Advisor Approval Page

Approved: GREGORY NELLIS

Professor Greg Nellis

Director of Solar Energy Lab

Approved:

Professor Mark Anderson

Director of Thermal Hydrualic Lab

EXPERIMENTAL CHARACTERIZATION OF ADDITIVELY MANUFACTURED, TOPOLOGY OPTIMIZED HEAT SINKS

by

Gunnar D. Maples

A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science

(Mechanical Engineering)

at the

University of Wisconsin-Madison

2022

Experimental Characterization of Additively Manufactured, Topology Optimized Heat sinks

Research completed under the supervision of
Professors Greg F. Nellis and Mark H. Anderson

Gunnar Maples

Abstract

An innovative design tool called Topology Optimization (TO) uses coupled thermal fluid models to generate non-conventional designs of a heat exchanger's surface in order to improve the energy transferred between fluids. This thesis explores the experimental performance of TO-based heat sinks built using the metal additive manufacturing (AM) process Direct Metal Laser Sintering (DMLS). The experimental performance of heat sinks is explored and compared directly to a conventional heat sink. Details of the as-built TO design that might impact the thermal performance such as the thermal conductivity of the AM material, flow maldistribution, surface roughness, and print accuracy are evaluated.

Acknowledgements

I need to first thank my parents. Mom and Dad, you have been there for me since day one. From offering sage advice to cheering me on the trail of life, I have appreciated you every step of the way. Thank you.

I need to thank my advisors Greg and Mark. Greg, thank you for teaching me how to objectively think and challenging my understanding of thermal systems. Mark, thank you for letting me join this group and for teaching me how to be an experimentalist. Thank you both for being supportive when I made mistakes and building a lab that is tangibly improving the world. I will forever be proud to look back at my time here.

I have had the great opportunity to work with many teams here at UW-Madison. Brett: thank you for being a true friend and intelligent mentor. Sun and Xiaoping: thank you for designing the heat sinks and working with me through the I-CORPS opportunity. Mythili and Dan: thank you for building these awesome heat sinks. TEAM Lab student and professional staff: thank you for your humor and focus on safety. Ian: thank you for improving my LabVIEW code and teaching me FEA. Paul and Seth: thank you for your patience as I explored how not to break things. MFVAL: thank you for introducing me to research. My fellow graduate students in the SEL: thank you for the laughs. Faculty in the Mechanical Engineering Department: thank you for teaching me how to be an engineer. Julie: thank you for turning my confusion into an exciting career.

Annie: thank you for getting me out into the sunshine and for your incredible support. I owe you many walks around La Luna.

This list is partial as the help and guidance I have received over the past six years at UW-Madison is incalculable. Thank you all.

Nomenclature

AR	Aspect Ratio	
β	Fin Parameter	
Bi	Biot Number	
c	Specific Heat Capacity	$\mathrm{J\,kg^{-1}\,K^{-1}}$
$\dot{C}$	Capacitance Rate	$\mathrm{W\,K^{-1}}$
C_R	Capacitance Ratio	
ε	Heat Exchanger Effectiveness	
η	Fin Efficiency	
H	Fin Height	m
$\hbar$	Average Heat Transfer Coefficient	$\mathrm{W\,m^{-1}\,K^{-1}}$
k	Thermal Conductivity	$\mathrm{W\,m^{-1}\,K^{-1}}$
L	Fin Length	m
$\dot{m}$	Mass Flow Rate	$\mathrm{kg\,s^{-1}}$
mH	Fin Parameter	
N	Number of Fins	
NTU	Number of Transfer Units	
$\dot{q}_w$	Heat Transfer Rate into Water	W
$\dot{q}_{wb}$	Maximum Heat Transfer Rate	W
R_{fin}	Thermal Resistance of Fin	$\mathrm{K\,W^{-1}}$
R_{unfin}	Thermal Resistance of Unfinned Area	$\mathrm{K\,W^{-1}}$
R_{total}	Total Thermal Resistance	$\mathrm{K\,W^{-1}}$
T_{base}	Heat Sink Base Temperature	K

T_f	Numerical Model Fluid Temperature	K
T_{in}	Numerical Model Fluid Inlet Temperature	K
T_{inlet}	Experiment Inlet Temperature	K
T_m	Numerical Model Material Temperature	K
T_{outlet}	Water Outlet Temperature	K
th	Fin Thickness	m
θ_f	Numerical Model Dimensionless Fluid Temperature	
θ_m	Numerical Model Dimensionless Material Temperature	
U_x	Uncertainty in Variable x	
UA	Conductance	$\mathrm{W\,K^{-1}}$
UA_an	Analytical Conductance	$\mathrm{W\,K^{-1}}$
x	Independent Variable in Uncertainty Analysis	
x	x-Direction	
Y	Dependent Variable in Uncertainty Analysis	
y	y-Direction	
z	z-Direction	
$\bar{x}$	Non-dimensional x-Direction	
$\bar{y}$	Non-dimensional y-Direction	
$\bar{z}$	Non-dimensional z-Direction	

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Thermal energy is created in any electronic circuit due to Joule Heating (G.D. Xia et al. 2014). Electronic processing chips, like the GPUs and CPUs in personal computers, generate enough energy that high chip temperatures chip can degrade the performance and reliability of the processor (Tamara Bechtold, Engenii B. Rudnyi, and Jan G. Korvink 2005). The increase in the performance of a processing chip is correlated with the number of transistors on the chip. As the chip size decreases and the number of transistors increase, the heat density of the chip increases (Fabis, Shum, and Windischmann 1999).

The need for faster processing chips, compact product design, and higher reliability increases the demand for novel thermal management of processing chips. Traditionally, heat sinks—devices that absorb and dissipate heat from a surface—are applied to the surface of a processor (*Definition of HEAT SINK* 2020). By removing thermal energy with a heat sink, these chips can maintain a lower operating temperature. Heat sinks are also used to thermally regulate field electric transistors (FETs), photo-optics, motors, and 5G networking hardware (*5G Telecom Heat Sinks - finskiving.com* 2021). One family of heat sinks, microchannel heat sink, are being studied due to their high performance.

Microchannel heat sinks are heat sinks with very small passage hydraulic diameters, on the order of 10-200 microns (Satish G. Kandlikar and William J. Grande 2003). Tuckerman and Pease found that reducing the hydraulic diameter increased the total surface area for convection and also led to higher convection coefficients (Tuckerman and Pease 1981). Therefore, they were able to reduce the thermal resistance of the heat sink. Conventional microchannel designs have been used on processing chips since the 1980s (Tisha Dixit and Indranil Ghosh 2014). They have been tested, analyzed, and modeled with correlations (Sambhaji T. Kadam and Ritunesh Kumar 2014). A conventional microchannel heat sink with plate or rectangular fins is seen in Figure 1.1.

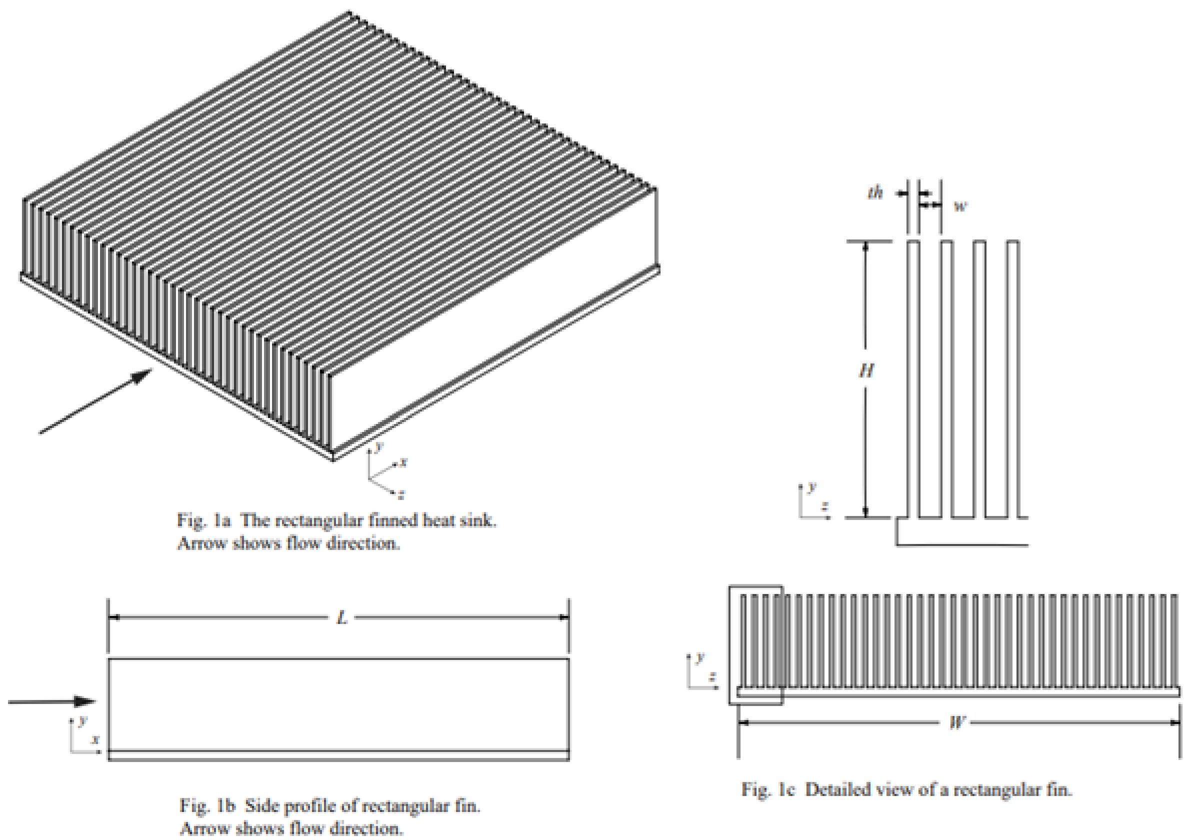


Figure 1.1: Geometry of a rectangular plate-fin heat sink.

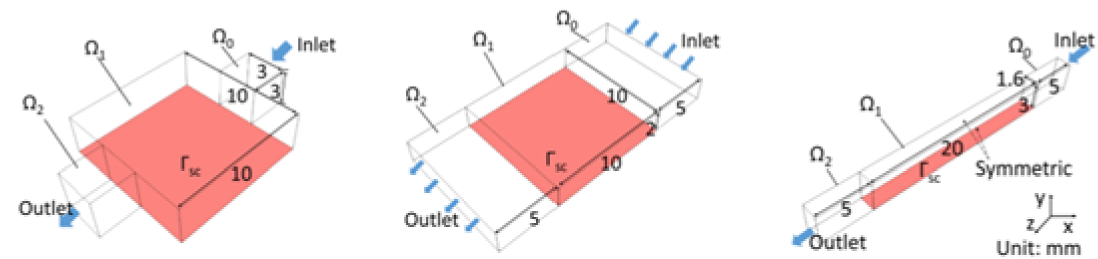
Microchannel heat sinks have been used and studied for 40+ years, but innovation is needed to further evolve heat sink performance. A new design tool (thermal-fluid Topology Optimization or TO) and a new manufacturing method (Direct Metal Laser Sintering or DMLS) offers a pathway for higher performing heat sinks.

1.1 Topology Optimized Heat Sinks Built with Additive Manufacturing

1.1.1 Topology Optimization

Topology optimization—"a computational design method for optimally distributing materials in a design domain under governing physics"—is the tool used in this project to design high performing heat sinks (Xiaoping Qian and Ercan Dede 2016). The goal of topology optimization (TO) in the context of this work is to build a geometry that minimizes the base temperature of the heat sink (which is related to the chip temperature) for a specific material, flow rate, and geometry constraints. The output of the TO model is a repeatable unit of a heat sink. This design tool is extremely computationally intensive and is only now being explored due to increased accessibility to high-performance computers. As seen in Figure 1.2, the symmetric strip corresponding to a single unit cell that extends from the inlet to the outlet is repeated to build the full size heat sink (Sicheng Sun, Piotr Leibersback, and Xiaoping Qian 2020).

The conventional manufacturing of heat sinks considers designs that are within the bounds of subtractive machining. Microchannel heat sinks are predominantly manufactured using one of the following methods: lithography, surface micromachining, electroplating, electron beam machining, laser micromachining, CNC milling, and extrusion (Tisha Dixit and Indranil Ghosh 2014). Additive manufacturing introduces a net increase in design freedoms as the requirements like tool size and entrance do not exist while new practical constraints like overhang angles are introduced. New geometries can be created with internal features and other traditionally non-machinable geometries (Tseng et al. 2019). The 3D manufacturing process employed in this research is Direct Metal Laser Sintering (DMLS) and offers the design freedom Topology Optimization leverages.



(a) Heat sink with small inlet and outlet extension

(b) Full size heat sink

(c) One strip cut

Figure 1.2: Design process for a TO heat sink
(Sicheng Sun, Piotr Leibersback, and Xiaoping Qian 2020)

1.1.2 Direct Metal Laser Sintering (DMLS)

DMLS printers use a high-powered laser to melt small particles of powdered metal. Before printing, the 3D object is modeled in a computer aided design program and then converted to an STL file. Printing companies (e.g. EOS) offer software to prepare the STL files for printing. The software slices the STL file into small, micro-scale thickness layers used to generate tool paths. The software also aids in support structure design and object orientation. Once the print is prepared, the software sends the file to the printer.

The printer uses the laser to scan and form the cross-sections of the object. To start, a metal plate is fastened into the machine to serve as a base for the print. A blade spreads an even and thin layer of the powder over the plate and the laser fuses the first layer by developing a melt pool at the laser-powder interface. After the laser tracks the first layer, the plate is lowered, and another layer of powder is spread. The laser fuses the next cross-section, and this process repeats until the print is complete. After the print finishes, the plate is removed from the machine and the part is machined off the base plate by electrical discharge machining (EDM). An aluminum composite, AlSi10Mg, was used to fabricate the heat sink. The parts were first printed on an EOS M290 Powder Bed DMLS 3D printer. The parts were then electrical discharge machined (EDM) off the base plate. No support structure was used.

The allure of TO design is that it can make designs targeted at optimizing a metric like minimizing the average base temperature of a heat sink. Additionally, the printing process can generate internal features that do not require tool access.

Experimental comparisons between the performance of TO models and TO printed parts are necessary to verify the TO technique and build confidence in its use. Additionally, experimental comparisons between TO parts and conventional geometries are necessary to demonstrate the advantage of this new technology.

1.1.3 Experimental Verification

The synergy of Topology Optimization and Direct Metal Laser Sintering is novel and a combination of many complex technologies. This thesis describes an optimized heat sink design that is fabricated and then installed in a test apparatus to experimentally measures its thermal and hydraulic performance. The experimental measurement is then compared with the model's prediction to validate the process.

1.1.4 Thermal Performance

The metric that is used to characterize or quantify the thermal performance of a heat sink can vary between researchers. Published methods include the fluid-to-base temperature difference (Fabis, Shum, and Windischmann 1999), the ratio of Nusselt number to friction factor (Li et al. 2020), and the thermal resistance (Dede, Joshi, and Zhou 2015). However, heat sinks are in fact heat exchangers as a fluid is used to exchange energy. A heat exchanger metric is therefore required to capture the effect of fluid temperature change as well as the heat sink thermal resistance. This allows for more accurate comparison between geometries, experiments, and models. The analyses in this thesis use the conductance of the heat sink determined through the effectiveness-NTU method to measure the thermal performance of heat sinks.

The effectiveness-NTU method predicts the effectiveness of the heat sink which is a measure of the rate of energy exchanged relative to the maximum rate of energy that it could theoretically exchange. For a heat sink, the theoretical maximum rate of energy transfer occurs if the fluid exited at the temperature of the heat sink's base. The effectiveness, ε, calculated in this thesis is defined in Equation (1.1) and is the ratio of the rate of energy input to the heat sink, $\dot{q}_w$, measured by the temperature rise in the water divided to the energy transfer that would occur if the coolant was heated to the base temperature, $\dot{q}_{wb}$, which is, again, the theoretical upper bound on the heat transfer rate.

$$\varepsilon = \frac{\dot{q}_w}{\dot{q}_{wb}} \tag{1.1}$$

The effectiveness is used in Equation (1.2) to calculate the number of transfer units, NTU, of the heat sink. The NTU is a dimensionless measure of the heat sink size. The capacitance ratio, C_R, compares the capacitance rates of the two fluids in a heat exchanger:

$$C_R = \frac{\dot{C}_{min}}{\dot{C}_{max}} \tag{1.2}$$

The capacitance rate is a measure of the rate of energy transfer needed to raise a fluid flow by 1 K. The capacitance ratio compares the capacitance rates of the two fluids: hot and cold. As the base of the heat sink is held at a constant temperature, it will take infinite energy to change that constant temperature and therefore the maximum capacitance rate is infinity and the capacitance ratio falls to zero. Equation (1.3) is the relationship between the NTU and ε for a heat exchanger in which the capacitance ratio is zero.

$$NTU = -ln(1 - \varepsilon) \tag{1.3}$$

The NTU value is used in Equation (1.4) to determine the conductance, UA, of the heat sink.

$$UA = NTU\ \dot{C}_{min} = NTU\ \dot{C}_w \tag{1.4}$$

For single-phase flow, the conductance is expected to be independent of heat input and only weakly dependent on flow rate under laminar conditions. The conductance of a heat sink is an ideal metric because 1) it is dependent on the expected fluid temperature rise (i.e., the capacitance rates and effectiveness) and 2) it is a quality of the heat sink that is fundamentally derivable. The inverse of the conductance is the total thermal resistance of the heat sink. By using a classical resistance analysis, the conductance can be theoretically approximated by a resistance network. However, this thesis will also explore the limitations of the classical fin theory with the development of a 2D numerical model for a rectangular fluid-fin problem.

1.2 Printed Heat Sinks

The heat sinks optimized in this Thesis were first built in an in-house TO program using Openfoam or FEniCS. The designs are then simulated in ANSYS Fuent to predict performance.

Five topology optimized heat sinks were fabricated for testing. One conventional, rectangular fin geometry was tested and is discussed in Chapter 3. The heat sinks are labeled in Figure 1.3. These heat sinks are designed to have a rectangular flow inlet of $5mm$ tall and $48mm$ wide in a domain $50mm$ long. The heat sinks are designed for a heat flux of $250kW/m^2$.

To go from TO model to print, the optimization model first generates a mesh. The number of elements used and size of elements used to design the geometries are listed in Table 5.3. In this table, the Reynolds numbers are calculated using averaged fluid properties of water and a characteristic length of $5mm$. This mesh is then smoothed and the performance is simulated using the parameters in Table 5.4. When the performance is deemed satisfactory, this smoothed mesh is sent to the printer to be printed. This process is discuss more in Chapter 5.

Table 1.1: TO design mesh parameters.

Heat Sink	Software	Mesh	Mesh Size (*microns*)	Re
TO-Al-1	OpenFOAM	2.5e6 cells	64x70x67	155
TO-Al-2	FEniCS	1e6 vertices	64x64x32	155
TO-Al-3	OpenFOAM	7.8e6 cells	33x33x67	155
TO-Al-4	OpenFOAM	7.8e6 cells	15x15x20	155
TO-Al-5	OpenFOAM	0.2e6 cells	106x125x200	155

Table 1.2: TO Post-design CFD simulation mesh parameters.

Heat Sink	Software	Mesh	Mesh Size (*microns*)
TO-Al-1	OpenFOAM	2.5e6 cells	64x70x67
TO-Al-3	OpenFOAM	7.8e6 cells	33x33x67
TO-Al-4	OpenFOAM	4e6 cells	30x66x50
TO-Al-5	OpenFOAM	7.8e6 cells	33x33x67

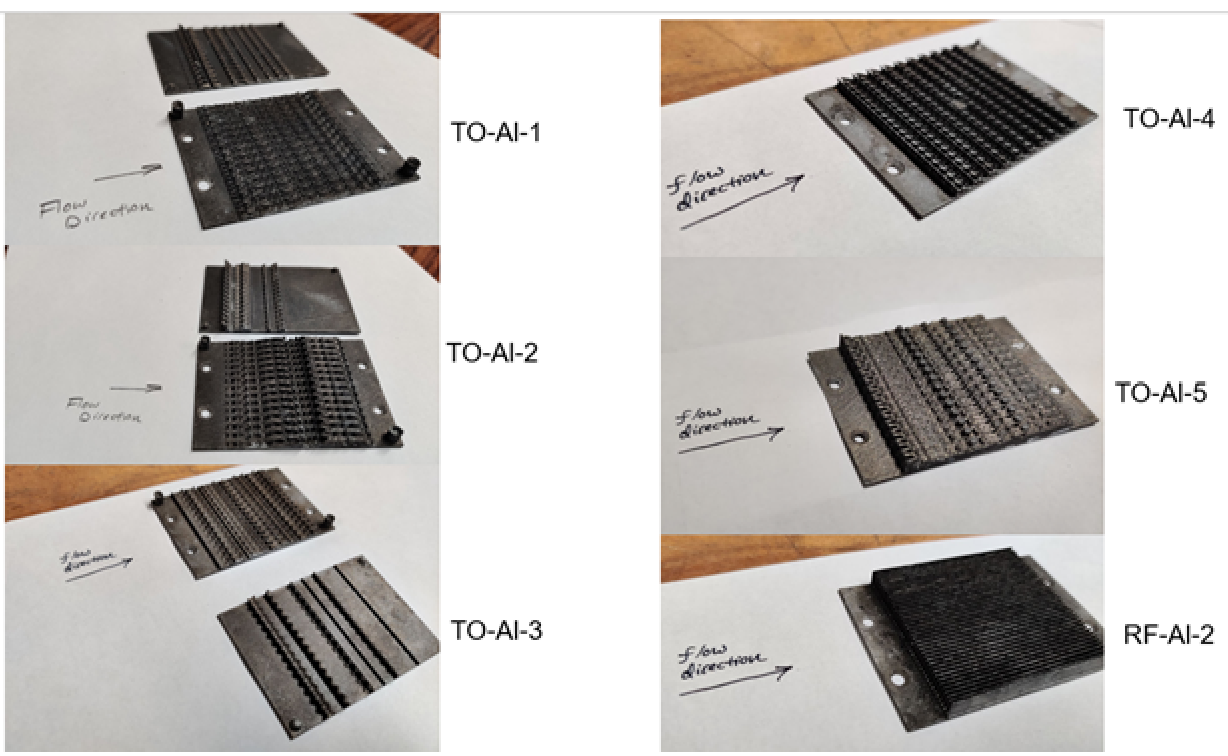
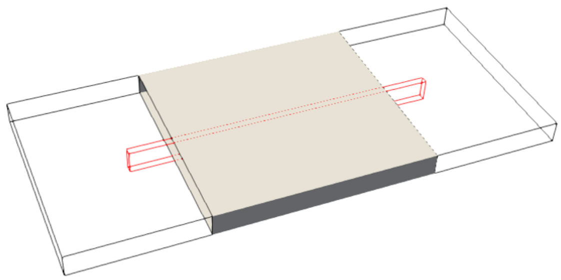
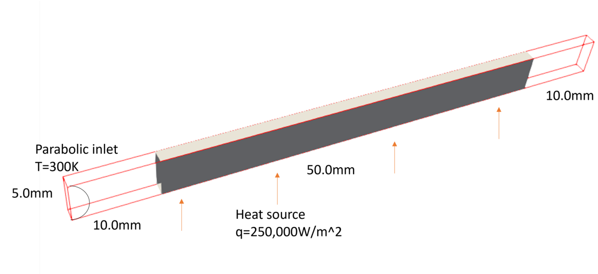


Figure 1.3: Labeled heat sinks that were printed and experimentally tested. TO: Topology Optimization. RF: Rectangular Fin (Conventional Design). Al: Aluminum Composite Material.



(a) Heat sink domain (tan) and fluid plenums (white). The red is the unit that is used to build the heat sink.

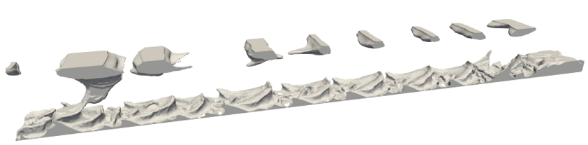


(b) The boundary conditions of the unit cell.

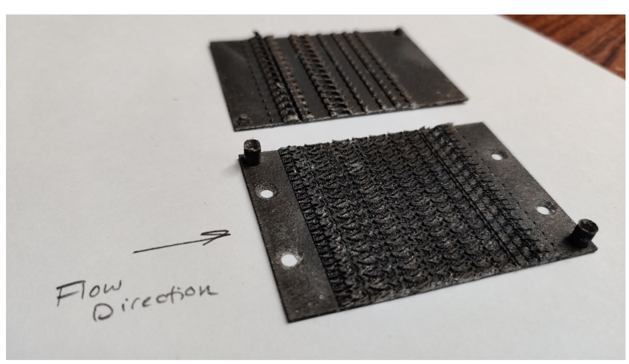
Figure 1.4: The TO heat sinks are built by optimizing a unit cell (red) and stacking it in cross-flow directions. CFD simulations are performed on these units cells. Figure credit: Sicheng Sun.

1.2.1 TO-Al-1

TO-Al-1 is designed similar to TO-Al-2,-3,-5 in that a long strip of a heat sink, noted in Figure 1.4a, is modeled with symmetric boundaries on the left and right sides. This strip is repeatedly stacked in cross flow directions to build the heat sink. Additionally, TO heat sinks -1,-2,-3 are designed to be cut in half. The design that was generated in Figure 1.5a is not able to be printed in one piece due to the floating features and overhang angles. This heat sink was optimized for thermal performance by minimizing the base temperature for a Reynolds number of 155.



(a) TO model of TO-Al-1.

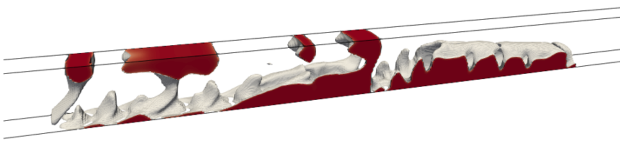


(b) The cut, two piece heat sink TO-Al-1.

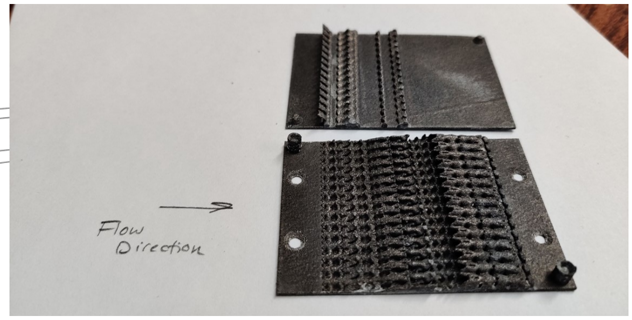
Figure 1.5: Heat sink TO-Al-1. Figure credit: Sicheng Sun.

1.2.2 TO-Al-2

TO-Al-2 was designed similarly to TO-Al-1 except it was optimized in FEniCS software.



(a) TO model of TO-Al-2.

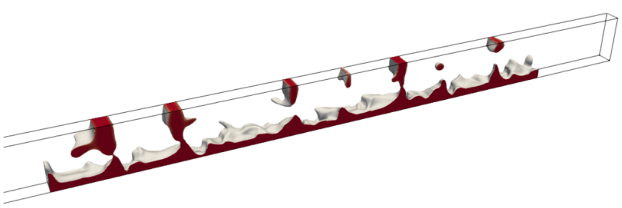


(b) The cut, two piece heat sink TO-Al-2.

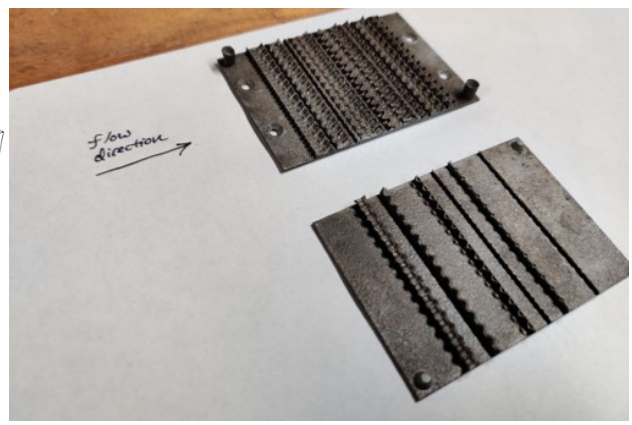
Figure 1.6: Heat sink TO-Al-2. Figure credit: Sicheng Sun.

1.2.3 TO-Al-3

TO-Al-3 was optimized for a higher flow rate of Re = 465 and used about 5x as many cells. TO-Al-1,-2 is optimized with 1-2.5 million cells. TO-Al-3 was optimized using 7.5 million cells.



(a) TO model of TO-Al-3.



(b) The cut, two piece heat sink TO-Al-3.

Figure 1.7: Heat sink TO-Al-3. Figure credit: Sicheng Sun.

1.2.4 TO-Al-4

Unlike the other TO heat sinks, TO-Al-4 was designed using a smaller unit cell that was stacked in flow and cross flow directions. The unit cell is drawn in Figure 1.8.

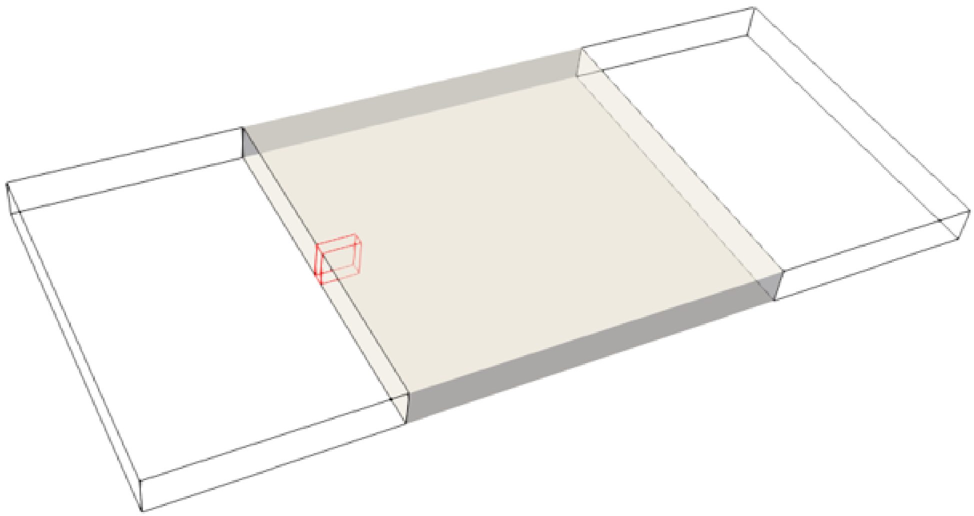
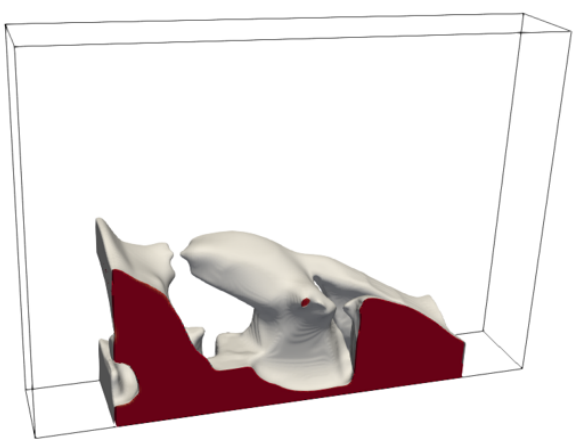
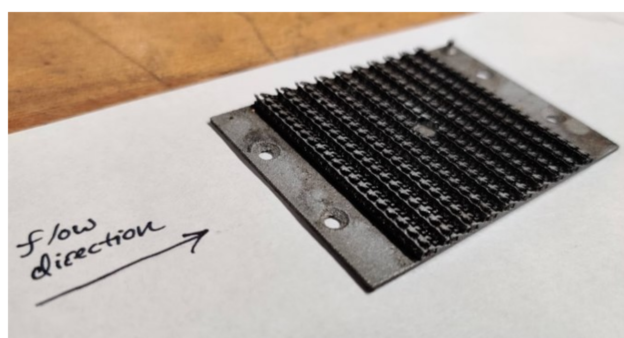


Figure 1.8: Unit cell used to design TO-Al-4. Figure credit: Sicheng Sun.

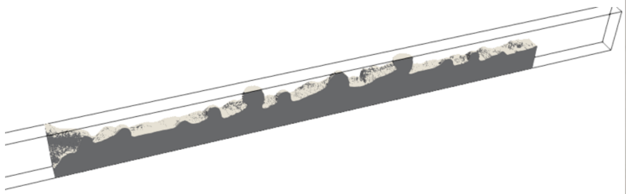


(a) TO model of TO-Al-4.

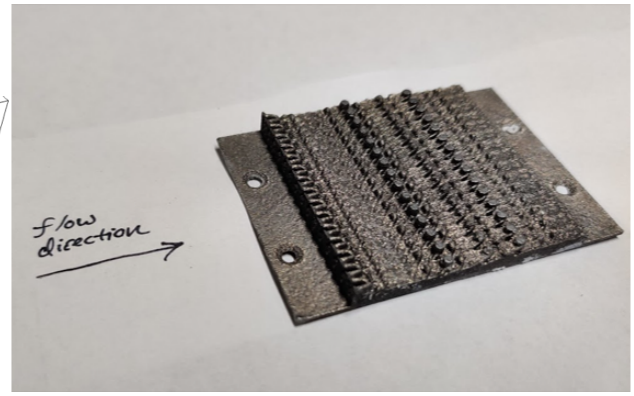


(b) The cut, two piece heat sink TO-Al-4.

Figure 1.9: Heat sink TO-Al-4. Figure credit: Sicheng Sun.



(a) TO model of TO-Al-5.



(b) The cut, two piece heat sink TO-Al-5.

Figure 1.10: Heat sink TO-Al-5. Figure credit: Sicheng Sun.

1.2.5 TO-Al-5

TO-Al-5 was designed to have large features that allow inspection and a more detailed study. Chapter 5 is heavily devoted to the analysis of TO-Al-5. Therefore, the number of elements in the design program was reduced to increase element size in Table 5.3.

This design was printed in three test articles (labeled: a, b, c) to test the performance repeatability between prints. The three articles are imaged in Figure 1.11.

This geometry is designed to mix the fluid in the laminar regime (there is no turbulent mixing). Figure 1.12 shows the flow path of TO-Al-5. The fluid is braided through the channels to circulate low temperature fluid near the top of the channel to the bottom. By substituting low temperature fluid for high temperature fluid, there is a larger thermal gradient to move fluid through the heat sinks. Additionally, the boundary layers are interrupted by the re-circulation. This increases the heat transfer coefficient.

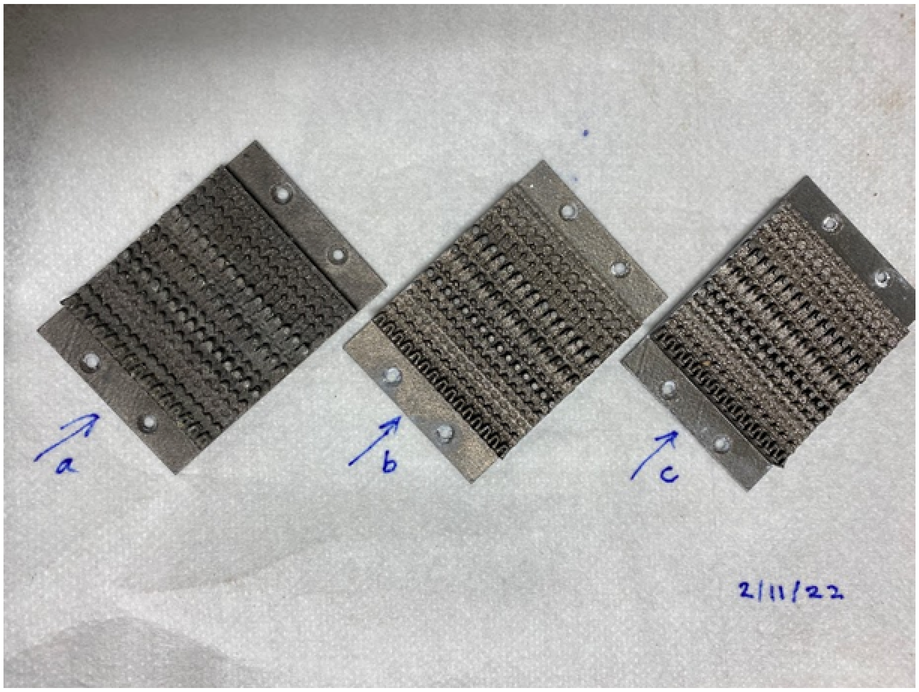


Figure 1.11: Topology optimized heat sink prints with the name TO-Al-5. Arrows indicate flow direction. Slight discoloration in (a) could be due to oxidation but no performance impact was observed.

1.2.6 RF-Al-2

RF-Al-2 is a rectangular finned heat sink optimized for Re = 155. The design is explored deeper in Chapter 3.

Table 1.3: Heat sink base thicknesses.

HS	Thickness (mm)
RF-Al-2	0.85
TO-Al-1	0.91
TO-Al-2	0.95
TO-Al-3	0.96
TO-Al-4	0.89
TO-Al-5a	0.94
TO-Al-5b	0.85
TO-Al-5c	0.96

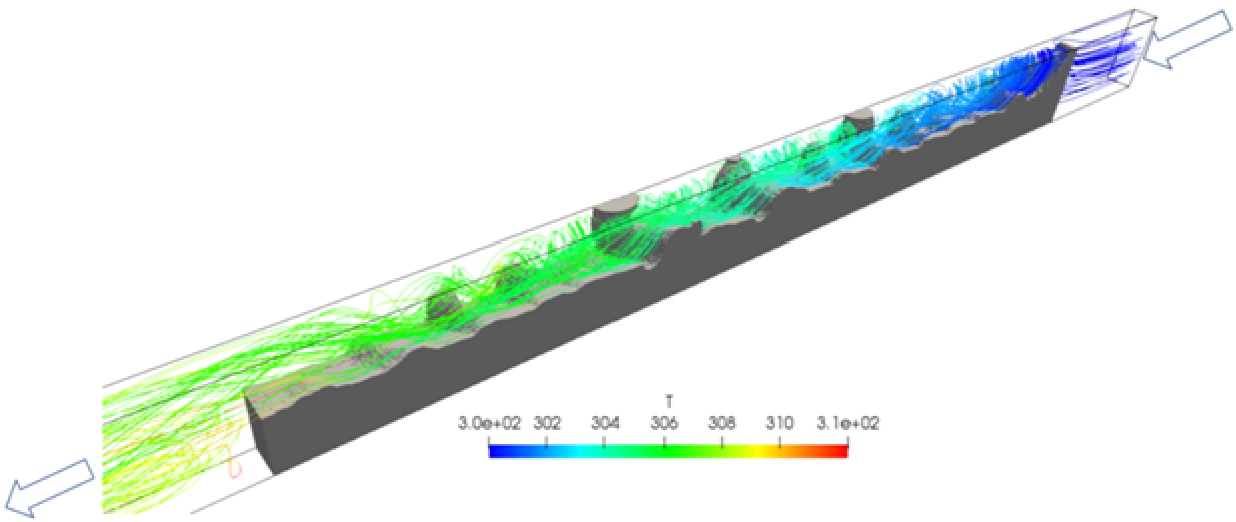


Figure 1.12: Flowlines of TO-Al-5. Color scale is in Kelvin (K).

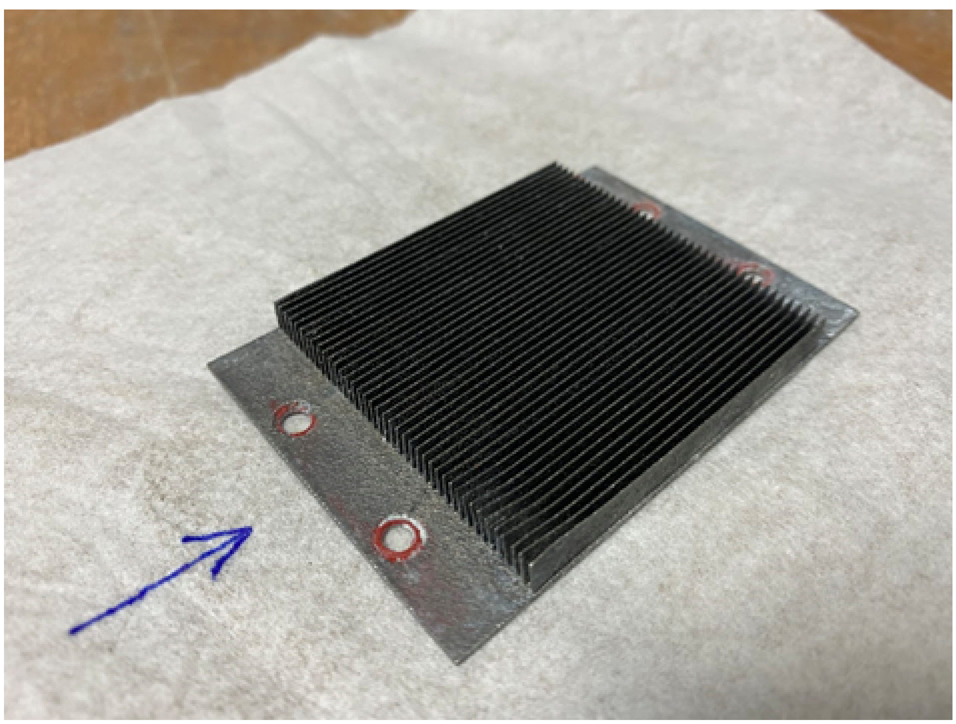


Figure 1.13: Rectangular finned heat sink print with the name RF-Al-2.

Chapter 2

Experiment

2.1 Goal

The goal of the experiment is to measure the conductance (thermal performance) and pressure drop (hydraulic performance) of a heat sink. The rate of energy entering the heat sink, $\dot{q}_w$, is measured by the temperature rise in the water forced through the heat sink:

$$\dot{q}_w = \dot{m}c(T_{outlet} - T_{inlet}) \tag{2.1}$$

where $\dot{m}$ is the mass flow rate of the water pushed through the heat sink, c is the specific heat capacity of the water, and T_{intlet}, T_{outlet} are the inlet and outlet temperatures of the water. The theoretical maximum heat entering the heat sink, $\dot{q}_{wb}$, is determined by assuming the fluid rises to the base temperature:

$$\dot{q}_{wb} = \dot{m}c(T_{base} - T_{inlet}) \tag{2.2}$$

where T_{base} is the heat sink base temperature. To calculate conductance, the inlet and outlet fluid temperature, base temperature, and mass flow rate must be measured. The pressure drop will also be directly measured.

2.2 Water Loop

A schematic for the test setup and circulating water loop in Figure 2.1 shows the devices and measurement location.

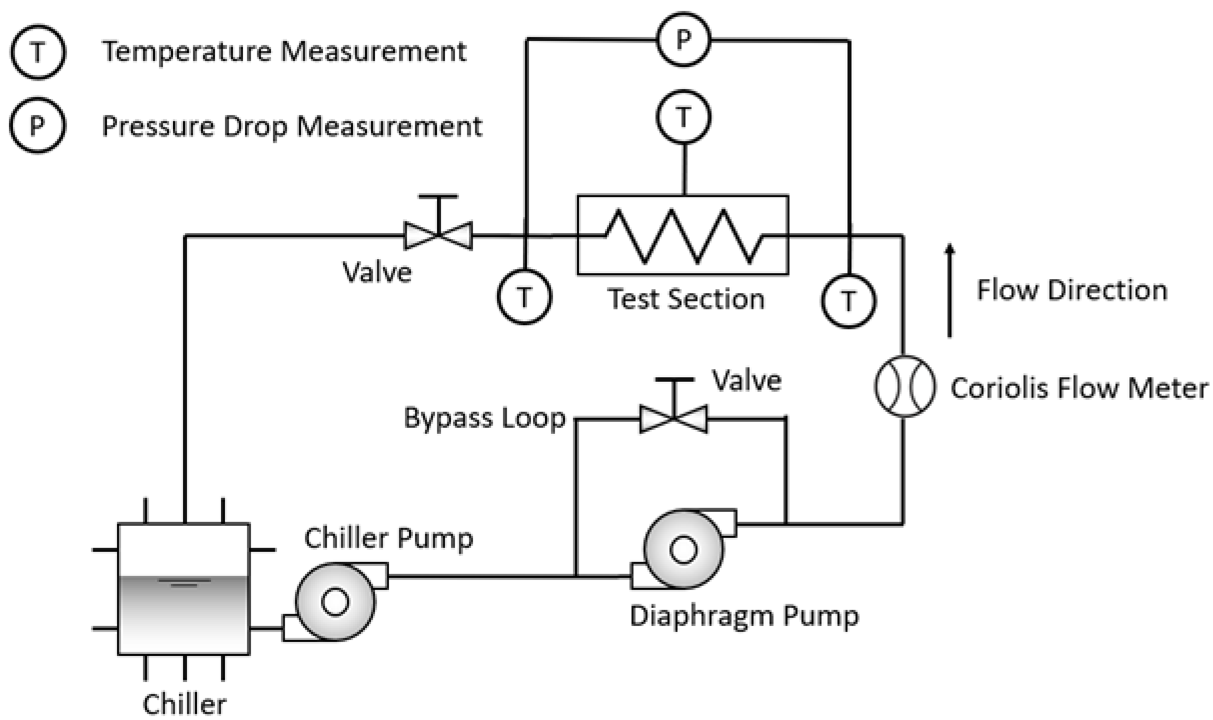


Figure 2.1: Test loop schematic. Water circulates counterclockwise.

The deionized water starts at the chiller where the temperature is maintained at 20°C. Moving counterclockwise, the chiller's internal pump and a diaphragm pump with a bypass loop regulates the mass flow. A Coriolis flow meter measures the volumetric flow rate of the fluid (the mass flow rate is calculated with density in post processing of the data). The flow enters the test section where two resistive temperature detectors (RTD's) measure the fluid inlet and outlet temperature and a thermocouple measures the heat sink base temperature. A differential pressure transducer measures the pressure drop across the heat sink. A secondary valve is placed after the test section to aid in flow regulation and deaeration.

2.3 Wiring

The wiring of devices, control, and measurement is overviewed here. Starting on the left of the wiring schematic in Figure 2.2, a LabVIEW program collects information from an NI Input and outputs signals from an NI Output. This LabVIEW program is detailed in Chapter 2.6.

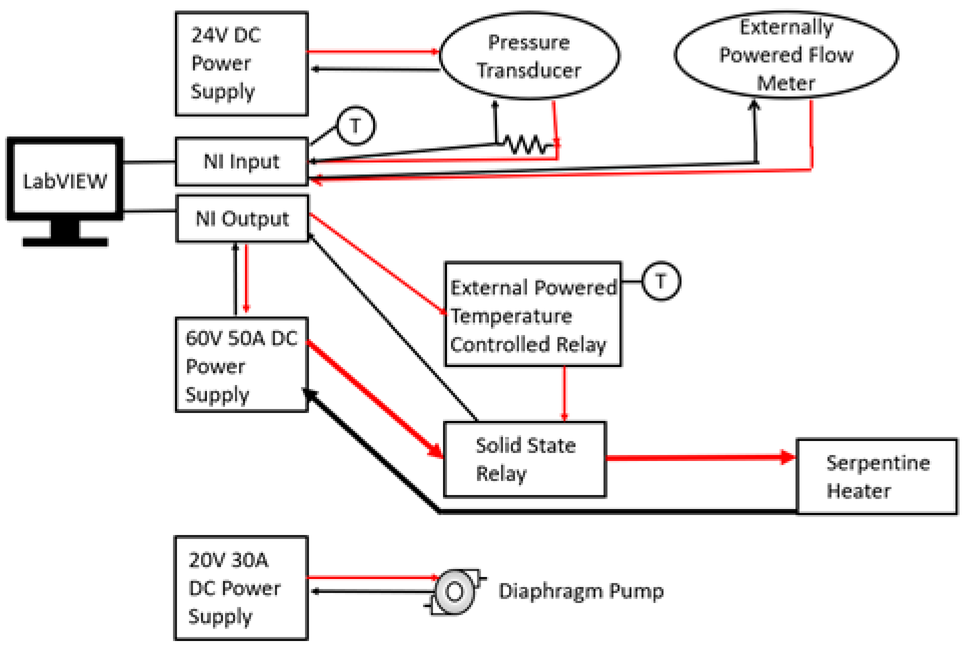


Figure 2.2: Wiring schematic.

The input/output port is a NI cDAQ-9174 data acquisition system. NI Input measures voltages on a NI 9215 card across a 250 precision resistor for the pressure transducer and voltages outputted from the flow meter. The voltage across the two resistors is directly proportional to the signal current outputted from the pressure transducer. The pressure transducer is electrically excited by a 24V DC power supply. The flow meter is externally powered by 120V AC wall power. The NI input also measures the TC temperatures using a NI 9213 thermocouple card and RTDs on a NI 9217 RTD card.

The NI 3263 output card sends a voltage signal to an Agilent 6032A 60V 50A DC Power

Supply to control the output power. This power supply applies DC current to a serpentine heater (discussed more in Chapter 2.5) to apply thermal energy to the heat sink. This output card also applies a 4V DC signal to a Crydom solid state replay. This relay is normally open and is closed when a signal is received. The LabVIEW program monitors temperatures and opens the signal (opening the relay) if a temperature exceeds a limit. There is also an externally powered Omega CN7533 Microcontroller with a RTD to monitor water temperatures. If the 45°C setpoint is exceeded, the microcontroller opens, and the solid state relay is opened.

The diaphragm pump is powered by a Sorensen DLM 20V 30A DC power supply. The chiller bath is a Cole Parmer PolyStat C315.

2.4 Devices

2.4.1 Instrumentation

The inlet and outlet water temperatures are measured with 2" long, 1/8" OD 100 Omega RTDs. The heat sink base temperature is measured with a 30 AWG Omega Type E thermocouple. The pressure drop is measured with a differential pressure transducer: Siemans SITRANS P. To measure the pressure drop of the system without the heat sink (i.e., the pressure drop related to headers, tubes, etc.) the flow was varied over the anticipated operating range and the pressure drop in the system was measured without a heat sink installed. This curve is shown in Figure 2.3 and this offset is applied to all measured pressure data. The flow rate is measured using a mass flow meter: Endress Hauser Promass A. The associated uncertainties in these measurement devices are tabulated in Table 2.1. The measurements are read through an NI cDAQ-9174 data acquisition system and collected in software application NI LabVIEW 2017.

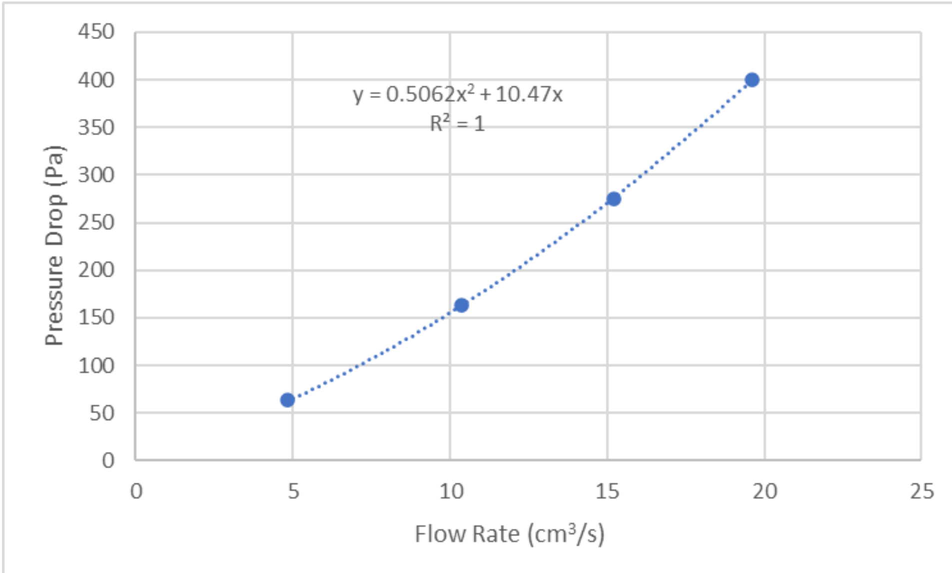


Figure 2.3: Pressure drop over tested flow rates without a heat sink. Best fit curve used to deduct screen and routing's pressure drop from heat sink measurment.

Table 2.1: Device Uncertainties.

Device Function	Device Name	Company	Uncertainty
Thermocouple	Type E TC	Omega	±1.5°C
Temperature Sensor	RTD	Omega	±0.15°C
Pressure Transducer	SITRANS P	SIEMENS	±0.20%
Flow Meter	Promass A	Endress + Hauser	±0.10%

2.4.2 Uncertainty Propagation

The uncertainty propagation in the collected measurements and calculated quantities is determined in the context of the following nominal experimental operation.

Before operation, the heat sink is fixed in position with the test section and loop fully assembled. The loop is pressure tested for leaks and then the fluid is pumped at the maximum flow rate ($20cm^3/s$). The system approaches steady state within 2 hours. An offset is taken to account for differences between RTD and thermocouple (TC) measurement. The high flow rate approaches a uniform temperature bath for the RTDs and TCs as the fluid has a high capacitance rate with no measurable thermal energy entering the test section.

Once the offset is accounted for, the flow rate is lowered to the test flow rate of $5cm^3/s$, the pressure taps are vented to ensure no accumulated air bubbles, and about $400W$ of power is applied to the serpentine heater. The system approaches steady state in under two hours (faster for higher flow rates). Steady state is determined by no measurable change in temperature outside of the device's uncertainty. To ensure this point was reached, initial trails waited longer (3-4hours) and identified no change in measured values. Once steady state is reached, 5min of data is collected. The flow is then changed, the power paused, air bubbles vented, and power reapplied. The process is repeated for flow rates from $5 - 20cm^3/s$. The variables that are recorded are flow rate, pressure drop, water temperatures, and base temperature.

The collected data for each flow rate value is averaged and the standard deviation in the collected measurement is recorded. The mean and standard deviations are tabulated in Table 2.2 together with the measurement device uncertainties for a test run. The total measured variable's uncertainty is a combination of the measurement device's uncertainty and the additional error associated with sample collection. This analysis considers the error with sample collection to be ± 2 standard deviations or 95% of the data scatter. These two errors are combined with a root sum square. Table 2.2 tabulated data for the rectangular finned heat sink used to validate experimental performance.

The conductance of the heat sink depends on the flow and temperature measurements. Therefore, the uncertainty in the conductance is influenced by the uncertainties in each of these measured variables. The propagated uncertainty was calculated following the NIST Technical Note 1297 (Barry N. Taylor and Chris E. Kuyatt 1994). The influence of an independent variable's uncertainty on the dependent (calculated) variable is related to the partial derivative of the calculated variable with respect to the independent variable as shown in Equation (2.3).

$$U_Y = \sqrt{\sum_{i=1}^{N} (\frac{\delta Y}{\delta x_i})^2 (U_{x_i})^2} \tag{2.3}$$

Table 2.2: Device Uncertainties.

Variable—Uncertainty	2x Sample Standard Deviation	Device	Total
Flow Rate (cm^3/s)	1.52e-7	5.3e-8	1.61e-7
Pressure Drop (Pa)	10.34	1.38	10.5
Fluid Inlet Temp (K)	0.02	0.19	0.191
Fluid Outlet Temp (K)	0.074	0.22	0.232
Base Temp (K)	0.058	1.7	1.71
Conductance (W/K)			2.2

2.5 Fixture

The fixture assembly is detailed in Figure 2.4. The purpose of the fixture is to mount a test heat sink, apply a known and uniform heat flux into the base of the heat sink, route water through the heat sink, and measure the fluid temperatures, base temperature, and pressure drop.

Starting at the serpentine heater, two leads to apply DC power are spot welded to the tabs and the wires feed out through the bottom mica plate and aluminum compression plate. This serpentine heater, dimensioned in Figure 2.5, is made from 0.004” stainless steel shim stock and laser cut to shape. Its dimensions were chosen such that at about 40 VDC, there would be 10 A of current pushing through for a power input of $400W$. The assumed resistivity of the stock is ρ_e=7.946E-07 ($ohm - m$).

The serpentine heater is electrically isolated with mica layers above and beneath it. The thick mica plate (0.25” thickness) acts as a thermal insulator, pushing thermal energy up through the thin mica sheet (0.015” thickness). The energy then passes through a 1/16” thick stainless steel plate with 4 M2 screws that mount the heat sink to the plate’s surface. A piece of g10-phenolic surrounds the heat sink and has two O-ring grooves to allow the stainless steel base plate and lid to seal. The phenolic cavity is taller than the heat

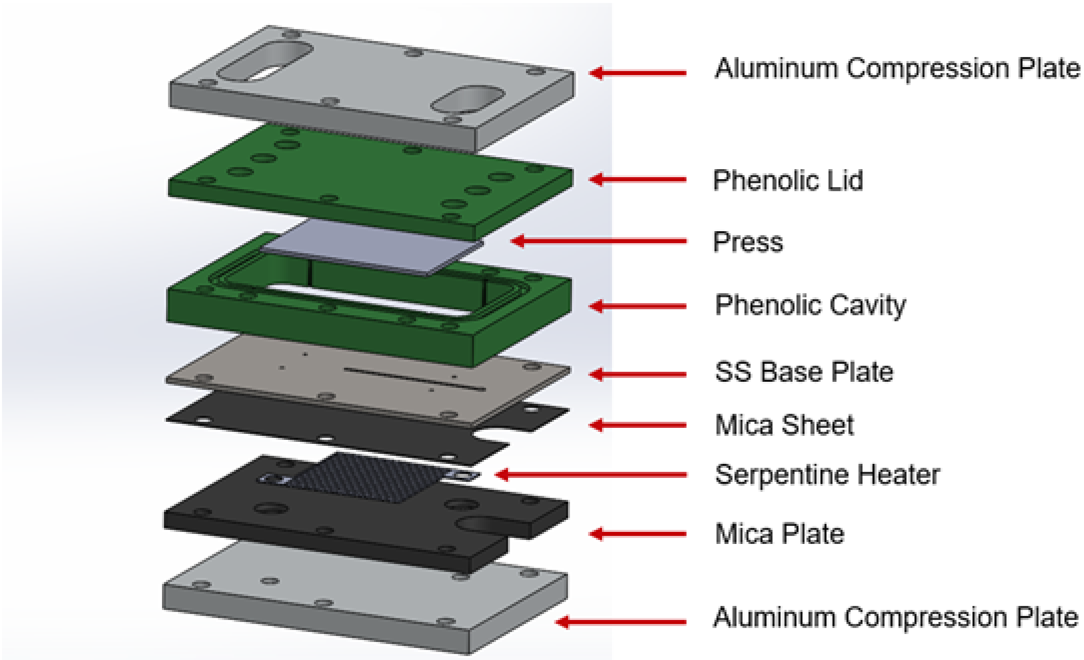


Figure 2.4: Exploded assembly of the heat sink fixture and test section. No fittings or hardware are shown.

sink, so above the heat sink there is a press made from mica to plug the gap between the heat sink and lid. The assembled fixture is modeled in Figure 2.6 with the flow path shown.

The phenolic lid seals the heat sink cavity and has 5 ports for fittings. Two are for water inlet/outlet ports with RTD temperature measurements, two are for pressure taps, and one is for the RTD of the external microcontroller acting as a redundant relay in Figure 2.7. As the phenolic is glass filled, it is also brittle. Silicon was applied on the pipe threads and the fittings were only hand tightened to prevent fracture. Additionally, small shims were made to line fit snuggly between the fittings and prevent further rotation while torquing connections on the fittings. The flow temperature RTDs are positioned coaxially with the flow in tubing just before and after the test section. This allows for flow mixing and a uniform temperature measurement. To ensure efficient thermal energy transfer, high temperature, high thermally conductive Paste (silicon base) from Omega is used to limit contact resistances between the heater, mica sheet, stainless steel base plate, and heat sink.

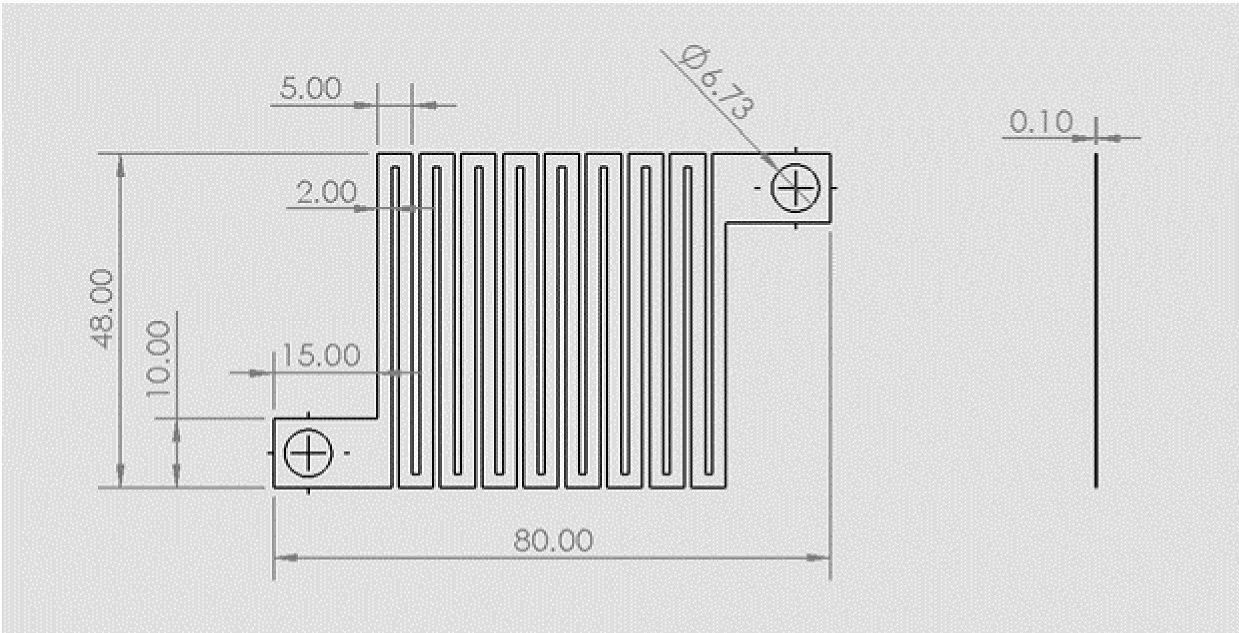


Figure 2.5: Drawing of serpentine heater. Units are in (mm).

The whole stack is then compressed by two 3/8" thick aluminum plates with 6 $\frac{1}{4}$-20 threaded rods to ensure uniform compression and O-ring seal. The entire test section is covered in a bath of powder Microtherm insulation to limit parasitic heat loss.

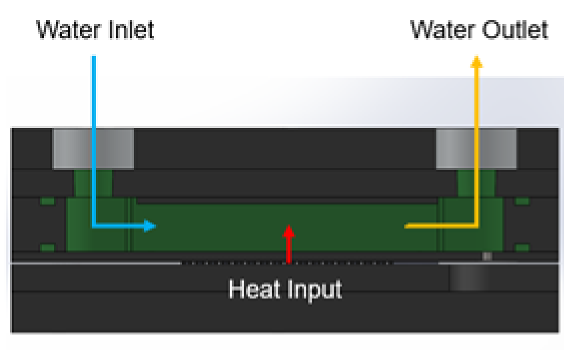


Figure 2.6: Assembled fixture with the flow path.

The base temperature of the heat sink is measured with a Type E TC that is cemented to the base of the heat sink with a SPI Silver Paste Plus 05063-AB. The TC wire is epoxied in the stainless steel plate with EA 1C Loctite epoxy to seal the feedthrough. The placement

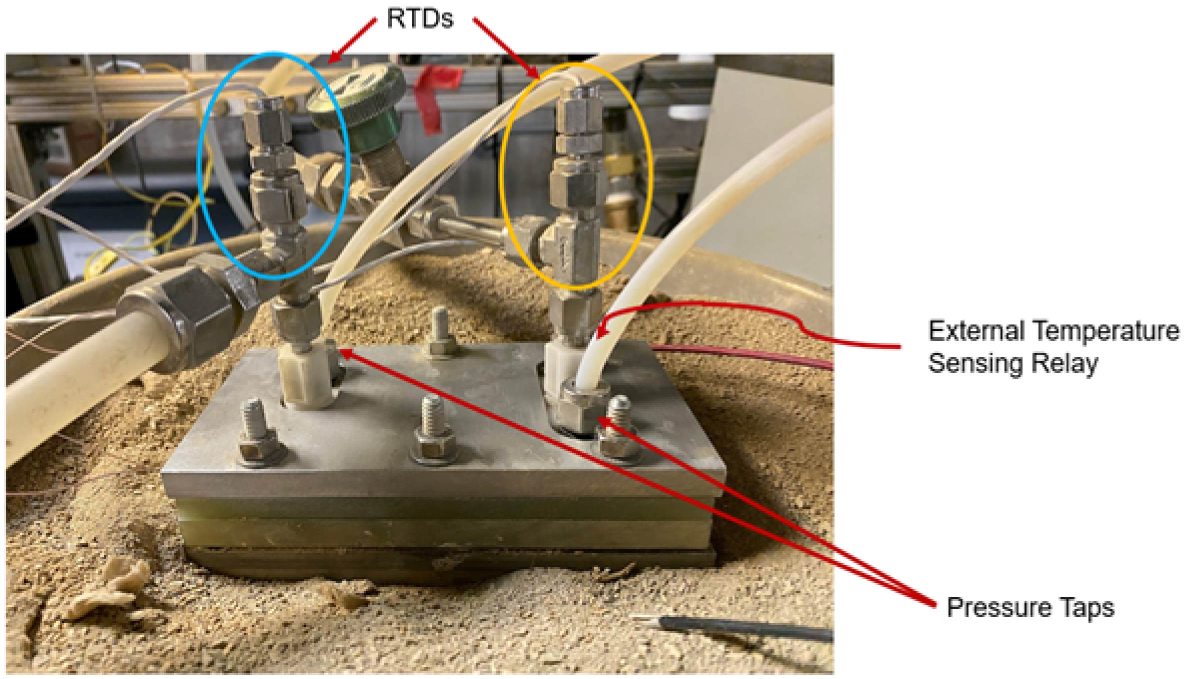


Figure 2.7: Ports to the test section.

of the TC bead is of great importance. The bead is centered on the heat sink base to allow for a temperature measurement comparable with simulations. Additionally, the bead must not be exposed to the contact between the heat sink and SS plate. Even with thermal grease, there is a temperature gradient between the heat sink base and SS plate. Therefore, if the TC is exposed to the interface it will read too high of a temperature and the measured performance will be too low. To defend against this, a 0.02" groove was milled into the bottom of the heat sinks. This allows the bead to be beneath the surface of the base and the silver cement will completely encapsulate the bead. When cementing the heat sink bead, it is important to apply force on the bead such that the bead remains below the surface. After the cement cures, the cement is sanded flush with the heat sink base as in Figure 2.8. It is important to make sure no TC bead is exposed after sanding. If a bead is visible, it is necessary to redo the cementing process.

As thermal energy is being applied to the fixture, temperature limits must be respected.

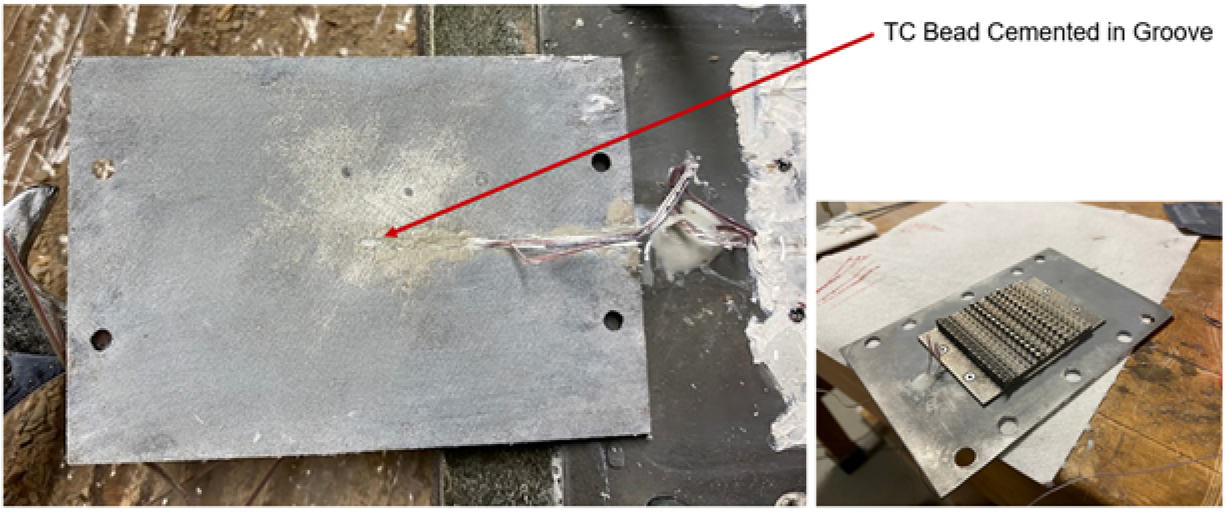


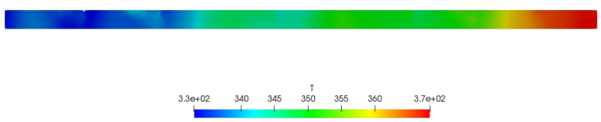
Figure 2.8: Thermocouple used to measure base temperature must be below the surface of the heat sink's base.

The Mica and metals may go to temperatures above 500°C, but the epoxy, base thermocouple, and phenolic have lower operating temperatures listed in Table 2.3. A thermocouple was added on the interface of the phenolic and stainless steel plate, and another was added next to the epoxy in the stainless steel plate to monitor these temperatures and defend against part failure.

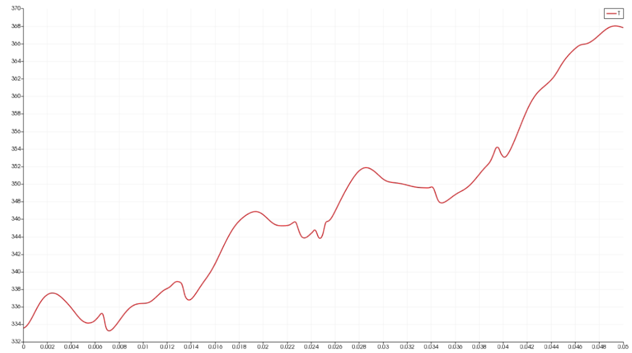
Table 2.3: Low temperature materials that can cause failure.

	Max Temp (°C)	Max Temp (°F)
EA 1C Loctite Epoxy	250	121
Omega Type E TC	392	200
g10-Phenolic	265	129

To ensure the experiment is compared accurately to CFD simulations, the middle and average base temperatures are collected. Base temperatures are not perfectly isothermal and thermocouple position is important. The temperature in the experiment measures middle temperature and the TO program builds a heat sink to minimize average base temperature. In the results of this thesis, conductance calculated with the middle (Mid) and average (Ave) temperature are compared.



(a) Color plot of a heat sink's base.



(b) Plot of color down heat sink position.

Figure 2.9: Base temperature of a simulated heat sink strip. Figure credit: Sicheng Sun.

2.6 LabVIEW

A LabVIEW program is created to monitor the test section during operation and collect data. Data is sampled continuously with 1 sample taken at a sampling rate of $1Hz$. A short term history of 1 hour is kept in the program to allow for plots to visualize where the signal has been. Temperatures, flow rate, pressure drop, and conductance are plotted live to allow for real-time tracking.

Steady state is defined as the point when the temperature and conductance signals level out and do not change beyond the expected device uncertainty. During operation, steady state takes about 1-2 hours and was validated by waiting longer (3-4 hours) and observing no change in performance.

The LabVIEW program continuously collects 5min of the most recent data. When steady state has been maintained for more than 5min, pressing a record button saves the 5min of data to an Excel file with a user chosen name. Pressing this record button does not stop the data monitoring, which is convenient if multiple test levels will be taken during one test session.

While the data is monitored, signals are also outputted by the LabVIEW program. Users send a voltage signal to the 50V, 60A DC power supply to control the power output of the serpentine heater and a signal to the relay is sent to keep the heater circuit closed. During this process, temperatures are monitored in the test section. If a temperature exceeds a user defined temperature limit, then the signal to the solid state relay is sent to zero, opening the circuit, and no more thermal energy is applied to the system. This ensures that there will be no damaging temperatures with the LabVIEW program running. Additionally, the Omega Microcontroller acts as a redundant relay with an external temperature sensor. If the LabVIEW program stops and the power supply remains on, the microcontroller can interrupt the power by opening the relay when the fluid temperature exceeds a set limit (about 45°C).

After data collection, the signal offset is applied, the Excel files are processed in an external MATLAB program where the data is read, the signal is averaged, and the standard deviation in the collected signal is recorded. The averages and standard deviations across different levels of the same heat sink are then written to one Excel file allowing for efficient data analysis. The collected data is then used in EES (Engineering Equation Solver) to plot the performance.

2.7 Test Levels

The topology optimized heat sinks are optimized for a Reynolds number of 300. This correlates to a flow rate of about $13cm^3/s$. To examine the performance of the heat sink around this flow rate, flow is measured at 5, 10, 15, and 20 cm3/s. This will give a trend through the design point.

The simulations use a heat flux of $250,000W/m^2$ or $600W$. However, this high heat input is not feasible due to the temperature limit of the phenolic and epoxy. 400W is the highest heat input the test could safely run at. Base temperature varies linearly with heat input, and conductance is independent of heat input, so the lower heat input does not fundamentally change the performance metric. Lower heat input will, however, increase the uncertainty in the measurement because the temperature rise between the base and fluid will be smaller. The chiller is maintained at 20°C, which leads to the test section inlet being maintained at 21°C from heat transfer in the pump, flow meter, and tubing. The simulation team is using an inlet flow temperature of 300K (26.9°C), so correct properties must be used when calculating conductance and comparing simulations with experiments.

Chapter 3

Experimental Verification

The test section's measurement of conductance is verified by measuring the performance of a rectangular finned heat sink. This conventional geometry was built with DMLS and the features were measured within $0.03mm$ as inputs to modelling. A numerical 2D-conduction model overcomes some limiting assumptions associated with the analytical classical fin efficiency model to accurately predict the thermal performance of the heat sink.

3.1 Rectangular Finned Heat Sink

The reference test article taken to represent conventional technology is referred to as RF-Al-2 and shown in Figure 1.3 is a rectangular finned (RF) heat sink. The geometry was chosen because plate fins are traditionally machined by milling, skiving (shearing the metal with a blade), or extrusion and the 2D rectangular profile of the fin allows for straightforward modeling. In this project, the RF heat sink is printed along with the TO design to allow for a direct comparison of conventional against optimized geometries. In order to optimize the RF heat sink, the fin height was set by the same vertical constraint of the TO design. With the heat sink width set, the number of fins and the fin width (or channel thickness) was varied to optimize the heat sink design. The numerical 2D-conduction model, discussed in Chapter 3.4, is used to predict the performance of the heat sink for optimization.

3.2 Geometric Measurements

The optimized RF heat sink was designed to have a $1mm$ base, 40 fins, a fin height of $5mm$, a fin length of $50mm$, a fin thickness of $0.4mm$, and a channel width of $0.82mm$ with perfectly smooth surfaces. After printing, the heat sink was machined off the base plate and lightly sanded to remove print artifacts. An Alicona InfiniteFocus optical profilometer was then used to measure the features of the RF heat sink within $0.03mm$ of measurement variation to accurately model the printed heat sink thermal and hydraulic performance.

The fin thickness was measured by imaging the heat sink from above, as shown in Figure 3.1, and tracing the fin at multiple locations to get a mean fin thickness. This image also gave the fin length. The fin height was measured by imaging the heat sink from the front as shown in Figure 3.2.

The surfaces, even after light sanding, are not perfectly flat surfaces. The roughness on the fins varied, but splatter marks averaged 40 microns. Surface characteristics are explored more in Chapter 5. Table 3.1 compares the as-designed and as-printed dimensions of the rectangular finned heat sink.

Table 3.1: Dimensions of the rectangular finned heat sink. Measured values had a standard deviation of 0.03mm.

(mm)	As-Designed	As-Printed
Fin Length	50	49.7
Heat Sink Width	48	47.8
Fin Height	5	5.06
Fin Thickness	0.4	0.257
Fin Thickness	1	0.830
Fin Roughness	0	0.040

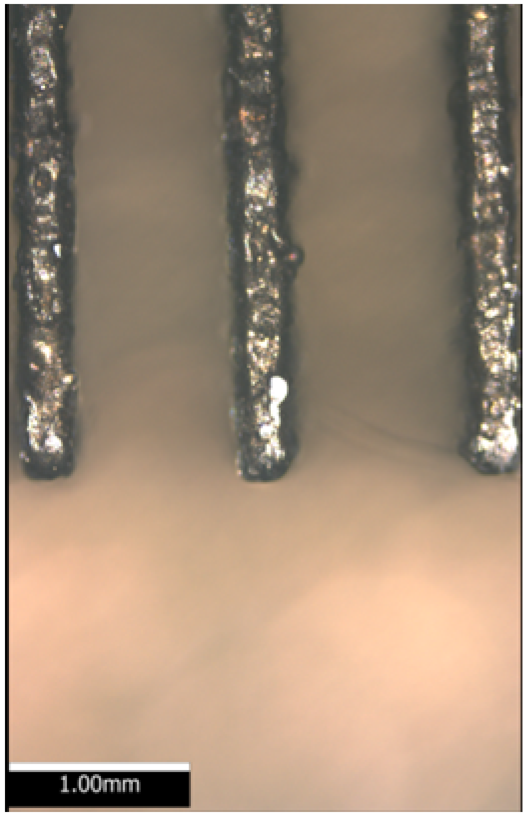


Figure 3.1: Partial aerial view of the scan of a set of fins of the RF heat sink. This scan was used to determine the fin thickness and fin length.

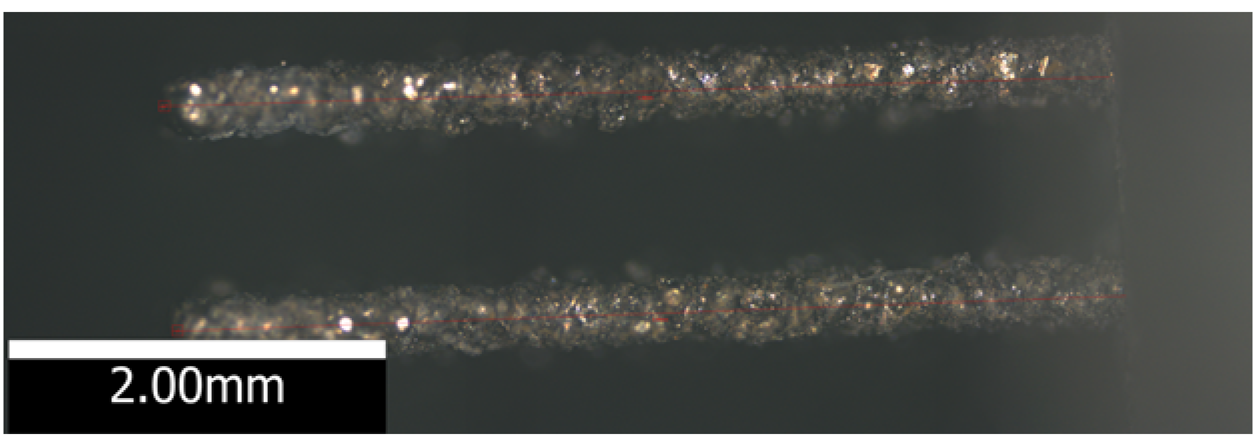


Figure 3.2: Partial front view of the scan of a set of fins of the RF heat sink. This scan was used to determine the fin height.

3.3 Classical Fin Efficiency

To model the thermal performance of the heat sink, an analytical classical fin efficiency was first used. This model assumes that the Biot number:

$$Bi = \frac{\hbar th}{k} \tag{3.1}$$

is much less than 1 where $\hbar$ is the average heat transfer coefficient, th is the fin thickness and k is the thermal conductivity. If Bi is much less than 1, the convection thermal resistance is dominant over the resistance to conduction in the fin thickness direction. The temperature drop in the fin thickness y-direction is therefore neglected.

The fin efficiency model also assumes:

- the fluid is at a bulk temperature at each point in the x-direction.
- the temperature profile that develops in the fin due to vertical or z-direction is fixed.

To capture the thermal performance of a heat sink, this analytical model uses a fin efficiency to account for the thermal energy moving up through the fin while escaping to the fluid on the sides of the fin. This pathway develops a unique temperature profile that is captured in a fin efficiency. The fin efficiency, according to (Gregory Nellis and Sanford Klein 2009), is:

$$\eta_{fin} = \frac{tanh(mH)}{mH} \tag{3.2}$$

where:

$$mH = \sqrt{\frac{2\hbar}{kth}}H \tag{3.3}$$

and is specific to a rectangular fin with an adiabatic tip. H is the height of the fin. A resistance network is built from the base of the heat sink to the fluid accounting for both the fin and unfinned area. The inverse of a resistance network is the analytical conductance:

$$R_{fin} = \frac{1}{\hbar 2LH\eta_{fin}} \tag{3.4}$$

$$R_{total} = (\frac{N}{R_{fin}} + \frac{N-1}{R_{unfin}})^{-1} \tag{3.5}$$

$$UA_{an} = \frac{1}{R_{total}} \tag{3.6}$$

where L is the length of the fin. Note this conductance, and the conductances discussed in this thesis, do not account for the base's thermal conduction resistance. This conductance is a measure of thermal performance from the base of the fin to the fluid. Experimental base temperature measurements are appropriately offset using Table 1.3 through a conduction resistance's temperature drop.

This conductance was calculated for the measured RF heat sink and compared with experimental performance in Figure 3.3. Thermal conductivity is sourced from the DMLS machine manufacturer's estimate (AD, WEIL 2014), and the average heat transfer coefficient is calculated with correlations for an internal rectangular duct under the respective flow conditions using the laminar duct flow correlation from (P. Wibulswas 1966). The analytical model does not fall within error bars and over predicts the measured performance by at least 20%. This over-prediction is likely due to the assumptions in the analytical mode (bulk fluid temperatures and constant fin efficiency). The next section's numerical model addresses these assumptions.

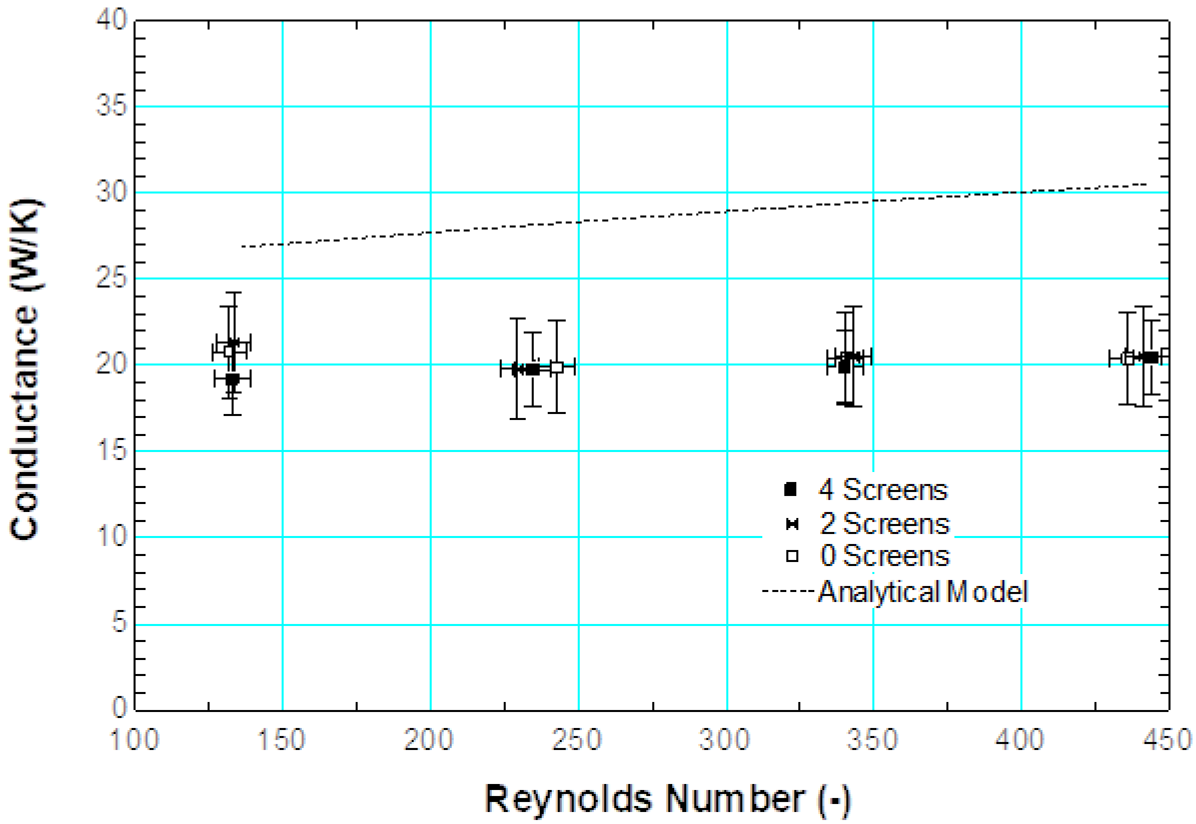


Figure 3.3: Analytical model compared to experimental data for the rectangular finned heat sink.

3.4 Numerical 2-D Conduction Model

The goal of this model is to capture effects that the analytical model neglects. Therefore, this model accounts for temperature gradients in the fluid that develop from the base to the tip of the fin (i.e., in the y-direction) as well as axial conduction within the fin material (in the x-direction). In other words, this model does not assume bulk fluid temperatures, does not assume constant fin temperature profiles, and accounts for axial conduction.

The model derived here assumes that the heat sink is at steady state and that the base temperature of the fin is constant. The fin material is assumed to be isothermal in the z-direction, which is justified provided that the relevant Biot number is much less that unity. The fin material temperature (T_m) is therefore a function of x and y and is governed by:

$$\frac{\delta^2 T_m}{\delta x^2} + \frac{\delta^2 T_m}{\delta y^2} - \frac{2\hbar}{kth}(T_m - T_f) = 0 \quad (3.7)$$

where $\hbar$ is the heat transfer coefficient, th is the thickness of the fin material, k is the fin material conductivity, and T_f is the fluid bulk temperature. The fluid bulk temperature in this context refers to the mass flow weighted average temperature at a particular x, y location. The fluid temperature is governed by:

$$\frac{\delta T_f}{\delta x} + \frac{2H\hbar}{\dot{m}c}(T_f - T_m) = 0 \quad (3.8)$$

where H is the height of the fin, $\dot{m}$ is the mass flow rate of coolant passing through a single passage, and c is the specific heat capacity of the coolant. Note that the conductivity of the fin material, the specific heat capacity of the coolant and the heat transfer coefficient are all assumed to be constant in the model. Further, conduction in the fluid in either the x- or y-direction is neglected.

The base of the fin (at $y = 0$) is assumed to be at a constant temperature, T_{base}. The remaining edges of the fin material (at $x = 0$, $x = L$, and $y = H$) are assumed to be adiabatic. The inlet temperature of the fluid (at $x = 0$) is assumed to be uniform.

$$T_{m_{y=0}} = T_{base} \quad (3.9)$$

$$\frac{\delta T_m}{\delta x}_{x=0} = 0 \quad (3.10)$$

$$\frac{\delta T_m}{\delta x}_{x=L} = 0 \quad (3.11)$$

$$\left.\frac{\delta T_m}{\delta y}\right|_{y=H} = 0 \tag{3.12}$$

$$T_{f,x=0} = T_{in} \tag{3.13}$$

The problem is nondimensionalized by introducing definitions for dimensionless temperature and positions.

$$\bar{x} = \frac{x}{L} \tag{3.14}$$

$$\bar{y} = \frac{y}{H} \tag{3.15}$$

$$\theta = \frac{T - T_{in}}{T_{base} - T_{in}} \tag{3.16}$$

Three additional dimensionless numbers are required to completely nondimensionalize the problem.

$$AR = \frac{L}{H} \tag{3.17}$$

$$\beta = \frac{2\hbar HL}{\dot{m}c} \tag{3.18}$$

$$mH = \sqrt{\frac{2\hbar}{kth}} \tag{3.19}$$

The aspect ratio, AR, is the ratio of the fin length to its height. The parameter β is the number of transfer units in the heat sink in the limit that the conductivity of the fin material approaches infinity (i.e., neglecting the conduction resistance in the fin). The parameter

mH is the fin constant and is related to the ratio of the resistance to conduction in the y-direction to the resistance to convection. Substituting the dimensionless parameters into the differential equations and boundary condition provides:

$$\frac{1}{AR^2}\frac{\delta^2\theta_m}{\delta\bar{x}^2} + \frac{\delta^2\theta_m}{\delta\bar{y}^2} = (mH)^2(\theta_m - \theta_f) \tag{3.20}$$

$$\frac{\delta\theta_f}{\delta\bar{x}} + \beta(\theta_m - \theta_f) = 0 \tag{3.21}$$

$$\theta_{m,\bar{y}=0} = 1 \tag{3.22}$$

$$\frac{\delta\theta_m}{\delta\bar{x}}_{x=0} = 0 \tag{3.23}$$

$$\frac{\delta\theta_m}{\delta\bar{x}}_{x=1} = 0 \tag{3.24}$$

$$\frac{\delta\theta_m}{\delta\bar{y}}_{y=1} = 0 \tag{3.25}$$

$$\theta_{f,\bar{x}=0} = 1 \tag{3.26}$$

The numerical solution is obtained by discretizing these differential equations using finite differences. For example, the discretization of Equation (3.20) becomes Equation (3.27), where indices i and j represent the position of the nodes in the x- and y-directions, respectively.

$$\frac{1}{AR^2}\frac{\theta_{m\ i+1,j} - 2\theta_{m\ i,j} + \theta_{m\ i-1,j}}{\Delta x^2} + \frac{\theta_{m\ i,j+1} - 2\theta_{m\ i,j} + \theta_{m\ i,j-1}}{\Delta y^2} = (mH)^2(\theta_{m\ i,j} - \theta_{f\ i,j}) \tag{3.27}$$

The resulting system of equations is solved through matrix decomposition; the solution is implemented in MATLAB and the code can be found in the appendix and downloaded from https://sel.me.wisc.edu/.

The effectiveness of the heat sink is defined as the ratio of the actual to the theoretically maximum rate of heat transfer from the heat sink:

$$\varepsilon = \frac{\dot{q}}{\dot{q}_{max}} \tag{3.28}$$

The actual rate of heat transfer can be computed from an energy balance on the fluid. The theoretically maximum rate of heat transfer occurs if the fluid temperature increases to the base temperature at the exit:

$$\varepsilon = \frac{\bar{T}_{out} - T_{in}}{T_{base} - T_{in}} \tag{3.29}$$

where $\bar{T}_{out}$ is the mass average fluid outlet temperature. The effectiveness can therefore be determined from the numerical model by calculating the average dimensionless fluid temperature at the outlet:

$$\varepsilon = \int_0^1 \theta_{f,\bar{x}=1} d\bar{y} \tag{3.30}$$

Figure 3.4 compares the fluid and fin temperature profiles. Notice how the fluid is not at a bulk fluid temperature. The fluid near the base ($\bar{y} = 0$) gets hotter than fluid near the fin tip ($\bar{y} = 1$), which makes sense because the fin base is hotter than the fin tip! Therefore, the bulk temperature assumption is not appropriate in the analytical model. Additionally, notice that the fin's temperature profile changes as the fluid moves through the heat sink ($\bar{x}$-direction). The temperature profile in fact changes and this must be accounted for by using a higher dimensional model than the 0D analytical fin efficiency.

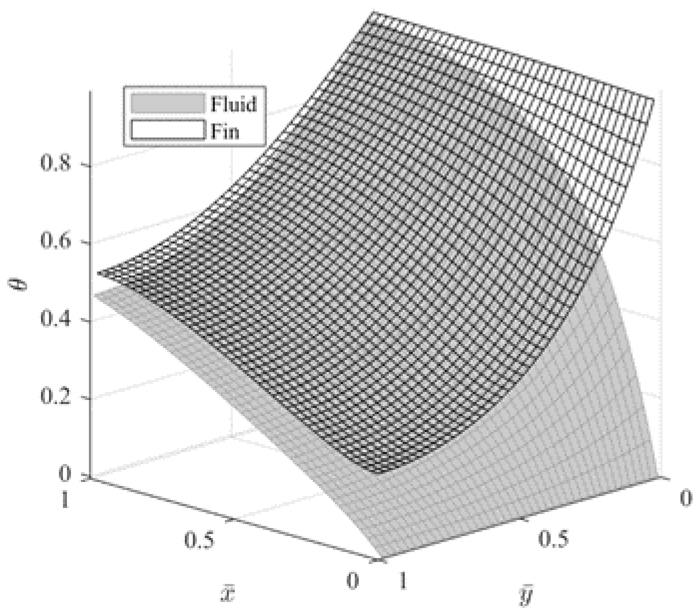


Figure 3.4: 2D temperature profiles of the fluid and fin.

This model is used to predict the heat sink performance. The three dimensionless parameters are inputted to the model and effectiveness is found. This effectiveness uses the effectiveness-NTU model:

$$NTU = -ln(1 - \varepsilon) \tag{3.31}$$

$$UA = \dot{C}_{min} NTU \tag{3.32}$$

Where NTU is the number of transfer units. The conductance computed using this model is compared with experimental data in Figure 3.5. The numerical model matches the experimental results within error bars. This work validates the experimental set up to some extent as it is able to measure the performance of a well understood heat sink geometry.

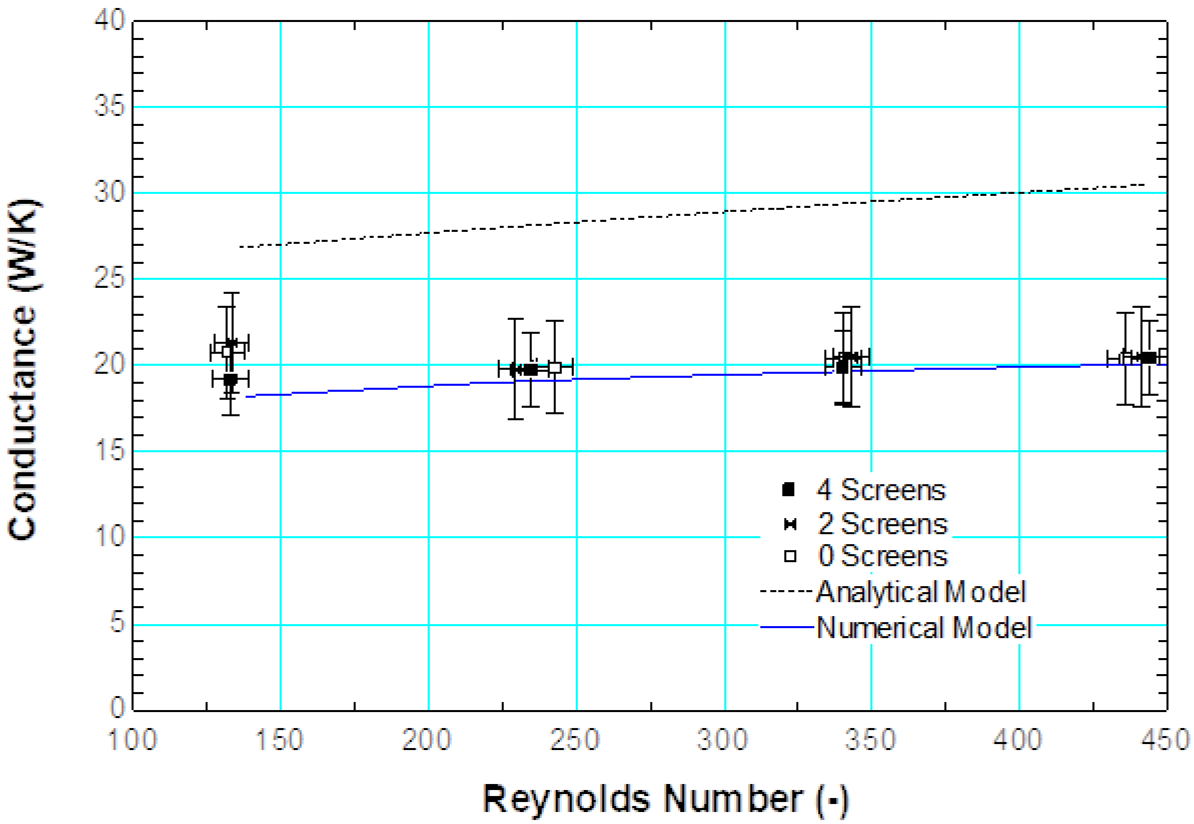


Figure 3.5: Numerical conductance matches the experimental performance of the heat sink within error bars.

This numerical model and experimental data was further validated with a CFD model executed by the TO design team in Figure 3.6. The CFD prediction using the middle temperature predicts conductance within error bars. The CFD prediction using the average temperature over-predicts performance by 25%.

In the experiment, base temperature is measured by a thermocouple in the middle. Therefore, it is appropriate to compare the CFD and experimental data with the middle temperature.

Figure 3.7 and Figure 3.8 compare the impact of hydraulic performance. In the estimate of pressure drop with the model, a friction factor and average properties are used. These average properties are for temperatures different than the CFD simulations (CFD uses 600W with an inlet of 300K). Additionally, it is possible that the experimental measurement of pressure drop was contaminated my small pockets of air.

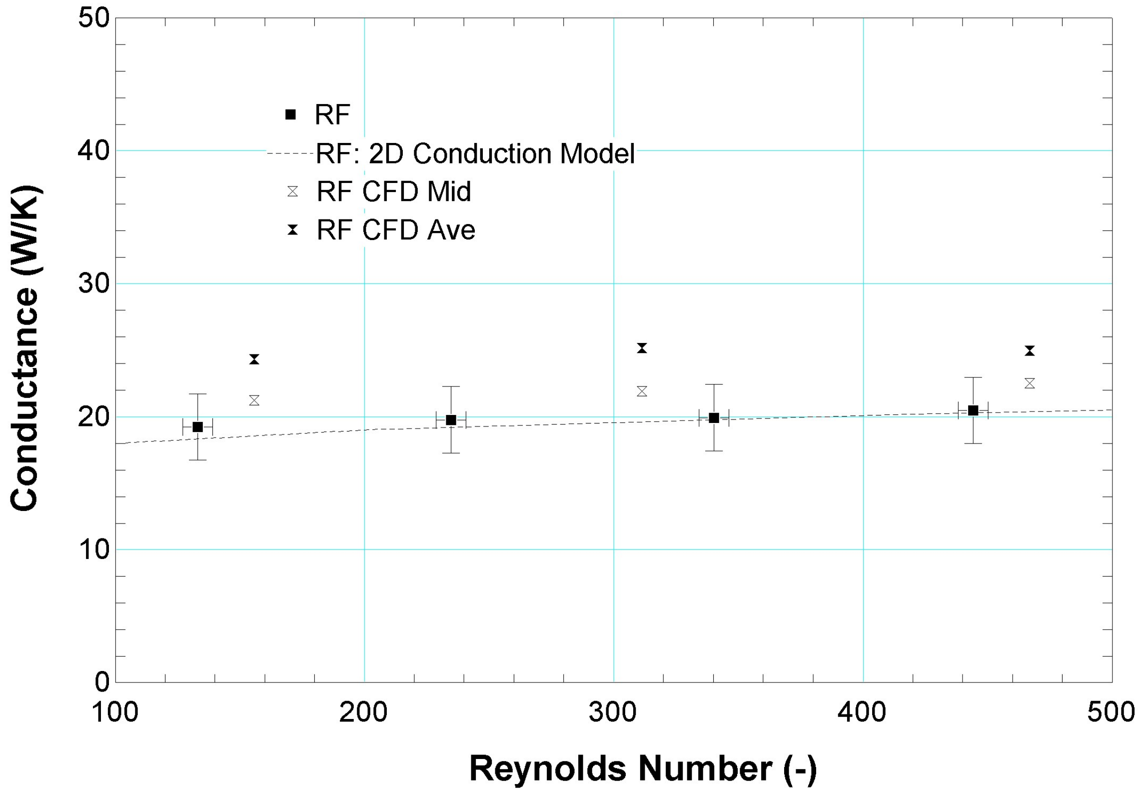


Figure 3.6: Conductance over a range of Reynolds numbers.

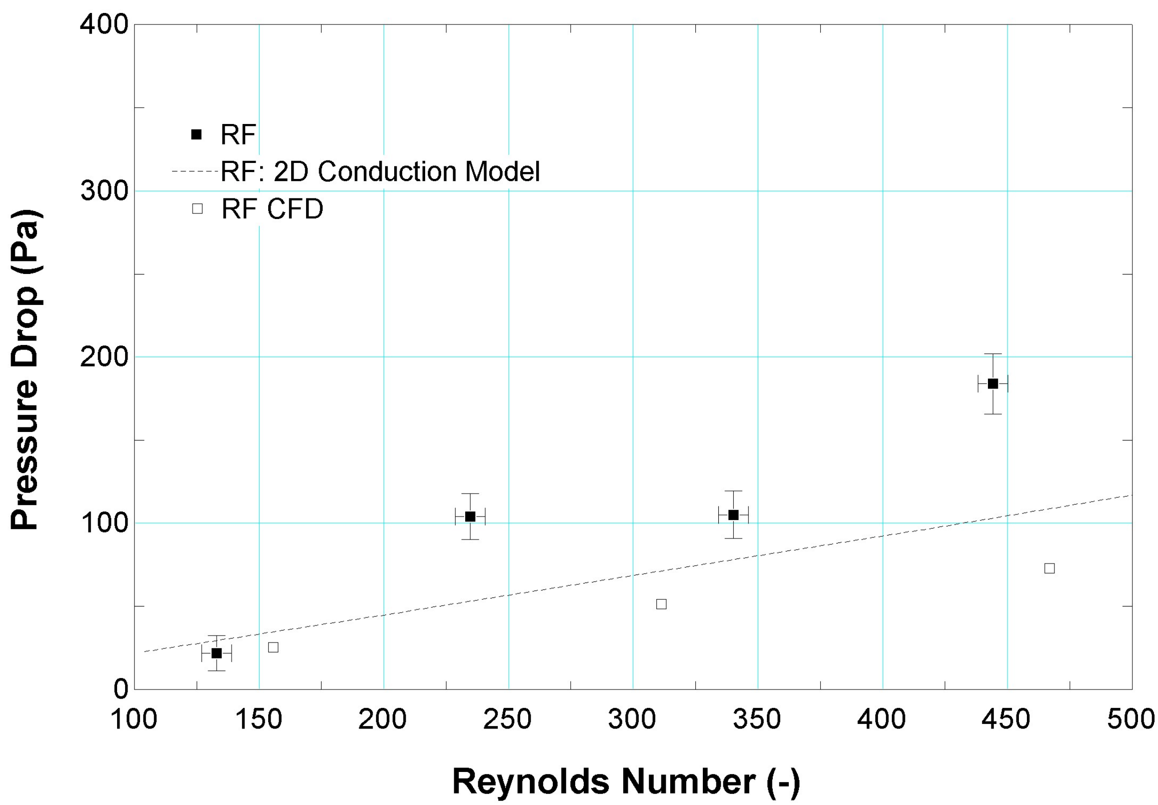


Figure 3.7: Pressure drop over a range of Reynolds numbers.

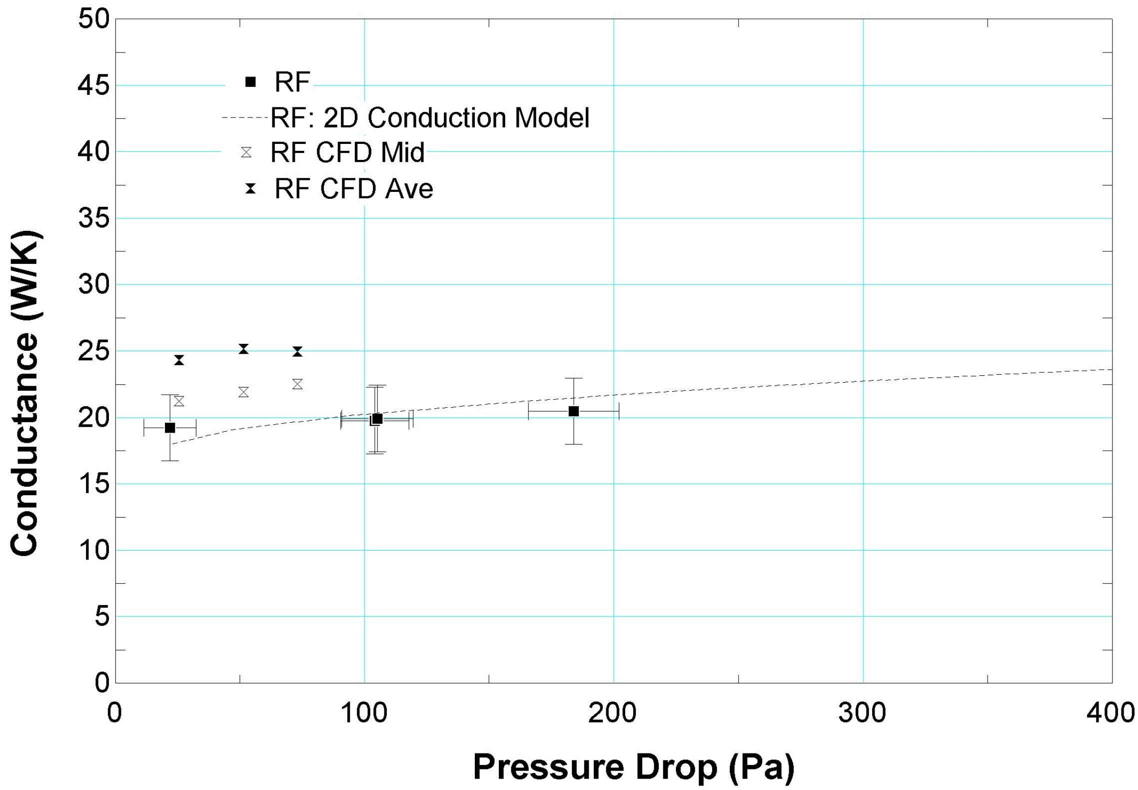


Figure 3.8: Conductance over a range of pressure drops.

Chapter 4

Topology Optimized Heat Sink Performance

Note: the experimental performance and 2D-conduction model is the work of this thesis. The CFD data was gathered by Sicheng Sun. Thank you Sun for allowing us to compare experimental and numerical results.

4.1 TO-Al-1

4.1.1 Design Goal

TO-Al-1 was designed in OpenFOAM and was optimized to minimize average base temperature at Re = 155. The design features two plates that mate on positive and negative cones as seen in Figure 2.9.

4.1.2 CFD vs Experimental Results

The conductance of both experimental and numerical results for TO-Al-1 are compared over a range of Reynolds numbers in Figure 4.1. The mesh used in this simulation was $64x70x67microns$. The CFD matches experimental data at Re = 150 but overestimates the thermal performances by 300% at Re = 300. Pressure drop over a range of Reynolds numbers is compared in Figure 4.2. The numerical results under-predict the performance by about 25%. The difference in prediction and measurement are further seen in Figure 4.3.

It is possible that build of the heat sink in two pieces is having an adverse impact. First, there may be contact region between the top and bottom parts that develop a contact resistance. The CFD predictions do not model the parts with a contact resistance and could explain the high numerical predictions. Second, the lid that is built features warpage (over 10%) that may not flatten out during compression of the test assembly. Third, the printed part may not be accurate. Chapter 5 explores the impact of additive manufacturing on a heat sink's geometry. Finally, the CFD models do not model a second plate. It only models the performance of the fins. The plates are added to support the fins. It is possible that axial conduction is negatively impacting performance by distributing energy.

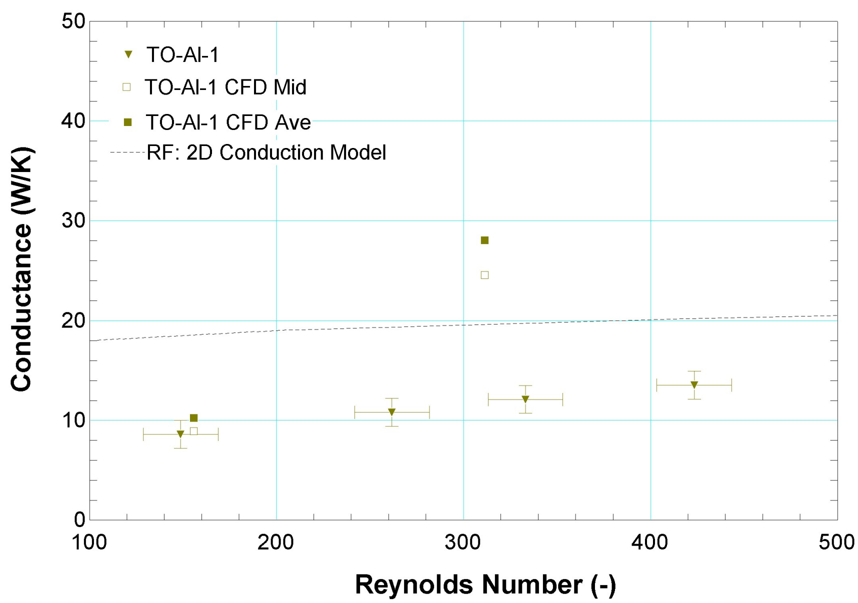


Figure 4.1: Conductance over a range of Reynolds number for TO-Al-1 compared with conventional benchmark.

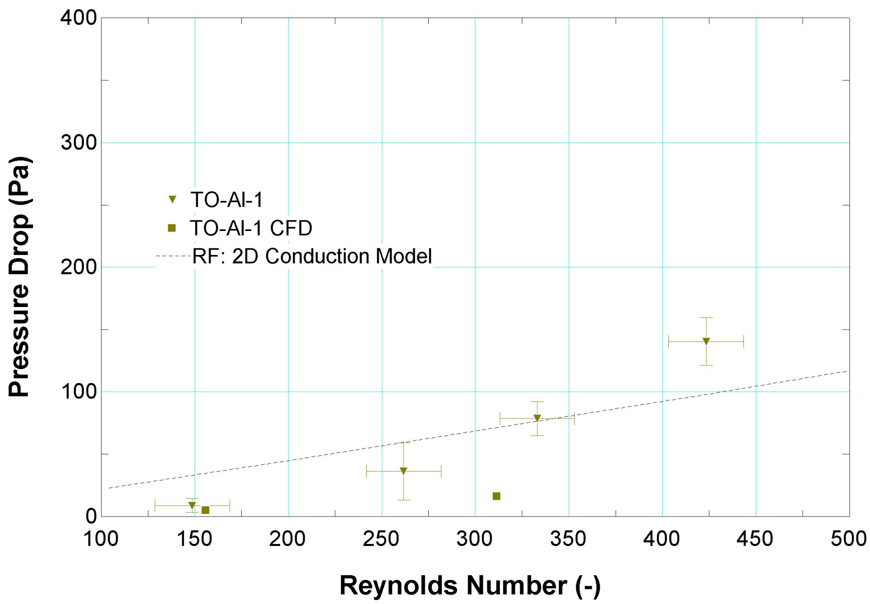


Figure 4.2: Pressure drop over a range of Reynolds number for TO-Al-1 compared with conventional benchmark.

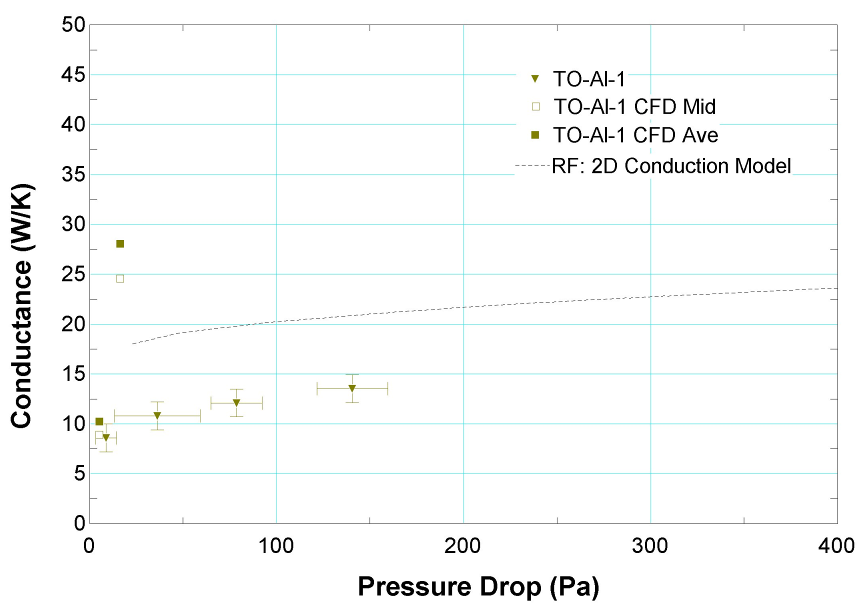


Figure 4.3: Conductance over a range of pressure drops for TO-Al-1 compared with conventional benchmark.

4.2 TO-Al-2

4.2.1 Design Goal

This heat sink was designed to be made in two parts. It's optimized to minimize average base temperature at Re = 155. It is designed in FEniCS instead of OpenFOAM.

4.2.2 CFD vs Experimental Results

CFD simulations were not obtained at the time of this thesis. That being said, the design team put is serious effort to get the CFD data used in this thesis. It would be interesting to compare the CFD predictions with this collected data as the heat sink performed as well as the rectangular finned geometry.

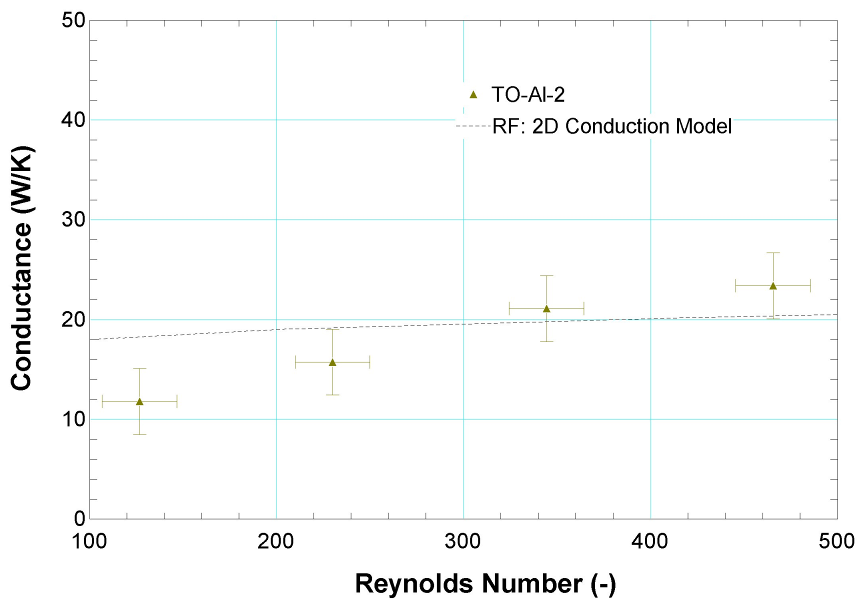


Figure 4.4: Conductance over a range of Reynolds number for TO-Al-2 compared with conventional benchmark.

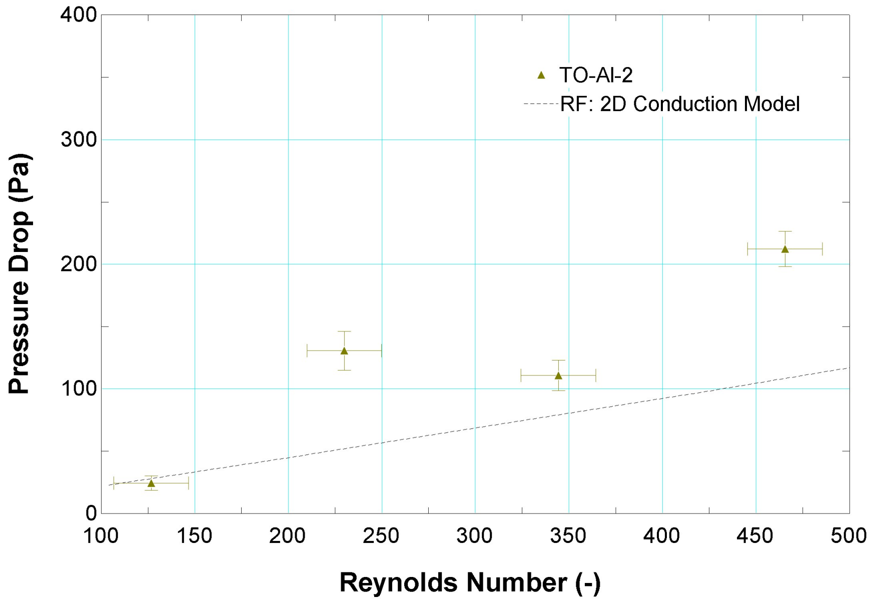


Figure 4.5: Pressure drop over a range of Reynolds number for TO-Al-2 compared with conventional benchmark.

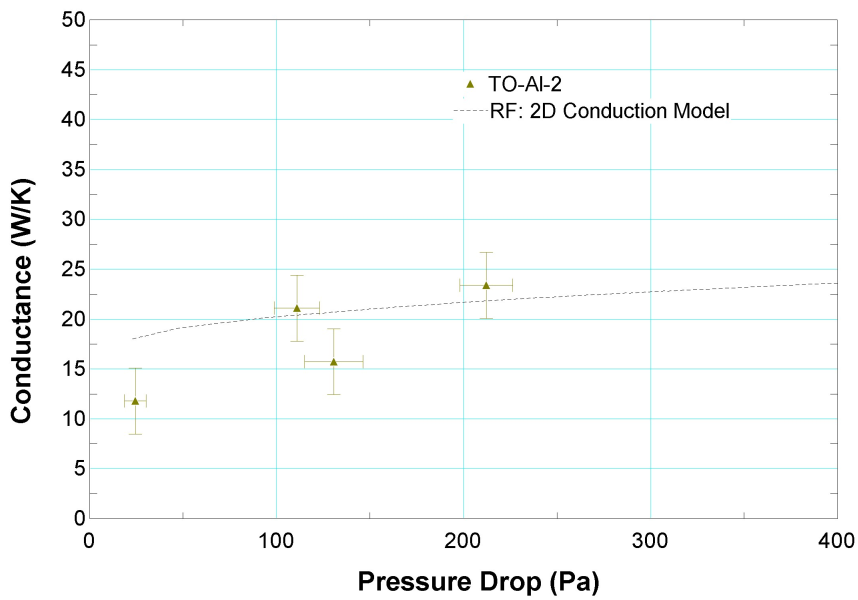


Figure 4.6: Conductance over a range of pressure drops for TO-Al-2 compared with conventional benchmark.

4.3 TO-Al-3

4.3.1 Design Goal

TO-Al-3 is designed to be in two parts. It is optimized to minimize average base temperature. It was designed in OpenFOAM with about 3x more cells than TO-Al-1. This heat sink was optimized for Re = 155.

4.3.2 CFD vs Experimental Results

The simulations used the same size mesh as the design program. Figure 4.7 compares thermal performance over a range of Reynolds numbers. At Re=155, the predictions only overestimate performance by 50%. However, predictions skyrocket to over 200% at higher Re. In Figure 4.8, the CFD under-predicts pressure drop by 50%.

It is interesting that the conductance of the CFD and experiment are closer at low flow rates than at high flow rates. The four potential causes of experimental deviation mentioned in TO-Al-1 also hold here.

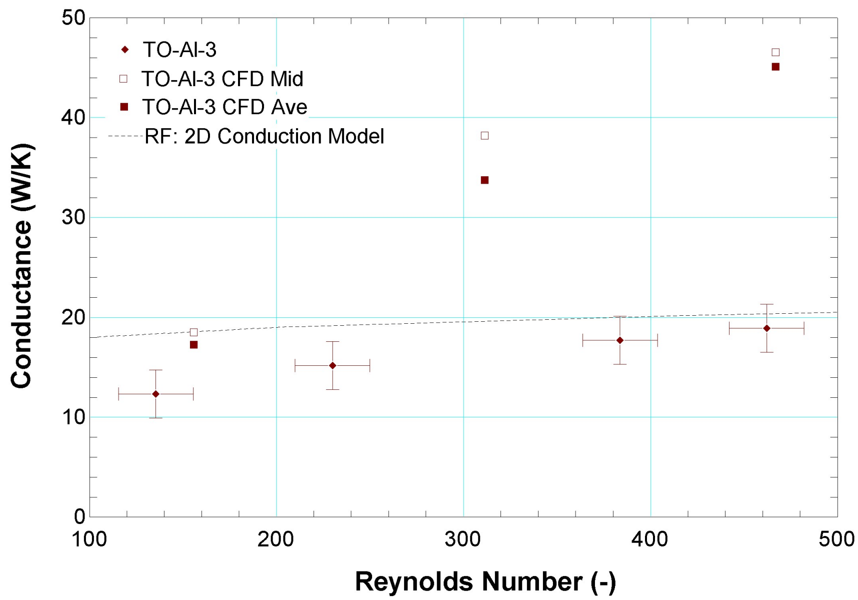


Figure 4.7: Conductance over a range of Reynolds number for TO-Al-3 compared with conventional benchmark.

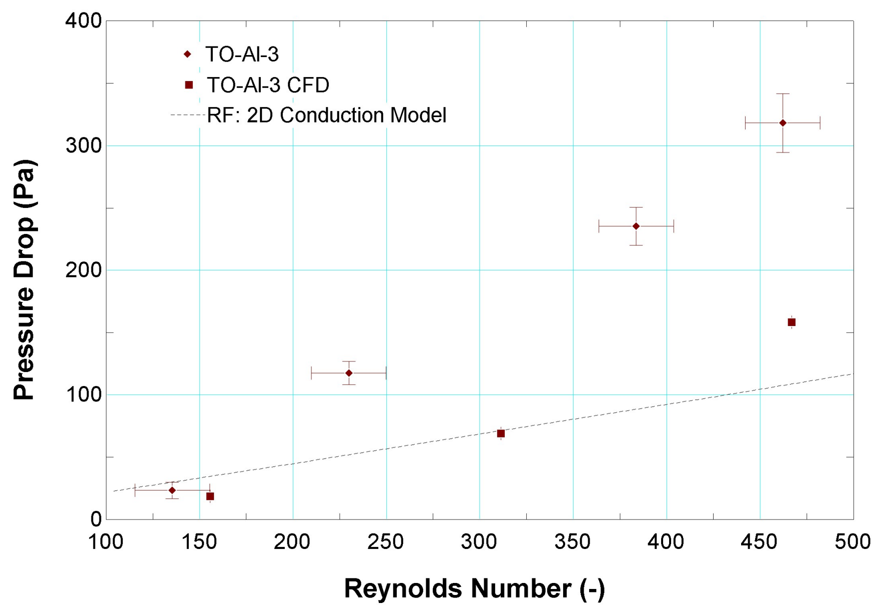


Figure 4.8: Pressure drop over a range of Reynolds number for TO-Al-3 compared with conventional benchmark.

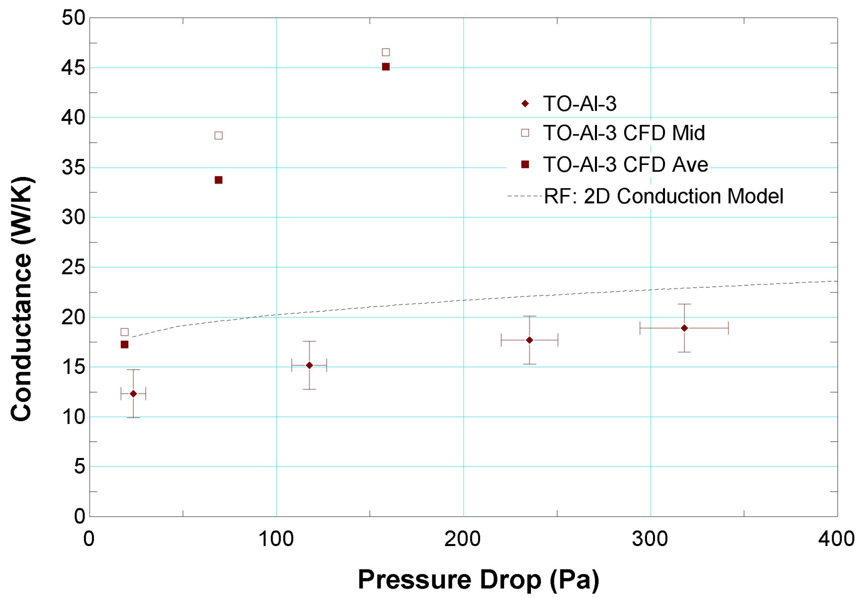


Figure 4.9: Conductance over a range of pressure drops for TO-Al-3 compared with conventional benchmark.

4.4 TO-Al-4

4.4.1 Design Goal

TO-Al-4 is different than TO-Al-1,-2,-3. First, TO-Al-4 is only built from one piece. Additionally, TO-Al-4 was built from a smaller unit cell than the other heat sinks. Finally, in contrast to all the other heat sinks, no part of the heat sink touches the top wall of the flow channel. This heat sink was still optimized to minimize base temperature at Re = 155.

4.4.2 CFD vs Experimental Results

The numerical model and experimental data conductances match within error bars in Figure 4.10. Pressure drop predictions in Figure 4.10 under predict experimental performance by over 50% at Re = 300. It is interesting that thermal performance predictions match experimental data for this heat sink. It is likely that by being built in one piece, the impact of contact resistances and assembled part geometry deviation is avoided. With respect to high pressure drop, a possibility is that the surface roughness plays a role.

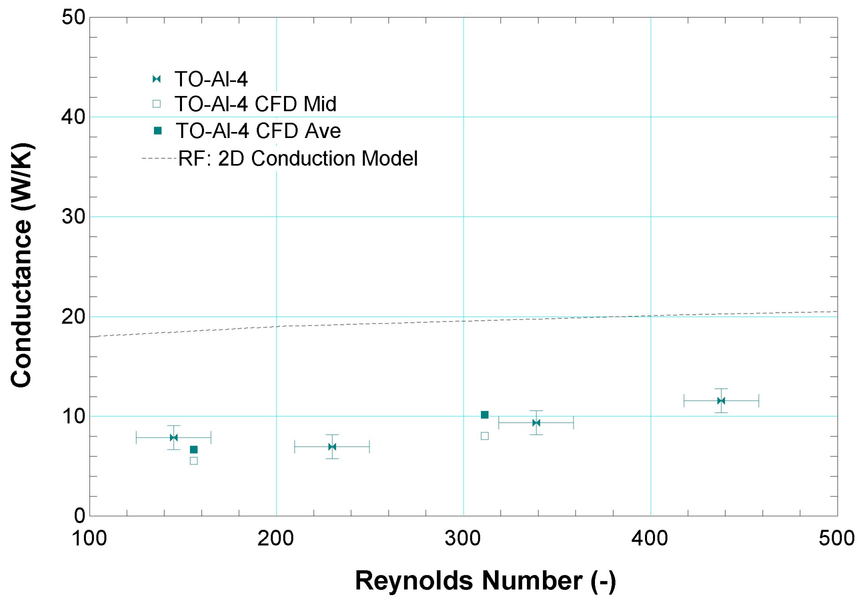


Figure 4.10: Conductance over a range of Reynolds number for TO-Al-4 compared with conventional benchmark.

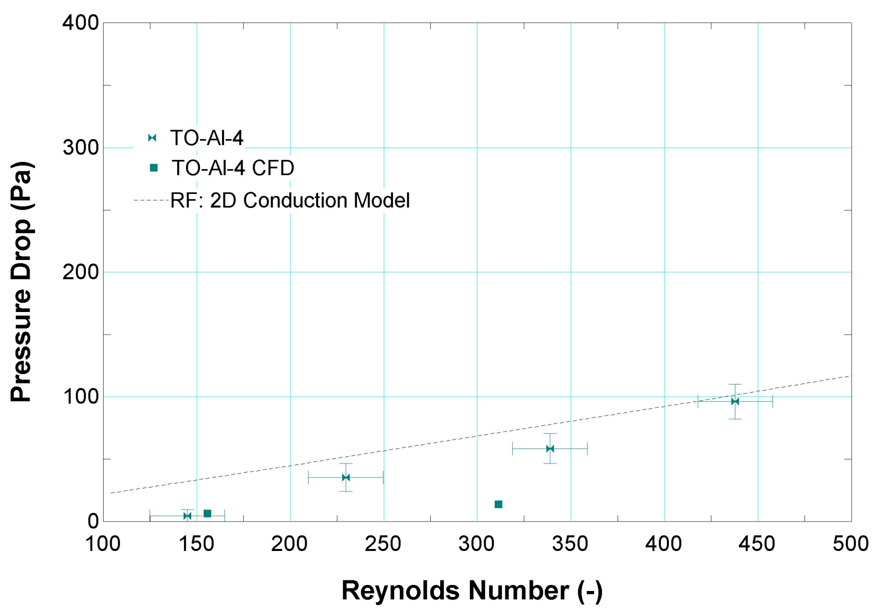


Figure 4.11: Pressure drop over a range of Reynolds number for TO-Al-4 compared with conventional benchmark.

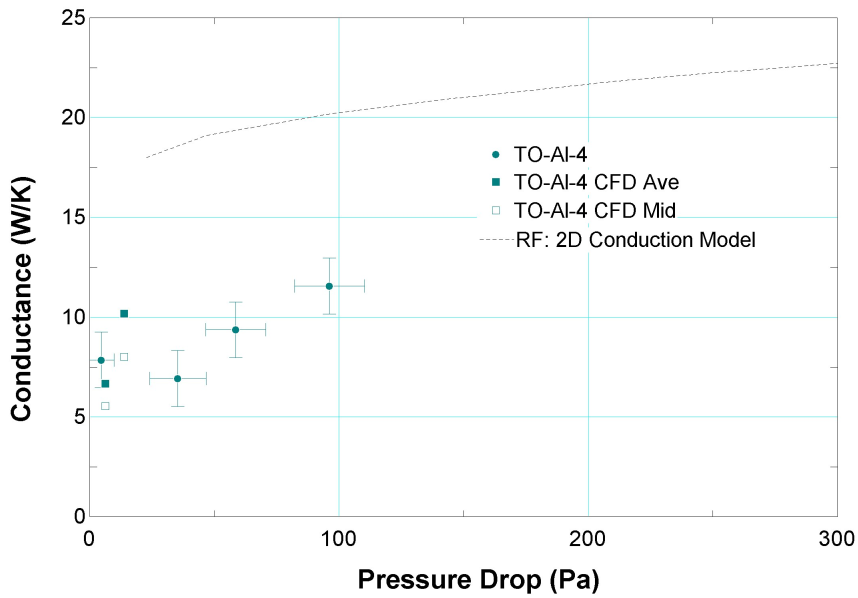


Figure 4.12: Conductance over a range of pressure drops for TO-Al-4 compared with conventional benchmark.

4.5 TO-Al-5

The performance of three test articles associated with the TO heat sink are compared with the CFD predictions and with the performance of the conventional geometry.

4.5.1 Design Goal

This heat sink was designed to be inspectable for a optical surface comparison. The design team used a coarse mesh to ensure printable features ($106x125x200microns$) and finely meshed the part for performance simulations ($33x33x67microns$). This heat sink was optimized to minimize base temperature at Re = 155.

This heat sink was also designed to be one piece (no top piece). During the testing process, the experimental and design teams learned that generating a design with large overhang angles, cutting it to allow for a successful print, and putting it back together in the test section will dramatically change the performance of the heat sink. Not only will alignment be a challenge, but there will be a thermal resistance between the parts where the heat sink model expected continuous thermally conductive material.

4.5.2 Screen Study

The simulations used to optimize and predict the performance of the TO heat sink assume a perfectly distributed flow; that is the velocity at the inlet is uniform. In Figure 2.7, the water inlet and outlet ports of the test fixture are positioned symmetrically but there could be jetting or other flow maldistribution. Additionally, unlike the RF geometry the "channels" in the TO design are not isolated from other channels and therefore could allow fluid to transfer between channels. This transfer could lead to unexpected flow patterns and therefore unexpected performance.

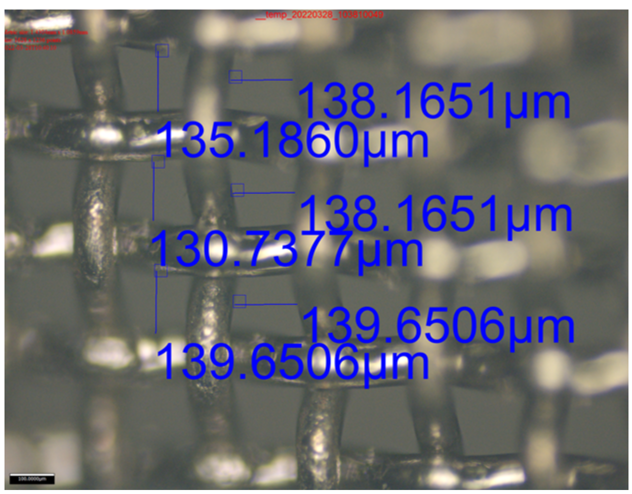


Figure 4.13: Measurement of mesh size using Alicona.

Screens with a mesh size of about 136*microns* as seen in Figure 4.13 were added to add pressure drop to the system and distribute the flow. The screens were added to the front and back of the heat sink. First, no screens were used, and the performance was recorded. Then, 2 screens were added to the front and back (total of 4) and performance was recorded. Finally, 4 screens were added to the front and back (total of 8) and the performance was recorded. Figure 4.14 compares the pressure drop over Reynolds Number for the different screen levels.

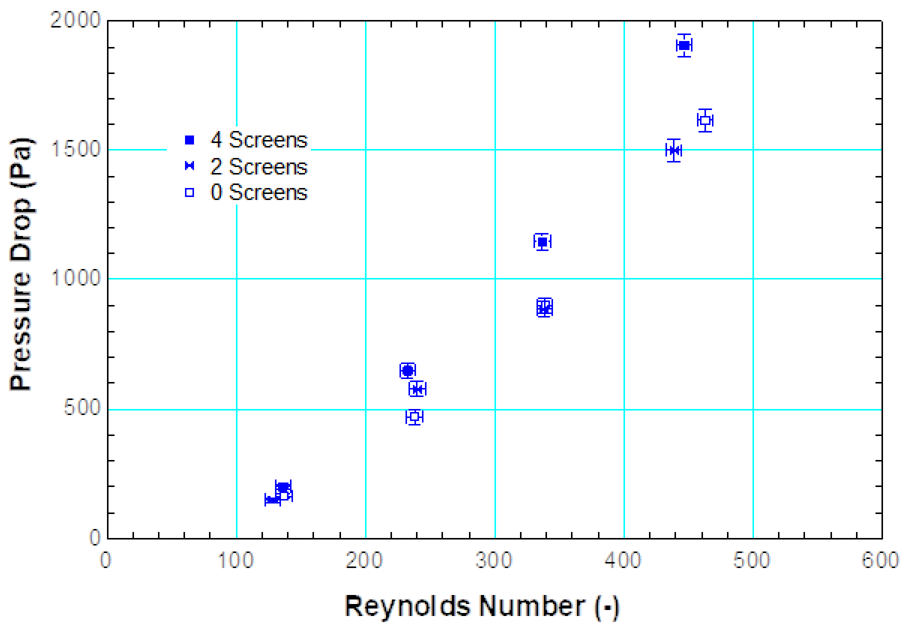


Figure 4.14: Pressure drop added through the addition of screens.

The addition of 4 screens increased pressure drop by about 25%. The pressure data collected for 2 screens does not meet the expectation of being greater than the no screen result for the same Re. It is possible air bubbles got trapped in the pressure taps and were not correctly vented. Additionally, a screen could have been slightly adjusted during operation. Figure 4.15 shows where the screens are fixed. They are notched into the green phenolic. If a screen became dislodged then flow may have had an easier pathway through the test section.

The increase in flow restriction from 0 screens to 4 screens is clear. However, the thermal performance in Figure 4.16 does not change with flow distribution. Therefore, the heat sink inherently achieves sufficient flow distribution. The TO heat sink ensures the flow is well distributed and acts as a filter, 4 screens are used in the tests of the articles. Note: the thermal performance in Figure 4.16 is less than the measured thermal performance later in this chapter. This is because the heat sink was thoroughly cleaned after this test which

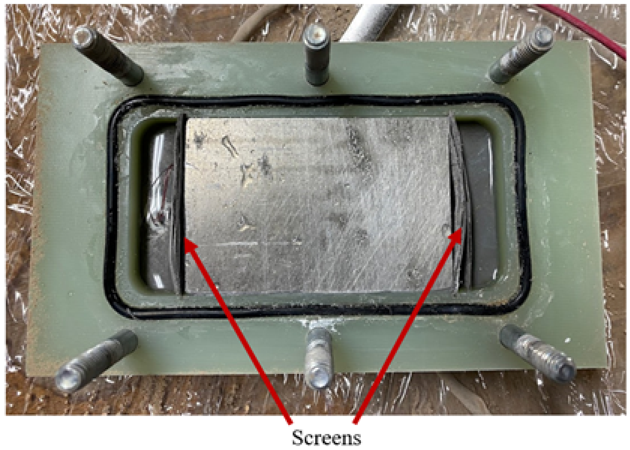


Figure 4.15: Location of the screens in the test section.

removed evidence of fouling.

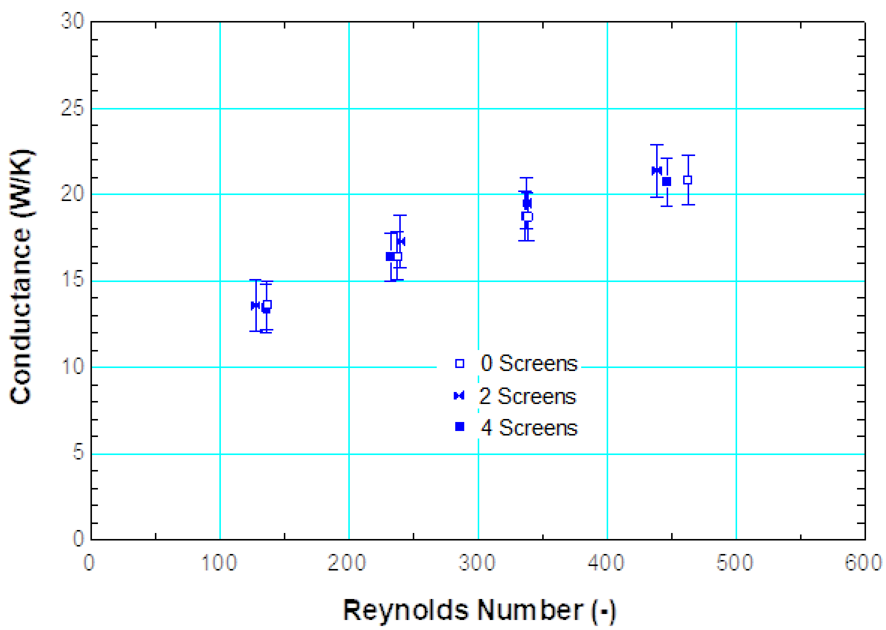


Figure 4.16: Thermal performance does not change with screens.

4.5.3 CFD vs Experimental Results

The numerical simulation methods used are not the focus of this thesis. However, the predictions obtained are needed in order for the measurements to validate the TO model. If more information about the computational fluid dynamics (CFD) model is needed, refer to Sicheng Sun and Dr. Xiaoping Qian (Sicheng Sun, Piotr Leibersback, and Xiaoping Qian 2020).

The experimental performance between the three copies of TO-Al-5 are compared Figure 4.17. The thermal performances are identical save for an outlier in TO-Al-5c at a low Reynolds number. Additionally, Figure 4.18 compares the pressure drop between the three test prints. The pressure drops overlay. Therefore, these prints are thermally and hydraulically repeatable.

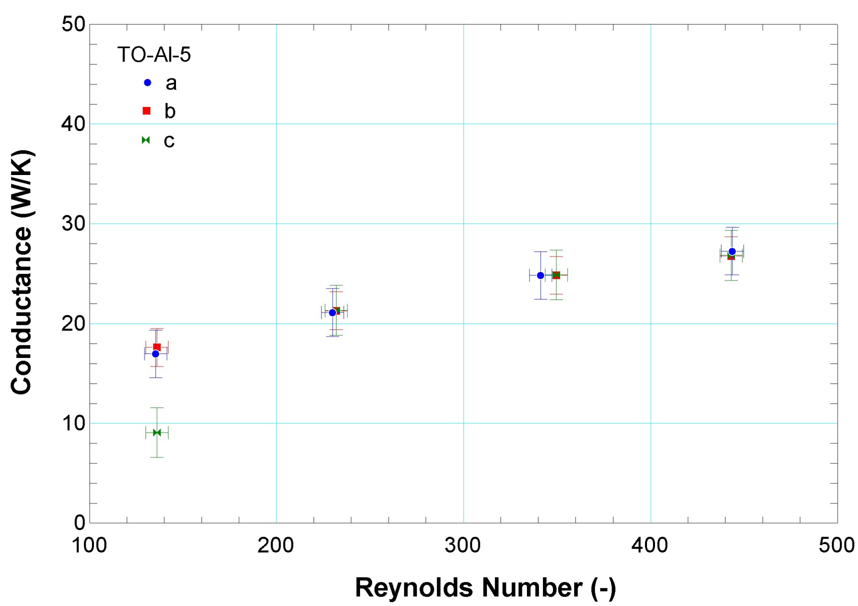


Figure 4.17: Conductance over a range of Reynolds Number for the 3 copies TO heat sink TO-Al-5.

The experimental performance of TO-Al-5 are compared in Figure 4.19, Figure 4.20, and Figure 4.21 with the numerical predictions of performance. Figure 4.19 compares the con-

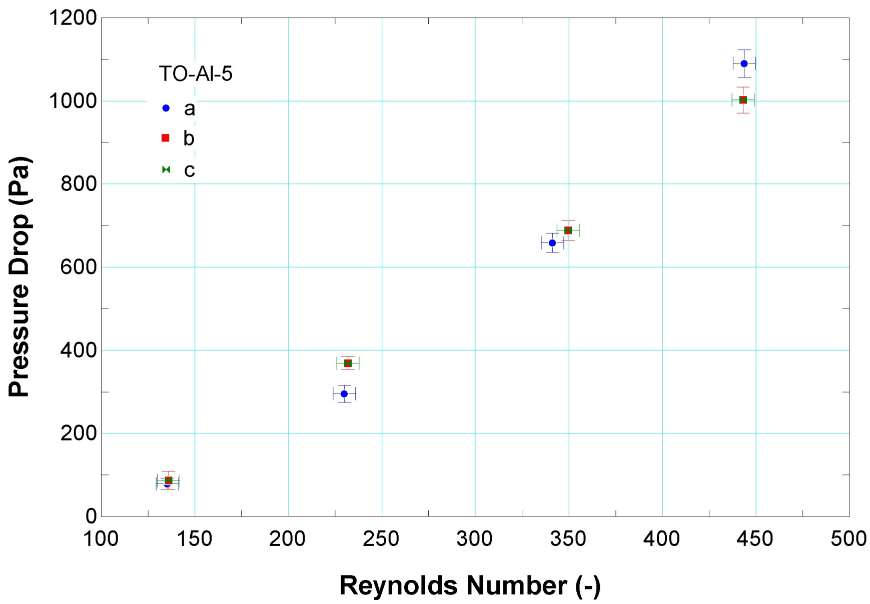


Figure 4.18: Pressure drop over a range of Reynolds Number for the 3 copies TO heat sink TO-Al-5.

ductance (thermal performance) as a function of Reynolds Number. The CFD overestimates thermal performance by 25% at low Re and 50% at high Re.

Figure 4.20 compares pressure drop (hydraulic performance) as a function of Reynolds Number. The pressure drop expectations line up with experimental results within 5%. Note that these experimental tests had screens in front and back of them. A run with screens and no heat sink was recorded to correctly offset the added pressure drop from the screens so when comparisons are made the pressure drop of the heat sink alone is used.

Figure 4.21 compares conductance as a function of pressure drop. Again, there are competing performance metrics in the design of a heat sink. To have a high thermal performing heat sink, increasing the surface area by decreasing the hydraulic diameter of the heat sink is a great way to increase thermal performance but the pressure drop will be too expensive. To have a high hydraulic performing heat sink (low pressure drop), use a flat plate. The challenge is the thermal performance will be miserable.

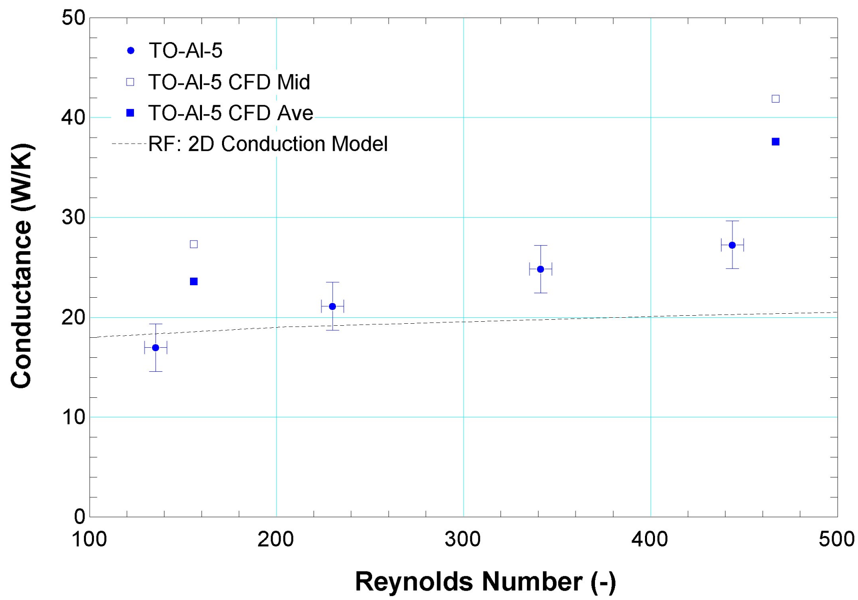


Figure 4.19: Conductance over a range of Reynolds Number for the TO heat sink TO-Al-5.

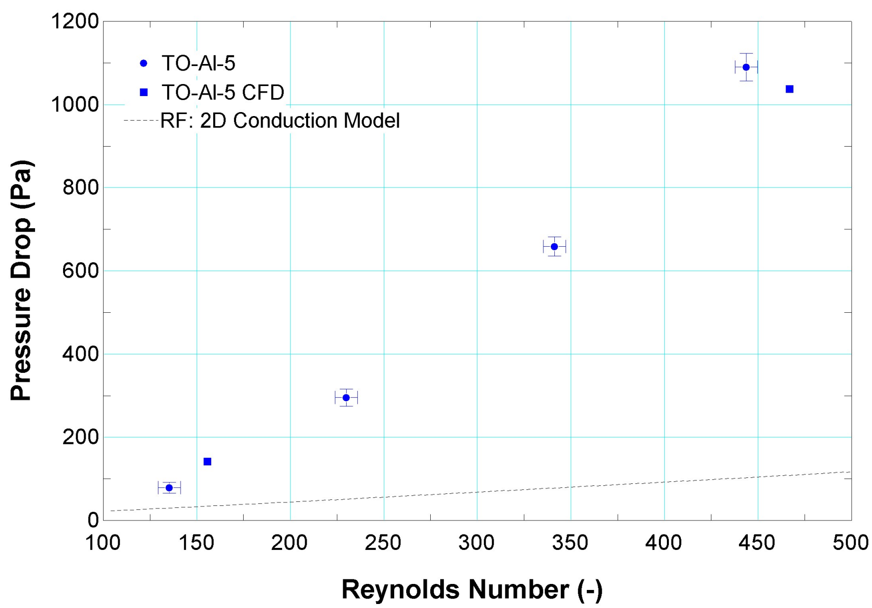


Figure 4.20: Pressure Drop over a range of Reynolds Number for the TO heat sink TO-Al-5.

The best heat sinks are in the top left of Figure 4.21 because this region combines high

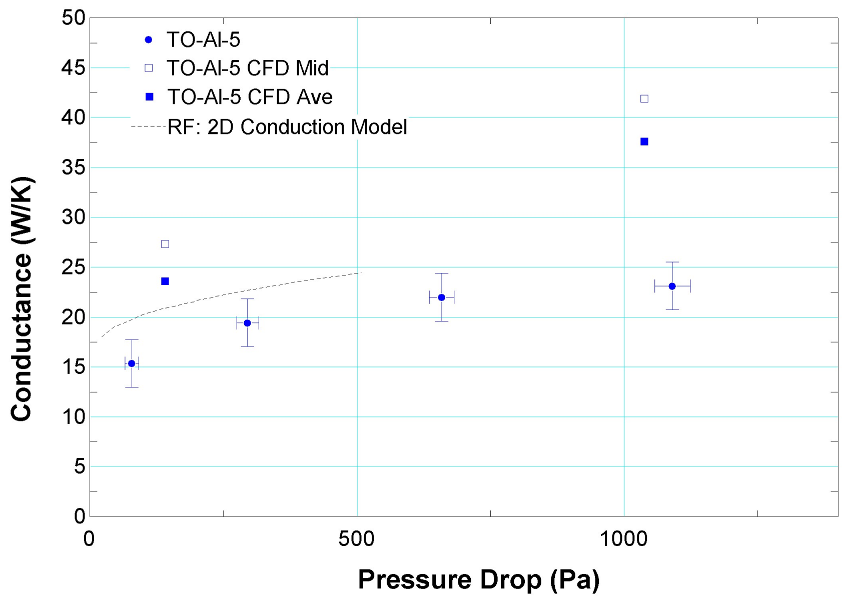


Figure 4.21: Conductance over a range of Pressure Drop for the TO heat sink TO-Al-5.

thermal performance and low flow restriction, or high hydraulic performance. Again, the CFD overestimates performance of the heat sink.

The CFD predicts thermal performance within 50% and hydraulic performance within 5%. This leads to the question: why does this numerical model over predict thermal performance?

4.5.4 Differences

The 50% error in thermal performance prediction of topology optimized heat sinks warrants inspection. Chapter 5 explores the sensitivity of performance measurements, measures the printed material properties, measures the surface roughness, and concludes with a as-designed vs as-printed inspection.

Chapter 5

Performance Analysis

The predicted and measured performance of a heat sink is dependent on factors such as geometric dimensions and material properties. Due to the material and manufacturing process, these factors can vary. This chapter explores the different variables impacting performance and identifies controllable sources of performance variation.

5.1 Sensitivity Study

The numerical model used to predict the rectangular finned heat sink performance uses variables that have uncertainty. To identify variables with the largest impact on performance, a sensitivity study is performed where fin thickness, fin height, heat transfer coefficient, and thermal conductivity are varied by 10% and 20%. The fin thickness's impact on conductance is varied in Figure 5.1. Increasing the fin thickness by 20% decreases the fin's conduction thermal resistance and improves conductance by about 10%.

The fin height's impact on conductance is varied in Figure 5.2. The rectangular fin's dimensions are optimized for this flow regime. The temperature profile is dropping as the energy moves up from the base of the fin to the tip, so there is not a large temperature difference between the fluid and fin near the tip. Increasing the surface area at the fin tip does not

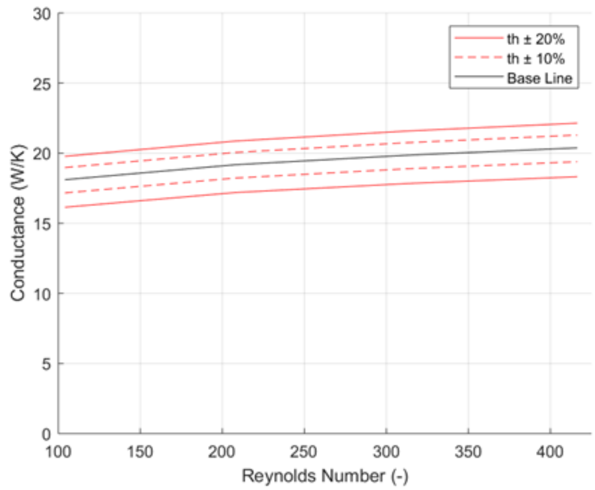


Figure 5.1: Impact of thickness variation on thermal performance.

decrease the resistance energy faces when moving from the base to the fluid because not much energy gets to the tip of the fin.

The heat transfer coefficient's impact on conductance is varied in Figure 5.3. The heat transfer coefficient could be improved due to a decrease in hydraulic diameter, change in fluid properties, or operating conditions. A 20% increase in heat transfer coefficient leads to at least a 10% increase in thermal performance.

The thermal conductivity's impact on conductance is varied in Figure 5.4. Like the thickness and heat transfer coefficient, increasing the thermal conductivity decreases the thermal resistance path and increases the conductance of the heat sink. This sensitivity analysis shows that the thermal performance of the heat sink is dependent on fin thickness, heat transfer coefficient, and thermal conductivity. If there is variation in these parameters, there will be variation in thermal performance.

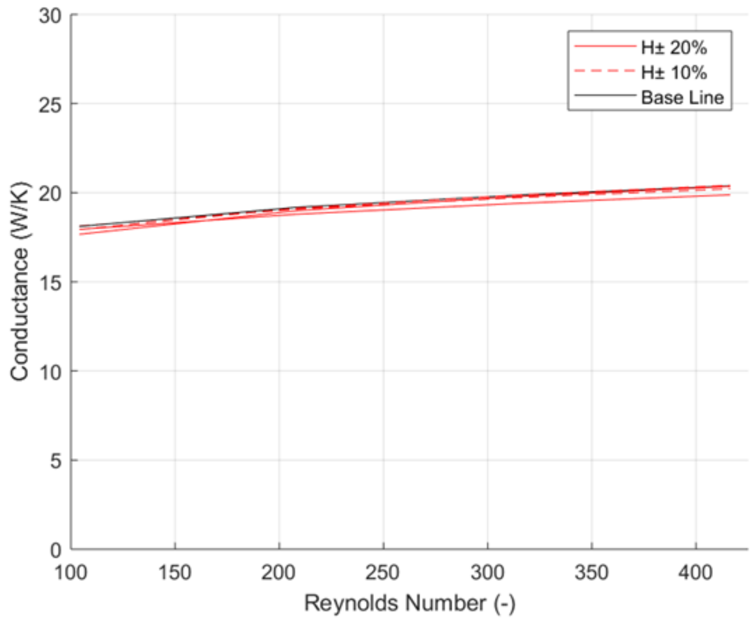


Figure 5.2: Impact of height variation on thermal performance.

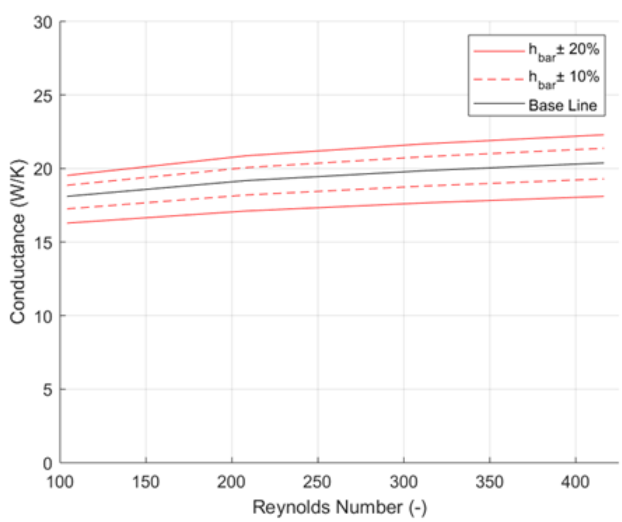


Figure 5.3: Impact of heat transfer coefficient variation on thermal performance.

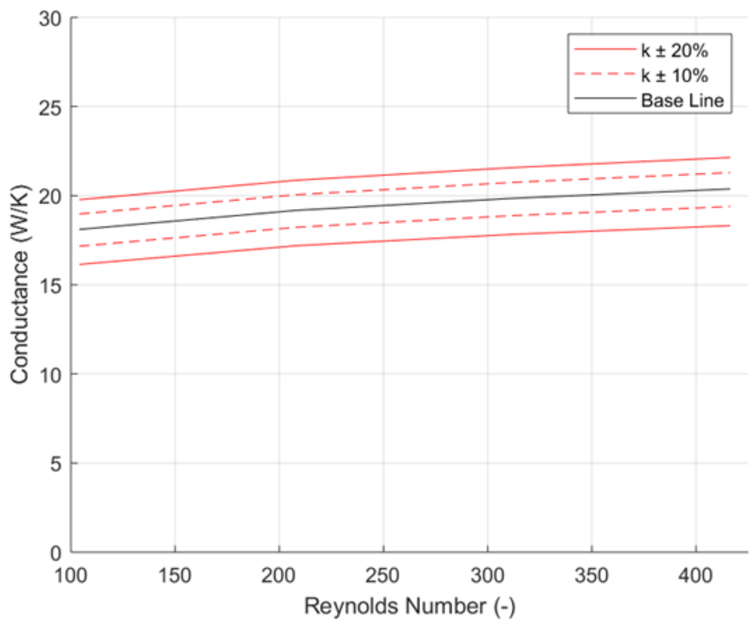
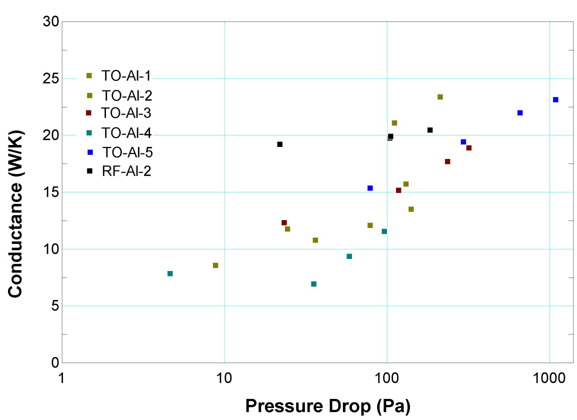


Figure 5.4: Impact of thermal conductivity variation on thermal performance.

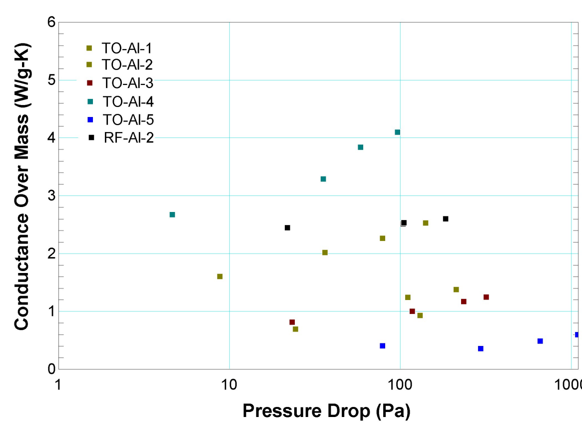
5.2 Mass Analysis

The heat sinks generated in this project look very different. The thermal and hydraulic performance has been compared. In addition to pressure drop and conductance, mass is briefly considered. Traditionally, more material used develops a higher part cost. While it is unknown if a larger part generates more material costs, a larger part does increase build time. Figure 5.5 compares the thermal and hydraulic experimental performance of the heat sinks tested in this thesis. On the left is just conductance. On the right, conductance is modified by dividing by the heat sink mass. This mass is measured with a precision scale and the mass of the plates are subtracted such that only the mass of the heat sink fins are collected.

Interestingly, TO-Al-4 has the highest thermal performance when compensated for mass. Additionally, TO-Al-5 drops in thermal performance when accounting for mass even with a higher pressure drop. In future optimization projects, it would be interesting to explore the cost impact of a larger heat sink and if it makes financial sense to optimize for mass.



(a) Conductance over a range of pressure drops.



(b) Conductance over mass over a range of pressure drops.

Figure 5.5: Heat sink performance with and without considering mass. Error bars are neglected for clarity. Note the log scale for pressure drop.

5.3 Conductivity Measurement

Thermal conductivity was determined to impact performance through the sensitivity study. This section explored measuring thermal conductivity.

Thermal conductivity is calculated by:

$$k = \alpha c_p \rho \tag{5.1}$$

Where α is the thermal diffusivity, c_p is the heat capacity, and ρ is the density. The density is calculated by measuring the mass of the sample with a scale accurate to 0.0001g and measuring the three primary dimensions of the rectangular solid within 0.1mm. The heat capacity is assumed because the lab did not have a set up to measure it. Additionally, if the thermal conductivity differs between the samples and the reference, it is more likely that the part was not printed well (change in density or diffusivity due to inclusions, part shape, or voids) than the material used being chemically different than the AlSi10Mg composite.

The thermal diffusivity is measured by a laser flash analysis (LFA). The LFA device flashes a laser on the bottom surface of the test article. The time-temperature response at the top surface of the test article is tracked to determine the thermal diffusivity of the piece. One way to think about thermal diffusivity is a thermal momentum. If a material has high thermal diffusivity, then the heat is moved through quickly and not caught up in the storage of the conducting medium. The time-temperature response and size of the conduction path is necessary in determining thermal diffusivity.

Sample test pieces were printed in the EOS M290 printer for a laser flash analysis (LFA) to measure the thermal diffusivity of the samples in a NETZSCH LFA 447. 8 parts, each $10mm$ x $10mm$ x $1mm$ rectangular extrusions, were printed. 4 lied flat on the base plate

($1mm$ dimension in the z or vertical axis) and were labeled H. The other 4 parts lied on the thin edge and labeled V. The H parts are designed to calculate thermal conductivity in the z-axis or build direction. The V parts are designed to calculate thermal conductivity in the x- or y-axis.

In addition to the 8 samples, a reference sample of 6061 aluminum with known conductivity was made to gauge the accuracy of the measurement. The uncertainty propagation in the calculation of thermal conductivity is exemplified in Figure 5.6. Table 5.1 compares the averaged, calculated thermal conductivities of the printed and reference samples with the tabulated values.

Unit Settings: SI K Pa J mass deg

Variable±Uncertainty	Partial derivative	% of uncertainty
k = 193.9±10.72 [W/m-K]		
α = 0.0000811±0.00000291 [m2/s]	∂k/∂α = 2.391E+06	42.11 %
D = 0.01251±0.0001 [m]	∂k/∂D = -31000	8.36 %
m = 0.0008429±1.000E-07 [kg]	∂k/∂m = 230042	0.00 %
th = 0.00257±0.0001 [m]	∂k/∂th = -75450	49.53 %

No unit problems were detected.
Compilation time = 110 ms   Calculation time = 16.92 s

Figure 5.6: Uncertainty calculation examples for thermal conductivity.

Table 5.1: Dimensions of the rectangular finned heat sink. Measured values had a standard deviation of 0.03mm.

Horiz. Conduction (V)	$\rho(\frac{g}{cm^3})$	$Urho$	$c_p(\frac{J}{kg-K})$	Uc_p	$\alpha(\frac{mm^2}{s})$	$U\alpha$	$k(\frac{W}{m-K})$	Uk
Measured or Calculated	1.98	0.283			71.5	9.91	129	7
Tabulated	2.67		0.92	0.05			103	5
Vert. Conduction (H)	$\rho(\frac{g}{cm^3})$	$Urho$	$c_p(\frac{J}{kg-K})$	Uc_p	$\alpha(\frac{mm^2}{s})$	$U\alpha$	$k(\frac{W}{m-K})$	Uk
Measured or Calculated	2.29	0.087			62	1.64	127.6	6
Tabulated	2.67		0.91	0.05			119	5
6061	$\rho(\frac{g}{cm^3})$	$Urho$	$c_p(\frac{J}{kg-K})$	Uc_p	$\alpha(\frac{mm^2}{s})$	$U\alpha$	$k(\frac{W}{m-K})$	Uk
Measured or Calculated	2.67	0.112			81.103	2.91	194	10.7
Tabulated	2.7		0.896		66		154	

Starting with the 6061 reference sample, the density was measured within the measurement uncertainty. The thermal diffusivity is 30% higher than expected and beyond the error in the measurement. This leads to a higher thermal conductivity than expected. Two candidate causes for this difference are: part size and measurement calibration. The part size is using ASTM standards, but because the thermal diffusivity is so high the thermal wave from the laser flash is measured within milliseconds of the flash. This is pushing the LFA as it is designed to measure diffusivities of metals to polymers. If the thickness of the part was increased, then the time response would be proportionally increased and would lead to a more resolved measurement. Additionally, this measurement device was dormant for over two years. It is possible that the machine needs calibration. This conductivity measurement was completed in April 2022.

It is also notable that the densities of the printed parts are lower than the tabulated values. As the parts are $1mm$ thick and the roughness is about 5-10% of the measured dimension, it is possible that this thin dimension and roughness is negatively impacting results.

The results of this test cannot be used to measure the thermal conductivity of the aluminum samples. It is necessary to repeat this measurement following these guidelines:

- Use thick parts such that the diffusive time is larger than 20 milliseconds. To test multiple parts, print them as one big block and machine them apart.
- Machine flat surfaces to negate the impediment of splatter on thickness measurements and laser absorption.
- Calibrate the LFA device such that there is confidence in its results.

5.4 Roughness

The direct metal laser sintering (DMLS) printing process starts with a bed of powder metal with particles 20-75 microns in diameter. A laser tracks the 2D cross-section of the part, the bed is lowered, a knife scrapes a 30 micron thick layer over the part, and the laser begins to track the next layer. This process repeats unit the part is built.

The surface roughness of a part printed with DMLS using an EOS printer is estimated to have a roughness of 30-40 microns (AD, WEIL 2014). After the printing process, the surface of the parts was inspected and splatter from the melt pool is measured to be 100 microns in Figure 5.7. The accuracy of the EOS printer is stated to be 100 micron, so this part dimension variation due to the splatter is within the printing resolution (AD, WEIL 2014). However, with a flow channel width of about 1000 microns, this splatter is 10% of the channel width and could impact the flow path.

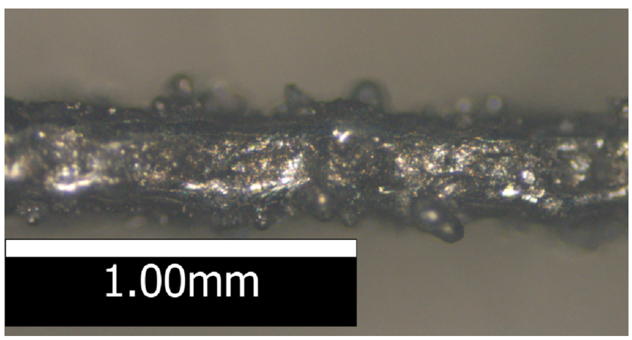


Figure 5.7: Roughness from splatter on the rectangular fin.

For the rectangular finned heat sink, the surface is abrasively sand blasted and sanded with over 500 grit sandpaper to break this splatter profile and obtain flat fins in Figure 5.8. After this process the fin dimensions are measured with an Alicona optical microscope to predict the heat sink performance. This sanding process was not feasible for the TO geometries due to the delicate and internal features. The observed printing splatter may act as unintended features for a part (deviating from the as-designed geometry) or a scale of roughness that is should be taken into account with laminar flow. Heat transfer correlations in the laminar flow regime are independent of surface roughness (P. Wibulswas 1966).

This large scale roughness could impact the flow path and therefore modify the heat transfer coefficient. Unsuccessful attempts at electro-polishing were made on a printed part to test the thermal performance of a TO heat sink with and without roughness. It would be interesting to test the thermal performance before and after sanding to measure the impact of sanding.

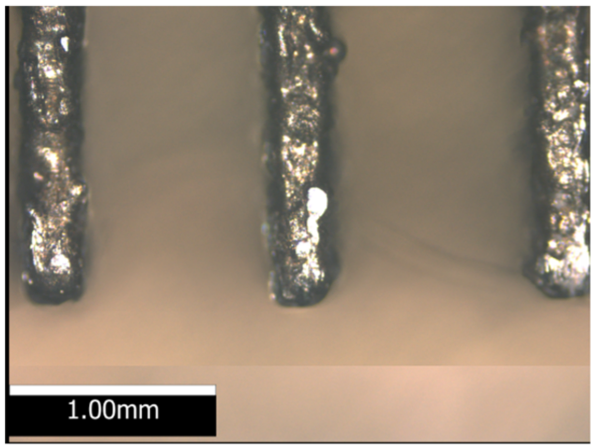


Figure 5.8: Sanded fins of the conventional heat sink.

5.5 CT Scan of Heat Sink

Optical images of the RF HS allowed for feature measurement and comparison, but the TO HS geometry's unique features warrant a digital comparison. A strip of the HS TO-Al-5 was printed along with the test article. This strip was scanned in a ZIESS Metrotom 800 micro-CT scanner that generated a point cloud in the Digital Studio VGA program. A mesh of the point cloud is compared with the mesh that was sent to the printer to allow for a direct comparison of as-designed and as-printed geometry.

5.5.1 As-Designed Geometry

The topology optimization program designs a strip of a heat sink that is stacked repeatably to build out the heat sink. The output strip is a mesh with a resolution of 33x33x67 microns as shown in Figure 5.9. This mesh strip is then smoothed as seen in Figure 5.10 and then stacked to build up the heat sink. The mesh is smoothed to reduce the right angle corners of the triangular mesh.

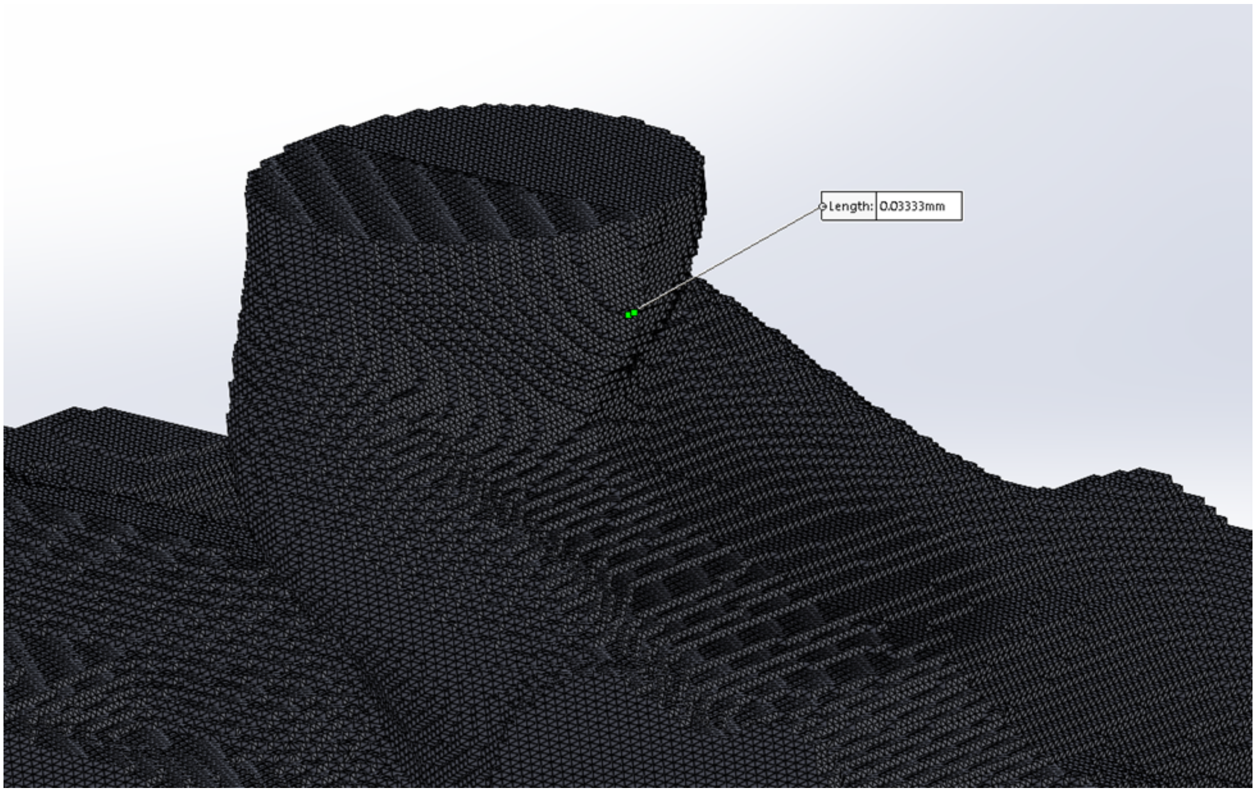


Figure 5.9: Mesh of the heat sink outputted from the optimization program.

5.5.2 As-Printed Geometry

A strip of the unit cell was printed along side the test articles for TO-Al-5 to get similar build quality. The strip was scanned with a ZIESS Metrotom 800 micro-CT scanner. The point cloud from this scan was found from a surface determination using VGA Studio Max. The point cloud's accuracy is between 6-8 microns. A mesh is created from this point cloud such that 90% of the mesh is within 0.003mm of the point cloud. This mesh resolution is 47 microns as seen in Figure 5.11.

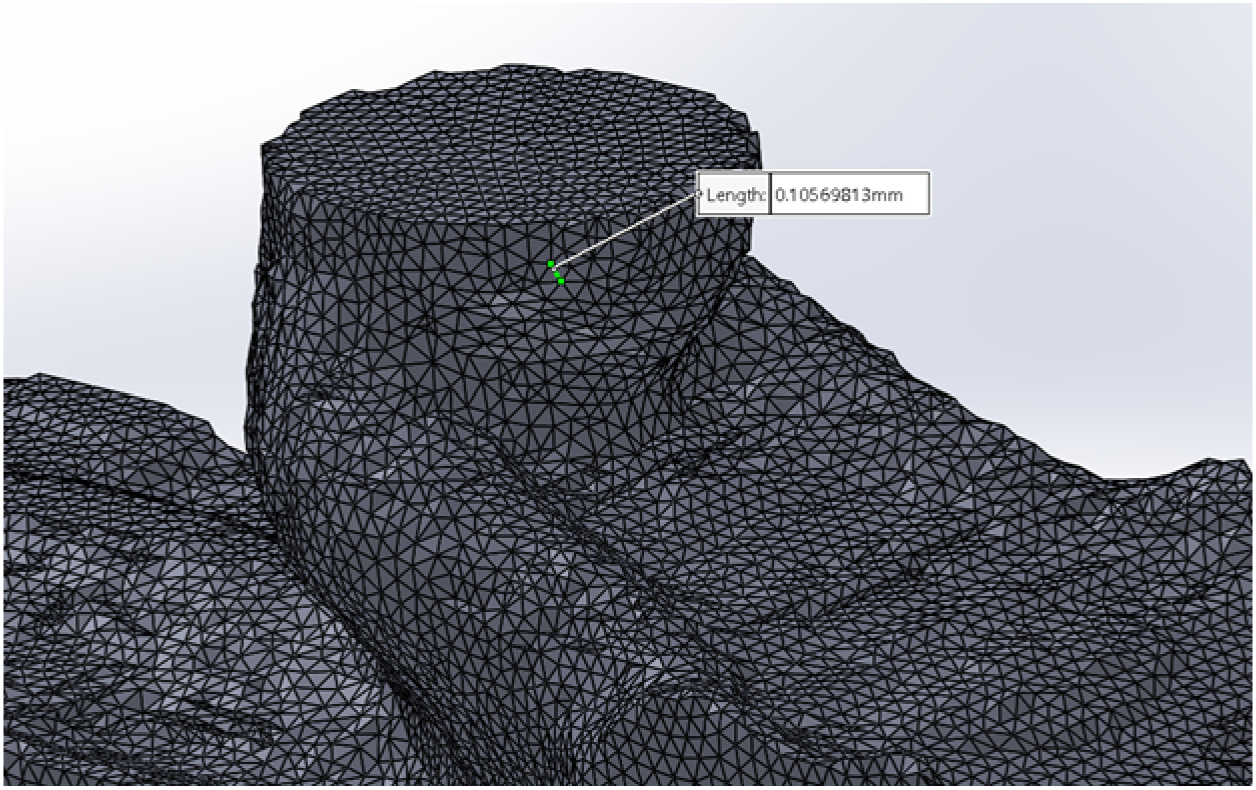


Figure 5.10: Smoothed mesh sent to the printer.

5.5.3 As-Printed vs As-Designed Geometry

The as-printed and as-designed meshes are first compared with an overlay. Then, they are sliced with a MATLAB program to obtain the contours for direct comparison.

3D Surface Comparison

The two meshes were compared in the VGA Studio software with a nominal (as-designed) vs. actual (as-printed) comparison. Figure 5.12 is the color plot of the comparison. The overhang angle regimes feature significant deviations of over 0.1mm. As a reference, the positive features in this plot are about 1mm in size so this deviation is about 10%. Additionally, the corners of the part (in blue) have less material than expected.

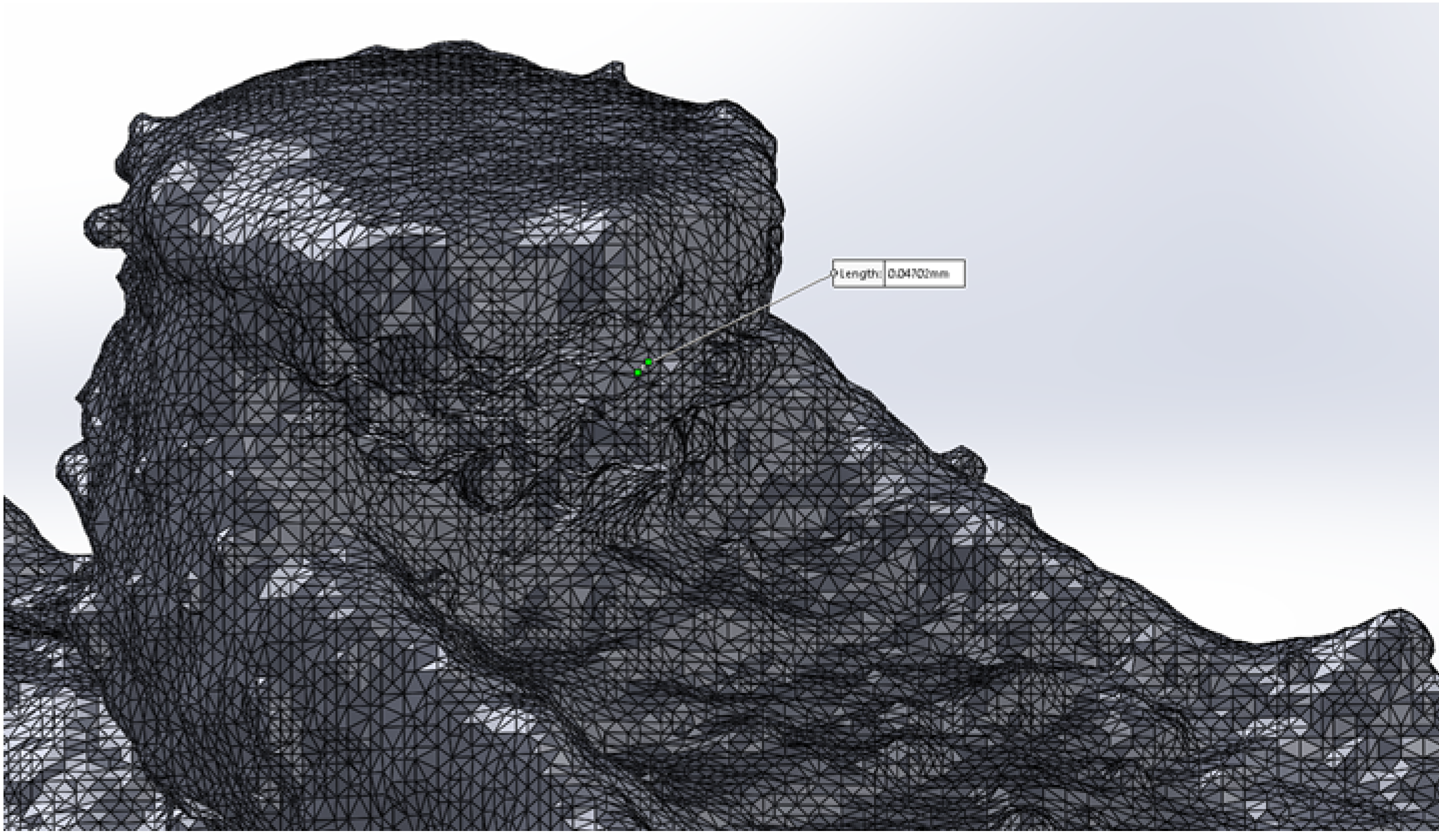


Figure 5.11: Mesh of the as-printed heat sink point cloud.

Vertical Plane

Starting with the vertical plane, the two meshes are imported into MATLAB and sliced in the same XZ plane. The positions of the contours are adjusted such that the two paths are located at the same corner (blue circle in Figure 5.13).

The as-printed strip is smaller than the as designed. This is noted by the right edge offset of 0.2mm. Additionally, there is some slight warpage as seen by the bending of the base at the bottom right. The shrinkage and warpage are likely due to residual stresses in the part during the printing process. The laser melt pool freezes quickly and there is no annealing process to allow for grains under loading to reform. When the part is removed from the base plate with EDM, the stresses can cause bending and other deformations.

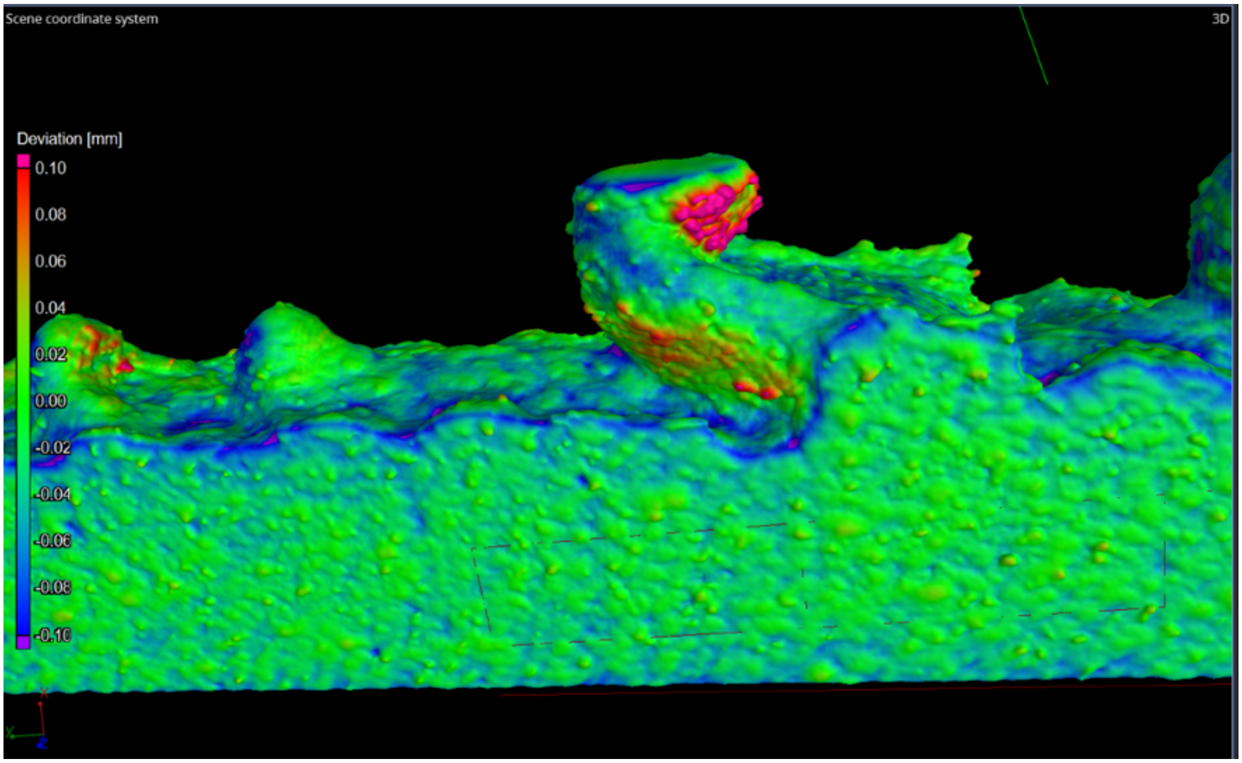


Figure 5.12: Nominal vs. Actual comparison of the TO-Al-5 strip. Notice the abundance of material in the overhang regions.

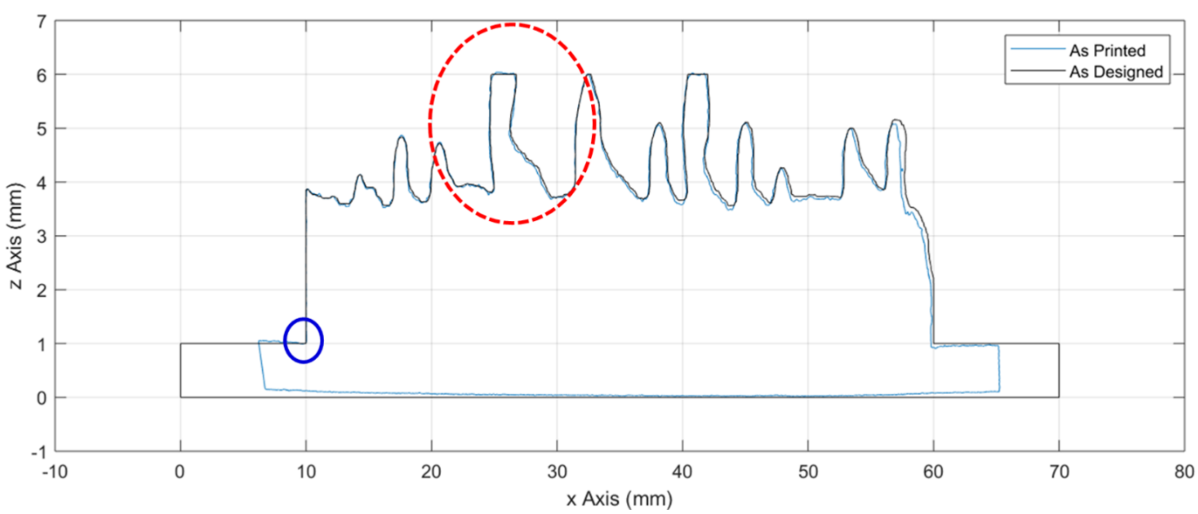


Figure 5.13: Full strip of TO-Al-5. Blue circle is where the contours line up and red circle is a feature that is studied in detail.

The red circle in Figure 5.13) focuses on a positive feature with overhang angles. Due to the early developmental stages of the TO program, manufacturing constraints were not

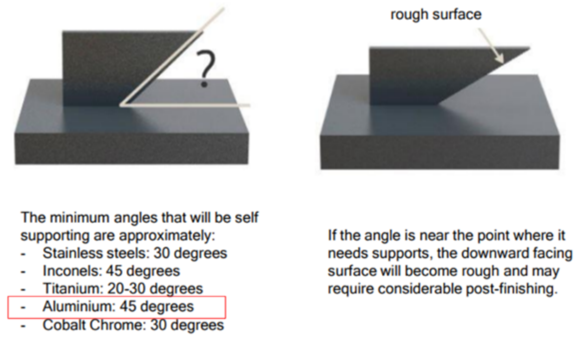


Figure 5.14: Design for printing guidelines from Crucible Industrial Design (*Design guidelines for Direct Metal Laser Sintering (DMLS)* 2014)

yet implemented. However, overhang angles can cause printing errors due to no material support. Figure 5.14 is a snapshot from DMLS printing guidelines. The minimum angle for aluminum is 45 degrees.

Figure 5.15 zooms in on the positive feature highlighted in Figure 5.13) and identifies two areas with an overhang angle.

Figures 5.16 and 5.17 feature measurements of the surface roughness, the waviness of the surface, and the offset of the as-printed surface from the as-designed.

Starting with Figure 5.16, the overhang angle is 40deg which is violating the printing recommendation. The surfaces are offset by 0.234mm and the roughness is 0.055mm. Table 5.2 lists the various printing parameters and feature sizes for the powder used.

Table 5.2: Printing parameters (AD, WEIL 2014).

Parameter	Value
Laser Diameter (μm)	100
Layer Height (μm)	30
Minimum Pringing Angle ($^{\circ}$)	45
Particle Size (μm)	25-70
EOS Accuracy (μm)	100

The roughness is on the order of magnitude of both the layer height and particle size. It is possible that the overhang angle regions are freezing particles before they fully fuse in the

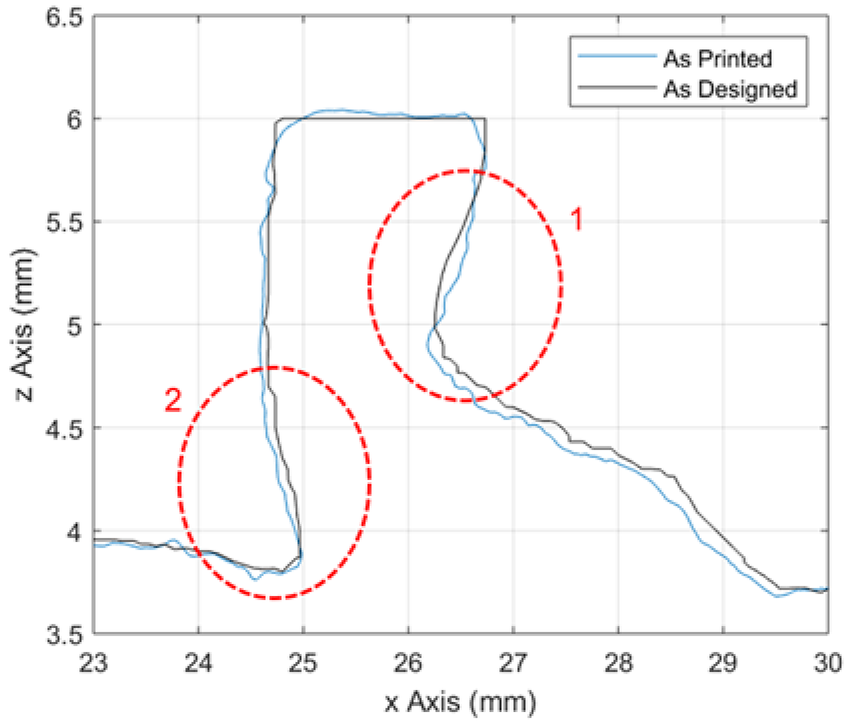


Figure 5.15: Large positive feature with two overhang angle regions.

melt pool. Additionally, the roughness could be the layers not fusing at an edge uniformly due to the overhang. The waviness of the roughness and the offset of the surfaces could be due to overhang angle and lack of support structure. Interestingly, Figure 5.17 has a permittable overhang angle of 67° and the offset between surfaces is 27% less than the overhang angle of 40°. Another observation is that with an overhang angle, the as-printed surface is larger than the as-designed. Material is accruing in these areas and could be impacting the flow path of the working fluid.

Horizontal Plane

A slice was also taken in a horizontal plate (eagle-eye view) through a feature with no overhang. Figure 5.18 identifies a slice of the positive feature discussed above. Figure 5.19 zooms into the deviation of the surfaces.

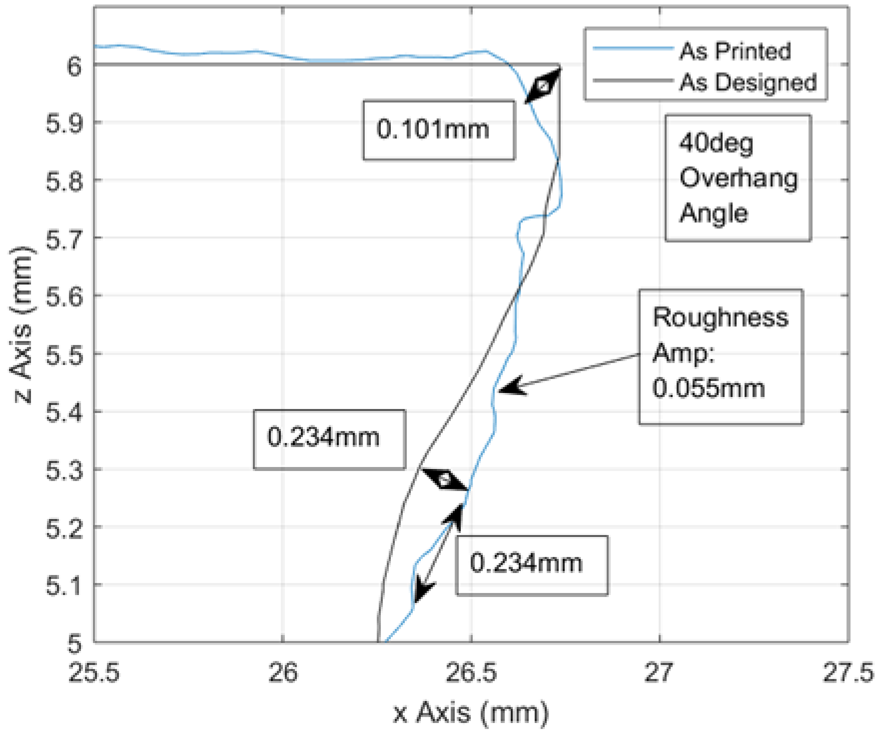


Figure 5.16: First overhang angle region

The roughness matches the vertical slice's roughness. Additionally, the surfaces are within spec as the error in printing is 0.1mm. The waviness in the roughness profile does not match any metrics in Table 5.2. It is possible that the melt pool is much larger than the 0.1mm setting, but more research into the pool's dynamics is needed to compare with the details of the roughness.

5.5.4 Of Meshes and Magnitude

Tables 5.3 and 5.4 are repeated below. The inspection of the surfaces identified roughness on the order of $40 microns$. This is the same size as the mesh used to simulate the performance of the heat sinks. Simulating these geometries requires significant computational power, but if flow is navigating around these elements, the experimental flow paths may not currently match the numerical models. If the element size of the smoothed mesh is on the same size as the roughness, these features may not be captured. It would be interesting to take

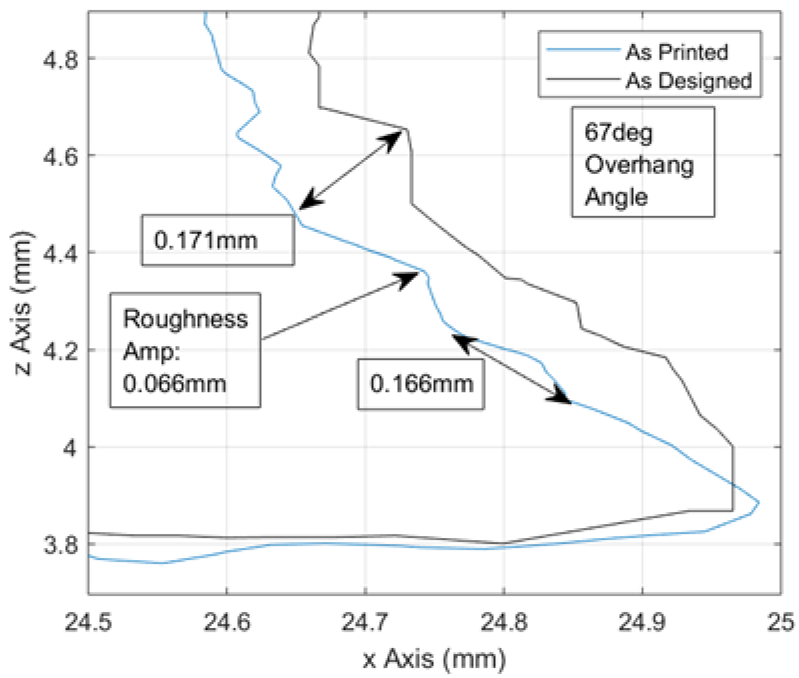


Figure 5.17: Second overhang angle region.

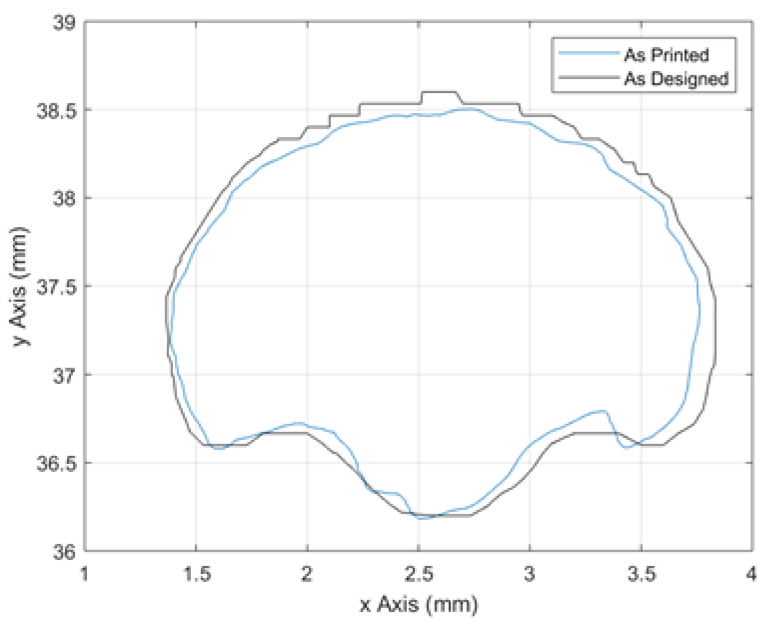


Figure 5.18: Horizontal slice of a positive feature.

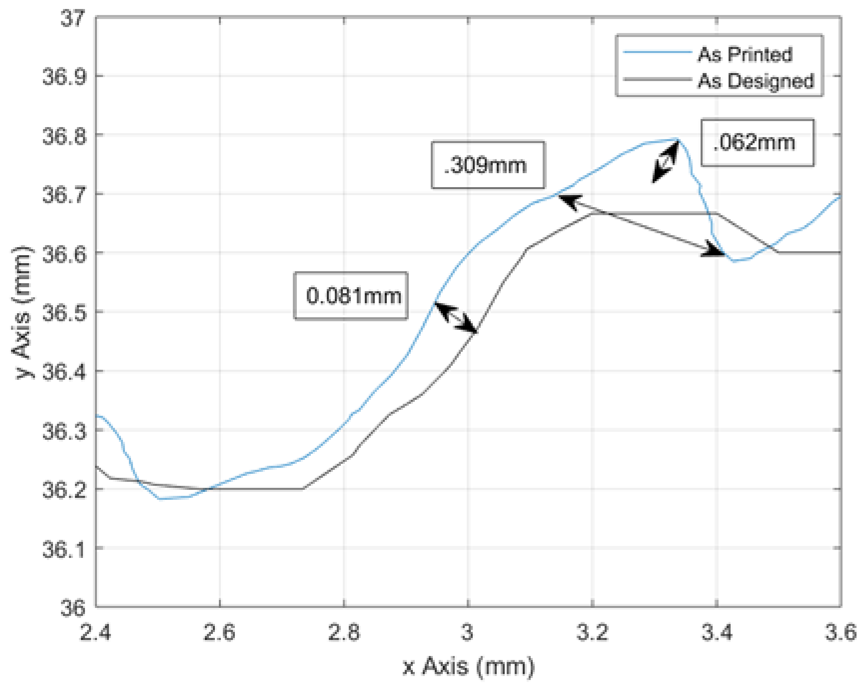


Figure 5.19: Zoomed in of horizontal slice.

the as-printed mesh and discretize the fluid domain such that the splatter marks are well resolve to observe the impact of these features.

Table 5.3: TO design mesh parameters.

Heat Sink	Software	Mesh	Mesh Size (*microns*)	Re
TO-Al-1	OpenFOAM	2.5e6 cells	64x70x67	155
TO-Al-2	FEniCS	1e6 vertices	64x64x32	155
TO-Al-3	OpenFOAM	7.8e6 cells	33x33x67	155
TO-Al-4	OpenFOAM	7.8e6 cells	15x15x20	155
TO-Al-5	OpenFOAM	0.2e6 cells	106x125x200	155

Table 5.4: TO Post-design CFD simulation mesh parameters.

Heat Sink	Software	Mesh	Mesh Size (*microns*)
TO-Al-1	OpenFOAM	2.5e6 cells	64x70x67
TO-Al-3	OpenFOAM	7.8e6 cells	33x33x67
TO-Al-4	OpenFOAM	4e6 cells	30x66x50
TO-Al-5	OpenFOAM	7.8e6 cells	33x33x67

Chapter 6

Conclusion

Heat sinks designed by topology optimization were built with direct metal laser sintering. A test apparatus was built and validated with a conventional geometry and 2D-conduction numerical model. The comparison of the experimental TO heat sink performance with the numerical predictions revealed a 25-50% over-prediction of performance. The inspection of the surface of the prints using a micro-CT scanner identified splatter roughness and deviation of the as-printed part from as-designed geometry. Regimes with overhang angles were identified as notable areas of part error. Future work could investigate the thermal conductivity of the printed material as the manufacturer's specifications may not be physical and the impact of the roughness on flow paths. Future designs should note the part error in overhang angle regions and design around these regions to increase part quality. There is also additional work needed in matching the experimental and numerical performance of the TO heat sinks. The complex geometries may play a role and a simpler (coarser features or 2D optimization) could be used to validate the design.

Appendix A

Appendix

```
$UnitSystem K Pa N kg s J
$TabStops 0.5 1 1.5

"-----------------------------------------------------------------------------------------------------------------------------
        Data Analysis
-----------------------------------------------------------------------------------------------------------------------------"

T1$ = '031721 TO_SS_1'
T2$ = '031721 TO_SS_1 U'

"LMTD"
W$ = 'water'
P = 1[atm]*convert(atm,Pa)
R_al_heater = 0.5[inch]*convert(inch,m)/(k_al_cast*W_al^2)
        W_al = 1.85[inch]*convert(inch,m)
        k_al_cast = conductivity(Aluminum, T=converttemp(C,K,150[C]))
A_hf = {3[cm]*3.2[cm]*convert(cm2,m2)}1[inch2]*convert(inch2,m2)

R_base = th_base/(14[W/m-K]*4[inch2]*convert(inch2,m2))
        th_base = 1.12e-3 [m]

{R_base = th_base/(103[W/m-K]*4[inch2]*convert(inch2,m2))
        th_base = 1.52e-3 [m]}

N_sigma = 2 [-]                 "number of standard deviations"

Duplicate i=1,7

        Flow[i] = lookup(T1$,i,1)*convert(cm3/s,m3/s)
        dP[i] = lookup(T1$,i,2)

        HF1[i] = lookup(T1$,i,3)
        HF2[i] = lookup(T1$,i,4)
        HF3[i] = lookup(T1$,i,5)
        HF4[i] = lookup(T1$,i,6)

        T_cav_in[i] = converttemp(C,K,lookup(T1$,i,7))          //cavity
        T_cav_out[i] = converttemp(C,K,lookup(T1$,i,8))         //cavity

        T_al_bot[i] = converttemp(C,K,lookup(T1$,i,9))
        T_al_top[i] = converttemp(C,K,lookup(T1$,i,10))

        T_tube_in[i] = converttemp(C,K,lookup(T1$,i,11))
        T_tube_out[i] = converttemp(C,K,lookup(T1$,i,12))

        TC_51b[i] = converttemp(C,K,lookup(T1$,i,13))
        {TC_51a[i] = converttemp(C,K,lookup(T1$,i,14))}
        TC_22[i] = converttemp(C,K,lookup(T1$,i,15))
        TC_37[i] = converttemp(C,K,lookup(T1$,i,16))
        TC_66[i] = converttemp(C,K,lookup(T1$,i,17))

        T_base[i] = average(TC_66[i],TC_22[i],TC_37[i]{,TC_51a[i]},TC_51b[i]) - dT_base[i]

        HF1_T[i] = converttemp(C,K,lookup(T1$,i,18))
        HF2_T[i] = converttemp(C,K,lookup(T1$,i,19))
        HF3_T[i] = converttemp(C,K,lookup(T1$,i,20))
        HF4_T[i] = converttemp(C,K,lookup(T1$,i,21))

        rho[i] = density(W$,T=(T_cav_in[i]+T_cav_out[i])/2,P=P)
        c[i] = cp(W$,T=(T_cav_in[i]+T_cav_out[i])/2,P=P)

        q_dot_tube[i] = Flow[i]*rho[i]*c[i]*(T_tube_out[i]-T_tube_in[i])
        q_dot_cav[i] = Flow[i]*rho[i]*c[i]*(T_cav_out[i]-T_cav_in[i])
```

```
{       q_dot_hf[i] = -A_hf*(HF1[i]+HF2[i]+HF3[i]+HF4[i])}
        q_dot_al[i] = (T_al_bot[i]-T_al_top[i])/R_al_heater

        dT_base[i] = q_v_total[i] * R_base

        "Effective-NTU Method: Source Greg Nellis"

        dt_lmtd[i] = (-(T_tube_in[i] - T_base[i]) + (T_tube_out[i] - T_base[i]))/(ln(-(T_tube_in[i] - T_base[i])/(-(T_tube_out[i] -
T_base[i]))))

        //q_dot_lmtd[i] = UA[i]*dt_lmtd[i]

        eff[i]=-q_v_total[i]/(Flow[i]*rho[i]*c[i]*(T_tube_in[i]-T_base[i]))
        NTU[i]=-ln(1-eff[i])
        UA_exp[i]=NTU[i]*rho[i]*c[i]*Flow[i]
        R_total[i]=1/UA_exp[i]

        "using voltages"
        HF_V_1[i] = lookup(T1$,i,22)
        HF_V_2[i] = lookup(T1$,i,23)
        HF_V_3[i] = lookup(T1$,i,24)
        HF_V_4[i] = lookup(T1$,i,25)

        q_v_1[i] = abs(HF_V_1[i])*(751.1308[W/Volt]) + 0.081 [W]
        q_v_2[i] = abs(HF_V_2[i])*(625.7098[W/Volt]) + 0.0987 [W]
        q_v_3[i] = abs(HF_V_3[i])*(677.2534[W/Volt]) + 0.0631 [W]
        q_v_4[i] = abs(HF_V_4[i])*(767.9383[W/Volt]) + 0.0369 [W]
        q_v_total[i] =sum(q_v_1[i],q_v_2[i],q_v_3[i],q_v_4[i])

        "Uncertainty Analysis"
        u_flow[i] = sqrt((N_sigma*lookup(T2$,i,1)*convert(cm3/s,m3/s))^2 + (0.01*Flow[i])^2)
        u_dP[i] = sqrt((N_sigma*lookup(T2$,i,2))^2 + (0.02*dP[i])^2)
        u_tube_inlet[i] = sqrt((N_sigma*lookup(T2$,i,11))^2 + (0.15[K])^2)
        u_tube_outlet[i] = sqrt((N_sigma*lookup(T2$,i,12))^2 + (0.15[K])^2)
        u_TC51b[i] = sqrt((N_sigma*lookup(T2$,i,13))^2 + (1.5[K])^2)
        u_TC51a[i] = sqrt((N_sigma*lookup(T2$,i,14))^2 + (1.5[K])^2)
        u_TC22[i] = sqrt((N_sigma*lookup(T2$,i,15))^2 + (1.5[K])^2)
        u_TC37[i] = sqrt((N_sigma*lookup(T2$,i,16))^2 + (1.5[K])^2)
        u_TC66[i] = sqrt((N_sigma*lookup(T2$,i,17))^2 + (1.5[K])^2)
        u_HFV1[i] = sqrt((N_sigma*lookup(T2$,i,22))^2 + (0.05*HF_V_1[i])^2)
        u_HFV2[i] = sqrt((N_sigma*lookup(T2$,i,23))^2 + (0.05*HF_V_2[i])^2)
        u_HFV3[i] = sqrt((N_sigma*lookup(T2$,i,24))^2 + (0.05*HF_V_3[i])^2)
        u_HFV4[i] = sqrt((N_sigma*lookup(T2$,i,25))^2 + (0.05*HF_V_4[i])^2)

        u_HFV1_dev[i] = 0.05*HF_V_1[i]
        u_dP_dev[i] = 0.02*dP[i]
        u_flow_dev[i] = 0.01*Flow[i]

        u_eff[i] = uncertaintyof(eff[i])
        u_UA[i] = uncertaintyof(UA_exp[i])

End
```

Unit Settings: SI K Pa J mass deg

Variable±Uncertainty	**Partial derivative**	**% of uncertainty**
eff_1 = 0.3002±0.01605 [-]		
dP_1 = 23.4±10.35 [Pa]	$\partial eff_1/\partial dP_1 = 0$	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_1/\partial dP_2 = 0$	0.00 %

dP_3 = 54.83±10.06 [Pa]	$\partial eff_1 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_1 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_1 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_1 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_1 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_1 / \partial Flow_1$ = -56524	27.96 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_1 / \partial Flow_2$ = -2.268E-12	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_1 / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_1 / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_1 / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_1 / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_1 / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_1 / \partial HF_{V,1,1}$ = -1.746	9.79 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_1 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_1 / \partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_1 / \partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_1 / \partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_1 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_1 / \partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_1 / \partial HF_{V,2,1}$ = -1.455	7.62 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_1 / \partial HF_{V,2,2}$ = -2.614E-17	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_1 / \partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_1 / \partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_1 / \partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_1 / \partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_1 / \partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_1 / \partial HF_{V,3,1}$ = -1.575	8.13 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_1 / \partial HF_{V,3,2}$ = -3.645E-17	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_1 / \partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_1 / \partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_1 / \partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_1 / \partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_1 / \partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_1 / \partial HF_{V,4,1}$ = -1.785	6.34 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_1 / \partial HF_{V,4,2}$ = -1.174E-17	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_1 / \partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_1 / \partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_1 / \partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_1 / \partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_1 / \partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_1 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_1 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_1 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_1 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_1 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_1 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_1 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_1 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_1 / \partial P$ = 6.798E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_1 / \partial T_{al,bot,7}$ = 0	0.00 %

$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_1 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_1 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_1 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_1 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_1 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_1 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_1 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,1}$ = 0.00005293	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_1 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,1}$ = 0.00005293	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_1 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,1}$ = 0.01281	1.43 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_1 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_1 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_1 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_1 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_1 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_1 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_1 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_1 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_1 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_1 / \partial TC_{22,1}$ = -0.003202	8.96 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_1 / \partial TC_{22,2}$ = 5.420E-20	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_1 / \partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_1 / \partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_1 / \partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_1 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_1 / \partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_1 / \partial TC_{51b,1}$ = -0.003202	8.96 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_1 / \partial TC_{51b,2}$ = 5.418E-20	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_1 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_1 / \partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_1 / \partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_1 / \partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_1 / \partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_1 / \partial TC_{66,1}$ = -0.003202	8.97 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_1 / \partial TC_{66,2}$ = -3.613E-20	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_1 / \partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_1 / \partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_1 / \partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_1 / \partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_1 / \partial TC_{66,7}$ = 0	0.00 %

th_{base} = 0.00112±0.0001 [m]	$\partial eff_1 / \partial th_{base}$ = 55.21	11.83 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_1 / \partial W_{al}$ = -6.234E-15	0.00 %

eff_2 = 0.2369±0.01264 [-]

dP_1 = 23.4±10.35 [Pa]	$\partial eff_2 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_2 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_2 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_2 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_2 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_2 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_2 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_2 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_2 / \partial Flow_2$ = -29864	11.49 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_2 / \partial Flow_3$ = -7.829E-14	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_2 / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_2 / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_2 / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_2 / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_2 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_2 / \partial HF_{V,1,2}$ = -1.392	10.38 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_2 / \partial HF_{V,1,3}$ = -2.284E-17	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_2 / \partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_2 / \partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_2 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_2 / \partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_2 / \partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_2 / \partial HF_{V,2,2}$ = -1.159	8.14 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_2 / \partial HF_{V,2,3}$ = -4.280E-18	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_2 / \partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_2 / \partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_2 / \partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_2 / \partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_2 / \partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_2 / \partial HF_{V,3,2}$ = -1.255	8.72 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_2 / \partial HF_{V,3,3}$ = -8.936E-18	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_2 / \partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_2 / \partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_2 / \partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_2 / \partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_2 / \partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_2 / \partial HF_{V,4,2}$ = -1.423	6.76 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_2 / \partial HF_{V,4,3}$ = 4.038E-17	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_2 / \partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_2 / \partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_2 / \partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_2 / \partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_2 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_2 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_2 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_2 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_2 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_2 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_2 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_2 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_2 / \partial P$ = 5.678E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,1}$ = 0	0.00 %

$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_2 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_2 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_2 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_2 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_2 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_2 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_2 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_2 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,2}$ = 0.00004209	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_2 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,2}$ = 0.00004209	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_2 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,2}$ = 0.01168	1.92 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,3}$ = 9.034E-20	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_2 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_2 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_2 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_2 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_2 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_2 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_2 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_2 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_2 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_2 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_2 / \partial TC_{22,2}$ = -0.00292	12.02 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_2 / \partial TC_{22,3}$ = 4.516E-20	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_2 / \partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_2 / \partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_2 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_2 / \partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_2 / \partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_2 / \partial TC_{51b,2}$ = -0.00292	12.02 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_2 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_2 / \partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_2 / \partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_2 / \partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_2 / \partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_2 / \partial TC_{66,1}$ = 0	0.00 %

$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_2 / \partial TC_{66,2}$ = -0.00292	12.02 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_2 / \partial TC_{66,3}$ = -2.709E-20	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_2 / \partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_2 / \partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_2 / \partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_2 / \partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_2 / \partial th_{base}$ = 51.38	16.53 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_2 / \partial W_{al}$ = -2.033E-15	0.00 %

<u>eff_3 = 0.2093±0.01181 [-]</u>

dP_1 = 23.4±10.35 [Pa]	$\partial eff_3 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_3 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_3 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_3 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_3 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_3 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_3 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_3 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_3 / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_3 / \partial Flow_3$ = -20976	9.45 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_3 / \partial Flow_4$ = 5.925E-14	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_3 / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_3 / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_3 / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_3 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_3 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_3 / \partial HF_{V,1,3}$ = -1.235	9.63 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_3 / \partial HF_{V,1,4}$ = -1.368E-17	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_3 / \partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_3 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_3 / \partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_3 / \partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_3 / \partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_3 / \partial HF_{V,2,3}$ = -1.029	7.61 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_3 / \partial HF_{V,2,4}$ = -1.280E-17	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_3 / \partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_3 / \partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_3 / \partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_3 / \partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_3 / \partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_3 / \partial HF_{V,3,3}$ = -1.114	8.18 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_3 / \partial HF_{V,3,4}$ = -4.454E-18	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_3 / \partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_3 / \partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_3 / \partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_3 / \partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_3 / \partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_3 / \partial HF_{V,4,3}$ = -1.263	6.31 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_3 / \partial HF_{V,4,4}$ = -3.456E-17	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_3 / \partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_3 / \partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_3 / \partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_3 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_3 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_3 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_3 / \partial HF2_{T,1}$ = 0	0.00 %

$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_3 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_3 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_3 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_3 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_3 / \partial P$ = 5.190E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_3 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_3 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_3 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_3 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_3 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_3 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_3 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_3 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,3}$ = 0.00003742	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_3 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,3}$ = 0.00003742	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_3 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,3}$ = 0.01128	2.05 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_3 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_3 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_3 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_3 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_3 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_3 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_3 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_3 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_3 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_3 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_3 / \partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_3 / \partial TC_{22,3}$ = -0.00282	12.83 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_3 / \partial TC_{22,4}$ = -1.807E-20	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_3 / \partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_3 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_3 / \partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_3 / \partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_3 / \partial TC_{51b,2}$ = 0	0.00 %

$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_3 / \partial TC_{51b,3}$ = -0.00282	12.84 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_3 / \partial TC_{51b,4}$ = 1.806E-20	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_3 / \partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_3 / \partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_3 / \partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_3 / \partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_3 / \partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_3 / \partial TC_{66,3}$ = -0.00282	12.84 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_3 / \partial TC_{66,4}$ = -1.807E-20	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_3 / \partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_3 / \partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_3 / \partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_3 / \partial th_{base}$ = 50.47	18.26 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_3 / \partial W_{al}$ = -5.692E-15	0.00 %

<u>eff_4 = 0.1856±0.01103 [-]</u>

dP_1 = 23.4±10.35 [Pa]	$\partial eff_4 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_4 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_4 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_4 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_4 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_4 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_4 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_4 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_4 / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_4 / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_4 / \partial Flow_4$ = -15444	10.26 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_4 / \partial Flow_5$ = -1.179E-13	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_4 / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_4 / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_4 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_4 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_4 / \partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_4 / \partial HF_{V,1,4}$ = -1.109	8.92 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_4 / \partial HF_{V,1,5}$ = 4.551E-18	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_4 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_4 / \partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_4 / \partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_4 / \partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_4 / \partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_4 / \partial HF_{V,2,4}$ = -0.9234	7.07 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_4 / \partial HF_{V,2,5}$ = -1.699E-17	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_4 / \partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_4 / \partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_4 / \partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_4 / \partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_4 / \partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_4 / \partial HF_{V,3,4}$ = -0.9995	7.60 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_4 / \partial HF_{V,3,5}$ = 1.768E-17	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_4 / \partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_4 / \partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_4 / \partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_4 / \partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_4 / \partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_4 / \partial HF_{V,4,4}$ = -1.133	5.85 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_4 / \partial HF_{V,4,5}$ = 5.725E-18	0.00 %

$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_4 / \partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_4 / \partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_4 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_4 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_4 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_4 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_4 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_4 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_4 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_4 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_4 / \partial P$ = 4.643E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_4 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_4 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_4 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_4 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_4 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_4 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_4 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_4 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,4}$ = 0.00003324	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_4 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,4}$ = 0.00003324	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_4 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_4 / \partial T_{tube,in,4}$ = 0.01066	2.10 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,5}$ = 9.034E-20	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_4 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_4 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_4 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_4 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_4 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_4 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_4 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_4 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_4 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_4 / \partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_4 / \partial TC_{22,3}$ = 0	0.00 %

$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_4 / \partial TC_{22,4}$ = -0.002664	13.13 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_4 / \partial TC_{22,5}$ = 4.517E-20	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_4 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_4 / \partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_4 / \partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_4 / \partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_4 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_4 / \partial TC_{51b,4}$ = -0.002664	13.14 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_4 / \partial TC_{51b,5}$ = -9.032E-21	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_4 / \partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_4 / \partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_4 / \partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_4 / \partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_4 / \partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_4 / \partial TC_{66,4}$ = -0.002664	13.13 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_4 / \partial TC_{66,5}$ = 5.420E-20	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_4 / \partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_4 / \partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_4 / \partial th_{base}$ = 47.79	18.78 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_4 / \partial W_{al}$ = -4.743E-15	0.00 %

eff_5 = 0.1676±0.01047 [-]

dP_1 = 23.4±10.35 [Pa]	$\partial eff_5 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_5 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_5 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_5 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_5 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_5 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_5 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_5 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_5 / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_5 / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_5 / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_5 / \partial Flow_5$ = -11429	6.30 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_5 / \partial Flow_6$ = -5.418E-14	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_5 / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_5 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_5 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_5 / \partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_5 / \partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_5 / \partial HF_{V,1,5}$ = -1.019	8.40 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_5 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_5 / \partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_5 / \partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_5 / \partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_5 / \partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_5 / \partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_5 / \partial HF_{V,2,5}$ = -0.8486	6.69 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_5 / \partial HF_{V,2,6}$ = 8.346E-18	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_5 / \partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_5 / \partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_5 / \partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_5 / \partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_5 / \partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_5 / \partial HF_{V,3,5}$ = -0.9185	7.24 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_5 / \partial HF_{V,3,6}$ = -1.298E-17	0.00 %

$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_5 / \partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_5 / \partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_5 / \partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_5 / \partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_5 / \partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_5 / \partial HF_{V,4,5}$ = -1.041	5.55 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_5 / \partial HF_{V,4,6}$ = 1.683E-17	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_5 / \partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_5 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_5 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_5 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_5 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_5 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_5 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_5 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_5 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_5 / \partial P$ = 4.285E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_5 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_5 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_5 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_5 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_5 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_5 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_5 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_5 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,5}$ = 0.00003017	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_5 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,5}$ = 0.00003017	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_5 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_5 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,5}$ = 0.01055	2.29 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,6}$ = 9.033E-20	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_5 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_5 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_5 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_5 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_5 / \partial T_{tube,out,4}$ = 0	0.00 %

$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_5 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_5 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_5 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_5 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_5 / \partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_5 / \partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_5 / \partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_5 / \partial TC_{22,5}$ = -0.002638	14.29 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_5 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_5 / \partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_5 / \partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_5 / \partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_5 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_5 / \partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_5 / \partial TC_{51b,5}$ = -0.002638	14.30 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_5 / \partial TC_{51b,6}$ = -4.517E-20	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_5 / \partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_5 / \partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_5 / \partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_5 / \partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_5 / \partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_5 / \partial TC_{66,5}$ = -0.002638	14.30 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_5 / \partial TC_{66,6}$ = -9.032E-21	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_5 / \partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_5 / \partial th_{base}$ = 47.57	20.65 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_5 / \partial W_{al}$ = -8.132E-15	0.00 %

eff_6 = 0.1479±0.01053 [-]

dP_1 = 23.4±10.35 [Pa]	$\partial eff_6 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_6 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_6 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_6 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_6 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_6 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_6 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_6 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_6 / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_6 / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_6 / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_6 / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_6 / \partial Flow_6$ = -7314	3.02 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_6 / \partial Flow_7$ = -4.529E-14	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_6 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_6 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_6 / \partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_6 / \partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_6 / \partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_6 / \partial HF_{V,1,6}$ = -0.9294	7.09 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_6 / \partial HF_{V,1,7}$ = 1.346E-17	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_6 / \partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_6 / \partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_6 / \partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_6 / \partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_6 / \partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_6 / \partial HF_{V,2,6}$ = -0.7742	5.70 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_6 / \partial HF_{V,2,7}$ = -8.332E-18	0.00 %

$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_6 / \partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_6 / \partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_6 / \partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_6 / \partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_6 / \partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_6 / \partial HF_{V,3,6}$ = -0.838	6.21 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_6 / \partial HF_{V,3,7}$ = 1.294E-17	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_6 / \partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_6 / \partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_6 / \partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_6 / \partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_6 / \partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_6 / \partial HF_{V,4,6}$ = -0.9502	4.75 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_6 / \partial HF_{V,4,7}$ = 5.601E-18	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_6 / \partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_6 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_6 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_6 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_6 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_6 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_6 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_6 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_6 / \partial P$ = 3.926E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_6 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_6 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_6 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_6 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_6 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_6 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_6 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_6 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,6}$ = 0.00002688	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_6 / \partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,6}$ = 0.00002688	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_6 / \partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_6 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,5}$ = 0	0.00 %

$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,6}$ = 0.01114	2.52 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_6 / \partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_6 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_6 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_6 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_6 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_6 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_6 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_6 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_6 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_6 / \partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_6 / \partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_6 / \partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_6 / \partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_6 / \partial TC_{22,6}$ = -0.002784	15.74 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_6 / \partial TC_{22,7}$ = -1.265E-19	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_6 / \partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_6 / \partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_6 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_6 / \partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_6 / \partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_6 / \partial TC_{51b,6}$ = -0.002784	15.72 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_6 / \partial TC_{51b,7}$ = -9.032E-20	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_6 / \partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_6 / \partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_6 / \partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_6 / \partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_6 / \partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_6 / \partial TC_{66,6}$ = -0.002784	15.73 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_6 / \partial TC_{66,7}$ = 5.415E-20	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_6 / \partial th_{base}$ = 51.11	23.54 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_6 / \partial W_{al}$ = -7.183E-15	0.00 %

eff_7 = 0.1299±0.009836 [-]

dP_1 = 23.4±10.35 [Pa]	$\partial eff_7 / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial eff_7 / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial eff_7 / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial eff_7 / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial eff_7 / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial eff_7 / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial eff_7 / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial eff_7 / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial eff_7 / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial eff_7 / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial eff_7 / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial eff_7 / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial eff_7 / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial eff_7 / \partial Flow_7$ = -5220	2.52 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial eff_7 / \partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial eff_7 / \partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial eff_7 / \partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial eff_7 / \partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial eff_7 / \partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial eff_7 / \partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial eff_7 / \partial HF_{V,1,7}$ = -0.833	6.55 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial eff_7 / \partial HF_{V,2,1}$ = 4.450E-18	0.00 %

$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial eff_7 / \partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial eff_7 / \partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial eff_7 / \partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial eff_7 / \partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial eff_7 / \partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial eff_7 / \partial HF_{V,2,7}$ = -0.6939	5.27 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial eff_7 / \partial HF_{V,3,1}$ = 1.866E-17	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial eff_7 / \partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial eff_7 / \partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial eff_7 / \partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial eff_7 / \partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial eff_7 / \partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial eff_7 / \partial HF_{V,3,7}$ = -0.7511	5.76 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial eff_7 / \partial HF_{V,4,1}$ = 5.988E-18	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial eff_7 / \partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial eff_7 / \partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial eff_7 / \partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial eff_7 / \partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial eff_7 / \partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial eff_7 / \partial HF_{V,4,7}$ = -0.8516	4.39 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial eff_7 / \partial HF1_1$ = -2.711E-20	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial eff_7 / \partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial eff_7 / \partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial eff_7 / \partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial eff_7 / \partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial eff_7 / \partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial eff_7 / \partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial eff_7 / \partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial eff_7 / \partial P$ = 3.478E-11	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial eff_7 / \partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial eff_7 / \partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial eff_7 / \partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial eff_7 / \partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial eff_7 / \partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial eff_7 / \partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial eff_7 / \partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial eff_7 / \partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial eff_7 / \partial T_{cav,in,7}$ = 0.00002367	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,6}$ = 0	0.00 %

$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial eff_7 / \partial T_{cav,out,7}$ = 0.00002367	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial eff_7 / \partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial eff_7 / \partial T_{tube,in,7}$ = 0.01055	2.59 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial eff_7 / \partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial eff_7 / \partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial eff_7 / \partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial eff_7 / \partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial eff_7 / \partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial eff_7 / \partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial eff_7 / \partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial eff_7 / \partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial eff_7 / \partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial eff_7 / \partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial eff_7 / \partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial eff_7 / \partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial eff_7 / \partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial eff_7 / \partial TC_{22,7}$ = -0.002638	16.19 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial eff_7 / \partial TC_{51b,1}$ = -6.323E-20	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial eff_7 / \partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial eff_7 / \partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial eff_7 / \partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial eff_7 / \partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial eff_7 / \partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial eff_7 / \partial TC_{51b,7}$ = -0.002638	16.19 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial eff_7 / \partial TC_{66,1}$ = -4.514E-20	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial eff_7 / \partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial eff_7 / \partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial eff_7 / \partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial eff_7 / \partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial eff_7 / \partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial eff_7 / \partial TC_{66,7}$ = -0.002638	16.22 %
th_{base} = 0.00112±0.0001 [m]	$\partial eff_7 / \partial th_{base}$ = 48.51	24.33 %
W_{al} = 0.04699±0.0001 [m]	$\partial eff_7 / \partial W_{al}$ = -4.743E-15	0.00 %

$q_{v,total,1}$ = 155.7±3.898 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,1} / \partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,1} / \partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,1} / \partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,1} / \partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,1} / \partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,1} / \partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,1} / \partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,1} / \partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,1} / \partial HF_{V,1,1}$ = -751.1	30.73 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,1} / \partial HF_{V,1,2}$ = 0	0.00 %

$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,1}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,1}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,1}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,1}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,1}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,1}$ = -625.7	23.90 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,1}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,1}$ = -677.3	25.49 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,1}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,1}$ = -767.9	19.89 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,1}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,1}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,1}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,1}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,1}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,1}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,1}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,1}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,1}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,1}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,1}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,in,7}$ = 0	0.00 %

$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,1}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,1}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,1}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,1}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,1}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,1}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,1}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,1}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,2}$ = 158.9±3.978 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,2}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,2}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,2}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,2}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,2}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,2}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,2}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_3$ = 0	0.00 %

$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,2}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,2}$ = -751.1	30.53 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,2}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,2}$ = -625.7	23.94 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,2}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,2}$ = -677.3	25.64 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,2}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,2}$ = -767.9	19.88 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,2}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,2}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,2}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,2}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,2}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,2}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,2}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,2}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,2}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,2}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,2}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,1}$ = 0	0.00 %

$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,2}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,2}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,2}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,2}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,2}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,2}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,2}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,2}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,3}$ = 161.6±4.046 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,3}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,3}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,3}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,3}/\partial dP_4$ = 0	0.00 %

dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,3}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,3}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,3}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,3}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,3}$ = -751.1	30.34 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,3}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,3}$ = -625.7	23.98 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,3}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,3}$ = -677.3	25.79 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,3}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,3}$ = -767.9	19.89 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,3}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,3}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,3}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,3}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,3}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,3}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,3}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,3}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,3}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,3}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,2}$ = 0	0.00 %

$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,3}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,3}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,3}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,3}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,3}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,3}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,3}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,3}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,3}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,4}$ = 162±4.055 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,4}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,4}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,4}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,4}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,4}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,4}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,4}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,4}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,4}$ = -751.1	30.30 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,4}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,4}$ = -625.7	24.02 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,4}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,4}$ = -677.3	25.82 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,4}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,4}$ = -767.9	19.85 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,4}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,4}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,4}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,4}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,4}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,4}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,4}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,4}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,4}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,4}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,3}$ = 0	0.00 %

$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,4}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,4}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,4}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,4}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,4}/\partial TC_{66,3}$ = 0	0.00 %

$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,4}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,4}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,4}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,4}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,5}$ = 162.8±4.076 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,5}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,5}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,5}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,5}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,5}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,5}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,5}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,5}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,5}$ = -751.1	30.13 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,5}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,5}$ = -625.7	24.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,5}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,5}$ = -677.3	25.98 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,5}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,5}$ = -767.9	19.90 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,5}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,5}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,5}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,5}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,5}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,5}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,5}/\partial HF3_{T,1}$ = 0	0.00 %

$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,5}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,5}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,5}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,5}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,5}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,5}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,5}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{51b,4}$ = 0	0.00 %

$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,5}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,5}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,5}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,5}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,5}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,6}$ = 165.8±4.148 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,6}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,6}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,6}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,6}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,6}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,6}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,6}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,6}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,6}$ = -751.1	29.87 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,6}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,6}$ = -625.7	24.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,6}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,6}$ = -677.3	26.14 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,6}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,6}$ = -767.9	19.99 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,6}/\partial HF_{V,4,7}$ = 0	0.00 %

$HF1_1$ = -39447±0.5 [W/m^2]	$\partial q_{v,total,6}/\partial HF1_1 = 0$	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,6}/\partial HF1_{T,1} = 0$	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial q_{v,total,6}/\partial HF2_1 = 0$	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,6}/\partial HF2_{T,1} = 0$	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial q_{v,total,6}/\partial HF3_1 = 0$	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,6}/\partial HF3_{T,1} = 0$	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial q_{v,total,6}/\partial HF4_1 = 0$	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,6}/\partial HF4_{T,1} = 0$	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,6}/\partial P = 0$	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,1} = 0$	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,2} = 0$	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,3} = 0$	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,4} = 0$	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,5} = 0$	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,6} = 0$	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,bot,7} = 0$	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,1} = 0$	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,2} = 0$	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,3} = 0$	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,4} = 0$	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,5} = 0$	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,6} = 0$	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,6}/\partial T_{al,top,7} = 0$	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,1} = 0$	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,2} = 0$	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,3} = 0$	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,4} = 0$	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,5} = 0$	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,6} = 0$	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,in,7} = 0$	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,1} = 0$	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,2} = 0$	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,3} = 0$	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,4} = 0$	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,5} = 0$	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,6} = 0$	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,6}/\partial T_{cav,out,7} = 0$	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,1} = 0$	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,2} = 0$	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,3} = 0$	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,4} = 0$	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,5} = 0$	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,6} = 0$	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,6}/\partial T_{tube,in,7} = 0$	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,1} = 0$	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,2} = 0$	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,3} = 0$	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,4} = 0$	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,5} = 0$	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,6} = 0$	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,6}/\partial T_{tube,out,7} = 0$	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{22,1} = 0$	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{22,2} = 0$	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{22,3} = 0$	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{22,4} = 0$	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{22,5} = 0$	0.00 %

$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,6}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,6}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,6}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,6}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,6}/\partial W_{al}$ = 0	0.00 %

$q_{v,total,7}$ = 166.1±4.156 [W]

dP_1 = 23.4±10.35 [Pa]	$\partial q_{v,total,7}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial q_{v,total,7}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial q_{v,total,7}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial q_{v,total,7}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial q_{v,total,7}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial q_{v,total,7}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial q_{v,total,7}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial q_{v,total,7}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial q_{v,total,7}/\partial HF_{V,1,7}$ = -751.1	29.81 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial q_{v,total,7}/\partial HF_{V,2,7}$ = -625.7	23.98 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial q_{v,total,7}/\partial HF_{V,3,7}$ = -677.3	26.22 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,1}$ = 0	0.00 %

$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial q_{v,total,7}/\partial HF_{V,4,7}$ = -767.9	19.99 %
$HF1_1$ = -39447±0.5 [W/m²]	$\partial q_{v,total,7}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial q_{v,total,7}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m²]	$\partial q_{v,total,7}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial q_{v,total,7}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m²]	$\partial q_{v,total,7}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial q_{v,total,7}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m²]	$\partial q_{v,total,7}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial q_{v,total,7}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial q_{v,total,7}/\partial P$ = 0	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial q_{v,total,7}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial q_{v,total,7}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial q_{v,total,7}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,6}$ = 0	0.00 %

$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial q_{v,total,7}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial q_{v,total,7}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial q_{v,total,7}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial q_{v,total,7}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial q_{v,total,7}/\partial th_{base}$ = 0	0.00 %
W_{al} = 0.04699±0.0001 [m]	$\partial q_{v,total,7}/\partial W_{al}$ = 0	0.00 %

<u>$UA_{exp,1}$ = 7.9±0.4332 [W/K]</u>

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,1}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,1}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,1}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,1}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,1}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,1}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,1}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_1$ = -300152	1.08 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_2$ = -7.257E-11	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,1}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,1}$ = -55.23	13.45 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,1}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,1}$ = -46.01	10.46 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,2}$ = -1.115E-15	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,1}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,1}$ = -49.8	11.16 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,2}$ = -1.167E-15	0.00 %

$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,1}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,1}$ = -56.46	8.70 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,2}$ = -7.511E-16	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,1}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,1}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,1}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,1}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,1}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,1}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,1}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,1}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,1}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial UA_{exp,1}/\partial P$ = 3.609E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,1}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,1}$ = 0.000281	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,1}$ = 0.000281	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,1}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,1}$ = 0.4051	1.97 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,1}/\partial T_{tube,in,7}$ = 0	0.00 %

$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,1}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{22,1}$ = -0.1013	12.31 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{22,2}$ = 8.672E-19	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{51b,1}$ = -0.1013	12.31 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{51b,2}$ = 8.670E-19	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{66,1}$ = -0.1013	12.32 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{66,2}$ = -2.312E-18	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,1}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,1}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,1}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,1}/\partial th_{base}$ = 1746	16.25 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,1}/\partial W_{al}$ = -2.038E-13	0.00 %

<u>$UA_{exp,2}$ = 8.942±0.5159 [W/K]</u>

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,2}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,2}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,2}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,2}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,2}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,2}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,2}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_2$ = -167109	0.22 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_3$ = -1.503E-11	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,2}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,2}$ = -60.32	11.70 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,3}$ = -1.754E-15	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,2}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,2}$ = -50.24	9.18 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,3}$ = -8.218E-16	0.00 %

$HF_{V,2,4} = -0.06352 \pm 0.003176$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,4} = 0$	0.00 %
$HF_{V,2,5} = -0.06381 \pm 0.003191$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,5} = 0$	0.00 %
$HF_{V,2,6} = -0.06496 \pm 0.003248$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,6} = 0$	0.00 %
$HF_{V,2,7} = -0.06506 \pm 0.003253$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,2,7} = 0$	0.00 %
$HF_{V,3,1} = -0.05811 \pm 0.002906$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,1} = 0$	0.00 %
$HF_{V,3,2} = -0.05948 \pm 0.002974$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,2} = -54.38$	9.83 %
$HF_{V,3,3} = -0.06067 \pm 0.003033$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,3} = -8.578E-16$	0.00 %
$HF_{V,3,4} = -0.06085 \pm 0.003042$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,4} = 0$	0.00 %
$HF_{V,3,5} = -0.06134 \pm 0.003067$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,5} = 0$	0.00 %
$HF_{V,3,6} = -0.06263 \pm 0.003132$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,6} = 0$	0.00 %
$HF_{V,3,7} = -0.06285 \pm 0.003142$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,3,7} = 0$	0.00 %
$HF_{V,4,1} = -0.04527 \pm 0.002263$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,1} = 0$	0.00 %
$HF_{V,4,2} = -0.04619 \pm 0.00231$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,2} = -61.67$	7.62 %
$HF_{V,4,3} = -0.04699 \pm 0.002349$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,3} = 1.108E-15$	0.00 %
$HF_{V,4,4} = -0.04706 \pm 0.002353$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,4} = 0$	0.00 %
$HF_{V,4,5} = -0.04735 \pm 0.002367$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,5} = 0$	0.00 %
$HF_{V,4,6} = -0.0483 \pm 0.002415$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,6} = 0$	0.00 %
$HF_{V,4,7} = -0.04839 \pm 0.00242$ [volts]	$\partial UA_{exp,2}/\partial HF_{V,4,7} = 0$	0.00 %
$HF1_1 = -39447 \pm 0.5$ [W/m^2]	$\partial UA_{exp,2}/\partial HF1_1 = 0$	0.00 %
$HF1_{T,1} = 363.1 \pm 0.003$ [K]	$\partial UA_{exp,2}/\partial HF1_{T,1} = 0$	0.00 %
$HF2_1 = -43899 \pm 0.5$ [W/m^2]	$\partial UA_{exp,2}/\partial HF2_1 = 0$	0.00 %
$HF2_{T,1} = 364.9 \pm 0.003$ [K]	$\partial UA_{exp,2}/\partial HF2_{T,1} = 0$	0.00 %
$HF3_1 = -43952 \pm 0.5$ [W/m^2]	$\partial UA_{exp,2}/\partial HF3_1 = 0$	0.00 %
$HF3_{T,1} = 366.3 \pm 0.003$ [K]	$\partial UA_{exp,2}/\partial HF3_{T,1} = 0$	0.00 %
$HF4_1 = -34005 \pm 0.5$ [W/m^2]	$\partial UA_{exp,2}/\partial HF4_1 = 0$	0.00 %
$HF4_{T,1} = 361.7 \pm 0.003$ [K]	$\partial UA_{exp,2}/\partial HF4_{T,1} = 0$	0.00 %
$P = 101325 \pm 5$ [Pa]	$\partial UA_{exp,2}/\partial P = 3.177E-10$	0.00 %
$T_{al,bot,1} = 438.5 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,1} = 0$	0.00 %
$T_{al,bot,2} = 437.6 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,2} = 0$	0.00 %
$T_{al,bot,3} = 436.7 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,3} = 0$	0.00 %
$T_{al,bot,4} = 436.2 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,4} = 0$	0.00 %
$T_{al,bot,5} = 434.9 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,5} = 0$	0.00 %
$T_{al,bot,6} = 432.9 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,6} = 0$	0.00 %
$T_{al,bot,7} = 432.2 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,bot,7} = 0$	0.00 %
$T_{al,top,1} = 436.2 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,1} = 0$	0.00 %
$T_{al,top,2} = 435.3 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,2} = 0$	0.00 %
$T_{al,top,3} = 434.4 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,3} = 0$	0.00 %
$T_{al,top,4} = 433.8 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,4} = 0$	0.00 %
$T_{al,top,5} = 432.4 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,5} = 0$	0.00 %
$T_{al,top,6} = 430.5 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,6} = 0$	0.00 %
$T_{al,top,7} = 429.7 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{al,top,7} = 0$	0.00 %
$T_{cav,in,1} = 298.1 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,1} = 0$	0.00 %
$T_{cav,in,2} = 297 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,2} = 0.0002355$	0.00 %
$T_{cav,in,3} = 296.2 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,3} = 0$	0.00 %
$T_{cav,in,4} = 296.1 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,4} = 0$	0.00 %
$T_{cav,in,5} = 295.7 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,5} = 0$	0.00 %
$T_{cav,in,6} = 294.8 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,6} = 0$	0.00 %
$T_{cav,in,7} = 294.7 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,in,7} = 0$	0.00 %
$T_{cav,out,1} = 301.7 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,1} = 0$	0.00 %
$T_{cav,out,2} = 299.6 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,2} = 0.0002355$	0.00 %
$T_{cav,out,3} = 298.4 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,3} = 0$	0.00 %
$T_{cav,out,4} = 298 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,4} = 0$	0.00 %
$T_{cav,out,5} = 297.2 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,5} = 0$	0.00 %
$T_{cav,out,6} = 296 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,6} = 0$	0.00 %
$T_{cav,out,7} = 295.6 \pm 0.005$ [K]	$\partial UA_{exp,2}/\partial T_{cav,out,7} = 0$	0.00 %
$T_{tube,in,1} = 299.2 \pm 0.15$ [K]	$\partial UA_{exp,2}/\partial T_{tube,in,1} = 0$	0.00 %

$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,2}$ = 0.5062	2.17 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,2}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,2}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{22,2}$ = -0.1266	13.55 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{22,3}$ = 1.734E-18	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{51b,2}$ = -0.1266	13.55 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{66,2}$ = -0.1266	13.55 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,2}/\partial TC_{66,3}$ = -1.734E-18	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,2}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,2}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,2}/\partial th_{base}$ = 2227	18.63 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,2}/\partial W_{al}$ = -9.541E-14	0.00 %

$UA_{exp,3}$ = 9.773±0.592 [W/K]

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,3}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,3}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,3}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,3}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,3}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,3}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,3}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_3$ = -124566	0.13 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,3}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,3}$ = -65.01	10.62 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,4}$ = 0	0.00 %

$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,3}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,3}$ = -54.16	8.39 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,3}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,3}$ = -58.62	9.02 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,3}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,3}$ = -66.47	6.96 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,4}$ = -1.106E-15	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,3}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,3}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,3}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,3}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,3}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,3}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,3}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,3}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,3}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial UA_{exp,3}/\partial P$ = 3.082E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,3}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,3}$ = 0.0002222	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,2}$ = 0	0.00 %

$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,3}$ = 0.0002222	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,3}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,3}$ = 0.5936	2.26 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,3}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,3}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{22,3}$ = -0.1484	14.15 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{51b,3}$ = -0.1484	14.16 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{51b,4}$ = 1.734E-18	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,3}/\partial TC_{66,3}$ = -0.1484	14.16 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,3}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,3}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,3}/\partial th_{base}$ = 2656	20.14 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,3}/\partial W_{al}$ = -2.862E-13	0.00 %

$UA_{exp,4}$ = 10.29±0.6433 [W/K]

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,4}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,4}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,4}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,4}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,4}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,4}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,4}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_4$ = -94228	0.11 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_5$ = -1.132E-11	0.00 %

$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,4}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,4}$ = -68.22	9.93 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,4}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,4}$ = -56.83	7.87 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,5}$ = -8.155E-16	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,4}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,4}$ = -61.51	8.46 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,5}$ = 1.131E-15	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,4}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,4}$ = -69.75	6.51 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,4}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,4}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,4}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,4}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,4}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,4}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,4}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,4}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,4}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial UA_{exp,4}/\partial P$ = 2.833E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,4}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,3}$ = 0	0.00 %

$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,4}$ = 0.0002028	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,4}$ = 0.0002028	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,4}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,4}$ = 0.6558	2.34 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,4}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,4}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{22,4}$ = -0.164	14.62 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{22,5}$ = 2.313E-18	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{51b,4}$ = -0.164	14.63 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{51b,5}$ = -1.734E-18	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{51b,6}$ = 0	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,4}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{66,4}$ = -0.164	14.62 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{66,5}$ = 2.312E-18	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,4}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,4}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,4}/\partial th_{base}$ = 2941	20.90 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,4}/\partial W_{al}$ = -2.949E-13	0.00 %

$UA_{exp,5}$ = 11.22±0.7449 [W/K]

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,5}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,5}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,5}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,5}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,5}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,5}/\partial dP_6$ = 0	0.00 %

dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,5}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_5$ = -74679	0.05 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,5}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,5}$ = -74.86	8.96 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,5}/\partial HF_{V,1,7}$ = 0	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,5}$ = -62.36	7.14 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,6}$ = 1.068E-15	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,5}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,5}$ = -67.5	7.72 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,5}/\partial HF_{V,3,7}$ = 0	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,5}$ = -76.54	5.92 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,6}$ = 1.437E-15	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,5}/\partial HF_{V,4,7}$ = 0	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,5}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,5}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,5}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,5}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,5}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,5}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,5}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,5}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial UA_{exp,5}/\partial P$ = 2.800E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,4}$ = 0	0.00 %

$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,5}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,5}$ = 0.0001971	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,5}$ = 0.0001971	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,5}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,5}$ = 0.7754	2.44 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,5}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,5}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{22,5}$ = -0.1939	15.25 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{22,7}$ = 0	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{51b,5}$ = -0.1939	15.25 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{51b,6}$ = -2.891E-18	0.00 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{51b,7}$ = 0	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,5}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{66,5}$ = -0.1939	15.25 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,5}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,5}/\partial TC_{66,7}$ = 0	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,5}/\partial th_{base}$ = 3496	22.03 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,5}/\partial W_{al}$ = -5.985E-13	0.00 %

$UA_{exp,6}$ = 13.51±1.028 [W/K]

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,6}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,6}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,6}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,6}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,6}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,6}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,6}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_6$ = -56423	0.02 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,6}/\partial Flow_7$ = 0	0.00 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,6}$ = -92.05	7.31 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,6}/\partial HF_{V,1,7}$ = 1.723E-15	0.00 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,6}$ = -76.68	5.87 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,6}/\partial HF_{V,2,7}$ = 0	0.00 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,1}$ = 0	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,6}$ = -83	6.40 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,6}/\partial HF_{V,3,7}$ = 1.656E-15	0.00 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,6}$ = -94.11	4.89 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,6}/\partial HF_{V,4,7}$ = 2.151E-15	0.00 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,6}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,6}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,6}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,6}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,6}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,6}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,6}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,6}/\partial HF4_{T,1}$ = 0	0.00 %
P = 101325±5 [Pa]	$\partial UA_{exp,6}/\partial P$ = 3.029E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,5}$ = 0	0.00 %

$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,6}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,6}$ = 0.0002074	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,in,7}$ = 0	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,6}$ = 0.0002074	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,6}/\partial T_{cav,out,7}$ = 0	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,6}$ = 1.103	2.59 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,6}/\partial T_{tube,in,7}$ = 0	0.00 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,6}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{22,6}$ = -0.2758	16.22 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{22,7}$ = -1.156E-17	0.00 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{51b,1}$ = 0	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{51b,6}$ = -0.2758	16.21 %
$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{51b,7}$ = -8.092E-18	0.00 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{66,1}$ = 0	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,6}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{66,5}$ = 0	0.00 %

$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,6}/\partial TC_{66,6}$ = -0.2758	16.22 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,6}/\partial TC_{66,7}$ = 7.509E-18	0.00 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,6}/\partial th_{base}$ = 5062	24.27 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,6}/\partial W_{al}$ = -7.026E-13	0.00 %

<u>$UA_{exp,7}$ = 14.45±1.159 [W/K]</u>

dP_1 = 23.4±10.35 [Pa]	$\partial UA_{exp,7}/\partial dP_1$ = 0	0.00 %
dP_2 = 44.3±11.22 [Pa]	$\partial UA_{exp,7}/\partial dP_2$ = 0	0.00 %
dP_3 = 54.83±10.06 [Pa]	$\partial UA_{exp,7}/\partial dP_3$ = 0	0.00 %
dP_4 = 75.3±13.02 [Pa]	$\partial UA_{exp,7}/\partial dP_4$ = 0	0.00 %
dP_5 = 98.14±11.44 [Pa]	$\partial UA_{exp,7}/\partial dP_5$ = 0	0.00 %
dP_6 = 158.9±12.9 [Pa]	$\partial UA_{exp,7}/\partial dP_6$ = 0	0.00 %
dP_7 = 234.9±11.68 [Pa]	$\partial UA_{exp,7}/\partial dP_7$ = 0	0.00 %
$Flow_1$ = 0.000005312±1.501E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_1$ = 0	0.00 %
$Flow_2$ = 0.000007933±1.434E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_2$ = 0	0.00 %
$Flow_3$ = 0.000009979±1.731E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_3$ = 0	0.00 %
$Flow_4$ = 0.00001202±2.288E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_4$ = 0	0.00 %
$Flow_5$ = 0.00001466±2.299E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_5$ = 0	0.00 %
$Flow_6$ = 0.00002022±2.502E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_6$ = 0	0.00 %
$Flow_7$ = 0.00002488±2.992E-07 [m3/s]	$\partial UA_{exp,7}/\partial Flow_7$ = -42336	0.01 %
$HF_{V,1,1}$ = -0.05753±0.002876 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,1}$ = 0	0.00 %
$HF_{V,1,2}$ = -0.05852±0.002926 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,2}$ = 0	0.00 %
$HF_{V,1,3}$ = -0.05934±0.002967 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,3}$ = 0	0.00 %
$HF_{V,1,4}$ = -0.05944±0.002972 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,4}$ = 0	0.00 %
$HF_{V,1,5}$ = -0.05956±0.002978 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,5}$ = 0	0.00 %
$HF_{V,1,6}$ = -0.06036±0.003018 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,6}$ = 0	0.00 %
$HF_{V,1,7}$ = -0.06042±0.003021 [volts]	$\partial UA_{exp,7}/\partial HF_{V,1,7}$ = -99.43	6.72 %
$HF_{V,2,1}$ = -0.06091±0.003045 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,1}$ = 0	0.00 %
$HF_{V,2,2}$ = -0.06222±0.003111 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,2}$ = 0	0.00 %
$HF_{V,2,3}$ = -0.06333±0.003166 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,3}$ = 0	0.00 %
$HF_{V,2,4}$ = -0.06352±0.003176 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,4}$ = 0	0.00 %
$HF_{V,2,5}$ = -0.06381±0.003191 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,5}$ = 0	0.00 %
$HF_{V,2,6}$ = -0.06496±0.003248 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,6}$ = 0	0.00 %
$HF_{V,2,7}$ = -0.06506±0.003253 [volts]	$\partial UA_{exp,7}/\partial HF_{V,2,7}$ = -82.82	5.40 %
$HF_{V,3,1}$ = -0.05811±0.002906 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,1}$ = 2.985E-15	0.00 %
$HF_{V,3,2}$ = -0.05948±0.002974 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,2}$ = 0	0.00 %
$HF_{V,3,3}$ = -0.06067±0.003033 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,3}$ = 0	0.00 %
$HF_{V,3,4}$ = -0.06085±0.003042 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,4}$ = 0	0.00 %
$HF_{V,3,5}$ = -0.06134±0.003067 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,5}$ = 0	0.00 %
$HF_{V,3,6}$ = -0.06263±0.003132 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,6}$ = 0	0.00 %
$HF_{V,3,7}$ = -0.06285±0.003142 [volts]	$\partial UA_{exp,7}/\partial HF_{V,3,7}$ = -89.65	5.91 %
$HF_{V,4,1}$ = -0.04527±0.002263 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,1}$ = 0	0.00 %
$HF_{V,4,2}$ = -0.04619±0.00231 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,2}$ = 0	0.00 %
$HF_{V,4,3}$ = -0.04699±0.002349 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,3}$ = 0	0.00 %
$HF_{V,4,4}$ = -0.04706±0.002353 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,4}$ = 0	0.00 %
$HF_{V,4,5}$ = -0.04735±0.002367 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,5}$ = 0	0.00 %
$HF_{V,4,6}$ = -0.0483±0.002415 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,6}$ = 0	0.00 %
$HF_{V,4,7}$ = -0.04839±0.00242 [volts]	$\partial UA_{exp,7}/\partial HF_{V,4,7}$ = -101.7	4.50 %
$HF1_1$ = -39447±0.5 [W/m^2]	$\partial UA_{exp,7}/\partial HF1_1$ = 0	0.00 %
$HF1_{T,1}$ = 363.1±0.003 [K]	$\partial UA_{exp,7}/\partial HF1_{T,1}$ = 0	0.00 %
$HF2_1$ = -43899±0.5 [W/m^2]	$\partial UA_{exp,7}/\partial HF2_1$ = 0	0.00 %
$HF2_{T,1}$ = 364.9±0.003 [K]	$\partial UA_{exp,7}/\partial HF2_{T,1}$ = 0	0.00 %
$HF3_1$ = -43952±0.5 [W/m^2]	$\partial UA_{exp,7}/\partial HF3_1$ = 0	0.00 %
$HF3_{T,1}$ = 366.3±0.003 [K]	$\partial UA_{exp,7}/\partial HF3_{T,1}$ = 0	0.00 %
$HF4_1$ = -34005±0.5 [W/m^2]	$\partial UA_{exp,7}/\partial HF4_1$ = 0	0.00 %
$HF4_{T,1}$ = 361.7±0.003 [K]	$\partial UA_{exp,7}/\partial HF4_{T,1}$ = 0	0.00 %

P = 101325±5 [Pa]	$\partial UA_{exp,7}/\partial P$ = 2.821E-10	0.00 %
$T_{al,bot,1}$ = 438.5±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,1}$ = 0	0.00 %
$T_{al,bot,2}$ = 437.6±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,2}$ = 0	0.00 %
$T_{al,bot,3}$ = 436.7±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,3}$ = 0	0.00 %
$T_{al,bot,4}$ = 436.2±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,4}$ = 0	0.00 %
$T_{al,bot,5}$ = 434.9±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,5}$ = 0	0.00 %
$T_{al,bot,6}$ = 432.9±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,6}$ = 0	0.00 %
$T_{al,bot,7}$ = 432.2±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,bot,7}$ = 0	0.00 %
$T_{al,top,1}$ = 436.2±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,1}$ = 0	0.00 %
$T_{al,top,2}$ = 435.3±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,2}$ = 0	0.00 %
$T_{al,top,3}$ = 434.4±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,3}$ = 0	0.00 %
$T_{al,top,4}$ = 433.8±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,4}$ = 0	0.00 %
$T_{al,top,5}$ = 432.4±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,5}$ = 0	0.00 %
$T_{al,top,6}$ = 430.5±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,6}$ = 0	0.00 %
$T_{al,top,7}$ = 429.7±0.005 [K]	$\partial UA_{exp,7}/\partial T_{al,top,7}$ = 0	0.00 %
$T_{cav,in,1}$ = 298.1±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,1}$ = 0	0.00 %
$T_{cav,in,2}$ = 297±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,2}$ = 0	0.00 %
$T_{cav,in,3}$ = 296.2±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,3}$ = 0	0.00 %
$T_{cav,in,4}$ = 296.1±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,4}$ = 0	0.00 %
$T_{cav,in,5}$ = 295.7±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,5}$ = 0	0.00 %
$T_{cav,in,6}$ = 294.8±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,6}$ = 0	0.00 %
$T_{cav,in,7}$ = 294.7±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,in,7}$ = 0.000192	0.00 %
$T_{cav,out,1}$ = 301.7±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,1}$ = 0	0.00 %
$T_{cav,out,2}$ = 299.6±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,2}$ = 0	0.00 %
$T_{cav,out,3}$ = 298.4±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,3}$ = 0	0.00 %
$T_{cav,out,4}$ = 298±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,4}$ = 0	0.00 %
$T_{cav,out,5}$ = 297.2±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,5}$ = 0	0.00 %
$T_{cav,out,6}$ = 296±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,6}$ = 0	0.00 %
$T_{cav,out,7}$ = 295.6±0.005 [K]	$\partial UA_{exp,7}/\partial T_{cav,out,7}$ = 0.000192	0.00 %
$T_{tube,in,1}$ = 299.2±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,1}$ = 0	0.00 %
$T_{tube,in,2}$ = 298.9±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,2}$ = 0	0.00 %
$T_{tube,in,3}$ = 298.8±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,3}$ = 0	0.00 %
$T_{tube,in,4}$ = 298.7±0.1501 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,4}$ = 0	0.00 %
$T_{tube,in,5}$ = 298.6±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,5}$ = 0	0.00 %
$T_{tube,in,6}$ = 298.3±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,6}$ = 0	0.00 %
$T_{tube,in,7}$ = 298.3±0.15 [K]	$\partial UA_{exp,7}/\partial T_{tube,in,7}$ = 1.259	2.66 %
$T_{tube,out,1}$ = 305.1±0.1525 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,1}$ = 0	0.00 %
$T_{tube,out,2}$ = 303.1±0.1509 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,2}$ = 0	0.00 %
$T_{tube,out,3}$ = 302.4±0.1503 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,3}$ = 0	0.00 %
$T_{tube,out,4}$ = 301.7±0.1501 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,4}$ = 0	0.00 %
$T_{tube,out,5}$ = 301±0.1501 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,5}$ = 0	0.00 %
$T_{tube,out,6}$ = 300.2±0.1657 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,6}$ = 0	0.00 %
$T_{tube,out,7}$ = 299.8±0.1521 [K]	$\partial UA_{exp,7}/\partial T_{tube,out,7}$ = 0	0.00 %
$TC_{22,1}$ = 326.1±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{22,1}$ = 0	0.00 %
$TC_{22,2}$ = 322.9±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{22,2}$ = 0	0.00 %
$TC_{22,3}$ = 321.1±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{22,3}$ = 0	0.00 %
$TC_{22,4}$ = 319.9±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{22,4}$ = 0	0.00 %
$TC_{22,5}$ = 318.4±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{22,5}$ = 0	0.00 %
$TC_{22,6}$ = 315.8±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{22,6}$ = 0	0.00 %
$TC_{22,7}$ = 314.8±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{22,7}$ = -0.3148	16.60 %
$TC_{51b,1}$ = 330.7±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{51b,1}$ = -8.671E-18	0.00 %
$TC_{51b,2}$ = 327.1±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{51b,2}$ = 0	0.00 %
$TC_{51b,3}$ = 325.4±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{51b,3}$ = 0	0.00 %
$TC_{51b,4}$ = 324.2±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{51b,4}$ = 0	0.00 %
$TC_{51b,5}$ = 322.5±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{51b,5}$ = 0	0.00 %
$TC_{51b,6}$ = 319.4±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{51b,6}$ = 0	0.00 %

$TC_{51b,7}$ = 318.4±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{51b,7}$ = -0.3148	16.61 %
$TC_{66,1}$ = 325.2±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{66,1}$ = -4.622E-18	0.00 %
$TC_{66,2}$ = 321.9±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{66,2}$ = 0	0.00 %
$TC_{66,3}$ = 320.2±1.501 [K]	$\partial UA_{exp,7}/\partial TC_{66,3}$ = 0	0.00 %
$TC_{66,4}$ = 318.9±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{66,4}$ = 0	0.00 %
$TC_{66,5}$ = 317.3±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{66,5}$ = 0	0.00 %
$TC_{66,6}$ = 314.5±1.5 [K]	$\partial UA_{exp,7}/\partial TC_{66,6}$ = 0	0.00 %
$TC_{66,7}$ = 313.5±1.502 [K]	$\partial UA_{exp,7}/\partial TC_{66,7}$ = -0.3148	16.63 %
th_{base} = 0.00112±0.0001 [m]	$\partial UA_{exp,7}/\partial th_{base}$ = 5791	24.96 %
W_{al} = 0.04699±0.0001 [m]	$\partial UA_{exp,7}/\partial W_{al}$ = -5.117E-13	0.00 %

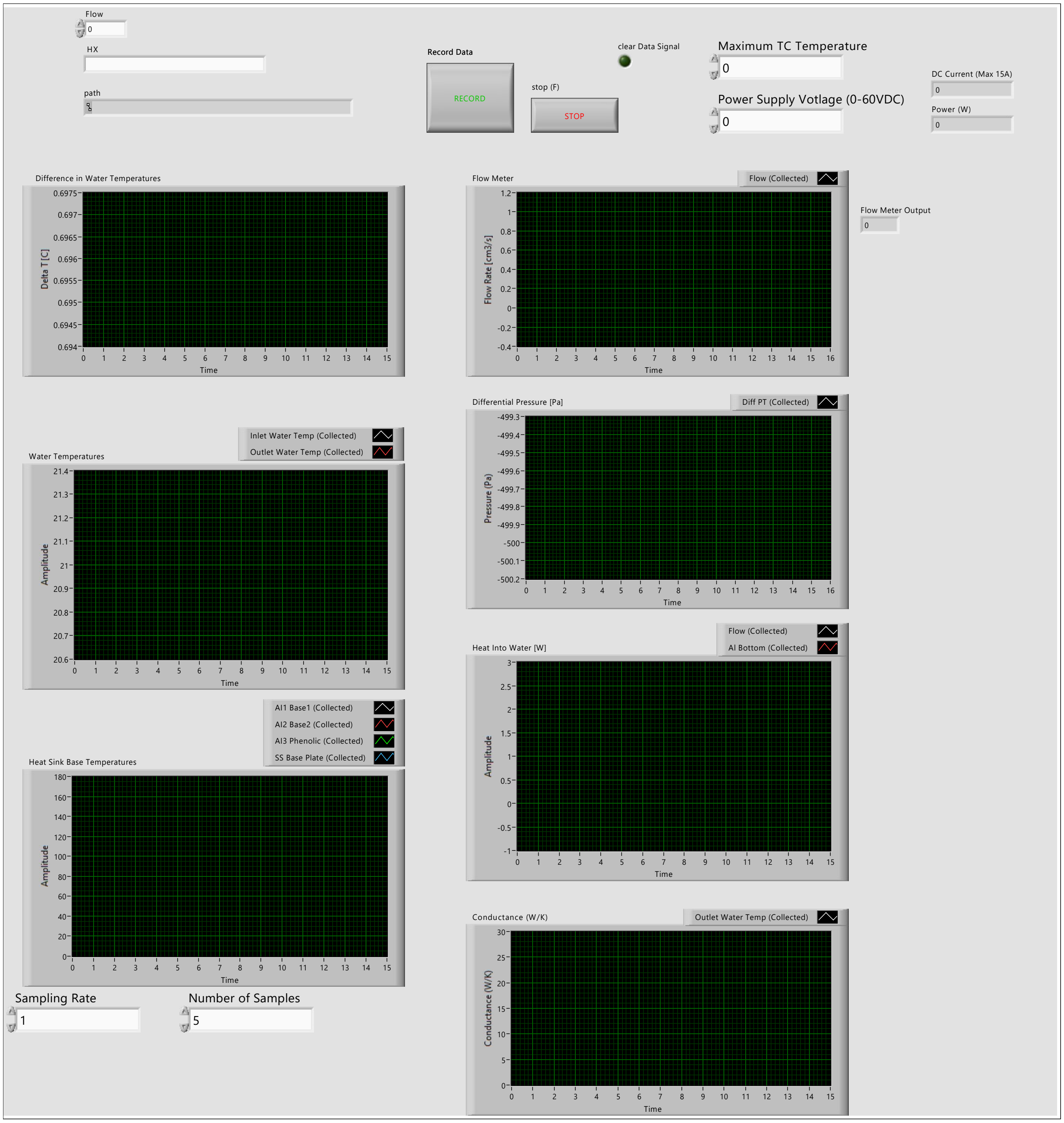
21 potential unit problems were detected.

Appendix B

Appendix

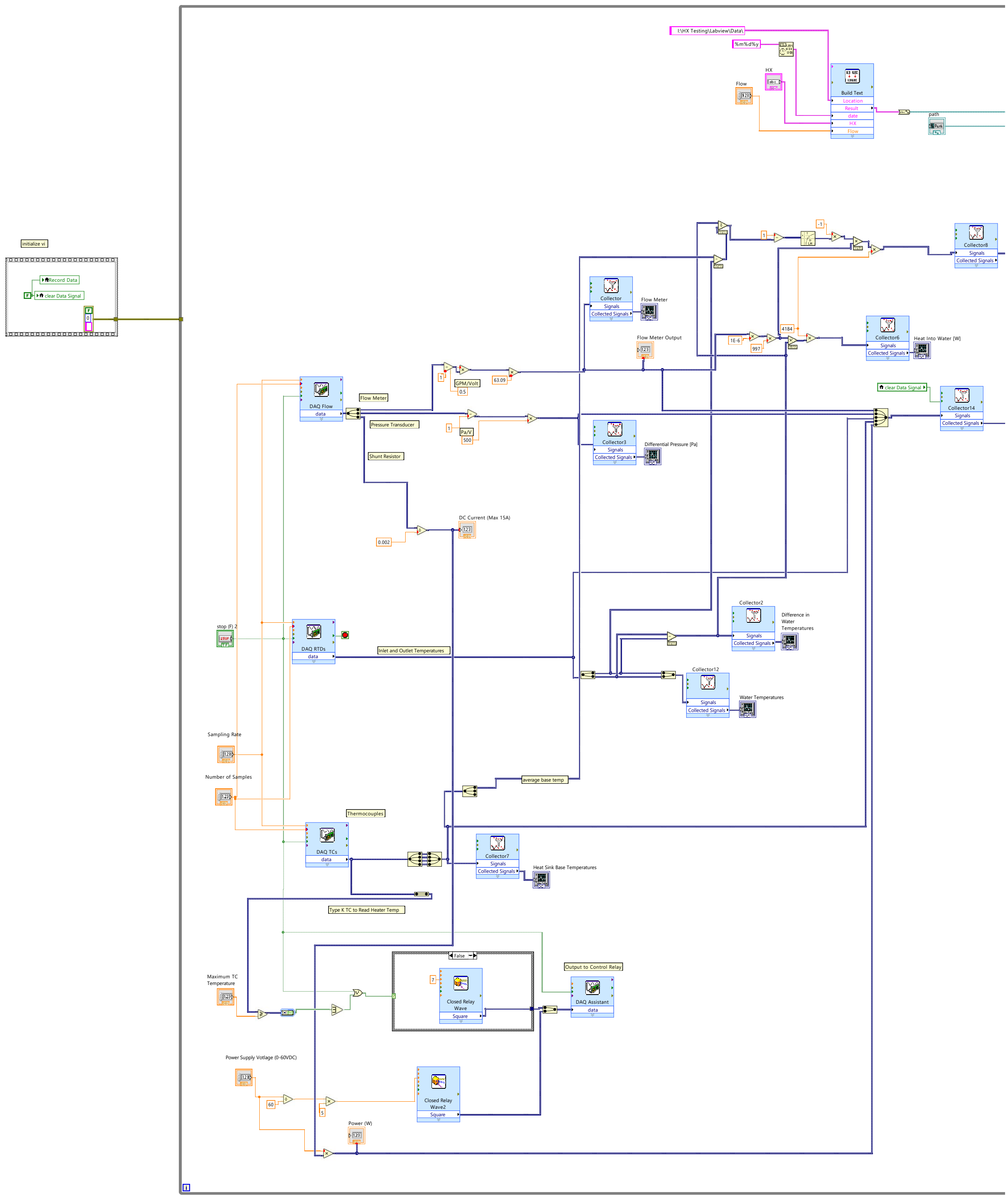
Experiment_01062022_ian.vi
C:\Users\Owner\Downloads\Experiment_01062022_ian.vi
Last modified on 5/12/2022 at 5:36 PM
Printed on 5/12/2022 at 5:37 PM

Experiment_01062022_ian.vi



Page 2

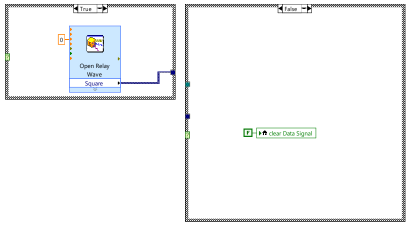
Experiment_01062022_ian.vi
C:\Users\Owner\Downloads\Experiment_01062022_ian.vi
Last modified on 5/12/2022 at 5:36 PM
Printed on 5/12/2022 at 5:37 PM



Page 3

Experiment_01062022_ian.vi
C:\Users\Owner\Downloads\Experiment_01062022_ian.vi
Last modified on 5/12/2022 at 5:36 PM
Printed on 5/12/2022 at 5:37 PM

Experiment_01062022_ian.vi
C:\Users\Owner\Downloads\Experiment_01062022_ian.vi
Last modified on 5/12/2022 at 5:36 PM
Printed on 5/12/2022 at 5:37 PM



Bibliography

G.D. Xia et al. (May 21, 2014). "Effects of different geometric structures on fluid flow and heat transfer performance in microchannel heat sinks". In:

Tamara Bechtold, Engenii B. Rudnyi, and Jan G. Korvink (2005). "Dynamic electro-thermal simulation of microsystems—a review". In: *Journal of Micromechanics and Microengineering*.

Fabis, P. M., D. Shum, and H. Windischmann (Mar. 1999). "Thermal modeling of diamond-based power electronics packaging". In: *Fifteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium (Cat. No.99CH36306)*. Fifteenth Annual IEEE Semiconductor Thermal Measurement and Management Symposium (Cat. No.99CH36306). ISSN: 1065-2221, pp. 98–104. DOI: 10.1109/STHERM.1999.762434.

Definition of HEAT SINK (2020). URL: https://www.merriam-webster.com/dictionary/heat+sink (visited on 11/04/2020).

5G Telecom Heat Sinks - finskiving.com (2021). URL: https://www.finskiving.com/heat-sink-industries-applications/5g-telecom-heat-sinks (visited on 03/17/2021).

Satish G. Kandlikar and William J. Grande (2003). "Evolution of Microchannel Flow Passages - Thermohydraulic Performance and Fabrication Technology". In: DOI: 10.1080/01457630304040.

Tuckerman, D. B. and R. F. W. Pease (May 1981). "High-performance heat sinking for VLSI". In: *IEEE Electron Device Letters* 2.5. Conference Name: IEEE Electron Device Letters, pp. 126–129. ISSN: 1558-0563. DOI: 10.1109/EDL.1981.25367.

Tisha Dixit and Indranil Ghosh (Apr. 20, 2014). “Review of micro- and mini-channel heat sinks and heat exchangers for single phase fluids”. In: *Renewable and Sustainable Energy Reviews*.

Sambhaji T. Kadam and Ritunesh Kumar (Feb. 8, 2014). “Twenty first century cooling solution: Microchannel heat sinks”. In: *International Journal of Thermal Sciences*.

Xiaoping Qian and Ercan Dede (2016). “Topology optimization of a coupled thermal-fluid system under a tangential thermal gradient constraint”. In: *Struct Multidisc Optim*.

Sicheng Sun, Piotr Leibersback, and Xiaoping Qian (2020). “3D topology optimization of heat sinks for liquid cooling”. In: *Applied Thermal Engineering*.

Tseng, Po-Hsiang et al. (July 1, 2019). “Performance of novel liquid-cooled porous heat sink via 3-D laser additive manufacturing”. In: *International Journal of Heat and Mass Transfer* 137, pp. 558–564. ISSN: 0017-9310. DOI: 10.1016/j.ijheatmasstransfer.2019.03.116. URL: https://www.sciencedirect.com/science/article/pii/S001793101834883X (visited on 05/02/2022).

Li, Yongtong et al. (Feb. 5, 2020). “Hydraulic and thermal performances of metal foam and pin fin hybrid heat sink”. In: *Applied Thermal Engineering* 166, p. 114665. ISSN: 1359-4311. DOI: 10.1016/j.applthermaleng.2019.114665. URL: https://www.sciencedirect.com/science/article/pii/S1359431119316229 (visited on 05/02/2022).

Dede, Ercan M., Shailesh N. Joshi, and Feng Zhou (Oct. 12, 2015). “Topology Optimization, Additive Layer Manufacturing, and Experimental Testing of an Air-Cooled Heat Sink”. In: *Journal of Mechanical Design* 137.11. ISSN: 1050-0472. DOI: 10.1115/1.4030989. URL: https://doi.org/10.1115/1.4030989 (visited on 05/02/2022).

Barry N. Taylor and Chris E. Kuyatt (Sept. 1994). *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*. URL: https://emtoolbox.nist.gov/Publications/NISTTechnicalNote1297s.pdf (visited on 12/03/2020).

Gregory Nellis and Sanford Klein (2009). *Heat Transfer*. Cambridge University Press. ISBN: 978-0-521-88107-4.

AD, WEIL (May 2014). *EOS Aluminum AlSi10Mg Material Data Sheet*. EOS GmbH.

P. Wibulswas (May 1966). "Laminar Flow Heat Transfer in Non-Circular Ducts". In: *Thesis*.

Design guidelines for Direct Metal Laser Sintering (DMLS) (2014). Crucible Industrial Design.