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Improving the Drying Process at Pacific Can - Beijing

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Abstract

The main goal of this project was to provide the Beijing plant of Pacific Can with a more cost-effective, energy-efficient alternative for drying their cans prior to paint coating. We analyzed the current drying process and conducted experiments to determine the feasibility of our proposed alternatives. Methods used include statistical analysis, time-study, seven-step process improvement, and cost-benefit analysis. We also took into consideration the potential for expansion of our alternatives to other facility locations of Pacific Can.

Authorship Statement

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Executive Summary

Pacific Can has been a leader in China's can making industry for many years. From a small startup in 1994 to a company with seven facilities producing over 10 million cans per day, they have certainly had much success. However, there is still room for improvement within their process of producing these cans.

This project will be focusing on how to make improvements on a specific segment of the whole manufacture – drying process. During the manufacturing process, the cans need to be dried completely in the drying process, after cleaning process, and before they move to the painting process. Currently, their method for drying the cans is a conveyor belt which runs 7.8 seconds for water to drop, and then enter an industrial size oven, running at temperatures of over 200 degrees Celsius and containing the cans for 50 seconds. If those cans are directly transmitted into the drying oven, the energy consumption during the drying process increases a great deal because of the amount of residual water that needs to be dried (average 2.1 grams for a 500 ml can).

The overall goal of the project being to find the most cost effective, quality solution for Pacific Can to implement in their current process, saving the company both money and energy usage. Based on DMAIC process improvement principle, we have decided to accomplish our overall project goal by completing the following five objectives:

1. Define – defined the scope of the process and identified the problem
2. Measure – measure the current performance of the can drying process by collecting data on some key aspects such as energy cost, energy usage, and production capabilities, then brainstorm possible solutions
3. Analyze – develop and design alternatives, and then choose feasible solutions for examination

4. Improve – design experiments and collect data for further data analysis
5. Control – make both short-term and long-term recommendations for the company to achieve continuous improvement

To better understand the problem, the team conducted preliminary analysis on the current process and possible solutions. Factors of optimizing the drying process include the cost, energy consumption, maintenance and implementation. Considering these and comparing them to the current oven drying process will lead to finding an improved and feasible solution. Energy consumption is a major contribution toward the decision of switching the process. The amount of energy used reflects temperature and cost, which means having high energy is impractical. The group brainstormed various alternatives and tested feasibility of each.

Our research methods for this project focused around time study, in order to accurately assess the current process and our proposed alternatives. The group conducted experiments on the use of infrared lighting to evaporate residual water in the cans. Once the experiments were completed, we performed a statistical analysis in order to provide Pacific Can with a range of options based on our recommended solutions.

With the capability of the infrared tube, there are positive signs in our results from the lab experiments that prove potential feasibility within the industry. The return of investment (ROI) for infrared tube system is approximately 264% (completely replacing oven with infrared).

Recommendations

Our main recommendation is for Pacific Can to implement infrared tubes underneath the conveyor belt that takes the cans from the washer to the oven, with an aluminum box around that section to retain heat. The box would have a ventilation system to remove excess moisture. The hot air removed during ventilation would then be cycled back into the box. This would cut down on the cleaning that would be necessary to avoid rust and allow the inside of the box to retain its luster and reflective properties. To be more specific, our recommendations can be divided into short term and long term recommendation:

Short Term

1. Having the cans in contact with the infrared for 10 seconds, and using the oven to complete the drying (at a lower time and temperature than Pacific Can currently uses) is the most feasible short-term recommendation based on our testing and current setup of Pacific Can's process.
2. Contact Epoxies Etc. to get assistance in regard to potential chemical compounds that could be used in wash process.

Long Term

1. Conducting experiments with multiple cans, having conveyor belt to transmit cans into the infrared tube system. If the results are positive, the company may completely replace the oven with infrared light system.
2. Another recommendation is to further investigate chemical compounds such as ME-50 that may help make the cans more hydrophobic making the drying process easier.

General Proposed Design for Infrared Tube System

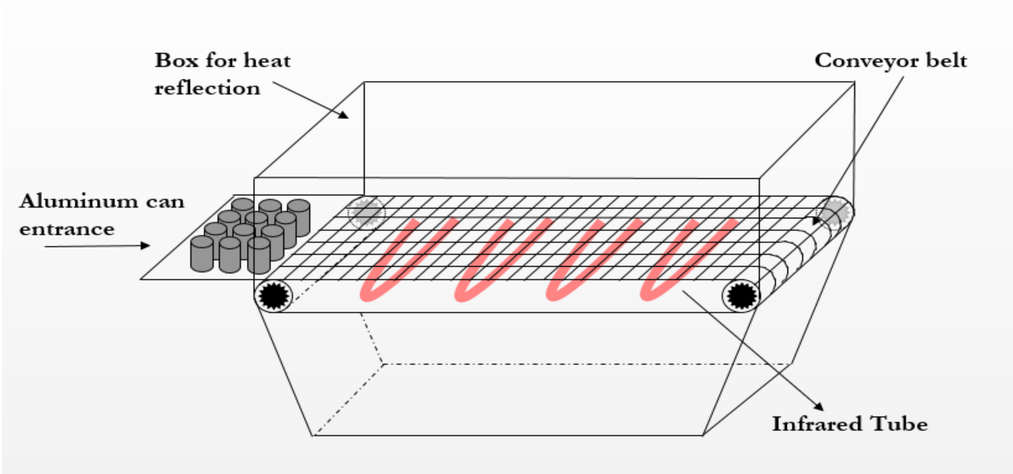

Figure 1 Proposed Design for Infrared Tube System

Innovation

Innovation means a new idea, device or method, or the process of introducing new ideas, devices, and methods. Innovation is something new whether a simple improvement or something that might change one's life completely. Some related process improvement principles related to Industrial Engineering include process flow charts, lean processing and six sigma, process analysis and operation analysis. To measure improvements in processes the use of cost-benefit analysis charts, benchmark tests and basic comparisons between results from the altered process and old process. The group conducted experiments, completed various cost analysis and recommended some innovative methods to enhance the current drying process for Pacific Can. Innovation in this project could affect the energy efficiency and consumption of a process, speed and production rate of a process, and long term savings for the company using the new process.

Limitations and Future Study

Hard constraints: Short time span (7 weeks), lab not accessible, lack of experiment equipment

Soft constraints: cultural differences, language barriers, group dynamics

Future Study: There are multiple opportunities for future study stemming from our project. Though the effectiveness of the infrared tubes was demonstrated through our experiments, a more strenuous time study using higher quality infrared tubes (those that Pacific Can would be more likely to use) and an environment closer to that of Pacific Cans' facility would provide an even more accurate estimate of that alternatives effectiveness. In regard to the our Acetone and ME-50 recommendations, future study either done by the engineers or in collaboration with Epoxies Etc. could yield even greater benefits industry-wide.

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Chapter 1 Introduction

1.1 Industry Background and Company Introduction

In 1959, the engineers at Bill Coors pioneered the use of aluminum cans in the beverage industry. [1] Aluminum cans have become one of the most popular and important packing methods because of its sustainability and recyclability. Statistics show that there are nearly eight billion aluminum cans sold in the United Kingdom alone every year. This type of material is not only light in weight, but also extremely recyclable. [2] Around 113,000 aluminum cans are recycled every minute. These recycled cans become new cans within 60 days. [3] The energy needed for recycling aluminum cans is only 5% of the energy used to produce it from the raw material bauxite. Cans may be recycled over and over again. The recycling process helps save a lot of energy without destroying the properties of the cans. [3] As a result, aluminum cans are frequently used by large beverage companies and have become the main product used by the majority of beverage package manufacturers.

This leads us to Pacific Can, China's leading 2-piece aluminum can manufacturer for beverage packing. The company believes that aluminum cans are relatively environmentally friendly, since they are easily recyclable. With the strong corporate ethics of honesty, fairness, and mutual respect for all stakeholders, Pacific Can has grown from a start-up business to one of the most well-known brands in the Chinese metal packaging industry. Pacific Can has had a great deal of success in implementing an active product-development cycle, leading to numerous innovative solutions. [4] However, there is still room for improvement within their process of producing these cans. This project will be focusing on how to make improvements on a specific segment of the whole manufacture – drying process.

1.2 Problem Statement

During the manufacturing process, the cans need to be dried completely in the drying process, after the cleaning process, and before they move to the painting process. The cleaning of the cans is totally automatic, with the cans utilizing being sprayed in a washer before moving along a conveyor belt. However, there is still about 2.1 grams (average for 500 ml can) of residual water droplets remaining in every can after the cleaning. If those cans are directly transmitted into the drying oven, the energy consumption during the drying process increases a great deal because of the amount of residual water that needs to be dried. With the objectives of saving energy and reducing costs, our project delves into the question of whether there are solutions to reduce the residual water droplets in cans during the cleaning process and drying process before cans go in the oven (if they need to go in the oven at all). If possible, changing the process and reducing the amount of time needed to dry the cans could help greatly increase the amount of cans produced. As a leader looking to remain at the forefront of the can industry, it's imperative for Pacific Can to adopt new measures to reduce energy consumption.

1.3 Project Goals and Objectives

Between the wash process and drying oven, the space is just about 1.4 meters long. Finding out a way to improve the process in such limited space is the main focus of the group. The overall goal of the project being to find the most cost effective, quality solution for Pacific Can to implement in their current process, saving the company both money and energy usage. The mission of the group is to do this by finding a way to reduce the amount of residual water during the cleaning process without slowing the production speed and output of aluminum cans. In order to better improve the process, the group evaluated the current performance of the drying process. We found the root cause of the problem could be attacked from two directions, changing the heat source of the drying process or implementing a way to remove water during the wash process. After understanding the root cause of the problem, the group brainstormed alternatives and researched companies who have had this problem in the past. The alternatives we focused on include altering the current mechanics of the process and the use of chemicals in the wash process.

The achievement of goals and objectives can be measured by statistical methods and the satisfactory level of the company. The group is expected to conduct and complete a set of experiments as well as various kinds of analysis to prove the feasibility and effectivity of potential alternatives. Experimental data and statistical figures can prove the effectiveness of possible solutions. Once the solutions are proved to be effective, the group will begin cost analysis and compare with the current situation. Final results and recommendations will be presented to the company. If the company is proved to be better off with our solutions (money and energy saved) and pleased with the results, goals and objectives of the project are achieved.

1.4 Company Profile

Pacific Can China Holdings Limited manufactures aluminum beverage cans. The company offers cans for beer, soft drinks, juice, and tea. Pacific Can China Holdings is based in Wan Chai, Hong Kong. [4]

Founded in 1991, Pacific Can has established a reputation for offering the highest standard of product quality, technical service and a growing product range. Pacific Can was established by former managers of the Continental Can Company, headquartered in the United States, an international producer of metal containers and packaging, and former colleagues, Mr. Glenn Yee. In 2003 Pacific Can’s Beijing plant production reached a milestone capacity of 1 billion cans per year.

In 2009, Pacific Can introduced their innovative two-piece Slick2oo can series. In 2012, Pacific Can was selected as the bronze winner of Cans of the Year for their Slick 355ml FUSION beer can. Pacific Can has six "large scale" production facilities (seven total). These plants are located in Beijing, Shenyang, Wuhan, Zhangzhou, Qingdao, and Zhao Qing. There are 1,070 employees working in these plants. These production facilities are all ISO9001 and FSSC 22000:2011 certified. The company has 13 total 2-piece aluminum can production lines. The Beijing location consists of three total production lines within its facility, all of which are constant production lines, with no delays throughout the entire process of the can. The Beijing facilities among others are all highly automated manufacturing environments; manual operation that exists within the facilities is for overseeing the daily process and for maintenance once at the end of each month. At the end of each month the production line is shut down to get a thorough cleaning and checklist to make sure the automated process is working properly. The Beijing facility incorporates multiple areas of the production line to seek out damaged or misshaped cans in order to keep the quality of the production high.

Pacific Can sells cans to an assortment of companies within China including China Pabst Blue Ribbon, Coca Cola, Tsingtao Beer, and Wusu Beer. Most of the companies are soft drink beverages or breweries in China that place orders for Pacific Can to manufacture.

Innovation is a large part of the work done at Pacific Can, which can be seen in their work by being the first to introduce a 500ml two-piece aluminum can, producing the first customized aluminum cans for JDB's herbal tea brand Wong Lo Kat, as well as, the Slick 200 can series. [5]

Figure 2 Pacific Can's Slick 2oo Can [5]

Chapter 2 Literature Review

The literature review for this project can be broken down into three sections. The first being innovation and entrepreneurship. There is a need for entrepreneurship and innovation in our specific project to implement a new idea or method to enhance the current drying process for Pacific Can. It's important to review these concepts in order to provide long term value for the company, and potentially the industry as a whole. By having an entrepreneurial mindset one is able to see the broader picture in regard to potential uses for our alternatives outside of this specific problem. The second focus of our literature review is Chemistry. Chemistry research is important in preparation for this project to fully understand how water interacts with certain types of heat, and the surface of the cans. It is especially important as we explore our chemical alternatives in the wash process as well. The third focus is on the principles of industrial engineering. Used properly, IE principles can help any project team or company make clearer decisions.

2.1 Defining Innovation

Innovation means a new idea, device or method, or the process of introducing new ideas, devices, and methods. Innovation is something new whether a simple improvement or something that might change one's life completely. The innovation lies within Entrepreneurship, which "According to Jeffrey Timmons research, entrepreneurship can be defined as a way of thinking and acting upon an opportunity to create new value". [6] Innovation is an important process in order to eliminate waste and further enhance a process. Being knowledgeable of the current process is crucial in order to make improvements.

Some related process improvement principles related to Industrial Engineering include process flow charts, lean processing and six sigma, process analysis and operation analysis. These principles help to enhance a particular process or method by reducing waste. One must understand the essentials of the process in order to further develop a solution for any problems that may exist. To measure improvements in processes the use of cost-benefit analysis charts, benchmark tests and basic comparisons between results from the altered process and old process. With the mentioned improvement principles and measurable improvement tests a process can be enhanced thoroughly and effectively to design an optimal solution.

There is a need for entrepreneurship and innovation in our specific project to implement a new idea or method to enhance the current drying process for Pacific Can. The need for a better method of drying the cans could create value for other companies or industries related to can manufacturing. Innovation could affect the energy efficiency and consumption of a process, speed and production rate of a process, and long term savings for the company using the new process. In order to develop a new method or process it is important to understand the old process and its limitations. Improving the process could lead to new value, for example - energy savings, reduced cost or increased production.

Innovation is important in Entrepreneurship because of the different mindsets and perspectives that may evolve from an idea or method. These ideas or methods may lead to the creation of a business that allows an individual to pursue further evolution of the idea or process. Entrepreneurs tend to think outside the box while being innovative with the way a business is approached and built. Example being that when a business is in its early stages it is important to devote focus to every aspect to mold the business to its original purpose and not lose sight of this purpose of creation. To be innovative one must be willing to take risks. Entrepreneurs do in pursuit of the end goal for the method or business created that implements and creates new value. An important aspect to focus on is having legal counsel, to ensure the method/process or business avoids copyright troubles and protects the intellectual property one has created.

Innovation and entrepreneurship are important to Industrial Engineers because the value of creating something new or improving an existing method is one of the main focuses of an Industrial Engineer. To implement a new method or idea is to be innovative while seizing the chance or opportunity to create a business out of the new idea or method created.

Since the industrial revolution in 1760 to 1820, according to the BBC [7], the manufacturing process went through a tremendous transformation from working by hand to machine. New processes have developed, new chemical plants, and the production of metals have increased. All of these changes have played a role in improving the efficiency and current operating conditions in industry.

The chemical revolution started in 1750s. It was when Joseph Black discovered carbon dioxide, which was the milestone of most commercial chemicals. After Black's discovering carbon dioxide in the air, the scientists started focusing on the composition of air, which led to discovering Nitrogen, Oxygen, Chlorine and Hydrogen. Also, the scientists discovered Alkaline Earth metals at that time, which was the foundation of the industrial revolution.

The industrial and chemical revolutions led to increased demands thus creating another revolution according to the BBC [7], which was the commercial revolution. The chemical discoveries were needed during that era. For example, using Chlorine to bleach linens, made the process more efficient. Thus it increased the demand for the Scottish linen in Europe.

BBC mentioned that after the previous revolutionized movements towards a better future, it made the people eager for better efficiency. At the beginning of these revolutions, the people were responsible for doing the actual job, which, indicates that the process was fluctuating depending on the people who worked in that process. It led the leaders of the industry, at that time, to focus their attention on the machining and automotive industries, to create a factory system. [7]

Since then, the plants and processes have undergone a more specific and continuous development in all aspects. It indicates humanity's instinct to seek the best in every subject. Optimization is to develop the need to specialize in certain knowledge to achieve a desired result.

2.2 Innovation in Our Project

Using acetone to reduce the flashpoint of the liquid stuck in the cans is one example of innovation tied into our project. This idea, if implemented (and void of safety concerns), would be extremely valuable to Pacific Can and others in the industry by lessening the amount of heat needed to run the oven. Without having done a cost-benefit analysis on this alternative, it is not known whether this would save Pacific Can money in the short term, but would definitely be beneficial to a company looking to reduce energy consumption.

Designing a compressed air system to remove the residual water out of the cans is also an innovative possibility within our project. An array of air nozzles would be set above the cans so the residual water can be blown out by the compressed air. This would allow for a stop and go process that may be quicker than the current slow moving process through the oven. Since compressed air would be a cheaper more energy efficient way to remove the residual water, there is value added from this process for the industry. Long and short term cost benefit analysis is needed in order to better understand the savings in this process. One thing's for sure, the initial cost would be high. Since a new design would be needed for implementing an air system for this process. This method would help the industry become more energy efficient.

One of the most common methods that coincide with optimizing a drying oven is to isolate the oven from the outside / inside, depending on the objective the designer wants to obtain. There would be a need to prevent the heat from escaping towards its surroundings. In order to proceed with this alternative, the engineer has to obtain data about the compatibility of the oven towards the coating material. Also, the engineer has to know the dimensions of the oven, in order to sense the amount of heat that escapes from the system. Finally, need to investigate the feasibility this alternative and see if it is easy to maintain at an optimal condition.

When the final alternative or alternatives are listed, it may come down to the comparison of multiple criteria such as cost, feasibility, material purchasing and implementation. The decision on which process to proceed with may be based on certain criteria desired from the company or specific process, as certain criteria may be more important to the final decision. So with the comparison of all the necessary criteria to correct the most viable alternative will be chosen.

2.3 How Can Industrial Engineering Help Lead to Better Decisions?

Though the goals can vary from project to project, we as industrial engineers have found that there are a few common themes to what we do. At the start of a project (and usually throughout), we research and ask questions to develop an understanding of how the system functions so that we are able to make practical recommendations. Problems rarely affect just one aspect of a business, so in developing a keen understanding of the whole, we can be better prepared to anticipate any externalities that may occur from our alternatives. In regard to our end goals, we find ways to make a product faster and easier to use. We find safer, and/or less expensive ways to complete a task. We accomplish this by examining and analyzing the current process or service to find better ways to solve the problem(s). IE's often team up with people from other fields in order to gain a richer understanding of the process and create more feasible alternatives. Put simply, industrial engineers do whatever they can to find a better way. Delving deep into the process is what separates the engineers from technicians. The engineers know where techniques/formulas came from and how to use them to solve problems. Our toolbox as engineers is vast, and continues to grow.

While an IE's toolbox is continuously growing, we understand that solutions to real-world problems can rarely be straight from a textbook, or apply identically to more than one situation. Flexibility in respect to the use of our tools is an essential skill for any industrial engineer who hopes to attain high performance for their clients.

In looking to help Pacific Can reduce costs, we defined some fundamental aspects and techniques of the decision making process that we will use to come up with and implement the alternatives. We started by answering two basic questions.

1. What is a process?

A process is a series of actions or steps in order to achieve a particular end", Oxford dictionary". An example of a process would be the steps in a recipe for how to cook a meal. Industrial Engineering is dependent on these different processes, including processes in departments such as social networking, manufacturing, and human resources. The specific process to focus on for Pacific Can is within the manufacturing process, with the drying process to remove the residual from the cans. The focus on improving this current process is our main objective.

2. How to measure process improvement?

In order to measure process improvement first you must establish standards and definitions of the process. These standards and definitions provide a uniform way to measure the process and they also provide a benchmark for testing and comparison. Using these standards definitions, an assessment can be made on whether the improvements were either positive or negative. The assessment also can identify the effects that the improvements made on the processes' outcomes. Depending on the results of the comparison, an action plan to improve the process can be established. This plan ensures continuous improvement based on the goals or objectives of the company and department.

2.4 Industrial Engineering Principles

What industrial engineering principles are relevant to our project? In this section, we will introduce some useful industrial engineering principles which can help us analyze and improve the process.

2.4.1 Time Study

Work Measurement Study is a productivity improvement tool used to “describe the systematic application of industrial engineering techniques to establish the work content and time it should take to complete a task or series of tasks”. [8] Time Study is the most common work measurement technique used in industry. It consists of using a timekeeping device such as decimal minute stopwatch and videotape camera to record the time required for a worker to accomplish a task by standard methods. The time it would take a qualified and well-trained operator working at a regular speed can be defined as standard time. [9] Standard times are essential for the estimation of inputs in production including manpower, equipment and raw material requirements. It can also help determine workers’ efficiency.

The application of time study method in industry for work planning and performance measuring was pioneered by Frederick W. Taylor in 1881. When Taylor first came up with the idea of altering management using scientific methods and make it calculable and writable techniques, he divided each job into small parts called “elements” and recorded time taken by each part to accomplish a specific task. Then he reorganized those elements in order to find the most efficient way. He presented a series of his study including time study and standardization to and alternation of working environment at the American Society of Mechanical Engineers meeting in June, 1903 and received positive feedbacks from a number of factory managers. By the end of 1979, more than 113 facility plants had implemented Taylor’s “Scientific Management” and 59 of them had great successes. [10]

Factories and companies conducted time study to establish standard times. This allow them set a working standard and rate operators’ performance. In operation and production, time study can help overall capacity planning by gaining information and calculating necessary inputs and estimated outputs.

Direct time study procedures including five phases: 1) Set study goal – define the task and standard methods needed to accomplish the task; 2) Conduct experiment – breakdown tasks into elements and determine job cycles; 3) Collect data – record the time taken by each work elements; 4) Data Analyze – Evaluate performance, compute normal time and standard time by applying allowance factors; 5) Report findings and continuously making improvements. [11]

Time study will be used in conjunction with our laboratory simulations to determine the amount of time necessary for the cans to dry, based on the amount of infrared lights or acetone used (and possibly other, currently unexplored, alternatives). According to the basic steps researched [12], time study experiment in our project is conducted by following these steps below:

(1) Obtaining and recording information of experiment equipment and weight of residual water

(2) Breaking down experiment process into elements (recording time at each 10 seconds)

(3) Measuring with timing device and recording the time

(4) Converting the observed times, to normal times.

(5) Determining the allowed time for the can to dry completely.

Flow chart for time study in our project is shown below in figure 3:

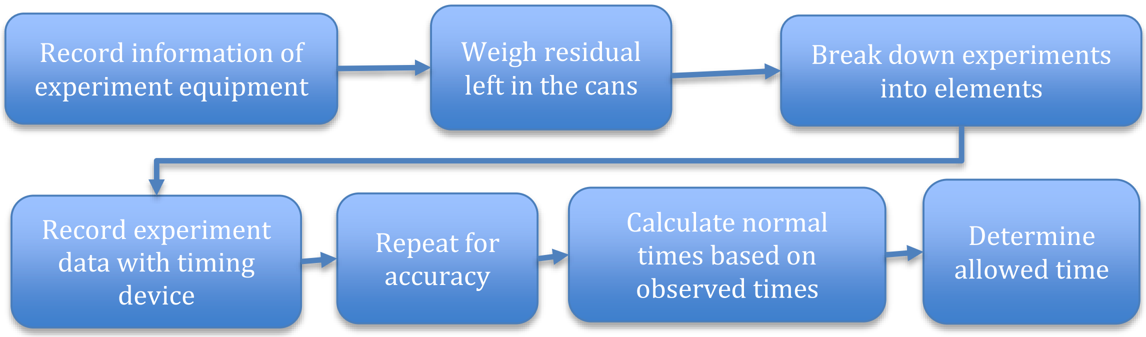

Figure 3 Time Study Steps for our project

2.4.2 Cost-Benefit Analysis

Cost benefit Analysis is a way to systematically measure the strengths and weaknesses of different alternatives. These alternatives are optimal solutions based upon the requirements of the business. [13] Cost Benefit Analysis compares the calculated labor, time and cost savings of alternatives that would best be adopted for practice within the business. When calculating these benefits each has a priority or rank. For example, labor costs being regulated by the government can conflict with a business's decision on which alternative to choose, not all decisions would be revolved around cost. [14] Cost Benefit Analysis helps portray these different alternatives against each other in order to find the one best suited for the business serving two purposes. Firstly to determine if an alternative is a sound and feasible investment. Secondly, to provide a detailed comparison between alternatives with respect to total costs, and total benefits of each. Whether or not the costs outweigh the benefits and vice versa. [15]

In Cost Benefit Analysis, benefits and costs are mentioned in monetary terms, and are adjusted to the time value of money. [16] So all benefits and costs of a project or alternative are expressed on similar terms of value relating to the net present value or NPV. Cost Effectiveness is closely related but distinct from Cost Benefit Analysis, CEA instead is displayed as a ratio and is common in the health industry comparing relative costs and outcomes. For example, gaining health displayed as the denominator and the cost of gaining health displayed as the numerator.

Cost Benefit Analysis is relevant to our project because we have multiple alternatives for the drying process. Each alternative including different total costs and benefits related to Pacific Can's goals. All alternatives will be considered for improving the drying process, but the most cost effective, energy efficient and feasible one will be selected. Using Cost Benefit Analysis to demonstrate a comparison for the optimal solution based on Pacific Can's expectations.

Relevant formulas: Return on Investment;

ROI: (gain from investment – cost of investment) / cost of investment

Gain from investment refers to the proceeds obtained from the sale of the investment. In this case, it is the difference between the current alternative (drying oven) and our recommended alternative. We have obtained this data through conversations with Pacific Can engineers in regard to energy use, and cost per energy unit. Cost of investment is the estimated cost that one of our given alternatives would be. This information is obtained through experiment results (which allows us to determine energy needed to obtain desired level of effectiveness), and online research regarding pricing for the energy units used.

2.4.3 SMART: Simple Multi-Attribute Rating Technique

Step one in a SMART process is to identify the decision makers. The decision makers in our case include the CEO and engineers at Pacific Can, and to some degree, our own team. Step two is to identify the alternative courses of action. For us, there are three. The current process, which is an oven used at the as the sole drying method. Second, infrared tubes placed under the conveyor belt. The third alternative being to add acetone into the wash process in order to reduce the temperature needed to evaporate the water off of cans in the oven.

Steps three and four are to identify and measure attributes (costs and benefits) that are relevant to the decision. In order to more easily see the attributes influencing this decision, a value tree can be created. This tree is broken down by costs and benefits, and becomes more specific as it goes down. These attributes should be complete, decomposable, and as small as possible without being redundant. [17] One begins by measuring the monetary attributes (such as rent, capital cost, profit, etc.), and comparing each of the alternatives in these categories. Next, one looks at the performance of each attribute in the non-monetary categories (size of building, comfort, employee morale, etc.) These attributes are given a weight (between 0 and 100) by the decision maker. [18]

Measuring non-quantifiable attributes (such as effect on employee morale) can be tricky. We do our best to clear this up by asking the decision makers to rank the alternatives from best to worst according to each non-quantifiable alternative. [19] We then assign a direct rating to each alternative through these rankings (100 points for the highest ranked, 0 for the lowest. Alternatives in the middle fall along the spectrum according to the decision makers). The next step is a little easier.

In measuring quantifiable attributes, the same 0 to 100 point rating system is used. However, a function can be used to determine where the middle alternatives should fall. For example, assume you were comparing the square footage between three houses. House #1 has a square footage of 3,000 feet, house #2 a square footage of 2850 feet, and the third a square footage of just 950 feet. It would not make sense for house #2 to receive only 50 points for this attribute when it is actually 95% as large as house #1 (which was given a 100 point rating). This process is done for each attribute. [20]

At this point in SMART we have weights for the attributes, and ratings given for each alternative based on these attributes. In order to summarize the data and help make a clear decision, we now multiply the weights (normalized) by the points for each alternative, and sum up the columns for each. The sum for each alternative is called the aggregate benefit.

After the aggregate benefits are found, we can make a provisional decision, and then conduct a sensitivity analysis to determine the uncertainty in our decision based on the inputs given by the decision makers.

2.4.4 Net Present Value (NPV)

Net present value is a reliable tool when choosing between alternatives on a project, as it accounts for the time value of money, not just cost alone. This is done using discounted cash inflows. For example, would you rather receive $100 today, or $100 a year from now? The $100 today certainly has more value than $100 a year from now, as there are many things you could do with that money over the next year that you would be missing out on had you chosen to wait a year (such as invest it). NPV uses the present value of net cash inflows generated by a project plus any salvage value (i.e. selling a truck after you've gotten your use out of it).

Before calculating NPV for an alternative, a target rate of return is set to discount the net cash inflows from a project. Net cash inflow is equal to total cash inflow during a period, minus the expenses that are caused by generating that cash flow (i.e. cost to use a machine during that period). [21] [22]

As one of our end goals is to save Pacific Can money on energy costs, comparing the net present value between the different alternatives will help provide a clearer picture (to both our group and the company) about which alternatives are most attractive.

NPV = ∑ {Net Period Cash Flow/(1+R)^T} - Initial Investment where R is the rate of return and T is the number of time periods. At this time, the interest rate for the People's Bank of China is 4.85%.

2.4.5 DMAIC and Seven-Step Process Improvement

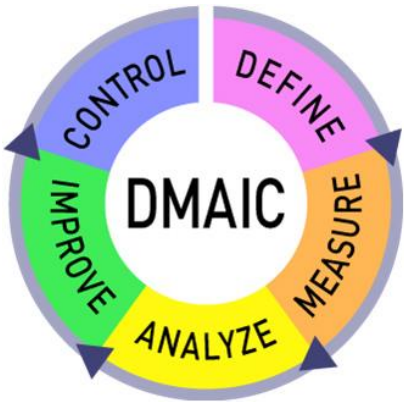

Figure 4 DMAIC [25]

DMAIC is a process improvement cycle focusing on data-driven changes. [23] This cycle starts by defining (D) the problem the company is facing, then using metrics to quantify/measure (M) the gap between current and wanted performance. The metrics are then analyzed (A) to identify the root causes of any problems that could be hindering the system from performing optimally. The system is then improved (I) by testing and then implementing solution(s) to the problem. The company would like to sustain these gains, so they create a control (C) plan to ensure that the improvements made can/will continue. [24] The seven step improvement process is similar. That process begins with defining should be measured, and then looking at what realistically can be measured. Then data collection/analysis occurs, and the information gathered is presented in a useful way. Implementing the corrective action is the final step. [26] General steps in DMAIC can be seen in figure 5.

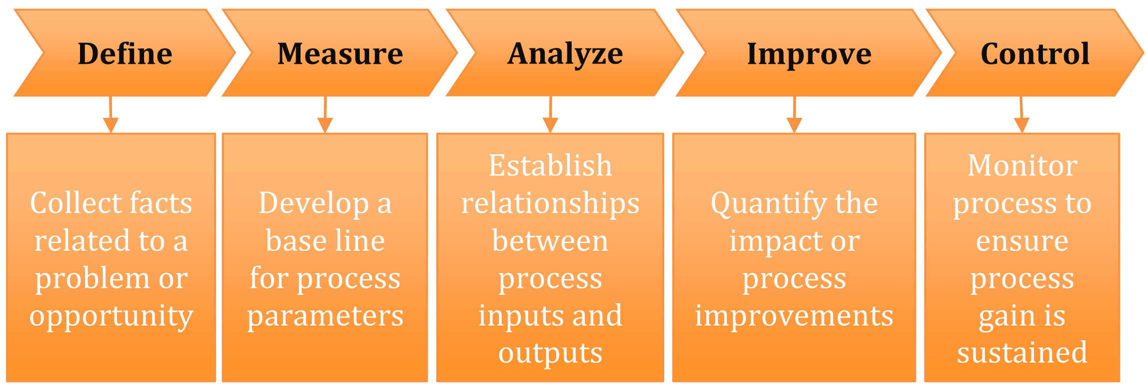

Figure 5 DMAIC process map [27]

Between DMAIC and seven step process improvement, we concluded that seven step would be more compatible to our project. Seven step process improvement provided us with an outline to schedule our project and define what we needed at each step prior to coming to Beijing. The figure below shows both the timeframe for each step and what was completed within that step. Detailed steps and contents are shown in figure 6 below:

Step 1 - Deciding What Should Be Measured PQP	Step 2 - Find Out What Can Be Measured PQP/Week One	Step 3 - Gathering Data PQP -Week Five	Steps 4/5 - Process and Analyze Data Weeks Three through Five	Step 6 - Present and Use Information Weeks Six-Seven	Step 7 - Implementation Future Study
In this step we: • Defined the problem • Identified root cause	• BUCT students conducted a time study for the current wash and drying process. • Pacific Can was able to provide us with energy costs, as well as relevant numbers for our lab simulations, such as the temperature of the oven and water in the cans	• Data we received from Pacific Can • Results from our laboratory experiments.	• Looking at results • Splitting data to find patterns • Calculating cost and effectiveness based on results	• Gave final presentation to Pacific Can with our recommendations based on experiments and other research (such as looking at companies to help with our chemical alternative)	• Not part of the process that we will be overseeing, but our recommendations provide them with a short term solution (infrared tubes underneath conveyor belt), options and the opportunity for future study to implement both long and short term solutions

Figure 6 Breakdown of Seven-Step in Our Project

2.4.6 Systems Thinking

Systems thinking is the process of understanding how one aspect of a system influences the whole system. [28] An example that came to mind is a person with a knee issue (the human body is the system in this example). The person could use a knee brace, but it could possibly affect the way they walk, causing an issue in another part of the system (i.e. back, hip). It's said that the full understanding of why a problem or element occurs is by understanding the parts in relation to the whole. Systems thinking is all about the understanding of how elements of the system are linked, their interactions, and the composition of the system as a whole. [29] [30]

Systems thinking is relevant to any project, because it is necessary to try to consider all possible externalities that may occur from changes made to a process. In our case, acetone may affect the paint's ability to stick and/or stay on the cans (a part of the process that another group is currently working on improving).

2.4.7 Design of Experiments

Design of experiments (DOE), according to Hugh Smallwood, means "the planning of a group of experiments so that their combined result will yield a maximum amount of information for the work which has been expended". [31] It is a statistical methodology which can help analytics determine the relationship between variables involved in a process. The purpose of design of experiments is to find the variability, in other words, how the process variables affect output variables under various situations. Analytics can change several variables at the same time. [32]

Experimental designs include many different types. The simplest one is called the "block experiment". The experiment divided selected items into groups to make sure there are not much difference between variation of medium and it between groups. The design of block experiments needs to avoid repetition in order to ensure desired results. The purpose of block experiment is to reduce as much variability of experimental medium as possible. The other type of experimental design is factorial experiment. The experiment is completed by assigning each variable with different number of values and combining each value with associated variables. [33]

Analysis of variance and randomization are two important factors in DOE. Analysis of variance (ANOVA) is the analysis variation among groups by using statistical. It is a very important topic in the study of statistics and quality management. Randomization also plays an important role in statistical analysis. It choose representatives from the general population without any biases. The use of randomization ensures that each element in the population has the same chance to be selected. “It is necessary and is an essential element in the design of experiments”, said by Brewer. [33]

To test our proposed alternatives, especially the implementation of infrared light tube system, we will need to conduct a series of experiments in order to collect enough data and prove the validation of the new system. Design of experiment will provide us a theoretical base and have a better design for our experiments.

Chapter 3 Methodology

3.1 Review of Overall Project Goal and Objectives

As we discussed earlier in the first chapter, our overall project goal is to find an innovative way which can help the company save both energy and cost. To achieve the goal of reducing residual water and improve efficiency, the group will analyze the current process and proposed alternatives by using all the industrial engineering principles mentioned in Chapter 3. Based on DMAIC process improvement principle, we have decided to accomplish our overall project goal by completing the following five objectives:

(1) Define – defined the scope of the process and identified the problem

(2) Measure – measure the current performance of the can drying process by collecting data on some key aspects such as energy cost, energy usage, and production capabilities, then brainstorm possible solutions

(3) Analyze – develop and design alternatives, and then choose feasible solutions for examination

(4) Improve – design experiments and collect data for further data analysis

(5) Control – make both short-term and long-term recommendations for the company to achieve continuous improvement

3.2 Project Overview (Flow Chart)

The total timeframe of the project is 14 week, which lasted from early March to late August in 2015. The first stage (7 weeks) is called PQP which was completed by the group on campus at Worcester Polytechnic Institute. The project description and problem statement was received at the beginning of March. During the PQP stage, the group communicated with sponsors to understand expectations and partners to brainstorm possible alternatives. We also researched literatures on relevant topics, and completed background section as well as methodology section of the project report.

The other half of the project was completed by the group in Beijing. At first we visited Pacific Can (Beijing branch in Huairou District) to gather useful information. During week 2 to week 4 in Beijing, the group, together with partners from Beijing University of Chemical Technology, started to conduct experiments on possible solutions. Data was recorded and analyzed in order to prove the feasibility and effectivity. Results were presented to the company at the fifth week for feedbacks. At the final stage of the project, we finished our final project report and provided a series of recommendations to the company. Figure 7 demonstrated the project flow in flow chart style.

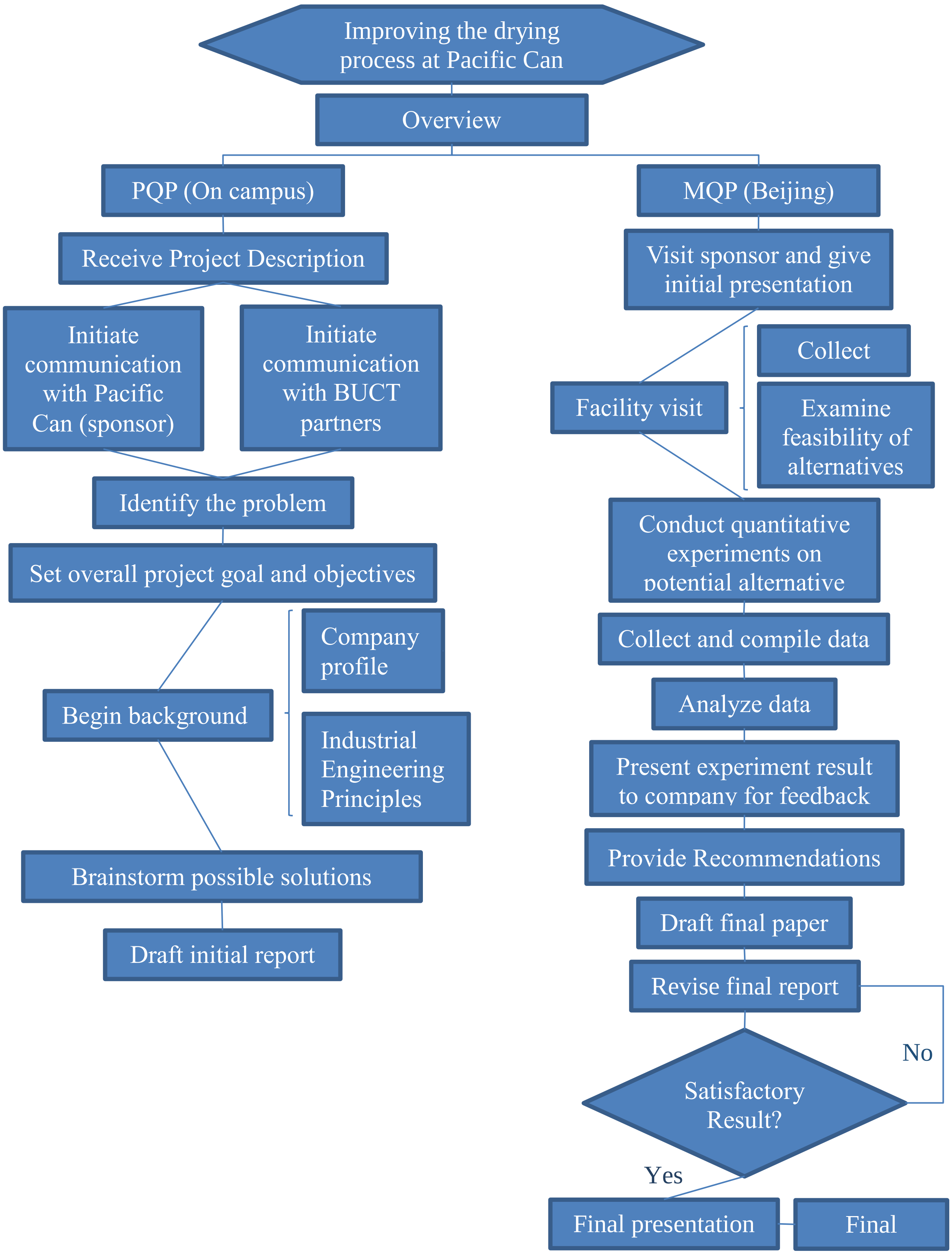

Figure 7 Project Flow Chart

3.3 Gantt Chart (Schedule)

Figures 8 and 9 show our outline of the project through the use of a Gantt chart. It is a scheduling tool that shows each step of the through the use of horizontal bars. The positioning and length of these bars is determined by the start and finish dates of the task. It allows project managers to easily see the order of tasks, dependencies (predecessors), and quickly compare project progress to where the project was expected to be when the chart was created. In our case, representing the problem, testing alternatives, selecting the recommended design, and developing the implementation plan were all our main tasks for the project. These are represented by the black bars on the charts in figure 9. Within these main tasks, subtasks provide depth and actionable activities that will be performed. Subtasks are represented as green bars on the chart.

MQP Drying Process Gantt Chart

	Task Name	Start Date	End Date	Duration	Predecessors
1	<Represent Problem>	06/30/15	07/02/15	3	
2	<Find/validate energy costs>	06/30/15	07/02/15	3	
3	<Testing Alternatives>	07/03/15	07/20/15	12	1
4	<narrow down alternatives>	07/03/15	07/06/15	2	
5	<test chosen alternatives>	07/07/15	07/09/15	3	4
6	<cost benefit analyses>	07/10/15	07/20/15	7	4, 5
7	<Select Recommended Design>	07/21/15	07/23/15	19	6
8	<select recommended design>	07/21/15	07/23/15	3	6
9	<Develop Implementation Plan>	07/24/15	08/14/15	16	8
10	<develop implementation plan>	07/24/15	08/06/15	10	
11	Wrap up/presentation prep	08/07/15	08/14/15	6	10

Figure 8 Gantt Chart Detailed Summary

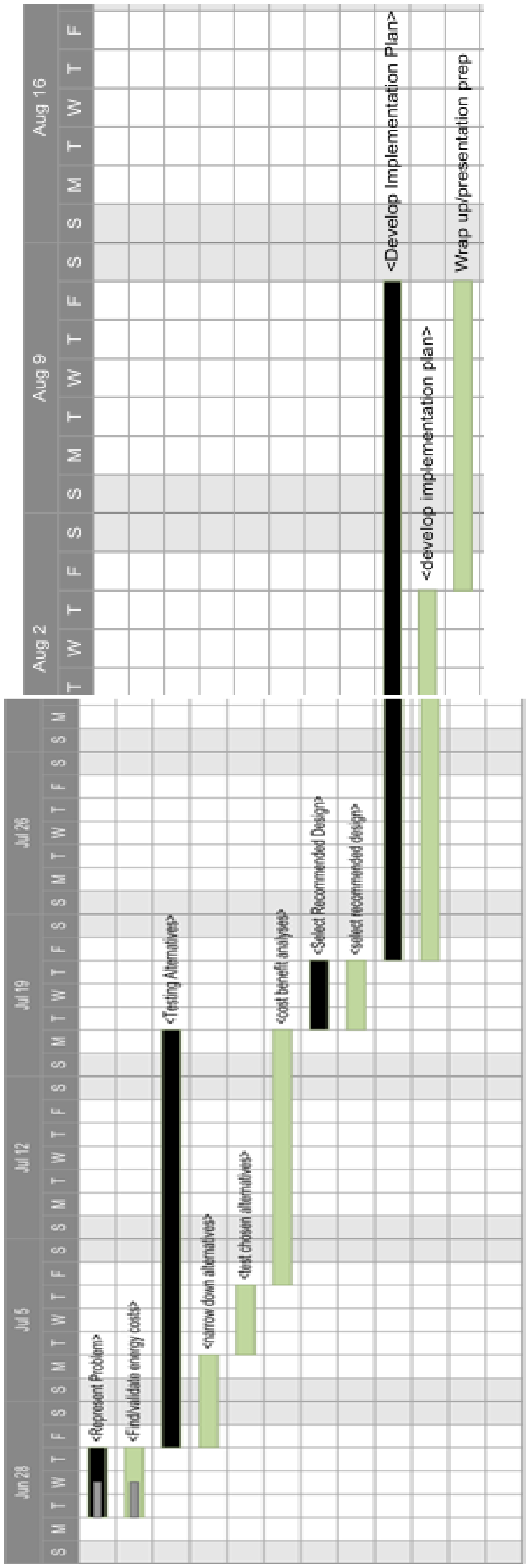

Figure 9 Gantt Chart

3.3 Revised Schedule, Using Seven-Step Process Improvement

Schedule (using 7-step process improvement)	
	What was done
Step 1 - Decide what should be measured	
PQP	Defined the problem; residual water in cans and excessive energy costs due to this (oven has to run very hot)
misc. notes	BUCT students began testing of infrared alternative
Deliverable	PQP Paper
Step 2 - Find out what CAN be measured	
PQP	Initial time study for current wash/drying process completed by BUCT students
Week 1	Pacific Can says energy costs, temperature of elements involved (oven, water, etc.) are available
misc. notes	
Deliverable	PQP Paper
Step 3 - Gather Data	
PQP	Received some data and initial experiment results from BUCT students
Week 1	Received concrete energy costs from Pacific can, began infrared experiments
Weeks 2-5	design simulation environment, collect data for Acetone alternative + Infrared/Acetone combinations, others as necessary
Weeks 3,5	visit Pacific Can, speak with and gather feedback from Engineers
Weeks 3-5	Gather costs, as possible, for infrared and acetone as if they were to be implemented
misc. notes	Lab was available Saturday 7/4 but will not be available again until Thursday 7/9
	Infrared experiment was completed in an open environment, looking to design closed environment to simulate Pacific Can's process
	Speaking with BUCT advisor to gather supplies necessary for acetone experiment and building closed environment
	Find out how acetone/chemicals will affect paint process
Steps 4 & 5 - Process/Analyze Data	
Week 3	Begin looking at costs for infrared implementation for Pacific Can
Week 4	Begin Cost Benefit analysis, results from time study

Week 5	Complete Cost Benefit analysis, IE methods, and results from time study
Step 6 - Present and Use Information	
Week 6	Provide recommendations to Pacific Can - request feedback
Week 7	Recommendations, adjusted if necessary based on feedback
Misc notes	
Deliverable	Objective recommendations to Pacific Can + Final Report to Advisors
Step 7 - Implementation	
Week 7	n/a while we are on-site
Misc notes	

Table 1 Project Revised Schedule

3.4 Overview of Research Methods

Method	How it was used	Outcome/Best Alternative (BA)
Time Study	Gathered comparable data for multiple alternatives and testing	Allowed for comparable data that pointed out which process improvement worked best. BA: **Infrared**
Cost Benefit Analysis	Compared costs of alternatives to current process in order to find cost effective alternative	Discovered most cost efficient alternative and ROI BA: **Infrared**
SMART	Created a value tree for costs vs benefits of each alternative with each attribute being appointed a value according to company needs	Value tree and subsequent SMART diagram helped point out which alternative was most desired according to companies' desires of lowering cost and energy consumption. BA: **Acetone/ME-50**
Systems Thinking	Look at externalities in other processes that might be affected by alternatives or externalities that might affect the alternatives	Changes to drying process based on our recommendations would not have known effect on other aspects of the system.
Seven Step Process Improvement	Applied to project, understand the problem, define what will be measured, gather data, analyze data, list alternative, choose alternative and implement ideal alternative	Allowed effective method of identifying the problem and creating a solution such as the infrared lighting

Table 2 Overview of Research Methods

Chapter 4 Preliminary Analysis

4.1 Current Process (Oven)

The company currently uses an oven to evaporate residual water left in cans. A picture of the current facility can be seen in figure 10. The energy usage is 365,000-m3/ year of natural gas for the first drying oven and 328,500-m^3/year of natural gas for the second oven in the manufacturing process. Assuming the plant is in operation 24 hours a day for the entire year except for the maintenance days once a month, the cost is about 2,621,430RMB, and in USD this is equal to about $422,811. The calculated cost is only for the operation of the two ovens in the manufacturing process. In 2015 from January to June, the twelve ovens between the 6 manufacturing plants consumed 0.94 million M^3 of natural gas. Assuming all ovens work on a similar schedule for the year this consumption would double to 1.88 million M^3 a year of natural gas roughly 7.2 million RMB and $1.2 million USD of coarse prices of natural gas vary between country and region.

Figure 10 Picture of Current Process

According to sources [34] 1 M^3 of natural gas is about 35,300 BTU, and the consumption per day is about 1000 M^3, which is 35,300,000 BTU per day. When broken down energy consumption per second is 409 BTU/sec, while there are 300 cans per batch and each batch is in the oven for 7.8 seconds consuming 3187 BTU drying the 630 g of residual water per batch. Picture demonstrated the current process is shown as figure 11 below.

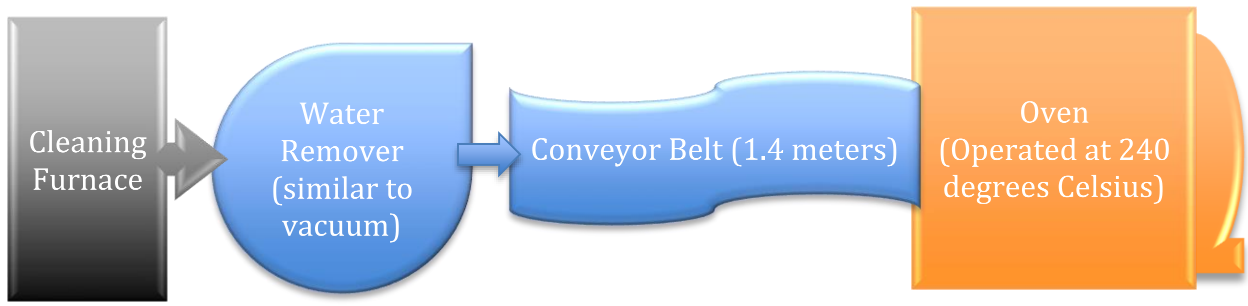

Figure 11 Simplified Diagram of Current Process

Factors of optimizing the drying process include the cost, energy consumption, maintenance and implementation. Considering these and comparing them to the current oven drying process will lead to finding an improved and feasible solution. The goal is to keep the time in the oven to a minimum and if possible remove the oven completely, while decreasing cost or energy consumption, having multiple ways to do so. While trying to find a viable solution compared to the current drying process, the current production rate should also be considered because Pacific Can would like to maintain the same rate.

Energy consumption is a major contribution toward the decision of switching the process. The amount of energy used reflects temperature and cost, which means having high energy or cost is impractical. Even more, if the heat energy is too high then the cans may become imperfect and melt.

Along with providing a high performing alternative, another major factor in this project is providing Pacific Can with a low cost solution. For instance, some companies invest large capital in order to save for the next ten years; however, Pacific Can investment cost may be low for a company of such value. Further information on the cost analysis is in the following sections.

Implementation is a key factor, in some cases, companies could figure out some new technique and strategies to further develop production, processes or technology. However, implementing that idea might not be possible at that moment, depending on funds, space and cost to company from the changes, therefore, they obtain only the patent on the idea or method.

The ability to control the process is what Pacific Can relies on to make further analysis and decisions. In this project, a Programmable Logic Controller (PLC) will be recommended in order to regulate the temperature of the drying process used. It takes some time (about two weeks, with computer science experience) to program, so it may not be feasible for us to test with one.

After gaining the initial data (Table 3), the team suggested the following solutions in different categories to achieve the goal of improving the drying process:

Data categories	**DATA**
Transmission time	7.8s
Transmission distance	1.2m
Width of the conveyor belt	1.29m
The number of aluminum cans on conveyor belt	300
The weight of residual water (average)	2g（500ml can）
Energy consumption of the old drying furnace	gas， 240centigrade， 8m， 52s

Table 3 Initial Data

4.2 Theorized Alternatives

In determining what possibilities there were to solve Pacific Can's high energy cost issue, we came up with a variety of alternatives. Some alternatives could not be expounded upon due to the lack of technology, technical skill and experience of workers and ourselves, space currently available in the facility, or government regulations. However, they can be proven to be a successful alternative in theory. Providing theoretical alternatives could lead to more effective solutions for the company in the future.

A good example of this is our chemical method alternative, in which the use of a certain compound would lower the boiling point and make the evaporation rate faster. This alternative can be proven in a lab with a time study experiment, given a proper environment and the use of random sampling to back up the results. However, there might be regulation on the use of chemicals in certain industries. Also, the lack of technologies and could restrict that alternative. Therefore, some of the alternatives are considered to be theoretical and must be tested.

4.2.1 Polymer Coating

Designing a polymer coating on the inside of the can in order to make the can hydrophobic. Silica Nano-coating is a cheap and common resource in order to proceed with such a design. Biphenyl A is another choice for creating a polymer as mentioned. Both Silica Nano-coating and Biphenyl A are non-reactive polymers that will not contaminate beverages within the cans being produced. Safety concerns of the chemical compounds vary by region and country for which chemicals are approved. Either compound will incur a different cost depending on the ratio used to create the compound and the availability of the compounds to Pacific Can. The polymer coating was not further experimented with because the difficulty to obtain chemicals at the project site, lack of resources and labs to conduct the experiments needed.

4.2.2 Vacuum System

Designing a vacuum system that increases the pressure to evaporate the water at room temperature so there is no need of an oven to heat the cans. [35] There is already a vacuum in the system but is used to transport the cans between various stages of production from and to different conveyors. Pacific Can once tried using a vacuum system to dry the residual water, but the problem that occurred was the pressure was too high and would crush the cans. This was not beneficial because there were more failed cans than the company wanted to allow from production. Since the company has previously tried using this process it was suggested to experiment different alternatives other than a vacuum system. Quality of the final product is a concern for Pacific Can using an alternative such as the vacuum system.

4.2.3 ME-50/Acetone

Adding a specific chemical such as Acetone or Me-50 to the water in the washing process would allow the physical properties of water to change. Doing so would make the water evaporate quicker, or become more viscous to the surface of the cans. Health concerns when using chemicals in the manufacturing process is crucial, making sure the correct grades of Acetone or ME-50 are used. Pacific Can currently uses the compound ME-50, which lowers the temperature needed in the oven by about 30 degrees Celsius. After consulting the engineers at Pacific Can it is brought to our attention that they do not know how the compound is made, the company purchases it and adds it to the process in some of the newer manufacturing plants. Pacific Can does not know enough about the ME-50 compound to provide details of how it works within the process they use it for, only that the temperature needed in the oven is reduced. Since this compound is already used our team looked more into alternate options that could possibly improve the drying process with other methods.

Table I. Integral Heat of Mixing of Water and Acetone at 90° C.

Mole % Water	Cal./Mole		Mole % Water	Cal./Mole	
	Water	Mixture		Water	Mixture
2.11	519	10.9	74.8	98.7	73.8
9.46	919	87.0	77.7	57.5	44.7
9.55	1083	103.5	79.9	34.2	27.4
12.3	859	106.0	84.4	23.7	20.1
14.8	713	105.5	85.4	4.6	3.9
26.9	703	189	90.4	−11.1	−10.0
31.2	641	200	93.2	−15.8	−14.7
31.9	611	195	95.4	−15.1	−14.4
34.8	542	189	96.7	−14.1	−16.7
37.9	505	192	97.8	−11.3	−11.1
44.9	393	177	99.0	−5.8	−5.7
60.6	190	115	99.1	−5.5	−5.5
69.0	113	78.1			

Figure 12 Mole Percent Ratio to Energy

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance *(physical state, color, etc.)*	Liquid. Colorless liquid / invisible vapor.
Odor	Sweet. Alcohol-like
Odor threshold	Specific data not available
pH	Specific data not available
Freezing point	-94°C (-137 °F)
Initial boiling point and boiling range	56 °C (133 °F)
Flash point	-20°C (-4°F) - closed cup (Acetone)
Evaporation rate	Specific data not available - expected to be rapid.
Flammability (solid, gas)	Flammable
Upper / Lower flammability or explosive limits	12.8 %(V) / 2.5 %(V)
Vapor pressure	245.3 hPa (184.0 mmHg) at 20.0 °C (68.0 °F)
Vapor Density	Specific data not available
Relative Density	0.791 g/cm3 at 25 °C (77 °F)
Solubility(ies)	Miscible
Partition coefficient n-octanol/water(ies)	Specific data not available
Auto-ignition temperature	465 °C (869°F) - (Acetone)
Decomposition temperature	Specific data not available
Formula (ACETONE)	C3H6O
Molecular Weight (ACETONE)	58.08 g/mol

Figure 13 Summary of Acetone's Properties

4.2.4 Examining Current Oven for Potential Inefficiencies

Analyzing the heat transfer and Air circulation in the oven and learning where leaks exist or open areas that could be sealed (Study the heat flow in the oven). Optimizing the heat loss of the process is related to simulation in order to see how much this heat transfer affects the production of cans. [36] Simulation is a key part in optimizing a process and learning where the faults exist in order to further enhance. Using a program to simulate the drying process would allow observers to see the faulted areas to improve, and mapping the results from multiple simulations to make sure the best accuracy is achieved. Another improvement capable from studies of the heat transfer experiments would be to analyze what areas of the oven that are not properly insulated resulting in additional loss of heat. [37] Figuring out if a different material or coating of metal would better suit the oven for insulation could be achieved. Not only do new materials have a high implementation cost possibly enough to turn to another option, but also feasibility of implementing them into the current process might be more than the potential savings. Maintenance of the new material or insulation may have higher costs than the current oven as well resulting in another problem to be solved if this alternative were to be pursued. In order to run this simulation proper programs are needed, which isn’t the case at the project site, so this alternative is not priority for our current goals with the project deadline.

4.2.5 Infrared Tubes

The BUCT students developed an alternative using infrared lights (IR) to help dry the cans after the washing process before the drying oven. This alternative would be implemented along with the oven, to help become more energy efficient by allowing the oven to operate at a lower temperature. Simulations performed in the labs at the project site using infrared lights to test how fast it takes to dry the cans using the same amount of water on the cans as recorded from the manufacturer. After researching costs and energy consumption of IR lights with implementing multiple before the oven under the conveyor, cost is roughly 34155RMB a year. Each IR tube experimented with cost 40RMB and the energy input for each is about 1killowatt/hour, costing an estimated 0.62RMB an hour. Based on testing in the labs 5 tubes seem to be enough to operate in the given space under the conveyor. Additionally the energy cost for 5 tubes would be 27262RMB, and a Programming Logic Controller (PLC) at a cost of 2000RMB would be needed to regulate the temperature of the IR lights. Maintenance for the IR lights looks less feasible and instead just replacing the actual tubes would be in the company's interest. Note: since there are two lines, calculations at multiplied times two.

4.3 Procedures

Infrared

Procedure #1

1. Though the average amount of water on the cans is 1 g (for 330 ml can), since the amount of water on the cans varies quite, we will randomly sample by dipping the cans in water
2. The can then goes, and the can goes inside box A (four sided box with infrared tubes on bottom.
3. Using box A, take off cans at desired intervals (10, 15, 20, 25, 30, 35, 40 seconds), record the amount lost. The experiment stops when all water has evaporated from the can. Repeat for box B, and in an open environment. All three types (box a, b, and open environment), are tested with two types of infrared tubes.

   Note: at the beginning of the project, the group studied the estimated time needed for the water to evaporate. This is where the chosen time intervals come from.
4. Three group members confer as to whether water is fully evaporated.

5. Results are then recorded in an excel sheet containing all aspects of the experiment, including experiment #, weight of H2O (g), evaporation time (sec), evaporation percentage, Temperature C, Can Size (ml), whether the system is open or closed, box used, tube used.

Procedure #2 Scale

1. 5 cans, each with the same amount of water on them (roughly 1 g).
2. Weigh before putting on infrared tubes.
3. Take 2 off at interval 1 (10 seconds), record water loss.
4. Take 2 other cans off at interval 2 (30 seconds), record water loss
5. Repeat minimum of 10 times.

ME-50

Same procedure as infrared, however we will use an oven (at a similar temperature to pacific cans' oven) instead of the infrared lights.

4.4 Cost Calculations and Cost Summary

Current Process (Oven)

1 m^3 natural gas = 0.61 RMB*

Daily energy use of oven:

Line 1 = 1000 m^3

Line 2 = 900 m^3

1000 * 0.61 = 601 RMB per day

900 * 0.61 = 549 RMB per day

NOTE: The factory typically operates 315 days per year

Energy Cost per year (601 + 549) * 315= 362,250 RMB

362,250 / 6.21** = **$58,333 USD**

**rate provided by Pacific Can*

***conversion rate as of 07/20/2015[38]*

Infrared

100 RMB per tube, 1 year lifespan

Tubes needed: 7

Energy use per tube: 0.8 RMB per hour

0.8 * 24 (hours/day) = 19.2 RMB

19.2 * 7 (tubes) = 134.4 RMB/hr. per day for all tubes

134.4*365 = 49,056 RMB energy cost per year (7,899.5 USD)

49,056 RMB + (cost per tube * number of tubes)

49,056 RMB + (100 RMB*7) = 49,756 RMB (cost for one line)

49,756 * 2 lines = **99,512 RMB (16,024 USD) total cost per year**

PLC = 2000 RMB

Silicon Controlled Rectifier = 600 RMB

Thermocouple temperature measuring instrument = 500 RMB

3100 RMB * 2 lines = 6200 extra cost

Total cost with PLC = **105,712 RMB**

Return on investment = (*Benefits – Cost) / Cost

*Benefits = Current Cost – Cost of Change

ROI (in RMB)

362,250 - 99,512 = 262,738 RMB

262,738 / 99,512 = **264% ROI (without PLCs)**

Cost Summary

	Annual Cost	Setup Costs	Energy Use/day	ROI
Current	**$58,333**	0	1000 m^3	-
Infrared	**$16,024**	$560	$21.64 USD	**264%**
Acetone	-	-	-	-

Table 4 Cost Summary

Based on these costs, using infrared tubes in the drying process would prove to be quite profitable for Pacific Can. A 264% return on investment provides a lot of leeway if a combination of the current process and infrared needed to be used (instead of relying completely on the infrared).

Chapter 5 Further Analyses and Results

5.1 Infrared

With the capability of the infrared tube, there are positive signs in our results from the lab experiments that prove potential feasibility within the industry. The data below (Figure 14) showed our initial test results of using infrared tubes to dry the aluminum cans. With a 355 milliliter can, 19 experiments were conducted, with 1 to 1.4 grams of water on each can. Evaporation was checked at 20, 25, 30, 35 and 40 seconds. A closed system means that we used box type 1 for the experiment, open means it was just the infrared tube in open space. Continuous means that the can was never taken off of the tube prior to that recording.

Experiment #	Weight of H2O (g)	Evaporation Time (sec)	% of liquid evaporated	Temperature - C	Volume of can (ml)	system	continuous
1	1	30	100%	200	355	opened	yes
2	1	20	100%	200		closed	yes
3	1	40	100%	200		opened	no
4	1	30	100%	200		opened	yes
5	1.2	40	95%	200		opened	no
6	1.4	30	90%	200		opened	yes
7	1.1	30	95%	200		opened	yes
8	1	30	99%	200		opened	yes
9	1	30	100%	200		opened	yes
10	1	30	99%	200		opened	yes
11	1	30	100%	200		opened	yes
12	1.1	30	100%	200		opened	yes
13	1.2	30	99%	200		opened	yes
14	1.1	30	95%	200		opened	yes
15	1	30	99%	200		opened	yes
16	1	30	100%	200		closed	yes
17	1	20	95%	200		closed	yes
18	1	20	90%	200		closed	yes
19	1	25	95%	200		closed	yes

Figure 14 Infrared Test Results: Design 1

These results show that it is possible to implement this technique as the future of the drying process, with all cans being completely dry by at least 40 seconds (the oven currently contains the cans for over 50 seconds**.** Within our initial experiments, we used both an open (exposed infrared tube) and closed systems (box design) as shown. Since these first results were estimated by our tests, the results are not entirely precise as the cans held different amounts of water results. This time study was important in order to get a good understanding of how the infrared tubes will perform in a similar environment as the manufacturer, and because we could not get access to a scale within the first few weeks on site.

The first step in this procedure was to place one of the aluminum cans on the infrared tube to get an understanding of the effectiveness of a single tube. Then to understand how the design of a containment box will affect the drying process of the cans using the infrared tubes. As a group we performed 35 experiments with this IR tube, which is labeled tube A along with Box 1 and 2. Then realizing the importance the reflection area had on the drying process with the IR tubes. Therefore, the group made these designs to study the effects of the reflection of the containment boxes for the IR lights. The three figures (Figure 15, Figure 16, Figure 17) below show our open space experiment (with tube A), box design 1, and tube design A, respectively.

Figure 15 Open Space Experiment

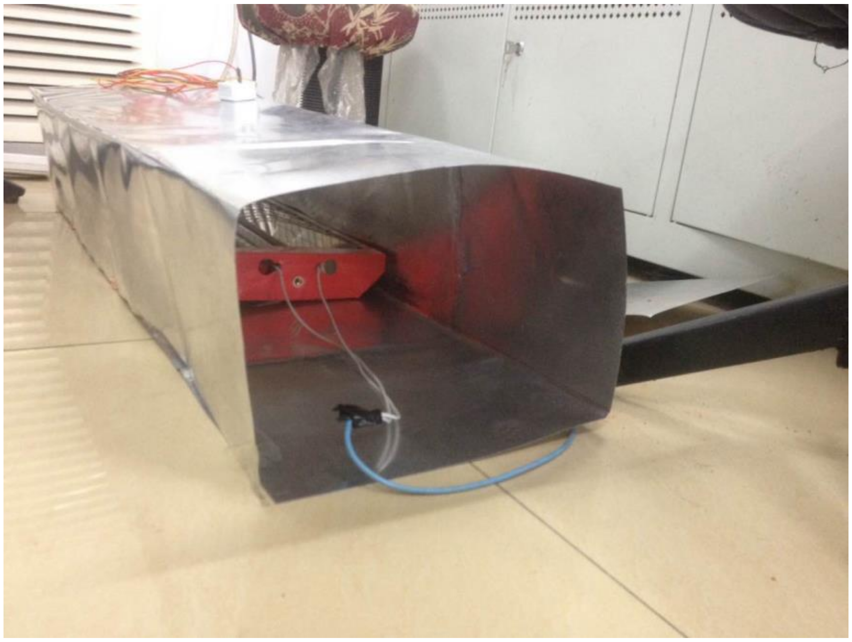

Figure 16 Box Design 1

Figure 17 Infrared Tube for Design 1

Furthermore, Figure 18 below represents the effectiveness of the containment design, containment box #1 measured 28cm by 28cm, which is large in proportion to this tube. Therefore, the light might reflect several times before it reaches the can, which would lead to an increase in the amount of time required to evaporate the water. In this containment box experiment, to reach a 95% evaporation level of the residual water in the can, the time varied between 30 and 40 seconds. The standard deviations for each time interval are 4.08, 0.00, 2.90, and 2.50 percent respectively. Figure 19 shows the evaporation of water in the cans over time.

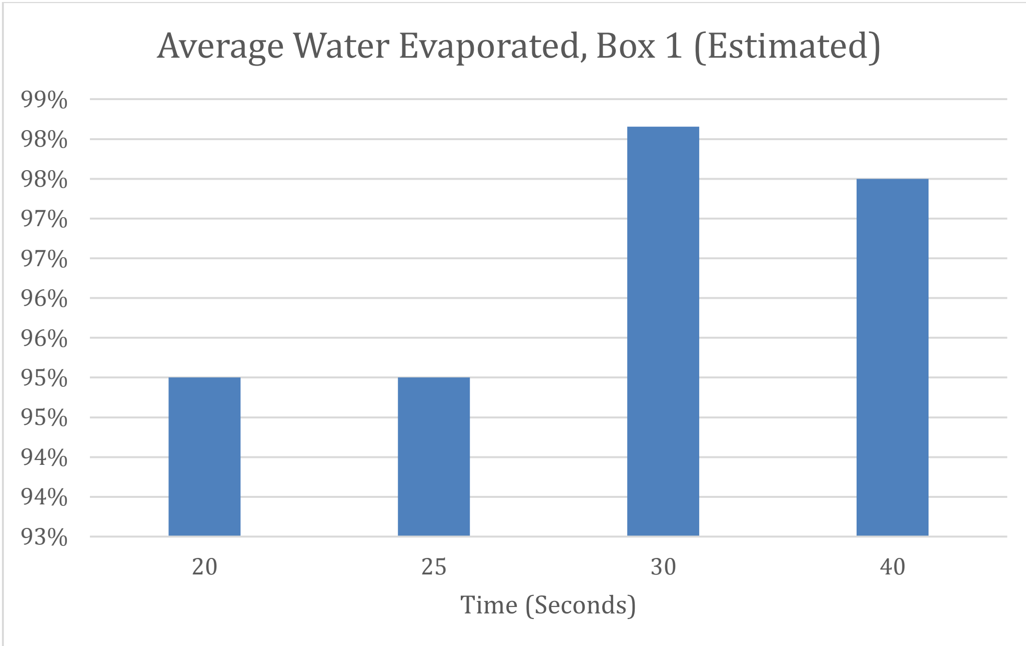

Figure 18 Percentage of Water Evaporated over Time, Design 1

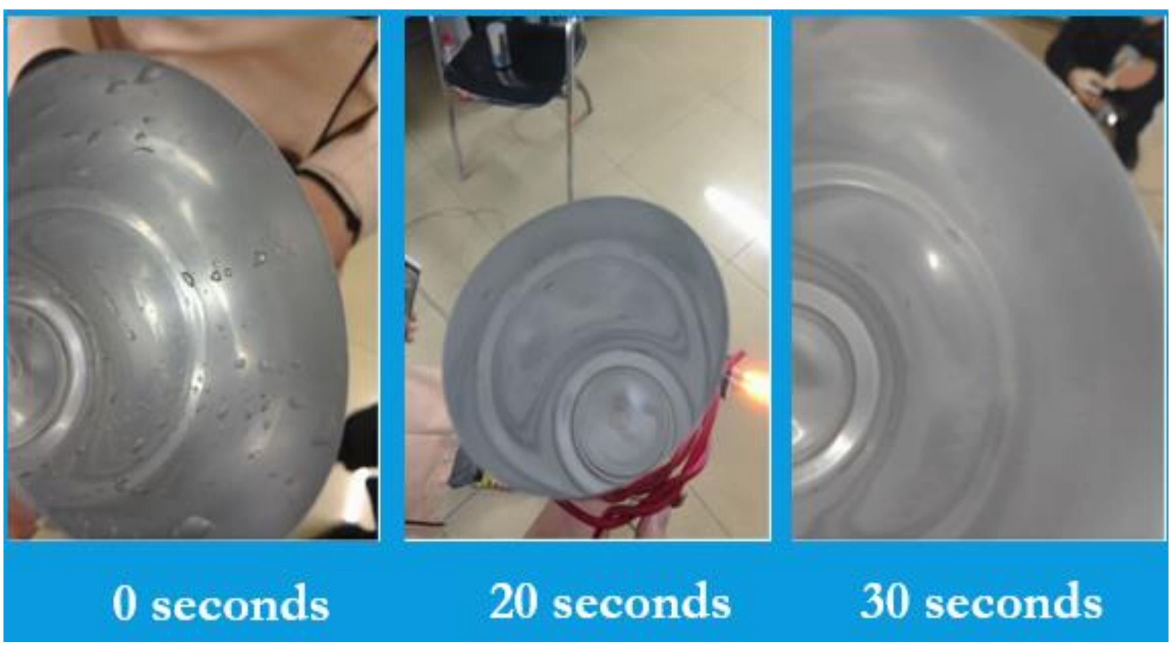

Figure 19 Water in Cans over Time

Box #2 was significantly better in terms of the evaporation rate as shown in Figure 9 below. Helping to support the importance of the reflection of the containment box within the IR tube drying process. The containment box is rectangular with dimensions 14.5cm by 28cm. For this design, reaching 95% dissipation of the residual water varied between 20 and 30 seconds, which is quicker than the larger reflective containment design. We tested two types of infrared tubes within box design 2. As seen in figure 15, tube A is a U shape, while tube B contains two straight tubes and is slightly bigger. Design 2B performed significantly better than design 1, and had a significant improvement at the 10 second mark compared to design 2A. Results of both design 2's can be seen in figures 20 and 21 below.

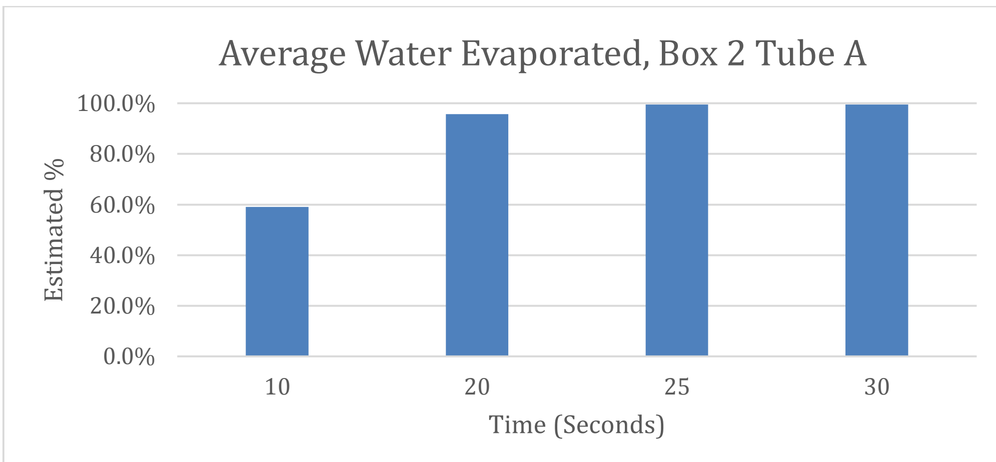

Figure 20 Percentage of Water Removed over Time, Design 2A

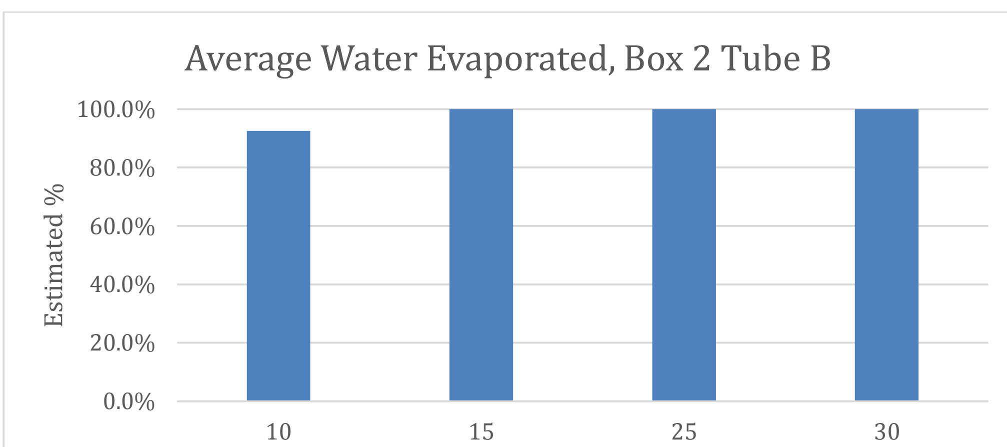

Figure 21 Percentage of Water Removed over Time, Design 2B

The group has expanded this experiment by simulating the plant's production line. Also, testing the feasibility of multiple tubes within the drying process, to study the efficiency of drying proportionally to the number of tubes being used. In figure 22, a picture of the new process and IR tube are shown listed as design #2.

Figure 22 Box Design 2 for Infrared Testing

Results of Experiments with Scale

Time (Seconds)	Average Water Remaining	Confidence Interval (95%)
10	39.31%	32.73% - 45.88%
20	10.16%	4.13% - 16.18%
30	2.34%	0.00% - 6.28%
40	0.00%	0.00%

Table 5 Results of Experiments with Scale

At 40 seconds, all cans in the experiment were back to their original weights (completely dry). This data confirms the positive results that came from of our earlier experiments where we estimated the amount of water lost, though the results are more varied. Pacific Can has told us that it is acceptable for the cans to not be completely dried from the infrared. At this stage, it appears that having the cans in contact with the infrared for 10 seconds, and using the oven to complete the drying (at a lower time and temperature than they use currently) is the most feasible short term recommendation. This is because the conveyor belt (where the infrared tubes would be placed) from which the cans go from the wash to the drying process needs to maintain speed to keep up with production. A potential long term recommendation would be to have the infrared tubes on the conveyor belt and creating an “oven” using infrared heat in lieu of the current oven (which uses natural gas).

5.2 Acetone/ME-50

At the beginning of this experiment performed at Beijing University of Chemical Technology (BUCT). The group requested the compound known as Acetone, but unfortunately, the school was not able to help obtain the compound in time to develop the experiment further. However, the manufacturer Pacific Can provided the team with a chemical compound they use in their washing process known as ME-50. As students we did not know much about the compound and questioned the engineering staff for further data on ME-50. Based on the limited information we gathered, a concern was raised of how the manufacturer was using a compound they didn’t understand themselves, but purchased only to implement into the washing process. Without having the Material Safety Data Sheet (MSDS) the properties and safety concerns of the compound are unknown. Looking into other literature about ME-50, the team found that there were two compounds that existed under the name ME-50. In order to gather more information on the compound, access to the instruments at BUCT, like Infrared microscopy and Nuclear Magnetic Resonance (NMR) are required, resulting in a constraint.

Regardless of the lack of information about ME-50, we proceeded to use the compound in experiments to test the effects in the drying process. Looking at results of the experiment related to change in temperature and time required for evaporation when using the compound.

The data in Figures 23 and 24 below illustrates the results of using ME-50 within the drying process deciphering between evaporation time and temperature.

20	1	30	99%	200		closed	yes
21	1	30	100%	200		closed	yes
22	1	25	99%	200		closed	yes
23	1	25	99%	200		closed	yes
24	1	25	100%	200		closed	yes
25	1	25	100%	200		closed	yes
26	1	20	95%	200		closed	yes
27	1	20	95%	200		closed	yes
28	1	20	95%	200		closed	yes
29	1	20	99%	200		closed	yes
30	1	20	95%	200		closed	yes
31	1	10	50%-60%	200		closed	yes
32	1	10	60%-70%	200		closed	yes
33	1	10	50%	200		closed	yes
34	1	10	60%-70%	200		closed	yes
35	1	10	50%	200		closed	yes

Figure 23 Infrared Test Results: Design 2

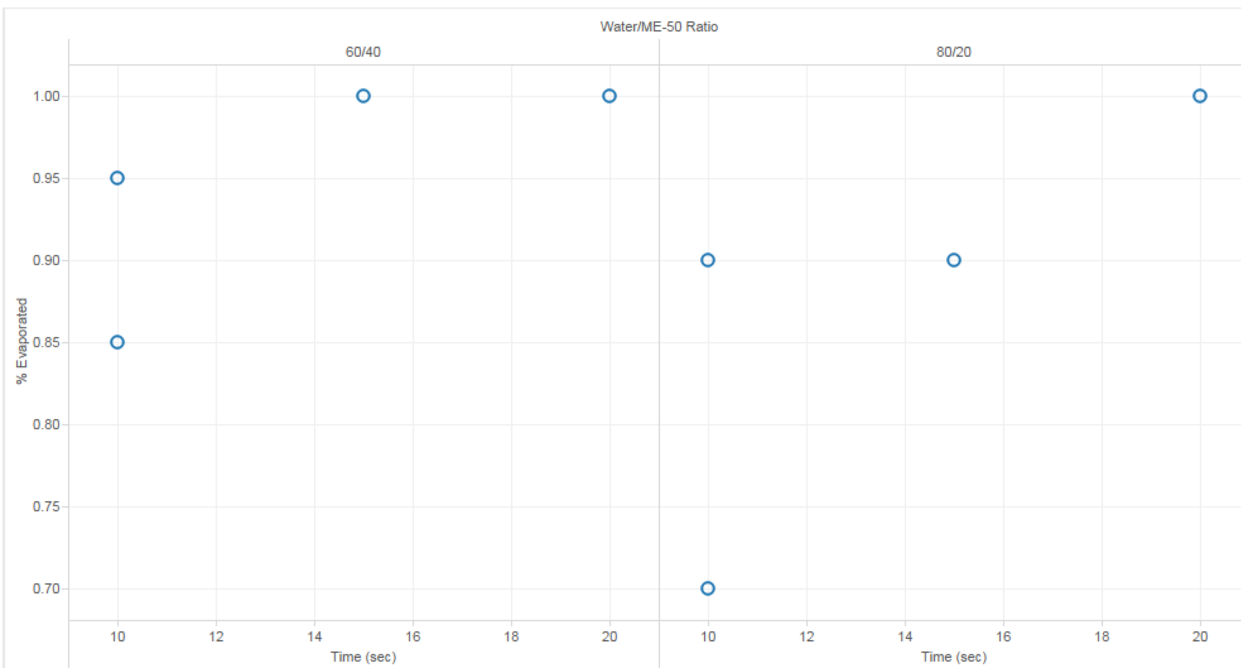

Figure 24 Data Points for ME-50 Tests

Unfortunately, the group was not able to study the effect of the temperature thoroughly, since the temperature is not constant in the experiment. Temperatures of the IR tubes range from 200 to 414 degrees Celsius. However, maintaining a constant temperature is possible with the right instruments. The use of proper sensors and a PLC would permit control over the temperature of the IR tubes based on the desired input code demanded by the manufacturer in case Pacific Can.

According to the engineers at Pacific can the use of ME-50 compound lowers the required temperature for drying the aluminum cans in the current oven by 30 degree Celsius. Pacific Can may confirm the effect of ME-50 after experimenting with a controlled environment when using a PLC.

Unfortunately, according to the experiments performed in the lab, the use of ME-50 did not reflect on the results of time for evaporation of the residual water. Pacific Can reported using 100:1 ratio (volume) with water and the ME-50 epoxy compound (an epoxy is method of bonding of two materials). The company has explained to us that this epoxy in particular is quite expensive. While testing multiple volumetric ratios such as 80:20 and 60:40 there were still no significant impacts on the data for evaporation time of the residual water in the cans.

Note: We understand that our data from initial testing in regard to the amount of water removed is qualitative and could be improved. Our plan was to obtain more quantitative data by randomly sampling two of five cans at suggested time intervals. However, BUCT was unable to provide access to a lab in time for this to happen. As such, this test has been added to our recommendations.

5.3 Industrial Engineering Methods and Results

Method #1 Time Study

Please refer to sections 5.1 and 5.2 for results of the time study.

Time study was an important principle for testing the feasibility of the proposed alternatives for the drying process. Using time study in the lab to set up experiments that are recorded and measured for speed. The cans were timed and monitored while set on the infrared lights in order test how quickly the residual water evaporated. Then running a similar experiment using the ME-50 mixed into the water was tested using the same process on the IR light. With the ME-50 test results suggested a slight decrease in time it took for evaporation to occur, time study allows us to compare these two different types of test results for qualitative data.

Method #2 Cost-Benefit Analysis

While trying to enhance the drying process, there are obstacles to overcome and to improve if possible. For example analyzing a new method and the changes it will cause whether it be cost, safety concerns, space requirements or energy consumption. Brainstorming all of these different obstacles to make a list of pros and cons will allow the best decision to be made based on goals of Pacific Can. A cost benefit analysis helps prioritize the goals of the enhancement and gather a comprehensive understanding of the cost of labor and benefits of the proposed alternative. So if the innovative process being designed is cheaper and more energy efficient then that would become a benefit to the company, while having other costs such as material handling, maintenance, labor, and new material purchasing. Providing a cost benefit analysis on the enhancement of the drying process as industrial engineers is crucial. After collecting data and test results of the feasibility of an alternative then seeing if it is applicable based off of the cost benefit analysis listing all the advantages and disadvantages in monetary terms.

SMART

Step 1. Identify Decision Makers

Discussed in section 2.4.3, decision makers are the CEO and engineers of Pacific Can, and our group.

Step 2. Identify Alternative courses of action

Alternatives discussed in section 2.4.3. Alternatives focused on in depth are infrared, Acetone/ME-50, and the current process (oven).

Step 3. Identify Relevant Attributes

The attributes in Figure 25 below were brainstormed by the group and discussed with Pacific Can.

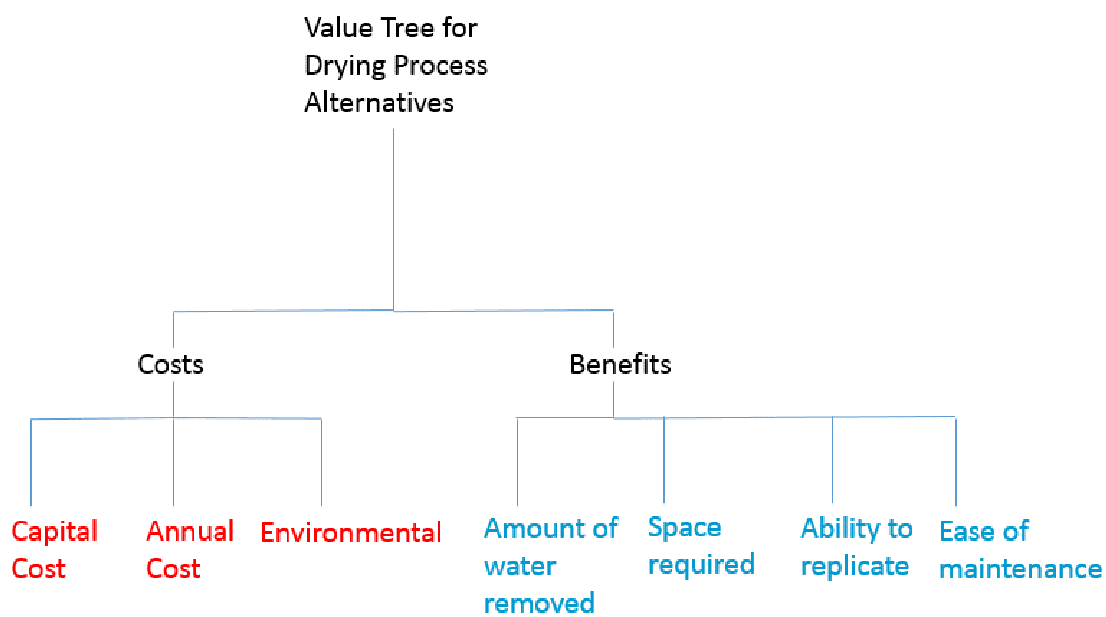

Figure 25 Value Tree

Steps 4&5. Measure performance of alternatives on that attribute, determine weight for each attribute

Swing Weights		
Attribute	OG Weight	Normalized
Amt. water removed	100	45
ease of maintenance	60	27
ablty to replicate	40	18
space required	20	9
Total	220	100

Figure 26 Swing Weights for SMART

Step 6. Weighted average of values

The top option based on SMART is acetone. This is mainly due to the ease of maintenance (none) and space required (least of the three).

	Acetone		
Attribute	Value (V)	Weight (W)	V*W
Amt. water removed	60	45	2727
ease of maintenance	100	27	2727
ablty to replicate	85	18	1545
space required	100	9	909
Total			7909
Aggregate Benefits			79.09

Figure 27 SMART Summary for Acetone/ME-50 Alternative

A close second best option, based on the SMART values, is the infrared. It would have been far and away the best option, but it came in third with respect to its potential to replicate to other facilities. This is because the space underneath the conveyor belt where we would place the infrared is very tight. It may not be possible to implement in another system, at least as easily as the acetone or oven. The values and aggregate benefit for the infrared can be found below.

	Infrared		
Attribute	Value (V)	Weight (W)	V*W
Amt. water removed	100	45	4545
ease of maintenance	60	27	1636
ablty to replicate	0	18	0
space required	95	9	864
Total			7045
Aggregate Benefits			70.45

Figure 28 SMART Summary for Infrared Alternative

Third is the current process (the oven), far worse based on the SMART values. This is because it removes the least amount of water, and takes up the most space out of the three alternatives. Figure 29 below shows all of the values and aggregate benefit for the oven.

	Oven		
Attribute	Value (V)	Weight (W)	V*W
Amt. water removed	0	45	0
ease of maintenance	0	27	0
ablty to replicate	100	18	1818
space required	0	9	0
Total			1818
Aggregate Benefits			18.18

Figure 29 SMART Summary for Oven (Current Process)

Step 7. Provisional Decision

Based on the SMART method, the acetone is the best alternative. It's important to note however, that this is based on non-monetary attributes.

<u>Method #3 Net Present Value (NPV)</u>

Net Present Value of using infrared in lieu of oven for 15 years

2,993,972 RMB. (Calculated in Excel; =NPV(0.0485, 285529 [savings per year] over 15 periods)

Calculated using People's Bank of China interest rate as of August 8th, 2015 (4.85%)

<u>Method #4 Seven-Step Process Improvement</u>

The method of seven-step process improvement provided us with an outline for our project schedule, providing us with questions to refine and expand upon our Gantt chart schedule from PQP. Please refer to chapter 3 for our use of seven-step process improvement within our project.

<u>Method #5 Systems Thinking</u>

In regard to systems thinking, our group discussed the possible externalities, such as how paint may be effected by changing the drying process. Since there was a group working on improving the paint process, this potential problem was discussing with them, and it was concluded that there would be no affect (given that our solution did in fact make the cans dryer than or at least as dry as the current process). Another possible externality discussed was whether exposure to infrared light causes radiation (it doesn't)

Environmental/Waste. This concern was directed mainly toward the use of acetone. However, as long as it is dried out of the can there will not be any health issues from drinking out of the can. Vapors released when the acetone is drying would have an effect on one's health, but only if prolonged, close exposure were to occur. Currently there are no workers consistently close enough to the washing or drying process to make this a concern.

Chapter 6 Discussions and Recommendations

Our main goal for this project was to implement a more innovative drying method into the aluminum can manufacturing process at Pacific Can. Objectives to keep in mind were to reduce the cost of the current drying process and possibly make the process cleaner for the environment. While reducing the amount of residual water on the cans after the washing process or maintain the current amount while reducing the cost also maintaining the current process speed and production capability. With the recommendations based on our testing in the lab experiments, using Infrared lighting in the drying process would help to achieve the goals and objectives of the project. Using infrared lighting showed improvement in drying the cans of the residual water, research also suggested that reducing the cost could be achieved being that the infrared lights are cheap in comparison to the natural gas oven currently used. In addition the amount of natural gas compared to the amount of electricity needed in order to dry the cans is significantly less meeting the goals of reducing the cost while possibly improving the impact on the environment lessening the energy consumption in the drying process. Though the new process is only a recommendation the company is interested with the suggestions and will continue exploration with the infrared lighting concept for future development. In conclusion, here are our final recommendations to Pacific Can:

Short-Term Recommendations

(1) Having the cans in contact with the infrared for 10 seconds, and using the oven to complete the drying (at a lower time and temperature than Pacific Can currently uses) is the most feasible short-term recommendation based on our testing. Reason being the conveyor belt (where the infrared tubes would be placed) from which the cans go from the wash to the drying process needs to maintain speed to keep up with production. Further investigation of

this option by making a detailed simulation at the manufacturer in order to see the effectiveness of the infrared tubes. By using random sampling in the suggested simulation with higher quality infrared tubes to retrieving more accurate data to help make a final decision. This data may suggest eliminating the oven in the current drying process completely, reducing the cost of production and amount of energy consumption with in the process.

(2) The Engineers should only use the chemical compounds that they fully know and understand, in order to avoid unnecessary problems. For instance, below are the two compounds that the group is assuming to be ME-50, each compound has it is own physical and chemical property. Contact Epoxies Etc. Epoxies Etc has been in the epoxy business for 25 years. The company has an extensive line of chemical products that they provide to companies like Pacific Can. After completing a product selection form online, a specialist from Epoxies Etc will contact the company and assist them in selecting the ideal product for their needs. Free samples are provided, and it is also possible to Epoxies Etc to provide a custom epoxy to meet the customers need.

Long-Term Recommendations

(1) Our main long term recommendation is to have the infrared tubes on the conveyor belt along with an "oven" using infrared heat in lieu of the current oven (which uses natural gas). This would eliminate the need for the oven currently being used in the drying process.

(2) Another recommendation is to further investigate chemical compounds such as ME-50 that may help make the cans more hydrophobic making the drying process easier. Knowing whether the current chemical compound used in the washing process is Peroxan ME-50 or Kerox is crucial for gathering data on the chemical properties and the effects on the drying

process. A concern with chemical compounds is knowing the health and safety concerns and how they react within the process if they are to be used. Having the MSDS to understand the compound if chosen is important to avoid unnecessary problems. The figure below (Figure 30) breaks down the two possible chemical compounds that Pacific Can is could be using when they use “ME-50”.

Section 2 - Ingredients and Identity Information				
		Exposure Limits		
Chemical / Common Name	**%Weight**	**PEL (ppm)**	**TLV (ppm)**	**CAS #**
Methyl Ethyl Ketone Peroxide (~9% Active Oxygen)	45 – 60 %	1.5 mg/m^3		1338-23-4
Dimethyl Phthalate	30 – 40 %	5.0 mg/m^3		131-11-3
Proprietary Safety Diluent	1 – 5 %			

Section 3 - Physical Data			
Boiling Point (^{o} C)	Unknown, Decomposes above 60^o C.	**Specific Gravity**	1.08
Vapor Density	> 1	**% Volatility by Weight**	Unknown
Evaporation Rate	Unknown	**Odor**	Sharp and Pungent

Section 4 - Fire and Explosion Hazard Data		
Flash Point (^{o} C) : >60	**LEL :** -	**Flammability :** Above Flash Point / NFPA Organic Peroxide Class III

Figure 30 Ingredients and Identity Information - ME-50

Limitations of the Project and Future Research

There are multiple opportunities for future study stemming from our project. Though the effectiveness of the infrared tubes was demonstrated through our experiments, a more strenuous time study using higher quality infrared tubes (those that Pacific Can would be more likely to use) and an environment closer to that of Pacific Cans’ facility would provide an even more accurate estimate of that alternatives effectiveness. In regard to the our Acetone and ME-50 recommendations, future study either done by the engineers or in collaboration with Epoxies Etc. could yield even greater benefits industry-wide.

Chapter 7 Reflections

7.1 Engineering Design

Engineering design is a process, or series of steps, that engineers use to solve problems. [39] First, the engineers identify the problem and its constraints and then research the problem for a better understanding. Next, they brainstorm for solutions with multiple alternatives and explore each one to find the best option to pursue. They then design a model to test and lastly refine the idea or model. This concept can be applied to most if not all disciplines of engineering. Within our project to improve the drying process for Pacific Can, we had to design an alternative solution that was more energy efficient and cost effective. After identifying the problems in the process we then brainstormed for new alternatives, then testing the most feasible ones in the lab to decide which was worth pursuing further. Looking at multiple methods between chemical compounds and IR lighting, we tested the effect of each within a simulation of the drying process to see which option would be feasible under the constraints. We also tested the evaporation rate of the residual water on the can and timed the process to benchmark each experiment, which allowed for comparisons between each. This helped us to eliminate other alternatives and then choose the optimal design. The optimal design, being the infrared light tubes under the conveyor belt, was suggested to be the solution to the existing drying process.

Design elements inherent to our project:

- Identifying cause of problem
- Understanding the current drying process
- Brainstorming potential alternatives for the drying process
- Identifying needs and constraints based on the small space availability

- Testing the alternatives that meet the established requirements
- Balancing effectiveness and cost of the tested alternatives (understanding the company's desired balance between cost and effectiveness)
- Recommendations on how to improve the current drying process based on the results

7.2 Constraints

Within every engineering design there exists constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, sustainability and time. A constraint is defined as a limitation, restriction or restraint that interferes and causes inefficiencies. Constraints can be categorized differently as either hard or soft constraints distinguishing what externalities can be changed and which cannot be changed. Examples of Hard constraints within our project would be economic, time, environment, company resources, and lab access. Soft constraints existing in our project are cultural, language, sickness and group dynamic. Group dynamic was a soft constraint such as knowing everyone's strengths and weaknesses, and delegating accordingly was applicable to our MQP. Economic and environmental constraints within our project included trying to solve the costs of energy consumption, costs for set up and material cost for the investment in the new alternative both of which we focused our MQP around making them Hard constraints. The language barrier and culture shock of living in a different community and not being able to communicate clearly whether it be for our MQP or for daily amenities was considered a soft constraint because there were ways to circumnavigate these limitations. The different types of food and way of life also presented some challenges with health issues throughout the project, multiple people within the group got sick from food or had challenges with losing a phone or related incidents also considered to be soft constraints. Limited and inconsistent accessibility to labs and equipment throughout the project made it difficult to perform tests and experiment with different alternatives to gather quantitative data to back up our suggestion on what to recommend to Pacific Can. We were able to overcome the constraints of culture and group dynamics over time with consistent communication, specifying tasks, and having one person designated as the "group leader" to communicate with the professors and edit/add-in sections of the report as they were completed. Lingyi stepping in as a translator helped in regards to obtaining a clearer communication with the BUCT students and Pacific Can staff. Some constraints, such as access to labs and equipment, we were not able to overcome considering they are out of our control. We worked around this constraint by obtaining as much data as possible from the beginning of the project and the little testing we were able to perform. The hard constraints mentioned previously are what guided our MQP's priorities.

7.3 Individual Reflection and Discussion of the Need for Lifelong Learning

Max Arnold

My overall project expectations were to explore a new culture and language while learning how engineering works in China. I did not have specific expectations for coming to China, except that communication would be a day-to-day challenge. For the MQP portion of the trip my expectations were that our group would be helping Pacific Can understand where they can improve the current drying process with industrial engineering principles. Such as simulating the current process and learning the details that might lack efficiency. One thing I learned from the project was that engineering is different in foreign cultures than in the States, also what it means to be a good engineer is to be able to improvise and work with what materials you have. For example running into problems such as money and lack of access to materials and labs helped us become more independent while learning on our own. This experience of independence within engineering is one of the valuable lessons I have taken from this project that would not necessarily be covered in the classroom and from coursework. One way I would continue the learning endeavor throughout my career would be to constantly challenge myself and take on projects that might seem overly difficult based on resources to challenge my learning ability. Doing this would help me keep focus different ways to learn and work, allowing me to constantly evolve and understand how other processes or people work. Overall the learning that would result from challenging myself as mentioned would also help me learn to work better in different environments while being more active in leadership positions to help future teams. One of the only consistencies in life is change, and adapting to these changes will help me learn and develop the skills necessary to pursue any challenge I seek.

Lingyi Xu

This project is a great opportunity for me to grow from both professional side and personal side. Working with partners from a Chinese university and having a project sponsored by a company/factory brought me a lot of new perspectives on how to think differently and solve a problem. As an industrial engineer, I implemented what I have learned in the past three year at WPI to an actual business setting. We used a lot of principles and concepts to evaluate current performance, analyze cost and benefits, as well as provide recommendations. The most challenging part of the project is how to figure out and balance the different between assumption and reality. During our PQP, our group had proposed a lot of different methods to solve the problem, however, after we arrived in Beijing and obtained more information, we found some of our proposals are unrealistic due to various limitations. And due to the lake of experiment equipment, we were not able to conduct experiments on multiple cans. Except those, this project did provide me a chance to take a close look at how Chinese companies do business and what a factory in China looks like. I enjoyed the facility visiting very much because I have never seen the manufacture process for aluminum cans. This is a wonderful experience and something I cannot learn in class. Also in our project group, we have a mix of industrial engineers and chemical engineers who are from three different countries. Working with them helped me understand how to work with multinational co-workers and set a step stone for my future career considering working in a multi-functional department or company.

From the personal side, being in a familiar environment but working with people from different ethnicities is an interesting and exciting experience for me. Not like the other teammates in our group who are from different countries, I grow up in China and speaks Chinese as my first language. Having this kind of advantage helped me quickly adapt the environment within the first few days. However, many students in our project group are from the United States, some are from Saudi Arabia and other countries. Being in a new environment and experiencing language barriers brought them a lot of difficulties. Some engineers and officials from the company do not use English very often. Our Chinese partners speak English but due to shyness and lack of practicing, communication and understanding becomes an issue sometimes. During the project, I helped a lot in translating and helping different parts understand each other. This helped me practice my communication skills as well as provided me a chance to learn how to coordinate and interact with people from different culture or backgrounds.

This project opportunity was a valuable experience for me. It was meaningful and educational. I believe these 14 weeks will be a lifelong memory and always benefits me in the future.

Mohammed Alrayas

In this Project, I have spent seven-weeks in Beijing, China working with Pacific Can Company alongside Beijing University of Chemical Technology (BUCT) to improve the drying process for Pacific Can. Throughout the weeks, I have gotten the opportunity to practice some of the chemical engineering concepts, including, Heat transfer, Mass transfer and Process design. I have also, learned the practical aspect of the drying process. Moreover, in this site, I was able to work with a group from different majors, which made me learn some of the major industrial engineering concepts alongside Automation Engineering. After graduating, I will continue on learning more about the new processes and I will implement what I have learned in my working environment.

T.D. O'Brien

Having never been abroad before, I saw this project as an opportunity for me to grow as both a person and student. After seven weeks in Beijing, I can safely say that I have grown in both aspects. While the project summarized the concepts in industrial engineering (and chemistry) that I have learned over the past three years at WPI, applying them in a new environment means overcoming obstacles you may not have thought of when dealing with problems in a classroom setting. The major obstacles for us were access to the labs and proper testing equipment, and scheduling with our Chinese partners (their school year ended week 4 of our project, after which they had a separate project they were working on). There were multiple instances where we had to adapt and improvise with the limited resources we had, whether it was financial, physical space to use, materials, etc.

Discussion of lifelong learning:

Being a lifelong learner doesn’t have to apply to just academics, or fall under the tent of what you do for a living. It’s about continuously improving (a foundational industrial engineering concept), expanding your knowledge so you can create a larger vision of yourself, what you want to be, and how you can provide value to others. I have found that in taking on challenges, whether you are successful in the endeavor or not, helps encourage one as a lifelong learner. Because even if you fail, you learn to catch yourself and climb back up with more knowledge than you had before. These seven weeks have been filled with both successes and failures. I think my peers and I are more likely to take on challenges in the future in spaces we may have hesitated previously.

I had few expectations coming into this project, beyond that we would be interacting with the company frequently, and base knowledge of the problem we were working on. I had an open-mind but little awareness about the culture here, initially.

Living in China for seven weeks and working on this project has been a stepping stone for me in both knowing myself better and continuing my path as a lifelong learner. I want to thank my peers who came on this trip for helping make this experience everything that it was, as well as WPI and our advisors for creating the opportunity.

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