ENGINE: ROTAX DS450

SPECIFICATIONS

Engine: Rotax 449 single cylinder
Source: BRP DS450 Quad
Valvetrain type: Double Over Head Cam (DOHC), 4-valve
Cooling type: Liquid-cooled with internal water pump
Fuel Delivery: Indirect Electronic Fuel Injection
Oil System: Dry-Sump
Transmission: 5-speed sequential, integrated gearbox
Drive Train: Chain driven

WHY A SINGLE CYLINDER?

- From Michigan 2016 endurance, the driver is only 10% of the time over 80% TPS. The rest of the time (90%) the cars would carry excessive weight with a bigger engine
- Better at fuel economy (small displacement)
- Easier and simpler to repair

CHOICE OF THE ROTAX 449

Last year engine: Rotax 449

- Reliable, though and easy to get parts

Previous engine: Aprillia 550

- Reason for change: unreliable, fragile, expensive and hard to get parts
- Advantages: light and very powerful for its weight

Sought after characteristics:

1) Electric start
2) Reliability
3) Accessibility of spare parts
4) Price
5) Water cooled
6) Fuel injection
7) Integrated Gearbox
8) Dry sump

Options considered this year

1. DS450
    - Chosen for low price (2500$), contact with company and easily accessible parts.
    - Many companies tuned this engine for racing: a lot of modifications are available

2. SUZUKI DRZ 400
    - Rejected for lubrication system (wet sump) – not suited for lateral G of a formula SAE car
3. Yamaha WRF450F
    - Rejected for high price (must buy the bike at the same time)
4. Honda CRF-450
    - Rejected for short lifespan

Other advantages:

- Experience with the engine
- The team has many spare parts
- Dyno already set up for this engine
- Contact at BRP that can answer the team's questions
- Ricardo wave model of the engine
    - Doesn't work because it's hard to modelize the combustion front (2 sparks plug)

PROBLEMS FACED WITH THE ENGINE

- Engine casing cracks due to bad engine mounts design (2013)
- Water pump seal failure due to use of deionized water as coolant (2014)
- Difficulties for cold start due to bad starting compensation (2015)
- Cylinder head overheating due to bad pressure in cooling system (2016)
- Early wear on exhaust camshaft due to bad oil system in dynamometer (2017)

POSITIONNING OF ENGINE

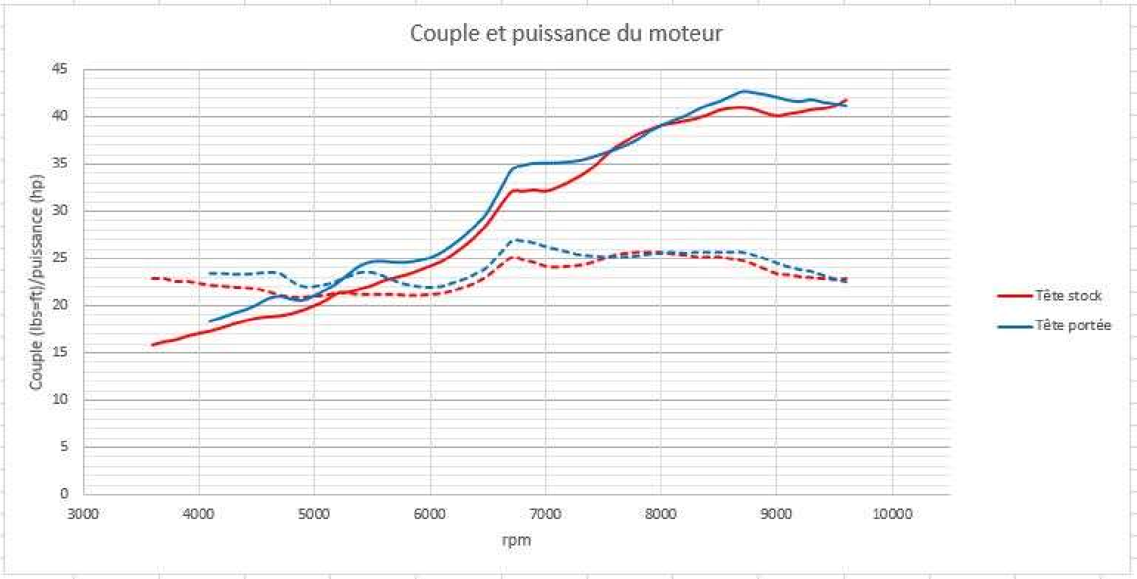
- Engine put as low as possible (not lower than frame)
- Engine as close as possible to firewall
- Engine is not utilized structurally because engine casing was cracking in previous years

MODIFICATIONS

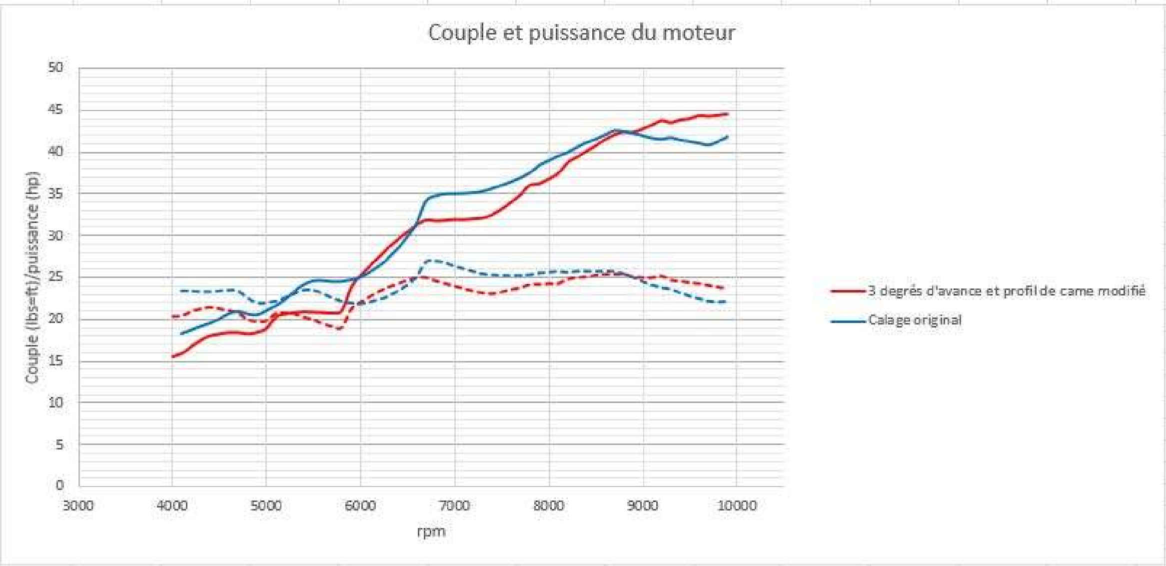
- Custom air intake
- Custom exhaust runner
- Custom fuel delivery system
- Custom oil delivery system
- Electronic Engine Control with PE3 ECU
- Stock springs, redline stock
- The team envisaged titanium valve, but other modifications give more gain for lower price

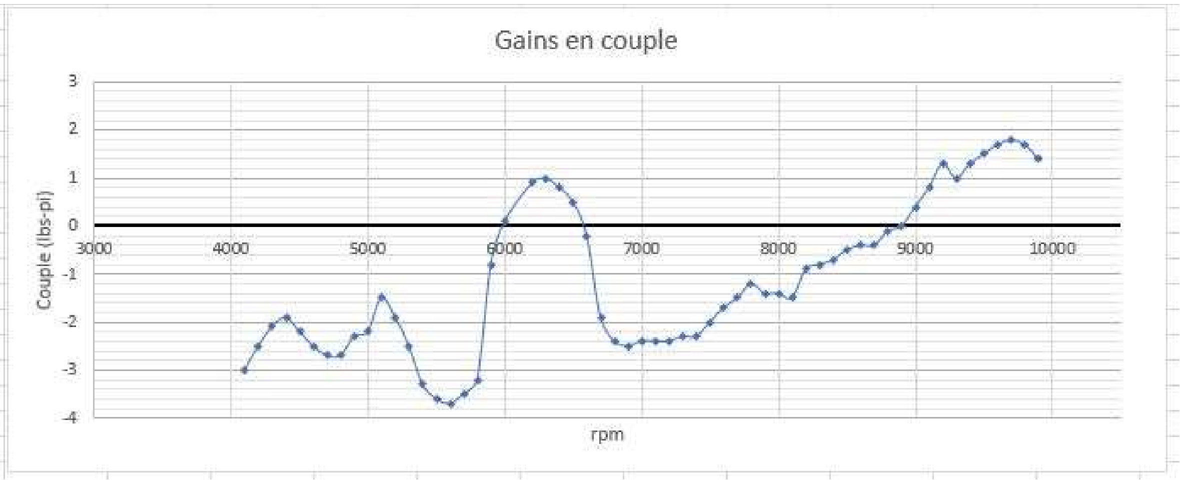
- Modifications that have been tested but not on the car:
    - Ported head
    - High compression piston (couldn't test on dyno because of rebuilding mistakes)
    - Exhaust camshaft at intake (recommended by BRP racing)

Ported head vs stock head



Modified camshaft vs stock camshaft

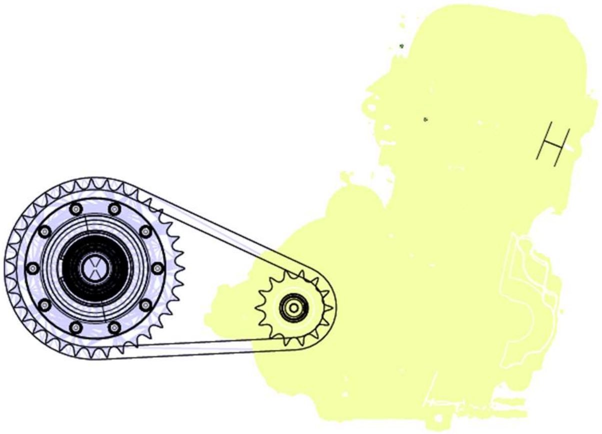




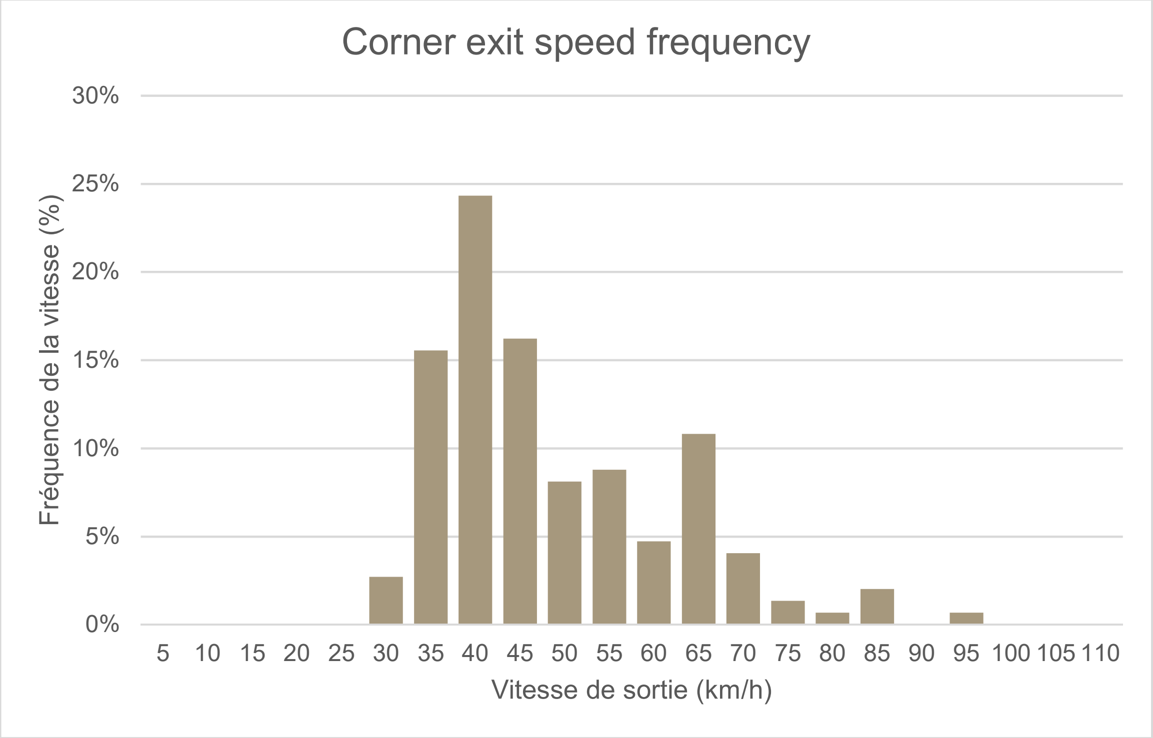
GEAR RATIOS

DESIGN OBJECTIVE

- Reduce the number of gears from last year
- Adjustable final ratio with interchangeable sprockets (differential and engine)
    - Adjustability: 2.26 – 2.76 ratio:

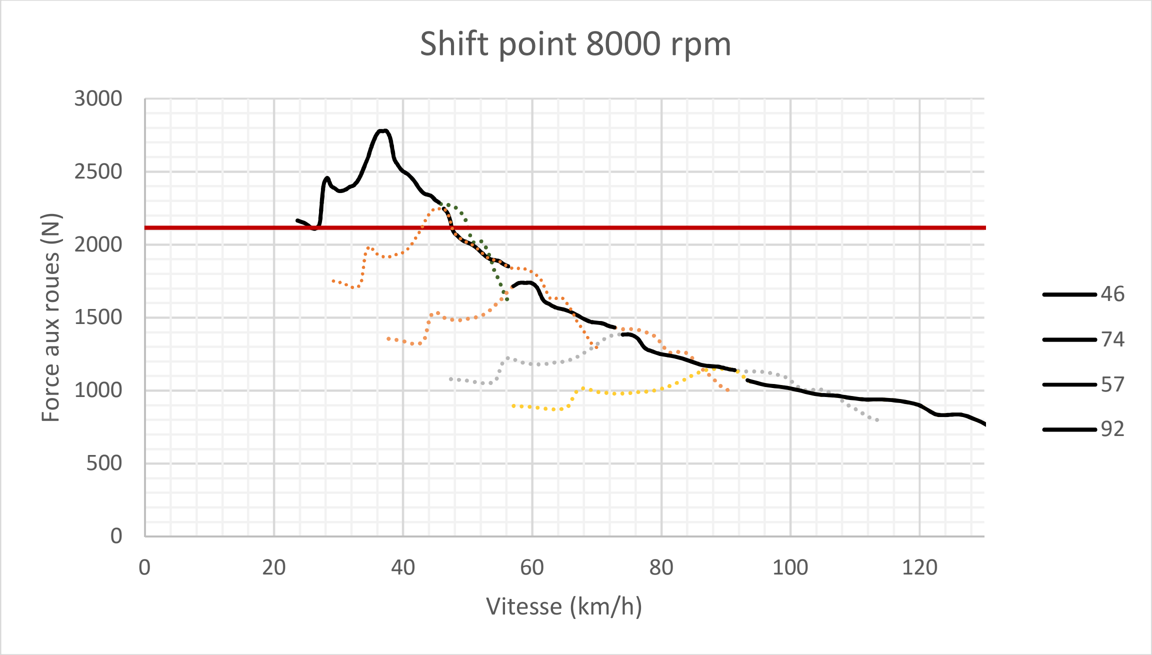


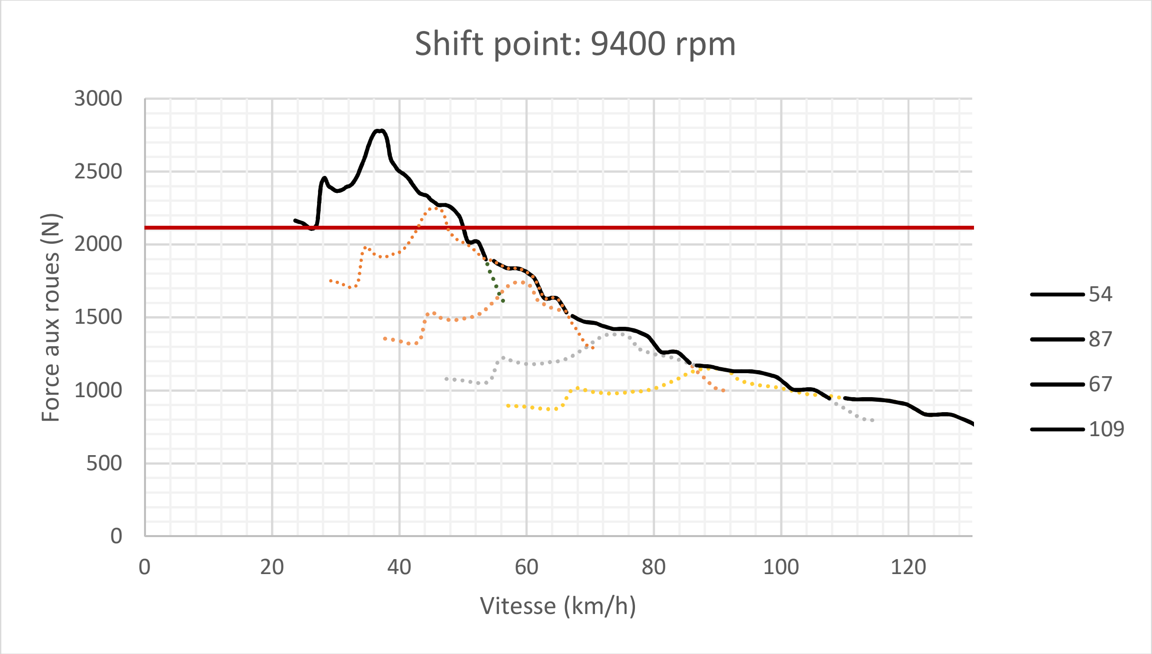
Analysis of tracks and corner exit speeds



2017

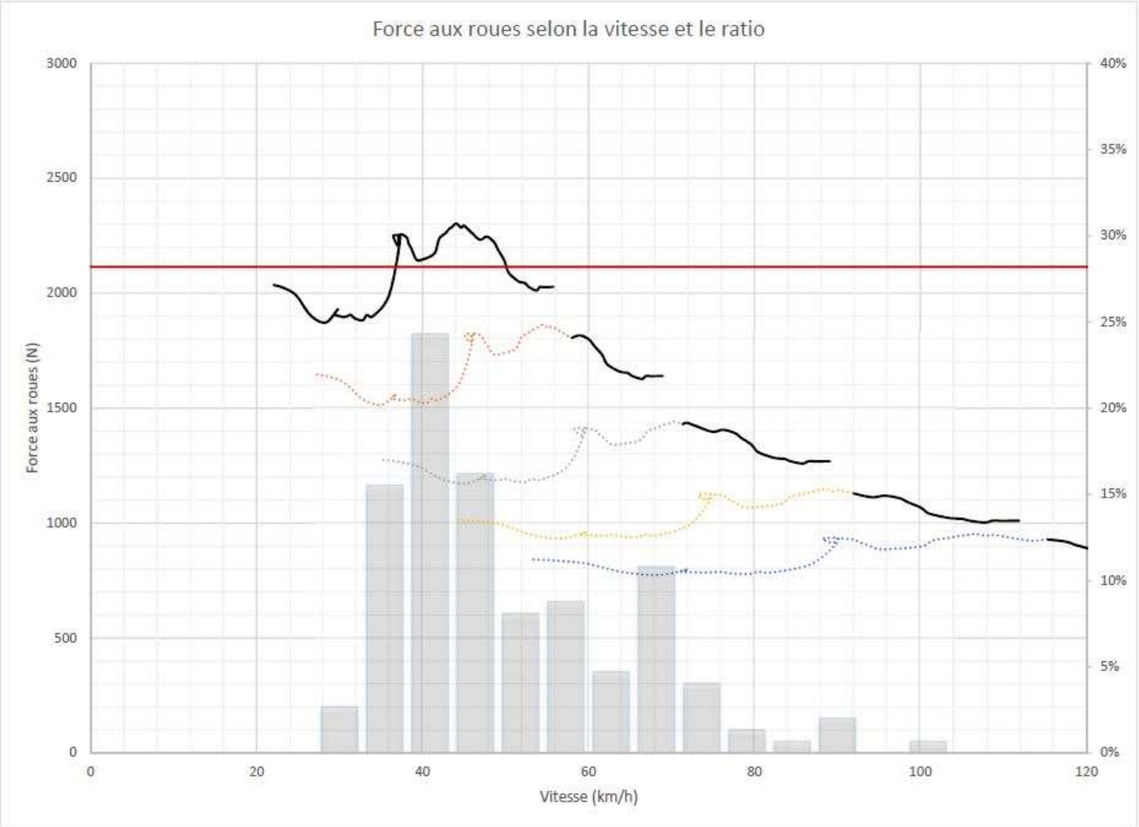
Best fitting gear ratio: 2.77 (36/13)





2016

Best fitting gear ratio: 2.4 (36/15)



MAXIMUM SPEED 2017:

- 1st gear: 57 km/h
- 2nd gear: 71 km/h
- 3rd gear: 91 km/h
- 4th gear: 115 km/h
- 5th gear: 138 km/h

VALIDATION

A second ratio was tested: 2.5 (35/14) to compare

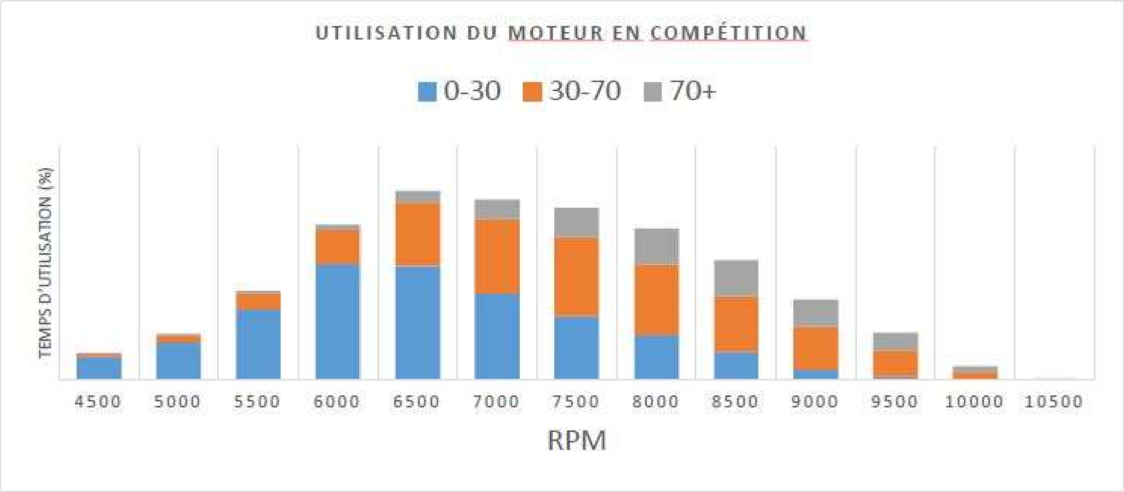
- Driver feedback: first gear is too short (hard to control) and second gear is too high
- The selected ratio was tested and liked by the drivers

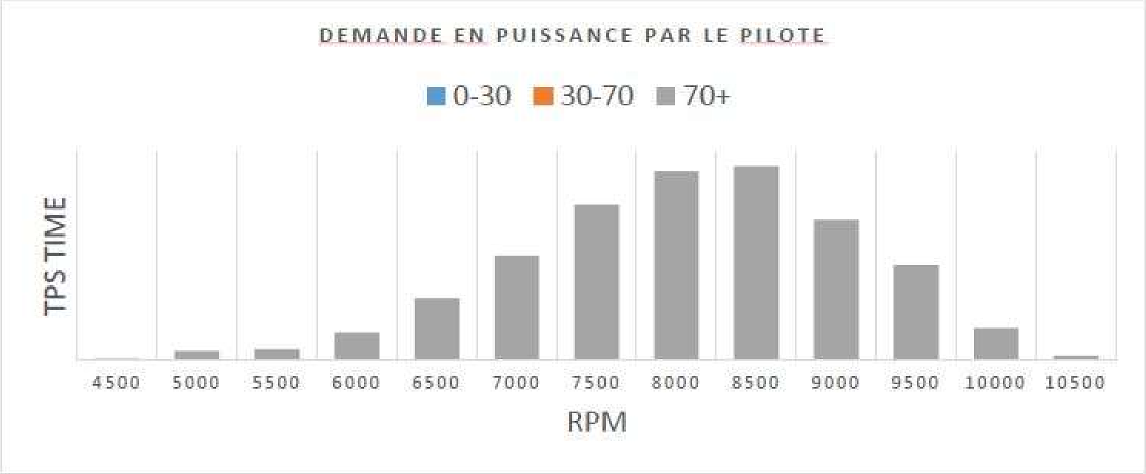
AIR INTAKE DESIGN AND SELECTION

DESIGN OBJECTIVE

- Peak torque target: 9000 rpm
- Increase max horsepower from last year
- Last year driver's feedback:
  - Not enough power in cornering exit
  - Not enough power at low rpm
- Increase power at low rpm

Engine use and TPS during an endurance (Barrie 2016):





2016 PLENUM AND RUNNER

Peak torque target: 8000 rpm

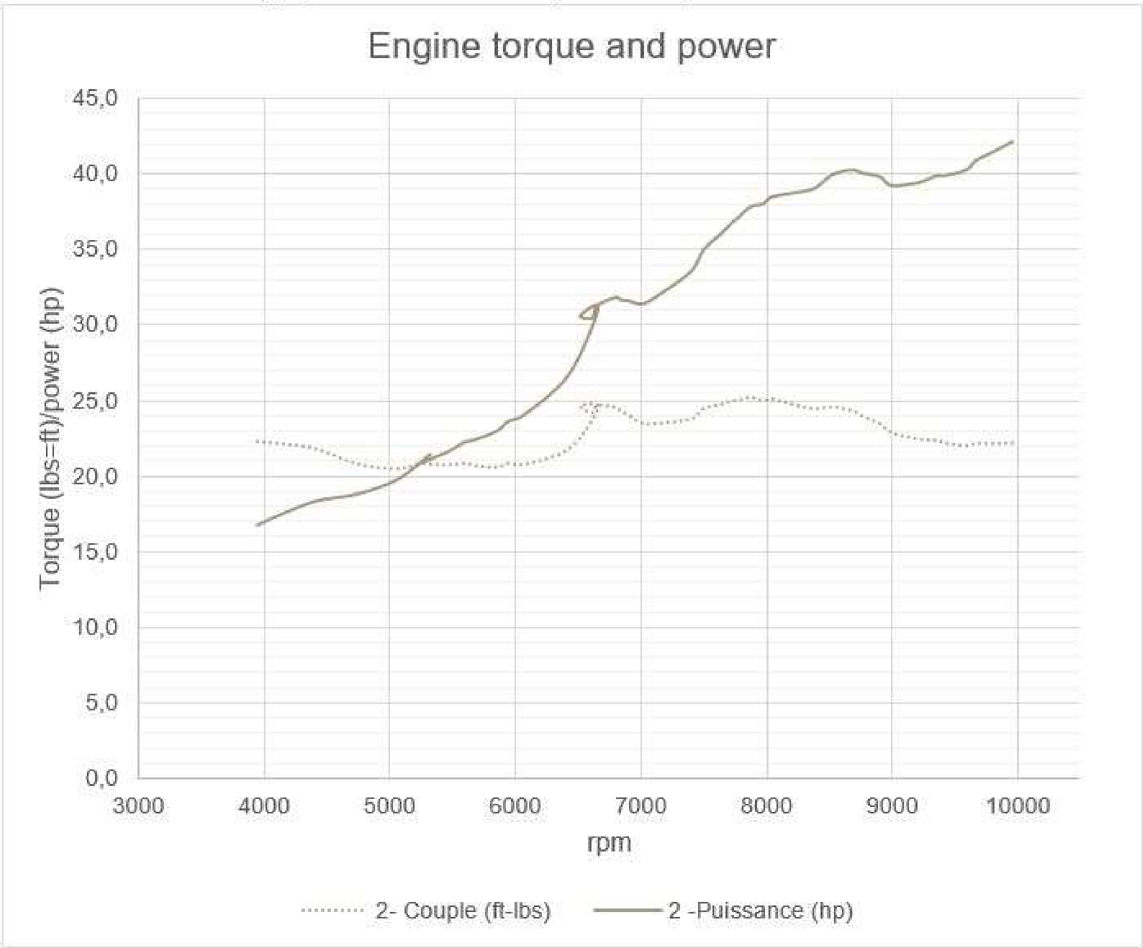
Designed using literature with goal to have peak torque at 8000 rpm

Runner length: 310 mm

Harmonics: 8392 rpm & 6294 rpm

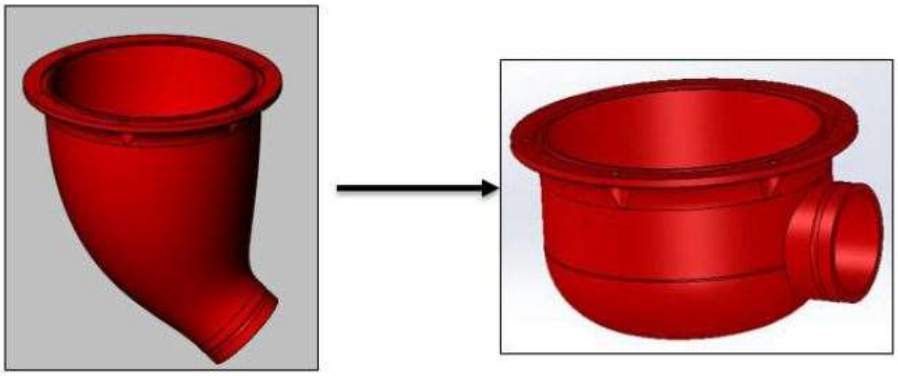
Plenum volume: 2L (approx. 4 times the displacement)

Last year power output

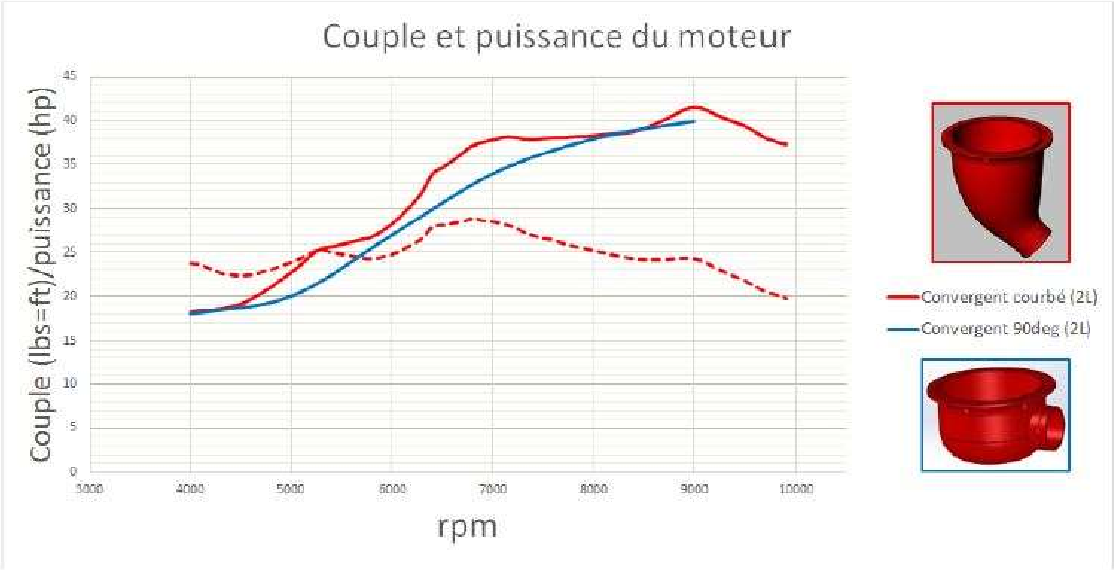


EXPERIMENTAL TEST (PLENUM AND CONVERGENT)

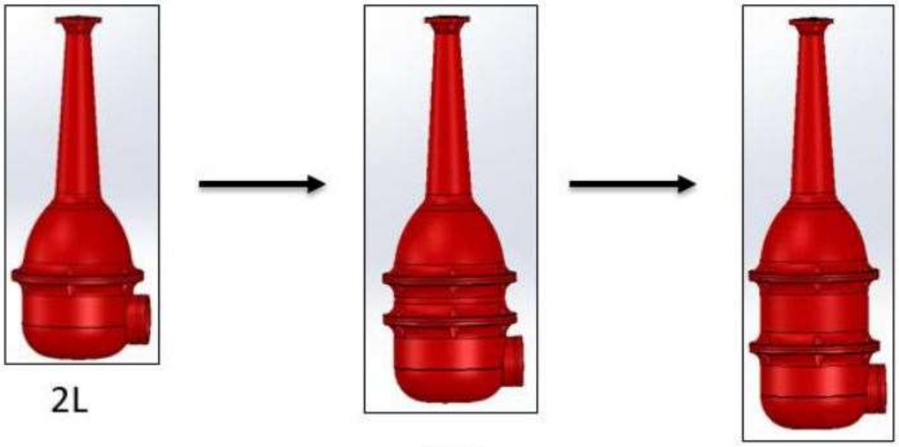
Convergent form options



Convergent form comparison



Plenum volume options

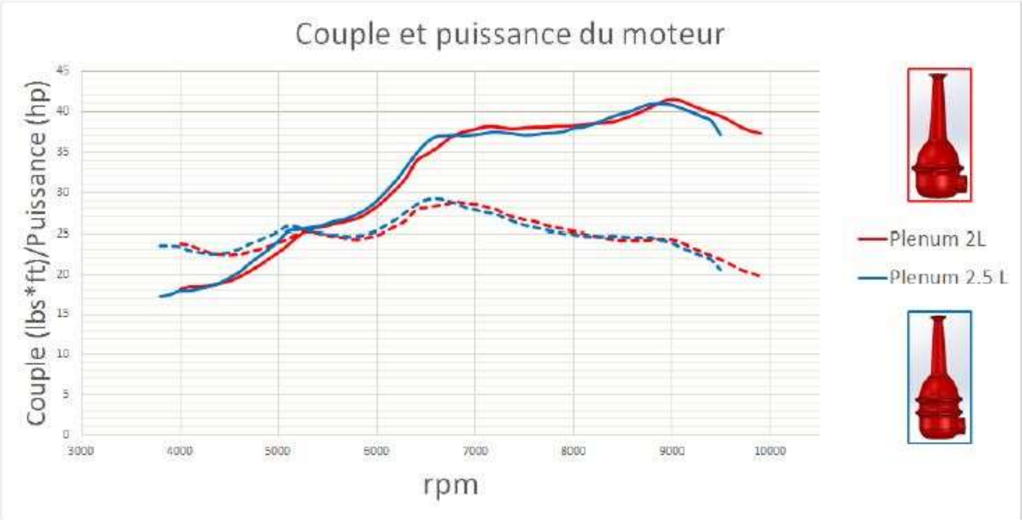


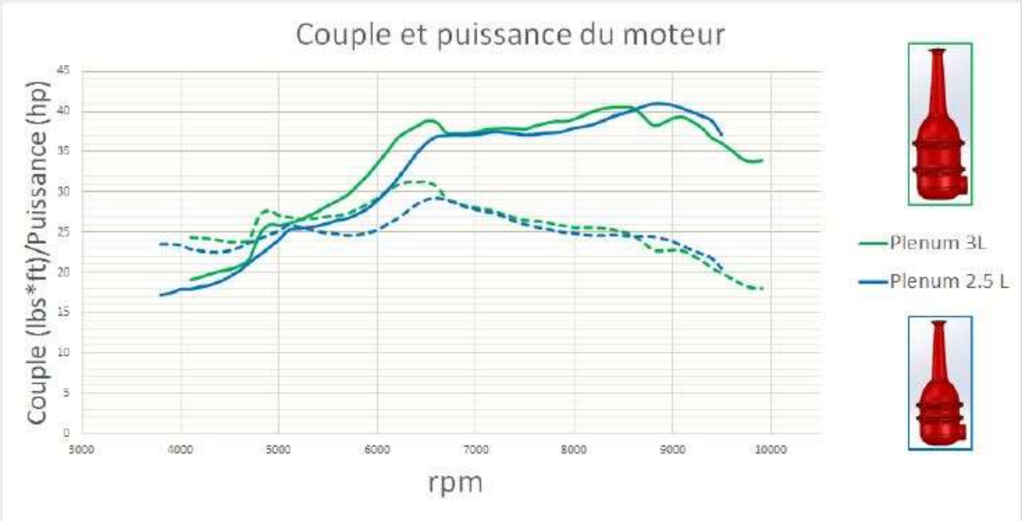
2L

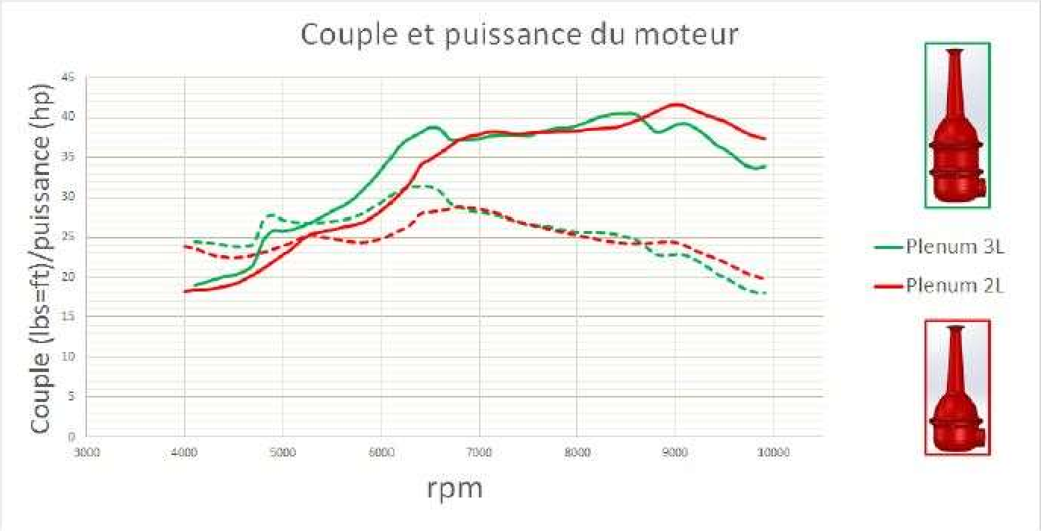
2,5L

3L

Plenum volume comparison

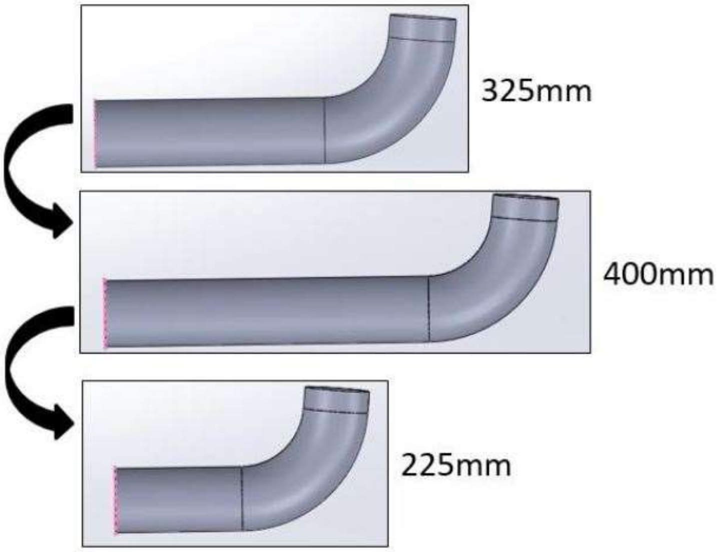






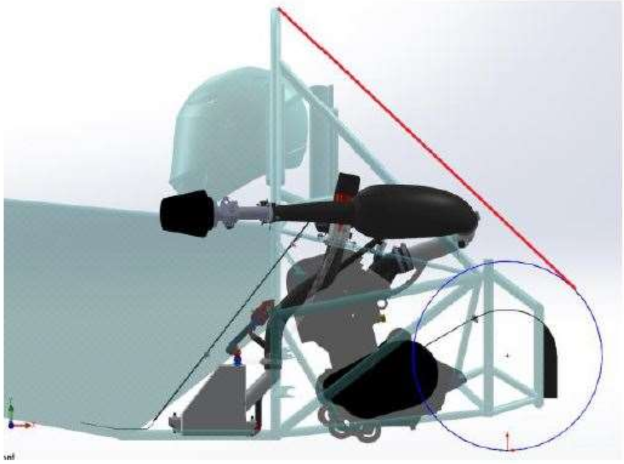
RUNNER LENGTH

The team wanted to test 3 different runner length but due to space restriction only the 325 mm was suitable. The team was also satisfied with the result of the 325mm runner.

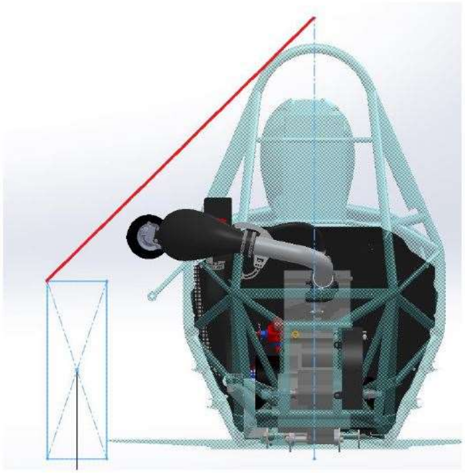


FINAL POSITION

Side view

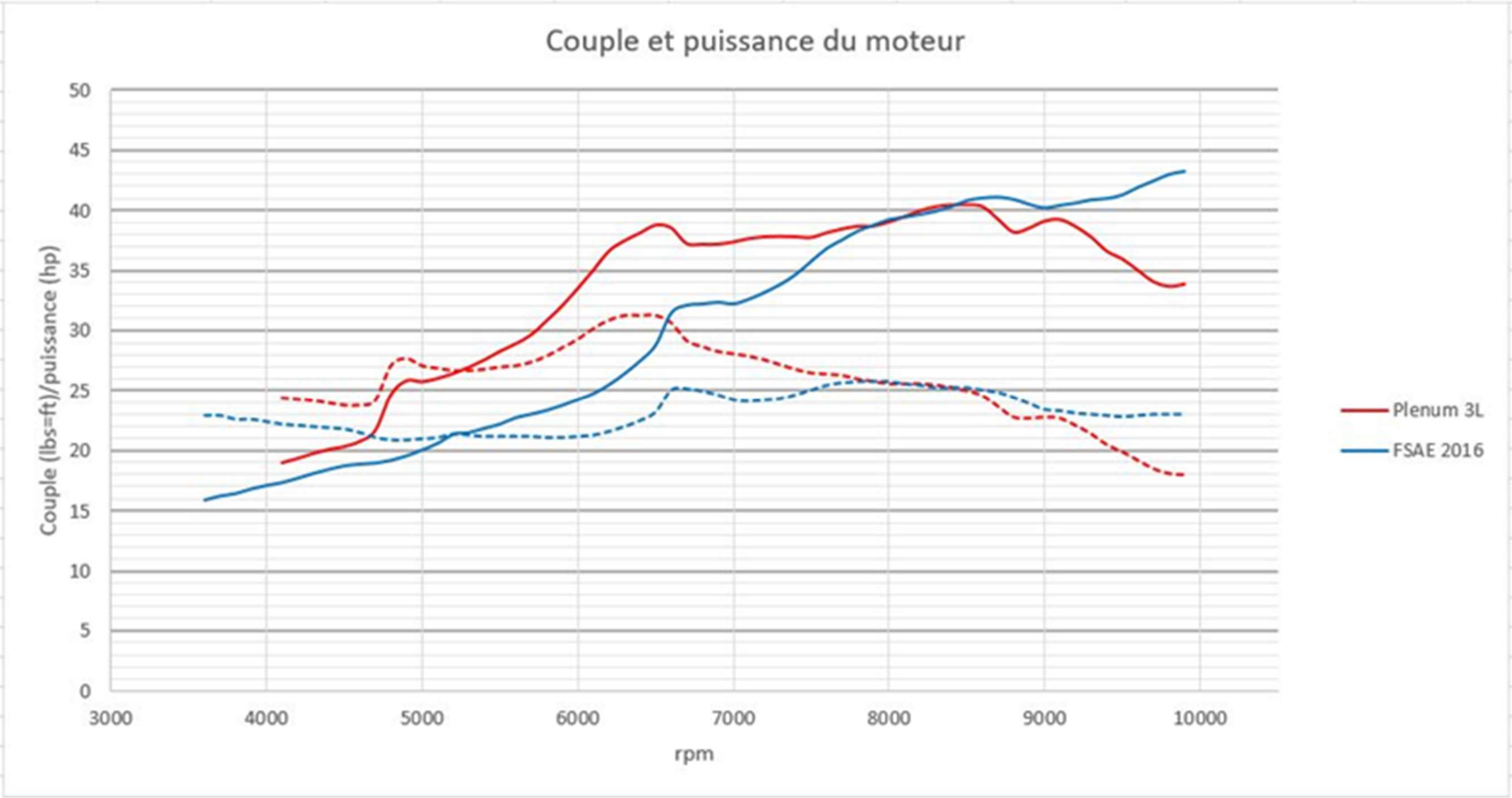


Rear view



Final choice: 3L plenum with curved convergent and 325 mm runner

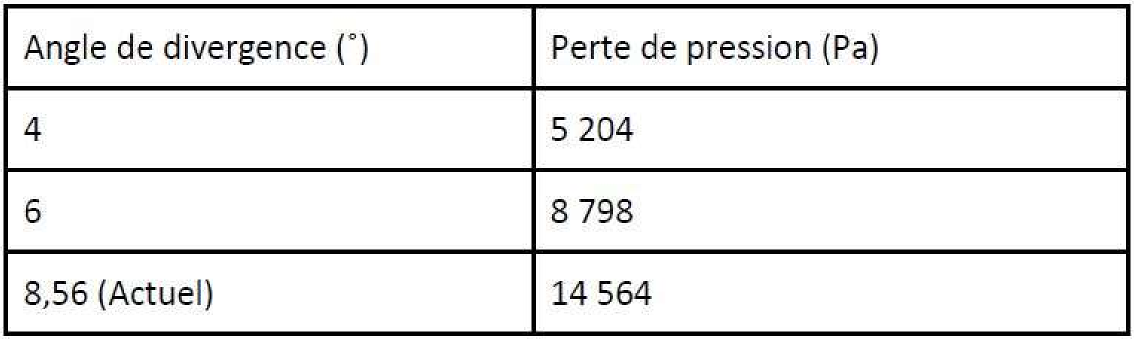
Last year vs this year power output



RESTRICTION

- Why an AT power throttle body?
  - Reliability of the restriction (Convergent – Straight)
  - Shaft-less butterfly valve (better airflow characteristics)
  - Lightweight (billet aluminium)
  - 28 mm butterfly valve

Pressure loss vs divergence angle after restriction



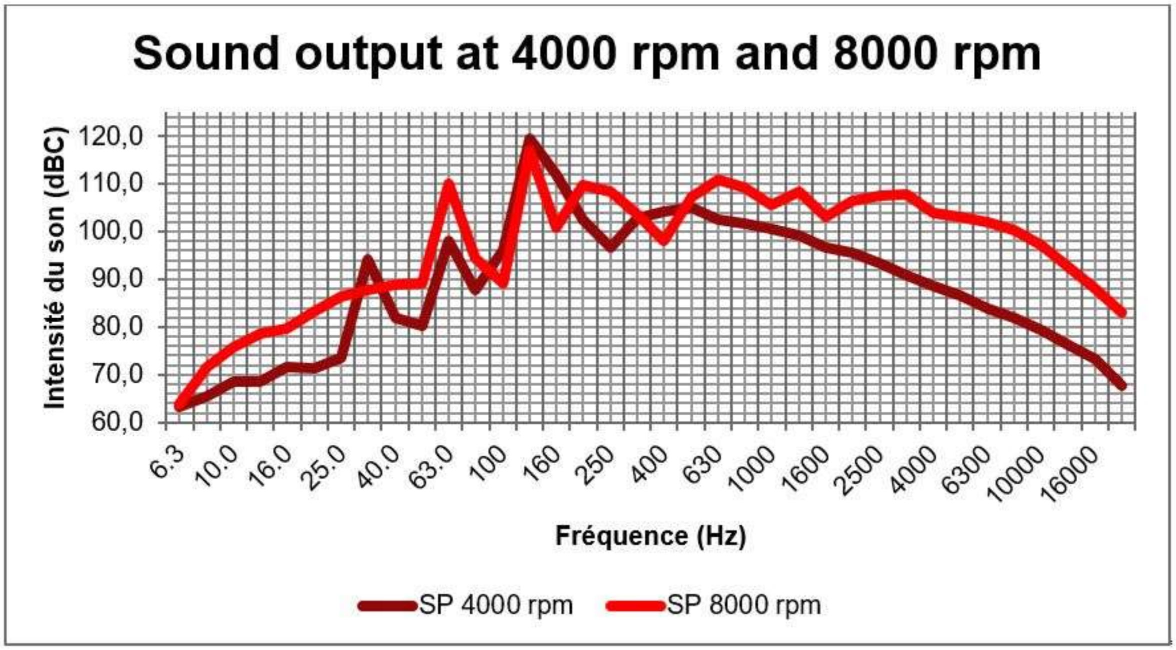
Angle de divergence (˚)	Perte de pression (Pa)
4	5 204
6	8 798
8,56 (Actuel)	14 564

Choke flow calculation:

At Mach=0,3 the incompressibility effect start to have a bigger impact and the air density is decreasing.
The engine will choke at 8544 RPM

EXHAUST SYSTEM

A sound test has been made by the team to see which frequencies have the biggest impact on the sound



DESIGN OBJECTIVE

From previous years:

- Team tried to design a custom muffler
- Team put a lot of time in the design and fabrication
- Finally, the team used the stock DS450 muffler because the designed one didn’t pass the sound test

This year the team decided to test different muffler and to pick the lighter one. (Time saving compared to a whole muffler design)

Available mufflers for testing:

- Stock DS450 muffler
  - Weight: 4,6kg
  - 103 dBC at idle and 109 dBC at 7500 RPM
- Stock Suzuki GSXR 750 muffler
  - Weight: 2,2kg
  - 106 dBC at idle and 115 dBC at 7500 RPM
- FMF high performance DS450 muffler
  - Weight: 1,9kg
  - 115 dBC at idle and 119

RUNNER

- 3 curve runner not optimal but no choice because of packaging
- Not fully welded to prevent cracks due to vibration
- Springs used on junction to let the runner take the vibrations
- Stainless steel to prevent rust from hot temperature

CHOICE AND POSITIONNING

Final muffler choice:

- Stock BRP muffler
- 4 chamber
- 30mm exhaust tip (12mm restriction)

Final muffler position:

- Outside of the engine bay to minimise the impact of engine bay sound
- As close as possible to the gravity center
- On the right to balance for intake and radiator

UPGRADES TO COME

- Modify the Suzuki muffler to make it pass the sound test (add a restriction)
- Use the same geometry as the stock DS450 muffler but reduce his weight

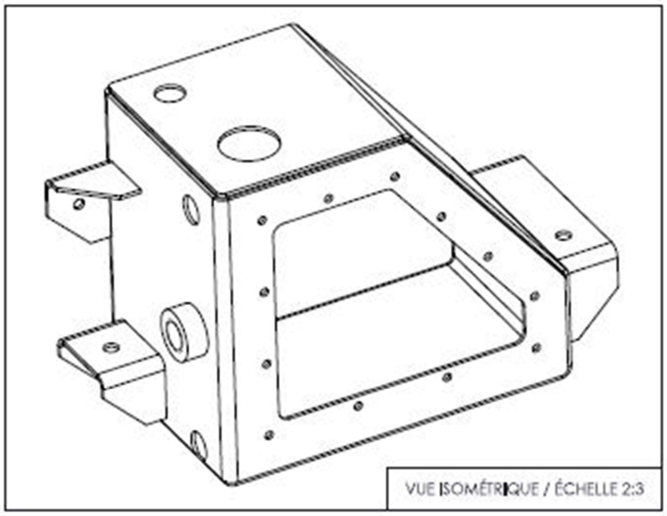
From left to right: FMF, Stock, Suzuki

OIL

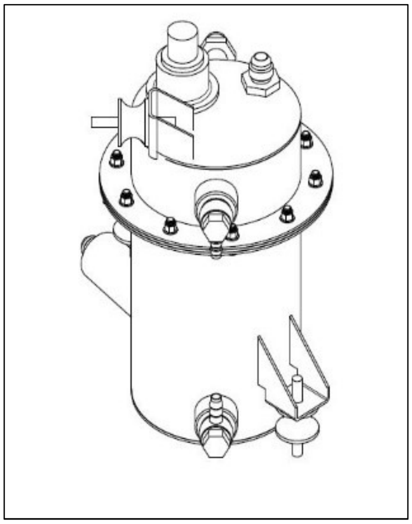
DESIGN OBJECTIVE

- Reduce weight
- Improve accessibility and packaging
- Last year oil tank was cylindrical and hard to package

This year oil tank



Last year oil tank



OIL TYPE

- Castrol GTX mineral 10W-40
- Limited by transmission
- Recommended by BRP Racing
- Same for engine and transmission (same casing)
- Without limited friction agent for clutch

SIZE AND POSITION OF TANK

- Oil tank capacity: 1.7L (OEM capacity 1.8L)
    - 1.5L minimum from BRP
    - Minimum 1.3L to make sure there is enough oil during 2G braking
- As close as possible to the firewall and as low as possible (to reduce the CG)
- Easy to remove (don’t need to take off the engine)

SPECIFICATIONS

- OEM internal oil pump
- OEM Dry Sump system
- AN6 aluminium fittings
- Starlite flexible line for vibration absorptions and lightweight
- OEM Oil filter and inline oil mesh
- Welded aluminum catch cans
- Mounted to chassis with lord mounts for vibration absorptions
- Complete oil system weights 1.09 kg without oil (last year: 2.1 kg)

PROBLEM FACED WITH LUBRIFICATION

- Early camshaft wear due to bad lubrification
- The team tried the stock semi-synthetic BRP oil but it didn’t solve the problem
- The dynamometer’s oil system was stuffy and the cause of the problem

UPGRADES TO COME

- Tangential entry to remove air from oil
- Better flange sealing to avoid leaks

COOLING

CHOICE OF RADIATOR

DD2 Rotax Kart Radiator

- Low price (sponsored)
- Easily accessible

COOLANT FLOW

Obtained from BRP

3000RPM (IDLE) = 17l/min

8000RPM (Peak Torque) = 52l/min

10000RPM (cut-off) = 67l/min

Thermostat

Opens at 70 degC

OBJECTIVE AND METHODOLOGY

Matlab program to find the necessary area

- Hypothesis: 29hp to evacuate
  - 1/3 heat evacuated by the exhaust
  - 1/3 of the heat evacuated by the cooling system
  - 1/3 of the heat evacuated by mechanical work
  - Average power developed between 7000-10000 rpm: 29 HP
- Type of fins dictated by the market availability
- **Simulated size**: 420 cm^2
- **Chosen size:** 594.5 cm^2, SF= 1.4

SPECIFICATIONS

- DD2 Rotax Kart Radiator
- Weight: 2.9kg without water
- Coolant cap: 16 psi (stock: 14 psi)
- Max water temperature: 121 degC
- Info light turns on at 97 degC
- Silicone flexible hoses (5/8” and 3/4")
- Aluminum welded catch cans

VALIDATION

Swirl pot and fan necessity validated while testing:

- Both individually allowed sufficient engine cooling, swirl pot chosen because of weight (200g less when swirl pot filled) and reduced strain on battery
- Engine overheating when no swirl pot or fan used

CUSTOM COOLING SYSTEM

- No fan used (weight reduction and hypothesis that not much is spent at idle)
- Swirl Pot to eliminate air from system

UPGRADES TO COME

- Cooling duct to optimise the efficiency of the radiator (reduce the airflow)

FUEL DELIVERY SYSTEM

FUEL TANK

- Capacity: 4L of useable volume (without filler neck)
- Based on fuel consumption of the 2016 car, SF of 1.33
- Fuel used during Michigan endurance 3L
- Need minimum 0.4L of fuel to ensure the good alimentation regardless of the manoeuvring
- Aluminum welded assembly
- As close as possible to the firewall and as low as possible (to reduce the CG)
- Easy to remove (don’t need to take off the engine)

INJECTOR AND PUMP

- Fuel effective pressure: 43 psi (stock)
- Bosch green injector: 4.4g/s @ 43psi
- Max duty cycle: 69%
- Internal Daetschwerk fuel pump (265l/h @ 43 psi)

SPECIFICATIONS

- Fuel system weight: 2.8 kg (last year: 3.4 kg)
- OEM Plastic injected single fuel rail
- 100 octane fuel
    - Ignition map done on dyno with 94 octane because it’s hard to get 100 octane in Montreal
    - More potential power than 93 octane because you can advance more the timing
- E85 was envisaged but rejected for these reasons:
    - Hard cold start
    - Not reliable in cold temperature (10 degC average during testing in Montreal)
- External fuel pressure regulator (43 psi adjusted)
- AN6 aluminum hard lines and 5/16 fuel flexible line

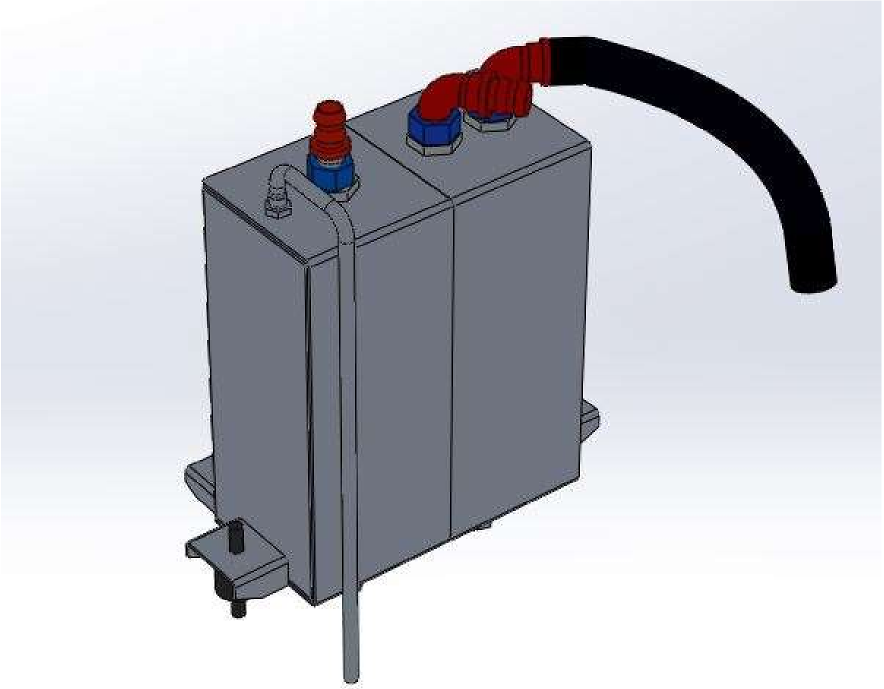
UPGRADES TO COME

- Better flange sealing to avoid leaks
- Reduce the volume (verification of fuel used during 2017 Michigan endurance)
- Change the injector for one that data is available

CATCH CANS

DESGIN OBJECTIVE

- Last year, the catch cans were Nalgene plastic bottles
- It was hard to package (cylinder), leaking and didn't look well integrated to the car
- This year the team decided to design fully welded aluminum catch cans:
  - Easier packaging
  - Look well integrated to the car
  - Mounted on lord mounts for vibration absorption
  - Easy to drain
- Disadvantages:
  - Little bit heavier than Nalgene bottles
  - Higher price in Cost Report



DIFFERENTIAL

WHY A LIMITED SLIP DIFFERENTIAL?

- With open diff, all the power would go on the less charged wheel. In cornering, the inside wheel would spin and the outside wheel wouldn't receive power from the engine
- With lock diff (spool), during cornering, one wheel would spin because they don't travel the same distance

SELECTION OF A LIMITED SLIP DIFFERENTIAL TYPE

- Clutch Pack Type
    - + Tuning possibility
    - + Lightweight (Drexler)
    - – Cost (Drexler)
    - – Maintenance
- ATB Helicoidal
    - + Progressive action
    - + Virtually no maintenance
    - + Automatic torque bias ratio
    - – Heavyweight
    - – No easy tune possibility

SPECIFICATIONS

- Drexler LSD FSAE V1
- Deep groove ball bearings for differentials mounts
- Aluminum machined differentials mounts
- X-ring chain (lubed often)

DIFFERENTIAL MOUNTS

Non-identical differential mount because they don't carry the same load. The right mount works in tension and the left in compression.

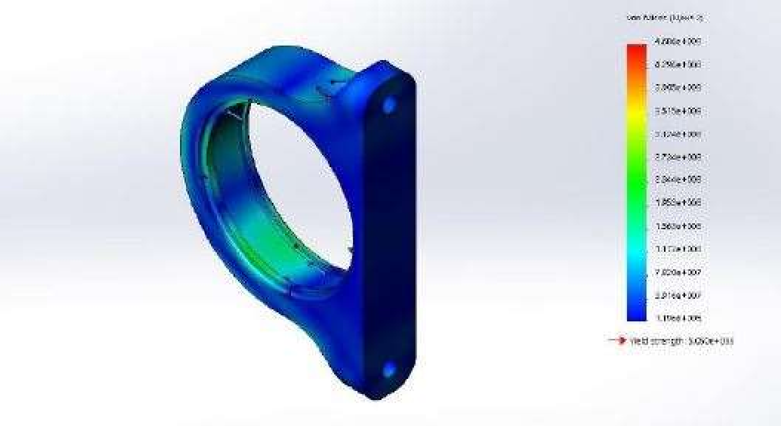
(See Diff.Mount load case Excel sheet)

Last year total differential mounts weight: 2*310g + 4*45g brackets = 800g total

This year total differentials mounts weight: 171g left + 383g right = 554g total

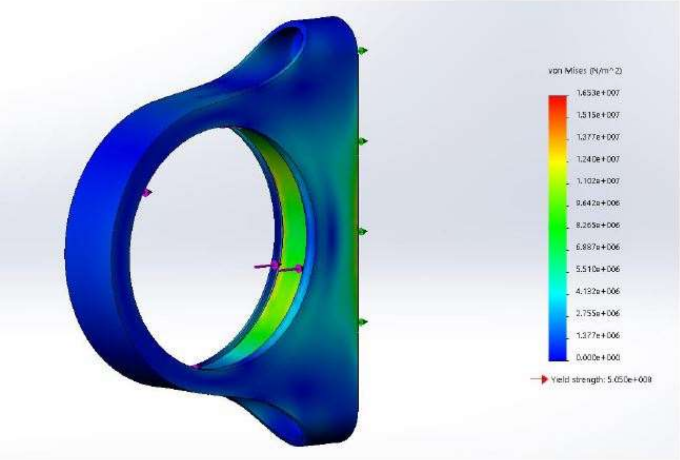
RIGHT DIFFERENTIAL MOUNT

- Tension Load
- 7075 T6 aluminum
- M8 bolts
- SKF 6011 (Ø90mm)



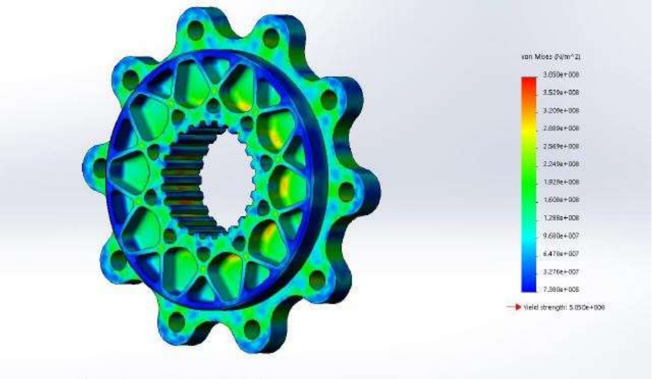
LEFT DIFFERENTIAL MOUNT:

- Compression load
- 6061 T6
- M6 bolts
- SKF 61910 (Ø72mm)

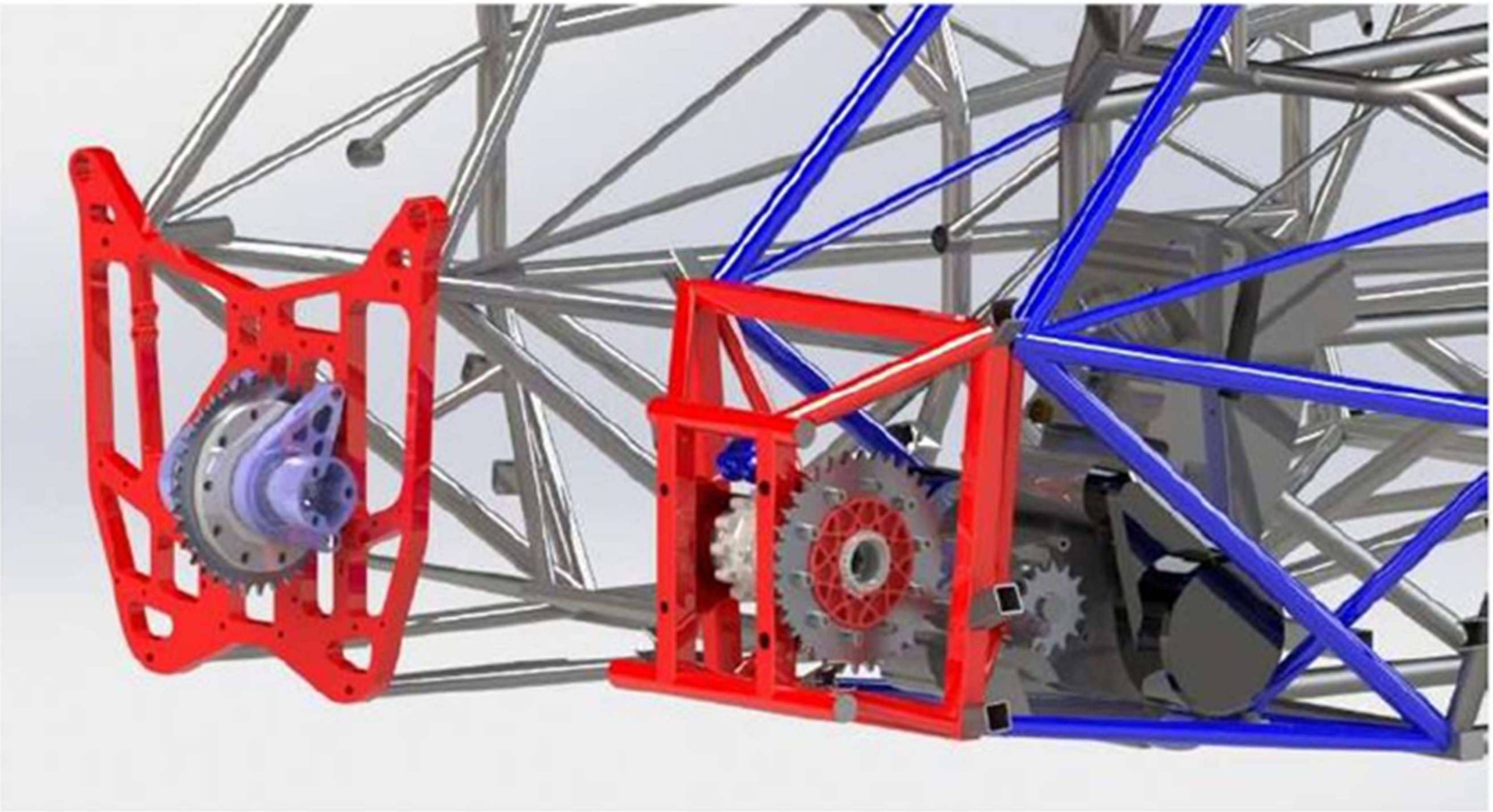


SPROCKET ADAPTER

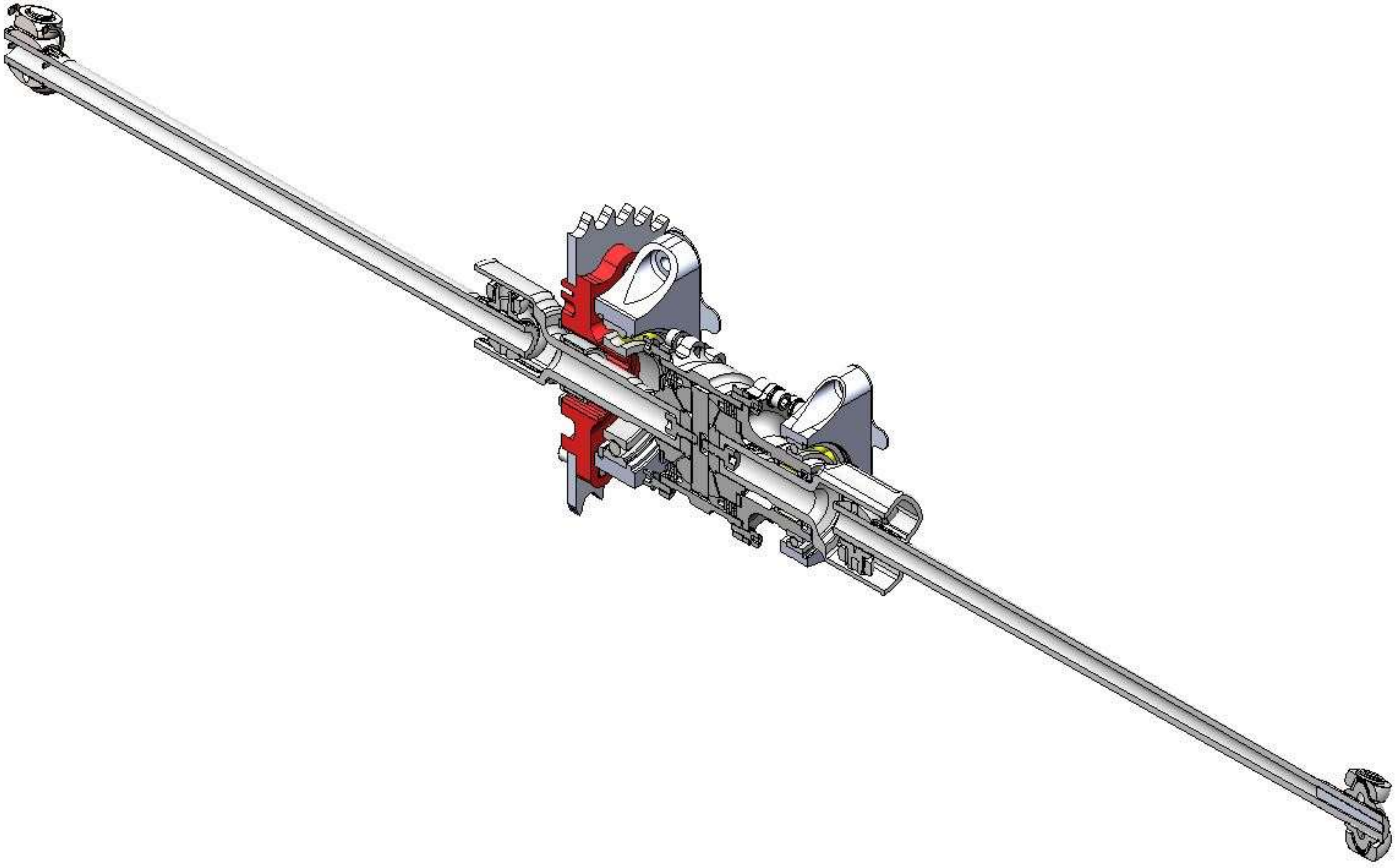
- 7075-T6
- Machining: Lathe +
  3 Axis CNC Milling
- Sprocket Bolt pattern: 5
- Sprocket Adapter bolt pattern:
  10 in case of thread failure
  (Aluminium)

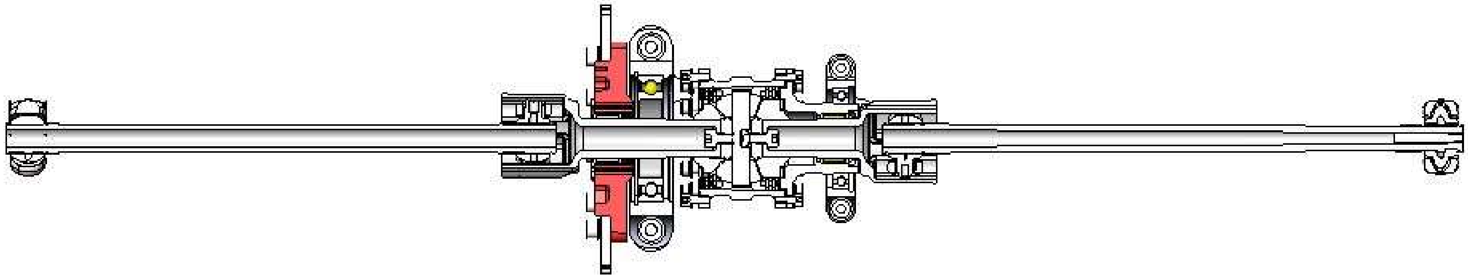


Last year vs this year differential system



Cut view of differential system

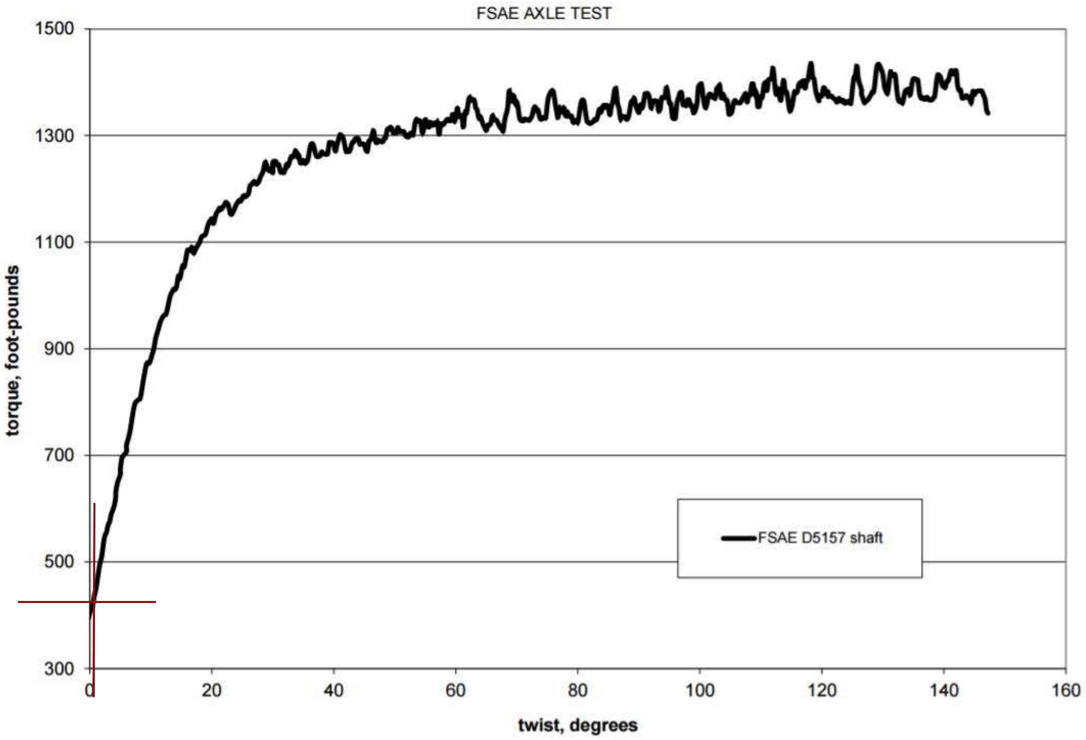




DRIVESHAFTS

SPECIFICATIONS

- 4130 steel tubing for reduced weight and superior strength
- From RCV



SIZING AND POSITIONNING

- To avoid the driveshafts to pop out of the housing, the team made fake driveshafts in wood to verify experimentally the length before cutting the real driveshafts.
- Driveshaft angle: 3,4 degrees

DRIVESHAFT CALCULATIONS

Right driveshaft

OD (in)	ID (in)	Length (in)	OD (mm)	ID (mm)	Length (mm)	Deflection
0.75	0.5	13.4	19.05	12.7	340.36	0.248

Left driveshaft

OD (in)	ID (in)	Length (in)	OD (mm)	ID (mm)	Length (mm)	Deflection
0.75	0.5	19.4	19.05	12.7	492.76	0.359

Case	**Yield/Ultimate tensile (Mpa)**	**Tau factor**	**Tau (Mpa)**	**Max torque**
Yield 4340	900	0.5	450	490.2
Rockwell 42	1351	0.6	810.6	883.0
Rockwell 47	1578	0.6	946.8	1031.3

Shear for 4130 steel (GPa)	**Peak torque (Nm)**	**J (mm^4)**
80	605	10375.5

FS=883Nm/69Nm=12,8

ENGINE CONTROL

ELECTRONIC CONTROL UNIT (ECU)

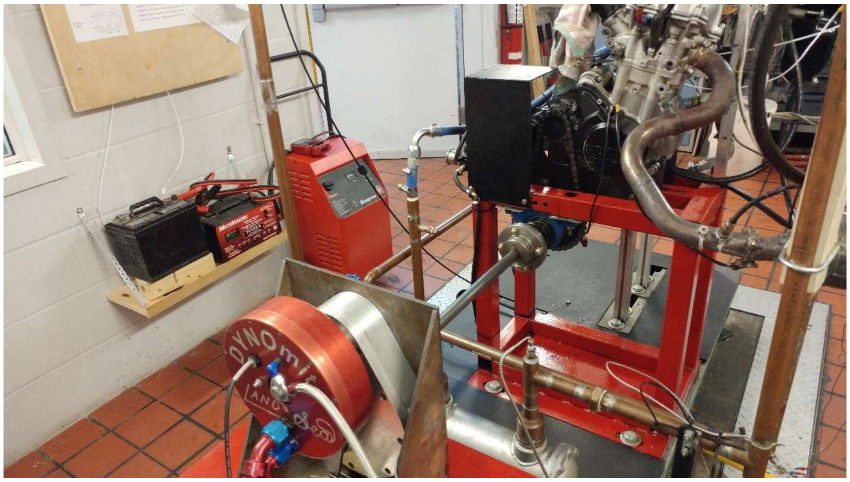
- PE3 Electronics
- Speed density (MAP and RPM)
    - Not ideal for a single cylinder with big plenum
    - The team previously used Alpha-N, but tried Speed density and noticed it was more stable and more convenient
    - The drivers gave a valuable feedback about the new mapping method
- Closed-Loop
- Compensations: Starting, Air Temperature, Coolant Temperature, Acceleration rate, Deceleration rate, Battery voltage
- Intake air temperature sensor not in intake, because it's harder to package and could break the 3D print intake.
    - The difference between the outside temperature and air intake temperature is around 1 degC (tested in dyno).

AFR METER

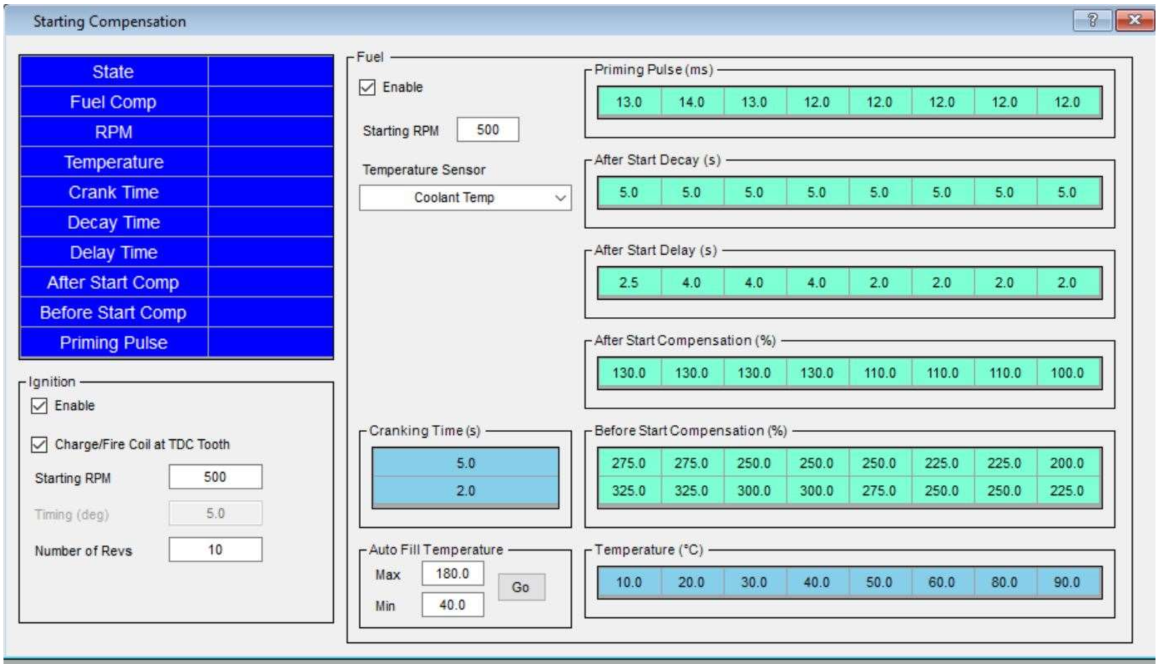
- Innovate Motorsports LC-2 Digital O_2 Controller
- Bosch Wideband O_2 sensor

DYNAMOMETER

- *Land and Sea* water brake dyno
- Tried to reproduce the same conditions than in the car:
    - Same oil tank
    - Same intake
    - Same exhaust system
    - Same ECU and electronics
- The only thing different is the cooling system
- An inertia wheel is missing to let the team do transient tuning



STARTING COMPENSATIONS



Starting Compensation

State	
Fuel Comp	
RPM	
Temperature	
Crank Time	
Decay Time	
Delay Time	
After Start Comp	
Before Start Comp	
Priming Pulse	

Ignition

☑ Enable

☑ Charge/Fire Coil at TDC Tooth

Starting RPM: 500

Timing (deg): 5.0

Number of Revs: 10

Fuel

☑ Enable

Starting RPM: 500

Temperature Sensor: Coolant Temp

Cranking Time (s)

5.0
2.0

Auto Fill Temperature

Max: 180.0

Min: 40.0

Go

Priming Pulse (ms)

13.0	14.0	13.0	12.0	12.0	12.0	12.0	12.0

After Start Decay (s)

5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

After Start Delay (s)

2.5	4.0	4.0	4.0	2.0	2.0	2.0	2.0

After Start Compensation (%)

130.0	130.0	130.0	130.0	110.0	110.0	110.0	100.0

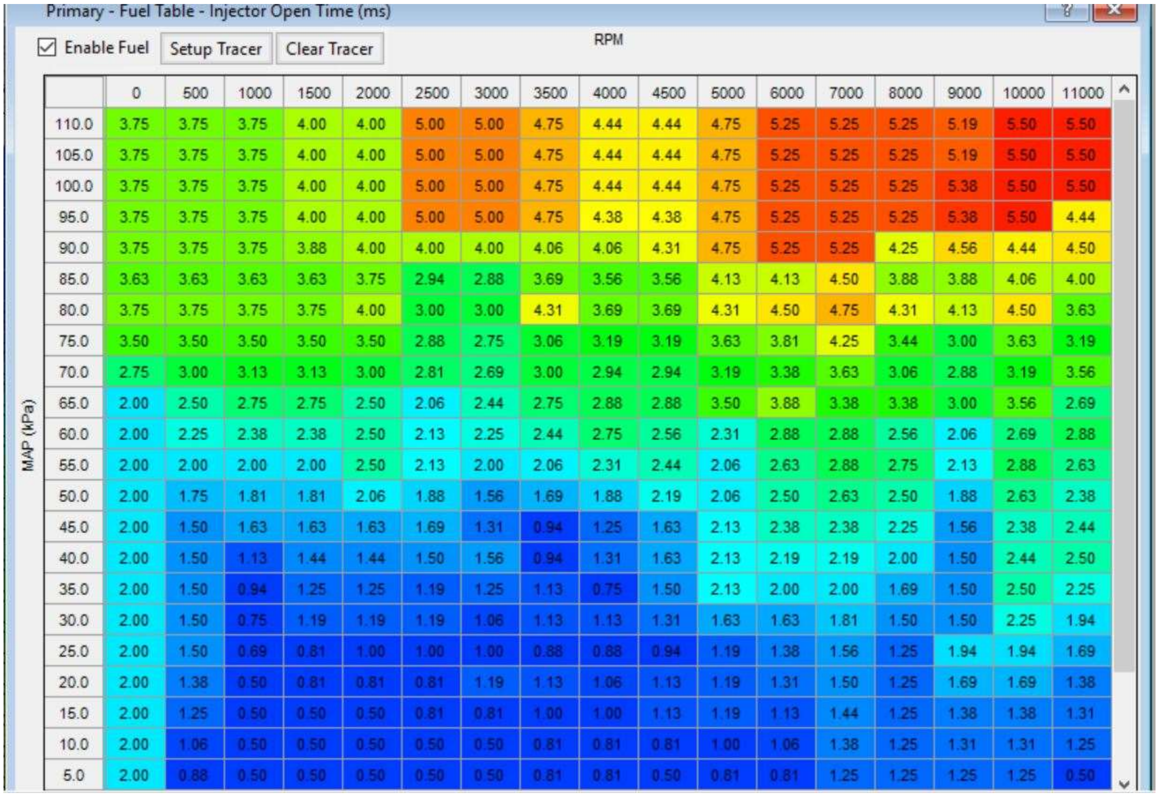
Before Start Compensation (%)

275.0	275.0	250.0	250.0	250.0	225.0	225.0	200.0
325.0	325.0	300.0	300.0	275.0	250.0	250.0	225.0

Temperature (°C)

10.0	20.0	30.0	40.0	50.0	60.0	80.0	90.0

FUEL TABLE



Primary - Fuel Table - Injector Open Time (ms)

☑ Enable Fuel

Setup Tracer

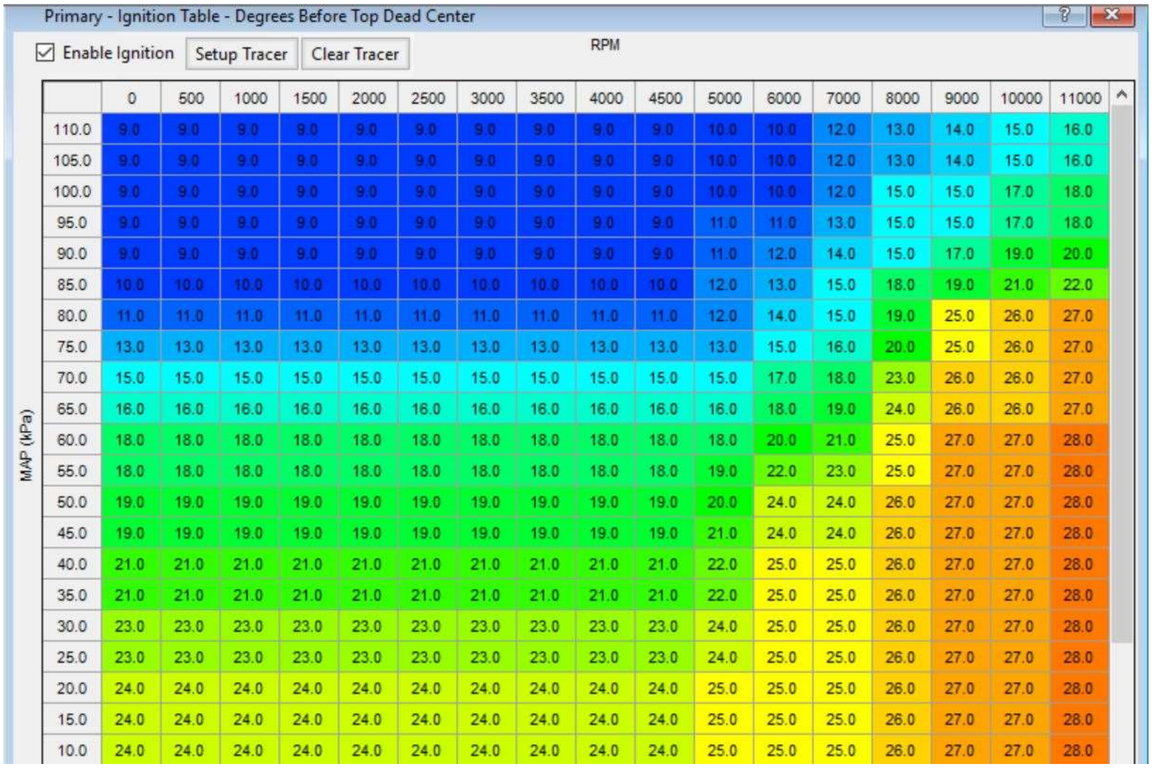
Clear Tracer

RPM

MAP (kPa)

	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000	11000
110.0	3.75	3.75	3.75	4.00	4.00	5.00	5.00	4.75	4.44	4.44	4.75	5.25	5.25	5.25	5.19	5.50	5.50
105.0	3.75	3.75	3.75	4.00	4.00	5.00	5.00	4.75	4.44	4.44	4.75	5.25	5.25	5.25	5.19	5.50	5.50
100.0	3.75	3.75	3.75	4.00	4.00	5.00	5.00	4.75	4.44	4.44	4.75	5.25	5.25	5.25	5.38	5.50	5.50
95.0	3.75	3.75	3.75	4.00	4.00	5.00	5.00	4.75	4.38	4.38	4.75	5.25	5.25	5.25	5.38	5.50	4.44
90.0	3.75	3.75	3.75	3.88	4.00	4.00	4.00	4.06	4.06	4.31	4.75	5.25	5.25	4.25	4.56	4.44	4.50
85.0	3.63	3.63	3.63	3.63	3.75	2.94	2.88	3.69	3.56	3.56	4.13	4.13	4.50	3.88	3.88	4.06	4.00
80.0	3.75	3.75	3.75	3.75	4.00	3.00	3.00	4.31	3.69	3.69	4.31	4.50	4.75	4.31	4.13	4.50	3.63
75.0	3.50	3.50	3.50	3.50	3.50	2.88	2.75	3.06	3.19	3.19	3.63	3.81	4.25	3.44	3.00	3.63	3.19
70.0	2.75	3.00	3.13	3.13	3.00	2.81	2.69	3.00	2.94	2.94	3.19	3.38	3.63	3.06	2.88	3.19	3.56
65.0	2.00	2.50	2.75	2.75	2.50	2.06	2.44	2.75	2.88	2.88	3.50	3.88	3.38	3.38	3.00	3.56	2.69
60.0	2.00	2.25	2.38	2.38	2.50	2.13	2.25	2.44	2.75	2.56	2.31	2.88	2.88	2.56	2.06	2.69	2.88
55.0	2.00	2.00	2.00	2.00	2.50	2.13	2.00	2.06	2.31	2.44	2.06	2.63	2.88	2.75	2.13	2.88	2.63
50.0	2.00	1.75	1.81	1.81	2.06	1.88	1.56	1.69	1.88	2.19	2.06	2.50	2.63	2.50	1.88	2.63	2.38
45.0	2.00	1.50	1.63	1.63	1.63	1.69	1.31	0.94	1.25	1.63	2.13	2.38	2.38	2.25	1.56	2.38	2.44
40.0	2.00	1.50	1.13	1.44	1.44	1.50	1.56	0.94	1.31	1.63	2.13	2.19	2.19	2.00	1.50	2.44	2.50
35.0	2.00	1.50	0.94	1.25	1.25	1.19	1.25	1.13	0.75	1.50	2.13	2.00	2.00	1.69	1.50	2.50	2.25
30.0	2.00	1.50	0.75	1.19	1.19	1.19	1.06	1.13	1.13	1.31	1.63	1.63	1.81	1.50	1.50	2.25	1.94
25.0	2.00	1.50	0.69	0.81	1.00	1.00	1.00	0.88	0.88	0.94	1.19	1.38	1.56	1.25	1.94	1.94	1.69
20.0	2.00	1.38	0.50	0.81	0.81	0.81	1.19	1.13	1.06	1.13	1.19	1.31	1.50	1.25	1.69	1.69	1.38
15.0	2.00	1.25	0.50	0.50	0.50	0.81	0.81	1.00	1.00	1.13	1.19	1.13	1.44	1.25	1.38	1.38	1.31
10.0	2.00	1.06	0.50	0.50	0.50	0.50	0.50	0.81	0.81	0.81	1.00	1.06	1.38	1.25	1.31	1.31	1.25
5.0	2.00	0.88	0.50	0.50	0.50	0.50	0.50	0.81	0.81	0.50	0.81	0.81	1.25	1.25	1.25	1.25	0.50

IGNITION TABLE



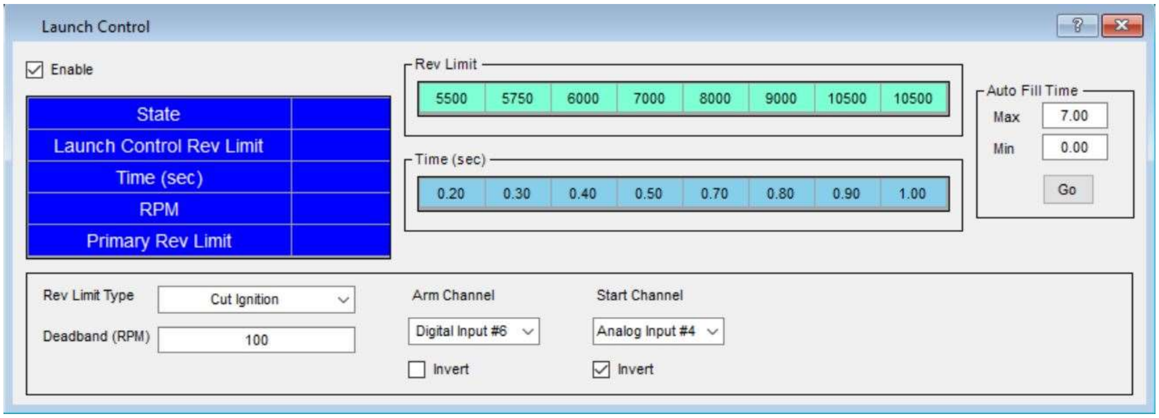
☑ Enable Ignition

RPM

MAP (kPa)

	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000	11000
110.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	10.0	10.0	12.0	13.0	14.0	15.0	16.0
105.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	10.0	10.0	12.0	13.0	14.0	15.0	16.0
100.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	10.0	10.0	12.0	15.0	15.0	17.0	18.0
95.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	11.0	11.0	13.0	15.0	15.0	17.0	18.0
90.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	11.0	12.0	14.0	15.0	17.0	19.0	20.0
85.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	12.0	13.0	15.0	18.0	19.0	21.0	22.0
80.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	12.0	14.0	15.0	19.0	25.0	26.0	27.0
75.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	15.0	16.0	20.0	25.0	26.0	27.0
70.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	17.0	18.0	23.0	26.0	26.0	27.0
65.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	18.0	19.0	24.0	26.0	26.0	27.0
60.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	20.0	21.0	25.0	27.0	27.0	28.0
55.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	19.0	22.0	23.0	25.0	27.0	27.0	28.0
50.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	20.0	24.0	24.0	26.0	27.0	27.0	28.0
45.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	21.0	24.0	24.0	26.0	27.0	27.0	28.0
40.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	22.0	25.0	25.0	26.0	27.0	27.0	28.0
35.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	22.0	25.0	25.0	26.0	27.0	27.0	28.0
30.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	24.0	25.0	25.0	26.0	27.0	27.0	28.0
25.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	24.0	25.0	25.0	26.0	27.0	27.0	28.0
20.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	25.0	25.0	25.0	26.0	27.0	27.0	28.0
15.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	25.0	25.0	25.0	26.0	27.0	27.0	28.0
10.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	25.0	25.0	25.0	26.0	27.0	27.0	28.0

LAUNCH CONTROL



☑ Enable

State	
Launch Control Rev Limit	
Time (sec)	
RPM	
Primary Rev Limit	

Rev Limit

5500	5750	6000	7000	8000	9000	10500	10500

Time (sec)

0.20	0.30	0.40	0.50	0.70	0.80	0.90	1.00

Auto Fill Time
Max 7.00
Min 0.00

Rev Limit Type: Cut Ignition
Deadband (RPM): 100

Arm Channel: Digital Input #6
☐ Invert

Start Channel: Analog Input #4
☑ Invert

SHIFTER

ELECTRO-PNEUMATIC SHIFTER

- Paintball HPA Carbon bottle 4500 psi 50 Cubic inches
- Paintball HPA Regulator (settled to 80psi)
- Pneumatic valve Festo
- Pneumatic cylinder Festo
- Stock DS450 lever
- 50 ms fuel cut

Validation during 2016 testing season:

- 4500 psi 50 cubic inches is enough for a full endurance