TWO SIMPLE CNC FEATURES

Vol. 216 No. 4536 • 10 - 23 June 2016

MODEL ENGINEER

Join our online community www.model-engineer.co.uk

COVER FEATURE

Making Skew Gears

Colour Light Signals

The Doncaster Show: First Report

mytimemedia ENGINEERING GROUP
£3.80

THE ORIGINAL MAGAZINE FOR MODEL ENGINEERS

NEWTON TESLA

SMOOTH, QUIET, HIGH PERFORMANCE VARIABLE SPEED CONTROL FOR YOUR LATHE OR MILL

Supplier to industry since 1987 of high power speed control systems from 100W to 2,200,000W,

MITSUBISHI D700

MITSUBISHI ELECTRIC HIGH PERFORMANCE INVERTERS

For serious machining duty!

240-volt 1-phase input Inverters for you to run a dual-voltage (Delta wired) three phase motor off your domestic 1-phase supply. Six sizes from 0.1kW(0.12hp) to 2.2kW(3hp). CNC COMPATIBLE.

Built-in user keypad, frequency display & Digital Speed Dial. Unique Emergency Stop Function.

Advanced Torque Vector control for optimum performance. High Reliability & Long design life. Fully CE/UL Marked and RoSH Compliant.

Compatible with our Remote Control stations, and can be supplied pre-programmed at no extra cost.

Prices from £133 inc VAT

MITSUBISHI ELECTRIC

INVERTER REMOTE PENDANTS

Remote control station Pendants suitable for use with all our Mitsubishi Electric, IMO Jaguar CUB and iDRIVE Inverters. Also available for other makes and models of VSD including TECO, OMRON & ABB.

Industrial grade push buttons;

Featuring START & STOP Pushbuttons, FWD & REVERSE, RUN, JOG, & VARIABLE SPEED POTENTIOMETER.

3-wire control, NVR (No-Volt-Release) function for greater safety. Beware of low quality copies of our original tried and tested controls. Fitted with 2-metre control cable and supplied with wiring diagram and programming instructions to suit your make and model of Inverter drive.

From £67 inc VAT

IMO iDrive2 INVERTERS

new

2-YEAR WARRANTY

230V 1-phase input, 220V 3-phase output, for you to run a dual voltage three phase motor off domestic single phase supply. Four models: 0.4kW (0.5hp) up to 2.2kW (3hp). Built-in programming keypad display & Digital Speed Dial. Low-cost Inverter drive with simplified torque vector control. CE Marked.

Compatible with our Remote Control stations, and can be supplied pre-programmed at no extra cost.

Prices from £127 inc VAT

JAGUAR CUB INVERTERS

IMO "Jaguar CUB" High Performance Inverters

5-Year Warranty

230V 1-phase input, 220V 3-phase output, to run a dual voltage three phase motor off domestic single phase supply. Four models: 0.4kW up to 2.2kW (3hp). Built-in programming keypad display and Digital Speed Dial. Advanced torque vector control for optimum motor performance at low speeds. **From £174 inc VAT**

PRE-WIRED INVERTER & MOTOR PACKAGES

The original and best lathe speed control system, suitable for MYFORD ML7, Super 7, RAGLAN Little John, & BOXFORD lathes. *Pre-wired ready to go!*

NOW WITH AN AMAZING 10-YEAR WARRANTY!

Power Range: 1/2hp, 1.0hp, 2.0hp and 3.0hp.

Smooth control across entire speed range, giving chatter free machining, and an excellent finish that is unattainable with single phase motors!

Quiet, vibration free operation. Fully EMC Compliant.

High torque even down to the lowest speed.

Powered from domestic 240V AC single phase mains.

Complete electronic motor protection. Featuring START & STOP, FWD & REV, RUN & JOG, and VARIABLE SPEED. Simplifies screw-cutting and tapping.

Designed & Manufactured here in the UK by Newton Tesla.

ISO9001/2008 Quality Assured.

Prices start from £359 + vat, UK Delivery is £18.

Full terms & conditions on Extended Warranty are available on our website.

METRIC MOTORS

We stock a large range of 240V Single Phase and 220V/415V Dual Voltage Three Phase motors in standard Metric sizes. Foot, Flange & Face mounting options. 4-pole (1450revs), 2-pole (2800revs) and 6-pole also available.

We have extensive knowledge regarding which motor frame sizes go on which machine, and will match the correct specification of motor for you.

IMPERIAL MOTORS

240V Single Phase and 220/415V 3PH "Dual Voltage" motors in standard imperial B56 frame sizes to suit Myford, Boxford and Raglan lathes. Foot, Flange & Resilient mounting versions available in a range of sizes from 0.33HP to 1.0HP.

PAYMENT ACCEPTED BY ALL LEADING CREDIT / DEBIT CARDS AND PAYPAL.

NO SURCHARGE FOR CREDIT / DEBIT CARDS. **TECHNICAL SUPPORT AVAILABLE 7-DAYS A WEEK**

CALL OUR SALES TEAM NOW ON 01925 444773 **www.lathespeedcontrol.com**

INVERTER, MOTOR & REMOTE PACKAGES

IMPERIAL & METRIC MOTOR PACKAGES, Comprising a Mitsubishi Electric D720S High Performance Vector Drive, new 3PH motor, and Remote Control Station. The Inverter drives are supplied ready pre-programmed and "auto-tuned" to the matched motor for optimum performance. Foot, Flange or Face mounting options. 4-pole (1450revs), 2-pole (2800revs) and 6-pole also available. Packages ranging from 1/8HP to 3.0HP. Prices from £208.

Newton Tesla (Electric Drives) Ltd,
Warrington Business Park, Long Lane, Warrington,
Cheshire WA2 8TX, Tel: 01925 444773, Fax: 01925 241477
E-mail: info@newton-tesla.com

Visit our new online webshop at www.newton-tesla.co.uk

systems *specialist*

Find us on Facebook

VISA MasterCard

MODEL ENGINEER

Published by **MyTimeMedia Ltd.**
Enterprise House, Enterprise Way,
Edenbridge, Kent TN8 6HF
+44 (0)1689 869840
www.model-engineer.co.uk

SUBSCRIPTIONS
UK - New, Renewals & Enquiries
Tel: 0344 243 9023
Email: help@me.secureorder.co.uk
USA & CANADA - New, Renewals & Enquiries
Tel: (001)-866-647-9191
REST OF WORLD - New, Renewals & Enquiries
Tel: +44 1604 828 748
Email: help@me.secureorder.co.uk

CURRENT AND BACK ISSUES
Tel: 01733 688964
Website: www.mags-uk.com

MODEL ENGINEERING PLANS
Contact: www.myhobbystore.co.uk/contact
Website: www.myhobbystore.co.uk/me-plans

EDITORIAL
Editor: Diane Carney
Tel: +44 (0)1539 564750
Email: diane.carney@mytimemedia.com
Tehnical Assistant: Stewart Hart

PRODUCTION
Designer: Yvette Green
Illustrator: Grahame Chambers
Retouching Manager: Brian Vickers
Ad Production: Robin Gray

ADVERTISING
Senior Account Manager: Duncan Armstrong
Email: duncan.armstrong@mytimemedia.com
Tel: 01634 238893

MARKETING & SUBSCRIPTIONS
Subscription Manager:
Kate Hall

MANAGEMENT
Publisher: Julie Miller
Group Advertising Manager: Rhona Bolger
Email: rhona.bolger@mytimemedia.com
Chief Executive: Owen Davies
Chairman: Peter Harkness

mytimemedia
print & digital media publishers

Model Engineer, ISSN 0026-7325, is published fortnightly with a third issue in May and October by MYTIMEMEDIA Ltd, Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF, UK. The US annual subscription price is 93.00GBP (equivalent to approximately 132USD). Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Periodicals postage paid at Jamaica NY 11431. US Postmaster: Send address changes to Model Engineer, Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Subscription records are maintained at dsb.net 3 Queensbridge, The Lakes, Northampton, NN4 7BF. Air Business Ltd is acting as our mailing agent.

http://www.facebook.com/modelengineersworkshop

http://twitter.com/modelengineers

IN THIS ISSUE

Vol. 216 No. 4536 10 - 23 June 2016

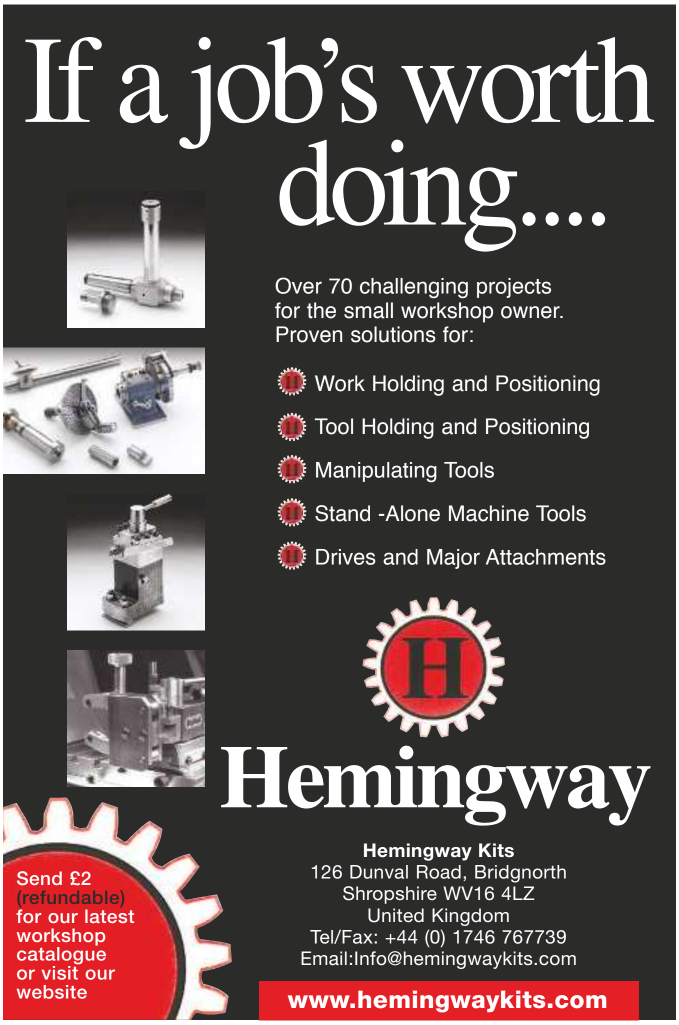
ON THE COVER…

Roderick Jenkins has a different approach to making skew gears for his E. T. Westbury Wyvern. Read his description on page 854. (Photo, Roderick Jenkins.)


metalcraft™
Hand powered metalforming tools
Handy for so many jobs
Punching
Cutting
Riveting
Bending
Rolling
Scrolling
Twisting
Also suppliers of a wide range of steel, fixings, clock components & much more.
Call today for your free catalogue and if you quote our promo code* MMENGW16, we will send you our demonstration DVD free of charge.
J & C R Wood Ltd, Dept MMENGW16, 66 Clough Road, HULL HU5 1SR
Tel: 01482 345067 Email: info@jandcrwood.co.uk
OR Visit our on-line store at
www.metal-craft.co.uk


POLLY MODEL ENGINEERING LIMITED
Incorporating BRUCE ENGINEERING
For all your model engineering requirements:
5" gauge Kit-build Live Steam Locos:
For the beginner or the serious club user! Range of 8 different models, tank locos, tender locos, main line outline and narrow gauge. All fully machined and designed for the inexperienced. Kit Loco Catalogue available £3 posted or visit webpage.
Stationary Engine designs and kits:
We supply a wide range of models including many designs by Anthony Mount based on historic engines. We also stock the famous Stuart Models which include models suited to beginners through to some serious power plants. The simpler engines can be the ideal introductory project in model engineering with books available detailing their construction. Details in our catalogue or visit the webpage.
Fine Scale Miniature Loco Designs:
For the serious model engineer, we supply a range of designs, castings and parts to facilitate construction of some very fine scale models in all the popular gauges. We are renowned for the quality of our GWR locomotive parts and our scale model tender kits. 'Practical Scale' models are now included in our main catalogue.
Model Engineers' Supplies:
Comprehensive range steam fittings, fasteners, consumables, materials, books, accessories, etc. Large stocks mean your order can be quickly despatched. New Combined Catalogue available £2 posted or download from the webpage. Whatever your requirements telephone or email.
Polly Model Engineering Limited
Atlas Mills, Birchwood Avenue, Long Eaton
NOTTINGHAM, ENGLAND, NG10 3ND
Tel: +44 115 9736700 Fax: +44 115 9727251 email: sales@pollymodelengineering.co.uk
www.pollymodelengineering.co.uk


MAXITRAK.COM
3/4" Allchin Now With Working Crane & Showman Conversion Kits!
From £1445
MAXITRAK AMUSEMENTS ON TOUR, STAPLEHURST, KENT
Finance now available!
Catalogue £3.50
7 1/4" Ruston 2
From £1640
Maidstone Engineering Supplies
A complete range of materials
B.M.S. Brass. Phos Bronze. Copper. St/Steel. Nuts &Bolts. Nylon. St/Tube. Screws.Studding. Rivets. Drills. Reamers. etc
PROMPT MAIL ORDER
TEL 01580 890066
NEW Copper Welded Boilers
ONLINE SHOP
MAIDSTONE-ENGINEERING.COM
MAXITRAK/M.E.S 10 Larkstore Park Lodge Road Staplehurst Kent TN12 0QY Tel : 01580 893030 Email : info@maxitrak.com


If a job's worth doing....
Over 70 challenging projects for the small workshop owner. Proven solutions for:
Work Holding and Positioning
Tool Holding and Positioning
Manipulating Tools
Stand -Alone Machine Tools
Drives and Major Attachments
Hemingway
Send £2 (refundable) for our latest workshop catalogue or visit our website
Hemingway Kits
126 Dunval Road, Bridgnorth
Shropshire WV16 4LZ
United Kingdom
Tel/Fax: +44 (0) 1746 767739
Email:Info@hemingwaykits.com
www.hemingwaykits.com

SPECIAL OFFER
WHILE STOCKS LAST

VMC TURRET MILLING MACHINE

Illustrated with optional power feeds, DRO and wide tray

Table size:	660x152mm
Longitudinal traverse:	370mm
Cross traverse:	152mm
Distance spindle to table:	345mm
Motor	1125w
Stand included	

£1,640
including VAT and UK mainland delivery by carrier

Special offer includes:
- 80mm swivel base milling vice
- 5 piece end mill set
- Set of 4 collets

- Available in metric or imperial, 3MT or R8 spindle
- Single phase

OPTIONAL ACCESSORIES FOR THE VMC:

BSO dividing head £285

HV6 rotary table £129

3 jaw chuck for the HV6 £95

Clamping kit £40

ER25 collet chuck set £100

Coolant system £160

Align power feed 110 volt, supplied with 240 volt transformer.
Left and right feed cut out switch with adjustable traverse stops.
Infinitely variable speed control with additional rapid approach switch.

Special offer price when purchased with VMC £300

Digital readout for customer fitting:

2 axis with scales and brackets: £275

3 axis with scales and brackets: £394

Brackets supplied need to be modified by the customer. Generic fitting instructions included.

Come and visit us at our
SUMMER OPEN DAY
13th August 9 am to 1 pm

Good selection of used and ex demo machines and used tooling at bargain prices.

Special offers on new machines and take away prices for new tooling. On site catering.
Free admission and plenty of free parking

T: 01428 682929 Warco House, Fisher Lane, Chiddingfold, Surrey GU8 4TD
E: sales@warco.co.uk W: www.warco.co.uk

gandmtools

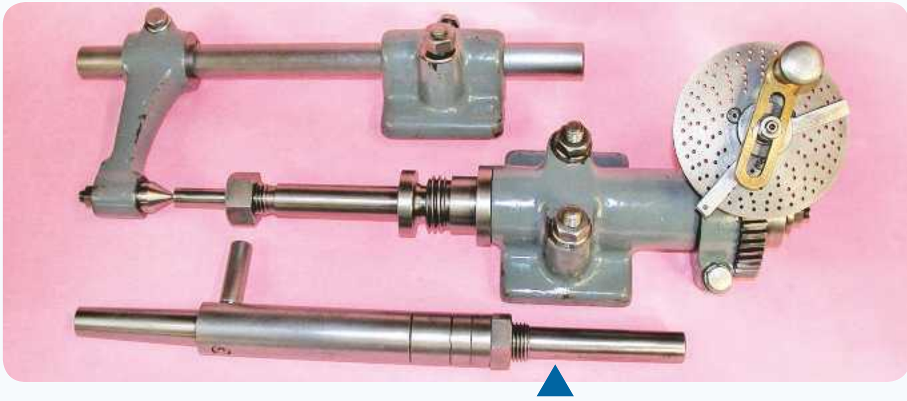
Just a small selection from our current stock

Buy online now at: www.gandmtools.co.uk

Boxford CUD 4½" x 18" Lathe, Tooled, 3ph, **£750.00** plus vat.

Boxford AUD 5" x 18" Lathe, Well Tooled, 3ph, **£1050.00** plus vat.

Sweeney & Blocksidge No 1 Flypress, VGC, **£110.00** plus vat.



Harrison Lathes Dividing Head, VGC, Arbors & Tailstock, **£475.00** plus vat.

Roland Camm Modela MDX-20 CNC Engraver, 1ph, **£625.00** plus vat.

Flamefast CM350 Tilting Type Crucible Furnace, Unused, **£650.00** plus vat.

Colchester Bantam 1600 Lathe, Well Tooled Inc. Collet Chuck etc, 3ph, **£1850.00** plus vat.

Marlow Vertical Millling Machine, 3 MT, Vice, Collet Chuck, 3ph, **£925.00** plus vat

Clarke Model 25 Single Shot Injection Moulding Machine, 1ph, **£425.00** plus vat.

• Telephone enquiries welcome on any item of stock. • We hold thousands of items not listed above. • All items are subject to availability. • All prices are subject to carriage and VAT @ 20%. • We can deliver to all parts of the UK and deliver worldwide. • Over 7,000 square feet of tools, machines and workshop equipment.

Opening times: 9am -1pm & 2pm – 5pm Monday to Friday. Closed Saturdays, except by appointment.

tel: 01903 892510 • **www.gandmtools.co.uk** • e-mail: sales@gandmtools.co.uk

G and M Tools, The Mill, Mill Lane Ashington, West Sussex RH20 3BX

MODEL ENGINEER SUBSCRIPTION ORDER FORM

DIRECT DEBIT SUBSCRIPTIONS (UK ONLY)

Yes, I would like to subscribe to *Model Engineer*

☐ Print + Digital: £73.00 per year
☐ Print Subscription: £61.00 per year

YOUR DETAILS MUST BE COMPLETED

Mr/Mrs/Miss/Ms...................Initial ....Surname ....
Address ....
....
Postcode .... Country ....
Tel .... Mobile......................................
Email .... D.O.B ....

I WOULD LIKE TO SEND A GIFT TO:

Mr/Mrs/Miss/Ms...................Initial ....Surname ....
Address ....
....
Postcode .... Country ....

INSTRUCTIONS TO YOUR BANK/BUILDING SOCIETY

Originator's reference 422562 — Direct Debit
Name of bank...
Address of bank ....
....
....Postcode ....
Account holder ....
Signature.. Date ....

Sort code ☐☐ ☐☐ ☐☐ Account number ☐☐☐☐☐☐☐☐

Instructions to your bank or building society: Please pay MyTimeMedia Ltd. Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with MyTimeMedia Ltd and if so, details will be passed electronically to my bank/building society.

Reference Number (official use only) ☐☐☐☐☐☐☐☐☐

Please note that banks and building societies may not accept Direct Debit instructions from some types of account.

CARD PAYMENTS & OVERSEAS

Yes, I would like to subscribe to *Model Engineer, for 1 year* (26 issues) with a one-off payment

UK ONLY:
☐ Print + Digital: £78.00
☐ Print: £66.00

EUROPE & ROW:
☐ EU Print + Digital: £105.00
☐ EU Print: £93.00
☐ ROW Print + Digital: £105.00
☐ ROW Print: £93.00

PAYMENT DETAILS

☐ Postal Order/Cheque ☐ Visa/MasterCard ☐ Maestro
Please make cheques payable to MyTimeMedia Ltd and write code V919 on the back
Cardholder's name...
Card no: (Maestro)
Valid from.............................. Expiry date................... Maestro issue no...................
Signature... Date...........................

TERMS & CONDITIONS: Offer ends 24th June 2016. MyTimeMedia Ltd & Model Engineer may contact you with information about our other products and services. If you DO NOT wish to be contacted by MyTimeMedia Ltd & Model Engineer please tick here: ❑ Email ❑ Post ❑ Phone. If you DO NOT wish to be contacted by carefully chosen 3rd parties, please tick here: ❑ Post ❑ Phone. If you wish to be contacted by email by carefully chosen 3rd parties, please tick here: ❑ Email

POST THIS FORM TO:
MODEL ENGINEER SUBSCRIPTIONS, MYTIMEMEDIA LTD, 3 QUEENSBRIDGE, THE LAKES, NORTHAMPTON NN4 7BF

Please visit **www.mytimemedia.co.uk/terms** for full terms & conditions

CODE V919

HURRY OFFER CLOSES 24th JUNE 2016

PRINT + DIGITAL SUBSCRIPTION

- ***Free*** Wixey Digital Angle Gauge*
- 26 Issues ***delivered to your door***
- ***Great Savings*** on the shop price
- ***Download*** each new issue to your device
- A ***75% discount*** on your Digital Subscription
- Access your subscription on ***multiple devices***
- Access to the ***Online Archive*** dating back to August 2001

PRINT SUBSCRIPTION

- ***Free*** Wixey Digital Angle Gauge*
- 26 Issues ***delivered to your door***
- ***Great Savings*** on the shop price

SUBSCRIBE TODAY

SMOKE RINGS

New Trade Series band saw from Axminster

A new metal cutting benchtop band saw with many unique features has been designed by Axminster Tools & Machinery and is well suited to the model engineer's workshop. The one piece frame is made from heavy gauge, welded steel and is extremely rigid to withstand high blade tensions. A cast iron deep section table is fitted, featuring a ground table surface and a rack and pinion tilt mechanism with indexing stops for common angles. The heavy gauge alloy rip fence is mounted on a cast alloy bracket which also incorporates a fine width adjustment. The fence is clamped with a cam action lever, which is easily released to allow swift adjustment.

Blade guides are all ball bearing with micro adjustment for accurate control. The top guide is mounted on a steel hexagon bar for stiffness and adjusted for height by a small rack and pinion system. Cast iron band wheels, well machined and balanced, are driven by a multi Vee belt with a choice of two ratios. The BS11-INV features a 750W induction motor with an inverter drive to control the motor speed. This band saw is suitable for cutting all types of metals. The price is currently £1124.96 inc. vat. **www.axminster.co.uk**

Model Railway Centre for Ashford Works

Part of the former railway works of the London & South Eastern Railway at Ashford has been promised a new lease of life after a group of model railway enthusiasts – collectively The Ashford International Model Railway Education Centre (AIMREC) – secured the support of Ashford Borough Council in the form of funding to enable the purchase of the land on which they hope to build a model railway centre that will rival the National Railway Museum. The new centre will be built on the historic Klondyke railway works site, a short walk from the town's international station with its HS1 fast links to London and Eurostar services to Continental Europe. Enthusiasts want to raise £4 million to build a 30,000 square foot facility that will include an exhibition and display area, lecture and demonstration theatre, specialist model shop and first-floor cafeteria overlooking Ashford railway works. AIMREC will showcase Ashford's illustrious heritage as a driving force in railway development; it will also promote this heritage to an international audience and chart the fascinating development of railways. Ashford has a proud historical association with both the earliest and contemporary development of rail services. Its connection with the railway can be traced back to the late 1830s, a time when the railway concept was in its infancy, all of which makes it an ideal place for what could potentially become the UK's leading model railway centre. **www.aimrec.co.uk**

Doug Hewson Models go to The Steam Workshop

Whilst at the Doncaster exhibition I learned that Doug Hewson has sold his locomotive designs and component supply business to Simon Hudson of The Steam Workshop. Doug will retain an interest in the business and will continue to provide design work and draughtsman services.

The Steam Workshop is a family concern based in Chester; their business is chiefly in the restoration and refurbishment of old and not-so-old but 'tired' model locomotives and road steam engines and in preparing them for resale. As well as offering mechanical restoration they also concentrate on finishing engines to a high standard. In this they are rather talented, judging by the condition they had achieved with their exhibition models on display at the show. They also provide a painting and lining service and restore model boats as well as steam engines. Sitting proudly along the wall of their stand was a 5 inch gauge Union Pacific 'Big Boy' which, as well as attracting a huge amount of attention - naturally - served to demonstrate their abilities in 'weathering'. This locomotive (which will feature in the next issue of *Model Engineer*) looked as though it had just come off six continuous week's work in the wild west! (**www.steamworkshop.co.uk**).

Doug Hewson can still be contacted by email on **doug@the-hewsons.co.uk** or by telephone: 01652 688408.

The Doncaster Show

In this issue I bring you a first report from the National Model Engineering and Modelling Show which, this year, took place at a new venue at Doncaster Racecourse. I think it has proved an ideal choice for the organisers, offering plenty of space both indoors and out, easy access for exhibitors bringing in models and some basic provision for those wishing to stay on site. The only minor criticism I heard was that the car parking space (of which there is ample) was a little disorganised but I doubt this is an insurmountable problem. How many model engineers are there within, say, a 50 mile radius of Doncaster? Quite a lot and, without doubt, a lot of competition standard models. I would urge you to consider doing what you can to boost the numbers of competitive entries for next year. I fear those judges got off rather lightly this year! Let's make sure they really earn their lunch in future!

MEET THE EDITORIAL TEAM

DIANE CARNEY
Editor

STEWART HART
Technical Assistant

YVETTE GREEN
Designer

SEE THIS AT THE MODEL ENGINEER MEX EXHIBITION

Saunderson & Mills Tractor Engine

PART 2

In *Model Engineer*, issue 4511 (26 June 2015) I began my description of the building of the chassis of this unusual tractor. Now I shall describe the engine. The engine is the heart of this tractor and is the most complicated part to design and make. This article and the accompanying drawings describe how I did it.

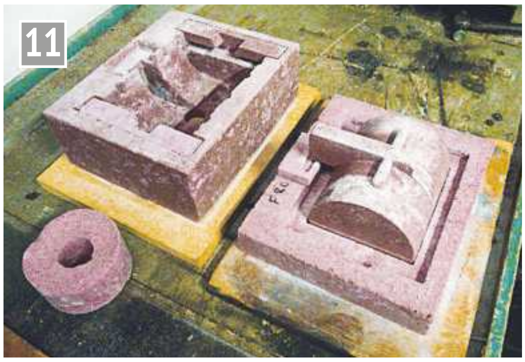
George Punter makes the engine for his 1913 agricultural tractor.

Continued from p.717
M.E. 4534, 13 May 2016

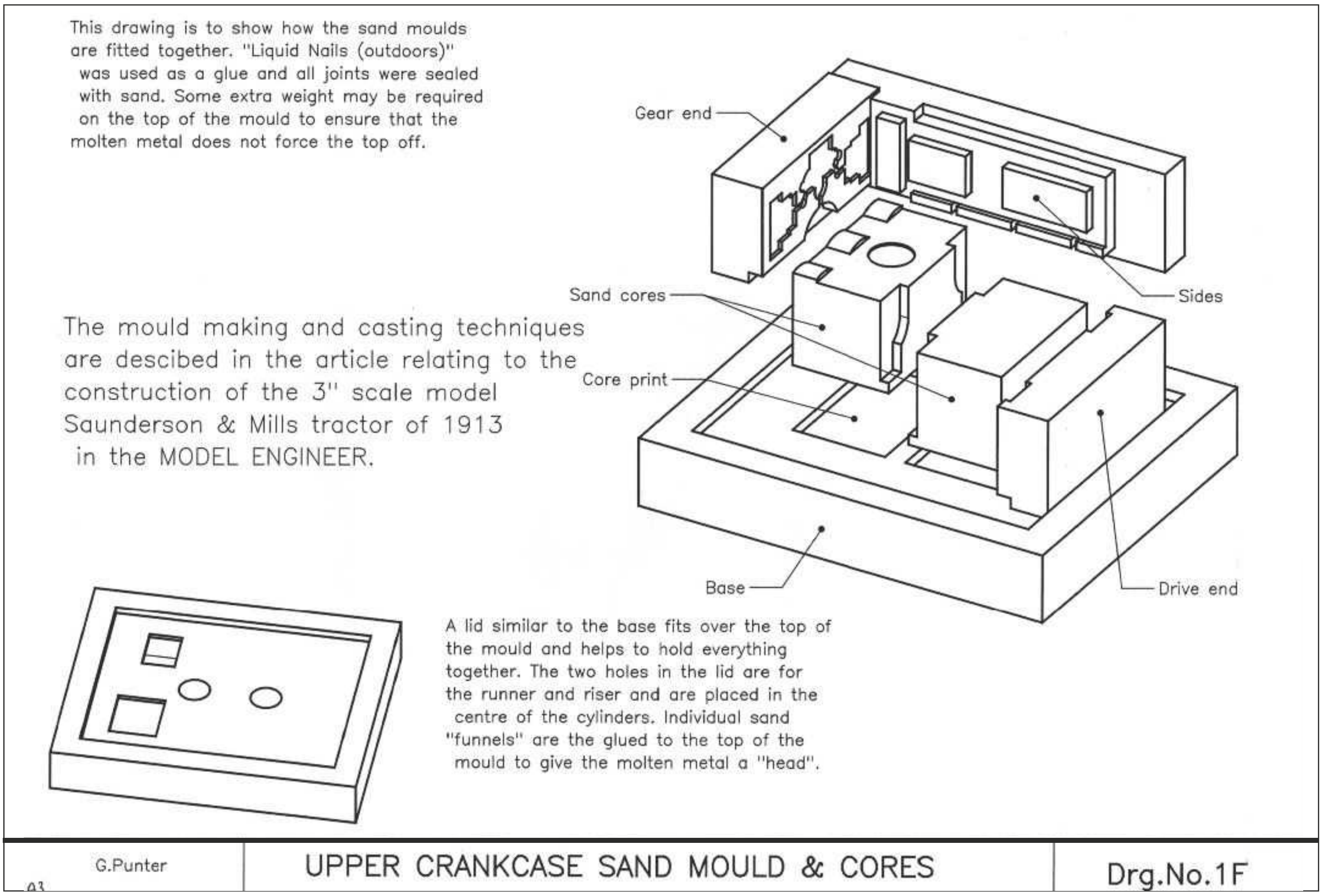
Continuing from my initial description, in *M.E.* 4534, of the making of patterns for the crankcase, the first three drawings this time describe sand moulds and cores. We then have the drawings of the lower crankcase.

The lower part of the crankcase (**drawings 2A** to **2D** and **photos 10** and **11**) has the sump cast in and this part projects to the front of the

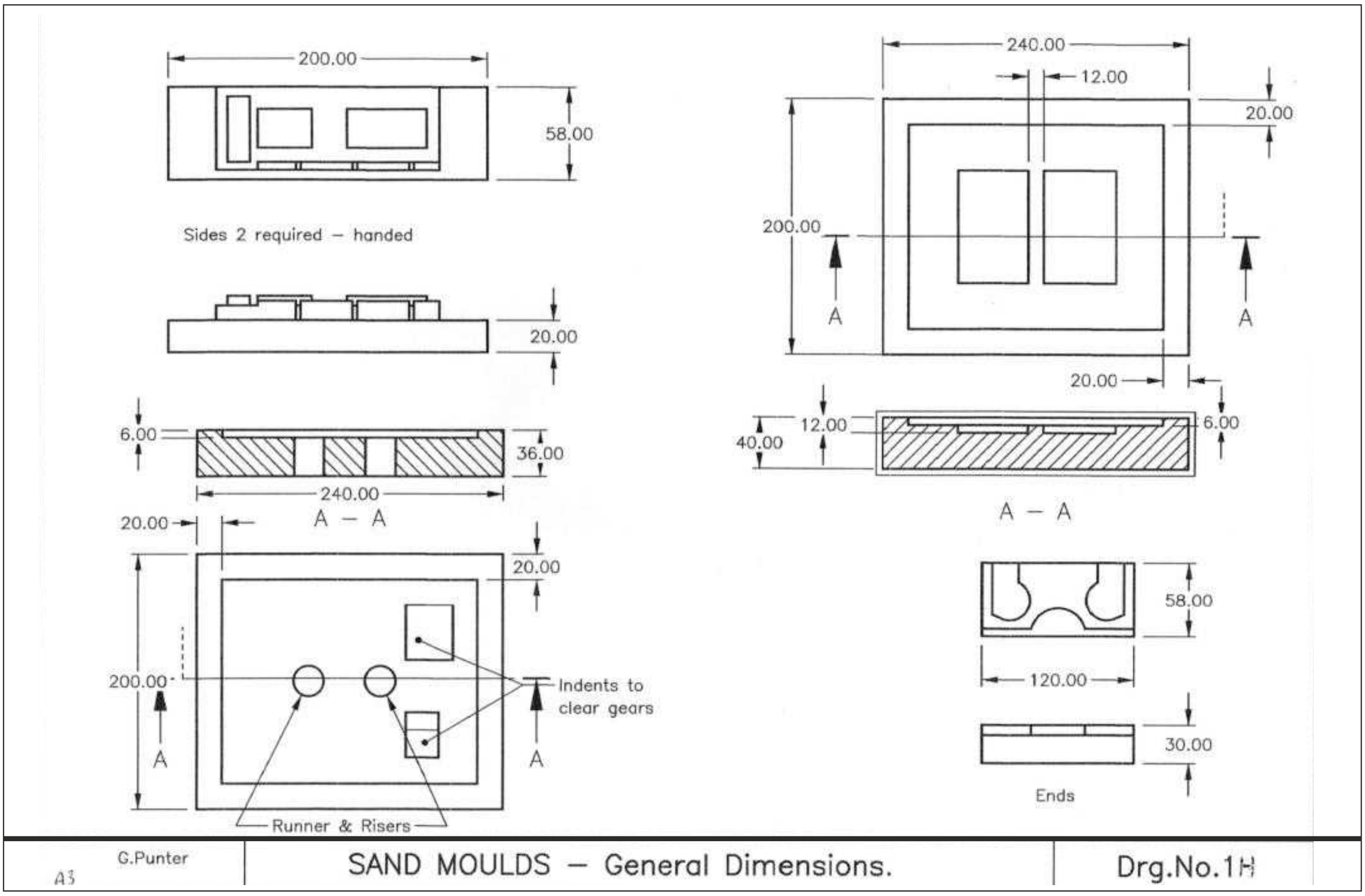
All the sump parts.

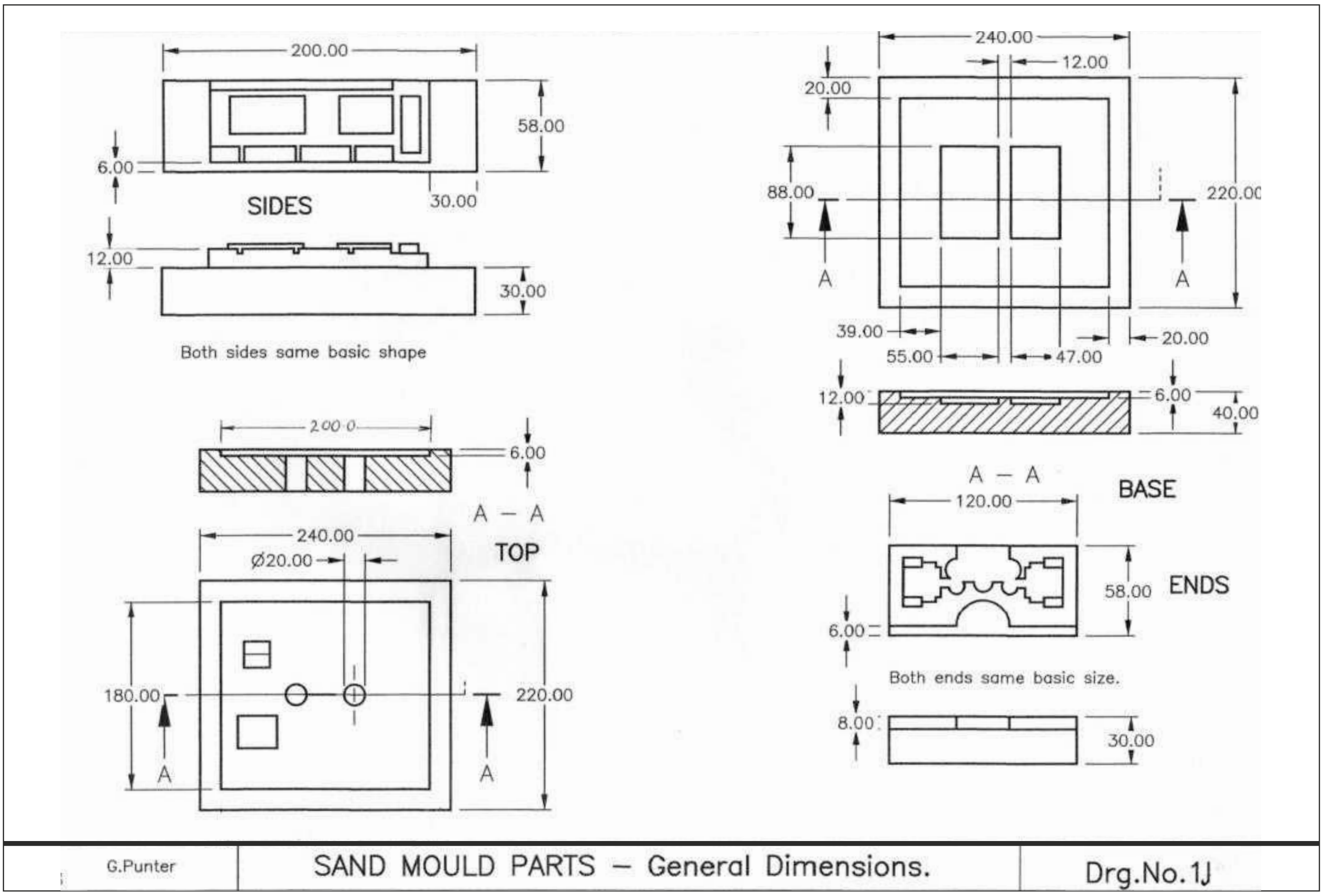


The sump core and mould.



>>

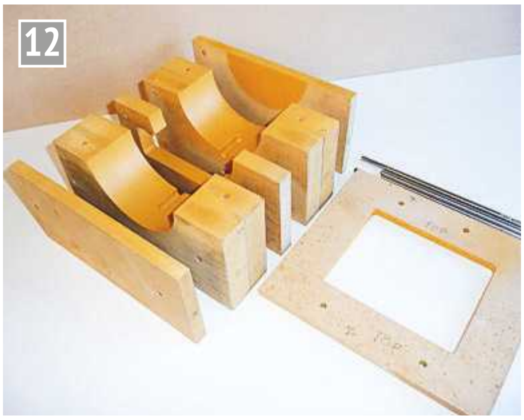

200.00
58.00
Sides 2 required – handed
20.00
6.00
36.00
240.00
A – A
20.00
20.00
200.00
A
A
Indents to clear gears
Runner & Risers
240.00
12.00
20.00
200.00
A
A
20.00
12.00
40.00
6.00
A – A
58.00
120.00
30.00
Ends
G.Punter
A3
SAND MOULDS – General Dimensions.
Drg.No.1H


200.00
58.00
6.00
SIDES
30.00
12.00
30.00
Both sides same basic shape
200.0
6.00
A – A
TOP
240.00
Ø20.00
180.00
220.00
A
A
240.00
12.00
20.00
88.00
220.00
A
A
39.00
55.00
47.00
20.00
12.00
6.00
40.00
A – A
BASE
120.00
58.00
ENDS
6.00
Both ends same basic size.
8.00
30.00
G.Punter
SAND MOULD PARTS – General Dimensions.
Drg.No.1J

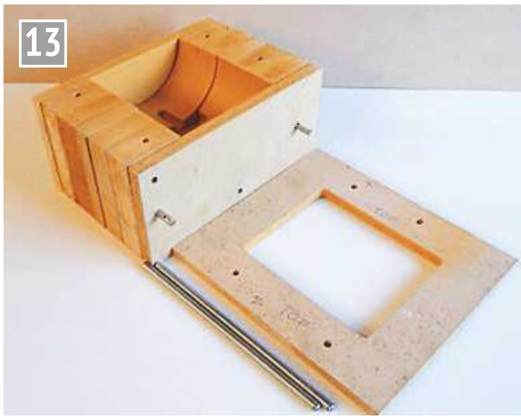
engine as it has a built in oil level float system that indicates to the driver when the oil level is low. This would then prompt some quick action from the driver to check the oil level in the external tank housed in the wooden box!

The external pattern is conventional (photo 10) but the core box for this part is made in many pieces to enable the sand shape to be removed (**photos 12**, **13**, **14** and **15**). The photographs will help to explain the situation. The lower casting was then made (**photo 16**), cleaned up and the top face machined flat ready to accept the top engine casting. The engine mounting points, which take the form of an angle, were also machined. This half of the crankcase weighs 1.2Kg. I use good quality aluminium when casting, this coming from old Briggs and Stratton engines, motorcycle and car parts.

●To be continued.



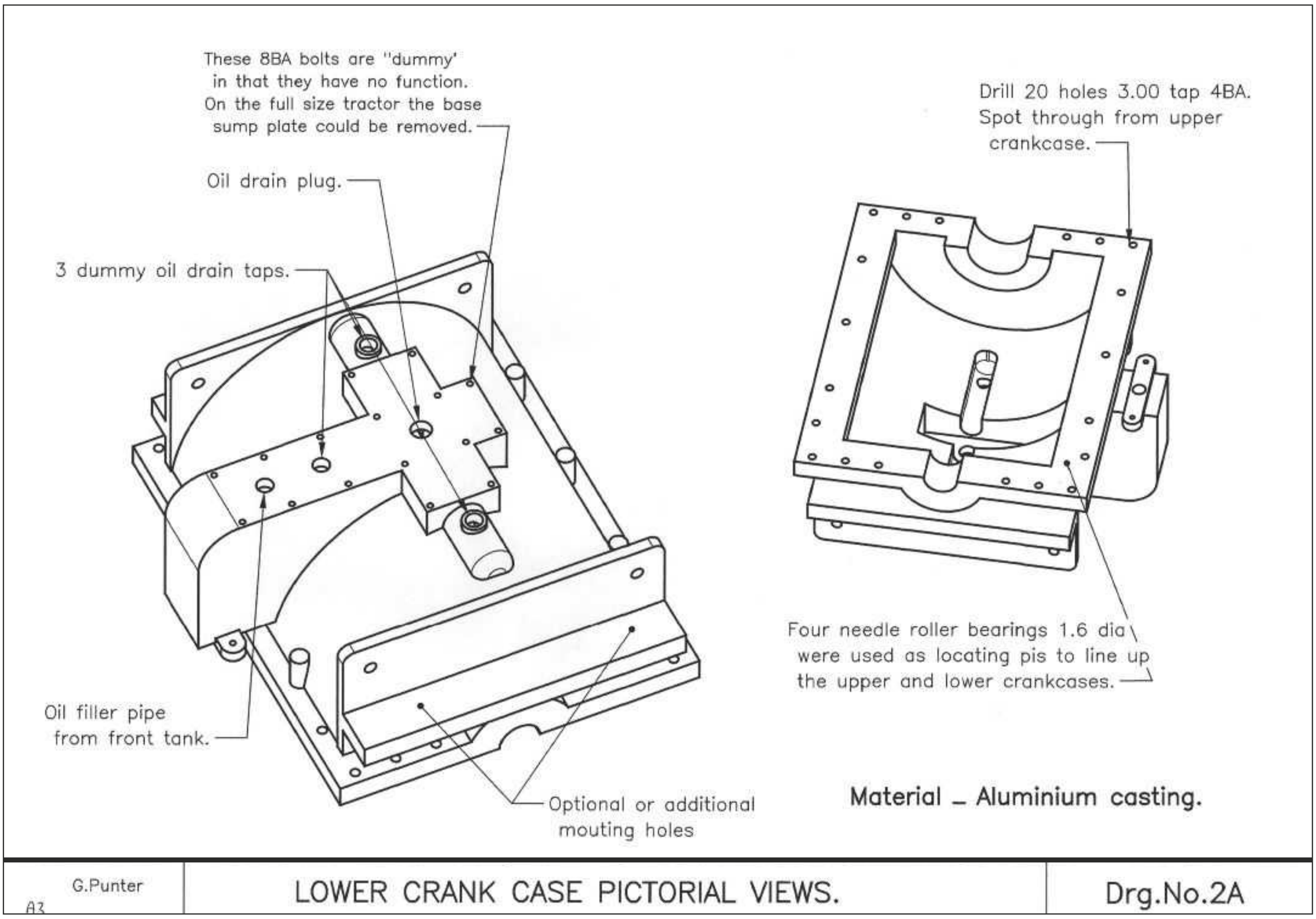
The engine sump core box components.

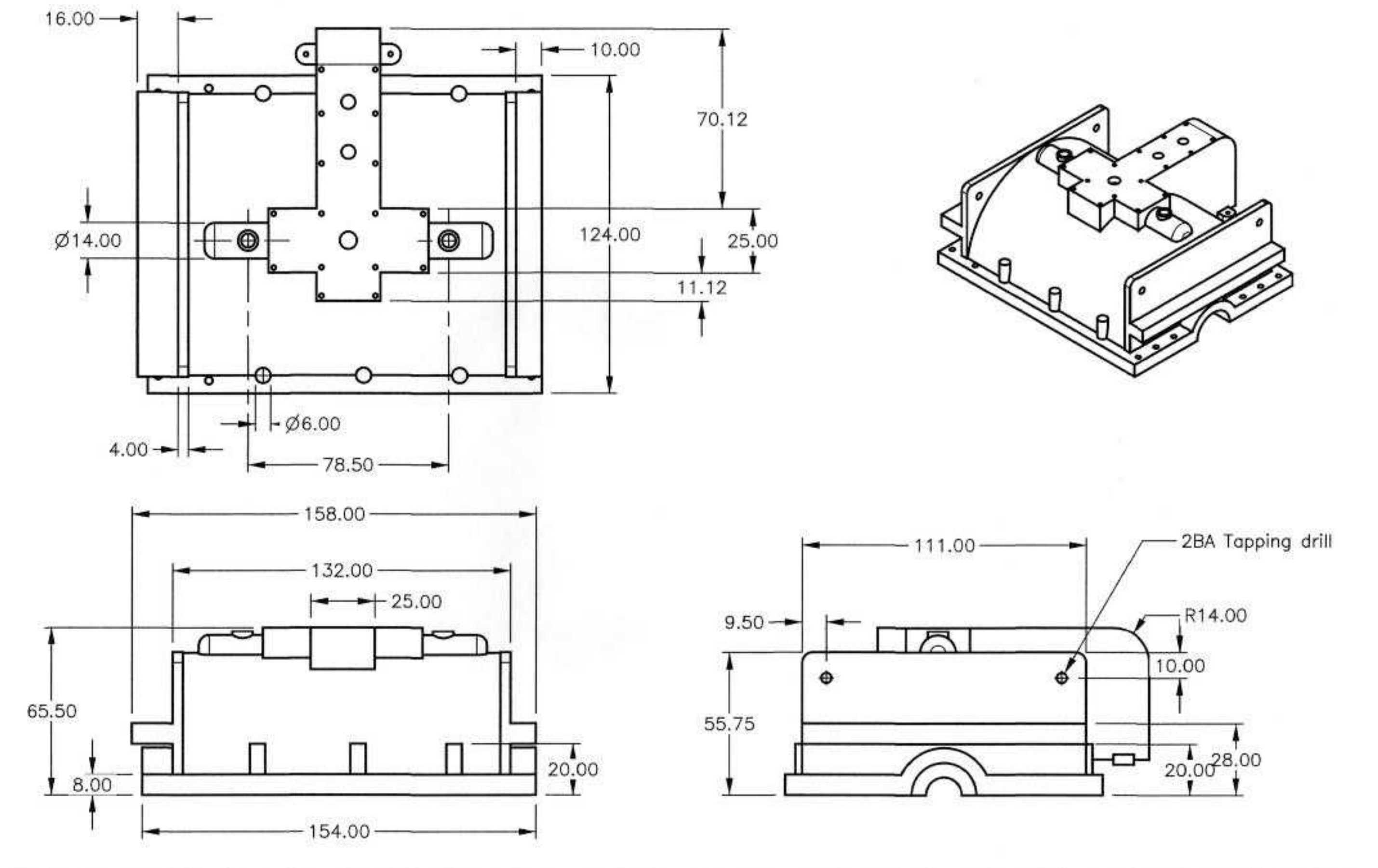


The sump core box parts assembled.

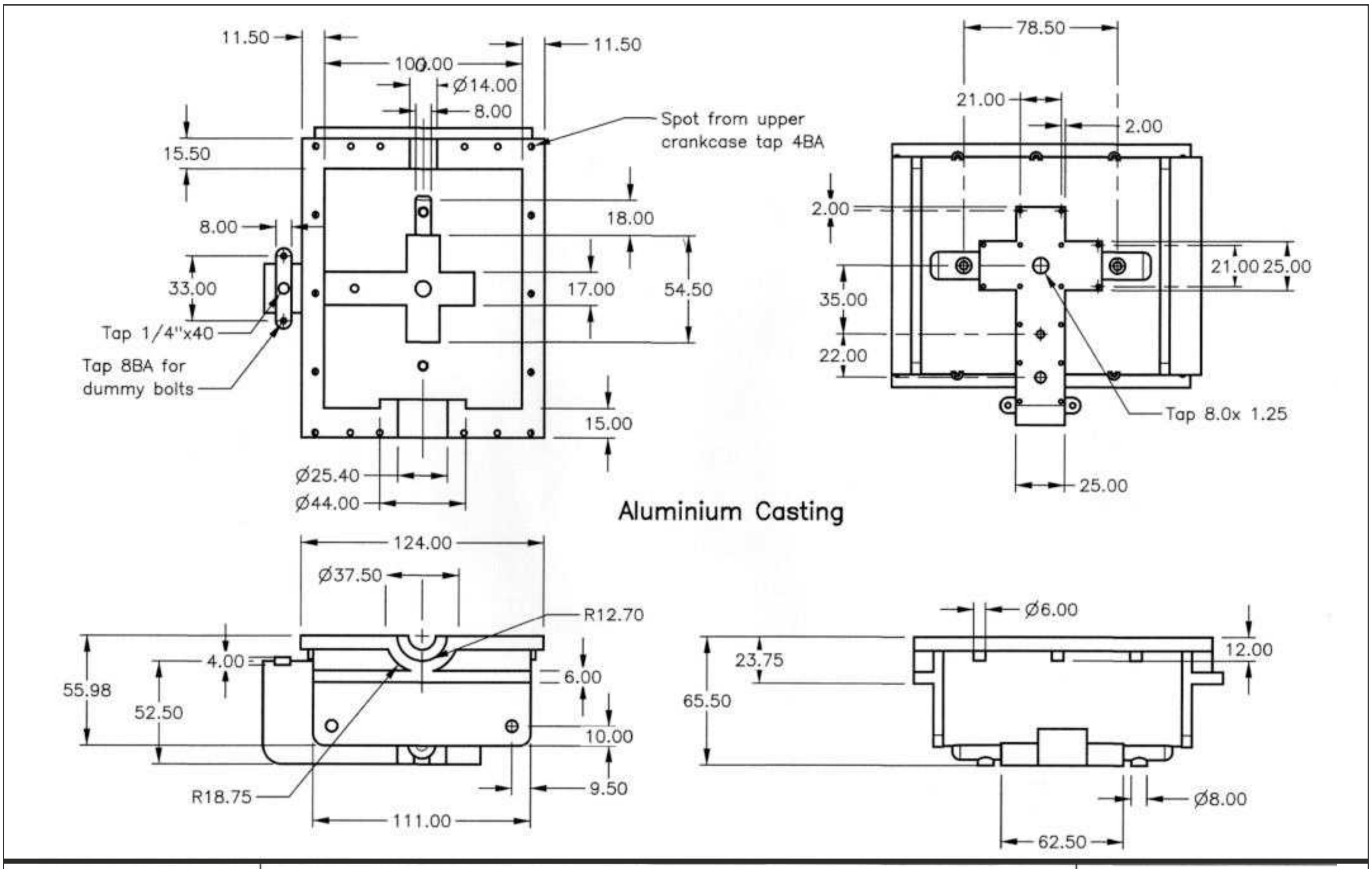
The core ready to be assembled with the outer.

The assembled sump mould.

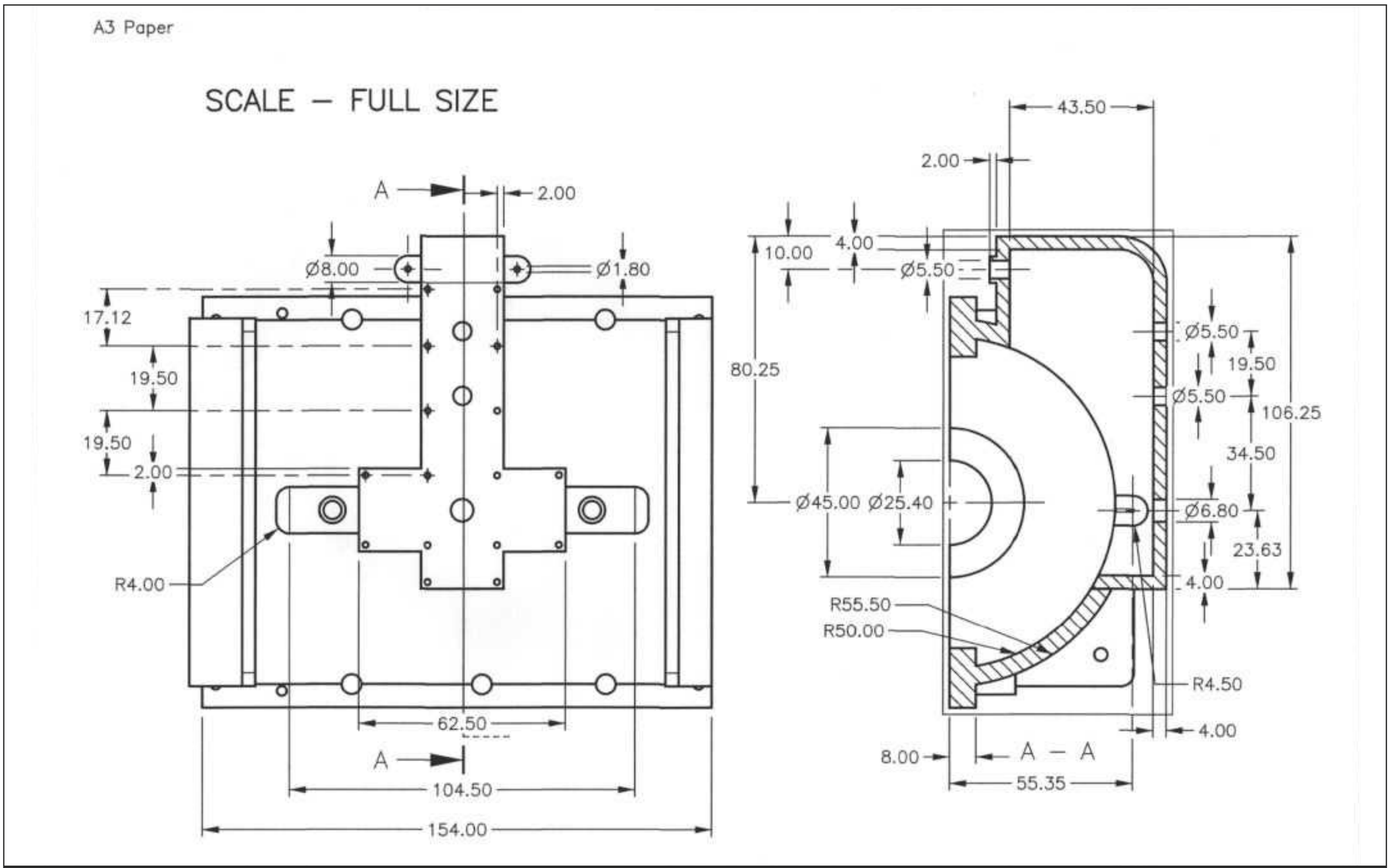




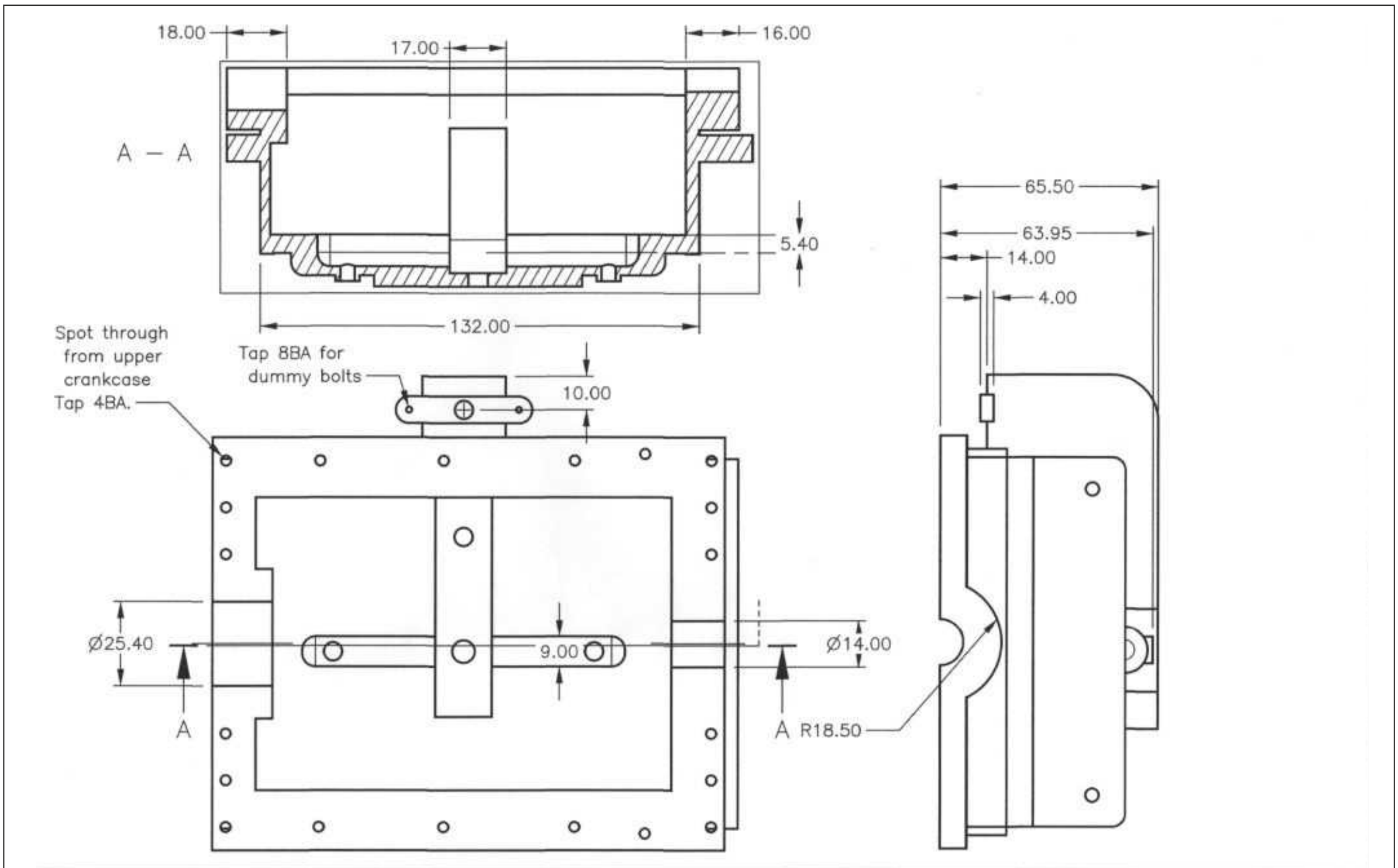
A3 G.Punter | LOWER CRANKCASE | Drg.No.2B



G.Punter A3 | LOWER CRANKCASE | Drg.No.2B2



A3 G.Punter | LOWER CRANKCASE SECTION. | Drg.No.2C1



G.Punter | LOWER CRANKCASE | Drg.No.2D

Effect of Rake Angle
on the Forces Acting on a Cutting Tool
PART 2

Jim Haslam looks at cutting tool grinding geometry.

Continued from p.787
M.E. 4535, 27 May 2015

Procedure: Machining with varying rake angles
(**Table 1**)

1. A specimen bar is mounted between the lathe chuck and tailstock centre then skim turned parallel.
2. The dynamometer, complete with DTIs, is fitted in the lathe toolpost (the dynamometer having been prior calibrated)
3. A knife tool - having zero rake angle, being one of a set of seven prior ground cutters, which increase in five degree rake angle steps - is fitted into the toolpost mounted dynamometer, with correct overhang, using a setting gauge piece for positon.

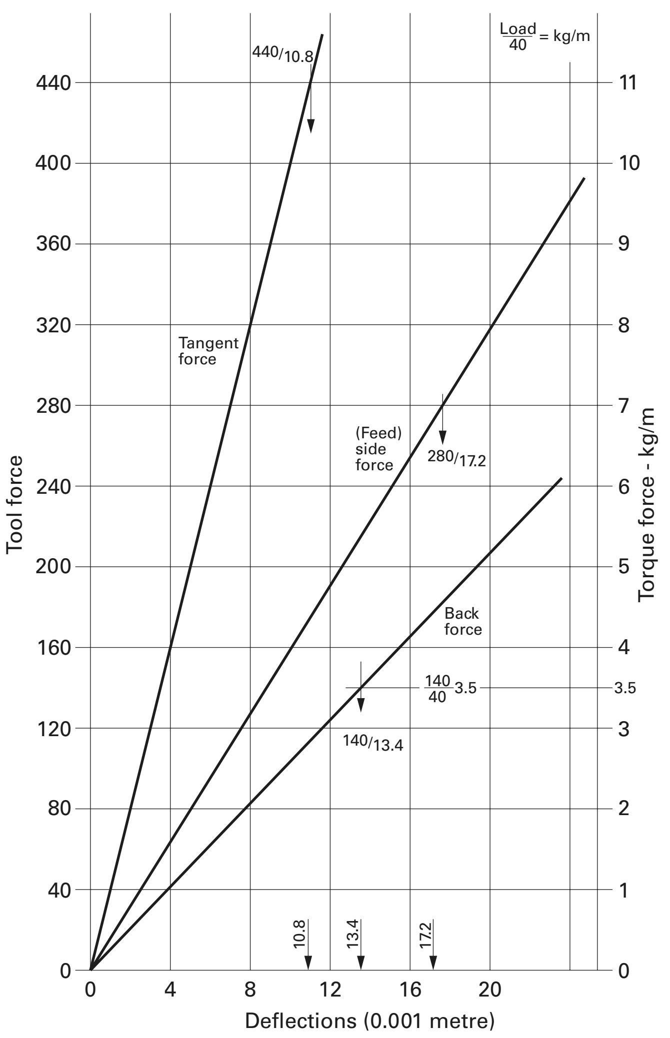
Table 1: Table of recorded DTI deflections

Forces acting on a lathe tool: Recorded typical data.
Diameter of bar to be machined: 57mm.
Depth of cut: 2.5mm.
Feed: 0.005 inch/rev
Revs per minute: 280
DTI graduations: 0.002mm

Rake angle (degrees)	Back force	Feed force	Tangential
0	0.022	0.016	0.020
5	0.024	0.018	0.018
10	0.018	0.013	0.018
15	0.017	0.010	0.012
20	0.016	0.007	0.010
25	0.013	0.006	0.009
30	0.009	0.004	0.008

High speed steel cutting tools, pre-ground in 5 degree rake angle steps.
No coolant during cuts.
The deflections are converted into force values and plotted against rake angle base.
Resulting graph being used to determine optimum rake angle for steel specimen being machined.

Fig 7



Tool Force/Deflection

The application of zero rake angle applied to screw thread chasers.

4. A suitable spindle speed selected to give approximately eighty feet per minute and five thousandth per revolution feed rate.
5. Set depth of cut - approximately ⅛ inch - set work rotating; engage traverse without coolant, noting D.T.I reading, type of cuttings (swarf) and surface finish produced.

This outline procedure is repeated with the remaining cutting tools of increasing rake angles, using same speed and feed and continuing the previous cut.

Tabulate collected data to enable graphs to be produced (**table 2** and **fig 7**).

Table 2: Rake angles and recorded data

Rake Angle Degrees	DYNAMOMETER READINGS						REMARKS
	Tangential		Feed		Back (axial)		
	Def'n	Ft	Def'n	Fa	Def'n	Fr	High tool force, finish rough, hot blue cuttings.
0	20	800	16	260	22	230	Readings were not consistent for tool
5	18	735	18	292	24	250	Improved finish; reduced loads
10	18	735	13	210	18	187	Improved swarf formation
15	12	490	10	160	17	176	Finish improving
20	10	410	7	110	16	167	Cutting swarf formation better
25	9	370	6	96	13	136	Acceptable finish
30	9	370	4	64	9	94	Good machined finish/ swarf flow

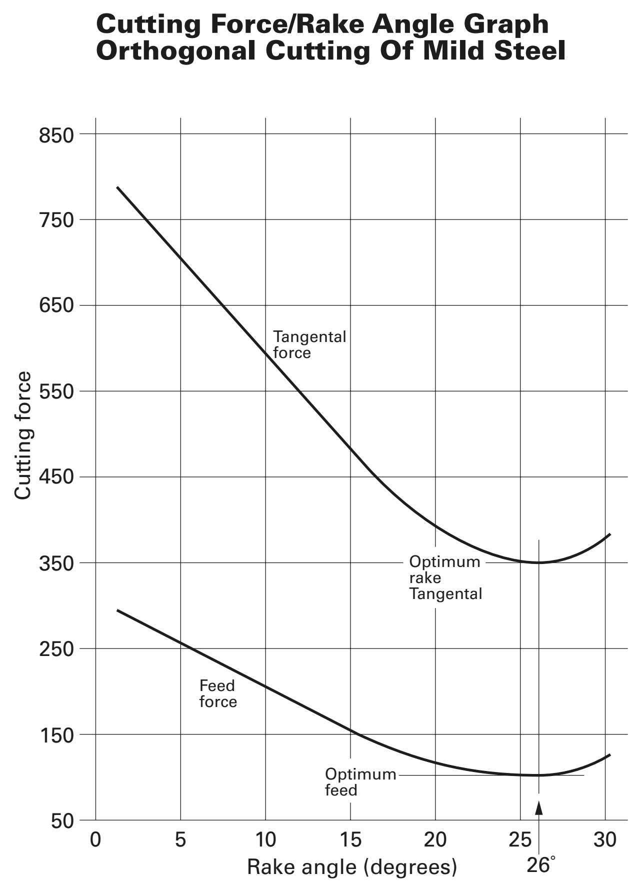
Summary

Loadings on a model engineer's cutting tools are not of high priority but the effects come to our notice particularly when a parting tool breaks with apparent ease. Similarly, with well used lathe tools the original standard tool shape is somewhat lost due to constant regrinds and often we need to alter the geometric outline shape to suit a particular need on the day. The alteration in shape etc. applies also to the rake and clearance angles.

The need for correct tool shape and angles are the province of the production department where long and effective production runs are of importance. In recent years they have been somewhat overtaken by preformed, sintered carbide disposable tooling.

Optimum rake angles, as indicated on the graph (**fig 8**): 26 degrees, for the mild steel sample are often reduced to give an increase in cutting tool life between regrinds. This increases the wedge angle and hence a stronger cutting tool tip.

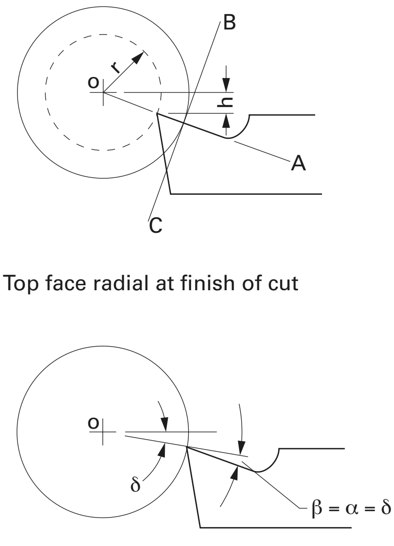
Photograph 1 shows the application of zero rake angle applied to screw thread chasers, which if provided with positive rake would result in a slightly modified thread form. For example, with a form tool produced having a true 10 millimetre radius and positive rake, then the resulting 20 millimetre form ball would appear noticeably elliptical. To avoid this, a measure of correction to the form tool



Optimum vaue 26˚ tangental rake modified to 21˚ in practice - refer to Fig.2

Fig 8

Fig 9



(a) Top face radial at finish of cut

(b) At start of cut

Form Tool With Top Rake Below Centreline Setting

Front face of tools require form modified & obtained by calculation

Ref. Senior Workshop Calculations by W. A. J. Chapman

>>

radius would require to be obtained by calculation and the radius of the tool modified accordingly.

Form tools with 'top rake'

If back slope is put on the cutting face of a form tool the cutting effect of the tool is somewhat curious because, for the purpose of obtaining an accurate relative reproduction of tool form on the work, the tool, at the finish of the cut, must have its top face lying on the radial line. This is shown in **fig 9a** where the tool is shown at the completion of its cut and its top face lies on the radial line OA. It will be noted that at this position the 'effective top rake' is zero, since the tool is cutting relative to tangent BC, which is perpendicular to OA.

When this tool starts its cut, however, the conditions are as shown at **fig 9b** and it will be seen that if the back slope, $\acute{\alpha}$ on the tool is made large enough, the tool will start cutting with an effective top rake of:

$$\beta = \acute{\alpha} - \delta$$

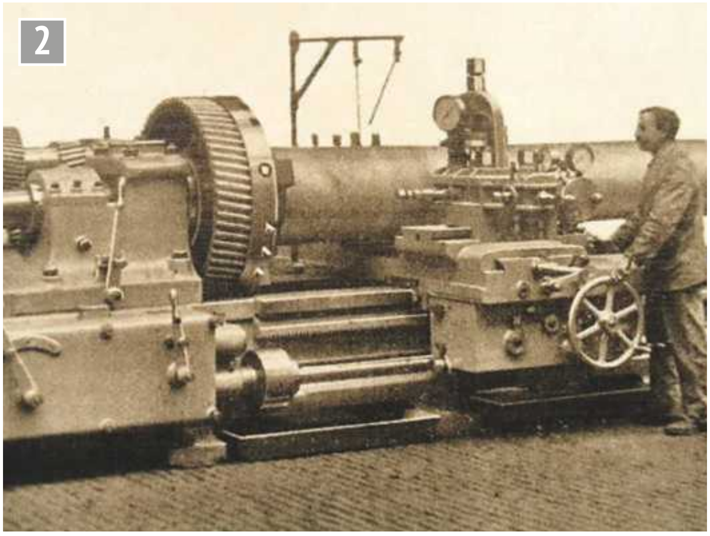
As the tool feeds in, this rake will gradually get less until, as seen in fig 9a, there is zero rake at the final position. It will be noticed that a tool of this type must be set below the centre by an amount, h:

$$h/r = \sin \acute{\alpha}$$

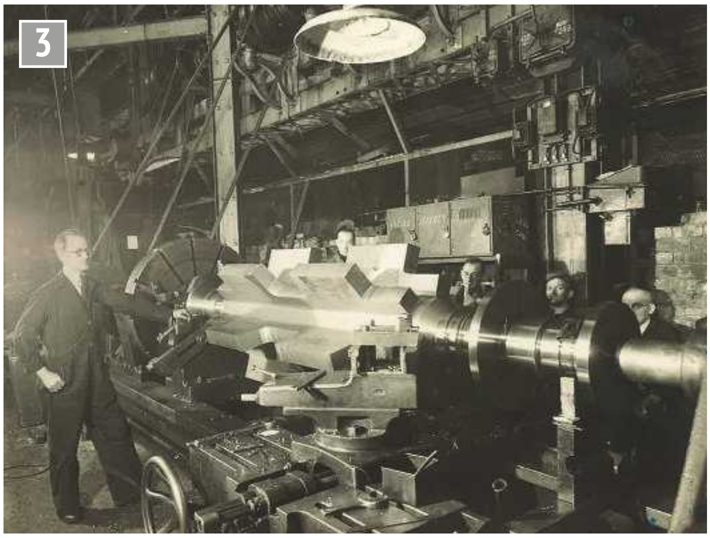
and r = the smallest radius being turned.

Photographs 2, **3**, **4** and **5** are included for interest and show my father at work at Metropolitan Vickers, Trafford Park, Manchester c.1950; the captions tell the story in each case.

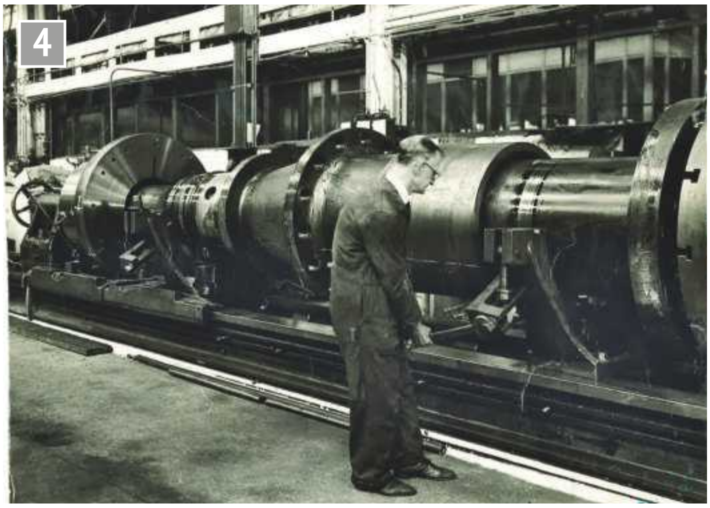
ME



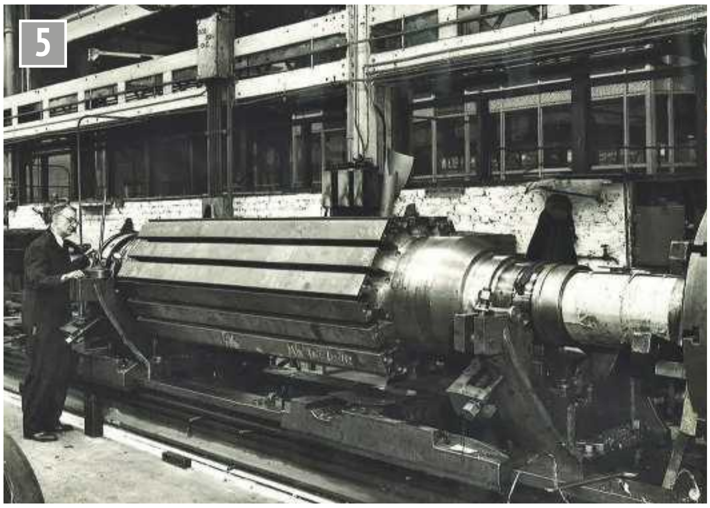
A 1911 lathe with dynamometer. A picture taken from an American engineering magazine, showing a lathe tool dynamometer in use. The lathe appears quite modern for its time. This 36 inch swing lathe was made by Armstrong-Whitworth of Openshaw, Manchester, in 1911 for the Japanese Navy. Made for experimental purposes, it was fitted with devices to measure either the force on the lathe tool (up to 7 tons vertically) or the torque on a drill (up to 3 inches diameter). It had a 60 HP variable speed motor made by the interestingly-named Lancashire Dynamo & Crypto Co.



A relatively small rotor shaft (the photograph was taken during dinner break, hence a good audience!). Note the belt drive and steady support. Main aisle, Metropolitan Vickers, Trafford Park, Manchester. Large work items were shipped in and out via railway lines running through the aisle. Large slotting machines and cylindrical grinders were located alongside the larger lathes.



A turbine shaft of approximately seventy tons, viewed from the rear of the lathe. Adjustment is being made to one of two fixed steadies, the bearing faces of which were 'Babbit' white metal. The lathe had two saddles complete with cross-slides (seen positioned at the tailstock end in this photo).



Photograph of a turbine shaft, note the paraffin soaked oily rag to lubricate the steady bearing faces. The chalkmark lettering states 'mark out for drilling'. Often manufactured on a 'penalty contract' basis to ensure on time and show potential customers the level of manufacture to date. Parts of some shafts, i.e. bearing surfaces were 'burnished' with a single, plain knurl-like roller. Approximately 1950.

PART 6

Building John Stevens' Skeleton Clock

Dennis Stones describes some of the more fascinating moments.

Continued from p.589
M.E. 4532, 15 April 2016

A sudden glitch

For three years the clock ran without a hint of any real problems. Then a minor catastrophe!

To transfer the power from the barrel to the fusée I had used braided plastic fishing line. The (yellow) fishing line was rated as having a breaking strength of 80lb. My fairly rough measurements had suggested that the main spring was exerting a tension in the line equivalent to a weight of about 10kg (22lb). There was plenty of strength to spare … or so I thought.

Returning home one afternoon, I was most disappointed to discover that the clock had stopped. It was easy to see why. The 80lb fishing line had broken (**photo 17**).

As the photograph shows, a large amount of the line remained wrapped around the barrel. It was clear from this that the line must have broken while still being subjected to the highest tension. One could imagine that the barrel must have spun around at a fair old lick as the spring released its energy. The only 'person' in the room at the time was the poor dog. What a fright she must have got! It can also be seen in photo 17 that the barrel click (ratchet) had (understandably) disengaged as the barrel and main spring flew around in the opposite direction.

Cogitating upon the issue, the clock had sat for three years in the shade behind vertical blinds. Now you would gather that we get a lot of sunshine in Australia. I had often wondered how much UV had been getting to the fishing line. Having spent many years in the plastics industry, it was hardly surprising that I had a fixation about ultraviolet (UV) degradation. Although I didn't really need proof, several of the plastics components which make up our north-facing vertical blinds have suffered failure from direct sunlight exposure.

Front view of the clock.

17

The broken fishing line.

>>

It took a wake-up call from another contributor in the Model Engineer forum (someone more familiar than I with regards to conditions in Australia), who suggested that the line had been 'attacked by the creep gremlin'. What a great description!

How could it be however, that I went ahead ignoring the creep characteristics of plastic fishing line while having ample knowledge about viscoelastic behaviour? I had even been working in a plastics laboratory where the very 1000 hour creep tests were being conducted. The resultant curves, to digress a little, became the source of many of my design projects. I had often applied 1% as the maximum strain for my design benchmark relating mostly to compressive and buckling phenomena.

I was now fully convinced that I needed to switch to a line or cord made from multi-strand metal, coated or uncoated; more of this later.

First, I needed to satisfy my curiosity about what had been taking place. I therefore removed two samples from the broken fishing line. I took one piece from near the broken section and which had been subjected to the greatest tensile stress. It had also been subjected to the average tensile stress for the whole three-year period. I took another sample of line from the opposite end where the tension had been lowest.

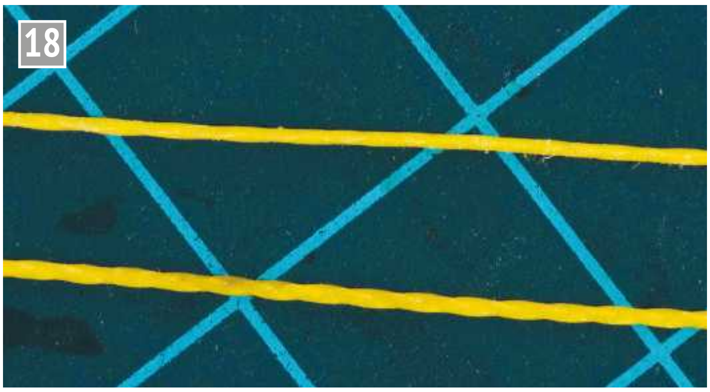
It is clear from **photo 18** that the line near the break had thinned substantially. However, this was not obvious until I got down to taking the close up photograph.

Clearly, I could not return to using the same stuff and my mind turned to the thoughts of how much nicer it would look with a chain drive. For several reasons, that was certainly out of the question.

I began to realise that as a very amateur clock-maker, my fixation for plastic fishing line came from blindly following instructions.

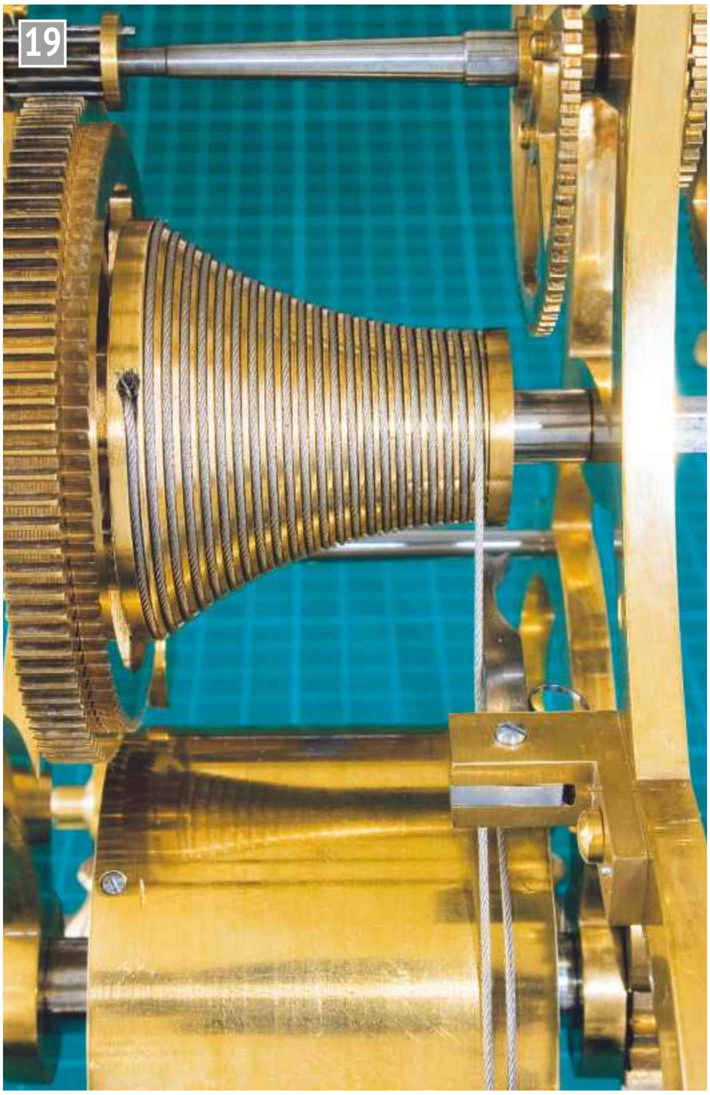
Following the failure of the fishing line, and with the gift of hindsight, I decided to check a few facts. I still had egg on my face from my lack of attention to viscoelastic creep (also known as cold flow). With the greatest of respect for the late Mr. Stevens, the following details may offer a number of reasons and somehow rescue me from my embarrassing situation. Why had I developed a fixation on fishing line and why were any serious modifications (to my fusée) prohibitive? I should also point out (yet again) that I no longer have workshop equipment to carry out any serious clock making.

It is worth noting here that I machined the fusée way back in the early 1970s, not long after Mr. Stevens' article was published. In his article commencing in February 1972, (especially Vol 138, issues 3334 and 3435, pages 139, 140, 168, and 169 of *Model Engineer*), Mr Stevens provided information and dimensions of:-



18

Close-up of the broken fishing line.



19

Replacement stainless steel wire in place.

a) The fusée and the barrel (page 139)
b) A recess in the edge of the barrel for the knot of a nylon fishing line (page 140)
c) An improvised fusée cutter (page 168)
d) The 0.035 inch wide bull-nosed cutter for machining the fusée groove (page 168)
e) A recess in the fusée for the knot in a Nylon washing line (page 169)

On page 140, Mr. Stevens describes:

A key-hole slot is made near the front edge of the barrel tube and a crescent filed on the cover immediately beneath. This is to take a nylon fishing line which serves admirably in place of the traditional gut.

On page 169 Mr. Stevens wrote:

A hole about 3⁄64 inch diameter (about 1.2 mm) is next drilled from the outside (of the fusée) into this recess which is to secure the nylon line, and a space for the knot milled out. (The nylon cord is obtained in the guise of a domestic washing line from any hardware shop!).

I began to realise that as a very amateur clock-maker, my fixation for plastic fishing line came from blindly following instructions.

Although I tried the local fishing-tackle shop for their best and strongest steel line which would fit into the fusée grooves without binding, my results at producing workable terminations (loops) from what they supplied were less than satisfactory. I should point out that my original method enjoyed the benefit of greater cord flexibility and I was able to hide the terminations completely.

I decided to make another trip to the eastern outskirts of Melbourne to discover what real professionals were using. Once more, they were more than generous with their help and I was soon heading home with sufficient stainless wire to make a far better job than I had done before (**photo 19**).

As if all this wasn't enough, I suddenly noticed in the very top left hand corner of photo 19, one of the ten pins in the lantern pinion had worked loose. 'Oh dear!' (or words to that effect). I shudder to think of the damage that would have been caused had the pin come free.

If you have been keeping up with my article, you will also have seen in photo 6 how I had to 'scoop' away a portion of the stop-work iron so that the snail-shaped hook would clear it during the final moments of fully winding the main spring.

The terminations (anchoring) of the steel wire were a totally different story. I had to be content with simple thumb knots which, when pulled really tight, were too big to pull through the holes in the barrel and the fusée. These knots were a tight squeeze in their respective ends - only just clearing other moving parts inside the fusée. By far the better way to terminate them is illustrated on page 106 of *Clock and Watch Repairing* written by Donald De Carle (soft-back edition).

There was still a little more work to do on the holes where the wire went into the fusée and also the barrel. As with the terminations, the stainless wire was less forgiving and I needed to increase the entry radii.

Once it was clear that I had a decent steel wire drive between the main-spring barrel and the fusée I found myself pondering over the possibility of setting the balance wheel screws to improve the clock's timing.

As reported before, my version of this skeleton clock had several issues of time-keeping. Some very simple attempts at torque measurement had revealed the cause of its poor time-keeping. Although crude, they provided enough information to show a distinct fusée mismatch, a situation which I was no longer in a position to rectify.

There followed a prolonged series of tests and adjustments, spanning several weeks. Once I was satisfied with my measurements I graphed the results (**fig 8**).

The heavy line displays daily errors. Readings were taken at 5am each morning based upon the assumption that they were perhaps the least affected by (Melbourne's) ambient temperature variations. I was not serious enough to collect night-time readings. The caterpillars crawling up and down the slopes are the results of hourly daytime variations. And, if I leave the clock running until the spring has fully run down, the clock speeds up leaving a result as indicated by the dotted line between day 8 and day 9. This is a further indication of the sensitivity of the escapement in relation to the applied torque.

Given that the fusée does not accurately compensate for the varying output torque of the main spring, my intention was to set the timing screws on the balance wheel to the best compromise. After several weeks of timing tests and adjustments, I had to accept that I had finally set the inertia of the balance wheel to the best compromise. Here are my observations:

- Over eight days, the variation ranged between +74 and -79 seconds.
- When the main spring was fully (tightly) wound, the stop-work lever was not pushed far enough into line with the brass stop and the stop-work mechanism failed to function. It couldn't.
- Within a few hours of the clock needing to be wound, the arc (swing) of the balance wheel begins to decline.
- When winding commenced after a complete run down, the torque through the winding key could be felt to be initially lower.
- The winding torque was felt to level out for most of the remaining rewind.

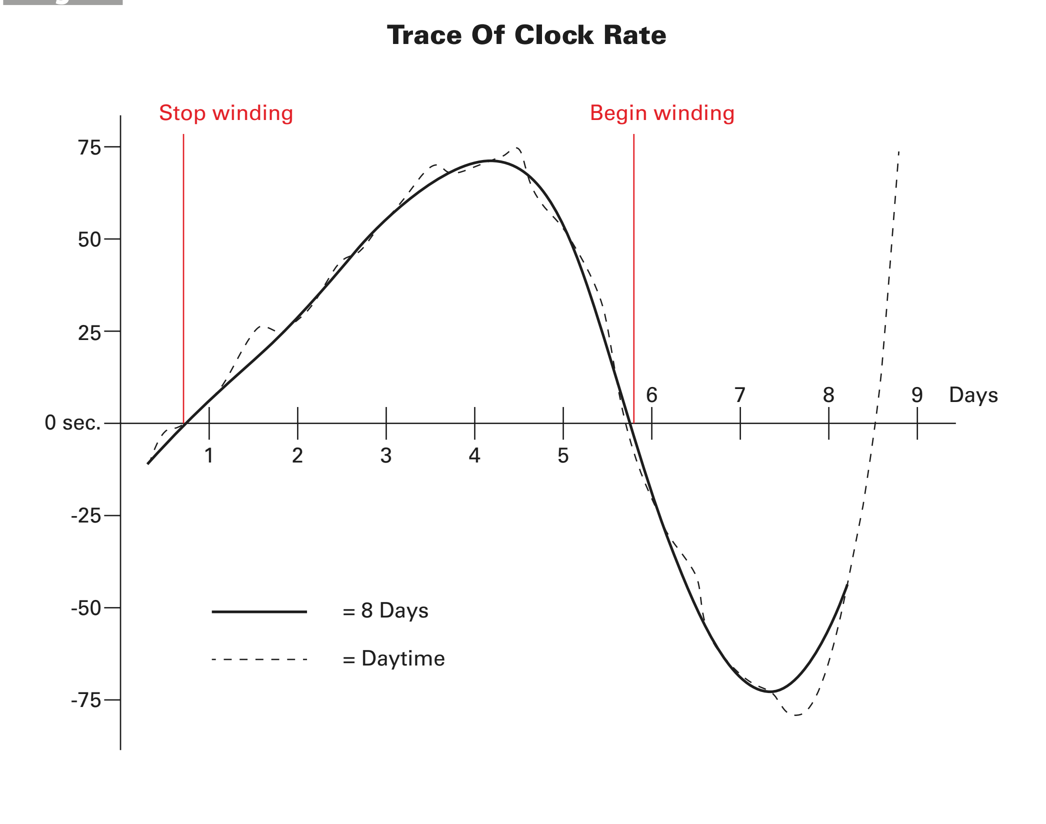
The two red lines in fig 8 are (in my opinion) where to begin and where to stop winding.

I shall now be content to wind the clock when it needs it and set the fingers to the appropriate time. However, I needed a case to both display and protect my work. I have written some thoughts about this and provided some pictures in the next instalment.

If you decide to have a go at building this delightful yet challenging exercise, expecting the clock to keep reasonable time, then it is essential that you accurately determine the characteristics of the main spring and that you then carefully calibrate the fusée accordingly.

●To be continued.

Fig 8



My trace of the clock rate spanning eight days.

PART 4

A CNC Beginner's Experience

Peter King continues his series of short, palatable articles for the CNC novice.

Continued from p.387
M.E. 4529, 4 March 2016

I hope the saga of problems and the advice that follows, in the form of a series of short articles, is helpful to those who may have experienced similar problems. I aim to lead you to some solutions and, eventually, to satisfactory operation of CNC machinery.

First faltering steps in CNC machining with a KX3

A week after I got everything working apparently properly I drew, for an exercise whilst at work, a Tool Storage Plate 'á la Mick Knights' in about 10 minutes and saved it as a .dxf file on a memory stick for home. In the workshop loading the .dxf file into Cut2D took but a moment and about three minutes later I had a couple of tool paths saved to file. First tool path being a drilling operation for mounting screws and piloting the positions for 3 Morse shank tool holders; the second being a 'pocketing' one to mill out the 3 Morse storage holes to size. The 'drilling & pocketing' combination is the result of brainwashing at Tech where the routine is 'spotting' – 'drilling' – 'milling'. Several friends who operate professional machines said they just plunged in and drilled holes without pilot holes and without 'spotting' by using 'split point/ four facet stub drills'. I guess if you want very high positional accuracy then 'spotting' first is the way to go, for work within 0.001 inch/0.0254mm then the quickest is plain drilling. However, such holes do not have the edges broken with a small bevel - this would automatically be done if the 'spotting' depth had been of suitable depth and the spotting drill of such size that the subsequent drilling would leave a small remnant of the spotting as a bevel. I guess that some would however hand de-burr the previous job with a tool like a Noga (www.noga.com) whilst watching over the machine.

Murphy was lurking yet again, however, and when I loaded the program into Mach3, whilst everything looked okay at a casual glance there were reefs in the course. As this was the first real/ actual chip producing operation, I had not noticed that Cut2D requires configuration to 'talk' to Mach3. This produces several weird results if not carried out. The sample programs, of course, had this information. I tried running this mess without tooling, which is how I found out it was of no use. Have you ever seen a CNC machine carrying out the machining movements for holes in a 20 x 300mm storage plate for No. 3 Morse tool holders in an area of about 3 x 1mm? I figured that it was scaling to about 100:1, even Z was moving by a just visible amount. I then did a check on what the digital read-outs showed. Oh Dear! X was clearly in inches and Y in millimetres (?) going by the position of the Z axis relative to the centre of the table (X0 / Y0 / Z0). I then spent some time checking stage by stage through what I had been doing – and still not noticing the cause. When going through the Cut2D program a fourth (fifth?) time I noticed that in the Saving window there was a line of text that mostly meant nothing to me but did have 'inch' in it. This puzzled me as I had set everything to millimetres. Investigation (mousepokeren) showed that this is a section in the routine for saving the newly created file that details the Control Program to be

Author's correction: in the last sentence of the last instalment (page 661, *M.E.* 4535) the word 'no' was omitted. The correct sentence is; there is no facility for auto tool changers on a KX3!

used – there are lots and lots of them. Light dawned – well I am ***NOT*** a computer Tech and only a learner driver in CNC – so I scrolled down the list until I found Mach2/3mm and clicked on this to place it in the box and saved the result. This resulted in a vastly more sensible operation with the KX3 proceeding with a stately 'rhumba'. I had set feeds to a low figure so I could see what it was doing and inhibited Z this time.

To round up the problems encountered, then, in getting into operation; the problems were about 30% faulty parallel port, 20% due to a readable but not executable section on the factory CD, 45% incompetent operator – with 'L-plates' very visible and 5% poor indices in both the KX3 and the Mach3 handbooks. The whole exercise was initially a very flat learning curve (no advance) as nothing is more disheartening than 'fingerenpoken' or 'mousepokeren' and nothing happens. However gradually as the 'whip and chair' stuff tamed the computer I gained back some confidence and then the 'curve' started to get steeper with practice.

The handbook defects are mostly that the paragraph number against a particular entry in the index is not reflected in the text at all, or some entirely different subject appears in the paragraph of that number. This is infuriating as I nearly made several calls on the forum that would not have been necessary if the entry had been there. For example: on the Mach3 main screen there is a box 'CV Mode' which is highlighted, i.e. it is 'ON'; the KX3 handbook index reference is '5 – 12' and Mach3 handbook is '6 – 12'. Not knowing what this 'CV Mode' meant I looked in the indices. Neither reference has anything to do with the text at those references. Eventually I found out at Tech' that 'CV Mode' 'ON' means the computer is also looking several lines ahead of the line in the G-code program it is actually dictating to the Mill - as a sort of advance warning.

The KX3 forum

The Forum for KX3 machines is free to registered owners – you will need your machine number and registration number to gain full access. I found the forum very useful indeed with weekday email replies (I am 12 hours and 12,000 miles away) within 12 – 14 hours. I don't expect weekend replies from the controller as they need a break too, so getting the accumulated cries of anguish I posted during the weekend replied to on Monday /Tuesday is okay by me.

Tool referencing

I now started actually cutting metal on my own jobs instead of test files and trials. The first job for the beginner to do is to find the handbook page that refers to the setting of tools and read it several times. Then make a list of all the tools (plain drills/ spotting drills/ milling cutters – each listed in separate groups – end mills/ slot mills/ ball nose /bull nose /FC3 and so on. *Number them!* I started with 1 to 10 for spotting drills and then allocated ten numbers for each of the tool types. Then follow the instructions for 'zeroing' the tools. Then re-create that same list in Cut2D – *with the same numbers!* Cut2D will then put that information into the register it creates as a G-code T-number (T1, for example). Mach3 will know which tool it is using as it should have the same tool under T1 in *its* tool index, *and* from there where its Z zero is in relation to datum tool, 0. Cut2D will have supplied Mach3 with – 'rotational speed/ how deep/ what feed' for that tool. Clever, isn't it? Provided you put the right tool into the spindle.

All the tool off-sets are tied to the basic Tool-0; this is often a plain steel bar a bit longer than all the tools. This Tool-0 is brought down to the work surface and zeroed. When 'zeroing' a cutting tool the same move is followed; Mach3 also requires you to tell the program what size of cutter you are using when you set this. This operation both sets the work surface to the tool – and its size is what sets the line of the 'tool-path' which the tool axis follows. There is also, in some programs, a facility to slightly off-set an endmill tool sideways during its primary operation to allow for a final small finishing cut (often a 'climbing cut' of about 0.1/ 0.2mm - 0.004/ 0.008 inch) which is to ensure that the machine leaves the job machined at designed size. All the tools are set relative to Tool-0 so that if a thicker work piece is used and Tool-0 is registered to it, all tools will register likewise. Clever, isn't it?

> The first job for the beginner to do is to find the handbook page that refers to the setting of tools and read it several times. Then make a list of all the tools.

My first real job

The first exercise I undertook, as mentioned earlier, was to prepare drawings for a pair of tool storage plates to the design of Mick Knights. With the system I have installed – CAD to CAD/ CAM conversion to Control Processor (i.e. Autosketch – Cut2D – Mach3) I therefore prepared a couple of drawings with a dispersion of holes to match the holders I have.

STAGE 1:

The first stage I used was to load the drawing into Cut2D, where the drawing appears just as I had it on screen at work, with a work blank, just visible, to fit exactly a size under it. The first operation is to define what system of measurement would be used and at the bottom of the fly-out window are boxes for 'inch' and 'mm' to tick. The next is to define where the 'work' datum is; 'X-0 and Y-0' and for the first job I used the centre of the work. Many would use the bottom left hand corner but I used the centre because the job was on the limits of the KX3 machine's 'envelope' and the corner would take the X-axis movement out to limits when 'homing'. All the actual machining would be inside the 'envelope' so the limit switches would not be triggered. After this I continued to use the work centre for convenience as this usually means the cutter path for the tool conveniently avoids all the clamps (if one or more have not been put in a stupid place! We all do it …)

Having got the drawing on screen, you must then define the size of blank plate from which the job is going to be cut. The info required is: overall dimensions in 'X' / 'Y' / 'Z', this produces an image of the blank on the screen. You also have to define where your Zero is; there are several options - as mentioned, mine is usually in the top surface centre. When happy with what you have, then click OK and a fresh screen appears. Now (Cut2D v.8) click the box marked with a 'centre image' logo (a box within a box with four centring arrows) and a further window opens – giving lots of options. Click on the one showing a centred work piece – *'Lo and Behold!'* the drawing appears centred on the blank. This operation has done several things; it has told the program where its 'job zero' is in 'X'/ 'Y' and how thick the job blank is – and so where 'Z' 'job zero' is to be defined when the work is installed on the mill and you 'zero' Tool-0 on it.

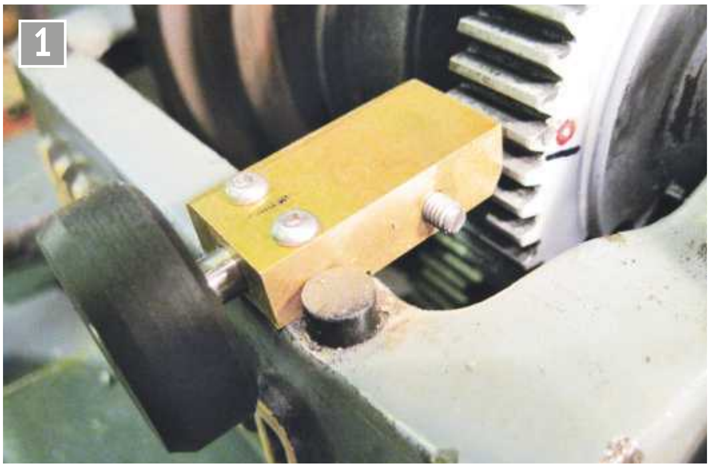
Now - if you later specify a drilling deeper than the blank, you will get a warning. This is also the reason for using sacrificial plates when you get it wrong!

●To be continued.

Never Throw Anything Away (You Never Know when...)

Patrick Hendra presses a fifty-year-old home-made attachment into service.

I visited the Midland Model Engineering Exhibition for the first time last year. Several of us from the Eastleigh and District Model Boat Club had entered the competition and I represented our Club competitors at the Presentation Ceremony. I had a look round the show and finished up at the Myford Stand. As the proud owner of an ancient Super Seven I noted that the latest version incorporated a little modification.



The indexing system.

A view of the read-out from the cross-slide. A 6 inch Mitutoyo calliper is cable connected to a Model SD-D1E display and is about 20yrs old.

The back gear has 60 teeth and Myford now paint the right hand face and print numbers thereon, identifying the teeth. They also fit a simple indexing system so that the shaft can be locked. Simple and potentially useful thought I. A 'must do' job.

Anyone who is familiar with Myford Lathes will know that it is advisable to run the drive belt until it is in shreds - because changing it is a nightmare. Mine shredded after at least 20 years and so, whilst dismantled, I duly painted the 60t gear and made up a simple indexing system; nothing elaborate, a piece of 6mm silver steel ground to a screwdriver end sliding in a reamed hole in a lump of brass (**photo 1**).

Now I can lock the shaft every 6 degrees but… *Ahhh!* All a bit useless though! What do I do with it?

I have just started to build a single cylinder steamboat engine (it is needed for a 1 inch scale Windermere launch being built by one of our Club's most perfectionist builders). I needed to drill and then tap six equidistant 2.1mm holes on an 8.5mm radius. I have a very old (20 years) amateur readout on the cross-slide based on a mangled set of Mitutoyo 6 winch Digital Calipers coupled to a small basic Mitutoyo display (**photo 2**) so setting the radius is trivial but how does one precisely define the hole centres?

An idea! Somewhere in my stockroom there should be a tool post grinder designed and built in the early 1960s by my Dad. The machine was duly found in its kaki WWII wooden box originally made to house a field telephone and proudly bearing the manufacturer's name, Truvox and a circuit diagram (**photo 3**).

The machine is comprised of a very nicely designed and built shaft set at exactly centre height when the machine is fitted on the toolpost. A belt drives it and it is fitted with a sewing machine brushed motor. For this application the spindle speed is about 3200 rpm.

The cable was rubber and was completely perished. The plug was of the old 5 amp, three pin variety so it had not been used for very many years. Appropriately rewired, reusing the massive in-line switch, the machine duly ran evenly but the motor emits a suspicious ‘burny’ smell!

Mind you the motor *is* nearly 60 years old.

Fortunately, Dad had collected a tiny Jacobs Chuck and had made arbors, all housed with grinding wheels in tobacco tins.

I duly mounted a small centre drill in the chuck and away I went. The accessory is centred onto a pre-centred rod (**photo 4**), the scale zeroed and six equi-spaced centres (**photos 5** and **6**).

Until now I have done this job in a dividing head on the mill but this new/old method is far more convenient and is very accurate. Fitting and removing the tool post drill takes less than a minute.

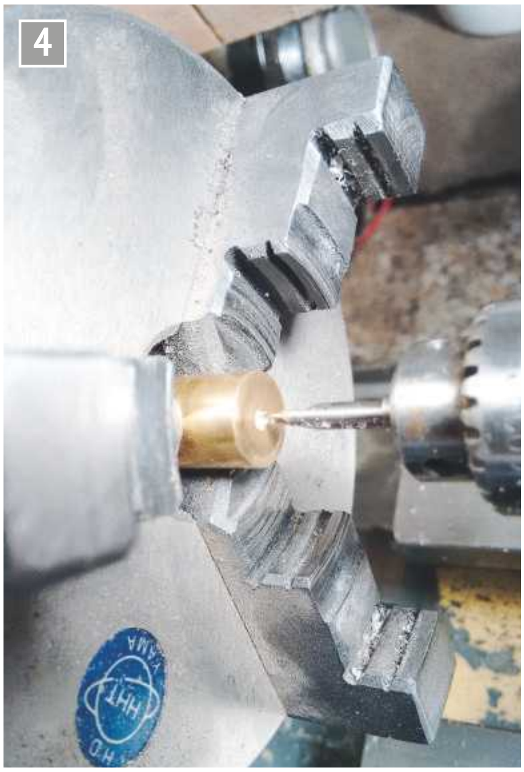
Replacing the vice and mounting the dividing head on the mill used to require patience and strength (a dwindling resource in my case.)

Now I have the accessory I wonder how I lived without it. In **photo 7** you will see my young colleague setting up a pulley; part of his latest project - a powered skateboard. (I have no plans to test the project!)

I’m sure that many readers can devise something like this using bits from their scrap boxes but it should be remembered that my Dad’s effort is really over designed for its new job. A simple ball race mounted spindle, a belt and a small motor are all that is required.

Eagle eyed readers will note that health and safety requirements are a bit more stringent today than they were in 1961! A belt guard *will* be fitted. **ME**

The tool-post grinder in its massive wooden box.



Centring.

Drilling the centre holes.

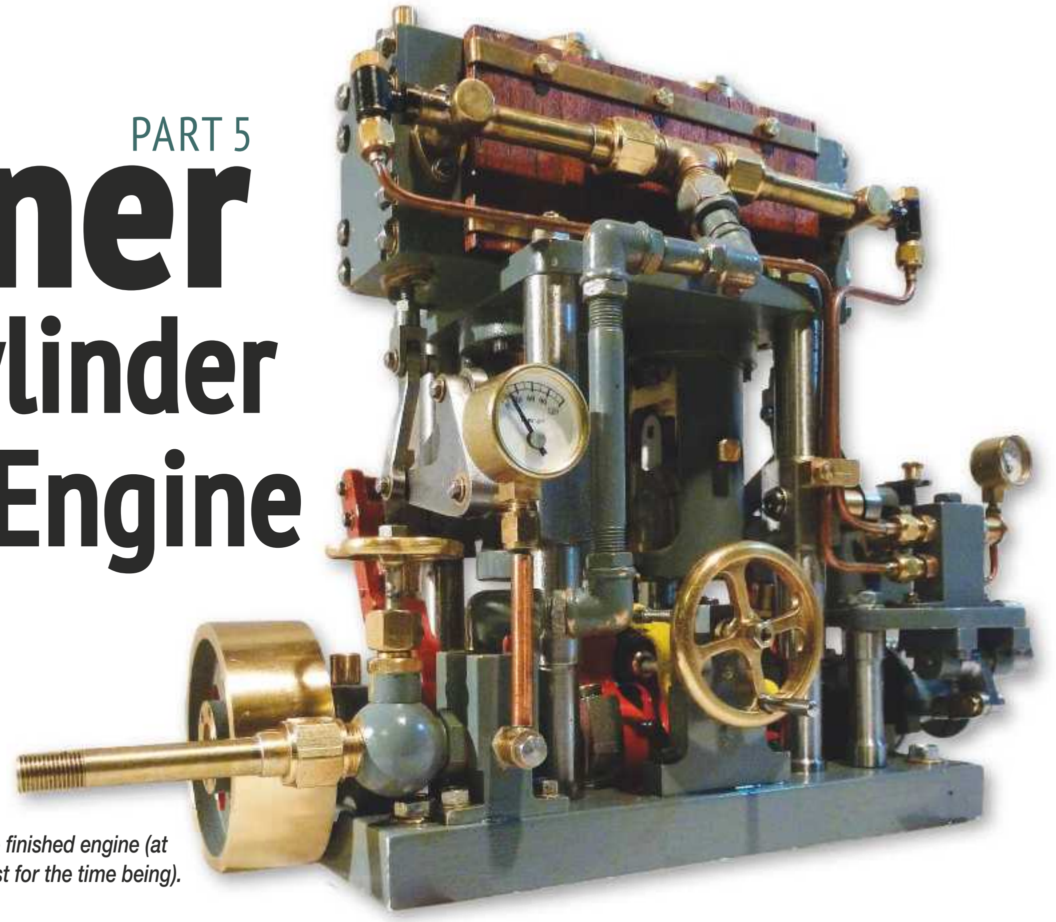
The product.

Angus drilling centres into a steel pulley.

PART 5

Mariner
A Two Cylinder Vertical Engine

Chris Walter continues with his description of a freelance marine type engine.



The finished engine (at least for the time being).

Continued from p.721
M.E. 4534, 13 May 2016

Inspired by sight of a smaller engine of a similar design, the subject of this article is a freelance, two cylinder, single expansion vertical engine with modified Hackworth valve gear, a bore of 1 inch and a stroke of 1¼ inch. It has a screw reverse and is, in its appearance, not untypical of a marine type engine.

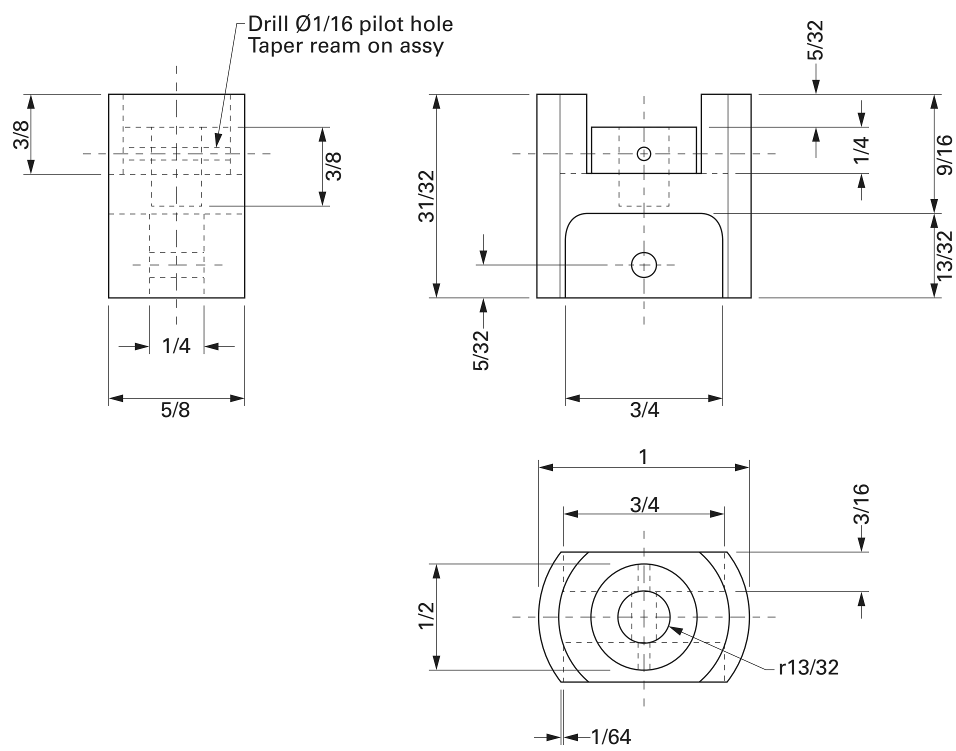


Fig 16

Connecting rod oil cups

I shall mention the main oil cups later on but the ones I have fitted to the connecting rods are by necessity so small that they are hardly deserving of the name, being just a very short tubular guide for the oil can (**photo 62**). Any bigger and they will start to foul the inside edge of the crosshead guide. (I blame the designer - wretched man!)

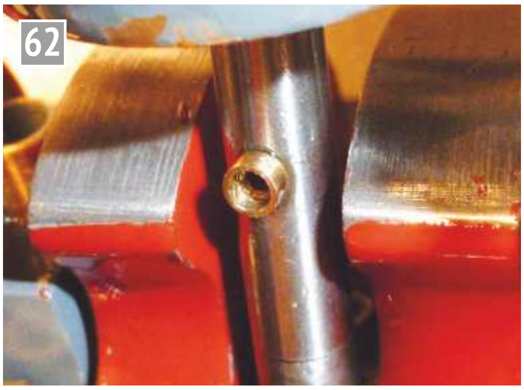
I started with a length of $\frac{1}{8}$ inch diameter brass rod and drilled right through $\frac{1}{16}$ inch. The $\frac{3}{32}$ inch step was then turned and then the cap parted at $\frac{3}{32}$ inch long. I now had to revert to my very old watch maker's lathe to put the cap the other way round in a collet and counterbore the inside to $\frac{3}{32}$ inch diameter to a depth of $\frac{1}{16}$ inch. Hardly worth it, you may say, but just a finishing touch. They are, however, just the right size for the nozzle of a small oil can and only have to guide the oil into the hollow rod.

Assembly

The final assembly of the complete rod was straightforward but I had to remember that the two rods are, in fact, handed. The two oil caps have to face in the same direction towards the operator's side of the engine (reverse gear wheel side) whilst the wrist pin heads have to face to either end of the engine. This is to facilitate the assembly of the rod forks and crossheads, and inserting the wrist pins into position is only possible from either end.

Before talking about the crossheads I must make an admission that when mentioning them, the connecting rods and the pistons I had originally made these items and used them in the completed engine. However, when I sat down to prepare this article I realised that I wasn't at all satisfied with their design so there was nothing for it but to drop everything and remake them in the form in which I have now described them.

Now that the engine is rebuilt I am much happier with the final result, especially with the pistons as I will later relate.



The final version showing the hollow intermediate rod (which acts as an oil reservoir) and its oil.

Completed crossheads and piston rods.

Ensuring the crosshead blanks are running true.

Turning the OD to finished size.

Crossheads

The crossheads (**fig 16** and **photo 63**) are 1 inch diameter brass running in brass guides. To start I cut two 1⅞ inch long blanks of 1¼ inch Diameter rod. These were checked for true running in the three jaw chuck and then faced and drilled 7/32 inch to a depth of 9/16 inch (**photo 64**). Using a ¼ inch slot drill in the tailstock chuck this was opened out to ¼ inch diameter for the full depth. I took my time doing this so that the result was a nice fit for the piston rod (a firm, sliding fit with no slop).

As soon as this was done the outside was turned down to 1 1/16 inch diameter for a distance of aprox 1⅛ inch (**photo 65**). I partially parted off at the finished length of 31/32 inch leaving a good ½ inch diameter remaining in the middle. This was so that I could see the completed length of the component but had extra chucking material for subsequent machining.

Using an edge finder for a datum on the outside of the crosshead.

Milling the circular cavity.

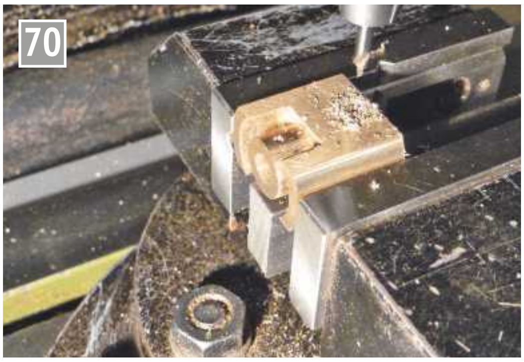
The cavity and boss.

Keeping the blank in the three jaw, the whole lot was transferred to the rotary table which is fitted with a Myford spindle nose. After using the DRO to centre it I milled out the circular cavity ⅜ inch deep leaving a ½ inch diameter boss in the middle around the piston rod hole. Once this was finished the top of the boss was milled down by 5/32 inch (**photos 66**, **67** and **68**).

Staying with the mill, the blank was turned on its side and held horizontal in the machine vice to machine a flat on the top and then subsequently, by turning the job over, a flat on the bottom bringing the overall dimension down to ⅝ inch (**photo 69**).

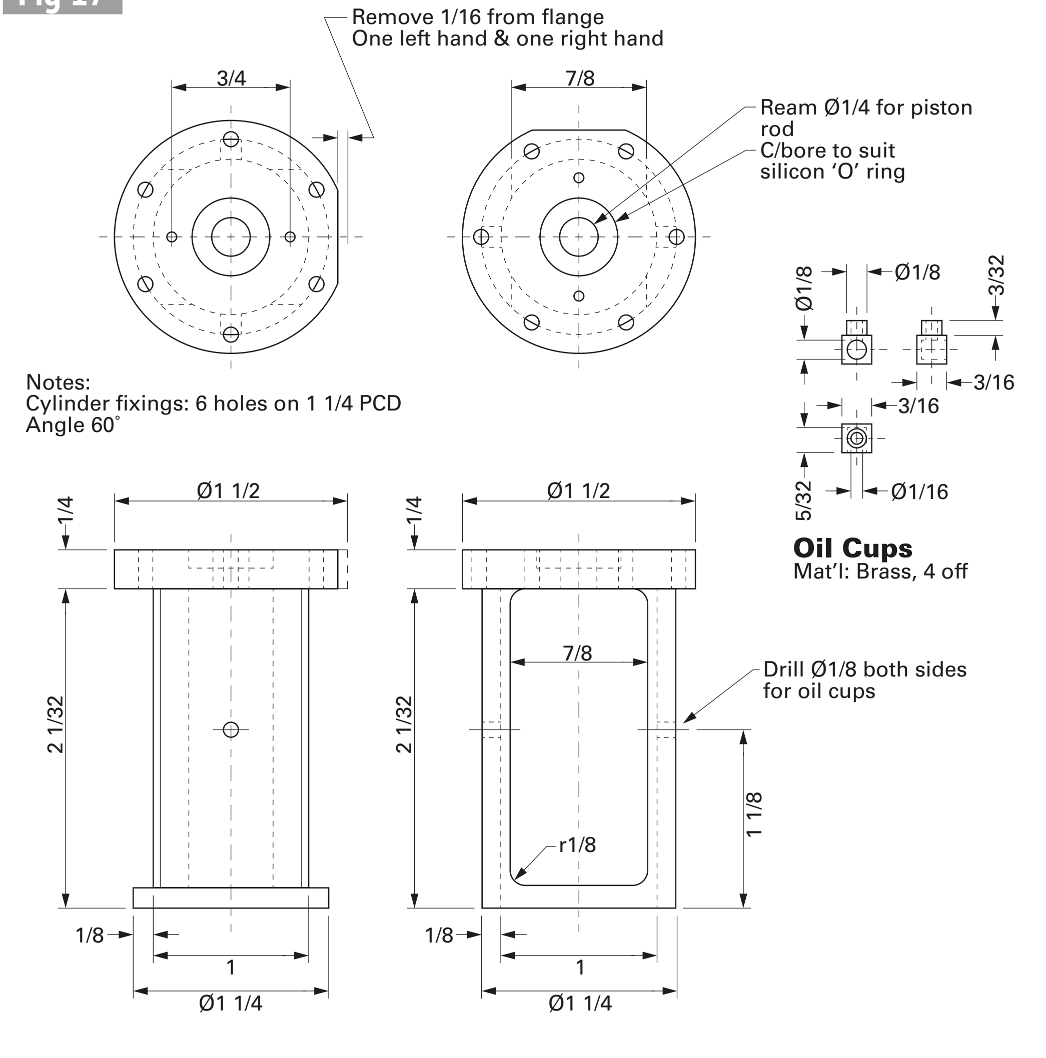
>>

Milling the two flats.



Centre drilling the crosshead for the wrist pin hole.

Fig 17



Still at the same setting, again using an edge finder and the DRO, the wrist pin hole was drilled and reamed ⅛ inch and a 1⁄16 inch pilot hole drilled for the taper pin which would later be put through the boss and the piston rod (**photo 70**).

Whilst still at the same setting an end mill was used to machine out the cavity on either side to accommodate the connecting rod fork (**photo 71**).

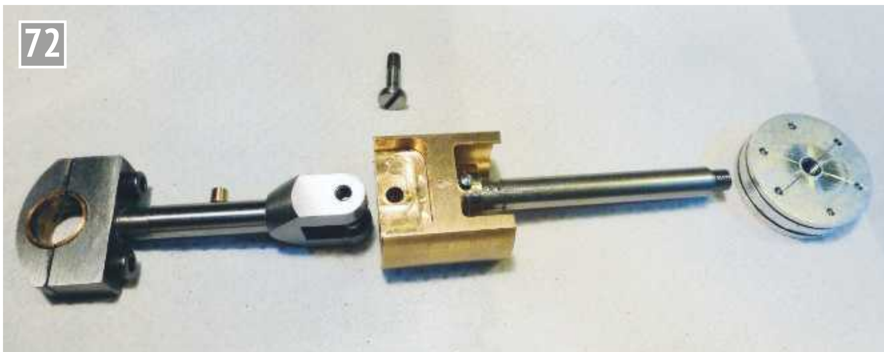
When the time came to assemble the piston and rod to the crosshead, the crosshead was held in a machine vice on the drilling machine table. With the rod in the correct position I first drilled No. 52 (1⁄16 inch) through the pilot hole and then right through the piston rod. After this I opened out the hole about half way through with a No. 50 drill and then, using a taper reamer, opened out the hole until a 1⁄16 inch taper pin was a good fit. There should be an equal amount of the pin protruding from either side of the crosshead boss (**photo 72**).

To finish off, the piston rod / crosshead assembly was held by the piston rod in a collet and the bottom of the crosshead supported by a running centre in the tailstock. The outside of the crosshead was now turned down to the finished size of 1 inch diameter by taking very light cuts and trying to get the best possible finish.

Crosshead guides

These were machined from two lengths of brass tube 1½ inch OD and 1 inch ID with a length of at least 2½ inch (**fig 17** and **photo 73**). The internal diameter was correct at 1 inch so the blanks were chucked in

Machining the centre tongue for the con rod forks.



All the reciprocating motion with the piston rod taper pin fitted.

Finished crosshead guides.

the three jaw in the lathe and checked with a DTI to ensure true running. I made up a $1\frac{1}{4}$ inch diameter x 1 inch thick disc plug which had a 1 inch diameter step machined to be a good fit in the end of the bore of the tube. A centre was machined in the middle so that a supporting tail stock centre could be used.

Once ready, the outside of the tube was turned down to $1\frac{1}{4}$ inch diameter leaving the $\frac{1}{4}$ inch flange at the chuck end at $1\frac{1}{2}$ inch diameter. I then partially parted it off to the finished length of $\frac{21}{32}$ inch. I left just enough to keep it safely supported and then removed it to the bench to finish removing it with a hand saw. It just needed returning to the three jaw chuck the other way round to take a very light finishing cut across the bottom face of the flange.

Now I needed yet another plug/mandrel (call it what you like). Again, this was a 1 inch disc that was a nice, tight, sliding fit in the bore of the guide. A $\frac{1}{4}$ inch diameter x $\frac{1}{4}$ inch deep boss was left on the outside face. This was placed in the flange end of the guide and the boss engaged in the piston rod hole in the cylinder support plate. They had to be placed in the correct orientation and then the fixing holes could be spotted through No. 43 (6BA tapping size) and I would ensure that the bore of the guide was concentric with the cylinder bore. I did one at a time and marked each guide and the support plate so that each would be returned to the correct position. Following this I opened out all the holes to 6BA clear.

When I sat down to prepare this article I realised that I wasn't at all satisfied with the design of the crossheads, pistons and rods so there was nothing for it but to remake them.

For the next step the guide was replaced back in the three jaw, again holding the flange end and with the support plug in the other end. The whole chuck was then mounted on the rotary table in the mill/drill but this time with the rotary table in the horizontal plane. Using its own tailstock to support the other end of the guides, the two side apertures were able to be machined so that they were at exactly 180 degrees to each other. It was necessary to ensure that this machining was carried out with the flange holes in the correct orientation. Perhaps an easy thing to forget in one's enthusiasm to get on with the job. (No your quite wrong. Not guilty! On this occasion I came out smelling of roses!!) **Photographs 74** and **75** show the apertures first being chain drilled and then finish milled. Whilst still held on the mill in this fashion a flat had to be milled $\frac{1}{16}$ inch in depth on the inner edge of the fixing flange. This, in fact, makes the two guides handed as these two flats allow the guides to fit together in the middle of the engine (fig 17 refers).

One of the remaining things was to counterbore the two holes in the bottom of each guide flange in order to clear the Allen cap heads of the screws securing the cylinder to the support plate. Of course, all the other securing screws that go through the crosshead guide flanges also do this as well, but this is incidental and these are put in afterwards. In addition there are two $\frac{1}{8}$ inch diameter holes, one each side of both crossheads for the oil cups.

These cups were easily made from $\frac{3}{16}$ inch square stock having a $\frac{1}{8}$ inch diameter boss turned on one side, which had a $\frac{1}{16}$ inch hole part drilled to connect with the oil reservoir. This was a $\frac{1}{8}$ inch hole drilled at right angles to a depth of $\frac{3}{32}$ inch.

●To be continued.

Initial drilling of the guide side apertures.

Milling the aperture profiles.

New Signals

Duncan Webster and his team fit colour light signals to Warrington's Daresbury track.

Let me start by saying that this is a joint effort between myself and fellow club members, Bruce Fairbairn and Paul Middlehurst. Some time ago (*M.E.* 4493, 17 October 2014) I described the semaphore signals we have installed at our track. These work off track circuiting and are fully automatic in operation. To briefly recap, the track is divided into sections; one rail is connected to ground and the other rail to the home signal control board. Between the rails is a 1k resistor and inside the home signal is a second 1k resistor connected to 5v, all as shown in **fig 1**. The connection line is thus normally at 2.5v, if a train is in section it falls to 0v and the control board puts the signal to danger. If the contact is lost the connection line rises to 5v and the control board sets the signal to danger with its lamp flashing. The distant is very similar but instead of a track circuit, the home signal switches the connection line to ground. The full article is at http://www.wdmes.org.uk/?page_id=1261

After a couple of teething problems, these signals have worked fine but as they are not weather proof, they have to be installed and taken down each running day. We are now planning to install more signals on our extension, so we have decided that the extra signals will be colour lights which we can leave out all summer, just taking them down for the closed season. This short article describes the trials and tribulations of what initially looked like a simple exercise. It is not meant to be a definitive 'how to build it' account but it might help others to not make the same mistakes. If anyone wants further details, contact me via http://www.wdmes.org.uk/

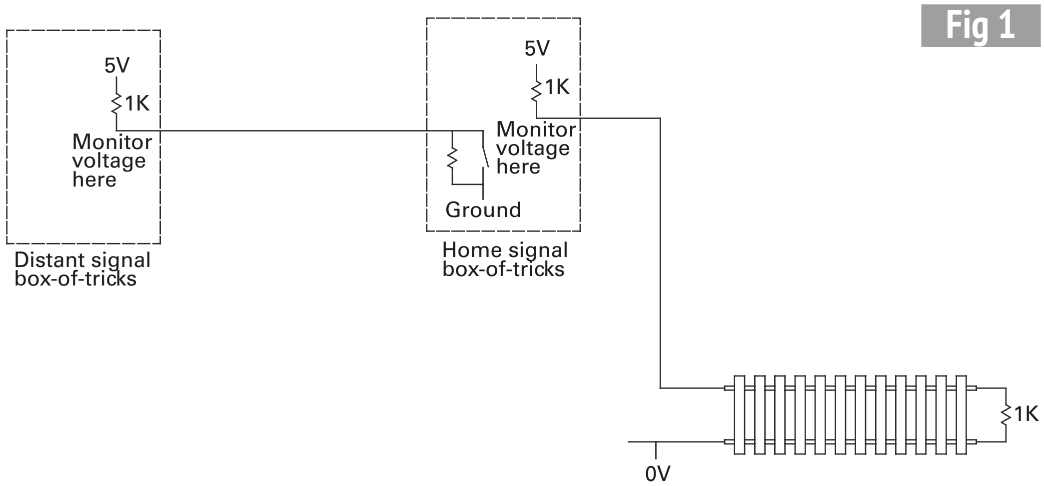


Fig 1

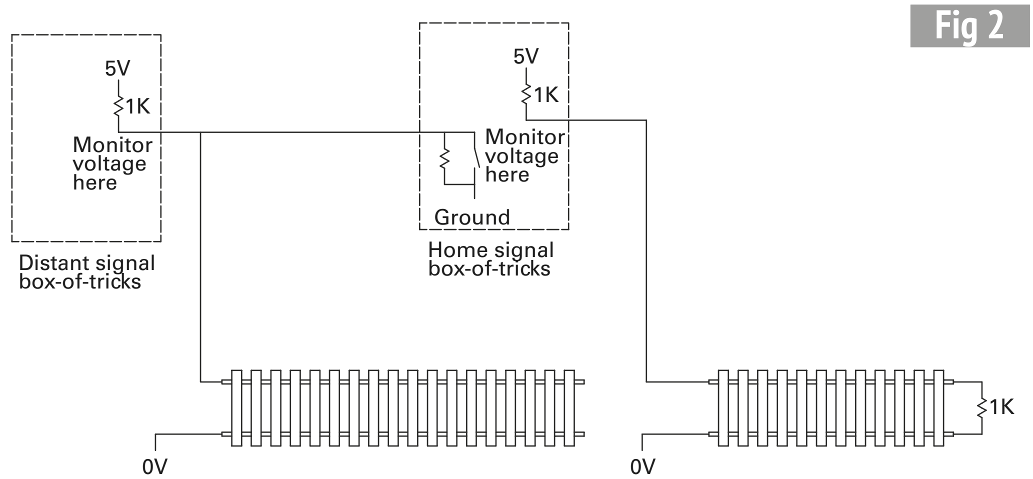


Fig 2

Experience with existing signals

As stated above we had a few teething problems: Firstly, the aluminium wire used to electrically connect the rails is very soft and seems to relax under the screws securing it to the track, at least the screws come loose over time and I doubt the screws are stretching. I've now tightened them all at least once and hope that the wire will have work hardened. We haven't actually lost connectivity but on the last section to be installed I used stainless steel welding wire, 0.8mm diameter. This is quite springy, so not as easy to get in place; if it proves successful, I'll make a jig to pre-bend it.

Second issue was my own fault but it took a long time to find. Between each track section we obviously need to isolate the rail joints. Actually we only need to isolate one side, as there is a common earth. One signal intermittently showed danger when the section in front was unoccupied. Of course, every time I took out a test truck it worked perfectly, so it was beginning to be one of those hair tearing issues (and I haven't got a lot left). Eventually I found that I'd isolated the wrong side but the very poor contact of aluminium fish plate with aluminium rail meant that most of the time it was isolated anyway, just occasionally it made contact. Moral is, get someone else to check it out, it's often the case that you don't spot your own mistakes.

The third issue was short battery life. As explained in the previous article, we do not have mains electricity and do not want to run the generator just to power signals. The semaphore signals take 220mA each all the time, the red LEDs in colour light signal used to indicate swinging link took 200mA each. The green and yellow took around 100mA each. We also found that the green cluster LED died completely when the battery got down to 10 volts but the reds carried on at full brightness, so, for those not familiar with the operation, it was tempting to assume there was a fault rather than changing the battery. Whilst investigating this, I found that the red LED has a built in voltage converter and will work down to very low voltages but as the input voltage goes down, the current drawn goes up; I had it at 800mA at one time. It was generally agreed that these LEDs were a lot brighter than needed.

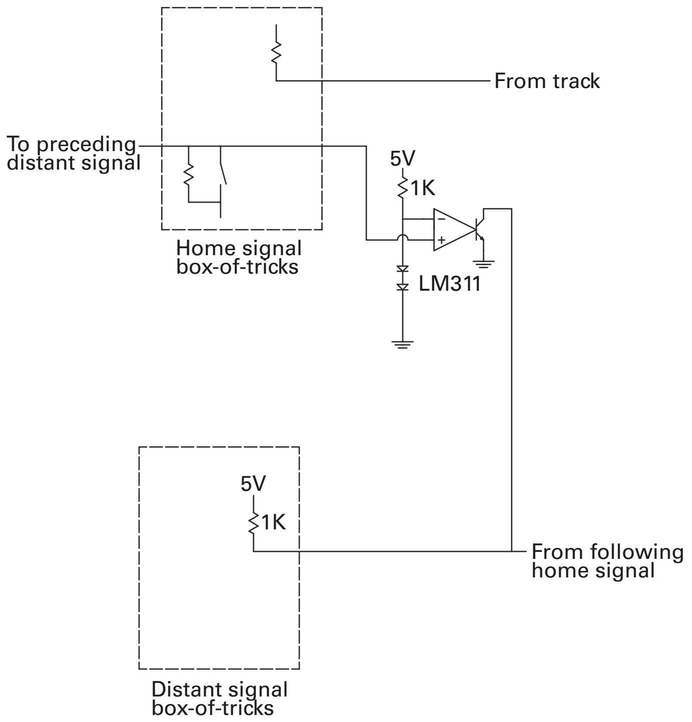
Fourth issue is that as we don't have continuous track circuit yet, the first distant could be showing clear when there was a train in section. Similarly, when there is a home and distant on the same post, the home could be at danger and the distant, clear. This is not how the big railway did it. The first was solved by track circuiting the section between first distant and first home and using this circuit to short the connection from home to distant to ground as shown in **fig 2**. Note there is no resistor across the track here, so loss of connection does not show up. The second will be solved by adding a small circuit board inside the distant signal junction box. The LM311 voltage comparator duplicates the action of the switch inside the home signal and puts the distant to stop if the home on the same post is at stop, no matter what the home on the next post is doing (**fig 3**).

Modifications to swing link signal

First thing to do was to replace the red LEDs. I couldn't find any 1 Watt MR16 red clusters, so I used six high brightness, 10mm diameter LEDs (**ref 1**) on a piece of stripboard. These are wired up as two sets of three in series, with a limiting resistor in each leg to limit the current to 20mA, 40mA total at 12.5v input. Owing to voltage lost in the control board (see later) the LEDs only see 11.1v max, 9.1v with flat battery. Due to the forward voltage drop characteristics of LEDs, running at 9.1v reduces the current to nominally 10mA each leg but they are plenty bright enough. I've also made it so that only one red shows for track occupied, they still flash alternately for swing link open. Current consumption is thus significantly reduced.

To indicate when the battery is getting flat, another of the Arduino inputs has been used to monitor battery voltage. If this drops below 10.5v, when the green LED should be showing it is made to flash on and off. I also fitted a piezo buzzer but although it seemed loud in my workshop, in the open air it is not easy to hear unless you stand next to the signal and will not be included in later versions.

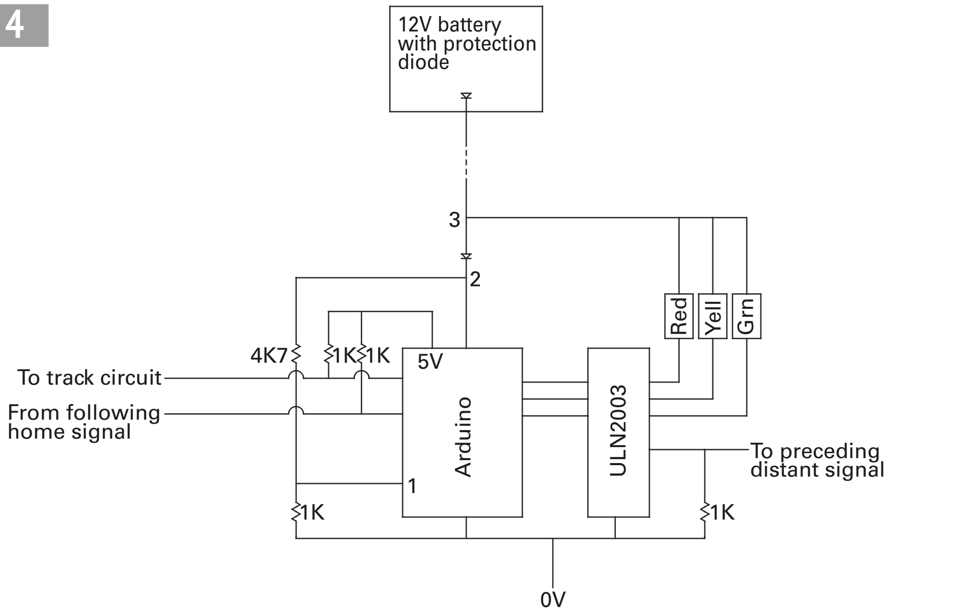
Fig 3



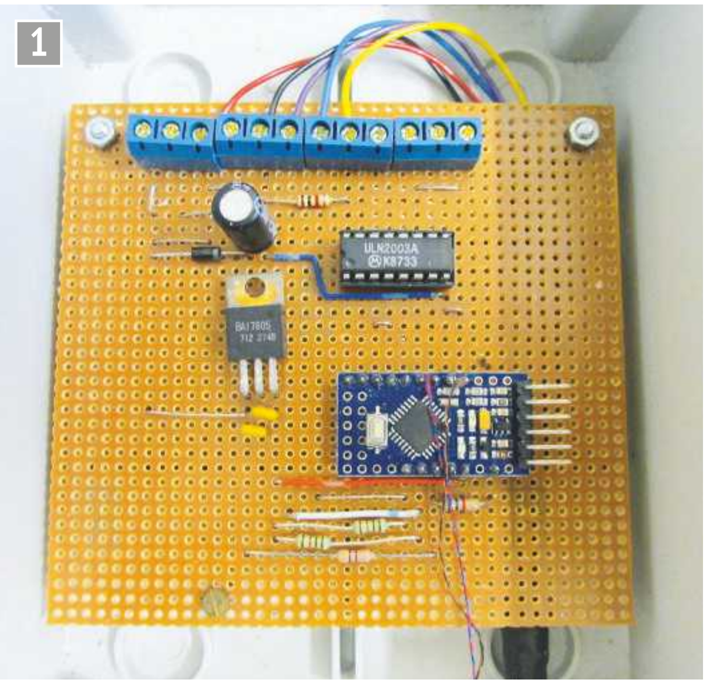
Control board

As the board doesn't have to drive the stepper motor this time, it could all have been done with individual chips but we'd need quite a few and a host of resistors, zenner diodes etc. It's all a lot easier with an Arduino, which costs about £2, less if you buy them in tens from China. The previous control board was a very good start but I altered the code quite a bit, not that there was anything wrong with Paul's code, I just like to do things my own way, then you learn something. The schematic (**fig 4**) is very similar to the

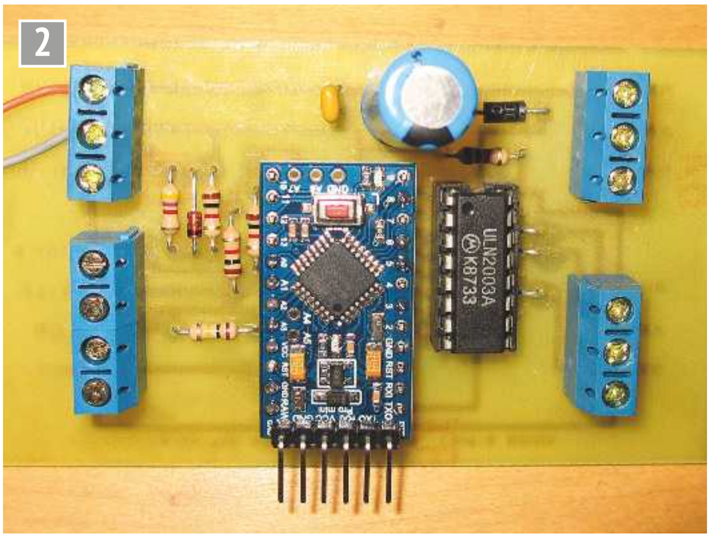
Fig 4



>>



The prototype board.



The production board.

semaphore board. Learning from the swing link, I've mounted the board in the back of the box and the LEDs in the front; it looks a lot less like a rabbit's intestines. **Photograph 1** shows the prototype and **photo 2** shows the production version on a bespoke pcb. It is a fair bit smaller. The (smaller) board layout and code are available from **http://www.wdmes.org.uk/?page_id=578**

Loss of voltage in control board

To prevent damage from connecting the battery the wrong way, the supply to the whole system is fed through a diode. This loses 0.6v. It could be replaced by a relay but this would be more complicated, more expensive and less reliable.

The outputs from the Arduino are amplified by a ULN2003 Darlington driver, this loses another 0.8v. It could have been replaced by logic level FETs, or even relays (wash your mouth out!) but it is a very neat package and standard with the control board for the semaphores. Thus with a 12.5 volt battery we have 11.1 volts available to drive the LEDs. With a battery down at 10.5v (we don't want to go any lower, it damages the battery) we have 9.1v

Characteristics of LEDs

The voltage drop across an LED does change with current but not like a resistor. For our purposes it can be approximated by a fixed voltage drop in series with a small resistor. At full current, the voltage drop for a single LED is about 2.1v for the red and yellow and about 3.4v for the green. When working out the series resistors, measure the forward voltage at the operating current.

If LEDs are used in parallel they should have some external load resistance to ensure they share the current.

Cluster LEDs Mk1

As the green and yellow cluster LEDs used on the swing link signal had been reasonably successful, our first attempt for this new signal was using MR11 1 watt clusters. The red and green were fine even with a low battery but the yellow was noticeably less bright and when the input voltage went down it died completely. It is not known why these greens were okay and the yellow were not. Current consumption on 12v was red 49mA, yellow 12.4mA, green 32mA.

These clusters have a 120 degree beam angle, so are easy to see from the side. This is not all that useful, as it means that the visibility is lower for a given total light output than it would be for a more focused beam. For a better description of this see John Lopez' article in *M.E.* 2009. Once fitted with a hood, a lot of this light spread is cut off and so wasted.

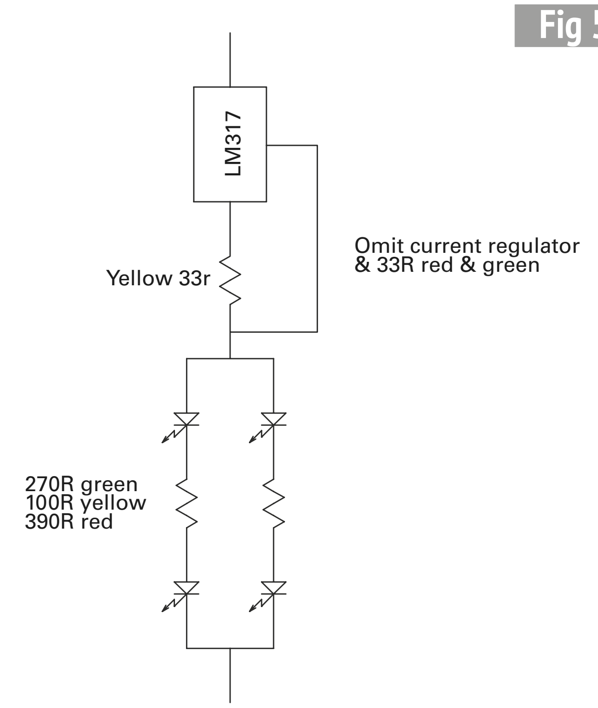
Cluster LEDs Mk2

We next tried clusters of white LEDs, the idea being to use pieces of floodlight filter material to get red/yellow/green. These appear to be 10 individual units, each having three LEDs built in. The filter material takes out a lot of light from the red and green, the yellow is okay down to about 10v, 11.4v at the battery. It does seem a shame to make white light (which isn't easy with LEDs) and then filter two thirds of it out. On 12v these units take 84mA.

Array of four individual LEDs Mk3

The swing link signal showed that we didn't need six LEDs, so I bought some more high brightness individual LEDs (**ref 1**) and arranged them in two lots of 2-in-series. When driven with the full 40mA, the red and green were blinding

Fig 5



but the yellow was noticeably less bright, this effect being more pronounced as the voltage dropped. What I have finished up with on yellow is a constant current source and a lower series resistor in each leg as shown in **fig 5**. This takes the full 40mA independent of supply voltage (until the battery is well below 10v) and the current sense resistors on red have been adjusted to give 10mA, giving the same perceived brightness as yellow. This didn't work on green; it appears the higher forward voltage drop doesn't leave enough for operation of the regulator. I have set the series resistors on green so that at full battery voltage the current would be 40mA but have the Arduino output a variable mark/space signal dependent on battery voltage to keep a constant 10mA average current. The method for working this out is given in **appendix 1**. The next batch will have this on reds instead of current control for simplicity.

The LEDs have a beam angle of 30 degrees (15 degrees either side of centre). The prototype assembly is shown in **photo 3**. The rubber band is temporary - it's a lot easier than four screws during development.

The only downside of this set-up is that the light is quite directional. This doesn't matter as you approach the signal, as being on rails constrains the beholder to be reasonably in line but when you draw up close to the signal it can be difficult to see which one is lit up, even with the inside of the hood white. I'm told that full size signals have an auxiliary side-facing lens for exactly this reason. If this proves to be a real problem, a lower powered diffuse LED facing sideways can be incorporated. To be pedantic, this side facing LED should be yellow, as failure of a single side facing red would give the false impression that the signal had changed. However, yellow is not as easy to see and LEDs are very reliable.

Array of four individual LEDs Mk4

We then found some LEDs advertised as 'suitable for use in signals' (**ref 2**). I doubt they meant railway signals. These are actually three LEDs in series in one unit, so the forward voltage drop is about 6v red and yellow, about 9v green, so the constant current arrangement used in mk3 won't work – again, there is not enough spare voltage to drive the regulator. The yellow is more like a traffic light (amber) than mk3 and the output is still okay at 9v even on green, which I don't fully understand (it might be that the mk1 clusters have a bridge rectifier built in, taking another 1.2 V out of the system). The complete array is shown in **photo 4**.

On full current the red and green are again brighter than needed and the spread of light is a lot higher than mk3, so the inside of the hood is well lit up. The downside is that each unit takes 30mA and there are four in parallel, 120mA total. If we eventually go down this route I will just accept the yellow getting slightly dimmer with reducing battery voltage and use the pulse width modulation (pwm) described above for red and green. Why not pwm the yellow you ask? If I set the series resistor to give full current at 9v and then the Arduino has a glitch and stops the pwm with the output 'on' and a fully charged battery it could burn out the LEDs. I think this is unlikely but I don't know how unlikely.

Enclosure

The enclosure in photo 4 is a IP56 box from Newey and Eyre, part number NLPE30A. As is often the case, it is the most expensive single component by far, all of about £5. If we use the mk 3 or mk 4 LEDs it is tempting to buy boxes with transparent lids and mount the LEDs inside - less chance of water getting in. The hoods are pieces of 40mm plastic waste pipe press fitted onto aluminium flanges. In the prototype I used some grey pipe I had in stock (junk box), production units will be white. For mk1 or mk2, the aluminium flange should be arranged to hold the clusters in place and support the filter material. As the beam angle on mk3 is quite narrow the mounting to the signal post must allow for rotation to be adjusted to point down the track and it works best to have the signal on the outside of a curve. I have a camera tripod on which I mount the box so it can be shuffled around for best position before concreting in the post.

An alternative answer to flat batteries

I then remembered that I have a 12v-24v step up converter which I bought to drive one of those ex radar blowers to use as a steam raiser. It wasn't powerful enough to run a motor but it's plenty powerful enough for these LEDs. It can be set to give 13.4v output (i.e. 12v at the LEDs) with any input voltage above about 5v, it's efficiency is about 60% with a 10v input - better with higher input volts. This might make mk1 or mk 2 viable but is not necessary with mk3 or 4.

The Mk 3 array.

The Mk 4 array.

Which one is best?

We've decided to make a trial batch of mk3. As the LED units are interchangeable, this is not irrevocable. As we have already got one set of mk4s we will use them as well. If you've got mains power, I'd go for reds and greens from mk1 and the yellow from mk2. It's a lot easier than making up the mk3 and 4 versions and current consumption isn't an issue. If you want to see them in action pay us a visit in Warrington.

Next step

With all the hype from the green lobby about renewable energy we've bought a solar panel. If this works out, we will have solved the flat battery problem. However, a trial installation in December, pointing straight at the noon day sun (okay … it was overcast) produced very little output. Watch this space; if it works I'll do a write up. Someone out there must have built a windmill but all those I can find on the web are too big. I know you can buy them for caravans and boats but they are not cheap. Otherwise I quite fancy a generator waggon. The big locomotive chaps can drag it round each running day and charge up the spare battery. Call it a dynamic test vehicle and they'll be queuing up!

Sooner or later the property developer next to our track will build houses and we will then try to get a mains supply laid on. **ME**

APPENDIX 1: HOW TO SIZE THE SERIES RESISTORS AND SET THE PWM OUTPUT

Sizing series resistors

Typical current vs. voltage curve for a red LED is shown in **fig 6**.

The forward voltage drop varies between 1.9v (V2) at 5mA ($I2$) to 2.05v (V1) at 30mA ($I2$). This can be approximated to a resistance in series with a fixed voltage drop. Resistance can be calculated as:

$$\frac{V1 - V2}{I1 - I2} = 6\ ohms$$

The fixed drop is then V1 - R x $I1$ = 1.87v. In most applications this small resistance can be ignored, and take the fwd voltage drop as 2v for red/yellow, 3v for green but when using several LEDs in series, the external resistance can become small, and the internal resistance becomes significant. For the Mk4 greens, the internal resistance was 66 ohms, fixed drop 8.5 volts.

To make this easy there is a routine on the spreadsheet. If you don't have a data sheet, just rig up a little test rig and measure it directly.

The reverse protection diode mounted on the battery drops 0.6v, and the ULN2003 Darlington driver drops another 0.8v.

Taking two red LEDs in series, with a 12.5 v battery, the voltage available to drive the current through the series resistor is 12.5 – 0.6 – 0.8 -2 x 1.87 = 7.36v. To get 20mA we therefore need 7.36/0.02 = 368 ohms. The internal resistance of the two LEDs is then subtracted giving 368 – 2 x 6 = 356 ohms. Select the nearest value above, which is 390 ohms. The power dissipation is 0.02^2 x 390 = 0.156W, so a ¼ Watt resistor will be fine.

Working out the PWM

The Arduino measures the voltage at point 1. It is a 10 bit Analogue to Digital converter; 5v would be read as 1024. Call the actual reading ADC.

$$V1 = \frac{ADC}{1024} \times 5$$

The the voltage at point 2 is:
V2 = V1 x 5.7
V2 = 0.0278 x ACD

and the voltage at point 3 is:
V3 = V2 + 0.6
V3 = 0.0278 x ADC + 0.6

Using the same values for voltage drops as before, the current through the LEDs is

$$A = \frac{0.287 \times ADC + 0.6 - 0.8 - 2 \times 1.87}{2 \times 6 + 390} = \frac{0.287 \times ADC - 3.94}{402}$$

we want the average current to be 10mA, so the fractional mark space ratio is

$$\frac{0.01}{A} = \frac{4.02}{0.028\ x\ ADC - 3.94}$$

The pulse width control outputs a value between 0 (off) and 255 (full on), so we multiply this value by 255. Using non integer numbers can give rise to peculiar results, so at the same time divide top and bottom by 0.0278 and round off.

$$pwm = \frac{36874}{ADC - 142}$$

put in some figures as a check, if the battery voltage is 11v,
V1 = (11 – 0.6)/5.7 = 1.825v
ADC = 1.825/5 x 1024 = 374
V2 = 10.4v as expected
V3 = 11v as expected

The peak current through the LEDs is (11 – 3.74)/402 = 0.0181A
The pwm value is 36874/(374 - 142) = 159
The average current is 0.018 x 159/255 = 0.011A which is near enough to 0.01A for me.
For green LEDs or different average current just alter the forward voltage, resistance and mean current values above, work out new values for 36874 and 142, and change the code accordingly.

There is a spreadsheet, *LED calculator* on the website which does it all for you. This gives the constants, K1 and K2 from the expression

$$pwm = \frac{K1}{ADC - K2}$$

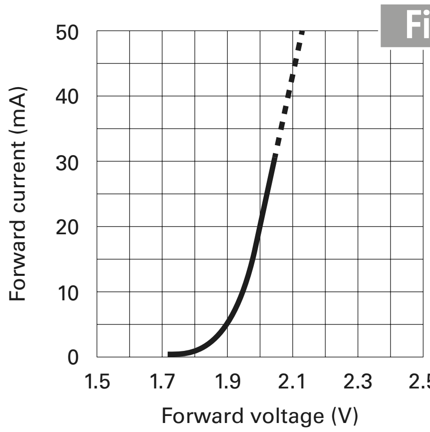


Fig 6

Forward Current vs. Forward Voltage

REFERENCES

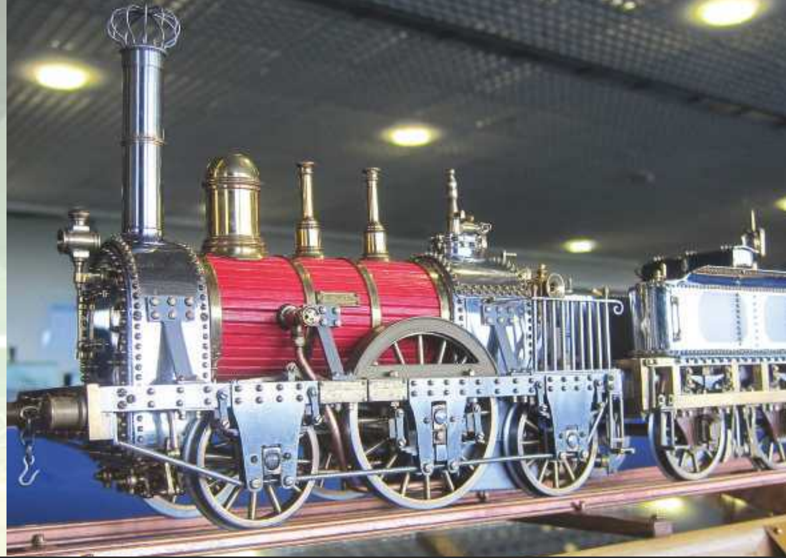
1. 10mm diameter, 30 degree viewing angle, at 20mA red = 8000mcd, yellow = 5000mcd, green = 12000mcd, obtained from *fusion_online* via eBay.

2. TruOpto OSR5M3Z4E1P red, OSY5M3Z4E1P yellow, OSG5M3Z4E1P green.

MODEL ENGINEER

MEX EXHIBITION

Since 1907



AN EXHIBITION OF TRULY INSPIRATIONAL MODEL ENGINEERING

BROOKLANDS MUSEUM

at the Birthplace of British Motor Sport and Aviation

16-18 SEPTEMBER 2016

World Class Competition
Clubs • Trade

Locomotives • Traction Engines • Aero Engines
Ships • Marine, Stationary Steam, I/C and
Hot Air Engines • Railway Layouts
Fairgrounds • Outdoor Live Steam

SMEE DEMONSTRATIONS and **LECTURES**

TICKETS INCLUDE ENTRY INTO BROOKLANDS MUSEUM AND THE LONDON BUS MUSEUM

Tickets are available online at
www.brooklandsmuseum.com
Telephone: 01932 857381 (ext 268)
Email: info@brooklandsmuseum.com

PRICES	In Advance	On the Day
Adults	£12.00	£15.00
Seniors	£11.00	£14.00
Child	£5.00	£6.00
Family	£30.00	£37.00

mytimemedia print & digital media publishers
www.mytimemedia.com
MODEL ENGINEER
MODEL ENGINEERS' WORKSHOP
BROOKLANDS MUSEUM

www.modelengineershow.co.uk

Making Gears for Wyvern

Roderick Jenkins mills helical gears in the lathe.

Edgar T. Westbury's Wyvern open crank internal combustion engine is typical of many of his designs in that the camshaft is driven by crossed helical gears, often called skew gears. As in most four stroke engines, the camshaft rotates at half the engine speed so the camshaft drive incorporates a 2:1 reduction. The skew gears give a convenient change of direction so that the rotation of the camshaft is at right angles to the crankshaft, allowing the camshaft to reach along the length of the engine to the cylinder head. These gears are generally available from the suppliers of castings for Westbury's designs; certainly in the case of Wyvern from Hemingway (**ref 1**). However, if, like me, you rather like making your own gears then there is an opportunity to learn another skill.

Commercial gears will usually be made by hobbing, a generating technique that will produce accurate gears that mesh correctly and should provide a smooth and efficient drive. Hobbing is possible in the home workshop but requires some rather specialised equipment that, in my case at least, is not really cost effective in terms of time or money for very occasional use. However, involute spur gears can also be milled using a set of cutters; a technique that was originally developed by Brown and Sharpe. A set of eight of these cutters covers the whole tooth range from about 12 teeth to a rack for a specific Diametrical Pitch

Table 1

No. of Teeth	Diametrical Pitch	Helix Angle		Pitch Diameter	Lead	Addendum	Whole Depth Tool	Outside Diameter	N. of Teeth for Cutter
N	DPs	a	a	PDh	L	S	W	OD	Nt
		degrees	radians	PD=N/DPs/Cos(a)	L=πxPDh/Tan (a)	S=1 / DPs	W=2.157/DPs	OD=PDh+(2xS)	N/Cos^3(a)
16	31.75	26.6	0.464	0.564	3.536	0.031	0.068	0.627	22
8	31.75	63.4	1.107	0.563	0.885	0.031	0.068	0.626	89

(or Metric Module). Clearly, there are compromises in being able to make a range of gears, which will have slightly differing tooth shapes, from a single cutter but it is possible to make satisfactory spur gears using this method. These cutters can also be used to make helical gears and, again, there are compromises to the perfection of the gears so made but for the sort of light duty work required to drive a model I/C engine camshaft they are perfectly satisfactory.

The various factors required to make helical gears differ from those required for spur gears because the helix angle needs to be taken into account. The Diametrical Pitch (DP) of a Helical gear equals the Diametrical Pitch of the nominal Spur Gear (that's the DP of the cutter we are going to use) divided by the cosine of the helix angle:

$$DPh = DPs \div Cos(a)$$

Consequently, the Pitch Diameter of a helical gear is given by

$$PDh = N \div DPh$$

where N is the number of teeth for the gear.

One of the advantages of helical gears is that they can mesh at any angle to each other. In the case of a right angle drive the helix angles of the two gears needs to add up to 90 degrees and the gears need to be of the same hand; that is, they are both left hand spiral or are both right hand spiral. As an example; let's have a camshaft at right angles to the crankshaft of an engine driven by a pair of 64 DP gears, both with a 45 degree helix. Cos (45 degrees) = 0.7071 and therefore for the 30 tooth gear:

$$PDh = 30 \div (64 \times 0.7071) = 0.663 \text{ inches}$$

Similarly, for the 15 tooth gear:

$$PDh = 15 \div (64 \times 0.7071) = 0.331 \text{ inches}$$

As can be seen from these results, a helical gear will have a larger pitch diameter than a spur gear of the same nominal DP, depending on the helix angle. This can lead to a, perhaps, surprising outcome: Say that we decided to make the perfectly reasonable decision to use a 15 tooth crankshaft gear with a 70 degree helix angle mating with a 30 tooth, 20 degree helix camshaft gear. The sum of the two helix angles comes to 90 degrees so they will still drive the shafts at right angles. In this case, for the 15 tooth gear:

$$PDh = 15 \div (64 \times Cos (70°)) = 0.685 \text{ inches}$$

For the 30 tooth gear:

$$PDh = 30 \div (64 \times Cos (20°)) = 0.499 \text{ inches}$$

The 15 tooth gear is bigger than the 30 tooth gear! From this it can be seen that there will be a pair of angles where the Pitch Diameters of two gears, one with twice the number teeth of the other, are the same. These 'magic' angles are 26.6 degrees and 63.4 degrees, a phenomenon that was used by E. T. Westbury in the design of his Wyvern open crank engine (although, at the time of publishing the design, he was somewhat vague about sourcing this type of gear; in the description of the similar but larger Centaur engine he suggested looking for motor car distributor drive gears).

The overall diameter for a helical gear is given by the pitch diameter plus twice the addendum or

$$OD = PDh + (2 \div DPs)$$

In order to make a gear we also need to know the lead of the helix: that is the distance travelled along the tooth by one revolution. The lead L = *(Pi x PDh)* divided by *Tan (a)* where a is the helix angle and Pi = 3.142. Finally, the depth of tooth is given by

$$W = \frac{2.157}{DPs}$$

When cutting a gear with a Brown and Sharpe type cutter we set the gear blank under the cutter which is at the helix angle and then rotate the blank with the correct lead. But which cutter do we choose? The various treatises on gear cutting I have consulted are either somewhat unclear on this or positively disagree. However, there does seem to be a consensus that an adequate gear can be made if we choose a cutter for the number of teeth given by dividing the actual tooth number by the cube of the Cosine of the helix angle:

$$Nt = \frac{N}{Cos(a) \times Cos(a) \times Cos(a)}$$

I found the easiest way to keep track of all these calculations was to use a spread sheet (**table 1**). Wyvern needs two gears of 32DP. It will be noted that my calculation uses gears of 31.75 DP. It has become customary to refer to Imperial involute gears by their Diametric Pitch (DP) and metric involute gears by the Modulus (MOD). Both of these gears, though, are of the involute form so they are directly comparable. 0.8 MOD gears are the same as 31.75 DP *(25.4 / 0.8)* which are as close to 32 DP as makes very little difference. High Speed Steel metric MOD cutters are available relatively cheaply from the Far East (**ref 2**).

Setting up

So, having all the information - how is it going to be put into practise? In industry a jobbing workshop would set up a universal milling machine with a dividing head on the table. The gear cutter would be mounted on a spiralling head set to the helix angle (or the table rotated) and the dividing head would be linked to the table drive with change wheels to provide the lead for the helix. The dividing head would be capable of being locked to the lead drive or freed to provide the indexing from tooth to tooth. None of these features are commonly available to the model engineer. However, amongst my tools I have a lathe, a milling spindle with driving arrangements, some dividing plates from my George Thomas Headstock Dividing Attachment and a swivelling vertical slide.

A screw cutting lathe is designed to link the rotation of the headstock to the lead screw so that can provide the helix and it would be possible to mount the cutter on a milling spindle and use the swivelling vertical slide to provide the helix angle. The indexing arrangements remain to be sorted out but the more important question at this stage was to determine whether it is possible to set up the required lead on the lathe. The maximum lead possible is restricted by the available change-wheels and the space to fit them on the quadrant.

My Myford Super 7 lathe has a quick change gearbox but is in fact a conversion so I have a large selection of change-wheels; the standard set plus additional gears for

1

Long lead gear train on the Myford.

metric screw cutting and then the metric set and quadrant for the gearbox. The length of leads required for cutting helical gears means that it is necessary to set up the largest gears as drivers and the smallest as driven gears (**photo 1**). A little experimentation showed that it was possible to set up 75,70,65 meshing with 21,20,20 on the gearbox quadrant. With the gearbox set to its coarsest thread of 8 tpi this change-wheel combination gives the maximum lead possible, just over 5 inches. I needed to work out the change-wheel train required to provide the leads for the two Wyvern gears. Fortunately, computers were able to help me by using so called 'brute force' methods to go through all the change-wheel combinations for a six gear train, looking for a result close enough to the lead it was asked to find. I wrote such a program many years ago (**ref 3**) and there are now several available to use on the internet. Tony Giffiths has a good one on his fascinating website at lathes.co.uk and the author has re-written his own as an Excel Visual Basic spreadsheet which is available for the asking via a personal message on the M.E. Forum (**ref 4**) or via the Editor. These calculators tend to be focused on finding a particular set of change-wheels for a screw pitch so it is worth remembering that the lead is simply 1 ÷ tpi. The calculators have an option to use screw-cutting gearbox ratios for those lathes fitted with a gearbox. On Myford Series 7 lathes with a gearbox the standard change-wheel set-up for thread cutting has a 1:1 ratio between the spindle and the gearbox. The gearbox therefore effectively adds another gear ratio of the selected thread divided by the leadscrew pitch or, if you like, is a variable pitch leadscrew. Other screw-cutting gearbox lathes may use a different ratio and this must be taken into account. For the 8 tooth gear the computer came up with an exact lead of 0.885 inch from drivers (28,65,75) to drivens (21,24,34) with the gearbox set to 9 tpi. For the 16 tooth gear lead of 3.536 inches the best match was (55,65,70) to (21,20,21) and the box set to 8 giving 3.547 inches. An 11 thou error in 3½ inches was deemed acceptable.

The next problem to be overcome was to index the gear from tooth to tooth. The gear blank needed to be held to cut a tooth then released to rotate the gear blank through the indexing angle and then re-gripped to cut the next tooth. In addition, some sort of indexing plate also needed to be held. My solution was to make a flanged collet to be held in the three jaw chuck, holding the gear blank and also holding a dividing plate from my HDA for direct indexing. Three jaw self centring chucks are very convenient but run out of 0.003 inch is deemed acceptable. This is fine for many jobs but is not good enough for cutting these small gears. However, repeatability is usually very good so I made the split collet with a stud that holds the collet against one of the chuck jaws and always used the same pinion hole to tighten the jaws. The chucking spigot and back of the flange were turned to size in the three jaw. After removal from the chuck the hole for the locating stud was drilled and tapped and the stud screwed in. The job was then reversed in the chuck so that the stud was snugly against the number one jaw and the chuck was tightened up using the marked pinion. The flange and plate register were made to size to suite my dividing plates. The through hole was bored and reamed 0.375 inch so that it was possible to use a ½ inch minimum diameter blank turned down to ⅜ inch to leave a 1⁄16 inch shoulder. The collet was then removed from the chuck and two saw cuts carefully made, along the length and across the diameter of the hole, so that the collet would close around the gear blank when the chuck was tightened. In use the chuck was tightened up using the same keyhole every time with the locating pin against the same jaw. The accuracy of the collet was checked by replacing it in the chuck and holding a piece of ⅜ inch precision ground mild steel which was inspected with a DTI at about 1½ inch from the collet. After removing, rotating and replacing the test bar several times the maximum run-out recorded was less than 0.001 inch. The gear blank was turned down to 0.375 inches for a 1 inch length. This spigot was then mounted in the indexing collet and the end turned to the gear blank diameter. Indexing was achieved using the specially made lathe carrier with indexing point which is shown, together with the collet, in **photos 2** and **3**.

The milling cutter was held on a No. 1 Morse taper arbor in an Arrand milling spindle which was bolted to the vertical slide. The plane of rotation of the cutter was set at the helix angle of the gear using the digital device shown in **photo 4**.

Involute spur gears can be milled using a set of cutters; a technique that was originally developed by Brown and Sharpe.

Split collet and indexing driver.

Another view of the collet and driver.

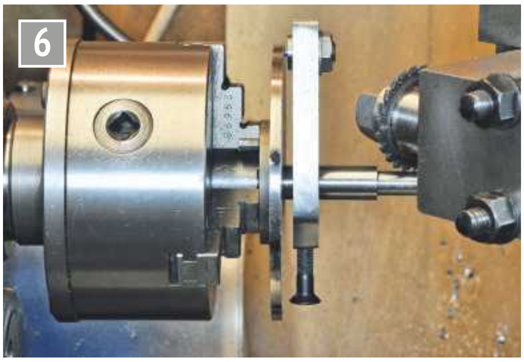
Setting the vertical slide to the helix angle.

Setting cutter to gear centre.

I found it useful when setting up the equipment to remember that a spur gear has a helix angle of 0 degrees. The cutter depth was governed by the vertical slide feed screw.

Before cutting metal the last remaining task was to set the centre of rotation of the cutter accurately above the axis of the blank. A length of precision ground ½ inch diameter mild steel was milled flat for one inch of its length to leave a D shape of exactly half of the diameter. This was then set up in a collet (or four jaw chuck) to run true and the flat set vertically with the aid of a square on the lathe bed. The cutter was advanced until it just touched the vertical face and the reading on the cross slide index was noted (**photo 5**). The bar was removed and the cross-slide used to advance the cutter towards the lathe axis a distance of half the cutter diameter multiplied by Sin(a) where a is the helix angle. The centre of the cutter was now exactly between the centres of the lathe. This method worked adequately for the 30 degree gear but for the 60 degree version the side rather than the periphery of the cutter touched the test bar. To overcome this I turned up a blank cutter that came to a sharp edge at the periphery and this is actually more accurate in use. Once the centre was found the cross slide was locked to prevent any inadvertent movement. The vertical slide was used to lower the cutter so that it just touched the gear blank and the reading on the index collar was noted (**photo 6**). This was then used to control the depth of cut. Photograph 6 also shows the indexing carrier in position and the collet stud snug against the chuck jaw.

Power to the milling spindle is supplied by a ⅙ HP 1425 rpm induction motor. A control box contains the motor capacitor, the on-off switch and the reversing switch. The motor is mounted on a half inch mild steel bar connected to a 2 foot length of ½ inch diameter mild steel bar mounted vertically on the lathe cross-slide. Connecting blocks with half inch holes drilled at right angles are used so that the motor can be mounted at any orientation using, if necessary, some auxiliary lengths of ½ inch bar. The drive from the motor to the milling spindle is provided by 5mm round urethane cord via a 5:1 countershaft to slow the cutting speed down to acceptable levels for the diameter of the gear cutter. The gear cutter is mounted on a 1 MT stub arbor in the milling spindle (**photo 7**).



Setting cutter to gear OD.

Milling spindle and motor drive.

The finished pair of gears.

Skew gears fitted to Wyvern.

Cutting the gear is straightforward. The cutting depth is regulated by the vertical slide. The lead-screw hand-wheel was used to wind the cutter clear of the blank and the required cut was put on using the vertical slide. The lead-screw hand-wheel was then used to slowly advance the cutter until the required length of gear had been cut. Once the process has started the lead screw clasp nuts must, of course, remain engaged throughout. There is a lot of backlash in these long lead gear trains so care was taken to only cut on the advancing movement, the cutter being wound up on the vertical slide before reversing. Failure to do this would have resulted in narrowing of the gear tooth. After taking a cut the blank was released by slackening off the chuck, indexing to the next position, ensuring that the locating stud was snug against the chuck jaw and that the blank was hard against the indexing plate, tightening up and taking the next cut. **Photograph 8** shows the pair of gears made for the Wyvern, in steel and brass.

Using this technique, usable small helical gears can be produced by milling. Theoretically, the gears may not be as good as those produced by hobbing but there are an awful lot of other approximations in the design and manufacture of gears yet they seem to work satisfactorily. Remember also that these gears do not have to deliver very much power in order to operate the cam gear. The important thing is that the timing is correct, so if they are less than perfect at transmitting power then this will not affect the operation of the engine.

The ultimate test was to install the gears in the Wyvern (**photo 9**). I'm pleased to report that they rotate smoothly together and the engine runs (**ref 5**). So, the resultant gears look right and they work. If you have a lathe with a milling spindle, a vertical slide and are already capable of milling spur gears then it is possible to extend the techniques to small helical gears. If I could contrive another gear pair into the set-up or, possibly better, a worm then we could get some really long leads … **ME**

REFERENCES

1. Hemingway Kits, 126 Dunval Road, Bridgnorth, Shropshire, WV16 4LZ (Usual disclaimer.)
2. ctctools.biz (Hong Kong). (Usual disclaimer.)
3. *Cutting Metric Screw Threads on Imperial Lathes.* R. F. E. Jenkins, *Engineering in Miniature*, November 1985.
4. www.model-engineer.co.uk/forums
5. www.youtube.com/watch?v=WS60rqETM5I

Garrett 4CD Tractor in 6 inch scale

PART 25

Chris Gunn starts to make the water pump.

Continued from p.733
M.E. 4534, 13 May 2016

This article has been written to guide the builder through the construction of the 6 inch scale Garrett 4CD tractor designed by Chris d'Alquen. The writer has previously built a 4 inch scale Garrett and a 6 inch scale Foden wagon so has the benefit of considerable experience in larger scale modelling. Most machining can be done in the average home workshop but the supplier from whom the castings and drawings are currently available is able to provide a machining service for the largest items if required.

This time we will make a start on the water pump, which is more complicated than that fitted to my small Garrett. The 4CD water pump is driven from an eccentric on a countershaft, which is in turn gear driven from the crankshaft so there are more components to make. I had seen a couple of completed 4CD models where the builder had incorporated a mechanism to disengage the gear drive so the engine could be run without the pump running. I decided to incorporate the same feature on my engine so some photographs were taken and I was able to modify the pump drive accordingly. The builder can make the pump drive as per the drawings, or adopt the dog clutch, which will be shown as a supplementary sketch next time.

The obvious starting point is the bronze pump body. The first move was to machine the back of the casting flat. I was able to hold the casting in the vice on the Bridgeport and flycut the back of the casting. Whilst the casting was still in the vice, I marked out the four fixing holes and drilled those from the back of the casting. The casting was flipped over and the holes spot faced. I then made a backing plate from an oddment from my scrap box, much bigger than the casting, with four tapped holes to secure the plate to the casting. I could then manipulate the casting as required to machine all the other features on the pump body. I bolted the casting onto the plate, fitted my swivelling angle plate to the Bridgeport and set the face square to the bed. The pump body mounting plate was clamped to the face of the plate and the casting bore set square as well. The pump bore is machined in three stages, the pump bore itself is ⅞ inch and this is counterbored 1⅛ inch for the piston gland, then the top section is bored 1⅝ inch for the bush that guides the pump piston. This means that the bush can easily be replaced when wear has taken place.

I started off by skimming the top face of the casting, then put the longest boring bar in my boring head, which just reached the bottom of the pump bore, and bored the casting to ⅞ inch. The counterbore for the gland was bored next. **Photograph 235** shows the boring under way.

Whilst the casting was still upright, I carried out some additional operations. There is a hole for a stiffener that is drilled and tapped between the top and lower sections of the pump body. I tackled this first, by machining the seating for the nut, as shown in **photo 236**.

Once the face was machined, I could then drill the hole through both sections. Then the two holes

Drawings, castings and machining services are available from A. N. Engineering: Email: **a.nutting@hotmail.co.uk** for the gland clamping screws were drilled and tapped. Thanks to the casting outer dimensions, I had to run an end mill down the sides of the casting to create a groove in the sides in order to get the drill to the appropriate spot. The holes were drilled and tapped using a centre to support the tap. This covered everything that could be dealt with in this position.

The casting was then clamped flat on the bed and the face where the pump gland would fit was machined (**photo 237**).

I decided to turn the pump gland casting next and fit that to the pump before I continued. I held the casting in the three jaw, faced it off and reamed the gland 7/8 inch diameter. Then I made a tapered pin nominally 7/8 inch diameter and tapped the gland on the pin and then turned the outside diameter of the gland to size. **Photograph 238** shows this underway.

To finish the gland off, I put it in the chuck in the spin indexer, centred it and drilled the gland mounting holes. I drilled one, spun the gland through 180 degrees and drilled the second. At this stage I also made the brass stiffener to fit between the two sections of the pump body and a stainless steel stud and fitted that to make the pump casting more rigid.

The pump body casting was then reclamped to the angle plate upside down and the base of the pump body machined flat. I also ran a drill through the base into the pump ram hole, just to clean it up (**photo 239**).

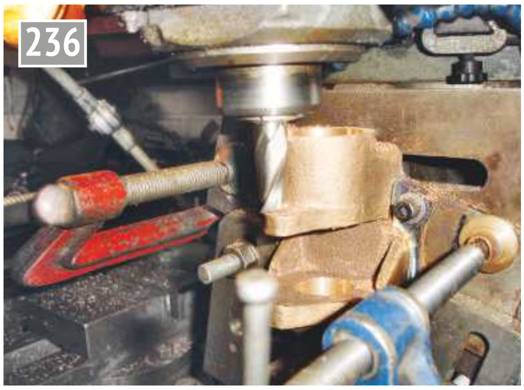
The next item to be dealt with was the pump valve body; again a bronze casting. The pump valve body is shown with a threaded boss to which the water feed pipe is connected via a tube nut. I decided to turn and thread this boss before any other operation, as I could hold the casting in the independent four jaw chuck, tightening the jaws onto the rough casting rather than a machined face which would be prone to damage from the jaws. I managed to get the boss running true and turned the boss and threaded it (**photo 240**).

The next step was to hold this in the vice. I now had the small face of the turned boss as a reference and I skimmed the joint face and drilled the four mounting holes (**photo 241**).

Then the main pump casting was held in the vice upside down, the pump valve casting clamped on top and the holes spotted through. They were drilled and tapped in the miller, using a centre to hold the tap square (photo 241),

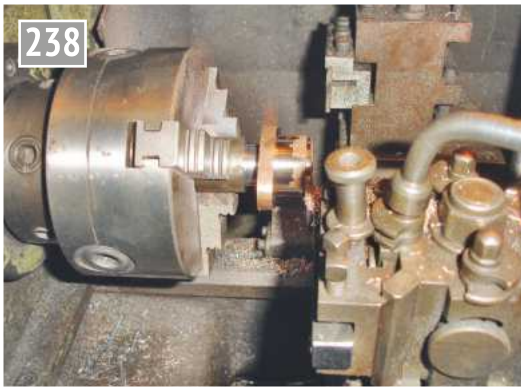
●To be continued.

Boring the water pump body.



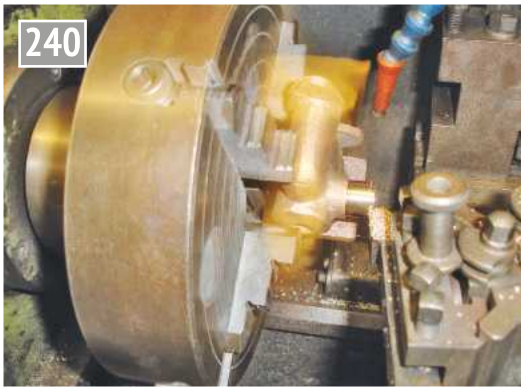
Machining the seating for the nut.

Machining the face for the gland.



Turning the pump gland.

Machining the pump body.



Turning the pump valve casting.

Drilling the pump body.

The Doncaster Show

The National Model Engineering and Modelling Exhibition

Diane Carney's first report from this established exhibition's new venue.

A splendid 5 inch gauge LMS/MR Black 5 took 'Best In Show' for Mr. D. Irvine.

As always, I was made very welcome at the new Doncaster Show where Lou and Gavin Rex and their friendly team had put on an excellent exhibition of model engineering featuring many of the 'northern' (particularly Yorkshire) clubs. The new venue proved very popular, offering, as it did, a good space with well laid out club displays around the perimeter of the room and a busy trade section in the centre; the show was, on the whole, as well supported by exhibitors and visitors as it always has been at the previous Harrogate venue. Club stands were packed with plenty to see, including - possibly due to the new venue - lots of models that I had not seen before together with some that it's always a pleasure to see year after year.

I will have a look at the club stands in my next report but for now I will bring you the competition results and start with the locomotives, which was probably the best attended class. (It has to be said that some classes, sadly, had not fielded the usual number of entries but this may be due to the new venue and exhibitors being a little unsure of access arrangements, etc.; now we know that it's very straightforward to get models in and out of this racecourse venue, perhaps a greater number of loan and competition entries will be forthcoming at next year's event.)

Whilst there was no presentation as such this time (I understand administration took longer than expected and the organisers were unable to stage an awards ceremony) the 'Best in Show' award was given to D. Irvine for a 5 inch gauge Class 5MT in BR livery. It's a lovely model of 44778, a 1947, Crewe built locomotive (**photo 1**). If there were any judges notes I am afraid I overlooked them so cannot bring you any more detail of the model. There were a dozen entries judged in the class and Mr. Irvine's locomotive certainly overcame some stiff competition.

Three further 'First Certificates' were awarded. A 7¼ inch gauge GWR 0-6-0 Collett tender engine has been a joint project between David Aitken and Pete Thomas (of Polly Engineering). The model (**photo 2**) represents the sole

GWR/WR Collett 0-6-0 tender engine, No. 3205 by Pete Thomas of Nottinghamshire.

The very accurate backhead of the 7¼ Great Western engine.

surviving example of this class, No. 3205 which, with its sister 3204, was a Gloucester engine almost all its days until eventual withdrawal from Templecombe in May 1965. Its present home is, I believe, the South Devon Railway. The class, which numbered 120 in total, were to be seen all over the GWR system being useful for short distance passenger trains and all kinds of goods trains. The model will prove a useful passenger hauler and this prototype example was beautifully finished with a very finely detailed backhead (**photo 3**) complete (I was told) with a copy of the *Beano*! (I was reminded of Alan Crossfield's copy of the *Daily Mail* in the tender of his Patriot at the 2014 MEX; maybe promotion on the Western Region was more rapid than on the Midland?).

Speaking of Alan Crossfield, it was a joy to see a Bolton engine on the competition stand! Alan, a resident of Horwich and a member at Leyland SME, had completed an LNWR 2-4-2 Radial Tank locomotive that had been started by a fellow club member, the late Tommy Withnell who had sadly passed on after getting the engine to a rolling chassis stage. Alan chose to depart from the usual finish as described by the model's designer, Martin Evans who modelled the first of the class (No. 1008 as residing in the National Railway Museum) by creating the very last of the class to survive in service, British Railways number 50850. This locomotive was a long bunkered, Belpaire boilered version with many differences from the class prototype and which required a considerable amount of research to recreate accurately. Once again, Alan has completed a beautiful model of an unusual engine and in only four years (**photo 4**).

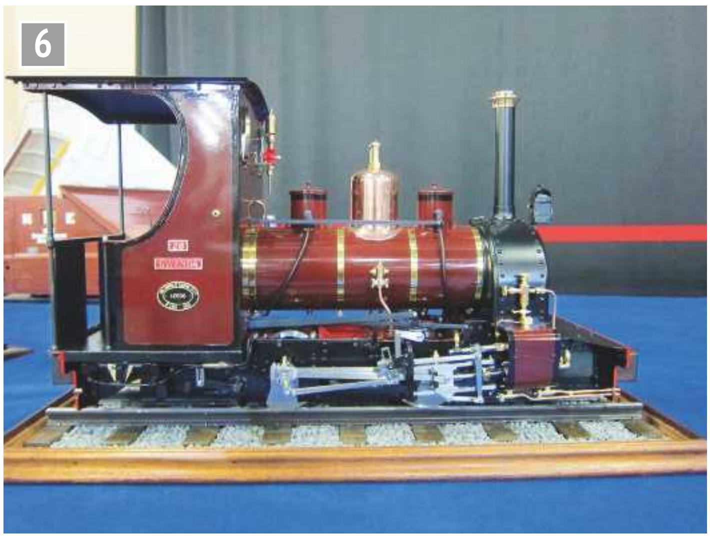
Alan Crossfield's beautifully finished and nicely presented 5 inch gauge LNWR 2-4-2T.

Finally, one more First Certificate in the locomotives section was awarded to B. Hatfied for a beautiful 2½ inch gauge Hunslet narrow gauge well tank (**photos 5** and **6**). I am going to take a guess that this is the same Mr. Bernard Hatfield who won a Second Certificate in 2014 with a model of *Lion* and also a 2 inch scale horsedrawn Farsley fire engine (*M.E.* 4484, June 2014). This little well tank was built from original Hunslet works drawings No. HE22695 and I *think* it is a model based on a prototype that was built in 1920 (although the model's maker's plate says 1918) of an 18 inch gauge locomotive named *Gwen* and which worked along with *Jack* - presently of Armley Mills Museum, Leeds - for John Knowles & Co. clay processing works in Leicestershire. Whilst it is certainly a faithful model of a prototype, its identity is possibly partly fictitious. As the photographs show it was very well deserving of its First Certificate.

Next time I will look at further prize winners and take a tour of some of the club stands.

●To be continued.

Mr. B. Hatfield's 0-4-0 Hunslet well tank.



The well tanks occupy much of the front end of the locomotive, beneath the smokebox.

Steam Turret

John Alexander Stewart explains how he used CNC to produce components for his Shay.

1

Completed turret awaiting painting, fitting and hydro testing. Connections on the left are for pressure gauge and lubricator; on the right is the hole for the holding bolt and the tapped hole for injector steam valve.

For my 3½ inch gauge Shay geared locomotive, I have once again veered away from Kozo Hiraoka's plans. I want to experiment with a steam operated lubricator as shown in these pages by Keith Gammage (**ref 1**) and others and I would like to try injector manufacture to the inspiring writings of authors Brown, Bramson and Lawrence (**refs 2**, **3** and **4**).

To fit the pressure gauge, injector and lubricator, I needed to create a turret with three connections, one facing the operator and two tucked out of the way in the front of the cab. The turret would fit to the boiler by a stout 8mm custom made bronze bolt, into an integral banjo fitting in the turret. **Photograph 1** shows the completed turret, ready for trial placement, piping and hydrotesting. On North American full size locomotives, turrets would supply dry, saturated steam for many of the appliances such as dynamo, injectors, pressure gauge, hydrostatic lubricator, air compressors, steam heat for passenger trains, oil burner atomizers … just about anything steam operated other than throttles and water level gauges. Turrets had a large valve handle allowing shutting off of steam to the turret and thus to all of the piping and valves extending to the appliances. Larger locomotives often had the turret placed outside, immediately in front of the cab under a sheet steel shroud, with valve spindles extended back into the cab, labelled, for ease of operation (look online, for instance, for Canadian National 4-8-4 pictures, or of New York Central 4-6-4s to see these shrouds).

As with most of my CNC work for this locomotive, I used 2D CAD to draw out the turret – 2D CAD is quick and simple and gets the job done. The turret is made in two parts - a top and bottom - which when silver soldered together, contain interior passages allowing pressurised steam to get to where it needs to go. **Figure 1** shows the CAD drawing, with two 'boomerang' shaped parts drawn in light blue. Cut into the interior are:

1) red - for a passage to get steam from the banjo fitting to the lubricator and pressure gauge

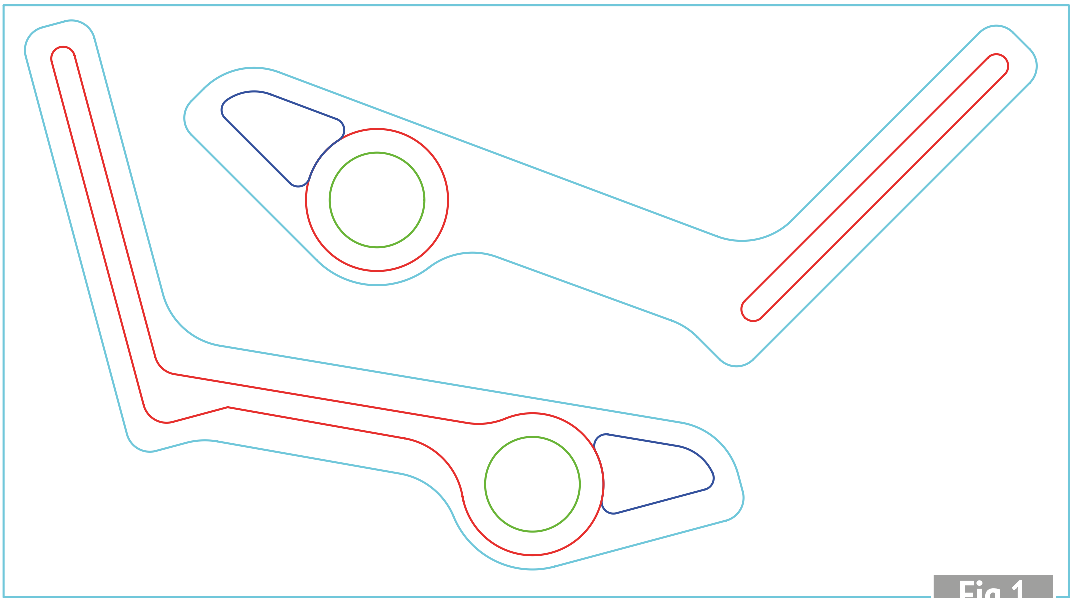


Fig 1

Brass sheet being cut with a 3mm endmill; air jet used to clear away swarf.

Finished cutting outlines and interior passages. Requires cleaning up and separating by skimming material off of the underside, leaving parts and remaining support material interconnected by holding tabs.

2) dark blue - a cavity for the injector steam valve and
3) green – a through-hole ('banjo fitting') for the attachment bolt.

Astute readers will notice that as steam follows the red passage (when the two halves are silver soldered together) from the banjo fitting through only the bottom half, it ends up in a long cavity that is cut in both top and bottom. This path routing allows for some further CNC work on the top to reduce the height somewhat, as described below. Overall thickness when complete is 10mm.

Photograph 2 shows the cutting in progress with a 3mm endmill and **photo 3** shows the results. I do use an air blast to clean the brass swarf away. The blue/orange Loc-line in the first picture is attached by a magnetic base, with an air-line coming from my air compressor. This compressor is noisy so I do use ear protectors. If I am comfortable with the progress of the cutting, I will leave the basement workshop and do a mundane task such as the washing up or other simple house tidying, always within a few steps in case of issues. The outline was cut to a depth of 5mm, in a piece of 6.35mm (¼ inch) brass. If you look closely again at photo 3, you can see the passages (depth 1.6mm) and both halves of what will become the banjo fitting, as well as the cavity (depth 3.5mm) where the steam valve for the injector will attach. There is some flashing apparent between this cavity and the banjo fitting hole that needed to be removed and this flashing is visible in the photograph. To release the two parts, the section of brass was mounted cut-side-down in a milling machine vice and a 1.35mm skim (made in multiple passes to minimize cutting forces) taken off of the back. I had added 'tabs' during the CAM operation to hold the parts to the parent material, so I was left with the outline of the parts easily seen. (I should add that my vice jaws were long enough that the clamping force went through the section which was uncut, otherwise I would have attached it directly to the table with either clamps, soft solder, or glue).

A little bit of hacksawing through the holding tabs followed by a quick filing finished the job. The two halves are shown in what will be their final resting place on the boiler of my Shay in **photo 4**.

Trial placement of the turret, just after separation from support material.

Silver soldering took place outside in a beautiful sunny, but cold Canadian winter day, with my soldering platform at about knee level because of the winter snow pack. (Tip: hot dropped parts cool quickly as they vaporize their way through the snow - but finding them again before spring can be problematic!) The two halves were lightly centre popped to keep a small sliver of clearance, fluxed, bolted together with an M8 bolt (not too tight, not too loose, but tight enough to keep the halves from moving when the flux becomes liquid when heating) and about 10mm of 1.6mm silver solder laid on the seam on a horizontal section and heated. The silver solder flowed beautifully and on cleaning in my citric acid bath, showed that it had completely filled the seam all around and inside of the banjo fitting cavity. Ensuring adequate clearance by centre popping the mating surfaces, chamfering the edges and cleaning in a citric acid bath are keys to successful silver soldering.

I wanted to reduce the height in the centre section of the turret for aesthetic purposes. As mentioned above, the red interior passage as shown in fig 1 only went through the bottom half of the turret. To reduce the height slightly, I took my original CAD file, selected key bits of it and created two different output files. The first file contained

The completed part, while not being super-detailed, will fit in well with the rest of the locomotive. Like a brush stroke on a French Impressionist painting, each part may not exude perfection but the sum of the parts makes the completed project really shine.

>>

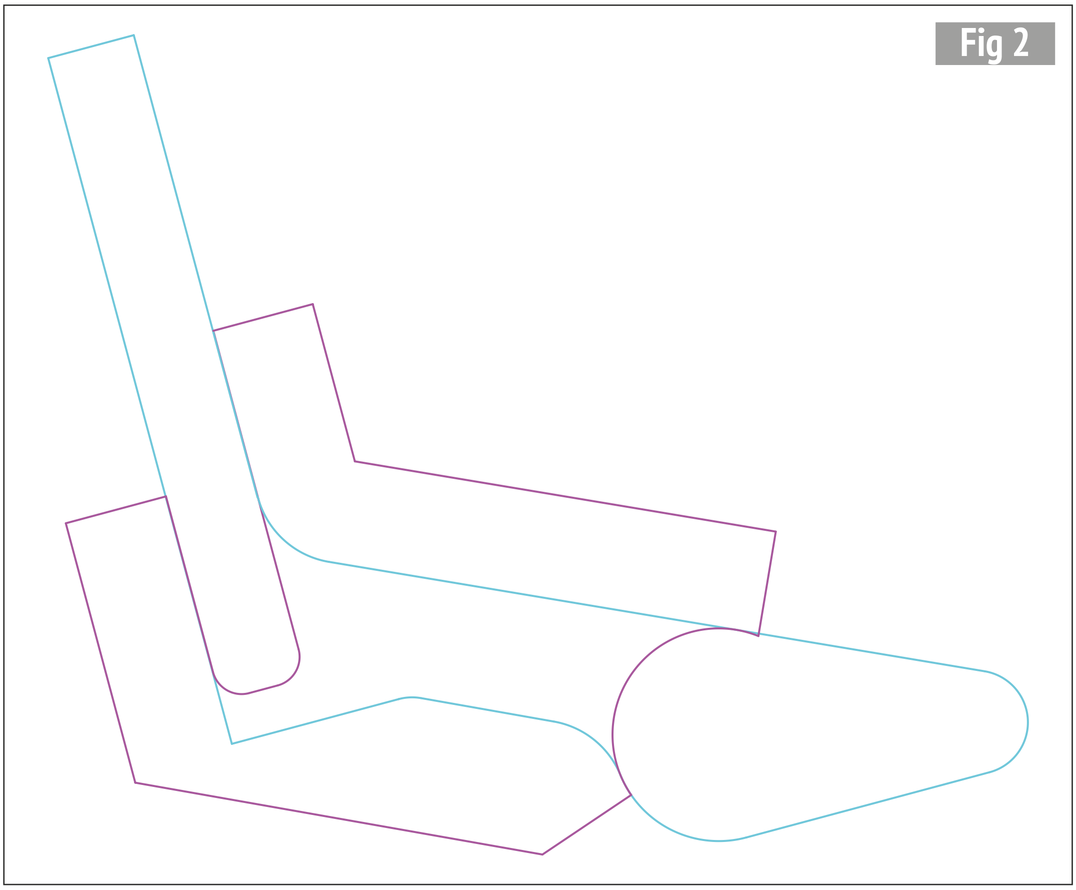
simply the light blue outline of the top but with some of the corners stretched out for ease of fitting (see below). The second file consisted of two radiused corners, joined by straight lines, to create a pocket for reducing the middle by 1.5mm in height. **Figure 2** shows the quickly drawn pocket in mauve, with the original blue outline kept for clarity. These border lines were placed far enough away from the desired cut area such that the CAM operation would move the milling cutter into position, but not too far away that extra moves were created. Still, for at least half of the running time, the endmill was 'cutting air'. Any corner or radius that does not matter is left simply as straight lines, so the CAD work can be accomplished quickly.

Both files were run through my CAM program to create G-code files. A bit of scrap aluminium was bolted to the table (**photo 5**) and the outline cut in it, to a depth of 1mm. I use a program called 'CamBam' to turn my CAD drawings into machine code and CamBam allows you to specify a 'roughing clearance' - I added negative 0.05mm as this clearance, which meant that it actually rendered the cut *oversize*. In **photo 6** you will see the turret bedding down within this pocket. I did need to spend a few minutes lightly filing the high spots on the interface where the turret beds, to allow it to bed snugly into this cavity. I used a 6mm endmill and I extended some of the radiused ends as mentioned above, as there would be more than enough material to ensure a snug and accurate fit.

Photograph 7 shows the 1.5mm deep aesthetic cuts in the centre section taking place. Yes, there are four clamps here; two to hold the aluminium jig down and two to hold the turret to the jig. Experience has taught me that, with this many clamps in a small area, extra care must be taken to ensure that the clearance height is set in the CAM program so that rapid moves between cuts does not drive the endmill or spindle into a clamp. Some of my clamps have witness marks as I had placed them too close to the cut line such that the endmill holder collided. Eagle-eyed readers might be able to see a blemish on the right clamp in photo 2 where such a grazing took place on a previous job. Photograph 1 shows the completed item with two steam take-offs for the pressure gauge and lubricator on the left, the M6 x 0.75 inch threaded hole for the injector steam valve is on the right.

For those interested, the software used for this project is 2D CAD ('QCAD, **ref 5**),

Fig 2



5

For the second CNC operation, a bit of aluminium was used to create a pocket to hold the embryo turret for further machining. Creating a pocket this way keys the part to the table such that it is automatically aligned for further CNC machining.

6

Turret bedded into the pocket. The pocket does not trap 100% of the turret but holds enough securely and in alignment. On the bottom left and right hand sides one can see that the pocket extends past the turret. This simplified the need to accurately de-burr the entire bottom of the turret.

Second CNC machining operation. An aluminium jig is held to the table by two clamps; a further two clamps holds the turret to this jig. One can see that the radii cut in this second operation closely match the radii of the first cut.

CAM (CamBam, **ref 6**), the machine controller (LinuxCNC, **ref 7**) and a small Sieg KX1 CNC Mill that was sold without the CNC stepper controller. I subsequently completed this mill with a dedicated computer containing a Mesa 5i25 FPGA interface card driving a Gecko G540 (**refs 8** and **9**) allowing impressive repeatability and table movement speed when required. Currently the 'rapids' are set to a maximum of 40mm of table movement per second, but cutting feeds are, of course, dependent on material, tooth loading and part rigidity.

Was it worth the bother?

Should I just have soldered bits of pipe together or gone to the other extreme and used 3D CAD and had the turret 3D printed? Certainly, there are many ways to manufacture parts. I am happy with this result as it was optimal use of my workshop time. The completed part, while not being super-detailed, will fit in well with the rest of the locomotive. Like a brush stroke on a French Impressionist painting, each part may not exude perfection but the sum of the parts makes the completed project really shine.

●To be continued.

REFERENCES

1. *Simple Hydrostatic Lubrication*. Keith Gammage. *Model Engineer*, 9 April 1999, pages 432 - 434.

2. *Miniature Injectors Inside and Out*. D.A.G. Brown. TEE Publishing Ltd. ISBN 57611349. www.teepublishing.co.uk

3. *All You Need To Know About Miniature Injectors and Ejectors*. Bob Bramson, C.Eng., MIET. Taunton Model Engineers. www.tauntonme.org.uk

4. *Laurie's Standard Live Steam Injectors*. D. E. Lawrence. *Model Engineer*, 4 April 1986 through 17 October 1986.

5. *QCAD – 2D CAD for Windows, Linux and Mac*. Andrew Mustin. www.qcad.org

6. CamBam. HexRay Ltd. www.cambam.info

7. *LinuxCNC*. Various Authors. www.linuxcnc.org

8. Mesa 5i25. http://mesanet.com

9. Gecko G540. http://geckodrive.com

PART 25

Internal Combustion Theory and Practice

Ron Wright, a retired technical college teacher, provides an in-depth course in I/C.

Continued from p.437
M.E. 4530, 18 March 2016

I've always thought that one of the most significant sayings in model engineering is that originated by the late L.B.S.C.; 'you can't scale nature' and I've come to regard this as being of special importance in the design, construction and operation of small I/C engines, where the working principles are exactly the same as those applying to full size engines. This forms the basis of this article which I hope will be useful and informative to readers who have a particular interest in I/C, especially those just starting out in our hobby.

Principles of S.U. Constant Vacuum

In all fixed choke carburettors the choke waist depression varies in proportion to the speed of the air passing through it; i.e.:-

High air speed - strong depression (low pressure)

Low air speed - weak depression (higher pressure but still less than atmospheric)

In constant vacuum carburettors the choke waist depression is maintained at a constant strength and the fuel supply is regulated mechanically by a tapered needle moving in a jet.

Design of S.U. carburettors

The diagram (**fig 177**) shows a schematic cross section of a S.U. carb' where the construction can be seen to consist essentially of a straightforward air intake tube, having a free moving and vertical choke piston fitted across it, which extends downwards from a large diameter vacuum disc housed within a sealed vacuum chamber.

A small hole (7) at the base of the chamber allows atmospheric pressure to act beneath the vacuum disc, and an exhaust hole (8) in the back of the choke piston allows air to flow from above the disc,

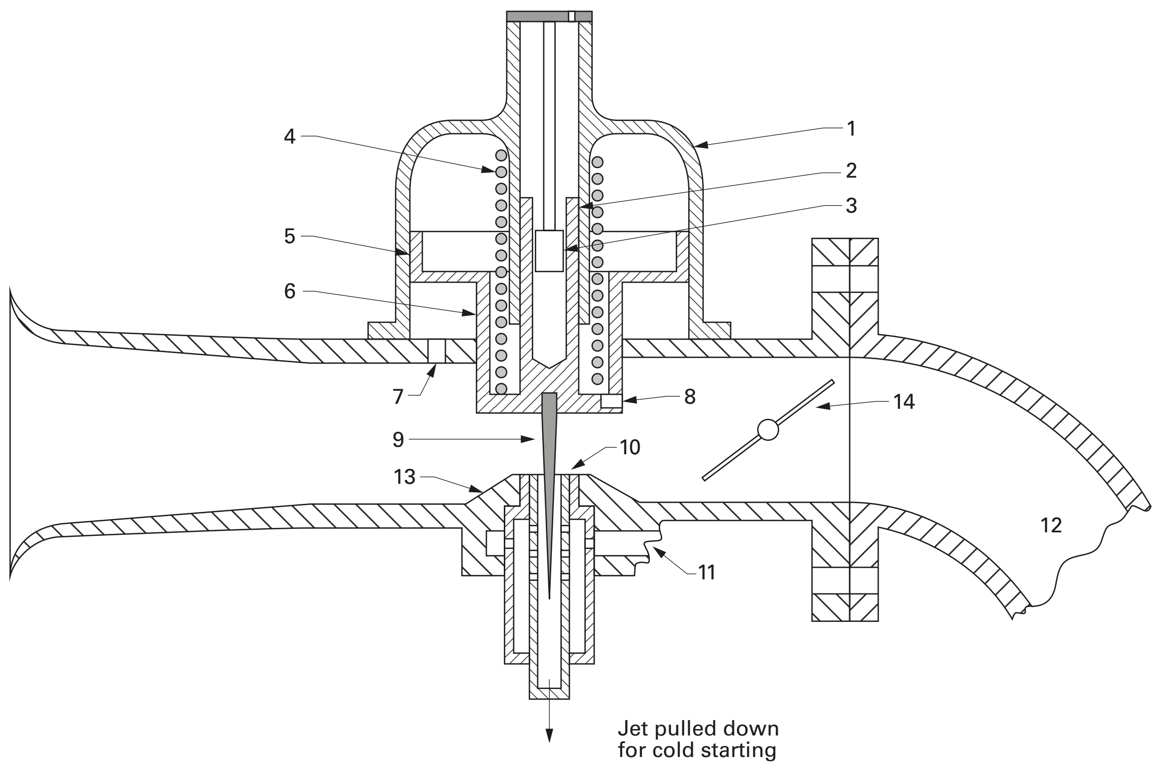


Fig 177

1. Vacuum Chamber
2. Piston Guide Rod
3. Damping Piston
4. Piston Return Spring
5. Vacuum Disc
6. Choke Piston
7. Atmospheric Air Hole
8. Exhaust Hole
9. Fuel Control Needle
10. Fuel Jet
11. Fuel Inlet
12. Inlet Manifold
13. Metering Bridge
14. Throttle

drawn out by the airstream passing into the engine.

Control of the choke piston's vertical movement is provided by a light return spring (4) and a simple hydraulic damper piston (3) located within the hollow piston guide rod (2) which contains a small quantity of light oil.

When in the fully down position (engine stationary) the choke piston rests on the metering bridge (13) which forms part of the venturi when the piston rises (engine running).

Operation

As air flows through the intake tube towards the manifold depression which exists down stream of the throttle, it causes air to be exhausted from above the vacuum disc.

Note: it is the passing of air (towards the engine) which creates this exhaustion and not the manifold depression which cannot act directly on hole (8) owing to the presence of the throttle butterfly which isolates the depression from regions upstream of the throttle.

The underside of the disc is in communication with atmospheric pressure via hole (7) which causes the choke piston to rise against the combined forces of its own weight and the light spring (4).

Note: the piston height is directly proportional to the mass air flow through the intake tube; ie :

High mass flow - piston up
Low mass flow - piston down

With the piston up a choke waist (venturi) is formed between the metering bridge (13) and the underside of the choke piston, which causes a depression to be formed exactly above the fuel jet.

Also the area of the waist varies in sympathy with the mass air flow; therefore the depression above the jet remains constant.

Fuel regulation

The tapered needle (9) extends into the jet and rises and falls with the piston; hence:

High mass air flow, needle up, increased jet area, increased fuel flow, and vice versa.

The jet diameter, needle profile and spring strength are determined by test bench and road test research.

Cold starting

The jet is pulled down from the needle by a manual 'choke' control (not shown) which increases the jet area to supply a rich mixture.

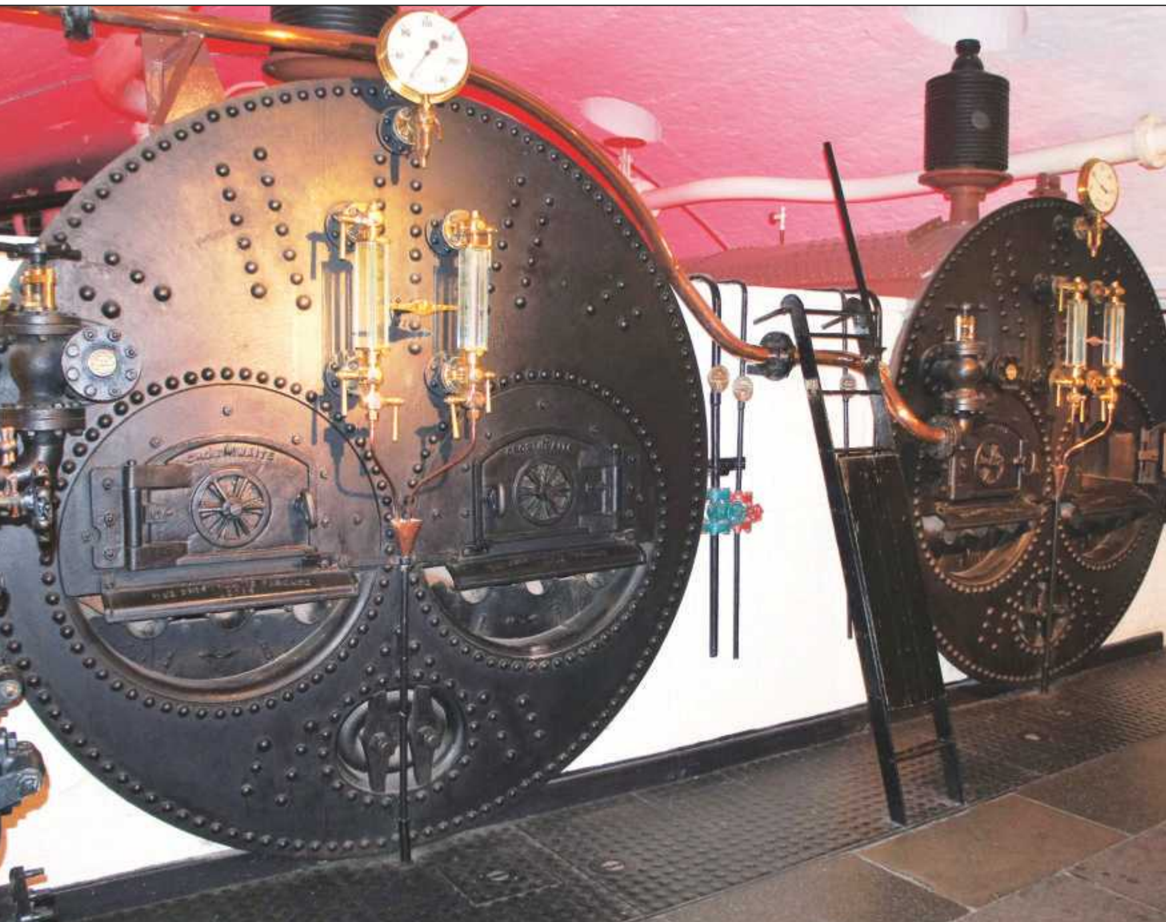
Acceleration

A rod fixed to the blanking plug at the top of the vacuum chamber extends down into the guide rod (2) which is hollow. A small piston (3) is fixed to the end of the rod and is a loose fit in the guide rod bore. A small quantity of oil in the hollow acts to damp the movement of the air disc.

Consequently on sudden throttle opening the choke piston is prevented from flying upwards and moves only slowly; i.e. out of proportion to the air speed. Therefore a strong depression is created over the jet (fast airspeed and small venturi area) which supplies a rich mixture for acceleration.

●To be continued.

NEXT ISSUE



- **Engineer's Day Out:** Tower Bridge
- **INDEX to volume 216**
- **A Perfecto 7 inch Powered Shaper:** Analysis and Use
- **Barclay Well Tanks of the Great War**
- **Halstead**
- **A New Design Miniature Magneto**
- **The Free Energy Fallacy**

Content may be subject to change.

ON SALE 24 JUNE 2016

PART 4

Compression in Steam Engines - Good or bad?

Inchanga continues his look at the mechanics of steam within a cylinder.

Continued from p.723
M.E. 4534, 13 May 2016

This topic is one that is often talked about but no clear answer has as yet been found in the model engineering fraternity. The traditional double acting steam engine has been made in many different types and utilised various types of valve gear, some of which are better than others. To understand the topic fully we have to go back to basics.

Watt's many other improvements included the spring loaded safety valve; centrifugal speed governor; his genius invention - Parallel Motion - which was a linkage that enabled the piston rod to remain aligned with the vertical cylinder, necessary, of course, in a double acting engine; external vacuum condenser; steam jacketing and thermal lagging of the cylinder to reduce condensation of the steam. Watt also invented proper pistons and piston rings to give good sealing. Early atmospheric engines had had rope wrapped around the piston groove and kept steam tight by pouring water into the top of the open cylinder. In Newcomen's engines the piston was often made of wood which expanded and contracted with heat and water and from rubbing on the rough cylinder casting, leaving a gap of one-eighth of an inch between it and the cylinder bore, which caused major leakage of air and steam. This caused a major loss of efficiency. Methods to solve this problem included leather washers and using wood for the cylinders. But skilled artisans to make such items were in very short supply in England. John Wilkinson then perfected a boring machine so that large cast iron and brass cylinders could be properly bored giving a truly round and smooth finish; up until this time the cylinders were left as cast and they had a rough surface. Watt also used animal fat based lubricants to reduce leakage and friction in the cylinders. Until then only water had been tried to seal the leakage. Later Watt turned to using steam expansively; using higher pressures than atmospheric steam, and invented the Compound Engine in 1781 to utilise the steam more efficiently. It was then largely due to Matthew Boulton and his excellent machining capability that major advances were made in the early steam engine development. Watt certainly didn't invent the steam engine but he probably more than any other person caused great improvements to take place due to his analytical work to determine how it could be improved. The Newcomen type pumping engines were used for 75 years but with Boulton & Watt's improved engines they became obsolete almost overnight.

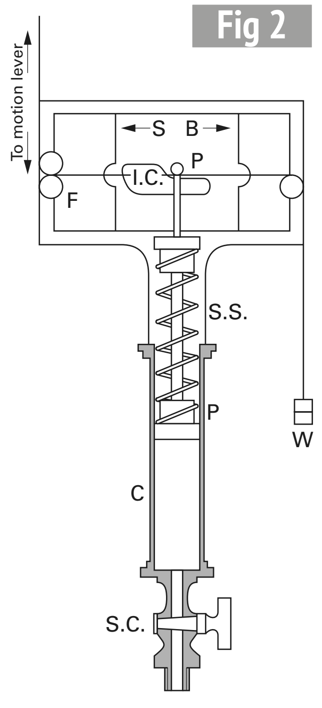
Perhaps the greatest invention accorded to James Watt was his definition of Horsepower, 33,000 foot-pounds per minute, which we still use today and the modern unit of power is named in his honour. However, today we know Watt's definition of Horsepower was a little too big as the actual power one horse can perform over a long period is only about two thirds of the actual value. To determine the power of a 'good horse' Watt rigged up a system of ropes and pulleys over a deep mine shaft and using shire horses timed how long a horse took to raise different weights. He concluded that a strong horse could do the work equivalent to raising 550 pounds by a foot per second. From this he arrived at the definition of the horsepower as being 33,000 foot-pounds per minute. As he didn't want his customers to be dissatisfied with the engines sold to them it was a wise marketing move to over specify the amount of work a 'good horse' could perform, as was often stated in the contract papers. But he omitted to see that the value he measured could only be made for short periods as horses do get tired whereas an engine, if it is fed with sufficient fuel and water, will keep going indefinitely - until it broke down, which early engines did quite often!

An amusing story about Horsepower

A farmer was driving along the lane in his horse and trap in the early 1900s when he came upon a motorist, in one of the first 'horseless carriages' he had seen, which was stopped in the lane. On enquiring what the problem was the driver told the farmer the engine had overheated and he needed to let it cool for a while. The farmer asked the driver how many horsepower the car was and he was told it is 30 horsepower. 'They must be very small horses' the farmer replied!

The writer can well remember a lecture at college where the students repeated Watt's experiment. As we didn't have any shire horses

Fig 2



handy the lecturer had us each run up a flight of stairs and timed how long each one took. We were then each weighed and we had to work out how many foot-pounds of work we had each done. We measured the height of the stairs so that we knew how many feet that we had lifted our weight. It was very sobering to see that even the most athletic member of the class didn't get anywhere near a horsepower.

Watt's Engine Indicator

Watt's original indicator device was fairly crude and consisted of a gas tight piston in a vertical cylinder that could move quite freely and being open at one end to the atmosphere. The bottom of the cylinder was connected to the steam engine cylinder via a test cock valve. The piston rod was restrained on the upper end by a compression spring such that a certain pressure caused it to rise a certain amount. The piston rod had attached a holder for a normal pencil that could be used to make marks on a paper. In essence it was a very accurate pressure gauge with a linear pointer affixed to the end of the piston rod. Watt was very secretive about this invention and kept it as a secret for some considerable time because he didn't want others to benefit from its use. Some historians suggest Watt didn't invent this instrument, it was the work of one of his employees but was naturally credited to Watt, as was the norm for such things. In the same way we know that George Stephenson or his son Robert also didn't invent the Stephenson Link Motion - an employee invented it.

Prior to this invention there was only one method of measuring pressure; a manometer tube that utilised a column of water or mercury. This was prior to the invention of pressure gauges as we know them today. As the pressure varied in the cylinder the pencil went up and down on the paper making a permanent mark. Although this was an important invention it was others who refined the design we know today.

At the time, the steam pressures being used were very low - about 4 to 7 pounds per square inch being the maximum due to the limitations in the existing soft soldered boilers that were in use. It was the Cornish engineer, Richard Trevithick who advocated still higher steam pressures, which he called 'strong steam' and later, when boiler technology improved, it became common to use steam pressures of 60psi and higher. But many boiler explosions often accompanied these early days as the wrought iron boilerplate was poor quality and did not have the strength required - and the expertise to make good riveted joints and form plates and stay them correctly was something that still had to be developed. Watt's safety valve prevented mishandling of many boilers and probably saved hundreds of lives! Later when good quality steel plate could be made the pressures rose to several hundred pounds per square inch. Initially Watt had a very low opinion of Trevithick and his apparent mania for the use of high-pressure steam. He is reputed to have called Trevithick *'That madman - who should be hung for promoting such dangerous practices'*. However, Watt had to admit many years later that Trevithick was correct to pursue this option, as the economy in fuel brought about by using strong steam was a definite advantage.

The major improvement made to Watt's Indicator was the addition of a moving board to which the graduated paper was attached (**fig 2**).

The sliding board (SB) is free to move sideways supported on frictionless guide-wheels. A cord having a weight (W) is attached to one side of the board running over a pulley so the weight caused the board to return to one side. The opposite side of the board has a similar cord and pulley arrangement (F) that could be attached to part of

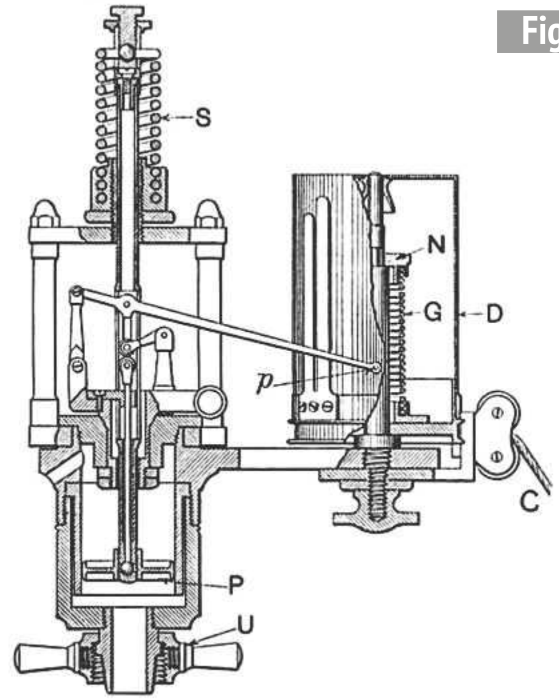


Fig 3

the engine under investigation such that the board moved sideways as the piston rod or some other related part of the engine moved. This moved the board in the X-axis related to piston position and the Y-axis movement was due to the pencil (P) and the cylinder pressure. By the addition of a light compression spring below the indicator piston the device could also read vacuum as well as pressure above atmospheric. It was Watt who was the first engineer to appreciate the importance of the pressure distribution and vacuum occurring in the steam engine cylinder. Today the paper chart is normally wrapped around a circular drum that oscillates around a central pivot when pulled by the cord. The drum is spring loaded to return it to a starting point. **Figure 3** shows a Crosby Indicator, which was one of the types popular at the time.

Calibration of the indicator is by comparing the pencil vertical movement against an accurate pressure gauge that is connected in parallel to a supply of pressure that can be varied. The springs supplied by the indicator manufacturer are normally marked with the tensile rate - in inches per pound per square inch - for the instrument; the piston diameter being chosen to suit the spring rate. For example, a piston of 1.14 inch diameter has an area of 1 square inch so if the spring has a rate of 100 pounds per inch, the pencil will move one inch when 100 psi gauge is applied. Having a linear measurement means that any point on the diagram can be accurately measured to ascertain the pressure by reading off the graph.

Although steam engines are no longer as widely used in marine engineering as they were a hundred years ago the use of the engine indicator has not fallen away. Today a modern version is used with marine diesel engines to ascertain the health of the engines on a regular basis - especially during diagnosis and after a repair has taken place - to ensure the engine is working at peak efficiency. The shape of the curve is of course quite different but the principle is the same and a skilled engineer can diagnose various faults by examining the indicator card. As mentioned earlier the modern indicator diagnostic instrument is all electronic so having to run cords over pulleys etc. is not required.

●To be continued.

CLUB NEWS

Geoff Theasby reports on the latest news from the Clubs.

Someone has dumped a flat screen TV down the road. I probably know what is wrong with it and could restore it to full vigour by replacing a few components. The screens are designed for 20 years' use but the most unreliable bits in any electronic device are the electrolytic capacitors in the power supply so changing them might work. If not, then it goes clunking back out the door! I am trying to reduce the quantity of junk in my workshop, actively encouraged by Debs, so I don't need any more!

An authoritative range of machining videos looks worthy of further investigation. MIT is a respected name in science (**ref 1**). They have also placed numbers of degree courses online, free, for our edification. No degree at the end of the course, obviously but the information is there.

A clock escapement by Roger Bunce, in which the pendulum does not 'know' the escapement is connected to it, yet influences it, is explained in http://modelengineeringwebsite.com/SeeSaw.html It is a relative of that invented by Baron Grimthorpe (whom God Preserve) of Grimthorpe and used in the Westminster Great Clock (Big Ben).

A fan letter has come flooding in; Gosh, such popularity! All so far received have been complimentary, thank goodness, so I must be doing something right.

John Gray's Hirondelle bicycle at Chelmsford. (Photo courtesy of John Dalton.)

And, here's another! Oh … it's from HMRC. My Self-Assessment Tax Return. Well, I'm tall, distinguished and well educated, with a GSOH and the profile of a young Greek God. I have my own hair and teeth and I was the originator of the slogan, 'You'll wonder where the yellow went, when you soak your teeth in Steradent.' What do you mean my financial worth? A lot more than I receive, that's for sure, Ducky!

The Rev. Chris Brown writes on the subject of inflammable clothing, as previously discussed, saying that such should be kept clean as otherwise the fire risk is increased - and, I thought, there may be a danger of spontaneous combustion of oil-soaked cloths. Vegetable oils like rapeseed/canola (used in steam oil, because it is miscible with water) and linseed oil, are most likely to self-combust, plus, bizarrely, pistachio nuts but we are unlikely to encounter those in our activities.

Visiting the hospital in April, I called in at the volunteers' fund-raising shop and found three DVDs of the Great Dorset Steam Fair, for 2006,7 and 8 for 50p each. Wonderful!

In this issue, a lapse, glue, the podium, oranges, fell running, trams, sublime and ridiculous, RTFM, air conditioning and dredgers.

Corrections, errors and omissions, lies, calumnies and untruths – Or something. The 70th Anniversary of the G1MRA is *NEXT* year and not this year, as stated in *M.E.* 4532, as is their event at The Fosse, also mentioned. I am very sorry. I may commit ritual 'Kinzoku no oritatami'.

For a 30 minute time-lapse video of **Edinburgh Society of Model Engineers'** *Big Dig*, look at, **https://www.youtube.com/watch?v=74gjmxGT8FY** (adjacent videos are NOT recommended). It's quite entertaining, with diggers thrashing about, dump trucks whizzing back and forth and huge tipper wagons arriving, unloading and departing, in a few seconds, all the while attended by Hi-Viz-clad ants.

The Link, April, from **Ottawa Valley Live Steam & Model Engineers**, produced a response from John Stewart regarding metrication, as previously discussed. On trying to buy a 7BA tap whilst living in Holland, he was informed that it would be cheaper for him to take the ferry to Harwich and buy one locally, than import one to Holland just for him. And so began his slow journey into metric light... Graham Copley continues his Royal Scot and the infinite pains he is taking to produce it.

W. http://www.trainweb.org/ovlsme

Another new member of our throng is **Chelmsford Society of Model Engineers**, which sent *Steam Lines*, Spring and celebrates winning EIM's Best in Show prize for their stand, on the first occasion of their exhibiting at Alexandra Palace. Dave Honey has made a magnificent mahogany display case for this award, the 'Society Shield'. A well-illustrated article by John Dalton shows some of the exhibits. This is John Gray's model of a French, Hirondelle 'Superbe' bicycle (**photo 1**). John D. also writes on the preparation and testing of miniature steam boilers.

W. www.chelmsfordsocietyofmodelengineers.org.uk

Chichester & District Society of Model Engineers are to hold a Steam on Sunday event on Fathers' Day, June 19th, between 2 & 5pm. Various steam & Diesel locomotives will be in use and a 'Drive Yourself' opportunity on the '00' circuits, with three controllers available.

W. www.cdsme.co.uk

Halesworth & District Model Engineering Society's Spring *Newsletter* opens with a good picture of Treasurer, Gary Edwards and his grandson Harvey, steaming Gary's 4 inch scale Foster Traction Engine after retubing last year. Chairman, Philip Hall has completed an RAF Vosper Crash Tender acquired as an unfinished

Philip Hall's RAF crash tender at Halesworth. (Photo courtesy of Philip Hall.)

model. It is radio controlled and electrically powered. The scrambling nets stowed on the after cabin were cut from the plastic nets in which supermarket oranges are sold (**photo 2**). I dimly remember seeing one of these launches stationed at Bridlington in the 1950s (reputedly, originally commissioned by Aircraftsman Shaw - Lawrence of Arabia - in that location) and I used to have an electrically driven Victory Models version as a kid. These were made from 1954 to 1969. Terry Fleet discusses his stationary engine collection, these are NOT models! Marion Rackham adds to her repertoire of crafts by learning stained glass working, making a 'GWR' roundel.
W. www.hdmes.co.uk

Birmingham Society of Model Engineers' *Newsletter* for February/March, has arrived, revealing that Editor, Jon Williams has been 'at it' for 15 years now. Peter Evans has been trying out Rosebud grates, with interesting results. David Piddington relates how he became a model engineer and John Walker writes on Loctite-type adhesives, their chemistry and uses.
W. www.birminghamsme.com

ConRod, Winter, from **Harrow & Wembley Society of Model Engineers**, says that 2016 is the society's 80th Anniversary. To celebrate, they gained the podium at Alexandra Palace Exhibition, coming 2nd to Chelmsford for their club stand. Michael and Barbara Orton are the new, proud parents of Arthur, whose arrival coincided with them moving house. This mightily confused the hospital, which had problems in discharging a patient to a different address from which they were admitted! Eric Basire discusses the Metropolitan 1200hp electric locomotives and his 5 inch gauge model is posed next to *Sarah Siddons* and in turn adjacent to his '00' gauge example. Brian Everett then describes the societies '00' gauge activities.
W. www.hwsme.org

The Link, April, from **Model Engineers' Society (NI)** reports on their Car Boot Sale/Swap Meet. Vincent Kelly describes his Austin 7 Special, built in 1980 on a 1937 Ruby chassis. Editor, Terence Aston was pleased that no editing was necessary for this contribution! *The Link* concludes with details of the major hand signals in use on their railway.
W. www.mesni.co.uk

Sheffield & District Society of Model & Experimental Engineers have a new website, courtesy of *Steam Whistle* Editor, Mick Savage. It is much improved, clearer, better laid out and easier to navigate. (Leave the envelope in the usual place, Mick, okay? - Geoff). The Society Open Weekend and Exhibition will be 2/3rd July, 2016, from 10am. Saturday for members & guests, Sunday for Public Running. The weekend is booked up for visiting locomotives, so it should be an excellent event.
W. www.sheffieldmodelengineers.com

On Track, April, from **Richmond Hill Live Steamers** (Ontario, Canada) advises us of a superb model railway belonging to Howard Zane. It occupies 3,000 square feet of his basement. http://tinyurl.com/jnhgjbk
W. www.richmond-hill-live-steamers.tripod.com

Modelling Ways, April, from **Fareham & District Society of Model Engineers**, reports an interesting addition to their library. It is a photocopy of Five Group Operations Order for the 'Dambusters' Raid, stamped 'Top Secret' on every page. Clem writes a regular column on Tramways in the UK. This is unusual for club newsletters, so I am glad to see a bit of original writing. I've travelled on all of the new UK systems except Croydon and Edinburgh (plus Dublin and Oslo). Proposals for raising the elevated track by 300mm and increasing the speed limit to 20mph have been considered. However, the cost of so doing and the superelevation required on curves makes it difficult. Whilst a locomotive may not fall off the track if stationary, it will appear to be in such danger. As for the cost, an agreement may be close involving sponsorship by a fast food outlet, providing its large yellow logo is positioned over the adjacent tunnel portals.

The Journal, April, from the **Society of Model & Experimental Engineers**, notes that mere possession of deactivated firearms, machine tools and associated books will not, in itself, be taken as 'intent' to reactivate such weapons. Adrian Garner discusses random numbers, whilst A. B. Lyre thinks about The Music of the Spheres and his related experiments. John Clarke writes on local inventor, Percy Cox, he of the steam bicycle, submarine gun and humane killer. (Nothing to do with Captain Percy Scott, RN, gunnery expert.)
W. www.sm-ee.co.uk

Ryedale Society of Model Engineers reports improvements scheduled to the internal telephone system. Editor, Bill Putman says, of the discussion after the AGM concluded; 'Among the features is the provision to put callers on hold and play music to them. This led to a fair amount of hilarity as members imagined the frustration of being put on hold and given the message – 'Your call is important to us' - followed by 'you are number four in the queue - when they are trying to ring a signal box.' Doing some grass cutting, Jean kept warm by wearing a hijab-style headscarf, which alarmed some of the more impressionable villagers into thinking the Taliban had arrived. Later, her fame grew even more after saying, 'isn't it nice to see so many of the workers enjoying themselves for a change?'
W. www.rsme.org.uk

Rugby Model Engineering Society is holding a commemoration on July 9/10th in recognition of the 50 years since the last Royal Scot locomotive was withdrawn. Models are invited in gauges 2½, 3½, 5 and 7¼ inch, the more the merrier! Admission will be free and camping space is available. E-mail **RoyalScotevent@outlook.com**
W. www.rugbymes.co.uk

Prospectus, April, from **Reading Society of Model Engineers**, opens with a picture of Alan Thatcher and his Bronze Award-winning flame gulper engine being demonstrated to fellow society members. Apart from the flywheel castings, everything was fabricated (**photo 3**). '61249' writes on the coming privatisation of the railways

Alan Thatcher's flame gulper at Reading SME. (Photo courtesy of John Spokes.)

David Turner's sawmill at Locomotion (NZ). (Photo courtesy of Lachlan Clark.)

(as in 1993) and the differing ways that sectors of BR dealt with it. Crash-worthiness of rolling stock improved but whilst 140 mph Mk 4 coaches were being designed (1989/92), so was the Pacer (1980/87)! From the sublime to the ridiculous... John Spokes describes Vincent Raven's S2 Uniflow locomotive, No. 825. He has a model, built by the late Jack Pickup and Syd Bennett, both members of the West Riding Small Locomotive Society. 'Wolverton Pug' became involved with the sale of Freightliner and the improvements to a container terminal near Cardiff.
W. www.rsme.co.uk

Duncan Webster, in the *Daresbury* Gazette, from **Warrington & District Model Engineering Society** says that the signalling problem has been rectified. It wasn't a case of RTFM, since the manual was wrong. As he wrote it, he craves our indulgence and abases himself. Solar panels have been fitted to charge the signal batteries, a very good use for these items, which are now supplying free power at about 1 Amp in daylight.
W. www.wdmes.org.uk
(and see the article on page 848 of this issue.)

Stamford Model Engineering Society informs us of an attempt at air conditioning *Edward Blount*, a Stroudley B1 locomotive, for the benefit of crews in an otherwise half-cab engine. This stems from a report in *Rail News*, at www.rail.co.uk to which readers are referred for further information. A visit to Taylors Bellfoundry in Loughborough has been arranged, which should be most interesting. I have toured their competitors, Whitechapel Bellfoundry.

Allan Woodcroft writes in reference to the V4 Brough Superior mentioned in *M.E.* 4529. When Allan was but an ephebe, he would have his motorcycle MOT'd at a little garage run by one Albert Wallis in Wilstead. Albert was a good friend of George Brough and when the factory closed, Albert was allowed to take what he wanted. He chose a V4 engine and was building a bike around it. He also had an ancient flat belt lathe, with which he could make very accurate parts. Allan was amazed at this, being only an apprentice at the time but 'there's many a good tune played on an old fiddle'. Did anything become of this V4 Special?

B&DSME News, April, from **Bournemouth & District Society of Model Engineers** begins with Editor, Dick Ganderton replacing the bearings on his Myford and subsequently finding that oil was not reaching them, despite using a Reilang oil can and the correct button lubricators. He therefore made some oil cups, which worked beautifully, so let joy be unconfined. Victory, the kit locomotive promoted by the 16mm NGM Association, has now ceased production, with 228 kits being produced. The accounts being settled, the £500 surplus was divided between Poole and Southampton hospital stroke units. http://www.16mm.org.uk/newsite/victory/default.html **W.** www.littledownrailway.co.uk

Blast Pipe, April, from **Hutt Valley & Maidstone Model Engineering Societies** says that Locomotion at Palmerston North was one of the biggest ever held and went extremely well. The Kapiti track has signs reminding people to 'Smile'. Are their visitors/train crews particularly dour, I wonder? There is only one original Fell locomotive left in existence, now in Featherstone (H199). http://www.teara.govt.nz/en/video/21377/fell-engine A 'Mini Fell' will be at the Cross Creek railway for their September Carnival.
W. www.hvmes.com

Another attendee at Locomotion was Editor, Lachlan Clark, from **Otago Model Engineering Society**. Conrod, April, mentions David Turner's miniature operational sawmill, driven by his Case Traction Engine. David is a member of the Hutt Valley Model Engineering Society (**photo 4**). The boat group channel was dredged by Murray Vince's interesting, fully working model of the bucket dredger, *Otakau*, built in 1929 in Paisley, Scotland, which was used to dredge the shipping channel in Dunedin (**photo 5**). This was taken at the Otago Model Engineering Festival Week in February. I recall from childhood the small, 1952 grab dredger *Skarthi*, which worked out of Scarborough and is now in Lagos, Nigeria. It was designed by the Harbourmaster and built for Scarborough Corporation.
W. www.omes.org.nz

Yet more approbation for this column comes from an ex-Rolls Royce car designer. Respect! I am not worthy! I am pleased - nay, honoured - to receive such a friendly welcome in your country. (… sidles off, stage left, accompanied by brickbats, oily rags and rusty, one inch Whitworth nuts, Boo, Hiss!...)

And finally, music for baby-boomers: From Roberta Flack, 'The first time ever I forgot your face', Johnny Nash, 'I can't see clearly now', The Commodores, 'Once, Twice, Three times to the bathroom'.

REFERENCE
1. http://video.mit.edu/watch/

Contact:
geofftheasby@gmail.com

Murray Vince's dredger at Otago MES. (Photo courtesy of Lachlan Clark.)

JUNE

8 St. Albans DMES. Club Night (TBC) Contact Roy Verden: 01923 220590.

11 Brighton & Hove SMLE. Public Running at Hove Park Rly. Contact Mick Funnell: 01323 892042.

11/12 Cardiff MES. Welsh Locomotive Rally. Contact Rob Matthews: 02920 255000.

11/12 Grimsby & Cleethorpes MES. Public running for the Queen's Birthday, noon – 7.45pm. Waltham Windmill site. Contact Dave Smith: 01507 605901.

11 Mid Wales Model Engineering Society. Running day at The Park, Newtown, Powys, 11am – 3.30pm. Contact Keith Elson: midwalesmes@engineer.com

11/12 North Norfolk MEC. Public running (Diesel Gala weekend) at Holt Minor Station. Contact Gordon Ford: 01263 512350.

11 SMEE. Polly Course, Day 2. Contact Peter Haycock: 01442 266050.

12 Bracknell Railway Society. Public running at Jocks Lane, Bracknell, 2.30 - 5pm. Contact Paul Archer: 07543 679256.

12 Harlington LS. Public running, 2 - 5pm. Contact Peter Tarrant: 01895 851168.

12 Leeds SMEE. Public Running at Eggborough Track from 10am. Contact Geoff Shackleton: 01977 798138.

12 Rugby MES. Contact Ken Eyre: 01788 842709. 2½ inch Gauge Society Annual Rally from 10.30 at Rainsbrook Valley Rly.

12 St. Albans DMES. Club steaming day - 10:30 at Puffing Field. Contact Roy Verden: 01923 220590.

12 Sutton MEC. Afternoon running from noon. Contact Jo Milan: 01737 352686.

12 York City & DSME. Special Running Day (non railway). Contact Bob Polley: 01653 618324.

15 Bristol SMEE. Ashton workshop demos. Contact Kevin Slater: 01275 331074.

16 Warrington DMES. Natter night. Contact Brian Renton: 01925 724265.

17 Rochdale SMEE. General Meeting Castleton Community Centre, Rochdale. 7pm. Contact Len Uff: 0161 928 5012.

17 Stockport DSME. Track night. Contact Dave Waggett: 0161 430 8963.

18 Bradford MES. Open Day at Northcliff Railway. 10am to 5pm approx. (Please emailebsite@bradfordmes.co.uk if you wish to attend.) Contact Kevin Smith: 07533 316341.

18 Brighton & Hove SMLE. Members' Day. Contact Mick Funnell: 01323 892042.

18 North Wiltshire MES. Play Day, visitors welcome but please contact Ken Parker: 07710 515507. (Public running every Sunday)

19 Chichester DSME. 'Steam on Sunday' at the Blackberry Lane track. 2pm – 5pm. Contact Ben Earnshaw-Mansell: 01243 773451.

19 Grimsby & Cleethorpes MES. Public running for Father's Day, noon - 4pm. Waltham Windmill site. Contact Dave Smith: 01507 605901.

19 Plymouth MSLS. Public running at Goodwin Park. Contact Malcolm Preen: 01752 778083.

19 Warrington DMES. Running day. Contact Brian Renton: 01925 724265.

19 Welling DMES. Public Running 2 - 5pm. (Behind Falconwood Elec Sub stn.). Contact Martin Thompson: 01689 851413.

21 Grimsby & Cleethorpes MES. General monthly meeting, 7.30pm. Contact Dave Smith: 01507 605901.

21 Lancaster & Morecambe MES. Members running afternoon. Contact Mike Glegg: 01995 606767.

24-26 Derby SMEE. **Northern Association of Model Engineers Annual Rally at Derby MES. Celebrating DMES's 80th Anniversary. (No public running.) Contact: Richard Hill: 07881535348.**

22 Leeds SMEE. Mid-summer Steam-up. 12.30 until late. Contact Geoff Shackleton: 01977 798138.

25 Brighton & Hove SMLE. Public Running at Hove Park Rly. Contact Mick Funnell: 01323 892042.

25 York City & DSME. Summer meeting. Contact Bob Polley: 01653 618324.

26 Grimsby & Cleethorpes MES. Public running, noon - 4pm. Waltham Windmill site. Contact Dave Smith: 01507 605901.

26 Harlington LS. Public running (Teddy Bears' Picnic), 2 - 5pm. Contact Peter Tarrant: 01895 851168.

26 Leyland SME. Narrow Gauge Day. 10am - 4pm. Refreshments. Contact A. P. Bibby: 01254 812049. facebook.com/LeylandSME

28 Wigan DMES. Bits & Pieces evening. Contact Kevin Grundy: 01942 522303.

30 Sutton MEC. Make and Fly Paper Aeroplanes. Contact Jo Milan: 01737 352686.

PRO MACHINE TOOLS LIMITED

Tel: +44(0)1780 740956
Fax: +44(0)1780 740957

CERIANI

Precision machines made in Italy for the discerning engineer!

ACCESSORIES

Lathe Chucks, Drill Chucks, Tipped Tools, Boring Bars, QCTP, HSS Tools, End Mills, Slot Drills, Machine Vices, Clamping Sets, Slitting Saws, Arbors, Boring Heads, Radius Mills, DROs, Rotary Table, CNC fits, Collet Chucks, Collet Sets, Flanges, Face Mills, Shell Mills and Much More...

All lathes and mills are backed by an extensive range of tools and accessories

Ceriani 400 Series Mill

- ISO30 Spindle
- Table size - 580 x 150mm
- Travel - 420 x 160 x 300mm (XYZ)
- 1.5 KW Motor
- 100-3000 rpm vari-speed
- Weight - 150 Kgs

Ceriani 203 Lathe

- Centre height - 100mm
- Swing over gap - 260mm
- Motor - 1 HP
- Centre distance - 500mm
- Spindle bore - 20 or 30mm
- Weight - 80 Kgs

- Optional splash-back and safety guard

- Semi Norton gearbox
- Vari-speed option
- Four selectable feed rates plus screw cutting

emco · WABECO · CERIANI · swiss tec · TECO · GOLmatic Maschinenbau · PROXXON · EMCO Hobbymaschinen

MORE MACHINES AND ACCESSORIES ON LINE

Our machines suit the discerning hobbyist as well as blue chip industry

We regularly ship worldwide

Please contact us for stock levels and more technical detail

All of our prices can be found on our web site:

www.emcomachinetools.co.uk

PRO Machine Tools Ltd.
17 Station Road Business Park, Barnack, Stamford, Lincolnshire PE9 3DW

tel: **01780 740956** • fax: **01780 740957**
email: **sales@emcomachinetools.co.uk**


adidas
RUNNING

Machine Mart

NOW 65 SUPERSTORES NATIONWIDE

WHERE QUALITY COSTS LESS

FREE 500 PAGE CATALOGUE

GET YOUR FREE COPY!
IN-STORE
PHONE 0844 880 1265
ONLINE www.machinemart.co.uk

Clarke 6 SPEED METAL LATHE WITH 12 SPEEDMILL DRILL- CL500M

£849.00 EXC.VAT £1018.80 INC.VAT

- 430mm between centres
- Compound slide with 4 way tool post
- Power fed screw cutting facility
- Forward/reverse lathe operation
- Clutch for independent mill/drill operation

ALSO AVAILABLE: CL430 - As above but without the Mill/Drill head £669.00 exc.VAT £838.80 inc.VAT

VIDEO ON-LINE

SHOWN WITH OPTIONAL FLOOR STAND/SUDS TRAY ONLY £241.80 INC VAT

FULL RANGE OF ACCESSORIES IN STOCK

Clarke MEASURING EQUIPMENT

FROM ONLY £9.98 EX.VAT £11.98 INC.VAT

MODEL	DESCRIPTION	EXC.VAT	INC.VAT
CM100	150mm/6" Vernier Caliper	£9.98	£11.98
CM180	0-25mm Micrometer	£9.98	£11.98
CM145	150mm/6" Digital Vernier	£16.99	£20.39
CM265	300mm/12" Digital Vernier	£36.99	£44.39

Clarke METAL LATHE

- 300mm between centres
- LH/RH thread screw cutting
- Electronic variable speed
- Gear change set
- Self centering 3 jaw chuck & guard
- Power feed

CL300M

£469.00 EXC.VAT £562.80 INC.VAT

Clarke ENGINEERS HEAVY DUTY STEEL WORKBENCHES

PRICE CUT NOW FROM £139.98 EXC.VAT £167.98 INC.VAT WAS £179.98 inc.VAT

- Sturdy lower shelf
- Durable powder coated finish

Shown with optional 3 drawer unit PRICE CUT ONLY £95.98 INC VAT

INC. SINGLE LOCKABLE DRAWER

MODEL	DIMS LxWxH (mm)	EXC. VAT	WAS INC.VAT	NOW INC.VAT
CWB1000B	1000x650x880	£139.98	~~£179.98~~	£167.98
CWB1500B	1500x650x880	£189.98	~~£239.98~~	£227.98
CWB2000B	2000x650x880	£249.98	~~£311.98~~	£299.98

Clarke BOLTLESS QUICK ASSEMBLY STEEL SHELVING

- Simple fast assembly in minutes using only a hammer

FROM ONLY £29.98 EX.VAT £35.98 INC.VAT

ASSEMBLES AS BENCH OR CORNER UNIT

CHOICE OF 5 COLOURS: RED, BLUE, BLACK, SILVER & GALVANISED STEEL

150 KG PER SHELF

Clarke MIG WELDERS

Quality machines from Britain's leading supplier

See online for included accessories

GAS, TIPS, SHROUDS & WIRE IN STOCK

MIG 135TE

FROM ONLY £179.98 EX.VAT £215.98 INC.VAT

MODEL	MIN-MAX AMPS	EXC.VAT	INC.VAT
PRO90	24-90	£179.98	£215.98
110E	30-100	£214.99	£257.99
135TE Turbo	30-130	£239.98	£287.98
151TE Turbo	30-150	£269.98	£323.98
165TEM Turbo	30-155	£339.00	£406.80
175TECM Turbo	30-170	£399.00	£478.80
205TE Turbo	30-185	£429.00	£514.80

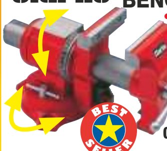
Clarke ENGINEERS BENCH VICES

- A range of fixed and swivel vices with top quality cast iron construction

BEST SELLER

FROM ONLY £18.99 EX.VAT £22.79 INC.VAT

CMV140



MODEL	JAW WIDTH	BASE	EXC.VAT	INC.VAT
CV100B	100mm	Fixed	£18.99	£22.79
CVR100B	100mm	Swivel	£21.99	£26.39
CV125B	125mm	Fixed	£29.98	£35.98
CVR125B	125mm	Swivel	£29.98	£35.98
CV150B	150mm	Fixed	£43.99	£52.79
CVR150B	150mm	Swivel	£46.99	£56.39
CMV140	140mm	Swivel	£64.99	£77.99

Clarke MILLING DRILLING MACHINE - CMD300

- Bench mountable, tilts 45° left & right from vertical
- Table travel 100x235mm
- Table Effective Size LxW: 92 x 400mm

CMD10

£499.00 EXC.VAT £598.80 INC.VAT

£349.00 EXC.VAT £418.80 INC.VAT

Clarke MICRO MILLING & DRILLING MACHINE

- Bench mountable
- MT2 Spindle Taper
- Face mill capacity 20mm, end mill 10mm
- Table cross travel 90mm, longitudinal travel 180mm

MODEL	MOTOR	SPINDLE SPEED	EXC.VAT	INC.VAT
CMD10	150W/230V	100-2000rpm	£349.00	£418.80
CMD300	470W/230V	0-2500rpm	£499.00	£598.80

Clarke DRILL PRESSES

FROM ONLY £59.98 EXC.VAT £71.98 INC.VAT

- Range of precision bench & floor presses for enthusiast, engineering & industrial applications

B = Bench mounted F = Floor standing
V = Variable speed

CDP152B

NEW RANGE

MODEL	MOTOR (W) SPEEDS	EXC. VAT	INC. VAT
CDP5EB	350 / 5	£59.98	£71.98
CDP102B	350 / 5	£69.98	£83.98
CDP152B	450 / 12	£119.98	£143.98
CDP202B	450 / 16	£159.98	£191.98
CDP10B	370 / 12	£169.98	£203.98
CDP352F	550 / 16	£199.98	£239.98
CDP350V	550 / V	£219.00	£262.80
CDP502F	1100 / 12	£449.00	£538.80

Clarke HEAVY DUTY & PROFESSIONAL TOOL CHESTS

PRICES SLASHED MASSIVE

PRICE CUT NOW FROM £97.98 EXC.VAT £117.58 INC.VAT WAS £119.98 inc.VAT

BALL BEARING

MODEL	DESCRIPTION	EXC. VAT	WAS INC.VAT	NOW INC.VAT
① CBB206B	6 Dr Chest	£97.98	~~£119.98~~	£117.58
② CBB209B	9 Dr Chest	£114.99	~~£143.98~~	£137.99
CBB210B	10 Dr Chest	£129.98	~~£167.98~~	£155.98
③ CBB203B	3 Dr step up	£67.98	~~£83.98~~	£81.58
CBB215B	5 Dr Cabinet	£194.99	~~£239.98~~	£233.99
④ CBB212B	3 Dr Cabinet	£169.98	–	£203.98
⑤ CBB217B	7 Dr Cabinet	£239.98	~~£299.98~~	£287.98
CBB213B	3 Dr Cabinet	£189.98	~~£239.98~~	£227.98

Clarke ARC/TIG INVERTERS

- Low amp operation - ideal for auto bodywork & mild /stainless steel

FROM ONLY £129.98 EX.VAT £155.98 INC.VAT

AT161

MODEL	AMPS	ELECTRODE DIA.	EXC.VAT	INC.VAT
AT101	10-80	1.6-2.5mm	£129.98	£155.98
AT132	10-130	1.6-3.2mm	£159.98	£191.98
AT161	10-160	1.6-4.0mm	£199.00	£238.80

Clarke ANGLE GRINDERS

NEW

FROM ONLY £22.99 EX.VAT £27.59 INC.VAT

CAG800B

INC. DISC & HANDLE

‡ was £41.99 inc.VAT

MODEL	DISC (MM)	MOTOR	EXC.VAT	INC.VAT
CAG800B NEW	115	800W	£22.99	£27.59
CON1050B NEW	115	1050W	£27.99	£33.59
CON115‡	115	1010W	£31.99	£38.39
CAG2350C NEW	230	2350W	£49.98	£59.98
CON2600	230	2600W	£69.98	£83.98

Clarke ROTARY TOOL KIT

£29.98 EX.VAT £35.98 INC.VAT

CRT40

Kit includes:
- Height adjustable stand with clamp
- Rotary tool
- 1m flexible drive
- 40x accessories/consumables

Clarke ARC ACTIVATED HEADSHIELDS

GWH4 £39.98 EXC.VAT £47.98 INC.VAT

CWH7 £44.99 EXC.VAT £53.99 INC.VAT

- Activates instantly when Arc is struck
- Protects to EN379
- Suitable for arc, MIG, TIG & gas welding

Clarke ENGINE CRANES

FROM ONLY £149.98 EX.VAT £179.98 INC.VAT

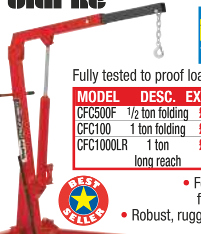
Fully tested to proof load

MODEL	DESC.	EXC.VAT	INC.VAT
CFC500F	1/2 ton folding	£149.98	£179.98
CFC100	1 ton folding	£154.99	£185.99
CFC1000LR	1 ton long reach	£199.98	£239.98

- Folding and fixed frames available
- Robust, rugged construction
- Overload safety valve

BEST SELLER

CFC100



Clarke TAP & DIE SETS

- High quality tungsten steel
- Supplied in metal storage case (except 16pce)

FROM ONLY £14.99 EX.VAT £17.99 INC.VAT

TYPE	EXC.VAT	INC.VAT
CHT203 16pce Metric	£14.99	£17.99
CHT302 24pce UNC/UNF/NPT	£19.98	£23.98
CHT303 28pce Metric	£23.99	£28.79
CHT304 33pce Metric/UNF/BSP	£31.99	£38.39
CHT774 37pce Metric NEW	£34.99	£41.99
CHT527 32pce Metric	£41.99	£50.39
CHT776 76pce Metric NEW	£59.98	£71.98

Clarke 3-IN-1 SHEET METAL MACHINES

- Bend, Roll & Shear metal up to 1mm thick
- Min. Rolling Diameter 39mm
- Bending angle 0-90°

FROM ONLY £189.98 EX.VAT £227.98 INC.VAT

ROLLING
SHEARING
FOLDING

MODEL	BED WIDTH	EX VAT	INC VAT
SBR305	305mm (12")	£189.98	£227.98
SBR610	610mm (24")	£359.00	£430.80

Clarke GRINDERS & STANDS

- Stands come complete with bolt mountings and feet anchor holes

6" & 8" AVAILABLE WITH LIGHT

FROM ONLY £29.98 EX.VAT £35.98 INC.VAT

STANDS FROM ONLY £47.98 INC.VAT

POLISHING KITS 4" TO 8" FROM ONLY £23.98 INC VAT

With sanding belt
* 8" whetstone/6" drystone ‡ was £67.19 inc.VAT

MODEL	DUTY	WHEEL DIA.	EXC.VAT	INC.VAT
CBG6RP	DIY	150mm	£29.98	£35.98
CBG6RZ	PRO	150mm	£39.98	£47.98
CBG6RSC	HD	150mm	£49.98	£59.98
CBG6SB#	PRO	150mm	£49.98	£59.98
CBG6RWC	HD	150mm	£54.99	£65.99
CBG8W* (wet)‡	HD	150/200mm	£49.98	£59.98

Clarke HYDRAULIC LIFTING TABLES

- Ideal for lifting & moving models
- Foot pedal operated

HTL500

FROM ONLY £259.00 EX.VAT £310.80 INC.VAT

MODEL	MAX. LOAD	TABLE HEIGHT MIN-MAX	EXC. VAT	INC. VAT
HTL300	300kg	340-900mm	£259.00	£310.80
HTL500	500kg	340-900mm	£289.00	£346.80

Clarke AC7000 AIR CONDITIONERS & DEHUMIDIFIERS

Mobile Units provide quick & effective cooling & drying
- Simple touch pad & remote control
- Includes ducting kit

FROM ONLY £199.98 EX.VAT £239.98 INC.VAT

*was £359.98 inc.VAT

MODEL	MOTOR	COOLING CAP	EXC.VAT	INC.VAT
AC7000	808W	7000 BTU (2kW)	£199.98	£239.98
AC10000*	1080W	9000 BTU (2.6kW)	£259.00	£310.80
AC13000*	1350W	12000 BTU (3.5kW)	£289.00	£346.80

airmaster TURBO AIR COMPRESSORS

- Superb range ideal for DIY, hobby & semi-professional use

BIG 2HP 7.5CFM

FROM ONLY £79.98 EX.VAT £95.98 INC.VAT

HUGE CHOICE OF SPRAY GUNS & AIRTOOLS

* Efficient V-Twin

8/250

MODEL	MOTOR	CFM	TANK	EXC.VAT	WAS INC.VAT	NOW INC.VAT
8/250	2HP	7.5	24ltr	£79.98	–	£95.98
7/250	2HP	7	24ltr	£89.98	–	£107.98
11/250	2.5HP	9.5	24ltr	£109.98	~~£143.98~~	£131.98
8/510	2HP	7.5	50ltr	£119.98	~~£155.98~~	£143.98
11/510	2.5HP	9.5	50ltr	£139.98	~~£179.98~~	£167.98
16/510*	3HP	14.5	50ltr	£209.00	~~£263.98~~	£250.80
16/1010*	3HP	14.5	100ltr	£259.98	~~£323.98~~	£311.98

VISIT YOUR LOCAL SUPERSTORE

OPEN MON-FRI 8.30-6.00, SAT 8.30-5.30, SUN 10.00-4.00

BARNSLEY Pontefract Rd, Barnsley, S71 1EZ	01226 732297
B'HAM GREAT BARR 4 Birmingham Rd.	0121 358 7977
B'HAM HAY MILLS 1152 Coventry Rd, Hay Mills	0121 7713433
BOLTON 1 Thynne St. BL3 6BD	01204 365799
BRADFORD 105-107 Manningham Lane. BD1 3BN	01274 390962
BRIGHTON 123 Lewes Rd, BN2 3QB	01273 915999
BRISTOL 1-3 Church Rd, Lawrence Hill. BS5 9JJ	0117 935 1060
BURTON UPON TRENT 12a Lichfield St. DE14 3QZ	01283 564 708
CAMBRIDGE 181-183 Histon Road, Cambridge. CB4 3HL	01223 322675
CARDIFF 44-46 City Rd. CF24 3DN	029 2046 5424
CARLISLE 85 London Rd. CA1 2LG	01228 591666
CHELTENHAM 84 Fairview Road. GL52 2EH	01242 514 402
CHESTER 43-45 St. James Street. CH1 3EY	01244 311258
COLCHESTER 4 North Station Rd. CO1 1RE	01206 762831
COVENTRY Bishop St. CV1 1HT	024 7622 4227
CROYDON 423-427 Brighton Rd, Sth Croydon	020 8763 0640
DARLINGTON 214 Northgate. DL1 1RB	01325 380 841
DEAL (KENT) 182-186 High St. CT14 6BQ	01304 373 434
DERBY Derwent St. DE1 2ED	01332 290 931
DONCASTER Wheatley Hall Road	01302 245 999
DUNDEE 24-26 Trades Lane. DD1 3ET	01382 225 140
EDINBURGH 163-171 Piersfield Terrace	0131 659 5919
EXETER 16 Trusham Rd. EX2 8QG	01392 256 744
GATESHEAD 50 Lobley Hill Rd. NE8 4YJ	0191 493 2520
GLASGOW 280 Gt Western Rd. G4 9EJ	0141 332 9231
GLOUCESTER 221A Barton St. GL1 4HY	01452 417 948
GRIMSBY ELLIS WAY, DN32 9BD	01472 354435
HULL 8-10 Holderness Rd. HU9 1EG	01482 223161
ILFORD 746-748 Eastern Ave. IG2 7HU	0208 518 4286
IPSWICH Unit 1 Ipswich Trade Centre, Commercial Road	01473 221253
LEEDS 227-229 Kirkstall Rd. LS4 2AS	0113 231 0400
LEICESTER 69 Melton Rd. LE4 6PN	0116 261 0688
LINCOLN Unit 5. The Pelham Centre. LN5 8HG	01522 543 036
LIVERPOOL 80-88 London Rd. L3 5NF	0151 709 4484
LONDON CATFORD 289/291 Southend Lane SE6 3RS	0208 695 5684
LONDON 6 Kendal Parade, Edmonton N18	020 8803 0861
LONDON 503-507 Lea Bridge Rd. Leyton, E10	020 8558 8284
LONDON 100 The Highway, Docklands	020 7488 2129
LUTON Unit 1, 326 Dunstable Rd, Luton LU4 8JS	01582 728 063
MAIDSTONE 57 Upper Stone St. ME15 6HE	01622 769 572
MANCHESTER ALTRINCHAM 71 Manchester Rd. Altrincham	0161 9412 666
MANCHESTER CENTRAL 209 Bury New Road M8 8DU	0161 241 1851
MANCHESTER OPENSHAW Unit 5, Tower Mill, Ashton Old Rd	0161 223 8376
MANSFIELD 169 Chesterfield Rd. South	01623 622160
MIDDLESBROUGH Mandale Triangle, Thornaby	01642 677881
NORWICH 282a Heigham St. NR2 4LZ	01603 766402
NOTTINGHAM 211 Lower Parliament St.	0115 956 1811
PETERBOROUGH 417 Lincoln Rd. Millfield	01733 311770
PLYMOUTH 58-64 Embankment Rd. PL4 9HY	01752 254050
POOLE 137-139 Bournemouth Rd. Parkstone	01202 717913
PORTSMOUTH 277-283 Copnor Rd. Copnor	023 9265 4777
PRESTON 53 Blackpool Rd. PR2 6BU	01772 703263
SHEFFIELD 453 London Rd. Heeley. S2 4HJ	0114 258 0831
SIDCUP 13 Blackfen Parade, Blackfen Rd	0208 3042069
SOUTHAMPTON 516-518 Portswood Rd.	023 8055 7788
SOUTHEND 1139-1141 London Rd. Leigh on Sea	01702 483 742
STOKE-ON-TRENT 382-396 Waterloo Rd. Hanley	01782 287321
SUNDERLAND 13-15 Ryhope Rd. Grangetown	0191 510 8773
SWANSEA 7 Samlet Rd. Llansamlet. SA7 9AG	01792 792969
SWINDON 21 Victoria Rd. SN1 3AW	01793 491717
TWICKENHAM 83-85 Heath Rd.TW1 4AW	020 8892 9117
WARRINGTON Unit 3, Hawley's Trade Pk.	01925 630 937
WIGAN 2 Harrison Street, WN5 9AU	01942 323 785
WOLVERHAMPTON Parkfield Rd. Bilston	01902 494186
WORCESTER 48a Upper Tything. WR1 1JZ	01905 723451

OPEN 7 DAYS

4 EASY WAYS TO BUY...

IN-STORE 65 SUPERSTORES

ONLINE www.machinemart.co.uk

MAIL ORDER 0115 956 5555

CLICK & COLLECT

25217