RESTORATION OF OCEAN IMAGERY

ROI '90

ADVISOR - DR. RICHARD A. MESSNER

LEADER - HEATHER CONLKIN

RALPH BEUTEL

TRACIE CLARKE

PAUL FRIEDMAN

SCOTT JENNATO

Acknowledgment

The ocean projects group ROI like to thank the following people for their generous donations towards the completion of our project:

Mr. Paul Dobbins of OLYMPUS CORP.
Mr. Dave Dunfee of D.G. O'BRIEN, INC.
Mr. George Hamilton of CALIBRATION TECHNOLOGY
Mr. Robert Levin of GTE SYLVANIA
Ms. Marinna Martini of OCEAN PROCESS ANALYSIS LABORATORY
Prof. Joseph B. Murdoch
Asst. Prof. Richard A. Messner

Table of Contents

LIST OF FIGURES

ABSTRACT

DEVELOPMENT OF AN UNDERWATER VIDEO IMAGING DATA BASE OF THE GREAT BAY ESTUARY

by

Project R.O.I.
University of New Hampshire, May, 1990

Visual image acquisition and processing is becoming more and more important in underwater scientific research and exploration. Currently there is limited information regarding underwater imagery in the Great Bay Estuary. Because of this, a submersible test bed structure consisting of a movable camera focused on a chart via fixed distances was constructed in order to establish a data base consisting of relationships between the clarity of underwater video imaging and distances through uncontrollable turbid channels.

With the development of such a database, these video images can then be enhanced through digital processing. Effectively, this research could be used to develop algorithms for video enhancement which in turn may assist in future underwater research.

Section 1

Introduction

1.1 Overview

ROI - Restoration of Ocean Imagery is a team of five undergraduate engineers who have dedicated the past 9 months to creating a data base of underwater ocean images. This team was advised by Professor Richard A. Messner, an Electrical Engineering professor specializing in Digital and Optical Signal Processing. The University does not have any data bases of ocean images. Professor Messner saw the need for this kind of data for underwater image restoration as applied to autonomous underwater vehicles. Great Bay was chosen as the target location because of the variety of turbid conditions and its proximity to UNH.

As strides are made to develop a totally autonomous underwater vehicle a lot of research is going to be needed to find exact relationships between the amount of turbidity in water and the distortion of an image being viewed or recorded. The reason why this type of research is important is because when a vehicle is truly autonomous everything that the vehicle does must be decided by the vehicle. The human eye can not be used to examine what is in front or around the vehicle to determine if it is safe for the vehicle to proceed or change its direction. Instead a vehicle must be capable of 'seeing' around itself, cleaning up the image it receives and making decisions based upon what it is 'seeing'. Here it starts to become clear why a relationship between the amount of turbidity in water and the distortion caused by the turbidity is so important. If a vehicle is in very turbid water it may not be able to see a mass until it is only a foot or less in front of it. At this point it may not have enough time to stop before hitting the object and causing severe damage to itself.

If the vehicle could measure the amount of turbidity in the water and relate it to the correct filtering equation on a continuous basis it would 'see' objects in the water with more time to change its course so as not to hit the object. This is of course only one practical use for our data but this example shows the present need for this kind of data base.

When deciding what the data base should contain it was agreed that there are specific parameters that we would be interested in and we would have to figure out if there are any other parameters that someone else, using the data, would need for their analysis. We came up with a very comprehensive list of variables. The result section of this report will contain tabulated lists of all of the variables we measured. These variables include; location in the bay, distance from the camera to the chart, depth of the camera, time of day, turbidity of the water, state of the tide, weather, and temperature of the water.

1.2 Approach

The initial problem which the ROI group faced was to obtain all of the instruments that would be needed to build the data collecting structure. A number of items were initially identified as necessary. These included; a camera, a VCR, a resolution chart, and lights. Many initial contacts were made in the hope to purchase all of the equipment. It was soon discovered that the allotted budget would not be enough to purchase everything so a new approach was taken. This approach was to borrow as much equipment as possible.

Another aspect was soon introduced into the project. If the data we would be taking was going to be in water with different levels of turbidity the amount of turbidity should also be recorded. This added dimension proved to be the most difficult to achieve as will be seen later in the paper although it can be said now that, the cost to purchase a turbidity meter was far too high for our budget and it is not an instrument that is in vast use or supply within this university.

Before all of the instruments were sought out some defining principles were decided upon. It was decided that a platform would be built to lower all of the under water equipment. This idea was adopted because we assumed it would be easier to set exact distances between the camera and resolution chart with both pieces of equipment attached to one structure. When it came to the kind of camera to use the two options were to find a camcorder or a camera that would send remote signals to the surface to be recorded. The remote camera was chosen because it could be controlled on the surface unlike the camcorder and the images that would be recorded would be of much higher quality. The lighting system that would be used required a bit of research, which will be discussed later in this paper. The decision was made to go with conventional spot lights with a narrow beam. These lights would need to be water proofed.

Unfortunately we did not have the same decision making power in choosing the turbidity meter. In this area we had to take what we could get.

After all of this equipment was received and put together, how the data base would be collected had to be decided. In order to determine how long the structure should be we took some pictures in a tank that was filled with turbid water. By moving the camera back and noting the distortion of the image we chose a maximum distance of eight feet for the distance we would take images at. We decided to take data at two feet intervals away from the resolution chart until the image could no longer be seen or until the end of the structure is reached. The depths we would lower the structure to would depend upon how deep the water is at the locations we choose. We did decide that we would not take data deeper than 35 feet since most of the bay is not deeper than 35 feet. This depth could then be used as a maximum in pressure calculation and a guideline for the lengths of the cables that would run from the structure to the surface.

This report will give an in-depth analysis of how all of these decisions were made, the problems that were encountered and improvements that could be made if it was to be done again. The report is broken up into five sections; structure design, camera system, lighting system, data acquisition, and finally image processing. The three points that were just mentioned will be discussed in each section for completeness. The report will be rounded out by making overall conclusions on the completion of the project and what we learned during the course of the past nine months.

Section 2.0

Turbidity for R.O.I.

2.1 Background

Restoration of Ocean Imagery (ROI) involves the recording of underwater video images. One of the key factors of interest to our project is how much the video picture is distorted by the surrounding water. We needed a quantifier that would give us a relationship between how much the video signal is obscured by the matter floating in front of the video camera. This quantifier is called turbidity which is defined below and differentiated from the term suspended solids. "Turbidity is the "cloudiness" in water produced by light scattered from suspended particles, colloidal materials, and droplets of oil. Turbidity is an apparent optical property that depends on the particle characteristics, lighting conditions (eg. night/day - fluorescent/incandescent), inherent properties, and the instrument used to measure it. ... Suspended solids are materials that can be separated from the water sample and accurately weighed to give a precise mass concentration expressed in parts per million (ppm) or milligrams per liter (mg/l)."[1] (D&A Instruments,TECHNOTE 3/89, pg 4) Turbidity is a difficult quality to measure accurately since the water is far from homogeneous. Also, the turbidity is not constant over time at the same location. The turbidity data can vary greatly over a single day by the incoming and outgoing tide in the estuary. The turbidity measured for this project was done by a sensor called Optical Back-scatterance Turbidity Monitor (OBS^tm) from Downing & Associates Instruments and Engineering. "OBS^tm sensors are miniature nephelometers that measure infrared radiation (IR) scattered by particles in the water at angles ranging from 140° to 165°."[1] (D&A Instruments,TECHNOTE 3/89, pg 2) University of New Hampshire Ocean Process Analysis Laboratory group (OPAL) uses an instrument package called CTD which includes a D & A turbidity sensor. Besides the turbidity sensor (Downing) this package includes Conductivity, Temperature and pressure sensors. Figure 2.1 is a system diagram of turbidity data collection.

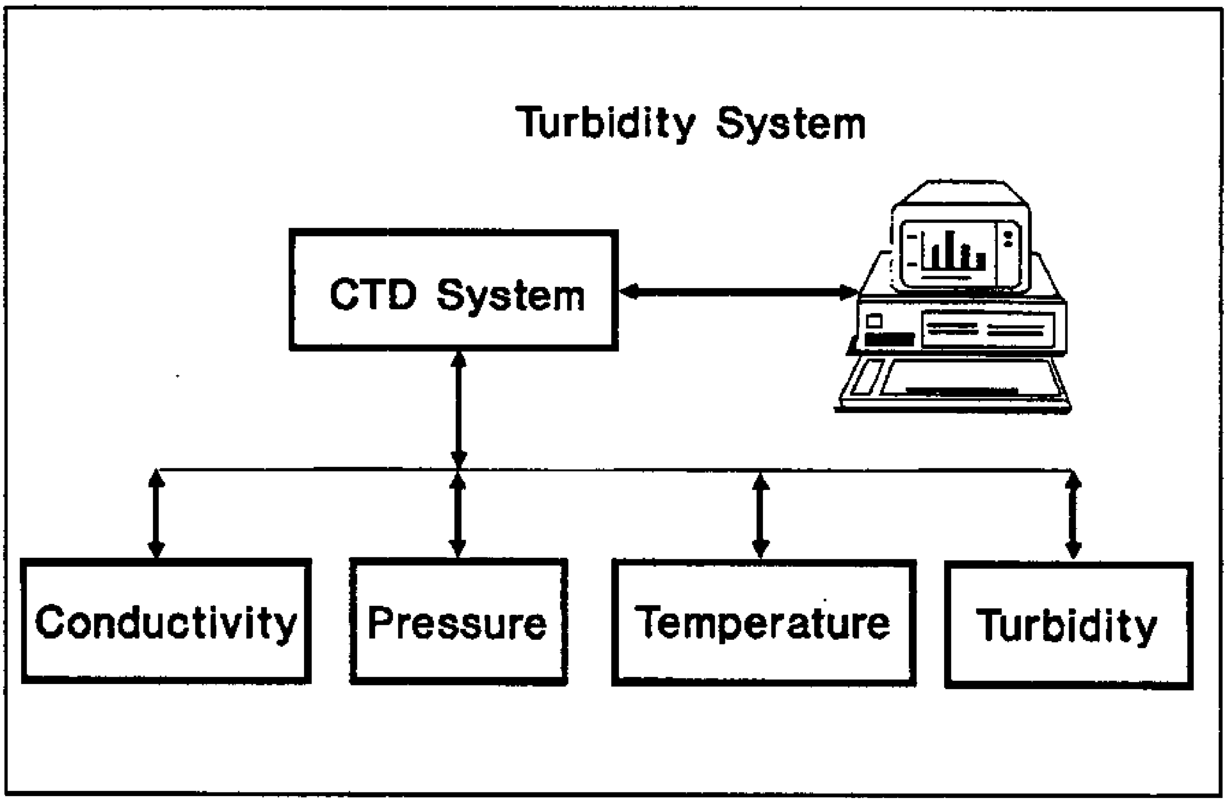


Figure 2.1 System Diagram of the Turbidity Data Collection

2.2 Turbidity for Restoration of Ocean Imagery

Our team choose to measure turbidity and measure it with the OBS^{tm} sensor for various reasons.

The choice to measure turbidity came with the definition of the projects goal and with the initial research done by the group. Turbidity measures the "cloudiness" of the water which is basically an optical quality. We wanted to provide for future research a quantifier of this quality. With this scientists would be able to draw up a ratio between the video picture's distortion and the suspended matter floating in the water between the resolution chart and video camera. We looked into three different options on how to accomplish our turbidity measurements: first, we could built our own turbidity sensor; second, we could buy the sensor, and third, we could borrow the sensor from another group. Our choice was based on the following

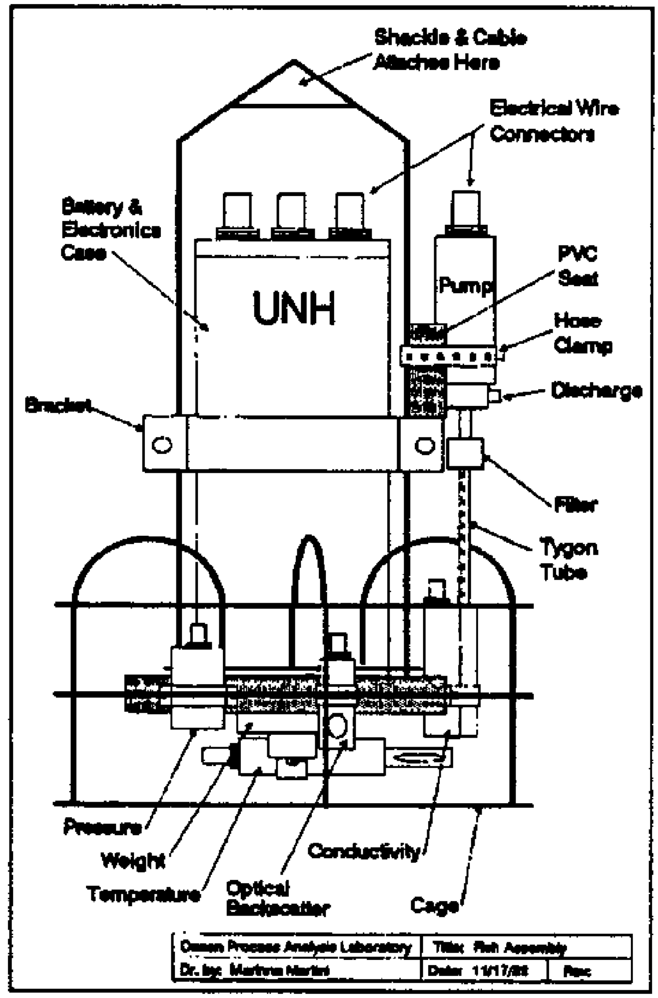


Figure 2.2 CTD unit from OPAL group

facts: our group had no experience in building a turbidity sensor which in itself could be an ocean project, buying the sensor would be expensive and beyond our budget; finally a turbidity sensor was available from another group at UNH. The OPAL group generously allowed us to use the CTD package which includes a turbidity sensor when ever they did not need it. Figure 2.2 shows the CTD package of the OPAL group.

2.3 Technical Overview of the OBS™ sensor and the CTD

The OBS™ sensor is a turbidity sensor which measures the "cloudiness" of the water. The sensor sends out infrared radiation and picks up the radiation that is scattered back to it from the water. The back-scatter of the radiation sent out by the sensor is influenced by the "cloudiness" of the water. The "cloudiness" is determined by how much mud, sand, vegetable matter and plankton is present as well as the size of the particles. In clear water the OBS™ beam pattern shown in Figure 2.3 is absorbed by 98% at 0.20 m. The instrument

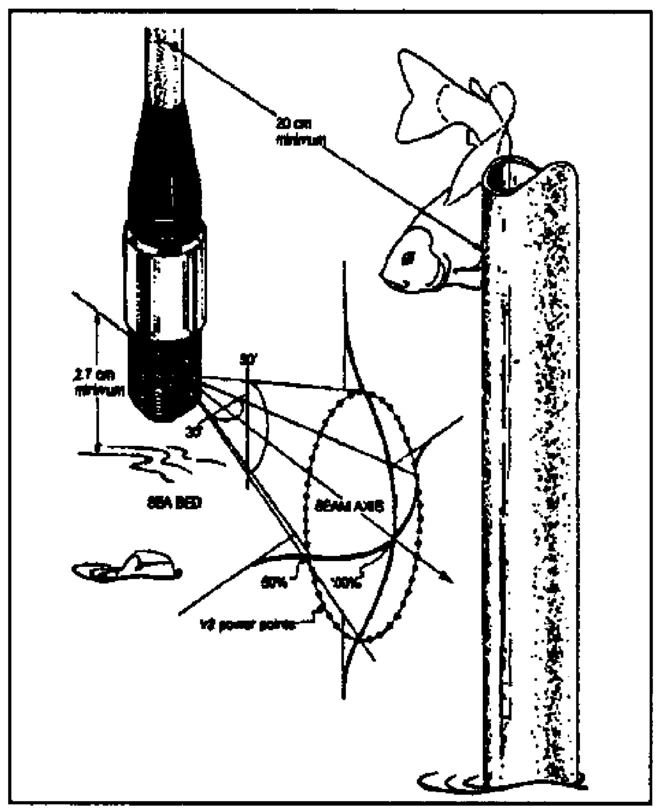


Figure 2.3 OBS™ Beam Pattern

produces a DC voltage signal which is proportional to the back-scattered energy it receives. The sensor is not affected by ambient optical energy in the water. Optical filtering and synchronous detection are used to eliminate these effects. The OBS™ sensor is best suited in medium turbid to muddy waters where its response is linear. (For more technical details of the OBS™ refer to the instruction manual.)[3] There are certain limits imposed upon the response by the hardware of the sensor and the CTD. Electrical noise and sensor signal instability which can distort low level voltage offsets. The analog to digital converter board of the CTD converts over a finite voltage range and is those limited.

The CTD is an independent unit from the structure of project R.O.I., it is lowered into the water separately from the camera structure for data collection. The CTD collects data samples from its sensors on the way going down and on the way up. The analog to digital card converts the samples into digital information and stores the data on its on board memory. The amount of memory allows the CTD up to 20 minutes of data collecting. With each cast the CTD collects a profile of the surrounding water. The CTD is only in communication with the PC compatible computer when it is on board the ship.

The water is not homogeneous therefore the CTD does not measure the turbidity of the water that is flowing in the channel of the camera system. The CTD measures a column of water for its turbidity levels at various depths; since the turbidity levels of each column of water varies, the average of all the columns would result in an average turbidity reading at each depth. The average turbidity at each water depth can then be compared to the average "cloudiness" of the video picture. For more technical details on the CTD refer to the OPAL manual on the CTD.[4]

2.4 Data acquired by the CTD Sensors

The first CTD data set was taken on April 4, 1990 at the position labeled in Figure 2.8. This data was taken at 14:00 hours and in a water depth of 11.6 m. The resulting turbidity graph in Figure 2.4 demonstrate that the OBS^{tm} sensor was not sensitive

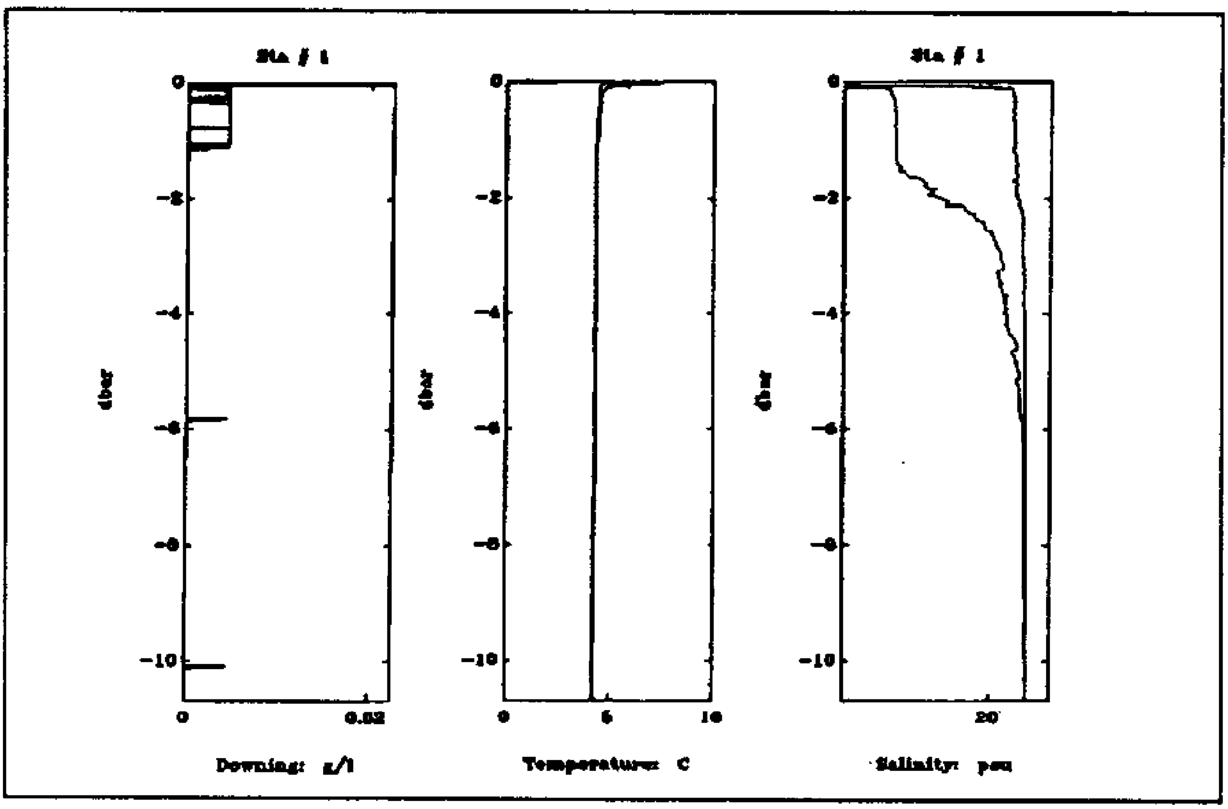


Figure 2.4 April 4, 1990 First CTD Data

enough to pick up the turbidity shown by the video images. The x-axis displays grams/liter and the y-axis displays the depth in db which can be read as meter. The other two graphs of Figure 2.4 show that the water temperature was constant but the salinity of the water changed drastically near the surface where the OBS[tm] picked up a little turbidity.

The salinity graph in Figure 2.4 explains to some extent the turbidity readings by showing the salt concentration of the water column. The graph shows two different lines, one beginning with low psu (popular salinity units) values, and then starting at two meters increases until it reaches a constant value. The other path

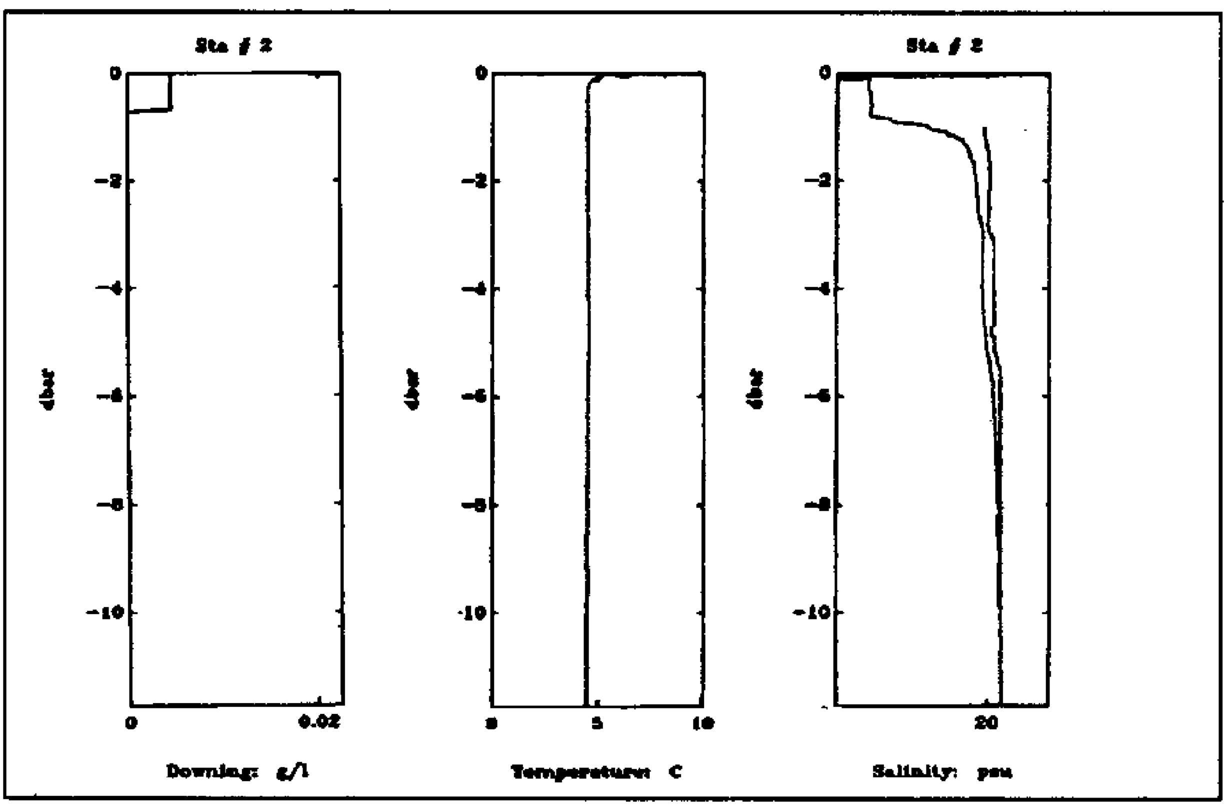


Figure 2.5 April 4, 1990 Second CTD Data

is at a constant value throughout the column of water. An explanation for this is that the surface layer of water was a pocket of muddy fresh water. The CTD taking data on the way down passed through that layer, but on the way up the boat drifted out of the pocket of fresh water giving the CTD a more constant salinity to sample. The second CTD reading shown in Figure 2.5, which was taken hours later, demonstrates that this is by no means an exception and that it reoccurs in the estuary. The turbidity sensor only picked up the muddy river water.

The results from the April 4 CTD measurements proved unsatisfactory compared to the muddy water seen by the video camera. The OBS^{tm} signal was to small for the analog to digital converter board of the CTD to be able to convert.

For, CTD measurements made on April 12, the signal from the OBS^{tm} board was put through an amplifier before it went to the analog to digital converter board of the CTD. For more details on the changes see Section 2.5. The location we chose on April 12 is shown in Figure 2.8, this position hopefully would give us more turbid water than the site chosen on April 4. The CTD data for Figure 2.6 was taken at 18:00 hours, in water at least 8.3 m deep. The video images recorded by ROI show that the water was indeed muddier than those from the previous spot. The turbidity graph was made from the raw data from the CTD. The x-axis displays the voltage and the y-axis displays the depth in db which can be read as meter. Since the sensor signal has been amplified, it also needs to be calibrated anew which would then allow us to convert the raw

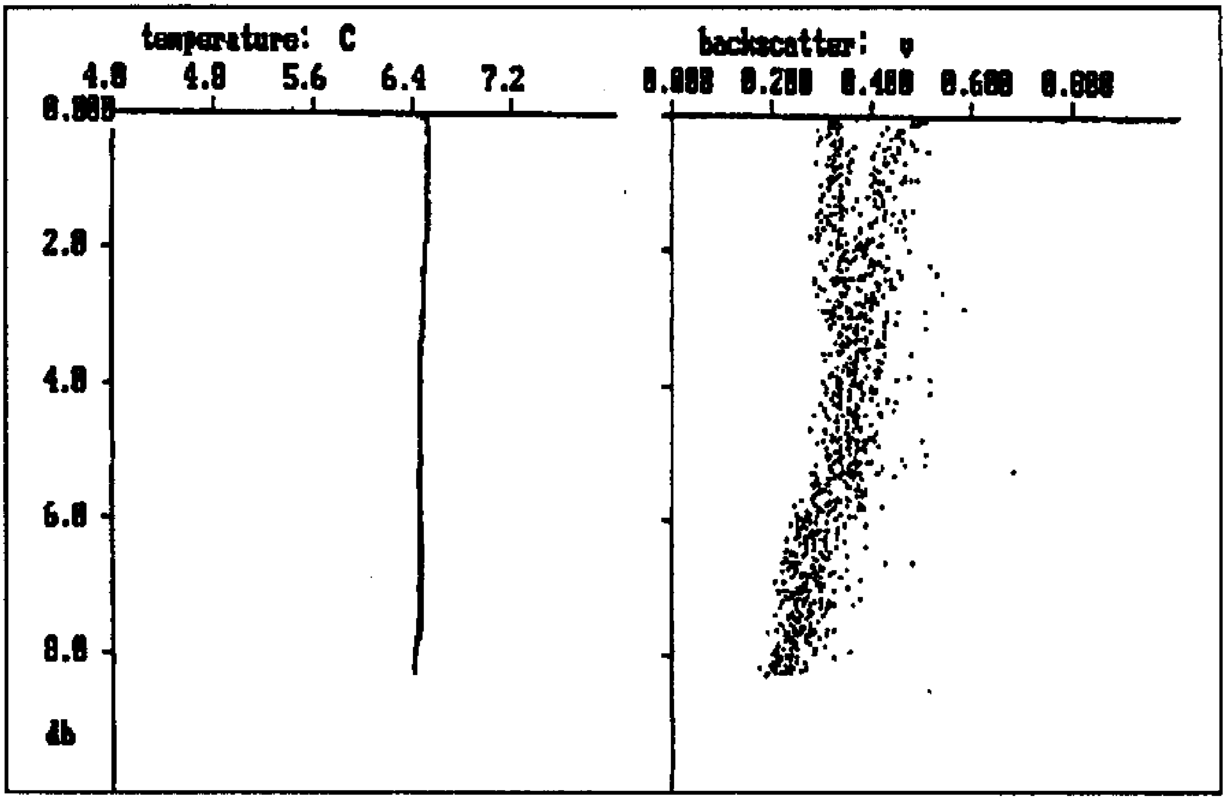


Figure 2.6 April 12, 1990 First CTD Data

data into the scales used in Figure 2.4 and 2.5. (See Section 2.5 on calibration)

The second CTD measurements shown in Figure 2.7 were taken at 19:45 hours at a water depth of 5 m, the tide was going out at the time. Comparing the two raw data graphs, Figures 2.6 and 2.7, shows us the back-scatter increased with the outgoing tide, especially at the surface. The shape of both back-scatter curves remains the same through the water depths, the curves show different levels of back-scatter. One could say from the graphs that the back-scatter increased linearly at each depth, but more data would be needed to support this.

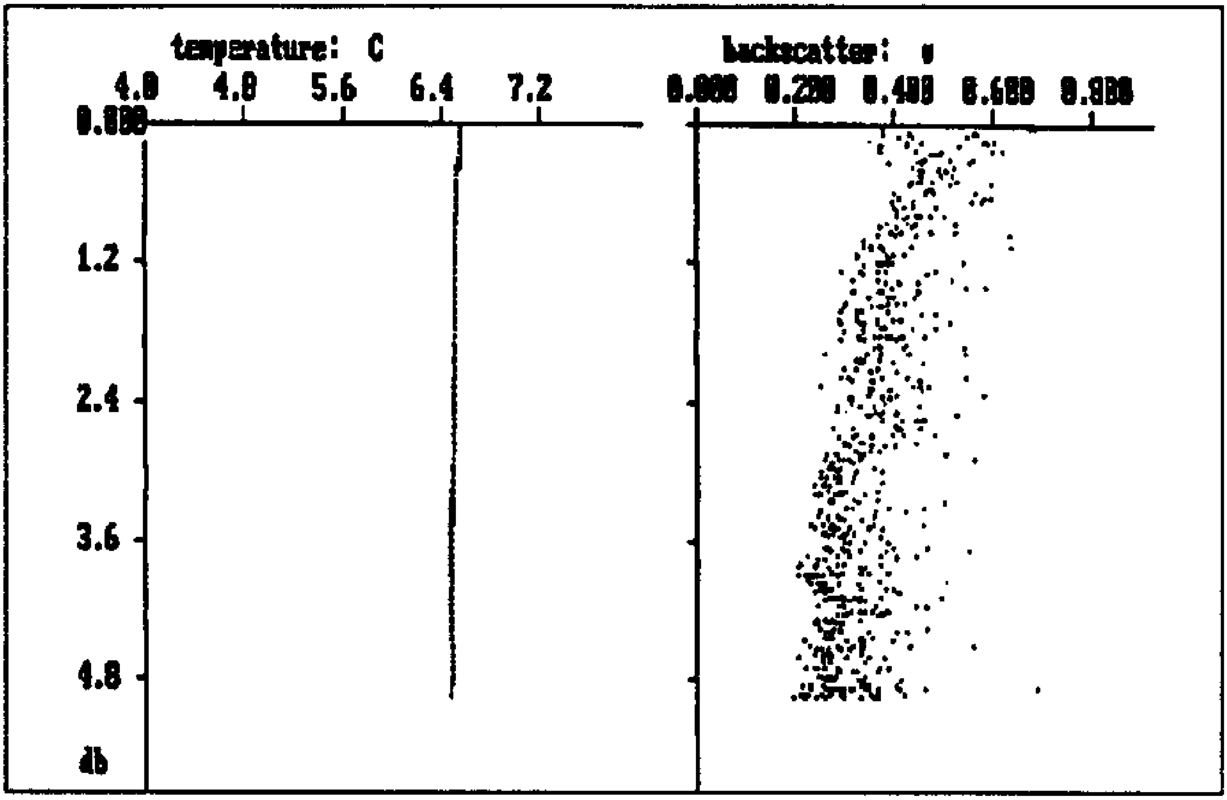


Figure 2.7 April 12, 1990 Second CTD Data

Section 2.5 Technical Changes on the OBS™ Output

The first water profile readings for project ROI with the CTD's Downing sensor proved not sensitive enough for the amount of turbidity present. Since according to the video images there was turbidity present the sensor signal was judged to be to weak to be converted by the CTD's analog to digital board. It was necessary to amplify the signal of the Downing sensor so that it could be detected. Hopefully, this would increase the sensitivity of the Downing sensor at the low end of the detection range. However, saturation of the analog to digital converter board could limit its use in high turbidity.

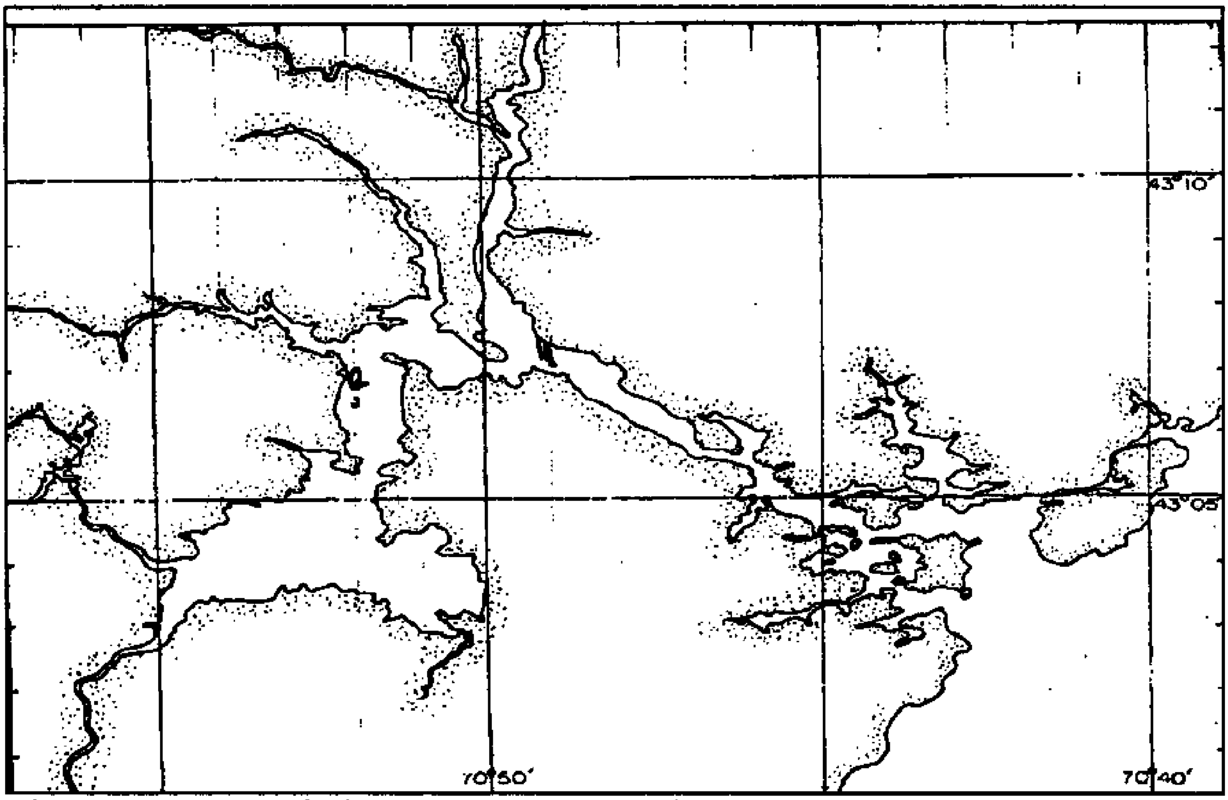


Figure 2.8 Turbidity measurement sites for April 4 and 12, 1990
APosition: 43°07'52"N 70°48'56"W Position: 43°06'38"N 70°51'27"W

The circuit was a simple low noise operational amplifier and to provide the necessary -5 volts power a voltage invertor. The CTD provide +5 volts to the amplifying circuit. The op-amp chip provided us with two operational amplifiers that could if combined amplify the signal be a factor of 121. The first try was done with the signal amplified 121 times, the result was that the signal was saturating the A/D board extremely fast. The testing was done out of the water first using a oscilloscope to compare the incoming wave verses the out coming wave. A second test was performed in a black walled water tank (to minimize the reflection) with about two liters of tap water. The zero point was adjusted on the Downing sensor board (for more details on the adjustment see the Downing sensor manual)[3] while the sensor was in the tank, then 5 grams of fine sediment from the Great Bay Estuary were added to the water. The result was that the sensor signal was peaked out instantly showing that the signal could be over-amplified. A true test of this assumption could only be made in the real environment. Since time was running short a more conservative approach was chosen the signal would only be amplified with one op-amp from the chip. This gave us a signal amplification of 11. Repeating the two tests of above, the margin until saturation of the sensor was increased.

A circuit of the final amplifier is show in Figure 2.9.

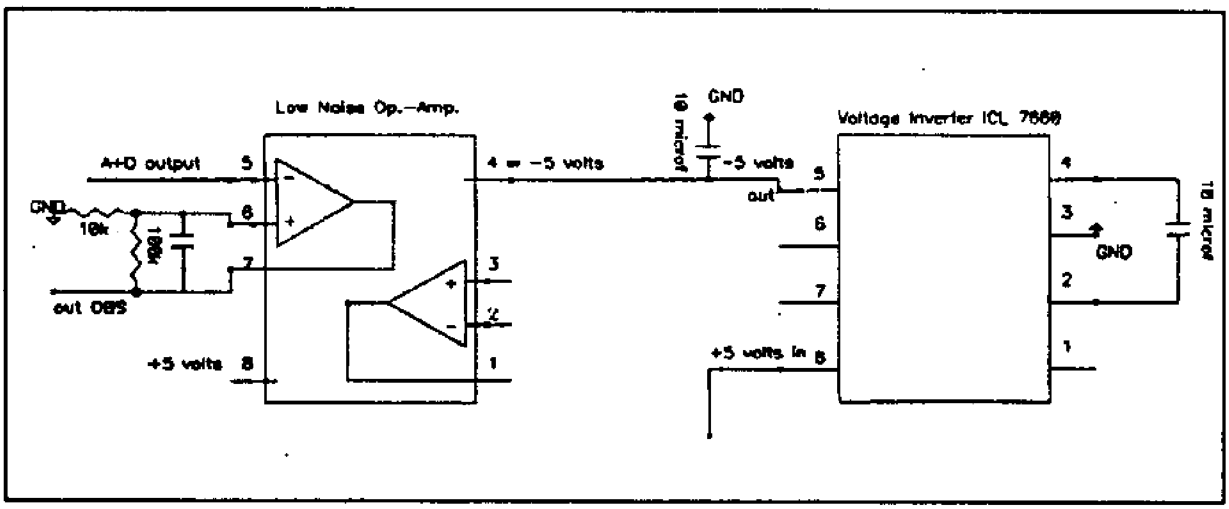


Figure 2.9 Circuit Diagram of the Amplifier

2.6 Procedure for Turbidity Data Collection

1. Connect computer through a Sail box to the CTD unit.
2. Start CTD computer software, from software menu chose

1.Communication then 1.Terminal Emulator

3. Ready the CTD unit press <d> for deploy then twice in capital letters <Y> for yes.
4. Remove the plastic tubes from the sensors. Check with the people that will lower the CTD into the water.
5. Press <g> for start taking data on the computer, go out to the CTD unit disconnect the computer link and insert the plug.
6. Lower the CTD into the water until bottom is reached then pull the CTD out of the water.
7. Reconnect the computer link and tell the CTD to stop taking data by pressing <Ctrl] B>.
8. To download the data from the CTD, press <Ctrl] C>, then chose 2.Data Dump from menu, make a file of CTD data.
9. To process data go to main menu chose 2.Normalize Data
10. For more specific and expanded information on the operation of the CTD consult the OPAL CTD manual [3].

Section 2.7 Conclusion

Up to the working of this report only four turbidity data samples have been made. A detailed study of the ratio between turbidity of the water and "cloudiness" of the video image would need more turbidity measurements in conjunction with taping underwater video images. Thanks to the help of the Ocean Process Analysis Laboratory group at the University of New Hampshire, our team was able to make a start on the turbidity measuring. The CTD was not available for more data collection after April 12; therefore it is strongly recommended that a turbidity sensor is bought for future research. Do to the lack of data from the Optical Back-scatterance Turbidity Monitor (OBS^{tm}) the sensor can neither be recommended nor dismissed as inappropriate. Future researchers must take in consideration how turbid the water is when choosing a turbidity sensor. For a brief discussion on different types of turbidity sensor see D&A Instruments, TECHNOTE 3/89 [1].

Section 3

Structure

3.1 Introduction

The structure for the R.O.I. project is made up of several separate components. These components are as follows: 1) Frame, 2) Camera case, 3) Light housings, and 4) Mounting of the resolution chart. The criteria and design for the various components will be discussed individually.

3.2 Frame - Criteria

Several criteria were taken into consideration when designing the frame. The first consideration was the physical size of the frame. The frame had to be at least 10 feet in length; the reason for this being that the frame had to allow for a maximum of 8 feet between the resolution chart and the video camera case, while still allowing 2 feet for the camera case itself.

Second, the frame had to be strong enough to withstand the weight of the camera case, the light housings (of which there were four), the resolution chart, and the added pressure of the water when the structure was submerged. The frame also had to be strong enough to withstand any extra weight that might be added in order to submerge the structure and keep it balanced.

Third, the frame had to be manageable, meaning that the structure had to be light weight and of a size/shape that could easily be maneuvered by the group. This factor was important because all the transportation to and from the research vessel would be conducted by the group members.

Forth, the lighting system would have to be attached to the resolution chart in such a way that both could be moved together without disturbing the lighting pattern. The design also had to allow for the resolution chart/lighting combination to be moved and fastened anywhere from 2 to 8 feet from the video camera case.

Finally, the design of the frame had to allow for ease in construction by the group members. It was decided, that due to limited time and finances for our project, the construction of the frame would be done by the group members, and not left to others. Also, by constructing the frame on our own, modifications could easily and quickly be made when found to be necessary.

3.3 Frame - Design

After weighing the alternatives, PVC piping, 2 inches in diameter, was chosen as the material out of which to build the frame. PVC is light weight, easy to work with, inexpensive, and although fairly brittle, strong enough to withstand the above listed criteria.

The PVC piping was cut to the desired lengths in the UNH - New Science Building's machine shop. When all the pieces were cut to the desired sizes, the frame was pieced together. Once the entire frame had been pieced together, in order to ensure proper fitting, we went back and fastened all the PVC connector joints using PVC cement. The basic frame was now complete; although it should be noted that the actual design varies slightly from the original design. This difference is a result of last minute design changes during construction. These changes were due to the lack of certain PVC connector joints, specifically connectors that form a 45 degree angle.

It was at this point that we were ready to attach the resolution chart/lighting system and the camera case. During this stage of construction it was discovered that the resolution chart/lighting system could be simplified. It was determined that it would be easier to fasten the resolution chart at one end of the frame while also fastening the lights at a set distance from the resolution chart (see Figure 3.1). This meant that the lighting pattern would not be disturbed because the only apparatus to be moved would be the video camera case.

Having fastened the resolution chart and the lights at one end of the frame, a method of moving the camera case had to be designed. The method chosen consisted of two parts: 1) two parallel tracks, and 2) a structure to support the video camera case. The support structure was constructed out of various pieces of preshaped steel bars (see Figures 3.2 and 3.3);

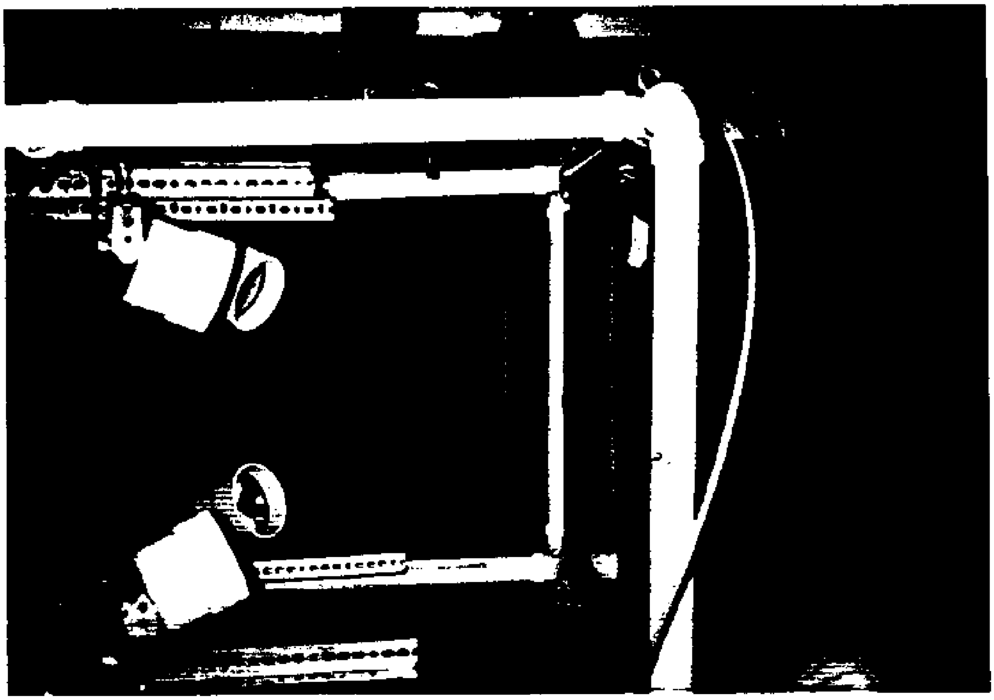


Figure 3.1 Light housings and resolution chart.

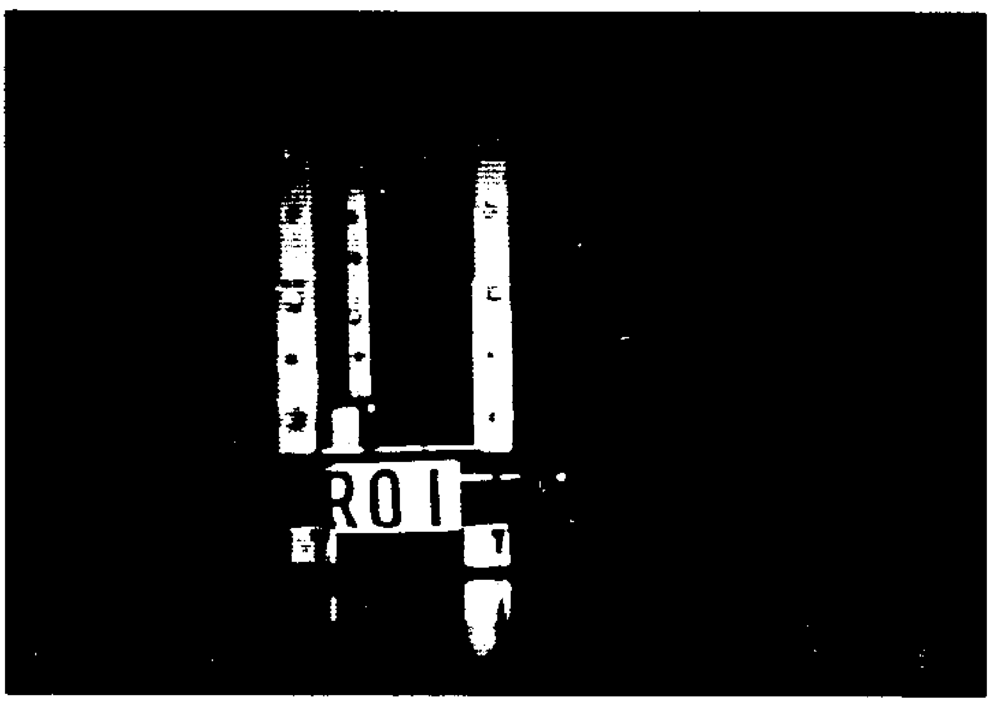


Figure 3.2 Side view of video camera support structure.

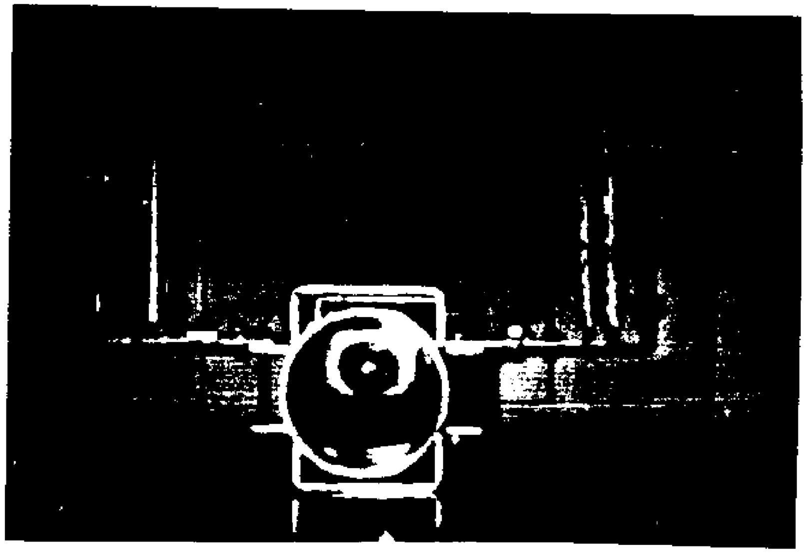


Figure 3.3 Front view of video camera support structure.

the track itself was constructed using angle irons. All the hardware used for the support structure and the track were store bought. There were several reasons for using store bought hardware: 1) the cost was within our budget, 2) hardware could be easily replaced, 3) there would be no time lost due to manufacturing. The angle irons that were used as a track are full of holes; these holes allowed the support structure to be bolted into place at the various distances from the resolution chart, as required in the criteria. The two steel bars were fastened to the frame using steel U - bolts (see Figure 3.4). By not permanently fastening the track, modifications and adjustments could have been made as necessary.

Another design problem was encountered when designing a method of relieving the bending stress associated with the raising and lowering of the structure. A spreader bar was built for this purpose. The spreader bar was built from 2 - 8 foot long 2 x 4's bolted over one another (see Figure 3.5).

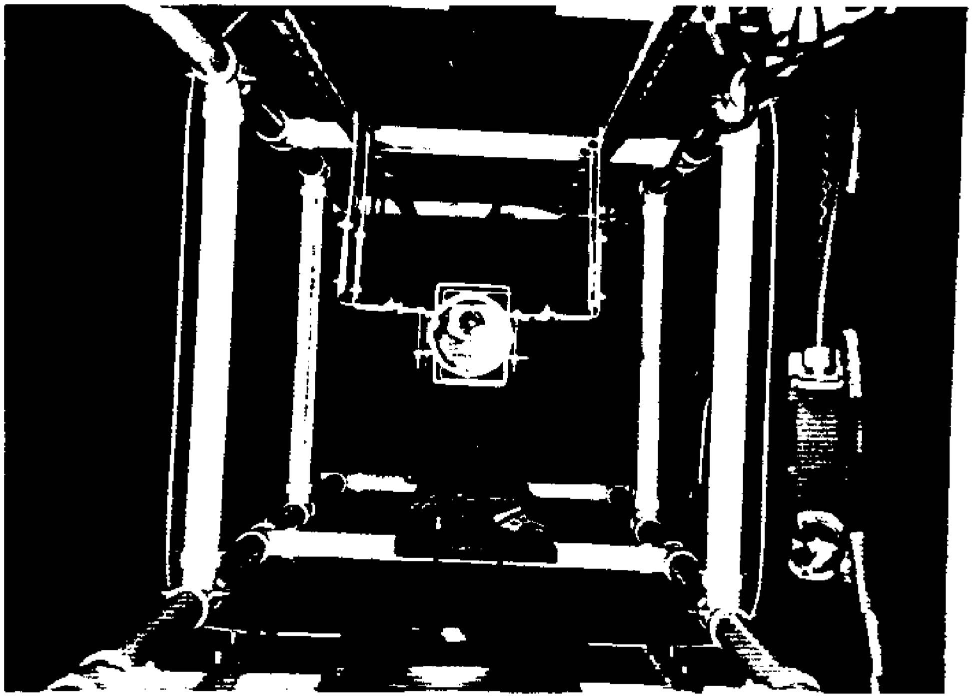


Figure 3.4 Video camera case support structure attached to the frame.

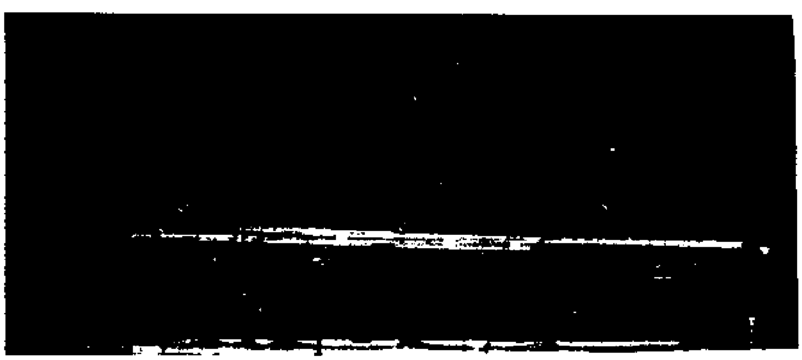


Figure 3.5 Spreader bar.

The final design problem was encountered in making sure that the structure would submerge properly. For this purpose, holes were drilled into the PVC so that the air inside the pipes could be replaced by water. It turned out that the weight of the structure along with the holes did in fact allow the structure to submerge, but was not enough to overcome the strong currents that were encountered. Therefore, 50 pounds of free weights were distributed over the bottom of the frame by bolting them to a wooden board which was in turn bolted to the bottom of the frame using steel U - bolts (see Figure 3.6).

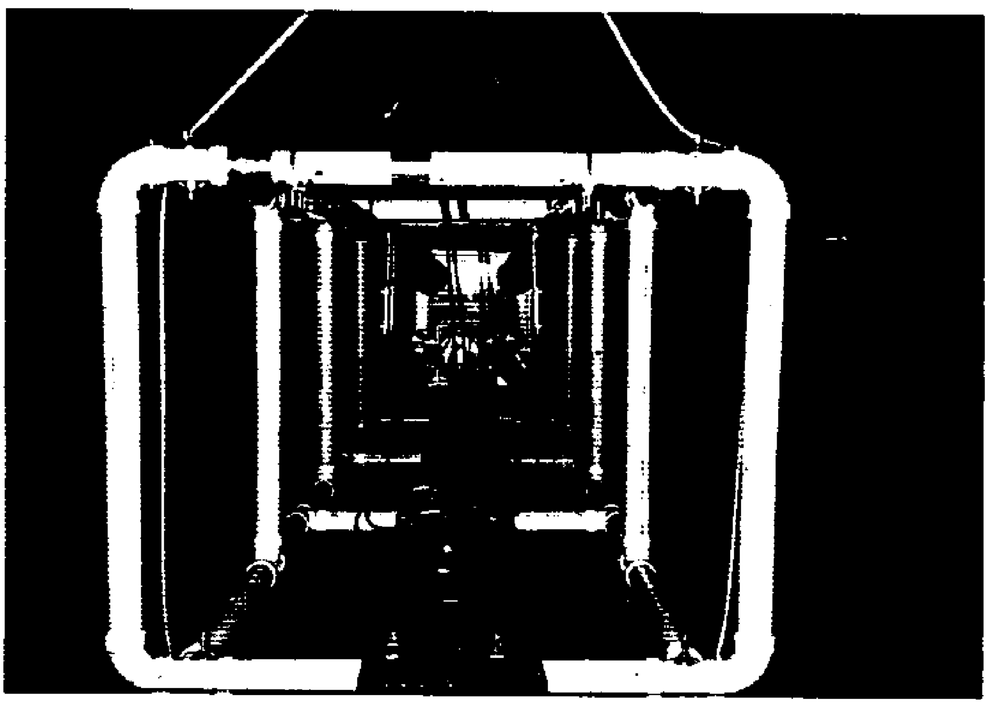


Figure 3.6 Free weights attached to the frame.

The added weight was successful in overcoming the strong currents that were later encountered. The completed structure (see Figure 3.7) was tested for stresses and displacements using the ADINA finite element package (see Appendix A).

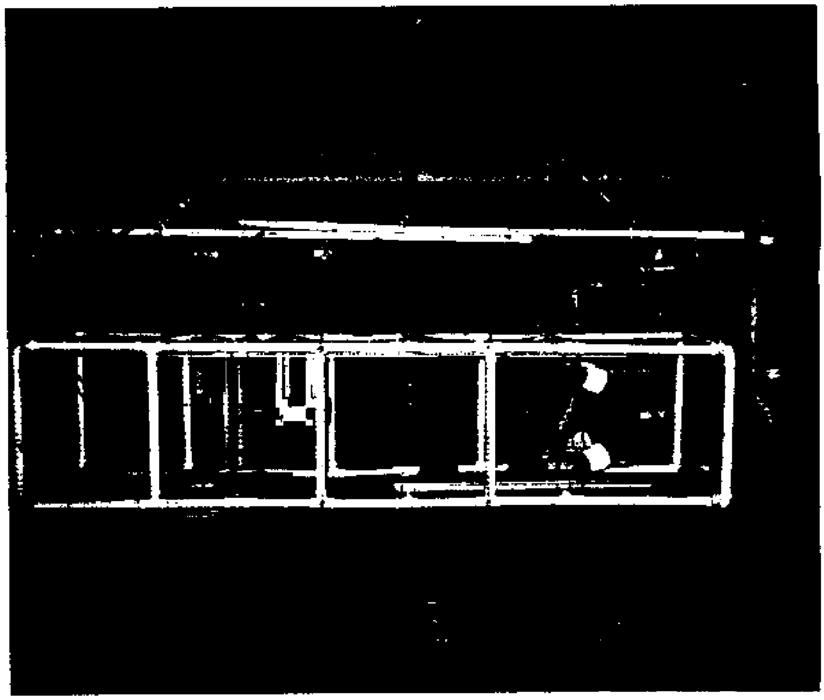


Figure 3.7 Completed structure.

3.4 Video Camera Case - Criteria

The criteria for the video camera case were extremely stringent. The closed circuit camera that we were using was borrowed, and crucial to our experiment, therefore it was important that nothing happen to it. All precautions had to be taken.

First, the case had to be water tight. It had to hold a watertight seal at depths of up to 40 feet. Second, the case had to have a clear endcap. The endcap also had to be removable so that the camera could be focused as necessary. Third, the case had to be as small as possible. The smaller the size of the case, the less buoyancy that it would create. Forth, the power and video cable connections had to be easily attached and detached whenever necessary. And finally, due to the limited finances for our project, the cost of the case had to be kept to a minimum.

3.5 Video Camera Case - Design

Having looked into several options, including borrowing or purchasing an existing camera case, we seeked the advice of Bob Duchese, the machinist at the UNH - Kingsbury machine shop. Mr. Duchese informed us that he had once constructed a similar case and would be able to construct a new one, that would fulfill the above criteria, for our use.

The case was constructed out of PVC piping, 4 inches in diameter (see Figures 3.2 and 3.3). The endcaps were constructed out of 1.25 inch thick plexiglass. Each endcap was fitted with 2 O-ring seals in order to insure a watertight seal. The endcaps fit into the PVC tightly, but were fastened using 4 screws at each end as an added safety measure. The video and power connections were made using underwater electrical connectors donated by D.G. O'Brien, Inc. (see Appendix B).

The video camera case was successfully tested at the UNH hyperbaric chamber. The case was submerged in water and brought to a pressure equivalent to that of the pressure at a depth of 20 feet. The case maintained a watertight seal without any leakage or damage. Although only tested to a depth of 20 feet, the design allowed for pressures of those much greater than at 20 feet.

3.6 Light Housings - Criteria

The criteria for the light housings were as follows. First, the housings had to be watertight in order to prevent contact of the water with the live connections. Second, they had to withstand the associated pressure of the water when submerged. Third, the power connections had to be simple, while preventing contact with the water. Forth, the housing had to be as small as possible in order to keep buoyancy at a minimum. And finally, the cost of the housings had to be within the limited finances available for our project.

3.7 Light Housings - Design

The design of the light housings was similar to that of the video camera case. The only major difference was in the fact that only one endcap would be necessary. The one endcap for the housing was different from the camera case in that it would not have to be removed, therefore it could be permanently attached to the housing.

A PVC coupler was chosen as the material out of which to build the housing. Not only would the coupler meet the pressure requirements, but it also had one end which extends over the light, thereby protecting it from accidentally being damaged. The endcap was built out of 1-1/4 inch thick sheet PVC. The endcaps were cut to the proper diameters by Bob Duchese at the UNH - Kingsbury machine shop and were then cemented to the end of the housing using PVC cement. The endcaps were fitted with the same underwater electrical connectors as used for the video camera case. The lights were fitted into the open end of the housing. Having made all the necessary electrical connections and having tested all the lights, they were epoxied into place in order to prevent water from leaking in around the edges (see Figure 3.8).

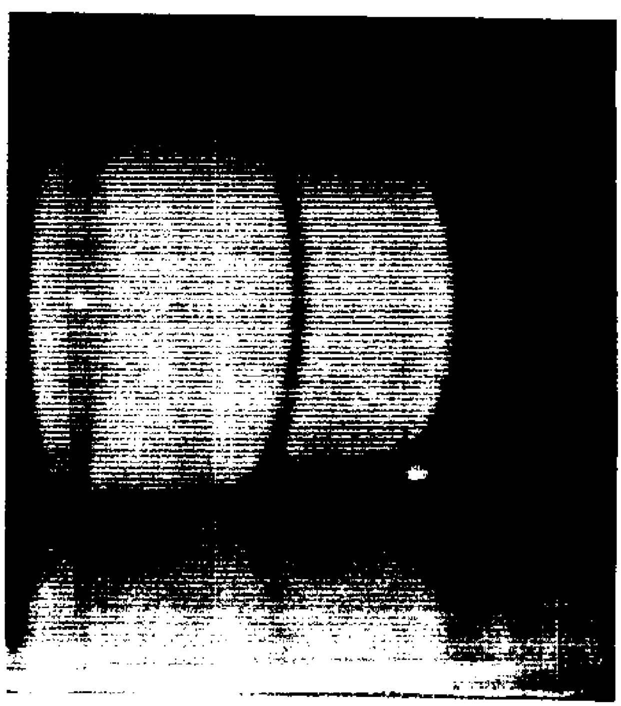


Figure 3.8 Light housing.

The lights were tested for leaks at the UNH hyperbaric chamber. The testing procedure was the same as that used for the testing of the video camera case. During testing, only one small leak was observed. This leak was later sealed using a silicon gel sealant.

3.8 Attaching of the Resolution Chart

Attaching the resolution chart was a simple task. In order to prevent it from getting wet, we had the resolution chart laminated. It was then attached to a 1/2 x 1/2 foot piece of PVC board, which had been left over from the construction of the endcaps, using contact cement. The board was then fastened to one end of the structure using pvc pipe hangers (see Figure 3.1).

3.9 Recommendations for Future Design

Although the structure performed without incident, there are a few modifications that could be made in the future in order to make data acquisition easier. The biggest difficulty that was observed during the use of the structure was the fact that the video camera case had to be maneuvered manually. Along with that, we had to manually focus and adjust the aperture for the video camera between data collections. The combination of these difficulties accounted for a large amount of the time spent. During this time no data could be taken. If more data is to be collected in the future, we would recommend that : 1) the maneuvering of the camera case be designed in order to allow movement of the case without raising the structure, i.e. a motorized rail, and 2) that a video camera where the focus and aperture opening can be manually operated from the surface be acquired. Aside from these two recommendations, the present structure is still adequate for the collection of data.

Section 4

Video System

4.1 Introduction

Project R.O.I. needed to create an underwater video image database. A goal for our research database was standardization. This would mean that the collected data could be easily used by those in the future and replicated by other underwater image acquisition systems. To follow through with the standardization, the equipment would have to be within the constraints of our budget, meet our specifications, and be easy to use out in the Great Bay Estuary environment. The video system would consist of

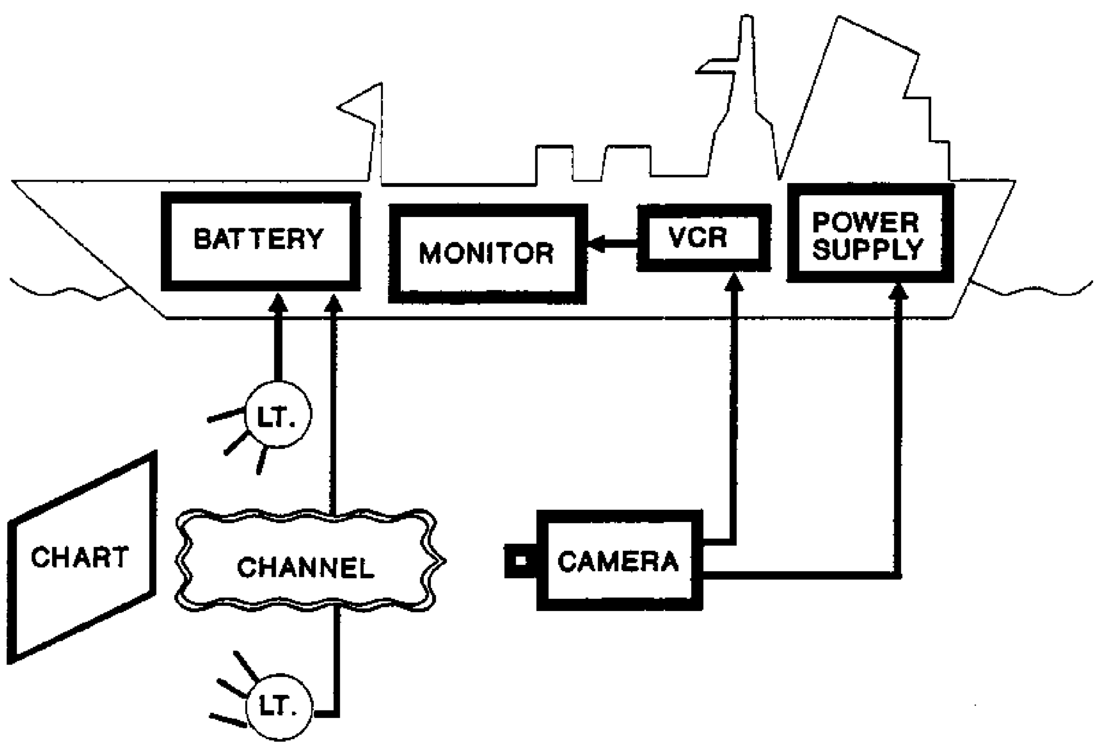


FIGURE 4.1
VIDEO SYSTEM

four components: a video camera to acquire visual data, a resolution chart to be the camera's target, a VCR to record the data, and a monitor to provide on-site real time viewing of the data. Lights were used to illuminate the resolution chart, and are discussed in Section 5. The integrated video system can be seen in Figure 4.1. The camera, chart and lights are mounted on the structure, and is discussed in Section 3. The battery, VCR, monitor, and power supply were secured on the Research Vessel Jere Chase.

4.2 Camera System

The camera system was the most important component of the video system. We choose a standard RS-170 output black and white video camera. This is because RS-170 is the standard input to most VCR's equipped with a video-in line, allowing flexibility in choosing this component. Also, a RS-170 video signal propagates with little attenuation through coax cable, which was what the underwater connectors were designed with.(See Section 3) The camera was black and white because this would be the least expensive and a there was a comparable black and white resolution chart. This type of camera is also relatively compact for ease of housing underwater and generally has a high resolution so as not to degrade the input image further.

After researching the video camera market and scrutinizing the budget, it was decided that a borrowed camera would be best.

Mr. Paul Dobbins of Olympus Corporation was contacted and an appropriate camera system (camera, lens, and power supply) was loaned to project R.O.I. The camera was a Canon video camera module, Ci-20R, approximately 2.75" wide x 3.5" long x 2.25" deep in size and the lens was 1.5" long x 1.5" in diameter. With this small size, underwater housing could be fabricated for the video camera and lens. The retail value of the camera is approximately $1200, placing it within the reach of future experiments if a camera needed to be purchased. With a horizontal resolution of 500 lines and a vertical resolution of 320 lines, the Canon Ci-20R camera produced excellent resolution for use in digital image processing. Resolution is primarily limited by the 0.5" charge couple device of the camera. Higher resolution will allow for better resolving power at shorter distances. The camera also had a automatic gain control, AGC, which would automatically adjust the gain according to the amount of light present at the aperture opening. This was an extra feature, but nice to have since the depth and turbidness of the water significantly decreased the amount of ambient light available.

Because of the turbidness of the water, it was expected that only short distances would be possible for viewing the resolution chart. To produce useful underwater video data, the camera lens would need to be able to focus at short distances and admit a significant amount of light. The lens specifications were 50mm with a f stop of 1:1.4. The 50mm corresponds to the lens mounting diameter and determines how large the f stop range can be. The f stop number is proportional to the focal distance. The Canon Ci-20R camera and lens could focus to a distance of two feet and output images in near darkness. Thus, these specifications would allow the camera system to focus at short distances from the resolution chart and operate under the necessary lighting conditions.

The power supply was the final component of the camera system. The power supply converted the 120 volt AC/15 amp outlet power down to 9 volt DC/1 amp supply to input into the camera. Low voltage was desired in the water in case of an accidental short to ground, and the handling of lines in a wet environment. If high voltage were present, damage could occur to the equipment and injury might befall the operator of the system. Thus, the power lead was altered to meet the low voltage condition,see Figure 4.2.

Several parts of the original camera system had to be altered to fit the completed camera housing, the desired safety margin, and on-site realizations of how the entire system would operate in the Great Bay Estuary environment. Figure 4.2 depicts the changes. The camera housing was designed with two watertight connectors (one for power and one for the video signal) with fixed coax leads on the inside of the housing. Also, a matching outer connector with 50 feet of coax cable was provided for each connector. Thus, coax cable was the type of cabling used for both the video signal and power transfer. In working with this, the outer shielding was unbraided and tinned and the inner core

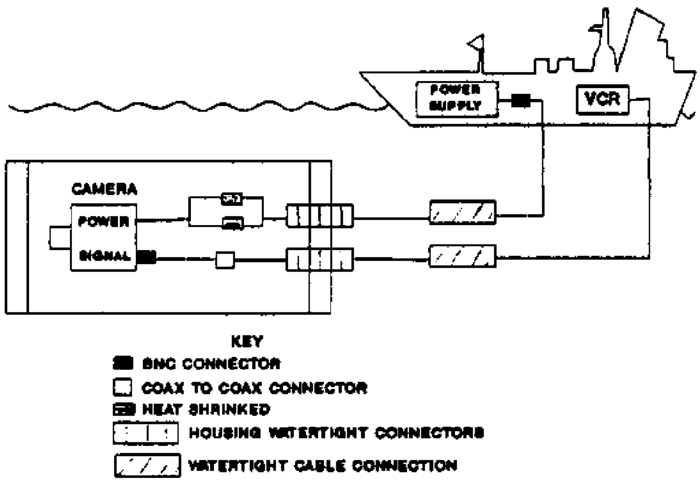


FIGURE 4.2
CAMERA SYSTEM CONNECTIONS

was stripped and tinned. To transfer power, the outer shielding was connected to ground and the inner core to hot. The original 50 feet could not reach the required depth due to extra line used in connecting the boat bound part of the system to the water portion. Thirty extra feet of cable was then added in the above manner and waterproofed with pliable black rubber. A specialized five pin connector made the connection for the camera power. To maintain only low voltage in the water, the original three foot power supply to camera line had to be cut and the appropriate connections made. The camera system was now integrated and functioning. The camera transferred the data at proper resolution and light level and would fit inside the watertight housing. The power line was low voltage for safety and the cables were lengthened. Thus, the camera system could reach the proper depth and perform its job.

4.3 Resolution Chart

The resolution chart was the target of the video camera. A sample of the chart is found in Figure 4.3. The actual size of the chart was 16 inches wide x 20 inches long. The image of the

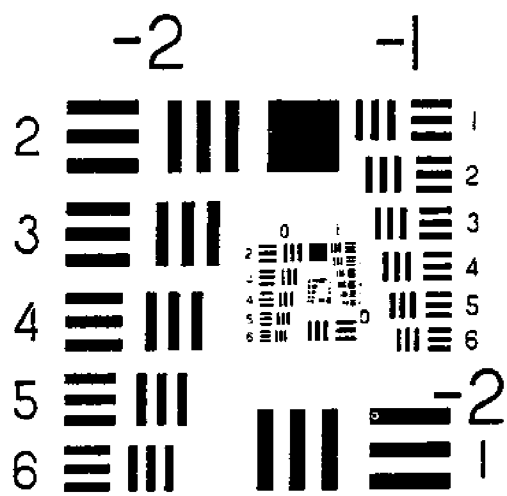


Figure 4.3

Resolution Chart

resolution chart would be degraded due to the channel, or turbid water. This degradation produced a distortion of the chart. The resolution chart was a standard Edmond Scientific Resolving Power Chart, No. 83,001. This chart was donated to project R.O.I. by Mr. Paul Dobbins of Olympus Corporation. The original chart was used for color resolution, containing a myriad of small resolution charts in black, yellow , blue and red. To adjust to our black and white based system, a small black resolution chart was photographically enlarged. And, since the chart would be submerged, it was waterproofed via a lamination process. The resolution chart was then centered on the structure and mounted. The camera would now be able to take a video image of the resolution chart through the turbid water.

4.4 Video Cassette Recorder

The Video Cassette Recorder (VCR) had three initial requirements for integration with the existing video system: it had to contain a direct RS-170 video-in port, record at a reasonable level of resolution, and be of standard format. Although the first two VCR's met these requirements, outside forces caused them to both stop functioning before the initial field test. Thus, a fourth requirement, keeping within the strained budget, evolved.

With help from the Ocean Project's monetary resources, cash was allotted to purchase a new VCR. We choose a GE VG-7575 VCR. This VCR cost $270, which fit within the expanded budget. It also had a direct video-in port, a horizontal resolution of 280 lines, a vertical resolution of 480 lines, and it was VHS - a popular recording format. Although the resolution of the VCR is significantly less than that of the video camera, it fit within a acceptable range for a basic VCR unit. For higher resolution, a studio quality or Super VHS VCR would provide increased resolution, but at a nearly quadrupled price. We recorded the data on Fugi Super HG T-120 VHS video cassette tapes. These tapes were donated by Mr. George Hamilton of Calibration Technology Incorporated. Thus, the VCR was standard in its VHS format, the resolution was average, and it could be integrated into the rest of the system.

4.5 Monitor

To view the turbid video image data as it was being recorded, a Electrohome LTD black and white monitor was used. This monitor was borrowed from the Synthetic Pattern and Vision Analysis Laboratory, SVPAL. The monitor allowed for the adjustment of the camera's focus and aperture opening. Before the system could be lowered, the camera had to be focused and then the aperture opened to allow for increased light in the underwater filming. This was done visually with the use of the monitor. Thus, the monitor completed the functioning video system.

4.6 Recommendations

There are a few changes in the video system that could increase the quality of the underwater image database. An alternate lens, either zoom or telephoto, could be housed in a larger case. Either lens would produce a larger image at an increased distance, and might improve the quality of that image. Because the resolution chart was photographically enlarged, there was some degradation of the original crispness of the bars. If an original 16 inch wide x 20 inch long chart could be found, it might increase the clarity of the final image. Also, if a Super VHS VCR was used to record the data, the elevated resolution would allow for better data to be digitally processed.

Section 5

Lighting

5.1 Introduction

A significant amount of work has been done in the study of underwater lighting to optimize light sources for underwater photography, video imaging, and human observation. Presently, the three major types of lights in demand are; the tungsten halogen light; the mercury vapor light; and the recently developed thallium iodide light.

The purpose of this section is to familiarize the reader with a basic operating theory of present day underwater lights and provide basic applications and limitations associated with Project ROI and their goal of developing an underwater video image data base.

5.2 Lighting Options

When designing underwater lighting there are a lot of questions that must be asked as well as answered in order to obtain a safe and efficient system. First, in being given a 2500 dollar budget there was much discussion on exactly which funds should be allocated to the lighting. Eventually, approximately 300 hundred dollars was decided upon.

With the issue of money resolved, the ROI group focused its attention on safety. The group was mainly concerned with the problem of sending high voltage electricity underwater and the possible results of personnel injury or equipment loss that might occur upon accidental mishaps (faulty wiring, exposed wiring, water leaking into equipment,...etc).

While keeping low voltage lighting in mind it was also discovered that different types of underwater bacteria absorb different types of light and in order to obtain the best average spectrum, for black and white video imaging a light with a high bluish-green spectrum would be needed. This type of lighting is characteristic of both mercury vapor and thallium iodide lamps. The problem with these lamps are their high costs, a 7 to 10 minute warm up time, and a ballast system which usually necessitates high voltage. Because of these problems, the group focused its attentions towards tungsten halogen lamps.

Tungsten halogen lamps are very inexpensive. Their power requirements are simple operating on AC or DC voltage as well as requiring no warm up time. The major disadvantage to these lights are their spectral output. For general lighting, television, black and white video imaging (as in our case), or black and white photography the spectral output of these lights, because of their high red energy region, are not as optimum for transmission in seawater as thallium iodide or mercury vapor lamps. This results in a higher water attenuation which in turn reduces the distance of viewing in water. For a more detailed discussion on lights and their spectral outputs, see *Facts On*

Underwater Illumination by Charles Strickland [4].

5.3 Scattering Effect

When discussing light attenuation another important stigma that must be accounted for is the scattering effect. The scattering effect is when foreground brightness produced by back-scatter, which is typical in turbid water, causes a limiting viewing factor underwater. This is analogous with the problem of vision in a dense fog.

When dealing with artificial light sources, the back-scattered light will be greater at the light than for the uniform radiance situation. In addition a greater proportion of the back-scatter will be derived from the region within one attenuation length of the lamp. An example of this phenomenon is illustrated in Fig. 5.1.

The optimum arrangement to minimize back-scatter will include 1.) separating the lamp from the viewer, 2.) employing reflectors which provide reasonably sharp cut off at the edge of the beam, and 3.) the use of multiple moderately focused intensity lamps rather than a single high intensity lamp. For a more detailed discussion on "scattering", see *Optical Oceanography by N.G. Jerlov [5].*

5.4 System Configuration

Eventually, it was this concern about the scattering effect that led project ROI to their current lighting design of four moderately intense lamps, each possessing a narrow beam spread, being placed in a square configuration encompassing the camera. A picture of this design is shown in Fig. 5.2.

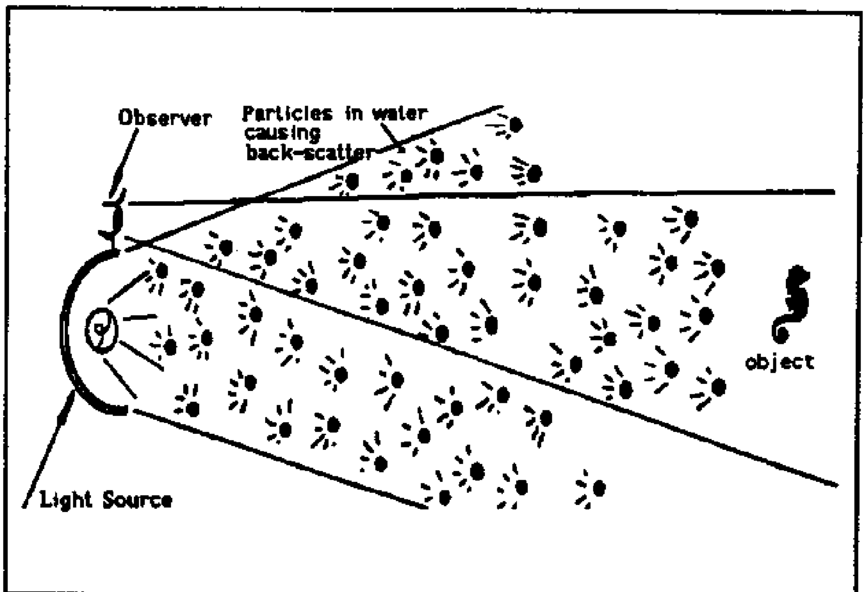


Figure 5.1 Diagram of Scattering Effect

It was at this point that the actual amount of footcandles needed for such a design was calculated (see appendix A). Once these results were analyzed a 12 volt 36PAR36CAP/VNSP (very narrow spot, tungsten halogen capsule) was decided upon. The candlepower distribution curve for this particular lamp is shown in Fig. 5.3.

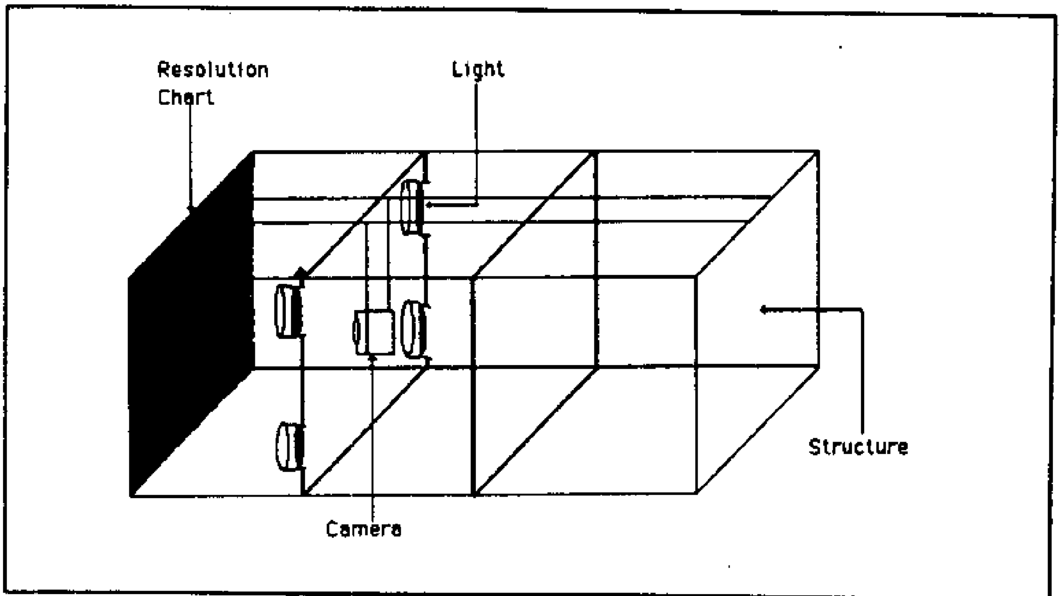


Figure 5.2 Diagram of Current Design

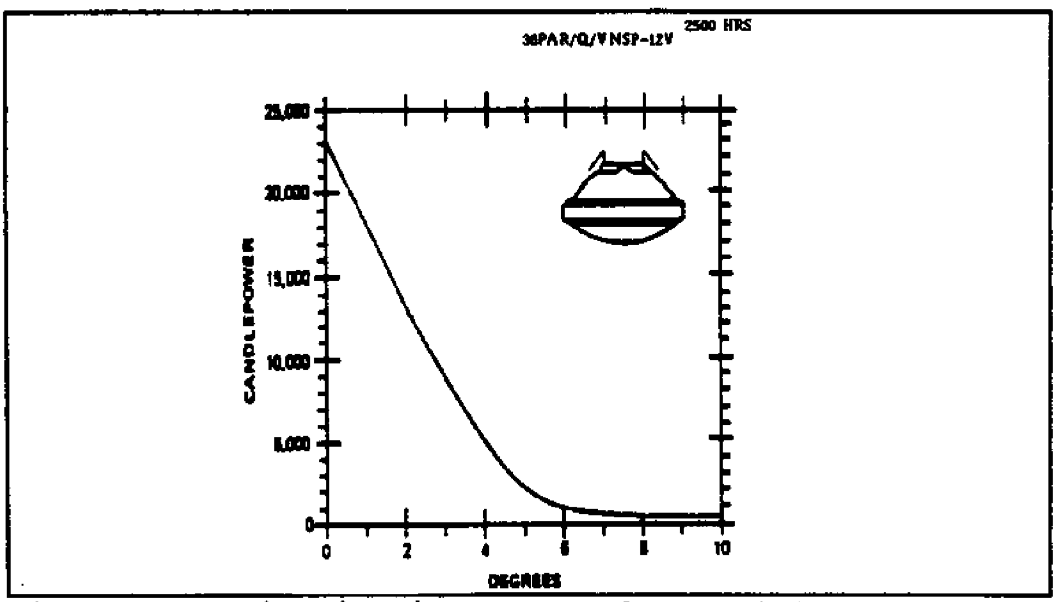


Figure 5.3 Distribution Curve of 36PAR/Q/VNSP

At this point ten 36PAR36CAP/VNSP lamps, four of which are currently attached to project ROI's structure, were donated by Robert Levin,Ph.D from GTE Research & Development. With the lights on order, a system to turn these ordinary household spot lights into submersible underwater lighting was then designed. First, the lights were mounted and secured into a hollow pvc structure. Then a solid, flat piece of pvc mounted with waterproofed connectors that were already joined to 50 feet of RG-58 A/U coax cable, donated from D.G. O'BRIEN, was epoxied to the rear of the initial hollow structure (refer to Fig. 5.4). At this point, the four pieces of RG-58 A/U coax cable (one cable from each light) was connected to 40 feet of submersible 12/3 gauge wire. (Note, the 12/3 gauge wire was chosen in order to handle the 12 amps of current, 3 amps for each light, that is needed to power 36PAR36CAP/VNSP lights.) The 12/3 gauge wire was soldered to a 15 amp fuse which in turn was connected to a 12 volt battery thus producing enough lumens for the camera to operate on.

5.5 Suggestions for Future Work

Once the lighting system was designed and successfully tested, project ROI began to develop ideas that might improve the presently existing system. The first idea that was worked on was the construction of a 2-dimensional intensity profile graph (see Fig. 5.5). Thanks to the help of professor Joseph B. Murdoch and his illumination meter the graph was successful in detecting

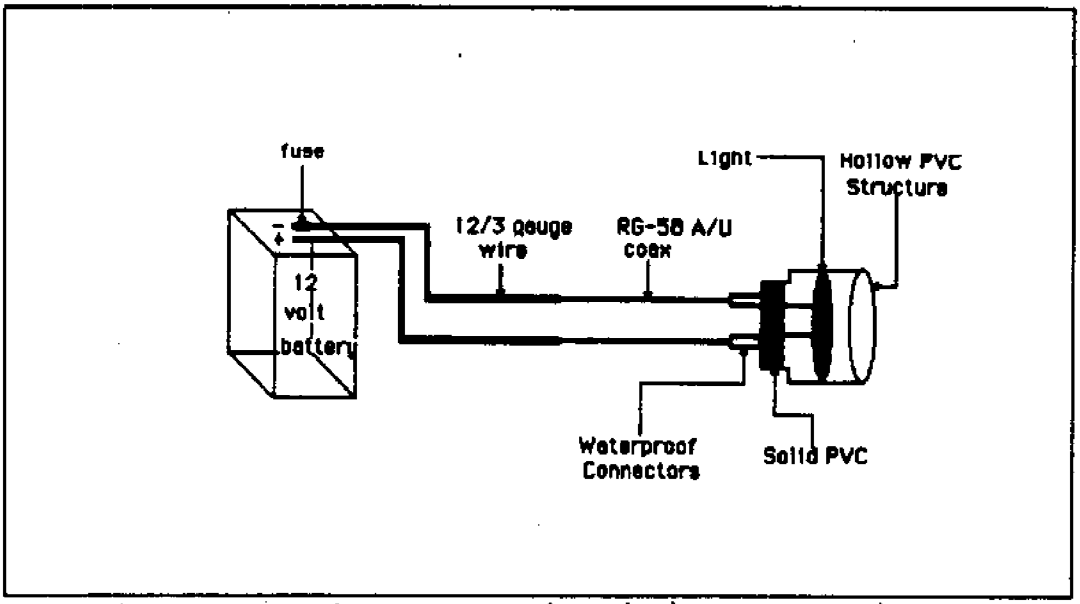


Figure 5.4 Diagram of Lighting Construction

"hotspots" which caused non uniform lighting patterns on the resolution chart. A possible way to improve the effect of non uniform lighting is to use a parabolic reflector . Parabolic reflectors have the ability to direct light in an even pattern, thus decreasing the "hotspots".

Another problem resulting from the results of the intensity profile graph was the amount of candlepower being generated from the 36PAR36CAP/VNSP lights. According to the graph approximately 83% of the calculated candlepower was missing. After further investigation it was discovered that the R6-58 A/U coax cable was causing a line drop of two volts. A two volt drop into a tungsten halogen lamp is a major problem in terms of efficiency. One way to remedy this problem is by replacing the R6-58 A/U coax cable with a low resistance cable such as 15/3 gauge wire.

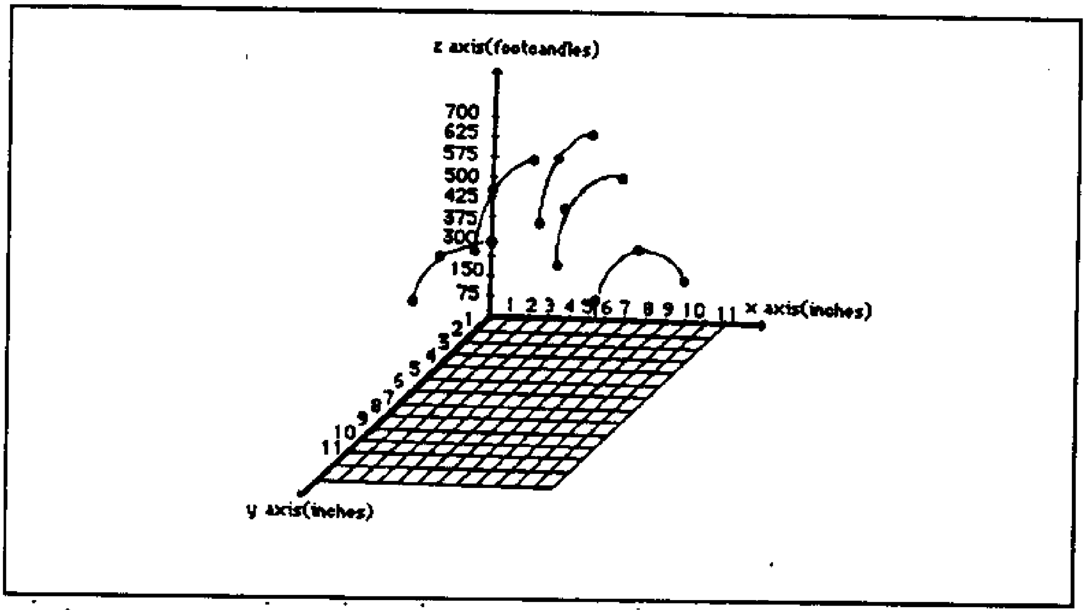


Figure 5.5 Graph of 2-Dimensional Intensity Profile

Other ideas of improvement on this system may consist of attaching the lights to the camera structure, being careful of scattering, in order for the lights to move with the camera. This type of configuration may be useful in simulating data from the point of view of a lighted structure approaching an unlit image rather than the visa-versa.

5.6 General Conclusion

In conclusion, because of the many aspects of underwater lighting there are numerous different types of lighting options. Each option having different pro's and con's when applied to a highly specialized problem. For this project tungsten halogen lamps were more than adequate in respect to expense, costing approximately 73 dollars (see appendix B for itemized list), lighting capacity, safety, and power flexibility. But as this project becomes more specialized careful consideration should be given for the use of parabolic reflectors, the replacing of R6-58 A/U coax cable, or even the design of a new system that utilizes mercury vapor or thallium iodide lamps.

Section 6.0

Data Collection

Section 6.1 Locations of Video Image Data Collection

The general location of project R.O.I.s video data collection was the Great Bay Estuary, Portsmouth, New Hampshire. All sites were located beyond the Interstate I-95 bridge. At this place of the estuary several rivers run into the bay. The project chose this general area to collected its video data because of its muddy water content.

The choice of this area was justified by the pictures on tape number 5. The tape shows picture from the location 43 degrees 05 minutes 46.0 seconds North and 70 degrees 46 minutes 40 seconds West. This location was the projects closes site to the Interstate I-95 bridge at incoming tide. The pictures show very little turbidity in the water, the resolution chart is visible at a water depth of 6.67 m (20 ft.) at a distance of 26 inches away from the camera with and without lights on.

Knowing the way the tide was coming, in or out, was important for the choice of location. The muddier pictures were taken when the tide was going out, and the river water predominated at the data collection position. For the initial data collection several sites at incoming and outgoing tide were chosen. This resulted in a good beginning of video image data base. All video data sites are show in Figure 6.1, also see Appendix A for the catalog of video cassettes.

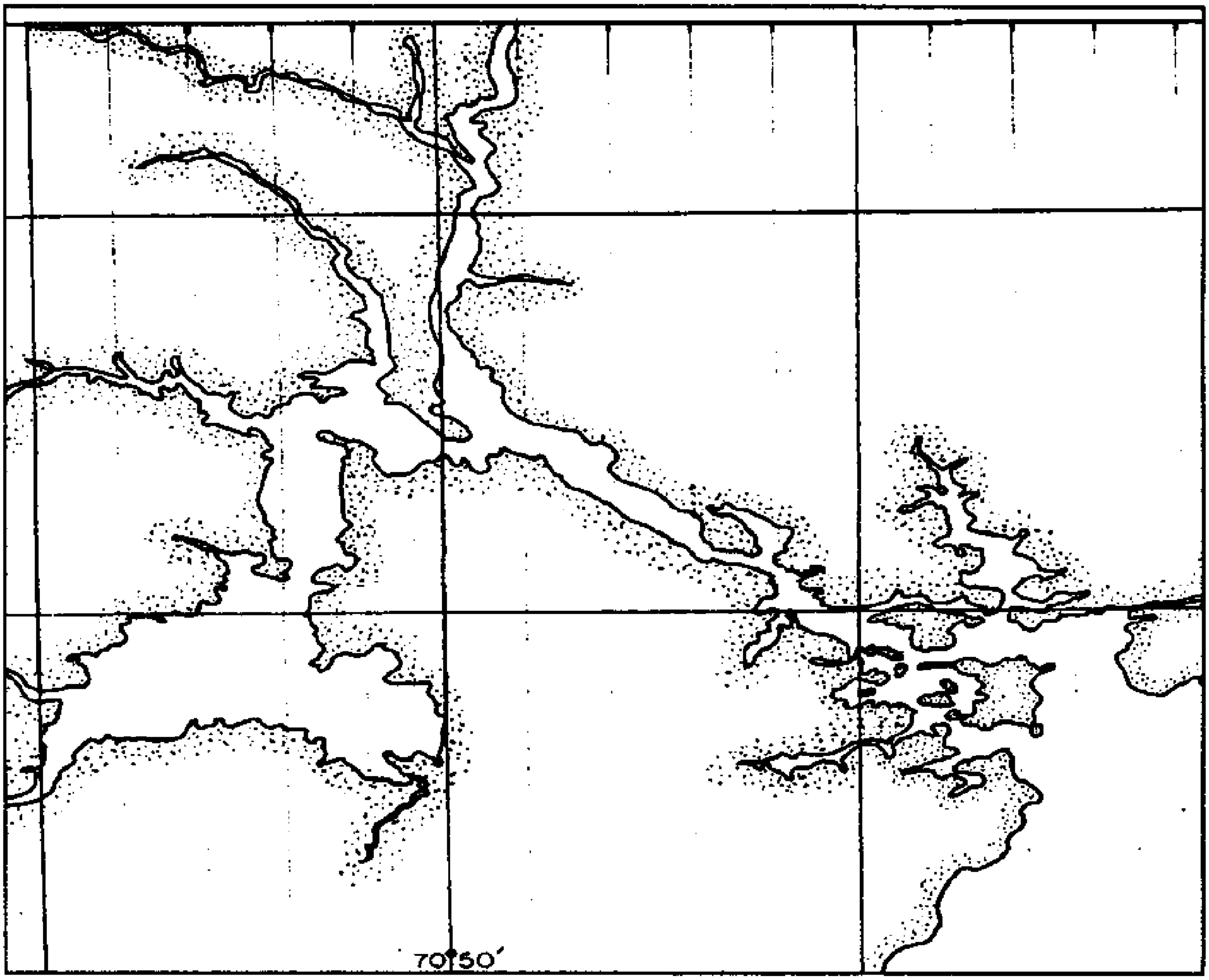


Figure 6.1 Video Image Data Collection Positions

6.2 Procedure of Video Image Data Collection

1. Chose site of data collecting.
2. Start with the camera being 2 ft. away from the resolution chart.
3. Adjust the camera focus and aperture.
4. Lower camera to lowest possible water depth without touching the bottom (35 ft.).
5. Start recording video images for 5 minutes at desired water depths (5 ft. decrement).
6. Move video camera in 2 ft. increments away from the resolution chart.
7. Repeat steps 3. through 6. until the resolution chart is no longer visible underwater.
8. Move to a new location and start with step 2.
9. Keep record like lists in Appendix E.

Section 7

Digital Image Processing

7.1 Introduction

Once our data was collected, our goal was to explore the fundamentals of digital image processing with the underwater database. Digital image processing refers to the processing of a two dimensional (ie. piece of paper) picture by a computer. In our case, the picture is an image from a video frame off a VHS tape. The digital image is an array of numbers that are represented by a finite number of bits [6]. A typical digital image processing sequence is represented in Figure 7.1. For our applications, we

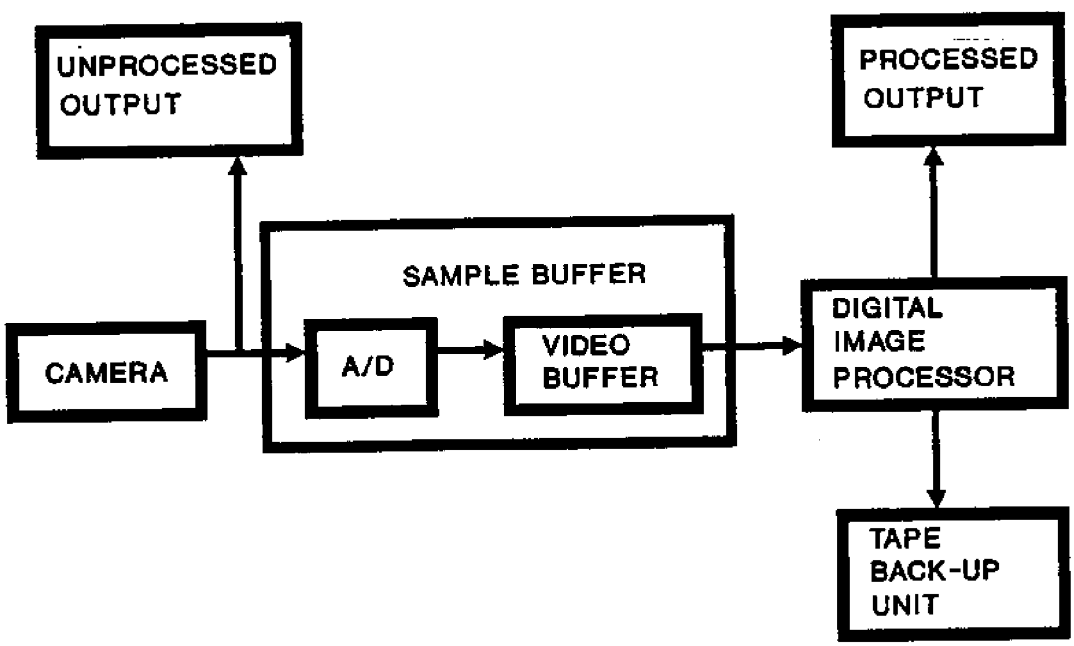


FIGURE 7.1
DIGITAL IMAGE PROCESSING SEQUENCE

will be using the digital image processor to restore the underwater image. This will remove or minimize the degradations in the image caused by the turbid water.

Some background is needed to completely understand the basics of digital image processing. A video image is composed scan lines forming even and odd fields. This can be seen in Figure 7.2, where each scan field consists of 265.5 lines [6]. It takes 1/30 second

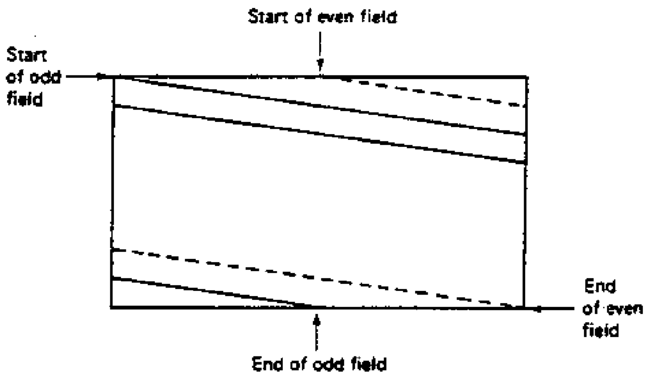


Figure 7.2

Scan Lines

to refresh the full frame of a RS-170 standard image. A gray scale is the range of color from black to white. Figure 7.3 depicts a 9 level gray scale. For our processor, there are 8 bits to hold

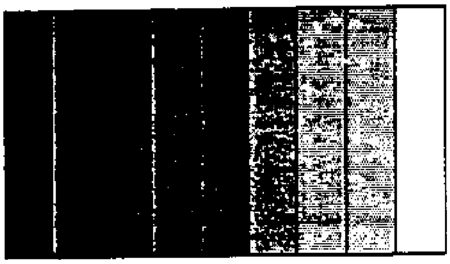


FIGURE 7.3
GRAY SCALE

the information on the amount of grayness. Thus, there are 256 possible shades, starting with 0 (00000000) equal to black and 255 (11111111) equal to white. A pixel is an area at a particular position on the screen of the monitor. Figure 7.4 shows 16 boxes which correspond to 16 pixels on a monitor. For video output, the screen is 512 wide x 480 long pixels. Sampling converts the two dimensional image into its digitized form. Sampling occurs in the sampling buffer. Here, the RS-170 video scan line is the input [7], as seen in Figure 7.4, and is sampled every delta t seconds. The voltage level of the sample is then converted to a corresponding gray scale number. In this figure, low voltage converts to white, and high voltage converts to black. Then, the gray scale number is mapped to the appropriate pixel and the digitized image is transferred to the output. Since only one scan line has been digitized, only one row of pixels contain digitized data. At this point, the original video image has been digitized and can be shown on a monitor unprocessed or can be the input to a digital restoration process.

7.2 Equipment and Additions

Digital image processing requires a large amount of hardware and specialized programs to perform the necessary restoration on the data. The Synthetic Vision and Pattern Analysis Laboratory, SVPAL, at U.N.H. contained most of the equipment needed. Figure 7.5 diagrams the basic equipment necessary for image processing.

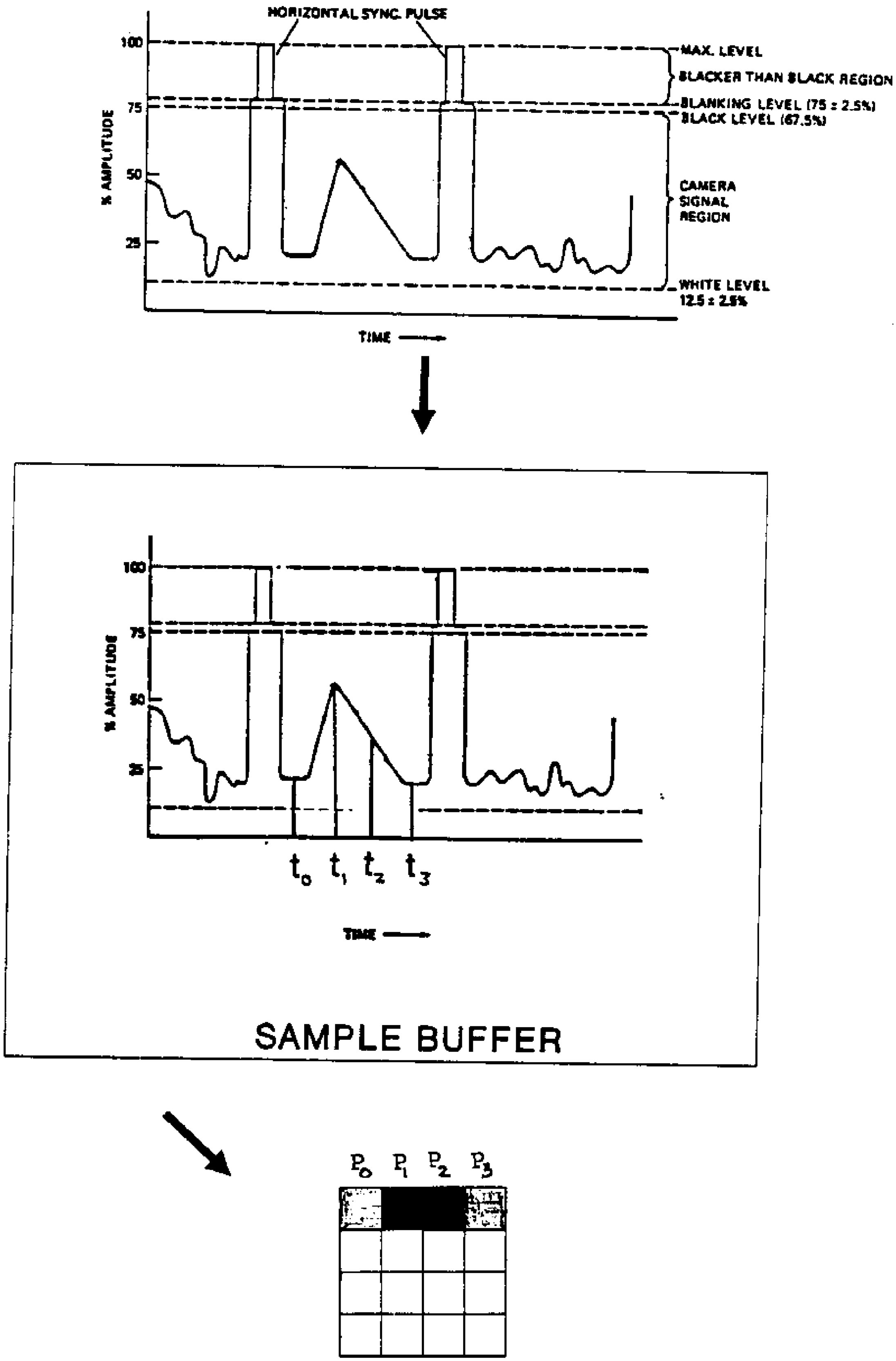


Figure 7.4

Sampling Sequence

UNPROCESSED VIDEO DATA

PROCESSED VIDEO DATA

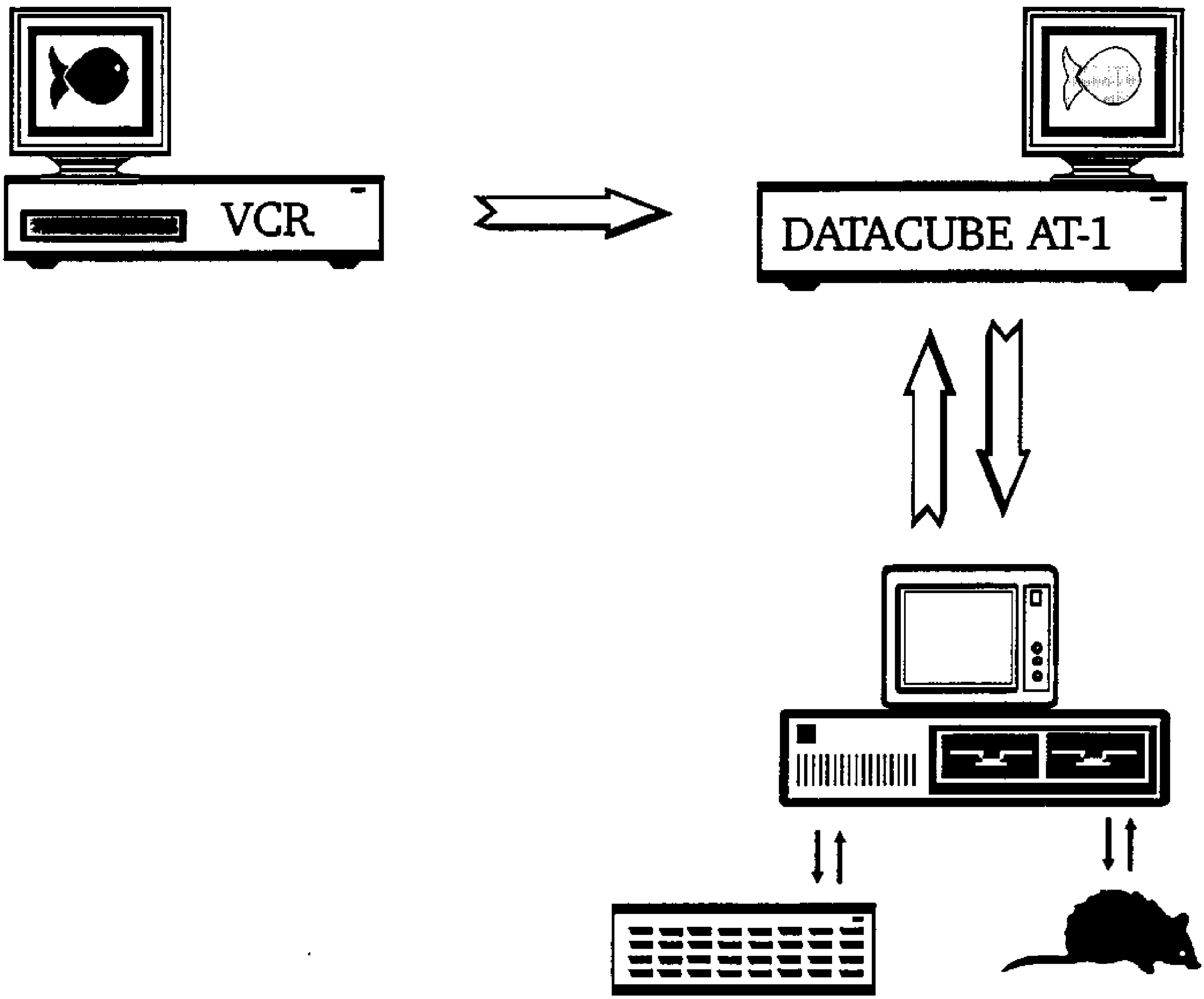


FIGURE 7.5

IMAGE PROCESSING SETUP

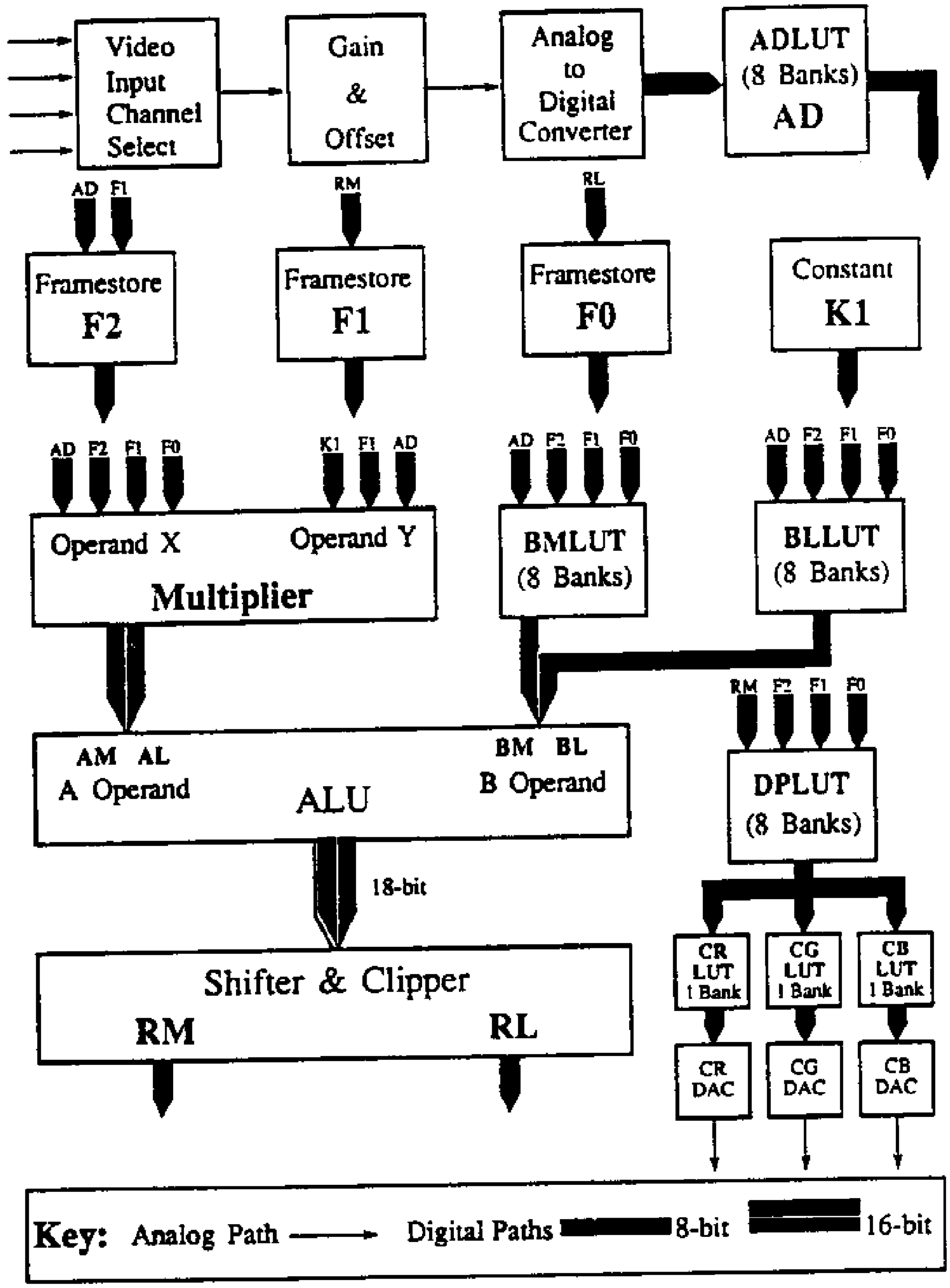


Figure 7.6

MaxVision data flow chart

The DataCube AT-1 is the digital image processor. This contains the sample buffer, frame grabber, and store the programs used for processing. Figure 7.6 shows the data flow chart [8]. The data is retrieved from the VHS tapes. The video frame, or data, is placed into a framestore. From this framestore, this data can be accessed and operated on in the arithmetic logic unit, ALU, depending upon the needs of the program and the desires of the user. Then, the processed video data can be shifted to a second framestore and used as output. The AT-1 is accessed by the user through a 386 computer with both keyboard and mouse. For the amount of data that we would be processing, we also needed to install two more pieces of equipment. An Intel Aboveboard + with 512k RAM was added to expand the memory to 1Meg. Also, since processed image occupy a significant amount of memory, a Colorado Memory Systems tape back-up unit with 40Mb and a floppy interface was purchased and installed for the storage of data on high density data cartridges. All equipment was integrated and the digital image processing could begin.

7.3 Arrangement of Data and Implications

Images from a resolution chart filmed through a turbid water channel formed the database. Both the chart and camera were fixed, but the current caused the water to flow with respect to the chart and camera. The turbid water is a stochastic or random environment, changing with the tides and various forms of debris suspended within it. Modeling of the turbid water environment would aid in digital image processing, but is beyond the scope and depth of this course. Digital restoration of the image is possible with out this though, and such restorations will be discussed in section 7.4, 7.5, and 7.5, which include histogram modification, temporal filtering, and edge enhancement.

7.4 Histogram Modification

The histogram of an image represents the relative frequency of occurrence of the various gray levels in the image [1]. The histogram was modified using the programs MaxVision by DataCube[#] and BaileyVision, which was developed in S.V.P.A.L. Figure 7.7 shows the restoration of an area, or region of interest (R.O.I.), of the image. 7.7a is the original image which has been put in digital form, but not processed. The diagonal line formed across the base of the picture is the retrace of the scan line. This is present due to the shutter speed of the camera versus the retrace time of 1/30th of a second. It does not affect the digital image processing. 7.7b is the histogram of the original image. As the histogram of the total image shows, there is an increased concentration of pixel gray scale at the lower or black end of the spectrum. This is due to the unlit area and also turbidness of the water.

Histogram modification produces the best results in areas of fairly narrow histograms. To achieve this, a R.O.I. is defined in

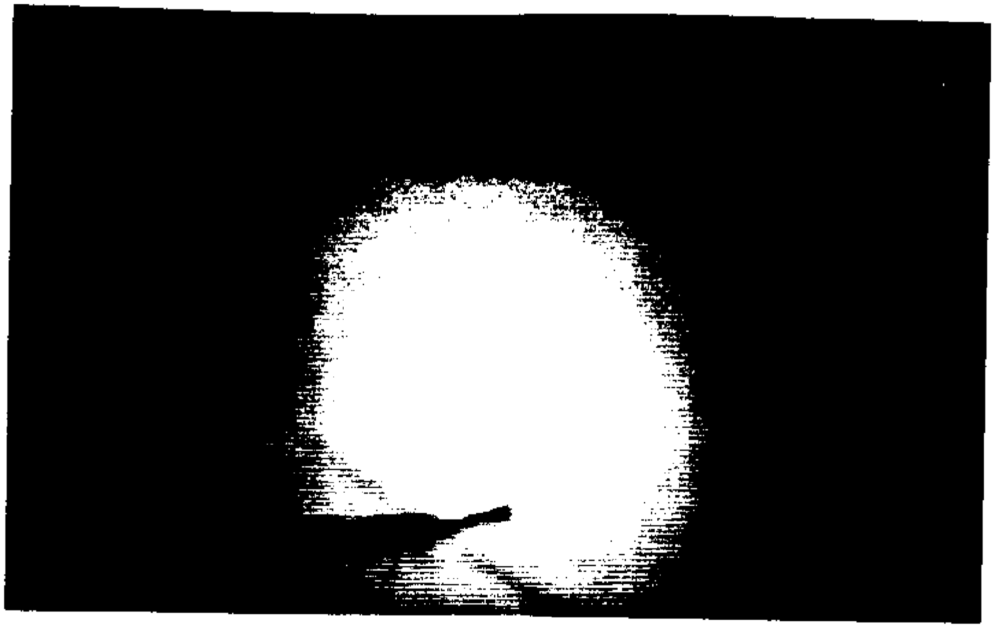


Figure 7.7a

Original Image

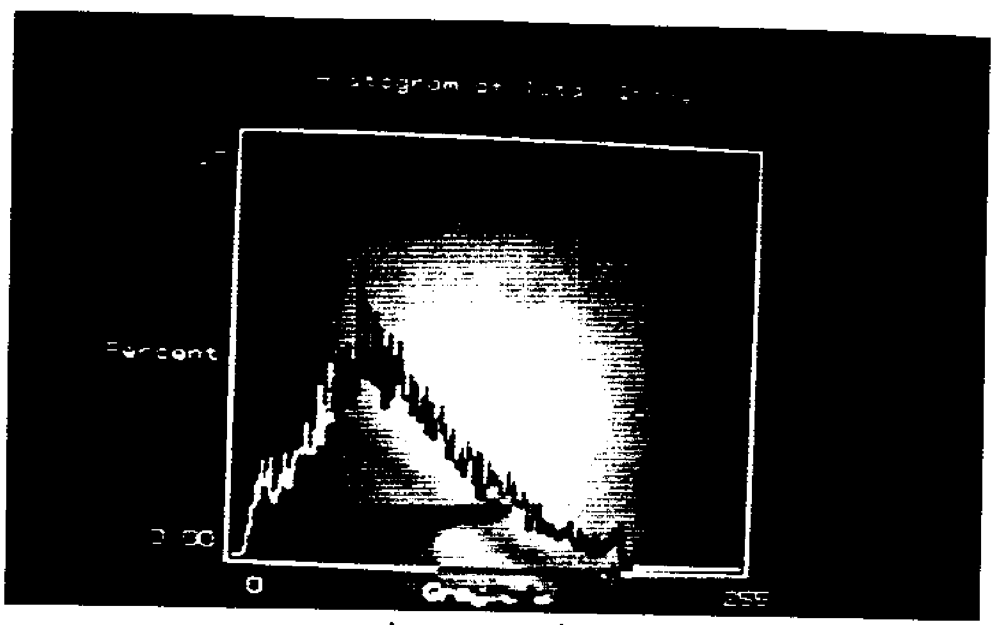


Figure 7.7b

Histogram of Original Image

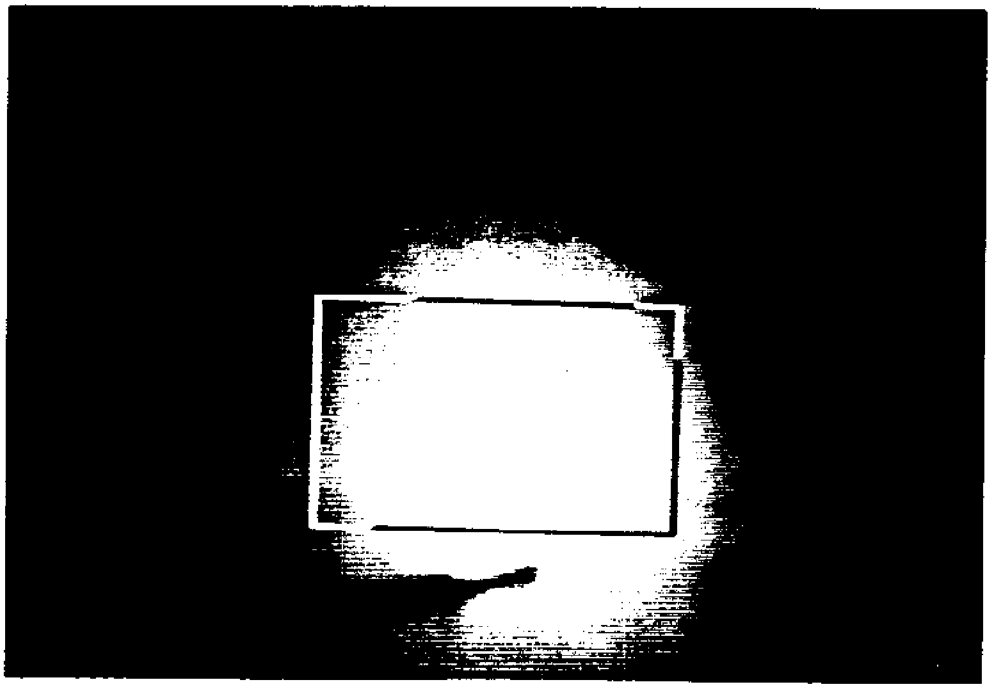


Figure 7.7c

Region of Image

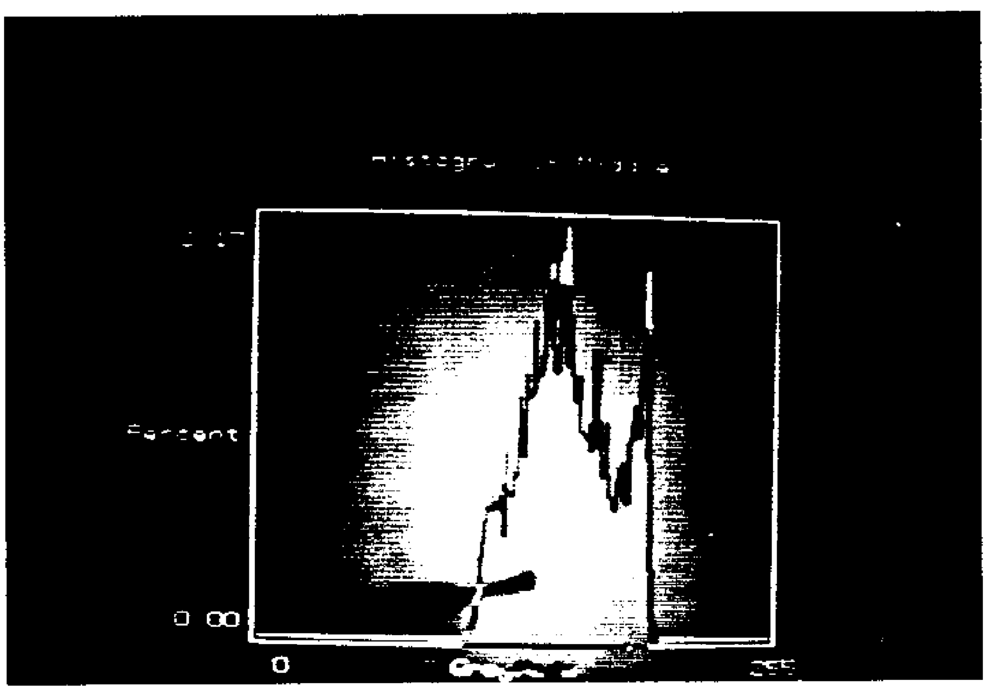


Figure 7.7d

Histogram of R.O.I.

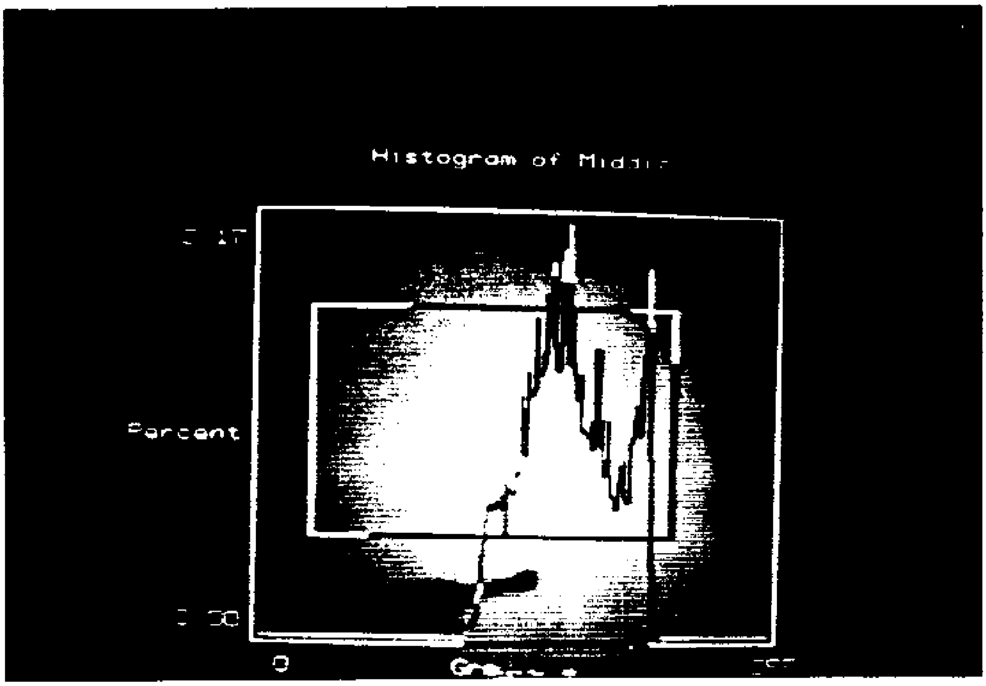


Figure 7.7e

R.O.I. Superimposed Over Histogram

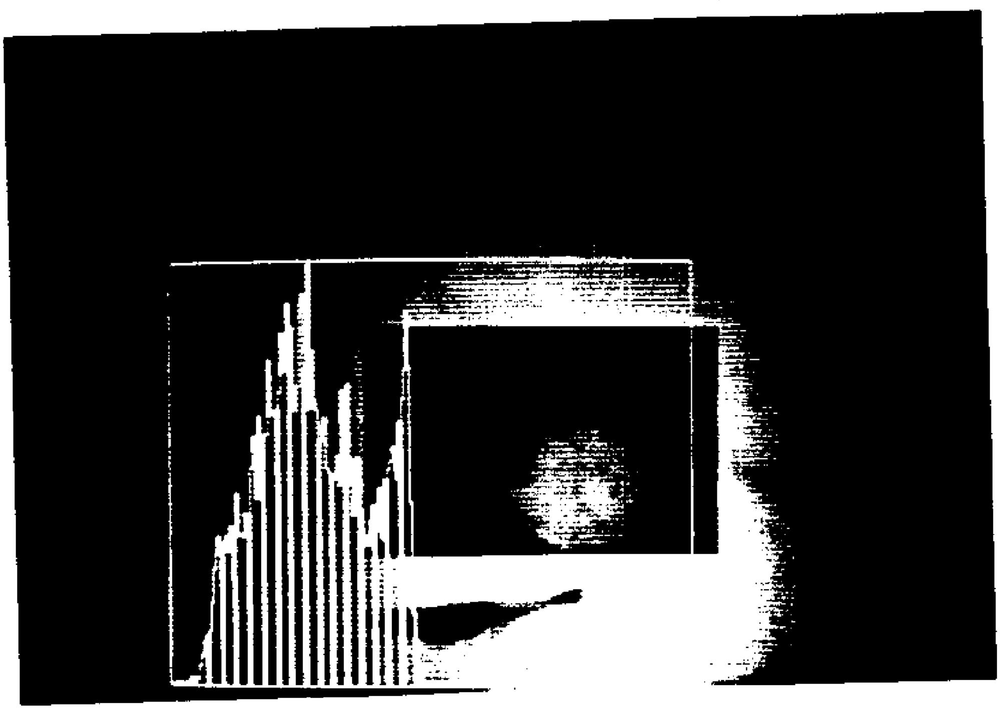


Figure 7.7f

Modified R.O.I. and Modified Histogram

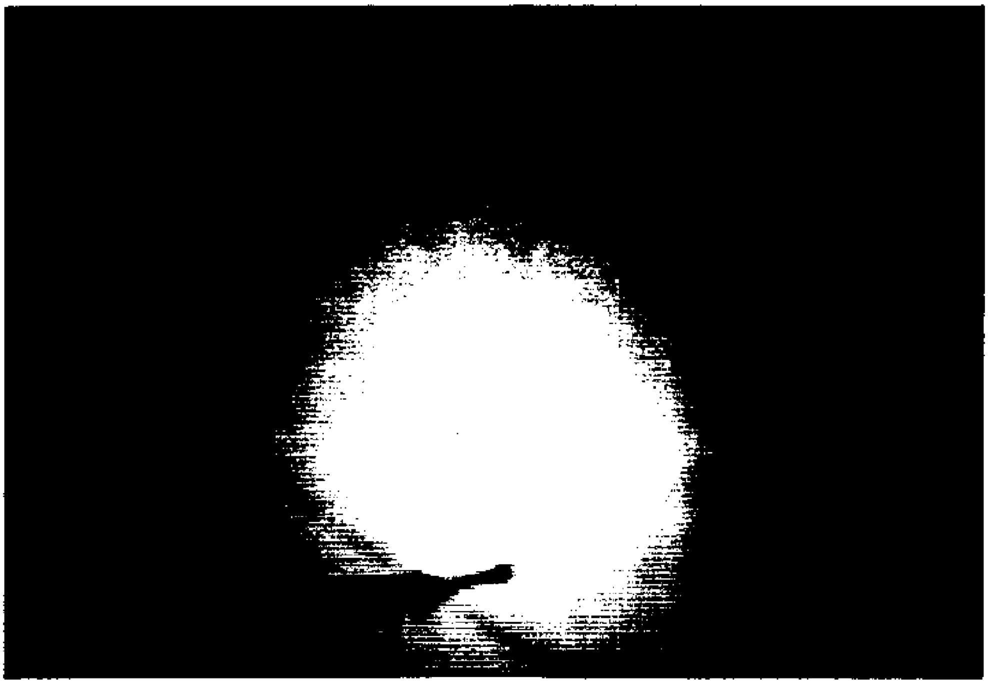


Figure 7.7g

Original Image

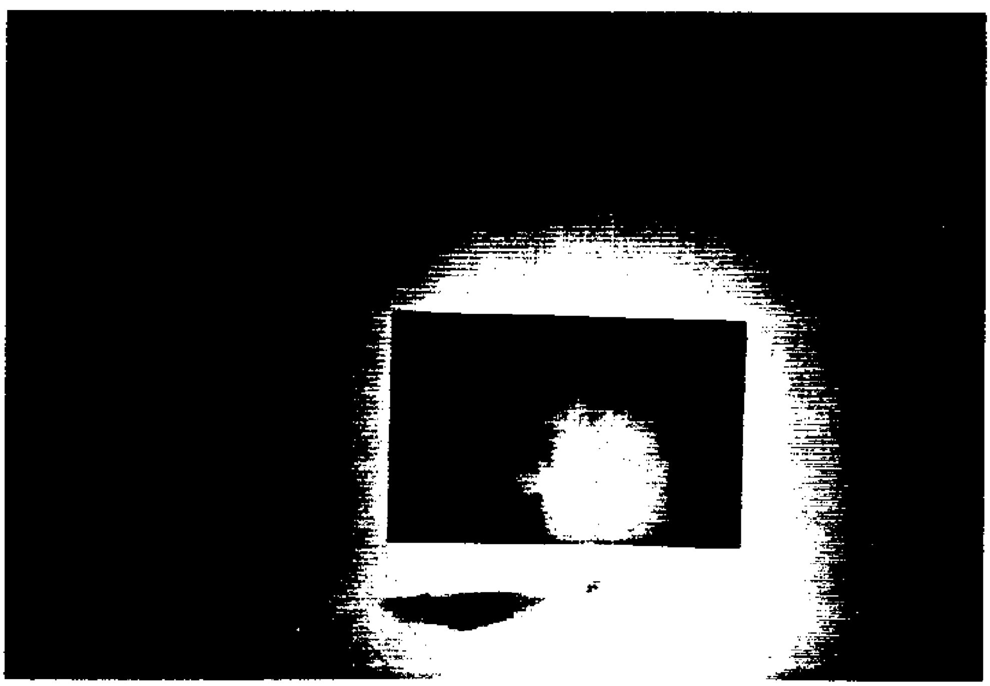


Figure 7.7h

Modified Image

an area containing the chart or valid data. The R.O.I. is shown in 7.7c and encloses the middle of the resolution chart. 7.7d shows the histogram of the R.O.I., or middle, and 7.7e superimposes the R.O.I. over the histogram. To modify the histogram, the mapping of the gray scale is altered. Because the R.O.I. is light,to restore the image we will linearly darken the region. Remember, 0 corresponds to black and 255 corresponds to white. The point x = 96 is mapped down to 0, and the point x = 205 is mapped to 128. In between 96 and 205, the gray scale is adjusted linearly to modify the image. This modification will stretch the gray levels to obtain a uniformly energized histogram. The modified R.O.I. is shown in 7.7f with the modified histogram superimposed on top. A comparison of the original image with the modified image is shown in 7.7g and 7.7h, respectively.

Histogram modification is effective for the data being used. With R.O.I.'s of varying size, eventually a significantly clearer image could be produced.

7.5 Temporal Filtering Techniques

Temporal filtering is the arithmetic time average of multiple image frames. By averaging the level of a pixel's gray scale over numerous frames, the effects of a degradation (such as a piece of debris) on the entire image can be minimized. The type of temporal filtering we performed added the effects of a degradation and then averaged the frames. This is shown in Figure 7.8. The averaging of these four frames would tend to blend the effects of the debris an a pixel's gray scale number. We used MaxVision to filter the input and restore the image. The number of frames averaged before output would depend on the amount and type of degradation.

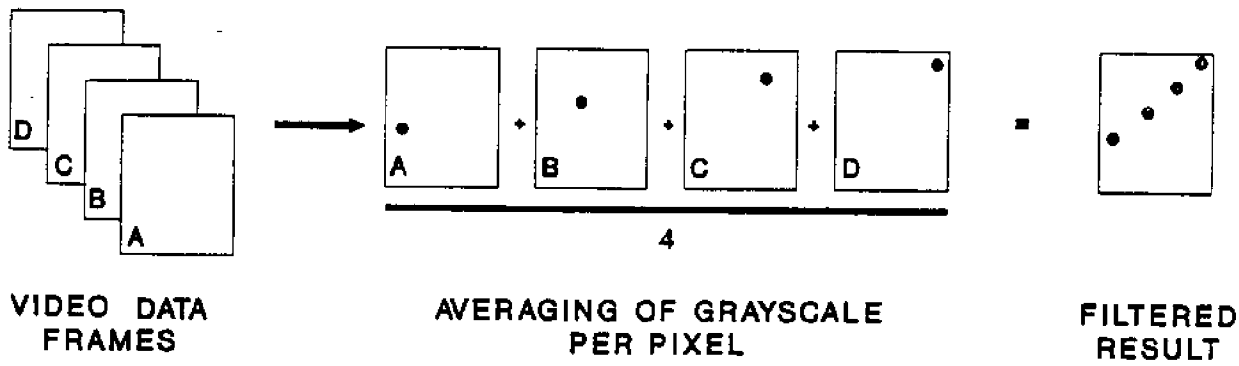


FIGURE 7.8
TEMPORAL FILTERING OF FOUR FRAMES

Inherently, the more frames averaged before output would provide a more visible restoration of the image.

Another way to use temporal filtering is to subtract two images from each other. The output would then be equal to degradation. Then, that output would be subtracted from one of the original images to produce a restored image. We did not implement the subtraction method of temporal filtering because there were too many degradations in our images.

Temporal filtering is a continuous operation, the output changes as more data is fed in. Because of this, it is difficult to freeze frame the results of the processing. Thus, pictures of the restored image image are not available.

Temporal filtering was not as noticeably effective as the histogram modification, but it did improve the image quality.

7.6 Recommendations

The field of digital image processing is still being developed. Project R.O.I. only touched on a few areas of digital image processing, but the usefulness of it is apparent. The database that was collected will have many future uses. Some other types of processing that may improve the image are unsharp masking and inverse filtering. Unfortunately, time did not allow for fully examining these areas.

APPENDIX A

A. ADINA ANALYSIS

ADINA is a finite element analysis package. Finite element analysis, when set up properly, will provide extremely accurate stress analysis results and their resulting displacements of the specimen being tested.

An input file was written for the R.O.I. structure (see pp. 71-74). The input file consists of: 1) Structure dimensions, 2) Material data, 3) Element (beam) properties, 3) Element (beam) locations, 4) Boundary conditions, 5) Gravitational loads, and 6) Applied loads. The input file used for this analysis can be assumed to be fairly accurate; very few assumptions had to be made.

The resulting displacements, at the points where separate elements were joined together (i.e. nodes), are shown within the data listed on p. 75. The maximum displacements have been highlighted for convenience. The maximum displacements occurring for any node are as follows:

Max. X - direction disp. = -0.0202303 inches
Max. Y - direction disp. = -0.997328 inches
Max. Z - direction disp. = -0.326777 inches

Most of the displacement is in the negative Y - direction, as would be expected. The displacements of the structure can also be observed graphically (see p. 76). The plots in the left hand column show the original shape. The plots in the right hand column show both the original shape (dashed lines) and the deformed shape (solid lines); it should be noted that the deformed shape has been exaggerated for ease in observing. Overall, the calculated displacements compared well to those observed experimentally.

```
FEPROGRAM ADINA
CONTROL ECHO=YES MODE=INTERACTIVE OR=LOWERLEFT PLOTUNIT=CM
WORKSTATION SYSTEM=2 DEVICE=4105 BAUDRATE=9600
HEAD 'R.O.I. - STRUCTURE ANALYSIS / ME 786 FINAL PROJECT'
*
MASTER IDOF=000000 REACTION=YES
ANALYSIS TYPE=DYNAMIC MASSMATRIX=LUMPED METHOD=NEWMARK
PRINTOUT IPDATA=4 IOUTPT=0 IVC=0 IAC=0
PORTHOLE VOLUME=MAX FORMATTED=YES
*
SYSTEM 1 CARTESIAN
COORDINATES
ENTRIES NODE   X   Y   Z
 SYSTEM    1   /   COORDINATES
*     NODE         X          Y          Z
         1        0.0       27.5       27.5
         2        0.0        0.0       27.5
         3       21.5       27.5       27.5
         4       21.5        0.0       27.5
         5       37.0       27.5       27.5
         6       37.0        0.0       27.5
         7       51.5       27.5       27.5
         8       51.5        0.0       27.5
         9       66.5       27.5       27.5
        10       66.5        0.0       27.5
        11       81.5       27.5       27.5
        12       81.5        0.0       27.5
        13       96.0       27.5       27.5
        14       96.0        0.0       27.5
        15      122.0       27.5       27.5
        16      122.0        0.0       27.5
        17      122.0       27.5        0.0
        18      122.0        0.0        0.0
        19       96.0       27.5        0.0
        20       96.0        0.0        0.0
        21       81.5       27.5        0.0
        22       81.5        0.0        0.0
        23       66.5       27.5        0.0
        24       66.5        0.0        0.0
        25       51.5       27.5        0.0
        26       51.5        0.0        0.0
        27       37.0       27.5        0.0
        28       37.0        0.0        0.0
        29       21.5       27.5        0.0
        30       21.5        0.0        0.0
        31        0.0       27.5        0.0
        32        0.0        0.0        0.0
        33        0.0       47.5       13.5
        34       51.5       47.5       13.5
        35       79.0       47.5       13.5
        36      122.0       47.5       13.5
        37       21.0       47.5       13.5
        38       64.5       47.5       13.5
        39      108.0       47.5       13.5
        40       64.5       87.5       13.5
        41       61.0       92.0        0.0
*PVC ELEMENTS - MATERIAL AND ELEMENT DATA
MATERIAL 1 ELASTIC E=4.6D5  NU=0.350  DENSITY=0.047
EG 1 BEAM SUBTYPE=DIM3 DISPLACEMENTS=SMALL MATERIAL=1
SECTION N=1 PROPERTIES RI=3.83D-4  SI=1.92D-4  TI=1.92D-4 AREA=2.41,
```

```
 SAREA=2.41 TAREA=2.41
GLINE   N1=1 N2=2  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=1 N2=3  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=3 N2=5  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=5 N2=7  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=7 N2=9  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=9 N2=11 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=11 N2=13 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=13 N2=15 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=15 N2=16  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=16 N2=14  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=14 N2=12  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=12 N2=10  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=10 N2=8  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=8 N2=6  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=6 N2=4  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=4 N2=2  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=31 N2=32  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=31 N2=29  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=29 N2=27  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=27 N2=25  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=25 N2=23  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=23 N2=21  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=21 N2=19 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=19 N2=17  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=17 N2=18  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=18 N2=20  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=20 N2=22  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=22 N2=24  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=24 N2=26  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=26 N2=28  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=28 N2=30  AUX=41  EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=30 N2=32  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=1 N2=31  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=5 N2=27  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=9 N2=23  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=13 N2=19  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=15 N2=17  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=16 N2=18  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=14 N2=20  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=10 N2=24  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=6 N2=28  AUX=41  EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=2 N2=32  AUX=41  EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=3 N2=4  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=7 N2=8  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=11 N2=12  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=21 N2=22  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=25 N2=26  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=29 N2=30  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
*STEEL CABLES - MATERIAL AND ELEMENT DATA
MATERIAL 2 ELASTIC E=28.006  NU=0.305  DENSITY=0.276
EG 2 BEAM SUBTYPE=DIM3 DISPLACEMENTS=SMALL MATERIAL=2
SECTION N=1 PROPERTIES RI=1.0  SI=1.0  TI=1.0  AREA=0.049,
 SAREA=0.049  TAREA=0.049
GLINE   N1=8 N2=26   AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=12 N2=22  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=1 N2=33   AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=31 N2=33  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=7 N2=34   AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=25 N2=34  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=11 N2=35  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
```

```
GLINE   N1=21 N2=35  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=15 N2=36  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=17 N2=36  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=37 N2=40  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=38 N2=40  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=39 N2=40  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=1 N2=2  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=15 N2=16  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=31 N2=32  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=17 N2=18  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=16 N2=18  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=2 N2=32  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=7 N2=8  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=11 N2=12  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=21 N2=22  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=25 N2=26  AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
*SET ENDRELEASE
     ENDRELEASE N=2 4 5 6 10 11 12
*     ENDRELEASE N=2
     EDAT
     ENT  EL  SECTION  IELREL
      1   1  2
      2   1  2
      3   1  2
      4   1  2
      5   1  2
      6   1  2
      7   1  2
      8   1  2
      9   1  2
     10   1  2
     11   1  2
     12   1  2
     13   1  2
     14   1  2
     15   1  2
     16   1  2
     17   1  2
     18   1  2
     19   1  2
     20   1  2
     21   1  2
     22   1  2
     23   1  2
*WOODEN SPREADER BAR - MATERIAL AND ELEMENT DATA
MATERIAL 3 ELASTIC E=1.2D6  NU=0.350  DENSITY=0.035
EG 3 BEAM SUBTYPE=DIM3 DISPLACEMENTS=SMALL MATERIAL=3
SECTION N=1 PROPERITIES RI=6.344 SI=5.36 TI=0.984 AREA=5.25,
 SAREA=5.25 TAREA=5.25
GLINE   N1=33 N2=37 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=37 N2=34 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=34 N2=38 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=38 N2=35 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=35 N2=39 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
GLINE   N1=39 N2=36 AUX=41 EL=1 NODES=2 NCOINCIDE=ALL
*SET LOAD MASSPROPORTIONAL
      LOAD  M  FDIRGR2=1 A=-1.0
*BOUNDARY CONDITIONS
      BOUNDARIES IDOF=111111   TYPE=NODES
      40
      BOUNDARIES IDOF=101000   TYPE=NODES
```

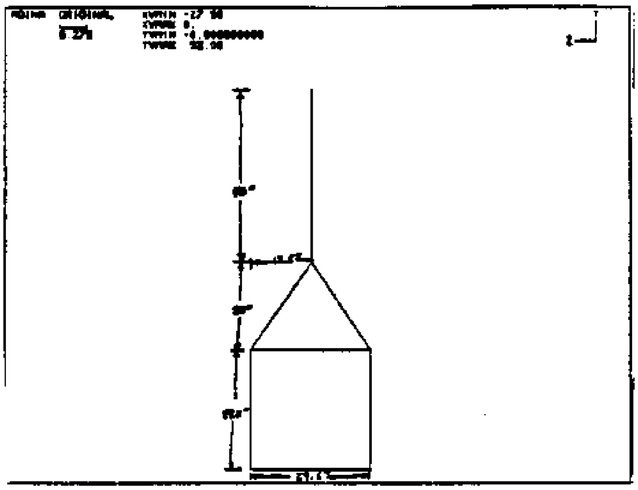
```
      32 18
      BOUNDARIES IDOF=001000   TYPE=NODES
      32
      BOUNDARIES IDOF=100000   TYPE=NODES
      2
      BOUNDARIES IDOF=000111   TYPE=NODES
      37 38 39
*EXTERNAL LOADS
      LOAD CONCENTRATED
      15  2  -12.5
      17  2  -12.5
      13  2  -3.0
      14  2  -3.0
      19  2  -3.0
      20  2  -3.0
      14  2  -8.755
      20  2  -8.755
      10  2  -6.745
      24  2  -6.745
      6   2  -3.775
      28  2  -3.775
      2   2  -5.925
      32  2  -5.925
*WT. OF CAMERA STRUCTURE AT NODES 7,25 -- 6 FT.
      7   2  -6.0
      25  2  -6.0
      ADINA
EXIT
```

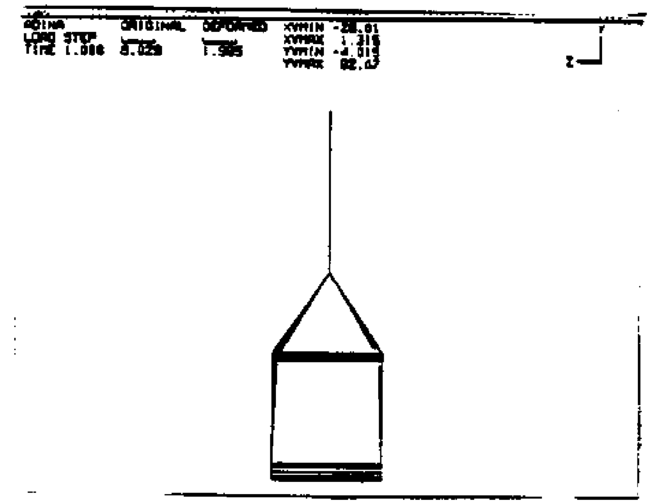
PROGRAM ADINA - VERSION ADINA 5.0/NL3 R.O.I. - STRUCTURE ANALYSIS / ME 786 FINAL PROJECT
LICENSED FROM A D I N A R & D INC. FOR USE BY UNIVERSITY OF NEW HAMPSHIRE

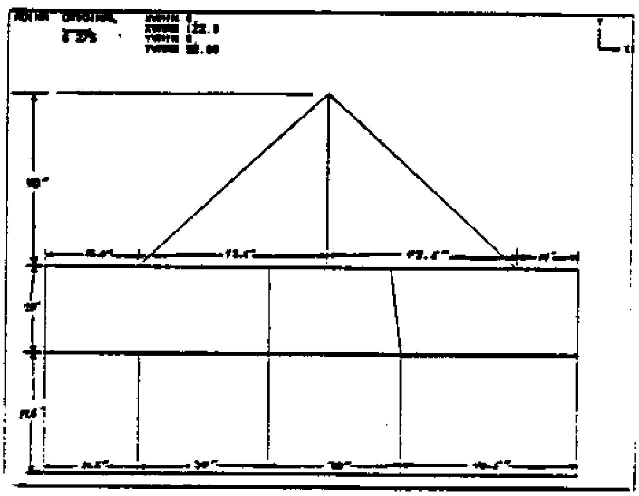
P R I N T O U T F O R T I M E (L O A D) S T E P 1 (TIME STEP= 0.10000E+01 SOLUTION TIME= 0.10000E+01

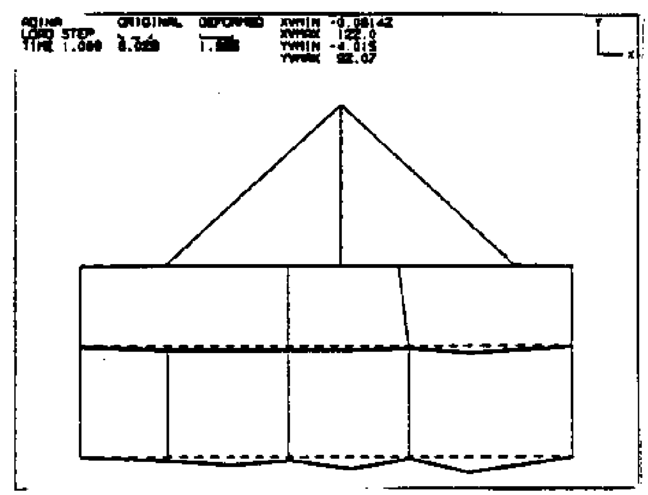
D I S P L A C E M E N T S

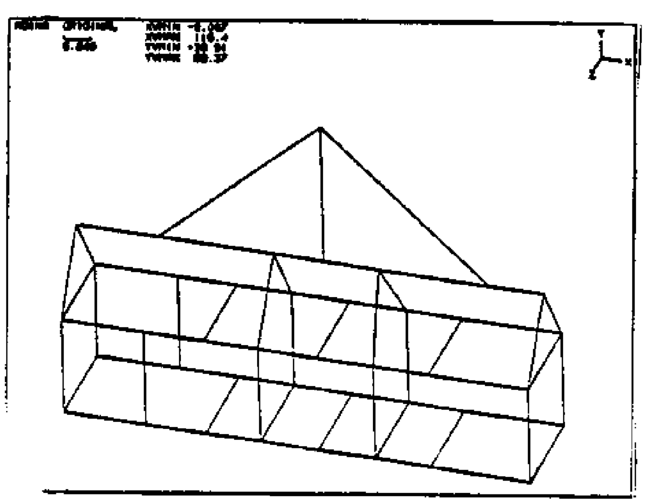
NODE	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X/V1-ROTATION	Y/V2-ROTATION	Z/VN-ROTATION	FLUID PHI/PO*	REF SYST TRAN-DOF	REF SYST ROT- DOF
1	-0.380631E-02	-0.594564E-01	0.418414E-03	0.195119E-03	0.153018E-02	-0.693569E-02	0.000000E+00	GLOBAL	GLOBAL
2	0.000000E+00	-0.595618E-01	-0.399325E-08	0.195047E-03	0.257875E-03	-0.944004E-03	0.000000E+00	GLOBAL	GLOBAL
3	-0.380780E-02	-0.251776E+00	0.196765E-02	-0.378892E-03	-0.485667E-02	-0.114957E-02	0.000000E+00	GLOBAL	GLOBAL
4	-0.149920E-08	-0.251777E+00	0.111329E-04	-0.378909E-03	-0.353300E-03	-0.178028E-01	0.000000E+00	GLOBAL	GLOBAL
5	-0.380984E-02	-0.249679E+00	-0.277619E-04	-0.285273E-02	0.167810E-01	0.158060E-02	0.000000E+00	GLOBAL	GLOBAL
6	0.185813E-06	-0.526913E+00	-0.935859E-08	-0.285273E-02	0.934821E-04	0.103185E-01	0.000000E+00	GLOBAL	GLOBAL
7	-0.381241E-02	-0.228128E+00	[redacted]	-0.924926E-02	-0.133645E-02	-0.125788E-03	0.000000E+00	GLOBAL	GLOBAL
8	0.361073E-06	-0.228135E+00	-0.132835E-05	-0.924926E-02	-0.782221E-04	-0.112100E-01	0.000000E+00	GLOBAL	GLOBAL
9	-0.381590E-02	-0.245665E+00	-0.251229E-04	-0.420074E-02	-0.708409E-02	0.646067E-02	0.000000E+00	GLOBAL	GLOBAL
10	0.652552E-06	-0.741973E+00	0.139239E-09	-0.420074E-02	-0.319321E-04	0.864366E-02	0.000000E+00	GLOBAL	GLOBAL
11	-0.382007E-02	-0.133455E+00	-0.178471E+00	-0.538623E-02	0.392950E-02	-0.680068E-02	0.000000E+00	GLOBAL	GLOBAL
12	0.944149E-06	-0.133478E+00	-0.490416E-06	-0.538624E-02	0.223441E-03	-0.445176E-02	0.000000E+00	GLOBAL	GLOBAL
13	-0.381871E-02	-0.439027E+00	-0.431734E-05	-0.180653E-02	-0.117547E-01	-0.112850E-01	0.000000E+00	GLOBAL	GLOBAL
14	0.133188E-05	-0.997483E+00	0.430555E-07	-0.180654E-02	-0.126155E-03	-0.434623E-01	0.000000E+00	GLOBAL	GLOBAL
15	-0.381763E-02	-0.657636E-01	-0.117838E-02	0.107622E-03	0.364538E-02	0.493394E-02	0.000000E+00	GLOBAL	GLOBAL
16	0.202762E-05	-0.658048E-01	-0.492318E-08	0.107527E-03	0.423869E-03	0.377335E-01	0.000000E+00	GLOBAL	GLOBAL
17	-0.395951E-02	-0.487338E-01	-0.833915E-03	0.443339E-03	-0.360064E-02	0.529188E-02	0.000000E+00	GLOBAL	GLOBAL
18	0.000000E+00	-0.487787E-01	0.000000E+00	0.443244E-03	-0.420673E-03	0.380913E-01	0.000000E+00	GLOBAL	GLOBAL
19	-0.396063E-02	-0.438872E+00	-0.310976E-05	0.186993E-02	0.117844E-01	-0.113045E-01	0.000000E+00	GLOBAL	GLOBAL
20	-0.847546E-06	[redacted]	0.433699E-07	0.186991E-02	0.125641E-03	-0.434818E-01	0.000000E+00	GLOBAL	GLOBAL
21	-0.396206E-02	-0.128714E+00	0.178609E+00	0.540094E-02	-0.391856E-02	-0.679465E-02	0.000000E+00	GLOBAL	GLOBAL
22	-0.132039E-05	-0.128738E+00	-0.455439E-06	0.540093E-02	-0.222766E-03	-0.444573E-02	0.000000E+00	GLOBAL	GLOBAL
23	-0.395774E-02	-0.245405E+00	-0.215033E-04	0.420780E-02	0.700098E-02	0.636958E-02	0.000000E+00	GLOBAL	GLOBAL
24	-0.170050E-05	-0.741714E+00	-0.174705E-07	0.420780E-02	0.317499E-04	0.855258E-02	0.000000E+00	GLOBAL	GLOBAL
25	-0.395411E-02	-0.221239E+00	0.324571E+00	0.919645E-02	0.134190E-02	-0.160512E-03	0.000000E+00	GLOBAL	GLOBAL
26	-0.208091E-05	-0.221246E+00	-0.124880E-05	0.919645E-02	0.785279E-04	-0.112447E-01	0.000000E+00	GLOBAL	GLOBAL
27	-0.395146E-02	-0.249554E+00	-0.252804E-04	0.285906E-02	-0.166952E-01	0.198583E-02	0.000000E+00	GLOBAL	GLOBAL
28	-0.234187E-05	-0.526788E+00	-0.245987E-07	0.285906E-02	-0.934741E-04	0.107236E-01	0.000000E+00	GLOBAL	GLOBAL
29	-0.394933E-02	-0.251740E+00	-0.194588E-02	0.435781E-03	0.485865E-02	-0.144468E-02	0.000000E+00	GLOBAL	GLOBAL
30	-0.262125E-05	-0.251741E+00	-0.165936E-04	0.435764E-03	0.352750E-03	-0.180979E-01	0.000000E+00	GLOBAL	GLOBAL
31	-0.394778E-02	-0.458180E-01	0.645954E-03	0.286735E-03	-0.149384E-02	-0.725890E-02	0.000000E+00	GLOBAL	GLOBAL
32	-0.274005E-05	-0.459263E-01	0.000000E+00	0.286664E-03	-0.255226E-03	-0.126711E-02	0.000000E+00	GLOBAL	GLOBAL
33	-0.195912E-01	-0.520874E-01	0.104499E-01	0.000000E+00	0.120070E-02	0.494694E-02	0.000000E+00	GLOBAL	GLOBAL
34	-0.198119E-01	-0.611315E-03	-0.201481E-02	0.000000E+00	-0.678487E-04	-0.283689E-03	0.000000E+00	GLOBAL	GLOBAL
35	-0.200124E-01	-0.102482E-01	0.283613E-03	0.000000E+00	-0.220286E-03	-0.919593E-03	0.000000E+00	GLOBAL	GLOBAL
36	-0.202300E-01	-0.564488E-01	0.113754E-01	0.000000E+00	-0.784009E-03	-0.322113E-02	0.000000E+00	GLOBAL	GLOBAL
37	-0.195918E-01	0.174261E-01	-0.635892E-02	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	GLOBAL	GLOBAL
38	-0.199064E-01	-0.796861E-03	-0.196588E-02	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	GLOBAL	GLOBAL
39	[redacted]	-0.261348E-01	0.405823E-02	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	GLOBAL	GLOBAL
40	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	GLOBAL	GLOBAL
41	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	GLOBAL	GLOBAL

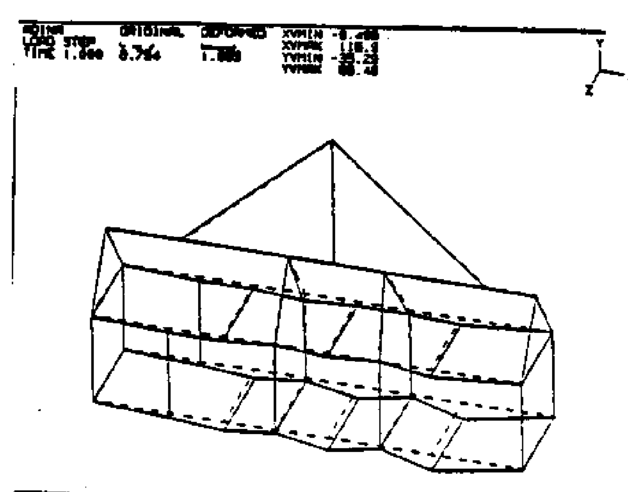

ADINA ORIGINAL


ADINA
LOAD STEP
TIME 1.000
ORIGINAL
DEFORMED


ADINA ORIGINAL

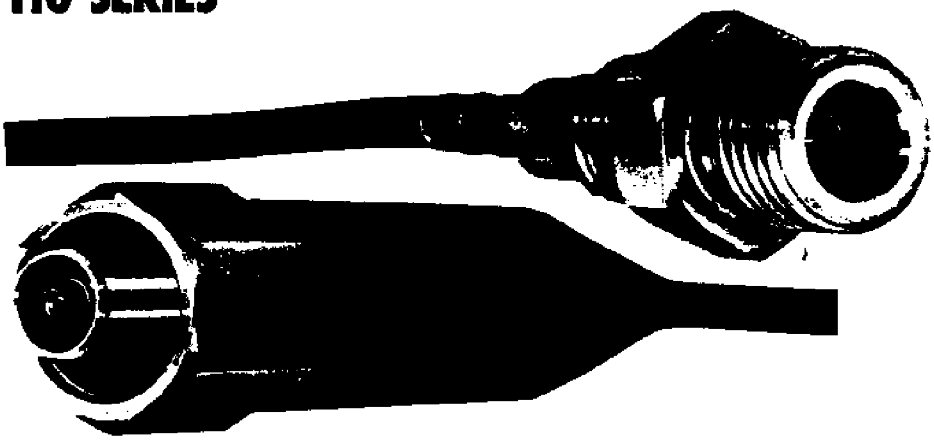

ADINA
LOAD STEP
TIME 1.000
ORIGINAL
DEFORMED


ADINA ORIGINAL


ADINA
LOAD STEP
TIME 1.000
ORIGINAL
DEFORMED

APPENDIX B

110 SERIES



110 Series miniature high-pressure coaxial connectors are designed to be compatible with miniature coaxial cables such as RG 58C/U. In addition to straight plug, 110 Series Connectors are also available in 2 receptacle styles for AN port mounting and in-line receptacles for cable-to-cable connection. Standard cable assemblies with RG-58C/U available.

MATERIALS

Item	Plug	Receptacle	Specification
Shell	316 S.S.	316L S.S.	QQ-S-763
Coupling Ring	316 S.S.		QQ-S-763
Contacts	Copper Alloy	Steel	N/A
Contact Plating	Gold	Gold	MIL-G-45204 Type II, Class I
O-rings	Buna-N	Buna-N	MIL-P-5516, Class B
Insulators	Nylon	Compression Glass	N/A

ELECTRICAL DATA

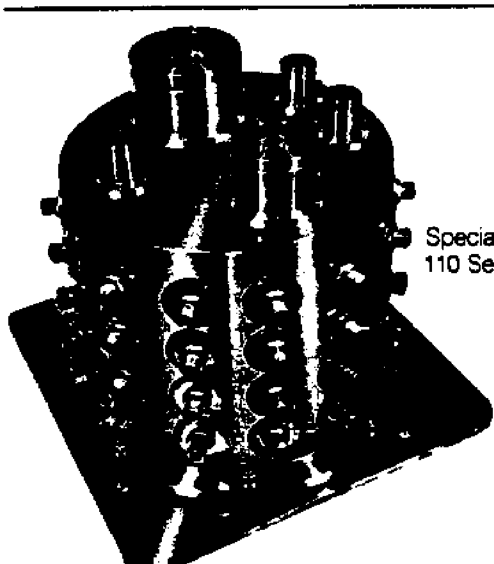
Characteristic Impedance 50 ohms

Dielectric Strength 1500 volts (RMS) 60 Hertz

ENVIRONMENTAL DATA

Hydrostatic Pressure 10,000 psig

Operating Temperature −67°F to +185°F

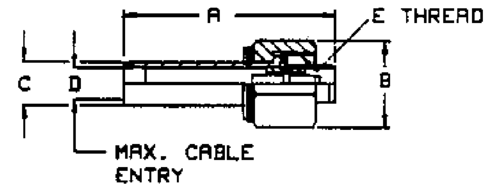


Special junction box employing a number of 110 Series Coax Connectors.

NOTE—ALL B DIMENSIONS ACROSS FLATS

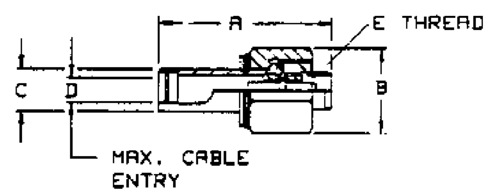
PLUG—STRAIGHT

Plug Part Number	No. of Contacts	Wire Accom.	A Nom.	B Nom.	C ±.002	D Max.	E Thread
C10C1001G09	1	16	2.125	.750	.436	.312	5/8-18UNF-2B
C10C1001G01	1	RG-58C/U	2.125	.750	.436	.312	5/8-18UNF-2B



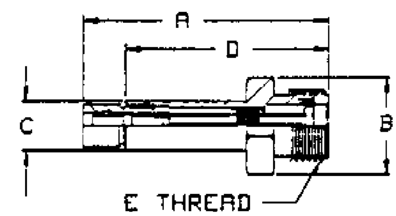
PLUG—RIGHT ANGLE

Plug Part Number	No. of Contacts	Wire Accom.	A Nom.	B Nom.	C ±.002	D Max.	E Thread
C10C1002G04	1	16	1.750	.750	.436	.245	5/8-18UNF-2B
C10C1002G01	1	RG-58C/U	1.750	.750	.436	.245	5/8-18UNF-2B



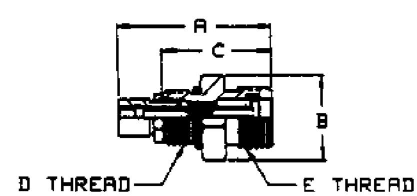
RECEPTACLE—IN LINE

Receptacle Part Number	No. of Contacts	Wire Accom.	A Ref.	B Nom.	C ±.002	D Nom.	E Thread
C10C0002G05	1	16	2.072	.750	.436	1.760	5/8-18UNF-2A
C10C0002G01	1	RG-58C/U	2.072	.750	.436	1.760	5/8-18UNF-2A



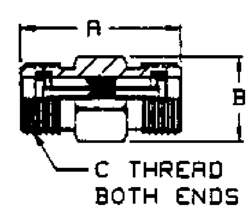
RECEPTACLE—BULKHEAD FITS STANDARD SAE PORT

Receptacle Part Number	No. of Contacts	Wire Accom.	A Ref.	B Nom.	C Nom.	D Thread	E Thread	SAE Port Size	Installation Detail Pg. 23 Table VII
C10C0001G07	1	16	1.500	.750	1.095	9/16-18UNF-2A	5/8-18UNF-2A	6	A
C10C0001G01	1	RG58C/U	1.500	.750	1.095	9/16-18UNF-2A	5/8-18UNF-2A	6	A



RECEPTACLE—SPLICE

Receptacle Part Number	No. of Contacts	A Nom.	B Nom.	C Thread
C10C0004G01	1 RG58C/U	1.380	.750	5/8-18UNF-2A



APPENDIX C

C. CALCULATIONS OF LIGHT INTENSITY NEEDED BY THE CAMERA

1.41 lm	{maximum lumens camera can handle}
8.5"x 11"	{size of resolution chart}
2 feet	{lights are 2 ft from resolution chart}
E	{illuminance}
p=.70	{reflection coefficient of laminated resolution chart}
M	{radiator power density}
I	{intensity}
L	{luminous }
.00136	{area of fully opened apature}
4	{amount of lights}
4_1	{camera distance from chart,squared}
$.9m^{-1}$	{typical particle attenuation coefficient in turbid water; reference Optical Oceanography}
A=.68'	{area of resolution chart}

1.41 lm=.00136*(I/4)*.9	I=4607.84 cd
I=L*A	L=6676.23 cd/ft^2
(22/7)*L=M	M=21288.17 lm/ft^2
$(M/p)/4_1$=E	E=7602.92 fc
E=candlepower/2^2	candlepower=30,411.67

36PAR36CAP/VNSP will generate 23,000 candlepower which will generate enough lumens to operate the camera, as it is moved between 2 and 10 feet from the chart, in between the high and middle end of its specs.(For more information on these calculations, refer to Illumination Engineering [9].)

APPENDIX D

D. EXPENSE REPORT

10 36PAR36CAP/VNSP	Donated
Underwater Connectors	Donated
RG-58 A/U Coax Cable	Donated
Epoxy	Donated
12 Volt Battery	Borrowed
12/3 Gauge Wire	$51.00
Duck Tape	$2.00
Solder	$3.00
Electric Tape	$2.00
Water Proofing Connection	$6.00
Multimeter Battery	$9.00
Total	$73.00

Appendix E

E1. Record of the Video Image Cassettes

E1.1 This Appendix provides important information about data which has been stored on VHS cassettes, for example information about weather, water depth, boat positioning, and recording times.

The VHS cassettes were recorded with the industry standard speed of SP. All images are referenced according to their distance from the resolution chart, their water depth, and their starting and ending recording revolutions.

April 4, 1990

Tape Number 1

Location: 43 degrees 07 minutes 52.0 seconds North
70 degrees 48 minutes 56.0 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time
26 inches	35 ft.	0000 - 0450	13:55
	30	0500 - 0950	
	25	1000 - 1450	
	20	1500 - 1950	
	15	2000 - 2450	
	10	2500 - 2950	
	05	3000 - 3450	
	00	3500 - 3600	

---

48 inches	00 ft.	4000 - 4100	15:30
	35	4500 - 4950	
	30	5000 - 5450	
	25	5500 - 5767	
	20	5796 - 5905	

April 4, 1990

Tape number 2

Location: 43 degrees 07 minutes 52.0 seconds North

70 degrees 48 minutes 56.0 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time

April 12, 1990

Tape number 3

Location: 43 degrees 06 minutes 38.0 seconds North

70 degrees 51 minutes 27.0 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time	
26 inches	25 ft.	0000 - 0530	18:00	Apt 13
	20	0600 - 1025		
	15	1100 - 1425		
	10	1500 - 1725		
	05	1800 - 2050		
	00	2100 - 2400		Apt 6
48 inches	20 ft.	2500 - 2740		
	15	2800 - 3050		
	10	3100 - 3350		
	05	3400 - 3670		
	00	3700 - 3770	19:25 19:40(LIGHTS)	
72 inches	00 ft	3770 - 3825	20:06 (no light)	

15	3900 - 4090
10	4150 - 4330
05	4400 - 4610

weather: sunny, partly cloudy

April 17, 1990 No Turbidity measurements

Tape number 4 Water depth 40 ft

Location: 43 degrees 07 minutes 04.7 seconds North

70 degrees 51 minutes 43.6 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time	
26 inches	25 ft	0000 - 0401	13:41	Apt 1.3
	20	0451 - 0900		
	15	0950 - 1349		
	10	1390 - 1685		
	05	1750 - 2107		
	00	2150 - 2424	no lights	

Camera to Chart	Depth	Revolution on tape	Starting time
48 inches	30 ft	2500 - 2840	14:56
	25	2900 - 3000	
	20	3050 - 3280	
	15	3325 - 3494	
	10	3550 - 3760	
	05	3796 - 3992	
	00	4051 - 4202	

---

72 inches	35 ft	4246 - 4429	16:10
	30	4478 - 4645	
	25	4701 - 4861	
	20	4901 - 5063	
	15	5100 - 5247	
	10	5302 - 5462	
	05	5504 - 5649	
	00	5702 - 5837	

weather: overcast,raining

April 17, 1990 No Turbidity measurements

Tape number 5 Water depth 40 ft

Location: 43 degrees 07 minutes 04.7 seconds North

70 degrees 51 minutes 43.6 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time
96 inches	35 ft	0000 - 0460	17:22
	30	0500 - 0900	
	25	0950 - 1360	
	20	1400 - 1669	
	15	1702 - 1997	
	10	2054 - 2299	
	05	2353 - 2605	
	00	2648 - 2900	

---

strong current

Location: 43 degrees 05 minutes 46.0 seconds North

70 degrees 46 minutes 40.0 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time

26 inches	20 ft	2953 - 3178	19:13 Ambient light/only
	20 ft	3252 - 3439	on bottom Apt 3
	15	3501 - 3703	
	10	3753 - 3936	
	05	3974 - 4172	
	00	4203 - 4290	Apt 16

---

96 inches	20 ft	4353 - 4565	20:30
	midrange	4603 - 4956	
pulling up structure		5001 - 5070	

weather overcast

April 23, 1990 No Turbidity measurements

Tape number 6 Water depth 20 ft

Location: 43 degrees 04 minutes 54.2 seconds North

70 degrees 51 minutes 41.1 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time	
26 inches	20 ft.	0000 - 0866	14:20	Apt 6
	15	0900 - 1500		
	10	1600 - 2100		
	05	2200 - 2600		
	00	2700 - 2800		Apt 12
48 inches	20 ft.	2900 - 3372		Apt 6
	15	3501 - 3898		
	10	4000 - 4394		
	05	4500 - 4800		
	05	4900 - 5050	Extra light 4950-5050	
	00	5100 - 5200		

weather: sunny

April 23, 1990 No Turbidity measurements

Tape number 7 Water depth 25 ft

Location: 43 degrees 06 minutes 39.0 seconds North

70 degrees 48 minutes 00.6 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time	
26 inches	20 ft	0000 - 0700	18:00	
	15	0800 - 1400		
	10	1500 - 2000		
	05	2100 - 2531		
	00	2650 - 2900		
48 inches	15 ft.	3000 - 3507	19:25	Apt 1.8
	10	3600 - 4010		
	05	4099 - 4471		
	00	4602 - 4680		Apt 1.3
96 inches	20 ft.	4750 - 5100	fish4936,5033,5055	Apt 1.8
	15	5200 - 5528	shrimp5200,5220,5363	

10	5601 - end

weather: sunny

Tape number 8 Water depth 25 ft

Location: 43 degrees 06 minutes 39.0 seconds North
70 degrees 48 minutes 00.6 seconds West

Camera to Chart	Depth	Revolution on tape	Starting time
96 inches	05 ft.	0000 - 0794	

APPENDIX F

F. JUSTIFICATION OF FINAL BUDGET

Photo meter $600
measure amount light in the ocean water

Water tight enclosures $300
allow equipment to be water safe

Lighting $300
allow for the taking of underwater data

Structure $600
needed for taking data underwater
{ pvc piping, ballast, connectors, etc.. }

Boat Fuel $100
needed to take data in the ocean { 5 trips }

Tank $50
needed to take control data in order to compare with ocean data

Miscellaneous $50
unexpected expenses

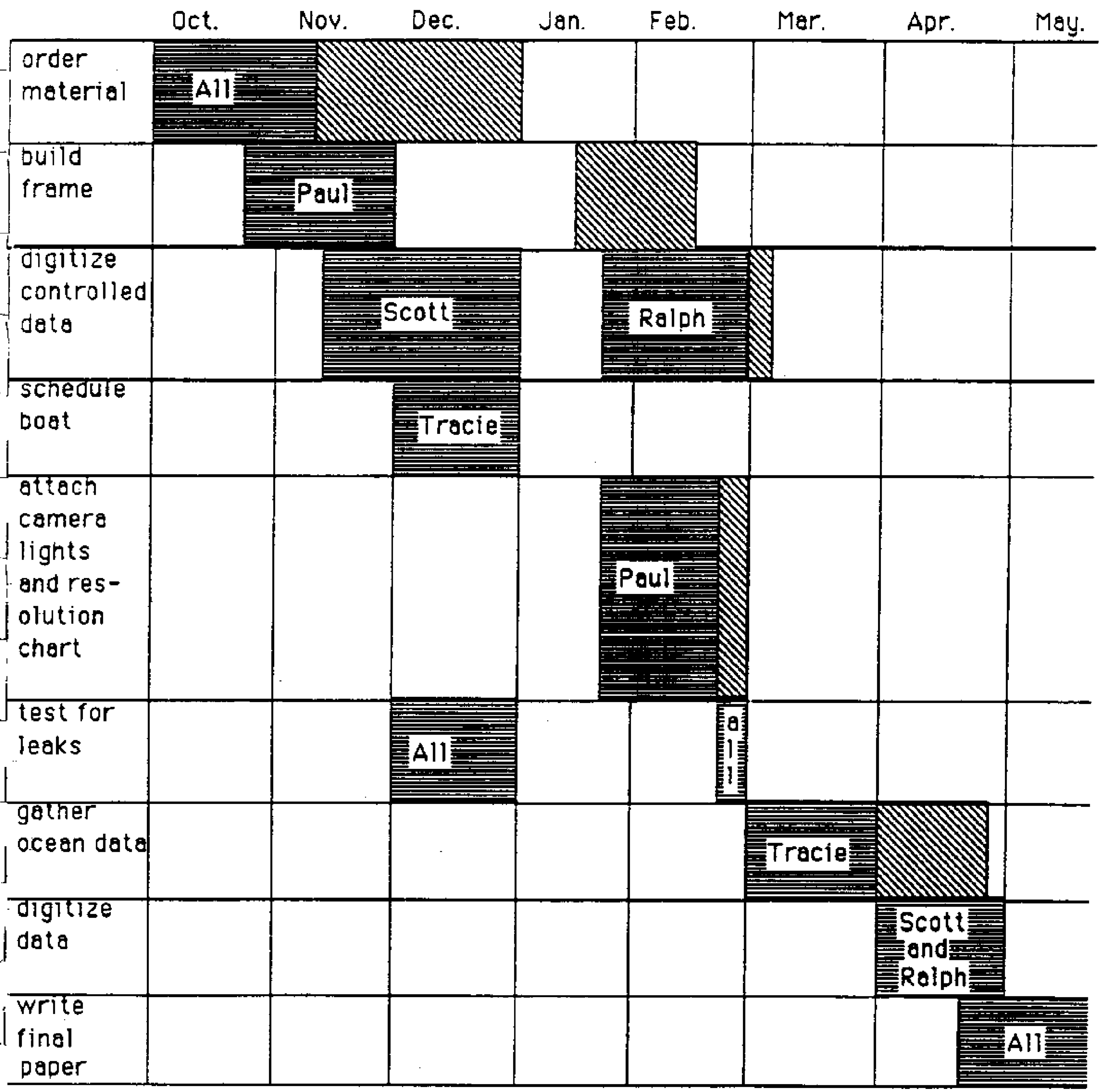
Telephone $100
monies needed to get in contact with people and companies about equipment prices and information about our project

Expansion Memory $300
computer that we are using needs more memory in order to handle our application needs

Watertight power cables $100
in order to supply electricity underwater

APPENDIX G

H. ACTUAL TIME LINE

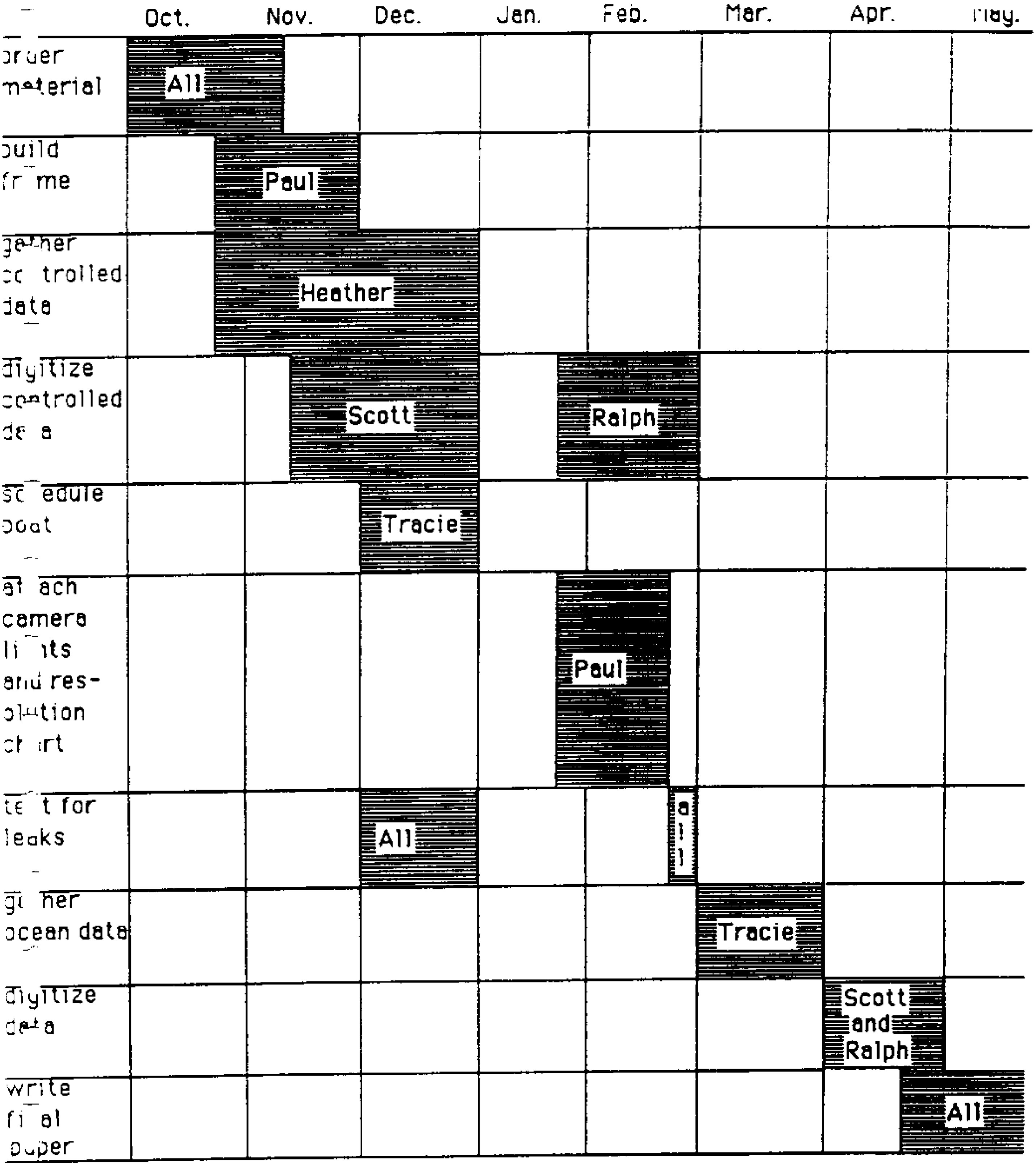


* Note: The gathering of Control Data was never finished due to a lack of time.

** The names listed for each task are the names of the task leader, everyone will be involved in every aspect of the project.

APPENDIX H

G. INITIAL TIME LINE



he names listed for each task are the names of the task leader, everyone will be involved in every aspect of the project.

REFERENCES

1. Optical Methods for Measuring Turbidity and Suspended Particles in Water, D&A Instruments, Technote (3/89).

2. OBS[tm] Optical Backscatterance Turbidity Monitor, D&A Instruments and Engineering, 2428 39th Street, N.W., Washington, D.C. 20007, (202) 333-5669.

3. Ocean Process Analysis Laboratory, UNH, New Science Building, Durham N.H., 03824-2242.

4. Strickland, Charles, Facts on Underwater Illumination, Hydro Products a Dillingham Company.

5. Jerlov, N.G., Optical Oceanography, Elsevier Publishing Co.,1968.

6. Jain, Anil K., Fundamentals of Digital Image Processing, Prentice Hall, Englewood Cliffs, NJ 07632, 1989.

7. M. Kiver, M. Kaufman, Television Electronics, Delmar Publishing, Albany, NY, 1983.

8. VFIR-MKII Second Generation Video Finite Impulse Response Filter Module, Datacube, Inc., 1988.

9. Murdoch, Joseph B., Illumination Engineering, Macmillan Publishing Company, 1985.