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Purdue University

NOTES ON AN EXPERIMENT TO DETERMINE THE EFFECT OF SURFACE GEOMETRY ON THE EMISSIVITY OF WATER

by T. A. Martin

INTRODUCTION: In most of the literature when apparent temperature of water is discussed, emissivity is assumed to be approximately .98 to .99 and constant under most conditions. There seemed to be no experimental evidence to firmly support this assumption. In the spirit of empiricism, the following is an attempt to test the assumption that water always has an emissivity of .98 to .99.

THE METHOD PROPOSED: The procedure to be used set up an environment that could be controlled with respect to temperature and water surface geometry. Then with the use of a Barnes Engineering PRT-5, measurements of apparent temperature were made as changes in temperature and surface geometry were affected, the emissivity was to be calculated as those changes occurred. The changes were to occur in one variable holding all else constant.

THE DIFFICULTIES: Measurement of apparent temperature of a body of water in the 8.00 to 14.00 micrometer band by the PRT-5 rely on the first .1 milimeter of water being the same temperature as the rest of the body.[1] This, in fact is only true when the water and in this

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[1] This might be overcome if one were sure that a surface contact measurement of temperature could be made. An idea for using a flake thermistor secured to a stabilized ping pong ball was considered but not implemented.

case air are at the same temperature and when the air is saturated to prevent evaporative cooling, or when the water is in a transition phase where the process overrides the normal interface process (at least this seems to be true). An environment chamber was obtained and preliminary experimentation was begun. The immediate problem was to generate specified surface geometries. The specified geometry, to simulate a roughened surface, might be generated in the field of view of the PRT-5 in a number of ways. For instance the following: (1) set up standing waves of varying frequency in parallel waves, (2) set up travelling waves (should be absorbed by tank walls) of different types (parallel, circular), and (3) freeze water in different shapes.[2] The third type utilizes a transition phase and does limit the experiment to two temperatures, essentially 0° and 100° Celsius (assuming pure water and standard atmospheric pressure). However, one can live with this limitation since such a variety of very specific shapes can be generated.

The question of what is rough as seen by the PRT-5 is an important question for the determination of the surface geometries to include in the measurements; however, that question will not be answered here because other problems turned attention from it. The only comment seeming appropriate is that the question, answered correctly, is not trivial.

In the preliminary experiments the third method of surface generation was used, because it was found that at higher temperatures

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[2]This idea was suggested by B. F. Robinson of LARS

condensation occured on the polyethylene window[3] which would tend to attenuate the energy from the surface in an undefined manner.

THE PRT-5: At this point attention turned to the PRT-5 where noise was thought to be on the output as measured by a digital voltmeter. The concern was the noise was larger than permitted to detect .1° Celsius changes in apparent temperature. Whether this degree of accuracy was needed for the emissivity experiments or not, it brought up the question of the instruments usefulness in measuring to .1° Celsius any apparent temperature. Another problem was that meter indications and recorder output calibration curves in a reference table in the PRT-5 manual were not in agreement. The readings being taken were of smooth and rough ice surfaces taken when a film of water covered the surface thus assuring the transition phase was occuring, but the readings were so unstable in the digits needed to determine if different apparent temperatures were occurring that no conclusions could be reached.

CONCLUSIONS AND RECOMMENDATIONS: Any conclusions cannot be made based on the present results; however, it is recommended that (1) a chamber be used that can contain the PRT-5 within the controlled environment, (2) a determination of the proper dimensions to be considered in specifying roughness be made (3) determine if the PRT-5 is sufficiently sensitive to make the needed measurements, (4) implement a method to measure by contact the surface temperature to a depth of less than .1 millimeter,

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[3]When the environment chamber is closed to set up a saturated atmosphere at the same temperature as the water body a means for viewing the surface is needed. Polyethylene has the best transmission characteristics in the 8 to 14 micrometer band, and was to be used as the view window.

and finally (5) try to predict what an instrument such as the PRT-5 would register for different black and gray body radiations. A beginning tool for part five is given in the appendix of this paper.

APPENDIX

Introduction: The need to know the energy being emitted from a black-body at some temperature, in specified wavelength intervals or band-widths, has promoted the development of the program described below. The program is written in Fortran IV language and is written for the LARS IBM 360-44 computer.

Description: The program described below computes the energy radiated from a blackbody with temperature T. The main purpose of the program was to find the total energy radiated by a blackbody in a specified bandwidth, but because of the ease of combining other features, the program now also computes energy values at single wavelengths, plus has the ability to iterate over both temperature and wavelength.

In all, there are six modes of operation controlled by the manner the data card is punched. These are outlined in the section on use. Temperature may be expressed in any units provided the units are signified in column 71 of the data card (K for Kelvin, C for Celsius, F for Farenheit, and R for Rankine). If the units are not signified the program assumes Kelvin units. At this writing, there is no protection in the program for error due to assigning the wrong units or leaving column 71 blank when using other than Kelvin units.

THE PROGRAM

The Main Routine: Formating, branching, and input-output operations are located in the main program section. Here the variables punched on the data cards are tested for mode selection, and the proper branching is taken. The main section also does the iteration for all modes.

<u>The Temperature Conversion Subroutine</u>: According to the letter assigned to card column 71, the temperature subroutine makes the proper conversion of the temperature data provided and sends Kelvin units to the computational subroutines in the program.

<u>The Integration Subroutine</u>: A modification of the Scientific Subroutine Package subroutine DQG32 is used here. The modification is to allow more variables to be changed in the function to be integrated.

<u>The Function Subroutine</u>: Here Planck's equation is implemented in the following form:

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FCT = 1.1909 D4 / (X**5* (DEXPLQ) - 1.0D0))*EX*SR

        where Q = 1.4388D4 / (X*T)
             EX = emissivity factor
             SR = system response (equals one now)
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<u>The Dummy Subroutines</u>: These subroutines are to be rewritten by future users when needed.

<u>The System Response Subroutine</u>: This subroutine is a catchall device, now set equal to one, to provide the capability for correction of the error of prediction due to system responses, atmospheric effects, ets.

<u>The Emissivity Subroutine</u>: We now assume emissivity to be a constant over temperature and wavelength, and now simply send the emissivity read from the data card to the function subroutine. If in the future, emissivity can be defined to be a function of temperature and wavelength, the program is ready to except an implementation of such a function in the rewriting of this subroutine.

<u>How to Use the Program:</u> The use of this program is simple and it is hoped the following table will clearly show its use. The table presents different modes of operation caused by specific ways to punch the single card needed per job. The program continues to read cards until it reads /*,/&, therefore, you may run as many jobs as you desire. Because the program reads jobs until the /*,/& cards are encountered, you have the option of leaving the /*,/& cards out of the deck until you are finished, then place them in the card reader to terminate the program.

There are six types of calculations available in this program, two integrating and four giving the energy at single wavelengths. The modes and their selections are discussed below.

<u>Discussion of Table:</u>

THE PROGRAM CAN HANDLE TEMPERATURES FROM ZERO$^+$ (NOT ZERO) OR EQUIVALENT IN OTHER UNITS TO 9999°K OR EQUIVALENT IN OTHER UNITS AND WAVELENGTHS FROM ZERO$^+$ (NOT ZERO) TO 99μm (SEE DEFAULT (2)).

All modes may have any emissivity from 0.0 - 1.0. The program assumes you have left out EM if 0.0 or blank and assigns EM = 1.0, also if EM is greater than one.

(A) Integrates Planck's equation over a bandwidth (μm) and a range of temperatures determined by the user and iterates the temperature in increments set by user.

(B) Integrates Planck's equation over a bandwidth (μM) at the single temperature determined by the user.

(C) Computes value of Planck's equation at a single wavelength (μM) and at a single temperature determined by the user.

(D) Computes value of Planck's equation at a single wavelength (μM) and over a range of temperatures by an increment determined by the user.

(E) Computes value of Planck's equation over a range of wavelengths (μM) by increments at a single temperature all determined by the user.

(F) Computes value of Planck's equation over a range of wavelengths (μM) by increments and over a range of temperatures by increments all determined by the user.

ALL FIELDS FLOATING (F10.2)

	cc 1–10 XL(μM)	cc 11–20 XU(μM)	cc 21–30 BI(μM)	cc 31–40 TL	cc 41–50 TU	cc 51–60 BY	cc 61–70 EM	cc 71 UT
CARD FOR MODE (A)	X	X	—	X	X	X	X/—	X/—
CARD FOR MODE (B)	X	X	—	X	—	—	X/—	X/—
CARD FOR MODE (C)	X	—	—	X	—	—	X/—	X/—
CARD FOR MODE (D)	X	—	—	X	X	X	X/—	X/—
CARD FOR MODE (E)	X	X	X	X	—	—	X/—	X/—
CARD FOR MODE (F)	X	X	X	X	X	X	X/—	X/—

— DENOTES FIELD LEFT BLANK
XL DENOTES LOWER WAVELENGTH
XU DENOTES UPPER WAVELENGTH
BI DENOTES WAVELENGTH INCREMENT
TL DENOTES LOWER TEMPERATURE
TU DENOTES UPPER TEMPERATURE
BY DENOTES TEMPERATURE INCREMENT
EM DENOTES EMISSIVITY
UT DENOTES TEMPERATURE UNITS
X DENOTES FIELD YOU PLACE YOUR VALUE IN

UT =
— KELVIN (ASSUMED)
K KELVIN
C CELSIUS
F FARENHEIT
R RANKINE

DEFAULTS:

(1) IF YOU MISTAKENLY LET XL BE GREATER THAN XU, THE PROGRAM WILL PERFORM MODE (D) IF YOU SPECIFY A TEMPERATURE RANGE, OR MODE (C) IF YOU SPECIFY A SINGLE TEMPERATURE.

(2) IF THE WAVELENGTH TIMES TEMPERATURE SPECIFIED IS NOT GREATER THAN 85, THE ENERGY PRINTOUT WILL CONTAIN ASTERICKS, BECAUSE THE MACHINE CANNOT COMPUTE THE EXPONENTIAL INVOLVED.