Impact panel

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/17210710
Student Report; no. SR-2010-23, 2010-12-20

DOCUMENTATION PAGE

REPORT NUMBER	NRC REPORT NUMBER	DATE		
SR-2010-23		December 2010		
REPORT SECURITY CLASSIFICATION		**DISTRIBUTION**		
Unclassified		Unlimited		
TITLE				
IMPACT PANEL				
AUTHOR (S)				
Jad Yassine				
CORPORATE AUTHOR (S)/PERFORMING AGENCY (S)				
National Research Council, Institute for Ocean Technology, St. John's, NL				
PUBLICATION				
SPONSORING AGENCY (S)				
IOT PROJECT NUMBER		**NRC FILE NUMBER**		
42_2275_16				
KEY WORDS		**PAGES**	**FIGS.**	**TABLES**
Impact Field Study, Acrylic Block, Pressure Sensing Technology, Lexan Housing, Grout, Lighting System		18	17	

SUMMARY

In June 2001, a first impact field study was accomplished where loads in the range of 5MN were measured resulting from a bergy bit / ship collision. A second Impact field study is taking place at the moment in which a unique impact panel is being designed. The new pressure sensing technology introduced to the panel allows the determination of accurate loads and pressure distribution. The impact panel contains an effective lighting system allowing a high-speed camera to record all the required data. The impact panel uses the interlocking method in its design, thus having a high stability and the capability to withstand loads in the range of 20 MN.

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IMPACT PANEL

SR-2010-23

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December 2010

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1. INTRODUCTION

1.1 General Overview

Ships have encountered several bergy bit collisions in the past decades. However, with the increase of population around the arctic region, the bergy bit / ship collision is expected to increase due to the fact that ships are navigating more frequently in that area. Researchers have been conducting several bergy bit / ship impact studies. One of these researchers is Dr. Robert Gagnon of National Research Council – Institute for Ocean Technology (NRC-IOT). His work was focused on designing an impact panel that uses a new pressure sensing technology to measure loads and pressure distribution upon the collision with these bergy bits.

1.2 Objective

So far, engineers and ship designers do not have sufficient data for their ship designs to withstand the pressure resulting from the collision with such massive masses as the bergy bits. Bergy bits are icebergs floating on the surface of water, mainly around the arctic regions. The size of these bergy bits varies between 1 to 5 meters in height, and 5 to 15 meters in length. Due to their relatively large mass and size, these bergy bits pose a great risk for passing by ships. When hit by theses bergy bits, a ship's structure along with the crew's safety might be jeopardized. Based on that fact, there was an urging need for scientists and researchers to conduct experiments to find out the real time numbers and figures involved in these kinds of impacts. One of these experiments carried out by Dr. Gagnon involved designing an impact panel to measure the load and pressure distribution resulting from the collision of a ship with a bergy bit.

1.2.1 First Impact Field Study

The first impact field study, which took place in June 2001, included an impact panels located at the port side of the icebreaker. This field study was conducted using the CCGS Terry Fox; while this impact field study was a success, only glancing impacts could be achieved (figure 1). The results showed that the maximum obtainable loads where in the 5 MN range due to the shape of the Terry Fox hull and the position of the impact panels (Gagnon, 2008).

Figure. 1. First begy bit impact field study

1.2.2 Second Impact Field Study

Another impact panel that is larger in size, with a vertical orientation at the center of the bow of the Terry Fox is being designed. Simulations and calculations show that loads of approximately 20 MN can be achieved in impacts with 2000 tonne range bergy bits, while the ship is moving at a moderate speed (Gagnon, 2008).

2. IMPACT PANEL MODULE

2.1 Location

The Impact panel unit consists of two parts; a mount welded to the center of the bow of the Terry Fox (figure 2) and the impact panel itself fixed to the mount (figure 3). The impact panel is secured with bolts all around, with the top part of the panel surfacing waterline.

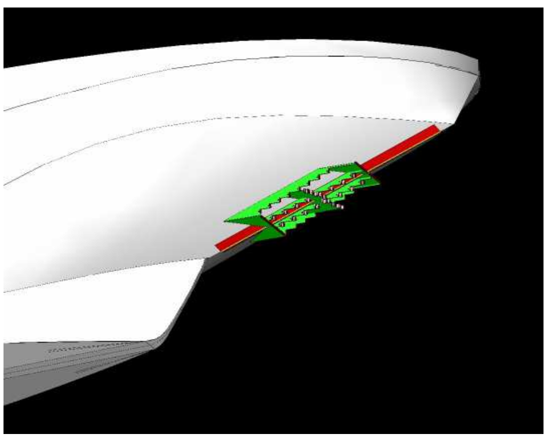

Figure. 2. Mount welded to the CCGS bow

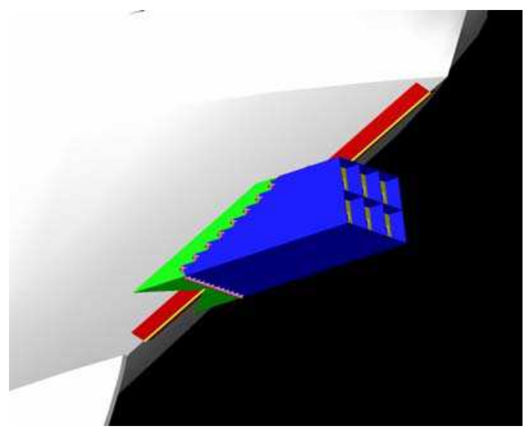

Figure. 3. Impact panel mounted (blue)

2.2 Structure

The front impacting surface is 3m x 2m (W x H), which gives a 6 square meters surface of contact with the bergy bit. The impact panel has a rigid steel structure and consists of 6 sensing modules. Each module is made out of clear/solid acrylic cuboid block with dimensions 1m x 1m x 0.46m (W x H x D) and housed in a stiff steel assembly. Several preliminary tests took place in the machine shop at (NRC-IOT) on a wooden version of the impact panel (figure 4). However, this version of the impact panel was constructed to accurate dimensions and represents a portion of 1/6th of the actual impact panel.

Figure. 4. Wooden version of the Impact panel

2.3 Interlocking Mechanism

Bolts are installed all around the impact panel when mounted to the steel mount located at the center of the bow of the Terry Fox. However, the absence of support in the middle region of the panel makes that area vulnerable to high impacts. The lack of support in the panel was a great issue for Dr. Gagnon, since the impact panel won't be able to withstand a range of 20MN of loads. The interlocking mechanism was introduced to the impact panel's design (figure 5); vinyl bags are installed onto these interlocks and filled up with grout. Grout is a type of concrete with a liquid state in its initial stage and hardens within few hours. The addition of grout will enhance the support of the panel allowing it to sustain the range of loads it's meant to measure.

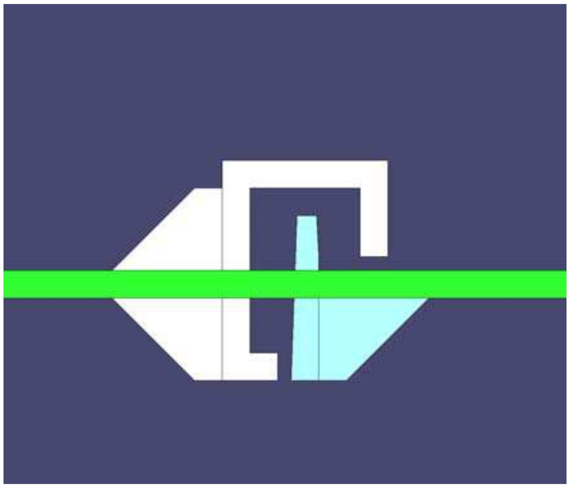

Figure. 5. Interlocking mechanism

Vinyl bags were fabricated at the machine shop at (NRC-IOT).Two designs were made for the bags, in the first design the vinyl bag was sewed in a cylindrical from were glue was added onto the stiches to prevent any water leakage, then two small tubes were attached using plastic lock straps (figure 6). Grout was injected through the bottom tube using a grout hand pump (figure 7) and the air trapped inside the bag escaped from the upper tube.

Figure. 6. First vinyl bag design

Figure. 7. Grout hand pump

2.3.1 First Bag Design

The first bag designed was installed onto the interlocks using a waterproof tape that's wrapped around the edges of the interlock. While this bag acted as an efficient support to the interlock, an error was detected in the bag's design; the vinyl bag over expanded when filled with grout. This error led to an excess of material being hanged out of the interlock, which added undesired extra weight to the panel.

2.3.2 Second Bag Design

Another design was considered for the bags, where the bag will have the exact same dimensions of the interlock after filling it with grout. The interlock's dimensions were taken accurately with a measuring tap, and then a vinyl sheet was cut and sewed according to these measures. This new design had a cylindrical shape as well; but instead of having an excess of material rapped around the tubes, two holes having the same circumference of the tubes were added (figure 8). Waterproof Glue was added onto the stiches to prevent any water leakage that may occur. This bag was installed on the interlock using screws instead of waterproof tape; however, Dr. Gagnon was a bit concerned that the bag may sag after filling it with grout. Grout was mixed with water and injected into the bag using a grout hand pump, where it's then left for the following day until it hardens (figure 9). The bag didn't encounter any sagging; it was fitting perfectly into the interlock, providing the panel with a more stable characteristic.

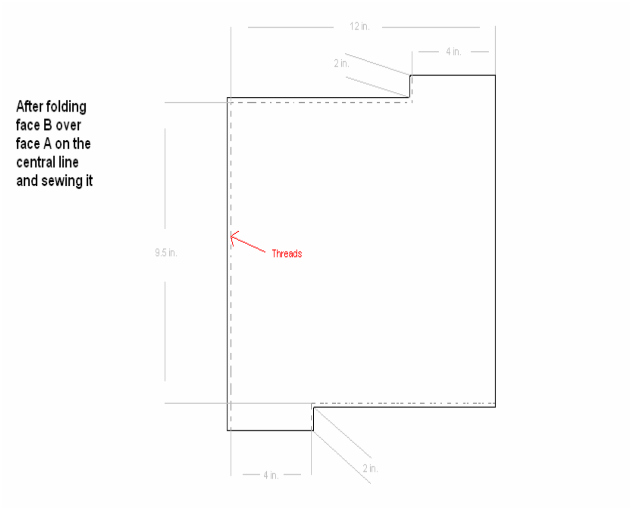

Figure. 8. Second vinyl bag design

Figure. 9. Vinyl bag filled with grout

2.4 Impact Module Details

The impact panel consists of six sensing module, where each module is made out of clear/ rigid acrylic block. As shown in the appendix, each acrylic block went through several machining at the machine shop at (NRC-IOT), where each block was cut accurately with dimensions 1m x 1m x 0.46m (W x H x D). Slots and holes were drilled in each block allowing the LEDs and wires to be installed perfectly in the panel. The acrylic block sits on flat load cells, which enable the impact panel to measure the load of the impact. The surface of the acrylic block is covered with a new mechanical pressure sensing technology, replacing thousands of electronic sensors. Numerous strips of acrylic, 13 mm wide and 4 mm in thickness and approximately 1 m in length, are fixed side-by-side covering the entire front surface of the acrylic block; each strip has a slight curvature of radius 0.23 m (Gagnon, 2008). A high-speed camera, which is able to capture up to 500 images per second, is located behind each acrylic block, allowing the panel to record all the desired data. Bright LEDs are place on the four edges of the acrylic block, enabling the high-speed camera of recording clear/ accurate data (figure 10).

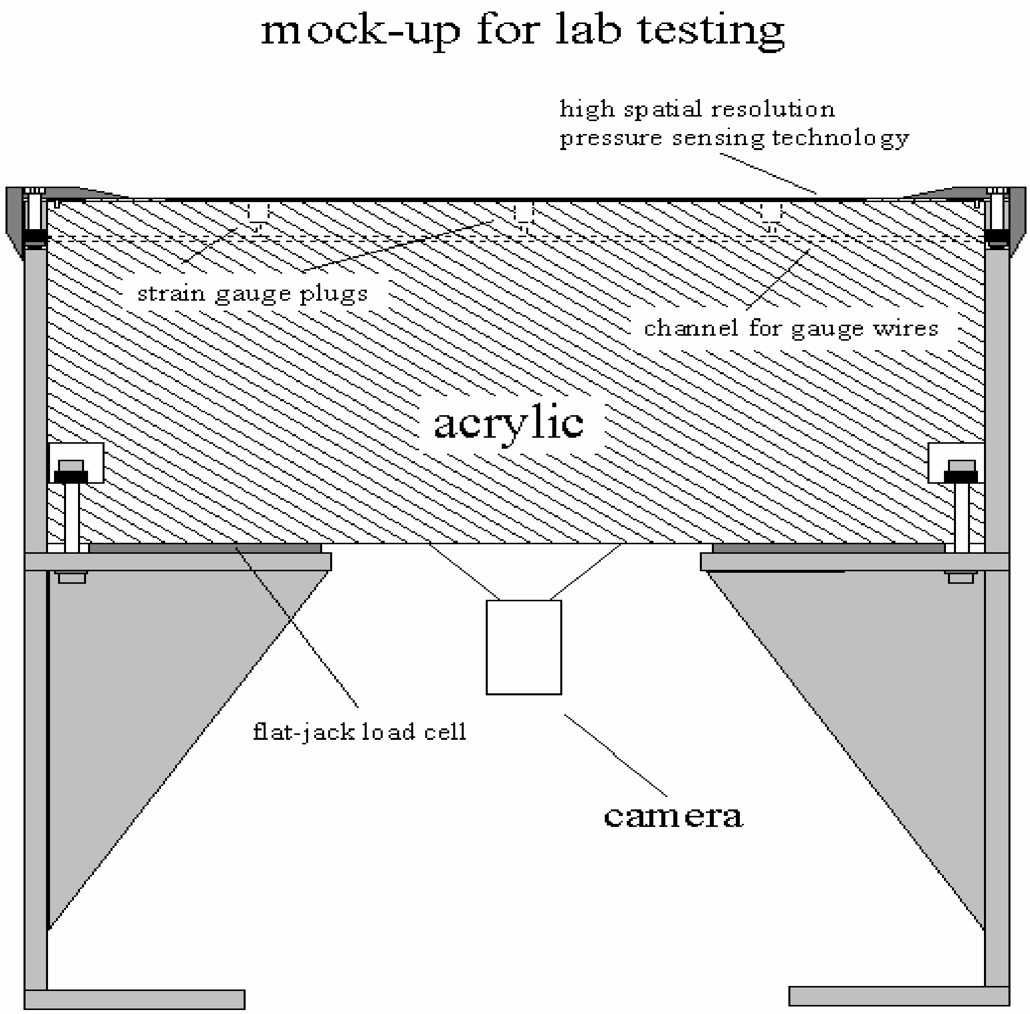

Figure. 10. Sectional view for the Impact module

2.5 Pressure Sensing Technology

A new pressure sensing technology is considered for the impact panel; this sensing technology is purely mechanical which can replace thousands of electronic sensors. The pressure applied to the panel due to the impact, causes the slightly curved acrylic strips to flatten against the acrylic block's surface (Gagnon, 2008). The degree of flat contact of the acrylic strips with the acrylic block is directly proportional to the pressure applied. Light rays directed from the sides, internally reflect off the block's internal surface where there is no contact with the strips (figure 11). The high-speed camera will record all the flattening process of the acrylic strips, which leads to the determination of the pressure distribution.

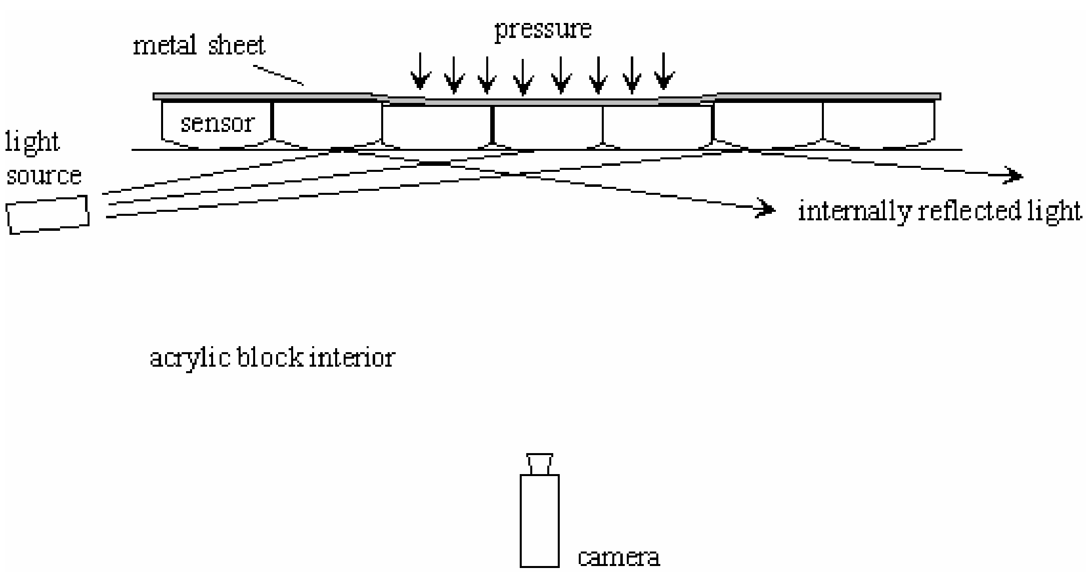

Figure. 11. Pressure sensing technology

3. LIGHTING SYSTEM

3.1 LEDs

Ultra bright LEDs are installed in the impact panel; these LEDs are place on a cupper bar (figure12), which facilitates the transfer of heat from the LEDs to the surrounding. Each acrylic requires 4 cupper bars thus having a total of 24 bars in the impact panel. The cupper bars fits perfectly into the slots drilled in the edges of the acrylic block (figure13). A lens having the same length of the cupper bar is placed over the LEDs to concentrate the light.

Figure. 12. LEDs placed on cupper bar

Figure. 13. Acrylic block with slots on the edges

3.2 Lexan Housing

The impact panel requires a waterproof lighting system due to its location under the water surface, thus a plastic housing was considered for the LEDs. Lexan sheet, a tough/ bendable type of plastic shown in the appendix, was cut with dimensions 0.91m x 0.053m (L x W) using the cutting machine at the workshop at (NRC-IOT).The edges of the Lexan strips were bent 90 degrees using the bending machine with 0.012m from both edges (figure 14). The Lexan strips were subjected to expansion during the bending process, thus a slight variation in the dimensions occurred. However, the sanding machine was used to adjust the existing error (figure 15) ending with dimensions 0.91m x 0.034m x 0.011m (L x W x H).

Figure. 14. Bending machine

Figure. 15. Sanding machine

A slight defect was detected in the Lexan strips after the cutting and bending process; several scratches were spotted on the upper surface of the strips, which may cause variation in the data collected by the high-speed camera. The upper surface of the Lexan strips were then polished using a product called Brasso; however, the scratches didn't fade completely.

A second Lexan sheet went through the same cutting and bending process. However, in this attempt the protective paper that covers the Lexan sheet was kept on, thus preventing any scratches that may be caused by the cutting and bending machines. The protective paper is then peeled of the bended edges of the Lexan strip; these edges were subjected to slight sanding using sand paper, which enables the Lexan strip to be glued rigidly onto the cupper bar, this can further be seen in the appendix.

3.3 Acrylic Pieces

A Rigid acrylic sheet was cut into small acrylic pieces, which were used to cover the opened ends of the Lexan strips. The acrylic pieces where cut to the most accurate dimension preventing any water flow into the LEDs. Each Lexan strip had two acrylic pieces, where one of them was drilled so that the electric wires can pass through. In addition to that, waterproof glue was applied to the acrylic pieces to fix them onto the Lexan strip and cupper bar, with its lower surface facing the cupper bar and the other three surfaces facing the Lexan sheet. A layout is further demonstrated in the appendix.

3.3.1 Cutting Process

The Acrylic sheet was cut into 50 small acrylic pieces with dimensions 0.02m x 0.027m x 0.0071m (W x L x H). A band saw at the workshop at (NRC-IOT) was used to cut the acrylic sheet; however, the acrylic pieces ended having cracked edges due to the wide teeth spacing of the band saw. Another acrylic sheet was then cut at the machine shop at (NRC-IOT), using a closer teeth spacing band saw. The acrylic pieces were cut perfectly with smooth/ straight edges, fitting completely into the Lexan strips ends (figure 16).

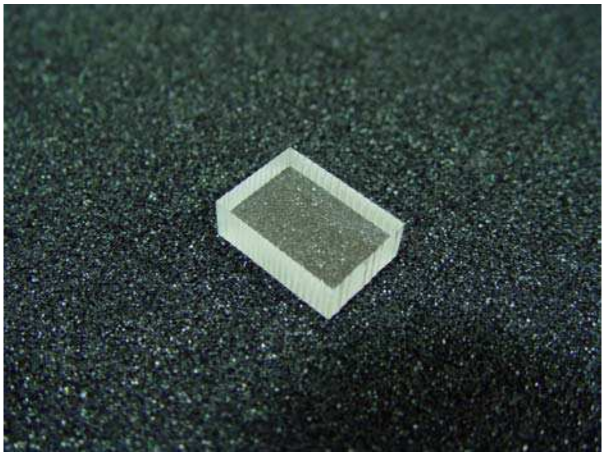

Figure. 16. Acrylic piece

3.3.2 Drilling Process

A drill was used at the machine shop at (NRC-IOT) to drill 4 holes in 25 of the acrylic pieces. The acrylic pieces were first marked right on the center of the 0.02m edges and then two marks were made on the 0.027m edges. Three drill bits with different diameters were used during the drilling process, where the drill bit with the greatest diameter is equal to that of the wires. The marks were first drilled with the drill bit having the smallest diameter, thus having small holes allowing the other drill bits to go through smoothly without cracking the edges (figure 17). The LED wires pass through the two holes drilled in the 0.0027m edges; then glue is injected through the other two holes drilled in the 0.02m edges to prevent any water leakage into the LEDs. The LEDs are now fully waterproof capable of emitting ultra bright light underneath the water line, hence sufficing the impact panel with the most effective lighting system.

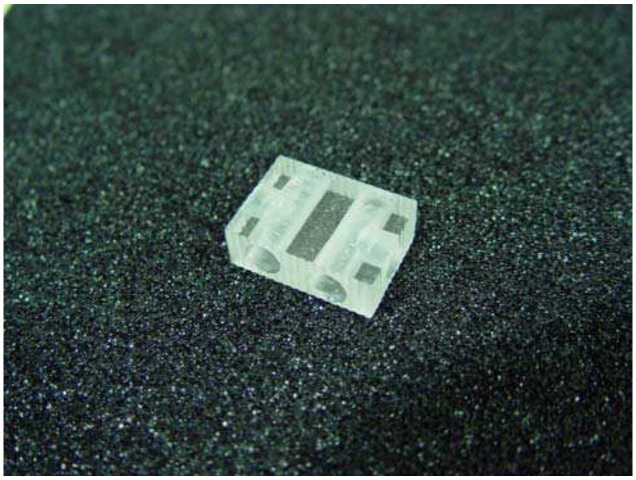

Figure. 17. Acrylic piece with 4 drills

4. CONCLUSION

A second impact panel field study in going to take place in the next few years; in which, a second impact panel has been designed using a new pressure sensing technology. Interlocking method was considered in the impact panel, allowing it to withstand loads with a range of 20MN. In addition to that, Ultra bright/ waterproof LEDs were installed in the panel, allowing the high-speed camera to record accurately all the required data regarding the loads and pressure distribution.

REFERENCES

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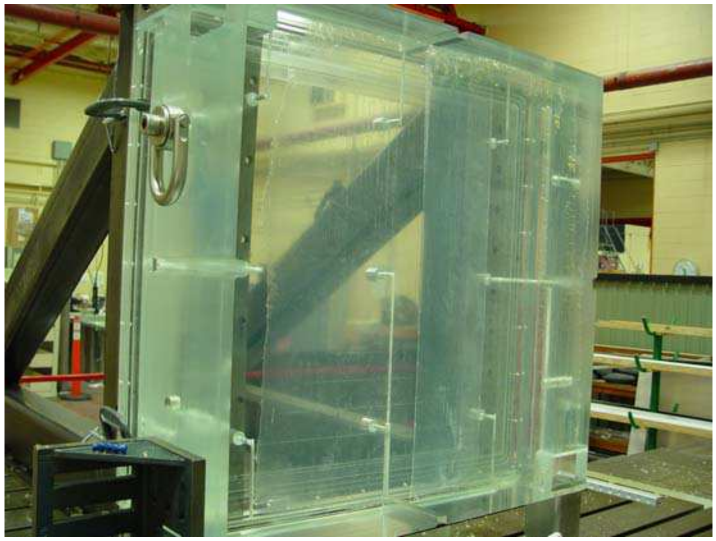
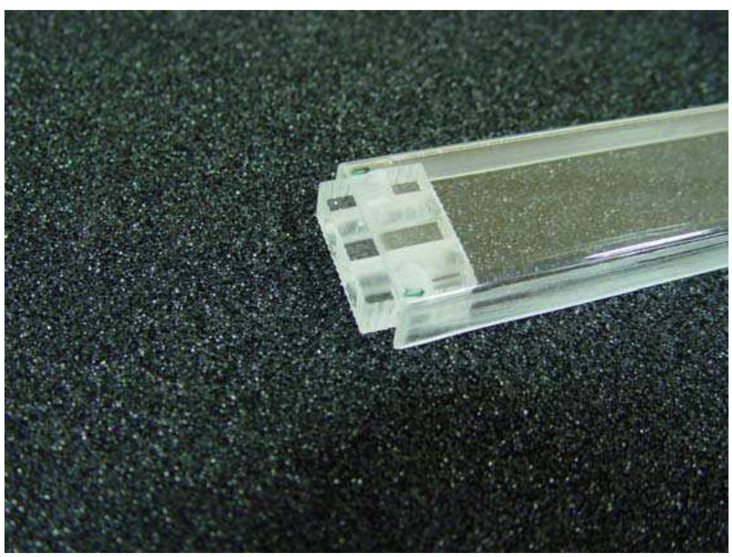
Appendix



Acrylic block undergoing some machining

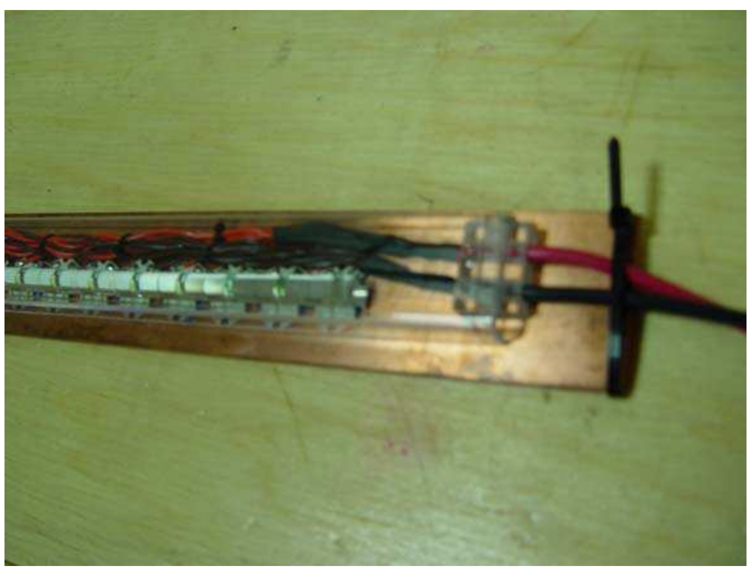
Lexan sheet in the cutting process

Sanding the Lexan Strip’s edges



Drilled acrylic piece and Lexan strip layout

Lens that covers the LEDs



LEDs, Lexan strip, cupper bar and acrylic piece assembled