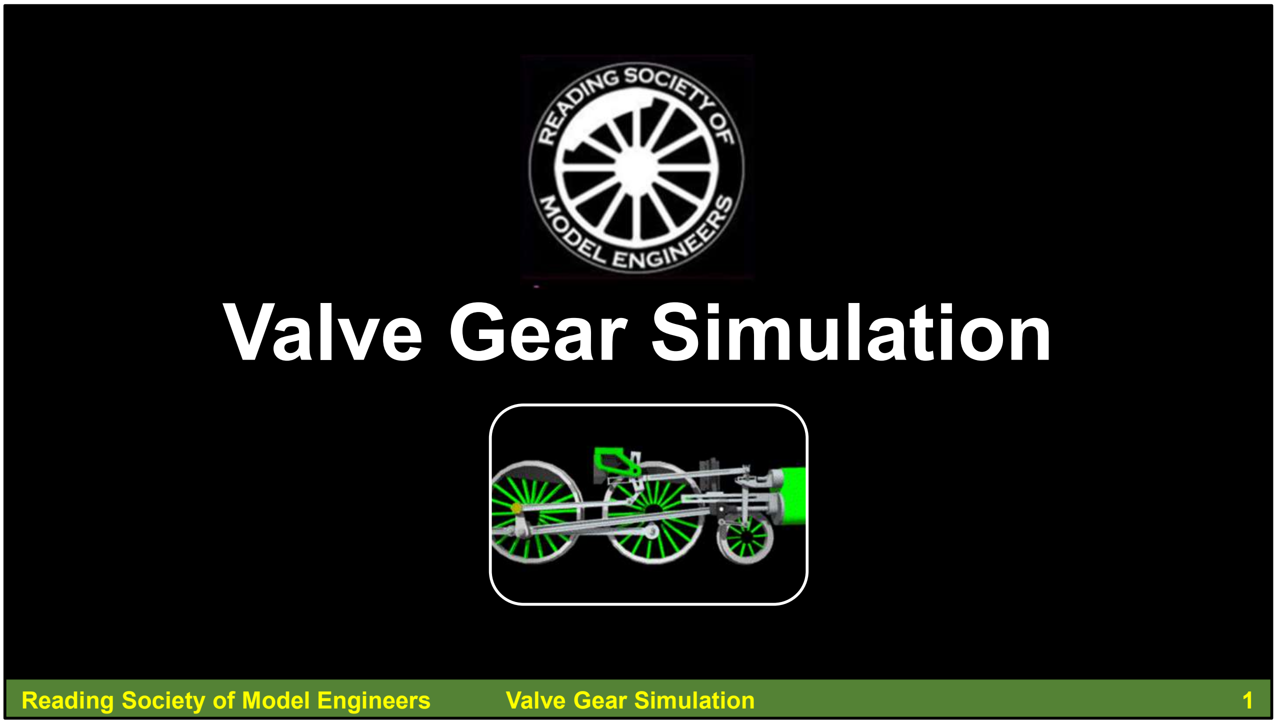
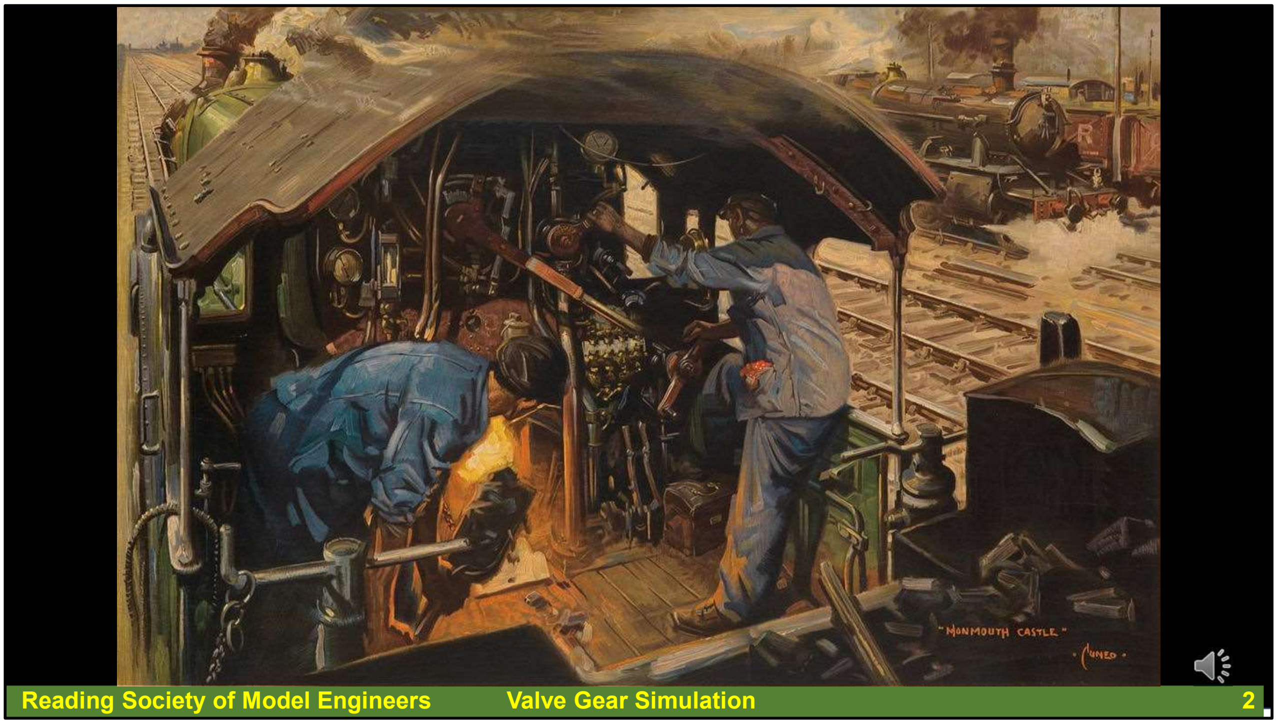


PC-Based Steam Locomotive Valve Gear Simulation

A quick look at simulation of steam locomotive valve gears and the use of Personal Computer applications to calculate the dimensions for, and show the operation of, valve gear, with particular reference to the Walshaerts gear.

We look at some of the issues involved in writing a valve gear simulation program, and conclude with a real-life case study using one computer-based simulation for miniature steam locomotive valve gear design.



Introduction

"…Whenever you hear a train go by,
Or hear a loco whistle cry,
Think of the man on the old footplate,
A-shovelling coal, the driver's Mate.

A loco fireman is me grade,
Boiling water is me trade.
The driver thinks he runs the show,
But if I'm not there, the train won't go…"

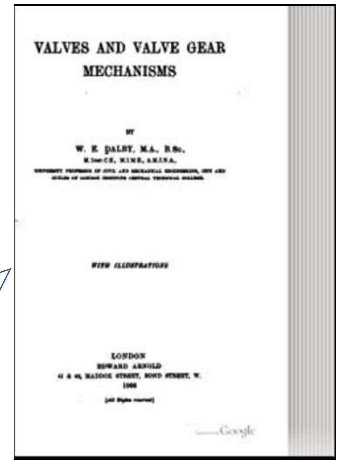
Don Bilston "The Fireman's Song" Farewell to Steam

Valve Gear

- Maximise the use of resource (pressurised steam)
- Reduce cost by using steam economically
- Provide appropriate torque at the appropriate time (prevent slipping)
- Make fireman's life easier

"… Valve gear mechanism have fascinated successive generations of engineers, and, if the truth were known, there are few mechanical engineers who have not at some time or other tried to invent a new gear.

In consequence, the number of valve gears described in the Patent Office Specifications, and indeed the number of different types which have been actually made, is exceedingly great …"


VALVES AND VALVE GEAR MECHANISMS

BY

W. E. DALBY, M.A., B.Sc.

LONDON

The Valve Gear on a steam locomotive is there to provide a number of functions. The main purpose is to get the steam to push on the piston at the right time, and then, when that work is done, to escape as quickly as possible.

No one ever said that the reason for improving valve gear design was make the fireman's job easier, but if the valve gear makes maximum use of a hard-won resource and uses it economically, it necessarily makes the fireman's job that bit easier.

And there have been many a valve gear invented – indeed patented – down the years, as this book by W. E. Dalby (1906) "Valve Gear and Valve Gear Mechanisms" mentions. Another book, by Charles Fessenden, "Valve Gears", published in the US – fifth impression 1915 – devotes *less than* 9% of the book to locomotive valve gears. Lots of valve gears for stationary steam engines – powering industry … or, here, shipping.

Inventions? Ye must stay in port to mak' a patent pay.
My Deeferential Valve-Gear taught me how that business lay.
I blame no chaps wi' clearer heads for aught they make or sell.
I found that I could not invent an' look to these as well.
So, wrestled wi' Apollyon---Nah!---fretted like a bairn---
But burned the workin'-plans last run, wi' all I hoped to earn.
…
Lord, send a man like Robbie Burns to sing the Song o' Steam!
To match wi' Scotia's noblest speech yon orchestra sublime
Whaurto---uplifted like the Just---the tail-rods mark the time.
The crank-throws give the double-bass, the feed-pump sobs an' heaves,
An' now the main eccentrics start their quarrel on the sheaves:
Her time, her own appointed time, the rocking link-head bides,
Till---hear that note?---the rod's return whings glimmerin' through the guides.
…
Interdependence absolute, forseen, ordained, decreed,
To work, Ye'll note, at ony tilt an' every rate o' speed….

McAndrew's Hymn

For some people, the sight of all those rods, flashing in the sunlight, is poetry – poetry in motion…

This should be read in a strong, Glaswegian accent.

Rudyard Kipling's poem – McAndrew's Hymn – begun in 1893 and published in 1894 – is a monologue by an elderly Scottish chief marine engineer serving in a passenger steamship, who is standing the nighttime middle watch.

(Did any of his shipmates aboard that enterprise call him "Scotty"?)

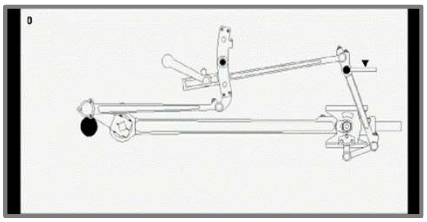
So this is about a MARINE steam engine, but does describe the poetry in motion of the valve gear,

Rudyard Kipling writing Scottish dialect – well!!

Egide Walschaerts

- In 1842 aged 22 joined the Belgian State Railways
- By1844 had reached the rank of foreman
- 1844 designed a new type of Valve Gear

Walschaerts was not permitted by the company to patent the device himself as he was deemed of too lowly a rank.



Reading Society of Model Engineers Valve Gear Simulation 5

The lines “.. Ye must stay in port to mak' a patent pay. .” had a strong echo in locomotive engineering.

Edige (pronounced Egg-eed) Walshaerts designed a new form of steam locomotive valve gear in 1844, but he was not allowed to patent it by the company he worked for!

Instead, an engineer colleague and friend, M. Fisher, applied for the patent on his behalf - but never claimed any contribution to it.

Walschaerts' name on the documents erroneously omitted the final 's' causing confusion over its correct spelling over the succeeding years.

Topics

- Why Simulate the Valve Gear?
- Computer-based simulation
- Case Study

Undoubtedly, at times, the Walschaerts valve gear looks like poetry in motion: it certainly is “in motion” since there are only two fixed points: the driving axle centre and the pivot pin of the expansion link.

There are two constraints, the piston rod and the valve rod that keep their respective pivots in the same straight-line forwards and backwards – and are nearly always, but not exclusively, parallel to each other.

Topics for this talk

- Why Simulate the Valve Gear?
- Computer-based simulation
- Case Study

Why Simulate Valve Gear Design?

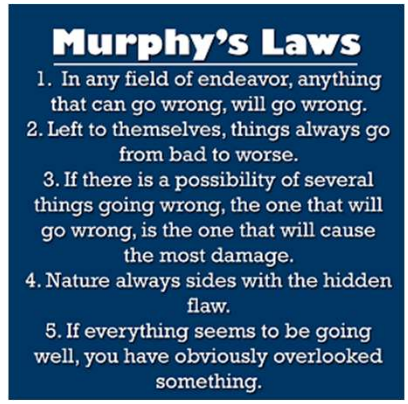
- Simulation allows you to iterate through the design at the design stage as many times as you need

  (Old adage: Plan three times, measure twice, cut once)

- Simulation allows you to see what happens if things go wrong - assume Murphy's Law is genuinely real

  (Projects doing this have higher success rate)

Wethern's Law of Suspended Judgment
Assumption is the mother of all screw-ups.



Why simulate the locomotive valve gear – after all, it is relatively easy to draw out the valve gear on the drawing board and to design the valve events accordingly – good draughtsmanship skills and the job is done.

Difficult then, however, to see what would be the effect of making simple changes to the design. With a simulation you can iterate round the design as many times as you need.

Simulation also allows you to force errors and see what happens – to works as if Murphy's Law was real… In software development, projects which were developed as if Murphy's Laws were true ended up with a higher success rate than those that did not.
By the way, Murphy was an optimist…

And there are many more "laws" about project development – here is just one of them:
"Assumption is the mother of all screw-ups".

Plan as if Murphy's Law is real

- What problems could occur and how?
- What variations of these problems are possible?
- How can the project design respond to each of these?
- How will these problems affect the ability to complete the project?
- How will these problems affect the team's belief in its success?

An alternative description is that of **defensive design.**
The designer should try to figure out what could go wrong
in use, and try to reduce or remove that possibility.

Reading Society of Model Engineers   Valve Gear Simulation   8

- What problems could occur and how?
- What variations of these problems are possible?
- How can the project design respond to each of these?
- How will these problems affect your ability to complete the project?
- How will these problems affect your (the team's) belief in its success?

- Think about where difficulties may arise and do a risk analysis
- Take reasonable measures against the risks
- Manage projects with foresight and vigilance, as unforeseen problems can arise at any time
- Don't let problems throw you off course, but actively look for solutions
- Play through worst-case scenarios so that you are prepared for as many eventualities as possible

An alternative description of this approach is "Defensive Design".

And see what happens IF…

- Design loco, position wheels, cylinders, other parts
  - How to position expansion link
    Frame mounted
    Flying frame
- Changing lengths of rods and issues arising
  (Motion paths change)

Basically, valve motion is given by the sum of two Simple Harmonic Motion curves (Sine waves) which have a phase difference between them

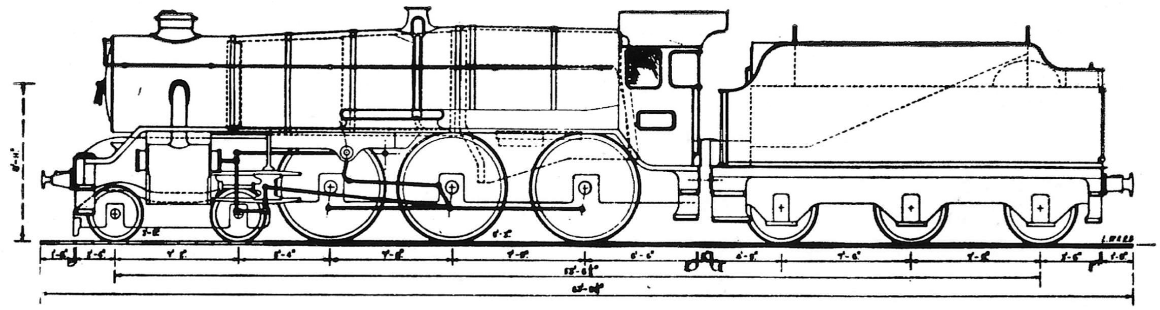
Simulation allows you to look at some of these questions before committing any design to paper, to work through some of the possible issues and problems.

And then: "…. all engines, should have their Walschaerts valve gear drawn out on a big board before one single bit of iron is sawn out…."
H. J. Coventry 1956

So you can check, for example, what happens if you change the positions of the wheels, the length of the cranks, the size and position of the cylinders:

All of these change the various motion paths.

In all this valve gear design work, all we are trying to do is to combine two Simple Harmonic Motion curves together to provide the full valve travel with some "dwell" over the ports (the "lap") and the point where the port is open to steam in relation to the position of the piston (the "lead").



Alternative design for "County" Class 4-6-0 (1944)

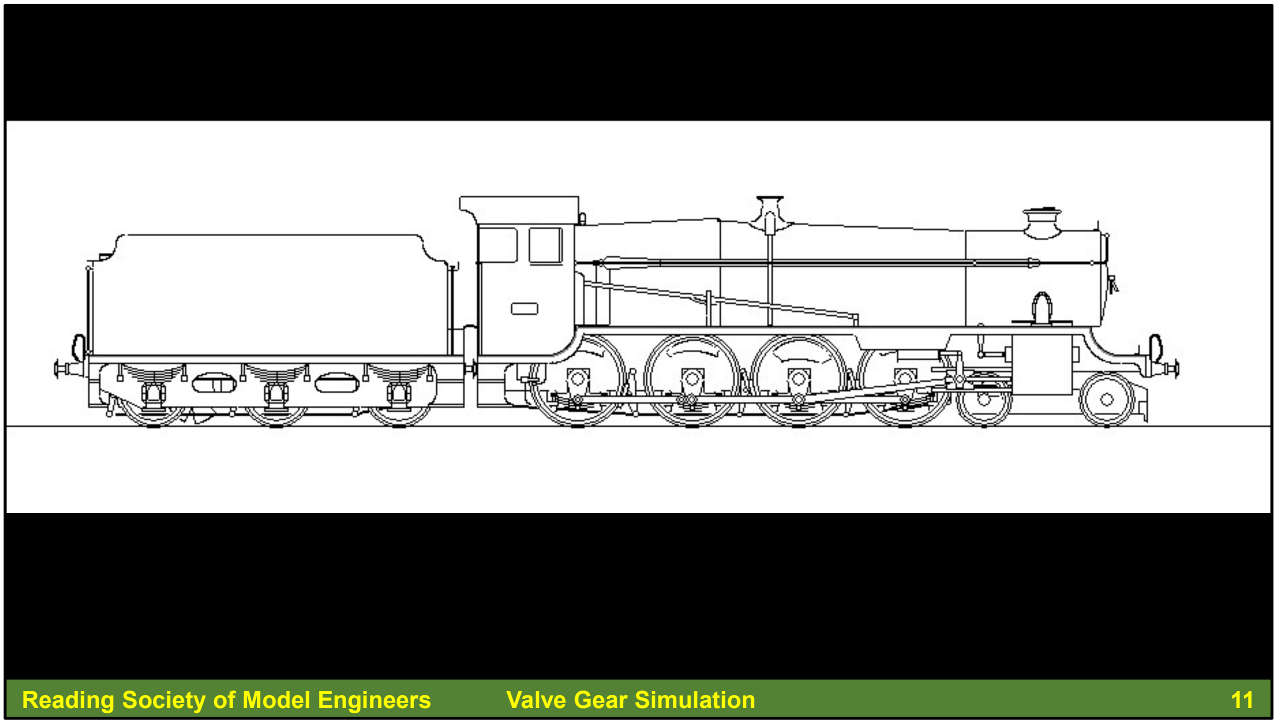
(9th of 13 proposals) J96

RCTS Part 9 Standard Two-Cylinder Classes

A quick look at some of the ways Simulation can benefit.

Let's pretend than it is 1944, and the Great Western Railway is looking to produce an improvement on its "Hall" locomotive.

Here is one of the proposed designs – the ninth proposal out of 13 outlined. It is almost identical to an LMS Black 5! We will base our design on this proposal

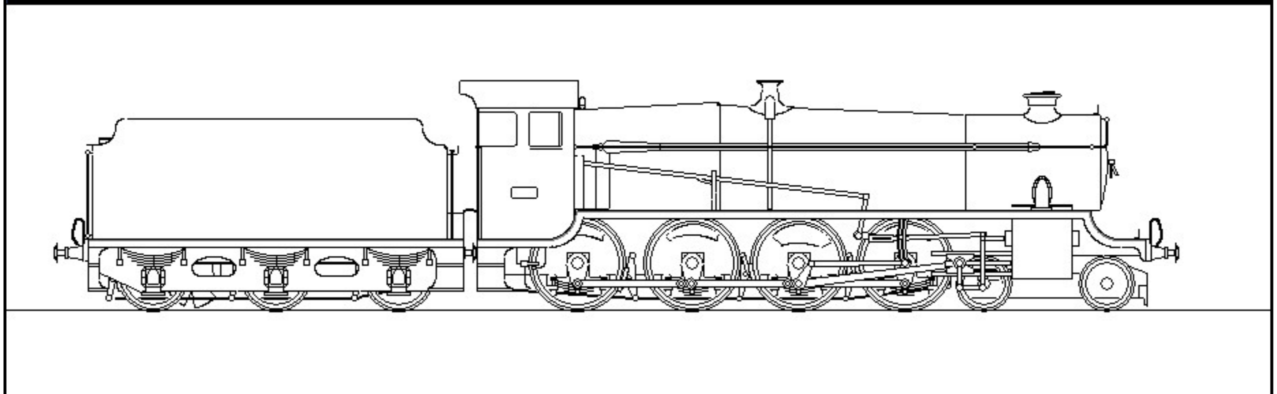


The GWR 2-8-0 47xx class locomotives were very successful mechanically, reliable and powerful, although their size was a drawback. So we will design a new 2-8-0.
No trailing wheels – the drivers can bite into the road when starting heavy loads or pounding up gradients, A deep firebox between the frames burning decent Welsh Steam Coal.

Most USA locomotives are designed on a basis of **diameter speed**, that is a speed in **miles per hour** equal numerically to diameter of the **driver** wheel in inches**.**

5 foot 8 ins wheels = 68 ins so we can assume a working speed of 68 mph.

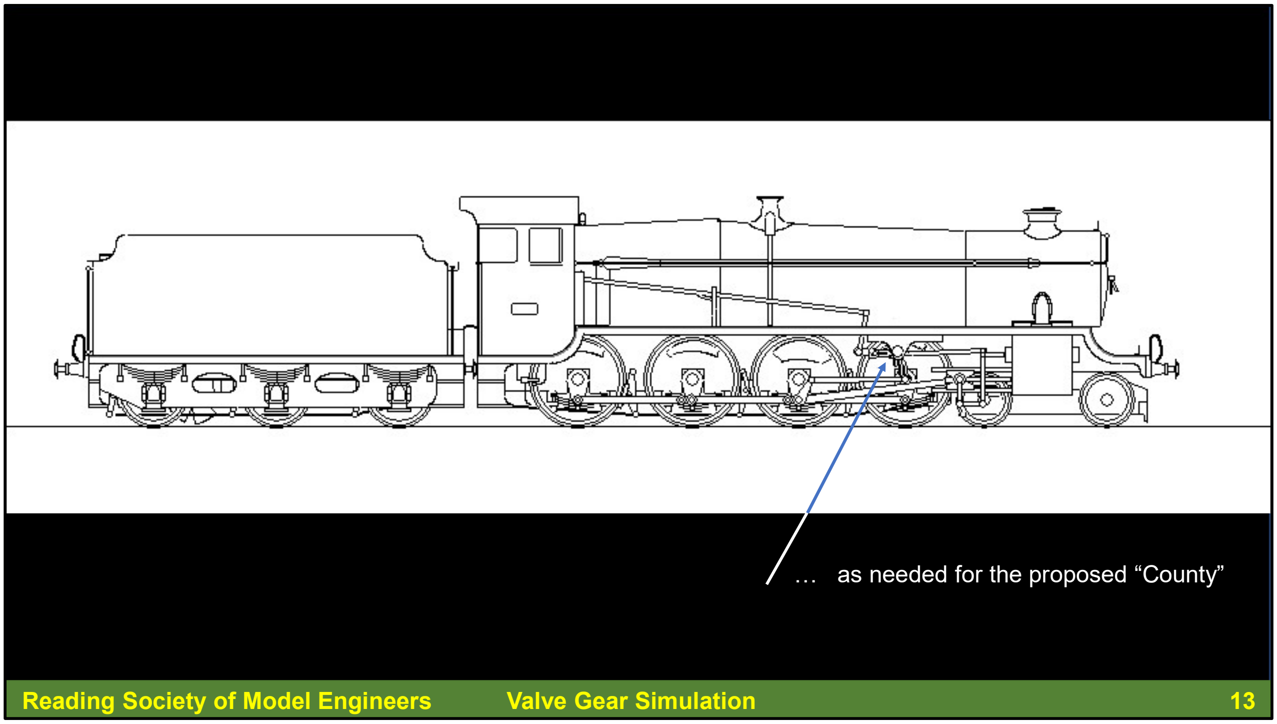
The drive for the 47xx "Night Owls" was on the second axle, so we will use that. Inside Stephenson's Valve gear, here.



But the proposed “County” was outlined with Walshaerts gear.

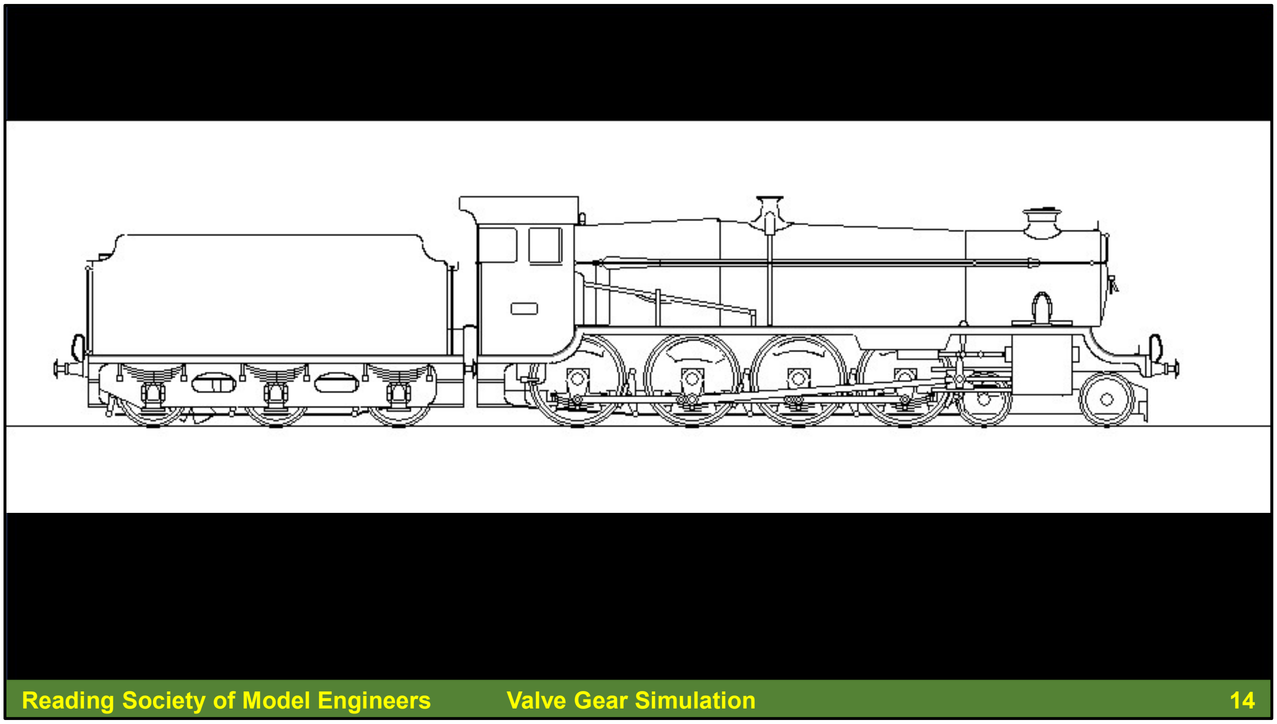
Two issues immediately apparent. The first is that we have lost the crosshead driven vacuum pump for the brakes – so we have got to find some way of maintaining the vacuum.

But most noticeable is that the expansion link for the Walschaerts’ gear is “floating around” in front of the leading driving wheel – and will need support.



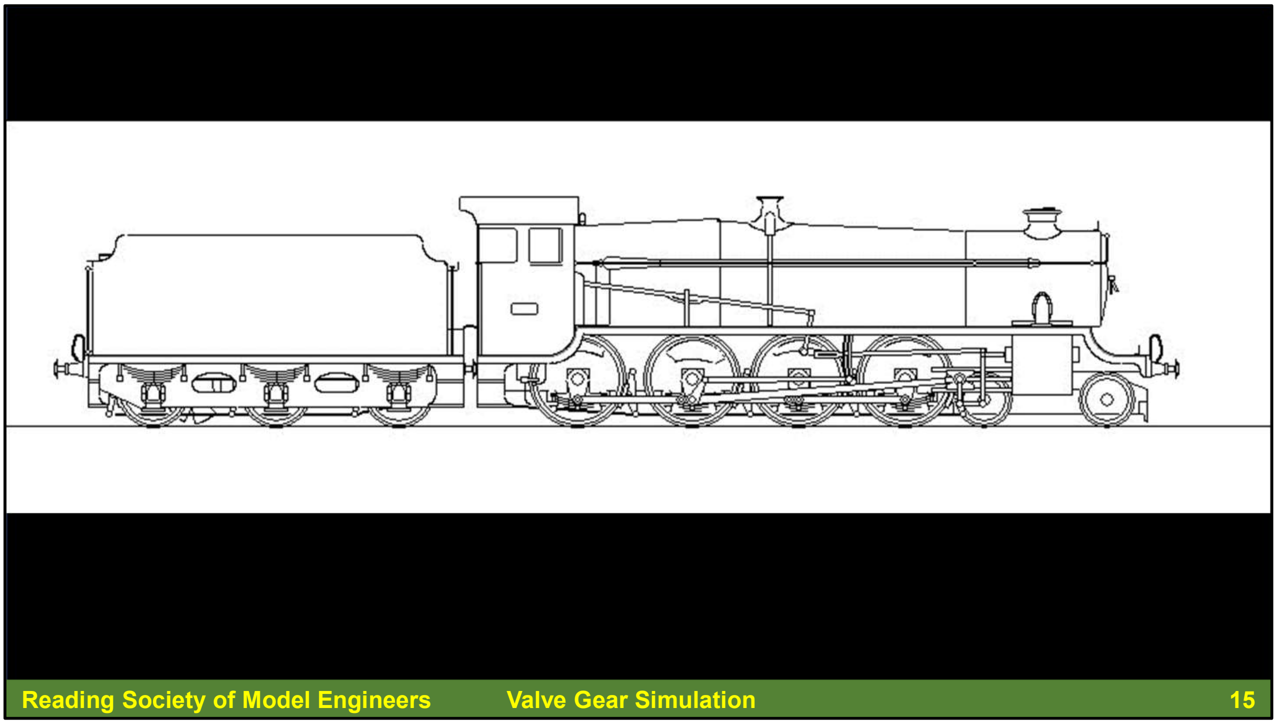
The same sort of support as shown for the proposed "County". This has got to be fixed to the frames at the ends of the extended support, to clear the driving wheel.

This is a very similar support to that provided for the STANIER LMS Locomotives.



What if we put the connecting rod onto the third axle – as with the 28xx heavy freight locomotives?

This is how it would look like with Stephenson’s link motion …



And now with Walshaerts' Radial gear.

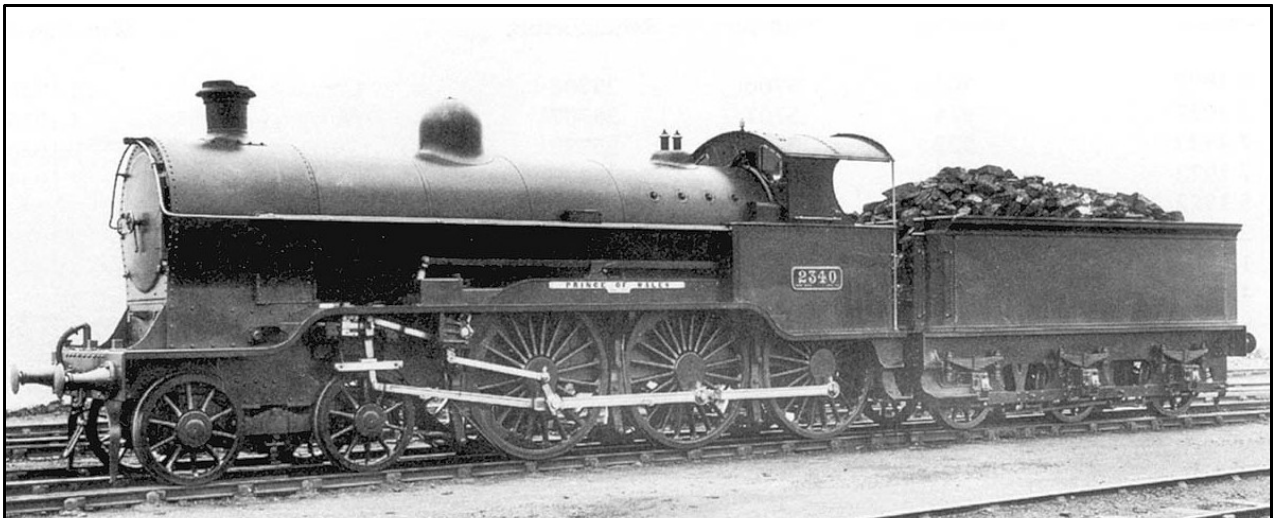
The pivot for the expansion link can now be fixed directly to the frame – no flying bearings or whatever.

By the way – the design program placed the expansion link all by itself – a sort of "Artificial Intelligence" application!

What problems do we encounter here?

Long connecting rods – and possible deflection under load.

Long eccentric rods and radial rods – possible expansion and contraction of the rods depending on the weather!

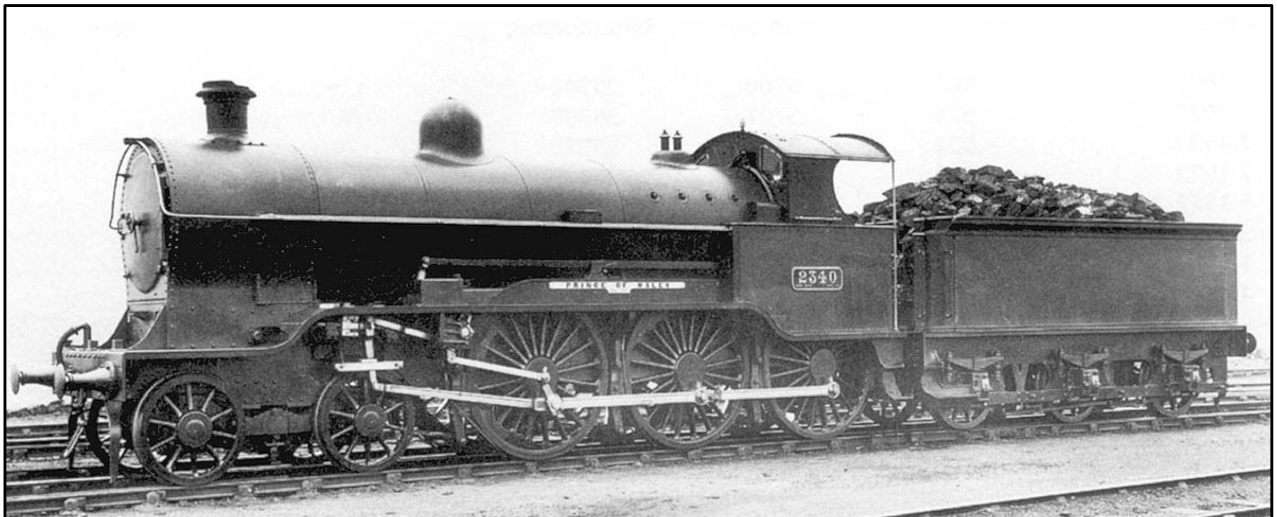


Ex-LNWR 4-6-0 No 2340 'Tara'   4th June 1924

Walschaerts gear outside the frames, instead of Joy valve motion between the frames, was provided to operate the inside cylinders

There is absolutely no reason why the return crank and the eccentric rod should be driven from the crank used by the connecting rod. As long as we get those two simple harmonic motions with their phase difference, it does not matter how they are derived.

This locomotive is a case in point – although I suspect the drive was onto the front coupled axle. The class originally had Joy valve motion between the frames – Joy gear was designed around the idea of the development of the Simple Harmonic Motion loci - but a total of five locomotives of this class were rebuilt with Walschaerts gear outside the frames to operate the inside cylinders' valves. Although arranged by Beames in the final months of the LNWR, the rebuilds were not implemented until after the Grouping This new motion required the running plate to be raised for most of its length. Engines No 964 and No 867 were so rebuilt in March 1923, followed by No 56 in March, and No 2340 in April 1924.



Ex-LNWR 4-6-0 No 2340 'Tara'   4th June 1924

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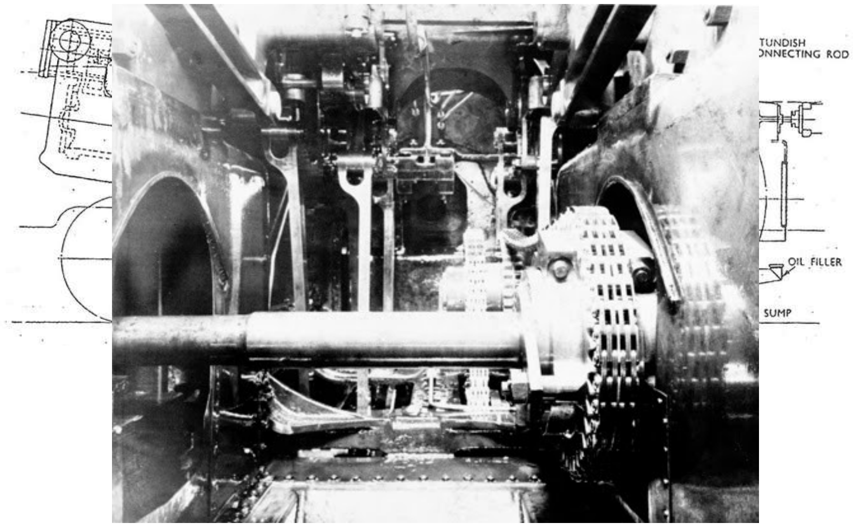
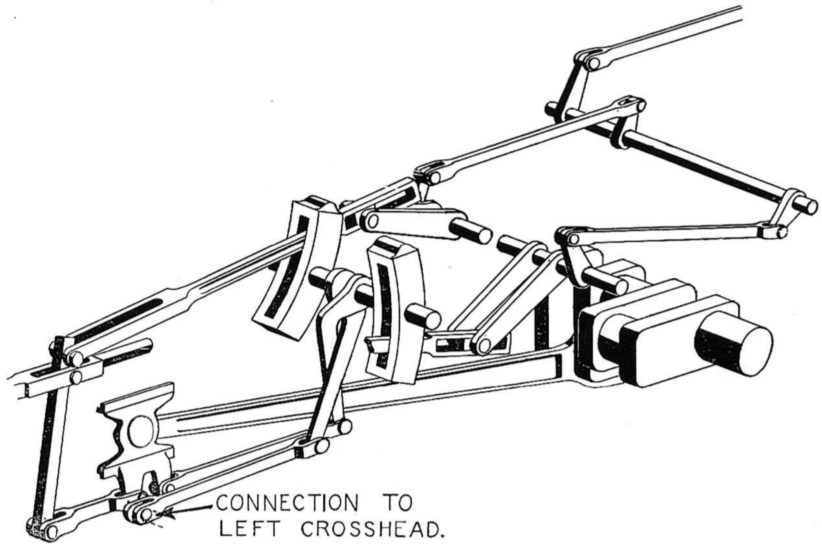
The locomotive No 2340 was one of five outside valve-gear engines which were nicknamed after a racehorse, "Tishy", which (apparently) had a disastrous habit of getting its forelegs crossed during races. It is assumed this nickname was derived from the action of the 'crossed rods' of the outside Walschaerts gear.

Ex-LNWR 4-6-0 No 2340 'Tara' seen on 4th June 1924 carrying the nameplate the 'Prince of Wales'. It’s not known why No 2340 was carrying the name plate 'Prince of Wales' as it was due to be fitted to ex-LNWR 4-6-0 'Prince of Wales’ class No 5845 for display at the Wembley Exhibition. Harry Jack writes 'LNWR No 2340 (Crewe motion No 5326, built April 1916) was named 'Tara' before and after this photograph was taken, so it is a bit of a mystery as to why it should have been photographed (just after rebuilding with outside valve gear) on 4th June 1924, with the nameplate later fitted to the Wembley Exhibition engine LMS No 5845. Ted Talbot's book "An Illustrated History of LNWR Engines" has a broadside photo of No 2340 taken at the same time as the above photograph (plate 485). It looks like No 5845's nameplate, which was different in detail from that on the first of the class No 819, but maybe it's a fake put on just for the photograph. (When did the Wembley Exhibition open? When did No 5845 first appear there? Did it have its nameplate from its first appearance? The engine is mentioned in the Railway Magazine of June 1924 as being exhibited at Wembley by Beardmore & Co, but no mention of a nameplate. More research needed!) I can only guess why these photos were taken - maybe LMS publicity shots when No 8545 wasn't available?



Another locomotive where the return crank and eccentric rod is not driven from the connecting rod crank is, of course, the Southern Railway's Bullied "Merchant Navy" and light pacific (WC and BB) locomotives. The miniaturised valve gear was driven by a chain from the driven axle to an idler, and then another chain to the valve gear mechanism itself.

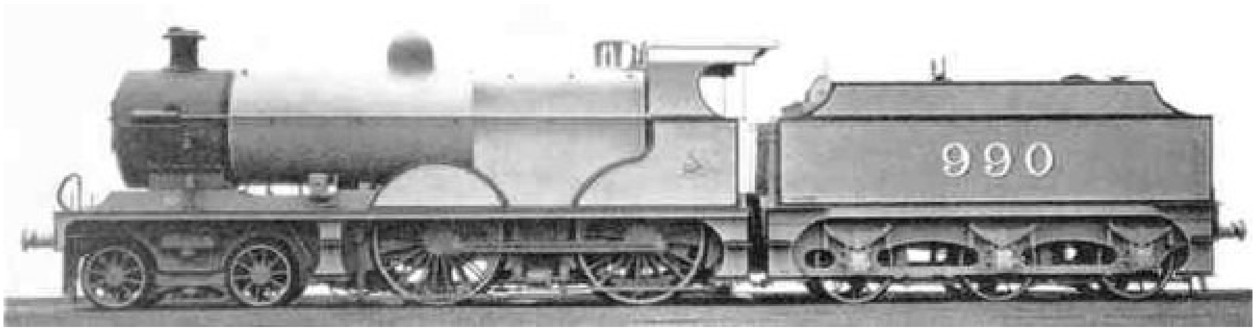
Other locomotives had valve gear which was not directly driven from the connecting rod crank – Gresley's conjugated gear used a derived motion for the inside cylinder, and the "Stars", Castles" and "Kings" had their outside cylinders' valves driven from the inside valve gear.



Pictorial drawing of the 'scissors' gear as applied to the 'North Star'

But one "Star" in particular did not have any return crank or eccentric rod. The motion for one side of the engine was driven by a connection from the crosshead of the other inside piston – and because of quartering, there was the necessary 90-degree difference between the expansion link motion and the combination rod motion.

This "scissors" gear was only ever fitted to "North Star" (40 as was) and was completed in April 1906. The main reason why it was not put into production was that if there was a fault that necessitated isolating the valve gear on one side of the engine, it disabled the complete engine. The scissors gear had been proposed to Churchward by W. H. Pearce in June 1905.



Meanwhile, over at the Midland Railway, much the same idea had occurred to R. M. Deeley when he was an assistant to S. W. Johnson. Johnson would have nothing to do with it – but when Deeley succeeded Johnson at Derby, he revived the idea for his large 4-4-0 no. 990. On 11th August 1905 he applied for a patent for this gear, the patent being granted in June 1906.

Deeley wrote to Churchward, accusing the GWR of using the Deeley patented gear without acknowledgement. There was no difficulty in showing that the Swindon gear was designed before Deeley applied for his patent, so that Churchward had every right to use it.

In operation, the “scissors” gear was very similar to Walschaerts, but with no return cranks or eccentric rods. The lead was constant at all cut-offs.

On the production versions of the Stars and Castles, the final section of the reversing shaft was split so that the left and right sides of the engine could be isolated independently.

Inside Cylinders	Outside Cylinders
Low Pressure	High pressure
16 ins x 26 ins	13ins x 20 ins (to get a ratio of approx. 1:2)
Very short connecting rods (4 feet)	"Regular" outside connecting rods
(High angularity)	(Normal angularity)
Drive: Leading coupled axle	Drive: Rear coupled axle
Inside **Stephenson's** Valve gear	Outside **Walshaerts'** Valve Gear

Boiler pressure: 200 psi

Howden "Locomotives of the World" (1910)

Ivatt built a four-cylinder compound version (No. 292) in March 1905. The outside cylinders drove the trailing coupled axle, whilst the inside cylinders drove the leading coupled axle.

His Great Northern compound Atlantic used:

Inside Stephenson's link motion for the inside LOW pressure cylinders and Outside Walschaerts radial valve gear for the outside HIGH pressure cylinders

Stephenson's valve gear is more resilient for use with rods of high angularity.

A valve was fitted beneath the smokebox, which switched the locomotive from simple to compound working. This was controlled from the cab, enabling a driver to switch between simple and compound working. The boiler was built to operate at 225psi, but actually operated at 200psi. No evidence has been found to suggest that 225psi was ever used. It was withdrawn from service in August 1928.

Stephenson link motion
Automatically advances timing (lead) as notched up from full gear.
Also better for high angularity connecting rods

Walschaerts radial motion
Has fixed lead in all cut-offs - the linear position of the valve remains fixed regardless of cut-off when the piston is at dead centre.

L. D. Porta
Reduce length of eccentric (return) crank - changes the lead in Walschaerts gear. This reduces a locomotive's starting capability but increases its ability to haul heavy loads at high speed – so produces high power at high speed.

One of the keys to getting equal valve movement in Walschaerts valve gear is the position of the expansion link pivot, which is not exactly at the center of the link curve.

This pin position is very critical: few ever get it right.

In summary:
Stephenson's advances timing as the locomotive is notched up.
Walschaerts' gear has a fixed lead at all cut-offs.

There is NO LEAD in Walschaerts' Valvel. But have found a quote - from "`Valve Gears" by C. D. Fessenden:

The Walschaert valve gear can be designed to give a variable lead. This practice has been followed recently in a number of cases. With a variable lead the longest possible cut-off in starting can be obtained, combined with the proper amount of lead at the ordinary running cut-off. In the case of passenger locomotives particularly, a steam distribution like this is often most desirable. The favorable results for starting are obtained, however, at the expense of the distortion of the valve events in the back motion. For this reason, the Walschaert valve gear with variable lead is suitable only for passanger and fast freight locomotives, and not for slow freight and switching locomotives.

With a variable lead so arranged that the lead increases as the reverse lever is hooked up, the eccentric crank lags behind the correct position for a constant lead; in other words, it is

Stephenson link motion
Automatically advances timing (lead) as notched up from full gear.
Also better for high angularity connecting rods

Walschaerts radial motion
Has fixed lead in all cut-offs - the linear position of the valve remains fixed regardless of cut-off when the piston is at dead centre.

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One of the keys to getting equal valve movement in Walschaerts valve gear is the position of the expansion link pivot, which is not exactly at the center of the link curve.

This pin position is very critical: few ever get it right.

This was in the 5th Impression dated 1915

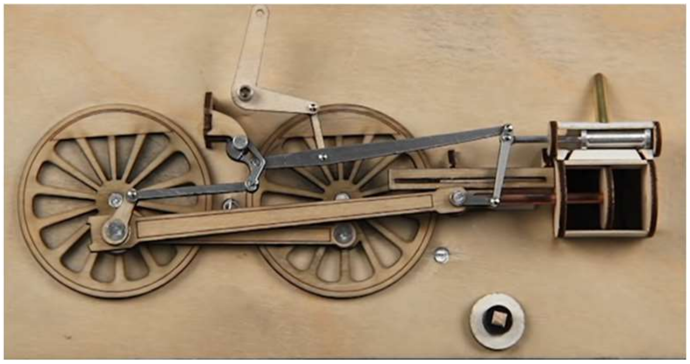
L. D. Porta (Argentina) produced variable lead in Walschaerts' gear by reducing the return crank length. In effect this single alteration advances the expansion link component in full forward gear and lessens towards mid gear, probably courting negative lead in full back gear. This made starting more difficult, but was effective at running speed with heavy loadings.

Porta was not born until 1922, so this potential variable lead had been known about for over a quarter of a century before Porta used the idea. If it was that good, it would have been implemented at large in those intervening years, rather than being "discovered" anew!

Full Variable lead in Walschaerts would be very very (very) tricky to arrange mechanically.

The critical item in designing Walshaerts' Valve Gear is getting the pivot of the expansion link in exactly the right place – which is NOT at the mid-point of the arc of the expansion link. This is critical – it is one of the only two fixed points in a convention Walschaerts layout.

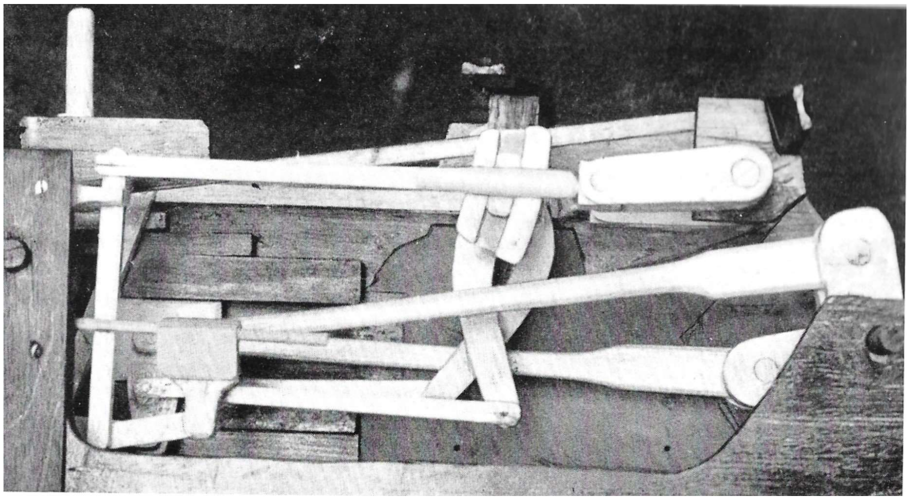
Many locomotive drawing offices used large adjustable frames to evaluate new valve gear designs and aid the detailed design of the required gear



So how did they do it in the old days?

In many of the drawing offices, there were models of the valve gear where the various dimensions could be adjusted. Often the mock up was made of wood, and various lengths of rod would be tried to get the right motion.

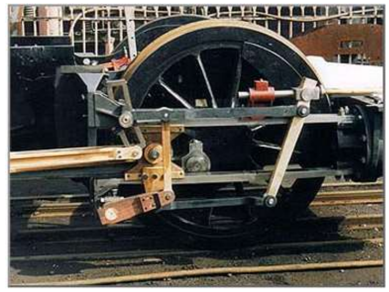
Wooden model of proposed valve gear for “Star” 40 (later, 4000) by W. H. Pearce, June 1905
(he previously had designed the Stephenson Gear for Churchward’s 2-cylinder locomotives)



This is the wooden model of the proposed “scissors” valve gear for “Star” 40 (later, 4000) by W. H. Pearce, June 1905.

GREAT WESTERN SOCIETY

Railmotor Rebuild



"… Due to the lack of original detailed drawings of the motion, connecting rods, valve and piston rod assembly, combination lever union link and reversing shaft were mocked up in timber…

These wooden components enabled us to align the frame, wheelsets and motion so that exact dimensions could be confirmed before ordering the … motion parts …"

In real life locomotive engineering, the Great Western group building the Railmotor resorted to wooden mock-ups of the valve gear tin order to get the motion correct – even with the drawings!

The valve gear for the Railmotor is very similar to that used on the original Vale of Rheidol steam locomotives, but even so the group found it difficult to get the valve gear correct!

"… Due to the lack of original detailed drawings of the motion, connecting rods, valve and piston rod assembly, combination lever union link and reversing shaft were mocked up in timber… These wooden components enabled us to align the frame, wheelsets and motion so that exact dimensions could be confirmed before ordering the … motion parts …"

"… The precise setting of the valves is to be undertaken using a computer assisted program as we have conflicting information on the settings, despite having obtained the additional valve gear drawings from the National Railway Museum…

Once the dimensions have been established the final machining will be done ….

We prefer to take a conservative approach as a mistake at this stage could well be costly in terms of both finance and time…"

But - the group were also going to use a computer assisted design program to get the valve gear designed before the final machining was done.

"… The valve gear was trial fitted … an adjustable drop rod was fitted to allow precise setting of the mid gear position…

In addition, a temporary radius rod was installed to precise setting of the valve leads…"

Temporary – and adjustable – rods were used to get the precise setting of the mid-gear position. And for the lead – but there is no (variable) lead in Walschaerts motion!

The Railmotor in action….

Computer based simulations available

- Charlie Dockstader
- Bill Hall
- Allan Wallace
- Don Ashton (Spreadsheet based)

So we now come to the some of the simulations currently available:

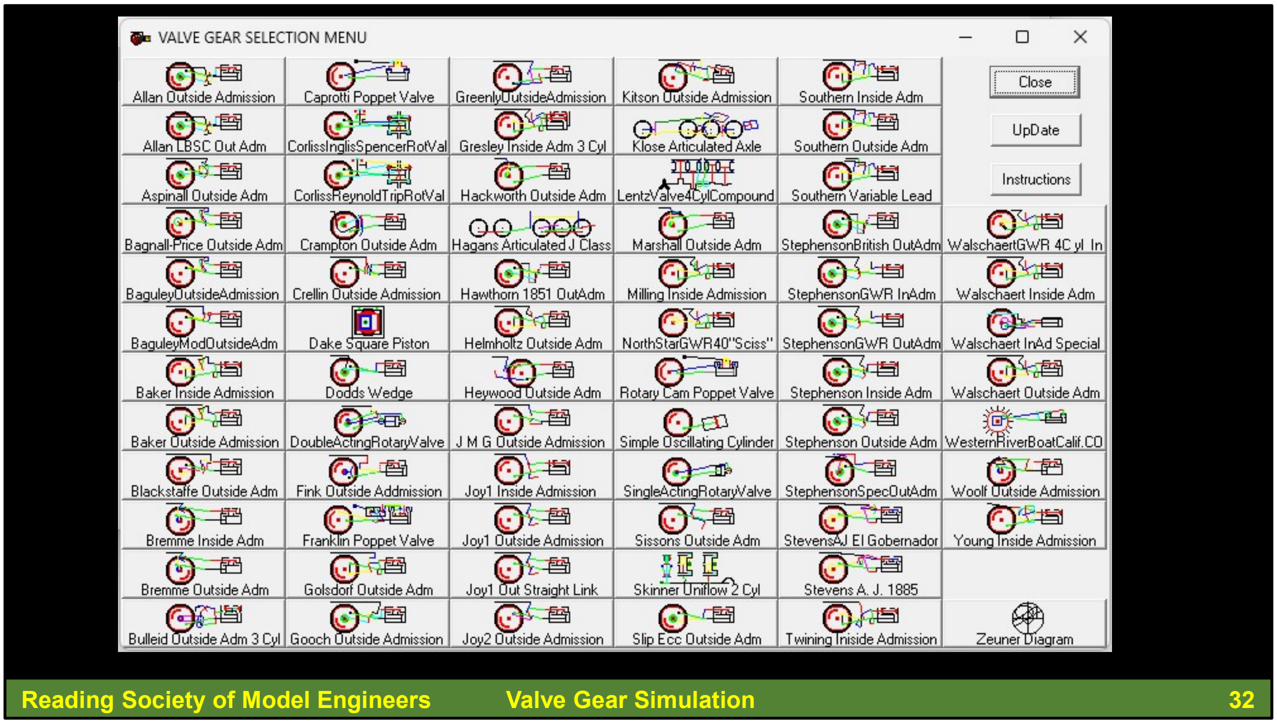
- Charlie Dockstader
- Bill Hall
- Allan Wallace
- Don Ashton (Spreadsheet based)

Charlie Dockstader

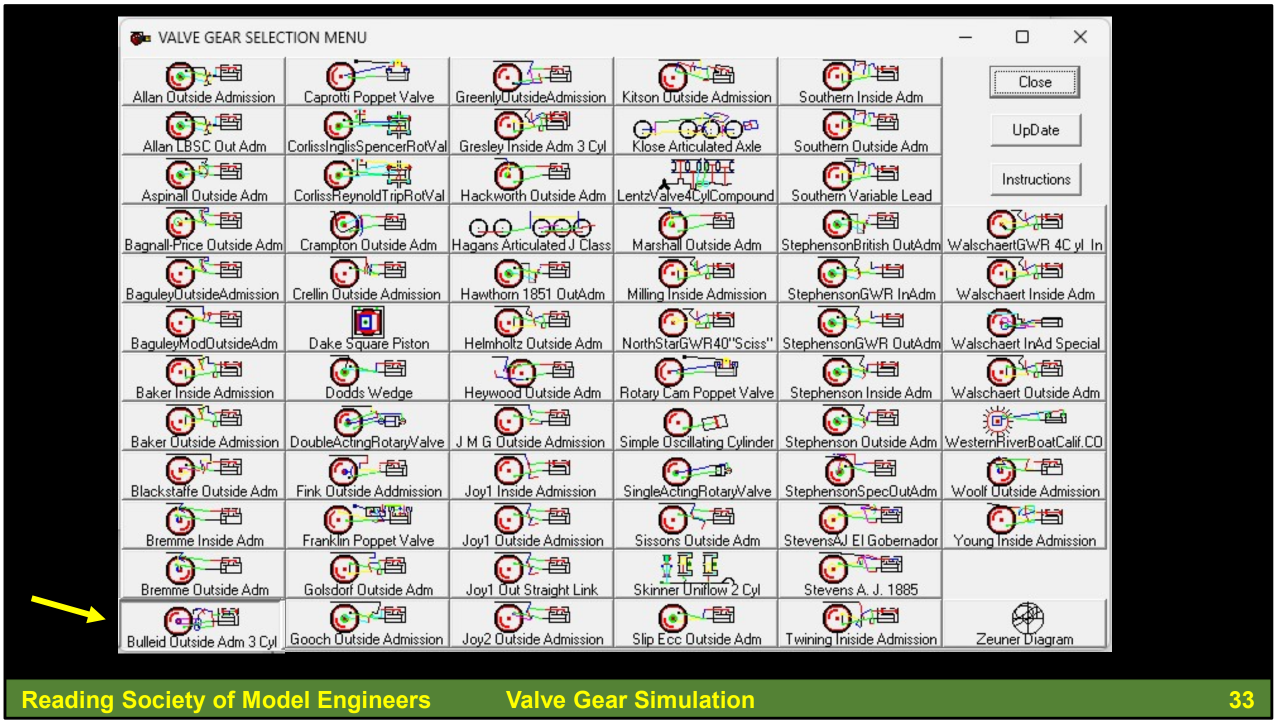
Charlie Dockstader in the grandaddy of the simulations –
He is driving his Central Pacific 229 4-8-0 at the Bitter Creek Western Railroad, located some 200 kilometres North-west from Los Angeles.

Charles wrote the first of the MS-Dos versions of the software in 1986 to simulate Baker valve gear. Since then he made continuous additions and improvements to add other types of valve gear and improve functionality and ease of use. In early 1999 he started converting one of the valve gears to the Windows format.

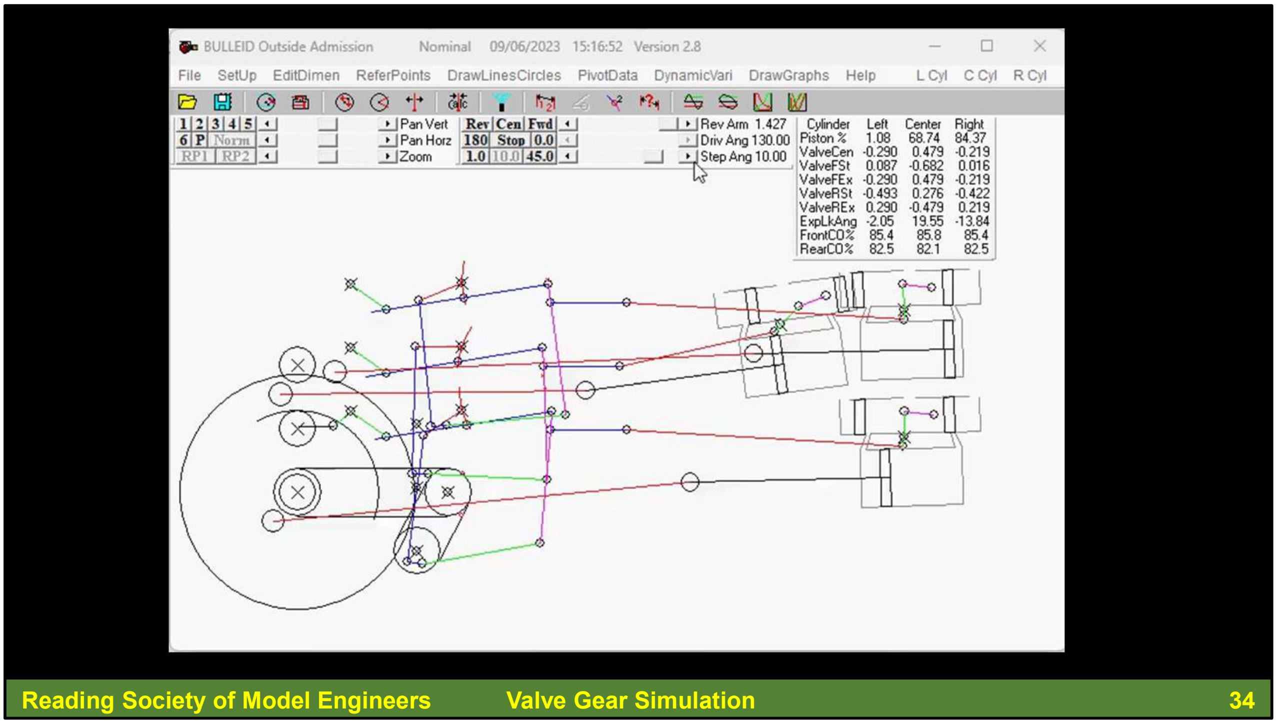
The programs can be used with the default settings to view operation and characteristics of any of the types of valve gear supported. They may also be used to check or change designs as all the dimensions in the gear can be modified. Performance for all types can be viewed using several different types of diagrams.
The default dimensions used in the programs are in inches and most are for 1.5-inch scale (7.25 gauge). They can be user modified to suite the scale desired or for use with the metric system.



67 Valve Gears available. Each one can be configured to show how it operates.



So we will press the button to see the Bullied 3-cylinder outside admission simulation in action.



Dockstader Simulation Running – more detail on this simulation when we look at the case study!

Benefits

- The fullest range of different locomotive valve gears
- Most simulations based on 1.5 inch scale (1/8th scale or 7.25 in gauge)

Certainly, the widest range of simulations available.

Issues

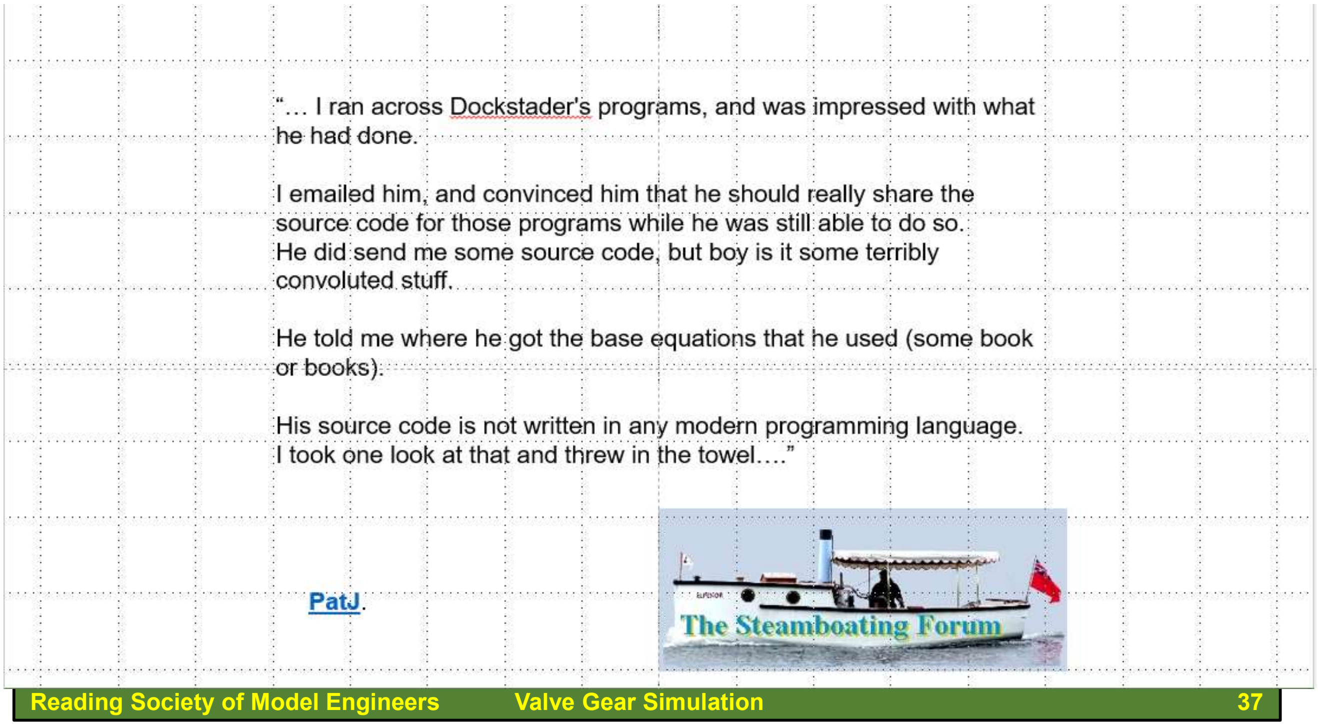
1. In mid-gear, the valves, pistons and wheels are in motion, when they should be stationary
2. It is not possible to see the effect of changing the position of the return crank compared to the main crank
3. There are separate applications for inside and outside admission
4. The graphs representing the valve events are the same for every position of cut-off – they should change as the loco is notched up
5. Any changed data should be saved if changes are to be compared
6. The user interface is not based on “best practice”.

In mitigation, some of this is a result of having first being written for MSDOS (1986).

Charles Dockstader’s valve gear simulations suffer from a number of problems:

1. In mid-gear, the valves, pistons and wheels are in motion, when they should be stationary
2. It is not possible to see the effect of changing the position of the return crank compared to the main crank
3. There are separate applications for inside and outside admission
4. The graphs representing the valve events are the same for every position of cut-off – they should change as the loco is notched up
5. Any changed data must be saved otherwise it does not get implemented in the application.
6. The user interface is not based on “best practice”.

In mitigation, some of this is a result of having first being written for MS-DOS (1986).



I was hoping that the Dockstader programs could be tweaked to remove some of the issues. To do that, you need to get the source code. I wrote to the guy at Bitter Creek Western Railroad – no reply.

Although the executables have been put in the public domain by Charlie, the software has not been made publicly available.

One person, PatJ, on the Steamboating Forum has actually seen the source code – but had some problems with it!

```
* Reference to : TCylDimen.Proc_00466900()
|
00467082   E879F8FFFF       call    00466900
00467087   D907             fld     dword ptr [edi]
00467089   83C4F4           add     esp, -$0C
0046708C   DB3C24           fstp    tbyte ptr [esp]
0046708F   9B               wait
00467090   8D8D00FFFFFF     lea     ecx, [ebp+$FFFFFF00]
00467096   BA03000000       mov     edx, $00000003
0046709B   B805000000       mov     eax, $00000005

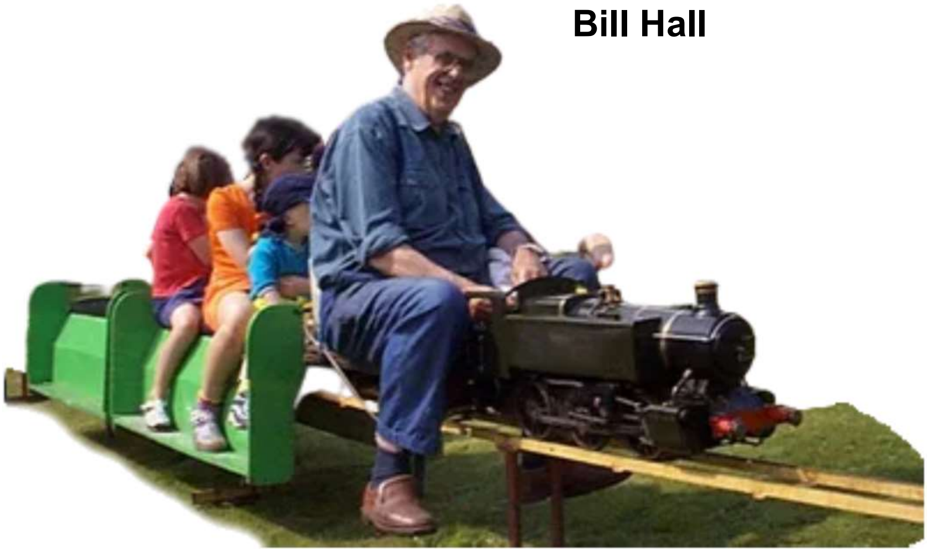
* Reference to: system.@Str2Ext;
|
004670A0   E8DAEAF9FF       call    00405B7F
004670A5   8D9500FFFFFF     lea     edx, [ebp+$FFFFFF00]
004670AB   8BC6             mov     eax, esi
004670AD   B10A             mov     cl, $0A
```

Reading Society of Model Engineers Valve Gear Simulation 38

I tried decompiling the executables. This provided the code for the User-interface forms, but not for the underlying computations and integrations. There is a considerable amount of assembler and machine code there, and it is just about impossible to follow it through. For example, there is little to help you understand how some of the variables are named.

Generally, the word on the street is that if you haven't got the source code, rewrite the application from scratch: there are firms out there who claim to be able to decompile fully, but it is extremely costly and there is no guarantee of success.

Bill Hall

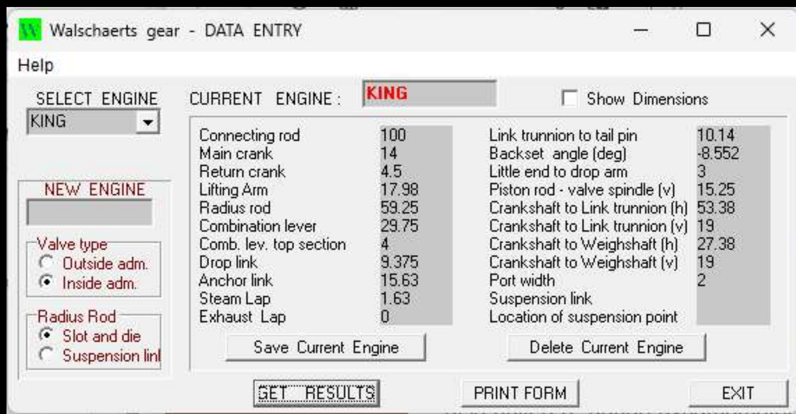


Professor (Bill) Hall F. R. Eng., F.I.Mech.E. was Professor of Nuclear Engineering at the University of Manchester (England) and took a leading role in the early development of nuclear power in the UK. He was also a devotee of the Ravenglass and Eskdale Railway for the benefit of whose members he developed his software packages.

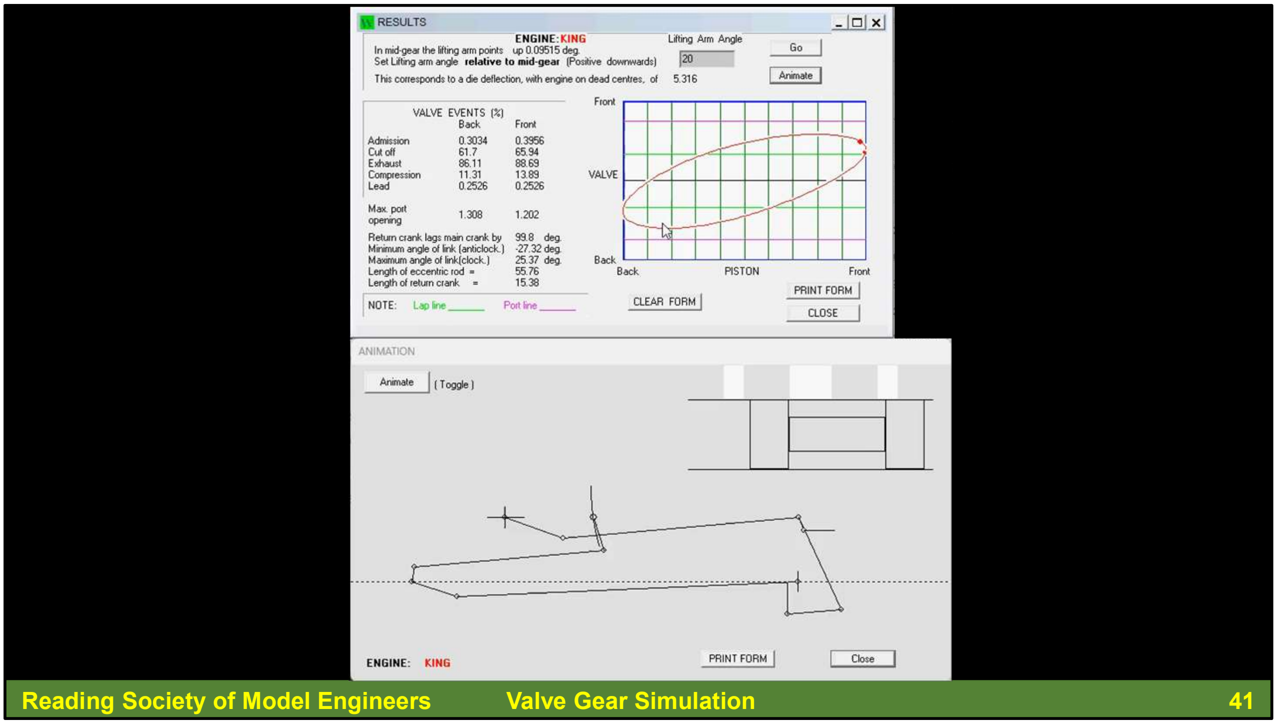
Bill died in 2003 at the age of 80 before he was able to complete a new program with which he intended to simulate locomotive combustion systems. He discovered the task to be profoundly difficult and declared the steam locomotive's firebox more complex to model than a nuclear reactor.

Bill developed two software packages – a simpler one called "*Perform*" and a supplementary one called "*Perwal*". "*Perform*" uses a simplified "generic" simulation of valve events whilst "*Perwal*" incorporates an algorithm that more accurately predicts valve events based on the use of Walschaerts valve gear (the valve gear's geometry being defined by the user).

Bill Hall: Set Dimensions



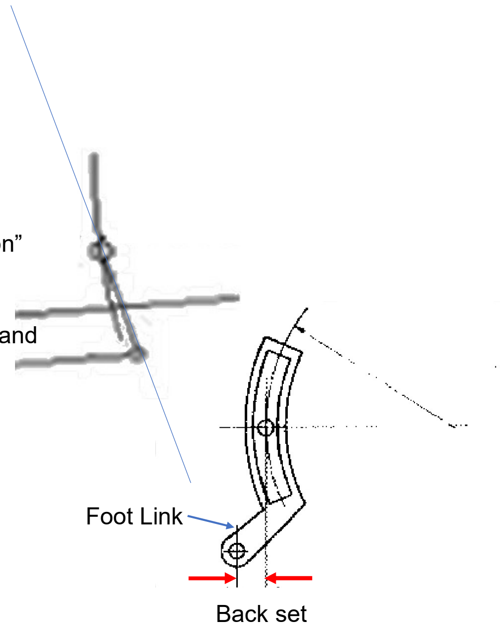
Set up the dimensions for the Simulation.



Running the Bill Hall Simulation.

Issues

- Can not dynamically change the cut-off
- Eccentric rod drives a straight line "approximation" to the Expansion Link
- What about the back set of the Expansion Link, and the dimensions of the Foot Link?
- How is the position of the die-block calculated?



NOTE: Used by John Billard

The eccentric rod drives a straight-line substitute for the expansion link.

No indication of the Back Set of the Expansion Link, although the user has to put in the angle of the back set.
No provision for the entry of the dimension of the Foot Link.

Both dimension changes could have very significant implications for the operation of the valve gear!

It is not clear how the position of the die block is then calculated!

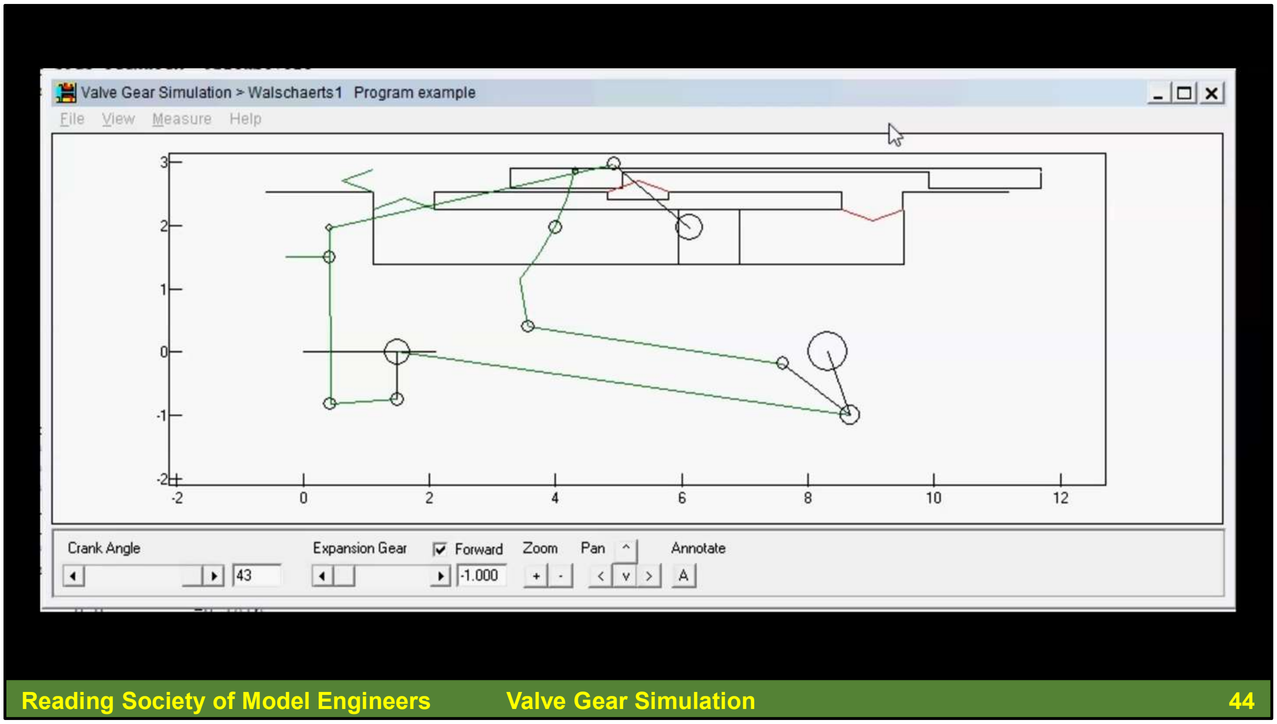
Allan Wallace

Dr Allan Wallace (PhD in mechanical engineering and fluid mechanics) runs his own engineering consulting company in Adelaide, South Australia, that specialises in solving unusual and difficult engineering problems. Allan has undertaken several railway-related projects including the design of specialized rail freight wagons.

Allan is an enthusiastic builder of 3½" and 5″ gauge steam locomotives, which he regularly runs in his spare time.

He has also built a 5″ gauge dynamometer car fitted with electronic load-cells and lap-top computer, for monitoring and comparing the performance of his and other builders' locomotives.

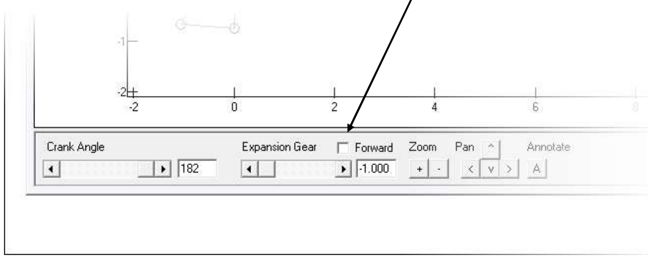
LBSC freely recognised his lack of detailed information regarding valve gears. He was in this respect an acknowledged 'pins and cardboard' juggler destined to produce some reasonable working gears and some inevitably much the poorer. In fact, it was suspicions regarding the efficacy of Speedy's valve gear that led both Professor Bill Hall, then of Manchester University, and Dr. Allan Wallace of Adelaide, to devise the simulated means of investigating the kinematics of valve motions.



Running the Wallace simulation.

Issues

- Can not dynamically change the cut-off
- Have to select the direction of rotation irrespective of where the radius rod is in the expansion link



Reading Society of Model Engineers Valve Gear Simulation 45

Issues

- Can not dynamically change the cut-off and change direction
- Have to select the direction of rotation irrespective of where the radius rod is in the expansion link

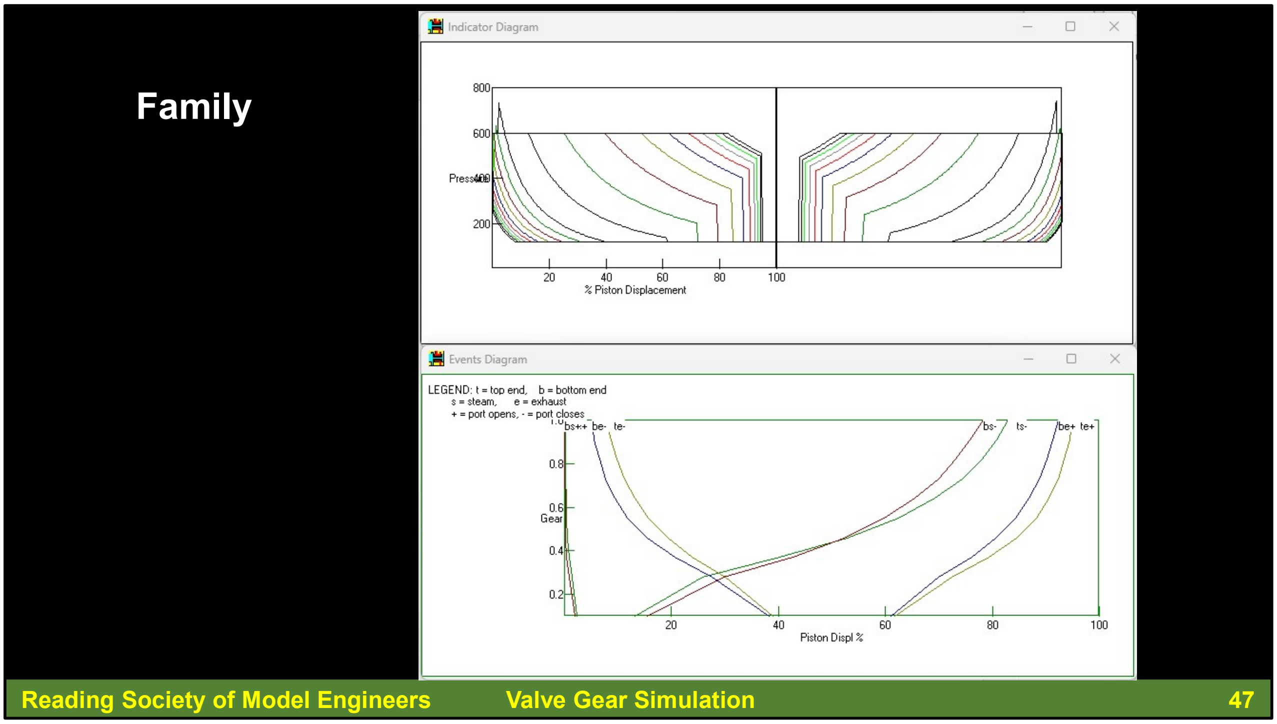
Messages

Edit

```
Event     %PistDispl          CrankAngle          ValveDisp
Top End
Steam on        0.2              355.4             -0.1571
Steam off      82.8              127.6             -0.1538
Exhaust on     94.9              151.9              0.0002
Exhaust off     7.7              329.9             -0.0022
Bottom End
Steam on      100.0              178.0              0.1580
Steam off      21.8              307.6              0.1520
Exhaust on      7.7              329.9             -0.0022
Exhaust off    94.9              151.9              0.0002

Admission angles, Top    132.2   Bottom    129.6   degrees of wheel rotation
Cutoff          , Top     82.8   Bottom     78.2   % stroke from dead centre
(For more accurate interpolated cutoffs, scroll to bottom of this listing.)
************************************************
************************************************
************************************************
This is a detailed listing from the last time the
valve events were calculated.
************************************************
Top stm  -0.1560 Top exh   0.0000 Bot stm   0.1560 Bot exh  -0.0000
Step   Crankangle       %PistDispl        Valvedisp
   0        0.0            0.0         -0.1816
   1        0.7            0.0         -0.1850
   2        1.3            0.0         -0.1883
   3        2.0            0.0         -0.1917
   4        2.6            0.1         -0.1950
   5        3.3            0.1         -0.1983
   6        3.9            0.1         -0.2016
   7        4.6            0.2         -0.2049
   8        5.2            0.2         -0.2081
   9        5.9            0.3         -0.2113
  10        6.5            0.4         -0.2145
  11        7.2            0.5         -0.2177
  12        7.9            0.5         -0.2208
  13        8.5            0.6         -0.2240
  14        9.2            0.7         -0.2271
  15        9.8            0.8         -0.2301
  16       10.5            1.0         -0.2332
  17       11.1            1.1         -0.2362
```

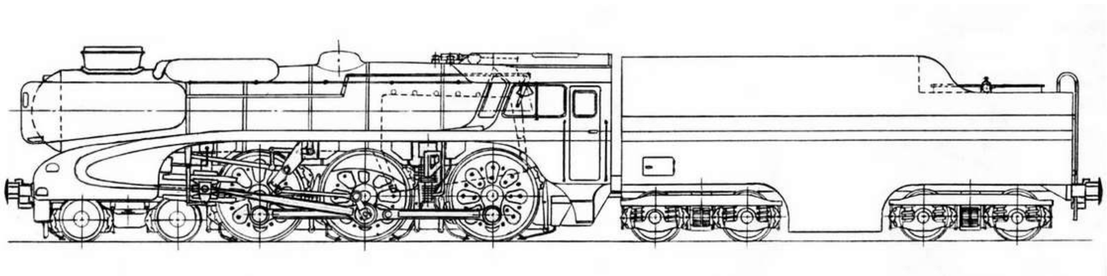

The Wallace Simulator provides a printout of the various events, which is useful when you want to work through the results.



And it provides a useful family of curves –including -

- Indicator diagrams
- Port opening in relation to the piston displacement

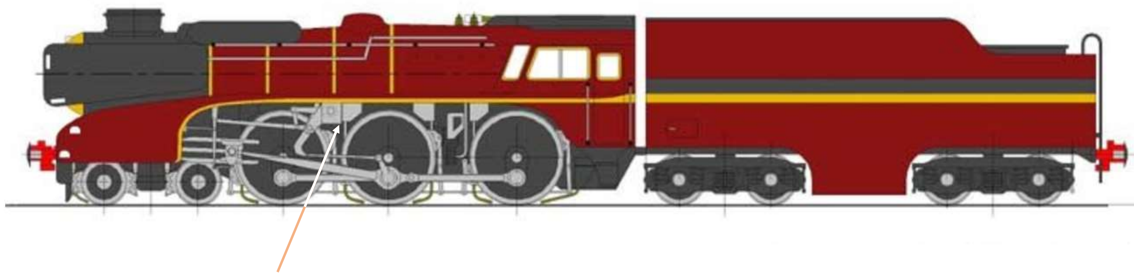
5AT Project



Used Wallace Valve Gear simulation
to help design the Valve Gear

The Wallace simulator was used in the calculation of the valve gear arrangement and dimensions for the 5AT project (David Wardale – of “Red Devil” fame)

5AT Project



Substantial mounting for the Expansion Link

But just look at the substantial mounting under the footplate for the expansion link pivot mount!

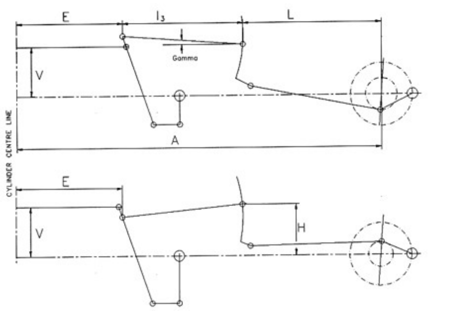
WALSCHAERTS' VALVEGEAR

Formulated by Alan Gettings from a geometric proposition by Don Ashton

Dimensions in inches — Graphics by Alan Green

Angles in degrees — LOCO: **BRITANNIA in 3/4 scale**

C		=	Connecting rod length	**8.000**	(enter)
A		=	Cylinder centre to driving wheel centre (horizontal)	**11.719**	(enter)
L		=	Exp. link trunnion to driving wheel centre (horizontal)	**3.991**	(enter)
H		=	Exp. link trunnion to driving wheel centre (vertical)	**1.188**	(enter)
V		=	Valve spindle centre to driving wheel centre (vertical)	**1.375**	(enter)
E		=	Cylinder centre to radius rod front pin (horizontal)	**2.875**	(enter)
l	1	=	Valve spindle to rad.rod front pin at dead ctr.(vertical)	**0.280**	
l	2	=	(V+l1-H) Inside admission	**0.467**	
l	2	=	(V-l1-H) Outside admission	**-0.093**	
l	3	=	A - (L + E)	**4.853**	
G	1	=	**Radius rod**, front pin to dieblock (inside admission)	**4.875**	
G	2	=	**Radius rod**, front pin to dieblock (outside admission)	**4.854**	
Gamma	γ1	=	Inclination of radius rod in mid gear (inside adm.)	**5.496**	degrees
Gamma	γ2	=	Inclination of radius rod in mid gear (outside adm.)	**-1.098**	degrees
e		=	Lap	**0.117**	(enter)
k		=	Lead	**0.004**	(enter)
a	1	=	Port opening in full gear	**0.125**	(enter)
w		=	Upper pins of combination lever	**0.305**	(enter)
s		=	Stroke	**1.750**	(enter)
R	(s/2)	=	Main crank throw	**0.875**	
c		=	Exp.link trunnion to operating pin	**1.063**	(enter)
u		=	Die depth in gear (full)	**0.563**	(enter)



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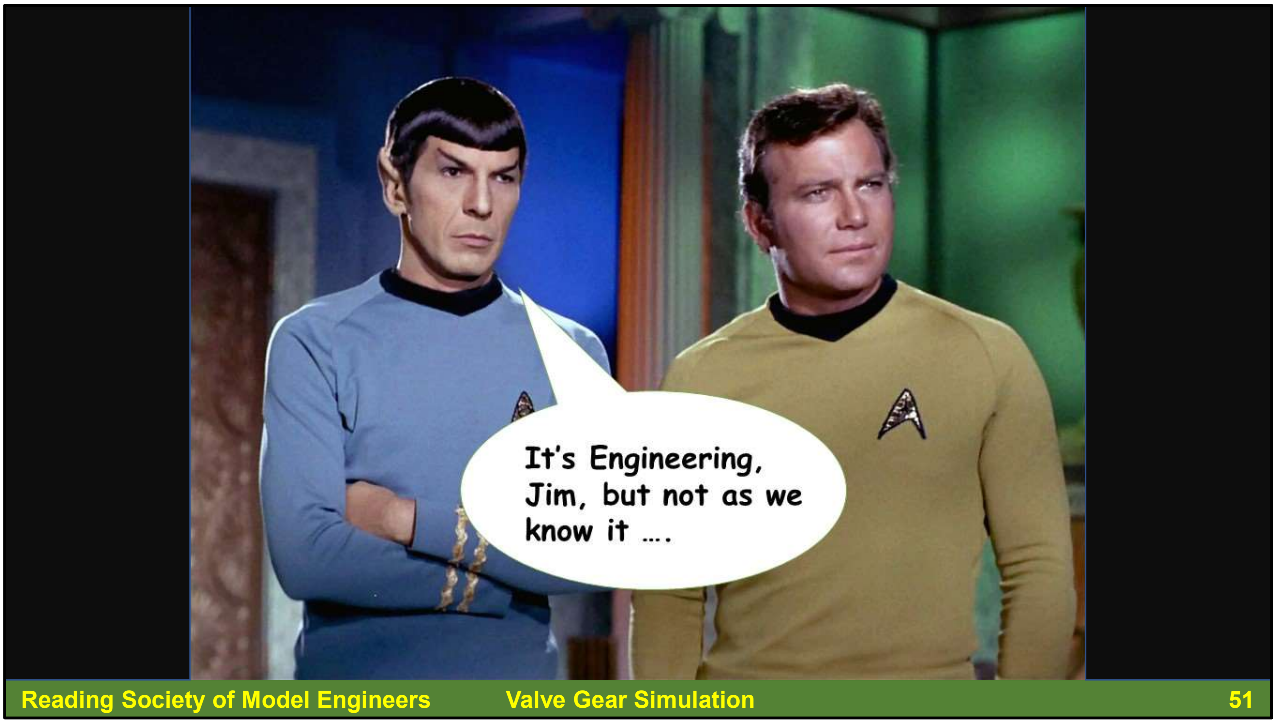
Don Ashton's Spreadsheet
Walshaerts' Valve gear

Don Ashton's Spreadsheet

Don Ashton was the technical lead for the Great Western Society's hybrid-build 4709 project until his death – from Covid – in 2020 – just three days short of his 81st birthday.

Don realised that the simulator could illustrate how even the smallest adjustments to certain areas of the gear could have a drastic effect on valve movement and performance. And it was natural that Don's involvement with simulators would lead him back to his own valve gear publications. He combined Walschaerts and Stephenson's into one book also updating them to incorporate computer simulation. He would always reflect on how the engineers in the heyday of steam would have loved these computer simulator programmes.

His spreadsheet allows you to enter various dimensions and then the spreadsheet calculates the others.



And so now we come onto Software Engineering….

Software engineering is the process of developing, testing and deploying computer applications to solve real-world problems by adhering to a set of engineering principles and best practices. It is the application of the systematic approach of physical world engineering to software development.

Computer Simulation

- **Graphics**
  - Just show an animation?
    OR
  - Fully implemented in real time?
    - showing any changes made to dimensions

Can use:
SolidWorks (CAD)
AutoCAD
Blender (free, open source)

- **Calculation and reporting** of all Valve Events,
  both graphically and tabulated

(actually needed if graphics are to display dimension changes in real time)

There are a couple of things we can do with Computer simulation.

We can do a straightforward animation, just to see how the whole thing works. Or we can work out the actual dimensions of, and relative movement of, every part of the valve gear, and report those values in an appropriate manner.

Note that you actually need to do much of the calculations to render the objects in the animation.

Many of the CAD design packages allow you to manipulate and animate the object that you are creating, and then generate out the files needed to drive CNC (Computer Numerically Controlled) machines to create the parts that you have designed.

Computer based simulation allows you to vary every part of the linkages - dimensions, angles, paths and so on – before cutting metal.

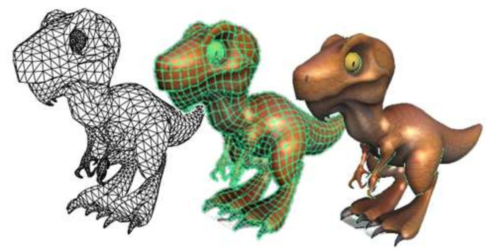
How to animate for a PC – techniques

- Redraw in background colour, draw new changed position
- Blank screen, start over – just draw new changed position

NOTE:

This is not how it is done in the movies – one way is: wire frameworks based on linked triangles with various overlays, using powerful rendering software

OR in fast action computer games, where the program interacts directly with the graphics display board



Before going any further, I must emphasise that what follows is for simple animations done on a home computer, not about the great and grand CGI effects that you see on TV or in the cinema! Those complex CGI effects use various techniques. One of the earlier ways of doing it was to construct the object using linked triangles, each one of which could be resized. This "wire-frame" was then rendered to provide the various surfaces, and then surface textures were applied.

Fast action computer games interact directly with the high-performance graphics board.

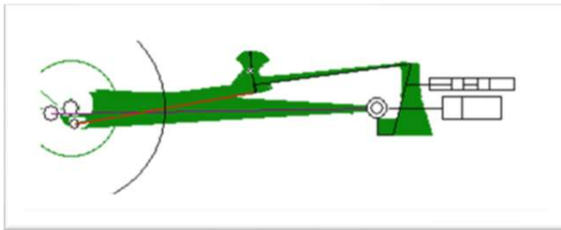
There are a number of programs around that help with making animations, but usually they are drawing-based: this description is about making an animation where every part has to be calculated.

There are two main ways of doing an animation on the Personal Computer (PC) or home computer programmatically.

You can either undraw a part of the picture and then redraw it in its new recalculated position, or you can clear the clear the screen of the existing drawing and then redraw the new recalculated picture. Each method has benefits and disadvantages. Here we look at both ways of doing the animation.

Benefits of overdraw

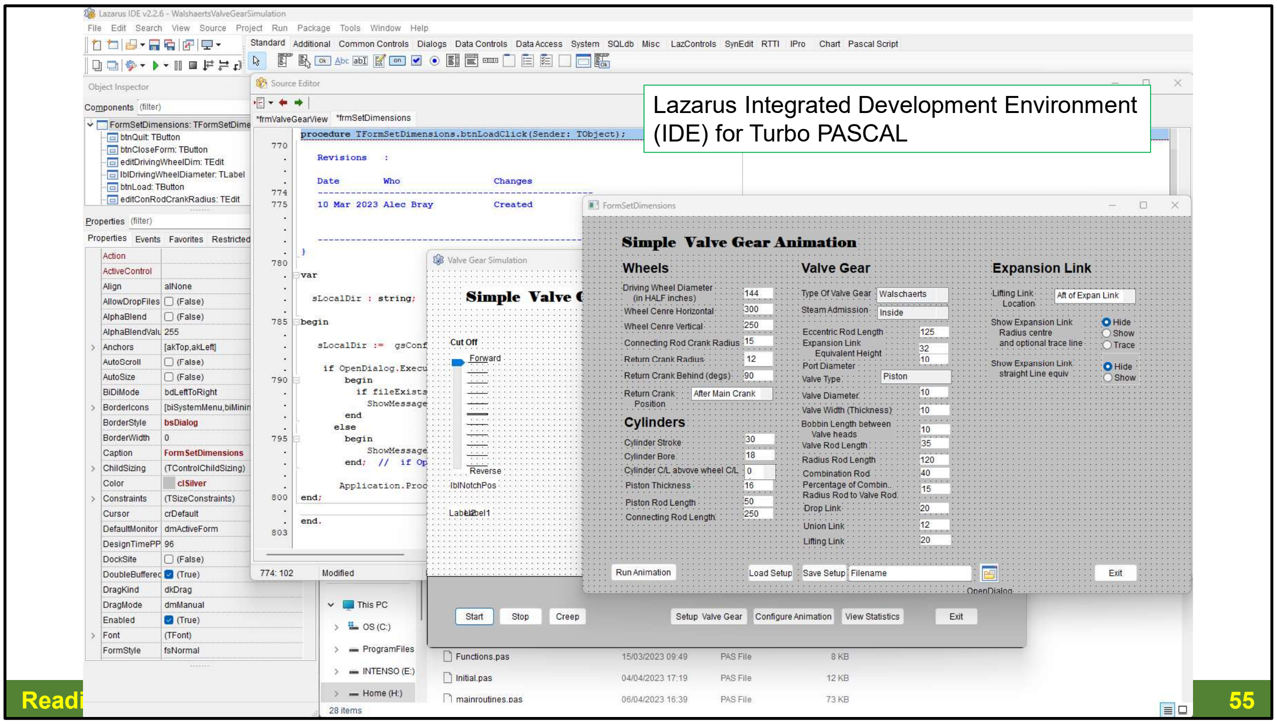
- Can easily show swept area by changing overdraw colour (keep other bits out of the way)



Downside of overdraw

- Double the time taken for every action – so slow!

One benefit of the overdraw method is that if you change the “undraw” colour, the result then shows the area “swept” by the movement of the object. The downside is that the undraw then redraw takes twice as long as blank then redraw – but then that approach can often produce a flicker effect.



This is the Integrated Development Environment (IDE) that I use – it is called “Lazarus”.

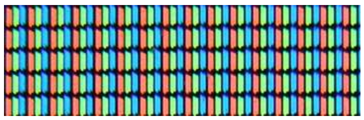
The computer language that it uses is Object PASCAL - put simply, PASCAL is a bit like BASIC on steroids.

BASIC = Beginners' All-purpose Symbolic Instruction Code
PASCAL - small, efficient language intended to encourage good programming practices using structured programming and data structuring based on developments of Algol 60

Writing the Simulation Program

Some things to think about ….

- Computer display – integer coordinates



Each "pixel" is made up of three dots, red, blue and green).

- and how the pixels are addressed depends, too, on the resolution of the PC screen display.

- Pre-load tricky maths functions, for example trig functions, but doing it step by step gives approximate values only

  (Only calculate to nearest degree)

```
// set up the lookup tables for the sines and cosines
// of discrete angles

     for iDegree := 0 to 360 do
        begin
             grSine[iDegree] :=  (SIN(iDegree * PI/180));
             grCosine[iDegree] :=  COS(iDegree * PI/180);
         end;   //  for iDegree := 0 to 360 do
```


One of the "problems" with doing an animation like this is the resolution of the PC screen display. The screen is divided up into "pixels": a pixel is the smallest picture element that can be manipulated through software, and usually is made up of three dots, red, blue and green, each part of which is varied in intensity to combine (using colour addition) to make any one of 16 million colours ("white" is full intensity of each component red, blue and green).

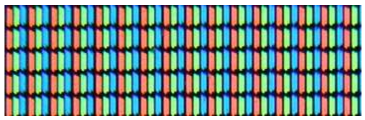
Each pixel on the screen is addressed – or "found" by counting along from the left and ***down*** from the ***top*** (unlike normal x/y graphs) – and each number used in the count has to be a whole number (an integer). So to draw a line, you find the start of the line – say 10 along and 10 down – and then state the end of the line – say 50 along and 10 down. You write these commands using a suitable programming language:

```
MoveTo(10, 10);
LineTo(50, 10);
```

Writing the Simulation Program

Some things to think about ….

- Computer display – integer coordinates



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         end;   //  for iDegree := 0 to 360 do
```


The programming language used here is Object PASCAL, which is a high-level language. When the program is written, the source is "compiled" – the computer itself is used to rewrite the instructions first into "assembler" language and then into machine code which is then used to move bits (binary digits – zeros and ones) between registers on the computer's integrated circuit or "chip". (comes from the Latin "*compilare*", to plunder of plagiarise!). One compiled, it is the machine code which is run every time – and so is quick. Programming languages like "BASIC" are "interpreted: each time you run the program, each instruction has to be converted line by line into machine code – and it takes a while.

Another reason for an approximate answer only is that to speed up the run of the program, you can "pre-load" tricky maths functions, for example trig functions, and store the answers in an array. When the program is run, the answer is looked up in the array – which is a reasonably quick operation - but using these "step by step" created results gives approximate values only. The other option, of course, is to calculate each trigonometric function fully whenever it is needed, and to the part of a degree needed. But this is a lot, lot slower! (Of course, if you by-pass the programming language and write code directly to the chip, the operation is much much faster – but then the code becomes much more difficult to debug, repair and update.)

Don Ashton

"… Computer simulation … shows that the two components comprising the valve movement cannot be altered individually without affecting each other.

The variables are legion and do not readily submit to formulaic construction. …"

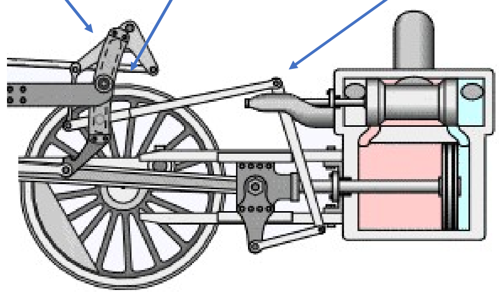
Don Ashton comment:
Remember that our valve gear movement is simply the sum of two distinct Simple Harmonic Motions which have a phase relationship with one another. Two simple components!

Changing one of these components affects the other – or affects the total valve movement.

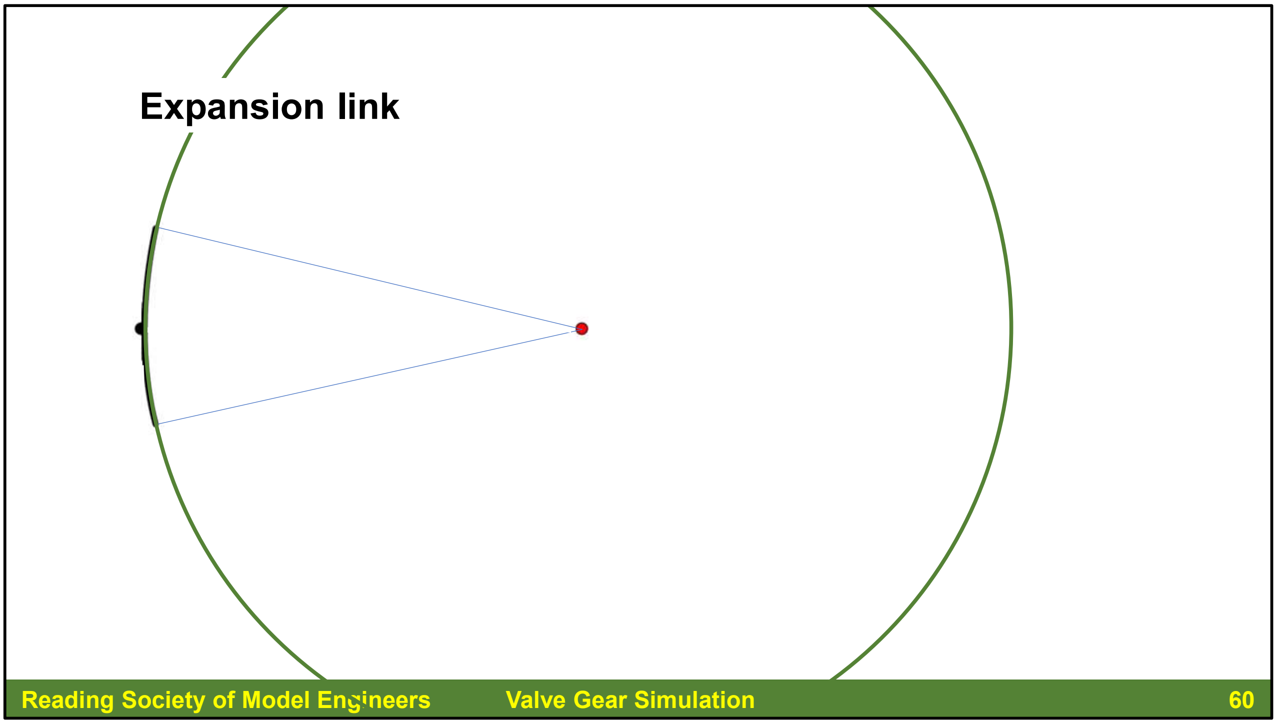
But there are very many variables that affect each one of these motions, and they are not all that easy to work out. In Walshaerts' gear, as typically constructed, there are only two fixed points, which means that it can be complicated to work out the various dimensions and angles (in the "scissors" valve gear, there is only ONE fixed point!). And everything is in motion.

Consider three elements of the gear –
and its animation

- Expansion link – its tangent, radius, and its moving centre
- Draw the arc of the expansion link from current centre (for the correct length of arc)
- Combination lever – calculations of position of pivots and linear valve movement



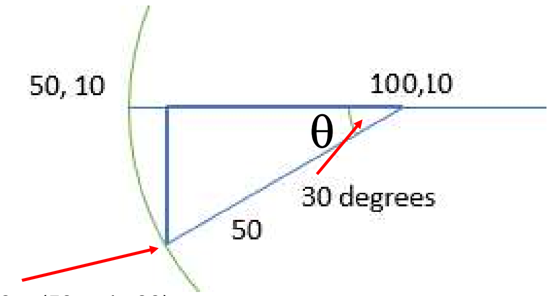
We are going to look at the implementation of just two components of the Walshaerts' valve gear – the Expansion Link and the Combination Lever. This will give you some idea of what is involved in this computer-based simulation



The expansion link is part of a circle – an arc with a defined radius (and start and end points).

Although most computer languages allow the drawing of predefined shapes, there are times when we have to draw the shape programmatically. This is the case in this instance, where we want to draw just part of a circle.

Expansion link



100 + (50 x cos 30), 10 + (50 x sin 30)

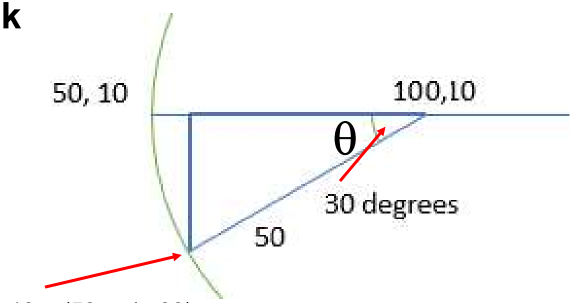
- All measures are from the origin (TOP, LEFT)
- A point on a circle is position of centre of circle (X,Y)
  PLUS (radius x cos angle) and (radius x sin angle)
- Degrees measured in RADIANS

We have the centre of the circle, and we have the radius. To find the start of the arc, we want to position this radius as aits first point - at an angle of 30 degrees from the horizontal, about the centre 10 along, 10 down. We know the angle – it's 30 degrees - **Oh no it isn't!!** Degrees of rotation in our computing languages start from the left facing horizontal line from the centre ("East" facing line if you like) and count clockwise, so our angle of rotation starts from 270 degrees PLUS 60 degrees = 330 degrees! And then we want to rotate this radius about the centre, from 330 degrees to 30 degrees (for example) – and pass zero degree *en route*. In our computer language we use a "loop". There are different types of loop control: as an example, we will do a simple count. It starts like this:

```
for iDegree := 330 to 360 do
```

(By the way, in PASCAL it is easy to think of ":=" as "becomes equal to".)

Expansion link



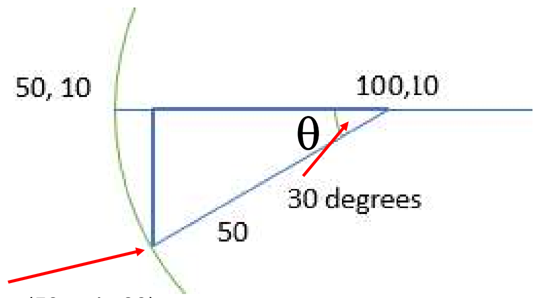
100 + (50 x cos 30), 10 + (50 x sin 30)

- All measures are from the origin (TOP, LEFT)
- A point on a circle is position of centre of circle (X,Y)
  PLUS (radius x cos angle) and (radius x sin angle)
- Degrees measured in RADIANS

So for each change in degree, we have to find the point on the circumference of the arc of the bounding circle on which the end of our line will be placed, and we use sines and cosines. Remember sin = o/h, cos = a/h, tan = o/a where h is the hypotenuse of a right-angled triangle – which in this case the radius of the circle.

So the new end point of the line at each increase in degree is given by (40 times cos(iDegree)) horizontally and (40 times sin(iDegree)) vertically – except that it isn't of course. These are distances from the origin of the radius (10, 10) so that has to be added in. The values of sines and cosines depends of the quadrant: counting quadrants from the "East" as it were, the positive values are All, Sines, Tangents, Cosines – so our cosine calculation is giving a negative value when we really want a positive value to add to our 10 along. Just to add to our joys, the program language command for sines and cosines are based on RADIANS, not degrees, so we need a conversion factor – multiply the number of degrees by (π/180) – yup, our old friend PI.

Expansion link



100 + (50 x cos 30), 10 + (50 x sin 30)

- All measures are from the origin (TOP, LEFT)
- A point on a circle is position of centre of circle (X,Y)
  PLUS (radius x cos angle) and (radius x sin angle)
- Degrees measured in RADIANS

So, to create part of the expansion link, we have a completed loop:

```
for iDegree :=330 to 360 do
    begin

     MoveTo(10, 10);
     LineTo(ROUND(10 + (-1 * (40 *
     COS(iDegree * PI/180)))),
            ROUND(10 + (40 * SIN(iDegree *
     PI/180))));

     iDegree := iDegree + 1;

     // NOW UNDRAW THIS LINE USING
     BACKGROUND COLOUR
     ...

    end;
```

Expansion link

- To move the expansion link, draw the current position of the link (from the centre, and for the number of degrees subtended by the arc)
- Then UNDRAW it ready for the new changed position
- ROUND up the answers, as whole numbers are used to address the pixels

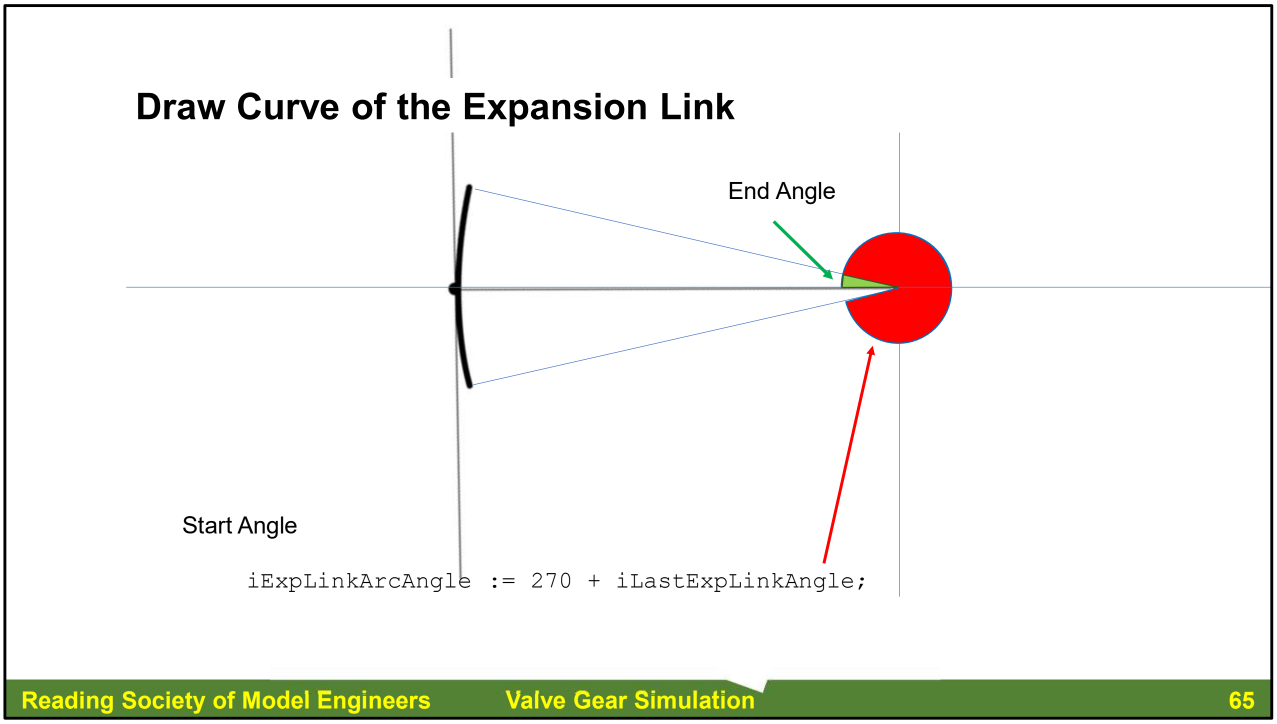
Immediately we have some rounding errors in our plotting….

So we can now draw this part of the arc.

We have to remember all the values so that we can then UNDRAW this arc so that we can redraw it in its new position.

We have to ROUND up the answers we get, because we can only use whole numbers to address the pixels.

So we have immediately some rounding errors in our plotting….



If we know the centre of the circle that makes up the expansion link, we can use this centre to draw the arc for the expansion link – the diagram shows the situation for the centre point being on the horizontal.

PASCAL Code to draw the expansion link

```
while iExpLinkArcAngle <= 420  do

     begin

       iLastExLinkCurveTop := (iLastExpLinkArcCentreVert  - ROUND(grRadiusRodLength
              * grSine[iExpLinkArcAngle MOD 360]));

       iLastExLinkCurveHoriz := (iLastExpLinkArcCentreHoriz - ROUND(grRadiusRodLength
              * grCosine[ iExpLinkArcAngle MOD 360]));

      if (iLastExLinkCurveTop <= iLastEccRodEndPosVert) And ( iLastExLinkCurveTop >= iLastExpLinkTopPointY ) then
           begin
                if (iLastExLinkCurveTop = iLastEccRodEndPosVert) then
                    begin

                         MoveTo(iLastExLinkCurveHoriz, iLastExLinkCurveTop);
                         bClearBottomOfExpLink := True;
                         giLastStartExpLinkCurve :=  iExpLinkArcAngle;

                     end;

                 if bClearBottomOfExpLink = True and (iLastExLinkCurveTop < iLastEccRodEndPosVert) then
                      begin
                          LineTo(iLastExLinkCurveHoriz, iLastExLinkCurveTop);
                      end;
            end;

         iExpLinkArcAngle := iExpLinkArcAngle + 1;

     end;  //  end of  while iExpLinkArcAngle <= 420 do
```

Here is where the line is actually drawn

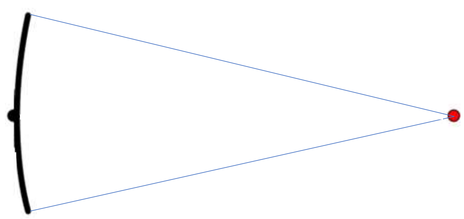
Remember positions so that we can UNDRAW this line

As described above, we have only drawn half the expansion link. We want our loop to run from 330 to 30 degrees, without having to worry about stopping at 360 degrees and restarting at zero degrees. So we use Modulo arithmetic, with the number of degrees going up past 360 (in this case, 420).

Modulo arithmetic is the REMAINDER you get when you divide a number by the modulus: 8 modulo 2 is zero. Here we use modulo 360.

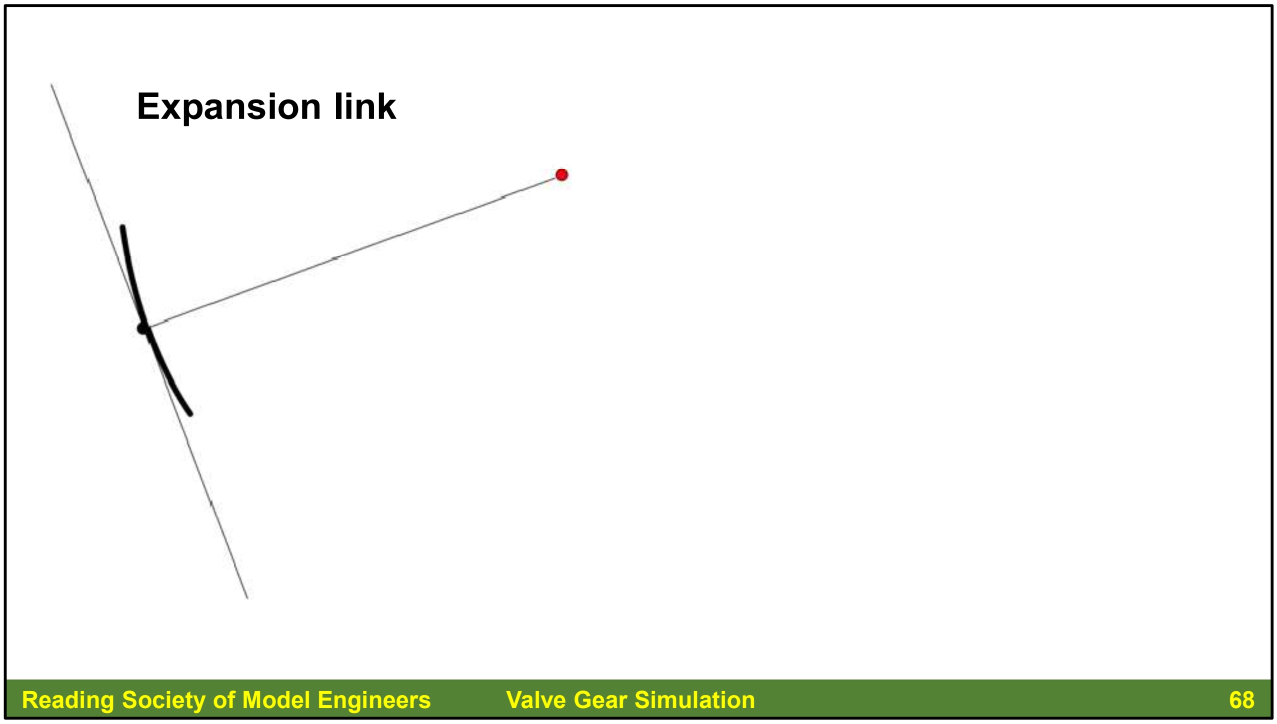
We use a “while” loop, because we include some checks for the start and end positions: because of this, we can not simply count the number of degrees for the arc.

Expansion link

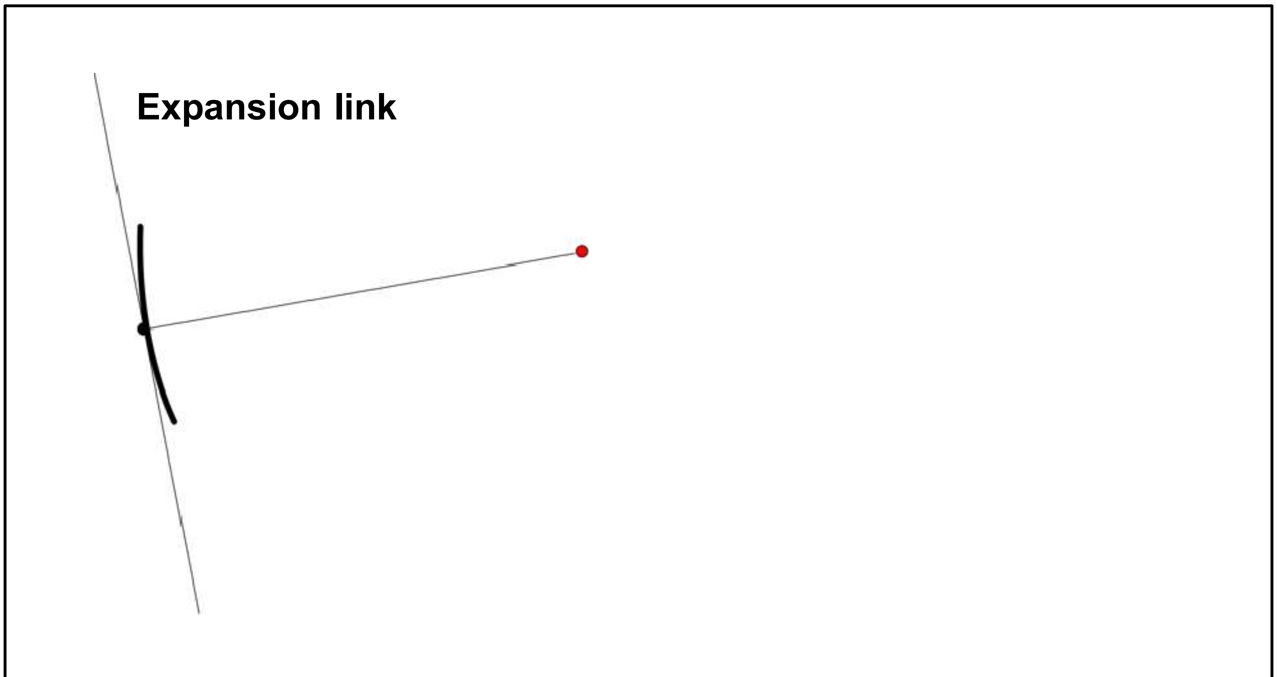


Reading Society of Model Engineers Valve Gear Simulation 67

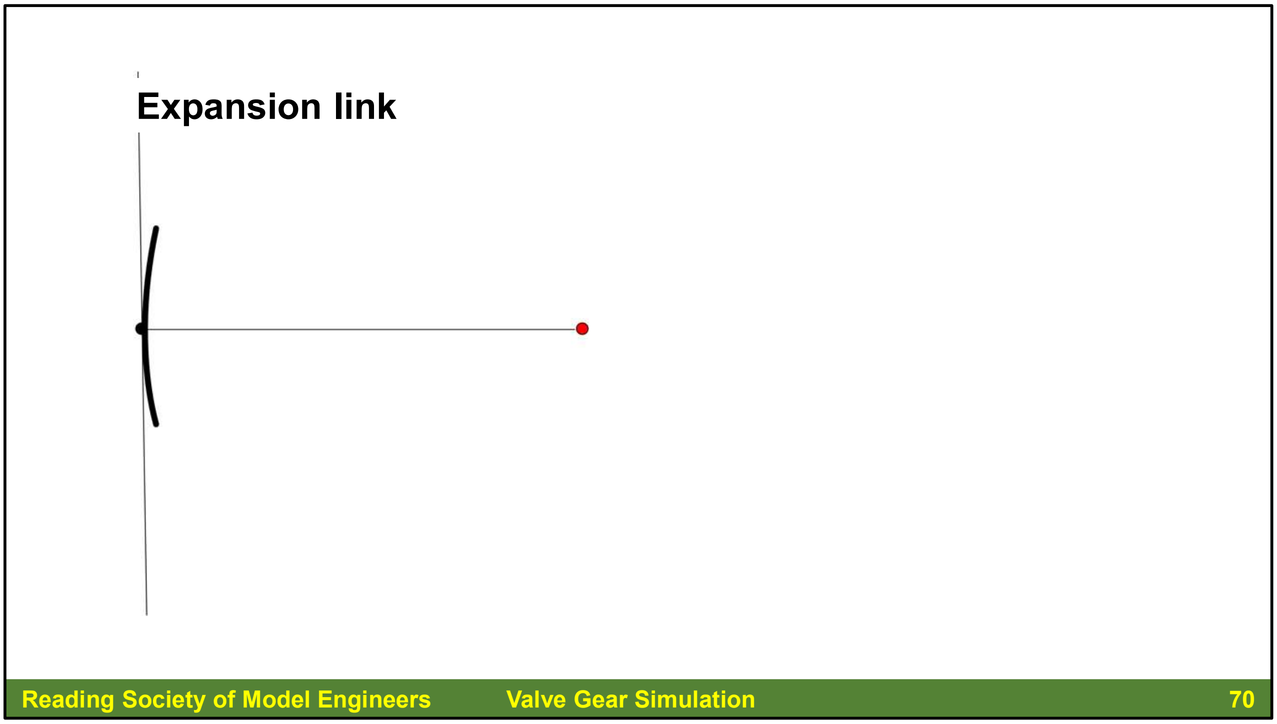
So here is the arc of the expansion link drawn correctly.



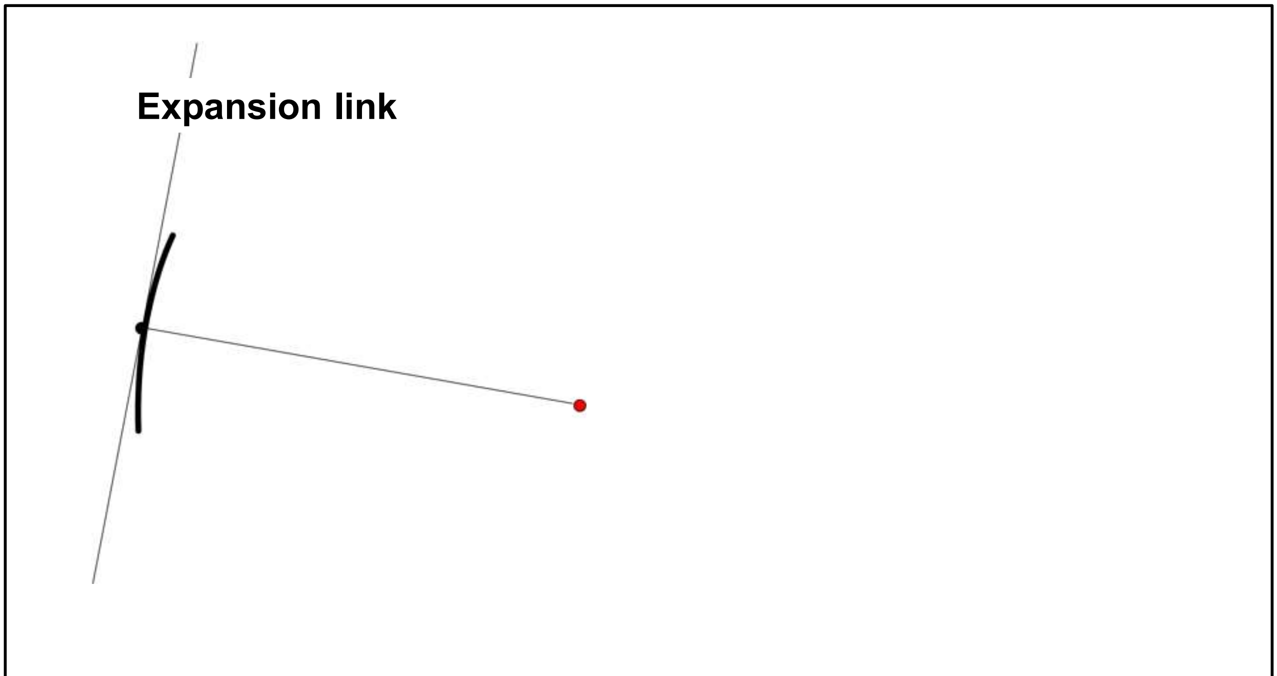
But the expansion link is rotated around its mounting by the eccentric rod in a conventional deployment of Walschaerts – and so the centre of the arc of that is the expansion link is moved. In actually moves in an arc.



The Expansion link is rotated about its mounting pin by the eccentric rod – and the centre of the Expansion Link moves as a result…



And the Expansion link is further rotated about its mounting pin by the eccentric rod – and the centre of the Expansion Link moves as a result…



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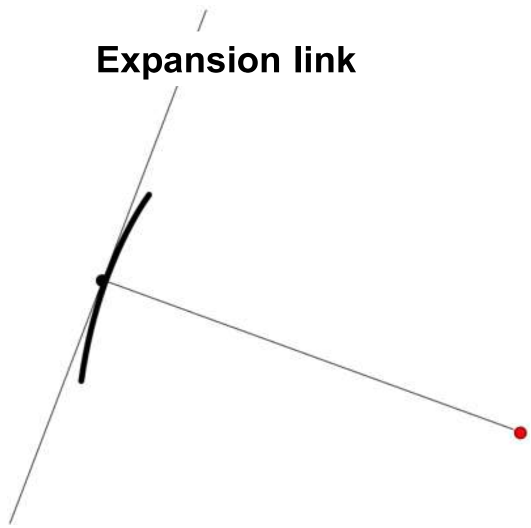
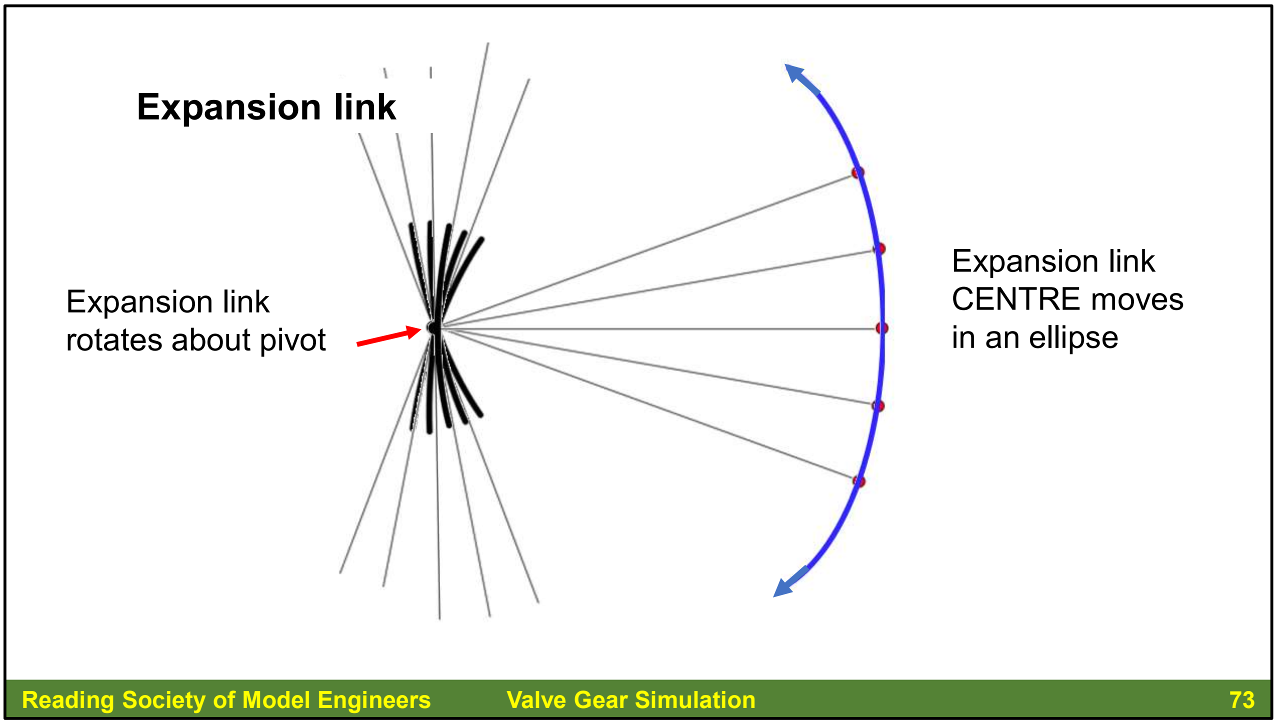
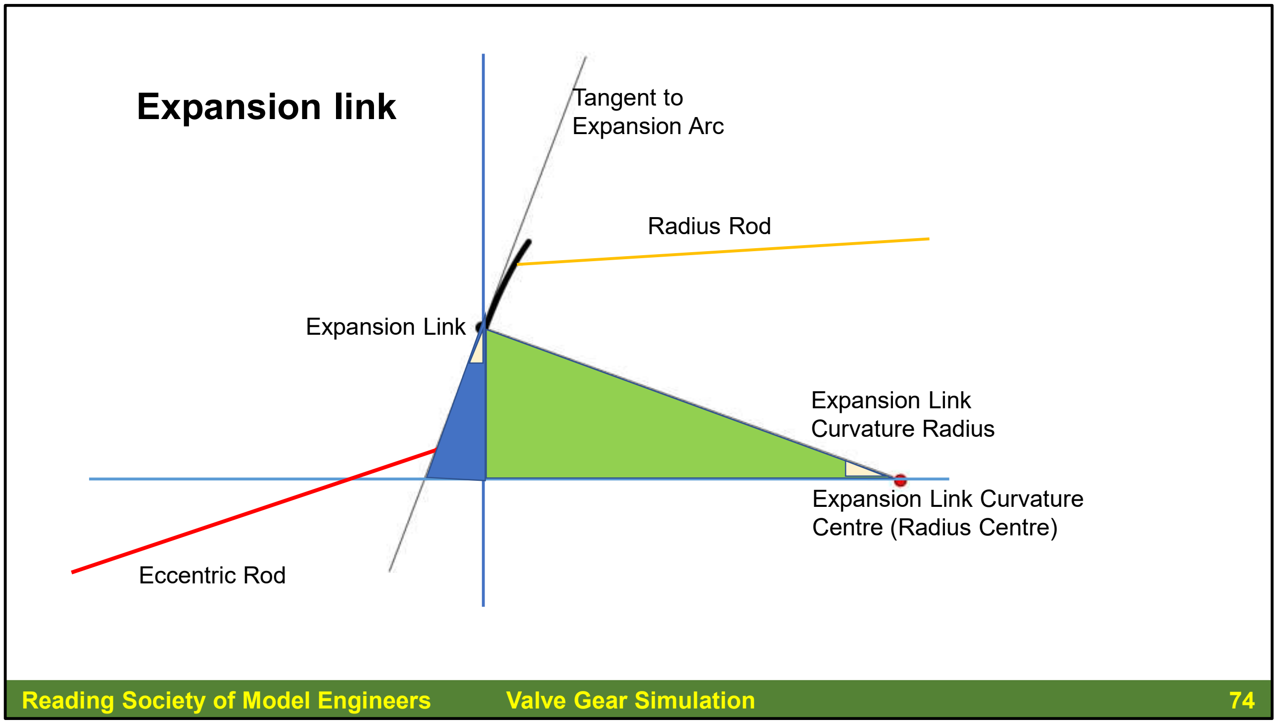


And the Expansion link is further rotated about its mounting pin by the eccentric rod – and the centre of the Expansion Link moves as a result…



So for every degree of rotation of the expansion link, we have to determine the new centre point and then recalculate the arc for the expansion link.

When you consider that one end of the eccentric rod in a point on the circle described by the return crank and the other end is a point on an arc described by the bottom end (foot link plus back set) of the expansion link as it pivots round its bearing, you can see some of the complexity of the mathematics that is involved. One end of the radius rod is a point on the arc of the expansion link, and this arc is being rotated around the expansion link bearing: the point of the radius rod on this arc also depends on the cut-off selected (how far up and down this arc it is placed).



To find the centre of the circle for the new position of the expansion link, so that we can then draw the arc using this new centre point, the simplest method is to use straightforward geometry.

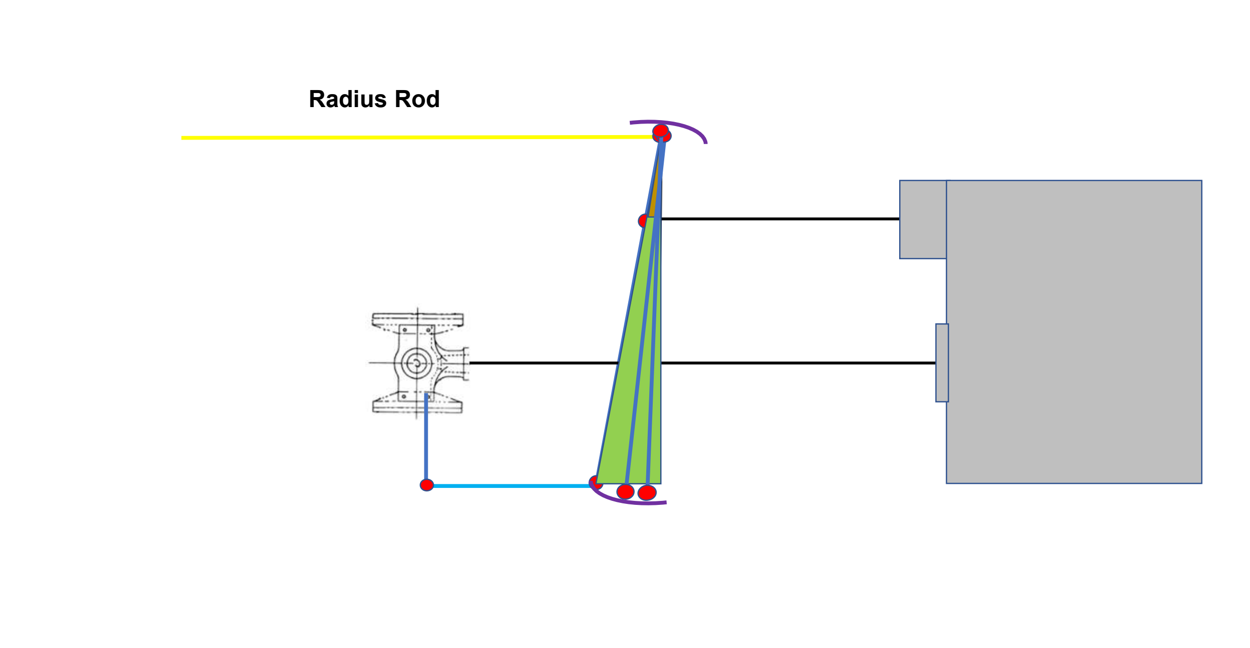
We can draw a (geometric) Tangent to the arc – the tangent makes a right angle with the radius at the point it touches.

There are a pair of similar triangles made:

One is a right-angled triangle made up of a vertical line passing through the expansion link centre of rotation (pivot) and a horizontal line passing through the centre of the current position of the expansion link arc radius centre, with the tangent to the arc (circle) line making up the hypotenuse,

The similar triangle uses the same horizontal and vertical lines, this triangle however has the radius of the expansion link making up the hypotenuse.

The two triangles are similar because all three angles in one of the triangles are the same as the three angles in the other triangle.



To find the centre of the circle for the new position of the expansion link, so that we can then draw the arc using this new centre point, the simplest method is to use straightforward geometry.

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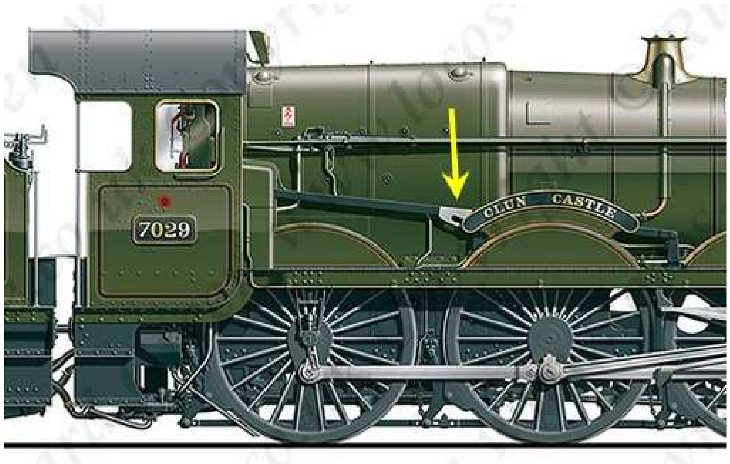
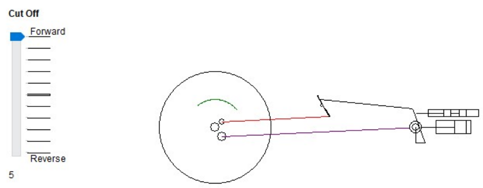
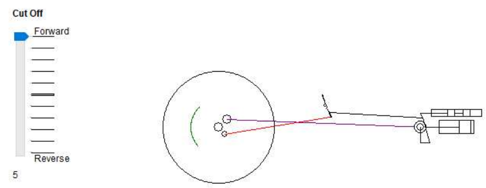


Other parts of the valve great describe arcs (parts of circles) when they move. As an illustration, here id the reach rod of a GWR "Castle" class locomotive, and you can see that its support runs in an arc as the far end, connected to the lifting link, has to move in an arc.

The eccentric crank is of a length such that the pin attachment to the eccentric rod is 90 degrees out of phase with the lead motion

But return crank can be BEFORE the crank or AFTER the crank (use the other end of the expansion link!)





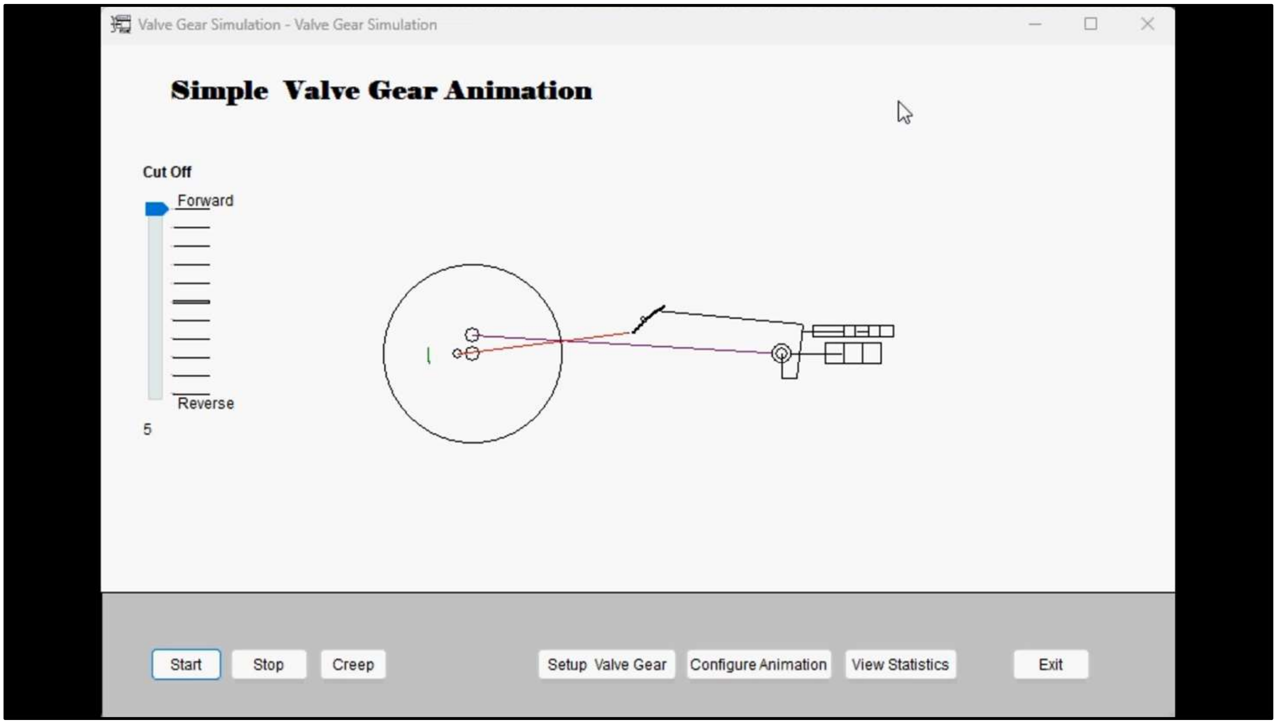
This actually gives a more "direct" drive to the valves in forward gear!

Just one other point – the return crank can be mounted BEFORE the connecting rod crank or AFTER the connecting rod crank. The majority of locomotives have the return crank mounted AFTER the crank, but actually, mounting it BEFORE the crank gives a more direct drive to the valves in forward gear.

The Valve Gear simulation – so far ….

The valve gear simulation – so far….

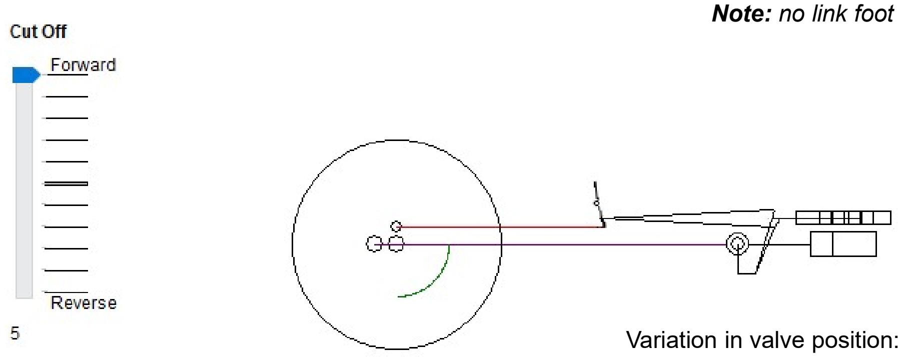
No more than this has been done, as the mathematics are quite tricky and I rather lost interest in coding it all….



My Valve Gear Simulation

Simple Valve Gear Animation

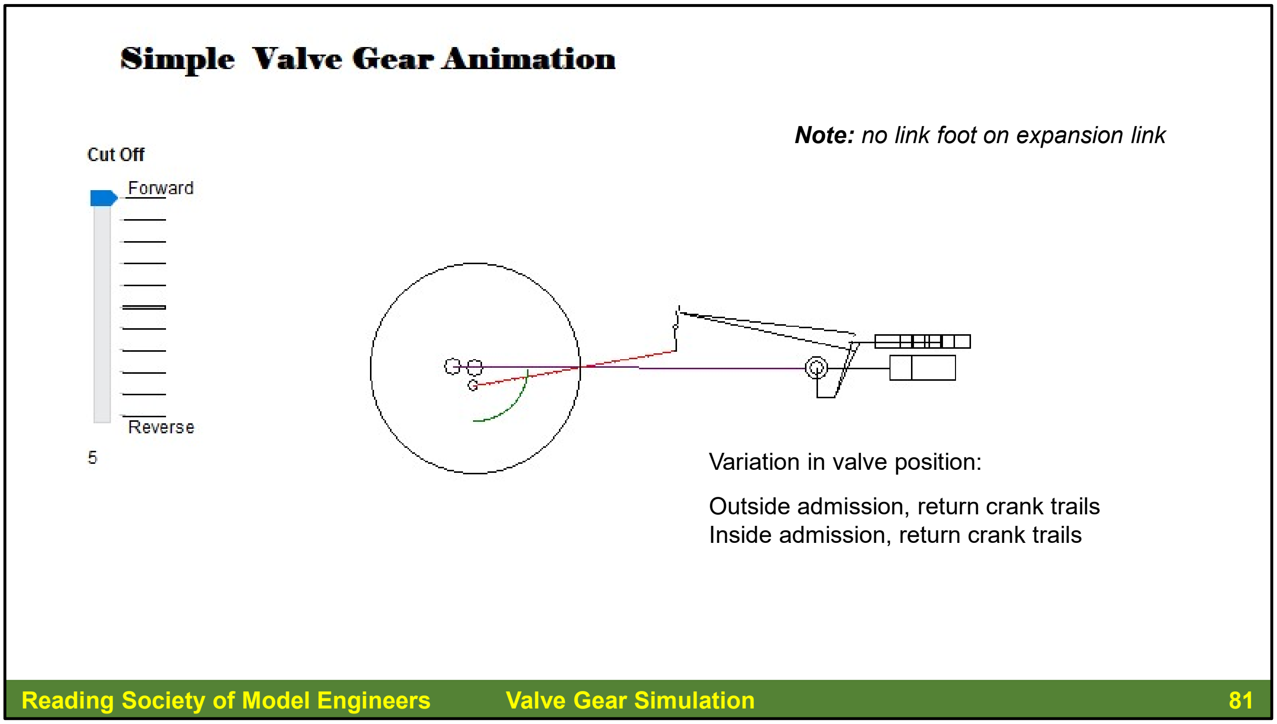
Note: *no link foot on expansion link*



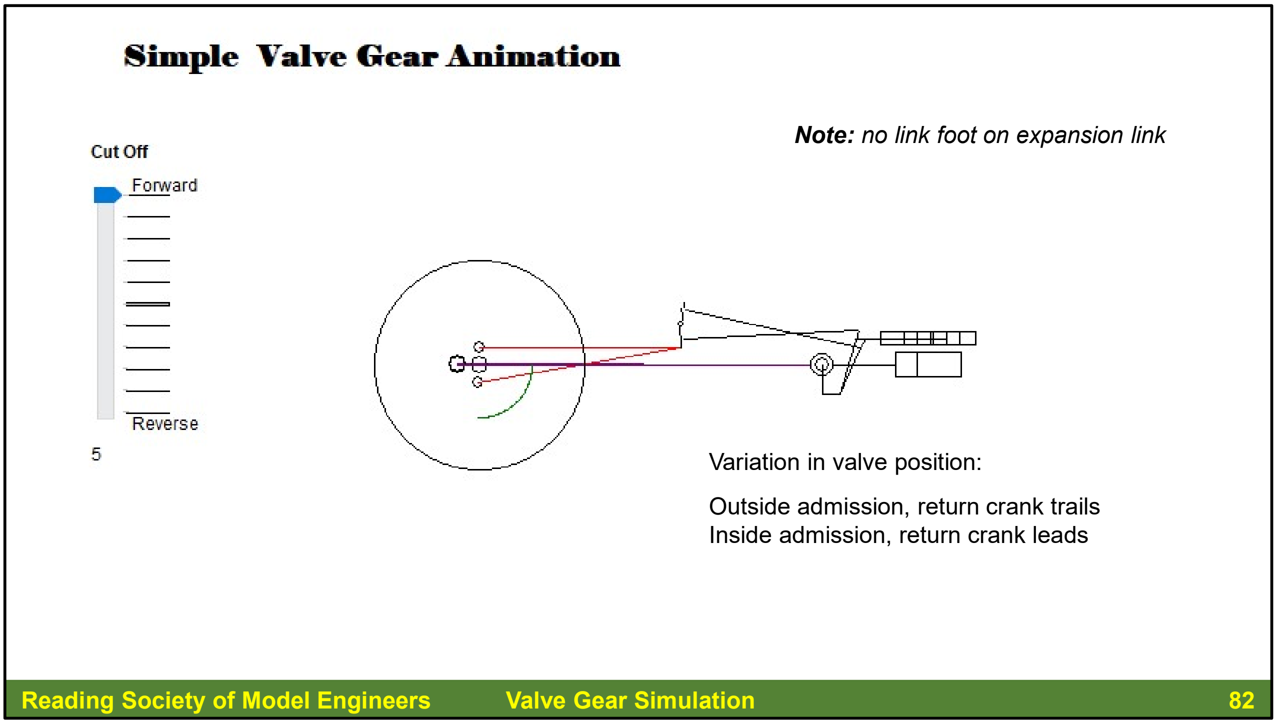
Variation in valve position:

Outside admission, return crank leads
Inside admission, return crank leads

But what it can do is to show you the differences in valve position for inside and outside admission when the return crank leads the connecting rod crank



And the differences in valve position for inside and outside admission when the return crank trails the connecting rod crank.



And, of course, some extremes…

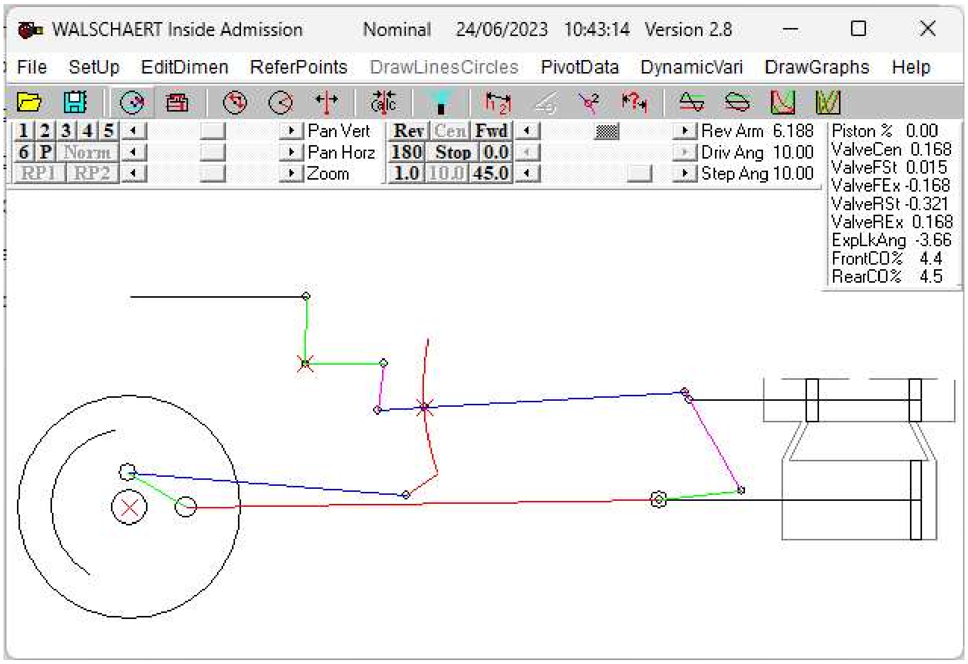
Acknowledgement:
I gratefully acknowledge the help and advice of Alasdair Milne and David Wilkinson throughout the development of the valve gear simulation so far...

Case Study

Charlie Dockstader Simulation

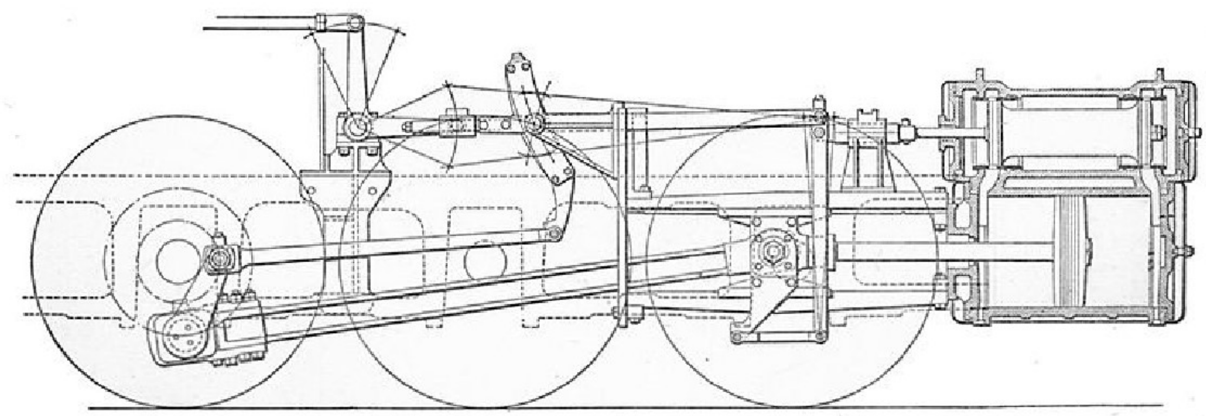
- Running the simulation
- Demo of Dockstader data entry
- Simulation of valve events as data and graphs of position (graphical form)

The presentation had originally been designed to show you how Charlie Dockstader's simulation helped in the design of one of the RSME members' locomotives' valve gear, but instead we are just going to look at how it can help with setting up the valve gear for a possible locomotive build.



We are using the Charlie Dockstader simulation of the standard Walshaerts Valve gear. First of all, this is a demonstration of the various features of the user interface using the default data:

- Running the simulation
  - Forward, Reverse, Centre
  - Slow, Fast, Step-by-step
- Graphs
  - Sine Wave
  - Oval
  - Steam Diagram
  - Port Open and Close

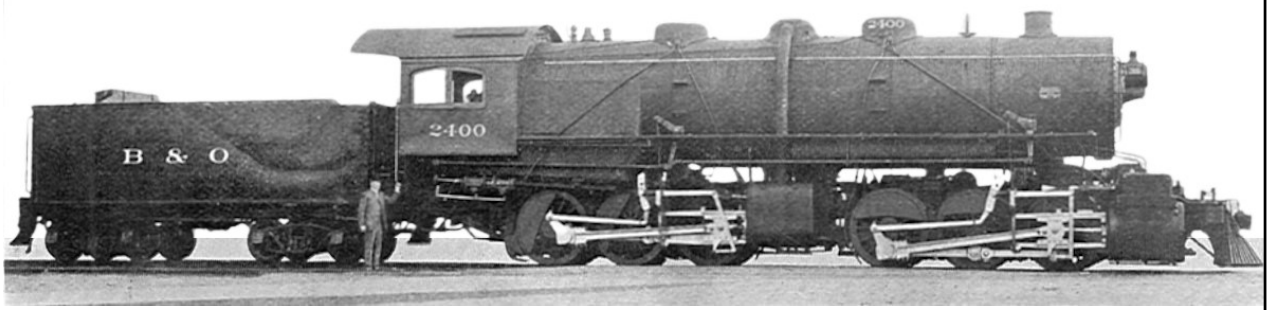


From Howden **The Boys' Book Of Locomotives** 1907

This is the business end of our locomotive that we shall use for the case study.

We can input the data directly from the drawing. If we scale up the drawing to the full size that we need, every single measurement has to be multiplied by the same factor, so it is immaterial whether we enter the raw data from the drawing or the scaled up sizes. We can equally well enter the full-size data without having to scale it down for the model, although there are necessarily some differences in the measures used on the full size locomotive and the model version!

Possibly one unit of this locomotive

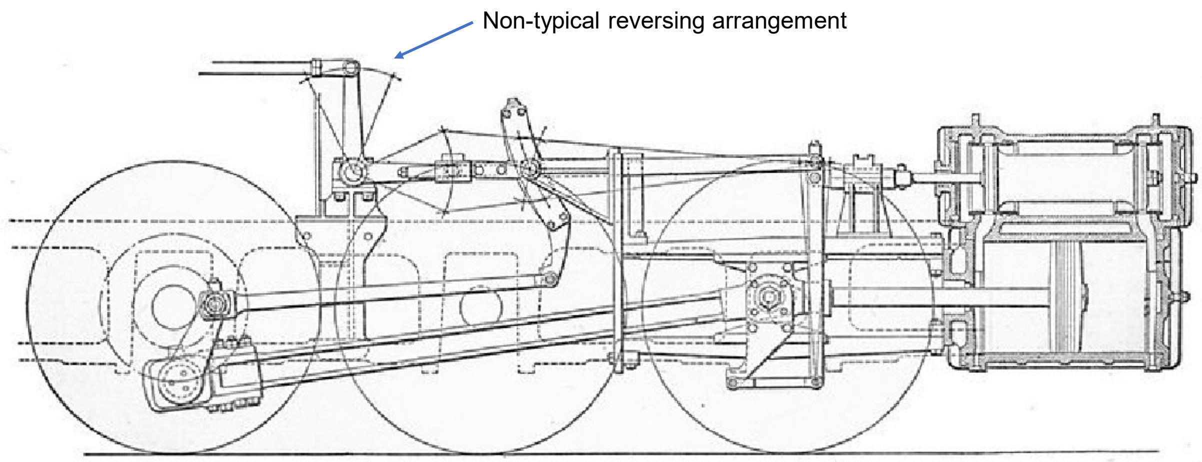


Baltimore and Ohio 0-6-6-0 Mallet

From Howden **The Boys' Book Of Locomotives** 1907

The unit we are using is (probably) one of the articulated units from a Baltimore and Ohio 0-6-6-0 Mallet, although the drawing does not quite match the photograph!

The first Mallet locomotive in North America was built in the United States and was of this type, the Baltimore and Ohio Railroad Class O no. 2400. Nicknamed Old Maude after a cartoon mule, it had a 71,500 pounds-force (318 kilonewtons) tractive effort and was a great success despite a top speed of only 21 miles per hour (34 kilometres per hour).



The linkage to raise the radius rod in its die block in the Expansion Link is different to that expected in the standard Dockstader valve gear layout, so that causes some issues in the various items of data entry.

Size on drawing
- not scaled up

Original data – taken from diagram

			mm
10	Union Link Length	Union link	21
11	Combination Lever Upper	rad rod to valve stem on com lever	3.5
12	Combination Lever Back Set	Combination Lever Back Set	0
13	Combination Lever Lower	valve stem to union link comb lever	50
14	Radius Road Length	radius rod	69
15	Link Radius	Expansion Link Radius	70
16	Link Crank Vert	Expansion Link -Tangent - half to bottom	20
17	Link Crank Back Set	Exansion Link back set	3.5
18	Eccentric Rod Length	eccentric rod	82
19		*colunm 2*	
20	Eccentric Crank Circle Diameter	Return crank circle diameter	10
21	Eccentric Crank Length	Return crank length	21
22	Radius Rod Exten Length	Radius Rod (Back) Extension for lifting link	20
23	Reverse Arm Vertical	Reverse Arm vertical measurement	25
24	Reverse Arm Back Set	reverse arm back set	25
25	Lifting Arm Length	liting link arm	25
26	Lifting Link Length	Lifting link	0
27	Reverse Arm Pivot Vert	Lifting link pivot vertical	35
28	Reverse Arm Pivot Horiz	Lifting link pivot horizontal	34.5
29	Link Center Pivot Vert	Exansion Link Pivot centre vertical	35
30	Link Cnter Pivot Horiz	Exansion Link Pivot centre Horizontal	88
31	Reverse Arm to Center Norm	reverse arm to centre norm	22

A glance at the original data input into the program.

The spreadsheet shows the Dockstader prompt for the entry, and the more recognizable name for us Brits.

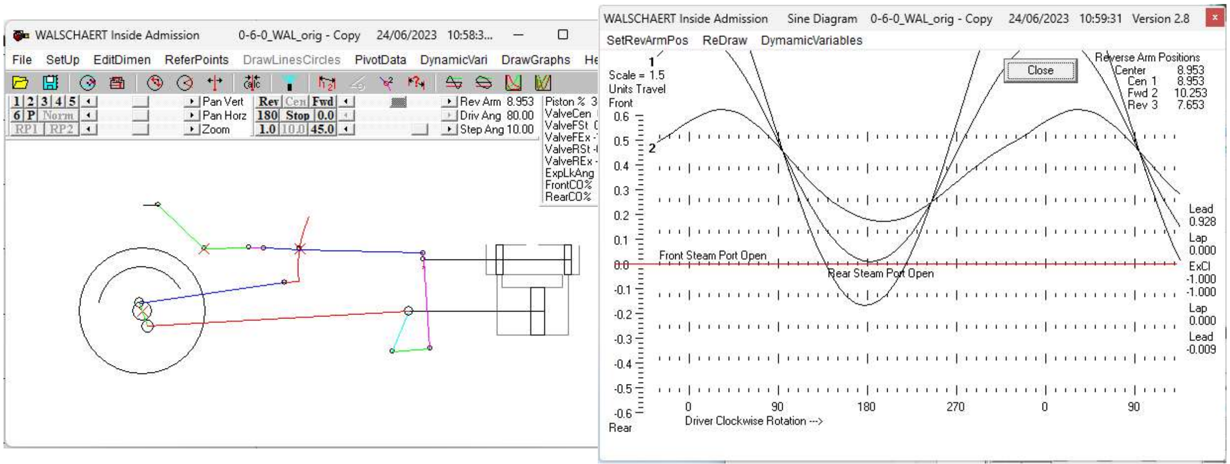
Now, what to enter? You can enter the measurements of the full size entity – model engine or real engine. As mentioned, you can enter the dimensions taken directly from the drawing – there is no need to scale them up to full size, as they should all be in proportion.

- Design Input:
  - Frame – Nomenclature
  - Cylinder – Nomenclature
  - Pivot Points
  - Limits – Range
  - Limits - Mechanical

Demonstration:
Sequence of changes

1. Dimensions as entered
2. Change length of the cylinder length (bore length)
3. Shorten Return Crank (as crank not at 90 degrees to main crank)
4. Widen steam ports

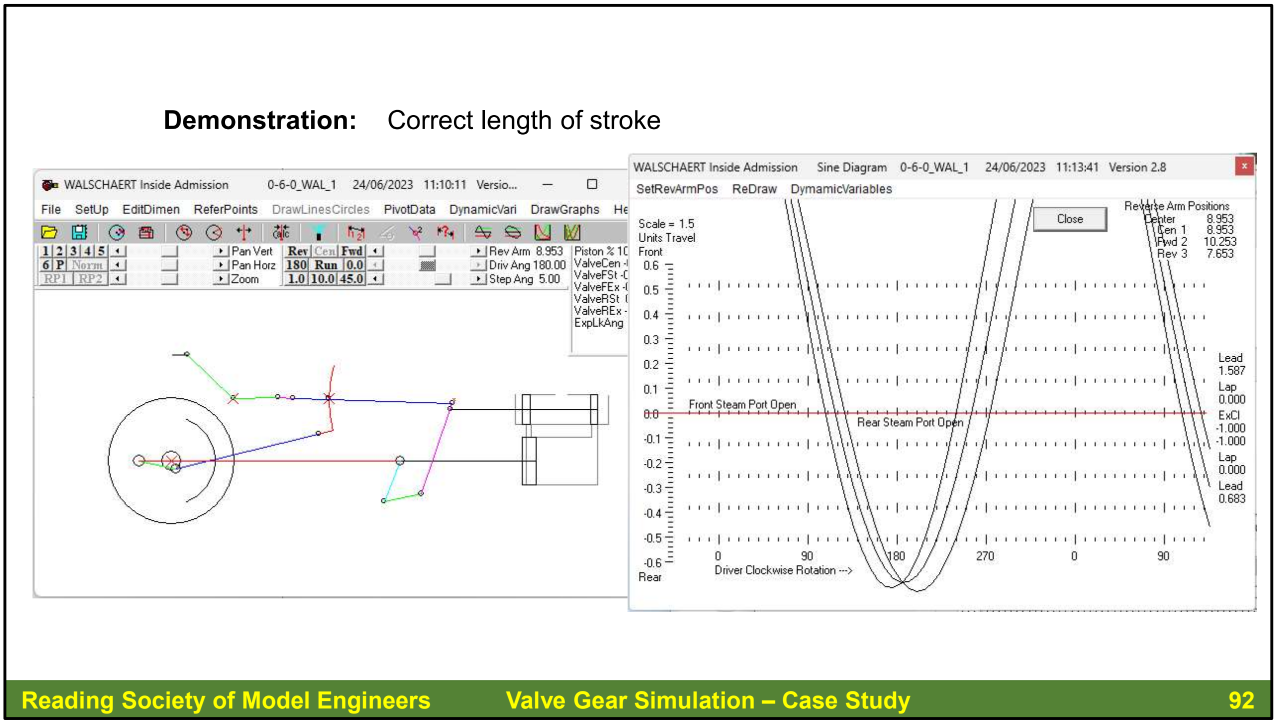
Demonstration: Dimensions as entered



Sine graph – looks very unbalanced

Error reporting has been turned off – for this and for all the demonstration. Dockstader just reports an error, but does not tell you where the error lies…

If we look at the graphs of the valve gear in operation, it is clear that something is amiss – the sine wave showed be symmetrical disposed about the x-axis, and it is not!



One error is immediately noticeable – the stroke has been entered as the RADIUS of the connecting crank, not the DIAMETER. If we put in the correct value for the stroke, as read off from the diagram, the stroke changes from 18 to 36 (units).

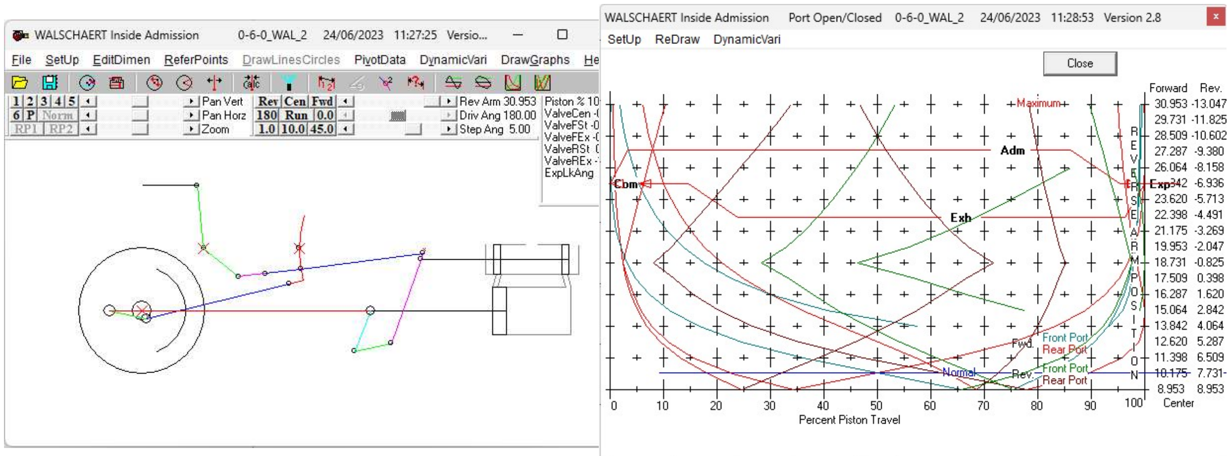
Biu now, the piston is moving way past the ends of the cylinder. We will have to make the cylinder longer to cope with the TDC and BTC (equivalents) of the piston.

On the other hand, the sine curve is looking much better – still not symmetrical about the x-axis, but seems to be getting there.

TDC – Top Dead Centre – on this diagram - the rightmost extreme position of the piston – at this point, the piston is not moving

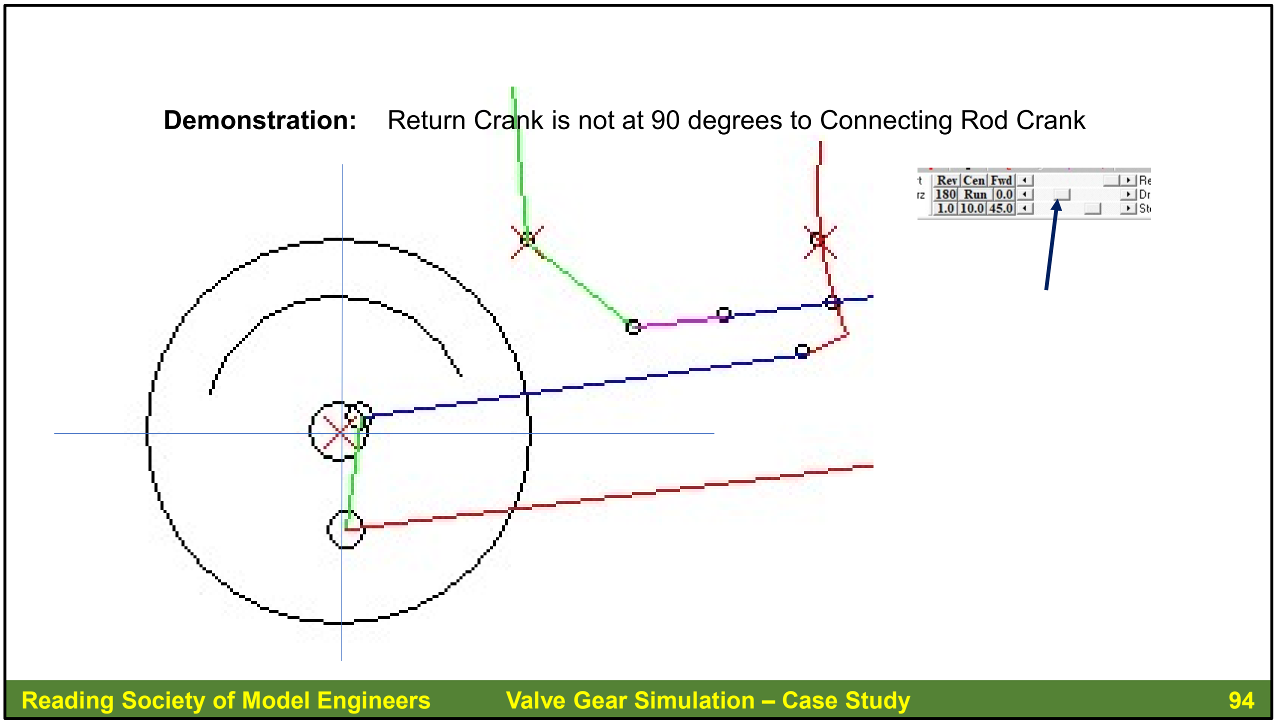
BDC – Bottom Dead Centre – on this diagram, the leftmost extreme position of the piston – at this point, the piston is not moving

Demonstration: Change length of the cylinder (bore length)



The cylinder length now matches that of the “stroke” Perhaps it could be a little more generous?

The Sine diagram is much the same as the previous one, so we look at one of the others. This is the graph of the ports opening and closing. This is a Mess! The ports should be opening in a far more symmetrical manner



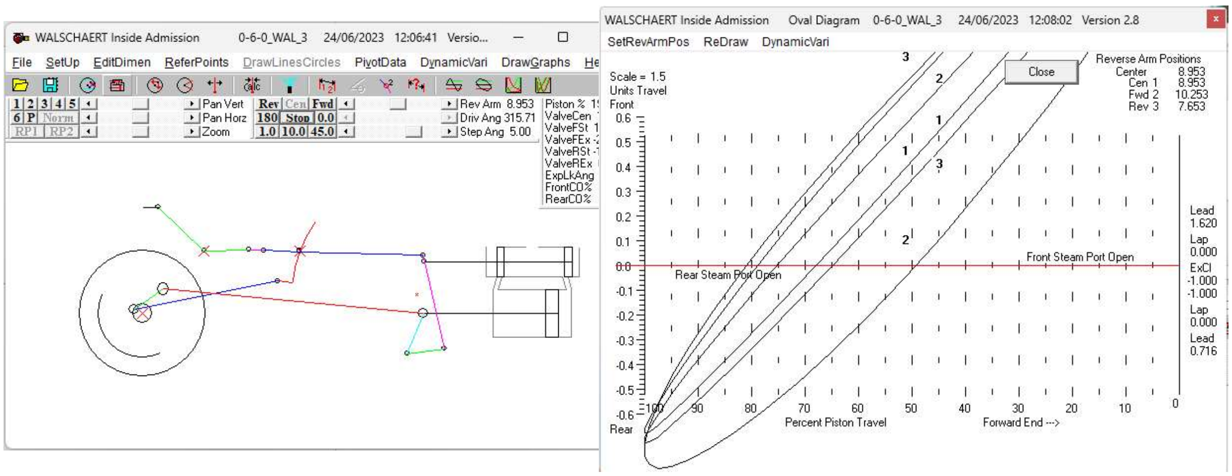
The return crank is clearly NOT at 90 degrees to the connecting rod crank!

We can check this by “stepping through” the animation rather than running it. Using the slider provided in the interface. You may have slide back from the centre position to get the driving wheel in exactly the right position.

We can shorten the return crank (American usage: eccentric crank) by a suitable amount to get it at right angles to the connecting rod crank and still be on its circle (maintaining its radius from the wheel axle centre.

As currently running, the locomotive might have some form of negative lead…

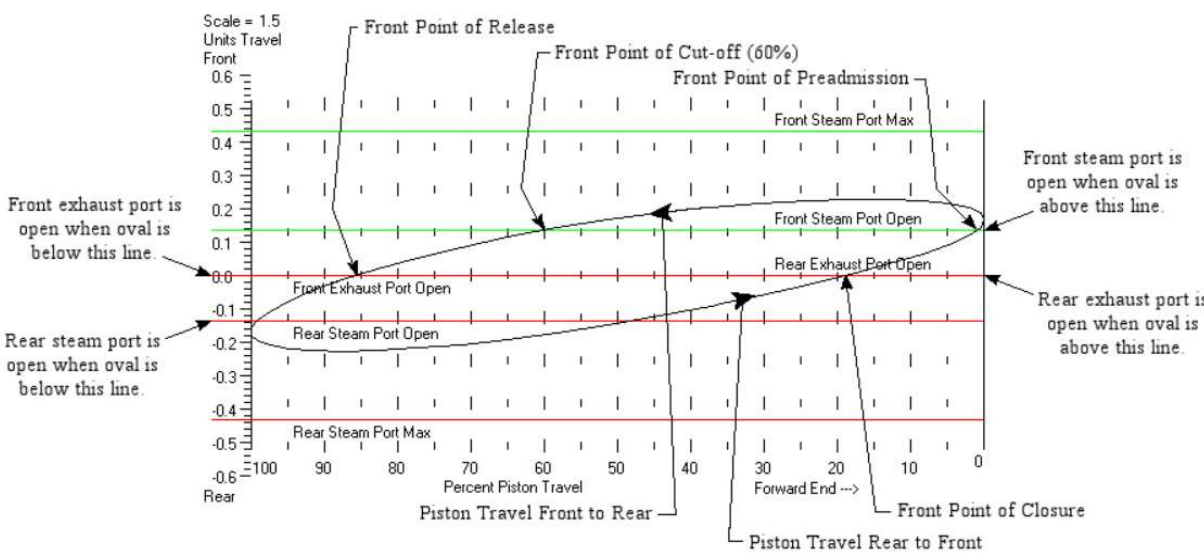
Demonstration: Shorten Return Crank



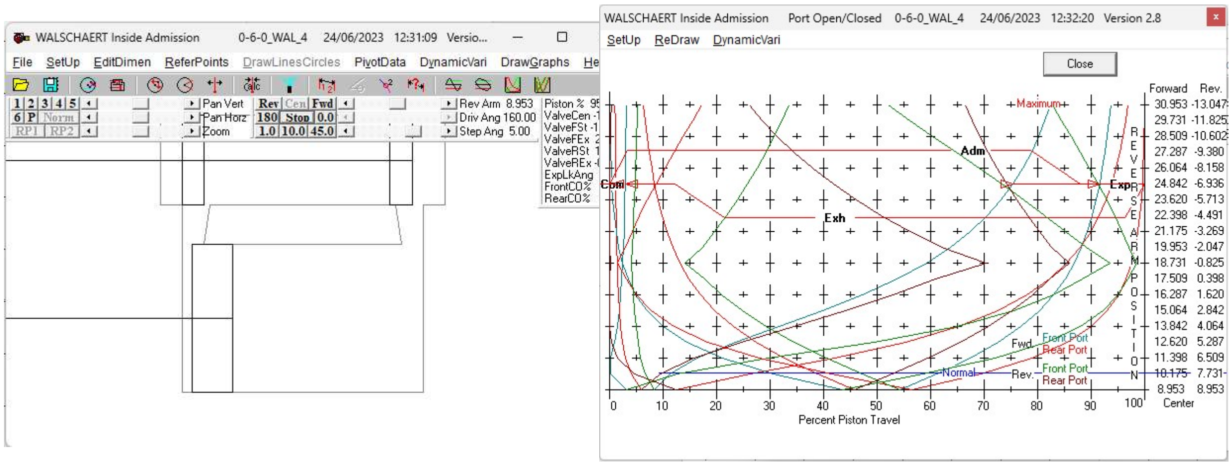
Shortening the radius rod has made an improvement.

The “oval diagram” (ellipse diagram) is a little more consistent but it is not correct!

Should be like this:



Demonstration: Widen steam ports



Widen the steam ports.

We are getting a little closer to the ideal. There is a lot more we can do to finesse the various settings.

This is just a brief overview of how computer-based simulation can help with valve gear design.

Demonstration:
Any other changes?

If there is sufficient time, enter any changes suggested by members of the audience.

The End ..

References

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