Steam and Steam Engines Part 4.

In part 3 of this saga, I made reference to the potential starting problems associated with multiple expansion engines (AKA Compound Engines) and also to the special valve used for this on the VIC 32.
All ships equipped with multiple expansion engines, be they 2-cylinder compound or 3 or 4 cylinder triple/quadruple expansion types, will be fitted with these starting valves.
Between the engineering crew of the VIC 32 this valve is referred to as the 'Whifter Valve', since it's purpose is to provide a whiff of steam to the LOW PRESSURE cylinder valve chamber (bypassing the HIGH PRESSURE cylinder), necessary to start the engine, should it have stopped with the HIGH PRESSURE cylinder in a dead spot. (I.E. with its valve gear closed to the steam).

In true steam parlance, such valves are known as 'SIMPLING VALVES'.

Why SIMPLING?….. Well, multiple expansion engines (that is those where, except for the first cylinder which receives its steam directly from the boiler, each successive cylinder receives its steam from the previous cylinders exhaust), regardless of the number of cylinders involved, are called COMPOUND ENGINES, whereas single/multiple cylinder engines of single expansion type (all cylinders are operating at the same steam pressure) are known a SIMPLE ENGINES.

These 'SIMPLING VALVES' effectively make COMPOUND engines into SIMPLE engines for as long as the valve is open. (Usually only a few seconds are necessary)

Ok, I think that is enough of the steam theory for now, so lets look a bit more at the engines and some of the valve control gear employed, particularly those that would more typically be used for our model ships.

Engine types.

Whilst many types/configurations of steam engines have been designed specifically for ship propulsion over the past decades, many, being very specialised types such as the 'SIDE LEVER' engines or 'OVERCRANK OSCILLATING' engines used on some paddle steamers, or indeed, the walking beam engines employed in some early American/Canadian great lakes steamers, are not generally considered as suitable for general purpose model ship power sources.
I think it is reasonable to suggest that, by far the majority of, current ship modellers would be more inclined to consider one of the more straightforward engine types, such as the IN LINE or DIAGONAL/HORIZONTAL type.

I accept, and acknowledge, that there are some very capable model shipbuilder, who are also highly skilled engineers, who have gone to great lengths, involving many hundreds of hours, to research, design and built accurate working scale representations of these early, specialised engine types, and then go on to employ them in their superb models, they remain, it must be said, the smaller minority group.

Not withstanding, I, for one, take my hat off to these extremely talented individuals as their superb efforts can only urge the rest of us ‘LESSER MORTALS’ to keep our dreams alive and our standards high.

The ‘LESSER MORTALS’ group, myself included, can be further divided into two sub groups: -

1/ Those individuals who are superb model builders, but who are non-engineering minded or lack the facilities required.
For this sub group the purchase of commercially manufactured model steam plant is the only way to go.

2/ A gradually increasing group, who are not only superb modellers, but who are also capable of, or are considering starting up in, model engineering with a view to, perhaps, building their own steam engines.

Whichever group, or sub group you consider yourself to belong to, I am sure that most of you will enjoy finding out more about how these engines work, if only to help in setting them up for best performance, or to understand some of the terminology used by steam buffs.

Therefore, whilst the following text is aimed more specifically at the larger, ‘LESSER MORTALS’ group, a lot of the content may be equally of some use to the more specialist group, since the fundamentals remain the same.

For typical model ship use, useable steam engines fall into 2 fundamental groups: -

‘BASIC’: - oscillating cylinder engines.

‘COMPLEX’: - Fixed cylinder, Slide valve / Piston valve engines, both reversing and non-reversing.

Either type may be a SINGLE ACTING or DOUBLE ACTING engine.

SINGLE ACTING engines are where the steam is admitted only at one end of the cylinder, and therefore the piston is only driven in one direction, (the return stoke relies upon inertia to get the piston back to the inlet end again), whereas DOUBLE ACTING engines have steam inlets at both ends of the cylinder thus the piston is driven both up and down the cylinder.
DOUBLE ACTING types are the more powerful, and, certainly at low speed/rpm, the smoother running of the two, but naturally, they use more steam.

The majority of model steam engines currently available are of the DOUBLE ACTING type

Oscillating Engines

From a model ship point of view, I think it is fair to say that there are probably more oscillating engines in use than any other type.
Certainly they are responsible for the rapid increase in steam ship/boat modellers over the last few decades if only because of their simplicity (having few moving parts), cheapness (when compared to other types) and relative ease of use. They are available as single cylinder or multiple cylinder versions, the latter being self-starting from any position.

So what is an OSCILLATING ENGINE?

Take a look at Fig 7.1

Here the top 2 diagrams show a cross section through a typical single cylinder, double acting oscillating engine.

In this type of engine, the PISTON and the CRANKSHAFT CRANKPIN are connected directly with a RIGID connecting rod.
As a result, when the CRANKSHAFT turns, causing the CRANKPIN to move in a circular path around the CRANKSHAFT centre, and thus moving the piston up and down inside the cylinder, the entire cylinder block will rock, or oscillate, hence the name, from side to side around a fixed pivot point. (AKA A TRUNNION).
This pivot point is more normally located on the centre line of the cylinder (as depicted in the diagrams); however, on some engines it can be located either at the top or indeed the bottom of the cylinder block.
Some of the larger, full size, PADDLER OSCILLATING engines had top or bottom pivots

This type of engine does not generally have, or need, separate valve gear, (although some of the more specialised full size types did have some minimal valve/port control), but rather they rely on the swinging motion of the cylinder/s to open and close the steam and exhaust ports.

So how is this achieved?

If you look at the top left diagram on FIG 7.1 you will see, on the centre line of the cylinder, two (2) round green coloured ports, one at the top and one at the bottom of the cylinder, these are the direct input/output from the cylinders and extend from the rubbing face (known as the PORT FACE) where the cylinder meets the ENGINE STANDARD (Crankcase) right through the cylinder walls into the cylinder. This can be seen in the top right hand diagram on Fig.7.1 as 2 thick green lines.

Returning to the top left diagram, you will also see, directly alongside each of these green ports, a RED port and a BLUE port. These ports are drilled/located in the engine STANDARD, not the cylinder, and extend into the STANDARD where each respective pair (either RED or BLUE) are interconnected by a transfer passage (shown as a dotted double line of the same colours) which in turn extend right up to the top of the STANDARD.

This is where the STEAM (RED) and EXHAUST (BLUE) connections to the engine are made.

I will return to this point a little later.

Ok, moving on to FIG 7.2

In Fig 7.2a you can see that the piston is at the top of its stroke and that the 2 green ports are directly in between the steam inlet (red) and exhaust outlet (blue) ports and therefore no transfer can take place in either direction. This is one of the 2 dead centres of the engine (Top Dead Centre (TDC)) they're being an identical one at the extreme bottom of the piston stroke (Bottom dead Centre (BDC)) and which is shown in fig 7.2c

If the crankshaft is moved in a CLOCKWISE direction, just a small amount, then the top GREEN port will move to the left, and begin to uncover the RED steam port and at the same time the bottom GREEN port moves to the right and begins to uncover the BLUE exhaust port.
Steam will now enter the cylinder from the top (via the RED port) pushing the piston down, and spent steam remaining in the bottom of the cylinder, from the previous stroke can now escape via the BLUE exhaust port.

At the position shown in Fig 7.2b (90 degrees of crank movement) you can see that the cylinder has pivoted by quite a few degrees and that the ports have now, progressively, opened to the FULLY OPEN position.

In Fig7.2c the piston is now at BDC and both ports are again closed, however, momentum in the engine will carry it over this point and again begin to open the STEAM and EXHAUST ports, but this time in the opposite sense.
The bottom port opens to STEAM and the top port opens to EXHAUST.

Fig 7.2d shows the ports again in the fully open position, but this time on the upward stroke of the piston.
This continues, as for the downward stroke, until the piston returns to TDC.

Momentum, (flywheel inertia) will carry the engine over both TOP and BOTTOM dead centres and the engine will remain running until the steam is turned off (or runs out).

REVERSING and SPEED control.

Returning to an earlier point, namely the steam and exhaust connections……

As shown in the Diagrams, the STEAM and EXHAUST ports/transfer passages are correct for CLOCKWISE rotation when viewed looking towards the CRANK.

In order to make the engine run in the opposite direction (ANTI-CLOCKWISE) then all that is required is for the STEAM AND EXHAUST connections to be swapped over.

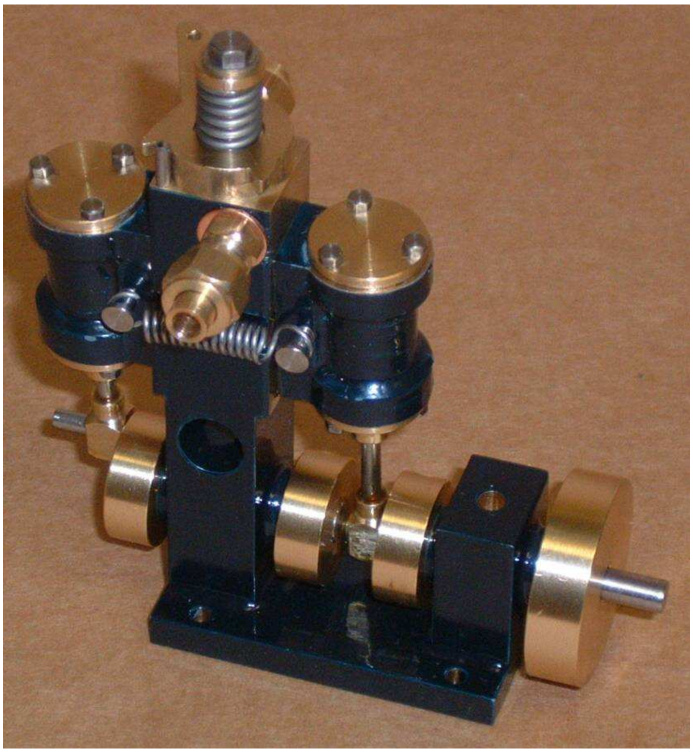
This can be achieved by including a port reversal valve in the connecting pipe work and a suitable type is shown in the bottom diagram of FIG 7.1.
Such a valve, which will also provide a means of speed control, may be made as a self contained unit, as shown in the diagram, and with the REVERSING disc held down against the DISTRIBUTION BLOCK using a suitable spring loaded pivot, or the ports etc, currently within the distribution block, can all be included in to the top of the ENGINE STANDARD and the reversing disc, with its curved slots on its bottom face, can be attached to the top of the ENGINE STANDARD, again with a suitable spring loaded pivot. (See photo below)

A single cylinder engine may prove difficult to start, without external manual or mechanical intervention, if the engine stops in either of the dead centres (TDC or BDC) since in these positions neither the STEAM or EXHAUST ports are open. For this reason single cylinder oscillating engines, or single cylinder slide valve engines for that matter, are not generally favoured for model boat use.
Some brave souls have added and electric motor, connected, via gears or belts, to the engine flywheel, which would provide the necessary external force required, however, most would opt for a multi cylinder engine with the cranks arranged at 90 degrees to each other which will guarantee at lest one cylinder is always in a ports open position and hence the engine will easily self start.

In order to add a second cylinder, all that is required is to extend the ports/passages in the ENGINE STANDARD to the opposite side of the STANDARD and to mount the second cylinder on the OPPOSITE face to the existing one.
A second crank can then be added (at 90 degrees to the first one) to the other end of the crankshaft, and with a suitable output shaft and bearing block, to give adequate support to the shaft, provided to give a connection for the flywheel and propeller shaft.

The single cylinder pivot, and compression spring (used to ensure the cylinder remains in contact with the port face) would be removed, and replaced with 2 separate, shorter, pivot pins (one per cylinder) and the necessary spring loading achieved by the use of 2 springs attached, one each side of the STANDARD, between the pair of cylinders.

Such an engine is shown in the following picture.



This engine also has the port reversal/speed control valve located on the top of the ENGINE STANDARD as described above.
The STEAM and EXHAUST connections are made via the 2 union nut and nipple connecting points on either side of the STANDARD.

So there you have it, that's how oscillators work, very simple and straightforward.

A couple of points now: -

MAX. Steam Pressure.

Oscillating engines are, generally, unable to handle high working steam pressures.
This is mainly due to the requirement to maintain steam-tight port rubbing faces with as little friction as possible.
High steam pressures would tend to lift the cylinder (and also the reversing valve rotor) from its port face, causing large steam loss; conversely, higher spring pressures, to help overcome this would, in turn, result in much higher friction on the rubbing port-faces leading to rapid wear.
Clearly then, there is a practical limit on the maximum working steam pressure, which on full size oscillating engines was rarely much higher than 80psi – 90psi, although there were a few exceptions.

For model oscillating engines, 40psi – 45psi is a practical maximum, with 30psi – 35psi being the more general range.

Condensate and Cold starting.

When starting from cold, these engines have a high propensity for HYDRAULIC LOCKING, caused by the hot steam condensing in the cold cylinders.
Whilst this is an ever-present issue in all types of steam engines, in an oscillating engine the only way this condensate can escape is via the ports, or by the cylinders lifting from their respective port faces against the spring pressure.
On fixed cylinder engines (cold starting still produces condensate) the addition of drain cocks, at either end of the cylinders can be employed to overcome this, however, the mechanical connections necessary to operate these cocks (they are usually interconnected to a single operating lever) becomes a very difficult task on oscillating engines, since the cylinders rock from side to side, and on multi cylinder engines, usually in opposite directions, making the task even more of a challenge.

Certainly they were fitted to some of the early, large, PADDLER OSCILLATORS, which tended to also operate at low RPM, however, this usually meant one of the engineers, or more likely his apprentice…. Remember them?… hanging over the cylinders whilst they were in motion to operate the drain cocks….. Both a dangerous and thankless task.

Steam usage and efficiency.

As you have seen, in an oscillating engine, the STEAM and EXHUAST ports are open for 99.9% of the whole piston travel in both directions; therefore, no effective use can be made of the expansion energy stored up in the steam, which means oscillating engines are very inefficient.

As mentioned earlier, some early, full size, PADDLER oscillating engines not only had the cylinder pivots (TRUNNIONS) either at the top or the bottom of the cylinders, which, incidentally, also incorporated the steam ports and transfer passages in the TRUNNION pins and bearing surfaces, but also they were, in a few cases, also fitted with fairly complex sliding/rotating sleeves, within the TRUNNION and around the TRUNNION PIN, which permitted some small amount of adjustment to the port timing when the engine was running thus giving a degree of expansion working.
Such modifications/additions were, however, complicated, expensive and not overly effective; and the best that could be achieved was rarely better than 10% to 15% of the total stroke being under expansion of the steam.

From this point of view, and that of the low steam pressure limit, oscillating engines soon became out of favour, especially for long distance travel, since they demanded a huge amount of water and coal to be carried, at the expense of FARE PAYING passenger space, in order to provide the engines with the huge amounts of steam they required for virtually the entire time they operated.

The way forward.

What was needed then was a relatively cheap and repeatable method of shutting off the steam supply to the cylinder, a function known as CUT-OFF, at a predictable point in its travel, and then let the natural expansion energy locked up in the steam complete the stroke.

Combined with the ability to use higher maximum steam pressures, thus giving higher expansion energy, then these 2 desirables would greatly reduce the overall amount of steam required for a given running period and also, therefore, lead to a substantial reduction in the amount of water/coal which needed to be carried.

Furthermore, the CUT-OFF point should, ideally, be variable to some degree, since, a steam engine only needs full pressure steam when starting and getting the load moving, after which, the amount of power required from the engines to sustain motion, especially with a large ship where the considerable inertia/kinetic energy stored in the mass of the vessel would provide some of the necessary motive power, would be much less.

So what could be done to overcome these problems?

Fortunately the industrial revolution was in full swing and the advancements made in land based steam railway locomotives and industrial engines, who's engineers were facing the same problems (cost and efficiency), were somewhat ahead of the marine engines and engineers in this quest……

ENTER THE FIXED CYLINDER engine, with independent valves and more complex valve gears.

Fixed cylinder engines were equipped with many types of VALVES such as rotary valves, poppet valves, slide valves and, somewhat later, piston valves, however, only the latter three (3) played any significant role in marine steam engines and it is these that the following text will explore.

VALVE CONTROL GEARS came in a bewildering array of different designs, each claiming advantages over others types and with more and more types evolving to overcome specific design issues, the list is endless.

The larger proportion of these VALVE GEARS were designed specifically for the STEAM LOCOMOTIVE whilst others were more specific to the huge INDUSTRIAL STEAM ENGINES of the time and they fell broadly into 2 categories, namely: -

LINK MOTION valve gears.

These include: - STEPHENSON, GOOCH and the ALLEN link motions.
Although the later two (2) of these were more predominantly used on railway locomotives.

RADIAL valve gears.

Such as; - WALSCHAERT, BAKER, HACKWORTH, JOY, MARSHALL, SISSONS…. The list is endless, and with each type having specific characteristics.

Of the many types available, only a very small number were ideally suited to the MARINE ENGINE and the type most commonly encountered is the STEPHENSON LINK MOTION, although several of the RADIAL types were used for specific applications.

Quite a few large PADDLER engines used JOY valve gear, since it required no eccentrics, meaning the engines could be made narrower and lighter.

HACKWORTH and MARSHALL gears were sometimes to be found on small riverboat engines.
OK, lets take a look at some of these items in more detail and get to know what the different part are, and what they are called, starting with a simple SLIDE VALVE ENGINE.

Take a look at FIG 8.

This shows a cross section through a simple single cylinder, double acting, OUTSIDE ADMISSION SLIDE VALVE engine, and the first thing you will notice is IT HAS A LOT MORE BITS than a single cylinder oscillating engine.

Some of these parts will be familiar to you, since they are also common to the oscillating engine, however, a good many have not yet been encountered.

The first thing to note is that the CYLINDER is FIXED to the ENGINE STANDARD (Crankcase); it cannot pivot as in the oscillating engine.
This leads us to the second big differences, which are THE CROSSHEAD and the CROSSHEAD GUIDES, which are situated directly below the CYLINDER and are associated with THE CONNECTING ROD joining the piston to the CRANKPIN on the CRANKSHAFT.

On an oscillating engine, the CONNECTING ROD can be a straight rigid rod between the PISTON and the CRANKPIN; this is possible since the CYLINDER can pivot from side to side on the oscillating engine in harmony with the rotational displacement of the CRANKPIN as the CRANKSHAFT rotates.
This cannot happen on a fixed cylinder engine, and the angular displacement of the CRANKPIN must be accommodated in a different way.
On this type of engine the connection between the PISTON and the CRANKPIN must be split into two (2) separate components, namely the PISTON ROD and the CONNECTING ROD, with a new pivoting joint between the two (2).
The CONNECTING ROD also differs in that it now has a pivot bearing at its top end known as the LITTLE END whilst the BIG END is retained as the CRANKPIN connection.
THE CROSSHEAD is the component where these two (2) items are joined.
The PISTON ROD is fixed rigidly to the top of the CROSSHEAD whilst the CONNECTING ROD SMALL END is connected towards the bottom of the CROSSHEAD via a pivot pin (referred to as the CROSSHEAD WRIST PIN), allowing the CONNECTING ROD to follow the angular displacement of the CRANKPIN.

We now have a further problem to overcome, namely SIDE LOADING.

When the crank is rotated away from the vertical then a considerable sideways force is applied to the CROSSHEAD by the angular displacement of the connecting rod

(NOTE: - this force is not a constant, but rises exponentially with the angular displacement, and reaches a maximum when the crank is at 90 degrees to the cylinder), which, in turn, would place a considerable sideways force on the PISTON ROD and its GLAND. This force would be sufficient to either bend the PISTON ROD, which, in turn, would damage the piston and the cylinder bore, or at best, damage the GLAND.

In order to correct this, it is necessary to support the CROSSHEAD throughout its entire stroke, and this is the job of the CROSSHEAD GUIDES, sometimes known as SLIDE BARS.
These GUIDES prevent the CROSSHEAD from deviating from its true up and down movement and thus remove the unwanted side loading on the PISTON ROD and the GLAND.
Such guides take many forms and the one shown takes the form of SLIPPERS and PLATES where the back face of the CROSSHEAD is TEE SHAPED and the arms of the TEE (SLIPPERS) run on slots created by the PLATES (usually 3 on either side of the CROSSHEAD, with the centre plates being narrower than the back and front plates), which in turn are firmly attached to the engine STANDARD.
Generally, some adjustment is provided in the guide mechanism, either by including adjustment shims between the PLATES or by adjustable SLIPPER linings, in order to take care of wear etc.
The GUIDE PLATES are generally made of steel, with the SLIPPERS being of bronze or white metal (more often the slippers are separate bronze/white metal linings attached to the crosshead by some suitable means).

Another common type of guide takes the form of an open sided cylinder, attached to, or integral with, the cylinder bottom cover, and the CROSSHEAD takes the form of an open bottomed piston attached to the bottom of the PISTON ROD.
This type is known as a TRUNK GUIDE and was often the type used on early MILL engines and also seen on some STERNWHEEL PADDLE ENGINES.

Quite a few of the currently available model steam engines use this TRUNK GUIDE type, with e.g. ‘JMC’,’COTSWOLD’ and the late ‘CHEDDAR’ being amongst them.

The SLIPPER and PLATE type, as shown in fig 8, is though, more typical of marine steam engines.

The SECTION A-A on FIG 8 shows the above items without the VALVE GEAR in the way.

STEAM CONTROL.

Ok, moving on to the steam control side ….. this is the other major addition to the engine and, as will be seen in the following chapters, is the means by which the steam, and exhaust, timing can be altered, thus achieving the desired goal of higher efficiency.

As can be seen in the side view the steam and exhaust are permitted to enter and leave the cylinder by means of a specially designed valve, known as a SLIDE VALVE.

The SLIDE VALVE is enclosed within a separate chamber, known as the STEAM CHEST and is connected to the outside world via the VALVE STEM, which is just a posh name for a pushrod.
This VALVE STEM is, like the PISTON ROD in the main cylinder, supported by a guide at the top, the VALVE STEM GUIDE, and at the bottom, it passes through a combined guide/gland, terminating in a small CROSSHEAD type connection.
On some larger engines this valve CROSSHEAD was also fitted with a guide/slide bar assembly just as the main piston rod/connecting rod.

The port face, over which the SLIDE VALVE travels, contains the STEAM INLET ports, one for each end of the cylinder, and the EXHAUST PORT, which is common to both ends. These ports are shown in FIG 8 section B-B in Reddish brown and Blue respectively and how these relate to the timing, and hence, running of the engine will be discussed at some great length in the following chapters.

The VALVE STEM, and hence the SLIDE VALVE are made to move up and down within the STEAM CHEST, thus opening and closing the STEAM and EXHAUST ports at the appropriate time, by means of an external pushrod assembly comprising the ECCENTRIC ROD and ECCENTRIC STRAP, which, in turn, are driven by a component known as the ECCENTRIC or ECCENTRIC SHEEVE, which is fixed to the CRANK SHAFT and rotates with it.
The valve gear is shown in SECTION B-B without the CONNECTING ROD, CROSSHEAD etc in the way.

Fig 8 shows all the components in the correct positions, relative to each other, when the PISTON is at TOP DEAD CENTRE and the engine rigged for CLOCKWISE rotation looking from the ECCENTRIC END.

Just how all these parts relate to each other, for different requirements/running conditions will be discussed in the next chapters.

The SLIDE VALVE shown is of the OUTSIDE admission type, which means that the steam, from the boiler, is admitted to the STEAM CHEST, above, or outside of the SLIDE VALVE and is only allowed to enter the cylinder via the outside edges of the SLIDE VALVE.

The EXHAUST STEAM is allowed to exit the cylinder via a separate path/chamber and is controlled by the INSIDE edges of the SLIDE VALVE.

This will all become clearer as we progress through the next chapter or so.

So there we have the basic SLIDE VALVE steam engine….. so how the hell does it work?

READ ON……. Pour yourself a stiff drink, smoke 20 fags and then go to part 5.