Engine Exhaust Coating Comparison

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Historically speaking, reducing engine bay component temperatures has been critical in achieving success for many types of automotive racing. The cooler that some of these components are during operation of the vehicle, the more efficient the engine becomes. Colder air coming into the engine also equals more power when compared to the same volume of air at a higher temperature. Manufacturers and race teams alike try to reduce the heat gains to incoming air with several techniques. This paper will discuss a couple of those techniques and utilize a state of the art infrared camera to visualize and measure the effectiveness of changing the heat transfer capabilities of exhaust components.

Modern engines with fuel injection and electronic computer controls have become increasingly complex and more efficient with each engineering advancement. Smaller displacement engines can now offer excellent gas mileage along with unheard of power and performance. In this test, we decided to use the car that we currently race at IHRA and NHRA drag strips across the east. Our test car is a 98 Buick Regal GS with a supercharged 3.8 liter fuel injected front wheel drive engine. The engine came stock with heat reducing radiant barriers on the exhaust components. This was a sign to me that heat reduction is carefully considered by the manufacturer during design on new vehicles.

Figure 1: The Engine

How can you take a good product and make it better for performance and racing? It can be a challenge given the level of care and thought put into today's cars. To start, we decided that in order to take advantage of increased air flow and pressures caused by our aftermarket supercharger changes, we would need to open up the stock exhaust system to handle the exiting gases. Our exhaust is composed of 5 basic parts that provide safe transfer of the exhaust gases to the rear of the car. These components also provide a quieting effect and reduce the harmful emissions of the engine that would make their way to the atmosphere.

Fig 2: GM L67 3800 Series 2 motor

The first exhaust components that you see in figure 2 are the only parts that are under the hood of the car and are the MOST significant when it comes to heating up the rest of the objects surrounding the engine. This is where we will attempt to reduce heating by using a couple different tried and true techniques.

Fig 3: Exhaust under the car

The next component, called the down pipe, directs the exhaust gas under the car's floor boards. A critical component to meeting the USA's strict emissions guidelines follows the down pipe: the catalytic converter. Oxygen sensors before and after the "cat" help control the car's performance and let the user know if the catalyst bed has need of replacement and can no longer keep up with the emissions being released.

The rest of the exhaust gets routed along the bottom of the car and normally goes through a resonator and a muffler on this Buick to quiet the engine noise both inside and outside of the car. This next picture shows an aftermarket custom exhaust that was placed on the Regal to increase performance. It was a necessary adjustment to keep up with the increased volume of air being pumped into the engine with a faster than stock

Eaton supercharger. The trade-off is that our family sedan is quite a bit louder than normal, and takes some getting used to!

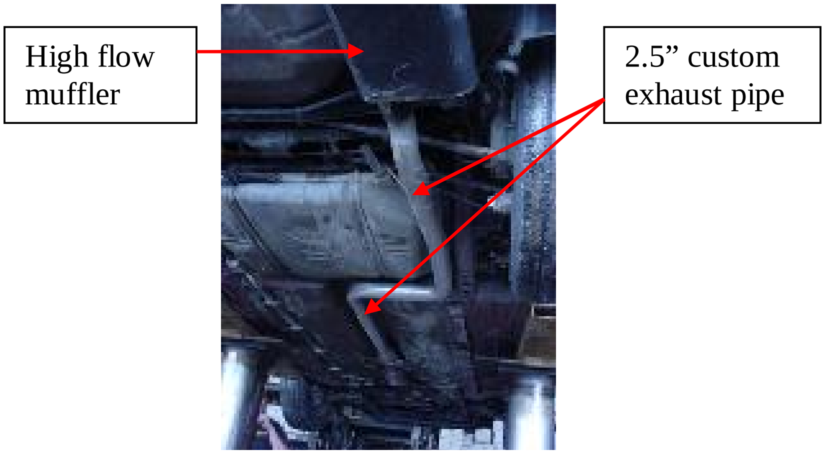


Fig 4: Exhaust pipe

There you have it, the exhaust flow of a Buick Regal GS! Most front wheel drive cars have similar exhaust trains.

1. Front and rear exhaust manifolds
2. Front exhaust needs to route through the cross-over pipe and over the transmission.
3. Down pipe and catalytic converter
4. Exhaust pipe
5. Muffler (and resonator for some)

There exists two techniques for reducing the amount of heat that comes from hot exhaust components under hood:

1. Radiant barrier coatings
2. Insulating heat wrap

We tested both methods during a hot August Summer night in 2003 to see if they were effective, and which heat reduction concept offered the best protection to the air intake components. For ease of performing this test, we concentrated on the cross-over pipe. This pipe can be removed far easier than the manifolds, and it is the closest piece to the air intake and throttle body so therefore the most important for heat reduction. See figure 5 and 6 for a comparison of some of the different cross-over pipes that were used.

Fig 5: Cross-over pipes

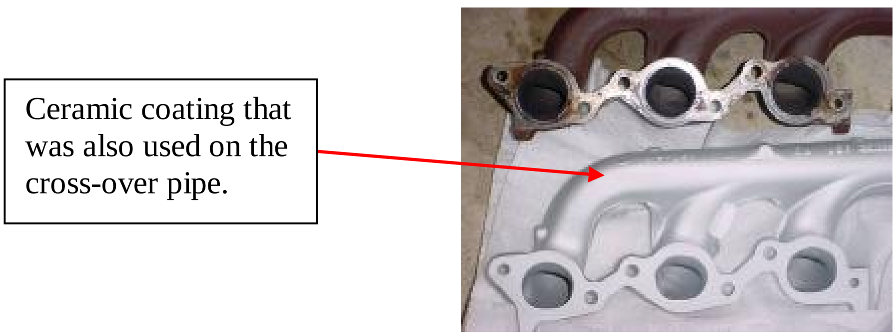


Fig 6: Side by side comparison of the silver ceramic coating on exhaust manifolds

Our goal was to perform three ¼ mile runs at Beaver Springs with each of the three different cross-over pipes in succession: wrapped, uncoated bare metal and silver ceramic coated. The results were amazing! Here are the track conditions at the start of the test.

Object parameter	**Value**
Time	7:14PM
Atmospheric temperature	85.5°F
Relative humidity	0.60

The first cross-over used was the silver ceramic coated. Our data was taken with a FLIR S60 longwave infrared camera. This camera detects infrared light and has the radiometric ability to convert the intensity of the infrared into a temperature measurement. We used the FLIR S60 to show us the thermal patterns of a large area under the car's hood, and make non-contact temperature measurements for comparison between the different exhaust pipes. Not all objects are efficient at emitting radiant energy, so we took care in the materials that we chose to measure. We will be looking at the throttle body and the F-duct due to their proximity to the cross-over pipe.

Fig 7: Throttle body and F-duct in the visible spectrum

Ceramic Coated

Object parameter	**Value**
Emissivity	0.95
Object distance	1.0 m
Atmospheric temp	85.5°F
Relative humidity	0.60

Label	**Value**
AR01 : max	123.2°F
AR01 : avg	114.6°F
AR02 : max	157.7°F
AR02 : avg	132.2°F

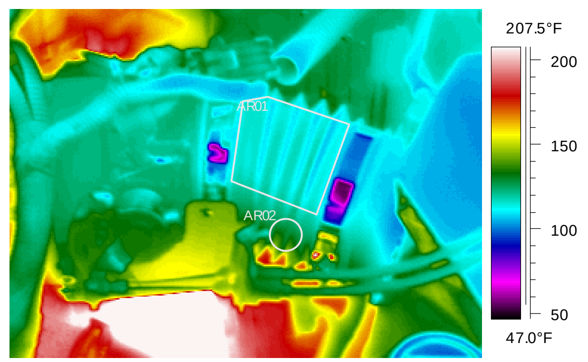


Fig 8: Throttle body and F-duct in infrared

As you can see in figure 8, the air induction components known as the throttle body and F-duct measure in the low 120°F range at the top, and increases to nearly 160°F towards the bottom. The cross-over is directly underneath these two components, so we were interested in how changing the pipe to one with a wrap would do.

One condition that we could not control was the changing weather towards the evening. It took approximately 20 minutes to change the pipes, and the outside air temperature and humidity did not stay constant. Here are the conditions for the test on the wrapped pipe:

IR information	**Value**
Time of creation	8:21:05 PM
Atmospheric temp	78.5°F
Relative humidity	0.82

Data was again taken with the FLIR S60, and the results were compared to the coated cross-over pipe.

Wrapped	
Object parameter	**Value**
Emissivity	0.95
Object distance	1.0 m

Label	**Value**
AR01 : max	131.5°F
AR01 : avg	121.3°F
AR02 : max	158.2°F
AR02 : avg	138.8°F

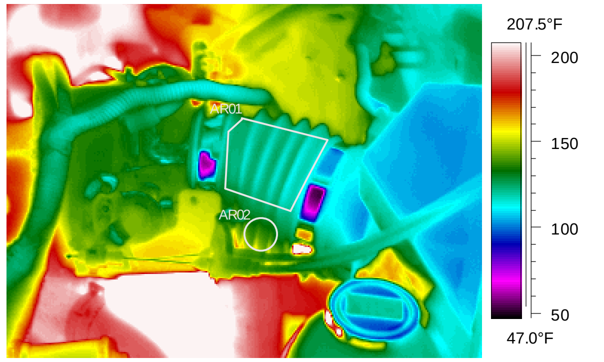


Fig 9: Throttle body and F-duct with wrapped cross-over

Next, the air temperature continued to drop and as things cooled outside, we were busy under the hood changing a pipe that was OVER 600°F!! I think I lost 20 pounds during this test. Here are the atmospheric conditions during the final three runs with the Buick and the uncoated/unwrapped cross-over pipe:

IR information	**Value**
Time of creation	9:42:32 PM
Atmospheric temp	76.0°F
Relative humidity	0.84

One more set of data and then we will graph the results.

Uncoated/unwrapped	
Object parameter	**Value**
Emissivity	0.95
Object distance	1.0 m

Label	**Value**
AR01 : max	139.8°F
AR01 : avg	132.0°F
AR02 : max	175.2°F
AR02 : avg	151.1°F

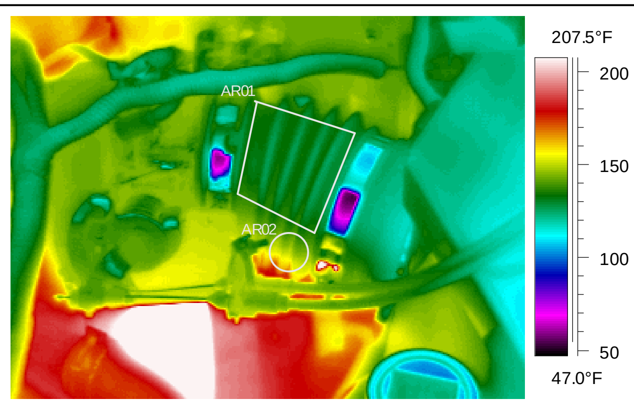
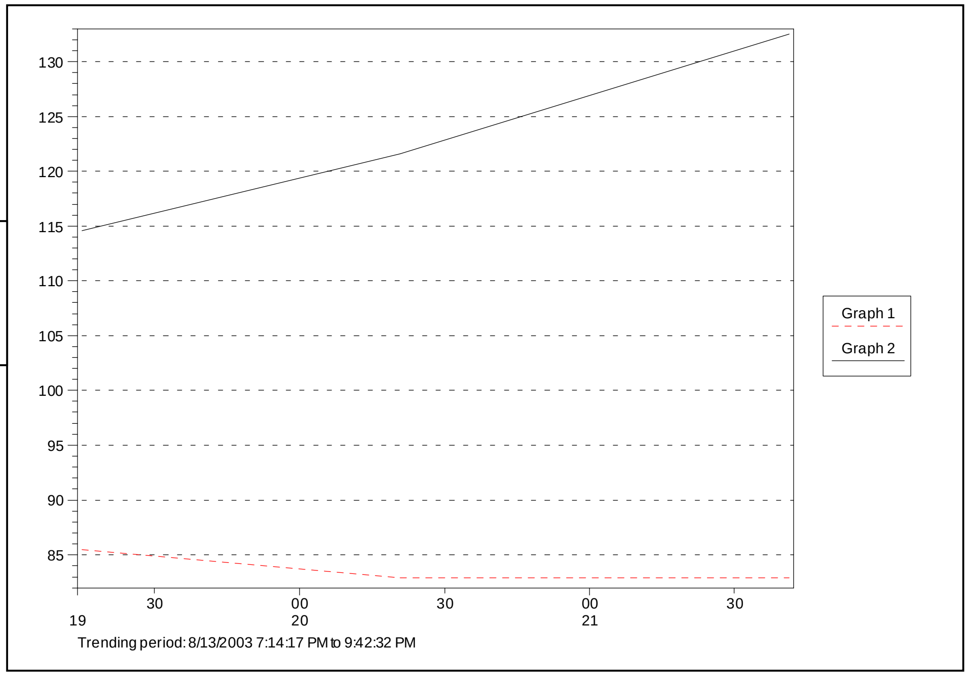


Fig 10: Throttle body and F-duct with the unwrapped/uncoated cross-over pipe

Here is a comparative graph that shows the correlation between outside air temperature (Graph 1) and average F-duct temperature (Graph 2). We also monitored the air inlet temperature at the air filter as the test went on.

Temp in °F



Time elapsed

This test showed us a few conclusions. The most important is how effective the ceramic coating proved to be. As outside air temps were dropping, under hood temps were going up! If you look at the three infrared images side by side, you will notice that a lot of the surrounding materials are increasing in temperature.

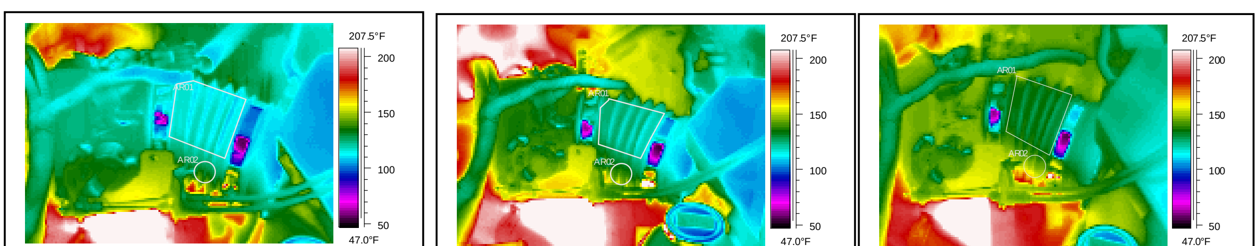


Fig 11: Side by side infrared comparison.

You can see that the color scale on the right of the images shows the temperatures associated with each color band. Light blues are cooler than green and green is cooler than yellow. There is much more yellow and green on the throttle body and f-duct and surrounding under hood materials in the right two images. I feel that the ceramic coating offers more than just heat reduction capabilities. It typically extends the life of exhaust components over exhaust components that are wrapped. Wrapped components have, in some cases, led to increased corrosion due to moisture become trapped against the metal of the exhaust pipe. Some aftermarket header manufacturers void the warranty of their exhaust components if you do wrap them.

How does the silver ceramic coating work so well when it is very thin? The coating has low efficiencies at radiating heat. This term is known as emissivity. Our test subject most likely had an emissivity below 20%, and was shown to be more effective than a comparably wrapped cross-over piece. Radiant heat transfer becomes increasingly powerful when the temperatures involved go up. The wrapped piece uses insulating cloth to act like a fiberglass-type barrier for conductive heat. It was more capable than the uncoated/unwrapped pipe, but not quite up to par to the coated pipe.

We all have a choice when it comes to purchasing aftermarket heat reducing components. I hope that with the use of an infrared camera, I am able to convey the importance of reducing that heat to other engine and intake parts. It just makes more sense when you can see a picture of the results of that heat through the use of a technology like infrared. Pictures are worth a thousand words.

For more info on Infrared and Aftermarket Performance check out the following companies:
FLIR Systems http://www.flir.com/
ZZPerformance http://www.zzperformance.com/