Santa Clara University

Department of Mechanical Engineering

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I HEREBY RECOMMEND THAT THE THESIS PREPARED
UNDER MY SUPERVISION BY

Todd Berk, Andrew Casanova

ENTITLED

SWATH: Autonomous Surface Vessel for Shallow Water Bathymetry

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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SWATH: Autonomous Surface Vehicle for Shallow Water Bathymetry

By

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THESIS

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SWATH: Autonomous Surface Vehicle for Shallow Water Bathymetry

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ABSTRACT

During the past year a Small Water-plane Area Twin Hull (SWATH) autonomous surface vessel (ASV) has been developed to perform autonomous collection of multibeam bathymetry data to produce accurate three dimensional maps of shallow water regions. A previously existing SWATH hull was modified and extended through the addition of a multibeam sonar, pose sensors, and an automated trajectory controller. In addition, improvements to the power system were made, and a powered hull ballast system was added. The resulting SWATH scientific development platform is less prone to pitch and roll when compared to a traditional monohull, catamaran, or kayak design, and will provide better quality maps of shallow regions than current methods. Elements of the final design were successfully tested and demonstrated in multiple field deployments in Stevens Creek Reservoir and Lake Tahoe.

Acknowledgments

The Autonomous SWATH Boat team would like to thank to following people for their generous support and contributions to us and this project:

Dr. Chris Kitts

Dr. Timothy Hight

Bill Kirkwood

Dr. Geoff Wheat

Paul Mahacek

Vivek Reddy

Jose Acain

Ignacio Mas

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1 Introduction

1.1 Background

There is more information known about the surface of the moon than the ocean floor. With approximately 70 percent of the earth being covered by ocean, it's surprising that more research related to ocean exploration is not being conducted. One of the most vital regions of the oceanic bodies of water that require research are the bay and coastal waters. The oceans and coastal estuaries provide a vast amount of resources to humankind. Our dependence on these resources is constantly increasing, while little is being done to monitor and evaluate the effects of this continued strain on animal species and their habitats.

There is a large lack of information due to the complex logistics and risk currently required to perform and acquire scientific measurements in shallow water areas such as estuaries, rivers, and bays[10]. Bathymetry data displays the seafloor terrain and topography and is a useful tool for monitoring the geographical features and habitats of a region. Bathymetry data is important because it allows scientists of many different fields to analyze ecosystems, habitats, and geological compositions and anomalies. Current platforms for performing coastal multibeam mapping and obtaining bathymetry data use relatively large manned vessels which have difficulty or cannot navigate in shallow water. If large vessels are used in these shallow waters, they may pose a danger to marine life, the habitat, the crew, and / or its equipment.

It is currently difficult to collect this data in shallow regions, which are prone to tides, high currents, and wave motion. Pitch and roll create large deviations and defects in the bathymetry data collected from a multibeam head, and will result in difficulty constructing grid and projection visualizations.

Figure 1.1 Seafloor Systems "Echo Runner". This is a manned vessel equipped with an echo sounder to collect bathymetry data in shallow regions.

Current methods for collecting multibeam bathymetry data in shallow coastal and inland regions are in the early stages of research and development. They generally involve using makeshift mounts to attach a multibeam or echo-sounder unit temporarily to a standard watercraft. One example of this is Seafloor Systems "Echo Runner" which consists of a Jet Ski watercraft equipped with an echo-sounder[1]. This system is driven by an operator who also is required to run the onboard laptop, causing a path of travel that is not as optimum as an autonomous control system. Also, a Jet Ski is a lightweight monohull that will be heavily subjected to the effects of waves, pitch, roll, and wind.

The SWATH (Small Waterplane Area Twin Hull) scientific development platform is less prone to these afflictions when compared to a traditional hull design and will provide better data quality than current methods. The SWATH hull design is a relatively new concept in naval engineering. It resolves or reduces many issues that plague hull designs such as monohulls, catamarans, and kayaks which suffer from pitch, roll, and heaving.[11] The SWATH boat's stability is attributed to its submerged hull design, small water-plane area, and high mass to damping ratio. These characteristics make SWATH an ideal candidate as an autonomous scientific development platform. The purpose of the SWATH autonomous surface vessel project is to create a stabilized autonomous multibeam mapping research vessel for the gathering of inland and coastal shallow water bathymetry data.

1.2 Previous Work

The SWATH Autonomous Surface Vessel project was started in the fall of 2004 as an interdisciplinary senior project consisting of mechanical, electrical, and computer engineers. The project concept and idea was the brainchild of Mr. Bill Kirkwood of MBARI, and Dr. Geoff Wheat of the University of Alaska Fairbanks, who was also the primary customer. The initial project goal was to create a vessel to perform autonomous conductivity, temperature, and depth measurements at various locations in Kasitsna Bay, Alaska. The SWATH ASV has been funded by two grants provided by the National Science Foundation, as well as funds from the MBARI, the Santa Clara University Robotics System Laboratory, and the University of Alaska Fairbanks. During that project the physical structure consisting of platform, struts, and pontoons was designed and constructed. The motors were mounted and preliminary power system implemented. An electronics system for driving the boat, and graphical user interface was also developed. During the summer of 2005 Paul Mahacek performed stability testing and modification to the boat as an intern at the Monterey Bay Aquarium (MBARI)[13]. The project was then dormant until the summer of 2007 when Todd Berk worked on it as an MBARI intern[14].

1.3 Field Literature Review

Figure 1.2 MBARI's Ventana ROV.[4]

For many years, there have been a number of robotic vehicles providing platforms for scientific research. The more popular of these vehicles has been the remotely operated vehicle, or ROV, which is managed through a tether by a remote user. Monterey Bay Aquarium Research Institute's (MBARI) Ventana, pictured in Figure 1.2, provides an example of an ROV that is used to perform deep sea research.[4]

The problem typically encountered with ROV's involves the man-hours required to manage the system. It requires a number of staff members to pilot the vehicle, supervise deployment and recovery, and monitor the tether. During the entire operation time, a user is required to control the system which, when embarked on prolonged missions, could lead to fatigue of the user.

The use of automated surface vehicles (ASV) is a relatively new topic that has been gaining some acceptance in ocean research. Companies such as ASV Limited, Incorporated, provide commercially available systems for automated surveillance and mine tracking.[12]

These vehicles provide a method for performing dangerous or time consuming tasks in ocean research.

In the past, there have been a limited number of small SWATH or catamaran style boats used for underwater research. These prior designs have been subject to numerous problems, such as excessive wave motion, or complete instability, such as the SWATH boat developed by the U.S. Department of Transportation.

Figure 1.3 U.S. D.O.T. SWATH - The department of Transportation's version of a SWATH boat was unstable and suffered from capsizing issues.[5]

The remotely controlled boat featured in Figure 1.3 was built by the Department of Transportation and was equipped with an ultrasonic transducer in order to measure the scouring of bridges. It suffered from stability issues due to the high center of gravity from the motor, and hulls providing flotation. It was so severe that it capsized numerous times while performing turns.[5]

1.4 Statement of Project Objectives

The goal of this years design team was to develop a robust vehicle capable of performing hydrographic and bathymetric data collection autonomously, for research in rivers, lakes, bays, estuaries, oceans, and reservoirs. The data would then be post-processed to make accurate, high quality three dimensional maps of the surfaces below it, providing valuable geospatial references. The vessel would be prepared and extensively tested for an anticipated deployment in the Puget Sound of Washington and Kasitsna Bay Alaska in upcoming years. In preparation for these deployments, there would be numerous testing deployments in Stevens Creek Reservoir, California, and a final testing phase in Lake Tahoe, Nevada.

To meet the primary goal, design objectives were established in order to improve the existing SWATH hull, and to add necessary functional capabilities. In order to provide sufficient power for a full day's deployment, the energy storage capacity of the boat needed to be greatly increased through the addition of more submerged batteries in the hull, with a possibility of an added generator. The distribution of power needs to be modular in order to allow instruments and additional power sources to be connected. To increase the map quality a set of pose sensors are required to measure accurate velocity, heading, pitch, and roll. To log the data from the multibeam and pose sensors an onboard laptop in a waterproof enclosure was required. To create maps of larger regions, it is necessary for the boat to travel autonomously, requiring a trajectory controller. The most time consuming part of launching the boat is adjusting buoyancy manually with weights, and therefore adding a ballasting system will greatly shorten launching time.

The resulting work based on the objectives was a success. Six new battery enclosures were constructed which were waterproof and robust, and would provide enough power for eight hours of operation. A modular power distribution box was built and designed to allow the simple addition of new instruments, as well as additional power sources. To provide accurate pose readings, a Doppler Velocity Log (DVL) was integrated into the system. To record the data from the multibeam, DVL, and GPS, a laptop with waterproof enclosure was integrated. Autonomous control was achieved by designing, simulating, and implementing a trajectory controller. To speed the boat launching process, a ballast system was designed and implemented.

2 System Level

2.1 Customer Needs

In the Fall quarter of 2007 a series of questionnaires were sent via e-mail to various individuals who specialized in robotic systems in marine environments. These individuals included Dr. Geoff Wheat, Professor of Research at University of Alaska Fairbanks, Bill Kirkwood, Associate Director of Engineering at Monterey Bay Aquarium Institute (MBARI), and Gary Greene, Professor emeritus of Moss Landings Marine Labs. In the questionnaire, important issues such as battery life, environments, instrumentation, and user preferences were covered. Through the collected responses, the specialists were able to relate the required and desired capabilities of the SWATH boat. The collected surveys are shown in Appendix C.

The general capabilities and customer needs of the boat were derived through the responses of the surveys.

These needs included:

A battery life of approximately eight hours
The ability to launch the SWATH boat from a boat ramp
The ability to incorporate a CTD (conductivity, temperature, and depth) instruments
The ability to charge the batteries without removing the boat from the water
The ability to withstand 30 knot winds and operate in seas up to one meter high
The ability to map 1/4 square kilometer within one eight hour shift
The ability to produce and log accurate three-dimensional maps

Table 2-1 Customer Needs. This table expresses the desired functionality based on a potential customer needs survey.

2.2 Benchmarking

Although there are no current products like the autonomous SWATH boat, there are designs that are similar in design and tasks. The boats that have already been developed include the unnamed vehicle developed by Autonomous Surface Vehicles (ASV) and the USV-2600 developed by Sea Robotics Corporation.

2.2.1 Autonomous Surface Vehicles

Figure 2.1 – ASV built by Autonomous Surface Vehicles Limited. This boat is powered by a diesel engine that can push it at a speed of ten knots while performing mapping.[12]

A boat developed by Autonomous Surface Vehicles (ASV) of Chichester, West Sussex, United Kingdom boasts more stable platform then conventional boats. The boat's design has most of its bulk submerged in a torpedo and fin like configuration to allow for a greater resistance to waves. As the boat encounters a wave, the change in submerged volume is considerably less then the overall volume, which results in only a small disturbance. The vehicle can either be pre-programmed or used remotely and is said to work at a fraction of the cost of conventional work boats and underwater vehicles. The vehicle uses the same type of diesel engine of typical boats and has a max speed of 10 knots and an endurance of 48 hours in rough sea conditions. It is to be used for marine surveillance, to identify illegally used vessels, and for commercial hydrographic survey activities.[12]

2.2.2 USV-2600, Sea Robotics Corporation

Figure 2.2 – USV-2600 by Sea Robotics Corporation. This ASV is equipped with a multibeam sonar and designed for shallow regions. It has been successfully deployed in the Florida panhandle[3].

Sea Robotics Corporation has developed the USV-2600 Mission Reconfigurable USV (Unmanned Surface Vehicle) for shallow water and estuary marine research. It can be configured with a large number of different scientific payloads. Scientific instruments can include combinations of side scan sonar, echo sounder, doppler velocity log, CTD (conductivity-temperature-depth), sub-bottom profiler, and multi-beam sonar. It can reach a top speed of 6 knots, and at a cruising speed of 4.4 knots the batteries will last approximately six hours. It was designed primarily to do research in shallow water marine habitats such as estuaries. One example was a deployment of it in Apalachicola bay in the Florida panhandle which is between one half and three meters deep, and contains the third largest oyster fishery in the United States. It gathered data about the sediment layers using a sub-bottom profiler and temperature using infrared sensors, where aerial photography and lidar techniques would not work.

2.3 System Architecture

2.3.1 Operation Scenerio

Under ideal deployment conditions the SWATH boat would be required to map a certain predefined geographical area. Once a deployment would be scheduled and location selected by GPS coordinates, the boat would be transported near the location. The boat would then be deployed in the water, and trajectory controller software would handle all path generation and navigation. Once the boat reaches the desired mapping area, it would begin a “mow-the-lawn” pattern to cover the area, while logging data from the mapping instruments. Once recovered from deployment, the data would be post-processed and maps generated.

2.3.2 System-Level Sketch

An enlarged version of the System level diagram is displayed in Appendix B

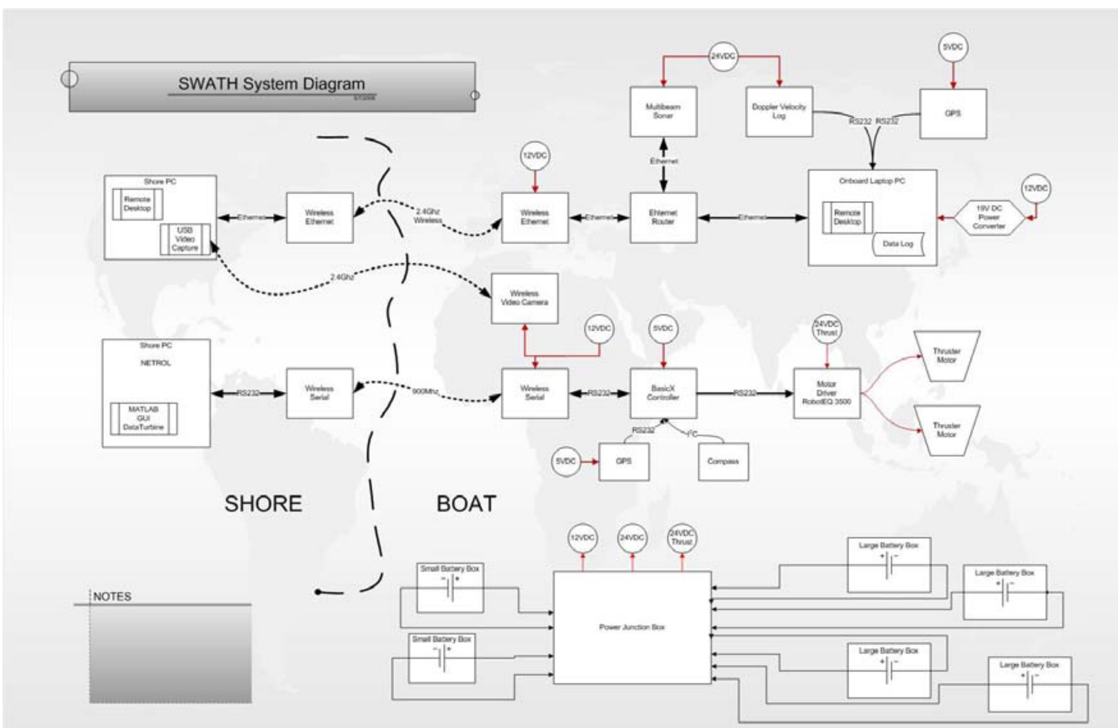

Figure 2.3 – SWATH System Level Diagram. This diagram shows the various subsystems on the boat, including the scientific, navigation and control, and power subsystems. Also shown are their power and communication paths.

2.3.3 Functional Analysis

The SWATH boat consists of numerous systems: science instruments, sensors, data logging, navigation, structure, and motors.

The scientific instruments system consists of multibeam sonar and a Doppler velocity log. The multibeam sonar is a device that contains hundreds of piezoelectric transducers and sensors which emit and detect ultrasonic wave frequencies at different angles. The amount of time it takes for the wave to travel to an object and reflect back is proportional to the distance the object is away. There are a number of dependant factors for accuracy of this device, such as speed of sound through medium, temperature gradients, relative velocities (Doppler effects), and pitch and roll.

The sensor system consists of an altitude, heading, and reference system (AHRS), global positioning system (GPS), and Doppler velocity log (DVL). The AHRS uses micro-electrical mechanical gyroscope transducers to obtain the pitch and roll, as well as a digital compass for heading. The GPS is a common instrument used to obtain position information by receiving data from satellites, which is also differentiated with respect to over-the-air radio signals for a high accuracy of better than 15 meters. The DVL operates similarly to the sonar by emitting and sensing sound waves from the surface below it and using the Doppler effect to get highly accurate (less than 1cm per second) vector components of the velocity over ground.

The motors are modified Minn-Kota RT55 salt water electric thrusters. They are brushed DC type and provide 55 pounds of thrust using 12 volts but will be able to provide nearly double the thrust using 24 volts.

The data logging system keeps an accurate time-stamped log of all the data from the sensors to create accurate maps. This is done using an on-board laptop and a serial port expander to interface with all the instruments.

2.3.4 Key System Level Issues

The key system level issues are the data logging, battery power, and navigation systems. These systems need to all operate reliably in order for the boat to perform its science mapping missions. The sensors used in these systems, namely the digital compass and AHRS need to relate information accurately to provide reliable information for the map generation. A single failure of any of these systems will result in a total mission failure.

Each system was developed, integrated, and heavily tested before actual scientific deployments can be performed. The AHRS needed to be tested and calibrated for accuracy in the heading, pitch, and roll directions. To increase its reliability, it was isolated from electromagnetic interference and the high frequency vibrations that are created through the motors.

The high powered lead-acid batteries needed to be mounted inside the submerged hulls of the SWATH boat to give it a low center of gravity and maintain stability. However, mounting the batteries below the surface in salt water is dangerous if not sealed and mounted properly. The salt water conductivity has the potential of creating an explosion if the batteries come in contact with the environment.

The data logging system's reliability is crucial to the success of accurate mapping. There are problems that the computer can encounter such as crashes, freezing, exposure to moisture, and overheating. The data logging computer was mounted on top of the boat's deck and was placed within a waterproof case. The case needed to be cooled in order to keep the computer from overheating. To monitor the computer system, login using a remote terminal service, which allows the user to see if the computer is frozen, or overheated, was necessary.

2.3.5 Layout of System

The project was comprised of three main systems where each system represents a variety of needs that were specified through the customer responses. The systems involved battery modification, data collecting and logging, and boat stability.

Battery modification was of the highest priority because it satisfies the greater number of customer needs. Modification involved the manufacturing of new, watertight battery housings, rechargeable battery systems, external energy sources, and implementation of higher quality batteries. These changes will result in longer range, a more robust system and higher mapping capabilities.

Data collecting and logging involved acquiring sensor and instrument readings and relating them to the user in a manageable format. A system linking the remote user location and the boat was developed and tested to work properly within the desired range. The data collected is logged on board and analyzed at a later time.

2.4 Team and Project Management

2.4.1 Project Challenges and Constraints

The challenge of the project was to produce a reliable and robust system that can withstand the Kasitsna Bay environment and provide reliable maps. Given the SWATH boat in its beginning state in fall 2008, the challenge involved modifying the battery housings, the logging system, the boat thrusters, and platform. The project had few limiting factors whereas as size and weight were not restricted. The main constraint involved the battery life and boat speed as described by the customer's needs. A series of designs for both the hardware and software were developed to satisfy the challenge.

2.4.2 Timeline

The schedule shown in Appendix D was to be followed for the 2007-2008 design year. In the calendar, dates for group meetings, deadlines and weekly tasks are presented to keep the project goals within the desired time-frame.

Within the first quarter of the design process, the group's tasks involved research and design for the various modified systems. Products were examined and compared through web based data sheets. Using these specifications, various parts, such as battery housings, were designed to fit and maintain the integrity of the member.

The winter quarter involved the accurate modeling and manufacturing of the system. In this stage, all components were added and hardwired to the system. The end of the stage produced a completely assembled prototype that was to be tested and examined.

The spring stage of the design involved the testing and debugging of the system. Numerous on-site tests were completed to check the integrity of the hardware and software. In this stage, all flaws were to be corrected and the boat was made ready for real time mission in Tahoe and Alaska.

2.4.3 Design Process

In designing the battery housings, many constraints and requirements were taken into consideration to produce a reliable design. The main restrictions were to make a housing that was watertight, allowed for in-water charging, and allowed for gas venting.

The first consideration involved the number of batteries that the housings were to hold. It was decided that there were to be a total of eight batteries with four batteries being held in each hull. However, it was concluded that the chosen batteries will not make the vertical clearance of the hull covers. The group decided to ignore the vertical clearance at this stage, therefore new covering designs would be necessary.

Figure 2.4 – Deep Sea Power Waterproof Battery Enclosure. MBARI uses these sealed battery enclosures in their moorings.[6]

To create a watertight seal, the housings developed by Deep Ocean Engineering were analyzed (Figure 2.4) and it was decided that the design would benefit the SWATH boat. The watertight characteristic is to be accomplished through a series of seals and plastic coverings to create a watertight chamber where the batteries are to be held. The chamber is to be filled with mineral oil and a pressure valve it to be attached to the plastic coverings to allow for gas ventilation. Watertight seals and connections are to be attached to allow for in water charging.

2.4.4 Risks

There are numerous risks involving the development of the SWATH boat. The main concern involves the loss of money through damaged equipment such as the multibeam and doppler velocity log. These losses would result in a halt and possible termination of the project. Also, there is the possibility that the SWATH boat and equipment are lost on missions if a complete system failure occurs and the boat is lost.

2.4.5 Team Management

The team consisted of two mechanical engineer undergraduates, Todd Berk and Andrew Casanova. The faculty advisors were Professor Chris Kitts, Robotics System Laboratory Director, and Professor Timothy Hight, Mechanical Engineering Department Chair. The team was small, which required that a tremendous amount of work be completed by each member.

However, through the guidance of the advisors and other helpful sources, the project goals have been reached.

Operations for the project included the involvement of both team members. Rather than dividing the work load between the members, it was agreed that work would be conducted in a team environment. The benefits of such a tactic included direct involvement with every system level, and continuous communication about the various project concerns.

3 Subsystems

The SWATH boat is comprised of numerous subsystems, which work together to enable the system to function as a whole. Each individual subsystem is a complex combination of materials, engineering, and hard work. In order for the boat to have a successful deployment, all of these subsystems must properly work. The subsystems are the power system, battery storage system, mapping instrument subsystem, data logging subsystem, autonomous control system, and ballasting system.

3.1 Power System

The various electronic subsystems on the boat require various forms of power. In order to make the vessel as versatile and reconfigurable as possible, a modular power system was required. This power system needed to provide 24 volts of power to the thrusters, as well as 12 and 24 volts to the various electronics. It needed to easily be rewired inside to distribute the loads among different batteries.

With these needs in mind, the power system was designed to allow the boat to be deployed with as little as two batteries and can connect as many as six. Two of the batteries were wired in series to power the electronics, and the other four batteries were connected in parallel pairs.

Figure 3.1 - Power Distribution Box. This waterproof box acts as a hub for the power system and provides 12 and 24 volts to the various subsystems.

To easily manage the various battery connections, a power distribution box was designed and created as the central component of the power system. The enclosure was created using a compact clear Otterbox which features watertight seals (Figure 3.1). Cable glands (Dorn connectors) were used to provide a sealed interface where the cables penetrate the box. Inside the box five bus bars were adhered to the base. A common ground was created for the system, and the other bus bars were used to create the voltages for the different subsystems using the various battery combinations. Wires can be easily arranged among the bus bars using basic hand tools, which allows the power system to be quickly reconfigured or expanded. Additional connections can be made simply using a ¾ inch fender punch and additional Dorn connectors

The onboard laptop did not have enough battery power to record data for an eight hour deployment. The laptop itself requires 19 volts DC and can consume up to 180 watts. During data collection, the laptop lasts less than one hour on its own batteries and it needed to be plugged into an external power source for extended missions. However, there was no existing DC power adapter that met the power draw and proprietary connector needs. A method that was considered involved using a DC to AC converter that would be powered by the boat. The laptop's AC to DC adapter would then be plugged into the adapter to allow for constant power supply. However, it was decided that this method would be unreliable and inefficient. Instead a high power generic laptop DC power supply was modified with a connector to fit the laptop.

Safety of the power system is a top priority. Batteries can discharge a large amount of current very quickly, and in the vicinity of water, these dangers are amplified. Not only could the batteries shock a human with lethal power. Batteries can also explode if the terminals are shorted after coming in contact with water, especially salt water. As a safety precaution, before every deployment it was necessary to check that every connection was made properly, and that all seals were watertight.

3.2 Battery Storage

To support the power system, it was necessary to design a containment system for the battery components. The containers needed to feature watertight seals, battery accessibility and modified shapes to allow for proper storage within the boat hulls.

Figure 3.2 and Figure 3.3 – Previous Power Containment Devices. Sealed buckets (left), and sealed dive bags (right) have previously been used to enclose the batteries underwater and protect them from being flooded.

Previous power containment devices for the SWATH boat battery system consisted of the use of watertight buckets and dive bags (Figure 3.2) with modified watertight connections. However, these methods were unsuccessful at creating a permanent containment system. The problems encountered consisted of insufficient rigidity of the materials and unreliable methods for creating watertight seals.

In the design for the battery containers, previous attempts and customer needs were taken into consideration. The most important features were considered and applied to the final design.

3.2.1 Design Considerations / Failed Designs

With the given specifications, various designs were developed and considered. The designs varied from the number of batteries that each container would hold to the type of materials that would be used for construction.

3.2.2 Multi-Battery Container

The first design that was considered consisted of a UHMW plastic container that would house multiple batteries. Initial designs considered only two batteries per container (Figure 3.4) but it was determined that, through some modifications of the boat hulls, as many as three batteries would fit into each container. However, there were a number of problems and issues that arose with this design.

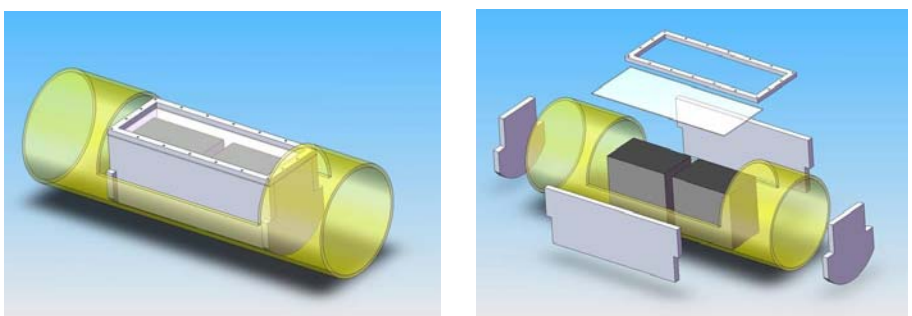

Figure 3.4 – Multi-battery Housings. Normal and exploded view of the first design consideration placed within the boat hulls

The first problem that was encountered was the need to have the design constructed by an outside source. It was decided that the rounded feature that was used in the design to mimic the hulls shape would needed to be cut out using a water-jet at MBARI's machine shop.

Upon review of the design, it was also concluded that the container itself would be holding too much weight. One of the design specifications required that the containers be removed and installed easily to allow for transportation. However, the design would require that each container hold as much as 250 pounds which would be difficult for an operator to manage.

The issue that led to the termination of the design was the need to modify the boat hulls and create new hull lids. It was determined that three batteries were needed for each hull, but the design required that material be removed from the boat hull to allow for the extended case length. This modification required that new lids be manufactured. Although it was decided that the existing lids could be modified with fiberglass material, it was concluded that this design was not worth the effort.

3.2.3 Fiberglass Containers

With the weight of the batteries in mind, it was decided that containers holding single batteries would be easier to manage. To allow for a watertight seal, the boxes were designed with an extended flange that would not only allow for an increased area for the gasket, but would also act as a handle to make transportation easier for the user. The lid for the container would simply be cut to the dimensions of the flange so that it could be bolted to the container to compress the gasket between the two materials, and create a watertight seal. With this design in hand, Figure 3.6, the discussion then focused on the material that would be best.

The material for the battery boxes needed to be durable, inexpensive, and able to provide uniform surfaces. After considering multiple materials, it was decided to use fiberglass to create the box and flange design. It was believed that the material would provide the necessary strength, surface area, and watertight features.

The boxes were created by using a cardboard frame with the desired dimensions. The cardboard was soaked in fiberglass resin and wrapped with fiberglass cloth. Multiple layers of fiberglass resin and cloth were applied to increase the rigidity of the box as shown in Figure 3.5.

Figure 3.5. Fiberglass Construction Process. Cardboard frames were covered in fiberglass coth and soaked in resin to create the rigid container.

Although the fiberglass provided the necessary strength, it did not provide the watertight feature. When testing the boxes for leaks, it was discovered that there were a number of voids in the material at the various corners and edges. In some cases, there were even leaks in the fiberglass mesh material. To counteract the problem, more fiberglass resin and cloth were added to the troubled areas. However, this method of repair was unsuccessful.

Figure 3.6. Fiberglass Resin Jelly Coat. Fiberglass resin jelly was used as another method to try and seal the fiberglass boxes. Unfortunately the boxes still had minor leaks.

Another method that was used to seal the boxes involved the application of fiberglass resin jelly to the outer surface of the box to create a watertight shell as shown in Figure 3.6. However, although the boxes were completely coated with the material, there still appeared a number of leaks at the corners and edges. This method also created a non-uniform surface with inconsistent dimensions.

3.2.4 Acrylonitrile Butadiene Styrene (ABS) Battery Boxes

When it was determined that there was no easy and inexpensive way to seal the fiberglass boxes, it was decided to use a different material. The team decided to change the material from fiberglass to acrylonitrile butadiene styrene (ABS) which would be 3/8 inch thick. Adhering to the same dimensions and as the previous design would assure the boxes would fit inside the hulls. It was believed that the tighter tolerances of the material would reduce the number of voids in the joints and that evaporative adhesives would melt the pieces together, supplying the required strength. As a safety precaution, and to ensure a watertight seal, silicone caulking was applied to the inner edges. The ABS design provided a method for easily creating a watertight, durable, battery container. A battery box can be put together relatively simply in a number of hours, compared to days or weeks of hard work required for fiberglass boxes.

Figure 3.7 – Finished Waterproof ABS Battery Boxes. These boxes were assembled using 3/8 inch thick ABS plastic. The pieces were bonded using a solvent which melts the pieces together, creating a strong and watertight seal.

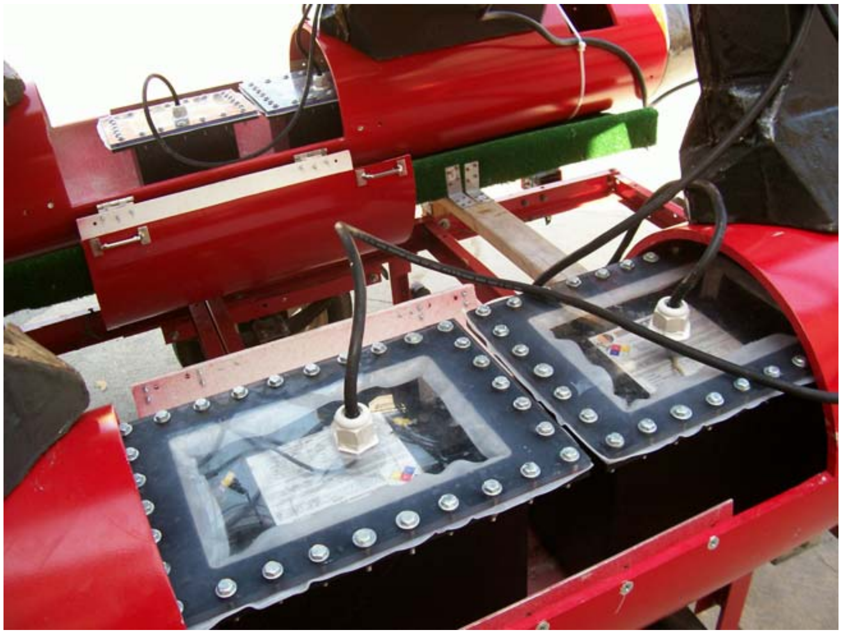

Figure 3.8 – ABS battery boxes assembled and in hulls. The boxes are shown here completely assembled, sealed, and electrical whips in place while sitting in the hulls of the boat. The loading configuration of inserting batteries is similar to loading shells into a shotgun. It is easy to see inside the boxes due to the clear lids, which were sealed using lubricated latex.

The ability to monitor the inside of the battery boxes is an important safety feature. In order to be able to visually inspect for water leaks, the lids of the boxes would need to be clear. There were to primary options for material to use, either acrylic or polycarbonate, both of which are clear. There are a number of pros and cons for each. Acrylic is a very cheap material, and is less than half the cost of polycarbonate, but it is very brittle. Acrylic would easily crack under the strains from drilling the one inch diameter hole for the power whips, or possibly if the boxes were dropped. Polycarbonate is much more durable than acrylic, and deforms plastically, however, it is more expensive. Polycarbonate was chosen in the end because of the critical safety required in this component, and was worth the extra expense.

3.3 Mapping Instrument Subsystem

The purpose of the mapping subsystem was to produce high quality three-dimensional maps of the marine surface below the boat. There are three main instruments required to make these maps. The primary instrument is a DeltaT multibeam sonar from Imagenex (Figure 3.9). The multibeam transmits 480 sonar beams in a selectable sweep of 15 to 120 degrees. This allows the user to adjust their desired resolution with the changes in depth because, as depth increases, resolution decreases. Decreasing the transmitting angle can compensate for increased depth to maintain resolution.

Figure 3.9 – Imagenex Multibeam Sonar. This multibeam unit is the primary instrument used to make maps. It emits 480 (300 Khz) sonar beams at an adjustable angle of up to 120 degrees. Left image is the manufacturer's image, and right image shows how it is mounted inside the hull.[9]

As previously mentioned, pitch and roll of the boat dramatically affect the quality of the maps produced. These disturbances can be accounted for in post processing if the boat attitude data can be recorded synchronously with the multibeam data. A Doppler velocity log (DVL) can provide highly accurate velocity readings by exploiting the Doppler effect and differential signaling. A Teledyne Instruments Workhorse DVL (Figure 3.10) was provided by MBARI and has an integrated attitude, heading, and reference system (AHRS) which gives the heading, pitch, and roll information to correct the maps. One of the project goals was also to produce maps which were geo-referenced and stitched together. To gather the position data, a Garmin global positioning system (GPS) is used.

Figure 3.10 – Teledyne RDI Workhorse Doppler Velocity Log (DVL). This instrument uses sonar and the Doppler effect in order to provide high resolution velocity readings. It also has a high quality integrated attitude, heading, and reference system to provide heading, pitch, and roll data as well.

3.4 Data Logging System

The data logging system on the SWATH boat is responsible for collecting the data from the multibeam, DVL, and GPS. The data logging system is comprised of a laptop computer mounted inside a waterproof housing on the rear of the deck of the SWATH boat (Figure 3.11). It interfaces to the various instruments using serial communications, with the exception of the multibeam, which uses an Ethernet protocol. The serial instruments are connected to the laptop using a USB to Serial port adapter with multiple ports. A wireless router is connected to the laptop and multibeam, which allows for a remote connection that can be used to monitor the system.

Figure 3.11 – Waterproof Laptop Enclosure. This Pelican case houses the laptop and prevents water from getting in. To remove some of the heat created by the laptop, the bottom of the box was replaced with an aluminum plae.

There are a number of important considerations that need to be taken into account when using a portable computer in a marine environment. Moisture and humidity can cause damage, such as corrosion and short circuits to important components such as the hard drive. To prevent this, the laptop was placed in a waterproof Pelican 1500 series case which was sealed and vented with a pressure relief valve. However, the Pelican case is made out of plastic which insulates the laptop and does not allow the large amount of heat generated by the laptop to escape. To determine if it was necessary to add additional cooling systems, a test was performed where a thermocouple was place within the case while the laptop was running to find the increase in temperature after a number of ours of operation. Through the test, it was concluded that the laptop would reach temperatures up to 112 degrees Fahrenheit, which would be too high for proper laptop usage. To remedy this situation, the bottom of the case was replaced with an aluminum plate to act as a heat sink. The plate was held into place using a two-part adhesive and sealed using silicone caulking. In conjunction with the CPU cooling fans, which blow directly onto the aluminum plate, the operating temperature was lowered significantly. During in-water testing, the laptop was able to run for a number of hours without overheating.

3.5 Autonomous Control System

One of the most crucial design requirements for the boat was autonomous control. During testing, it was determined that it was too difficult to drive the boat in a continuous straight line. The process of trying to accomplish this for prolonged periods of time would prove tiring and monotonous. There are two primary different types of navigational control. Waypoint control involves a series of points along which the path of travel between them is not much of a concern. Trajectory control has a series of desired points as well, but the path between them is also defined. As a result trajectory control was chosen as the autonomous navigation method for the SWATH boat since straight paths are more desirable for quality maps.

$$\begin{bmatrix} \dot{x} \\ \ddot{x} \\ \dot{\theta} \\ \ddot{\theta} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & \frac{-\rho A C_D L_x}{M} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & \frac{-\rho A C_D L_\theta}{I} \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \theta \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 1/M & 1/M \\ 0 & 0 \\ -r/I & r/I \end{bmatrix} \begin{bmatrix} F_P \\ F_S \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \dot{x} \\ \theta \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \theta \\ \dot{\theta} \end{bmatrix}$$

Figure 3.12 – SWATH boat state-space system model. These equations represent the system dynamics of the SWATH boat. The inputs are the port and starboard thruster force, and the outputs are forward velocity and heading.

Before the trajectory controller could be designed and tested, a mathematical model of the SWATH boat needed to be created using Simulink. Since viscous fluid drag is nonlinear, a linear fit would be used for drag. This is because nonlinear equations used in control systems are very complex, and would not provide a significant increase in precision to justify the complexity. The inputs to the transfer function are the force produced by the starboard and port thruster. From the inputs, two outputs are derived, consisting of velocity and heading. The velocity could be combined with the sine and cosine of the heading and integrated to produce the X and Y position of the boat. A multiple input multiple output (MIMO) state space model would correctly capture the relationship between changing the forward velocity and turning rate of the boat.

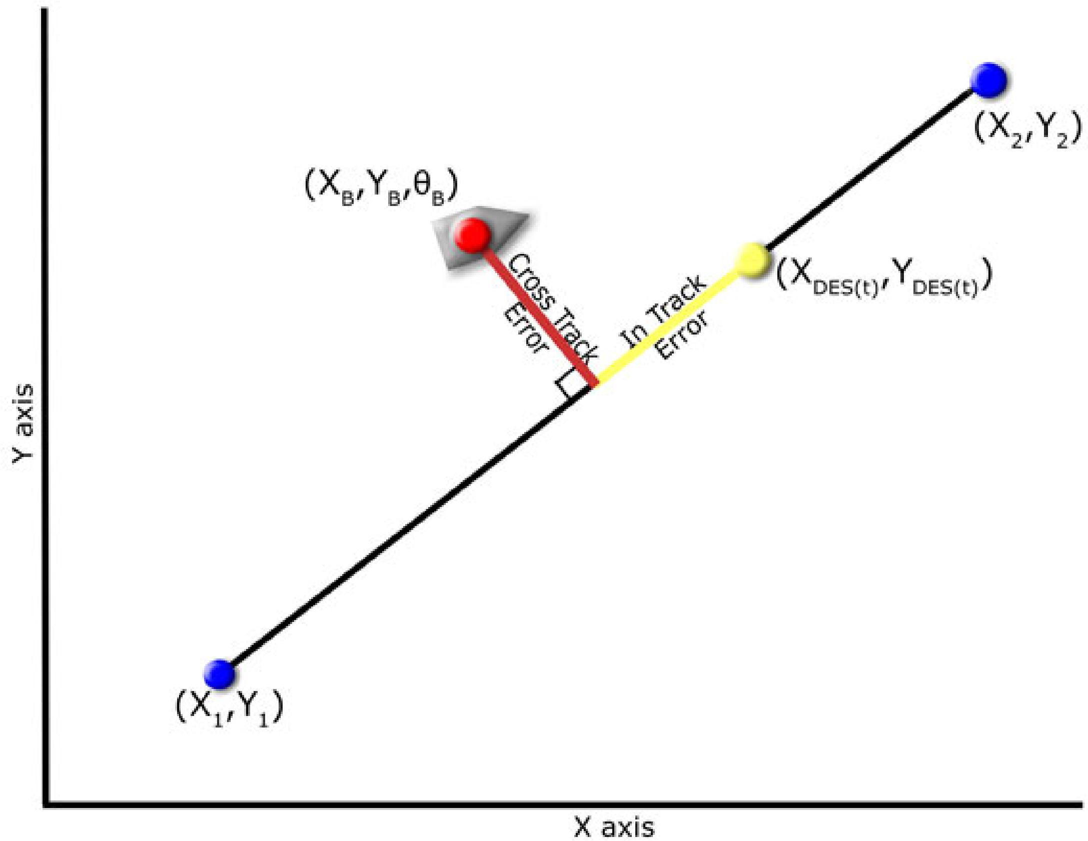

Figure 3.13 - Trajectory Control Concept Diagram. It is desired that the boat follow a line path between points 1 and 2. Due to disturbances such as currents and wind, open loop control will not suffice. Therefore cross track error and in track error are used for closed loop control.

The trajectory controller implemented is designed to follow a straight line in between points, with a certain amount of time specified to travel the distance. Using linear interpolation between points 1 and 2, the desired XY location as a function of time can be found. The shortest distance from the boat, point B, to the trajectory line between points 1 and 2, is known as the cross track error (red line in Figure 3.13). The length of this line represents how far off the desired track the boat is. This line should meet the desired trajectory at a 90 degree angle. The perpendicular distance from the cross track error to the desired point in time along the trajectory, XYdes, is known as the in track error (yellow line in Figure 3.13). It represents the distance along the trajectory in which the boat is either ahead or behind.

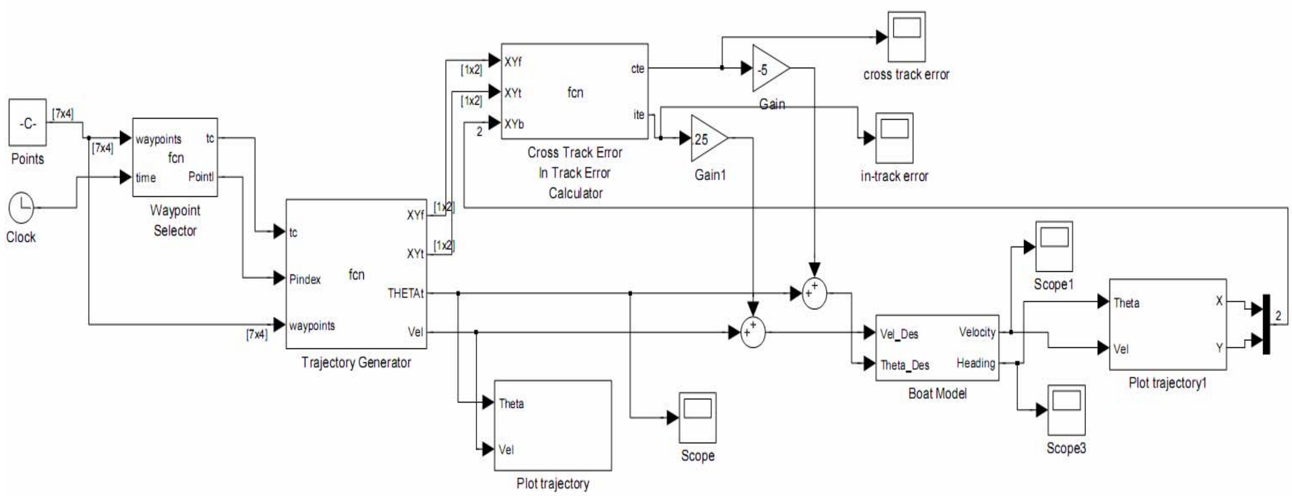

Figure 3.14 – Trajectory Controller Simu-link model. Using the system dynamics of the boat, a model in simu-link was able to be developed in order to test functionality of trajectory control. In the actual system, the boat model would be replaced with communications to the physical boat.

The implemented trajectory controller requires an input of a list of XY coordinate points, and the amount of time allotted for travel in between them. The path between the points is a linear interpolation as a function of time. There are four sets of coordinates used in the controller: initial position (Xi, Yi), final position (Xf, Yf), current desired position in time (Xt, Yt), and current position and heading of the boat (Xb, Yb, θb). The positive Y axis is defined as zero degrees in order to correlate with north heading. The desired heading, θd, is then defined as the angle between the positive Y axis, and the line through points (Xi, Yi) and (Xf, Yf). The desired velocity is calculated as the distance between points (Xi,Yi) and (Xf, Yf) divided by the desired time. In an ideal world, cross track error and in track errors would always be zero. The real world system contains disturbances and transients, therefore, any errors such as in track and cross track should be controlled and minimized. One method of achieving this is to use proportional linear controllers which will correct the desired heading and velocity in order to minimize tracking errors. This can be done by calculating the in track error, multiplying it by a gain, and adding it to the desired velocity. This will cause the boat to speed up when it is behind, and slow down when it is ahead. Once the cross track error is calculated it will be multiplied by a gain, and added to the desired heading. This will cause the boat to take an intersecting path to the desired trajectory, rather than run parallel to it. Once this was done, errors are controlled and minimized, and the boat will stay its course on the trajectory. Simulation results of the trajectory controller and boat model are shown in Figure 3.15.

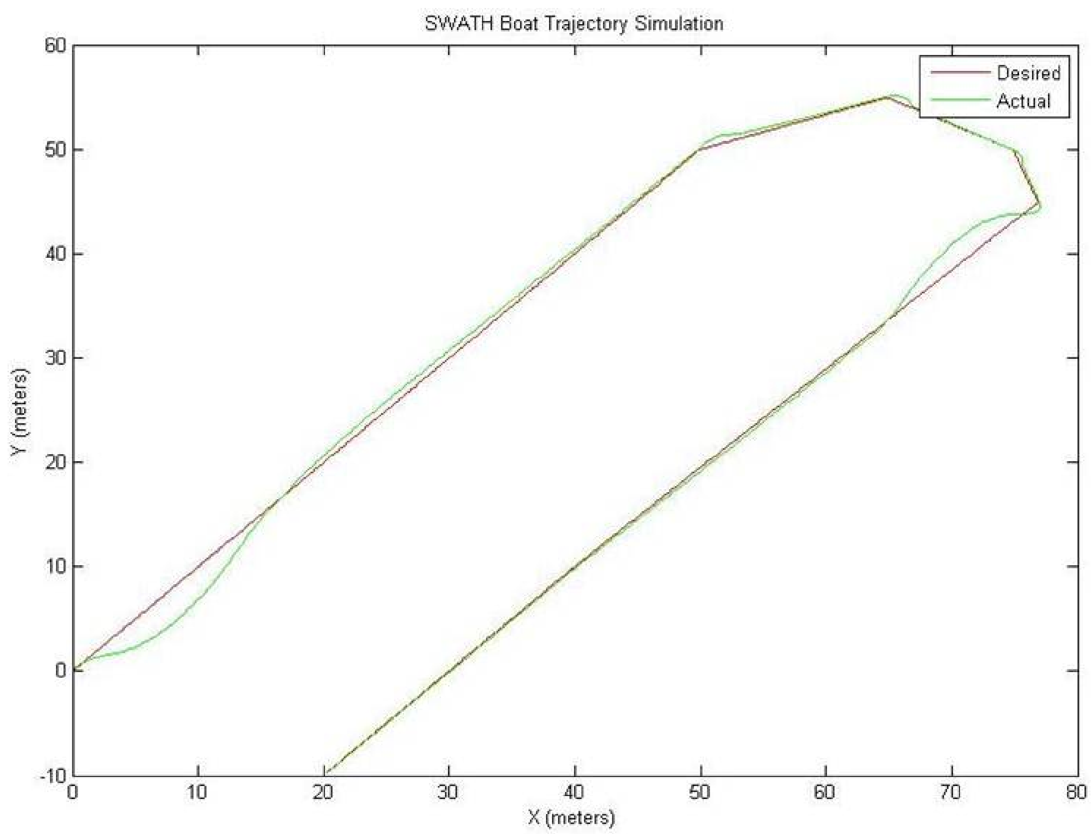

Figure 3.15 – SWATH Boat Model and Trajectory Controller Simulation. The red line represents the desired trajectory along five coordinate paths, and the green line shows the actual

trajectory. The boat starts at standstill facing north, and initially overshoots in turning in order to minimize the cross track error.

3.6 Ballasting System

When launching the SWATH boat, one of the tasks which consumed the largest amount of time is adjusting the height of the boat's deck, also known as freeboard, and leveling the boat in the water. Initially, this was accomplished by adding lead weights into the corners of the boat. However, the payload of the boat was constantly being adjusted, and as a result the lead weight distribution needed to be continuously changed, consuming valuable test time. A ballasting system was devised which would allow the boat to be adjusted quickly with each deployment, and minimize the amount of time spent leveling the boat. The system was developed to allow the boat to be manually adjusted in water for each deployment. Eventually this task could be automated. The system consisted of four ABS plastic boxes with about 0.7 cubic feet of available displacement. This gave each ballast approximately 45 pounds of water displacement with a maximum of 180 pounds overall. One of these tanks was mounted in each of the four corners of the hulls.

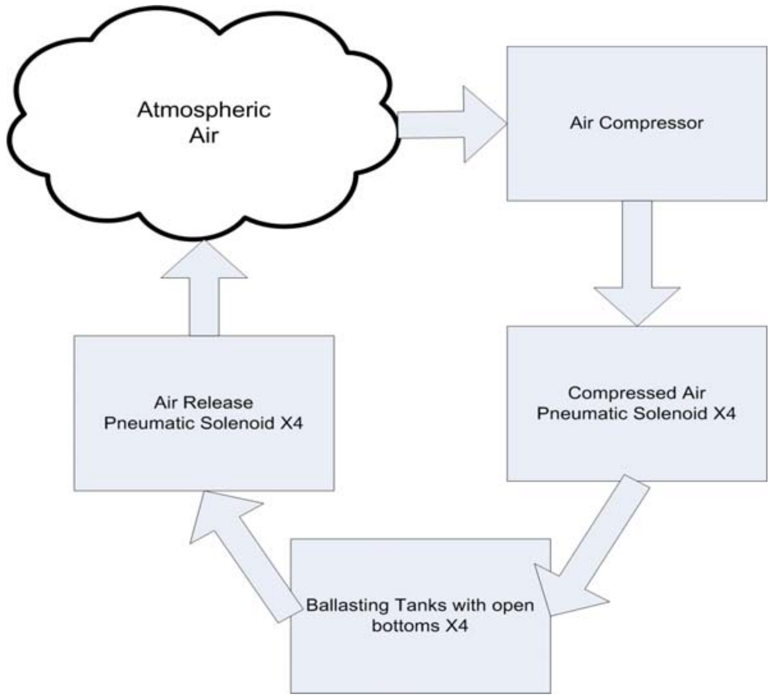

Figure 3.16 – Ballast System Diagram. The ballast system works by filling the ballast tanks with compressed air to displace water and increase lift, or releasing air to add water and decrease lift.

A portable DC air compressor was modified and used to pump air into the four ballasts. Two tubes, one eighth inch inside diameter, were run to each ballasting box. One tube was responsible for letting air into the system, and the other was responsible for releasing air. This process was accomplished using pneumatic 12 volt solenoids to actuate the air distribution process where a total of eight solenoids had to be used. Letting air into the ballasts would displace water and increase floatation, while releasing air would decrease flotation.

The solenoids and air compressor were all mounted in a ventilated case that was mounted on the top deck of the boat. The case was made splash proof, but not completely watertight. It was decided that the added cost of providing a watertight box was not necessary since the box would ideally never be completely submerged. However, when the boat is embarked on missions involving large waves, it would be necessary to use watertight housings with venting snorkels.

4 System Integration, Test, and Results

In comparison with other autonomous robotic platforms, a characterization of the performance parameters of the SWATH boat needed to be determined. This analysis allows the strengths and weaknesses to be determined, and points out areas that need improvement. The following parameters were desired to be quantified throughout numerous tests:

Damping factor of boat
Battery box seal rating
battery life

Table 4-1 – Performace Parameters to be evaluated. Through the quantification of these parameters more the boat can be improved.

4.1 Expirimental Protocol

4.1.1 Evaluation

Damping factor of boat:

The damping factor is used to make an accurate model to perform simulations of the boat in software such as Matlab and/or Simulink. This will assist in designing and prototyping a trajectory controller for autonomous navigation. A Related equation is the standard drag equation, which will need to be linearized in order to be used in a linear control system.

Battery Box Seal Test:

The battery box seals need to be tested for leaks to verify their safety and determine their performance characteristics. IP-68 is a standard rating which the boxes should, at minimum, satisfy. This means that they should be able to surpass the minimum IP-67 specification, which is to be able to be submerged in one meter of water for one half hour. IP-68 is a specification for a hermetically sealed enclosure, where the manufacturer can specify the depth and length of submersion. The goal for our battery boxes is to withstand 72 hours at 1 meter depth in water without leaks.

Battery Life Test:

It was determined that the power system should maintain continuous power for a duration of eight hours. Through the use of a power budget, it was concluded that a total of eight batteries would supply the desired power.

4.1.2 Plan

Damping Factor Evaluation:

In order to determine the forward velocity damping factor of the boat, velocity data from the boat during deployment will be recorded. To determine the free response of the velocity of the system, the boat will need to be taken up to full speed, at which point the input power will be stopped. Two trials will be sufficient. This data will be recorded from the Doppler Velocity Log, but will require custom software to properly record the data. The response should look like a first order system. This should require 1 person-hour to perform the test, and 2 to 3 person-hours to produce results from the data.

Battery Box Seal Test:

In order to test the rating of the boxes, they will be assembled and filled with water to simulate a depth close to one meter for an initial leak test. They will be left for 72 hours where successful completion of the test will be determined by a completely leak-proof environment. The battery boxes will then be drained, filled with their respective batteries, and tested on the SWATH boat during a 6 hour deployment, continually checking for water inside the containers for safety reasons.

Battery Life Test:

To determine the actual duration of the system, the initial voltage output of the batteries will be recorded and compared to a voltage obtained after a set amount of time. With the decay of the battery voltage, it will be determined how much longer the boat will be able to maintain the battery discharge using a linear fit.

4.2 Stevens Creek Reservoir Testing

Stevens Creek reservoir, located in Santa Clara County, California, was used as a testing location for the SWATH boat to determine any complications in the components. The reservoir was used due to its proximity to the SWATH boat development location, its boat ramp access, and calm water features.

4.2.1 Stevens Creek Reservoir Test 1: April 10, 2008

The initial test was performed to determine any problems with the motor controls and newly installed hardware. The deployment served as a means of pointing out the many initial problems with the system. Also, since the fiberglass battery boxes were unable to be sealed, and the ABS boxes had not been constructed yet, makeshift battery enclosures were made out of buckets sealed with a large amount of silicone.

The first problem that was addressed was the inability to acquire a response from the DVL. Since it was the first in-water testing for the instrument, it was uncertain whether the issue was a result of improper installation or the actual instrument itself. Although it was never determined what the cause of the problem was, it was resolved by performing a full power cycle for the instrument.

The second problem that occurred during the initial test involved the laptop power adapter voltage settings. The voltage selection switch was slightly offset from the 19 volt setting and did not provide the proper voltage required to power the laptop for the duration of the test. The resolution for the power adapter problem was to permanently adhere the switch to the proper setting.

The third problem occurred with the boat's wireless video system. The equipment was unable to receive a signal with the given receiver and transceiver. It was determined that there were a number of issues with the wiring and connections going into the television.

During the test, it was determined that the motor controls using the basicX boards were working properly using manual joystick control. It was concluded that the system would run properly using this method and that the software had been implemented properly.

4.2.2 Stevens Creek Reservoir Test 2: May 1, 2008

The second Stevens Creek Reservoir test brought success in many respects. The DVL and other scientific instruments that had not been working during the first deployment were functioning properly. Also, the ABS battery boxes had been finished and were tested during this deployment. They were verified to be leak proof, and this was a large accomplishment. The wireless video was able to be transmitted and recorded via a USB - Video adapter on a laptop. The on board data logging on the laptop also functioned as planned. Also, the trajectory controller was tested successfully but the results were inconclusive due to computer failure. The greatest success was attributed to the ability to collect data for the map generation.

4.3 Lake Tahoe Testing

During the third week of May, the SWATH boat was disassembled and taken to Lake Tahoe for a multi-day mapping deployment and testing. The boat was disassembled by removing all the instruments and electronics, which were hauled inside the vehicle to minimize road vibrations and any damage, as well as reduce weight on the trailer. Once the boat reached northern Lake Tahoe, it was reassembled. During the first day of testing, the boat was launched near Kings Beach. The laptop control system was unable to communicate with the on-board BasicX boards, and it was discovered that some sort of electrical surge had damaged them.

Therefore, the boat was unable to be maneuvered under its own power. The ballast system had been newly installed at this point, so the backup plan was to test the ballasts. It was discovered that there were some leaks in the threads of the mounting bolts. After additional testing, the leaks were sealed using silicone caulking left to dry overnight. The next day, some new BasicX boards were acquired, but communication with them was still unable to be acquired.

The primary objective at Lake Tahoe was to acquire a map using logged data from the onboard instruments, which were all functional. Therefore if the boat could not be powered on its own, it could still be towed by another vessel. The SWATH boat was launched from the U.S. Coast Guard boat ramp and towed with a kayak being driven by one of the team members with the instruments running and logging data to generate a map. The ballasts leaks had also been sealed and they functioned to increase and decrease the height of the boat deck above water.

4.4 Test Results

Throughout the three separate deployments of the SWATH boat, sufficient data was collected from its instruments to generate two different maps. During the second Stevens Creek Reservoir deployment, while testing the driving capabilities via a joystick, a basic map generated that shows the varying depths of water the boat traveled over.

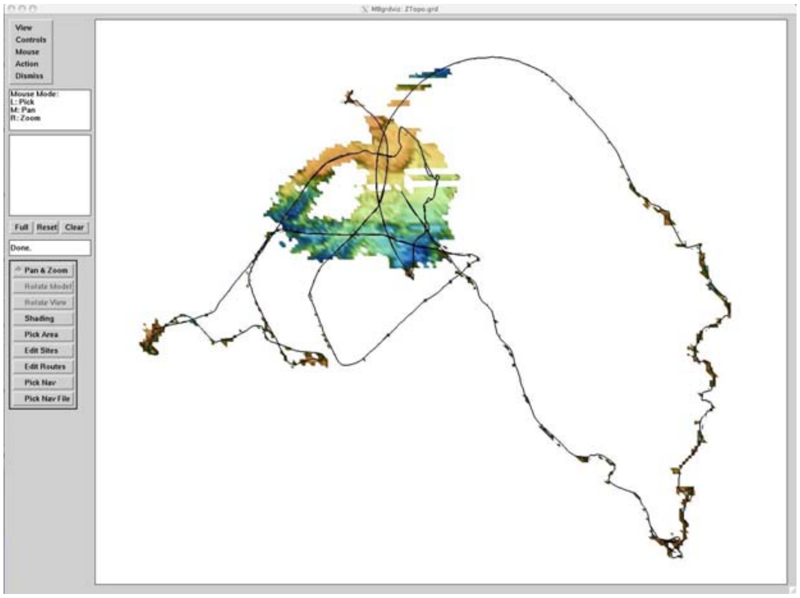

Figure 4.1 - Bathymetry map generated from Stevens Creek Reservoir. The black line is the path traveled by the boat which is non-geometrical since it was under manual control.

During the Lake Tahoe deployment, the approximate damping factors of the system were unable to be determined due to a failure in the electronic system that prevented the boat from communicating and therefore moving under its own power. This also eliminated the ability to test the battery life, since the motor batteries were not drained. However, the seals and waterproof endurance of the battery containers were able to be evaluated. During the Lake Tahoe deployment, the boat was in the water, and batteries submerged for more than 8 hours, and none leaked. For the last deployment of the SWATH boat in Lake Tahoe it was towed around using a powered Kayak in a pattern as close to ideal as conditions and steering accuracy would permit. A high quality map of the surface of Lake Tahoe was generated from this test run, and is the most significant data to date from the SWATH boat.

Figure 4.2- SWATH boat in Lake Tahoe. The SWATH boat had to be towed by a powered kayak on Lake Tahoe in order to collect data due to an electronics failure.

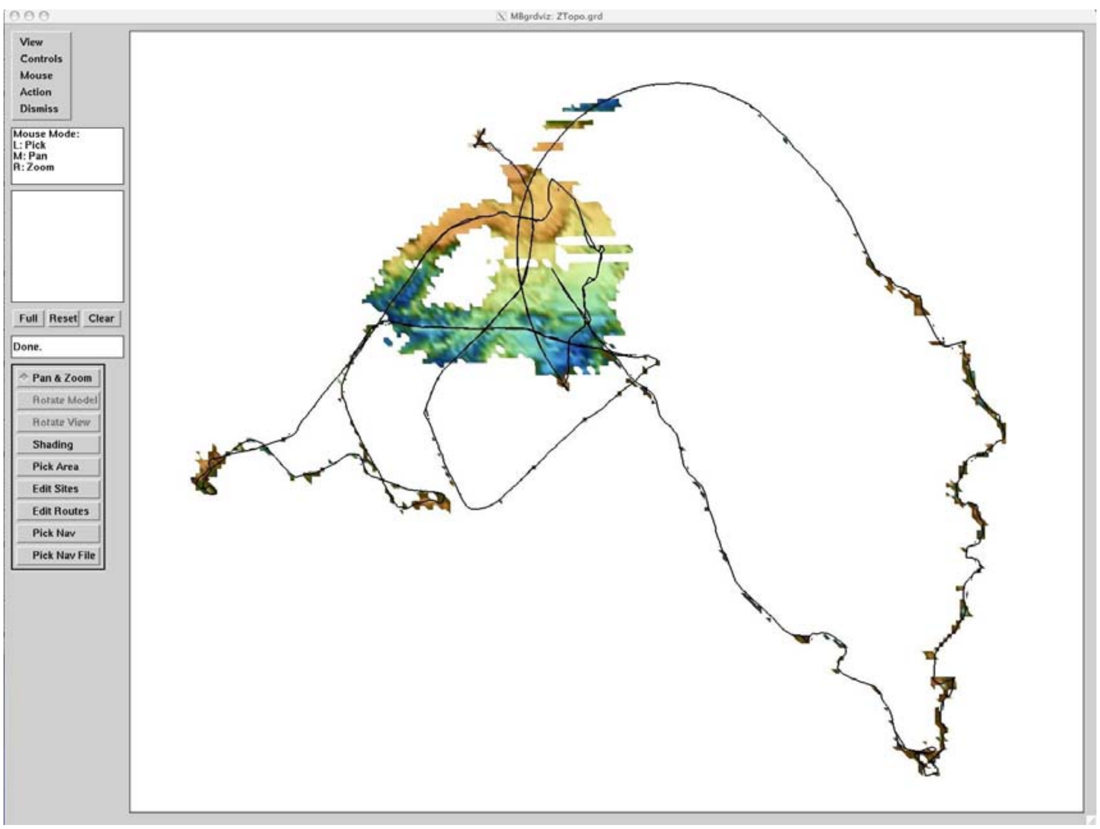

Figure 4.3 – Stevens Creek Reservoir bathymetry map. Map generated from merged multibeam, gps, and DVL data in Stevens Creek Reservoir.

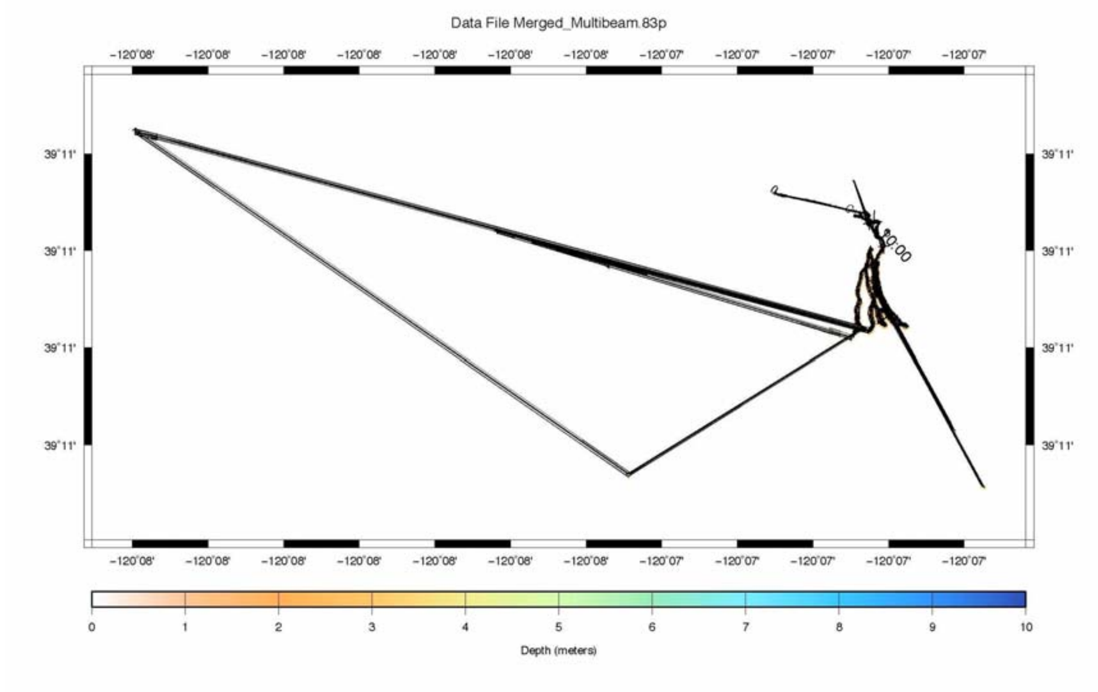

Figure 4.4- Bathymetry Map of Lake Tahoe. Map generated using MB-system from merged multibeam, GPS, and DVL data in Lake Tahoe south of Dollar Point.

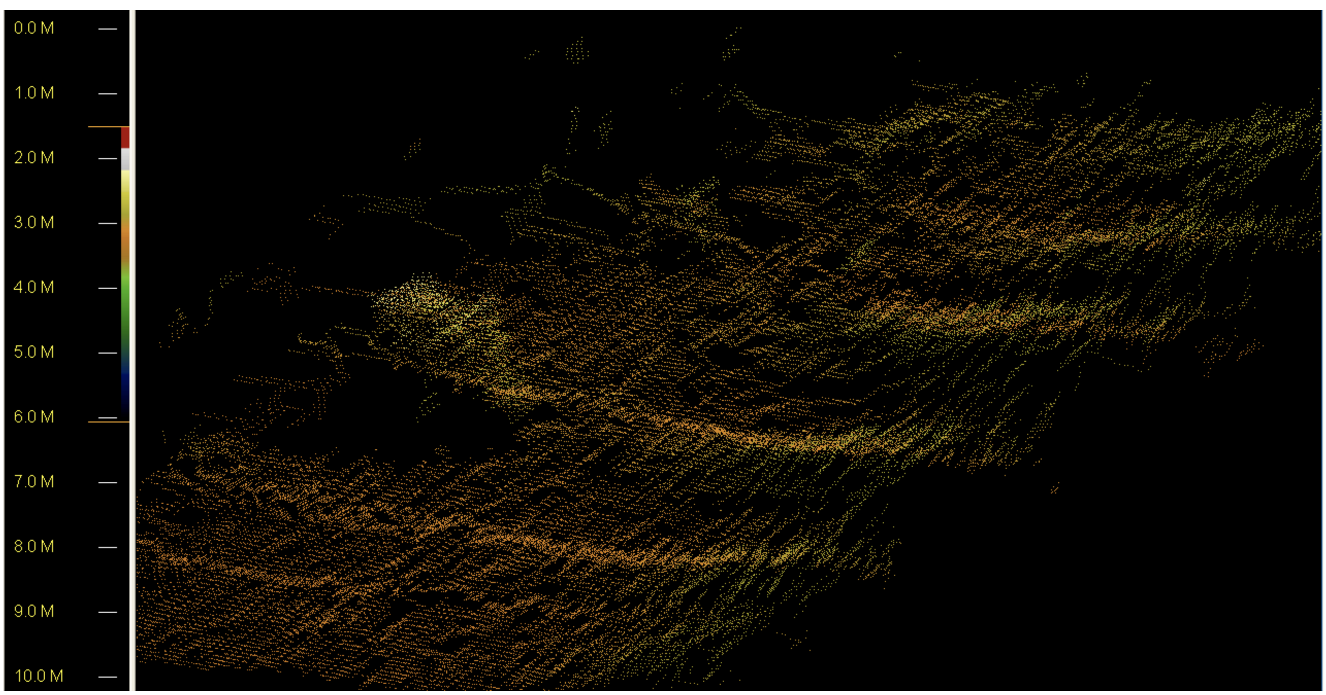

Figure 4.5 - Lake Tahoe Bathymetry Data. The immense amount of detail that can be reproduced by the multibeam sonar instrument is shown here. This is a 3D gradient of a small section of the surface of Lake Tahoe.

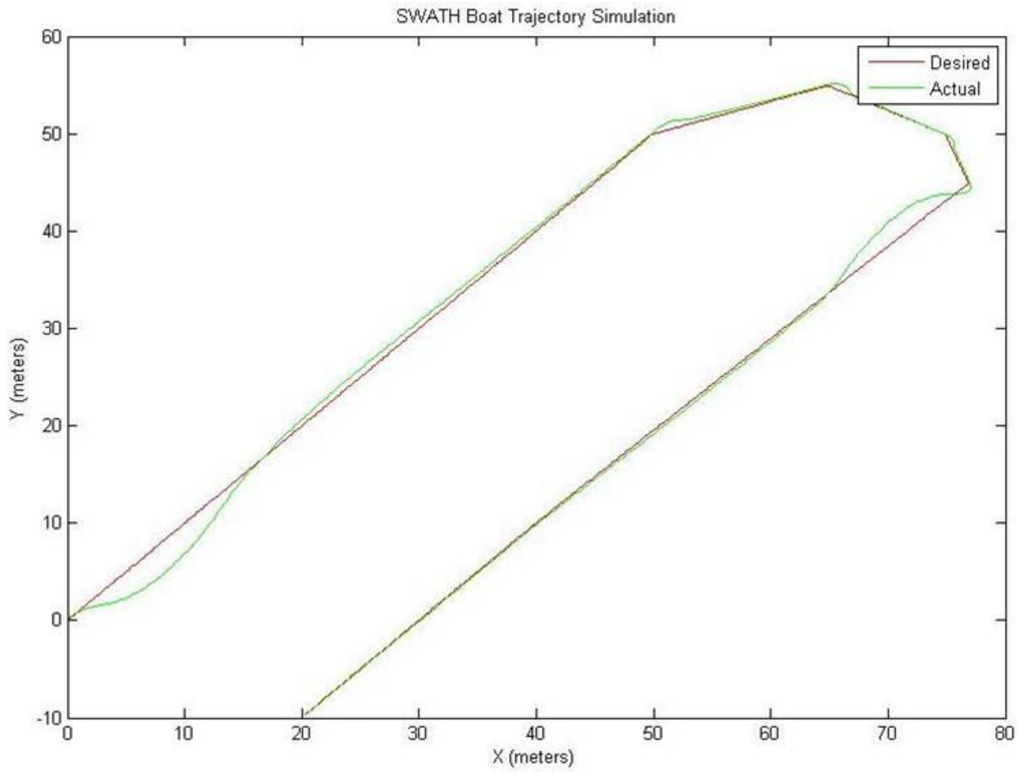

Figure 4.6 - SWATH boat trajectory controller simulation results. The boat starts at the initial (zero) location and initially overshoots, then returns back on track for each change in heading. The red line is desired position and the green line is the actual trajectory of the boat.

5 Costing Analysis

The SWATH project budget was given a boost at the beginning of the year by a $1,000 grant given by the dean's office. The SWATH project budget at the beginning of the year was estimated to be between two and three thousand dollars. The final SWATH budget is a little over this range, but was inflated because of the additional costs of abandoning the fiberglass battery boxes and money spent on them in favor of ABS plastic boxes. The polycarbonate lids were able to be reused, but the cost of the ABS plastic for all six battery boxes was around an additional $400 dollars. The ballast system was not in the initial requirements for the system either, which cost approximately another $400 for ABS box materials, compressor, actuators, enclosure, and tubing.

6 Patent Search

6.1 Battery Container and Classification:

The main components that were designed and developed by the group were the watertight battery containers, which delivered power to the various subsystems of the boat. At first, the group had decided to purchase watertight containers that would fit the battery dimensions, and that could be modified to allow for the addition of cables and Dorn connectors. However, the attempts to find such an existing product were unsuccessful.

As a result of being unable to find existing products, it was decided that it would be more cost effective to build containers that offered the desired characteristics. The design was to allow for watertight features with a modified cubic shape that would allow for easy transportation. The difference in the design from already existent products involved the ability to completely submerge the container for a prolonged period of time. Most marine battery casings that were encountered only featured splash-proof seals and did not allow for complete submersion. Designs that did allow for submersion did not provide dimensions for small scale applications, or would fit inside the hulls.

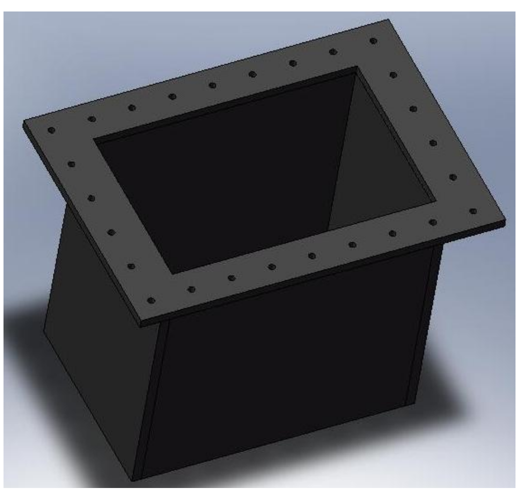

Figure 6.1 – SWATH waterproof battery boxes. The final design is made out of ABS plastic and utilizes a clear lid.

As shown in Figure 6.1, the design utilizes the flange feature that created the watertight seal as handles to aid in transportation. The size of the container allows for the use of a single battery with the common dimensions. The clear polycarbonate lid allows for visual inspection of the connections and seals, and features durable material characteristics, which make for a strong and rigid container. Although this design is novel in its application, there are existing patents that try to accomplish the same goals.

The design itself satisfies a number of different US classifications that deal mainly with the storage of battery cells. Classification 429/100 describes the most basic purpose of the design by describing it as a support container for various cells. US classification 206/811 describes the ability to be waterproof and 429/6 makes note of the ability for the container to equalize pressure when submerged. Finally classification 180/220 describes the use as being for electric motors. However, there are current patents that deal with a combination of these various classifications.

6.2 Current Patents

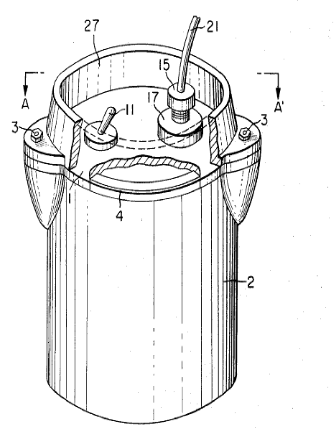

Figure 6.2 – US Patent 3829332. This patent demonstrates another approach to waterproof battery enclosures.

Patent number 3829332 (Figure 6.2) accomplishes the same tasks as the SWATH boat's containment system. It is described as being used to power appliances in marine or outdoor environments and features watertight seals and connectors. However, the cost of such a containment system seems to be far too high for applications such as the SWATH boat. The designer specifies that the patent be machined out of aluminum to give the cylindrical appearance and that the seals be created by threading the metal lids and body. The design also calls for the use of numerous stainless steel parts, which would add significant costs if multiple containers needed to be purchased.

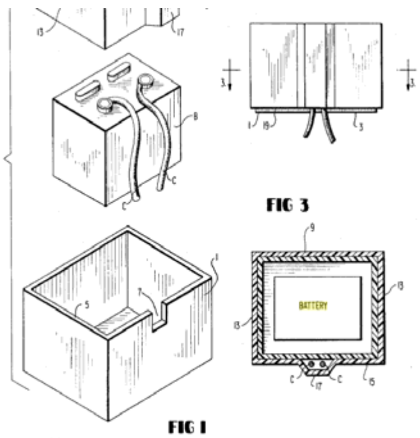

Figure 6.3 – US Patent 4225655. This patent uses cavities of water to prevent from filling past a certain point.

Patent number 4225655, (Figure 6.3) is to be used in a marine environment, but its main purpose is to apply watertight features during an emergency situation that may plague a boat such as excessive rain, or high waves that could cause flooding in the boat's storage compartment. The difference in this design is that it does not use bolts or screws to adhere one surface to another. The seal is created by allowing water to fill certain cavities that prevents the container from being filled past a certain point. However, in the instance of the SWATH boat, this design would not be applicable. Without devices to seal the lids together, there exists the risk of parts being moved into undesired positions, which could lead to the damaging of the battery.

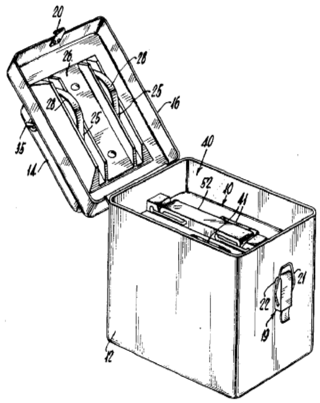

Figure 6.4 – US Patent 4160857. This waterproof battery enclosure uses a latch to apply pressure to create a seal.

The design featured in Figure 6.4 for patent number 4160857 is simply another method in which a watertight battery housing was created. It offers the same features as previous designs, but boasts the ability to have easy access to the inner container. Rather then using a series of bolts to create the seal, a latching mechanism is used to apply the proper amount of pressure.

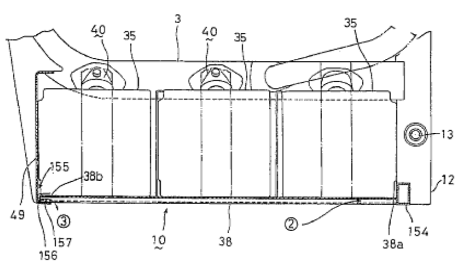

Figure 6.5 – US Patent 5513721. This patent is designed for electric vehicles, and uses water-filled channels to prevent excess amounts of water from coming in.

Patent 5513721 (Figure 6.5) deals mainly with the use of the container and battery power. It is designed to be used specifically with electric vehicles, namely electric scooters. However, although it is not being made for a marine vehicle, the container still requires some of the same feature such as the ability to withstand excessive amounts of water. The seal is formed in a similar manner as patent 4225655, where a series of channels are allowed to fill with water to prevent excess flow within the main compartment. However, once again, this method does not appear to provide a reliable seal during harsher conditions.

Although there does already exist several designs that are similar to the SWATH boat's battery containers, none of them appear to have all the same capabilities. What makes the boat's system unique is the ability to incorporate all the features in one design. Based on this conclusion, it is believed that the battery containment system is a patentable design. It claims to be an affordable, durable watertight method for containing a single battery in a marine environment.

7 Engineering Standards and Realistic Constraints

7.1 Economic

If the SWATH Autonomous Mapping Boat were to be produced, it would have an impact on the economy. The retail price of an Autonomous SWATH Mapping Boat would be well over $100,000, therefore contributing to the United States gross domestic product. There are also costs associated with maintaining the boat, and a staff of at least two people are required to manage the deployment, supervise operation, and recover the boat. During a one month mapping deployment, consisting of twenty days, the costs of operating the SWATH autonomous boat would be approximately $15,900. This figure is based on a full time staff of two people, estimated at $30 per hour for wages and eight hours of deployment per day, totaling $9,600 in wages. Since deployments typically take place in remote locations, there would likely be an additional per diem cost to cover lodging and food for the staff, averaged approximately $120 per day per person, or $4,800. Maintenance costs should cover occurrences such as failed batteries, electricity, and replacement hardware, and be $1,000 or less. Miscellaneous expenses for things such as boat launch fees and short range transportation should total less than $500. Therefore the total cost for a twenty day mapping deployment would be approximately $15,900, an average of $795 per day operating cost.

The cost of operating a traditional research vessel equipped with a multibeam sonar would be much greater. The rental of a thirty foot research vessel at Lake Tahoe costs more than $900 per eight hour day, and the fees to hire an approved captain are approximately $200. There would also have to be at least one qualified person in charge of operating the multibeam sonar and other instruments at $30 per hour, and a deckhand hired to assist with the boat operations at $80 per day. The total approximate costs of renting a research vessel and staffing it in Lake

Tahoe for 20 days is $28,400, or averages $1420 per day. This is a significantly higher cost (79% higher) compared to deploying the autonomous SWATH boat.

7.2 Environmental Impact

The environment is a limited resource and must be conserved as a whole to the best of our abilities using the tools we have. The ozone is heavily effected by carbon emissions, which can cause global warming and radiation holes. A major design decision was to use electric thrusters powered by batteries instead of a gas outboard motor or portable generator. In 2006, 23 percent of the United States electric power is supplied by natural gas, which is one of the most efficient methods of generation[2]. There are also more environmentally friendly methods of generation as well, such as hydro-power. The SWATH boat's onboard batteries, which hold enough power for an eight hour deployment, contain the equivalent of 4.9 Kilowatt-hours of power. A natural gas plant produces approximately two pounds of CO_2 to generate that much electricity. A similar 5 horsepower motor consumes one half gallon of gasoline per hour, which emits 19.56 pounds of CO_2. Therefore an eight hour deployment on gasoline would produce 80 pounds of CO_2, about 40 times more than electric thrusters. With respect to the environment, it was an obvious choice to use electric batteries.

A more direct danger the SWATH boat poses to the environment is the large batteries submerged inside the hulls of the vessel. These batteries are sealed absorbed glass mat (AGM) cells, and should not leak acid, but extra precautions must always be taken. The batteries are sealed inside waterproof enclosures. If water were to leak inside the enclosures, and salt water amplifies this effect, there is the possibility of shorting the battery terminals and causing an explosion, releasing sulfuric acid and other contaminates into the water, posing an environmental threat. Precautions have been taken to minimize the probability that this should happen.

Overshadowing the negative environmental facts are the positive contributions data from successful missions will provide. The observation of marine habitats will give biologists and geologists the ability to distinguish the differences between thriving and struggling marine communities. Using the bathymetry data collected, geologists will be able to study the movements of the earth and formations resulting from volcanic activity and other anomalies.

7.3 Safety

Safety is a key component to the success of any mission. The SWATH boat contains many safety hazards such as powerful propellers and motors, batteries that can supply high amounts of current, and many moving parts. The boat is also deployed in marine environment which poses risks such as drowning, hypothermia, and electrical shock. When the boat is eventually deployed in Kisitsna Bay, Alaska, the water temperature averages around 45 degrees in the summer, and can actually drop below freezing in the winter. In water temperatures between 32 to 45 degrees Fahrenheit, the average person is only expected to survive between 30 to 90 minutes, with exhaustion setting in after 15. If an operator were to slip or fall into the water it could be a life threatening situation. This means that is important, while deploying in cold water regions, to have life preservation equipment and ocean survival suits available.

water temperature (Fahrenheit)	Exhaustion of Unconsciousness	Expected Survival Time
70-80	3-12 hours	3 hours - indefinitely
60-70	2-7 hours	2-40 hours
50-60	1-2 hours	1-6 hours
40-50	30-60 minutes	1-3 hours
32.5-40	15-30 minutes	30-90 minutes
<32	< 15 minutes	under 15 to 45 minutes

Table 7-1 – Expected Water Survival Times. United States Search and Rescue Task Force (USSARTF) estimated human survival times based on water temperatures.[7]

The materials used in the boat are also susceptible to failure. During an analysis of the SWATH boat while being hoisted by a crane, it was discovered that the vertical struts had a very low safety factor. The honeycomb aluminum material in the vertical struts is very lightweight and strong in certain loading configurations, but not as strong in its bending stress condition. Aluminum does not have an endurance limit to allow for design of infinite life. Therefore the aluminum will continually degrade, and using a small safety factor is a poor design decision. A decision was made that the boat will no longer be hoisted out of the water by a crane, or have to be hoisted very slowly to allow all water to drain out if absolutely necessary.

7.4 Usability

When a customer or consumer purchases a product, he has a number of expectations. According to the engineering handbook the product should be easy to learn and remember, effective and efficient, relatively free of failures, satisfying to use, and sustainable. While the SWATH boat is not a completely integrated and finished product, it meets many of these criteria, and future plans would include provisions to meet all of them. The SWATH boat's goal is to be easy to operate since it must be operated by technicians with diverse backgrounds which may not include engineering or technical degrees. The SWATH boat control system will be integrated into an easy to use graphical user interface to accomplish route planning and monitoring. This program will tie in with the autonomous functionality of the boat to accomplish the usability goals.

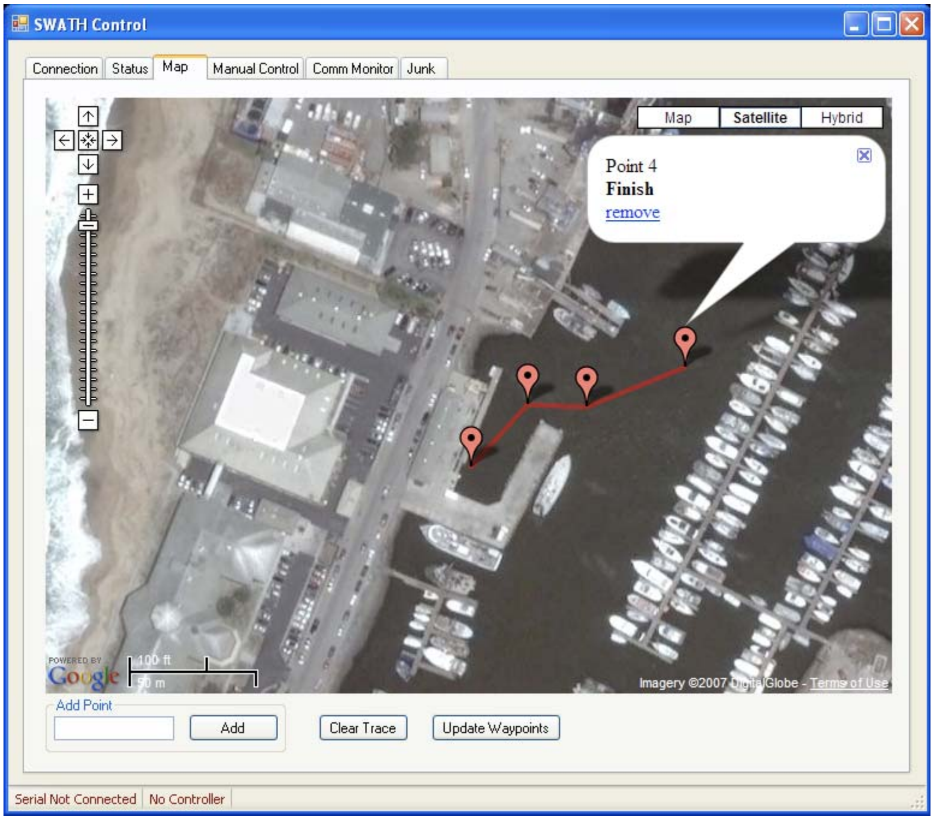

Figure 7.1- Google Maps Interface. Using C# hooks into JavaScript, Google Maps was able to be utilized for real time monitoring and way-point routing for the autonomous SWATH boat. The red icon represents the current position of the boat, and light red teardrops are way-points. The way-points can be nicknamed, drag-and-dropped, and rearranged in real time.

7.5 Sustainability

Sustainability is an important factor with the SWATH boat as with any other research vessel. By using electric thrusters, the boat only creates about two pounds of carbon emissions, compared to the equivalent gas motor carbon emissions of 80 pounds, for an eight hour deployment. There are new and emerging technologies which will allow the SWATH boat to become more sustainable. Solar cells would be a promising way to power the boat entirely from the energy of the sun. The solar panels on the market today achieve approximately 80 watts peak power per square meter, but this is always increasing as time goes on. The deck of the SWATH boat only has approximately two square meters of area, and therefore assuming eight hours of maximum sun power, could only provide 1280 watts of power. This is about one quarter of the power required by the boat. Solar power would be a great addition to the power system, but currently does not provide enough of it to completely satisfy the needs of the boat.

Figure 7.2-Solar Panel. The Kyocera KC85TS solar electric panel produces 87 peak watts and covers an area of .7 meters.[8]

8 Summary and Conclusions

8.1 Summary

During the course of this project many goals were met and milestones completed. The primary goal of the project was to create an autonomous research platform capable of high resolution bathymetry. A number of new scientific instruments were integrated into the autonomous SWATH mapping surface vessel, including a multibeam sonar for three dimensional mapping, and a Doppler Velocity Log (DVL) for high resolution velocity, heading, pitch, and roll tracking. A laptop was integrated on-board the vessel inside a waterproof housing in order to log the data from these instruments, as well as from a global positioning system (GPS). Using this collected data, high quality sub surface maps of portions of Stevens Creek Reservoir and Lake Tahoe were produced. In order to provide power to the instruments and motors of the SWATH boat, and maintain stability, new waterproof battery boxes were designed, built, and tested. To connect the power from the batteries to the instruments, new cabling was fashioned, as well as a power distribution box to provide modularity to the system. To control the path of the boat through the water autonomously, a multiple input multiple output (MIMO) state space trajectory controller was also designed and implemented.

There were four test deployments with the SWATH boat. Two deployments were in Steven's Creek Reservoir, and the other two were in Lake Tahoe. Bathymetric maps were generated from both of these locations. Much was learned through these tests about the robustness of the boat, through which many issues arose and were resolved. Maps were generated from the data collected in both Stevens Creek Reservoir and Lake Tahoe.

The end result of this project is an autonomous research surface vehicle which is capable of producing high quality three dimensional bathymetric maps. It can follow a path autonomously through a defined set of points using a developed trajectory controller and log data from its instruments in order to produce these maps. It contains a modular power system allowing it to be easily reconfigurable, and a pneumatic ballasting system allows quick deployment. Although a fully integrated field test was not completed, all key functionality was successfully demonstrated on an individual basis during field tests.

8.2 Future Work

Although much was accomplished throughout the course of this project, there are always new opportunities to expand and improve the current functionality. The durability and robustness of the boat and its subsystems needs to be further tested and improved in order to provide a greater chance of success in real world missions. The trajectory controller developed for autonomous control of the boat has also received very little testing outside of the simulation environment, so that it has yet to be proved reliable. The batteries currently being used inside the hulls were handed down from MBARI, and during nearly every deployment, another battery seems to fail. Therefore, for safety and reliability reasons, it would be beneficial to replace the current AGM batteries with new ones. While launching the boat for deployment, the current height of the boat on its trailer is too high. It currently requires backing the vehicle into the water on most boat ramps, then the operators have to get into the water to load and unload the boat to and from the trailer. Therefore, the trailer needs to be modified so that it sits in a lower position on the trailer. Finally, the boat needs to be extensively tested in real environments and situations in order to prove its reliability, and to work out any additional bugs or flaws.

8.3 Lessons Learned

Many valuable lessons were learned during the duration of the project. The boat is comprised of various systems that span all of the engineering disciplines. There were many challenges that arose from having only two mechanical engineers on an inter-disciplinary engineering project. There were many instances where we found ourselves consulting with computer engineers and electrical engineers, who were helpful in interfacing and resolving issues with the controller boards.

The submerged waterproof battery boxes presented many technical challenges and scheduling delays. The initial design of the boxes called for them to be made out of fiberglass resin, so that they would be one solid piece. It was a costly mistake to assume that they would work, be quick to make, and would easily seal. The opposite was true, and a lot of time and money would have been saved if only one box was prototyped and tested, instead of making all six at once. The boxes either contained microscopic leaks in the corners, or their flanges were never able to be perfectly sealed. The boxes were never able to be completely sealed even after adding endless layers of additional fiberglass and bondo. They eventually had to be abandoned at the last minute in favor of ABS boxes, which were comparable in cost, but were able to be completely assembled in a matter of hours instead of weeks. The lesson learned was the importance and benefits of prototyping in a time-sensitive environment.

The Lake Tahoe deployment resulted in a few disappointments and the learning of a few lessons as well. There had been some type of electrical surge in the electronics box prior to, or during the first deployment, which harmed the sensitive electronic control micro-controllers. When going on a deployment, backup copies of sensitive hardware and components should be brought along in case of such circumstances. Additional protection for these boards against power surges should be implemented as well.

Appendix

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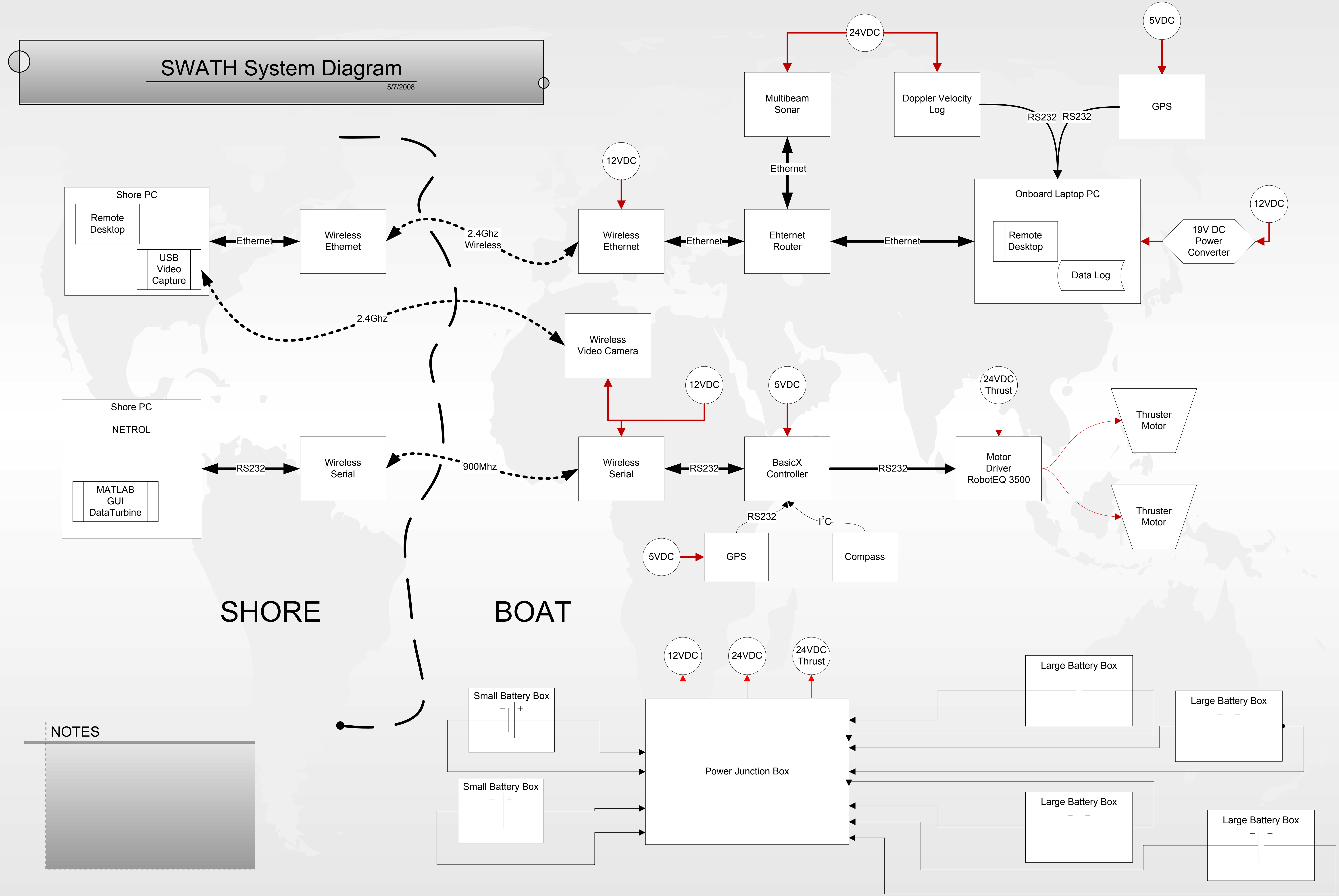
Appendix A – Block Diagrams

A-1 System Level Diagram



SWATH System Diagram
5/7/2008
Shore PC
Remote Desktop
USB Video Capture
Ethernet
Wireless Ethernet
2.4Ghz Wireless
12VDC
Wireless Ethernet
Ethernet
Ethernet Router
Ethernet
Multibeam Sonar
24VDC
Doppler Velocity Log
RS232
RS232
5VDC
GPS
Onboard Laptop PC
Remote Desktop
Data Log
12VDC
19V DC Power Converter
2.4Ghz
Wireless Video Camera
Shore PC
NETROL
MATLAB GUI DataTurbine
RS232
Wireless Serial
900Mhz
Wireless Serial
12VDC
RS232
5VDC
BasicX Controller
RS232
24VDC Thrust
Motor Driver RobotEQ 3500
Thruster Motor
Thruster Motor
RS232
I²C
5VDC
GPS
Compass
SHORE
BOAT
12VDC
24VDC
24VDC Thrust
Small Battery Box
Small Battery Box
Power Junction Box
Large Battery Box
Large Battery Box
Large Battery Box
Large Battery Box
NOTES

Appendix B – Customer Needs Survey Response

B-1 – Response from Geoff Wheat

Gmail by Google BETA

Todd Berk <toddberk@gmail.com>

SWATH boat customer needs

Geoff Wheat <wheat@mbari.org> **Fri, Oct 26, 2007 at 9:18 AM**
To: Todd Berk <toddberk@gmail.com>

Todd Berk wrote:

> The following survey is a customer needs survey for our senior design class. Your input will help us prioritize and shape our goals. Please fill out as much as you have time, I know you are very busy, and we appreciate your time. Please reply by Thursday morning.
>
> What would be your main purpose for using the boat and / or its multi-beam sonar?

The boat represents a prototype that I would use to test a variety of sampling types and procedures. The multi-beam represents on type of instrument and one mode of operation. I would like to use the boat and multi-beam to map shallow waters where traditional methods are not possible.

> How important is accuracy when gathering multi-beam data?

Accuracy is important to get the best possible product.

> What is the desired battery life and operating range you would like to see?

Ideally the battery life would exceed 12 hours with an operating range of 20 miles

> What water conditions would you expect the boat to operate in?

In a variety of sea states. Ideally in all weather but the boat must be able to withstand a squall (30 knot winds) as these sometimes appear without much notice and before the boat can be retrieved from a remote location.

> Are there any additional instruments / sensors you would like to see implemented, and why?

I would like to see a suite of weather instruments (to discern changes in weather patterns that might affect operations), a camera (to provide a visual assessment of surface objects (nets, boats) that may result in problems for the boat), a bottom tracking system (for the best possible (and redundant with GPS) navigation), roll etc sensors to get the best multi-beam and assess sea conditions, and several in hull instruments for continuous oceanographic characterization (an ADCP for measuring currents and a CTD with a fluorometer and oxygen sensor. This package could be identical to the one that will be used with the AUV).

> What is your preferred method of control in manual operation? (i.e. joystick, game controller, keyboard...)

game controller

> How would you prefer to place the boat and remove it from the water?

From a trailer so that ere are more options available

> Is Internet access available where you would deploy the boat?

With the certain communication packages there is internet every where

> What is the skill level of the normal operator?

Not skilled

> Is there anything you like about the existing boat?

It floats and moves, but I am looking forward to seeing it in the water with the new thrusters and cables.

> What do you dislike about the existing boat?

It is not ready for prime time, I wonder about its stability in rough water, and I am concerned about its general performance..

B-2 – Response from Bill Kirkwood

Gmail by Google BETA

Todd Berk <toddberk@gmail.com>

SWATH boat customer needs

Kirkwood, Bill <kiwi@mbari.org> **Wed, Oct 24, 2007 at 4:11 PM**
To: Todd Berk <toddberk@gmail.com>, "Wheat, Geoff" <wheat@mbari.org>
Cc: Chris Kitts <ckitts@engr.scu.edu>

Well let's see if this helps out…

From: Todd Berk [mailto:toddberk@gmail.com]
Sent: Tuesday, October 23, 2007 11:27 PM
To: Kirkwood, Bill; Wheat, Geoff
Subject: SWATH boat customer needs

The following survey is a customer needs survey for our senior design class. Your input will help us prioritize and shape our goals. Please fill out as much as you have time, I know you are very busy, and we appreciate your time. Please reply by Thursday morning.

What would be your main purpose for using the boat and / or its multi-beam sonar?

Gaining an understanding of the topology is the primary purpose of a tool like this. The information can be used for a host of purposes not the least of which is selecting sites of interest to apply other assets, often more expensive, with some reasoning versus blindly searching around. The particular multibeam we are working with is useful for fisheries as one example defining the areas where fish make seek shelter, or where outflows could have adverse impacts on fish population, erosion issues due to anthropomorphic sources… the list goes on and on.

How important is accuracy when gathering multi-beam data?

That depends on the data output / processing. The simplest answer is the highest resolution and accuracy possible is always better than lower. The practicality is the methods of taking the data with the available tools should be traded against the use of the final products and the associated costs.

What is the desired battery life and operating range you would like to see?

Again, as far as possible with the maximum power is how science answers this type of question. Certainly mapping several square kilometers over a single "shift" would be a minimum. Assuming an average speed of 1.5 m per second and a swath width (beam coverage) of 10 meters (fairly shallow operation) a 8 hour mission should yield an approximate area of .5 km2. If we are higher up the coverage is much larger but the resolution changes, it's a multi-dimensional issue and depends on the mission, but a 6 to 8 hour endurance running the basic systems should be our ultimate goal.

What water conditions would you expect the boat to operate in?

For mapping functions I don't expect things to be to high on the Beaufort scale. Sea State 0 to 1 would be great. If we use the boat to do other missions like CTD runs, we should be willing to up that to sea state 2 at least.

Are there any additional instruments / sensors you would like to see implemented, and why?

First and foremost we need to have a small SVT (sound velocity transducer) or a CTD with science grade data output. This is required in the long haul to correct errors in the maps due to speed of sound in water differences. We could also use a Doppler velocity logger to correct navigation over time (Kalman filtering type issues) and the best roll sensor we can afford. These together make for a very solid mapping system and make the maps quality as well as properly geo-locate the maps… the system is just setup right versus being sub-grade for science purposes. This isn't to say that any data isn't useful, science will take what it does now… but to really be peer review level in today's world we'll be expected to do better.

What is your preferred method of control in manual operation? (i.e. joystick, game controller, keyboard...)

The game controller is fine, a joystick tends to me more intuitive for older guys (like me). Doesn't really matter much since this mode is intended to launch and recovery mostly, the autonomous mode working will have users forgetting about the manual interface as long as it doesn't fail. Key to the manual interface is it must be reliable as should the system in general.

How would you prefer to place the boat and remove it from the water?

I think the best method for launch and recovery would be to do what most private fishing or ski boats do, use a boat ramp. It makes it flexible, useable at almost any port or marina and doesn't really impact the ability to launch from a vessel of opportunity, such as a UNOLS boat. So, for the basic use in Lake Tahoe, the Elkhorn Slough or SF harbor… I would think a boat trailer to a boat ramp is the best overall method.

Is Internet access available where you would deploy the boat?

In today's world it is likely some internet access is available at a lot of places. However, I wouldn't make a system dependant on it. It can be flaky, you might not have control over other traffic or operational issues, plus as the boat runs in places with obstacles it could create issues we'd rather avoid. I would have internet from the base station to the boat for our own purposes (wireless modem) but not worry about the internet most people talk about. The boat should be capable of being on the net so that in the field we have options.

What is the skill level of the normal operator?

Currently we have to use someone who is trained specifically or a technically oriented person who has "expert knowledge" of the system. Eventually we'd like to put the systems (anything we create) into the hands of scientist without technical people required on a day to day basis. I think for maintenance and so forth there are other considerations which weigh-in. Such as how much it costs to make a bullet proof system versus having an "expert" fix it is a trade study about the best solution for the life of the system.

Is there anything you like about the existing boat?

I like everything about it, others have tried this concept and failed so I'm feeling pretty good about the Sea WASP as a prototype. I think with careful planning and good decision making we can get some really compelling data out of the system that would encourage the community to consider further investment.

What do you dislike about the existing boat?

The only thing I would complain about, if I can call it that, is the overall system stability. I think with a little further spread on the pontoons and a few changes we could really make it operate in higher "sea state" conditions and do some really good work. Presently the system is limited to minimal weather which is hard to come by. That said, as a prototype built by students on a limited budget in a short amount of time… I'm pretty proud of the effort and results overall.

B-3 – Response from Gary Greene

Todd Berk <toddberk@gmail.com>

Autonomous SWATH boat customer needs survey

Gary Greene <greene@mlml.calstate.edu> **Sun, Nov 4, 2007 at 4:03 PM**
To: Todd Berk <toddberk@gmail.com>

Todd,
Sorry for the delay in getting back to you. Obviously I am too late for your Thursday last deadline, but I have gone ahead and filled out your survey just in case it may help you sometime down the road.
Cheers, Gary Greene
On Oct 23, 2007, at 11:50 PM, Todd Berk wrote:

> Hello Gary, I was a Intern at MBARI over the summer and went on the geology tour with you. I worked on an autonomous SWATH multi-beam mapping boat, and am continuing with it as a senior engineering project. Attached is an image of the boat, and an image of output from the multi-beam that shows the indentation left by the Western Flyer's hulls where it docks.
>
> The following survey is a customer needs survey for my senior design project at Santa Clara Univeristy. Your input will help us prioritize and shape our goals. Please fill out as much as you have time, I know you are very busy, and I appreciate your time. Please reply by Thursday morning. If you have any questions, don't hesitate to call me at 408-771-3532 or reply. Thank you very much.
>
> What would be your main purpose for using the boat and / or its multi-beam sonar?

My main purpose of using such a system would be to fill in the so-called "white zone" between deep water (~3 m a deeper) and the coastline where it is difficult to obtain multibeam data safely today.

> How important is accuracy when gathering multi-beam data?

Accuracy is important especially in navigation as many time repeat surveys are done for time analyses purposes and images collected from one survey need to be accurately georeferenced if the analyses are to be done.

> What is the desired battery life and operating range you would like to see?

For me, I would say 6-8 hours would be adequate.

> What water conditions would you expect the boat to operate in?

The rougher water conditions, the better, but if the vessel could operate in seas up to 1 m high that would work.

> Are there any additional instruments / sensors you would like to see implemented, and why?

If a sub-bottom profile system could be adapted to the vessel that would be helpful as we could obtain seismic reflection data as well as bathymetry and backscatter or side scan sonar data.

> What is your preferred method of control in manual operation? (i.e. joystick, game controller, keyboard...)

Probably a joy stick with on screen real-time navigation, sort of like driving a boat with a joy stick.

> How would you prefer to place the boat and remove it from the water?

Probably over the side deployment from a mother vessel using a davit or small crane.

> Is Internet access available where you would deploy the boat?

General not. However, internet might be able to be establish in some places, but generally I would envision the use of such vehicles in remote areas but monitored from a mother boat.

> What is the skill level of the normal operator?

If real-time multibeam data is to stream from your vessel than you would need someone who understands multibeam processing and navigation.

> Is there anything you like about the existing boat?

I like the idea that this vessel is very shallow draft and can get in close to shore in rocky and hazardous areas thus filling in gaps that historically have not been possible to fill.

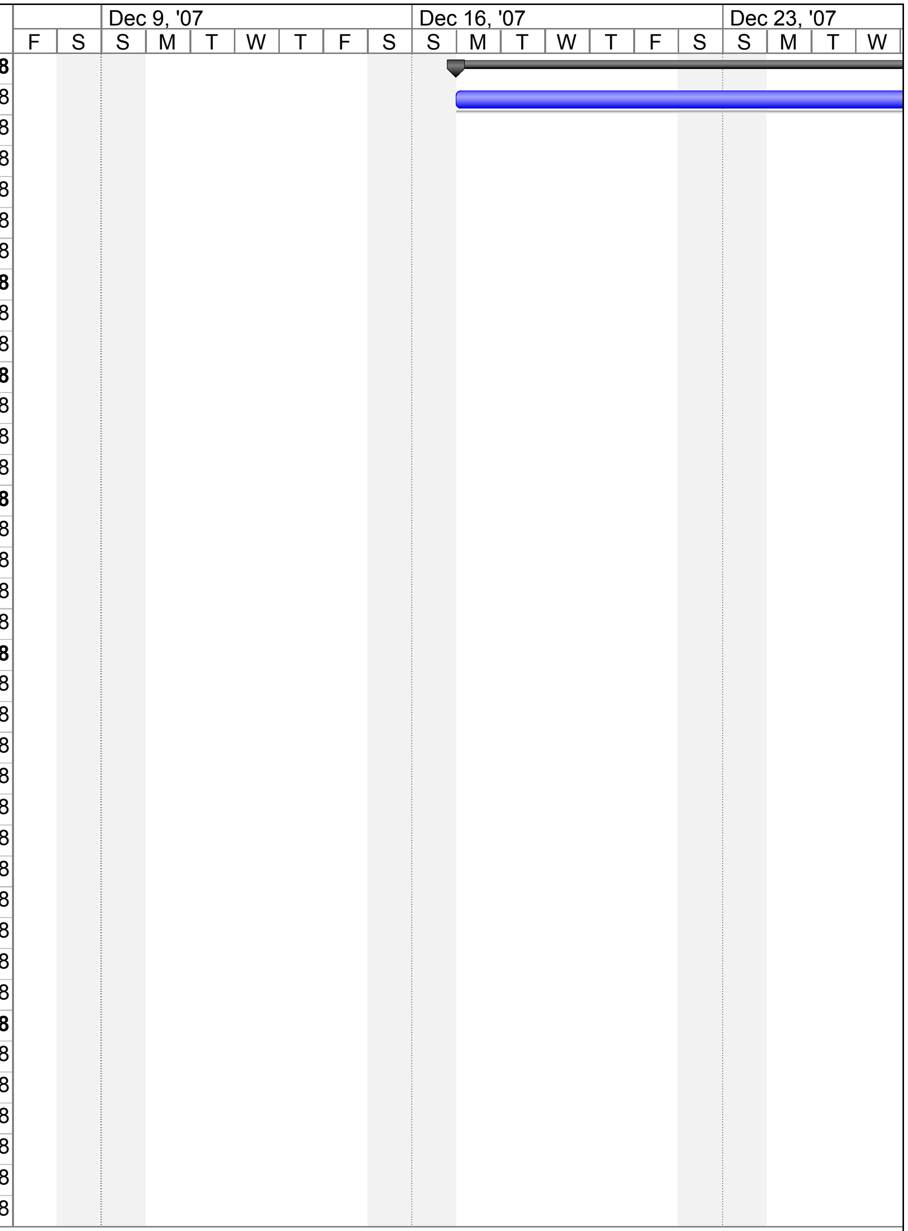
> What do you dislike about the existing boat?

I am not sure. It is kinda of ugly, but if it works, what the heck it will be a valuable tool.

> <swathmb_harbor1.jpg>
> <Multibeam 5.png>

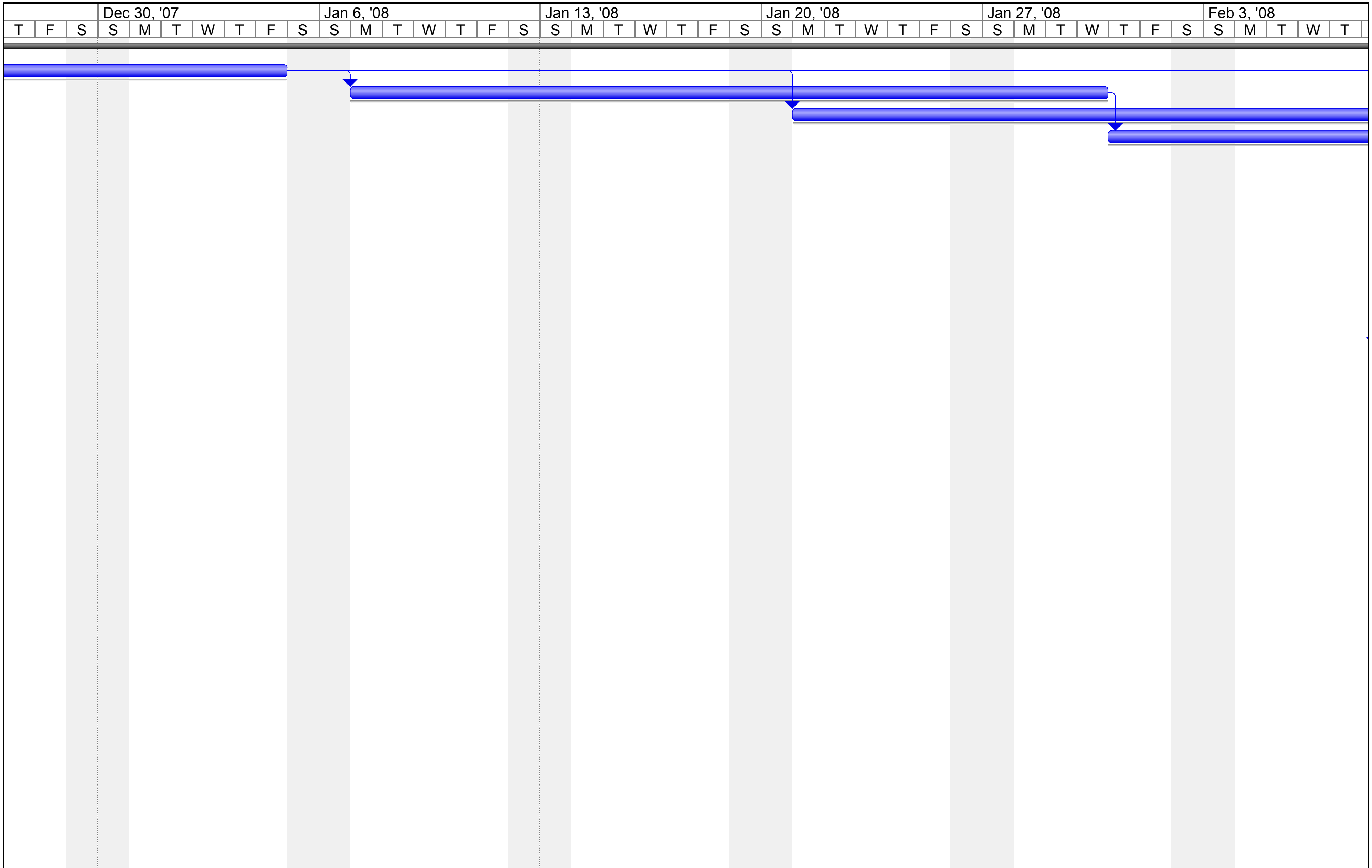
Appendix C – Timeline

ID		Task Name	Duration	Start	Finish
1		**Battery Boxes**	**55 days**	**Mon 12/17/07**	**Fri 2/29/08**
2		Design Battery Boxes	15 days	Mon 12/17/07	Fri 1/4/08
3		Machine Battery Boxes	18 days	Mon 1/7/08	Wed 1/30/08
4		Order Battery Box Connectors	15 days	Mon 1/21/08	Fri 2/8/08
5		Assemble Battery Boxes	10 days	Thu 1/31/08	Wed 2/13/08
6		Wire Battery Boxes	7 days	Thu 2/14/08	Fri 2/22/08
7		Test Waterproof Bat Boxes	5 days	Mon 2/25/08	Fri 2/29/08
17		**Batteries**	**11 days**	**Mon 2/11/08**	**Mon 2/25/08**
18		Select Batteries	3 days	Mon 2/11/08	Wed 2/13/08
19		Order Batteries	8 days	Thu 2/14/08	Mon 2/25/08
20		**Data Logging**	**30 days**	**Tue 3/4/08**	**Mon 4/14/08**
21		Log Multibeam Data	10 days	Tue 3/4/08	Mon 3/17/08
22		Log GPS Data	10 days	Tue 3/18/08	Mon 3/31/08
23		Log DVL Data	10 days	Tue 4/1/08	Mon 4/14/08
8		**DVL Mount**	**25 days**	**Wed 3/26/08**	**Tue 4/29/08**
9		Design DVL Mount	5 days	Wed 3/26/08	Tue 4/1/08
10		Machine DVL Mount	15 days	Wed 4/2/08	Tue 4/22/08
11		Assemble DVL Mount	5 days	Wed 4/23/08	Tue 4/29/08
28		Modify Motor Cones	6 days	Wed 4/2/08	Wed 4/9/08
29		**Thesis**	**48 days?**	**Wed 4/9/08**	**Fri 6/13/08**
30		Table of Contents & Introduction	1 day?	Wed 4/9/08	Wed 4/9/08
31		Expirimental Protocol & PDS	1 day?	Wed 4/16/08	Wed 4/16/08
32		Senior Design Conference	1 day?	Thu 5/8/08	Thu 5/8/08
33		Societal environmental impact report	1 day?	Fri 5/16/08	Fri 5/16/08
34		Thesis Draft	1 day?	Wed 5/21/08	Wed 5/21/08
35		Patent Search of Business Plan	1 day?	Fri 5/30/08	Fri 5/30/08
36		Expirimental Results	1 day?	Fri 5/30/08	Fri 5/30/08
37		Open House [Hardware Due]	1 day?	Fri 6/6/08	Fri 6/6/08
38		Final Thesis Due	1 day?	Fri 6/13/08	Fri 6/13/08
24		In Water Test #1	1 day	Tue 4/15/08	Tue 4/15/08
25		In Water Test #2	1 day	Tue 4/22/08	Tue 4/22/08
12		**Laptop Case**	**20 days**	**Wed 4/30/08**	**Tue 5/27/08**
13		Order Laptop Case	4 days	Wed 4/30/08	Mon 5/5/08
14		Modify Laptop Case for Ventilatoin	8 days	Tue 5/6/08	Thu 5/15/08
15		Mount Laptop Case	3 days	Fri 5/16/08	Tue 5/20/08
16		Wire Laptop Case	5 days	Wed 5/21/08	Tue 5/27/08
27		Senior Design Conference	1 day	Thu 5/8/08	Thu 5/8/08
26		Lake Tahoe Deployment	4 days	Fri 5/16/08	Wed 5/21/08



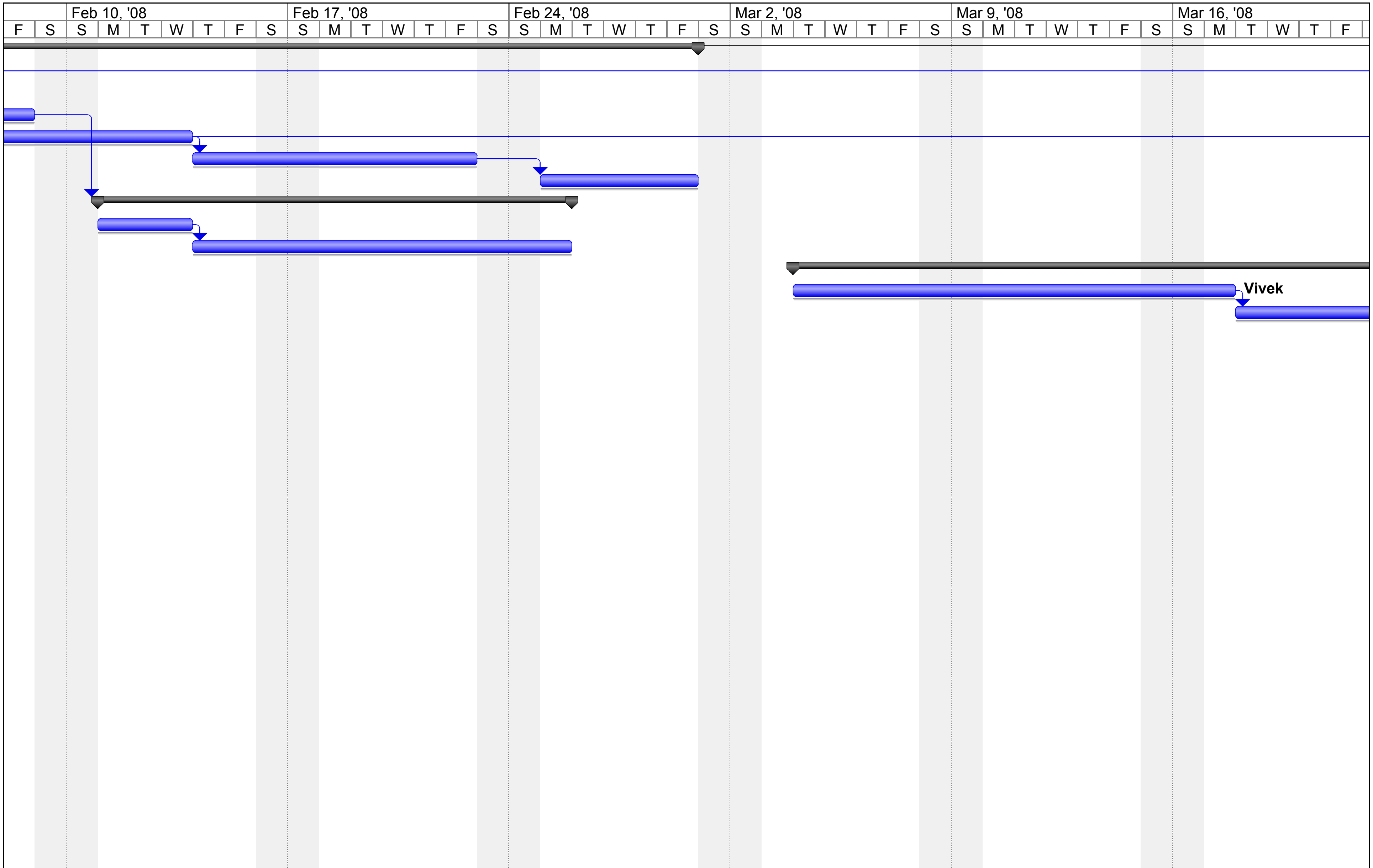
Project: SWATH_TIMELINE2.mpp
Date: Wed 6/18/08

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: SWATH_TIMELINE2.mpp
Date: Wed 6/18/08

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline



Project: SWATH_TIMELINE2.mpp
Date: Wed 6/18/08

Task		Milestone		External Tasks	
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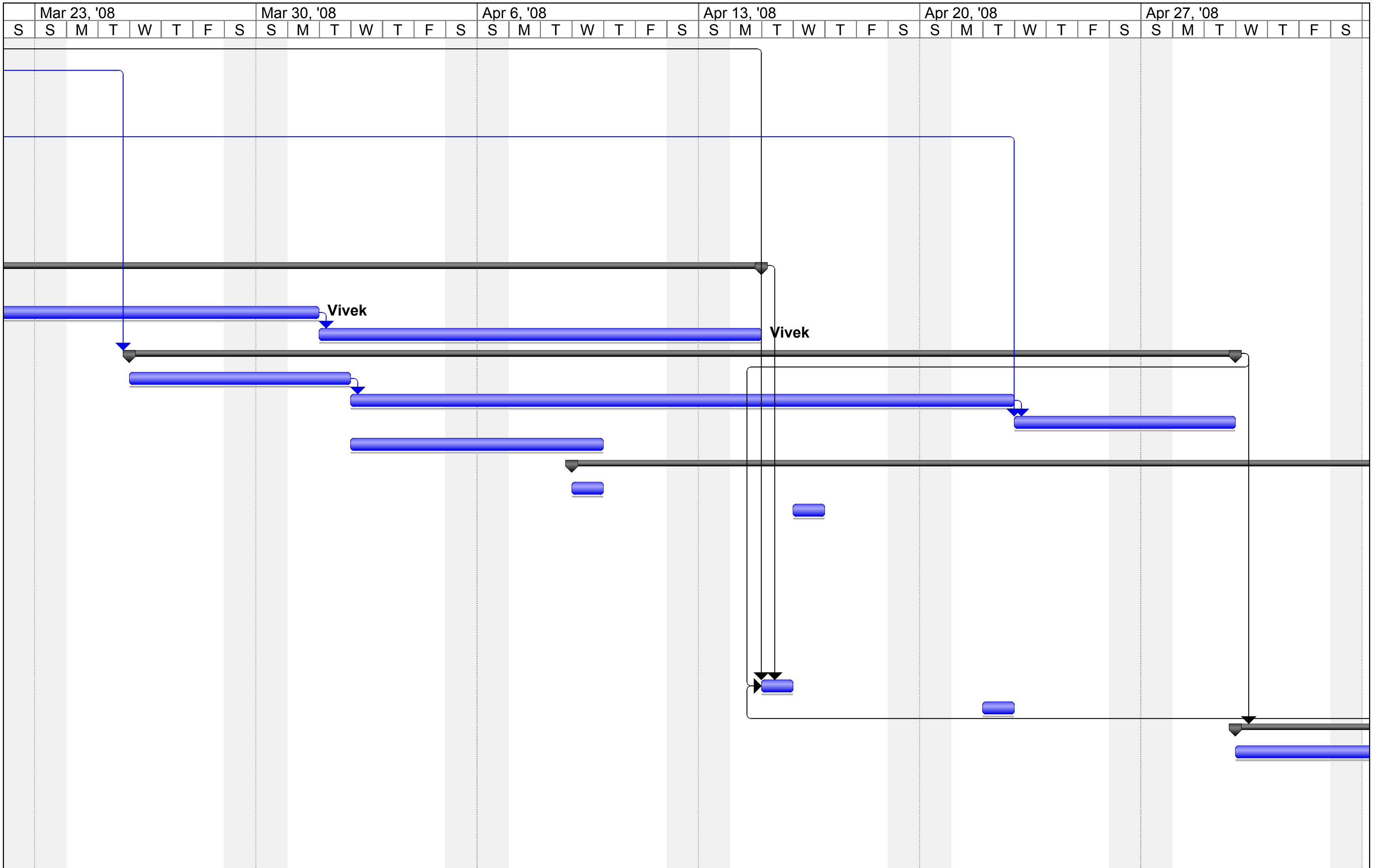
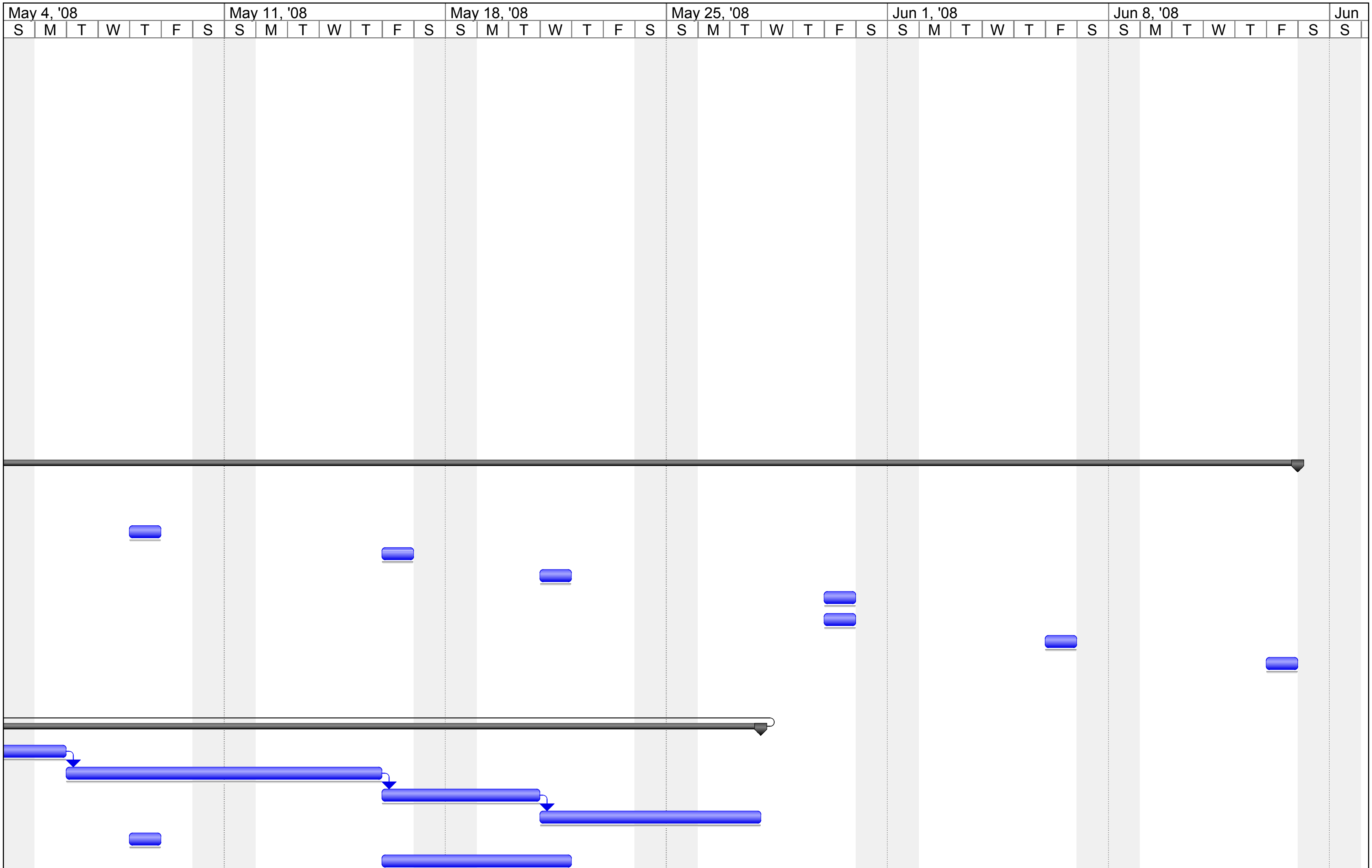
Progress		Project Summary		Deadline	



Project: SWATH_TIMELINE2.mpp
Date: Wed 6/18/08

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: SWATH_TIMELINE2.mpp
Date: Wed 6/18/08

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

Appendix D – Budget

Power Consumption

Electronics

Component	Description	Voltage (V)	Ave. Current (A)	Power (W)
Multibeam		24	0.5	12
DVL	Doppler Velocity Log	24	0.5	12
Laptop	Data Logging	12	7	84
Camera	1 Watt Wireless	12	0.25	3
Basic X Control Boards		5	0.1	0.5
Motor Controller	RobotEq AX3500	12	0.2	2.4
Wireless Router		12	0.4	4.8
GPS		5	0.055	0.275
				0

Motors

Velocity (Knots)		Voltage(V)	Ave. Current / Motor (A)	Power (W)	Running Time (Hr)	Range (Miles)
1.6		24	6	288	7.52	13.83

Power Supply

Component	Quantity	Voltage (V)	Current Each (A-H)	Power (W)	Maximum Drain %
Large Batteries	4	12	85	4080	25%
Small Batteries	2	12	34	816	25%

Appendix E – Calculations

E-1 – Power Budget

Power Consumption

Electronics

Component	Description	Voltage (V)	Ave. Current (A)	Power (W)
Multibeam		24	0.5	12
DVL	Doppler Velocity Log	24	0.5	12
Laptop	Data Logging	12	7	84
Camera	1 Watt Wireless	12	0.25	3
Basic X Control Boards		5	0.1	0.5
Motor Controller	RobotEq AX3500	12	0.2	2.4
Wireless Router		12	0.4	4.8
GPS		5	0.055	0.275
				0

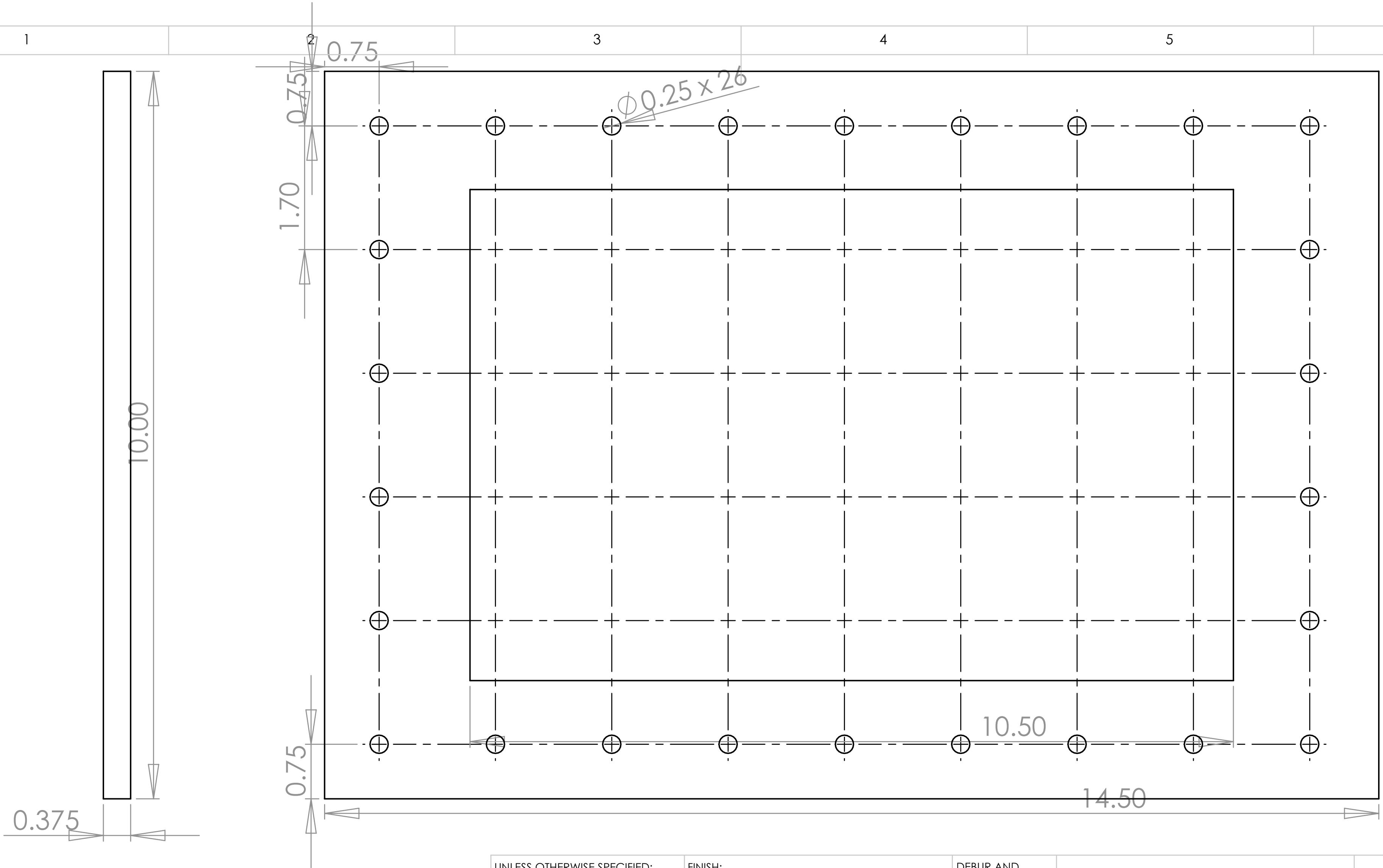
Motors

Velocity (Knots)		Voltage(V)	Ave. Current / Motor (A)	Power (W)	Running Time (Hr)	Range (Miles)
1.6		24	6	288	7.52	13.83

Power Supply

Component	Quantity	Voltage (V)	Current Each (A-H)	Power (W)	Maximum Drain %
Large Batteries	4	12	85	4080	25%
Small Batteries	2	12	34	816	25%

Appendix F – Detail / Assembly Drawings



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: +-.05
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Todd Berk		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: ABS Plastic Waterproof Battery Boxes

MATERIAL: ABS PLASTIC .375 inch

DWG NO. flange

A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: +-.05
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Todd Berk		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: ABS Plastic Waterproof Battery Boxes

MATERIAL: Clear Polycarbonate
.375 inch

WEIGHT:

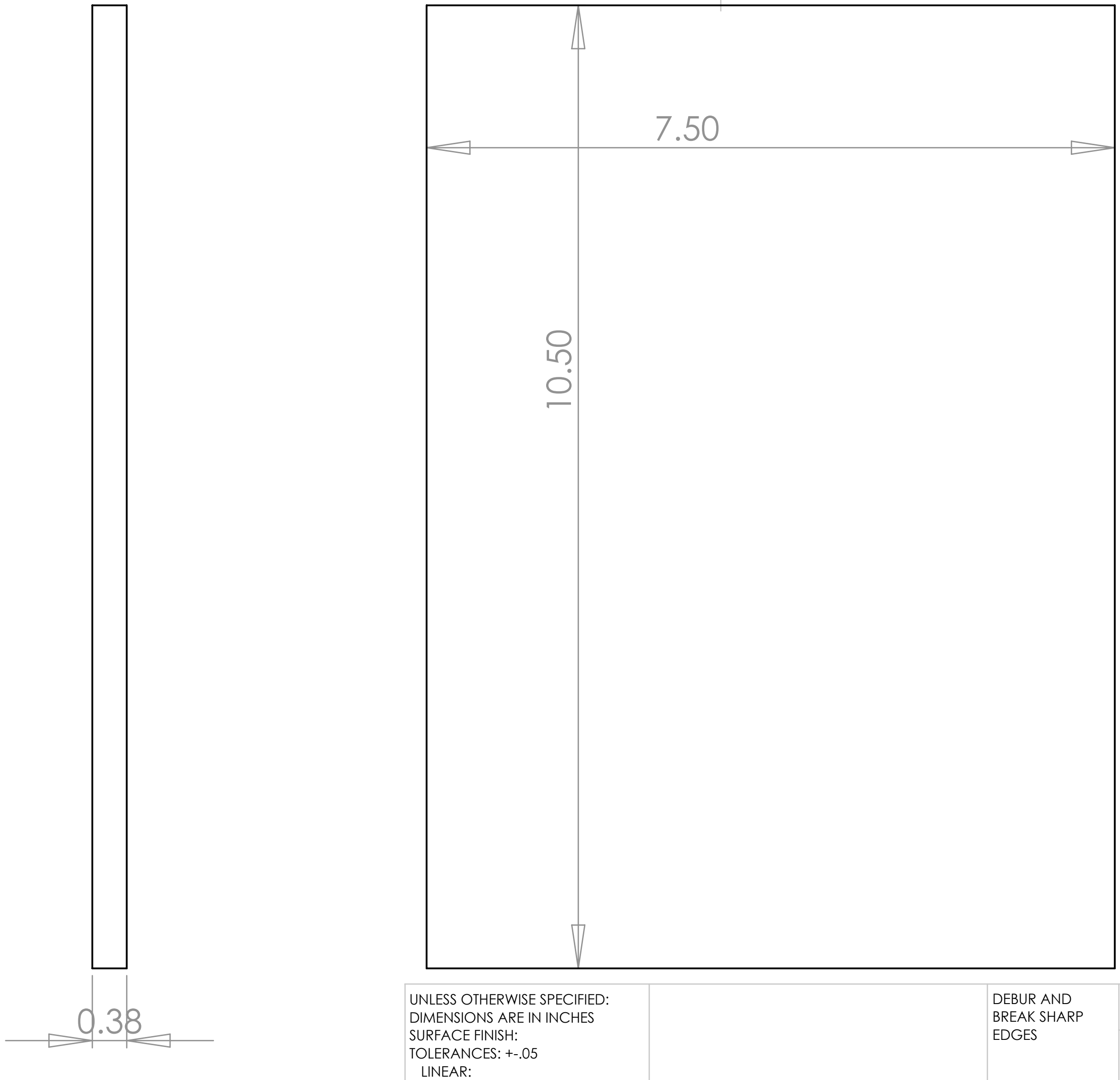
DWG NO.

LID

A4

SCALE:1:5

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: +-.05
LINEAR:
ANGULAR:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Todd Berk		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: ABS Plastic Waterproof Battery Boxes

MATERIAL: ABS PLASTIC .375 inch

DWG NO. Side

A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: +-.05
LINEAR:
ANGULAR:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Todd Berk		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: ABS Plastic Waterproof Battery Boxes

MATERIAL: ABS PLASTIC .375 inch

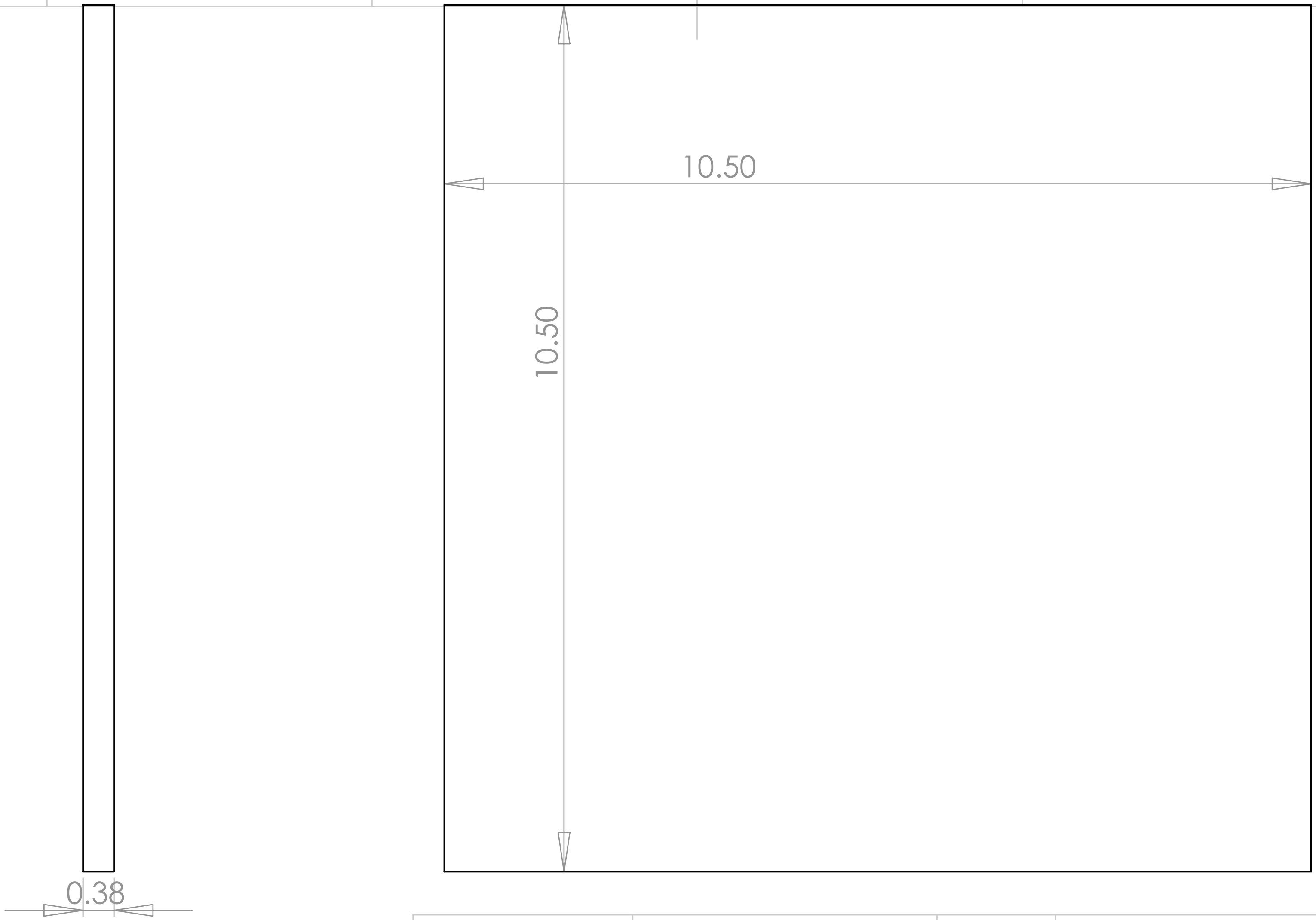
DWG NO. base

A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES: +-.05
LINEAR:
ANGULAR:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Todd Berk		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: ABS Plastic Waterproof Battery Boxes

MATERIAL: ABS PLASTIC .375 inch

DWG NO. Front

A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1

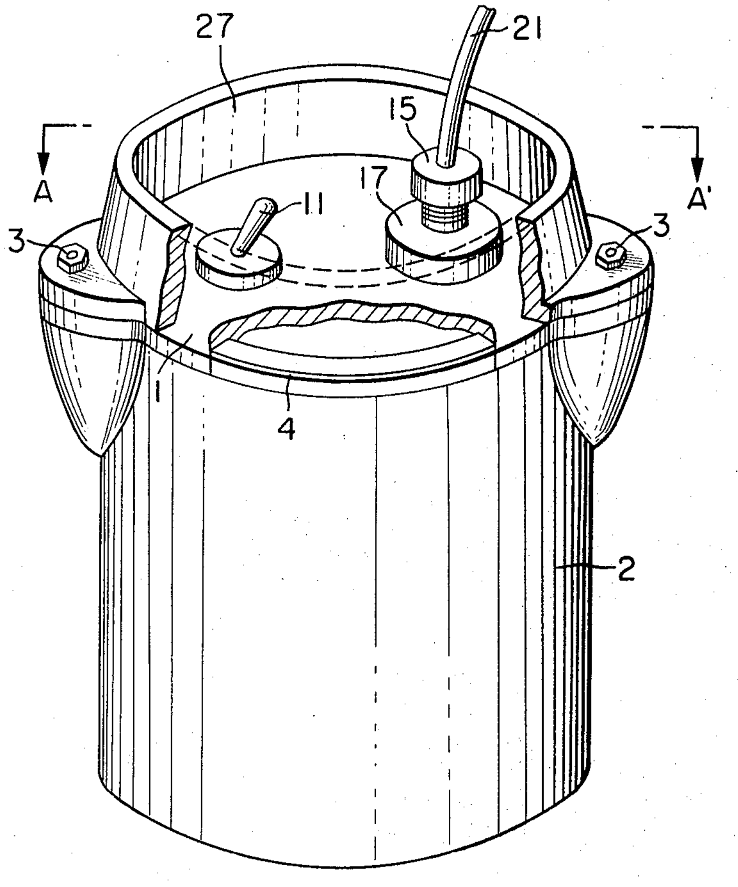
Appendix G – Patent Search

Aug. 13, 1974 TORU IIZUKA ET AL 3,829,332

WATERPROOF BATTERY CASE

Filed June 20, 1972 2 Sheets-Sheet 1

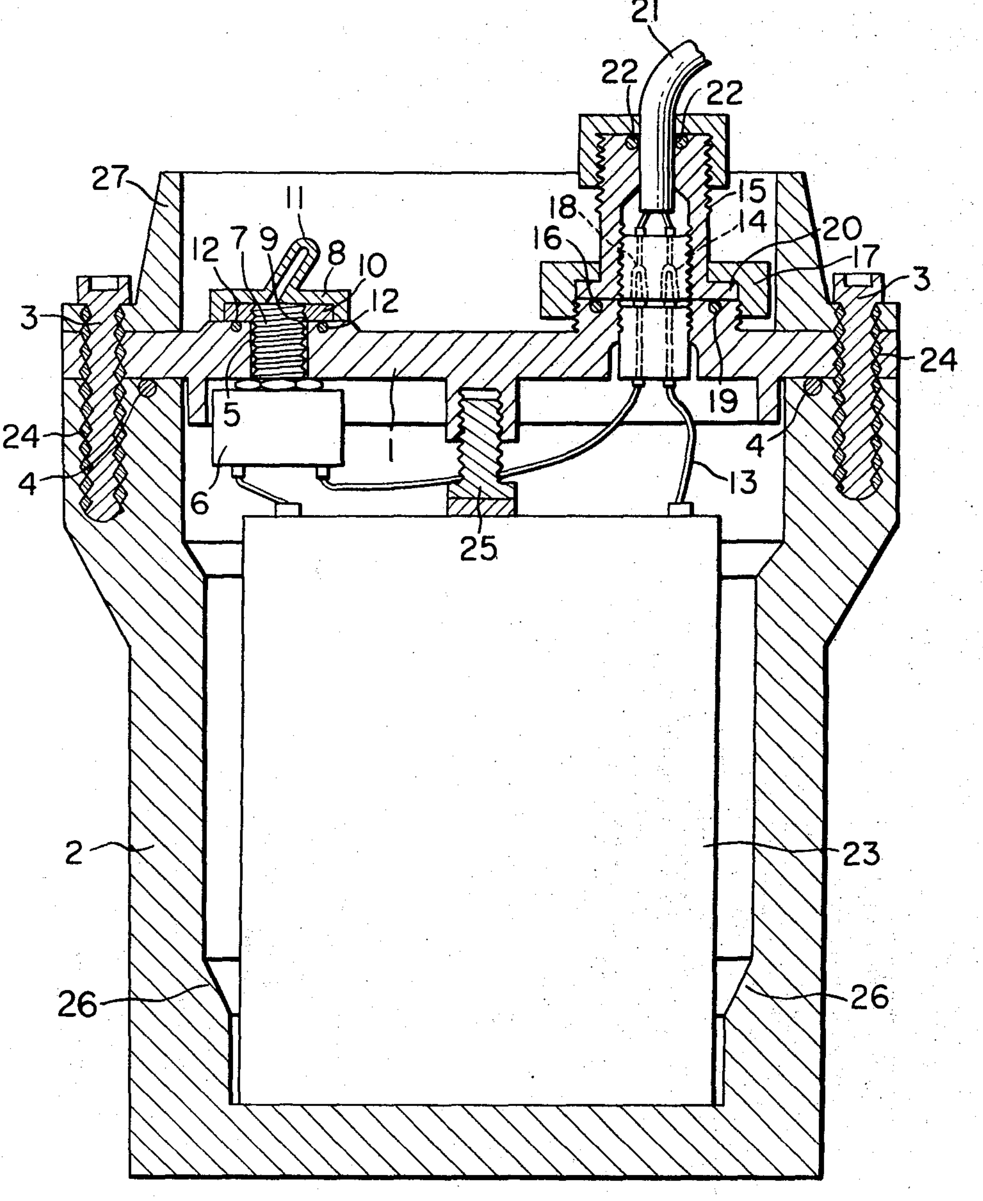
FIG. 1



WATERPROOF BATTERY CASE

Filed June 20, 1972

FIG. 2



nited States Patent ce 3,829,332
Patented Aug. 13, 1974

1

3,829,332

WATERPROOF BATTERY CASE

Toru Iizuka and Katsuo Tonooka, Ashikaga, Torahiko Saitoh, Tokyo, and Isao Yasuda, Ashikaga, Japan, assignors to Kohkoku Chemical Industry Co., Ltd., Tokyo, Japan

Filed June 20, 1972, Ser. No. 264,437
Claims priority, application Japan, July 6, 1971, 46/58,868
Int. Cl. H01m *1/06*
U.S. Cl. 136—173 4 Claims

ABSTRACT OF THE DISCLOSURE

A waterproof battery case, comprising a waterproof switch part and a waterproof cord connector part.

The present invention relates to a waterproof battery case, having a waterproof switch part and a waterproof cord connector part and aims at that when a battery or a dry cell is applied to an electric source for electric appliances, used under water or in the rain, the electric source can be kept in a complete waterproof condition. For the above-mentioned electric appliances, used under water or in the rain, many examples can be enumerated, for example an underwater searchlight, a submersible driving motor or electric heaters, set in a wet suit or a rain shoe, etc.

An embodiment article of the present invention shall be explained referring to the drawing.

FIG. 1 is a perspective view, partly in section, of an embodiment article according to the present invention and FIG. 2, an enlarged sectional view, taken along the line A–A' of FIG. 1.

A battery case consists of a cover part (1) and a cylindrical case part (2). Both the cover part (1) and the case part (2) are made of ingot aluminium and soaked all over with synthetic resins to be constructed completely in a water-proof condition. The cover part (1) and the cylindrical case part (2) are firmly held in a water-tight condition by being jointed together with a suitable binder (3), for example, by being screwed together with a screw. Moreover, the case part (2) is fixed with a rubber ring-shaped sealing member (4). When the cover part (1) is jointed with the case part (2), the gap between the cover part (1) and the case part (2) is hermetically sealed by said sealing member (4), whereby the battery case is further held in a water-tight condition. The male screw part (7) of a switch (6) is inserted through from inside to a hole (5), made on the cover part (1). The male screw part (7), protruding from this hole (5), is screwed with a waterproof seat plate (8). Thus, the waterproof switch part is constructed. The waterproof seat plate (8) consists of a seat plate part (10), having a female screw (9), and a water-proof film (11) of such as rubber, covering the seat plate part completely from above. The waterproof seat plate (8) is screwed to the male screw part (7) of the switch (6), whereby the ring-shaped sealing member (12), fixed to the upper face of the case part (1) around the hole (5), is held between the lower surface of the seat plate part (10) and the upper surface of the cover part (1) to seal the gap between the waterproof seat plate (8) and the cover part (1). Further, the cover part (1) is attached with a waterproof cord connector part. In the water-proof cord connector part, a lead wire (13) of the electric source, contained in the case part (2), is connected with a terminal (14), fixed to the surface of the cover part (1) in a condition, insulated electrically from the cover part (1). The waterproof cord connector part consists of the terminal (14) and a connector (15), connected detachably with the terminal (14). The connection of said terminal (14) and said connector (15) is performed by that cylindrical male screw member (16), set around said terminal (14), is screwed together with a female screw member (17) of the connector (15), so that the terminal (18) of the connector (15) is made contacted with the terminal (14), attached to the cover part (1). By this screw connection, the gap between the seat plate (20) of the connector (15) and the male screw member (16) is sealed with the rubber ring-shaped sealing member (19) on the upper end of the male screw member (16) to be kept in a water-tight condition. For a lead wire (21), extending outwards from the terminal (18) of the connector (15), there is used a cabtire cord, having the outer surface coated with a waterproof synthetic resin film. This lead wire (21) is in a water-tight condition led out of the connector (15) through such as a rubber ring-shaped sealing member (22). The other end of the lead wire (21) is connected with an electric appliance, used under water or in the rain, or an interconnecting cord connector for the same. The lead wire (13) inside the case part (2) is led out of the electric source, such as a battery or a dry cell (23), and is connected in series with the switch (6) and the terminal (14) of the cord connector.

2

In case of a screw, such as made of stainless steel, being used for the binder (3), which makes the cover part (1) and the case part (2) jointed together to be a battery case, if the female screw of the case part (2) to be screwed with said screw is made of aluminium like the main body of the case part (2), a kind of cell is composed of stainless steel, aluminium and impure water at the screwed portion and the screw is so rusted as unable to be detached.

Therefore, according to the present invention, a stainless steel female screw member (24), made of the same metal as that of said screw, is put on the surface of the female screw of the case part (2), to be screwed with said screw, whereby, such a kind of cell as above-mentioned, is not composed at the screwed portion, so that the screw can be prevented from rust.

If for example a colloidal cell is used for a battery to be contained in a battery case in accordance with the present invention, it is quite favorable that there is no leakage of solution and no generation of such as hydrogen gas.

A holding element (25) of the cell (23) may be attached to the middle or other part of the inside of the cover part (1), or corresponding to the width of the cell, a projection (26) may be made on the lower circumference inside the case part (2). Thus, the cell (23) can be firmly placed inside the case part (2).

When the battery (23), contained in the battery case according to the present invention, is charged with electricity, the battery may be of course taken out to be connected directly with a charger, but in another method, the charger may be connected with the connector (15), composing the cord connector part, used in the battery case in accordance with the present invention. Then, the switch (6) of the battery case is turned on to charge the contained battery (23).

According to the present invention, such as corrosion resisting metals or synthetic resins, having excellent strength may favorably used for the material of the battery case. However, it is required to be waterproof.

A cylindrical protector (27) is attached to the circumferential upper face of the cover part (1), so that the switch part and the cord connector part, protruding above the upper face of the cover part (1) can be protected from shocks. The protector (27) may be connected with the cover part (1) and also, the case part (2) by means of the binder (3), which joints the cover part (1) and the case part (2) together.

The battery case in accordance with the present invention is provided as above-mentioned with a waterproof switch part and a waterproof cord connector part, so that an electric source can be protected from water when an electric appliance is used under water or in the rain. This battery case can be made small-sized because the waterproof switch part, the waterproof cord connector part and the cell are collected in one body. Accordingly, it can be easily carried. For example, it can be freely done to swim under water with an electric heater being passed with electricity. And also, the battery case can be applied to an electric source for a portable electric appliance, such as a waterproof electric torch, used under water or in the rain. In this case, such as light alloys are used for the material of the battery case in order to make handy to carry, so that the battry case becomes favorably lightweighted. The battery case according to the present invention can resist a large hydraulic pressure because it is made of waterproof metals and synthetic resins, having great strength.

What is claimed is:

1. Waterproof battery case for electrical appliances adaptable for underwater use comprising a cover member and a case member both made of waterproof ingot light metal, a coating of synthetic resin material completely covering each of said cover member and case member, binder means attaching said cover member and said case member together, said members being so constructed as to be bound together in a watertight condition by said binder means, a rubber ring-type sealer extending between said cover member and said case member completely along

the joint formed therebetween by said binder means, a waterproof switch member and a waterproof cord connector member provided in said cover member, and a tubular protector member provided on the outer face of said cover member for said waterproof switch member and said waterproof cord connector member as a protective covering therefor, said protector member being bound to said cover and case members by said binder means.

2. A battery case, according to claim **1**, including a battery holder set on the interior of said battery case to support therein a battery to be contained within said case.

3. A battery case, according to claim **1**, including a colloidal cell contained within the interior thereof operative to perform as a power source.

4. A battery case, according to claim **1**, wherein said binder means comprise a female screw member and a male screw member, said female screw member being formed of the same material as said male screw member, with said female screw member being affixed to said battery case and adapted to receive said male screw member therein.

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DONALD L. WALTON, Primary Examiner

U.S. Cl. X.R.

240—10.66

United States Patent [19] | [11] **4,225,655**
Pesce | [45] **Sep. 30, 1980**

[54] **WATERTIGHT BATTERY BOX**

[76] Inventor: **Louis Pesce**, 1311 W. Webster Ave., Winter Park, Fla. 32789

[21] Appl. No.: **28,923**

[22] Filed: **Apr. 10, 1979**

[51] **Int. Cl.**[3] **H01M 2/10**
[52] **U.S. Cl.** **429/100**; 429/6; 206/811; 220/8
[58] **Field of Search** .... 429/6, 96, 99, 100, 429/163, 175, 176, 65; 174/17 GF, 17.06, 17.07; 220/8, 228, 352, 356; 206/811

[56] **References Cited**

FOREIGN PATENT DOCUMENTS

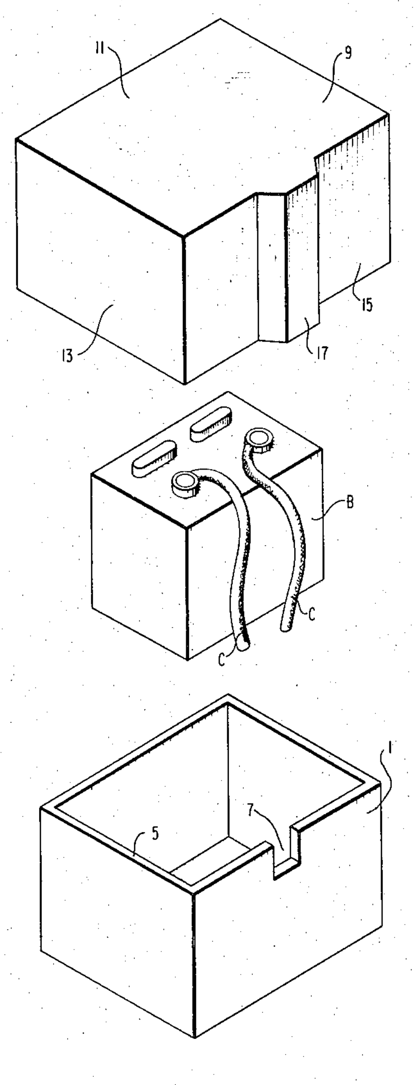
1239652 7/1971 United Kingdom 429/6

Primary Examiner—Donald L. Walton
Attorney, Agent, or Firm—Young & Thompson

[57] **ABSTRACT**

A watertight battery box comprises an upwardly open base and a downwardly open lid which rests on the upper edges of the base. One edge of the base has a recess therein for receiving the battery cables, and the lid has a downwardly opening channel therein for receiving the cables. In use, water can rise around the battery box without entering the battery box, because the lid traps air beneath itself but has little or no buoyancy.

4 Claims, 3 Drawing Figures



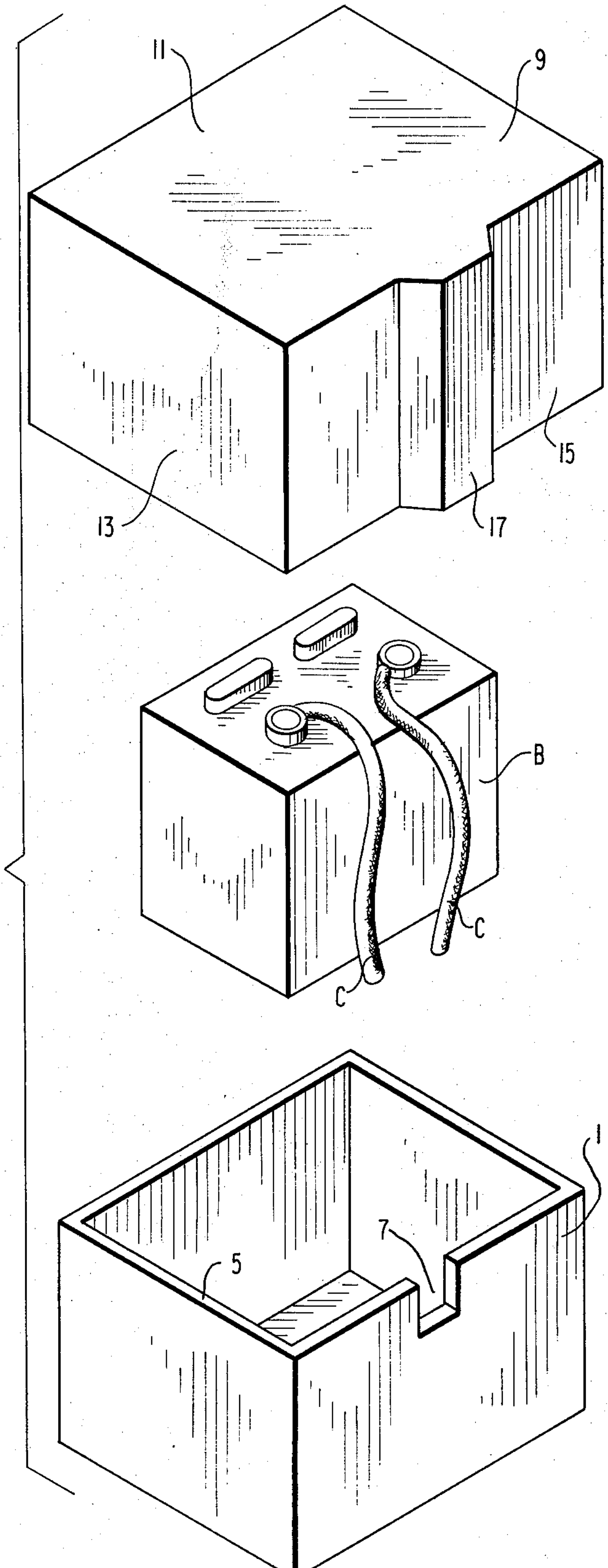


FIG I

FIG 2

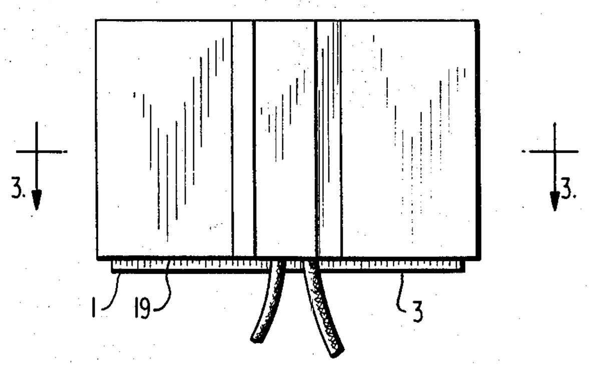
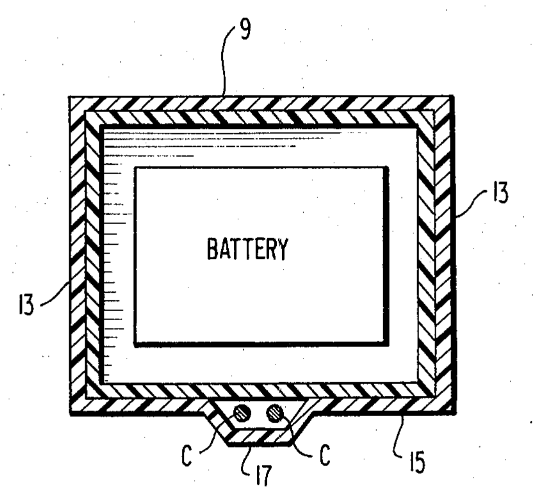


FIG 3



WATERTIGHT BATTERY BOX

The present invention relates to a waterproof battery box, and more particularly to a battery box which protects a contained battery against water which may rise around the battery box.

The present invention is thus of particular utility in boats, in which the battery may be partially or totally submerged when the boat swamps or when a heavy rain occurs, or when the boat leaks or ships water, and in other emergency situations. Should the battery itself become immersed, the water, and particularly salt water, tends to short the battery terminals, with total loss of battery power. Especially in an emergency situation, loss of battery power is intolerable, because the ship's lights, radio, engine starter and other vital electrically powered equipment cannot be used.

It is accordingly an object of the present invention to provide a watertight battery box, which will keep the battery dry even when fully submerged.

Another object of the present invention is the provision of a watertight battery box the components of which have little or no buoyancy and hence substantially no tendency to float away when submerged.

Finally, it is an object of the present invention to provide a watertight battery box which will be simple and inexpensive to maufacture, easy to manipulate, and rugged and durable in use.

Other objects, features and advantages of the present invention will become apparent from a consideration of the following description, taken in connection with the accompanying drawing, in which:

FIG. 1 is an exploded perspective view of a battery and watertight battery box according to the present invention;

FIG. 2 is a side elevational view of a closed watertight battery box according to the invention, with the battery inside; and

FIG. 3 is a cross-sectional view taken on the line 3—3 of FIG. 2.

Referring now to the drawing in greater detail, there is shown a watertight battery box according to the present invention, comprising a base **1** which is of parallelepipedal overall configuration and watertight construction and is upwardly open, comprising a closed bottom **3** from which four walls upstand and terminate in upper edges **5** disposed in a common horizontal plane. One of the side walls of the base, which can arbitrarily be regarded as the front wall of the base, is provided with an upwardly opening recess **7** in the upper edge **5** thereof, centrally of its length.

The other half of the battery box comprises a watertight cover **9** comprised by a closed upper wall **11** from which depend side walls **13** and a rear wall and what may arbitrarily be regarded as a front wall **15**.

Integral with front wall **15** is a vertical, elongated, inwardly-opening channel **17**, closed at its upper end but open at its lower end. Channel **17** may have any desired cross-sectional configuration, which is preferably uniform from top to bottom thereof, and may for example be rounded or polygonal. Channel **17** may also be in the form of two subchannels, disposed side-by-side on front wall **15**, or with one on the front wall and the other on the rear wall.

Base **1** and cover **9** are preferably of plastic or other waterproof electrically insulating material, each being of one-piece molded construction. As best seen in FIG.

3, they preferably interfit rather snugly, for a reason that will appear hereinafter.

In use, the components of the present invention are assembled as suggested in FIG. **1**: the base **1** is placed with its open top uppermost, and then a battery B, which may be any conventional battery such as a marine battery for powering the electrical system of a boat, is lowered into base **1**. Battery B need not fit snugly within base **1**, because the weight of battery B will in any event be enough to prevent base **1** from floating away even when fully submerged. Obviously, however, base **1** should not be much larger than battery B, so as to save space and material. Upper edge **5** of base **1** will extend a short distance above the terminals and other structure on the top of battery B, when battery B is fully lowered into base **1**.

In the assembled position of battery B and base **1**, the conventional battery cables C from the positive and negative terminals of the battery, will extend through recess **7**, entirely below the top of the recess, and thence downwardly.

Cover **9** is then applied by sliding it on over base **1** which now contains battery B, until the underside of top wall **11** rests on upper edges **5** of base **1** and is then spaced a short distance above any structure on battery B. Channel **17** is in alignment with recess **7** in the assembled condition, and so receives and contains within it the cables C between the interior of channel **17** and the front wall of base **1**, as best seen in FIG. **3**.

As shown in FIG. **2**, the lower edge **19** of cover **9** does not extend down as far as the underside of bottom **3** of base **1**. Thus, when base **1** is resting on a flat horizontal surface, as is ordinarily the case, lower edge **19** will be spaced above that surface. The reason for this is that it permits the cables C to run out freely from beneath cover **9**, without elevating or tilting cover **9** relative to base **1**. Of course, the bottom of recess **7** is a substantial distance above lower edge **19** of cover **9** when cover **9** is in place.

It will therefore be apparent that, with the parts in the assembled position of FIGS. **2** and **3**, rising water cannot enter the battery box of the present invention. The cover **9** in effect constitutes a dome which traps a body of air beneath it. However, almost all of the space beneath cover **9** will be occupied by base **1**, so that cover **9** will have substantially only its own buoyancy and that of the interior of channel **17**. Ordinarily, the mere weight of cover **9** will be ample to overcome this buoyancy, so that there will be no tendency whatsoever for cover **9** to float away even when fully submerged. It is for this reason that it is preferred that cover **9** be a rather close sliding fit on base **1**.

Of course, base **1** will have the buoyancy of any upwardly open vessel. But almost all of base **1** will be occupied by battery B, which will ordinarily be quite heavy, of a weight ample to overcome the buoyancy of base **1**.

Therefore, the battery box of the present invention, with a battery inside, will have substantially no buoyancy even when fully submerged; and so there is no need to weight cover **9** to prevent anything from floating away.

Also, it will be evident that water cannot rise within the watertight battery box much above the level of lower edge **19** of cover **9**, and in any event not as high as the bottom of recess **7**. Therefore, water will be completely excluded from base **1**, and hence from any contact with battery B.

From a consideration of the foregoing disclosure, therefore, it will be evident that all of the initially recited objects of the present invention have been achieved.

Although the present invention has been described and illustrated in connection with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit of the invention, as those skilled in this art will readily understand. Such modifications and variations are considered to be within the purview and scope of the present invention, as defined by the appended claims.

What is claimed is:

1. A watertight battery box for receiving a battery having positive and negative terminals and a cable extending from each of said terminals, comprising an upwardly open base and a downwardly opening cover, the cover having a vertically extending inwardly opening channel on at least one side wall thereof, said at least one channel being closed at its top and open at its bottom to confine said cables between the interior of said at least one channel and at least one side wall of said base, said base and cover snugly interfitting with each other and the outer contour of said channel extending outwardly from the outer contour of said cover which is disposed on opposite sides of said channel.

2. A watertight battery box for receiving a battery having positive and negative terminals and a cable extending from each of said terminals, comprising an upwardly open base and a downwardly opening cover, the cover having a vertically extending inwardly opening channel on at least one side wall thereof, said at least one channel being closed at its top and open at its bottom to confine said cables between the interior of said at least one channel and at least one side wall of said base, said cover resting on the upper edges of said base, said at least one side wall of said base having at least one upwardly opening recess therein in registry with said at least one channel, for receiving said cables as they pass out of said base and into said at least one channel.

3. A watertight battery box for receiving a battery having positive and negative terminals and a cable extending from each of said terminals, comprising an upwardly open base and a downwardly opening cover, the cover having a vertically extending inwardly opening channel on at least one side wall thereof, said at least one channel being closed at its top and open at its bottom to confine said cables between the interior of said at least one channel and at least one side wall of said base, the lower end of said at least one channel terminating a short distance above the bottom of said base when said cover rests on said base, to permit said cables to leave said channel at an elevation above the elevation of the bottom of the base.

4. A watertight battery box for receiving a battery having positive and negative terminals and a cable extending from each of said terminals, comprising an upwardly open base and a downwardly opening cover, the cover having a vertically extending inwardly opening channel on at least one side wall thereof, said at least one channel being closed at its top and open at its bottom to confine said cables between the interior of said at least one channel and at least one side wall of said base, the cover having negative buoyancy in water when the cover is fully seated on the base, said base and cover snugly interfitting with each other and the outer contour of said channel extending outwardly from the outer contour of said cover which is disposed on opposite sides of said channel, said cover resting on the upper edges of said base, said at least one side wall of said base having at least one upwardly opening recess therein in registry with said at least one channel, for receiving said cables as they pass out of said base and into said at least one channel, the lower end of said at least one channel terminating a short distance above the bottom of said base when said cover rests on said base, to permit said cables to leave said channel at an elevation above the elevation of the bottom of the base.

* * * * *

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United States Patent [19]

Ogawa et al.

[11] Patent Number: 5,513,721

[45] Date of Patent: May 7, 1996

[54] COVER STRUCTURE AND BATTERY STORING CASE STRUCTURE FOR AN ELECTRIC VEHICLE

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[21] Appl. No.: 325,877

[22] Filed: Oct. 19, 1994

[30] Foreign Application Priority Data

Oct. 19, 1993 [JP] Japan 5-261337

[51] Int. Cl.[6] B62K 19/40

[52] U.S. Cl. 180/220; 180/68.5

[58] Field of Search 180/220, 225, 180/68.1, 68.2, 68.3, 68.5, 65.1, 69.2, 69.25

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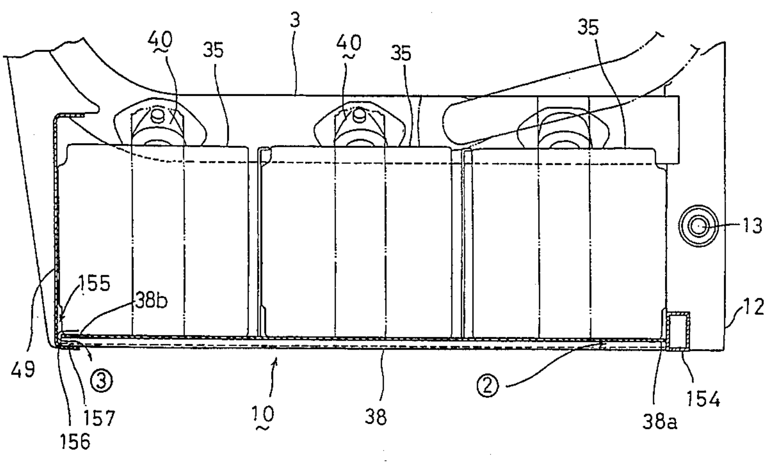
Primary Examiner—Kevin T. Hurley
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

[57] ABSTRACT

A cover structure to improve a waterproof performance of a front surface of a battery storing case in an electric vehicle wherein subcovers are provided between a front fender covering a front wheel and a front surface of a battery storing case. In addition, a gap formed between the subcovers and the fender or the front surface of the battery storing case is formed like a maze so as to stop an upward flow of muddy water.

8 Claims, 14 Drawing Sheets



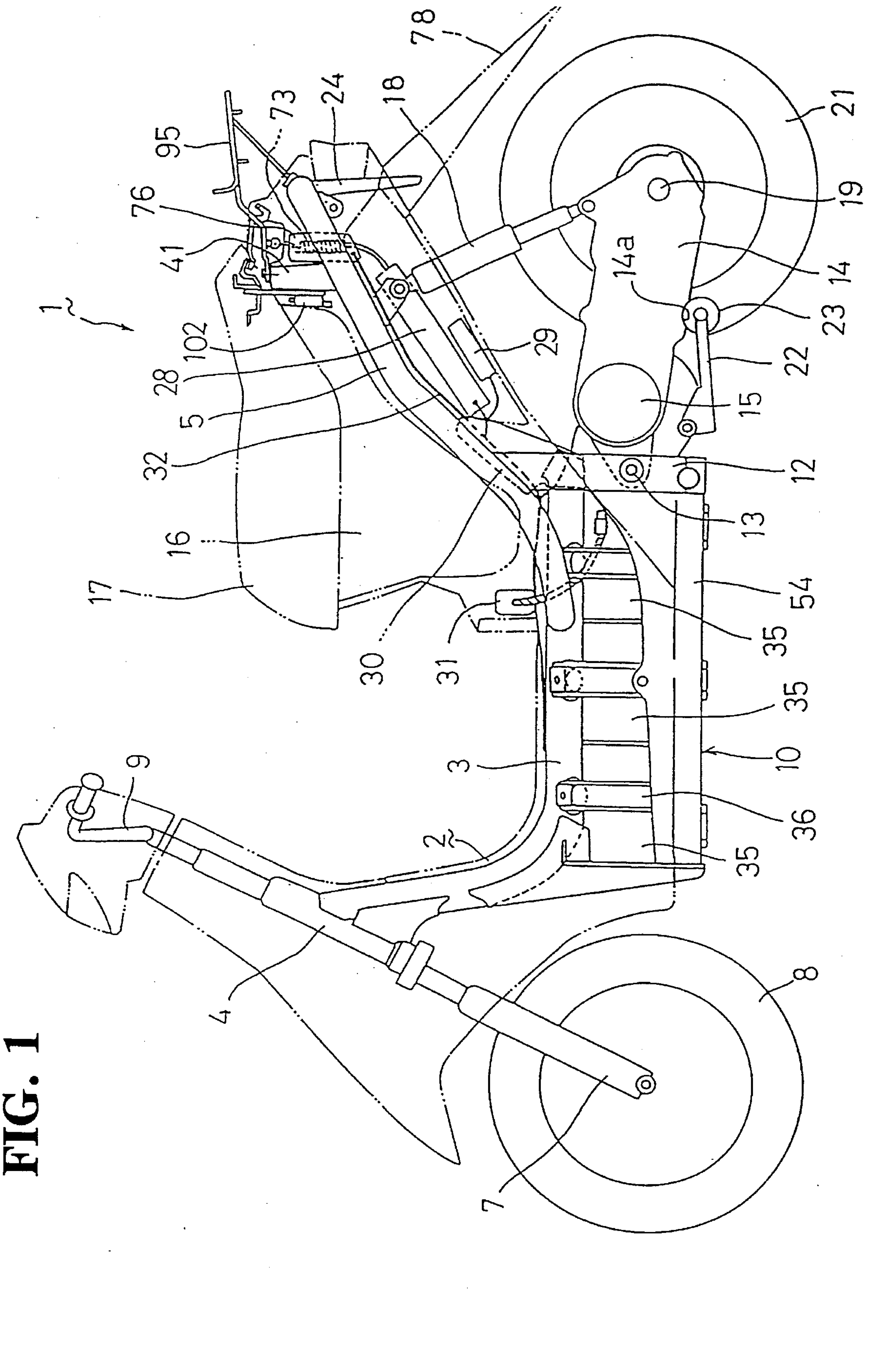

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FIG. 1

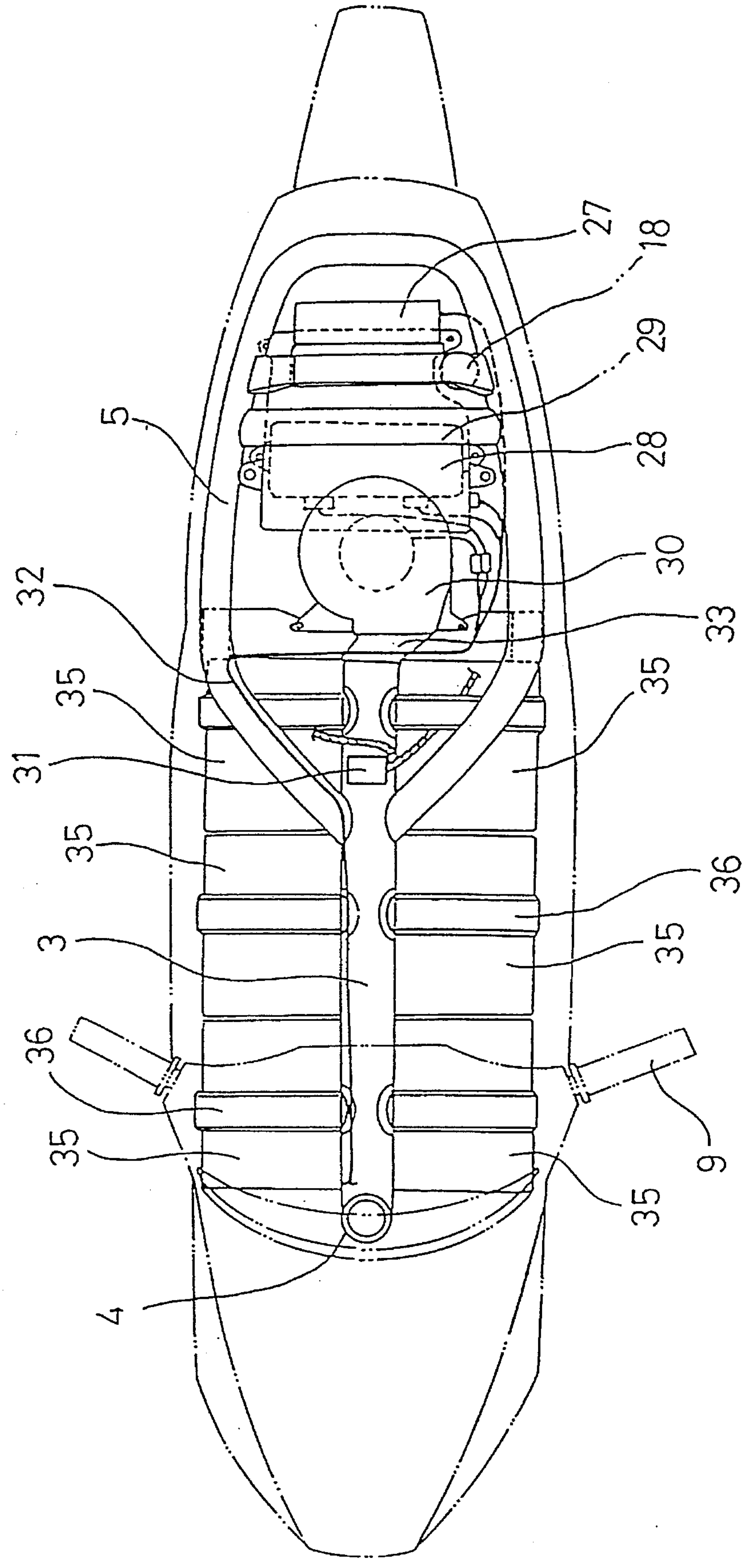

FIG. 2

FIG. 3

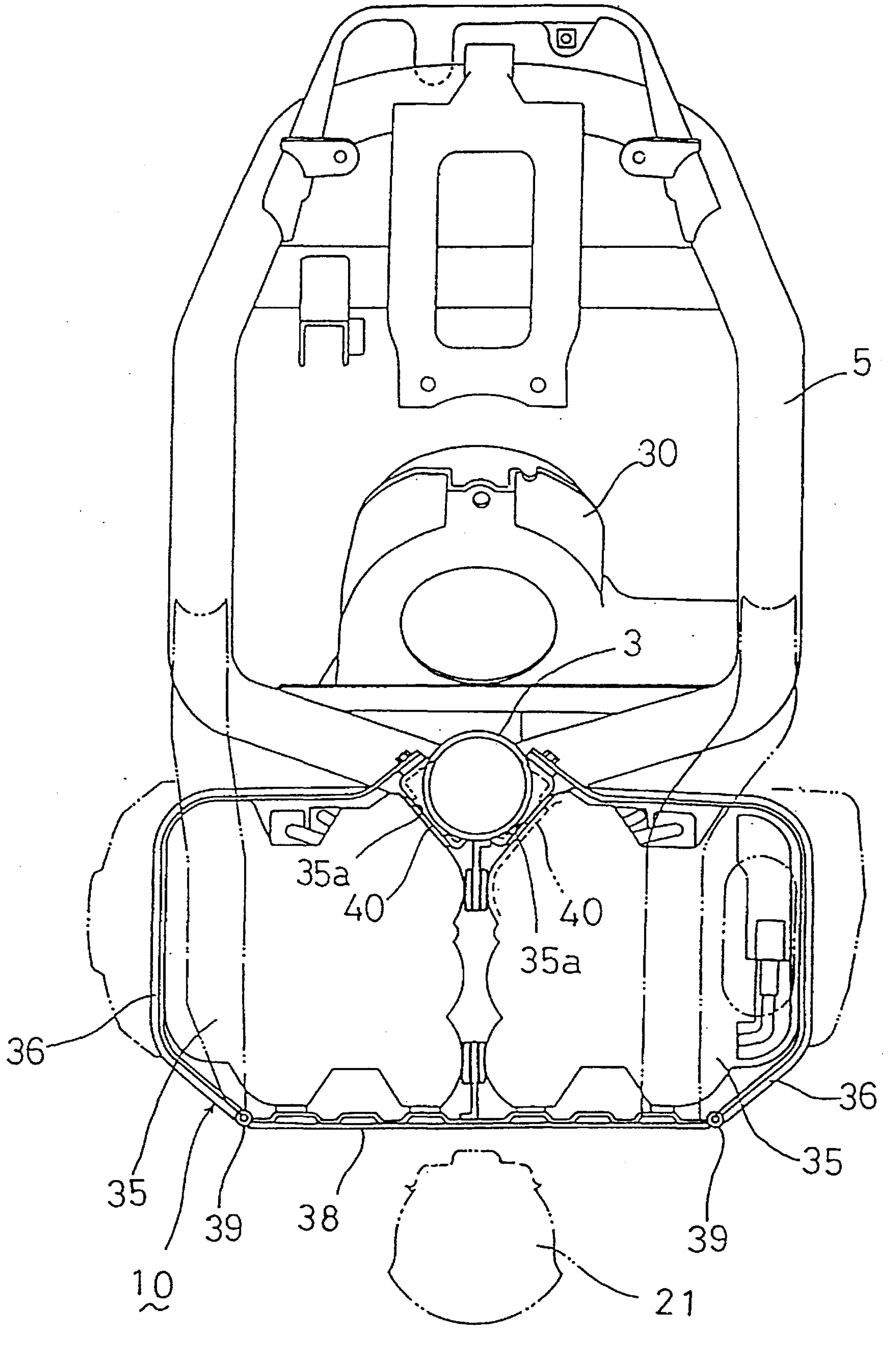

FIG. 4

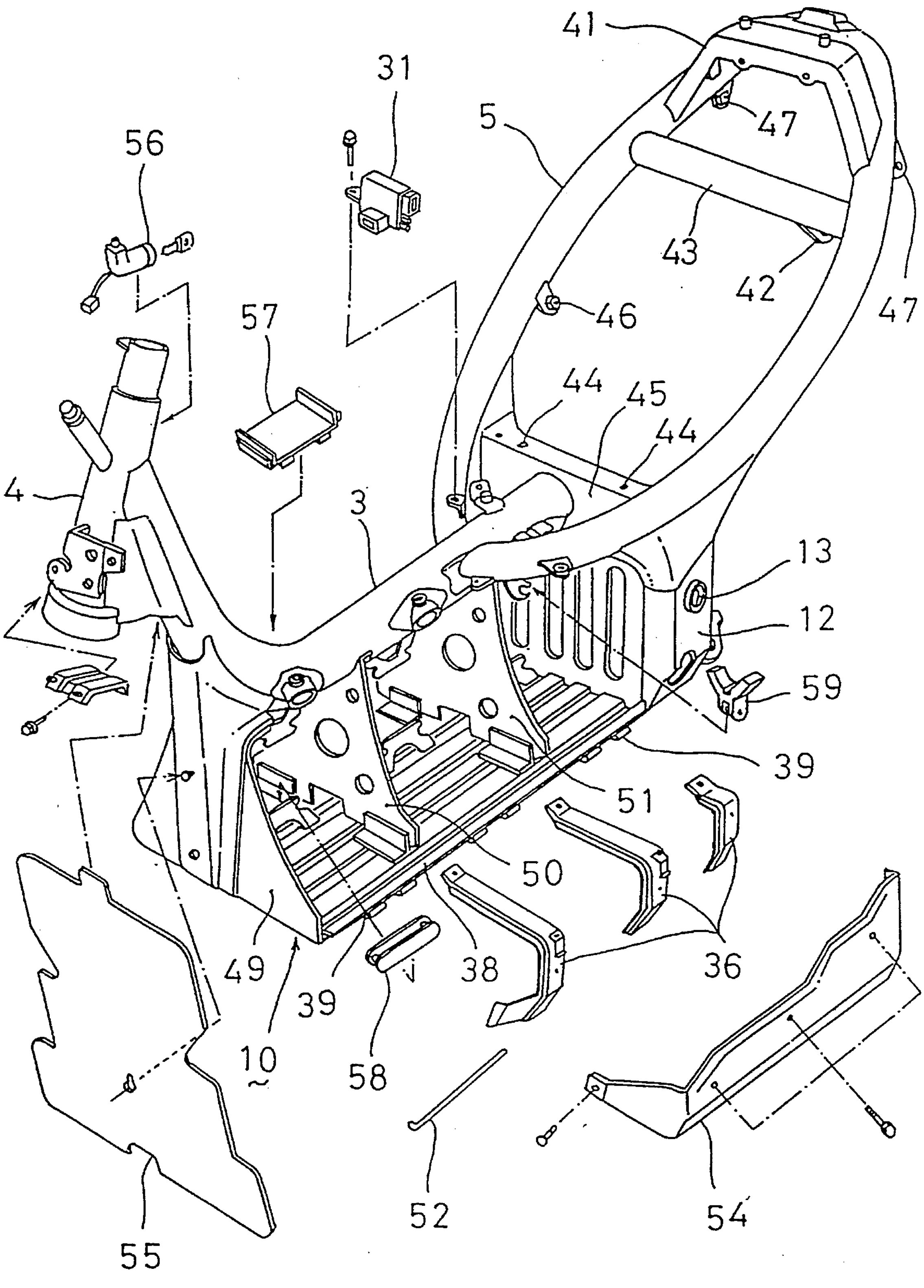
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FIG. 5

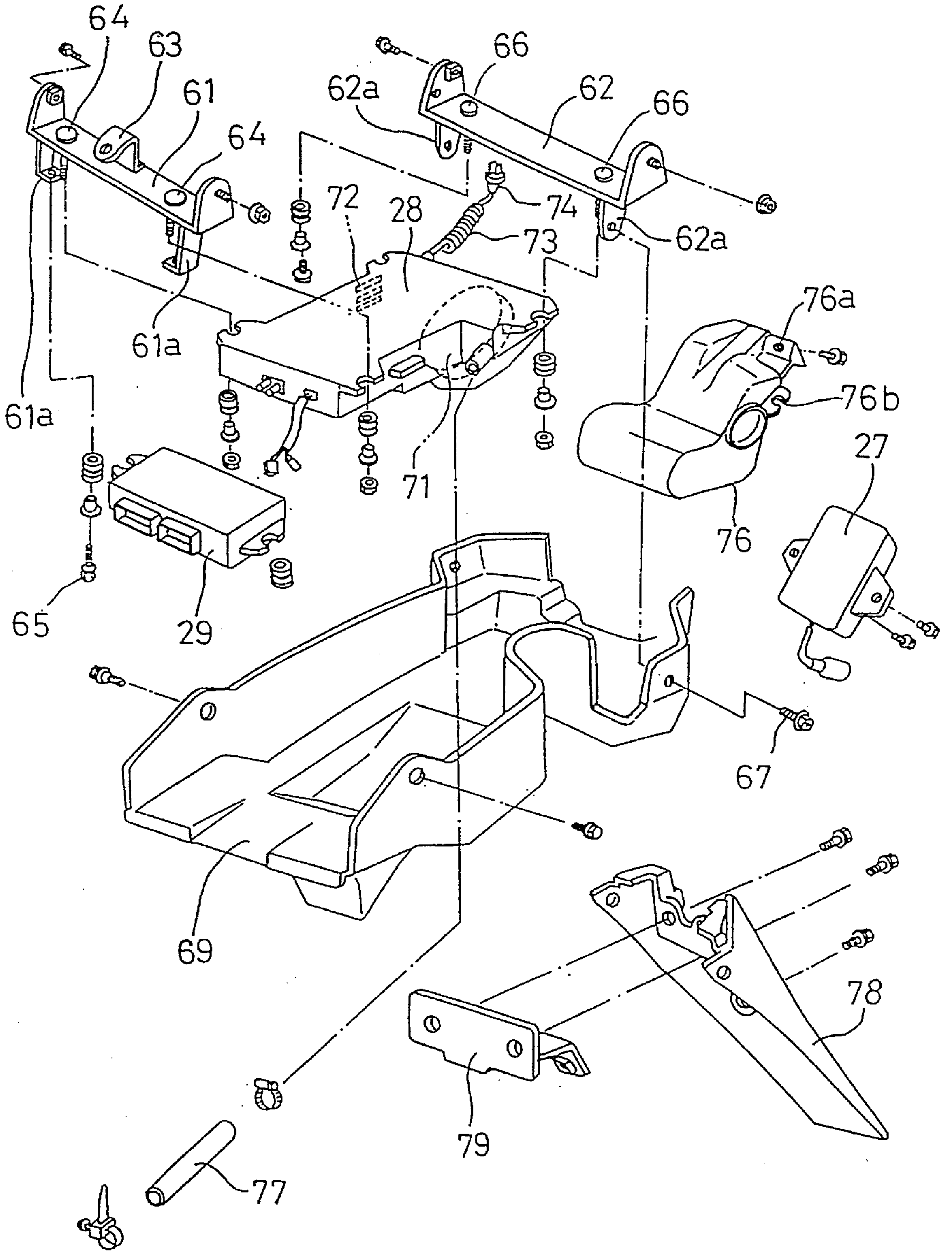
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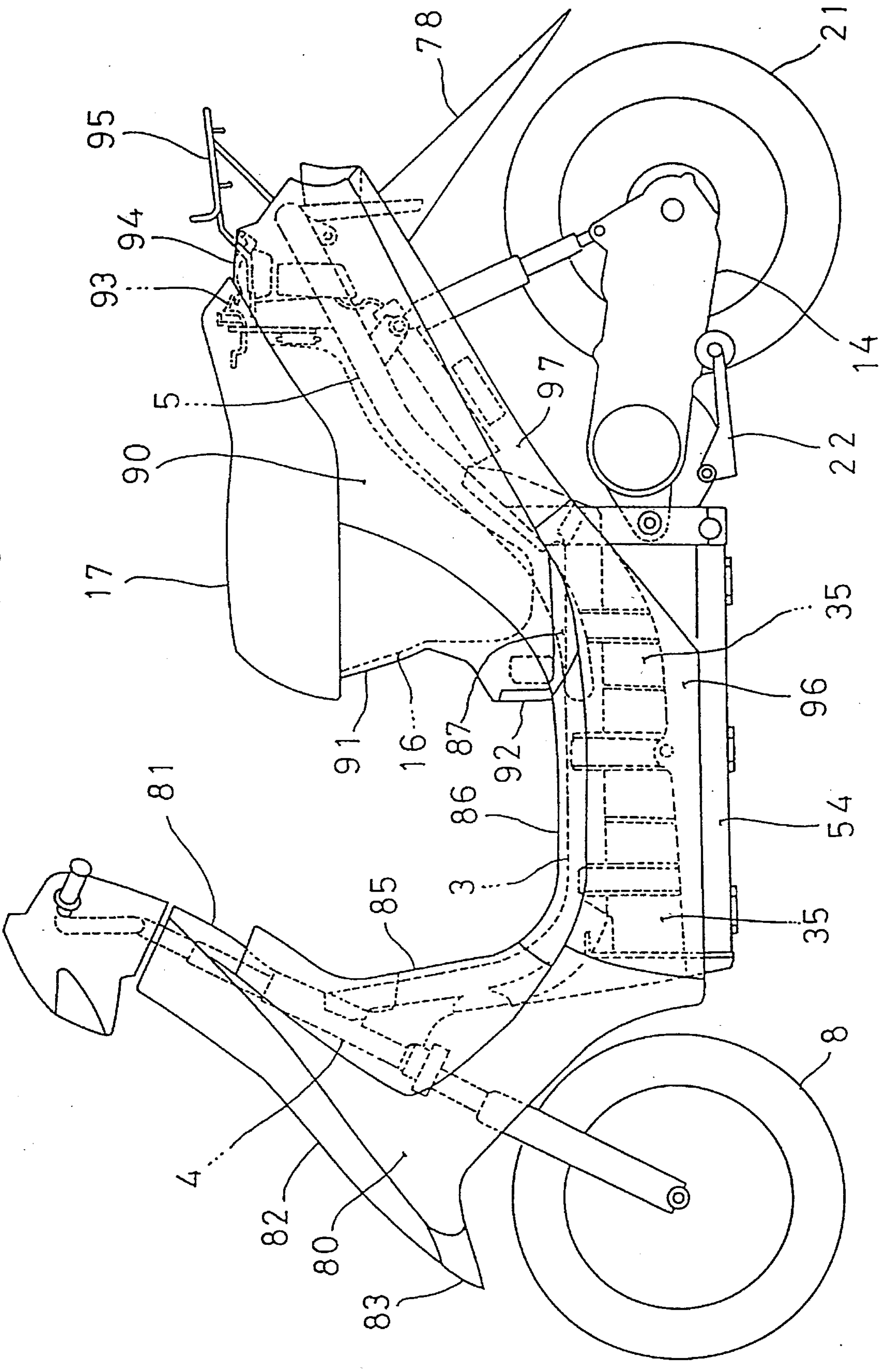
FIG. 6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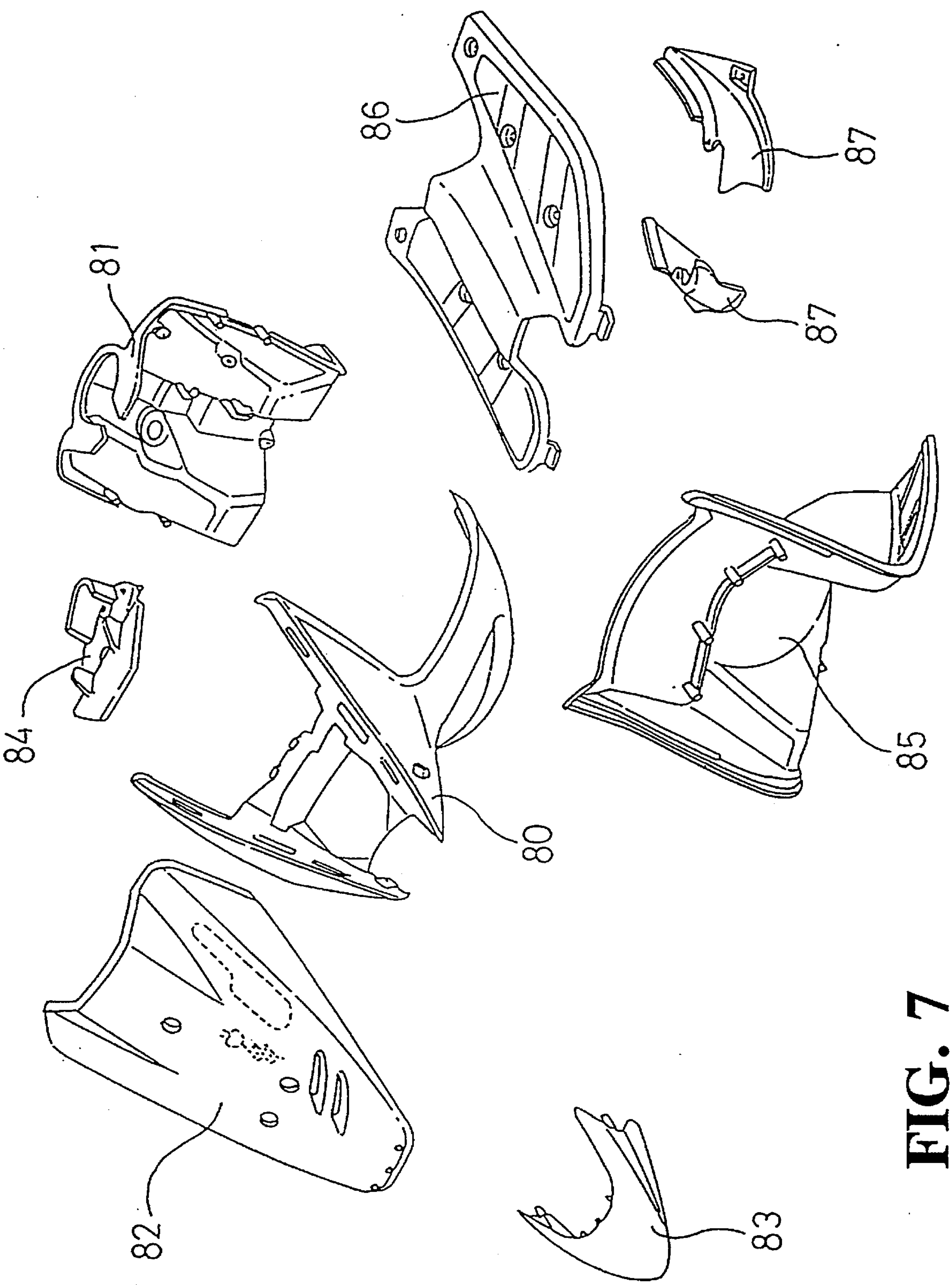


FIG. 7

FIG. 8

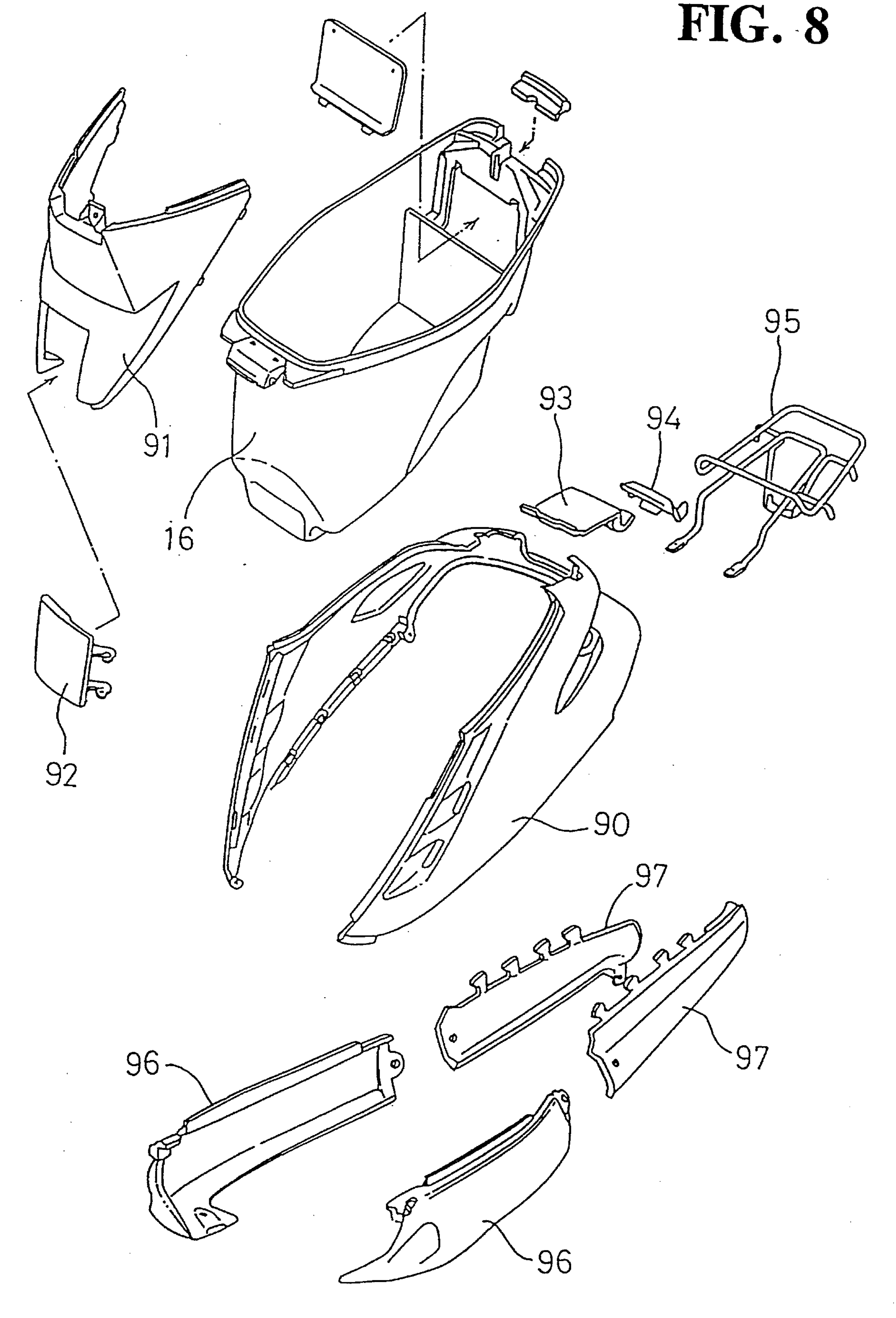


FIG. 9

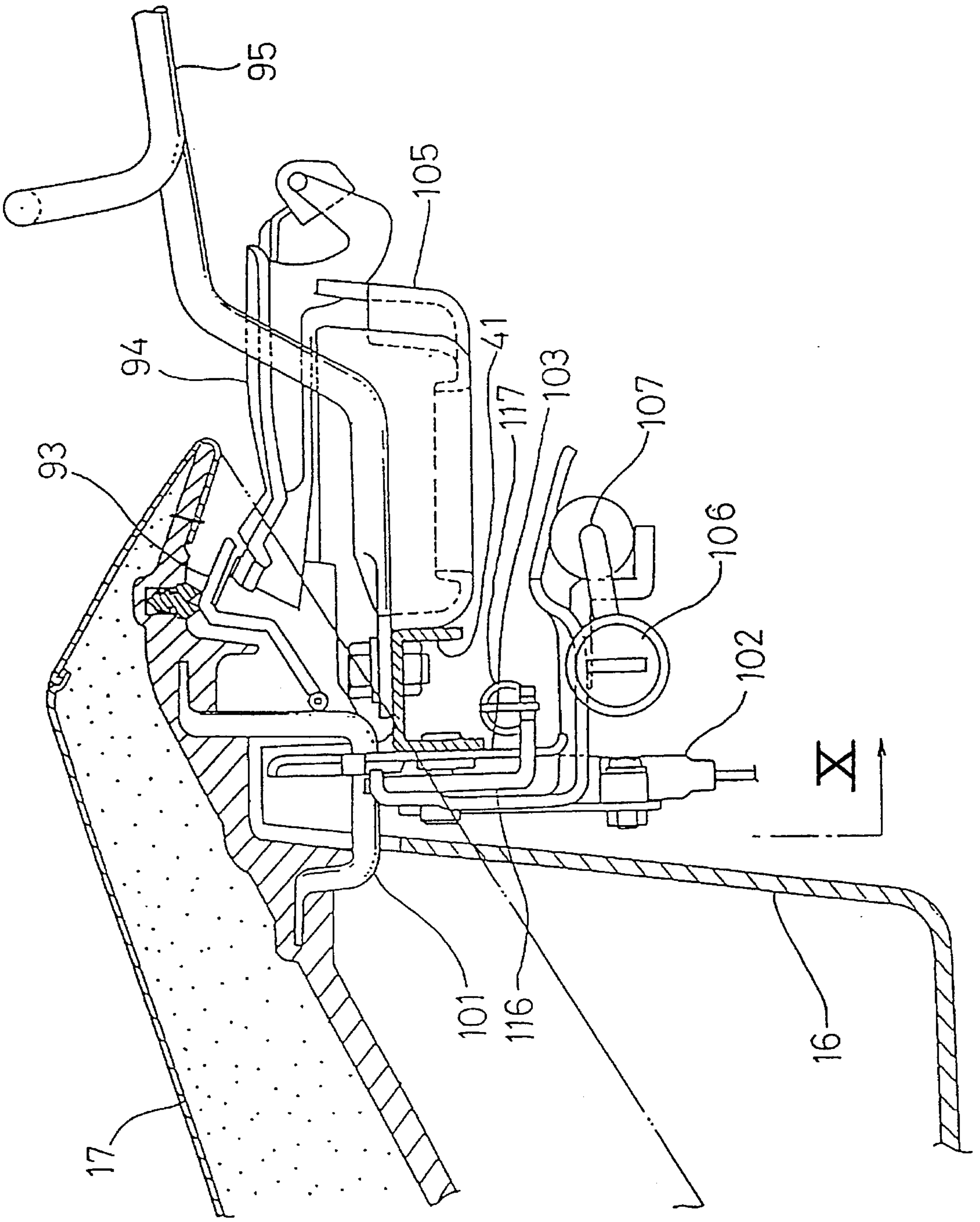


FIG. 10

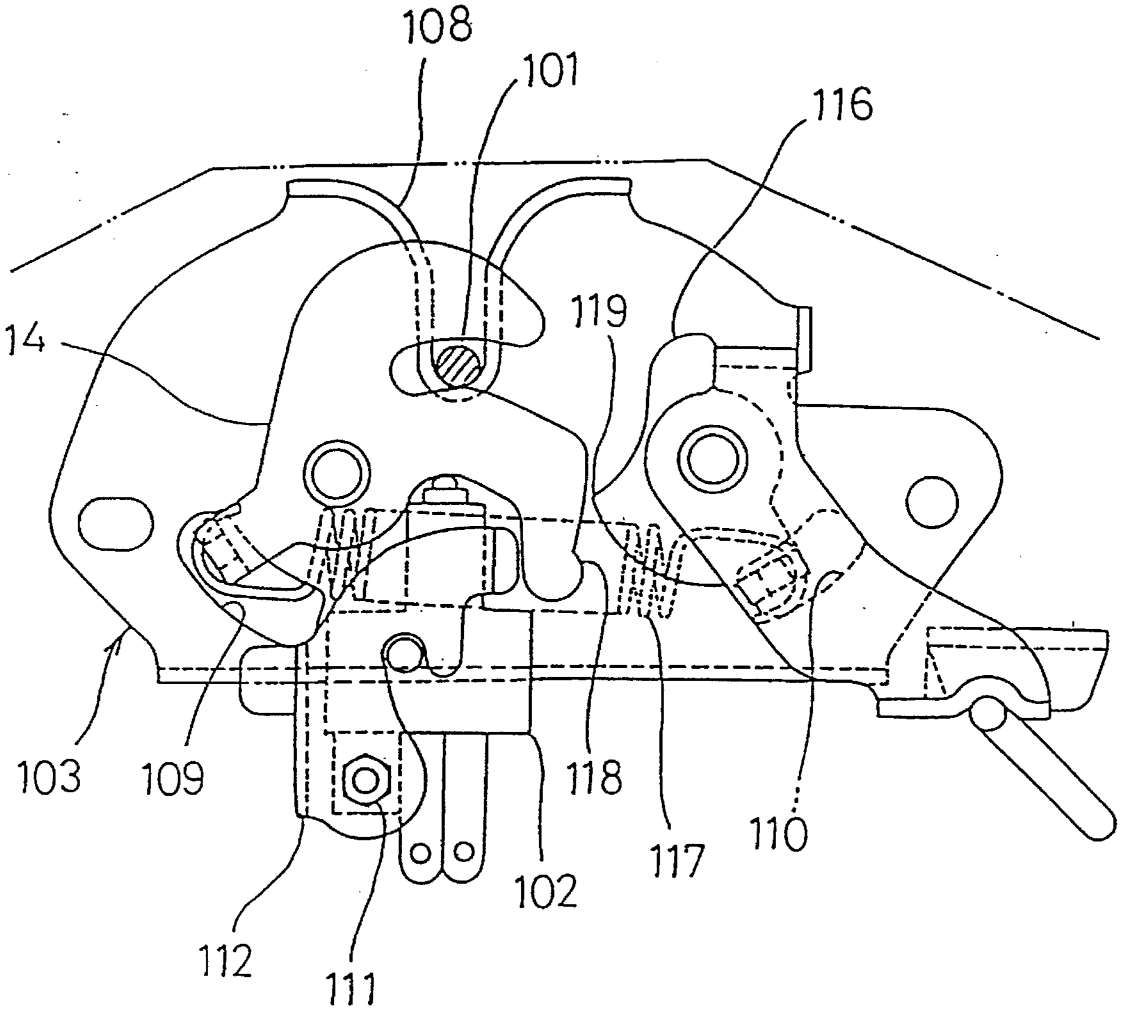
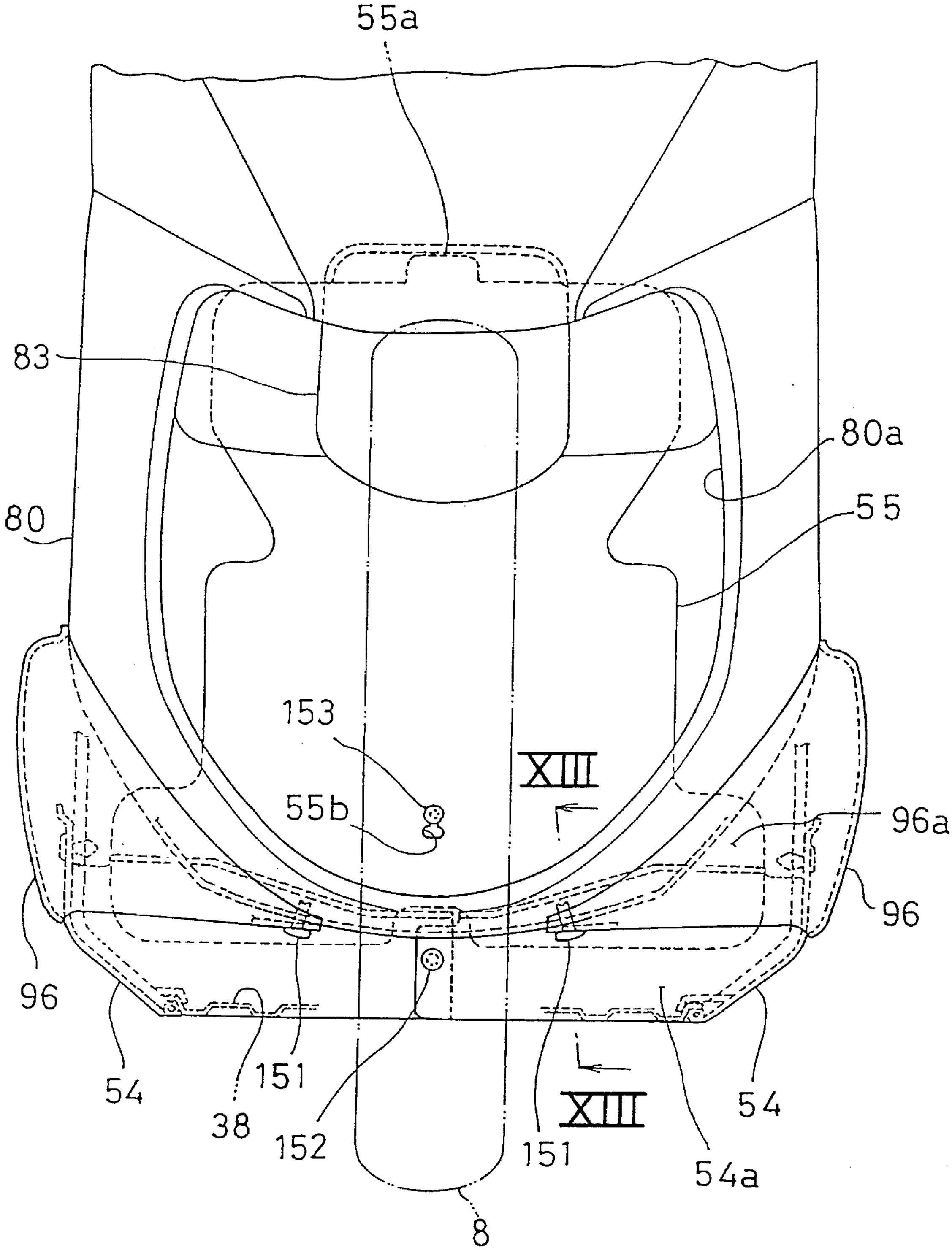


FIG. 11



55a
83
80a
80
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153
XIII
55b
96a
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151
38
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XIII
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54a
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FIG. 12

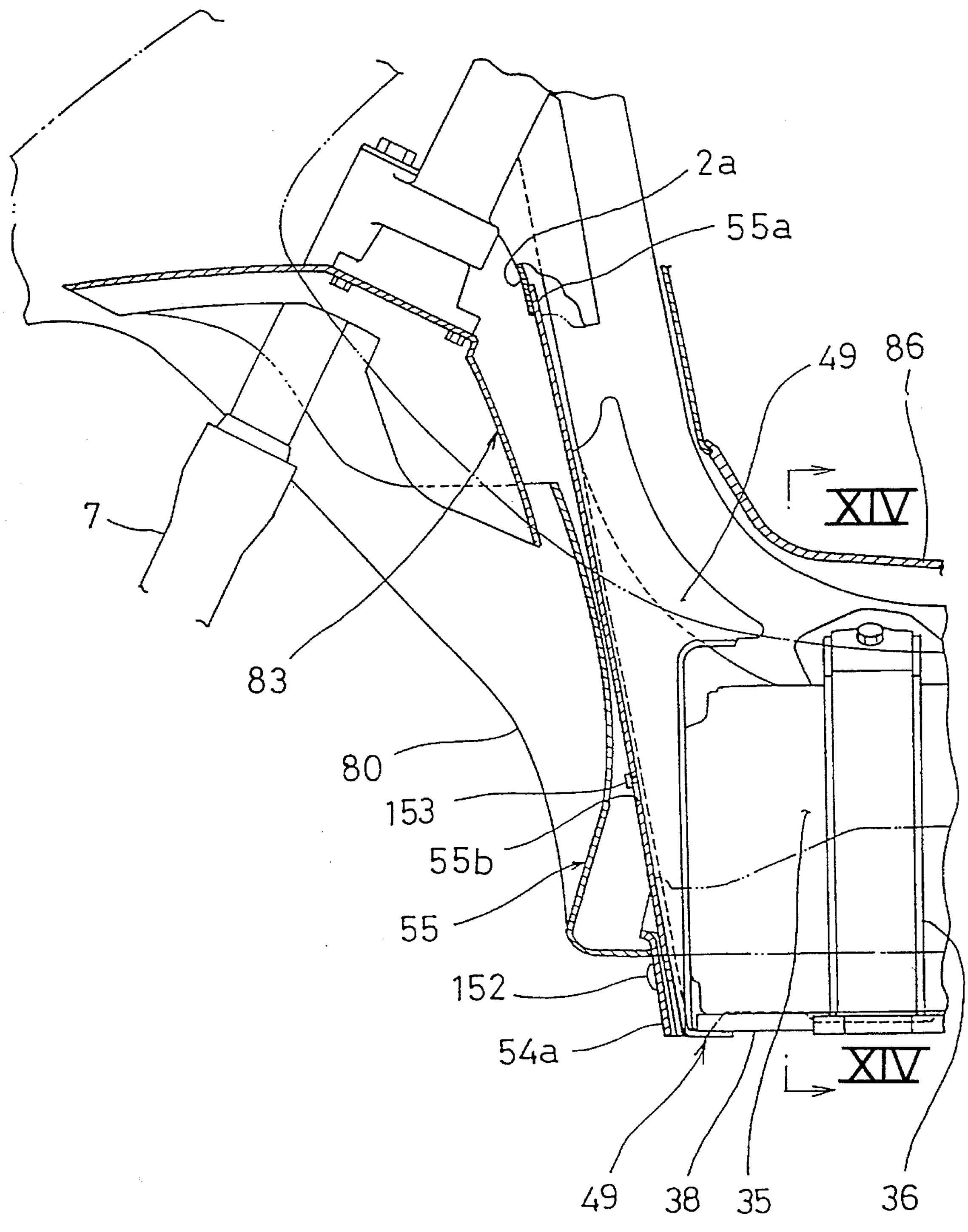
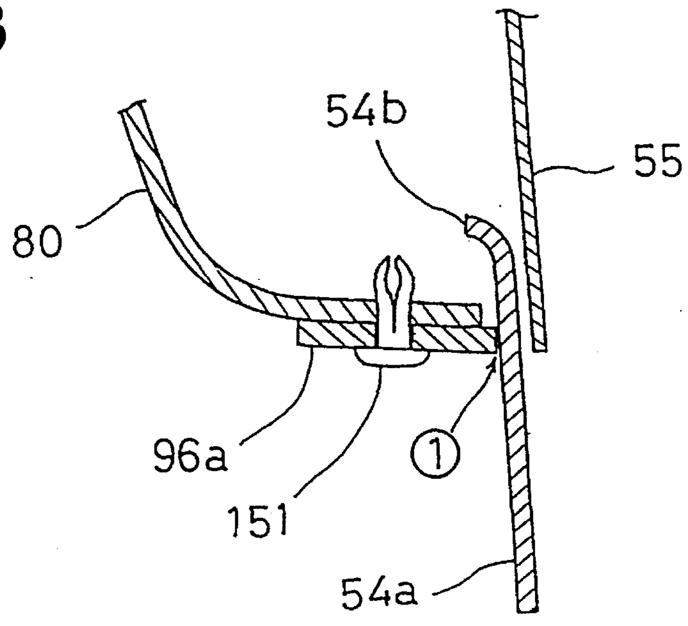


FIG. 13



54b
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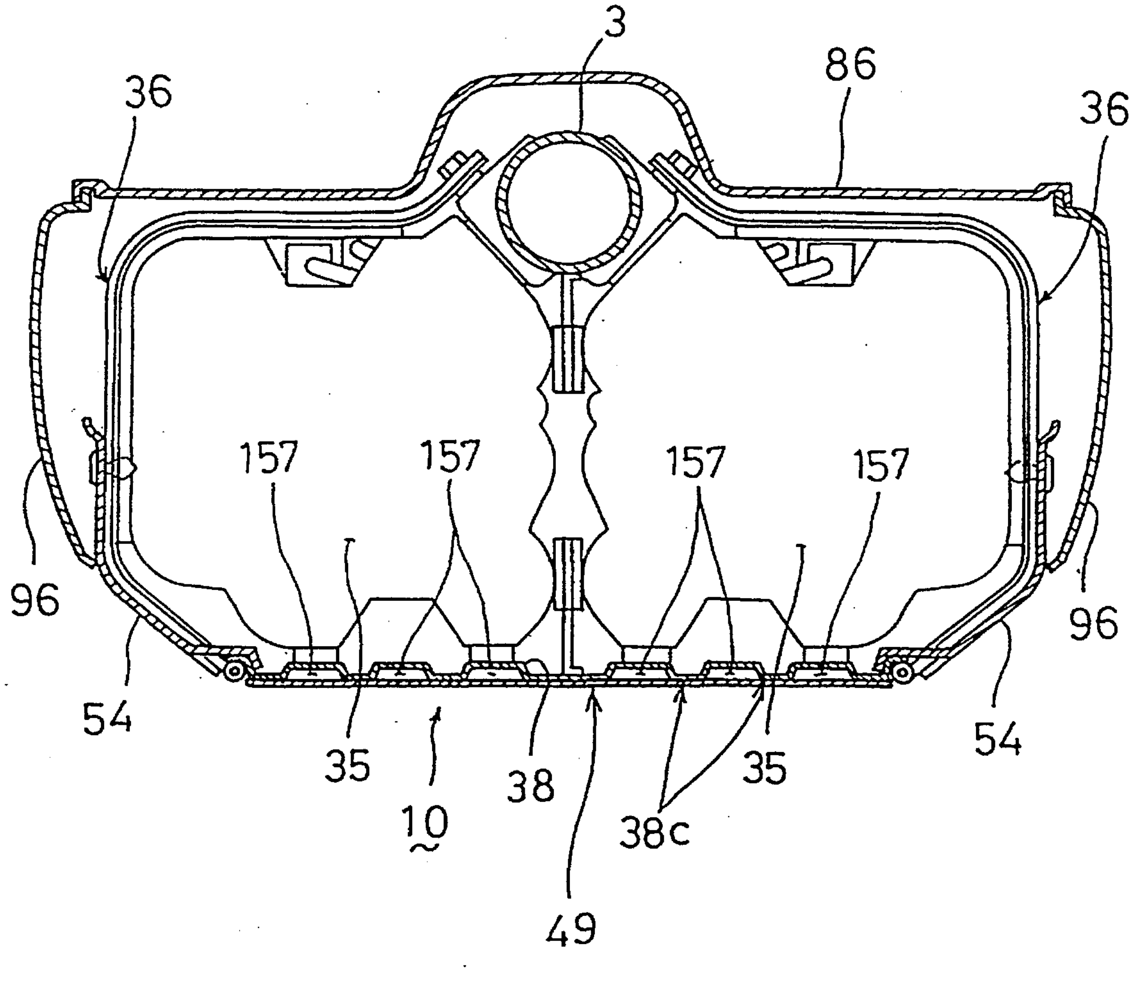
FIG. 14



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38c
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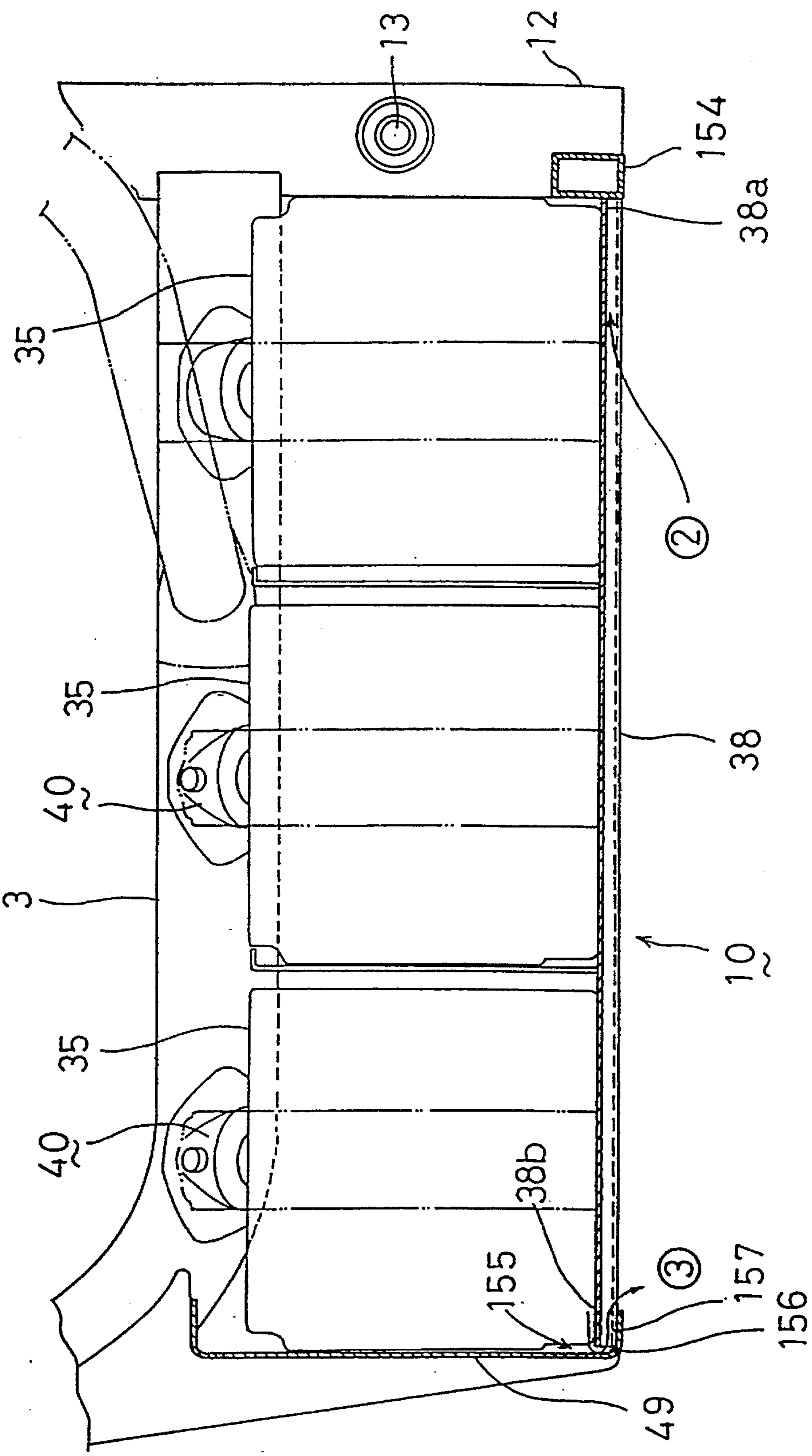
FIG. 15



COVER STRUCTURE AND BATTERY STORING CASE STRUCTURE FOR AN ELECTRIC VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an improvement in waterproof and drain performances of a cover and a battery storing case in an electric vehicle.

2. Background of Related Art

The present applicant has already proposed a battery supporting device for an electric vehicle in Japanese Patent Laid-open No. 5-112270, in which there is shown a motorcycle having a plurality of batteries arranged under a step floor. The batteries are stored in a battery case.

SUMMARY AND OBJECTS OF THE INVENTION

It is a principle of the present invention to include the battery case which is located just behind a front wheel, so that muddy water splashed by the front wheel directly strikes against the battery case. Accordingly, the battery case is required to have a strict sealing structure.

It is therefore an object of the present invention to provide a relatively simple cover structure which is waterproof and to also provide a cover structure and a battery storing case which can easily drain in the event that water may enter the battery storing case.

It is another object of the present invention to provide a cover structure for an electric vehicle wherein a subcover is provided between a fender covering the wheel and a front surface of the battery storing case. In addition, a gap between the subcover and the fender or the front surface of the battery storing case is formed like a maze so as to stop an upward flow of muddy water.

Further, there is provided a battery storing case for an electric vehicle wherein right and left ends of a bottom plate on which a battery is placed are in close contact with battery case side covers, a rear end of the bottom plate is in close contact with a vehicular frame, and a front end of the bottom plate is separate from the vehicular frame to define a space therebetween. The space comprising a first passage having one end exposed into the battery storing case and a second passage having one end connected to another end of the first passage and another end directed rearward of the vehicle and opening to an outside of the battery storing case.

Preferably, the bottom plate comprises a corrugated plate, and the second passage is formed between a crest and a trough of the corrugated plate.

The subcover functions to receive muddy water splashed by the wheel, thereby preventing the water from entering the battery storing case. Further, the gap relating to the subcover is formed like a maze to thereby stop an upward flow of the splashed muddy water.

Water present in the battery storing case is discharged through the first passage and the second passage to the outside of the battery storing case.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

FIG. **1** is a side view of an electric vehicle according to the present invention;

FIG. **2** is a plan view of the vehicle with a vehicular frame primarily illustrated according to the present invention;

FIG. **3** is a transverse sectional view of the vehicle at a substantially central portion thereof according to the present invention;

FIG. **4** is an exploded perspective view of the vehicular frame, a battery storing case, and accessories according to the present invention;

FIG. **5** is an exploded perspective view of controllers, a rear fender, and parts provided near it according to the present invention;

FIG. **6** is a side view of assembled fenders and covers of the electric vehicle according to the present invention;

FIG. **7** is an exploded perspective view of the fenders and the covers at a front portion of the vehicle according to the present invention;

FIG. **8** is an exploded perspective view of the fenders and the covers at a rear portion of the vehicle according to the present invention;

FIG. **9** is an enlarged view of a rear portion of a seat of the vehicle according to the present invention (a view showing a combined seat lock mechanism and plug lid lock mechanism);

FIG. **10** is a view taken in a direction shown by an arrow X in FIG. **9**;

FIG. **11** is a front view of a cover structure according to the present invention as viewed from the front side of the vehicle;

FIG. **12** is a sectional side view of the cover structure shown in FIG. **11**;

FIG. **13** is a cross section taken along the line XIII—XIII in FIG. **11**;

FIG. **14** is a cross section taken along the line XIV—XIV in FIG. **12**; and

FIG. **15** is a longitudinal sectional view of a bottom plate of a battery storing case according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings.

FIG. **1** is a side view of an electric motorcycle according to the present invention. A vehicular frame **2** of the electric vehicle **1** comprises a main frame **3**, a head pipe **4** provided before the main frame **3**, and a rear frame **5** provided behind the main frame **3**. A front wheel **8** is mounted through a front fork **7** to the head pipe **4**. A steering handle **9** is provided at an upper portion of the head pipe **4**. A battery storing case **10** is suspended from the main frame **3**. A power swing unit **14** (including a traveling motor **15**) is pivotally connected at a front end thereof through right and left brackets **12** and a pivot shaft **13** to a rear portion of the main frame **3**. A helmet storing portion **16** and a seat **17** are mounted on the upper side of the rear frame **5** inclined upwardly toward the rear end of the vehicle and a rear suspension **18** is mounted on the lower side of the rear frame **5**. A rear-portion of the power swing unit **14** is supported by a lower end of the rear suspension **18**. A rear wheel **21** is mounted through an axle **19** to the rear portion of the power swing unit **14**.

Electric parts such as a charger are arranged along the rear frame **5**, and the vehicular frame **2** is generally covered with a cowl and a fender. This construction will be hereinafter described in detail with reference to the different drawings. Further, while a combined seat lock mechanism and plug lid lock mechanism is provided behind the seat **17**, this construction will also be hereinafter described in detail.

FIG. **1** illustrates a side stand **22**; a roller **23**; a recess **14*a*** for receiving the roller **23**; and a license plate mounting plate **24**.

FIG. **2** is a plan view of the vehicle according to the present invention in which the vehicular frame is primarily shown. As shown in FIG. **2**, the rear frame **5** is substantially oval-shaped in plan. Inside the rear frame **5** there are arranged a down regulator **27**, controllers **28** and **29** (the controller **28** is a charge controller for performing control in charging batteries and the controller **29** is a travel controller for performing control of a motor or the like in relation to traveling of the vehicle), a battery cooling fan **30**, and a fuse box **31** in this order from the rear toward the front of the vehicle. A harness **32** is provided for connecting electric components.

The main frame **3** is a hollow pipe, which also serves as an air duct connected at one end thereof to a discharge duct **33** of the battery cooling fan **30**. The structure of the main frame **3** also serving as the air duct will be hereinafter described.

In this preferred embodiment, six batteries **35** are mounted to the main frame **3** and are arranged in right and left, two rows each consisting of three batteries and extending in a longitudinal direction of the vehicle. A battery fixing band **36** is provided for securing each battery **35**.

FIG. **3** is a transverse sectional view of the vehicle at a substantially central portion thereof according to the present invention. As shown in FIG. **3** viewed from the front of the vehicle, a bottom plate **38** of the battery storing case **10** is located under the main frame **3**. The batteries **35** are placed on the bottom plate **38**. An air induction hole **35*a*** of each battery **35** is in contact with the main frame **3** through a branch passage **40**. The bottom plate **38** is a so-called corrugated plate, which is so formed as to have a large rigidity in a vertical direction. The battery fixing bands **36** are engaged at their lower ends with hinges **39** formed at right and left ends of the bottom plate **38**.

FIG. **4** is an exploded perspective view of the vehicular frame, the battery storing case, and accessories. Although not described with reference to FIGS. **2** and **3**, a bridge bracket **41**, a cross pipe **43** having a mounting tab **42** for the rear suspension **18**, and a cross panel **45** having cooling fan mounting holes **44**, extending between right and left curved portions of the oval-shaped rear frame **5** in the transverse direction of the vehicle. The cross panel **45** is a member also extending between the right and left brackets **12** for supporting the pivot shaft **13**.

Controller mounting tabs **46**, **47** are provided on the rear frame.

Substantially triangular support brackets **49**, **50**, and **51** are suspended from the main frame **3** to support the bottom plate **38**. The lower ends of the battery fixing bands **36** are fitted with hinges **39** connected to the bottom plate **38** on each side, and are pivotally supported by an elongated pin **52**.

A battery case side lower cover **54** is provided for covering a lower portion of each side of the battery storing case **10**. The battery case front cover **55** covers the front end of the battery storing case **10**.

A main switch **56** is provided with an ignition key switch. A battery receiving plate **57** and cushion members **58** and **59** prevent transverse slip of each battery **35**.

FIG. **5** is an exploded perspective view of the controllers, a rear fender, and parts provided near it. A controller front support **61** is bolted to the controller mounting tabs **46** shown in FIG. **4**, and a controller rear support **62** is bolted to the controller mounting tabs **47** shown in FIG. **4**.

The controller front support **61** is provided with an upper mounting tab **63** for mounting the battery cooling fan **30**, bolts **64** for supporting a front portion of the charge controller **28**, and leg portions **61*a*** and bolts **65** for supporting the travel controller **29**.

The controller rear support **62** is provided with bolts **66** for supporting a rear portion of the charge controller **28** and leg portions **62*a*** and bolts **67** for supporting a rear portion of a rear fender **69**. The rear fender **69** is located over the rear wheel **21** not shown in FIG. **5** to originally serve as a mudguard and also serve as a storing box for the controllers **28** and **29** etc. as shown.

The charge controller **28** must be forcibly cooled because internal elements generate heat during charging. Accordingly, the charge controller **28** is provided with a charger cooling fan **71** and an air induction hole **72**.

A charging cord **73** and a charging plug **74** are provided on said controller **28**. The charging cord **73** is stored in a charging cord box **76**. The charging cord box **76** is formed as a resin blow molding, and it is fixed at mounting tabs **76*a*** and **76*b*** to the vehicular frame **2**.

An air discharge hose **77** is provided for permitting heat inside of the charger to escape. A tail fender **78** is mounted on a stay **79**.

FIG. **6** is a side view of assembled fenders and covers of the electric vehicle according to the present invention; FIG. **7** is an exploded perspective view of the fenders and the covers at the front portion of the vehicle; and FIG. **8** is an exploded perspective view of the fenders and the covers at the rear portion of the vehicle.

Referring to FIG. **7**, a front fender **80** is provided and has a front inner upper cover **81** which is connected thereto. A front cover **82** is mounted on a front upper portion of the front fender **80**. A fender mudguard **83** is mounted on a front lower portion of the front fender **80**. A steering mudguard **84** is also provided. A front inner lower cover **85** is provided as shown in FIG. **6**. A step floor **86** and right and left side floors **87** are provided above the battery case **10**. These parts are so mounted as to cover the main frame **3** and the head pipe **4** as shown in FIG. **6**.

Referring to FIG. **8**, a body main cover **90** and a center cover **91** are provided. These parts are so mounted as to cover the helmet storing portion **16**. A fuse box lid **92** is provided which is operated for replacement of a fuse at any time. A first and a second lid **93** and **94** are provided for closing a cord outlet opening. A rack **95** is attached to the body main frame. Right and left floor side covers **96** are suspended from the step floor **86** to cover right and left side portions of the battery storing case **10**. Right and left side covers **97** extend along right and left lower edges of a rear portion of the body main frame **90**. These parts are so mounted as to cover the main frame **3** and the rear frame **5** as shown in FIG. **6**.

Parts shown by broken lines in FIG. **6** are the same as those shown in FIG. **1** so the explanation thereof will be omitted herein.

FIG. **9** is an enlarged view of a rear portion of the seat of the vehicle according to the present invention (a view showing a combined seat lock mechanism and plug lid lock mechanism). A bent bar (or bent pipe) **101** is mounted to a rear lower portion of the seat **17** closing an upper opening of the helmet storing portion **16**.

A seat switch **102** is located under the bent bar **101**. The seat switch **102** is bolted through a switch mounting plate **103** to the bridge bracket **41**. The switch mounting plate **103** will be hereinafter described in detail.

The charging cord **73** shown in FIG. **1** can be drawn out by first opening the seat **17**, secondly opening the first lid **93**, and finally opening the second lid **94**. A plug stop **105** is provided for retaining a plug provided at one end of the charging cord **73**.

A key cylinder **106** has a lever **107** linked thereto. When the key cylinder **106** is turned, the lever **107** is raised to permit the seat **17** to be opened. This mechanism will be next described in detail.

FIG. **10** is a view taken in a direction shown by an arrow **10** in FIG. **9**. The switch mounting plate **103** is a plate member having a guide groove **108** for guiding the bent bar **101** at an upper portion and also having two arcuate holes **109** and **110** at right and left lower portions.

The seat switch **102** is secured to a small bracket **112** by a bolt **111**. The small bracket **112** is welded to a front surface of the switch mounting plate **103**. Thus, the seat switch **102** is mounted to the switch mounting plate **103** at a central lower portion thereof.

A first swing plate **114** for depressing the seat switch **102** by a lowering motion of the bent bar **101** is pivotably mounted to the switch mounting plate **103**.

Further, a second swing plate **116** is pivotably mounted to the switch mounting plate **103**.

The first switch plate **114** is normally biased in a counterclockwise direction by a spring **117**, and the second swing plate **116** is normally biased in a clockwise direction by the spring **117**.

When a passenger leaves the seat **17**, the first swing plate **114** is slightly rotated in the counterclockwise direction from the position shown in FIG. **10** by the operation of the spring **117**, so that an arm **118** of the first swing plate **114** comes into abutment against a cam **119** of the second swing plate **116** to stop in this position.

Since the second swing plate **116** is in rest, no further rotation of the first swing plate **114** in the counterclockwise direction is inhibited, so that further rising of the bent bar **101** is restricted by the first swing plate **114**. Accordingly, the seat **17** is in a closed position.

In other words, when a passenger sits on the seat **17**, the first swing plate **114** is rotated in the clockwise direction by the bent bar **101** to depress the seat switch **102** and close it as shown in FIG. **10**. Conversely, when the passenger leaves the seat **17**, the first swing plate **114** is slightly rotated in the counterclockwise direction from the condition shown in FIG. **10** by the operation of the spring **117** to thereby open the seat switch **102**. Thus, the presence or the absence of the passenger on the seat **17** can be electrically detected with the seat **17** kept locked.

The seat **17** is opened in the following procedure.

First, the key cylinder **106** shown in FIG. **9** is turned to raise the lever **107**. As a result, the second swing plate **116** shown in FIG. **10** is rotated in the counterclockwise direction, and the cam **119** of the second swing plate **116** becomes lower in level than the arm **118** of the first swing plate **114**. As a result, the locking operation of the cam **119** is lost, and the first swing plate **114** is largely rotated in the counterclockwise direction by the operation of the spring **117** to permit free rise of the bent bar **101**. Thereafter, the seat **17** is opened by hand.

FIG. **11** is a front view of a cover structure according to the present invention as viewed from the front side of the vehicle. The floor side covers **96** are mounted to right and left lower portions of the front fender **80**, and the battery case side lower covers **54** are mounted inside and under the floor side covers **96**. While the floor side covers **96** and the battery case side lower covers **54** are so mounted as to cover right and left sides of the battery storing case **10**, front portions (which will be hereinafter referred to as "first subcovers") **96***a* of the floor side covers **96** are bent toward the transverse center of the vehicle and are secured to the front fender **80** by clips **151**, and similarly front portions (which will be hereinafter referred to as "second subcovers") **54***a* of the battery case side lower covers **54** are bent to the transverse center of the vehicle and are secured to the battery case front cover **55** by a common clip **152**.

It is featured that the first subcovers **96***a*, the second subcovers **54***a*, and the battery case front cover **55** are mounted in this order from the front to the rear of the vehicle, and especially that the battery case front cover **55** is formed as a large, substantially rectangular plate to substantially close a large opening **80***a* of the front fender **80**.

FIG. **12** is a sectional side view of the cover structure shown in FIG. **11**. The battery case front cover **55** behind the front fender **80** is mounted to the vehicular frame **2** by inserting a tongue portion **55***a* formed at an upper end of the cover **55** into a receiving portion **2***a* of the vehicular frame **2** and bringing a key hole **55***b* formed at a transverse central, lower portion of the cover **55** into engagement with a pin head **153** provided on the front surface of the support bracket **49**.

FIG. **13** is a cross section taken along the line XIII—XIII in FIG. **11**. There is shown in FIG. **13** a mounting structure such that each second subcover **54***a* is disposed just before the lower end of the battery case front cover **55**, each first subcover **96***a* is disposed closely before the second subcover **54***a*, and the first subcover **96***a* is closely mounted on the front fender **80** by the corresponding clip **151**.

FIG. **14** is a cross section taken along the line XIV—XIV in FIG. **12**, illustrating a covered condition of the battery storing case **10**.

That is, the batteries **35** arranged in the right and left rows below the main frame **3** and placed on the bottom plate **38** are covered with the step floor **86** on the upper side, with the floor side covers **96** on the right and left upper sides, and with the battery case side lower covers **54** on the right and left lower sides.

FIG. **15** is a longitudinal sectional view of the bottom plate **38** of the battery storing case **10** according to the present invention. The bottom plate **38** is formed as a saw-toothed corrugated plate in order to improve a flexural rigidity. A rear end **38***a* of the bottom plate **38** is in close contact with a square bar **154** extending between the right and left brackets **12** which support the pivot shaft **13**. On the other hand, a front end **38***b* of the bottom plate **38** is welded to the support bracket **49** only at trough portions **38***c* of the bottom plate **38** with a given space **155** defined between the front end **38***b* and the support bracket **49**.

This space **155** is composed of first passages **156** having upper ends exposed into the battery storing case **10** and second passages **157** having front ends connected with lower ends of the first passages **156** and rear ends exposed to the outside of the battery storing case **10**.

The operation of the cover structure shown in FIGS. **11** to **15** will now be described.

Referring to FIG. **11**, when the front wheel **8** is rotated at high speeds to splash muddy water on the road, it is anticipated that the muddy water strongly strikes against an area near the clips **152** and **151** behind the front wheel **8**. In particular when the front wheel **8** rushes into a water pool, the water pool is cut in a V-shape by the front wheel **8**. Accordingly, the muddy water more strongly strikes against the area near the clips **151**.

The second subcovers **54***a* are overlapped and secured together by the clip **152** at the transverse center of the vehicle, so that a high waterproof performance at this portion can be ensured.

Further, as shown in FIG. **13**, it is featured that each first subcover **96***a* is overlapped with the lower end of the front fender **80** near the corresponding clip **151**. It is also shown that the rear end of the first subcover **96***a* is in close contact with the corresponding second subcover **54***a*. Finally, an upper end **54***b* of each second subcover **54***a* is bent to the front side of the vehicle.

Accordingly, a splash of muddy water from the road (as shown by an arrow **1**) is basically stopped by each first subcover **96***a*. Further, the remainder of the muddy water forced upward between the first subcover **96***a* and the corresponding second subcover **54***a* is stopped by the upper end **54***b* of each second subcover **54***a*. Thus, the entry of the muddy water can be effectively prevented by such a maze structure.

Referring next to FIG. **15**, the splash of the muddy water also strikes against the lower surface of the bottom plate **38** as shown by an arrow **2**. However, since the rear end **38***a* of the bottom plate **38** is in close contact with the square bar **154**, the muddy water is prevented from entering the battery storing case **10** from this portion.

Further, a small amount of water gathered inside the battery storing case **10** because of dewing of the inside air, for example, is discharged through the first passages **156** at the front end **38***b* of the bottom plate **38** and the second passages **157** defined by the crests and the troughs of the bottom plate **38** as shown by an arrow **3**. Since the first passages **156** and the second passages **157** form maze passages and the splash of the muddy water from the road comes in the direction shown by the arrow **2**, there is no possibility that the muddy water may reversely flow in the maze passages to enter the battery storing case **10**.

Although the cover structure is applied to the front wheel **8** and the front fender **80** in the above preferred embodiment, it may be applied to the rear wheel **21** and the rear fender **69**.

As described above, according to the present invention, in a cover structure for an electric vehicle having a battery storing case provided behind a wheel, a subcover is provided between a fender covering the wheel and a front surface of the battery storing case, and a gap generating between the subcover and the fender or the front surface of the battery storing case is formed like a maze so as to stop an upward flow of muddy water. Accordingly, the entry of the muddy water into the battery storing case can be effectively prevented.

Further, in a battery storing case for an electric vehicle wherein right and left ends of a bottom plate on which a battery is placed are in close contact with battery case side covers, a rear end of the bottom plate is in close contact with a vehicular frame, and a front end of the bottom plate is separate from the vehicular frame to define a space therebetween; the space comprises a first passage having one end exposed into the battery storing case and a second passage having one end connected to another end of the first passage and another end directed rearward of the vehicle and opening to an outside of the battery storing case. Accordingly, the muddy water flowing along the lower surface of the bottom plate is prevented from entering the battery storing case. Moreover, water present in the battery storing case can be discharged through the first passage and the second passage. Since the second passage opens to the rear side of the vehicle, there is no possibility that the muddy water may reversely flow in the first and second passages to enter the battery storing case.

In a form of the present invention, the bottom plate comprises a corrugated plate, and the second passage is formed between a crest and a trough of the corrugated plate. Accordingly, the second passage can be easily formed, so that a working cost for forming the second passage can be saved.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. An electric vehicle including a cover structure, said cover structure comprising:

a battery storing case provided behind a wheel;

a fender partially covering a rear portion of said wheel;

a subcover provided between said fender and a front surface of said battery storing case, wherein a gap between said subcover and said fender forms a tortuous path so as to stop an upward flow of muddy water through said gap, and

wherein said subcover includes a pair of first subcovers which are attached to said front fender, and a pair of second subcovers which are attached to said front surface of said battery storing case.

2. The electric vehicle according to claim **1**, wherein said first subcovers are integrally formed as a unitary piece with floor side covers of said electric vehicle.

3. The electric vehicle according to claim **2**, wherein said first subcovers are disposed at front portions of said floor side covers and are bent toward a transverse center of the vehicle.

4. The electric vehicle according to claim **1**, wherein said second subcovers are integrally formed as a unitary piece with battery case side covers.

5. The electric vehicle according to claim **4**, wherein said second subcovers are disposed at front portions of said battery case side covers and are bent toward a transverse center of the vehicle.

6. The electric vehicle according to claim **1**, wherein said second subcovers each have an upper end which is bent forward relative to a traveling direction of said electric vehicle.

7. An electric vehicle including a battery storing case, said battery storing case comprising:

a bottom plate on which a battery is placed;

a pair of battery case side covers in close contact with right and left ends of said bottom plate, wherein a rear end of said bottom plate is in close contact with a vehicular frame, and a front end of said bottom plate is separate from said vehicular frame to define a space therebetween, said space comprising a first passage having one end exposed into said battery storing case and a second passage having one end connected to another end of said first passage and another end opening to an outside of said battery storing case and directed rearward of said vehicle.

8. The electric vehicle according to claim **7**, wherein said bottom plate comprises a corrugated plate having crests and troughs, and said second passage is formed between the crests and the troughs of said corrugated plate.

* * * * *

United States Patent [19]

Nardella et al.

[11] **4,160,857**

[45] **Jul. 10, 1979**

[54] **CANISTER AND REMOVABLE BATTERY PACK UNIT THEREFOR**

[75] Inventors: **Paul C. Nardella**, North Easton; **Joseph D. Feeney**, Carver; **Thomas A. Wrublewski**, Braintree; **Anthony W. Gonsalves**, Randolph, all of Mass.

[73] Assignee: **Codman & Shurtleff, Inc.**, Randolph, Mass.

[21] Appl. No.: **878,493**

[22] Filed: **Feb. 16, 1978**

[51] **Int. Cl.**[2] **H01M 2/10**

[52] **U.S. Cl.** **429/97**; 429/99

[58] **Field of Search** 429/97, 99, 1, 9

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Primary Examiner—Donald L. Walton

Attorney, Agent, or Firm—Richard J. Rodrick

[57] **ABSTRACT**

A canister for a removable battery comprises a receptacle for receiving the battery therein. The battery is insertable so that its electrical terminals are upwardly facing and exposed for contact. A cover is provided for enclosing the battery in the receptacle and electrical contacts are associated with the cover for contacting the battery terminals when the cover is positioned over the receptacle with the battery inside. An electrical connector is electrically connected to the electrical contacts inside the cover and provides means on the outside of the cover for an electrical connection in order to derive voltage from the battery.

A battery pack unit in combination with the canister comprises a plurality of batteries electrically connected to each other and has electrical terminals in contact with the electrical contacts in the cover. The terminals are electrically connected to the batteries in order to provide a source of electrical current from the pack unit.

A further combination includes the canister and battery pack unit together with a tool electrically operated by direct current with a cable connecting the canister with the tool for providing direct current from the battery unit in the canister to the tool for driving the same.

5 Claims, 6 Drawing Figures

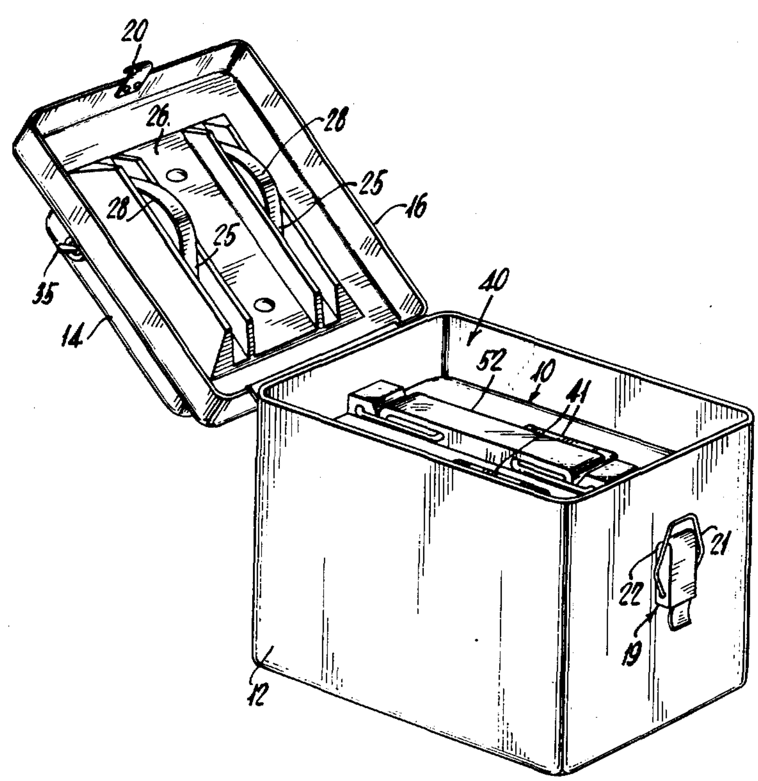

FIG. 1.

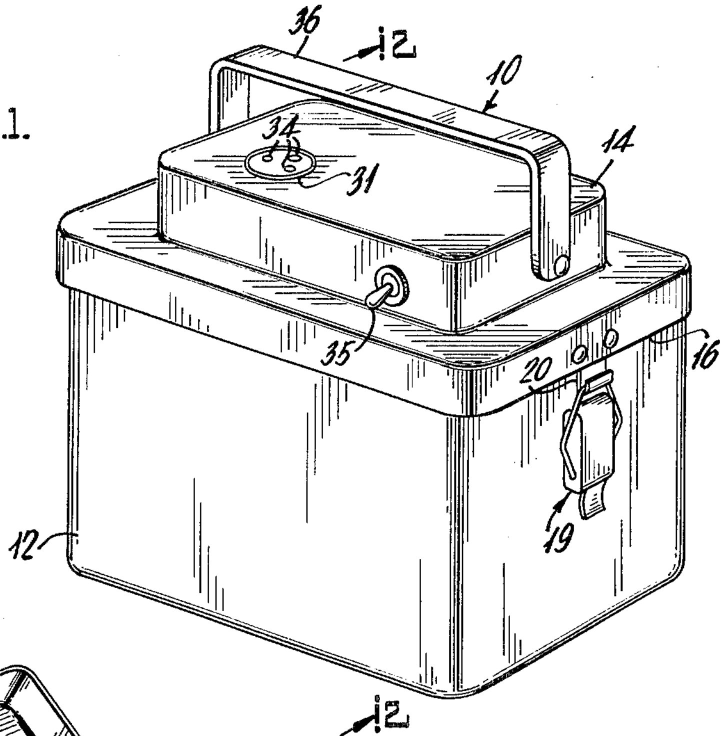
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FIG. 3.

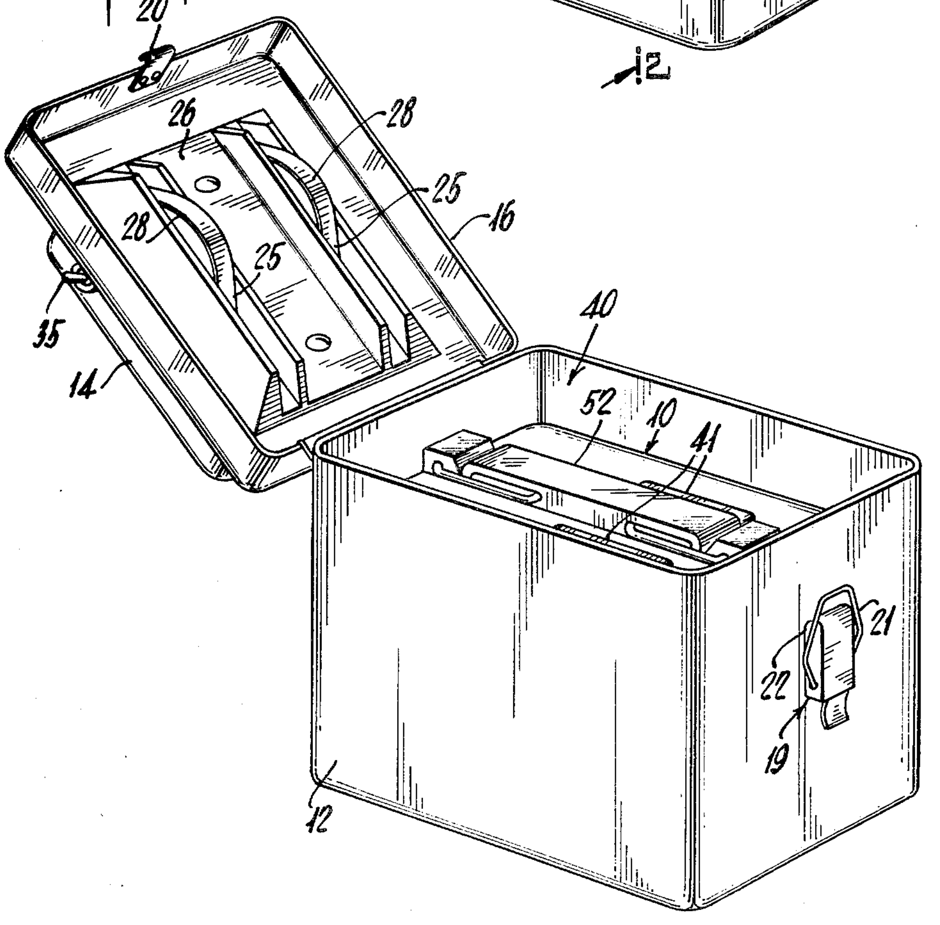
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Fig. 2.

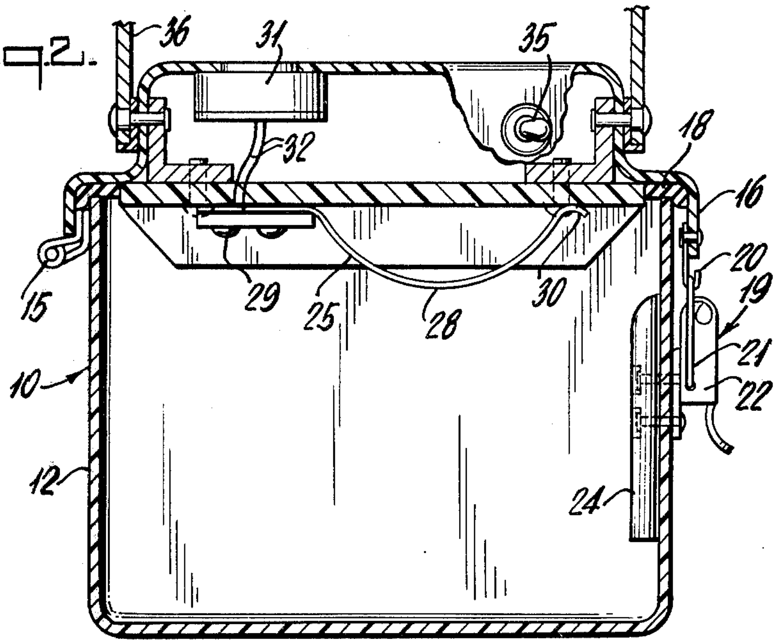


Fig. 4.

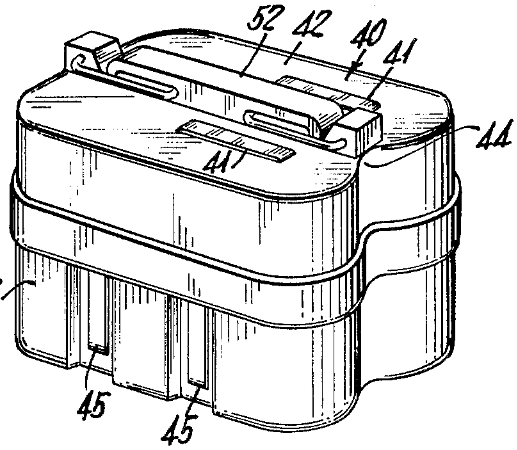


Fig. 5.

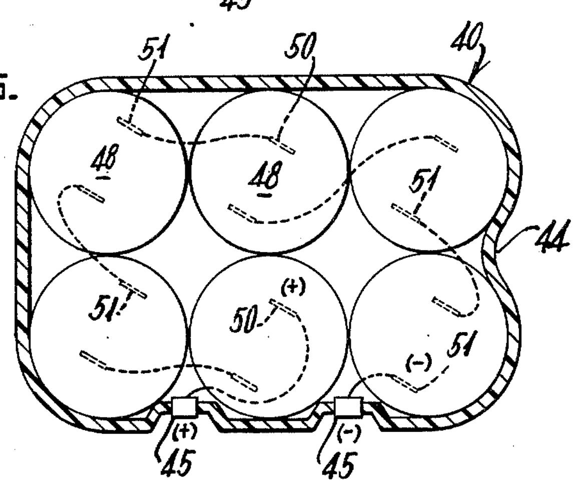
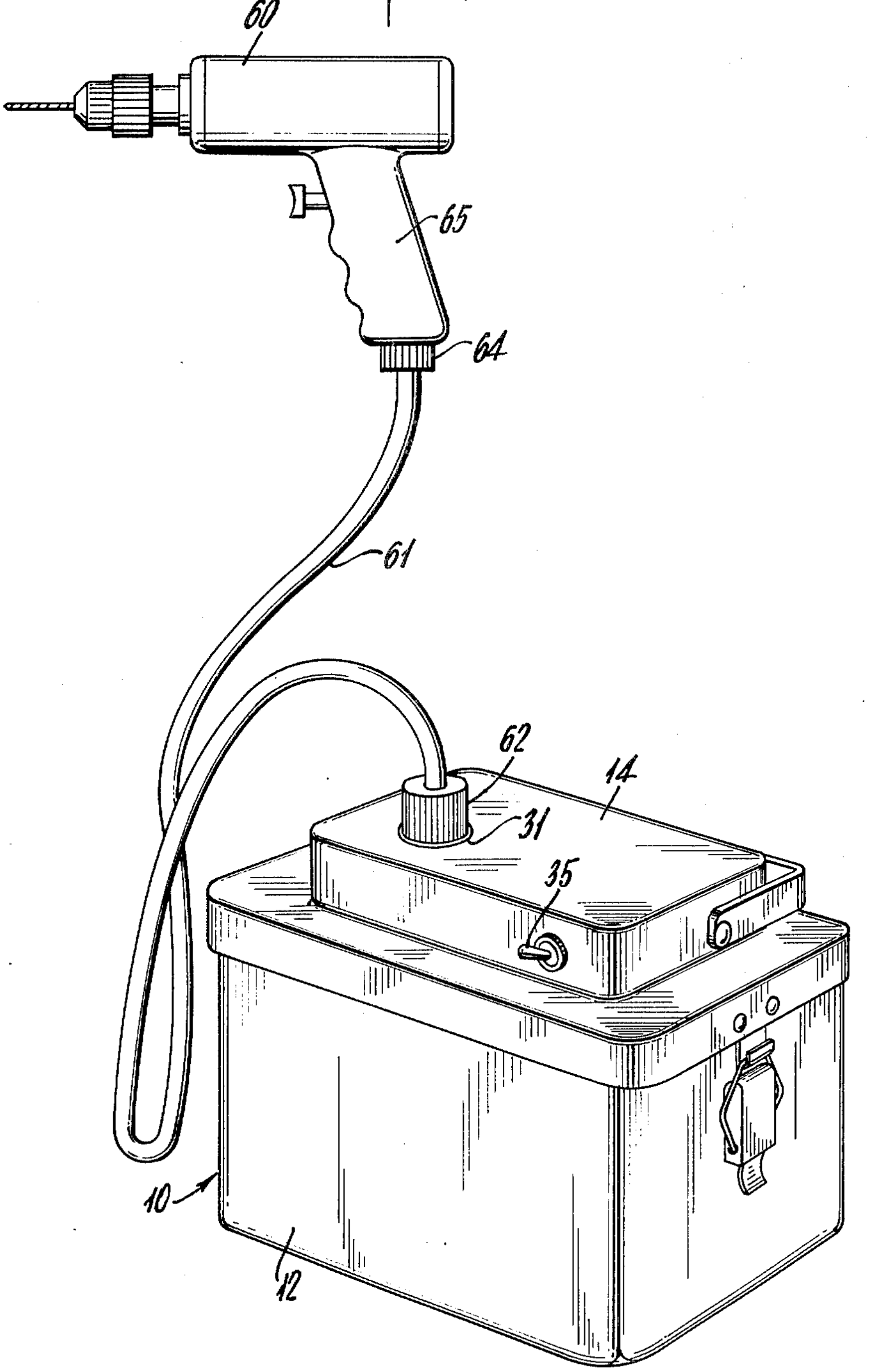


Fig. 6.



CANISTER AND REMOVABLE BATTERY PACK UNIT THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates to a canister for holding a removable battery therein with connection means to derive current from the battery, and, more particularly, concerns a removable battery pack unit in a canister which provides an electrical connection to that unit. The present invention further relates to a canister with a removable battery pack unit therein in combination with a tool electrically operated by direct current which is provided by the battery pack unit.

Many electrically operated surgical tools are being designed to perform under direct current rather than alternating current in the operating rooms of hospitals and the like. Use of anesthesia during surgery complicates the use of electrically operated tools inasmuch as an inadvertent spark may cause the anesthesia to ignite. With this in mind battery powered surgical tools, such as drivers for drills, saws, reamers and the like, have become more prominent. In addition to the necessity of sometimes providing large amounts of direct current for tools which, for example, must drill through bone structure, the battery should also be sterilized to be compatible with its inclusion in the clean operating area. Most commonly used batteries for use with electrically operated surgical tools, such as the rechargeable secondary cell type, and particularly, sealed lead-acid cells, are not sterilizable in their normal condition inasmuch as the autoclaving process or similar sterilization process may cause the battery to weaken or produce other defects. Accordingly, it is desirable to provide a container for a battery which can be sterilized, and also a container which can include a battery or a number of batteries with sufficient energy required to drive electrically operated surgical tools.

In U.S. Pat. No. 2,861,578, there is disclosed a utility cabinet assembly, preferably directed for manicuring purposes, which includes an electrically powered manicure implement and a portable carrying cabinet therefor in which there is stored an electrical power supply for the implement. This type of utility assembly does not meet the above defined requirements for a container to hold a battery which can be used in a clean surgical operating area.

It is also desirable to employ batteries of the secondary cell type which are rechargeable since the electrically operated tools drain a considerable amount of energy during their use. A rechargeable battery pack unit and a battery charger are disclosed in the applicant's co-pending patent application Ser. No. 878,494 filed on even date with this application, the specific battery pack unit disclosed therein being adaptable for inclusion in a container which meets the requirements set forth above.

SUMMARY OF THE INVENTION

A canister for a removable battery comprises a receptacle for receiving the battery therein. The battery is insertable so that its electrical terminals are upwardly facing and exposed for contact. A cover is provided for enclosing the battery in the receptacle. There are electrical contacts associated with the cover for contact with the battery terminals when the cover is positioned over the receptacle with the battery therein. An electrical connector is connected to the electrical contacts inside the cover and it provides means on the outside of the cover for an electrical connection in order to derive voltage from the battery.

In the preferred embodiment of the canister of the present invention, the cover is hingedly attached to the receptacle and a resilient gasket is provided for location between the cover and the receptacle so that the canister is capable of being sterilized for use in clean areas. A pair of spring-resilient metallic strips serve as the electrical contacts mounted inside the cover and are arranged to springably contact the terminals of the battery when the cover is positioned over the receptacle with the battery inside. One of the strips will contact the negative terminal, the other will contact the positive terminal. Latching means is provided for maintaining the cover in a closed position on the receptacle. There is also included in the preferable embodiment a switch mounted in the cover and operable from the outside surface thereof. This switch is adapted to interrupt the flow of electrical current from the battery to the connector when in the off position, and adapted to allow current to flow from the battery to the connector when in the on position.

Another aspect of the present invention is a combined canister and removable battery pack unit, the canister being substantially as described above. The battery pack unit comprises a plurality of batteries electrically connected to each other and has electrical terminals in contact with the electrical contacts of the canister. The terminals are electrically connected to the batteries in order to provide a means of deriving energy from the pack unit. Preferably, the pack unit has a pair of metallic strips on an upper surface thereof to serve as the terminals for contacting the electrical contacts in the cover. In addition, the batteries are preferably secondary, rechargeable cells.

A further aspect of the present invention is a combined canister removably enclosing a battery pack unit therein, the canister having means associated therewith for making electrical contact with the pack unit. An electrical connector is included on the outside surface of the canister to provide energy from the pack unit. This pack unit comprises a plurality of batteries electrically connected to each other. These elements are combined with a tool electrically operated by direct current and a cable connected at one end to the tool and at its other end to the connector on the canister, the cable providing a flow of direct current from the battery unit in the canister to the tool for driving the same.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating the preferred canister of the present invention in the closed position;

FIG. 2 is a cross-sectional view taken along lines 2—2 of FIG. 1;

FIG. 3 is a perspective view illustrating the preferred canister of the present invention in the open position with the preferred battery pack unit therein;

FIG. 4 is a perspective view illustrating the preferred battery pack unit of the present invention;

FIG. 5 is a plan view of the preferred battery pack unit with its cover removed for viewing of the batteries and electrical connections inside; and

FIG. 6 is a perspective view illustrating the preferred canister and battery pack unit assembly together with an electrically operated tool, electrically connected to the canister.

DETAILED DESCRIPTION

While this invention is satisfied by embodiments in many different forms there is shown in the drawings and will be herein described in detail preferred embodiments of the invention, with the understanding that the present disclosure is to be considered as exemplary of the principles of the invention and is not intended to limit the invention to the embodiments illustrated. The scope of the invention will be pointed out in the appended claims.

Referring to the drawings, particularly to FIGS. **1** and **2**, there is illustrated a canister **10**. Canister **10** is comprised of a receptacle **12** which is generally a box-like container preferably of a rectangular cross-section. Receptacle **12** is constructed to have four walls and a bottom surface, with its top portion being open so that the battery may be inserted therein. A one-piece receptacle **12** is preferably employed inasmuch as this is often conveniently fabricated. Canister **10** further includes a cover **14** which is mounted atop receptacle **12** by a hinge **15** so that cover **14** may swing open for access to the inside of receptacle **12**. Cover **14** is preferably provided with an overlapping lip **16** so that a resilient gasket **18**, such as rubber or the like, may be located at the top of receptacle **12** between the receptacle and cover **14**. Lip **16** assists in positioning gasket **18** and holding the same in place when the cover is closed on the receptacle. To also assist in keeping cover **14** closed on receptacle **12** a latching device **19** is included on the canister. This latching device includes a hook **20** attached to cover **14** and a ring **21** freely connected to a bracket **22** which is mounted on the wall of receptacle **12**. Once ring **21** is slipped over hook **20**, bracket **22** is operable to be pushed inwardly in order to render ring **21** taut on hook **20**. This arrangement serves to maintain cover **14** closed against receptacle **12**, and together with gasket **18** provides a tight seal. Accordingly, this arrangement provides a sufficient container assembly for sterilization purposes since the contents of the receptacle inside are unaffected by the sterilization process.

On the inside surface of the same wall of receptacle **12** opposite from latching device **19**, there is a guiding key **24**. This guiding key is merely to assure that the particular type battery pack unit, preferably adaptable for reception in canister **10**, is insertable in the proper orientation. A provision is included on the battery pack unit to matingly correspond with guiding key **24**, as will hereinafter be described.

In FIGS. **2** and **3** it can be seen that a pair of spring-resilient metallic strips **25** are mounted inside cover **14**. An electrically non-conductive mounting pad **26** serves as a support member for strips **25** and also to electrically isolate the strips. Strips **25** are formed to include a smoothly curved raised portion **28**; curved portion **28** protrudes downwardly and is the portion of the metallic strip which contacts the terminals on the battery pack unit. Metallic strips are connected at one end **29** to mounting pad **26**, whereas the other end **30** of the strip is free thereby allowing curved portion **28** to flexibly compress during contact with the terminals of the battery unit when the cover is positioned over the receptacle with that unit therein.

An electrical connector **31** is mounted in cover **14**. Inside cover **14** connector **31** makes a connection with metallic strips **25** by appropriate wiring means **32**. The wires are connected to female pegs **34** in connector **31** which are accessible on the outside surface of cover **14**. A mating plug device is conveniently plugged into female peg **34** in order to make the electrical connection to the canister for deriving voltage from the battery. In addition, a toggle switch **35**, or similar switch operable from the outside of the canister, is mounted in the cover **14**. By appropriate electrical wiring (not shown, but well known) switch **35** is adapted to interrupt the flow of electrical current from the battery inside receptacle **12** to connector **31** when in the off position, and adapted to allow current to flow from the battery to connector **31** when in the on position. This, of course, provides a measure of control during use of the canister-battery assembly, such as, for example, eliminating unnecessary drain of the battery when the tool is not being used.

A handle **36** is optionally attached to cover **14** to provide a convenient means to lift the canister.

Turning now to FIG. **3**, canister **10** is illustrated in the open position so that cover **14** is swung back to allow access to receptacle **12**. The preferred battery pack unit **40** is shown inserted in receptacle **12** so that its electrical, metallic terminals **41**, on the upper surface **42** of unit **40**, are upwardly facing and exposed for contact with metallic strips **25** and particularly curved portion **28**. It can be seen that, in this preferable embodiment, there is mating alignment between electrical contacts **25** in the cover and electrical terminals **41** on the battery unit to assure positive contact when the cover is closed over the receptacle. It is noted that battery pack unit **40** has an indentation **44** on one of its end surfaces; this indentation mates with guiding key **24** in receptacle **12** so that pack unit **40** may be properly inserted in the correct orientation in the receptacle.

Adverting now to FIGS. **4** and **5**, the preferred battery pack unit **40** is illustrated. This pack unit is also, and in more detail, described in the co-pending patent application filed even date herewith, but the pertinent components of the pack unit will be pointed out herein. In addition to terminals **41** on upper portion **42**, there is also another pair of metallic strips **45** on a side portion **46** of the battery pack unit; these side terminals **45** allow pack unit **40** to be recharged in the particular type battery charger described in said co-pending patent application. Inside pack unit **40** are a plurality of batteries **48**, such as the secondary, rechargeable cell type, particularly sealed lead-acid cells. Each battery **48** has a positive terminal **50** and a negative terminal **51**. The batteries are electrically connected, by appropriate wiring, to each other, generally positive terminal **50** of one battery to negative terminal **51** of adjacent battery. A positive terminal **50** on one battery and a negative terminal **51** on another battery are left free for connection to the pack unit terminals **41** and **45**. Accordingly, one of the metallic strips **41** on the battery unit is a negative terminal, while the other of the metallic strips **41** is a positive terminal. A handle **52** is included on battery pack unit **40** for conveniently lifting the unit in and out of receptacle **12**.

While the canister may be fabricated from many different materials, a light weight metal such as aluminum, for strength purposes and for withstanding sterilization processes, is preferred. In order to hold a battery pack unit such as described herein, typical dimensions of the overall canister, including cover and receptacle, are $6\frac{1}{2}$ by $4\frac{1}{2}$ by $5\frac{3}{4}$ inches high (16.5 by 11.5 by 14.5 cm.).

Referring now to FIG. **6**, canister **10** is illustrated in its mode of use in conjunction with a tool **60** which is electrically operated by direct current. Although not shown because the cover **14** is sealably closed over receptacle **12**, the preferred battery pack unit is incorporated inside the canister. A cable **61** includes a connector **62** at one end, this connector is adapted to mate with connector **31** on cover **14** of the canister. This, in turn, allows energy to be derived from the battery unit within, since connector **31** is in electrical contact with that unit. The other end of cable **61** has another connector **64** which is adapted to mate with a corresponding electrical connection on the tool **60**, in this instance on the handle portion **65** thereof. Accordingly, as soon as toggle switch **35** is flipped to the on position, direct current flows from canister **12** through cable **61** and into electrically operated tool **60**. This tool may be any number of tools preferably employed for surgical purposes, including, but not limited to, hand-held drivers for use in surgical operations such as drills, saws, reamers and the like.

Thus, the present invention provides a canister particularly suitable for receiving and holding a removable battery pack unit, particularly of the rechargeable type, which can be sealably closed and sufficiently sterilized to be used in clean areas such as hospital operating rooms. The canister-battery pack unit assembly provides the energy for electrically operated tools driven by direct current, the battery pack unit being accessible for recharge when its energy level becomes diminished by use of the tool.

What is claimed is:

1. In combination, a canister and a removable battery pack unit, said canister comprising a receptacle into which said battery pack unit is positioned; a cover enclosing said battery pack unit in said receptacle; a pair of electrical spring contacts located on the inside of said cover projecting downwardly for contact with said battery pack unit; an electrical connector in said cover electrically connected to said electrical spring contacts, said connector providing means on the outside of said cover for an electrical connection in order to derive voltage from said battery pack unit; and said pack unit comprising a plurality of batteries electrically connected to each other, said batteries enclosed in a housing which includes two pairs of metallic strips serving as electrical contacts, both pairs of strips electrically connected to said batteries so that one of said strips in each pair is a negative terminal and the other of said strips in each pair is a positive terminal, one pair of metallic strips located in a side portion of said housing and not making electrical contacts with said receptacle, the other pair of metallic strips located in the upper portion of said housing and adapted to be contacted by said spring contacts when said cover is closed to thereby provide a means of deriving energy from said pack unit.

2. A combination as defined in claim **1** wherein said battery pack unit further includes a handle on its upper surface for lifting the unit in and out of the receptacle, said handle positioned between the metallic strips on the upper surface of the battery pack unit housing.

3. A combination as defined in claim **1** which further includes a tool electrically operated by a direct current and a cable connected at one end to said tool and at the other end to said connector on said canister, said cable providing a flow of direct current from said battery unit in said canister to said tool for driving the same.

4. A combination as defined in claim **3** wherein said tool is a hand-held driver for use in surgical operations.

5. A combination as defined in claim **1** wherein said batteries in said pack unit are secondary, rechargeable cells.

* * * * *

Appendix H – Manufacturer Specifications

IMAGENEX MODEL 837 “Delta T” MULTIBEAM PROFILING SONAR

APPLICATIONS:

- ROV, AUV, & UUV
- Offshore Oil & Gas
- Sunken Timber Recovery
- Diving Support
- Surveying
- Search & Recovery
- Inspection
- Underwater Archaeology
- Scientific Research

FEATURES:

- Programmable
- High speed
- High performance
- Lower cost
- Low power
- Simple set-up and installation
- Ethernet
- 5 m to 100 m range
- Integrated Video Capture and Display
- Built in GPS Track Plotter

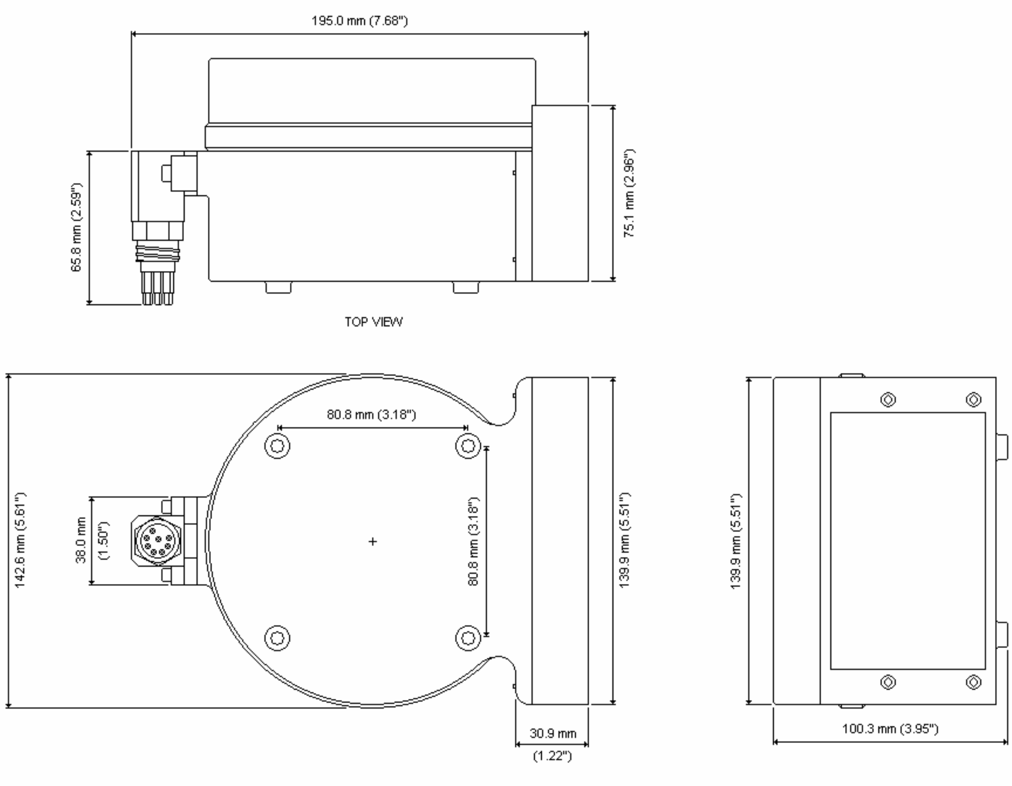
The Imagenex Model 837 “Delta T” is a multiple receiver sonar system designed to provide video-like imaging with all the advantages of underwater sonar. Innovative digital signal processing is used to optimize data usage from all channels to achieve the best possible resolution at every point in the field of view. Recent advances in computing power have made it possible to transfer and process this data at resolutions equal to computer monitor resolution, and with image frame rates of better than 20 frames per second!

The Delta T system has been designed from the ground up with the most advanced, high accuracy, low power electronic components available to provide breakthroughs in system power consumption, package size, and price. This advanced electronics package has built in flexibility and programmability to accommodate a wide range of transducer arrays. Thus, the Delta T is the first in a family of new technology products which will have imaging and profiling capabilities to suit your underwater application. Imagenex sonars: advancing underwater imaging capability for the everyday user.

Patent Pending

HARDWARE SPECIFICATIONS:	
FREQUENCY	260 kHz
TRANSDUCER BEAM WIDTH (nominal)	Receive: 120° x 3° Transmit: 120° x 3°
EFFECTIVE BEAM WIDTH	0.75° (with 600 beams)
BEAMS*	75, 150, 300, 600
RANGE RESOLUTION	0.2% of range
MIN. DETECTABLE RANGE	0.5 m
MAX. OPERATING DEPTH	300 m
FRAME RATE	Up to 20 fps
INTERFACE TO PC	10 Mbps Ethernet (10 BASE-T) using TCP/IP
MAX. CABLE LENGTH	100 m on CAT5e
CONNECTOR	Side mounted right angle, 8 conductor, wet mateable (Subconn MCBH-8M-SS)
POWER SUPPLY	22 – 50 VDC at less than 12 Watts
DIMENSIONS	See drawing
WEIGHT: In Air **In Water**	2.49 kg (5.5 lbs) 0.7 kg (1.5 lbs)
MATERIALS	6061-T6 Aluminum, Epoxy, PVC, Stainless Steel connector
FINISH	Hard Anodize

*Data is acquired at full resolution every shot: processing the data for screen display on a PC can slow the system at highest number of beams. 75 beam mode is recommended for real time data acquisition. The data can then be played back at highest resolution (600 beam).



SOFTWARE SPECIFICATIONS:	**DeltaT.exe**
WINDOWS™ OPERATING SYSTEM	Windows™ XP
DISPLAY MODES	Sector, Linear, Perspective, Profile, Beam Test
PERSISTENCE (TRAIL)	1 – 300 seconds
RANGE SCALES	5 m, 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 80 m, 100 m
SECTOR SIZES	30°, 60°, 90°, 120°
FILE FORMAT: **RAW DATA** **PROFILE POINT**	 (filename).837 (filename).83P
RECOMMENDED MINIMUM COMPUTER REQUIREMENTS:	2 GHz Pentium 4 256 MB RAM 20 GB Hard Disk 1024 x 768 screen resolution

ORDERING INFORMATION:		
300 m UNIT	Standard	837-000-200
Straight Connector	Option	-009
IP Address*	Option	-020

*Note: Standard IP Address is 192.168.0.2
A different IP Address may be specified upon ordering.

Workhorse Navigator

DOPPLER VELOCITY LOG (DVL)

Precision Navigation for the Marine Environment

The Workhorse Navigator is the industry's first choice for precision navigation applications. Teledyne RDI's highly acclaimed Doppler Velocity Log (DVL) provides precise velocity and altitude updates for a wide variety of underwater tasks.

The highly flexible design allows the unit to be used in a standalone configuration or integrated with other navigation systems.

The compact and powerful Workhorse Navigator provides:

- Patented BroadBand processing technology, providing users with both short and long-term high-precision velocity data
- Reliable and accurate high-rate navigation and positioning data
- Proven bottom detection algorithms, and single ping bottom location, for robust and reliable bottom tracking over indeterminate terrain
- Superior low-altitude bottom tracking capability
- Real-time current profiling data

Navigator Applications:

- *Subsea vehicle and surface vessel navigation*
- *Hydrographic, geophysical, and oceanographic survey positioning data*
- *LBL and USBL position aiding*
- *Spool piece metrology*
- *Inertial navigation correction and integration*
- *Cable burial operations*
- *Deep water positioning*
- *Station keeping and autopilot control*
- *Pipeline touchdown monitoring*
- *Dredge spoils, plume, and sediment tracking*

Navigator full suite of capabilities:

- *Bottom track velocity*
- *Water track velocity*
- *Altitude: 4 individual measurements*
- *Error velocity (data quality indicator)*
- *Temperature*
- *Heading/Tilt*
- *Acoustic echo intensity*
- *Pressure and depth (optional)*
- *Current profiling (optional)*

MEASURING WATER IN MOTION AND MOTION IN WATER

TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Navigator

DOPPLER VELOCITY LOG (DVL)

Technical Specifications

Model	WHN 300	WHN 600	WHN 1200
Bottom Velocity			
Single-ping precision			
Std dev at 1m/s[1]	*±0.3cm/s*	*±0.3cm/s*	*±0.3cm/s*
Std dev at 3m/s[1]	*±0.6cm/s*	*±0.5cm/s*	*±0.4cm/s*
Std dev at 5m/s[1]	*±0.8cm/s*	*±0.6cm/s*	*±0.5cm/s*
Long-term accuracy	*±0.4%±0.2cm/s*	*±0.2%±0.1cm/s*	*±0.2%±0.1cm/s*
Minimum altitude[2]	*1.0m*	*0.7m*	*0.5m*
Maximum altitude[2]	*200m*	*90m*	*30m*
Parameters			
Velocity range[3]	*±10m/s*	*±10m/s*	*±10m/s*
Velocity resolution	*0.1cm/s*	*0.1cm/s*	*0.1cm/s*
Ping rate	*7Hz max*	*7Hz max*	*7Hz max*
Water Reference Velocity			
Accuracy	*±0.4% ±0.2cm/s*	*±0.3% ±0.2cm/s*	*±0.2% ±0.1cm/s*
Layer size	*selectable*	*selectable*	*selectable*
Minimum range	*1m*	*0.7m*	*0.25m*
Maximum range	*110m*	*50m*	*18m*
Environmental			
Operating temperature	*-5 to 45°C*	*-5 to 45°C*	*-5 to 45°C*
Storage temperature	*-30 to 75°C*	*-30 to 75°C*	*-30 to 75°C*
Depth rating	*3000m or 6000m*		
Weight in air: 3000m	*15.8kg*	*15.8kg*	*12.4kg*
6000m	*20.1kg*	*20.1kg*	*18.0kg*
Weight in water: 3000m	*8.8kg*	*8.8kg*	*6.1kg*
6000m	*13.6kg*	*13.6kg*	*12.1kg*
Power			
DC input	*20–50VDC, external supply (48VDC typical)*		
Current	*0.4A minimum power supply capability*		
Transmit[4]			
Peak power @ 24VDC	*66w*	*21w*	*8w*
Average power (typical)	*8w*	*3w*	*3w*

[1]Standard deviation refers to single-ping horizontal velocity, specified at half the maximum altitude.
[2]@5°C and 35 ppt, 42VDC.
[3]Maximum bottom-tracking range may be reduced due to flow noise at high speed and/or cavitation.
[4]@ 15% duty cycle at peak power (standby 1mW).

Standard Sensors

Compass: ±2° @ 60° dip, 0.5g
Tilt: ±0.5° up to ±15°
Temperature: -5° to 45°C

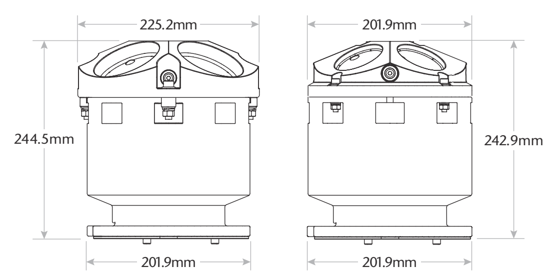
Hardware

Configuration: 4-beam Janus array convex transducer, 30° beam angle
Communications: NMEA0183, ASCII or binary outputs at 1200–115,200 baud user-selectable; serial port is switch-selectable for RS232 or RS422
Trigger inputs: 1) ASCII; 2) RDS3; 3) low latency

Options

- Current profiling firmware upgrade
- Integrated pressure sensor (±0.25% full scale)
- 25m serial/DC/computer cable
- 5m serial/DC/computer cable
- Internal memory cards (2GB max)
- Enhanced low altitude bottom tracking for model 1200

Dimensions



600/300 *1200*

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