MODEL SUBMARINES

THER DIVING SYSTEMS, BALLAST TANKS & RADIO CONTROL

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DIVING SYSTEMS

Dynamic Diving

This system is the next step up from a surface runner. Dynamic Diving is probably a good way to start in model submarines as it gives the builder the opportunity to experiment with a model that submerges without recourse to more elaborate diving systems. The model has a sealed watertight compartment to house all the electronics and it is ballasted down so that it is in a 'decks awash' condition. It is then driven under the water and back up to the surface by a down or up angle on front, rear, or both sets of diving planes. A low freeboard due to the decks awash state and the usually oversized diving planes can look a little odd, but the positive buoyancy returns the model to the surface if the power or radio signal fails, so a sort of natural fail-safe is built into the system. It is a good idea to get confident using the hydroplanes before going on to other diving systems.

Dynamic diving is used on many commercial models.

Sealed Tank and Water Pump

Possibly the oldest and simplest form of diving system for a model submarine consists of a wind-screen washer pump flooding a sealed tank, such as an old tobacco tin. The water pump forces water into the sealed tank pressurising the air above it. The submarine gets heavier as more water is pumped in. A windscreen washer pump can only pump one way, and so compresses water into the ballast tank. The air inside, being pressurised, cannot escape and so the water is eventually pushed back out through the pump. It will be seen that the model will only dive when the tank is pumped and will automatically rise as the pressure pushes the water out.

The same system can be used but with a bypass loop and pressure release valve around the pump. Again, the pump is only used to dive, but the valve will give greater control over surfacing allowing the pressurised air to force the water out of the ballast tank, thus lightening the submarine. Alternatively, a reversible pump can be used so that the water can be pushed in or out. This will enable the boat to dive and surface statically.

Vented Tank and Water Pump

This is the next stage on from the sealed tank, but this time the pump is connected to draw water from the tank. The ballast tank is open at the top and this is usually disguised as a periscope or mast. The boat needs forward motion to dive dynamically so that the top of the mast is below the surface. At this point a one-way pump is used to draw water into the tank via the mast. To surface with this system the top of the mast has to be above the surface so that when the pump is run it will take water out of the ballast tank and replace it with air. However, whilst
this system does take on water to dive, it will be seen that this is not true static diving. The same system can be used but with a bypass loop and pressure release valve around the pump. The valve will allow the boat to static dive as water will simply flood the tank. To surface the mast must once again be above the surface for the pump to draw water out and replace it with air. Alternatively, a reversible pump can be used so that the water can be pushed in or out. This will enable the boat to dive and surface statically.

Air Systems

As air is some eight hundred times less dense than water it is easier move around and to compress. You may have already noticed, that in the Sealed Tank system mentioned above, it is the air compressed into the tank that eventually forces the water back out for the boat to surface. Please note that where "compressed air" is referred to this only means a pressure of one or two pounds per square inch above atmospheric pressure. It is very benign and nowhere near the sort of pressure that can be found in model steamboats.

Many people prefer air systems to water systems, the only drawback being that it can be hard to find the air-tight release valves needed. Some manufacturers have them really available and these can be quite small, but many of these cannot be moved by a servo arm and so most people prefer to make their own from an old car tyre valve or similar.

Air Bag and Bottle

The bag and bottle system consists of a sort of water wing (in fact a large speed boat buoyancy bag) placed in a free-flooding area of the hull, and a U.S.E. reciprocating steam engine unit driven by an electric motor acts as a simple air pump. The pump takes the air out of the bag pushing it into a rather large fibreglass bottle, which has also been placed in the free-flooding area of the boat. The bottle has to be large as the U.S.E. pump is not a compressor and can only move the air around, rather than compress it. No air is lost. By reversing the current to the electric motor the air is taken out of the bottle and placed in the bag. It will be seen that as the bag deflates the boat will dive and that as it inflates the boat will surface again - simple but effective!

This was the system used by John Damell in his British S, T, U/V, P Class and Type VII and XXI U-Boats

Compressor

The bag and bottle system always uses electric power to push the air around. The U.S.E. pump can be replaced by an electric car tyre inflator, which would normally run off a twelve-volt motor. This compresses the air into the bottle via one-way valves. A bypass loop with a release valve is added around the compressor and the valves. This means that battery power is only used to dive, and the boat should be able to surface even if the main batteries were to fail. Naturally this system allows for a little more sailing time. At this stage you may wish to replace the bag (which can be prone to damage) with a solid tank, which has open vent holes in the bottom.

It will be realised that the large bottle is not really needed now that the air is being compressed, and if you were to compress the air directly into the sealed watertight box, then you could release the pressure in the same manner as before. Safeguards such as probes at the top of the ballast tank, or washing machine type pressure valves can be used to turn off the compressor, which will prevent the water level getting too high and being drawn through into the water-tight compartment. What is more, the pressure in the watertight compartment is above atmospheric pressure and so water should find it difficult to get in under normal circumstances. As we have seen, compressing the air renders the large air bottle redundant, but some people prefer to use a smaller reservoir of some sort (such as an empty spray can) so as to prevent any pressure fluctuations from affecting the watertight gasket.

Modified Compressor

This is a further development of the Compressor System - with its origins in the 'Bag and Bottle' system. The submarine is kept afloat on the ballast tank, which is vented at the bottom to allow water in. When a valve is opened at the top of the tank, the model submerges. To surface, the valve at the top of the tank is closed and a second valve is opened which allows compressed air from an on-board reservoir to force the water out of the ballast tank (similar to the gas system below). The compressor recharges the air reservoir whilst the boat is on the surface. This can be done via a discrete valve and ball-float hidden below the deck/conning tower.

Full size systems use bottled air to initiate the surfacing procedure and as the fin/conning tower breaks surface they then use a compressor in order to blow the ballast more efficiently and save bottled air. Whether or not you use the compressor to recharge the reservoir on a separate radio channel, or whether you use it on the same channel as the 'surface' release valve, is only a matter of how you set the system up. In any case this is an economical system if the compressor is used infrequently (which will depend on the size of the reservoir compared with the size of the ballast tank) and is the one that most closely mimics the full size submarines.

Piston Tanks

This uses pistons like a pair of giant syringes. A geared motor drives a piston on a threaded rod inwards or outwards to pull the water in or push it out of the ballast tank/tubes. The air behind the tanks is compressed into the boat. These tanks can either be placed in the watertight area of the boat in which case they are filled and
emptied via a plastic tube connected through the outer hull, or can extend directly into the fee flooding area of the boat. Most models which use this system have two tanks, one forward and one aft, which allows you to get a good trim as they can be very precise at diving and depth control. Micro switches at each end act as circuit breakers to stop the motor.

Be careful as excess pressure in the watertight compartment may blow the watertight gasket.

This system is that used in the well-known Engel's boats. A variation to this uses a square threaded rod allowing the piston to move in and out without the rod moving back into the boat.

Bellows

A variation on the piston system, this system was developed by one of our members and has worked well on its own or in conjunction with other diving systems. In place of the ridged piston and cylinder is a car steering rack bellows (it must be the kind that does not have a breather hole for obvious reasons). The bellows is simply wound in or out on a threaded rod and protrudes into the free-flooding area of the boat, thus changing the buoyancy. A limit cam is placed on the inside end of the rod which will contact micro-switches to automatically turn off the motor at the full 'in' or 'out' of the run.

As with the piston system a square threaded rod may be used instead. Again, excess pressure in the watertight compartment may blow the watertight gasket.

Gas System

This system uses a ballast tank where the air can be vented out from the top in order to dive. A canister of compressed air or other compressed gas is used to force the water out to surface. The gases used are usually those used in spray-painting and may not be very environmentally friendly.

Other gases used may be highly explosive butane or propane - so be very careful.

The disadvantage with this system is that surfacing is limited before you have to replace the gas in the reservoir.

BALLAST TANK DESIGN

Free Surface Effect

The free surface motion of water (the 'swilling around' of water) is well known in naval architecture, but there seems to be little recognition of it in our models.

Imagine if you will, that you have a cylindrical ballast tank positioned low down in the centre of your boat. You have dived the boat and so now the ballast tank is for example, half full. By using the hydroplanes to point the bow down you can drive the boat lower. But what happens to the water in the ballast tank? Similarly, what happens if you now drive the boat toward the surface? Water being water will always try to find its lowest point and not only will it slip and slide along the inside of your smooth ballast tank (the free surfaces) but when it hits the end of the tank it will briefly appear to weigh more than it otherwise does for the simple reason that it has been in motion. So not only is there the problem of the weight of water sitting at the end of the ballast tank, but also in its journey to get there it has gained momentum before hitting the end of the tank. This, understandably, causes instability in the boat. Indeed, it may be that diving systems susceptible to these phenomena render a boat unable to change its depth on the hydroplanes due to the effect of the water in the tanks. These boats may only be able to surface run, static dive, then run submerged horizontally with a Salcon doing all the work. Clearly this is not a very satisfactory way of going about things.

Many model submarines have a Salcon (short for Submarine Automatic Level CONtrol) or AST (Automatic Submarine Trim). These devices are good, make no mistake. To have a something that can keep your boat on an even keel whilst running submerged is probably one of the more important innovations to the hobby. But they are not a be-all to end-all.

So how then can we control free surface effect? The answer is surprisingly simple - the water has to be slowed down. No one is saying that the water can, or indeed, needs to be stopped altogether. But, by adding baffles to the ballast tank to start with, the motion of the water can be slowed down to a point where it no longer affects the stability of the boat.

Design

First your ballast tank should be able to hold a volume of water equal to 3 1/2 times the weight of everything above the waterline. This will allow the boat to dive without over-filling the tank.

The ballast tank is sub-divided fore to aft along the centre line to negate any transverse (side-to-side) instability. It is then sub-divided into sections parallel with the ends of the tank. These sections should be at a ratio of approximately 1:6, that is to say the distance between these is equal to the height of the tank divided by six. There is no need to take the baffle right the way up to the top of the tank, about 90% of the way is enough, as any free circulation of air is not necessarily a bad thing and anyway it is not advisable to fill the ballast tank right up as you are then likely to draw water into the boat. The baffles can be made from glass-fibre or plastic sheet.

Now here's the paradox. There should be a hole in each baffle so that water can pass between them. These holes are approximately 4 mm in diameter and are situated about half way up the baffle. In this way we control the flow of water by slowing it down, as it takes longer to pass through a series of 4mm holes that it does to flow down and un-baffled length of say 4 inch pipe. Even if your boat has a small number of ballast tanks rather than one large one you should still baffle them in this manner.
Other Stability Considerations

What else could affect the stability of a model submarine? Un-scale models can be great fun to start with, but they can be unsightly. It has to be true that the closer we copy the full size boat then the more the model will behave like it, particularly if the hull shape is true to the original. You cannot scale down the water that you sail in and so models generally need as much help as possible in order to have them perform like the originals. But free surface effect is still going to be the major contribution to instability in a model submarine.

Do place your ballast tank low down in the boat, in a central position and perhaps slightly forward. Do baffle the ballast tank and don't let the free surface effects run wild! Do make sure that there is plenty of lead in the keel (if it has one) - but a false keel should never be necessary. Do try to get the hull shape as close to the original as possible, and do try to achieve some balance when fitting out your boat. For example; a central ballast tank with two batteries of the same size, one at each end, will obviously have a better trim than a boat where the battery has simply been dumped in the flooding area at the bow! Remember that the weight of a battery may be more than the weight of a fully flooded ballast tank.

Your Aim

You should be able to dive your model statically or dynamically, or use a combination of both, and then use the hydroplanes to control the depth when submerged, as does a full size submarine. The stability and control of your boat can only benefit from the careful positioning and construction of the ballast tank and its baffles.

RADIO CONTROL - FAQs

Here are a few of the more common questions that we get asked about radio control and model submarines.

QUESTION: What sort of radio will I need?
ANSWER: Any of the commercial equipment available in your local model shop will be more than adequate.

QUESTION: What frequency is best?
ANSWER: Any of the frequencies used for surface craft will do, the only advantage that 40 MHz may have over the 27 MHz is the number of slots available in that band.

QUESTION: Does the RX antenna have to be out of the water?
ANSWER: No, all you have to do is to seal the end of the antenna wire with epoxy resin from contact with the water and then lay the antenna within the confines of the hull. It is not necessary to put the antenna inside the watertight compartment.

QUESTION: How deep can you go down with a model submarine?
ANSWER: Within the club most people have found that ten feet is about the maximum depth that control can still be maintained, but this depth is only reachable in a swimming pool with the transmitter in close proximity to the model. In practical terms we have found that at a depth of around 1 foot to eighteen inches, the model can be controlled out to a distance of about thirty yards. However at this distance and at periscope depth the model is invisible to the operator, so even this moderate range may not be practical.

QUESTION: How does the radio work underwater?
ANSWER: In fresh water reception with the antenna submerged is not a problem. When the model is far away signals do tend to 'skip' off the water so reception below a few feet degrades as the model moves further away. Silty or salt water does interfere with the signal so it is best to avoid these completely. The most enjoyable submarine operations are in clear water and close to shore. Water is not the same in any two locations and sometimes it can be even different at the same location. Remember the conditions of the water may have a great effect on the way your submarine operates. Colder water is more buoyant than warm water. Thus a submarine diving in cold water could be in trouble if it hits a sudden warm layer. The saltier the water, the more buoyant it is. Therefore if you set the ballast of your model in salt water, you could have trouble when submerging in fresh water. The same applies, but to a lesser extent, in chlorinated water.