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Engineering Projects

at Apollo Health and Beauty Care

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MECHANICAL ENGINEERING
MECHATRONICS CONCENTRATION
3RD YEAR

Date of admission to UOIT: Sept 2013

Expected date of graduation: May 2016

Is it a co-op or internship: Co-op

How many co-ops or internships done before: 0

Work term duration (start & end date): Feb 2, 2015 to May 15, 2015

Employer name: Apollo Health & Beauty Care

Brief description of what company does: Manufacturers Private Label personal care products for major retailers.

Is this the first time with this employer: Yes

Job title (position): Mechatronics and Maintenance Engineering Co-op (including projects)

Brief job description: Identify issues to be remedied by either new guidelines or new equipment

Name of department/division in the company: Engineering and Maintenance Department

Name and title of immediate supervisor: Rudy Bartus, PEng.

Supervisor's phone number and email address: 647-271-6837 / rbartus@apollocorp.com

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Executive Summary

The following report is both a reflection and a reference to the tasks completed during my 4 month term at Apollo Health and Beauty Care. This is a manufacturing facility with 14 lines of production and frequent changeovers based on constantly dynamic retail specifications. Products from this private labeling facility are found ubiquitously throughout North and South America. During my time at Apollo, I worked in the maintenance and engineering department where I assisted in aiding in improving processes and equipment both in the research department and the production floor. The scope of my report covers occupational health and safety, documentation created, design and implementation of new equipment, and an introduction of a new prototyping workflow. Specifically, work discussed in this report includes:

- Prevention of floor leaks in the 500 series tanks and other tasks adhering to current Good Manufacturing Principles (cGMP).
- Creation of a standard operating procedure for a pigging system.
- Creating the Clean-in-Place Troubleshooting guideline for a clean in place.
- Design and implementation of a roller guide rail system, laser sight.
- Design and implementation of a rapid prototyping platform for small parts and product design.

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Introduction

Based on 'Inside Real Innovation' by E. Fitzgerald et. Al., commercialization and innovation in a new business requires one of two things, either that it is modelled as vertically integrated in a new market or that it is horizontally integrated in a competitive market. Vertically integrated businesses are formed around a product or technology, stacking platforms of raw materials, manufacturing, distribution, research and development, marketing, etc. from which a final product is outputted (Fig. 1). When an industry grows large and has multiple competitors it must become horizontally integrated to stay viable. A horizontally integrated business spins off one of its basic platforms to create a sustainable and monopolized business model. A good example of this would be Global Foundries, a spin-off of AMDs chip manufacturing business. Starting out as a division of AMD, today Global Foundries has grown to have a net value comparable to AMD itself. The way that the horizontally integrated business model works is that when a company is dedicated to a single platform, say liquid manufacturing, there is only a fixed-cost associated with creating the company, which means that volume can scale up with relatively less additional cost. This division between volume and fixed-cost creates a value added product that is low-cost enough that similar companies will have to become clients of the larger company. This is the genius behind the creation of Apollo Health and Beauty Care.

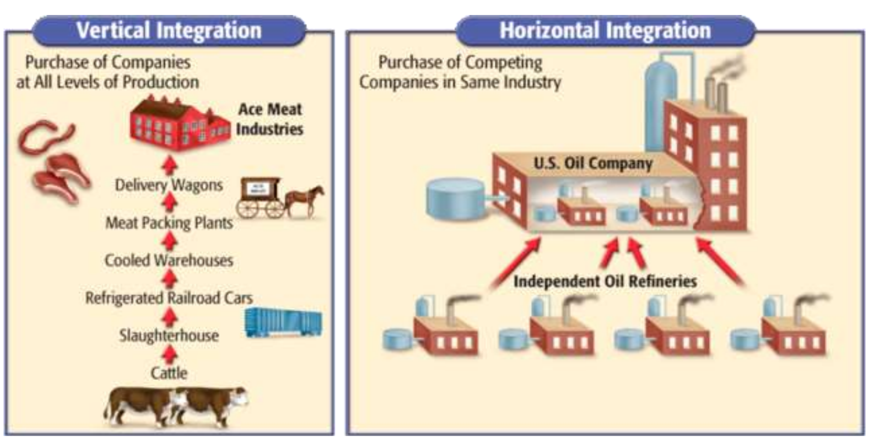

Figure 1: A google image on vertical integration versus horizontal integration (source unknown).

Apollo Health and Beauty Care is a private company formed in 1993 by the partnership of brothers. The company monopolizes on the demanding health-related regulations set forth by the Canadian government for the personal care industry, an area difficult to trust or enforce in foreign countries. Apollo, i.e. sale, research, and production developments, has only existed in its current locate for the past year. Apollo runs 13 lines of production each generating an estimated retail value of $117000/hr at peak potential. The value is estimated by multiplying 50 bottles per minute (bpm)* 60 mph * $3 value per bottle * 13 lines. At this scale and revenue, Apollo can afford to compete with generic products as well as established juggernauts such as Proctor and Gamble or Johnson & Johnson. Personal care products are ubiquitous throughout first world nations promoted by critical hygiene education, which is instilled at a young age. Therefore with the security of purchasing Canadian manufactured personal care products and the ability of a horizontally integrated business to out scale the national brands of competing clients. Apollo positions itself as a sustainable and long term business investment with near universal demand. So vast are the clients that an average person may either see or have an Apollo product if located within this continent. This brings everything back to the fixed costs of manufacturing, because being an engineer at Apollo is about dominating my share on that fixed cost.

I worked in the engineering and maintenance department which consisted of chemical engineers at a majority, mechanical engineers, and an electrical engineer. The factory consists of 4 major areas, the batching area where raw materials are brought together based on a specifically developed formula, the holding area, where formulas are held until routed to the correct filler lines, the production floor, where products are checked and palletized for shipment, and the distribution area, where each skid unit was sorted for transport to retailers or tertiary shipment (overseas). There are two additional specialized departments, one in research and development and another in sales and marketing (for commercial clients).

Within the maintenance group, I worked in the capacity of a project engineer, I was first placed with the mechanics in the production floor, to learn about both the kinematics, standard operation, calibration, and repair of each of the equipment available on the line. Then I learned about batching and holding area procedures among the operators on duty. Finally, I was introduced to a cubicle and asked to investigate and procure solutions to various problems in production either observed by supervisors, complained by operators, or requested by senior engineers. Sometimes there were tasks critical to Apollo as a whole, surprise inspections by clients and auditors, which required me to direct cleaning efforts or maintain a safe environment. My responsibilities throughout the term have been:

- Small scale value-driven design work
- Ensure that each line was augmented with the necessary or specialized equipment to output products most efficiency.
- Plan, prepare standard operating procedures or troubleshooting guides to streamline the recurring issues.
- Work and assist contractors during installation of new equipment of my design

Documentation Dilemmas

Before diving into the details of each document, it would be good to take a moment to reflect upon the informal training which lead to the creation of excellent documentation. The first 2 weeks of this coop was spent shadowing the mechanics and observing how regular issues had plagued the lines. Apollo is a frequent changeover company, i.e. where an automobile manufacturer might have a changeover once a year, Apollo would changeover daily, based on batch scheduling and client requirements. During these changeovers, instead of stopping an entire line, the mechanics adapted Shigeo Shingo’s Single Minute Exchange of Die (SMED) to speed up the process. SMED was developed by Shigeo-san in the 1970’s as a means to organize and plan changeovers in order to execute them in less time. The entire process of SMED is based on the process of separating changeover activities that can be completed during the operation of the machine (internal setup) versus activities that could be completed when the machine is static (external setup). To demonstrate SMED, a changeover process that was participated in, the labeller, was broken down into the respective as presented in Table 1.

Internal Setup	External Setup
• Adjust screws for correct orientation • Adjust height of gripper • Adjust parameters (x, y, tilt, speed) for label placement	• Install changeover screws • Install new labels • Route new label through machine

Table 1: The internal and external changeover components of a 'Labeller' though the SMED process.

It was through this process of organization and planning that formed the basis of the preparation and scope needed in forming guidelines. It is costly and less than ideal to stop any part of the line during production as it directly affects output. So it was important in developing guidelines that were efficient and can be refined by future counterparts.

Creating a Standard Operating Procedure

Part of the changeover between products is a mandatory clean-in-place (CIP) system used to prevent cross contamination and to sanitize the route between each product. Of the multitude of proprietary formulas that are developed, there is bound to be formula which is viscous and cohesive enough to be very slow to clear. At Apollo, this product is Petrolatum popularly known by a national brand name 'Vaseline'. The time spent waiting for water pressure to accumulate enough to clear the petrolatum is time consuming and that is before taking into account the potential of water to penetrate the petrolatum which bypasses cleaning entirely. To make cleaning the petrolatum more efficient and to speed up the change over time. A pig, is used in the pipe to prevent the amalgamation of petrolatum and water.

Figure 2: Nylon pig used to increase pressure and prevent the amalgamation of materials.

As the first exercise in creating the standard operating procedure (SOP), there were a few steps to learn, namely communication and social implications. In order to create the SOP it was necessary to communicate with the manufacturing engineer for their time to organize a walkthrough of the procedure, to create a rough outline of the procedure, and then to prototype the rough procedure with an operator during their free time so as to iterate changes. For a student, communicating with staff, especially addressing an operator for their spare time, required learning skills in communicating professionally and this means being confident. The social implications fell into place when safety was taken into consideration. While preforming the prototype of the procedure there were situations where if certain pneumatic valves were left open could result in exposure to petrolatum. This situation had to be emphasized in the SOP. Social implications are important not only due to moral obligations, but also for the risk of legal implications if in neglect.

Creating a Troubleshooting Guide for Daily Use

SOPs are accessed primarily during the initial stages by a trainee, so the next task was more imperative to daily use, a clean-in-place (CIP) troubleshooting guide. The necessity of this document is that when the CIP cells are stalled the engineering manager and automation engineer are place hold their current responsibilities to resolve rudimentary problems. The cost of this interruption is a minimum $30+/hr per engineer plus the cost of place hold. Creating this document would be a reduction of that time to the operator cost of ~$20/hr.

Figure 3: A state of the art Clean-In-Place (CIP) system depicting setup complexity.

To create the CIP guide, the first step was to run through the SOP which provided an in depth overview of the entire process, however this SOP will not cover any of the 18000 permutations, i.e. 13 lines * 7 cat. * 20 transfers * 67 formulas, of the specific situations that the CIP will encounter. So to assess common problems a meeting is arranged with: the automation engineer, i.e. to review the PLC infrastructure, the operators, and the engineering manager, whose advice must be iterated cumulatively and preciously. There was quite a bit learned in reviewing the CIP system, such as the thermodynamic requirements of maintaining the CIP and the ladder logic of the PLC, during which a problematic drain timer was found and corrected. A rough structure of the document is then created, sent in for approval, which means figuring out and then selecting the right tabs for the first step. The next step was to travel the plant with assistance from either the operator or engineer in photographing the right valves, pumps, and replacement parts to provide visual cues in the guide. At the very end of each process a high level overview of the issue is provided for the curious operator. Knowledge is power and the purpose of a high level overview is to potentially receive new feedback that is unobserved by the busy engineer. After the final draft of the document is approved, it was important to leave a guide on how to make further modifications for future iterations.

Project Designs based on Analysis

Projects must be chosen that provide maximum value to activities, if maximum value is not exploited it makes the engineer disposable, this is one of the practical experiences learned. The base approach in creating a project idea is to stroll the production floor and speak with supervisors of ailments, to identify chronic issues that were engineering-related to investigate, i.e. those that create fixed-cost associated downtime, and for developing a solution. When deciding to develop a solution it is critical to differentiate between what can be developed in-house versus those best developed with a contractor. There were three principle designs undertaken during the term, the industrial grade laser alignment tool, the frictionless roller guide rails, and the PID based heating element.

Figure 4: Alignment tool in action

Laser Alignment Apparatus

The necessity of the laser assignment tool came from quality control, where packaging was found to be variably unaligned when crimped. This is necessary because of the imprecision of alignment by eye. A straight line laser was the obvious choice to prevent misalignment, but an industrial solution did not exist upon research. There were a previous iteration of this design when this project was taken over. The first iteration only adjusted the height of the laser in order to account for placement. The material was stainless steel because of exposure to caustic materials and GMP rules. The laser itself had to be an off-the-shelf solution with warranty and be battery replaceable. A critical design requirement is security, production employees had a frequent turnover and consequently posed a risk of theft, so a bolt was added. This design did not account for bed leveling, so an engineering drawing had to be created for the apparatus. The new design was built in consultation with the resident welder. Thermal requirements and elastic properties of steel had to be taken into consideration in order to not damage the laser.

Figure 5: Final laser alignment apparatus (left), the variation (middle), and previous design (right).

Low Friction Roller Bearing Guide Rails

The roller guide rail solution was brought on by a new product line, traditionally Apollo fulfilled large- to medium-sized orders. However, there was a demand for smaller products, i.e. hand sanitizers, promotional swag, hotel toiletries, etc. Every bottle has a potential value beyond material cost as they can be filled, but there was an issue with small bottle production (see Fig. 4). The existing rail system was insufficient to account for the static friction threshold of small bottles and caused bottles to tip over when accumulated. So this task required research into roller guide rails known in the industry for low friction applications. Roller bearings instead of solid rails provided a static friction content negligent enough to prevent bottles from tipping over. Initially, a European solution was found which charged $60/feet before shipping for unibody aluminum rails. A counter PVC-based solution was found through a value industrial supplier, i.e. McMaster-Carr, for $14/feet. At over 90 feet required per line this solutions cost $5400 versus

$1260 respectively. The issue with the low cost solution was the stiffness, without adequate stiffness these rails would introduce more production variations then solved. At this point, research was concluded and prototyping began with first ordering a sample to test and iterate.

Scheduling

Scheduling is a major factor in a production environment with rapid changeovers, contractor schedules had to align with changeover shutdown schedules. Production shutdown schedules required coordinating with production supervisors for specific time on the day and coordinating with the scheduling supervisor that determined the source day, either weekly or monthly. Contractor were coordinated through email correspondence and through phone for proposed schedules. Contract schedules needed to be reviewed to ensure properly allocated times, because while quote times were free, design time had a cost. It was essential to create a rough outline that scheduled the prototyping in a logical sequence to account for all parties. This coordination lead to enhanced communication skills, experience in understanding timing of equipment replacement and set up, and experience in broad variability of timing in activities that needed learning.

Contractors

There were two contractors consulted during the design and implementation of this system, the first was an equipment manufacturer from the alcoholic beverage industry and the second was a custom tooling company. Contractors are typically required to sign nondisclosure agreements so there is a preference in working with contractors under existing partnerships. There is confidence and trust that is built with regular partners that supersedes the risk associated with taking on new contractors. The first contractor worked with was brought on to detail the scope of the work. Together, a clear cause was examined and a solution was proposed during the operation of the line. The work with this first meeting is essential in formulating alternative solutions. The second contractor is met with the explicit interest in designing a solution with the prototype on hand. This leads to the development of a quote which is exchanged through email. Upon approval, a purchase order is created and the work schedule is taken over by the scheduling supervisor, where personally lead supervision is a factor.

Figure 6: The type of small bottle susceptible to frictional forces presented from different orientations.

After meeting with the first contractor, a decision was made on the best course of action with the key criteria that health products require a food-safe grade solution. It was decided to adapt the plastic rails for the line with aluminum lining. The second contractor meeting was used to design a modification to implement the lining and find a price on labor. After haggling between solutions the price came to $24/feet for the solution or ~$2160 a line.

PID based Heating Element

Another project presented itself upon an issue that occurred daily with a particular product. This project tested the range of knowledge acquired during third year and was internally designed for its significant cost savings versus established solutions. Specific products can solidify overnight in a filler, a ‘filler’ works as the name implies, causing a large cost overhead during the clean-in-place process. So this design required a heating element to keep stagnant materials from flowing. The ideas first brainstormed were either to tap the side of the filler, use a flexible flat heated element to surround the tank, or to have a generic immersion heater. These solutions required $3k-$10k in cost and were a result of discussions with a variety of manufactures over the phone. With knowledge of 3rd year engineering, it was relativity simple to design a robust industrial-grade solution through off-the-shelf components, i.e. PID, thermocouple, and suspended heating element. The cost of this solution ranged around a grand and the return-on-investment (ROI) was substantial. The portability of this design was essential in making it a permanent solution per filler room.

Risk Assessment

This is a checklist that goes through all the possible hazards associated the installation or modification of equipment before implementation. The checklist contents can be based of the findings of the occupational health and safety association team or be sourced from ISO standards. Design proposals that use energy are consulted with contractors to include countermeasures. In this case the partnered electrical contractor, to ensure that all possible hazards are captured in the assessment, doing the assessment requires the attendance of maintenance and engineering manager or representative. The primary chronic hazards identified were associated with electric shocks or burn prevention with the equipment. The countermeasure to this would be to have appropriate lockout/tag out procedures. As well as instructions that detail wiring and construction for modification and repairs of the equipment.

Introduction of a Rapid Prototyping System

In a company with frequent changeovers and is a start-up based on age, there were two areas that could benefit from the introduction from new technology that were once reserved for Fortune 500 companies. These areas were small part design and rapid product prototyping and this new technology is 3D printing. While most equipment at Apollo were manufactured locally or within North America, some of the equipment were foreign sourced, ex. a Korean pouch filler. For any type of modification required by these equipment there was a significant cost overhead to order parts from Korea. For example, pulleys that used flat belts versus the existing round belts would cost an initial design fee of $300 augmented by manufacturing cost and number of parts ordered. This is a problem ubiquitous among manufacturers, but recent innovations in 3D printing has introduced the ability to print in multiple materials. High tensile strength and high melting point materials such as Nylon, Carbon fiber composite, and other fiber composites could be produced quickly through Solidworks. The other area that required rapid prototyping was product development, i.e. the design of bottles for both testing in the production line and for sampling to clients before making a mass order. Materials that could be printed included T-Glase glass like material, HEPA material that could be sanded to a smooth finish, and flexible material.

Figure 7: To meet specifications a new system might need to be built from scratch.

Currently, Apollo has to spend $300 per print per design at a local printing house or potentially would have to wait weeks for sample from a manufacturer. The scope of this project required the finding of a system that could print on all highlighted materials, support bottles up to 14” in height and 11” in diameter, and be low maintenance, i.e. through auto calibration. Establishing a system by which to rapidly prototype was the last activity that was created and pursued before the end of the term.

Conclusion

My original intention for taking on an internship in mid-third year was to be put back in touch with my intuition of the core tenants of my engineering education. The physics, the thermodynamics, the design and construction of technology, all of which that made me feel lost without context. By taking a step forward and observing what the actual profession was like, I learned that engineering is more than just the design and implementation of technology. As people have already created technologies, engineering is instead about creating a value proposition where your ability to interpret natural physical changes enables you to value yourself as worth hundred plus dollar per hour of work. I always viewed engineering through a false mirror, unable to distinguish the work I created to that of a technologist or a technician. Not only has this co-op restored by determination in completing my program and succeeding in my future career. It has also shown me how to morally separate work that will enable me to grow in value versus work that will only deter me and make me disposable. At my 3.5 months in Apollo, I was able to gain experience in all 5 areas of professional engineering, i.e. application of theory, practical experience, communication skills, social implications, and management of engineering. The constant communication by phone, e-mail, and meetings between the respective parties helped me improve my communications skills. That said, all of the work highlighted above are only the activities which were pursued from start to completion by myself under advice. There were activities that were completed with other members and are not included, nor the activities that required low-level relegation.

My take away from my experience brings me to the most important lesson learned, to be essential to the company it is imperative to always maintain a position of high level work, because that is the value of STEM education. A melancholic example of this can be found in the last world war, where industrialists could segregate skilled workers essential to war-related production from those fated for worse persecution. This taboo remembrance is an important reminder to any working individual of the harsh reality of our world, to always further your personal return-on-investment above all and to quarrel against relegation. Today, the success of any individual can be seen as a propagation of this memory, as to how close they are to reality.

I would like to thank all of the very professional engineers that work at Apollo Health and Beauty Care. Without their intelligence, charisma, and empathy this document could not have been possible. They alone made this endeavour a valuable experience.

Figure 8: Bidding adieu to a second home.

Appendix