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Design of Fire Alarm with Dual Color Strobes and Speaker

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Design of Fire Alarm With Dual Color Strobes and Speaker:

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____________________ ____________________

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Abstract

As buildings become larger and more crowded, evacuation becomes more difficult to manage. Fire alarms that provide voice instructions can decrease confusion during a fire or other emergency. However, these alarms must also be capable of providing the hearing impaired with the same information. A fire alarm was designed which incorporates a speaker which can provide detailed response instructions and two different-colored strobe lights to notify the hearing impaired of either a fire requiring full evacuation or a general emergency.

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Introduction

Traditionally, fire alarm systems in buildings have had the single purpose of alerting occupants of a building that evacuation of the building is necessary. The most common types of alarms contain either a horn, which produces an audible signal, a strobe that flashes to alert hearing impaired people, or both. Tyco International, one of the largest manufacturers of fire protections systems, has a diverse product line to accomplish this purpose. However, in many buildings such as large skyscrapers, complete evacuation of the building is not always the most appropriate response to a fire or other emergency. In these situations, fire alarm systems containing a speaker rather than a horn are installed. The speaker allows for specific voice directions to be broadcast throughout a building and allows the instructions to be varied depending upon the location. For example, the floor on which a fire started might broadcast instructions to evacuate, while occupants on floors not near the fire might simply be alerted of the presence of a fire but not instructed to evacuate until the floors closer to the fire have been evacuated.

One drawback to a speaker system is that the hearing impaired cannot receive specialized instructions through the strobe appliance. The problem has been alleviated through the use of dual-color strobe appliances and text message boards. In a building with a speaker fire alarm system, a message board can be installed in one or more central locations and the strobe appliances can contain two strobes; one clear like traditional strobe and one amber in color. Activation of the clear strobe would signal that an evacuation is necessary, and activation of the amber strobe would indicate to the hearing impaired occupants that they should proceed to the nearest message board to obtain more detailed instructions. This method is gaining in popularity in large buildings both to establish controlled evacuations during a fire and to function as a public address system in general emergencies.

We intend to create a new product, which combines the functionality of the speaker/strobe appliance with the functionality of the dual strobe appliance. In order to increase manufacturing efficiency and keep the cost low, we will be using the assemblies already in use in Tyco's speaker/strobe appliance and their standalone strobe appliance. Size of the product and the ease of installation are of key importance to the success of this product. With that in mind our goal is to design the product so that it has the smallest possible footprint and can be mounted onto a standard 4-inch electrical box or onto a surface without the need for any custom mounting plates.

Understanding of the control circuits of the two existing products are required in this project, since we should take into account the outside wires to be joined and combine the separate wires of the two units to make them into one product. Besides, problems like heat dissipation and current balance also arise if the original two wires come into one. Moreover, the limited size of the 4-inch electrical box makes it challenging to find a proper arrangement for the wires. And this project involves students from two countries with different languages, backgrounds and ways of thinking, which could be a challenge as well as an incentive. Since Tyco would like the adaptation of these products done in 7 weeks, time will also be a crucial factor that cannot be stressed more. The results of this project can be divided into 3 parts. First of all, efficiency is Tyco's main concern in making this product, so we should accomplish the task in 7 weeks as expected. Second, the cost of the mounting appliance should be relative to the cost of producing the current models. For current markets, the more we exceed current costs the less attractive the combined unit will be to the builders that are purchasing them. Last but not the least, the mounting appliance should meet the demand of Tyco’s market by allowing quick and simple installation and mounting.

Since Tyco’s products outdo other companies in reliability and performance, the resulting quality of the product is our first priority. Making the product accessible to the current mounting options is also important. Controlling cost by design, and meeting the price demands of the consumer, will be our final goal in this project.

Background

Tyco background

Arthur Rosenberg founded Tyco Incorporated in 1962. Since it's founding Tyco has made many acquisitions to establish itself as a major manufacturer of metals, plastics electronics, security equipment, and fire protection supplies. Tyco has acquired many well-known companies such as Simplex in 1974, Grinnell in 1976, and ADT in 2007 to name a few. The company's success was proved many times over by the time the Board of Directors decided to approve the business plan in 2006, which split Tyco Incorporated into Tyco Healthcare, Tyco Electronics, and Tyco International. Tyco Fire and Security, a division of Tyco International, has been the World's largest supplier of fire protection equipment since the split but Tyco international has been the world's top seller of fire alarms since 2001. Tyco fire protection supplies cover a global range, including but not limited to 80% of the worlds top 100 retailers, 80% of commercial sea vessels and over 300 international airports including the largest covered building in the world, the Hong Kong Airport. However, there is currently a gap in Tyco's product line. Tyco produces speaker notification appliances with a single clear strobe, and strobe notification appliances with clear and amber strobes. However, there is no single appliance that can provide voice instructions to occupants and also provide two different notifications to hearing impaired occupants. (Products, 2010)

Tyco visit

During a visit to the Tyco manufacturing center in Westminster, MA, USA, part of the team was able to observe the quality control process and see some of Tyco's competitor's products. A.J. Capowski, the regional director of R&D North America was able to share manufacturing information that will help the design process. Tyco's products use reflectors to focus the light of the strobe in a T-pattern. This saves power as energy is not wasted shining light where it is not needed and contractors can install more units per circuit, which means power consumption is important in this design. One important fact though, is that we will be integrating the older strobe that has a previous generation reflector design, which illuminates 180 degrees and uses a higher wattage as the second light source. The convenience of using an established product outweighs the small cost of power increase in so far as this project is concerned. A challenge that we will face is keeping the ease of installation of the product high; this is a major factor in the decision of the buyer of the product. Ideally, the unit will be mounted using four-inch square electrical boxes with extension. This poses another challenge as the speaker already consumes most of this space. The wiring from the central control panel feeds from the wall directly to the circuit board mounted on the speaker, with the attached strobe's circuit being a slave to that circuit. The new strobe will also connect to the speaker circuit so considerations will have to be made for space and connection of the added wiring.

Data Sheets

In order to design a successful product it is crucial to have knowledge of the industry. In order to prepare for this project, we examined the data sheets of Tyco's existing products and prepared a glossary of terms that would be necessary to be familiar with. This glossary can be found in Appendix B.

The model designed in this project was adapted from Tyco's existing product, data sheet 4903-0016. This model has three main components that make up the entire assembly, the plastic shell, which protects the internal components, and presents the cosmetic appearance, the speaker appliance, and the strobe light appliance.

The plastic cover of the unit is made from injection-molded plastic, GE Lexan 141. Background research on injection molding and cost analysis is presented in later sections.

The speaker is an audio appliance for fire protection signaling, and its specifications follow.

- Input Voltage: (Vrms)
    - 25
    - 70.7
- Power Taps: (Watts)
    - ¼, ½, 1, 2
- Fire Alarm Frequency: (Hz)
    - 400 ~ 4000
- Speaker Output Ratings: (dBA) at 10 feet (3 meter) UL1480 rating
    - ¼ W – 80
    - ½ W – 83
    - 1 W – 86
    - 2 w – 89

The high intensity xenon strobe is multiple candela (15, 30 75, 110) for fire protection signaling to the hearing impaired and its specifications follow.

- Rated Voltage Range: (VDC)

    - UL listed – 24
    - ULC listed – 24-30 (per ULC 526-M87)
- Flash Rate: (Hz)
    - 1
- Maximum RMS Current Rating per Strobe Output: (mA)
    - 15 cd – 90
    - 30 cd – 128
    - 110 cd – 285
- Reference Current at 24 VDC: (mA)
    - 15 cd – 60
    - 30 cd – 85
    - 110 cd – 190

The speaker and strobe are installed in a circuit, which is then controlled by a fire alarm control panel or FACP. The control panel is responsible for sending current and signal to all units installed on the same circuit. Selection of the visual notification settings are regulated by building codes, which take into consideration factors such as occupancy, location, and local codes.

The unit has mounting holes placed on the front side, conforming to a standard North American four-inch electrical box. A standard new installation will utilize a 4-inch box, with a 4-inch box extension. This is to allow for the depth of the speaker, which is too large for a single box. For mounting configurations where a four-inch box is not possible, such as a retrofit, adapter plates and cosmetic extension boxes must be utilized. The design for this project is compatible with the same mounting considerations as the model 4903-0016 and 4903-0017. The mounting situations are reviewed from the data sheets provided by Tyco.

The two current incarnations of this design incorporated two different audio hardware configurations. One design uses the same speaker included for this project, the other, a simpler horn device. The horn device has become outdated, since more specific information must be related to occupants of a building. A horn can only provided the evacuation signal, and not other information, such as route or emergency information. From a design standpoint the largest difference in the two technologies is the size. A horn takes up a far smaller volume (depth, extending from the front plane of the unit into the wall) in the design than a speaker, which requires electrical conduit adapters or extensions in order to be mounted flush to a wall. Whether using a horn or speaker, there are similar and dissimilar configurations for mounting the appliance to the wall of a building. One of the goals of this project is to design an appliance that can be mounted to any of the existing situations, with as few adaptations as possible.

The speaker and horn unit have several mounting situations in common and several differences due to the increased size of the speaker.

Both units are designed with mounting holes corresponding to standard American four-inch electrical boxes and will mount without further adaptation. It should be noted that the version with the speaker requires a standard four-inch extension ring to allow for the extra space the speaker takes up, while the horn version can fit on either system. Both boxes are pictured below in the standard flush mount configuration.

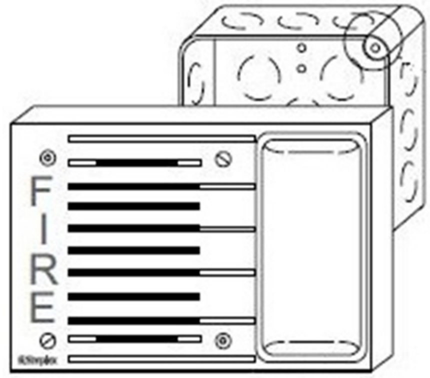

Figure 1 Four-inch electrical box (Products, 2010)

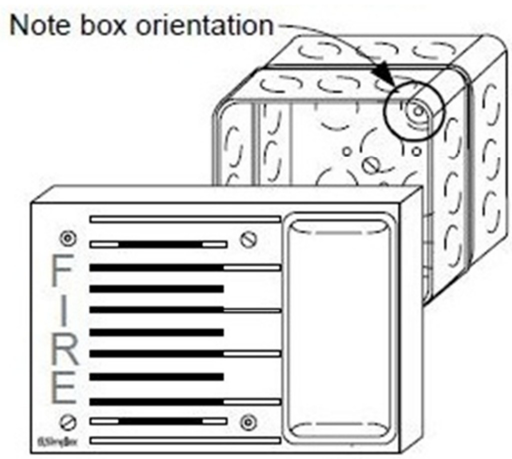

Figure 2 Four-inch electrical box with extension (Products, 2010)

Another mounting configuration that is common to both versions is the compatibility to Tyco's brand of surface mounted electrical boxes. (Part numbers 4905-9923/24 and 2975-9145). The mounting system for both of these boxes is shown below.

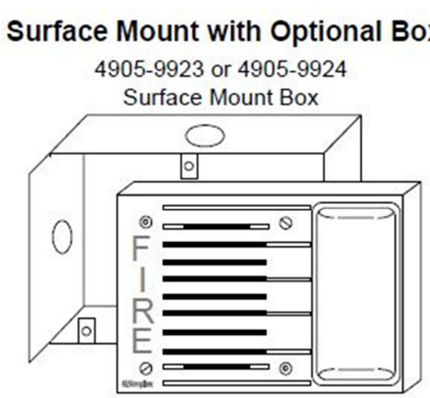

Figure 3 Tyco 4905 series surface mount electrical box (Products, 2010)

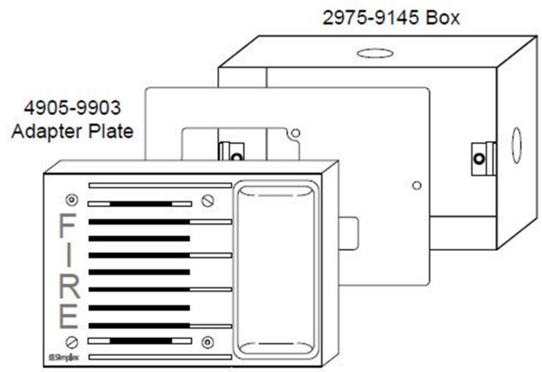

Figure 4 Tyco series 2974 surface mount electrical box (Products, 2010)

There is one mounting system that is unique to the horn version of the alarm, gang boxes. The horn version of the alarm has an adapter plate available from Tyco that allows mounting to either 2-gang or 3-gang boxes. The size of the American electrical gang box does not allow for the speaker of the other version. The standard distance between mounting holes on the boxes are meant to affix outlets and switches, and are set at a distance of 3” 9/32” apart. This is not sufficient for clearance of the speaker. Upon further review of the data sheets it does appear that if a shallow skirt were to be used, the speaker could also be used with gang box.

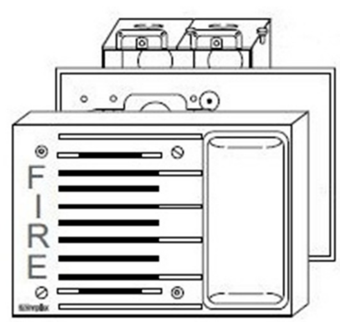

Figure 5 Mounting to gang boxes (Products, 2010)

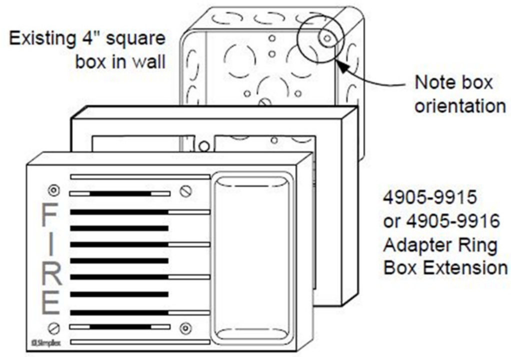

Figure 6 Illustration of plastic skirt (Products, 2010)

Below is a table showing all the Tyco made products from that data sheets used for the background research of this product. The table includes all different configurations of the notification unit and all mounting accessories and adaptors used in the different mounting situations.

4903-9150	Speaker, Red	
4903-9148		
4903-9149		
	……………………………………	
4903-9193	Speaker, White	
4903-9194		
4903-9195		
4903-9153	…………………………………….	
	Speaker, Red, Vertical mount	
	……………………………………	
4903-9252	Horn, Red	
4903-9253		
4903-9255		

4903-9257 4903-9258 4903-9255 4903-9256	.... Horn, White .... Horn, Red, Vertical mount	
4905-9923 4905-9924	Red White Tyco surface mounting box	
2975-9145	Red Tyco alternate surface mounting box	
4905-9903	Adapter plate for mounting to 2975-9145	
4905-9939	Adapter plate for gang boxes. Plate also hides exposed electronics when surface mounted.	
4905-9915 4905-9916	White Red Cosmetic skirts to extend base from wall when semi-flush mounted.	

Table 1 Tyco products reviewed for mounting options (Products, 2010)

Standard American four-inch electrical box.	

1.5 inch depth	
Standard American four-inch electrical box extension ring. 1.5 inch depth	
Standard American gang-able electrical box. 2.5 inch depth	

Table 2 Standard American electrical boxes reviewed for mounting options (Products, 2010)

Patents

Finding patents that include part or all of our design and functions was started to find any benchmarks in the design that we could follow. Patent research is also important to make sure that any existing patents for similar devices are not infringed upon in any way, making our design potentially illegal. After searching the United States Patent database after key words "strobe, speaker alarm, mounting and cover", no existing design that has combined a speaker strobe with another standalone strobe in different color was found. However, various patents concerning mounting plates, mounting methods (with or without fastener), electrical outlet and cover are also relative and instructive to our design.

Injection molding

Injection molding is a manufacturing process that allows complex parts to be created at relatively low costs. In the modern era of manufacturing, reducing costs is the key to the success of any company. As products become more complex they in turn, become more expensive to manufacture. When a product is constructed from complicated geometry, it is usually broken down into smaller, constituent pieces, which are much easier to create, and then assembled near the end of the production line. Injecting molten plastic into the cavities of a mold and allowing it to solidify can achieve more complex shapes achieved in single, eliminating the extra assembly steps. (何满才, 2005) Mold engineering is the process of optimizing the steps going from raw material to part by finding ways to decrease cycle time, energy used, and raw material waste.

Injection molding processes are made up of three steps, Filling, Cooling, and ejection. During the filling step, plastic is melted into liquid form and injected into the mold cavities. Cooling then takes place starting by heat loss via convection by the walls of the mold and is usually aided by cooling the mold rapidly with a coolant fluid. During the last step, ejection, the mold is opened, the part is ejected and the mold setup is reset for the next part (何满才, 2005; Boothroyd & Dewhurst, 1994).

Filling can further be broken down into several steps. The raw materials used in the injection molding process are usually in the form of plastic pellets, commonly polyethylene or polystyrene. The colors are mixed and melted inside the hopper, and after homogenization in color and temperature are reached, injected via nozzle into the waiting mold cavity. As the shot enters the mold, the pressure inside the cavity increases as the fluid mass fills in the empty spaces. When the mold is filled, pressure increases very rapidly and fluid flow rate drops while the molten material packs into the extremities of the mold cavity. The speed and ability of the fluid to fill small gaps in the cavity are determined by the properties of the molten fluid. Packing is the last stage of the filling process and immediately afterward (also during, to a small degree), cooling begins (何满才, 2005; Boothroyd & Dewhurst, 1994).

Cooling time makes up the longest part in any injection molding process, partly because it begins the moment the fluid leaves the nozzle of the injector and comes into contact with the mold surfaces. Cooling time is a function of the thickness of the part as well as the design of the mold and it's ability to conduct heat to the surrounding atmosphere. One of the largest challenges of designing for cooling is planning for the pressure drop that occurs when the injector nozzle is disconnected from the mold after the packing phase. The gate of the mold can be a point of egress for the cooling plastic and if it hasn't already solidified enough to seal the pressurized material inside the mold, the loss of material can occur causing waste and very possibly ruining the part. As the material cools the pressure drops and eventually a 'sealing point' is reached when there is no way material will escape from the gate opening and backflow is no longer an issue. Determining the time it takes for the mod design to reach this point is very important for controlling waste, energy, and cost (Boothroyd & Dewhurst, 1994)

The power used in creating an injection-molded plastic part is mostly used in the ejection stage of the part. In order to keep the two halves of the mold coupled in such a way that the pressure does not force the molten material to flash between the seals, large amounts of force are required to press the mold together. The cooling system, along with the weight of the steel mold, and taking into consideration that it is desired to have the mold opened, ejected, and closed in the shortest possible time, make for a very power intensive machine. Power consumption is just one factor in engineering the ejection phase. The speed of the ejection phases is another critical factor in mold design. Mold complexity determines the ease of which the part can be ejected. Equilibrium between quality and economy must be reached for if the part is ejected too fast there is risk of damaging the delicate part and possibly the mold. If it is too slow than time/money are wasted in resetting the cycle (Boothroyd & Dewhurst, 1994)

Cost of Injection Molding

In order to minimize the costs in the product, an accurate method of estimating injection-molding costs must be utilized. The three main costs related to injection molding are material cost, machine cost, and mold cost. Material cost is the easiest to calculate, as it only depends on the volume of the part and runner system and the unit price of the material used to make the part. The material cost per part will always be constant, regardless of how many parts are made. Machine cost is simply the hourly cost of running the injection-molding machine divided by the number of parts the machine can produce in one hour. The number of parts the machine can produce is derived from the cycle time of a part, which includes the time for injecting plastic into the mold, the time for the plastic to cool, and the time for the mold to open and close to let the new part fall out and reset for another part to be made. Like material cost, the machine cost per part is independent of how many parts are made, assuming that the molding machine always operates at a constant rate. (Boothroyd & Dewhurst, 1994) Mold cost, the cost of the base material for a mold and the labor associated with machining the cavity or cavities of the mold depends on the size and complexity of the part and is the most difficult cost to determine. However, using the equations found in Appendix B it is possible to estimate how many hours it will take to machine the mold based on the features and dimensions of the part. If the hourly rate a machine shop charges is known, a fairly accurate estimate of the mold cost can be obtained. The key difference between the mold cost and the material cost is that the mold cost is fixed for the life of the mold. As long as the mold doesn't deteriorate, the cost per part will decrease as the number of parts produced increases. Thus, in order to truly optimize part cost, the number of parts made with a single mold must be known. For small quantities, the mold cost will represent a significant portion of the part cost, and should be minimized even at the cost of adding material to the part. However, with increased production quantities the mold cost per part will diminish and the material cost will become the most important factor. For the purposes of this project, all three costs were estimated and production volume was assumed to be 5000 units. However, during the selection of design only the material costs were considered because the actual production rates are not known and also because Tyco considers the purchase of molds to be investment capital and thus are treated differently than production costs. (Boothroyd & Dewhurst, 1994)

Sheet metal

Sheet metal working is one of the machining processes, which forms sheet metal into desired shape. It has applications in car bodies, airplane wings, medical tables, roofs for building and many other things. By applying machining procedures such as stretching, bending, punching and pressing, the original flat pieces or coil strips of metal are manufactured into functioning sheet metal parts (詹友刚, 2006; Boothroyd & Dewhurst, 1994).

There are generally two sheet metal working methods. The traditional method uses dedicated individual dies to realize the profile forming, piercing and bending of the sheet metal. The other method uses computer numerically controlled (CNC) turret press where series of punches are installed on a rotatable platform. The advantage of this method is that it uses general-purpose punches and dies that can be used to manufacture a wide range of different parts and the punches and dies fit into standard holders. These general-purpose tools can be purchased from tool suppliers in a large variety of standard profiles or made to custom order. The shortcoming is that bending should be carried out individually on a press brake and the machining time is relatively longer than dedicated dies.

For sheet metal working with dedicated dies, the cost mainly comes from:

1. The cost of raw materials
2. The cost of operating the machine.
3. The cost of the die sets.

The material cost depends on the material chosen and the part volume, i.e. area and thickness of the sheet metal. (Boothroyd & Dewhurst, 1994)

The machine operation cost depends on the machine chosen and the manufacturing time, which varies with the complexity of the part. The more procedures are required the more time it would take. Detailed analysis procedure will be included in Appendix C.

And for each type of die cost always include a basic die set, which also add to the cost of the sheet metal working. (Boothroyd & Dewhurst, 1994)

For sheet metal working with turret press and press brake, the cost is different from that of dedicated dies in that it excludes the die sets cost since the turret press setup is equipped with general-purpose punches and dies which can be used to manufacture a wide range of different parts. (Boothroyd & Dewhurst, 1994)

In this case, the cost of the sheet metal working using turret press would depend mainly on the complexity hence the machining time of the part. Detailed analysis procedure will also be included in Appendix C

Objectives

The objective of this project was to design the plastic frame and mounting system for an all-new emergency notification appliance, which combines the functions of a clear strobe, amber strobe, and speaker.

Methodology

This being a project focused on the design of a new product, we decided to follow Professor Robert Norton's ten-step design process as a guide to take our design from concept to reality. The steps have been altered to better fit the project, since this is an international MQP, which has a corresponding PQP in the term leading up to the project to prepare. The steps are:

Identification of need:

- The project information from Tyco stated we were to combine existing strobe and speaker technology into an all new notification unit. The need for this unit was left for our team to discover. The need is an update to current fire alarm technology to provide clear instruction to the hearing impaired as well as the fully-baled occupants of a building in case of emergencies where structured evacuation strategies are necessary.

Background Research:

- Background research was done on Tyco's existing product line and identifying the gap where a new product was needed. Also research was done on competitor’s products and patents, to find if anything similar was being developed or on the market. We also visited Tyco’s facilities in America and China to get information on how the design process of the company can be implemented by us on this project. In order to help with the design phase, background research on injection molding and sheet metal design procedures, as well as the cost analysis associated with these was done during weeks 1-4 of the MQP. Background research about ProEngineer: Wildfire 2.0 was necessary throughout the project to ensure the quality of created files.

Goal Statement:

- Our goal statement was: Design a new fire alarm that incorporates the speaker, clear strobe, and amber strobe of the older models, and combines them into one unit.

Task Specifications:

- By the end of the PQP we had a list of task specifications that guided the creation of the design. At the end of week 2 of MQP the list was altered slightly due to new information and then finalized.

Ideation and Invention:

- Concepts for the positioning of the two strobe lights based on meeting requirements set by the task specifications were finished and presented by end of week one of the MQP.

Analysis and Selection:

- Analysis was done on the concepts was performed on the concepts and occurred from start of week 2 and lasted until end of week 5. Analysis was performed in two steps listed by importance to the project: 1. Conformation check to codes and standards, 2. Cost analysis of the injection molded part. Concepts were then eliminated using these processes. Firstly, any concept that failed step one was eliminated from consideration. Secondly, production ready CAD files were produced for the remaining concepts and detailed cost analysis methods were performed. Selection of the final design based on economical advantage over other concepts.

Detailed Design:

- During week 5 and six mounting accessories and adapter plates as well as their cost analyses were created for the final design. The reason for waiting so late in the project is that the accessories are dependent on the design of the unit and cannot be created independently.

Prototype:

- During week six of the MQP a prototype of the plastic frame of the unit was created by SJTU's rapid prototyping machine out of photo setting resin.

Results:

The results of this project are documented in the MQP report which was created over the entire span of the 8-week MQP

The first four steps of the project were completed during the PQP phase. Identification of need was provided to us from Tyco and also our own research into the products offered by the company. Most of the background research was done during PQP but some background research was necessary during MQP due to unforeseen design elements. Our goal statement was refined and finalized during our introductory meeting at Tyco in China.

The project started with a meeting with our Tyco sponsors, Bob Lin and Helen Han. We restated the work we have completed thus far with the PQP and our intentions with the MQP. After combining our work with the feedback they provided, we were able to form an updated set of goals for the project and begin work immediately.

Ideation and Invention

The design requirements that our product must conform to were updated and restated.

1. Must be compatible with existing mounts.
2. Strobes must be positioned as not to interfere with one another.
3. Must incorporate 2 strobes (1 amber and 1 clear), as well as a speaker.
4. Must use the existing speaker and strobe components from previous models.
5. Strobes must be aligned in a configuration parallel to each other as well as the floor.
6. Must not violate any codes and/or standards that the current product applies to.
7. Must support both flush and surface mounting systems.
8. The material cost of the new product must not add more than $5 US to the existing product.

Using these specifications we able to form a clear concept of the basic shape of the device, and came up with several configurations of lights and strobe that satisfied the requirements 1-5. Requirement 7 was not considered at this point due to insufficient data. Requirement 6 was thus far only considered insofar as not making it impossible, but further considerations were at this point still needed. Five configurations were produced and are shown below and are named concepts 1-5.

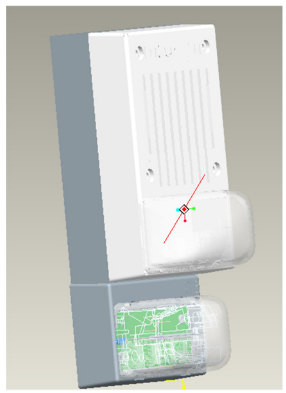

Figure 7 Concept 1

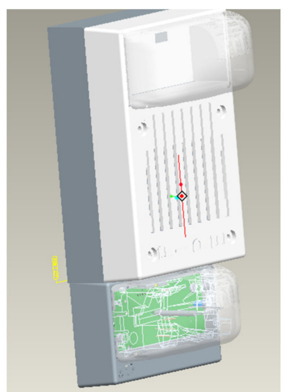

Figure 8 Concept 2

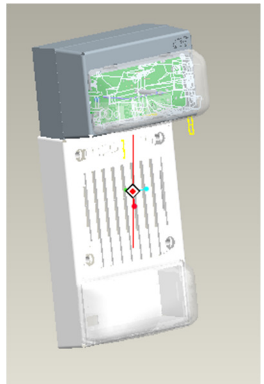

Figure 9 Concept 3

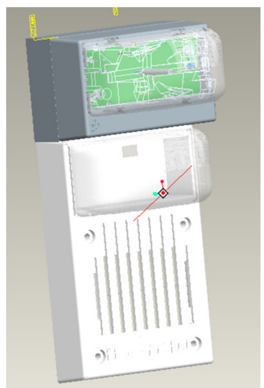

Figure 10 Concept 4

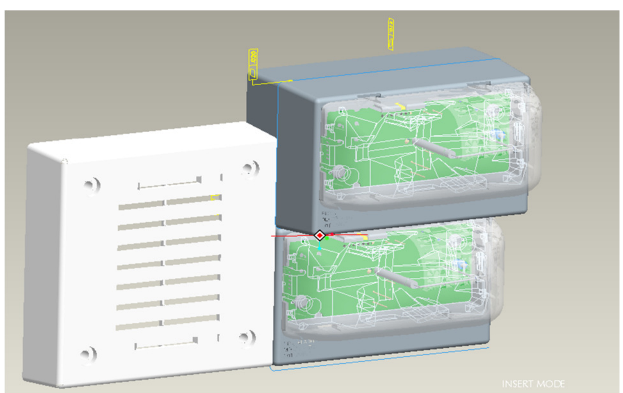

Figure 11 Concept 5

Analysis and Selection

We began the process of analyzing our concepts by verifying that each design would satisfy the requirements we had previously established.

Requirement 1: Compatible with existing mounts

All configurations use the same mounting holes from the previous models, that is, holes that match a standard American four-inch electrical box.

Note that concepts one and two both extent the mounting plane further from the wall by a distance equal to the height of the strobe fixture. This consideration was made to account for the extra space the speaker takes up and possibly eliminate the need for an extension to the electrical box.

Requirement 2: Strobes must be positioned as not to interfere with one another.

In all concepts a distance equal to the height of the strobe offsets the planes in which the two strobes are placed. This is to assure that the plastic lens in no way interferes with the light emitted from the other strobe when in operation.

Requirements 3 and 4: Must incorporate 2 strobes (1 amber and 1 clear), as well as a speaker.

Using ProEngineer as our CAD software, we were able to use existing models of Tyco's products to form the systems shown in concepts 1-5. There were no issues in including spear or strobes from the older models.

Requirement 5: Strobes must be aligned in a configuration parallel to each other as well as the floor.

This requirement is to satisfy that the pattern of light emitted from the strobe matches the pattern from the previous model. Initially it was thought that by making the strobes perpendicular a cost savings might be found, but light dispersion and conformity to NFPA 72 might be violated.

Requirement 6: Must not violate any codes and/or standards that the current product applies to.

Additional background research into NFPA 72, coupled with feedback from Tyco's fire detection division provided two bits of crucial information. Strobe lights in fire alarm notification units must be positioned between eighty and ninety six inches from the floor or they violated the code. Also, when walls in new buildings are constructed, the contractors install the four-inch electrical, which the speaker mount to directly, at a height of eighty inches from the floor. We deduced from this information that concepts 1, 2, and 3 all had the possibility of violating NFPA code, and were removed from consideration, this left concepts 4 and 5 to be considered. We began the evaluation process of concepts 4 and 5 by making finished CAD files in ProEngineer, that were exact in detail and dimension to what the production model would be.

Figure 12 Concept 4, detail

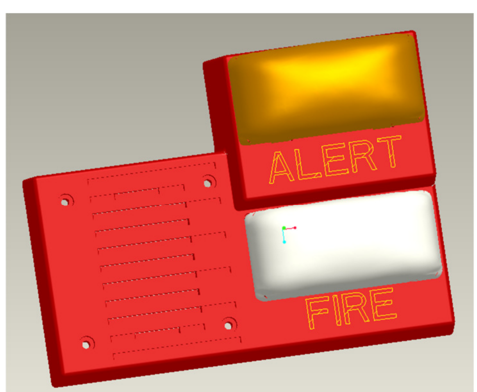

Figure 13 Concept 5, detail

To develop a product that is compatible with the speaker and strobe components of the previous models, it was necessary to inherit as many dimensions as possible from the Tyco design. The dimensions of the pockets that the strobe circuits are enclosed by, and which the lens snaps onto are repeated to the minute detail. Also the dimensions of the gussets and ribs for the speaker attachment were inherited. The positions of the mounting holes to attach the unit to the wall are fixed, as that is set by American electrical code.

Cost Analysis

The two remaining concepts were then subjected to injection molding cost analysis based on two methods. The first was the method taught to us during our courses using formulas found in "Product Design for Manufacture and Assembly". The second being an online injection molding cost analysis site called http://www.custompart.net, used only to check the validity of the formula we had used. The costs associated with constructing each concept are found in the following table, and the complete breakdown of formulas used is found in appendix B.

Concept	Material Cost Per Part ($)	Machining Cost per Part ($)	Mold Cost ($)	Total Cost Per Part ($)
4	0.947	0.306	46933	10.63928
5	0.942	0.306	47685	10.78508

Table 3 Injection mold cost analysis for concepts 4, 5 (Boothroyd & Dewhurst, 1994)

Using this cost analysis matrix, we were able to eliminate concept four from consideration, making concept 5 the first iteration of our final design. Looking back to the table, it is clearly seen that mold costs can be large and can have a huge impact on the cost per part of the product. There are some key factors in reducing mold cost. If mold complexity is reduced, than the price of the mold is greatly reduced. Also, reduction in projected area or volume of the part can also reduce the cost of the mold. Keeping these things in mind, we first tried to reduce the volume of plastic that the part would require, thereby reducing the shot size per part. To do this we designed a part that instead of using two separate planes to separate the strobes, we offset the strobes by a sufficient distance as to not interfere. The new design was called concept 6, and performed the same cost analysis to obtain comparative data. (Boothroyd & Dewhurst, 1994)

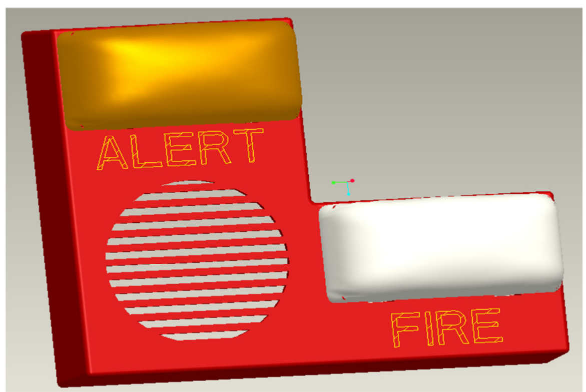

Figure 14 Concept 6, detail

Concept	Material Cost Per Part ($)	Machining Cost per Part ($)	Mold Cost ($)	Total Cost Per Part ($)
4	0.947	0.306	46933	10.63928
5	0.942	0.306	47685	10.78508
6	0.814	0.297	46399	10.39008

Table 4 cost comparisons for concepts 4, 5, 6 (Boothroyd & Dewhurst, 1994)

Concept 6 had advantages over the previous design as far as costs were concerned, but Tyco has a certain aesthetic that they adhere to in this product line. Also we cannot take the chance to potentially break any current or future NFPA 72 regulations, so for these reasons, this concept was eliminated. We applied the same techniques to concept 5 to reduce the amount of plastic used per shot and found if we moved the cosmetic lettering on the front of the part we could greatly reduce the projected area of the part. This became iteration 2 of the final design, and we again applied our cost analysis methods.

Figure 15 Concept 7, detail

Concept	Material Cost Per Part ($)	Machining Cost per Part ($)	Mold Cost ($)	Total Cost Per Part ($)
4	0.947	0.306	46933	10.63928
5	0.942	0.306	47685	10.78508
6	0.814	0.297	46399	10.39008
7	0.895	0.306	45581	10.31700

Table 5 cost comparisons for Concepts 4, 5, 6, and 7

The last thing we tried before final selection was to find a way to reduce the complexity of the mold, and by doing so, greatly reduce the cost. The most complex feature on all concepts is the pockets where the strobe components attach to the plastic frame.

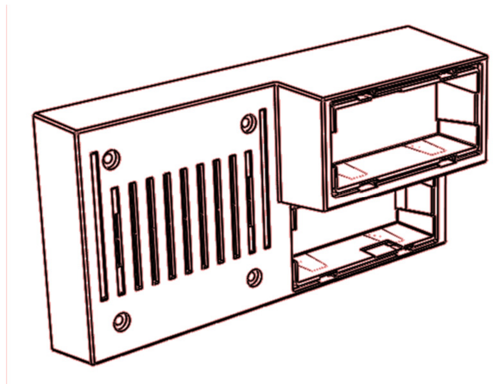

Figure 16 Mold cavity complexity

These features have purposes, too allow the strobe circuit to snap into the plastic frame, as well as covering and protecting these same components from the inside. These features also provided the snap fittings for the lenses to lock onto when the unit is installed. Since we were challenged to reduce cost as much as possible we opted to try a sheet metal with escutcheon design similar in concept to the simplex product 4906-0009.

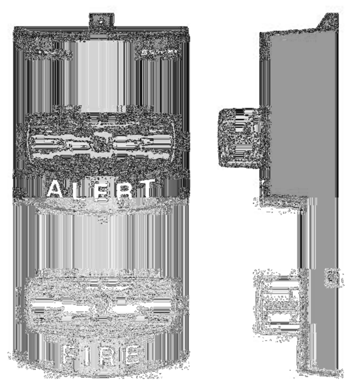

Figure 17 Tyco product 4906-0009 (Products, 2010)

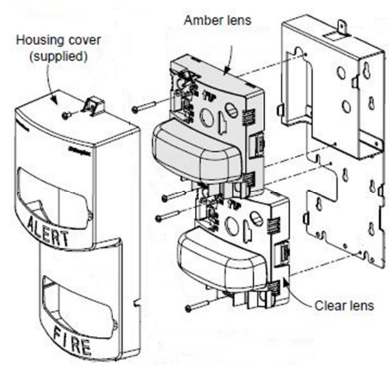

Figure 18 Tyco product 4906-0009, exploded view (Products, 2010)

In such a design the strobe and associated circuitry and hardware are attached to a sheet metal frame, then a cosmetic plastic escutcheon is snapped over to cover the assembly. The idea of exploring such a design is to verify whether or not the increased cost of sheet metal due to stamping and bending is offset and overcome by the reduced mold cost due to greatly simplified cavities.

This led to yet another iteration of the final design in which we designed a sheet metal frame, to which the components of the unit would attach. This would then attach to the various electrical boxes and surface-mounting components via mounting holes punched in the sheet metal. After the frame is attached to the wall a plastic escutcheon, which in outward appearance is identical to our final design shape would be snapped on to complete the installation. The mold for the escutcheon would be greatly simplified when compared to the mold for the current of older designs. Pictured below is concept 8 with the corresponding sheet metal frame, along with the costs associated with producing this product compared to the cost of concept 7.

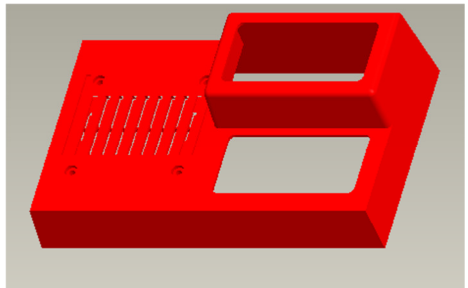

Figure 19 simple plastic escutcheons, detail

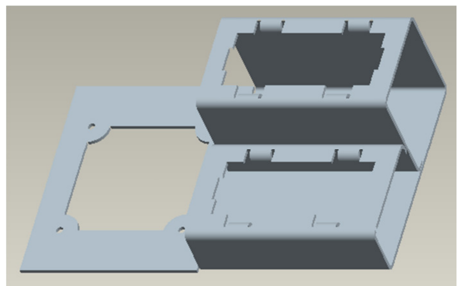

Figure 20 Sheet metal frame for concept 8

Concept 7	Material Cost Per Part ($)	Machining Cost per Part ($)	Tooling Cost ($)	Total Cost Per Part ($)
7	0.895	0.306	45581	10.31700

Table 6 Cost analysis of concept 7 (Boothroyd & Dewhurst, 1994)

Concept 8	Material Cost Per Part ($)	Machining Cost per Part ($)	Tooling Cost ($)	Total Cost Per Part ($)
Plastic	0.944	0.306	31987	15.4488
Sheet metal	4.25	1.169	11972	

Table 7 Comprehensive cost analysis of concept 8 (Boothroyd & Dewhurst, 1994)

It is immediately obvious upon looking at these tables that concept 8 would be a very poor choice. The mold cost is reduced very significantly, but it does not offset the drastically increased cost due to the large sheet metal component, which alone comes close to exceeding the requirement of being no more than five dollars more per part to produce. This iteration was provided a challenge to save cost to the company, and the failure in doing so brought more value in deciding concept 7 is the design to move forward with.

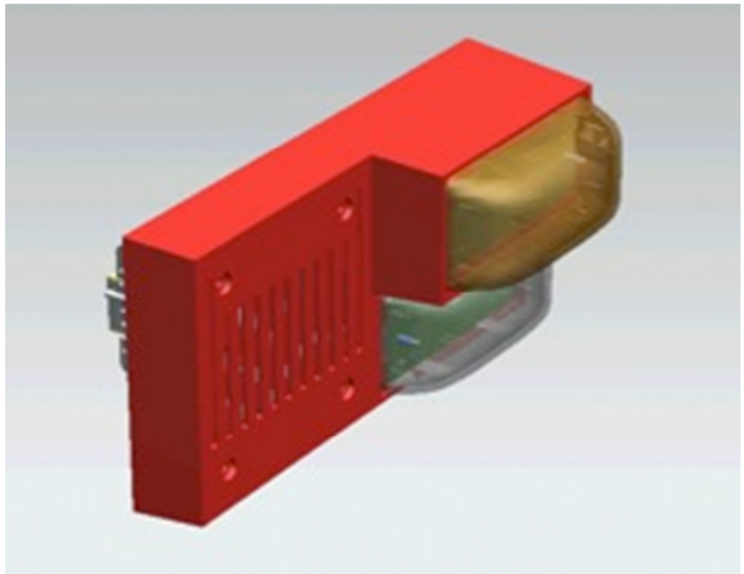

Figure 21 Final Design

Detailed Design

A detailed CAD file of the final design was necessary before selection in order to obtain accurate figure to use in injection mold cost analysis. In order to finish the part however, mounting considerations must be made. It was learned from the background research on the datasheets provided by Tyco that the older models were designed with mounting holes to standard American four-inch electrical boxes for standard installation. With the advent of speakers to the design, extension rings needed to be used to account for the added depth. Also surface mounting considerations were made in cases where retrofitting was necessary and the four-inch boxes were not in use. Finally adapter plates were created to aid with surface mounting boxes as well as make the alarm compatible with standard American multi-gang boxes.

Altogether, there are six different mounting situations that in order to be compliant with the older models, and be backward compatible; the new design must conform to.

1. Standard four-inch electrical box plus extension ring, both inside the wall, unit flush mounted to the wall.
2. Standard four-inch electrical box plus extension ring, box flush with wall, and ring extending out of wall. A distance equal will offset the unit from the wall to the depth of the extension ring. This is a semi-flush mount and will require a skirt to cover the distance from the base of the part to the wall.
3. Standard four-inch electrical box plus extension ring, both mounted outside the wall. The unit will be offset a distance of both boxes. This is a surface mount. And will require a deep skirt to cover the distance between the base of the part and the wall.
4. Multi-gang boxes, 2-gang or 3-gang, mounted inside the wall. The unit will be semi-flush mounted with a skirt to extend the speaker out from the wall, because the diameter of the speaker magnet exceeds the opening of the standard gang box. There will also be an adapter plate to go from the mounting holes that match the four-inch boxes to the gang box mounting holes.
5. Tyco box 4905-9923/24 (identical dimensions) surface mount box, outside the wall. The unit will be offset from the wall by a distance equal to the depth of the box and require an adapter plate to cover the back of the unit since the new alarm is larger than the previous models. This is necessary to comply with electrical and fire codes.

6. Tyco box 2975-9145 surface mount box, outside the wall. The unit will be offset from the wall by a distance equal to the depth of the box and require an adapter plate to go from the four-inch box holes to the mounting holes on the box.

To make the previous alarms compatible with these situations two separate adapter plates were designed, a shallow skirt, and a deep skirt. Since we had the fortune of knowing ahead of time what the two adapter plates dimensions and purposes were. We were able to design single adapter plate that combines the functions of the two previous plates. The design of an adapter plate was necessary, but we are able to save costs by combing the two into one.

Combination Adapter	Material Cost Per Part ($)	Machining Cost per Part ($)	Tooling Cost ($)	Total Cost Per Part ($)
	1.71	0.14	6888	3.2318

Table 8 Cost analysis of combination adapter plate (Boothroyd & Dewhurst, 1994)

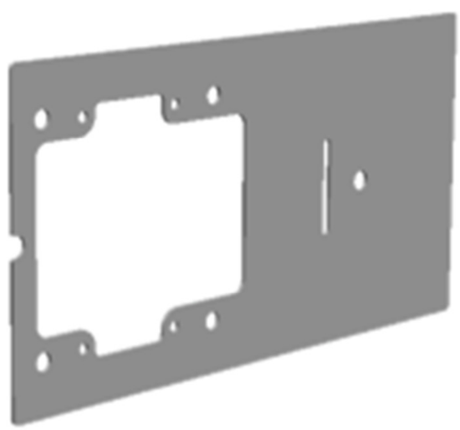

Figure 22 Combination adapter plate, detail (詹友刚, 2006)

For semi-flush mounting, a shallow shirt was needed that corresponded to the shallow skirt of the previous models. Since the base area of the final design is larger than the previous models it was necessary to design a new skirt. Also since the projected depth is different for separate situations, an additional deep skirt needed to be designed as well. With the design of these accessories, the final design is compatible with all the mounting situations that the previous model conformed to.

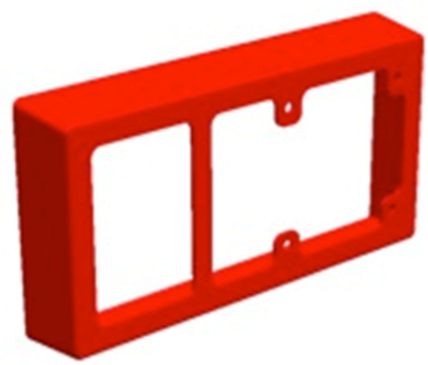

Figure 23 Shallow Skirt, detail (何满才, 2005)

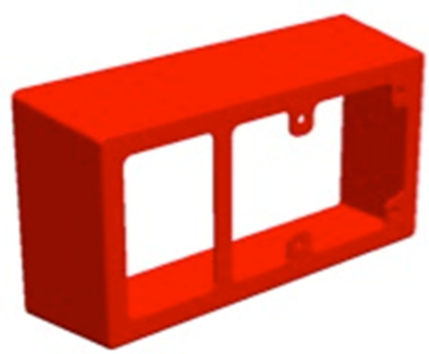

Figure 24 Deep Skirt, detail (何满才, 2005)

Prototype

One of the optional deliverables to Tyco at the end of the project was a prototype of the final design. A first generation prototype assists in finding potential errors in the design, or potential hazards of the injection molding process. At the Xujui campus of Shanghai Jiao tong University; there is a rapid prototyping facility within the medical technologies school. With the help of this department, we were able to construct a prototype of the final design not only for purposes of verifying fit of the components, but to also present a tangible product to our peers and sponsors at the end of the project.

Results

Tyco requested three deliverables for the end of the project: 3D ProEngineer files for the notification unit and all mounting accessories that were designed, 2D part drawings for the notification unit and all mounting accessories that were designed, and, if time and budget permitted, a physical prototype of the plastic base. Since all of the parts were designed using ProEngineer, 3D data was already available and 2D drawings were constructed from the information in our existing CAD files in ProEngineer. The resin prototype was made in one of the 3D printers at SJTU's Plastic Forming Division.

In total, four different parts were designed for the project: the plastic base for the notification unit, to which holds the speaker and strobe assemblies are mounted, a shallow plastic skirt, to aid in semi-flush mounting, a deep skirt, to facilitate a full surface mount with a four-inch electrical box with extension, and a sheet metal adapter plate, which is a cost effective method of combining the two existing adapter plates, to ensure compatibility with all other semi-flush and surface mounting situations. All six mounting situations can be achieved with an added material cost of less than $5. The products, along with their material costs are below in table 9.

Dual Strobe/Speaker Notification Unit	$ 0.895
Sheet Adapter Plate	$ 1.71
Shallow Skirt	$ 0.408
Deep Skirt	$ 0.714

Table 9 material costs of designed products (Boothroyd & Dewhurst, 1994)

As is shown in the table the most expensive mounting option is the combination of the plastic base and the combination adapter plate. This would be used least often, only during a retrofit of the alarm systems in a building with existing and/or unchangeable electrical conduit systems, in which the former speaker/strobe device were being replaced by the dual color speaker/strobe device and would utilize the existing surface mount boxes.

Conclusion

A product that has the ability to notify both the hearing and the hearing impaired of fires and provide more specific instructions for evacuation and emergency situations is a necessary step in the evolution of fire alarms. When used in conjunction with electronic message boards or other notifying devised for the hearing-impaired, the dual color speaker/strobe can provide detailed evacuation instructions while still being compliant with the ADA's requirements. As buildings become larger and evacuations become more complicated, this product will likely become a standard in large public buildings.

Since it if the first product of its kind in the American market, it will help Tyco offer a more complete line of notification devices and maintain its position as a leader in the fire protection industry. The cost-minimizing techniques used during the project will ensure that the device can be produced economically even if Tyco's competitors build similar products.

Appendix A - Performance Specifications

The following performance specifications were used as selection criteria for the different concepts and designs. Some of the specifications were given by Tyco, and some of the specifications were determined by the design team as a result of research on existing Tyco products and codes from organizations such as NFPA (National Fire Protection Association), UL (Underwriters Laboratories, and ADA (Americans with Disabilities Act).

1. Must be compatible with existing mounts
2. Must support both flush (semi-flush) and surface mounting
3. Strobes must be positioned so as not to interfere with one another
4. Must have two different color strobes and a speaker appliance
5. Must use existing speaker and strobe assemblies
6. All designed parts must be manufacturable
7. Intended Market: Commercial
8. Cost: $5 more than the two existing products
9. Operating environment: indoors
10. Materials: Injection-molded plastic and industrial electrical mounting plates

Appendix B - Injection Molding Cost Estimation

The following equations were used to estimate the cost of the plastic parts that were designed. We constructed a spreadsheet in excel with the relevant formulas and input the necessary parameters of each design into the spreadsheet to calculate the total part cost. Parameters of each design were measured from the CAD models we generated.

Injection molding cost of a part

$$C = C_{material} + C_r t_s / n + C_{mold} / N_t \qquad (1)$$

$C_{material}$: cost of thermoplastic per component (including runners) [$]

C_r: operating cost of injection molding machine [$/hour]

t_s: cycle time [sec]

n: number of cavities in the mold

C_{mold}: cost of mold [$]

N_t: total number of production

Material cost

$$C_{material} = c_p \rangle V (1 + f_r)$$

(2)

C_p : cost of thermoplastic [$/kg]

ρ: density of thermoplastic [kg/m3]

V: volume of part to be injection molded [m3]

f_r: runner volume rate

Machine operating cost Cr

F ε $Ap(1+fr)n$·0.5pj
vs εV (1+ fr)n
Lsε2D+0.05

(3)

F: clamping force [N]

V_s: maximum shot size [m3]

L_s: maximum clamp stroke [m]

A_p : projected area of part to be injection molded [m2]

p_j: recommended injection pressure [N/m2]

D: depth of required mold cavity [m]

Cycle time

$ts=tf+tc+tr$

(4)

tf : injection (fill) time [sec]

tc : cooling time [sec] (minimum cooling time is 3 second)

tr : mold resetting time [sec] (mold opening, part ejection, mold closing times)

t_f=2V(1+f_r)n·p_j/P_j

(5)

$$t_c = k\frac{h^2{}_{\max}}{\pi^2\alpha}\ln\frac{4(T_i - T_m)}{\pi(T_x - T_m)}$$

(6)

$$t_r = 1 + 1.75t_d\sqrt{(2D + 0.05)/L_s}$$

(7)

P_j : injection power [W]

k: geometry correction factor; k = 1 for rectangular wall,

k = 2/3 for circular wall

h_{max}: maximum wall thickness [mm] (thinner is better!)

T_x: recommended part ejection temperature [oC]

T_m: recommended mold temperature [oC]

T_i: polymer injection temperature [oC]

α: thermal diffusivity coefficient [mm2/sec]

t_d: dry cycle time [sec]

L_s: maximum clamp stroke [m]

Mold cost

$$C_{mold} = C_b + C_{c1}n^m$$

(8)

C_b : cost of mold base [$]

C_{c1} : cost of single-cavity mold [$]

n: number of cavity mold

m: multi-cavity mold index = 0.7

Mold base cost

$C = 1000 + 0.45 A h_{0.4}$

(9)

A_c: surface area of mold base cavity plate [cm2]

h_p: combined thickness of cavity and core plates in mold base [cm]

Cost of single-cavity mold

$C_{c1} = R(M_e + M_{po} + M_x + 65 n_s + 150 n_i + 250 n_u + M_s + M_t + M_{tex} + M_p)$ (10)

R: rate of mold manufacturing = $60/hour

n_s: number of side pulls required

n_i: number of internal core lifters

n_u: number of unscrewing device

M_e: Manufacturing hours of ejection system

M_{po}: Manufacturing hours of cavity and core (size factor)

M_x: Manufacturing hours of cavity and core (geometrical complexity factor)

M_s: Additional mold manufacturing hours due to surface finish

M_t: Additional mold manufacturing hours due to tolerance

M_{tex}: Additional mold manufacturing hours due to texture

M_p: Additional mold manufacturing hours due to parting surface

M_e =2.5 sqrt (A_p)

(11)

$$M_{po} = 5 + 0.085 A_p^{1.2}$$

(12)

A_p : projected area of part to be injection

molded [cm_2]

M_x =45(X_i +X_o)$_{1.27}$

(13)

X_i: complexity of inner surface

Xi=0.01N_{sp} +0.04N_{hd}

(14)

N_{sp}: number of surface patches in inner surface (ignore small blending surfaces and parting surface)

N_{hd}: number of holes and depressions in inner surface

X_o: complexity of outer surface, calculated the same way as X_i

M_s = f_s(M_e +M_{po} +M_x)

(15)

$$M_t = f_t(M_x)$$

(16)

$$M_{tex} = 0.05(M_e + M_{po} + M_x)$$

(17)

$$M_p = f_p(A_p)$$

(18)

fs: surface finish cost factor

ft: tolerance cost factor

fp: parting surface cost factor

Optimum number of cavities per mold

$$n = (N_t k_1 t_s / mC_{c1})^{1/(m+1)}$$

(19)

$k_1 = 25$; $m = 0.7$

need to guess t_s (cycle time, which depends on n) initially to find n

N_t: total number of production

C_{c1} : cost of single-cavity mold

(Boothroyd & Dewhurst, 1994)

Appendix C - Sheet metal cost analysis equations

A spreadsheet similar to the one used to estimate the cost of injection molded parts was made to estimate the cost of the sheet metal parts. Parameters were also taken from the relevant CAD models and input into a spreadsheet based on the following equations.

Cost of individual dies:

For each type of die cost always include a basic die set.

$$C_{ds} = 120 + 0.36A_u \tag{1}$$

where

C_{ds} = die set purchase cost, $

A_u = usable area, cm^2

When determining A_u, leave enough margins (typical value is 50mm) to both side of the part for securing of the die plate and installation of strip guides.

A system for estimating the cost of tooling includes the time for manufacturing the die elements and for assembly and tryout of the die. Assembly includes custom work on the die set, such as the drilling and tapping of holes and the fitting of metal strips or dowel pins to guide the sheet metal stock in the die.

Profile complexity is measured by index X_p as

$$X_p = P^2 /(LW) \qquad (2)$$

where

P = perimeter length to be sheared, cm

L,W = length and width of smallest rectangle which surround the punch, cm

For a blanking die, or a cut-off die L and W are the length and width of the smallest rectangle which surrounds the entire part. For a part-off die, L is the distance across the strip while W is the width of the zone which is removed from between adjacent parts. For all cases, a minimum punch width W of about 6mm should be allowed to ensure sufficient punch strength.

According to the complexity index, we can give a basic manufacturing time M_{po}, which will be used as a base for further estimation see below.

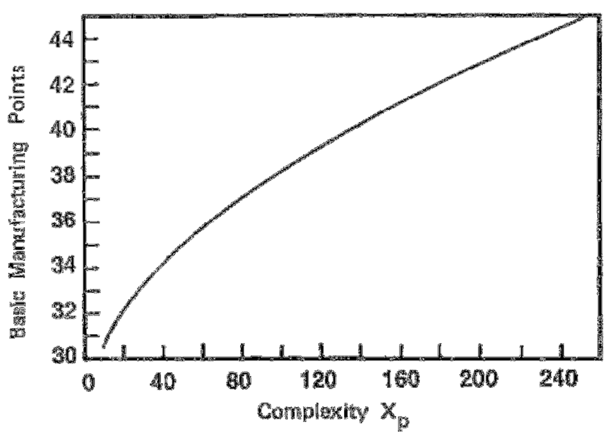

Table 10 Estimation of manufacturing points as a function of complexity (Boothroyd & Dewhurst, 1994)

Then the basic manufacturing time should be multiplied by two correction factors:

f_{lw} = plane area correction factor

f_d = die plate thickness correction factor

P.S. These factors are based on blanking dies. If we need get the estimation of cut-off die or part-off die, a new modification factor should be involved, which will be discussed at the end of this section.

f_{lw} can be found according to the following chart.

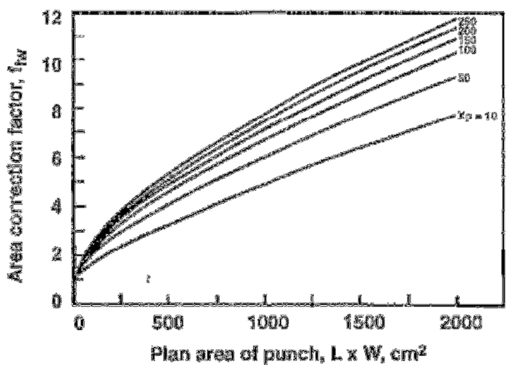

Table 11 Estimation of correction factor (Boothroyd & Dewhurst, 1994)

f_d depends on the die plate thickness, which is recommended by the following equations:

$$h_d = 9 + 2.5 \times \ln((U / U_{ms})V^h)\text{, mm} \tag{3}$$

where

U = the ultimate tensile stress of the sheet metal to be sheared

U_{ms} = the ultimate tensile stress of annealed mild steal

V = required production volume, thousands

h = sheet metal thickness, mm

Then f_d can be defined as:

$$f_d = \max\{0.5 + 0.02h_d, 0.75\} \tag{4}$$

Thus the manufacturing time M_p for a blanking die are given by

$$M_p = f_d f_{lw} M_{po} \text{ ,h,h} \tag{5}$$

where

M_{po} = basic manufacturing time, h

f_{lw} = plane area correction factor

f_d = die plate thickness correction factor

the manufacturing time for a cut-off die is approximately 12% less than for blanking

the manufacturing time for a part-off die is approximately 9% less than for blanking

Individual dies for piercing operations

A piercing die is essentially the same as blanking die except that the material is sheared by the punching action to produce internal holes or cut-outs into the blank. The estimation of manufacturing time involves three parts: basic manufacturing time, custom punch manufacturing time and standard punch manufacturing time.

Firstly, the basic manufacturing time is given by

$$M_{po} = 23 + 0.03LW, \quad \text{h} \tag{6}$$

where

L, W = length and width of the rectangle which encloses all the holes which are to be punched, cm

Secondly, the custom punch manufacturing time is given by

$$M_{pc} = 8 + 0.6P_p + 3N_p, \text{ h} \quad (7)$$

where

P_p = total perimeter of all punches, cm

N_p = number of punches

Lastly, standard punch manufacturing time is given by

$$M_{ps} = KN_p + 0.4N_d, \text{ h} \quad (8)$$

where

K=2 for round holes

=3.5 for square, rectangular or obround holes

Np = number of punches

Nd = number of different punch shapes and sizes

So the total estimated manufacturing time is the sum of all the above three parts.

Individual dies for bending operations

The basic manufacturing time is given by

$$M_{po} = (18 + 0.023LW) \times (0.9 + 0.02D), \text{ h} \quad (9)$$

where

L, W = length and width of rectangle which surrounds the part, cm

D = final depth of bent part, cm, or 5.0, whichever is larger.

The additional manufacturing time is given by

$$M_{pn} = 0.68L_b + 5.8N_b, \text{ h} \quad (10)$$

where

L_b= total length of bendlines, cm

N_b= number of different bends to be formed in the die.

The total manufacturing time is the sum of the above two parts.

Press selection and cycle times

Required Force

The required force for operations like blanking, piercing, etc., is given by

$$f = 0.5\ Uhl_s, \text{ kN} \quad (11)$$

where

h=gage thickness, m

l_s= length to be sheared, m

The force required for bending is much less than that for shearing, an empirical relationship for wiper die bending is given by

$$f = 0.333UL\ h_2/(r + r)\ , \text{ kN} \quad (12)$$

where

r_1=profile radius of punch

r_2=profile radius of die

Cycle time

The time for loading and unloading a blank or part can be given by

$$t = 3.8 + 0.11(L + W), \text{ s} \tag{13}$$

where

L, W= rectangular envelope length and width, cm

P.S. For shearing operation, which automatic press ejection would be appropriate, 2/3 of time given above should be used.

Turret press working

Machining cost estimation of using a Turret press

Time studies carried out on a variety of turret press parts suggest that an average of 0.5s per his is appropriate for early cost estimating where hole spacing is of the order of 50mm or less. For large parts with significantly greater distances between holes, extra sheet movement times of 0.1s for each additional 50mm can be added.

The punching time per part is estimated to be

$$t_1 = 0.5N_h, \text{ s} \tag{14}$$

N_h= number of hits for one part

The loading plus unloading time can be given by

$$t_2 = 2 + 0.15(L + W), \mathbf{s} \qquad (15)$$

L,W = the whole sheet length and width, cm

The time per part consumed can be expressed as $t_1 + t_2 / n$, where n is the number of the parts on a whole sheet metal. Then we can get the machining cost by multiplying this time with the machine rate from above equation.

Machining cost estimation of using a press brake

Empirical relationship for brake bending time can be given by

$$t = 2(1 + N_b) + 0.05(2 + N_b)(L + W), \mathbf{s} \qquad (16)$$

Where

N_b= number of required bending operations

L,W = length and width of part, cm

Appendix D - Glossary of Terms

During the background research for the project, we encountered the following words which were necessary to be familiar with. When any of the following words appear in the paper, they use these definitions.

Candela – Term describing the intensity of the strobe light. The Simplex 4903-0016 strobe is available in 16, 30, and 110 candelas. 15 are the minimum required by law in most areas.

VDC – Volts of Direct Current. The Simplex 4903-0016 runs on 24 VDC

Watt – Describes the power output of the speaker. Can range from .25 to 2 Watts.

VRMS – Root Mean Square Voltage, or the effective DC voltage. The Simplex 4903-0016 can run on either 25 or 70.7 Volts RMS. For instance, UL standard 1971 requires 16-33 VDC and 25 VRMS qualifies.

Free Run and Synchronized – The strobe in the unit can either be configured to run in Free Run mode, in which it blinks independently, or Synchronized with other units in the building. This is done to reduce the chances of causing epileptic seizures.

UL Standard 1971 – UL code covering "Signaling devices for the hearing impaired"

UL Standard 1480 – UL code covering "Speakers for Fire Protective Signaling Systems"

Alarm: A warning of danger

Alert Tone: An attention getting signal to alert occupants of the pending transmission of a voice message.

Average Ambient Sound Level: The rms, A-weighted sound pressure level measured over the period of time that any person is present.

Emergency Voice/Alarm Communications: Dedicated manual/auto equipment for originating and distributing voice instructions, as well as alert ant evacuation signals pertaining to a fire emergency, to the occupants of the building. Note—NFPA 72 does not require voice, but building codes might require voice in the aid of systematic evacuations.

Mass Notification System: A MNS may use intelligible voice communications, visible signals, text, graphics, tactile (touch or vibration), or other methods. The system may be used to initiate evacuation or relocation or to provide information to occupants. The system may be intended for fire, weather, terror, etc. emergencies or any combination. The system can be manual/auto, have multiple access points, and be wired/wireless.—related to above

Signal: Status indication communicated by various means.

Alarm: signal indicating an emergency condition or alert that requires action

Delinquency: signal indicating need for action in connection with supervision.

Evacuation: distinctive signal intended to be recognized by the occupants as requiring evacuation of the building. Note: NFPA 72 requires 3-pulse temporal pattern that meets the standards of ANSI S3.41, American National Standard Audible Emergency Evacuation Signal.

Fire Alarm: signal initiated by device such as fire alarm box, auto detector, water flow switch, etc.

Zone: A defined area within the protected premises. Note: a zone can define an area where signals can be received, or an area where signal is sent.

Injection Molding: Method of producing plastic parts in which a thermoplastic material is heating to its melting point and forced into a mold which has been cut in the shape of the desired part. Once the material cools, the mold is pulled apart and the part is ejected.

Sprue: A passage in a mold base through which the liquid material is injected into the mold cavity.

Runner: Small passage in a mold that connects the sprue to the one or more cavities in the mold.

Mold Base: Set of metal plates in which cavities have been machined to match the feature of a desired part.

Parting Plane: Location at which the two halves of the mold join together. When the part is ejected, the halves separate at the parting plane.

Cavity: Depression in a mold that has been machined out to produce one part. Molds can have one or more cavities depending on how many parts they produce in a single shot.

Shot Size: Amount of molten material that is injected into the mold during each cycle of the mold. Includes volume of each cavity as well as the volume of the sprue and runners.

Clamp Force: Amount of force required to hold the two halves of the mold together while the molten material is injected into it.

Mold Cost: Cost of purchasing the raw materials to make a mold plus the cost of machining the necessary cavities, sprue, and runners into the mold base.

Machine Cost: Cost associated with running the injection-molding machine, expressed in dollars per hour. Includes the cost of electricity consumed by the machine as well as the labor cost of a worker running the machine.

Material Cost: Cost of material required for one cycle of the injection-molding machine. Equal to the unit price of the material multiplied by the shot size, although material associated with the sprue and runners can be recycled.

Dedicated Die: Method of manufacturing sheet metal parts in which a metal die is cut to the shape of a desired part and forced against a piece of sheet metal, cutting a part to exactly the outline of the die. Usually used for high-volume sheet metalworking.

Turret Press: Device used to manufacture sheet metal parts in lower volume than dedicated dies. A computer-controlled press contains multiple dies, which can generate a variety of standard shapes.

Die-Forming: Method of forming bends in sheet metal in which a die is made to produce a specific bend pattern in a sheet metal part. Used when high volume of parts is needed.

Press Brake: Machine, which can produce a variety of bends in sheet metal parts, but must be setup and operated manually. Used for low volumes of sheet metal parts, which require bends.

Appendix E - Codes Relevant to project (reference)

It is important for the product to adhere to all of the codes and standards that the previous Tyco products adhered to. In order to achieve this, we inherited many features from the original product and became familiar with the codes and standards to make sure that any modifications we made did not affect the product's compliancy with the codes. All of the codes and standards that we researched are below.

Book: NFPA 101 Life Safety Code Handbook ISBN 978-087765826-9

- A fire alarm system required for life safety shall be installed, tested and maintained in accordance with NFPA 70, NFPA 72. Pg356
- All systems and components shall be approved for the purpose for which they are installed. Pg356
    - In the form of test reports issued by FM Global (insurance), UL
- All new alarms must be powered by the building's electrical system; they cannot rely on battery power. Pg361
- NFPA 72 specifies the audibility requirements for alarm signals in sleeping areas. Audible appliances must have a sound level at least 15dB above average ambient level, 5dB above the maximum sound level having a duration of at least 60 seconds, or a level of 75dB, whichever is greater. Pg362
- Visible notification is not required in stairwells or elevators. Stairs are a point of egress and thus it is not necessary to inform people already evacuating-plus, the system invites confusion in a crowded stairwell. When elevator doors open,

people will see/hear notification and egress. Pg364

- In large volume spaces (stadiums, etc.)-Occupant load of greater than 1000 it is recognized that strobes are not as effective for the hearing impaired and some sort of improved notification system is required. Pg365
- Code 9.6.3.6.1 the general evacuation signal shall operate throughout the entire building. Pg365
- Code 9.6.3.6.2 where total evacuation is impractical due to building configuration, only the occupants in the affected zones shall be notified initially. Provisions shall be made to selectively notify other zones to afford orderly evacuation of entire building.pg365
- Evacuation plans consider these parameters: building compartmentalization, detection and suppression systems, and number/arrangement of means of egress. Pg365
- Note for high rise-Order of evacuation is 1.Fire floor, 2.Floor immediately above, 3.Floor immediately below, 4.Remaining floors as fire develops. Pg365
    - **Conclusion:** Training plans (fire drills) must be developed for these situations in order to reduce panic. Our design can significantly reduce this training time for large occupancy buildings. No one is comfortable remaining in a building when they find out it is on fire (or other emergency)
- In places where age, disability, or restraint is an issue, a private alarm mode may be used. This alarm mode notifies the staff, or a particular unit of the building of a fire or emergency via coded fire alarm signal. Then the people in charge of

responding initiate an evacuation plan for that situation. Pg365

- Alarms throughout the building should be the same volume, frequency, and sound at the same duty cycle to avoid confusion. Pg367
- Code 9.6.3.9.2 Automatically transmitted or live voice announcements shall be permitted to be made via a voice communication or a public address system that complies with the following: (1) Occupant notification-live or recorded, shall be initiated at a constantly attended receiving station by personnel trained for emergency response. (2) An approved secondary power supply for other than previously existing systems. (3) Shall be audible above expected ambient noise level. (4) Emergency announcements take precedence above all other announcements. Pg367
- Things approved for above voice- assembly occupancies, malls, existing mercantile occupancies, existing bulk merchandise retail buildings, existing business occupancies. Note that these buildings usually have a public address system installed. Pg367.
- **NPFA 72: National Fire Alarm Code Handbook** isbn 978-087765719-4

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