“Ralph” Steam Engine Construction Notes

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I. Introduction

This is a set of construction notes that built up for my Ralph steam engine, which is loosely based on the Polly steam engine by Tubal Cain (the UK one, not the YouTube Tubalcain/Mr. Pete). Along with quite a long list of various changes (miscellaneous and otherwise) I have substituted various threads, bolts and nuts for ones that are more easily obtained in the USA.

This build is dedicated to my Uncle Ralph, many years since passed on. When I was 6 years old, I spent many an hour standing in the tiny workshop of my uncle in Adelaide, South Australia, as he built various stationary steam engines and “locos”.

Remembering the delight of seeing a “metho burning” steam engine fire up at a tender age, I decided that I should build one for my own grandson. Take a look at my YouTube channel Eclectic Builds, for pictures of the delighted face of my grandson when he first saw my Ralph Engine run.

This is not a complete build document; it is recommended that you obtain a copy of **Building Simple Model Steam Engines by Tubal Cain** to guarantee success if you are planning to build a Ralph or Polly of your own. The book is great value for what you get and well worth recognizing the creativity of a long-standing model engineer. Copies may be found on Amazon here (I do not obtain any commercial consideration) or by scanning this QR code:

There is also a 6-week training course run by the **Society of Model and Experimental Engineers** courses in London, specifically the Basic Training for Model Engineers course - Part II Building the “Polly” Steam Engine. But these notes are assuming that you can’t make that course.

These notes also assume you have found a suitable copper pipe to use for the boiler so the jointing operations for the cylinder build are omitted.

A full Bill of Materials is provided bellow, and various prints designed to align with the way that (at least I do) go about various lathe and milling machine operations.

II. Audience

The machinists building this version of Polly are assumed to have access to a lathe and mill – given the price and proliferation of Chinese imports most folks should have access to both.

Optional alternatives not covered based on the availability of a lathe, but the Tubalcain book will provide various alternate methods for building Polly (another good reason to make the purchase)

III. Resources

In selecting my alternative thread and bolt sizes, I utilized the following resources. Feel free to make alternative selections if you don't like mine.

A. British / American Thread Conversion

Thread Table
Local version

B. British / Metric Thread Conversion

Thread Table

IV. Materials List

A. Bar Stock

Material	Type	Dimensions	Size	Quantity
Brass	Round	1/2	12”	1
		3/8	6”	1
	Hex	3/8	6”	1
	Square	3/4	6”	1
	Bar	1/8 x 1	3”	1
Tool Steel	Round	1/8	9”	1
Stainless Steel	Round	1/8	12”	1
	Round	3/8	12”	1
Mild Steel	Round	2	3”	1
		1 3/4	6”	1
		1 1/2	4”	1
		1	2”	1
		3/4	6”	1
	Square	3/8	3”	1
		1	2”	1
	Bar	1/4 x 1/2	4”	1

B. Sheet Metal

Material	Type	Dimensions	Size	Quantity
Brass	Sheet	20 swg	5 x 1	1
		26 swg	6 x 1	1
Copper		16 swg	3 x 6	1
Mild Steel		22 swg	12 x 6	1

C. Tubing

Material	Type	Dimensions	Size	Quantity
Copper	Tube	22 swg	1 3/4 ø x 3”	1
		22 swg	1/2 ø x 6”	1
	Pipe	1/8 OD	12”	1

Find copper tubing at your local plumber’s supply house (maybe at a big box hardware store) it saves a huge amount of grief constructing the boiler and dramatically increases your likelihood of successfully constructing a steam tight boiler.

D. Wire

Material	Type	Dimensions	Size	Quantity
Brass	Wire	1/16	12"	1
Bronze	Wire	0.5mm	12"	1
	Wire	28 swg	12"	1
	Wire	30 swg	12"	1

On the subject of the wire (mainly for spring making), if you have problems obtaining this as I did, it turns out that musical instrument suppliers provided a wide set of options at pretty reasonable prices.

E. Hardware

Material	Type	Dimensions	Size	Substitute	Quantity
Brass	Nut		0 BA	NC 1/4-20	1
	Nut		10 BA	NC 1-64	2
	Nut		6 BA	NC 4-40	6
	Washer		10 BA	NC 1-64	2
	Washer		8 BA	NC 2-56	1
	Rivet	1/16	5/32		2
	Ball		3/16		
Steel	Bolt	3/4	UNC 5-40 or UNC 6-32	??	1
	Bolt	3/16	UNC 4-40		3
	Rivet	3/32	5/16		4
	Ball		3/16		1
	Grub Screw	1/4	UNC 2-56		1

F. Miscellaneous

- Bakers Fluid (soft soldering)
- Soft Solder
- Silver Solder
- Silver soldering equipment
- Silver Solder Flux
- 1/8" snap rivet x 1
- Dividers
- Centre punch
- Mark out fluid
- Reamer
    - 1/8"
    - 5/16
- Emery paper (fine)

- Taps:
    - UNF ¼-28
    - UNF 0-80
    - UNC 2-56
    - UNC 4-40
    - UNC 5-40
  - Dies:
    - UNF 0-80
    - UNC 5-40

V.Drawing Errata and Notes

A.Fig 2-7 Engine Standard

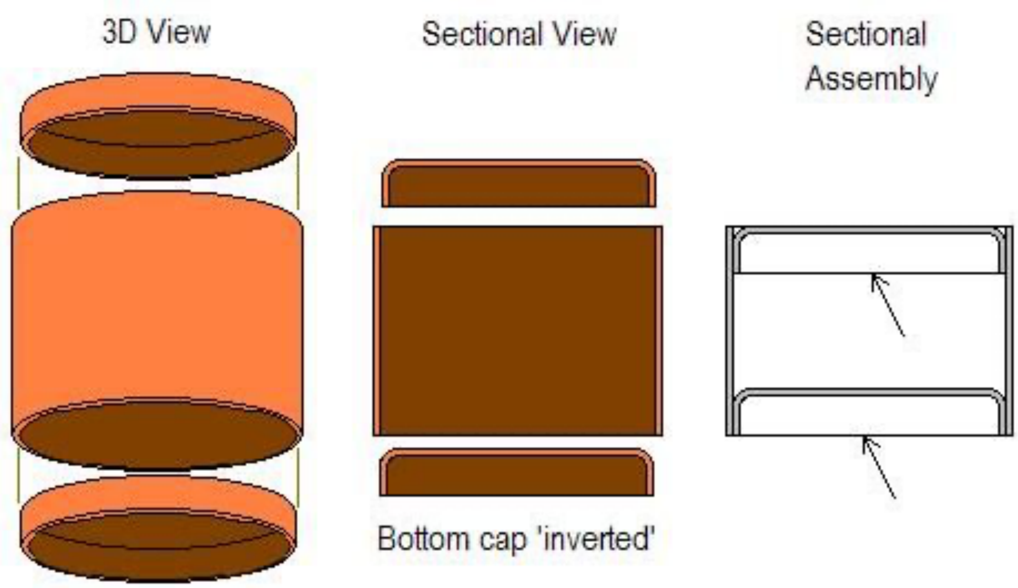
1. Placement of lower #52 hole

Placement of lower #52 hole should be 5/16 from centre of the #33 hole, not from the top edge as shown in the plans. Alternatively, the #52 hole should be placed 15/32 from the top edge.

B.Boiler Plates / End Caps

1. Placement of boiler plates

This useful picture showing the boiler cap orientation came from the Model Engineer web site: (http://www.model-engineer.co.uk/forums/postings.asp?th=64451)



Polly Boiler construction

VI. Thread Substitutions

I am not planning to do restoration work, and frankly the investment in taps (multiple per size) and dies is prohibitive when you are starting out. There is a lot of debate about which way to jump on the issue of threads, nuts and bolts base on the BA or ME specifications.

As a result, for practical reasons, I chose to substitute nearest equivalents based on the US UNC spec.

The alternative is to opt for Metric equivalents and that is arguably actually be the smarter way to go, but based on my current residence in the USA it still means I need to invest in at least two thread standards.

I have included references to conversion charts so you can make up your own mind. The drawing notes shows where substitutions have been made. As always, alternate suggestions from those who have been through this process are welcome.

A copy of BA, Metric and Unified thread equivalents is included as an appendix. Apologies to the author, but I could not find the original publisher or location – if anyone knows where it comes from I am happy to provide attribution.

VII. Construction Highlights

A.Boiler

1. Boiler Layout (Fig 2-2, p 18)

- End plate rough dimensions = boiler tube diameter + 0.5”
- Valve bush and steam pipe centered 5/8” from centre line on top plate
- Tapped hole substitution 4x **UNC 2-56**

2. Chimney (p 22)

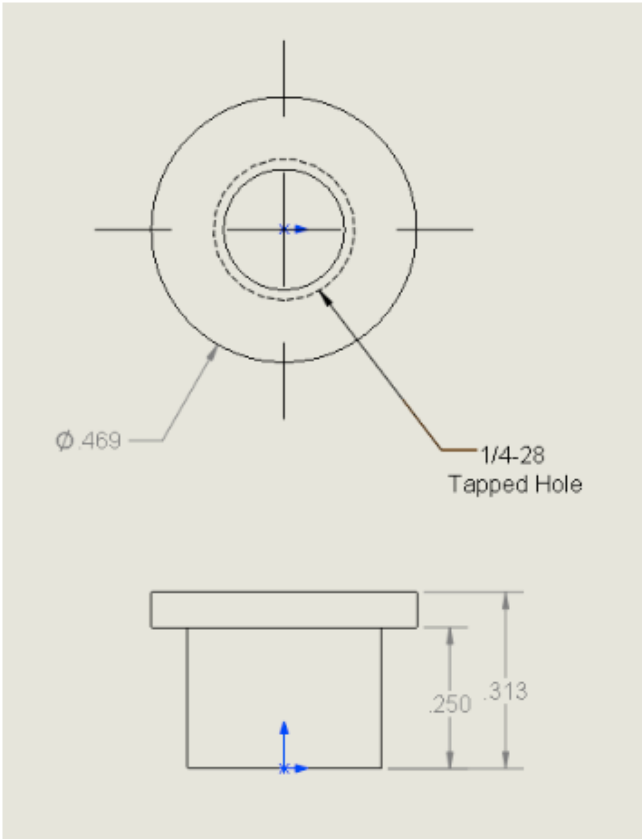
- Cut 5 ¾” length copper pipe
- Hold in collet and polish w fine emery
- Verify copper pipe diam (nominal = ½”)
- Note that trimming on lathe does not use power

3. End-plate Construction (Fig 2-2, p 22)

- Deburr after cutting out disks
- Drill 9/32 holes in centre of each plate for former bolt
- Anneal end plates
- Former diameter turned on lathe = tube diam – (2 x sheet thickness)
- Drill 9/32 holes in former
- Anneal end plates and form edges
- File edges as required
- Enlarge original 9/32” holes by 1/64” increments to match chimney tube OD
- Drill holes for safety valve (11/32”) and steam pipe (1/8”)

4. Safety Valve Bushing Construction (Fig 2-2, p 22)

- 1/2” brass round
- Turn to 15/32” (0.4687) diam x 5/16” (0.3125) length
- Centre drill
- Drill 7/32” (0.2188) x 1/2” (0.500)
- Tap UNF 1/4-28 (taper + plug taps) ****substitution**
- Turn 11/32” (0.344) diam x 1/4” (0.250) length (fit to valve hole in end plate)



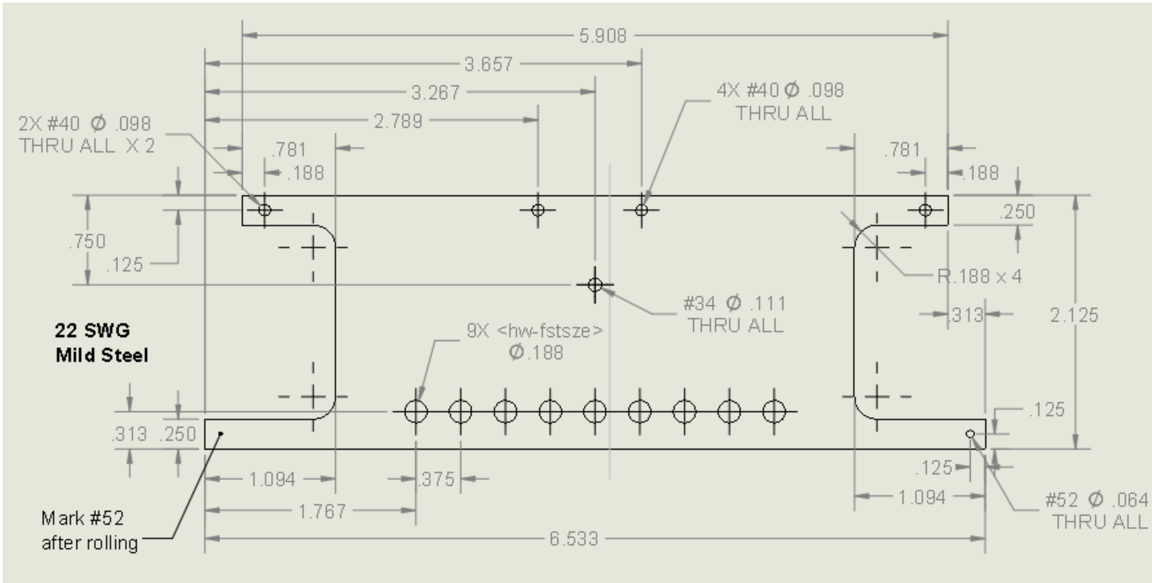
5. Boiler Construction

- Position top plate w/r to boiler tube seam
- (optional) 1/16 rivets to hold plate in place during brazing
- Insert safety valve bushing
- Insert chimney into fluxed holes
- Dull red heat level for copper during brazing
- Test boiler via safety valve bushing under water

B.Firebox and Base

1. Firebox Layout (Fig 2-6, pp 24-27)

- Firebox length = 22/7 x Boiler OD + 1/4"
- #33 holes replace #34 holes due to UNC 4-40 substitution for 5 BA
- Layout "most" holes
  - 2^{nd} #52 rivet hole will be transferred after rolling
  - 2 x #33 holes will be transferred from Engine Standard
    - Updated to UNC 4-40 ****substitution**
- 4x #40 holes still valid for UNC 2-56 bolts

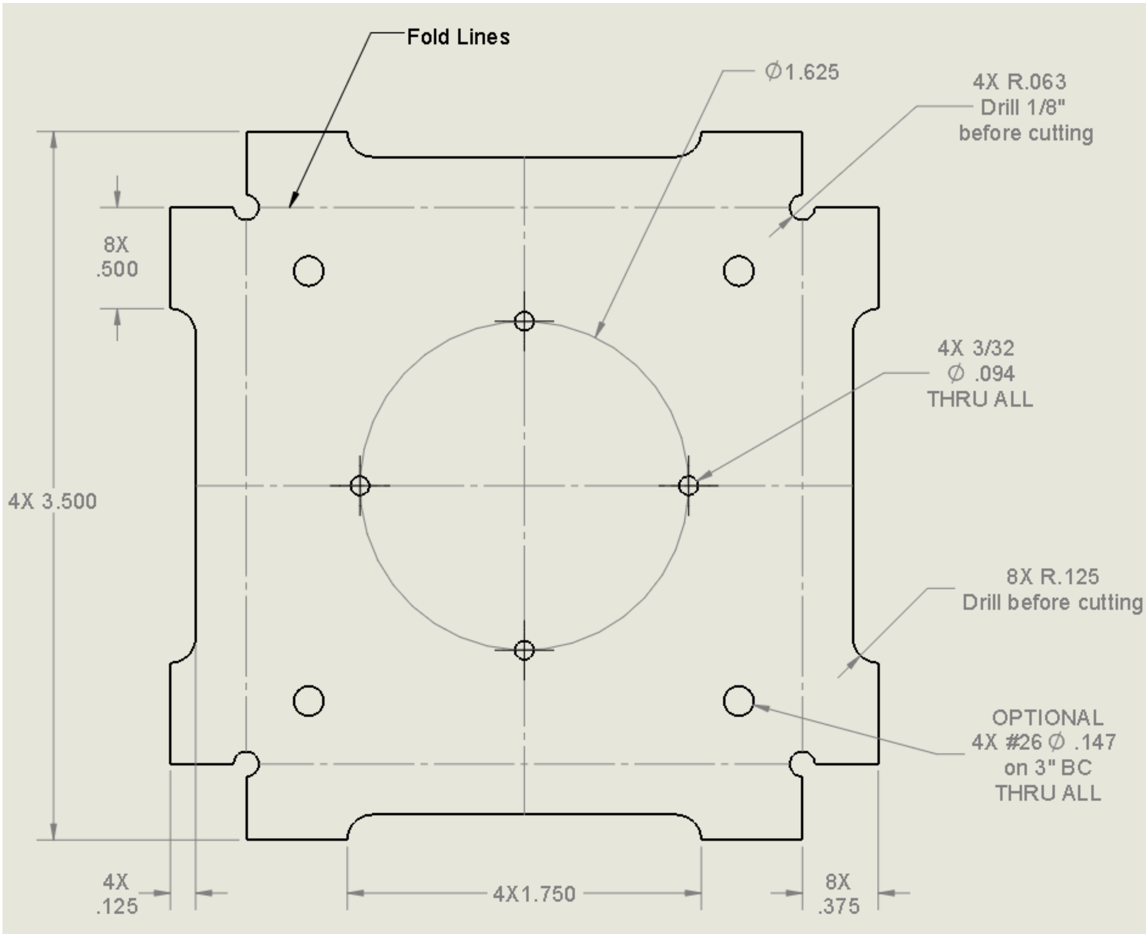


2. Firebox Cutting

- Drill 3/16" holes at inside corners before cutting
- Q: can sheet layout be cut on Mill?
- Drill only one of #52 holes; mark second when rolled
- 1/16" Rivet
- Flux and tin 1/4" up from bottom edge

3. Base Layout (Fig 2-6, pp. 24-27)

- Scribe centre circle Firebox OD + 1/8”



4. Base Cutting

- Drill 1/8” inside corners before cutting / folding
- Flux and tin top surface to 1/16” ***inside*** centre circle
- Flux and tin inside of corners

5. Firebox, Base and Cylinder Assembly

- Align fire hole door with one edge of base
- Soft solder from inside
- Align seam of boiler to fire hole
- Transfer 2 diagonal #40 holes from firebox to cylinder
- Drill #50 holes – still valid for UNC 2-56 tap ****substitution**
- Square up boiler to base, transfer remaining 2 #50 holes and tap
- Dismantle and clean
- Cellulose undercoat and black spray paint (engine enamel?)

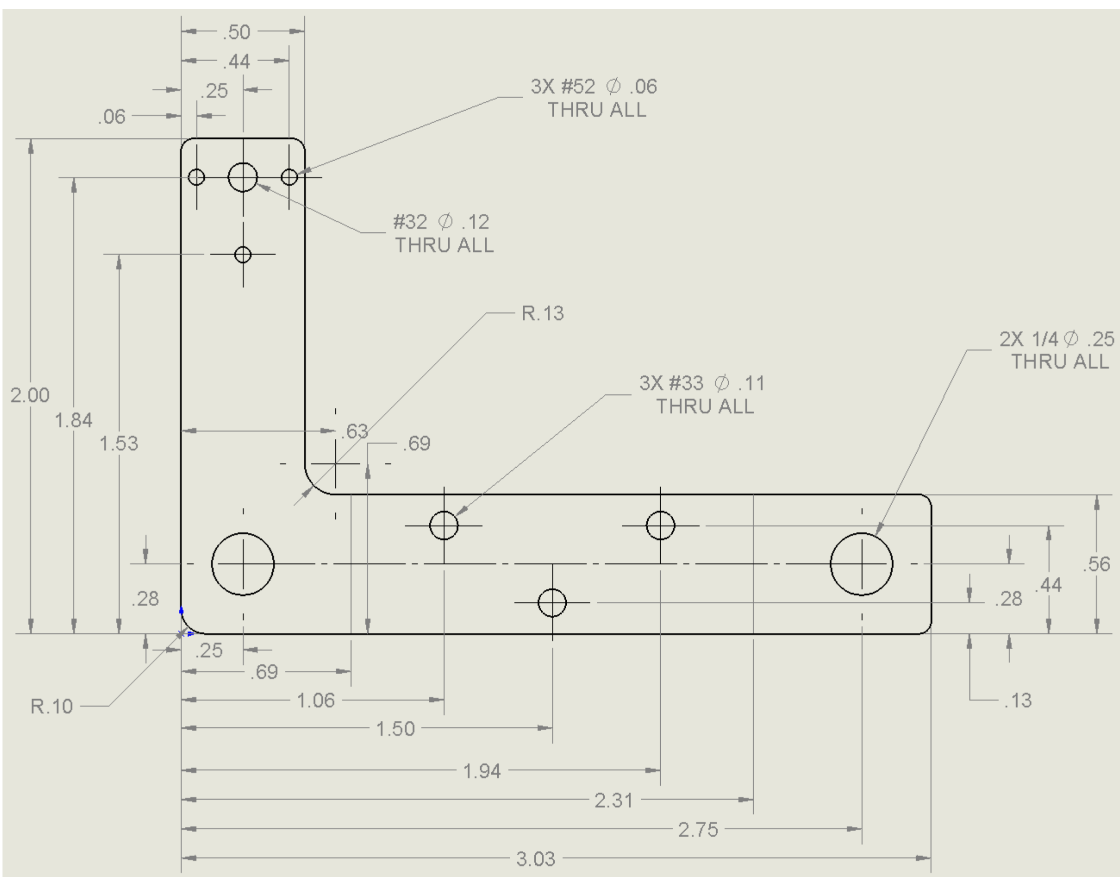
C.Engine Mount

1. Layout (Fig 2-7, pp. 27-29)

If you have a height gauge (or carefully use a set of digital calipers) the layout process is considerably easier and less confusing. That is the method I used but if you are restricted to ruler and dividers follow along the method described in the book – both will work, but you will need to use more care.

To support the use of a height gauge a drawing of the engine support in decimal inches is provided. All measurements are specified from the two references edges.

- 22 swg mild steel 2 1/8 x 3 1/8
- Rather than dividers use surface plate, perpendicular reference and height gauge
- **#32 hole replaces** #33 centre hole due to UNC 4-40 ****substitution**
- **3x #33 holes replace** #34 holes for UNC 4-40 bolts to secure standard to firebox ****substitution**
- Layout as per instructions on p 27 if you are using dividers
- Centre punch all holes
- Drill 1/4" at elbow

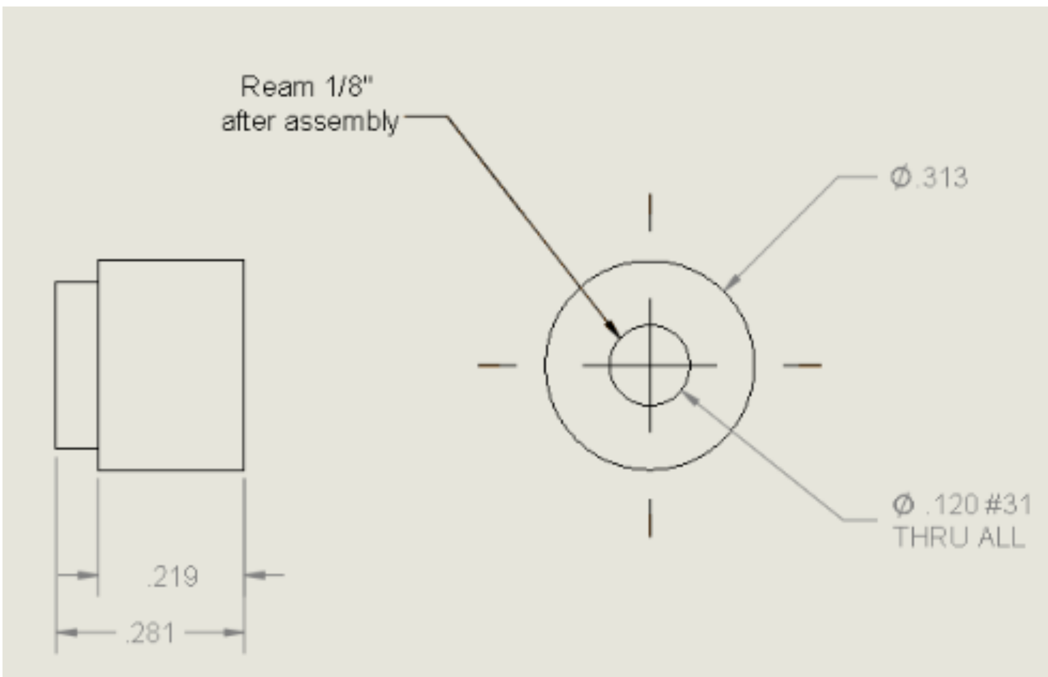


2. Cutting

- Drill and de-burr all holes before cutting out arms
- Drill elbow with 1/4” bit
- Use light CD to prior to drilling #32 and 1/4" holes

3. Bushings (Fig 2-7, p 29)

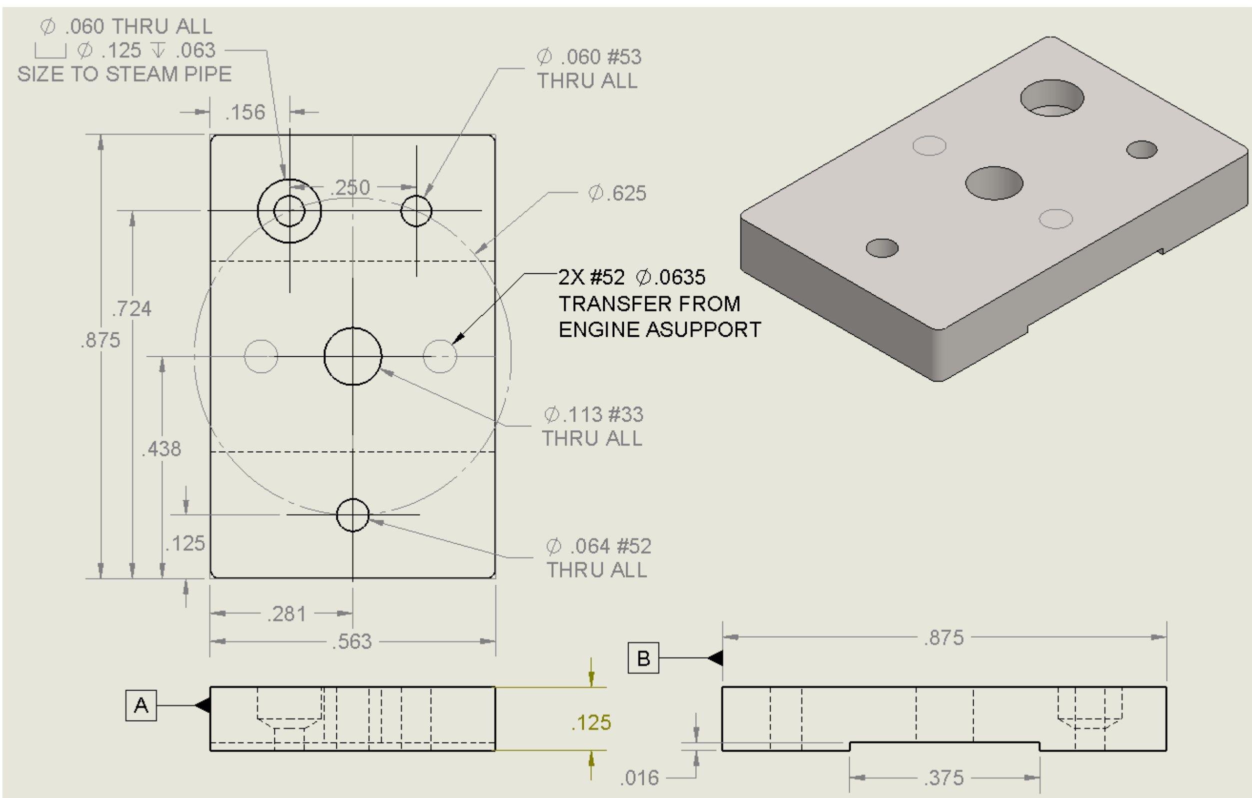
- 5/16 diam x 1/2” brass round
- Drill centre hole #31 x 1/2” for both bushings and countersink
- Turn down 0.250” x 0.650”
- Part off oversize
- Facing cut
- Repeat for 2nd bushing



D.Port Face

1. Layout (Fig 2-8, pp. 29-31)

- Drawn brass flat 5/32”
- Thickness is not critical
- Flatten with emery paper
- Form reference edge for mark out
- Mark 2 centre lines, centre punch intersection
- **#33 hole replaces** #34 hole for UNC 4-40 ****substitution**
- Use values for height gauge if you have one, otherwise use directions P 30
- Leave 2 x #52 holes (on centre line) for transfer from engine standard



2. Cutting

- Drill all holes (with exception of 2 x #53)
- Drill steam ports with #53 bit
- Centre Drill #33 hole
- Drill #52 holes
- Flip port face
- Carefully choose steam port
- Drill #31 x 1/16” deep
- File part to shape

3. Assembly and layout (Fig 2-8, p 30)

- Bolt port face to engine standard with a UNC 4-40 bolt through the **#33** centre hole ****substitution**
- Line up port face using wire through #52 hole
- Transfer 2x #52 holes from engine standard to port face
- Drill 2x #52 holes
- Counter sink all 3x #52 holes on front face
- Cut 1/16” relief on front face
- Fine emery to remove marks from front face
- Flux and tin back of port face and front of standard
- Rivets through #52 holes next to centre hole, round head against standard and round over
- Rivet through 3rd #52 hole, cut and filed flush with port face
- Heat until solder runs between standard and port face
- Emery paper to bring 3rd rivet flush with port face
- Flux bearing bushes and standard, clamp and sweat
- UNC 4-40 used to bolt standard to firebox through #33 hole (Fig 2-6) ****substitution**
- Mark and drill 2x #33 holes through firebox and fit UNC 4-40 bolts ****substitution**
- Ream through both bushes with 1/8” reamer
- Remove standard and prime and paint steel parts

E. Crank

- Disk **UNC 5-40 tap and die** substituted for 5 BA

1. Layout (fig 2-9, pp. 31-33)

- Turn 1" diam to 7/8" x 1/2"
- Face and turn boss 5/16" diam x 3/16"
- Scribe centre for crank pin 5/16" from centre with lathe tool

2. Disk Construction

- **Use #38 drill to replace** #37 for centre hole
- Open out 1/8" dim x 7/32"
- Tap UNC 5-40 ****substitution**
- Part off over dimension
- Centre punch on scribed line for crank pin hole
- Drill #43 for crank pin hole
- Re-run 5-40 tap

3. Pin Construction

- 3/32 Tool steel round
- Turn down to 1/8" for tight fit to #43 hole in disk
- Part off 11/32"
- Press fit to disk

4. Shaft Construction

- Cut 1/8" tool steel rod to 2 3/4"
- Cut 5-40 thread using die and holder ****substitution**
- Screw into disk

F. Flywheel

1. Construction (Fig 2-10, pp 33-35)

- 1 3/4 " diam x 1 3/8" mild steel round
- Face end
- Roughing cut to form cylinder
- Flip & face end
- Fine finish cylinder
- Form boss 10 thou oversize and 1/16" long
- Machine recess
- Cut groove in boss
- Drill centre with #1 CD and #31 drill x 1"
- 1/8" reamer
- Assume bushing is not required

- Part off wheel for 3/8" (+0.003") wide rim
- Re-chuck, true up and face off stub
- Machine recess
- Countersink hole
- Form set screw hole with #50 drill and tap **UNC 2-56 **substitution**

G. Cylinder

1. Barrel Construction (Fig 2-11 pp. 35-38)

- Chuck 3/8" diam brass round x 1 3/8" with ¼" stick out
- Face end
- Drill centre with CD and N drill

2. Cap Construction

- Turn down 5/16" diam spigot (tight fit to barrel)
- Flip over and round over top
- Polish with emery

3. Port Block Construction

- Mill this piece
- Chuck 3/4" brass square
- Face ends and size to 7/8"
- Drill 3/8" hole down length
- Smooth side and square with ends 11/32" from centre line
- Drill #43 through
- Tap UNC 4-40 ****substitution**
- Recess steam port centre 1/64" x 3/8" (1/4" from each end)
- Split down centre and dimension to 5/16" from port face
- Bevel sides

4. Pivot Pin Construction

- Turn 1/8" tool steel down to 0.112" x 15/16" finish length
- Cut UNC 4-40 thread both ends ****substitution**

5. Assembly

- Flux and tin Port Block and Cylinder barrel
- Clamp and sweat together
- Tin top edge of cylinder
- Ream barrel with 5/16" reamer
- Tin cylinder head and cold press into barrel
- Heat head till solder runs

H.Piston

The description of the turning setup for the piston (p 38) may be a little obtuse for American audiences. Essentially it is turning the piston between centres using a lathe dog. The piston has a hole drilled with a Centre Drill in each face. The “soft centre” is usually a mild steel round chucked in a 3-jaw chuck and turned to 60° cone. As long as it is not removed it will establish a reliable centre for the piston, which is then placed between the soft centre and a live or dead centre in the tailstock. A lathe dog is attached to the piston stock and driven by one of the jaws in the chuck.

Figure 1 Turning a camshaft between centres

Alternatively a collect could be used to hold the round stock in conjunction with a centre in the tailstock to provide some support for cutting the stainless steel.

1. Construction

Additional views of the piston are provided with metric inch dimensions for anyone using a micrometer or calipers.

- Chuck Stainless Steel round 3/8" diam x 2 3/4'
- Take cuts of at least 0.005"

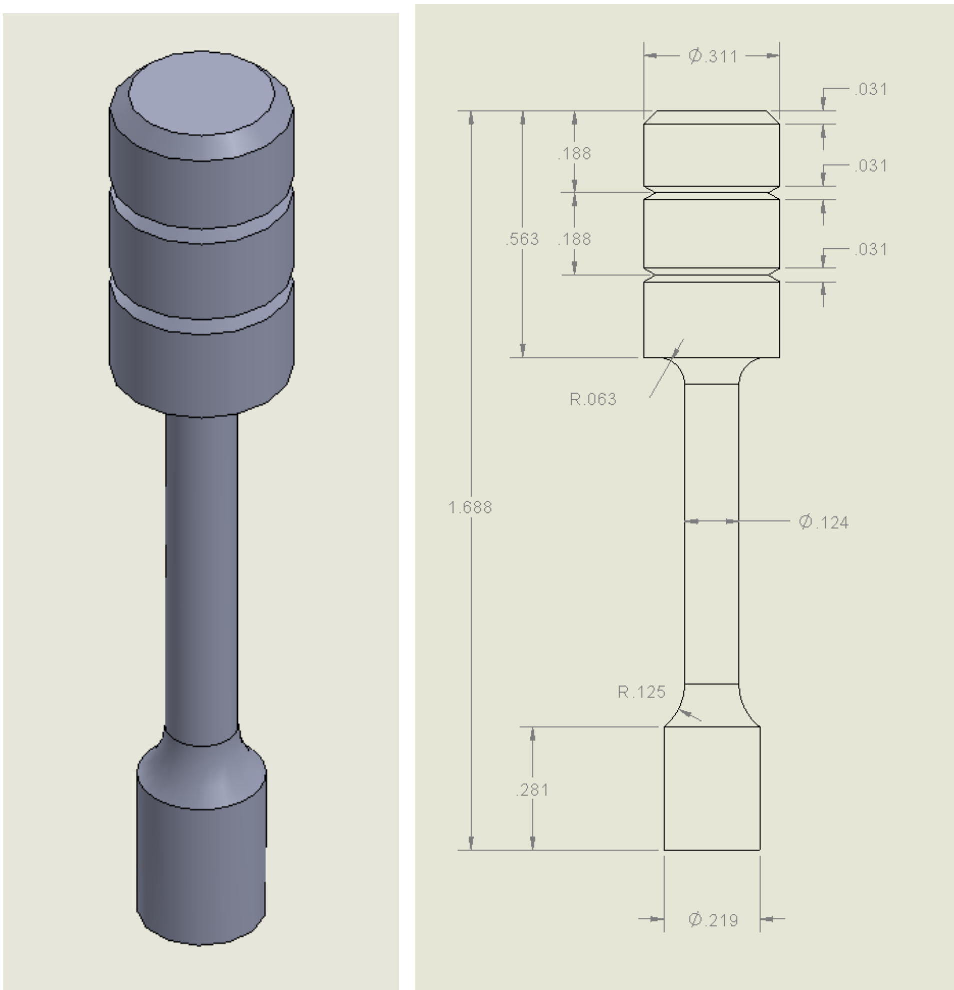


Figure 2 Piston Turning - Isometric and Print Views

- Turn diameter to fit cylinder + 0.010" (for 5/16 this will be 0.3225)
- Turn piston head down to 0.311 (providing 0.0015 cylinder clearance)
- Turn 7/32" (0.219) diam - big end and piston rod
- Turn 7/64" (0.124) diam piston rod
- Cut two grooves to 0.020" depth (60° threading tool)
- Chamfer top edge of piston
- Lap piston in cylinder

- Although Tubal Cain relies heavily on bench methods, if you have a mill, things are considerably easier

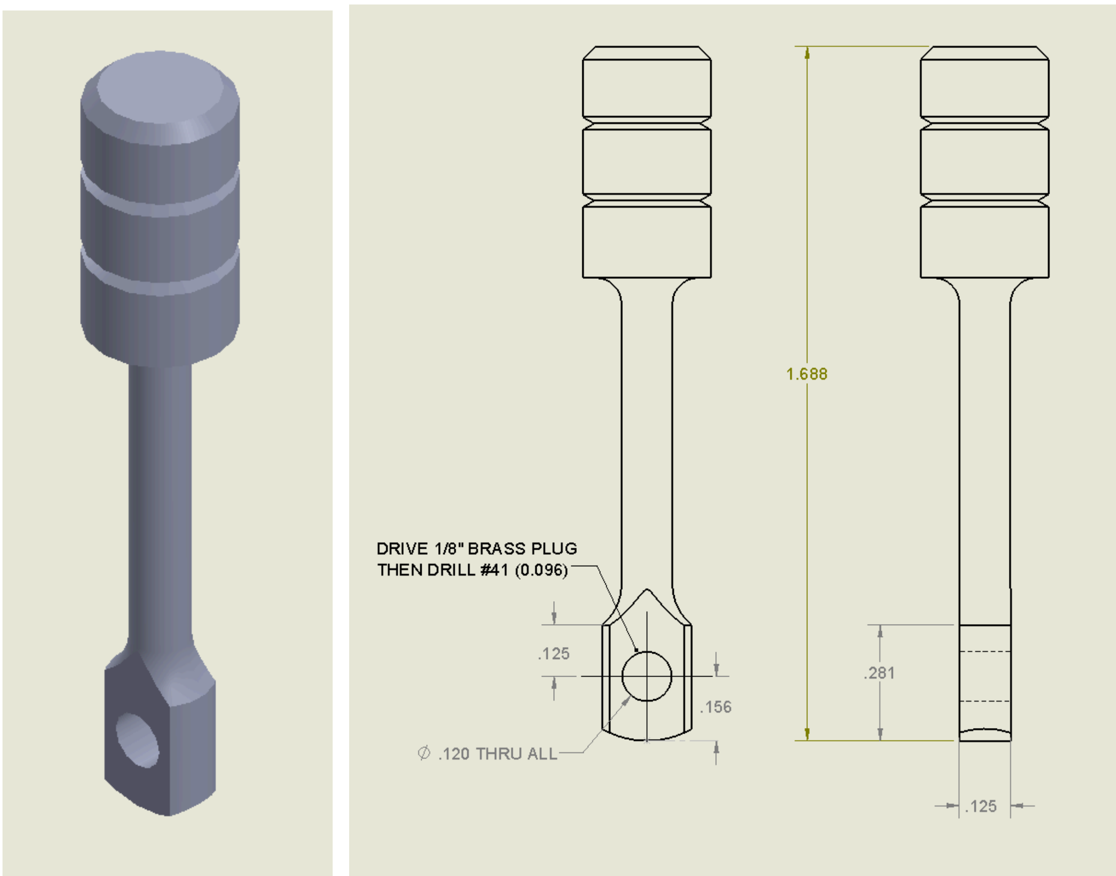


Figure 3 Piston Milled - Isometric and Print Views

- Mill flats on the cylinder big end
- Drill #31 hole
- Widen slightly with a broach or round file
- Press fit 1/8" brass plug
- Drill #41 hole in brass plug

I. Cylinder Ports

1. Layout (pp. 40 – 41)

- Attach boiler to firebox
- Attach engine standard
- Attach flywheel – lightly snug screw
- Insert piston in cylinder and attach crankpin
- Set crank to Position A (Fig 2-14)
- Mark through hole “a” with a #53 drill
- Set crank to position B
- Mark through hole “b” with #53 drill
- Dismantle cylinder and remove piston

2. Construction

- Use small v-block
- Level port face
- Drill each port through with #53 drill
- **DO NOT DEBUR**
- Reassemble and verify hole locations when the crank is at position A and B
- If necessary enlarge steam port w #52 drill
- Remove crank and spring
- Lap port faces

J. Safety Valve

The description of the safety valve construction is a little hard to follow (especially as there are one or two errors in the text) and I have updated the threads from BA to UNF in a number of places. I have included some additional drawings (showing decimal inch dimensions) of the components as well as the notes for this little device.

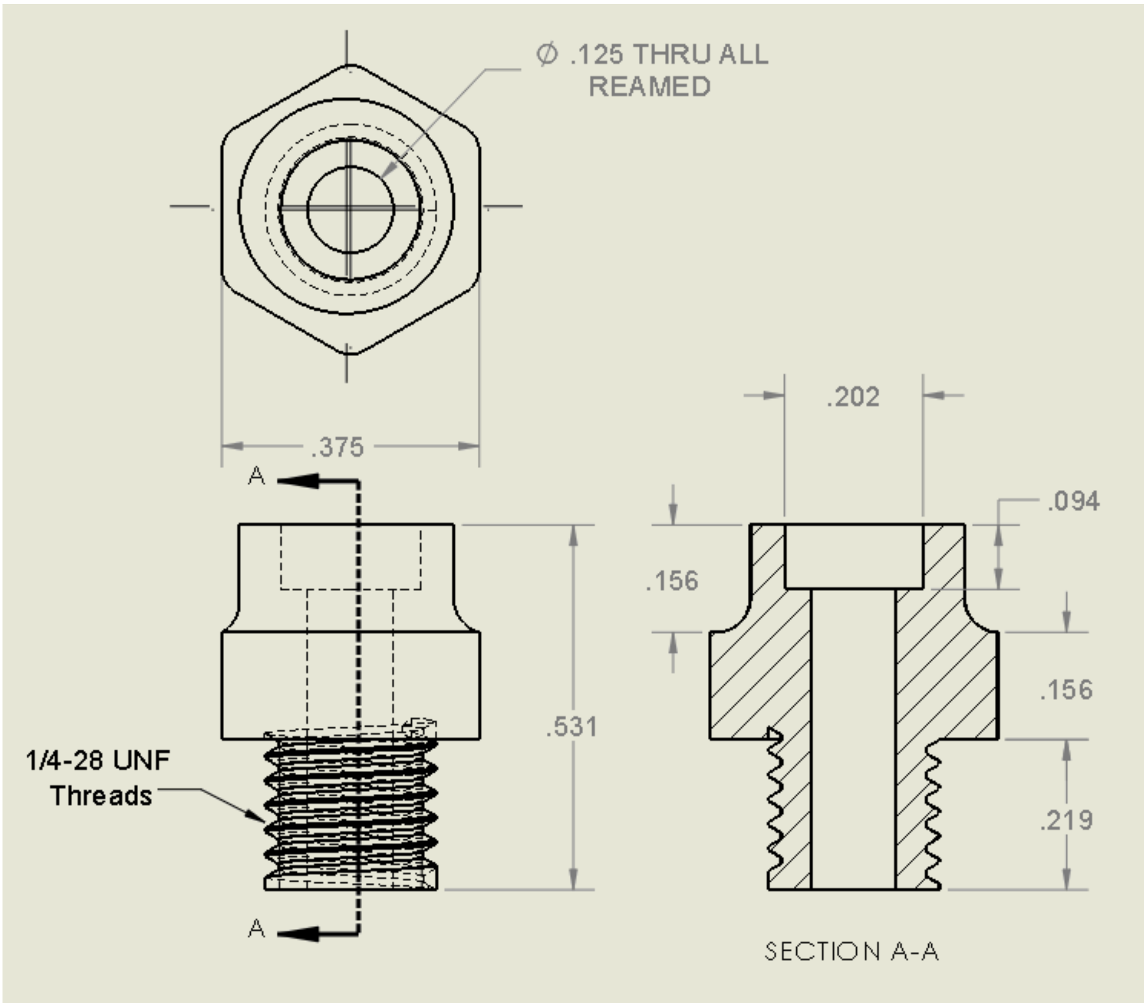
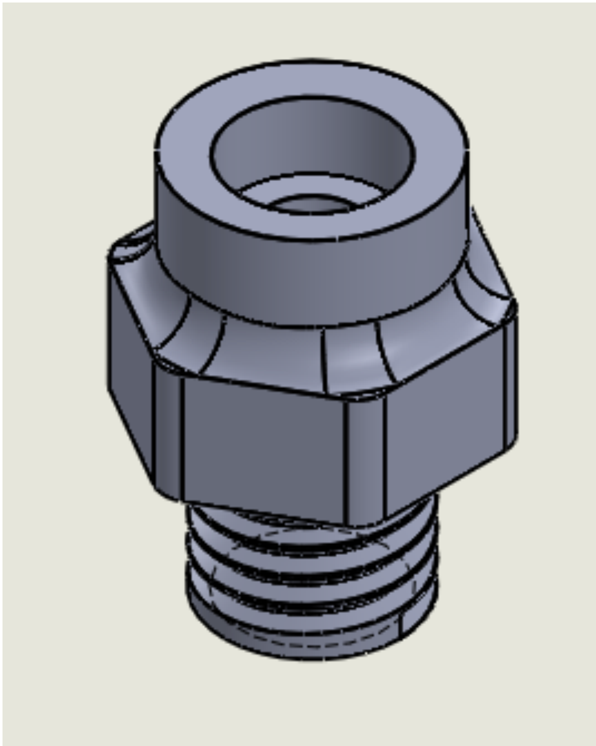


Figure 4 Safety Valve Body



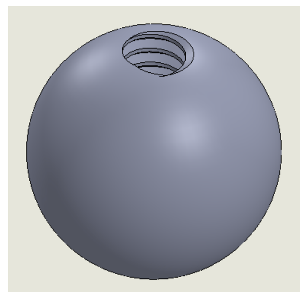
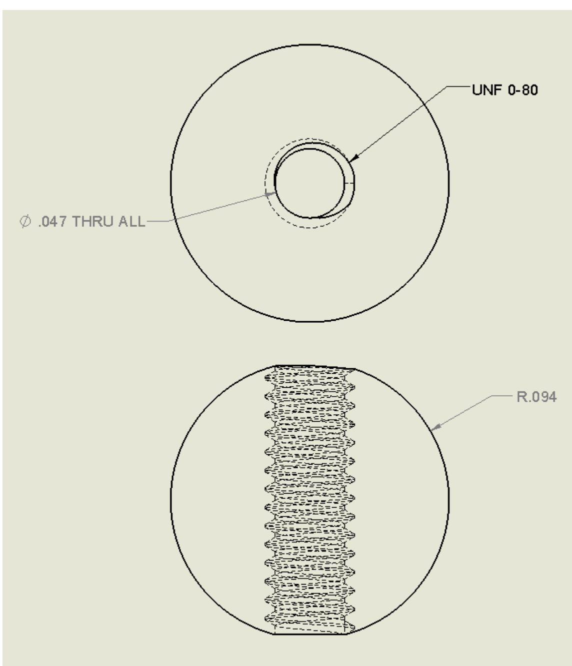


Figure 5 Safety Valve Body and Valve Ball (Isometric)



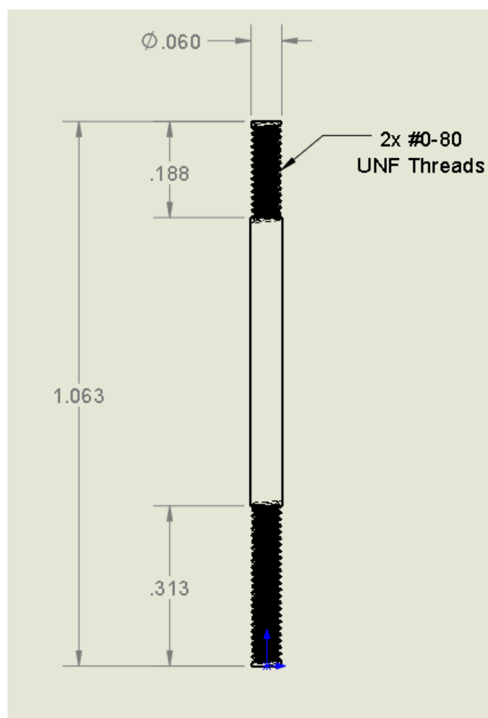


Figure 6 Valve Ball and Valve Stem

1. Valve Body Construction (Fig 2-15, pp. 41-43)

- Chuck 3/8" hex brass stock x 1.5"
- Turn 7/32 (0.219") to 1/4" (0.250)
- Tailstock die holder to thread UNF 1/4-28 ****substitution**
- Bevel hex corners
- Part off
- Chuck scrap brass round 1/2" diam
    - Drill #3 and tap 1/4-28
    - Screw in valve stem
- Face end to dimension
- Drill centre with CD and #34 drill
- Enlarge with 13/64" drill and D-bit to depth of 3/32 for ball seat
- Ream centre hole with 1/8" reamer
- Turn down a decorative edge leaving 5/32 of hex profile
- Tap a 3/16 steel ball to create a seat for the valve ball

2. Valve Ball

- Chuck 3/16 brass ball
- Face 1/16 flat for drilling
- Centre drill
- Drill 3/64 through all
- Tap UNF 0-80 ****substitution**

3. Valve Stem

- Chuck 1/16" brass rod x 1"
- Turn down to 0.600 Φ x 5/16" one end and x 3/16" on the other
- Use 0-80 die to cut thread on each end

4. Valve Assembly

- Screw 3/16" thread of valve stem into ball
- Wind 9 turns of 28 swg wire on 1/16" former
- Assemble valve stem and ball into valve body
- Attach spring single 0-80 nut on valve stem
- Adjust nut and spring until valve opens with 2 -3 oz of force
- Add a lock nut
- Screw into boiler w fibre or leather washer

K. Lamp

1. Construction

- 1/4" wick is available on Amazon cheaply
- Top and bottom are 2" diam
- Drill 3x 1/4" holes for wicks
- Drill 1/8" hole in centre for vent
- Cut barrel from 1 x 4 15/16" (check this length based on diam of top and bottom plates)
- Roll using a 1 1/2" former
- Scribe vertical joint and flux ends
- Silver solder ends lapping
- Braze end plates
- 3 Wick tubes are brass 5/8 x 2" wrapped around 1/4" former
- Handle formed from 28 swg brass sheet 1/2 x 2"
- Soft solder wick tubes
- Soft solder handle
- Polish and cut wicks

L. Engine Assembly

1. Construction (p 41)

- Add weight to underside of base
- Touch up paint and polish copper surfaces
- Assemble standard
- Insert shaft in bearings and adjust to run freely, tweaking lugs
- Fit flywheel w 1/64" side play
- Cut 1/8" copper pipe to length for steam pipe
- Enlarge cylinder end with taper pin to make a tight fit in hole
- Mask off exhaust port
- Soft solder steam pipe to port face

2. Test Run

- Check boiler capacity – 2/3 of full is a normal fill
- Fill with hot water
- Oil bearings
- Cylinder oil on port face and in cylinder
- Check safety valve will blow off
- Supply with cylinder oil and light oil

VIII.Finished Models

1. ***Tubal Cain "POLLY" live steam like mamod home made.***
2. **Steam engine "Polly" manufacturing process**
3. **Polly Engine / Boiler 1st run**
4. **Tubal Cain "Polly" Steam Engine**
5. **Tony Wright Polly**

IX. Appendix: British / Metric / US Thread Substitutions

British (inch)	American (inch)	Metric (mm)	Outside Dia (inch)	Tap Drill	Tap Drill Dia (thou)	Alternate Tap Drill	Alternate Tap Dia
16 BA			0.0311	0.60 mm	0.0236		
15 BA			0.0354	0.70 mm	0.0276		
14 BA			0.0394	0.80 mm	0.0315		
13 BA			0.0472	0.98 mm	0.0386		
12 BA			0.0512	1.05 mm	0.0413		
	0 - 80		0.0600	3/64	0.0469		
1/16 - 60			0.0625	3/64	0.0469		
11 BA			0.0591	1.20 mm	0.0472		
10 BA			0.0669	no. 54	0.0550		
	1 – 64 UNC		0.0730	no. 53	0.0595		
	1 – 72 UNF		0.0730	no. 53	0.0595		
9 BA			0.0748	no. 53	0.0559		
	2 - 56 UNC		0.0860	no. 50	0.0700		
	2 - 64 UNF		0.0860	no. 50	0.0700		
8 BA			0.0865	1.8 mm	0.0709	no. 50	0.0700
3/32 – 48 BSW			0.0937	no. 48	0.0760		
7 BA			0.0983	no. 47	0.0785		
	3 - 48 UNC		0.0990	no. 47	0.0785		
	3 - 56 UNF		0.0990	no. 46	0.0810	no. 45	0.0820
6 BA			0.1102	2.3 mm	0.0905	no .43	0.0890
	4 - 40 UNC		0.1120	no. 43	0.0890	no. 44	0.0860
	4 - 48 UNF		0.1120	no. 42	0.0935	no. 43	0.0890
		3.0 - 0.6	0.1181	2.4 mm	0.0945	3/32	0.0938
		3.0 - 0.5	0.1181	2.5 mm	0.0984	no. 40	0.0980

British (inch)	American (inch)	Metric (mm)	Outside Dia (inch)	Tap Drill	Tap Drill Dia (thou)	Alternate Tap Drill	Alternate Tap Dia
1/8 - 40 BSW/ME			0.1250	no. 38	0.1015		
	5 - 40 UNC		0.1250	no. 38	0.1015		
	5 - 44 UNF		0.1250	no. 37	0.1040		
5 BA			0.1259	no. 37	0.1040		
		3.5 - 0.6	0.1378	2.9 mm	0.1142	no. 33	0.1130
	6 - 32 UNC		0.1380	no. 36	0.1065		
	6 - 40 UNF		0.1380	no. 33	0.1130		
4 BA			0.1417	3.0 mm	0.1181	no. 32	0.1160
		4.0 -0.75	0.1575	3.2 mm	0.1260	1/8	0.1250
		4.0 - 0.7	0.1575	3.3 mm	0.1299	no. 30	0.1285
3 BA			0.1614	no. 29	0.1360		
	8 – 32 UNC		0.1640	no. 29	0.1360		
	8 - 36 UNF		0.1640	no. 29	0.1360		
2 BA			0.1850	4.0 mm	0.1575	no. 22	0.1570
3/16 - 24 BSW			0.1875	no. 27	0.1440		
3/16 - 32 BSF/ME			0.1875	no .23	0.1540		
	10 - 24 UNC		0.1900	no. 25	0.1495	no. 26	0.1470
	10 - 32 UNF		0.1900	no. 21	0.1590		
		5 - 0.9	0.1968	4.1 mm	0.1614	no. 20	0.1610
		5 - 0.8	0.1968	4.2 mm	0.1654	no. 19	0.1660
1 BA			0.2086	4.5 mm	0.1772	no. 16	0.1770
	12 - 24 UNC		0.2160	no. 16	0.1770		
	12 - 28 UNF		0.2160	no. 15	0.1800	no. 14	0.1820

British (inch)	American (inch)	Metric (mm)	Outside Dia (inch)	Tap Drill	Tap Drill Dia (thou)	Alternate Tap Drill	Alternate Tap Dia
7/32 - 24 BSW			0.2187	no. 16	0.1770		
7/32 - 26 BSB			0.2187	no. 15	0.1800		
7/32 - 28 BSF			0.2187	no. 14	0.1820		
0 BA			0.2362	5.1 mm	0.2008	no. 7	0.2010
		6 - 1.0	0.2362	5.0 mm	0.1968	no. 9	0.1960
	1/4 - 20 UNC		0.2500	no. 9	0.1960		
1/4 - 20			0.2500	no. 7	0.2010		
1/4 - 26			0.2500	no. 4	0.2090		
	1/4 - 28 UNF		0.2500	no. 3	0.2130		
		7 - 1.0	0.2756	6.0 mm	0.2362	15/64	0.2344
	5/16 - 18 UNC		0.3125	1/4	0.2500		
5/16 - 18 BSW			0.3125	F	0.2570		
5/16 - 22 BSF			0.3125	G	0.2610		
	5/16 - 24 UNF		0.3125	I	0.2720		
5/16 - 26 BSB			0.3125	J	0.2770		
		8 - 1.25	0.3150	6.8 mm	0.2677	H	0.2720
		8 - 1.0	0.3150	7.0 mm	0.2756	I	0.2660
3/8 – 16 BSW			0.3750	7.9 mm	0.3110		
	3/8 - 16 UNC		0.3750	5/16	0.3125		
3/8 - 20 BSF			0.3750	P	0.3230		
	3/8 - 24 UNF		0.3750	Q	0.3320		
3/8 - 26 BSB			0.3750	Q	0.3320		
		10 - 1.5	0.3937	8.5 mm	0.3346	Q	0.3320

British (inch)	American (inch)	Metric (mm)	Outside Dia (inch)	Tap Drill	Tap Drill Dia (thou)	Alternate Tap Drill	Alternate Tap Dia
		10 - 1.25	0.3973	8.8 mm	0.3465	S	0.3480
		10 - 1.0	0.3973	9.0 mm	0.3543	S	0.3480
7/16 - 14 BSW			0.4375	23/64	0.3594		
	7/16 - 14 UNC		0.4375	U	0.3680		
7/16 - 18 BSF			0.4375	3/8	0.3750		
	7/16 - 20 UNF		0.4375	25/64	0.3906		
7/16 - 26 BSB			0.4375	Y	0.4040		
		12 - 1.75	0.4724	10.3 mm	0.4055	Y	0.4040
		12 - 1.5	0.4724	10.5 mm	0.4134	Z	0.4130
		12 - 1.25	0.4724	10.8 mm	10.8 mm	27/64	0.4219
		12 - 1.0	0.4724	11.0 mm	0.4331	7/16	0.4375
1/2 - 12 BSW			0.5000	13/32	0.4062		
	1/2 - 13 UNC		0.5000	27/64	0.4219		
1/2 – 20			0.5000	7/16	0.4375		
	1/2 - 20 UNF		0.5000	29/64	0.4531		
1/2 - 26 BSB			0.5000	29/64	0.4531		
		14 - 2.0	0.5512	12.0 mm	0.4724	15/32	0.4688
		14 - 1.75	0.5512	12.3 mm	0.4842	31/64	0.4844
		14 - 1.5	0.5512	12.5 mm	0.4921	1/2	0.5000
		14 - 1.25	0.5512	12.8 mm	0.5039	1/2	0.5000
		14 - 1.0	0.5512	13.0 mm	0.5118	33/64	0.5156