SOLIDWORKS

Fluid Flow Simulation Project Report

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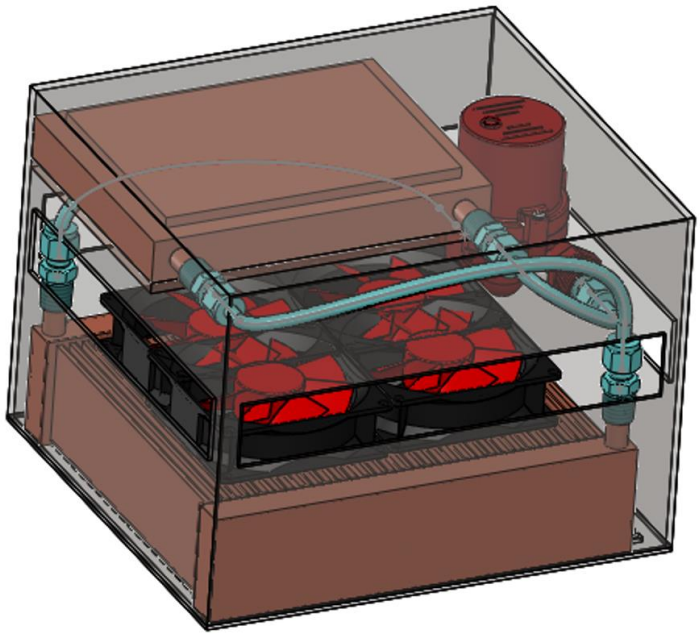

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1 General Information

Objective of the simulation: The objective of this simulation is to model a system to dissipate 2000W of heat using a microchannel cold plate with custom radiator assembly to limit the maximum temperature at 60 degrees Celsius in a compact enclosure with CFD analysis.

Fig 1 : Simulation Layout

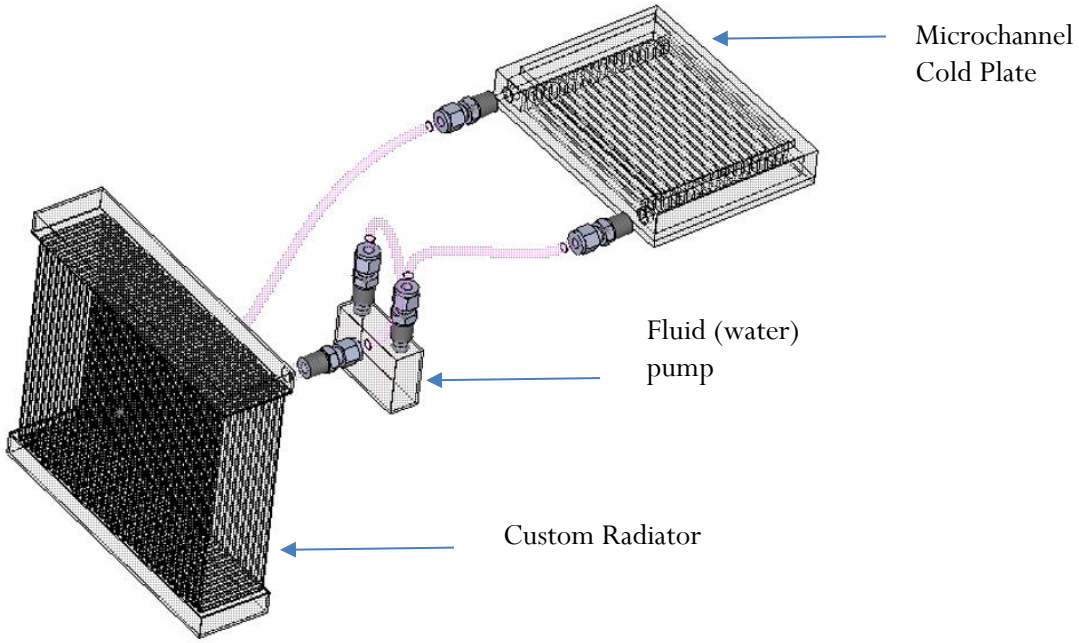


Fig 2 : Enclosure Design

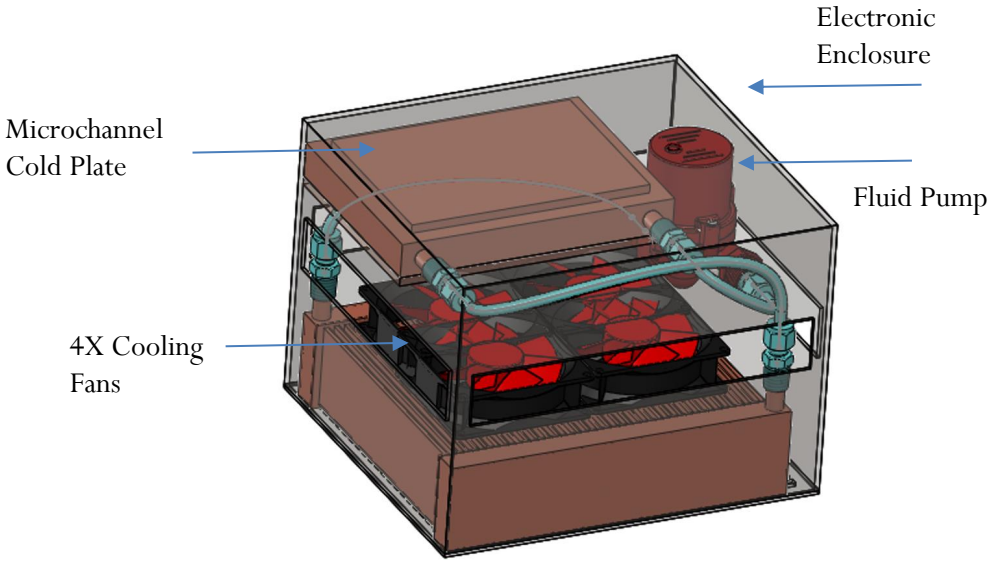
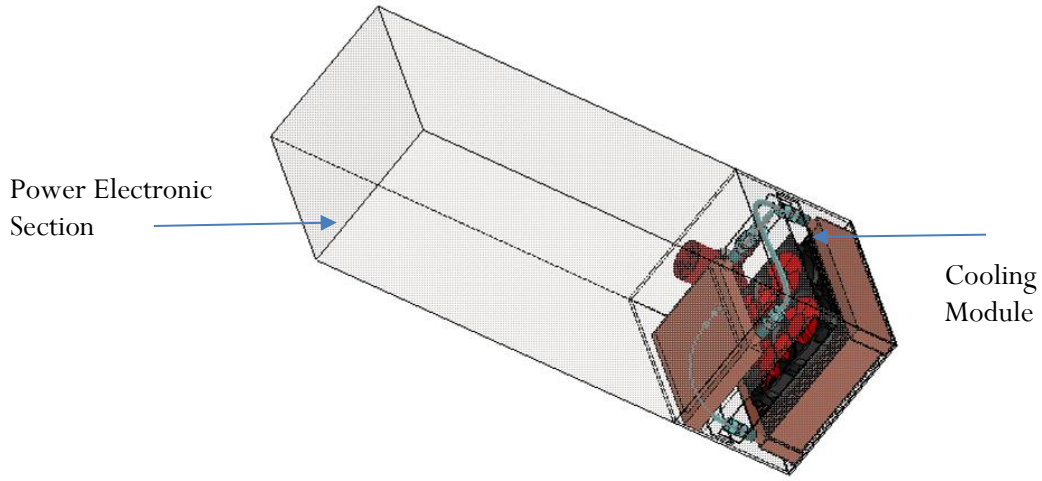


Fig 3 : Complete enclosure



1.1 Analysis Environment

Software Product:	Flow Simulation 2019 SP4.0. Build: 4631
CPU Type:	Intel(R) Xeon(R) CPU E3-1585L v5 @ 3.00GHz
CPU Speed:	3000 MHz
RAM:	8061 MB / 134217727 MB
Operating System:	Windows 10 (or higher) (Version 10.0.14393)

1.2 Model Information

Model Name:	1radiatorfinaltest.SLDASM
Project Name:	finaltest1(2)

1.3 Project Comments:

Unit System:	SI (m-kg-s)
Analysis Type:	External (not exclude internal spaces)

1.4 Size of Computational Domain

Size

X min	-0.124 m
X max	0.433 m
Y min	-0.189 m
Y max	0.331 m
Z min	0.180 m
Z max	0.479 m
X size	0.557 m
Y size	0.520 m
Z size	0.299 m

1.5 Simulation Parameters

1.5.1 Mesh Settings

1.5.1.1 Basic Mesh

Basic Mesh Dimensions

Number of cells in X	15
Number of cells in Y	16
Number of cells in Z	11

1.5.1.2 Analysis Mesh

Total Cell count: 158313
Fluid Cells: 100664
Solid Cells: 57649
Partial Cells: 44488
Trimmed Cells: 0

1.5.1.3 Additional Physical Calculation Options

Heat Transfer Analysis: Heat conduction in solids: OnHeat conduction in solids only: Off
Flow Type: Laminar and turbulent
Time-Dependent Analysis: Off
Gravity: Off
Radiation: Off
Humidity: Off
Default Wall Roughness: 0 micrometer

1.5.2 Material Settings

Material Settings

Fluids

Air
Water

Solids

Brass material for tubing connections, copper material for radiator and cold plate.

1.5.3 Initial Conditions

Ambient Conditions

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 20.05 °C
Velocity parameters	Velocity vector Velocity in X direction: 0 m/s Velocity in Y direction: 40.000 m/s (4X fans) Velocity in Z direction: 0 m/s
Solid parameters	Default material: Brass Initial solid temperature: 20.05 °C
Turbulence parameters	

1.5.4 Boundary Conditions

Boundary Conditions

Inlet Mass Flow 1

Type	Inlet Mass Flow
Faces	Tube_1-1radiatorfinaltest-1/LID21-1/Imported1//Face
Coordinate system	Face Coordinate System
Reference axis	X
Flow parameters	Flow vectors direction: Normal to face Mass flow rate: 0.0945 kg/s = 1.5 GPM Fully developed flow: No Inlet profile: 0
Thermodynamic parameters	Temperature type: Temperature of initial components Temperature: 24.00 °C, water entering cold plate
Turbulence parameters	Boundary layer parameters
Boundary layer type: Turbulent	

Environment Pressure 1

Type	Environment Pressure
Faces	Tube_1-1radiatorfinaltest-1/LID22-1/Imported1//Face
Coordinate system	Face Coordinate System
Reference axis	X
Thermodynamic parameters	Environment pressure: 101325.00 Pa Temperature type: Temperature of initial components Temperature: 20.05 °C
Turbulence parameters	Boundary layer parameters
Boundary layer type: Turbulent	

1.5.5 Volumetric Heat Sources

No volumentric heat source. Surface heat source of 2000 W at cold plate.

1.5.6 Engineering Goals

Goals

Global Goals

GG Maximum Temperature (Fluid) 1

Type	Global Goal
Goal type	Temperature (Fluid)
Calculate	Maximum value
Coordinate system	Global coordinate system
Use in convergence	On

GG Maximum Wall Temperature 1

Type	Global Goal
Goal type	Wall Temperature
Calculate	Maximum value
Coordinate system	Global coordinate system
Use in convergence	On

GG Maximum Temperature (Solid) 1

Type	Global Goal
Goal type	Temperature (Solid)
Calculate	Maximum value
Coordinate system	Global coordinate system
Use in convergence	On

Surface Goals

SG Maximum Temperature (Solid) 1

Type	Surface Goal
Goal type	Temperature (Solid)
Calculate	Maximum value
Faces	Face<1>@microchannelcoldplateassembled-1/Iteration3.2.1microchannelcoldplate-1
Coordinate system	Global coordinate system
Use in convergence	On

1.6 Analysis Time

Calculation Time: 393 s
Number of Iterations: 170
Warnings:

2 Results

2.1 Analysis Goals

Goals

Name	Unit	Value	Progress	Criteria	Delta	Use in convergence
GG Maximum Temperature (Fluid) 1	°C	59.69	100	0.802407961	0.741701587	On
GG Maximum Wall Temperature 1	°C	59.69	100	0.802407961	0.741701587	On
GG Maximum Temperature (Solid) 1	°C	59.71	100	0.802998179	0.735128044	On
SG Maximum Temperature (Solid) 1	°C	59.69	100	0.802407919	0.741701443	On

2.2 Global Min-Max-Table

Min/Max Table

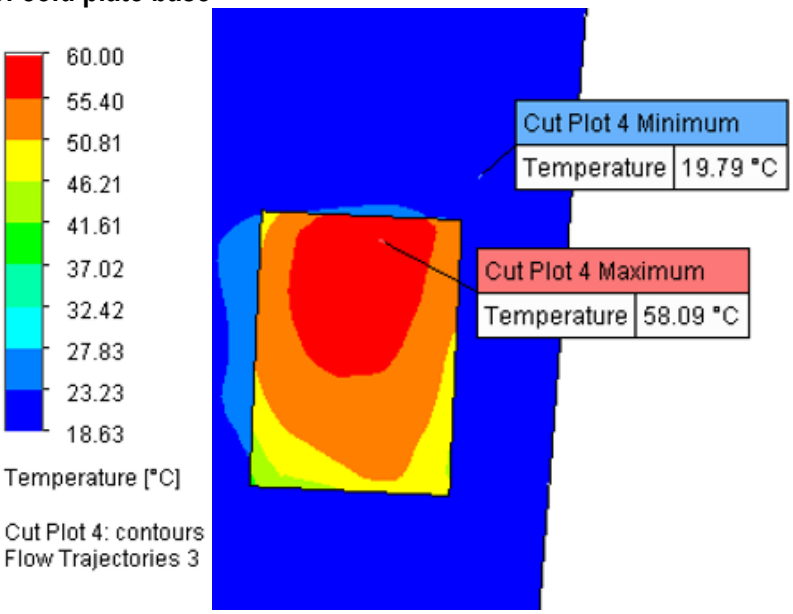
Name	Minimum	Maximum
Density (Fluid) [kg/m^3]	1.15	997.57
Density (Solid) [kg/m^3]	8400.00	8400.00
Mass Fraction of Air [ ]	1.0000	1.0000
Mass Fraction of Water [ ]	1.0000	1.0000
Pressure [Pa]	96949.16	209629.21
Temperature [°C]	18.77	59.71
Temperature (Fluid) [°C]	18.77	59.69
Temperature (Solid) [°C]	20.06	59.71
Velocity [m/s]	0	57.727
Velocity (X) [m/s]	-52.884	43.054
Velocity (Y) [m/s]	-15.982	57.206
Velocity (Z) [m/s]	-50.457	44.268
Volume Fraction of Air [ ]	1.0000	1.0000
Volume Fraction of Water [ ]	1.0000	1.0000
Mach Number [ ]	0	0.17
Velocity RRF [m/s]	0	57.727
Velocity RRF (X) [m/s]	-52.884	43.054
Velocity RRF (Y) [m/s]	-15.982	57.206

Velocity RRF (Z) [m/s]	-50.457	44.268
Vorticity [1/s]	3.52e-04	22645.57
Relative Pressure [Pa]	-4375.84	108304.21
Shear Stress [Pa]	0	351.56
Bottleneck Number [ ]	6.6065337e-15	1.0000000
Heat Flux [W/m^2]	5.908	285556.534
Heat Transfer Coefficient [W/m^2/K]	0	26459.597
Overheat above Melting Temperature [K]	-864.939	-825.290
ShortCut Number [ ]	3.0056187e-14	1.0000000
Surface Heat Flux [W/m^2]	-28228.642	205930.725
Surface Heat Flux (Conductive) [W/m^2]	0	0
Surface Heat Flux (Convective) [W/m^2]	-3.375e+09	2.118e+09
Acoustic Power [W/m^3]	0	0.124
Acoustic Power Level [dB]	0	110.95

2.3 Results

Cut plot of the surface of the cold plate with maximum temperature below the permissible limit of 60 degrees C. The thermal resistance of the entire system is 0.019 C/W.

Fig 4: Cut plot diagram of cold plate base



2.4 Conclusion

The CFD simulation concluded that the design can limit the maximum surface temperature of the cold plate that is in contact with the heat generating source of 2000 W. The water, used as a coolant has a flow rate of 1.5 GPM and an axial fan source impinging air at 40 m/s over the radiator assembly. Improvement in the radiator assembly will make it possible to use fan source with lower air velocity (CFM) thus requiring reduced power.

The reference dimensions of each part can be found after the appendix section along with cut plots, flow trajectories, and reference images.

3 Appendix

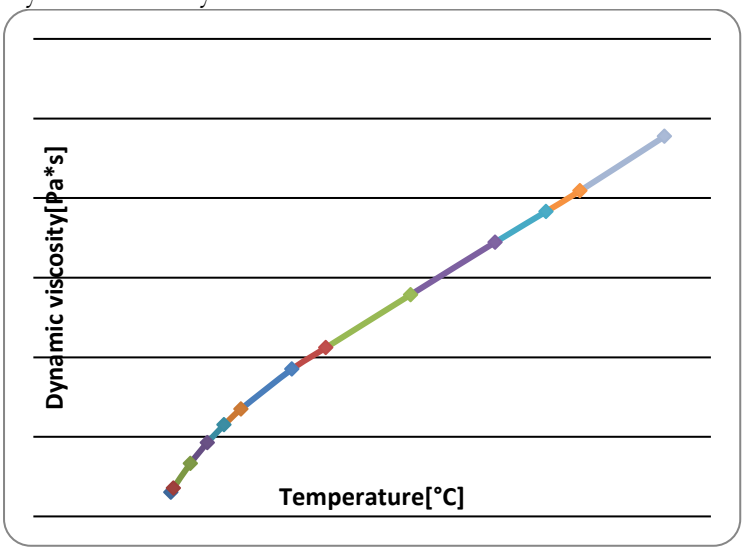
3.1 Material Data

Engineering Database

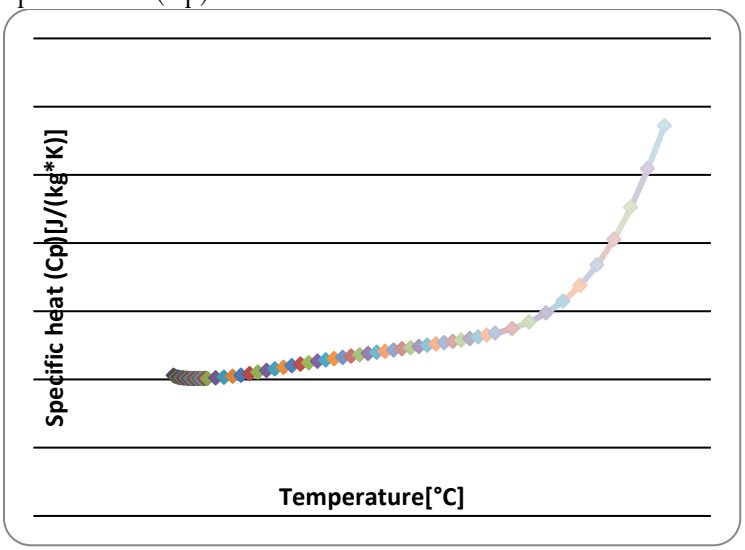
Gases

Air

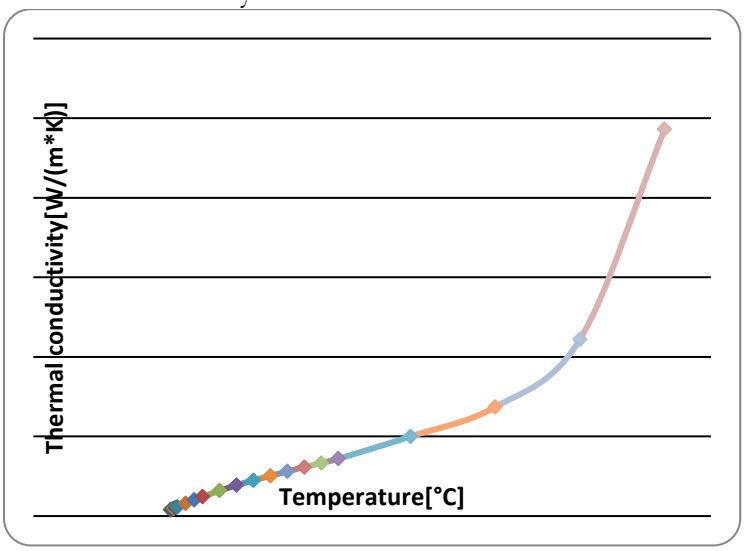
Path: Gases Pre-Defined
Specific heat ratio (Cp/Cv): 1.399
Molecular mass: 0.0290 kg/mol
Dynamic viscosity



Specific heat (Cp)



Thermal conductivity

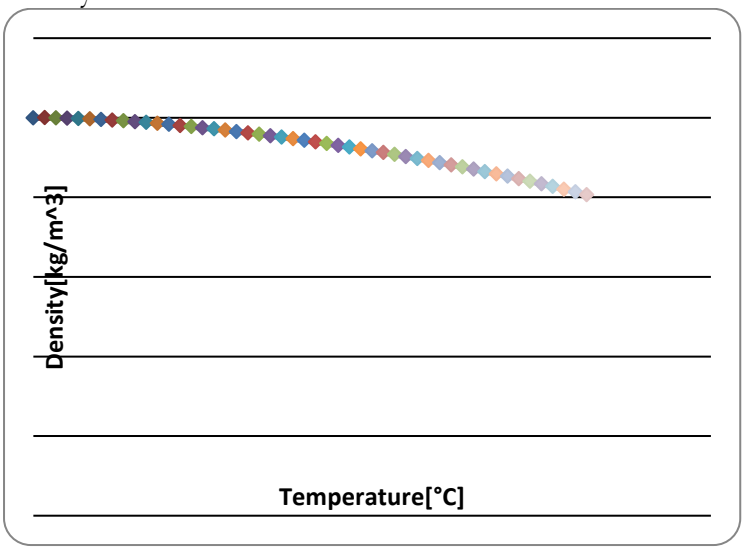


Liquids

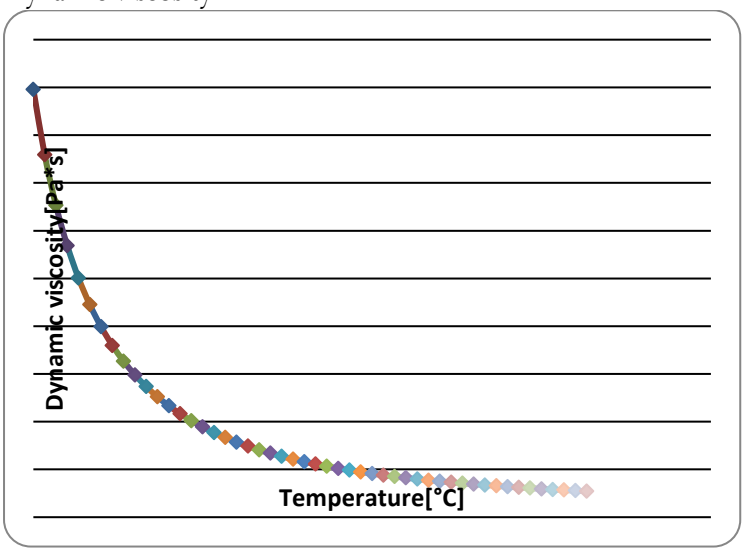
Water

Path: Liquids Pre-Defined

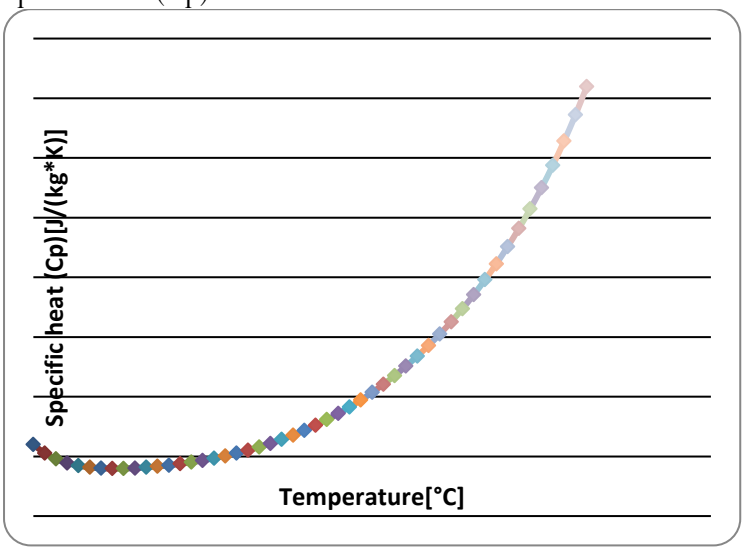
Density



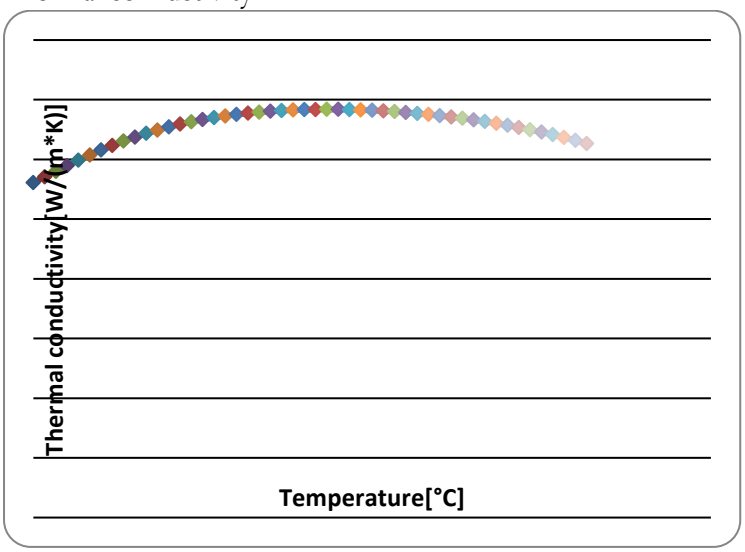
Dynamic viscosity



Specific heat (Cp)



Thermal conductivity



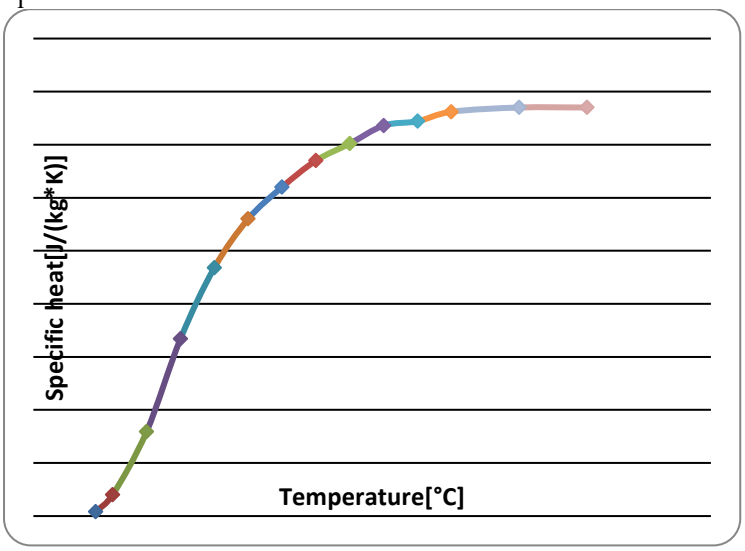
Cavitation effect: Yes
Temperature: -273.15 °C
Saturation pressure: 0 Pa
Radiation properties: No

Solids

Brass

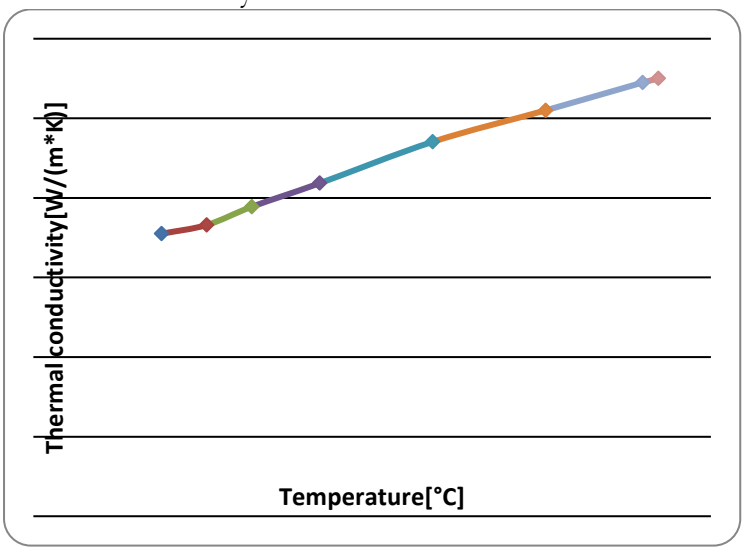
Path: Solids Pre-Defined\Alloys
Density: 8400.00 kg/m^3

Specific heat



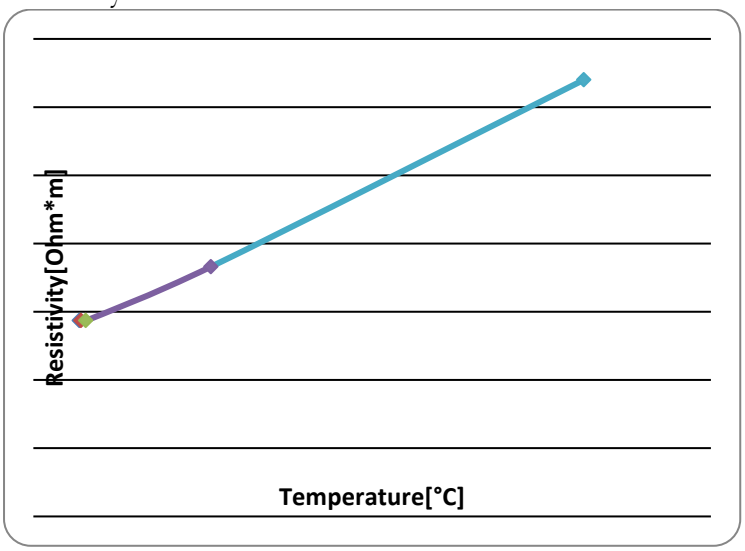
Conductivity type: Isotropic

Thermal conductivity



Electrical conductivity: Conductor

Resistivity



Radiation properties: No

Melting temperature: Yes

Temperature: 885.00 °C

Fig 5: Image depicting heat source and coolant (water) flow trajectories.

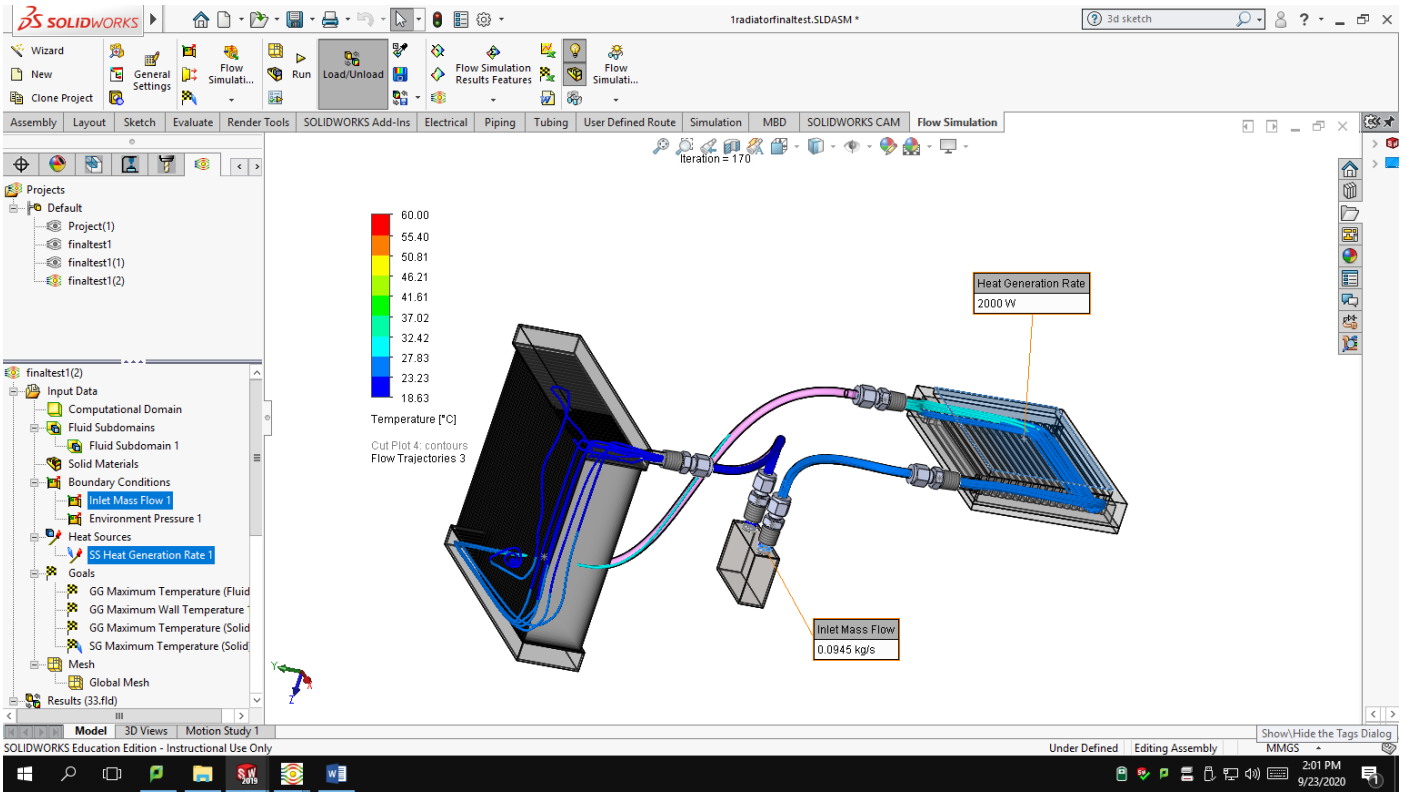


Fig 6: Image depicting cut plot of the surface of the cold plate that can be bolted to heat generating device (e.g. IGBT)

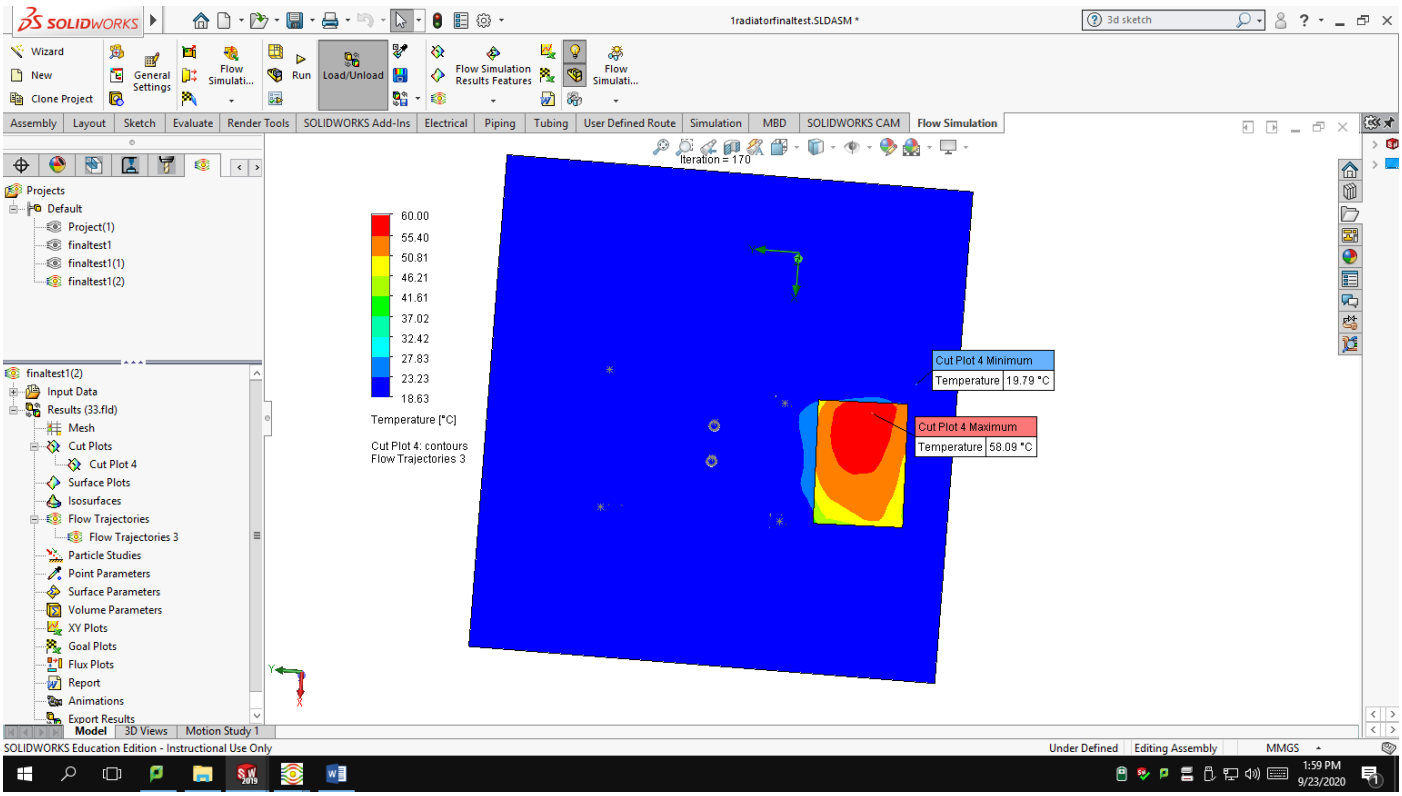


Fig 7: Part Dimensions: Microchannel Cold Plate. Use for reference purpose only, this is not a complete engineering drawing. (All dimensions in mm.)

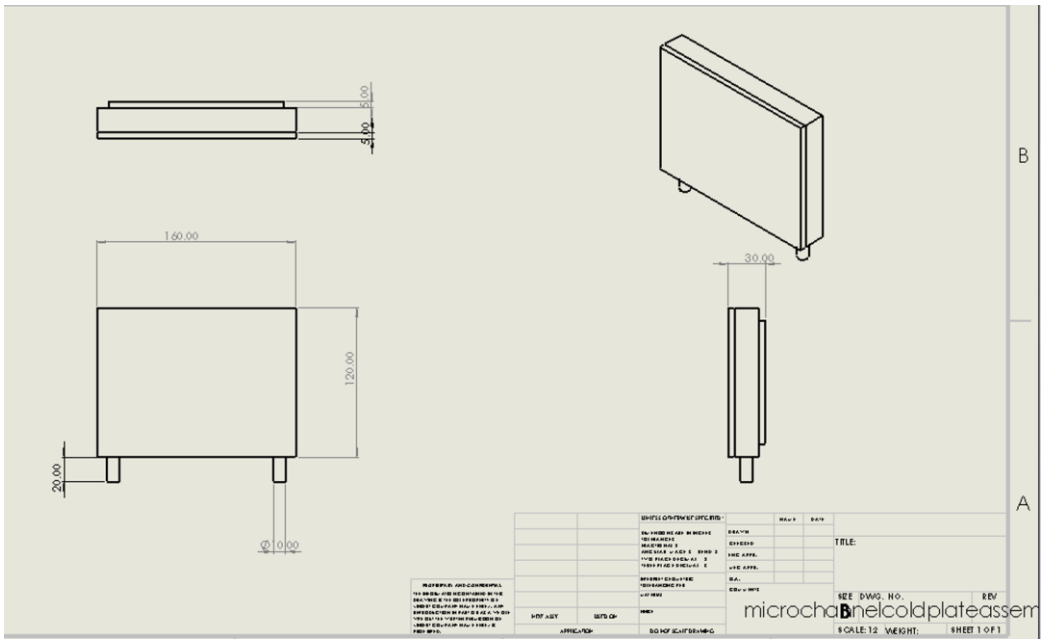


Fig 8: Image depicting uniform fluid flow trajectories through the sectional view of custom microchannel cold plate for uniform temperature gradient.

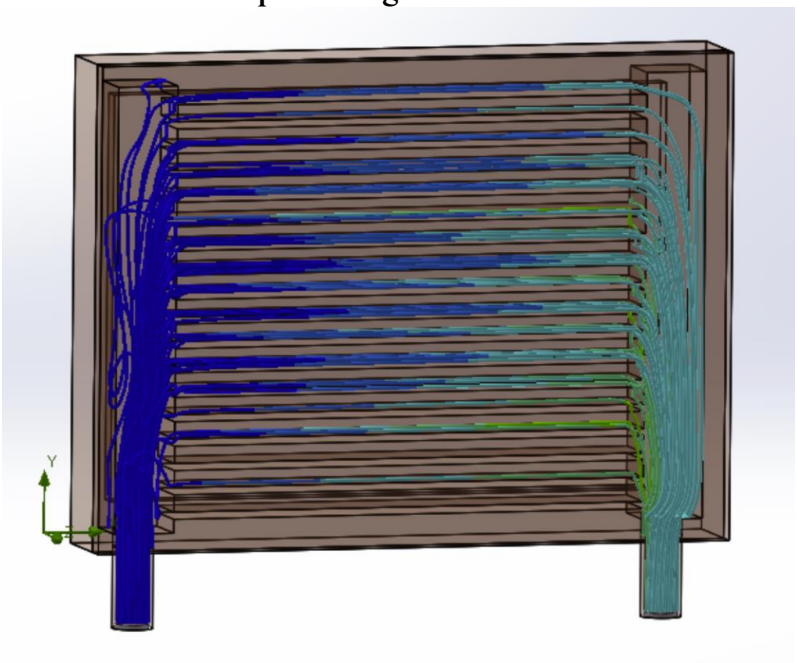


Fig 9: Part Dimensions: Custom Radiator. Use for reference only, this is not a complete engineering drawing.

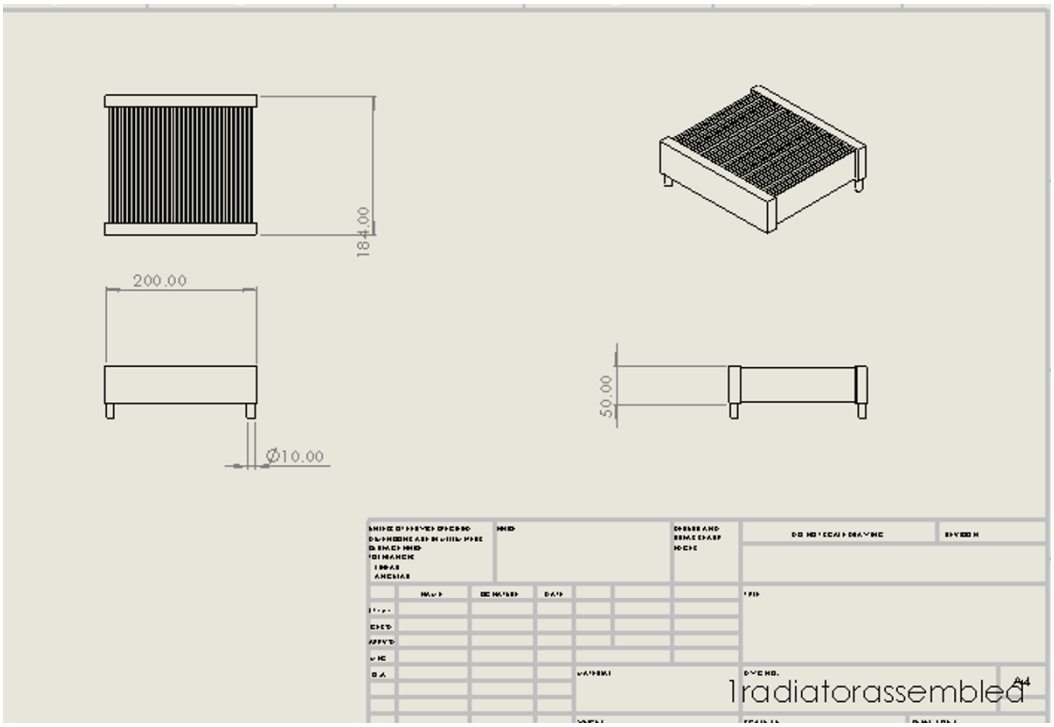


Fig 10: Part Dimensions: Example pump. Use for reference purpose only, this is not a complete engineering drawing.

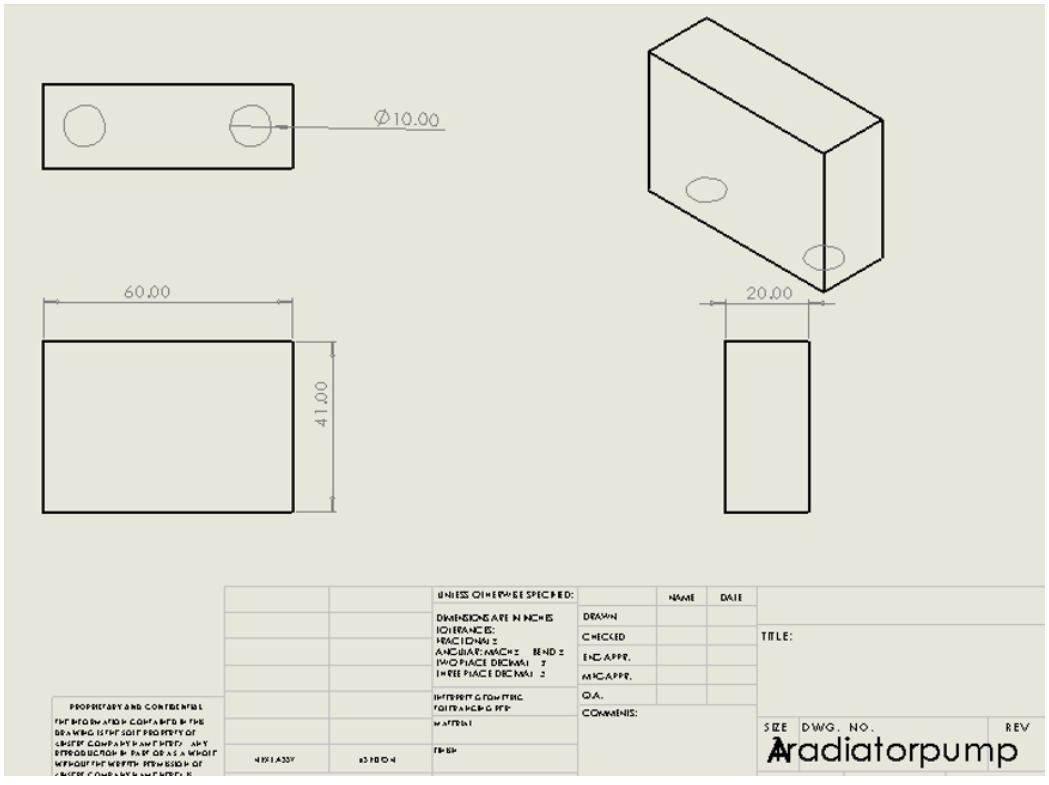


Fig 11: Image depicting one of the possible combinations of the cold plate, fluid pump, cooling fans and radiator.

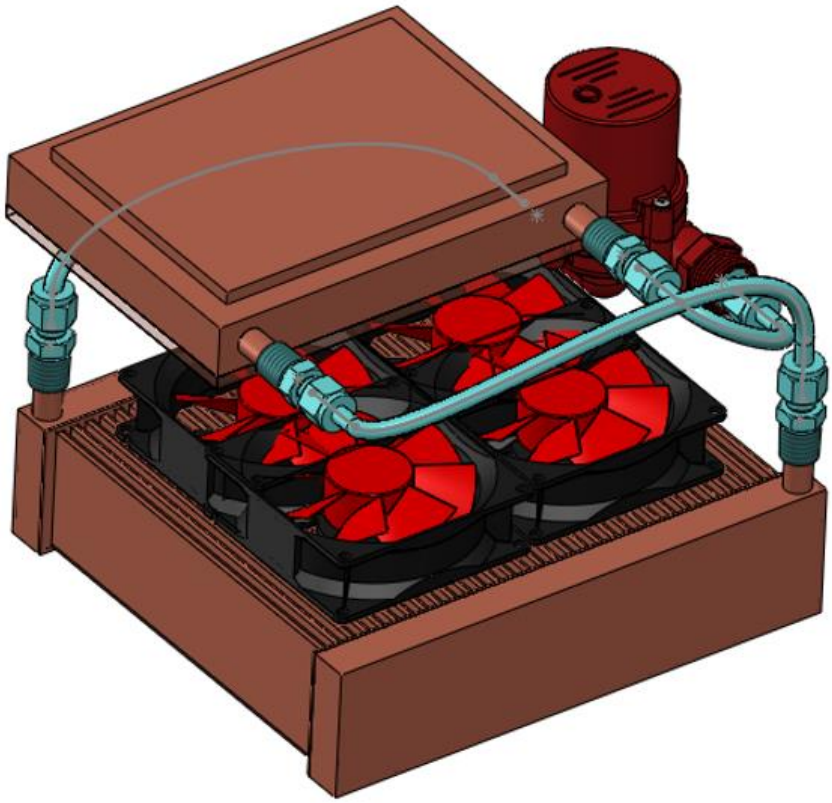


Fig 12: Image depicting cooling module enclosure that can be attached to the power electronic module for heat dissipation.

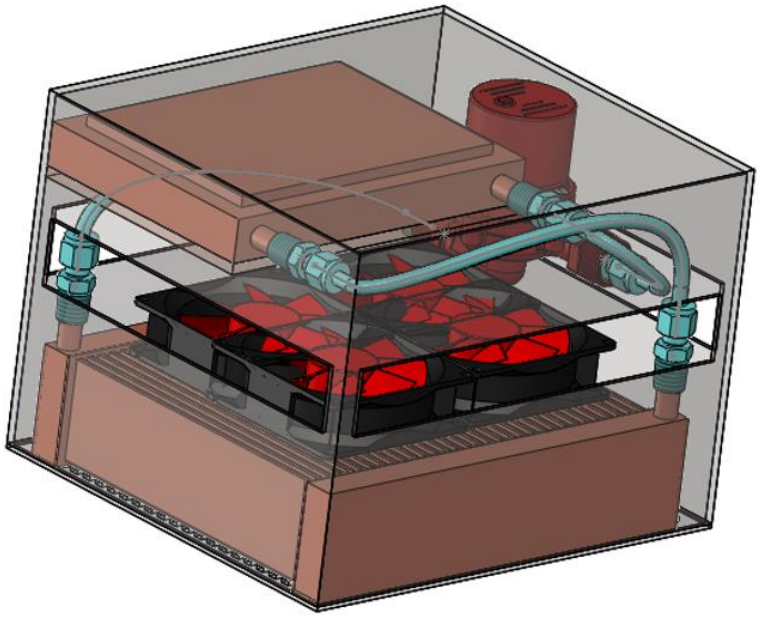


Fig 13: Part Dimensions: Cooling module enclosure. Use for reference purpose only, this is not a complete engineering drawing.

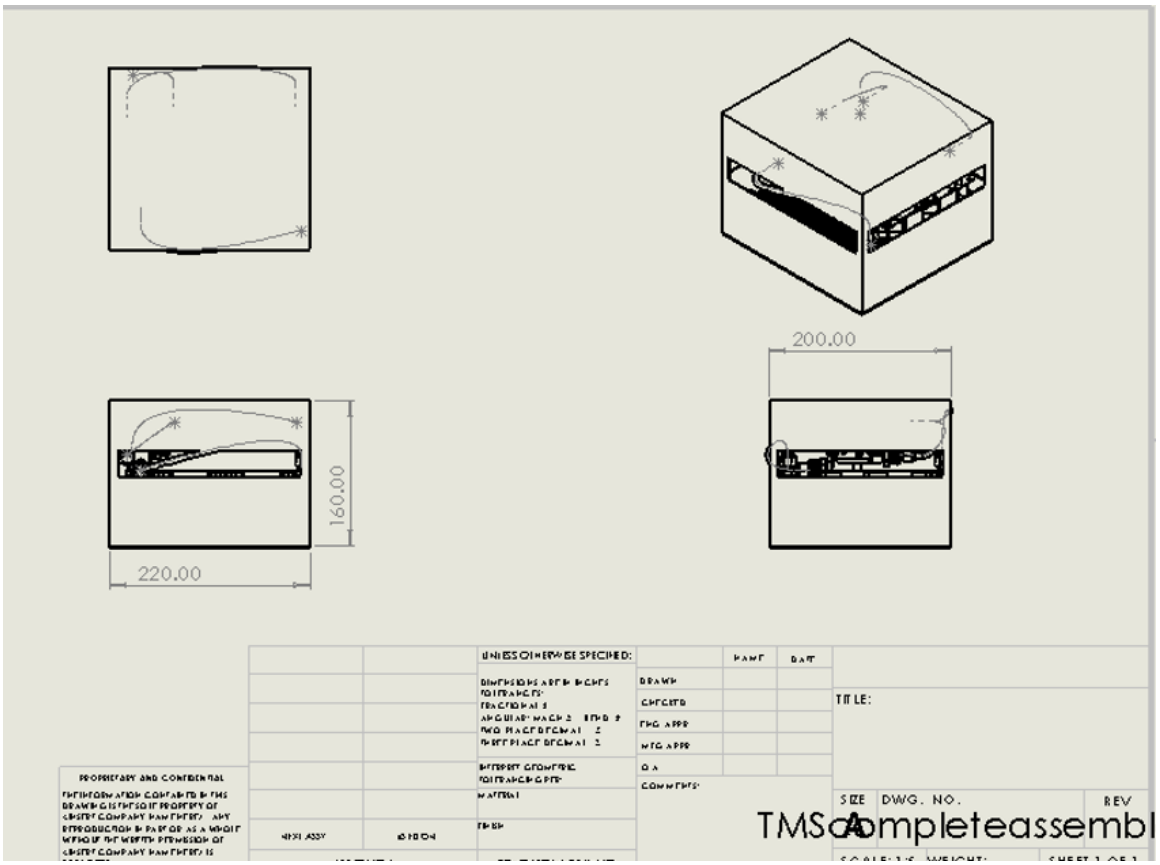


Fig 14: Image depicting power electronic module with a cooling module attached to the lower right section.