

# 2013




*Composite  
Consulting  
Canada*



## IONIZED AIR CORE CLEANER REDESIGN

Team 1 – Final Design Report – MECH 4860

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Submission Date: December 2<sup>nd</sup>, 2013

Letter of Transmittal

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December 2<sup>nd</sup>, 2013

Curtis Kowalchuk



Dear Mr. Curtis Kowalchuk,

On behalf of Composite Consulting Canada please find attached the report titled "Ionized Air Core Cleaner Redesign" due on December 2<sup>nd</sup>, 2013 in agreement with the Engineering Design course (MECH 4860) administered by Dr. Paul Labossiere.

The report includes the final redesign of the ionized air core cleaner in accordance with the criteria and target specification presented by [REDACTED]. In the report you will also find methods used to create the design, assembly and part models of the machine, as well as additional considerations regarding the out-of-scope topics which will further enhance your understanding of the proposed design.

We would like to express our gratitude and appreciation to Dr. Paul Labossiere for providing the team with his expertise and advice throughout the duration of the project.

Composite Consulting Canada would like to thank you for your time and hope the report not only meets, but exceeds your expectations. Should you have any questions regarding the report, please do not hesitate to contact us by either phone or email.

Sincerely,

Stefano Lisi  
Project Manager

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Letter of Transmittal

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December 2<sup>nd</sup>, 2013

Paul L. Labossiere  
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Dear Dr. Paul Labossiere,

On behalf of Team 1, please find attached the report titled "Ionized Air Core Cleaner Redesign" due on December 2<sup>nd</sup>, 2013 in agreement with the Engineering Design course (MECH 4860) administered by Dr. Paul Labossiere.

The report includes the final redesign of the ionized air core cleaner in accordance with the criteria and target specification presented by [REDACTED]. This is a stand-alone report generated from the previous progress and conceptual design reports, and therefore contains all of the information from those two previously submitted reports.

This final design report successfully meets the requirements laid out for the completion of the Engineering Design course (MECH 4860).

We have agreed to have our report published by the Faculty of Engineering library at the University of Manitoba should the university see fit to do so.

Sincerely,

Stefano Lisi  
Project Manager

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## Executive Summary

This report outlines the ionized air core cleaner redesign for [REDACTED] [REDACTED] [REDACTED]. The ionized air core cleaner redesign began with a series of on-site customer meetings with [REDACTED] in order to develop customer needs and requirements. The customer's needs were used to develop metrics and then assigned target specifications for those that could be quantified. Project constraints and limitations were also based off the needs, which include a maximum budget of \$40,000, to abide by CSA and ULC safety regulations, a deadline of December 2<sup>nd</sup>, and a machine footprint of 87" x 60".

The final design submitted by Composite Consulting Canada (CCC) comprises of multiple integrated systems to fulfill the requirements requested by [REDACTED] [REDACTED] [REDACTED]. A conveyor system is utilized to control the feed rate of the core sheets through the core cleaner, which increases the consistency and effectiveness of the core cleaning. An EXAIR ionized super air knife, installed inside of the cleaner hood, is selected as the active cleaning component. The air knife's cleaning ability is further improved by using linear actuators within the top hood of the cleaner. The linear actuator controls the height of the EXAIR air knife with respect to the thickness of the core sheet being cleaned. A vacuum system located underneath the cleaning table is used to remove the dust blown off and out of the honeycomb core cells by the EXAIR air knife. An electric hydraulic scissor lift is used to control the overall height of the entire cleaner. The lift will vertically adjust the core cleaner assembly to receive core sheet from the block saw. The integrated lift and conveyor systems will improve the ergonomics and safety of the final design as compared to the current cleaner.

The final design meets all of [REDACTED] [REDACTED] [REDACTED]'s needs and improves on the current core cleaner being used. Although there is a production downtime associated with the installation of the final design, the long term benefits far outweigh the short term inconvenience. The new ionized air core cleaner being suggested will help improve the cleaning consistency and cleaning effectiveness of the core cleaning process. The improved cleaning process will produce higher quality core sheets used in production.



## 1. Introduction

Our project sponsor and primary customer, [REDACTED] ([REDACTED]), tasked our team, Composites Consulting Canada (CCC), to redesign the aging core cleaning machine at [REDACTED]'s Winnipeg location. The customer needs, target specifications, constraints and limitations were primarily generated from on-site meetings, email correspondence, and demonstrations with [REDACTED]. Metrics were developed from the customer needs and target specifications. To give the project direction, both project and team objectives were outlined. Relevant research required to support brainstorming activities for the core cleaner redesign was also performed.

Following the collection of customer requirements and development of project objectives was concept generation. The concept generation procedure consisted of brainstorming 100 concepts, after which similar ideas were grouped and labelled. Some of the 100 concepts were removed immediately due to infeasibility or constraints, while the remaining ideas were screened using matrix methods. After screening, three remaining ideas were put through a scoring matrix and compared against the current core cleaner. The screening and scoring methods, along with the concepts and ideas that were screened and scored, are covered in this report. Based on customer feedback from the scored three ideas, a final design was chosen for Composite Consulting Canada to pursue in the final design phase.

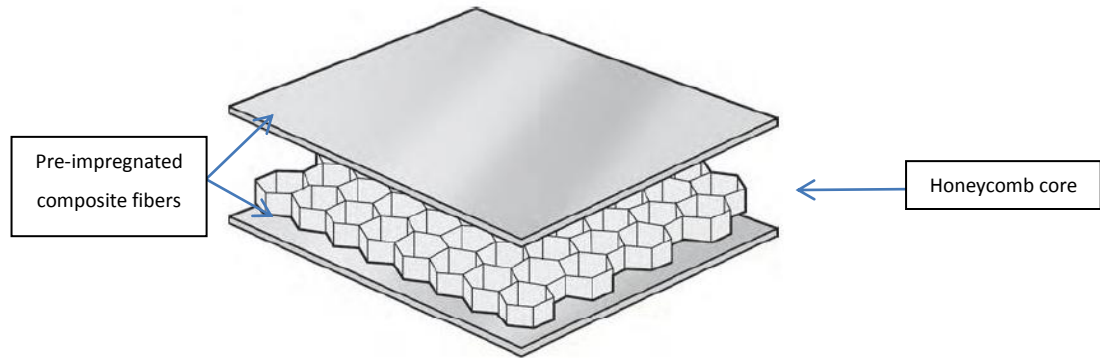
The final design phase entails a house of quality for comparison of the existing core cleaner to CCC's redesign. The final design section also covers the following items: outsourced systems, bill of materials, fit form function breakdown for all major components, cost analysis, machine operation, and additional considerations. Drawings for all the components and systems for the final design are also included in Appendix G.

### 1.1. [REDACTED] Background Information

[REDACTED] produces sandwich composite panels and metallic subassemblies [REDACTED]  
[REDACTED]. [REDACTED]  
[REDACTED].

As a part of the process for creating a composite panel at [REDACTED], a slice of honeycomb core must be placed on top of a layup of pre-impregnated composite fibers, as shown in Figure 1. The

pre-impregnated composite serves as the structural material for the panel, where the honeycomb core acts as a lightweight and low-cost interface which increases the stiffness of the panel.



**Figure 1: Honeycomb composite layup [2].**

The honeycomb core comes in varying densities and two different types of material: paper and fiberglass composites. A horizontal band saw cuts a large honeycomb block into sheets. These honeycomb sheets come in a variety of thicknesses, according to what size is desired. The core passes through a pressurized air/vacuum cleaner onto a secondary height-adjustable table. The operator then carries the sheet to its storage location before the sheet is trimmed to its net geometry.

The cutting process using the horizontal band saw creates a large amount of dust. These dust particulates cling to the inside of the honeycomb cells due to static charging from the band saw blade. The residual static charge limits the ability of existing core cleaning equipment to remove dust from the cell walls, decreasing the quality of the product being built.

The project ██████████ Winnipeg has sponsored incorporates the need for a redesigned core cleaning system which adequately removes statically charged dust clinging to the cell walls. ██████████ has also expressed interest in redesigning the sorting table used to carry the cleaned and cut core; however, the sorting table redesign has been declared an additional consideration due to time and resource constraints. To fulfill the need for a core cleaning redesign, ██████████ has asked Composites Consulting Canada to find a design solution to the current, aging system.

## 1.2. Project and Team Objectives

The purpose of this project is to design a ionized core cleaner that is able to remove the remaining statically charged dust created by the band saw core cutting process. The design objectives can be summarized as follows:

1. The new ionized core cleaner will have a better cleaning performance than the current one.
2. The new design will have automatic height adjustability to accept a variety of core sheet thicknesses from the block saw table
3. The design will adjust to accept core sheets cut from differing heights of the core block during cutting.
4. An automatic constant-speed feeding system will be implemented to improve dust removal and reduce errors from human-material interactions.
5. The cleaning time must be well controlled to avoid unnecessary delay in the band cutting process.
6. The prototype development of the design will be capable of being implemented within the department, while the current machine continues operation, and will be within the budget provided.
7. The designed machine will be more reliable than the existing equipment, and its regular maintenance will be performed by factory technicians.

██████ has proposed a project that requires real world solutions to replace their current core cleaning machine. ██████ has identified a rough estimate budget, and a deadline has been set in place by the Engineering Design course. This project can be regarded as a great opportunity to learn best practices from industry.

There are four learning objectives listed below:

1. We will improve our abilities to work together as a functioning team.
2. We will learn how to communicate and work with our clients more effectively and to understand the culture, standards, and regulations of their company.
3. We will learn how to work with other companies.
4. We will apply project management techniques to the project proposed by ██████.



### **1.3. Customer Needs, Associated Metrics and Target Specifications**

Based on the meetings with [REDACTED], Composite Consulting Canada was able to compile a list of the customer needs required for successful completion of the project. To help organize the determined customer needs, each need has been given an identification number and an importance level. The importance level was decided upon based on discussions within the team and with [REDACTED]. In Table I, the customer needs are displayed with their associated identification number and importance rating. The most vital of these needs that CCC focused on solving were numbers 1, 4, 9, and 12. Assurance that the honeycomb cores are cleaned to an acceptable degree, the core cleaning process in no way hinders the core cutting process, the design is ergonomic for the involved personnel, and that the dust spread from the cleaning process be controlled, are needs 1, 4, 9, and 12, respectively.



**TABLE I: LIST OF CUSTOMER NEEDS**

Imp*	ID	Customer Needs
1	1	The redesigned cleaner needs to remove a sufficient amount of dust so that the panels can be fed into the production line without additional cleaning.
1	2	The redesigned cleaner needs to function with composite cores of differing densities.
1	3	The redesigned cleaner needs to function with composite cores of differing thicknesses.
1	4	The cleaner redesign will not slow down block saw throughput rate.
1	5	The cleaner redesign adheres to safety standards and regulations.
1	6	The cleaner redesign needs to pass Manitoba Labour Inspection.
3	7	The cleaner redesign needs to stay within the allotted overall project budget.
2	8	Maintenance of the redesigned cleaner is faster, easier, and more efficient than the current one. Dust should not impede consistent operation of machine.
2	9	The operation of the cleaner redesign will be ergonomic.
4	10	The cleaner redesign will be outsourced to an external company for fabrication.
2	11	The cleaner redesign will reduce the frequency of core panels getting damaged during the process.
1	12	Residual dust from the process will be controlled and contained.
2	13	The machine will replace the old core cleaner within the department. The new design is limited to the available department space.
2	14	Core panels can be easily and safely fed into and out of designed machine to reduce frequency of damage.
3	15	Machine must be designed to be durable and function under rough use.

**\*Note: The values in the left column indicate the importance of the need. 1 – 4 (High – Low)**

From these customer needs, the next step taken was to further expand on the detail of each need, and quantify each item to the point where measurable metrics were assigned. Some of the needs produced multiple metrics as multiple methods were required to verify that the need was being met. Table II lists the created metrics and indicates the respective target specification when applicable. Target specifications were only created when the metric could be quantified and placed within a range or a specific measurement.

**TABLE II: PROJECT METRICS AND RELATED TARGET SPECIFICATIONS**

ID	Metric	Metric Units	ID	Target Specifications
1	Amount of dust remaining on core panel, sufficient enough to proceed with manufacturing process.	Subjective		
2	Amount of effort required from operators to implement the core cleaner into the cutting and sorting process of the composite cores.	Subjective		
3	Manufacturability of design. Must be capable of being made in-house or being outsourced while remaining cost efficient.	Subjective		
4	Transfer of cut core panel sheets from block saw table and through core cleaner machine must be quick, simple, and easy.	Subjective		
5	Durability of machine to function under rough conditions, including impacts and collisions.	Subjective		
6	Composites of varying densities can be accepted and cleaned by machine.	lb/ft <sup>3</sup>	1	Dust created from the fiberglass composite of densities varying between 3.5 to 16 lb/ft <sup>3</sup> .
			2	Dust created from the paper composite of densities varying between 2 to 8 lb/ft <sup>3</sup> .
7	Composites of different thickness can pass through design without hindrance.	Inches	3	Height adjustment from 0.5" (thinnest panel) to 6" (thickest panel) for 10' X 50" panels [2].
			4	Height adjustment from 0.5" (thinnest panel) to 6" (thickest panel) for 8' X 44" panels [2].
8	Time to complete cleaning of a single composite core panel does not impede block saw throughput rate.	Seconds	5	Can accept new core panel every 60 seconds.
9	Budget of project remains within ██████'s limit.	\$	6	Ideal budget: \$25K – 30K. Extra items additional cost.
10	Time required for machine maintenance must be reduced from the current amount of time spent each month.	Hours/month		
11	Number of damaged core panels reported from the core cleaning process must be reduced when compared to the original process.	# of damage reports		
12	Amount of dust spread from entire process with design installed.	Air Quality		
13	Must follow the Canadian Standards Association (CSA) guidelines and regulations.	Pass/Fail	7	Specifically CSA Z432-04 [3].
14	Must follow the Unlimited Liability Corporation (ULC) guidelines and regulations.	Pass/Fail		
15	Final design will be subjected to a Manitoba Labour Inspection.	Pass/Fail		



All information outlined in Section 1.3 was verified by [REDACTED] and is strictly followed through the entire project process – from concept generation to final design proposal and presentation.

### 1.4. Constraints & Limitations of Project

Any design requirements that could not be adjusted or modified have been compiled into a tabulated list of constraints and limitations. The constraints and limitations acted as a guide for the design selection during concept generation process outlined in Table III.

**TABLE III: CONSTRAINTS & LIMITATIONS**

ID	Constraining Elements	Limitation Details
1	Safety Regulations and Codes	The design must meet applicable safety regulations and codes set by CSA and ULC. Additionally, the design must pass a Manitoba Labour Inspection [3].
2	Overall Budget	The maximum budget [REDACTED] is currently willing to spend on the entire core cleaner project is \$40K.
3	Time	There is no project deadline set from [REDACTED]; however the course MECH 4860 provides a project deadline/submission of 2/12/2013.
4	Machine Dimensions	The span of the machine must be less than or equal to 87”, and the width must be less than or equal to 60”.

The customer needs each have room for deviations to accommodate the design, but the constraints are what the design will be based around and therefore cannot be changed.

## 2. Pertinent CSA Standards

In our design, the automatic constant feeding system will require a belt or conveyor to move the core along the process. This feature will expose rotating machinery to the working environment in the department, leading to a potential safety hazard. The potential safety hazard posed by the conveyor system requires an assessment based on the Canadian Standards Association. Safeguarding for the conveyor is necessary to prevent any accident. In the designing process, we need to follow the CSA-Z432-04 Safeguarding of Machinery standard [3], to ensure no safety hazards are created.

Furthermore, we need to provide detailed maintenance procedures to [REDACTED] based on CSA-Z432-04 standard. When performing maintenance tasks for the rotating components, proper lock-out procedure for the Motor Control Unit (MCU) is needed. All the locks and keys need to be controlled by the supervisors to control access to the machine and components.



For the design to be acceptable, it must adhere to the guidelines laid out by the above mentioned CSA standard. It is Composite Consulting Canada's responsibility to ensure that the design creates a safe working environment for any and all people involved in its operation. Additional details on the CSA-Z4320-04 standard or any other project research conducted can be found in Appendix A.

### **3. Project Organization and Management**

Project organization included the use of a project charter and stakeholder register. The project charter served as a high-level outline of the project and included the project objectives, requirements, risks, milestones, and major project stakeholders. Prior to the project initiation, the project charter was signed for approval by team 1, the project advisor, and the project sponsor. A detailed list of all project stakeholders was developed using a stakeholder register. Information for identified stakeholder included their project role, interest, influence, and mode of communication.

To help monitor and control the project timeline, both a work breakdown structure (WBS) and a Gantt chart were utilized. Throughout the project the team remained on schedule – successfully meeting both internal and external deadlines. For additional information, the project charter, stakeholder register, WBS, and Gantt chart are included in Appendix B.

### **4. Concept Generation Overview**

The final design selection to replace the current air core cleaner involves an iterative process consisting of concept generation, concept evaluation, and concept elimination. Appendix C details the concept generation process followed by CCC to achieve a final design selection.

The first step in the concept generation process was for each team member to develop twenty concepts that either solved a problem or met a customer need. The possibilities were not limited outside of the customer needs in order to allow for creativity in solving the design problem. A total of 100 concepts were generated to solve the ionized air core cleaner problem and grouped into a total of fourteen categories. Each category grouped similar ideas trending throughout the 100 concepts. Using the 100 concepts and the fourteen categories selected,



each member of CCC developed three semi-detailed design concepts for a total of fifteen semi-detailed designs. From these fifteen designs, the team collaborated to create ten designs to be put through the concept screening process.

The results of the concept screening process highlighted the features of each design that had positive influences on the core cleaning process. Using the identified positive features, CCC developed three comprehensive designs that best encompassed the positive features. To determine which of the three concepts would be selected for the final design, a concept scoring matrix was utilized. The selection criteria for the concept scoring matrix were first chosen then ranked using a criteria weighting matrix. With each criterion assigned a weight, the concepts could be scored in each category and assigned an overall rating via the concept scoring matrix.

The final step in the concept selection was to take the final results from the concept scoring matrix and present them to [REDACTED]. This allowed Composite Consulting Canada to present the three comprehensive designs and receive feedback from [REDACTED] on what they liked about each concept. The final concept selected was the vibrating rollers and EXAIR air knife concept. Section 5 outlines the final design proposed by CCC.

## **5. Final Design**

Moving from design concept selection to final design development requires much more detail on each component of the proposed machine. Amendments have been made in order to progress from the final design concept to the final design. Specifics on the changes made from the final design concept to the final design are documented in Appendix D.

The final design was developed through the integration of pre-engineered systems and custom components. Outsourcing – when possible – was chosen over custom design for ease of integration, installation, lower cost, dependability, and effectiveness at performing their specified task. Section 5.1 provides an overview of the assemblies outsourced by CCC.

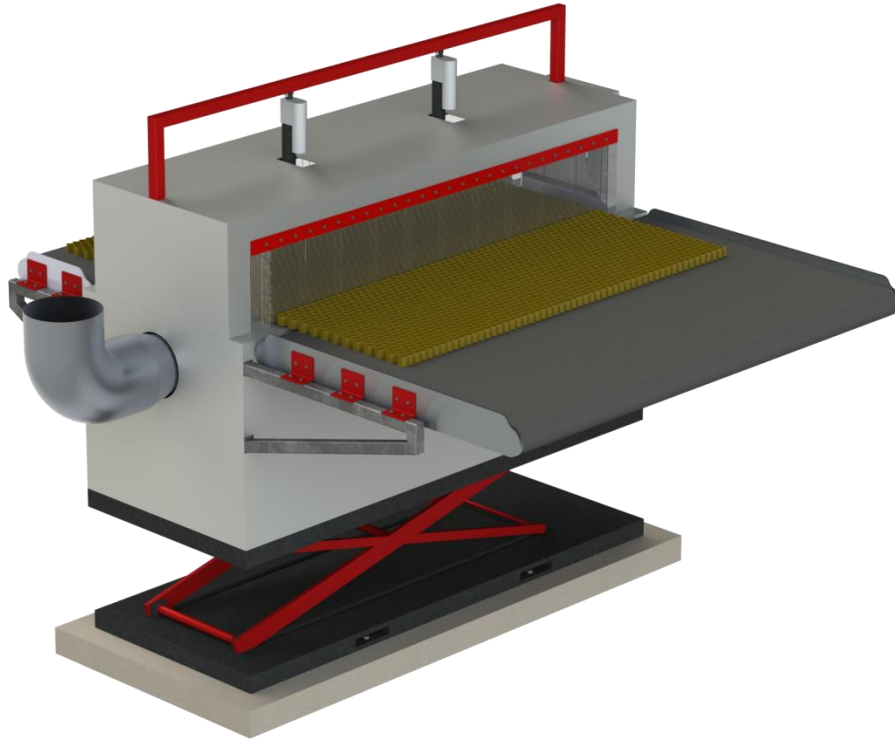
A complete list of components for the final design is contained in the bill of materials (Section 5.2). The major design features for the final design are detailed in Section 5.3. Based on the final design features and the bill of materials, CCC conducted a cost analysis for the materials of the



design. A general study of the overall design has also been conducted in Section 5.4 utilizing a house of quality. An explanation of how to operate the machine is shown in the section 5.5. Finally, any aspects of the design which are outside of the scope are summarized and briefly discussed in Section 5.6 to ensure that further development of the final design can be continued by [REDACTED].

The overall proposed design incorporates multiple outsourced systems interfaced with a custom frame. An Aerdon SSL-8 electric hydraulic scissor lift system is used to adjust the overall height of the core cleaning machine. Conveyors at both ends of the table move the core sheet through the cleaner and onto the sorting table after cleaning. An EXAIR Super Ion Air Knife is used as the active cleaning component to remove dust from the core cells. Rail and carriage systems coupled with two linear actuators are used to control the height of the EXAIR air knife to improve the air penetration for a variety of core sheet thicknesses. A vacuum duct system is built into the tabletop to help the air flow from the EXAIR air knife, while containing the dust blown from the honeycomb core cells. Finally, containment flaps have been installed to control the dust spread during the cleaning operation. Figure 2 shows the full assembly of the proposed core cleaner design.





**Figure 2: Proposed core cleaner design.**

The following sections will provide further details on each individual system of the design, as well as the overall function, assembly, cost, and operation.

## **5.1. Outsourced Systems**

Four features of the final design were outsourced to external companies, which include the EXAIR air knife, linear actuator hood lift, base lift, and conveyor systems of the new core cleaner. These systems have been implemented in the final design and contribute to fulfilling the design objectives and customer needs.

### **5.1.1. EXAIR Air Knife System**

The ionized air system is one of the key elements for completing the final design. EXAIR super ion air knife (Figure 3) was chosen due to its high performance rating, high energy efficiency, low maintenance, and customizable size.

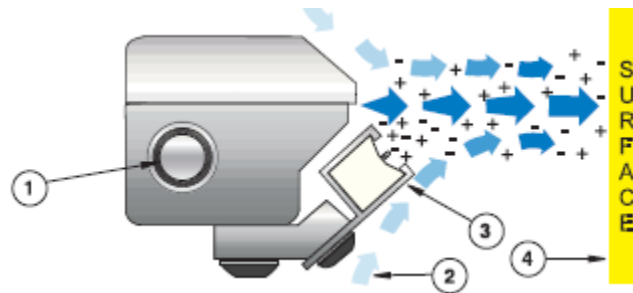


**Figure 3: EXAIR Super Ion Air Knife [4].**

Figure 3 shows an example of the air knife's theory of operation. The proposed design will integrate this system as the main method of cleaning the honeycomb core cells.

#### **5.1.1.1. Air Knife Function**

Figure 4 provides a demonstration of how the EXAIR air knife operates using numbered steps (1 through 4) to illustrate the process of how the ionized air discharges dust.



**Figure 4: EXAIR air knife operation theory demonstration [4]**

Shop air is delivered through an air intake (1) which is distributed across an air chamber contained within the air knife and guided to a slotted orifice. The escaping air creates a uniform sheet of high-velocity air which draws ambient air into its flow (2). Electricity generated from an ionized bar (3) statically charges the airstream. The statically charged airstream is then delivered to its target, eliminating the static charge of the target (4) [4]. The ability of the EXAIR Super Ion Air Knife to eliminate static charge from a target while delivering high pressure air suits the need for the final design requirements. The EXAIR air knife can both neutralize the static cling of dust to core cells, while allowing the high pressure air to remove the dust particulate from the core cell walls.

### 5.1.1.2. Super Ion Air Knife's Performance and Reliability

EXAIR's Super Ion Air Knife generates "a laminar sheet of air to sweep a surface clean of static, particulate, dust and dirt" [4]. When the supplying air pressure is high, the air knife can clean surfaces effectively up to 20' away [4]. In the new ionized air core cleaner application, the EXAIR air knife will be placed just above the composite core.

Maintenance in the air knife is minimal, as there are no moving parts. Another benefit of the air knife is that seals have a long life due to the absence of any temperature changes. Seals should be changed on the air knife when leaking occurs and when cleaning becomes less effective.

### 5.1.1.3. Health and Safety

The EXAIR air knife is very efficient in terms of consuming compressed air providing a compressed air to external flow ratio of 1:40 [4]. Since the compressed air is not the main source of the blow off function, the super ion air knife is quiet compared to other products in the market.

TABLE IV: EXAIR AIR KNIFE OPERATION DETAILS [4].

Pressure Supply		Air Consumption per Inch (25 mm)		Velocity @ 6" (152mm) from target		Sound Level @ 3' (914 mm)	Force per Inch (25 mm) @ 6" (152 mm) from target	
PSIG	BAR	SCFM	SLPM	FPM	M/S	dBA	ONCES	GRAMS
20	1.4	1.1	31	5000	25.4	57	0.6	17
40	2.8	1.7	48	7000	35.6	61	1.1	31
60	4.1	2.3	65	9600	48.8	65	1.8	51
80	5.5	2.9	82	11800	59.9	69	2.5	71
100	6.9	3.5	99	13500	68.5	72	3.2	91

Table IV shows that when 90 psi shop air is applied to the system, the sound level is around 70 dBA, below the 85 dBA permanent hearing damage level for eight hours of exposure. Moreover the EXAIR air knife eliminates harmful nozzle pressures typically higher than 30 psig. In the event an operator's hand were to block the air stream, the EXAIR air knife would not exceed the 30 psig as the flow can bypass a blocked section [4].

### 5.1.1.4. Accessories and Controls

Super air knives must maintain uniform airflow across the length of the knife to achieve a satisfactory cleaning result. If the Super Ion Air Knife is more than 42" long, a universal air knife



plumbing kit is required. The plumbing kit delivers air to center and ends of the knife; uniformly distributing air across the length of the knife. An example of a plumbing kit is shown in Figure 5. For the final design application, the length is 50", so a plumbing kit must be added to this system.



**Figure 5: Super air knife plumbing kit [4]**

Additionally, an Electronic Flow Control (EFC) system is required to control the timing of the flow. Electronic Flow Control System (EFC) is a unit that combines a photoelectric sensor with a timing control that limits compressed air use by turning it off when no part is present. Instead of having the air knife operating 24 hours/day, an EFC allows the super ion knife to only turn on when needed, so compressed air waste can be prevented. Figure 6 shows an example of an installed EFC.



**Figure 6: Electronic flow control system [4].**

The EXAIR supplier can provide an EFC which has eight programmable on and off modes with one photoelectric sensor [4]. For the manufactured final design, the “on” mode will be set to the laser sensor input which is used to detect a core sheet being placed on the conveyor belt. A delay turn off time will also be set based on the cleaning time of the thickest and densest core.

### **5.1.2. Linear Actuator Hood Lift System**

Linear actuators are required for raising and lowering the EXAIR air knife to accommodate varying thicknesses of core sheets. Two linear actuators are used to maintain rigidity while raising and lowering the air knife. Since the core sheet thickness varies from 0.5” to 6”, an adjustability range of around 6” is required. The linear actuator CCC chose is the PA-14P-6-150 from Progressive Automations. Progressive Automations quoted a total price of \$434.64 for two actuators, a wiring kit, two mounting brackets, and a power adapter. The PA-14P-6-150 is capable of adjusting the 6” required for core cleaning and can lift a maximum of 150 lbs each, making it ideal for the final design [5]. Appendix E contains additional details of the PA-14P-6-150, as well as the other outsourced products of the design.

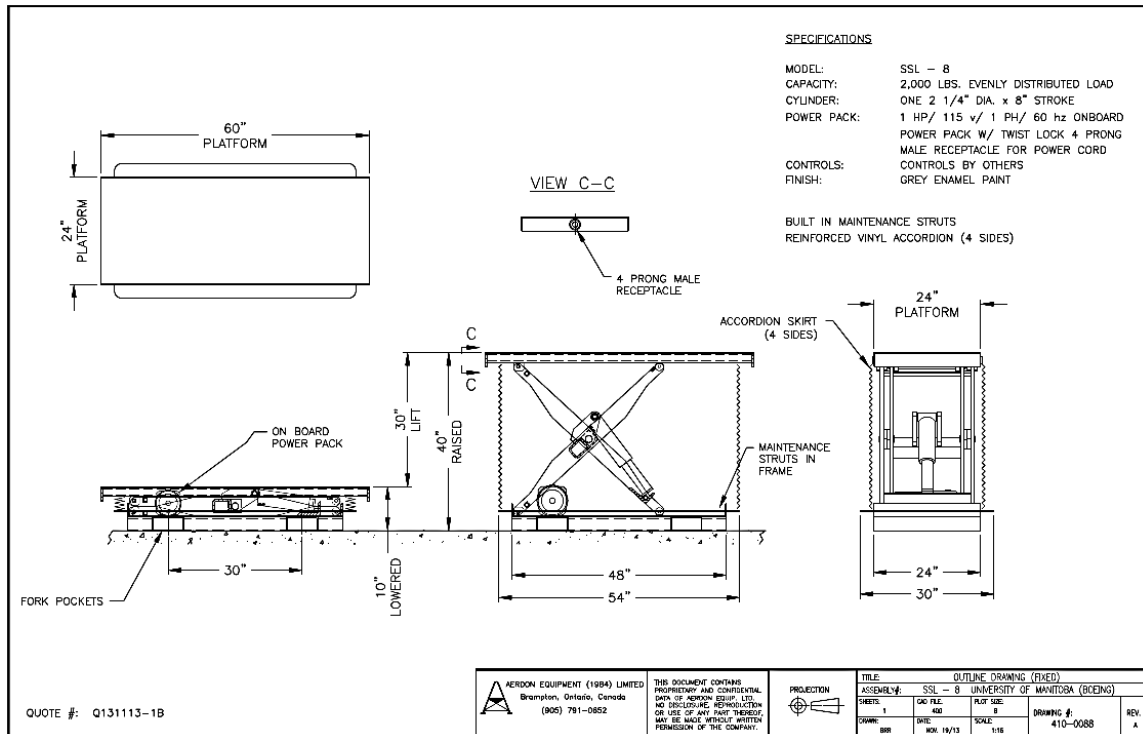


**Figure 7: PA-14P-6-150 linear actuator used in final design [5]**

Figure 7 shows the PA-14P-6-150 without any wiring or mounting brackets. The linear actuators each require a 4"x 4"x8" housing above the hood to compensate for their size.

### **5.1.3. Hydraulic Base Lift System**

Ross Equipment of Winnipeg, Manitoba is the company used to outsource the lift system. Ross Equipment was chosen because previous lift systems had been purchased for [REDACTED], through Ross Equipment. Ross Equipment specified an Aerdon SSL-8 electric hydraulic portable scissor lift for our final design. This lift system can support up to 2000 lbs, has a lifting range of 30" to 36", and is driven by a one horsepower 110 volt electric motor. The standard base of the lift platform is 24"x 48", but can expand to a 48"x72". A drawing of the Aerdon SSL-8 is shown in Figure 8 [6].



**Figure 8: Schematic of Aerdon SSL-8 electric hydraulic scissor lift system [6].**

The quote for the Aerdon SSL-8 also includes a 24" x 60" steel table, and a vinyl accordion skirt. The frame for the core cleaner will be fastened to the 24" x 60" table. The vinyl skirt acts as a safety barrier, which prevents hands from reaching into the scissor lift assembly. The lift system is also capable of being integrated with a laser-height system, such that the height of the core cleaner will follow the height of the horizontal band saw. For a full list of specifications, please see Appendix E.

### 5.1.4. Conveyor System

Part of the final design concept is the implementation of a conveyor system to pass the core sheets through the ionized air core cleaner. Using a conveyor system will provide a constant feed rate of the core to ensure even cleaning over the length of the core. Prior to selecting a conveyor system, design parameters were outlined based on the project needs, specifications, and constraints as displayed in Table V.

**TABLE V: CONVEYOR SYSTEM PARAMETERS [7]**

ID	Design Parameter	Parameter Details
1	Variable Feed Rate	Pass core through cleaner under 60 seconds. Clean various core thicknesses and densities equivalently.
2	Accommodate Core Widths	Transport core from 44" wide to 50" wide.
3	Maximum Conveyor Length	Each conveyor must be 3' or less to stay within specified dimensions.
4	Vertical Adjustment	Conveyor must vertically adjust with the core cleaner.
5	Safety Requirements	The system must guard the operator from the moving belt and contain an emergency stop.
6	Maximum Load	Conveyor must support a maximum load of 300 lbs.
7	Anti-static Belt	The belt must not create a static charge on the core.

In order to consistently clean cores with a range densities and thicknesses, the feed rate of the conveyor system will be variable. At the request of [REDACTED], the feed rate will be manually adjustable by the operator and will not be automatically controlled. The feed rate range selected will vary between 20 feet/minute and 60 feet/minute. Selection of the feed rate was based on the maximum core length of 10' and the required time to move through the core cleaner. Table VI shows the estimated time for a 10' core sheet to be cleaned at various feed rates.

**TABLE VI: CONVEYOR SYSTEM FEED RATES**

Feed Rate [ft/min]	Time [sec]
20	30
30	20
40	15
50	12
60	10

The estimated times in Table VI are all below 30 seconds which is well within the maximum allotted time of 60 seconds.

A belt width of 56" was selected based on design parameter two from Table V. A 56" belt will allow for 6" of placement variation of the core on the conveyor making it easier for the operator to place the core on the belt while staying within the entrance width of the core cleaner.



Different conveyor lengths were selected for the inlet and outlet conveyors. The inlet conveyor was selected to be 3' long as the core sheets are initially placed on the conveyor and must be supported. The outlet conveyor was selected to be 1' as it only needs to transport the core to the sorting table. The conveyors are required to be within the overall machine footprint of 87" long by 60" wide as outlined in Table VII. With a total length of 48" due to the conveyors and 24" from the length of the frame, the overall length of the assembly is 72" which is less than the maximum 87". The overall specifications are summarized in Table VII.

**TABLE VII: CONVEYOR SYSTEM DETAILS**

Specification	Value
Variable Feed Rate	20–60 feet/minute
Inlet Conveyor Length	3'
Outlet Conveyor Length	1'
Belt Width	56"

A custom conveyor system is required for the application since the dimensions are not standard. McKenzie Conveyors, based in Bessemer, Alabama, manufactures non-standard conveyor systems for custom applications. The custom conveyor is able to meet the required specifications for the conveyor including an anti-static belt. The conveyor frame width is 0.5" wider than the belt itself for a total of 56.5" still within the maximum width of 60". The vertical height of the conveyor system frame excluding the motor is 2.875" [7]. The conveyor is an end drive system consisting of manual feed rate adjustability, automatic start and stop via a traveling eye, an emergency stop button, and side guide rails.

It should be noted that in Appendix F, the provided quote by McKenzie Conveyors only covers the 3' conveyor type. Further correspondence with the supplier is required to obtain the quote for the 1' conveyor system and the associated side rail system.

## **5.2. Bill of Materials and Cost Analysis**

Based on the analysis that CCC conducted, the cost of the ionized core cleaner project can be classified into two categories: external cost and internal cost. The external cost is derived from the outsourced products that [REDACTED] needs to purchase to construct the design.

The outsourced products that Composite Consulting Canada proposed to [REDACTED] are the air knife, linear actuators, wide conveyor belts, cleaner hood, base assembly, and the lifting system. The Bill of Material (BOM) in Table VIII summarizes the estimated costs of the aforementioned products and systems. The costs listed in the table are all off-the-shelf retail prices that CCC obtained from a variety of companies. A detailed BOM and its corresponding cost spreadsheet are included in Appendix F to clarify the product specifications and the cost of each designed component. Also included in Appendix F is the list of required fasteners and their respective costs.

**TABLE VIII: BILL OF MATERIAL AND CORRESPONDING COSTS.**

<b>BOM (Bill of Materials)</b>		
<b>Parts</b>	<b>Quantity</b>	<b>Cost</b>
Super Ionized Air Knife	1	\$3 293.30
Linear Actuators	2	\$434.64
Wide Belt Conveyor	2	\$11 200.00
Lifting System	1	\$7 900.00
Cleaner Hood	1	\$888.50
Base Assembly	1	\$742.75
Fasteners	--	\$205.82
<b>Total Cost</b>		<b>\$24 665.01</b>

Since the ionized air core cleaner is not designed to economically benefit [REDACTED] directly, a systematic cost-benefit analysis of the final design would be inconclusive. Based on the changes that CCC added to the current cleaner baseline, the machine efficiency, core quality after cleaning, and the operator ergonomics will improve.

Prior to an installation and labour cost evaluation, [REDACTED] will have to approve the final design and select appropriate vendors for manufacture and installation. The raw material cost is therefore the only included cost analysis for the final design.

### **5.3. Component Form, Fit, and Function**

Each component of the new ionized air core cleaner redesign is part of a greater system which must meet [REDACTED]'s demands. It is therefore necessary for each of these systems to not only

accomplish their individual goals, but also work together to function as one integrated machine. The form, fit, function section provides details on all of the major components of the new ionized air core cleaner, specifically, about how the different components meet a demand (function), how they mate and connect with the neighboring components (fit), and finally a model representation is included to aid in understanding (form). Table IX organizes these three sections into a table and lists the major components of the new design being proposed.

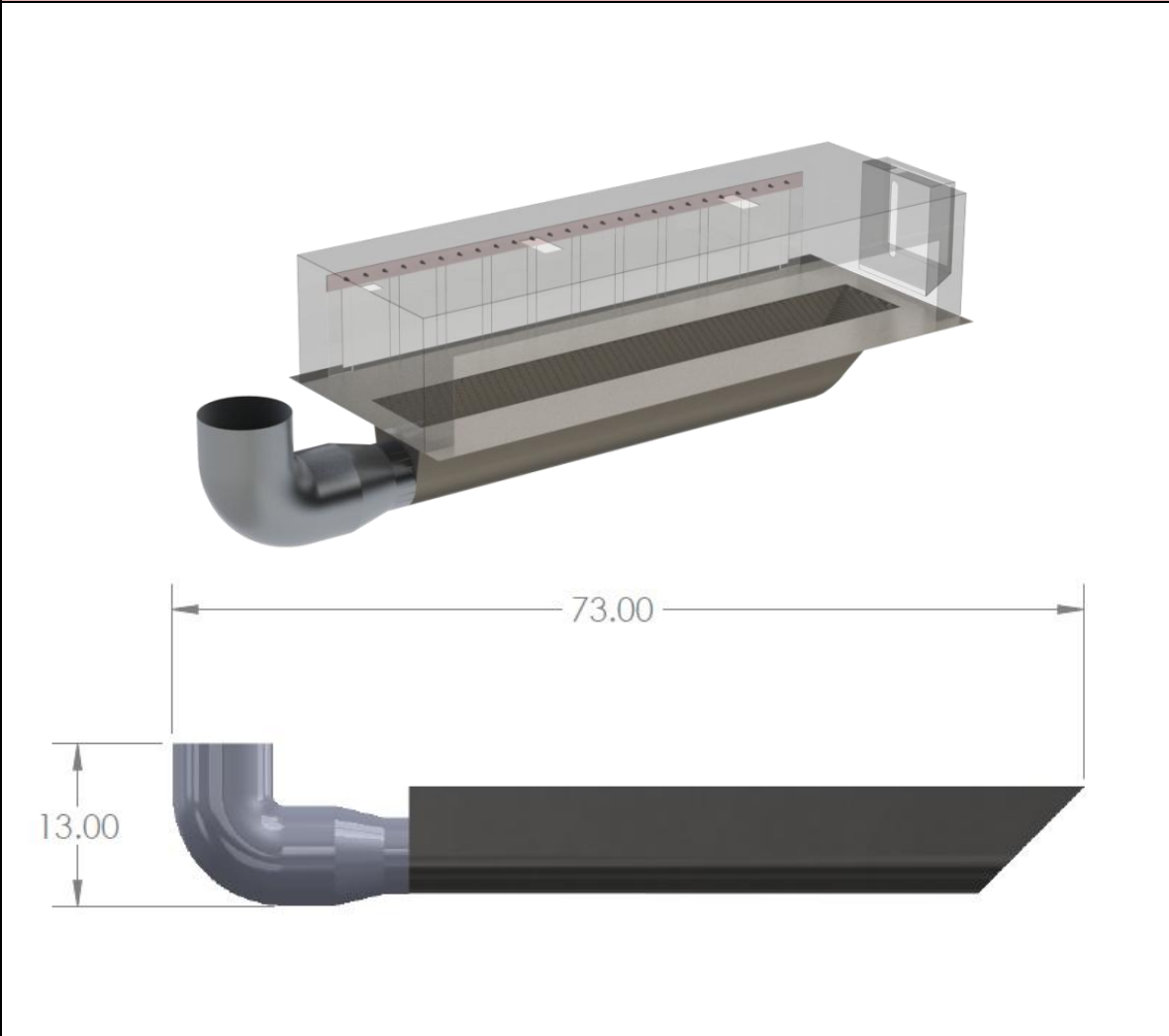


**TABLE IX: COMPONENT FORM, FIT, & FUNCTION**

<b>Form</b>	
Base Frame & Electric Hydraulic Scissor Lift	
Fit	Function
<p>The Aerdon SSL-8 electric hydraulic scissor lift system will be secured to the floor with internal thread concrete anchors and 1/2" – 2" long bolts as shown.</p> <p>The base frame is bolted to the top plate of the hydraulic scissor lift using 5/16" – 2" long hex head cap screws.</p> <p>The frame members are to be welded together to form one part.</p>	<p>The purpose of the electric hydraulic scissor lift is to adjust the overall height of the core cleaner with respect to the block saw cutting process. This allows the core cleaner to easily accept core sheets being cut from each part of the stock core block.</p> <p>The base frame houses the vacuum system of the ionized air core cleaner and makes up the minimum required height of the overall design for when the base lift system is at its absolute minimum.</p>

**Form**

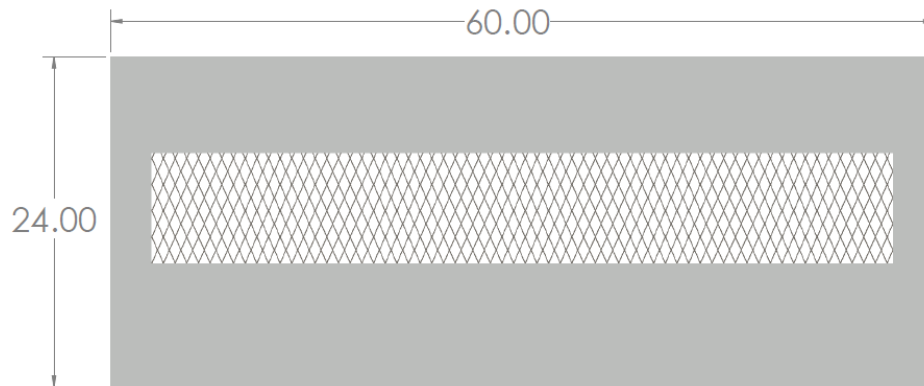
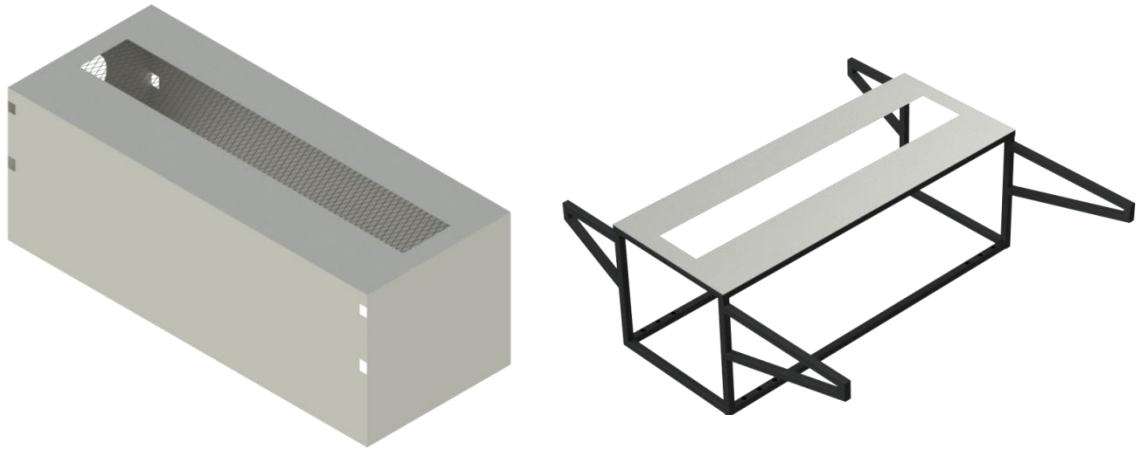
Vacuum System



Fit	Function
<p>The top edge of the reducer is welded to the edge of the square cut out on the top panel. This top panel is then welded to the base frame.</p> <p>The vacuum system consists of a 52"x8" to 52"x6" reducer welded to a 6" round duct. The duct is then attached to a 6" to 8" reducer with a 90° elbow attached to the 8" end.</p>	<p>The purpose of the vacuum system is to improve the performance of the EXAIR air knife by removing loose dust from the hood enclosure. Removal of the dust by the vacuum will limit unwanted dust from settling on surrounding surfaces.</p>

## Form

### Base Frame Enclosure and Table Top



#### Fit

The core cleaner tabletop is welded to the base frame with a flattened steel grating. The grating is welded along the perimeter of the rectangular cut out.

The base frame walls are fastened to the base frame using 10-16 – 3/4” drilling screws.

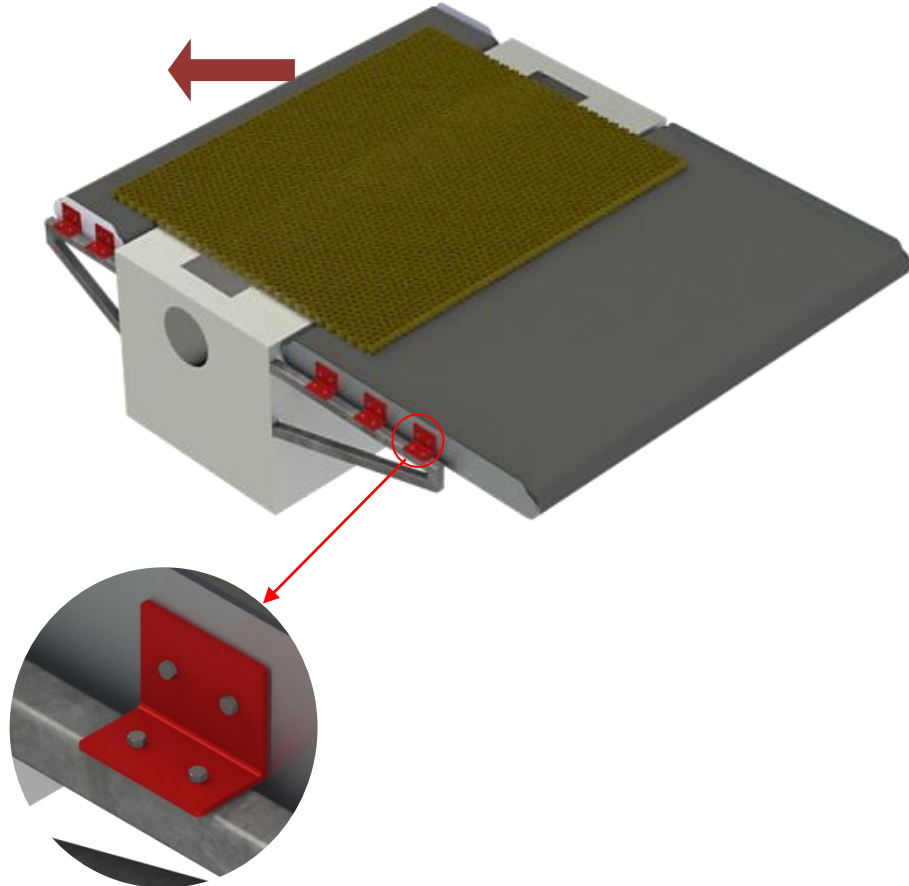
#### Function

The welded edges of the tabletop to the base frame provide a smooth transition for the core when exiting the inlet conveyor. The grating provides a surface that will not damage the core while allowing airflow from the EXAIR air knife to the vacuum.



## Form

### Conveyor System



#### Fit

The conveyor system is bolted to the base frame through the use of 90° angle brackets.

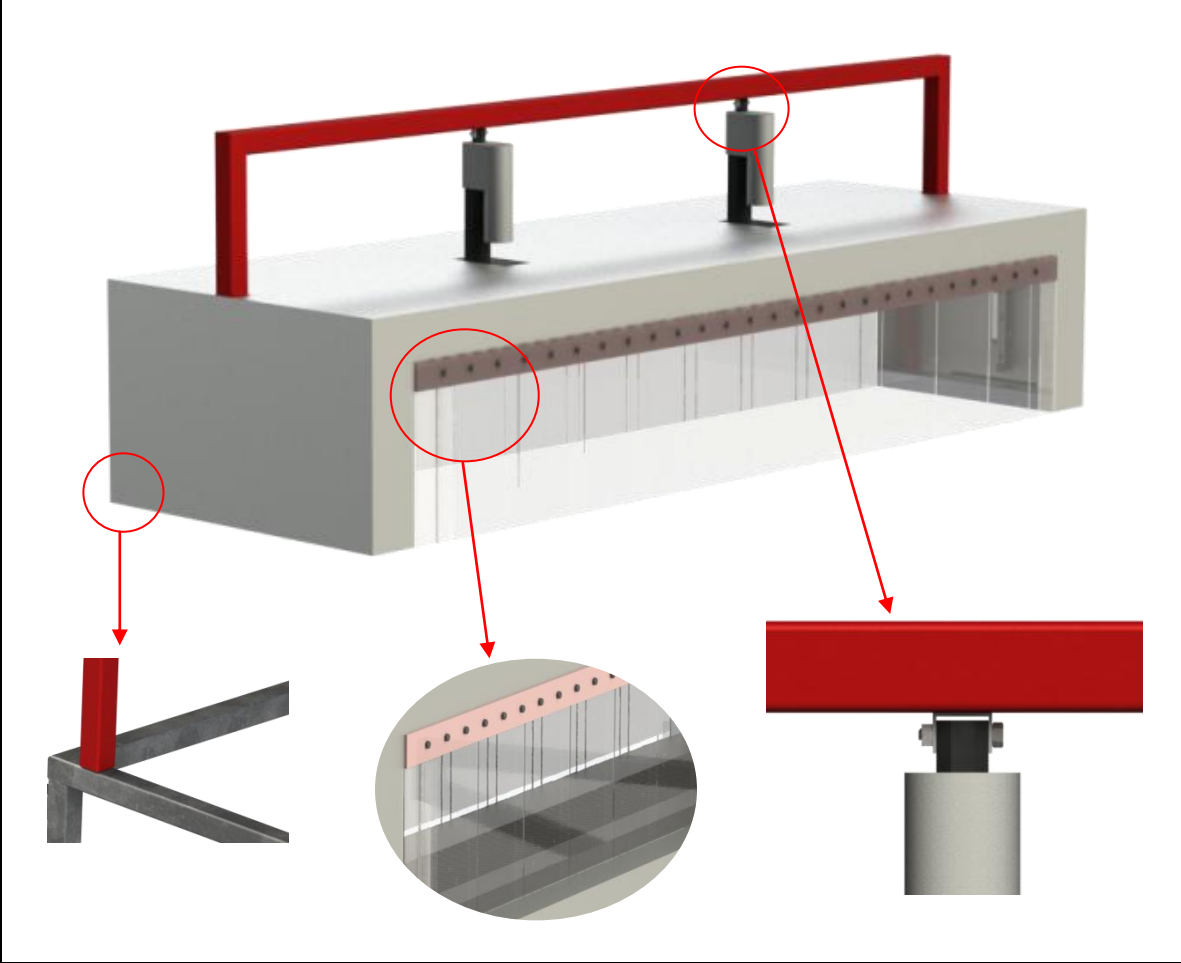
5/16" – 1-1/2" long cap screws are used to fasten the brackets to the conveyor and the base frame support arms.

#### Function

The conveyor system is used maintain a constant feed rate of the core while cleaning to ensure consistent dust removal. The conveyors move the core sheets through the ionized air stream. The panels are fed from the outlet conveyor onto a sorting table for future processing and arrangement.



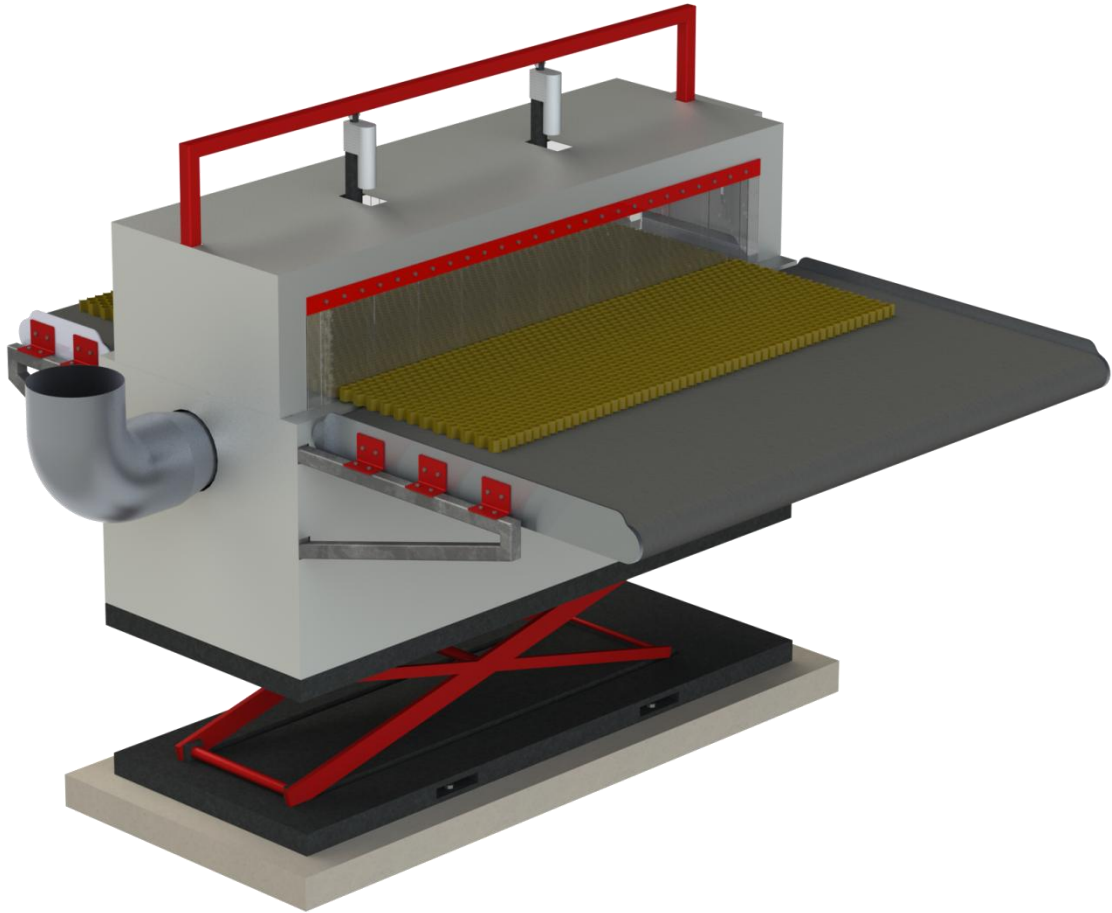
**Form**  
Hood Frame



Fit	Function
<p>The hood frame is welded to the side beams of the base frame.</p> <p>The linear actuators are held to the hood frame using a clevis mount and 5/16" – 1-1/2" long cap screw. The slider rails are bolted to the side walls of the hood using M4 – 25 mm long low head socket cap screws.</p> <p>The walls of the hood are attached to the hood frame using 10-16 – 3/4" long drilling screws.</p> <p>The PVC flap assembly will be bolted with 5/16" – 1-1/2" long cap screws using the mounting plate at the inlet and outlet of the hood.</p>	<p>The hood frame functions as a dust containment system and support structure for the EXAIR air knife. The dust containment is achieved via PVC flaps located at the inlet and outlet of the hood. When the core enters the hood, the flaps continue to limit dust spread by maintaining surface contact with the core.</p>

<b>Form</b>	
EXAIR Air Knife	
Fit	Function
<p>The EXAIR air knife is connected to two linear actuators with brackets using 5/16" – 2" long cap screws.</p> <p>The EXAIR air knife is attached by a custom sheet metal bracket fastened to the slider carriage using 10-24 – 1" long socket cap screws and 5/16" – 2" long cap screws.</p>	<p>The EXAIR air knife projects a uniform band of ionized air down and through the honeycomb cells to discharge and remove all the dust clinging to the core sheets.</p> <p>The actuators provide vertical adjustability of the EXAIR air knife to accommodate varying core thicknesses. The slider rails restrict the movement of the air knife so motion is strictly in the vertical line of action.</p>

The final proposal of the new ionized air core cleaner design has been modeled using computer aided design software (SolidWorks). All of the required components of the machine have been modeled and are included in the full design assembly representation, which is shown in Figure 9.



**Figure 9: Full design assembly of ionized air core cleaner redesign.**

The BOM outlined in Section 5.2 complements the final model assembly as it contains the remainder of the parts not included in this Section 5.3.

#### **5.4. House of Quality**

In order to ensure that the product meets the customer needs, the quality function deployment (QFD) method known as a house of quality has been implemented to compare how well the new design achieves the set goals versus the current ionized air core cleaner [8]. A house of quality integrates a variety of different parameters and displays them all in a multifaceted table. Some of the sections include target specifications, trade-offs between specifications, technical and competitive benchmarks, and customer needs. The customer needs stated in the introduction of this report must be modified in order to be correctly employed in the house of quality. Therefore, a new set of needs were selected, weighted, and then used to evaluate the new and current core cleaners. Table X shows the results of the customer needs weighting process.



TABLE X: CUSTOMER NEEDS WEIGHTING MATRIX

Customer Needs Weighting Matrix									
Customer Needs		Remove dust from honeycomb core panels	Does not damage core panels during process	Limits dust spread during cleaning	Ergonomic design for operators	Machine is safe to operate	Minimal downtime design replacement	Cleans the panels quickly	Low design cost
	ID	A	B	C	D	E	F	G	H
Remove dust from honeycomb core panels	A		A	A	A	E	A	A	A
Does not damage core panels during process	B			B	D	E	B	G	B
Limits dust spread during cleaning	C				C	E	C	C	C
Ergonomic design for operators	D					E	D	G	D
Machine is safe to operate	E						E	E	E
Minimal downtime design replacement	F							G	F
Cleans the panels quickly	G								G
Low design cost	H								
	Customer Need ID	A	B	C	D	E	F	G	H
	Occurrence	6	3	4	3	7	1	4	0
	Calculated Weight [%]	21.43	10.71	14.29	10.71	25.00	3.57	14.29	0.00

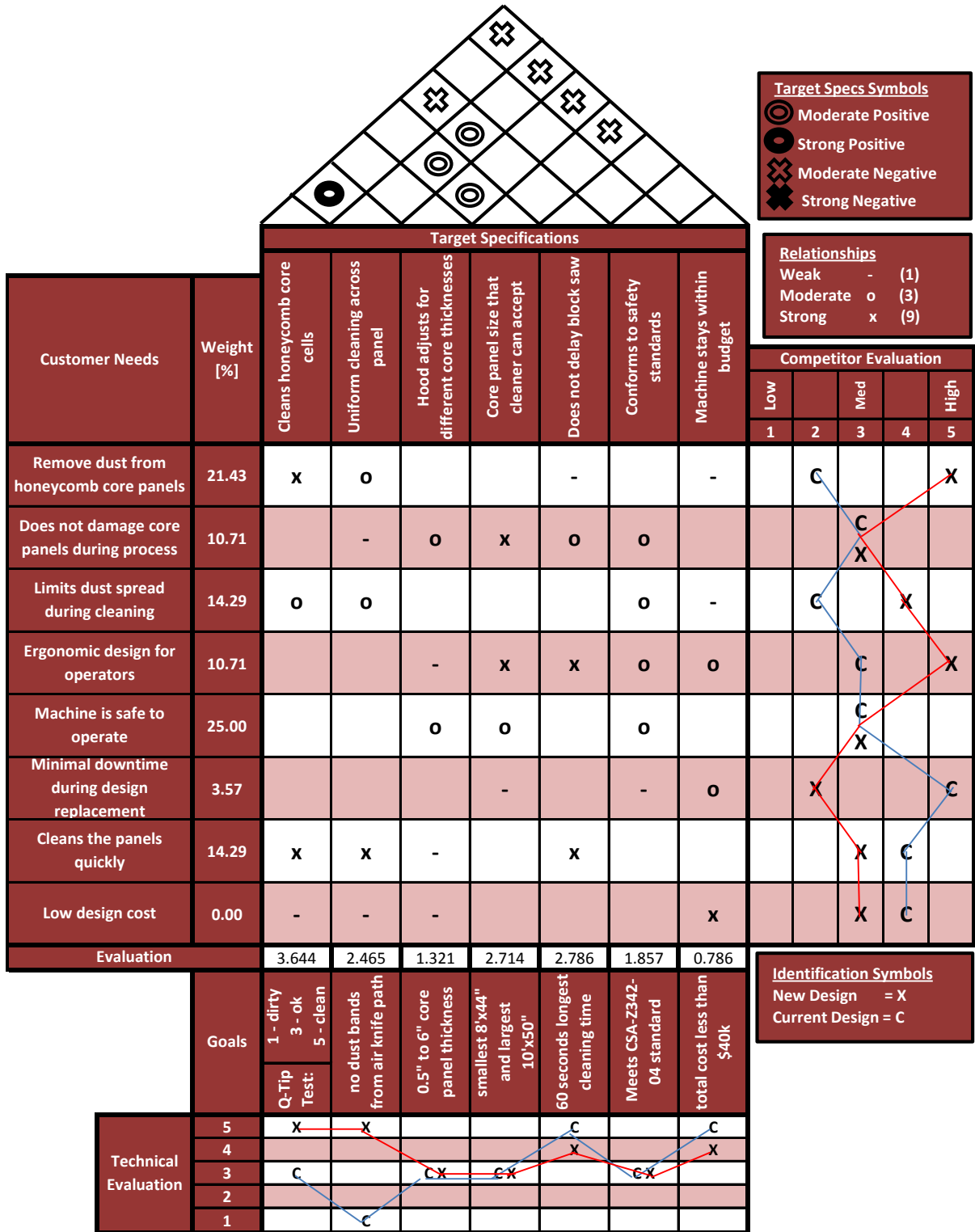
With the calculated weights from the above table for each of the selected customer needs, a house of quality was created to compare the two designs. The house of quality is an appropriate tool in comparing two products since it combines metrics of all design aspects. The house of quality also provides the relation between the selection criteria and the target specifications. The relations, along with the strength of relation, are used to calculate an importance rating of the target specifications. The tracking lines for both designs in the benchmarking and technical



evaluation sections provide a visual representation of how the products compare. The house of quality is therefore included to outline the potential of the new ionized air core cleaner with respect to the current core cleaner's performance. Table XI shows the entire house of quality table, including the required legends on the right which indicate the value of each symbol used throughout the different sections.



TABLE XI: HOUSE OF QUALITY



Based on the results in the house of quality the new ionized air core cleaner design matches or out-performs the current machine in all of the crucial design categories.

### **5.5. End User Operation of Machine**

The final design of the air core cleaner can be operated by one technician. Prior to operation, the technician is required to input the core sheet program into the CNC to set the height of the air knife and horizontal band saw. Vertical height adjustment of the entire machine is automated via the pre-existing travelling eye mounted on the frame, requiring no operator input. The feed rate of the conveyor system is to be manually set prior to operation via a control dial. The conveyor system will be equipped with an emergency stop button to be pushed in the event of an emergency or breakdown. The sorting table height will be manually set to be level with the output conveyor to accept the core after cleaning. Once the core is cut, the technician is to place the core partially onto the conveyor system leaving a portion of the core supported by the honeycomb core block it was previously cut from. When placed on the conveyor, the system will register the core and automatically start to feed the core through the cleaner at the pre-set feed rate. The core will pass through the cleaning area of the system and onto another conveyor which will sense the core and start moving. Once the core leaves each conveyor system, the belts will automatically stop moving.

### **5.6. Additional Considerations**

The complete redesign of the air core cleaner currently in use at [REDACTED] consists of a wide variety of systems which require careful attention during the design and implementation processes. Due to the fact that the core cleaner machine consists of multiple systems, additional considerations that go beyond the scope of this report must be addressed. Some of the items are not included in the main content of this report but require attention prior to design implementation. These items include the electrical wiring schematics and components for the many electric systems such as the lift systems, the conveyor system, the sensors and other similar features. Other items requiring further consideration and design work are the system programming and integration. Finally, the two supplementary features that [REDACTED] has requested will be included as additional modifications. These two supplementary features include an attachment point for their sorting table and a honeycomb core thickness verification system.



All of these systems fall outside of the project scope set before CCC at the beginning of this project, but still represent important additions that improve the effectiveness of the machine. Even without these additional systems, all of [REDACTED]'s needs have been met by the proposed final design which will improve the current cleaning process efficiency.

### **5.6.1. Electrical System Requirements**

The newly redesigned ionized air core cleaner consists of many different systems which require electrical power to be supplied. Systems requiring electrical wiring and control include the electric hydraulic scissor lift system, the linear actuator, the conveyor system, and all the sensors used with the various control systems.

The electrical requirements of the electric hydraulic scissor lift system are as follows: 110 volt supply for a one horsepower, single phase, 60 hertz motor with a dedicated 20 ampere line with a properly sized conductor.

The electrical requirements of the linear actuators are as follows: twelve volt input voltage with five ampere current at full load. A 10 000 ohm potentiometer is also included but requires no additional power supply.

The electrical requirements of the conveyor system are as follows: 230 volt supply for a 0.75 horsepower, 3-phase, 60 hertz inverter motor as well as a 115 volt supply for a single phase, 60 hertz inverter for the conveyors control.

The electrical requirement of the sensor systems will be not be significant, but each will need to be connected to the system they respectively control. Therefore wires will need to be run to connect the sensors to the conveyor systems, the linear actuators, and the electric hydraulic lift system.

### **5.6.2. System Programming**

With the electrical systems introduced in Section 5.6.1, the next aspect that must be considered to improve the proposed ionized air core cleaner is the programming and integration of each of these systems.



The electric hydraulic scissor lift system will need to be integrated with the block saw cutting process to match the block saw's height during operation. The honeycomb composite core panels are cut from a large core block nearly 3' thick. The core block sits on the block saw table while the band saw is set to the programmed height, ranging from 0.5" to 6". The block saw will cut through the core block, which are typically 8' to 10' long. Depending on the height that the panel is being cut at, the core cleaner table must adjust its own height to alleviate the effort required to move the panel from the top of the core block on the block saw table, to the conveyor system of the new ionized air core cleaner.

The programming for the electric hydraulic scissor lift system must be tied to the height of the block saw blade cutting height. The travelling eye height sensor system has been included in the design to aid in this aspect and help evaluate the current cutting height of the block saw.

The next system which will require programming is the linear actuators in the top hood of the new machine. These actuators control the height of the EXAIR air knife which adjusts its height to accommodate the different core panel thicknesses, ranging from 0.5" to 6". The purpose of the height adjustment is to maintain the air knife just above the core panel surface to maximize the air penetration through the core cells. Therefore, the height of the EXAIR air knife will have to adjust depending on the panel thickness being cut by the block saw. The block saw is controlled by a CNC control station within the core cutting department. The linear actuators programming will need to be related to the CNC system which controls the core panel thicknesses being cut.

The next system requiring programming considerations is the conveyor system which will be used to control the throughput rate of the ionized air core cleaner. The conveyor system will have a dial with multiple settings to accommodate the different core densities cut by the block saw, ranging from 2 to 16 lb/ft<sup>3</sup>. The dial settings determined by CCC are the following: 0, 20, 30, 40, 50, and 60 feet/minute. This means that even considering the longest panel (10' long) and the slowest conveyor speed (20 feet/minute), the honeycomb core panel will still pass through the ionized air core cleaner within in 30 seconds. An emergency shutoff button will be also be included to cut off power to the air knife, conveyors, and actuators.



The last programming schemes that will require further attention are the sensor systems which are involved in the activation of the EXAIR air knife and the conveyor system. These two systems will likely be connected to the same two sensors which will sense the presence of new core sheets on the conveyors at the entrance and exit of the core cleaner. The front sensor will detect the presence of a placed core sheet and initiate the motion of the conveyors. The second sensor at the exit of the hood must be clear before the conveyors will stop. The EXAIR air knife will be programmed to turn on when the entrance sensor is tripped and will shut off when the exit sensor is not being tripped. A delay in the programming of the conveyor should be implemented such that the core will fully clear the exit conveyor.

These programs should be implemented to best integrate the new ionized air core cleaner design into the core cutting department operations.

### **5.6.3. Sorting Table Attachment**

An additional request from [REDACTED] was the replacement of their sorting table at the output of the ionized air core cleaner. [REDACTED] requested not only a new table, but a method to attach the table to the output of the air core cleaner machine to ensure that no panels were fed off over the edge without the table present to catch them. Correcting this issue can be achieved by installing a docking system at the end of the new ionized air core cleaner which connects to the end of the sorting table. Due to the limited timeline of this project, the design of a new sorting table docking system was not possible. This sorting table is not necessary for the operation of the core cleaner, the existing table suffices but there is room for improvement in the future.

### **5.6.4. Thickness Verification System**

The last item that requires additional consideration is the installation of a thickness verification system. The current quality procedure for determining the nominal core sheet thickness involves the operator leaving his station at the CNC interface and measuring the panel using a caliper. This is an inefficient verification method since it requires the operator to stop the block saw cutting process, walk to the recently cut panel, measure the panel's thickness using the caliper, and finally feed it through the cleaner. Not only is this verification process slow and inefficient, but it also introduces human error in the caliper measuring process.



A proposed solution for the height verification issue is to integrate the thickness verification process into the cleaning process. This can be achieved by installing a laser height measurement system at the inlet of the ionized air core cleaner which measures the thickness of the panel as it passes through the hood. The EXAIR air knife and suction of the vacuum system will hold the panel flush against the tabletop, providing an accurate measurement of thickness for the recently cut core.

Addressing all of these additional considerations will yield a fully-functional ionized air core cleaner which meets every single one of [REDACTED]'s requests, even those outside of the scope of this project.

### **5.7. Final Assembly and Design Summary**

The final design of CCC's core cleaning machine incorporates many systems to achieve the needs of our client. The frame containing the dust collection duct is made of tubular steel, with 18-gage steel siding. The frame is welded together, and the steel siding is attached to the frame with sheet metal screws. The ducts contained within the frame connect to the supply vacuum line. A CNC height-adjustable EXAIR air knife 54" long is used to remove dust from the interior of the core cells. An Aerdon SSL-8 electric pneumatic lift system is used to achieve a machine height adjustability of 30". The 30" of machine height adjustability is required for the machine height to match the core block height during core block cutting. The base frame is attached to the steel lift table with fasteners. A 56.5" x 36" inlet conveyor and a 56.5" x 12" outlet conveyor were selected to move core through the cleaner to the sorting table. A metallic mesh underneath the air knife prevents the core sheets from falling into the machine, while allowing dust to pass into the vacuum duct. The EXAIR air knife is housed inside a hood with linear actuators and sliders. These actuators coupled with sliders are capable of vertically raising and lowering a total of 6.0". The height adjustability of the linear actuators is large enough to compensate for all thicknesses of core sheets dictated by the customer needs. All locations where dust can escape will be sealed with silicon to mitigate dust spread in the factory area. Bolts are used to fasten all components with the exception of the frame, which is welded. For the dimensions and more information on the parts of the design, a drawing package is included in Appendix G.



## 6. Project Summary and Conclusion

The existing core cleaner at [REDACTED] [REDACTED] [REDACTED] is an aging system that is ineffective at cleaning the dust from core sheets. As an added issue, the dust that does get removed from the core sheets is spreading to the factory area and not being adequately cleaned by its vacuum setup. The current core cleaner is also not ergonomic, as the operator has to pass a sheet through the machine manually.

The proposed final design from CCC is capable of cleaning all densities and thicknesses of core. Through the use of an electric hydraulic scissor lift, the proposed core cleaner can also raise and lower a total of 30" to accommodate the different heights of core blocks. The lift system used to achieve the 30" lift is integrated with a laser-height system that automatically matches the cutting height of the block saw. The air knife contained within the hood of the final design is capable of raising and lowering 6" to accommodate varying core thicknesses.

The new ionized core cleaner proposed contains a conveyor system that is capable of moving the core sheets through the hood, and placing the core sheets onto a secondary table. CCC recommends that the conveyors and EXAIR air knife should be synchronized to operate strictly when a core sheet is detected on the conveyors. The final design also includes plastic flaps at the inlet and outlet of the cleaning hood. The plastic flaps allow the core to pass through the cleaner, but prevent dust from spreading into the factory area. The new core cleaner also incorporates a dust collection duct, which is connected to the vacuum available on the factory floor. The pressurized air supply line will be connected to the air intake port of the EXAIR Super Ion Air Knife. Other salient features of the final design include side rails for the conveyors, accordion-style vinyl safety guard for the lift system, a conveyor speed dial, and an emergency shutoff button. The final dimensions of the cleaner are 60" wide by 24" long (excluding the conveyors).

CCC recommends that the final design be manufactured off-site. Outsourcing the manufacturing will prevent [REDACTED]'s manufacturing support staff from being overwhelmed. Following the manufacture of the proposed ionized air core cleaner, the old cleaner should be removed and the new machine installed. The installation of the new core cleaner should parallel the removal of the current core cleaner to minimize downtime. Down time will be required for the



replacement of the current cleaner; however the benefits of the new core cleaner's outweigh the replacement down time. Benefits of replacing the current core cleaner include an increase in core sheet quality, a decrease in material handling, and a reduction in dust spread into the factory area. Overall, the final design pushes towards automation of the core cleaning process, while improving upon the most important aspect: safety.



## 7. References

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- [6] ROSS EQUIPMENT Ltd. "*Aerdon SSI-8 Electric Hydraulic Portable Scissor Lift*", Winnipeg MB Canada: ROSS EQUIPMENT Ltd. [November 22, 2013]
- [7] McKenzie Handling System Inc. "*Wide Belt Conveyor*", Winnipeg MB Canada: McKenzie Handling System, 2013. [November 22, 2013]
- [8] Ulrich, K. T., and Eppinger, S. D., (2008). *Product Design and Developments*, 4<sup>th</sup> Edition, Mcgraw Hill, New York. [November 15, 2013].



# **Appendix A: Project Research and Important Resources**



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## **1. Project Research and Consultations**

Gathering relevant information relevant to the ionized air core cleaner has been a major task for CCC because the problems presented by the air core cleaner redesign are beyond the experience of CCC. Due to this lack of experience, the research and consultations conducted with respect to the project have proven to be invaluable tools in both the concept generation and selection process. Some of the documents which have been considered include CSA standards, relevant and related patents, notes taken during meetings with [REDACTED], as well as basic online searches for required information.

### **1.1.CSA Z432-04 Safeguarding of Machinery**

The CSA standard provided below outlines safety considerations for machine designs, mechanical design and controls, performance requirements for safety control systems, performance and application requirements for safeguarding devices, and other miscellaneous requirements for safeguarding machines. Composite Consulting Canada will adhere to all these requirements when developing the final design.

# STANDARDS INFORMATION

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## CSA Standard Z432-04 Safeguarding of Machinery

### Scope:

This standard applies to the protection of persons from the hazards arising from the use of mobile or stationary machinery. It provides the criteria to be observed and the description, selection, and application of guards and safety devices.  
This Standard does not apply to portable hand tools.

### Application:

This Standard is intended to be applied to newly manufactured, newly installed machinery, and rebuilt or redeployed machinery. The aim of the Standard is to promote a high standard of machinery safety during use.

### Definitions:

This Standard provides a number of definitions that apply to safeguarding of machinery.

### Risk Assessment and Reduction:

This Standard includes details for: Risk assessment; responsibilities for risk assessment and risk reduction; risk assessment methodology; identifying the hazards; estimating the risk from the hazard; risk reduction; documentation.

### Basic Concepts and General Safety Considerations for Design

- **Hazards to be considered when designing machinery** which includes: using standardized measurements methods; technical principles; mechanical hazards which includes: elementary forms of mechanical hazards; factors in the generation of mechanical hazards; slipping tripping, and falling. Other hazards which includes: electrical hazards; thermal hazards; hazards generated by noise; hazards generated by vibration; hazards generated by radiation; hazards generated by lasers; hazards generated by materials and substances; hazards generated by neglecting ergonomic principles in machine design; hazards combination; hazards associated with the environment in which the machine is used; linking mechanical and non-mechanical hazards.
- **Technical Principles** which includes: intrinsic design measures; avoiding sharp edges, corners, and protruding parts; consideration of geometrical and physical factors; considering technical knowledge of machine design and construction; using intrinsically safe technologies, processes, energy sources; applying principles of positive mechanical action of components; observing ergonomic principles; applying intrinsic design measures to control systems; starting of internal energy sources/switching on external energy sources;

### Mechanical Design and Controls:

This section provides details on various devices, machines, system, device design, warning signals and others such as: down-stroking platens; rotating shafts, spindles, and couplings; hydraulic and pneumatic system; electrical systems; workholding devices; safety colours and symbols; operating stations; lubrication and maintenance; interlocking of pneumatic and hydraulics systems; emergency stop; lighting; electromagnetic interference; safeguard-operator interface principles; warning signals and indicators.

### Performance requirements for safety control systems:

This section provides details on Safety control system performance criteria for safety-related software and firmware-based controllers.

Figure 1: CSA Standard Z432-04 Safeguarding of Machinery [1].



**Performance and application requirements for safeguarding devices:**

This section provides details on the design and construction with the goal of preventing any part of the body from reaching a danger point or area and that safeguarding devices shall be designed, constructed, installed, and maintained to ensure that people cannot reach over, around, or through the device undetected to reach the hazard. Included in this section are: barrier guards fixed and locked, safety light curtains/screens; area scanning safeguarding devices; safety mat systems; single and multiple beam safety systems; two handed control systems; safeguarding device safety distance; minimum distance from hazard;

Additional information provides details on:

**Lasers:**

Safeguards for laser use.

**Ergonomics:**

Machine design with respect to Body sizes and shapes; adjustable features; working posture; visual consideration; physical effort; machine pace; displays; controls; foot-operated controls;

**Environmental considerations:**

For machinery in certain industries notably food processing and pharmaceuticals for hygiene and guard design.

**Maintenance:**

Access to machinery for maintenance; operational maintenance of safeguards; waste and spillage removal; user responsibility;

**Safe work Practices and Supervisory control:**

Safe Work practices for working machinery in combination with supervisory control including Permit-to-work systems.

**Information and Communication:**

Instruction placards and warning labels; installation, operation, and maintenance instructions;

**Training:**

Training procedures for machinery operators, plant engineers and maintenance staff.

**This bulletin contains a summary of excerpts taken from the Standards for general information purposes only. This bulletin is not reflective of the complete requirements that the Standard prescribes.**

**Note:** Manitoba Regulation M.R. 217/2006 Section 1.4 inconsistency:

If there is an inconsistency between this regulation and a requirement contained in a publication, code or standard referenced in this regulation, the provisions in this regulation prevail.



## 1.2. Design Relevant Patents

As part of research into the design of the core cleaner, a patent search was made in order to find if there were pre-existing patents that were related to a honeycomb core cleaner. A very closely related [REDACTED] was found after an online search. Patent number [REDACTED] outlines the design of a [REDACTED] having a patent date of [REDACTED] and the patent assignee as 'The [REDACTED], [REDACTED], [REDACTED]' [2]. A design patent in the [REDACTED] expires fourteen years after the date granted, indicating that the patent is currently expired [3]. The patent details a concept design that will remove dust from the cells of honeycomb core, which is the same as the task assigned to Composite Consulting Canada by [REDACTED] [REDACTED]. Comparing the patent to the selected concept design, a few similarities were found. These similarities include conveyor belts to move the core through the cleaner, pressurized air flowing through the core cells, and a dust collection system to prevent the dust from entering the atmosphere. As the patent purpose is closely related to the one assigned to our project team, it will be used as reference throughout the design phase.

A patent of honeycomb core dust removal system, which belongs to The [REDACTED], [REDACTED], [REDACTED], was found online by Composite Consulting Canada and posted in the following text. The patent number is [REDACTED], and the publication date of the patent is [REDACTED]. The following text includes schematic drawings, dimensions, background and a summary of the invention. It is noted that all elements utilized in the system are listed and introduced accordingly at the end of the text, thus the whole text can be used as a legitimate example to follow in coming up with Composite Consulting Canada's design solution.

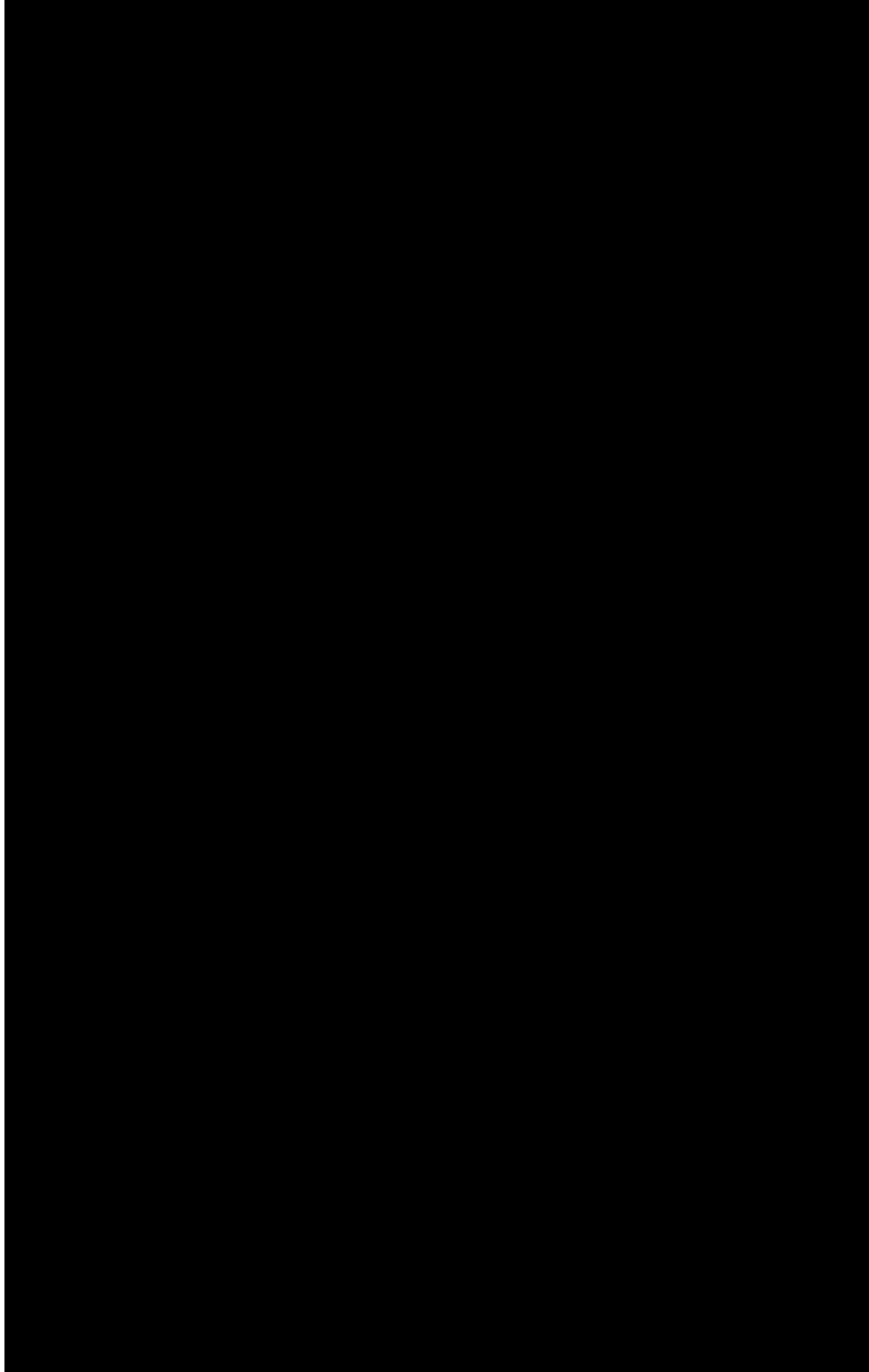
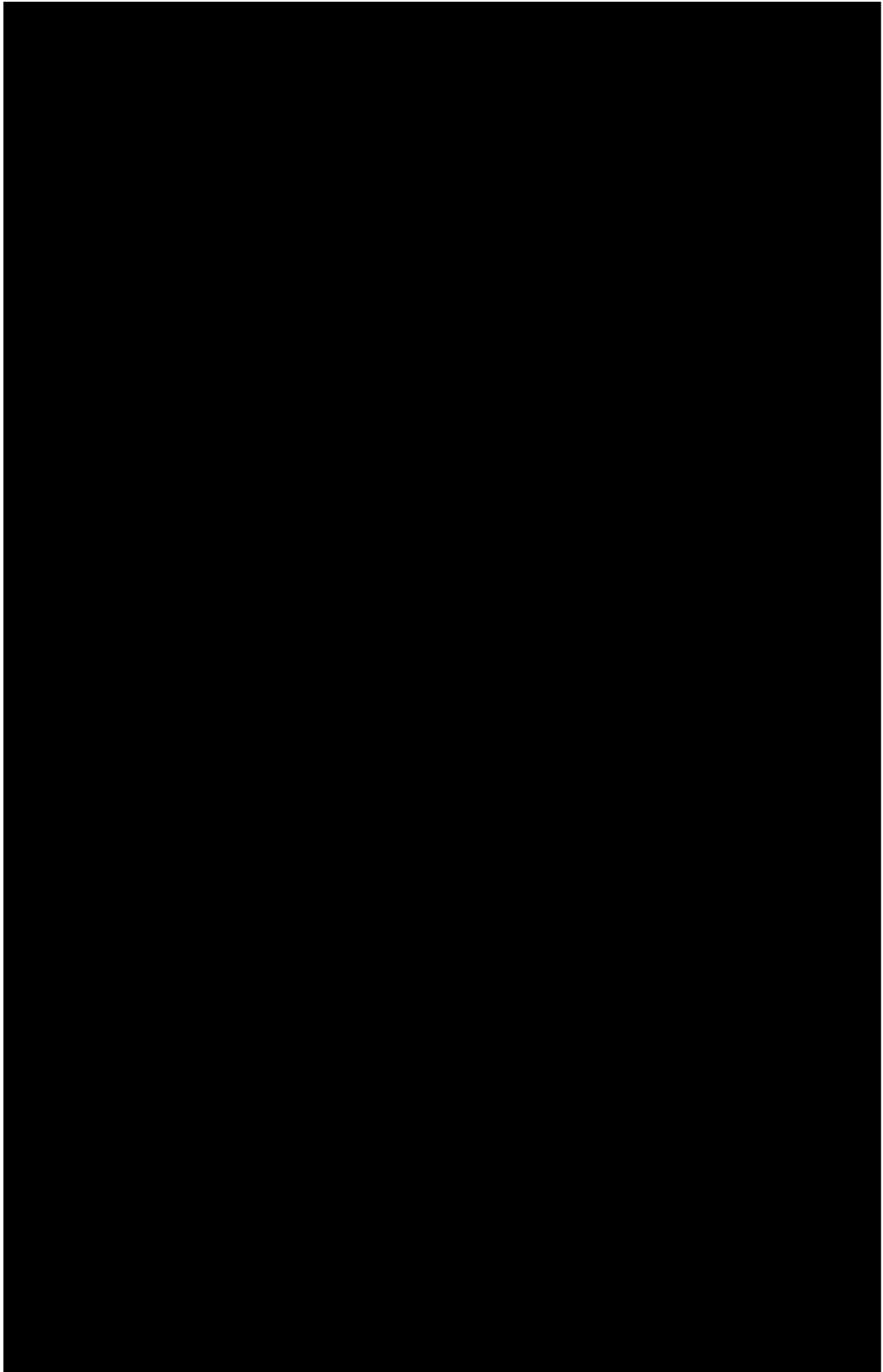
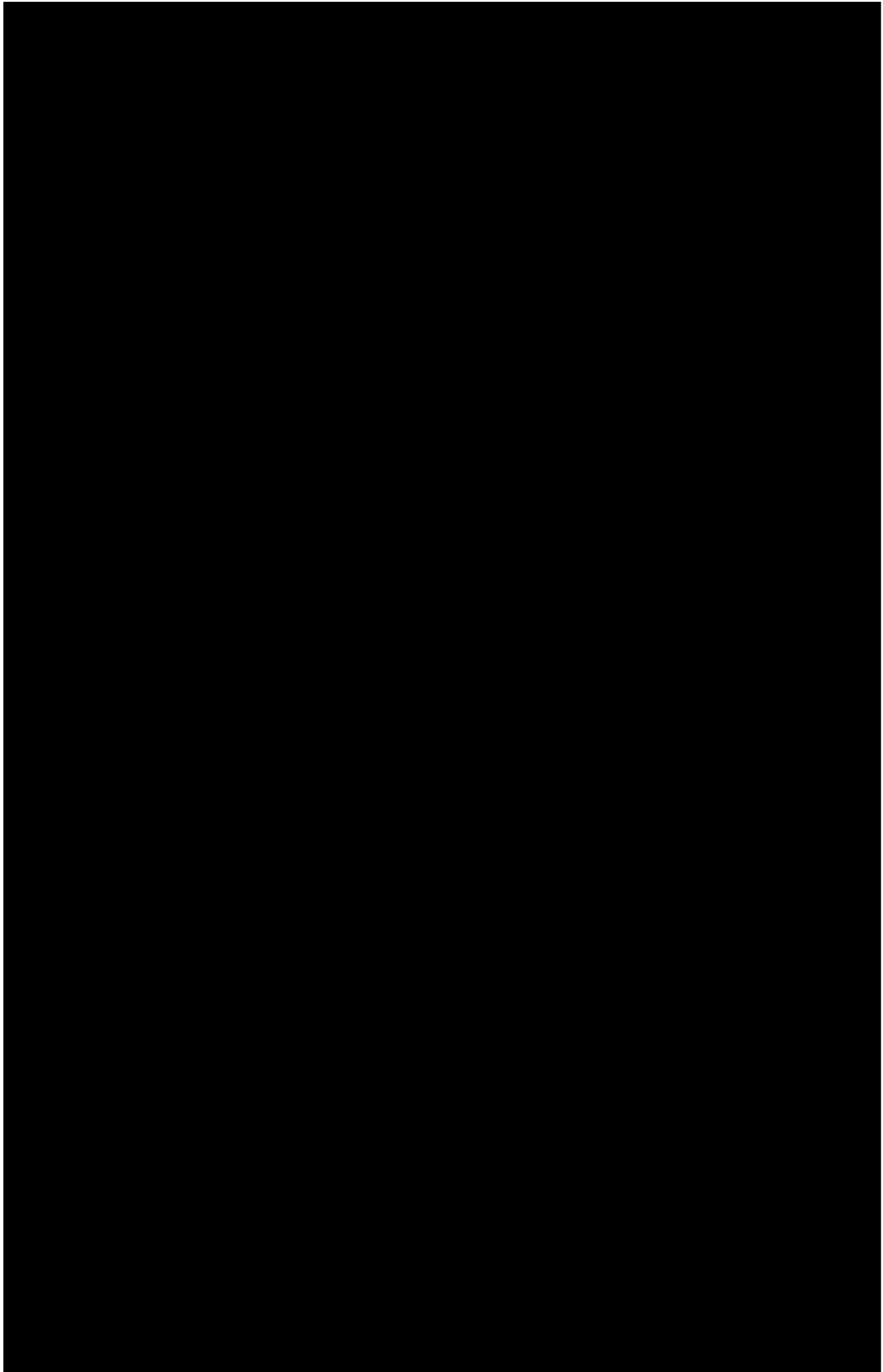
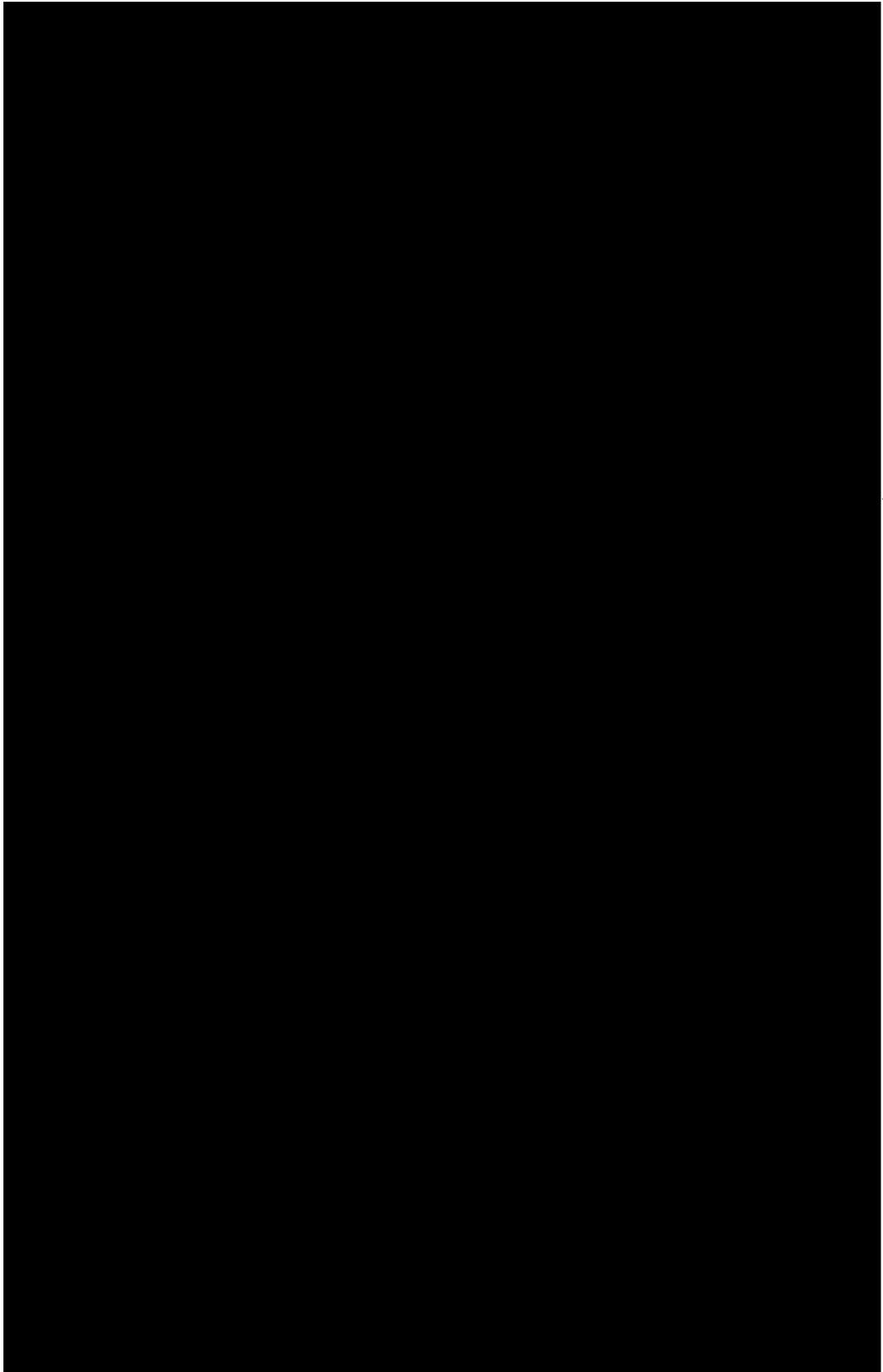
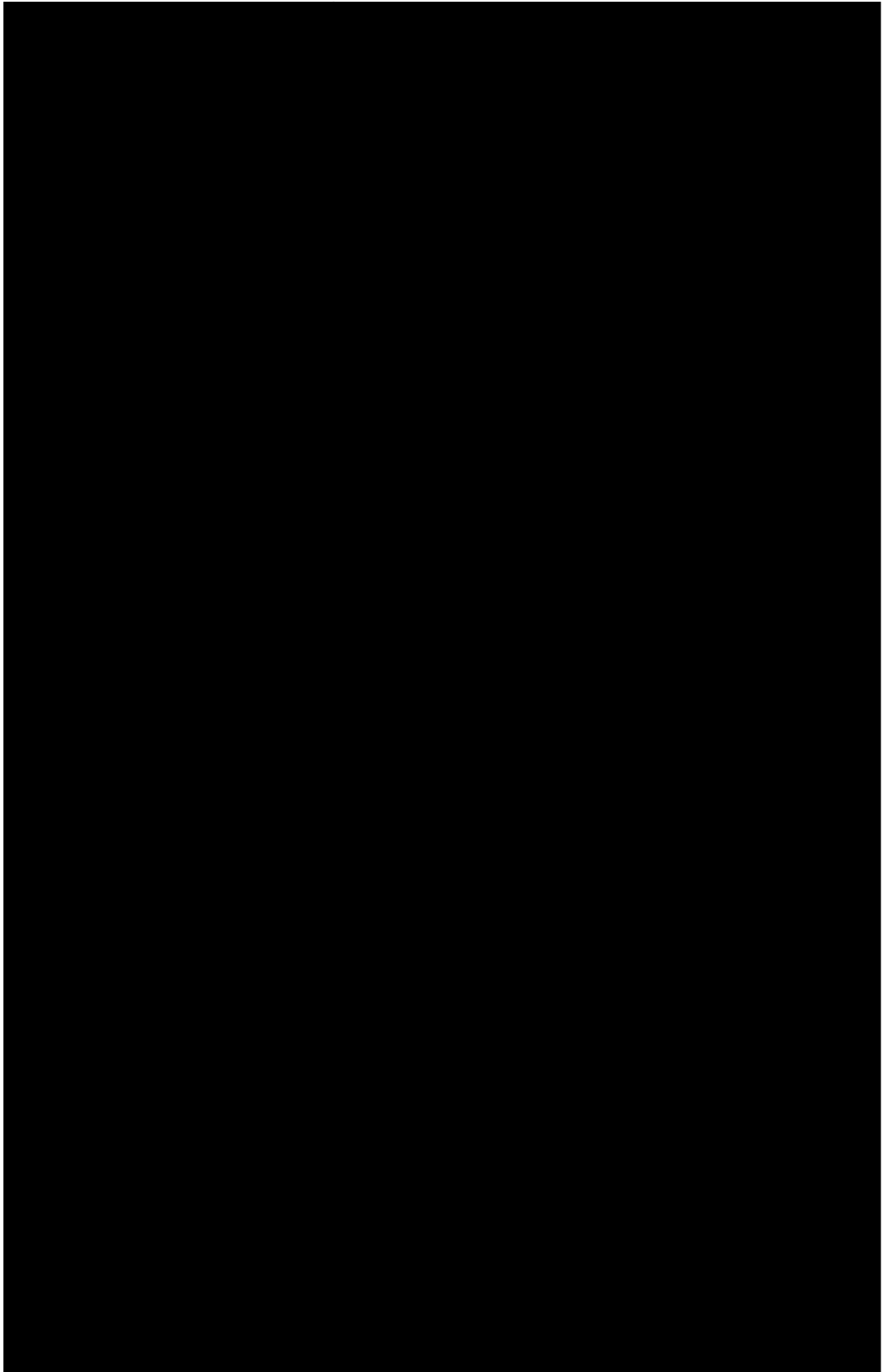


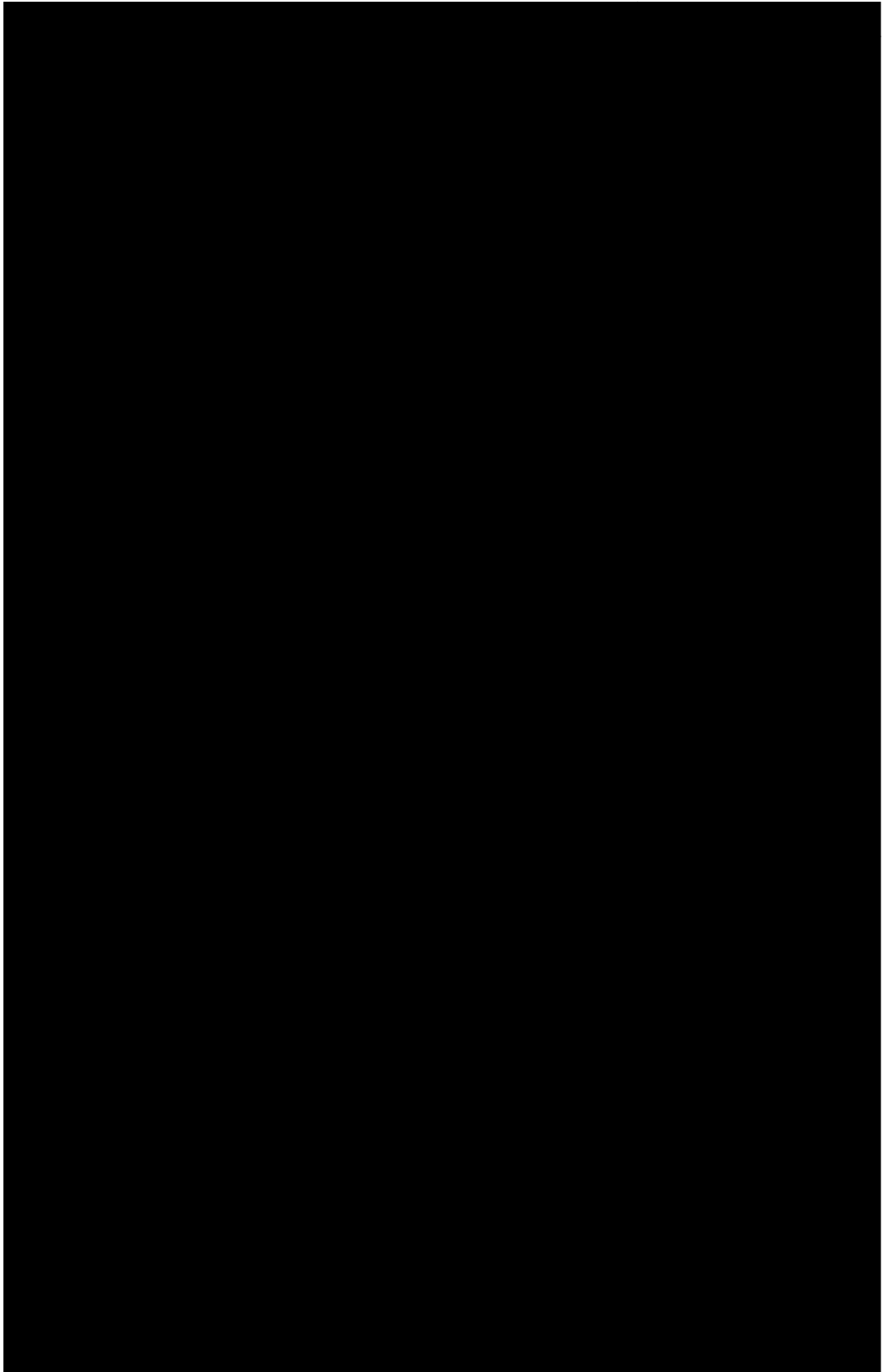
Figure 2: Honeycomb Core Cleaner Redesign Patent [4].

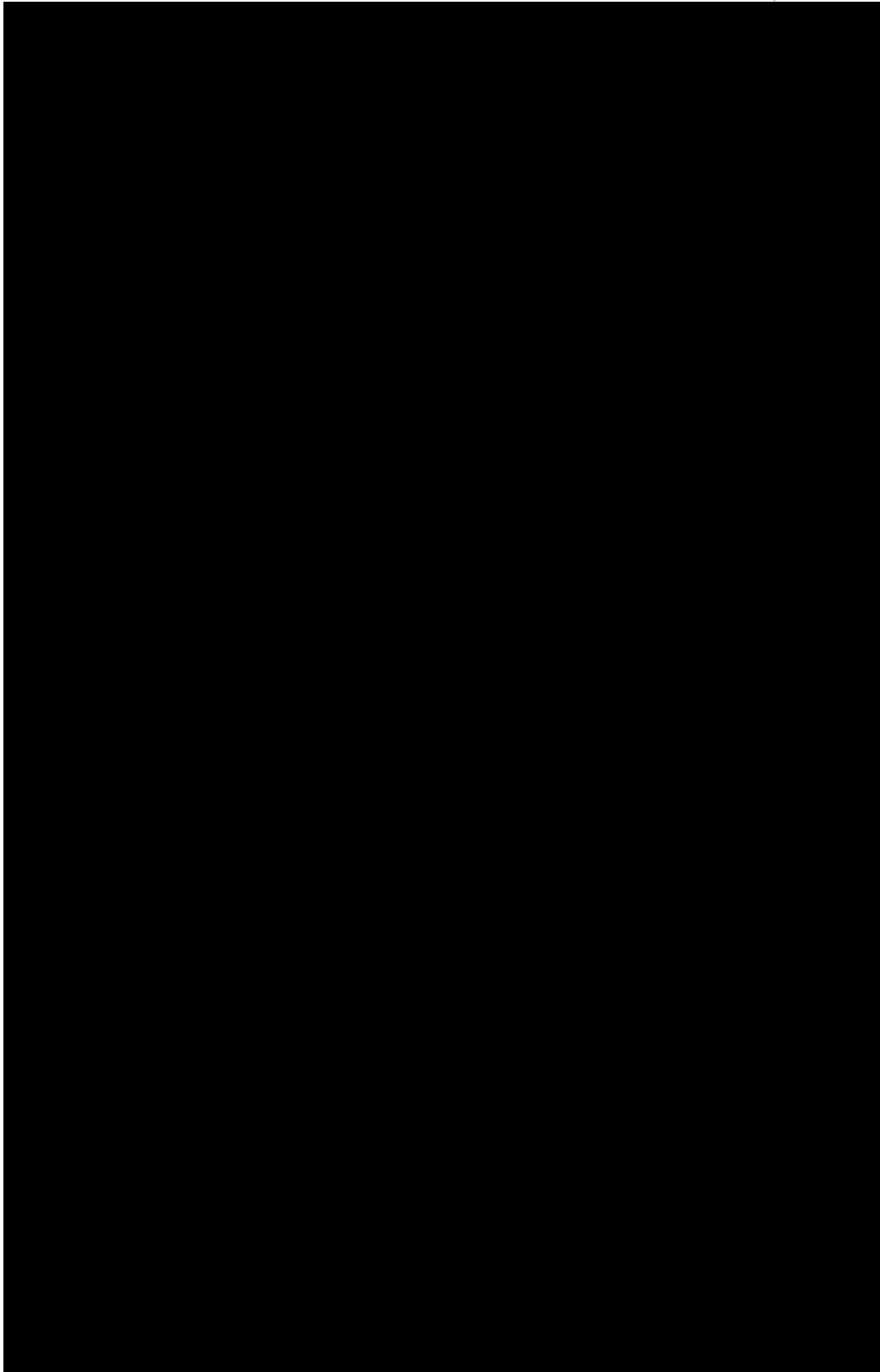


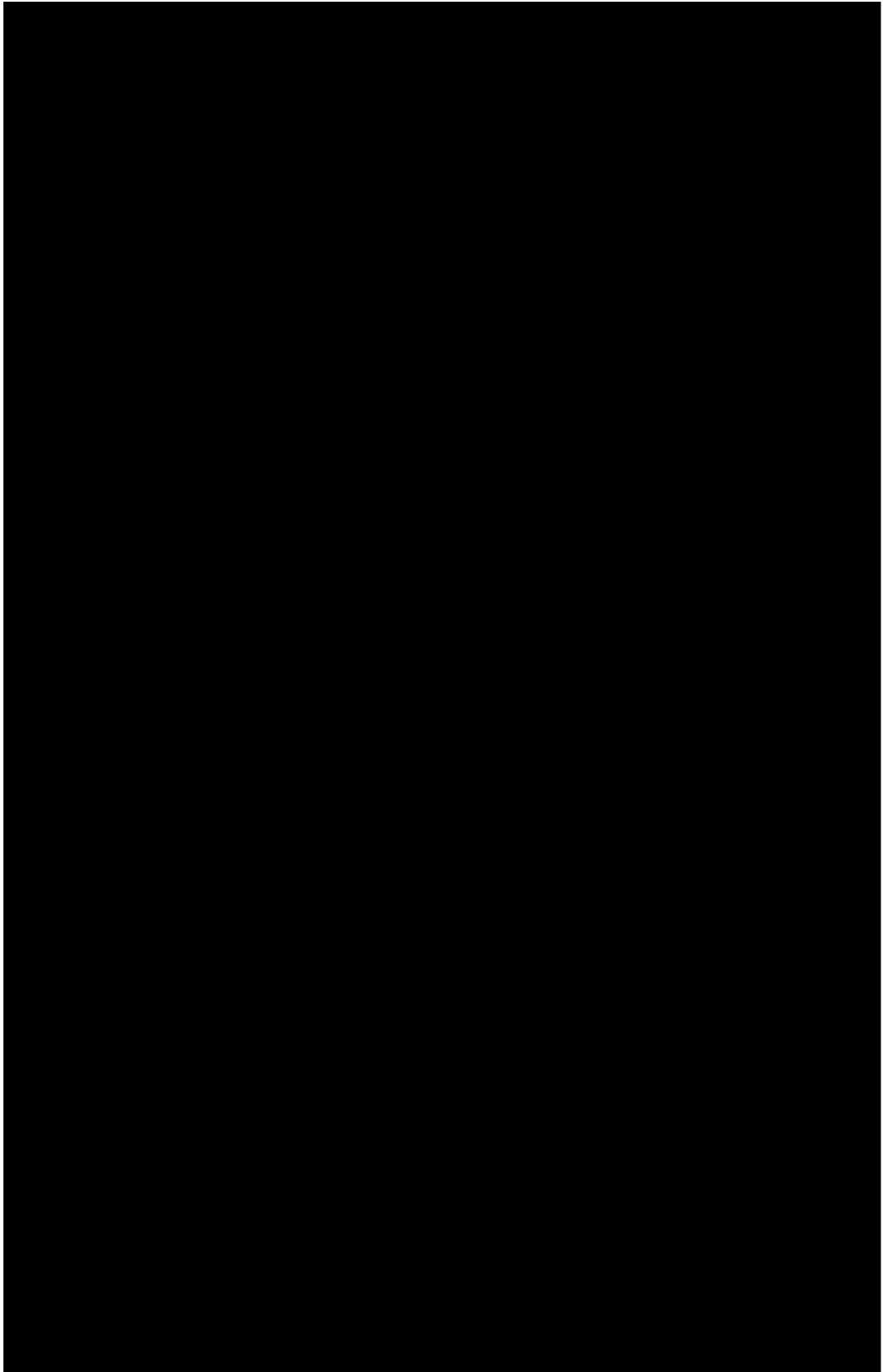


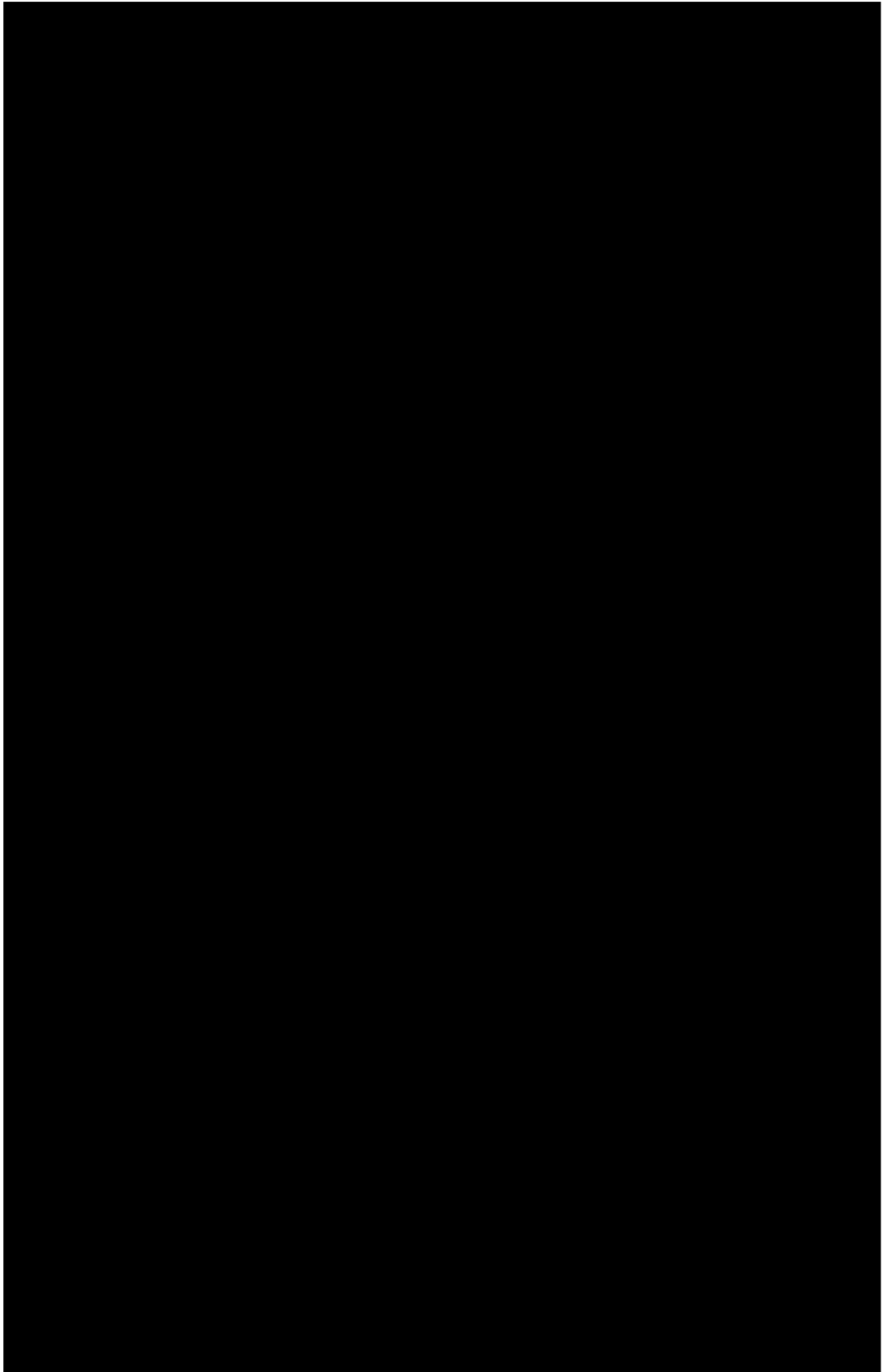


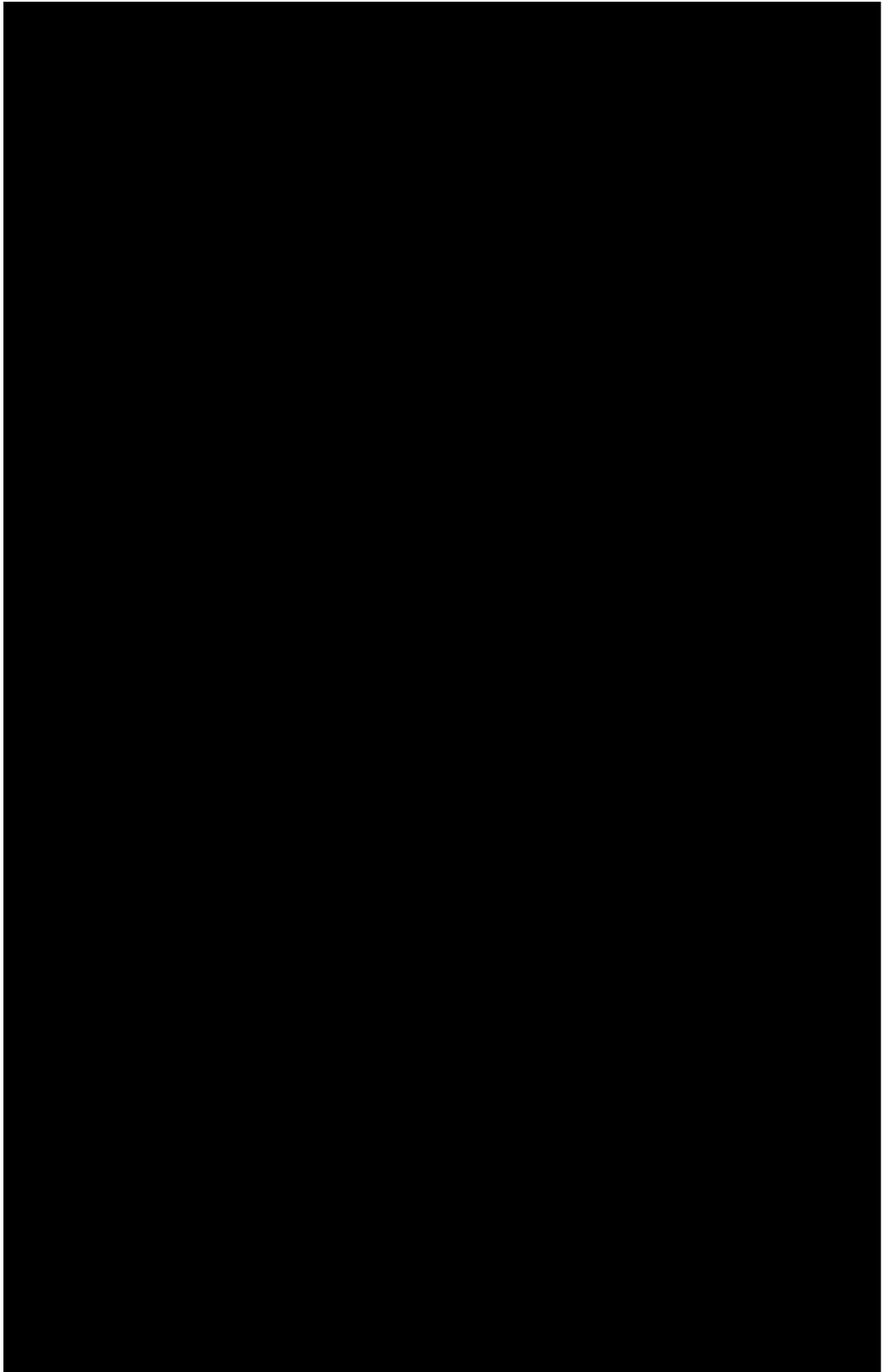


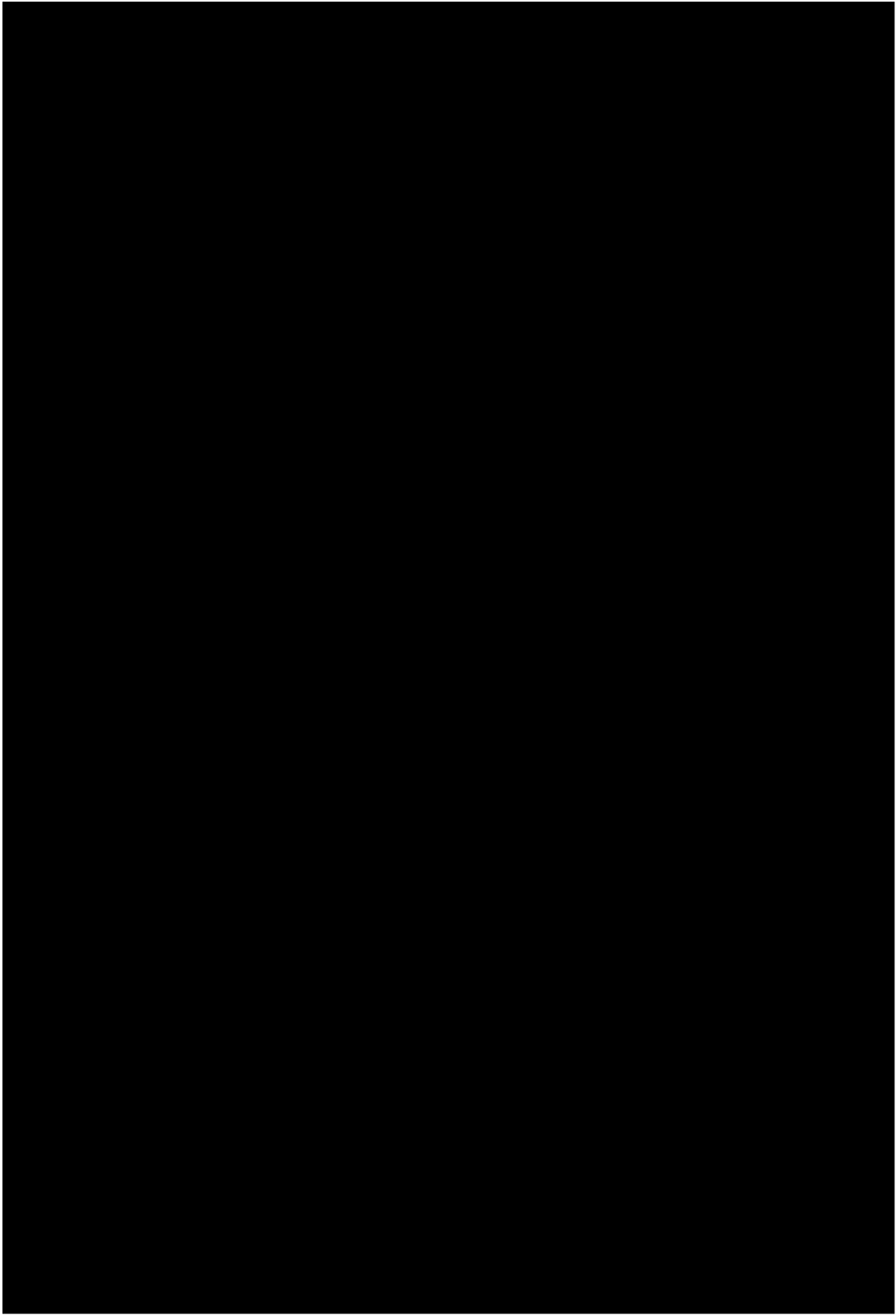












### 1.3. ■ Consultations

For the first two phases of our design processes we had a total of three site meetings with ■. During these meetings, a variety of information was collected and exchanged regarding the redesign of the core cleaner. Our first site visitation on September 19<sup>th</sup>, 2013, was used as a means to understand how the core fit into the overall process for the creation of composite panels, and for ■ to show the current core cleaning system. During this meeting, our team also asked a variety of questions to further define the problem statement, regarding things such as the purpose and importance of the project to ■, and safety requirements. Customer needs, target specifications, limitations, and constraints were collected primarily by email correspondence.

For our first meeting, Curtis Kowalchuk was the source of all information. Our second meeting, which occurred on September 26<sup>th</sup>, 2013, allowed us to observe and record the current cutting and core cleaning processes. Samples of dust were collected from pre-cleaned and post-cleaned core sheets. Figure 3 shows the effectiveness of the current core cleaning machine, where cotton swabs were used to obtain core dust from a 1.00" thick core sheet.

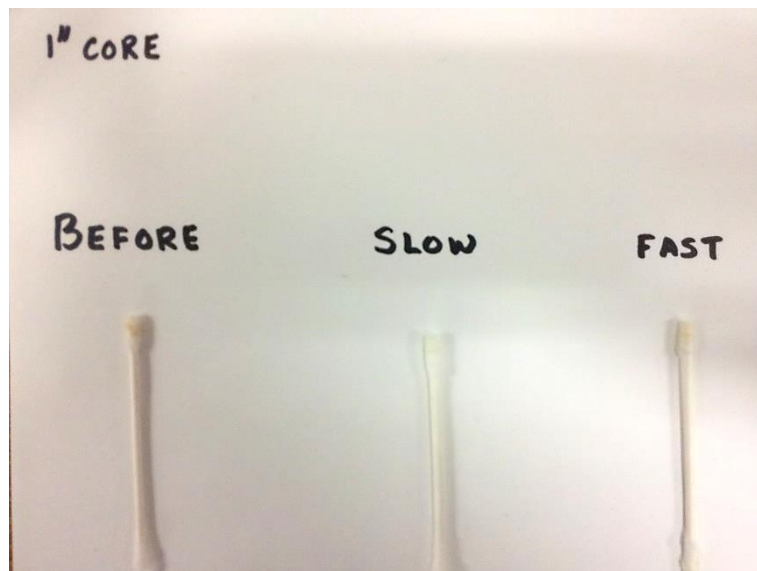
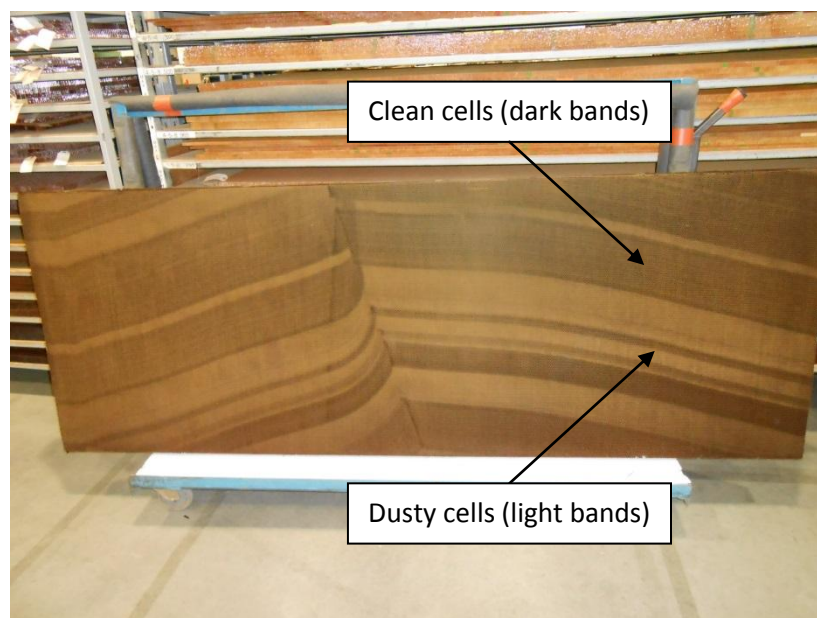


Figure 3: Dust removal test swab comparison.

The comparison shows that as the rate of core sheet cleaning throughput increases, the amount of dust removed decreases. This trend will be a key consideration when determining the rate of core sheet cleaning for our final design phase.

Another lesson learned from the demonstration was that the current core cleaning machine was inconsistent at removing dust from the core cells. The current core cleaner uses an array of nozzles to blow ionized air, which causes only sections of the core to be cleaned. The net effect of the inconsistent dust removal is illustrated in Figure 4 where waves can be observed from where the nozzles did or did not clean.



**Figure 4: Inconsistent dust removal causing wavy appearance in core sheets.**

The sudden change in direction of the light and dark bands of the dust can be attributed to how the operator had to push then pull the core sheet through the core cleaning machine. These two actions changed the direction the core sheet was going through the machine, causing the discontinuity of the wavy pattern.

Following the demonstration, we got feedback from the operators regarding features they would like to see in the redesign, including a core height-measurement system, automation of the cleaning process, and other miscellaneous items. Dimensions of the current core cleaner were taken, as well as notes of anything Chris Godin or the operators mentioned about the core cleaning system.

Our third and most recent meeting, which occurred on October 10<sup>th</sup>, 2013, was the least research oriented. Our team presented three viable designs, from which we collected more feedback from Albert Ducharme and Curtis Kowalchuk.

#### **1.4. Product and Process Research**

The online research during the concept brainstorming was conducted individually by the Composite Consulting Canada team. Since the main goal of the project was to remove dust from the interior of core cells, Composite Consulting Canada applied keyword searching at the beginning to refine search items. Firstly, to breakdown the subject heading, the team underlined the keywords “ionized air core cleaner”, “remove dust”, “fiberglass core cell”, “static charge” and “band saw cutting”. Boolean searching was utilized to refine a search, so the team used “AND” operator between the “dust removal” and the rest of the keywords separately to combine different concepts. During the concept searching, the team performed online research, where article databases and online catalogues were used to broaden the external searching scope. All the valuable search results and constructive comments are listed under each search subject as following.

##### **“Dust Removal” AND “ionized air core cleaner”**

Most results generated from this topic search had a common point in explaining the working mechanism and functionality of ionized air cleaners. Ionized air cleaners emit a steady stream of negative ions into the air; these negative ions attach to airborne molecules, making them negatively charged and attractive to nearby positively charged particles [5]. Figure 5 demonstrates the power of an EXAIR air knife as it uses pressurized air to wipe rocks off of the table top.



Figure 5: EXAIR air knife blowing off rocks from the conveyor [6].

The development of the ionized air cleaner has undergone tremendous improvements in recent years; however, the major purpose of the equipment is to purify and discharge the dusty air. Therefore, air blowing and its pressure enhancement become two major concerns in the implementation of the core cleaner redesign. By expanding the searching criteria, Composite Consulting Canada found a corporation called 'EXAIR', which has engaged in designing and manufacturing air knives. EXAIR utilizes compressed air for industrial applications that include drying, removing excess oils and liquids, dust blow off and cooling [7]. The team proposed to utilize the air knives is because of their practical adaptability, as they can be manufactured in various lengths and can be mounted to accommodate many industrial applications in tight spaces [7] with tremendous air pressure.

### **“Dust Removal” AND “Fiberglass Core Cells”**

In this part of search refining, the searched term “Fiberglass Core Cells” did not yield verbatim results since there were no similar topics within the search areas. However, there were a few subjects dedicated to fiberglass dust removal from other materials. Boat and car exteriors are typical surfaces that fiberglass dust may adhere to. Typical methods to clean it are to firstly ensure the cleaning room is sealed, and then turn on the air filter or dust collector [8]. Respirators, goggles, and Tyvek suits are recommended for the cleaning operator to avoid silicosis [8].

## **“Dust Removal” AND “Static Charge”**

Many search results were generated from this keywords combination. It is important to recognize that fiberglass can only possess positive static charge due to the existence of glass fibres. In general, grounding is the least expensive way to eliminate static charge. Via wire connections to the earth, the excess electrons or positive charges on the static charged object would be neutralized. However, the rate of static charge spread depends on the material of the object, since conductivity and the kind of static charge are determined by the material being used. Thus the team collected some electronic properties of fiberglass. Fibreglass does not conduct electricity and the composites are thus ideally suited to applications where metallic materials would require costly grounding. Also, Fiberglass trays can hold static charges, and until now there hasn't been a way to ground them [9].

In addition to grounding, anti-static spray can also have a significant effect in preventing the static charge. An anti-static composition is sometimes sprayed onto the surface of fiberglass insulation mats during the cooling step. Cooling air drawn through the mat causes the anti-static agent to penetrate the entire thickness of the mat. “The anti-static agent consists of two ingredients—a material that minimizes the generation of static electricity, and a material that serves as a corrosion inhibitor and stabilizer” [10].

Water is also an effective substance for static charge reduction, since water is one of the best electrical conductors in existence. When there is some moisture in the air, electric charge can enter the water droplets floating in the air. As droplets bump into other droplets, the charges can spread out even more. The moving droplets also carry charge to other surfaces, often to conductors [11]. Therefore, the more humid the air is, the greater the opportunity of the static charge to leave the object surface.

These are possible methods Composite Consulting Canada will investigate to help mitigate the problem of dust clinging to the honeycomb core cells due to being statically charged. Additional methods will be explored through other research methods.

## 2. References

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- [2] [REDACTED]. ([REDACTED]) “[REDACTED]”, [REDACTED] [Online]. Available: [REDACTED] [October 18, 2013].
- [3] The United States Patent and Trademark Office (July 31, 2013). “uspto.gov,” [Online]. Available: <http://www.uspto.gov/inventors/patents.jsp>. [October 20, 2013].
- [4] [REDACTED]. ([REDACTED]) [REDACTED] [Online]. Available: [REDACTED] [October 18, 2013].
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- [10]ADVAMEG (2009). “*PROTECTIVE COATINGS*”. [Online]. Available: <http://www.madehow.com/Volume-2/Fiberglass.html> [October 18, 2013]
- [11]Dr. Ken Mellendorf (2012). “*ELECTROSTATIC AND HUMIDITY*”. *Newton* [Online]. Available: <http://www.newton.dep.anl.gov/askasci/phy00/phy00286.htm> [October 18, 2013]



# **Appendix B: Project Organization**

## **Project Charter, Stakeholder Register, Work Breakdown Structure, and Gantt Chart**



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## 1. Project Charter

The project charter includes a summary of the all primary information regarding the ionized air core cleaner redesign tasked to Composite Consulting Canada by [REDACTED]. The full project charter includes a high-level list of the milestones, risks, and stakeholders. The charter also contains a brief statement of the project purpose and its associated objectives. The project charter is the document which requires client approval since it summarizes the projects intentions. Figure 1 shows the completed project charter with approval from Chris Godin, a delegate for the project sponsor, Curtis Kowalchuk, and Kevin Robbins, the secondary project sponsor.



Figure 1: Project Charter.

## **2. Stakeholder Register**

The stakeholder register provides a list of all key stakeholders involved in the project. Each stakeholder is identified in the register by their position and role to be met throughout the course of the project.

The stakeholder register provides a detailed list of the people who have an influence or interest in the project. Table I shows the register which outlines each stakeholder's participation in the project, their contact information, mode of communication, influence in the project, interest in the project, and their project role.



TABLE I: STAKEHOLDER REGISTER

 <b>Composite Consulting Canada - Stakeholder Register</b>							
Stakeholder Type	Name/Company	Contact Information	Project Role	Influence	Interest	Communication Frequency	Type of Communication
Project Manager			Oversee project, budget and timeline on track, meet deliverable, follow gantt chart, integrate team	High	High	Weekly	Email, Phone, Informal Meetings, Scheduled Meeting
Document Coordinator			Organize and keeps team docs up to date, provide necessary template, manage graphics, posters, report binding	High	High	Weekly	Email, Phone, Informal Meetings, Scheduled Meeting
Communications Coordinator			Main client contact, relay progress to contact, relay customer demands to team, keep all stakeholders informed	High	High	Weekly	Email, Phone, Informal Meetings, Scheduled Meeting
Technical Coordinator			Ensure software is available, modeling is up to standards, model is complete, model is updated on a regular basis, model revision control, part/assembly naming convention	High	High	Weekly	Email, Phone, Informal Meetings, Scheduled Meeting
Secretary			Take complete meeting minutes for team and client meetings, send out team agendas and minutes, organize team meetings and locations	High	High	Weekly	Email, Phone, Informal Meetings, Scheduled Meeting
Project Sponsor			Inform team of project purpose, information, and requirements, provide access to facility, design approval, assign project budget	High	Low	Weekly	Email, Phone, Scheduled Meeting
Secondary Sponsor			Inform team of project purpose, information, and requirements, provide access to facility, design approval, assign project budget	High	High	Weekly	Email, Phone, Scheduled Meeting
Project Advisor, Course Instructor			Provide team direction for project, evaluation of reports and presentations, moderate sponsor/student relationship, project consulting, project mentor, organize course direction, assign final grade	High	High	Weekly	Email, Phone, Informal Meetings
TechComm Group			Evaluate report format, structure, completeness, orthography	High	Low	Bi-Weekly	Scheduled Meeting
TechComm Group			Report evaluation, project and report consulting for TechComm group	High	Low	Bi-Weekly	Scheduled Meeting
TechComm Group			Provide IEEE reference consulting, evaluate format of source material on reports	High	Low	Bi-Weekly	Scheduled Meeting
Equipment Operator			Provide applied knowledge of equipment operation, maintenance, ergonomics, provide design feedback	Low	High	Monthly	Scheduled Meeting
TA			Report evaluation, project and report consulting	High	Low	Monthly	Informal Meeting
Area Manager			-	High	Low	Monthly	Email, Phone, Informal Meetings
Lead Operator			-	High	Low	Monthly	Through Sponsor
Maintenance			-	High	Low	Monthly	Through Sponsor



### 3. Identified Project Risks

To implement this project successfully, we need to manage risks appropriately. The Risk Assessment Matrix is the tool needed to focus on medium and high-priority risks. Composite Consulting Canada has been tasked to design an air core cleaner to fulfill [REDACTED]'s needs, and monitoring and controlling the associated risks will ensure the project's success. Since prototyping the product is not in the scope of this project, the consequence parameter in the Risk Assessment Matrix should not be the manufacturing cost, but rather the time delay of the project completion.

Using Table II, each risk can be given a numbered value using the following scoring scheme. The Likelihood rows and Consequences columns each has a number from one to five assigned to them. Each risk will be placed along the scale depending on its probability of occurring, and estimated amount of delay. Based on the risks position in the matrix, the two corresponding numbers will be multiplied to give a quantified risk score.

Using the risk assessment matrix and scoring scheme, the risks are organized into categories and given a priority based on the risk score. The risks have been organized using a color code (green, yellow, and red) which identifies the level of importance. The risks are organized into three main categories: schedule, scope, and resource. The non-weighted average of each of these categories is also listed in the risk score column.



**TABLE II: RISK ASSESSMENT MATRIX AND SCORING**

		Consequences				
		Insignificant (1 days delay)	Minor (3 days delay)	Moderate (5 days delay)	Major (7 days delay)	Catastrophic (10 days delay)
Likelihood	Almost Certain (>90%)	High	High	Extreme	Extreme	Extreme
	Likely (>50%)	Moderate	High	High	Extreme	Extreme
	Moderate (>20%)	Low	Moderate	High	Extreme	Extreme
	Unlikely (>10%)	Low	Low	Moderate	High	Extreme
	Rare (<10%)	Low	Low	Moderate	High	High
	Risks			Risk Score		
Schedule Risk			1.33			
Parts Delays for product prototype			0			
Decision Delay			4			
Hardware Delay for product prototype			0			
Scope Risk			7.17			
Project information Dependencies			6			
Assumption errors			9			
Scope creep			12			
Hardware defect			0			
Software defect			2			
Dependency change (unexpected legal, regulatory, etc.)			4			
Resource Risk			8			
Limited time availability from project sponsor			8			
Restrained information due to proprietary information			10			
Lack of funds for product prototype			0			
Attrition of resources			4			
Scarcity of skills			16			
Limited on site availability			6			

The consequence parameter in the risk assessment matrix is not the cost incurred by the risk, but rather the time delay the risk has on the project completion date. The major risks identified



have been indicated in red, which are the ones which have scored the highest in the risk assessment matrix. Composite Consulting Canada will address all the above mentioned risks, giving special attention to the high scoring risks in the following analysis.

#### 1. Scarcity of Skills

The scarcity of skills risk received a score of sixteen, the highest score in the risk assessment matrix. This is because the project members of Composite Consulting Canada are mechanical engineering students; therefore professional experience and knowledge regarding electronic hardware and software for this project are lacking. The scarcity of skills risk was mitigated by working with an electrical engineer provided by [REDACTED]. The power, electronics, wiring, and programming aspects will be done by the electrical engineer [REDACTED] assigned to help with the core cleaner project.

#### 2. Scope Creep

The scope creep risk received the second highest score, twelve. [REDACTED] expressed interest in a sorting table which the core cleaner feeds the panels onto after cleaning. Though the design of a new sorting table would improve the entire core cleaning and storing process, it falls outside of the project scope and has therefore been excluded from the main design goals. Deviating from the main scope of the project would have a major time delay on the project progress. Time and effort would have been spent on tasks that are non-essential and this waste of time would have had a detrimental effect on the project. Composite Consulting Canada mitigate this risk by creating a list of additional features which require further consideration to be implemented but would have a positive impact on the overall performance of the design.

### **4. Work Breakdown Structure (WBS)**

The fully expanded work breakdown structure includes all necessary tasks determined by Composite Consulting Canada (CCC) for successful completion of this project. Figure 2 outlines the WBS hierarchy of said necessary tasks giving a clear view of the phase that each task falls into.



In the initiation phase, a project charter and stakeholder register were developed. The project charter provided the team with a high level project summary which included the project purpose, design approach, objectives, requirements, risks, a milestone timeline, and a time budget. Additionally, team members, project roles, and signing authorities were identified. The project charter was presented to the project sponsor for approval and signing. The stakeholder register was developed to list all project stakeholders, their role in the project, contact information, communication frequency, and the mode of communication between each stakeholder.



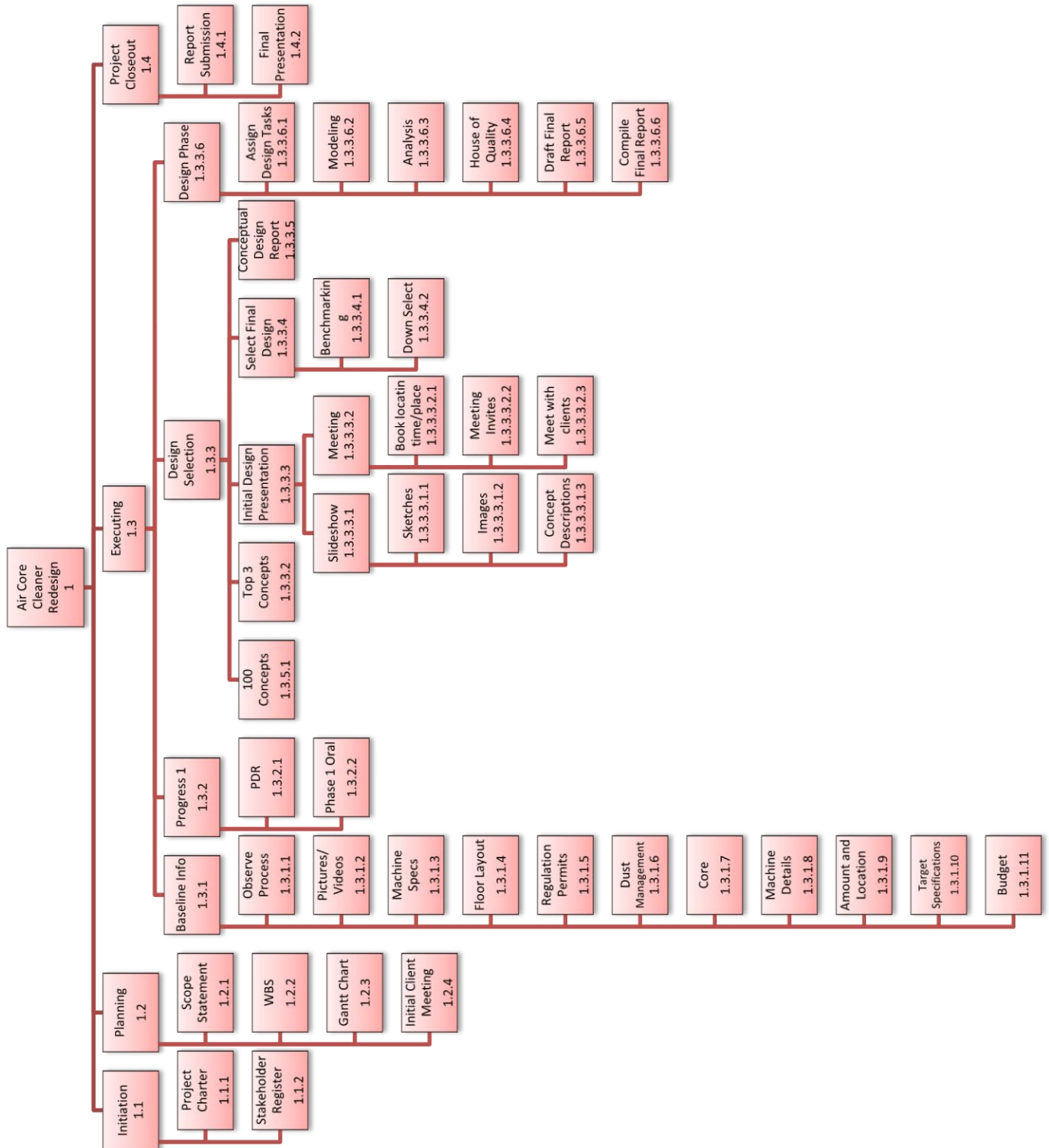


Figure 2: Work breakdown structure.



## 5. Gantt Chart

The project schedule CCC will be following is outlined in the full Gantt chart presented in Figure 3. The tasks outlined in the WBS are used as the scheduled tasks in the Gantt chart. Each task was assigned an estimated time duration in days then linked to required predecessors to obtain the schedule. Currently, CCC is on schedule having not missed or fallen behind the proposed deadlines.

In the planning phase, a detailed scope statement was developed from communication with [REDACTED] representatives and the provided project outline. After developing the scope, the WBS and Gantt chart were created in order to develop an accurate and detailed project timeline that would be followed throughout the project. Once the timeline was in place, the team met with [REDACTED] to discuss the project timeline, scope, and transition into the executing phase.

The executing phase encompasses the vast majority of all project tasks. This phase was split up into four major tasks: baseline information, progress 1, design selection, and design phase. With the design phase complete the executing phase of the project came to a close. The project closeout phase was then started by CCC. The team is on schedule for the final project report submission and presentation on December 2 and 3, 2013, respectively.



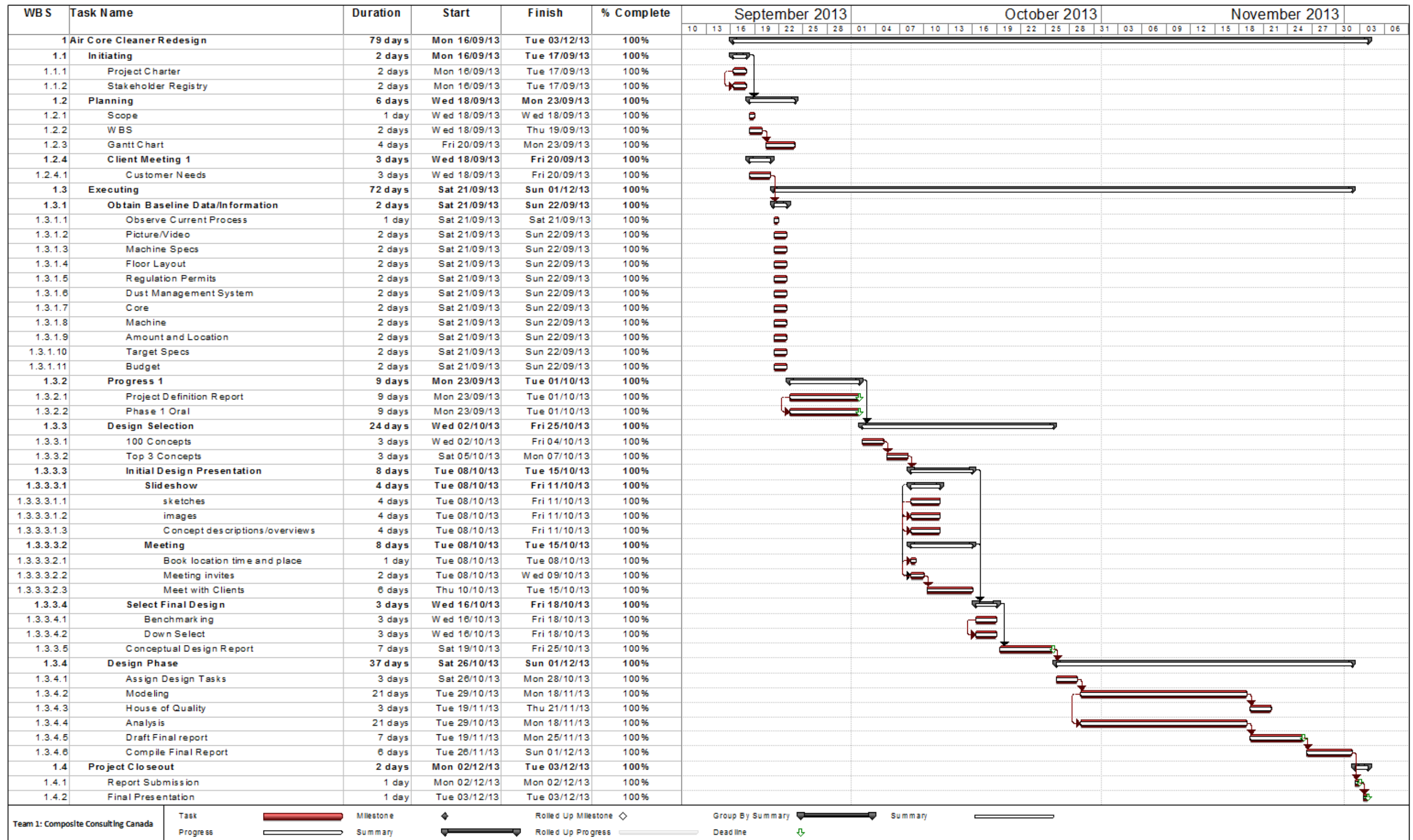


Figure 3: Gantt chart.

# **Appendix C: Entire Concept Generation Process**



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## **1. Concept Generation and Selection**

The redesign of the current ionized air core cleaner machine used at [REDACTED] [REDACTED] [REDACTED] requires the investigation and consideration of many different concepts and designs. To develop the best core cleaner possible for [REDACTED], the concept generation process will incorporate much iteration to ensure maximum creativity and innovation. The following sections describe the process followed by Composite Consulting Canada to generate and select the final design concept for the core cleaner redesign. The stages followed in the concept generation and selection process include preliminary brainstorming, down selection from generated concepts, concept evaluation and, finally, selection of final design concept.

### **1.1.Preliminary Brainstorming**

Preliminary concept generation was completed by developing methods to be followed and applying these methods to begin the first phase of concept creation. The preliminary brainstorming started after the project objectives, customer needs, target specifications, design constraints, and design limitations were outlined.

#### **1.1.1. Methods Used During Process**

Part one consisted of group brainstorming. This portion of the brainstorming was used as a way to generate high level ideas of how to remove a static charge and dust. The team started by listing ways a static charge could be eliminated, which included humidity, anti-static spray, ionized air, and grounding. Next, the team listed ways that dust could be removed from a surface, which included vibrations, air pressure, various types of liquid, wiping the surface, and burning dust particulates. With these initial ideas for static charge and dust removal in mind, each team member was assigned the generation of twenty preliminary concepts specific to removing dust on the honeycomb core after the cutting process.

#### **1.1.2. Development of 100 Concepts**

Part two of the preliminary concept generation consisted of individual brainstorming. The goal was to have a total of 100 preliminary concepts, which was to be achieved by combining twenty concepts from each team member. For this process to be effective and allow for maximum innovation and creativity, the team agreed that at this stage of the design phase all ideas brought to the table would be received with an open mind. Ideas would not be dismissed until they were discussed as a group and the potential of each design was considered.

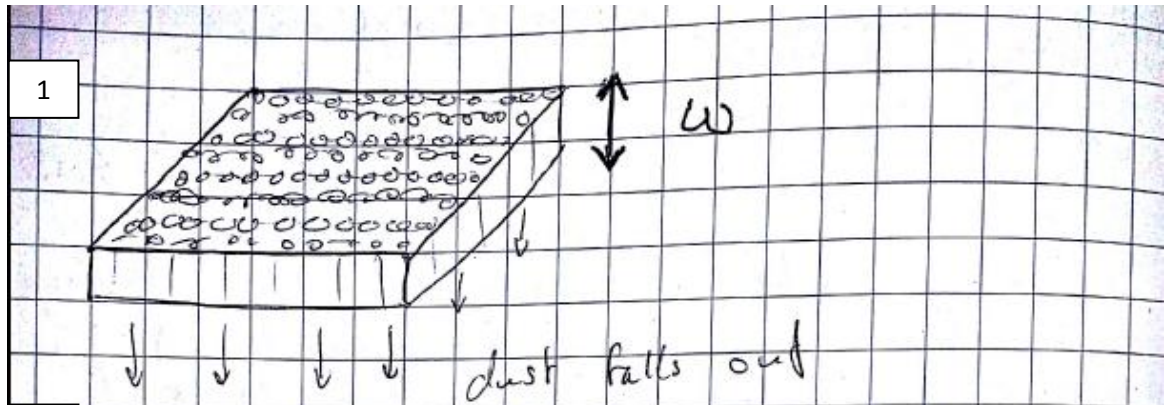


Each design was required to have a brief description and sketch prior to being presented to the team. The ideas discussed in part one were used by each member to develop the high level ideas into concepts specific to cleaning the core. However, members were not restricted to using the initial ideas from the team brainstorming session. Alternative ideas were encouraged by each member during the individual brainstorming. The following images contain all 100 sketched concepts.



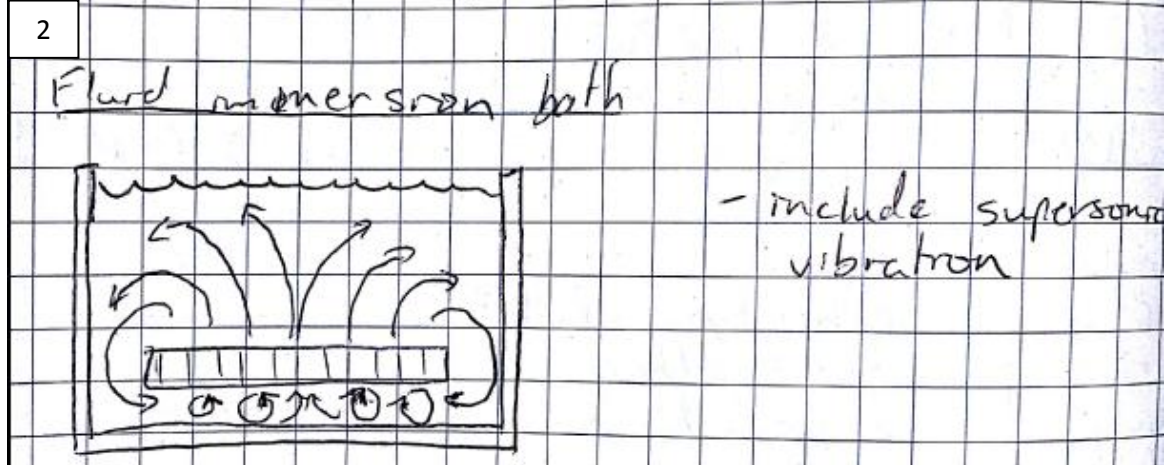
Stephen M. Roche's 20 concepts

1



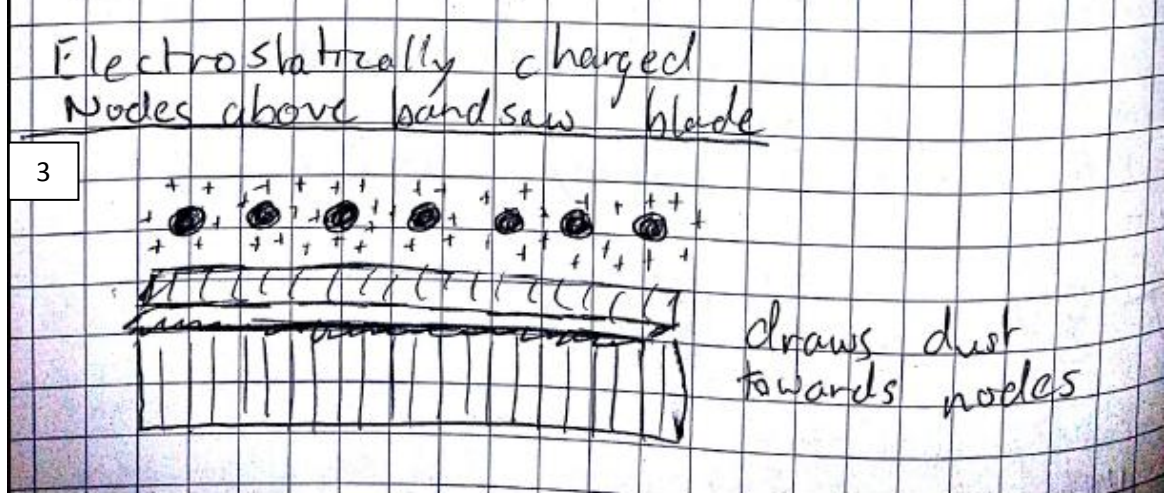
2

Fluid immersion both



Electrostatically charged  
Nodes above bandsaw blade

3

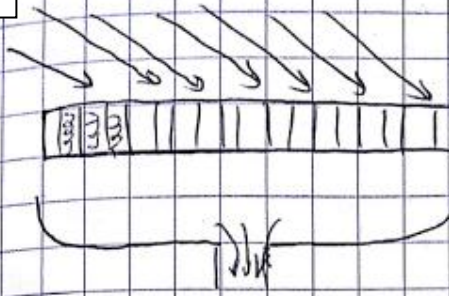


draws dust towards nodes



Angled air blower/vacuum

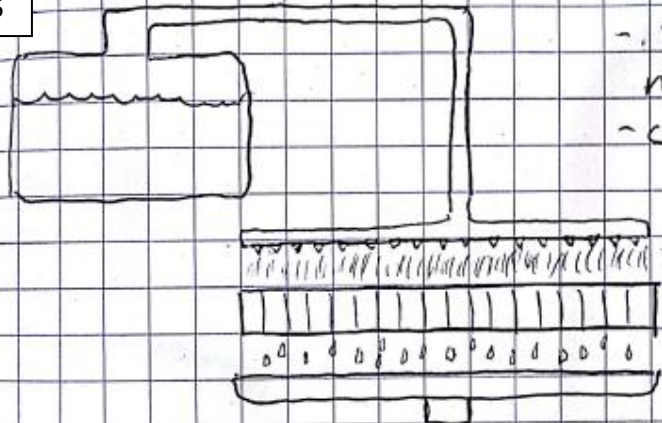
4



- Creates turbulence inside cells
- vacuum at bottom

Superheated vapour

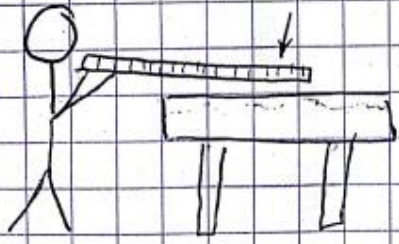
5



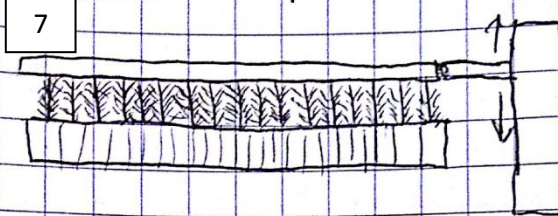
- SV pushed through nozzles into cells
- collected in basin

Do nothing Shake over bin

6

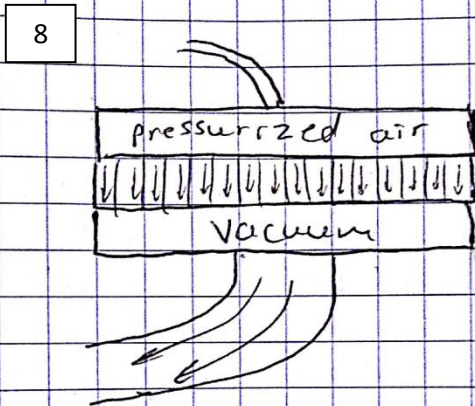


## Miniature Pipe Cleaners



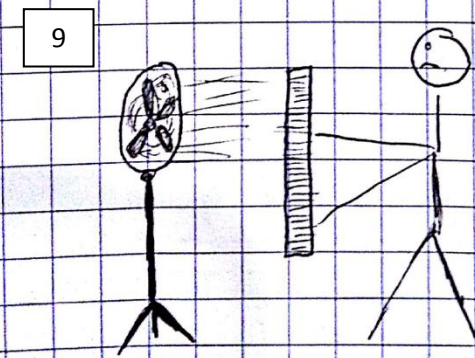
- dip and clean
- interchangeable cleaning heads

## Sealed Pressurized Arr/Vacuum



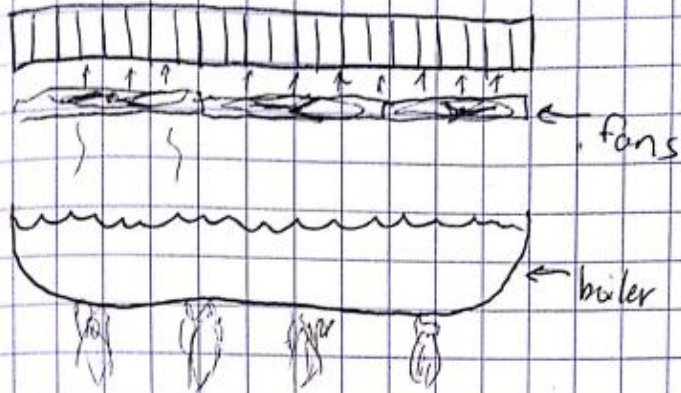
- enough contact pressure on top and bottom of cells to create a seal.

## Use a fan



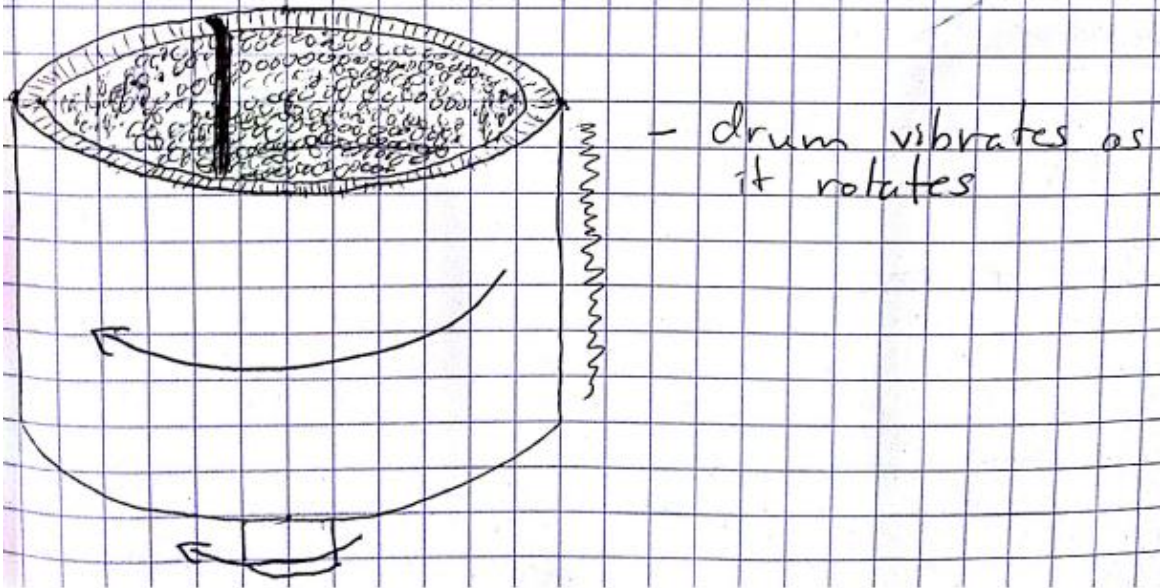
10

Boil water and direct with fan  
vacuum?

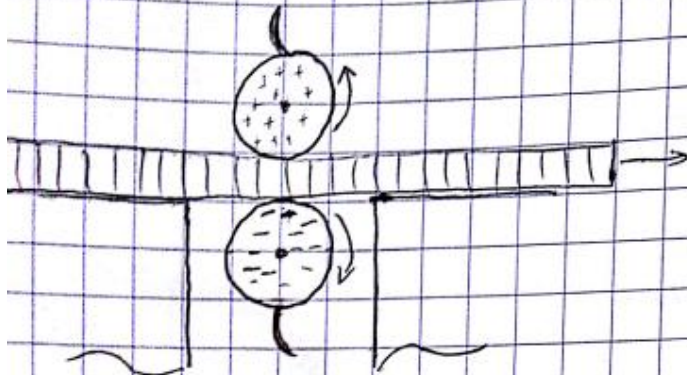


11

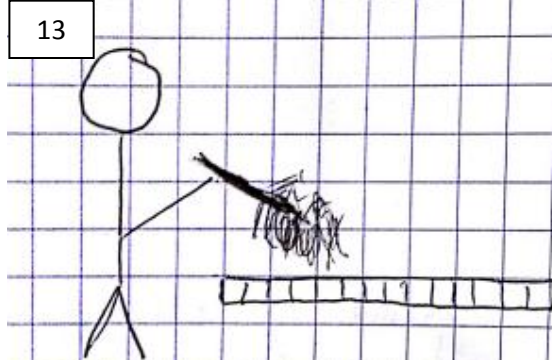
Centrifuge w/ vibration



## 12 Charged Rollers

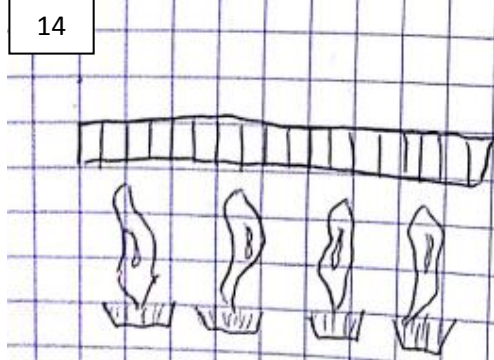


## 13 Electrostatic Cloth



- material is negatively charged
- can be automated

## 14 Dust burnoff

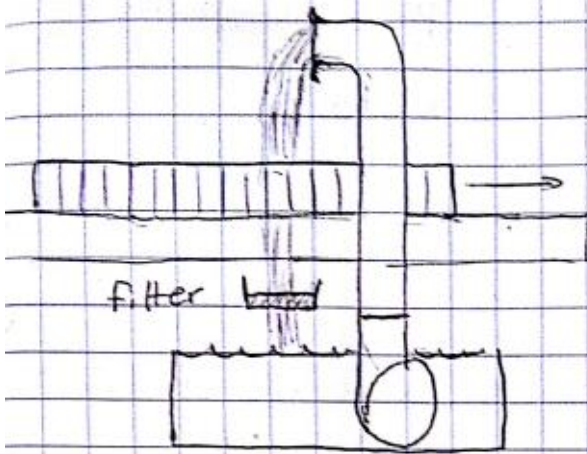


- likely destructive



## Waterfall (Charged)

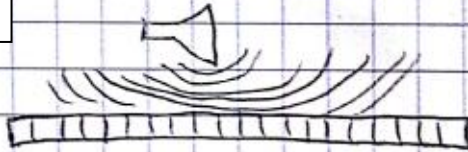
15



- could be a chemical that evaporates quickly

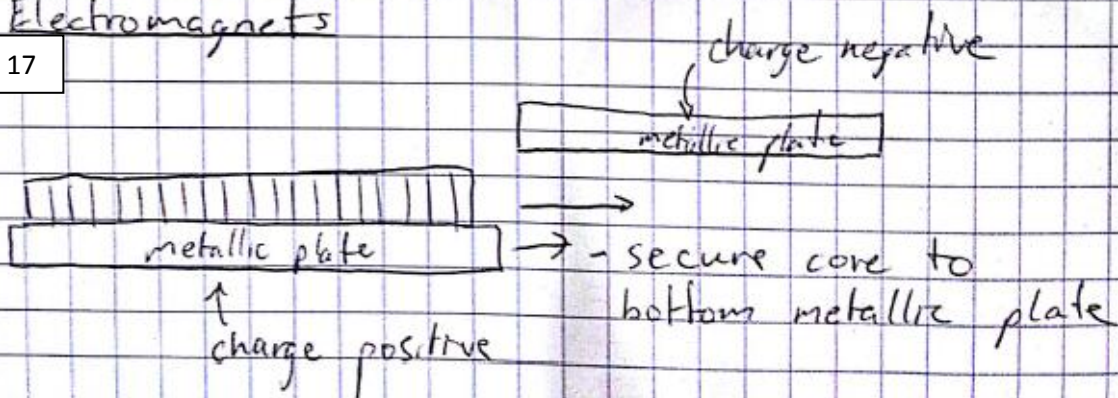
## Sound/Pressure Waves

16



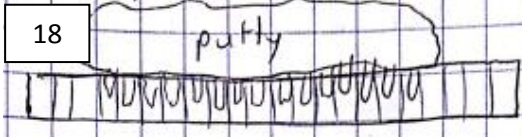
## Electromagnets

17



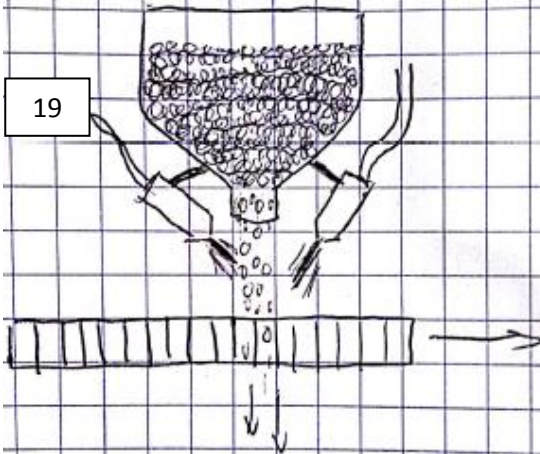
### Cyberclean

→ peel off



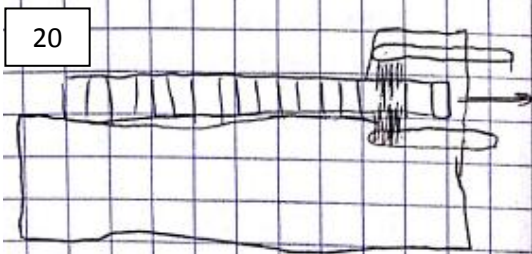
- washable putty that is used for keyboards
- put onto rollers to automate

### Bead Waterfall (charged)



- option to charge beads to grab dust.
- use pressurized air to force beads through

### Soft bristles

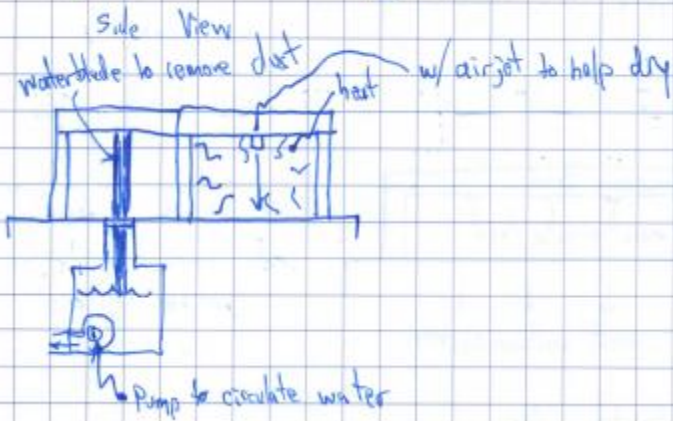


## Stefano N. Lisi's 20 concepts

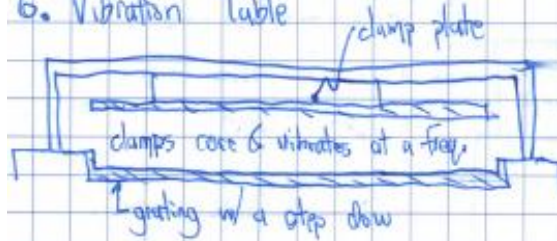

4. Fine carbon fiber brushes with air knife



### 5. Waterjet w/ Convection Drying

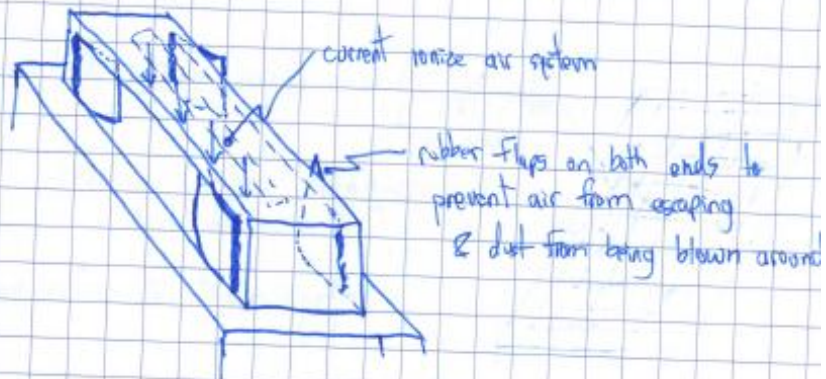


### 6. Vibration Table

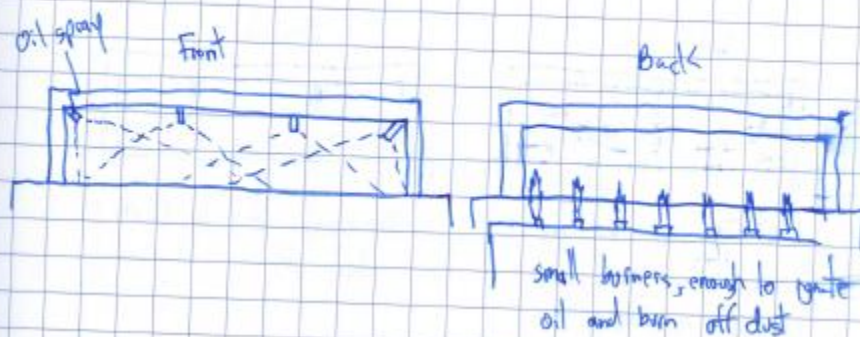


- Concerns - core damage  
 - size of machine  
 - cleaning process time

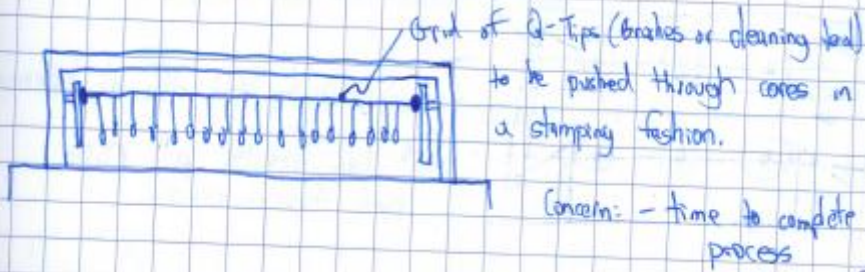
### 7. Flaps to contain & focus Air



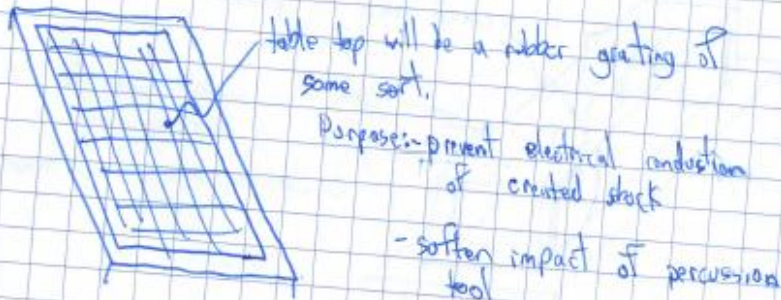
### 8. Thin oil film + Burning



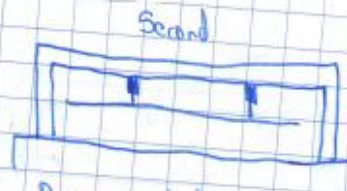
## 9. Q-Tip Stamp



## 10. "Thor Core" Cleaner



Electricity core in an attempt to remove static charge completely.

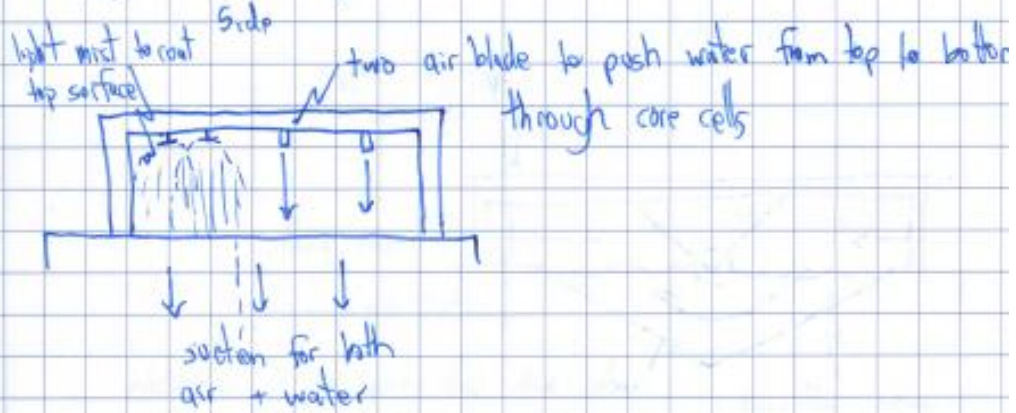


Percussion tool to knock dust off

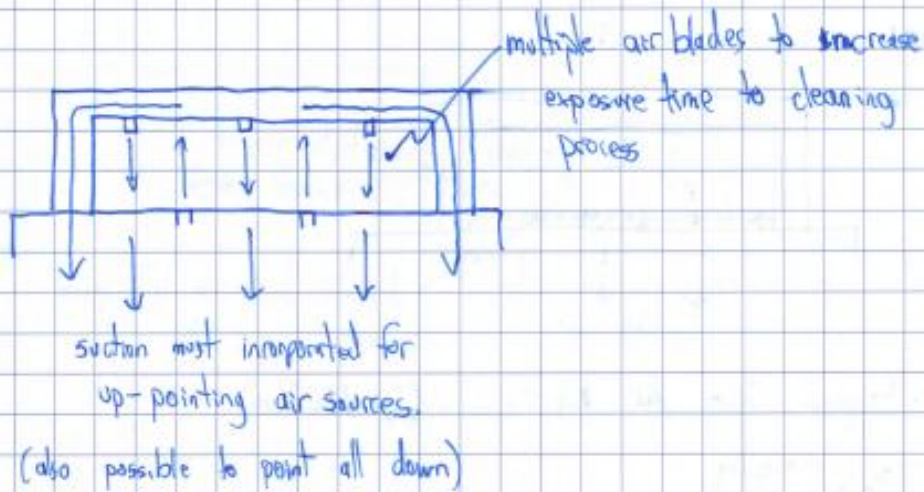
## 11. Rollers w/ Vibration



## 12. Spray & Air Dry



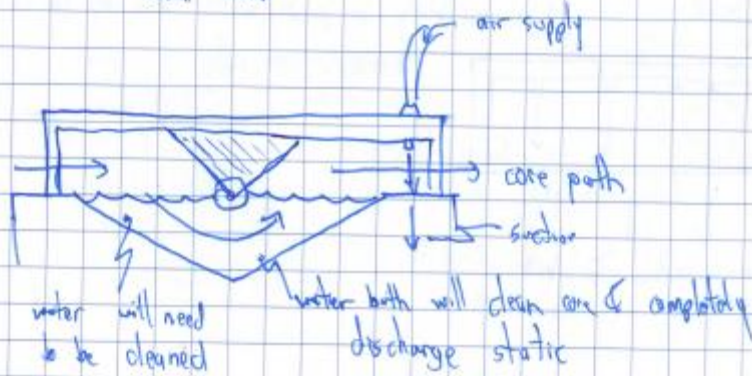
## 13. Multiple Airblades



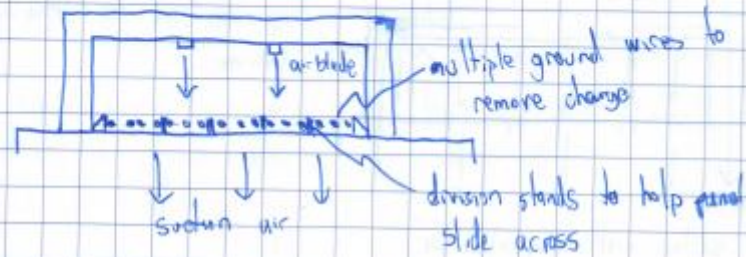
## 14. Ground Wire & Air Blade



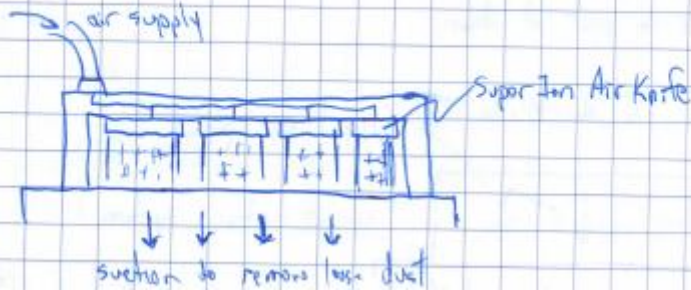
15. Submerge & Dry  
Side View



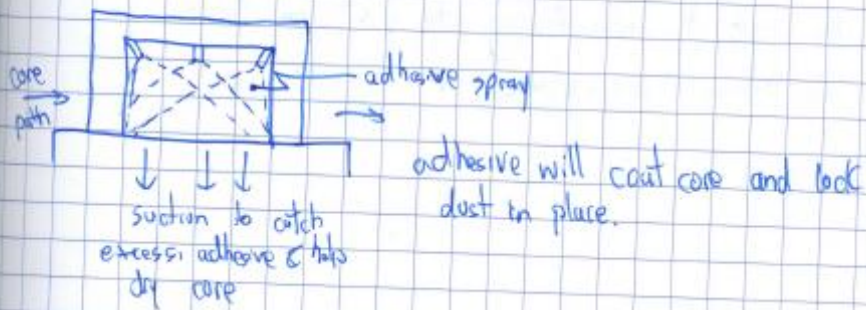
16. Ground Wire Conveyor & Air  
Side View



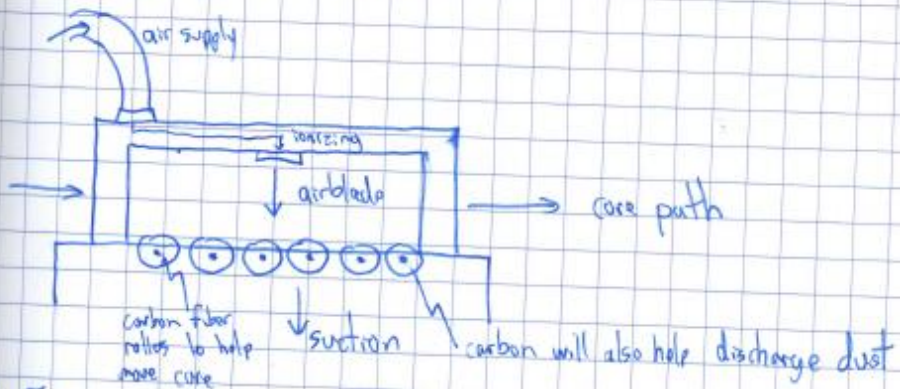
17. Super Ion Air Knife (EXAIR Ion)



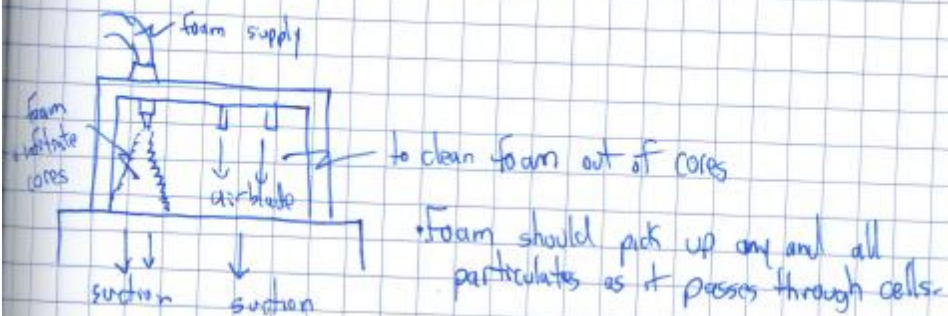
18. Quick-Dry Adhesive Spray  
Side View



19. Roller Conveyor and Airblade



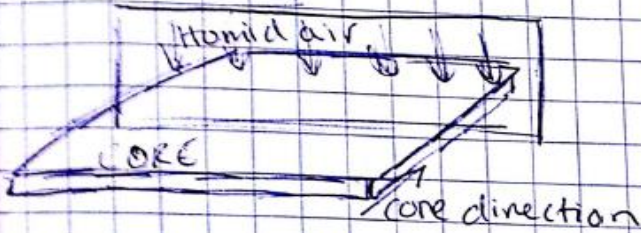
20. Foam and Clean



**Carolyn A. Blonski's 20 concepts**

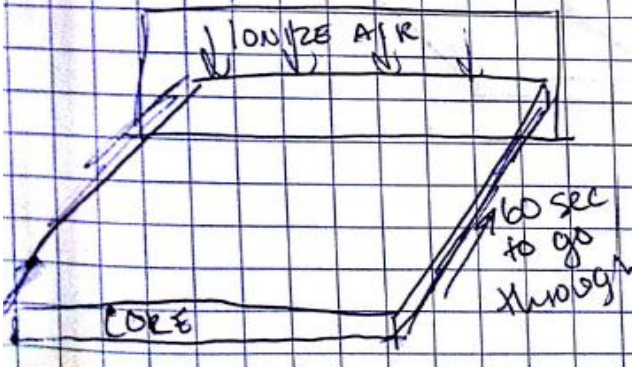
Option 1

Humid air through core cells



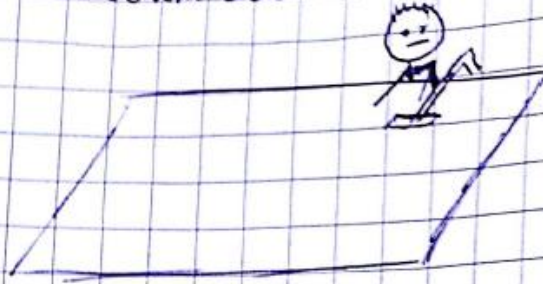
OPTION 2

move core through ionized air slower (60 seconds to go through)



OPTION 3

Vacuum dust out of core cells.



Option 4: Operator will blow air through individual honeycomb cells

Option 5

Blow out dust with can of compressed gas.

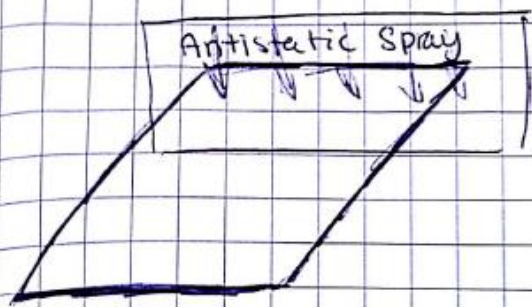


Option 6

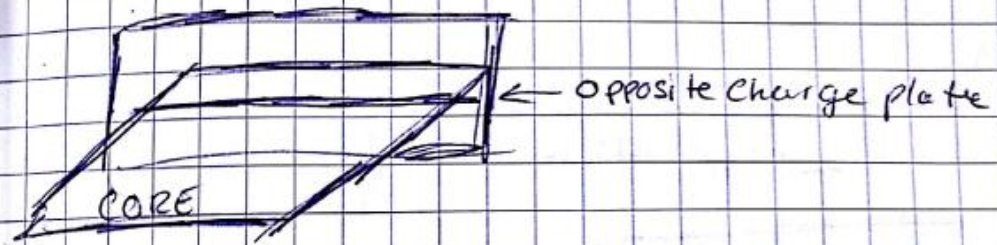
Put core in bath of water and then dry with compressed air



Option 7  
Spray antistatic spray on core @ high pressure

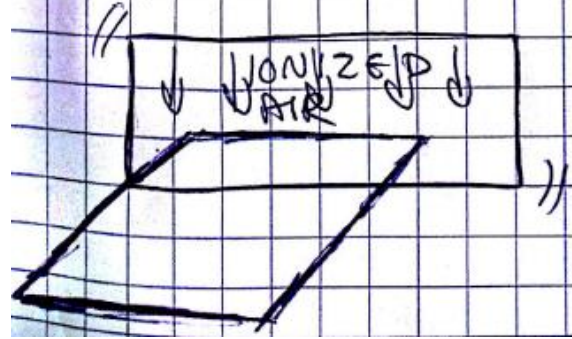


Option 8  
Ground core



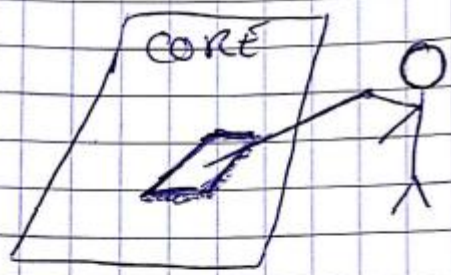
Option 9  
Ionized air : EXAIR (EXAIR.COM)

Option 10  
VIBRATING TABLE

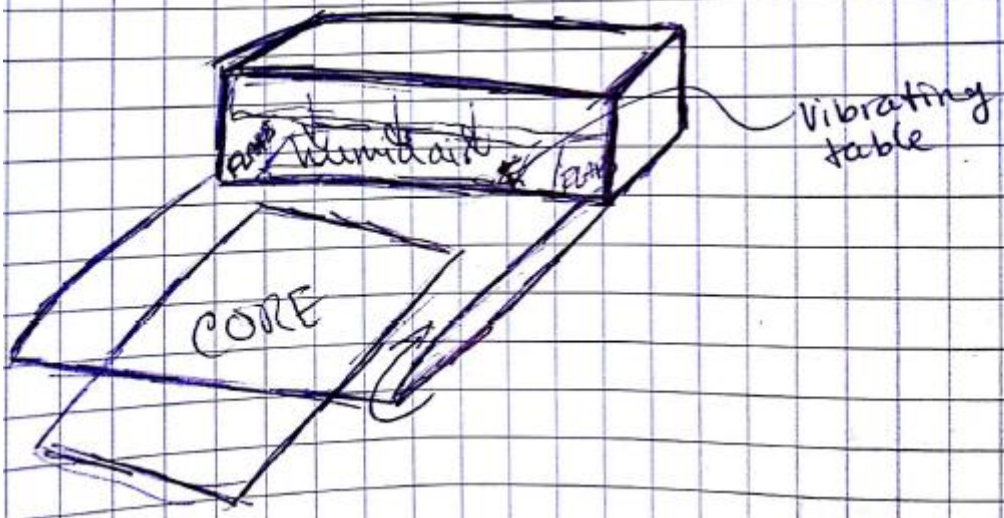


Option 11  
Honeycomb core dist removal system patent

Option 12  
giant swifter

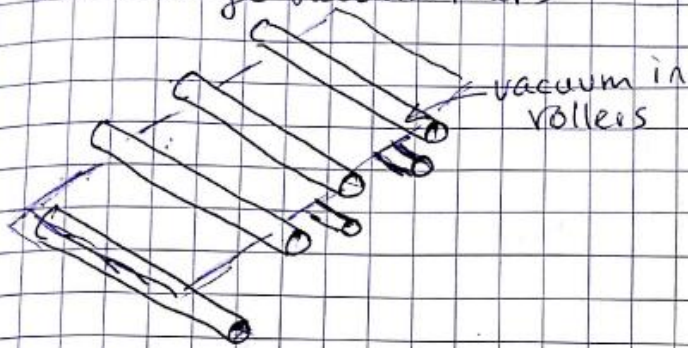


Option 13  
IONIZED VIBRATING HUMID AIR CORE CLEANER WITH FLAPS TO  
contain air and a conveyor belt to control speed of core



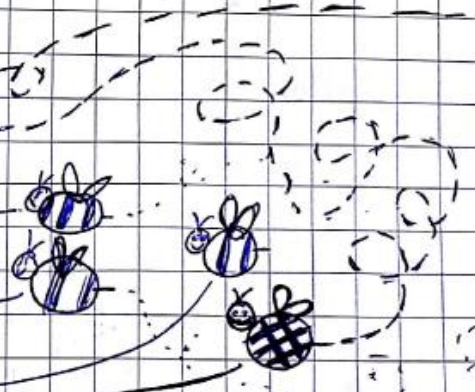
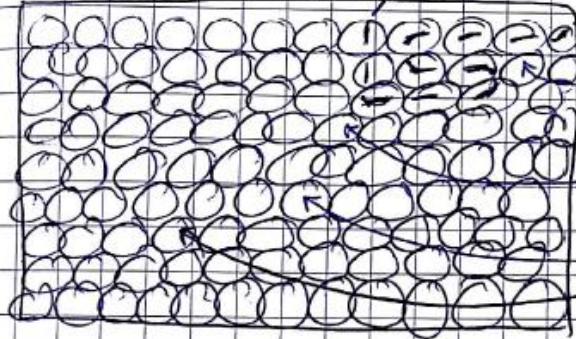
Option 14

+VE charge vacuum rollers



Option 15

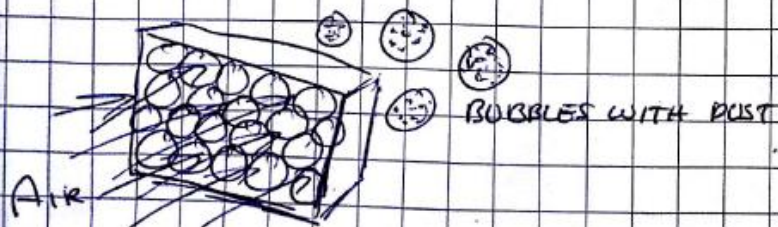
CORE



Bees fly through cells and pick up dust on fuzzy bodies/legs

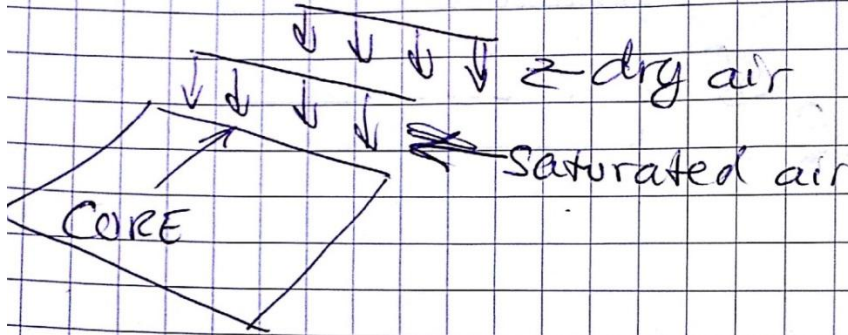
Option 16

Dunk core in soapy water, then blow air to make bubbles that would trap dust



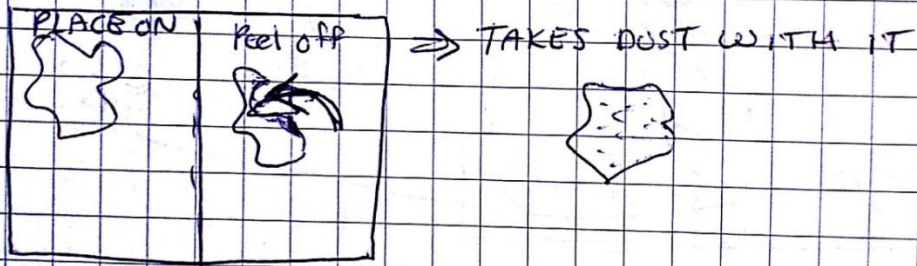
Option 17

high pressure air blade with water vapour / saturated air



Option 18

DUST PUTTY



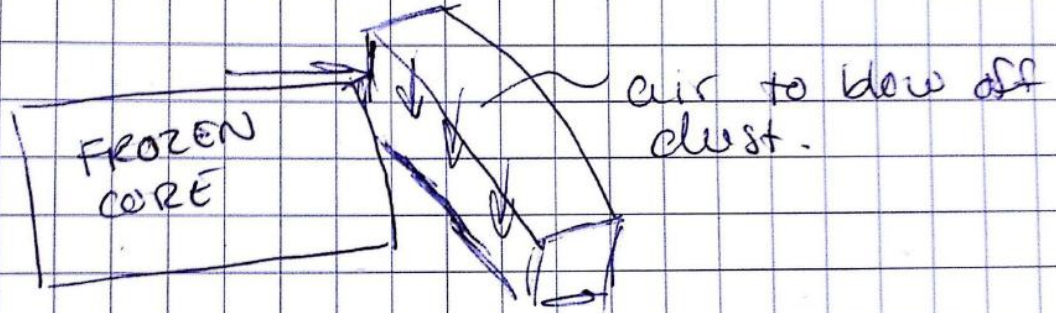
Option 19

water fall

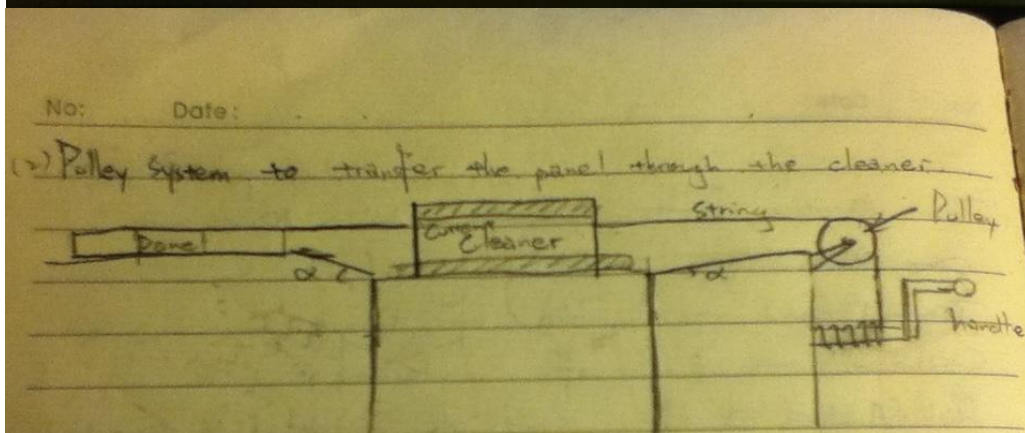
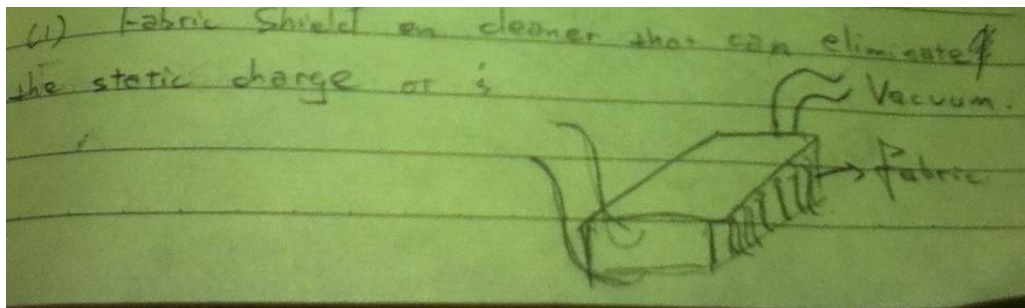


Option 20

FREEZE CORES and BLOW OFF DUST

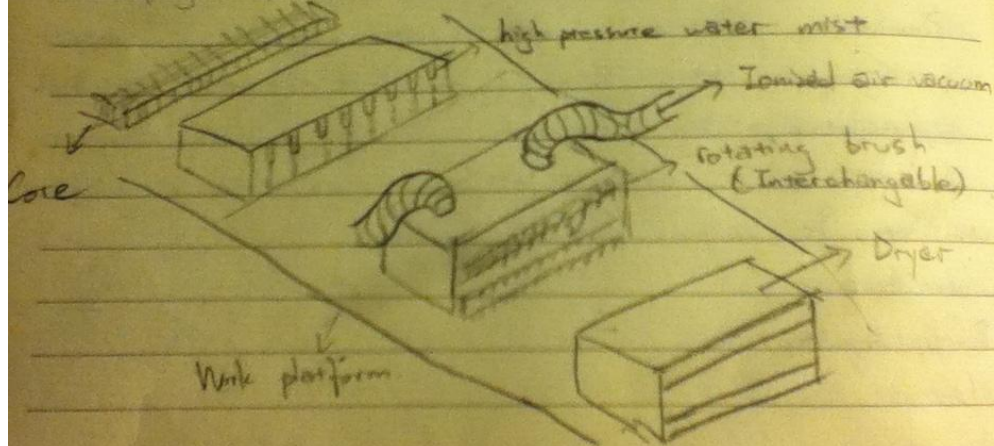


**Xiaodi (Tim) Wang's 20 concepts**



(3) Increase the power of the cleaner (vacuum rate ionized air amount)

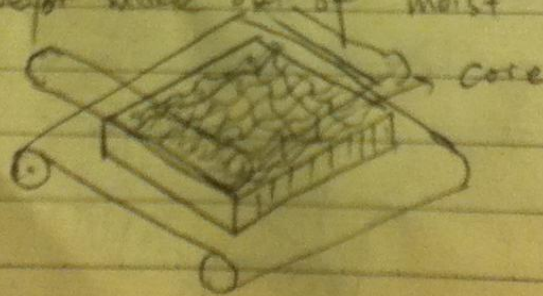
(4) Wiping with water-based cleaner



(5) High pressure water mist

(6) Rotating Brush

(7) Conveyor made out of moist rags



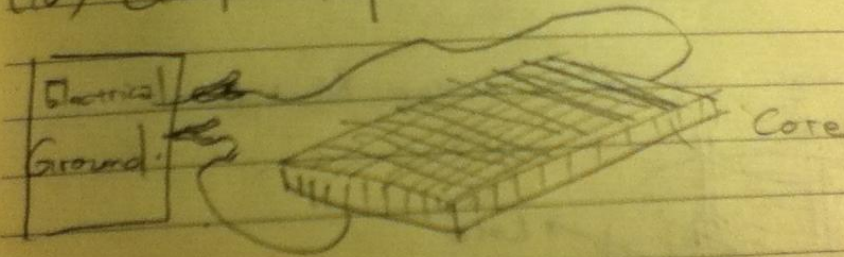
(8) Anti-static spray before cutting



(9) Anti-static paint (Anti-static agent)

Antistat → website

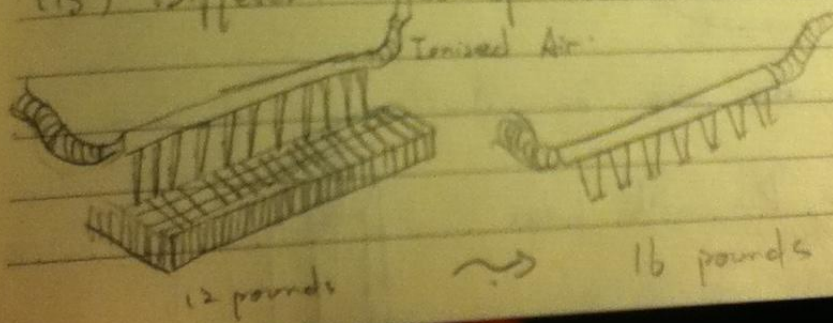
(10) Group strap

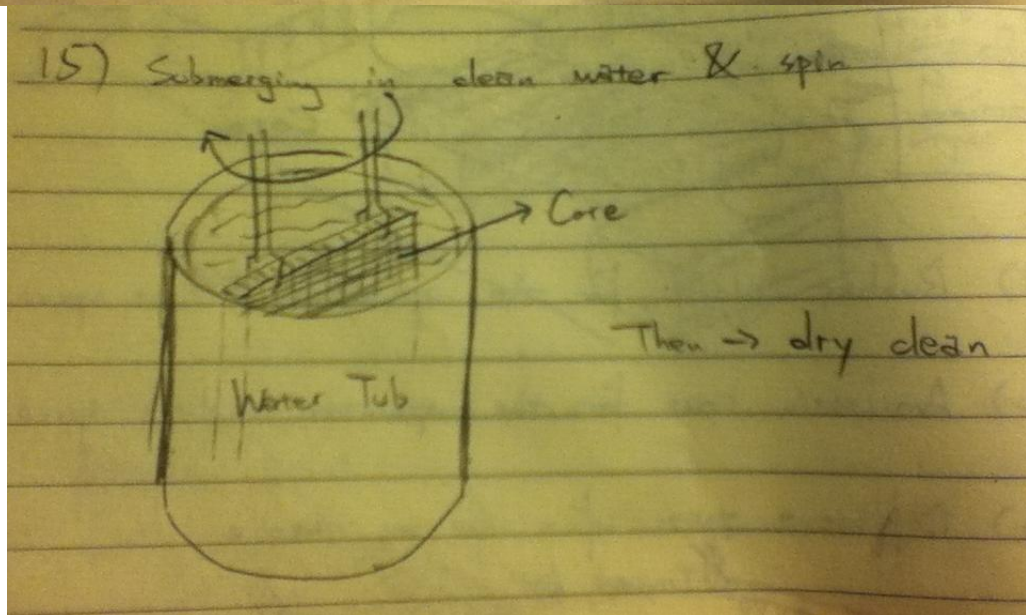
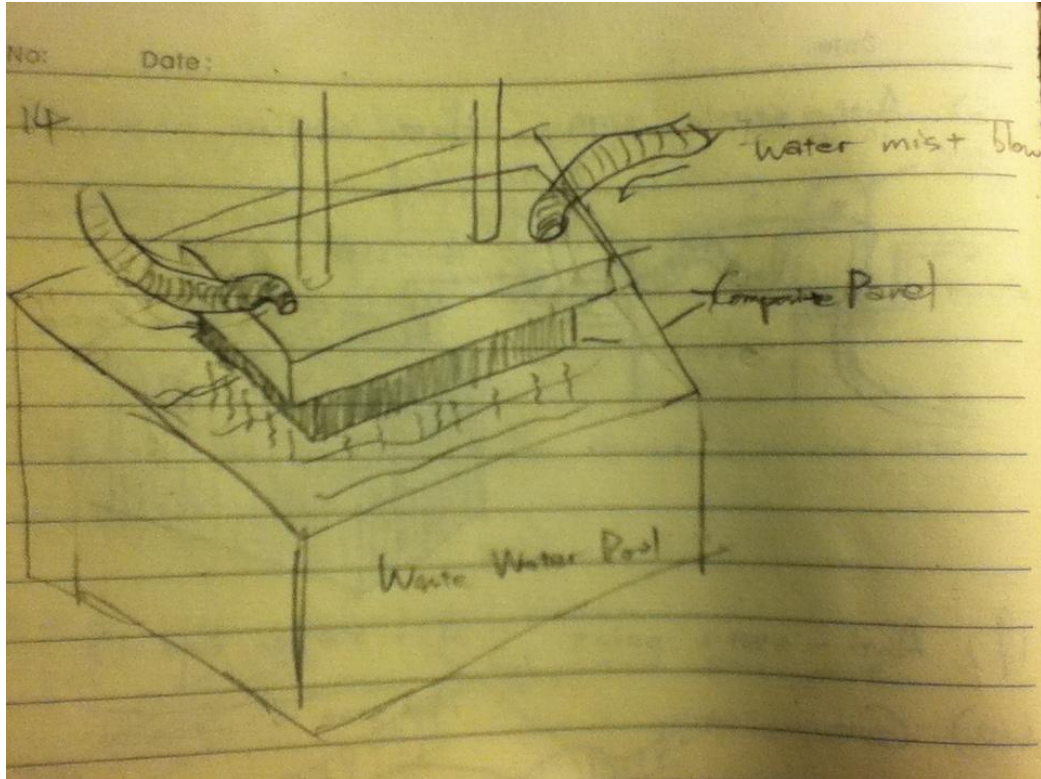


(11) Rubber gloves for the operator (dust spread)

(12) Antistatic coat for the operator (dust spread)

(13) Different types of vacuum needle





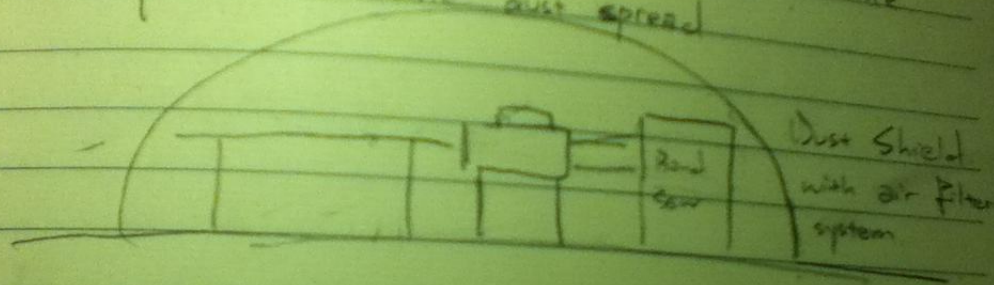
16. Rotating in plastic BB pellets tub, same as water tub

17. Rotating in moisture tub same as water tub

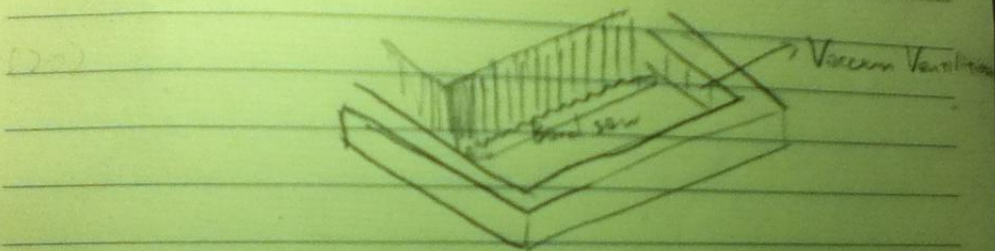


No:      Date:

(18) Isolate the operating environment in the workshop to eliminate dust spread



(19) Vacuum around the band saw



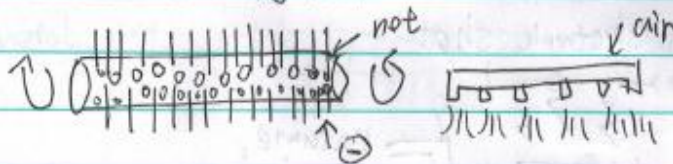
(20) Remove the operation outdoors & blow the core



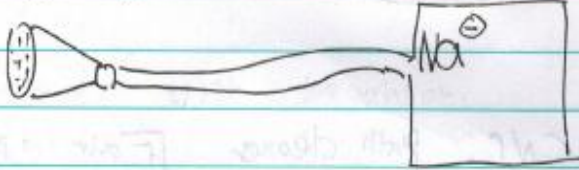
## Hao (Dylan) Liu's 20 concepts

Oct 4<sup>th</sup> 2013  
Concept generation.


1 Metal brush rotating tub.



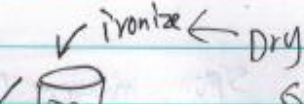
2 spray ironize liquid



3 Water Rinse.

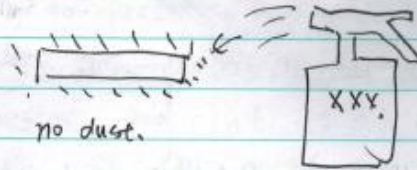


4 Plastic + metal coating balls



6. Green Beans (same as BB (method 4))

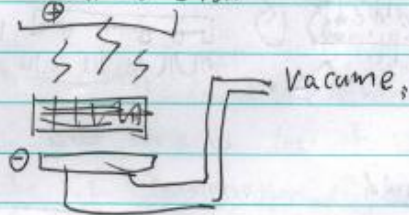
6. Spray coating



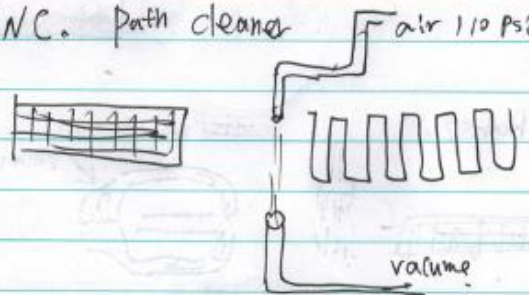
7. Vibration



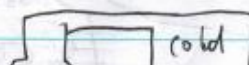
8. 'electronic shot'



9. CNC. path cleaner



10. Snow maker. Use snow to clean it



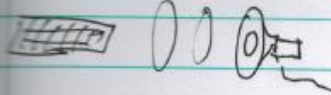
11. Fire burn.



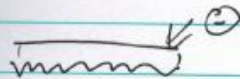
Sand protectal easy to burn.



12. Supper sonic. find to Frequency and shake it off.



13. ~~electronic pulse to panel,~~  
electronic the cutting process. electric blade.



14. metal net



on top and bottom.  
on ground.



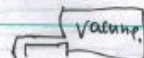
15. metal sand. with megantor.



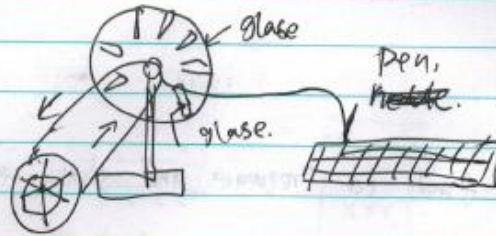
pure steel sand

clean with megantor.  
then shake off dust.

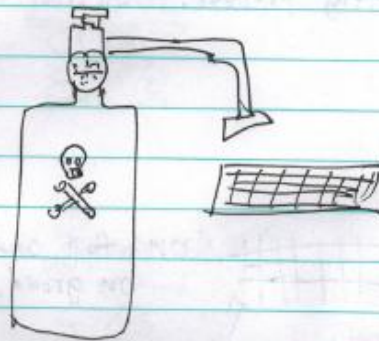
16. Use moisture air.



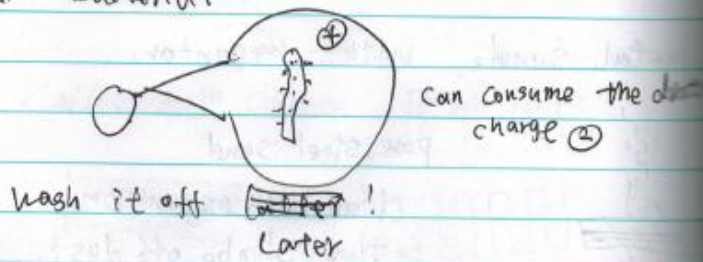
17: try give static charge to a cance



18: chemical gas



19: bacteria.



20: water then vacume bag.



Table I provides a brief summary of each of the 100 concepts created during the concept generation process.

**TABLE I: 100 CONCEPT GENERATION BRAINSTORMING**

Idea Number	Project Members				
	Stefano N. Lisi	Carolyn A. Blonski	Hao (Dylan) Liu	Stephen M. Roche	Xiaodi (Tim) Wang
1	Use magnets to attract dust	Pass humid air through core cells to remove static charge and dust	Rotating metal brush to feed core through ionized air	Vibrate core to remove dust	Install fabric shield on cleaner inlet and outlet
2	Increase the supply air pressure	Pass core through ionized air at a slower and constant rate	Remove dust by passing ionized liquid through core cells	Immerse core in a water bath with supersonic vibrations	Install pulley system across the cleaner to control feed rate
3	Increase suction air	Vacuum dust out of core cells	Rinse core with water to remove dust	Place electrostatically charged nodes above cutting blade to attract dust	Improve power of the cleaner by increase the vacuum rate
4	Pass core through brush wall	Have operator blow air through core cells	Pass small plastic/metal balls through core cells	Blow air through cells at an angle to create turbulence within the cells	Wipe the core with water-based cleaner
5	Pass through water jet and convection dry	Blow dust from core cells with compressed gas	Pass green beans through core cells	Pass superheated vapor through cells	High pressure water mist to eliminate static charge
6	Two table clamp core and vibrate	Place core in a water bath and dry with pressurized air	Spray core with anti-static spray to remove static charge	Manually shake core over a dust collection bin	Use rotating brush to clean the core surface
7	Rubber flaps to contain dust and focus air	Pass high pressure anti-static spray through core cells	Vibrate core to shake off dust	Pass small pipe cleaners through core cells to capture dust	Pass the core through conveyors made out of moist rags
8	Cover core in thin oil film and burn off	Ground core to remove static charge	Ground core to remove static charge and collect dust with a vacuum	Seal segments of core and pass pressurized air through each segment	Spray anti-static chemicals before cutting
9	Press or die with Q-tips to clean inside cores	Use commercial EXAIR air knife to pass ionized air through core	CNC air nozzle that will pass over all core cells sequentially	Use a fan to blow air through core cells	Spray anti-static paint on the core before the cutting process
10	Electrocute core and use percussion hammering to remove dust	Pass core over a vibrating table to shake off dust	Pass snow through the core cells to loosen and remove dust	Pass steam through core cells	Ground the core with straps to eliminate static charge
11	Top and bottom rollers which vibrate the core as it passes through	Look into the current patent owned by ██████ for a honeycomb dust removal system	Burn dust particles off the core	Place core in a vibrating centrifuge to remove dust	Equip operators with rubber gloves to control dust spread



Idea Number	Project Members				
	Stefano N. Lisi	Carolyn A. Blonski	Hao (Dylan) Liu	Stephen M. Roche	Xiaodi (Tim) Wang
12	Spray water mist to catch dust and dry core	Wipe core with and electrostatic cloth	Use sound waves to vibrate core to remove dust	Pass core through charged rollers to remove static charge	Equip operators with anti-static suit to control dust spread
13	Use multiple air nozzles in both upwards and downwards direction	Combine ionized air, humid air, vibrations, and conveyor belt	Create an opposite charge on the cutting blade	Wipe core with and electrostatic cloth	Implement small scale of vacuum needle
14	Ground wire before cleaner to discharge the core	Pass core through charged vacuum rollers	Place a grounded mesh net over the core to remove the static charge.	Burn dust particles off the core	Blow mist through the core above the waste water pool
15	Submerge core in water bath and then dry core	Pass fuzzy particles through core cells capture dust	Pass fine metal particulate through core cells to remove dust	Pass core through a waterfall	Dip the core in the water pool and spin it
16	Create a conveyor bed of ground wires and use air nozzles	Place core in soapy water, blow air through cells to capture dust in bubbles	Pass humid air through the core cells to remove static charge and dust	Use sound waves to vibrate the core and remove dust particles	Rub the core with the moist blanket
17	Super ion air knife from EXAIR company	Use high pressure air knife to pass saturated air the dry air through core cells	Place charged metal mesh net over core and control charge	Secure core to a positively charged magnetic plate to remove charge	Use vacuum pins to penetrate into the core cell
18	Coat core with quick dry adhesive spray to trap dust	Use washable keyboard dust removing putty to remove dust	Remove dust via chemical application	Use washable keyboard dust removing putty to remove dust	Isolate the operating environment in the workshop
19	Roller conveyor to move core with air knife above	Pass core through waterfall	Use bacteria to consume dust and charge	Pass charged beads through core cells	Vacuum around the band saw
20	Spray foam through core and clean/dry after	Freeze core and blow	Place core in a bath of water and dry with vacuum	Pass soft brush bristles through core cells	Remove the operation system outdoor and blow the core

## 1.2.Down Selection from Initial Concepts

The process of taking the information gathered during brainstorming sessions and research involves determining the best attributes of the original concepts and producing a new set of improved designs. Iteration is the key to maximizing the creativity of each new level and in the end produces the highest quality of designs. Composite Consulting Canada went through a long down selection process to ensure the highest quality design was developed. The steps followed include organizing the concepts into categories (Section 1.2.1), developing a new set of fifteen designs (Section 1.2.2), creating a list of ten concepts from the previous fifteen to screen (Section 1.2.3), and finally developing a final three design concepts based on the concept screening results (Section 1.2.4).



### 1.2.1. Concept Categories

To help organize these design concepts, they have been assigned categories listed in the rows of Table II, and the concept creator is listed in the columns above. The numbers one through twenty have been assigned to the column, where each number represents one of the twenty design concepts listed in Section 1.1.2. of each team member. Table II summarizes all the concepts generated by Composite Consulting Canada.

**TABLE II: 100 CONCEPTS ORGANIZED BY CATEGORIES**

Categories	Project Members				
	Stefano N. Lisi	Carolyn A. Blonski	Hao (Dylan) Liu	Stephen M. Roche	Xiaodi (Tim) Wang
<b>Magnetic Influence</b>	1		15	17	
<b>Pressurized Air</b>	2, 3, 13, 17, 19	3, 4, 5, 6, 9, 13, 14, 17	9	4, 8, 9	1, 2, 3, 4, 13, 17, 19
<b>Core Vibration</b>	6, 10, 11	10, 13	7	1, 6, 11	7
<b>Fluid/Moisture Applications</b>	5, 12, 15	1, 6, 13, 16, 19	3, 10, 16, 20	2, 5, 10, 15	4, 5, 14, 15, 16
<b>Brush/Flap Uses</b>	4, 7	12	1, 14	7, 13, 20	1, 4, 6
<b>Fire/Ignition</b>	8		11	14	
<b>Chemical Sprays</b>	18, 20	7	2, 6, 18	5, 15	8, 9, 12
<b>Electricity and Grounding</b>	10, 14, 16	8	1, 8, 13, 14, 17	3, 12	10, 11
<b>Speed/Path Control</b>		2, 13	9		
<b>Particulate Infiltration</b>	4	15	4, 5, 19	19	
<b>Sound Applications</b>			12	16	
<b>Stamp/Press/Die</b>	9	18		18	
<b>Patent</b>		11			
<b>Environment</b>					18, 20

The fourteen categories created were selected based on the team discussions of all the 100 created concepts. The categories were developed to help group similar ideas into like categories to help encompass all the features, functions, and methods proposed. There were many



concepts that fell within multiple categories due to the common use of simple and effective cleaning techniques. For the purpose of clarity, the concepts were organized based on their main methods of cleaning the honeycomb core cells. Thus, a few concepts may fall in more than one category if there are multiple unique cleaning methods applied, but most others were limited to one location despite the fact that they include a generic cleaning technique.

### **1.2.2. Fifteen Semi-Detailed Designs**

Using the fourteen categories created to classify the initial design concepts, each team member was tasked with developing three semi-detailed designs. These semi-detailed designs had to be feasible solutions to the proposed project problem and meet, at least, some of the design objectives. Combining created designs of each team member produced fifteen viable concepts for Composite Consulting Canada to further develop and pursue. The fifteen semi-detailed designs created by the team are listed in Table III.

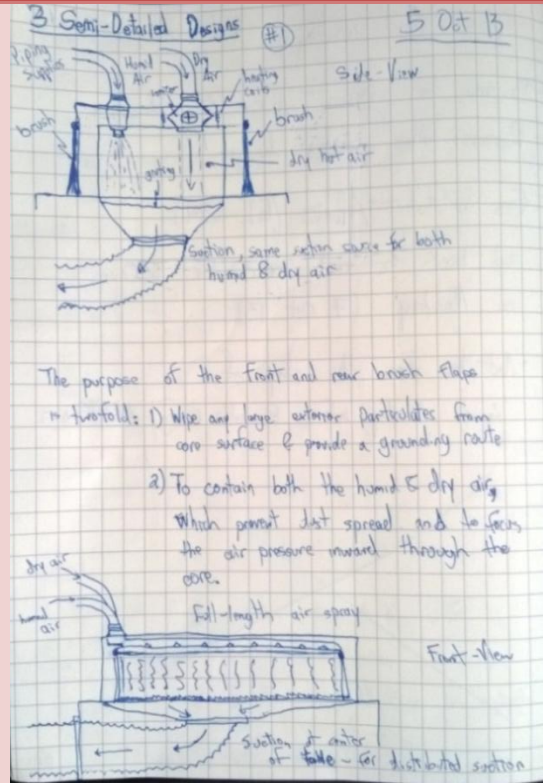


TABLE III: 15 SEMI-DETAILED DESIGNS

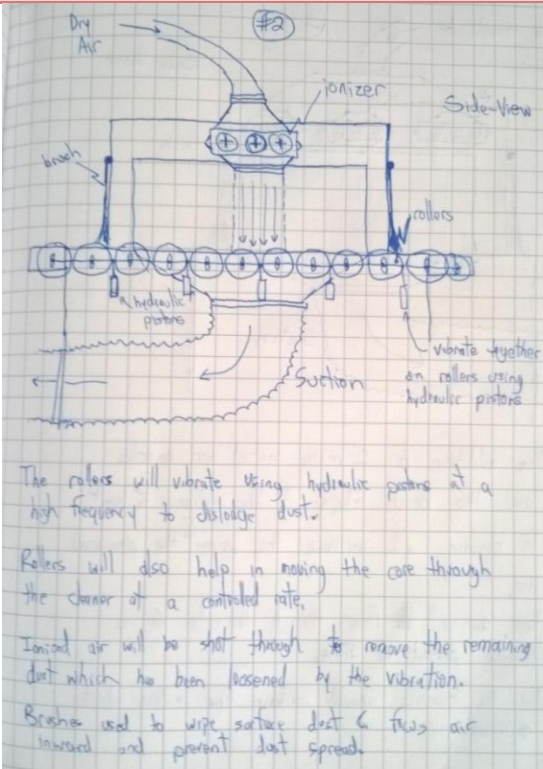
Design Name

Figure

Humid Air followed by Drying

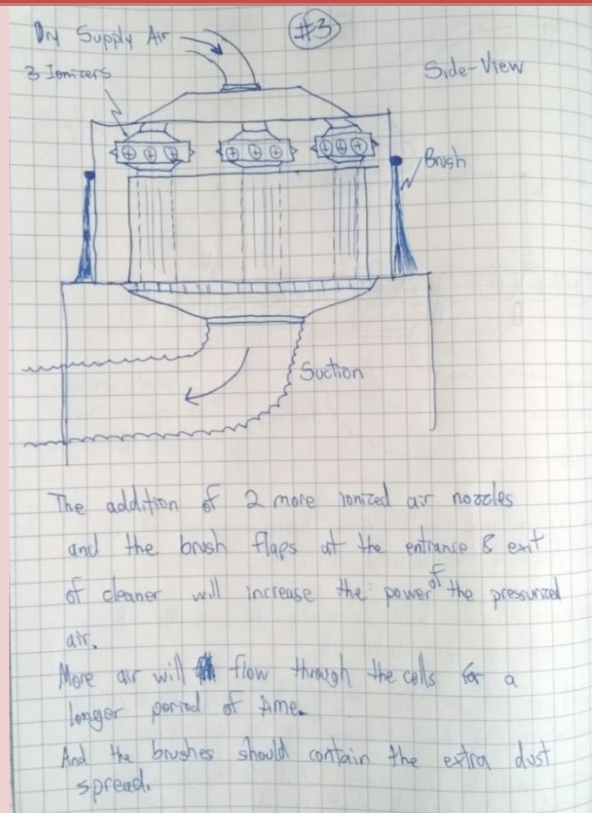


Vibrating Rollers and Ionized Air

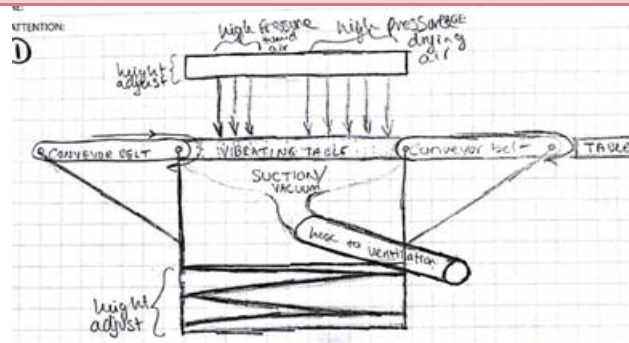


## Design Name      Figure

### Increased Ionized Air Pressure and Area



### Humid Air with Conveyors

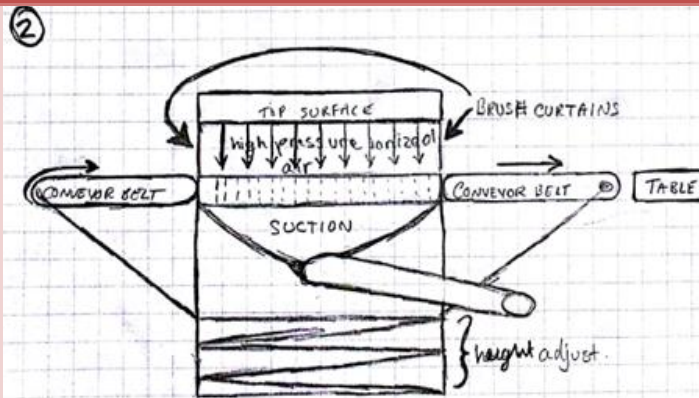


- Design 1 has a height adjustment for the air application to accommodate other slides.
- humid ionized air will blow down through the core cells to clean the dust.
- high pressure drying air will blow through the core after the humid air.
- a conveyor belt will move the core at a constant rate into and out of the air streams.
- a vibrating table will be used to loosen dust particles in the core cells.
- a vacuum underneath the table will be used to contain dust being blown out of the core cells.
- height adjustment of the entire assembly will be consistent with the current design.



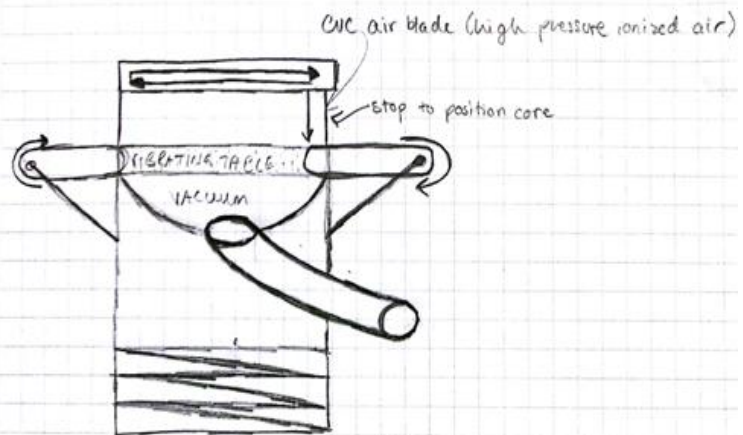
## Design Name      Figure

### Brushes and Conveyor



- conveyor belts will be used to push the core through the machine.
- the ~~top~~ top surface will be stationary with brush curtains extending from the sides to loosen particles on top.
- the core will push through the brushes where multiple streams of ionized air will push through the cells.
- a vacuum will be under the main bed to suck dust down and contain it.
- core will be fed at a consistent rate.

### Vibrating Table and Conveyors

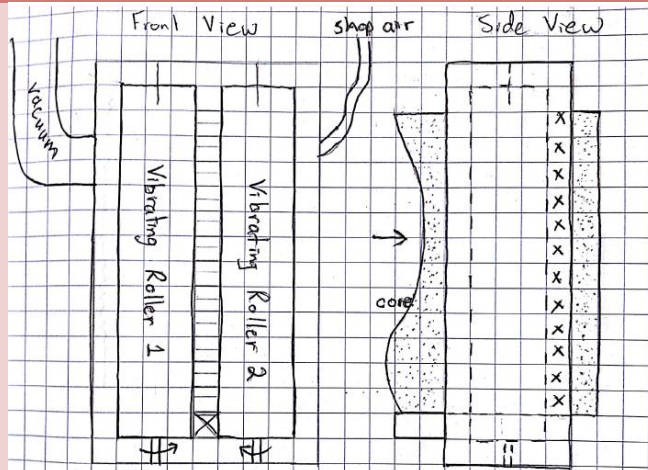


- core will be fed with a conveyor belt on to a large ~~down~~ down draft table.
- the table will vibrate.
- a CNC Air blade will move over the core twice.
- a vacuum will be used to suck the dust and contain it.
- A stop will be used when the core is fed into the machine. after a conveyor belt will be used to remove the core from the machine.



**Design Name**      **Figure**

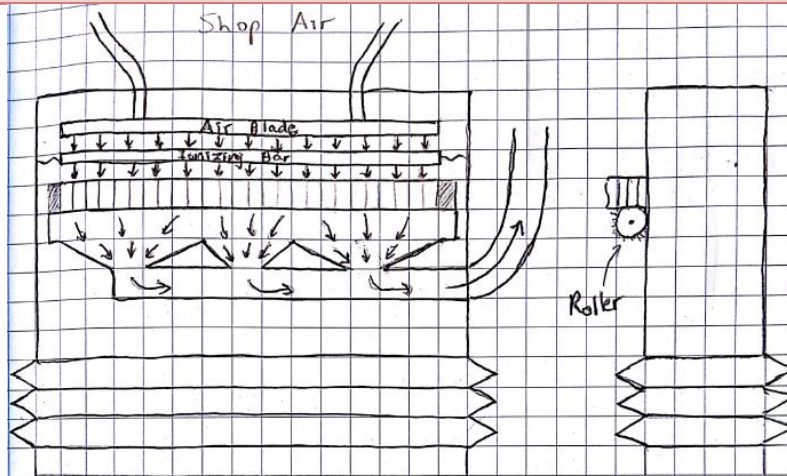
**Vertical 2-Roller  
Vibration**



Vertical 2-roller Vibration  
With Shop Air & Vacuum

- Notes:
- core is fed into cleaner vertically to alleviate ergo issue
  - rollers vibrate, core to loosen dust
  - shop air pushes air through cells, vacuum collects
  - shroud designed to isolate dust (spring-loaded flaps)
  - x's mark airflow vectors

**Baseline  
Improvements with  
Shop Air**



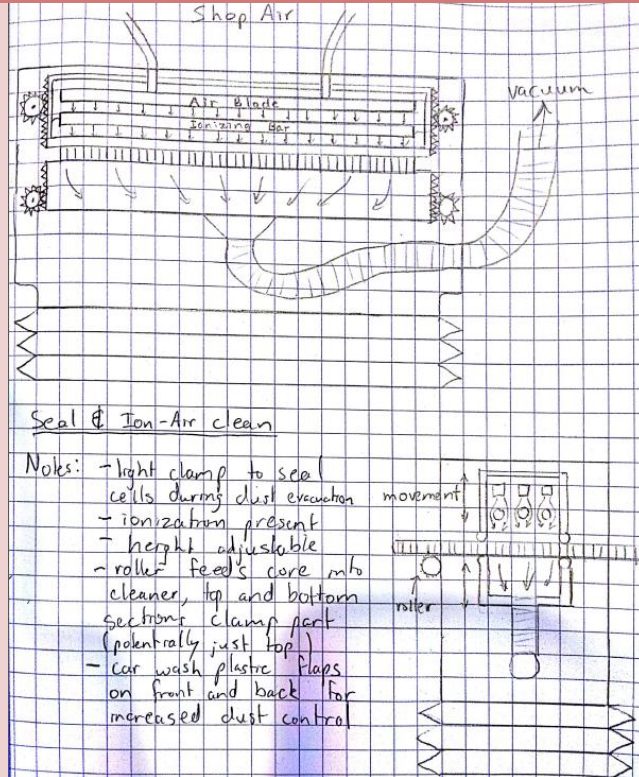
Baseline With Improvements\*

- Notes:
- shroud designed to isolate dust (spring loaded flaps)
  - height adjustable with CNC
  - corrugated roller to control feed rate
  - use of air blade (like dyson) instead of nozzles

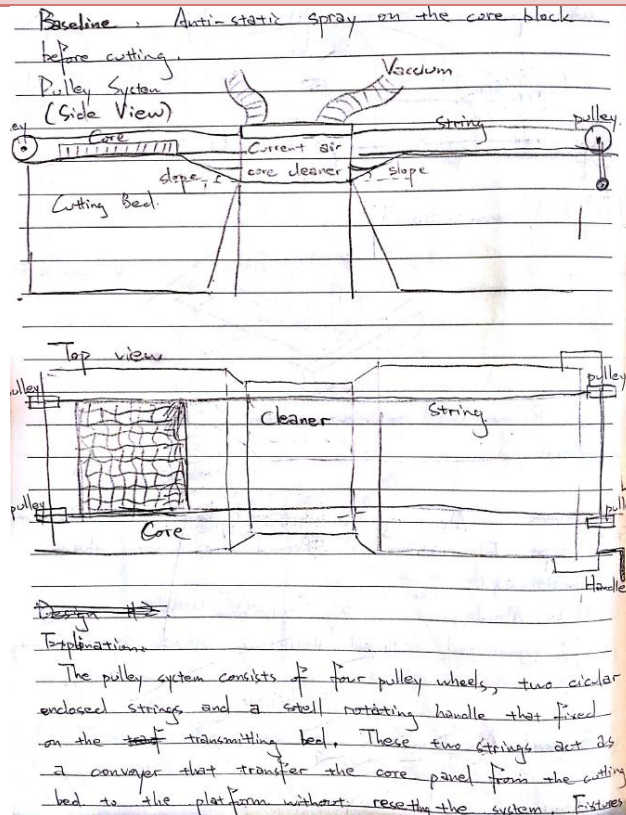


**Design Name      Figure**

**Ionized Air over Sealed Section**

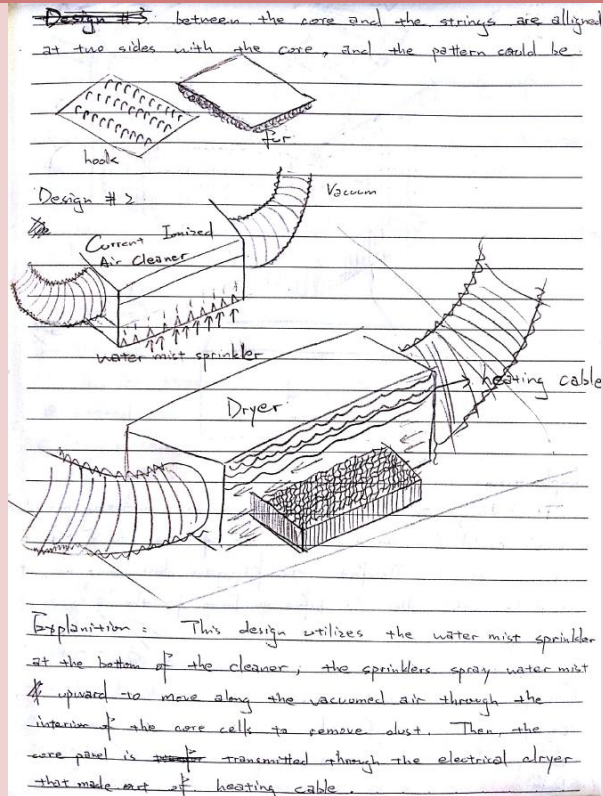


**Wire Conveyor Guide**

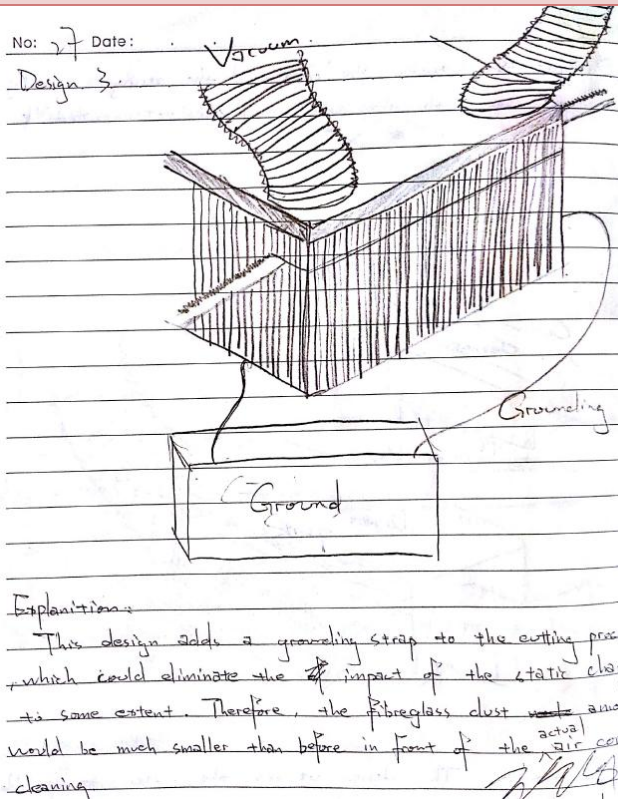


**Design Name      Figure**

**Separate Humid Air and Dryer**

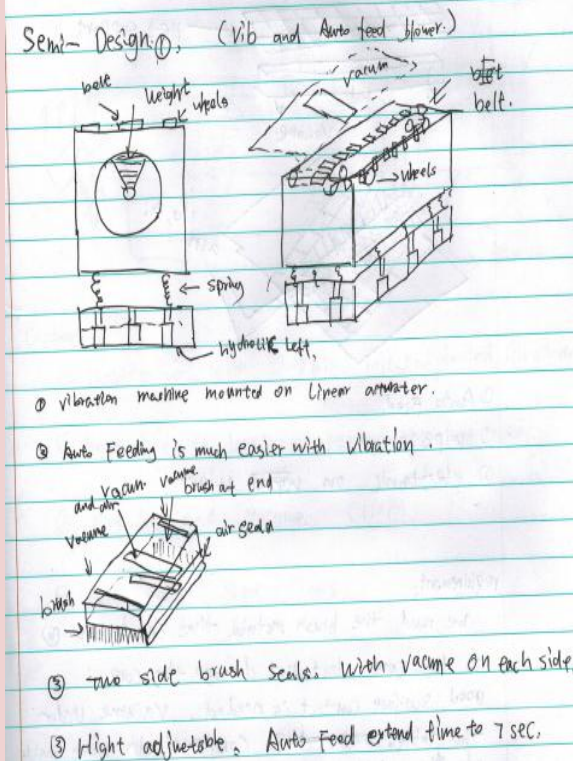


**Block Saw Knife Grounding**

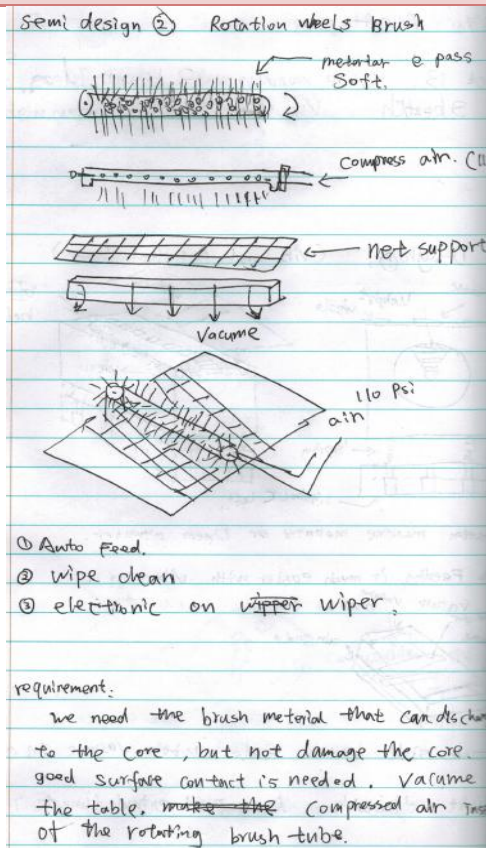


**Design Name      Figure**

**Vibration and Auto-feed Blower**

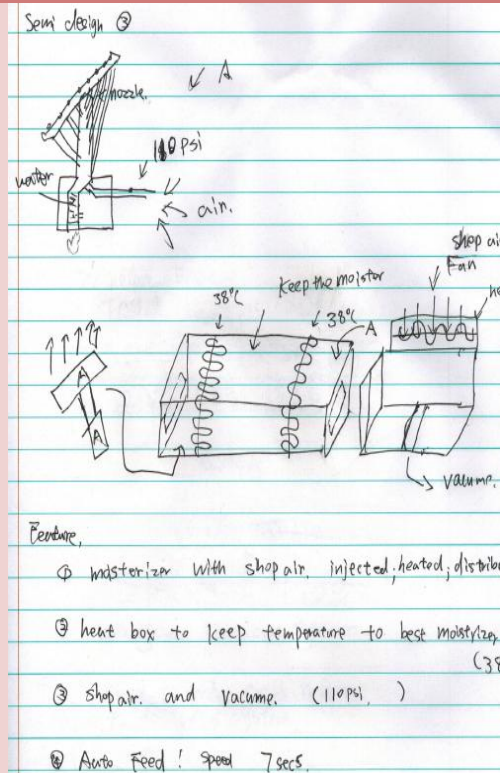


**Rotating Brush Wheels**



## Design Name      Figure

### Humid Air with Constant Heat Box



Each individual team member interpreted the categories and applied them to develop these unique and original semi-detailed design concepts. This method maximizes the amount of creativity explored by the team as a whole, ensuring as wide of a scope of possibilities was explored.

### 1.2.3. Ten Different Identified Concepts

The next step in the concept generation process was to select and modify ideas from the fifteen semi-detailed concepts to then be screened and scored using concept analysis techniques. Composite Consulting Canada decided to screen a total of ten new concept designs as well as the current ionized air core cleaner as a reference point. The ten concepts were developed using the fifteen semi-detailed designs listed in Table III. Some were extracted directly from these ideas, while others were modified and adjusted to produce a list of ten uniquely different concepts. Since multiple of these concepts were similar, some features from the original 100 concepts were reintroduced to differentiate between proposed designs.



The point of generating these ten concepts to be screened was to measure the benefits and drawbacks of each feature or method. This required that all the possible techniques proposed be included in the screening process to ensure that the pros and cons of every method were evaluated. Keeping these issues in mind, the following ten concepts were developed and approved for screening:

- Humid air spray followed by a drying process to remove all condensation
- Air nozzles above vibrating rollers with brushes at inlet and outlet to contain dust
- Air knife above a vibrating table for even air distribution
- Conveyor to control the feed rate of the core panels through the ionized air core cleaner
- Grounding the block saw blade to eliminate the static charge of the dust
- Air knife for even air distribution with brushes or flaps to limit dust spread
- CNC moving high pressure air knife
- Rotating soft cleaning brushes with integrated air jets
- Multiple air knives in consecutive order
- Foam-sealed air knife to focus air pressure and eliminate dust spread

Composite Consulting Canada moved to the concept screening down selection process using the above mentioned 10 concepts.

#### **1.2.4. Concept Screening**

The goal of this process is to compare each of the newly developed concepts against a baseline reference; in our case this will be the current system in place. Using the selection criteria, each design will compete against the baseline, and depending on whether the concept is better, equal, or worse a plus, zero, or minus will be assigned, respectively. Table IV shows the results of this down selection process.

**TABLE IV: CONCEPT SCREENING**

Concept Screening											
Selection Criteria	Design Options										
	Baseline (Reference)	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
	Current Ionized Air Core Cleaner	Humid Air/Dryer	Vibrating Roller, Brushes, Air Knife	Vibrating Tables, Air Knife	Conveyor to Control Feed Rate	Grinding Saw Blade and Core	Air Knife with Brushes/Flaps	CNC Moving Knife	Rotating Cleaning Brushes	Multiple Air Knives	Foam-sealed Air Knife
	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -	+ o -
Dust removal	o	+	+	+	+	+	+	+	+	+	+
Core size compensation	o	o	o	o	o	o	o	+	o	o	+
Control speed	o	o	-	o	+	o	o	+	+	o	+
Safety of operation	o	o	o	o	-	o	+	o	-	o	-
Required maintenance	o	-	-	-	-	-	-	-	-	-	-
Ergonomics	o	o	o	o	+	o	o	o	o	o	-
Manufacturability	o	-	-	-	-	-	-	-	-	o	-
Core damage	o	o	-	-	+	o	o	o	-	o	-
Dust spread	o	+	+	o	o	-	+	o	o	+	+
Machine footprint	o	-	o	o	-	o	o	-	-	o	o
Core panel transfer	o	o	o	o	+	o	o	o	+	o	+
Durability/reliability	o	-	-	-	-	-	o	-	-	+	-
Scores	Ref. Summary	Option 1 Summary	Option 2 Summary	Option 3 Summary	Option 4 Summary	Option 5 Summary	Option 6 Summary	Option 7 Summary	Option 8 Summary	Option 9 Summary	Option 10 Summary
+	0	2	2	1	5	1	3	3	3	3	5
o	12	6	5	7	2	7	7	5	3	8	1
-	0	4	5	4	5	4	2	4	6	1	6
Net Score	0	-2	-3	-3	0	-3	1	-1	-3	2	-1
Relative Rank	4	7	10	8/9	3	8/9	2	5	11	1	6
Pass/Fail	Pass	Fail	Fail	Fail	Pass	Fail	Pass	Pass	Fail	Pass	Fail

The selection criterion used in Table IV were developed using the sixteen metrics created from the customer needs. From these metrics, twelve selection criteria were created and chosen to help screen and score the possible design concepts. It should be noted that cost is not included here as [REDACTED] has expressed their willingness to spend the required money to receive a quality product which fulfills all of their needs. Cost was also not included due to the fact that the baseline reference concept is the current ionized air core cleaner and would therefore



receive points much higher than all other concepts, since it has already been installed. This would skew the results, creating erroneous data which would not be as reliable.

The purpose of determining which concepts improve on the baseline is to allow new design concepts to be created using the positives found using the concept screening table. Composite Consulting Canada now has the information to identify where each design fails and succeeds. The last row of the concept screening table is simply an indication of which of the concepts scored higher than the baseline, but the pass/fail notation in no ways restricts the further development of the positives in those design columns. The concepts which scored well include the conveyor option, the air knife and brush wall, the CNC air knife operation concept, and the use of multiple air knives. The next step is to develop a new set of designs using the salvaged good features and produce a higher tier of design concepts to pursue.

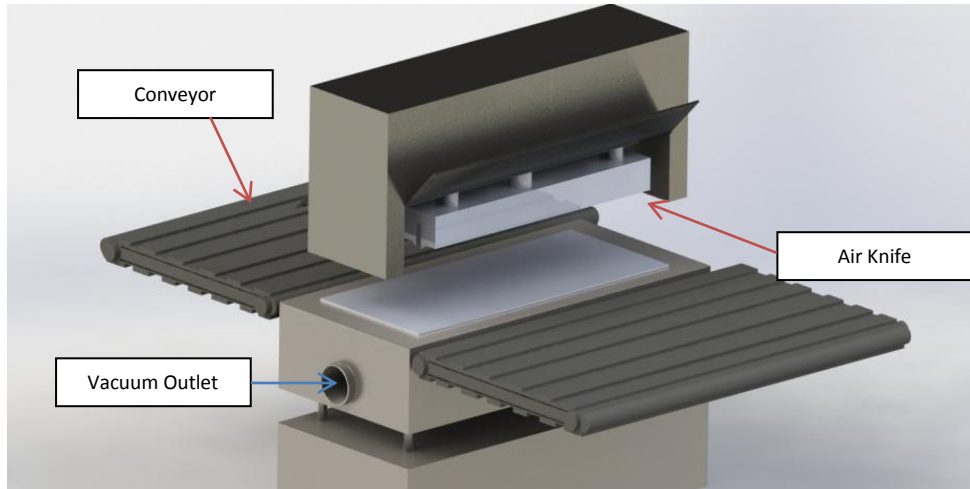
### **1.2.5. Generation of Three Comprehensive Concepts**

The next step in the concept generation and down selection process is to develop new design concepts based on the information gathered from the concept screening table and score these concepts using a more detailed analysis. Composite Consulting Canada executed this step together as a team, as opposed to how the previous concept generation stages were conducted. This allowed the team to work together and develop each team member's idea from many different perspectives. From these sessions, Composite Consulting Canada produced the following three design concepts: Baseline modification, EXAIR foam-sealed air knife, Vibrating rollers and EXAIR air knife.

#### **1.2.5.1. Baseline Modification**

The baseline modification concept is by far the least expensive option, as it is based on reusing the current system. The modifications included in this concept are the addition of a conveyor at the inlet and outlet of the ionized air core cleaner to help control the feed rate and reduce the operator-material contact. The addition of a soft bristle brush wall at the inlet and outlet openings of the actual ionizer air core cleaner hood to reduce the amount of dust spread from the dispersing air. Finally, the current height adjustment system would be removed and integrated into the CNC operation of the block saw. Figures 1 and 2 show preliminary models of the proposed baseline modification concept.





**Figure 1: Baseline modification model of entire machine.**



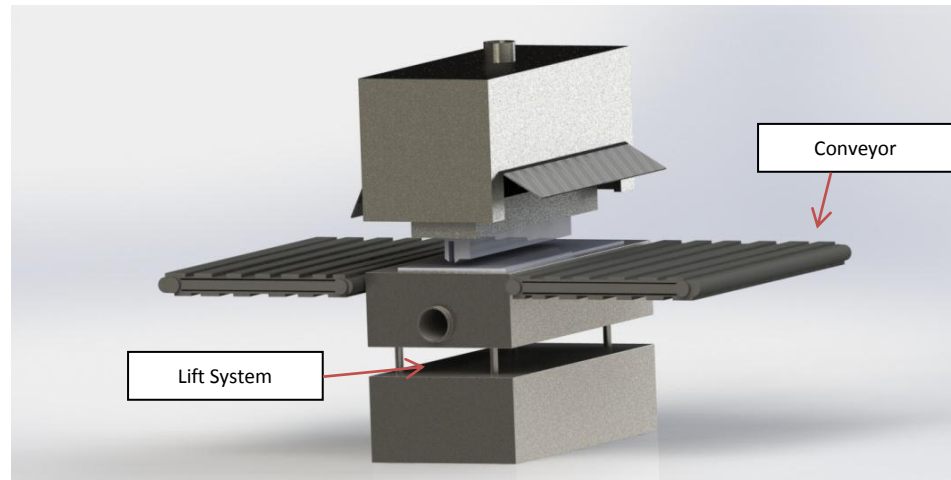
**Figure 2: Baseline modification model of brush wall and conveyors.**

### **1.2.5.2. EXAIR Foam-Sealed Air Knife**

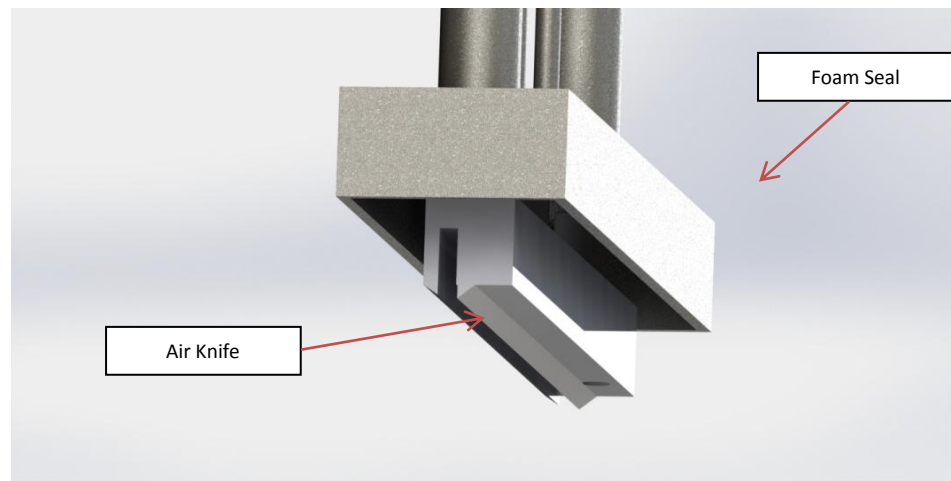
The EXAIR foam-sealed air knife concept involves a complete redesign of the core cleaner machine and would therefore be more costly than the baseline modification option. However, the benefits of the more expensive design would pay off in the long run when taking reliability into account. Newer equipment means a longer engineering life cycle when compared to the already twenty year old equipment currently in place. The same argument can be made for the third design concept.

The features of this second concept include the same conveyor and brush systems as the baseline modification, but also include a new lift apparatus and vacuum system. The ionized air

nozzles currently used would be replaced by an EXAIR air knife accompanied with a foam seal surrounding the air knife. This seal would completely enclose the honeycomb core cells and not only improve the air pressure and associated vacuum suction, but also eliminate dust spread during the process. The conveyors would not run constantly, but would instead operate periodically, moving the core forward, allowing the foam seal to lock down and clean the core before repeating the pattern. Figures 3 and 4 show preliminary models of the proposed EXAIR foam-sealed air knife.



**Figure 3: EXAIR foam-sealed air knife model of entire machine.**

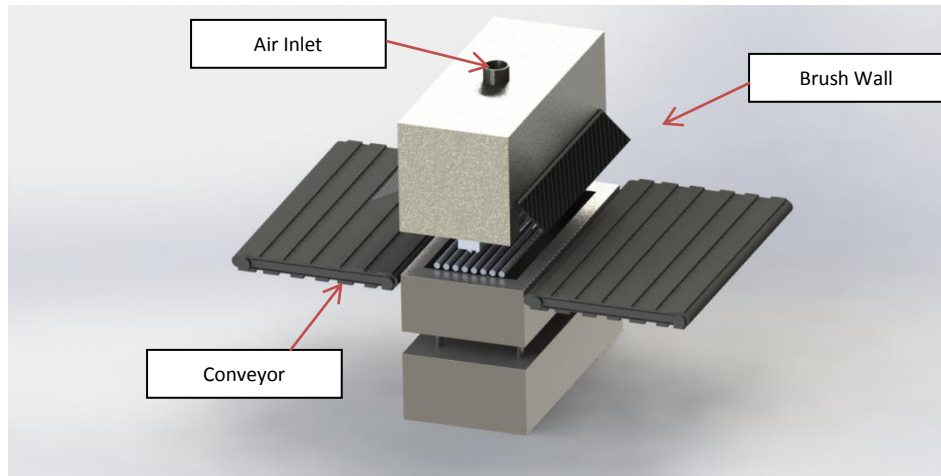


**Figure 4: EXAIR foam-sealed air knife model of air knife with foam seal.**

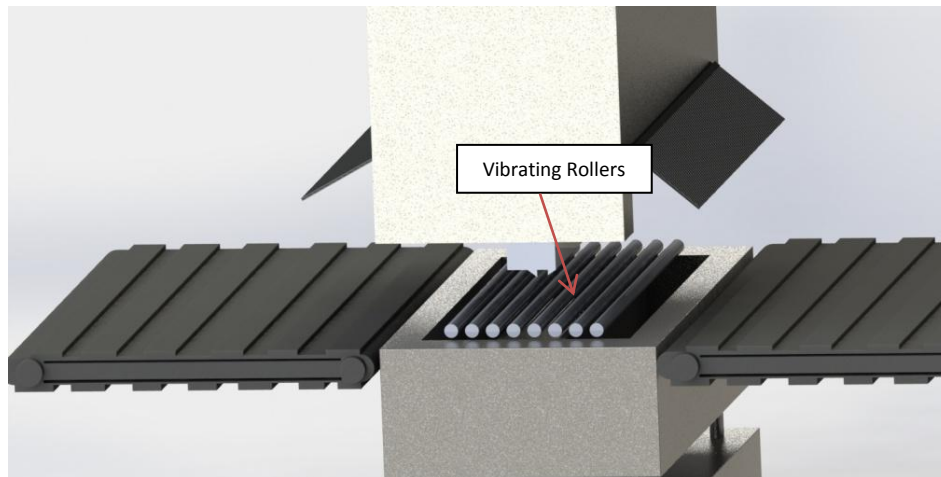
### **1.2.5.3. Vibrating Rollers and EXAIR Air Knife**

The last of these design concepts to be scored is the vibrating rollers and EXAIR air knife model. The major difference in this design is the use of vibration to loosen the dust from the honeycomb core cells. Otherwise, the same conveyor and vacuum systems as for the last two

concepts are also included in this comprehensive concept design. The conveyor, soft brush wall, and integrated height adjustment system are features. The feed rate through the core will be constant, and is therefore simpler than the EXAIR foam-sealed air knife conveyor system. The vibrating rollers introduce the issue of dust spread of the core outside of the brush walls due to the vibrations. The vibration effect has great potential to improve the cleaning performance of the core cleaner design. Figures 5 and 6 show preliminary models for the vibrating rollers and EXAIR air knife design.



**Figure 5: Vibrating rollers and air knife model of entire machine.**



**Figure 6: Vibrating rollers and air knife model of conveyors and rollers setup.**

It should be noted that all of the preliminary models shown in this section are only drafts, and should not be taken as final proposed designs.

### **1.3. Final Concept Evaluation and Selection**

At this point in the concept generation and selection process, the development of new designs has concluded and the evaluation of the current proposals begins. A more numerical and quantifiable path was taken to determine which of the proposed designs was the best solution for [REDACTED].

#### **1.3.1. Selection Criteria Weighting**

To use the selection technique of concept scoring, the selection criteria developed in the concept screening stage must be given quantifiable values so that scores can be given for each design concept. This means that the twelve selection criteria will have to be given a relative weight before the concept scoring process can begin. The method Composite Consulting Canada used to accomplish this task was a criteria weighting matrix. Table V shows the results of this method.



**TABLE V: CRITERIA WEIGHTING MATRIX**

Criteria Weight Matrix													
Criteria		Dust Removal	Core Size	Control Speed	Safety of operation	Required maintenance	Ergonomics	Manufacturability	Core damage	Dust spread	Machine footprint	Core panel transfer	Durability/reliability
	ID	A	B	C	D	E	F	G	H	I	J	K	L
Dust Removal	A		A	A	D	A	A	A	H	A	A	A	A
Core size compensation	B			B	D	B	F	B	H	I	B	B	B
Control Speed	C				D	E	F	C	H	I	C	C	C
Safety of operation	D					D	D	D	D	D	D	D	D
Required maintenance	E						F	E	H	I	E	K	L
Ergonomics	F							F	H	I	F	F	L
Manufacturability	G								H	I	G	K	L
Core Damage	H									H	H	H	H
Dust spread	I										I	I	L
Machine footprint	J											K	L
Transfer of core panels	K												L
Durability/ Reliability	L												
Criteria ID		A	B	C	D	E	F	G	H	I	J	K	L
Occurrence		9	6	4	11	3	6	1	10	7	0	3	6
Calculated Weight [%]		13.6	9.09	6.06	16.7	4.55	9.09	1.52	15.2	10.6	0	4.55	9.09

The selection criteria are listed both on the leftmost column and the top row, creating an intersection between each criterion with every other selection criterion. In every box, two different criteria converge, and the matrix requires that the identification code (ID) of the more important criteria be input in the box. This is called the matched pairs method of evaluating criteria because each criteria is being paired with another and evaluated. The final step is to determine the occurrence of each selection criteria ID in the matrix and use this to determine the weight of said criterion. The last row of Table V lists the calculated weights for all twelve of the selection criteria. The criteria which scored the highest in the matrix was found to be the

safety of operation, whereas the criteria which scored the lowest was the machine footprint. In fact, the machine footprint criteria was found to be less important than all other criterion.

### **1.3.2. Concept Scoring**

With three design concepts created from the positive features of the screening process and the selection criteria assigned weights, the next step is concept scoring. Each of the three design concepts listed in the previous section will be scored, as well as the current system as a reference datum. The concepts will be given a rating from one to five for each of the twelve selection criteria, and since each criterion now has a weight, the given rating can be quantified into a weighted score. To calculate the final total score, all the weighted scores from each of the selection criterion get added up for each design. Table VI shows the results of the concept scoring.



**TABLE VI: CONCEPT SCORING**

Concept Scoring									
		Design Options							
		Baseline (Reference)		Design #1		Design #2		Design #3	
		Current Ionized Air Core Cleaner		Baseline Modification		EXAIR/Foam Air Knife		Vibration and Air Knife	
Selection Criteria	Weight [%]	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Dust removal	13.6	3	0.409	4	0.545	5	0.682	5	0.682
Core size compensation	9.1	3	0.273	3	0.273	5	0.455	4	0.364
Control speed	6.1	1	0.061	5	0.303	5	0.303	5	0.303
Safety of operation	16.7	4	0.667	3	0.500	2	0.333	4	0.667
Required maintenance	4.5	4	0.182	3	0.136	2	0.091	3	0.136
Ergonomics	9.1	1	0.091	4	0.364	4	0.364	4	0.364
Manufacturability	1.5	3	0.045	5	0.076	3	0.045	3	0.045
Core damage	15.2	3	0.455	4	0.606	2	0.303	3	0.455
Dust spread	10.6	2	0.212	4	0.424	5	0.530	4	0.424
Machine footprint	0.0	4	0.000	3	0.000	2	0.000	3	0.000
Core panel transfer	4.5	2	0.091	4	0.182	4	0.182	4	0.182
Durability/reliability	9.1	2	0.182	2	0.182	4	0.364	4	0.364
Total Weight [%]	100.0	Baseline Summary		Design #1 Summary		Design #2 Summary		Design #3 Summary	
	Total Score	2.67		3.59		3.65		3.98	
	Relative Rank	4		3		2		1	
	Pass/Fail	Fail		Fail		Fail		Pass	

A relative rank has been assigned to each of the concepts based on the concepts total score, which is the summation of all the weighted scores. It should be noted that for cases when there is no clear leader, a sensitivity study should be conducted to ensure the ranking between the concepts. A sensitivity study involves scoring the design concepts another time to test if the same rankings are produced.

In this case, the vibrating rollers and EXAIR air knife is the clear front runner based on the selected criteria. However, further development of the selection process is required to confirm the results of the concept scoring before a final decision can be made.

### 1.3.3. Final Concepts Presentation

On October 10<sup>th</sup>, 2013, our team met with Curtis Kowalchuk of equipment engineering, and the core cutting and cleaning area manager, Albert Ducharme. Our team explained how we brainstormed concepts, and eliminated concepts we felt were infeasible or did not fit the constraints. We also showed how we took the remaining concepts and grouped them by their similarity. From the grouped concepts, we explained how we came up with fifteen semi-detailed designs, and then put these semi-detailed designs through a screening matrix. The results of the screening matrix left our team with three viable designs, which we presented to both Curtis and Albert. Included in all three viable designs was an EXAIR ionized air knife. The air knife was explained as a very attractive feature for the core cleaner because of its ability to remove dust uniformly, unlike the current system, as shown in Figure 7.



**Figure 7: Core sheet experiencing partial cleaning (waviness) due to nozzle configuration.**

Curtis showed interest in the air knife, and told the team he wanted to do independent research on the air knife. During the presentation, we distributed renders of the three viable designs for Curtis and Albert to keep and write on. Immediate feedback from Curtis and Albert was positive – they were pleased with the three designs we had selected and the process we had used to reach these designs. After discussion, Albert was concerned with the potential dust spread into the work area from the vibration concept, and said that this would need to be experimentally determined to see if his concern was justified. From conversations with a summer student



██████ employee, our team discovered that research had been done using vibration to clean dust from the core, and that Albert would get back to us with the results. Curtis expressed the need for safety guards or pressure pads for the conveyor system, which was included in the final design. Albert also wanted a height-measurement system integrated into the redesigned core-cleaning machine. General consensus from the meeting was that the ionized air knife available from EXAIR was to be pursued. Research on both vibration and the air knife was determined to be the best course of action for the final design.

#### **1.3.4. Final Design Concept Selection**

CCC brainstormed 100 ideas and grouped them by their conceptual similarities. After conceptual grouping, CCC generated fifteen semi-detailed designs. The fifteen semi-detailed designs were put through a screening matrix to help determine their feasibility for a final design. Designs from the screening matrix that had positive scores were recombined to form three semi-detailed designs. These three semi-detailed designs were evaluated in a scoring matrix and presented to ████████ for feedback. The completion of the ████████ presentation on October 10<sup>th</sup>, 2013 allowed CCC to identify the best combination of concepts for the final design.

Key features of the final design include a conveyor at the entrance and exit of the cleaner, with a variable-height hood that blows dust downwards using an EXAIR ionized air knife, into a vacuum collection bay directly beneath the air knife. The hood containing the air knife will have four sets of polymer brushes – two rows at the entrance, and two rows at the exit. The hood will be able to accommodate a height variability of 0.5” to 6” core thicknesses, and be wide enough to accommodate 50” sheets. The final design will include a safety feature that will either be a pressure pad or conveyor guard so that operators cannot get pulled into the machine. The entire core cleaning system will also be mounted on some form of a lift system with a 3’ range of vertical motion. The height of the core cleaning system and the height of the hood will be fully integrated with the CNC, such that the set core programs are readable by the cleaner, and the heights will adjust to run the specified programs.



# **Appendix D: Final Design Modifications from Selected Concept**



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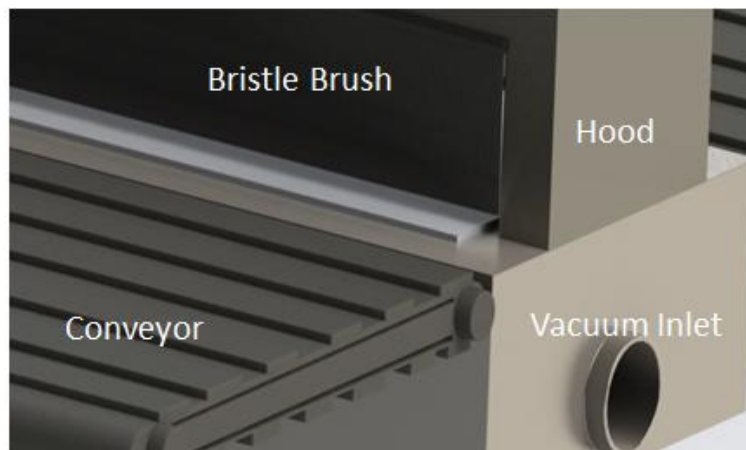


## 1. Modifications to Final Selected Design

The final design being proposed has been slightly modified to better meet the requirements set by [REDACTED]. Thus, the original concept developed during the concept generation stage has been changed by replacing and removing some of the features and components. These alterations are believed to improve the performance of the air core cleaner redesign for different criteria, namely dust spreading control, ease of maintenance, and manufacturability. The following section comprises of the changes made to the final design and the purpose for each modification.

### 1.1. Flap Design

Composite Consulting Canada decided to alter several parts of the design to accommodate to better meet [REDACTED]'s needs. Initial concepts of CCC's core cleaner included a concept that had bristle brushes at the inlet and outlet of the hood, as shown in Figure 1. The purpose of the bristle brushes was to contain dust within the hood during core dust removal. In the final design stage CCC chose to change the bristle brushes to plastic flaps.

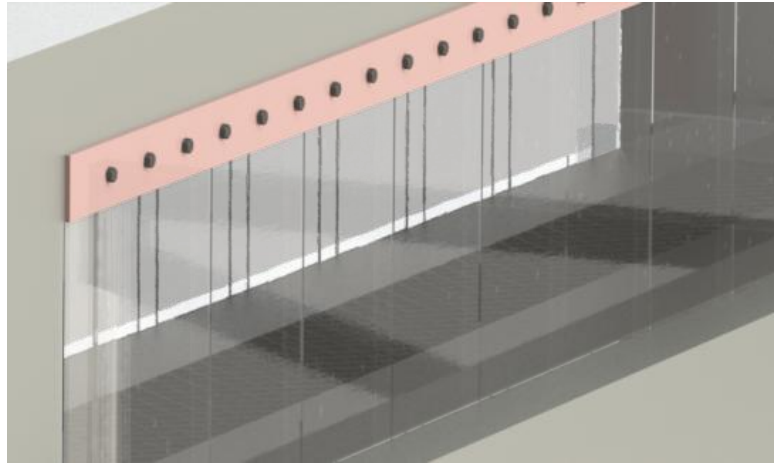


**Figure 1: Brush design at the cleaner outlet.**

The decision to change over to plastic flaps was because bristle brushes are easily worn and lead to bristles becoming dislodged. These dislodged bristles could fall into the core, potentially introducing foreign object debris. Moreover, the bristles would be cyclically loaded, causing the spacing between the bristles to increase. The increased spacing would reduce the effectiveness of the hood to contain dust. Flaps are favourable because they can withstand cyclic loading and are capable of producing a better seal



along the flap edge in contact with the core. The recommended flap material is PVC, which is a thermoplastic with low density and high strength. The total outer surface area of the gap is 54"x8", and the flap thickness is 0.2", which would let the flap hang vertically in the absence of a core sheet. The purchase of the flaps will be completed by [REDACTED] since they have expressed a preference to outsource the fabrication of the design. The final plastic flap configuration is shown in Figure 2



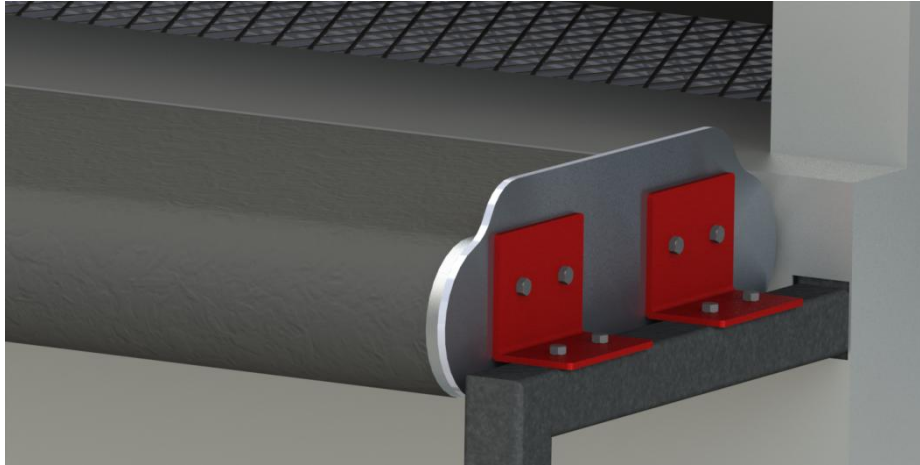
**Figure 2: Multiple flaps at the cleaner inlet**

There are two reasons why Composite Consulting Canada proposed multiple flaps rather than two singular flaps at the inlet and the outlet. The first reason is the independent installations of each flap makes design easy to maintain, since replacing only one flap would be easier than a long-span flap if a flap is damaged. The second reason is that multiple flaps could possibly seal the side of the gap if the width of the core panel is less than the width of the gap, whereas a singular flap would not be able to do the same job.

## **1.2. Side Guard Design**

To direct the composite core sheets through the cleaner and out onto the sorting table, side guards were designed on the edges of the inlet and outlet conveyors. The side guards will limit the amount any given core passing through the cleaner can skew from its desired path. The directional control of the core sheets will ensure a consistent cleaning and prevent core from getting stuck inside the core cleaner.



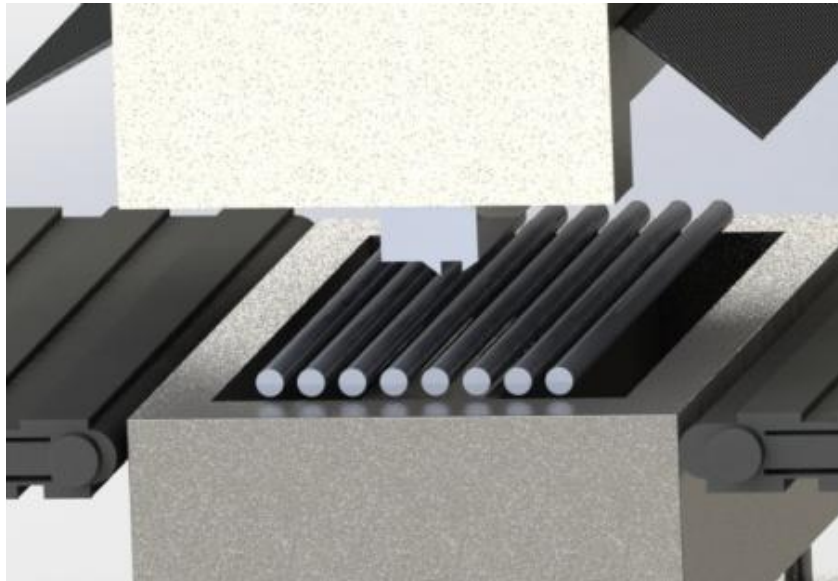


**Figure 3: Side guards.**

As shown Figure 3, four side guards will be installed along the edges of both conveyors, restricting the path of the core sheets. This will limit any possibility of sheets falling off the sides of the table and becoming damaged.

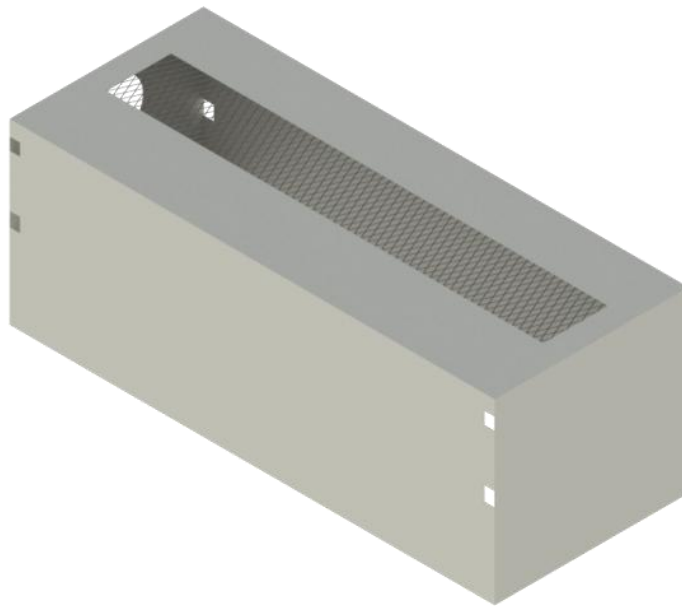
### **1.3. Removal of Vibrating Rollers from the Final Design**

The concept of vibrating rollers inside of the hood was initially introduced to help loosen the dust clinging to the inside of the core cells by shaking the core panel at high frequencies shown in Figure 4.



**Figure 4: Vibrating rollers concept**

The team realized the difficulty in implementing this feature after discussion with [REDACTED]. The vibration caused by the rollers would cause the entire core sheet to shake and induce dust spread when the front of the core began vibrating. The vibrating rollers added a level of complexity as installation, maintenance, and vibration frequency would become increasingly difficult. The vibrating rollers were replaced by a steel mesh grate that would allow for air to pass from the EXAIR air knife to the vacuum system while providing a table surface that will not damage the core shown in Figure 5.



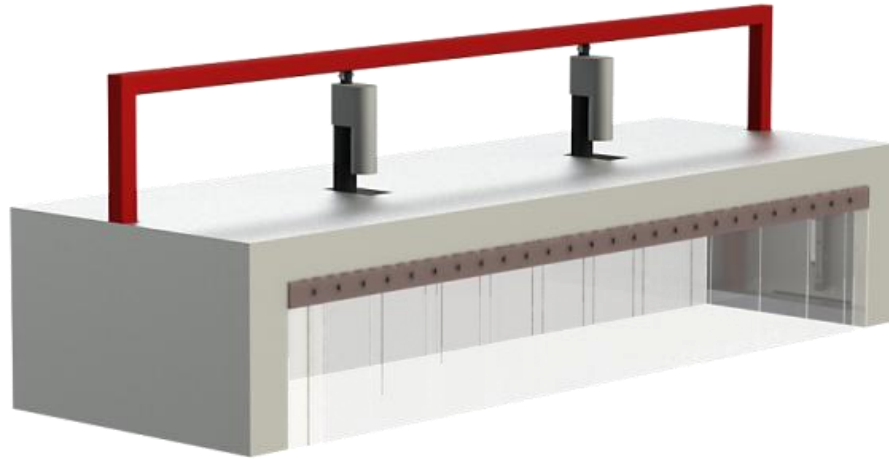
**Figure 5: Flattened mesh grating**

#### **1.4. The Hood Design**

In the initial design concept, the entire hood system was to be vertically adjustable. In order to reduce complexity, the hood design was modified such that the hood would remain stationary and only the EXAIR air knife would be vertically adjustable. The final hood design of the core cleaner serves two functions as a dust containment system and support structure for the EXAIR air knife. The left and right side walls of the hood are constructed from 16 gauge steel sheet metal in order to support the sliders for the EXAIR air knife. Slightly thinner 18 gauge sheet metal is used for the top, inlet and outlet walls of the hood as load bearing components are not mounted to these faces. The containment flaps are mounted to the inlet and outlet wall as in the initial concept



design. The side walls of the hood were to be initially welded to the hood frame. To increase accessibility however, mounting of the sheet metal walls was changed to sheet metal machine screws. Figure 6 shows the final design for the



**Figure 6: New core cleaner hood design**



# **Appendix E: Product Specifications**

## **Specifications and Quotes for Outsourced Design Components**



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## **1. List of Product Specifications**

The products included in here are the PA-14P Linear Actuators from Progressive Automations, the Aerdon SSL – 8 electric hydraulic scissor lift from Ross Equipment Limited, the Horizontal low profile slider bed belt conveyor from McKenzie Handling Systems, Inc., the EXAIR Super Ion Air knife from EXAIR Corporation, and finally the rails and carriages from IGUS. Each of these products have detailed specifications which show the dimensions of the part, installation procedures, operating procedures, required power supplies, and any other supplementary information required. It should be of note that the McKenzie Handling Systems conveyor quote does not include side guards, and does not include the price for the 12” conveyor at the hood outlet.







PROGRESSIVE AUTOMATIONS & ACTUATORS

# PA-14P LINEAR ACTUATOR WITH POTENTIOMETER

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CLICK TO ACTIVATE)

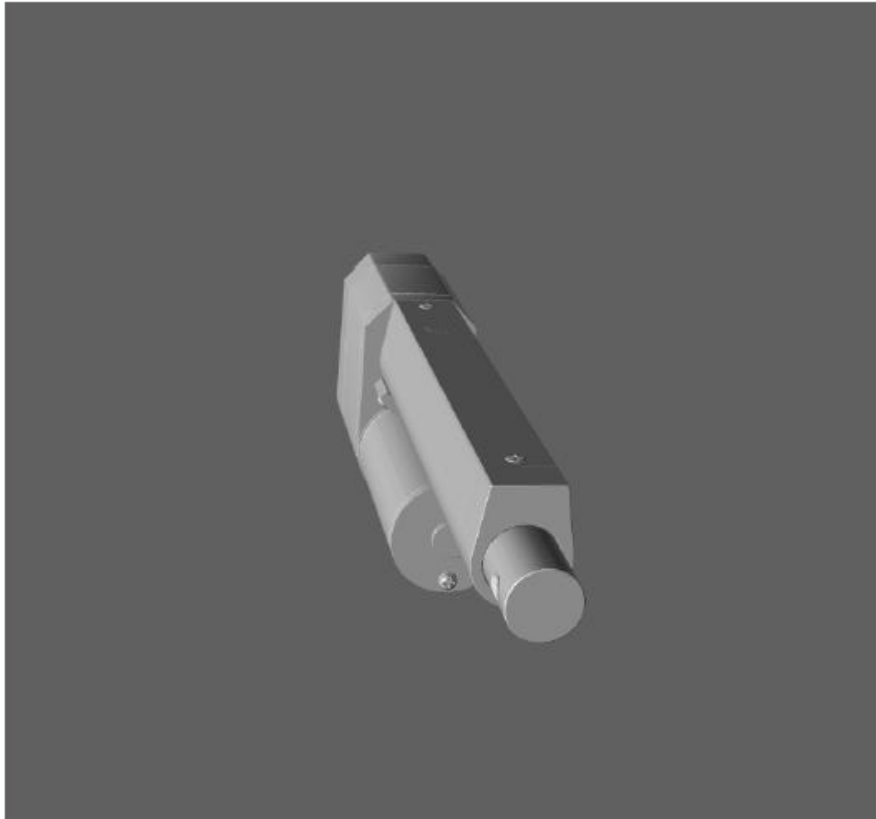
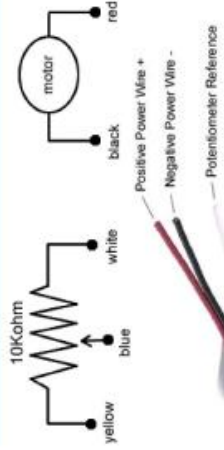
## HOLE TO HOLE DIMENSIONS


Stroke Sizes (in inches)	PA-14P Model AC	
	Fully Retracted (in inches)	Full
0	5.51	
1	6.51	
2	7.51	
3	8.51	
4	9.51	
6	11.51	
8	13.51	
9	14.51	
10	15.51	
12	17.51	
14	19.51	
16	21.51	
18	23.51	
20	25.51	
22	27.51	
24	29.51	
30	35.51	
40	45.51	

## PRODUCT ACCESSORIES:

- Will work with any PA's AC & DC controls boxes
- Mounting Brackets: BRK-14 (for each end); BRK-03
- Rocker Switches: any PA's Rocker Switches
- Foot Controls: PDL-01, PDL-02 and PDL-03
- Rubber Boot: AC-20

## POTENTIOMETER





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**OPTIONS:**

- : 24/36/48
- : IP65
- :k: Hall Effect Sensor
- length: Customizable
- stroke size: 1" - 40" in increments of 0.25"
- Mounting Holes: Customizable size and Dimensions
- Connectors: Add your specific connector
- Dimensions: Change size and stroke of unit based on your requirement
- Material: Full metal gears or plastic gears
- Customizable forces available: 35 lbs (speed 2"/sec) and 50 lbs (1.2"/sec)

**ADDITIONAL OPTIONS ARE ALWAYS BEING ADDED, PLEASE GIVE US A CALL IF YOU WANT TO SEE A CUSTOM OPTION YOU DO NOT SEE HERE 1-800-676-6123.**



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**Aerdon's** SSL scissor lift series, are the most versatile and hardest working models we produce. The SSL can be configured in a multitude of ways to handle the smallest jobs to the most demanding lifting & production work.

**Standard Features:** ITS certification, UL, CSA, Hydro approved power packs & controls, Remote 1hp 115/1/60 power pack, ( requires dedicated 20amp circuit ) 3 hp 220/575/3/60 TENV motor, Nema 4 motor rated push button controls, Power pack includes pressure relief valve, check and flow control valve, Ground and hard chrome solid rod hydraulic cylinders rated at 3,000 psi working pressure, Velocity fuse fall safe protection, Abrasion, oil and weather resistant hydraulic hose with 4 to 1 safety factor at 3,000 psi, Solid steel scissor legs, ( 44,000 psi minimum yield ) Smooth steel platform, Structural steel base frame, Ground superior shafting pivot pins, Lifetime lubricated teflon coated bushings, Sealed cam follower rollers, Safety warning striping on platform sides.

**Options:** Higher capacities, Oversized platforms & bases, Higher lift heights, Tapered or Electric toe guards, Conveyor platforms, Rotating platforms, ( Manual or Powered ) Tilt platforms, Portability ( casters, wheels, air bearings ) 1 - 3 hp, 220-575/3/60, 12 - 24V DC, 1 - 4 hp air motors, Wash down, Explosion proof, Foot pedal controls, Automated operation, Accordion curtain enclosures, Custom finishes ( paint or galvanize ) Stainless steel platforms, **Custom designed & built to Customers Specifications**

MODEL	CAPACITY	STD.BASE PLATFORM	MAX. PLATFORM	LOWERED HEIGHT	LIFT HEIGHT	RAISED HEIGHT	STD. MOTOR	SHIPPING WEIGHT
SSL - 8	2000 lbs.	24" x 48"	48" x 72"	7"	30-36"	37-43"	1 h.p./110 v.	490 lbs.
SSL - 10	4000 lbs.	24" x 48"	48" x 72"	9"	30-36"	39-45"	1 h.p./110 v.	725 lbs.
SSL - 12	6000 lbs.	24" x 48"	48" x 72"	9"	30"	39"	1 h.p./110 v.	850 lbs.
SSL - 13	8000 lbs.	36" x 48"	48" x 72"	12"	30"	42"	3 h.p./3 ph.	975 lbs.
SSL - 14	10000 lbs.	36" x 48"	48" x 72"	12"	30"	42"	3 h.p./3 ph.	1010 lbs.
SSL - 15	2000 lbs.	24" x 60"	48" x 88"	7"	40"	47"	1 h.p./110 v.	625 lbs.
SSL - 17	4000 lbs.	24" x 60"	48" x 88"	9"	40"	49"	1 h.p./110 v.	850 lbs.
SSL - 19	6000 lbs.	24" x 60"	48" x 88"	9"	40"	49"	1 h.p./110 v.	1000 lbs.
SSL - 20	8000 lbs.	36" x 60"	48" x 88"	12"	40"	52"	3 h.p./3 ph.	1100 lbs.
SSL - 21	10000 lbs.	36" x 60"	48" x 88"	12"	40"	52"	3 h.p./3 ph.	1200 lbs.
SSL - 30	2000 lbs.	24" x 72"	48" x 102"	8"	48"	56"	1 h.p./110 v.	825 lbs.
SSL - 32	4000 lbs.	24" x 72"	48" x 102"	9"	48"	57"	1 h.p./110 v.	1000 lbs.
SSL - 34	6000 lbs.	24" x 72"	48" x 102"	9"	48"	57"	1 h.p./110 v.	1275 lbs.
SSL - 35	8000 lbs.	36" x 72"	48" x 102"	12"	48"	60"	3 h.p./3 ph.	1350 lbs.
SSL - 36	10000 lbs.	36" x 72"	48" x 102"	12"	48"	60"	3 h.p./3 ph.	1395 lbs.
SSL - 37	2000 lbs.	24" x 88"	48" x 108"	8"	59"	67"	1 h.p./110 v.	910 lbs.
SSL - 39	4000 lbs.	24" x 88"	48" x 108"	9"	59"	68"	1 h.p./110 v.	1150 lbs.

Figure 2: Aerdon equipment SSL scissor lift series specification sheet [2].



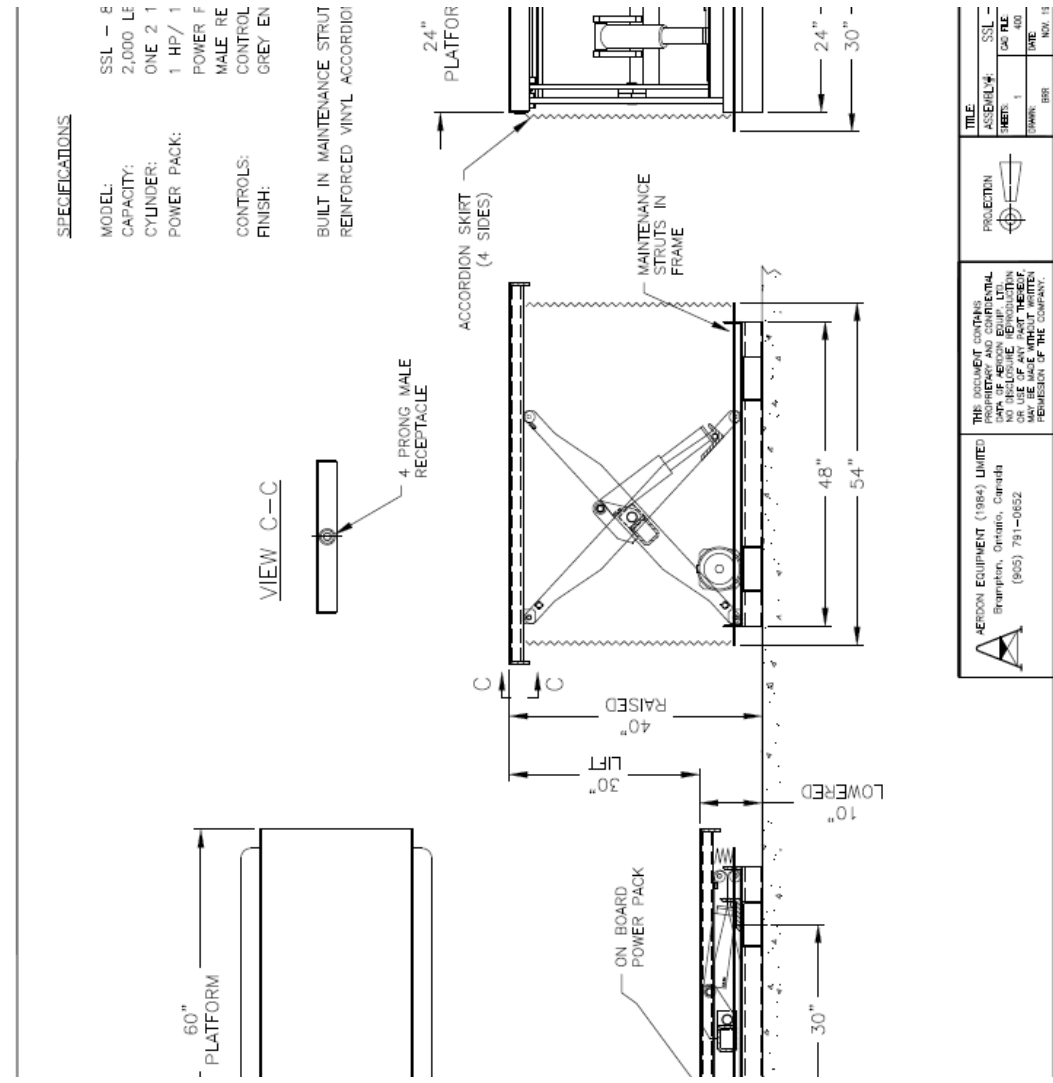
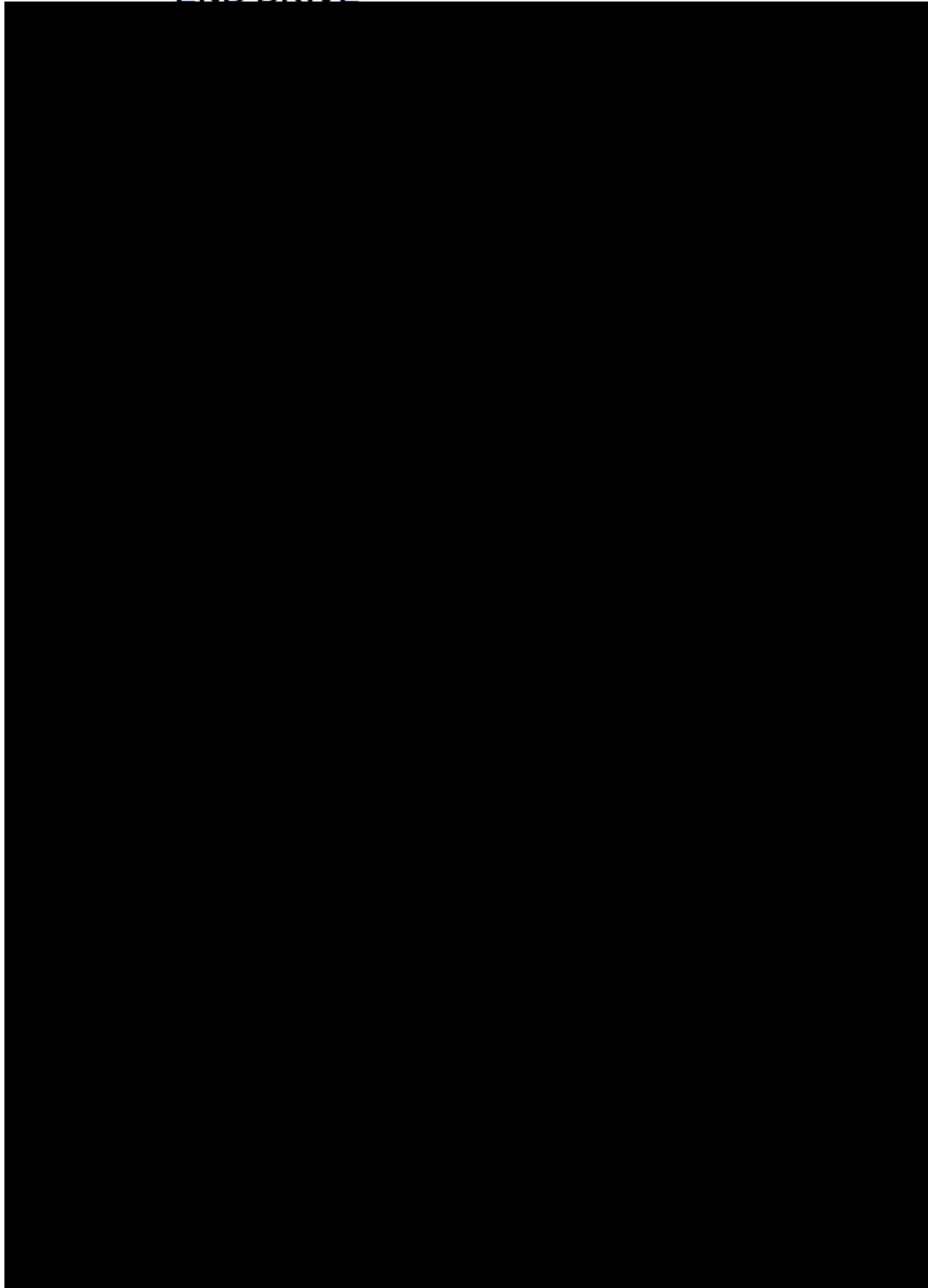


Figure 3: Aerdon SSL scissor lift specifications drawing [2].



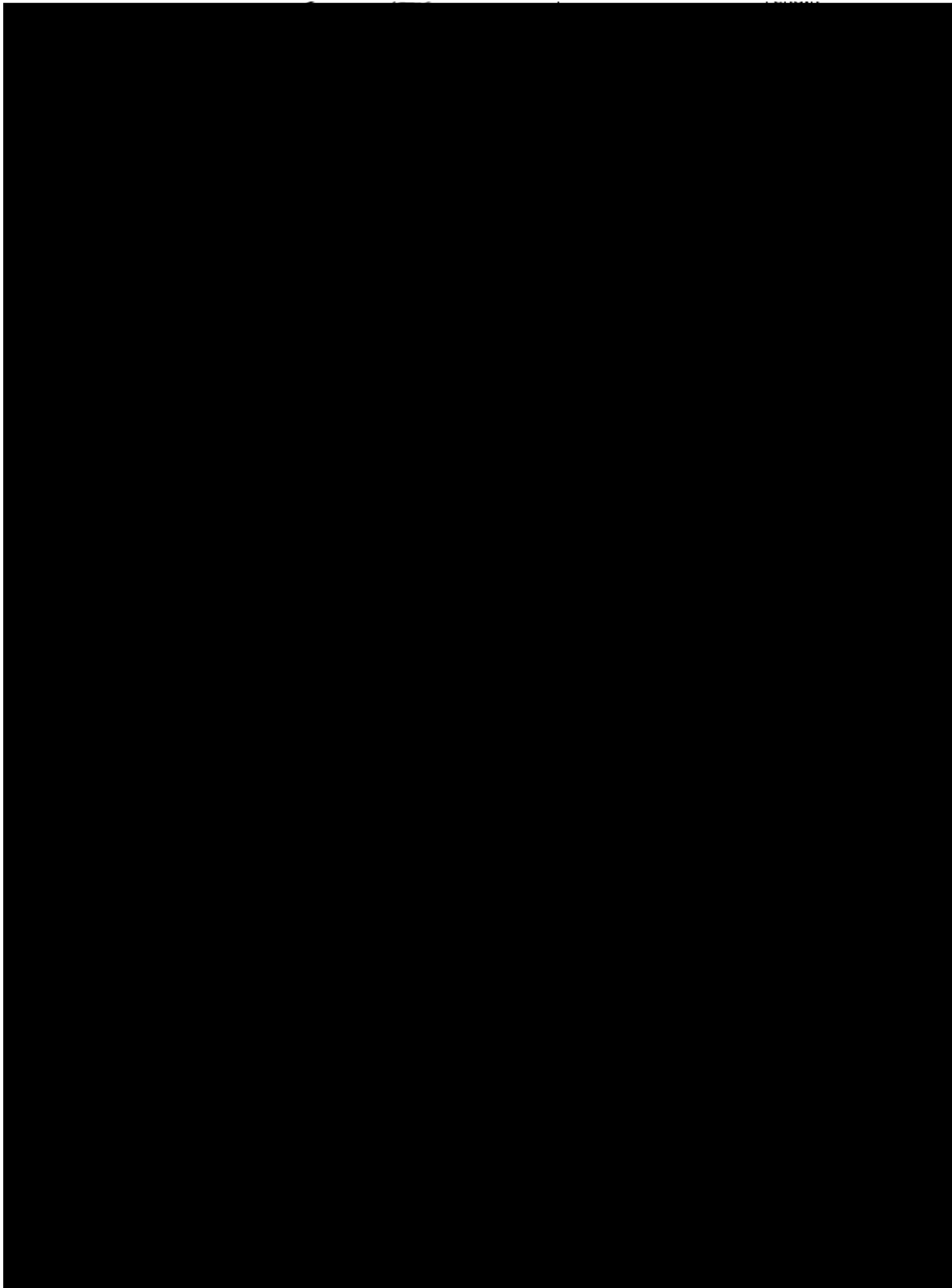


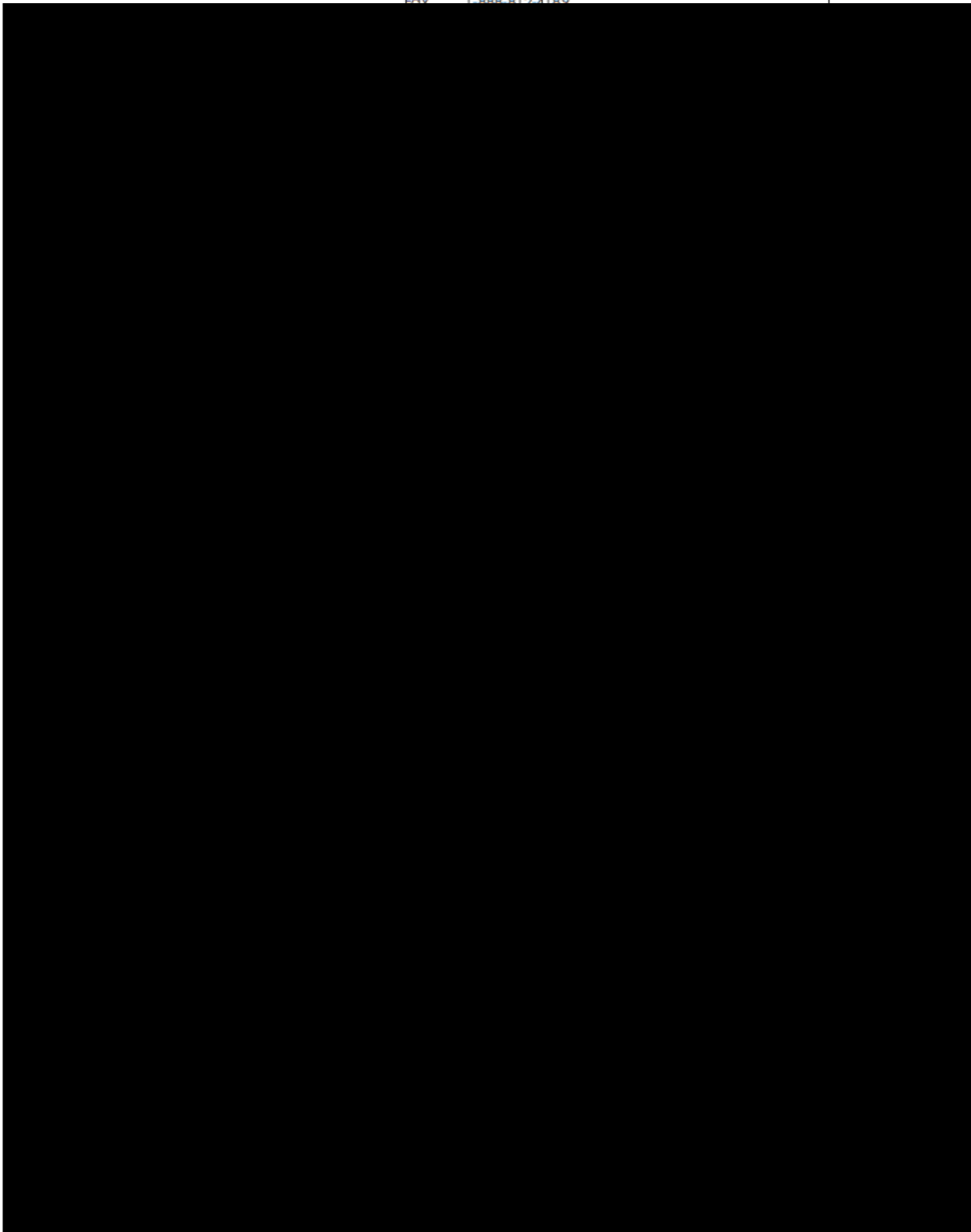


Figure 5: TK-01-15-1,229 sliders with rail and carriage from IGUS specification sheet [5].

## 2. List of Product Quotes

The products included in here are the PA-14P Linear Actuators from Progressive Automations, the Aerdon SSL – 8 electric hydraulic scissor lift from Ross Equipment Limited, the Horizontal low profile slider bed belt conveyor from McKenzie Handling Systems, Inc., the EXAIR Super Ion Air knife from EXAIR Corporation, and finally the rails and carriages from IGUS. Each of these products have been outsourced from their respective companies and thus have an associate quote that has been provided to CCC for the acquisition of these required components.

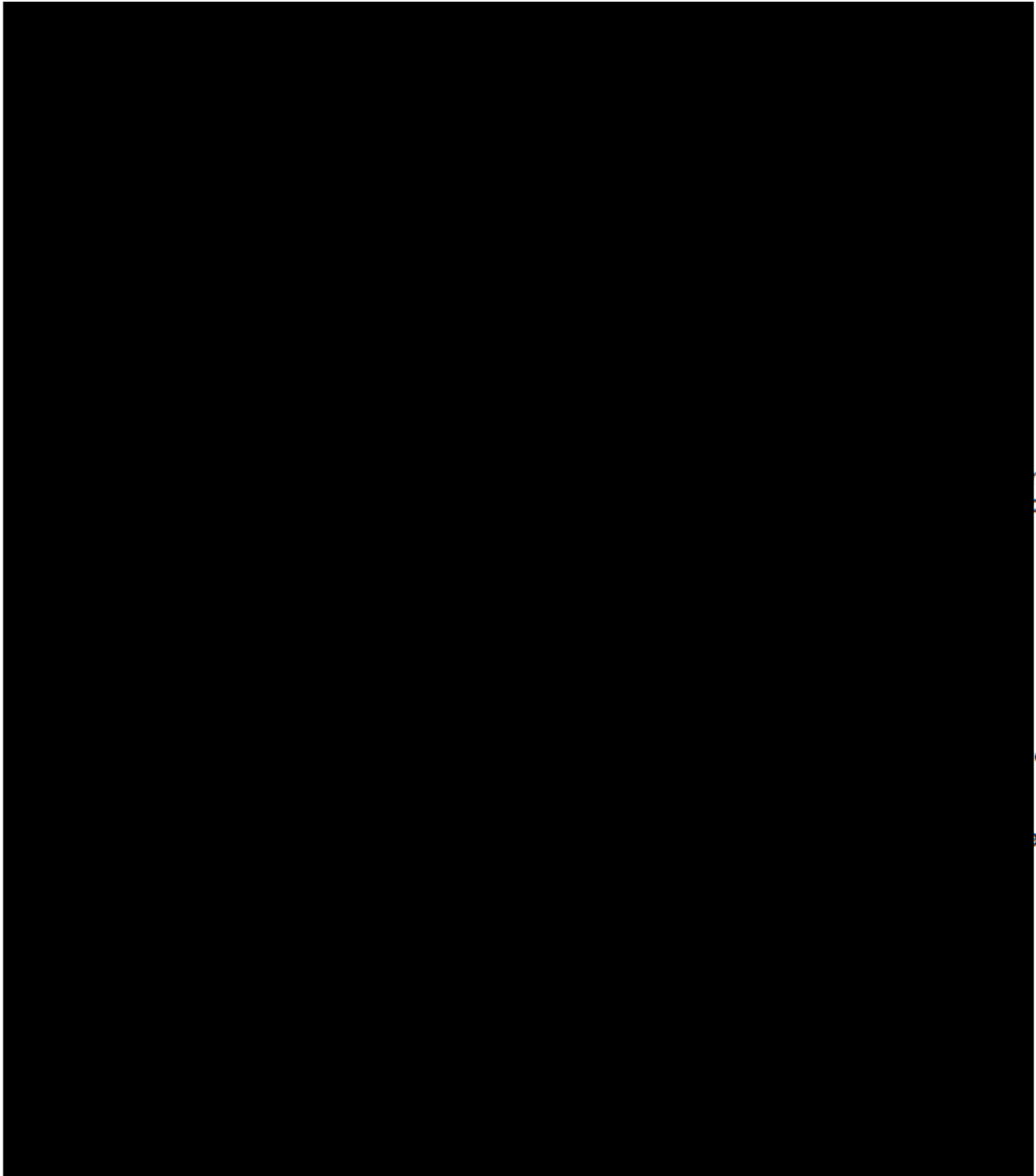




	Sub-Total
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	\$17.0
	\$83.9
	\$29.9
	\$408.9
	\$25.6
	\$434.6



221 SHEPPARD STREET

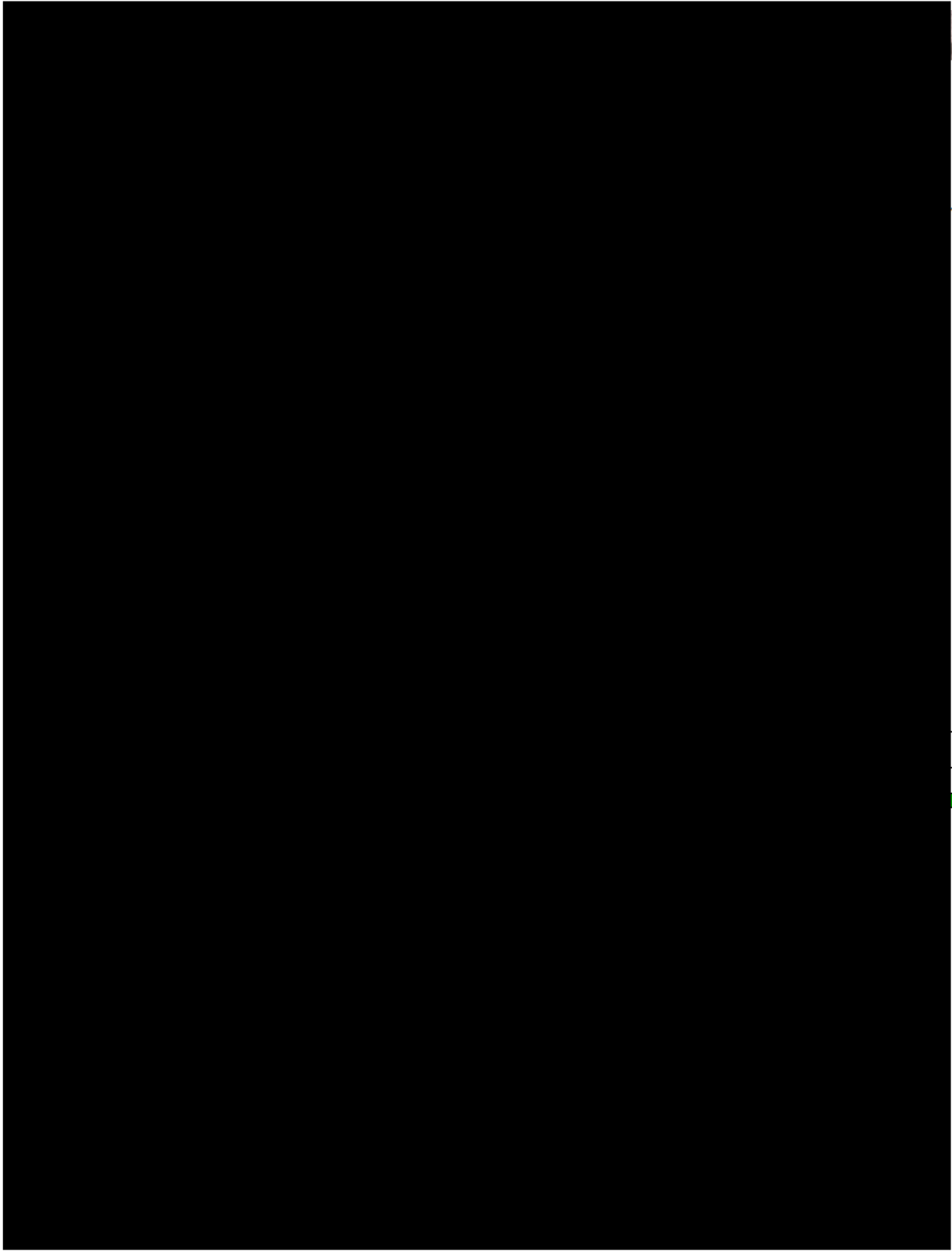


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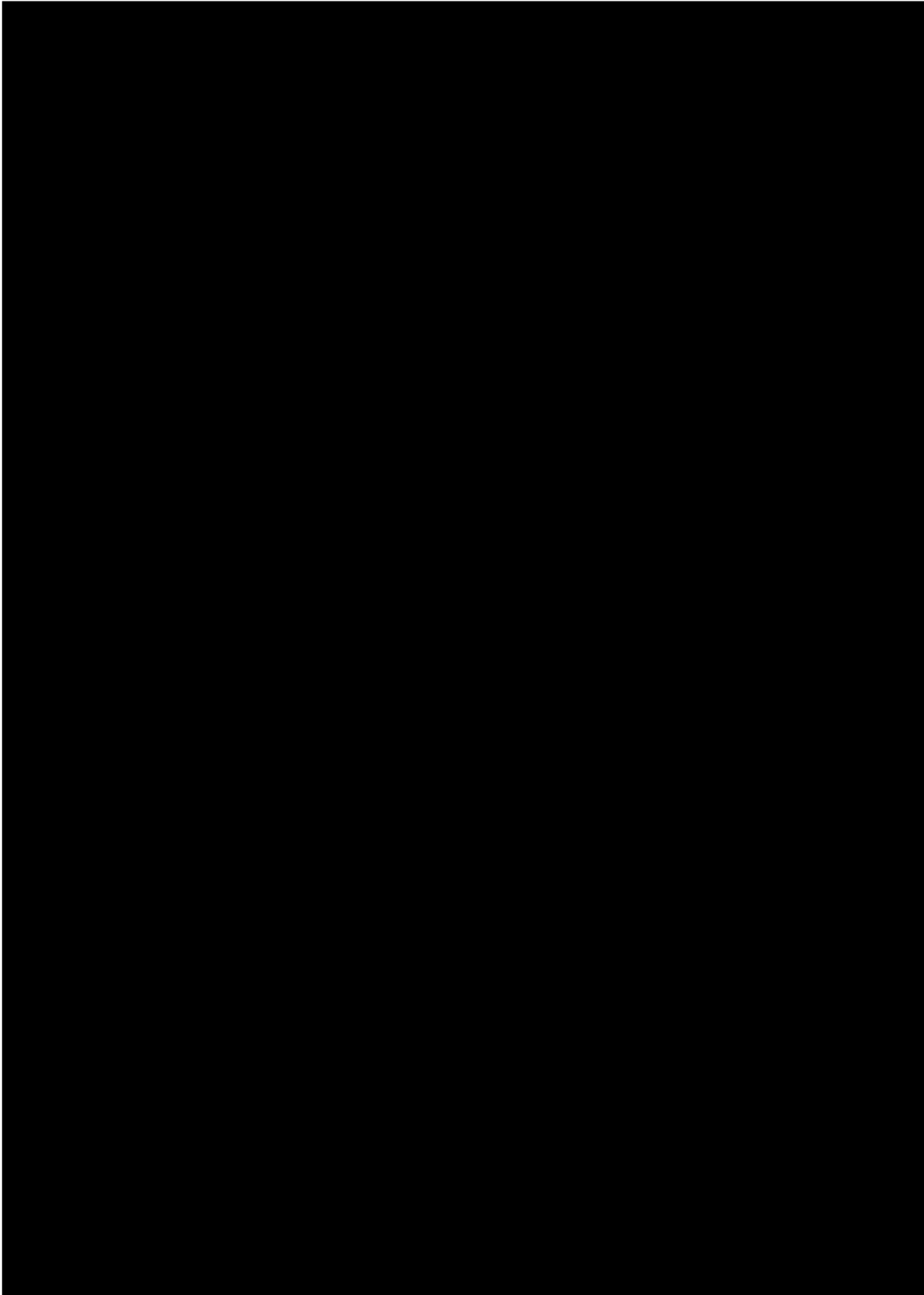


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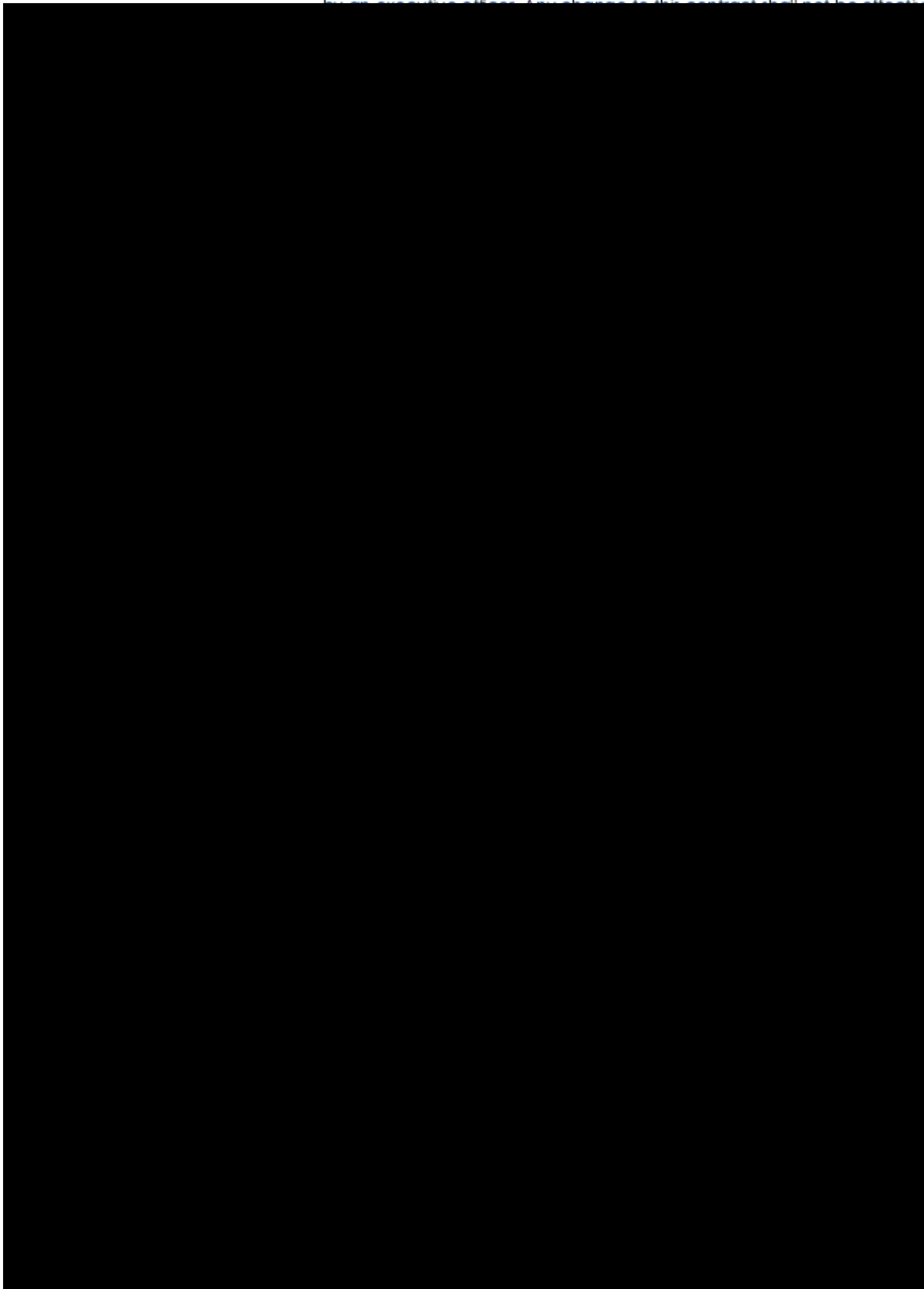


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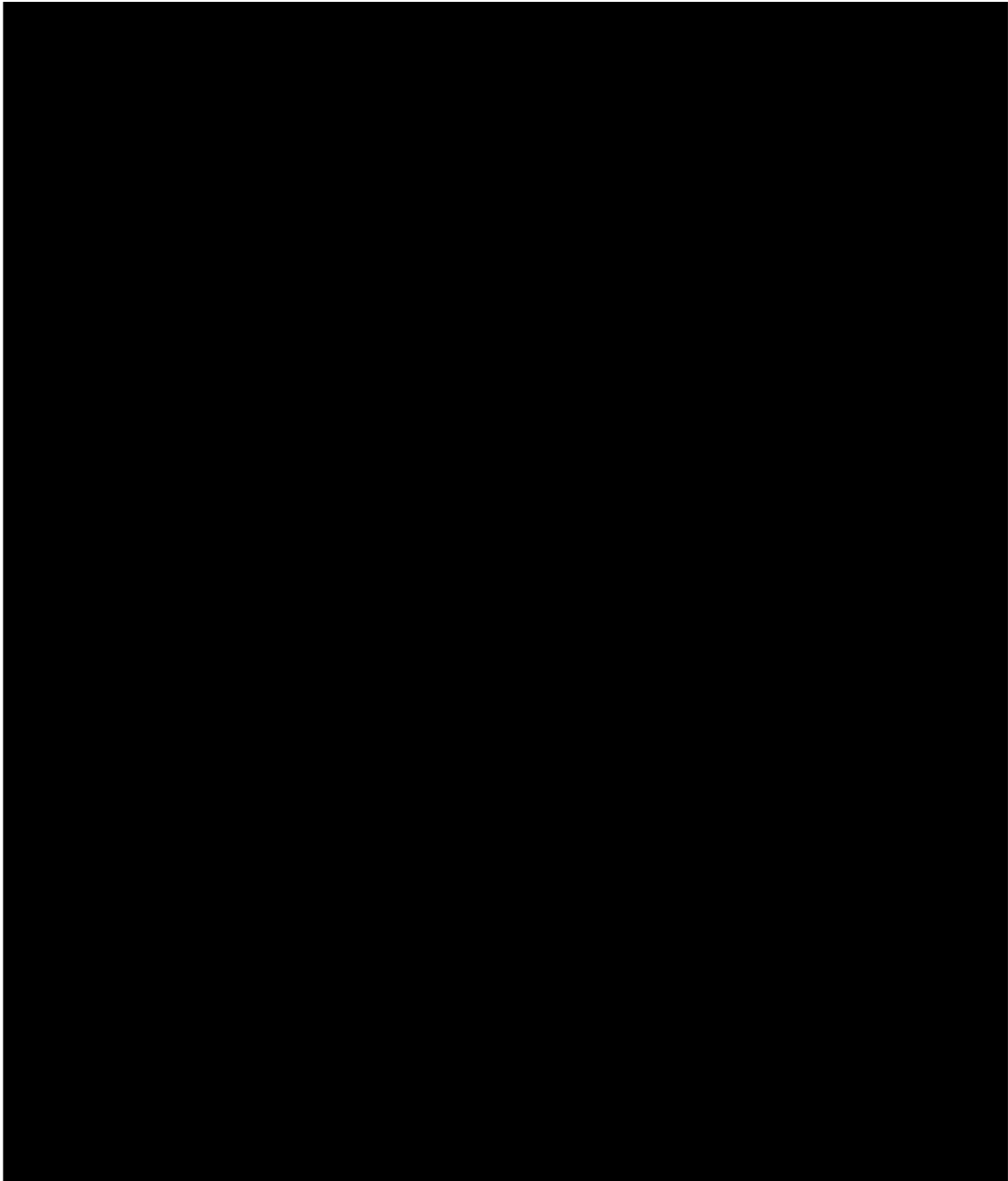
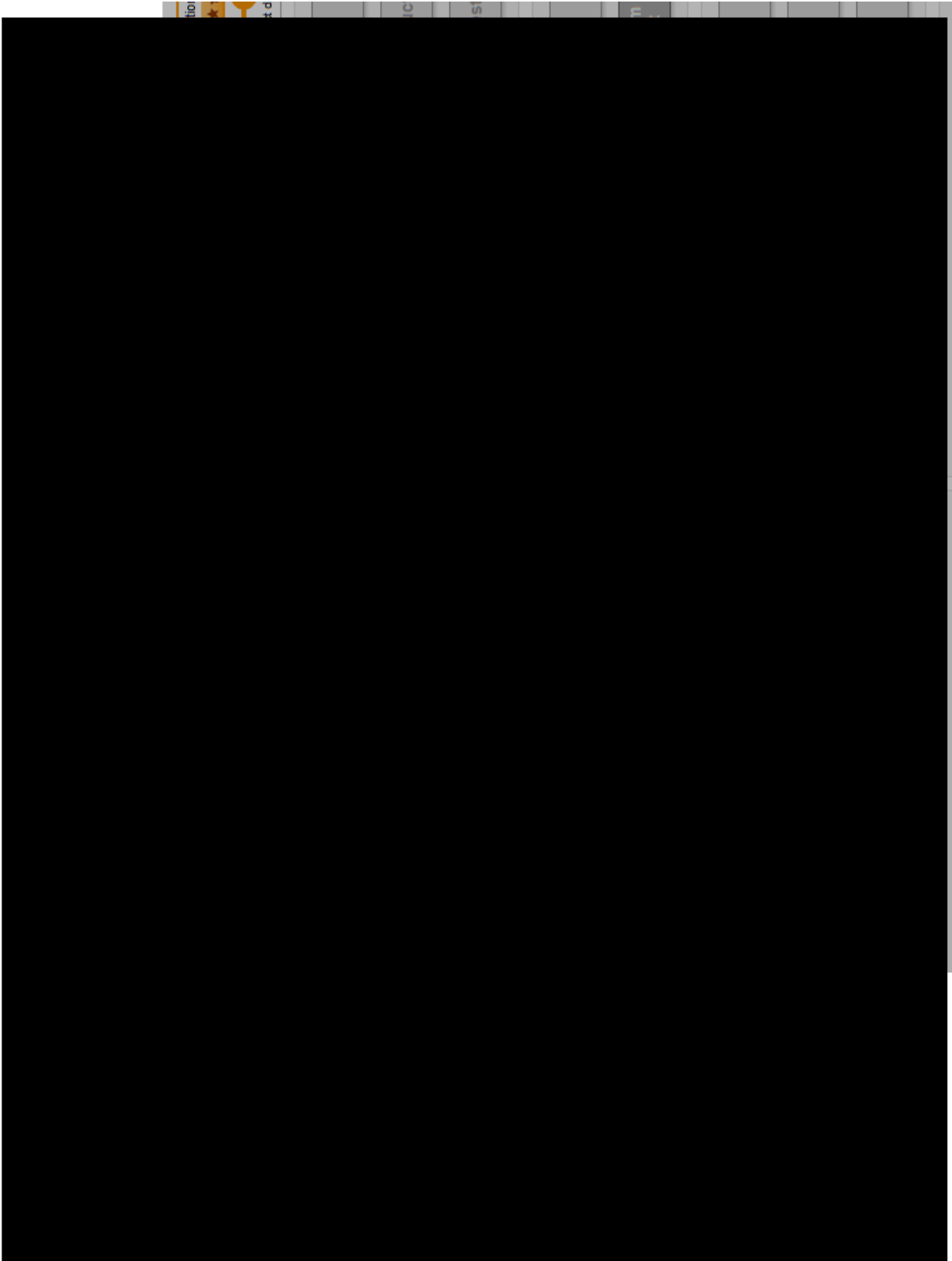


Figure 9: EXAIR Corporation Super Ion Air Knife quote [4].



Winnipeg MB Canada: ROSS EQUIPMENT Ltd. [November 21, 2013].

- [3] McKenzie Handling System Inc. (2013) *“Wide Belt Conveyor”*, Winnipeg MB Canada: McKenzie Handling System, 2013. [November 21, 2013].
- [4] EXAIR Inc. (2013) *“Super Ion Air Knives”*, Cincinnati OH USA: Russ Bowman, November 19<sup>th</sup>, 2013. [November 21, 2013].
- [5] IGUS plastic for longer life Inc. (2013) *“TK-0-15-1,229”* DryLin Expert 2.0. Northampton UK: IGUS plastic for longer life Inc. 2013. [November 21, 2013].



# **Appendix F: BOM and Cost Analysis**

## **Bill of Materials and Cost Analysis with Full Details**



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1. Complete Bill of Materials with Corresponding Costs .....	A122
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## **1. Complete Bill of Materials with Corresponding Costs**



The detailed BOM (Bill of Material) and its corresponding cost analysis are displayed in table below. Descriptions and specifications regarding the different features are provided in Table I, based on the data sheets collected from several industrial companies to help define the component dimensions. Note that five of these design component prices can only be scaled by length (feet) or area (square inches) rather than the numerical quantity of the component being purchased. A column of sub-total cost was also created to illustrate the cost summary of each purchased part. Ultimately, the total cost of all the raw material purchases for the ionized air core redesign is estimated to be \$24,665.01; however, fees of freight, manufacturing, installation and taxes are not included in the cost analysis due to the inability to accurately estimate their final cost at the time of purchase.



**TABLE I: HIGH-LEVEL BOM AND COST ANALYSIS**

BOM (Bill of Material)							Cost Analysis	
Parts	Vendor	Component	Descriptions/Specifications	Quantity/ Dimension	Unit Cost	Sub-total		
<b>Super Ionized Air Knife [1]</b>	EXAIR Corporation (11510 Goldcoast Dr, Cincinnati OH, USA)	111254PKI	54" Super Ion Air Knife Kit w/Plumbing Kit Installed	1	\$2,123.30	\$3,293.30		
		9057	EFC Electronic Flow Control	1	\$1,163.00			
<b>Linear Actuators [2]</b>	Progressive Automations Inc. (11388 Steveston Hwy, Richmond, BC Canada)	PA-14P-6-150	12 VDC, 6" stroke, 150 lbs, POT	2	\$138.89	\$434.64		
		BRK-14	Mounting Brackets for PA-14 Actuator Models	2	\$8.50			
		AC-15	Power Adaptor - 12VDC - 10A	1	\$83.99			
		AC-17	Wiring Kit (24' of wires - 18 awg, 12 connectors, 2 fuse holders, 2 limit switches)	1	\$29.99			
		Freight	n/a	n/a	\$25.68			
<b>Wide Belt Conveyor [3]</b>	McKenzie Handling System Inc. (3127 Dublin Lane - Bessemer, Alabama, USA)	Belt	56" Wide 2 ply PVC Belt with endless belt splice	2	n/a	\$11,200.00		
		Frame	Aluminum Extrusion 2 7/8" deep x 56.5" wide	2				
		Drive Motor	3/4 HP Inverter motor for 230/3/60	2				
		Angle Brackets	Support in feed and discharge	20				
		Tail Pulley	3" Bearing steel plates flush with top of conveyor	2				
		End Drive	Drive Pulley flush with top of conveyor	2				
<b>Lifting System [4]</b>	Ross Equipment Ltd. (221 Sheppard Street Winnipeg, MB Canada)	Steel Platform	24" wide x 60" long	1	n/a	\$7,900.00		
		Frame	Structural steel base frame with casters & fork pockets mount under base frame	1				
		Phenolic Casters	2 swivel on fixed end c/w wheel brakes, 2 rigid on roller end	4				
		Protective Bellow	40" maximum stretch, with the cross sectional area of 24"X60"	1				
		Valve	Anti-drift valve on power pack	1				



<b>Cleaner Hood</b>		Steel Sheet	Stainless steel sheet [5]	84"X44"	\$12.09/ft <sup>2</sup>	\$888.50
		Flaps	24"X48" PVC flap with thickness of 0.125" [6]	1	\$47.54	
		Frame	0.125" thickness, 1.22" X 1.22" stainless steel square tubes [5]	330"	\$12.96/ft	
		Flattened Mesh	4'X8' sheet, 0.115" width, 0.048" thick alloy 1008 carbon steel [6]	1	\$75.07	
		Slider	9" rail, 2.68" carriage [8]	2	\$50.26	
<b>Base</b>		Vacuum Duct	6" diameter aluminum duct and span of 53" [7]	53"	\$12.20/ft	\$742.75
		Rectangular Reducer	8"X52" to 6"X52", 26 gauge aluminum sheet metal [5]	52"X26"	\$3.60/ft <sup>2</sup>	
		Pipe Reducer	8" to 6" diameter, 26 gauge aluminum duct [7]	1	\$32.04	
		Vacuum Elbow	8" diameter, 90 degree aluminum duct elbow [7]	1	\$22.46	
		Frame	0.125" thickness, 1.22" X 1.22" stainless steel square tubes [5]	557"	\$12.96/ft	
<b>Total Raw Material Cost</b>						<b>\$24,459.19</b>



## **2. List of Fasteners and Corresponding Costs**

A list of the required fasteners for the construction of the new ionized air core cleaner design has been compiled and is shown in Table II. The types of fasteners used are described as well as where they should be installed to correctly assemble the machine. The prices for the fasteners have been sourced per package and therefore require the purchase of extra fasteners in some situations. The total cost of all required fasteners has also been calculated and is shown at the end of Table II.



**TABLE II: LIST OF FASTENERS REQUIRED [6]**

Description	Size	Length	Part No.	Supplier	Cost	Qty	Location	Total
<b>Black Oxide Alloy Steel Socket Cap Screws</b>	10-24	1"	91251A247	McMaster -Carr	\$12.37/100	8	Rail and carriage slider mounting brackets	\$12.37
<b>Type 316 Stainless Steel Undersized Machine Screw Hex Nuts</b>	10-24		90205A313	McMaster -Carr	\$11.29/50	8	Associated nut for tightening socket cap screws	\$11.29
<b>Metric Low Head Socket cap Screws</b>	M4-pitch 0.7 mm	25 mm	92855A422	McMaster -Carr	\$5.48/25	8	Rail attachment to hood frame side walls	\$5.48
<b>High Strength Steel – Grade 8 Cap Screws – Fully Threaded</b>	5/16" – 18	2"	92620A591	McMaster -Carr	\$8.66/10	12	Base frame to lift system mounting plate	\$17.32
						4	Slider mounting brackets	
						4	EXAIR air knife mounting brackets	
<b>High Strength Steel – Grade 8 Cap Screws – Fully Threaded</b>	5/16" – 18	1-1/2"	92620A587	McMaster -Carr	\$11.15/50	52	Flap mounting plate	\$22.30
						2	Linear actuator mounts	
<b>Hex Nuts – Grade 8 Steel – Ultra Coated</b>	5/16"-18		93827A219	McMaster -Carr	\$9.74/100	74	Associated nut for tightening cap screws	\$9.74
<b>Drilling Screws for Metals</b>	10-16	3/4"	94056A380	McMaster -Carr	\$11.27/100	28	Base frame side walls	\$22.54
						56	Base frame front and back walls	
						28	Hood frame side walls	
						40	Hood frame front and back walls	
<b>Type 316 Stainless Steel Internally Threaded Anchors for Concrete</b>	1/2" – 13	2"	97095A131	McMaster -Carr	\$8.36/1	8	Anchor the lifting system to the concrete floor	\$66.88
<b>Threaded Anchors Installation Tools</b>	1/2" – 13	5-1/2"	97077A130	McMaster -Carr	\$4.80/1	8	Tool used during the installation of each concrete anchor	\$38.4
<b>Total Cost</b>							<b>\$205.82</b>	

### 3. References

- [1] EXAIR Inc. (2013). *“Super Ion Air Knives”*, Cincinnati OH USA: Russ Bowman, [November 19, 2013].
- [2] Progressive Automations Inc. (2013). *“Sales Quote”*, Richmond BC Canada: Progressive Automations, 2013.
- [3] McKenzie Handling System Inc. (2013). *“Wide Belt Conveyor”*, Winnipeg MB Canada: McKenzie Handling System, 2013. [November 20, 2013]
- [4] ROSS EQUIPMENT Ltd. (2013) *“Aerdon SSL-8 Electric Hydraulic Portable Scissor Lift”*, Winnipeg MB Canada: ROSS EQUIPMENT Ltd. [November 21, 2013].
- [5] MetalsDepot Inc. (2012). *“Metals Depot Shopping Cart”* [Online]. Available: [http://www.metalsdepot.com/catalog\\_cart\\_view.php?msg=](http://www.metalsdepot.com/catalog_cart_view.php?msg=) [November 21, 2013].
- [6] McMASTER-CARR (2013). *“Over 51,000 Products”* [Online]. Available: <http://www.mcmaster.com/#> [November 21, 2013].
- [7] ECCO Supply (2012). *“Product Guide”* [Online]. Available: <http://www.eccosupply.ca/products.html> [November 21, 2013].



## **Appendix G: Design Drawing Package**



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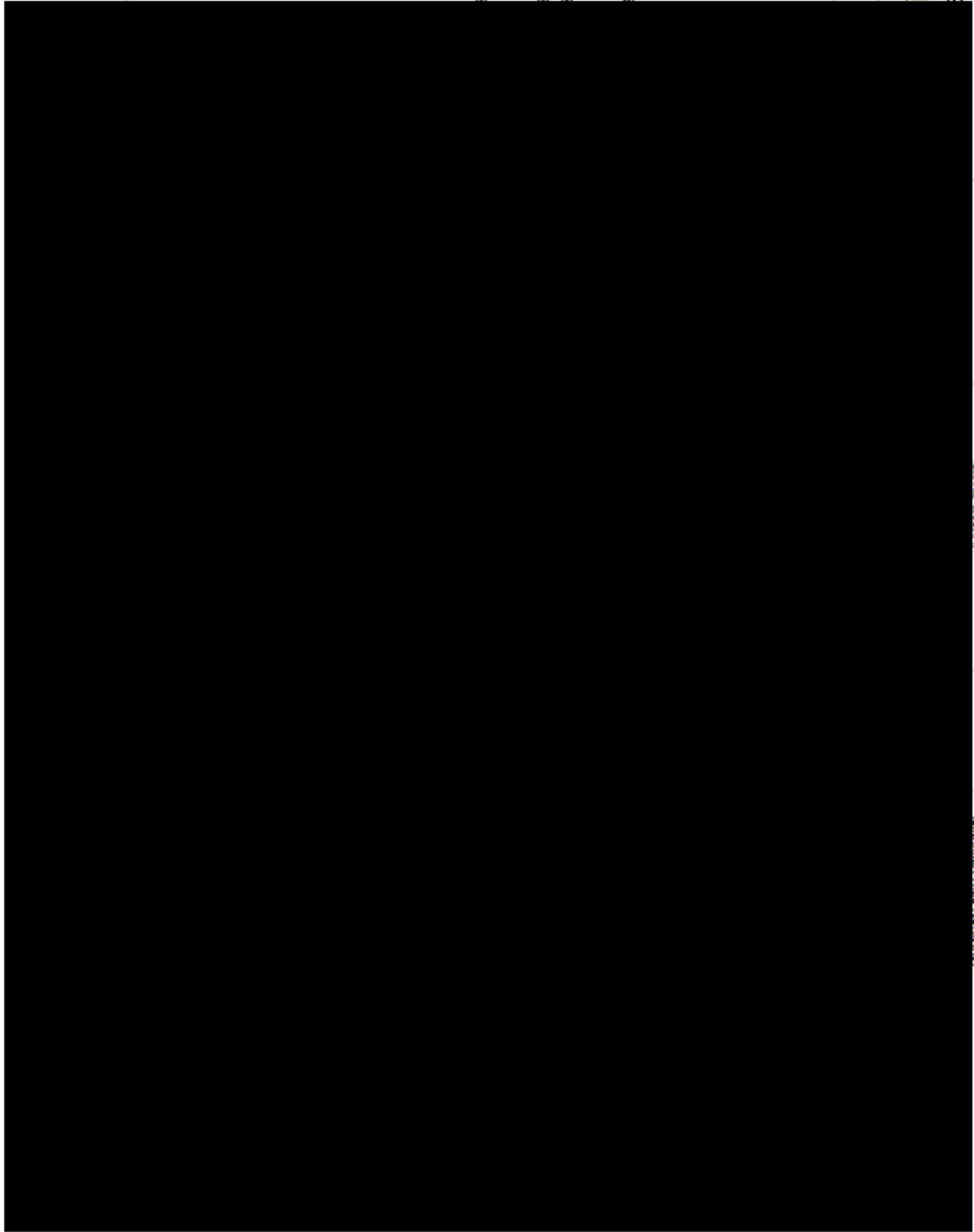


## 1. Design Drawings

The drawing package for the new ionized air core cleaner design is comprised of Figures 1 through 13. The final design has been sub-divided into multiple parts and assemblies. Each of these components have a corresponding drawing contained in the included design drawing package. The purpose of this drawing package is to facilitate the manufacturing and acquisition of the new ionized air core cleaner design by [REDACTED], should they choose to implement the recommended redesign.







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**A** Vacuum House

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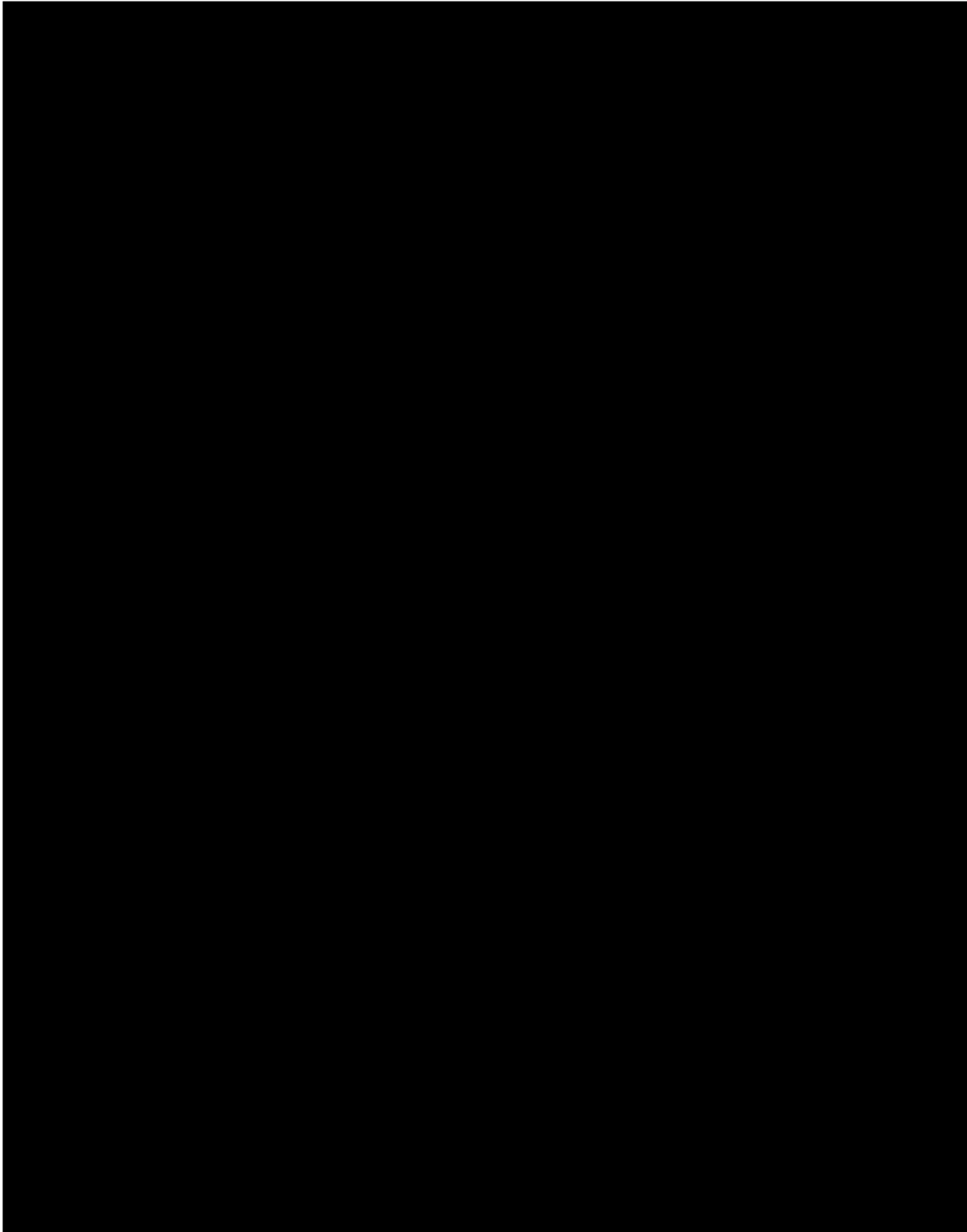
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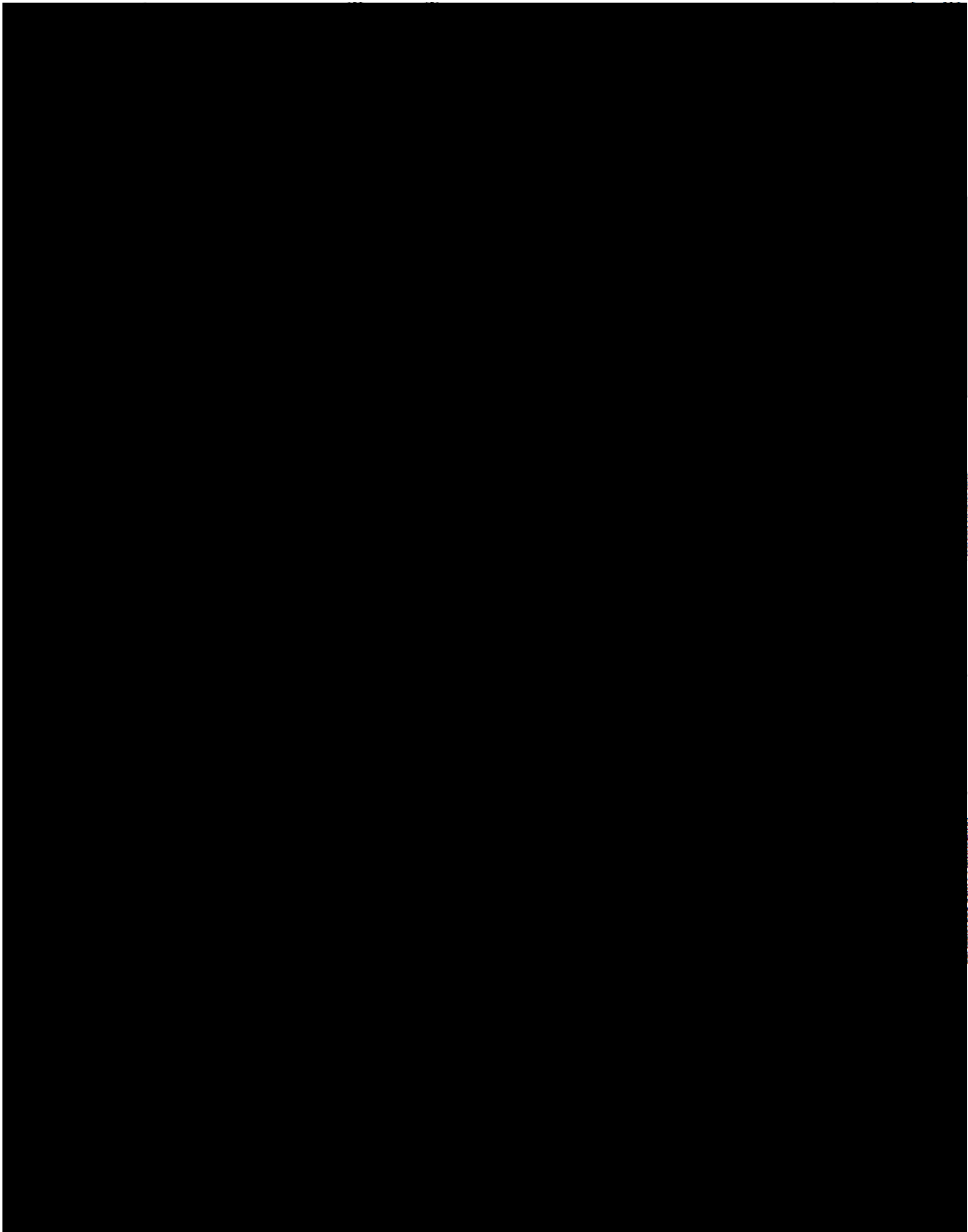
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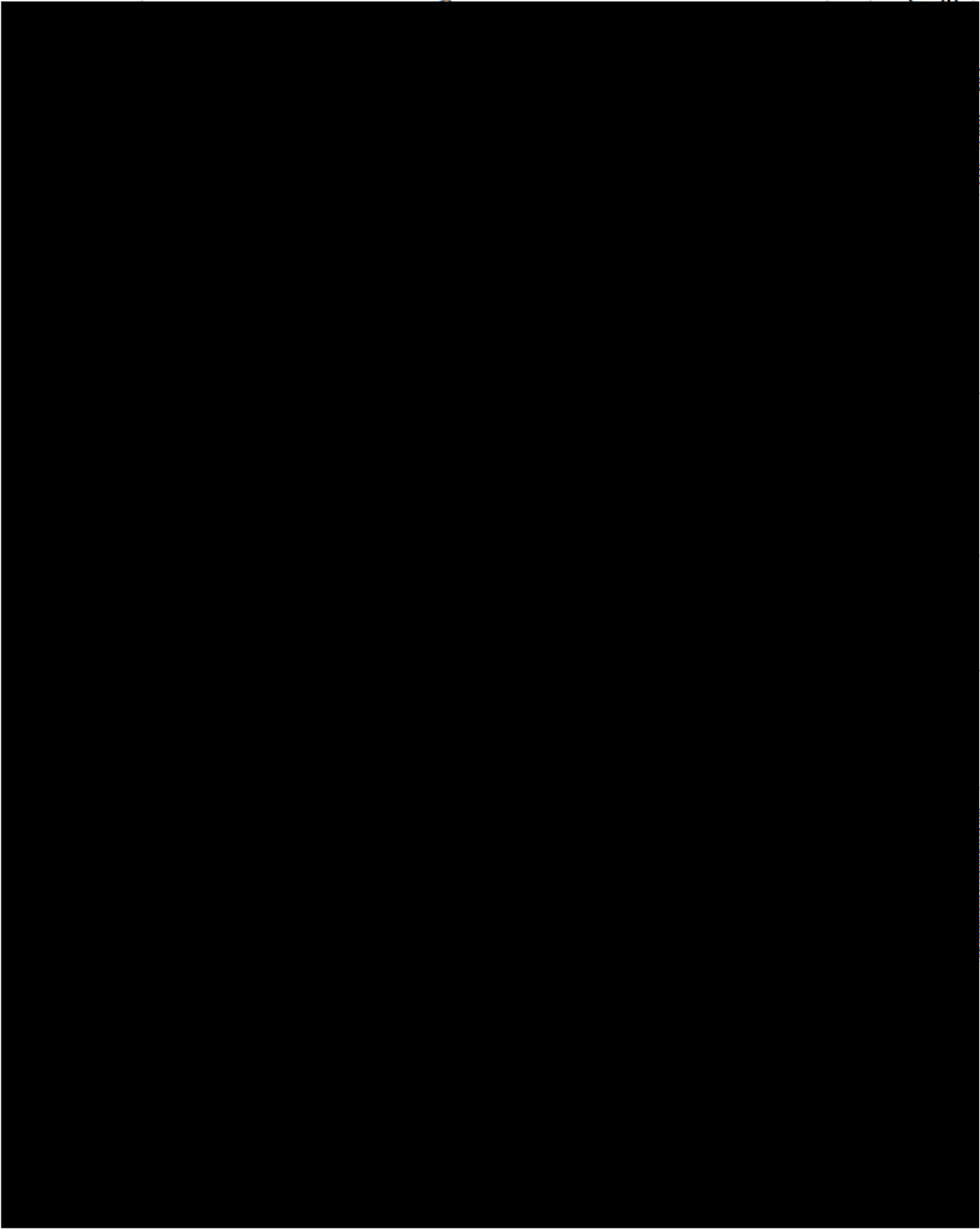
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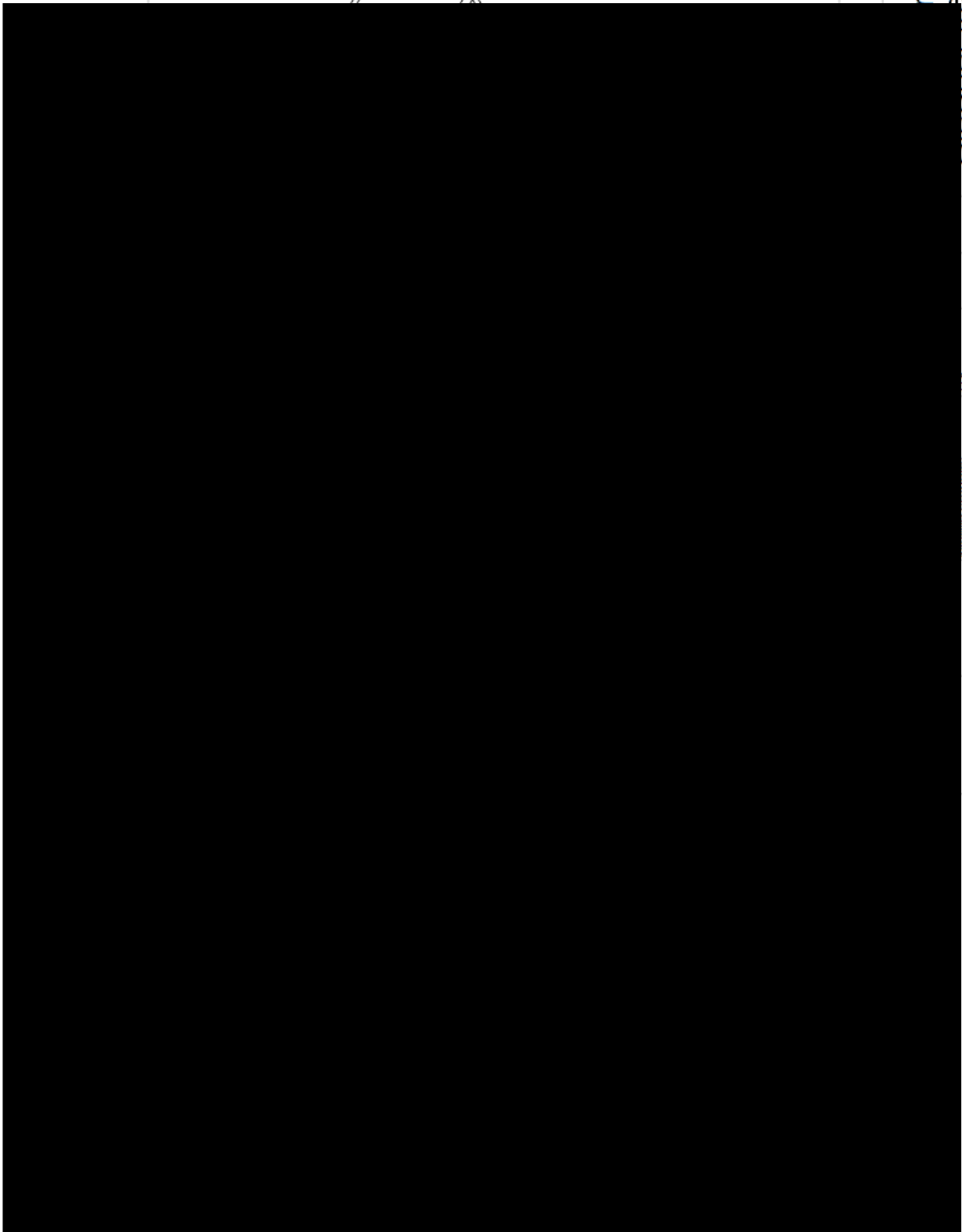
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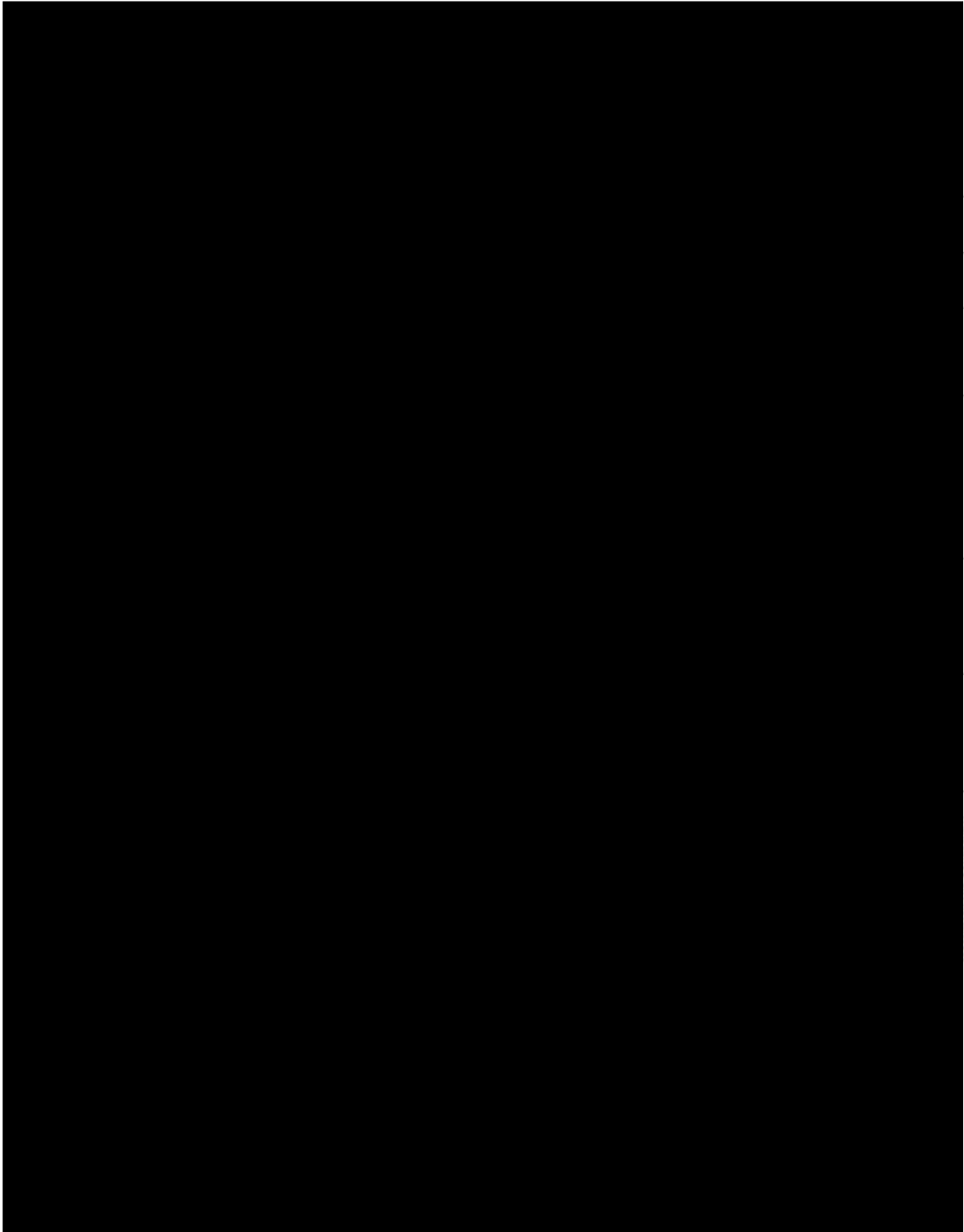
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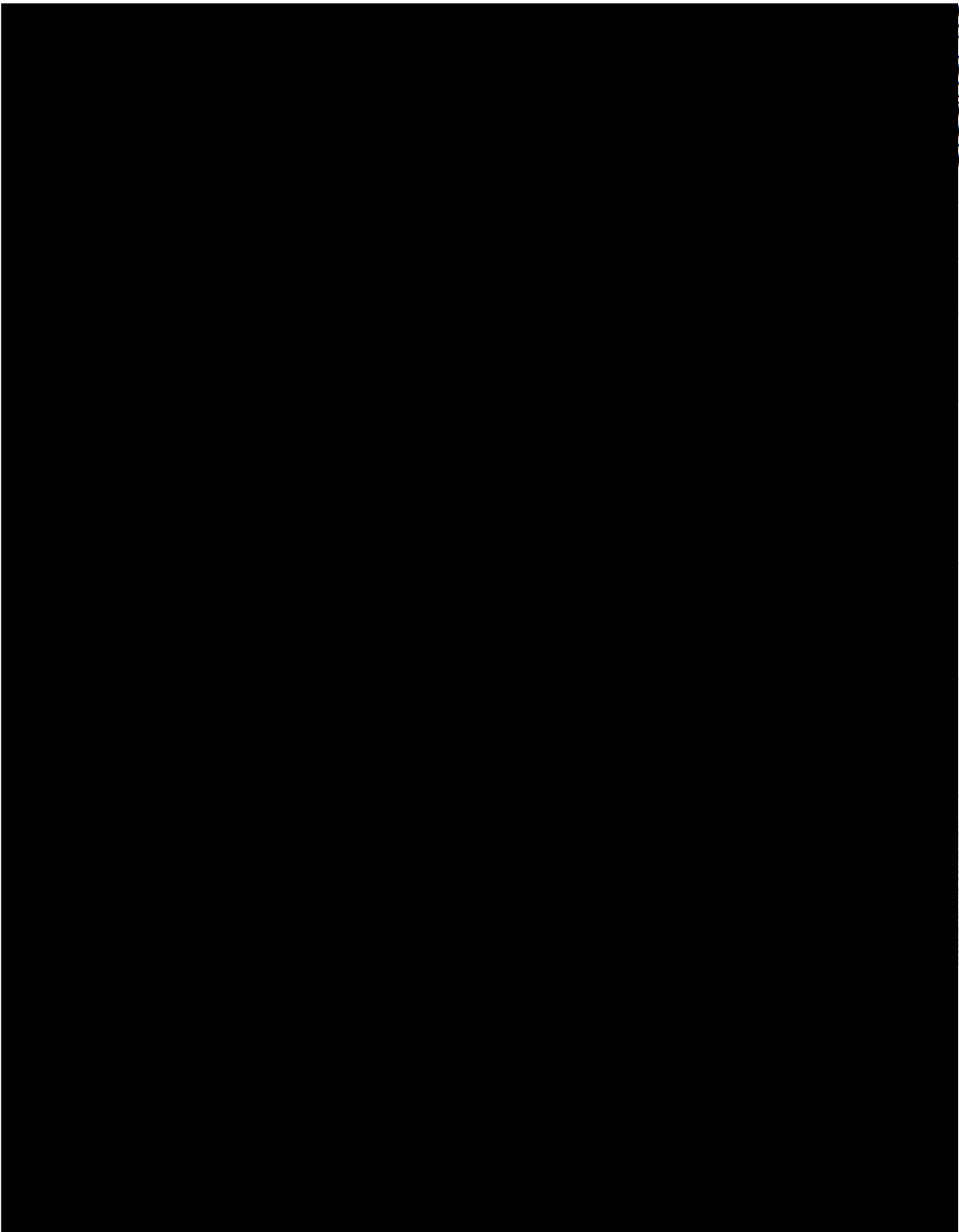
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**A** Vacuum D  
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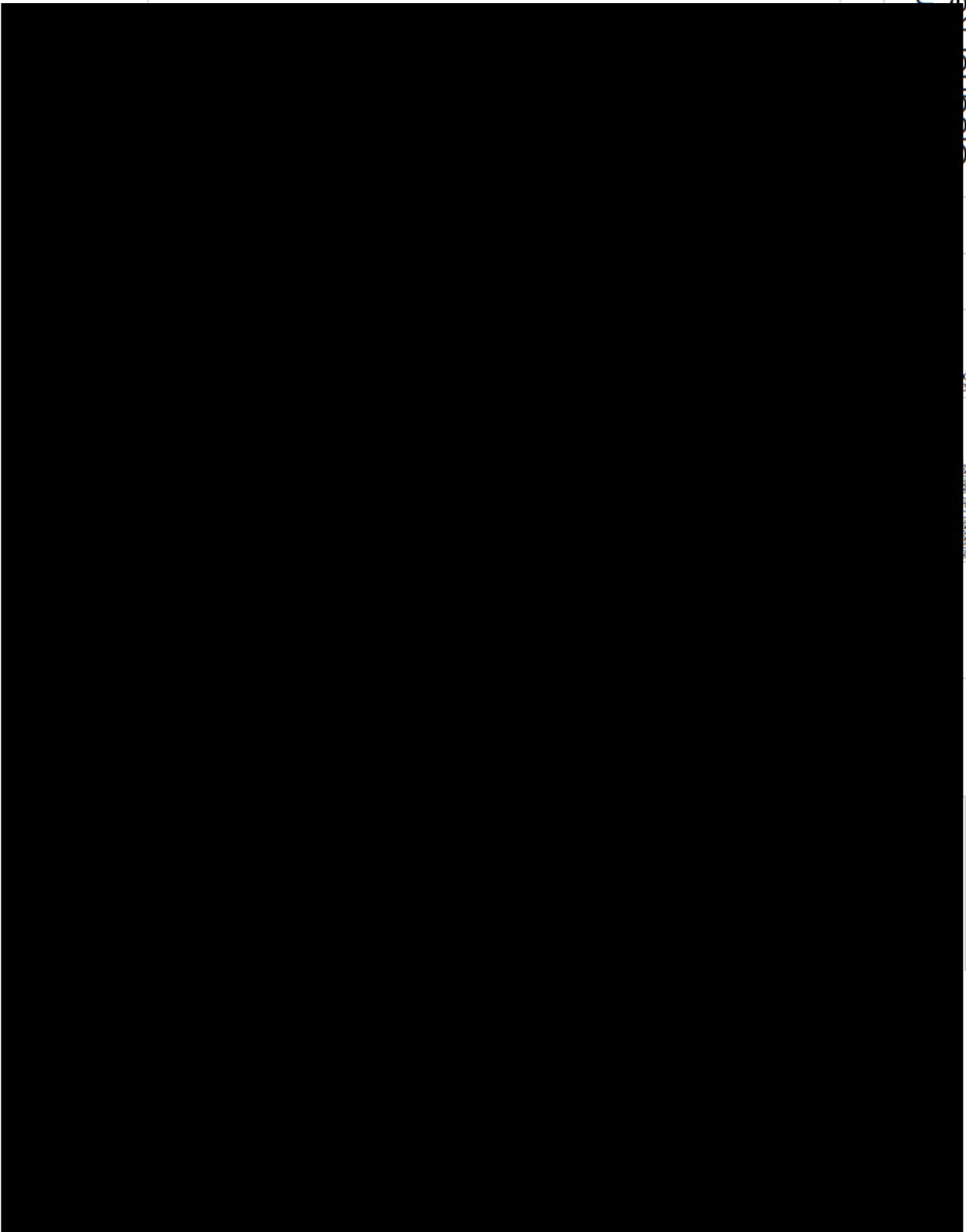
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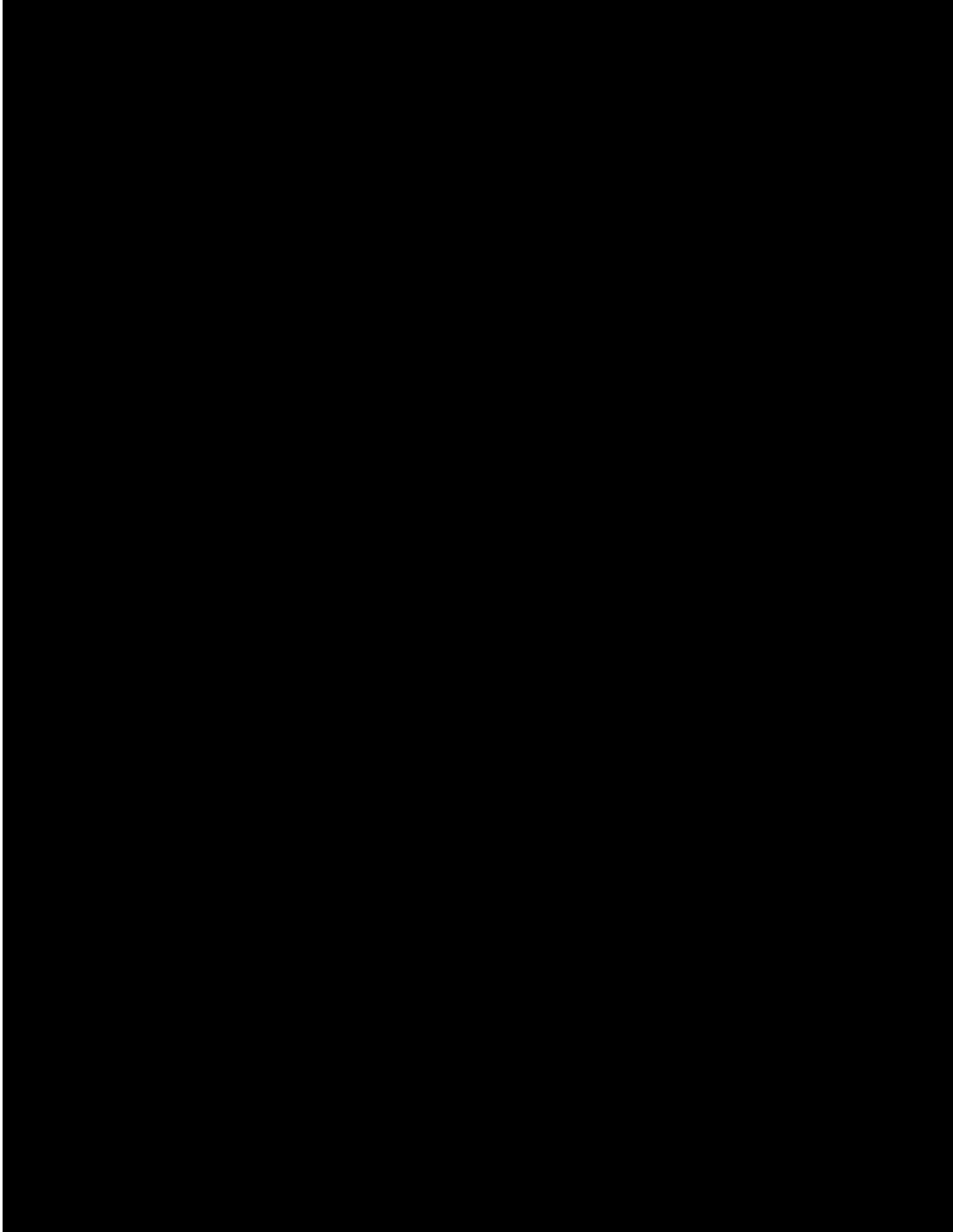
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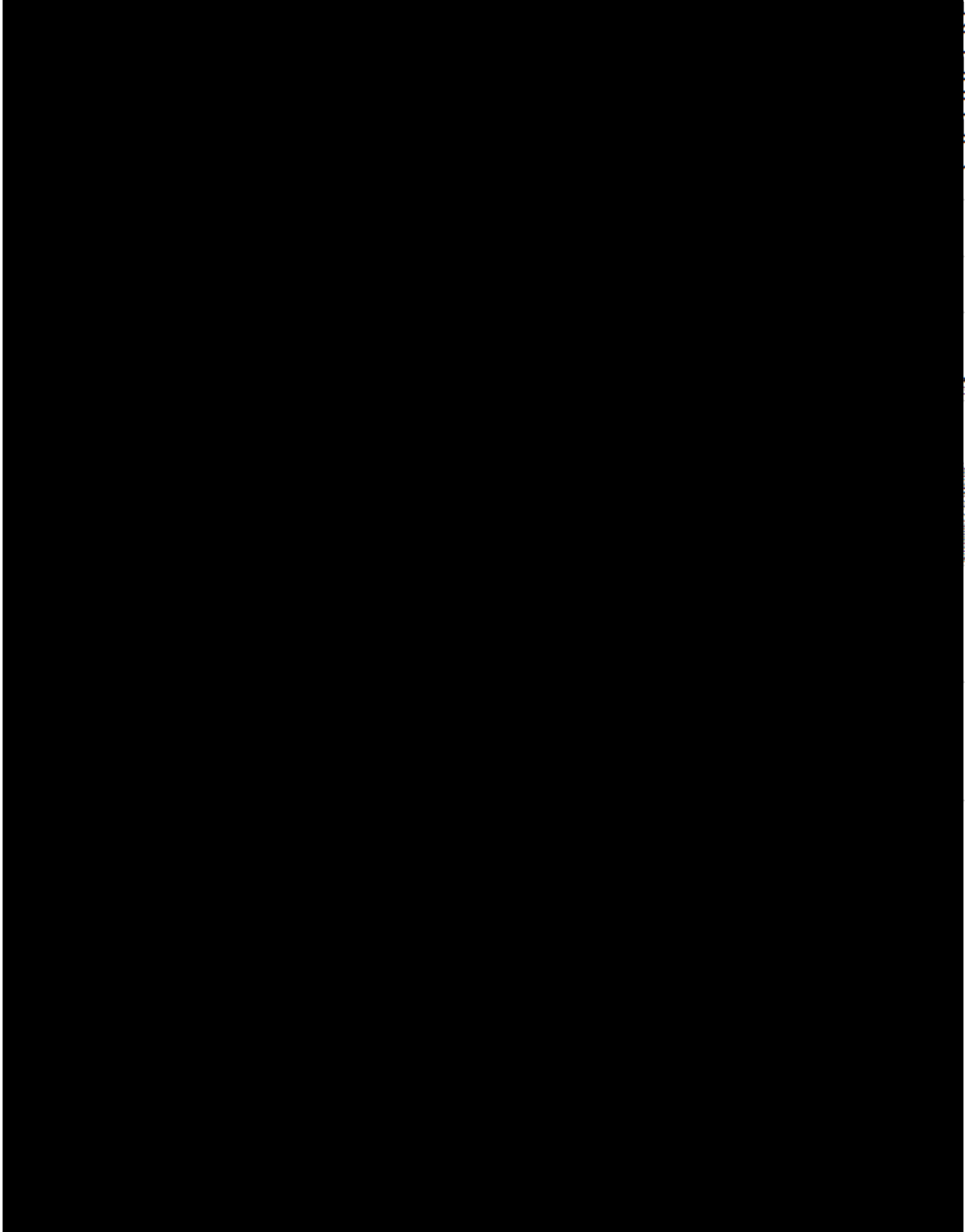
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**A** Air Blade Brc

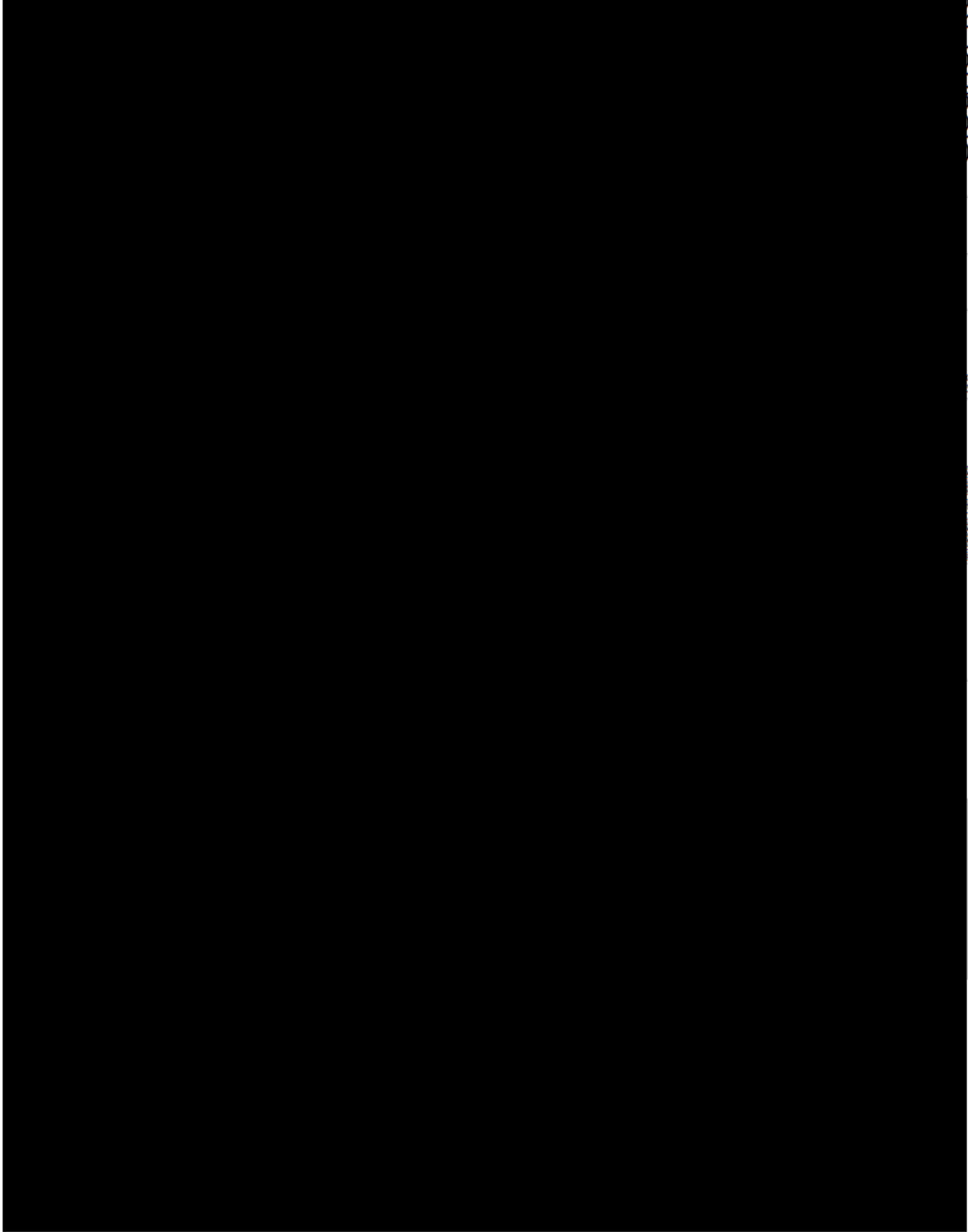
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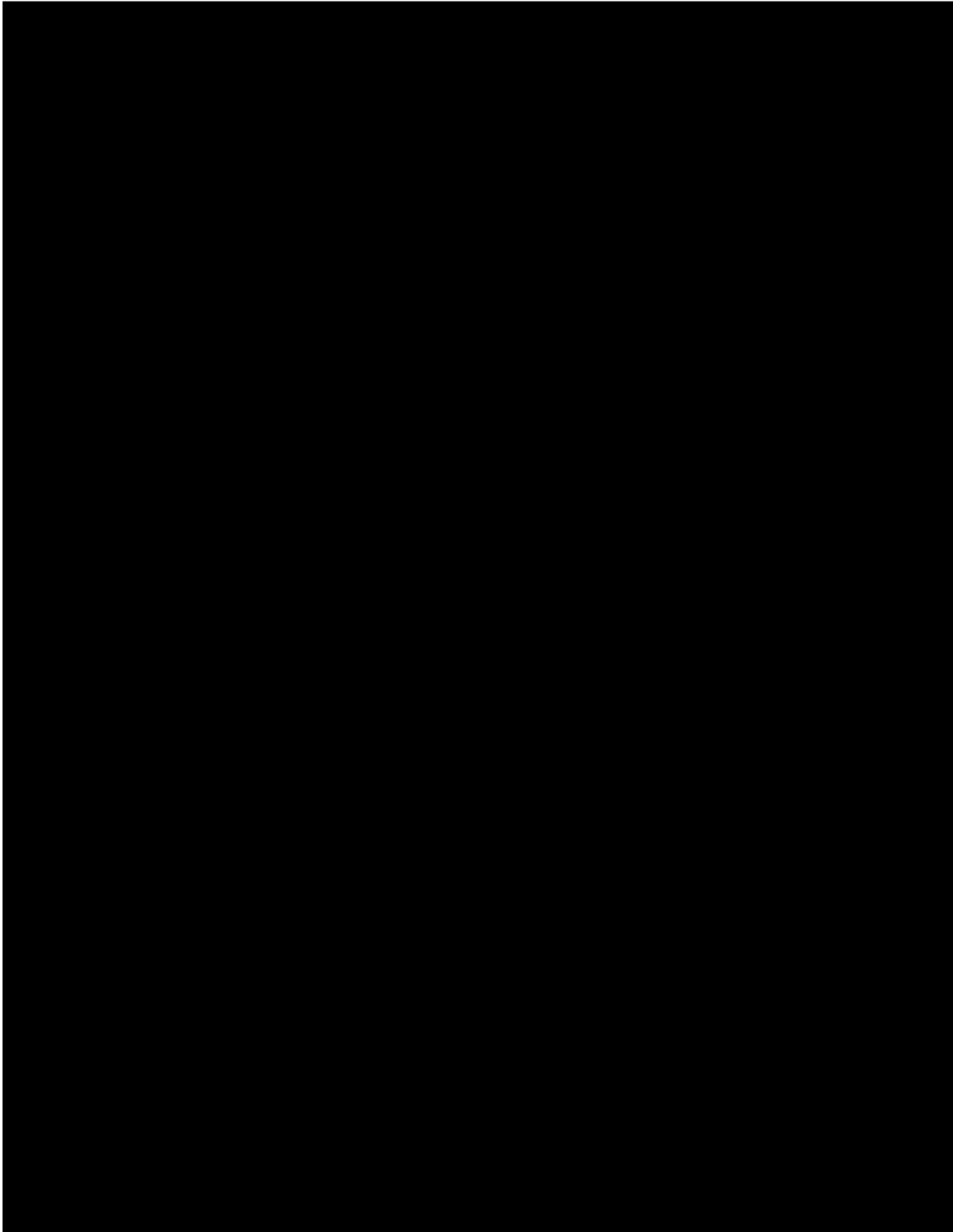
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**A** Flaps

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