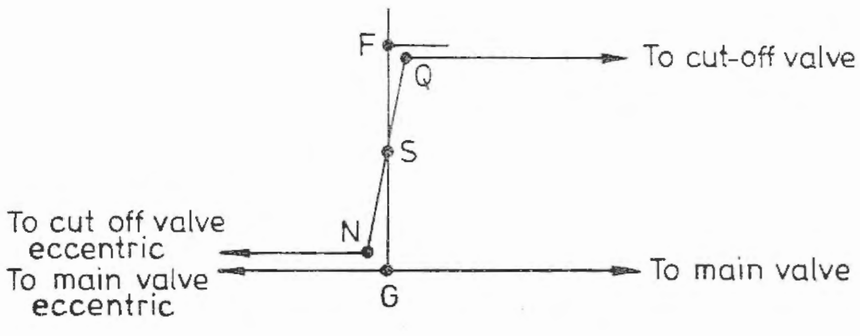
ACHIEVING INDEPENDENT CUT-OFF WITH A MODEL LOCOMOTIVE VALVE GEAR

by F. L. Jaggi (U.S.A.)

Part I

ENGINEERS HAVE LONG recognised the advantages of using a riding valve operated by a separate motion to control cut-off independently of other valve events i.e., release, compression, and admission. I would like to describe the independent cut-off valve gear I have used on my 3½ in. gauge 4-6-6-T Boston & Albany locomotive. I'll cover how this valve gear was developed plus features of its design and performance.

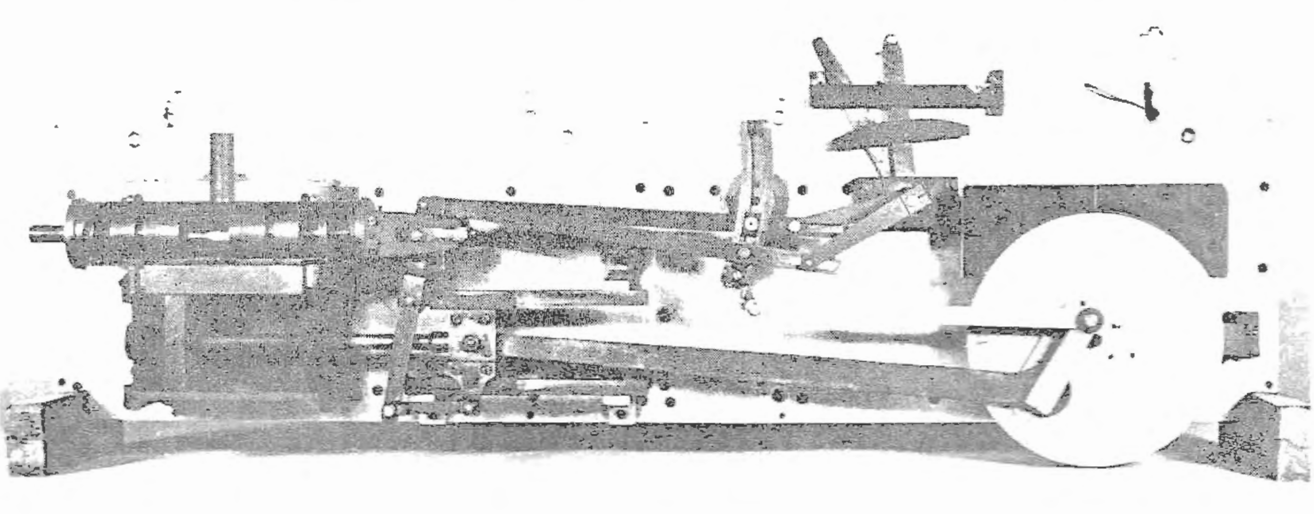


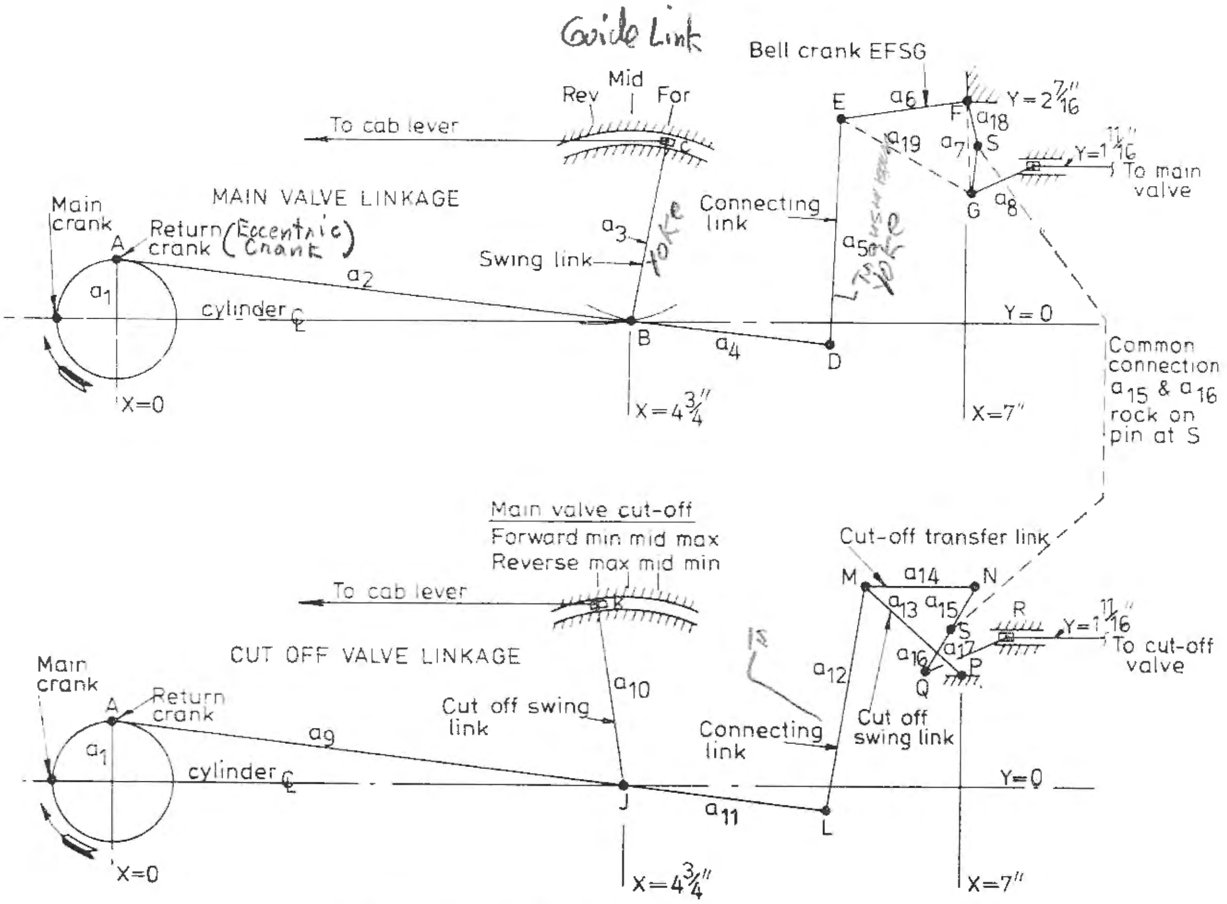
BUCKEYE LINKAGE
Fig. 1

Riding cut-off valves were frequently applied to stationary steam engines. Although not so well known, separate independent valves to govern cut-off were often used on many locomotives in the United States before the adoption of link motion in the 1850's. At first, hook and grab motion was employed to control the riding valve. This gave either a single or at most two fixed points of cut-off in forward gear. Between 1850 and 1857, variable cut-off mechanisms using a curved link and sliding block, attached to the main valve rocker shaft, to drive the riding valve became popular. Subsequently a single valve, driven at first by link motion and ultimately by radial gear, became the accepted standard. The single valve gears were reversible and achieved variable cut-off — but at the expense of other valve events — however, their simplicity and ruggedness led to their universal adoption. Later, as experience was gained with radial valve gears, a number of independent cut-off mechanisms were proposed and some prototypes were built in Britain and France, but none gained commercial acceptance because of their complexity.

I first became interested in independent

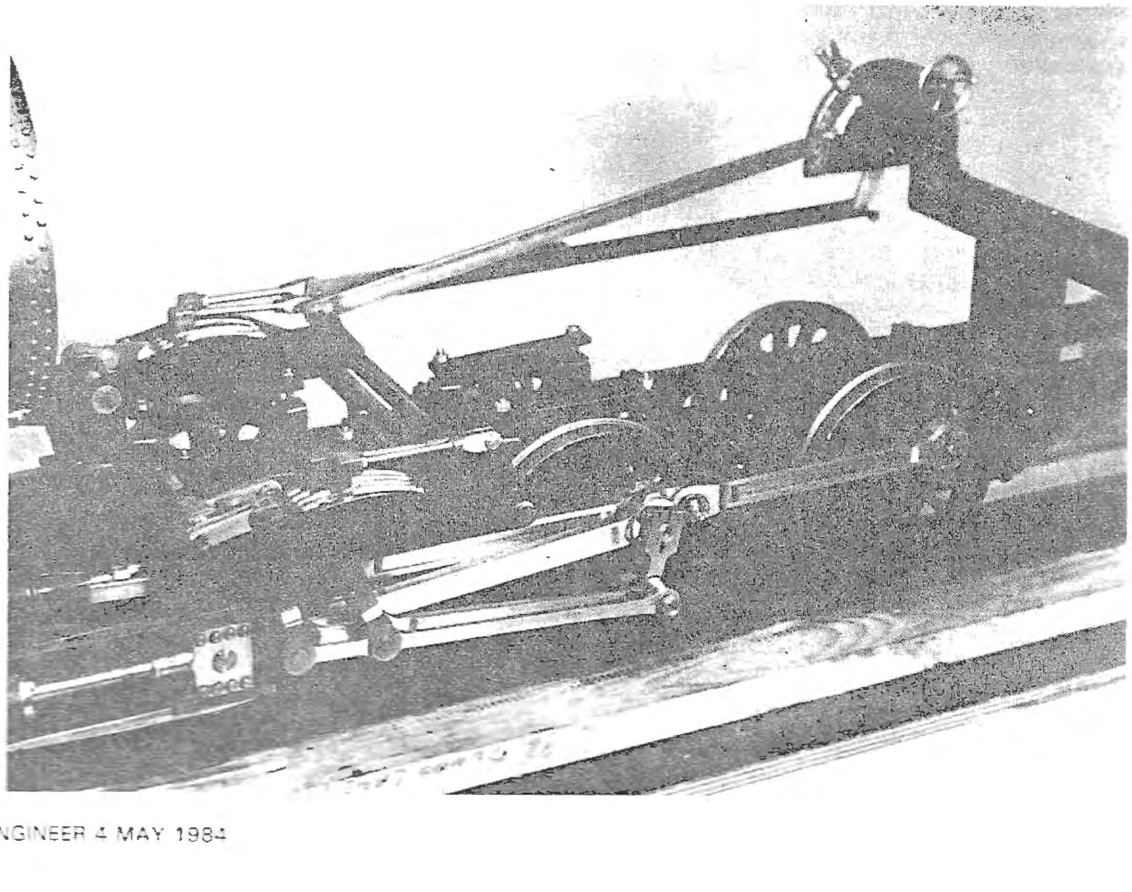
Below: L. S. Bennett's two times scale model of the valve gear mechanism. Opposite page: The Author's Strong, Buckeye valve gear.

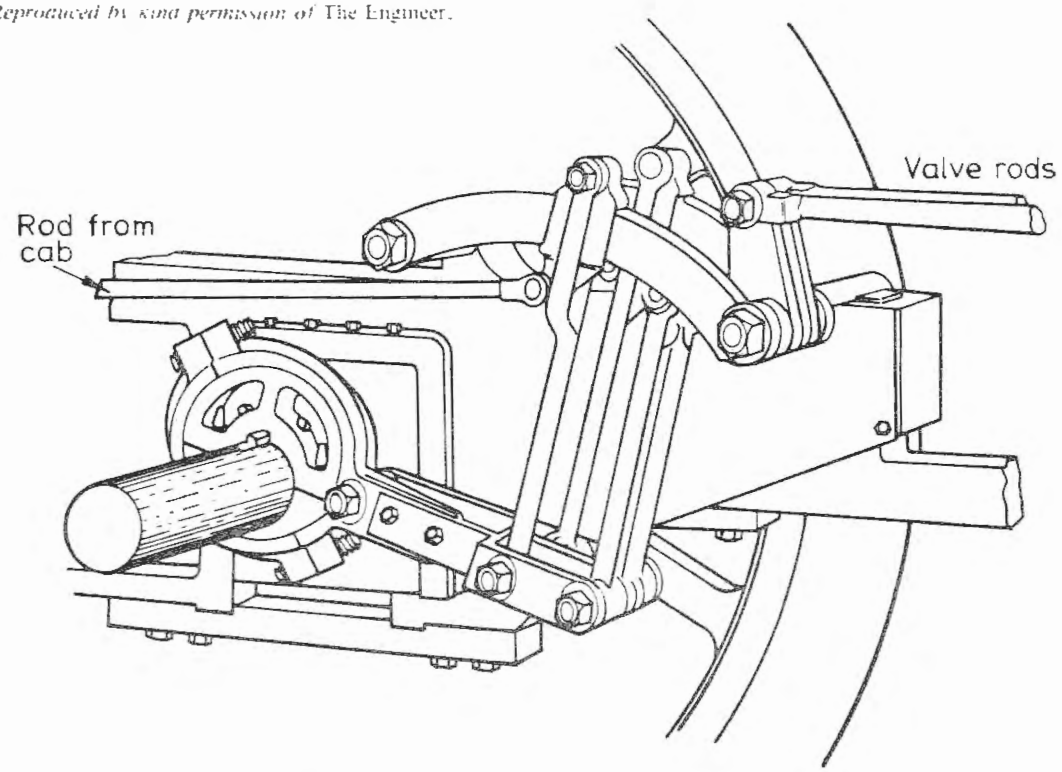




STRONG BUCKEYE VALVE GEAR

Fig. 2

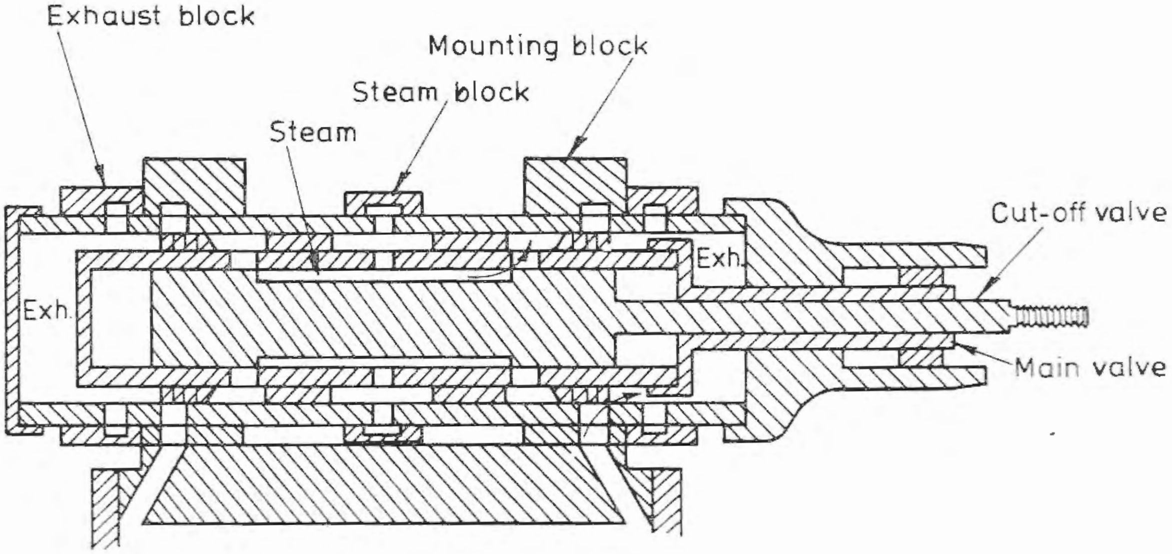




VALVE-GEAR OF THE STRONG LOCOMOTIVE

Fig. 3

cut-off valves for model locomotives through the efforts of the late L. S. Bennett of Walthamstow, whose magnificent 5 in. gauge "Director" class locomotive used this concept, controlling the riding valve with an independent set of Walschaert's links. Photo 1 shows a two times scale model he made of the valve gear mechanism. Ben's design was successful. His locomotive was run for a number of years with no difficulties and, in fact, came in second in the 1972 I.M.L.E.C. trials at Newcastle. In studying Ben's gear, which achieves varying cut-off by changing the angle of advance of the riding valve in relation to the main valve, it became apparent that considerable wire drawing will occur since cut-off is achieved at a point where both valves are travelling in the same direction but at a different velocity.



BUCKEYE VALVE

Fig. 4

In stationary engineering practice, one of the most successful independent cut-off valve gears was manufactured by the Buckeye Engine Company of Ohio. The linkage of the Buckeye gear, shown in Fig. 1, translates the movement of the cut-off eccentric rod relative to a fixed point to an equal and opposite movement of the cut-off valve, which is riding on the main valve, relative to the main valve. Thus the motion of the cut-off valve relative to the main valves is the same as that of a single valve to a fixed valve seat.

I thought it would be interesting to apply this system to a model locomotive. The problem was how to fit the necessary links in the space available and to achieve variable events for both the riding and main valve with a radial gear. After studying the problem further, it looked as if link FSG in Fig. 1 could be made one arm of a bell crank. Since the Southern valve gear is one of the more common and reliable gears utilizing a bell crank, the final design that was evolved used this gear to control the main valve. A second Southern valve gear was used to control the cut-off valve. Rather than using a separate bell crank to feed the rocking lever of the cut-off valve (link NSQ), a swinging arm was used. The gear is shown in Fig. 2 and Photo 2.

Southern valve gear is based on the gear invented by George S. Strong. The only difference being that Strong's original design used an eccentric, whereas the Southern gear uses a return crank. In looking up references to Strong's design, I came across an article in *The Engineer* dated September 13, 1889 which described the use of his then novel gear on a remarkable locomotive. Fig. 3 taken from this article shows his valve gear. Interestingly, he had inlet valves controlled independently from exhaust valves by two sets of gears, just the same as I wanted to do on my B & A Tanker! The only difference being that on my locomotive I wanted to use the Buckeye valve arrangement whereas Strong used gridiron valves for steam and exhaust.

Fig. 4 shows the actual valve I used which is patterned after the Buckeye piston valve. It is actually two concentric piston valves, the inner cut-off valve controlling steam admission and the outer main valve with rings controlling exhaust.

The main valve linkage shown in the upper part of Fig 2 is essentially the Strong configuration. The cut-off rocker arms, NS and QS are pivoted at point S of the mid-point of the vertical arm (FSG) of the main valve linkage bell crank. These rocker arms are the essential features of the Buckeye linkage. To avoid the use of a second bell crank, a radius arm, MP, from the fixed point P is used to translate the motion of point L to N and hence to the valve. Although the swing link, MP, causes considerable harmonic distortion, it's much more efficient in space requirements and by careful layout results in the important valve events occurring where required.

Continued

WHAT'S IN STORE

We have received the following catalogues from some of our advertisers:

K.R. Whiston Ltd's new 1984 catalogue has been published and, to get it, merely send a 9 in. by 4½ in. stamped addressed envelope to Whiston's and it will plop through your letter box by return post. Whiston's have issued over 100 catalogues in about 36 years of trading and the current one runs into 44 pages of close print, listing hundreds and hundreds of items of far too varied kinds to do more than a mention of the range. Nuts, bolts, all sorts of fasteners, screws, ball races, both new and used, tools, tool lists, drills, surplus instruments, regular and surplus metal sections, electric motors and all sorts of odd hardware. Mail order service is prompt and callers can often get discounts on many items. K.R. Whiston Ltd is at New Mills, Stockport, SK12 4PT.

Visitors to the Model Engineer Exhibition will doubtless know of the remarkably varied assortment of "goodies" to be seen on the Stand of **Proops Brothers Ltd.** We have a copy of the latest catalogue they have now issued and, whilst it is not exhaustive (only a part of their products is listed) there are many items of interest. Electric Kilns, small hand tools, magnifiers, assorted electric and electronic goods, files, instruments, walkie talkies — for use round the tracks! — all of which are their "regular" items. Proops, of course, have a great deal of other odd hardware including packs of nuts, screws, springs etc. etc. Their catalogue costs 30p from them at 52 Tottenham Court Road, London W1P OBA.

For the Gauge 1 enthusiast, **Loco Steam** are the people. Their well produced catalogue with a score of good colour photographs, lists 19 designs, whole or in part, available. A few designs in larger scales are also available as are castings, materials, fittings, track parts to make track to G.1. MRA standard, butane fuelling valves and firing control blocks. Loco Steam's catalogue is priced £1.00 from Keswick Lodge, Keswick, Norwich NR4 6TY.

The catalogue issued by **Nathan Shestopal Ltd.** is a prestigious 128 page affair. It costs £1.50 to callers and £2.00 by post. Originally of major interest to clock and watchmakers, the range of goods offered has been widened considerably for model engineers generally. Besides the clockmaking tools and sundries, there is a large section on hand tools, six pages of books, a section on machines, Myford, Unimat, Emco and lathe accessories. Shesto have developed a CNC version of the Myford ML 10, mainly for educational purposes which aroused much interest at the last Exhibition. Shesto are main distributors for Sievert LPG appliances and the full range of their products is shown. Most of the hundreds of items in the catalogue have a description of their usage and application and there are many hints and tips on "how to do". Lastly, for the true miniaturist, their BA taps and dies go down to 16 BA(!). Shesto are at 1 Grangeway, Kilburn, London NW6 2BW.

Another large catalogue; this one a 78 pager from **Meadows and Passmore** which costs £2.00 post free. It caters for the clockmaker and lists mainsprings through to the decorative additions for a variety of styles of clocks; dials in huge variety, glass panels, hands, keys, cleaning materials, waxes, fillers etc. etc. Meadows & Passmore are at Farningham Road, Jarvis Brook, Crowborough, East Sussex TN6 2JP.

Kennions Bros. (Hertford) Ltd. have two catalogues, one for Locomotive designs and one for Materials and tools priced at 60p each. The locomotive catalogue lists 45 designs from 7¼ in. gauge down to "O" gauge with plenty of photographs and line drawings to illustrate them. A very large range of locomotive wheel castings is shown as well as Kennions well known range of steam fittings. In the materials and tool catalogue will be found the 40, 32, 26 t.p.i. "Model Engineer" series of taps and dies as well as those for other popular threads, miniature end mills, drills, boring bars, a whole range of hexagon headed screws, rivets, metal sections and sheet, "O" rings from 7/64 in. bore to 2in., and, of course, for the live steam enthusiast to see what's going on in the boiler, Pyrex toughened gauge glass.

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by F. L. Jaggi (U.S.A.)

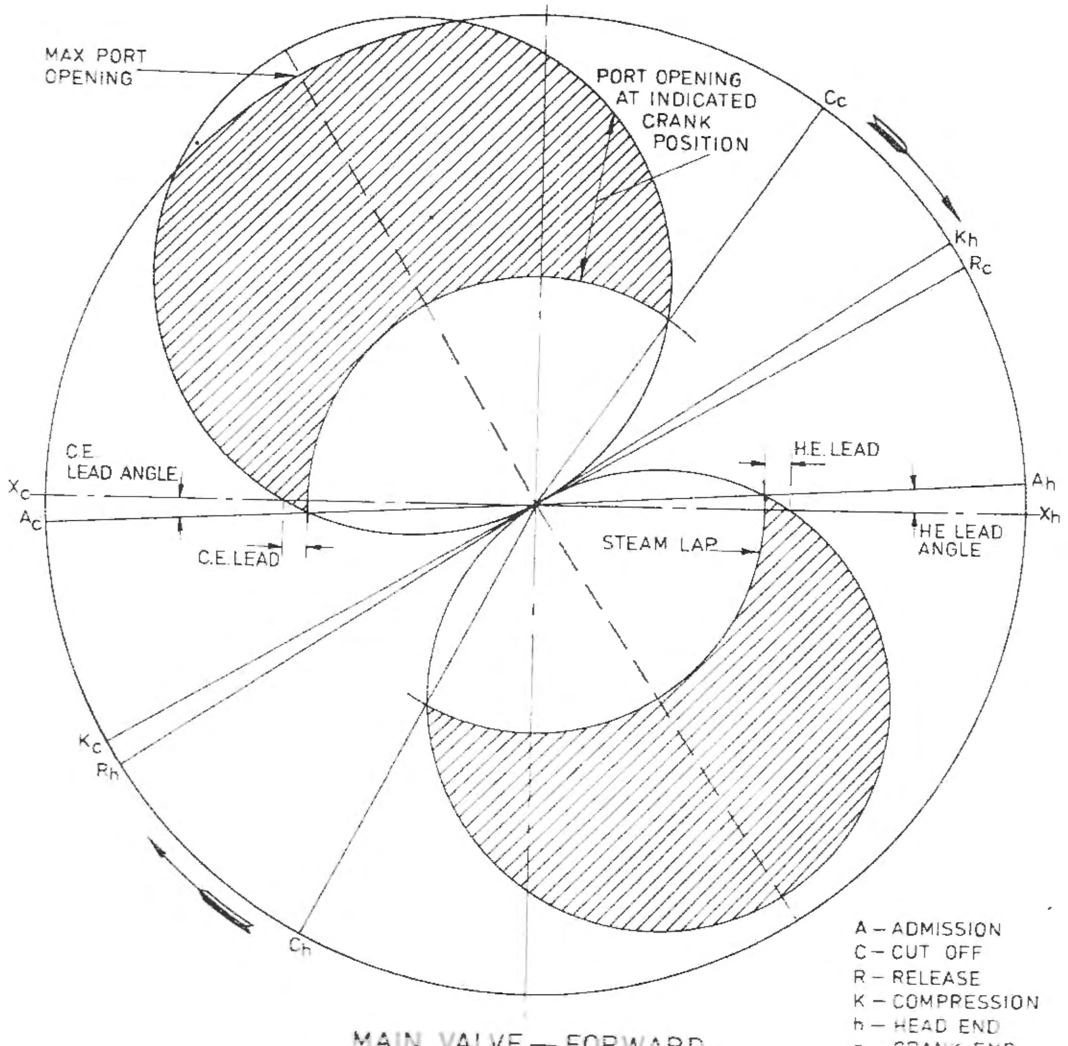
Part II (Conclusion)

From Page 515

TO LAY OUT the valve gear, I first used the method described by J. M. Liversage in his article starting on Page 380 of the 18 April 1969 issue of *Model Engineer*. Mr. Liversage's previous article, Page 351, *Model Engineer*, 4 April 1969, gives further details of Strong's engine described above. To understand the operation better, I plotted Zeuner diagrams for the gear and ultimately calculated the actual motions by analytical geometry, using a Hewlett-Packard programmable calculator.

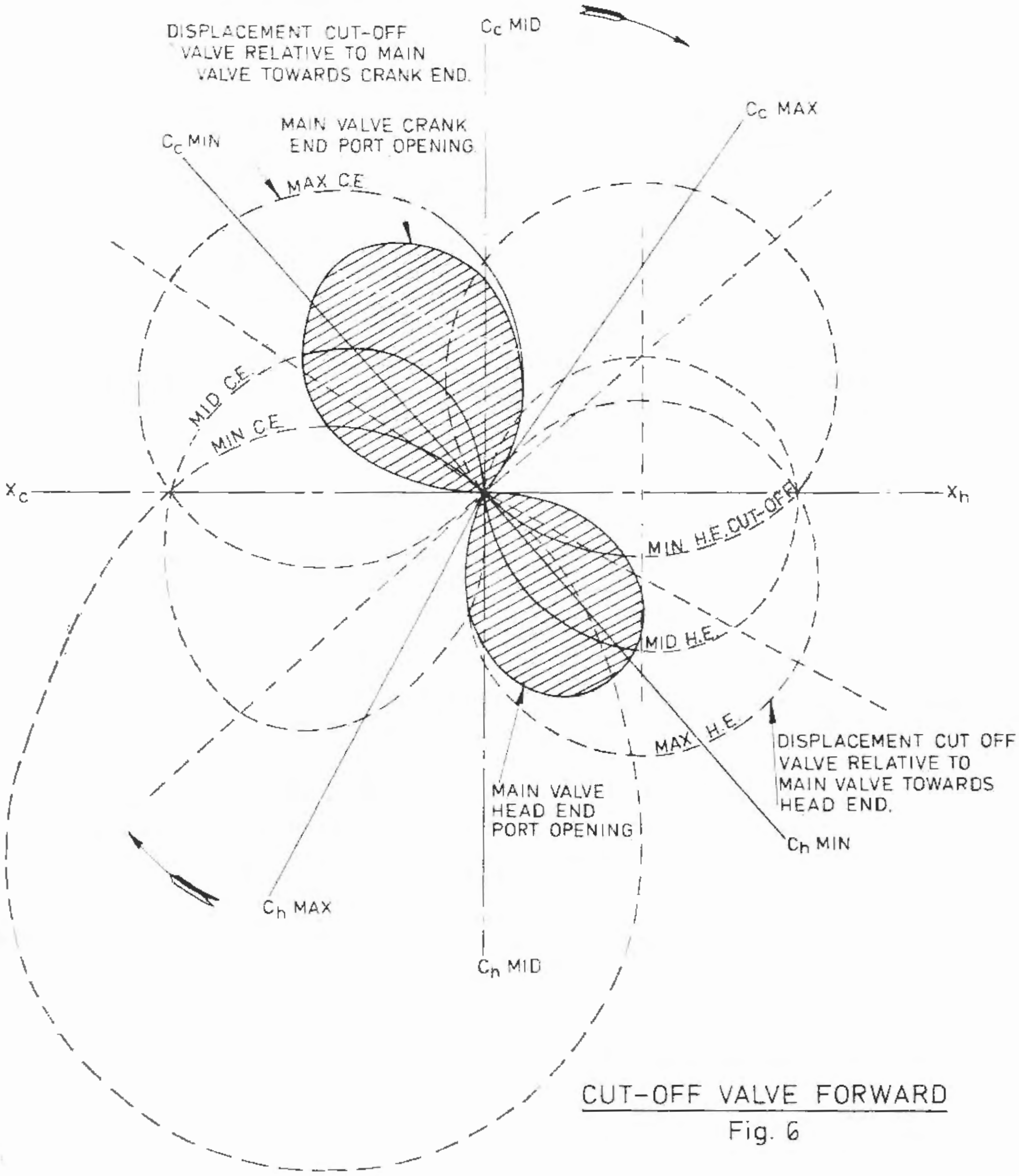
Fig. 5 illustrates the Zeuner diagram for the main valve in the forward running position. Fig. 6 shows the Zeuner diagram for the cut-off valve at various degrees of cut-off when the locomotive is running forward. The Zeuner diagram uses the interesting geometric principle that if harmonic motion, that is a sine wave, is graphed by polar coordinates, the plot turns out to be a circle. This makes the diagrams easy to construct and easy to interpret. In practice valve movements are shown on the centre-line of the crank such that the distance from the centre-line to the point being plotted represents displacement of the valve from its mid-point at that crank angle. Operation of the valve and its effect on the piston become readily apparent by a brief inspection of the diagram. Normally Zeuner diagrams are plotted assuming that the valve travel is symmetrical and, of course, the Zeuner lines are true circles. But it also can be used to represent actual valve movements for any given valve gear presuming these can be measured, or calculated analytically.

Referring to Fig. 5, as we follow the crank through a revolution, the main valve starts to admit steam at AH and as the crank revolves to top dead centre, XH, the valve is opened an amount defined as the Head End Lead. As the crank rotates further, the valve continues



MAIN VALVE — FORWARD

Fig. 5



CUT-OFF VALVE FORWARD

Fig. 6

to open, reaches its maximum at the dashed line on the drawing, then starts to close. The crank is at C_H when the valve closes. Steam expands until the crank reaches R_H at which point the valve starts to open to exhaust and steam is released from the cylinder. The cylinder remains open to exhaust until point K_H is reached at which point the main valve again closes and the remaining steam is compressed until point A_H is reached. Corresponding events, phased 180 deg. apart, occur at the crank end of the cylinder.

All mechanisms that convert circular to linear motion create some distortion from true harmonic. The obliquity of connecting rods, vibrating levers, etc., cause distortion of the circles on the Zeuner diagram. This is not necessarily bad, provided key events occur where they are intended. In Fig. 5, for example, which shows actual, not theoretical, valve events, the lead is kept constant and the cut-off is within 1% of stroke between the head end and crank end of the cylinder.

Fig. 6 shows how effective the Strong-Buckeye valve arrangement is. The main valve is operated at full travel giving only the amount of compression necessary to bring the steam remaining in the cylinder back up to the inlet pressure at the end of the piston stroke thus avoiding energy loss through over compression and at the same time cushioning the piston. The main valve gives a free and full exhaust. At cut-off, the riding valve is travelling in the opposite direction to the main valve giving a sharp cut-off with no wire-drawing. The gear operates equally well from full cut-off, which in my case was approximately 76%, down to less than 10 percent.

Let's look at Fig. 6 more closely. Zeuner "circles" are drawn for the cut-off valve in three modes of operation: full cut-off, mid cut-off, and minimum cut-off. There is considerable distortion from true harmonic in certain phases of the valve operation but as we shall see later, this has little effect on the key valve events. Remember, we can draw diagrams for the cut-off valve just as for any single valve, since the Buckeye linkage allows the relative motion of the cut-off valve to the main valve to be the same as a single valve to a fixed seat. Superimposed on the Zeuner diagram for the cut-off valve is the steam opening of the main valve.

At T.D.C. the cut-off valve is open a considerable distance. When the cut-off valve linkage is set for maximum cut-off, the valve continues to open, then starts to close simultaneously with closure of the main valve and cut-off occurs at C_H max of 76% equal to the main valve. Other events effecting the cylinder — release, compression, and admission — are controlled by the main valve and are unaffected by the cut-off valve. As the cut-off valve linkage is adjusted to mid and then minimum cut-off, the cut-off valve closes earlier in the stroke and cut-off is shortened for the head end through C_H mid to C_H min. and for the crank end through C_C mid to C_C minimum Fig. 7 presents a summary of the key valve events.

From the diagram it is clear that the steam port opens quickly, stays open full, and then snaps shut at the point where cut-off is required. The design eliminates wire drawing. Although cut-off valve travel is far from symmetrical because of simplifications to the cut-off linkage, positions at key events are sufficiently close to acceptable. If I were laying out the gear again, I would slightly modify the position of point G in Fig. 2 by altering dimension a19 by trial and error to improve the equality of cut-off valve travel.

The main valve is set to give equal lead just as in any other radial valve gear arrangement. The cut-off valve is set to give equal relative displacement to the main valve when the cut-off valve is at mid-point. This occurs whether the main valve is in forward, neutral or reverse positions because of the Buckeye element of the motion. The cab contains two controls for operating the locomotive: A wheel for regulating the cut-off valve and a lever for the main valve which is set either in full forward, mid-point, or reverse with no intermediate steps.

The gear has been designed for long life with ease of maintenance. The sliding blocks at points C and K in Fig. 2, are actually sealed miniature ball bearings and these are also used at points B and D. All other connections use hardened and tempered silver steel pins operating in porous bronze bearings.

Although the gear is rather complicated, it fits neatly and compactly on the model. It has run successfully on air. I believe its wide range of cut-off and ease of operation and maintenance have justified the effort that went into its design and construction. Besides, it has been rewarding to attempt to achieve the standards of performance set by L. S. Bennett's "Director" and proposed by LBSC for his "Thunder & Lightning" valve gear.

FIG. 7
SUMMARY OF VALVE EVENTS

		Forward	Reverse
MAIN VALVE			
Lead, inches	H.E.	0.011	0.011
	C.E.	0.011	0.011
Max Port opening, inches	H.E.	6.2/64	6.1/64
	C.E.	7.5/64	8.5/64
Cut-off, %	H.E.	75.5	72.9
	C.E.	76.3	80.4
Release, %	H.E.	92.8	92.0
	C.E.	92.6	90.0
Compression, %	H.E.	9.2	10.0
	C.E.	5.9	11.5
CUT-OFF VALVE			
Max Cut-off, %	H.E.	75.5	72.9
	C.E.	76.3	80.4
Mid Cut-off, %	H.E.	53.0	53.0
	C.E.	47.0	47.0
Min Cut-off, %	H.E.	18.6	15.5
	C.E.	14.9	11.5

LBSC MEMORIAL BOWL COMPETITION 1984

To be held on Sunday, 2nd September 1984 by permission of the **Leyland Society of Model Engineers, at Worden Park, Leyland.**

The Competition is for Steam Locomotives of 2½, 3½, and 5 inch gauges built to the designs of the late LBSC.

Prizes to be awarded are:
First Prize the Memorial Bowl and, providing six or more enter, additional prizes will be awarded as follows: First £15.00 Second £10.00 Third: £5.00.

Applications for Entry Forms should be made to the **Exhibition Manager, c/o Model Engineer, Wolsey House, Wolsey Rd, P.O. Box 35, Hemel Hempstead, Herts. HP2 4SS.** It will be first come first served and it may be necessary to limit the number of entries. Closing date for entries is the **31st July 1984** and full conditions for the Competition will be included with the Entry Form, and are available on request.

Post Bag

Independent Cut-off — further information

SIR. — Thanks for publishing my article on independent cut-off. I hope it was interesting to the readers. I have noticed that the data for Fig. 2, page 513 *Model Engineer* No. 3730 1-14 June 1984, was inadvertently left off the diagram. Below is a copy of the missing data for information.

a1 = 1/2 in.	a10 = 2 1/4 in.
a2 = 4.776 in.	a11 = 1.345 in.
a3 = 2 1/4 in.	a12 = 2.449 in.
a4 = 1.154 in.	a13 = 1.290 in.
a5 = 2 7/16 in.	a14 = 0.910 in.
a6 = 1.10	a15 = 15/32 in.
a7 = 1.00 in.	a16 = 15/32 in.
a8 = 2 3/16 in.	a17 = 1 5/16 in.
a9 = 4.776 in.	a18 = 15/32 in.
<EFS = 90 deg.	a19 = 1 5/16 in.

	Main valve	*Cut-off valve*
Lap	3/32 in.	0
Lead	.011	—
Valve travel	7/16±	—
Port opening	1/8 in.	1/8 in.
Exhaust	Line on line	—

Mass, U.S.A. F.L. Jaggi

G.W.R. Crosshead Bearings

SIR. — As an ex-Swindon apprentice (of some 30 plus years ago!) I have been following the Martin Evans series on the 28XX locomotive with much interest. I was surprised to read in the current *Model Engineer* that the crossheads were steel castings with separate bronze slipper blocks.

To the best of my recollection, they were fabricated by welding together three partially machined steel stampings — at least all the later ones were. Once assembled the crosshead was then planed to a very rough finish in way of the slide-bars. Strips of "brass" were then riveted on the slippers and the whole face then white metalled. After machining, the white metal was scraped to a fit between the slide bars already erected. At no time was the "brass" (it may have been bronze) visible; the crosshead ran on white metal — the "brass" we were told was to "save" things, if the white metal ran! The only ones with bronze slippers, that I can remember, were some of the old inside cylindered locomotives with 4-bar crossheads.

Swindon, Wilts Dennis E. Harber

Footnote from Martin Evans:-

I think the earlier crossheads were steel castings, the slippers probably iron castings with white metal linings. I have Swindon official drawings 45771 dated 1912 which shows a crosshead of this type, without brasses, the white metal being attached to the slippers by the usual serrations. A later drawing, No. 109500 dated 1937 and marked for 2800 class engines shows a similar construction but with bronze strips held to the slippers by brass countersunk screws, the white metal lining being on top of these strips. Steel plates (5 1/4 in. wide) were welded on the front of the crosshead to stiffen the ends of the slippers. In both these designs the slippers were bolted to the centre of the crossheads by two 7/8 in. dia. bolts to each.

The type of crosshead described by Mr. Harber was probably introduced at some time after 1937; my photograph, actually taken on a 4575 type 2-6-2 tank engine, shows this type of crosshead.

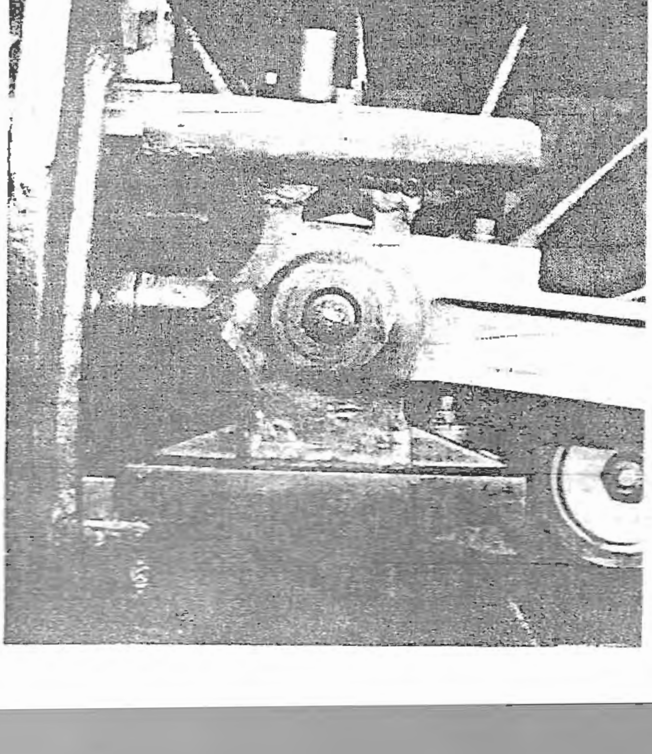
A 5 in gauge locomotive adaptation

SIR. — I have been a reader of your magazine for some 50 years now and still enjoy modelling, having completed my fourth locomotive, LBSC's *Speedy* in 5 in gauge. Various other projects have kept me busy, including the M.E. Refrigerator, which ran 12 years, also a washing machine of my own design.

I have recently given up driving a car, so am without transport to get to any local tracks. Laying out a garden track is not convenient, so I had to mount *Speedy* on rollers for a steam-up. This has palled after a while, and set me thinking how to improve the situation with the result which you can now see in the photos, a locomotive cum traction engine. This problem must be a common one with many trackless locomotives in existence. The "L.C.T.E." is a practical answer to any owner of an engine who is without a track to run on.

The chassis on which *Speedy* is mounted can be lifted off in minutes by removing four screws and a chain link. Used in such a way the chassis can be provided with a power take-off shaft and

Below: A typical G.W.R. crosshead. Photograph courtesy B. Western.



Below: Mr. Parris's Speedy *in her converted role.*