Refractory Brick Recycler
ArcelorMittal

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Executive Summary

We studied possible solutions to handling refractory brick originating from a steel processing furnace. Since we reasoned that it would not be wise to simply dispose of the bricks, we attempted to design various systems to recycle the brick’s core materials instead. This was figured to be the most sustainable and monetarily efficient solution.

The main ingredients in the refractory brick mostly consist of Magnesium Oxide, Calcium Oxide, Aluminum Oxide and Steel. The plan was to separate these ingredients, send the steel back to ArcelorMittal to repurpose, and send the MgO, CaO, and Al$_2$O$_3$ back to the Company that initially created the refractory brick.

To complete this plan, we created a machine that would first crush up the bricks into gravel sized rocks. Magnets would then extract most of the steel particles out of the rubble. Although the magnets may not remove all of the steel, the remaining may be removed by using water to dissolve the magnesium and aluminum oxide.

The extracted steel is recycled back into the process of making more steel products. The MgO and Al$_2$O$_3$ that is extracted is sent back to the refractory brick making companies to make more bricks. We found this solution, instead of having a linear cradle to grave system of all the components, creates a circular system that puts the “waste” back into the system to be re-used.
Introduction and Problem Statement

Our main goal behind this project is to reduce the amount of waste refractory brick by eighty percent in order to make the steel making process more sustainable. We would like to aid ArcelorMittal in reducing the amount of refractory brick waste and either finding a safer, greener way to dispose of them, or to repurpose the bricks themselves.

Currently, waste brick is thrown into landfills, which is a huge waste stream because of how often the bricks need to be replaced (twice a week). With the large quantity of bricks that are being used, they will soon be an even bigger detriment to the environment. This affects our sponsor ArcelorMittal as well as most other steel plants. The issue of replacing all of these bricks is that they end up in the landfills, which is not good for landfills because these chemicals are not environmentally friendly. And the fact that all steel companies do this compounds this issue. This issue occurs currently and over time, and the consequences will build as landfills fill up. So we would want to solve this problem as soon as possible - hopefully in the next few years.

We want to examine the chemical composition of the bricks and see if these chemicals can be separated and recycled for use in other processes. This would be, what we determined to be, the most feasible plan in finding a greener way to deal with the refractory brick.

Definition of Sustainability

We wanted to create a system for ArcelorMittal that would improve its sustainability. The main issue with non-sustainable system is that they create waste that isn’t reused. So we defined
a sustainable system as one where outputs of the system could be used as inputs. The more inputs that can be gathered from system outputs, the more sustainable a system is.

Background

Over the course of this project, it fairly difficult to find specific, reliable information on refractory bricks from ArcelorMittal. There wasn’t much information available to the public, so we made do with what information that we could find. One patent we took interest in US 5538526 A. It proposed taking crushed refractory brick into glass products by melting them. The only problem we had with this was that it didn’t specify Steel refinery refractory brick as something that could be used in the process, so we decided not to make that assumption.

We tried to research information on Refractory Brick recycling with respect to steel furnaces, as in the case of ArcelorMittal. However, we were only able to find information on iron furnaces. One of the documents we found [3] talked about the general recycling of waste brick in the U.S. It informed us that in the case of refractory brick resulting from aluminum manufacturing, there were many toxins that leached into the brick during the process. In the case of steel manufacturing, the only product that leaked into the bricks were bits of steel.

Customer Needs

After getting our background information done, we started to take a look at the customer needs. We found these on the kick-off presentation. Additionally, we created a list of our own customer needs and then created criteria which satisfied these needs. Because of the magnitude of customer needs, we came up with eight specific criteria that we felt fulfilled almost every need. The criteria as showcased in Image 2 below, are Safe, Affordable, Effective,
Environmentally Benign, Resource Efficient (Materials), Required Manpower, Time Efficient, and finally Ease of Use. Something I would like to point out really quickly is the distinction we made between the Resource Efficient and Manpower.

![Design Select Matrix](image)

**Figure 2 Design Select Matrix**

In some cases people would consider manpower to be included in overall company resources, however we choose to separate the two since it was more fitting to let material resources be its own criteria. Next up we used the AHP to find a ranking for our criteria. The full matrix can be seen below, Figure 3.
Our highest ranked criterion was Environmentally Benign with nearly a quarter weight. Of course this was not a surprise since we expected Environmentally Benign to be the most important. The entire point of this project was to create a system or method that reduces waste and helps the environment. Now if we created a system that produced more harmful byproducts it would be a complete waste. Our second ranked criteria was Effective, which again was no surprise. If the process to help reduce waste takes a lot of money, time, and resources yet only reduces trivial amounts of waste would do more damage than good.

**Concept Generation**

We began by bouncing around possible ways to use the brick as it is. This was before we were able to see what the brick looked like, and we assumed that since it was brick, it may serve some purpose as building material. Our two ideas that stemmed from this thought were to use the bricks in modern construction as a potential foundation, or use the bricks to build homes in third world countries. Another thought was to reuse the bricks in brick ovens. Furnace brick can withstand large amounts of heat, therefore we considering reusing them in furnace brick ovens.
Our last option was to somehow recycle the bricks by grinding them up reusing their components.

Concept Selection

The major issue we ran into with the construction approach was that the brick is very heavy, difficult to transport, and not necessarily structurally sound. We considered the brick oven approach, but we ran into issues about the safety of using recycled steel manufacturing bricks in food production. This caused us to move on to solutions to reuse the brick. We found that the bricks were made primarily out of magnesium oxide and calcium oxide. We also found that it is possible to reuse the components to remake brick if it could be separated from the existing steel. This led us to a primitive version of our current design. We brainstormed ways to remove steel from the brick and explored ways to use the fact that magnesium oxide and calcium oxide are water soluble. Our original ideas involved just dissolving the bricks in water. This became an issue because the water would saturate very quickly and create massive amounts of waste water. To reduce the amount of water used to a point where it would be a plausible solution, we decided to break up the brick. Then came the question of removing the steel from the magnesium. We decided to design a machine that combined these two processes. The grinder would break down the brick, and the magnets would remove the steel, leaving a magnesium oxide chunks to be recycled.
Design Review

We found that our design received very positive feedback during the design review. The group reviewing our design only had a few negative remarks to make about our design, and did not provide many suggestions for improvement. The main negative comment made was about the cost of the entire project. They found that it seemed to be very costly to implement this design. Our response to this was to reduce the size of the overall model slightly and also instead of buying a single huge magnet, we decided to buy more than one smaller magnet. This allowed us to reduce to the cost however we still found the startup cost to be slightly high. However one of our team members pointed out that these were only single startup costs and eventually over time it would be made up by the sales of the brick material. We all decided to showcase this startup cost as an investment in making a greener company. Next up the review group suggested that we look into the idea of having workers scan the grinded down brick material to make sure no steel was left over. This was a huge suggestion since it never occurred to us that metal pieces could get pass the magnets. We took this suggestion back with us to discuss and figured it would be a good safety check to have at least one person scan the grinded brick once we prepare to ship it away for any leftover steel. And in the situation where steel is found left over we can transport that section to be reprocessed through the grinding and magnet process. Overall even though the design review group was not able to provide many suggestions for improvement, the few ideas they gave us were a huge help.
Figure 4 is the final render of our SolidWorks model of our proposed system. Starting from the far right side, brick is dropped into the top of the cylinder that is attached by two beams and is held over the top of the slope. Inside this cylinder the brick is crushed into smaller pieces, roughly the size of gravel. As the pieces move down the slope the magnets, which are the three square blocks held up by metal beams, will remove all the steel from the crushed bricks. The remaining debris that is stuck to the steel pieces will be removed by adding the steel chunks to water. All components of the brick are water soluble, so they will separate from the brick by dissolving. The remaining brick chunks without any steel will continue down the slope and collect in the container at the bottom where it will be shipped out and resold to brick manufacturers.
Figure 5 System Diagram

Figure 5 is our system diagram. It is meant to explain exactly what goes into and out of our system, as well as the initial inputs and final outputs. The entire goal is to turn waste refractory brick into a recyclable substance, rather than landfill waste. To do this, our design causes everything inside the black box to occur with the help of electricity and magnets, the system is able to physically break down the brick and remove the raw steel, eventually producing brick materials.

Cost and Feasibility Analysis

We expect the initial costs to be high to implement this system. The initial costs are the planning and assembly of the design. This will include the construction of a ramp and bucket, the industrial grinder and chute, and the magnets. The ramp construction should be pretty simple and we don’t expect this to cost more than a few hundred dollars. Allocating a budget of 800 dollars should be reasonable for this construction. We found magnets for about 13 hundred dollars each
[1]. We will probably use two or three magnets so this cost will be about 3 thousand dollars. We expect the majority of the cost to come from the industrial grinder. We could not find an exact price because industrial grinders are not sold to the general public. For the sake of estimation, we expect this piece of equipment to cost between 15 and 20 thousand dollars. This puts total cost at around 22 thousand dollars.

Long term costs include the power required to run the machine, paying workers to operate the machine, and transportation of recycled material. We estimate the sum of these costs should be 200 dollars per ton of brick recycled.

Furnace brick is mostly MgO. Other chemical manufacturers are selling MgO at approximately this purity for 350 dollars per ton [2]. Assuming that each ton of material will cost
200 dollars to produce from workers’ salary, transportation, and power costs, this process will pay off after 147 tons of brick are recycled (see Figure 6).

We believe this design to be pretty easy to implement at ArcelorMittal Steelton Plant. It is pretty sustainable and benefits ArcelorMittal by being profitable. The only issue would be getting brick companies to participate. However, they also want to be sustainable and so they will probably participate. ArcelorMittal could also cut initial costs by starting small scale and recycling only 10 or 20 percent of the bricks. Then, once the design has proven its value, they can expand and recycle closer to 80 to 100 percent. While the design should be refined by AM engineers to more suitably fit their needs, the concept is solid.

**Life Cycle Analysis**

ArcelorMittal’s life cycle is currently a linear system. What this basically means is that the brick material is created, used, and discarded with no reuse or recycling. The outline in black below shows this linear process. The goal is to find a way to make this system more circular, which basically means recycling or reusing the brick material so it does not all go to landfills. In green, you can see the new step that allows us to create this more circular life cycle. The brick material is sent back to makers to aid in the process of making bricks. This effectively kills the need for the material to be transported to landfills since we will be sending the crushed material back to the companies that make it.
Conclusions

Under our current circumstances we were not able to build a prototype of our design, therefore it is difficult to know for sure what will and won’t work. We have predicted that there will need to be more thorough calculations and experimentation with the actual grinding of the brick, as well as the position and strength of the magnets. However, I believe that our design is fundamentally sound, and therefore with more research is definitely a viable option. One other major setback is the cost of the machine. We were unable to tell exactly how much the machine would cost, or the cost to run it. Fortunately we don’t anticipate it to be more expensive than the cost to landfill the bricks. The magnesium can be resold to offset some of the cost. Most importantly however, this method reduces the eco-footprint without economically harming
ArcelorMittal. From here the project will definitely require more research as well as a physical and economic plan for implementation into ArcelorMittal factories.
References

   <http://www.mcmaster.com/#electromagnets/=wys6r8>

