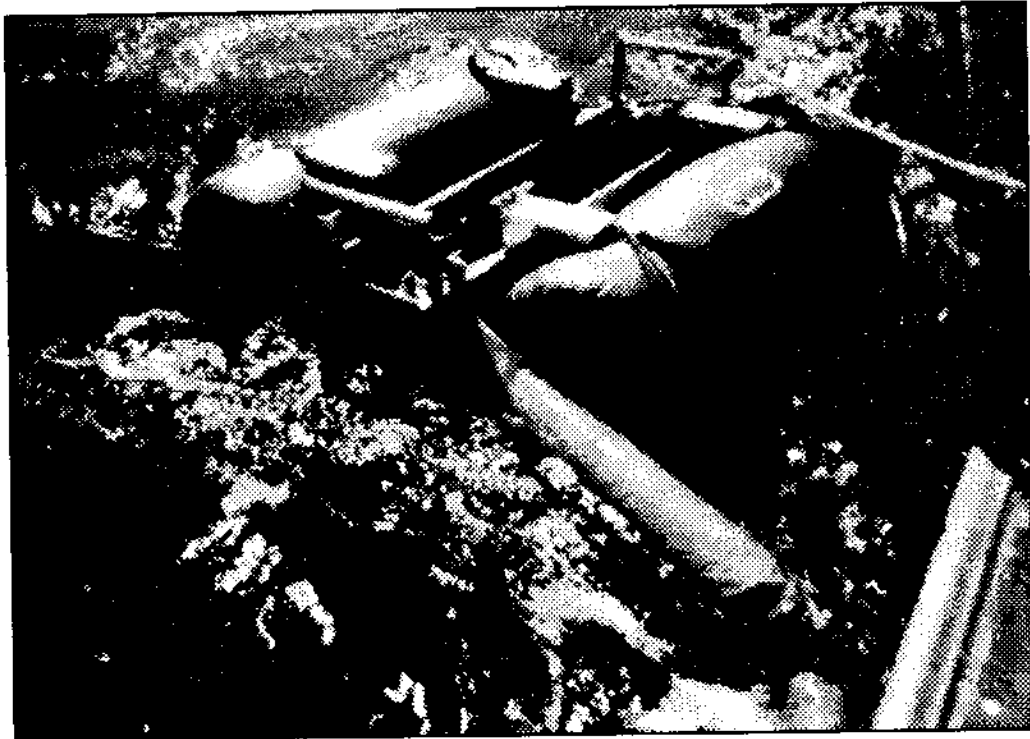


# SURFACE OIL SKIMMER

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Senior Design Project  
May 3, 1993

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# PROLOGUE

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# ABSTRACT

The Surface Oil Skimmer(SOS) is a side-mounted oil recovery system which is adaptable to many different boats. In the event of a small oil spill the SOS is a very accessible solution for fisherman and local authorities involved in clean up. This paper describes the development of the system including technical analysis of each major component. Tests were done which verified the integrity of the SOS system.

# ACKNOWLEDGEMENTS

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We would furthermore like to thank the following:

- ❖ JBF Scientific Company, Ralph Bianchi, for donating the skimmer.
- ❖ JPS/Oiltrol Company, Joe Santamaria, for donating the booms.
- ❖ Oil Mop Incorporated, Russell Kirby, for donating the oil drum
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- ❖ Ata Bilgili, ME Graduate Student, for assisting in transportation.

We would especially like to thank Paul Lavoie for his inestimable knowledge and labor during all aspects of the project.

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# OBJECTIVES

1. Design and assemble a system to fit three specific types of boats which can be used to efficiently skim and collect oil.
2. Design a process to transfer skimmed oil to the boat and/or to an other storage barge.
3. Implement a method to regulate the skimmer belt speed.
4. Time permitting, conduct an investigation of methods to heat the skimmed oil, to aid in the collection process.

# TECHNICAL



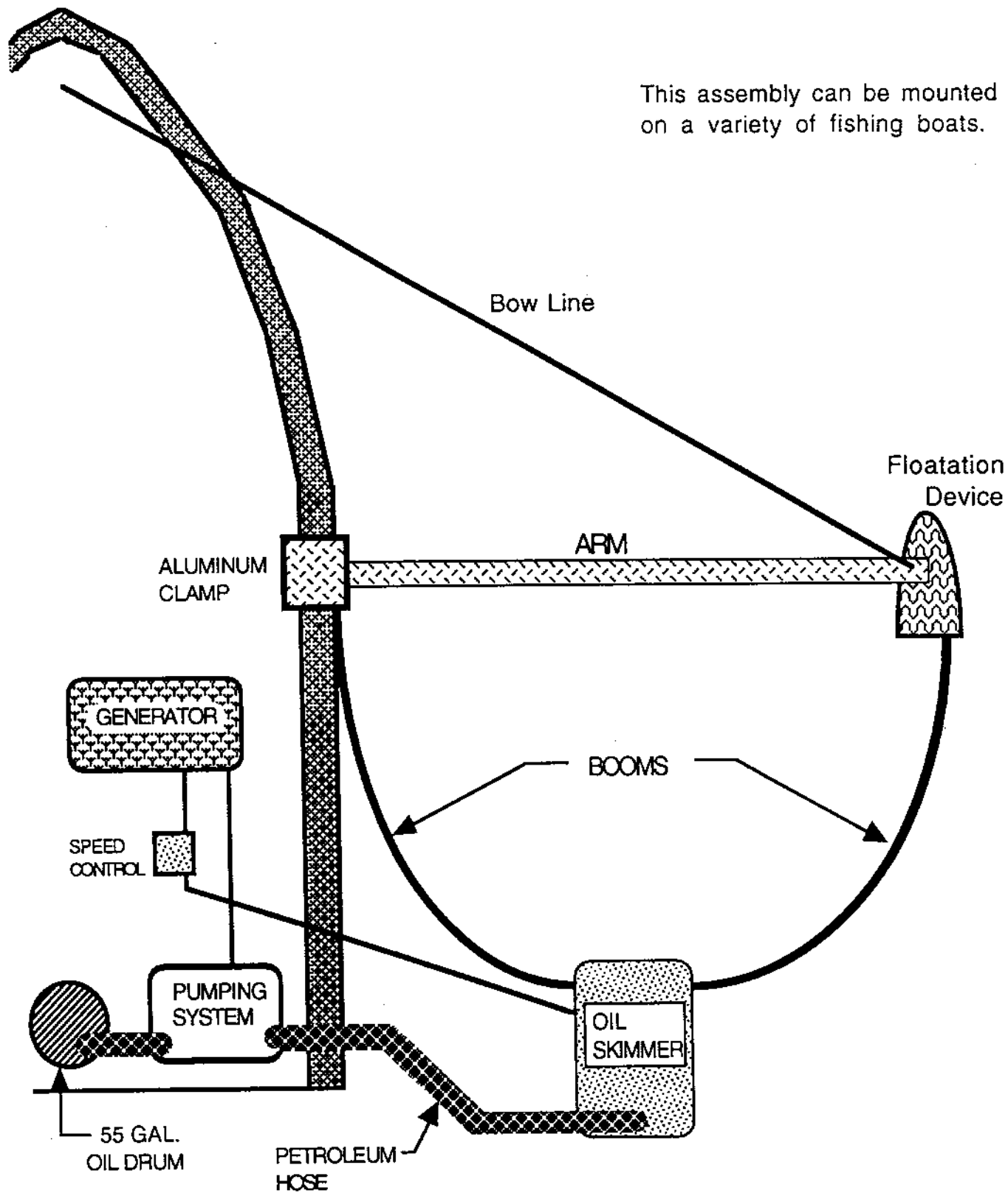
# INTRODUCTION

There is an ever increasing need for quick response to oil spills worldwide. Most recently major spills occurred off the northern coast of Spain and the southern end of the Mississippi River. Preliminary data from the Alaskan spill predicts that it will take two decades for the marine life to fully recover. Ideally, steps will be taken to eliminate any future spills. Realistically, precautions need to be taken for effective cleanup. The Surface Oil Skimmer project is an effort to do just that.

The Surface Oil Skimmer (SOS) is an effective method of responding to and aiding in the clean up of oil spills. In order to increase the rate of response to an oil spill, it is evident that any oil skimming device must include local available resources. The SOS is an oil recovery system which is adaptable to many different vessels of opportunity found in local marinas. This enables the whole apparatus to be brought out of storage, set up on a fishing boat, and deployed to a spill quickly. The SOS offers local authorities a head start on the clean up before the national authorities arrive.

The conceptual design of the SOS is displayed in Figure 1. It is set up as an outrigger to avoid the turbulence attributed to the boat and motor. As the boat passes through an oil spill it tends to churn up the water and force the spill beneath the surface where it is nearly impossible to recover. The outrigger allows the skimmer to be placed on the starboard side of the boat alleviating this difficulty. This placement decreases the length of the cords and hoses necessary to run the skimmer. Also, it provides for a smaller load applied to the pump.

The entire skimming system consists of a number of subsystems described individually in the following sections.



**FIGURE 1: SKETCH OF ENTIRE S.O.S. ASSEMBLY**

# OVERALL DESIGN SPECIFICATIONS

1. **Effective:** The main goal of this project is to design a system which effectively skims oil from the water's surface.
2. **Quickly Deployable:** The oil skimming system needs to be able to respond quickly to a spill.
3. **Adaptable:** The system needs to be adaptable to many different types of vessels in order to be effective.
4. **Self-Contained:** The surface oil skimmer needs to be self sufficient, containing all the necessary parts to be placed on a boat and used immediately.
5. **Cost Effective:** The market for this skimmer would consist of marinas and environmental agencies that would find it necessary to own and operate a rapidly deployed oil clean up system. Thus, the system needs to be competitive with other skimmers and reasonable for a relatively small budget.

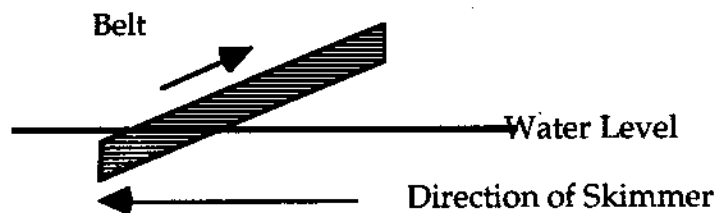
# SELECTION OF SKIMMER

The critical element of the SOS assembly is its dynamic inclined plane (DIP) skimmer. The DIP module was developed by JBF Scientific Company, Inc. Many private companies and government agencies worldwide are dedicated to creating the most effective, efficient method of collecting oil from bodies of water. To gain an understanding of the DIP skimmer provided for the SOS assembly, two different collection techniques will be investigated.

The Marine Spill Response Corporation (MSRC) was created to meet oil companies' need for quick, effective cleanup of oil spills. MSRC has purchased weir skimmers for response to oil spills. The specific weir skimmer suggested by MSRC for VOSS application is the GT-185 stationery weir skimmer. As outlined by the its fact sheet, the skimmer has a large suction opening for heavy oils, with an adapter for lighter oils. Debris entering the skimmer is broken down with cutter heads and scraping discs. The skimmer's size is 7.5 ft long, 6.2 ft wide, and 2.8 ft tall. It weighs approximately 289 lb. when dry.

There are many inherent problems with the weir skimmer. By using a pump, the skimmer will be collecting a lot of water with the oil. The complex design of the skimmer increases the chance for parts to wear down or break. Finally, the skimmer's large size and weight are a deterrent for use in small applications.

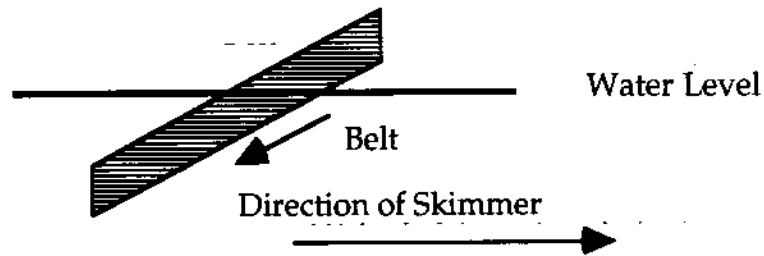
Marco Pollution Control has developed a skimmer which uses a moving inclined belt. The lower end of the belt is submerged in the water. The belt picks up oil from the water's surface and carries it up the belt to a collection area. This design does an excellent job of deterring the formation of a head wave. See Figure 2.



**FIGURE 2: The Marco Skimmer**

There do exist some problems with this design. Once the oil is collected onto the belt, the oil must resist slipping down towards the water. Some remedies to this problem are adding types of absorbents to the oil or increasing the adhesive properties of the belt.

Simply from its name, JBF's dynamic inclined plane (DIP) skimmer also contains a moving inclined belt. In contrast to the Marco skimmer, once the oil initially touches the belt, it is moved down below the water's surface level. See Figure 3.



**FIGURE 3: The DIP Skimmer**

There are many benefits to this oil collection method. First, by maintaining the belt speed equal to the water flow rate, the zero relative velocity helps the oil to adhere to the belt. Also the hydrodynamic pressure of the water helps to keep the oil on the belt. Once the belt carries the oil to the collection zone, the lighter density of oil as compared to sea water forces the oil to the surface of the collection zone. The oil is then pumped into a storage container on the boat.

Another important advantage of this skimmer as by Ralph Bianci, CEO of JBF Scientific Co. Inc., states, "The DIP never owns the water. Once you take in the water, you own it. And in order to discharge that water in a decanting style, you have to take a sample and show that it has only so many parts per million of oil in it."<sup>1</sup> By separating the oil and water in the collection well on the basis of physical properties, the storage area required is greatly reduced.

Finally, the skimmer's relatively small size is attractive for VOSS applications. With the pontoons included, the skimmer is 4.5 ft long, 4.5 ft wide, and 2.75 ft tall. Its weight when dry is approximately 150 lb.

# MODIFICATIONS OF DIP SKIMMER

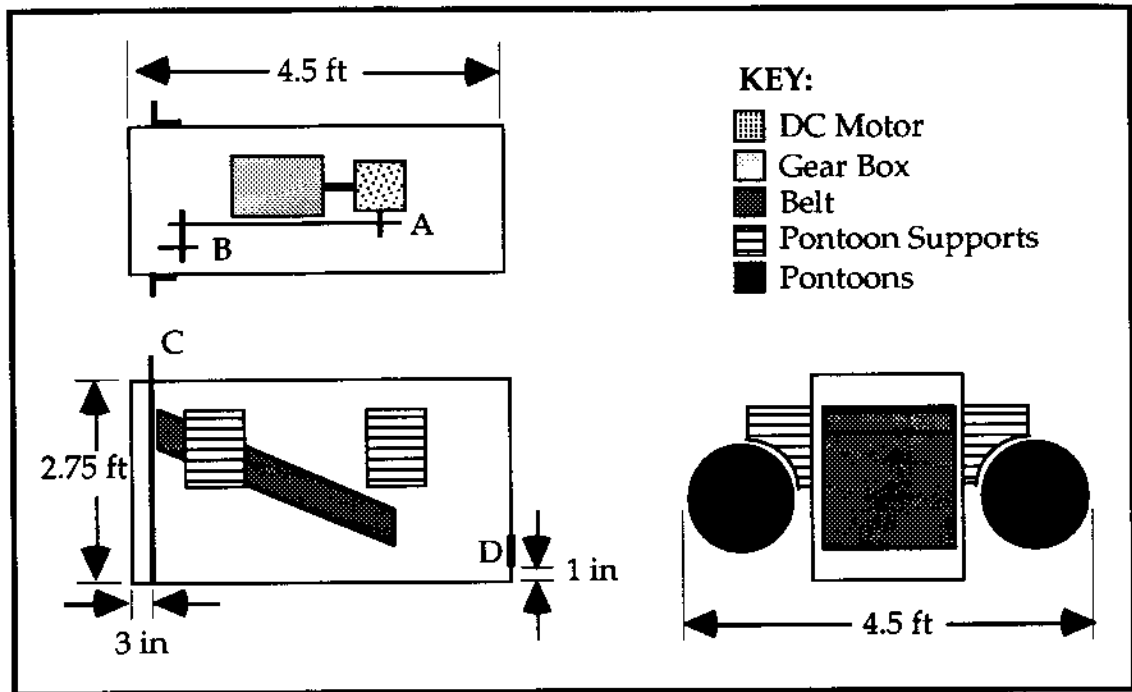


FIGURE 4: Overview of Skimmer

## Motor

The skimmer's belt was originally driven by a Dayton AC 1/4 hp, 1725 rpm single speed motor. This motor and the gear system rotated the belt at a fixed speed of roughly 2.5 knots.

The skimmer belt is now driven by a Dayton DC, 1/4 hp, 1725 rpm variable speed motor. (See Appendix) As a result the belt speed can be adjusted from the boat in accordance with the water's flow rate. The belt's velocity is regulated by a dial on a speed control box. The dial settings range from 0 to 100. After overcoming friction losses, the belt begins to rotate at a dial setting of 25. The length of the belt was measured at 7.9 ft. The time it took for the belt to complete one revolution was recorded at various dial settings. With this data, the speed control box was calibrated. See Table 1 and Figure 5.

The maximum belt speed of 2.61 knots is sufficient for the SOS assembly. While the belt speed can be modified for fast current situations, the booms will not be able to retain the oil. When the relative velocity between the current and the boom becomes too large, a

# SOS Skimmer Belt Speed Calibration

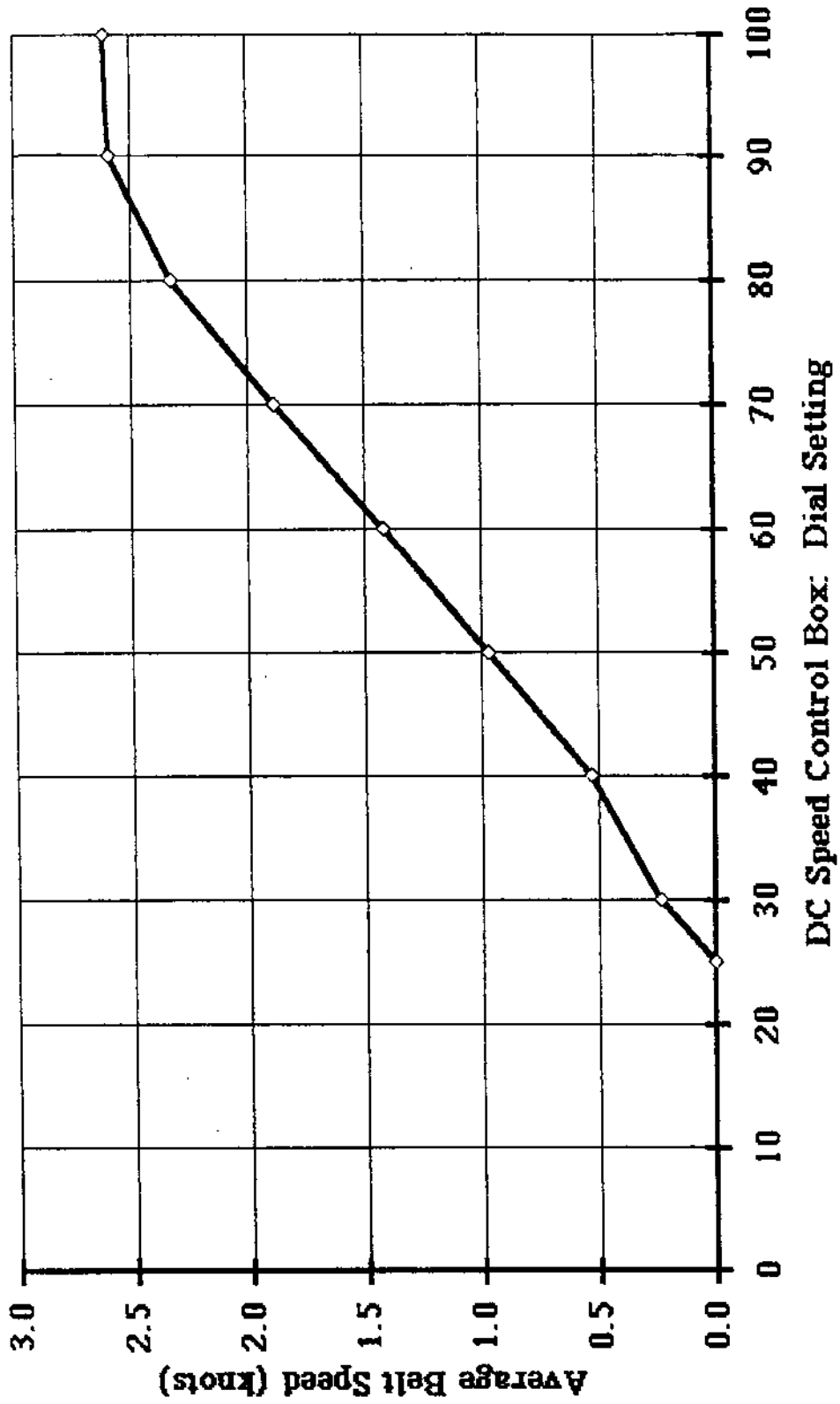


FIGURE 5

head wave of oil will form in front of the boom. The current will shear oil from the head wave and carry it underneath the boom. Therefore, the limiting factor in the speed of collection will be the performance of the booms and not the skimmer.

The speed control box of the DC motor rectifies 115V AC input and sends this power to the motor. Since the same flange mount was on the AC and DC motors, the new motor easily adapted to the existing gear box. Another feature of the motor is that it operates in clockwise and counterclockwise modes. For operation, the skimmer will be used the counterclockwise mode. In the case of the belt jamming from debris, the clockwise mode will be used to free the trapped object.

Upon delivery, the power cord from the speed control box to the motor was only six feet long. As determined by the 14.5 foot arm, the distance between the skimmer motor cord and speed control box may be much greater than six feet. Per motor specification, a new 14 gage, 3 conductor, 20 ft long power cord was installed.

### Flow Control Opening

At the end of the skimmer, a one inch high opening equal to the belt width was cut at the base of the skimmer. See Figure 4, Location D. As a result water will flow out the back of the skimmer rather than being forced out of the front. This will create less turbulence in the collection zone and less overall skimmer drag.

### Chain

Torque from the gear box is transmitted to the belt using two size 35 chains. See Figure 4. The longer chain (A) was steel and the shorter one(B) was aluminum. Due to the rust the steel chain was replaced by a nickel plated steel chain. The nickle plating is very corrosion resistant, while the steel core will retain the strength of the original chain. Due to its excellent corrosion resistance, the short aluminum chain was cleaned with paint thinner and will continue to be used. Due to cost restraints, aluminum and/or stainless steel was not bought to replace the longer chain. See Table 2.

Table 2: Selection of Chain\*

Chain Material	Min.Ult.Strength(lb)	Cost per Foot
Steel	1758	-
Nickel Plated Steel	1758	\$6.60
Stainless Steel	1620	\$15.00
Aluminum	1028	\$9.95
Plastic	15**	\$9.50

\*Information supplied by Bearings, Inc. Dover, NH

\*\*Termed as 'Working Load'.



### **Boom Attachments**

Twenty eight (28) inch lengths of two inch angle iron were bolted to each side of the front of the skimmer. See Figure 4, Location C. Booms will attach to these segments using 1/2 inch diameter bolts. Slots can be cut in the boom attachment side so that various boom types can be used.

# MODIFICATIONS OF THE ARM

## Specifications of Arm

The arm, donated by JBF Scientific Co. Inc., consisted of two segments of two inch diameter, 1/4 inch thickness aluminum tubing. Modifications involved joining the two segments with a cuplink and changing the floatation device. The float will be addressed later in this report.

A six foot PVC tube was used as a cuplink to join the two segments. The cuplink was fastened using two 3/8 inch diameter stainless steel bolts. The location of the cuplink and bolts can be seen in Figure 6.

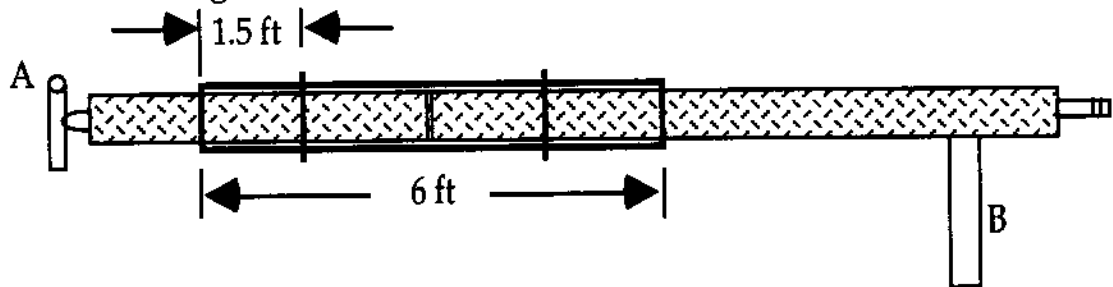


FIGURE 6: Overview of Arm

Within the cuplink, the two aluminum arm segments are flush in order to maximize the strength of the arm. Segments A and B were exactly in line during drilling of the arm to assure that the float was parallel to the surface of the water.

## Stress Analysis of the Arm

There are two significant design reasons to analyze the forces acting on the arm. First, it is important to verify that the arm itself can sustain loading without plastic deformation or breaking. Secondly, stress analysis of the arm determines the loading conditions that the clamp must be able to withstand.

By using the Catenary Diversion Modeling Program<sup>2</sup> (Divcat), the magnitude and direction of the drag force experienced by the boom was calculated. The information entered into the Divcat program is outline in Figure 7.

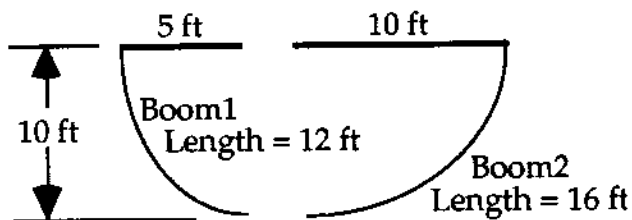


FIGURE 7: Input to Divcat Program

Worst case conditions of a 3 ft boom depth and a 3 knot current were also entered. None of the standard fluid properties specified in the Divcat program were changed. With this input  $F_{\text{drag Boom1}} = 112.4 \text{ lbf}$ , and  $F_{\text{drag Boom2}} = 247.6 \text{ lbf}$  were determined. See Figure A.8 for the Divcat output.

The drag force of the float, although minimal in comparison to the booms, was calculated using the following formula<sup>3</sup>.

$$F_{\text{DRAG FLOAT}} = \frac{1}{2} C_D \rho v^2 A$$

where  $C_D$  is the aspect ratio,  $\rho$  is the water's density,  $v$  is the water's velocity, and  $A$  is the area of the float normal to the current. Calculations show  $F_{\text{drag float}} = 3.7 \text{ lbf}$ . See Figure A.9 for calculations.

The forces acting on the arm were due to the drag forces of the booms and float, the tension in the bow line, and the reaction of the clamp. Using the calculations above, the bow line tension was found to be 493.11 lbf. The force on the clamp normal to the arm was 110.9 lbf. The force on the clamp parallel to the arm was 481.7 lbf. See Figure A.9.

As Figure A.9 shows, the primary force experienced by the arm is a compression force. The strength of the aluminum arm in compression is far greater than the stress it experiences. Therefore the arm shall be capable of withstanding calculated loads without failure.

# PRODUCTION OF FLOTATION DEVICE

## Design Specifications

1. **Reduced Turbidity:** To avoid any churning of the oil and water due to the flotation device, its shape must be hydrodynamic.
2. **Lightweight:** This is necessary for ease of transportation.
3. **Buoyant:** The flotation devices purpose is to support the weight of the arm and oil booms.
4. **Strong:** Materials must withstand wave pressure and the stresses associated with the arm.
5. **Cost Effective:** Cost is always an important consideration.

## Design Process

Originally, a flotation device was donated by JBF Scientific Company to accompany the arm. However, from the original tests, it was evident that the donated flotation device created a lot of excess turbulence and drag, which led to a reduction in skimming efficiency. The turbulence churned up the water surface and would allow oil in its vicinity to pass underneath the booms.

A new design was necessary to achieve a hydrodynamic flow around the device and incorporate the strength and buoyancy of the original float. The form for the flotation device was modeled out of wood and chicken wire, and made to resemble a boat hull including a keel for stability. Eastern Marine then fiberglassed the form in order to provide a water tight case. The result is a fiberglass hull which fulfills the design specifications for weight and cost effectiveness.

# PRODUCTION OF CLAMPING DEVICE

## Design Specifications

1. **Stable:** The clamp must be strong enough to withstand the forces associated with the arm attachment and the boom attachment.
2. **Adjustable:** The clamp is to be designed for a variety of vessels of opportunity and thus needs to fit different gunnel widths.
3. **Lightweight:** A major goal of the project is a quick turn around time. Thus, it is important for the clamp to be easily transportable. To accomplish this, the weight must be reasonable for one person to carry.
4. **Adaptable:** The clamp is the centerpiece of the entire system. Therefore, it must be adaptable to all the system components that it comes into contact with. The clamp must fit the boat's gunnel, provide an attachment for the arm and securely fasten the boom section next to the boat.
5. **Self Contained:** It is important that the attachment of the clamp does not damage the vessel used in the oil skimming process. Thus, it can not have any permanent attachments to the boat's gunnel, i.e.drilling holes in the gunnel in order to fasten the clamp with bolts.
6. **Safe:** The design of the clamp must maintain a high level of safety for the operator.
7. **Cost Effective:** Materials must be used in the production of this component that are cost effective. Also, cost must play a major role in its overall manufacturing.
8. **Corrosion Resistant:** Since the clamp will be in contact with salt water, materials must also be chosen for their resistance to corrosion.
9. **Simple:** The K.I.S.S. principle must be well represented in this component's design. The clamp must be kept simple to operate because it will be used by a variety of individuals in situations where time is a factor. Furthermore, as the system becomes more complex, it becomes limited in its variety of applications.

## Design Process

In order to construct a device that follows all of the design parameters, it is necessary to consider its specific application. The device has to attach to a vessel of opportunity in a manner that does not damage or permanently change the vessel's structure. This rules out the possibility of bolting a device onto the gunnel of the boat or to the boat's cabin. Thus, it became apparent very early that the device would have to act as a clamp and fit the gunnel of the vessel in use.

In order to accommodate a large variety of boats to be used in the skimming process, a range of sizes of boats had to be established in order to design a suitable clamp. Through discussions with fishermen and the local marinas, it was decided to choose Eastern boats as a common vessel of opportunity. This decision enabled our group to determine accurate gunnel widths for a variety of their boats. Of course, the gunnel width of the Admiral Voss was also incorporated into these figures. Table 3, below is a representation of the boat sizes deemed adequate for the oil skimming system and their respective gunnel widths.

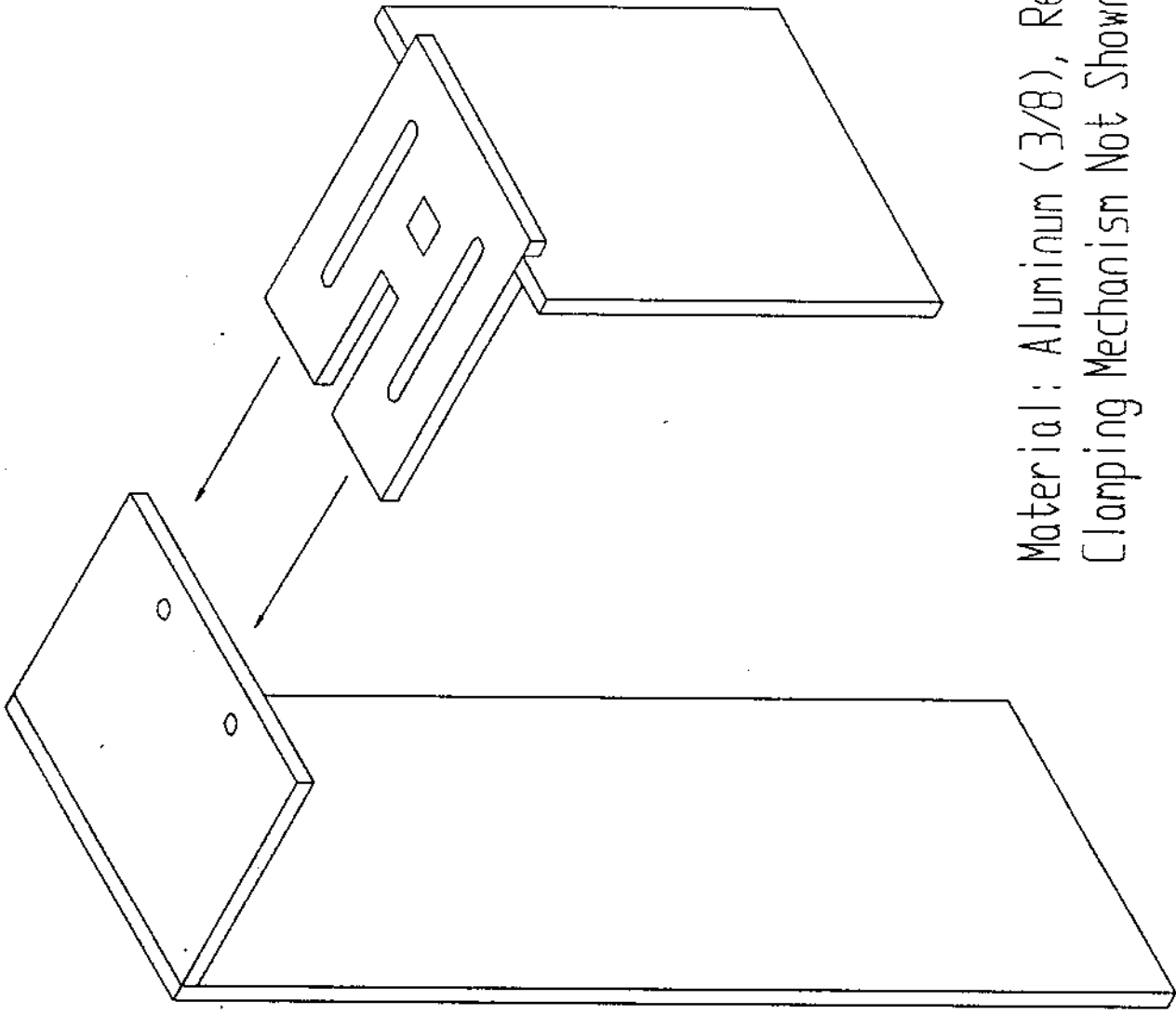
Table 3: Gunnel Widths of Selected Boats

Boat Size (Eastern)	Gunnel Width
22 ft	11 in
27 ft	12 in
30 ft (Admiral Voss)	15 in

From Table 3, it is easily determined that the clamp needs to be adjustable from seven and a half inches to fifteen inches.

Several different approaches to the overall clamp design were discussed, however it was determined that the clamp function much like a vise because of its safety, reliability and strength. Other options, such as a spring loaded clamp were discarded because of the risk of injury. The forces on the clamp from the boom and arm attachments are large enough to require a spring with a large spring constant. The danger involved in this design provides for a more complex system. Figures A.10 and 11 show two different conceptual designs of the "vice type" clamp before the final design was developed. Original designs proved to be too complex to remain cost effective and, most importantly, simple. Thus Figure A.20, displays the final assembly diagram of the clamp followed by the specific plates used in its production (Figures A.12 - A.18).

In order to choose the material to be used for this design, it is necessary to consider the material's strength, corrosion resistance, weight and cost. For this application, only two



Material: Aluminum (3/8), Reinforced  
Clamping Mechanism Not Shown

Figure 11

materials display the characteristics necessary to fit these conditions effectively. They are stainless steel and aluminum. Table 4 summarizes the properties associated with each material.

Table 4: Properties of Aluminum and Steel

	Stainless Steel	Aluminum
Yield Strength (kpsia)	43.5	21.04
Corrosion Resistance	Good	Good
Weight (lb/in <sup>3</sup> )	.276	.096
Cost (\$/lb)	3	1

In order to compare the two materials on the basis of strength and stability, it is first necessary to calculate the resultant forces acting on the clamp. These forces are calculated in Figure A.9. It is difficult to consider the overall stability of the clamp in operation because there are so many variables involved. For example, the surface area in contact between the clamp and the gunnel varies greatly with each boat. The Admiral Voss has a very small contact surface because of a thin ridge that runs along the outside of the gunnel. Surface area is an important consideration because of the force of the boom which acts perpendicularly to the clamp. Thus, a smaller contact area decreases the ability of the clamp to grip the gunnel. In order to test the strength of the materials, we are limited to the compressive force of the arm acting on the outside section of the clamp. This force of 481.7 lbs. acting on a 6 sq. inch are of the clamp, produces a stress of 80.28 psia. From Table 4, it is quickly determined that this value is well below the yield strength of aluminum.

From this analysis, it is easily determined that either material would be effective for the application in terms of strength. While stainless steel has a higher yield strength, there is no advantage in choosing it based on this information. In terms of corrosion resistance, both aluminum and stainless steel display similar properties and, thus, there is no clear choice based on this criteria either. However, in terms of weight and cost, aluminum is the clear choice. Table 4, shows that stainless steel is nearly three times as heavy and three times as expensive as aluminum. In order to remain cost effective and light weight, stainless steel must be ruled out. The materials for the clamp were purchased from NorthStar Aluminum and Steel, and the hardware was purchased from McMaster Carr corporation. A list of materials is included as Figure A.21.

Finally, the clamp is designed to accomodate the attachments previously mentioned. The outrigger, which consists of the arm, the flotation device and the outside boom attachment, connects to the clamp as shown in Figure A.19. The inside boom also attaches to the clamp through the use of the angle iron shown in the same figure.



For the prototype of the clamp, some simplifications were made which should be modified in the production of this clamp as a workable solution. First, in order to avoid damaging the gunnel of the boat, a hard plastic or rubber padding should be added to the inside surfaces of the clamp. Also, a stainless steel threaded rod (1/2" - 13) was used as a power screw for clamping. This should be substituted with an acme thread to provide more strength in the threads. The acme thread also provides a lower risk of being damaged on board ship as a result of an object hitting it.

In summary, the prototype clamp cost approximately \$600.00 to construct and weighs about 60 lbs.. It consists of aluminum plates and stainless steel hardware. Finally, the design incorporates all of the initial specifications and performed its function adequately in testing.

# PUMPING SYSTEM

After traveling to the collection zone in the skimmer, the oil must be pumped into some type of storage bin. The three major components needed to achieve this goal are a pump, appropriate tubing, and a storage container.

Initially, a DC vane pump was purchased that could pump oil at a rate of 5.5 gallons per minute. The pump required a 12 volt, 8 amp power input. See specifications sheet in appendix. Hoses and fittings were also purchased which adapted to the 1/2 inch internal pipe thread and 1 inch external hose barb.

Problems arose with further research on the changing properties of spilled oil. Emulsification and evaporation cause both the density and viscosity of oil to increase.<sup>4</sup> With these changes, it is very difficult to pump the oil through tubing. The ease of oil transfer increases with increasing pressure differential along the tubing. One way to increase this pressure change is to increase the diameter of the tubing. Another difficulty with this pump was its inability to handle debris.

An alternative pump was selected which resolved these problems. The diaphragm pump has two inch ports and is capable of handling debris. The pump requires 1/2 hp, AC. Petroleum hose, capable of handling mixtures with large oil percentages, was purchased. See appendix for specifications sheet. The two inch diameter hose was purchased in two segments of 8 and 18 feet. Each connection was fitted with quick release attachments.

The final item obtained was a 55 gallon oil drum. This drum, donated by OIL MOP, INC. is DOT, OCEA, and EPA approved. The smaller sized drum is excellent for small oil spill collection. The drum's rigidity was also superior to the instability of an oil bladder.

# POWER REQUIREMENTS

The total power requirements for the SOS assembly is  $3/4$  hp. The variable speed motor draws  $1/4$  hp. The diaphragm pump draws  $1/2$  hp.

# TEST METHODS

## OCTOBER 7, 1992 THE ORANGE COLLECTING TEST

The objective of this test was to verify the current patterns in the Piscataqua river, Newington, NH. This was overseen by graduate student David Fredriksson and associate professor M. R. Swift. The SOS team's purpose was to test the performance of the arm, the donated flotation device, and the whole system in general. To accomplish this oranges were deposited into the Piscataqua river up stream from the collection site, their paths were monitored and they were collected using a set-up similar to the SOS. The differences in the systems included using a crate incased in chicken wire instead of the skimmer and the clamp was made of wood. The clamp was attached by simply drilling holes into the Admiral VOSS and bolting it to the gunnel.

The objective of the test was proven successful, the currents were verified to be as predicted. Also, the SOS team was able to prove that their theory of the system was feasible except for four flaws. The first flaw seen was from the donated flotation device. It simply was not buoyant enough to support the arm and the boom attachment. The result of which was the end of the arm submersed in the water causing turbulence. In an oil spill situation this turbulence would churn up the oil and water thus reducing skimmer efficiency. Our solution was to redesign a flotation device that was more buoant and had a form that was more streamline to reduce turbulence.

Secondly, the bow line was not the correct length; we had to stop the boat to re-adjust it. At the time this was inconvient because the bow line was supporting the arm. To remedy this the bow line could be threaded through a cleat at the bow of the boat and lead to a winch. This would allow a crew member to increase or decrease the tension in the bow line without having to stop skimming. Also, the arm was bending and twisting due to the forces at the end of the arm caused by the flotation device and the boom. Its pieces were also only held together by duck tape. Our answer to this problem was to telescope the pieces together using stainless steel bolts and screws. The cuplink could also be made of aluminum tubing instead of the PVC tubing that was used. This would make for a more stable and versitile arm because it would also be possible to lengthen or shorten the length of the arm.

Lastly, the booms closest to the boat were only attached by a rope. This made the booms very unstable which lead to the loss of oranges. Our solution was to attach the boom to the clamp and put weights on the ends of the booms to keep them perpendicular to the water. These are both solutions that would increase boom efficiency.

Another important fact that was discovered was that the maximum speed that the boat could go was only 3 knots. At higher speeds the booms would fail and turbulence would occur near the boom attachments.

### **APRIL 2, 1993 UNH POOL TEST**

The objective of this test was to test the buoyancy of the skimmer, to find where the water level occurred, and to figure out how easy it would be to lift the skimmer in and out of the water. This test was performed at the University of New Hampshire indoor pool. The test was a success. The pontoons were found to be sufficiently buoyant to handle the weight of the skimmer. It took at least three people to lift the skimmer in and out of the pool. It was also harder to lift the skimmer out of the pool because of the weight of the water inside the skimmer containment. The water line was initially at the top of the belt which decreased skimmer efficiency. Fortunately, the pontoon holders were adjustable. (refer to Figure 4) We adjusted the pontoon holders such that the water line would be where the belt begins to slope downwards, maximizing skimmer efficiency. The booms and the skimmer were held next to each other in the pool to find where they coincide. This was used to determine where to attach the booms. Lastly, we discovered that it was easier to transport the skimmer when the pontoons were not connected.

### **APRIL 30, 1993 FINAL TEST**

The final test was our opportunity to examine how the working SOS system functioned. This test took place on the Admiral VOSS in the Piscataqua river and popcorn was used to simulate an oil spill. In preparation for the test it was necessary to check the tides for the day. We wanted to deploy the SOS during the middle of high and low tide to ensure we encountered the smallest current. This would be the optimum testing time because it was the first time the DIP skimmer was used in the ocean and we weren't sure how it would react to the waves and current. The total deployment time was approximately 1 hour.

Overall the SOS proved to be successful in performing its designated function. However, there were a few areas that need improvement.

- ❖ First is the clamp which rotated in high current situations. To remedy this, the clamp's strength needs to be increased. One way to accomplish this is to use a better threaded power screw.
- ❖ Secondly, the floatation device was not running parallel to the boat as it was designed to do. One explanation is that it wasn't perfectly hydrodynamic. Also the force of the boom on it tended to force the floatation device's bow to dip downward. To fix this, the direction of the float needs to be secured. The device's stability needs to be increased by lengthening the float, forward of the arm attachment to create more buoyancy.
- ❖ Unfortunately, the pump wasn't working properly. Had it been functioning, the pumping system would have been effective.
- ❖ The last and possibly the greatest challenge was getting the skimmer out of the water. It was very difficult to hoist the skimmer and all of its attachments over the gunnel. A crane or pulley system would have been very useful. Although, lifting the skimmer can be accomplished with sufficient manpower, approximately four people.

# SUMMARY

In order to summarize the effectiveness of our project, it is necessary to consider the design specifications. The main goal of the project was to design a system that skimmed oil from the water's surface effectively. The Surface Oil Skimmer proved to be an effective design when tested in April. Popcorn was used in the place of oil for the test. The popcorn was spread in front of the boat to simulate an oil spill. The boat, with the Surface Oil Skimmer attached, then manouvered alongside the spill. The popcorn was then collected between the two oil booms and directed towards the skimmer. Finally, the belt swept the mock spill into the holding tank for pumping. The Surface Oil Skimmer proved to be quickly deployable during this trial run, also. The whole system was set up and deployed in less than an hour. Table 3 shows the adaptability of the clamp. It can be adjusted to fit vessels ranging from approximately 22' to 30' in length. The fourth specification was that the entire system be self contained. Once an organization has purchased all of the components listed in the Assembly Instructions, the Surface Oil Skimmer would be effectively self-contained. Finally, the Surface Oil Skimmer needs to be cost effective. The entire system would cost approximately \$17,858.00 to manufacture and operate. This figure neglects any profit to be made by the manufacturer, however. This is a reasonably inexpensive solution when compared to other methods already in use.

For our specific design, there were a few areas which could be improved. First, the boom attachments need to be more adaptable to different size boom. The boom attachment at the end of the arm is a good example of an adaptable attachment. Second, the clamp needs to be equipped with a stronger clamping mechanism. As mentioned previously, an acme thread should be used in place of the conventional thread used for the power screw of the prototype. Also, a thicker power screw would be more effective at preventing bending. The flotation device needs to be more bouyant forward of the arm attachment. This would offset the torque produced by the outside boom attachment. The float also needs to be securely fastened to the arm so that it stays parallel to the boat. Finally, higher quality booms should be used in order to insure that the oil is not able to flow underneath them.

The Surface Oil Skimmer group was successful in designing an operating system that met all objectives set at the start of the project.

# COST ESTIMATE



# ACTUAL SOS BUDGET 92-93

## Assembly & Control of Arm \$800.00

<u>Date</u>	<u>Description</u>	<u>Where Purchased</u>	<u>Amount</u>
3/12	Aluminum Matl's	Northstar	\$212.75
3/12	Clamp Matls	McMaster	\$ 52.98
4/16	Cutting Matls	Kingsbury Machine Shop	\$180.00
4/16	Welding Matls	Space Science Center	\$150.00
4/23	Fiberglass Float	Eastern Marine	<u>\$ 75.00</u>
			\$670.73

## Skimmer Operation & Oil Collection \$1000.00

<u>Date</u>	<u>Description</u>	<u>Where Purchased</u>	<u>Amount</u>
3/5	DC Vane Pump	Eastern Marine	\$ 159.60
3/12	55 Gallon Drum	OIL MOP, INC.	\$ ---
4/2	Nickel Plated Chain	Bearings, Inc.	\$ 73.65
4/8	Variable Speed Motor	ElectricMotorServicenter	\$411.34
4/22	AC Mudsucker Pump	B. Celikkol	\$ ---
4/27	Return DC Vane Pump	Eastern Marine	-\$140.00
4/27	Petroleum Hose	Omni & Tool Crib	<u>\$368.75</u>
			\$873.34

## Miscellaneous \$200.00

<u>Date</u>	<u>Description</u>	<u>Amount</u>
October	Trip to JBF	\$ 24.21
March	Phone Charges	<u>\$ 3.96</u>
		\$ 28.17*

Total Alloted	\$2000.00
Total Spent	<u>\$1572.24</u>
Total Remaining	\$ 427.76

\*Some miscellaneous charges have not yet been submitted.

# SOS ESTIMATED PRODUCTION BUDGET

SKIMMER	\$15,000.00
BOOMS	\$ 308.00
ARM including the boom attachment	\$ 200.00
CLAMP	\$ 600.00
FLOTATION DEVICE including the manufacturing of the model for the fibreglassing	\$ 100.00
PUMPING SYSTEM includes the pump, the hosing, and necessary fittings	\$ 900.00
POWER SUPPLY	\$ 600.00
MISCELLANEOUS includes rope, assembly tools, and extra nuts and bolts	\$ 150.00
<hr/>	
TOTAL	\$17,858.00

NOTE: This price excludes the operation of the boat and the labor needed to assemble and deploy the SOS.

# ASSEMBLY INSTRUCTIONS

# LIST OF COMPONENTS

1. DIP skimmer
2. Two lengths of boom: 12 ft and 16 ft
3. 14.5 ft arm
4. Flotation device capable of supporting arm and outer boom
5. 20 feet rope with an ultimate strength of at least 500 lb. for a bow line
6. SOS clamp
7. Two petroleum hoses with lengths of 18 ft and 8 ft
8. Diaphragm or Trash pump
9. 3/4 hp generator with continuous duty operation
10. Crescent wrench
11. 55 gallon oil drum
12. Winch
13. Spare gas for generator
14. Extra nuts and bolts

# VESSEL REQUIREMENTS

1. Boat needs to be in the range of 22 to 30 feet in length.
2. The gunnel width should be between 7.5 and 15 inches.
3. The minimum deck space required is 80 square feet.
4. A crane or pulley system is optional for easy in maneuvering the skimmer.

# INSTRUCTIONS

1. Blow-up pontoons and connect boom lengths
2. Load equipment on boat
3. Check component list
4. While moving to oil spill, attach all parts:
  - booms to skimmer
  - pontoons on skimmer
  - boom to arm
  - boom to clamp
  - arm pieced together
  - flotation on arm
  - bowline from arm to winch
  - tubing from skimmer to pump
  - tubing from pump to drum
  - plug pump and speed control box into generator
5. Start warming up generator
6. Attach clamp
7. Place skimmer in water
8. Attach arm to clamp
9. Tighten bow line
10. Turn skimmer and pump on
11. Adjust belt speed
12. Maneuver on edge of spill heading towards center of spill
13. Maintain tension on bow line
14. Skim until drum is full
15. Empty oil into some sort of storage or switch to a new drum if necessary
16. Bring in equipment in reverse order of deployment

# APPENDIX

## CALIBRATION OF SPEED CONTROL BOX

Length of Belt (ft) = 7.875

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>30</b>	1	1	56.25	0.140	0.24
	2	1	57.33	0.137	0.23
Ave. Speed (knots) =					<b>0.24</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>40</b>	1	1	24.88	0.317	0.54
	2	1	25.22	0.312	0.53
	3	1	24.76	0.318	0.54
Ave. Speed (knots) =					<b>0.54</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>50</b>	1	1	14.02	0.562	0.95
	2	1	13.82	0.570	0.97
	3	1	13.54	0.582	0.99
Ave. Speed (knots) =					<b>0.97</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>60</b>	1	1	9.47	0.832	1.41
	2	1	9.43	0.835	1.42
	3	1	9.44	0.834	1.42
Ave. Speed (knots) =					<b>1.42</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>70</b>	1	1	7.07	1.114	1.89
	2	1	7.08	1.112	1.89
	3	1	7.09	1.111	1.89
Ave. Speed (knots) =					<b>1.89</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>80</b>	1	2	11.62	1.355	2.30
	2	2	11.37	1.385	2.35
	3	2	11.49	1.371	2.33
Ave. Speed (knots) =					<b>2.33</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>90</b>	1	2	10.44	1.509	2.56
	2	2	10.32	1.526	2.59
	3	2	10.3	1.529	2.60
Ave. Speed (knots) =					<b>2.59</b>

SETTING	TRIAL	REVOLUTIONS	TIME(sec)	SPEED(ft/sec)	SPEED (knots)
<b>100</b>	1	2	10.25	1.537	2.61
	2	2	10.24	1.538	2.61
	3	2	10.24	1.538	2.61
Ave. Speed (knots) =					<b>2.61</b>

**TABLE A.1**

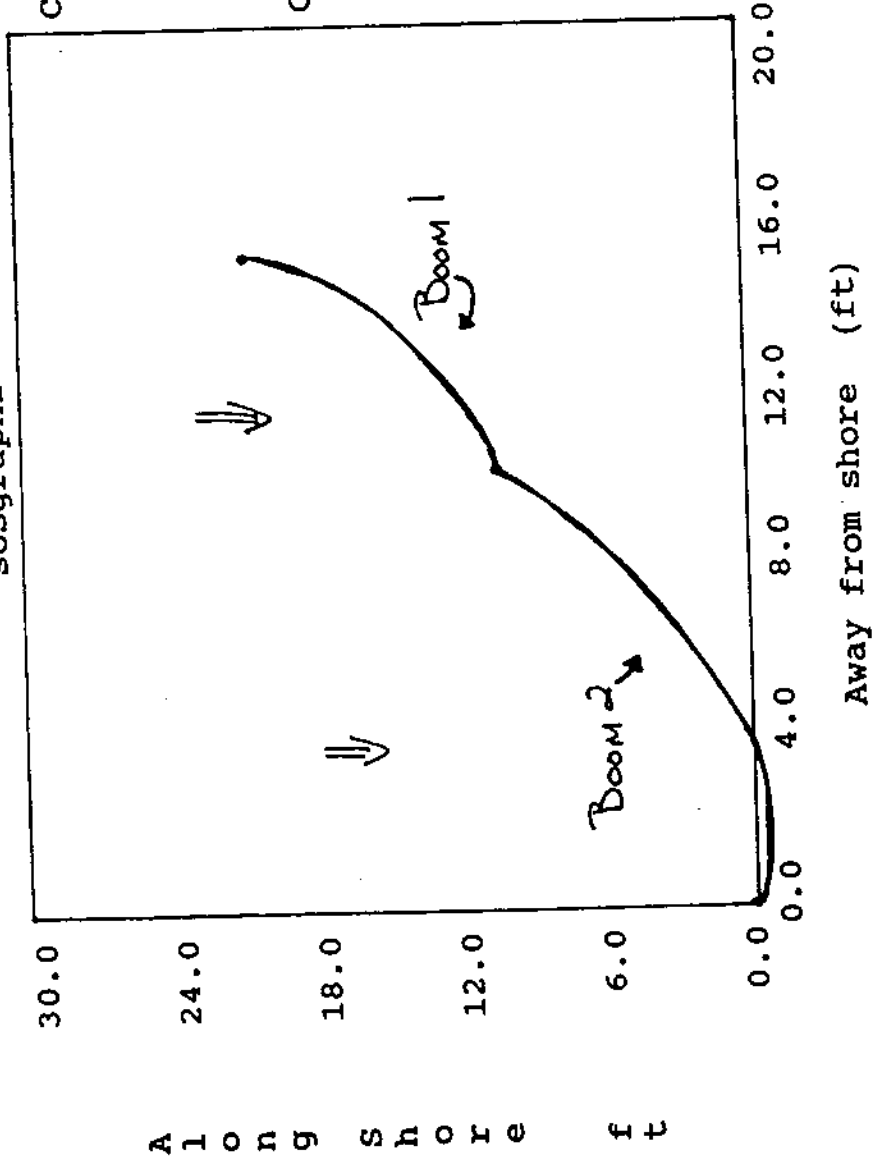


sosgraph1

Constants:  
Cd = 1.8  
skirt = 1.25 ft  
density = 63.7 lb/ft<sup>3</sup>

Currents:  
1: 3.0 knots at 0.0 $\frac{1}{2}$   
2: 3.0 knots at 0.0 $\frac{1}{2}$

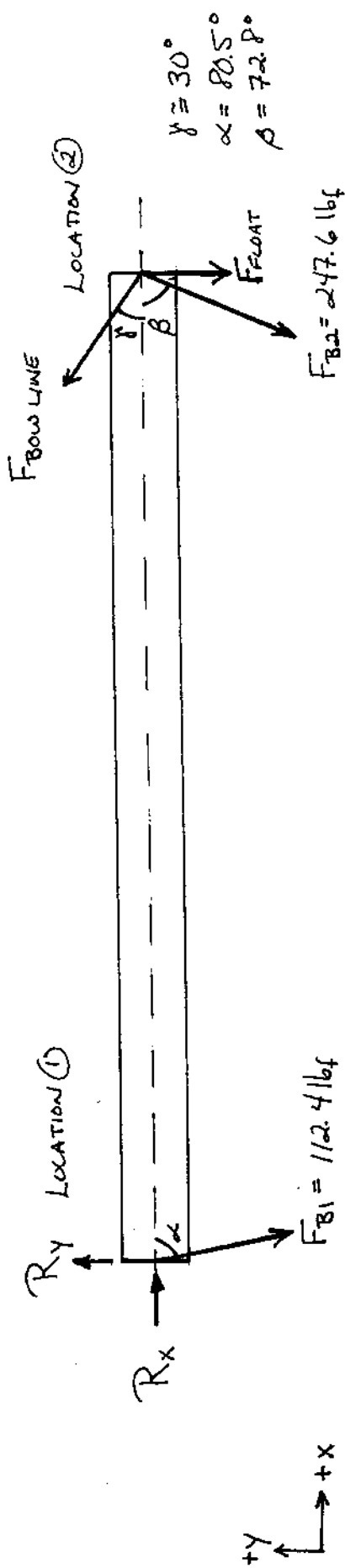
↘ = Direction of current.



Shift-Printscrn to print

Figure A.8

# STRESS ANALYSIS OF ARM



$\vec{V} = 3 \text{ knots}$

DRAG FORCE ON FLOAT ( $F_{\text{FLOAT}}$ ):

$$F_{\text{FLOAT}} = \frac{1}{2} C_D^* \rho \vec{V}^2 A$$

$$= \frac{1}{2} (1.2) \left[ 63.7 \frac{\text{lb}_m}{\text{ft}^3} \times \frac{\text{lbf sec}^2}{32.2 \text{ lb}_m \text{ ft}} \right] (1.76 \frac{\text{ft}}{\text{sec}})^2 (1 \text{ft}^2)$$

$$F_{\text{FLOAT}} = 3.7 \text{ lbf} \quad (* C_D \text{ from Fluids Fig. 9.10})$$

WORSE CASE:  $F_{\text{FLOAT}} = 10 \text{ lbf}$

LOCATION 2

$$\Sigma F_y = 0 = (F_{\text{BOW LINE}}) \sin \delta - F_{\text{FLOAT}} - (F_{\text{B2}}) \sin \beta$$

$$F_{\text{BOW LINE}} = 493.1 \text{ lbf}$$

$$\Sigma F_x = - (F_{\text{BOW LINE}}) \cos \delta - (F_{\text{B2}}) \cos \beta = -500.2 \text{ lbf}$$

LOCATION 1

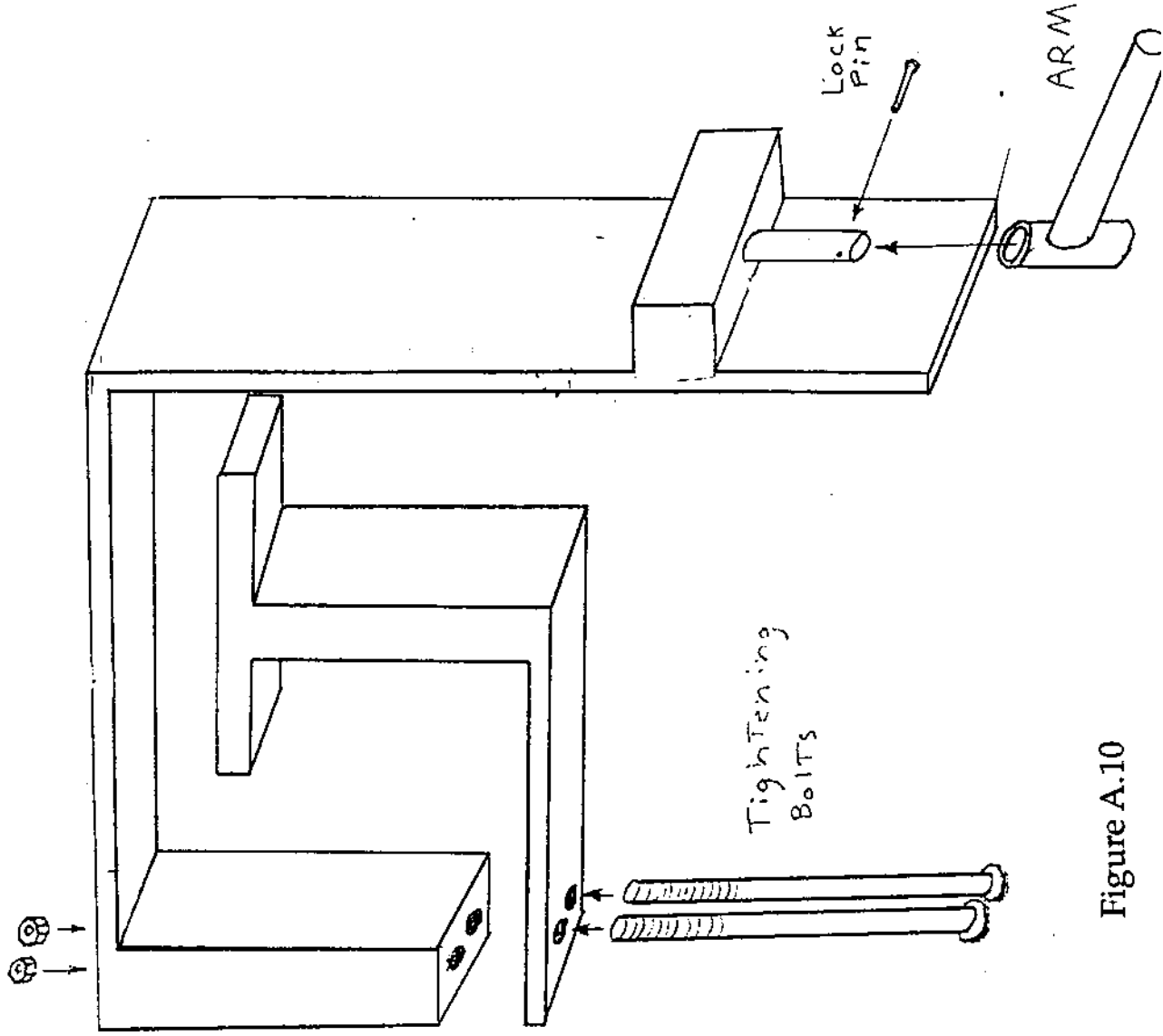
$$\Sigma F_y = 0 = R_y - (F_{\text{B1}}) \sin \alpha \quad | \quad R_y = 110.9 \text{ lbf}$$

TOTAL ARM

$$\Sigma F_x = 0 = R_x + (F_{\text{B1}}) \cos \alpha - F_{\text{X0}} \quad | \quad R_x = 481.7 \text{ lbf}$$

Figure A.9

Conceptual Design of Clamp  
(Not To Scale)



Cross Section  
Of Boat

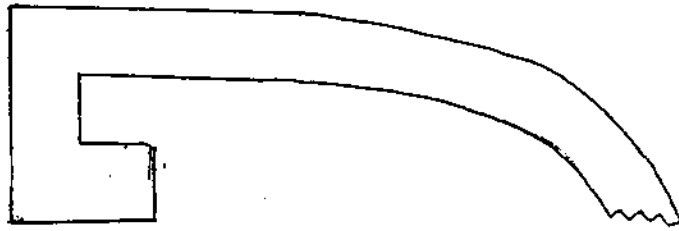
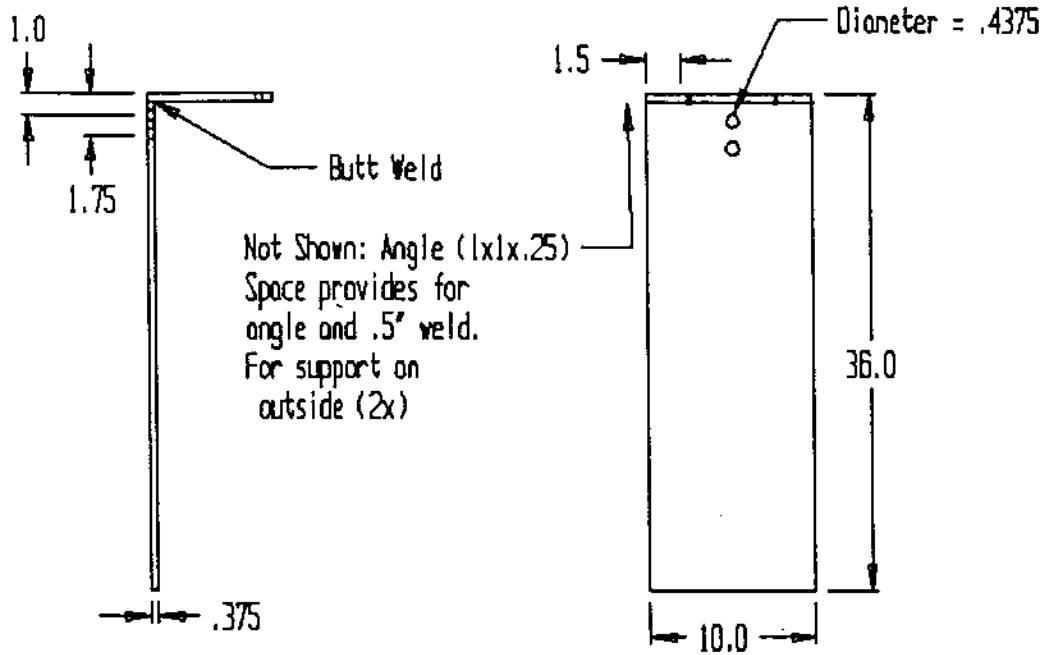
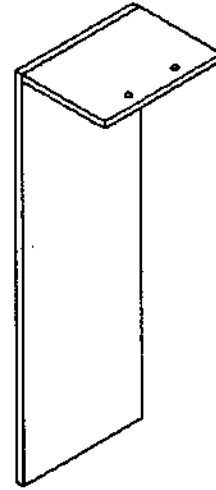
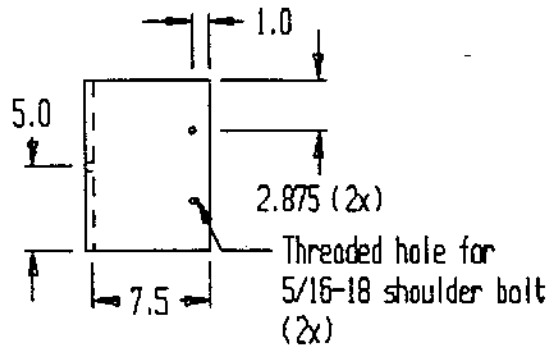


Figure A.10

Material: Aluminum  
 Dimensions: Inches



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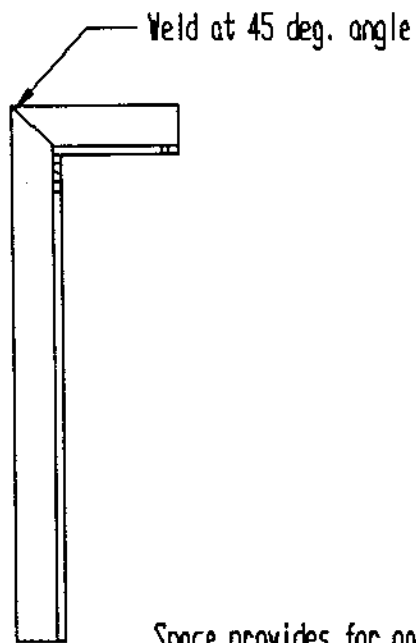
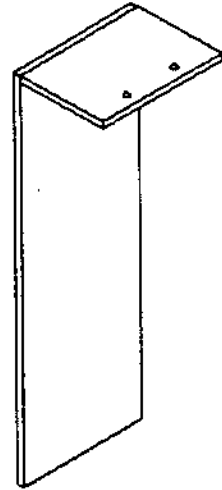
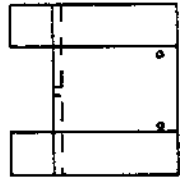
Title: Clamp (Figure 1)

Name: Nathaniel M. Stanton  
 Date: February, 1993

Plate  
 No. 1

Figure A.12

Material: Aluminum  
Dimensions: Inches



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Title: Angle Reinforcement of Clamp  
Din: 1x1x.25

Name: Nathaniel M. Stanton  
Date: February, 1993

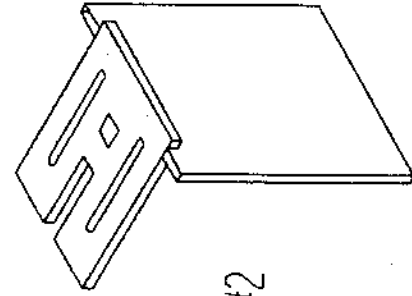
Plate  
No.2

Figure A.13

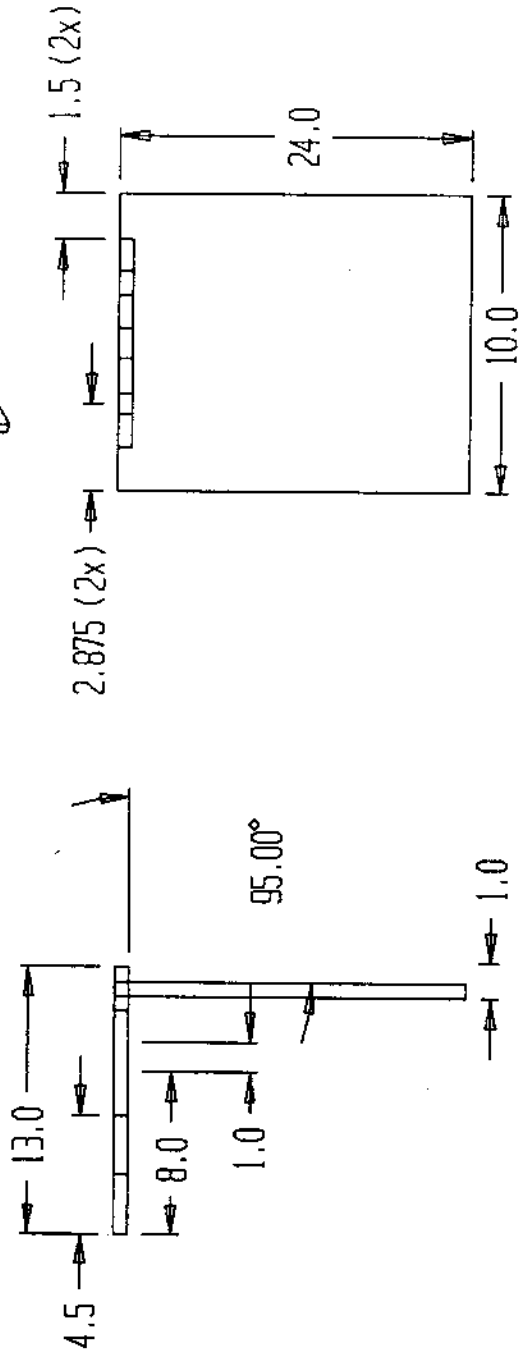
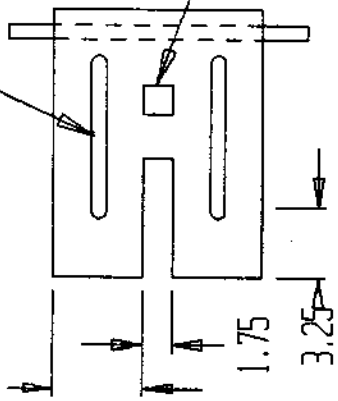
Mat.: Aluminum  
 Thick.: 0.375  
 Dim.: Inches  
 Not to Scale

Hole: Diam. = 0.5  
 Length (cc) = 8.0

Space for Block #2  
 Dim: 1.0x1.5x1.5



2.625 (2x)



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Title: Clamp (Figure 2)

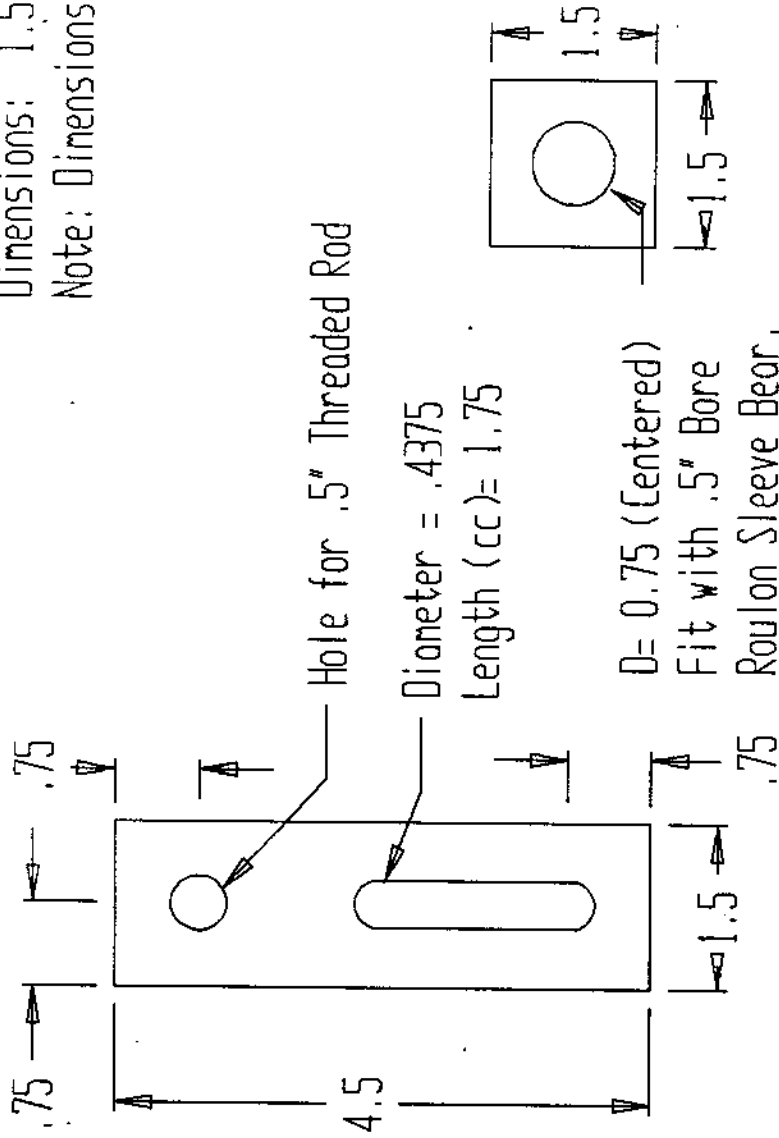
Name: Nathaniel M. Stanton

Date: March 1993

Plate  
 No. 3

Figure A.14

Material: Aluminum Bar Stock  
 Dimensions: 1.5 x 1  
 Note: Dimensions in Inches



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Title: Clamping Blocks for Screw

Name: Nathaniel M. Stanton

Date: March 1993

Plate  
 No. 4

Figure A.15

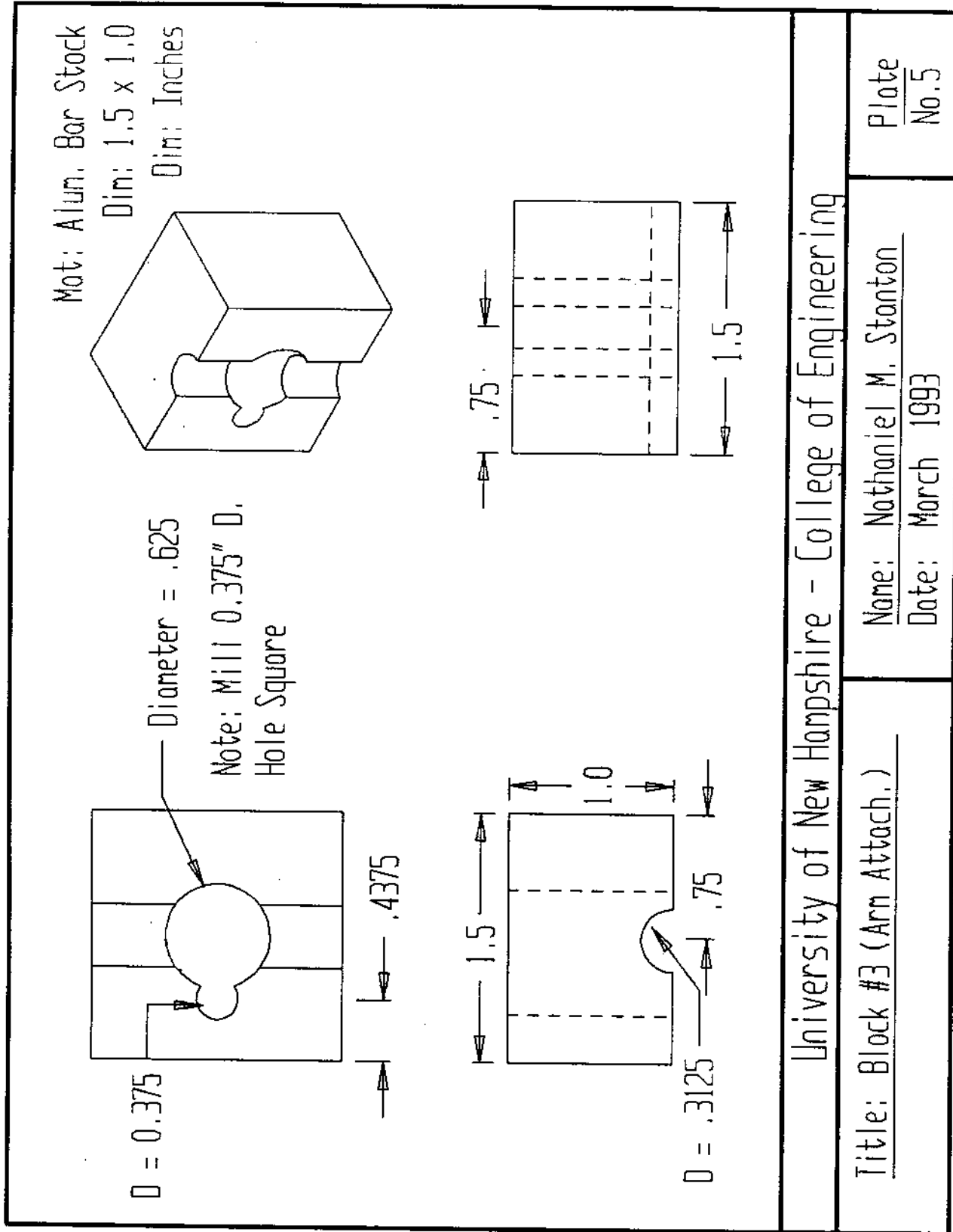
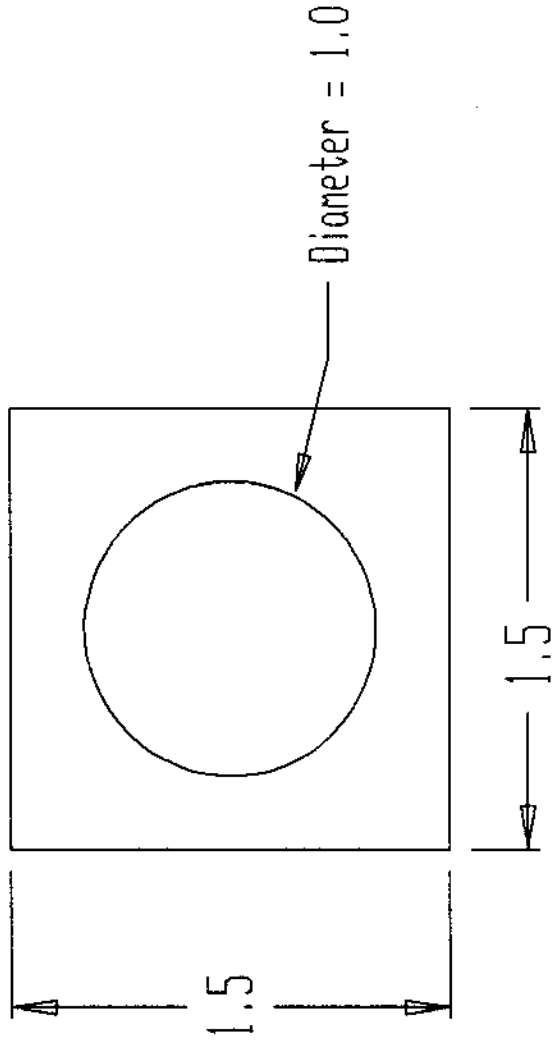


Figure A.16



Material: Aluminum Bar Stock  
Dimensions: 1.0 x 1.5  
Dimensions in Inches



University of New Hampshire - College of Engineering

Title: Block (Arm Attach.)

Name: Nathaniel M. Stanton  
Date: March 1993

Plate No. 6

Figure A.17

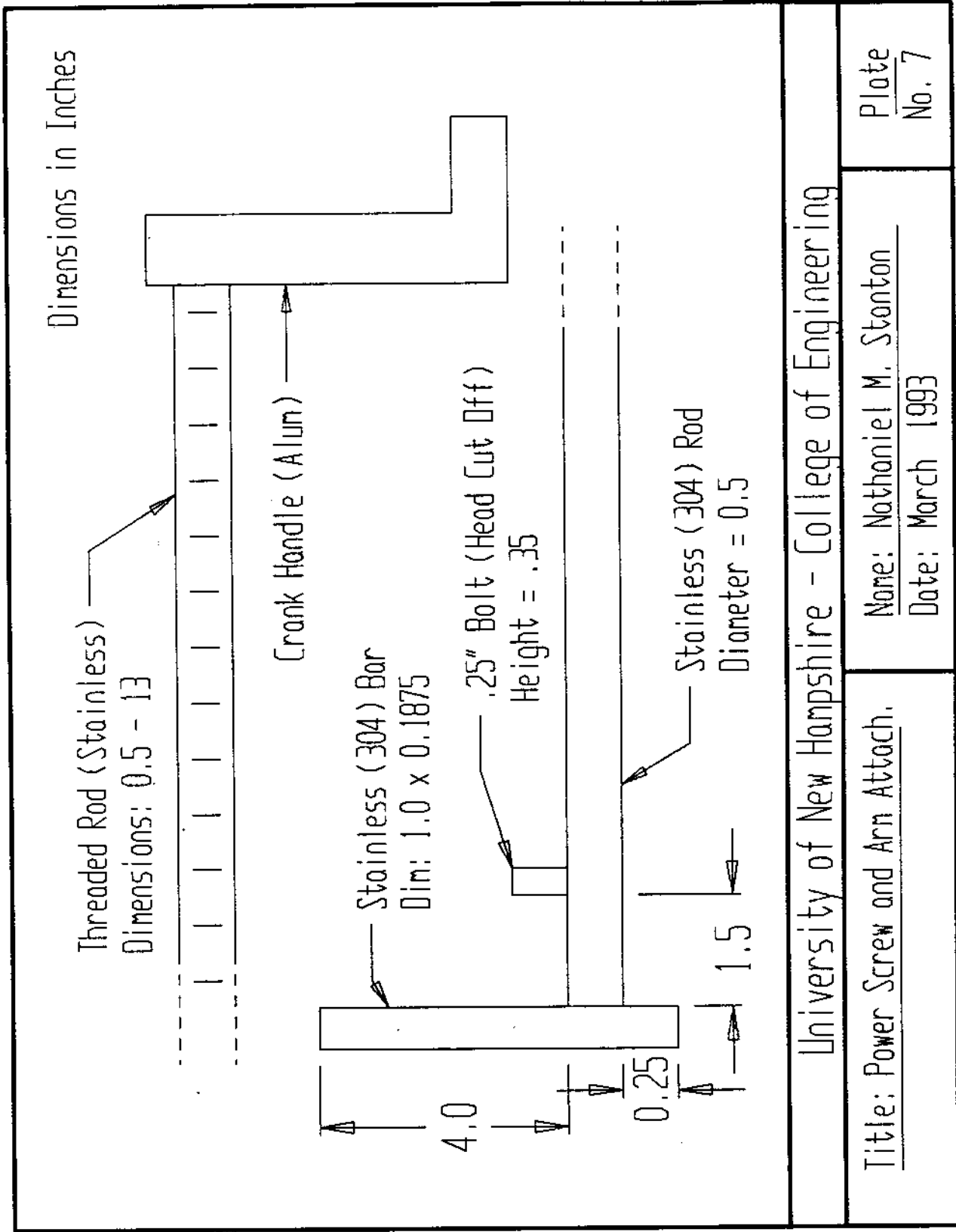
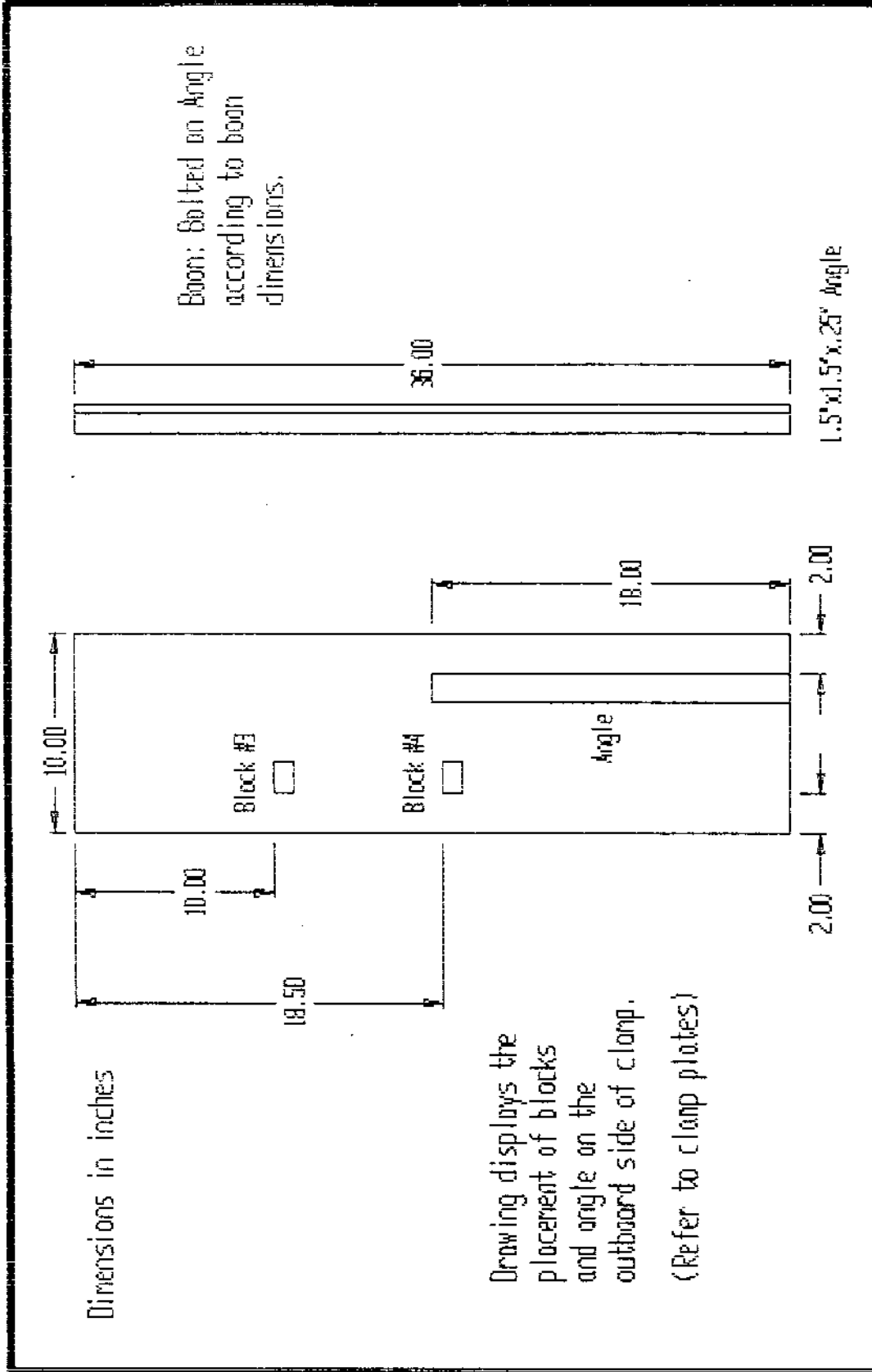


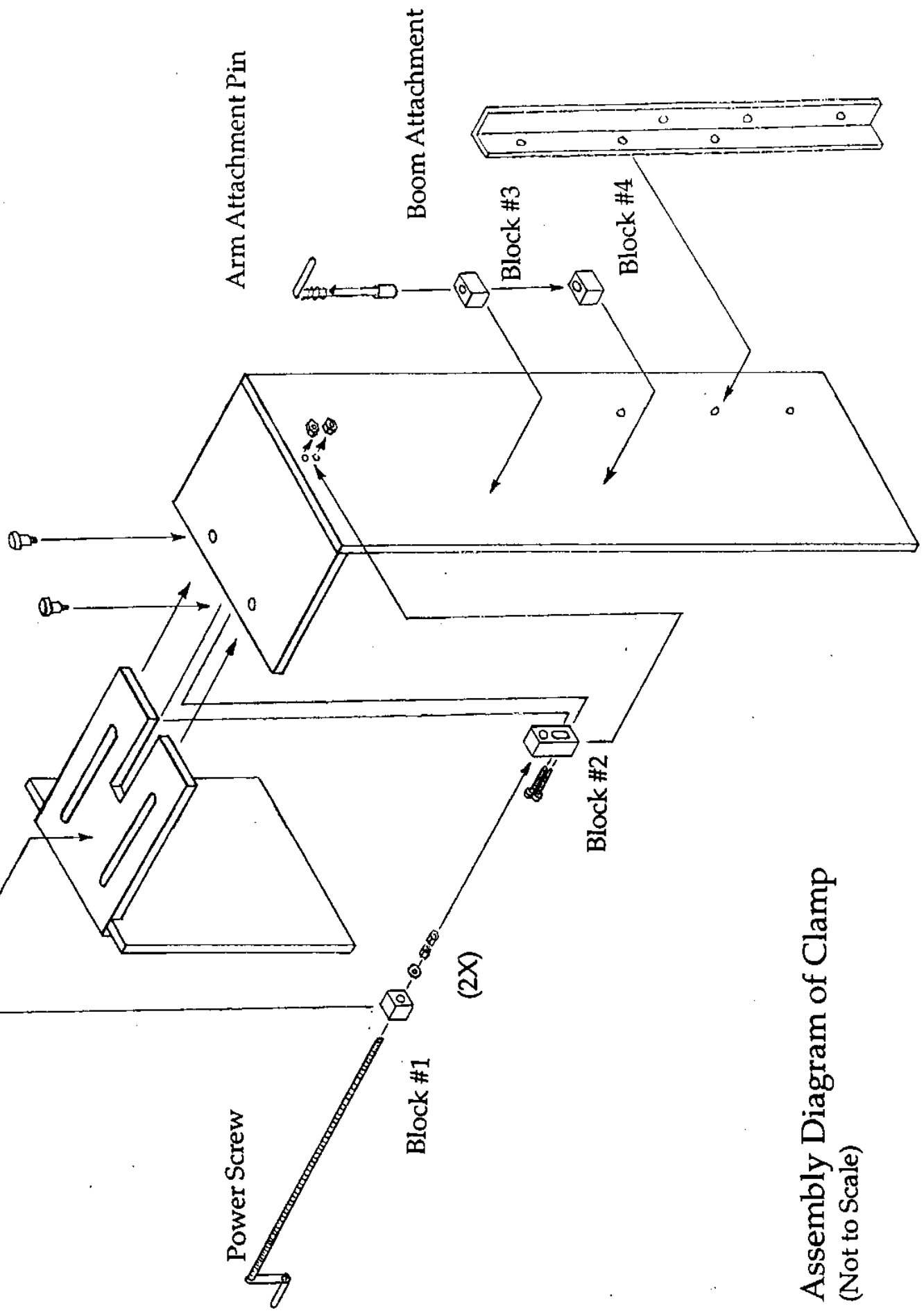
Figure A.18



University of New Hampshire - College of Engineering

Title: Placement Diagram	Name: Nathaniel M. Stanton Date: April, 1993	Plate No. 8
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Figure A.19



Assembly Diagram of Clamp  
(Not to Scale)

Figure A.20