A Study of the Venturi Effect and
The Venturi Exhaust Primer

by

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Abstract

This study experimentally examined the relationship between prime vacuum generated and the venturi jet and venturi throat geometry. Engine exhaust is routed through the venturi to create the vacuum needed to prime the water pump. Pilot research was performed using a ten horsepower Yanmar engine and several venturi style throats and jets. After pilot testing, a compressed air hose was used to simulate exhaust gas flow and test modified venturi component combinations. It was concluded that the throat and jet combination that should be used for production produced the second highest vacuum reading and created less back pressure than the other combinations. The most promising jet and throat combination found using exhaust was then tested on the same engine used for the pilot research to verify the expected vacuum levels.

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I would like to thank my parents for their support and encouragement. They taught me to be dedicated to where I am going and love what I am doing.

Table of Contents

List of Tables

List of Figures

Chapter I: Introduction

Firefighters rely heavily upon the equipment that they are using. The equipment's performance directly affects the success of the firefighter in reducing structural damage and saving lives. For instance, the fire pump is a vital extension of the firefighter. When coming to a scene, it is the first piece of equipment that is used to battle the flames or prevent them from spreading. In order for the pump to run, it must be able to start quickly and effectively. Before water can begin pumping, the pump must achieve prime.

In order to achieve prime (fill pump with fluid initially), an exhaust primer is used on many small, combustion engine driven portable pump units (under 200 pounds per NFPA 1901 Standard). The exhaust primer uses the exhaust from the engine to create a vacuum for the water pump by means of the venturi effect. The Venturi Effect is when a flow of high pressure low volume fluid passes through a temporary constriction, causing the resulting fluid flow after the constriction to be at a higher velocity and lower pressure than the air flow before the constriction. The resulting increase in velocity (in this case, of the exhaust gas), creates a vacuum. The vacuum is translated into lift due to the primer tube connecting the exhaust venturi to the suction side of the pump. The greater the vacuum that is created, the less time it will take for the pump to achieve prime. The vacuum, or lift, is measured in inches of mercury.

The basic components of the exhaust primer are the primer body (including valve), the jet, and the throat. The jet and the throat are the two main variables in the exhaust primer that affect the amount of vacuum that is achieved. The jet is on the side of the airway that is before the constriction and also creates the beginning of the constriction. The throat provides the second half of the constriction as well as the airway after the constriction. Combined, the jet and the throat act as the venturi that produces vacuum.

Statement of the Problem

In an exhaust primer assembly, there are a large number of variables that can affect the amount of vacuum produced. These variables are both climate related and the various geometry, sizes, and proportions of the assembly. By testing at times when atmospheric conditions are similar to each other between days of testing, correlations were made between the geometric variables of the jet and the throat to find the optimal values. By recognizing this correlation, the exhaust primer can be made more efficient (able to achieve higher lifts) which ultimately means that the prime is more effective.

Purpose of the Study

The purpose of the study was to design a venturi jet and throat combination that could maximize the lift of the priming system. This was to be accomplished by variations made only to the jet and the throat of the primer system. By increasing the efficiency (increasing the lift) of the primer system, the pump will be able to achieve prime very quickly. This means that the pump, in the fire service industry, can be used sooner during a life threatening event such as a structural fire.

Assumptions of the Study

The first assumption was that the results would be similar in any reasonable environment outside of the testing facility. Reasonable, in this case, applies to any conditions that the pump would normally operate in (high temperature, close to open flame, extreme cold weather, etc.).

The second assumption was that, by limiting testing to take place during similar atmospheric conditions (temperature, humidity, barometric pressure), changes in the data were caused by geometric differences in the venturi components.

The third assumption was that the composition of the fuel being used in the engine during testing was consistent and conformed to conventional standards. This would indicate that exhaust temperature and composition did not vary based on fuel related causes.

The fifth assumption was that the fluid flow through the venturi components was an isentropic process that was diabatic, meaning that the flow through the venturi jet and throat changed the fluid temperature.

The sixth assumption was that the friction loss inside of the components of the venturi was small enough to be negligible.

Definition of Terms

Venturi Effect. The reduction in pressure and increase in velocity when a fluid passes through a constriction

Lift. Measured in inches of mercury, the height of the manometer column that results due to the vacuum created with the change in pressure before and after a constriction of flow of a substance through a pipe.

Pump Prime. The preparation of the pump to start flowing water from the suction side to the discharge side of the impeller

Isentropic. At a constant entropy

Entropy. Measure of energy not available to do work – constantly increasing until at a maximum state

Diabatic. Occurring with the gain or loss of heat

Coaxial. Having a common axis

Head Pressure. Resistance to the flow of a pump

Feet of Head. Feet of vertical lift - Converted from inches of mercury, 1 foot of head = .8827 inches of mercury

Exhaust Primer. Priming system using exhaust gas to create vacuum to prime a centrifugal pump

Primer Body. Houses primer valve to route exhaust gas through venturi components

Jet. Venturi component providing inlet for fluid and first part of constriction

Throat. Venturi component providing second part of constriction and outlet for fluid

Limitations of the Study

The first limitation of the study was that it allowed changes to be made to only two components of the exhaust primer: the jet and the throat. There are several variables related to the jet and throat geometry. The following table represents the variables studied within the geometry of the jet and throat:

Table 1: Geometric Variables for Jet and Throat Components

Variables for Jet	
A	Cross sectional area of constriction
B	Entrance angle
C	Angle after constriction
D	Entrance diameter
E	Constriction Length
F	Exit distance
Variables for Throat	
G	Cross sectional area of constriction
H	Entrance diameter
J	Exit angle
K	Length after constriction
L	Overall length
M	Entrance length before thread
N	Entrance radius
P	Length before constriction
R	Length of Constriction

The second limitation was that the primer must function based on the exhaust flow routed through it.

Methodology

After the initial testing of the existing components, modifications were made to the jet and throat that yielded the highest reading. In this study, the jet and throat that were being used as starting points were the T3 throat and J3 jet (See Appendix A for component drawings). By starting from these components, modifications were made to change the cross sectional area of both the constriction in the jet and the constriction in the throat. With this method, a new combination of components was determined to be a better baseline for further testing. These components will be referred to as the control components through the remainder of the paper.

After finding this new combination of components, variables A through P were then altered one at a time to eliminate some of the variables. Results of this testing can be seen in Chapter III.

Chapter II: Literature Review

The centrifugal pump emerged on the fire service market as early as 1912 as an alternative to the positive displacement pump (Teske, 2003). The centrifugal pump is a major competitor because it has fewer moving parts than most other pumps used in fire apparatus. Centrifugal pumps are also capable of much higher flows than self priming positive displacement pumps of comparable size and weight. Today, the market is flooded with centrifugal pumps because of their simplicity, capability, and reliability.

Despite the benefits of the centrifugal pump, one of their downfalls is that a primer is required. Centrifugal pumps may also "lose prime" when pumping if excess air penetrates the suction side of the pump. This means that the primer needs to be ready to re-prime the pump at any time and with little effort. A primer can come in many forms, including fluid-filled electric, fluid-less electric, rotary gear, gasoline engine manifold, and venturi style exhaust primers (Teske, 2003).

For portable pumps, having to add the extra weight of an entirely separate pump for priming can be a disadvantage. In addition, many of the auxiliary priming systems can be troublesome in the field. The fluid-filled electric pump, for instance, may leak or cease and require that the fluid be changed. The fluid-less electric primer, on the other hand, tends to have a shorter lifespan because the lubrication needed for the critical wear components is made by slowly wearing away parts of those components. Rotary gear and gasoline engine manifold primers are cumbersome and inefficient. They can also easily cause damage to the engine. The venturi style exhaust primer emerges from these options as the smallest and, if correctly designed, the most reliable primer available for portable pump applications. (Teske, 2003)

The venturi style exhaust primer also shares with the centrifugal pump the benefit of simplicity. The primer uses exhaust to create a vacuum that pulls water into the suction side of the pump, causing a flooded suction and allowing the pump to begin creating discharge pressure. The discharge pressure then takes over and keeps the pump primed (barring any suction leaks that can cause loss of prime).

The basis of the venturi style exhaust primer is what is known as the "venturi effect". The venturi effect can be described as a fluid flowing through a constriction, where the constriction causes a decrease in pressure (Lamb, 1953). The fluid then passes through the constriction and the pressure increases, creating a vacuum. This vacuum acts to "pull" liquid into the pump allowing the suction to flood and the pump to prime. In order for the venturi primer to function properly, the venturi geometry is critical.

The components of the venturi (the jet and throat) must be sized according to many factors. These factors include, but are not limited to, the speed of the air passing through the venturi, the height that the fluid must be lifted in order to enter the pump, the barometric pressure, the temperature of the working components, and the back pressure (Tuszon, 2000).

The Centrifugal Pump Primer

The centrifugal pump has proven to be a reliable, and often a necessary, presence on the fire scene. At a fire scene, the pump must be able to overcome almost any condition because, if the pump fails, lives are at risk. One of the major concerns and most terrifying scenarios for the firefighter is that, with discharge line pulled into a burning structure, the pump will lose prime and the firefighter will be left without any means of defense in the burning structure.

An area of concern with centrifugal pumps may come from the shaft sealing mechanism. The impeller shaft is driven either directly from the engine shaft or through a gearbox that acts as a transmission. The shaft enters the pump through the eye of the impeller. This means that the area between either the impeller shaft and the gearbox or the impeller shaft and the engine must be sealed. "Seal failure in critical applications can have severe implications" (Green, 2001). One possible implication is that the seal will fail and the gearbox will then fill with water. This can cause the gears to cease due to lack of lubrication when the oil is diluted to the point of being ineffective against the extreme heat that is generated by the meshing of the gears. If the gears cease, the impeller shaft stops rotating and the pump stops pumping. In this situation, sever damage can be caused to both the pump and the engine that is driving the pump. The firefighter is then left without the safety of the water for protection.

Centrifugal pumps have also advanced to the point where they are self-priming. With the self-priming pump, water is added to the pump through the priming port. The water then fills the discharge reservoir and travels through the eye of the impeller. The pump is primed without first filling the suction line as is typically needed with most centrifugal pump designs. In this case, all of the connections on the pump must be air tight (Bechtler, 1994). If air enters the pump inlet while it is pumping, it can cause cavitation.

Cavitation can have severe consequences to the components of the pump. The water inside of the pump is pressurized which allows the pump to provide the discharge pressure needed. Gases, including air, are compressible (Dellar, 2003) so, when air enters the pump and is subjected to the extreme pressures within the water, the compression causes the gases to attempt to vaporize (Isaacs, 2009). When the pressure reaches a critical value, and the gas bubbles attempt to expand to relieve the pressure, the bubbles implode. The implosion of these bubbles can cause severe damage to the internal components of the pump. Cavitation can sound like pieces of metal being thrown into the pump and the resulting damage looks like the components were shot with buckshot.

Although much research has been done in preventing catastrophic pump failures, loss of prime while pumping is also of major concern. This is particularly important on portable pumps that are used in areas where other pumps may not be able to go. With portable pumps, the pump is typically carried to an area where it will be the most effective in fighting the fire. This could be a brush or wildfire where the water source is a reservoir (natural or manmade). The pump is almost exclusively used while pumping from draft. The suction line inlet must be completely submerged in the water source in order to allow the pump to continue pumping without drafting air. If too much air is drafted, the pump will lose prime.

Research in centrifugal pumps regaining prime is still needed. Typical primers may be slow to prime and it is often difficult to determine, after having already achieved and lost prime, whether or not all of the air has been effectively removed from the pump. (Teske, 2003)

According to the NFPA 1901 standard, the primer is meant to fully prime the pump in less than 30 seconds for pumps under 1,250 gpm. The exhaust primer is always connected to the exhaust of the engine and so, as long as the engine is running, the primer is always available to prime by simply opening the valve on the primer body to redirect the air through the venturi portion of the primer.

Though little research has been done to correlate exhaust primers to the venturi effect, there has been research on venturi design as it relates to jet pumps (Wakefield, 2002). One of the leading experts on this topic is A.W. Wakefield of Genflo Technology Limited. Wakefield's publication of "An Introduction to the Jet Pump", released in August of 2002, discusses the basic science behind the venturi. Wakefield briefly discusses the geometric relationship between the venturi components and their effectiveness.

The purpose of this paper is to find and document the connection between the exhaust primer venturi geometry and measurable engine and environmental characteristics. The ultimate goal is to eventually be able to correctly and effectively size the venturi components without relying on the typical trial and error technique.

Chapter III: Methodology

Portable centrifugal firefighting pumps require a primer that is auxiliary to the pump in order to achieve prime. Though these primers can come in many different forms, the venturi exhaust primer is the most compact and is quickly becoming one of the most popular primer systems used on portable pumps. In the exhaust primer assembly, two components can determine the efficiency of the primer. These components are the jet and the throat. By finding the correlation between the geometry of the jet and the throat assembly and the engine that is being used to drive the pump, a more accurate and more reliable venturi exhaust primer can be designed.

Data Required

Many determinations were made before testing to make certain that the correct aspects of the experimentation were recorded. Criteria for testing were largely determined through evaluation of the needs of the user of the centrifugal pump.

The first determination that was made was that the actual lift (feet of head) achieved through the primer was the main factor of a good primer. The second determination was that the time to reach prime was also of concern. According to NFPA 1901, pumps under 1,250 gpm must prime within 30 seconds.

For this research, the same 10 horsepower Yanmar engine was used both for the pilot study and testing. The Yanmar engine was chosen due to recent changes in emissions requirements that caused the engine exhaust pressure to decrease. This change also decreased the efficiency of the primer components previously used that were designed for the higher exhaust pressure. The combination of jet and throat used previously on the Yanmar engine (J3 and T3) yielded a vacuum of approximately 12 inches of mercury (13.60 feet of head/ lift) after the emissions changes. Previous to the emissions changes, the J3 and T3 combination yielded a vacuum of approximately 20 inches of mercury (22.66 feet of head/ lift).

Testing began with modifications that were made only to the constriction diameter on the jet and throat. With this method, a new set of jet and throat were determined to be effective. These components were numbered T5 throat and J5 jet. This combination yielded approximately 22 inches of mercury (24.92 feet of head/ lift) and was used for further testing.

After examining the specific criteria that would allow testing to be measured effectively, the variables of the testing were determined. The controlled variables that were changed by the researcher throughout testing included the jet and throat geometry. This was accomplished by starting with the control components (T5 and J5) and creating new components that were slight variations of the controls. The intention was to change one geometry variable at a time. See Appendix A for components and corresponding geometry.

The environmental variables that were not controlled but needed for reference to explain anomalies included the barometric pressure and the air temperature.

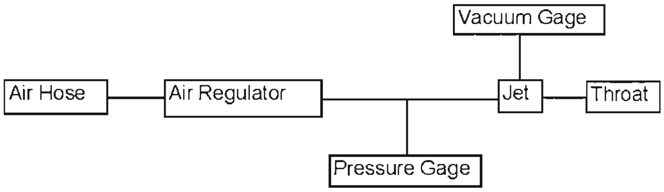
Instrumentation

Instruments used for testing included a vacuum gage, pressure gage, 10 horsepower Yanmar engine, exhaust primer body and internal components, compressed air hose and several jets and throats.

The exhaust primer was attached to the exhaust of the Yanmar engine. A vacuum gage was threaded into the jet to simulate the primer tap on the pump. This allowed for an accurate reading of the amount of vacuum that was produced without priming the pump and then draining it between each test.

An adapter was made with a pressure tap to place between the exhaust and the primer body to determine the inlet pressure to the venturi primer. Copper tubing was run from the pressure tap to a pressure gage. This pressure was used to set a regulator placed between the air hose and primer components (See Figure 1) to use for further testing with component combinations that yielded favorable results verified using the 10 horsepower Yanmar engine.

Figure 1: Primer System Test Setup for Venturi Component Testing Using an Air Hose Supply



Data Collection Procedures

There were four "standard" combinations of jet and throat components that were used on portable pumps at the company where this research was conducted. Verifying these existing combinations for a baseline using a ten horsepower Yanmar engine yielded the following results (values in inches of mercury):

Table 2: Pilot Study for Existing Venturi Components Vacuum Test Results

*** All values in inches of Mercury**

	Throat			
Jet	T1	T2	T3	T4
J1	18.5	11.25	19	*
J2	16	12	1.5	*
J3	16.25	8	19.5	2.5
J4	8.75	5	12.25	19

After initial testing of the existing venturi components, modifications were made to the jet and throat that yielded the highest vacuum reading. Jet J3 and throat T3 were used as the control components for further testing.

During testing, the control jet and throat were retested at the start of each test day to verify that the results were comparable and repeatable.

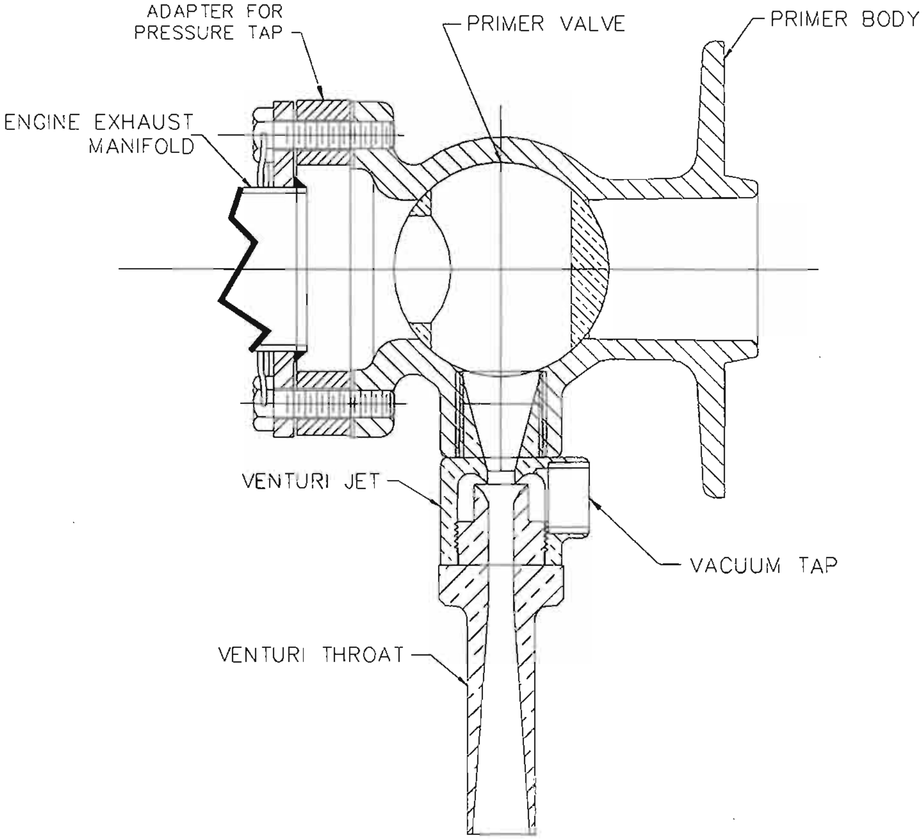
The engine was run without the pump but with the inboard head, which acts as an adapter between the engine and pump, attached to the engine mounting face to act as a guard to the spinning engine shaft.

An exhaust primer body was attached to the muffler of the engine. From the exhaust primer body, a hose was run to a quick connection that connected a professionally calibrated vacuum gage.

An adapter was fitted between the exhaust outlet on the engine and the primer body with a pressure tap to measure the outlet pressure from the engine.

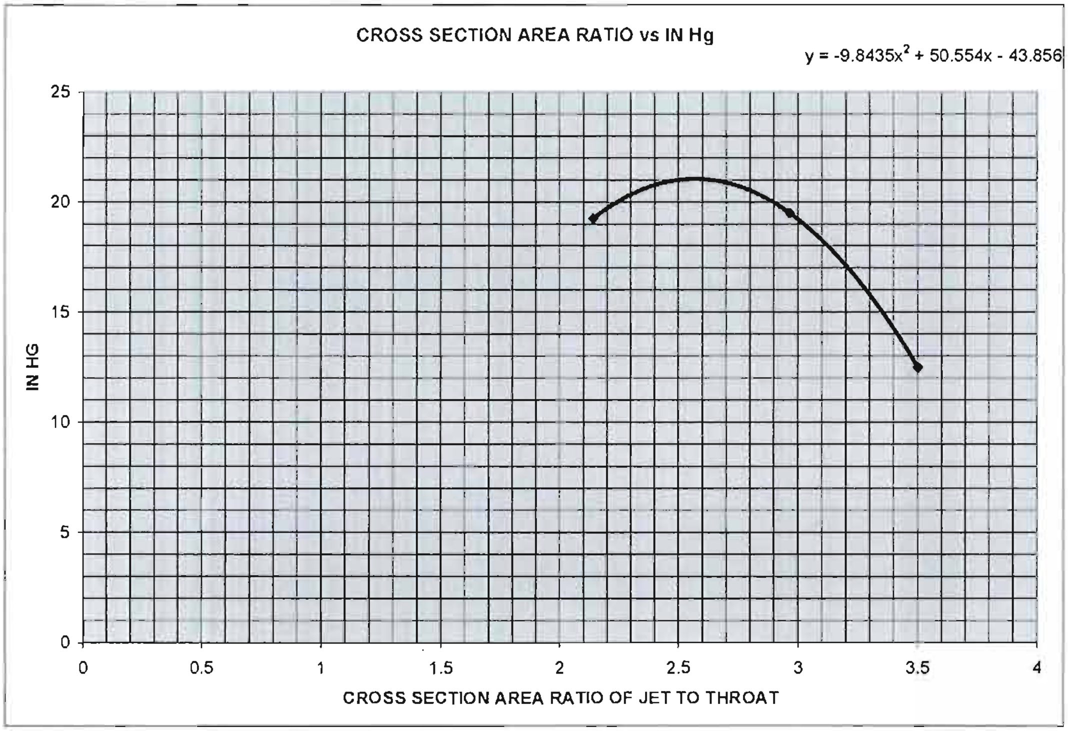
The exhaust primer body housed a valve that was actuated by a hand lever. The valve activated the venturi components by routing the exhaust of the engine through them. See figure 2 for the exhaust primer system cross section. During testing, the valve was held in the prime position to allow the exhaust to route through the primer components. The valve was held in the prime position until the reading from the vacuum gage stabilized for 3 seconds. The stabilized reading was recorded in a table that included barometric pressure and air temperature. The engine temperature was assumed to remain constant by running the engine before testing.

Figure 2: Exhaust Primer System Cross Section



Data analysis. During the pilot study with the 10 horsepower Yanmar engine where the ratio of the cross sectional areas of the jet and throat were studied, a graphical analysis based on the results yielded from testing was used as an attempt to predict the next geometry that should be tested. The graphical analysis plotted the vacuum readings obtained with the ratio of the cross sectional areas of the jet and the throat being tested. By graphing some the cross sectional area ratios versus the resulting vacuum, an optimum point can be found. The optimum point is the maximum point of the curve drawn to relate three plotted points from the actual test data. The maximum point from the quadratic equation was used as the next ratio to test. An example of this analysis technique can be seen in Figure 3 or Appendix C.

Figure 3: Prediction Technique for CSA Ratio Graphical Analysis Used During Pilot Study



It was determined during the pilot testing that basing the research solely on the ratio of the cross sectional areas provided random and unpredictable results. This meant that the pilot testing was done by the trial and error method. After a combination (labeled J5 jet and T5 throat) reached 22 inches of mercury, the combination was further improved by identifying several possible geometry variables for the jet and throat. From the list of variables, five new jets and four new throats were created. During this portion of the testing, jets J6, J7, J8, J9 and J10 were tested with the control throat (T5). Throats T6, T7, T8, and T9 were tested with the control jet (J5). All other combinations were then tested also using the 10 horsepower Yanmar engine.

Limitations

Some limitations to research using a venturi exhaust primer are the measurement instruments that are able to be used in high temperature environments. A flow meter that could withstand the high exhaust temperatures to measure the flow rate from the exhaust of the engine could not be found.

Another limitation during testing was that only existing jet and throat geometry dimensions were altered. This helped to prevent the number of variables from being infinite.

Chapter IV: Results

This chapter will present the results of the study performed by the researcher. A pilot study was conducted based on venturi components that were already in production.

Referencing the pilot study, possible geometry variables for both the jet and the throat were listed. These variables were used to create new components that each had one variance from the control components (T5 and J5).

Test Data

It was found during testing that some of the predetermined variables had little to no effect on the level of vacuum achieved by some combinations of components. Variables that had little to no effect on vacuum readings were eliminated from further exploration based on comparison of data between the control components testing (T5 and J5) and the variable components testing (Jets J6 – J10 and Throats T6 – T9). Eliminated variables included the constriction length and the entrance diameter.

Table 3 indicates test results using the control and variable components. This testing was done using an air hose to simulate exhaust flow through the venturi components. The column labeled "Best Inlet Air Pressure" is the inlet pressure that was able to achieve the highest vacuum.

Table 3: Venturi Component Testing on Air Hose vs. 10 hp Yanmar Engine

Throat	Jet	Best inlet pressure – air hose (psi)	Vacuum Achieved (air hose – in Hg)	Actual inlet pressure – engine exhaust (psi)	Vacuum Achieved -10hp Yanmar (in Hg)
T8	J9	16.9	21	19.2	20.4
T5 (Control)	J7	20.1	21	18.4	19.5
T7	J10	19.8	19.5	19.1	20
T8	J10	22	21	19.4	20.2
T9	J7	26.3	21	18.8	19.5
T9	J10	28.8	21.2	19	19.5
T5 (Control)	J9	16.8	16.25	19.2	19.5
T9	J9	19.9	16	19.2	19.5
T7	J9	17.8	15.75	19.4	19.7
T5 (Control)	J10	20.5	18.5	19.4	19.5
T7	J7	20.5	20.5	19.6	19.7
T5 (Control)	J8	22.8	19.75	18.9	18.7
T9	J8	26.9	18.5	18.9	18.5
T9	J6	21	21.2	19.6	19
T7	J8	21.7	19.5	19	18.2
T8	J8	21.3	19	19.1	18.2
T8	J6	21.2	20.75	20.3	19
T6	J9	17.7	15.5	19.2	17.8
T6	J8	22.9	18	19.1	17.6
T6	J7	19.9	18	19.5	18
T8	J7	21.1	22	19.5	18
T6	J10	18.3	18.5	19.5	18
T5 (Control)	J6	21	22.75	21.7	19.5
T8	J5 (Control)	46.3	20.5	22.4	20
T9	J5 (Control)	54.2	21	21.9	19
T6	J6	20.3	19.5	21.7	18.5
T7	J5 (Control)	47.8	21	22.9	19.5
T5 (control)	J5 (Control)	50.3	23.75	24.6	20.5
T6	J5 (Control)	47.4	21	23.7	18.5
T7	J6	17.3	5	20.8	0

Testing indicates that the combination of components that produced the highest vacuum was the control components (T5 and J5). The second highest vacuum reading obtained was from variable components J9 and T8. Jet J9 varies from the control jet (J5) by the angle after the constriction. Throat Z varies from the control throat (T5) by the entrance length before the thread.

The control component combination, according to testing with the air hose, is capable of achieving 23.75 inches of mercury of vacuum. This is with an inlet pressure of 50.3 psi. During testing using the 10 hp Yanmar engine, it was found that this combination produced approximately 20.5 inches of mercury with an inlet pressure of 24.6 psi. The second best combination of components (Jet J9 and Throat T8) showed during testing with the air hose a capability of achieving 21 inches of mercury. During testing with the 10 hp Yanmar engine, it was found that this combination produced approximately 20.4 inches of mercury with and actual inlet pressure of 19.2 psi.

Chapter V: Discussion

Limitations

Some limitations to research using a venturi exhaust primer are the measurement instruments that are able to be used in high temperature environments. A flow meter that could withstand the high exhaust temperatures to measure the flow rate from the exhaust of the engine could not be found.

Another limitation during testing was that only existing jet and throat geometry dimensions were altered. This helped to prevent the number of variables from being infinite.

Conclusions

Using an air hose to simulate exhaust inlet gas for testing, it was found that the optimum inlet pressure for T5 throat and J5 jet was 50.3 psi. This yielded a test result of 23.75 in hg indicating that a large amount of back pressure was created.

The component combination with the second highest vacuum reading was throat T8 and jet J9. The optimum inlet pressure for this combination was 16.9 psi. This yielded a test result of 21 in hg indicating that this combination caused less back pressure than the T5 and J5 control combination.

Back pressure from exhaust components can cause severe damage to the engine from soot build up. For this reason, throat Z and Jet U were determined to be most well suited for the exhaust primer application from the components that were tested.

Research Comparison

According to A.W. Wakefield, the inlet and outlet angle on the venturi are the most critical in terms of producing high vacuum readings. Test results appear to support this.

The main difference in Wakefield's research is that the fluid Wakefield was using was a liquid. In this case, the fluid is a gas. This changes results in terms of compressible versus non-compressible fluids. This could account for the indication found during testing that the angle after the constriction of the jet also greatly changes the amount of vacuum that is achieved.

Another interesting finding was that the control components yielded different results at different times. This indicates that environmental factors also created changes in results.

Recommendations

One recommendation for further research is to create a more controlled environment for testing to aid in eliminating environmental factors. This could be done either by using a climate controlled room for testing or running all tests consecutively on the same day.

Another recommendation would be to further explore the relationship between the engine and the exhaust primer. A correlation should be found between the engine displacement and various other factors, and the amount of vacuum achieved. This could be done by performing tests on several different engines. These engines may need to be segregated into test groups based on the manufacturer of the engine for the most comparable vacuum levels. Atmospheric conditions during simulated exhaust testing definitely influence the amount of vacuum produced. However, exhaust primers in service experience temperatures much higher than atmosphere and the engine exhaust has consistent moisture content.

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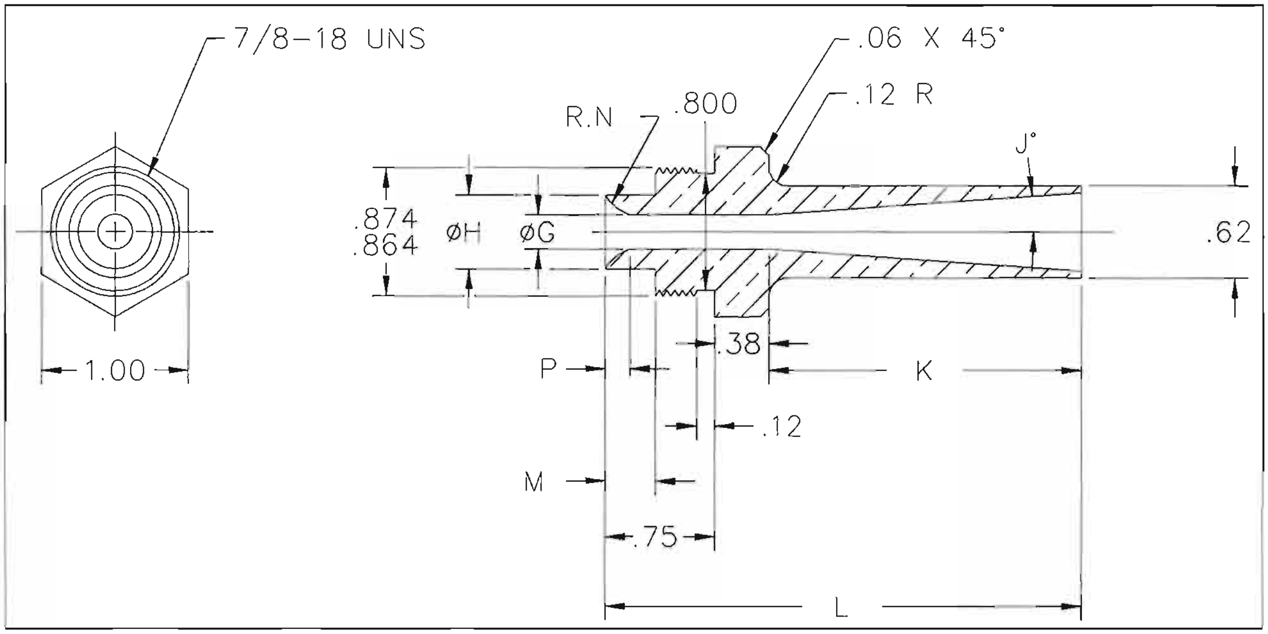
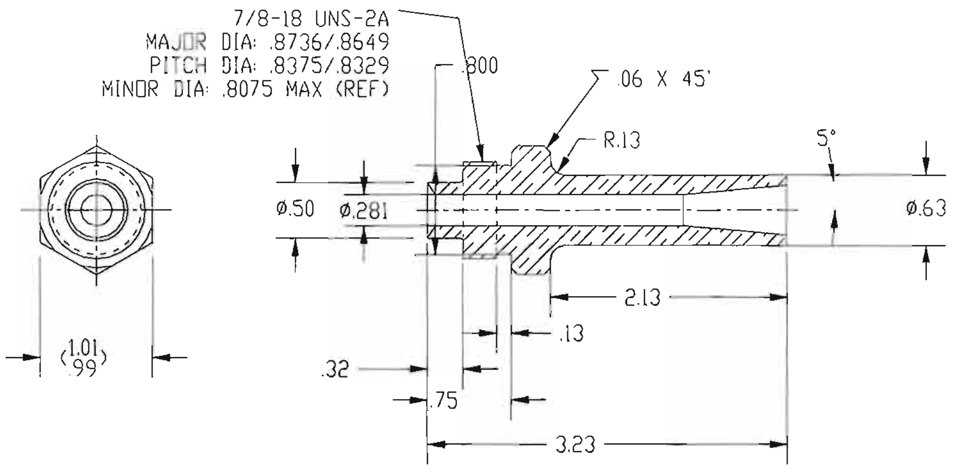
Appendix A: Part Drawings

Throats



Variables for Throat		**J5**	**T5**	**T6**	**T7**
G	Cross sectional area of constriction	0.234	0.247	0.247	0.247
H	Entrance diameter	0.5	0.5	0.5	0.5
J	Exit angle	4	5	5	5
K	Length after constriction	2.12	0.938	0.938	0.938
L	Overall length	3.25	3.23	3.23	3.23
M	Entrance length before thread	0.34	0.32	0.32	0.32
N	Entrance radius	0.312	0	0	0.5
P	Length before constriction	0.1696	0.07	0.15	0.07
R	Length of Constriction	0.955	2.22	2.142	2.222

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D
A	ADDED NOTE 1	20MAR2007	2007-112	JWG



NOTES:
1: 1.00 HEX x3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME	MDL CREATED	SHEET	
4416802	7/24/08	1/1	A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO. G622-2

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

THROAT - PRIMER
-

MATERIAL DESCRIPTION:
1.00 HEX x 3.38 LG BRASS - SEE NOTE 1

MATERIAL NO. 1101604

PATTERN NO. -

DR'N RAH
CHKD -
TRCD JSS011604

DATE 07-May-56
SCALE 1/1

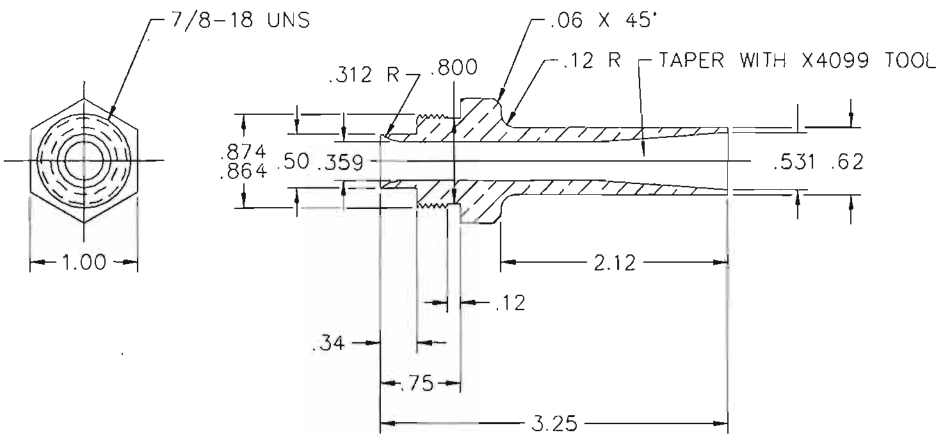
T1

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



FINISH ALL OVER

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

MATERIAL MUST COMPLY WITH ASTM B16

OLD PART NO. G622-6

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. DARLEY & CO.
MELROSE PARK, IL - CHIPPEWA FALLS, WI

THROAT - PRIMER

MATERIAL DESCRIPTION:
1" HEX X 3.38 360 BRASS

MATERIAL NO. 1101604

PATTERN NO. -

DR'N RAH
CHKD
TRCD

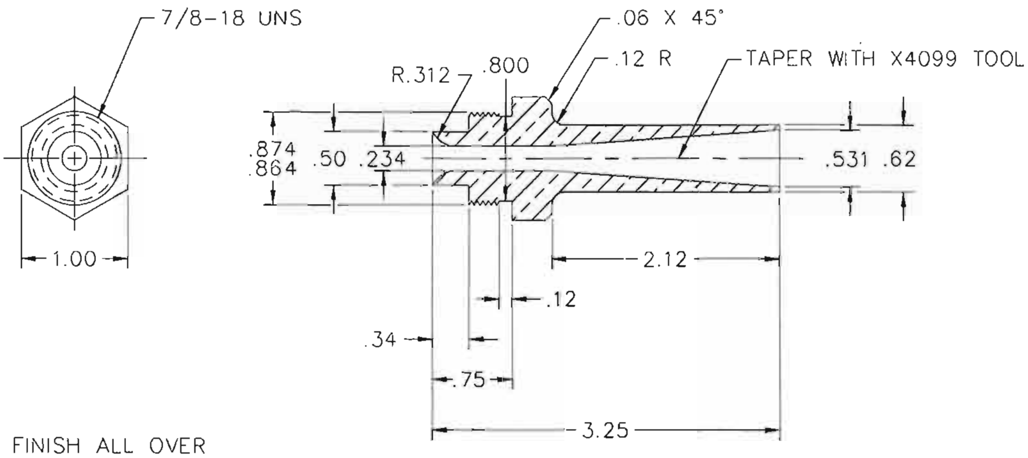
DATE MAY05,56
SCALE 1/1

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



FINISH ALL OVER

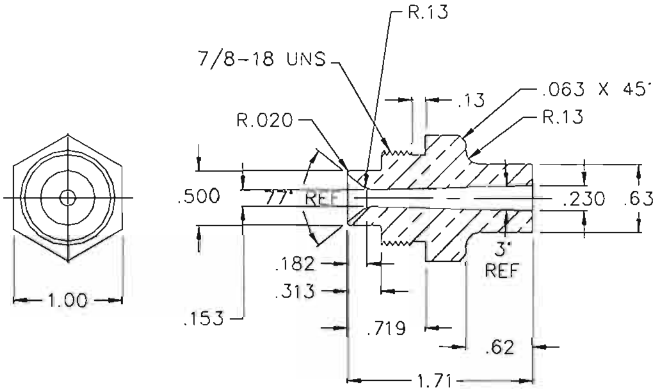
REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

		OLD PART NO. –	TOLERANCE EXCEPT AS NOTED .00 ±.03 .000 ±.010 ANGLES ±1°	W.S. DARLEY & Co. MELROSE PARK, IL – CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION: 1" HEX X 3.38 360 BRASS	MATERIAL NO. 1101604	PATTERN NO. –		THROAT – PRIMER
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. – UNAUTHORIZED REPRODUCTION IS PROHIBITED	ALL DIMENSIONS IN INCHES UNLESS NOTED	DO NOT SCALE PRINT	DR'N CKE CHKD TRCO	DATE 15MAY,00 SCALE 1/1

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



MATERIAL: 360 BRASS

REMOVE SHARP EDGES

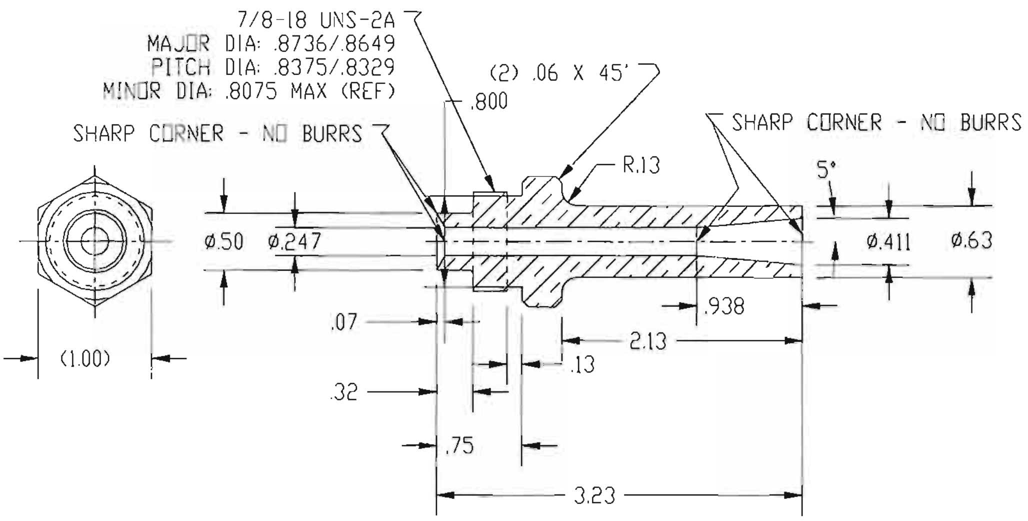
INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

		OLD PART NO. –	TOLERANCE EXCEPT AS NOTED .00 ±.03 .000 ±.010 ANGLES ±1°	W.S. DARLEY & Co. MELROSE PARK, IL – CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION: 1" HEX X 1.84"	MATERIAL NO. 1101604	PATTERN NO. –		THROAT – PRIMER, USE W/4416707 10HP INTEK
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. – UNAUTHORIZED REPRODUCTION IS PROHIBITED	ALL DIMENSIONS IN INCHES UNLESS NOTED	DO NOT SCALE PRINT	DR'N DMD CHKD CKE TRCO	DATE 09OCT2002 SCALE 1/1

REVISIONS

LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



NOTES:
1) 1.00 HEX X 3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME 4416810
MDL CREATED 7/24/08
SHEET 1/1
A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO

MATERIAL DESCRIPTION:
1.00 HEX x 3.38 LG BRASS - SEE NOTE 1

MATERIAL NO.
1101604

PATTERN NO.
-

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

TOLERANCE
EXCEPT
AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

DR'N AAN
CHKD TED
TRCD

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

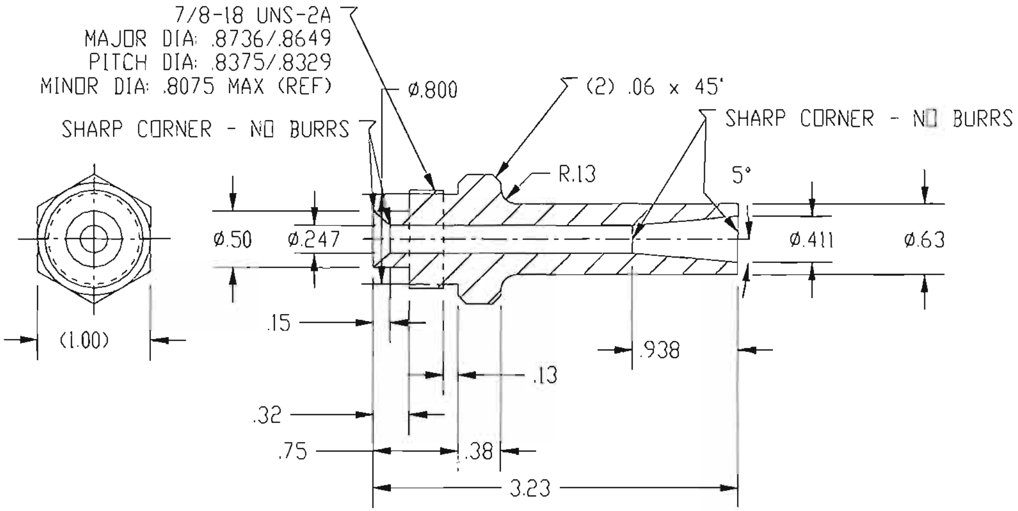
THROAT - PRIMER
-

DATE 24-Jul-08
SCALE 1/1

T5

REVISIONS

LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



NOTES:
1) 1.00 HEX X 3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME THROAT X
MDL CREATED 8/13/09
SHEET 1/1
A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO.

MATERIAL DESCRIPTION
1" HEX X 3.35 360 BRASS

MATERIAL NO.
1101604

PATTERN NO.
-

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

TOLERANCE
EXCEPT
AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

DR'N AAN
CHKD -
TRCD

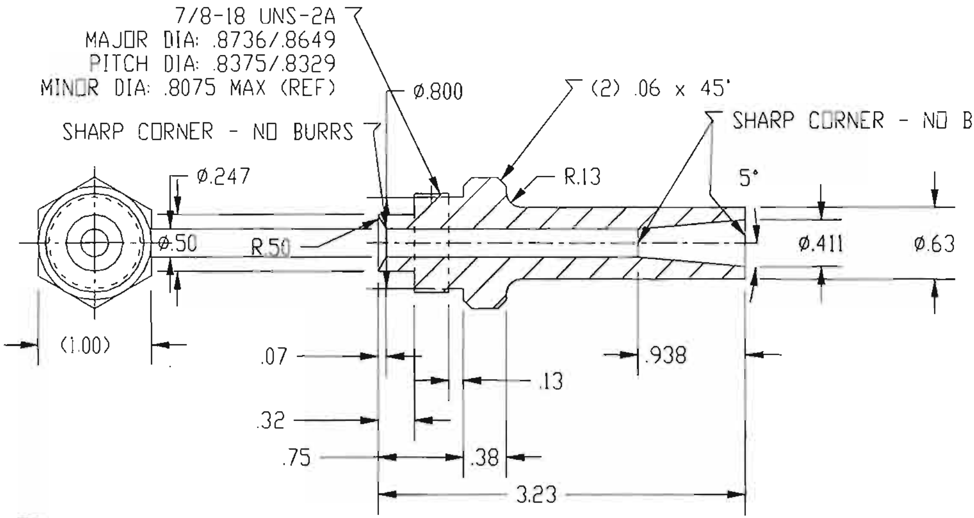
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

THROAT - PRIMER
-

DATE 13-Aug-09
SCALE 1/1

T6

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D

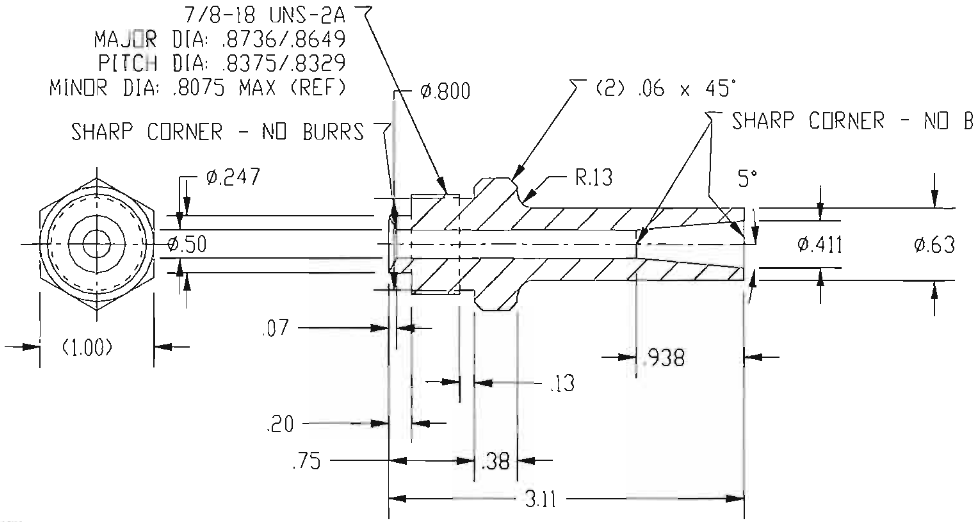


NOTES:
1) 1.00 HEX X 3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME: THROAT_Y
MDL CREATED: 8/13/09
SHEET: 1/1
A

REMOVE SHARP EDGES
INCH [MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
THROAT - PRIMER
-
MATERIAL DESCRIPTION:
1" HEX X 3.35 360 BRASS
MATERIAL NO. 1101604
PATTERN NO. -
DR'N AAN
CHKD -
TRCD
DATE 13-Aug-09
SCALE 1/1
T7
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED
ALL DIMENSIONS IN INCHES UNLESS NOTED
DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D

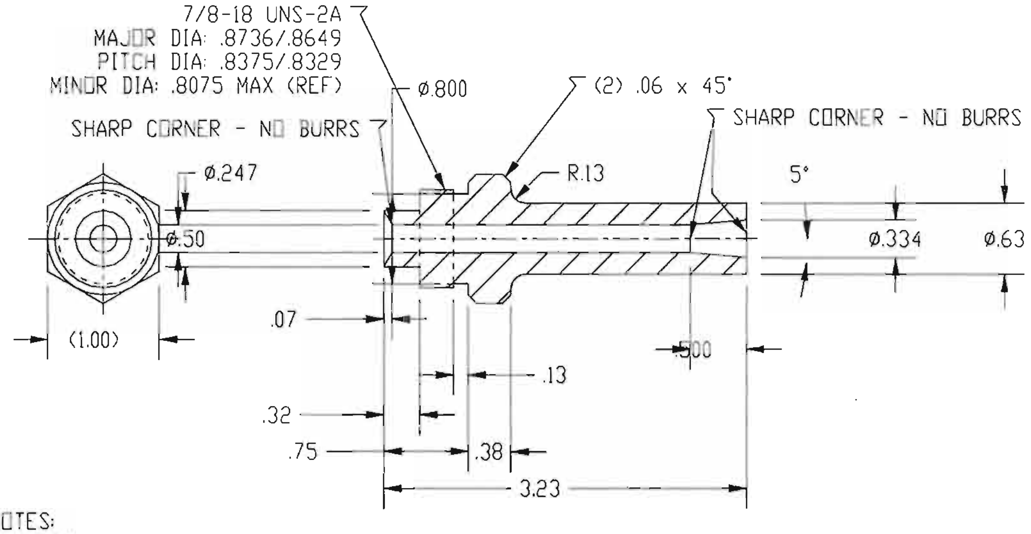


NOTES:
1) 1.00 HEX X 3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME: THROAT_Z
MDL CREATED: 8/13/09
SHEET: 1/1
A

REMOVE SHARP EDGES
INCH [MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
THROAT - PRIMER
-
MATERIAL DESCRIPTION:
1" HEX X 3.35 360 BRASS
MATERIAL NO. 1101604
PATTERN NO. -
DR'N AAN
CHKD -
TRCD
DATE 13-Aug-09
SCALE 1/1
T8
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED
ALL DIMENSIONS IN INCHES UNLESS NOTED
DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



NOTES:
1) 1.00 HEX X 3.51 EACH (42.125" BAR MAKES 12)

MODEL NAME: THROAT_AA
MDL CREATED: 8/13/09
SHEET: 1/1 | A

REMOVE SHARP EDGES

INCH [MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO.

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

THROAT - PRIMER
-

MATERIAL DESCRIPTION: 1" HEX X 3.35 360 BRASS
MATERIAL NO.: 1101604
PATTERN NO.: -

DR'N: AAN
CHKD: -
TRCD

DATE: 13-Aug-09
SCALE: 1/1

T9

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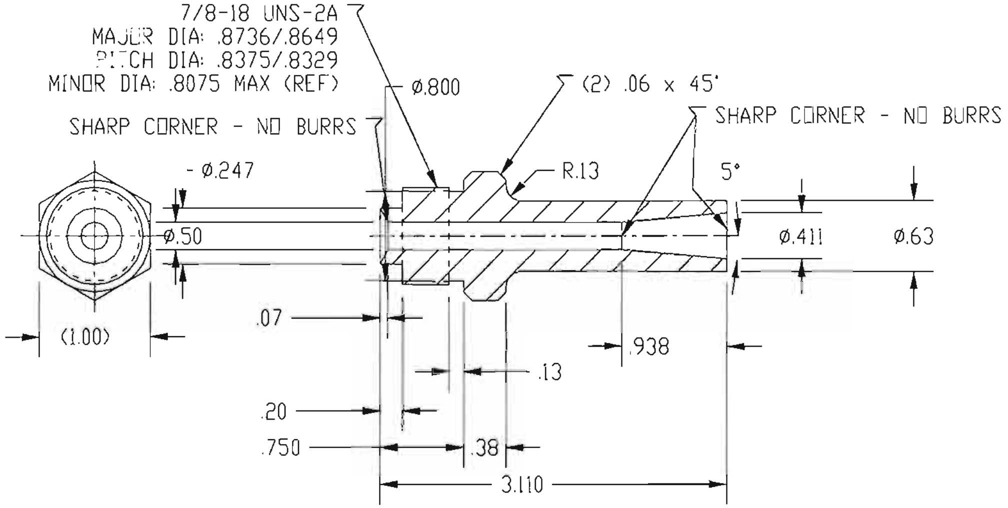
ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D



NOTES:
1) 1.00 HEX X 3.35 EACH (42.125" BAR MAKES 12)

MODEL NAME: 4416811
MDL CREATED: 8/13/09
SHEET: 1/1 | A

REMOVE SHARP EDGES

INCH [MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

THROAT - PRIMER, USE W/4416709
P100

MATERIAL DESCRIPTION: 1" HEX X 3.35 360 BRASS
MATERIAL NO.: 1101604
PATTERN NO: -

DR'N: AAN
CHKD: -
TRCD

DATE: 3/3/10
SCALE: 1/1

T10

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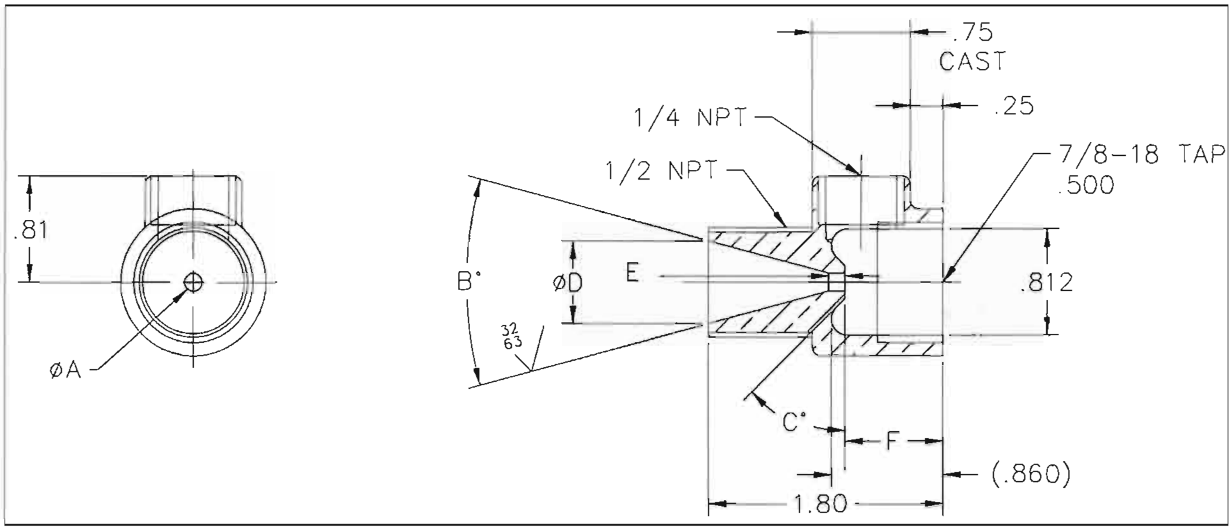
ALL DIMENSIONS IN INCHES UNLESS NOTED

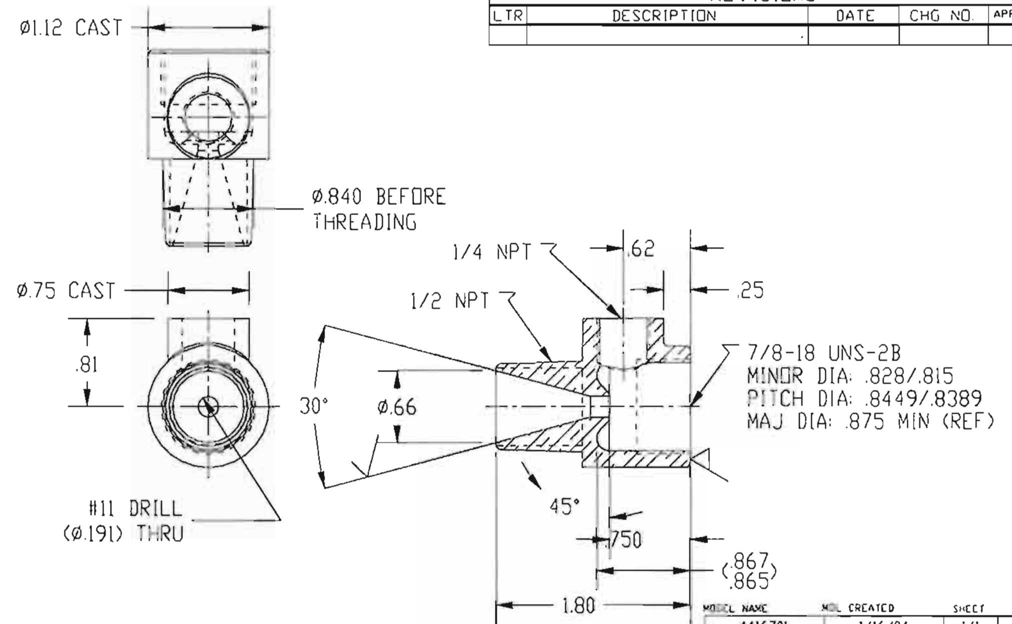
DO NOT SCALE PRINT

Jets



Variables for Jet		J3	J5	J6	J7	J8	J9	J10
A	Cross sectional area of constriction	0.136	0.157	0.157	0.157	0.157	0.157	0.157
B	Entrance angle	30	30	30	28	30	30	45
C	Angle after constriction	45	45	63	45	45	70	45
D	Entrance diameter	0.63	0.66	0.66	0.66	0.5	0.66	0.66
E	Constriction Length	0.12	0.11	0.17	0.05	0.41	0.11	0.44
F	Exit distance	0.75	0.75	0.688	0.75	0.75	0.75	0.75

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D
	.			



MODEL NAME	MDL CREATED	SHEET	
4416701	1/16/04	1/1	A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO. G620-1

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

JET - PRIMER
-

MATERIAL DESCRIPTION:
CAST BRASS 81-3-7-9

MATERIAL NO. 4416798

PATTERN NO. G620

DR'N REY
CHKD -
TRCD JSS011604

DATE 04-May-56
SCALE 1/1

J1

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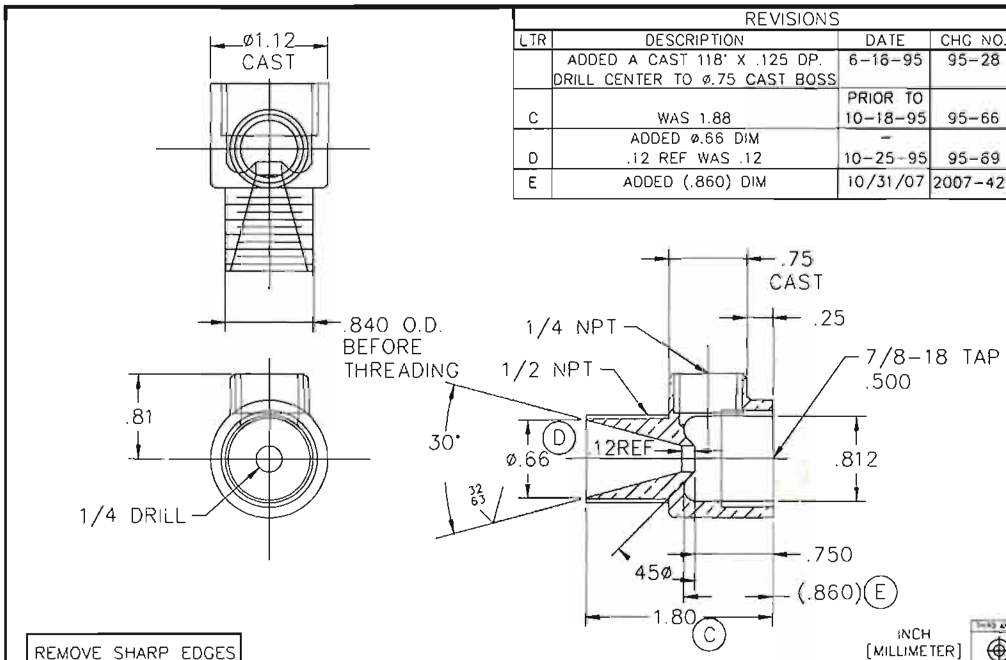
ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D
	ADDED A CAST 118° X .125 DP. DRILL CENTER TO Ø.75 CAST BOSS	6-16-95	95-28	TED
C	WAS 1.88	PRIOR TO 10-18-95	95-66	TED
D	ADDED Ø.66 DIM .12 REF WAS .12	– 10-25-95	95-69	TED
E	ADDED (.860) DIM	10/31/07	2007-427	RJG



REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

MATERIAL MUST COMPLY WITH ASTM B505-82A

OLD PART NO. G620-4

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

W.S. DARLEY & Co.
MELROSE PARK, IL - CHIPPEWA FALLS, WI

JET - PRIMER

MATERIAL DESCRIPTION:
81-3-7-9 CAST BRASS

MATERIAL NO. 4416798

PATTERN NO. G620

DR'N REY
CHKD DSH
TRCD TED101895

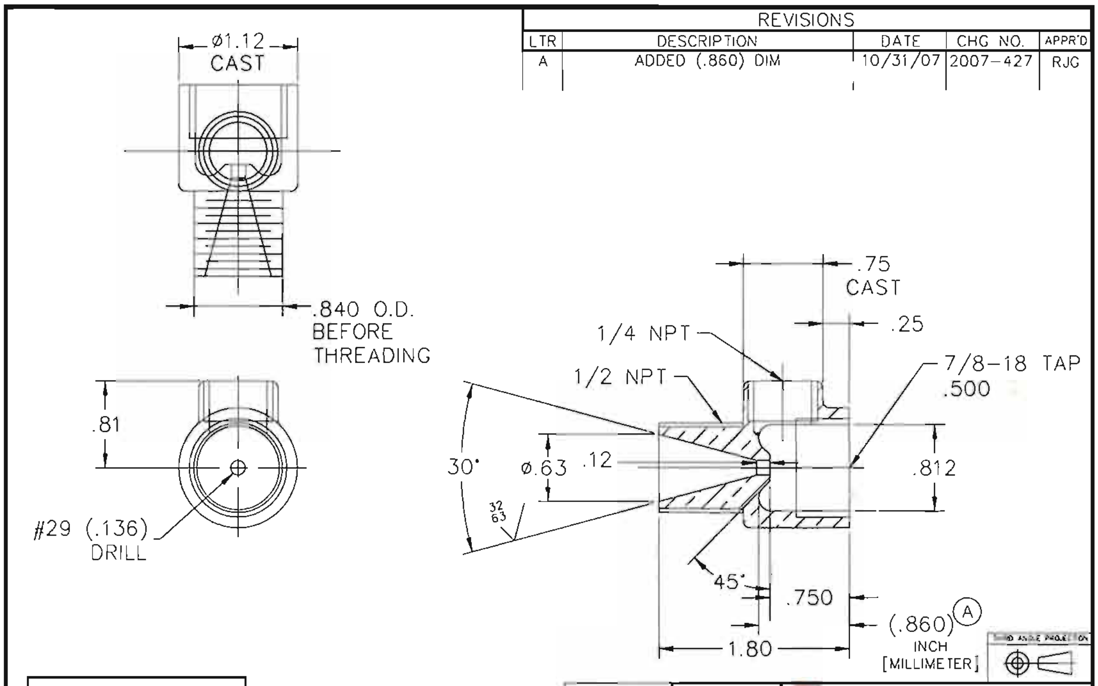
DATE 5-4-56
SCALE 1/1

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

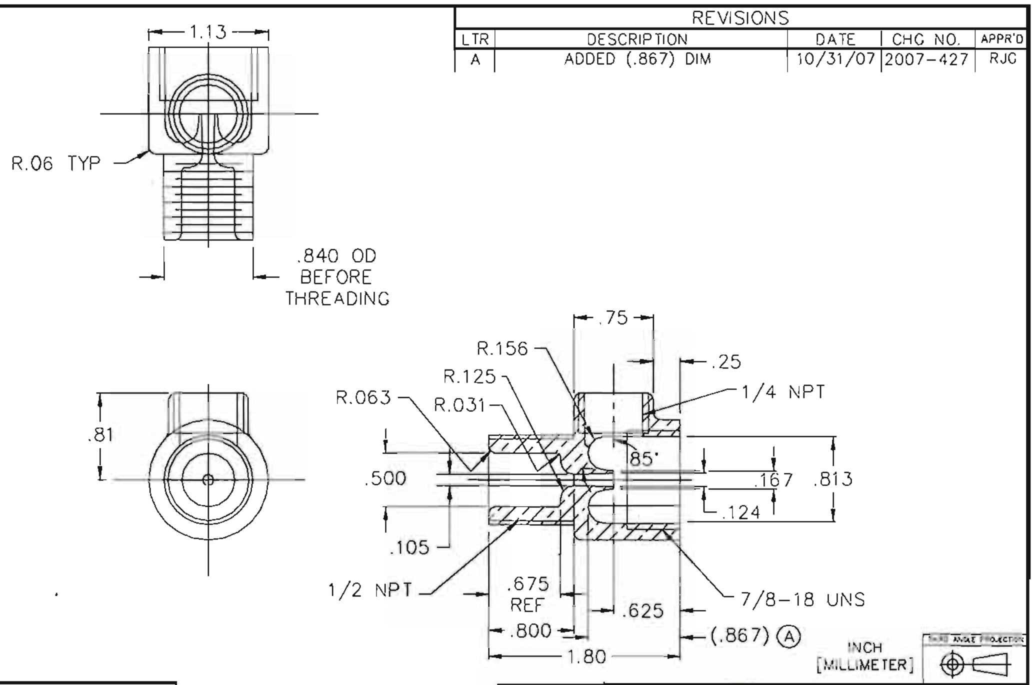
REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D
A	ADDED (.860) DIM	10/31/07	2007-427	RJG



REMOVE SHARP EDGES

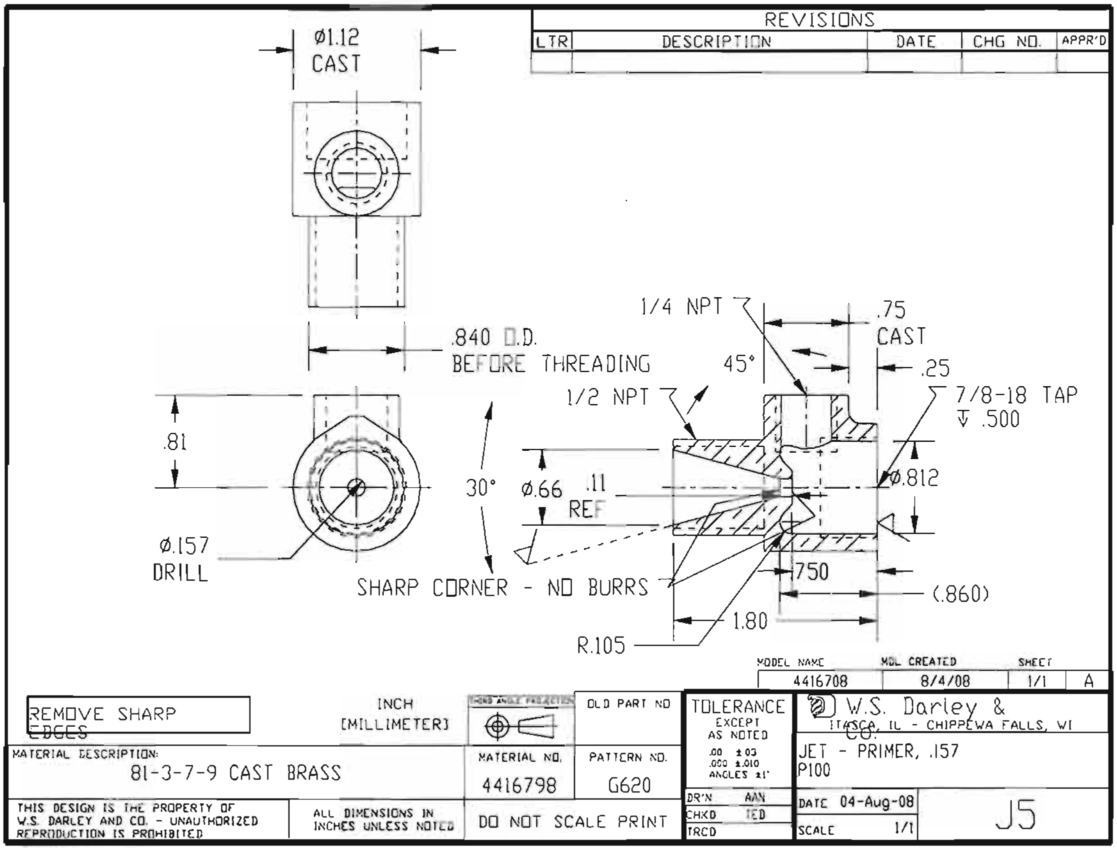
	OLD PART NO. –	TOLERANCE EXCEPT AS NOTED .00 ±.03 .000 ±.010 ANGLES ±1°	W.S. DARLEY & Co. MELROSE PARK, IL – CHIPPEWA FALLS, WI	
MATERIAL DESCRIPTION: 81-3-7-9 CAST BRASS	MATERIAL NO. 4416798	PATTERN NO. G620	JET – PRIMER	
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. – UNAUTHORIZED REPRODUCTION IS PROHIBITED	ALL DIMENSIONS IN INCHES UNLESS NOTED	DO NOT SCALE PRINT	DR'N CKE CHKD – TRCD –	DATE 15MAY,00 SCALE 1/1

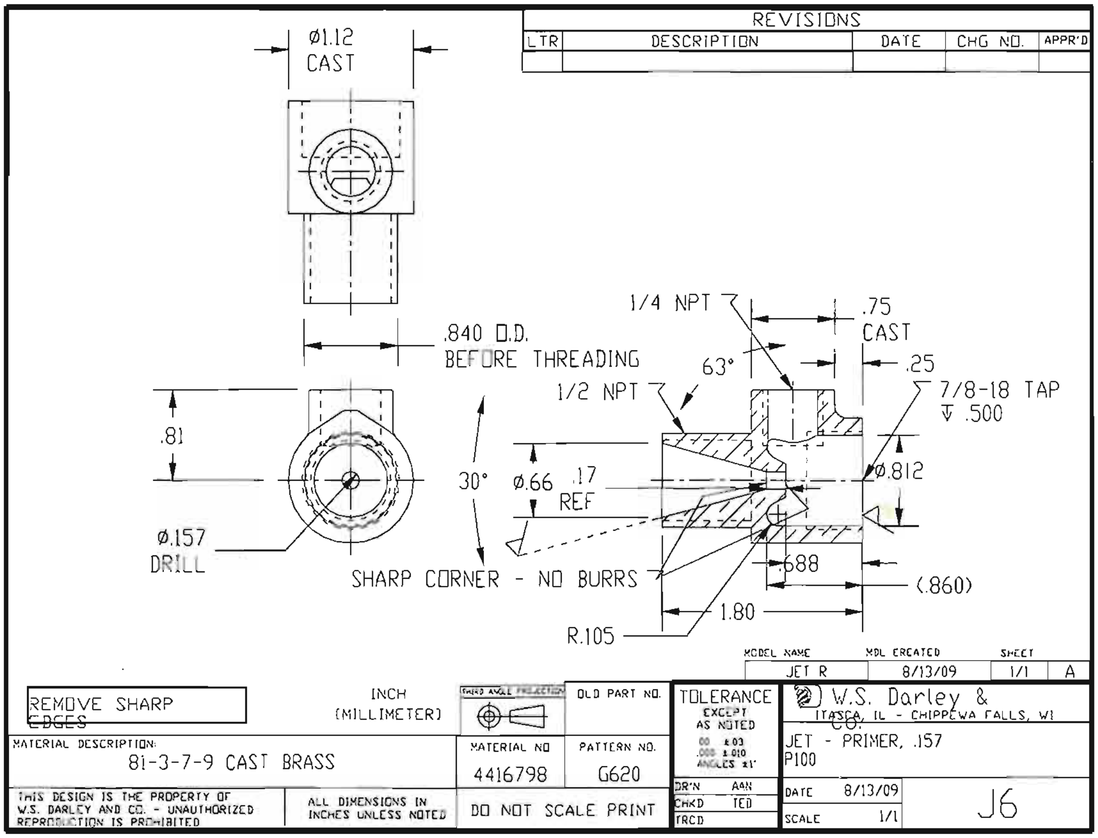
REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D
A	ADDED (.867) DIM	10/31/07	2007-427	RJG

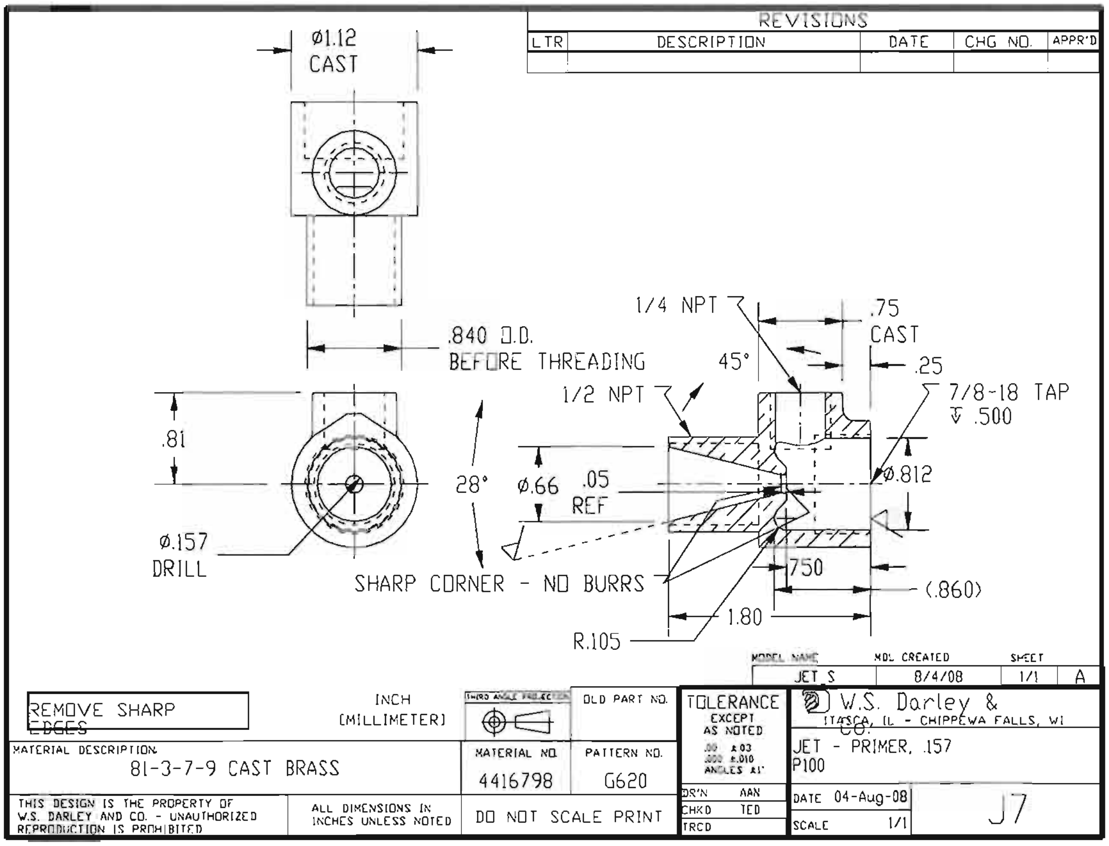


REMOVE SHARP EDGES

	OLD PART NO. –	TOLERANCE EXCEPT AS NOTED .00 ±.03 .000 ±.010 ANGLES ±1°	W.S. DARLEY & Co. MELROSE PARK, IL – CHIPPEWA FALLS, WI	
MATERIAL DESCRIPTION: 87-3-7-9 CAST BRASS	MATERIAL NO. 4416798	PATTERN NO. G620	JET – PRIMER, USE W/4416809 10HP INTEK	
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. – UNAUTHORIZED REPRODUCTION IS PROHIBITED	ALL DIMENSIONS IN INCHES UNLESS NOTED	DO NOT SCALE PRINT	DR'N DMD CHKD CKE TRCD	DATE 09OCT2002 SCALE 1/1


REVISIONS
LTR
DESCRIPTION
DATE
CHG NO.
APPR'D
Ø1.12
CAST
.840 O.D.
BEFORE THREADING
1/4 NPT
.75
CAST
45°
.25
1/2 NPT
7/8-18 TAP
↧ .500
.81
30°
Ø.66
.11
REF
Ø.812
Ø.157
DRILL
SHARP CORNER - NO BURRS
.750
(.860)
1.80
R.105
MODEL NAME
4416798
MDL CREATED
8/4/08
SHEET
1/1
A
REMOVE SHARP EDGES
INCH
[MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO
TOLERANCE
EXCEPT
AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION:
81-3-7-9 CAST BRASS
MATERIAL NO.
4416798
PATTERN NO.
G620
JET - PRIMER, .157
P100
DR'N AAN
CHKD TED
TRCD
DATE 04-Aug-08
SCALE 1/1
J5
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED
ALL DIMENSIONS IN INCHES UNLESS NOTED
DO NOT SCALE PRINT


REVISIONS
LTR
DESCRIPTION
DATE
CHG NO.
APPR'D
Ø1.12
CAST
.840 O.D.
BEFORE THREADING
1/4 NPT
.75
CAST
63°
.25
1/2 NPT
7/8-18 TAP
↧ .500
.81
30°
Ø.66
.17
REF
Ø.812
Ø.157
DRILL
SHARP CORNER - NO BURRS
.688
(.860)
1.80
R.105
MODEL NAME
JET R
MDL CREATED
8/13/09
SHEET
1/1
A
REMOVE SHARP EDGES
INCH
[MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE
EXCEPT
AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION:
81-3-7-9 CAST BRASS
MATERIAL NO
4416798
PATTERN NO.
G620
JET - PRIMER, .157
P100
DR'N AAN
CHKD TED
TRCD
DATE 8/13/09
SCALE 1/1
J6
THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED
ALL DIMENSIONS IN INCHES UNLESS NOTED
DO NOT SCALE PRINT



REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D

MODEL NAME	MDL CREATED	SHEET	
JET S	8/4/08	1/1	A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO.

MATERIAL DESCRIPTION: 81-3-7-9 CAST BRASS

MATERIAL NO. 4416798

PATTERN NO. G620

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

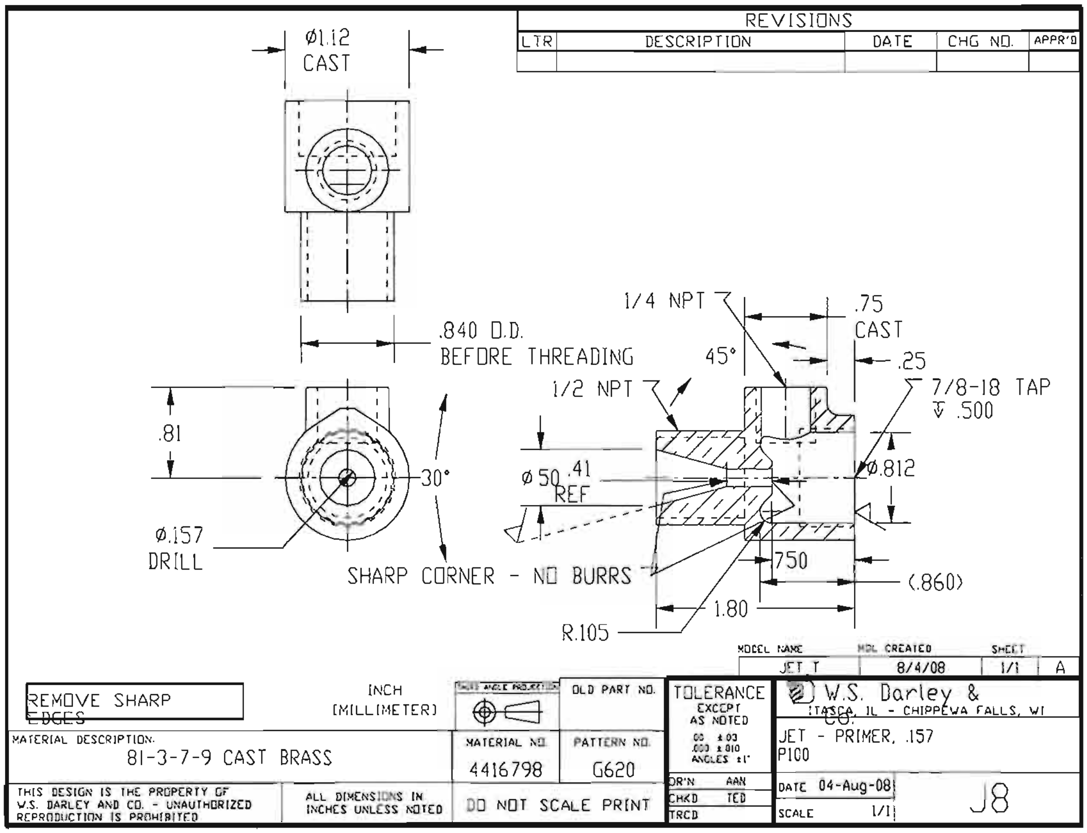
DR'N AAN
CHK'D TED
TRCD

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

JET - PRIMER, .157
P100

DATE 04-Aug-08
SCALE 1/1

J7



REVISIONS				
LTR	DESCRIPTION	DATE	CHG NO.	APPR'D

MODEL NAME	MDL CREATED	SHEET	
JET T	8/4/08	1/1	A

REMOVE SHARP EDGES

INCH
[MILLIMETER]

THIRD ANGLE PROJECTION

OLD PART NO.

MATERIAL DESCRIPTION: 81-3-7-9 CAST BRASS

MATERIAL NO. 4416798

PATTERN NO. G620

THIS DESIGN IS THE PROPERTY OF W.S. DARLEY AND CO. - UNAUTHORIZED REPRODUCTION IS PROHIBITED

ALL DIMENSIONS IN INCHES UNLESS NOTED

DO NOT SCALE PRINT

TOLERANCE EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°

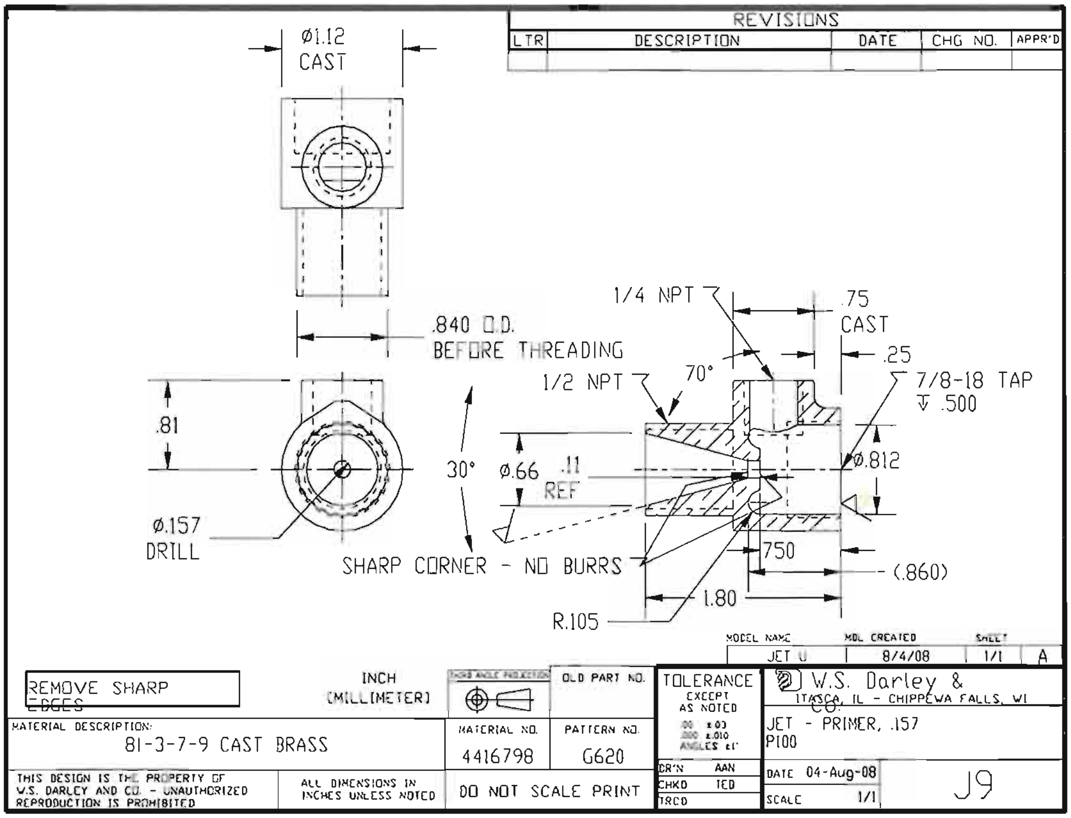
DR'N AAN
CHK'D TED
TRCD

W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI

JET - PRIMER, .157
P100

DATE 04-Aug-08
SCALE 1/1

J8


REVISIONS
LTR
DESCRIPTION
DATE
CHG NO.
APPR'D
Ø1.12
CAST
.840 O.D.
BEFORE THREADING
1/4 NPT
.75
CAST
.25
70°
1/2 NPT
7/8-18 TAP
↧ .500
.81
30°
Ø.66
.11
REF
Ø.812
Ø.157
DRILL
SHARP CORNER - NO BURRS
750
(.860)
1.80
R.105
MODEL NAME
MDL CREATED
SHEET
JET U
8/4/08
1/1
A
REMOVE SHARP EDGES
INCH
[MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE
EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION:
81-3-7-9 CAST BRASS
MATERIAL NO.
4416798
PATTERN NO.
G620
JET - PRIMER, .157
P100
DR'N AAN
CHKD TED
TRCD
DATE 04-Aug-08
SCALE 1/1
J9
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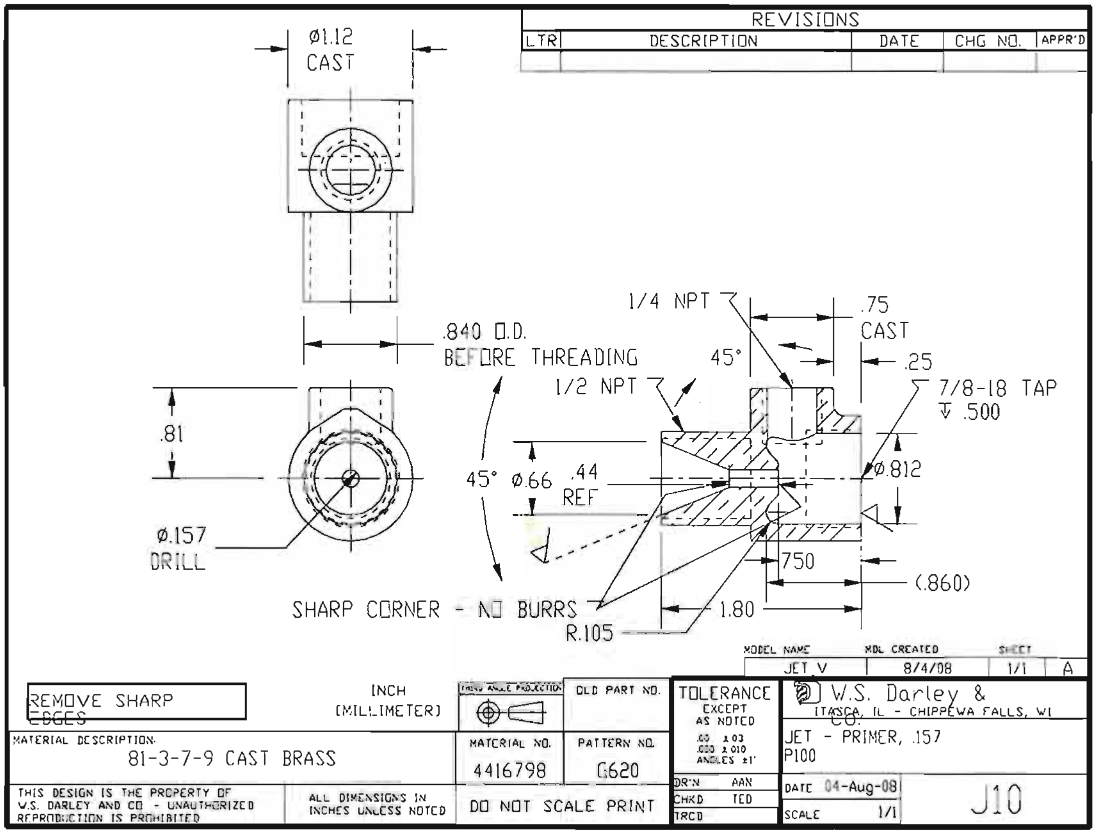
ALL DIMENSIONS IN INCHES UNLESS NOTED
DO NOT SCALE PRINT


REVISIONS
LTR
DESCRIPTION
DATE
CHG NO.
APPR'D
Ø1.12
CAST
.840 O.D.
BEFORE THREADING
1/4 NPT
.75
CAST
45°
.25
1/2 NPT
7/8-18 TAP
↧ .500
.81
45°
Ø.66
.44
REF
Ø.812
Ø.157
DRILL
750
(.860)
SHARP CORNER - NO BURRS
1.80
R.105
MODEL NAME
MDL CREATED
SHEET
JET V
8/4/08
1/1
A
REMOVE SHARP EDGES
INCH
[MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE
EXCEPT AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION:
81-3-7-9 CAST BRASS
MATERIAL NO.
4416798
PATTERN NO.
G620
JET - PRIMER, .157
P100
DR'N AAN
CHKD TED
TRCD
DATE 04-Aug-08
SCALE 1/1
J10
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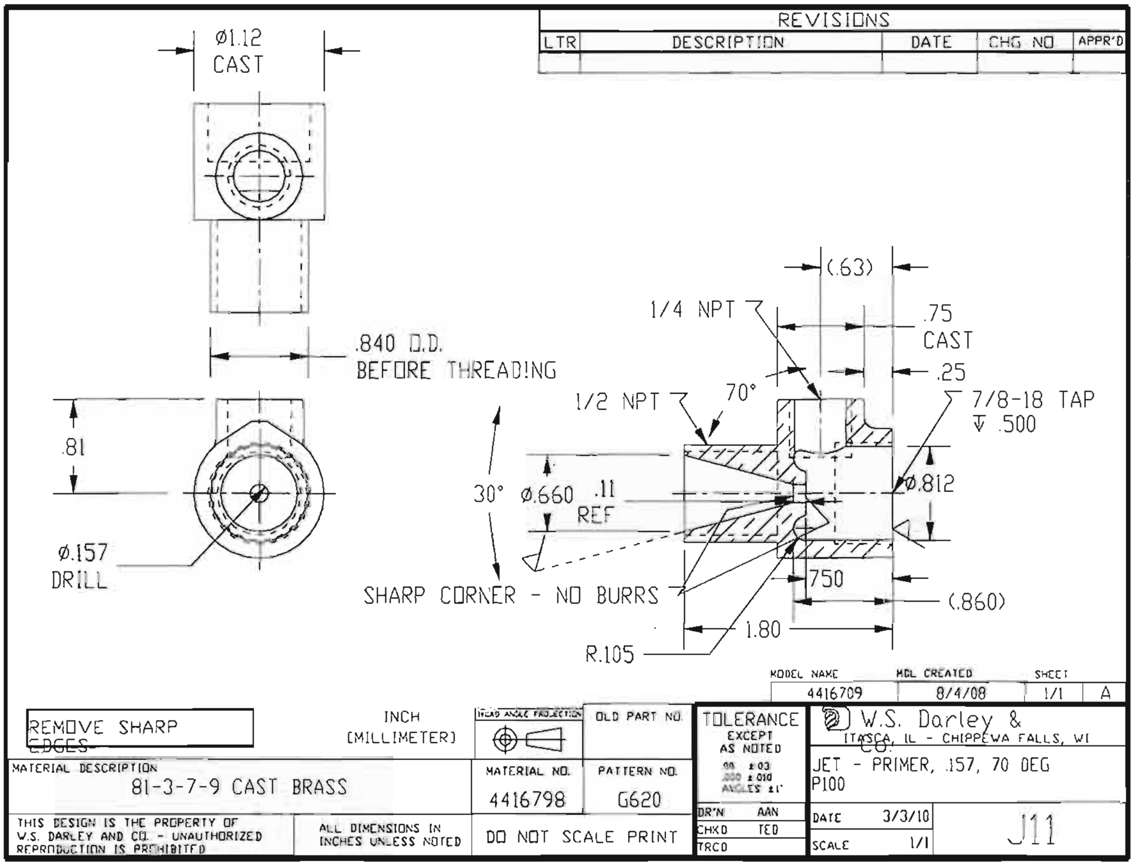
REVISIONS
LTR
DESCRIPTION
DATE
CHG NO
APPR'D
Ø1.12
CAST
.840 O.D.
BEFORE THREADING
.81
Ø.157
DRILL
(.63)
1/4 NPT
.75
CAST
.25
70°
1/2 NPT
7/8-18 TAP
↧ .500
30°
Ø.660
.11
REF
Ø.812
SHARP CORNER - NO BURRS
.750
(.860)
1.80
R.105
MODEL NAME
4416709
MDL CREATED
8/4/08
SHEET
1/1
A
REMOVE SHARP EDGES
INCH
[MILLIMETER]
THIRD ANGLE PROJECTION
OLD PART NO.
TOLERANCE
EXCEPT
AS NOTED
.00 ±.03
.000 ±.010
ANGLES ±1°
W.S. Darley & Co.
ITASCA, IL - CHIPPEWA FALLS, WI
MATERIAL DESCRIPTION
81-3-7-9 CAST BRASS
MATERIAL NO.
4416798
PATTERN NO.
G620
JET - PRIMER, .157, 70 DEG
P100
DR'N AAN
CHKD TED
TRCD
DATE 3/3/10
SCALE 1/1
J11
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Appendix B: Test Data

Pilot Testing:

date	humidity	barometer	throat	CSA	jet	CSA	CSA RATIO	reading	engine hot?
2-Jul		29.62	T5	0.043	J3	0.0145	2.97	19.5	Y
2-Jul		29.62	T5	0.043	J1	0.0287	1.50	16.5	Y
2-Jul		29.62	T5	0.043	J2	0.0491	0.88	8	Y
2-Jul		29.62	T5	0.043	J4	0.0087	4.94	2.5	Y
2-Jul		29.62	T1	0.062	J3	0.0145	4.28	19	Y
2-Jul		29.62	T1	0.062	J1	0.0287	2.16	18.5	Y
2-Jul		29.62	T1	0.062	J2	0.0491	1.26	11.25	Y
2-Jul		29.62	T1	0.062	J4	0.0087	7.13	0	Y
2-Jul		29.62	T2	0.1012	J3	0.0145	6.98	1.5	y
2-Jul		29.62	T2	0.1012	J1	0.0287	3.53	16	Y
2-Jul		29.62	T2	0.1012	J2	0.0491	2.06	12	Y
2-Jul		29.62	T2	0.1012	J3	0.0145	6.98	0	Y
2-Jul		29.62	T4	0.0184	J3	0.0145	1.27	12.25	Y
2-Jul		29.62	T4	0.0184	J1	0.0287	0.64	9	Y
2-Jul		29.62	T4	0.0184	J2	0.0491	0.37	5	Y
2-Jul		29.62	T4	0.0184	J4	0.0087	2.11	19.5	Y
2-Jul		29.62	T1	0.0409	J3	0.0145	2.82	17	N
2-Jul		29.62	T4	0.0184	J4	0.0087	2.11	18.5	N
2-Jul		29.62	T3	0.043	J1	0.0287	1.50	19	N
2-Jul		29.62	T3	0.043	J3	0.0145	2.97	19.5	N

* The following values represent versions of throat T5 and J3 with a control test of the original each day for comparison:

date	humidity	barometer	throat	CSA	jet	CSA	CSA RATIO	reading	engine hot?
3-Jul		30.05	0.16	0.0201	J3	0.0145	1.39	19.25	Y
3-Jul		30.05	0.125	0.0123	J3	0.0145	0.85	12.5	Y
8-Jul		29.7	0.215	0.043	0.215	0.0363	1.18	19	Y
8-Jul		29.7	T3	0.043	J3	0.0145	2.97	17.5	Y
9-Jul	14%	29.9	T3	0.043	J3	0.0145	2.97	17.5	Y
9-Jul	14%	29.9	0.246	0.043	0.246	0.0475	0.91	16.5	Y
9-Jul	14%	29.9	0.218	0.043	0.218	0.0373	1.15	19.5	Y
9-Jul	27%	29.9	T5	0.043	J3	0.0145	2.97	17	Y
9-Jul	27%	29.9	0.246	0.043	0.246	0.0475	0.91	15.5	Y
9-Jul	27%	29.9	0.218	0.043	0.218	0.0373	1.15	20	Y
10-Jul	42%	29.9	T3	0.043	J3	0.0145	2.97	16	Y
10-Jul	42%	29.9	0.218	0.043	0.218	0.0373	1.15	19.5	Y
10-Jul	42%	29.9	0.246	0.043	0.246	0.0475	0.91	15.5	Y
10-Jul	50%	29.85	T3	0.043	J3	0.0145	2.97	15.5	Y
10-Jul	50%	29.85	T3	0.043	J3	0.0145	2.97	16	Y
10-Jul	50%	29.85	T3	0.043	J3	0.0145	2.97	17.5	Y
10-Jul	52%	29.85	0.218	0.0373	J3	0.043	0.87	19.2	Y
10-Jul	53%	29.85	0.218	0.0373	J5	0.043	0.87	19.75	Y
10-Jul	54%	29.85	0.218	0.0373	J5	0.043	0.87	20.2	Y

10-Jul	55%	29.85	0.246	0.0475	J5	0.043	1.10	16	Y
10-Jul	57%	29.85	0.218	0.0373	J5	0.043	0.87	20.3	Y
10-Jul	59%	29.85	T3	0.043	J3	0.0145	2.97	18	Y
10-Jul	60%	29.85	T3	0.043	J3	0.0145	2.97	17.5	Y

date	humidity	barometer	throat	CSA	jet	CSA	CSA RATIO	reading	engine hot?
10-Jul	70%	29.8	T3	0.043	J3	0.0145	2.97	17.5	Y
10-Jul	71%	29.8	T3	0.043	J3	0.0145	2.97	17.75	Y
10-Jul	73%	29.8	T3	0.043	J3	0.0145	2.97	17.5	Y
10-Jul	77%	29.8	0.218	0.043	0.218	0.0373	1.15	19.5	Y
10-Jul	79%	29.8	0.218	0.043	0.218	0.0373	1.15	20	Y
10-Jul	79%	29.8	0.218	0.043	0.218	0.0373	1.15	20.2	Y
10-Jul	80%	29.8	0.246	0.043	0.246	0.0475	0.91	16	Y
10-Jul	80%	29.8	0.246	0.043	0.246	0.0475	0.91	16	Y
10-Jul	81%	29.8	0.246	0.043	0.246	0.0475	0.91	14.5	Y
10-Jul	85%	29.8	0.218	0.043	0.218	0.0373	1.15	19.5	Y
10-Jul	86%	29.8	T3	0.043	J3	0.0145	2.97	17.5	Y
10-Jul	87%	29.8	T3	0.043	J3	0.0145	2.97	17	Y
14-Jul	7%		0.218	0.0373	J3	0.0145	2.57	21.5/19.5	Y
14-Jul	7%		0.246	0.0475	J3	0.0145	3.28	15.5	Y
14-Jul	7%		0.218	0.0373	J1	0.0287	1.30	6.5/7.0	Y
14-Jul	7%		0.246	0.0475	J1	0.0287	1.66	16/16.25	Y
14-Jul	7%		0.218	0.0373	J4	0.0087	4.29	18.19.5	Y
14-Jul	7%		0.246	0.0475	J4	0.0087	5.46	14/14.5	Y
14-Jul	7%		0.218	0.0373	J2	0.0491	0.76	0	Y
14-Jul	7%		0.246	0.0475	J2	0.0491	0.97	0	Y
15-Jul	28%		T3	0.043	J2	0.0491	0.88	0	Y
15-Jul	28%		T4	0.0184	J2	0.0491	0.37	0	Y
15-Jul	28%		T2	0.1012	J2	0.0491	2.06	14.5/15	Y
15-Jul	28%		T1	0.0409	J2	0.0491	0.83	17/17.25	Y

date	humidity	barometer	throat		jet			reading	engine hot?
23-Jul			T1	0.062	0.16	0.0201	3.08	18.75	Y
23-Jul			T1	0.062	0.15	0.0177	3.50	18	Y
23-Jul			T1	0.062	0.17	0.0227	2.73	19.75	Y
23-Jul			0.218	0.0373	0.16	0.0201	1.86	16	Y
23-Jul			0.218	0.0373	0.15	0.0177	2.11	19	Y
23-Jul			0.218	0.0373	0.17	0.0227	1.64	15	Y
23-Jul			0.246	0.0475	0.16	0.0201	2.36	19.5	Y
23-Jul	Does not bog down engine		0.246	0.0475	0.15	0.0177	2.68	20.5	Y
23-Jul			0.246	0.0475	0.17	0.0227	2.09	19	Y

date	humidity	barometer	throat		jet		CSA Ratio	reading	engine hot?
8/13/2008			0.146	0.0167	0.157	0.0194	0.86	0	y
8/13/2008			0.157	0.0194	0.157	0.0194	1.00	1	y
8/13/2008			0.167	0.0219	0.157	0.0194	1.13	3.5	y
8/13/2008			0.177	0.0246	0.157	0.0194	1.27	14	y
8/13/2008			0.187	0.0275	0.157	0.0194	1.42	16	y
8/13/2008			0.197	0.0305	0.157	0.0194	1.57	16	y
8/13/2008			0.207	0.0337	0.157	0.0194	1.74	18	y
8/13/2008			0.217	0.037	0.157	0.0194	1.91	19.25	y
8/13/2008			0.227	0.0405	0.157	0.0194	2.09	20	y
8/13/2008			0.237	0.0441	0.157	0.0194	2.27	20.25	y
8/13/2008	Does not bog down engine		0.247	0.0479	0.157	0.0194	2.47	22	y
8/13/2008			0.257	0.0519	0.157	0.0194	2.68	21	y
8/13/2008			0.267	0.056	0.157	0.0194	2.89	19.75	y

Testing 7/2/08 10 hp Yanmar

* Variations of T3 jet and J3 Jet with changes only to the CSA of the constriction

Throat (number or dia of Con.)	Jet (number or dia of Con.)	In Hg
T3	J3	19.5
0.16	J3	19.25
0.125	J3	12.5
0.215	0.215	19
0.246	0.246	16.5
0.218	0.218	19.5
0.218	J3	20.2
T3	0.246	16

Testing 7/3/08 10 hp Yanmar

Barometer: 7/3: 29.85
Temp: 7/3: 82 F

Throat (number or dia of Con.)	Jet (number or dia of Con.)	In Hg
T3	J3	19.5
T1	0.16	18.75
T1	0.15	18
T1	0.17	19.75
0.218	0.16	16
0.218	0.15	19
0.218	0.17	15
0.246	0.16	19.5
0.246	0.15	20.5
0.246	0.17	19

Testing 8/13/08 10 hp Yanmar

Barometer: 7/8: 29.8
Temp: 7/8: 86 F

Throat (number or dia of Con.)	Jet (number or dia of Con.)	In Hg
T3	J3	19.5
0.146	0.157	0
0.157	0.157	1
0.167	0.157	3.5
0.177	0.157	14
0.187	0.157	16
0.197	0.157	16
0.207	0.157	18
0.217	0.157	19.25
0.227	0.157	20
0.237	0.157	20.25
0.247	0.157	22
0.257	0.157	21
0.267	0.157	19.75

Test Results for Research (Beyond Initial Pilot Study)

Testing 9/1/09-9/2/09 10 hp Yanmar

Barometer: 9/1: 30.35; 9/2: 30.34
Temp: 9/1: 55 F; 9/2: 74 F

	Jet				
Throat	J5	J7	J8	J9	J10
T5	19	19	19	18.75	19
T6	18	18.5	18	18	18
T7	19.5	20	19.25	20	20
T8	19.25	21	17.5	20.5	20
T9	18.5	19.5	18.75	19.5	19

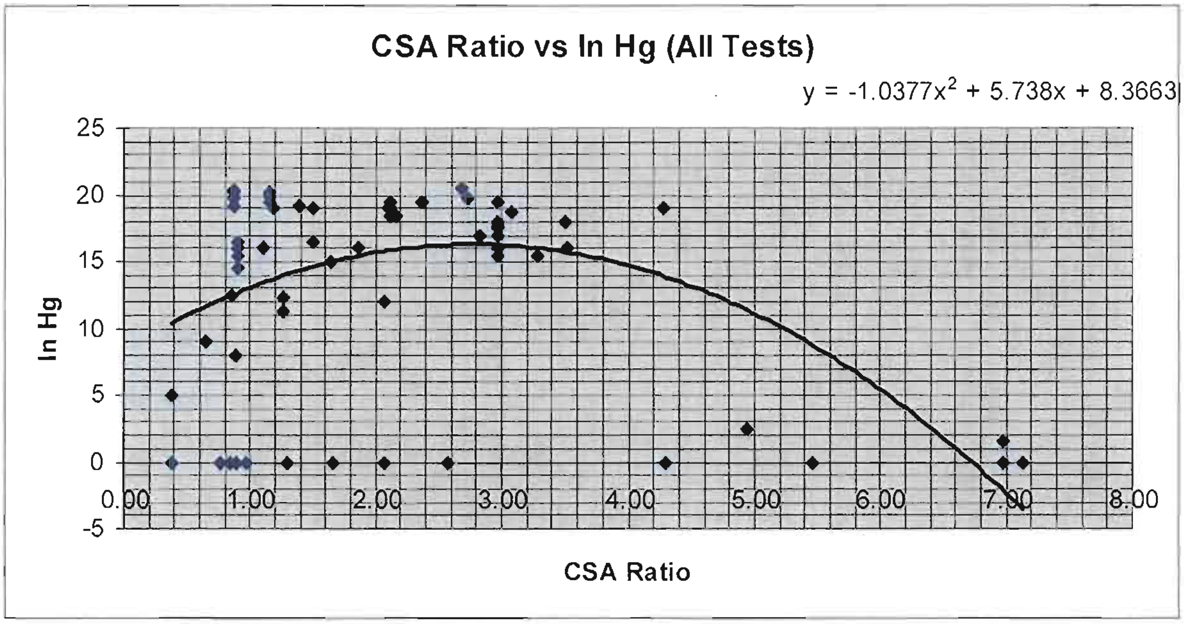
Testing 2/11/10 with Air Hose

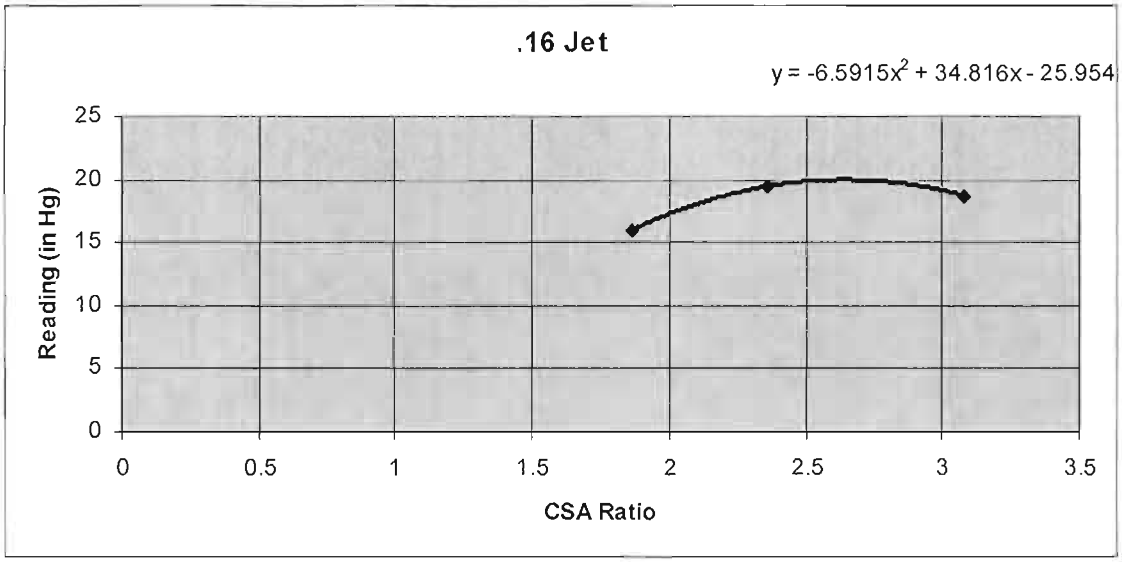
Barometer:
Temp:

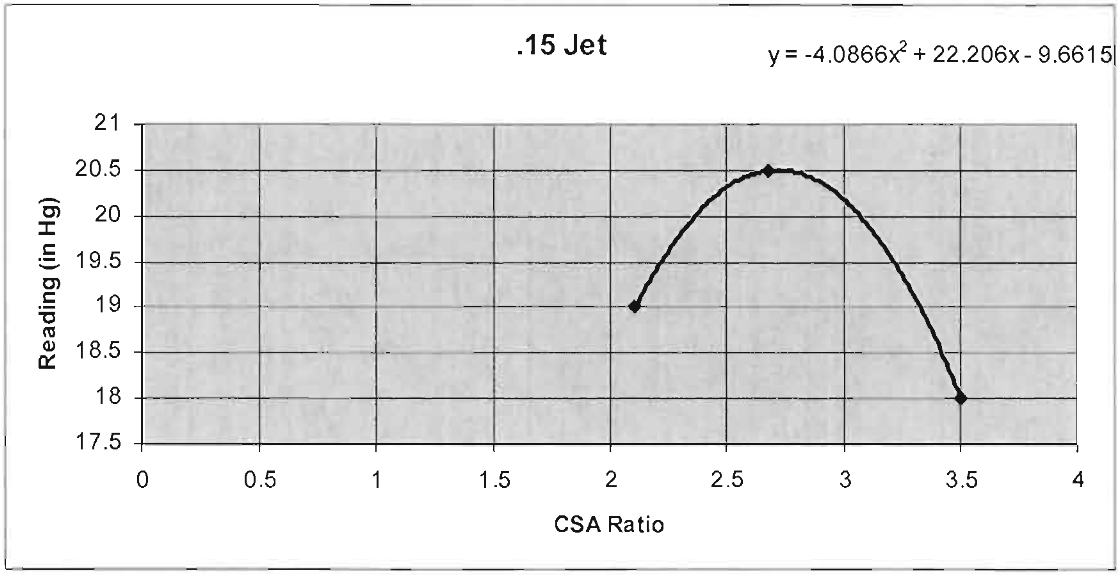
Inlet Pressure/ Vacuum Reading

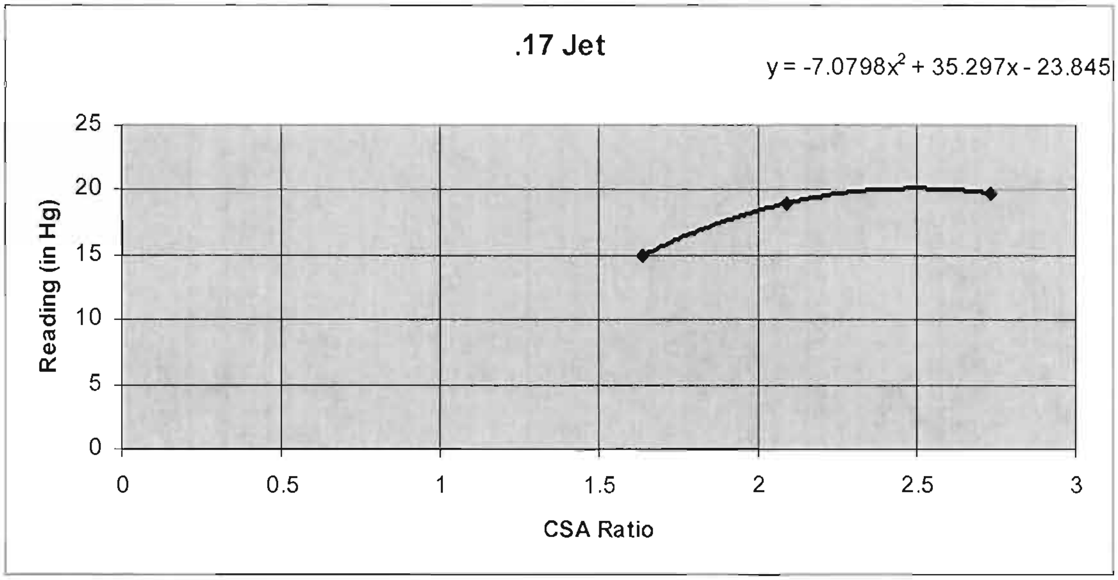
	Jet				
Throat	J5	J7	J8	J9	J10
T5	50.3/ 23.75	20.1/ 21	22.8/ 19.75	16.8/ 16.25	20.5/ 18.5
T6	47.4/ 21	19.9/ 18	22.9/ 18	17.7/ 15.5	18.3/ 18.5
T7	47.8/ 21	20.5/ 20.5	21.7/ 19.5	17.8/ 15.75	19.8/ 19.5
T8	46.3/ 20.5	21.1/ 22	21.3/ 19	16.9/ 16	22/ 21
T9	54.2/ 21	26.3/ 21	26.9/ 18.5	19.9/ 16	28.8/ 21.2

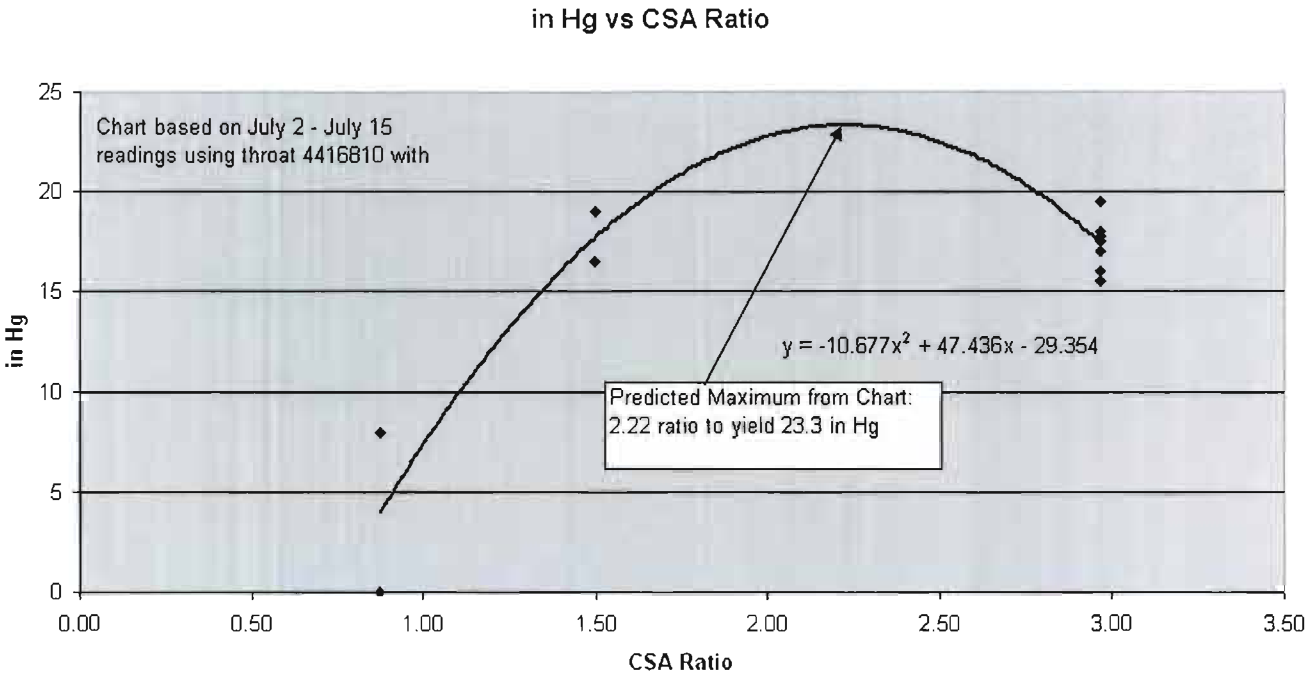
Appendix C: Graphical Analysis


CSA Ratio vs In Hg (All Tests)
y = -1.0377x2 + 5.738x + 8.3663
25
20
15
10
5
0
-5
In Hg
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
CSA Ratio


.16 Jet
y = -6.5915x2 + 34.816x - 25.954
25
20
15
10
5
0
Reading (in Hg)
0
0.5
1
1.5
2
2.5
3
3.5
CSA Ratio


.15 Jet
y = -4.0866x2 + 22.206x - 9.6615
Reading (in Hg)
21
20.5
20
19.5
19
18.5
18
17.5
0
0.5
1
1.5
2
2.5
3
3.5
4
CSA Ratio


.17 Jet
y = -7.0798x2 + 35.297x - 23.845
Reading (in Hg)
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
CSA Ratio


in Hg vs CSA Ratio
Chart based on July 2 - July 15
readings using throat 4416810 with
y = -10.677x² + 47.436x - 29.354
Predicted Maximum from Chart:
2.22 ratio to yield 23.3 in Hg
in Hg
0
5
10
15
20
25
CSA Ratio
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50