NORBERT KEELEY ROBINSON HOT AIR ENGINE CASTINGS, by Brad Smith

Norbert Keeley, of Ohio, made the patterns for a model of the Robinson hot air engine, in the 1970's. In the February 20, 1970 issue of Model Engineer Magazine, published in Great Britain, Edgar T. Westbury presented his design for a loose model of a Robinson engine. Mr. Westbury admitted that the model was not an exact replica of a Robinson. Model builders trusted Mr. Westbury's designs as being good running engines. Many model builders thus built this engine from the plans and were unpleasantly surprised to find that the engine would not run. Some months later, an English model engineering club took on the task of testing the engine and re-designing it to make it run. The results made the model engine look much less like the full sized Robinson engine.

The Robinson engine was a workhorse, popular in England, for use on such devices as dentists' drills and other small machinery. Engines were built in sizes from small to 11 inch bore engines. They ran very well. One would pour the water for cooling in through a hole in the top of the table and the water could boil and the engine would still run. They were short, compact engines, as opposed to the physically larger engines sold at this time.

Norbert Keeley took the Westbury plans from the Model Engineer Magazine article and double sized the design. He then made the patterns and sold the castings and prints. I and two of my friends, who were accomplished hot air engine builders, bought castings in the 1970's. My two friends built the engine, according to the prints and it didn't run. Since the half size engine in Model Engineer didn't work, it was logical that the double size engine wouldn't run, and it didn't. Try as they may, they couldn't get the engines to run. Eventually they gave up. I heard of other people who couldn't get the engine to run, so I set my castings aside. One man got his engine to run by using acetylene gas to heat it. I don't call that running as it won't run for long.

There are also a couple of other casting kits for Robinson engines, sold in Great Britain. One ran well and the other didn't run well. What was the difference? Here it is. Conventional hot air engines use a long, displacer piston that is an air tight, hollow piston. The displacer cylinder has a hot end and a cold end. That is where the similarity ends. The Robinson design has a displacer cylinder without a cold end. Since it doesn't have a cold end, the displacer cylinder length is very short and all hot. The displacer piston is made of a porous material, such as wire mesh. This cylinder acts as a regenerator to make better use of the heat.

In the Robinson, the "cold end" is the air passage between the displacer cylinder and the power cylinder. Since the table is filled with cooling water, this becomes the cold end of the Stirling cycle. This is the secret to the Robinson engine.

In the Fall of 2012, I decided to give the engine a try and see if I could figure out why it didn't run. I had a tool that the guys in the 1970's, and of course, Norbert Keeley didn't have; the Internet, and some good friends with experience and helpful advice. I studied Robinson engines. A full set of original drawings are available on the Internet.

The original prints that I downloaded from the web are the drawings for the real Robinson #5 engine, which has a power piston diameter of 7.500 inches and a stroke of 7.500 inches, with a displacer piston of 18.000 inches diameter and a stroke of 5.000 inches. The displacer piston is only 4.125 inches thick. I calculated the swept volume of that engine and it is 3.840:1. No wonder the engine runs so well with a very thin displacer piston and on very little heat.

As a comparison, Westbury designed the Robinson engine for Model Engineer Magazine, and his engine did not work at all. He claims that he scaled down a full sized Robinson, but his swept volume was only 1.004:1. A London model engineering society researched the Westbury engine (ME, 15 June, 1973, page 610) and made tests with a manometer. They also built two more Robinson type test engines to prove the theory. They found that the displacer needed to be enlarged in both diameter and length, on the Westbury engine to make it run well. The Westbury displacer was very "flat". They determined that a flat displacer works on a full sized engine, but not on a model. When finished with the modifications, their swept volume ratio was 2.259:1 These people used a "can" displacer piston and the full sized Robinson engines used a displacer piston made of a steel wool of fine wire. How this would have impacted the tests of the Westbury engine, we don't know.

Norbert Keeley doubled the Westbury engine in size, rounding off the dimensions, but he kept the double sized Westbury flat displacer piston and of course it doesn't run. Coles' Power Models also doubled the size of the Westbury engine, but made a displacer piston almost 4 times as long as the Keeley engine. The Coles' engine runs. Both the Keeley and Coles' engines use a "can" displacer piston.

I enlarged the diameter of the displacer to the maximum that I can get into the castings and will lengthen the displacer to that of the Coles' engine. This will give me a swept volume ration of 2.344:1, while the Coles' engine has only a 1.224:1 ratio. My modified Keeley engine runs very well with this ratio. If I need to, I can sleeve the power piston down to give a swept volume ratio of 2.771:1. I will also make two displacer pistons, one a "can" type and the other a wound steel wool piston. Since writing this, I have determined that one need not enlarge the diameter of the Displacer cylinder and piston.

Cooling the Robinson Engine

As stated above, the cooling of this engine takes place in the hollow table. Except for the air passage, the table is hollow and filled with water. On Keeley's engine, and Westbury's, cooling takes place in a ring at the top of the displacer cylinder, making it a conventional Stirling engine, but neglecting the fact that this wasn't how a Robinson is designed. Also, both men kept the Robinson's short displacer cylinder. This combination insures that the engine will not run.

Changes I made to the Keeley Robinson engine.

1. Reduced air passages in the table from 3/8" diameter to ¼" diameter.

2. Lengthened the Displacer cylinder and piston.

3. Enlarged the diameter of the displacer cylinder and piston to 3-1/4" O.D. I now, don't think this is necessary. Keep it as drawn because enlarging made more problems than it was worth.

4. Turn the crank disc so that the counterweight faces toward the water hopper. This was the way the full sized engine was built.

5. Clarence, have the crank disc cast in iron or brass because it has a built in counterweight. Aluminum doesn't make a very good counterweight

6. Make the flywheel the 7" diameter iron flywheel that is used on the Bremen Caloric engine.

7. Install a heat shield to vent the heat out the two openings in the sides of the furnace. This keep the waste heat from rising to heat the table.

8. Do not drill the vent holes in the top of the furnace. The escaping heat will only heat up the table, stopping the engine. Instead install a "stove pipe" to vent the heat.

9. Change the design of the main piston rod from a fluted, steam engine type rod, to a "fin" with three bosses, as this is what Robinson piston rods looked like.

10. The Keeley drawn design for the upper link shows a straight link that requires a slot to be cut into the top of the cylinder for clearance, as the link penetrates into the cylinder. Robinson engines that have a straight upper link have a very tall clevis to hold the end of the link. The Keeley engine does not. Robinson engines with the shorter clevis have a bent or "dogleg" shaped upper rod, in the shape of a "fin" with three bosses. While the Keeley design will work, slotting the cylinder is a poor way to accomplish the motion. It is easy to make a proper upper rod.

11. Instead of using needle bearings for the main crankshaft bearings, as per the Keeley drawings, I used Oilite bushings.

12. I used an O-ring to seal the gap between the power cylinder cover and the table where the air passage is.

13. I used an O-ring to seal the space between the water tank and the table where the holes are drilled into the cooling ring. These holes have to be laid out carefully to hit the water ring and not hit the O-ring groove that seals the upper end of the displacer cylinder liner.

14. I used an O-ring to seal the displacer cylinder liner top and bottom, at the water ring in the table piece.

15. I bushed each moving part. The upper beam had 3 Oilite bushings, the connecting rod has 2 Oilite bushings and the 4 links each have two bushings cut from K&S, 0.015" wall brass tubing, available from hobby shops and some hardware stores.

16. While not affecting the operation of the Robinson model, full sized Robinson engines had a throttle on the end of the cylinder. Pushing in on the throttle would stop the engine by cutting off the flow of hot air to the power cylinder. This would permit a dentist to stop the drill to change the bit, for instance. When finished, the person would pull back on the throttle and give the flywheel a spin and the engine would start. Westbury realized this and designed a rotary throttle with a lever on the back end of the stem. Keeley neglected to include a throttle. I designed a push-pull throttle that resembles the throttle on a Robinson.

After the modifications, my Robinson ran the first time I put a fire under it. This was two days before I left for the 2013 NAMES show, in Wyandotte, MI. At the NAMES model engineering show, my Keeley Robinson ran continuously for 7.5 hours. each of the two days. It ran with a very low flame. I changed the cooling water every hour or so. I had decided that I could mill 1/8" off the top of the table and then hollow the table out, except for the air passage, then install a 1/8" thick steel plate to seal the cavity and provide for proper cooling. While this would provide more cooling, I do not believe that it is necessary, as it would still require a thermo-syphon water tank anyway, as do model Robinson engines to run continuously. Making this modification would be much work and would only lengthen the time before the water would have to be changed.

While at NAMES, a man stopped by my display of the running Robinson and was surprised to see a Keeley engine running. He had built the engine, according to the prints and it didn't run. He said that he put 60 hours into trying to get it to run and then, when it didn't, he got mad, and threw the engine away.