

# PUERTO RICAN SUGAR MILL RESTORATION

Restoration of the Steam Powered Sugar Mill at the Hacienda La Esperanza



Fideicomiso de Conservación de Puerto Rico  
*Conservation Trust of Puerto Rico*



# WPI

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## ABSTRACT

Para La Naturaleza, a division of The Conservation Trust of Puerto Rico, owns the Hacienda La Esperanza estate, which contains an historic sugar mill located in Manatí, Puerto Rico. This mill displays the impact technology and slavery had on the Puerto Rican culture. This WPI project team recommended an exhibit design displaying the social context of the Hacienda and the evolution of steam power in mill machinery, and determined the steam requirements for restoring the mill's engine to historical accuracy.

*Keywords: Puerto Rico, Sugar, Hacienda La Esperanza, IQP, WPI, Para La Naturaleza*

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## EXECUTIVE SUMMARY

Puerto Rico was once a slave to the sugar industry. It relied on the sugar plantations and the people who worked them. During the 1800s, nearly every Puerto Rican was impacted by the sugar industry. Though this industry supported Puerto Rico, the real story lies within the people who worked on these plantations. The slaves, who left their blood and sweat in the fields, were the driving force behind the sugar industry. The largest sugar plantation was the Hacienda La Esperanza, which at its peak used over 150 slaves to work the estate. Hacienda La Esperanza's role in history along with its historic steam-powered sugar mill made it an ideal property for The Conservation Trust of Puerto Rico to preserve and restore. The Trust and its operational division, Para La Naturaleza, are preserving the culture that was shaped by the sugar industry through their efforts at the Hacienda La Esperanza.

Para La Naturaleza sought this WPI project team's help in restoring the Hacienda La Esperanza sugar mill to be run by its original power source: steam. This restoration process included designing an educational exhibit on the social context of the Hacienda and the evolution of steam power in mill machinery. This process also included determining the steam requirements to operate the mill with historical accuracy.

To provide recommendations for the mill's exhibit design, we interviewed three tour guides at the Hacienda La Esperanza and a curator from the Worcester Art Museum, we visited another hacienda previously restored by Para La Naturaleza and researched materials to be included in our exhibit proposal. The information gained from these interviews shaped the five exhibit plaques in our design. We provided Para La Naturaleza with our design for the plaques, which include informative text, pictures and graphics.

In addition, we developed an interactive 3D digital model of the exhibit that includes the placement of the plaques and the overall design of the exhibit around the mill. The model can be a valuable tool as it allows viewers to see all sides of the mill and may be used as a fundraising tool for Para La Naturaleza. In addition, we have identified an opportunity for a Major Qualifying Project (MQP) to produce an interactive website that allows visitors to gain more information about the historic site and steam technology. This MQP would develop a website that could be accessed using the Quick Response (QR) codes attached to the exhibit plaques.

In order to run the engine on steam power, the mill at the Hacienda La Esperanza requires a modern boiler since an historically accurate one would not be safe. Para La Naturaleza previously commissioned an engineering firm to determine the engine's steam requirements. After reviewing these calculations, we contacted an expert engineer in the field of steam power and we interviewed two other engineers involved in the project. We found that the previous calculations completed for this project were incorrect. We accepted that the current operating

speed of 10 RPM is sufficient for demonstration purposes. Using information gathered from our sources, we calculated the steam requirement necessary to run the engine at this speed.

We recommend that Para La Naturaleza purchase a boiler that can provide approximately 750 pounds per hour of steam to the piston. This would allow the mill to operate at 10 RPM, ignoring inertia during start-up and frictional forces. We recommend that a MQP be established to complete the design of the steam engine, including a specific boiler recommendation and all other necessary parts. This MQP would accomplish more detailed calculations, which would provide Para La Naturaleza with more specific boiler requirements.

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## PUERTO RICAN SUGAR MILL RESTORATION

Culture is defined as the beliefs, customs, practices and social behavior of a particular nation or people (Culture, 2013). Culture brings the community closer together and creates a sense of identity. As times and industries change, many communities struggle with the preservation of their culture.

Industry shapes culture in many ways. An example of this is the creation of jobs. Jobs impact not only the present workforce, but the generations that follow. Moreover, a nation's industries strongly impact the rate of employment. When an industry changes, it alters the culture and impacts the future of the society.

Puerto Rico's sugar industry is a prime example of how industry impacts culture. In the late 1800s and early 1900s, Puerto Rican sugar production boomed. By 1930, over half the population of Puerto Rico was employed by the sugar industry (Pfoh, 2006). The process of making sugar became so respected in Puerto Rico that the people who produced it were considered artisans (EPRL, 2010).

The sugar industry in Puerto Rico was prominent for over half a century. However, around 1950, the sugar industry declined until it disappeared almost entirely from the island in the 1980s. This was partly due to workers leaving the sugarcane fields for better opportunities in the factories. The U.S. Government implemented Operation Bootstrap to increase the number of jobs available in Puerto Rico ("Operation Bootstrap," 2008). This program allowed U.S. companies that established sites in Puerto Rico to operate with federal tax exemptions. This increased the number of manufacturing facilities, which resulted in manufacturers buying land previously used for sugarcane fields. Furthermore, Operation Bootstrap did not bring the expected employment opportunities to Puerto Rico. Plantation owners lost or sold their farmland to the manufacturing companies and consequently, the sugar workers lost their jobs.

The Conservation Trust of Puerto Rico is an organization that seeks to protect lands of cultural and ecological value. The operational division of this trust is Para La Naturaleza, which is a non-profit group that oversees conservation in Puerto Rico. Para La Naturaleza operates the Hacienda La Esperanza nature reserve located in Manatí, Puerto Rico. This 2265-acre nature reserve is a valuable part of the history of the sugar industry in Puerto Rico.

The centerpiece of the Hacienda La Esperanza site is a steam-powered sugar mill. When the sugar industry thrived in Puerto Rico this mill made the Hacienda one of the island's most productive sugar plantations. However, as the sugar industry declined the mill and the estate were abandoned and the mill fell apart.

Para La Naturaleza began the restoration process of the mill following the acquisition of the Hacienda La Esperanza. This American manufactured steam engine is one of only eight known

to be in existence today and has been established as a national landmark (“Hacienda La Esperanza Sugar Mill Steam Engine,” 1979).

However, for the past decade the mill has been powered by an electric motor to display how it functions because it is unsafe to operate historically accurate steam boilers. Para La Naturaleza determined that they want the mill to operate using steam power, even if this requires a modern boiler. This would produce a more historically realistic overall exhibit.

The goal of this project was to provide Para La Naturaleza with recommendations to restore the mill to be historically accurate. Para La Naturaleza has commissioned this WPI project team to complete two objectives: 1) to design an educational exhibit on the social context of the Hacienda and the evolution of steam power in mill machinery and 2) to determine the steam requirements for restoring the mill’s engine to historical accuracy. For the first objective, we visited sites operated by Para La Naturaleza, interviewed three tour guides at the Hacienda La Esperanza, conducted research on different exhibit materials and created a 3D digital model of our exhibit design. To accomplish the second objective, we met with two engineers, interviewed an expert on steam power, evaluated previous calculations and completed our own calculations.

## BACKGROUND

The Conservation Trust of Puerto Rico has a goal to conserve 33 percent of Puerto Rican land by 2033. Government and private organizations combined currently conserve only eight percent of the land (Para La Naturaleza). The Conservation Trust of Puerto Rico tasked our team with providing recommendations for the restoration of the Hacienda La Esperanza sugar mill.

In this chapter, we will discuss topics that provide context for our project. These topics include: history of the sugar industry, steam engines, sugar making process, the Hacienda La Esperanza, restoration of the mill, regulations for restoration and museums.

### HISTORY OF THE SUGAR INDUSTRY

Prior to the 1800s, Puerto Rico was primarily used as a Spanish military fortification. However, in the 1800s Puerto Rico began to shift to an agricultural economy. This shift can be attributed to the rich soil which was ideal for sugar farming. As the agricultural industry grew, a large working class developed. This working class was called the *Jíbaro*, who became a centerpiece of Puerto Rican culture (Crist, 1948). The *Jíbaro* worked as laborers or farmers and were typically uneducated and poor. Yet, today they are viewed as the pioneers of Puerto Rico because they helped shape the culture with their skills and hard work in the late 1800s and early 1900s (Crist, 1948).

In the early 1900s, the sugar industry in Puerto Rico boomed because the rich soil provided ideal land for growing sugarcane. Prior to U.S. control of Puerto Rico, Louisiana was the United States' main provider of sugar. However, when the industry boomed in Puerto Rico, the island was capable of producing much more sugar than Louisiana (Bridgman, Maio, & Schmitz, 2012). U.S. companies became very interested in profits from Puerto Rican sugar. The U.S. established the Foraker Act which allowed unrestricted trade between the U.S. and Puerto Rico (César, 2007). By 1930, over half of the Puerto Rican population was directly or indirectly affected by the sugar industry; by 1940 agriculture made up 33.7% of the island's Gross National Product (Pfoh, 2006). Even with the continued growth of the sugar industry, the overall employment rate in Puerto Rico continued to decline due to the steady increase of the population. Moreover, the United States influence on the Puerto Rican population had unexpected effects.

When the United States gained control of Puerto Rico in 1898, the U.S. brought many things to the island. For example, the U.S. provided improved healthcare. As a result, infant mortalities decreased and life expectancies increased; therefore, the overall population increased (Pfoh, 2006). As the island's population grew, there were not enough jobs to accommodate the increasing population so the unemployment rate rose.

As a result of the high unemployment rate, the U.S. attempted to bring more jobs to Puerto Rico to support the local families. In 1947, the U.S. enacted Operation Bootstrap. This

program offered U.S. companies federal tax exemptions if they created facilities in Puerto Rico. The anticipated result of this program was that both the people of Puerto Rico and the U.S. companies would benefit from an increase in commerce (“Operation Bootstrap,” 2008). This program attracted a lot of companies to Puerto Rico and as a result the manufacturing industry grew rapidly. The number of manufacturing facilities continued to expand and began to take up the land that was once used for sugarcane (“Operation Bootstrap,” 2008). The sugar industry began to decline on the island and the people who had once worked the fields lost their jobs. After ten years, agriculture had fallen to 9.8% of the Gross National Product; however, manufacturing rose to 21.9%. By 1989, agriculture had diminished to 2.1% while manufacturing rose to 55% (Pfoh, 2006).

Operation Bootstrap displaced more workers from the fields than the manufacturing industry could employ (“Operation Bootstrap,” 2008). However, this program was not the only reason the Puerto Rican sugar industry collapsed. Prior to the 1930s, the U.S. controlled the economic policies on the island. However, Puerto Rico gained more control over economic regulations during the 1930s (Bridgman, Maio, Schmitz, Teixeira, 2012). The local Puerto Rican government enacted policies that restricted the growth of large sugar farms. These policies caused major setbacks to both the island’s economic development and the sugar industry (Bridgman, Maio, Schmitz, Teixeira, 2012). These policies heavily favored small farms. However, the small farms did not have the capital to purchase the machinery used by large farms. This made the small farms much less efficient. As the Puerto Rican sugar industry grew more inefficient, the sugar industry in Louisiana became more efficient and reclaimed the title of the biggest sugar producer in the U.S. Eventually the Puerto Rican sugar industry was no longer profitable because it could not match the production efficiency of Louisiana and therefore declined (Bridgman, Maio, Schmitz, Teixeira, 2012).

## **STEAM ENGINES**

Thomas Newcomen developed the Newcomen steam engine in 1712. This engine was the first practical steam engine widely used in industry (Hills, 1993). The Newcomen engine had several qualities that made it superior to previous engines. One of these qualities was the ability to produce more power than other engines used at the time. Another quality was a reciprocating (or back-and-forth) motion that could be used to power mechanisms such as pumps (Nuvolari, 2004). However, this new engine was inefficient and expensive to operate, which limited the use of the engine to areas with abundant fuel sources (Hills, 1993).

James Watt, a famous inventor and mechanical engineer, significantly improved the efficiency and power output of the Newcomen engine in 1765 (Nuvolari, 2004). Watt’s engine did not require as much fuel per unit of work as the Newcomen engine. For this reason, his new

engine design increased the number of farms that could afford to use steam power. Some farms and factories that previously used water wheels, animals or slaves to drive machinery switched to Watt's steam engine to increase productivity. This encouraged the adoption of steam power in mills around the world (Musson & Robinson, 1959). For example, the sugar mill at the Hacienda La Esperanza was powered by a Watt steam engine during the 19<sup>th</sup> and 20<sup>th</sup> centuries.

## SUGAR MAKING PROCESS



*Figure 1. The large rollers that crushed the cane*

The sugar making process begins with growing sugar cane in the plantation fields. At the Hacienda La Esperanza, slaves were used to plant, grow, harvest and process the sugar cane. Once the cane was harvested, the slaves working at the mill would cut the cane into short lengths and load them onto a conveyor that fed the large mill rollers. The rollers produced cane juice and bagasse (pressed cane waste that was burned in the furnace that heated the mill's boiler and the Jamaica Train).

The Jamaica Train turns the cane juice into molasses and eventually granulated sugar. The Jamaica Train uses five large pots heated by a single furnace. Slaves ladled the cane juice from pot to pot. Each pot had a higher concentration of sugar than the previous one because more water evaporated.



*Figure 2. Illustration of slaves operating the Jamaica Train (Curlee. n.d)*

When the final pot was deemed ready, it was drained, leaving behind unrefined sugar. The slaves working at the Jamaica Train transferred molasses at extreme temperatures and in close quarters. The slaves were subjected to injury on a daily basis, especially the *pointer*. The pointer was the slave responsible for determining if the sugar was ready to move to the next pot. He or she placed his or her unprotected finger into the boiling molasses and test its consistency.

## HACIENDA LA ESPERANZA

Sugar was once an important industry in Puerto Rico, but since the 1980s it has been only a memory. A prime example of what the sugar industry used to be can be found at the Hacienda La Esperanza. The Hacienda La Esperanza is a 2,265-acre estate located in the fertile valley of the Río Grande de Manatí, about 35 miles west of San Juan, Puerto Rico (“Hacienda La Esperanza Sugar Mill Steam Engine,” 1979).

A visit to the Hacienda estate begins with a drive up a long road with wide open spaces on either side. The views include karst formations to the south of the Hacienda and various species of sugarcane. Once the short drive is complete, a walk up to the manor house reveals views of protected species of plants and animals, the sugar mill and the drying house.

Today, The Conservation Trust of Puerto Rico owns the estate and plans to have it restored as part of its on-going conservation and education efforts (Para La Naturaleza). To understand the conservation efforts, a deeper understanding of the estate and the mill is necessary. We will focus on the history of the Hacienda La Esperanza, the impact of slaves and the sugar mill.

In the 1830s, a military man by the name of Fernando Fernández began purchasing land for his sugar business. Fernández was given a plot of land from the Spanish government in the Rio Grande de Manatí and then decided to purchase some of the surrounding land. He saw the potential profit of harvesting sugar and expanded his estate. This laid the groundwork for his eldest son, José Ramón Fernández y Martínez, to grow the business.

With the additions to the estate, José Ramón became one of the wealthiest men in Puerto Rico during the late 1800s. The family’s wealth was due to several elements: 1) the expansion of their nutrient-rich estate, 2) the use of cheap labor (slaves), and 3) the use of a steam engine in the mill.

The land that José Ramón and his father bought was rich in nutrients necessary for sugarcane growth. This land is classified as an alluvial plain, which is ideal for the growth of sugarcane for several reasons including an abundance of nutrients, soil that was resistant to erosion and flat plains for space to grow the sugarcane. There was a need for someone to tend the land even before its expansion to become the largest sugar plantation in Puerto Rico. Fernando Fernández had a solution for this need: slaves.

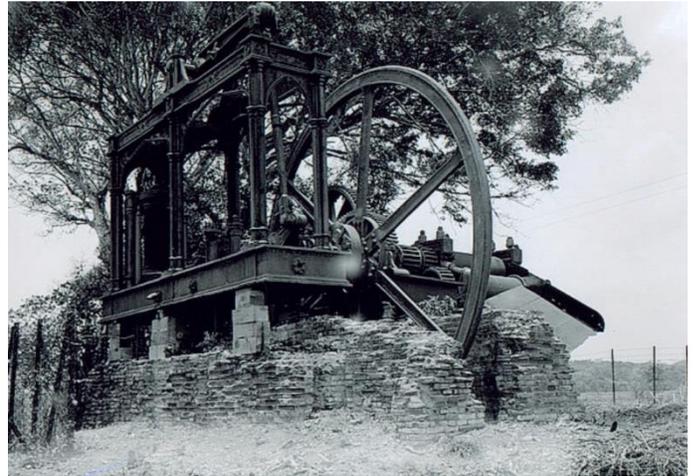
The history of the slaves at the Hacienda La Esperanza is a story within itself. Fernández was a proponent of the use of slaves; moreover, he was one of the largest slave importers on the island. He used his 152 slaves for every step of the process from planting and harvesting the cane to extracting the cane juice (Para La Naturaleza). Comparatively, this is a large number of slaves for a Caribbean plantation. The manual labor provided by the slaves is one reason the Hacienda La Esperanza became the largest producer of sugar in Puerto Rico. At the Hacienda La Esperanza and other plantations the slaves were considered property, not humans. Fernández and his eldest son, José Ramón, were very unforgiving to their “property.” One way to measure the brutality the owners imposed on the slaves is the number of grievances or complaints of abuse against the owners. The process of submitting grievances started with a slave running away to the local town where the *major* resided. The major was the person who headed the police force. He would hear the complaint and then contact the owner. Most of the time the owner was not found guilty and the slave would be returned to the plantation. At the Hacienda La Esperanza, 45 grievances were logged with the local major of the town over a five year span (Para La Naturaleza). Furthermore, the slaves who left the Hacienda La Esperanza but were caught would be punished or killed as an example to the rest of the slaves. Despite the poor treatment of the slaves, they were considered the driving force behind the sugar operations at the Hacienda La Esperanza.

The third step the family took to increase their wealth and power was installing a steam engine on the estate between 1847 and 1861 (“Hacienda La Esperanza Sugar Mill Steam Engine,” 1979). There is an interesting story as to how the engine arrived at the Hacienda. José Ramón had an inside man at the West Point Foundry where the steam engine was manufactured. This inside man managed to smuggle the engine out piece by piece and then load the pieces onto José Ramón’s boats. José Ramón purchased land with water access to establish a personal port. The boats would enter the river at this port and travel until they reached his estate. This allowed him to import and export goods without having to pay tariffs.

The installation of the machinery accomplished two things: 1) it made sugar production much faster and cheaper, and 2) it made the Hacienda one of the biggest producers of sugar in the 1870s. The average sugar production per harvest before the steam-powered mill was approximately 200 tons (“Hacienda La Esperanza,” 2010). Once the engine was installed, the mill was capable of manufacturing between 500 and 600 tons of sugar per harvest (EPRL, 2009). This is equivalent to approximately \$1.3 million in today’s market (Bridgman, 2012). With the high productivity of the mill, José Ramón Fernández y Martínez gained the title of Marqués de La Esperanza due to his wealth and power.

José Ramón Fernández y Martínez became very powerful during the late 1800s; however his status as an elite businessman was short lived. On March 26, 1873, the Spanish National

Assembly, the governing body of Puerto Rico at the time, abolished slavery (“Abolition of Slavery in Puerto Rico,” 2011). The abolition of slavery increased the cost of running a sugar plantation because the owners now had to pay workers instead of using slave labor. At the time of José Ramón’s death in 1893, the estate was in considerable debt. The estate was purchased by Wenceslao Borda for only 40,000 pesos despite being valued at over 300,000 pesos (“Hacienda La Esperanza Sugar Mill Steam Engine,” 1979). The Borda family did not have any interest in running the plantation and chose to lease the land to people who used it solely for growing sugarcane. The mill was eventually left abandoned and unused.



*Figure 3. The abandoned mill*

The historical significance of the engine, mill and estate garnered attention from The Conservation Trust of Puerto Rico. In 1975, The Conservation Trust of Puerto Rico purchased part of the estate from a private organization and then acquired the rest of the land from government organizations. The Conservation Trust of Puerto Rico at the time lacked the funds to fully restore the site but purchased it anyway to protect it from further damage. In the last five years, funds have become available to begin the restoration process. So far, the manor house has been restored and the first stage of the mill and steam engine restoration has been completed. This first stage included manufacturing missing parts, restoring damaged parts, repainting the mill and installing an electric motor to demonstrate how the mill works.

The Hacienda La Esperanza is one of many important areas of the island that should be preserved for the people of Puerto Rico and those who care about the preservation of the island’s culture (Para La Naturaleza).

## **RESTORATION OF THE MILL**

There have been a number of studies conducted to assess the current condition of the engine and the feasibility of running it on steam power. In 2007, Alpha Engineering, an engineering consulting firm, made recommendations for the conversion of the mill back to steam power (Castillo, 2007). The report recommends a diesel-burning boiler be used to produce the steam to run the engine. In addition, a condenser system would need to be added to recycle the water from the engine back to the boiler. A new pressure regulator, as well as other safety valves and small regulators, would also be required to control the flow of steam (Castillo, 2007).

In a 2009 report, A.M Consultant Incorporated investigated the condition of the engine and found major issues with the cylinder liner, the steel tube that contains the high pressure steam and the piston. This report also identified defective welds and extensive corrosion damage. This means a new tube would be required if restoration were to take place (Martinez, 2009).

## **REGULATIONS FOR RESTORATION**

The restoration must be in compliance with the Occupational Safety and Health Administration's (OSHA) guidelines. One of the relevant regulations by OSHA is under the Compressed Gases general requirements: safety relief devices for compressed gas cylinders ("Compressed Gases (general requirements)," 2010). The engine would be classified as a compressed gas cylinder. Other relevant regulations are ASME section I for boiler construction, ASME section VIII for pressure vessels which applies to the cylinder, ASME B31.1 for power piping and valves, ASME section II for general materials, and the other ASME regulations that are referenced in the previous sections. The ASME regulations are enforced according to the National Board Inspection Code (NBIC). These regulations are necessary for the safety of employees and visitors of the Hacienda La Esperanza.

## **MUSEUMS**

The Hacienda La Esperanza contains a museum with a rich history centered on the sugar industry. A museum is an institution that assembles, studies, protects, interprets and displays the culture of a society (Tufts & Milne, 1999). Moreover, museums collect and display relics that are culturally important. Often these relics represent the culture's perception of things such as time, knowledge and nature (Macdonald, 1990).

Museums are unique places where the public can commemorate the past and the community can create a sense of cultural identity. They are places where people can learn about the practices and beliefs of their ancestors. The museum at the Hacienda La Esperanza reflects an important part of Puerto Rican history and its cultural impact. In today's world, museums are expected to be more than just a place of culture; they are expected to carry out economic functions, most notably to help the local economy (Tufts & Milne, 1999). Museums draw visitors from their respective communities. Tourists of the museum might go out to eat at a local restaurant, buy souvenirs from a local shop or stay in the local hotels.

In addition to helping the economy, museums also educate the community, especially the children. The Conservation Trust of Puerto Rico wants the restoration of the mill to be child friendly since many school groups visit the museum. Museums are a complementary form of learning outside of the classroom (Haywood & Cairns, 2006). In addition, Haywood & Cairns (2006) say that when children attend museums with their parents, they receive an informal education that they otherwise might not have experienced.

Furthermore, museums provide a form of leisure and entertainment to the general public. Museums accomplish this through interactive or hands-on exhibits (Haywood & Cairns, 2006). The use of hands-on exhibits has been increasing in popularity over the last few years. In fact, one of the more effective and well-liked types of museums is a hands-on science museum (Danilov, 2010). A hands-on science center encourages learning through displays that involve touching, using and even playing with parts of the exhibits. Danilov (2010) says this approach has been proven successful in understanding topics such as life-sciences, technology and physical sciences; moreover, these centers have become some of the best-attended and fastest-growing types of museums. Hands-on science centers have changed visitors' expectations, so much so that they expect to be able to touch and interact with exhibits (Danilov, 2010).

Prior to going to Puerto Rico, we consulted with a curator at the Worcester Art Museum about what makes a good exhibit. She gave us insight as to the important aspects of an exhibit that make them function properly including lighting, choice of content, exhibit arrangements, wall color, content, font and text size, and flow of information. Lighting is important because the entire exhibit must be easily viewable. If the lighting is too bright it can damage light sensitive parts of the exhibit as well as be a distraction to the viewer.



*Figure 4. The photograph on the left shows a well-lit exhibit and the photograph on the right shows a poorly lit exhibit at Hacienda Buena Vista.*

It is essential that the right content be chosen for the exhibit. If the information provided is unnecessary then it will be distracting. In contrast, if information is missing the tour guide may have a difficult time relaying the message of the exhibit without a visual. The arrangement is important because crowded items may cause the visitor to have a hard time focusing on the message of the exhibit. However, if items are too spread out the visitor may become bored. Also, failure to give items proper spacing will make it difficult for visitors to move around. The wall or background color of an exhibit sets a tone for the exhibit. For example, dark colors give more of a serious tone while soft colors give a sense of calmness. When designing an exhibit, all the content included must convey an aspect of the overall message of the exhibit. The information must be displayed well; therefore, a simple and easy-to-read font with large text size is

important. The text must be able to be read by all members of the audience. Lastly, the flow of information throughout the exhibit is crucial. The information should be concise and add to each piece of the exhibit in a logical manner.

## METHODOLOGY

The goal for this project was to propose recommendations for the restoration of the Hacienda La Esperanza sugar mill. In order to accomplish this, we had two main objectives:

1. To design an educational exhibit on the social context of the Hacienda and the evolution of steam power.
2. To determine the steam requirements for restoring the mill's engine to historical accuracy.

To achieve the first objective we visited the Hacienda La Esperanza and another site operated by Para La Naturaleza, interviewed three tour guides at the Hacienda La Esperanza, researched exhibit materials and created a 3D digital model of our exhibit design. To accomplish the second objective, we interviewed three engineers, measured the current speed of the flywheel, evaluated previous calculations and completed our own calculations.

### EDUCATIONAL EXHIBIT

The goal of our educational exhibit is to provide information on the social context of the Hacienda and the evolution of steam power. We completed several tasks to provide these recommendations. They included interviews with tour guides at the Hacienda La Esperanza, a visit to an existing site (Hacienda Buena Vista) operated by Para La Naturaleza and researching exhibit materials. We interviewed tour guides at the Hacienda La Esperanza to learn which aspects of the exhibit were popular and what areas could be improved. We visited the Hacienda Buena Vista to see fully restored exhibits and better understand our sponsor's intentions. We researched what content should be included in the Hacienda La Esperanza exhibit as well as the materials used for the exhibit design. After completing all of these tasks we provided recommendations for an exhibit design at the Hacienda La Esperanza.

#### Tour guide interviews at Hacienda La Esperanza

To gather information about what makes a museum successful, we considered surveys, interviews and observation periods. We chose interviews instead of surveys and observation periods because it would provide timely feedback and incorporate the tour guides' experiences over previous years.

We interviewed tour guides at the Hacienda La Esperanza since they have in-depth knowledge of the entire estate. The tour guides spend several months learning each tour on the estate and give several tours over the course of a week. For this reason, tour guides were ideal sources of information. The Hacienda La Esperanza has four full time tour guides and we interviewed three—José Antonio Nevarez Rivera, Manuel Sepúlveda Vázquez and Edwin Figueroa Rodríguez—all Environmental Interpreters for Para La Naturaleza. These interviews

gave us a wide range of answers and opinions. The interview questions and each tour guide's responses can be found in the Results section and in

*Appendix B: Tour Guide Interviews.*

### **Visit to existing site: Hacienda Buena Vista**

For comparison, we visited a historic site that was restored and is currently run by Para La Naturaleza. The site we visited was Hacienda Buena Vista in Ponce, Puerto Rico. This site contains a large estate house, slave quarters, a corn mill and a coffee mill.

We went to this site to gain a better understanding of our sponsor's intentions and to see a fully operational museum and historic site. During this visit we saw completed exhibits by Para La Naturaleza; this was beneficial because we formed several ideas for our exhibit and we analyzed the pros and cons of the current exhibits.

In order to evaluate these exhibits, we created our own evaluation sheet based on the information gathered from our consultations at the Worcester Art Museum. It includes evaluations of organization, interaction and visual interest. This evaluation can be found in *Appendix C: Site Evaluations.*

### **Selection of information for exhibit design**

To determine the information included in our exhibit design, we used a system recommended by a curator at the Worcester Art Museum. After our research on the topics of the evolution of steam power and the history of the Hacienda La Esperanza, we individually selected five key pieces of information that we believed should be in our exhibit design. Then we took all the information we selected individually and compiled it into a single list. From this list we grouped the information into paragraphs and assigned each paragraph a topic.

There were limitations to this method such as being restricted to only five key pieces of information due the amount of space available for text. This means that some information had to be left out of our exhibit design. However, the content chosen is sufficient to allow visitors to understand the evolution of steam power without being overwhelmed by too much text.

### **Exhibit materials research**

To determine the material for our exhibit design, we searched for companies in brochures and online. We contacted all companies who responded to emails in order to provide as much information as possible. In these emails, we asked for pricing, material descriptions and availability. Then we requested quotes for several orders of the possible materials they offered. Once we received the quotes, we chose which price and material was appropriate for our exhibit design. The quotes from these companies can be found in *Appendix F: Exhibit Quotes.*

## **Exhibit model**

To display our exhibit recommendations, we constructed a 3D digital model of the proposed exhibit. First, we took measurements and photographs of the engine, the platform and the surrounding space. Next, using measuring tools in *Adobe Photoshop*, we derived measurements that could not be made directly. This method allowed us to produce accurate dimensions of the engine and mill for use in our 3D model. Using these dimensions, we created a 3D model in Autodesk Inventor. Once the model of the mill was complete, we added our designs for the planned exhibit information. The 3D model allowed us to easily add or subtract display pieces in order to find the best exhibit arrangement.

## **STEAM REQUIREMENTS FOR MILL CONVERSION**

In order to determine the steam requirements, we completed several tasks. They included meeting with three engineers, determining the engine's target operating speed and evaluating previous calculations. We met with the engineers to gain more information about the engine, the boiler and the important safety regulations. We determined the target speed of the engine's flywheel, in revolutions per minute (RPM), which we used in our subsequent calculations. With the help of a professor with expertise in steam power, we evaluated previous calculations that determined the steam requirement for operating the mill at its historic speed. Using the information from these sources, we calculated the steam requirements necessary to run the engine at constant speed.

### **Meeting with on-site engineer**

Throughout our project, we worked closely with the Hacienda La Esperanza's on-site engineer, John Murphy. He is a mechanical engineer and has been working for The Conservation of Trust of Puerto Rico for over four years. We had meetings with him in addition to e-mail correspondence, during which we asked him various questions about the restoration and the future plans for the mill.

### **Meeting with consulting engineer**

We met with Julio E. Abreu, a certified professional mechanical engineer who works for A.M. Consultant Incorporated and the Department of Labor. He is also a consulting engineer for Para La Naturaleza on their project at the Hacienda La Esperanza. We met with him to learn about the calculations needed to determine the boiler system for the mill in addition to the federal safety regulations that all boilers must meet. We accounted for these regulations in our recommendations.

## Flywheel speed determination

After discussions with the on-site engineer at the Hacienda La Esperanza, we concluded that the speed of the engine should remain the same before and after the restoration process. Historically, the mill was operated at 25 RPM. However, the current operating speed of the electrically powered mill is slower, yet still sufficient for demonstration purposes. Using the current speed will keep the power requirement for running the mill lower; therefore, reducing the operating cost.

Before we could begin our steam requirement calculations, we had to determine the current speed of the engine's flywheel. To measure the speed of the flywheel, we used two methods to check our measurements. For the first method, we selected one spoke as a reference point and timed how long it took the spoke to complete one rotation. To do this, we used a stopwatch to time 20 rotations of the flywheel. We averaged our findings to determine the amount of time it takes for one rotation. Then we converted the units in order to determine the speed of the flywheel in revolutions per minute.

$$\text{Flywheel Speed} = \frac{1 \text{ revolution}}{\text{avg time (sec)}} \times \frac{60 \text{ sec}}{1 \text{ min}}$$

For the second method, we counted the rotations of the reference spoke over the course of one minute using stopwatches. We repeated this measurement three times for accuracy. The



*Figure 5. This shows the flywheel at the Hacienda La Esperanza.*

measurements using each method were averaged and rounded up to the nearest whole number to be used as our target speed for our recommendations. This data can be found in *Appendix J: Flywheel RPM Measurements*.

### Evaluating previous calculations

In 2007, Para La Naturaleza hired Alpha Engineering, a consulting firm located in Old San Juan, Puerto Rico. Alpha Engineering calculated the steam requirement for running the mill at 25 RPM. In order to evaluate and verify their work, we requested a copy of their calculations and supporting documents. In addition to reviewing them, we sent these calculations to an expert, Dr. Cecil Huey, a mechanical and manufacturing systems professor at Clemson University. He is a member of ASME and the Society for the History of Technology, and he also consults for Para La Naturaleza. During a phone interview, we asked Dr. Huey about the necessary calculations and the calculations provided by Alpha Engineering. The interview questions and answers can be found in *Appendix K: Dr. Huey Phone Interview*.

### Calculations

The methods used for our calculations were based on the suggestions made by Dr. Huey in our interview. We made several assumptions in our calculations to solve for the steam requirements of the engine. The assumptions are described in the Recommendations section of this report. Because of our assumptions, there remains a possibility of error. We state our recommendations for overcoming these limitations in the Results and Recommendation section.

We began our calculations by using *Figure 6*, which shows the output of steam as a percentage of the ‘from and at’ rating<sup>1</sup> versus the boiler’s feed water temperature (in degrees Celsius). We chose four feed water temperatures in order to take into account the different environments. These environments may include water from the stream next to the boiler or water sitting in a flash tank (the main difference is temperature). We used *Figure 6* to find the output under the conditions of 20, 40, 60 and 80°C, and a pressure of 5 bar<sup>2</sup>. We assumed 5 bar as our pressure because Dr. Huey informed us that this is a typical output pressure for a modern boiler. Using this graph, we were able to convert the steam engine demands to a boiler rating.

Next we found the steam density using a Properties of Saturated Steam table at 5 bar. This steam table can be found in *Appendix N: Steam Table*. Then we calculated the steam required using the following equation provided by Dr. Huey:

$$\text{Steam Required} = \frac{\pi d^2 l}{4} \times n\rho \times \frac{1}{y}$$

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<sup>1</sup> Rating that indicates the quantity of steam in kilogram per hour (kg/h) that boiler may generate at atmospheric pressure.

<sup>2</sup> A bar is a unit of pressure equal to 0.987 atmospheres.

$d$  = diameter of cylinder (in inches)

$l$  = stroke length (in inches)

$n$  = strokes per minute (twice the RPM previously calculated because the piston is double acting)

$\rho$  = density of steam at operating condition (in kg/m<sup>3</sup>)

$y$  = output percentage ('from and at' rating)

In this equation,  $\frac{\pi d^2 l}{4}$  corresponds to the volume of the cylinder. This is multiplied by the number of times steam fills the cylinder in one minute and the density of steam at the operating temperature and pressure. Lastly, the equation is multiplied by the reciprocal of the 'from and at' rating, which is found on the graph above using the specific operating temperature. This equation solves for the steam required to run the mill at the operating conditions.

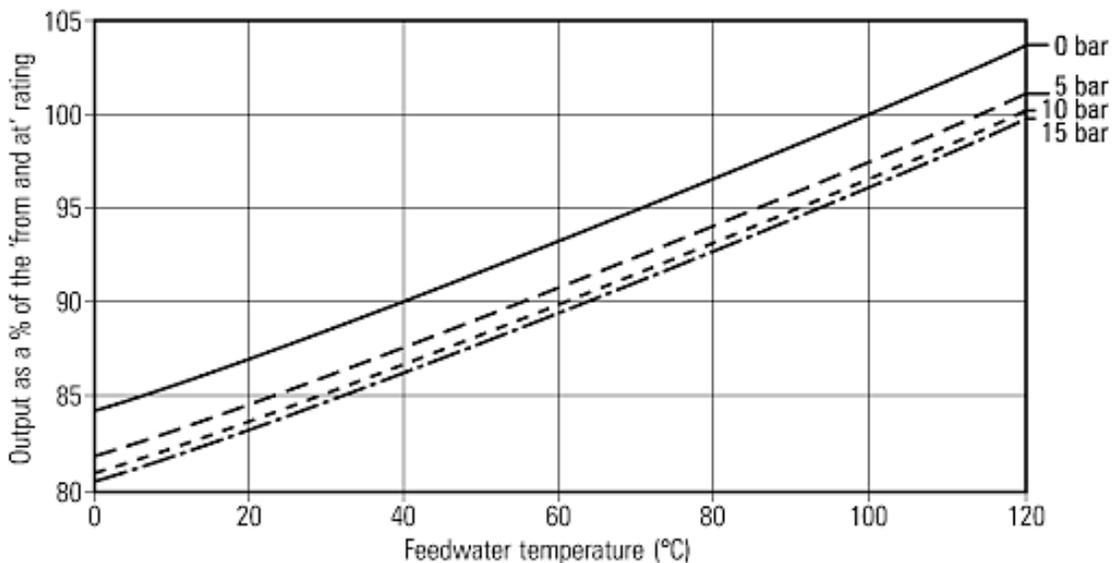


Figure 6. Graph showing the relation between the feed water temperature and the 'from and at' rating. (SpiraxSarco, 2011)

To complete the calculations, unit conversions are necessary:

$$\left(\frac{\text{ft}^3}{1728\text{in}^3}\right) * \left(\frac{\text{strokes}}{\text{min}}\right) * \left(\frac{\text{min}}{\text{hr}}\right) * \left(\frac{2.669\text{kg}}{\text{m}^3}\right) * \left(\frac{0.0623\text{lbs}}{\frac{\text{ft}^3}{\frac{\text{kg}}{\text{m}^3}}}\right)$$

The above equation converts the amount of steam required from  $\frac{\text{in}^3 * \text{kg}}{\text{m}^3 * \text{min}}$  to  $\frac{\text{lbs}}{\text{hr}}$ , which is easier to quantify because it is a common flow rate unit. With the steam requirements in  $\frac{\text{lbs}}{\text{hr}}$ , we converted the steam required into Boiler Horsepower (BHP) using the following conversion:

$$1\text{BHP} = \frac{\text{Steam Required} \left(\frac{\text{lbs}}{\text{hr}}\right)}{34.5}$$

## SUMMARY

These tasks allowed us to complete our goals of designing an educational exhibit and providing steam requirements for the conversion of the mill's machinery. To complete our recommendation for an educational exhibit we interviewed tour guides at the Hacienda La Esperanza, visited an existing site at the Hacienda Buena Vista and researched exhibit materials. To complete the calculation of steam requirements, we collected engine data, met with two engineers and consulted with a professor who is an expert in steam power. Once we completed these tasks we analyzed our findings to draw conclusions for the educational exhibit and the mill's conversion.

## RESULTS AND RECOMMENDATIONS

### RESULTS PART 1: EDUCATIONAL EXHIBIT

#### Interview of tour guides at the Hacienda La Esperanza

We interviewed José Antonio Nevarez Rivera, Edwin Figueroa Rodriguez and Manuel Sepúlveda Vásquez, who are all environmental interpreters at the Hacienda La Esperanza. Together, they have 17 years of combined experience, making them excellent sources of information. In general, they provided the same or similar responses to many of our questions. They said that the machinery and the manor house were the most interesting exhibits to visitors of the Hacienda. They also agreed that the Jamaica Train is the most difficult aspect of the tour to explain because there is no visual aid to help the visitors understand this concept.

Each interpreter has a different way of delivering the information for each exhibit. José uses his hands to help the audience visualize what he is describing. Edwin tells a story and explains in detail so the audience can feel as if they are a part of the history. Manuel tries to make connections between how things were done in the 1800s and how things are done today. Though each guide has a different style, they have similar suggestions for how the exhibits can be improved, the most common being more visuals throughout the tour. The more visuals included on the tour, the easier it is for the tour guide to get the point across. At some points during the tour, the exhibits lack visuals and the visitors can become distracted. One example of this is the Drying House where the Blood Mill is located. The interpreters feel the information presented is not as clear because the visitors can not touch or see what is being described to them. This guided our design recommendations to include enough visuals to help the visitors understand.

The tour guides change the content and delivery of the tour depending on the audience. For example, when Edwin gives a tour to foreigners he tells fewer stories and provides the information in simpler terms. Also, when the tour is for school kids, he changes his vocabulary so they can understand the information. Edwin would like to see the tour include sugarcane being fed through the machine, so the kids can see how it works.

#### Site visits

The following site evaluations were based on our experiences during the tours at the Hacienda Buena Vista and the Hacienda La Esperanza. Through our firsthand experience on the tours we were able to analyze and evaluate the pros and cons of the exhibits. We used our research background on museum exhibits in order to evaluate the sites. We are aware of the limitations of our evaluations, in that they are mostly opinion-based. We provided reasons for

our assertions in order to avoid as much bias as possible. The evaluations that follow provide the basic information of the sites, the positives of the current sites and the problems we encountered.

### Evaluation of the Hacienda Buena Vista and its exhibits

The Hacienda Buena Vista is an historic, 1800s estate containing a corn mill and a coffee plantation. The tour of this site is organized into five parts: the old estate house, the water channel, the coffee mill, the slave house and the corn mill. We found that the overall tour flows well; one exhibit leads into the next seamlessly. The first exhibit, the estate house, gives background knowledge necessary to understand the following four exhibits. The walk along the water channel provides insight into the life of the slaves, and since it powers the machinery it connects with the following coffee mill and corn mill parts of the tour. The mills show the technology of the time and also give more information about slave life. Throughout the tour, the life of the slaves links everything together.

In general, the site is targeted more towards Puerto Ricans but it is also marketed to English speaking tourists. The tours are conducted in both Spanish and English; however, the signs and labels are all in Spanish, which was discouraging to us as non-Spanish speakers. The machines and buildings are all well restored and in working condition. In our opinion, the site meets expectations with the exception of a lack of content written in English.

Throughout the tour, we found that the purpose of the exhibits was clear and gave a comprehensive understanding of the history of the estate. First, the estate house shows the history of the family that owned the site and their lifestyle. Next, the walk along the water channel gave a better understanding of the environment and teaches how the land was used to improve the success of the Hacienda Buena Vista. Then the demonstration of the coffee mill gives background about the technology of the time. In addition, it shows the working conditions



*Figure 7. Hands on with the coffee at Buena Vista*

of the people that operated the site. Next, the explanation of the slave/drying house contributes to the overall goal by giving more insight into the harsh conditions the slaves endured. Also, as seen in *Figure 7*, the coffee drying racks provide an interactive experience for the visitors. Lastly, the corn mill contributes to the overall goal because it demonstrates the production of the estate's primary product.

The tour provides a number of visuals that we found to be useful. Each section of the tour includes something with which the visitors can interact with, such as a basket for harvesting coffee, the coffee beans themselves and the water in the channel. In addition, examples of almost every item discussed on the tour are provided.

In general, we observed that there is not much written information in this tour. We relied mostly on the tour guide for information. The one part of the tour that does contain writing is the timeline on the first floor of the estate house. We feel that font size is too small because it was hard to read unless a visitor is fairly close to it. *Figure 8* shows the large amount of text and the small font size. In addition, there was insufficient time allotted to read all of the text.



*Figure 8. Photo of the first exhibit at the Hacienda Buena Vista showing the small font size and large amount of text.*

### **Evaluation of the Hacienda La Esperanza**

The Hacienda La Esperanza is an historic estate containing a steam-powered sugar mill. The tour of this estate is organized with three main exhibits. These exhibits have the same overall theme of slavery and sugar production on the estate in the late 1800s. The first exhibit is the manor house where the owner of the estate (Fernando Fernández) and his family lived. The next exhibit is the historic sugar mill which the slaves of the estate used to process the sugar cane. The final exhibit is the drying house which includes the blood mill. We found that the exhibits flow together well and give a lot of historical information on both the prosperity of the sugar plantation and the dark past of slavery on the estate.

Overall, this tour does not have a specific audience. Tours are given to groups of tourists, school groups and local families. This tour includes a lot of history on both the sugar industry and slavery, which makes it very interesting to tourists who do not know the local history. Also, this tour meets the educational expectation of school groups because it offers valuable insight into the local Puerto Rican history. This is important for locals and children to learn so they can better understand their families' pasts.

We found that each exhibit on the tour has a clear and concise objective and for the most part is well conveyed. This allows for a natural flow between exhibits which contribute to the overall story. We believe the tour through the manor house exhibit clearly conveys its message about the Fernández family and their ties to the slave trade and sugar industry. The poor conditions the slaves experienced were displayed clearly through the use of visuals like the machete collection and the grievance quilt. Also, the steam engine exhibit shows how steam engines function and the visitors are given a firsthand look at the machinery. In our opinion, the drying house lacked the visuals that other exhibits had with the exception of the blood mill. During this exhibit we were forced to imagine what the tour guide was explaining to us. For this reason, the message was not as clear as the other exhibits and we did not fully understand what the tour guide was saying. The drying house is the last stop of the tour and ideally would leave us with a lasting impression; instead due to the lack of text and visuals there is confusion. Also, none of the exhibits have interactive parts, which could allow for a clearer message. Finally, written text is rarely used during the tour. There is some text in the manor house; however, there is no text in the sugar mill and drying house exhibits.

## RECOMMENDATIONS PART 1: EDUCATIONAL EXHIBIT

### Selection of information to be included in the exhibit design

Our recommended exhibit content, with both Spanish and English text, includes the following five plaques:

- **Steam Power:** Steam power is a series of energy conversions, where the thermal or “heat” energy is converted to kinetic or “motion” energy to move the mill. Water and a heat source are necessary to produce steam to power the mill. This mill uses a boiler that burns diesel fuel to create heat that converts the water to steam. The steam from the boiler goes through pipes to the engine’s piston. Once the steam exits the piston, the temperature drops, which changes it back to water. This water returns to the boiler and the process begins again. When the steam reaches the piston its thermal energy is converted into kinetic energy. The steam pressure moves the piston, and that movement powers the mill. The mechanical energy produced in the piston moves the beam, crank, gears and finally the massive rollers. The mill extracts the cane juice and leaves behind

bagasse (pressed cane). In the original system, the boiler generated heat from burning bagasse. A picture of this proposed plaque can be viewed in *Appendix D: Steam Power*.

- **History of Steam Engines:** The first useful steam engines were invented in England during the 1700s. They were used to pump water out of the bottom of mines. The Newcomen engine was the first true steam engine. The steam was used to pull the piston down. However, this engine did not have the capability to push the piston back up. The Watt engine was the first engine to use steam to push the piston both up and down. It also used an external condenser for cooling the returning steam, allowing the engine to stay at a more efficient temperature. A picture of this plaque can be found in *Appendix D: History of Steam Engine*.
- **Improved Watt Engine:** This engine is an improved Watt Engine. Watt's improvements allowed the piston to produce power when it moved both up and down. Previously the piston could only produce power when being pushed down. This was accomplished through the use of a linkage which connected the piston to the overhead beam. This linkage allowed the piston to produce power in both directions. A photograph of this plaque can be found in *Appendix D: Improved Watt Steam Engine*.
- **Mill Technology:** Prior to the invention of the steam engine, mills relied on flowing water or manual labor from animals and slaves for power. Steam engines, however, were only used by large farms because they were expensive to buy and maintain. This competition resulted in smaller farms going out of business. The steam engine has a number of advantages over water or animal power. For example, an engine can work longer than animals and is more accessible than water. A picture of this is located in *Appendix D: Mill Technology*.
- **Slavery at the Hacienda La Esperanza:** The slaves at the Hacienda La Esperanza were vital to all aspects of the estate. The slaves used machetes to dig holes, to plant the sugarcane and to cut down the cane stalks. They grew and harvested the sugarcane in the field, operated the engine to extract the sugar juice and worked the Jamaica Train to refine the sugar. At the engine, the slaves loaded the cane stalks into the mill rollers. They also moved the bagasse from the engine to the furnaces, which powered the engine and the Jamaica Train. The Jamaica Train is a series of large kettles that evaporate water out of the juice. Slaves transferred the boiling syrup from one kettle to the next. Each kettle evaporated more and more water until the molasses was all that remained. A photograph of our design for this plaque is in *Appendix D:*
- *Slavery in Sugar Mills*.

We took into account spacing and design on our plaques to include both English and Spanish text. This allowed us to accommodate both locals and foreigners, considering that most visitors speak English or Spanish. The translation from English to Spanish was done by our sponsor, Juan Rodríguez.

### **Selection of exhibit materials**

Once we researched companies that produce exhibit materials, we requested more information from all eight companies we found. A table of their information can be found in *Appendix E: Exhibit Panel Research*. Of the eight companies, only four responded. The companies were *EnviroSigns*, *Pannier Graphics*, *Hopewell Manufacturing* and *Fossil Industries*. After comparing the products of these companies, the main difference was essentially price. All of the companies use similar materials for the graphic panels and the pedestals. Considering the similarities, *Pannier Graphics's NPS Cantilever Base* that is 24 by 36 inches with post and fiberglass embedment interpretive panels were the best choice. The reason this set of materials was better is because of the price compared to the other products in addition to the provided information. The price for five (5) sets, panels and pedestals, is approximately \$4930 including shipping costs. The panels carry a 10 year warranty, have UV and weather resistance, are easy to maintain and clean, have high quality digital printing and are usable for outdoor conditions. The pedestals meet National Park Service standards, are rust free, tamper proof and constructed of high-strength aluminum.

*EnviroSigns* is very similar to *Pannier Graphics* in terms of materials they use for their products; however, they are more expensive and their panels carry a limited 10 year warranty instead of the full 10 year warranty that *Pannier Graphics* provides. For this reason, *EnviroSigns* was eliminated from our considerations. *Fossil Industries* had a better price than *Pannier Graphics*; however, they did not provide detailed information on their products such as warranty and materials used to construct their products. Since warranty is an important issue, *Fossil Industries* was eliminated as a choice. *Hopewell Manufacturing* had the most expensive options for similar products and they do not provide a warranty on their products so they were also eliminated from our considerations.

Taking into account all the factors mentioned *Pannier Graphics* has all the pertinent information and appropriate pricing. The approximate price for our recommendation is well within Para La Naturaleza's estimated budget of \$10,000. If however, *Pannier Graphics* is not chosen, then *EnviroSigns* is the next best option. They have the next best price and credentials for this type of exhibit.

## EXHIBIT MODEL

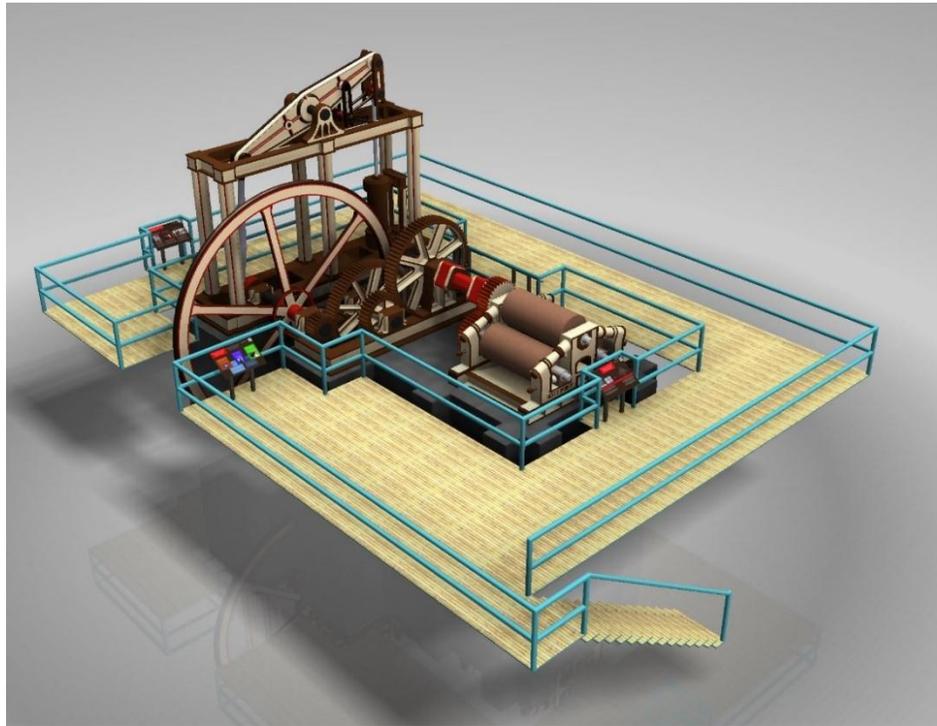


Figure 9. Rendering showing the placement of the exhibit panels and our recommended platform.

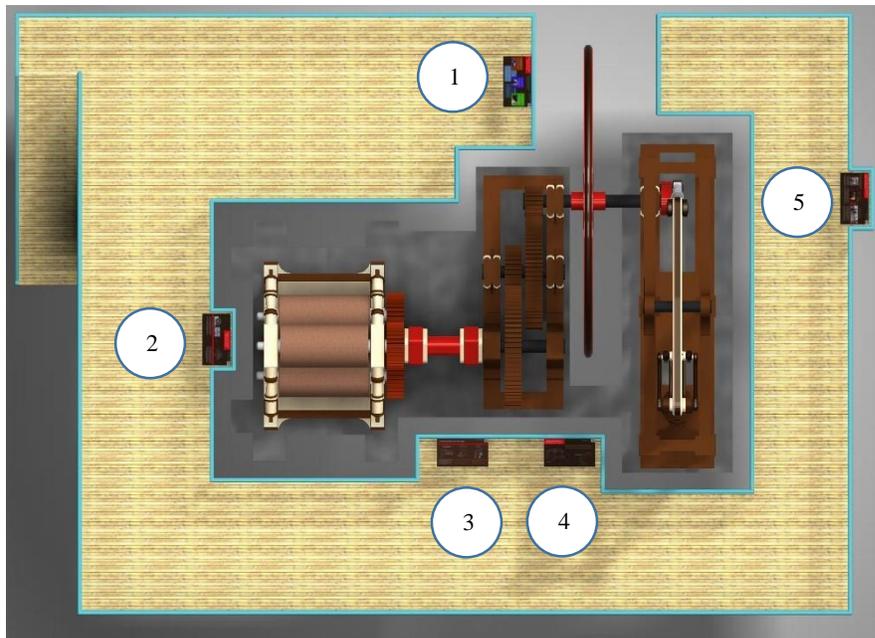


Figure 10. Our recommended plaque locations: 1-Steam Power, 2-Mill Technology, 3-History of Steam Power, 4-Watt Steam Engine, 5-Slavery at the Hacienda La Esperanza.

The model that we created shows the mill and its engine, the platform surrounding the engine, and the placement and content of the exhibit panels. The model can be used by Para La

Naturaleza for presentations, fundraising and visualizations. We have included the files for the model and basic instructions for its use. This model may also be of use to any future IQP or MQP teams that work with the Para La Naturaleza on the restoration of the Hacienda La Esperanza sugar mill.

Our recommended placement of the exhibit panels was determined by how the content on the panel relates to the surrounding space. The reasoning behind the placement of each panel is described below.

1. The Steam Power exhibit panel should be the first one that the visitors see. It provides an overview of the steam process and will help the visitors to understand how the engine works and where the energy to run it comes from.
2. The next panel is Mill Technology and should be placed close to the mill's rollers. This panel compares the old mill power technologies such as animal power or water wheels to the Hacienda's mill. It should be placed to the side of the rollers to make sure that it does not interfere with the any future demonstrations of sugar production.
3. The History of Steam Power exhibit panel should be placed in the relatively empty space between the rollers and the gears. This is because the panel provides the background for the next panel, which needs to be placed near the center of the engine.
4. The Improved Watt Engine exhibit panel should be placed near the engine because it explains the differences between the original Watt engine and the improved Watt engine that is used at the Hacienda La Esperanza.
5. The final panel explains the slaves' role in the operation of the Hacienda La Esperanza and provides a visual for the Jamaica Train. The panel should be placed as a transition between the engine exhibit and the Jamaica Train exhibit.

### **Exhibit design**

The model in *Figure 9* shows our design of the exhibit. It includes an in depth look at the mill, the platform around it, the number of exhibit plaques and their locations. We recommend placing five plaques around the mill for several reasons. These reasons are the flow of traffic of visitors, the content of the exhibit and the need for visual aids. The flow of traffic is important because tours at the Hacienda can have up to 75 people. For this reason, we do not want to have large crowds surrounding a single plaque.

Five plaques are ideal because the information in our exhibit fits best when split into five categories. These five categories are Steam Power, Improved Watt Engine, Mill Technology, Slavery at the Hacienda La Esperanza and the History of Steam Engines. We believe the information chosen in each of these categories is best shown when each has its own plaque. Each plaque will also include a visual to aid the audience in understanding the information presented.

*Figure 10* displays our recommended plaque locations. We determined the plaque location to match the information on the plaques with corresponding visuals. For example, the Slavery at the Hacienda plaque overlooks the Jamaica Train.

We recommend that Para La Naturaleza use our 3D model as a fundraising tool and to create more public interest in visiting the Hacienda La Esperanza. Presenting our model to a potential benefactor would have more impact than a series of photographs because it displays the mill functioning and provides a visual of Para La Naturaleza's goal for the restoration process. A guide to accessing and using our exhibit model can be found in *Appendix G: How to Open the Exhibit Model*.

We created a general outline for a site evaluation of the completed exhibit. The outline includes ideas for measuring the success of exhibits such as focus groups and interviews. We recommend Para La Naturaleza uses the evaluation techniques found in *Appendix H: General Outline for Site Evaluation*.

We recommend that a Worcester Polytechnic Institute Major Qualifying Project (MQP) be carried out to improve the Hacienda La Esperanza steam engine tour. This type of project is similar to an IQP with the exception that it is a major specific project completed by seniors. We recommend a computer science MQP to create an interactive website for visitors. This website would allow visitors to gain additional information about the sugar mill either before or after their visit. The following is a list of our ideas for the website's content:

- The website should include detailed information on the inner workings of the engine. It should focus on the unique characteristics of this engine for example it is a six column beam engine.
- The website should have more specific information on the slaves at the Hacienda such as their treatment and the gruesome jobs they had to do on the estate. We recommend using pictures of the different places the slaves worked for example, the Jamaica Train.
- We recommend that the website include an animation that shows the complete process of sugar production from cutting down the cane to its refinement in the mill. This was the purpose of the entire estate and this process cannot be shown during a tour.
- We also recommend that Quick Response (QR) codes be placed on the corresponding exhibit plaques. A QR code is a type of barcode and can be scanned using a smartphone with a QR code reader application. This code contains information related to the item it is attached to. In this



*Figure 11. A QR code for the Para La Naturaleza website.*

case, the QR code will bring the user to a website like the one we have recommended above. An example of a QR code is in *Figure 11*.

## **RESULTS PART 2: MILL CONVERSION**

### **Meeting with on-site engineer**

Although we did not have a structured interview with the on-site engineer, John Murphy, we did meet with him several times throughout our project to receive advice and additional information. During our first visit to the Hacienda La Esperanza, Mr. Murphy gave us a private tour of the machinery to see how the engine functioned. Mr. Murphy also provided us with detailed drawings of the mill and its proposed enclosure. We were able to use these drawings for both our exhibit design and our calculations. He also provided our team with the original calculations completed by Alpha Engineering and contact information for Dr. Huey.

### **Meeting with consulting engineer**

In order to gain additional information about the boiler requirements for our project, we interviewed Mr. Abreu. For this project, the boiler will be used to run the steam engine during tours throughout the day. Mr. Abreu informed us that there are three main types of boilers: thermal (fire-tube), water tube and scotch marine. He recommended a thermal boiler over the other two types. He said water tube boilers are bigger than the other two boilers and therefore more expensive, making them impractical for this application. Since this site requires the boiler to stop and start according to tour times, a scotch marine boiler is not appropriate because the short heating and cooling cycles can cause these boilers to explode. A thermal boiler is safer for intermittent heating cycles in addition to being less expensive than a water tube boiler. For these reasons, Mr. Abreu recommended a thermal boiler. He also encouraged the use of a condenser for the system. A condenser increases the efficiency of the steam engine by reducing the amount of heat loss to the surroundings. This means that there is less energy wasted to heat the water in the system. Mr. Abreu also taught us about the many ASME regulations that apply to this project. Our meeting notes can be found in *Appendix I: Interview with Julio E. Abreu*.

### **Flywheel speed determination**

To determine the target operating speed, we timed 20 flywheel rotations and averaged our times to find that the flywheel rotates completely in about 6.4 seconds. Using the equation given in the Methodology section, the speed of the flywheel was calculated to be 9.375 RPM. The data set can be found in *Appendix J: Flywheel RPM Measurements*.

The second method was used to double check our findings for the target operating speed of the flywheel. We counted the rotations of a reference spoke over the duration of one minute. Using this method we determined the flywheel's speed was just under 9.5 RPM. Using the

results from both methods, we have concluded that our target speed for our calculations was 10 RPM. We arrived at this number by rounding the flywheel speed up to the nearest whole number.

### Evaluating previous calculations

The previous calculations completed by Alpha Engineering used 25 RPM, which was the commercial speed of the mill (Para La Naturaleza). We accepted that the engine’s existing 10 RPM speed is sufficient and we planned on using their calculations as a reference. Before doing so, we had to verify the validity of their work. The calculations completed by Alpha Engineering contained some inconsistencies as well as some mathematical errors. They also lacked justifications, assumptions or explanations in multiple lines of the equations.

After Dr. Cecil Huey reviewed the calculations from Alpha engineering, he told us he had little confidence in them. The specific parts of the calculations in which we were unsure can be found in the *Appendix L: Alpha Engineering Calculation*. In addition, Dr. Huey provided us with equations he believed were valid and applicable.

### Calculations

Here are the dimensions we used for our calculations:

- Piston’s cylinder diameter ( $d$ ) is 12 inches
- Stroke length ( $l$ ) is 48 inches
- Strokes per minute ( $n$ ) is 20 (Two strokes per revolution of the flywheel)
- Density ( $\rho$ ) is 2.669 kg per cubic meter (using 5 bar).

| Steam Flow Rate and Horsepower Required at a Pressure of 5 Bar |                          |                                  |
|--|--------------------------|----------------------------------|
| Temperature (°C)   | Steam Flow Rate (lbs/hr) | Boiler Horsepower Required (BHP) |
| 20   | 746.26                   | 21.63                            |
| 40   | 716.04                   | 20.75                            |
| 60   | 688.85                   | 19.97                            |
| 80   | 666.87                   | 19.33                            |

*Figure 12. Table of results showing the steam flow rate and the required boiler horsepower for a given temperature.*

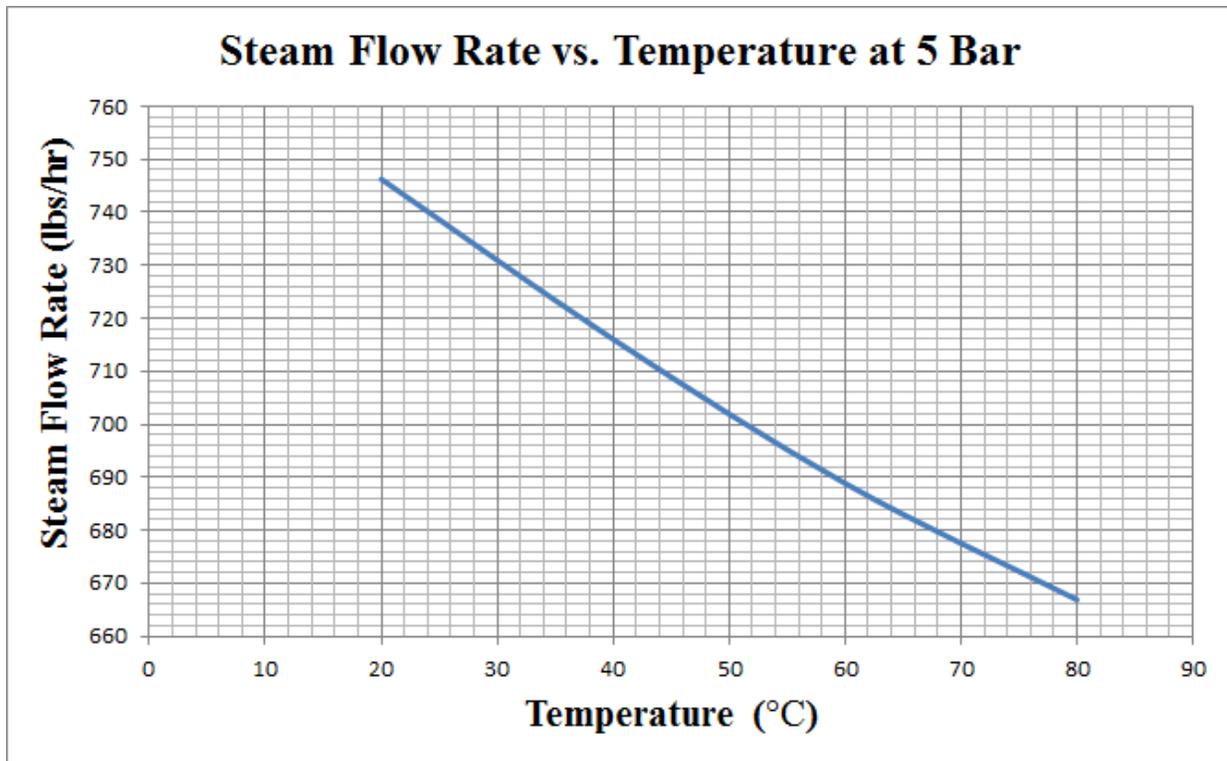


Figure 13. Graph showing the flow rate of the steam versus the temperature at five bar.

Based on the values in *Figure 12*, a minimum of 22 boiler horsepower (BHP) is required to run the engine’s flywheel at 10 RPM. A 22 BHP boiler will deliver the amount of steam calculated at the specified temperatures and pressure to the system. *Figure 13* shows the relationship between the temperatures of the feed water *versus* the steam flow rate required for the engine to run at 10 RPM. The 22 BHP we found is approximately one-fifth of the size of the boiler Alpha Engineering recommended (100 BHP).

## RECOMMENDATIONS PART 2:

Although it is possible to run the steam engine at 5 bar and any of the temperatures we used, we recommend running the boiler with a feed water temperature of 20°C. We decided on 20°C because a lower temperature is unrealistic due to environmental conditions such as surrounding temperature. The average temperature of the surrounding environment is approximately 27°C. Also the BHP required at 20°C is the highest and only differs slightly from the other temperatures. For this reason, it is the most appropriate operating temperature. At this temperature and pressure, the amount of steam required to run the engine at 10 RPM is approximately 750 pounds per hour. However, this requirement is basic and only accounts for constant operation at 10 RPM. Our calculation does not consider the initial start-up power requirement and does not include other factors such as frictional forces. Considering the complicated nature of these calculations, we recommend a more in-depth project. Moreover, we

recommend another MQP. We recommend that the MQP look into all of the following areas in order to complete a full analysis.

- Initial Start-up: overcoming inertia, static friction and dynamic friction
- Pipes connecting the boiler and piston: including factors such as pipe insulation, steam flow (i.e. turbulent or laminar flow) and weathering on the pipes
- Boiler Selection: completing a cost benefit analysis for the following criteria
  - Resistance to weathering
  - Warranty length
  - Required maintenance

The initial start-up of the system would likely require more power than running the mill at constant speed. This is because of the large inertia and static forces that exist when the machine is at rest. These need to be overcome to run the machinery. Also, the system would have to overcome dynamic friction while running at a constant speed. These two factors would require a boiler with more HP than we determined in our calculations.

Another important factor to consider in a full analysis is the distance between the boiler and piston. This is an important factor because Para La Naturaleza plans to have the new boiler approximately 100 feet from the piston, where the steam enters the mill machinery. The steam will be carried this distance in a pipe, which poses some potential difficulties. It is important to ensure that the steam remains at constant temperature throughout the pipe. This may require that the pipe be installed underground or have insulation placed around it. Also, the state of the flow through this pipe should be analyzed. Whether the steam flow is laminar or turbulent could affect the regularity of the steam entering the system.

There are many factors that must be researched during the boiler selection process and we recommend a cost-benefit analysis be completed in order to determine the best boiler. We carefully chose the above criteria to be included in this analysis. The resistance to weathering of the boiler material is crucial because the environment in Puerto Rico can be hot and humid which can cause materials to weather quickly. The warranty length should also be considered for this reason. Another important factor is the maintenance the boiler requires. For example, the cost of hiring someone qualified to maintain it and how often this is necessary must be considered. It is important to only include boilers in this analysis that meet all the necessary rules and regulations. These regulations are part of the ASME Boiler and Pressure Vessel Code. The relevant sections of this code are Section 1 for the boiler construction, Section 2 for the piping material and Section 8 for the cylinder construction. In addition to ASME regulations, the boiler must abide by National Board Inspection Code (NBIC). The NBIC is a collection of standards that govern work on boilers and pressure vessels.

# CONCLUSION

## SUMMARY

The Hacienda La Esperanza is a 2,265-acre nature reserve located in Manatí, Puerto Rico. It is important to the Puerto Rican culture because of its strong ties to both slavery and the sugar industry. Nearly every Puerto Rican in the 1800s was affected by slavery or the sugar industry which impacted the generations that followed. Since the sugar industry has disappeared from Puerto Rico in the last few decades, it is important to preserve the history of this industry due to its substantial impact on the society and culture. Para La Naturaleza is the current owner of the Hacienda La Esperanza and they have made efforts to conserve this estate. However, recently they have had issues concerning the restoration of the historic sugar mill located on the estate. For this reason, the project completed by this WPI project team addresses some of the issues that are necessary for the restoration process.

The sugar mill is part of a museum that attempts to educate visitors on the history of the Hacienda La Esperanza. However, the museum lacks several aspects needed to convey the history and culture of the sugar industry. The exhibit design aspect of this project gives Para La Naturaleza a model that can be used in several different ways: it can be used to further educate visitors on the culture surrounding the estate, it can be used as a basis for other museum exhibits, and it can be used as a fundraising tool to acquire funds for the restoration of the mill. The exhibit design is illustrated by a 3D digital model that shows the overall design of the mill, the informational plaques and the locations of the plaques.

The sugar mill has an historic “steam engine.” This steam engine, however, is no longer run by steam; it is powered by an electric motor. Para La Naturaleza wants the engine to be run by steam so it is historically accurate which will leave a more lasting impression on the visitors. The engine’s flywheel currently runs at approximately 10 RPM, which is sufficient to show visitors how the mill works. Calculations were completed based on the advice of an expert in the field of steam power. These calculations indicate that Para La Naturaleza needs approximately 750 pounds of steam per hour to run the engine at 10 RPM. However, the calculations do not take into account the additional power required to start the engine. The calculations and research recommended in this report provide an excellent starting point for converting the engine to steam power. In the future this will enable Para La Naturaleza to run the mill on steam, as it was originally done.

## TECHNOLOGY AND SOCIETY

The underlying connection of people in a society is culture. The culture of Puerto Rico during the 1800s and early 1900s was shaped by the need for sugar and slaves. The culture of the

people has been and will always be affected in one way or another by technology. This phenomenon is true for the Hacienda La Esperanza estate. The introduction of the steam-powered mill at the Hacienda propelled the estate to be the largest sugar producer on the island. The environmental interpreters of the site detail the history of the Hacienda to familiarize visitors with the impact the steam-powered mill had on the lives of both the slaves and the owners of the estate. There were disparities in the quality of life; a gap made larger because of the use of technology to better one's life over another. However, the changes that occurred before, during and after the introduction of the steam-powered mill are important to the connection between society and technology.

## REFERENCES

Bridgman, B., Maio, M., Schmitz, J., & Teixeira, A. (2012). What Ever Happened to the Puerto Rican Sugar Manufacturing Industry? *Federal Reserve Bank of Minneapolis*.

Castillo, C. (2007). Proposal for the Conceptual Design of the Steam Generation System for Hacienda La Esperanza at Manatí, Puerto Rico: Alpha Engineering Group.

Compressed Gases (general requirements). (2010). *Occupational Safety and Health Standards*. Retrieved September 30th, 2013, from [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9747](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9747)

Crist, R. E. (1948). Sugar Cane and Coffee in Puerto Rico, I: The Rôle of Privilege and Monopoly in the Expropriation of the Jibaro. *American Journal of Economics and Sociology*, 7(2), 173-184. doi: 10.1111/j.1536-7150.1948.tb00673.x

Curlee, Walt. n.d. Slaves Refining Sugar Cane Jamaica Train Historical Old South American Life. [Digital Painting]. Retrieved from <http://fineartamerica.com/featured/slaves-refining-sugar-cane-jamaica-train-historical-old-south-americana-life-walt-curlee.html>

César, J. A. (2006). *Puerto Rico in the American Century: A History Since 1898*: University of North Carolina Press.

Danilov, V. J., (2010). Hands-on science centers: a directory of interactive museums and sites in the United States. Jefferson, N.C: McFarland & Co.

EPRL, G. E. (2009). Economy/Hacienda La Esperanza/ Sugar Mill. Retrieved September 20th, 2013, from <http://www.encyclopediapr.org/ing/article.cfm?ref=08072213>

Hacienda La Esperanza Sugar Mill Steam Engine. (1979): The American Society of Mechanical Engineers.

Haywood, N., & Cairns, P. (2006). Engagement with an Interactive Museum Exhibit (pp. 113-129). London: Springer London.

Hills, R. L. (1993, August 19). *Power from steam: A history of the stationary steam engine*. Cambridge University Press

Historic American Engineering Record, National Park Service / Freeman. Belmont. 1976. Isometric Projection of Valves, Cylinder, and Parallel Motion Mechanism. [Technical Drawing]

Leavens, D. H. (1915). Linkages. *The American Mathematical Monthly*, 22(10), 330-334.

Macdonald, S. (1990). Posing Questions about the Purposes of Museums (Vol. 31, pp. 225-228): Wenner-Gren Foundation for Anthropological Research.

Martinez, R., & Abreu, J. (2009). Integrity Assessment to Housing Sleeve of Steam Piston at Hacienda La Esperanza.

Musson, A. E., & Robinson, E. (1959). The early growth of steam power. *The Economic History Review*, 11(3), 418-439.

Para La Naturaleza. 33% by 2033. Retrieved 9-18-2013, 2013

Nuvolari, A. (2004). Collective invention during the British Industrial Revolution: the case of the Cornish pumping engine.

Operation Bootstrap. (2008) (Vol. 6, pp. 44-45). Detroit: Thomson Gale.

Pfoh, E. R. (2006). Puerto Rican Migration: Culture & Family. *Intelli-fridge*.  
<http://hdl.handle.net/2047/d10006382>

SpiraxSarco. (2011). The Steam and Condensate Loop Book.

Tufts, S., & Milne, S. (1999). Museums. *Annals of Tourism Research*, 26(3), 613-631.  
doi: 10.1016/S0160-7383(99)00024-9

## APPENDIX A: ANNOTATED BIBLIOGRAPHY

Bridgman, B., Maio, M., Schmitz, J., & Teixeira, A. (2012). "What Ever Happened to the Puerto Rican Sugar Manufacturing Industry?" *Federal Reserve Bank of Minneapolis*.

This journal article discusses the rise and fall of the sugar industry in Puerto Rico. This information is important to our project because it identifies a major part of the Puerto Rican history and culture. This gives valuable input on the importance of a historic sugar mill.

Castillo, C. (2007). Proposal for the Conceptual Design of the Steam Generation System for Hacienda La Esperanza at Manatí, Puerto Rico: Alpha Engineering Group.

A report commissioned by the Para La Naturaleza to provide recommendations for the restoration of the Hacienda La Esperanza's steam engine. It provided information on the mills current condition, and acted as a starting point for research relating to the restoration of the mill.

Compressed Gases (general requirements). (2010). *Occupational Safety and Health Standards*. Retrieved September 30th, 2013, from

[https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9747](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9747)

This is from the Occupational Safety and Health Standards website. This source is helpful because it covers the necessary regulations for compressed gases. As a part of the project, we will be handling a compressed gas (steam in an engine cylinder), so it is necessary to understand the regulations that will need to be followed in order for recommendations to be made.

Crist, R. E. (1948). Sugar Cane and Coffee in Puerto Rico, I: The Rôle of Privilege and Monopoly in the Expropriation of the Jibaro. *American Journal of Economics and Sociology*, 7(2), 173-184. doi: 10.1111/j.1536-7150.1948.tb00673.x

This journal discusses the rise of the sugar and coffee industry and more importantly the rise of the working class the Jibaro in Puerto Rico. This information is important because it identifies a major part of Puerto Rico's history and culture. This is useful to our project because we are able to identify the importance of the historical mill and the industry to the Puerto Rican culture.

Curlee, Walt. n.d. Slaves Refining Sugar Cane Jamaica Train Historical Old South American Life. [Digital Painting]. Retrieved from <http://fineartamerica.com/featured/slaves-refining-sugar-cane-jamaica-train-historical-old-south-americana-life-walt-curlee.html>

The photo of the Jamaica Train used in the background of the report to illustrate the sugar making process. The image is a digital drawing taken from the internet.

César, J. A. (2006). *Puerto Rico in the American Century: A History Since 1898*: University of North Carolina Press.

This book discusses the history of Puerto Rico under U.S. control. This book details the history between the U.S. and Puerto Rico as well as numerous acts and laws passed by the U.S. which affected both the mainland and Puerto Rico. This information is important to our project because understanding the history of Puerto Rico and the sugar industry will help us to produce recommendations for an educational exhibit

Danilov, V. J., (2010). *Hands-on science centers: a directory of interactive museums and sites in the United States*. Jefferson, N.C: McFarland & Co.

This book describes hands-on science centers and includes information about the importance, popularity and success of these centers. This information is important because it gave insight into one of the more successful ways to create a museum exhibit. This will contribute greatly to the design of the museum exhibit involving steam evolution.

*EPRL, G. E.* (2009). *Economy/Hacienda La Esperanza/ Sugar Mill*. Retrieved September 20th, 2013, from <http://www.encyclopediapr.org/ing/article.cfm?ref=08072213>

This article provided a concise history of the sugar plantation itself. This was used for establishing the sugar production of the mill during the late 1800s as well as the ecological importance of the estate. The ecological value provided by the estate is important to why we are being tasked to restore and conserve a historic national landmark of Puerto Rico.

*Hacienda La Esperanza Sugar Mill Steam Engine.* (1979): The American Society of Mechanical Engineers.

This brochure was helpful with providing a detailed history of Hacienda La Esperanza. The Hacienda is more than just a sugar mill; it is an entire nature reserve. Knowing this allowed us to get a better understanding of the environment we will be working in. In addition, the brochure covered history of the mill, the estate, and the owners of the estate since its start, and the engine and its manufacturer.

Haywood, N., & Cairns, P. (2006). *Engagement with an Interactive Museum Exhibit* (pp. 113-129). London: Springer London.

This book contributed to our project because it detailed how learning and engaging children contribute to the effectiveness of interactive museum exhibits.

Hills, R. L. (1993, August 19). *Power from steam: A history of the stationary steam engine*. Cambridge University Press

Information regarding the spread of steam power during the industrial revolution. The information from sections of this book was used in the background section to provide more information about the Newcomen and Watt steam engines.

Historic American Engineering Record, National Park Service / Freeman. Belmont. 1976. Isometric Projection of Valves, Cylinder, and Parallel Motion Mechanism. [Technical Drawing]

The images used in the report to illustrate the Watt Parallel motion linkage. The image is a part of a set produced by the National Park Service in 1976 that recorded the mill and engine at the Hacienda La Esperanza site. Our sponsor organization, Para La Naturaleza, provided the image set for us to use in our project.

Leavens, D. H. (1915). Linkages. *The American Mathematical Monthly*, 22(10), 330-334.

This journal excerpt from a 1915 edition of *The American Mathematical Monthly* detailing James Watt's parallel linkage. The source was used to provide additional support to the background section discussing the linkage used in the steam engine.

Macdonald, S. (1990). Posing Questions about the Purposes of Museums (Vol. 31, pp. 225-228): Wenner-Gren Foundation for Anthropological Research.

This review article talks about the increase in museum popularity as well as museum importance. It contributed to the project because it gave insight into why museum artifacts and relics are important to a community's culture and confirmed information found in other sources.

Martinez, R., & Abreu, J. (2009). Integrity Assessment to Housing Sleeve of Steam Piston at Hacienda La Esperanza.

An inspector's report commissioned by the Para La Naturaleza detailing the condition of the sugar mills pressure system. This report found specific instances of damage in the cylinder lining, and connecting welds of the mill's steam engine.

Musson, A. E., & Robinson, E. (1959). The early growth of steam power. *The Economic History Review*, 11(3), 418-439.

A paper based on collections of works by Boulton and Watt talking about the early economics of steam power. This source was used to support claims in the background regarding the expansion and of steam power.

Para La Naturaleza. 33% by 2033. Retrieved 9-18-2013, 2013

This is a section of the sponsor's website concerned with the Para La Naturaleza's goal of preserving 33 percent of Puerto Rico and its islands by 2033. This directly impacts our

project in the sense that we are helping to restore a part of Para La Naturaleza's property. The Hacienda La Esperanza is one part of this conservation effort and to have an understanding of the impact our project will have on their efforts, gives us a foundation to build off of.

Nuvolari, A. (2004). Collective invention during the British Industrial Revolution: the case of the Cornish pumping engine. *Cambridge Journal of Economics*, 28(3), 347-363

Journal about the development of steam power from an economic perspective. This source was used in the background to provide support for a comparison of the running costs of the Watt steam engine versus the Newcomen steam engine.

Operation Bootstrap. (2008) (Vol. 6, pp. 44-45). Detroit: Thomson Gale.

This article discusses the major points of Operation Bootstrap and the effects it had on Puerto Rico. This program played a large part in the fall of the sugar industry in Puerto Rico. This information is important to our project because it gives us important information on the history and culture of Puerto Rico and how the U.S. effected it. This gives us valuable insight into the importance of preserving a historic sugar mill.

Pfoh, E. R. (2006). Puerto Rican Migration: Culture & Family. *Intelli-fridge*.

<http://hdl.handle.net/2047/d10006382>

This journal discusses Puerto Rican migration to the U.S. and specifically how U.S. laws and interventions caused migration through the disappearance of the sugar industry. This is important to our report because understanding why the sugar industry disappeared from Puerto Rico will aid us in developing recommendations for our educational exhibit. It will also help us to identify the importance of the historical mill.

SpiraxSarco. (2011). *The Steam and Condensate Loop Book*.

A book published detailing the best practices for steam boiler design, selection and use. The book can be found on the Spirax Sarco website.

Tufts, S., & Milne, S. (1999). Museums. *Annals of Tourism Research*, 26(3), 613-631. doi: 10.1016/S0160-7383(99)00024-9

This paper describes the immense impact museums have on the local economy. It contributed to the project because it gave important insight into how the community can benefit from a well-established museum.

## APPENDIX B: TOUR GUIDE INTERVIEWS

### INTERVIEW WITH EDWIN FIGUEROA RODRIGUEZ

1. What is your name and title?
  - Edwin Figueroa Rodriguez
  - Environmental Interpreter
2. How long have you been working for Para La Naturaleza?
  - He has worked full time for 6 years and worked part time for two years prior to then.
  - He has worked at La Esperanza since August 2013. He previously worked at Buena Vista for the first 7+ years.
  - He gives all the tours offered at La Esperanza.
3. What grabs people's attention during a tour?
  - Slave history
  - Machine, sugar mill
  - The house where the blood mill usually loses the audience's attention because the information can sometimes be confusing (Also called La Casa Secador or La Casa de Purga).
4. What aids or helps you to get your points across to the audience?
  - He tells stories of the Hacienda.
  - A model of the sugar process (Jamaican train) would help aid in getting the point across (A picture, drawing or exhibition would also help).
  - When giving the history in the manor house, some people get confused because the information cannot be seen by everyone at the same time.
5. Do you do anything different on the tour when it is locals compared to tourists?
  - Usually give more tours to locals than tourists. For tourists, he tells fewer stories and uses more simple terms.
  - Locals generally have more questions, may be because of the connection to their culture.
6. How does the tour change based on the audience?
  - For kids, the vocabulary is changed so they can understand.
  - He would like to show the sugarcane being crushed in the mill for kids

## 7. Other comments

- The tour at Buena Vista was easier for him because there is more props and hands-on parts of the tour.
- La Esperanza relies much more on the tour guide talking than visuals.
- He would like to find more information on the West Point Foundry.

## INTERVIEW WITH MANUEL SEPÚLVEDA VÁSQUEZ

### 1. What is your name and title?

- Manuel Sepúlveda Vásquez
- Environmental Interpreter

### 2. How long have you been working for Para La Naturaleza?

- He has worked full time for Para for 4 years.
- He worked with environmental agencies such as DNER, USDA, and U.S. Forestry Service prior to Para.

### 3. What grabs people's attention during a tour?

- He does all tours (16 protected areas in Puerto Rico), sometimes he goes to other regions to help out
- Depends upon the audience, usually the house and the mill, most people never see a machine like the sugar mill in the condition it is in.
- Interpreters are trained to try to keep the audience connected to tour.
- It can be difficult because he has to condense 100 years of history into an hour and a half tour.
- It depends upon the audience on what loses their attention. For example, for school groups it is harder to keep the childrens attention and sometimes it is necessary to leave out certain information.

### 4. What aids or helps you to get your points across to the audience?

- 5 points they hit to get the point across to the audience; catch the eye of the audience
- He presents the audience with a visual and then explains it.
- Provide them with enough information so they want to go home and find the information themselves.
- Hardest thing is to connect the 1800s to modern times or even the 1900s
- Uses the layout of the house as an example, different accents can be seen such as French and Spanish. Many houses today have various influences too.

- Props help the audience visualize, they are very important to the tour
- Hands-on props: machete collection, blood mill, sugar mill
- They have DVD clips of the history of Manatí, reference photos of the restoration process for the audience (attempting to put it together, time constraints).
- Jamaican train is probably the hardest or most confusing part of the tour for both the audience and the tour guide.
- Layout of the train is different from place to place, only 30% of the building for the train is left
- Would like to develop a structure (such as a model) so the audience can view the ruins and the area around the Jamaican train
- Para has books about the Jamaican train from an Hacienda in Cuba for reference
- Making connections to how things are done today compared to the 1800s is the best way to capture the audience and get the point across.

5. Do you do anything different on the tour for locals compared to a tour for tourists?

- He finds out where they are from if they are tourists in order to connect with them.
- He helps them make the connection of the history of the estate to the things done today.
- Most people come here because they don't know the history and are interested in it.
- School groups are handled differently because they are here for educational purposes while others come here out of enjoyment.

6. How has the tour changed during your time at Hacienda La Esperanza?

- At first, before opening to the public, tours were up to four hours long.
- Once open to the public, the tours were cut to approximately an hour and a half
- They do not have enough time to touch upon everything in the history of the estate. For this reason, he usually leave out information about the restoration.
- There are three tours a day, up to 75 people per tour (split into 3 groups of 25).

## **INTERVIEW WITH JOSE ANTONIO NEVAREZ RIVERA**

1. What is your job here at Para La Naturaleza?

- Jose Antonio Nevarez Rivera
- Environmental Interpreter, the link between the public and La Esperanza

2. How long have you worked here?
  - Since August 29, 2013 so approximately two months
  - Previously volunteered at Para La Naturaleza since 2008 as part of the Citizen Science Project
  - Internship at Hacienda La Esperanza then became a research assistant for three years before being offered his current position
3. What do visitors find most interesting about the Hacienda?
  - The open space, the coastal areas, the machine (steam engine) and the house
4. What do visitors find most interesting about the steam engine?
  - The story about how it got to the Hacienda (contraband)
  - The actual speed of the mill (it is much slower than expected)
5. What do visitors find the least interesting?
  - Visitors usually get confused about the Jamaica Train. It is a confusing topic for the tour guide to explain and the visitors usually don't understand and stop listening to the tour
6. How do you keep visitors interested in the tour?
  - I talk with my hands and use visuals
7. What tour do you usually give?
  - Since I am new, I have only done tours of the house and the mill (the Historic Trail)
8. What other trails are offered at La Esperanza?
  - The Historic, Coast, River, Karst and Estuary trails are the five main tours
  - We have two new trails: a kayak tour in the river and a bicycle tour through the property

## APPENDIX C: SITE EVALUATIONS

### EVALUATION OF HACIENDA LA ESPERANZA

1. How is this site organized? Is there an overall theme or is each exhibit different? Do all the exhibits flow together well or is there a disconnect between them? Explain.

This tour is organized with three main exhibits. These exhibits have the same overall theme of slavery and sugar production on the estate in the late 1800s. The first exhibit is the manor house where the owner of the estate (Fernando Fernández) and his family lived. The next exhibit is the historic sugar mill which the slaves of the estate used to process the sugar cane. The final exhibit is the drying house which includes the blood mill. The exhibits flow together well and give a lot of historical information on both the prosperity of the sugar plantation and the dark past of slavery on the estate.

The only disconnect between exhibits occurs when walking between exhibits. The walk is not long but the tour guide does not provide information on the walk. The walk is used for questions the audience may have. It is a little awkward if the visitors do not have questions and it is hard to hear the guide because he is walking away.

2. Does the site have a specific audience? If so who is the audience and how does it meet their expectations? If not, how does each exhibit meet all different visitors' expectations?

This tour does not have a specific audience. Tours are given to groups of tourists, school groups and local families. This exhibit meets the expectations of tourists because it offers a very interesting tour. This tour includes a lot of history on the sugar industry and slavery which makes it very interesting to tourists who do not know the history of the area. This tour meets the expectation of school groups because it offers valuable insight into the local Puerto Rican history. This is important for children to learn so they can better understand their families past. The tour can also be changed slightly to leave out some of the gruesome slave history which might be too much for small children. This exhibit meets the expectations of local families by providing valuable information on the local history and giving insight into what life was like for their ancestors.

3. Is the message that each exhibit is conveying clear and concise? Explain for individual exhibits.

For the most part, each exhibit conveys its objective clearly and concisely. The tour through the manor house exhibit clearly conveys its message about the Fernández family and Fernando's ties to the slave trade and sugar industry. The poor conditions the slaves experienced is conveyed very clearly through the use of visuals like the machete

collection and the grievance quilt. The steam engine exhibit shows very clearly how steam engines function and the visitors are given a firsthand look at the machinery. The drying house lacked the visuals that other exhibits had with the exception of the blood mill. During the tour we were forced to imagine what the tour guide was explaining to us, instead of having visuals. For this reason the messages were not as clear as the other exhibits and may not be fully understood by visitors. This is the last stop of the tour, and ideally visitors would be left with a lasting impression; instead due to the lack of text and visuals, there is confusion.

4. Does each exhibit contribute to the overall goal/purpose of the site? Explain for individual exhibits.

Each exhibit contributes to the overall story of the estate and the tour naturally flows from exhibit to exhibit. For example, the manor exhibit begins by talking about the basics of the plantation and slavery. Then the visitors get to see the mills where some of the slaves worked.

5. Is each exhibit interactive? Can visitors learn through more than just seeing the exhibit?

None of the exhibits on this site have interactive parts. The visitor learns through listening to the tour guide and seeing the objects being discussed. Occasionally during the tour the site does not have the object being discussed and the visitors have to imagine it. When the visitors need to imagine the part, it is much easier for them get lost or lose focus. Unfortunately, this occurs most at the end of the tour. This is problematic because they just went on a long tour with visuals and therefore it would be easy to be tired and lose focus.

6. Does the exhibit provide visuals for all parts of the tour or do visitors have to imagine the objects being discussed?

The visitors have to imagine a few of the objects being discussed throughout the tour.

7. Does everything in the exhibit serve a purpose/ enhance the visitors' experiences?

Almost everything in this exhibit serves a purpose and enhances the visitor's experience. However, there is a timeline provided on the wall in the manor house and it gives too much information and is hard to understand. Part of this is because the tour group has barely any time to look at it and really understand what message it is conveying.

8. Is the text size readable for most visitors? Is there too much/ too little text? Is the text worthwhile to read?

Almost no text is used during this tour, the information is learned from a tour guide who is discussing the information. The timeline mentioned above was one of the only parts of the tour which included text and the amount of information was overwhelming. The only other part to have text was a tapestry outlining slave grievances at the Hacienda. This has large clearly readable text with interesting information on it for the visitors. The text in this situation is very beneficial to the visitors.

## **EVALUATION OF HACIENDA BUENA VISTA AND ITS EXHIBITS**

1. How is this site organized? Is there an overall theme or is each exhibit different? Do all the exhibits flow together well or is there a disconnect between them? Explain.

This site is organized into five sections: the old estate house, the water channel, the coffee mill, the slave house and the corn mill. All the exhibits display the same overall theme of 1800's agriculture. The overall tour flows well; one exhibit led into the next seamlessly. The first exhibit, the estate house, gives background knowledge necessary to understand the following four exhibits. The walk along the water channel provides insight into the life of the slaves and since it powers the machinery it connects smoothly into the coffee and corn mills. The mills show the technology of the time and also give more information about slave life. Throughout the tour, the life of the slaves links everything together.

2. Does the site have a specific audience? If so who is the audience and how does it meet their expectations? If not, how does each exhibit meet all different visitors' expectations?

The site seems targeted at Puerto Ricans, but it is also marketed to English speaking tourists. The tours are conducted in both Spanish and English, however the signs and labels are all in Spanish, which can be discouraging to non-Spanish speakers. The Spanish tours do not allow enough time to read all of the signage, which could also be a letdown. The machines and buildings are all well restored and in working condition. The site meets expectations to all audiences with the exception of a lack of written content for English speakers.

3. Is the message that each exhibit is conveying clear and concise? Explain for individual exhibits.

The first exhibit is the estate house, where a series of information panels are setup. The exhibit provides a timeline for the site, but only has text in Spanish. The tour then moves

upstairs to a restored portion of the estate house where the family lived. The house has the original furnishings and shows how the family lived in the 1800s. It also shows the wealth they had through the cutting edge technology they had for the time period. The exhibit has a clear message and other than the issues stated above is well presented.

The next exhibit is a walk along the channel that supplies water to the mill's machinery. The walk shows the environment that surrounds the site and the amount of work necessary to produce a channel that can provide water to power the two mills. The walk also shows why the Hacienda Buena Vista got its name by showing a beautiful view of a waterfall. In addition, the walk along the water channel exhibited the engineering of the time and the work the slaves had to do to keep the mills moving. This exhibit has a clear message and does a good job displaying it.

The third portion of the exhibit is the coffee mill. The mill is in fully functional and is powered by the original water wheel. The mills run using their original methods and this provides a very clear picture of how the mills were used. This exhibit is very clear and gives valuable insight into how the mills used to be used.

Next on the tour is the slave house. The house has been converted to a drying barn for the coffee as slavery had been abolished by the time that coffee production started. The guide explains the poor conditions of the slaves then moves on to explain the coffee drying process. Less time was spent on this exhibit than the others; however the message was still clear and interesting.

The last exhibit was the old corn mill. The mill was a set of grinding wheels powered by a water turbine. We were shown the wheels first and the guide demonstrated how corn was ground into meal. The second part of the exhibit shows the turbine running, but the visibility was poor due to the housing of the turbine. The exhibit was informative however because the turbine was not very accessible, it was a little difficult to understand.

4. Does each exhibit contribute to the overall goal/purpose of the site? Explain for individual exhibits.

The estate house shows the history of the family that operated the site and their lifestyle. It provides context for the rest of the tour.

The walk along the water channel gave a better understanding of the environment and teaches how the land was used to improve the success of the Hacienda.

Demonstrating the coffee mill shows how the mill operates, which gives background about the technology of the time; in addition it shows the working conditions of the people that operated the site.

The explanation of the slave house / drying house contributes to the overall goal by giving more insight into the harsh conditions the slaves endured. Also, the coffee drying racks provide an interactive experience for the visitors.

The corn mill contributes to the overall goal because it demonstrates the production of the estate's primary product.

5. Is each exhibit interactive? Can visitors learn through more than just seeing the exhibit?

Throughout this tour there are several interactive aspects which allow visitors to learn more about the information provided. For example, there were several items that the visitors are allowed to touch. These include:

- The house had sacks that were used to transport coffee from the mill. Allowing the visitors to touch the sacks gave insight into how hard it was for slaves to transport coffee due to the size and weight of the sacks.
- The coffee mill had a basket used for harvesting the coffee, as well as the coffee beans themselves. This gave valuable insight into how hard it was for the slaves to pick the coffee beans and fill a number of buckets each day.
- The drying house had large carts of dried coffee
- The corn mill allowed visitors to see the before and after products of the mill.
- The walk had opportunities to interact with the environment including the water in the channel and certain plants the tour guide pointed out.
- Also, the walk along the channel allows the visitors to see the amazing engineering that went into the mills and how much work went into them. There were a number of interactive elements to the exhibit which made it much easier for visitors to understand the message of the tour.

6. Does the exhibit provide visuals for all parts of the tour or do visitors have to imagine the objects being discussed?

The exhibit provides a number of visuals which are very useful to understanding all parts of the tour. Each section of the tour includes something in which the visitors can interact with. Examples of almost every item discussed on the tour are provided.

7. Does everything in the exhibit serve a purpose/ enhance the visitors' experiences?

All of the exhibits on the site serve a purpose and enhance the visitor's experience. The tour flows cleanly from exhibit to exhibit and each provides additional information for the overall message of the site.

8. Is the text size readable for most visitors? Is there too much/ too little text? Is the text worthwhile to read?

We feel that font size is too small because it was hard to read unless we were fairly close to the text. The lighting, especially in the basement of the estate house, was poor and made reading the text difficult. In addition, there was large amounts of text and time was not allotted during the tour to read most of it. If more time was given to visitors the written information might be very useful.

# APPENDIX D: EXHIBIT PANELS

## STEAM POWER

### La Energía del Vapor Steam Power

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La energía proveniente del vapor es el resultado de una serie de transformaciones, donde la fuente de energía térmica o "de calor" se convierte en energía cinética "movimiento" para mover el trapiche.

Steam power is a series of energy conversions, where the thermal or "heat" energy is converted to kinetic or "motion" energy to move the mill.

El agua y una fuente de calor son necesarios para producir el vapor requerido para mover el molino. La maquinaria presente en el trapiche, posee una caldera la cual utiliza combustible diesel para crear el calor necesario lo que convierte el agua en vapor.

Water and a heat source are necessary to produce steam to power the mill. This mill uses a boiler that burns diesel fuel to create heat that converts the water to steam.



En el momento donde el vapor llega hasta el pistón, su energía térmica se convierte en energía cinética. La presión del vapor mueve el pistón, el pistón a su vez los engranajes y finalmente los impresionantes rollos del trapiche.

When the steam reaches the piston its thermal energy is converted into kinetic energy. The steam pressure moves the piston, and that movement powers the mill.



El trapiche extrae el jugo de la caña teniendo como resultado el bagazo (Caña triturada). En el sistema original, la caldera generaba calor como resultado de la quema del bagazo.

The mill extracts the cane juice and leaves behind bagasse (pressed cane). In the original system, the boiler generated heat from burning bagasse.



El vapor de la caldera discurre a través de la tubería hasta el pistón del motor. Una vez que el vapor sale del pistón, la temperatura se reduce lo que convierte el vapor en agua. El agua regresa a la caldera y así inicia nuevamente todo el ciclo.

The steam from the boiler goes through pipes to the engine's piston. Once the steam exits the piston, the temperature drops, which changes it back to water. This water returns to the boiler and the process begins again.

La energía mecánica producida en el pistón se mueve el haz, manivela, engranajes y, finalmente, los rollos enormes.

The mechanical energy produced in the piston moves the beam, crank, gears and finally the massive rollers.

## HISTORY OF STEAM ENGINES

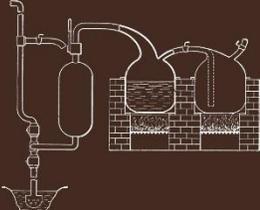
### Historia de los Motores de Vapor History of Steam Engines

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Inventado por Thomas Savery en 1699

#### Bomba de vapor Savery Savery Steam Pump

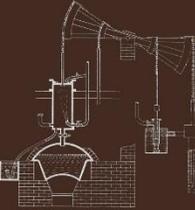


Los primeros motores de vapor exitosos fueron inventados en Inglaterra durante los 1700. Los mismos fueron utilizados para extraer el agua de las profundidades de las minas.

The first useful steam engines were invented in England during the 1700s. They were used to pump water out of the bottom of mines.

Inventado por Thomas Newcomen en 1712

#### Newcomen Engine

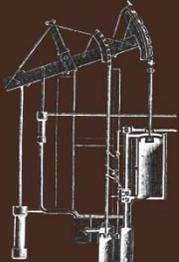


El motor Newcomen fue el verdadero primer motor de vapor. El vapor fue utilizado para mantener el pistón abajo. Sin embargo este tipo de motor no tenía la capacidad de levantar el pistón de vuelta.

The Newcomen engine was the first true steam engine. The steam was used to pull the piston down. However, this engine did not have the capability to push the piston back up.

Inventado por James Watt en 1776

#### Watt Engine



El motor Watt fue el primero en utilizar el vapor para levantar y bajar el pistón. Este utilizaba un condensador externo para enfriar el vapor de retorno, lo que permitió que el motor pudiese trabajar a una temperatura más eficiente.

The Watt engine was the first engine to use steam to push the piston both up and down. It also used an external condenser for cooling the returning steam, allowing the engine to stay at a more efficient temperature.

## IMPROVED WATT STEAM ENGINE

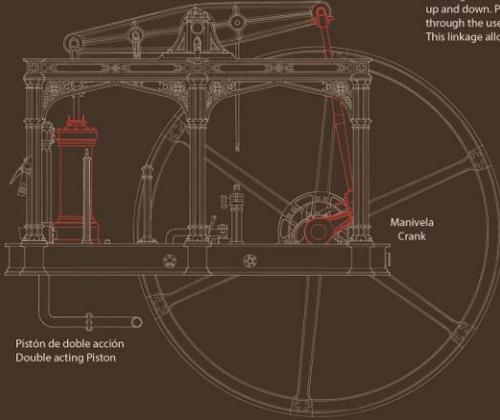
### Motor Watt Mejorado Improved Watt Engine

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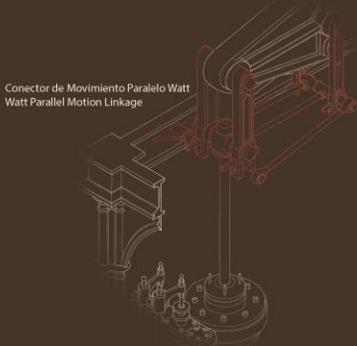
Este motor es una versión renovada del Motor Watt. Sus mejoras permitieron al pistón producir energía tanto cuando se mueve hacia arriba como hacia abajo. Lo anterior se logró utilizando un conector que une al pistón con la viga superior. Esta conexión permitió generar energía en ambas direcciones.

This engine is an improved Watt Engine. Watt's improvements allowed the piston to produce power when it moved both up and down. Previously the piston could only produce power when being pushed down. This was accomplished through the use of a linkage which connected the piston to the overhead beam. This linkage allowed the piston to produce power in both directions.



Manivela  
Crank

Pistón de doble acción  
Double acting Piston



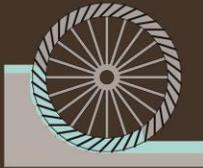
Conector de Movimiento Paralelo Watt  
Watt Parallel Motion Linkage

## MILL TECHNOLOGY

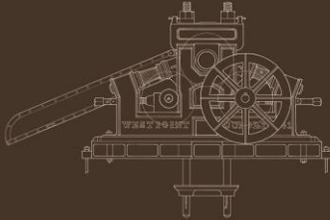
### La Tecnología del Trapiche Mill Technology

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Siglo 3 AC - Siglo 20  
3rd Century BC - 20th Century



~1770 - Presente  
~1770 - Present

Anterior al uso del motor de vapor, los trapiches dependían tanto del agua así como del trabajo de esclavos y animales para su funcionamiento. Sin embargo los motores de vapor solo eran utilizados por las grandes haciendas, debido a lo costoso de su adquisición así como de su mantenimiento. La competencia entre los diversos hacendados resultó en que las haciendas pequeñas eventualmente no pudiesen permanecer en operación.

Prior to the invention of the steam engine, mills relied on water or manual labor from animals and slaves for power. However, steam engines were only used by large farms because they were expensive to buy and maintain. This competition resulted in smaller farms going out of business.

El motor de vapor posee una serie de ventajas sobre el uso de la energía hidráulica o de la proveniente de animales. Un dato específico, un motor podía trabajar más tiempo y en mayor cantidad de lugares que los animales o el uso del agua.

The steam engine has a number of advantages over water or animal power. For example, an engine can work longer than animals and in more locations than water.

# SLAVERY IN SUGAR MILLS

## La Esclavitud en La Esperanza Slavery at La Esperanza

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Los esclavos de la Hacienda La Esperanza eran vitales para todos los aspectos de la propiedad...

The slaves at the Hacienda La Esperanza were vital to all aspects of the estate. They grew and harvested the sugarcane in the field...



Los esclavos utilizaban machetes tanto para realizar los hoyos para la siembra de la caña así como para cortar los tallos de la misma.

The slaves in the field used machetes to dig holes to plant the sugarcane and to cut down the cane stalks.

...operado el motor para extraer el jugo de azúcar...

...operated the engine to extract the sugar juice...

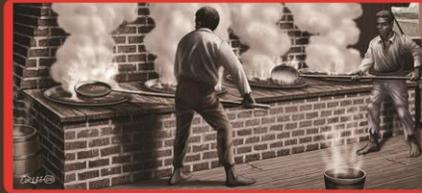


En la maquinaria los esclavos se encargaban de llenar los rolillos del trapiche con la caña de azúcar. En adición llevaban el bagazo desde el trapiche hasta los hornos, los cuales proporcionaban toda la energía necesaria para el funcionamiento del motor así como del Tren Jamaíquino.

At the engine, the slaves loaded the cane stalks into the mill rollers. They also moved the bagasse from the engine to the furnaces, which powered the engine and the Jamaica Train.

...y trabajó el Tren Jamaica para refinar el azúcar.

...and worked the Jamaica Train to refine the sugar.



El Tren Jamaíquino es una serie de recipientes conocidos como peroles donde se evaporaba el agua del jugo de la caña. Los esclavos transferían el líquido resultante de un recipiente al siguiente. Cada perol evaporaba mayor cantidad de agua hasta el punto que sólo quedaban las melazas.

The Jamaica Train is a series of large kettles that evaporate water out of the juice. Slaves transferred the boiling syrup from one kettle to the next. Each kettle evaporated more and more water until the molasses was all that remained.

## APPENDIX E: EXHIBIT PANEL RESEARCH

| Company           | Exhibit Material                    | Color      | Availability       | Unit Cost |
|-------------------|-------------------------------------|------------|--------------------|-----------|
| EnviroSIGNS       | DuraFrame 24x36                     | Black      | 4 week lead time   | \$317.09  |
| EnviroSIGNS       | DuraFrame 24x36                     | Brown      | 4 week lead time   | \$392.09  |
| EnviroSIGNS       | DuraFrame 24x36 with post           | Black      | 4 week lead time   | \$518.49  |
| EnviroSIGNS       | DuraFrame 24x36 with post           | Brown      | 4 week lead time   | \$593.49  |
| EnviroSIGNS       | NPS Cantilever 24x36                | Black      | 4 week lead time   | \$576.29  |
| EnviroSIGNS       | NPS Cantilever 24x36                | Brown      | 4 week lead time   | \$651.29  |
| EnviroSIGNS       | NPS Traditional 24x36               | Black      | 4 week lead time   | \$576.29  |
| EnviroSIGNS       | NPS Traditional 24x36               | Brown      | 4 week lead time   | \$651.29  |
| Fossil Industries | Double Cantilever Pedestal 24x36    | Black      | 4-6 week lead time | \$420.00  |
| Pannier Graphics  | NPS Cantilever Base 24x36 with post | Black      | 4 week lead time   | \$500.00  |
| Pannier Graphics  | NPS Cantilever Base 24x36 with post | Brown      | 4 week lead time   | \$500.00  |
| Pannier Graphics  | NPS Cantilever Base 24x36 with post | Dark Brown | 4 week lead time   | \$500.00  |

|                        |   |      |                  |           |
|------------------------|---|------|------------------|-----------|
| Pannier Graphics       | NPS Cantilever Base 24x36 with post                       | Gray | 4 week lead time | \$500.00  |
| Pannier Graphics       | Graphic Panel   | N/A  | 4 week lead time | \$350.00  |
| Hopewell Manufacturing | NPS Cantilever Base 24x36 w/fiberglass panel              | N/A  | 4 week lead time | \$1251.60 |
| Hopewell Manufacturing | NPS Cantilever Base 24x36 w/ high pressure laminate panel | N/A  | 4 week lead time | \$1258.60 |





**EnviroSigns, Ltd**  
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 WOOSTER, OH 44691  
 ph. 888-492-5377  
 fax: 888-492-5377  
 email: sales@envirosigns.com

# Estimate

Estimate: 897228  
 Printed 11/28/2013 3:27:35PM

**24x36 Frames and Exhibit base options**

| Product   | Qty | Sides | Height | Width | Unit Cost  | Item Total |
|---|-----|-------|--------|-------|------------|------------|
| 6 EnviroReader<br>Color: <b>Font:</b><br><b>Description:</b> Shatterproof, graffiti-resistant (graffiti can be removed), scratch-resistant UV resistant clear, non-yellowing 10 year material embedded with high resolution graphics - 3 year warranty<br><br>IMPORTANT! Enviroreader panels require a frame with a backing (our pedestal-style EnviroFrame, our NPS Style frame, or your frame)<br><br>Design Note: Do not put any logos, photos or text closer than 1-1/2" from edge of sign or the graphics and/or text may be covered by the frame edging<br><b>Text:</b> | 1   | 1     | 24     | 36    | \$338.0000 | \$338.00   |
| 7 AlumaReader<br>Color: <b>Font:</b><br><b>Description:</b> AlumaReader panels are rated for 5 year outdoor life (non-warranty) and are perfect for when you need to switch out panels in an EnviroFrame or NPS Style Frame/Exhibit Base. The AlumaReader comes in an .080 thickness and features a high quality digital print and UV and abrasion resistant lamination. The AlumaReader is not graffiti resistant like the EnviroReader and the DuraReader, but is a high quality panel for a temporary or low-traffic application.<br><b>Text:</b>                          | 1   | 1     | 24     | 36    | \$162.5100 | \$162.51   |
| 8 Paint<br>Color: NPS Brown <b>Font:</b><br><b>Description:</b> UP Charge for NPS Brown Powder Coat<br><b>Text:</b>   | *   | 1     | 1      | 1     | \$75.0000  | \$75.00    |
| 9 Set Up Fee<br>Color: <b>Font:</b><br><b>Description:</b> SET UP CHARGE FOR ANY COLOR POWDER COAT OTHER THAN NPS BROWN.<br><b>Text:</b>  | *   | 1     | 1      | 1     | \$175.0000 | \$175.00   |
| 10 Wrapping & Crating<br>Color: <b>Font:</b><br><b>Description:</b> All items are bulk packaged for shipment. If you have specific packaging requirements they must be quoted separately. Our panels are wrapped and/or crated for maximum protection against shipping damage.<br><b>Text:</b>  | 1   | 1     | 1      | 1     | \$45.0000  | \$45.00    |

Estimates are valid for 30 days



## Material descriptions and additional information

### DuraReader:

The DuraReader is a Digital High Pressure Laminate (dHPL) phenolic interpretive sign panel – the Interpretive Sign specified most by the National Park Service. It's the toughest, most durable phenolic interpretive sign panel available anywhere. It combines the most advanced graphic imaging with the proven durability of Digital High Pressure Laminate. Using extreme heat & pressure, the final DuraReader dHPL interpretive sign panel is a permanent fusion of image and HPL that can never delaminate, separate, crack or peel.

The DuraReader dHPL Interpretive Signs are available in standard Matte Finish, Ice Finish or Gloss. Available for use with all NPS Style exhibit bases, DuraFrame, pedestal & kiosk options!

### DuraReader dHPL Interpretive Signs Feature...

- 100% Post-Consumer Recycled Core!
- UV Resistant
- Graffiti Resistant
- Abrasion Resistant
- Burn Resistant
- Recyclable
- Shatterproof
- 12 Color Printing
- Will Not Delaminate
- True, Solid, Double-Sided Panels
- 10 Year Limited Warranty
- Made in the USA
- Lead Time: 4-6 weeks from proof approval (rush options available)

DuraReader interpretive signs are made from a high pressure laminate material used for exterior interpretive signs and graphic elements, wall murals and displays. The DuraReader is perfect for pedestal mounting or wall mounting.

### EnviroReader:

Got graffiti? We have the solution.

The EnviroReader interpretive sign panel is a high impact, fully recyclable interpretive sign that is created for use with our frames and exhibit bases. Made from abrasion-resistant and impact-resistant polycarbonate, EnviroReader interpretive signs feature a 100% three year anti-vandal guarantee.

Park systems, government agencies, museums and zoos turn to the EnviroReader when they need the most graffiti proof and impact resistant interpretive sign.

The EnviroReader interpretive sign panel is durable, non-yellowing, and recyclable! Your interpretive information will look great embedded in the EnviroReader interpretive sign panel.

The EnviroReader interpretive sign panel comes in a clear, glass-like finish (but 250 times the impact strength of glass!) and is available for use with our pedestal-like DuraFrames, Kiosks and NPS Style Exhibit Bases.

EnviroReader Interpretive Signs Feature...

Graffiti proof properties similar to glass – graffiti is easily removed

Abrasion Resistant

Virtually Unbreakable

Mar resistance due to permanent silicone hardcoat

Sub-surface graphics

High resistance to many chemicals, such as cleaning fluids, paints and adhesives.

Fits existing NPS style Frames – easily replace existing fiberglass embedded panels

UV resistant coating

Brilliant Eco-Solvent Inks

Recyclable

Made in the U.S.A.

“One stop for your entire project – signs, frames, pedestals, design. Saves you time and hassle.”

If you need an interpretive sign that is both vibrant and tough enough to stand up to the unscrupulous, the EnviroReader is perfect for you.

The EnviroReader is 1/8" thick and easily fits into the NPS standard frames, which we also provide. No interpretive sign holds up to graffiti better.

AlumnaReader:

A vibrant interpretive panel for those on a budget!

The AlumnaReader interpretive sign panel is an affordable solution for those needing to put interpretive signs up temporarily, or in a low-traffic area where graffiti and heavy abrasion aren't a concern.

AlumnaReader interpretive sign panels are made from 080 aluminum (with up to 10% post-industrial recycled content) covered with eco-solvent digital graphics and UV and abrasion resistant laminate. The AlumnaReader interpretive sign panel does not come with a warranty, but has an outdoor usage rating of up to 5 years.

The AlumnaReader interpretive sign panel comes standard in a satin finish – gloss & matte available upon request.

Available for use with all NPS Style exhibit bases, DuraFrames, Kiosks & direct wall mount.

#### AlumaReader Interpretive Signs Feature...

- UV Resistant
- Abrasion Resistant
- Shatterproof
- Recyclable
- Brilliant Eco-Solvent Inks
- Economical
- Made in the USA
- Lead Time: 4 weeks from proof approval

#### NPS Style Traditional Low Profile Exhibit Base:

This is the original low profile exhibit base. Constructed of aluminum extrusion, the legs are wider than the cantilever, and extend from the center line of the frame. The frame is displayed between the two posts. This exhibit base is used with frames which are 18" to 24" high. Interpretive sign widths are 24", 36" and 42". Interpretive signs are easily installed by removing the top rail of the frame, inserting the interpretive sign, and replacing the top rail. Mounting height from ground level to the bottom edge of the frame is 28" to 32".

#### Custom Sizes

Custom sizes are available.

#### Standard Sizes

Most Popular: 18×24 and 24×36

All: 18×24, 18×36, 24×36, 24×42

### Surface Mount Options

Our aluminum posts come standard for in-ground installation, but surface mounts are available in standard and deluxe options.

#### Our NPS Style Exhibit Bases Feature...

- Highly durable extruded aluminum construction
- Up to 10% post-industrial recycled aluminum
- Lead Time: 4-6 weeks from project/proof approval (rush orders may be available)
- Available with in-ground or surface mount (in-ground is standard)
- Custom finishes available (please ask)
- CUSTOM FABRICATION AVAILABLE!

Our NPS Style Exhibit Bases have a full metal backing, and are made for use with our 1/8" EnviroReader interpretive signs and our 1/8" DuraReader interpretive signs from 10%

post-industrial recycled aluminum. Our NPS Style Exhibit Bases are fabricated from 100% extruded aluminum. Standard finish is a black powder coat, but several custom finishes are available. Custom exhibit bases are also available.

Available in 30 and 45 degree angles, but 45 degree is our standard angle.

NPS Style Cantilever Low Profile Exhibit Base:

The Cantilever Exhibit Base is the preferred low profile exhibit base. Constructed of aluminum extrusion, the design is simple and unobtrusive. The frame is displayed between the two posts. This base is used with frames which are 18" to 24" high. Interpretive sign widths are 24", 36" and 42". Interpretive signs are easily installed by removing the top rail of the frame, inserting the sign, and replacing the top rail. Mounting height from ground level to the bottom edge of the frame is 28" to 32".

Custom Sizes

Custom sizes are available.

Standard Sizes

Most Popular: 18×24 and 24×36

All: 18×24, 18×36, 24×36, 24×42

### Surface Mount Options

Our aluminum posts come standard for in-ground installation, but surface mounts are available in standard and deluxe options.

Our NPS Style Exhibit Bases Feature...

- Highly durable extruded aluminum construction
- Up to 10% post-industrial recycled aluminum
- Lead Time: 4-6 weeks from project/proof approval (rush orders may be available)
- Available with in-ground or surface mount (in-ground is standard)
- Custom finishes available (please ask)
- CUSTOM FABRICATION AVAILABLE!

Our NPS Style Exhibit Bases have a full metal backing, and are made for use with our 1/8" EnviroReader interpretive signs and our 1/8" DuraReader interpretive signs from 10% post-industrial recycled aluminum. Our NPS Style Exhibit Bases are fabricated from 100% extruded aluminum. Standard finish is a black powder coat, but several custom finishes are available. Custom exhibit bases are also available.

Available in 30 and 45 degree angles, but 45 degree is our standard angle.

Double Post DuraFrame:

One of our most popular interpretive sign frame options is the DuraFrame with Posts. It gives the minimalist look of a pedestal, but has the protection of a frame with a full metal backing. It is highly durable, yet gives your budget a break when compared with most our

popular NPS Style Exhibit Base options. This frame is made to fit our 1/8" EnviroReader interpretive signs or our 1/8" DuraReader interpretive panel. Just remove the top rail (attached by vandal-resistant hardware) and slide your panel in and these are ready to go! Mounting height from ground level to the bottom edge of the frame is 28" to 32".

#### Custom Sizes

Custom sizes are available.

#### Standard Sizes

Most Popular: 18×24 single post and 24×36 double post

Single Post: 8.5×11, 8×12, 9×12, 11×17, 12×18, 18×24, 24×24

Double Post: 18×36, 24×30, 24×36, 24×42, 24×48, 30×48, 36×48, 48×48

### Surface Mount Options

Our aluminum posts come standard for in-ground installation, but surface mounts are available in standard and deluxe options.

Our DuraFrame Interpretive Sign Frames Feature...

- Highly durable extruded aluminum construction
- Up to 10% post-industrial recycled aluminum
- Lead Time: 4-6 weeks from project/proof approval (rush orders may be available)
- Available with in-ground or surface mount (in-ground is standard)
- Custom finishes available (please ask)
- CUSTOM FABRICATION AVAILABLE!

Our DuraFrame Interpretive Sign Frame has a full metal backing, and is made for use with our 1/8" EnviroReader Interpretive Sign and our 1/8" DuraReader Interpretive Sign from 10% post-industrial recycled aluminum. Our DuraFrames are fabricated from 100% extruded aluminum. Standard finish is a black powder coat, but several custom finishes are available. This frame offers the look of a pedestal with the durability of a full frame with a backing.



## File Prep Detail

Helping you navigate the interpretive jungle since 1994

[www.envirosigns.com](http://www.envirosigns.com)

### Submittal Checklist

- **Submit Individual Panel Files**  
*Please do not "gang" panels in a single document*
- **Include Instructions**  
*Submittal letter (or "read me" file): include a detailed list of panel size, qty, finish, etc...*
- **Include Proofs**  
*Send paper or PDF proofs for reference, write size and qty on each proof.*
- **Shop Drawings for Special Cuts/Corners**  
*Include drawings that will clarify hole locations, special cuts, bevels, etc...*
- **Include Fonts & Images**  
*Convert fonts whenever possible. If submitting "native" files, send your fonts folder. Include any imbedded scans, logos, etc...*

### Color Management & Proofing

- **CMYK or RGB**  
*Create your panel documents at 100% of final size*
- **Solid Color Matching**  
*Create files with Pantone Solid Coated colors for best solid color match*
- **Custom Color Matching**  
*We can match your provided color sample. Call for custom estimate*
- **Color Lab Samples are 8"x10"**  
*The only proofing option to proof actual color*
- **Paper Proofs**  
*For content only - tabloid size paper*
- **PDF Proofs**  
*For content only - emailed at low resolution*

### Artwork Checklist

- **Artwork Size**  
*Create your panel documents at 100% of final size*
- **Bleeds & Margins**  
*See our Bleed Guide PDF for instructions on setting up file for your hardware*
- **Contour Cuts**  
*Create and label a separate non-printing layer for cut lines*
- **Non-Standard Holes**  
*If you need holes/threaded holes for hardware not purchased from Envirosigns, create and label a separate non-printing layer for holes & specify hole type & size (e.g. 1/4"-20 threaded hole, or 1/8" countersunk through holes)*

### Preferred Applications

- **Adobe CS5.5 or lower**  
*Illustrator (preferred), InDesign and Photoshop*

### Other Applications

- **Other Professional Programs**  
*CorelDRAW, Freehand and Quark may require export procedures. Please contact us.*
- **Microsoft Programs**  
*Word, Publisher and PowerPoint often require setup time to be print-ready. Please read all of our documents carefully, check all of your images, follow the instructions and send your file to us. We will check it and let you know if work is needed before proceeding.*

### How to Send Files

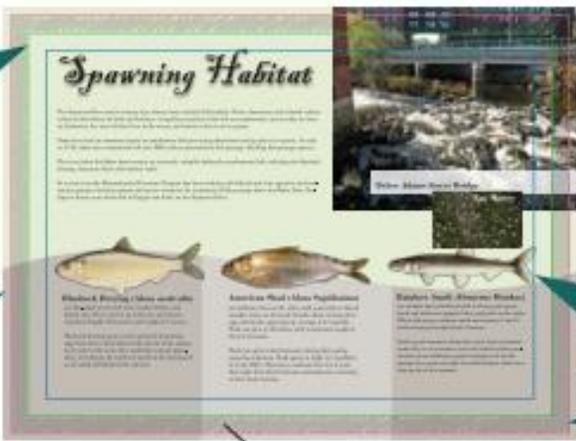
**Email** Files under 10MB total  
may be sent to  
[sales@envirosigns.com](mailto:sales@envirosigns.com)

**FTP** Please contact us for  
FTP instructions at  
[sales@envirosigns.com](mailto:sales@envirosigns.com)

**Disk** Send disks/other to  
Envirosigns, Ltd  
2700 Fulton Drive NW  
Canton, OH 44718

© 2012 Envirosigns, Ltd.

Toll Free: 1-888-492-5377 | Fax: 330-455-2220 | 2700 Fulton Drive NW. Canton. OH 44718



*Approx. inner edge of frame*

**1/4" BLEED** out from panel edge

**1 1/2" MARGIN** in from panel edge

**Panel edge**

**Frame Area (Do not draw in your file)**

## Framed Panels

- EACH side should have a 1/4" bleed
- All important text and photos must be 1.5" in from EACH side (for panels under 18"x24" reduce margin to 1" in)

## Frameless Pedestal / Frameless Wall Mount

- EACH side must have a 1/4" bleed
- All important text and photos must be 1/2" in from EACH side



**1/4" BLEED** out from panel edge

**1/2" MARGIN** in from panel edge

**Panel edge**

If you are unable to complete any of these steps, please contact us for a set-up quote

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Toll Free: 1-888-492-5277 | Fax: 330-455-2220 | 2700 Fulton Drive, NW, Canton, OH 44703



## File preparation guidelines



# FOSSIL INDUSTRIES

### File Prep Guidelines

The Fossil Art Department is available to answer questions and assist in preparing your files. We also offer art production and design services.

M-F 8:30-5:30 EST  
631.254.9200 x323  
ArtDepartment@FossilGraphics.com

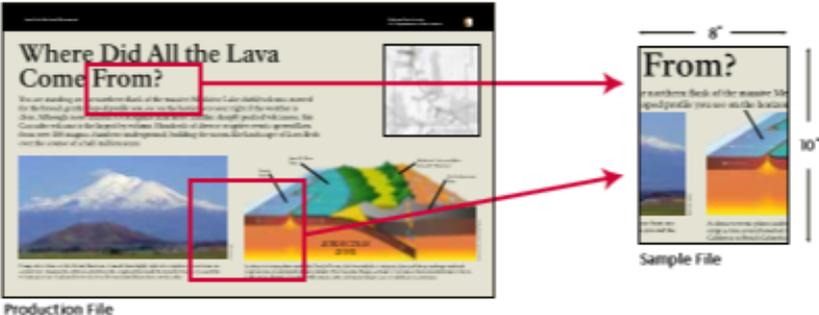
#### Checklist

- Panel files set up individually (one panel per file) at 100% with page layouts set to final size.
- RGB color mode preferred. Blacks set to Rich Black (0/0/0).
- Critical colors specified as solid uncoated Pantone.
- Panels include a .25" bleed from the final edge.
- Panels include a .5" margin of graphic elements/inset borders. NPS hardware requires 1" margins.
- Double sided panels have a maximum panel size of 56.5" x 141.75".
- Fonts fully outlined.
- Raster images 240 DPI at final output.
- Color Sample file included in the same format as production files.
- Paper prints or PDF's provided for layout reference.
- Vector path for custom cut panels provided on a separate, non-printing layer labeled "Cut Path".
- Standard corner radius is 1/16". Any radius is available. Specify size in inches.
- Insert and hole placement indicated on a separate, non-printing layer (not required for standard Fossil hardware.)
- Fossil does not guarantee the availability of archived files.

#### Color Samples

Color Samples help insure that your finished project matches your expectations.

Color Samples are manufactured exactly as finished panels, but are 1/16" thick. They are produced from 8" x 10" files created in the same format as final production files. Graphics and text should be 100% of final printed size. The file can be a section of a panel, or a collage of elements from one or multiple panels (see example below). More than one Color Sample may be helpful. Color Samples may be waived, at your discretion.



Production File

Sample File

#### Murals

- Maximum panel size: 58.5" x 143.75".
- Include crop marks to indicate the panel sizes and final mural size.
- Include a .5" inch bleed around mural perimeter.
- Image tolerance: less than .25" over 12'.

#### Proofing

- Color Sample: For color matching and resolution.
- PDF Proof: For layout and content only. Not for color matching.
- Paper Proof: For layout and content only. Not for color matching.

#### Software

- Preferred: Adobe CS6: Illustrator, Photoshop, InDesign.
- Supported: The following programs may require export procedures:  
Quark XPress, Corel Draw, Freehand, Powerpoint and Microsoft Word.

#### File Submittal

##### FTP

- Files less than 1GB.
- The FTP link is on our homepage: [www.FossilGraphics.com](http://www.FossilGraphics.com)
- Username: client
- Password: file
- Compress files for one upload.
- Include PDF's for reference.
- Label folder with Fossil quote number (FXXXXX).
- Notify us of the filename once the file has fully upload.

##### E - MAIL

- Files less than 10mb
- ArtDepartment@FossilGraphics.com

##### MAIL

Fossil Industries, Inc.  
44 Jefryn Boulevard  
Deer Park, NY 11729  
Attn: Art Department

**FOSSIL**  
INDUSTRIES

FOSSIL INDUSTRIES, INC. - 44 Jefryn Boulevard - Deer Park, NY 11729  
p: 631.254.9200  
Info@FossilGraphics.com - [www.FossilGraphics.com](http://www.FossilGraphics.com)

Guidelines: 10-11-2013

# HOPEWELL MANUFACTURING

## Quotes

Re: Quote - Google Chrome

<https://exchange.wpi.edu/owa/?ae=Item&a=Open&t=IPM.Note&id=RgAAAADSePlrRIQFSKNc3HJtV7pgBwAehTtPskwmSpYY8%2f63hp5eAAAAABWAAD0tharVIDXTqO3wV>

Reply Reply All Forward Chat

**Re: Quote**

Hopewell Manufacturing [info@hopewellmfg.com]

-You replied on 12/2/2013 11:02 AM.

**Sent:** Monday, December 02, 2013 10:53 AM

**To:** Portera, Andrew Alexander

**Attachments:** HopewellMfg-Jackie.pdf (467 KB); ATT00001.txt (824B)

Hi Andrew,

One (1) 36" x 24" Low Profile Cantilevered in-ground mount unit is \$420.00 + shipping

One (1) 36" x 24" with graphic design and fiberglass panel production is \$787.00 + shipping

One (1) 36" x 24" with graphic design and high pressure laminate panel production is \$905.00 + shipping

(4) or more units will have a price break.

More than one panel will also have price breaks, just let me know how many you are interested in and I will figure it up.

Let me know if you would like me to work up a formal quote and send to you.

Once I have your ship zip code, I can figure the shipping

Jackie

**HOPEWELL MANUFACTURING  
COST PROPOSAL**

12/06/2013

\* This quote is good for 30 Days

**billing address:**

**Ship Address:**

Para La Naturaleza  
(787) 722-5834  
Attn: Andrew Portera  
Prepared by Jackie Woodcock

Manati, PR 00674

We propose to furnish labor and/or material for the following:

**Five (5) interpretive exhibits, 36”w x 24”h, full color ink jet digital image for fiberglass embedment.**

The customer will supply the changes needed to the file that we will pull from GS Images.

Hopewell will design, and revise as needed, a PDF graphic layout for customer review and approval. One (1) full size 600 dpi ink jet proof will be produced for each exhibit. One (1) full size 600 dpi ink jet print will then be produced for each exhibit. The prints will be fiberglass embedded at a thickness of approximately .090”. **Five (5) 36” x 24” Low Profile Cantilevered in-ground mount aluminum exhibit display structures.**

The fiberglass exhibit panels and aluminum exhibit structures will be shipped prepaid to Manati, PR 00674 *(off truck delivery only, any other needs will be an extra charge)*  
**\*\*\*Note 30 days from the date of this quote, the shipping charges will need to be reassessed.**

We propose to furnish the above for the sum of:  
Six Thousand, Two Hundred Fifty-Eight -----00/100                   \$6,258.00  
*(\*\*\*all orders subject to 6% PA sales tax, to be added, unless we receive a tax exempt form)*

Payment to be made as follows: **50% Due when ordering, Balance Due Before Delivery**

The above prices, specifications and conditions are satisfactory and are hereby accepted. You are authorized to do the work specified. Payment will be made as outlined above.

Date of Acceptance \_\_\_\_\_ Authorized Signature \_\_\_\_\_

|   |                                   |                           |
|---|-----------------------------------|---------------------------|
|  | <b>HOPEWELL</b> & <b>HOPEWELL</b> | 217 N Franklin Street     |
|   | <b>MANUFACTURING INC</b>          | <i>Graphics</i>           |
|   |                                   | 301-582-2343 877-521-2787 |
|   |                                   | 301-582-4736 fax          |
|   |                                   | www.hopewellmfg.com       |

**HOPEWELL MANUFACTURING  
COST PROPOSAL**

12/06/2013

\* This quote is good for 30 Days

**billing address:**

**Ship Address:**

Para La Naturaleza  
(787) 722-5834  
Attn: Andrew Portera  
Prepared by Jackie Woodcock

Manati, PR 00674

Prepared by Jackie Woodcock  
We propose to furnish labor and/or material for the following:

**Five (5) interpretive exhibits, 36”w x 24”h, full color digital image for high pressure laminate.**

The customer will supply a complete exhibit plan including title, text and mixed-media production-ready artwork (suitable to Hopewell).

Hopewell will design, and revise as needed, a PDF graphic layout for customer review and approval. One (1) full size 600 dpi ink jet proof will be produced for each exhibit. One (1) full size full color high pressure laminate panel, .090” thick, will then be produced for each exhibit. **Five (5) 36” x 24” Low Profile Cantilevered in-ground mount aluminum exhibit display structures.**

The high pressure laminate panels and aluminum exhibit structures will be shipped prepaid to Manati, PR 00674 *(off truck delivery only, any other needs will be an extra charge)*  
**\*\*\*\*Note 30 days from the date of this quote, the shipping charges will need to be reassessed.**

We propose to furnish the above for the sum of:  
Six Thousand, Two Hundred Ninety-Three -----00/100 \$6,293.00  
*(\*\*\*all orders subject to 6% PA sales tax, to be added, unless we receive a tax exempt form)*

Payment to be made as follows: **50% Due when ordering, Balance Due Before Delivery**

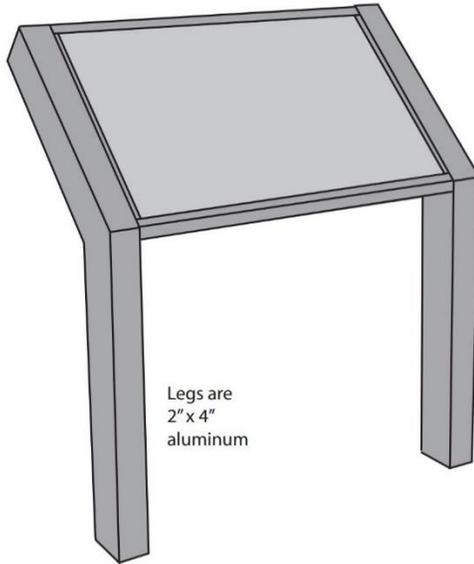
The above prices, specifications and conditions are satisfactory and are hereby accepted. You are authorized to do the work specified. Payment will be made as outlined above.

Date of Acceptance \_\_\_\_\_ Authorized Signature \_\_\_\_\_

|   |   |   |
|---|---|---|
|  | <b>HOPEWELL</b> & <i>Graphics</i><br><b>MANUFACTURING INC</b> | 217 N Franklin Street<br>Waynesboro, PA 17268<br>301-582-2343 877-521-2787<br>301-582-4736 fax<br>www.hopewellmfg.com |
|   |   |   |

## Material descriptions and additional information

### low profile cantilevered unit



Legs are  
2" x 4"  
aluminum

panel sizes : 42x20, 36x20, 30x20,  
42x24, 36x24, 24x18, 20x14, 16x12  
inches, and custom sizes

mounts : in-ground, socket base,  
surface mount

colors : G1 charcoal, medium gray,  
NPS brown, yorktown green, and  
custom colors



# Hopewell Manufacturing Inc.

## EXHIBIT BASE SPECIALIST

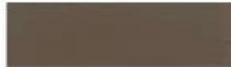
All of our exhibit bases come in standard panel sizes and colors but can also be customized to fit any specifications. There are four standard types of bases: low profile, upright, the kiosk, and ancillaries. Standard panel sizes for low profile units are: 42x20, 36x20, 30x20, 42x24, 36x24, 24x18, 20x14, and 16x12 inches. Standard panel sizes for upright units are: 36x24, 32x40, 36x54, and 36x48 inches. Standard kiosk panel sizes are the same as upright units. Upright units and kiosks can also have any combination of either graphic carriers or hinged bulletin cases. Ancillaries include audio units, pamphlet dispensers, coin collection box, and a small trailside unit. There are also several ways of mounting our exhibit bases. In-ground installation, which is the most popular method, uses concrete to permanently mount the unit. We also provide movable bases in the form of freestanding units or Removable in ground units that use socket bases which allow you to dismount and maintain the base and signs anytime necessary. Every base is made out of Aluminium which has great durability and strength yet is still light weight. Every unit is carefully sand blasted before painting to allow proper adhesion which greatly lowers the risk of weathering or damage to the unit's surface and paint. There are four standard colors for our exhibit bases.



### EXHIBIT BASE & FRAME COLORS



MEDIUM GRAY



NPS BROWN



GI CHARCOAL



YORKTOWN GREEN

## File preparation guidelines

# Hopewell Graphics

- Graphic Services
- Interpretive panels
- 25 Years design experience

Let us design your next interpretive project, we have over 25 years interpretive design experience. Or if you prefer send us your production ready files. It is important to us to make your experience working with Hopewell Graphics both enjoyable and efficient. Please follow the guidelines below when preparing your files. If you have any questions or need more information please call to speak with our design specialist.

### Supported Software Programs

Adobe Illustrator  
Adobe Photoshop  
Adobe Acrobat (PDF)  
Quark Xpress  
Adobe Indesign

### Acceptable Media

CD  
DVD

### File Specs

Documents need to be spec'd to the FINAL SIZE of the exhibits.

**Fonts:** ALWAYS send us your fonts unless you are changing your fonts to outlines. If in doubt, send your fonts. We must have both your screen fonts and your printer fonts.

**Photographs:** need to be scanned to yield 150 DPI (or PPI) at final size for clarity. All scans need to be saved as RGB TIFF files.

**Line Images:** We suggest that the scans be done in gray scale at 1200 DPI at final size. The image then is converted in Photoshop from gray scale to bitmap mode at 600 pixels per inch with the method option set at 50% threshold. This process makes it possible to control any negation or fill in of line weights.

Send all fonts and imported or linked elements.  
Also send elements that may be embedded within imported or linked elements (example: if you have an imported picture in your Quark document that is an EPS file and that picture has text in it that has a different font than what you are using for the rest of the document).

### Proofing

Send us a printout of your file. Otherwise we cannot check our file to yours.

DO NOT EXPECT THAT THE COLORS YOU SEE ON YOUR MONITOR ARE GOING TO MATCH THE COLORS YOU SEE IN THE FINAL PIECE.

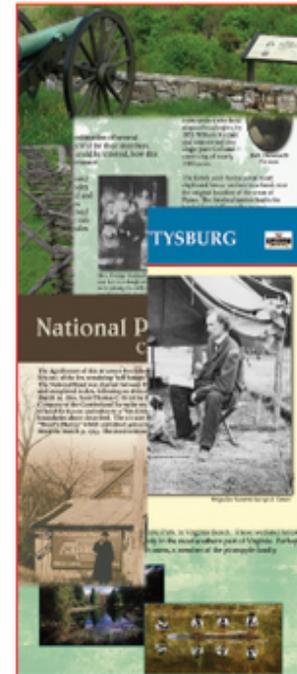
Also, do not expect that the colors you see on your printout will be matched. All printer devices and monitors give a different look. The printout you send will aid us in determining if all your parts are there and if your text/fonts are behaving as you expect. Without a printout we are at the mercy of your file.

It is also helpful to send us a list of all the files included on your disk showing file name and application. Please indicate to us on this list which file you want us to print from.

### Finally

We ask that you double check the disk(s) you are sending us. In addition to insuring that both the screen fonts and printer fonts for all fonts used and all nested and linked files are there, the page layout program should be updated or linked to OK status.

[Go here for our shipping address.](#)



# PANNIER GRAPHICS

## Quotes

Ball park prices. - Google Chrome

<https://exchange.wpi.edu/owa/?ae=Item&a=Open&t=IPM.Note&id=RgAAAADSePlrRIQFSKNc3HJtV7pgBwAehTtPskwmSpYY8%2f63hp5eAAAAABWAAD0tharVIDXTqO3wVmOHEr6AAAAA>

Reply Reply All Forward Chat

**Ball park prices.**  
Szemes, Amanda [amandas@pannier.com]

- You replied on 12/2/2013 3:18 PM.

**Sent:** Monday, December 02, 2013 3:14 PM  
**To:** Portera, Andrew Alexander

Hi Andrew-

It was great getting to talk with you about your sugar mill restoration project. As we discussed on the phone, for (5) 36" w x 24" h panels it is going to be around \$350 each and for the cantilevered exhibit bases it is going to be around \$500 each. As for shipping, I spoke with our shipping department and I need to know a complete address including the zip code before I can tell you a price. Would you be able to get that to me?

Thanks,  
Amanda



Amanda R. Szemes, Market Specialist  
345 Oak Road . Gibsonia, PA 15044  
800.544.8428 x204 . 724.265.4300 (fax)  
[amandas@pannier.com](mailto:amandas@pannier.com) . [www.PannierGraphics.com](http://www.PannierGraphics.com)  
Follow us on Twitter! | Like us on Facebook!

## Material descriptions and additional information

### Cantilevered Exhibit Bases:

The preferred style for NPS interpretive wayside exhibits, our Cantilevered base provides your panel with a minimal, but strong structure, and an optimal viewing angle.

- Exhibit Base and Frame Features
  - Constructed of rust-free, high-strength aluminum;
  - Full capture frame to keep panel in place;
  - Custom aluminum extrusions, eliminating unnecessary welds;
  - All corners are rounded for both safety and aesthetics;
  - Weep holes along bottom for water drainage;
  - Removable top rail for easy panel changes;

- Tamper proof connections used to protect from theft;
- Painted or powder coated;
  
- Built to strict National Park Service standards;
- Virtually unlimited mounting options-we can built to suit your need.

#### Interpretive Panels and Signage:

Pannier signs and panels are ideal for interpretive exhibits. Our embedment process creates durable panels with full-color, high-resolution graphics capable of delivering exactly what you want – from detailed photographs and colorful diagrams to bold text and bright graphics.

- 
- Features
    - Cutting edge high-definition digital printing;
    - Advanced UV-resistant embedment;
    - Solid, one-piece construction with no seal to compromise;
    - Easy to clean and maintain;
    - Resistant to the extremes of weather;
    - Recoverable from graffiti and vandalism;
    - Available in custom shapes & sizes;
    - For outdoor or indoor use, from .040” to .250” thickness;
    - 10-year warranty on all Pannier signs & panels.

## File preparation guidelines

### Preparing Files: What to Include When Sending Artwork

- 1. All Native Files** (from Desktop Publishing software)
  - Occasionally, Pannier needs to problem-solve due to printing or PostScript errors. Because of this, we prefer to work with your native files whenever possible.
- 2. If submitting production-ready PDFs**
  - Please follow the guidelines in this document for **bleed, crop marks, and image quality**.
  - Additionally, when exporting your PDF:
    - Export to PDF version 1.7 (Acrobat 8/9)
    - Do not downsample images, or use compression
    - Create crop marks when exporting PDF
    - Do not use color conversion
    - Using InDesign? Download ".joboptions" file [here](#)
- 3. All Linked Images** (See our section on Images)
  - All images must be linked in your layout software. Embedded files can cause printing errors, and if any image adjustments are needed, we cannot work with embedded images.
- 4. All Used Fonts** (See our section on Fonts)
  - It is always a good idea to include your font files in case we have processing issues. Or, if you require a minor text change during the production process, it can be easily corrected before printing.
- 5. Reference Layout PDFs if uploading files**
  - To be sure our proofs match your expectations, please provide PDFs to reference for layout.
- 6. Reference Printouts if Sending CD**
  - To be sure our proofs match your expectations, please provide PDFs to reference for layout. Please also indicate if you'd like us to match the colors as closely as possible.
  - Please label each print with final trim size and quantity.

### Transferring Artwork: How to Get Your Files to Us

- 1. Online File Prep Form**  
<http://www.panniergraphics.com/file-information-form.html>
  - Fill out this simple form to tell us what kind of files you are sending, what any key colors are, and any information our artists should know.
- 2. Direct Link to FTP (via HTTP)**  
<http://upload.panniergraphics.com>
  - Use "Anonymous Login" using your email address.
  - Create a folder for your project and upload the files inside this newly created folder.
  - Log out to automatically notify us that your files are available.
  - Instructions are also at the top of each page, after you log in.
- 3. Login Information for FTP (via FTP)**  
<ftp://ftp.panniergraphics.com>
  - Username:** general
  - Password:** your email address
  - Create a folder for your project and upload the files inside this newly created folder.
  - Log out to automatically notify us that your files are available.
- 4. FTP Client Software**  
(Pannier recommends Fetch)
  - Follow download instructions on the Fetch site.
  - Server name:** ftp://upload.panniergraphics.com
  - Username:** general
  - Password:** your email address
- 5. Email Large Files with 3rd Party Software**  
(Pannier recommends YouSendIt)
  - Follow download instructions on the YouSendIt site.
  - Email your file to [marketing@pannier.com](mailto:marketing@pannier.com)
- 6. Removable Devices Such as CD/DVD, Jump/Flash Drive, External Hard Drive**
  - Fill out our file information form, and include it with your removable device.  
<http://panniergraphics.com/file/fileinfo.pdf>

## Supported Graphics Applications

| Program             | Version       | Notes  | Extension         | MAC | PC |
|---------------------|---------------|--|-------------------|-----|----|
| Quark XPress        | Up to 9       | Collect files for output                       | .qxd              | X   | X  |
| Adobe Illustrator   | Up to CS6     |  | .ai<br>.eps       | X   | X  |
| Adobe InDesign      | Up to CS6     | Package files                                  | .indd             | X   | X  |
| Adobe PageMaker     | 6.5, 7        | Fannier will convert files to Illustrator.     | .pmd              | X   | X  |
| Adobe Photoshop     | Up to CS6     | Provide layered PSD file, if possible.         | .psd .tif<br>.jpg | X   | X  |
| Macromedia Freehand | 9, 10, MX     | Fannier will convert files to Illustrator.     | .fh10<br>.fh      | X   | X  |
| Adobe Acrobat       | Up to 10      | Please see our section on Adobe Acrobat files. | .pdf              | X   | X  |
| CorelDraw           | Up to 14 (X5) |  | .cdr              |     | X  |

| Program                               | Version | Notes  | Extension | MAC | PC |
|---------------------------------------|---------|--|-----------|-----|----|
| Microsoft Publisher                   | 2010    |  | .pub      |     | X  |
| Microsoft PowerPoint                  | 2010    |  | .ppt      | X   | X  |
| Microsoft Word                        | 2010    |  | .doc      | X   | X  |
| Map Making Programs<br>CAD or CAD/CAM |         | If possible, export a high resolution JPG to use in your layout, or to send to us.<br><br>You can also export a PDF or EPS, using these settings:<br>- CMYK output<br>- PS level 3<br>- Image Compression None<br>- Convert everything to polygons<br>- Embed all document fonts | .dxf      |     | X  |

## General Setup and Layout

### 1. Document Setup

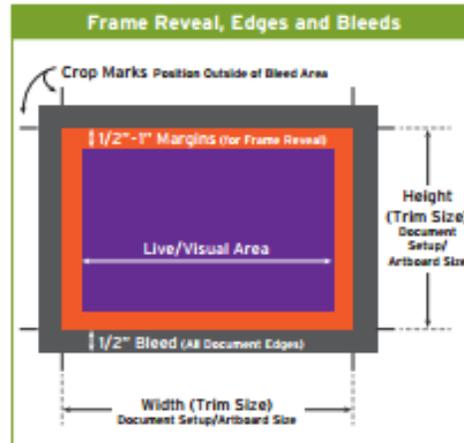
- As often as possible, set up your document size to the trim size of your panel.
- Scaled documents are acceptable, but try to keep them no less than 50% of finished size.

### 2. Frame Reveal, Edges and Bleeds

- Pannier frames are approximately 1/2" wide. This is also known as "Frame Reveal."
- Keep important information 3/4" to 1" away from trim edge to ensure it isn't lost due to expansion, contraction, and general shifting inside the frame.
- If no frame is used, allow 1/2" from trim edge to ensure nothing is too close to the edge.
- If you are using a frame from an alternate supplier, please provide the visual area dimensions to us. We'll place them on the proof.
- 1/2" bleed should extend past all edges of your document.

### 3. Templates for Common Sizes

- Templates for InDesign, Illustrator, Photoshop, Quark Xpress, and CorelDraw are available for download in the [Customer Tools](#) section of our website.
- The chart to the right lists available template sizes.



| Template Sizes Available (width x height) |                                      |
|---|--------------------------------------|
| 5-9/16" x 11-7/16"<br>(Plant ID Size)     | 30" x 20"<br>36" x 48" and 48" x 36" |
| 18" x 24" and 24" x 18"                   | 40" x 30"                            |
| 24" x 24"                                 | 42" x 24"                            |
| 24" x 36" and 36" x 24"                   | 48" x 24"                            |



## Color Matching

### 1. Color Space

- Please keep all of your photographic/raster images in the RGB color space. We utilize the Adobe RGB (1998) color profile, if you start in that space, you'll have the most predictable results possible.
- We choose to have you keep your images in this color space and profile to minimize the transitions from your images to our printers. Converting your images to CMYK prior to sending to us can result in unnecessary clipping of color gamut.
- For advanced design professionals, you can request a copy of our printer profile to enable soft proofing in Photoshop. We provide this for your use in predetermining how your files will print but cannot guarantee that it will be an exact match – room lighting, monitor calibration, and software settings all play a role in establishing accurate color management.

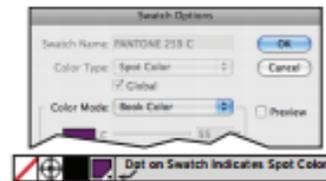
### 2. Specifying Pantone (PMS) Colors

- Our printers are calibrated, daily, to Pantone (PMS) color standards. Therefore, specifying Pantone (PMS) colors (Solid Coated at 100%) in your files is the best method for ensuring color accuracy.
- Do not alter names of Pantone (PMS) colors.
- Use Pantone (PMS) colors when creating monotones, duotones, tritones, and quadtones.
- Do not gradate from Pantone (PMS) to Pantone (PMS), or from 100% Pantone (PMS) to a tint. This may not output correctly. For best results, when used in gradations, convert Pantone (PMS) colors to CMYK.
- Do not use "Registration" as the color black. Instead, specify either "Rich Black" (c60; m50; y50; k100), or use 100% Black in CMYK build (c0; m0; y0; k100).
- See examples of Pantone (PMS) spot colors and Pantone (PMS) CMYK builds to the right. We only show Illustrator and InDesign examples, but the process is similar in many programs.

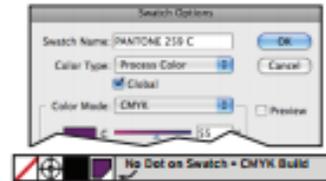
### 3. Providing Color Samples and Printed Samples

- It is helpful to provide color samples if you have something specific you want to match.
- For any color requirements you may have, please list them in our File Information Form ([Online version](#), or the [PDF version](#)), we will pay special attention to those colors.

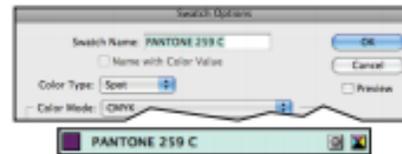
### Specifying Pantone (PMS) Colors



Spot Pantone (PMS) Color - Illustrator



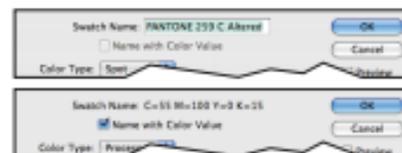
Pantone (PMS) Color Converted to CMYK - Illustrator



Spot Pantone (PMS) Color - InDesign



Pantone (PMS) Color Converted to CMYK - InDesign



Do NOT Alter Names of Pantone (PMS) Colors

## Images

### 1. Resolution

- We recommend using at least 150 pixels per inch at full size to gain maximum resolution when printing. We can easily work with higher resolution images, but this will not ensure higher quality images.
- **Keep in mind that if your layout is scaled, your resolution will scale as well.** For example, a layout that is set up at 18" x 12," but needs to be scaled up to 36" x 24," should have images placed in at 300PPI, so when the layout is doubled, the resolution is half – down to 150PPL

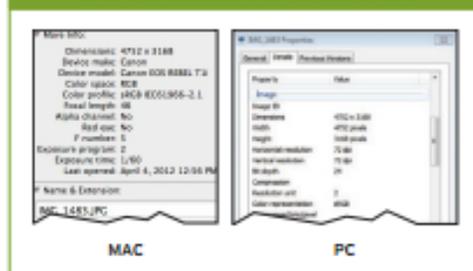
Megapixels vs. Maximum Print Size Chart

| Megapixels         | Print size @ 150ppi |
|--------------------|---------------------|
| 3                  | 13.65" x 10.24"     |
| 4                  | 16.42" x 10.88"     |
| 6                  | 20.05" x 13.34"     |
| 8                  | 21.76" x 16.32"     |
| 10                 | 25.81" x 17.28"     |
| 12                 | 28.60" x 18.67"     |
| 16                 | 32.80" x 21.76"     |
| 35mm film, scanned | 35.87" x 24.13"     |

### 2. Converting Pixels to Inches

- Pixels divided by 150 equals final size.
- For example, an image that is 1500px x 1000px will be 10" x 6.6" at full size.

View Pixel Dimensions in Info Panel



### 3. File Formats

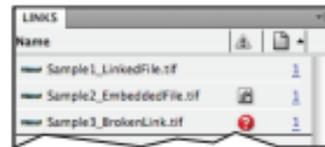
- We recommend PSD or TIF (uncompressed) files for maximum resolution.
- JPG and EPS files are also usable, though not as highly recommended.
- BMP, PNG, and GIF are typically not suitable for high quality digital output.

- **Note:** Images downloaded from websites are typically downsampled to be suitable for website viewing. It is best to contact the Webmaster for a higher resolution copy of the photograph you are downloading.

### 4. All Images Must be Linked

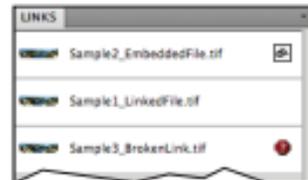
- If any image adjustments are needed, we will require the images to be linked. We cannot work with embedded images. The example to the right shows how to identify linked, embedded or missing images in the "Links" palette of several common applications.

Linked, Embedded and Missing Images



InDesign Palette

- Linked File Icon is Blank
- Embedded File Icon
- Missing/Broken Link Icon



Illustrator Palette

- Linked File Icon is Blank
- Embedded File Icon
- Missing/Broken Link Icon



QuarkXPress Usage Panel

- Linked File Status
- Broken Link Status

## Fonts

### 1. What We Need

- If you are sending your fonts to us, we will need your printer and screen fonts. Refer to the chart below to find out how many files you need of each font.
- When sending fonts, compress your files. This will ensure that all necessary files (such as Mac resource forks) are included. To do this, gather all fonts into one folder. Open that folder, select all font files (don't just select the folder itself) and zip (or stuff) the individual files into one compressed file. See example to the right.
- Listed below are two file compression applications:  
<http://www.stuffit.com> offers "stuffing" and "zipping" options for Windows and Mac.  
<http://www.winzip.com> offers "zipping" options for Windows and Mac.

| PC/Windows Platform |            |   |  |
|---------------------|------------|---|--|
| Font                | # of Files | Extension/Description   | Notes  |
| True Type           | 1          | TTF   |  |
| Open Type           | 1          | OTF   | Newest font format   |
| PostScript & Type 1 | 2          | PFB (outline/printer font)<br>PFM (metric information/<br>screen fonts) | PFB & PFM files must have the same filename                  |
| Bitmap              | 1          | BMP, SCR  | Comparable to raster images. Will pixelate with enlargement. |
| MAC OS X            |            |   |  |
| Font                | # of Files | Extension/Description   | Notes  |
| True Type           | 1          | TTF   |  |
| Open Type           | 1          | OTF   | Newest font format   |
| PostScript & Type 1 | 2          | Postscript<br>Type 1 Outline Font<br>Font Suitcase                      | The Font Suitcase links to the PS Type 1 fonts               |
| Bitmap              | 1          | BMP, SCR  | Comparable to raster images. Will pixelate with enlargement. |
| Data Fork Font      | 1          | DFONT   | Newer version of Open Type font. Available only on Mac.      |

ITC Fonts are made by a different company, the International Typeface Corporation, therefore they are not interchangeable with non-ITC fonts.

### 2. How to Gather Fonts

- InDesign and Quark offer "package" and "collect for output" services that will gather all fonts, linked images, and layout files necessary for outside printing. We strongly recommend using these.
- **Suitcase Fusion** is a font management program that helps organize fonts on your system and offers a "Collect Fonts for Output" service.

### 3. Outline vs. Live Text

- Problems occasionally arise with supplied fonts that cause text re-flow or incorrect font placement. Outlining fonts will eliminate any chance of this.
- The downside to outlining text: we will not be able to make any textual changes for you. If you outline fonts, please make sure all information is grammatically accurate and spelling is checked before sending to us.

#### Font Compression (MAC)



Step 1 - Select Collected "Font" Folder Contents

---



Step 2 - Stuff/Zip Folder Contents

---



Step 3 - Submit "Archive.sit (.zip)" File with the Art

---

### Our Scanning Capabilities

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- In-house, we can scan transparencies, negatives, slides, or original artwork (Photographs, paintings, illustrations) up to 12" x 17".
- We also utilize outside services for larger size scans. Please [contact us](#) for more information on our capabilities.

---

### Proofs

---

#### What is Included in the Price of Your Quote

- First round of hard copy proofs.
- We typically print 1/2 - 2/3 scale proofs.
- We can make arrangements for full size proofs. Please contact us for details.

#### Optional PDFs

- When changes are made, we typically resubmit proofs in the form of PDFs.
- Hard copy proofs can be sent a second time, but additional charges may apply for materials costs.
- PDFs are provided free of charge.

#### Approval Form

- All proofs are sent with a cover sheet, outlining what is include, what scale they are at, and any additional notes necessary to your project.
- If you require any changes to your files, simply mark them directly on the proofs. You can also write notes on the cover sheet, or the transmittal that is also sent with the proofs.
- Please sign, send all back, and production begins!

## APPENDIX G: HOW TO OPEN THE EXHIBIT MODEL

This guide will walk you through how to open the model produced for the Hacienda La Esperanza exhibit. This model was created using Autodesk Inventor 2014 and is primarily made up of four types of files. To make sure that the model can be opened correctly it is important to keep all of files together in the same folder. These file types are:

- Image files (.jpg). These files are used for the textures in the model, so the parts look more realistic.
- Part files (.ipt). These files are for all the different parts that make up the model. To open the model it is necessary to keep all of these files in the same folder as the assembly files.
- Assembly files (.iam). The assemblies are collections of parts and subassemblies combined into larger and more complex models. It is necessary to save all parts and subassemblies, included in the assembly, in the same folder.
- Project file (.ipj). This is an important file if the model is being opened with *Autodesk Inventor* or *Autodesk Inventor Viewer* because *Autodesk Inventor* needs this file to locate the folder containing the model files.

The software that we will use to open the file is Autodesk Inventor Viewer 2014 64-bit version. The installer for this is included in the model folder, and is called *Autodesk\_Inventor\_View\_2014\_English\_Win\_64bit\_dlm.sfx.exe*. Launch this installer, and follow the directions.

After the viewer is installed, launch the program and click *File-> Projects* which will launch a new window titled *Inventor Project Editor 2014*. At the bottom of the *Inventor Project Editor 2014* window, there is a *Browse* button. Click on this button and navigate to the folder containing *Engine.ipj* included in the model file. Double click on *Engine.ipj* to set the project and then close the *Inventor Project Editor 2014* window.

Now that the project is set, we can proceed to opening the model file. In the main *Inventor View* window click *File-> Open* and double click *Engine.iam* to open the exhibit model.

All of the navigation and view commands in *Inventor View* are in the top left of the window, and are explained well in the Autodesk help files which can be accessed at any time by pressing F1.

## APPENDIX H: GENERAL OUTLINE FOR SITE EVALUATION

We recommend that each tour guide answer these questions prior to and after completion of the mill exhibit.

- What is the central idea of the exhibit? Is it outlined in detail with clarity?
- Does the exhibit connect to the other parts of the museum or tour?
- What is the target audience for this exhibit? If there is more than one target audience, does this exhibit appeal to each audience?
- What do we want the audience to learn from the exhibit?
- Does the exhibit have any resources for funding from potential sponsors or donors?
- Will the exhibit/tour lead to stronger ties with the community?

The following are ideas for evaluating the success of an exhibit. We feel it is important to measure the success overtime and therefore recommend the exhibit be evaluated at least once a year.

- Using a stopwatch, measure the amount of time each visitor spends at the different parts of the exhibit. We recommend timing about ten visitors per tour during the course of ten tours in order to get a range of data. From this it can be inferred which parts captured the visitors' attention
- Offer different brochures that give additional information on the topics discussed throughout the tour. Inventory the brochures after every two weeks. From the number of brochures taken by visitors, it can be inferred which topics are most interesting to visitors. This may impact the amount of time spent on topics during a tour. For example, if all of the brochures about the evolution of steam power are taken, then the tour guides may want to add more of this information to the tour.
- We recommend interviewing visitors after the tour about their experience. We believe interviewing ten locals, ten school children and ten tourists will provide a useful range of information that can be used to alter the tour and if necessary the exhibit design.
- Record how many hits the QR codes lead to on the website to infer which aspects of the tour interest visitors the most.
- Hold a focus group that includes the following people:
  - Tour guides
  - Community members who have visited the site
  - Educators
  - Donors/ Sponsors

During these focus groups, ask open-ended questions about what could be improved at the site. It is important to include tour guides because they see the reactions of the visitors every day. Community members who have been to the site provide information from a visitor's perspective. Educators who have visited the site can provide information about whether or not the children were entertained or bored. Donors or site sponsors can give opinions on where they would like to see improvements in the future.

## **APPENDIX I: INTERVIEW WITH JULIO E. ABREU**

### **OUR TASK:**

To recommend specifications or a system for the restoration of the mill. They will pick the actual parts for the restoration because there is not enough time for us to. Our calculations will provide us with the boiler specifications that are required.

### **TITLE AND BACKGROUND:**

Department of Labor. Certified PE Mechanical engineer.

### **ENGINE INFORMATION:**

James Watt engine with one tower. Generally, the Watt engines have two towers.

For this type of engine, there are three possible types of boilers and they are thermal boiler, scotch marine boiler or a water tube boiler.

### **RECOMMENDATIONS:**

Abreu recommended the thermal boiler for this restoration for a few main reasons. Water tube boilers are bigger and therefore more expensive than the other boilers. This makes it impractical for this project. The design of the scotch marine boiler is less tolerant to the repeated heating and cooling that the boiler will be put through as part of the Para La Naturaleza application. The application of the Para La Naturaleza is to use the boiler a few times a day. The short heating and cooling cycles can cause the scotch marine type boilers to explode. The thermal boiler is much safer for the type of intermittent heating cycles that running the engine for tours will require. For these reasons, the thermal boiler is the recommended boiler.

Abreu also recommends the use of a condenser for the system.

### **REGULATIONS TO FOLLOW:**

For boilers: Section 1 ASME (For Construction)

For pressure vessels (the cylinder): Section 8 ASME (For Construction)

For power piping standards ASME B31.1 (Valves must be in compliance as well)

Boilers and pressure vessels in operation follow NBIC guidelines

The ASME regulations are mainly in the sections mentioned; however, they will reference other sections.

Section 2 ASME is going to be important to our paper.

### **POTENTIAL PROBLEMS:**

Julio thinks the biggest problem we will face is determining the amount of steam necessary to move the piston.

## **CALCULATIONS:**

There are not any equations Julio can give us to solve for the boiler power and steam requirements. However, using the 10-RPM speed of the flywheel and the fact that the current generator is 20 HP we can solve for the information.

The equations we will be using require safety factors from the ASME regulations. Our calculations need to take these factors into account or they will not be in compliance.

## **JOHN MURPHY INFORMATION:**

John Murphy was also present at this interview. He said that with the flywheel at 10 RPM Para La Naturaleza can still demonstrate the sugar mills process. However, John said we can decide if we want to use 10 or 15 RPM as a reference.

John is looking for this information in our calculations:

- How much steam we need
- HP of engine
- The regulations necessary included in our calculations.

## **MISCELLANEOUS:**

Fulton boilers are a common type of thermal boiler

ASME compliance power piping general

Potentially useful for our work.

## APPENDIX J: FLYWHEEL RPM MEASUREMENTS

| Lap       | Rotation |
|-----------|----------|
| 1         | 6.1      |
| 2         | 6.8      |
| 3         | 6.4      |
| 4         | 6.4      |
| 5         | 6.4      |
| 6         | 6.1      |
| 7         | 6.8      |
| 8         | 6.1      |
| 9         | 6.3      |
| 10        | 6.3      |
| 11        | 6.6      |
| 12        | 6.6      |
| 13        | 6.6      |
| 14        | 6.4      |
| 15        | 6.4      |
| 16        | 6.3      |
| 17        | 6.2      |
| 18        | 6.5      |
| 19        | 6.6      |
| 20        | 6.1      |
|           |          |
| Average = | 6.4      |

## APPENDIX K: DR. HUEY PHONE INTERVIEW

### QUESTIONS:

What is the efficiency of the engine, or engines like this one?

How much more power will the engine need for startup? (overcome inertia)

How does this requirement translate to the steam requirements?

How do you determine the lbs/hr of steam required? They use two different methods and we are not sure which is correct.

How do we determine the temperature rise? Is it occurring in the piston?

What is the relation between the RPM of the flywheel and the steam flow rate? How do we make this connection?

Where did the engineer include the 25 RPM in his calculations?

How would we replicate it for our calculations?

What is the importance of the pressure? In the engineer's calculations, he determined the flow rate not incorporating the pressure then did a completely separate calculation using the pressure. Do these relate? Is there a reason to do the calculations on the first page because it doesn't appear to be used again?

Do you think the 3000 lbs/hr steam is reasonable? If we are unable to complete calculations, would this number allow the engine to run at the 10 RPM Para wants?

### NOTES:

Online there might be some nice calculators to determine how much hp we need.

He found a convenient sight that converts horsepower to lbs. of steam.

The units on the alpha engineering calculation do not work out. Maybe conversion factors that aren't easily recognized are involved but it is very troubling.

He suggests using the basics and not referring to their work in our calculations. This is because he does not have confidence in the numbers given and does not believe they are correct. Confirming our group suspicion.

He will work with the basic and will get back to us by tomorrow if he is able to draw any conclusions. He will try to get as much as possible on this.

### DR. HUEY'S QUESTIONS ABOUT THE CALCULATIONS:

Report starts by finding the cylinder volume but 4 lines down it changes the term to gallons/ minute and this confused him quite a bit, for every flywheel revolution the cylinder is going to be filled twice. So at 10 RPM that means it'll be filled 20 times per minute so these numbers are troubling. This is one of the same problems we identified.

They make an assumption that the full volume of the cylinder will be applied at 60 psi, but he would guess the engine is using a 50% cutoff, so if they're cutting off 50% it affects the stroke. In an earlier report this engine was over powered. The higher the cutoff the more power and less efficient. However his question above is the biggest one, some of the relations they used he is not familiar with. Many questions with Alpha Engineering's calculations and neither our group or Dr. Huey could make the units work at all.

## APPENDIX L: ALPHA ENGINEERING CALCULATIONS

These pages are taken from the materials from Alpha Engineering, and show the type of error that is prevalent throughout the supplied notes.

HACIENDA LA ESPERANZA - MANATI, P.R. OCT. 3/07

TABLE OF THE PROPORTION OF WATER TO STEAM - DATA FROM ENGINEERING ENCYCLOPEDIA

| STM.    | CO. IN OF WATER<br>IN A CU FT OF STEAM | ENGR. JOHN O. VINTON - MECH.<br>ENGR W. J. MILLAR - CIVIL |
|---------|--|---|
| 30 PSIG | 2,842                                  |   |
| 35 PSIG | 3,130                                  |   |
| 40 PSIG | 3,415                                  |   |
| 45 PSIG | 3,700                                  |   |
| 50 PSIG | 3,981                                  |   |
| 55 PSIG | 4,256                                  |   |
| 60 PSIG | 4,535                                  |   |
| 65 PSIG | 4,812                                  |   |
| 70 PSIG | 5,052                                  |   |
| 75 PSIG | 5,317                                  |   |
| 80 PSIG | 5,650                                  |   |

PROPERTY OF SATURATED STEAM - TABLE 11

| AT 60 PSIG = 75 PSIG | SAT. TEMP = 307 | SPECIFIC VOL. CO. FT <sup>3</sup> /LB = 5.79 | SAT. LAT. HEAT = 1181 | = 703 LAT. HEAT |
|----------------------|-----------------|--|-----------------------|-----------------|
| AT 65 PSIG = 80 PSIG | 312             | 5.45   | 1182                  | 900 LAT. HEAT   |
| AT 70 PSIG = 85 PSIG | 316             | 5.14   | 1183                  | 897 LAT. HEAT   |

FORMULA TO CONVERT TO LBS/HR. STEAM OR GPM TO LBS/HR. STEAM

$$\frac{\text{GPM} \times 8.33 \times \text{°F RISE}}{\text{LATENT HEAT}} = \text{LBS/HR. STM.}$$

Assumptions not stated.

$$\frac{\text{LBS/HR. STM.}}{500} = \text{GPM}$$

ALPHA

$$\frac{\text{GPM} \times \text{TEMP. RISE} \times 1.1}{2} = \text{LBS/HR. STM.}$$

ALPHA

HACIENDA LA ESPERANZA - MANATI, P.R. OCT. 3/2007

STEAM AT 60 PSIG = 4.535 <sup>CU IN OF WATER</sup> IN A CU FT OF STM.

$\frac{4535 \text{ CU IN}}{1728 \text{ CU IN/CU FT}} = 2.62 \text{ CU FT.}$

20 GALS. ÷ 3.785 LITERS = 5.28 LITERS  
MIN.

$2.62 \text{ CU FT} \times 7.48 = 19.63 \text{ GALS}$

$19.63 \text{ G.} \times 60 \text{ MIN} = 697.8 \text{ GPH}$

Math does not add up.  
 $19.63 * 60 = 1177.8$

307°F AT 60 PSIG.  
- 70°F  
237°F RISE

$\frac{697.8 \text{ GPH} \times 8.33 \times 237^\circ \text{ F RISE}}{903 \text{ LATENT HEAT}} = 1,526.6 \text{ HR. STM}$

STEAM AT 70 PSIG = 5.052 <sup>CU IN OF WATER</sup> IN A CU FT OF STM.

$\frac{5052 \text{ CU IN}}{1728 \text{ CU IN/CU FT}} = 2.92 \text{ CU FT.}$

$2.92 \text{ CU FT} \times 7.48 = 21.86 \text{ GALS}$

$21.86 \text{ G} \times 60 \text{ MIN.} = 1312 \text{ GPH}$

316°F AT 70 PSIG  
- 70°F  
246°F RISE

$\frac{1312 \text{ GPH} \times 8.33 \times 246^\circ \text{ F RISE}}{897 \text{ LATENT HEAT}} = 2,997.23 \text{ HR. STM.}$

ALPHA

~~XXXXXXXXXX~~

## APPENDIX M: STEAM CALCULATIONS

### USING A TEMPERATURE OF 20°C

$$T = 20^{\circ}\text{C}$$

$$P = 5 \text{ bar}$$

$$d = 12 \text{ in}$$

$$L = 48 \text{ in}$$

$$\rho = 2.669 \frac{\text{kg}}{\text{m}^3}$$

$$n = 20 \frac{\text{strokes}}{\text{min}}$$

$$y = 0.84$$

S = Steam required

$$S = \frac{\pi d^2(\text{in}^2)L(\text{in})}{4} * n \left( \frac{\text{strokes}}{\text{min}} \right) \rho \left( \frac{\text{kg}}{\text{m}^3} \right) * \left( \frac{1}{y} \right) \left( \frac{\text{ft}^3}{1728\text{in}^3} \right) * \left( \frac{\text{strokes}}{\text{min}} \right) * \left( \frac{\text{min}}{\text{hr}} \right) * \left( \frac{2.669\text{kg}}{\text{m}^3} \right) * \left( \frac{0.0623\text{lbs}}{\frac{\text{ft}^3}{\frac{\text{kg}}{\text{m}^3}}} \right)$$
$$S_{20^{\circ}\text{C}} = 746.26 \frac{\text{lb}}{\text{hr}}$$

### USING A TEMPERATURE OF 40°C

$$T = 40^{\circ}\text{C}$$

$$P = 5 \text{ bar}$$

$$d = 12 \text{ in}$$

$$L = 48 \text{ in}$$

$$\rho = 2.669 \frac{\text{kg}}{\text{m}^3}$$

$$n = 20 \frac{\text{strokes}}{\text{min}}$$

$$y = 0.875$$

S = Steam required

$$S = \frac{\pi d^2(\text{in}^2)L(\text{in})}{4} * n \left( \frac{\text{strokes}}{\text{min}} \right) \rho \left( \frac{\text{kg}}{\text{m}^3} \right) * \left( \frac{1}{y} \right) \left( \frac{\text{ft}^3}{1728\text{in}^3} \right) * \left( \frac{\text{strokes}}{\text{min}} \right) * \left( \frac{\text{min}}{\text{hr}} \right) * \left( \frac{2.669\text{kg}}{\text{m}^3} \right) * \left( \frac{0.0623\text{lbs}}{\frac{\text{ft}^3}{\frac{\text{kg}}{\text{m}^3}}} \right)$$
$$S_{40^{\circ}\text{C}} = 716.04 \frac{\text{lb}}{\text{hr}}$$

### USING A TEMPERATURE OF 60°C

$$T = 60^{\circ}\text{C}$$

$$P = 5 \text{ bar}$$

$$d = 12 \text{ in}$$

$$L = 48 \text{ in}$$

$$\rho = 2.669 \frac{\text{kg}}{\text{m}^3}$$

$$n = 20 \frac{\text{strokes}}{\text{min}}$$

$$y = 0.91$$

S = Steam required

$$S = \frac{\pi d^2 (\text{in}^2) L (\text{in})}{4} * n \left( \frac{\text{strokes}}{\text{min}} \right) \rho \left( \frac{\text{kg}}{\text{m}^3} \right) * \left( \frac{1}{y} \right) \left( \frac{\text{ft}^3}{1728 \text{in}^3} \right) * \left( \frac{\text{strokes}}{\text{min}} \right) * \left( \frac{\text{min}}{\text{hr}} \right) * \left( \frac{2.669 \text{kg}}{\text{m}^3} \right) * \left( \frac{0.0623 \text{lbs}}{\frac{\text{ft}^3}{\frac{\text{kg}}{\text{m}^3}}} \right)$$

$$S_{60^\circ\text{C}} = 688.85 \frac{\text{lb}}{\text{hr}}$$

## USING A TEMPERATURE OF 80°C

$$T = 80^\circ\text{C}$$

$$P = 5 \text{ bar}$$

$$d = 12 \text{ in}$$

$$L = 48 \text{ in}$$

$$\rho = 2.669 \frac{\text{kg}}{\text{m}^3}$$

$$n = 20 \frac{\text{strokes}}{\text{min}}$$

$$y = 0.94$$

S = Steam required

$$S = \frac{\pi d^2 (\text{in}^2) L (\text{in})}{4} * n \left( \frac{\text{strokes}}{\text{min}} \right) \rho \left( \frac{\text{kg}}{\text{m}^3} \right) * \left( \frac{1}{y} \right) \left( \frac{\text{ft}^3}{1728 \text{in}^3} \right) * \left( \frac{\text{strokes}}{\text{min}} \right) * \left( \frac{\text{min}}{\text{hr}} \right) * \left( \frac{2.669 \text{kg}}{\text{m}^3} \right) * \left( \frac{0.0623 \text{lbs}}{\frac{\text{ft}^3}{\frac{\text{kg}}{\text{m}^3}}} \right)$$

$$S_{80^\circ\text{C}} = 666.87 \frac{\text{lb}}{\text{hr}}$$

## APPENDIX N: STEAM TABLE

| Absolute pressure | Boiling point | Specific volume (steam) | Density (steam)      | Specific enthalpy of liquid water (sensible heat) |           | Specific enthalpy of steam (total heat) |           | Latent heat of vaporization |           | Specific heat |
|-------------------|---------------|-------------------------|----------------------|---|-----------|---|-----------|-----------------------------|-----------|---------------|
|                   |               |                         |                      | (kJ/kg)   | (kcal/kg) | (kJ/kg)                                 | (kcal/kg) | (kJ/kg)                     | (kcal/kg) |               |
| (bar)             | (°C)          | (m <sup>3</sup> /kg)    | (kg/m <sup>3</sup> ) | (kJ/kg)   | (kcal/kg) | (kJ/kg)                                 | (kcal/kg) | (kJ/kg)                     | (kcal/kg) | (kJ/kg.K)     |
| 5                 | 151.85        | 0.375                   | 2.669                | 640.12  | 152.89    | 2747.54                                 | 656.24    | 2107.42                     | 503.35    | 2.3289        |
| 5.5               | 155.47        | 0.342                   | 2.920                | 655.81  | 156.64    | 2751.70                                 | 657.23    | 2095.90                     | 500.60    | 2.3585        |
| 6                 | 158.84        | 0.315                   | 3.170                | 670.43  | 160.13    | 2755.46                                 | 658.13    | 2085.03                     | 498.00    | 2.3873        |
| 6.5               | 161.99        | 0.292                   | 3.419                | 684.14  | 163.40    | 2758.87                                 | 658.94    | 2074.73                     | 495.54    | 2.4152        |
| 7                 | 164.96        | 0.273                   | 3.667                | 697.07  | 166.49    | 2761.98                                 | 659.69    | 2064.92                     | 493.20    | 2.4424        |
| 7.5               | 167.76        | 0.255                   | 3.915                | 709.30  | 169.41    | 2764.84                                 | 660.37    | 2055.53                     | 490.96    | 2.4690        |
| 8                 | 170.42        | 0.240                   | 4.162                | 720.94  | 172.19    | 2767.46                                 | 661.00    | 2046.53                     | 488.80    | 2.4951        |
| 8.5               | 172.94        | 0.227                   | 4.409                | 732.03  | 174.84    | 2769.89                                 | 661.58    | 2037.86                     | 486.73    | 2.5206        |
| 9                 | 175.36        | 0.215                   | 4.655                | 742.64  | 177.38    | 2772.13                                 | 662.11    | 2029.49                     | 484.74    | 2.5456        |
| 9.5               | 177.67        | 0.204                   | 4.901                | 752.82  | 179.81    | 2774.22                                 | 662.61    | 2021.40                     | 482.80    | 2.5702        |
| 10                | 179.88        | 0.194                   | 5.147                | 762.60  | 182.14    | 2776.16                                 | 663.07    | 2013.56                     | 480.93    | 2.5944        |
| 11                | 184.06        | 0.177                   | 5.638                | 781.11  | 186.57    | 2779.66                                 | 663.91    | 1998.55                     | 477.35    | 2.6418        |
| 12                | 187.96        | 0.163                   | 6.127                | 798.42  | 190.70    | 2782.73                                 | 664.64    | 1984.31                     | 473.94    | 2.6878        |
| 13                | 191.60        | 0.151                   | 6.617                | 814.68  | 194.58    | 2785.42                                 | 665.29    | 1970.73                     | 470.70    | 2.7327        |
| 14                | 195.04        | 0.141                   | 7.106                | 830.05  | 198.26    | 2787.79                                 | 665.85    | 1957.73                     | 467.60    | 2.7767        |
| 15                | 198.28        | 0.132                   | 7.596                | 844.64  | 201.74    | 2789.88                                 | 666.35    | 1945.24                     | 464.61    | 2.8197        |
| 16                | 201.37        | 0.124                   | 8.085                | 858.54  | 205.06    | 2791.73                                 | 666.79    | 1933.19                     | 461.74    | 2.8620        |
| 17                | 204.30        | 0.117                   | 8.575                | 871.82  | 208.23    | 2793.37                                 | 667.18    | 1921.55                     | 458.95    | 2.9036        |
| 18                | 207.11        | 0.110                   | 9.065                | 884.55  | 211.27    | 2794.81                                 | 667.53    | 1910.27                     | 456.26    | 2.9445        |
| 19                | 209.79        | 0.105                   | 9.556                | 896.78  | 214.19    | 2796.09                                 | 667.83    | 1899.31                     | 453.64    | 2.9849        |
| 20                | 212.37        | 0.100                   | 10.047               | 908.56  | 217.01    | 2797.21                                 | 668.10    | 1888.65                     | 451.10    | 3.0248        |
| 21                | 214.85        | 0.095                   | 10.539               | 919.93  | 219.72    | 2798.18                                 | 668.33    | 1878.25                     | 448.61    | 3.0643        |
| 22                | 217.24        | 0.091                   | 11.032               | 930.92  | 222.35    | 2799.03                                 | 668.54    | 1868.11                     | 446.19    | 3.1034        |
| 23                | 219.55        | 0.087                   | 11.525               | 941.57  | 224.89    | 2799.77                                 | 668.71    | 1858.20                     | 443.82    | 3.1421        |
| 24                | 221.78        | 0.083                   | 12.020               | 951.90  | 227.36    | 2800.39                                 | 668.86    | 1848.49                     | 441.50    | 3.1805        |
| 25                | 223.94        | 0.080                   | 12.515               | 961.93  | 229.75    | 2800.91                                 | 668.99    | 1838.98                     | 439.23    | 3.2187        |
| 26                | 226.03        | 0.077                   | 13.012               | 971.69  | 232.08    | 2801.35                                 | 669.09    | 1829.66                     | 437.01    | 3.2567        |
| 27                | 228.06        | 0.074                   | 13.509               | 981.19  | 234.35    | 2801.69                                 | 669.17    | 1820.50                     | 434.82    | 3.2944        |
| 28                | 230.04        | 0.071                   | 14.008               | 990.46  | 236.57    | 2801.96                                 | 669.24    | 1811.50                     | 432.67    | 3.3320        |
| 29                | 231.96        | 0.069                   | 14.508               | 999.50  | 238.73    | 2802.15                                 | 669.28    | 1802.65                     | 430.56    | 3.3695        |

## **APPENDIX O: OVERVIEW OF STEAM ENGINE MECHANICS**

Steam engines use a fluid, commonly water, to turn heat from a boiler into mechanical work in the cylinder. The boiler is similar to a giant tea kettle, and is where steam is generated. The high pressure steam from the boiler is then piped to the cylinder. The cylinder can be thought of as the wall of a syringe and the piston is like the plunger. As steam is pumped into the top of the cylinder, it forces the piston to move to the bottom. The power generated from this force is used to turn or push the engine; this power is measured in horsepower or kilowatts. The push from the piston is a linear motion however many applications require rotary movement. The method used to convert the linear motion of the piston to rotating motion varies by engine. The mill at the Hacienda La Esperanza uses James Watt's parallel linkage ("Hacienda La Esperanza Sugar Mill Steam Engine," 1979). The Watt parallel linkage interfaces the straight line motion of the piston with the arc that the end of the beam traces through the air (Leavens, 1915). The crankshaft is just like the handle of a hand driven crank, and is driven by a bar attached to the overhead beam in much the same way. Steam engines also have a device called a flywheel, which is a heavy wheel attached to the output shaft of the engine that makes the motion of the piston smoother.