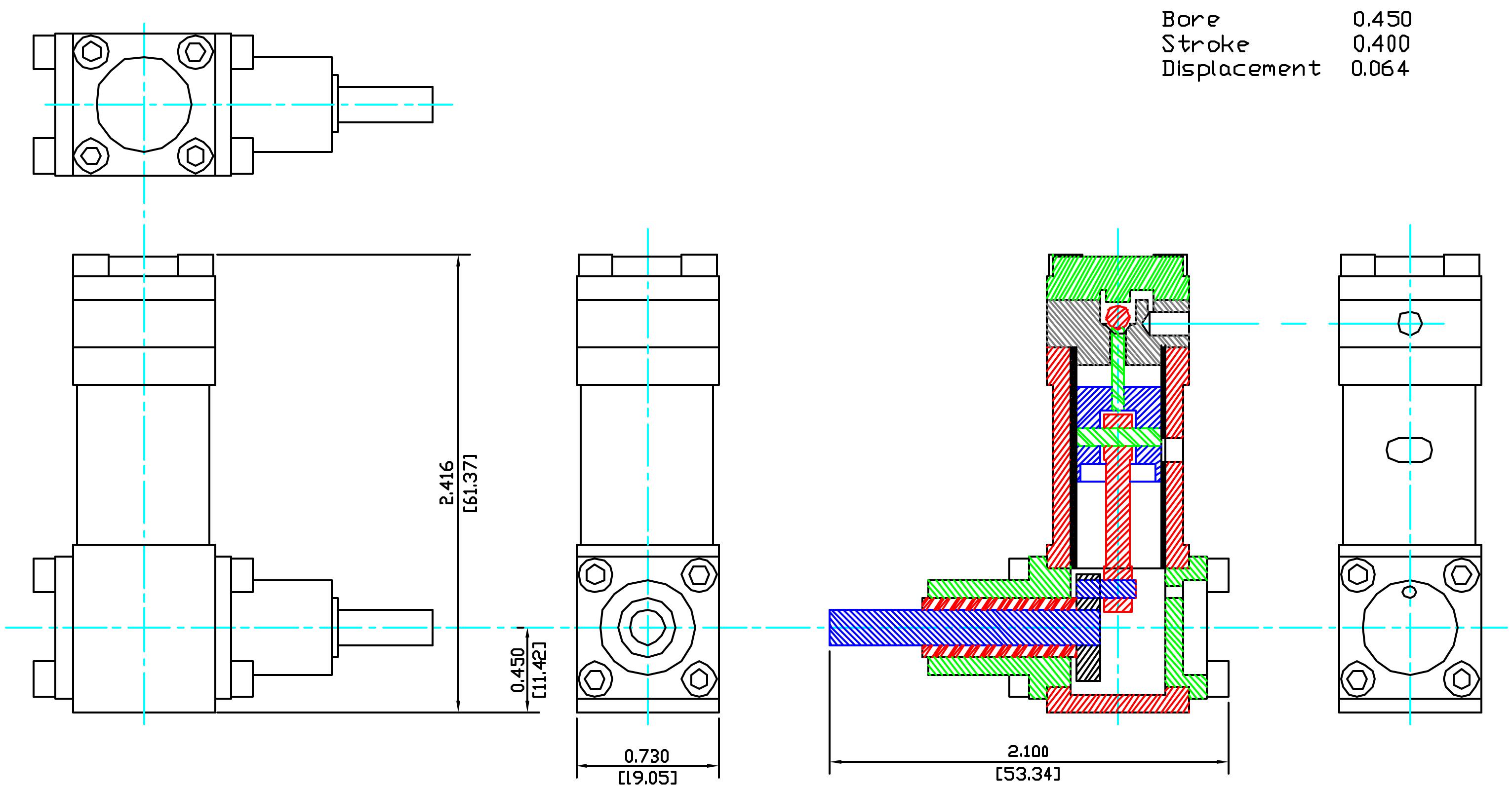


Modular Engine 1

This first modular design is a simple design that operates on compressed air. It is based on CO_2 engines used on small model airplanes. It was chosen as engine number 1 because of its simplicity.

The valve is a ball, located in the Valve Block. Compressed air is applied to the engine. For most of the cycle the ball blocks the flow of compressed air into the cylinder. When the piston is at the top of the stroke, a pin attached to the piston, lifts the ball and allows the compressed air to enter the cylinder. The pressure forces the piston down for the power stroke. Near the bottom of the stroke the piston uncovers exhaust holes in the side of the cylinder. The inertia of the flywheel or prop causes the piston to move up compressing the air in the cylinder. The pin finally opens the ball valve again for the next power cycle. Because the cylinder is filled with pressurized air when the pin opens the valve, only a small amount of compressed air enters the cylinder making the engine efficient.

David Kerzel

Pompano Beach, Florida USA

Assembly:
Pin & Ball Valve Air Engine

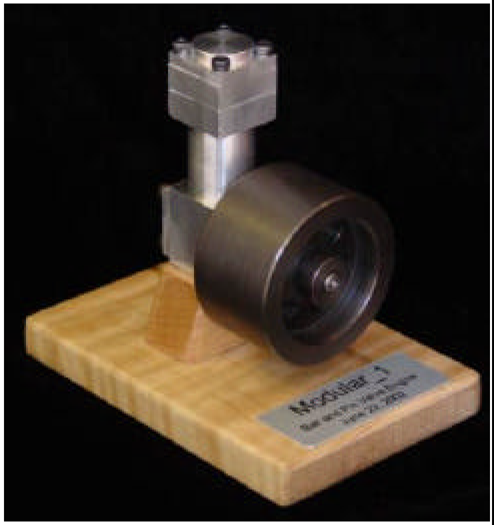
Title:
Complete Engine

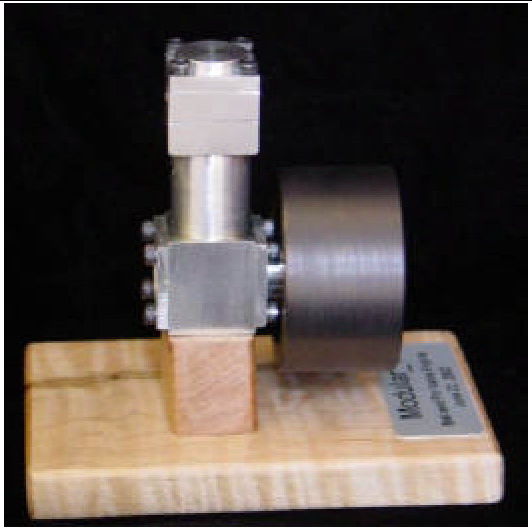
Date: 3/4/2003

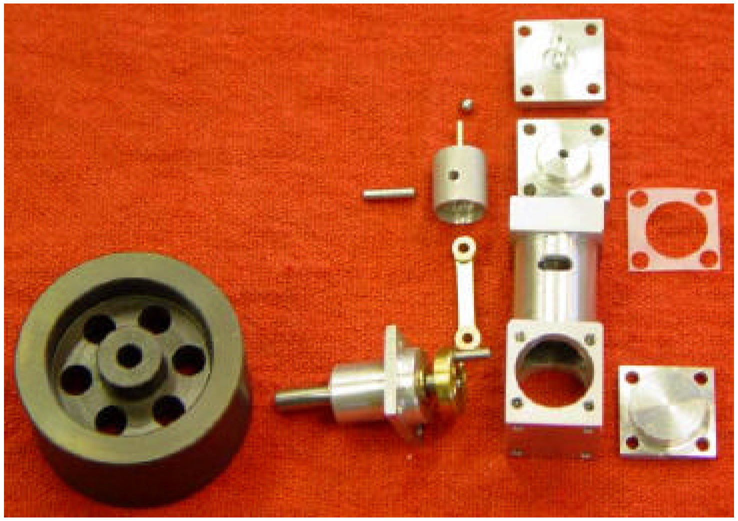
Revision: 1.3

Drawing:
Modular_1

Modular Engine 1







Construction Notes: The following construction notes are how I decided to build this engine. There are many other ways to make each of the parts. Some of my choices may not be applicable to your tools and machines. Feel free to change everything.

Quantity	Drawing	Description		Quantity	Drawing	Description
1	Modular_0_1	Cylinder with Exhaust Port		1	Modular_0_8	Piston with Pin
1	Modular_0_2	Main Bearing		1	Modular_0_9	Flywheel
1	Modular_0_3	Crank Shaft		1	Modular_0_10	Gasket
1	Modular_0_4	Crank Shaft End		8		4-40 X ¼ cap screw
1	Modular_0_5	Valve Block		4		4-40 X 5/8 cap screw
1	Modular_0_6	Top Block		1		4-40 X 1/8 set screw
1	Modular_0_7	Connecting Rod		1		1/8 Stainless steel ball

Materials: The main parts are made from ¾ square 6061 aluminum stock. The material in the prints has 0.010 milled from each side to get a uniform finish. All the parts are small enough that they could be faced in the lathe. The parts can also be made from the ¾ square stock with just surface sanding to improve the finish.

Cylinder with Exhaust, Drawing: Modular_0_1, Make the liner from 303 or 304 series stainless steel. Drill and then bore the ID. Leave the cylinder liner slightly over length. Next drill and bore the hole for the cylinder liner. Drill and bore the cross drilling for the crankshaft. Make a plug 0.062 diameter that can be put in the crank bore to stop the cylinder liner when it is pressed in. **Cylinder liner fit**: The exact outside diameter used for the cylinder liner is not critical. What is critical is having approximately 0.0002 to 0.0006 inches of interference between the cylinder body and the liner. The parts will need to be pressed together using a press or a large vice. Heating the aluminum body to 400°F will expand the part and make the pressing operation easier. If the fit ends up loose, use some LockTite when pressing the parts together. Face the extra length of the liner off and ensure the cylinder top is smooth for good sealing. Drill and then mill the exhaust port. Two drilled holes can be used if milling is a problem. **Cylinder Lapping**: The exact inside diameter used for the cylinder liner is not critical as long as the piston is properly fitted. The ID of the liner should be lapped with 280 grit (aprox) silicon carbide lapping compound. Use a commercial expanding adjustable lap. When the ID has a uniform dull finish it is done. This should be done before the part is pressed into the body. After the parts are pressed together, the exhaust port needs to be machined. If there are visible burrs on the inside at the exhaust port, lap again with 280 grit using a blind lap. When lap drag is constant, clean it and continue with 600 grit (aprox) lapping compound. A good uniform finish is more important than a specific diameter. The surface will remain dull and uniform in appearance. The dull finish will hold oil and provide a good seal. Clean toughly and oil lightly. Finally, drill and tap all of the screw holes.

Main Bearing, Drawing: Modular_0_2, Turn the 0.500 diameter end from stock bar. Reverse part in lathe chuck and turn 0.625 diameter and drill/bore 0.310 hole for bearing. Make bearing from oil impregnated sintered bronze. Make the bearing 0.001 larger than the hole in the body. Press the bearing into the body. Return the part to the lathe, face it to length, drill, and ream the part for the shaft. Ream 0.001 larger than crankshaft rod. If the crankshaft still seems slightly tight, put the crank in a drill chuck and spin it to burnish the fit. When correct it needs to spin freely many revolutions.

Crank Shaft, Drawing: Modular_0_3, This is a 3 piece assembly. Make the disk first. Careful layout and drilling is essential. The four .125 holes are for balance. Ream the shat and crank pin holes so parts made from drill rod have light resistance when fitted. Use LockTite 640 to secure these parts.

Crank End Cap, Drawing: Modular_0_4, This part is a frill and not actually needed. It will help keep dirt out and make the engine look more finished. Turn the 0.623 dia and part it off. Face to correct length. This engine is based on a model aircraft engine so weight was important and the boring was added. The vent hole is important if the engine is run for long periods. The compressed air can build up in the crankcase and slow or stop the engine. The 4 hole pattern in all parts is identical and drilling all of them at one time will save setup time.

Valve Block, Drawing: Modular_0_5, Start by turning the 0.450 diameter and part off the block**.** Reverse the part and face to length. Drill the #46 thru hole. Drill the relief hole to 0.125 depth. Use a ball end mill and make the round surface to seat the ball. **Seating the valve ball**: Drop the ball into the concave cavity in the Valve Plate. Using a pin punch drive the ball into the seating area with several moderate hammer blows. When this has been done, the ball should still fall out of the seat by its own weight when the Valve Plate is turned over. If it does not it is likely the drilled portion is not deep enough. Finish by adding the air inlet 10-32 port (blind tap) and the #67 metering hole. Use a sensitive drill chuck for the #67 hole. The .450 diameter plug that goes into the cylinder can have its length changed to determine cylinder compression ratio, that affects how much gas will be used on each cycle.

Top Block, Drawing: Modular_0_6, Turn the 0.550 diameter and part off the block. Reverse the part in the lathe. Face to length leaving the extended pin. Grind a small cutting tool to cut the trepan grove around the post. Use a 1/8 end mill and plunge to make the air passage. The design could be enhanced by making the end of the pin a concaved surface formed by the 1/8 ball end mill with the maximum depth at the 0.020 level.

Connecting Rod, Drawing: Modular_0_7, The connecting rod may be made from 0.125 thick stock if milling is a problem. Make the blank about 1 3/6 long. Center drill one end to turn the center portion. Accurate layout of the centerline and 0.800 dimension are essential. Drill the holes initially #43 (0.089) for 2-56 screws. Make the lathe chuck mounting block for turning the rod. Mount it in the 4 jaw chuck and position so one of the screw heads turns true. Turn one of the bosses on the connecting rod. Reverse the part and turn the other end. Do the other side. Put the short end in the chuck, only two jaws are used on a small part like this. The other end is supported by a live center while the center is turned to 0.150 dia. Using a rotary table and an end mill make the ends round, this can be done freehand with a file or mini grinder. Ream the holes by hand, make sure the reamer is square when working.

Piston, Drawing: Modular_0_8, The piston should not be made until the cylinder liner is in and fully lapped. The piston should be made 0.003 larger than the lapped cylinder bore. Make a split lap and use 280 grit (approximately) silicon carbide lapping compound. Continually measure the diameter and switch to 600 grit when the diameter is 0.0002 oversize. Continue until the piston will just start to enter the cylinder. Continue with extreme care. When the piston will go into the cylinder but has a tight fit, do a final lap using the piston in the cylinder and 600 grit lapping compound. **Piston fit**: The piston when properly fit will fall through the clean dry cylinder liner (in cylinder body) with only its weight to move it. With the connecting rod attached, pushing the piston into the cylinder with the end blocked with a finger, and letting go of it will have it pop back up. If the piston is pushed to the bottom and pulled up quickly, it will POP as it comes out of the cylinder.

Flywheel, Drawing: Modular_0_9, The flywheel can be made from any heavy metal. The diameter can be 1.5 or the thickness could be reduced to 0.5. The 6 holes are not required. The setscrew can be drilled perpendicular to the axis rather than at an angle. The cast iron flywheel was heated to red heat, which made a black oxide and it was finished with tung oil to prevent rust. Ream the shaft hole 0.001 larger than the shaft used.

Gaskets, Drawing: Modular_0_10, Gaskets made from 0.005 thick Teflon seal well and are reusable. Paper gaskets can be used. The full-size area on the drawing can be used as a full size template. If you don't want to punch the corner holes, cut the corners off at 45 degrees.

Assembly:

Fit the connecting rod to the piston with the wrist pin. The piston should pivot on the connecting rod but be a close fit. Secure the wrist pin with some LockTite. Put the piston in the cylinder. Put the crankshaft in the main bearing, that fit should already be good. Put the crankshaft pin through the connecting rod hole and mount the main bearing with ¼ long screws. Oil the moving parts. The shaft must be able to be rotated easily and the piston moves freely with no binding. Put the valve block on the cylinder top with a gasket. **Piston pin**: The piston pin should be able to lift the ball 0 .020 to 0.030. Add the top plate with a second gasket and 5/8 long screws. If the engine is shaken, the ball can be heard rattling. Mount the flywheel, support the engine, connect compressed air, and its done.

How the engine feels: When the engine is spun by hand it pumps air out the compressed air inlet and makes a pop sound as the exhaust opens. The flywheel should be able to cause the engine to carry though about 6 cycles.

Start Up Notes: The engine will start in either direction with 35 PSI applied and a gentile spin. The engine appears to run faster one direction, but I suspect it is the way it is most often started. Keep it well oiled and it just runs. Air consumption is low. Once the engine is running it will operate in any position. The engine needs to be oiled at every starting and will operate for about 3 hours with one drop of oil. Dry lubricants such as Teflon spry or molybendium work well too.

Air Pressures and operation:

Air Pressure	RPM
14	380
22	550
40	1600
60	2600
80	3800

The engine runs well at 14 PSI but fails to operate after a few minutes at 12 PSI.

A 20 gallon compressor tank, starting at 135 PSI, regulated to 20 PSI operates the engine for 119 minutes.

Building it: This engine is a good first engine or first machine shop project. Reasonable precision is required, but the use of compressed air con cover some minor discretions. It comes together quickly and uses few special tools.

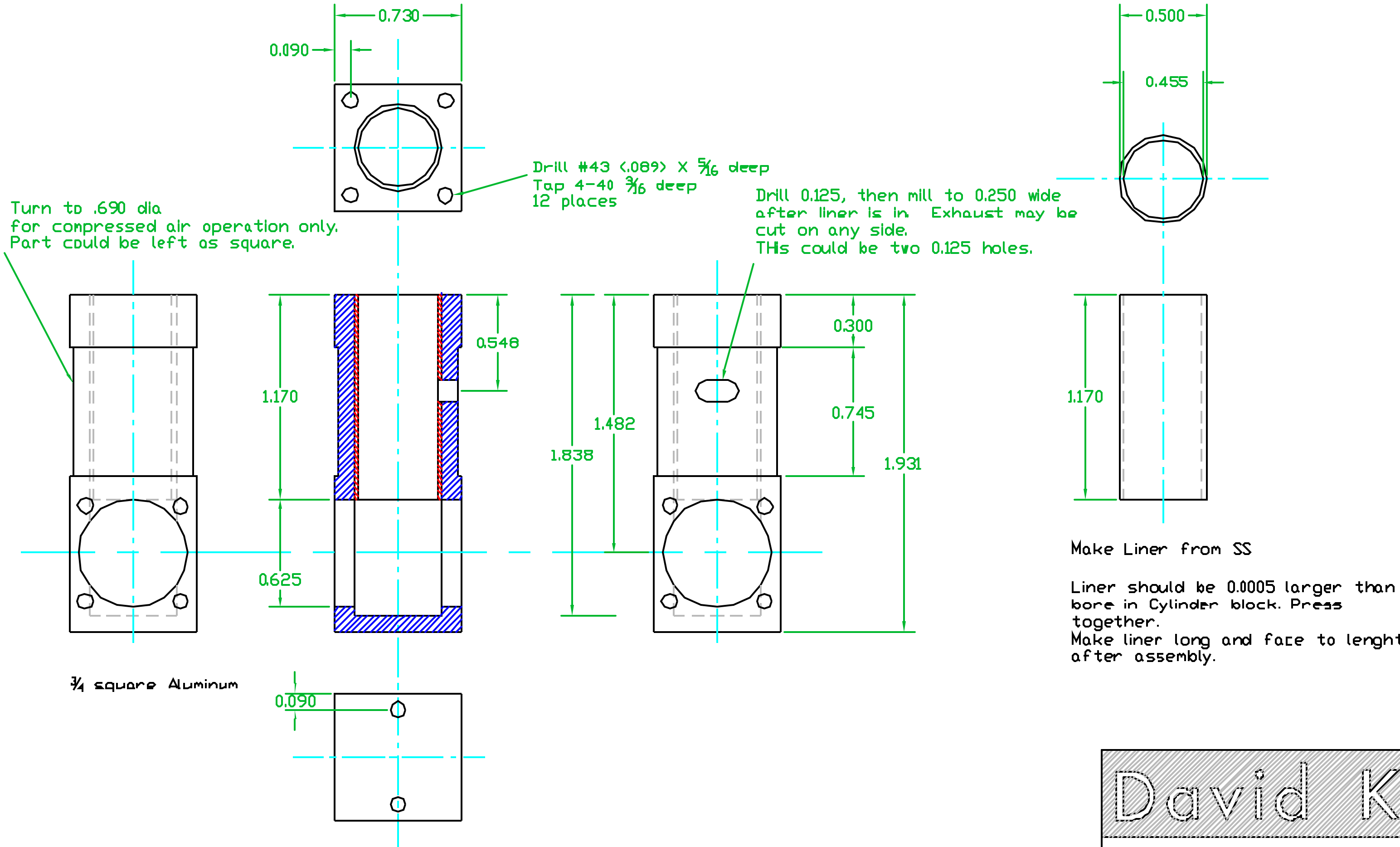
Metric: This is a pure inch design, but if any metric builders are interested, a metric version can be made.
CAD Drawings: If you need DWG or DXF format drawings I will provide them.

Questions, Comments, Problems, or Success: please contact me to discuss anything relating to these plans, david@FloridaAME.org. As of this date, the plans have not been verified in construction. Please let me know if you build one and let me know if there are problems in the drawings. I often find drawings don't have the exact dimension I need. If you find that, let me know and I will correct any problems. I would appreciate photos of any completed engines. Please also consider submitting your engine to the gallery at www.FloridaAME.org.

Revisions:
- 1.0 6/1/2002 Initial plans.
- 1.1 6/7/2002 Reduced size so main parts could be made from ¾ inch square stock.
- 1.2 6/23/2002 First engine finished.
- 1.3 3/4/2003 Piston Diameter and Main Bearing fixed to agree with text.

3/4/2003 Rev 1.3

This part is used on:
Engine_1



David Kerzel

Pompano Beach, Florida USA

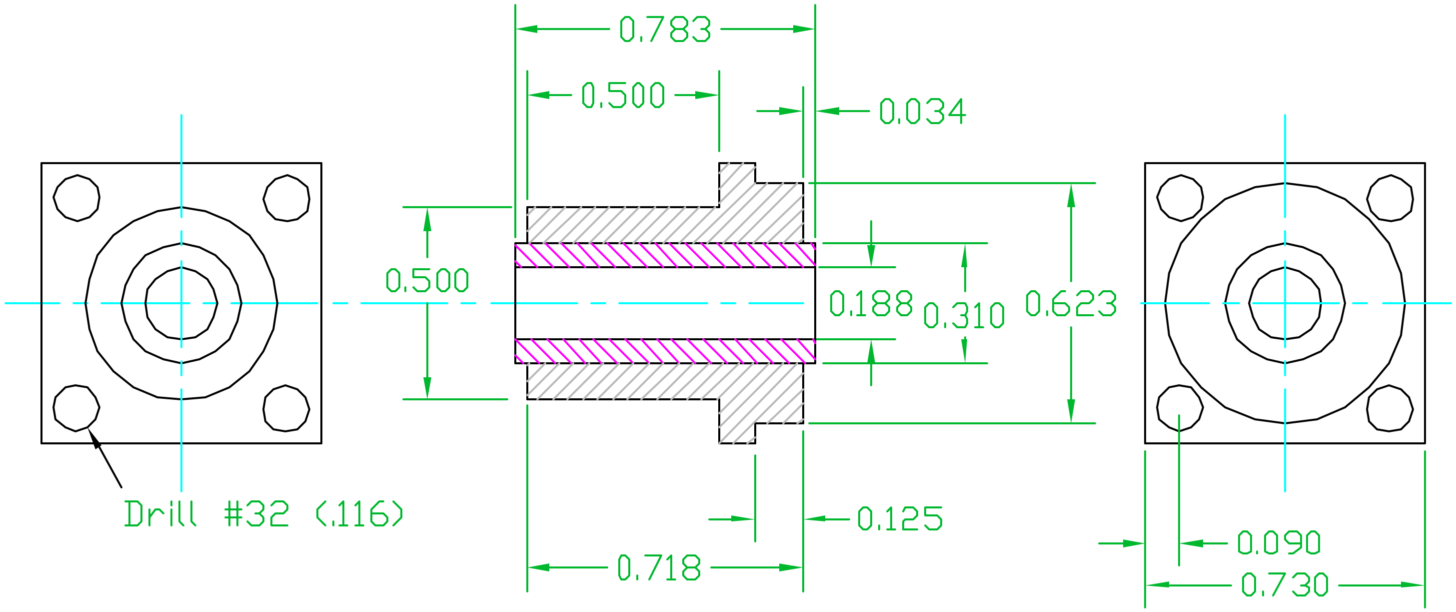
Assembly:
Cylinder with Exhaust

Title:
Cylinder with Exhaust

Date: 6/5/2002
Revision: 1.1

Drawing:
Modular_0_1

This part is used on:
Engine_1
Engine_3
Engine_4



Body is Aluminum
Bearing is oil filled sintered bronze
Set diameters for 0.001 interference

David Kerzel
Pompano Beach, Florida USA

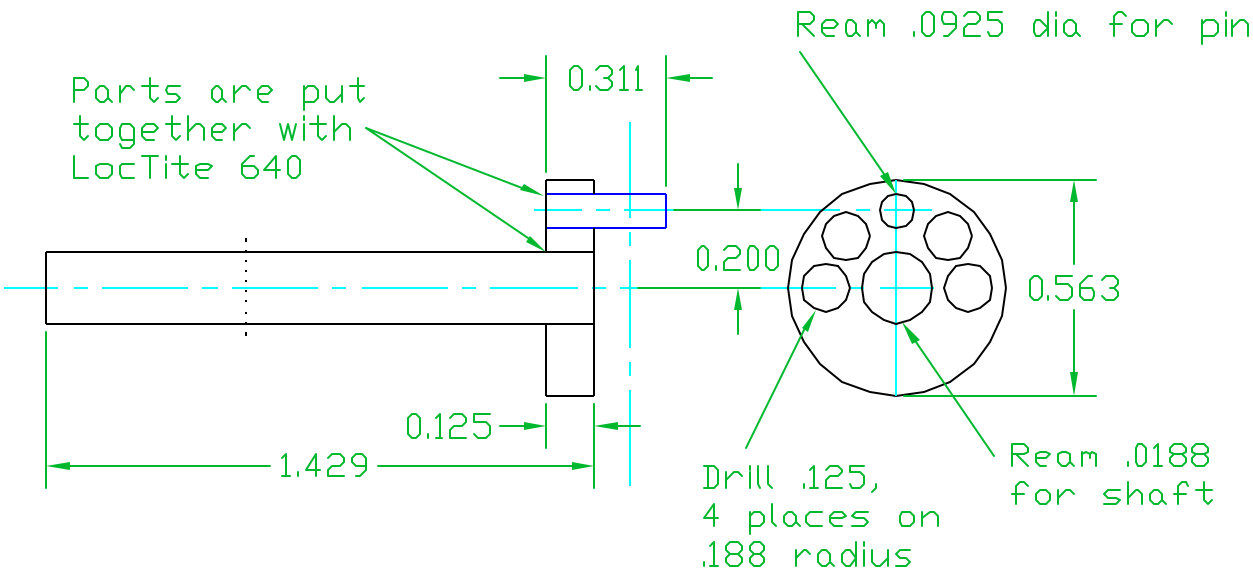
Assembly:
Pin & Ball Valve Air Engine

Title:
Main Bearing

Date: 3/4/2003
Revision: 1.3

Drawing:
Modular_0_2

This part is used on:
Engine_1



Shaft is 3/16 drill rod
pin is 3/32 dril rod
Disk is SS steel or brass

David Kerzel

Pompano Beach, Florida USA

Assembly: Pin & Ball Valve Air Engine

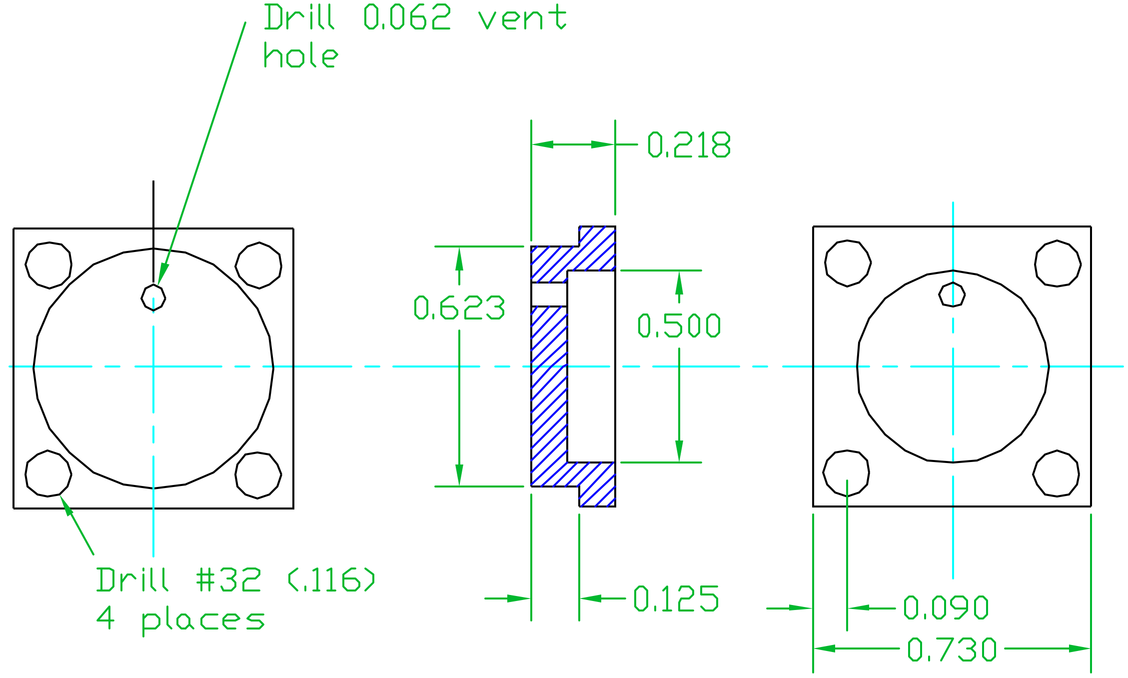
Title: Crank Shaft

Date: 5/30/2002

Revision: 1.0

Drawing: Modular_0_3

This part is used on:
Engine_1



Counterbore is optional.

Aluminum

David Kerzel

Pompano Beach, Florida USA

Assembly: Pin & Ball Valve Air Engine

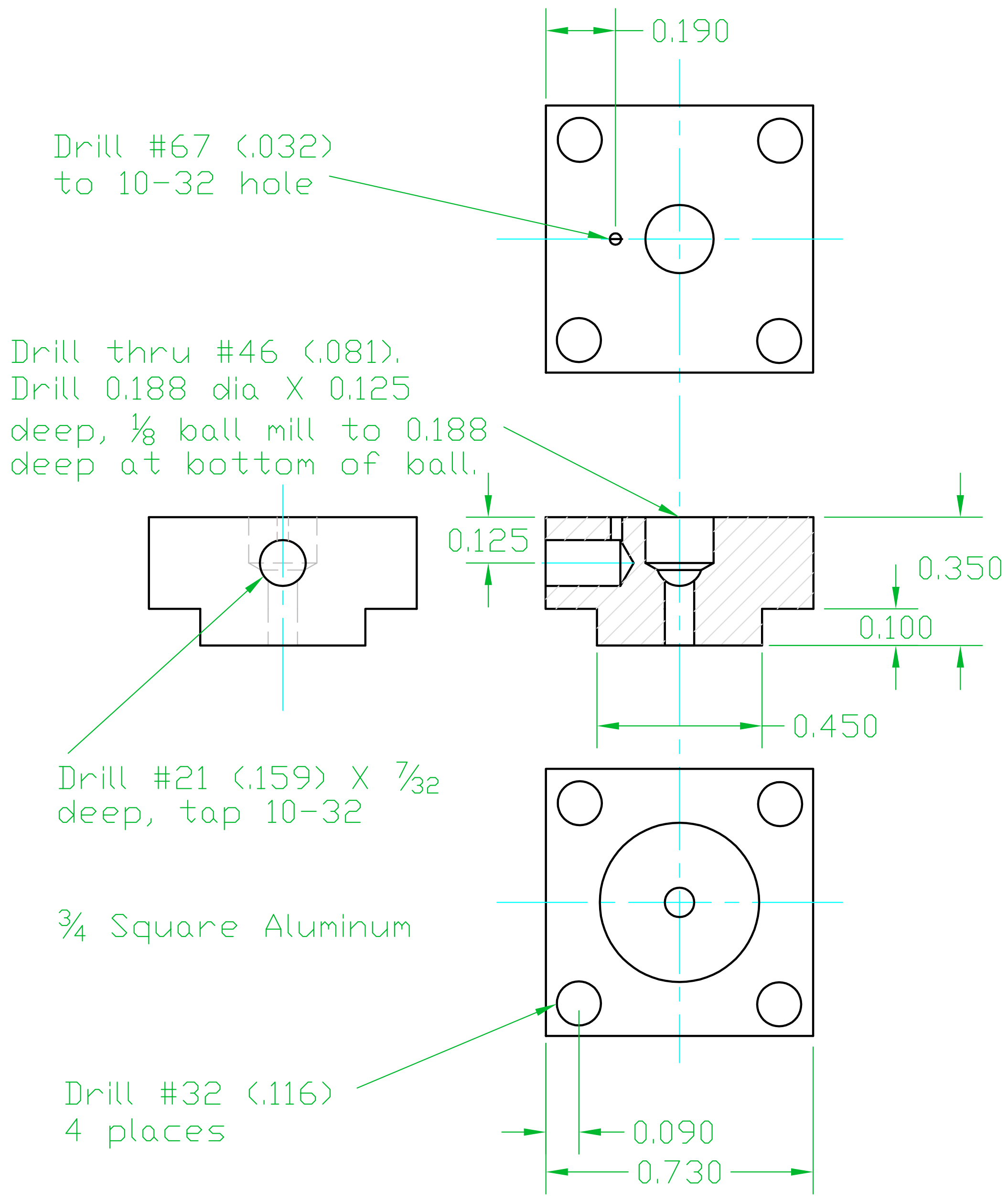
Title: Crank End Cap

Date: 6/5/2002

Revision: 1.1

Drawing: Modular_0_4

This part is used on:
Engine_1



David Kerzel

Pompano Beach, Florida USA

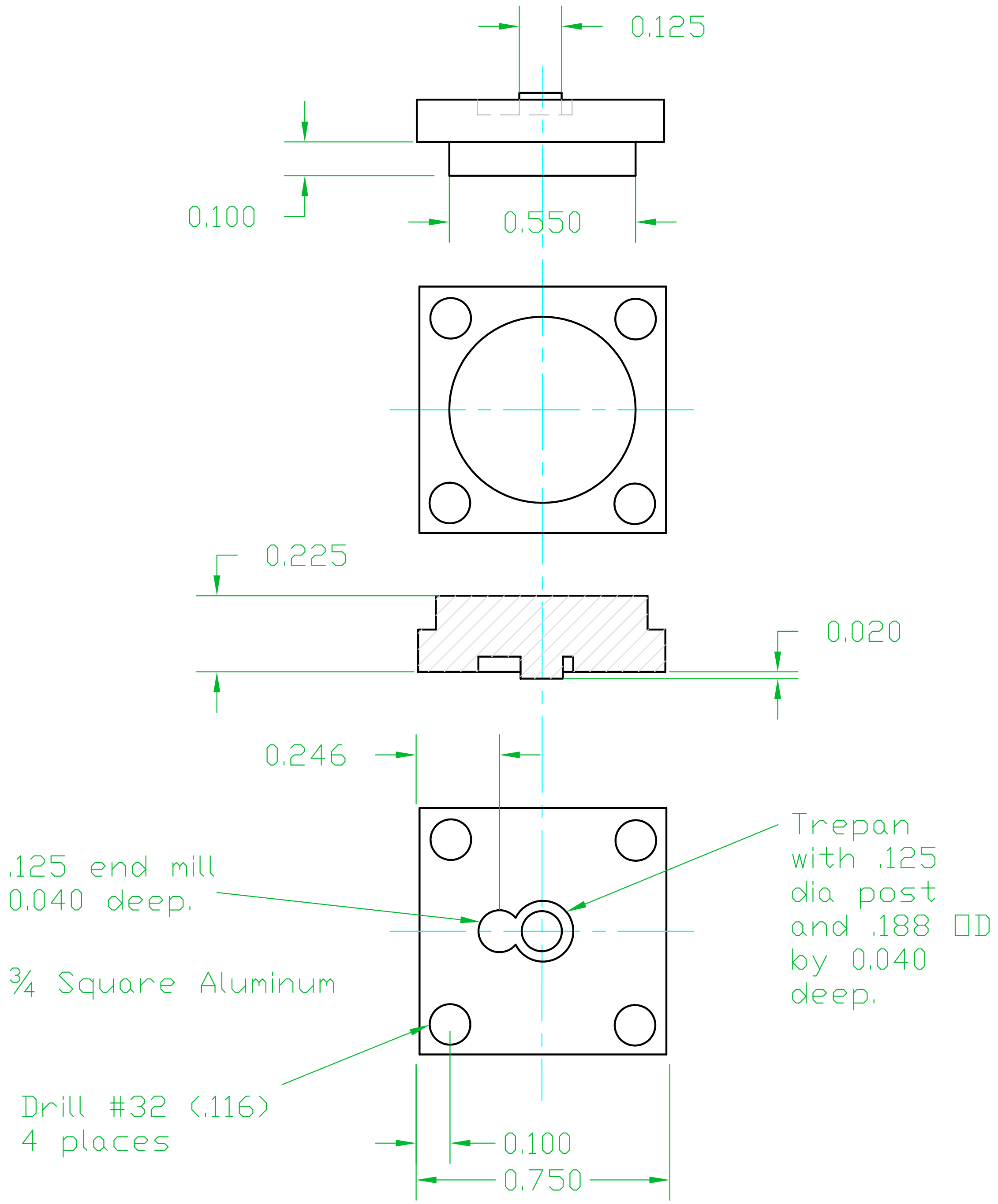
Assembly:
Pin & Ball Valve - Valve

Title:
Valve Block

Date: 6/5/2002
Revision: 1.1

Drawing:
Modular_0_5

This part is used on:
Engine_1



David Kerzel

Pompano Beach, Florida USA

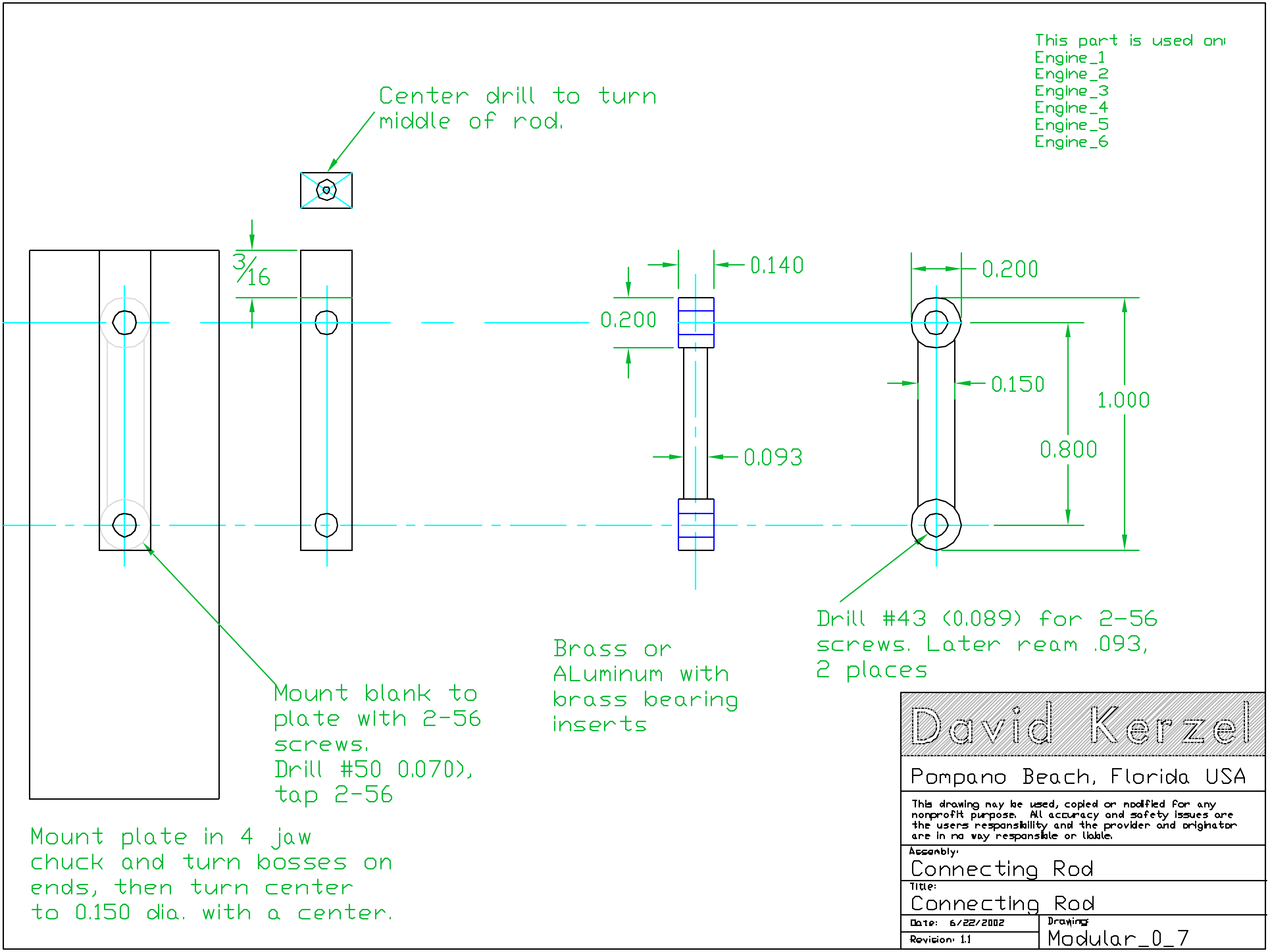
Assembly: Pin & Ball Valve - Valve

Title: Top Plate

Date: 6/5/2002

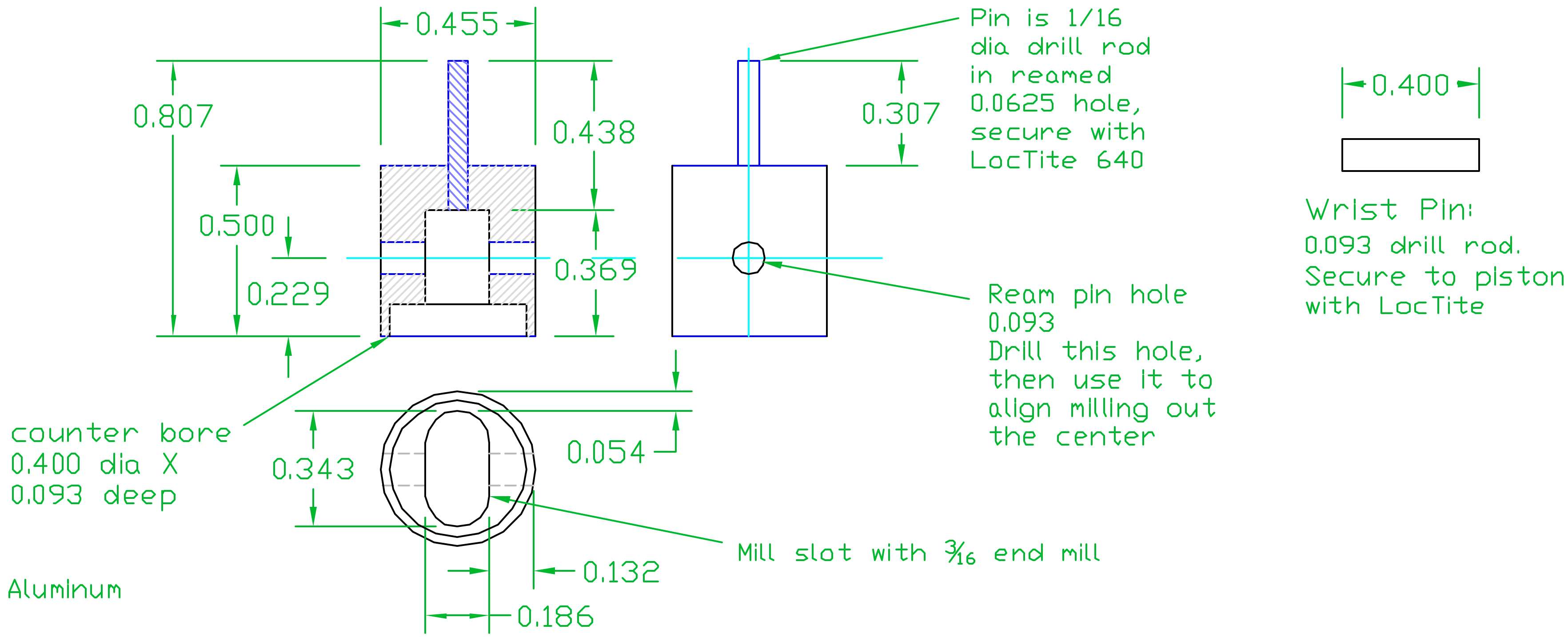
Revision: 1.1

Drawing: Modular_0_6



This part is used on:
Engine_1
Engine_2
Engine_3
Engine_4
Engine_5
Engine_6
Center drill to turn middle of rod.
3/16
0.140
0.200
0.200
0.150
1.000
0.800
0.093
Drill #43 (0.089) for 2-56 screws. Later ream .093, 2 places
Brass or ALuminum with brass bearing inserts
Mount blank to plate with 2-56 screws. Drill #50 0.070), tap 2-56
Mount plate in 4 jaw chuck and turn bosses on ends, then turn center to 0.150 dia. with a center.
David Kerzel
Pompano Beach, Florida USA
This drawing may be used, copied or modified for any nonprofit purpose. All accuracy and safety issues are the users responsibility and the provider and originator are in no way responsible or liable.
Assembly:
Connecting Rod
Title:
Connecting Rod
Date: 6/22/2002
Revision: 1.1
Drawing:
Modular_0_7

This part is used on:
Engine_1



Piston is to be turned 0.003 oversize and lapped to size.
Exact fit will have dry piston fall through cylinder and oiled
piston will pop back up when pushed into a closed cylinder.

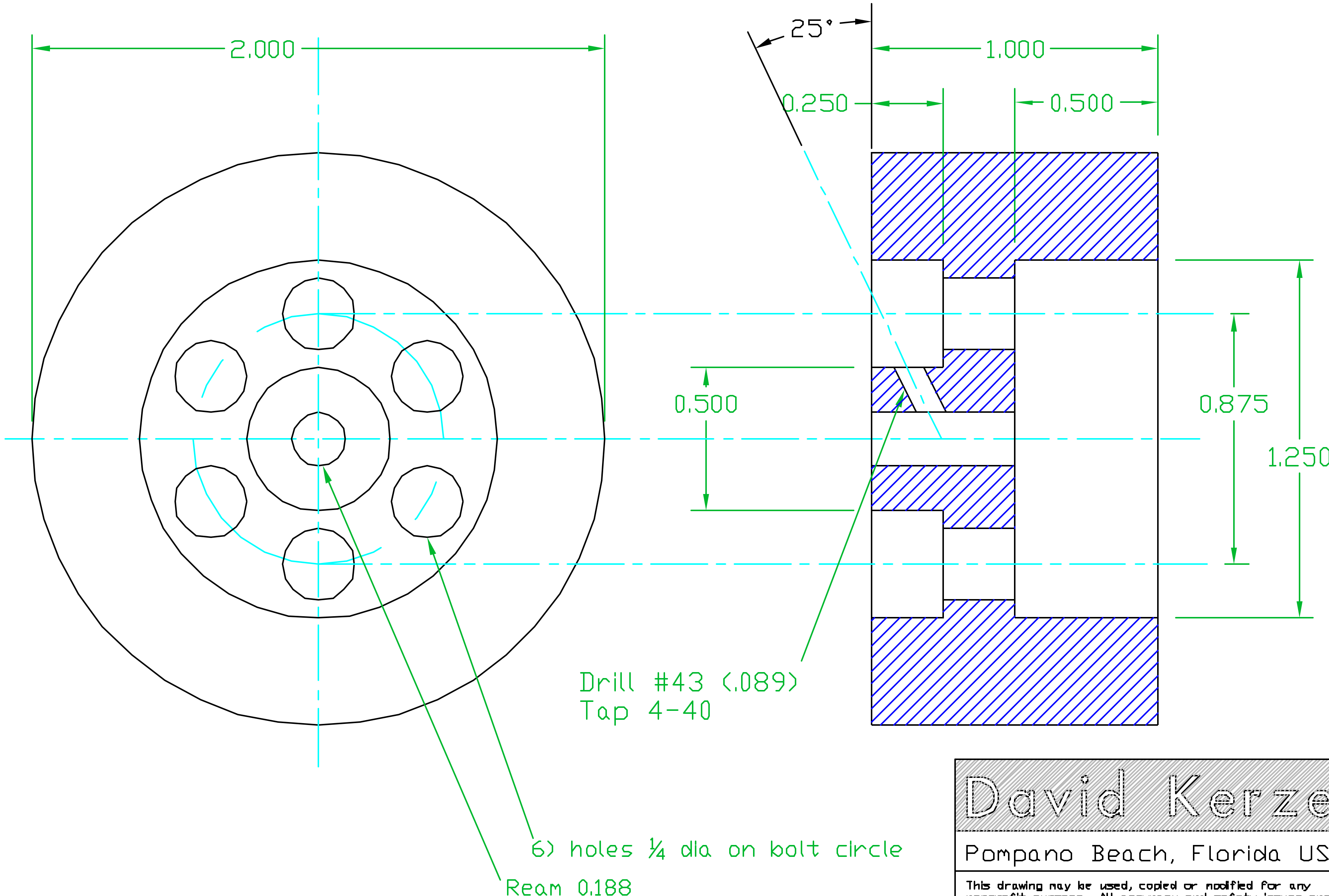
David Kerzel
Pompano Beach, Florida USA

Assembly:
Pin & Ball Valve - Piston

Title:
Piston &n Wrist Pin

Date: 3/4/2003
Revision: 1.0

Drawing:
Modular_0_8



This part is used on:
Engine_1
Engine_2
Engine_3
Engine_4
Engine_5
Engine_6

Cast Iron, SS, or Brass

David Kerzel

Pompano Beach, Florida USA

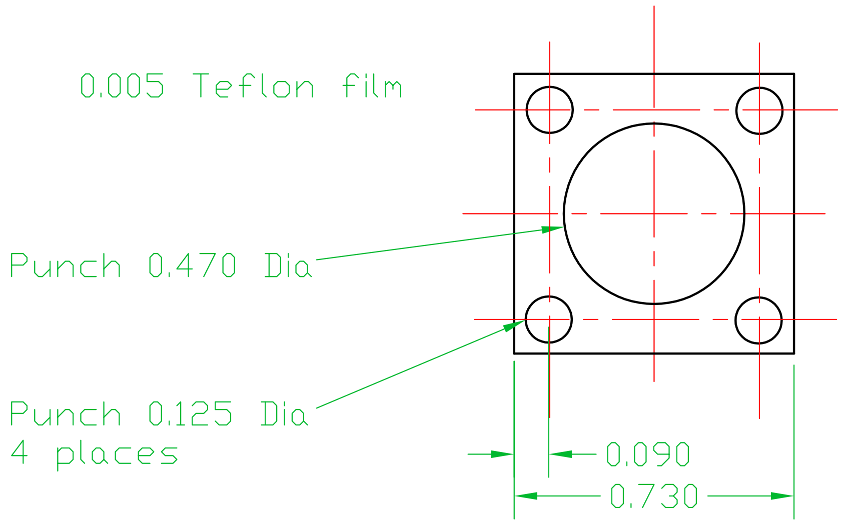
Assembly:
Fly Wheel

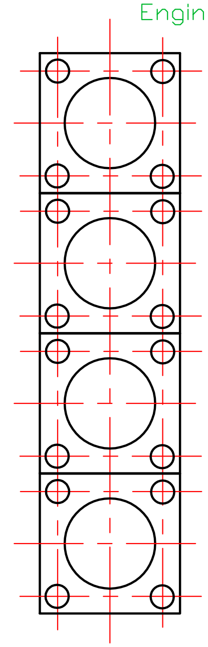
Title:
Fly Wheel

Date: 5/30/2002
Revision: 1.0

Drawing:
Modular_0_9

This part is used on:
Engine_1
Engine_2
Engine_3
Engine_4
Engine_5
Engine_6





Full Scale

Tape Teflon film over full size drawing.
Punch holes.

Make .125 punch fron .125 OD brass tube, counter sink ID to make cutting edge.
Make 0.470 punch from steel, turn to 0.470 OD bore to 0.380 dia, chanmper ID to make cutting edge at 60°.
Place Teflon and drawing on wood and punch.

David Kerzel
Pompano Beach, Florida USA

Assembly: Head Gasket	
Title: Head Gasket	
Date: 6/5/2002	Drawing: Modular_0_10
Revision: 1.0	

Modular Engine 1, 2008 revision

August 3, 2008

David Kerzel

Back in 2002 I wanted to build a bunch of different engines without a lot of detail to learn how to build an engine, what works and what does not work. Modular 1 was the first in the series. It is a simple CO2 type that ended up with a lot of difficult details because it was the first one. When I finished it, I started building smaller versions and then multi cylinder versions.

This is a new version of that first engine. It has been streamlined so it can be built on a small lathe like a Sherline. A 3 and 4 jaw chuck are needed, as is a drill press. It is intended as a first engine or as a fun fast build that leads to more complex air operated engines. The design can be scaled up or down, or built with no detailed plans. There are no complicated valves or valve timing involved so all energy can go to design and details.

CO2 engines operate at higher pressures than many people expect. Even though the engines are often little they need high pressure to run. It's not about friction in the engine it is just how the engine cycle works.

When the piston moves up past the exhaust ports in the cylinder it is compressing the air in the cylinder. This engine has a 2.9:1 compression from exhaust ports to TDC so the pressure peaks at 29 PSI (if there are no leaks). If the supply pressure is less than the compression pressure the engine will act as a compressor and pump air out the inlet port. With a supply of 30 PSI or more, the supply pressure keeps the valve ball seated just like a check valve, no air flows. Just before TDC is reached the pin pushes the ball open and increases the pressure in the cylinder to 30 PSI. This is actually only a 1 PSI increase over the compression pressure. As the cylinder moves down the air expands and drops to about 1 PSI when it hits the exhaust port. The engine is almost silent if everything is in balance. Nearly 95% of the energy in the compressed air is used.

Higher pressure causes the engine to run faster and produce more power. It gets louder and the energy efficiency drops off rapidly. When one of these engines operates on low pressures, it indicates the piston/cylinder is leaking and not fully compressing the air. If they need higher pressure, it is due to friction and will hopefully break in.

Construction Notes:

The following construction notes are how I decided to build this engine. There are many other ways to make each of the parts. Some of my choices may not be applicable to your tools and machines. Feel free to change everything.

Hardware:

Quantity	Description
1	3/16 SS ball
8	4-40 X ¼ inch Allen Cap Screws
4	4-40 X 5/8 inch Allen Cap Screws
1	4-40 X 1/8 inch Set Screws

I used high strength screws because that's what I had but any common 4-4 screws are fine.

Cylinder with Exhaust: The cylinder is made from ¾ square 6061 aluminum stock. Put it in the 4 jaw chuck and turn one long side flat removing about 0.010. The concentric tool marks from turning will show up in the finished engine so take time to center the part in the chuck. Rotate the part 90 degrees to do the next face. Be sure to use a scrap of thin aluminum or brass to prevent the chuck jaw from damaging the newly turned surface. The flat and true square surfaces in the chuck jaws will cause the resulting part to be flat and square. When the third and fourth sides are faced, take care to properly size the part. When the part is square, mount it in the 4 jaw chuck length wise, and then turn the bottom end clean and flat. Reverse the part making sure centering is less than 0.002 TIR, turn to length and center drill. Use a live center while turning the center portion of the cylinder OD which is basically decorative and can be left square or have fins if you wish. First drill then bore the cylinder bore leaving it slightly undersize 0.499/0.498. Layout the holes for the crank shaft and the rear mounting screws. I recommend drilling and tapping the screw holes and adding a pilot hole for the crank shaft next. This is a good time to add the holes in the top and bottom as well. Drill the exhaust port. Return the cylinder to the lathe, line up the pilot hole for the crank shaft, insure it is centered on the cylinder body and then drill and bore it to size.

Piston: The piston can be made of aluminum or ½ inch drill rod. I used drill rod last time, it is ground round and about 0.001 under size, the cylinder bore will be lapped to match this. Face one end and drill the hole for the valve pin, do not drill to deep. Flip the part and turn the counterbore, then drill the center hole. Switch to a 4 jaw chuck and make the center hole flat bottom using a ¼ inch center cutting end mill. Use the 4 jaw chuck to offset the part 0.060, and then use the end mill again to cut half the slot for the connecting rod. Now move the piston the opposite direction 0.060 past center to finish the slot. Yes there is a little wave in the side but the connecting rod is only 0.180 thick so there is plenty of clearance. Drill the wrist pin hole using the elongated area for alignment.

Cylinder Lapping: The ID of the cylinder should be lapped first with 220 grit (aprox) silicon carbide lapping compound. Don't use diamond compound, it never goes away and the engine will quickly fail. A commercial expanding adjustable blind lap can be used. The lap is a brass cylinder with a tapered thread that slowly expands its diameter. With the expanding lap start with it loose and expand in small steps as the torque lessens. In all cases watch out for the lap grabbing or binding. Clean and replace the lapping compound often it gets contaminated with metal. As the ideal size is approached switch to 400 or 600 grit compound.

If the piston is drill rod, cut 3 short lengths as laps. Turn about 0.001 from the OD of one so it can just fit in the cylinder. Add some lapping compound. The lapping compound fills the gap between part and lap so it may grab. Both the cylinder and lap get ground away, so do it again with a new lap when the fist one gets to loose. The third lap should have finer lapping compound used. Instead of turning down the OD, reduce it 0.0003 using wet/dry sand paper.

The lapping will produce a uniform dull finish on the ID. It seems to take forever to get close, then you went too far. The ideal fit has some drag but can be easily pushed through the cylinder with light pressure, I use a flat toothpick, and if it does not break, it should be fine. Once the piston starts moving at speed it will burnish or polish the cylinder and get the free movement needed. The dull finish will hold oil and provide a good seal. Clean thoroughly preferably in an ultrasonic cleaner. .

Crank End Cap: Start by cleaning up some ¾ square stock in the 4 jaw chuck, use a length about 1 1/8 long. This part is a frill and not actually needed. It will help keep dirt out and make the engine look more finished. Turn the 0.623 dia and part it off. Face to correct length. This engine is based on a model aircraft engine so weight was important and the boring was added. The vent hole is important if the engine is run because some air always leaks past the piston. The compressed air can build up in the crankcase and slow or stop the engine. The 4 hole pattern in all parts is identical and drilling all of them at one time will save setup time.

Main Bearing: Start with the square left from the Crank end cap. Turn the 0.500 diameter end from cleaned up bar stock. Reverse part in lathe chuck and turn 0.623 diameter and drill/bore 0.310 hole for bearing. Make bearing from oil impregnated sintered bronze. Make the bearing 0.001 larger than the hole in the body. Press the bearing into the body. Return the part to the lathe, face it to length, drill, and ream the part for the shaft. Ream 0.001 larger than crankshaft rod (if you use 3/16 drill rod, the drill rod is undersize so ream it to 3/16). If the crankshaft still seems slightly tight, put the crank in a drill chuck and spin it to burnish the fit. When correct, it needs to spin freely many revolutions when flipped between two fingers.

Valve Block: Start by cleaning up some more ¾ square stock in the 4 jaw chuck, use a length about 7/8 long. First turning the 0.496 diameter and part off the block**.** Reverse the part and face to length. Drill the center hole with a #3 combination drill counter sink. Drill the hole to a depth where the 3/16 ball rests 0.060 under the square surface. The .496 diameter plug that goes into the cylinder can have its length changed to determine the cylinder compression ratio that affects how much gas will be used on each cycle.

Seating the valve ball: Drop the ball into the concave cavity in the Valve Block. Using a pin punch drive the ball into the seating area with several moderate hammer blows. When this has been done, the ball should still fall out of the seat by its own weight when the Valve Plate is turned over.

Top Block: Start with the square left from the Valve Block, Turn the 0.550 diameter. Reverse the part in the lathe. Face to length then drill all the holes.

Crank Shaft: This is a 3 piece assembly. Make the disk first. Careful layout and drilling is essential. The four .125 holes are for balance. Ream the shaft and crank pin holes so parts made from drill rod have light resistance when fitted. Use LocTite 640 to secure these parts.

Connecting Rod: The Make the blank about 1 1/2 long form 3/16 diameter aluminum. Turn the center section to 0.150 diameter and add the 45 degree champers, then part to length. Drill the holes initially #33 (0.110) for 4-40 screws. Make the lathe chuck mounting block for turning the rod. Mount it in the 4 jaw chuck and center so the center screw head turns true. A short set screw is used in the second location. Turn one of the end bosses on the connecting rod. Reverse the part and turn the other end. Do the other side. Mount the part again with the set screw now in the center and the regular screw at the far end. Turn the center web of connecting rod. Reverse and flip to finish all the cuts. Turn 2 brass bearing inserts, enlarge the end holes in the connecting rod and press in the bearings.

Flywheel: The flywheel can be made from any heavy metal. The diameter can be reduced to 1.5 or the thickness could be reduced to 0.5. The 6 holes are not required. The setscrew can be drilled perpendicular to the axis rather than at an angle or it could even be fastened with LocTite. My steel flywheel was heated to red heat, which made a black oxide and it was finished with tung oil to prevent rust. Ream the shaft hole 0.001 larger than the shaft used.

Gaskets: Gaskets made from 0.005 thick Teflon seal well and are reusable. Paper gaskets can be used. If you don't want to punch the corner holes, cut the corners off at 45 degrees. The gaskets are needed because if the top of the cylinder leaks it will have a big impact on performance.

Assembly:

Fit the connecting rod to the piston with the wrist pin. The piston should wiggle in the connecting rod but be a close fit. Secure the wrist pin with some LocTite. Put the piston in the cylinder. Put the crankshaft in the main bearing, that fit should already be good. Put the crankshaft pin through the connecting rod hole and mount the main bearing with ¼ long screws. Oil the moving parts. The shaft must be able to be rotated easily and the piston moves freely with no binding. If it is tight, start turning it by hand with lots of oil. A quick run powered by the lathe may also help, starting at the lowest speed and use lots of oil.

Put the valve block on the cylinder top with a gasket. **Piston pin**: The piston pin should be able to lift the ball 0 .010 to 0.020. Add the top plate with a second gasket and 5/8 long screws. If the engine is shaken, the ball can be heard rattling. Mount the flywheel, support the engine, connect compressed air, and it's done.

How the engine feels: When the engine is spun by hand, it pumps air out the compressed air inlet and makes a pop sound as the exhaust opens. The flywheel should be able to cause the engine to carry though about 4 cycles with a good flip.

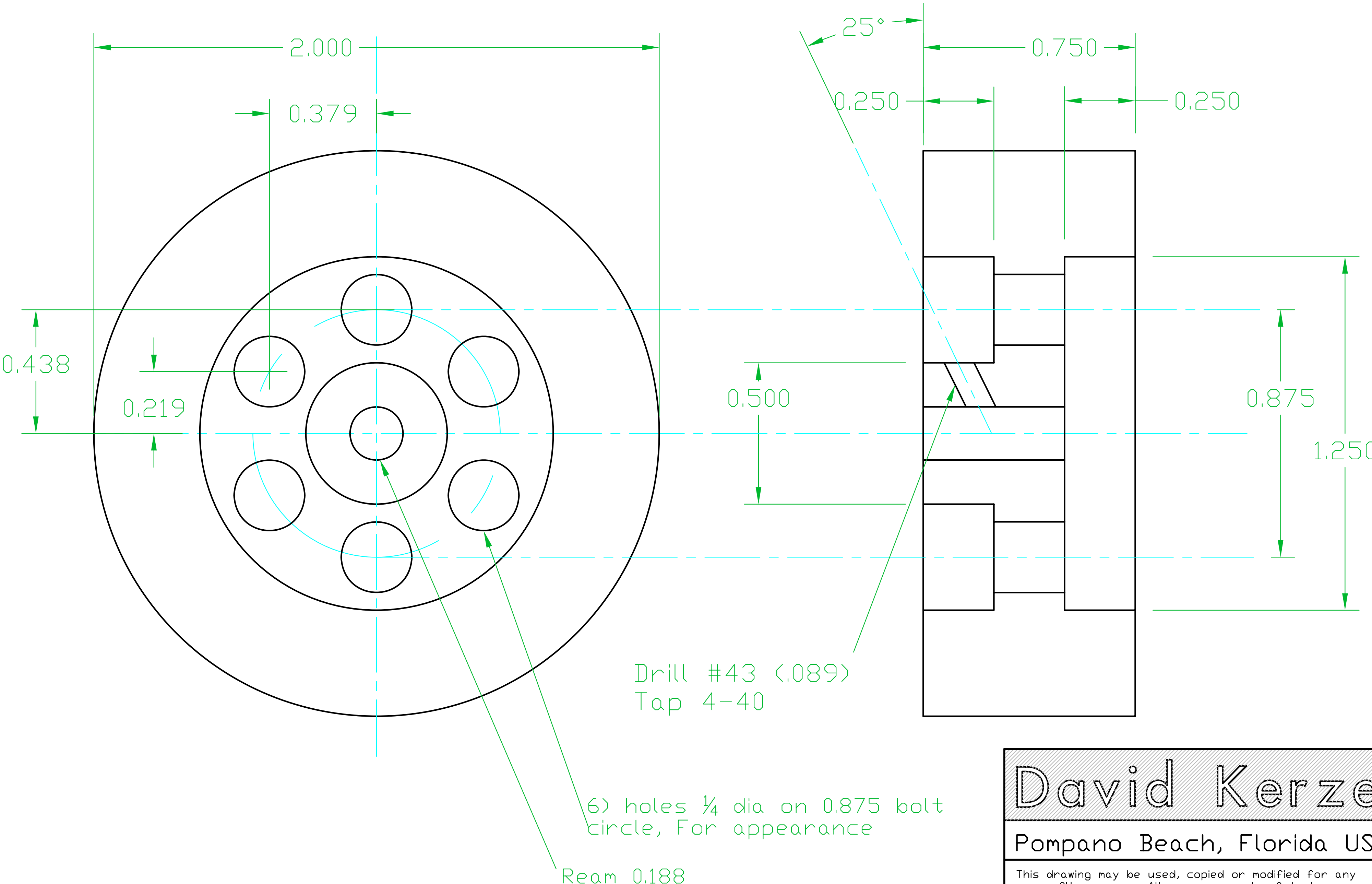
Start Up Notes: The engine will start in either direction with 35 PSI applied and a gentile spin. The engine may appear to run faster one direction, but I suspect it is the way it is most often started. Keep it well oiled and it just runs. Air consumption is low. Once the engine is running it will operate in any position. The engine needs to be oiled at every starting and will operate for about 3 hours with one drop of oil. Plain #30 oil seems to work best. Dry lubricants such as Teflon spry or molybendium work well too.

What if it does not work: I can only think of 4 reasons this engine will not run, well you might have a new one.

1. <u>Is the engine free from binding?</u> A good flip should carry through 4 or more cycles. There should be no tight spots and they should move smoothly.
2. <u>Does the valve leak?</u> The air pressure will push the valve ball closed. It should not leak air out the exhaust port when the piston is at the bottom of the stroke. If it does leak, give the ball another tap with a small hammer and pin to form a perfect seating surface.

3. <u>Does the piston leak too much?</u> With the piston at the top of the stroke the pin will push the ball open, air should not be rushing past the piston. If it leaks, try some 40 weight oil on the piston. Try starting with the piston pointing down and lots of oil, remember the engine runs in any position.
4. <u>Is the crankcase getting pressurized by leaks?</u> Take the end cover off the crankcase.
5. <u>If all else fails just fiddle with it.</u> Once it starts, it will get easier to start. If leaks are big it may not run well or for long. If fits are reasonable, it will just run. Reasonable fit for these engines is not good enough for internal combustion. If fits are marginal, make the parts again, most do not take that long to make.

Have fun with this engine and let it be a starting point your fun fast designs.



Cast Iron, SS, or Brass
Fly wheel can be smaller or
thinner.

David Kerzel	
Pompano Beach, Florida USA	
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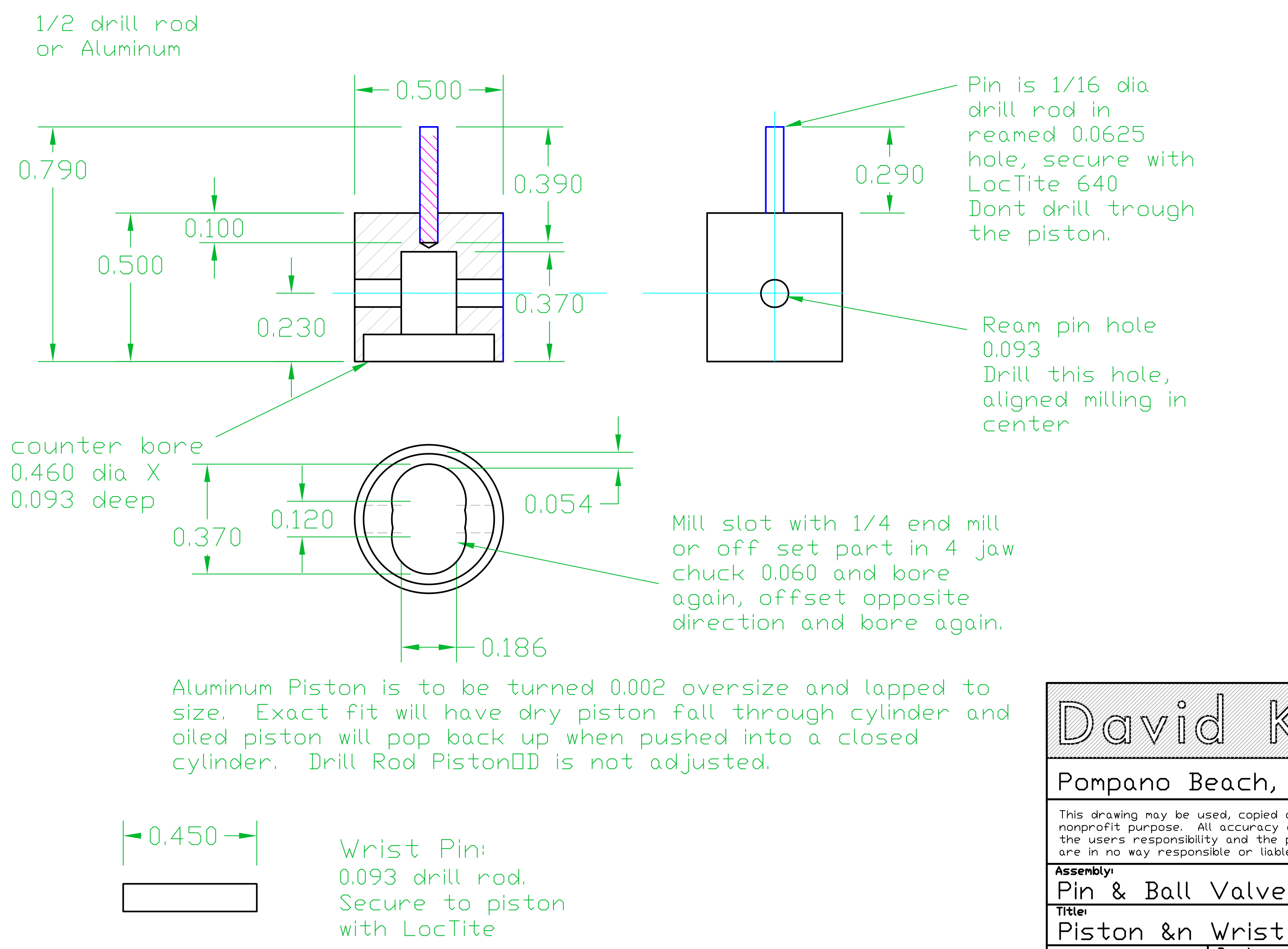
Assembly: Fly Wheel	
Title: Fly Wheel	
Date: 7/2/2008	Drawing: Modular_0_9
Revision: 2.0	



David Kerzel

Pompano Beach, Florida USA

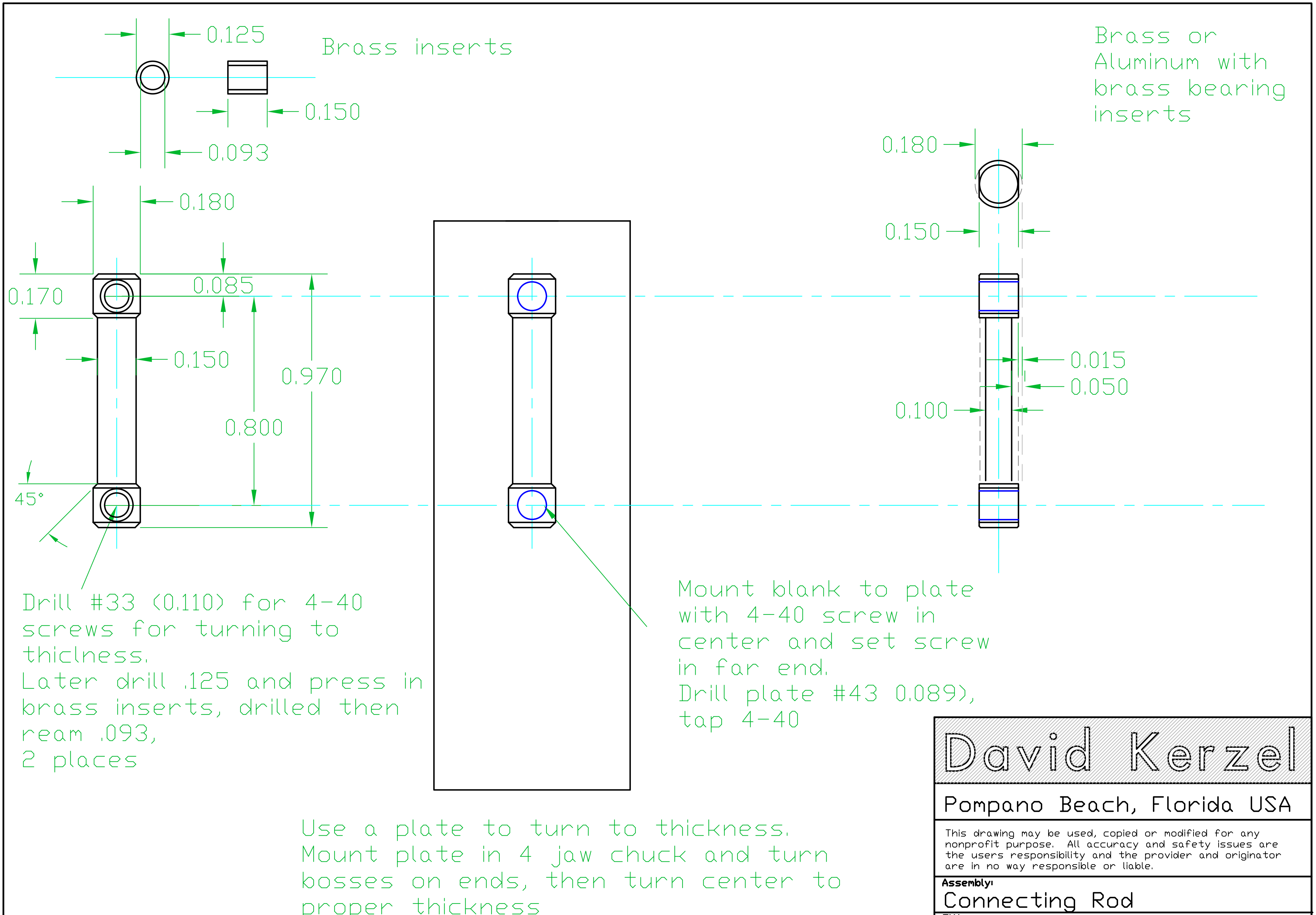
Assembly: Pin & Ball Valve - Piston

Title: Piston &n Wrist Pin

Date: 6/8/2008

Revision: 2.0

Drawing: Modular_0_8



David Kerzel

Pompano Beach, Florida USA

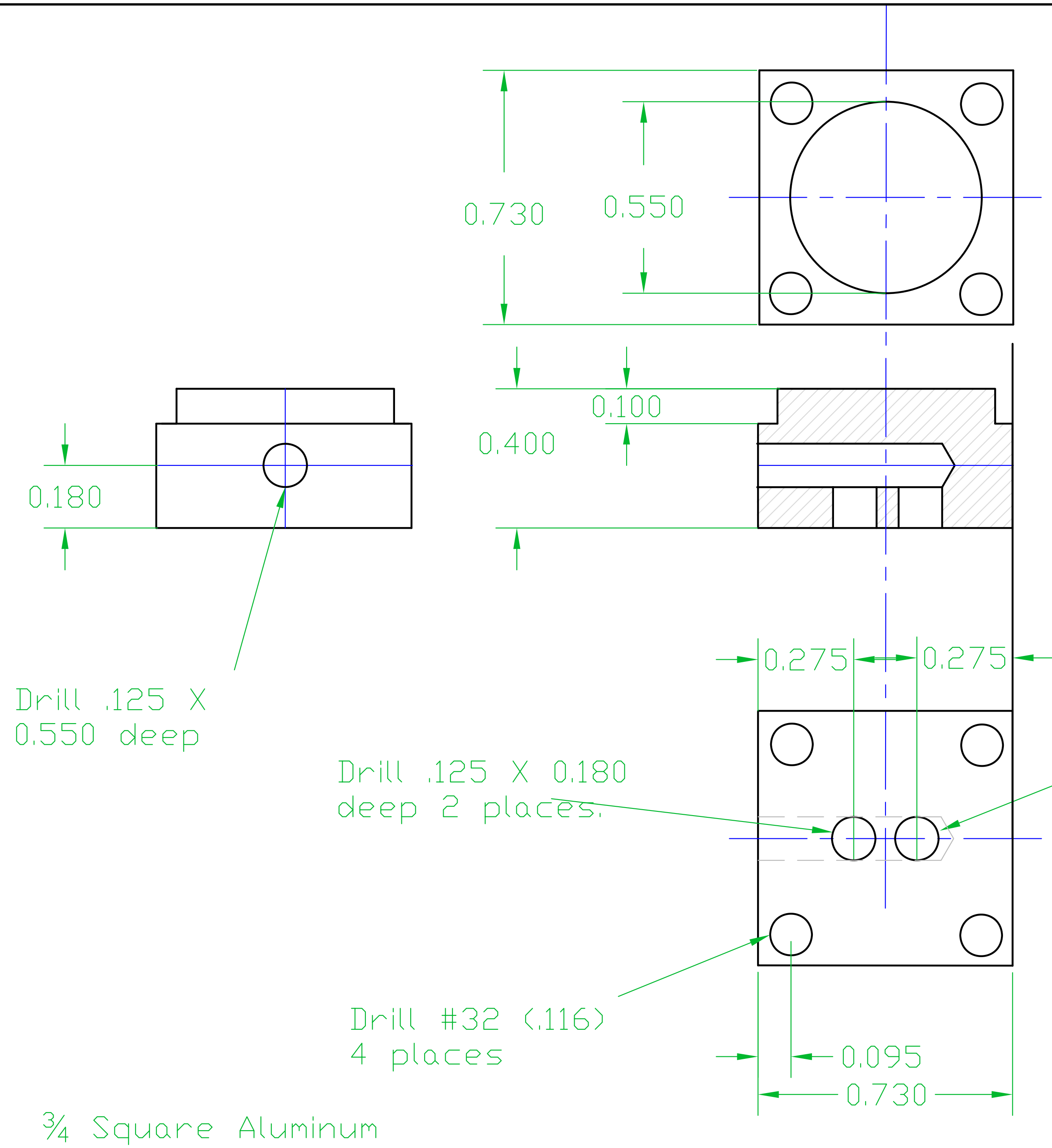
Assembly: Connecting Rod

Title: Connecting Rod

Date: 7/6/2008

Revision: 2.1

Drawing: Modular_0_7



David Kerzel

Pompano Beach, Florida USA

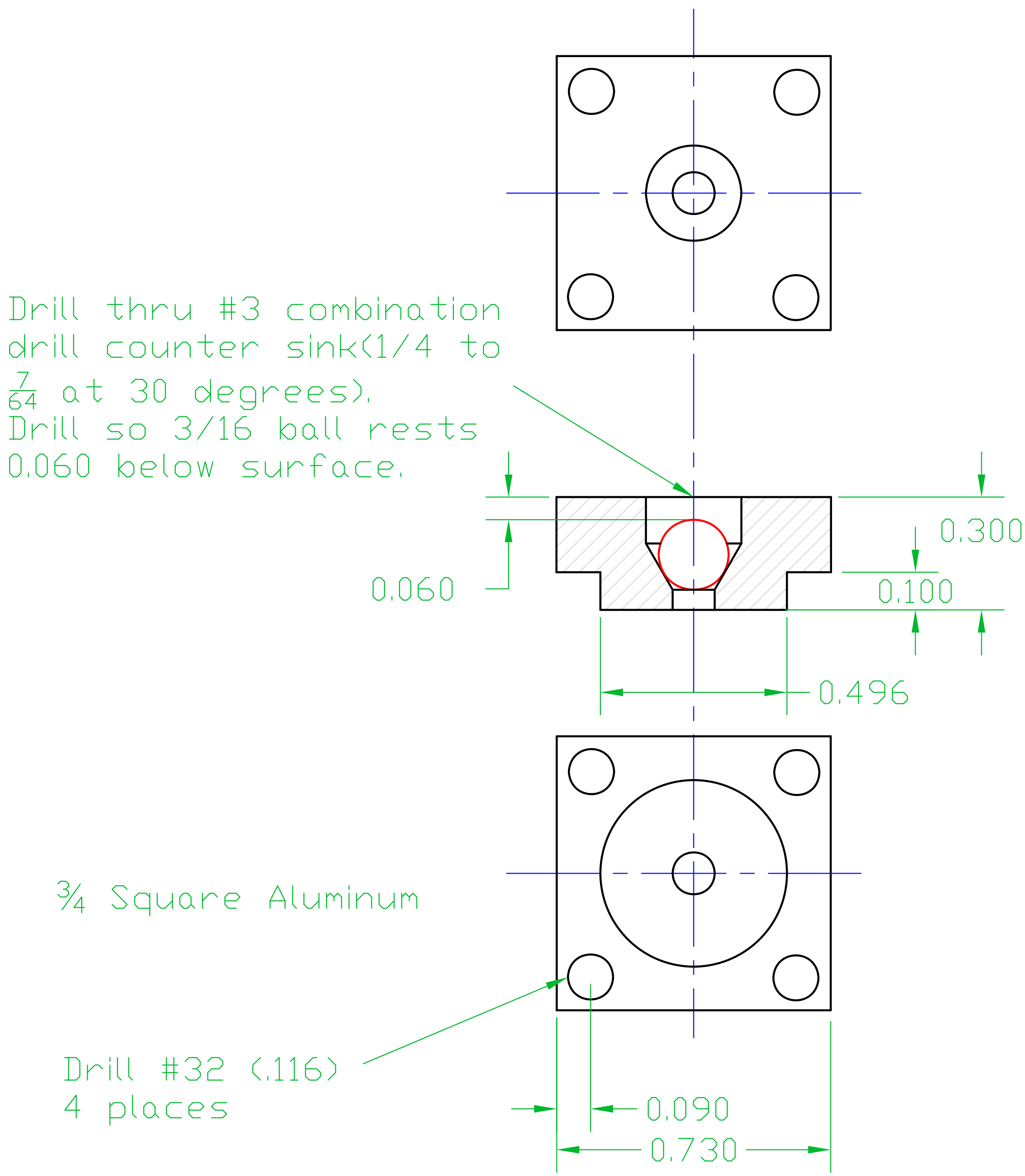
Assembly: Pin & Ball Valve - Valve

Title: Top Plate

Date: 6/1/2008

Revision: 2.0

Drawing: Modular_0_6



David Kerzel	
Pompano Beach, Florida USA	
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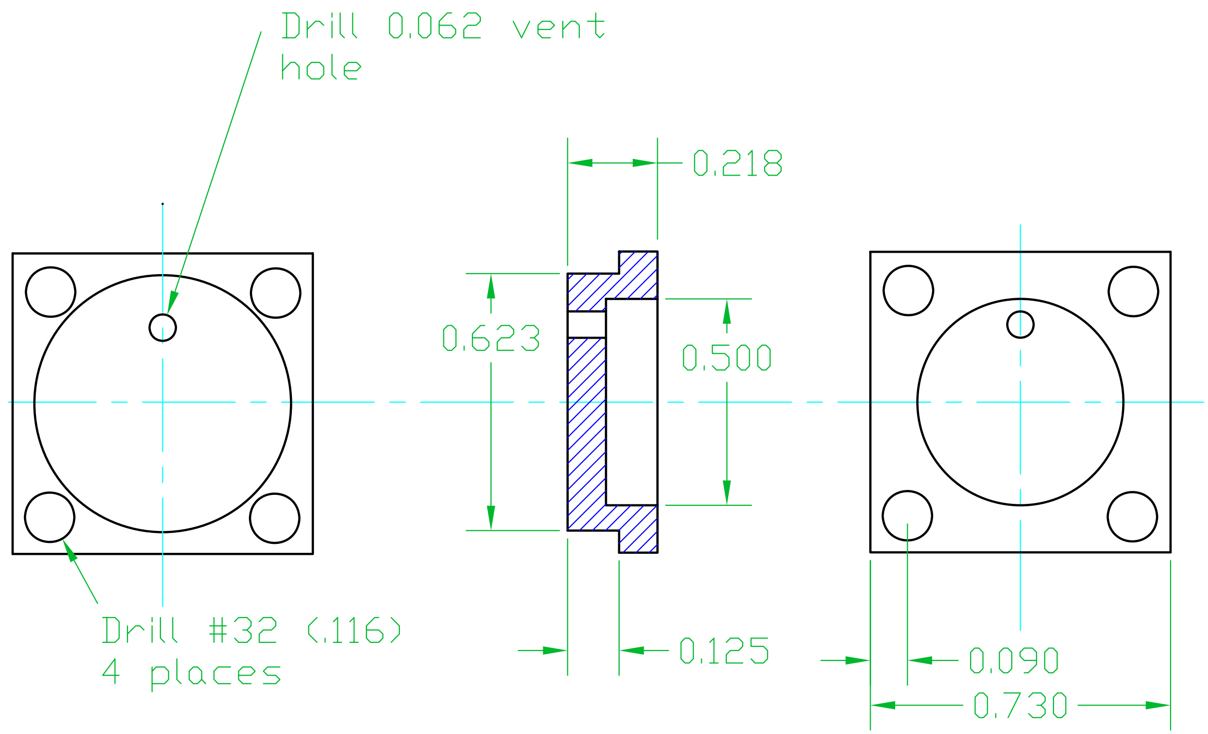
Assembly: Pin & Ball Valve - Valve	
Title: Valve Block	
Date: 6/8/2008	Drawing: Modular_0_5
Revision: 2.0	



Counterbore is optional.

Aluminum

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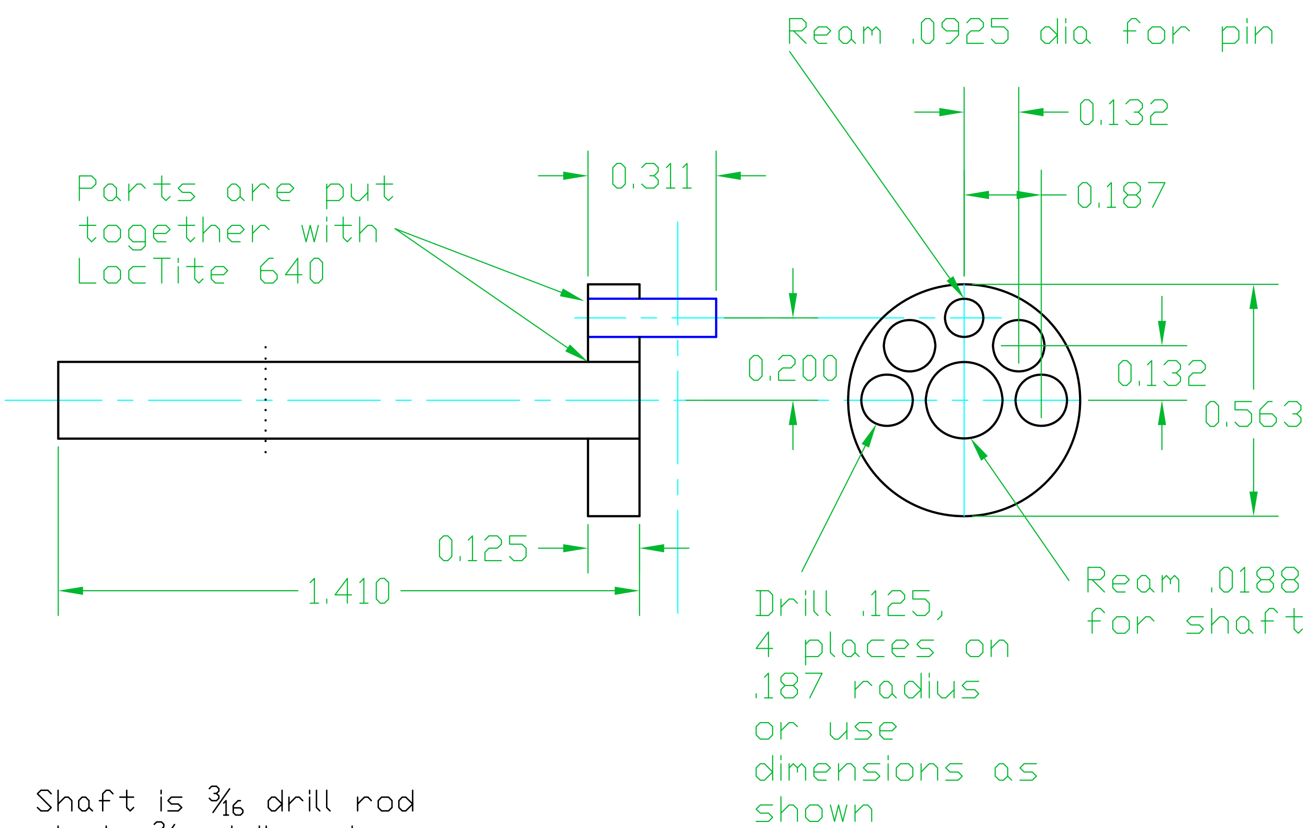
Assembly: Pin & Ball Valve Air Engine	
Title: Crank End Cap	
Date: 6/5/2002	**Drawing:** Modular_0_4
Revision: 1.1	



Shaft is 3/16 drill rod
pin is 3/32 dril rod
Disk is steel or brass

David Kerzel

Pompano Beach, Florida USA

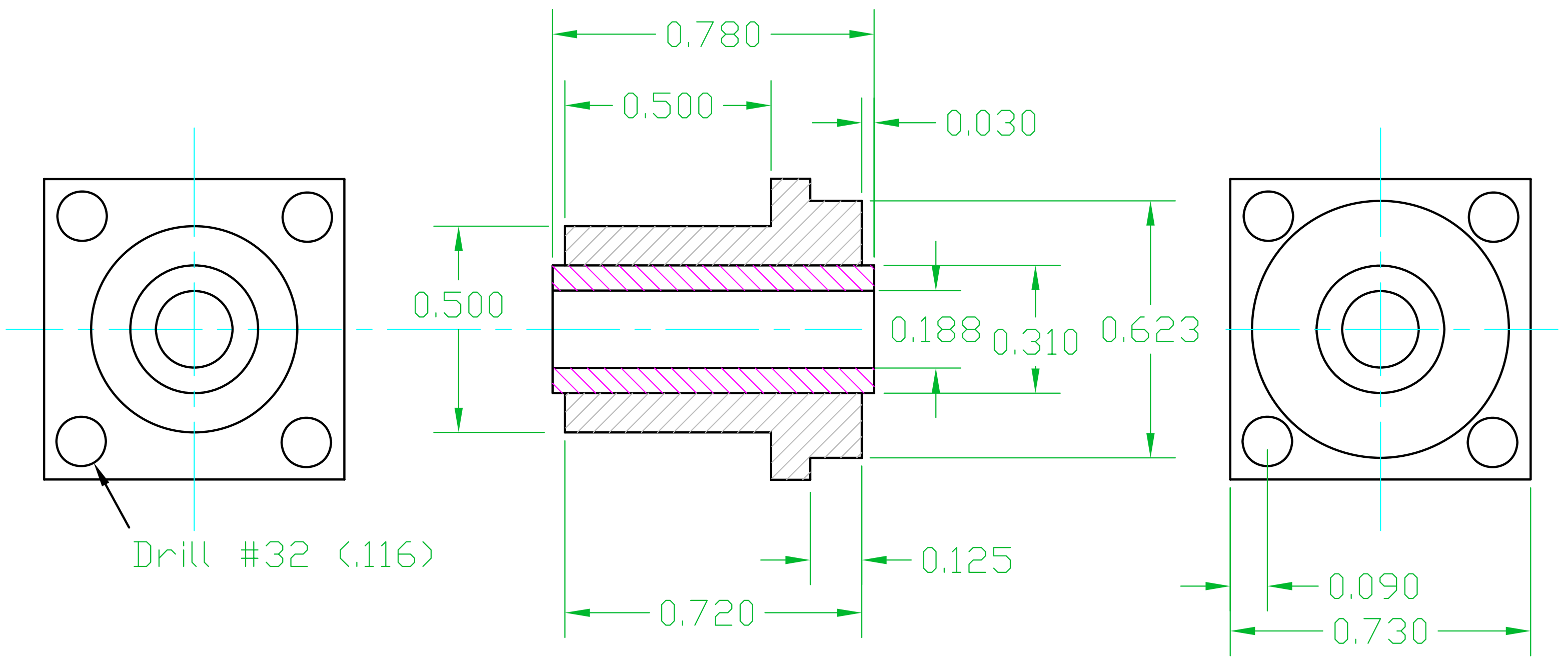
Assembly: Pin & Ball Valve Air Engine

Title: Crank Shaft

Date: 7/3/2008

Revision: 2.0

Drawing: Modular_0_3



Body is Aluminum
Bearing is oil filled sintered bronze
Set diameters for 0.001 interference

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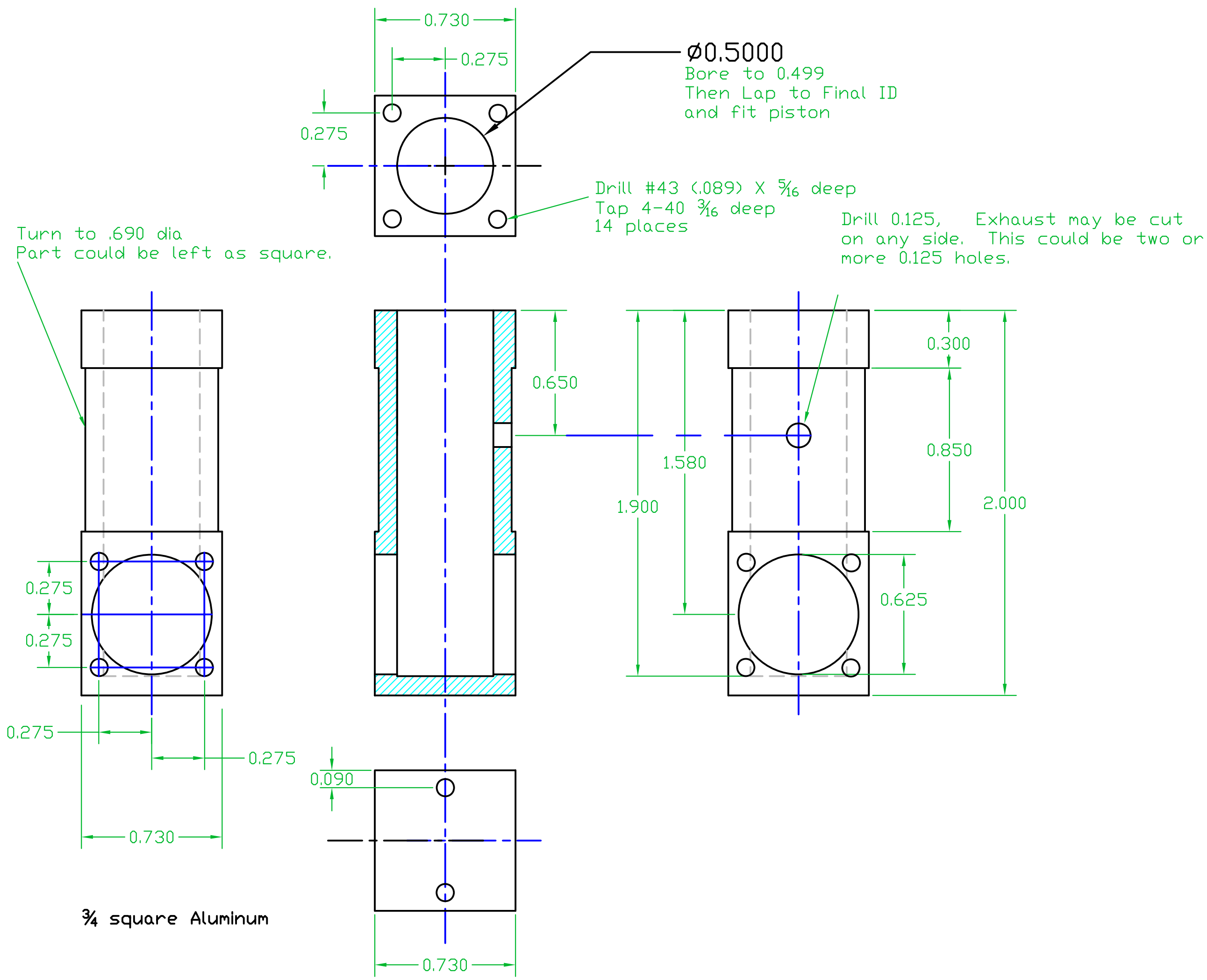
Assembly: Pin & Ball Valve Air Engine	
Title: Main Bearing	
Date: 3/4/2003	Drawing: Modular_0_2
Revision: 1.3	



David Kerzel

Pompano Beach, Florida USA

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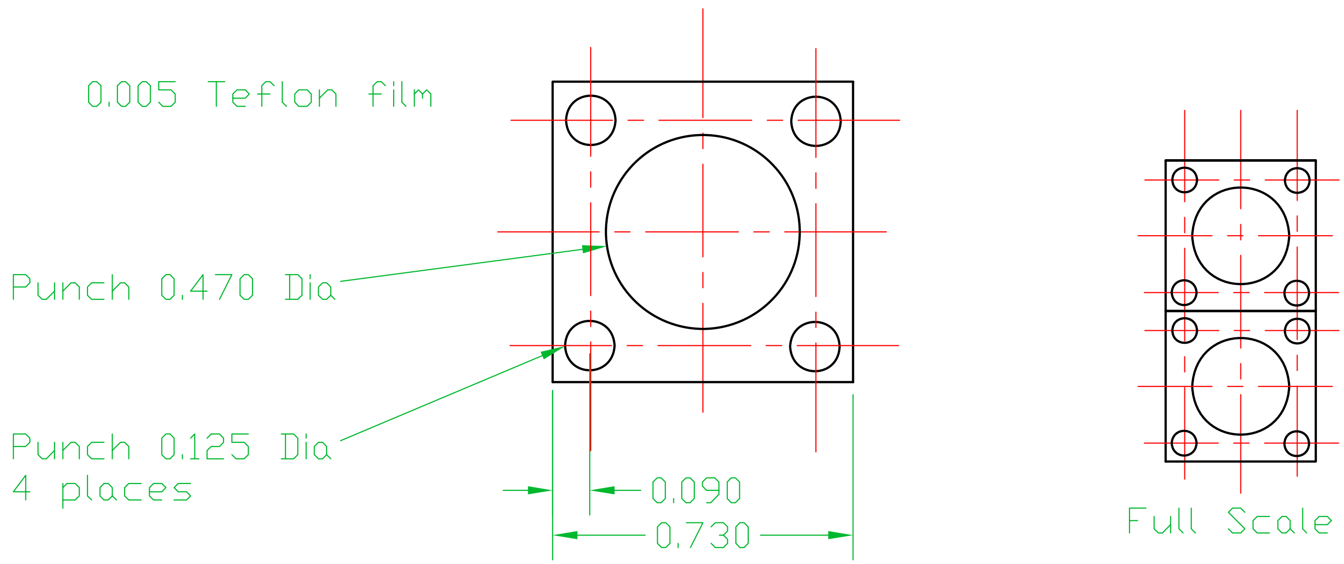
Assembly: Cylinder with Exhaust

Title: Cylinder with Exhaust

Date: 6/1/2008

Drawing: Modular_0_1

Revision: 2.0



Tape Teflon film over full size drawing.
Punch holes.

Make .125 punch fron .125 OD brass tube, counter sink ID to make cutting edge.
Make 0.470 punch from steel, turn to 0.470 OD bore to 0.380 dia, chanmper ID to make cutting edge at 60°.
Place Teflon and drawing on wood and punch.

David Kerzel
Pompano Beach, Florida USA

Assembly: Head Gasket	
Title: Head Gasket	
Date: 6/5/2002	Drawing: Modular_0_10
Revision: 2.0	