

A Midrange Aluminum Sheet Metal Intake Manifold

by

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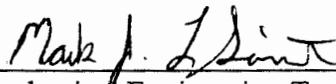
at the

OMI College of Applied Science
University of Cincinnati
May 2002

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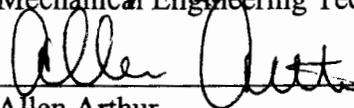
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Abstract

Drag Racing is a sport, involving maximizing performance of a vehicle to minimize travel time over a quarter of a mile on a drag strip. Aftermarket performance parts can enhance a vehicle's performance; however cost is large factor in part selection. An intake manifold is an example of this. There are cast aluminum and sheet metal aluminum intake manifolds available from several different companies. The problem lies in the fact that these intake manifolds jump in price from \$300 to \$2500. This jump in price is very unwelcome to drag racers.

The design objectives involved in creating an intake manifold were to be more affordable than the current high price aluminum sheet metal intake manifold and perform better than the low performance cast aluminum intake manifold. These objectives create an intake manifold with a midrange price and performance. The benefit is giving drag racers a third option when purchasing an aftermarket intake manifold.

The performance of the intake manifold was increased by designing for better air flow. The performance is demonstrated by testing the airflow of the cast aluminum intake manifold against the prototype on a flow bench. Eliminating machining and welding time reduced the price of manufacturing. The final price per unit was found by having a bid made by a sheet metal facility in the area based on a two hundred and fifty unit order.

This newly designed and constructed aluminum sheet metal intake manifold successfully met all design criteria. It performs twelve percent better than the cast aluminum and is forty percent cheaper than the existing aluminum sheet metal intake manifold. This prototype manifold gives drag racers a midrange option for upgrading their intake manifolds.

Table of Contents

Abstract.....	ii
List of Tables.....	iv
List of Figures.....	iv
Introduction.....	1
Design Solution.....	4
Air Flow.....	4
Price.....	5
General Design Parameters and Specifications.....	7
Building and Testing.....	8
Conclusion and Recommendations.....	10
References.....	11
Appendices	
Appendix A – Survey.....	A-1
Appendix B – Proof of Design.....	B-1
Appendix C – Schedule.....	C-1
Appendix D – Manufacturer’s Information.....	D-1
Appendix E – Drawings.....	E-1
Appendix F – Vender Bid.....	F-1
Appendix G – Charts of Test Results.....	G-1

List of Figures

Figure 1 – Edelbrock “Victor”	1
Figure 2 – Hogan’s Racing Manifolds “Sheet Metal Intake Manifold”	1
Figure 3 – Superflow 600 FlowBench.....	8

Introduction

An intake manifold is a key component in an engine that transfers and divides the air/fuel mixture from the carburetor into the ports on the cylinder heads. Modifying the design of this manifold can increase the overall performance of an engine. Fuel is sent from the cylinder heads into the combustion chamber. The fuel is then compressed and ignited to produce an explosion forcing the piston down. The stronger this explosion, the more power the engine is creating. Changing other components can enhance power output also. The right combination of high performance components is a key factor in maximizing overall performance. Changing cylinder heads can improve the fuel flow and velocity into the combustion chamber but can lead to other problems. The air intake and intake manifold are still designed for the original cylinder heads. Now the air intake and the intake manifold become the most restrictive components. These two components have to be replaced to allow a higher air/fuel mixture flow to best utilize the high performance cylinder heads.

Aluminum is the material of choice for an upgrade from the stock cast iron intake manifold. The problem lies in the fact that these aftermarket intake manifolds have a large jump in price. The Edelbrock Victor (figure 1), which is cast aluminum, costs \$300 and has low air flow. The sheet metal intake manifold available from Hogans Racing Manifolds (figure 2) has higher air flow and a higher price of \$2500. The large jump in price is very unwelcome to drag racers. The solution is to create an intake manifold with air flow and cost between the Edelbrock Victor and the Hogans Racing Manifold. [4,5]



Figure 1 – “The Victor” A Cast Aluminum Intake Manifold available from Edelbrock.

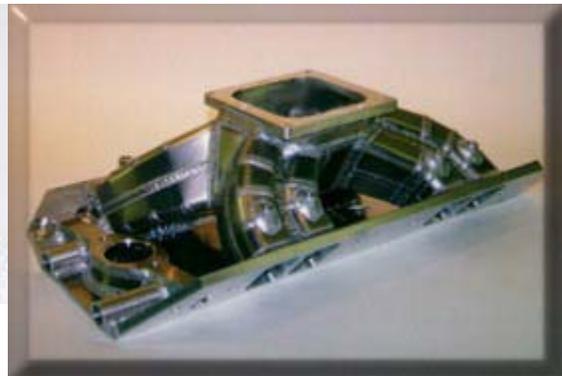


Figure 2 – Sheet Metal Intake Manifold available from Hogans Racing Manifolds.

A prototype that solves this problem will have to be completed and tested. The prototype has to be set up for 1050cfm carburetor. This is the same carburetor that the Edelbrock Victor is set up for; this sets up a fair test. For the prototype to be considered a solution to the problem, test results have to prove that airflow and price will fall between the two current aftermarket choices.

Based on an interview with Tom Bieckern, President of Midwest Fabricators, the cost factors with the manufacturing of the intake manifold are time for welding and machining. The materials are required regardless of the design, which takes materials out of the factors that lower cost. Aluminum is around \$1 per pound regardless of size or shape (i.e. sheet metal, bar stock, etc.). Modifying a current design to require less welding and machining reduces the price.[3]

The targeted customer for this product is an owner of Ford 460. Tri-state Dragway and Edge Water Raceway are home to many drag racers in the area. These racetracks visited were found to contained several potential customers. Several have developed their own custom aluminum sheet metal intakes to fit their 460s based on the design from Hogan's Racing Manifolds. The Ford 460 is discontinued, but existing blocks and parts are readily available. Many drag racers are interested in the intake manifold as an upgrade to their existing manifolds providing the cost is beneath \$2500. Four Ford 460 owners filled out the survey in appendix A. The results of this survey will guide the design process to accommodate the important needs of the customer. The results were tallied and placed behind each question in Appendix A. [1,6]

The proof of design is located in appendix B. This is a written agreement that illustrates exactly what the design criteria are for the project. One intake manifold will be designed and constructed that is 15% cheaper than the aluminum sheet metal intake manifold available from Hogan's Racing Manifolds, while increasing performance over the Edelbrock Victor intake manifold.

The cost is estimated for each unit based on production of two hundred and fifty units. This estimate comes from a machine shop with the capability to produce this manifold. The production number of two hundred and fifty was based on how many Ford 460 owners are known at the two tracks visited, multiplied by an estimate of how many drag strips are in the country. This estimate on production is based on a assumption that one out of every four 460 owners will buy this manifold. [1]

Flow bench testing will prove the performance increase. The resulting average runner flow of the prototype manifold was proven and compared to the average runner flow of the Edelbrock Victor cast aluminum manifold. This comparison showed a twelve percent increase in air flow to the Edelbrock Victor. A schedule that includes construction and testing is available in appendix C.

Design Solution

The design solution was broken into three areas: air flow, price, and general design parameters and specifications. The proof of design in Appendix B says that a prototype must be constructed with air flow and price being specific areas of concentration. Other parameters of designing the intake manifold exist but are not relevant to air flow and price, but to create a functional prototype.

Air Flow

High velocity and turbulent air flow are known to be important factors of high performance by the professional drag racers at Edgewater Race Way and Tri-State Drag Way. The Edelbrock Victor was analyzed to find good and bad design characteristics.

To create a high velocity system the prototype intake manifold has been designed with a more direct path from the carburetor to the cylinder heads. The path will separate in the plenum into 8 portions. This division will have no obstructions except the base plate of the plenum and the runner bends. The Victor receives the air/fuel mixture from the carburetor into the plenum. This plenum has runners connected on its sides. This forces the mixture to take a ninety-degree corner, which slows the flow dramatically. The next part of the flow is through the runners. The runners exit the plenum completely horizontal then bend downward to meet the cylinder heads. Another corner is created in the bend. The air/fuel mixture is forced make one hundred and thirty five degrees worth of bends. These conditions are not favorable and must be modified in the prototype.

To correct this, the prototype has been designed with runners that connect to the plenum with forty five-degree angles off the bottom. The runners also contain no bends for little resistance. The new design only requires the air/fuel mixture to take 45 degrees worth of bends. This is much more favorable than the 135 degrees currently required by the Edelbrock Victor.

The increase in velocity is a factor of area in the tapered runners. The taper decreases the cross-sectional area of the runner using the following formula.

$Velocity = \frac{FlowRate}{Area}$. This is the formula that illustrates the rise in velocity is directly

proportional to the area. The new prototype and the Edelbrock Victor contain similar tapers. The reduction in area is the same but method to accomplish the taper is completely different. [7]

The Victor's runners keep a constant width while the height of the cross-section decreases. The end of the runner transitions into an oval. The prototype's design has a large area circle that gradually tapers and transitions into an oval. Using the taper to also transition the runner is a common design characteristic shared between several intake manifolds. [4,5]

The base of the plenum is a 'V' shape. This will help to create a pocket in the middle of the runners that will feed the runners. The flow of the carburetor is higher than the flow required by the engine, which will let this fuel/air pocket develop. The plenum had three designs initially. All three were built from cardboard and tested to see which had the best flow characteristics. This plenum was then built out of aluminum and added to the assembly.

Price

The materials required to produce this intake manifold were very inexpensive. The aluminum was approximately two hundred dollars for the prototype. Reducing cost is solely based on the amount of machining and welding time that can be reduced.

The base of the manifold is designed after the Edelbrock Victor base. Instead of the cast base, the current design uses one piece of aluminum sheet metal to form the mating surface to the engine. The high-grade aluminum will stand up better to vibration than the cast aluminum thereby increasing the resistance to fail during operation. The

one piece of aluminum required is very inexpensive to have cut out by a water jet cutter. The prototype was \$79 for just the base. The bending required takes only two minutes. No machining is required to the base after construction.

The cost is an important factor in this project, so the taper has gone through several design concepts. The most inexpensive method of acquiring a taper was selected. After the runner is welded to the base, it was filled with a high-temperature epoxy that was machined into the taper. This taper is also where the runner begins the transition from a circle to an oval, which is the shape of the port on the head. This allowed the design to utilize a standard constant diameter aluminum tube. This tube was \$20 for twenty feet. The tube was simply band saw cut to the length required. The epoxy was \$200 for two gallons. This is enough epoxy to make approximately six intake manifolds. The epoxy selected had to be able to stand up to gasoline, handle high temperature, bond to aluminum, and be machineable. Product #641 from Epoxy Systems Int. (appendix D) was selected. After one runner was filled with epoxy a wax mold could be made of the ported runner. This mold could be used in the other runners and the epoxy would be poured in around it. After the epoxy set up the wax mold could be melted out. The production of the runners would be very inexpensive and cost effective.

The plenum was also designed for assemble. The drawings in appendix E show a flat pattern for the plenum. The long sides of the plenum are bent into the final shape and the shorter end caps are welded on. This requires very little welding. The plenum is thin and can be laser cut.

The adapter plate is simply a flat sheet of aluminum. This sheet is laser cut and bolts onto the top of the plenum. No welding is required to attach the adapter plate. Another benefit to this design gives the intake manifold operator an easy way to change adapter plates for different carburetors, blowers, or even fuel injection. This is a favorable design characteristic to the drag racers interviewed and surveyed.

Every component of this intake manifold has been reduced in cost from the current production intake manifold. The base plate is bolted to an engine block while the runners are welded. The plenum is then welded to the top of the runners. The material is very thin and welds easily. No machining is required after assemble except porting the runners. The key element that makes this method effective is that there was no harm to the function of the intake manifold to produce it forty percent less expensive than the current aftermarket sheet metal intake manifold.

General Design Parameters and Specifications

The type of aluminum used is a combination of 6061 T6 and 5052 H32. 6061 T6 is aircraft grade aluminum. The T6 means this metal has steel added for strength. This material will be good for any flat plates in the manifold. It is not suitable for the bending found in the plenum design. 5052 H32 is more pliable. It is non-ferrous and strain tempered for strength. Both types of aluminum are readily available in sheet form and have a thickness tolerance of plus or minus .013 inches. [3]

The weld strength is based on the size of the welds. The welds for this project will produce a bonded area that will be equal to or greater than the thickness of the aftermarket intake manifolds. This takes most stress concerns out of the project. The only stress seen by the intake manifold is vibration stress and thermal stress. The expertise of the welders at Midwest Fabricators will be required to ensure the welds are strong with ample penetration and no leaks. The top of the engine will reach a temperature of no higher than two hundred and fifty degrees Fahrenheit. This small amount of heat is negligible when expansion due to heat is calculated. The design of the intake manifold allows for expansion in any direction with the help of the cylinder head gasket. Intake manifolds and cylinder heads can maintain a tight bond with heat applied in various areas. This is proven also by the long history of drag racing. [3]

Building and Testing

The side plates of the intake manifold base are very complex with fillets, chamfers, and angles. Rather than sending a detailed drawing with a complex dimension scheme another approach was taken. The dimensions from the existing manifold were taken carefully with a scale and Venire Caliper. In AutoCAD 2002, a two dimensional sketch was created. The sketch was printed out on a Hewlett Packard Plotter accurate to four decimal places. The plotted drawing was cut out carefully and compared to the existing intake manifold. This was done three times until all fillets, chamfers, angles, and holes matched accurately. The electronic sketch was then converted to a DXF format. This format is compatible with the water jet cutter. The water jet cutter is accurate to five decimal places. The file is loaded into an interface and the computer finds the best cut pattern for the parts. The base was created with no drawings. The sketches of the base are available in Appendix E.

The plan for construction was to build the base and runners immediately. Three plenums of various designs were constructed from cardboard to find which configuration produces the highest flow. The flow characteristics will be determined from flow bench testing at Paul's Automotive Engineering. The resulting plenum was constructed and added to the already assembled base and runners. The final prototype was tested against the Edelbrock Victor on a flow bench. A flow bench measures velocity of the air as it passes through a chamber. The flow bench is available at Paul's Automotive Engineering in Blue Ash. The Superflow 600 combined with a Flowcomm computer bring the accuracy of the flow bench to one tenth of a percent (see figure 3). All fabrication was done at Midwest Fabricators in Northern Kentucky. [6]



Figure 3 – Superflow 600

The price had to be decreased by at least fifteen percent from the aftermarket equivalent. The aluminum sheet metal intake manifold available from Hogan's Racing Manifolds cost \$2500. The price of the prototype manifold was found by taking the

finished product, drawings, and specifications to the company president, Don South. He produced an estimate for what it would cost for Midwest Fabricators to produce two hundred and fifty units and make a profit. [5]

Test Results from the flow bench testing on May 15th show the Edelbrock Victor at an average runner velocity of 510 cubic feet per minute. The prototype manifold had an average runner flow rate of 611 cubic feet per minute. The estimated price of the prototype manifold based on production of 250 is \$1500 per unit from Don South at Midwest Fabricators (appendix F). A cost comparison and flow rate comparison chart is available in appendix F.

Conclusion and Recommendations

Applying the methods of construction found in the research portion of the project, an aluminum sheet metal intake manifold was constructed that performs better than the Edelbrock Victor cast aluminum intake manifold by twelve percent. This completed project will cost forty percent less to produce than the aftermarket intake manifold available from Hogan's Racing Manifolds. This completes all design requirements in the Proof of Design (appendix B).

The completed intake manifold will allow drag racers another choice when selecting a level of performance. Every drag racer interviewed has agreed that the aluminum sheet metal intake manifolds available are too expensive. By manipulating the design of the current aluminum sheet metal intake manifold, the cost of manufacturing this aftermarket has been reduced. The background in drag racing, Midwest Fabricators, Paul's Automotive Engineering, and knowledge gained in classes at The University of Cincinnati have led to a less expensive design that was constructed and tested. The test results in the previous section and Appendix G prove that a midrange aluminum sheet metal intake manifold has been created.

Customer input has been a driving factor in several design characteristics. After reviewing the final product a recommendation was made. Finding a way to lengthen the runners would have a huge benefit to the air flow. The flow could reach a higher velocity by the end of the runner which would ultimately result in an increase in torque. It is very important to always find ways to produce products as inexpensively as possible. Reducing machining and welding time is the key to lowering the manufacturing cost. Any new ways to produce a part cheaper without sacrificing quality or function are strongly recommended.

References

1. Ken Herbert, Tony Mann, Bill Chambers, and Tim Chardine - Professional Drag Racers
2. Pak/Teem Inc. – Keith Sumey, Shop Manager
3. Tom Bieckern, Don South – Midwest fabricators
4. www.Enderle.com
5. www.Hogansracingmanifolds.com
6. Paul's Automotive Engineering – Paul
7. Introduction to Fluid Mechanics, William S. Janna. PWS Publishing Co., 1993.

Appendix A

Survey

Survey for Ford 460 owners with cobra-jet heads

1=not satisfied 2=somewhat satisfied 3=satisfied 4=very satisfied
5=extremely satisfied

How satisfied are you with your current intake manifold?

1 2 3 4 5 **3**

How satisfied are you with the current price of aluminum sheet metal intake manifolds between \$2000 and \$2500?

1 2 3 4 5 **2**

How satisfied would you be with aluminum sheet metal intake manifold that costs under \$800 that had a 70% weight reduction from the stock manifold?

1 2 3 4 5 **5**

How satisfied would you be with an Aluminum sheet metal intake manifold that was setup for rpm's of 7000 or higher that costs less than \$800?

1 2 3 4 5 **5**

How satisfied would you be paying less than \$800 for an aluminum sheet metal intake manifold that increases engine performance up to 10%?

1 2 3 4 5 **4.75**

Comments _____

The Cheaper the better

Appendix **B**

Proof of Design

Proof of Design
Student: Mark J. LeSaint
Advisor: Allen Arthur
2/6/02

I will construct ~~one~~ design and manufacturing one aluminum sheet metal intake manifold for a Ford 460 that is 15% cheaper than the aftermarket aluminum sheet metal intake manifold available from Hogan's Racing Manifolds, while increasing performance over the cast aluminum Edelbrock Victor intake manifold.

The base plate dimensions will conform to the engine block and cylinder heads only. All other dimensions will be determined based on fuel flow characteristics. The top will allow for an adapter plate to fit fuel injection and a variety of carburetors. Two adapter plates will be manufactured: for a 1050cfm carburetor and for a 3000cfm Enderle Bird Catcher.

The cost will be estimated for each unit based on production of two hundred and fifty units.

Flow bench testing will prove the performance increase. The resulting average runner flow of the prototype manifold will be compared to the average runner flow of the Edelbrock Victor cast aluminum manifold. These intake manifolds will be tested on a flow bench only, not on an engine. The prototype will be tested with a 1050cfm carburetor configuration, which will match the Edelbrock Victor for a true comparison.

All construction and testing will be completed by May 6th.

Student Signature

x Mark J. LeSaint

Advisor Signature

x Allen Arthur 2/12/02

Appendix **C**

Schedule

Schedule for Project Revised on 1/10/02

Month	Date	Month	Date	Month	Date	Month	Date	Month	Date	Month	Date
September	20-22	September	23-29	September	30-6	October	7-13	October	14-20	October	21-27
October	28-3	November	4-10	November	11-17	November	18-24	December	25-1	December	2-8
December	9-15	December	16-22	December	23-29	January	30-5	January	6-12	January	13-19
January	20-26	January	27-2	February	3-9	February	10-16	February	17-23	February	24-2
February	3-9	February	10-16	February	17-23	February	24-2	March	3-9	March	10-16
March	17-23	March	24-30	March	31-6	April	7-13	April	14-20	April	21-27
April	28-4	May	5-11	May	12-18	May	19-25	June	26-1	June	2-8
June	9-15										

Assignment

3 Problem Definitions

1 Page Problem Definition

Survey

Proposal

Concepts

Proof of Design

Interim Design Report

Drawings with Dimensions

Design Freeze

Bill of Materials

Construction

Final Report

Oral Presentation

Advisor Proof of Design

Tech Expo

Appendix D

Manufacturer's Data

High Temp Epoxy #641

The Right Product For The Right Job
Since 1980

[[Home](#)] [[Up](#)]



EpoxySystems'™ Product #641

Heat Resistant Epoxy Coating

DESCRIPTION

EPOXYSYSTEMS' PRODUCT #641 is a moisture-insensitive, two-component, 100% solids epoxy coating. EPOXYSYSTEMS' PRODUCT #641 is especially formulated to protect concrete, steel and wood subject to high temperatures and corrosion. EPOXYSYSTEMS' PRODUCT #641 has a convenient 1:1 by volume mix ratio and is easy to apply.

ADVANTAGES

EPOXYSYSTEMS' PRODUCT #641 is resistant to high temperatures (300⁰-400⁰F) in addition to its high chemical resistance.

- High chemical resistance to acids, alkalies and other chemicals
- Cure under high humid conditions
- High build
- Excellent hardness and gloss
- Not brittle
- No blush or exudation
- High temperature resistance

USES

- Wall and Floor Coating for:

<http://www.epoxysystems.com/641.htm>

4/13/2002

Appendix **E**

Drawings and Sketches

[DWG1ASSY.DWG](#)

[DWG2BASETEMP.dwg](#)

[DWG3RUNN.dwg](#)

[DWG4TOP.dwg](#)

Appendix **F**

Vender Bid

Midwest Fabricators
215 Main St.
Dayton, Ky. 41074
(606) 261-4000

Quote # 0866

Quote

Customer

Name Mark LeSaint
 Address _____
 City _____ State Ohio ZIP _____
 Attn: _____

Date 5/16/02
 Order No. _____
 Rep _____
 FOB OUR DOCK

Qty	Description	Unit Price	TOTAL
250	460 alum. Sheet metal intake per prototype	\$1,500.00	\$375,000.00

Net 30
 Lead Time: 15-20 weeks

SubTotal	\$375,000.00
Shipping & Handling	\$0.00
Taxes State	\$0.00
TOTAL	\$375,000.00

DON SOUTH

Appendix **G**

Charts of Testing Results

