

# In Situ Emissivity Measurements of Natural and Artificial Surfaces by the Cone Method

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## Abstract

During the Clark Atlanta University (CAU), summer 2002 Research Experiences for Undergraduates, field measurements of radiative and kinetic temperatures of various artificial and natural surfaces were made. Measurements of a granite monadock, brown loam soil, red clay soil and the rubber roof, concrete, brick and asphalt of the surroundings of the Research Center for Science and Technology (RCST) on the CAU campus were made using the cone method first devised by Fuchs and Tanner<sup>2</sup>. Two cones were used to take the measurements and calculate the emissivities, one had a highly polished aperture and one had an unpolished aperture. The calculated emissivity values were compared to published data and recommendations for further data analysis and more accurate measurements were made.

## Introduction

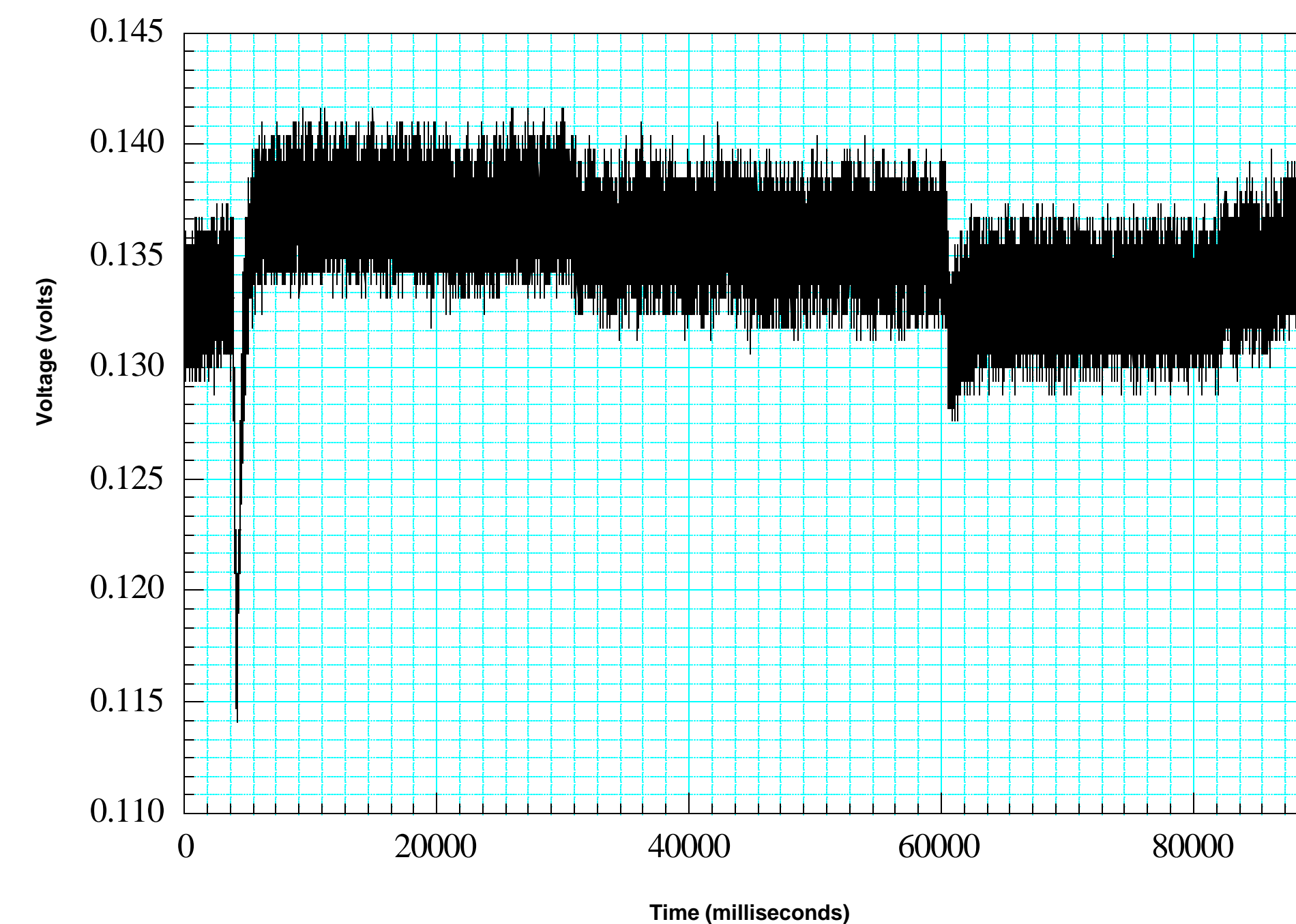
Measurements of the surface temperature by contact thermometry are subject to serious error. It is difficult to maintain good thermal contact between the sensor and the surface without disturbing the conditions of the surface. That is because every thermometer has its own thermal and radiative properties, and the surface itself constantly emits and receives radiation from the atmosphere, which has a different temperature. Remote sensing techniques, like infrared thermometry provide a partial solution to this problem because they don't enter in contact with the surface under study, but they too have their limitations. If the emissivity of the surface is not taken into account no instrument can yield a correct estimate of the surface temperature. Emissivity is defined as the relative emissive power of a radiating surface expressed as a fraction of the emissive power of a blackbody radiator at the same temperature. A blackbody is defined as a theoretical object that radiates the maximum amount of energy at a given temperature, and absorbs all the energy incident upon it. In reality, surfaces don't behave as a blackbody because they reflect radiation to the atmosphere; this makes it difficult to determine the emissivity. Two cones, a polished and an unpolished one of 11" height, 15" diameter at the base and 2.25" diameter at the apex were used to provide a black body chamber where the IR temperature sensor was able to measure the kinetic temperature of the target surface, thereby removing the emissivity effect of the gray body target. The cone method compares the measured apparent radiative (without the cone) temperature of the target to the measured kinetic (with the cone) temperature of the target. This comparison is actually done by comparing radiances derived from the temperature measurements, and these radiance values are each corrected for the amount of incoming radiance from the sky. The ratio of the corrected radiance from the surface measured without the cone to the corrected radiance from the surface measured while under the cone is taken to be the emissivity of the target surface.

## Procedures and Data

Multiple runs were made on each surface. A data acquisition board was used, gathering readings at a rate of 1,000 measurements per second. The OS 532 Infrared Temperature Sensor was used, set at varying emissivities. A voltmeter was connected to the sensor to allow for verification of the digitally acquired data.

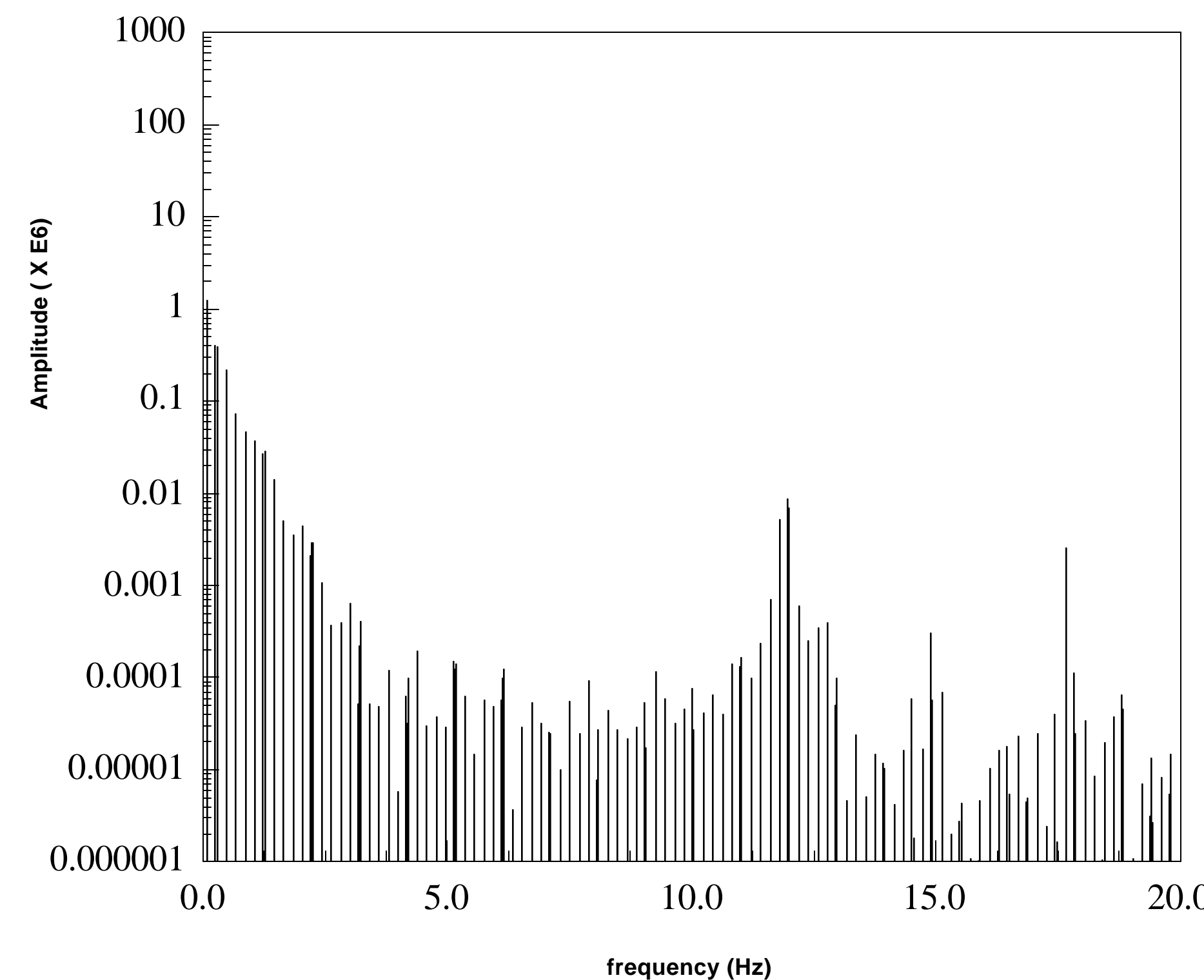
The collected data was extremely noisy, likely resulting from electrical activity in the vicinity of the sites. The noise made it nearly impossible to get an accurate temperature from the data.

Emissivity Run 2 9 July 02 Rubber Roof of RCST  
Time Series of All Data OS 532

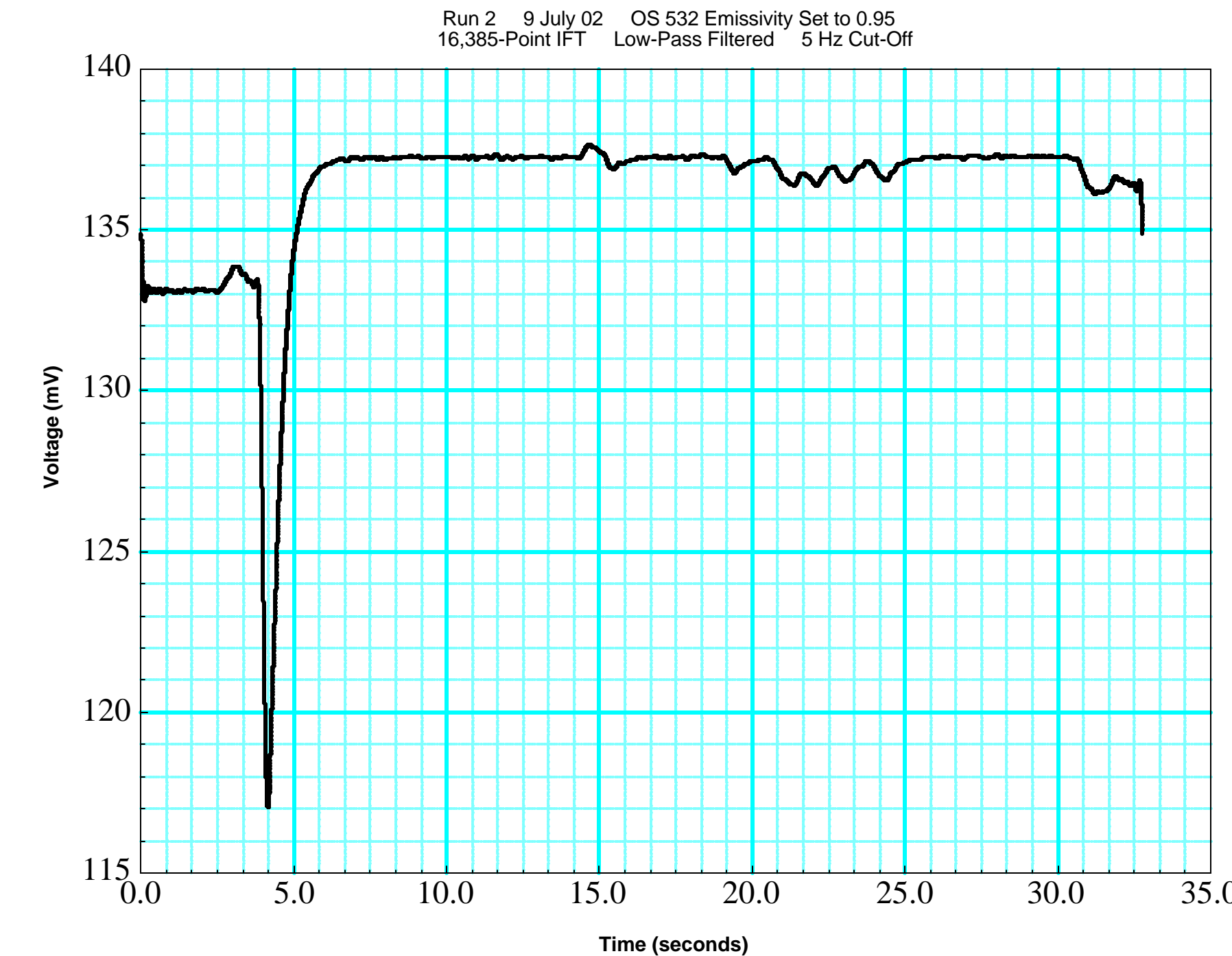


In order to interpret the data accurately, a Forward Fourier Transform was performed to determine at what frequency the signal for the data ended and the noise began.

Amplitude Spectrum of Run 2 on 9 July 2002  
32,768-point FFT OS 532 Emissivity Set to 0.95



After filtering the data at the correct frequency, an Inverse Fourier Transform was performed, and the temperatures could be read with more accuracy.



With the temperatures easily read from the IFT charts, the difference in temperatures was used to calculate emissivity for each run.

Run#	surface	time of day	cone	Emissivity
1	concrete	late afternoon	shiny	0.85
2	concrete	late afternoon	shiny	0.91
3	concrete	late afternoon	shiny	0.85
4	concrete	late afternoon	shiny	0.89
5	concrete	early afternoon	shiny	0.97
6	concrete	early afternoon	shiny	0.94
7	concrete	early afternoon	shiny	0.89
8	concrete	early afternoon	shiny	0.97
9	concrete	early afternoon	shiny	0.93
10	concrete	early afternoon	shiny	0.95
11	concrete	early afternoon	shiny	0.88
12	concrete	early afternoon	shiny	0.98
			St.Dev.=	0.04595
			Average=	0.9175

Run#	surface	time of day	cone	Emissivity
1	asphalt	late afternoon	shiny	0.97
2	asphalt	late afternoon	shiny	0.96
3	asphalt	late afternoon	shiny	0.94
4	asphalt	late afternoon	shiny	0.96
5	asphalt	early afternoon	shiny	0.85
6	asphalt	early afternoon	shiny	0.89
7	asphalt	early afternoon	shiny	0.86
8	asphalt	early afternoon	shiny	0.89
9	asphalt	early afternoon	shiny	0.89
10	asphalt	early afternoon	shiny	0.86
11	asphalt	early afternoon	shiny	0.92
12	asphalt	early afternoon	shiny	0.88
			St.Dev =	0.0427377
			Average =	0.9058333

Run#	surface	time of day	cone	Emissivity
2	R.Roof	afternoon	Dull	0.92
3	R.Roof	afternoon	shiny	0.93
4	R.Roof	afternoon	Dull	0.96
6	R.Roof	afternoon	Dull	0.9
7	R.Roof	night	Dull	0.81
9	R.Roof	night	Dull	0.87
10	R.Roof	night	shiny	0.82
11	R.Roof	night	Dull	0.88
			St.Dev. =	0.052355
			Average =	0.88625

Run#	surface	time of day	cone	Emissivity
19	brick	evening	shiny	0.9
20	brick	evening	dull	0.9
21	brick	evening	shiny	0.88
22	brick	evening	dull	0.83
23	brick	evening	shiny	0.87
23-2	brick	evening	shiny	0.9
24	brick	evening	dull	0.72
			St. Dev. =	0.065502
			Average =	0.857143

Run#	surface	time of day	cone	Emissivity
31	brick	night	shiny	0.88
32	brick	night	shiny	0.88
33	brick	night	shiny	0.88
34	brick	night	shiny	0.86
35	brick	night	shiny	0.86
36	brick	night	shiny	0.85
37	brick	night	shiny	0.88
38	brick	night	shiny	0.86
39	brick	night	shiny	0.86
			St.Dev. =	0.0120185
			Average =	0.8677778

## And finally...

The above tables report the calculated emissivity for each run, and the average and standard deviation for each group of runs.

There is further data that remains to be analyzed, as well as suggested refinements for improving the data. The measurements were made in urban areas, in which walls were nearby. The walls radiate in all directions, including towards the measured area. To improve the data, measurements should be made in open areas as much as possible. Additionally, data taken during the day tends to have significantly more noise than data taken in the evening. Further measurement should be taken after sunset or before sunrise whenever possible.