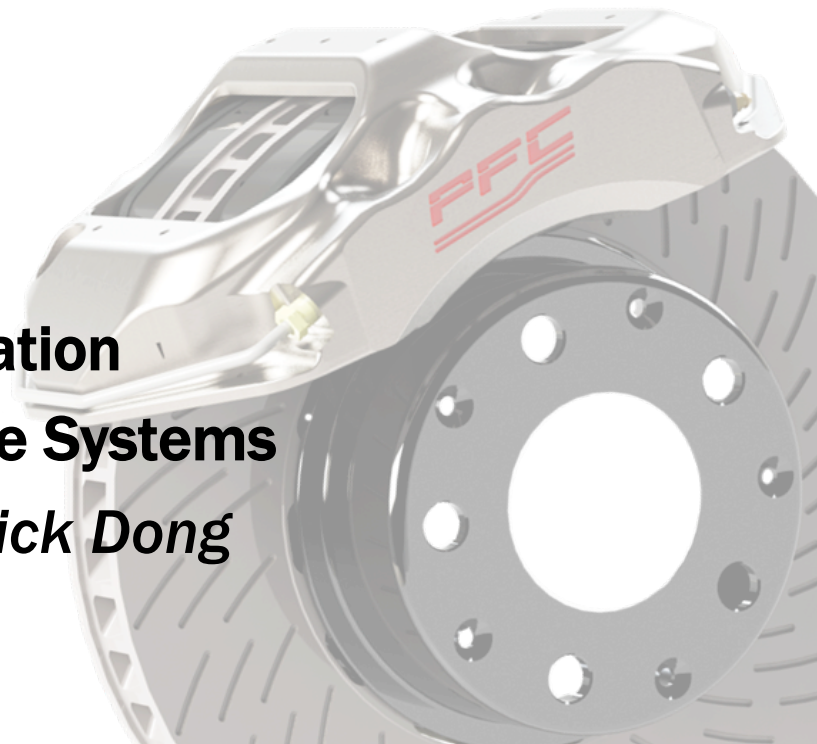




Brake Presentation
Racing and ABS Style Systems
Presented by: Darrick Dong



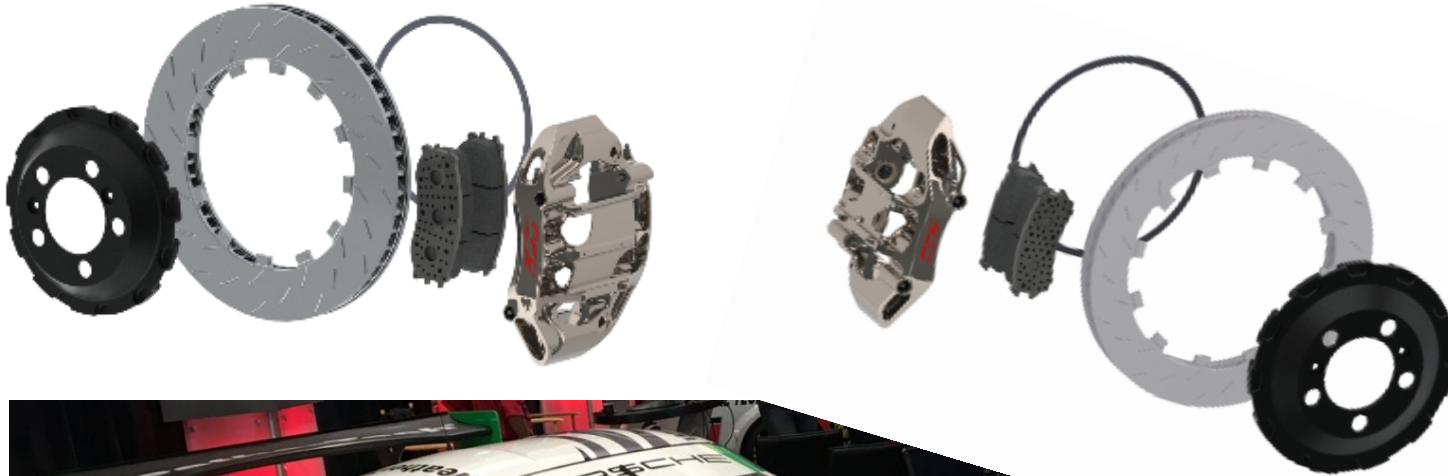
Porsche 981 Cayman GT4CS Technical Brake Seminar





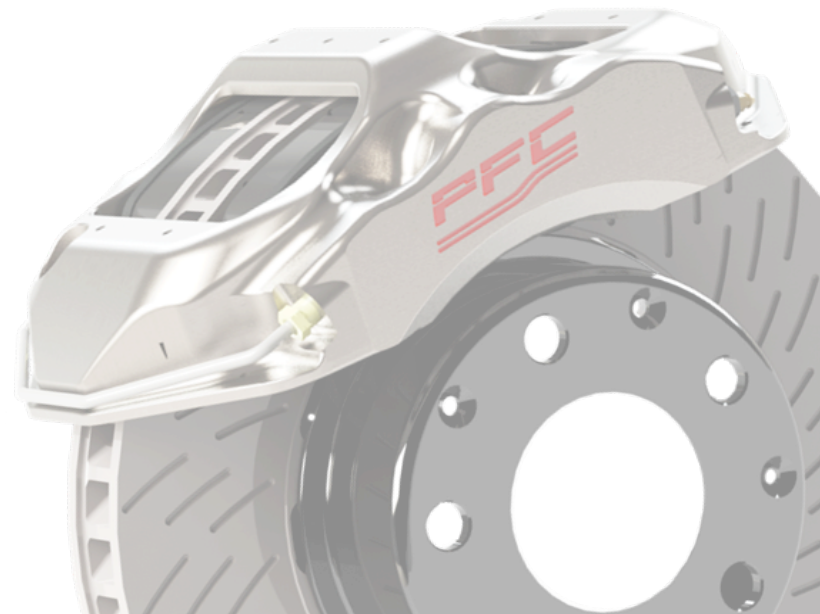
Brake Packages GT3R and Cayman 981 GT4CS

What Can We talk about?



-Glossary of Terms

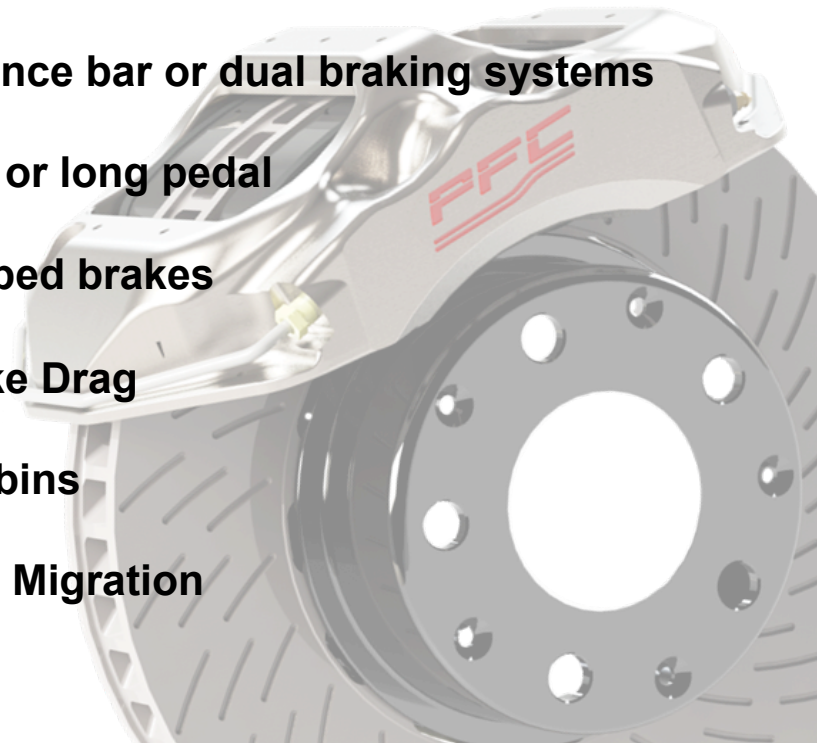
- Assisted Brake Booster Master Cylinder**
- Balance Bar Setup and Maintenance**
- ABS strategies**
- Brake System Bleeding**
- Brake Pads**
- Discs**
- Calipers**
- Proportioning Valves**



PFC Racing Brake Terms

BRAKES

1. Bite
2. Torque
3. Mu
4. Release
5. Feel
6. Threshold braking
7. Race ready
8. Pre-bedded or Dyno-bedded
9. Transfer layer
10. Oxidation layer
11. Hard, Medium, and Soft brake pads
12. Brake Fade
13. Boiled brake fluid
14. Knock-back or Knock-off
15. Judder or brake shake
16. Balance bar or dual braking systems
17. Soft or long pedal
18. Warped brakes
19. Brake Drag
20. Bobbins
21. Bias Migration





981 GT4CS Standard master cylinder and booster

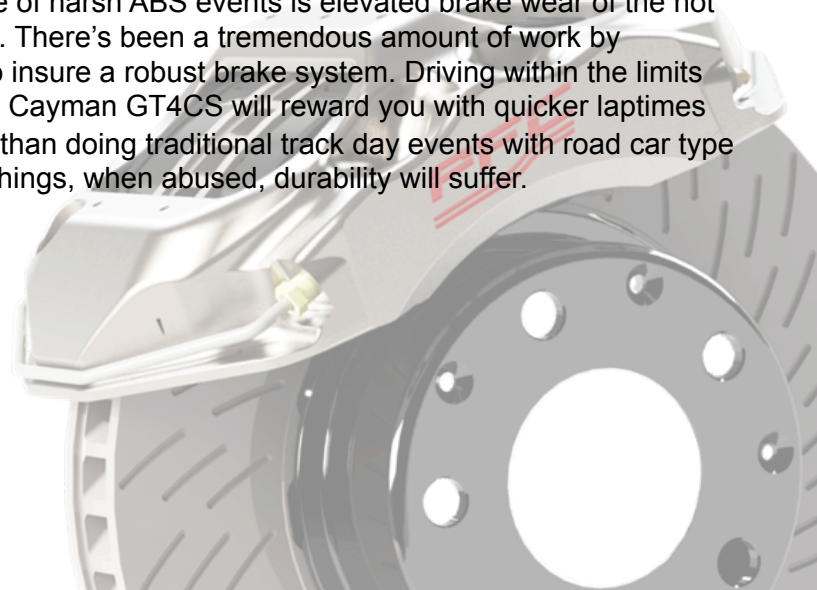
Purpose:

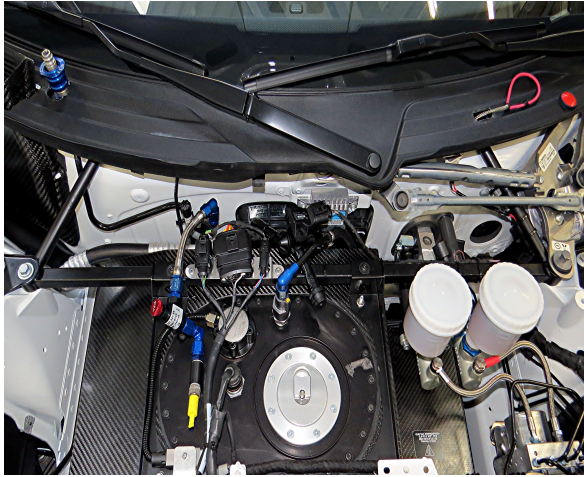
Much thought and testing has gone into the production master cylinder and booster assembly as to its output and “jump-in” strategies and as a system has been optimized to work with the updated Porsche Motorsports ABS and the pure racing brake GT3 Cup hot end brake components.

“Jump-in” is the assisted apply in the brake system to reduce driver effort and add “bite” to the braking event. The system is optimized to reward smooth driver inputs. You will notice how quickly the pedal firmness increases at the apply for great feel for threshold braking.

It is not necessary to “attack” the brakes when driving deep into the braking zones. In fact, attacking the brake pedal with this package will deteriorate your lap times as the ABS reactive mode if too harsh in its magnitude will simply over-slow you and will take away tire grip and upset the car’s platform. Effectively, attacking the brakes will be inducing brake understeer and negatively affect corner exit speed. Smooth is fast.

The other consequence of harsh ABS events is elevated brake wear of the hot end brake components. There’s been a tremendous amount of work by Porsche Motorsports to insure a robust brake system. Driving within the limits of the grip model of the Cayman GT4CS will reward you with quicker lap times and longer brake wear than doing traditional track day events with road car type brakes. But like many things, when abused, durability will suffer.





Brake Balance Bar User Notes

Purpose:

The function of the balance bar is to adjust the distribution of pedal force between two master cylinders. This is accomplished by changing the location of the balance bar pivot towards one master cylinder pushrod or the other. If the pivot is perfectly centered between the pushrods, the force applied to each master cylinder will be equal. This is called the “neutral position” of the bias adjuster. If the pivot is moved closer to one pushrod or the other, then that master cylinders will receive a higher force that is proportional to the distance between the balance bar pivot point and master cylinder center lines. Porsche Motorsports has adjusted the brake balance to a optimum but more importantly to a safe interface with the ABS and the car’s grip balance.

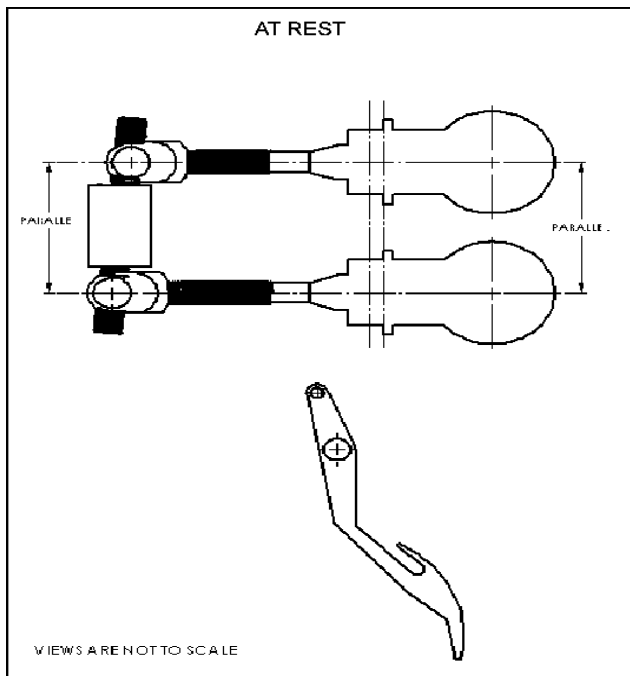
The added benefit is Porsche designed the balance bar which comes from the 991 GT3 Cup is increased pedal firmness and added ‘feel’ for threshold braking. This helps with reducing ABS events and allows a added capacity for more aggressive driving technique. This is also the preferred package for professional racing events.

- Front master cylinder size=17.8mm
- Rear master cylinder size=17.8mm



PFC BRAKES Balance Bar

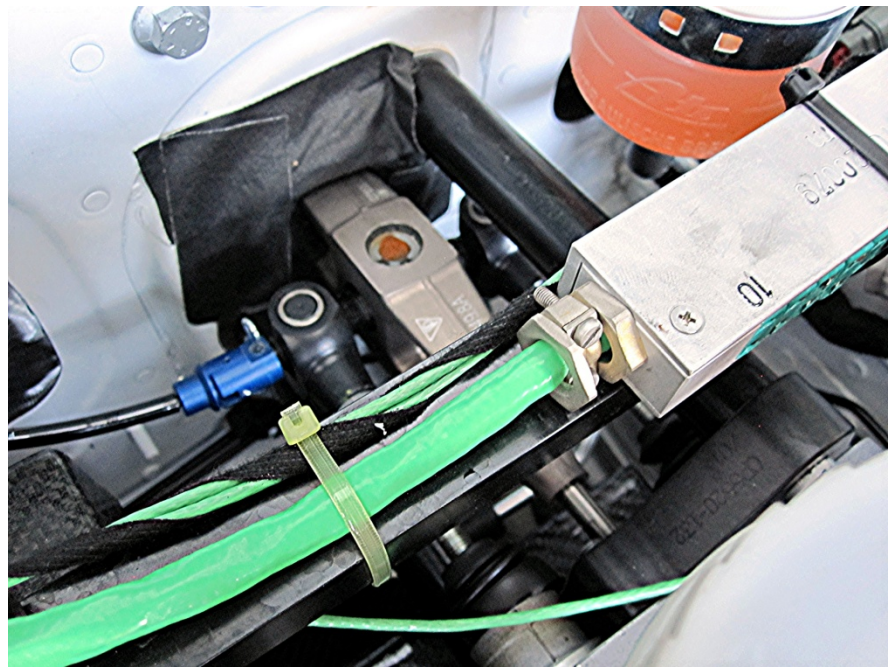
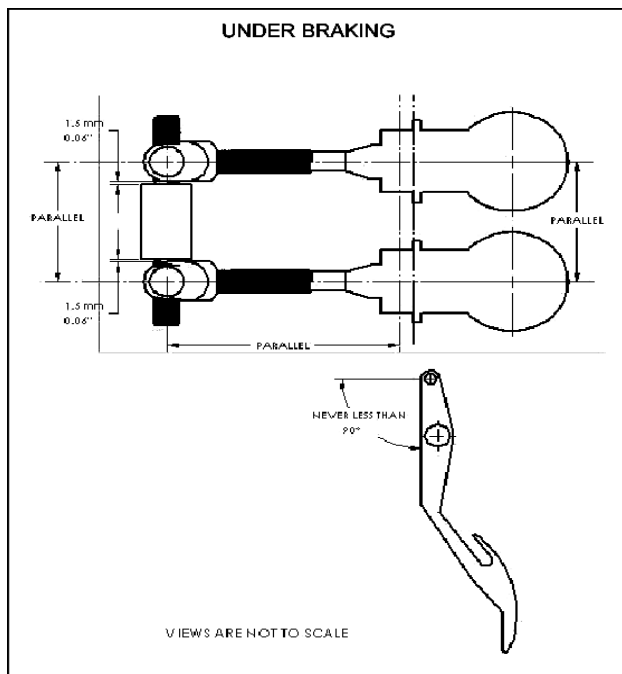
- Balance bar adjusts the distribution of pedal force between two master cylinders.
 - Accomplished by changing the location of the balance bar pivot towards one master cylinder pushrod or the other.
 - If the pivot is perfectly centered between the pushrods, the force applied to each master cylinder will be equal.
- This is called the “neutral position” of the bias adjuster.



Proper Master Cylinder push rod geometry when at rest: 17.8mm front master cylinder push-rod at rest should be 4 - 6.0mm longer than the rear push-rod.

PFC Balance Bar

- If the pivot is moved closer to one pushrod or the other, then that master cylinder will receive a higher force that is proportional to the distance between the balance bar pivot point and master cylinder center lines.
- Being able to adjust the balance bar allows the driver to make incremental adjustments to the braking characteristics of the car (front-to-rear brake bias) and to alter those characteristics to account for changes in fuel load, track conditions and handling of the car.



Proper Master Cylinder push rod geometry when depressed at 70 bar front line pressure: Be sure brake pedal does not go over-center. At 70 bar front pressure output, 49/51% brake bias, front push-rod should have a slight 1.0mm longer length than the rear push-rod to ensure optimized rear brake stability and reduced bias migration.



Key:

Pedalkraft = pedal force,

Bremskraft = brake power

HA = rear axle

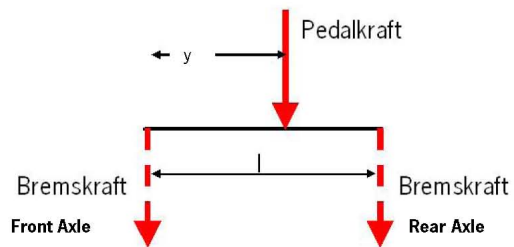
VA = front axle

HA= Front Axle

VA= Rear Axle

3.8.2 Calculating the brake power

The braking power of the front axle brake and the rear axle brake can be calculated as follows:

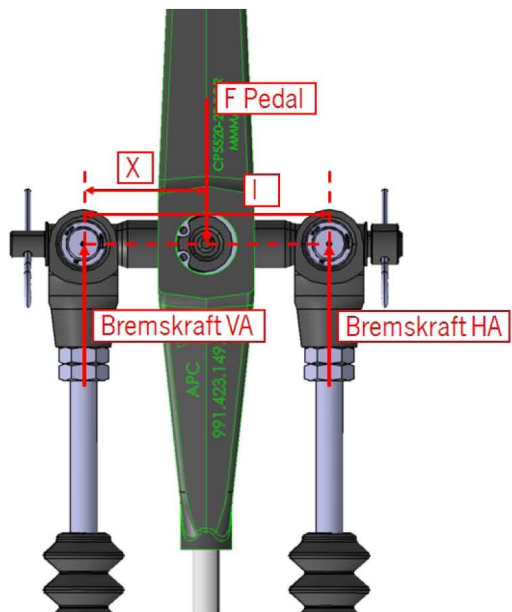


3.8.2.1

$$Bremskraft_{HA} = \frac{Pedalkraft \cdot y}{l}$$

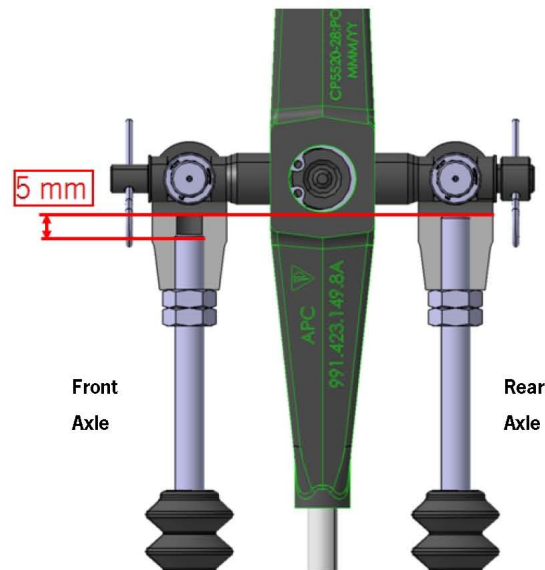
$$Bremskraft_{VA} = Pedalkraft - Bremskraft_{HA}$$

3.8.2.2



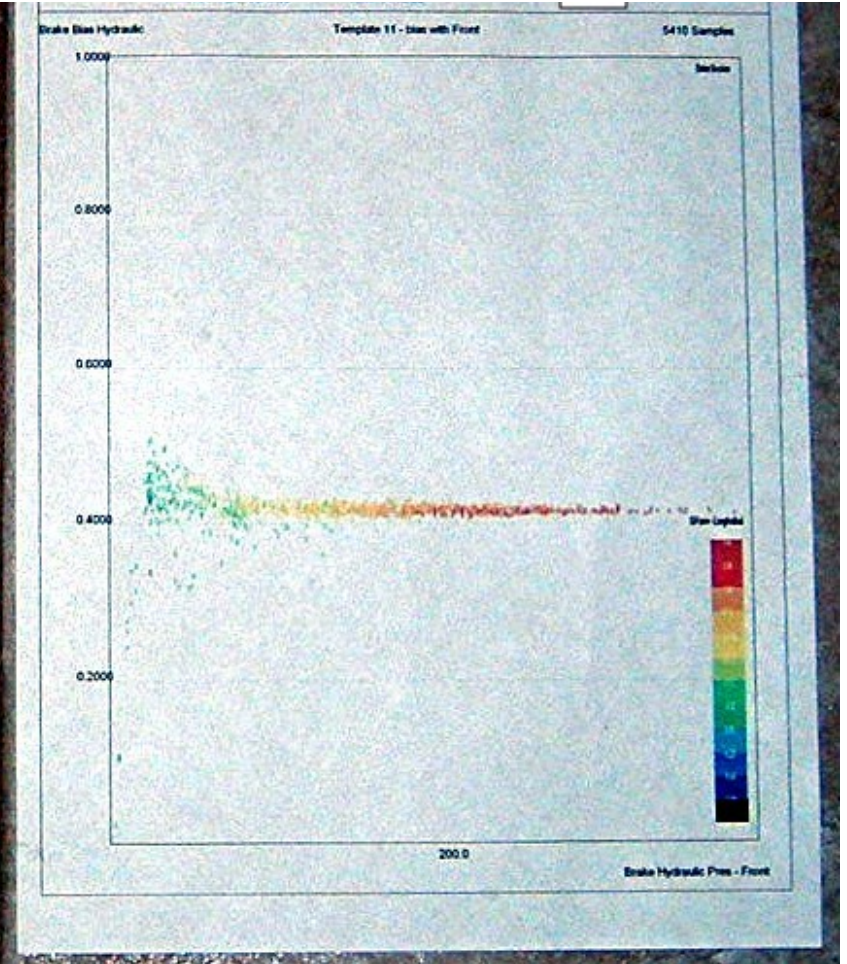
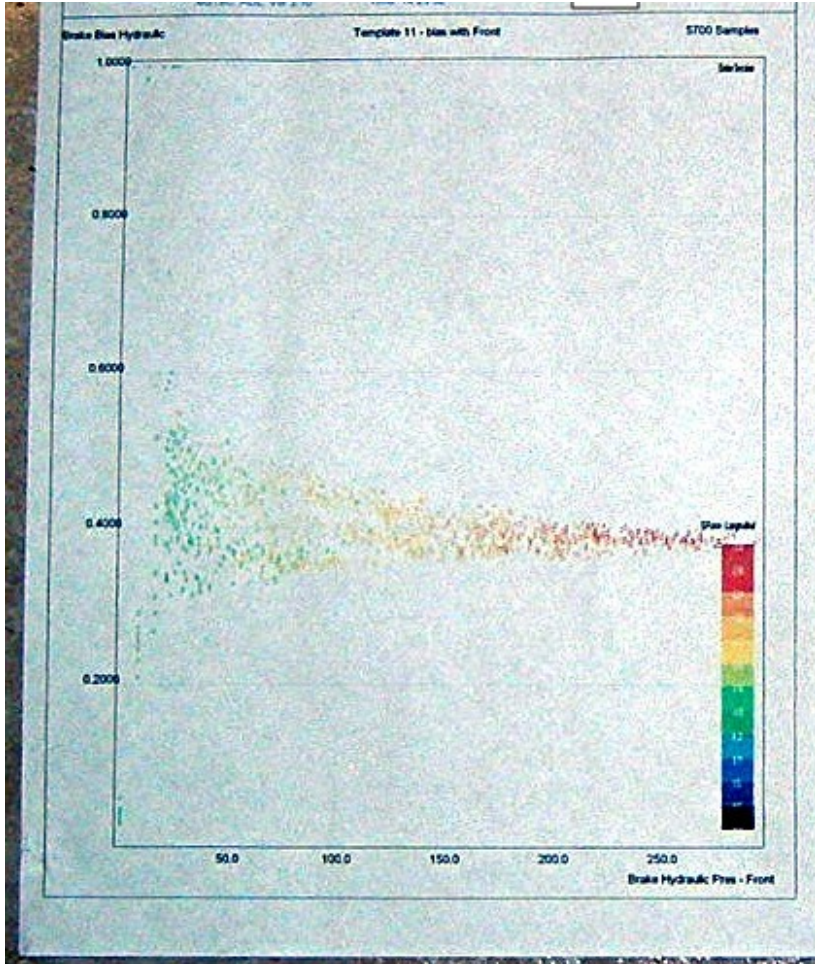
3.8.2.3

Set a clearance of approx. 5 mm between joint thread base and master cylinder threaded rod at the connection of the balance beam to the front axle master cylinder. This ensures that the balance beam is perpendicular to the push rod under load.



3.8.1.2

Bias Migration Graph

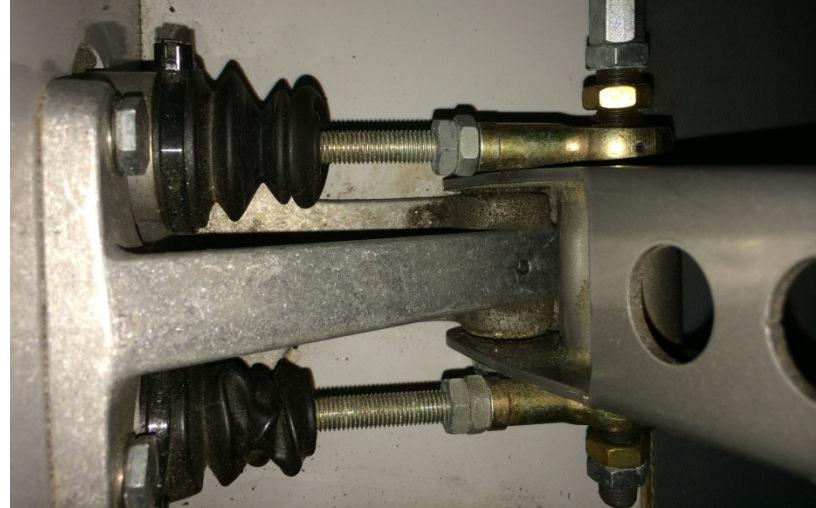


PFC Pedal Assembly BRAKES

Typical floor mounted pedal assembly.

What details need to be addressed with this setup?

- 1) Notice how easy the pushrod rod ends can rub the pedal assembly? This adds a tremendous amount of friction at both apply and release. This friction influences both erratic brake behavior and bias migration.
- 2) Note the reservoirs. Brake fluid level must always be above the bleed screws of the caliper. One should always check brake bleed screw height at full bump.





ABS Braking Events

- What are jump-in strategies?
- What is preemptive strategies?
- What is reactive strategies?





Adjustable ABS:

Purpose:

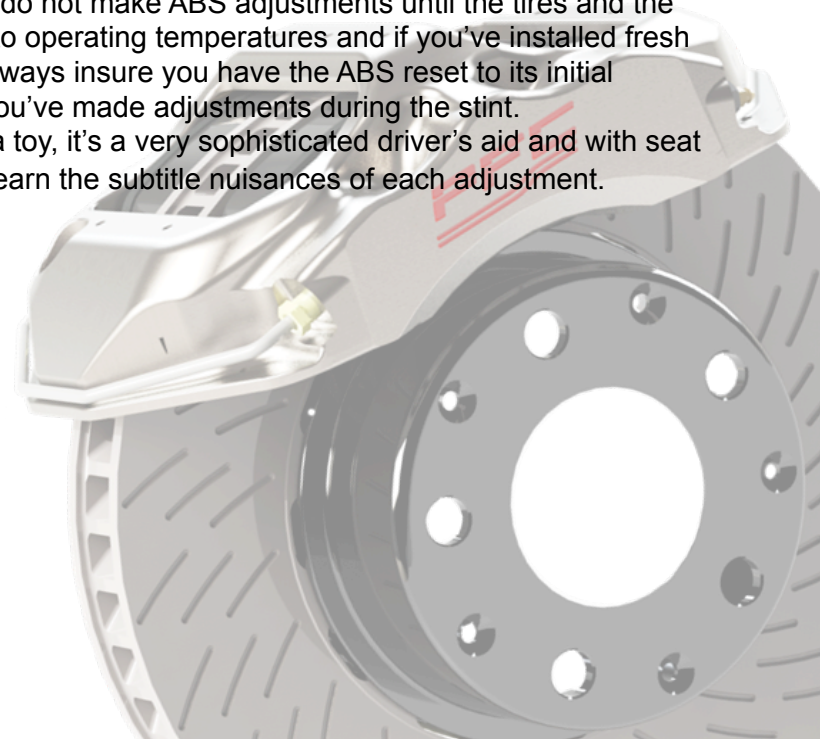
Porsche Motorsports has developed a unique adjustable racing ABS system. This system can be adjusted to compensate for 3 distinct track conditions and 2 different tire configurations, from racing slicks or racing rain tires.

It's important the choice of race tires used on the GT4CS has Porsche Motorsports approval as to the tire configurations and construction. Details like the circumference of the tires have a great deal of influence on the ABS strategies.

On a smooth dry racetrack with racing slicks, setting 3 is a good starting place. The higher the setting number, the more ABS intervention, you always want to strive for the least intrusive ABS strategy. As the track or the tires deteriorate you can then adjust the ABS for those conditions. In wet conditions, setting 10 is a good starting place.

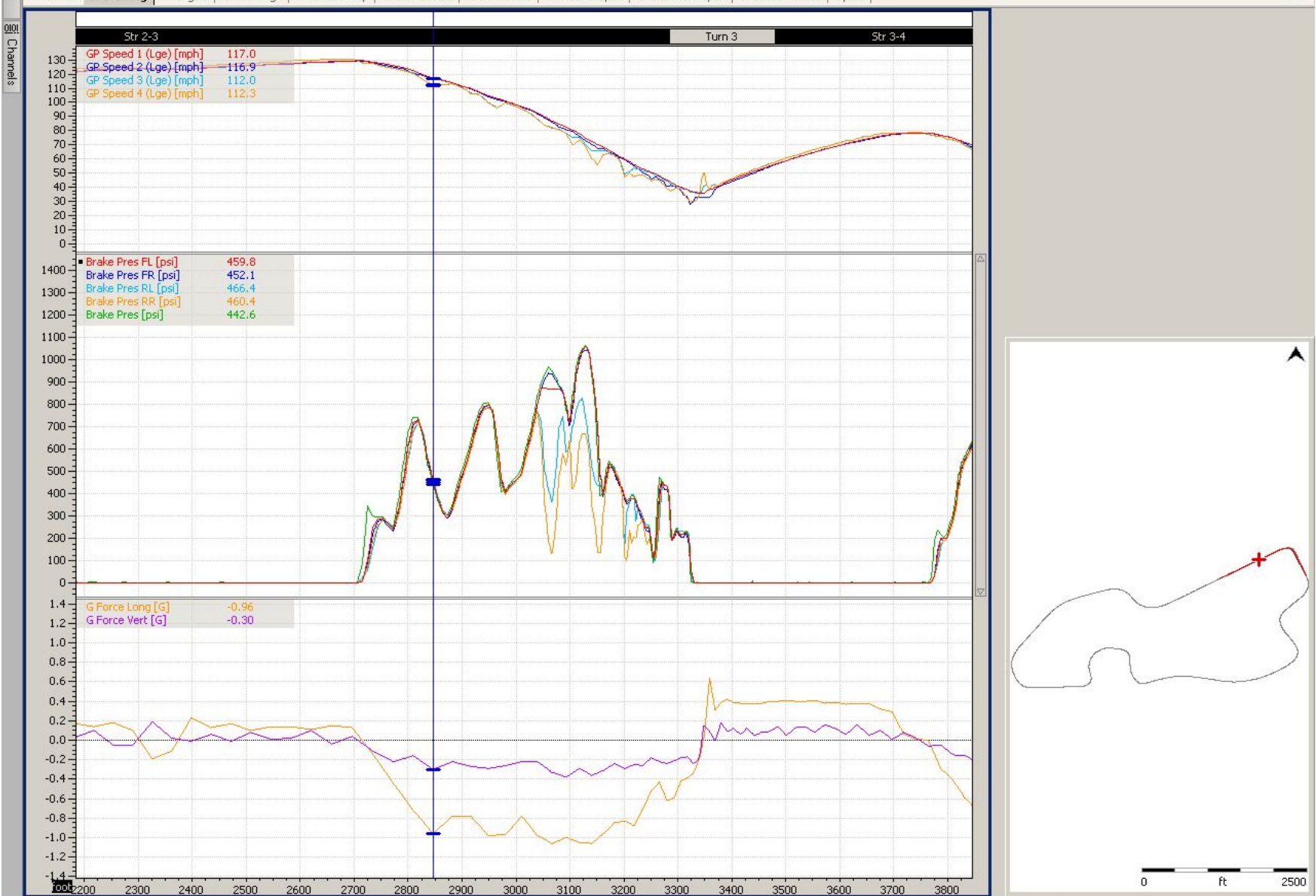
Remember do not make ABS adjustments until the tires and the brakes get to operating temperatures and if you've installed fresh race tires always insure you have the ABS reset to its initial settings if you've made adjustments during the stint.

This is not a toy, it's a very sophisticated driver's aid and with seat time you'll learn the subtle nuisances of each adjustment.





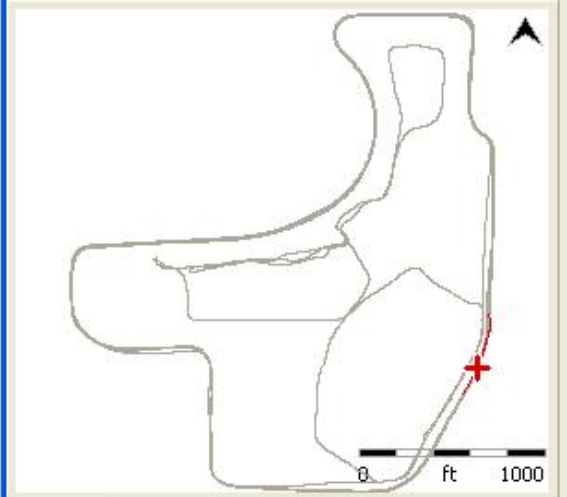
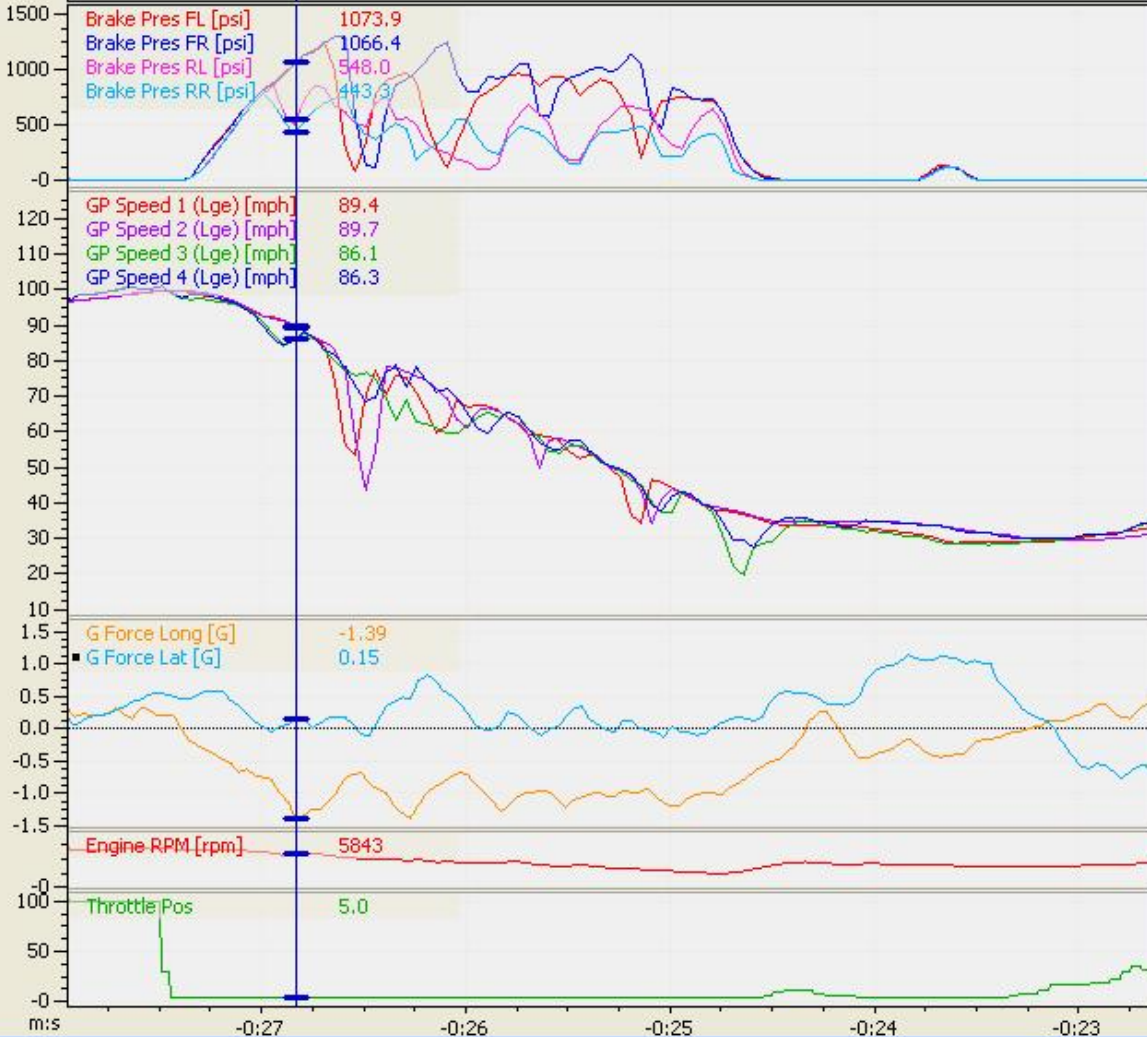
[1:48.050] Lap 7, 9:13:30 AM, 6/2/2013, Ric Bushey, Detroit, [20130602-0139800.Id]
 Laps 1 2 3 4 5 6 7 8 9 10 11 12 P13 14 15 16 In
 1: Driver 2: Braking 3: Engine 4: Fuel / Ign 5: Mixture Map 6: Oil Pressure 7: RPM Histo 8: Track Report 9: Channel Report 0: Section Times Spare



[M] [1:28.775] Lap 6, 9:00:51 PM, 10/4/2013, Ric Bushey, Houston Grand Prix, [20131004-0139802.ld]

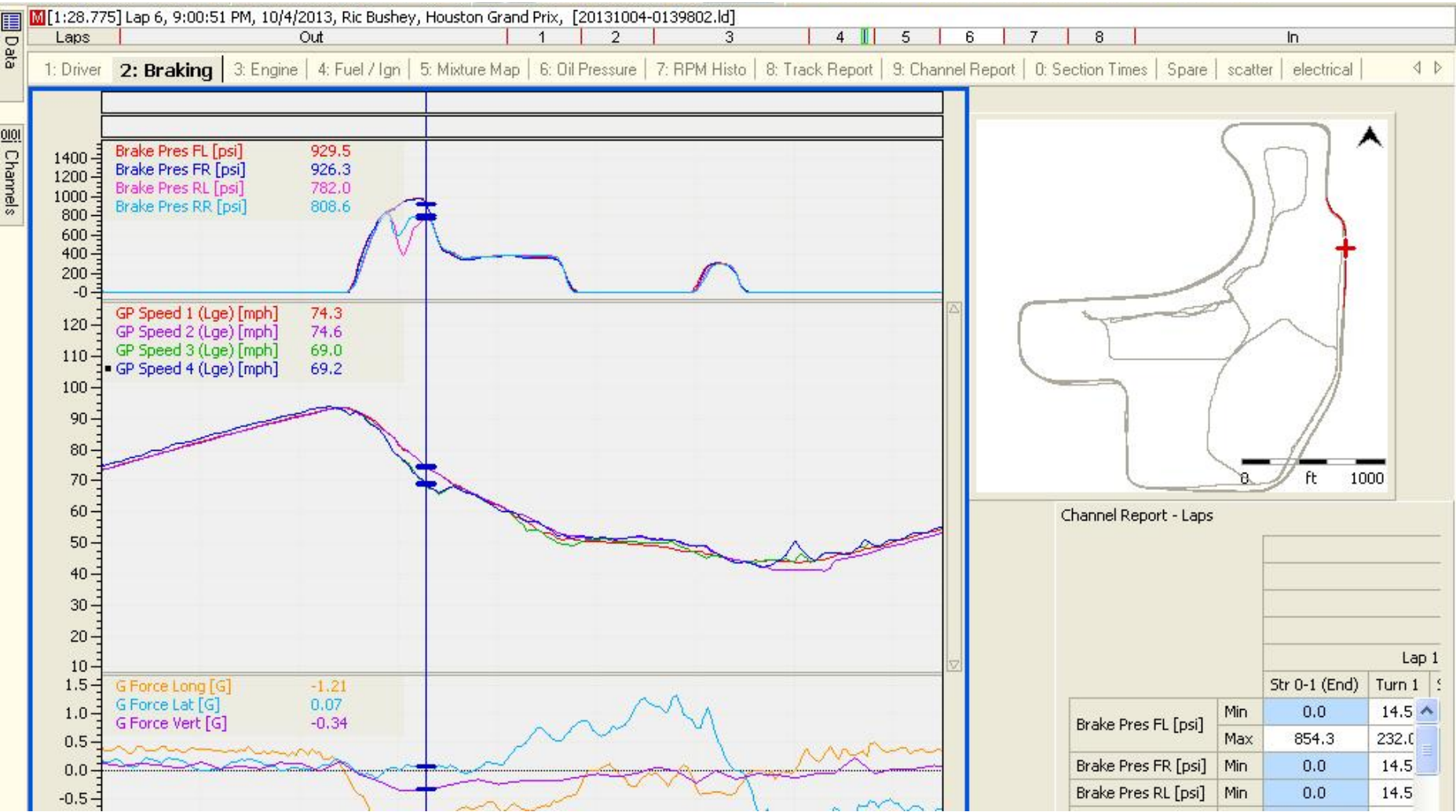
Laps | Out | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | In

1: Driver | **2: Braking** | 3: Engine | 4: Fuel / Ign | 5: Mixture Map | 6: Oil Pressure | 7: RPM Histo | 8: Track Report | 9: Channel Report | 0: Section Times | Spare | scatter | electrical



Channel Report - Laps

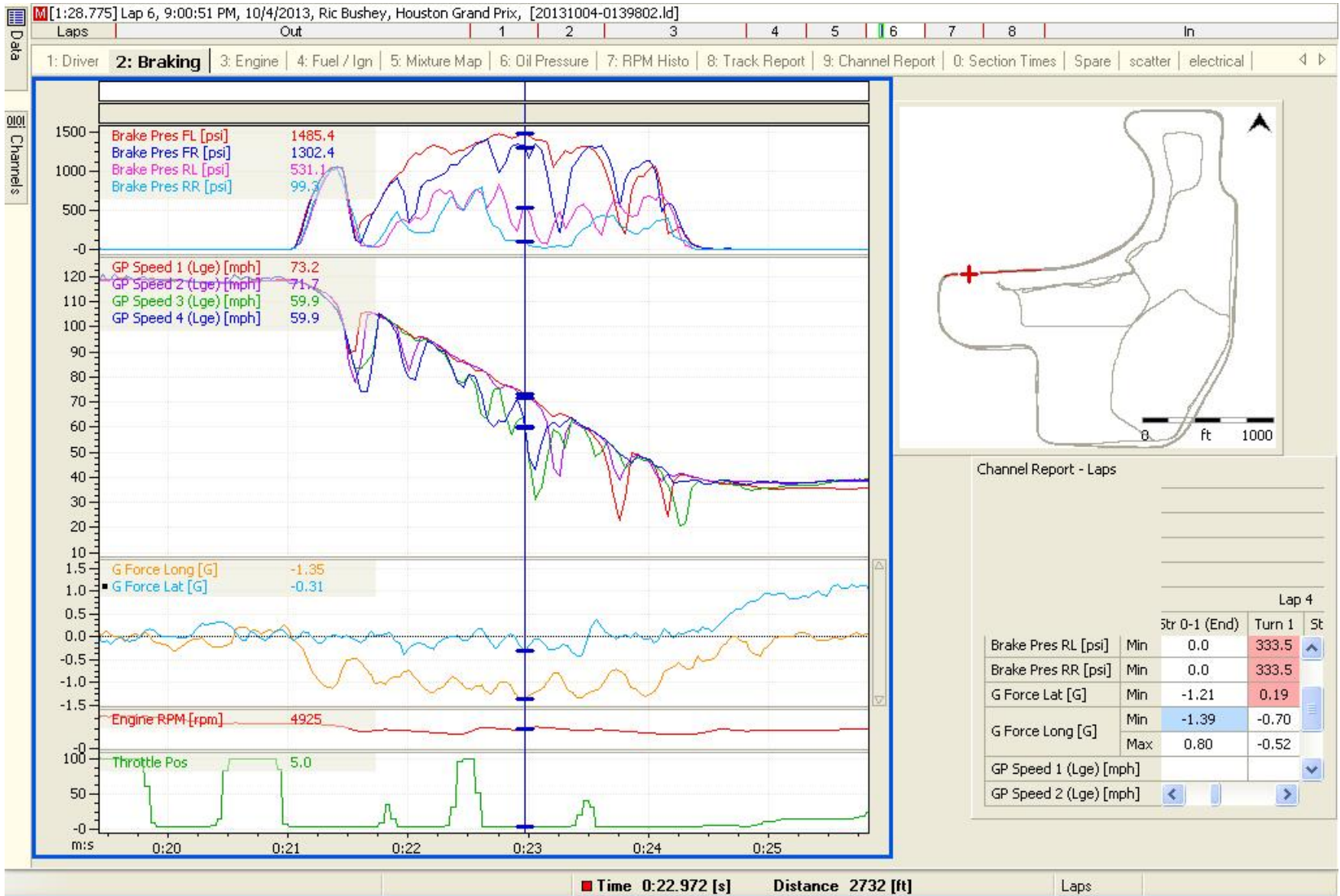
	Lap 4		
	Str 0-1 (End)	Turn 1	St
Brake Pres RL [psi]	Min 0.0	333.5	
Brake Pres RR [psi]	Min 0.0	333.5	
G Force Lat [G]	Min -1.21	0.19	
G Force Long [G]	Min	-1.39	-0.70
	Max	0.80	-0.52
GP Speed 1 (Lge) [mph]			
GP Speed 2 (Lge) [mph]			



Note: The rear pressure dump to shift bias forward. Notice no reactive ABS event.



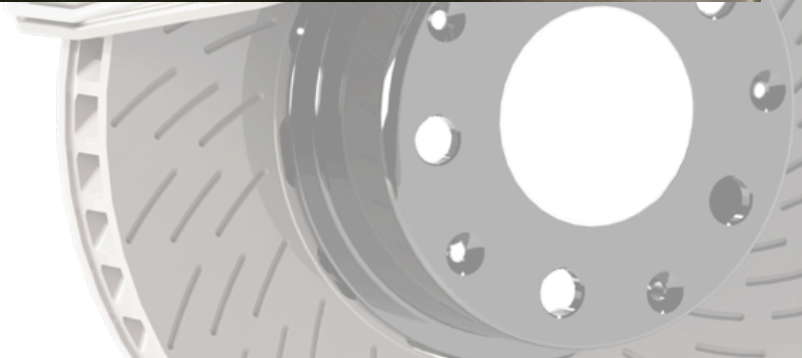
Notice this event shows too aggressive apply method. ABS has an immediate rear psi dump.



Notice how reactive the ABS is controlling wheel slip?

PFC BRAKES **Bleeding Your Brakes**

- Inspect the entire brake system for leaks or damaged parts including the pedal assembly (refer to the Balance Bar setup guide).
- Inspect the master cylinder reservoir cap(s) to see that they are venting properly.
- Begin the bleeding process and refilling the master cylinder reservoir with clean, fresh, PFC RH665 Racing brake fluid.



- It is helpful for the bleed bottle to be clear so a visual inspection of the fluid being purged is possible.
- The use of clear hose that fits tightly around the bleed screws adds a visual aid to bleeding then just relying on what is seen through the bleeder bottle.
- For PFC calipers, this hose should have a 6.0mm ID to fit the PFC bleeders properly. Insure that the bleed hose is inserted deeply enough into the bottle so that the end is submerged in brake fluid to help close the loop.
- With a balance braking system, with two master cylinders, it is important to bleed **front** and **rear** calipers at the same time. Initially fill the calipers with both bleed screws open. Start with the inside bleed screw, then to the outside, then once more to the inside—so long as both systems are bled simultaneously.



Performance Friction RH665 DOT 4 Brake Fluid

...NOT THE SAME AS OTHER RACING BRAKE FLUIDS



Less Compressibility

No mushy pedal—even under the most extreme racing conditions.

Lower Drag

Allowing the brake system to deliver maximum stopping power, faster transition time, and quicker pedal response.

Higher Boiling Point

Guards against vapor lock and gives a rock hard pedal under extreme racing conditions.

Less Viscosity Change

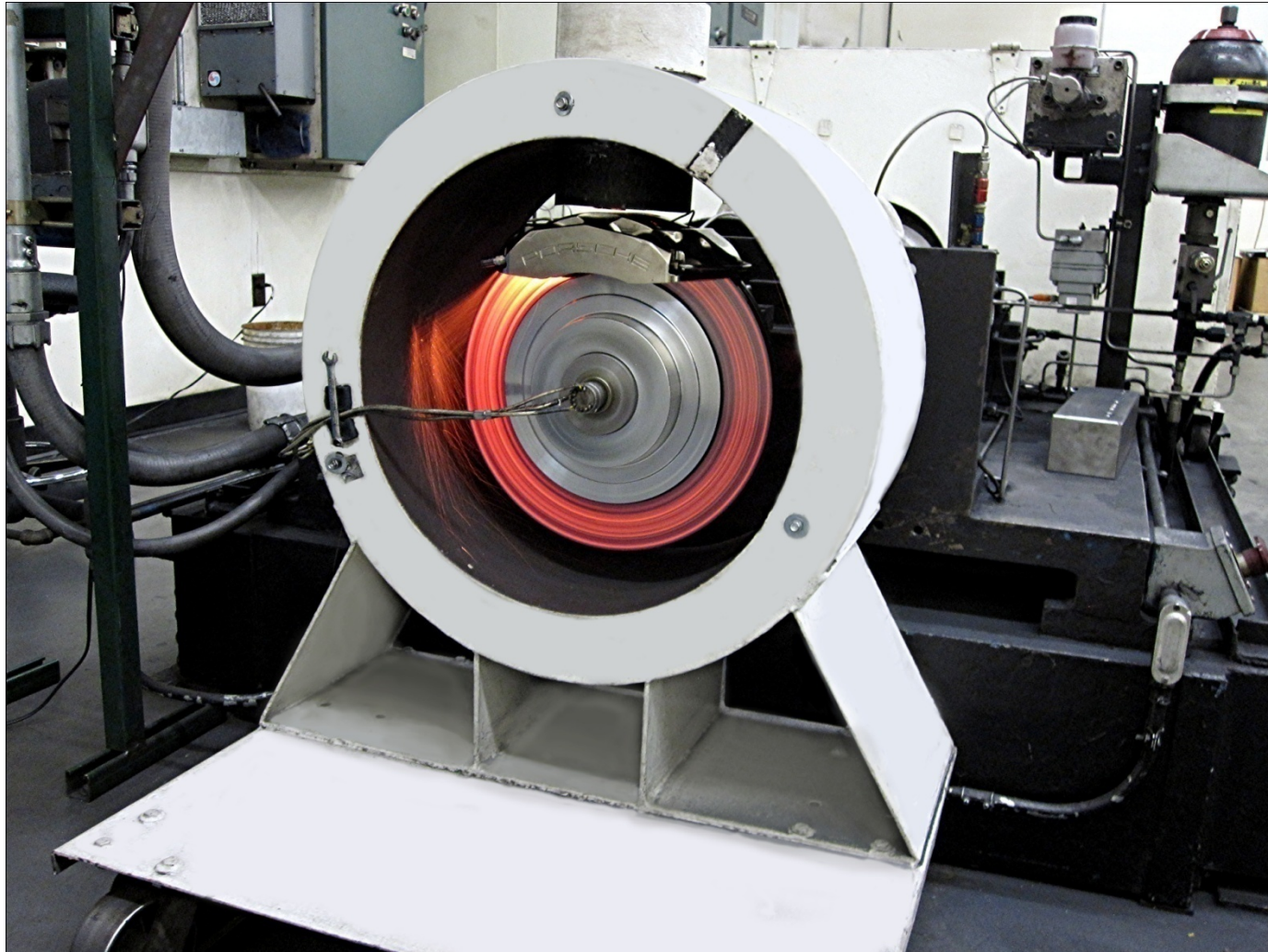
Ensures a good bleed, brake efficiency, pedal return, and prolongs the life of the brake system.

PFC RH665 DOT 4 RACING BRAKE FLUID

Type	Synthetic
Specification	FMVSS 116 DOT 4
ERBP Dry Boiling Point	617°F*
ERBP Wet Boiling Point	383°F*
Viscosity at 100°C	2.6 cSt
Viscosity at - 40°C	1475 cSt
pH	7.12
Density at 20°C	1.073
Compressibility at 100°C	1.01 x 10 ⁻³ MPa ⁻¹

*Guaranteed Minimum Specification

PFC Dynamometer Testing **BRAKES**



NO COMPROMISES™

PFC
BRAKES



Bedding Brake Discs and Pads



PFC Brakes are “Race Ready” and complex bedding procedures are not required, nor recommended.

- On your out lap perform six to ten brake “snubs” with progressively higher pedal force. Be sure to check your mirrors to ensure competitors are at a safe distance. This is also the quickest way to build temperature into the tires.
- It doesn’t matter using new pads with new discs as there is very little green effectiveness with PFC discs and pads. Run the car at 80-90% of speed for one or two more laps. This is to get a sense of brake balance in the car. No cool off laps are required. No taping of brake cooling is needed.
- If three-color rotor paints are used, the green paint should be fully oxidized and the orange paint beginning to oxidize to white.
- A transfer layer of pad material may deposit on the disc; this is the grey/black coloration on the disc friction surface.
- Do **not** sand or machine discs.



Uniform Disc Transfer Layer

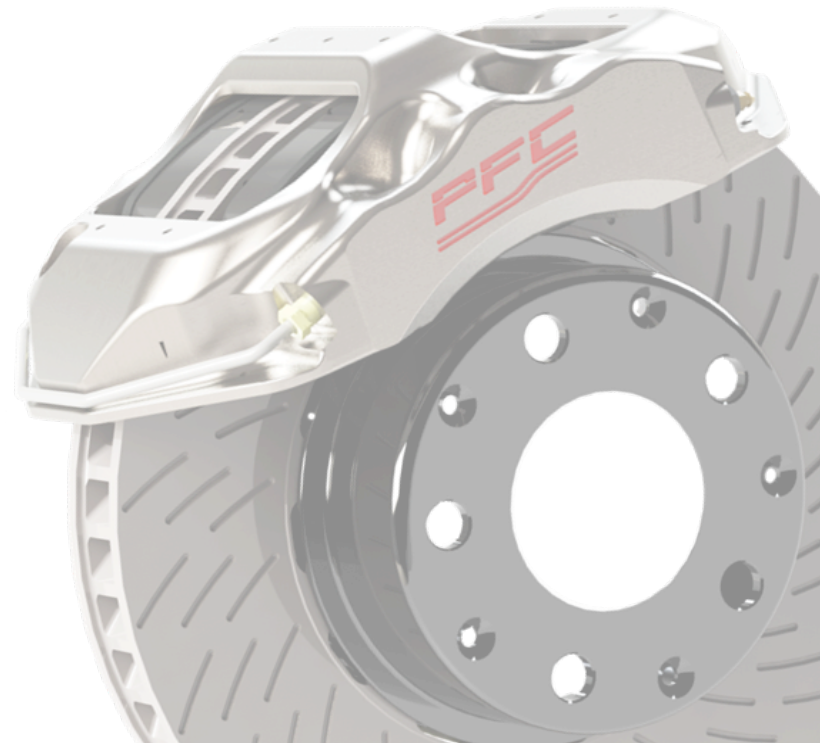




It's the Little Details...

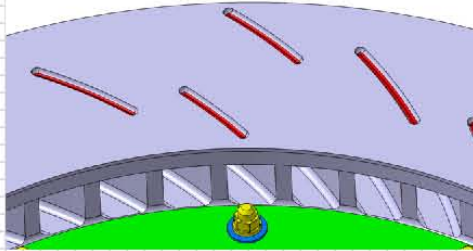


Uniform Temperature Distribution starts with proper force distribution and dynamic symmetry of the hot end components.



Brake disk wear limit

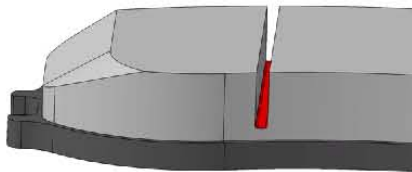
The wear limit is reached when the disk has been worn down to the bottom of the slot (figure 3.7.1.2). The disk should also be replaced if there are cracks up to the edge of the disk that are caused by increased thermal stress.



3.7.1.2

Brake pad wear limit

The wear limit is reached when the disk has been worn down to the bottom of the slot. In addition, the pads should also be replaced if excessive diagonal wear is detected. In this case, the brake pistons of the caliper have to be checked immediately to find out the cause.



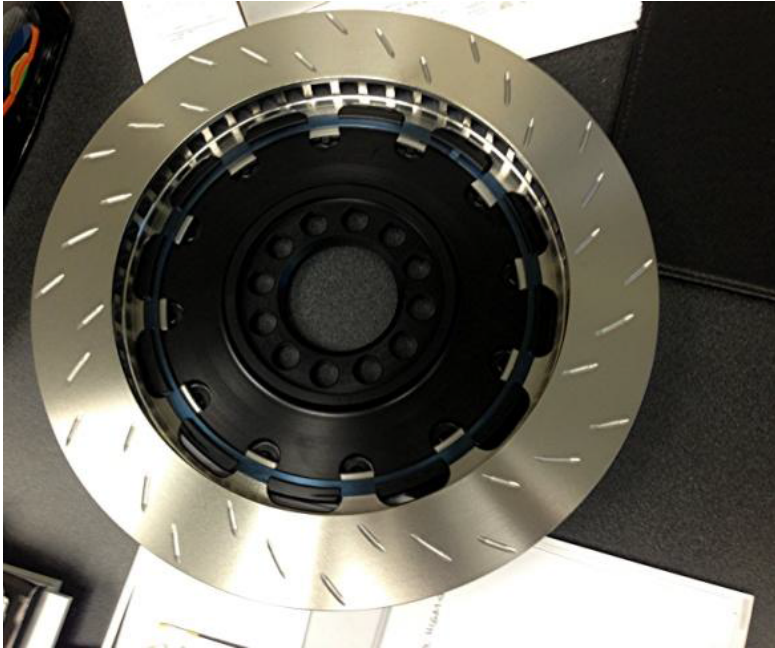
3.7.1.3

Repair instructions

A repair kit with seals and pistons is available, as well as a repair kit containing only seals. Pistons have to be replaced only if they are mechanically damaged. The service life of the seals is 60 hours before they have to be replaced. Under extreme temperature load, they may have to be replaced even earlier. This is indicated by sluggishly moving wheels or stuck pistons. Repair kits can be purchased at Porsche Motorsport.

Refer to the maintenance section, chapter 7.4.7 „Replacing the piston seal rings”

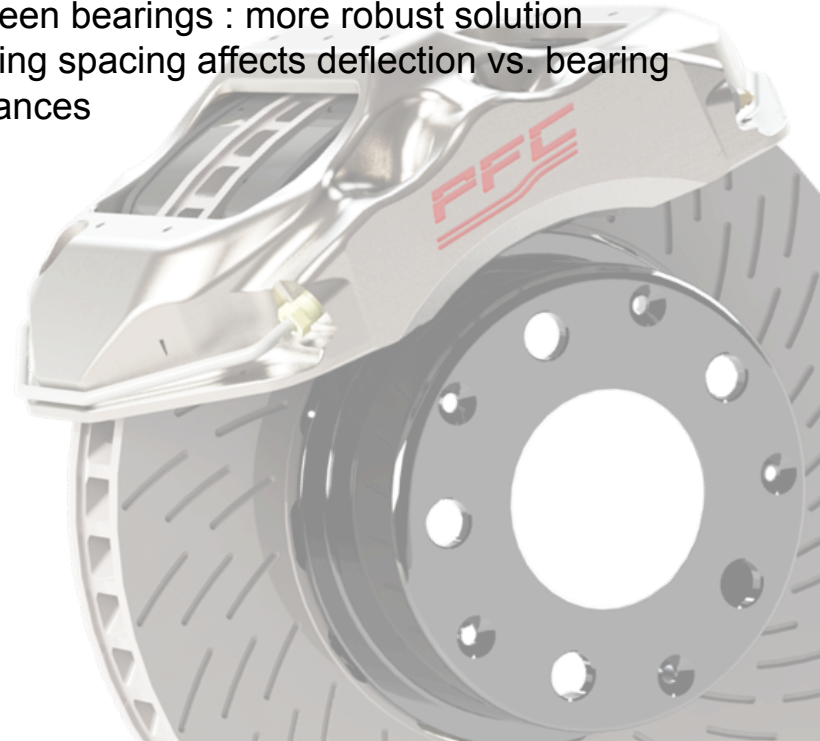
PFC BRAKES V3 Disc Attachment



- Reduces 1st & 2nd order thermal distortion.
- Reduced coning.
- Increase robustness.

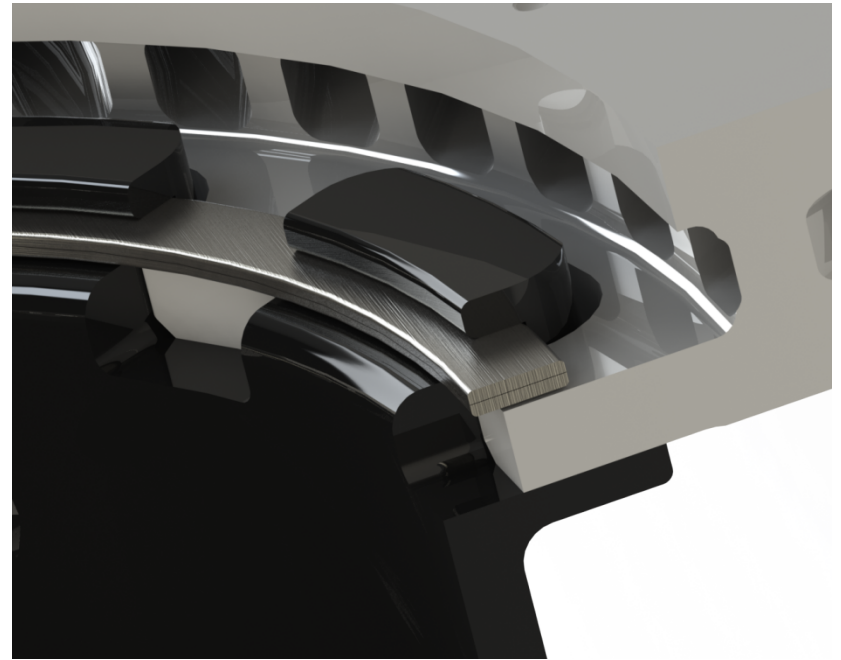
Integrated assembly:

- Allows for larger bearing and more spacing between bearings : more robust solution
- Bearing spacing affects deflection vs. bearing tolerances



PFC Patented V3 Disc Technology BRAKES

The next generation of disc attachment. No Hardware. No Wrenches. No Problem.

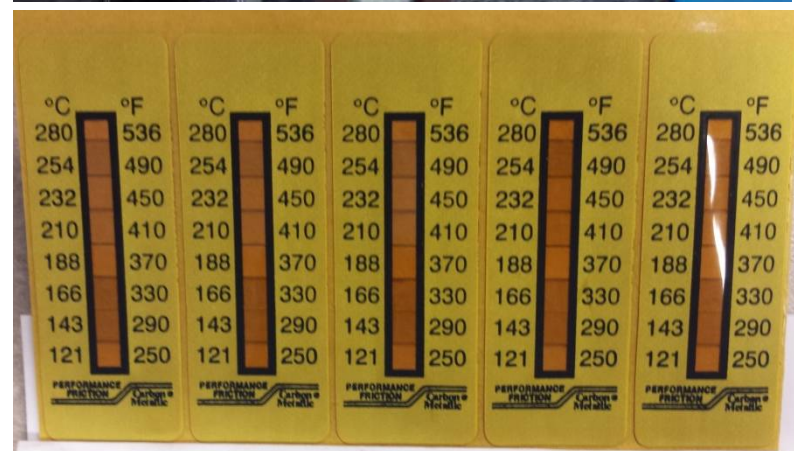


NO COMPROMISES™

PFC
BRAKES

This is a simple, inexpensive method of monitoring brake temperatures without sensors.

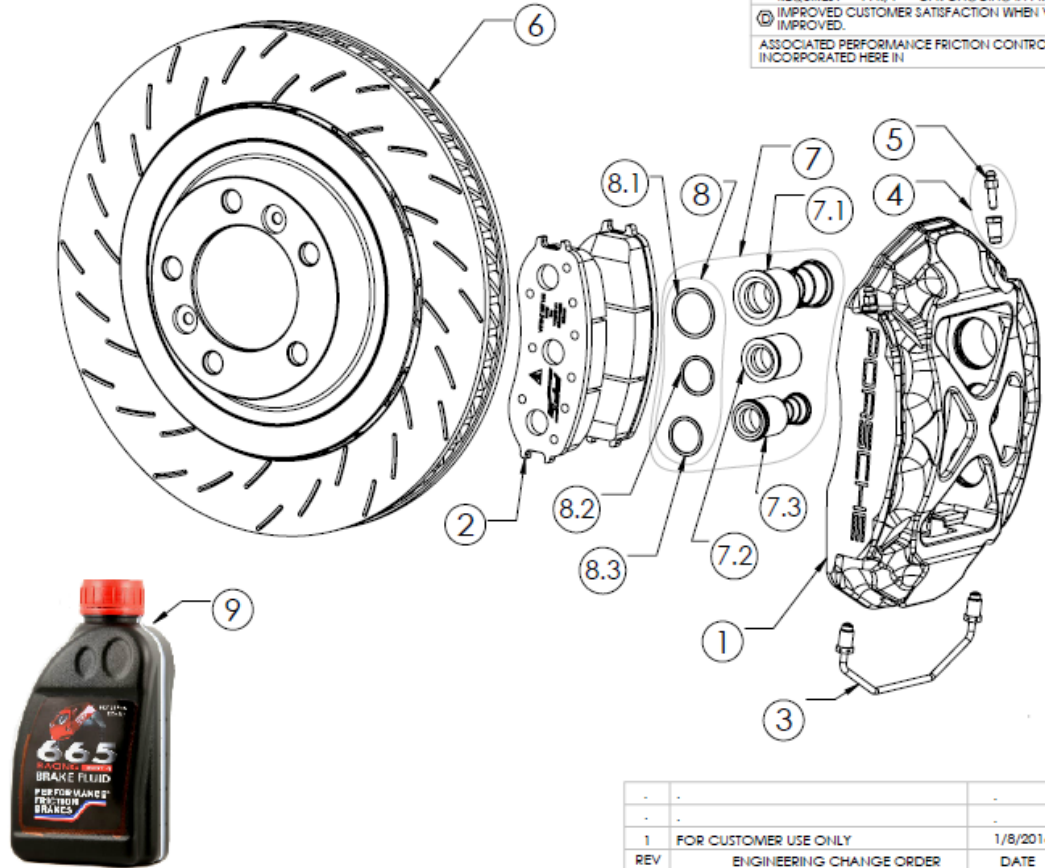
1. Always use the 3 color temperature sensitive paints. These paints can be applied on both discs and the OD of the pads.
2. **Green** = 450°C
Orange = 550°C
Red = 610°C
Goal = do not oxidize 100% of Red
3. Use PFC 032.0007 caliper temperature stickers.
RANGE = 121°C – 280°C
GOAL = Stay under 210°C



Front Package 981 GT4CS

Ⓐ CONTROL CHAR. REQ'D BY FEDERAL REGULATION OR LAW
 Ⓑ CRITICAL CHAR. REQ'D FOR CONT SALE PERFORMANCE
 REQUIRES: PPK, CPK ONGOING IN PROCESS
 Ⓒ MAJOR CHAR. REQ'D FOR PROPER FIT OR FUNCTION
 REQUIRES: PPK, CPK ONGOING IN PROCESS
 Ⓓ IMPROVED CUSTOMER SATISFACTION WHEN VARIATION IS
 IMPROVED.
 ASSOCIATED PERFORMANCE FRICTION CONTROL PLANS TO BE
 INCORPORATED HERE IN

Pos.	Bezeichnung / Description	Pro Ecke/ Per Corner	Teil Nr./Part No.
1	Bremssattel V.A. links / brake caliper front left	1	991.351.427.8A
	Bremssattel V.A. rechts / brake caliper front right	1	991.351.428.8A
2	V.A. Bremsbeläge 22mm 4 Stücke pro sate / front brake pads 22mm 4 pads per set	1	991.351.947.8A
	V.A. Dauerlaufft Bremsbeläge 28mm 4 Stücke pro sate / front endurance brake pads 28mm 4 pads per set	1	991.351.947.8B
3	V.A. übergebende leitung/ cross-over pipe kit front	1	991.351.961.8A
4	Entlüftungsschraube Satz (4 pro sate) / bleed screw kit (4 per set)	1	991.351.919.8A
5	Entlüftungsschraube Satz ohne Einsatz (4 pro sate) / bleed screw kit w/o insert (4 per set)	1	991.355.601.8A
6	V.A. Bremsscheibe links Aufbau 32mm / front left brake disk assembly 32mm	1	981.351.105.8A
	V.A. Bremsscheibe rechts Aufbau 32mm / front right brake disk assembly 32mm	1	981.351.106.8A
7	V.A. Bremssattel Kolbensatz / Front caliper piston kit	1	991.351.959.8A
Kolbensatz/ Piston kit	7.1 36.5 mm Bremskolben / 36.5 mm Brake piston	2	
	7.2 32.0 mm Bremskolben / 32.0 mm Brake piston	2	
	7.3 29.0 mm Bremskolben / 29.0 mm Brake piston	2	
8	V.A. Bremssattel Dichtungssatz/ Front caliper seal kit	1	991.351.960.8A
Dichtungssatz/ Seal kit	8.1 36.5 mm Kolbendichtung / 36.5 mm Piston seal	2	
	8.2 32.0 mm Kolbendichtung / 32.0 mm Piston seal	2	
	8.3 29.0 mm Kolbendichtung / 29.0 mm Piston seal	2	
9	RH665PFC Bremsflüssigkeit 1-500ml / RH665 PFC Brake fluid 1-500ml	N/A	991.355.960.8A



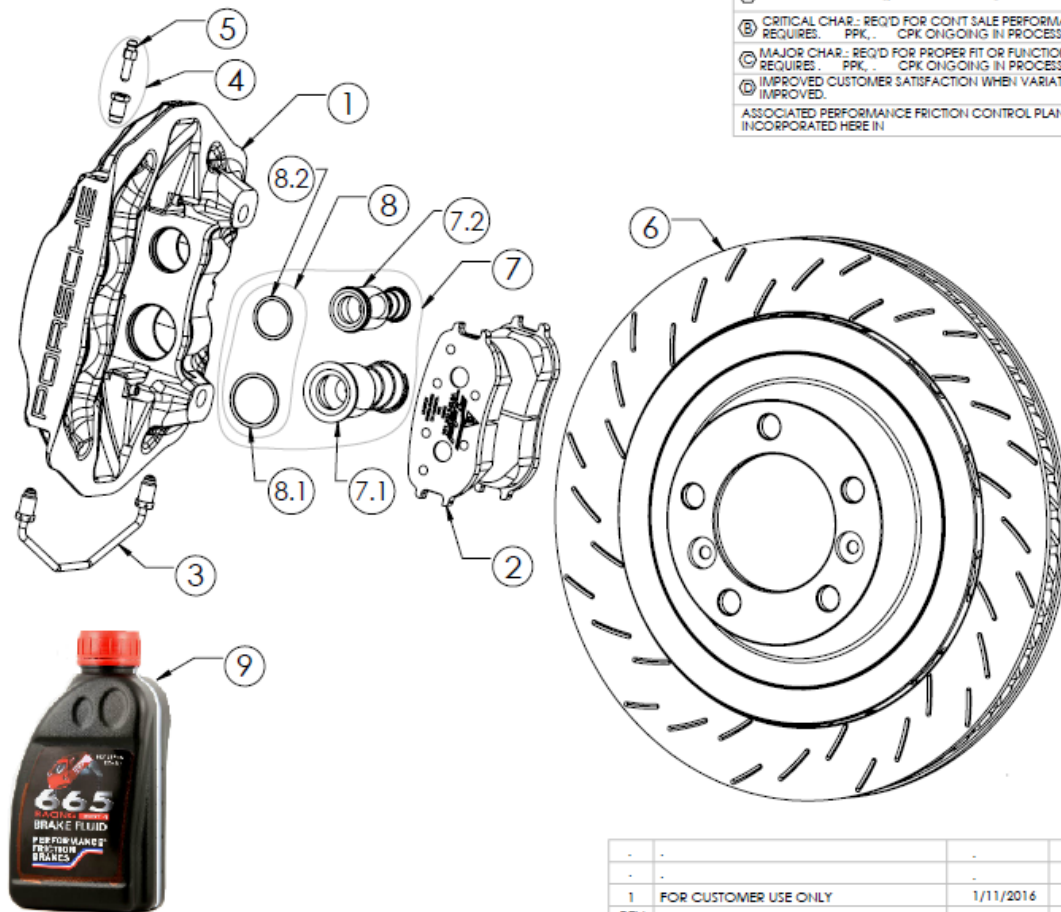
PROPRIETARY AND CONFIDENTIAL
 THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF PERFORMANCE FRICTION. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF PERFORMANCE FRICTION IS PROHIBITED.

APPROVED SIGNATURE		SCALE 1:4	PFC PART NO.
ORIGINATOR	C. WYKER	DIMENSIONS: MILLIMETERS	GT4CS Front Assembly
DESIGN ENG	.	TOLERANCES UNLESS SPECIFIED	DATE
PROCESS ENG	.	1 PLACE DECIMAL ±	01/08/2016
QUALITY	.	2 PLACE DECIMAL ±	FILE NAME
PURCHASING	.	ANGLE (DEG) ±	
PRESIDENT	.	DWG CLASS	DRAWN BY
MATERIAL:	.	C	C. WYKER
			PERFORMANCE FRICTION CORP 83 CARBON METALLIC HIGHWAY CLOVER, SC 29710
			SHEET 1 OF 1

Rear Package 981 GT4CS

(A) CONTROL CHAR.: REQ'D BY FEDERAL REGULATION OR LAW
 (B) CRITICAL CHAR.: REQ'D FOR CONT. SALE PERFORMANCE REQUIRES: PPK, CPK ONGOING IN PROCESS
 (C) MAJOR CHAR.: REQ'D FOR PROPER FIT OR FUNCTION REQUIRES: PPK, CPK ONGOING IN PROCESS
 (D) IMPROVED CUSTOMER SATISFACTION WHEN VARIATION IS IMPROVED
 ASSOCIATED PERFORMANCE FRICTION CONTROL PLANS TO BE INCORPORATED HERE IN

Pos.	Bezeichnung / Description	Pro Ecke/ Per Corner	Teil Nr./Part No.
1	Bremssattel H.A. links / brake caliper rear left	1	991.352.427.8A
	Bremssattel H.A. rechts / brake caliper rear right	1	991.352.428.8A
2	H.A. Bremsbeläge 20mm 4 Stücke pro sate / rear brake pads 20mm 4 pads per set	1	991.352.947.8A
	H.A. Dauerlauff Bremsbeläge 26mm 4 Stücke pro sate / rear endurance brake pads 26mm 4 pads per set	1	991.352.947.8B
3	H.A. übergebende leitung/ cross-over pipe kit rear	1	991.352.961.8A
4	Entlüftungsschraube Satz (4 pro sate) / bleed screw kit (4 per set)	1	991.351.919.8A
5	Entlüftungsschraube Satz ohne Einsatz (4 pro sate) / bleed screw kit w/o insert (4 per set)	1	991.355.601.8A
6	H.A. Bremsscheibe links Aufbau 30mm / rear left brake disk assembly 30mm	1	981.352.107.8A
	H.A. Bremsscheibe rechts Aufbau 30mm / rear right brake disk assembly 30mm	1	981.352.108.8A
7	H.A. Bremssattel Kolbensatz / Rear caliper piston kit	1	991.352.959.8A
Kolbensatz/ Piston kit	7.1 36.5 mm Bremskolben / 36.5 mm Brake piston	2	
	7.2 29.0 mm Bremskolben / 29.0 mm Brake piston	2	
8	H.A. Bremssattel Dichtungssatz/ Rear caliper seal kit	1	991.352.960.8A
Dichtungssatz/ Seal Kit	8.1 36.5 mm Kolbendichtung / 36.5 mm Piston seal	2	
	8.2 29.0 mm Kolbendichtung / 29.0 mm Piston seal	2	
9	RH665PFC Bremsflüssigkeit 1-500ml / RH665 PFC Brake fluid 1-500ml	N/A	991.355.960.8A



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APPROVED SIGNATURE	
ORIGINATOR	C. WYKER
DESIGN ENG	.
PROCESS ENG	.
QUALITY	.
PURCHASING	.
PRESIDENT	.
MATERIAL:	.

SCALE 1:4
 DIMENSIONS: MILLIMETERS
 TOLERANCES UNLESS SPECIFIED
 1 PLACE DECIMAL ± .
 2 PLACE DECIMAL ± .
 ANGLE (DEG) ± .
 DWG CLASS C

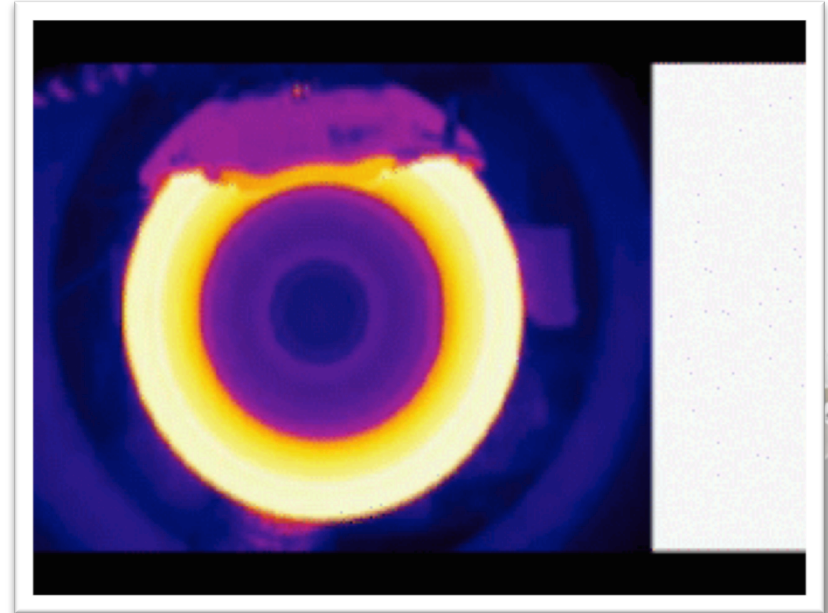
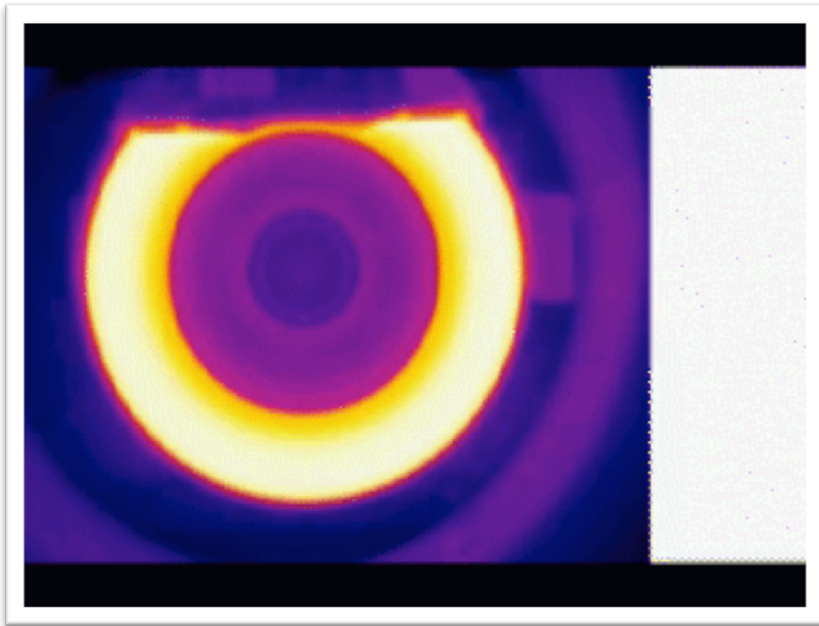
REV	FOR CUSTOMER USE ONLY	1/11/2016	CAW
REV	ENGINEERING CHANGE ORDER	DATE	INITIALS
1			

PFC PART NO.	PFC
GT4CS Rear Assembly DATE	
01/11/2016 FILE NAME	PERFORMANCE FRICTION CORP 83 CARBON METALLIC HIGHWAY CLOVER, SC 29710
DRAWN BY C. WYKER	

SHEET 1 OF 1

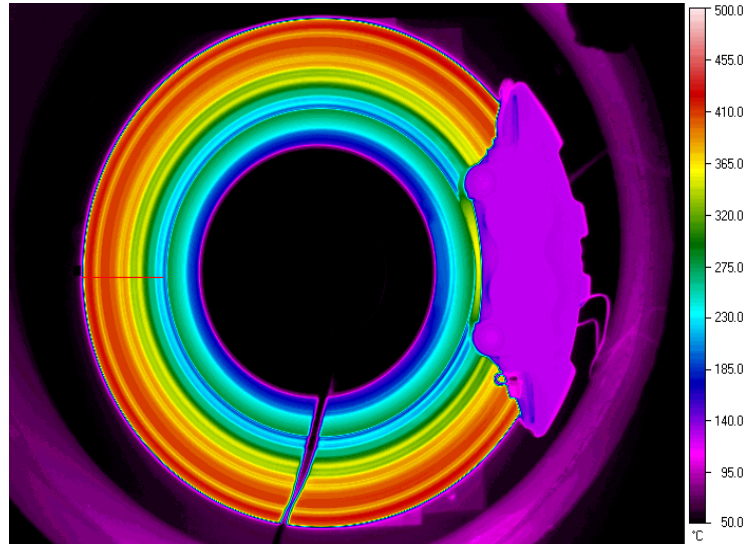


Thermal Imaging of Uniform Thermal Distribution

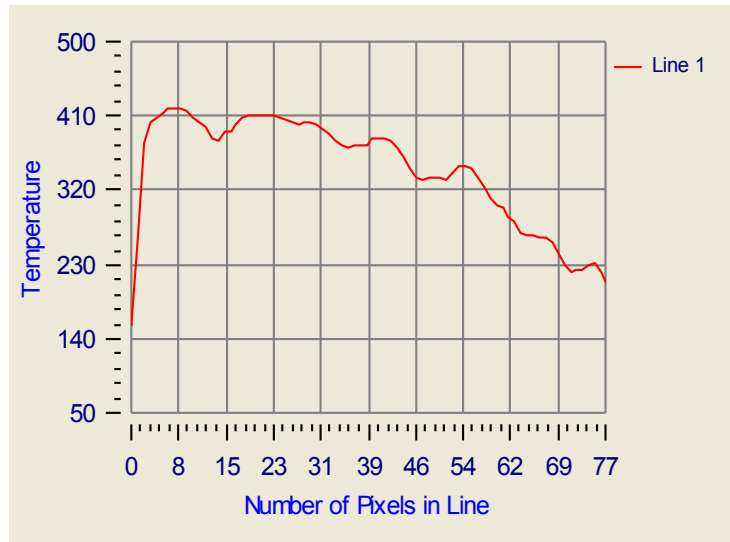


Competitor

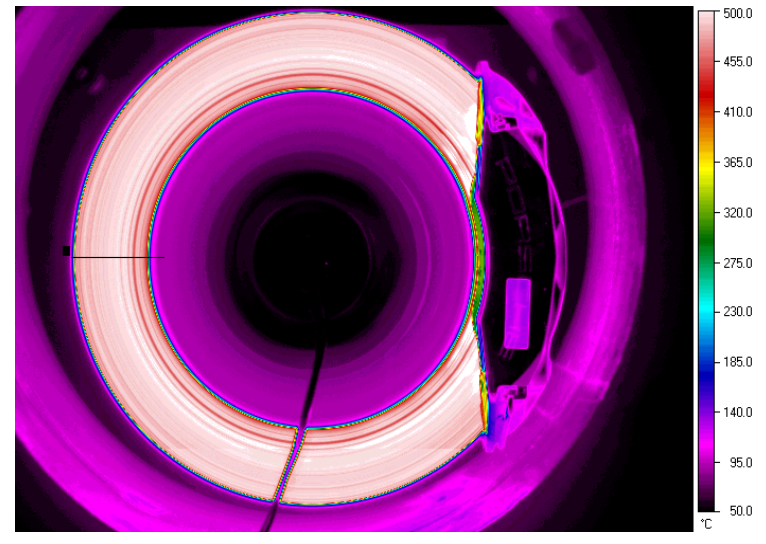
Competitor Thermal Imaging



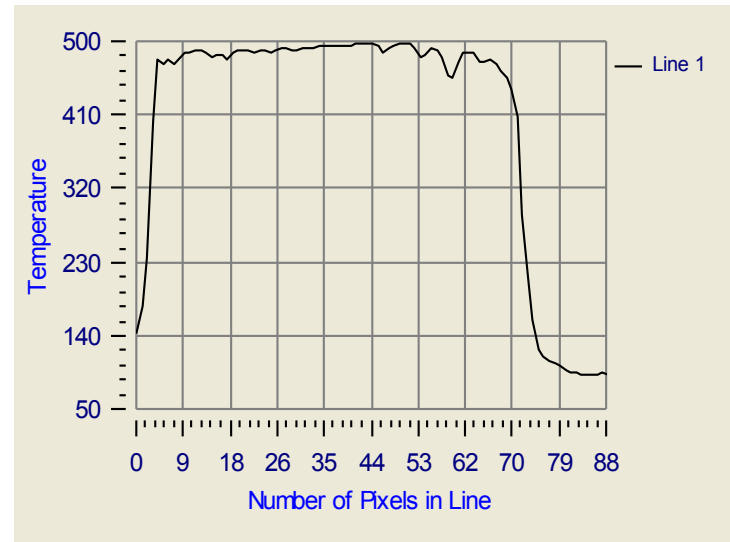
	Min. °C	Max. °C	Avg. °C	Range °C
Line 1	157.2	420.0	344.6	262.8



PFC Thermal Imaging



	Min. °C	Max. °C	Avg. °C	Range °C
Line 1	92.2	498.6	403.6	406.4





Brake Packages

Lighter

PFC Packages are lighter than the competition

Stiffer

PFC Calipers are 40% stiffer than the competition

Cooler

PFC Pistons reduce caliper operating temperature by 100°

Quicker

Zero Drag Calipers = Improved Lap Times

