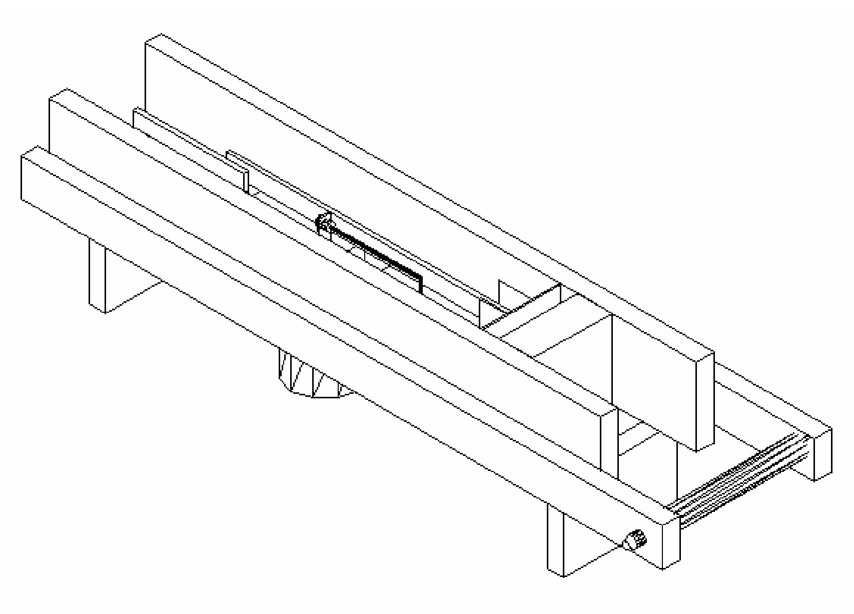
Final Report for the Design of the CAOS Crusher by

CAOS®

Crushing and Organizing Specialists



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Abstract

The can crusher built by CAOS was an engineering project that gave the team knowledge and insight into what professionals must do to complete their goals. The reason to build a can crusher is so that Americans will recycle more and so that these cans can be stored properly, safely and efficiently. CAOS has designed a can crusher that is simple and easy to use. We have met all the functional requirements set by our instructor. In our time designing and building, we faced many challenges and setbacks, but our team persevered through these difficult times. Our team has accomplished the project with great success.

Introduction

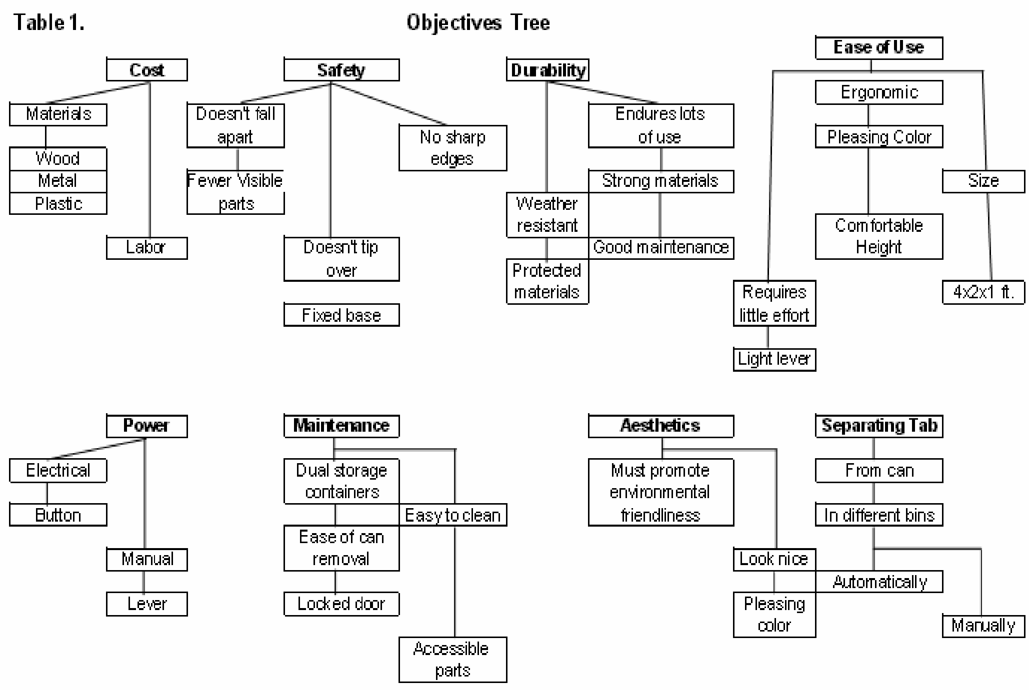
The goal of CAOS was to create a functional can crusher that efficiently processes a can and stores it. The can crusher needed to be easy to use and promote environmental friendliness. It had to be inexpensive and compact. The design needed to crush and store the can, while at the same time remove and store the tab. CAOS, from the beginning, intended to make this process as simple as possible with the least possible number of steps.

CAOS initially decided on certain objectives that were not only required by our professor, but also ones which we personally wanted to accomplish. As stated before, we wanted to make the most simple and efficient can crusher possible. As shown on Table 1 under the “Ease of Use” heading, we wanted to make our product ergonomic, comfortable, easy to operate and pleasing to the eye. These objectives were so important because CAOS really wanted to make a product that would make a difference in the recycling habits of Americans. The can crusher needed to be durable, easy to maintain and cost very little to produce. As shown on Table 1, we wanted to make our product out of a combination of wood, metal, and plastic. All of these materials were used in the final design and have proven to be very cost-effective.

The required objective of pulling the tab from the can was originally what perplexed CAOS. It was not initially clear how this would be accomplished. Table 1 shows that the tab needed to be stored in a different bin from the can, and could be removed automatically or manually. Fortunately, in keeping with our primary goals of simplicity and efficiency, we were able to make the tab removal an automatic process.

Powering the can crusher was a concern, but a manual lever proved to be much more simple and inexpensive than using electrical power. The product needed to withstand repeated use and be weather resistant. Our final design turned out to be a very effective product that is easily operated and aesthetically pleasing. CAOS hopes that its product will promote Americans to recycle more than ever.

Table 1.



Over the course of the past few months, CAOS, as well as many other teams worked very hard to devise and build a can crusher. Our team focused on innovation as opposed to inventing an entirely new device. We believe that we have achieved in making a very effective product that fully accomplishes all of the goals set by our instructor and the goals we had imposed on ourselves.

The Aluminum Can Industry and the Need for Recycling

The aluminum industry today is a multi-billion dollar industry, and aluminum cans make up 20% of this market. Canning began in the 1800's as a way to feed mobilized armies. Cans, at first were crude and poorly constructed. The first carbonated beverage appeared in cans in 1935. Cans around this time were made of steel, not aluminum. Aluminum cans first appeared in 1958, but were far different from the sleek, efficient can we have today. They were thick and expensive. Over the past few decades, the aluminum can industry has found better and more efficient ways to produce this can until they made the product we have today. About 100 billion aluminum cans are produced every year. It is a very cost driven industry, where a 1% reduction in aluminum used for the can could save a manufacturer millions. The current industry is incredibly efficient with only 1 in 50,000 cans defective. The industry has driven the 4 domestic manufacturers of aluminum cans to incorporate the latest and best manufacturing methods.

With all these cans being produced every year, there is an incredible energy cost. About 6 watt-hours of energy are used to process the aluminum for a single can. The energy saved by recycling a 12 ounce aluminum can is equivalent to six ounces of gasoline. The United States recycling rate has steadily declined and is under 50% now. This is an unfortunate figure. Americans throw cans away because of convenience. A recycling bin is usually not readily available, or they are simply too lazy to collect their empty cans and take them to a recycling center. This must be changed. Literally trillions of watt-hours of energy are lost every year due to throwing away aluminum cans. It is essential that aluminum can recycling bins become more readily available to Americans, and that these cans are stored efficiently and safely. Hopefully, with the construction and implementation of the CAOS Crusher, Americans will recycle more aluminum cans. As stated before, the recycling habits of Americans need to be changed. Only with the convenience and functionality of a CAOS can crusher, can this dream become reality.

Source Info- Aken, David C. Van; Cooley, John: *The Manufacture and Recycling of Aluminum Beverage Cans*

Management Structure

The management structure of CAOS was very loose so that each member of the team had equal say in decisions, and felt equally important to the welfare of the team. The leader was Matt, but he tried more to keep the flow of progress moving, as opposed to actually directing and telling the other members what to do. Each member, however, did have expected duties which he was expected to do competently, and in a timely manner. Matt made it clear that, since we rely on each other for everything, late work and laziness simply would not be tolerated. The rest of the group fully agreed with that assertion.

One thing that has helped to make CAOS a successful team is the hard work and dedication to not only get the work done, but to do above and beyond what was expected by the rest of the team. Matt, as the leader, provided the encouragement and support to push the team to accomplish its goals. He designed the team logo, did two of the memos and helped the rest of the team with their memos. He was there every step of the way until the completion of the project. Nathan was responsible for the actual creation of the can crusher. From concept to reality, he was there and built a majority of the final can crusher. Nathan also did all of the AutoCAD drawings because of his skill with the program. As CAOS got into the model and prototyping stage, Nathan became more of a leader as his practical knowledge grew more and more important to the stage of development. David was also responsible in the creation of the can crusher. He was always there to help construct the can crusher. Grant was the secretary of the team, and was also involved with the construction of the can crusher. Ben was responsible for one of the memos and keeping track of expenses.

All members of CAOS were responsible for the actual design of the can crusher. Each member has an idea that was built into the final product. It was this type of collaboration that has made CAOS so successful.

Designs Considered

The can crusher has five main functions. Several designs were considered for each of the following functions. The main functions are importing the can into the crusher, removing the tab from the can, crushing the can, and placing the can and tab into separate containers.

Four different ways were thought of to put the can into the crusher, one of which would be to place the can in an opening by hand. Another option was to have a chute or a conveyor belt that would deliver the can to the crushing apparatus. The can could also have been drop kicked into the crusher.

The can crusher also needed to remove the tab from the can. One way this could have been accomplished was with a hook. The hook could be mobile or stationary. In addition, the tab could have simply been removed by hand. A more dramatic approach would have been to use a micro explosion to detach the tab from the can.

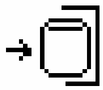
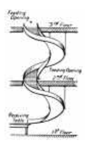
Next, the crusher needs to crush the can. This could have been accomplished by manually smashing it with a metal cylinder or by using an electric motor to smash the can with a metal cylinder. Another way would have been to squeeze the can or to drop a weight on the can.

The crusher also has to place the can into a separate container. This could have been done by having the can slide down a chute into the appropriate container. Another approach would have been to use a spring-loaded mechanism to push it into the bin. An alternative would have been to use a catapult to shoot it into the bin. Another idea would have been to have a trap door that the can would have fallen through after it was crushed.

Last of all the tab must be placed in its appropriate storage container. One thought was to have a manually operated hook drop it into the bin or alternatively, there could have been a spring-loaded hook that would fling the tab into the bin. An easier way would have been to have the operator place the tab into the bin by hand. One last idea was to use compressed air to blow the tab into the container.

These various solutions to the functional requirements of the can crusher are arranged in Table 2. The previous paragraphs are the brief descriptions of the solutions that were thought of for the five main functions. These were the five functions that the can crusher had to perform.

From these different ideas CAOS formulated 5 unique solutions for the can crusher. The first solution involves placing the can in the apparatus by hand and removing the tab with a stationary hook when the can is crushed. Then a spring loaded mechanism would catapult the can and tab into separate containers. The second solution involves placing the tab in the can crusher after removing the tab by hand. The can will be crushed by a metal cylinder that is operated by a lever. The can will then slide down a chute separate from the tab, which the operator will place into another container. The third solution also has the can placed in the apparatus by the hand. It will then be crushed by an electrically driven metal cylinder. The can then falls through a trap door and the tab is placed into a bin by the operator.

Table 2. Solution Table for Can Crusher				
Sub-function	**Solution Idea**			
Import Can	Place in apparatus by hand. 	Drop in chute 	Drop onto conveyor belt 	Drop kick can into apparatus 
Remove Tab	Pull with hook. 	Smash can with hook attached to stationary object. 	Remove tab by hand. 	A micro-explosion removes tab. 
Crush Can	Smash with metal cylinder by hand. 	Smash can with electrically powered metal cylinder. 	Squeeze Can 	Drop a large weight on can. 
Place can into separate container from tab.	Can slides down a separate chute from tab. 	Spring loaded mechanism pushes can into bin. 	Catapult shoots can into storage container. 	Can falls through trap door into the bin. 
Place tab into separate container from can.	Hook removes tab and drops into bin. 	Spring loaded hook flings tab into bin. 	Operator places tab into bin. 	Compressed air blows tab into bin. 

Solution four involves removing the tab by hand and then dropping the can into a chute where it will be crushed from the sides. A spring loaded mechanism will push the can into a bin and the tab will be blown into another container by compressed air. The fifth solution is similar to the first in that the can will be placed in by hand, a stationary hook will remove the tab, but instead a trap door will collect the crushed can as opposed to falling through a spring loaded mechanism. Figure 1 shows some of our possible design solutions.

Figure 1

Our final design turned out to not be exactly anyone of these product solutions, although it most closely resembled solution 5. This just illustrates that engineering is an iterative process and that at any time along the engineering process, the design can be altered, overhauled or sometimes completely changed.

Analysis

CAOS considered many design solutions in the early stages of the engineering process. These design solutions discussed in the previous section were all very unique from each other. We wanted to consider as many possible designs as we could think of. However, each particular design had its own pros and cons. The most important factor was the process time. A single second could be worth a hundred points or more on the figure of merit. As shown on Table 3, our various solutions had a wide range of projected times. The ones with the lowest time (T) had, by far, the largest figure of merits, as illustrated by Table 4.

CAOS made very rough estimates of the various factors for the figure of merit. We took our conceptual idea and tried to imagine it working. We based our figures off of previous experience with similar products. For example, solution 3 involved an electrical motor. From our experience and lack of expertise with electrical devices, we decided that this solution would take a long time to crush a can and would be larger than the other solutions, not to mention being much more expensive. The one distinct advantage of this solution was that it would obviously not require much force (F). The cost (C) was estimated by the complexity and volume (V) of the design. Environmental impact was an estimate of the amount of recyclable material that would be used to build each solution. Design innovation (D) and industrial design (ID) were figures that were based on the originality and aesthetic merit of the solution.

Table 3. Estimation of Parameters

	C	*V*	*T*	*R*	*EI*	*F*	*D*	*ID*
Solution 1	$35	0.075m^3	10 s	1	90%	40 N	4	3
Solution 2	$20	0.075m^3	20 s	1	80%	40 N	2	2
Solution 3	$45	0.085m^3	25 s	0	75%	15 N	3	4
Solution 4	$40	0.100m^3	15 s	1	80%	35 N	3	3
Solution 5	$30	0.075m^3	10 s	1	85%	40 N	4	3

The figure of merit for each solution was derived from the various parameters of our product solution. As stated before and illustrated by Table 4, time was by far the most important contributor of points to the figure of merit. Cost was also a very important factor for the figure of merit. All of the various factors were important to CAOS. We not only tried to maximize the figures that contributed the most to our total score, but also tried to obtain the highest score possible for all of the parameters. In our final design, which will be discussed in the next section, our figure merit turned out to be much higher than we anticipated in our product solutions. The final figure of merit turned out to be over 1900. Clearly, CAOS was capable of more than we originally imagined. The figure of merits overall were a good way of leading our design into the final stages and helping us to decide what direction to take. Our final design end up not being exactly what we planned, but fortunately it ended up being much better than what we could have imagined.

Table 4. Figure of Merit Decision Grid

	10·(50-C)	*1000·(0.216-V)*	*2·(30-T)²*	*50·R*	*15·sqrt(EI)*	*1000/(F+1)*	*8·(D+ID)*	***Total FOM***
Solution 1	150	141	800	50	142.3	24.4	56	1363.7
Solution 2	300	141	200	50	134.2	24.4	32	881.6
Solution 3	50	131	50	0	130.0	62.5	56	479.5
Solution 4	100	116	450	50	134.2	27.8	48	926.0
Solution 5	200	141	800	50	138.3	24.4	56	1409.7

Final Design Selection

Our initial design proved to be too small and also had a few other flaws. Previously the lever arm pushed downward on the piston too much to crush the can easily. We noticed that the lever arm needed to be attached lower on the sides of the can crusher. This creates a more horizontal force on the piston to crush the can more easily. The lever arm also seemed too short to function within the user force requirement. On our final design, we lengthened the lever arm about ten inches to greatly reduce the amount of user force required (see fig. 4). This idea worked successfully and brought the user force down to 8 pounds.

The final design also incorporated the use of a new piston design. Our initial piston was made out of wood and had angle pieces made from metal to attach the lever arms to it. It also had two angle iron pieces for the guide rails (fig. 2). The new design was made from a sheet of metal and bent to incorporate the pieces for the guide rails and the attachments for the lever arms (fig. 3). It was all bent to prevent rough spots from welds. The only pieces welded on this piece were on the inside of the piston to reinforce the piston so it would not bend or warp under pressure. The piston was made from metal because metal is smoother than wood and also stronger and thinner. A piece of pipe was used to keep the tab from flying off of the hook when it snapped from the top of the can. In our initial design the hook was pulled through the thickness of the wood which created a similar effect as the pipe on the new design. When we tested the new design of the piston the tab snapped off and was launched off of the hook. We immediately decided that we needed something to help hold it in place for that moment. The final design of the piston also used a longer body to prevent twisting (see figs. 2 and 3 for comparison).

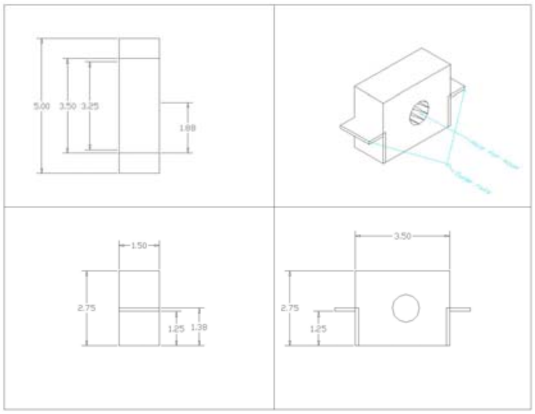


Figure 2

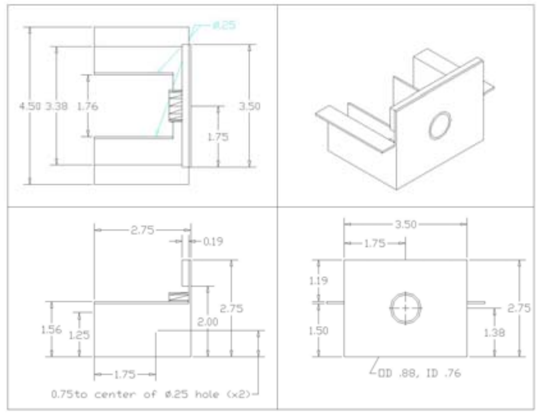


Figure 3

The final design used metal for the lever arms that attached the piston and the main lever arm. We chose metal once again for its strength to size ratio. However, we now believe that the metal we used was too thick for the application. The main lever arms were attached by a length of metal that was welded to the bolt that was welded to the other lever arms (see fig. 4). These pieces of metal were screwed on with three screws in each side to prevent the wood from splitting when the can crusher was used.

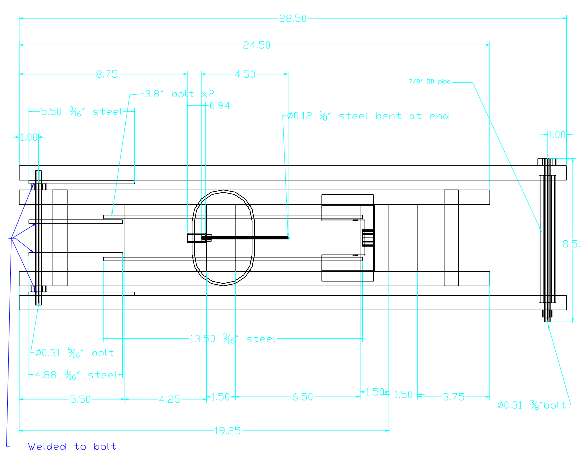


Figure 4

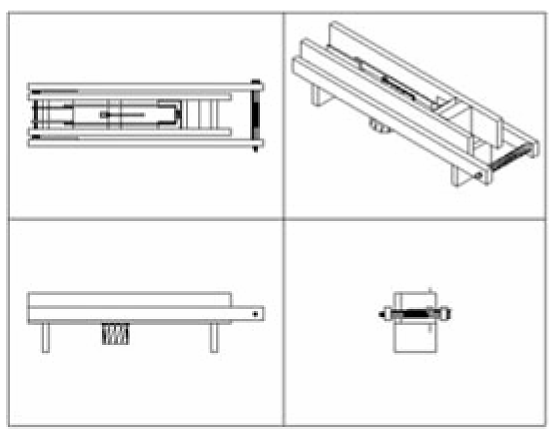


Figure 5

Our main goal was to create a can crusher that crushed the can in a device that is affordable, safe, easy to use, lightweight, and pleasing to look at. We feel that we have accomplished these goals with our final design. Our prototype design would have been close to meeting these goals; however, our final design, as shown in figures 5 and 6, proved to be much more effective

Figure 6

Construction and Materials

We began the construction process of our can crusher by marking dimensions on the wood on where to cut it. It was then held securely with a vice and cut perpendicularly. After cutting all of the wood, we had seven pieces to use for the main body. These included two long lever arms, two long side walls, two square pieces spaced out for the tab and can to fall through, and one piece that served as a crushing wall. Using a table saw, we cut a fairly long slit down the side of each wall for the plunger to glide back and forth. Next we used a power screwdriver and several wood screws to fasten the wood pieces together to form the body.

Cutting the steel bars was the next step in the construction process. We cut two long steel arms and four shorter ones for the lever mechanism. A simple hand saw was used for that task. A hole on each end of the long and two of the shorter bars were made using a power drill. Three holes on one end of the other two short bars were drilled for supporting the lever arms. Next, a hole on each end of the two side walls was drilled for the bolt to slide through. Then two of the steel bars were welded onto the bolt and the two long ones were fastened with a bolt, washer, and a nut. The other two bars were fastened to the lever arms to support it. We attached a cylindrical handle onto the lever for ease of use and comfort.

Now we needed the steel plunger to crush the can. A sheet of steel was marked and cut to fit inside the can crusher. Two “wings” were cut and formed which allow it to glide smoothly, two parts were formed so it can be attached to the lever mechanism, and the flat surface for crushing the can was bent into place. Then we drilled a hole on each side of the part that was to be attached to the lever mechanism and a larger hole on the crushing surface to allow the hook to pass through. We fastened these together with two bolts, two nuts, and two washers.

For the tab removal we constructed a stationary hook mechanism which pulled the tab off as the can is being crushed. We fastened a bracket to the base right behind the tab slot with a wood screw. Then the hook was attached to the bracket with a bolt and a nut. To catch the tabs and store them, we attached a small plastic bin under the can crusher.

The last components that were constructed were the wood supports which allowed the can crusher to be fitted onto the receptacle. Brackets were attached to the wood supports and the bottom of the base by wood screws. For aesthetic and protective purposes we stained the wood and applied a clear coat to protect it from the elements. This made for not only a strong protection against the elements but also an extremely nice looking can crusher.

All of the components that were used for the can crusher were fairly inexpensive. Table 5 shows the exact value of each component that was built into the can crusher. The cost of welding and forming the metal has been included in the price of the steel rod. In use of materials, CAOS tried to be as economical as possible. Every component on the parts list is needed for the proper operation of the can crusher. This makes for an overall inexpensive product. CAOS is very pleased with the way the construction process went.

Table 5. Parts List

Item	Unit Price ($)	Amount Used	Cost ($)
Drywall Screws (100)	1.97	0.42	0.83
1X4X8 Wood (96 in)	2.39	1.10	2.63
Steel Rod (36 in)	8.54	1.33	11.39
CPVC Pipe (5 in)	0.20	1.00	0.20
Sheet Metal (144 in^2)	7.77	0.28	2.18
Washer (1)	0.08	9.00	0.72
Carriage Bolt (1)	0.32	2.00	0.64
Nuts (1)	0.04	9.00	0.36
Threaded Rod (1)	0.89	0.50	0.45
L Brackets (8)	1.66	0.50	0.83
Tab Container (3)	1.97	0.33	0.65
Stain (1)	4.58	0.02	0.09
Polyeurethane Spray (1)	4.74	0.05	0.24
Epoxy Glue (1)	1.97	0.01	0.02
Total			**21.21**

Results of Testing

Our team spent a long time working out theories and different techniques of how to safely crush a can and remove the tab, so when it came to building a prototype we had a good design basis and did not have to work as much at making the can crusher work. When we did finish the initial model we were happy with our accomplishment even if it was flawed.

All of the hard work during the design process paid off as a basic prototype was built to observe how it would look and work once finished. During construction, however, we came across some design flaws and problems that had to be overcome, such as the handle. The handle placement was a problem because of the force needed was dependant on how the lever was attached to the plunger device. We just decided to place it on the center and tried it. Once the prototype was finished and properly tested we determined that it would not make a good product because of its length. It did not allow enough space to get some force going before the plunger hit the can, and on top of that it would be awkward when placed on a receptacle.

We then proceeded to build another model, changing the lever design and building it longer to create less strain on the operator. Once this design was tested, we decided that it worked fine. Unfortunately this design had a problem with the tab hook. The hook became misaligned after several uses and had to be braced to prolong its lifespan. In addition to this, the crushing part bent after several uses. This was remedied by adding some metal to the part that bent.

When it came to actually testing our final design officially, it performed very well. It lived up to and exceeded our projected figure of merit in the categories of time taken and force used. We also underestimated the recyclable material by not considering wood to be recyclable. As stated before our hook for the tab bent a bit during testing but this has since been fixed. The can was crushed to about one inch. Our can crusher performed consistently during the testing. It worked every time as well as it was intended. The slight problems we had were not major by any means and were quickly fixed. Our figure of merit was initially estimated to be about 1889. Our final figure of merit actually turned out to be 1938.1, as shown in Table 6, due to the additional boost in the Environmental Impact category.

Table 6

C	V	T	R	EI	F	D	ID
$21.21	0.013m^3	6 s	1	95%	8 lbs	4.5	4.5

10·(50-C)	1000·(0.216-V)	2·(30-T)^2	50·R	15·sqrt(EI)	1000/(F+1)	8·(D+ID)	Total FOM
287.9	203	1152	50	146.2	27	72	1938.1

Although CAOS essentially had to scrap its original product five days before the deadline for testing, our talented team amended our original design and rebuilt from scratch a new can crusher that far exceeded our original product and our expectations too. The testing went very well for CAOS, and we feel very confident that we have built an excellent can crusher.

Summary and Conclusion

The need for a revolutionary can crusher arose. For many years aluminum has been wasted. It has been very inconvenient to recycle aluminum cans. And even when people did recycle, some aluminum was wasted. The can tabs are made of pure aluminum whereas the can is not pure aluminum. The pure tab aluminum was recycled with the can and thus it was never able to be purified again. Our can crusher needed not only to be able crush a can but also to remove the tab and place the tab and can into separate containers. This would allow the tabs to be recycled separately from the cans, allowing the purer aluminum used in the tab to reach its fullest potential through the recycling process. The problem was making such a device that would work well and yet be small and affordable.

Through a careful design process, CAOS designed a crusher that not only met, but far exceeded the requirements that had been placed on it. This can crusher is certainly the best of its kind, and we are thrilled with the wonderful results of our work. The operator needs only to use a mere eight pounds of force to crush the can to one inch. And not only is it easy, but it is also very quick. In only six seconds, with one smooth push and pull of the lever, the can is crushed, the tab is removed and the can and tab fall into separate containers. Our crusher also uses no electrical power. This allows the crusher to be placed anywhere without worrying about ugly extension cords or the need for underground wiring. The crusher is also very small and lightweight, allowing the shipping cost to be minimized and the aesthetic appearance to be greatly enhanced. We believe that if every city, college campus and park had one of these amazing can crushers, Americans would recycle much more and better the world in the process. The CAOS Crusher is truly a one-of-a-kind product that will change the recycling habits of Americans for years to come.