Team 7 – Average Joes

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Executive Summary (on someone’s computer):

Arcelor Mittal needs us to design a sustainable system that will recycle one of the following materials: Brick, plastic totes, wooden pallets, and metal drums. The company has a large waste footprint and is looking to decrease it to become a greener company. Our goal is to create a system that is sustainable, meaning that once it is removed from the earth it stays in a cycle and never returns. The system will be low-energy, cost effective, and won’t hinder the process of steel production.

In developing the design, we evaluated the chemical process and structures of all of the materials as well as how they react with other materials. After defining exactly what we needed to accomplish we generated two concepts, one with recycling the wooden pallets and the other with recycling the bricks. We evaluated these concepts using a scoring matrix and scoring them based off of the customer needs. Our final design included recycling the bricks in a multitude of different ways. Our concept focuses on using the bricks that can no longer be used at Arcelor Mittal and sending back to where the bricks are made. It is cost effective because the bricks can be transported back to manufacturing plant on the same trucks that deliver the new bricks to Arcelor Mittal.

Our design would recycle the bricks at the plant to make new bricks that can be used at Arcelor Mittal or if need be other places. Our design epitomizes sustainability by never returning the original material to the earth, and never disposing of it as waste. Risks would be that the process of recycling the bricks is
not clean. Another risk is that the recycled brick will not have the same longevity, as well as quality as bricks that are brand new. This could cause a catastrophic failure when they are used in the steel making process. This risk will be avoided by mixing the recycled brick material with material that is being used to make new bricks. This prototype will be delivered 29 April, 2015.

**Introduction:**

In order for there to be a sustainable community, not only do we need to change the ways that we live at home, but also to change the way that the materials we manufacture become more sustainable. ArcelorMittal is one of the leading steel manufacturers in the world. Much of their waste stream is a result of the processes that occur outside of producing steel in the factory. As a result, they have asked us to engineer a design process to recycle at least one of the following in a sustainable manner: wooden pallets, plastic totes, refractory brick, and metal drums.

**Mission Statement:**

Our goal is design a sustainable, easy to implement system to recycle ArcelorMittal’s refractory brick.
Customer Analysis

When first given the task of helping ArcelorMittal with their waste, it was slightly unclear what was needed. After breaking down the prompt given it was concluded that we would be dealing with the waste from the factories, and try to reduce costs of the products by recycling products back to themselves. This would cut the current cost of disposing waste and lessen ArcelorMittal’s economic footprint. However, through development of a recycling plan, we must not cut out products, like pallets, as a whole. The inputs and outputs must be considered, as well as the geographic location of the plant, both for physical and judicial reason (must be up to state code). The team-generated process created must be detailed, economically viable and also appeal to the shareholders of ArceclorMittal. All opportunities to recycle must be considered. The final product should have a diagram, and maybe a CAD model if necessary, all concepts created are also to be in the final report. It should also include a plan of implementation, and how much waste is saved from landfills.

Needs Statements

- ArcelorMittal needs to recycle their waste products from their factories.
- The company needs to recycle their products to make more of the same product.
- The company is looking to reduce their economic footprint.
- The process needs to remake the product it is recycling.
- The process needs to reduce the overall waste of ArcelorMittal.
- The process needs to cut the current cost of disposing waste.
- The process must not get rid of the pallets as a whole.
- The process must recycle waste materials.
- The process must include inputs and outputs.
- The process must consider the location of the plant.
- The process must reduce ArcelorMittal's waste footprint.
- The process must be appealing to shareholders.
- The process must be in line with state code and be economically viable.
- The process must be detailed.
- The process must be team generated.
- The process must consider all opportunities.
- The process must include an implementation plan.
- The process must include the amount of waste taken from landfills.
- The process must have a CAD drawing (if necessary).
- The process must have a diagram.
- The process must be modeled.
The report must include all concepts created.

**Needs-Metrics Matrix**

The needs statements were then turned into a needs-metrics matrix to clarify what target specifications we should aim for. This also allowed for us to constructively brainstorm ideas relevant to ArcelorMittal’s needs.

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**External Research**

Refractory and ingot shop bricks are made from modified fire clay. Clay itself is classified into several different types; kaolin clay, ball clay, fire clay, bentonite, Fuller’s Earth, common clay a shale. Fire clay is an adequate choice in a steel factory because it can withstand temperatures of over 2700 degrees Fahrenheit. Clay deposits are found several meters below the
earth’s surface, starting anywhere from 12-15 meters below ground level. Fire clay is one of the more common types of clay and is typically found alongside deposits of coal.

The clay must first be processed into a workable form before it can be manufactured into brick. After being mined, it is delivered to a large storage warehouse with open walls. At this point, the clay’s moisture content resides between 15-22%. Since fire clay is typically found alongside other forms of clay, workers carry out a chemical analysis to sort each batch of clay based on mineral composition and purity. The separated fire clay is then delivered to a processing mill, where it will be prepared for manufacturing.

The fireclay first gets put into a revolving tub that breaks the batch up into smaller pieces using several large knives. It then gets moved to a large oven where it undergoes “flash drying” to reduce the moisture content to about 1-2%. This makes the batch of clay easy to filter and transport. After flash drying, it then goes placed into a hopper which leads to a grinding mill. The grinding mill breaks the clay up again into a powder with grains finer than sand. The powder is then vacuumed up and filtered to separate the clay from unnecessary impurities such as dirt and sand. After several tests from chemists to verify the compound’s purity, it then gets sent off to a brick manufacturing plant.

Once at the plant, water and other chemical mixtures are added to the clay to regain its plasticity and increase its moisture content. In the case of refractory and ingot shop brick, minerals such as magnesium oxide are added to the clay to reduce the brick’s porosity and increase slag resistance. Once molded into the desired shape, the uncooked bricks are then placed into a kiln to eliminate all moisture from the clay. It is then ready to be shipped out.

ArcelorMittal replaces the ingot shop brick in its factories weekly. The bricks are used to mold liquid steel into ingots. Once stripped, the bricks often break and have to be disposed of. Many of the unbroken bricks must be disposed of as well since liquid steel can enter the brick’s pores and reduce its refractory properties. All of ArcelorMittal’s bricks have several compounds in common; magnesium oxide, calcium oxide, silica, aluminum oxide, and ferric oxide. Due to the ingot brick’s modified chemical analysis, they are resistant to slag adhering.

**Concept Generation**

The needs-metrics matrix and external research allowed for us to brainstorm three main design ideas. These ideas focused on either repairing the brick or recycling the bricks components into producing a new brick.
Concept Selection

1. Take the brick and break it down into a powder. Ingot shop brick is made of many known elements including carbon, Al2O3, Fe2O3, SiO2, CaO, and MgO. We would separate all of the elements using their individual physical and chemical properties. We would begin by pulverizing the brick and using a magnet to separate the Fe2O3. To extract the CaO we would add water to the pulverized mixture because CaO reacts with H2O. Both MgO and SiO2 are insoluable in water, but we can use acids to extract them. We would then place all the components of the brick together in a mixture and add moisture in attempt to remake the same clay that was present before it was made into brick. After finishing up the research phase of our project, we realized that once clay is fired and made into brick, it undergoes irreversible chemical changes so it is impossible to take a pure sample of broken down brick and make the same clay.

2. Since brick cannot be broken down into its original, clay-state, we realized that it is impossible to make a one hundred percent renewable energy process in which we take old brick and make it into new brick. Old ingot shop brick is replaced weekly at ArcelorMittal not because the brick losses its original durability or any of its physical properties, but because part of the brick begins to erode after time. From this information we found that if we took the old brick as a whole and placed it into its original mold and then poured new clay to fill all the empty space within the mold and let the mold be fired, a new and improved brick would be formed. (The empty space is there because of the erosion the brick has undergone within the furnace). Although this solution works and would save a great amount of energy and money, we were not convinced that this was the best solution. We had doubts that the bonds at points where the new brick formed with the old brick could possibly be slightly weaker than the bonds at any other point in the newly formed brick.

3. The solution that we went with is to break down the old brick to a powder and place it in the mold along with the new clay solution. Since the old brick will still have its same properties, the powder added to the new clay will not change the composition of the new brick. This would end up saving a huge amount of energy because ArcelorMittal will
save and reuse the majority of each brick. This will also be extremely profitable because they will not have to purchase nearly as much brick.

**Final Design Description**

Our design uses the minerals in the unusable ingot shop bricks in order to make new bricks. First, the bricks must be pulverised into small grains. This can be done manually or, if need be, using a tool such as a rock crusher. In order for the minerals to be reusable we must extract any liquid steel that infiltrated the brick’s pores. Since steel is ferromagnetic, we can extract any steel and ferric oxide dust from the brick’s remains using a magnet.

Since the ferric oxide is a necessary component in the bricks, we must separate the ferric oxide particles from the steel particles. Since ferric oxide is soluble in hydrochloric acid and steel is not, we can add the ferric oxide and steel grains into a small pool of hydrochloric acid. After stirring, we can collect the steel from the solution using filtration. In order to remove the ferric oxide from the hydrochloric acid we must perform a chemical distillation. The solution is first placed inside of a holding tank. The tank either sits on top of a heat plate or is made up of a metal that easily holds heat, depending on which distillation equipment is purchased. Waste heat from ArcelorMittal’s ovens and liquid steel transportation can be moved using an energy recovery ventilation system (ERV). Once the tank heats up, the hydrochloric acid moves from a liquid to a gas phase and gets vacuumed into an adjacent heating tank, preserving the acid for the next distillation. Once inside the tank, the gas can turn from a gas phase back into a liquid phase, leaving the ferric oxide particles remaining in the first chamber. After washing the ferric oxide to remove any hydrochloric acid, it can be transported alongside all of the other minerals in the brick back to the clay processing mill. The minerals can be added to a liquid clay solution, reducing the amount of clay needed to produce a new batch of bricks. The separated steel is returned to ArcelorMittal for reuse in their steel manufacturing plant.

Our process is successful in that it creates very little waste, and can be applied to any type of brick in addition to the ingot shop bricks as long as any slag is removed beforehand. It also finds a use for some of ArcelorMittal’s excess heat from its steel production. The only costs to the process include hydrochloric acid, distillation chamber, labor costs and transportation back to the clay processing mill. All in all, the budget becomes only a few thousand dollars each year.
Conclusion (Luke D. or somebody):

A fully sustainable cycle is impossible to achieve because there will always be some waste and some input. With this in mind we created a cycle that reduced the amount of waste and input that ArcelorMittal had. By crushing up the brick and recycling it back into the brick making process we reduce the amount of clay that is needed to be mined. In the process of cleaning the refractory brick we are able to take everything that can be recycled apart. We are able to extract a small amount of metal that can be sent back to ArcelorMittal and by adding the crushed brick to the clay we reduce that footprint as well. ArcelorMittal has to replace these bricks on a weekly basis meaning that reducing the amount of new clay that goes into them is not only more sustainable for the environment but also means that it is cheaper for ArcelorMittal.
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