SFSA Cast in Steel 2025 – George Washington Sword Technical Report

University of Northern Iowa – UNI Metal Casters

Team Members:

Luke Crosgrove, Andrew Nii Anang, Patrick Niland, Mehmet Aydin,

Advisor(s):

Dr. Scott Giese, Nathaniel Bryant, Bert Cantu

Foundry Partner:

University of Northern Iowa Metal Casting Center and American Pattern

Table of Contents

1. List of Tables and Figures

2. Abstract

George Washington had a variety of swords throughout his battles during the Revolutionary War. This SFSA Cast in Steel competition allowed students to cast their own authentic version of a George Washington sword. The UNI sword design was based off the Silver Lion-Headed Cuttoe. Many manufacturing steps were taken to finish the sword including pattern making, molding, pouring, and post processing. American Pattern helped create core molds with the design print of the sword and UNI metal casting center poured the sword. Components of the hilt were crafted and then assembled with a handguard, handle, knuckle guard, and pommel. The sword was finished once the hilt was threaded onto the tang with a pommel threaded tightly to the end.

3. Introduction/Background (Historical Background and Accuracy)

George Washington had several swords throughout history used in battle. The categories of these swords have been smallswords, broadswords, and cuttoes. The seven swords Washington had throughout history were the 1753 Silver-Hilted Smallsword, 1767 Silver-Hilted Smallsword, the Silver Lion-Headed Cuttoe, the Bailey Silver & Ivory-Hilted Cuttoe, the Model 1767 French Officer's Epee, the Steel Hilted Smallsword, and the Alte Presentation Broadsword (George Washington's Mount Vernon, n.d.). SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available. For this Cast in Steel competition our group chose to go with recreating the Silver Lion-Headed Cuttoe.

Some reasons for choosing this sword were because of the history behind the sword, the overall look, and complexity of the blade. The history behind the Silver Lion-Headed Cuttoe is very interesting. From researching Washington acquired this sword from Jacob Gooding which was most likely in the city of Philadelphia. The most interesting fact of the history of the sword that made our group choose this sword was the fact that George Washington most likely carried this sword across the Delaware River in the famous Battle of Trenton (George Washington's Mount Vernon, n.d.). The overall look of this sword is quite menacing regarding the lion-headed pommel and snake-like handguard. Plus, the complexity of the curved blade meant challenges throughout the project. These are the three main reasons for choosing this sword.

The reason the group's sword is an accurate version of this George Washington sword is because the length, weight, and overall curvature of the sword is nearly identical to the original sword. Some parts of the sword that were not like the original were some parts of the hilt. The handle was made from hickory instead of animal bone or ivory and the handguard was made from brass instead of steel. The pommel was made from steel just like the original sword without a detailed lion. Throughout the project 5160 spring steel was cast into a no-bake sand mold to create the rough cast sword. Heat treatment, grinding, polishing, and assembly of the hilt were done to create an accurate version of this sword. To ensure the sword would be effective in hardness, sharpness, and durability testing the group did Rockwell C hardness tests and also cutting tests on various objects.

4. Design/Process

The start of the design and process for this competition was choosing a sword. The style of George Washington sword that was recreated was "The Silver Lion Headed Cuttoe". The blade dimensions of this sword are 30" long x 1 ½" wide at the hilt x 3/8" casted thickness. The overall sword dimensions are 35 ½" x 3 ½" x ¼ sharpened blade. After the dimensions were chosen a rough sketch was drawn of paper to visualize a way to create the sword in CAD. Once, envisioned computer aided design (CAD) was used to create a model for the finished product. The CAD product used throughout this competition was Autodesk Inventor.

Figure .1 - 3D CAD model of the assembled George Washington sword.

After, the model was created a gating ratio of 1: 3: 3 was used because of the use of an unpressurized gating design. As seen in Figure .2 the rigging system is used for one complete sword with three gates, a stepped runner, and a metal trap at the end.

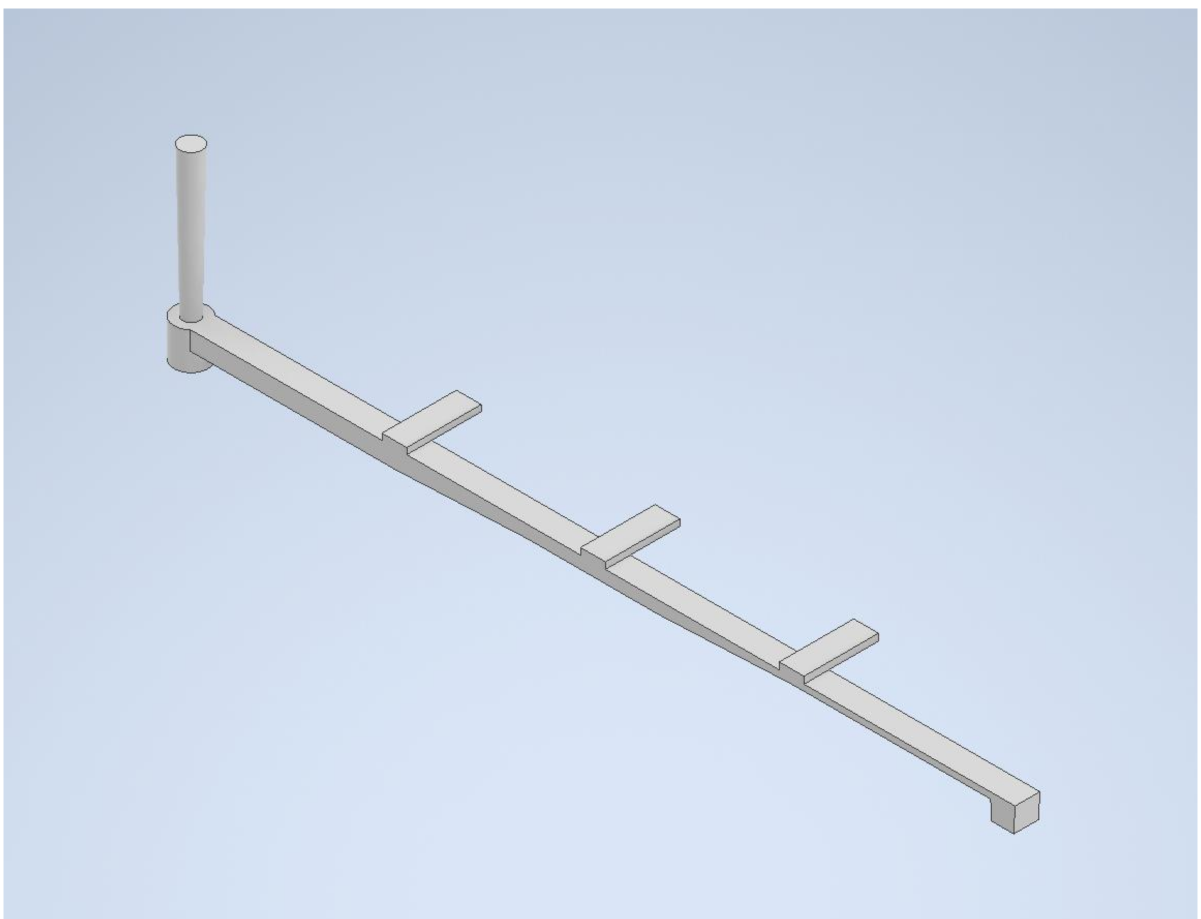

Figure .2 - The final rigging system design for The Silver Lion-Headed Cuttoe.

The reason for the metal trap at the end of the runner is for possible contaminated metal to flow into the trap so it will not go into the sword geometry casting. The three gates purpose is to evenly distribute the flow of the metal into the sword geometry. Since the flow is evenly distributed the solidification of the sword will progressively solidify causing the sword to not have as many stresses and porosity areas.

5. Magma Simulation

The purpose of using Magma Software is to see different variables within the pouring of the sword casting. The two variables in this case that were looked at were solidification and velocity. The reason for solidification is to see if there is directional solidification throughout the sword and if there will be any hotspots that could cause defects within the sword. In Table .1 various parameters were used in this Magma simulation.

Table .1 - Magma simulation parameters.

Parameters	Pouring	Mold	Metal Alloy	Initial Temp	Heat Transfer
	2 seconds	Silica Sand	5160 Steel	2966 °F	Constant 800

These parameters were used for the purpose of resembling what the actual pouring of the metal would be like. The design process within Magma was to add a cope, drag, casting geometry, and inlet. The purpose of the inlet was to allow the flow of simulated metal through the sprue of the casting geometry. Overall, the Magma simulation was a small yet major step into creating the George Washington sword.

6. Pattern Making

The steps to producing the molds for the casting were to first design a cope and drag pattern based off the rigging system design and part design. The actual sword pattern was to be designed with the help of American Pattern to produce a urethane injected pattern which would sit into a mold cavity. By using 3D modeling software (Autodesk Inventor) the layout of Figure .3 cope and the layout of Figure .4 drag could be made.

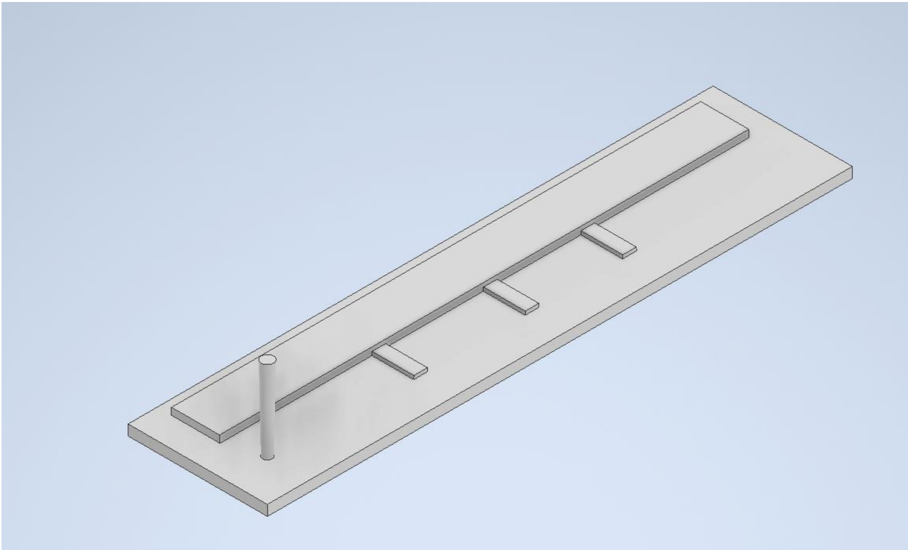

Figure .3 - Cope pattern layout including the sprue and gates.

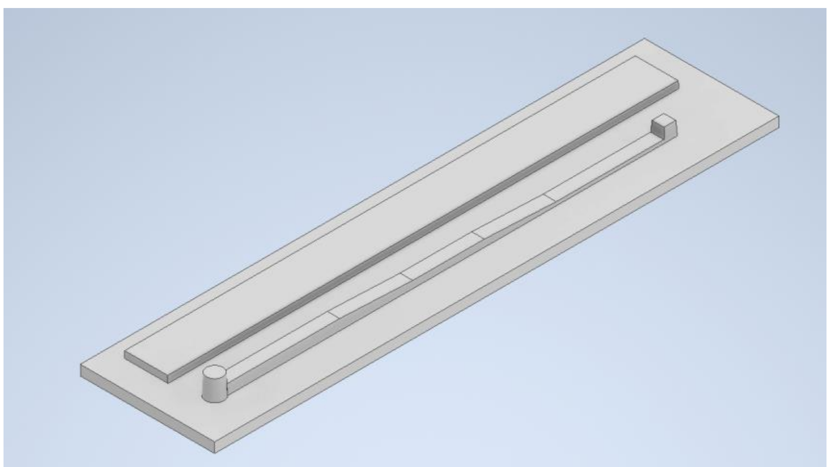

Figure .4 - Drag pattern layout including the sprue well, stepped runner, and trap.

The purpose of using this cad layout was to get a sense of where everything would go for pattern making. The pattern is all made from wood to make the pattern stronger compared to 3D printed cavities. All of the pattern layout was drafted to ensure the mold can release from the pattern smoothly.

7. Molding Process

The no-bake molding process was chosen for this Cast in Steel competition. The reason for choosing this method was because there was easy access to a no-bake sand mixer at our university. The other possible molding option was to create investment casting molds, but there were uncertainties about the new heat furnaces at the university. The molds were created using a Sinto Tinker Omega (TOM 125) no-bake sand mixer. This is an automated sand mixer which chemicals such as part 1, part 2, and catalyst chemicals go in with the sand and mix using an auger that shoots out a spout.

Patterns in Figure .3 and Figure .4 were used to produce these no-bake sand molds. The cope in Figure .3 was eight inches tall while the drag in Figure .4 was 6 inch tall. The finished molds shown in Figure .5

and Figure .6 shows the finished molds before the melting process. Figure .5 shows the drag portion of the mold where locator pins are used for when the cope is placed on top to align the molds together. Also, regarding the molds, core sand molds were placed in the molds holding the sword geometry in them. These molds were done by American Pattern located in Cedar Falls, Iowa. The core molds were made from a Exone SuperMax sand printer. Thus, making the molds furan sand. The purpose in going with this core approach was to save on sand printing costs because this was the most expensive process throughout the project.

Figure .5 - Drag mold with locator pins and core mold with the sword geometry.

Figure .6 - Full no-bake sand mold before melting process.

The cope and drag molds were placed onto each other by using an electric power crane with a load capacity of 5,000 lbs. A steel clamp attachment was used to pick up the cope and place it onto the drag while guiding the mold into the locators. The drag had core glue on the surface before the cope was placed on top to help the molds stay together easily. More no-bake sand was placed all around the parting line to make sure no metal could possibly escape the molds. This same process including the core glue and excess no-bake sand was also used to put the pouring cup on top of the sprue. The purpose of the pouring cup in Figure .7 was to create a larger target area to hit while pouring the steel.

Figure .7 - Pouring cup placed on top of the sprue with core glue and no-bake sand.

The core molds shown in Figure .8, Figure .9, and Figure .10 were used to create the geometric shape of the cast sword. 3D CAD modeling (Autodesk Inventor) was used to generate these molds. In Figure .8 this shows the part of the core which will be in the cope of the mold. This mold includes gates and locator pins. The gates will align with the gates in the pattern mold in Figure .3. In Figure .9 the part of the core that will be in the drag is modeled. The only difference is that this drag mold has locator holders so the locator pins can place the molds together resulting in Figure .10. Figure .10 is both the core and drag parts assembled with vents made in the cope side. Once again American Pattern helped design and produce these core molds.

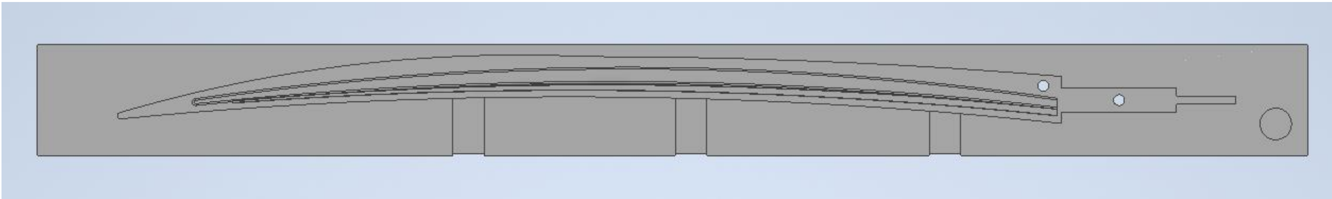

Figure .8 - Cope side of the core insert in the no-bake molds.

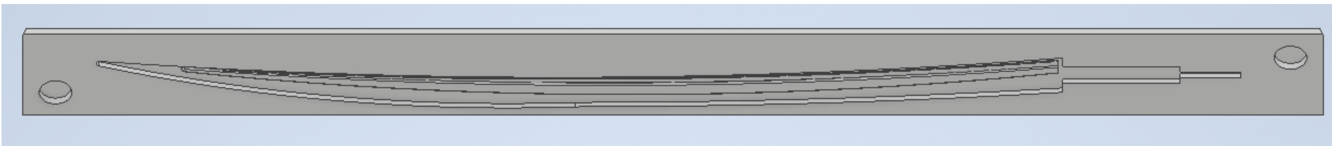

Figure .9 - Drag side of the core insert in the no-bake molds.

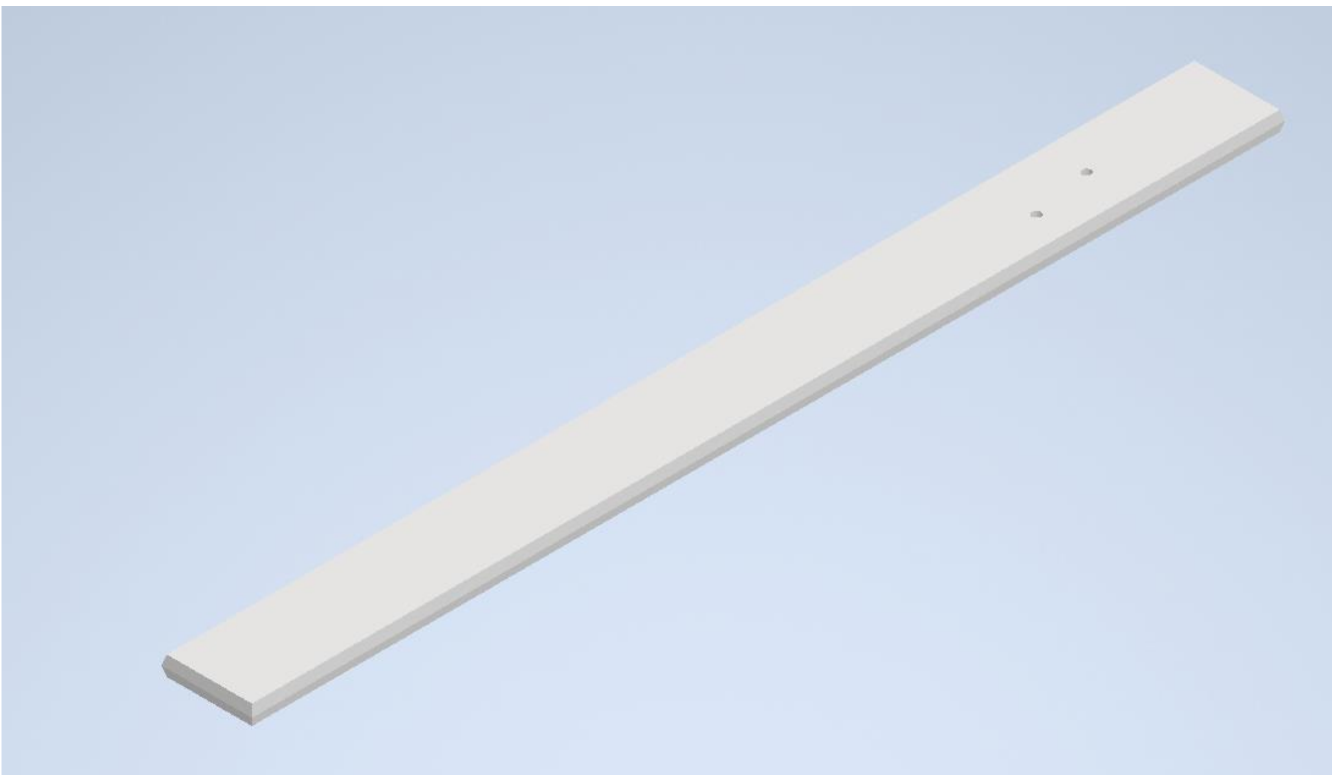

Figure .10 - Cope and Drag assembled into core mold insert for the no-bake molds.

8. Pouring Process

The pouring process for this George Washington sword was poured at the University of Northern Iowa's metal casting center. This is a famous type of alloyed steel used to make swords because of the composition creating a strong and ductile blade. The alloy used for this sword was 5160 spring steel due to it being a steel with high carbon and chromium content. The chemistry of 5160 steel is in the figure below.

Table .2 - AISI and UNS chemical composition for 5160 steel.

5160 Steel	Carbon (C)	Manganese (Mn)	Phosphorus (P)	Sulfur (S)	Silicon (Si)	Chrome (Cr)
Percentages	0.56 - 0.64	0.75 - 1.00	0.035(Max)	0.040(Max)	0.15 - 0.30	0.70 - 0.90

The process in creating 5160 steel was first to use a low to medium carbon content steel 1020 and alloy the 1020 steel with carbon, high carbon ferritic chromium, and also manganese. The total weight being poured is 200 pounds. After the 5160 steel was melted to the desired temperature the team members brought over a preheated pouring crucible to take the 5160 steels to the sword molds. The team members then poured both sword molds while taking a spectrometer sample as well to ensure the steel was within the chemistry of 5160 steel.

Table .3 - Final composition before pouring the 5160 steel castings.

5160 Steel	Carbon (C)	Manganese (Mn)	Phosphorus (P)	Sulfur (S)	Silicon (Si)	Chrome (Cr)
Percentages	0.543	0.765	0.0142	0.0175	0.320	0.795

According to (Table .2) the final chemistry before pouring the castings was low in carbon by 0.017% and high in silicon by 0.02%. During the pouring process, which was after the chemistry readings the team members used a large, preheated crucible for the pouring process. The team had three roles including one in charge of the crane which holds up the crucible, one tilts the crucible using a wheel, and the other balancing the crucible on the opposite side of the member tilting the crucible. Once the members got in place to receive the metal from the furnace a project advisor poured the steel into the preheated crucible, while another team member put in 0.2 pounds of aluminum nails to help deoxidize the steel. Right before pouring the castings another advisor help take the slag off by applying slag buster on top of the steel and removing the slag. The steel castings then were poured and waited to solidify. The castings were then broken out of the molds after solidification to be brought to post processing including sharpening, assembling, and polishing the sword. The ending measurements for the cast sword were 29 inches in length with a casting weight with flash defects of 6.2 pounds.

9. Post Process

The start of the post casting process was by normalizing the casting. The reason for normalizing the casting was to relieve internal stresses within the sword. This was to help lower the risk of the sword being brittle and have easier machinability as well. For 5160 steel the normalizing was done at 1600 °F (871 °C) for 45 minutes followed by cooling in air.

Table .4 - 5160 steel mechanical properties (*AISI 5160 Steel, Normalized 855°c (1570°F)*, 2024

Steel	Tensile Strength (psi)	Yield Strength (psi)	Elongation (in 50 mm) %	Rockwell C	Heat Treatment Process
AISI 5160 Steel	139,000 psi	76,900 psi	17.5 %	27	Normalized at 855 °C

This table is used for reference to see what outcomes of mechanical properties would be if the sword is normalized at 855 °C. The other objectives of the post casting process were machining, grinding, sharpening, polishing, and creating the hilt of the sword. The machining process was to first machine off the rigging system consisting of the sprue, sprue well, runner, and gates. Then rough grind both sides of the sword and the tang down to the same level using an angle grinder. After rough grinding, more grinding was done to shape the sword to the right look of the George Washington sword.

Figure .11 - Components of the hilt including the handguard, handle, pommel, and knuckle guard.

The hilt was split into three separate parts. These parts were the handguard, handle, and pommel. The handguard was created from 1/8-inch-thick brass stock. The brass stock was then sawed from a horizontal band saw to 3 x 1 ½ x 1/8 inch. Once the base stock was cut out creating an oval shape was done on a metal bandsaw to create an old model revolutionary sword handguard. After shaping the handguard, cutting out a tang shaped hole was done and filed to fit onto the tang. Going along with the handguard is the knuckle guard. The knuckle guards purpose is to protect from potential attacks on the hand. The knuckle guard was made from decorative chain link and welded onto the pommel.

The creation of the handle was done by turning down a hickory turning blank on a wood lathe. The shaping process of the handle was also helped by a belt sander to create a choked handle look. Sandpaper was also used by sanding with grain. Since hickory is an extremely hard wood sanding with the grain takes out the unevenness within the handle. Creating the tang opening for the handle was done by using a drill press, die grinder, and file. The final touches on the handle were to wrap leather around the handle to ensure a better grip for the testing of the competition.

Finally, the pommel was made from 2-inch mild steel bar stock. The stock was cut to 1 inch long using a horizontal band saw. A 5/16-inch drill was then pressed through the center of the bar stock to create a way to attach the pommel onto the tang. A 3/8 - 16-inch tap and die were used to help thread the tang and thread the center drilled pommel. The tap and die process was the best way to ensure the pommel would help tighten all the elements of the hilt together securely. To shape the pommel correctly both a die grinder and angle grinder were used. The angle grinder was used to get material off faster and the die grinder was used to shape it fine.

10. Finished Results / Assembly

The finished results of the group's George Washington sword were within competition requirements of weight (4.4 pounds), overall length (40 in.), and 2-inch tolerance within the chosen replica. The group's sword ended up resulting in a weight of 3.6 pounds, 29-inch-long blade, and a 34-inch-long overall length. This being within specs of the competition requirements. The hardness testing results were done by using a Wilson Hardness (Rockwell 574) Tester. The type of measurement was Rockwell C hardness using a 150 kg load. Data collected was done in Microsoft excel and converted into Table .4.

Table .5 - Rockwell C hardness results for 2 gate samples.

HRC	Test 1	Test 2	Test 3	Test 4	Test 5	Avg
Sample 1	24.5	13.9	24.6	27.2	14.7	20.98
Sample 2	11	12	11	10	13	11.4

The hardness results show that the averages are low compared to the values from Table .3. Sample 1 is 6 hardness points from the regular normalized value while sample 2 is 16 points from the normalized value. These gate samples were heat treated on their own after being machined from the sword casting. Surface area of two small gate samples could be the reason for the values being low. However, I think the team thinks the average of the first sample to be sufficient enough for the sword. The ideal hardness value that the team would have liked would be Rockwell C average value of 27. However, since the gate sample 1 average being 21 shows that the sword should still work well enough in tests. Further testing was done by using the sword on various objects including pine wood, fruits, and water bottles. The pine wood, being used for hardness tests and the other objects for sharpness tests. Both the edge and tip of the sword were tested during these tests as well.

The assembly of the sword consisted of fully applying the hilt onto the sword tang. The process the team used was by applying epoxy to the handguard, handle, and pommel. Then by threading the pommel onto the handle as firm as possible the epoxy process was finished. After the epoxy was applied wiping away excess amounts from the hilt was done. Since, the pommel was screwed on tightly a ¼ inch of the tang was left to cut off using an angle grinder. The finishing process to the assembly was by welding the pommel end to the tang and grinding that flat surface end as flat as possible. As well as welding the knuckle guard onto the pommel was well to give a more authentic look.

11. Conclusion

This project was a great way for my team and I to learn new applications within casting steel and also project management. During the project there were also some challenges including the team members never melting steel before and also myself never managing a project as well. The team overcame these challenges by researching, modeling, molding, pouring, post processing, and testing the George Washington sword. The Cast in Steel competition created a unique and fun work experience to problem solve and create the best cast sword possible. The completed sword turned out the way the team wanted it to turn out and the testing results came back positive as well. An authentic version of the Silver Lion-Headed Cuttoe used by George Washington was completed for the Cast in Steel competition to be tested.

12. References

Washington's swords. George Washington's Mount Vernon. (n.d.). https://www.mountvernon.org/preservation/collections-holdings/washingtons-swords

AISI 5160 Steel, normalized 855°C (1570°F). (2024). Matweb.com. https://matweb.com/search/datasheet_print.aspx?matguid=972ec49b746d47c2a31db406e9213247