A Concrete Method

ArcelorMittal Design Project

Team Susteelable

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Executive Summary:

Currently, ArcelorMittal has no method in place to recycle, reduce, or reuse the waste stream presented by the steel drums they receive containing toxic chemicals necessary for the steelmaking process. Our design functions to solve this problem by reusing the steel drums to create a more sustainable life cycle.

Our design consists of a pressure washer and drain system that an employee will operate with the proper safety equipment and precautions. The operator will wash and rinse the drums with a pressure washer, turning the residue into an extremely diluted (i.e. safe) substance which will travel into a drain. After cleaning, the steel drums will be filled with concrete and shipped to various construction companies, while the collected waste liquid will then be sent to water treatment plants.

We found that this design would not only be effective in creating a sustainable method to reduce ArcelorMittal’s waste stream, but would also be successful in providing a profit to ArcelorMittal.
**Problem Statement:**

ArcelorMittal would like to increase the sustainability of their steelmaking process by reducing, recycling or reusing their excess, chemically polluted steel drums that create a waste stream.

From the months of December to March, steel drums are used to transport chemicals used in the steelmaking process at the ArcelorMittal factories. Currently, ArcelorMittal has no method in place to reduce, recycle or reuse the steel drums after use, which results in an unresolved waste stream. This lack of recycling affects not only ArcelorMittal and their stakeholders, but also the environment and the future sustainability of planet Earth. Through implementation of our design, ArcelorMittal would be able to increase sustainability of their waste materials in the next few years. It is important that this problem be fixed to improve profitability, help the long term sustainability of ArcelorMittal, and reduce the amount of waste going to landfills.

Through the design process and studying the inputs and outputs of ArcelorMittal steel making process, we will provide a sustainable solution to reduce the steel drum waste stream and yield a profit.
**Sustainability:**

Sustainability is built upon the three interconnected spheres of People, Profit, and Planet. These spheres encompass each of the various areas that impact society. Socially, sustainability functions to raise the standard of living for all and allow equal access to the limited resources available. Economically, being sustainable saves time, money, and resources. Lastly, from an environmental standpoint, sustainability provides a positive environmental impact and works to reduce pollution emitted. To be sustainable is to be repeatable, beneficial, and long lasting.
**Background:**

In our patent search, we found patents on various aspects of our design, but not our design as a whole. The products which are currently available that we found include a cleaning process of chemical containers (US6793740 B1), cleaning machines through vacuum extraction (WO2000038839 A1), cleaning machines through shot blasting chemical drums (US4723377 A), and a cleaning process containing a high pressure spray and drain as well as a sulfuric bath (US3798066). This background search provided us information on the ways that we could move forward with our designs and concept selection processes, without infringing upon other peoples’ ideas.
Customer Needs:

During the brainstorming process, we selected the following eight criteria that we believed were most applicable for a successful design by considering all the stakeholders in the design. We chose to evaluate the designs according to affordability, environmental impact, safety for employees, legality, sustainability (repeatability), time efficiency, profitability, and space efficiency. As seen in our APH matrix (Figure 1), legality, safety for employees, and environmental impact were the highest ranking criteria, scoring 0.24, 0.21, and 0.19 respectively. On the other hand, affordability, time efficiency, and space efficiency were ranked the lowest scoring 0.06, 0.05, and 0.04 respectively. Knowing the most and least important criteria for our design became beneficial in the design selection process to determine which design met the most important requirements.

![Figure 1. Analytic Hierarchy Process matrix that rank the relative importance of each of the 8 requirements of our design.](image)
**Concept Generation:**

For our concept generation, we brainstormed multiple ideas for the two parts of our design as seen in Figure 2. The first part of our design was determining a method to clean the steel drums, while the second part was determining how to reuse the cleaned steel drums to give them a new life.

To clean the steel drums of the chemical reside, we brainstormed the following methods: a bush to scrub away the chemicals, a sponge-like material laid into the drums to soak up the chemicals, a vacuum to suck up the chemicals, a pressure washer to rinse of the chemicals, and lastly, a freezer to freeze the drums then scrape the chemicals off. Before we could select a design, we developed a list of requirements and used an APH matrix to rank the most important and the least important requirements for our design. As seen in the previous section titled “Customer Needs” and in our APH matrix in Figure 1, we calculated the weights of each criteria. With the weights of our requirements, we used a design selection matrix (Figure 3) to aid us in determining which of our brainstormed ideas met the most requirements necessary for a successful design. As seen in our design selection matrix (Figure 3), our top two designs, the pressure washer which scored a 4 and the brush which scored a 4.03, were the designs that we chose between. Ultimately, we chose to move forward with the pressure washer design because it seemed more practical and reliable than the brush design.

For the second part, concerning how to reuse the cleaned steel drums, we brainstormed different ideas which included melting the steel to be molded into another product, cutting the drums in half to be reused, or filling the drums with concrete and using them as a building material. While we did discuss the pros and cons of the various steel drum reuse methods, our
top idea was to fill the drums with concrete and use them as a building material. We decided to reuse the steel drums as a building material because it was our most creative idea to give the drums a new life.
Q4: Concept Generation

**Step 1 (INDIVIDUAL):** Brainstorm ideas to solve the problems associated with your selected source of refuse from Q1. The idea here is to develop as many ideas as possible and to not discount your own out of the box ideas. Write down/sketch everything that comes to mind. You have 15 minutes to come up with 10 ideas.

**Step 2 (GROUP):** Reassemble as a group and discuss each of the ideas generated by the individual group members. Using these ideas, generate additional ideas that build upon them. Write/sketch them here.

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Figure 2. Initial concept generation brainstorming that was conducted between the group members. These initial sketches highlight the various designs and ideas that we originally brainstormed as solutions to the ongoing problem.
Concept Selection:

When it came to finally choosing one of our ideas to go on to the final design stages of our project, we had to compare the pros and cons of each of our ideas. First we compared our four cleaning options that were outlined in our design selection matrix (Figure 3). We felt that the low scores of the sponge material and freeze and scrape method being a 3.16 and 3.66, respectively, demonstrated that the cons outweighed the pros for these two ideas. One major con of the sponge material included the potential danger that employees would have to face while coming in contact with this sponge. We felt that the safety of the employees was something that should not be jeopardized, and that justified our elimination of this design. Although we felt that the freeze and scrape method was one of our more creative ideas, we felt that this design would be impractical. Too much time and space would be compromised while conducting the entire freezing and scraping process. In addition, we did not successfully find a scraper that would be both strong enough and safe enough for employees to use.

Thus, we were left with our two highest-scoring designs, which included the high-pressure washer (with a score of an even 4) and the brush design (with a score of 4.03). Although the matrix results showed the brush as the winning design, we felt that there were critical cons of the brush and pros of the high-pressure washer that were not addressed in our matrix. These two design ideas were similar in the way that they would both vigorously clean the inside of these steel drums. However, we felt that by doing this with the brush, we would then face the issue of having to keep the bristles of the brush clean. This would not be an issue for the high-pressure washer. Instead, we would only have to check the final concentration of the waste water to ensure that the chemicals were diluted enough to go down a drain. We felt that we would be able
to get a more straightforward answer by checking the cleanliness of our waste water solution, rather than checking the cleanliness of our brush bristles. Thus, we decided to stray slightly from our design selection matrix by choosing the high-pressure washer as our best option when it came to cleaning the interior of ArcelorMittal’s steel drums.

Secondly, we compared the pros and cons of our options of what to do with the steel drums upon cleaning them. Our options included melting down the steel in order to mold it again, cutting the drums in half, and filling the drums with concrete to be used as building materials. This was a much easier decision for us. The biggest pro of our chosen idea, which was to fill our drums with concrete, was that we felt that this was our most creative and innovative idea. Also, the concrete-filled steel drums being used as a building material would be more versatile compared to melted down steel or cut-up pieces of steel scrap.

With all of these pros and cons in mind, we were able to come up with our final design process, which we call A Concrete Method. Our process can be split up into three major steps. First, the emptied steel drums that still contain some chemical residue will be cleaned with a high-pressure washer which will intensely rinse out the interior of our steel drums with water. The waste water that results will be tested with a chemical indicator to ensure that it is diluted enough to go down the drain like any other water would. If this is the case, the waste water will be sent to a water treatment facility, while our drums will be send to the second step of our process. In this step, the clean steel drums will be filled with concrete and sold to participating construction companies. This step will allow ArcelorMittal to profit. Lastly, these construction companies will utilize our concrete-filled steel drums to be used as building materials in whatever way they see fit. Therefore, this last step will give these steel drums another life and
extend the life cycle of all steel drums that make their way through ArcelorMittal’s steel-making process. This design was better than our other ideas because it met all necessary requirements and it incorporated sustainability and profitability while also reducing ArcelorMittal’s waste stream.

Our design, **A Concrete Method**, which utilizes the high pressure washer, met the majority of our requirements very well. For example, the pressure washer scored a 4 or 5 (out of 5) in all requirements except environmental impact. Displayed in Figure 3, the pressure washer scored second to the brush, but only by 0.03. Because our design scored so well, it validated our decision and proved that our design would meet ArcelorMittal’s needs.

Currently, ArcelorMittal disposes of the residue-filled steel drums in local landfills. This not only is an issue for ArcelorMittal, but also for the environment as a whole because this process increases the company’s waste stream. However, our design aims to reduce the waste stream by providing a sustainable and repeatable process to clean and reuse the steel drums. Our product uses water and a high-pressure washer to clean out the chemical residue from the drums. The solution will be diluted to a nontoxic level and thus will be able to go down the drain to a local water treatment plant. We will use a testing strip to test the toxicity of the diluted solution to make sure it is safe to go straight down the drain. At the treatment plant, various physical, biological or chemical processes will be used to clean the water so that it can be safely discharged into the environment for reuse. The remaining drums will be filled with concrete and sold to construction companies for reuse. This lengthens and renews the lifespan of the steel drums which normally would be sent to landfill. After the initial setup and installation of our design, the process for recycling, reusing, and reducing the excess steel drums of ArcelorMittal,
should be simply repeatable in terms of year after year and in terms of reproducing at other ArcelorMittal plants. Our design reduces the amount of steel drums in landfills, thereby reducing ArcelorMittal’s waste footprint.

ArcelorMittal will implement our design by purchasing and installing around five 4000 PSI Pressure Washer - 13HP, Honda GX Engine, Cat Pumps to their factory. Then, after pressure washing the steel drums and testing for toxicity, they will fill them with concrete and find a buyer to accept the concrete filled drums to use as a construction material. After a year or so of this process, ArcelorMittal would form a relationship with the buyers and possibly be able to decrease their costs by mutually negotiating on a contract. After the success of our design process has been proven, ArcelorMittal would be able to repeat it in multiple factories to greater decrease their waste stream footprint.

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3 Figure 3. Concept selection matrix that was used to determine how well each of our design ideas fits the necessary requirements. Though the brush method scored highest on this matrix, we decided that the high-pressure washer method would be more the most applicable and efficient solution to the problem.
Design Review:

Our design review with another team provided some valuable feedback that we could use to improve our design. Some of the things for which the group commended us was our ability to reduce the total waste stream of ArcelorMittal as well as our effective use of visual aids in conveying our design. On the other hand, the group recommended that we do a full cost analysis of our design in order to completely understand environmental and economical effects of our design. The other group also suggested that we find a way to test the chemical residue in the drums after washing as well as the concentration of the runoff solution that will go to a water treatment plant. Furthermore, the team advised us to investigate the environmental effects of burying the concrete-filled drums underground for construction uses.

We utilized this feedback in order to build upon our strengths as well as improve upon our mistakes. One of the first things we added to our design that we would implement if able to create a second prototype, was a chemical indicator that would change colors to reveal the concentration of chemicals in both the drums and the waste water. The second way in which our final design was affected by the design review was in our cost analysis. As a result of the feedback we received, we researched and compiled a more comprehensive cost analysis. The design review ultimately improved our design because we were able to build upon our design weaknesses.
**SolidWorks Model:**

Our final SolidWorks models help to clearly visualize our process. Figure 4 shows our intent to pressure wash the drum in it a pressure hose can be seen using to remove the chemicals from said drum. Figure 5 is a representation of our intent to fill these previously cleaned barrels with concrete, as a pipe can be seen pouring the concrete into the drums. Finally, Figure 6 is a representation of our intent to use these filled drums as a building material. Figure 6 shows a drum used as a weighted base for a light stand commonly found around the country for stadium lighting. The drums could be used in a similar fashion for signs, and can function as a solid weight base for just about any project.

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4 Figure 4. (Top Left) SolidWorks 3D model of the high-pressure washer cleaning out the chemical residue of GE depositrol, diethylene glycol, and propylene glycol out of the steel drums.
5 Figure 5. (Top Right) SolidWorks 3D model of the concrete being poured into the steel drums for the second step in our method.
6 Figure 6. (Bottom) SolidWorks 3D model of the applications of our concrete-filled steel drums. The drums will be used as foundations for light posts, housing foundations and other applicable uses.
Figure 7. Systems diagram that highlights a step by step model of our solution. The drums will be cleaned by a high pressure washer and then filled with concrete and sold to various construction companies. The diluted solution will go down the drain to a local water treatment plant. (Picture http://www.best-pressure-washers-reviews.the-best-review.com/wp-content/uploads/2012/05/best-electric-power-washers.jpeg)
Cost and Feasibility Analysis:

A key component of our design was making our method as profitable as possible. For A Concrete Method, ArcelorMittal will need to purchase several pressure washers and concrete mix. After the initial purchase cost, the expense of maintaining the system is low. Quality industrial grade pressure washers can cost upwards of $1,000. In addition, the concrete needed to fill a chemical drum should cost no more than $17. While this seems like a large setup cost it is quickly covered by the price of selling the concrete-filled chemical drums as construction material. On average steel chemical drums cost about $100 per drum. We assume that we could sell these filled drums at around $50 a drum. It is hard to calculate the cost of water for this process as without testing we do not know how long it takes to clean the drums. The current cost of water in Pennsylvania is about 69¢ per 100 gallons. The pressure washer we are looking is 4000 PSI Pressure Washer - 13HP, Honda GX Engine, Cat Pump which pumps out 3.5 gallons per second. The cost to run that pressure washer for 10 minutes is only 24¢. On average it costs 37¢ to transport 1 ton (weight of a filled drum) 1 mile by truck. So, selling one of these concrete filled drums and transporting it 1,000 miles by truck would net a profit of $29 per drum. By this estimate if the initial setup cost for the design was $5,000 (5 pressure washers) ArcelorMittal would only need to sell 172 drums before they started making money.

In terms of feasibility for adoption of this design by the stakeholders, we expect they would be understanding of pros and cons of our design, ultimately agreeing that the pros outweigh the cons. Additionally, we anticipate that the stakeholders would provide feedback for us to improve upon our design. The only legal issues our design presents is ensuring the runoff water is not polluting the environment, which is where our chemical indicator would come into
place. Legality and safety of both the environment and the employees are the most important requirements to our design.
Life Cycle Analysis:

The current life cycle of a steel drum used in ArcelorMittal’s steel making process is very short and linear. The “cradle-to-grave” process that is presently in place results in countless tons of steel drums to ending up in landfills every year. However, by implementing a “cradle-to-cradle” process, the steel drums can be given another life. Thus, the environment, ArcelorMittal, and ArcelorMittal's stakeholders will benefit.

Our process, A Concrete Method, functions to create a cyclic life cycle for the steel drums. After the chemicals from the drums are used, the drums will then be cleaned thoroughly by a pressure washer, checked to ensure the chemical levels are legal and safe, and filled with concrete. These new concrete-filled drums will be sold to construction companies to be used as building materials. Not only will these new drums be versatile in terms of what they can be used to build, but they will also be given a “new life” resulting in a cradle to cradle process. Our decision to use the cleaned steel drums as construction material was directly related to our goal of redirecting the life cycle towards sustainability.
Conclusions:

Our product serves as a cost-effective and eco-friendly solution to ArcelorMittal’s ongoing waste stream of the steel drums containing chemical residue of GE Depositrol, Diethylene Glycol, and Propylene Glycol. Our product solves two major issues for ArcelorMittal: eliminating the chemical residue within the drums as well as reusing the drums to ensure a profit for the company. First, a high-pressure washer would use water to rinse the chemicals from the drums. We would then test both the insides of the drums and the runoff water with a chemical indicator to ensure they are at nontoxic levels. Finally, we will fill the drums with concrete and ship them to various construction companies in return for a profit per drum.

There are both pros and cons to **A Concrete Method**. Some of the benefits that our design presents are time efficiency and profitability. With the high-pressure washer, each drum will take an estimated ten minutes to fully rinse and clean. However, this is just a rough estimate as we would be unable to record the specific speed of the method without manual testing of our product. Through our cost-analysis, we also estimated a net profit of $20 to $30 per drum which would provide sufficient revenue for the drums that are currently going straight to landfill after the steelmaking process. We also took into account some of the drawbacks of our solution which included finding a buyer for the concrete-filled steel drums and financing the large initial investment. Several construction companies such as Vulcan Materials Company may be interested in such a product, but we would not be able to accurately know the market until we put our product for sale. Another potential issue is the $1,000 per pressure washer that our method requires which ArcelorMittal may not want to spend if the return on investment would be longer than expected due to the previous issue of finding a buyer. As seen under the section “Cost and
Feasibility Analysis” this steep initial investment is expected to be earned back after selling 172 drums. So, the expense of the initial investment will be earned back, the only variable is the time it would take to earn it back. Even with these concerns, we are confident that our product is able to satisfy a majority of ArcelorMittal’s needs and act as an effective method to reusing their steel drums.

The next steps in our design include testing our prototype, setting the final specifications of our product, and planning for future development. For future progress, we must test our prototype in order to observe vital information about the effectiveness and the flaws of our product. We would conduct multiple trials of washing the drums to determine approximately how long it would take to wash out each drum, if the pressure washer cleans the chemicals off well enough, if the runoff water is legal to travel down the drain, and if there are any improvements to be made to our design. This information would bring some clarity to the exact specifications of our product. It will be essential in effectively marketing our product with its specific details to ArcelorMittal. After this testing process, we would need to develop a marketing scheme with ArcelorMittal to effectively promote and sell our concrete-filled steel drums. Lastly, after a couple years of implementation of A Concrete Method, other companies may want to adopt our design and we could increase sustainability by decreasing the steel drums’ waste stream.

Throughout this project, we learned many valuable lessons about the various aspects of the design process. We learned to complete tasks on time by cooperating to complete them or by dividing the tasks to accomplish them quicker. Time management was very important to practice throughout this project and the time constraints on our various assignments functioned to teach
us how to manage our time most effectively. Furthermore, we learned to use the feedback from
the design review as a valuable resource to help improve and modify our method. The design
review taught us the importance of continuously refining our project to meet the requirements of
our design. Overall, this project served as great way to practice teamwork, creativity, and to
become exposed to the process similar to what real engineers use to problem solve.
References:


