

# WALSCHAERTS & STEPHENSON VALVEGEAR PROGRAMMES (Version C-4)

These programmes were originally written over 12 years ago for the BBC Computer. This current PC version, written in the language C, gives identical results but is faster and much easier to use. It will run on virtually any PC operating under DOS, Windows 3.x, Windows 95, and Windows 98. [Version C-4 simplifies the solution of valvegears with the radius rod suspended from a link when the suspension point is to the rear of the expansion link. Data files for the two gears now have different names to avoid the programmes getting the wrong set of data! However the file format is the same as the 'Eng\_data.dat' files of Version 3, so if you rename them 'wal\_data.dat' or 'ste\_data.dat' as appropriate they will work with Version 4.

## Running

1. Run from floppy or preferably hard disc. If the latter, make sure that the files 'wal\_data.dat' or 'ste\_data.dat' are in the same directory as their RUN file (i.e. 'Walsch.exe' or 'Steph.exe' ). Both sets of files can be in the same directory if you wish. From DOS get into the same directory as the RUN file, and enter the file name (Walsch or Steph). From Windows, double-click on the file icon in the File Manager (or Windows Explorer ).
2. You should now have a list of the engines whose data are stored on disc in the file 'Eng\_data.dat'. (Windows may choose to run the programme in a window, but you will find that running in a full screen is better. You can toggle between the two using Alt-Enter). You can either select an engine from the list or enter the name of a new engine; in the latter case you will need to enter a list of all the valvegear dimensions when asked. To get going select one from the list, type its name and press Enter. If it looks OK press Y, or if you make a mistake press N and start again. Notice that the engine name is **CASE SENSITIVE**.
3. A list of the valvegear dimensions is displayed, or if you opted for a new engine you will be invited to enter the dimensions one by one, and a diagram of the gear will be displayed to help identify the items. If you want to make changes enter Y when asked, and you will be taken through the list and invited to write in a new dimension or to accept the existing (default) value.
4. When you finally agree a list of dimensions you will have the opportunity to save the record (only necessary with a new or modified record) - or you may wish to just use the modified dimension without changing the record on disc. (Do make sure you save after entering a new engine's dimensions, or you will have to go through the rigmarole of entering dimensions again!)
5. The computer then finds mid-gear and tells you the inclination of the lifting arm at mid-gear. 'Notching up' is measured by the change in inclination of the lifting arm from the mid-gear position. This will of course depend upon the engine, but to get going, try 10° (positive for forward and negative for back gear). The computer then calculates the shift of the die from its mid position in the link, so you can check whether this is reasonable.
6. A menu then appears, and the rest of the procedure is pretty obvious - follow the instructions and see what happens! It may be that you will wish to record some of the results, in which case you can press 'Print Screen', whereupon a copy of the screen will be deposited on the Clipboard and can be printed out from Paint, Corel Draw, etc. You will also find that the programme has been kind enough to deposit a list of piston and

valve positions for the last run in a file called 'Results.txt'; it can be read with any text editor such as Notepad. This is quite handy if you want to check against the programme the motion measured with clocks on valve and piston on a real engine. (The programme is always right of course!).

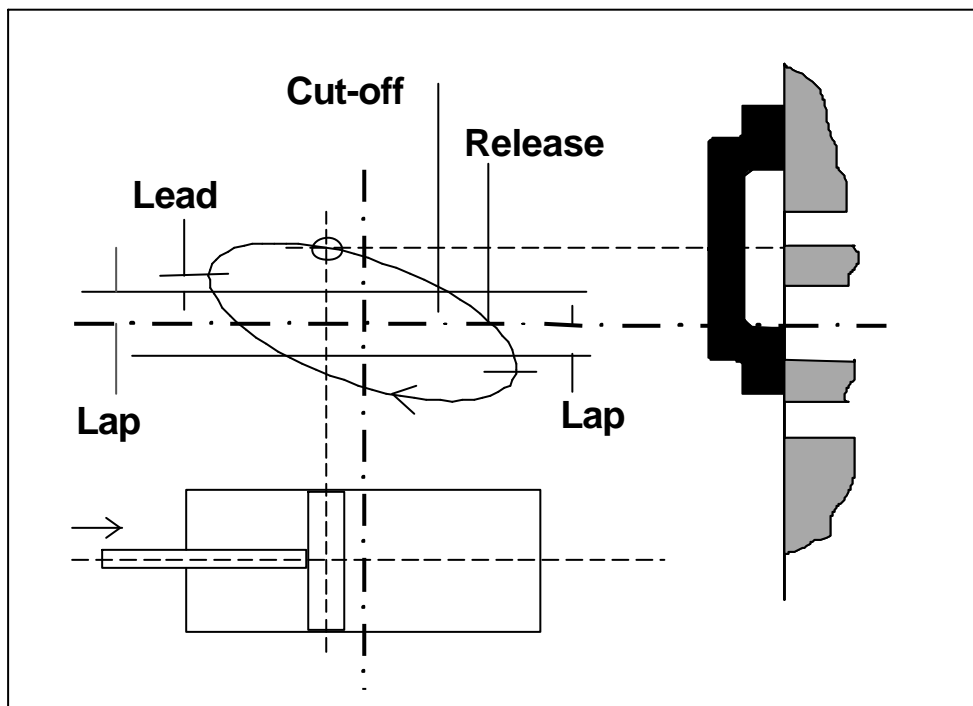
**Note: Walschaerts in Version C-4 differs from that in C-2 in that the dimension (no. 23 on list) locating the suspension point on the radius rod is from the combination lever joint to the suspension point, rather than from the link to the suspension point. This simplifies things when the suspension point is to the rear of the link.**

**IT WOULD BE USEFUL IF USERS OF THE PROGRAMMES COLLABORATED BY SWAPPING DATA FILES (WAL\_DATA.DAT and STE\_DATA.DAT) CONTAINING DATA FOR ANY ENGINES THEY ADD TO THE FILES. Perhaps the 'www.modeleng.org' site would be the best contact.**

### Understanding

Setting aside the animation and other cosmetic effects, the useful output is the table of valve events and the oval diagram. Both display the same information, but the oval diagram, when you get used to it, gives a very quick and clear indication of the valvegear performance. For the uninitiated, a brief description of the oval diagram follows.

In the diagram I show how a point on the oval diagram relates to the positions of piston and valve. (Since in the diagram the piston and valve *displacements* are drawn at right angles I have also drawn the piston and valve spindle centrelines at right angles). As the crank rotates the point representing piston and valve position moves round the oval; this shows how the two motions are related.



When the valve moves from its central position a distance equal to the 'lap', one of the ports cracks open to steam, so I have added to the diagram 'lap lines' that are spaced from the central position by a distance equal to the lap. The points where these are intersected by the oval represent opening or closing of the steam ports. (To avoid complicating the diagram I have assumed that there is no exhaust lap - the exhaust is set 'line for line'. Release and compression events then occur when the oval crosses the centre line. The programme will however deal with a finite exhaust lap.)

Notice that the oval crosses the lap line just before the piston reaches the end of the cylinder; i.e the port opens before the end of the stroke - the amount by which it opens is the 'lead'. For a 'constant lead' valvegear (e.g Walschaerts) the programme automatically adjusts the position of the valve on its spindle to ensure that the lead is the same at each end of the cylinder; this adjustment is repeated as the gear is 'notched up', and the leads remain equalised. For a gear like Stephenson, which is not constant lead, one has to select for the first run the lifting arm position at which the leads are to be equalised; the programme then retains the same setting for subsequent lifting arm positions in spite of the fact that leads will not then be equal at each end of the cylinder.

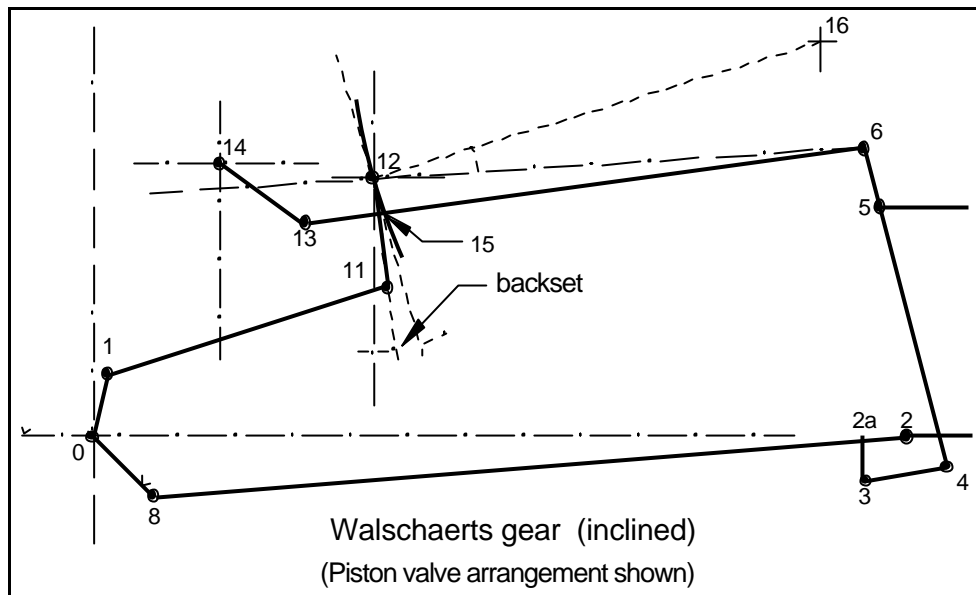
The things to look for in the oval diagram are:

1. A reasonably late cut-off in **full gear** (say, 75% or 80%). Cut-off too early means difficult starting.
2. Some lead, although small engines are relatively insensitive to the ill effects of no lead that are found in full scale engines. Say one tenth or one twentieth of the lap.
3. Adequate port opening. Ports do not need to be larger than scale, and could be less, but the problem is to ensure reasonably balanced opening when notched up. Larger-than-scale inaccuracies in the gear mean that 'small' can become 'zero', giving lumpy running when notched up. Therefore look carefully at the port openings at short cut-off.
4. The oval diagram will usually be somewhat distorted for a real valvegear - try fiddling around with the dimensions to see what changes make improvements. For example, shifting the fore-and-aft position of the weighshaft in the type of Walschaerts gear in which the radius rod is positioned by a suspension link can sometimes improve things. In Stephenson, changing the radial position of the suspension point on the link is a useful thing to try. Aim for reasonably balanced cut-off points for the fore and back strokes at say 50% cut-off.
5. Use the table of valve events to finally judge the proposed gear - these values are more accurate than reading off the oval diagram.
6. Above all, remember that time running the programme is well spent **before** you start cutting metal!

If you are starting from scratch and do not have an initial design you may get some help from the programme 'Stewal.exe', also on the disc. This gives you the approximate value of the main scantlings of the gear, using a much simplified calculation model. However, you can then move on to Steph or Walsch to firm down the design. Alternatively, you can of course adapt an existing gear, testing the effect of any changes using the programmes. If you wish to adapt a programme that is already on the disc, you can load it, modify it and save it with a new name. (The programme gives an opportunity to change the name when saving)

## How the programmes work

### Walschaerts



#### Preliminary Calculations

1. If the gear is to be truly 'constant lead' certain conditions must be met. When the piston is set at either dead centre, the expansion link centre of curvature must coincide with the pin connecting the radius rod to the combination lever ( point 6 in the diagram). When this is the case, movement of the reversing lever will not cause movement of the valve when the main crank is on either dead centre - i.e. the lead will remain the same as the gear is 'notched up'.
2. Clearly the position of point 6 should be the same when the combination lever is at both dead centre positions (with the reversing lever set in mid-gear). Since the vertical distance from point 5 to point 6 depends upon the angle of the combination lever, this means that the lever should swing equal angles each side of vertical as the crank moves between dead centres. Whilst strictly correct, this requirement is not crucial. The programme assumes that it is met; if not there will be some slight variation in lead as the engine is notched up.
3. Having established where the expansion link must point when the engine is on dead centres, the programme goes on to calculate the angular position of the return crank and the length of the eccentric rod. (Note the similarity with the usual procedure for setting up Walschaerts and finding the length of the eccentric rod).
4. Subsequent calculations make extensive use of two routines which simulate the use of dividers on a drawing board. The routine 'find' when given the co-ordinates of two points and the distance from each to a third, locates the third point. 'Circline', as its name suggests, locates the intersections of a line with a circle. In each case it is necessary to specify which of the two points found is the appropriate one.

### Motion of the expansion link

5. Given the crank angle, points 1 and 8 are known. 'Find' is then used to locate point 11 from points 1 and 12. Given the backset angle of the 'tailpin' of the expansion link, the centre of curvature of the link can then be located (point 16).

### Crosshead linkages

6. Location of points 2, 2a, and 3 for a given crank angle is by direct calculation. The horizontal co-ordinate of point 5 is then guessed (the guess will be refined later in an iterative process). 'Find' is then used between 3 and 5 to locate 4, and the position of 6 then follows by direct calculation.

### Radius rod

7. Point 13 is found by direct calculation given the position of the lifting arm. This, together with point 6 defines the position of the radius rod.

### Closure

8. 'Circline' is then used to find the intersection of the radius rod and the expansion link (point 15). In general this will not coincide with the pin in the radius rod. The discrepancy is calculated, and its elimination forms the basis of a 'trial and error' procedure in which the true position of point 5 is determined. Then the pin connecting the radius rod and the die in the link can be inserted, the solution of the linkage is complete, and the position of the valve spindle can be found.

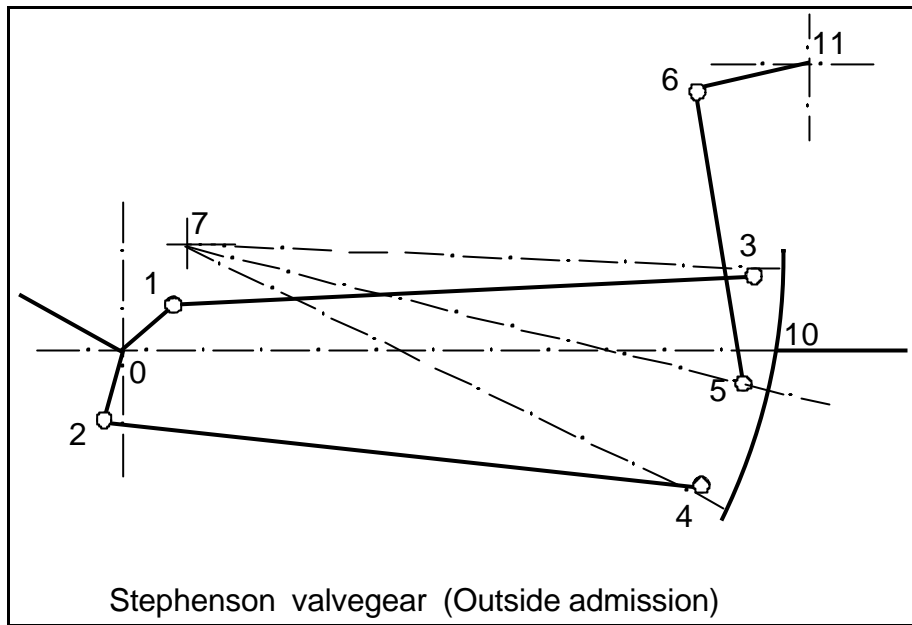
### Setting the valve

9. This is simply a matter of specifying a distance from point 5 to the valve, such that the lead is the same at each end of the stroke. This is done automatically for each calculation for a particular setting of the lifting arm. If the gear is truly 'constant lead' the value should be the same for each setting. The valve events follow directly from the motion of the valve and the steam and exhaust laps.

The above illustration is based on Walschaerts gear with the radius rod located by a die at the end of the lifting arm. The alternative arrangement, in which the radius rod is suspended by a rod from the end of the lifting arm, is dealt with in a similar manner by iterating on the horizontal position of point 5 until the pin connecting radius rod and link can be inserted.

The arrangement for inside admission is shown above. The programme will deal also with outside admission; no significant changes to the method of solution are involved.

## Stephenson



### Preliminary Calculations

Given the crank angle, the position of the eccentrics, 1 and 2, can be calculated. Also, if the position of the lifting arm is known, so are the co-ordinates of point 6.

### The Iterative process

The vertical co-ordinate of point 3 is guessed. Its horizontal co-ordinate can then be found using 'circline' on a circle based on point 1 and a horizontal line through point 3. Point 4 can then be located using 'find' on the known distance from 2, and the known distance from 3. Point 7 can then be located knowing the radius of the link, and in the example shown, point 5 lies on the bisector of the angle subtended by 3 and 4 at point 7.

Now we have the positions of points 5 and 6, the length of the suspension link can be calculated. In general this calculated length will not correspond with the actual length (unless we were very lucky in guessing the position of point 3!). So it is now necessary to vary the vertical height of point 3 until the calculated length of the suspension link corresponds to the actual length. The programme actually uses the Secant Method to do this (The Secant Method is a routine that finds the root of a nonlinear equation - in this case an equation expressing the difference between the calculated and actual lengths of the suspension link; the root is the vertical co-ordinate of point 3.)

All that remains is to find the intersection of the link with the line of the valve spindle, which defines the position of the valve. As with Walschaerts, the programme then equalises the lead at each end of the stroke of the piston. However, since Stephenson is not a constant lead gear, one must choose in the first run the lifting arm angle at which leads are to be equalised. The programme then retains this value if you stay in the programme and run different lifting arm positions.

w.b.h, 2000.