BRONCO MOTORSPORTS

California State Polytechnic University, Pomona
Formula SAE

2023-2024 Design Binder

Cooling

Isaac Haynes

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Abstract

The Cal Poly Pomona Formula SAE team (Bronco Motorsports) is a student design team that designs and builds an open wheel, formula-style race car for international competitions held by the Society of Automotive Engineers (SAE). The purpose of this project is to use data collected through physical testing, analytical calculations, and computer simulation to design and manufacture a cooling system capable of reliably rejecting enough heat from the engine to maintain operating temperatures while minimizing weight, drag, and loss of downforce. This paper will discuss the process involved in designing the ducting and radiator along with the justifications behind the selection of the system's new radiator fan motors, oil cooler, and materials. Additionally, the project will provide an in-depth overview of manufacturing techniques and on-track testing leading up to 2024 competition and during competition as well.

BM 24 Full Vehicle Objectives

After the suffering of a mechanical DNF in our 2023 Michigan Competition, reliability and serviceability have been a main concern for future competition. We struggled with cooling, shifting, and electrical problems leading up to the competition, and because of this, our testing time was reduced. This year we started with top-down vehicle goals regarding weight, power, downforce, and Tire Sensitivity analysis, to understand how certain changes can affect lap time for all 4 different dynamic events at our specific competition. With that being said, taking these lessons learned, and further development of the car in terms of reliability, without sacrificing innovation towards performance has been a fine line; however, a line that has guided our design for the 2024 Car.

Purpose of Subsystem

The cooling system is designed to maintain a targeted temperature range of our engine by way of rejecting the engine-generated heat energy to ambient air. Without a way of cooling our engine, overheating would occur, components would go out of tolerance due to thermal-expansion, and a snowball effect would render the car in need of much repair in several subsystems. Exclusive to our internal combustion engine, this process is done through water-cooling.

FSAE 2024 Rules

T.5.4 Coolant Fluid

T.5.4.1 Water cooled engines must use only plain water with no additives of any kind

T.5.4.2 Liquid coolant for electric motors, Accumulators or HV electronics must be one of:

- plain water with no additives
- oil

T.5.4.3 (EV only) Liquid coolant must not directly touch the cells in the Accumulator

T.5.5 System Sealing

T.5.5.1 Any cooling or lubrication system must be sealed to prevent leakage

T.5.5.2 The vehicle must be capable of being tilted to a 45° angle without leaking fluid of any type.

T.5.5.3 Flammable liquid and vapors or other leaks must not collect or contact the driver

T.5.5.4 Two holes of minimum diameter 25 mm each must be provided in the structure or belly pan at the locations:

a. The lowest point of the chassis

b. Rearward of the driver position, forward of a fuel tank or other liquid source

c. If the lowest point of the chassis obeys T.5.5.4.b, then only one set of holes T.5.5.4.a is necessary

T.5.5.5 Absorbent material and open collection devices (regardless of material) are prohibited in compartments containing engine, drivetrain, exhaust and fuel systems below the highest point on the exhaust system.

T.5.6 Catch Cans

T.5.6.1 The vehicle must have separate containers (catch cans) to retain fluids from any vents from the powertrain systems.

T.5.6.2 Catch cans must be:

a. Capable of containing boiling water without deformation

b. Located rearwards of the Firewall below the driver's shoulder level

c. Positively retained, using no tie wraps or tape

T.5.6.3 Catch cans for the engine coolant system and engine lubrication system must have a minimum capacity of 10% of the fluid being contained or 0.9 liter, whichever is higher

T.5.6.4 Catch cans for any vent on other systems containing liquid lubricant or coolant, including a differential, gearbox, or electric motor, must have a minimum capacity of 10% of the fluid being contained or 0.5 liter, whichever is higher

T.5.6.5 Any catch can on the cooling system must vent through a hose with a minimum internal diameter of 3 mm down to the bottom levels of the Chassis.

Background and Theory

To properly design an FSAE Cooling System, or any closed-loop fluid cooling system for that matter, a robust understanding of thermodynamics, heat transfer, and fluid mechanics is necessary.

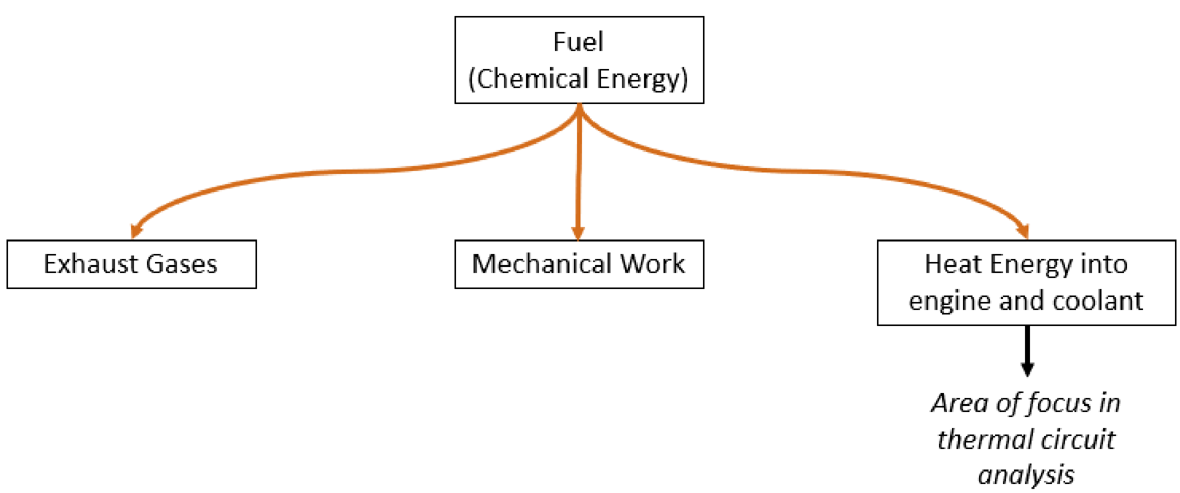
The First Law of Thermodynamics

$$E_{in} = E_{out}$$

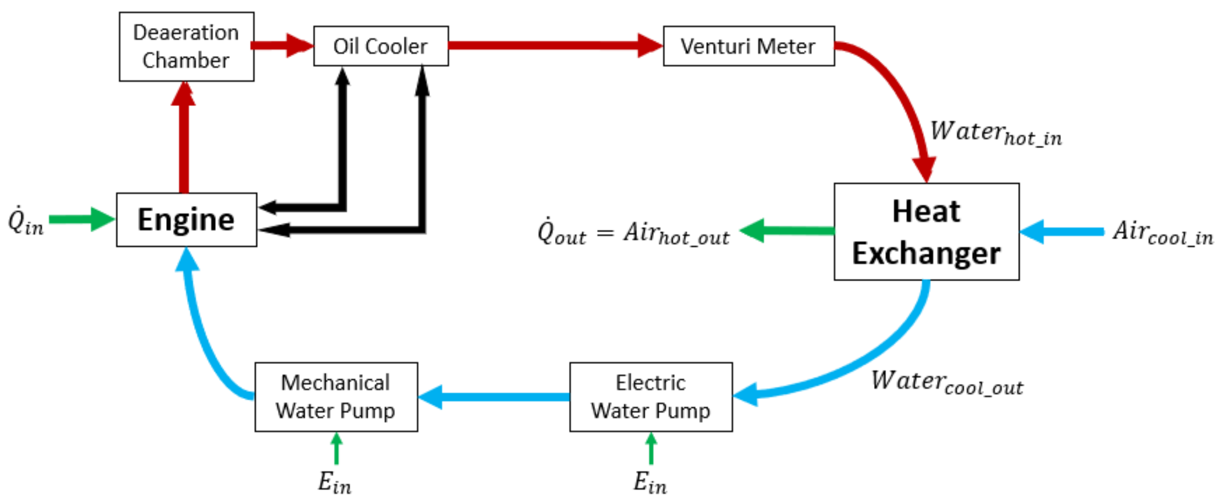
*Energy is conserved. It may change form but cannot be created or destroyed.

The fact of the matter is that when we analyze this cooling system, it needs to be understood how the energy (in the form of heat) changes throughout the process of not only cooling but simply driving the car. Think of it like this: With a racecar, energy begins in the form of chemical energy (fuel) and combusts into a flame inside a pressurized cylinder. From here, energy gets split into three directions (hot coolant, mechanical work, and exhaust gases) A portion of energy is absorbed by the aluminum head/block and into the liquid coolant. A second portion goes into the crank and drivetrain itself in the form of mechanical work. The final portion of energy exits the vehicle in the form of hot exhaust gases.

Energy Conservation



Heat Flow Diagram



This diagram conveys the transfer of heat from the engine and through the heat exchanger and water pumps. One note to make is the actual removal of the mechanical pump in our system to increase flow rate. I'll touch more on this later on.

The fluid mechanics of internal pipe flow

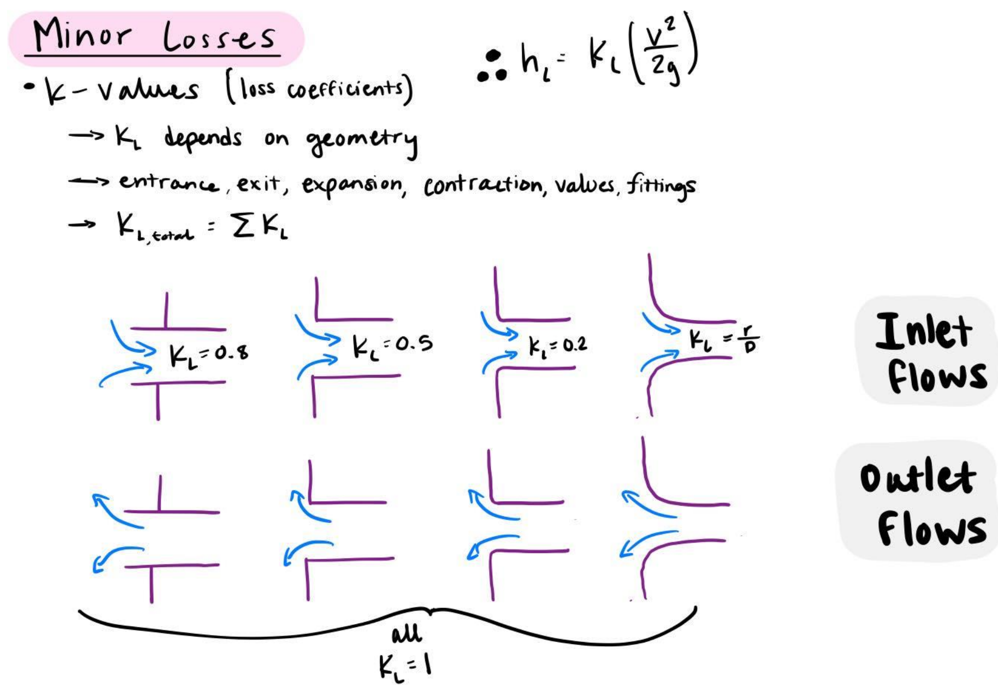
Being able to understand the fluid's Reynolds Number at any point in the system is crucial in deriving the radiator's ability to reject heat as a function of time, mass flow rate, fluid properties, and many more variables. Fundamentally, the Reynolds Number (Re) is the ratio of a fluid's inertial effects over its viscous effects. This dimensionless number will dictate which heat transfer formulas we use to set targets later on.

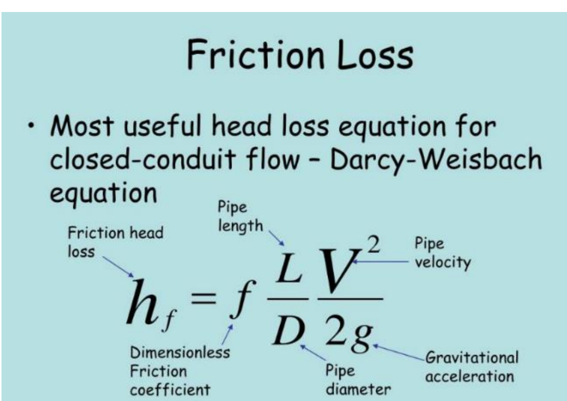
$$Re = \frac{\rho V d}{\mu}$$

ρ = density
V = velocity
d = diameter
μ = viscosity

Other concepts to understand:

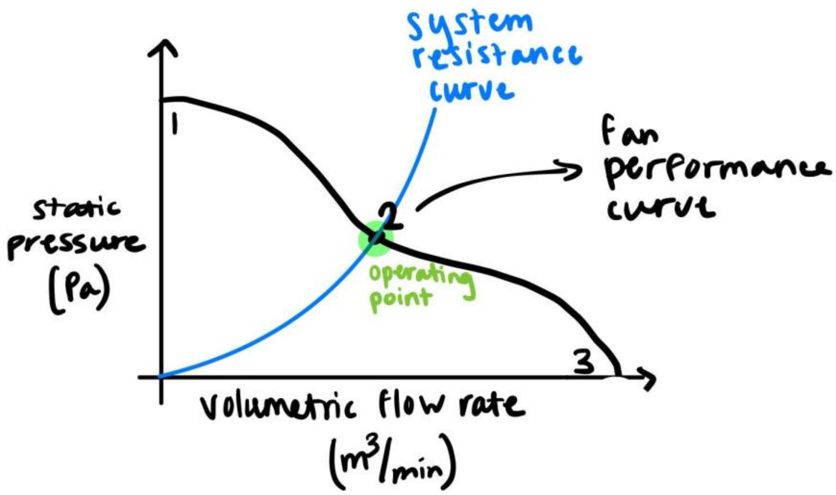
- Major and Minor losses





Major losses, also known as frictional losses, are the primary consequences of pressure drop across a pipe and ultimately the mass flow rate of the fluid itself as well

- Pump performance characteristics
  - Refer to Professor Nissenson's notes on the next page
- Fan performance characteristics



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- Bernoulli's Equation

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

  - Pressure increases as velocity decreases and vice versa.

The three modes of heat transfer for internal pipe flow and heat exchangers

1. Conduction
   a. Fourier's Law

$$q = k \cdot A \cdot \frac{(T_H - T_C)}{L}$$

$k = \text{thermalconductivity}$
$A = Area$
$T_H = hottemp$
$T_C = coldtemp$
$L = length$

2. Convection
   a. This year's cooling system will feature a convection-based design as convection is the most controllable mode of heat transfer from a feasible design perspective.

$$\dot{Q}_{conv} = \dot{m}C_p\Delta T$$

ε = emissivity (0 ≤ ε ≤ 1)
σ = Stefan-Boltzmann constant (5.67×10^{-8} W/m²·K⁴)
A = area emitting radiation
T_s = surface temperature (absolute)

$\dot{Q}_{conv} = Convection\ Heat\ Transfer\ Rate$

$\dot{m} = mass\ flow\ rate$

$C_p = specific\ heat\ @\ constant\ pressure$

$\Delta T = Temp_{hot} - Temp_{cold}$

3. Radiation

$$q = \varepsilon\sigma A{T_S}^4$$

Application to the vehicle dynamic challenge posed by racing

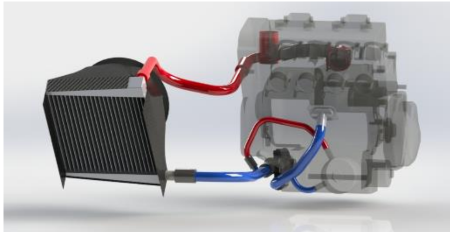
One potentially overlooked factor when designing this cooling system is how much it will weigh and how it will be mounted/oriented onto the racecar. The whole goal of a racecar in Formula SAE is to put down fast lap times in a variety of events at competition. In order to do this, we need to understand how the placement & weight of our cooling system will affect the vehicle's center of gravity, yaw inertia, and mechanical grip at the tire. Finding a balance between physical weight, radiator orientation, and heat rejection effectiveness is the name of the game for you, the engineer. Take a look at these slides from an OptimumG seminar on vehicle dynamics on the next page.

Key Takeaways

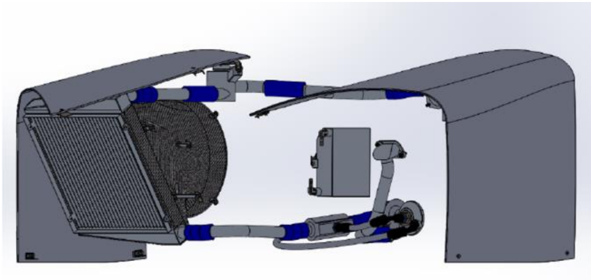
1. Mass flow rate of either fluid is directly proportional to heat transfer rate and convection coefficient
2. Convection is the best method for heat transfer
3. Turbulent flow (without recirculation) is ideal in facilitating heat transfer (greater energy input)
4. One of the more important concepts I needed to learn was how any closed loop fluid system innately operates within a system curve dictated by the geometry of the piping, engine, and heat exchanger itself. Regardless of how well the pump can flow, it is constrained to the system curve it works within. Taking a look at a pump performance curve, you have the pump curve and system curve. The point at which these curves intersect is the system's operating point.

Historical Accord

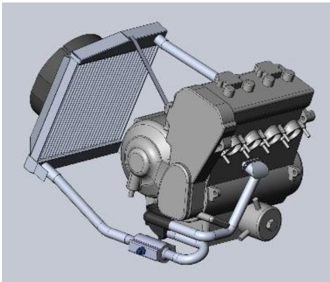
- 2012 | TBD
- 2015 | Michael Curtis



- 2017 | Michael Curtis



- 2019 | Owen Wilkening



- 2022 | Logan Datin

- 2023 | Isaac Haynes

Design Procedure

Now that we've reviewed the basics, let's use these tools given to us to design our cooling system!

1. Start with identifying your design goals and constraints.

- ✓ Minimum 15kW Heat Transfer Rate (Perfect Energy Split)
- ✓ Elegant integration with Aerodynamic Drag Coefficient >= 1.4
- ✓ Net reduction in system weight (>=25%)
- ✓ Reliable and Serviceable
- ✓ Design within constraints of 2024 Formula SAE and Formula Student Ruleset

2. Then go into calculating required heat load from existing MoTeC data
   a. For our purposes, I set the minimum required heat load as 15kW which assumes an even energy split from the 62hp of max power input from the engine. This would be a worst-case scenario and allows for an FOS regarding the radiator's effectiveness itself. Basically, it'll reject much more than that in practice, but from a pure design standpoint, this is minimum of what the cooling system needs to reject as max engine load.

3. Analyze water convection (internal pipe, turb, fully-dev, constant q"), aluminum conduction, and air convection (flat plate, turb, avg)
   a. Using a textbook known as "Fundamentals of Heat and Mass Transfer" you can apply a few theoretical formulas to get within the ball park of what the systems sees on track but that is really all they are good for. Stick to the Q=mcat and Q=UAdt_lm formulas shown below. They're as simple as it gets but when it comes to successfully implementing the targets derived from them, on-track testing data reigns king.

Design – **Sizing the Heat Exchanger**

1st Law of Thermodynamics

$$\dot{Q} - \dot{W} = \dot{m}[(\Delta h) + \Delta KE + \Delta PE]$$

Assumptions for heat exchangers:

$$\dot{W} = 0,\quad \Delta KE = 0,\quad \Delta PE = 0,\quad \Delta h = C_p \Delta T$$

$$\dot{Q} = \dot{m} C_p \Delta T$$

$\dot{m} = mass\ flow\ rate$
$C_p = specific\ heat\ capacity\ at\ constant\ pressure$
$\Delta T = T_{out} - T_{in}$
$\Delta h = enthalpy\ change$
$\dot{W} = work\ rate$

Applying 1st Law to a heat exchanger:

$$\dot{Q}_{total} = \dot{Q}_{water} = \dot{Q}_{air}$$

$$\dot{Q}_{water} = \dot{m}_{water} C_{p_{water}} \Delta T$$

$\dot{m}_{water} = 0.77 \frac{kg}{s}$ 2012 Cooling Data

$C_{p_{water}} = 4.21 \frac{kJ}{kg \cdot K}$

$\Delta T = 2.78°C\ (5°F)$ 2022 Successful Endurance DT avg

$$\dot{Q}_{req} = 15\ kW$$

$\dot{Q}_{req} = 15kW$
$A_{assumed} = 1.352\ m^2$
$\Delta T_{LMTD} = 14.544°C$

$$U_{req} = \frac{\dot{Q}_{req}}{A_{req} \cdot \Delta T_{LMTD}} = 765.71 \frac{W}{m^2 \cdot K}$$

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4. Analyze air flow into the sidepod based on pitot tube data or avg vehicle speed via 1st Law of Thermodynamics. Communicate this air mass flow requirement to aero team.

Design – **Sizing the Heat Exchanger**

1st Law of Thermodynamics

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Assumptions for heat exchangers:

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$\Delta T = T_{out} - T_{in}$
$\Delta h = enthalpy\ change$
$\dot{W} = work\ rate$

Applying 1st Law to a heat exchanger:

$$\dot{m}_{air} = \frac{\dot{m}_{water}(h_{in} - h_{out})}{C_{p_{air}}(T_{out} - T_{in})}$$

$h_{in} = 186.69 \frac{Btu}{lb_m}$, $P_{in} = 32\ psi$, $T_{in} = 216\ °F$

$h_{out} = 180.21 \frac{Btu}{lb_m}$, $P_{out} = 32\ psi$, $T_{out} = 211\ °F$

$C_{p_{air}} = 0.241 \frac{Btu}{lb_m \cdot R}$, $\dot{m}_{water} = 1.706 \frac{lb_m}{s}$

$$\dot{m}_{air} = 1.585 \frac{lb_m}{s}$$

$$\dot{m}_{air} = 0.719 \frac{kg}{s}$$

(where we want to be)

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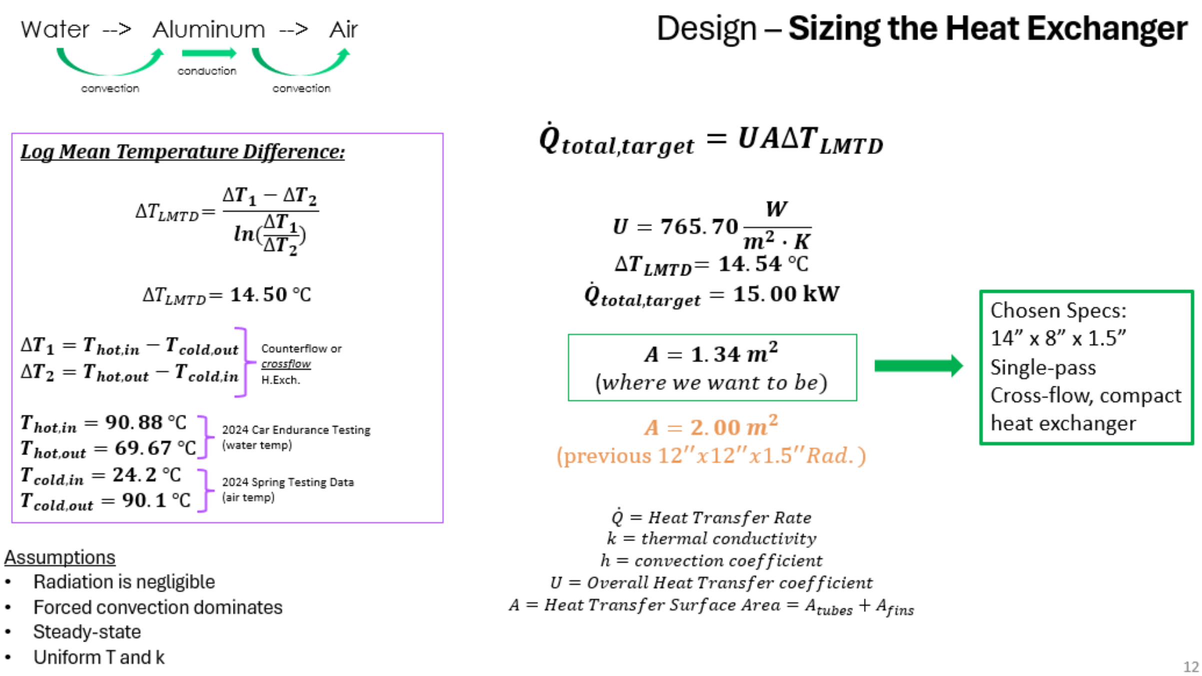
5. Determine the required Overall Heat Transfer Coefficient of the heat exchanger.
6. Determine the Log Mean Temperature Difference with latest temperature data from 2024 Spring testing.
7. **Final Outcome:**
    a. We obtain a target radiator core size that equates to a calculated average heat rejection rate across 1 endurance event.

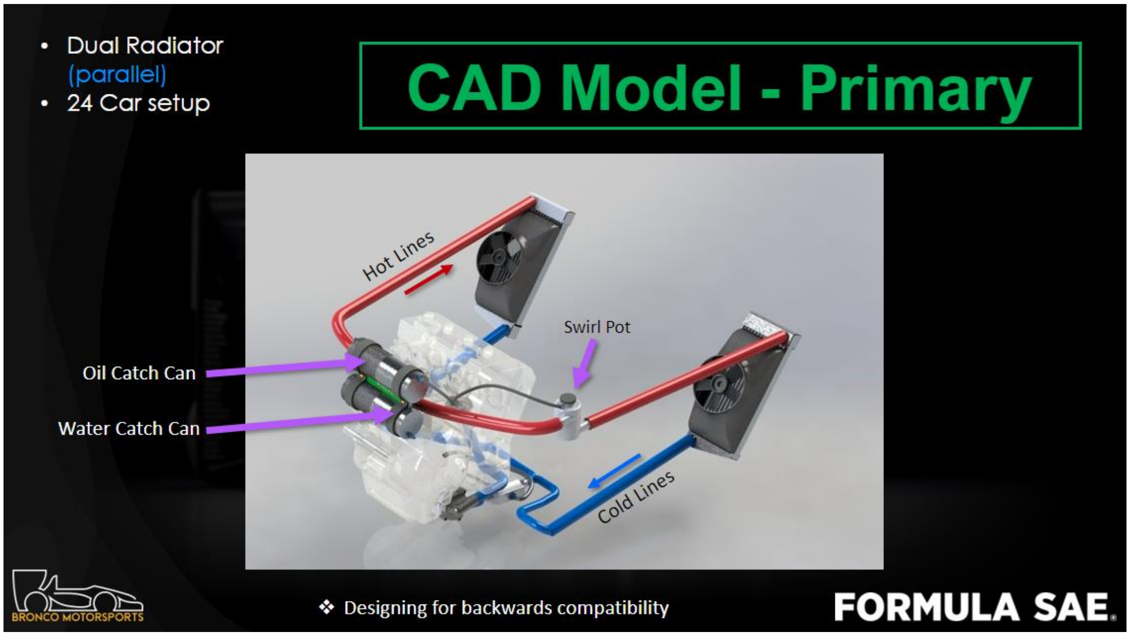


General Talking Points about this Cooling System

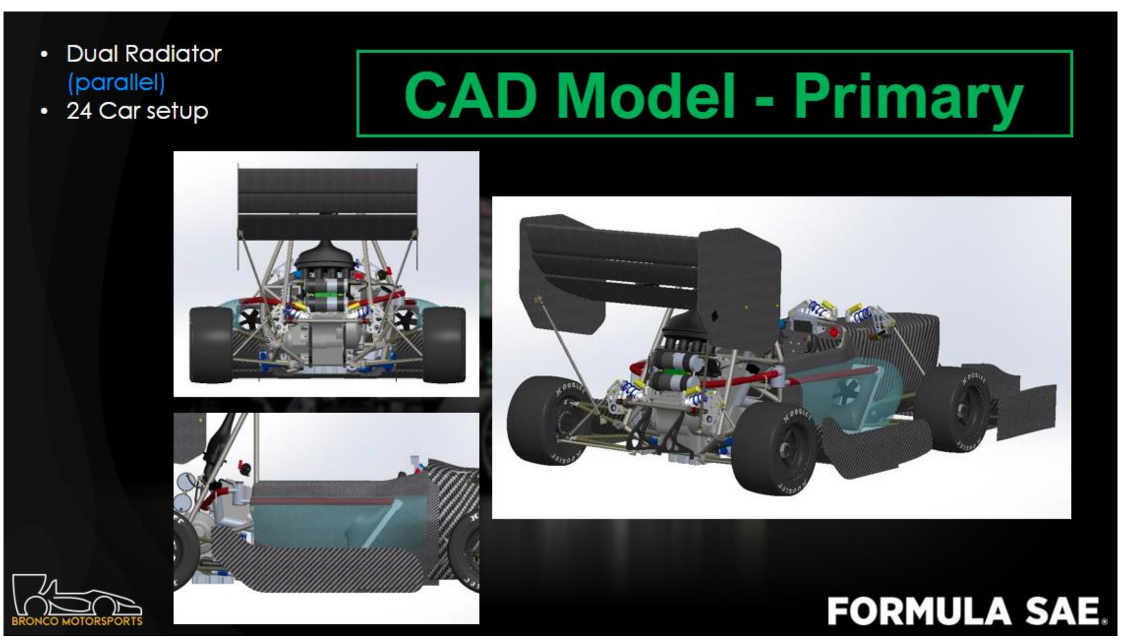
- System has seen a 35% reduction in weight.
- A fully ducted 3-ply carbon fiber inlet, shroud, & outlet is a new addition that is intended to increase air mass flow through the core without allowing pockets of recirculation (a characteristic of last year’s cooling-sidepod system).
- An electric water pump has been added to assist water flow rate at low RPMs on track. The mechanical pump has also been removed to prevent pump starvation since the two pumps (routed in series) would always be running at different RPMs. They’d always be working against each other thus reducing the net mass flow of water.
- Radiator size has decreased whilst maintaining a targeted heat rejection rate
- Two small fans (5.2in OD) are being used instead of one (10in OD) fan which saves weight and allows air to be channeled through core more efficiently with greater fan area
- A custom-made venturi meter has been installed into the system to accurately track water flow rate on-track and allow the derivation of several key parameters (heat rate, pressure drop, flow rate curves vs RPM, thermal efficiency)

Design Revisions

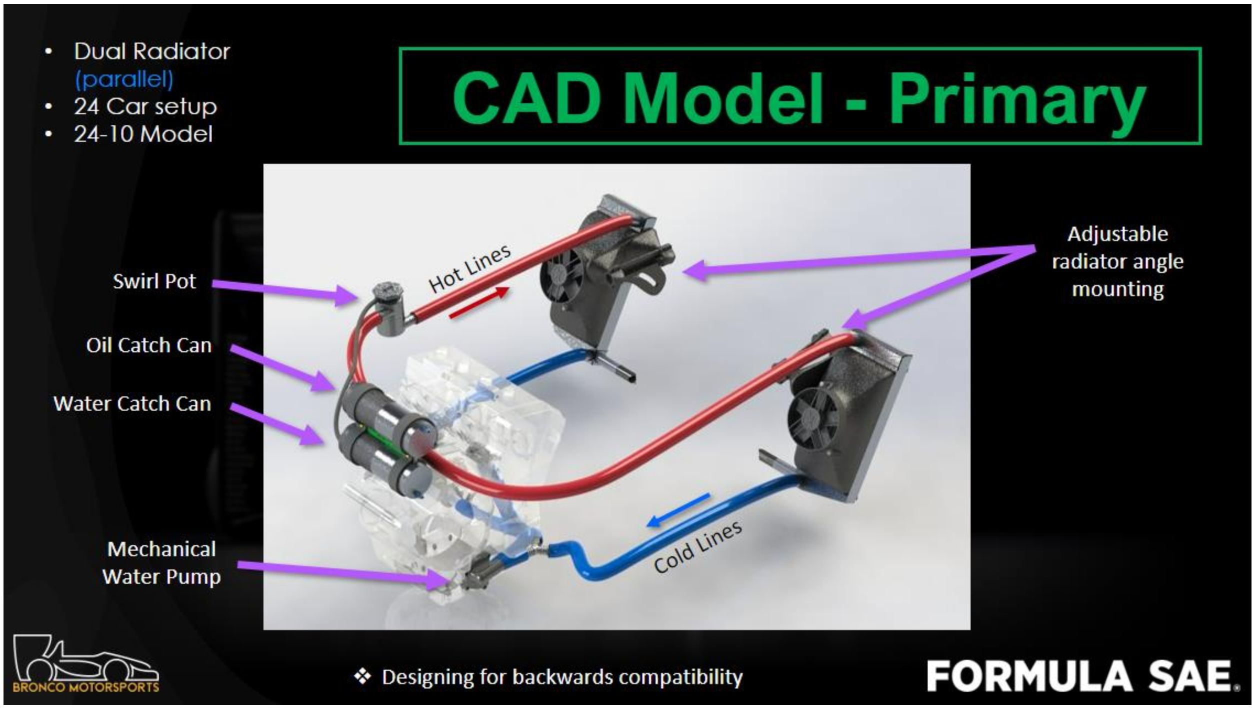
<u>24-01 – Fall 2023</u>

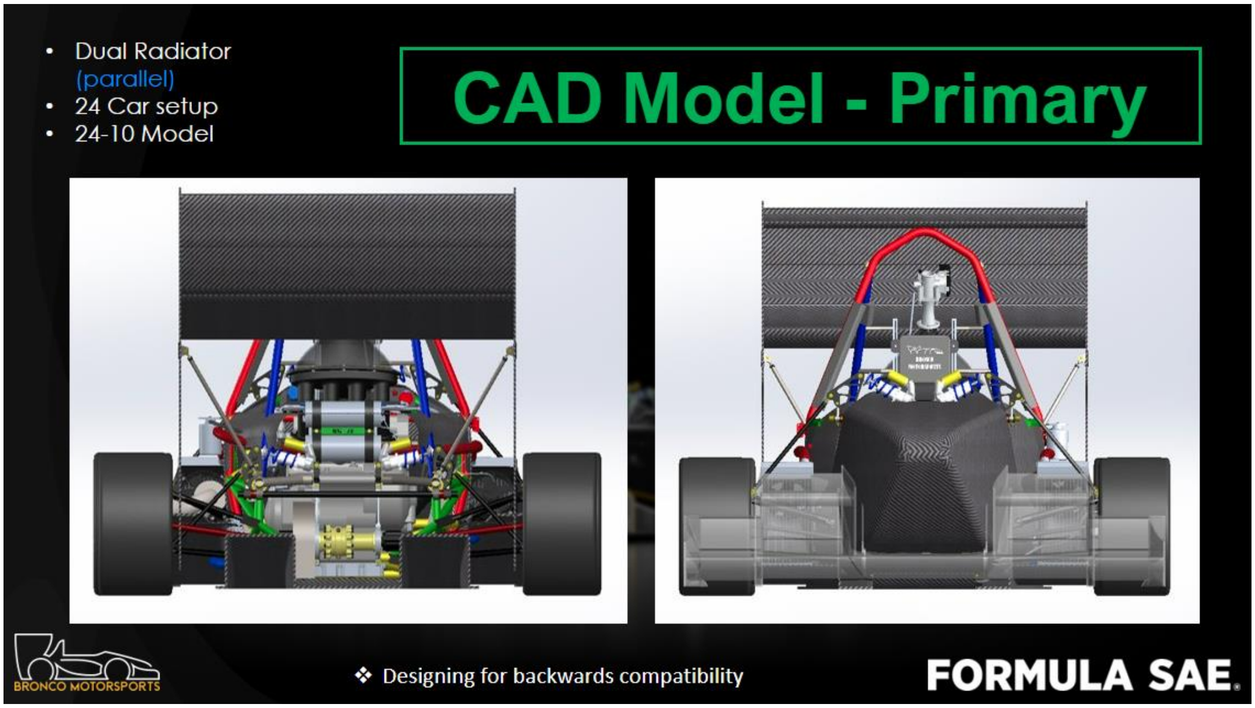


Let's start with the first initial concept (24-01) and make our way down to our final product (24-22). 24-01 began with a very promising dual radiator configuration. Featuring two 12"x6"x1.5" radiator core in both sidepods, the intent was to allow for greater vehicle balance, minimize airflow starvation (by allowing one side to always be seeing air supply).

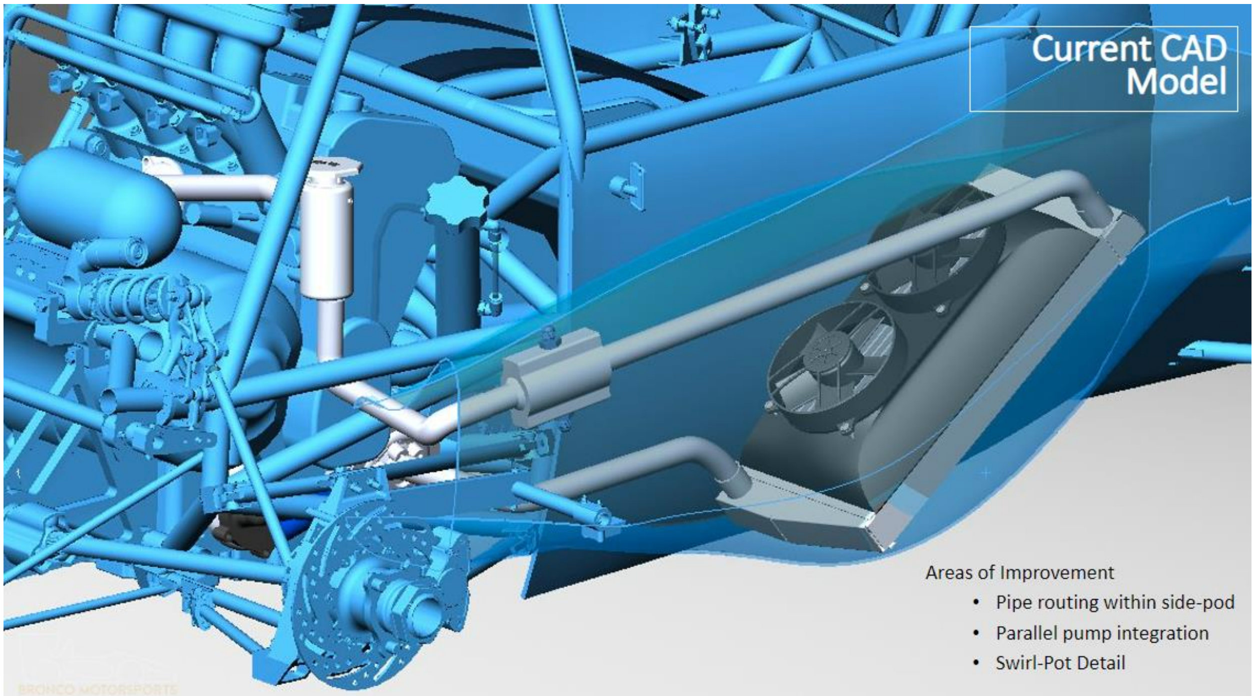


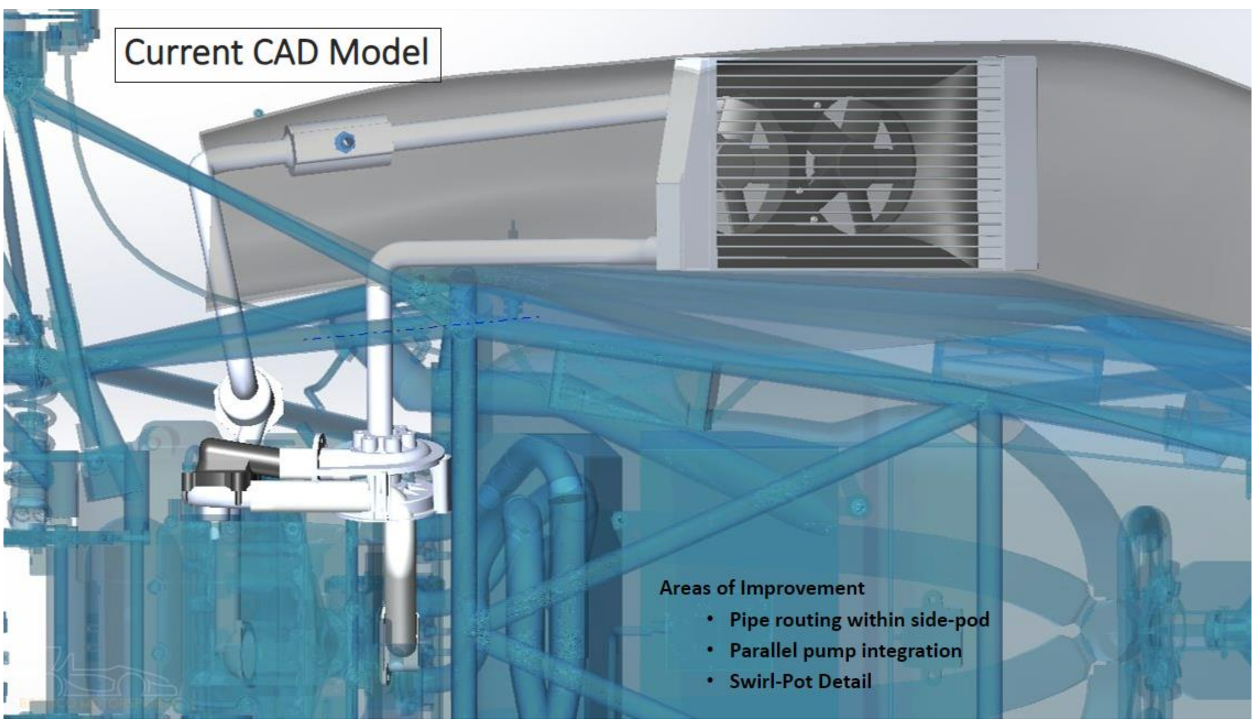
<u>24-10</u>


• Dual Radiator
(parallel)
• 24 Car setup
• 24-10 Model
CAD Model - Primary
Hot Lines
Cold Lines
Swirl Pot
Oil Catch Can
Water Catch Can
Mechanical
Water Pump
Adjustable
radiator angle
mounting
BRONCO MOTORSPORTS
❖ Designing for backwards compatibility
FORMULA SAE.


• Dual Radiator
(parallel)
• 24 Car setup
• 24-10 Model
CAD Model - Primary
BRONCO MOTORSPORTS
❖ Designing for backwards compatibility
FORMULA SAE.

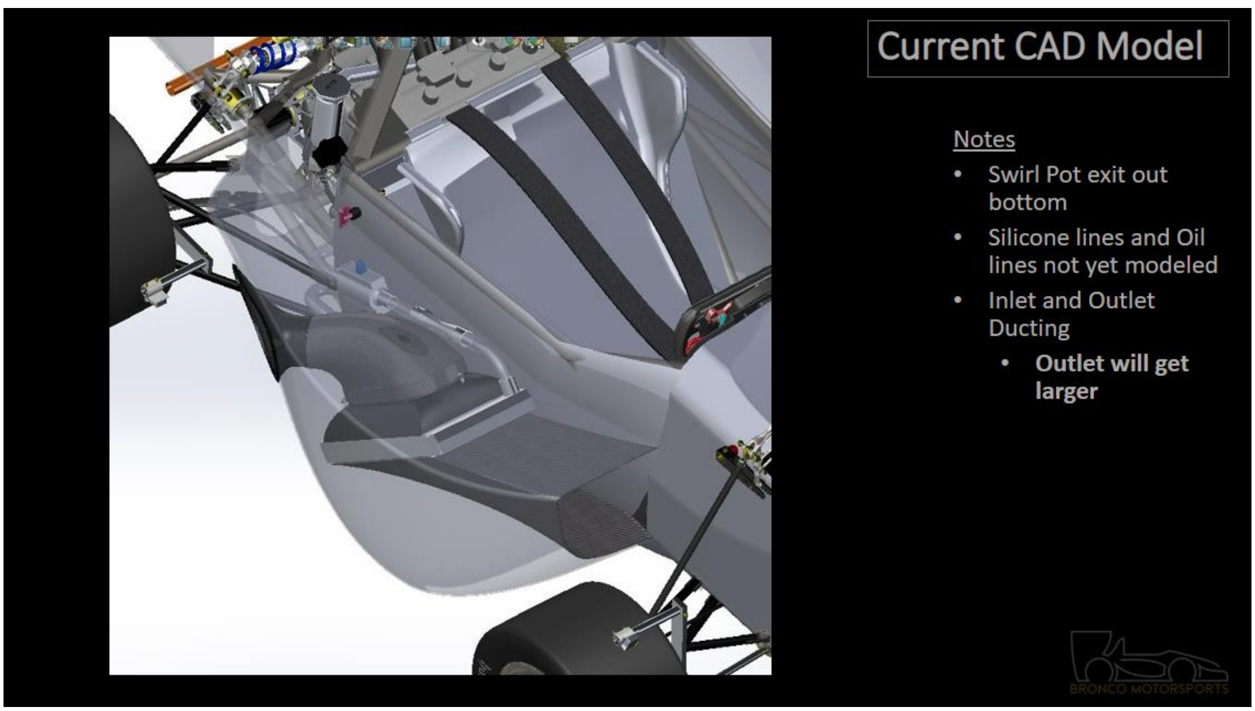
24-17


Current CAD Model
Areas of Improvement
Pipe routing within side-pod
Parallel pump integration
Swirl-Pot Detail

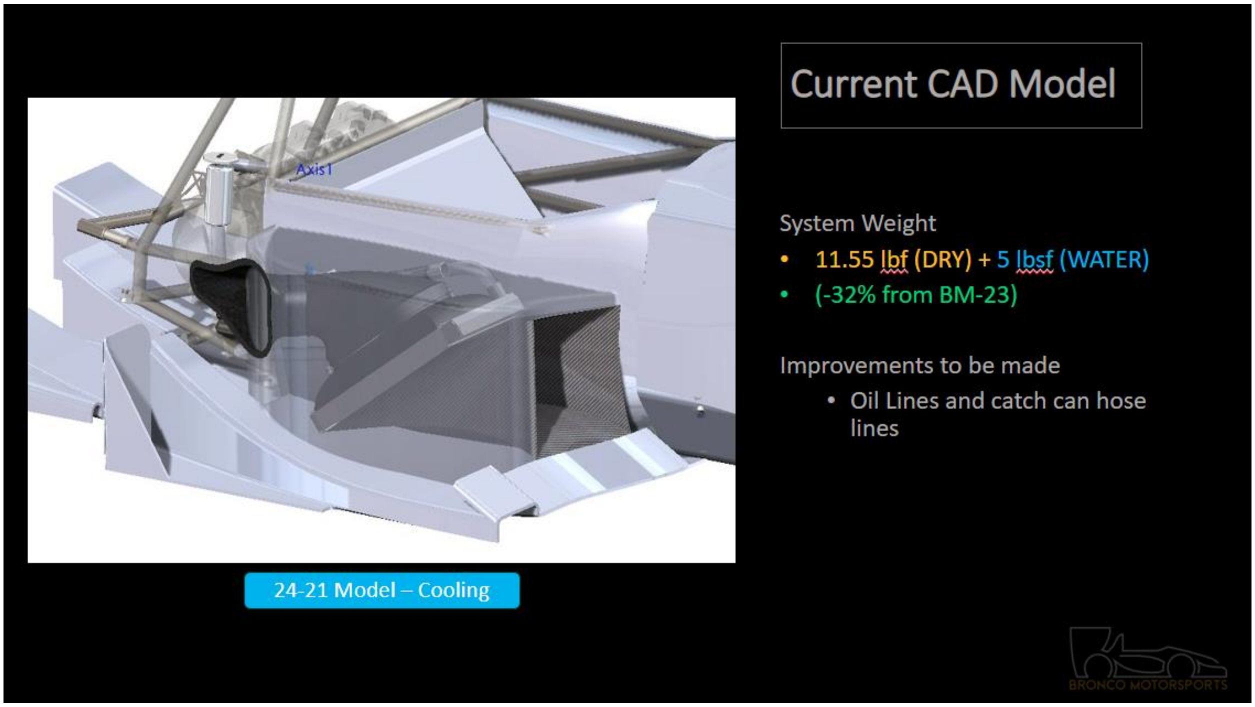

Current CAD Model
Areas of Improvement
Pipe routing within side-pod
Parallel pump integration
Swirl-Pot Detail

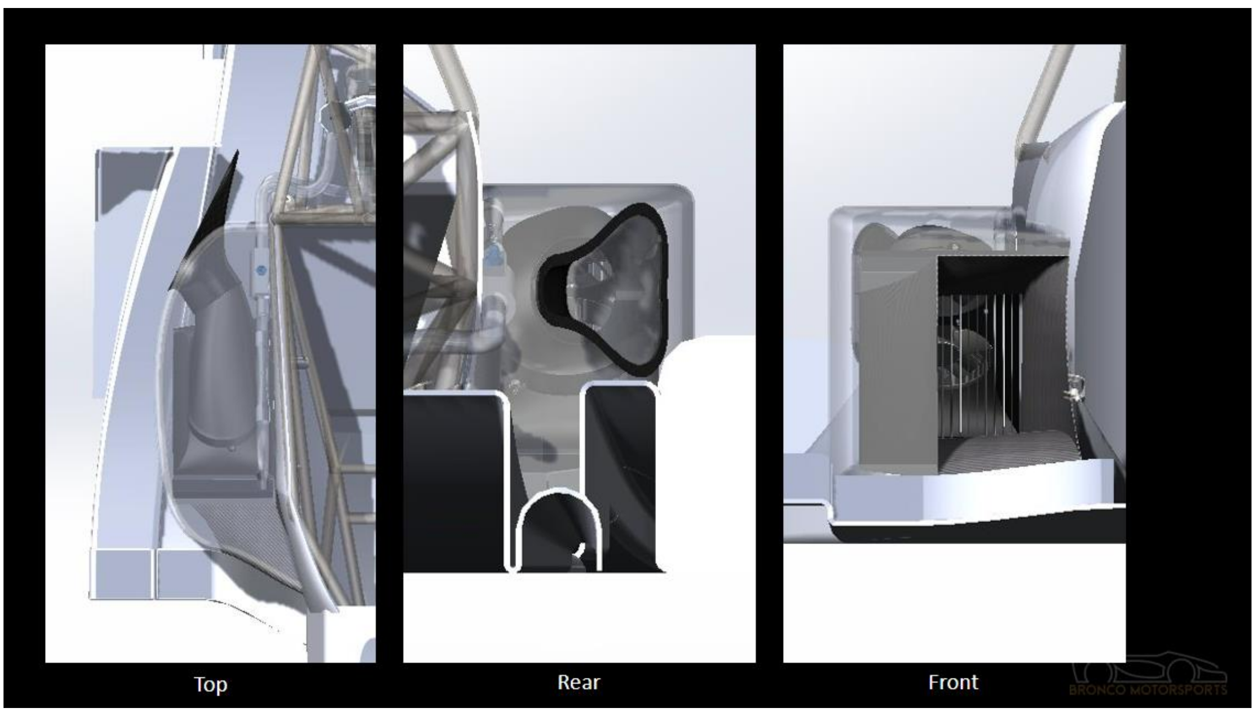
24-19


Current CAD Model
Notes
• Swirl Pot exit out bottom
• Silicone lines and Oil lines not yet modeled
• Inlet and Outlet Ducting
• Outlet will get larger
24-18 Model – Cooling
BRONCO MOTORSPORTS


Current CAD Model
Notes
• Swirl Pot exit out bottom
• Silicone lines and Oil lines not yet modeled
• Inlet and Outlet Ducting
• Outlet will get larger
BRONCO MOTORSPORTS

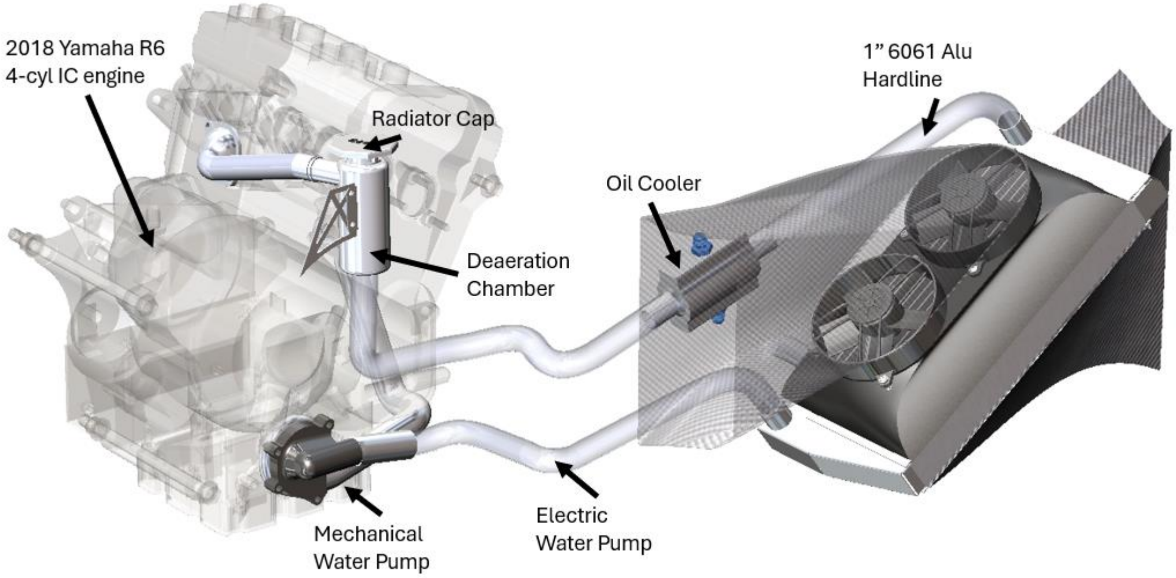
24-21 – Critical Design Review | October 2023





Final CAD Model | 24-22

FINAL CAD MODEL



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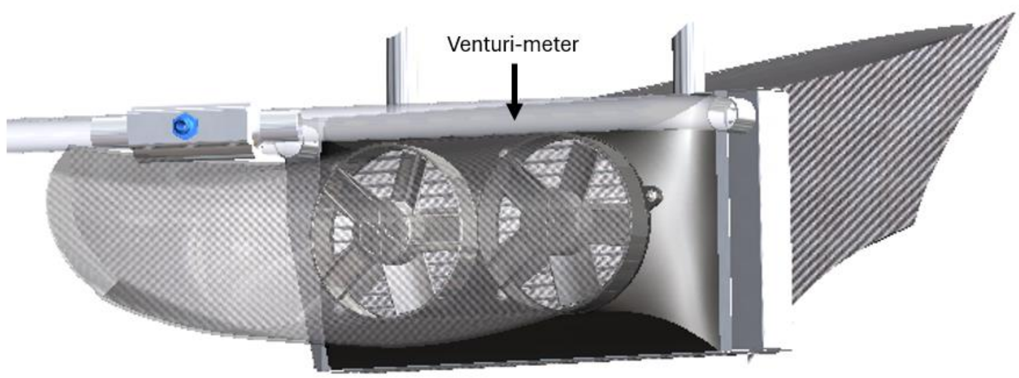
FINAL CAD MODEL



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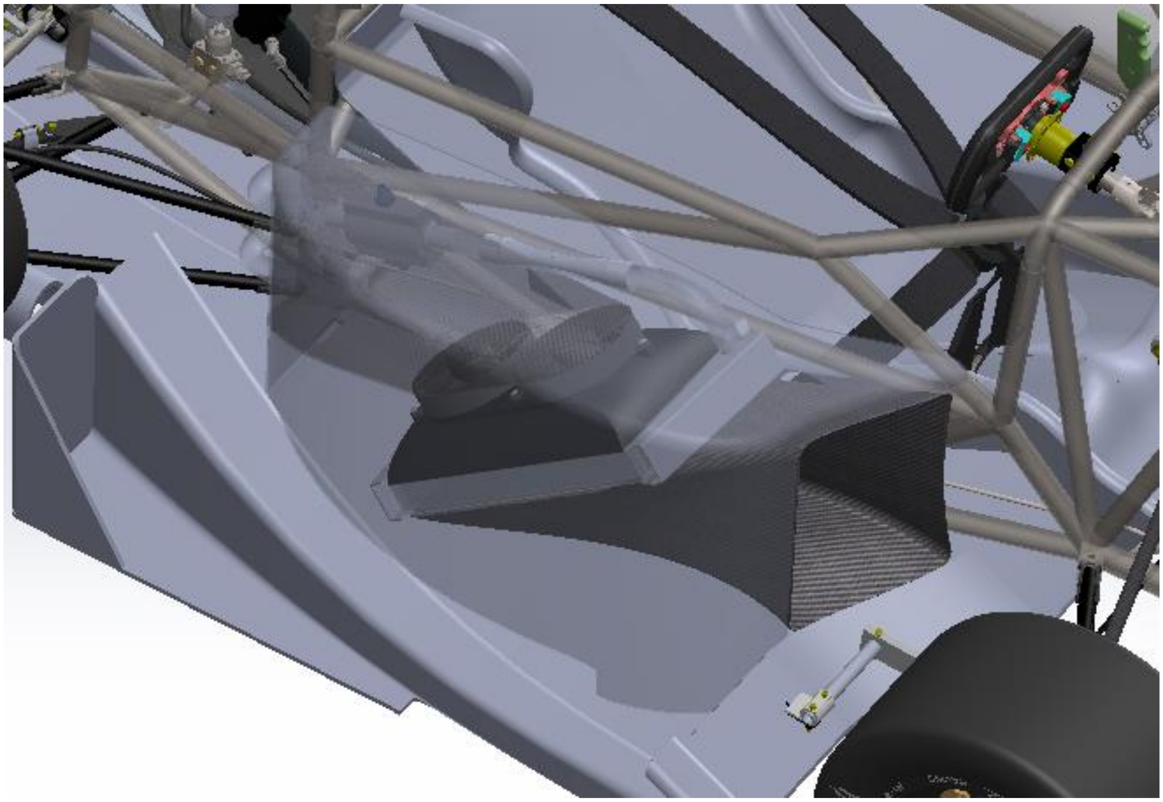
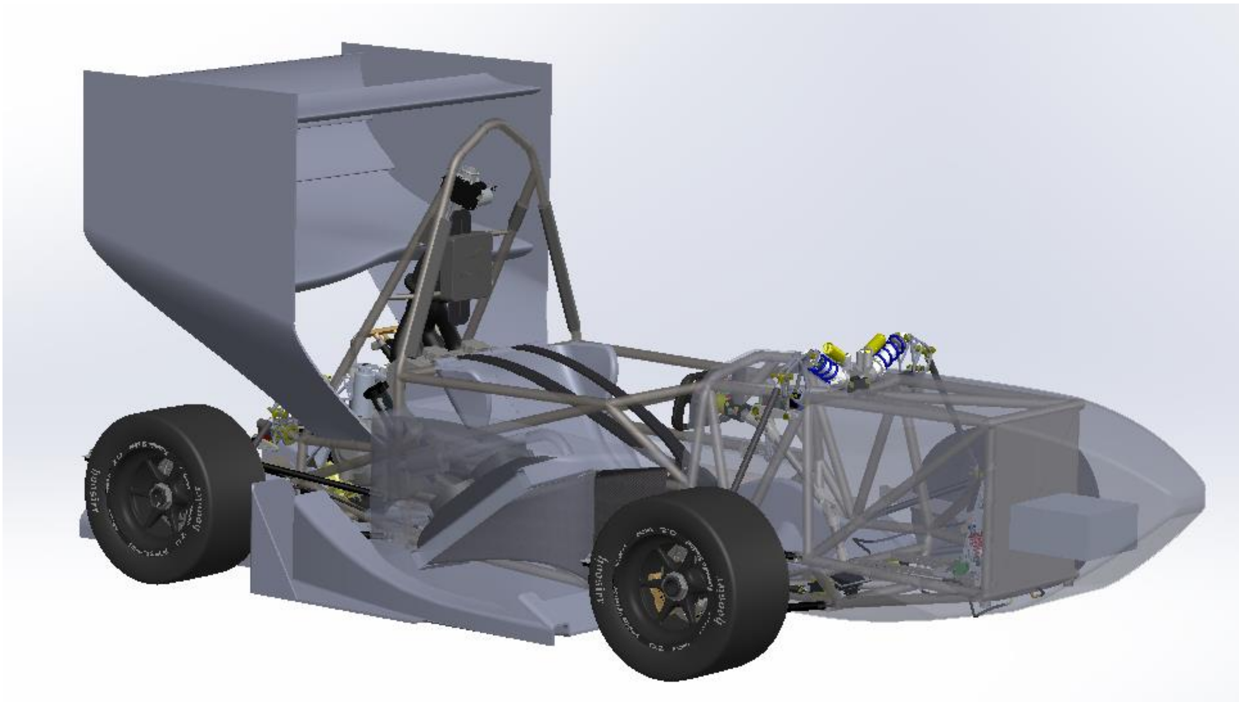
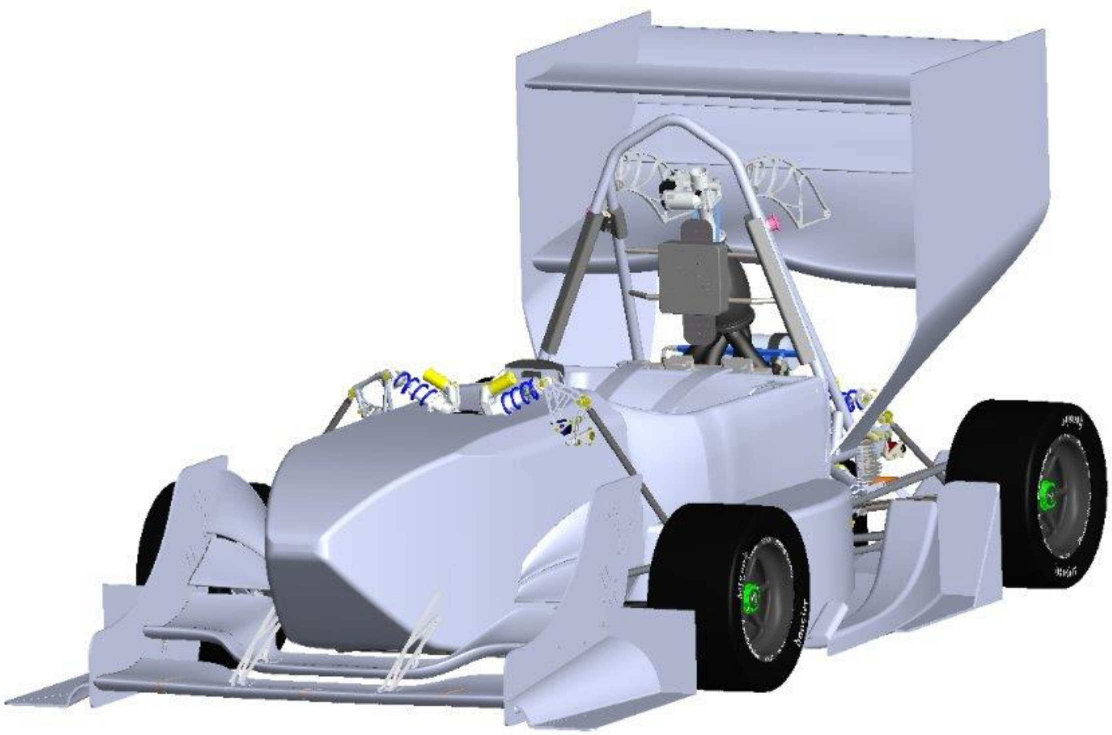
Cooling System housed within side-pod



24-22 Full Vehicle Model

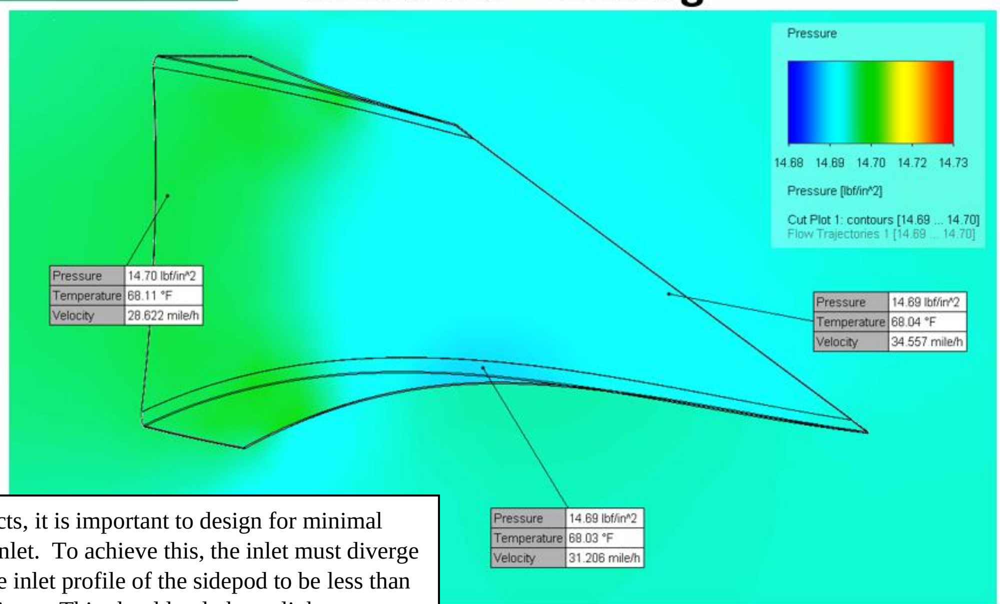




Simulations

0.1% Pressure Drop -> negligible

Simulation – **Ducting**

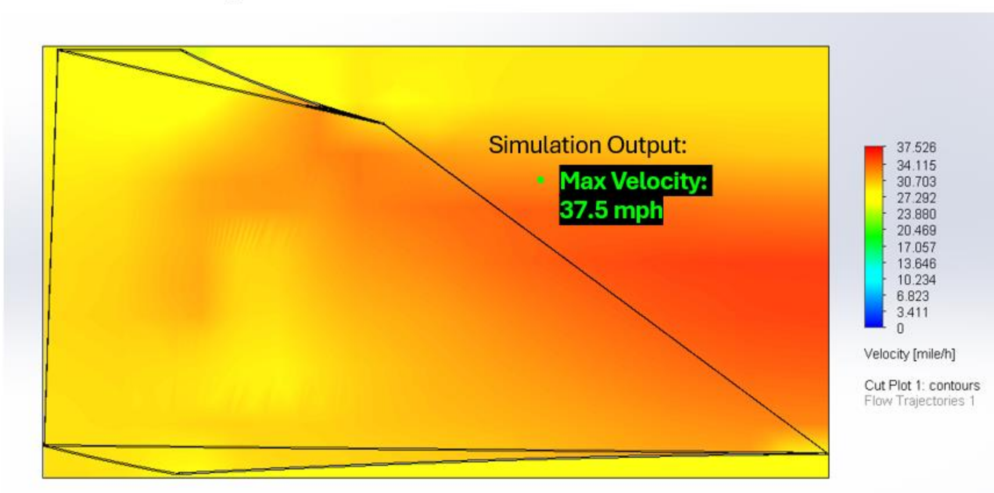


When designing these ducts, it is important to design for minimal pressure drop across the inlet. To achieve this, the inlet must diverge (open up) thus causing the inlet profile of the sidepod to be less than the frontal area of the radiator. This should only be a slight divergence as to not promote flow separation and recirculation before air enters the core. This is the primary reason for the splined guide curves between each profile. Air speed slightly increases, pressure drop is avoided, and flow recirculation is prevented with a fully ducted system. At the end of the day, it's the pressure difference across the core that drives mass flow and heat rejection.

Simulation Setup: CUTPLOT

- 30 mph
- Horizontal Flow
- 68°F Ambient air at 14.7 psi

Simulation – **Ducting**

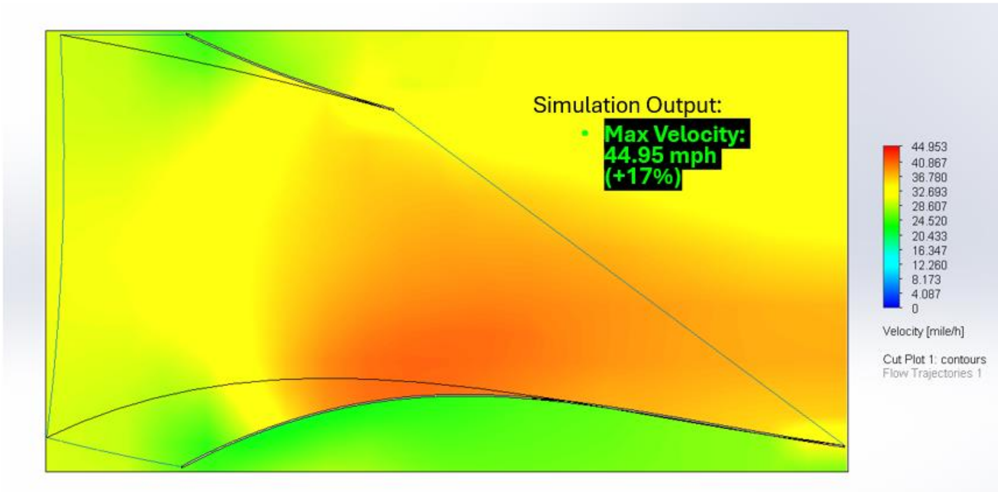


Linear Guide Curves

Simulation Setup: CUTPLOT

- 30 mph
- Horizontal Flow
- 68°F Ambient air at 14.7 psi

Simulation – **Ducting**



Splined Guide Curves

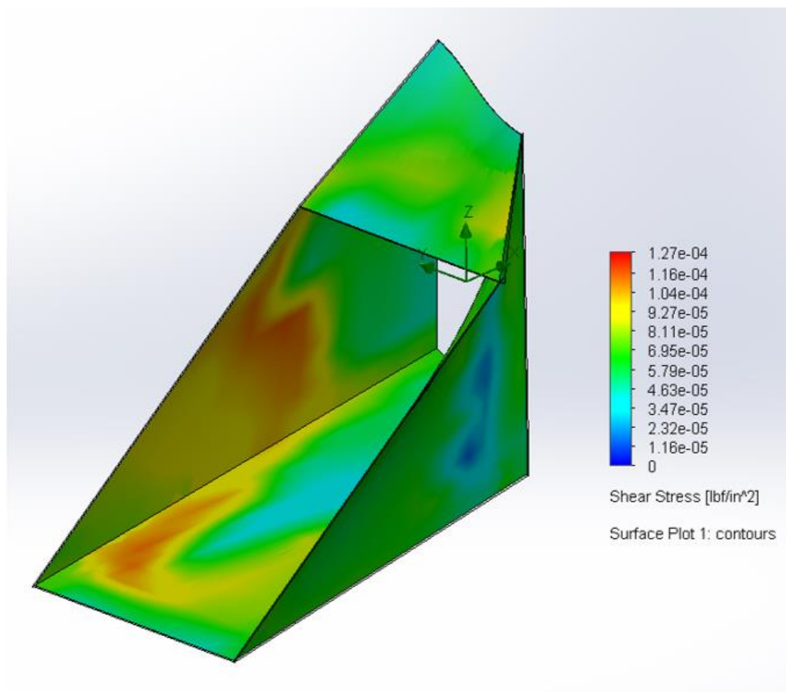
Simulation – **Ducting**

Simulation Setup: Surface Contour

- 30 mph
- Horizontal Flow
- 68°F Ambient air at 14.7 psi

Simulation Output:

- **Max Internal Shear Stress**
  - **1.27e-4 psi**



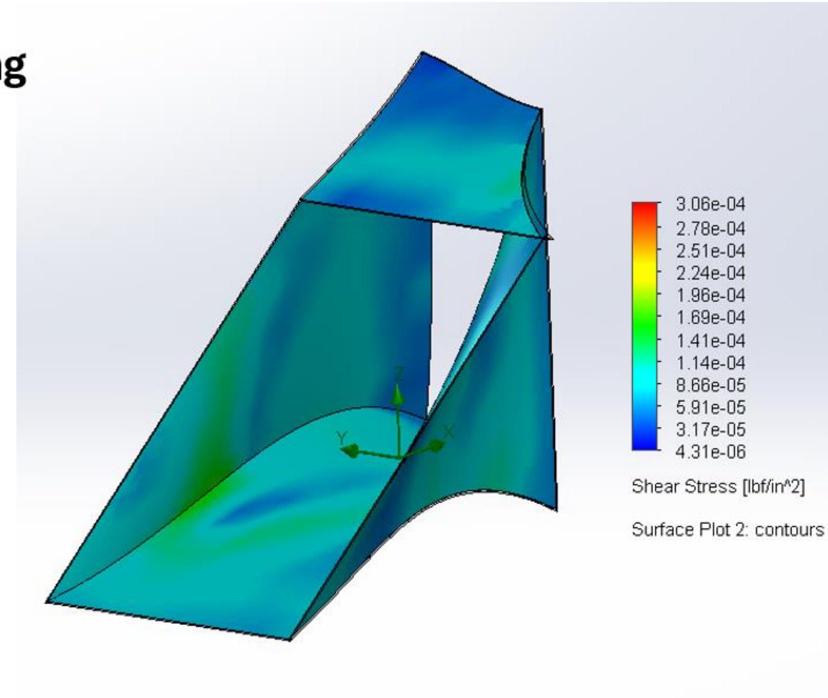
Simulation – **Ducting**

Simulation Setup: Surface Contour

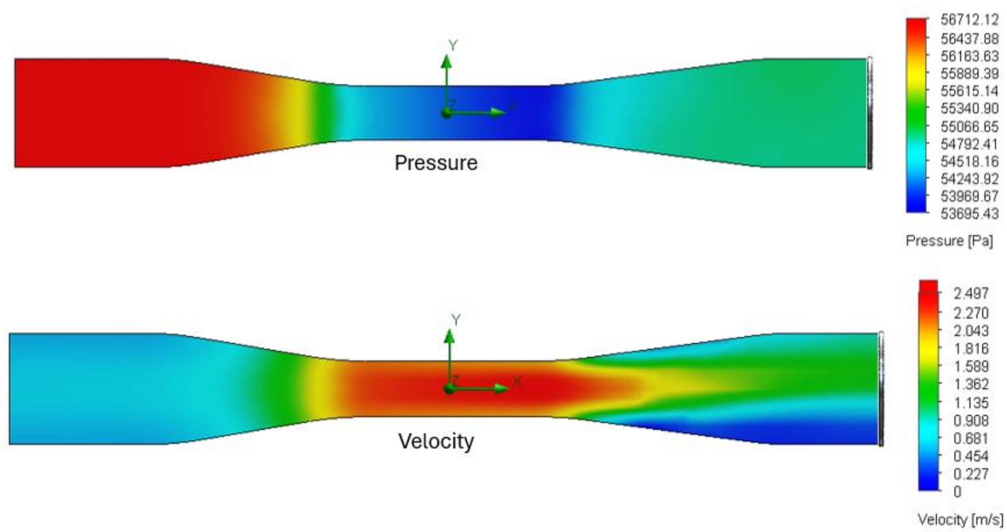
- 30 mph
- Horizontal Flow
- 68°F Ambient air at 14.7 psi

Simulation Output:

- **Max Internal Shear Stress**
  - **3.06e-4 psi (-58%)**



Simulation – **Venturi Meter**



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Manufacturing

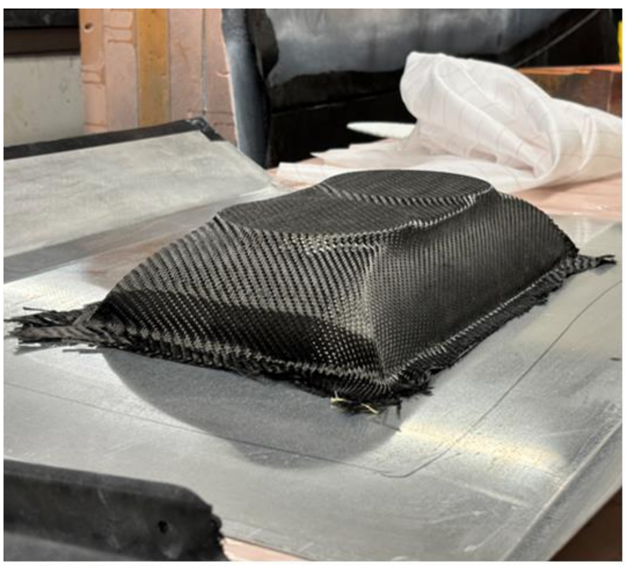
Total Spent: **$1394.76**

(Don't spend more than this, but this should be how much you use to dictate spending when crunch time rolls around)

BOM		
Component	Description	Quantity
Radiator Core	Additive, Milled, Water Jet	1
Endtanks	Additive, Milled, Water Jet	2
Laminova	Carbon Tube	1
Softlines	Carbon Tube	Linear Ft
Hardlines	Steel Round Stock - Lathed	Linear Ft
Inlet Duct	Steel Round Stock - Lathed	1
Outlet Duct	Housed within rocker pivot	1
SPAL 5.2" Fan	Between bolt and Ball Bearing	2
Swirl Pot	7075-T6 Alu	1
Electric Water Pump	Davies Craig EWP80	1
Radiator Mounting Sleeves	Alu Lathed in-house welded on core	2
Engine Inlet	Carbon layup	1
Engine Outlet	Carbon nylon print	1
Swirl Pot Mounting Tab	6061 Alu - Refer to current thickn.	1
Water Pressure Sensor	AEM	2
Water Temp Sensor	AEM	2
Venturi Meter	Machining Sponsor	1
Hose Clamps	Minimize quantity when	20
Fan Shroud Inserts	94180A353_Tapered-Heat-Set-Inserts-for-Plastic	6
Fan Bolts	97654A211_18-8-Stainless-Steel-Flanged-Button-Head-Screw	6
Engine Cooling Bolts	Possessed	4
Radiator Cap	Use existing company	1
Radiator Shroud	Carbon nylon print	1
Oil Lines + fittings	Get from that same place OR Dyme	1 set

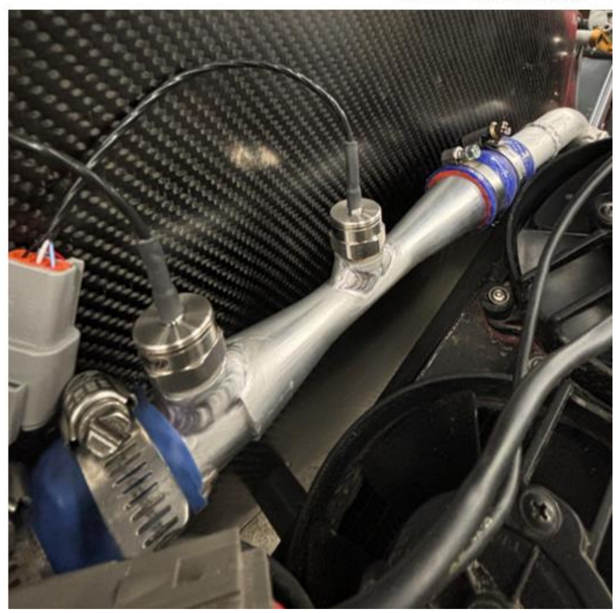
Sizing Oil Lines

Verifying Radiator Angle



Carbon Fiber Shroud layup

Venturi-meter install

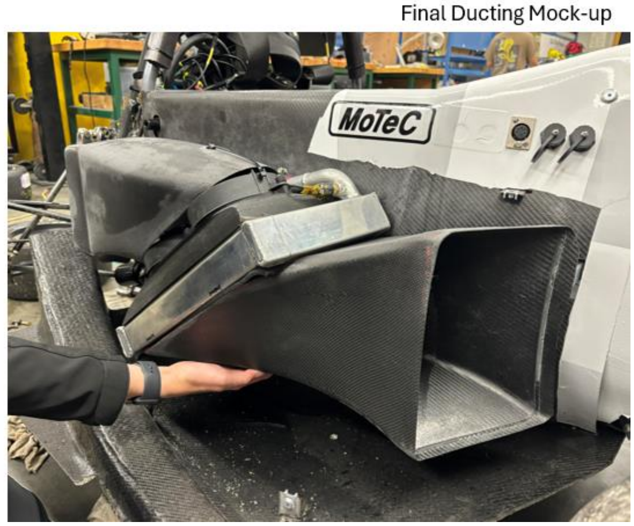


2024 Vehicle Unveiling

CF ducting via Resin Infusion

Engine's first run with radiator

Final Ducting Mock-up



Full Duct Assembly before final trimming

Inlet Duct with black foam media to prevent rocks from entering core whilst maintaining sufficient airflow

Outlet Duct with cutouts to allow for Oil Cooler fitment and flush sidepod mounting


55X12X12 BTM


4C

Testing

Data Acquisitions Items Required? -> 2 temp sensors, 2 pressure sensors, Thermistors for air temps in/out, could we get pitot tubes for inlet/outlet of sidepods?

1. Obtain on-track motec data of inlet/outlet air temps and water temps to validate heat rejection rate target
    a. Output graphs in Excel, MATLAB, or MoTeC i2Pro and compare with existing theoretical data (ask me for my MoTeC workspace)
2. Vary parameters such as EWP on/off and fans on/off to look at their effects on cooling performance. With and without ducting as well.
3. How do the temperature deltas look as a function of RPM and Mass Flow Rate

Finally, apply the same testing analysis to Competition MoTeC data which will hopefully get added to this Design Binder on the next few pages

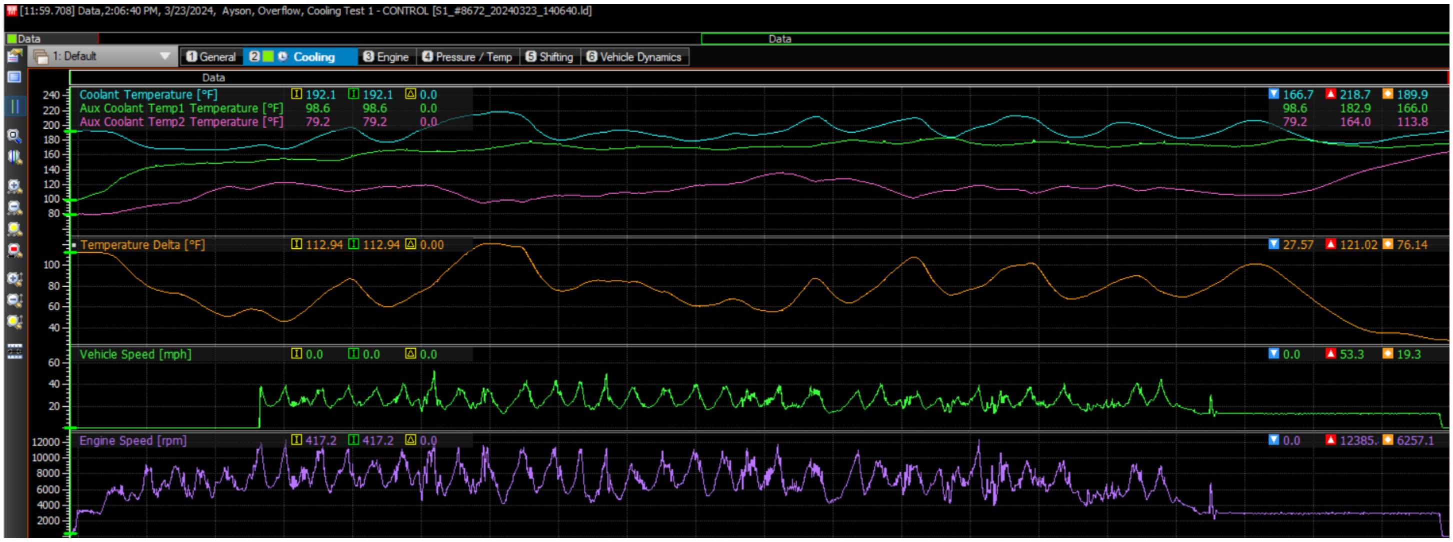
Ultimately we need ON-CAR DELIVERABLES to derive performance correlations.

1. Inlet
    a. Pressure
    b. Temperature
    c. Air flow rate
    d. Water flow rate
2. Outlet
    a. Pressure
    b. Temperature
    c. Air flow rate
    d. Water flow rate
3. Total Pressure Drop (Use of Pitot tubes)
    a. With fans
    b. Without fans

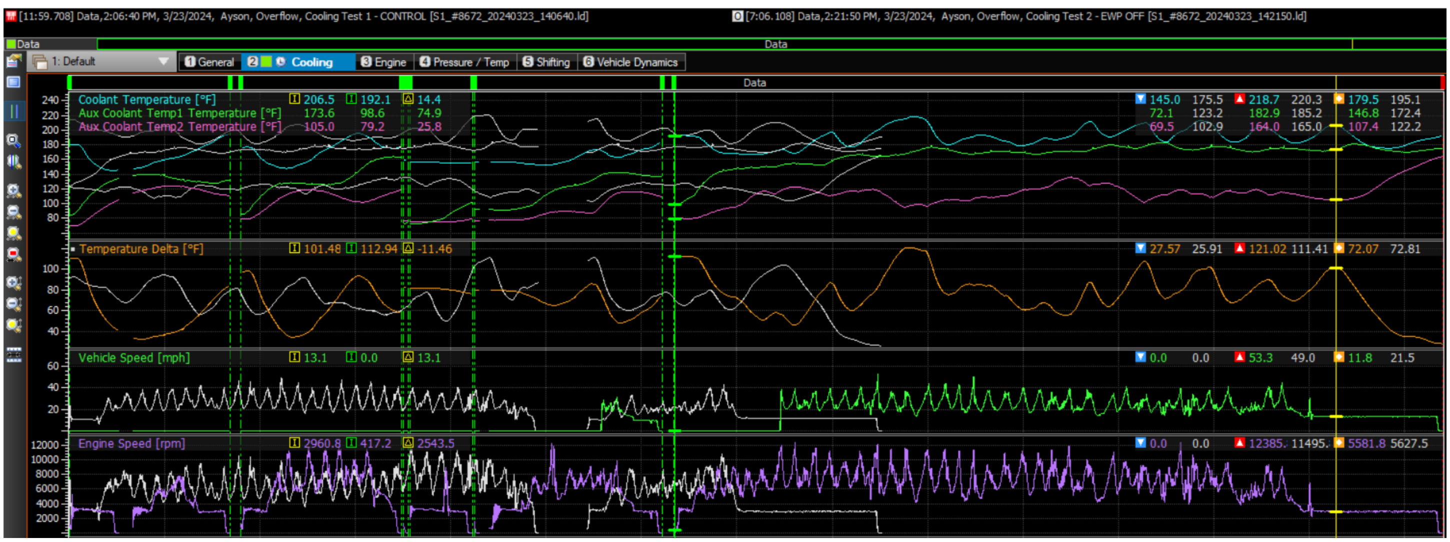
RESULTS

Variable	Required	Actual
$\dot{Q}$ = Heat Transfer Rate	$15.00\ kW$	$28.00\ kW$
U = Overall HTC	$765.71\ \frac{W}{m^2 \cdot K}$	$1170.32\ \frac{W}{m^2 \cdot K}$
A = Heat Transfer Surface Area	$1.32\ m^2$	$1.65\ m^2$
ΔT = Temperature Delta	5.00°F	33.18°F
$\dot{m}_{water\_avg}$ = Water Mass Flow Rate	$0.77\frac{kg}{s}$	$0.34\frac{kg}{s}$

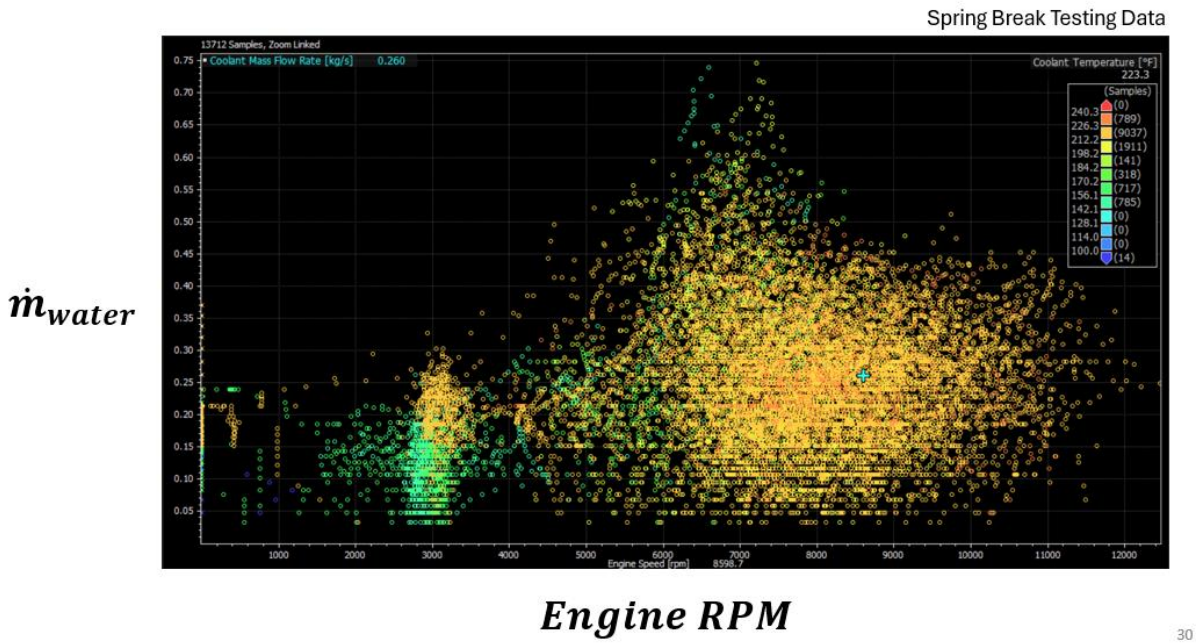
Cooling Test 1 – 3/23/34 – CONTROL: FAN + EWP RUNNING, 5 min driving + 1min idle



Cooling Test 1 – 3/23/34 – FAN + EWP OFF, 5 min driving + 1min idle

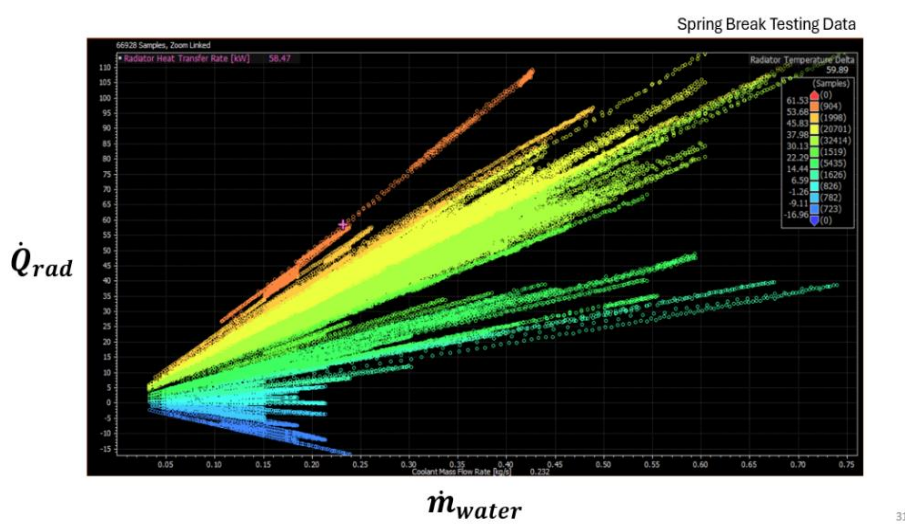


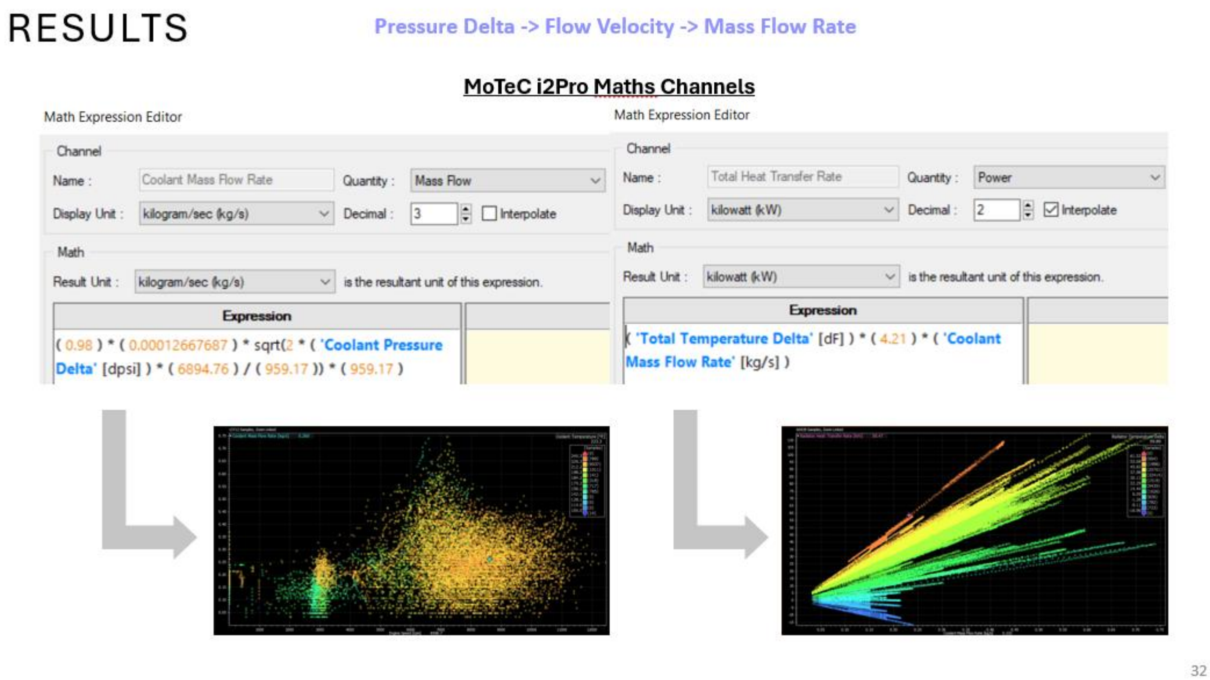
Venturimeter Testing – Spring Break



Notice how mass flow rate peaks out at 7000RPM. You would think it'd be linear with engine RPM, but it is not. The pumps reach a best efficiency point at 7000RPM then drop off due to the system curve. It is important to note that this is with both the mechanical and electric pumps running. I'd be very curious to run the venturi meter and see how this scatter plot changes with a single steady-state electric water pump + dynamic heat input from the engine on-track. I'll definitely plan to do this over summer or fall semester 2024.

Heat Transfer Rate as a function of Coolant mass flow rate.
Linear due to the nature of the formula. Notice the much higher linear slopes with increasing radiator temperature deltas. Efficiency increases.



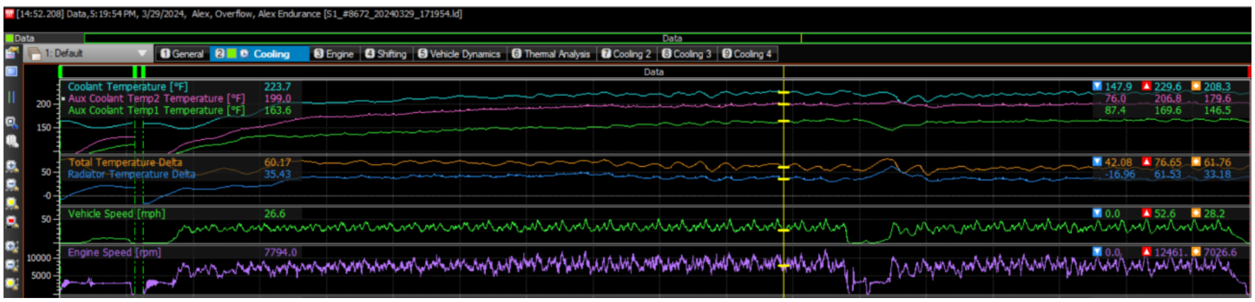


These are the formulas through which raw pressure data gets converted to a flow velocity and ultimately into a mass flow rate. A variation of Bernoulli's equation. Plenty of online resources to pick from.

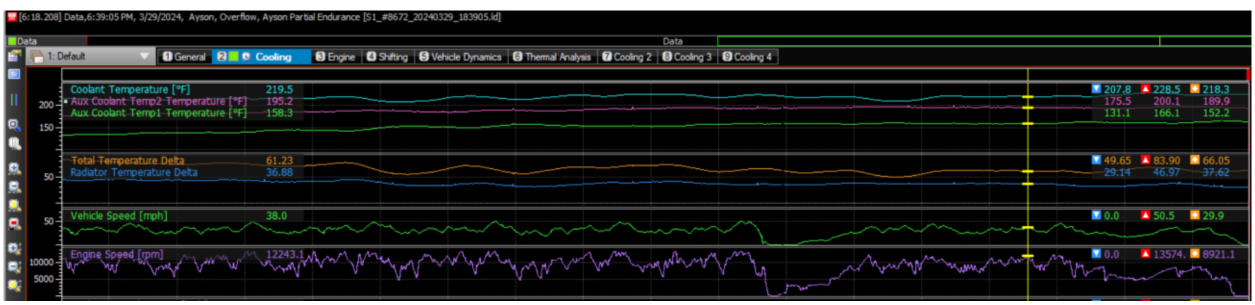
Endurance Testing

The last really solid testing outings we had were on March 29th and April 29th. We were able to get through entire endurance stints without overheating. On March 29th, we were running no aero and the radiator was exposed to ambient air. We averaged a delta of 33 degrees across the radiator with a max temp of 230F. This is really what we want. Just think about the cooling performance with even higher water flow rates (mechanical pump delete). On April 29th, Thomas was able to complete his endurance stint uninterrupted though needed to feather the throttle when engine temp went above 230F to avoid going into limp mode and completely losing throttle at 250F. Unfortunately, this run did not have radiator temp sensors plugged in and we weren't able to obtain an average temp delta for the run. I would expect it to be in the range of 20-30degF similar to the March 29th run. Frankly, the amount of cooling testing was severely limited due to the series of engine issues we had to solve for the two weeks leading up to competition. 2024 Michigan Endurance will be the ultimate test of our cooling system.

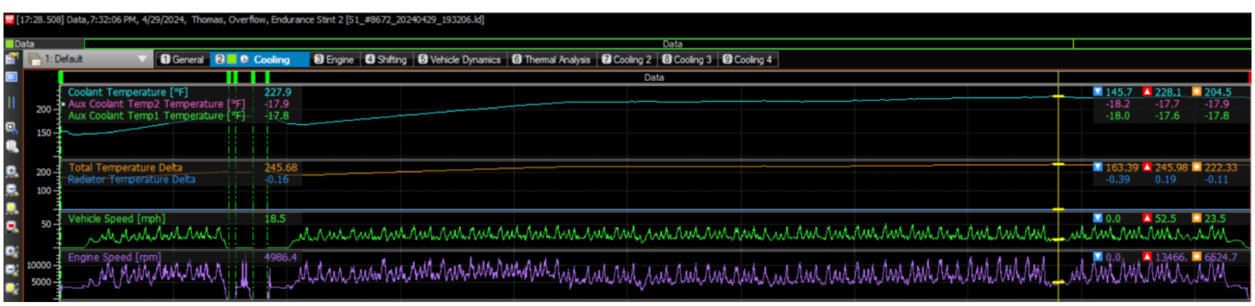
Alex's Endurance Stint – 3/29/24 (No ducting or aero)



Ayson's Partial Endurance Stint – 3/29/24 (No ducting or aero)



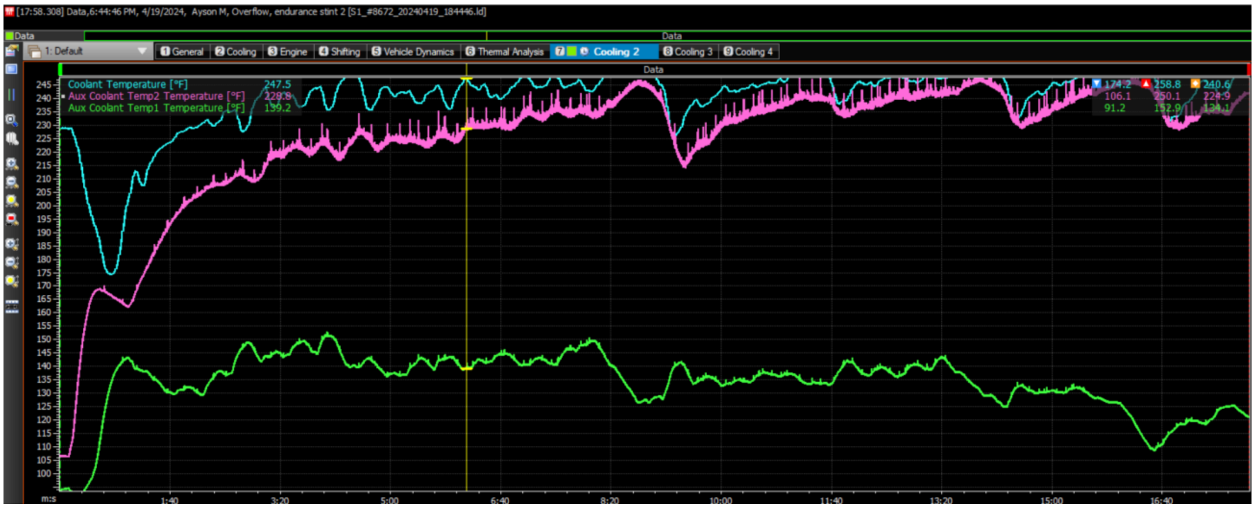
Thomas' Endurance Stint – 4/29/24 (Full ducting and aero, mechanical and EWP ON)

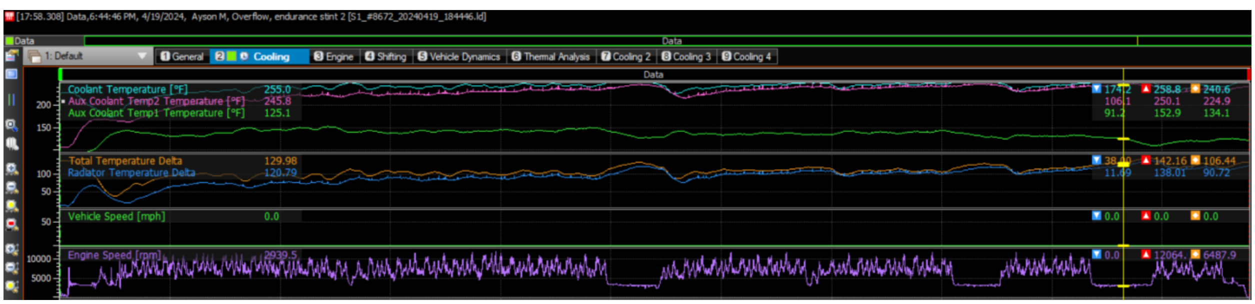


<u>An important conclusion during the weekend of 4/19:</u>

Notice the huge drop in temp from pink (inlet) to green (outlet). That isn't the radiator working super well. That means we aren't getting any water flow at all. The radiator water is staying in there and not circulating. After disassembling the engine, we concluded that there was water leaking into the oil system and heating everything up. One way to verify flow rate is to idle until the fans turn on. Check if the air being blown out is hot or cold. If cold, no flow and do not run the car. If hot, flow is occurring and should be good to run on-track.

Ayson Endurance – 4/19/24 (Engine Issues – Crankcase and Oil Pressure)





Future Plans

Follow @haynesengineering in Instagram

Advice to the next captain

1. Put an emphasis on on-car live data acquisition.
2. Design as close as humanly possible with whoever is designing Side Aero

Even with the number of great developments the cooling system has seen, there are a few more ideas I have I'd love to test over Summer 2024 and Spring 2024. Here are those future plans listed in bullet point format below.

1. PWM Closed Feedback Loop Control for fans and pump. If engine heat input isn't constant, why should water mass flow be constant?
2. Pitot Static Tube data to determine overall air pressure drop across radiator
3. Fine tuning of Venturi Meter data. It is there, but its overall accuracy and sensor noise has plenty of room for improvement.
4. Creation of a MATLAB/Simulink or GT-Suite 1D model of cooling system to correlate to on-track MoTeC data. This could allow for the validation of a much smaller and efficient design in addition to greater insight into which design parameters have the most influential effects on heat rejection

Conclusion

I know for a fact that there is way too much information here to digest in one sitting. I would recommend going to a few different coffee shops and really take your time to dive into the specifics of my designs. Hopefully in the process, you'll be able to catch some of my mistakes I never had the chance to catch. Nevertheless, this design binder is the culmination of two years of design, manufacturing, and testing of the cooling system. At the time of writing this, it's May 4th, 2024 and the competition is just around corner (next week). I'm a true believer in what I've done to improve cooling on the car but only time will tell once that Endurance event rolls around. The last major change we made to the cooling system was essentially grinding down the plastic impeller on the mechanical pump down to what would resemble a black mushroom. After doing this, we'd run the electric pump and water would visibly flow much faster from the view at the swirl pot. Now perhaps this might be different at RPM with the mechanical, but for now, we're feeling confident that this may be the most influential cooling modification to date. A few other FSAE teams running an R6 have also removed their stock pump in place of a standalone electric water pump. Finally, the ducting should also help allow more consistent air flow into the sidepod while on track. It looks quite awesome if I do say so myself. Best of luck to the next cooling captain and future ones to come. I'll be in touch whenever you need me.

Regards,

Isaac Haynes

(626) 491-3945

Works Cited

[1] – 2017 Senior Project – Michael Curtis and Kevin Valencia

[2] – Logan Datin Senior Project

[3] – FSAE Rules 2024

[4] – Fundamentals of Heat and Mass Transfer

[5] – Professor Paul Nissenson

[6] – Radiator: Bell Intercoolers

[7] – Oil Cooler: Mocal USA’s Laminova

[8] – Davies Craig EWP80 Electric Water Pump

[9] – DymePSI Oil Lines