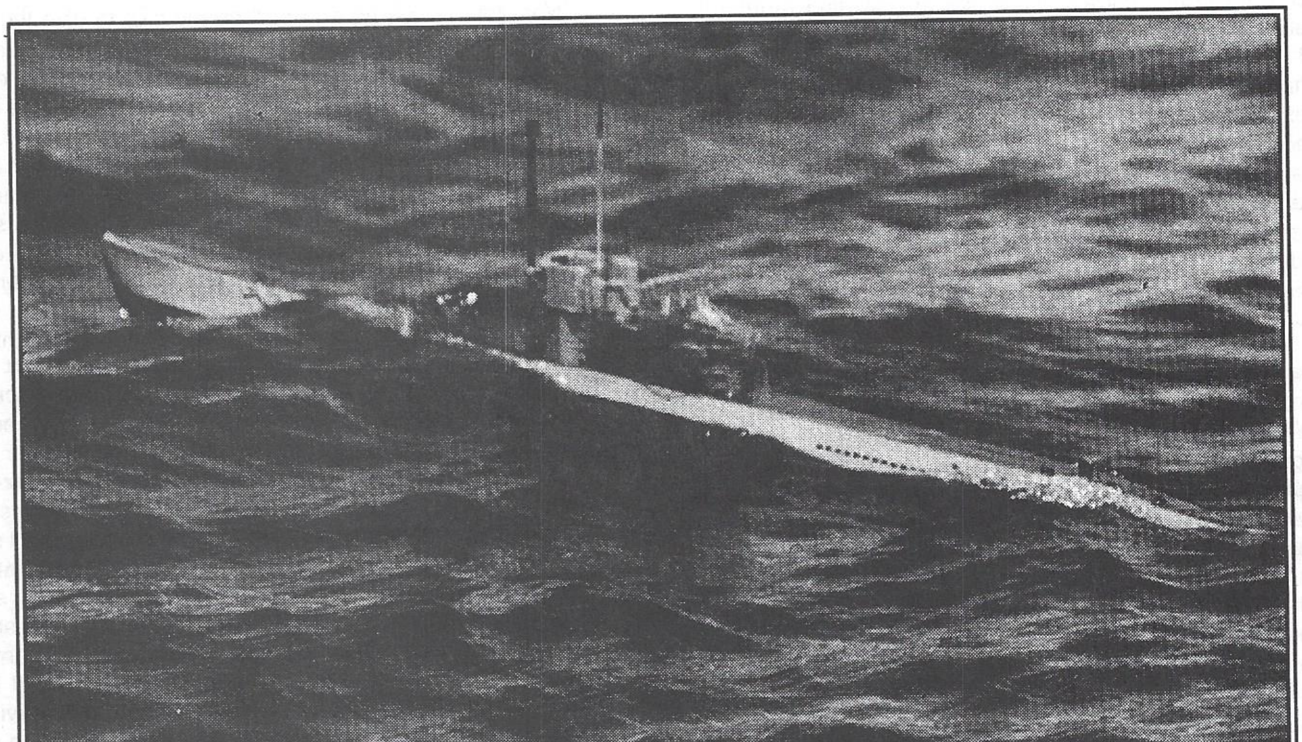
Model Submarines IN DEPTH!

by *Skip Asay*



From the series originally published in Flying Models magazine

Ballast Systems

There are a variety of methods available to the model builder to enable his pride and joy to surface after being the "Enemy Below". Please note that I said "surface". There is no secret involved in getting your boat to go under. There are many non-submarines that have performed this daring feat. The trick is to bring your boat back to the surface on command.

The most popular methods include pumping water in and out of the tank using a windshield washer pump or similar device, pumping water in and out of a hospital I. V. bag, piston-type variable size tanks (MRC/Engel), or Propel (airbrush propellant)/compressed air. If anyone has noticed I haven't mentioned "dynamic diving", congratulations. You're obviously paying attention. The reason for this omission is not that I don't consider this type of boat to be worth mentioning, but, quite simply, there is no ballast system involved.

Let me highlight some of the good and bad points of the above-mentioned systems. The worst type, as far as the boat's safety is concerned, is the plain pump system. The reason for this is the fact that the boat MUST have the periscope, snorkel or some type of air pickup tube above water to be able to pull air into the tank to surface. Now by itself this is not a major thing, but let's look a little deeper. The radios we have available today are very reliable; however, they are not perfect. In the event of a radio failure there's nothing you can do except go for a swim. The same holds true if the boat should get tangled in weeds, stuck in soft silt, or if the drive battery doesn't have the oomph to drive the boat back to the surface. Now I'm sure that some of you are saying that with positive buoyancy, none of these occurrences are a problem. To a certain extent this may be true, but for true scale-like submerged operations the closer to neutral buoyancy the better. I'll cover this aspect in the installment on balancing and trimming.

The second system (I.V. bag), which still uses a pump, eliminates most of the above problems except one. Since most windshield washer pumps use a fairly heavy amount of current, a weak battery can still force you to go for a swim. Another short-fall is that you have no real indicator to stop you from overfilling the bag which will make the boat too heavy and consequently too difficult to handle when submerged. Something to keep in mind is that one ounce of water displaces a little less than two cubic inches. With a flexible bag, it's next to impossible to fill that accurately every time and since one ounce can make all the difference in the world, I would rather stay away. I have seen the use of a micro-switch which is activated by the swelling of the bag, but this is not as exact as needed. Using windshield washer pumps has another drawback and that is that their flow capacity is pretty small, which means that it takes too long to submerge and surface.

The variable size tanks as used by MRC/Sun Lane (Engel) consist of a cylinder in which one end moves in and out on a threaded rod powered by a separate electric motor for each tank. When the movable end of the tank is all the way down to the fixed end, the tank itself is empty of water and the boat floats on the surface. When the movable end is at the other extreme, the tank is full of water and the boat is now heavy enough to submerge. The good side to this system is that the volume of the tank is fixed and the difference between surfaced and submerged displacement is exactly the same every time. Unfortunately, these tanks are relatively small requiring the use of 2 tanks in a larger-sized boat. The threaded rod sticking out of one end of the tank also forces the need for a considerable amount of free space inside the boat or, at best, a fair amount of juggling of hardware within an already crowded area. Since this system uses 2 motors (1 per tank), each of which needs a substantial amount of battery power, a weak battery can be a problem just as with the previous two methods. These tanks must also be mounted inside the hull, which leaves several more points of potential leakage.

This brings us to the final method, which also happens to be my favorite. Originally, I mentioned Propel and compressed air together. While the result is the same with either one, there is a world of difference between them. To be able to store enough compressed air to allow a sufficient number of surfacings, a very high pressure is required which can be dangerous as far as the boat is concerned (can you imagine a leak inside a sealed pressure hull?) and, of course, can be dangerous to you or anyone around the boat. It also requires a very strong and thus heavy storage tank, piping and valve. One way around this would be to have a small reservoir and an on-board compressor which could replenish the necessary air for the next surfacing. However, several things can happen. One, the compressor is going to need a substantial amount of current to operate, just as the pump-type systems previously described; two, only enough air for one, or at most two, surfacings will be available depending on the size of the tank and the pressure of the air inside it. Finally, it takes time to pump up to the required pressure and, from the shore, how will you know when to turn off the compressor?

With Propel, none of the above problems exist. Propel is stored in a liquid state when under pressure and expands tremendously when released, allowing many "blows" from a small-volume storage tank. For example, my Type XXIII U-Boat has a Propel storage tank with a capacity of less than four and a half cubic inches and still allows at least 20 "blows". This is with a ballast tank capacity of 32 ounces of water or approximately 55 cubic inches. Now, while Propel is stored under pressure, this is only in the range of approximately 30 - 60 P.S.I., which is a whole lot safer than the pressure involved with compressed air alone. Half or three-quarter inch copper pipe makes a very nice, easily constructed tank which is quite capable of handling this pressure. An added benefit is that, since the Propel is in liquid form in the storage tank, it has weight. When the tank is empty, the boat will now be lighter. What this means is that you have a built-in indicator of when the tank is empty since the boat will now be too light to submerge. Built-in positive buoyancy!

Another added benefit is that if the boat should become entangled in weeds or stuck in soft silt preventing it from surfacing, you have a locator in the form of a bubble patch to point out exact location. This happened to me on one occasion and when I returned the next morning with a diver, the boat was back on shore within 3 minutes after the diver entered the water. The visibility in this lake was approximately 2 inches and depth about 10 feet. I've gone swimming after my boats before, but when you add large snapping turtles to the depth and visibility problem, discretion was the better part of valor.

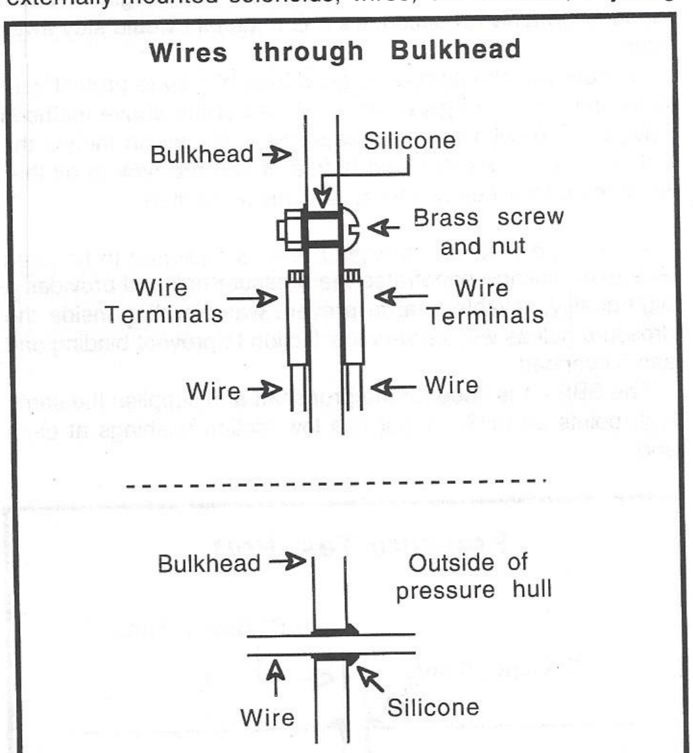
The next important factor in the ballast system is whether to use one tank or two, and where to place it them. Since we are dealing with a miniature version of the real thing, the best and simplest thing to do would be to follow full-size practice and use a single tank mounted midships. Yes, I know, full-size sub-

Watertight Integrity

If you think that keeping all that precious radio equipment, batteries, etc. dry in a model boat that only runs on the surface can be a real chore, then you probably think that accomplishing the same thing in a boat that is designed to go under the water is impossible. Wrong! Keeping your "powder" dry is not difficult at all. In fact, with just a little effort a model submarine can be made to withstand surprising water pressure and stay dry inside too. Please note that I said "a little effort". This means, among other things, common sense and attention to detail. A chain is only as strong as its weakest link and the best prepared submarine is going to get wet, or worse yet, sink, if a minor detail such as an unsealed propshaft/stuffing box is overlooked. With this in mind, let's see what it takes to make your pride and joy capable of diving below the surface and coming back up dry.

The average operating depth of most model submarines is 5 feet or less so this is where we'll concentrate our efforts. I know that many modelers don't want their boats to go any deeper than periscope depth which would allow for a somewhat simpler method of sealing; however, don't forget Murphy's law. Just a little extra time is the best insurance. After all, isn't your boat worth it?

To begin with, the items that need to be sealed, besides the pressure hull itself, are the main hatches for access to the inside of the pressure hull, propshaft/stuffing box, linkage push rods, on/off switch (if it's external), and any wires used for externally-mounted solenoids, wires, etc. In short, anything



that penetrates the pressure hull MUST be capable of withstanding outside pressure. This also includes any solenoids or other electrical apparatus that's mounted outside the pressure hull. By the way, that pressure is over 4 pounds at 10 feet and if you don't think 4 pounds is that much, punch a hole in a small plastic Tupperware-type container with a straight pin and see how fast it fills up when you hold it on the bottom of a bucket full of water. You'll be surprised. One more thing about that pressure. That's 4 pounds per square INCH!

With the exception of wires, virtually everything that penetrates the pressure hull is a shaft or rod of some sort. This includes the propshaft, linkage rods, and a push/pull power switch. This simplifies our needs to the extent that we only need one type of seal for everything except wires. (See note 2)

Wires can be sealed by just applying a bead of silicone around them and then gently pulling them back through the hole so that the silicone starts to bunch up around the hole. This gets silicone inside the hole as well as around it. Be careful not to move the wires at all until the silicone sets for at least an hour. A little extra time spent here is well worth it. Then another bead can be built up around the wire for further strength. With this method, make sure that the hole is not too much larger than the wire itself. In other words, if the wire is 1/16 inch diameter, don't put it through a 1/4 inch hole! If two or more wires are going through the same hole, make sure you separate the wires at the point of penetration and put some silicone between them. Then they can be twisted back together and put through the hole. A safer and stronger method would be to use wire terminals both inside and outside with a brass screw and nut passing through the bulkhead. Put a little silicone on the threads where the screw goes through the bulkhead and it will never leak. Again, check the diagram. One more thing about wires - where they attach to whatever component outside the pressure hull (solenoids, pumps, etc.), make sure the end of the wire itself is well tinned with solder to a point past the end of the insulation. Then put a sleeve of heat-shrink tubing over the end of the insulation and the exposed tinned wire. This prevents water from working its way back into the boat between the individual strands of wire. It's amazing where water under pressure can go!

The largest opening to seal and probably the simplest is the main hatch/hatches for access to the inside of the pressure hull itself. My personal preference here is Lexan which is a stronger, more flexible version of plexiglass. This material is easy to cut, quite strong and has the added benefit of being clear, which allows you to see what's happening inside. Now this is where I stray quite a bit from the norm. I don't screw these lids down but instead, I glue them down using silicone. Sounds too permanent, you say? Not at all. While it's true that it involves a little more time, in the long run it is far more efficient. For one thing, with plastics of this type, warpage around the screws can render the lids unusable because they just won't seal any more. The most obvious problem is that you now have a very large area for possible leaks. Gluing the lids on eliminates all of this. Access is still possible by using an Exacto knife and cutting through the silicone and then using a single edge razor blade to clean up the surfaces so that the lids can be re-installed. Notice on the diagram that the hatch coaming is slightly higher than the hull. This is to allow the knife blade to get in between. Immediate entry (to charge batteries, etc.) can be had by using plastic bottle necks and tops. (The tops themselves don't have to be plastic.) This allows you to get in and out quickly at dockside with a minimum of fuss and with very little chance for leaks. If the on/off switch is mounted just under this bottle top, that's one less seal to be made and one less potential leak. Any major work that must

Control Systems

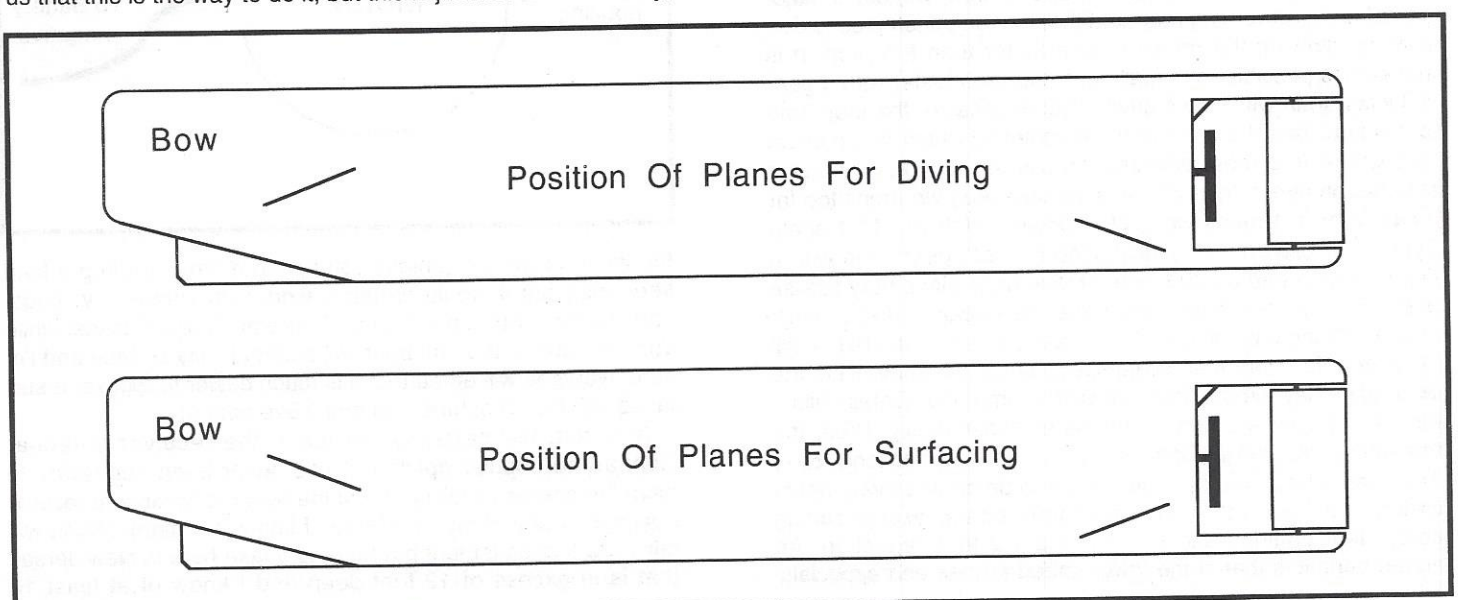
In previous installments, we covered how to make your submarine surface after patrolling the deep, and how to keep the insides dry while it was on patrol. Now we'll get into the systems which allow the boat to navigate beneath the waves and how best to use them. These systems include control surfaces as well as electronics.

I'm sure that if you're reading this article, you're interested in submarines and already have a basic knowledge of what the diving planes do, but how about a short refresher course first? As everyone knows, the rudder on any vessel controls whether the vessel itself turns left or right. On a submarine, this of course works the same way but for changes in depth and angle, the rudder must now be moved to the side of the boat and rotate up and down instead of left and right. Since before World War II, all submarine designers have used diving planes in the stern, some behind the prop(s) and some ahead of them. Since we're concerned primarily with scale models which already have these locations determined, I won't go into any detail about which location is best except to say that, basically, increased speed and noise reduction are the main reasons for putting the planes ahead of the prop on all subs designed since World War II. Not all submarines have had forward planes but the overwhelming majority have and these are not mounted at the extreme bow because of hydrodynamic considerations (they just won't work!) and dynamic center of gravity, but at some point behind the bow and ahead of midships. What is important for us to know is what the bow and stern planes do and how we can use that knowledge to make our boats perform underwater just like the full-size boats do.

In general, both fore and aft planes can do the same thing, that is they can change the attitude (or angle) of the boat. However, the rate of change differs greatly between them. For the purposes of this article, I won't waste any time on the engineering formulas to explain this. The bottom line is that in model form, reactions of the diving planes duplicate the full-size boats in that, generally speaking, the forward planes are used to control the depth of the boat and stern planes control the angle. I know there are many model subs that use forward planes only and there have even been articles written telling us that this is the way to do it, but this is just not true. In reality, a boat can be controlled by bow planes only but just barely. The stern planes are a completely different story, though. A submarine, whether full-size or model, can be controlled quite efficiently using stern planes alone. It's very much the same as an airplane. The control surfaces are located in the rear and change the angle of the fuselage and, more importantly, the wings. The wings want to keep going in the direction they're pointing, so to go up, the rear is dropped. To go down, the rear is raised. It's really much more difficult to pull the stern than it is to push the bow. How many vessels have the rudder in the bow? Now that we have that out of the way, let's get down to brass tacks.

I firmly recommend that if you are limited to only one channel for diving planes, you control the stern planes and, if the boat you are building has forward planes, they should be fixed in a neutral position. Don't fix them with any up or down angle since they will react differently to different speeds. I recommend that you do NOT link both fore and aft planes together on the same channel. Since the forces generated by the planes are greatly different, a great deal of time would be needed to properly synchronize them. The problem here is that these same forces vary according to speed and the net result is that the boat would work reasonably well at one speed and not so well at higher and lower speeds. It can be done, but it's just not worth it. If at all possible, try to use both sets of planes with each on its own channel.

One of the biggest problems with properly controlling a model submarine while it is submerged is to keep it level. Putting a boat under water is a whole new experience since we are now adding a third dimension - vertical movement. Trying to maintain a reasonable "periscope depth" when you can only see a small piece of tubing sticking out of the water and maybe a shadow under water is difficult, if not impossible. The reason for this is that if the boat takes on a two or three degree angle, it's almost impossible for you to see that little change from the shore. two or three degrees is enough to cause the boat to rise to the point of having the conning tower out of the water or dive to the point of going out of sight. By the time you notice that the angle is off, the damage has been done. Needless to say, this is not too realistic. The ideal solu-



model submarines that have been purposely put on the bottom and then brought back up again ON COMMAND. Those boats included 4 belonging to Bud Lederer, a well-known model submariner, Manny Duran, a builder who is not as well known but certainly an extremely capable "bubble head", and three of mine. There is also a quarry which has seen 2 boats operate at depths of over 30 feet! This was with a diver swimming with the model to verify the depth and recover the boat if necessary. These were all different models but all had one thing in common - the antennas were all ENTIRELY INSIDE the pressure hull. This was nothing more than the antenna wire inside a plastic tube (Nyrod) which was then molded around the inside of the pressure hull. Almost sounds too simple, doesn't it? It is, but the bottom line is that it works. For those curious about range, I've been as far as 100 yards away from two different boats that were submerged to periscope depth and could go no further but that was because I couldn't see them and not because of radio problems. None of the radios used in the boats mentioned above had any modifications to the output. Out of the box and into the boat and the frequencies used were 27, 53, 72 and 75. I hope this can calm any fears some of you might have. All of the previous refers to FRESH WATER ONLY!

To prevent potential interference from the motor, capacitors should be placed between the two terminals and between each terminal and the case, and a wire should be connected between the case and the main drive battery ground (negative). Study the sketch below.

Another area to keep in mind is the transmitter stick functions. There's enough to think about when your boat is submerged without having to think about which stick does what when it's moved in which direction. Try to keep everything as natural and relative to the boat itself as possible. In other words, don't use a left/right stick for the planes or use a forward/backward stick for the rudder. The diagram shows a comfortable layout which is adaptable for those of you who are left-handed. The main thing is that the forward planes and the rudder are on the same stick which makes submerged maneuvering a matter of using just one finger (with an A.P.C.). In this situation, one finger does it all. Since I use an A.P.C. in all my boats, I don't really use the stern planes except when diving and surfacing. It's still very easy to control the stern planes if you aren't using an A.P.C. since you would be using your other hand. I know that this explanation might sound somewhat picky, but in view of some of the layouts I've seen, it's best that I get into it. (See note 7)

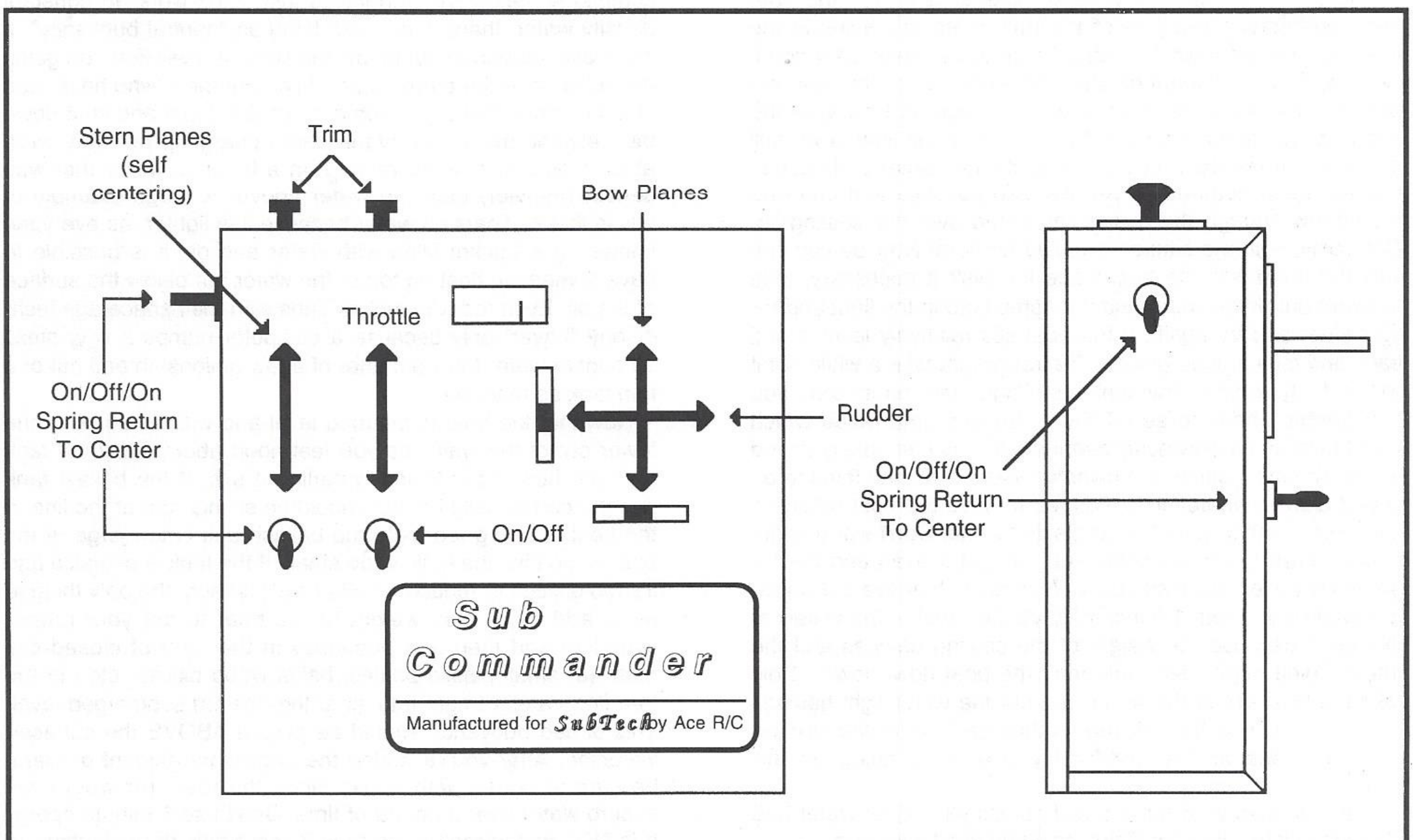
Note 3 - APC - 2 is the smallest, most efficient, and most reliable automatic leveling device on the market today and is the result of 17 years of learning the hard way - in the water.

Note 4 - The BE/VR (battery eliminator/voltage regulator) is designed for this and has the added benefit of being able to be used efficiently with a 6 volt battery.

Note 5 - The DRU combines small size, compatibility, and quiet operation into the ideal package for virtually any application.

Note 6 - SubSafe will operate a servo or any other device which is normally operated by a receiver signal. It also has an added benefit in that, during normal operation, the signal is "boosted" as it passes through which eliminates potential problems when using older servos with some of the newer radios.

Note 7 - The Sub Commander System uses all ACE R/C electronics but boasts a stick layout designed especially for submarines. (See sketch below)



do is make it larger. While doing this part of the trimming and balancing, make sure that the ballast tank is completely filled with water with no air bubbles when you're submerged and completely empty of water when on the surface. Now is the time to check that the vent valve, etc. is properly located. Another thing to look for is whether there are any areas under the free-flooding deck that may retain air bubbles when you dive. A simple way to test for this is, after you've trimmed for proper submerged depth and blown the tank to check for surfaced waterline height, vent the tank and submerge again with the deck in place. If it does not go back under all the way or if the bow or stern is higher, there's a bubble trapped somewhere. The result is the same as not filling the ballast tank enough. It will probably be necessary to drill a small hole (1/8-3/16 inch) in the deck as far forward and another as far aft as possible since these points will be highest when either diving or surfacing. It breaks from scale a little, but in some cases these holes can be disguised (bullnose, etc.) To simulate actual diving under power, it might be wise to hold the stern up just a bit to duplicate the angle the boat would have at that time.

Now, we are finally ready to take a trip down to the pond. Make sure your batteries are charged and again, if you are using Propel, make sure the tank is full. Once in the water, run around a bit on the surface to get a feel for the way it handles and check basic controls (rudder, speed, etc.). Don't rush this part. Relax, get comfortable and enjoy the fruits of all your labor for awhile and then, if possible, have the boat run parallel to the shore and as close as possible before you flood the tank. Be sure you check for submerged rocks, logs or other obstructions first. Now, with a deep breath, a faint smile and crossed fingers (legs, toes, arms!), fill the ballast tank and see what happens. If you've built a WWII era boat with a wide flat deck, it might tend to stick there with just the conning tower out of the water. If so, move the stern planes to the "dive" position which should raise the stern, causing the bow to go completely under. The "dive" position is obvious for the bow planes but the proper angle for the stern planes is the exact opposite. In other words, the leading edge should be up with the trailing edge down. This helps to increase the dive angle by raising the stern. As soon as the conning tower goes under, pull back slightly on the stern planes and try to get the boat level. It might also be necessary to use the bow planes to get the bow under. If the boat doesn't want to go under completely, that may be because it needs to sit lower when the tank is full and the boat is stationary. If you left yourself with some extra buoyancy, you will probably have to increase speed.

Now it's up to you. If there is no A.P.C. or similar device to keep the boat level, then you will have to do it yourself and that means with the stern planes only at first. The idea here is to see how violently the boat wants to pitch up or down with the stick in the neutral position (hands off). Of course, it's assumed that when installing the radio all controls were set to neutral. If it is severe, move the trim lever in the appropriate direction to counter the pitch. That is, if the boat pitches down by the bow, the trailing edge should move up. If the boat wants to surface, the trailing edge should move down. During this, keep an eye on where you are going so you don't run into something. I speak from experience! When you achieve what you feel is the best position for the trim lever, then go to the forward planes and repeat the process. You will probably have to keep going back and forth between fore and aft planes until you reach a happy medium and by all means don't get upset if you don't master this the first day out. Once you have gotten the boat to run with some consistency when submerged, you'll probably notice that either the bow or stern planes, or both, are not at their neutral position. This is normal and varies primarily according to the form of the hull. Those with a full flat deck such as a U.S. fleet boat or a Type IX German U-Boat are generally further away from neutral than a tear drop shaped "nuke". The reason is that the earlier boats had a smooth well-shaped hull below the waterline and an awful lot of hydrodynamically inefficient upper works above the waterline. This generally causes the bow to pitch up when under water but just how much is pretty much determined by speed. From this point on, it is just a matter of trial-and-error and practice. In other words, just get out there and do it. And do it, and do it. Practice doesn't always make perfect, but it sure beats whatever is in second place!

If you have been following this series from the beginning, you should have enough hints now to get your boat to work well. I must emphasize that everything that I have written is a result of years of trial-and-error and many mistakes and, if done the way I have laid it out, will work. But there are very few things in life that are etched in stone and it is certain that improvements can be made. It is very much recommended that, for the beginner especially, use what I have supplied and get to know the basics first before you try to improve on anything.

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