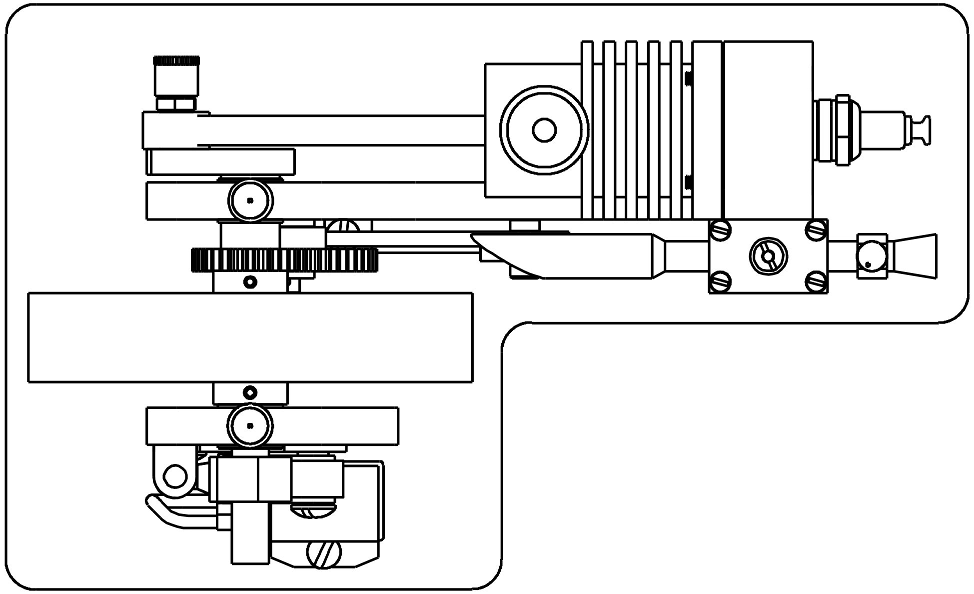
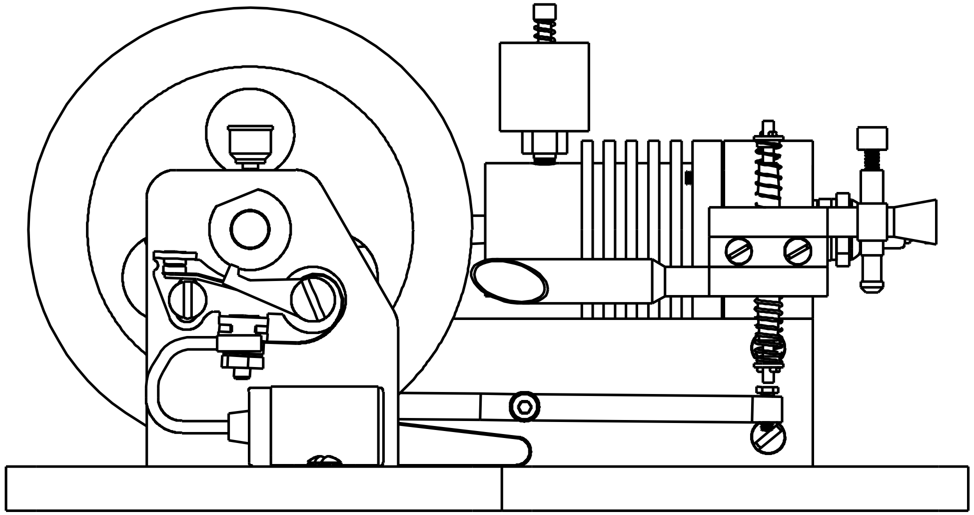
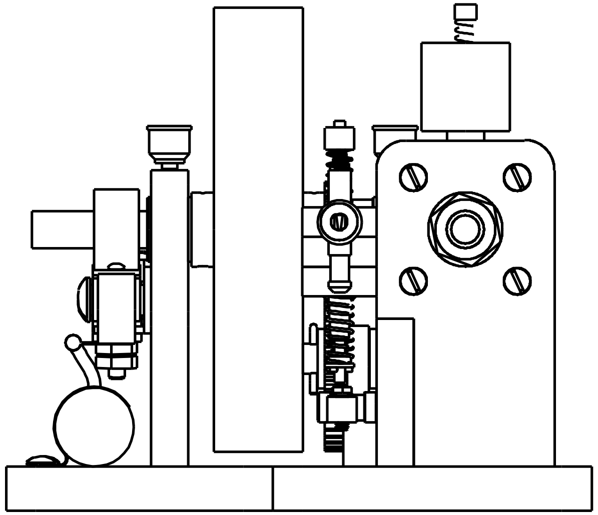


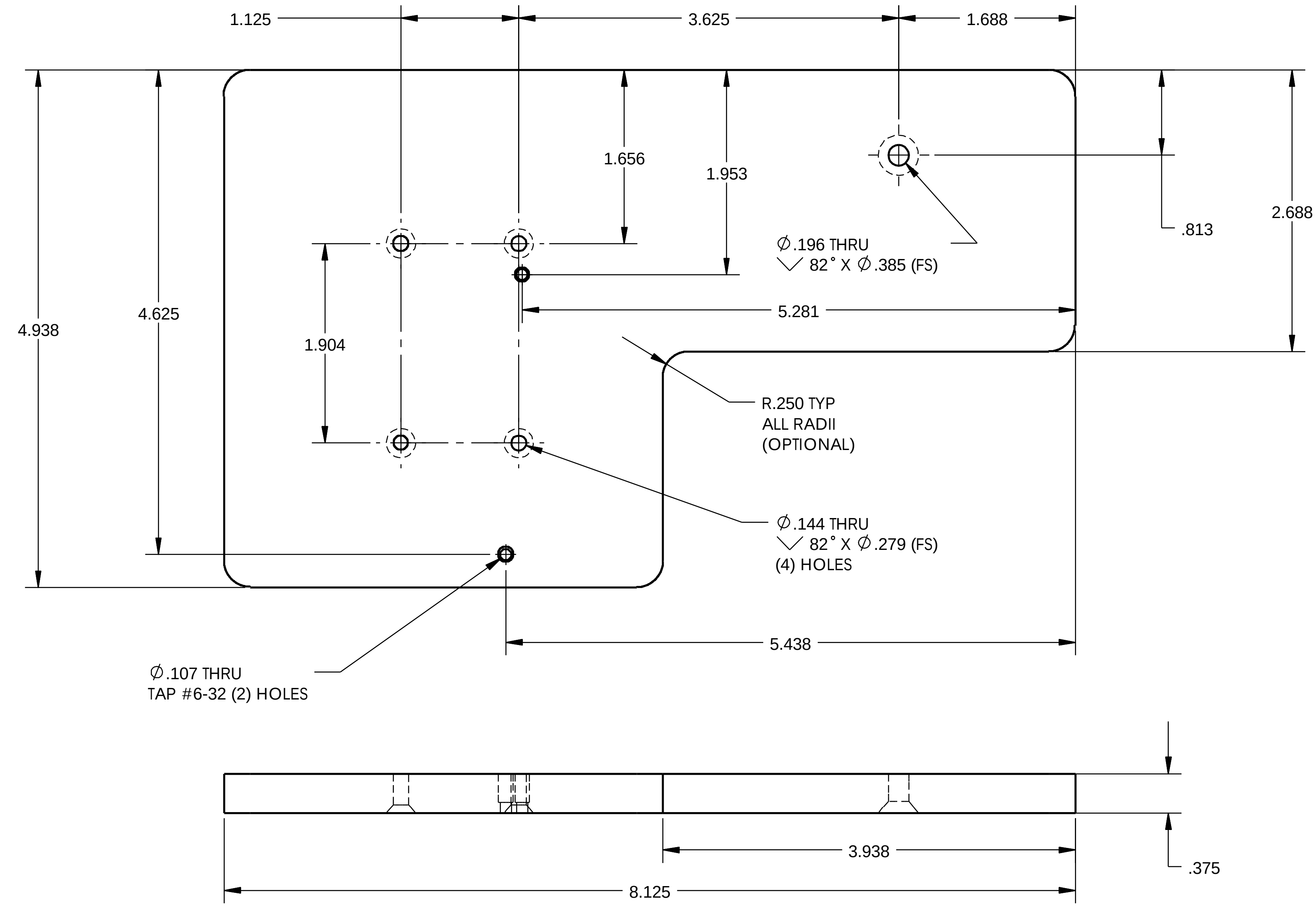
Webster Engine Works
4 Cycle Gas Engine

Displacement: .75 ci
Bore: .875"
Stroke 1.25"





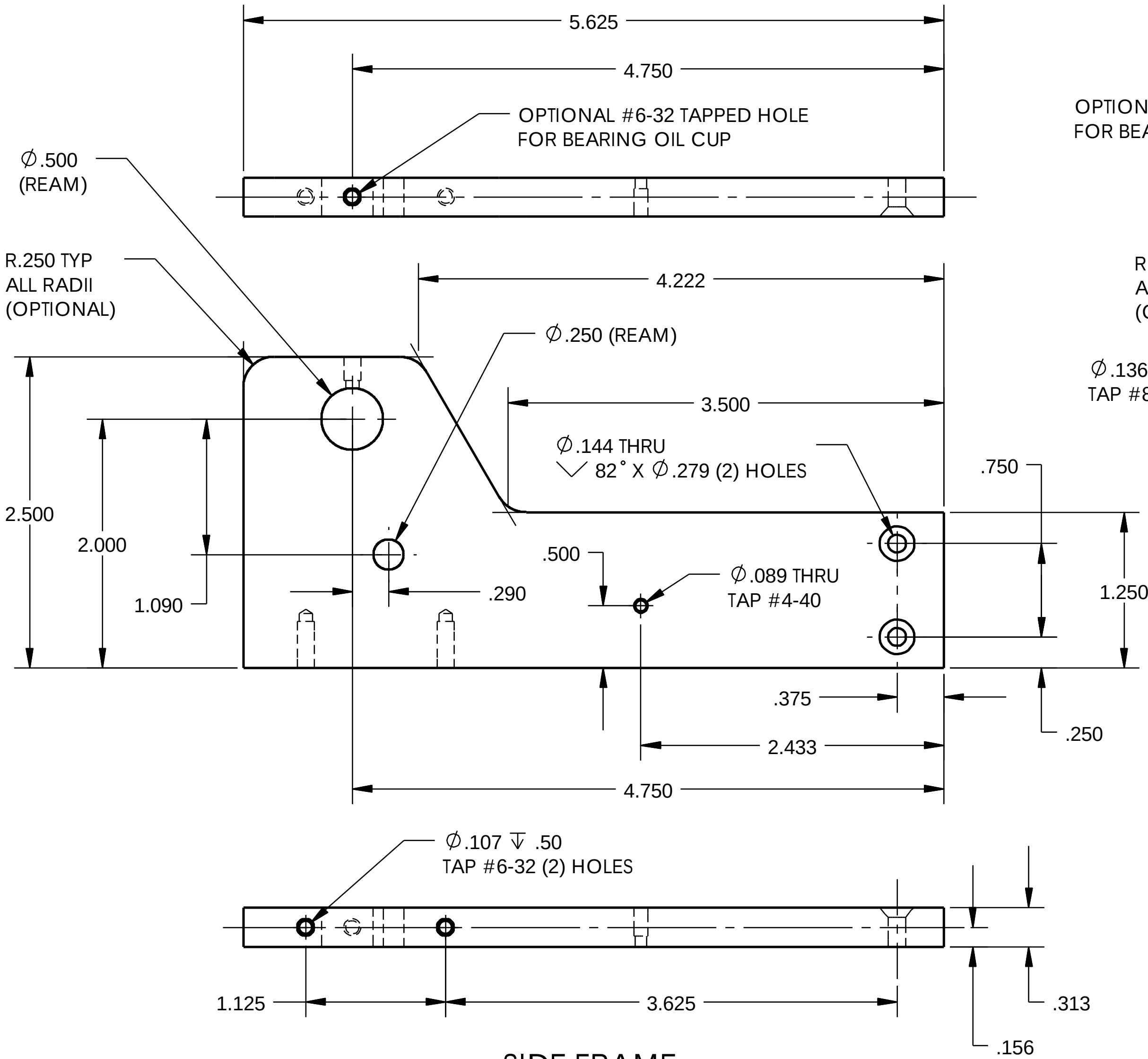
125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	.9 : 1	B	GENERAL ARRANGEMENT
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
						JBW	1 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004



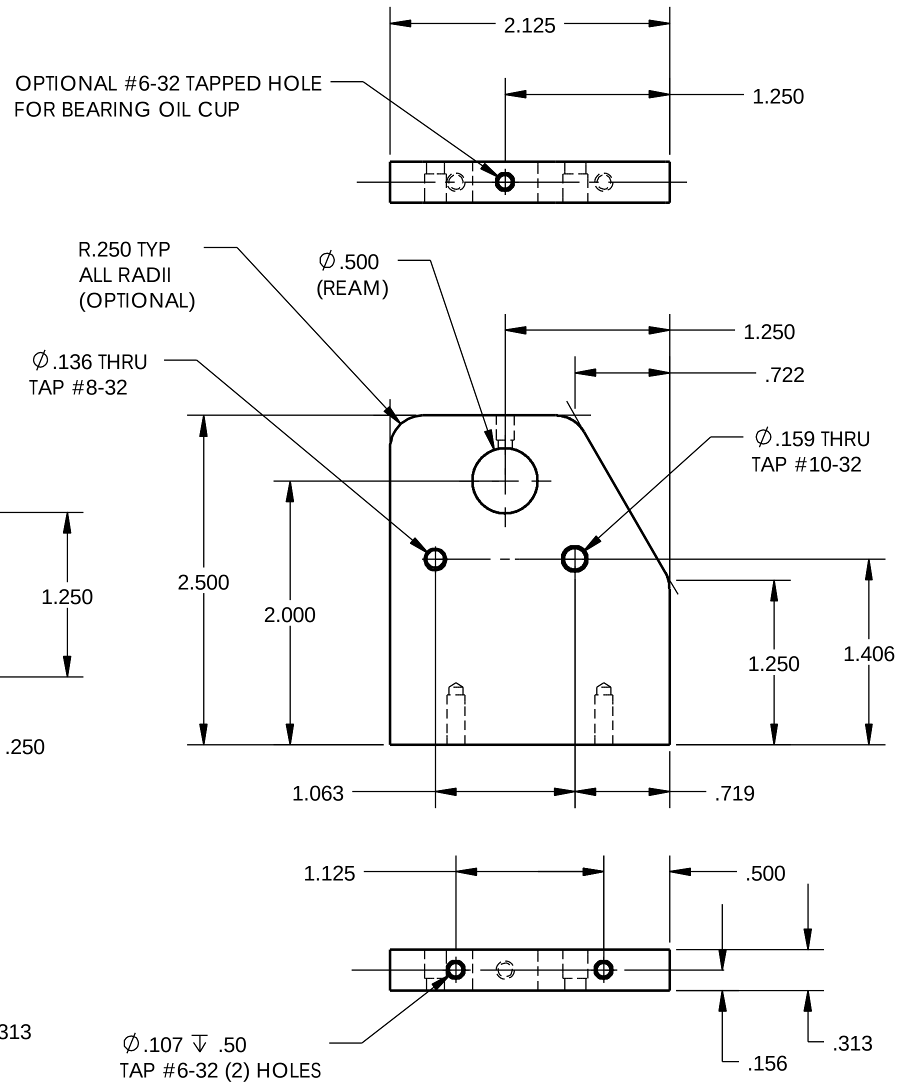
This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 √	+/- .015	+/- .005	+/- 30'	ANODIZE, DYE BLACK	ALUMINUM ALLOY	7/27/2004	1:1	B	BASE PLATE (1) REQD.
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	2 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2

1



SIDE FRAME

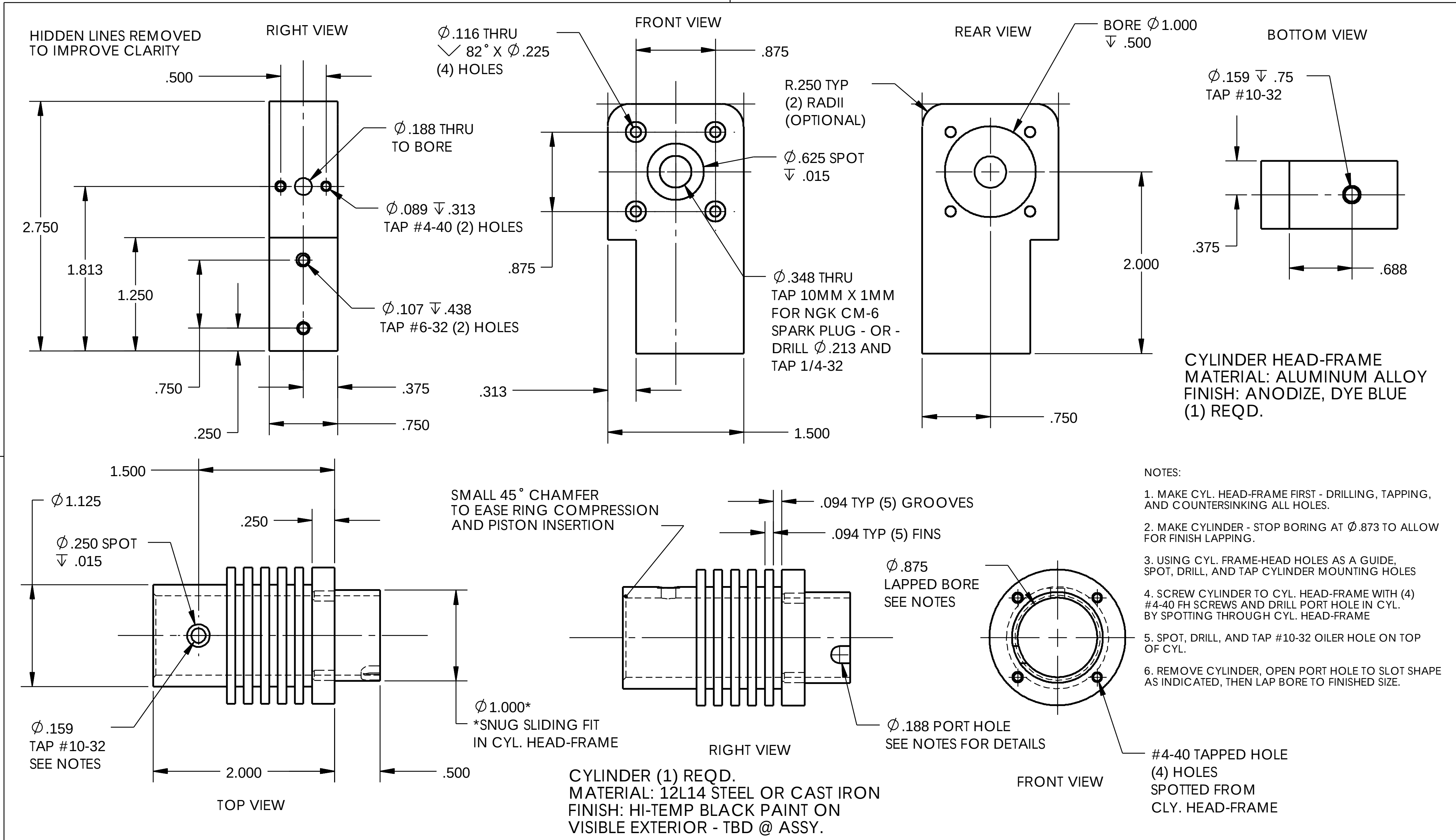


CRANKSHAFT SUPPORT

125 ╱	+/- .015	+/- .005	+/- 30'	ANODIZE, DYE BLUE	ALUMINUM ALLOY	7/27/2004	1:1	B	SIDE FRAME & CRANKSHAFT SUPPORT (1) EACH REQD.
						DATE	SCALE		
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	3 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2

1

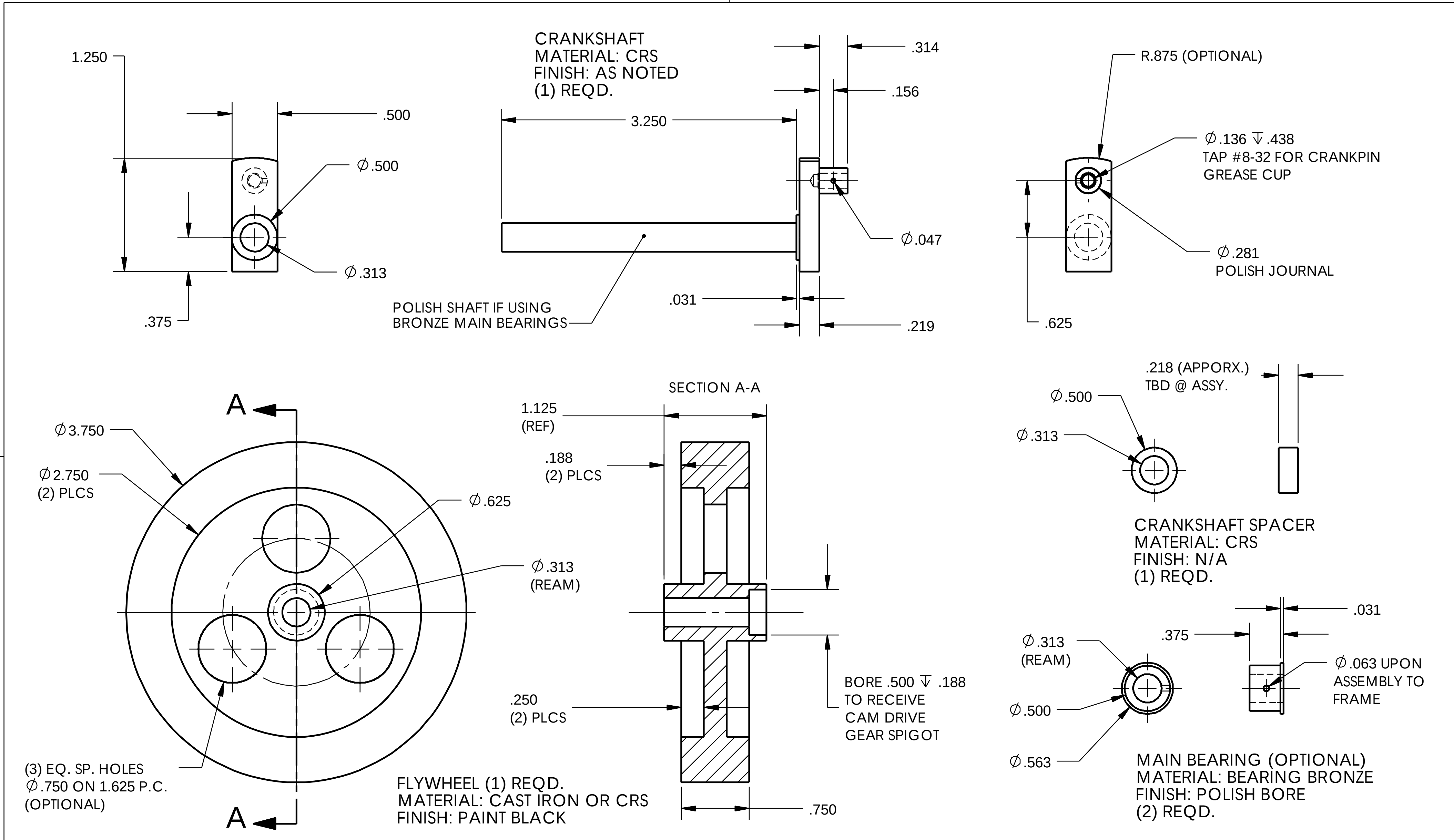


NOTES:

1. MAKE CYL. HEAD-FRAME FIRST - DRILLING, TAPPING, AND COUNTERSINKING ALL HOLES.
2. MAKE CYLINDER - STOP BORING AT Ø.873 TO ALLOW FOR FINISH LAPPING.
3. USING CYL. FRAME-HEAD HOLES AS A GUIDE, SPOT, DRILL, AND TAP CYLINDER MOUNTING HOLES
4. SCREW CYLINDER TO CYL. HEAD-FRAME WITH (4) #4-40 FH SCREWS AND DRILL PORT HOLE IN CYL. BY SPOTTING THROUGH CYL. HEAD-FRAME
5. SPOT, DRILL, AND TAP #10-32 OILER HOLE ON TOP OF CYL.
6. REMOVE CYLINDER, OPEN PORT HOLE TO SLOT SHAPE AS INDICATED, THEN LAP BORE TO FINISHED SIZE.

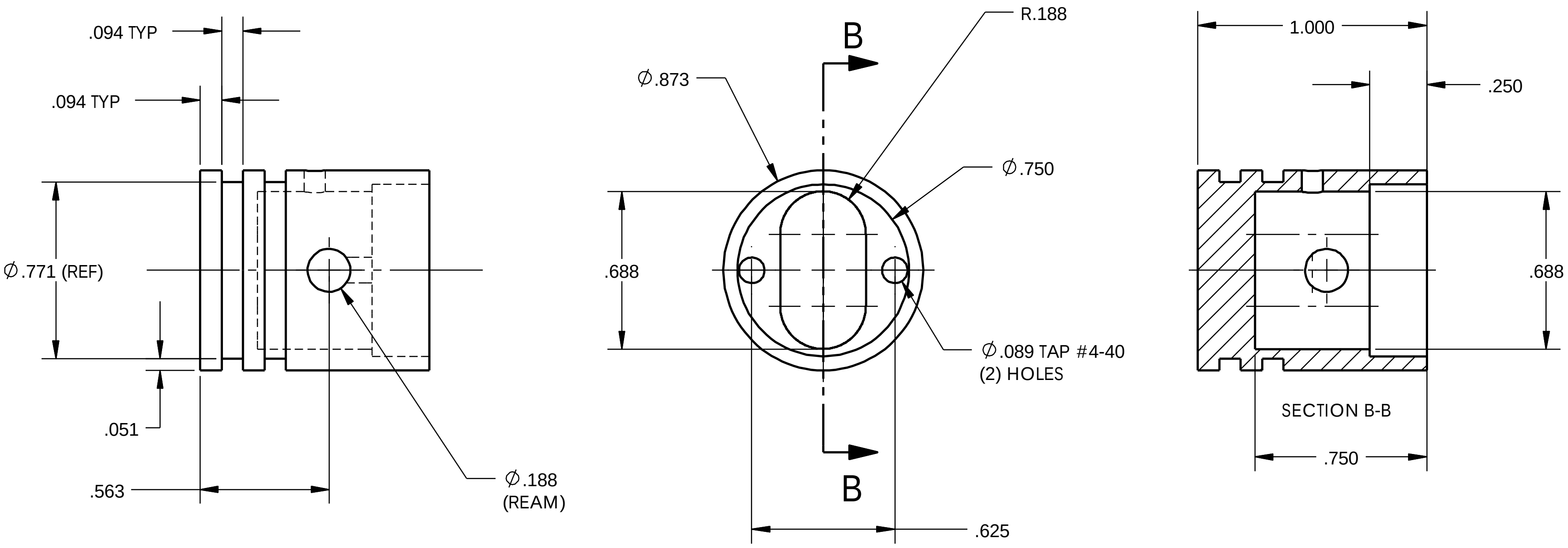
125 √	+/- .015	+/- .005	+/- 30'	SEE ABOVE	SEE ABOVE	7/27/2004	1:1	B	CYL. HEAD-FRAME & CYLINDER (1) EACH REQD.
						DATE	SCALE		
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	4 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

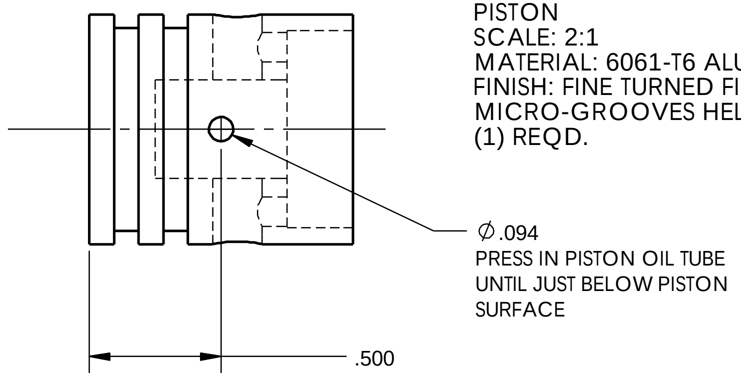
2 1



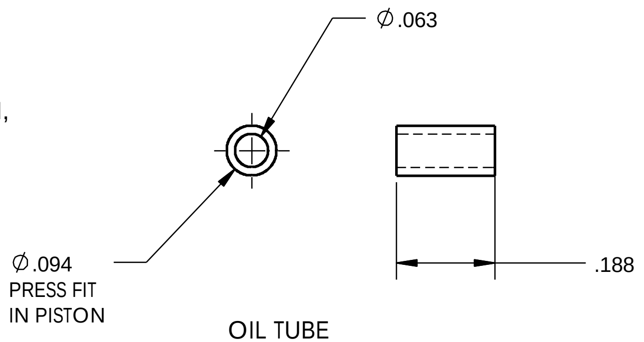
This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 ✓	+/- .015	+/- .005	+/- 30'	SEE NOTES	SEE NOTES	7/27/2004	1:1	B	CRANKSHAFT, FLYWHEEL, CRANK SPACER AND MAIN BEARING
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	5 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2 1





PISTON
SCALE: 2:1
MATERIAL: 6061-T6 ALUMINUM
FINISH: FINE TURNED FINISH, DO NOT POLISH,
MICRO-GROOVES HELP TO HOLD OIL
(1) REQD.



OIL TUBE
SCALE: 4:1
MATERIAL: BRASS
FINISH: N/A
(1) REQD.

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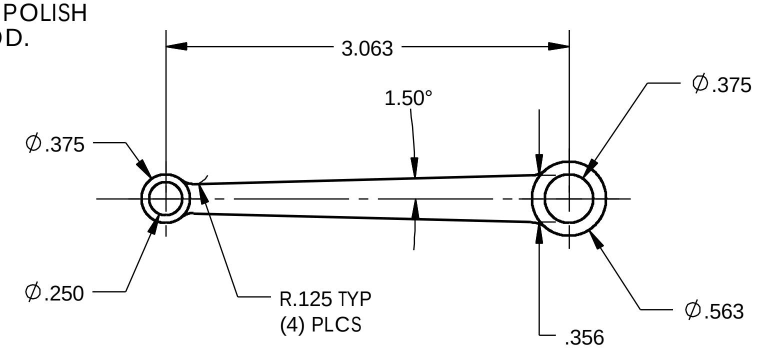
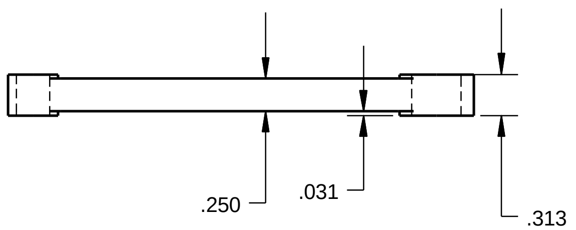
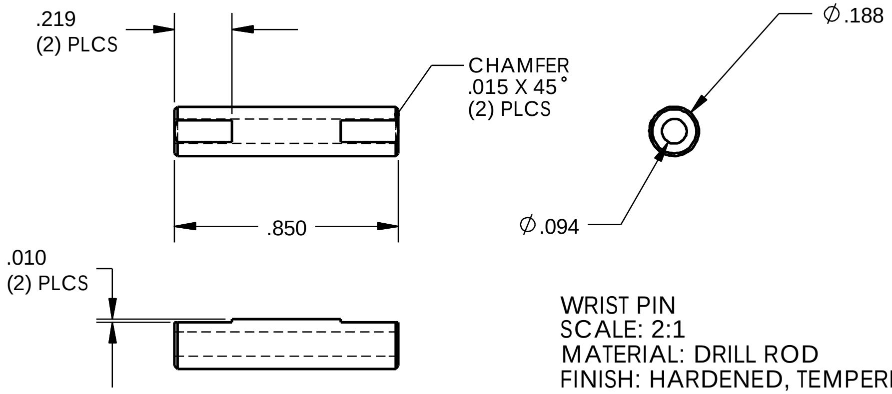
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	6 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

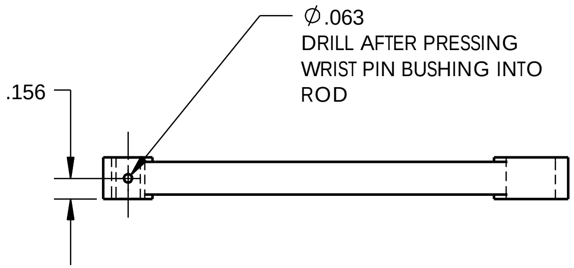
CONNECTING ROD
MATERIAL: 6061-T6 ALUMINUM
FINISH: POLISH
(1) REQD.

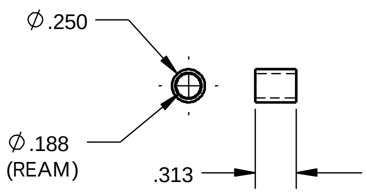


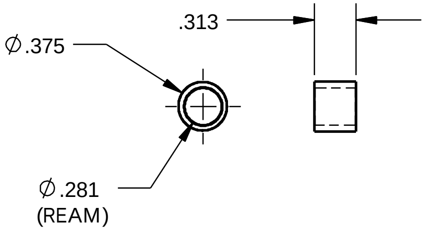




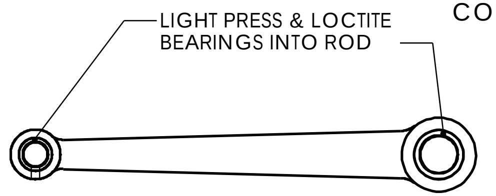
WRIST PIN
SCALE: 2:1
MATERIAL: DRILL ROD
FINISH: HARDENED, TEMPERED & POLISHED
(1) REQD.







CONNECTING ROD ASSY.



WRIST PIN BUSHING
MATERIAL: BEARING BRONZE
FINISH: POLISH BORE AFTER INSTALLATION
(1) REQD.

CON ROD BUSHING
MATERIAL: BEARING BRONZE
FINISH: POLISH BORE AFTER INSTALLATION
(1) REQD.

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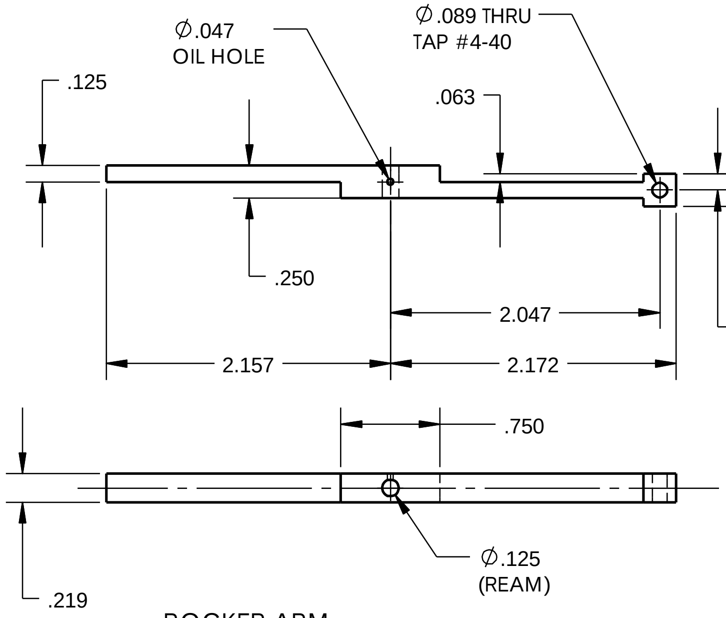
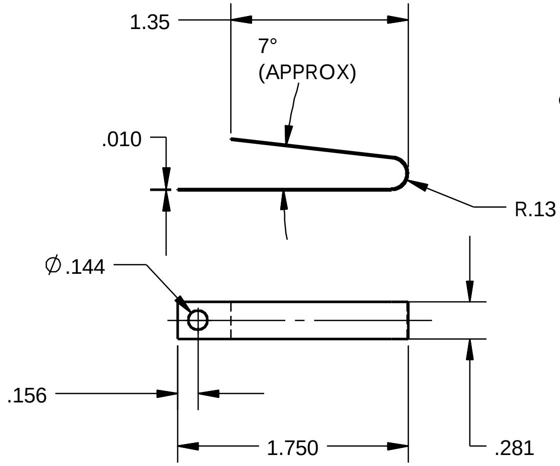
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	7 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

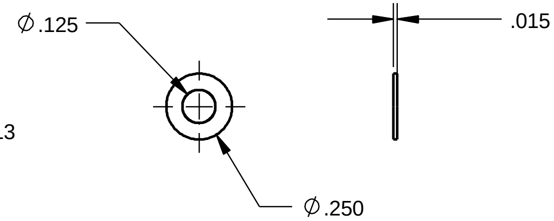
2 | 1



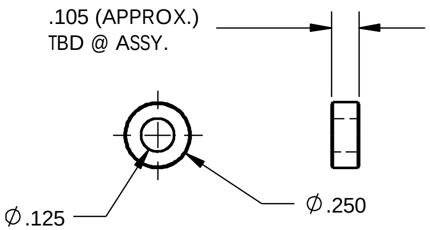
ROCKER ARM
MATERIAL: CRS
FINISH: CASE HARDEN (OPTIONAL)
(1) REQD.



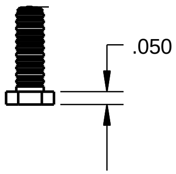
ROCKER ARM SPRING
MATERIAL: SPRING STEEL
FINISH: N/A
(1) REQD.



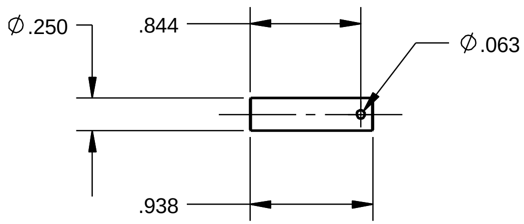
ROCKER ARM WASHER
SCALE: 2:1
MATERIAL: BRASS
FINISH: N/A
(1) REQD.



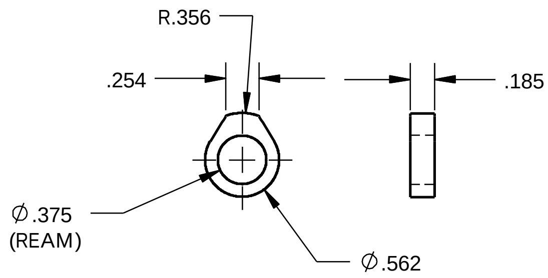
ROCKER ARM SPACER
SCALE: 2:1
MATERIAL: CRS
FINISH: N/A
(1) REQD.



TAPPET
SCALE: 2:1
MATERIAL: 3/8" X #4-40 S.S. SCREW
FINISH: THIN HEAD TO DIM. SHOWN
(1) REQD.



CAM SHAFT
MATERIAL: DRILL ROD
FINISH: HARDEN, TEMPER, POLISH
(1) REQD.



EXHAUST CAM
MATERIAL: CRS
FINISH: CASE HARDEN, POLISH
(1) REQD.

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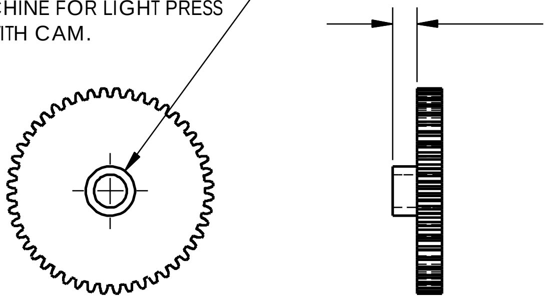
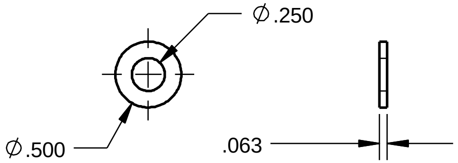
							DATE	SCALE		
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	8 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2 | 1

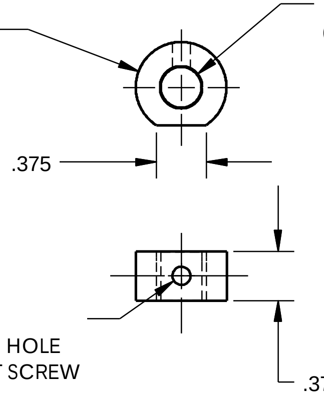
2	1



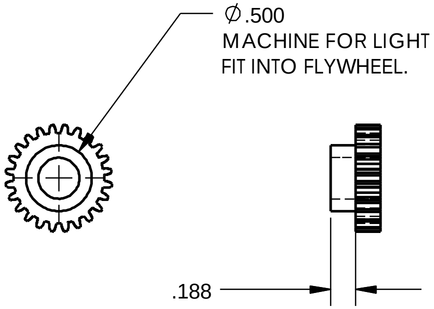
CAM GEAR MODIFICATION (BRASS)
STOCK DRIVE PRODUCTS: A 1B 2-N32048
W.M. BERG: P32S-28-48
(1) REQD.



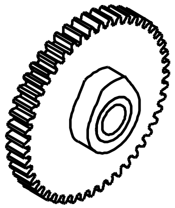
CAM GEAR WASHER
MATERIAL: CRS
FINISH: N/A
(2) REQD.



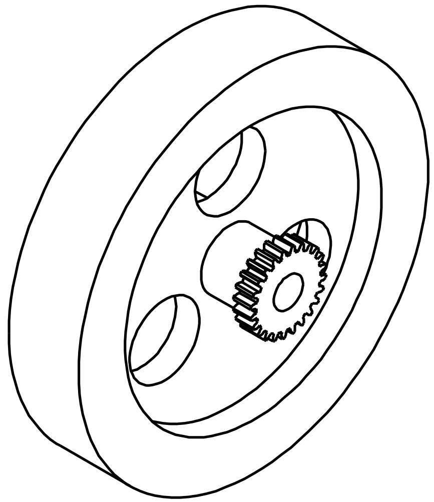
IGNITION CAM
MATERIAL: CRS
FINISH: BREAK SHARP EDGES
(1) REQD.



DRIVE GEAR MODIFICATION (STEEL)
STOCK DRIVE PRODUCTS: A 1C 2-N32024
W.M. BERG: P32S28-24
(1) REQD.



CAM GEAR ASSEMBLY -
LOCTITE AND PRESS CAM TO
CAM GEAR, ARBITRARY POSITION.



FLYWHEEL ASSEMBLY -
LOCTITE AND PRESS CAM DRIVE GEAR
TO FLYWHEEL, ARBITRARY POSITION.

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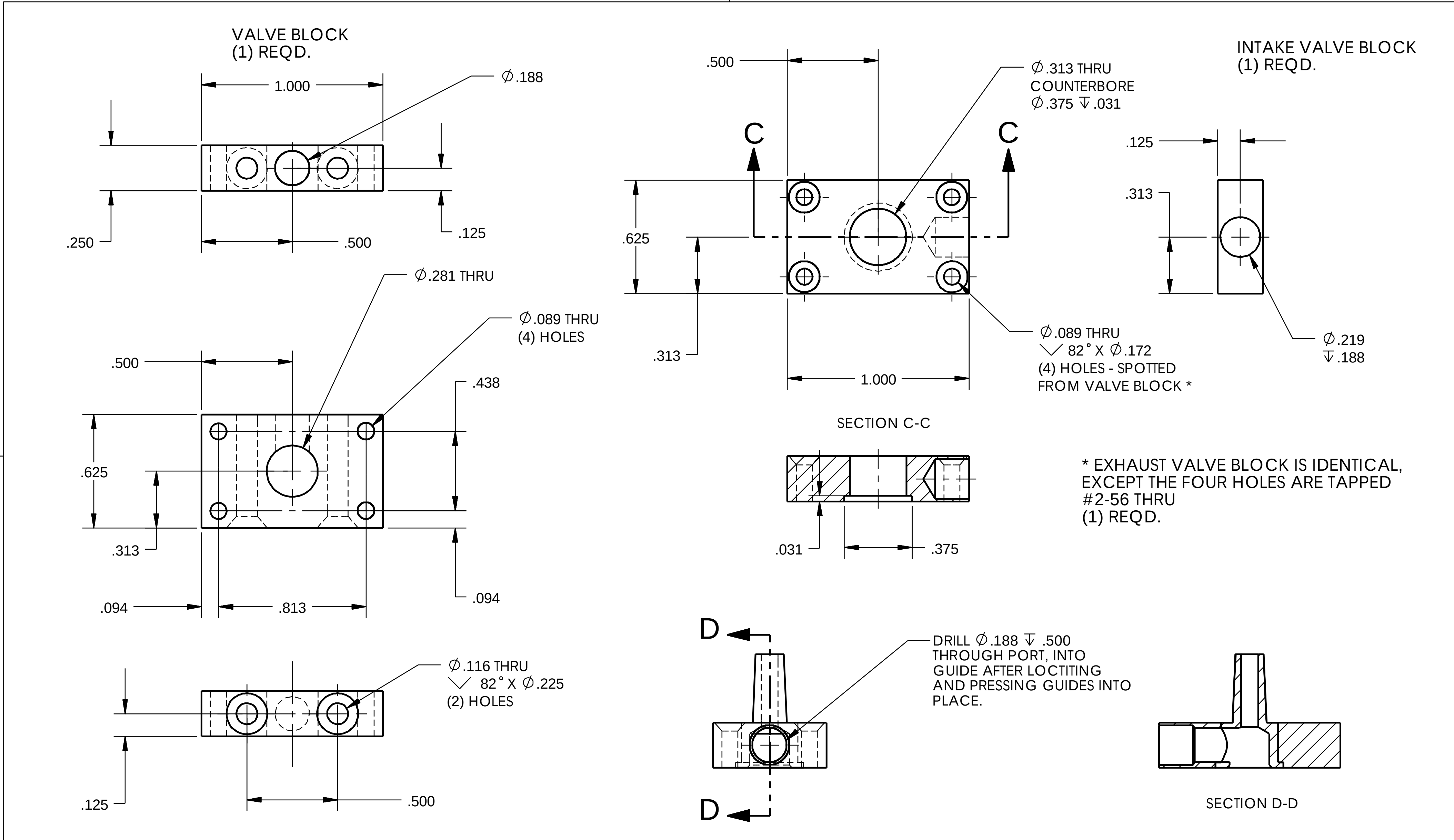
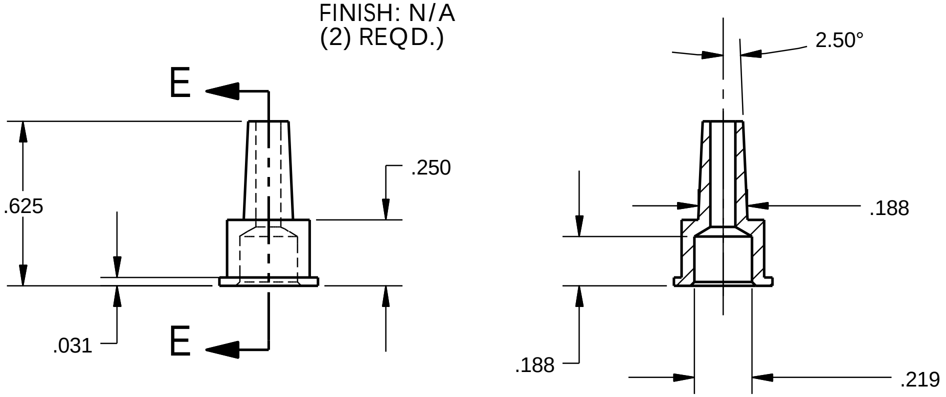
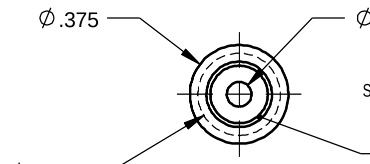
							DATE	SCALE		
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	9 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004



SURFACES	2 PLC DEC	3 PLC DEC	ANGLES	FINISH	MATERIAL	DATE	SCALE	SIZE	
125 √	+/- .015	+/- .005	+/- 30'	NATURAL	ALUMINUM ALLOY	7/27/2004	2:1	B	VALVE BLOCK, INTAKE VALVE BLOCK, & EXHAUST VALVE BLOCK
TOLERANCE UNLESS OTHERWISE NOTED						DETAILER: JBW	SHEET NO.: 10 OF 21		

VALVE GUIDE
MATERIAL: BRONZE / BRASS
FINISH: N/A
(2) REQD.)

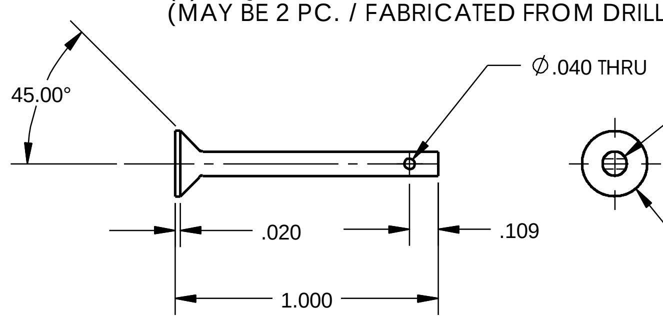


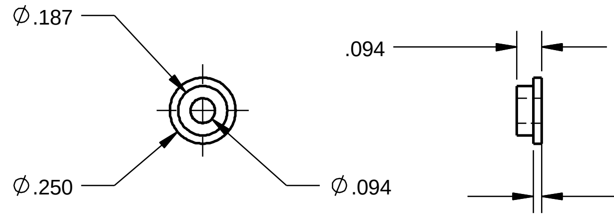


SOME HIDDEN LINES REMOVED TO IMPROVE CLARITY

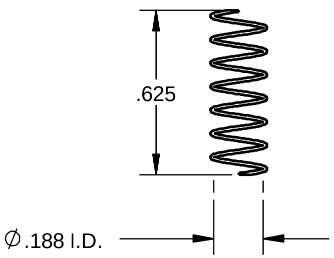
MACHINE 45° X .015 VALVE SEAT - LAP VALVE TO VALVE GUIDE USING FINE VALVE GRINDING COMPUND UPON FINAL ASSY.

VALVE
MATERIAL: STEEL / STAINLESS STEEL
FINISH: POLISH STEM
(2) REQD.
(MAY BE 2 PC. / FABRICATED FROM DRILL ROD)

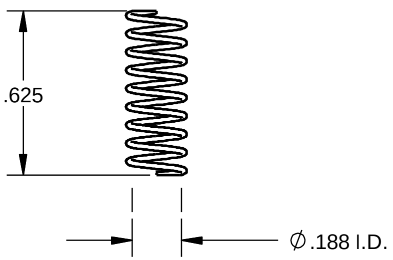




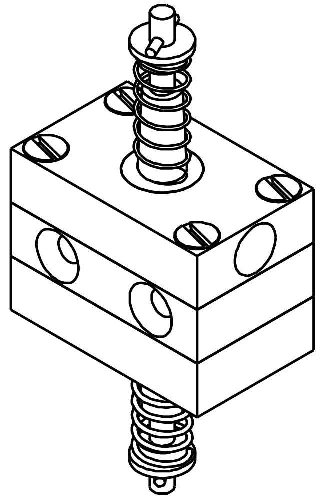
VALVE RETAINER
MATERIAL: STEEL
FINISH: BLUED
(2) REQD.



INTAKE VALVE SPRING
SEVEN TURNS ∅.013 MUSIC WIRE
(1) REQD.



EXHAUST VALVE SPRING
NINE TURNS ∅.022 MUSIC WIRE
(1) REQD.



VALVE BLOCK ASSY. -
1. INTAKE VALVE SPRING ON TOP WITH INTAKE PORT POINTING TOWARDS THE FRONT OF THE ENGINE.

2. VALVE BLOCK SANDWICHED BETWEEN INT. & EXH. VALVE BLOCKS - NO GASKET OR SEALER REQD. W/ CAREFUL MACHINING.

3. RETAINER PINS ARE .25 LONG SECTIONS OF DRILL ROD, MUSIC WIRE, ETC...

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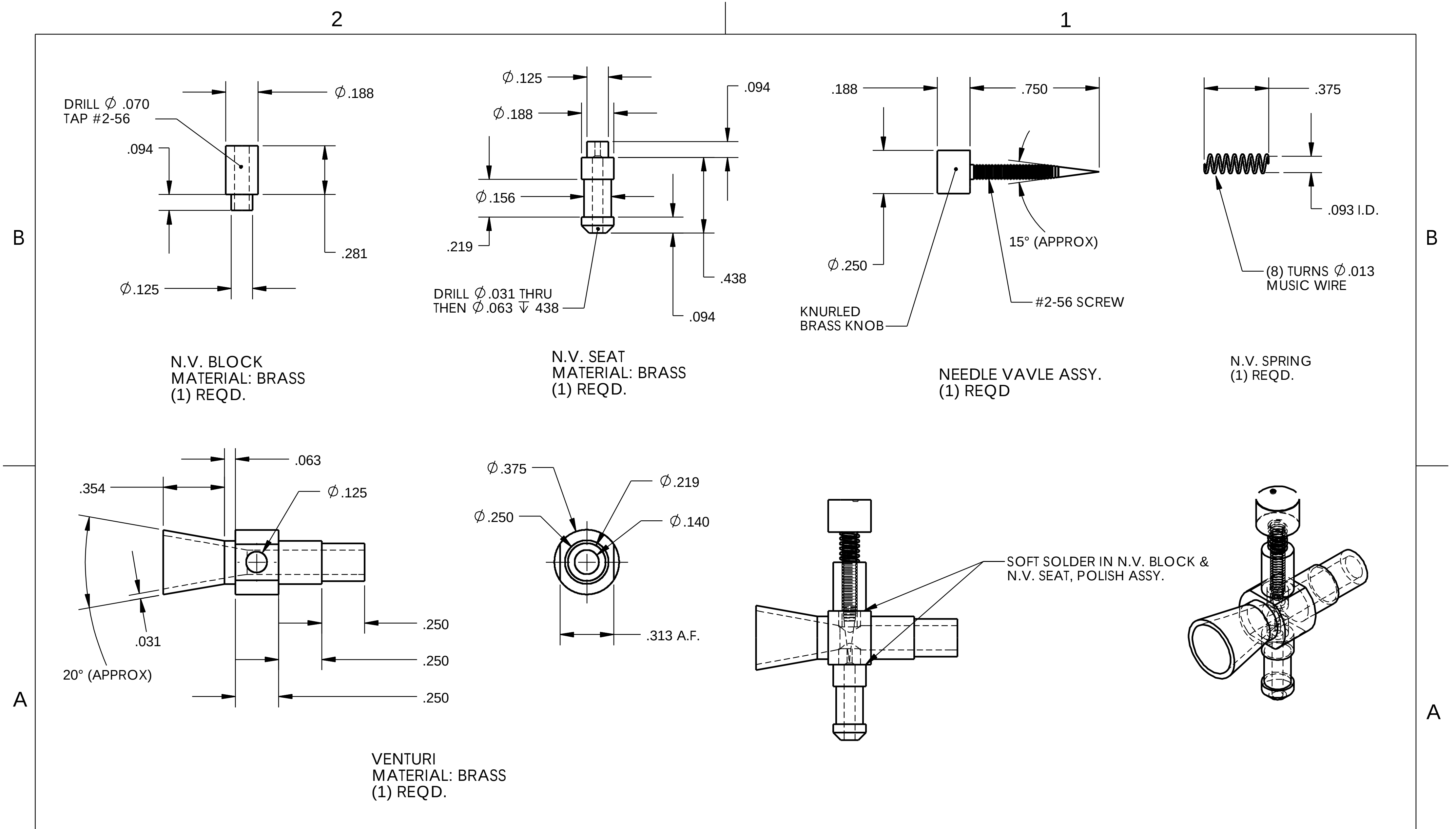
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	11 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004



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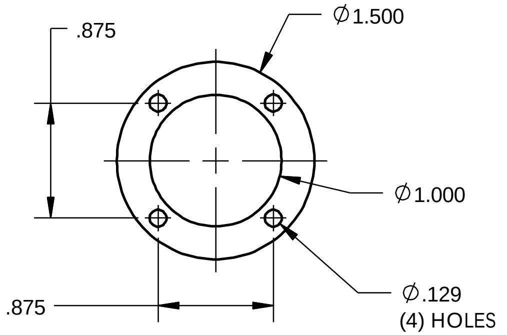
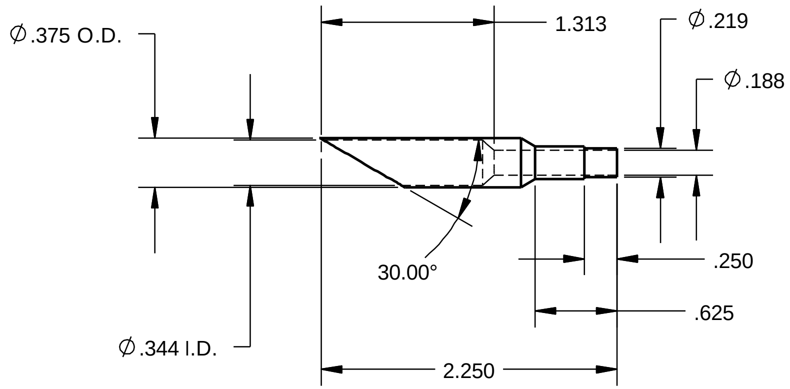
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	12 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

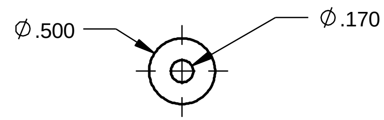
2 1



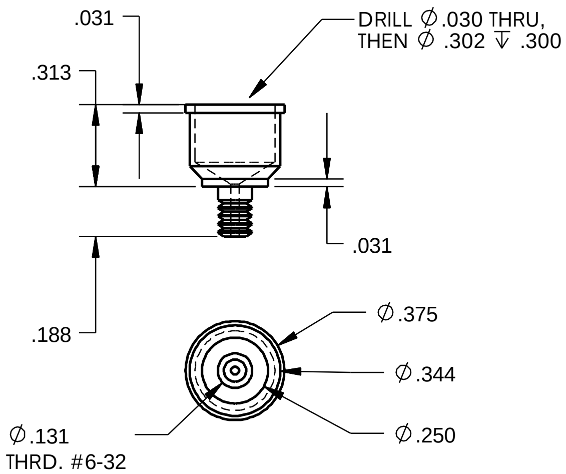
HEAD GASKET
MATERIAL: .015 COPPER, TEFLON, OR STD. AUTO GASKET STOCK.
(1) REQD.



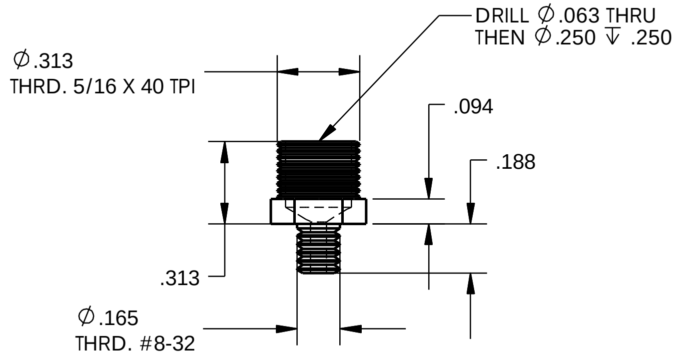
EXHAUST PIPE
MATERIAL: ALUMINUM, BRASS, OR STEEL
FINISH: POLISH
(1) REQD.



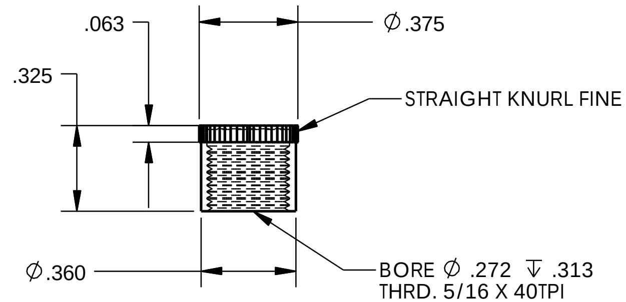
CON ROD KEEPER
MATERIAL: .015 THK. BRASS OR STEEL
(1) REQD.



CRANK OILIER CUP
MATERIAL: BRASS
FINISH: POLISH
(2) REQD.
SCALE: 2:1

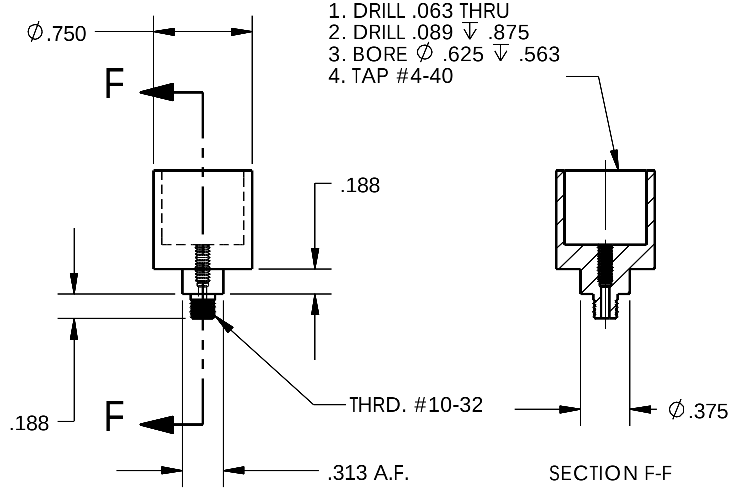


CRANK PIN GREASE CUP BODY
MATERIAL: 5/16" HEX BRASS
FINISH: POLISH
(1) REQD.
SCALE: 2:1

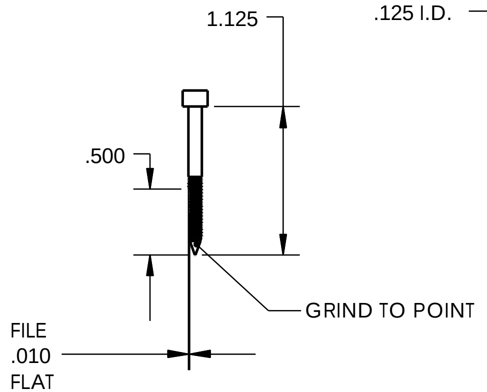


CRANK PIN GREASE CUP CAP
MATERIAL: BRASS
FINISH: POLISH
(1) REQD.
SCALE: 2:1

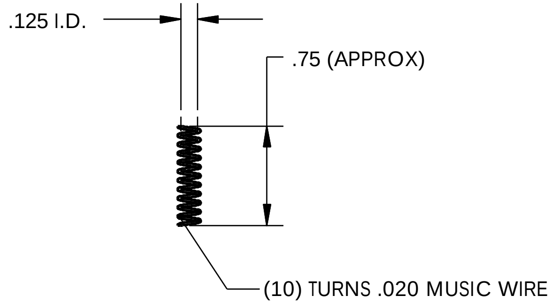
125 ✓	+/- .015	+/- .005	+/- 30'	SEE NOTES	SEE NOTES	7/27/2004	1:1	B	HEAD GASKET, EXH. PIPE, CRK. KEEPER, CRK. OILER & GREASE CUP ASSY.
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
TOLERANCE UNLESS OTHERWISE NOTED						JBW	13 OF 21		
				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004



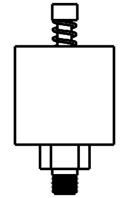
CYL. OILIER BODY
MATERIAL: BRASS OR ALUMINUM
FINISH: POLISH
(1) REQD.

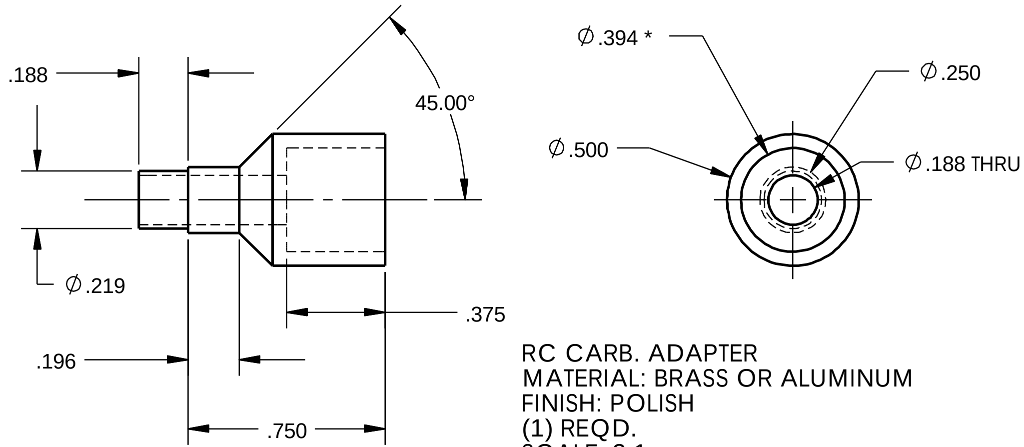


CYL. OILIER VALVE
MATERIAL: #4-40 SHCS
FINISH: AS SHOWN
(1) REQD.



CYL. OILIER SPRING
(1) REQD.





RC CARB. ADAPTER
MATERIAL: BRASS OR ALUMINUM
FINISH: POLISH
(1) REQD.
SCALE: 2:1

* SIZED TO FIT CHOICE OF CARBURETOR. THROUGH EXPERIMENTATION IT WAS FOUND THAT THE ENGINE RUNS BEST WITH RATHER A SMALL BORE CARB. I USED A CARB FROM AN O.S. MAX .12 CZ RADIO CONTROL CAR ENGINE THAT HAS A BORE OF .166" AND IT GIVES AN RPM RANGE OF ABOUT 1000 - 5000 RPM.

IT IS RECOMMENDED THAT A SIMILAR CARB BE USED OR FABRICATED BECAUSE THE NEEDLE VALVE AND VENTURI GIVES ONLY MARGINAL PERFORMANCE - ALTHOUGH IT IS AN EASY/CHEAP ALTERNATIVE.

(I SIMPLY USED HI-TEMP LOCTITE TO AFFIX THE CARB INTO THE ADAPTER.)

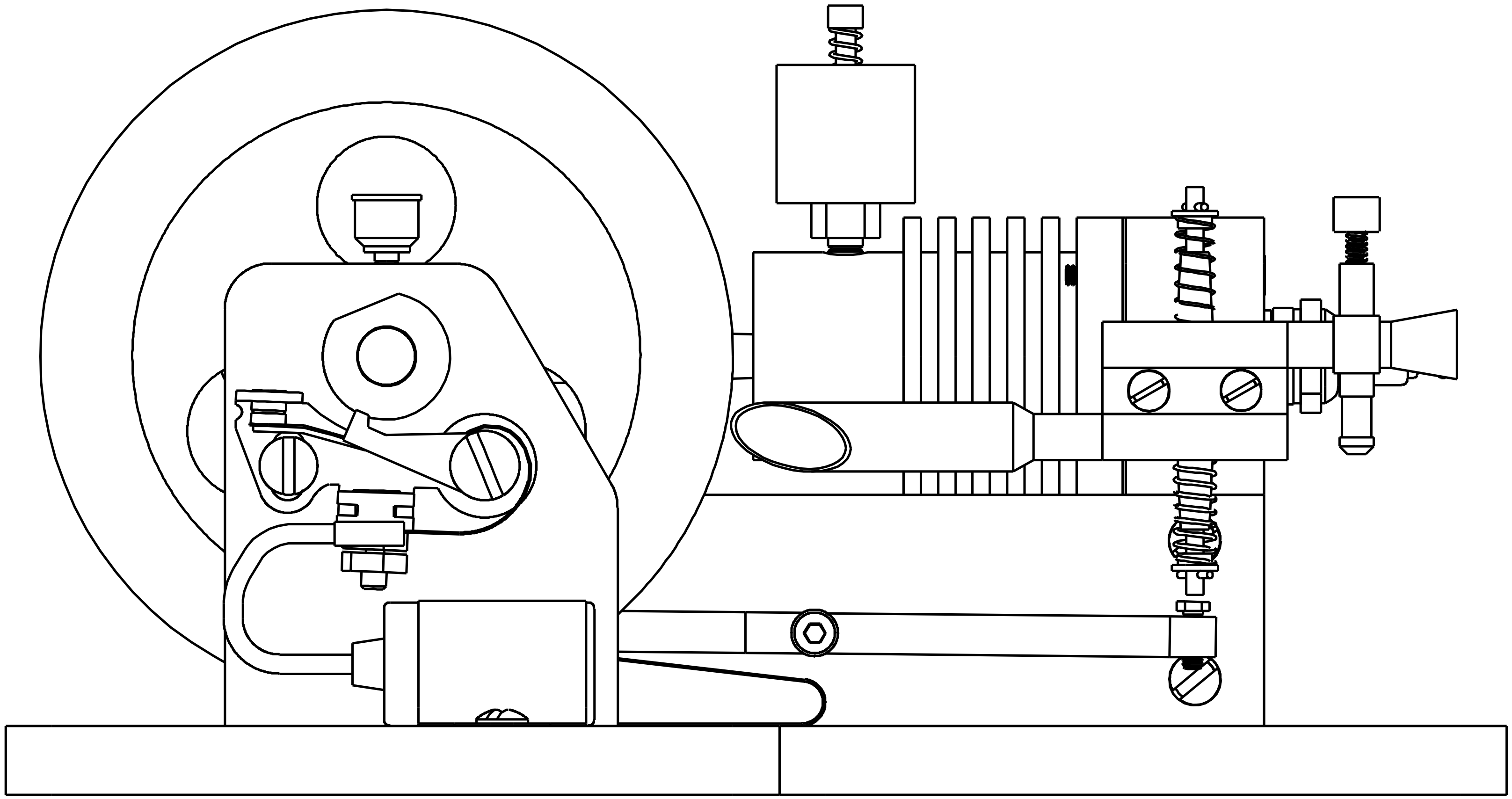
125 √	+/- .015	+/- .005	+/- 30'	SEE NOTES	SEE NOTES	7/27/2004	1:1	B	CYL. OILER & CARB. ADAPTER,
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
						JBW	14 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2

1

B

B



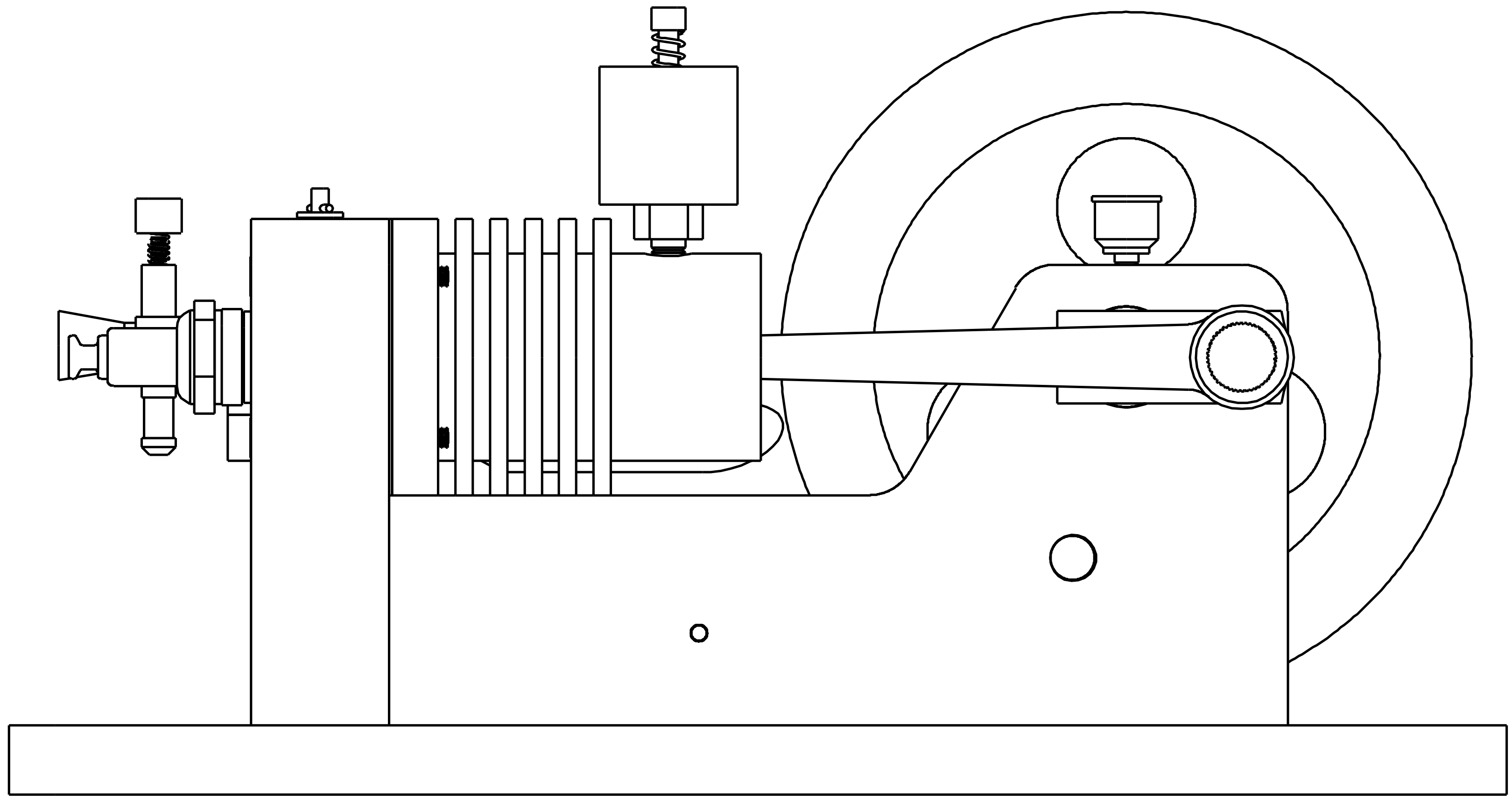
A

A

This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1.5:1	B	RIGHT SIDE VIEW
							DATE	SCALE		
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	15 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2

1

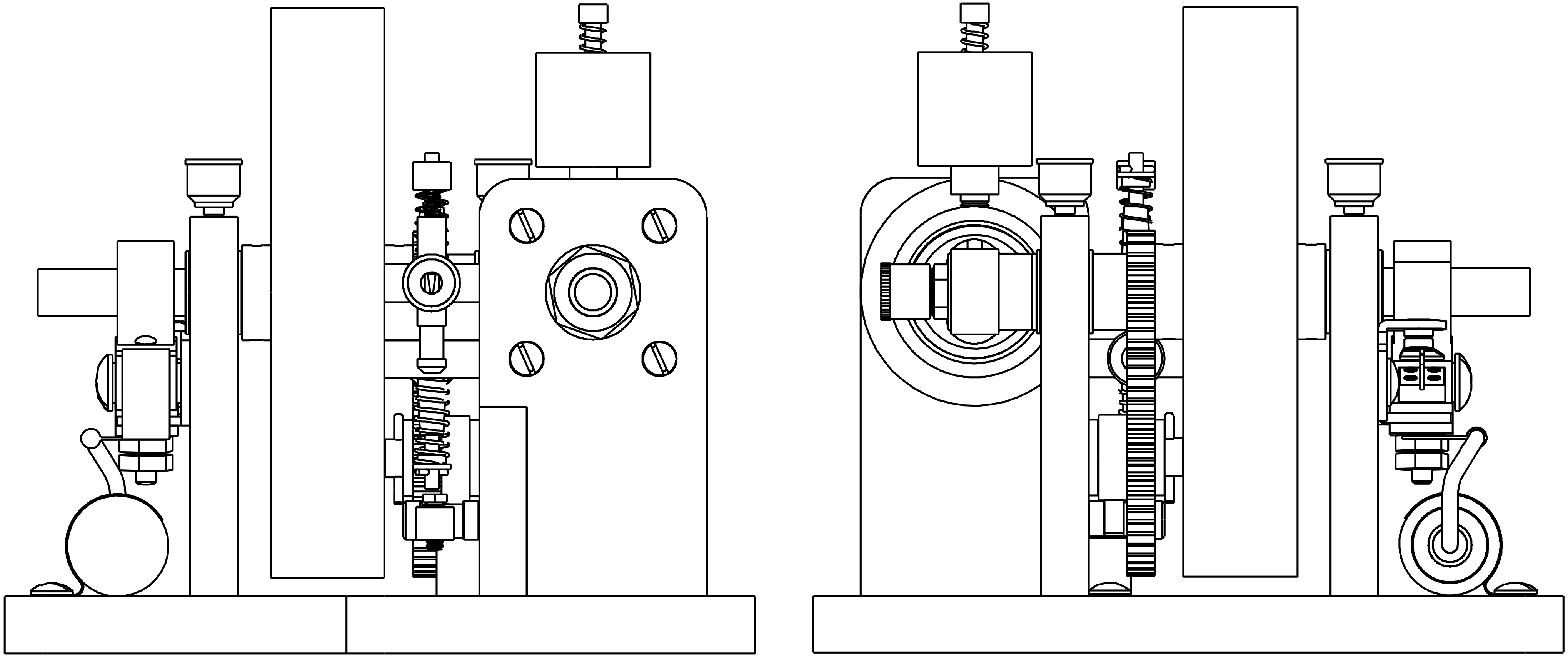


This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1.5:1	B
							DATE	SCALE	
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	16 OF 21	
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE

LEFT SIDE VIEW

2 1

B B



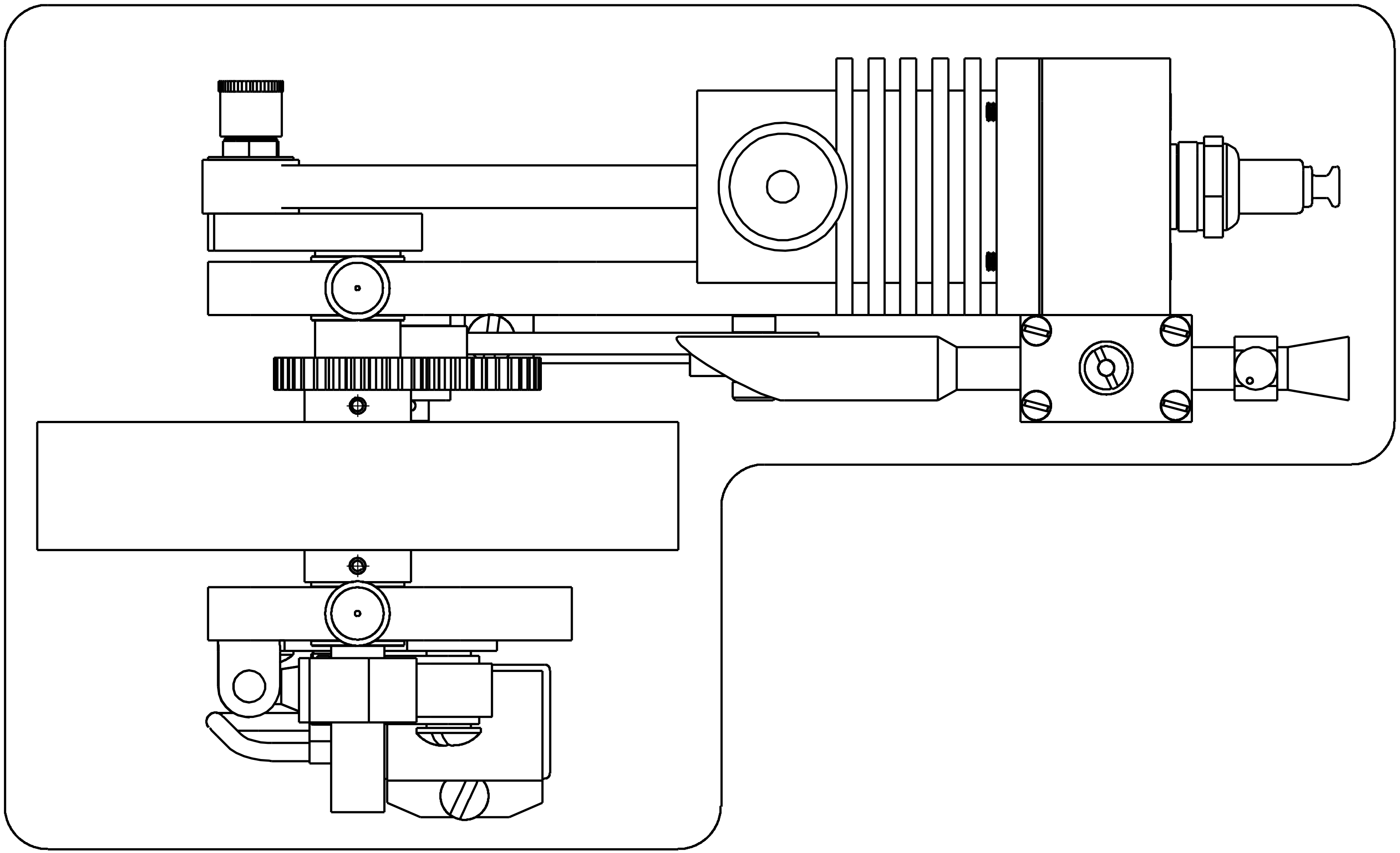
A A

This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1.5:1	B	FRONT AND REAR VIEW
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	17 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2 1

2 1

B B



A A

This drawing may be freely used or modified for any non-profit purpose. All accuracy and safety issuses are the users responsibility. The originator and the provider are not responsible or liable for any losses or damages incurred from the creation or use of the products contained in this drawing.	125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1:1	B	TOP VIEW
							DATE	SCALE		
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			JBW	18 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2 1

2 | 1

The following notes aren't meant to be comprehensive, step-by-step building instructions, just a few notes on how and why I did things.

SHEET 1. Just a few views to show the general arrangement of parts.

SHEET 2. BASE - This is the engine baseplate. Since all engine parts mount and align off of this, it is suggested that the holes be layed out and located somewhat accurately. Notice that the countersunk holes are on the bottom of the plate. The external dimensions can be altered to suit as long as the hole spacings for the engine frame remains the same.

SHEET 3. SIDE FRAME & CRANKSHAFT SUPPORT - Again, try to stick to the dimensions given, as these parts, along with the BASE make up the backbone of the engine. Alignment of the remaining engine parts rely on good workmanship here. Also, the bearing and cam shaft holes need to be sized for light press fits of their respective parts and accurately placed for proper gear spacing.

SHEET 4. CYLINDER HEAD-FRAME & CYLINDER - Nothing especially difficult here, but two things are worth noting. There are two options given for a spark plug - use whatever you are comfortable with. I started with the tiny 1/4"-32tpi sparkplug because it is also the same size of a model airplane engine glow plug which I could use to start the engine on glow fuel (without having to rig oiling and an ignition system). I then switched to spark with gas and oil mix, and quickly fouled this tiny spark plug. So I redrilled and retapped for a 10mm x 1mm NGK CM-6 spark plug that I could get from my local motorcycle dealer for a lot cheaper.

The cylinder bore is the other item that needs particular attention - make sure to bore it straight and without any taper. Finish within .002" of size, drill port and oiler holes (using cyl. head-frame as a guide), then lap to a finished size of .875". Simple laps can be fabricated or purchased, and details on how to use them can be found on the Internet, in the model engine newsgroups/web sites.

SHEET 5. CRANKSHAFT, FLYWHEEL, SPACER, and BEARING - I made my crankshaft from a 5" section of 1/2" X 1 1/4" Cold Rolled Steel, both shaft and crankpin were turned between centers, but it could be fabricated and silver solder together from three pieces if you wanted to go that route. Also, notice that it's not counter-balanced for ease of construction - a lot smoother engine would result if you took the time to redesign the crank and add the appropriate wieghts. The end of the crankpin is drilled and tapped to receive the grease cup - don't forget the tiny crossdrilled hole, and to polish the journal.

The flywheel can be made from cast iron, CRS, bronze, etc... - any heavy metal should work fine. I chose cast iron, in the form of a dumbbell that I purchased from Wal-mart. Be careful if you take this approach as there can be small voids/casting flaws where it matters - I was lucky and none presented any problems. Be certain when boring the .500" counter bore that it's concentric with the crankshaft bore, and that the modified CAM DRIVE GEAR is a snug fit - it will need to be pressed and Loctited in place. See sheet #9 for details.

SHEET 5. cont. - The three .750" holes are for appearance only, as a matter of fact, I skipped them altogether on the prototype engine. A nice cosmetic touch would have been a spoked flywheel, but since it would require a rotary table for the mill, I didn't bother. Again, feel free to experiment.

If you choose not to use ball bearings to support the crankshaft, then you will have to make the two bronze MAIN BEARINGS as shown. Aim for a light press fit into the SIDE FRAME and CRANKSHAFT SUPPORT. Using Loctite as good measure, press them in with the flanges toward the inside of the engine, making sure to align the oil holes with the #6-32 tapped oil cup holes. (Alternatively, wait until bearings are in place before dilling the .063" oil holes.)

Also on this sheet is the CRANKSHAFT SPACER - adjust thickness on final assembly for .001" to .003" of crankshaft endplay.

SHEET 6. PISTON & OIL TUBE - The ring grooves in the PISTON were sized for the rings mentioned elsewhere in these plans. 1/16" wide rings would offer less friction and probably seal just as well - simply adjust the ring grooves to accomodate. Use a 3/8" endmill to machine the con rod slot, being careful not to go beyond the .688" dimension because you may cut into the lower ring groove. Be sure to drill the wrist pin perpendicular and on the exact centerline of the piston - this is not the time to rush things. (Make sure the con rod slot is going in the right direction.) Small #4 set-screws are used to retain the wristpin in it's bore. The OIL TUBE is simply a short section of brass tubing, Loctited into the piston as indicated.

SHEET 7. Nothing too remarkable here. Just be sure to drill both CON ROD holes at the same setting and size the BUSHINGS for a light press fit into the rod ends - use Loctite for added security. Drill the .063" hole in the wrist pin end after the bushing is installed. Be sure this hole is pointed up (towards the OIL TUBE, and ultimately towards the CYLINDER OILER) upon final assy.

SHEET 8. The EXHAUST CAM started out as a .185" thk. disk of steel .712" in diameter with a reamed .375" hole though it. It was offset turned on the lathe as described by Hamilton Upshur in Volume 79 of Strictly I.C. magazine. There are many other methods - use whatever you are comfortable with. The plans call for hardenening of many parts, i.e. CAMSHAFT, CAM, ROCKER ARM, etc... This not necessary, but doing so should result in a longer wearing engine.

When making the CAM SHAFT, shoot for a press fit into the engine frame and a free rotating fit with the CAM GEAR. Alternatively, you could use a set screw though the bottom of the SIDE FRAME to retain the CAM SHAFT in it's bore.

SHEET 9. Modify CAM GEAR and CAM DRIVE GEAR as shown. Use Loctite and press them to their respective parts. The position of the gear teeth are not important at this stage - the engine will be timed on final assembly. When making the IGNITION CAM, round off the sharp edges created when milling the flat spot - it is this flat that operates the ignition points. Use a short #6 set-screw to hold this CAM to the crankshaft - see assembly notes for locating details.

SHEET 10. The INTAKE & EXHAUST VALVE BLOCKS are nearly identical with one exception - the four holes for the #2 screws. I used studs screwed into the EXH. VALVE BLOCK so my INT. VALVE BLOCK had only though holes - no coutersinks. Doesn't really matter what you choose, just make sure all mating surfaces are flat and smooth so you won't need gaskets or messy sealers. The 3/16" port holes aren't drilled until the VALVE GUIDES (shown on sheet 11) are pressed in.

125 √	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1:1	B	NOTES
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
						JBW	19 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

2 | 1

SHEET 11. Onto the VALVE GUIDES - make sure your 3/32" reamed holes are concentric with the valve seats. To cut the valve seats, I simply used a 90° chamfering bit in the lathe's tailstock and lightly touched it to the rotating valve guide, creating a narrow valve seat which was later lapped to the valve. I used brass for the guides on the prototype engine, but I think bronze or cast iron would be a better choice.

The VALVES were made one piece out of whatever steel I had laying around. Stainless steel would be a great choice, or two piece vavles can be fabricated and silver soldered together.

SHEET 12. Do yourself a favor and skip building this VENTURI and NEEDLE VALVE ASSY. While OK for initial starting and breaking in - much better results can be had from conventional throttling carburetors - either ones from radio control glow engines, or ones fabricated to work like one. Shoot for a small bore carb, something from a .10 - .15 ci 2-stroke glow engine or one with a bore of .156" - .188", you won't need anything larger than this.

SHEET 13, 14. Nothing special here, just the remaining components that will need to be fabricated. If you're careful about machining the cylinder spigot and it's fit into the head, you may not need a head gasket - I used one for good measure. The design of the exhaust pipe is mostly cosmetic - I like balogna cut pipes, but do whatever you wish here. (Originally I had second thoughts about pointing the exhaust back, but it was actually found to have a benefit - the unburned oil in the exhaust helps to keep the gears and cam lubricated.)

The CRANK OILER CUP and the CRANK PIN GREASE CUP were purchased from a vendor at Cabin Fever - unfourtunately I don't remember who it was. Approximate dimensions are given should you wish to fabricate your own.

The CYLINDER OILER is an optional item if you mix oil in your fuel. Again, there are other, more attractive designs out there, but this was a quick and dirty way to do it.

Also shown is the optional RC CARB ADAPTER... highly recommended.

ASSEMBLY - Assembly should pose no particular problems, however it is suggested that the parts be made in the order that they are presented on the plan sheets. Although I've tried to be thorough with the notes on the plans themselves, a few points are worth mentioning.

Press the bearing(s) and CAM SHAFT into the SIDE FRAME, slide on one CAM GEAR WASHER, the CAM GEAR ASSY (with the CAM pointing towards the frame) followed by another washer, and secure with a cotter pin. Be sure that the gear spins freely on the shaft - adjust as necessary.

Attach the ROCKER ARM (with TAPPET in place) to the SIDE FRAME using the shoulder screw, washer, and spacer. Fasten on the CYL. HEAD-FRAME and secure this assembly to the BASE PLATE. Attach the CRANKSHAFT SUPPORT (with bearing(s) in place) to the BASE PLATE.

Assemble the CRANKSHAFT, CRANK SPACER, and FLYWHEEL ASSY. - at this point the crank should spin freely, independently of the flywheel - we will adjust timing and secure this later.

The CYLINDER, it's gasket, and the piston/rod assy. must be installed as one group. Slide the piston/rod assy. into the cylinder, and with the crank at BDC, slide the big end of the rod onto the crank pin. Rotate the crank while moving the assy. forward, into the head's bore (don't forget to align the ports). Secure the cylinder to the head, then attach the GREASE CUP using the CON ROD KEEPER like a washer. You did remember to make sure the oil holes in the rod and piston were pointing up, didn't you?

The assembled valve block can now be attatched to the head - no sealer is required if both surfaces are flat and smooth. Exhaust valve timing is set by rotating the crankshaft counter-clockwise (as viewed from the cam side) until it is about 15 - 30° before it's outward most stroke. It is then held in place while the flywheel is rotated C.C. until the cam just starts to lift the exhaust valve off of it's seat. Clamp, lock, & secure everything in place and drill the two roll pin holes as shown on the next sheet. If set properly, the exhaust valve will close a few degrees before TDC.

Timing the IGNITION CAM is much simpler. With the points and ignition cam installed, set the points gap to about .020". Rotate the flywheel until the piston is about 15° before TDC. Loosen the set screw on the ignition cam and rotate it clockwise until the points close and just start to open, lock the ignition cam in place.

The INTAKE and EXHAUST pieces are simply pressed and Loctited in place for sake of simplicity and I haven't had a problem with them so far.

Finish assembly with the oilers, spark plug, igntion condenser, etc... Check that all moving parts are free, and that you have compression / no leaks. Rotating the flywheel counter-clockwise (viewed from the flywheel side) should produce a "snorting" sound through the carburetor as the intake valve lifts. As you pass TDC on the compression stroke the engine should feel "bouncy" or "snappy", indicating good compression and that your engine is ready to run. Some folks like to break-in their engine by driving them with an electric motor, or even connected to the lathe spindle. If yours is free enough, it shouldn't be necessary to do this.

STARTING and RUNNING - I use a 12 volt car coil and 12 volt battery for my ignition system because I don't want any doubts whether it's firing or not. I have a 1 oz. fuel tank set so that the fuel level when full is about 1/4" lower than the needle valve. My engine runs good on straight Ozark Trails camping lantern fuel with 5w-30 motor oil in the cylinder oiler. (Some folks run straight methanol, some run gasoline and oil mix - do whatever works for you.) If you use the oiler, set it so that it drips oil about once every 6-10 seconds - experimentation may be in order to find the right setting to limit smoke, fouled plugs, oily mess, etc... When using an RC carb set at about 1/8 throttle, my engine starts on the first flip and will rev like crazy when prompted. Keep in mind, this is not a high speed engine, there's no balancing and inadequate cooling, so keep the speeds low.

SUMMARY - This engine was designed to be easy & quick to build, so there are no fancy radiuses, complicated governors, forced cooling, exotic materials, etc... It's a bare-bones internal combustion engine in the rawest form. As a matter of fact, mine isn't even painted. Sure, I specify to anodize this, polish that, etc... it's not necessary for operation, but it would be a nice touch don't ya think? If someone took their time and incorporated a few cosmetic details, it would be a pretty decent looking engine (I should know, I did just that in CAD).

125 ✓	+/- .015	+/- .005	+/- 30'	N/A	N/A	7/27/2004	1:1	B	NOTES, PG. 2
SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
						JBW	20 OF 21		
TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

THE FOLLOWING ADDITIONAL (NON-DETAILED) ITEMS ARE NEEDED FOR ASSEMBLY:

IGNITION POINTS:
(1) REQ.
SOURCE: PEP BOYS, AUTOZONE, NAPA, ETC...
(1969 DODGE CHARGER, 383, 4BL, W/SINGLE POINT DIST.)

IGNITION CONDENSER:
(1) REQ.
SOURCE: SOURCE: PEP BOYS, AUTOZONE, NAPA, ETC...
(1969 DODGE CHARGER, 383, 4BL, W/SINGLE POINT DIST.)

SPARK PLUG: NGK CM-6
SOURCE: MOTORCYCLE SHOP, ONLINE, ETC...

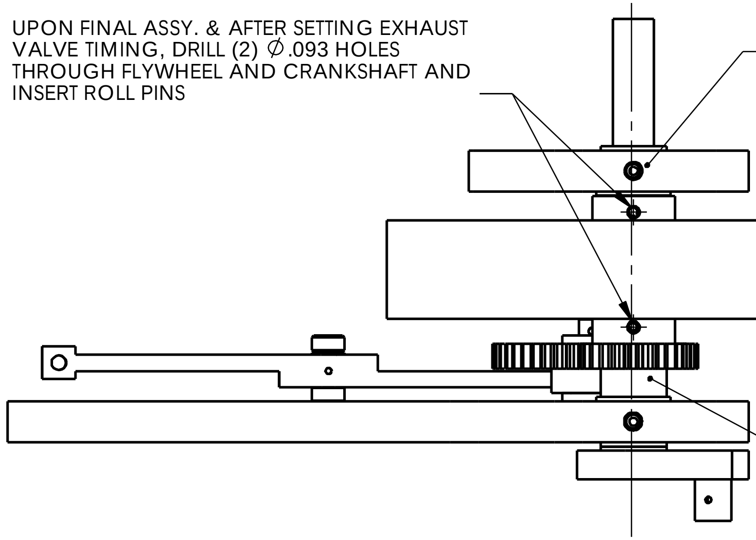
CRANKSHAFT BALL BEARINGS: 5/16" I.D. X 1/2" O.D X 5/32" THK., FLANGED
SOURCE: W.M. BERG: P/N B2-21 -OR- STOCK DRIVE PRODUCTS: P/N A 7Y55-FS5031
(4) REQD.

PISTON RINGS - 3/32" X .875"
(2) REQD.
SOURCE: OTTO GAS ENGINE WORKS
(410)-398-7340
2167 Blue Ball Rd
Elkton MD 21921-3330
http://www.dol.net/~dave.reed/otto.html

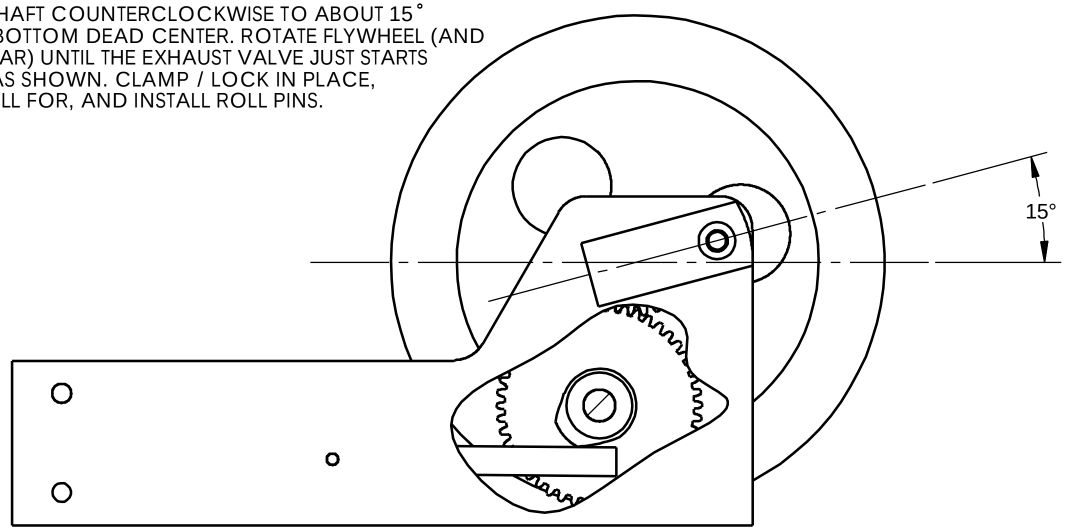
SHOULDER SCREW: 1/8" X 3/8"
(1) REQD.
SOURCE: WM. BERG: P/N PL-5 -OR- STOCK DRIVE PRODUCTS P/N A 9X15-0412

ROLL PIN: .093" X 5/8"
(2) REQD.
SOURCE: HW STORE, STOCK DRIVE PRODUCTS, W.M. BERG, ETC...

COTTER PIN: 1/16" X 1/2"
SOURCE: HW STORE, STOCK DRIVE PRODUCTS, W.M. BERG, ETC...
(1) REQD.



EXHAUST VALVE TIMING IS SET BY ROTATING CRANKSHAFT COUNTERCLOCKWISE TO ABOUT 15° BEFORE BOTTOM DEAD CENTER. ROTATE FLYWHEEL (AND CAM GEAR) UNTIL THE EXHAUST VALVE JUST STARTS TO LIFT, AS SHOWN. CLAMP / LOCK IN PLACE, THEN DRILL FOR, AND INSTALL ROLL PINS.



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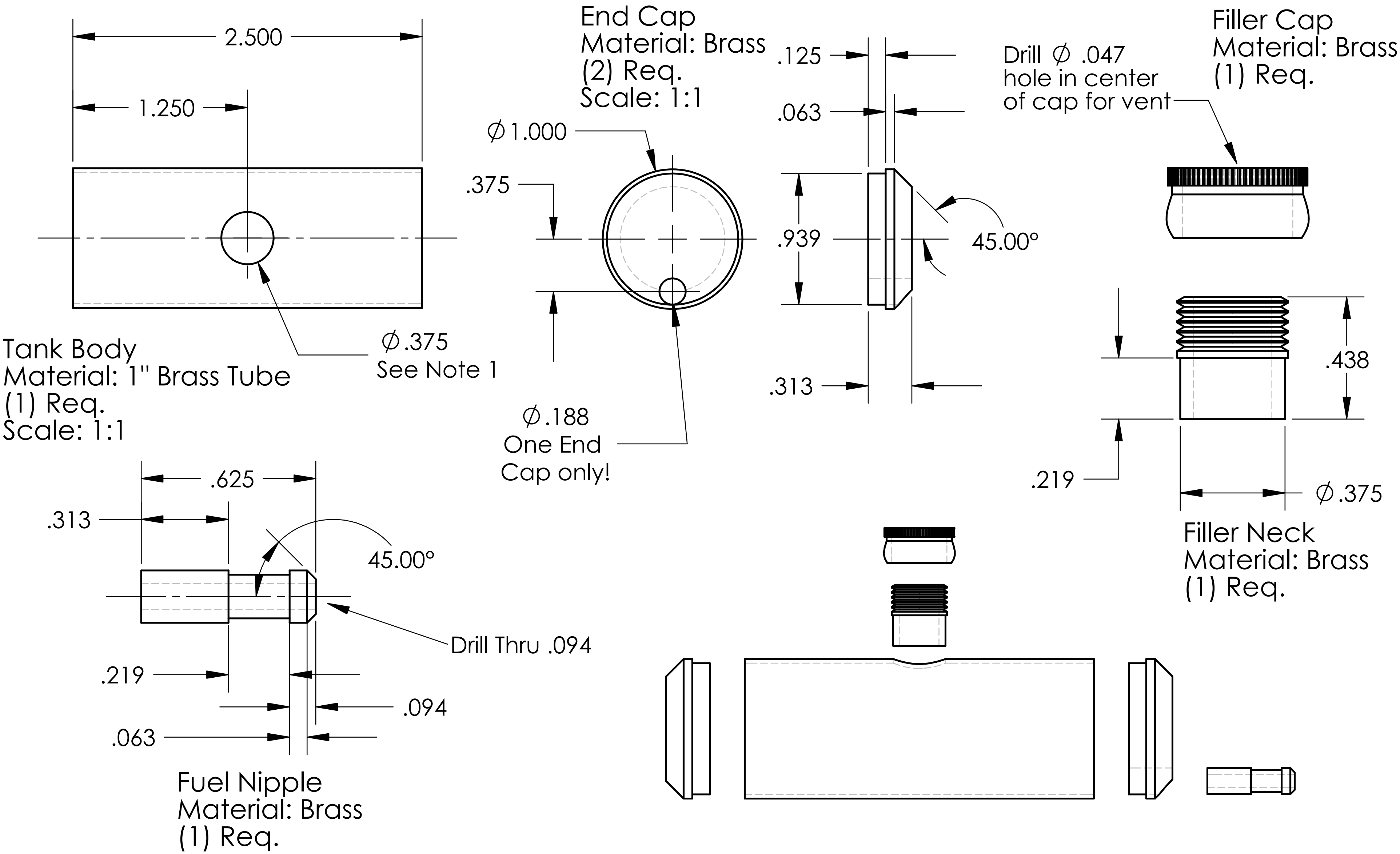
	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES			DATE	SCALE		
							JBW	21 OF 21		
	TOLERANCE UNLESS OTHERWISE NOTED				FINISH	MATERIAL	DETAILER	SHEET NO.	SIZE	(C) Joe Webster 2004

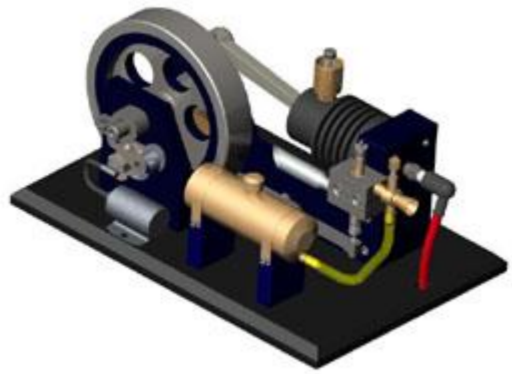


1.) Use 3/8" ∅ end mill to create hole, machine neck of filler tube for snug fit (leaving threads unmodified).
2.) Cap and Filler Neck are made from standard brass home lighting hardware (modified as shown).
3.) Soft solder mating parts.

REV	DESCRIPTION	BY	DATE	SURFACES	2 PLC DEC	3 PLC DEC	ANGLES	FINISH	MATERIAL	DATE	SCALE	SIZE	NAME
				125 ✓	± .015	± .005	± 30'	POLISH	BRASS	6/1/2006	2:1	A	WEW Fuel Tank
				TOLERANCE UNLESS OTHERWISE NOTED						DETAILER: JBW	SHEET NO.: 1 OF 1		NUMBER

Webster Engine Works Single Cylinder 4 Stroke Gas Engine

Introduction / Background:

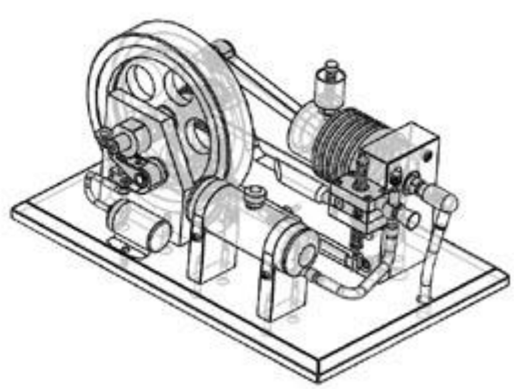


I am a mechanical designer / 3D CAD operator by trade and used to design parts and assemblies for a shop ran by some of the nation's best machinists and metalworkers. Since I'm generally a hands-on, do-it-yourselfer, gear-head kinda guy, I've always wanted to try my hand at metalworking, and more specifically, the building of model internal combustion engines. Through a discussion with one of the guys in the shop, I learned of the annual Cabin Fever Expo in York, PA. I attended the expo in January 2003 and even though I was still in the information gathering stage, I picked up a set of plans for Jerry Howell's "Powerhouse" gas engine because I liked the way it sounded when running, and it was relatively simple for the beginner to build. Shortly after I learned of Hamilton Upshur's wonderfully simplistic "Farm Engine" in Strictly IC magazine and ordered the plans. I also spent a lot if time at Ron's Model Engineering and Model IC Engine Projects and ordered plans for "Midge" - a small diesel model airplane engine. I used Solidworks 3D modeling software to model nearly every plan I came across, and let me tell you, between the internet, books, and magazines, I found multitudes of them!
It's pretty hard to be a machinist without any machine tools, so in April, 2003 I purchased a Smithy Granite 1324 3-in-1 lathe-mill-drill. (The purists frown on these types of 3-in-1 machines, but I felt it was justifiable for my soon to be small shop.) I spent many hours making chips and even made a few working steam and stirling engines to get my feet wet.
Although the designs that I had acquired were well executed examples of model IC engines, I felt that I needed something simpler. "Borrowing" ideas from the above mentioned engines, and also Philip

Duclos' Odds-n-Ends, I designed an engine which, even I - a complete novice, could build with the tools and most of the materials that I had on hand.

Specifications:

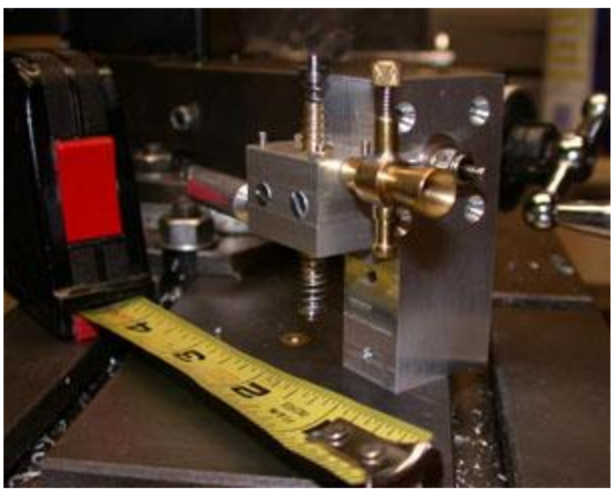
- Displacement: .75 c.i. / 12 cc
- Bore: 7/8" / 22.2 mm
- Stroke: 1 1/4" / 31.8 mm
- RPM: 1000 - 5000 RPM (measured)
- Spark ignition w/ 12 V high tension coil, points and condenser.
- Atmospheric intake valve (poppet valve), and cam/rocker operated exhaust valve.
- Throttle governed with an O.S. radio control car engine carburetor (.12 c.i. size).



Some of the main design considerations were:

- General ease of construction with minimal tooling (basic lathe and mill work).
- No fancy radiuses, spokes or bolt patterns requiring the use of a rotary table.
- "Smallish" proportions to limit material costs.
- Limited number of parts for speed of construction.
- Availability of gears, bearings and other components.

Design of this engine was started around the middle of May '03 and it was only a couple of weeks before I was making chips. There were a few bumps in the road along the way, mostly because of intimidation (which of course caused me to loose momentum), but in January '04 I fired 'er for the first time. Since then, I have run nearly a gallon of fuel through it and it's still going strong. It usually starts on the first flip and has a very pleasing sound. For fun, I sometimes hook a small generator to it to power a few Christmas tree lights. I won't bore you with the laying out, set-up and machining operations (not that I really knew what I was doing), but I'll be happy to share some pictures, sounds, and videos taken along the way.



This shot shows the valve block, head, and venturi / needle valve. I later went with a carburetor from a radio control car engine because it gave me much better speed and mixture control. The spark plug hole was tapped 1/4" X 32 tpi so that I could use either glow or more traditionally, spark ignition. The valve blocks and engine frame were made from 6061-T6 aluminum, the valve guides and venturi from brass (although bronze would have been a better choice for the valve guides).

Here we see a completed piston, rocker arm, and the start of the cylinder. Boring and honing the cylinder was one of my major stumbling blocks, but it turned out to be not much of an issue. I used 12L14 leaded steel for the cylinder (which cut like butter) and 6061-T6 for the piston. The piston rings came from Otto Gas Engine Works, and the ball bearings & gears from Stock Drive Products. Hidden behind the large brass gear is the exhaust cam.

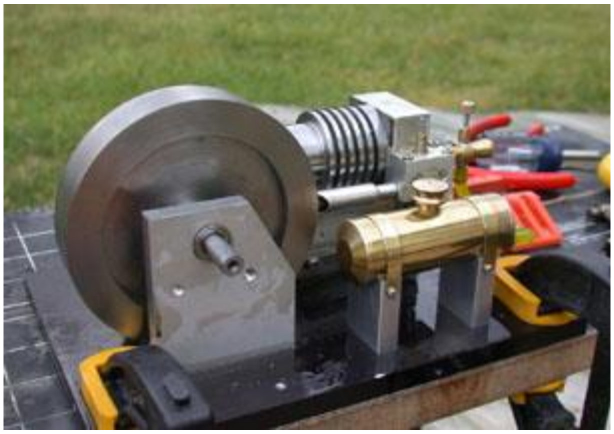
Just a close-up of the piston showing the rod cut out and the two 4-40 tapped holes for the wrist pin set screws. Notice the small brass tube? At the end of the piston's stroke, this tube aligns with the cylinder oiler and supplies lubrication to the wrist pin - this was done on full-size, antique, gas engines, and it works in smaller scale too.

This picture kind of gives you a sense of scale. The rod, made from more 6061-T6, is 3.063" between centers. Profiling of the rod ends was done without the aid of a rotary table. Basically the end to be profiled was attached to a snug fitting, vertical pivot on the milling machine and the rod swung by hand against the side of a running end mill. (Needless to say, this is rod #2.) Check this link for a better explanation and even a nice photo. The wrist pin is .188", drilled through .094" and both ends of the rod are bronze bushed.

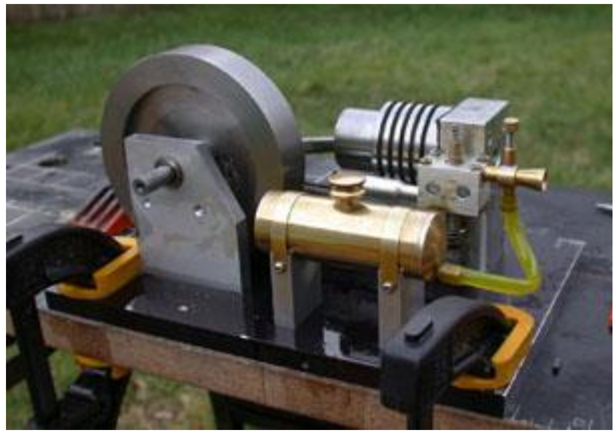
Here's a 3D rendering that I did in Solidworks showing the valve-train detail. As mentioned earlier, the intake valve (on top) is actuated by the vacuum created by the piston on it's outward stroke. Compression, combustion,

OK, here's a semi-exploded view of all of the parts. Just where do you get a chunk of cast iron large and cheap enough to make a flywheel this size (3.75" dia.)? Well Walmart of course... in the sporting goods section, and subsequent exhaust pressure keeps the valve closed during their respective cycles. The exhaust valve is operated by the steel cam attached to the brass gear and is timed to open on the exhaust about 15 degrees before BDC and to close the exhaust valve a few degrees before TDC.

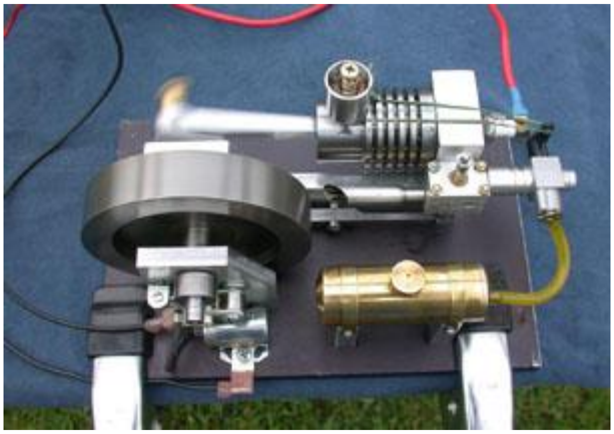
disguised as a dumbbell. One word of caution though, it's a pretty cheap casting that has a few voids - luckily none of them caused any problems though. The crankshaft started out as a piece of CRS flatbar 1.5" X .5" X 5" and both shaft and crank pin were turned as one piece, between centers.

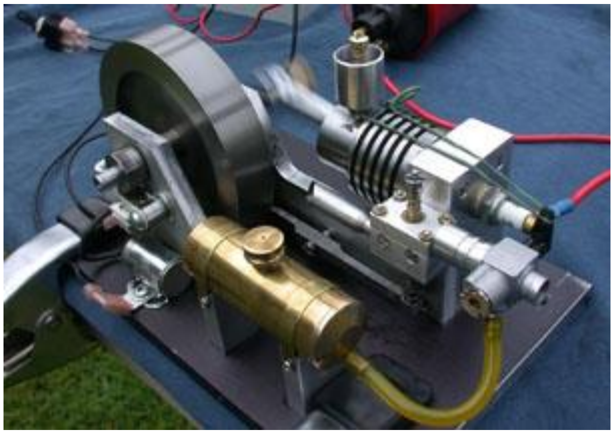


"It lives, I have created life!" What you see here is the engine just after it's first run on model airplane fuel (10% nitromethane, 18% oil, balance methanol) and glow ignition. The first few runs were pretty short as the piston to cylinder fit was still fairly tight, and the engine would slow to a stop as the aluminum piston heated and expanded in the bore. Check out the oily mess that glow-fuel leaves behind... great for breaking-in a new engine, but quite the chore to clean up. The date was January 3rd, 2004.



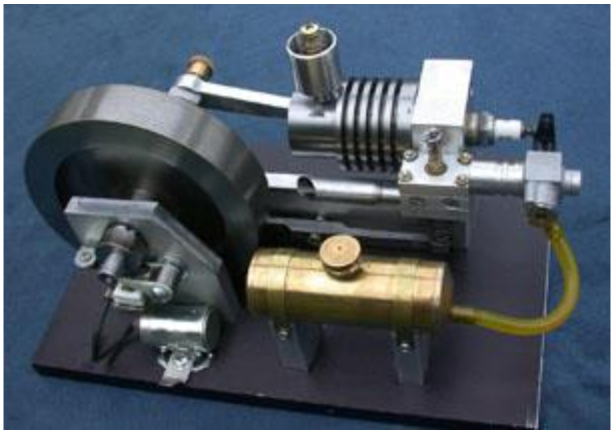
Another shot, taken the same day. Notice the small pits in the depressed section of the flywheel, these are some of the voids that I mentioned above. Also notice the small section of broken roll pin in the right foreground. This was the roll pin that held the flywheel to the crankshaft, but it had sheared while running. Even though I had planned on using two 3/32" cross-drilled roll pins to attach the flywheel, in my haste to get the engine running, I only took the time to affix one. Lesson learned. The engine now uses two roll pins (one each on opposite sides of the flywheel) and they have held up fine.

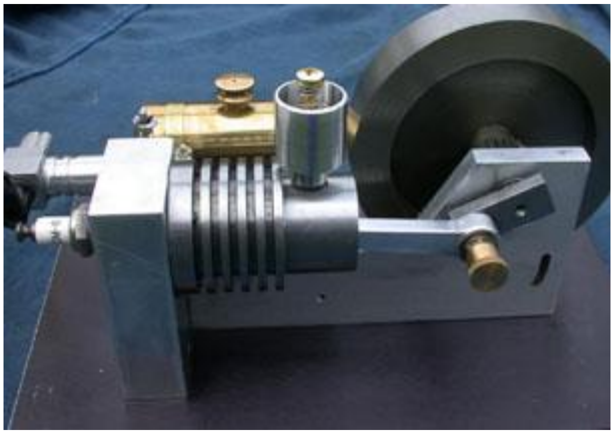




Here were are running on gas and spark ignition. Originally, I was using a 1/4" X 32 tpi spark plug, but it was too easy to foul, too hard to get, and too darned expensive (~$15) to replace. I've drilled and retapped the head for a 10mm NGK CM-6 spark plug. With it's larger electrode and insulator it's pretty hard to foul and only $3 to replace at my local Honda motorcycle dealer. Photo was taken on July 12th, 2004 and at that time, nearly a gallon of fuel has been through the engine. (At an average of 14 minutes per ounce, that's about 28 hours of run time.)

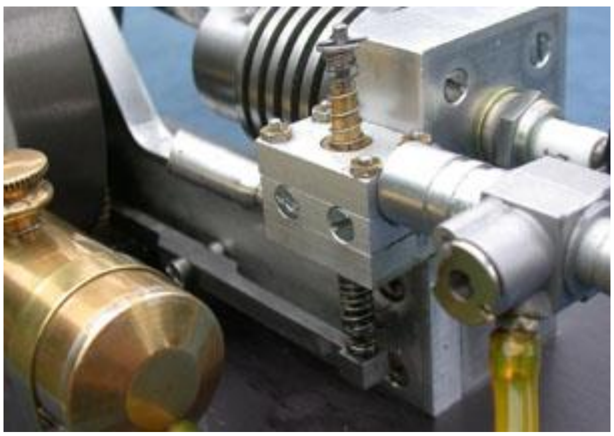
In this photo you can see the RC carb retrofit and the NGK CM-6 spark plug (10mm X 1mm pitch). I run this engine on straight Ozark Trails lantern fuel, which is the Walmart brand of the popular Coleman fuel - only a dollar a gallon cheaper. I use regular 5w-30 motor oil in the cylinder oiler. I have also tried running the engine on straight gasoline, but since it is less refined than the lantern fuel, it just plain stinks when running - the lantern fuel almost has a pleasing smell. Anyone who has been to Cabin Fever knows what I'm talking about. (Or is that just me?)





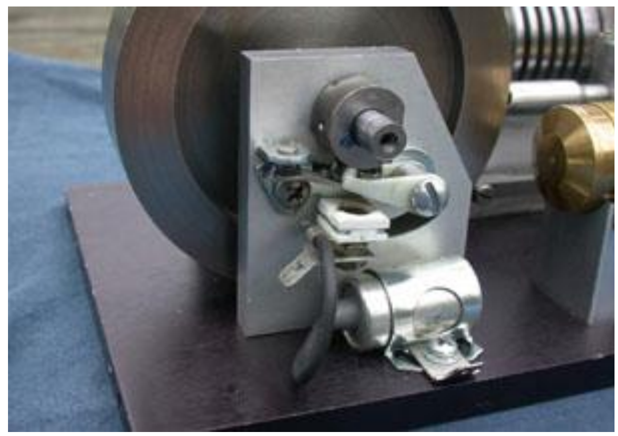
Just a right side view showing the general arrangement and the spot where I ran an end mill into the cylinder as I was spot-facing for the oiler threads. (D-Oh!) The base plate was sawed out of 3/8" thick plate of anodized

Left side view showing the purchased grease cup for crank pin lubrication. You unscrew the knurled cap, pack it full of grease, then screw it back onto the "cup", forcing grease through a small hole in the crank pin, lubricating the aluminum - not pretty, but it works. (I picked up close to 150 lbs of aluminum plate and bar from a farm auction for $15 - just one of those rare days when I was in the right place at the right time). Oh yea, the fuel tank was soldered up from brass tube and bar stock, holds about an ounce, and I'm kinda happy with the way it turned out.

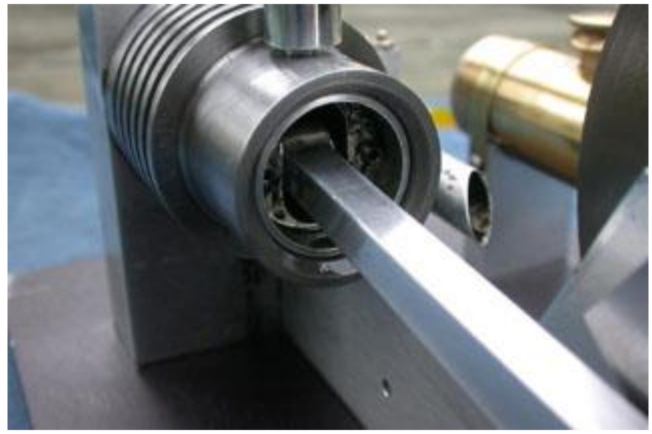


Here's a close-up of the valve block showing the springs, valves, valve guides, rocker arm, and the RC carb adapter. The valves are mild steel, with .093" stems and .250" heads. The valve stems are cross-drilled .040 for the spring retainer pins. The intake and exhaust ports are .188". Also, the carb has a rather diminutive bore of about .166", which is fine for an engine such as this. Oh, I almost forgot to mention, the intake valve spring is relatively light to allow it to be self-operating. When you crank the engine over by hand, you should hear a "snort" as the intake valve opens and draws air through the carb.

pin and bearing. Just give it a quarter turn or so before each time you start it. (Hey, it's how they used to do it in the good ole days.) See the curved slot on the lower right of the engine frame? That was to be used for the adjustable electronic ignition, but I decided it was easier to stick on a set of old fashioned ignition points than to fuss with hall effect ICs and driver circuits. Breaker points are much more forgiving of "user error" than ICs!



Anybody recognize these? I had read that points for any early Mopar product would work nicely for model engines, so I walked into my local auto parts store and asked for a set of points and condenser for a 1969 Dodge Charger, 383, 4 bbl... It wouldn't have been too cool to ask for something from a Dodge Volare'! The kid behind the counter looked at me kinda funny and said, "Oh, I won't have anything like that." I pressured him to look anyway, and whattaya know... he had 'em in stock. (The cost for both were around $10 US.)



Just a rear view to show the cam gears. So what lubricates these babies? Mostly unburned oil from the exhaust - you know, whatever blows by the rings coming from the cylinder lubricator. If the gears look a little dry, I'll put a drop or two of oil on 'em. Yea, I know, it's crude, but it works... (Looks like it's time to fill the grease cup again, too.)

And a view to show the back of the cylinder - I kinda like the perspective of this shot. If you look closely at the end of the rod, you can see the hole in the rod that receives oil from the cylinder lubricator above it. That's grease splattered onto the back of the piston from the crank pin grease cup.

Finally, here is a video and a few sounds of the engine running:

Start-Up (VIDEO) Idle Revving Driving a load

Update! 02/02/05 Another Webster Runs! I received the following video from a builder in California who has just fired his engine for the first time. (This would be the second running "Webster" known to exist). Click here to see his engine in action. Way to go Rich!

Update! 03/02/05 ***Another*** Webster Runs - also in California! Phil started building his "Webster" the day after Christmas 2004, and had it running three weeks ago (that's an amazing build time of 5-6 weeks folks). He has also added a slick adjustable breaker plate and counterbalanced crankshaft. Click here for a video of his engine, and check out that looooow idle speed. Here's to a job well done!

Update! 04/22/05 - No one else has come forward with a completed engine (but I know of a few that are nearing completion). So while I have your attention, I'd like to share one of my other designs with you - it's a .056 cubic inch, compression ignition, 2-cycle, model airplane engine. Details can be found here, on the "The Next Generation EZE" page. If you're not ready to take on a project the size of the Webster 4-cycle, maybe a smaller, simpler engine is right up your alley - check it out. (Don't get your hopes up though, I'm not offering free plans for this one!) Oh, while I'm thinking of it, if you maintain a list of links on your web page, feel free to add either of my pages!

Update! 10/23/05 - Another Webster Runs - this one in the UK! How's this for inspiration - Warren built his Webster in an incredible two weeks! OK, so he "cheated" and used his home shop CNC, but this still warrants big praise. Currently he's running his engine on glow fuel but plans to switch it over to gas soon. Here's a short video clip. Congratulations Warren!

Update! 11/21/05 - Bob P. checks in with his running Webster. Unfortunately I don't have any pictures or video to share - Bob, if you're reading this, send a few pics or a video so we can brag about it here!

Update! 01/01/06 - Peter from Slovakia proudly writes to say that he's completed and ran his Webster at 11:44 pm on New Years Eve! Peter has done a fantastic job on his engine with neat additions such as a ball bearing supported cam, a ball bearing on the big end of the cod rod, a roller tipped rocker arm, large-press-on cooling fins, a larger flywheel, an adjustable breaker plate, a removable carb adapter, AND on top of this, he cut his own gears. He also reports that his engine is a "smooth runner" and with the aforementioned mods it's no wonder! Also, Peter frequently displays his engine at antique steam and gas engine shows and always draws quite a crowd!

Update! 03/04/06 - Eric in Canada has completed his Webster and it's truly unique. Sporting mods like a curved spoke flywheel, fully radiused corners, counterweighted crank, oversized ball bearings, shop-made gears and a Viton O-ring installed on the piston instead of cast iron rings, Eric's engine is a real beauty. One thing though - Eric must have been looking at the plans from the wrong side because his version is a mirror image of all the other Websters out there (don't worry Eric, your secret's safe with me)! Have a look at this "one of a kind" here then come back and check out his video (9 Mb offsite).

Update! 06/02/06 - John from western Australia writes with details on his engine. Let me just say that this one's built like a tank! With 12mm thick marine grade aluminum alloy frame pieces, stainless steel valves, sealed ball bearings on every rotating bit, a fabricated / silver soldered crankshaft, and a shop-cast bronze flywheel, this one should last a lifetime. Some other interesting (if not clever) details are the bronze crank gear (sourced from a photocopier) mated to the plastic cam gear which John bought from his local hobby shop. While John was perusing the store, he picked up a piston / ring / wrist pin combo (from a .60-.90 size RC aero engine presumably) and is using them in his engine. Now that's thinking! You can have a peek at John's engine here.

Update! 01/01/07 - Julian from the UK checks in with another New Years Day Baby. Like many of us with "household duties" Julian didn't have a whole lot of time to build his engine, but with with a few spare evenings and time around the holidays, he managed to turn out a fine example of the engine. Some modifications & deviations worth noting are the built-up spoked flywheel, two-piece valve block, silver soldered crankshaft, lapped cast iron cylinder/piston combo (no rings), stainless steel valves, micro-switch ignition, and ball bearings used throughout (most of which were sourced from old hard drives). Oh, and I almost forgot to mention Julian made his own throttling carburetor by using Nemett's design in a recent Model Engineer article. The engine starts and throttles well, but as Julian reports he'll need to install a muffler of sorts if he wishes to keep the peace around the house. Don't worry Julian, you're not the only one with that problem!

Update! 01/06/07 - Due to popular request, I've updated the plans link to include fuel tank fabrication details.

Update! 05/26/08 - We have two new engines to report: The first is from Bill H. in MI, USA. Bill had little trouble with the build of his engine and turned out a beautiful example of The Webster, complete with a real honest-to-goodness spoked flywheel. The "running" part of the build however, was a bit elusive. Bill and I shared many e-mails back and forth and although everything appeared to check out, we couldn't get it to run for much more than a couple of short bursts. Sadly Bill ran out of time and patience for his project and shelved it for nearly two years, but in February of this year Bill excitedly checked in with good news - his Webster now runs! It turns out that the intake valve wasn't sealing as good as it could have, and after recutting and lapping the valve seat all is good. Persistence pays off and Bill has a runner -way to go!

The second Webster to surface this year is a little unique as it's the first water cooled Webster known to exist. That's right, Jens S. from Norway added a water jacket, a wick lubricator, a balanced crankshaft, a massive brass flywheel and a carburetor of his own design. He also made his own piston rings using Professor Chaddock's method and even went as far as to intentionally produce a slightly tapered piston to reduce running friction. Wow, talk about taking a scientific approach to engine building! Video of Jens' engine can be found here. (A water cooled Webster... how cool is that?)

Conclusion:

I'm sure a lot of people reading this right now are cringing at the way I did some things. Remember, I wanted an easy and quick to build engine requiring minimal tooling and materials. I think anyone who has built a couple of successful steam / stirling engines and has an idea of which fits are important could build one.

Pros:

- Quick, inexpensive, and relatively easy to build.
- No castings required.
- Minimal tooling required.
- Uses many easy to find items ie: gears, bearing and ignition parts.
- Very forgiving design - no super-critical dimensions.
- Can actually drive a useful load.
- Easy speed control, no small and finicky governor parts to be made.

Cons:

- Limited run time due to inadequate cooling, but I kinda figured this going into it. This engine was never meant to run 24/7, just the occasional smoke, fire, and noise show for friends and family... well, OK, me. Needs more and / or larger cooling fins, a fan, or possibly a water jacket on the cylinder. Not a major issue, and certainly one that's easily resolved by thermally isolating the carb.
- Possibly needs thinner piston rings to reduce drag and friction (1/16" -vs- 3/32").
- Messy (but effective) lubrication scheme.