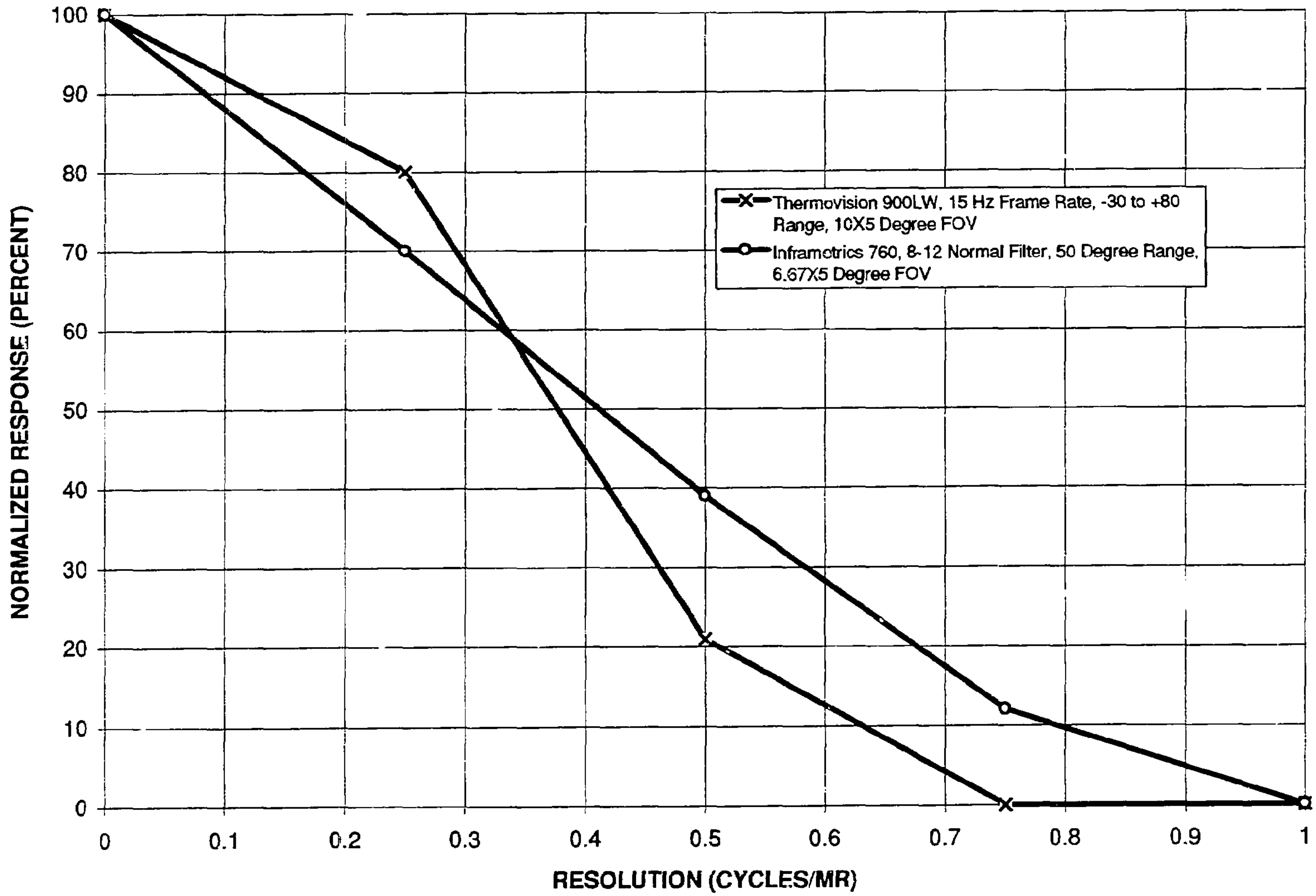
Plot #2 compares the vertical square wave responses between the Thermovision and the Inframetrics. The results are virtually the same as the horizontal SWR. According to AGEMA's specs the sensor has 136 lines in a 87.3 mr vertical FOV with the 3X lens which translates to .66 line pairs (cycle)/mr. This agrees with the vertical SWR data. The Inframetrics specs indicates that the sensor has 192 lines in a 87.3 mr vertical FOV, however, the actual spatial resolution is .60 mr (50% modulation) which is the same as the horizontal case. Thus the Inframetrics calculated vertical cutoff is again .83 cycle/mr. Instead of a 1 to 1 sample vs resolution element as with the AGEMA, the Inframetrics use about a 1.3 to 1 sample vs resolution element ratio.

Resolution (cy/mr)	Thermovision Horizontal SWR (Percent)	Inframetrics Horizontal SWR (Percent)	Thermovision Vertical SWR (Percent)	Inframetrics Vertical SWR (Percent)
0.00	100	100	100	100
.25	80	ND	82	ND
.50	21	39	26	37
.75	0	12	0	11
1.00	0	0	0	0

ND = No Data

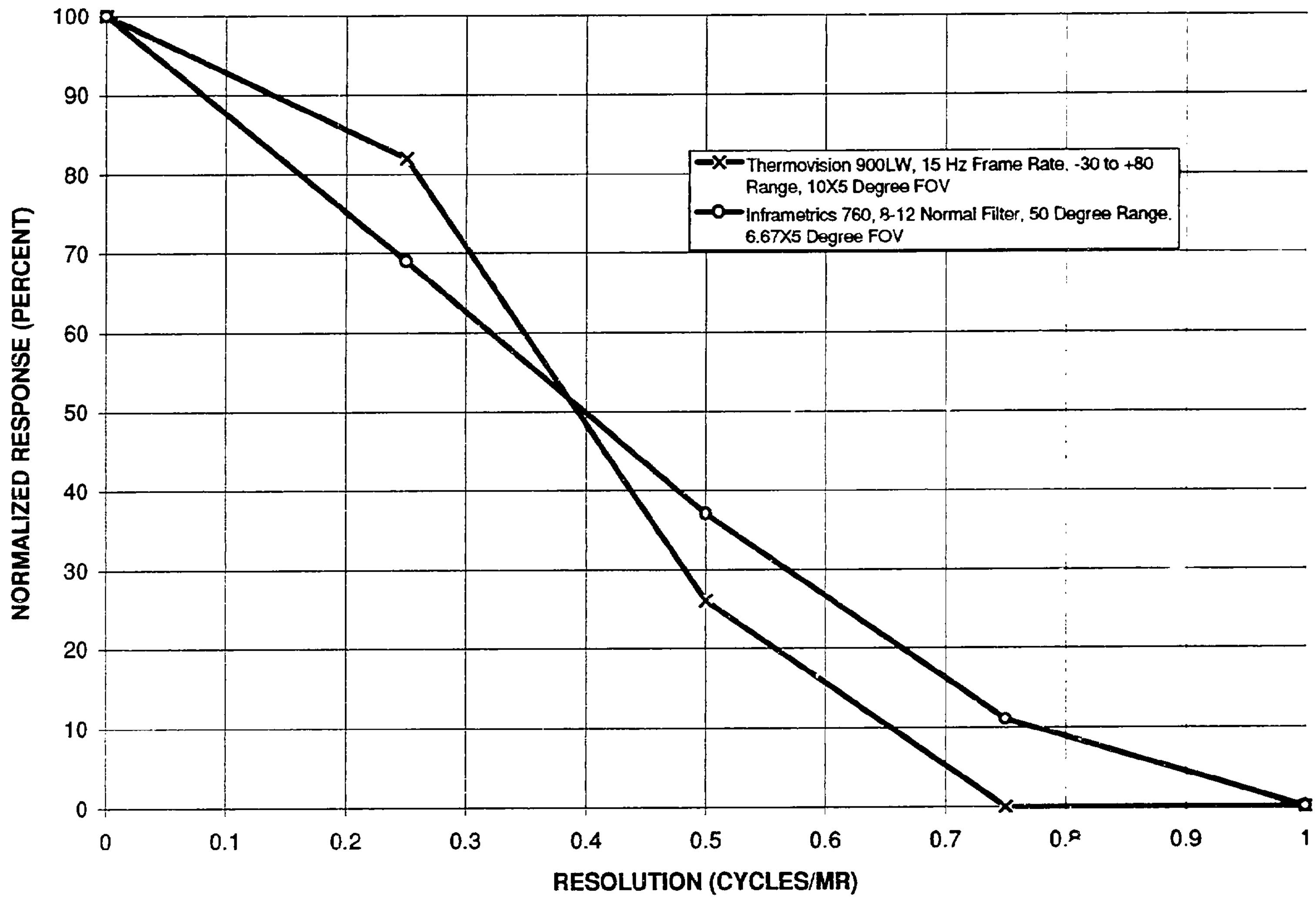
Table #1

HORIZONTAL SQUARE WAVE RESPONSE



PLOT #1

VERTICAL SQUARE WAVE RESPONSE



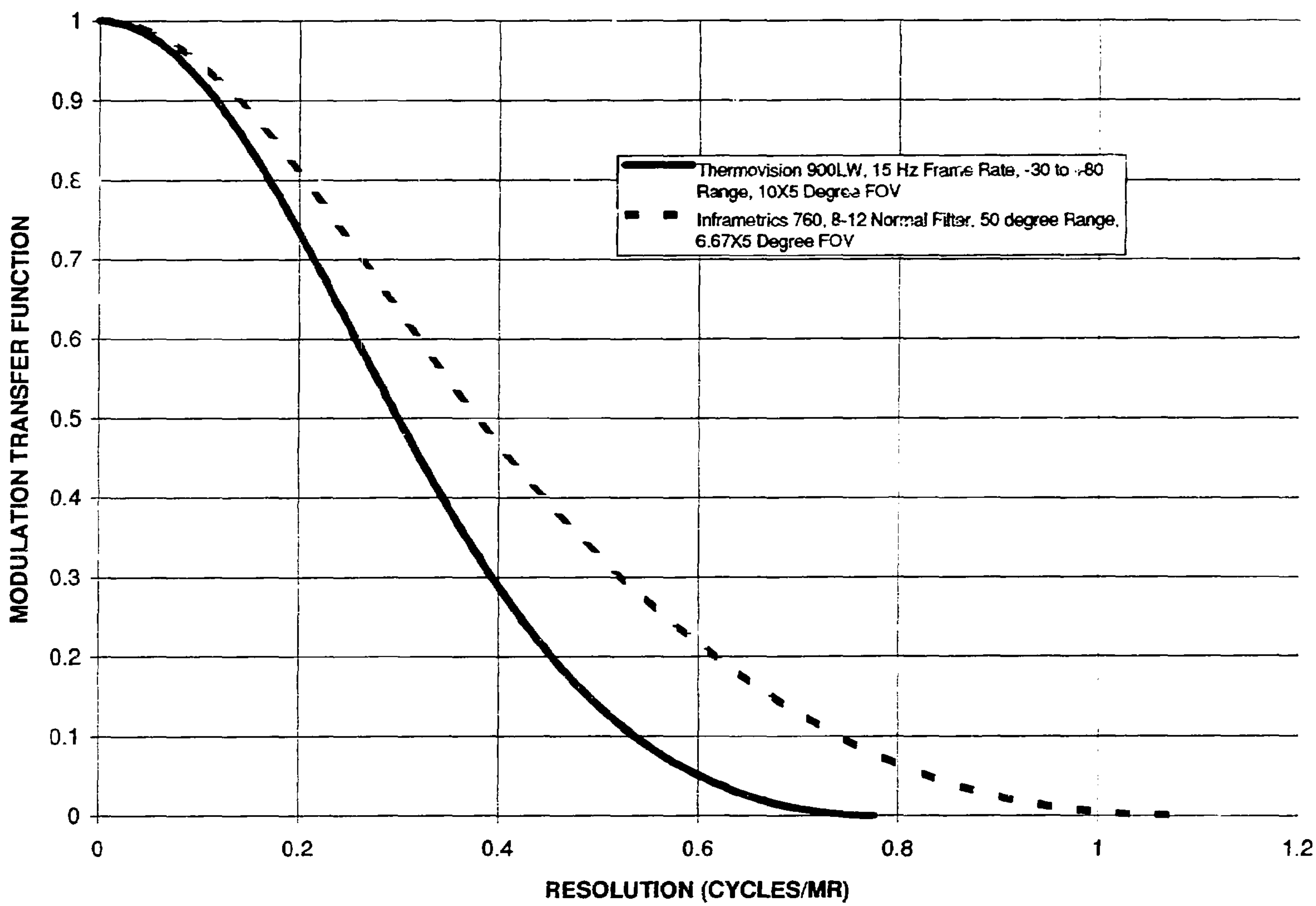
PLOT #2

MODULATION TRANSFER FUNCTION

TEST METHODOLOGY AND PROCEDURES -
Measurements were made for the digital horizontal MTFs on-axis. A vertical slit pattern was positioned in the collimator focal plane to provide an image in the central portion of the sensor's format. The delta temperature of this slit was set to zero degrees Celsius and a set of 50 digital frames acquired and stored. The delta temperature was incremented upward and another set of 50 digital frames acquired and stored. The delta temperatures were incremented higher and higher and the acquisition and storage procedure repeated until the source limitations were reached. The purpose of acquiring this slit signal transfer data was to determine the sensor's linear operating range. The highest temperature slit within the linear range was used to calculate the sensor's representative MTF. The zero delta temperature slit was used to subtract the nonuniformities from the selected slit image prior to computing the MTF. The slit width was 66.25 microradians for both radiometers. The AGEMA Thermovision was operated at 15 Hz frame rate, -30 to +80 degree window, and 10X5 degree FOV. The Inframetrics 760 was operated at 30 Hz frame rate, 50 degree differential window, auto level, 8-12 micrometer normal filter, and 6.67X5 degree FOV.

RESULTS -
Plot #3 compares the horizontal MTFs of the Thermovision and the Inframetrics. The plots agree with the SWR results which show the Inframetrics MTF to be better than the Thermovision for these particular system configurations. The measured cutoff angular resolution for the Thermovision is about .7 cycles/mr as compared to the calculated Nyquist resolution of .66 cycles/mr. The measured cutoff angular resolution for the Inframetrics is about .9 cycles/mr as compared to the calculated Nyquist resolution of .83 cycles/mr. The MTF response at most points are lower than the SWR response at the comparable resolution. This is expected, especially at the lower resolutions, since the MTFs begin to drop in magnitude immediately with a reduction in sensor frequency response, while the square wave will show rounded edges with constant magnitude at lower frequencies before dropping off in magnitude at higher frequencies. Thus, typically, the SWR will be higher than the MTFs at lower frequencies and converges towards the MTF magnitudes at higher frequencies.

HORIZONTAL MODULATION TRANSFER FUNCTION



PLOT #3

SIGNAL AND NOISE

TEST METHODOLOGY AND PROCEDURES -

A square aperture pattern (12 mr) was collimated and centered in the radiometer's FOV. The deltat temperature was set to a selected negative delta temperature which either saturated the video or reached the source limitations. Fifty digital frames were acquired and stored on the radiometer's disk system. The delta temperature was incremented upward and the process repeated. This continued until the high end saturation of the video or until source limitation was reached. The 50 frames were reduced to two frames (average and standard deviation frames) using the Sun workstations. Representative areas in the target and background for the average frame were used to determine the delta signal while the same areas in the standard deviation frame were used to determine the temporal noise. The standard deviation frame was calculated by computing the standard deviation of each pixel for the 50 frames. The temporal noise equivalent delta temperature (TNEDT) was calculated by multiplying the delta temperature with the temporal noise and dividing the result by the delta signal.

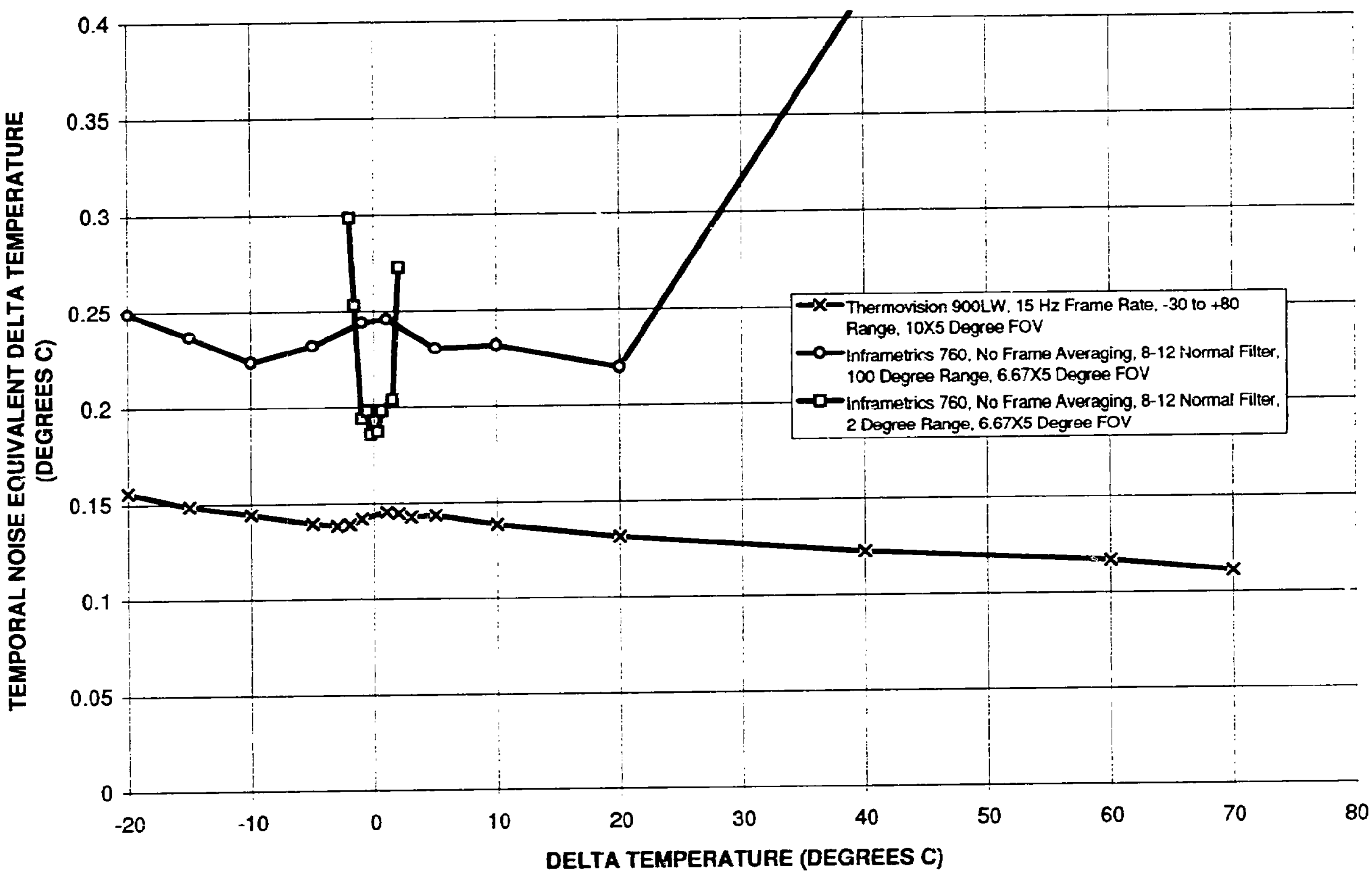
RESULTS -

Plot #4 compares the temporal noise equivalent delta temperature of the Thermovision and the Inframetrics at two range settings (2 and 100 degrees Celsius). The Thermovision is clearly better than the Inframetrics at either range setting. The Thermovision TNEDT varied from about .16 at -20 degrees delta temperature to .11 at 70 degrees delta temperature. This downward slope with increasing delta temperatures is primarily due to the nonlinear relationship between temperature and radiance. At -20 degrees delta temperature the absolute temperature is about 2 degrees C and at 70 degrees delta temperature the absolute temperature is about 92 degrees C. At the lower absolute temperatures a delta temperature of one degree has less total radiance in the 8-12 band than a one degree delta temperature at the higher absolute temperatures. This results in lower (or higher) delta signals per degree C because the radiometers are linear with respect to radiance rather than temperature. The Inframetrics TNEDT for the 100 range setting varies between .25 and .22 degrees C except for the last point. The TNEDT rises sharply at 40 degrees delta temperature because the delta signal is saturating. The TNEDT for the 2 range setting improves to about .18 degrees C at its best. The curve is U shaped due to saturation effects at both low and high ends. The 2 degree range has better results than the 100 degree range because of better temporal noise values at this range setting. This indicates that the some of the radiometer's temporal noise is gain independent which will result in worse TNEDT values with increasing gain.

Delta Temperature Degrees C	Thermovision TNEDT Degrees C		Delta Temperature Degrees C	Infra -100 Deg Range TNEDT Degrees C		Delta Temperature Degrees C	Infra - 2 Deg Range TNEDT Degrees C
-20.0	.156		-19.97	.249		-1.98	.298
-15.0	.149		-14.97	.237		-1.58	.253
-10.0	.144		-9.97	.224		-.98	.194
-5.0	.139		-4.97	.232		-.58	.198
-3.0	.138		-.97	.244		-.28	.186
-2.0	.139		1.03	.245		.32	.187
-1.0	.142		5.03	.230		.62	.198
1.0	.145		10.03	.232		1.52	.204
2.0	.144		20.03	.220		2.02	.272
3.0	.143		40.03	.413			
5.0	.143		70.03	.744			
10.0	.138						
20.0	.131						
40.0	.122						
60.0	.117						
70.0	.111						

Table #2

TEMPORAL NOISE EQUIVALENT DELTA TEMPERATURE



PLOT #4

SPATIAL AND TEMPORAL NOISE

TEST METHODOLOGY AND PROCEDURES -

The primary purpose of this test was to obtain spatial uniformity data, however, temporal noise is also obtained as a fallout from this test. Due to the relatively wide FOV of the radiometers the collimator, which was designed to handle narrow FOVs, was not used. A 7X7 uniform blackbody source was setup to cap the radiometer input optical aperture. The source temperature was varied from 2 degrees C to 62 degrees C to simulate different background temperatures that might be encountered by the radiometer in the field. At each background temperature 50 frames of digital video were acquired and stored for postprocessing. The 50 frames were reduced to two frames (average and standard deviation frames) using the Sun workstations. The entire average frame was used to determine the spatial noise (standard deviation of average frame) while the entire standard deviation frame was used to compute the temporal noise (average of standard deviation frame). A combined noise result was also calculated by taking the square root of the sum of the squares for the spatial and temporal noise data. The noise equivalent delta temperatures were obtained by using the delta signal per degree C calibration from the signal and noise data since the same radiometer gain settings were employed.

The AGEMA Thermovision was operated at 15 Hz frame rate, -30 to +80 degree window, and 10X5 degree FOV. The Inframetrics 760 was operated at 30 Hz frame rate, 2 and 100 degree differential windows, auto level, 8-12 micrometer normal filter, and 6.67X5 degree FOV.

RESULTS -

Plot #5 compares the spatial noise equivalent delta temperature (SNEDT) between the Thermovision and the Inframetrics at two range settings (2 and 100 degree C). The Inframetrics at 2 degree C range is about equal to the Thermovision except at the higher source temperatures, where the Thermovision is slightly better. At the 100 degree C range the Inframetrics is about equal to the Thermovision for source temperatures above 30 degrees C, however, at lower source temperatures the SNEDT becomes clearly worse than the Thermovision. Spatial noise generally gets worse as background temperatures deviate from the sensor housing temperatures. This is the reason for the U shaped curves in the plot. For example, if the optics had high transmission at the center of the format and slightly lower transmission at the edge the nonuniformity would not be obvious if both the optics and the scene temperatures were the same since no differential temperatures would exist. If the scene was hotter than the optics, however, transmission difference would show up as a hot center and colder edge. The opposite would occur if the scene were colder than the optics. The SNEDT results indicate that both sensors are about equal in overall results.

Plot #6 compares the temporal noise equivalent delta temperature (TNEDT) between the Thermovision and the Inframetrics at two range setting (2 and 100 degree C). The Thermovision is clearly better with temporal noise than the Inframetrics in either range mode. This agrees with the signal and noise temporal data. The Thermovision TNEDT

varied from about .15 to .17 degrees C with a slight upward slope with increasing background temperatures. This upward slope may be due to a signal dependent noise. The Inframetrics at 2 degree C range varies from about .19 to .21 degrees C with a slight upward slope with increasing background temperatures. The Inframetrics at 100 degree C range is quite different than the other two data sets. The TNEDT drops from about .35 to .20 degrees C with increasing background temperatures. The data was expected to be similar in trend to the 2 degree C range plot except higher in magnitude. This departure in expected and measured result may be due to a problem with the radiometer which could have been caused by the mismatch between radiometer head and electronics.
Plot #7 compares the combined temporal and spatial noise equivalent delta temperatures (CNEDT) between the Thermovision and the Inframetrics at 2 and 100 degree C range setting. The Thermovision was better than the Inframetrics in either range modes. The CNEDT ranged from a low of about .17 degrees C to a high of .22 degrees C. The Inframetrics at 2 degree C range varied from a low of .20 degrees C to a high of .27 degrees C. The Inframetrics CNEDT data at 100 degree C range is also suspect since the TNEDT is a primary component of the result. The data varies from about .21 degrees C to .44 degrees C.

AGEMA Thermovision

Bkgnd Temperature Degrees C	SNEDT Degrees C	TNEDT Degrees C	CNEDT Degrees C
2	.135	.155	.206
12	.109	.159	.193
22	.074	.160	.176
32	.042	.159	.165
42	.054	.161	.170
52	.083	.161	.181
62	.136	.168	.216

Table #3

Inframetrics - 100 Degree C Range

Bkgnd Temperature Degrees C	SNEDT Degrees C	TNEDT Degrees C	CNEDT Degrees C
2	.259	.345	.431
12	.159	.321	.358
22	.090	.271	.286
32	.045	.257	.261
42	.047	.202	.207
52	.091	.212	.231

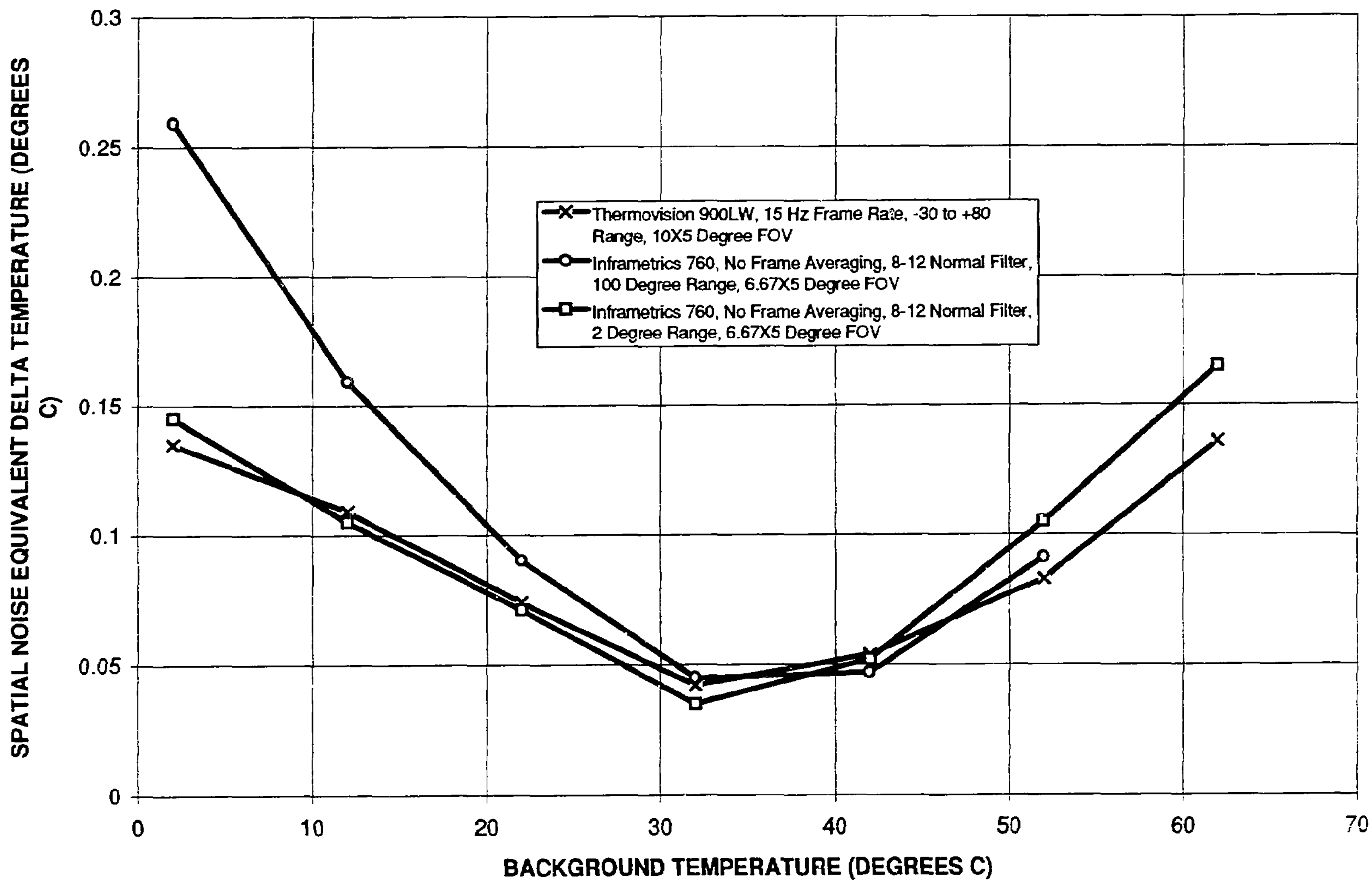
Table #4

Inframetrics - 2 Degree C Range

Bkgnd Temperature Degrees C	SNEDT Degrees C	TNEDT Degrees C	CNEDT Degrees C
2	.145	.187	.237
12	.105	.190	.217
22	.071	.194	.207
32	.035	.197	.200
42	.052	.202	.209
52	.105	.206	.231
62	.165	.210	.267

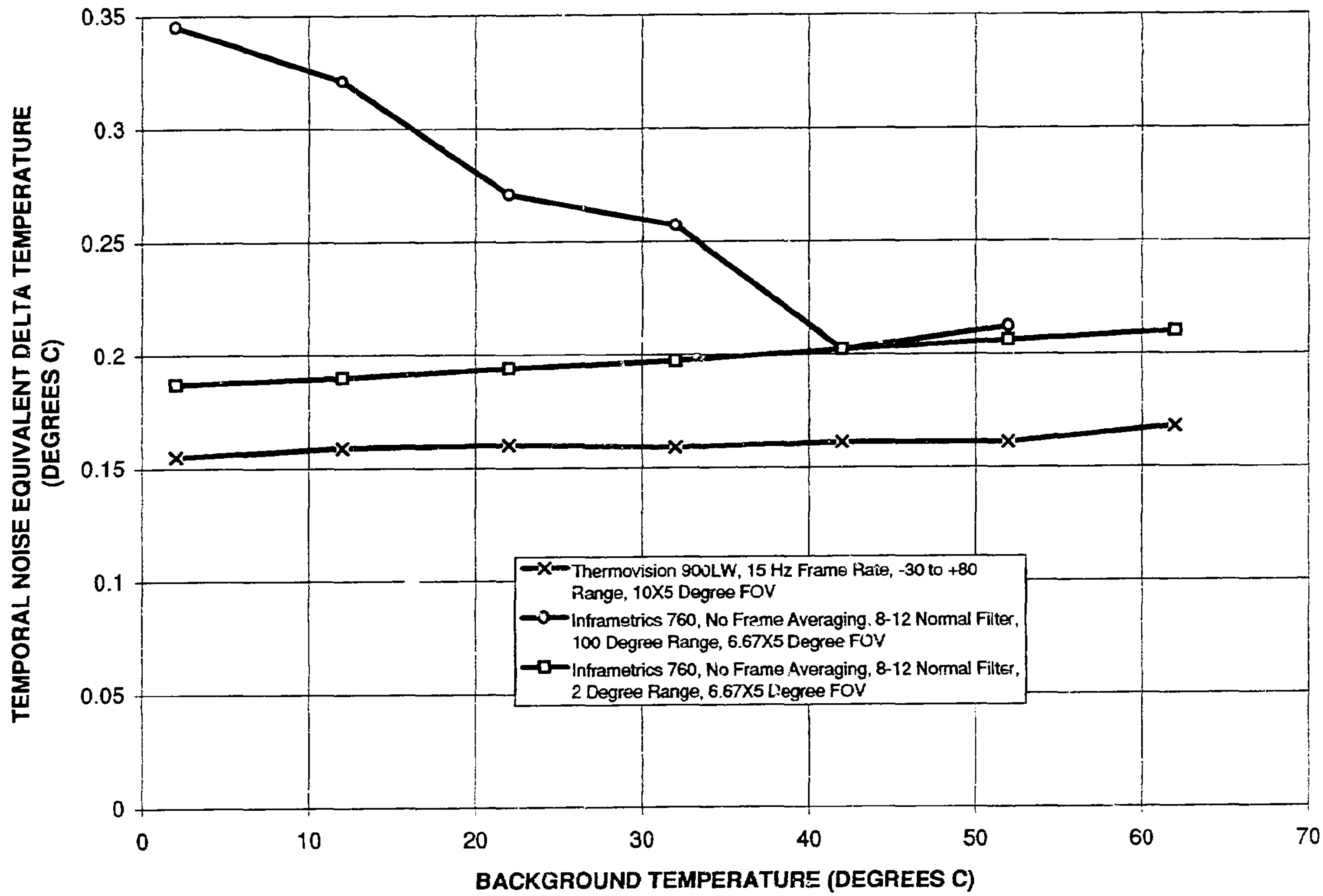
Table #5

SPATIAL NOISE EQUIVALENT DELTA TEMPERATURE

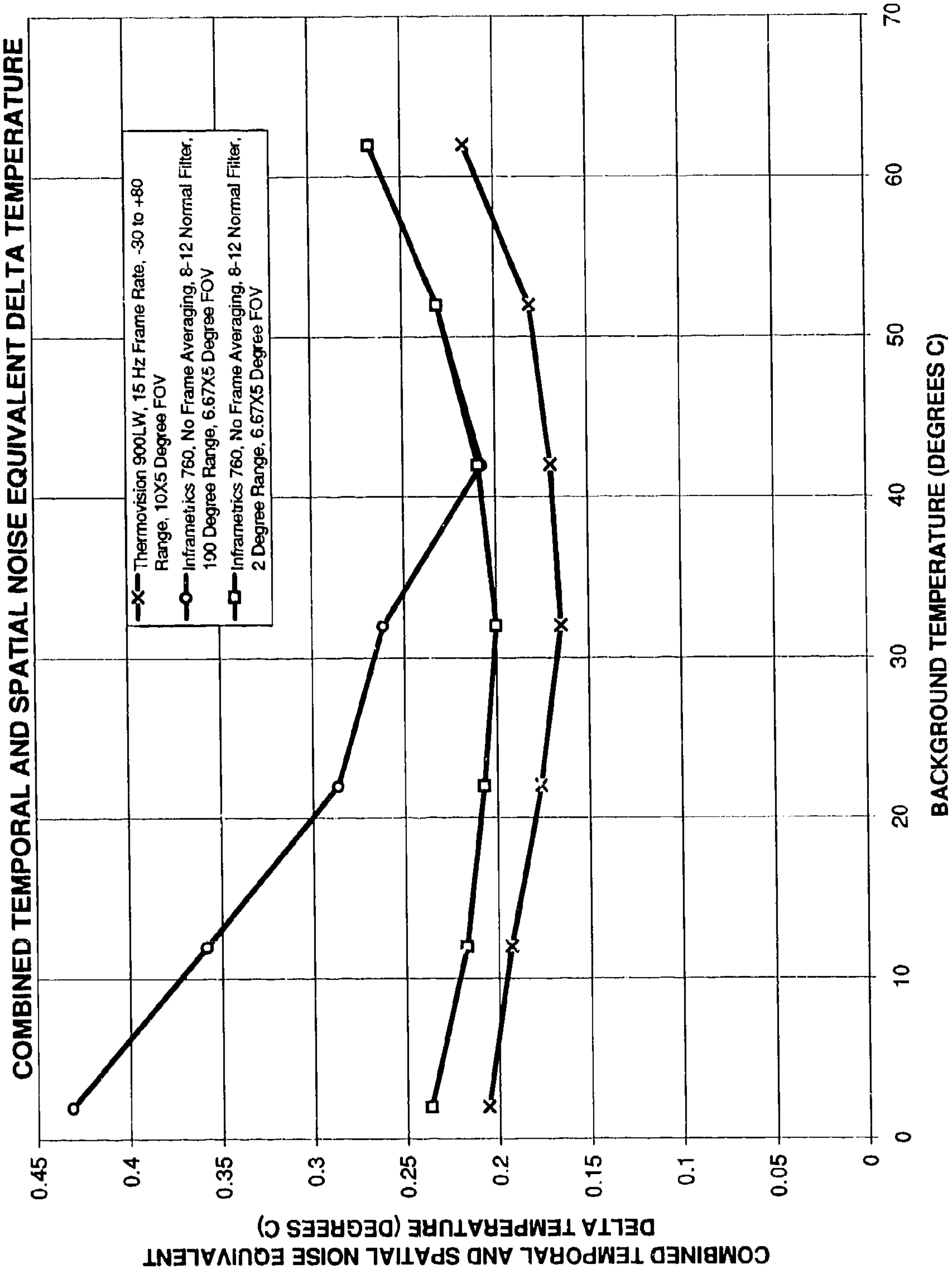


PLOT #5

TEMPORAL NOISE EQUIVALENT DELTA TEMPERATURE



PLOT #6



COMBINED TEMPORAL AND SPATIAL NOISE EQUIVALENT DELTA TEMPERATURE
Thermovision 900LW, 15 Hz Frame Rate, -30 to +80 Range, 10X5 Degree FOV
Inframetrics 760, No Frame Averaging, 8-12 Normal Filter, 100 Degree Range, 6.67X5 Degree FOV
Inframetrics 760, No Frame Averaging, 8-12 Normal Filter, 2 Degree Range, 6.67X5 Degree FOV
COMBINED TEMPORAL AND SPATIAL NOISE EQUIVALENT DELTA TEMPERATURE (DEGREES C)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10
20
30
40
50
60
70
BACKGROUND TEMPERATURE (DEGREES C)

PLOT #7

BLOOMING

TEST METHODOLOGY AND PROCEDURES -

The purpose of this measurement was to determine the amount of image spread (crosstalk) vs increasing target temperatures. Three circular targets were used (7.81 mr, 3.33 mr, and 1.67 mr) with temperatures ranging from 100 to 1000 degrees C. The target was setup in the collimator and centered in the radiometer's FOV. The target temperature was set to 100 degrees C and 50 digital frames were acquired and stored on the radiometer's disk system. The target was switched and another set of digital frames acquired and stored. This procedure was repeated for the third target. The target temperature was increased only after the acquisition of data for the various target and radiometer window settings were completed. The target temperature was the last variable to be reset because of the extensive amount of time required to reach and stabilize at the set temperature point. Each 50 frame set was averaged to obtain an average frame which was used to make the measurement. The 50% amplitude width for a line through the center of the target image in the horizontal direction was measured in terms of pixels (digital samples). In order to compare the Thermovision with the Inframetrics the image spread was expressed as a factor of the calculated reference size. For example, the 7.81 mr target was expected to have 12.03 samples across the image diameter. This was the normalizing constant used for all the Thermovision data for the 7.81 mr target. At 200 degrees C target temperature the measured width was 13.35 samples thus, the image spread factor was 13.35 divided by 12.03 or 1.11.

The AGEMA Thermovision was operated at 15 Hz frame rate, -30 to +80 and 0 to 250 degrees C windows, and 10X5 degree FOV. The Inframetrics 760 was operated at 30 Hz frame rate, 100 degree C differential window, auto level, 8-12 micrometer normal filter, and 6.67X5 degree FOV.

RESULTS -

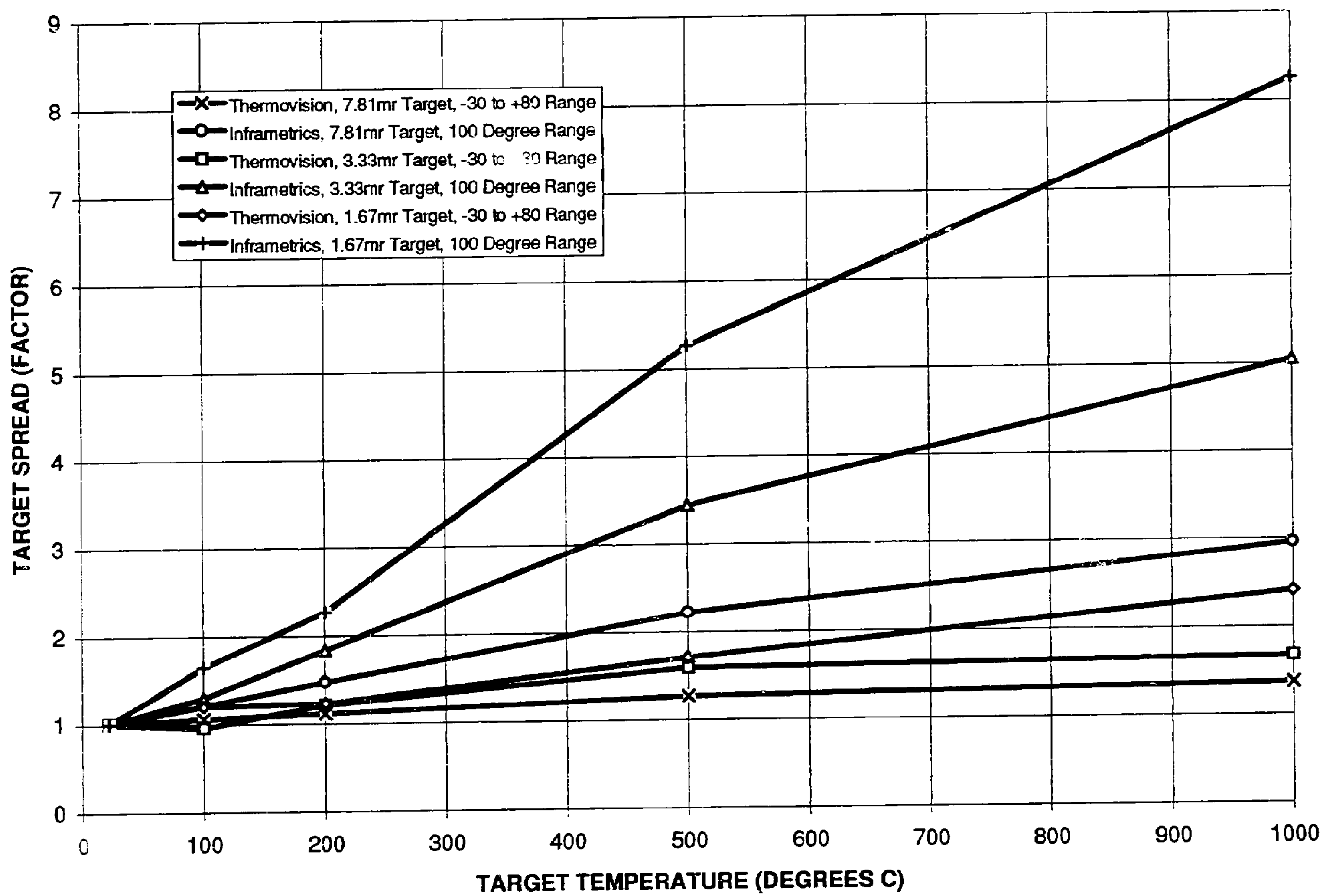
Plot #8 compares the horizontal image spread for the Thermovision and the Inframetrics for three different targets. The Inframetrics showed much greater image spread than the Thermovision for all target sizes.
Image #1 shows the blooming effect in the Thermovision for a 7.81 mr circular target at 1000 degrees C with the range set at -30 to +80 degrees C window.
Image #2 shows the blooming effect in the Inframetrics for a 7.81 mr circular target at 1000 degrees C with the range set at 100 degrees C window. The image spread is much greater for the inframetrics than with the Thermovision.

Target Temp (Deg C)	AGEMA 7.81 mr Target	Infra 760 7.81 mr Target	AGEMA 3.33 mr Target	Infra 760 3.33 mr Target	AGEMA 1.67 mr Target	Infra 760 1.67 mr Target
22	1.00	1.00	1.00	1.00	1.00	1.00
100	1.06*	1.21	0.96	1.30	1.20	1.64
200	1.11	1.47	1.21	1.83	1.23	2.26
500	1.27	2.22*	1.59	3.44*	1.71	5.26*
1000	1.37	2.96	1.67	5.05	2.41	8.25

* - Indicates that this value is a calculated linear interpolated point.

Table #6

HORIZONTAL BLOOMING



PLOT #8

Thermovision Blooming Image

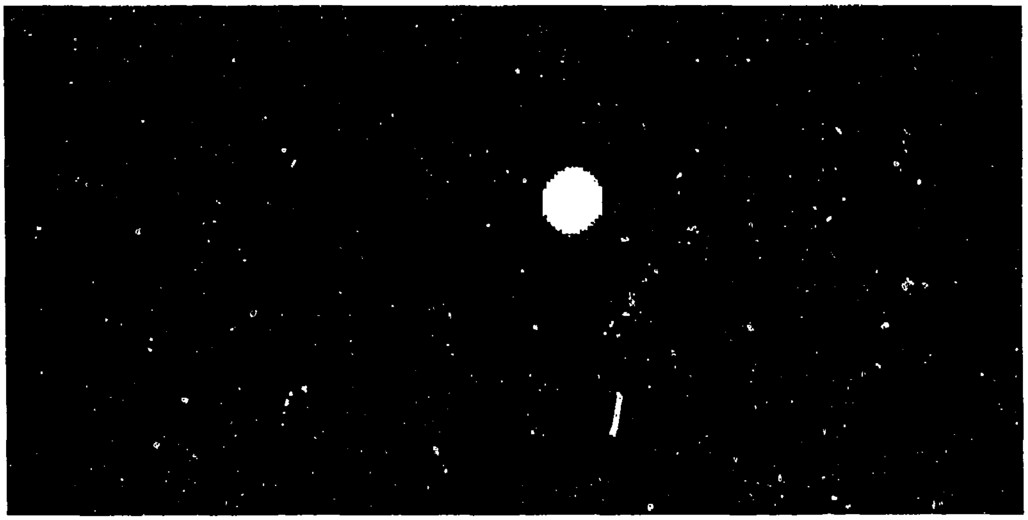


Image #1 - 7.81 mr target, 1000 degrees C, -30 to +80 degree range.

Inframetrics Blooming Image

Image #2 - 7.81 mr target, 1000 degrees C, 100 degree C range.