Navigator ADCP/DVL
Installation Guide

P/N 957-6178-00 (September 2002)

RD Instruments
Acoustic Doppler Solutions

Table of Contents

1 Introduction **1**

2 Over-the-Side Mounting **2**
2.1 Floating Objects 2
2.2 Example of an Over-the-Side Mount 3
2.3 Over-the-Side Mounting Special Considerations 4

3 In-Hull and ROV Mounting **4**
3.1 Transducer Head Mounting Considerations 5
3.2 Location 5
3.3 Sea Chest In-Hull Mounting 6
3.4 Mounting Considerations 6
3.4.1 How to Mount 6
3.4.2 Orientation 7
3.4.3 Fairing 7
3.4.4 Acoustic Window 7
3.4.5 Air Bubbles 10
3.4.6 Flow Noise 11
3.4.7 Corrosion and Cathodic Disbondment 11
3.4.8 Ringing 11
3.4.9 Acoustic Isolation 12
3.4.10 Interference 13
3.4.11 Maintenance 13
3.5 Cabling Considerations 15

4 Computer Considerations **16**

5 Power Considerations **17**
5.1 Power Consumption 17
5.2 Current Limiting 18
5.3 Choosing a Power Supply 18
5.4 Optional External Battery Pack 18

6 Installation Procedures (Overview) **19**

7 Alignment Procedures (Overview) **19**
7.1 Alignment Jig 20

8 Specifications **21**

9 Outline Installation Drawings **25**
967-6003 Sheet 1 26
967-6003 Sheet 2 27
967-6004 Sheet 1 28
967-6004 Sheet 2 29
967-6006 Sheet 1 30
967-6006 Sheet 2 31
967-1020 32
967-6007 33

List of Figures

Figure 1. Over-the-Side Mount (WorkHorse Sentinel Shown) 2
Figure 2. Mounting an ADCP/DVL to a boat 3
Figure 3. Navigator Mounted on a ROV 4
Figure 4. Sea Chest Mounted Transducer 6
Figure 5. Barnacle Damage to Urethane Face 14
Figure 6. I/O Cable Wiring 16
Figure 7. Transducer Misalignment Reference Points 20

List of Tables

Table 1: Window Thickness 9
Table 2: Wavelength of sound in seawater (1500 m/s sound speed) 10
Table 3: Minimum Computer Hardware Requirements 16
Table 4: Input Voltage vs. Bottom-Track Range 17
Table 5: Navigator Altitude (Uncertainty $\pm$1%) 22
Table 6: Navigator Bottom Velocity (for |V| < 10 m/s) 22
Table 7: Navigator Water Velocity (Reference Layer*) 23
Table 8: Echo Intensity Profile 23
Table 9: Navigator Water Profiling 23
Table 10: Long Range Mode 24
Table 11: Standard Sensors 24
Table 12: Transducer and Hardware 24
Table 13: Environmental 25
Table 14: Power 25
Table 15: Outline Installation Drawings 25

RD Instruments
Acoustic Doppler Solutions

Navigator Installation Guide

1 Introduction

This book is a *guide* for installing the Navigator on a ROV or vessel. Use this section to plan your installation layout. You can also use this book to see what requirements you must consider before purchasing an ADCP/DVL. We recommend you distribute this information to your organization's decision-makers and installation engineers.

We are not experts in installing the Navigator aboard a ship. There are too many installation methods. We suggest you seek expert advice in this area because of its importance in ADCP/DVL performance. However, we can give you information about how others have installed their systems. In return, we do appreciate receiving information about your installation and the results.

CAUTION. Always use caution when mounting the Navigator. Never rest the transducer head on a rough surface. Use foam padding to protect the transducer during handling.

2 Over-the-Side Mounting

The over-the-side mount is common if you want the ability to move the Navigator from one ship to another. You must make the mount as rigid as possible to limit the amount of pitch and roll applied to the ADCP/DVL. Although the tilt sensor can measure a ±20° influence, anything beyond 15° will cause bias to the data that cannot be removed. No matter what mounting type used, the ADCP/DVL must be below the bubble layer. Bubbles will cling to the urethane faces of the ADCP/DVL and reduce the range to almost nothing. Usually a mount somewhere aft of amidship is used. A stern mount will cause all sorts of problems due to propeller wake, bubbles, and turbulent water conditions.

NOTE. Avoid using ferro-magnetic materials in the mounting fixtures or near the ADCP/DVL. They affect the compass. Use 304 stainless steel for fresh water and 316 stainless steel for salt-water applications.

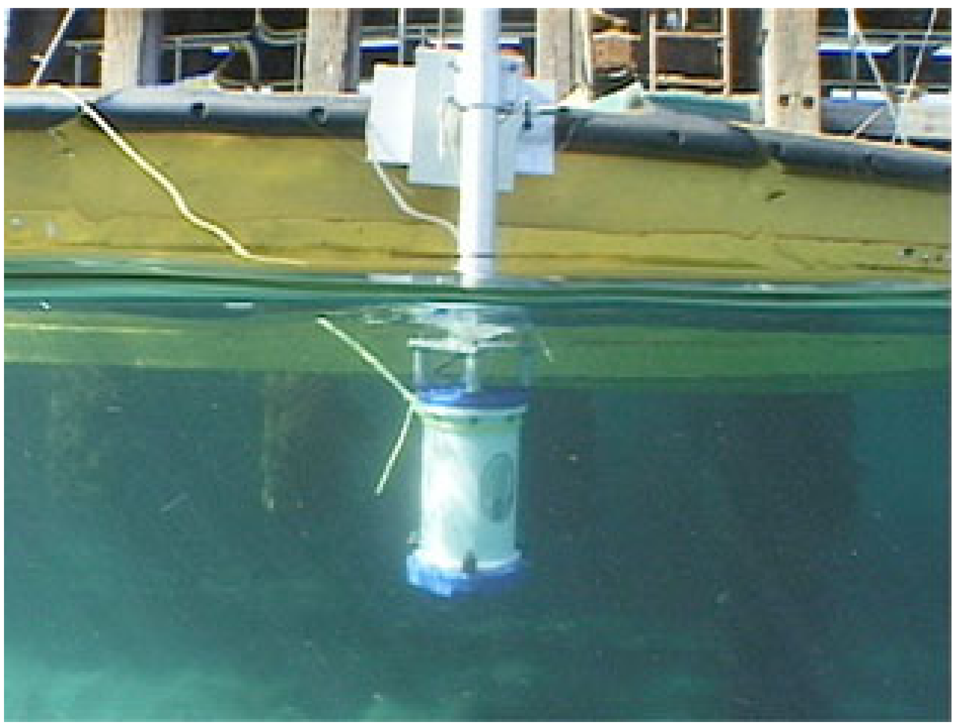


Figure 1. Over-the-Side Mount (WorkHorse Sentinel Shown)
Photo courtesy of John Skadberg, US Navy SPAWAR System Center in San Diego, CA. Sent to RDI by Steve Monismith.

2.1 Floating Objects

Our transducer assembly is sturdy, but we did not design it to withstand collisions with all floating objects. We strongly suggest you use the in-hull mount (see "In-Hull and ROV Mounting," page 4) if this is a possibility.

2.2 Example of an Over-the-Side Mount

When mounting the ADCP/DVL to a boat, use the following sequence.

- Test the ADCP/DVL
- Align the compass
- Mount to the vessel (Figure 2, page 3 shows an ADCP/DVL mounted to a boat).

1. Hand winch with cable or rope.
2. Boat cleat to tie off the lower end of the channel.
3. Aluminum channel, 5" base x 2" high x 3/16" thick. You need to determine how long the channel needs to be as the drawing is not to any scale. The channel should be notched for the end-cap flange of the Housing Assembly. This will give the system a positive lock after the ADCP/DVL has been strapped to the channel.
4. Pivot housing - This could be a very heavy one-piece bent housing, or a three-piece assembly. Bolt the pivot housing to the deck of the boat (or buoy).
5. Nylon strap clamps - Two clamps are needed. Place some rubber or foam between the housing and the aluminum channel before clamping to protect the ADCP/DVL.

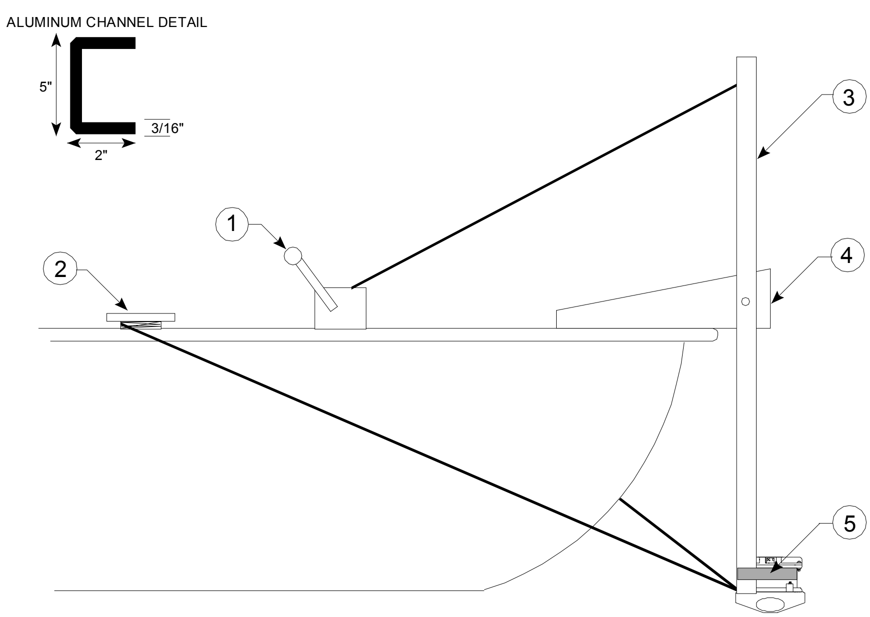


Figure 2. Mounting an ADCP/DVL to a boat

2.3 Over-the-Side Mounting Special Considerations

Use the following suggestions when mounting the ADCP/DVL to a moving platform.

- It is desirable to rigidly mount the ADCP/DVL to the vessel. You want to avoid the free spinning of the ADCP/DVL in this application. The ADCP/DVL must stay in the water at all times.
- The ADCP/DVL must be mounted deep enough so that turbulence caused by its movement through the water does not allow air bubbles to be attached to the transducer faces.
- Avoid mounting the ADCP/DVL near motors and thrusters. They cause air bubbles and will cause bias to the internal compass.
- Avoid mountings that will cause the ADCP/DVL to see severe accelerations.

3 In-Hull and ROV Mounting

The in-hull or ROV mounted ADCP/DVL is common when it is intended to keep the system on a single vessel or when over-the-side mounting is not practical for your vessel. For this type of mounting, there are issues of beam clearance and access.

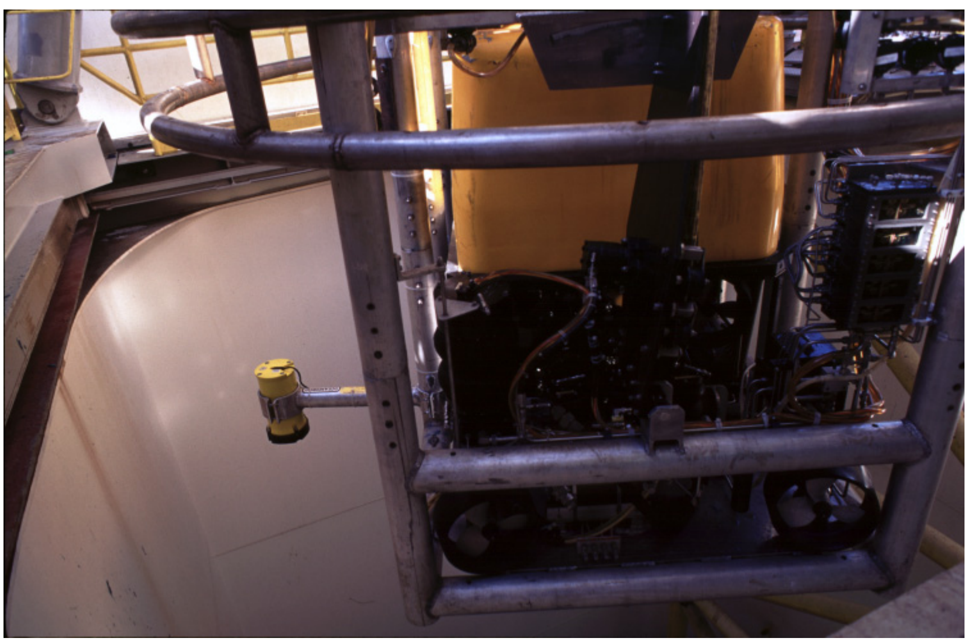


Figure 3. Navigator Mounted on a ROV

3.1 Transducer Head Mounting Considerations

You must consider several potential problems before installing the transducer head assembly. Read this section before deciding where to install the transducer assembly. See the outline installation drawings for specifications on our standard ADCP/DVL transducer heads.

3.2 Location

Ideally, you want to install the transducer head:

- Where it is accessible both internally (for access to transducer electronics) and externally (to remove biofouling).
- Away from shipboard protrusions that reflect ADCP/DVL energy. Allow for a reflection-free clearance of 15° around each beam (see the outline installation drawings).
- Away from other acoustic/sonar devices, especially those operating at the same frequency (or harmonic) of the ADCP/DVL.
- Close to the ship's fore-to-aft centerline. As distance from the centerline increases, vertical accelerations caused by the roll of the ship also increase. These accelerations can cause additional uncertainties in ADCP/DVL velocity measurements.
- As far away as possible from thrusters and motors.
- If mounting to a ROV that tends to kick up sediment, mount the DVL as far forward as possible.

Other considerations may be:

- Ease of installation.
- Portability (wanting to move the instrument from vessel to vessel).
- Permanent installation.

With all of these choices there are good and bad points. We will show you several options for installation and then go through specific concerns that you may have to deal with once you install or mount the Navigator.

3.3 Sea Chest In-Hull Mounting

A sea chest (Figure 4) is a fixture that surrounds and holds the transducer head, protecting it from debris in the water. The bottom of the sea chest must be open to seawater to allow the acoustic beams to pass through freely. If using a sea chest interests you, call us for the latest information. Ask for Application Note 7 - Conceptual Design of a Sea Chest for an RDI ADCP/DVL Transducer.

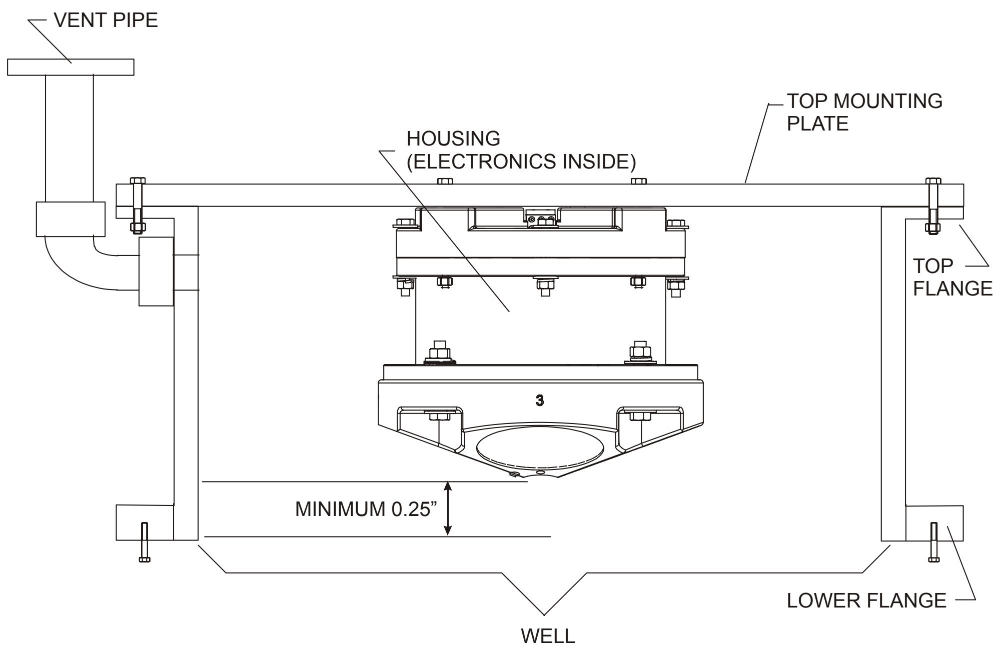


Figure 4. Sea Chest Mounted Transducer

3.4 Mounting Considerations

Now that we have shown you the main methods of mounting the ADCP/DVL, you must be aware of issues that may cause reduction in range, biased data, fouling, and other performance related considerations.

3.4.1 How to Mount

The DVL should be mounted from the end cap or by a clamp around the body. The mounting surface should be electrically isolated from the DVL (i.e. with rubber between the touching surfaces). This is to ensure that the sacrificial anode works on the DVL and not the clamps.

There are four bolt holes on the 300/600kHz end-cap/housing assembly that can be used for mounting. There are eight bolt holes used to hold the 1200kHz end cap on. For mounting, it is recommended that only four of the bolts are removed from the end cap, and use those four bolts for mounting. It is recommended that every other bolt be used.

3.4.2 Orientation

We recommend you mount the transducer head with Beam 3 rotated to a ship-relative angle of 45° (see "Alignment Procedures (Overview)," page 19 and Figure 7, page 20). This causes the magnitude of the signal in each beam to be about the same. This improves error rejection, reduces the effect of ringing (see "Acoustic Isolation," page 12), and increases the ADCP/DVL's effective velocity range by a factor of 1.4. If you align Beam 3 at an angle other than zero, you must nullify this offset. You can do this using the EA command (see the Workhorse Commands and Output Data Format Guide).

Use the ship's roll and pitch reference to mount the transducer head as level as possible. If the head is not level, depth cell (bin) mapping will be incorrect. Large misalignments can cause large velocity measurement errors. If you cannot mechanically make the transducer head level, you can use a direct command to enter offset values for roll and pitch.

3.4.3 Fairing

A fairing is a structure that produces a smooth outline and reduces drag or water resistance. The fairing also diverts floating objects away from the transducer. A fairing that is shaped like a teardrop, sloped such that the leading edge (closer to the bow) is higher than the back edge, and extends below the hull (typically 12 inches) will divert the air bubbles away from the transducer faces.

3.4.4 Acoustic Window

While we do not fully understand windows, we do believe that windows can be used to produce overall performance improvements in vessel-mounted ADCP/DVLs. Additionally, if the ship operates where there is danger of barnacle damage or a high density of ice or other floating objects, then the use of an acoustic window is the only option.

It is theoretically possible to use a window successfully, however there are several advantages and disadvantages to consider before using an acoustic window.

Advantages

- Well will not fill with air bubbles caused by the ship moving through the surface water, see "Sea Chest In-Hull Mounting," page 6
- Flow noise is reduced, see "Flow Noise," page 11.
- The well can be filled with fresh water to limit corrosion.

- Barnacles can not grow on the transducer faces. Barnacle growth is the number one cause of failure of the transducer beams.
- The transducer is protected from debris floating in the water.

Disadvantages

- The range of the ADCP/DVL will be reduced because the window can and will absorb some of the transmit and receive energy.
- The transmit signal could be reflected into the well, causing the well to "ring" like a bell. This will cause the data being collected during the ringing to be biased. Some ships have reported a loss in range as great as 50 meters. The ringing may be damped by applying sound absorbing material on the well walls (standard neoprene wet suit material has been found to work well), see "Ringing," page 11.
- The transmit signal could be reflected off the window and back into the other beams.

Our experience has allowed us to put together some minimum specific recommendations:

Window orientation. The acoustic window should be flat and parallel to the transducer mounting plate. Note this is not an absolute requirement. However, if the water temperatures inside the window and outside the window are not the same, all four beams will be refracted and actual velocity components will be rotated into a new coordinate system. In particular, some of the horizontal velocity will appear as a vertical velocity.

Window material. Important acoustic properties of the window include acoustic refractive index (which should be as close as possible to that of water), insertion loss (which should be as small as possible) and speed of sound. There are two acoustic refractive indices: one for shear waves and one for plane waves. The acoustic refractive indices are simply the ratios of speed of sound in water to speed of sounds in the material. Insertion loss combines absorption and reflection of sound, and it depends on both the thickness and the material properties of the window. In particular, you should avoid using window thickness equal to odd multiples of shear mode quarter-waves (Dubbelday and Rittenmeyer, 1987; Dubbleday, 1986). Refer to Selfridge (1985) and Thompson (1990) for more information. Note that the speeds of sound in plastics decrease with increasing temperature and that causes the resonant frequencies to shift. This can be a large effect. Neither Selfridge nor Thompson has much information on the temperature coefficients of sound speeds.

Our experience has shown that Polycarbonate windows are very good for the WorkHorse ADCP/DVLs. The thickness of the materials depends on the frequency you intend to use. Table 2 will help to choose the maximum thickness you should use.

NOTE. One concern with window selection is that it be able to support the weight of the water inside the well once the ship is dry-docked. RDI recommends that you always fill/drain the well at the same time that you are either filling/draining the dry dock area.

Table 1: Window Thickness

Frequency	Thickness
300	0.5 inches
600	0.25 inches
1200	0.25 inches

Spacing between window and transducer. The primary geometrical factor in design of windows is the reflection of a beam into another beam, causing crosstalk between the beams. The distance of the transducer from the window should be at least 0.25 to 0.5 inches. If installed farther than 0.25 to 0.5 inches, then be sure your window aperture is large enough to clear the OD convex beams.

The optimum distance for the bottom of the transducer assembly from the window is 0.25 inches ±0.125 inches. Never allow the transducer to touch the window. The farther away the transducer is from the window, the more the sound is reflected off of one beam and then reflected into another beam.

Example

One of our representatives uses a 0.25-inch thick window. He then drills two 30mm holes in the window along the edges. The inside walls are painted with anti-fouling paint. This allows the water to be full of anti-foulant during the time the ship is docked, which is when the barnacle growth occurs. The holes allow the water to exchange when the ship is in motion and allows for draining when the ship is dry-docked (a 0.25” window will not support the weight of the water). He has never had a failure with the window, and has seen only a minimal loss in range (5-30 meters).

It is best if the window is parallel to the bottom edge of the transducer. If the window is at an angle to the transducer, it will change the absorption. We do not have experience with different angles, but we have had customers use domes or have the window follow the contour of the ship bottom without noticeable degradation of the data.

Acoustically-absorbing sea chest liner. A sound absorbing material should be used inside the sea chest to minimize the effects of sound ringing within the sea chest. The material should be a minimum of one wavelength thick (include the sound speed of the absorbing material when calculating the size of a wavelength). Approximate wavelengths of sound in seawater are given below in Table 3. Using standard neoprene wet suit material has been found to work well with 300 and 600hKz frequency ADCP/DVLs.

Table 2: Wavelength of sound in seawater (1500 m/s sound speed)

FREQUENCY (kHz)	WAVELENGTH (mm)
300	5
600	2.5
1200	1.25

Fluid in the sea chest. The sea chest should be filled with fresh water. Seawater can be used, but at the cost of increased corrosion. Seawater should not be circulated through the sea chest unless the sea chest has been painted with anti-fouling paint. The pressure within the sea chest should be adjusted to keep the window from bowing in and out, and thereafter, the volume should be kept constant.

3.4.5 Air Bubbles

Design your installation to minimize the volume of air bubbles in the path of the acoustic beams. Air bubbles attenuate (weaken) the signal strength and reduce the ADCP/DVL profiling range. Ships with a deep draft or a non-flat bottom have fewer problems with bubbles. Ways to reduce bubble flow vary with ship characteristics, but two options are available. Mount the transducers below or away from the bubble layer.

- The flow layer is usually within the first two feet below the hull. Bubbles can get trapped in this layer. Mounting the transducer head amidship on the fore-to-aft centerline may help. For ships with propulsion systems that make large amounts of bubbles, use a mounting technique that lets you lower the transducer head below the hull while underway.

> **NOTE.** If you use locally made or existing extension hardware instead of the hardware available from RDI, you may need to make an adapter plate to connect your hardware to our transducer head. Please call us for the exact dimensions and layout of our transducer head bolt holes for your system.

- Divert the bubble layer so it flows around the transducers - You can use fairings to alter the bubble flow. An acoustic window (see "Acoustic Window," page 7) may help reduce the bubble problem, but can cause ringing (see "Acoustic Isolation," page 12) and attenuation problems.

3.4.6 Flow Noise

Water flowing over the transducer faces increases the acoustic noise level, which decreases the profiling range of the ADCP/DVL. You can reduce the flow across the transducer faces with a sea chest, fairing, or acoustic window.

3.4.7 Corrosion and Cathodic Disbondment

Your ADCP/DVL is made of naval bronze, aluminum, or other materials. Standard anode protection used for the ship should be installed outside of the well of the transducer head. Mounting of ship's standard anode protection outside of the transducer well will typically protect the parts that may corrode. However, you should plan regular inspections of mounting hardware for signs of corrosion. Replace and parts that are questionable (corrosion can be further reduced if the well is covered with a window and then filled with fresh water).

3.4.8 Ringing

The ADCP/DVL transmits an acoustic pulse into the water. The main lobe of this pulse bounces off particles in the water and the signals returned from these particles are used to calculate the velocity of the water.

As stated, the main lobe of the transmitted pulse is what we are using to process and calculate a velocity. The transmitted pulse, however, is made up of many side lobes off the main lobe. These side lobes will come in contact with metal of the transducer beam itself and other items in either the water or the well.

The energy from the side lobes will excite the metal of the transducer and anything bolted to the transducer. This causes the transducer and anything attached to it to resonate at the system's transmit frequency. We refer to this as "ringing."

If the ADCP/DVL is in its receive mode while the transducer is ringing then it will receive both the return signals from the water and the "ringing." Both of these signals are then processed by the ADCP/DVL. The ringing causes bias to the velocity data.

All ADCP/DVLs "ring" for some amount of time. Therefore, each ADCP/DVL requires a blanking period (time of no data processing) to keep from processing the ringing energy. Each ADCP/DVL frequency has a different typical ringing duration. The typical ringing period for each ADCP/DVL frequency is as follows; 300kHz ADCP/DVLs is 2 meters, 600kHz ADCP/DVLs is 1.5 meters, and 1200kHz ADCP/DVLs is 0.8 meters. These typical ringing values are recommended as the minimum setting for all ADCP/DVLs using default setups.

It should be noted, on some installations the effects of ringing will last longer than the recommended settings above. For example, the effects of ringing will last longer if the transmit signal becomes trapped inside the transducer well. This can occur because the well itself is ringing with the transducer or when windows covering the opening of the well reflect the signal back inside the well.

The window causes the transmit signal to reflect back into the well due to the difference in impedance between the window and the water. When the transmit signal is reflected in the well it becomes trapped and this results in longer ringing periods. To keep from processing this signal, the blanking period must be increased.

Line the inside walls of the well with a sound absorbing material to damp the ringing effect. Using standard neoprene wet suit material has been found to work well.

3.4.9 Acoustic Isolation

Try to minimize the acoustic coupling between the transducer head and the ship. Without adequate acoustic isolation, the transducer output will "ring" throughout the ship and feeds back into the ADCP/DVL receive circuits. Ringing causes bias errors in water-track velocities and results in the loss of data in the closest depth cells (bins). Reflections inside a sea chest with an acoustic window also can cause ringing.

You can attain acoustic isolation several ways. At a minimum, use gaskets to isolate all contact points between the ship and the transducer head. Design your installation for:

- A minimum number of contact points between the transducer head and the ship.
- Minimal contact area.
- Single points of contact for positioning and support (when possible).

You also should try to separate the transducer head from the ship using intermediate connections. This is because direct connections transfer the most acoustic energy. Texas A & M used the following installation technique and had minimal ringing problems.

- Transducer mounted to a thin steel plate
- Steel plate positioned with three pins set into mounting holes on the hull; pins isolated with gaskets
- Steel plate held in place with four I-beams welded to a frame
- Frame bolted to another frame and separated by gaskets

- Second frame bolted to the ship and separated by gaskets

Acoustic isolation from other acoustic devices on the ship is also necessary. You can do this using the following techniques.

- Mount the other acoustic devices as far apart as possible.
- Make sure neither the main lobes nor the side lobes of the acoustic devices point at the transducers, including acoustic reflections.
- Try not to operate devices that use the same frequency or a harmonic of the ADCP/DVL's frequency.

3.4.10 Interference

Interference from other acoustic devices can cause velocity and direction biases. In extreme cases it the can prevent the DVL from operating. However, it is possible to avoid this circumstance. If the other device operating frequency is within 25% of the operating frequency of the DVL or is an odd multiple of the DVL frequency (e.g. DVL is 307,200Hz, then a third harmonic (multiple) of another device would be 100,000Hz) then you may want to make both devices transmit at the same time. By transmitting at the same time the two systems usually do not interfere.

The DVL transmits a pulse or series of pulses that contain four carrier cycles. The transmit bandwidth is 25% (Sin χ / χ) and the front end receive bandwidth is determined by the transducer and is 40% about the carrier frequency.

3.4.11 Maintenance

The Maintenance guide explains routine maintenance procedures. You rarely need access to the electronics inside the transducer head. However, one external maintenance item is important enough to mention here as it may affect how you install the transducer head.

Objects deployed within about 100 meters (328 feet) of the surface are subject to the buildup of organic sea life (biofouling). This means WorkHorse Navigators are subject to biofouling. Soft-bodied organisms usually cause no problems, but hard barnacle shells can cut through the urethane transducer face causing transducer failure and leakage into the ADCP/DVL (see Figure 5, page 14).

Figure 5. Barnacle Damage to Urethane Face

The best-known way to control biofouling is cleaning the ADCP/DVL transducer faces often. However, in many cases this is not possible. The other alternatives include the use of a window or some sort of anti-foulant protection.

Some of our users have had success applying a thin coat (≈4 mm; ≈0.16 in.) of either a 50:50 mix of chili powder and Vaseline or chili powder and silicone grease to the transducer faces. The chili powder should be the hottest that can be found. Water flowing across the transducers will wash this mix away over time. The silicone mixture tends to last longer.

Some organizations may decide to use antifouling grease. However, most antifouling greases are toxic and may cause problems. Recent tests suggest antifouling grease may cause the urethane on the transducer faces to develop cracks. Warmer temperatures accelerate this effect.

The other method is to use antifoulant paint. At present, we recommend the following antifouling paint manufacturer and paint brand: Courtalds Finishes Interlux brand paints, US Telephone: 908-686-1300, Web Page: www.interlux.com.

CAUTION.

1. Read the Material Safety Date Sheet before using any of the listed solvents and paints.
2. Some antifouling coatings may not be legal for use in all areas. Check with your local environmental agency before using the antifouling paint.
3. Do not arbitrarily use antifouling paints. Be aware that antifouling paints can accelerate the dezincification corrosion of brass. Once initiated, dezincificatioin will rapidly destroy the brass.
4. RDI no longer recommends the use of Nopcocide for the prevention of biofouling. If using antifouling grease, remove it immediately after recovering the ADCP/DVL.
5. Antifouling grease is toxic. Read the product safety data sheet before using the grease. Wear gloves and a face shield when applying the grease. If the skin comes in contact with the grease, immediately wash the affected area with warm, soapy water.
6. When possible, do not coat the transducer faces with cuprous oxide or related paints that contain chemicals such as copper, chrome, or arsenic. These paints advance the corrosion of the transducer assembly and will cause the urethane to separate from the transducer cups.
7. All US Coastal States prohibit the use of tributyl-tins on boat hulls. The European Economic Commission has released a draft directive that would prohibit the use of many organo-tins after July 1989. We strongly recommend you obey your local laws.

3.5 Cabling Considerations

Use care when routing the Input/Output (I/O) cable through bulkheads, deck plates, cable runs, and watertight spaces. Make allowances in cable length and engineering design plans for cable routing. When necessary, use strain reliefs on the cable.

The Navigator is shipped with a pigtail I/O cable. The I/O cable connects the transducer head to the computer. The transducer-end connector is molded on, so you can use it below the waterline. Determine what communication setting you will be using and the connector type required (not supplied by RDI) and wire the pigtail cable as shown in Figure 6, page 16. The cable is custom-made in lengths specified by the user. Route this cable so:

- It does not have kinks or sharp bends.
- You can easily replace it if it fails.

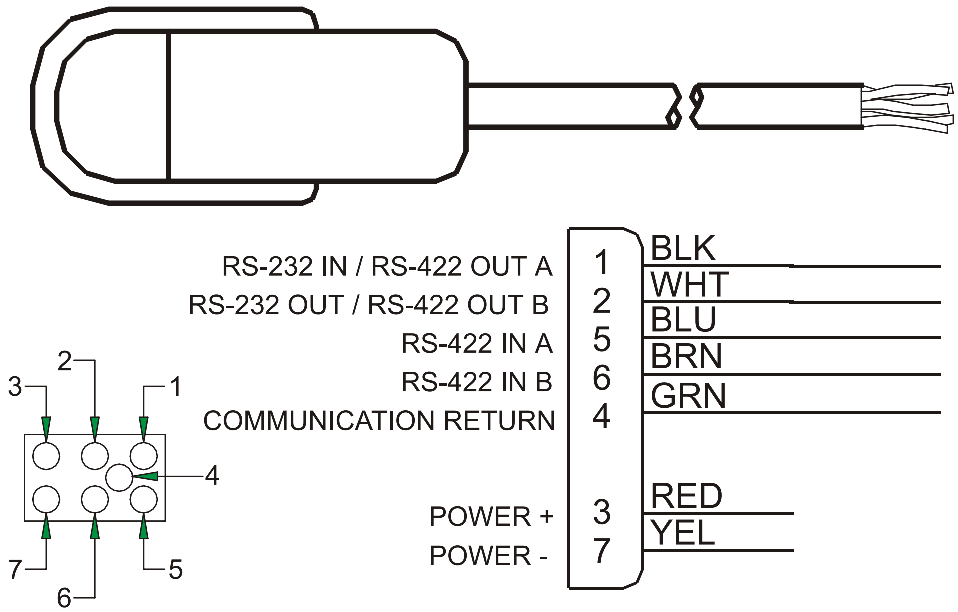


Figure 6. I/O Cable Wiring

> **NOTE.** Color code is shown for reference only. Your cable may be different.

The I/O end-cap connector part number is LPMBH-7-MP from Impulse. The connector on the cable has to be an LPMIL-7-FS. It has 7 pins: two power lines, five for RS422, or three RS232 and two RS485.

4 Computer Considerations

We designed the Navigator ADCP/DVL to use a Windows® compatible computer. The computer controls the ADCP/DVL and displays its data, usually through our *BBTalk* or *SHIPTRAK* (DOS only) programs. Table 4 lists the minimum computer requirements.

Table 3: Minimum Computer Hardware Requirements

Windows 95®, Windows 98®, Windows NT 4.0® with Service Pack 4 installed, Windows 2000®, or Windows XP®
Pentium class PC 233 MHz (350 MHz or higher recommended)
32 megabytes of RAM (64 MB RAM recommended)
6 MB Free Disk Space (20 MB recommended)
One Serial Port (two or more High Speed UART Serial Port recommended)
Minimum display resolution of 800 x 600, 256 color (1280 x 760 High Color recommended)
CD-ROM Drive
Mouse or other pointing device

5 Power Considerations

The AC power adapter provided by RDI is designed for testing where AC power is available. It provides up to 30 watts at 48 VDC. For deployments, the Navigator requires a power supply designed to supply between 20 to 50 VDC, 25 watts. Navigator power requirements are discussed below.

Sonar performance depends on supply voltage, but not very strongly. The processing electronics use a DC/DC converter so their function is independent of the supply voltage over the 20 to 50 volt range. However, the raw supply voltage is provided directly to the transmitter so that the transmitted acoustic power is proportional to V_{in}^2. Table 5 shows the bottom-track range (assuming a salinity of 35 ppt and temperature of 5° C) versus supply voltage:

Table 4: Input Voltage vs. Bottom-Track Range

Power Supply Voltage (VDC)	Bottom-Track Range (meters)		
	1200kHz	600kHz	300kHz
20	23	90	237
24	24	92	245
30	25	95	253
40	26	99	262
50	27	101	268

Many customers have successfully operated the Navigator using 24 volts. It may be worth the cost of providing a higher supply voltage to achieve the maximum bottom-tracking range.

5.1 Power Consumption

The average power drawn by a Navigator pinging at its maximum rate at maximum altitude is 3 Watts for a 1200kHz, 5 Watts for a 600kHz and 16 Watts for a 300kHz. This is based on an input voltage of 32 volts. There is a constant background power consumption of 2.2 watts for the processing electronics as long as the Navigator does not “go to sleep.”

The average power consumption depends upon the transmit duty cycle which is a function of many factors. For a Navigator pinging at its maximum rate, the maximum duty cycle is about 13%. By reducing the ping rate, the duty cycle is reduced and therefore overall power consumption may be reduced.

The Navigator contains a capacitor that provides filtering of the high power consumption during transmit. This means that the Navigator should not be adversely affected by reasonable variations in the power supply voltage. It also means that the Navigator should not unduly affect the power supply circuit.

5.2 Current Limiting

Peak current drawn by the Navigator is never more than 3 amps due to a current limiting circuit that is provided to prevent blowing a 3 amp internal fuse. At start up this translates to 96 Watts at 32V input.

Note that the power supply must be able to provide at least 10 volts continuously at a current draw of 0.4 amps to get the processor started.

5.3 Choosing a Power Supply

There are two keys to choosing a power supply for the Navigator:

- Including loss in the wiring, the power supply must be able to supply more then 10 Volts to the Navigator's input connector if the there is 0.4 amp being drawn by the Navigator. This is the minimum voltage needed to start the Navigator.
- Should the supply current limit *it must not turn it's output completely off*. The power supply should maintain current flow into the Navigator ("fold back", not "hiccup"). If the supply turns off to protect itself, it will cause the Navigator's internal discharge circuit to discharge the internal capacitors and the Navigator will not start.

CAUTION. When using an external DC power supply, set the power supply to the proper voltage BEFORE connecting it to the Navigator, and then turn the power supply OFF when connecting it to the Navigator. Do NOT exceed the rated voltage or equipment damage may occur.

5.4 Optional External Battery Pack

If both the optional External Battery Pack and power supply are connected, the Navigator will select the *highest* voltage source for use. The External Battery Pack (when fresh) supply +42 VDC and the AC power adapter output is +48 VDC.

NOTE. The AC Adapter input voltage is sufficient to override the optional external battery voltage (i.e. the ADCP will draw all power from the AC adapter even if the battery is installed and connected).

6 Installation Procedures (Overview)

Read these steps before doing them. In general, follow them in the order listed. Some may differ for your installation, so modify them as necessary. Some can be done simultaneously (e.g., hardware installation and software loading). If you have problems or questions, call us.

a. On receipt of the system, read the Read This First book.

b. Before installing the system, test the transducer right out of the shipping container. Do the following.

   1. All power to the system DISCONNECTED.
   2. Review "Power Considerations," page 17.
   3. Connect the I/O cable from the computer to the ADCP/DVL.
   4. Connect the power cable to the I/O cable connector and apply power to the system (the Navigator User's Guide shows all cable connections for testing).
   5. Follow testing procedures in the Test Guide. Test the system. If errors occur, use the Troubleshooting book.

c. Prepare the system for shipboard installation. Disconnect all power to the system. Disconnect all interface cables.

d. Review "Transducer Head Mounting Considerations," page 5. Install the transducer head. Mechanically align the system (see "Alignment Procedures (Overview)," page 19).

e. Review "Computer Considerations," page 16. Install the computer.

f. Review "Cabling Considerations," page 15. As necessary, route and connect the I/O cable.

g. As necessary, load the software on the computer's hard drive. See the Navigator User's Guide for help on using the software.

h. Do the Sea Acceptance testing (see the Test Guide). The Sea Acceptance tests include a Bottom-track (range, accuracy) check.

7 Alignment Procedures (Overview)

The mechanical alignment of the transducer head is important to ADCP/DVL data accuracy. Mechanically mount the head as close as possible to your reference point. This is usually with the Beam 3 mark at 0° or 45° relative to the ship's fore-to-aft centerline. You also must mount the transducer head as level as possible using the ship's roll and pitch references. Review the "Transducer Head Mounting Considerations," page 5 for alignment considerations.

When the Navigator is aboard a vessel, the mechanical alignment of the transducer head (Beam 3 mark) is usually aligned with the ship's fore-to-aft centerline (0°), or rotated 45° clockwise. To conceptually determine the misalignment angle, visually hold the ADCP/DVL still and turn the ship gyro's north reference to match the ADCP/DVL's north reference. For example, if the Beam 3 mark is pointing at the bow (Figure 7), the misalignment angle is zero. If the Beam 3 mark is pointing 45° to starboard (Figure 7), you must turn the ship a +45° to align the two north reference points. Conversely, if the Beam 3 mark is pointing 45° to port, you must turn the ship a -45° to align the two reference points.

NOTE. We recommend you mount the Navigator with Beam 3 rotated to a ship-relative angle of 45°. This causes the magnitude of the signal in each beam to be about the same. This improves error rejection, reduces the effect of *ringing*, and increases the Navigator's effective velocity range by a factor of 1.4.

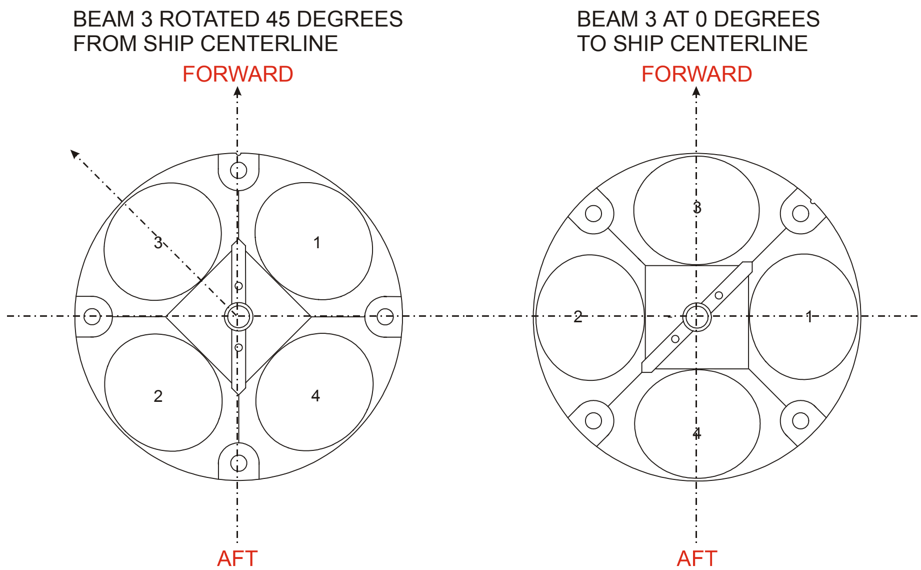


Figure 7. Transducer Misalignment Reference Points

7.1 Alignment Jig

The alignment jig is a straight bar with two screw holes to attach it to the transducer head. Use the jig to help you align the transducer. Mount the transducer in the mounting frame/hardware but allow the transducer to still be able to be rotated. Attach the jig to the transducer using the provided screws. Use the jig to rotate the transducer to the proper angle. Tighten the mounting hardware so that the transducer will not rotate.

NOTE. If your Navigator ADCP/DVL has the optional pressure sensor, the pressure sensor will interfere with the alignment jig.

8 Specifications

A brief review of ADCP/DVL operation may help you understand the specifications listed in this section.

> **NOTE.** The specifications and dimensions listed in this section are subject to change without notice.

The ADCP/DVL emits an acoustic pulse called a PING. Scatterers that float ambiently with the water currents reflect some of the energy from the ping back to the ADCP/DVL. The ADCP/DVL uses the return signal to calculate a velocity. The energy in this signal is the *echo intensity*. Echo intensity is sometimes used to determine information about the scatterers.

The velocity calculated from each ping has a *statistical uncertainty*; however, each ping is an independent sample. The ADCP/DVL reduces this statistical uncertainty by averaging a collection of pings. A collection of pings averaged together is an *ensemble*. The ADCP/DVL's maximum *ping rate* limits the time required to reduce the statistical uncertainty to acceptable levels.

The ADCP/DVL does not measure velocity at a single point; it measures velocities throughout the water column. The ADCP/DVL measures velocities from its transducer head to a specified range and divides this range into uniform segments called *depth cells* (or *bins*). The collection of depth cells yields a *profile*. The ADCP/DVL produces two profiles, one for velocity, and one for echo intensity.

The ADCP/DVL calculates velocity data relative to the ADCP/DVL. The velocity data has both speed and direction information. If the ADCP/DVL is moving, and is within range of the bottom, it can obtain a velocity from returns off the bottom. This is called *bottom tracking*. The bottom track information can be used to calculate the absolute velocity of the water. The ADCP/DVL can get absolute direction information from a heading sensor.

The following tables list the specifications for the WorkHorse ADCP/DVL. About the specifications:

a. All these specifications assume minimal ADCP/DVL motion - pitch, roll, heave, rotation, and translation.

b. Except where noted, this specification table applies to typical setups and conditions. Typical setups use the default input values for each parameter (exceptions include Pings Per Ensemble and Number of Depth Cells). Typical conditions assume uniform seawater velocities at a given depth, moderate shear, moderate ADCP/DVL motion, and typical echo intensity levels.

c. The total measurement error of the ADCP/DVL is the sum of:

- Long-term instrument error (as limited by instrument accuracy).
- The remaining statistical uncertainty after averaging.
- Errors introduced by measurement of ADCP/DVL heading and motion.

d. Because individual pings are independent, the statistical uncertainty of the measurement can be reduced according to the equation:

$$\frac{\text{Statistical Uncertainty for One Ping}}{\sqrt{\text{Number of Pings}}}$$

Table 5: Navigator Altitude (Uncertainty±1%)

System Frequency	1200kHz	600kHz	300kHz
Maximum Altitude (m)	30	90	200
Minimum Altitude (m)	0.5	0.7	1.0

Table 6: Navigator Bottom Velocity (for |V| < 10 m/s)

Precision (cm/s)*	1200 kHz	600 kHz	300 kHz
V=1.0 m/s	0.3	0.3	0.3
V=3.0 m/s	0.4	0.5	0.6
V=5.0 m/s	0.5	0.6	0.8
Accuracy (cm/s)	±0.2% ±0.2	±0.3% ±0.2	±0.4% ± 0.4
Maximum Ping Rate**	1 to 10 Hz	0.5 to 7 Hz	0.5 to 7 Hz

* Water and Bottom velocity precision are standard deviations of horizontal velocities for single pings. The standard deviation for an ensemble of pings will decrease proportional to the square root of the number of pings averaged together.

* Single Ping Precision calculated for an altitude of one-half maximum altitude for a given frequency.

** Ping rates vary due to altitude, baud rate, and amount of water profiled.

Table 7: Navigator Water Velocity (Reference Layer*)

Range limits(m)	1200 kHz	300 kHz
Minimum	0.25	1.0
Maximum	18	110
Short-term error: Precision (cm/s)**		
Ref. Layer Size=1.0 m	6	15
Ref. Layer Size=2.0 m	5	9
Ref. Layer Size=4.0 m	3	6
Ref. Layer Size=8.0 m	2	5
Long-term Error: Accuracy (cm/s)	±0.2% ±0.01	±0.4% ±0.4
Ping Rate***	1 to 10 Hz	0.5 to 7 Hz

* Reference layer maximum ranges are for typical water conditions: 35% salinity, 10°C temperature.

** Water and Bottom velocity precision are standard deviations of horizontal velocities for single pings. The standard deviation for an ensemble of pings will decrease proportional to the square root of the number of pings averaged together.

** Single Ping Precision calculated for an altitude of one-half maximum altitude for a given frequency.

*** Ping rates vary due to altitude, baud rate, and amount of water profiled.

Table 8: Echo Intensity Profile

Vertical resolution	Depth cell size
Dynamic range	80 dB
Precision	± 1.5dB (relative measure)

Table 9: Navigator Water Profiling

Depth Cell Size[1]	Nominal range 15m[2] 1200kHz		Nominal range 55m[2] 600kHz		Nominal range 135m[2] 300kHz	
Vertical Resolution	**Range[3] (m)**	**Std. dev.[4] (mm/s)**	**Range[3] (m)**	**Std. dev.[4] (mm/s)**	**Range[3] (m)**	**Std. dev.[4] (mm/s)**
0.25m	12	182				
0.50m	13	66	40	182		
1.0m	15	30	45	66	97	182
2.0m	16	18	50	30	110	66
4.0m			56	18	123	30
8.0m					138	18

NOTES

1. User's choice of depth cell size is not limited to the typical values specified.
2. Longer ranges are available.
3. Range, which depends on cell size, is specified here for BroadBand mode at 5° C, typical ocean back-scatter, and nominal 48 VDC power.
4. Broad bandwidth mode single-ping standard deviation

NOTE. Water Profiling is an upgrade feature for the Navigator.

Table 10: Long Range Mode

	Range (m) @ 33VDC	Range (m) @ 48VDC	Depth Cell Size (m)	Std. dev. (mm/s)
1200kHz	19	20	2	35
600kHz	67	70	4	38
300kHz	165	175	8	38

Range, which depends on cell size, is specified here for narrow bandwidth mode at 5° C, typical ocean backscatter, and nominal 33 VDC battery power (Sentinel) and 48VDC input power (Mariner/Monitor).

Table 11: Standard Sensors

Temperature (mounted on transducer)

Range: -5° to 45° C

Precision: ± 0.4° C

Resolution: 0.01°

Tilt

Range: ± 15°

Accuracy: ± 0.5°

Precision: ± 0.5°

Resolution: 0.01°

Compass (fluxgate type, includes built-in field calibration feature)

Accuracy: ± 2°[1]

Precision: ± 0.50[1]

Resolution: 0.01°

Maximum tilt: ± 15°

Note: 1) @ 60° magnetic dip angle, 0.5G total field

Table 12: Transducer and Hardware

	1200kHz	300kHz	600kHz
Available Frequency	1,228,800 actual	307,200 actual	614,400 actual
Beamwidth	1.2°	3.9°	2.0°
Beam Angle	30°		
Configuration	4-beam, convex		
Housing & Transducer material	6061 or 7075 Aluminum or Titanium		
External connector	7-pin low-profile		
Internal memory	Memory card not included with Navigator models. Two PCMCIA card slots are available (16 to 220 Mb each).		
Communications	Serial port selectable by switch for RS-232 or RS-422. ASCII or binary output at 1200 to 115,400 baud.		

Table 13: Environmental

Standard depth rating	2000m (Optional 3000 and 6000-meter housings available)
Operating temperature	-5° to 45°C
Storage temperature	-30° to 75°C
Battery Storage	Batteries should be stored in dry air with a temperature O° C to 21° C
Battery Shelf Life	Use within one year.
Weight in air/water	See outline installation drawings

Table 14: Power

System	Specification
DC input	20 to 60 VDC external power supply
External Battery Pack	42 VDC (new), 28 VDC (depleted). Holds up to two 400 watt hour batteries
Transmit	16W @ 35V (1200kHz), 37W @ 35V (600kHz), 115W @ 35V (300kHz) 22W @ 48V (1200kHz), 60W @ 48V (600kHz), 190W @ 48V (300kHz)

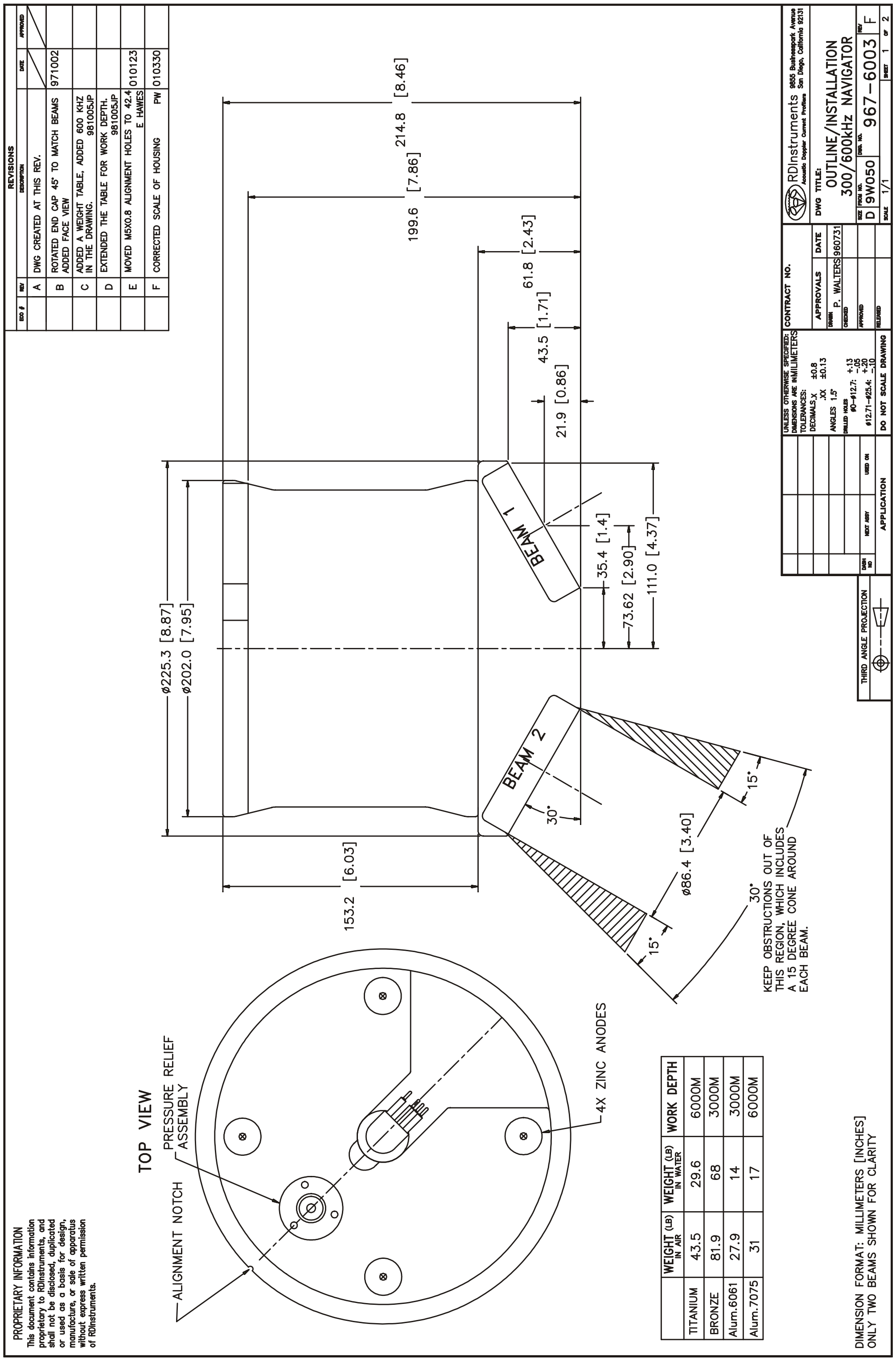
9 Outline Installation Drawings

The following drawings show the standard Workhorse Navigator dimensions and weights.

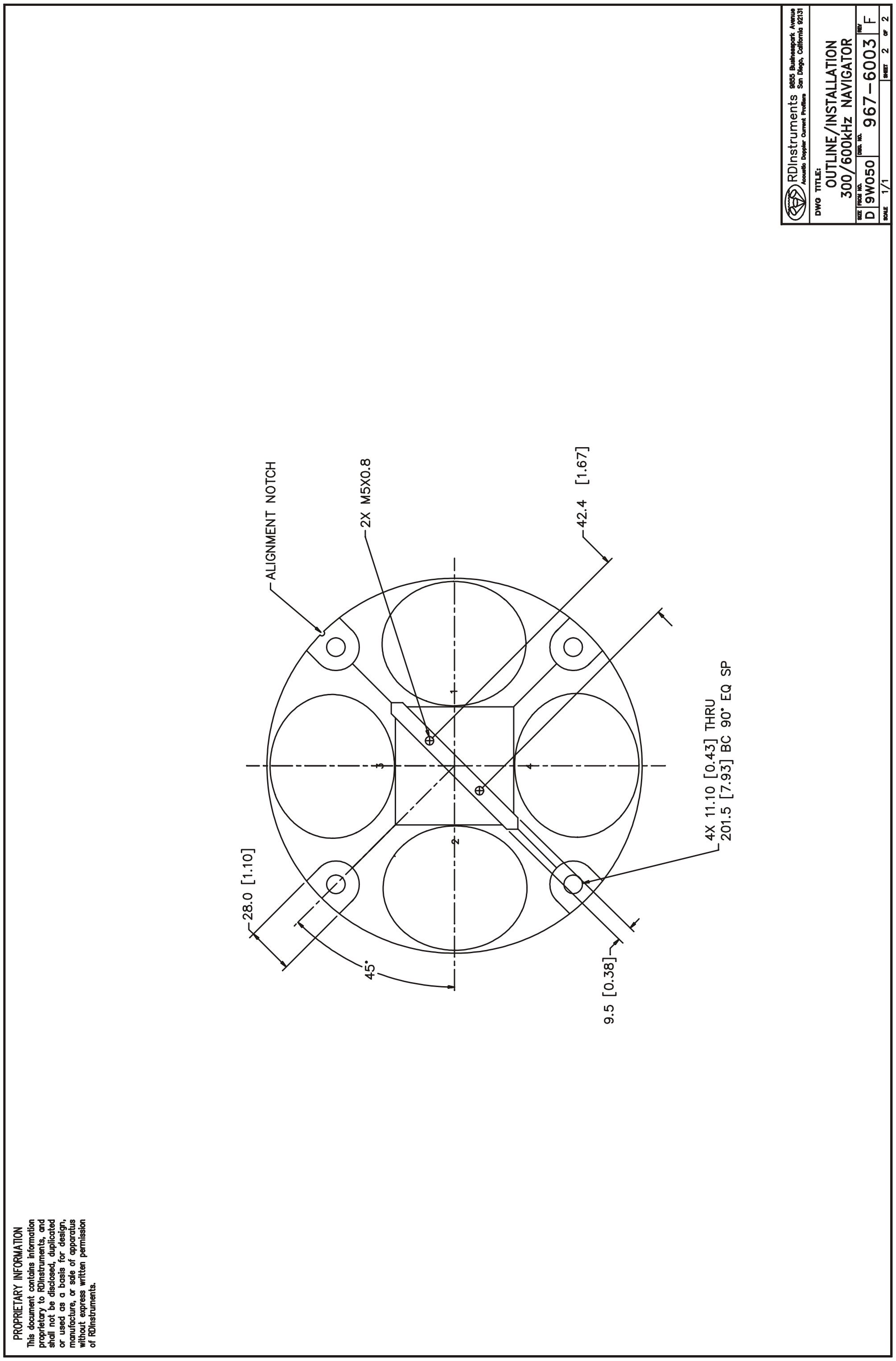
Table 15: Outline Installation Drawings

Description	Drawing #
300/600 kHz Navigator 3000/6000 meter	967-6003
300/600kHz Navigator	967-6004
1200kHz Navigator	967-6006
1200kHz Navigator II, 6000 meter	967-1020
External Battery Case	967-6007

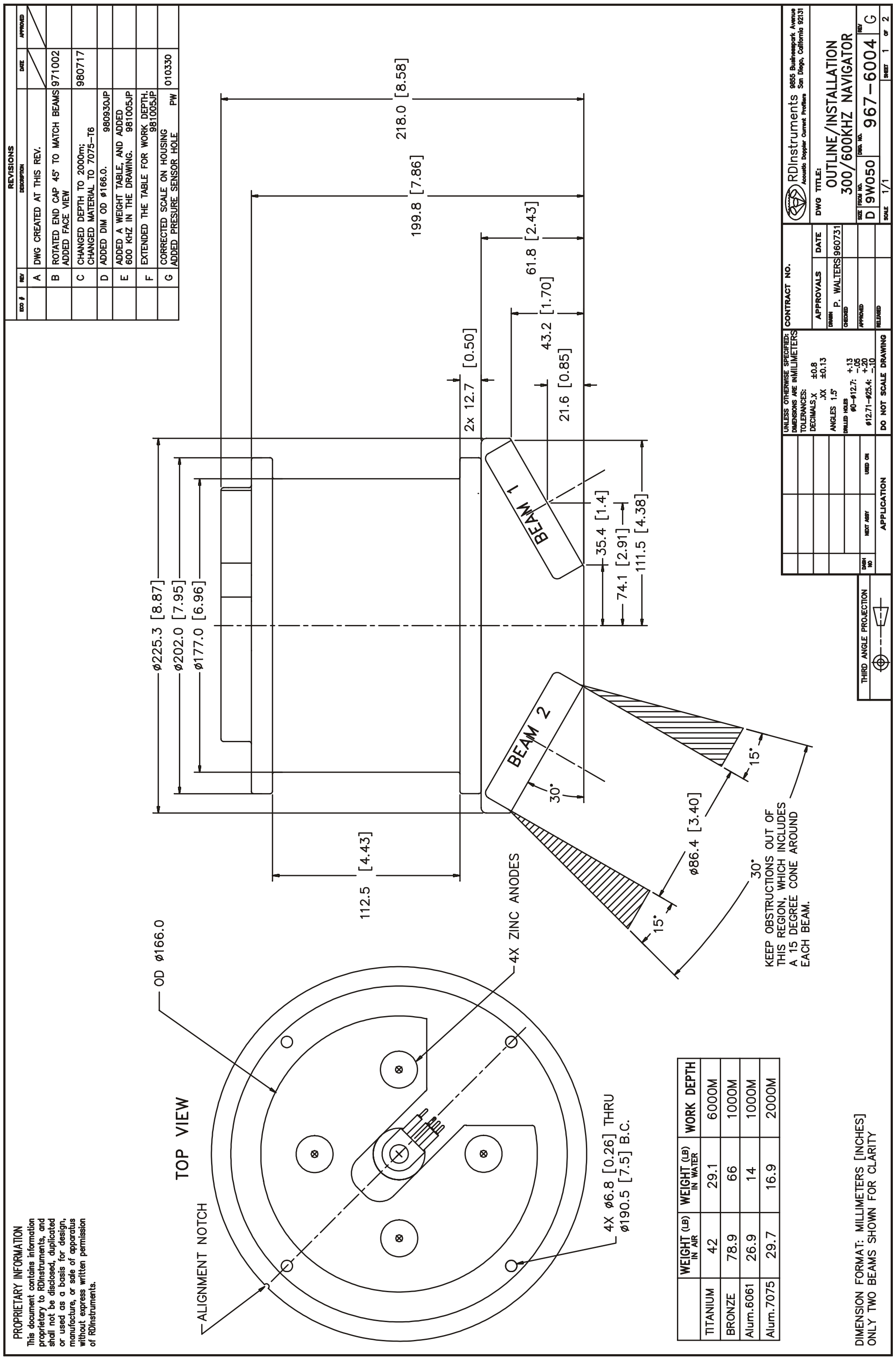
967-6003 Sheet 1



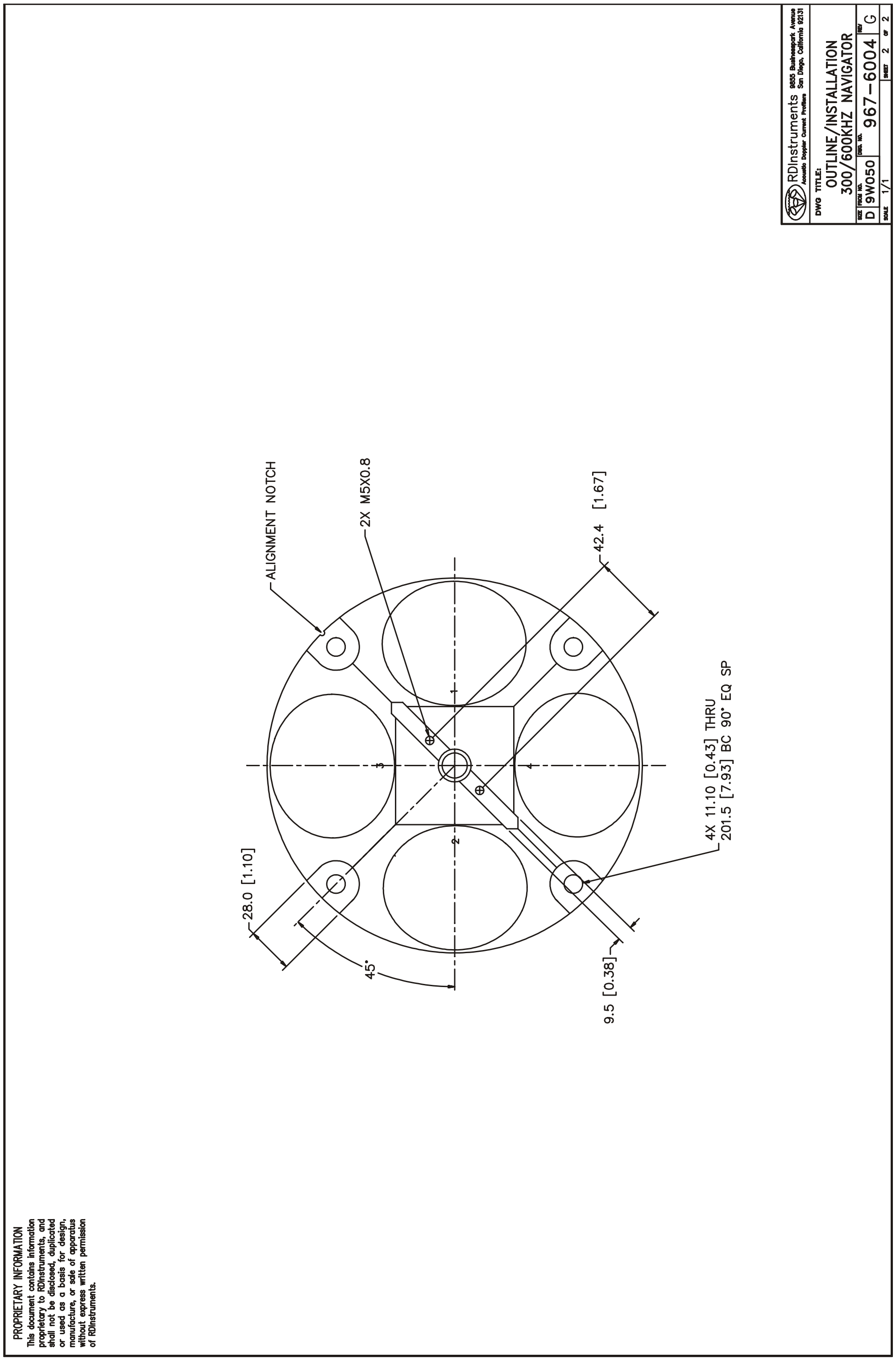
967-6003 Sheet 2



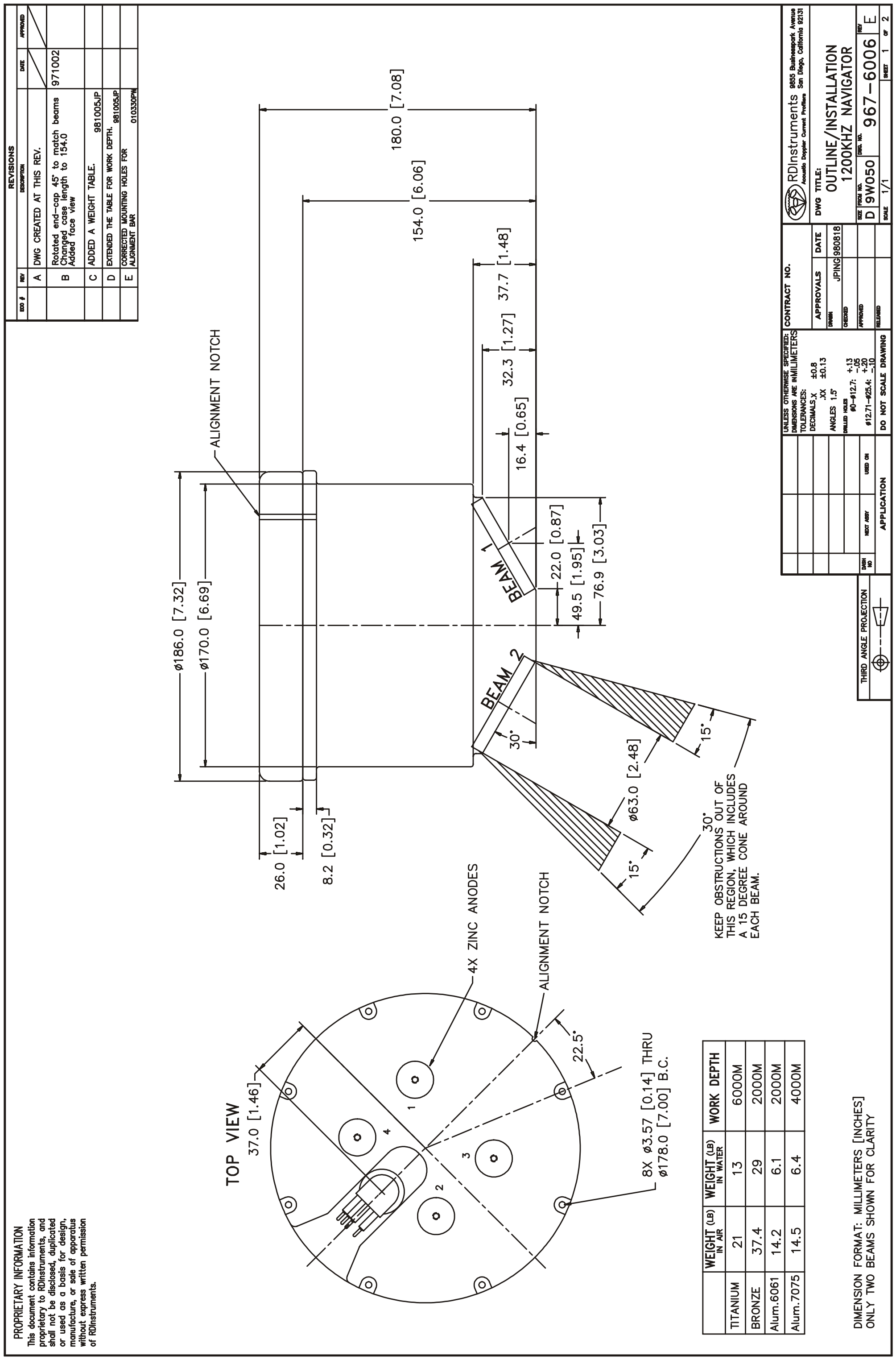
967-6004 Sheet 1



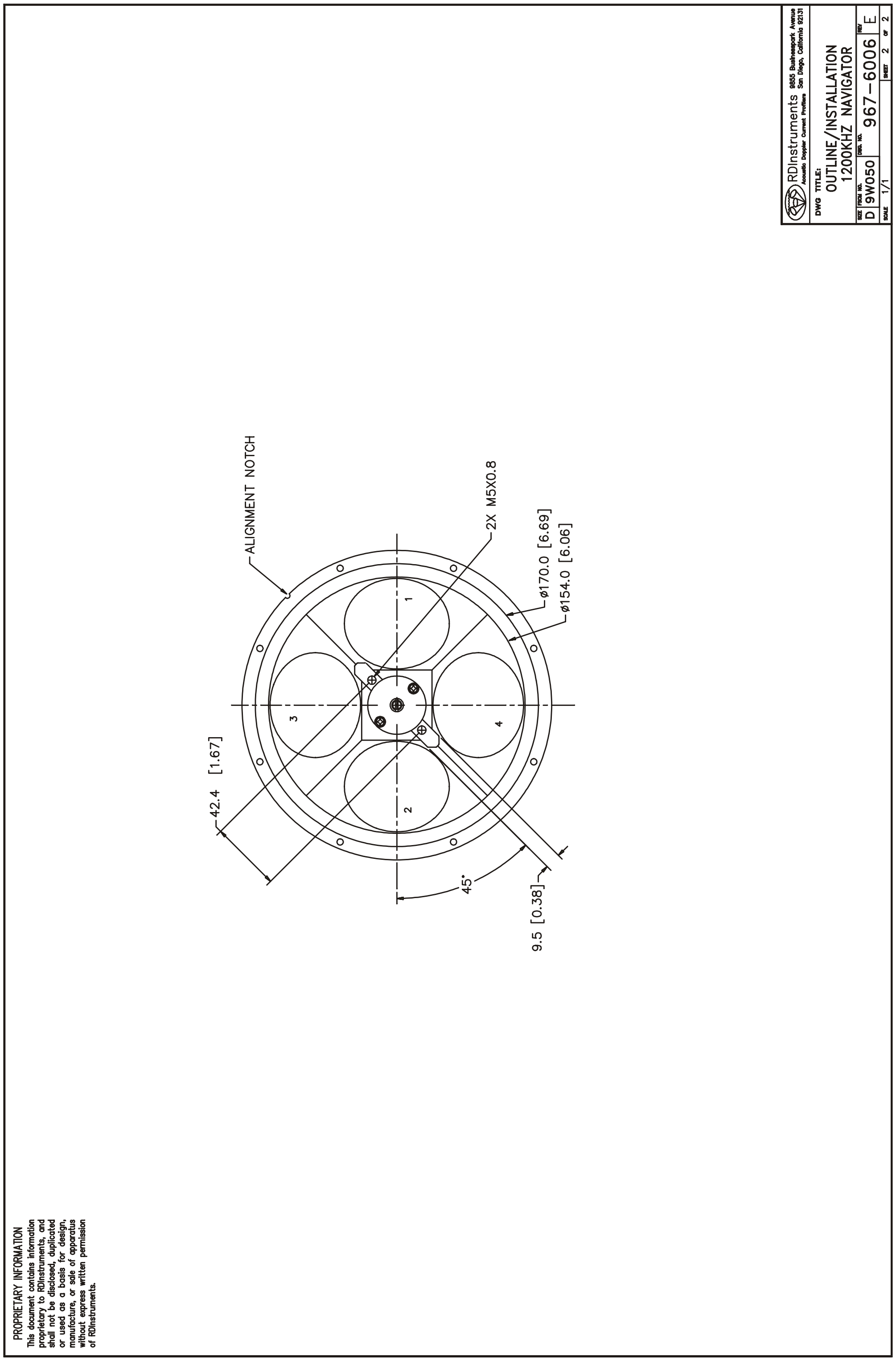
967-6004 Sheet 2



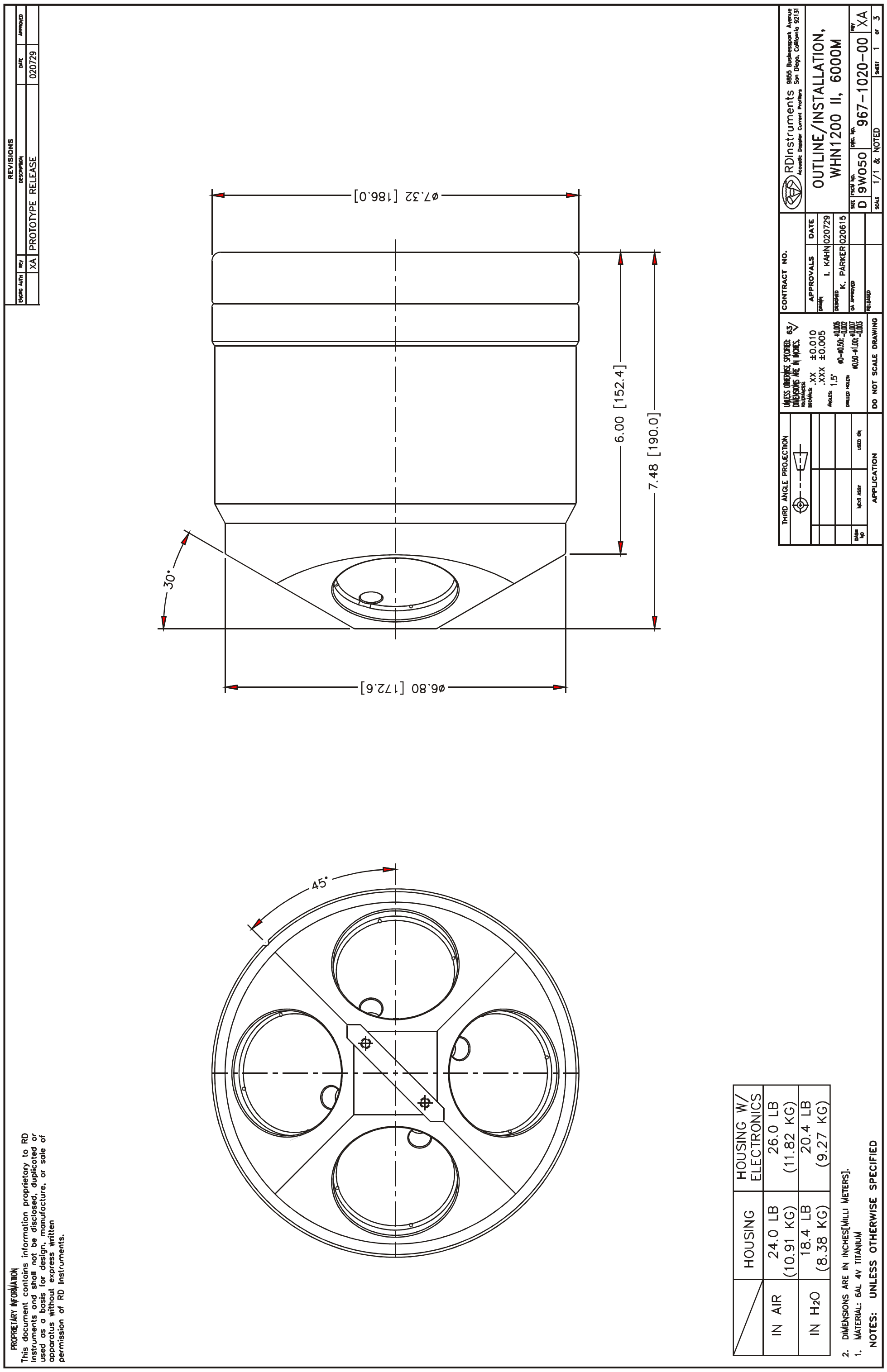
967-6006 Sheet 1



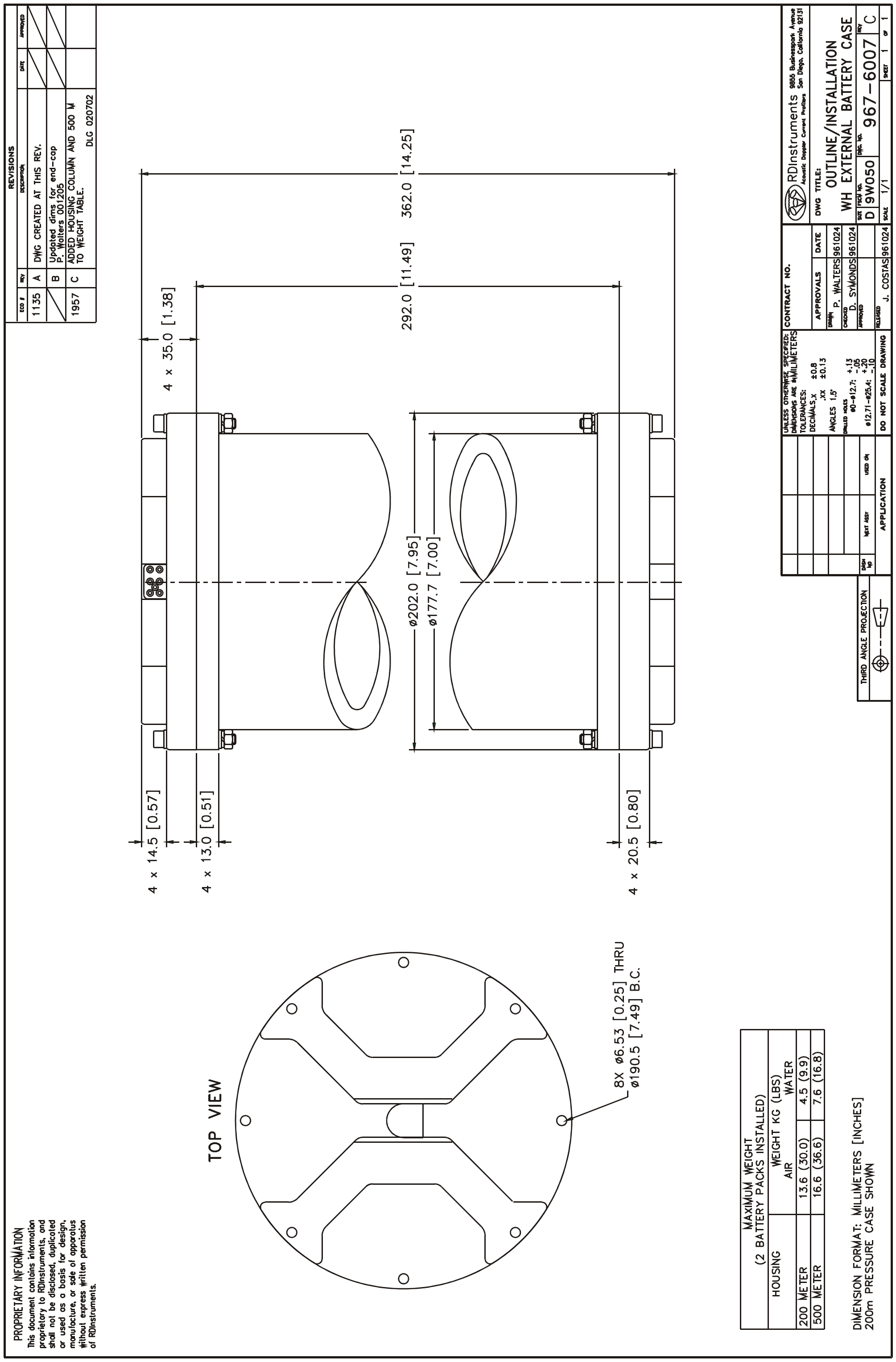
967-6006 Sheet 2



967-1020


REVISIONS
XA PROTOTYPE RELEASE 020729
ø7.32 [186.0]
6.00 [152.4]
7.48 [190.0]
30°
ø6.80 [172.6]
45°
RDInstruments
OUTLINE/INSTALLATION,
WHN1200 II, 6000M
D 9W050 967-1020-00 XA
I. KAHN 020729
K. PARKER 020615
DO NOT SCALE DRAWING
THIRD ANGLE PROJECTION
HOUSING
HOUSING W/ ELECTRONICS
IN AIR 24.0 LB (10.91 KG) 26.0 LB (11.82 KG)
IN H2O 18.4 LB (8.38 KG) 20.4 LB (9.27 KG)
NOTES: UNLESS OTHERWISE SPECIFIED
1. MATERIAL: 6AL 4V TITANIUM
2. DIMENSIONS ARE IN INCHES[MILLI METERS].
PROPRIETARY INFORMATION
This document contains information proprietary to RD Instruments and shall not be disclosed, duplicated or used as a basis for design, manufacture, or sale of apparatus without express written permission of RD Instruments.

967-6007


REVISIONS
ECO # | REV | DESCRIPTION | DATE | APPROVED
1135 | A | DWG CREATED AT THIS REV.
B | Updated dims for end-cap P. Walters 001205
1957 | C | ADDED HOUSING COLUMN AND 500 M TO WEIGHT TABLE. DLG 020702
362.0 [14.25]
292.0 [11.49]
4 x 35.0 [1.38]
ø202.0 [7.95]
ø177.7 [7.00]
4 x 14.5 [0.57]
4 x 13.0 [0.51]
4 x 20.5 [0.80]
TOP VIEW
8X ø6.53 [0.25] THRU
ø190.5 [7.49] B.C.
MAXIMUM WEIGHT
(2 BATTERY PACKS INSTALLED)
HOUSING | WEIGHT KG (LBS) AIR | WATER
200 METER | 13.6 (30.0) | 4.5 (9.9)
500 METER | 16.6 (36.6) | 7.6 (16.8)
DIMENSION FORMAT: MILLIMETERS [INCHES]
200m PRESSURE CASE SHOWN
PROPRIETARY INFORMATION
This document contains information proprietary to RDInstruments, and shall not be disclosed, duplicated or used as a basis for design, manufacture, or sale of apparatus without express written permission of RDInstruments.
THIRD ANGLE PROJECTION
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE MILLIMETERS
TOLERANCES: DECIMALS .X ±0.8 .XX ±0.13
ANGLES 1.5°
DO NOT SCALE DRAWING
APPLICATION
CONTRACT NO.
APPROVALS | DATE
P. WALTERS 961024
D. SYMONDS 961024
J. COSTAS 961024
RDInstruments 9855 Businesspark Avenue San Diego, California 92131
Acoustic Doppler Current Profilers
DWG TITLE: OUTLINE/INSTALLATION WH EXTERNAL BATTERY CASE
D 9W050 967-6007 C
SCALE 1/1 SHEET 1 of 1

NOTES