# Document Status

Update Calculations (at the end)

# Executive Summary

# Design Parameters

* Fbp= the force output of the brake pedal assembly
* Fd = the force applied to the pedal pad by the driver
* Pmc = the hydraulic pressure generated by the master cylinder
* Amc = the effective area of the master cylinder hydraulic piston
* Pcal = the hydraulic pressure transmitted to the calliper
* Fcal = the one-sided linear mechanical force generated by the caliper
* Acal = the effective area of the calliper hydraulic piston(s) found on one half of the calliper body
* Fcl = the clamp force generated by the caliper
* Ffriction = the frictional force generated by the brake pads opposing the rotation of the rotor
* μbp = the coefficient of friction between the brake pad and the rotor
* Tr = the torque generated by the rotor
* Reff = the effective radius (effective moment arm) of the rotor (measured from the rotor centre of rotation to the centre of pressure of the caliper pistons)
* Ftire = the force reacted between the tire and the ground (assuming friction exists to support the force)
* Ftotal = the total braking force reacted between the vehicle and the ground (assuming adequate traction exists)
* av = the deceleration of the vehicle
* mv= the mass of the vehicle= 500 Kg
* Ds = the stopping distance of the vehicle
* Vv =velocity of moving vehicle
* Vf = the front axle vertical force (weight)
* Vr = the rear axle vertical force (weight)
* WT = the absolute weight transferred from the rear axle to the front axle
* g = the acceleration due to gravity (effectively expressing av in units of g’s)
* hCG = the vertical distance from the CG to ground.
* Vf,d = the front axle dynamic vertical force for a given deceleration
* Vr,d = the rear axle dynamic vertical force for a given deceleration
* Ftires,f = the combined front tire braking forces
* Ftires,r = the combined rear tire braking forces
* μpeak,f = the maximum effective coefficient of friction between the front tires and the road
* μpeak,r = the maximum effective coefficient of friction between the rear tires and the road

# Braking Calculation

## ASC Requirement

As per ASC2022 10.5.C:

Solar cars must be able to repeatedly stop from speeds of 50 km/h (31 mph) or greater, with an average deceleration, on level wetted pavement, exceeding 4.72 m/s2. Performance shall be demonstrated with mechanical braking only.

For buffer, we have selected the velocity to be 60km/h and the deceleration to 6 m/s2.

## Brake Pedal Force (Fbp)

Fd = the force applied to the pedal pad by the driver = 130 N

l1 = The distance from the brake pedal arm pivot to the output rod clevis attachment

l2 = The distance from the brake pedal arm pivot to the brake pedal pad

= Pedal ratio = 5.1

## Master Cylinder Pressure (Pmc)

MC Bore = 0.625 in = 0.01587 m

Amc = Effective area of the master cylinder = = 1.98 \* 10­-4

## Force generated by caliper piston (Fcal)

Acal = 3in2 = 0.001935 m2

Pcal = Pmc­ = 3348484.84

## Caliper Clamp Load (Fcl)

## Force on disc by brake pads (Ffriction)

## Torque of rotor (Tr)

Reff = Effective rolling radius = 12 in = 0.3048 m

## Force on a tire (Ftire)

Rt = 0.254 m

## Kinetic energy of the vehicle

KE =

## Stopping Distance

F =

ds =

**Deceleration**

av =

v = 0; u = 60km/h = 16.67 m/s

av = = -5.89 m/s^2

CGf  = Distance between front axle to CG = 1.47 m

CGr  = Distance between rear axle to CG = 1.47 m

WB = Distance between front axle to rear axle = 2.94 m

hcg = Height of Centre of gravity = 0.5775 m

V­t = 500 \* 9.8 = 4900 N

## Rear axle vertical force (weight)

## Front axle vertical force (weight)

## Dynamic absolute weight transferred

## Dynamic Vertical Force

Front Axle

Rear Axle

## Effect of weight transfer on Tire Output

Front Tire

Rear Tire

## Maximum Braking Force Produced By axle

Front Axle

Rear Axle

## Breaking Efficiency

# Brake Metering Valve

A brake metering valve controls fluid flow from the master cylinder causing the rear drum brakes to engage just before the front disc brakes (MP Brakes, 2018).

Diagram

Description automatically generated

When the pedal is pressed:

1. Pressure created in the master cylinder causes fluid to flow through the brake lines.\
2. Fluid flow to the front calipers is blocked by the metering valve.This allows more pressure to build in the lines gong to the rear drums.
3. Around 75-125 psi,

* The wheel cylinders in the rear drums begin to overcome the return springs and move the brake shoes.
* The fluid pressure forces the metering valve piston to compress the spring.

1. The piston opens the valve and pressurized fluid is sent to the front calipers.

When the pedal is released and pressure is reduced, the spring returns the piston and valve to the closed position. (Summit Racing, 2020)

# Residual Valves

A residual Pressure valve is a special type of one-way check valve. They are used to keep a small amount of pressure in the brake lines. This reduces pedal travel and helps the brakes engage more quickly.

The two main types of residual valves are of 10-psi and 2-psi.



For most disc brake applications, such as in our project, a residual valve is not required. However, a 2-psi valve is used when the master cylinder is lower than the calipers. (Summit Racing, 2020a)

# Combination Valve

Its is a single unit that performs multiple functions to achieve the goal of balanced braking.

A picture containing text, device, caliper

Description automatically generated

Most combination valves perform 3 functions:

1. The Proportioning Valve keeps the rear brakes from locking up during a panic stop.
2. The Metering Valve delays the front brakes long enough for the fluid pressure to overcome the rear brake return springs.
3. A pressure switch sends an electrical signal. (Summit Racing, 2020b)

# Pressure Differential Valve

The pressure differential valve is the device that alerts you if you have a leak in one of your brake circuits. The valve contains a specially shaped piston in the middle of a cylinder. Each side of the piston is exposed to the pressure in one of the two brake circuits.

As long as the pressure in both circuits is the same, the piston will stay centered in its cylinder. But if one side develops a leak, the pressure will drop in that circuit, forcing the piston off-center. This closes a switch, which turns on a light in the instrument panel of the car. The wires for this switch are visible in the picture above.

MP Brakes. (2018, December 5). *Brake Valve Overview*. Master Power Brakes. https://techtalk.mpbrakes.com/how-to-series/brake-valve-overview#:%7E:text=residual%20valve%20is%20used%20to,down%20into%20the%20master%20cylinder.

Summit Racing. (2020a, July 9). *What is a residual valve?* Summit Racing Equipment. https://help.summitracing.com/app/answers/detail/a\_id/5297/%7E/what-is-a-residual-valve%3F

Summit Racing. (2020b, July 21). *What is a brake combination valve?* Summit Racing Equipment. https://help.summitracing.com/app/answers/detail/a\_id/5144/%7E/what-is-a-brake-combination-valve%3F#:%7E:text=It%20is%20a%20single%20unit,disc%20and%20rear%20drum%20brakes.

Summit Racing. (2020c, July 21). *What is a brake metering valve?* Summit Racing Equipment. https://help.summitracing.com/app/answers/detail/a\_id/5159/%7E/what-is-a-brake-metering-valve%3F#:%7E:text=A%20brake%20metering%20valve%20is,as%20a%20%E2%80%9Cmetering%20block.%E2%80%9D