Nov 1993 THE BOULTON AND WATT BELLCRANK ENGINE

This Meccano model is an accurate copy of all the salient features of the original and is a pleasure to build and to operate. It dates from 1802-so is a part of our industrial heritage and a worthy subject for the model-builder. Before you commence-to build-note that the flywheel is made from two replica channel rings fitted with eight spokes-and the drive to the crankshaft is via an Exacto toothed ring and coarse tooth matching pinion. This ring is attached to four spokes spaced from the ring by collars-and MUST run true and firm-use two bush wheels for spoke attachment and adjust with care. Another important area is the position of the valve arm running at the edge of the circ girder bolted to the flywheel in an offset position. The arm has an end brng with the lugs slightly opened-and running at the edge of the circ girder DIRECTLY IN LINE with the crankshaft which means the setting of the crankshaft is crucial-with the position of the arm at the side of the cylinder being directly at top dead centre. The motion of the circ girder-being offset-must NOT cause the end bearing to bind or jerk-and a drop of oil on the rim of the circ girder will make all the difference. I have used a small mains Induction motor-but ANY motor can be utilised to give a slow measured display speed.The plinth holding the flywheel and gear-ring,is made from two Sector plates attached to flat girders-these girders also bolted to SLOTTED holes in two slotted strips bolted to the top of the base plinth-but adjusted to be directly in line with the other half of the crankshaft on the main engine body. The bearings for this part of the crankshaft are two couplings fixed to the SLOTTED holes of a short angle girder bolted to the top edge of the main engine frame-which allows for any adjustments-but see my diagram for this. The two side Bell cranks MUST be built EXACTLY identical-so choose your parts with care. The valve chest is a special MW Models sleeve piece of 3½" length and in a green enamel finish(or in Blue). The main baseplate is in rectangular shape and is 2½" in height but see diagram for other measurements-and the position of the two "wells" for the side-cranks and for the flywheel. If you do NOT have the right length girders-make them from compound girders-but make sure any joined girders are in line and firmly bolted together.The two bell-crank frames are free to pivot under the main body and rise and fall from two built up cranks on the crankshaft-to operate together in unison to avoid any binding. Counter-weights are bolted to each side crank and these are wheel discs in multiples for each frame. These are essential for free-running and rise and fall in the two "wells" at each side. Some dexterity is required to make the valve operating mechanism with the use of handrail supports and couplings for the vertical valve spindle to operate freely. Always use STRAIGHT strips and rods and choose bush wheels with firm bosses and true running-essential.

THE BASE PLINTH.You can start with this unit which is made up from long and short angle girders and flat plates of different sizes as available. The length is 18½" and the width 12½" with 2½" girders at the four corners. Looking at the engine from the front side(the rear side is the motor side) bolt long angle girders lengthways at 7 holes/11 hole/14 holes and 18 holes-by their round holes and with flanges outwards.This leaves spaces for the WELLS and the flywheel slot. The main engine unit is 9½"long X 3½"high and 2½"width with the cylinder part 4½" high-see diagrams.The main cylinder is a boiler section curved and bolted at the join to fit inside wheel flanges at both ends without any "play".But the length is extended by small circ plates or wheel flanges etc-to give an overall lemgth of 5½" when in position.

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The main engine body. Consists of two 9½" a/girders for the length-with a 4½x2½"flat plate bolted vertically at the left end and inside the ROUND holes of the girder-next a 5½x3½"flat plate lengthways and butted against the 4½x2½ plate-and then a 3½x1½"plate next to it in a vertical position-these plates take up the length of the girder. At the left end-bolt a 4½"a/girder in a vertical position behind the 4½" plate-and a 3½"a/girder inside the far end plate(3½x1½") and also beneath the plate. Repeat for the other side and join the two sides with a further 4½x2½"plate and a 3½"x2½"plate to form a box shape.

THE WELLS. For the side cranks-these are 11" long x 1½"wide-the measurements being for the clear apertures.The flywheel slot is 8" long and 1½"wide clear.The position of the wells and slot is shown in a diagram.

The rectangular box form of the engine is bolted to two of the long angle girders-by their slotted holes-the flanges under-in a position 5 holes in from the far end of the base plinth. Secure the box in several places-but make sure it lies square and level. The top of the box at the left has a 3½"a/girder fixed by it's round holes and flange outwards. This flange is to be level and also hold two couplings with short bolts and thin washers to enable them to be adjusted.These coupling bores hold the main crankshaft rod and MUST allow a straight rod to rotate freely in the two bores of the couplings. A longer rod through the couplings also passes through the apex holes of the sector plates on the flywheel plinth-and the sector plates have to be adjusted in their fixing holes to allow this long rod to rotate freely. Remove this long rod when correct rotation is achieved. To give better support for the eventual flywheel-you can fit extra bearings-such as d/a cranks or wheel discs to the sector plate tops. It is important that ALL bearings are bind-free and in line and at right angles to the engine body.

The top of the engine frame at the higher end(the left)has a 2½x1½"flanged plate bolted in a central position across the two vertical plates-but use packing strips on the holding bolts to give true vertical position-this flanged plate holds the main cylinder. Another 2½x1½"flanged plate is bolted across the lower side plates at a position three holes along from the vertical 4½" plate-and this has a boiler end attached.The boiler end has a flex 1½"wide bolted around on the inside of the flange-and represents the pump body. Two "top hat" brkts are also held by the boiler end holding bolts-one inside the boiler end-the other under the flanged plate-their centre holes to allow a rod to slide freely in a vertical plane. Next-bolt two 2½x½" double a/brkts across a 4½"x2½" flat plate-this plate rests over the far end of the box and is held in place by rods passed through the sideplates and D/A strips thus holding the flat plate in place. Two triangular plates 3½"x1½" are bolted each side of two ½x½"double brkts at the centre of the plate-tapered down to the far right. A semi circular "tank" is made from two semi circ plates attached to 2½"a/girders at the far end with a formed flex plate curved around as seen in the photos.

THE MAIN CYLINDER.This is 5½"in height due to extra circ parts at both ends-the top has five wheel discs and a bush wheel-boss uppermost at the centre-and held in place by two threaded bosses screwed onto long screw rods passed down the cylinder and held by nuts on the small flanged plate at the bottom. The threaded bosses are hand-tightened and allow for some movement when lining up the piston rod. This rod only passes a short way into the cylinder-but must be STRAIGHT and operate through the wheel discs & bush wheel. But before you fix the cylinder-the valve gear has to be fitted and you need two flat gdrs of 1½"size-both of which have 1" cnr brkts attached by SHORT screws(see sketch).These flat gdrs are /contd

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bolted by their SLOTTED holes to the opposite sides of the main cylinder three holes down from the top and with 1½"strips overlaid for strength by the holding bolts. The 1" cnr brkts allow a rod to pass through both flat gdrs-and not touch the cylinder jacket-the slotted holes in the girders allow for some movement. The rod that passes at the rear of the cylinder should then be in line with the circ girder edge on the flywheel at it's middle throw-being offset. The next item is the valve chest which consists of a 3½"MW sleeve piece which has two threaded bosses fixed at one side-and held at the side of the cylinder by screws six holes apart. Two small flanged wheels are a tight press fit in the ends of the sleeve piece with their grub screws removed. Two handrail supports are screwed into the bosses of the flanged wheels-but not too impede the valve rod which is free to slide in the top flange wheel boss. A short rod only for the valve spindle. A collar is fixed to the top of the valve rod and is held in place by a further handrail support with grub screw. This is then fitted to a rod which passes through the other two h/rail supports in the flanged wheel bosses and must be adjusted to slide freely and then locked in place with nuts(the two flanged wheels with their bosses and h/rail supports). The valve chest should now be in a position just under the top cyl plate-and clear of the flat gdr brkt at the cyl side.A 4½" rod is next passed through the flat gdr bearings and held at both sides of the cyl by collars. The valve end has a single crank fitted-and a collar on the valve operating vertical rod has a set screw passed into the end slotted hole of the crank and fixed tightly to the collar tapped hole on the operating vertical rod. This crank imparts too and fro motion to the valve operating rod that slides in the heads of the two h/rail supports fixed in the flanged wheels(see sketch). The other end of the 4½" transverse rod has a fixed coupling in it's end transverse hole-and a further rod with an end bearing is fixed to the coupling so that the end bearing(slightly opened) is free to slide at the edge of the circ girder on the flywheel. Fix the cylinder tightly to the engine by means of the two threaded bosses at the top and adjust to line up. When the flywheel is rotated-the circ girder will impart up & down motion to the rod and crank at the rear of the cylinder-and to the valve operating rod and valve spindle. Oil all bearings.

THE IDENTICAL BELL CRANK LINKS. See my sketch for ONE side only and the position of the threaded pins that carry loose couplings holding both vertical rods for the cylinder and pump. There is a double crank between the flywheel and the engine plinth-and a single crank at the nearside.Both cranks have identical throws and work in unison-to rock the bell cranks through linkage.Strips of 9½" 7½" and 5½" are employed-plus flat trunnions and 1" cnr brkts-and two double arm cranks for the bearings at the rocking pivot. See the full size sketch of one frame and the position of threaded pins etc. Some strips are doubled in thickness for strength-but BOTH frames MUST be identical to work properly. As the model rotates-the two cranks on the main c/shaft rock the frames and thus raise and lower the vertical pivoted rods for the main cylinder and pump. The circ girder operates the valve-and counterweights even out the motion. You will need plenty of wheel discs for this model and need to select rods to fit properly. The photographs show most of the features I have described so far but CARE must be observed in the setting-up of the various components-especially the valve chest with it's handrail supports as sliding bearings. Parts must be selected to give smooth running and a drop.of oil will make all the difference when set in motion.Now study all the diagrams before finally connecting the motor drive.

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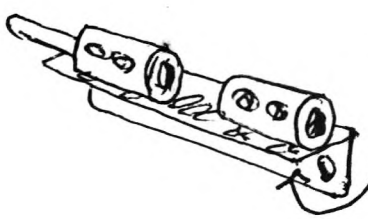
THE PISTON AND PUMP RODS.The main piston rod has a handrail coupling fixed at the top-and holds a transverse rod in a central position over the cylinder. This rod also has two more h/rail couplings-loose on the rod but retained by a collar at each end. Two long 11½" rods are fixed in the bosses of the h/rail couplings and with couplings fixed to the bottom end of the rods-in such a way as to allow their drilled portions to swivel on threaded pins fixed to the bottom bars of the bell-cranks.Repeat with the pump rod fixing-but use shorter side rods-the pump piston being a short rod to clear the top hat brackets in the boiler end attached to the plate. Note that the top lateral bell crank strip(9½") has a rod held by rod and strip connectors placed over it and held at each end by collars. The far end of the bell cranks also has a screwed rod across the engine-and held by threaded bosses on the threads of the threaded pins.This screwed rod holds the frame together. The bottom frame pivot on each side has a double arm crank over the flat trunnions -and with a rod passing under the engine through the slotted holes of the long angle girders-but with short strips bolted to the flanges to give bearing surface. This rod is seven holes along the girders from the far right end of the plinth.

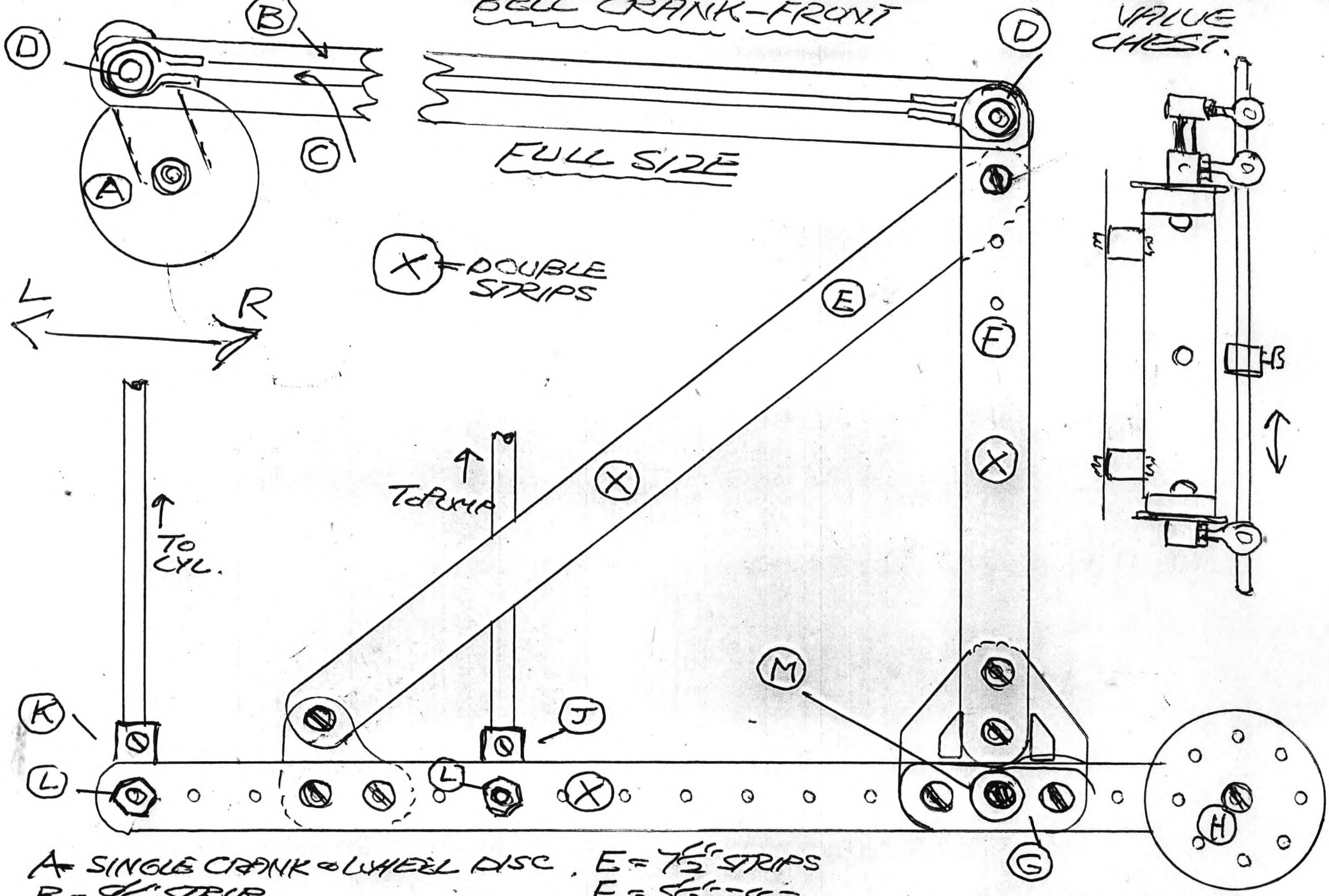
The frame operating cranks on the crankshaft are single arm cranks with wheel discs bolted to them as shown for effect only-the cranks have their slotted holes for the fixing of a threaded pin in the single crank at the nearside-but the two inner cranks are joined across by a long bolt held by nuts. This bolt has two spacing loose collars-and the 9½"strip runs between the collars to operate the frame. Small 1" bush wheels are fixed to two sides of the valve chest to represent the inlet and exhaust pipe joins-but must clear the valve rods.

This completes the engine apart from the motor employed. The wheel disc counterweights at the far end of the frame strips should have a long bolt to hold them in layers-you will need several to balance the engine for good operation. Now study the diagrams and sketches and check all movements before the motor is connected. Tooth mesh of the gear ring and pinion drive should be done with care-any binding will result in a poor display exhibit. Any queries-contact me please. FINIS.

Notes.

The top of the base plinth should be filled with either flat or flexible plates-leaving wells and flywheel slot clear. Use other girders under top for support as necessary. Use small washers under bolt heads to prevent scratching of parts-NOT Meccano-but small M4 type which are flat and smooth.Exacto have small circ plates for cyl top-or use semi-circ plates in their absence. Cyl and pump rods MUST move smoothly in their bosses-use oil. Flywheel needs to run true and the circ gdr is offset ONE hole only from centre. Use face plates for flywheel spoke attachment. The two Sector plates have their flanges INWARDS to allow the slotted strips to be attached to the plates-see sketch. Adjustments either upwards or sideways to line up with engine crankshaft.Use a double arm crank for the rod with the coarse ½"pinion-and adjust for good mesh with toothed ring. Both Wells and flywheel slot are edged with green strips-leaving 1½"clear width.





A = SINGLE CRANK & WHEEL DISC.
B = 9½" STRIP
C = ROD (ROD & STRIP CONNECTORS)
D = COLLARS
E = 7½" STRIPS
F = 5½" " "
G = P/A CRANK
H = WHEEL DISCS
J/K = COUPLINGS
L - THREADED PINS.
M = PIVOT ROD

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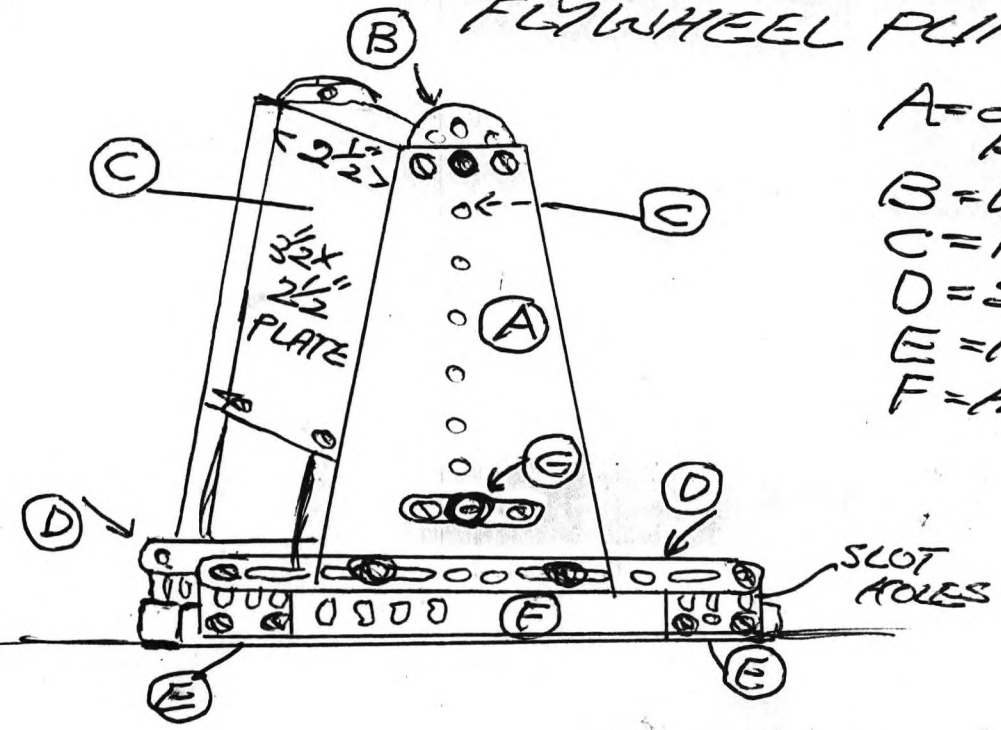
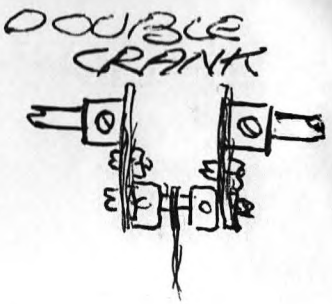
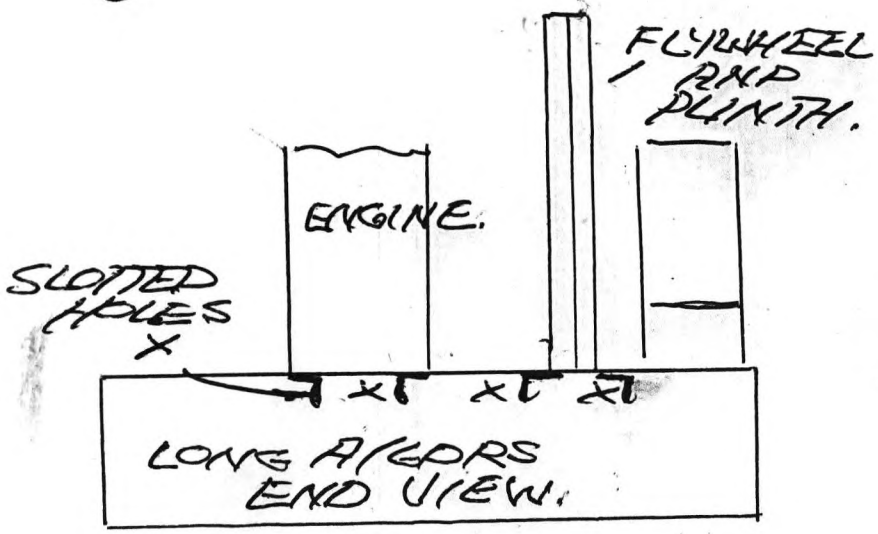
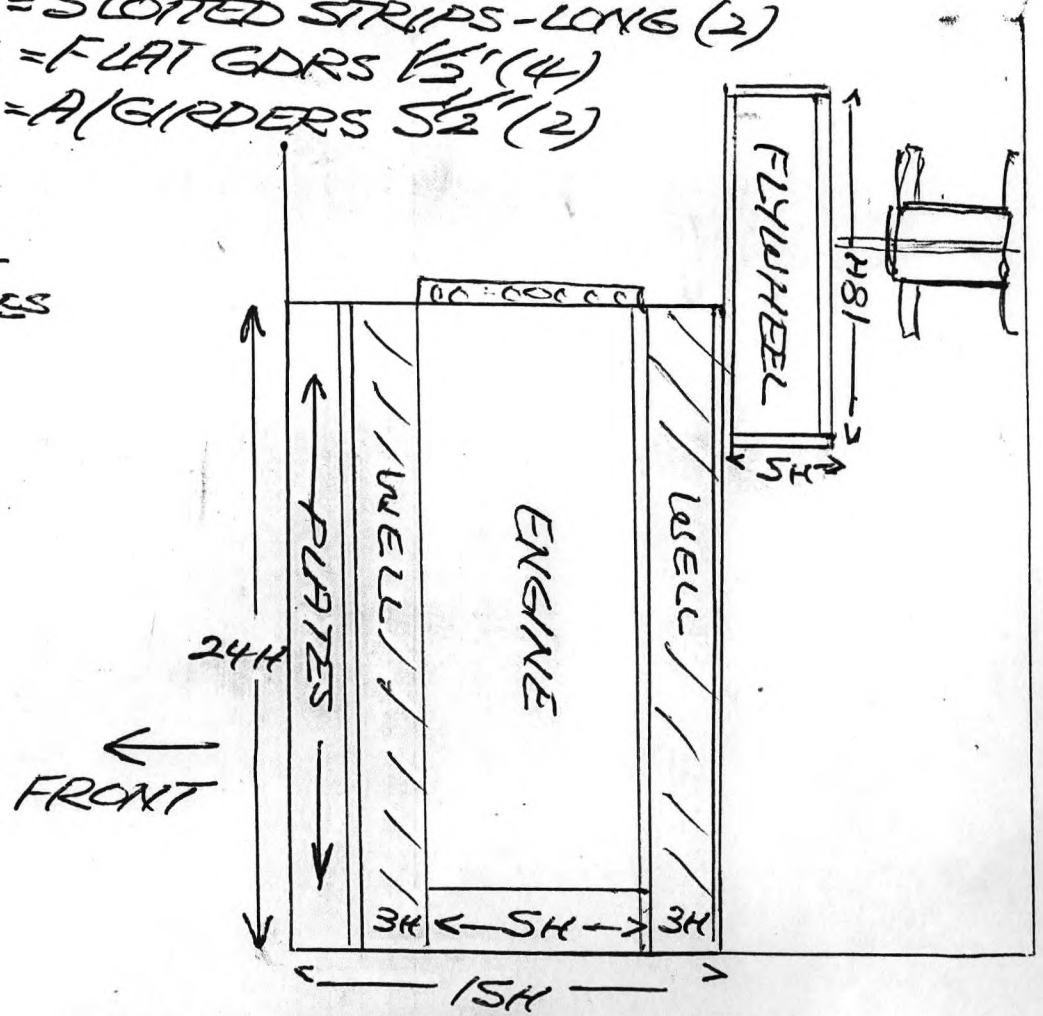
FLYWHEEL PLINTH.



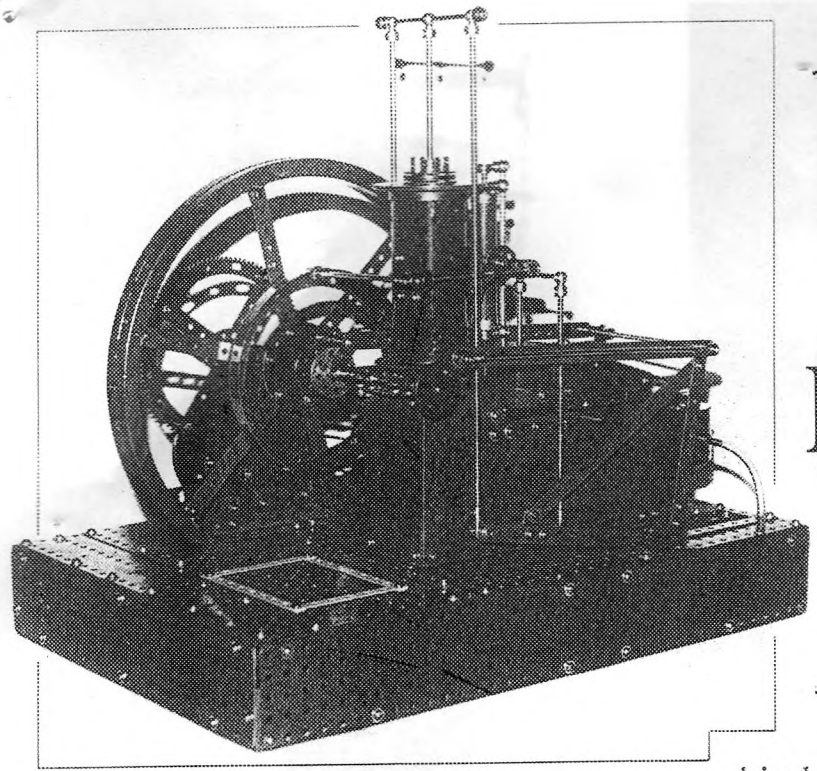
A = 2 SECTOR PLATES BOTH FLANGES IN.
B = WHEEL DISCS (2)
C = FLAT PLATE (2) 3½ × 2½
D = SLOTTED STRIPS - LONG (2)
E = FLAT GDRS ½" (4)
F = A/GIRDERS 5½" (2)







PLAN VIEW.



A Boulton & Watt Bell Crank Engine of 1802

by Brian Rowe

Fig.1 Bell-Crank Engine showing the front (left of picture) and right side (right of picture). One of the twin bell-cranks is conspicuous on the right side.

THE early days of steam produced a great variety of stationary engines in what appear to us as very strange designs. None looks stranger than the bell-crank engine, with its profusion of link work from the piston to the crankshaft and flywheel, and for good measure a quite extraordinary drive to the valve gear. However, all this makes it a good subject for an exhibition model.

For the orientation which will be used in this description please see the photograph and its caption. The plinth is 25 holes wide, 37 holes front to back, and 5 holes high. On top of this are two separate blocks; one for the vertical cylinder, valve gear etc.; and one for a shaft which carries the flywheel and at the extreme left a drive gear. This latter block, seen in the photograph through the flywheel, is made chiefly from two Flanged Sector Plates, bolted to the slotted holes of two Flat Girders. The slotted holes allow the flywheel shaft to be lined up accurately with the crankshaft on the other block. This block, set towards the rear and right of the plinth, is 5 holes wide, 16 holes front to back, and 9 holes high. On either side of this block the plinth has wells 2 holes wide for the bell-cranks, and a further well 3 holes wide is needed for the flywheel. The crankshaft, with cranks of 2" throw at each end, is mounted just in front of the base of the vertical cylinder. The photograph gives a good view of one bell-crank, with a large triangular brace, on the right side. Its upright limb has a long horizontal connecting rod to the crankshaft, while its horizontal limb has an even longer vertical connecting rod to a bar across the top of the piston rod. The horizontal limb also extends back to a counterweight which in the position shown is hidden in the right well. All of the bell-crank and double connecting rod work is duplicated on the left side of the cylinder and its mounting block, and the top rear corners of the bell-cranks are joined across. This mounting block contains a cooling tank and an exhaust pump, worked from upright connecting rods 7 holes back from those to the piston.

The valve chest is immediately behind the cylinder. A vertical rod within it is joined top and bottom to an external vertical rod behind it, which is driven as follows. Bearings half way up the cylinder support a rod which passes from front to back. The rear end of this has a rod which is linked to the external rod of the valve gear. The front end has a rod, situated vertically above the crankshaft, which has at its left end an End Bearing, slightly opened, which embraces a Circular Girder bolted eccentrically to the flywheel. The drive gear shown in the photograph is not a Meccano one; but a step down drive from a quiet mains motor, to produce an impressively slow action, can easily be devised in Meccano parts.

The data for the construction of this model have been taken from an article in "Engineering in Miniature" July 1993, pages 38 - 41. This includes several line drawings of the original*, which was designed by the manager of Boulton & Watt's Soho Foundry and William Murdoch. It was in production from 1802 to 1806, with variations in detail and size. The one copied had a flywheel 7ft 4ins diameter and was rated at 4hp. A larger version still exists in the Science Museum, South Kensington. The purpose of the design was to have an engine which could be erected in an existing factory, requiring much less floor area than a horizontal engine, but slightly more headroom. The plinth and blocks on it would be built from local materials, and only the essential metal parts would be sent from Soho for assembly on site by Boulton & Watt's engineer. A separate boiler would, of course, be needed. When the Meccano version is running it can be viewed as just a fascinating piece of machinery, or historically as one among many steps in the nineteenth century development of the steam engine.

*Alan Partridge is keeping the set of drawings Brian sent us - Ed.