Increased Horsepower and Efficiency of Internal Combustion Engine

A Baccalaureate thesis submitted to the School of Dynamic Systems College of Engineering and Applied Science University of Cincinnati

in partial fulfillment of the requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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TABLE OF CONTENTS

TABLE OF CONTENTS .................................................................................................. II
LIST OF TABLES ........................................................................................................... IV
ABSTRACT .................................................................................................................... V
INTRODUCTION ........................................................................................................... 1
  PROBLEM STATEMENT .......................................................................................... 1
EXISTING METHODS ................................................................................................. 1
  BOLT ON TURBO KIT ....................................................................................... 1
  TURBONETICS SINGLE TURBO KIT ............................................................... 2
  WHIPPLE SUPERCHARGER ........................................................................... 3
  RUNNING ENGINE ASSEMBLIES .................................................................. 4
  CENTRIFUGAL SUPERCHARGER ................................................................ 5
DESIGN AND LOADING CONDITIONS ................................................................... 6
  ENGINE CFM CALCULATIONS ..................................................................... 6
  CARBURETOR FLOW CALCULATIONS ......................................................... 7
  BENDING STRESS CALCULATIONS ........................................................... 8
  SHEAR STRESS ON BOLTS .......................................................................... 10
  TURBO HOUSING CALCULATIONS ........................................................... 10
FABRICATION ........................................................................................................... 12
TESTING .................................................................................................................... 26
RESULTS .................................................................................................................... 29
CUSTOMER FEEDBACK, FEATURES, AND OBJECTIVES .................................... 30
  SURVEY ............................................................................................................ 30
  ENGINEERING CHARACTERISTICS .......................................................... 31
  PRODUCT OBJECTIVES ............................................................................. 32
SCHEDULE AND BUDGET .................................................................................... 33
  SCHEDULE ...................................................................................................... 33
  BUDGET ......................................................................................................... 34
WORKS CITED .......................................................................................................... 36
APPENDIX B CUSTOMER SURVEY ................................................................ 1
APPENDIX C QFD ................................................................................................. 1
APPENDIX D PRODUCT OBJECTIVES ............................................................. 1
APPENDIX E SCHEDULE ................................................................................. 1
APPENDIX F BUDGET .......................................................................................... 1
LIST OF FIGURES
Figure 1 Jeff Witeman 2003 Cobra turbo kit ................................................................. 1
Figure 2 Turbonetics single turbo kit ................................................................................. 2
Figure 3 Whipple Supercharger ......................................................................................... 3
Figure 4 Performance Clinic BBC blueprint engines ......................................................... 4
Figure 5 Pro Charger F1R centrifugal supercharger ......................................................... 5
Figure 6 Illustration of Venturi effect .................................................................................. 7
Figure 7 Exhaust Housing Map .......................................................................................... 11
Figure 8 Long Block Assembly ......................................................................................... 12
Figure 9 Complete Engine ................................................................................................. 12
Figure 10 Exhaust Header Flange ....................................................................................... 13
Figure 11 Engine Bay ......................................................................................................... 13
Figure 12 Header Design .................................................................................................... 14
Figure 13 Header Design Forward distance ......................................................................... 14
Figure 14 Exhaust Housing Flange Location ....................................................................... 15
Figure 15 Header and Turbo Charger ................................................................................ 15
Figure 16 Engine, Header, Turbo Charger Assembly ......................................................... 16
Figure 17 Front View of Engine, Header, Turbo Charger Assembly ................................. 16
Figure 18 Clearance Check ............................................................................................... 17
Figure 19 Turbo Charger Clearance ................................................................................ 17
Figure 20 Clearance - Rear View ...................................................................................... 18
Figure 21 Clearance - Front View ...................................................................................... 18
Figure 22 Clearance - Side View ....................................................................................... 19
Figure 23 Cold Side Plumbing ........................................................................................... 19
Figure 24 Cold Side Plumbing - Rear View ....................................................................... 20
Figure 25 - Cold Side Plumbing Restrictions ................................................................... 20
Figure 26 Passenger Downpipe ......................................................................................... 21
Figure 27 Driver Side Downpipe ....................................................................................... 21
Figure 28 Driver Side Downpipe Location ........................................................................ 22
Figure 29 Front Passenger View ....................................................................................... 22
Figure 30 Front View ......................................................................................................... 23
Figure 31 Top Driver View ............................................................................................... 23
Figure 32 Complete Assembly .......................................................................................... 24
Figure 33 Installed - Front View ....................................................................................... 24
Figure 34 Installed - Driver Side View ............................................................................... 25
Figure 35 Installed - Passenger Side View ....................................................................... 25
Figure 36 Dyno Run 1- Naturally Aspirated ..................................................................... 26
Figure 37 Dyno Run 2- Naturally Aspirated ..................................................................... 26
Figure 38 Dyno .................................................................................................................. 27
Figure 39 Dyno Run 3- Twin Turbo LM-2 Log ................................................................. 28
Figure 40 - Dyno Run 4 Twin Turbo ................................................................................. 28
Figure 41 Proposed Schedule ............................................................................................ 33
Figure 42 Actual Schedule ............................................................................................... 33
Figure 43 Proposed Budget .............................................................................................. 34
Figure 44 Actual Budget ................................................................................................... 34
LIST OF TABLES
Table 1 Feature Satisfaction
Table 3 Weighted Customer Features
Table 5 Customer Objectives
Table 2 Feature Importance
Table 4 Engineering Characteristics
ABSTRACT

The racing community is always looking to increase horsepower and efficiency of the internal combustion engine. This paper will explain the development of a system that will increase the horsepower and efficiency of the internal combustion engine. It will detail the research development, design, manufacture, and results of the system.
INTRODUCTION

**PROBLEM STATEMENT**

The Racing community is always looking to increase horse power and efficiency of the internal combustion engine. In a naturally aspirated form, this engine can only transform one third of the total energy into mechanical torque. There have been many improvements however the current designs are not optimized. This project will develop a system that is capable of dramatically increasing horsepower and efficiency of the internal combustion engine.

EXISTING METHODS

**BOLT ON TURBO KIT**

Precision Autosports offers a bolt on turbo kit used on the Ford Mustang however this design limits the amount of boost due to the pre-set waste gate setting. Figure 1 (1) shows the small size of the exhaust housing allows for a fast spool time but is not large enough for the engines cfm output. This bolt on kit is intended for a mild horsepower increase and not intended to optimize the engines ability to transfer the fuels energy into rotation. The engine monitoring system doesn't allow for further tuning or modification. Also, the lack of intercooler or methanol injection causes intake charge temperatures to rise inversely effecting efficiency.

![Figure 1 Jeff Witeman 2003 Cobra turbo kit](image)
**TURBONETICS SINGLE TURBO KIT**

Turbonetics has a specialized kit made for only the 2010/2011 Camaro. This kit has very limited horse power gains due to the factory preset waste gates. Figure 2 (2) shows that the kit does use an intercooler to reduce intake charge temperatures but comes at a cost of restricting intake cfm. The Maximum power output is only stated at 614 horsepower which only is an increase of 30%. For a high price of $6,999.99 you only get a relatively minimal gain.

Figure 2 Turbonetics single turbo kit
**WHIPPLE SUPERCHARGER**

Whipple is one of the leading supercharger companies; they specialize in the roots blower. The conventional roots style supercharger allows immediate boost upon throttle. As shown in Figure 3 (3) it is driven directly from the crankshaft superchargers have linear power to rpm curves. However because they are driven from the crankshaft they use a considerable amount of torque to drive the internal lobs that compress air providing boost. The level of energy taken from the engine to drive the unit is dependent on the size of supercharger and many other factors. It is not uncommon to see these parasitic losses taking 50-800 horsepower depending on application.

![Figure 3 Whipple Supercharger](image)

Drive pulley - connected to the crankshaft via belt

Compressed air exits here and is forced through the intake
**RUNNING ENGINE ASSEMBLIES**

Performance clinic offers many different blue print, turnkey engines. These are built from aftermarket blocks, rotating assemblies, valve train, and fuel systems to increase the horsepower and efficiency output. There are several downfalls to these custom engines such as price, part availability, efficiency. As shown in in figure 4 (4) a custom built engine is one of the more expensive options to increase horsepower. They require added maintenance and constant tuning. This added power comes at a big cost. They provide up to 80% power increase but at the highest cost. They are all naturally aspirated and because of this have the lowest efficiency.

<table>
<thead>
<tr>
<th>BIG BLOCK CHEVY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RUNNING ASSEMBLY Including Carb, Distributor &amp; Dyno Sheet:</strong></td>
</tr>
<tr>
<td>800-850HP 509-522 CI, Dart block, Pro One aluminum heads, roller cam: $12,950</td>
</tr>
<tr>
<td>930 + HP 555 CI, Dart clock, Dart CNC Aluminum heads, roller cam: $14,950</td>
</tr>
<tr>
<td>1030+ HP 588 CI, Dart Block, Brodix CNC Aluminum Heads, Jesel belt &amp; rockers: $17,950</td>
</tr>
<tr>
<td>1150 HP 598CI, Dart block, Dart Big Chief 14-degree CNC Heads, Jesel belt &amp; rockers, vacuum pump; $19,950</td>
</tr>
</tbody>
</table>

Gas or Alcohol, Nitrous Set-Ups available.

Figure 4 Performance Clinic BBC blueprint engines
**CENTRIFUGAL SUPERCHARGER**

Pro Charger is one of the leading manufacturers of centrifugal superchargers. In Figure 5 (5) Pro Charger's F1R is a very common supercharger that is reasonably priced at $4,000.00. As with the roots style blower this supercharger has a linear relationship with the crankshaft. This results in a linear horse power to rpm graph but also to unwanted power draw. The centrifugal supercharger is similar to a roots style supercharger in the effect that both require energy pulled from the engine to provide useful boost. The centrifugal supercharger does not have the instantaneous boost of the roots style but has lower parasitic losses.

These current methods of increasing the horsepower and efficiency of an internal combustion engine lack both high horsepower increases and increased efficiency. Many of these methods offer either increased horsepower or efficiency; of the few that can increase both horsepower and efficiency they lack an affordable cost, large increase of horsepower over baseline, or the ability for adjustment/tuning.
DESIGN AND LOADING CONDITIONS

ENGINE CFM CALCULATIONS

Engine CFM must be calculated in order to size the exhaust housing A/R ratio on the turbo, and build the boost reference power valve in the carburetor. This is a crucial step in assuring the correct turbos are selected.

\[
CFM = \frac{\text{Displacement} \times \text{max rpm} \times \text{volumetric efficiency}}{3456}
\]

\[
CFM = \frac{540 \times 7200 \times .8}{3456}
\]

\[CFM = 900\]

As seen in the above equation, the engine is 540 cubic inches. The max rpm is 7200, limited by the high lift cam. 3456 is a conversion factor from cubic inches to cubic feet and includes a 1/2 parameter needed for four-stroke engines in which only exhausts every other revolution. The volumetric efficiency is figured based on the engines ability to fill the cylinder with a fresh charge of air. The volumetric efficiency value was taken based upon the following criteria.

Volumetric efficiency is increased by larger valves, more valves, increased valve lift/duration, the cams lob separation angle, intake port design, and head design. This engine is equipped with fully cnc head, high rise single plane intake and 2.300" intake valves. Therefore with these considerations a volumetric efficiency of .8 was determined.
CARBURETOR FLOW CALCULATIONS

This engine will be using a high performance Carburetor. Carburetors operate on the Venturi principle which states that a low pressure region exists where air velocity is increased. Below is an illustration of a cross section of the Venturi body. Normally in a naturally aspirated engine this low pressure region draws fuel from the metering blocks inside the carburetor. This pressure decreases as engine rpm increases drawing more fuel in as the engine increases rpm. However, in boosted applications the Venturi principle is only effective in low load conditions before boost has been made. Once boost is made, the carb will then switch from the existing idle circuit to the main fuel circuit. Once this switch has been made, the custom power valves will be used.

![Venturi effect illustration](image)

Figure 6 Illustration of Venturi effect
In order to achieve a continuous supply of fuel from the Venturi in the carburetor the incoming air velocity must be calculated to determine the correct power valve size. Once the carb sees pressure above the external reference, the main fuel circuit is used. The inverted power valve delivers fuel through the metering blocks in a linear fashion relative to the pressurized air flow.

Air at standard temperature and pressure has the following density according to page 1063 in Thermal-Fluid Sciences (6):

\[
\text{Density } (\rho) = \frac{0.07489 \text{ lbm}}{\text{ft}^3}
\]

\[
900 \text{ cfm} = 15 \frac{\text{ft}^3}{s}
\]

\[
cross \text{ sectional area} = \pi r^2
\]

\[
cross \text{ sectional area} = \pi \cdot 0.333^2
\]

\[
cross \text{ sectional area} = 0.087 \text{ ft}^2
\]

\[
v = 15 \frac{\text{ft}^3}{s} \cdot \left( \frac{1}{0.087 \text{ ft}^2} \right)
\]

\[
v_{\text{max}} = 172 \frac{\text{ft}}{s}
\]

**BENDING STRESS CALCULATIONS**

The design is restricted with limited space. Both turbos and cold side intake plumbing will be forced to hang on the end of the exhaust manifold. This will cause a bending moment on the header.

Weights listed below:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo</td>
<td>53 lbs</td>
</tr>
<tr>
<td>Headers</td>
<td>18 lbs</td>
</tr>
<tr>
<td>Cold side plumbing</td>
<td>10 lbs</td>
</tr>
<tr>
<td>Total weight</td>
<td>81 lbs</td>
</tr>
</tbody>
</table>
The section modulus must be calculated to find the bending stress. Using stainless 321 the following properties were obtained from Robert Mott's Applied Strength of Materials (7).

Properties at 1500°F
- Tensile - 7500psi
- Yield - 22000psi

Using the moment and section modulus we can calculate the bending stress.

\[
S = \frac{\pi (D^4 - d^4)}{32D} \\
S = \frac{\pi (3.5^4 - 3.25^4)}{32 * 3.5} \\
S = 1.07
\]

Using the moment and section modulus we can calculate the bending stress.

\[
\sigma_{\text{max}} = \frac{M}{S} \\
\sigma_{\text{max}} = \frac{1296}{1.07} \\
\sigma_{\text{max}} = 1211 \text{psi}
\]


\[
\sigma_d = Su_{/12} \\
\sigma_d = 22,000_{/12} \\
\sigma_d = 1833 \text{psi}
\]

The worst case scenario stress is less then the design stress with a factor of safety of 12.
**SHEAR STRESS ON BOLTS**

The worst case in shear would come from the weight of header, turbo, and cold side plumbing. The design stress must be calculated using Robert Mott's Applied Strength of Materials (7) table 3-8. The stock bolts are grade 8 3/8-16.

\[
\tau_d = \frac{S_{ys}}{12} = \frac{81,000}{12} = 6,750 \text{psi}
\]

\[
\tau = \frac{F}{\pi \frac{d^2}{4}} = \frac{81}{\pi \frac{375^2}{4}} = 733.4 \text{psi}
\]

Therefore, one bolt can successfully hold the header, turbo, and cold side plumbing during impact.

**TURBO HOUSING CALCULATIONS**

The exhaust housing must be correctly sized to the engine flow, required boost, and desired peak torque range.

A pressure ratio must be calculated based on desired boost level.

\[
Pr = \frac{\text{boost} + \text{atm}}{\text{atm}} = \frac{20 + 14.696}{14.696} = 2.36
\]

Volumetric flow

\[
V = Pr \times CFM = 2.36 \times 900 = 2124 \text{ ft}^3/\text{min}
\]

Mass flow

\[
M = \rho \times V = 0.07489 \times 2124 = 159 \text{ lb/min}
\]
Thus, the engine will flow 159lb of air per minute at 20psi and 7200 rpm. To size the turbo exhaust housing the engine flow must be divided by 2. Using the final 79lb per minute mass flow rate the best housing is chosen. As seen in figure 9, the best suited turbo would be the Garrett GT4708 with a 108mm exhaust wheel and .69A/R exhaust housing. At 20psi the turbine shaft will be spinning at 73,000 rpm.

Figure 7 Exhaust Housing Map
FABRICATION

The Fabrication process started with the long block assembly. Due to the increased stress of a highly boosted platform the Dart Big M BBC block was used. Callies Magnum Crankshaft, Billet Oliver Connecting rods, and custom dish Diamond Pistons completed the rotating assembly. The valve train was comprised of a fully roller set up capable of turning 7600 rpm. Arguably the most important component of todays race engine, the heads choose are a fully cnc 345cc AFR aluminum head. 2.3" intake valves and Inconel exhaust valves were chosen to withstand the 1400 degree exhaust temperatures.
Measurements were taken from the exhaust ports allowing fabrication of the exhaust header flanges as shown in figure 10.

![Figure 10 Exhaust Header Flange](image1)

The primary tubes were mandrel bent and tacked together. The header design was very restricted in the engine compartment. The primaries were forced to take a sharp forward angle to maintain sufficient clearance from the steering shaft as shown in figure 11.

![Figure 11 Engine Bay](image2)
The headers were also restricted vertically by the stock Chevelle hood, this only allows one path for the header design as shown in figure 12.

![Figure 12 Header Design](image1)

Both turbos will be mounted in front of the block, this required a forward overhang of 10".

![Figure 13 Header Design Forward distance](image2)
Due to the large size of the turbo chargers, their location was limited to the front left and front right of the engine bay. The headers required 1D 90 degree bends to mate with the exhaust housing flange.

The headers were fully tig welded and then bolted to the Garrett gt4708 80mm turbo chargers.
The assembly could then be bolted to the heads as shown below.

Figure 16 Engine, Header, Turbo Charger Assembly

Figure 17 Front View of Engine, Header, Turbo Charger Assembly
The assembly was installed in the engine bay to check for clearance issues.
Figure 20 Clearance - Rear View

Figure 21 Clearance - Front View
The following step in the fabrication process required the build of the cold side plumbing. This would carry the compressed air from both turbochargers and combine them before routing the pressurized air into the carb hat.
The cold side plumbing was restricted by the location of the hood, carb hat, turbo location, water pump, accessory pulleys, radiator, and cooling fan as shown in figure 25.
Lastly, the downpipes were fabricated. They direct the exhaust gases expelled from the exhaust housing to the rear of the car. To reduce exhaust back pressure, the downpipes were designed to use the largest tubing available.

Figure 26 Passenger Downpipe

The Driver side downpipe had many obstacles and was required to intertwine with the steering linkage. The downpipe is shown below in figure 27.

Figure 27 Driver Side Downpipe
The following figures show the final product.
Figure 28 Driver Side Downpipe Location

Figure 29 Front Passenger View
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Figure 30 Front View

Figure 31 Top Driver View
The entire assembly was designed to be installed and removed together.

Figure 32 Complete Assembly

The following figures show the complete assembly installed in the engine bay.

Figure 33 Installed - Front View
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Figure 34 Installed - Driver Side View

Figure 35 Installed - Passenger Side View
TESTING

In order to test the product, the engine was removed from the car and dyno tested. Two baseline dyno runs were made to acquire the engines output without the turbo setup. The following figures show the dyno graph illustrating the engines horsepower and torque vs rpm.

Figure 36 Dyno Run 1- Naturally Aspirated

Figure 37 Dyno Run 2- Naturally Aspirated
Several runs were completed to do a proper break in. Both air bleeds were adjusted to maintain a safe air fuel ratio of 12:1 while the engine runs in the idle circuit. Primary and secondary jetting was then tuned to maintain 11:1 afr while in steady state acceleration or during constant rpm under load.

After all preliminary tuning was completed two dyno pulls were made. The first dyno pull resulted in 504hp and 460ft*lb of torque. The afr was adjusted 5 points leaner for the second run which resulted in 601hp and 584ft*lb of torque. Timing was kept to 14 degrees before top dead center and reached the maximum at 33 degrees at 3000rpm.

The twin turbo system was installed on the engine and tested via engine dyno. The inverted power valve which is in charge of supplying the extra fuel needed for the increased air flow, was adjusted to reduce the afr to below 11:1 during boost. Several test runs were made to check oil pressure, correct the wideband sensor settings, and reduce timing to 8 degrees advance. The figure below shows the engine and turbo system on the dyno warming up for the first dyno pull.
The following figures show the dyno graph results of the complete twin turbo system for the first run. This graph shows the horsepower and torque curve recorded from the stand alone LM-2.

Figure 39 Dyno Run 3 - Twin Turbo LM-2 Log

The boost reference power valve was overloading secondary jetting causing the afr to drop below 10:1. The power valves were adjusted and the timing was increased to 12 degrees and the maximum being 30 degrees at 3500rpm. The wastegates were adjusted to achieve 26psi of boost. The last run was made with the engine installed in the chassis and performed at Precision Autosports.

Figure 40 - Dyno Run 4 Twin Turbo

The final run resulted in 1477 hp and above 1500ft*lb of torque. The Chassis dyno was unable to handle to torque about 1500 ft*lb.
RESULTS

Efficiency was increased 12%. Naturally aspirated brake specific fuel consumption was 374.1 lb/hp*h. Forced induction brake specific fuel consumption was 240.5 lb/hp*h.

Naturally aspirated
Efficiency = \frac{1}{bsfc*0.01222}
Efficiency = 22%

Forced induction
Efficiency = \frac{1}{bsfc*0.01222}
Efficiency = 34%

Horsepower was increased over 289%. Naturally aspirated horsepower was 601. Forced induction horsepower was increased to 1742.
CUSTOMER FEEDBACK, FEATURES, AND OBJECTIVES

SURVEY

A Survey was used to gain knowledge on the importance and satisfaction of the customer features. The survey was distributed at a local racing community meeting at Kil Kare Raceway. Eleven surveys were returned ranking the customer features and expressing the wants of the racers. As seen below in Table 1, price and efficiency are the top features whereas safety and size ranked least important. Table 2 shows that the racing community is satisfied with the ease of operation of current systems however they are unsatisfied with the prices and current efficiencies.

<table>
<thead>
<tr>
<th>Price</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>5</td>
</tr>
<tr>
<td>Reliability</td>
<td>5</td>
</tr>
<tr>
<td>Durability</td>
<td>4.7</td>
</tr>
<tr>
<td>Resistance to heat</td>
<td>4.7</td>
</tr>
<tr>
<td>Consistent results</td>
<td>4.5</td>
</tr>
<tr>
<td>Ease of operation</td>
<td>4.2</td>
</tr>
<tr>
<td>Compatibility</td>
<td>3.5</td>
</tr>
<tr>
<td>Size</td>
<td>3.2</td>
</tr>
<tr>
<td>Safety</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 1 Feature Satisfaction

<table>
<thead>
<tr>
<th>Ease of operation</th>
<th>4.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>4.7</td>
</tr>
<tr>
<td>Consistent results</td>
<td>4.6</td>
</tr>
<tr>
<td>Resistance to heat</td>
<td>4.1</td>
</tr>
<tr>
<td>Size</td>
<td>3.6</td>
</tr>
<tr>
<td>Reliability</td>
<td>3.5</td>
</tr>
<tr>
<td>Durability</td>
<td>2.9</td>
</tr>
<tr>
<td>Compatibility</td>
<td>2.8</td>
</tr>
<tr>
<td>Efficiency</td>
<td>2.3</td>
</tr>
<tr>
<td>Price</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 2 Feature Importance
ENGINEERING CHARACTERISTICS

The Survey ranked the importance of the customer features which provided critical information for the QFD. A correlation was made linking the customer features to the engineering characteristics. Table 3 shows the customer features with their weighted rank. They relate to the engineering characteristics in Table 4.

<table>
<thead>
<tr>
<th>Price</th>
<th>19%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>16%</td>
</tr>
<tr>
<td>Durability</td>
<td>15%</td>
</tr>
<tr>
<td>Reliability</td>
<td>13%</td>
</tr>
<tr>
<td>Resistance to heat</td>
<td>11%</td>
</tr>
<tr>
<td>Size</td>
<td>9%</td>
</tr>
<tr>
<td>Consistent results</td>
<td>9%</td>
</tr>
<tr>
<td>Compatibility</td>
<td>8%</td>
</tr>
<tr>
<td>Ease of operation</td>
<td>8%</td>
</tr>
<tr>
<td>Safety</td>
<td>4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>0.14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Finish</td>
<td>0.13</td>
</tr>
<tr>
<td>Filtration/oil supply</td>
<td>0.13</td>
</tr>
<tr>
<td>Standard Components</td>
<td>0.13</td>
</tr>
<tr>
<td>Boost control</td>
<td>0.12</td>
</tr>
<tr>
<td>Manufacturability</td>
<td>0.10</td>
</tr>
<tr>
<td>Boost protection</td>
<td>0.09</td>
</tr>
<tr>
<td>Clearance</td>
<td>0.06</td>
</tr>
<tr>
<td>Size</td>
<td>0.06</td>
</tr>
<tr>
<td>Weight</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 3 Weighted Customer Features
Table 4 Engineering Characteristics
PRODUCT OBJECTIVES

The product objectives listed in Table 2 are in order from greater importance to least importance. This represents the wants of the customer and the method in which to achieve those goals. Price was the highest importance to the customer and will be less than ten thousand dollars. Efficiency and durability followed closely with price; the design will in cure no parasitic loses, increase engine efficiency, and be made of a corrosion resistant durable material.

1. Price 19%
   a. Less than $10,000
2. Efficiency 16%
   a. Increases original efficiency
   b. No parasitic losses
   c. Increase horsepower
3. Durability 15%
   a. Robust center section
   b. Standard bearings
   c. Corrosion resistant exhaust tubing
4. Reliability 13%
   a. Oil pressure maintained at minimum 20psi
   b. Maintenance free center housing
   c. Reliable waste gate operation
   d. Reliable blow off valve operation
5. Resistance to heat 11%
   a. Correct material for hot side tubing
6. Size 9%
   a. Size of inducer/exducer
   b. Size of exhaust/compressor wheels
   c. Size of exhaust/intake tubing
   d. Sized of bov
   e. Sized of waste gates
7. Consistent results 9%
   a. Builds boost pressure consistently
   b. Maintains constant pressure while on waste gate
   c. Relieves excess pressure when throttle is relieved
8. Compatibility 8%
   a. Interchangeable blow off valve, bearing center-section, wheels, and wastegates
9. Ease of operation 8%
   a. Self sustained system
10. Safety 4%
    a. Inlet tubing to protect compressor wheel
    b. Internally vented waste gate to retain hot exhaust gases

Table 5 Customer Objectives
SCHEDULE AND BUDGET

SCHEDULE
As shown in the Figure below, the Schedule starts the design of the project on October 24 2012. 3D modeling, part design and sizing all must be complete by the design freeze on Dec 15. Assembly and testing will be conducted starting the 19th of January 2013 and ending the 1st of March 2013. Testing and presentations will be conducted From March 1 2013 through April 13 2013.

<table>
<thead>
<tr>
<th>3D Modeling</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>February</th>
<th>March</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot side/cold side design</td>
<td></td>
<td></td>
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Figure 41 Proposed Schedule

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Figure 42 Actual Schedule
The Budget was constructed keeping the customers requirements and part costs in mind. The budget will be funded in full through Kyle's Lawn Care LLC.

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<tr>
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TOTAL 10719.00

Figure 43 Proposed Budget

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TOTAL 10719.00

Figure 44 Actual Budget
ACKNOWLEDGEMENTS

I would like to thank Professor Ahmed Elgafy, Ph.D. for excellent guidance throughout the project and a very meaningful learning experience over the past 5 years.

Jeff Whiteman at Precision Autosports was very influential in the tuning process.

Dave Middleton put in a lot of time helping with the short block assembly.
WORKS CITED

1. **Whiteman, Jeff.** *Precision Autosports Owner*. Beavercreek oh, 09 17, 2012.
Interview with Supernatural Turbo owner Reed Patridge: Kammer and Kammer Engine inc. 4990 Nebraska Ave. Dayton, OH 45424 on 9/17/12.

He has been in the forced induction business for 12 years. He mentioned the benefits of turbo charging over the other forms of forced induction. The energy powering the device is almost 100% free and isn't limited by a storage device similar to nitrous-oxide. The benefits over roots and centrifugal superchargers become larger as the horsepower and torque needs increase as in high performance racing. When making the design calculations, lag can be almost eliminated based on boost/power needs.

Interview with owner of Performance Clinic Dave Middleton: 715 North Orchard Lane Beavercreek OH 45434 on 9/17/12.

Dave has been in the race engine building for over 30 years and specializes in high performance race car engine building. Although the cost of a turbo system is higher than the other forms of increasing the horsepower, it is the most efficient route. Dave also mentioned that the rotating assembly must be of forged construction in order to handle the increased cylinder pressure.

2003 single turbo 5.4 liter Ford Mustang Cobra made by Jeff Whiteman at Precision Autosports. Total engine/turbo cost $12,200.00.

Notes:
This design limits the amount of boost due to the small size of the turbo in relation to the needed cfm. All engine monitoring is preset and not interchangeable. No intercooler or methanol injection is used, causing intake charge temperatures to rise decreasing efficiency.
Interview with Precision Autosports owner Jeff Whiteman: 1031 Cincinnati Ave. Xenia OH 45385 on 9/17/12

He has been in the engine tuning business for 8 years locally. He has built several forced induction engines for high horsepower applications. Most of his expertise is in the tuning process. All forced induction engines require more attention to a correct air fuel ratio to prevent detonation. The difference between a tune on a high horsepower turbo engine and roots or centrifugal supercharger is the ramp rate that fuel is introduced. The turbo requires fuel in a parabolic rate compared to a linear rate with a crankshaft driven supercharger. He also mentioned the efficiency will vary depending on the size of the exhaust and compressor housings.

Notes:
This company sells bolt on superchargers. They require a different hood because of the space requirement. They sell for $2,600.00 up to $8,000.00 and require tuning and fuel requirements. They are much less efficient due to parasitic draw from the crankshaft.

This centrifugal supercharger kit allows for different boost levels however the supercharger requires 70 horsepower to create 12psi manifold pressure, very inefficient due to parasitic losses. This Kit sells for $7600.00

BIG BLOCK CHEVY

**RUNNING ASSEMBLY** Including Carb, Distributor & Dyno Sheet:

- **800-850HP** 509-522 CI, Dart block, Pro One aluminum heads, roller cam: **$12,950**
- **930 + HP** 555 CI, Dart clock, Dart CNC Aluminum heads, roller cam: **$14,950**
- **1030+ HP** 588 CI, Dart Block, Brodix CNC Aluminum Heads, Jesel belt & rockers: **$17,950**
- **1150 HP** 598CI, Dart block, Dart Big Chief 14-degree CNC Heads, Jesel belt & rockers, vacuum pump; **$19,950**

Gas or Alcohol, Nitrous Set-Ups available.

http://www.performanceclinic.net/chevyeng.htm 9/17/12.

Notes:

These are engine kits made by Performance Clinic in Beavercreek OH. Because they are naturally aspirated they lack any efficiency gain of forced induction. The prices are extremely high and the engines would still require fuel set ups.
Turbonetics Single Turbo Kit

Engines: 6.2L V8
HP Gains: 614chp
Boost: 8 PSI
Price: $6,999.99

Price Match Guarantee Contact Us For More Info
Turbonetics’ complete, bolt on single turbo kit takes your 2010 Camaro SS from 426 Crankshaft HP to approximately 614HP (578lb/ft) at just under 8psi of boost. The installation can be completed in a day with http://www.turbokits.com/Chevy/Camaro_SS/Turbo_Kits/9/17/12.

Notes:
This is a specialized kit made for only the 2010 Camaro. The power is very limited due to the waste gate restrictions. The Maximum power output is only stated at 614HP. The Size of the compressor housing only allows for a fast spool up and not high boost.
For $6,999.99 you only get an increase of 188HP.
APPENDIX B  
CUSTOMER SURVEY

Turbo system to increase horsepower and efficiency of internal combustion engine

High horsepower racing applications are always looking for ways to increase horsepower and efficiency. A turbo setup will both increase horsepower and efficiency. This survey will show desirable customer features of a turbo system to be used in high horsepower applications.

How important is each feature to you for the design of a turbo kit to increase horsepower and efficiency?

Please circle the appropriate answer.  
1 = low importance  
5 = high importance

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How satisfied are you with the current supercharger systems?

Please circle the appropriate answer. 
1 = very Unsatisfied  
5 = very satisfied

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How much would you be willing to fund for this project?
$500 $1,000, $1,000-$2,000, $2,000-$5,000 $5,000-$10,000, $10,000-$20,000

(3) (7) (1)

Thank you for your time.
| Material | Clearance | Size | Weight | Manufacturability | Metal Finish | Boost control | Boost protection | Standard Components | Filtration/oil supply | Customer importance | Designer's Multiplier | Current Satisfaction | Planned Satisfaction | Improvement ratio | Modified Importance | Relative weight | Relative weight % |
|----------|-----------|------|--------|------------------|-------------|--------------|----------------|-------------------|---------------------|---------------------|--------------------|---------------------|--------------------|---------------------|---------------------|---------------------|-------------------|------------------|
| 1        | 3         | 3    | 3      | 3                | 3           | 3            | 3              | 3                 | 3                  | 3                  | 3                  | 3                  | 3                  | 3                  | 3                  | 3                | 3               |
| 5.0      | 1.0       | 1.5  | 9      | 1.0              | 5.0         | 2.3          | 4.0            | 1.7              | 8.7                | 0.16               | 16%                | 4.7                | 1.0                | 2.9               | 5.0              | 1.4              | 7.1              |
| 9        | 3         | 9    | 3      | 9                | 9           | 3            | 3              | 3                 | 9                  | 9                  | 4.7                | 1.0                | 2.9               | 5.0              | 1.4              | 7.1              |
| 1.14     | 0.06      | 0.06 | 0.06   | 0.10            | 0.13        | 0.02         | 0.08           | 0.08              | 0.08               | 0.08               | 0.08               | 0.08               | 0.08               | 0.08              | 0.08             | 0.08             | 0.08             |

Appendix C1
APPENDIX D  PRODUCT OBJECTIVES

1. Price 19%
   a. Less than $10,000
2. Efficiency 16%
   a. Increases original efficiency
   b. No parasitic losses
   c. Increase horsepower
3. Durability 15%
   a. Robust center section
   b. Standard bearings
   c. Corrosion resistant exhaust tubing
4. Reliability 13%
   a. Oil pressure maintained at minimum 20psi
   b. Maintenance free center housing
   c. Reliable waste gate operation
   d. Reliable blow off valve operation
5. Resistance to heat 11%
   a. Correct material for hot side tubing
6. Size 9%
   a. Size of inducer/exducer
   b. Size of exhaust/compressor wheels
   c. Size of exhaust/intake tubing
   d. Sized of bov
   e. Sized of waste gates
7. Consistent results 9%
   a. Builds boost pressure consistently
   b. Maintains constant pressure while on waste gate
   c. Relieves excess pressure when throttle is relieved
8. Compatibility 8%
   a. Interchangeable blow off valve, bearing center-section, wheels, and wastegates
9. Ease of operation 8%
   a. Self sustained system
10. Safety 4%
    a. Inlet tubing to protect compressor wheel
    b. Internally vented waste gate to retain hot exhaust gases
## Appendix E

### Schedule

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Appendix F2

Exhaust elbow

Engine Assembly
Driver Side Header

Passenger Side Header

Appendix F4