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A Multidisciplinary Approach to Retrofitting a Vintage Pinball Machine with a Unique Fog Generation System

Pinventions

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***Abstract*— An innovative fog feature has been designed and integrated into the back-glass of a restored vintage pinball machine. The fog feature adds an interesting effect to a zombie graveyard scene painted on to the back glass of the *Night of the Living Dead* themed game. The designed system is able to produce fog instantaneously through the use of a newly created atomizer design. The groundbreaking design features an atomizer unit with a common source reservoir supplying multiple vaporization wicks. The design also features an exhaust system that is capable of manipulating and removing the created fog within the acrylic containment system. The prototype is controlled through a programmable microcontroller allowing it to function seamlessly with the outputs of the pinball machine. The project requires an understanding of various engineering fields and exemplifies how to thoroughly design and complete a project using a multidisciplinary approach.**

Keywords—fog; production; containment; cleaning; exhaust; pinball; back-glass;

I. INTRODUCTION

The Engineering program at Roger Williams University requires that engineering students take part in a senior design project in the last two semesters of their undergraduate studies. This class enrolls students from different areas of engineering such as mechanical, electrical, computer and civil as well as computer science to work together in small teams with the goal of completing a multidisciplinary engineering project. The projects vary in both scope and goal, but are selected to allow the different engineering disciplines to contribute to solving an open-ended design problem. The authors of this article were assigned a rather unique project that exemplifies how the intermingling of different engineering disciplines and the input of technical advisors, who also share diverse engineering backgrounds, are able to collaborate to complete a singular project.

The task presented to the authors of this paper is simple in its goal, but complex in its solution. The task involved the design, fabrication and implementation of a fog production system that fits in the back-glass of a retro pinball machine such that it can be triggered by actions performed by the player to enhance the aesthetics of the machine. The client for this particular project was a Vice President and Manager of Engineering Products and System Development at a global service company. In his spare time the client restores retro pinball machines as a hobby thus allowing him the opportunity to use his engineering knowledge in a creative way [1]. One of his current projects is restoring a machine and reinventing its design using the theme of the classic horror movie, *Night of the Living Dead*. It is this design choice that piqued his interest for creating a fog production system that would greatly improve the level of immersion of the refurbished pinball machine. The client found it to be a project unique enough in its goal that he brought it to the capstone engineering design class at Roger Williams University. The faculty of the class recognized the complexity of design task such that it was included in the portfolio of projects presented to the class for consideration.

The authors, hereto referred as the Pinventions design team, shared the interest that the client had in this particular design project. Working with antique pinball machines sparked the curiosity and imagination of the Pinventions team as well as the myriad of approaches that might provide a solution to the challenge. The Pinventions design team consists of three students that specialize in mechanical engineering and one specializing in electrical engineering. The mix of disciplines in the Pinventions design team is an example of having engineers of different disciplines collaborate on a project. While it may seem logical to have team members work on individual areas of expertise, the design challenges of the project did not allow this approach.

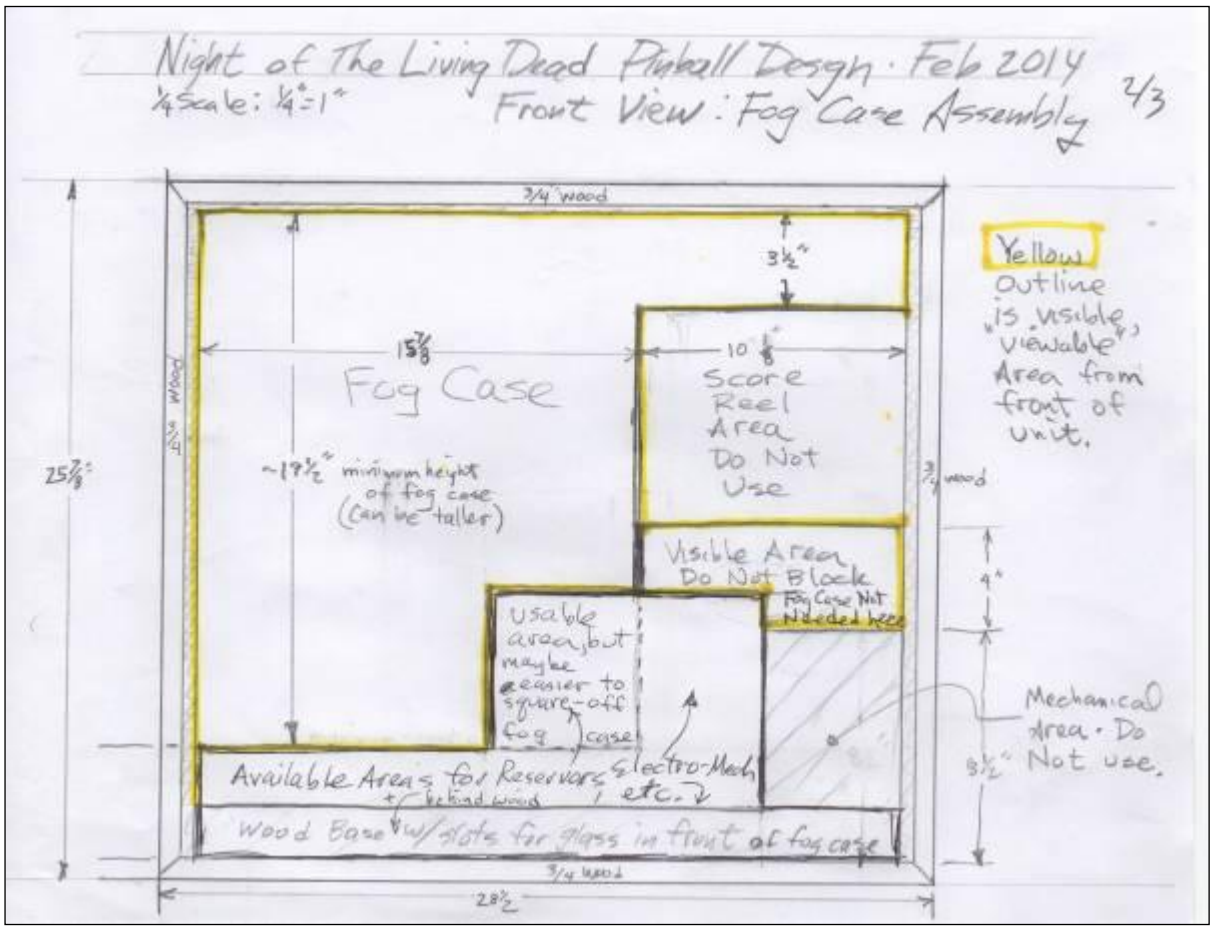

Fig. 1. Detailed drawing of the pinball back-glass demonstrating the space where the different components of the project will be located.

II. Design Process

When examining the aspects of the project that needed to be addressed, four major areas were identified to successfully complete the project: fog production, fog containment, fog exhausting, and fog cleansing. Solving these design problem requires a device that produces fog, under the constraints that it be relatively silent, quick to startup, and easily integrated with the existing architecture of the machine. Exhausting the fog followed similar constraints while requiring that none of the vented fluid come in contact with any electrical components in the machine. Similarly, the containment of the fog had to keep the fluid isolated from the rest of the machine, while designed to allow the fog to be visible as it rises in the back-glass of the pinball machine. Lastly, the chance of residue remaining from the fog production system is relatively high, so a system must be put in place to minimize that residue and any excess needs to be removed easily without compromising the integrity of the system.

Having separated the design project into several systems made it clear to the Pinventions design team that working solely to their strengths was not an option. The project requires a vast understanding of different engineering areas to fully understand how to best tackle each individual system and the project as a whole.

A. Fog Generation System

The fog production systems requires an understanding of electronics, heat transfer, and material science. At its most basic level, the fog production system uses a vapor producing method similar to atomizers [2] [3]. The system supplies an electrical current to a heating element, a metallic coil that surrounds a steel-mesh wick, which is partially submerged in the liquid fog solution [4]. The fog solution is then vaporized, traveling through the wick and creating the fog feature inside of the containment fixture. In order to optimize the system, it is crucial to optimize the amount of power provided to the heating element so that is economical enough to utilize the electricity provided by the pinball machine. Determining how much heat can be supplied to the heating element without disrupting the integrity of the container it is surrounded by, or the components it comes in contact with, is also an issue of great importance. Likewise, the materials chosen for both the housing of the fog production system and the heating elements play an important role in the overall performance of the device. To best tackle this particular system of the design project, the Pinventions design team consulted with several technical

advisors. The first of which was a mechatronics faculty member at Roger Williams University. This faculty member possesses extensive experience in the field of Robotics. The semester when the Pinventions team was introduced to their project was the same semester they were enrolled in a mechatronics course; a course where content is based on the intermingling of electrical and mechanical engineering. The faculty member was able to direct the focus of the electrical portion of the fog production system as well as how to best utilize a microcontroller to manipulate the system to the team's advantage. Understanding what material would best suit the goals of the design project brought the Pinventions team to a material science faculty member at Roger Williams University. He offered suggestions for what materials would best mitigate the extreme heat that the system was experiencing.

As a result of instructor input, the casing of the fog production system is made of aluminum. The cost of aluminum was economical enough to fit within the project budget and fabricating the case will reduce the risk of fog solution leaking from the case. Moreover, any metallic components are made of similar aluminum alloys to reduce the risk of corrosion. In order to isolate any bonding agents or sensitive components from the aluminum case, ceramic components are added as a means of insulating both heat and electricity. With respect to automating the fog-production system for communication between system variables, Arduino® microcontrollers run this task. The microcontroller responds to nine unique inputs that trigger different states in the amount of fog produced, the duration of fog production, and any fog manipulation from external fans [5]. The unique triggers vary from the ball hitting specific bumpers on the playfield or the player reaching a predetermined score. Logic gates are implemented to streamline communication between the inputs and the behaviors that the fog-production system performs.

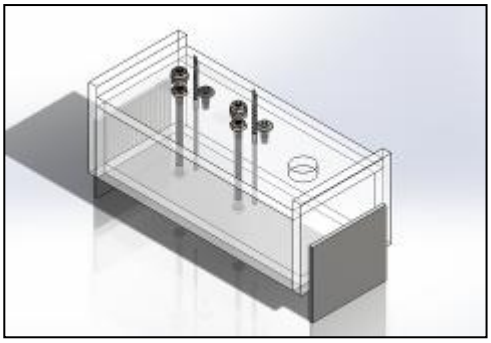

Fig. 2. The figure above is a SolidWorks® rendering of the prototype that was created for the fog production system.

B. Containment and Cleaning Systems

The cleansing and containment system of the project required knowledge in similar engineering fields. While the containment unit would not be subject to extreme heat or stress, it is crucial none of the fog escape from the unit. This criterion brought the Pinventions team to the Laboratory Manager for the School of Engineering. His guidance allowed the team to purchase materials that would best suit the design constraints as well as what specialized bonding agents and cutting instruments should be used to ensure no leakage occurs in the containment unit. Initial solutions for the cleansing system for the project were brought to another professor at the school, a professor of computer science and one of the course coordinators. He made it apparent that in addition to having a hydrophobic coating on the inside of the containment unit, a mechanical apparatus would likely need to be constructed for the project. He emphasized the need for the apparatus to be designed in such a way that it is easy to manipulate and integrate with the final design for the project thus reducing the risk of damaging the system.

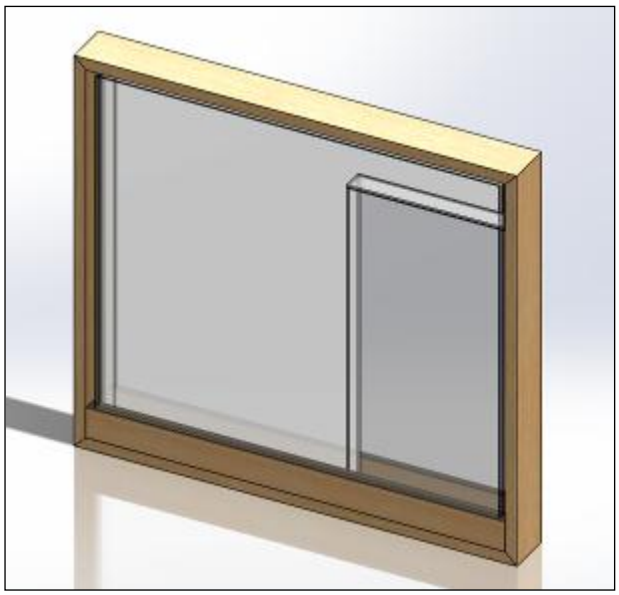

Fig. 3. This is the Solidworks® rendering for the containment fixture that sits in the back-glass area.

The material selected for the containment unit was 1/8 inch acrylic because of its transparency, ease of manufacturability, and inexpensiveness. An acrylic-specific epoxy is used to construct the finalized design for the containment fixture. As well, several measures are taken to prevent any vaporized fog from escaping the container. The edges of the container are reinforced with transparent caulking strips and then coated with clear bonding agent. The inner walls of the containment unit are coated in a hydrophobic solution that reduces the need for manual cleaning of the case. Lastly, a manual cleaning apparatus is constructed such that it adheres to the dimensions of the containment unit so that the structural integrity of the unit will not be impacted from human error.

C. Exhaust System

Designing the exhaust system for the device is an area of the project that requires a fair amount of attention, since it poses the risk of damaging the electrical components of the pinball machine. The Pinventions team discussed possible solutions primarily amongst themselves, as well as with the client. The mechanics of having a system that ensures the containment system can transition from completely sealed to venting seamlessly introduces significant complexity to the final design. The design team is working with a professor of fluid mechanics at Roger Williams University. Understanding how to manipulate the fog in its vaporized state minimizes the

risks associated with venting the fog and may create opportunities for greater player immersion when manipulating the fog in the containment unit.

There are currently two options for exhausting the fog from the pinball machine. The first is to route it from the containment unit, through a duct that travels beneath the playfield, where it will eventually exhaust from the front of the pinball machine where the player is standing. This solution requires a series of fans placed at different sections of the exhaust duct and an electronic valve that allows outside air to flow into the containment unit so that the fans are not working against a vacuum. Spatial constraints and fluid flow efficiency issues make this solution difficult, but not impossible. The second method for venting would be to vent from the containment unit to directly outside of the pinball back glass. This method employs the same duct-and-fan approach as the previous method, except that the distance that the fog would travel would be considerably shorter. As was the case with the fog generation system, the exhaust system will be controlled through the Arduino® microcontroller, responding to events triggered by the player during the game.

III. Conclusion

Throughout the entirety of the project design project, the Pinventions design team has met on a regular basis with their project mentor Dr. Linda Riley, who has a background in systems engineering. The design team regularly makes progress reports to Dr. Riley, addressing any roadblocks that they have encountered and brainstorming new solutions. Her support is also what led the team to create a device that was unique enough in its design that the Pinventions team is pursuing a patent for their system. The team was also introduced to the formal design report process, documenting their entire process and preparing a lengthy report describing that process. The report also includes a variety of engineering analyses that one might encounter in their professional career as well as considering larger implications and future prospects of the project.

The senior design project at Roger Williams University exemplifies how the interdisciplinary collaboration of different fields of expertise can supplement the engineering education experience. The hidden complexity that underlies any engineering project demonstrates how important it is to have a knowledge base that covers a wide range of engineering topics. For the Pinventions design team, who share a limited amount of professional experience, having a diverse engineering faculty allowed the team to fill in knowledge gaps. It is with the diverse range of support and resources that the Pinventions design team intends to finalize the design project mid-April of this year, and have the design fully integrated with the refurbished pinball machine to create an experience that will fully immerse any player.

Acknowledgment

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