ENGR110
TEST-TUBE STIRLING-CYCLE ENGINE LABORATORY

David Haywood
Stirling-cycle Research Group
Department of Mechanical Engineering
University of Canterbury

WARNING #1 – EXTREME CAUTION SHOULD BE EXERCISED WHEN USING THE CRAFT-KNIFE – THE BLADE IS VERY SHARP.

WARNING #2 – EXTREME CAUTION SHOULD BE EXERCISED WHEN USING THE BURNER – THE FUEL IS VERY FLAMMABLE. PLEASE AVOID SETTING FIRE TO THE ROOM OR OTHER STUDENTS.

WARNING #3 – PARTS OF THE ENGINE (PARTICLUARLY THE END OF THE TEST-TUBE) WILL GET HOT DURING OPERATION. USE CAUTION WHEN ADJUSTING THE ENGINE – DO NOT BURN YOURSELF.

WARNING #4 – USE ONLY GENTLE FORCE TO INSERT BUNG IN TEST TUBE. EXCESSIVE FORCE WILL BREAK GLASS AND PROBABLY CUT HAND.

LABORATORY TASK TO BE COMPLETED IN GROUPS OF TWO

1. MATERIALS

The following materials are required for the Test-tube Stirling-cycle engine:

(a) Aluminium foil (strip approximately 25mm x 120mm)
(b) Bungs to fit test-tube bored with inner hole to fit U-tube (2 required)
(c) Cardboard sheet 2.25mm thickness (95mm x 220mm)
(d) Duct tape (approximately 250mm length)
(e) Insulation tape (approximately 350mm length)
(f) Marbles (1mm→3mm smaller in diameter than the test-tube inner diameter)
(g) Paperclips (large)
(h) Plasticine balance mass
(i) Small balloons ("water bomb" balloons are good)
(j) Steel wool
(k) Test-tube (size: 150mm x ϕ20mm)
(l) U-tube (copper)

Supplementary items required are:

(m) Alcohol burner
(n) Craft knife
(o) Matches

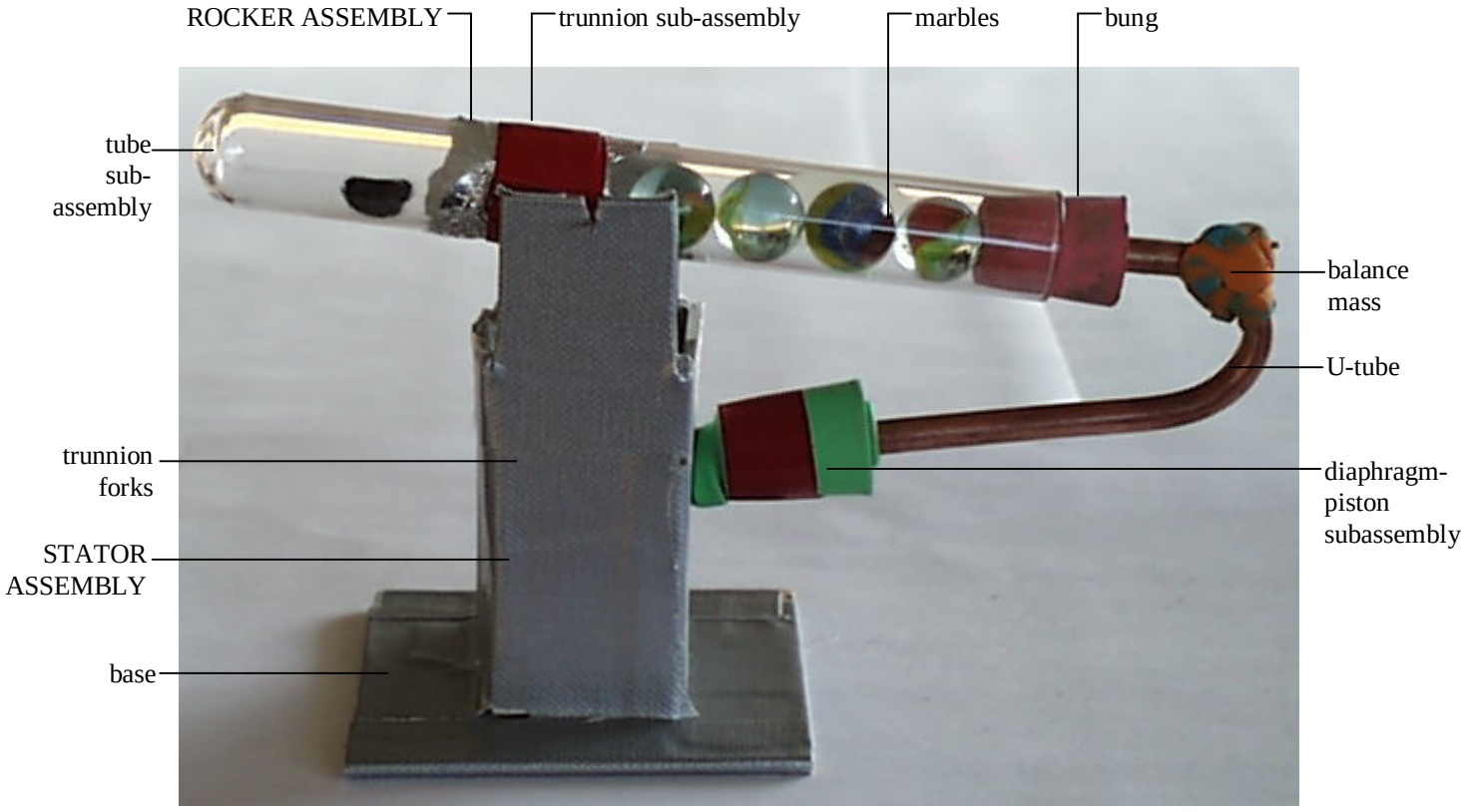

Figure A. The test-tube Stirling-cycle engine.

2. ASSEMBLY INSTRUCTIONS

Note: your tutor has a working Test-tube Stirling-cycle engine that you may use as a guide for assembly of your machine.

2.1. Engine stator

(a) Cut out cardboard base and trunnion forks as shown in Figure 2.1. Don't forget to cut out the trunnion vees.

(b) Partially cut along the "fold" lines (this makes the folding easier), and fold the trunnion fork cutout to form the trunnion assembly.

(c) Attach the trunnion fork subassembly to the base in a secure manner with duct tape. The trunnion fork assembly should be oriented so that the test-tube will sit parallel to the long axis of the base. (Hint: use the back of the craft-knife blade to get the duct tape into those tricky corners).

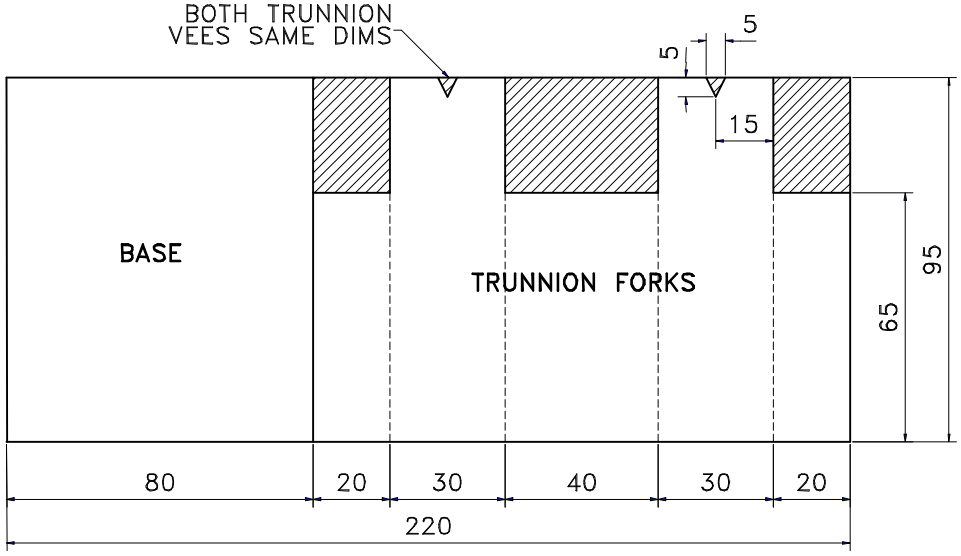

Figure 2.1. Pattern for Engine Stator – solid lines are cuts, dashed lines are folds, hatched areas are wastage.

2.2. Tube subassembly

(a) Wrap several turns of aluminium foil around the test tube and secure with insulation tape. Note: this allows the tube pivot point to be altered by sliding the trunnion assembly along the tube, so tension the tape for a medium friction fit.

(b) Modify two paperclips to form the trunnion shafts and secure to the aluminium foil (on opposite sides) with insulation tape, as shown in Figure 2.2.

(c) Roll a small amount of steel wool into a ball, and insert it in the test-tube as shown in Figure 2.3. – this acts as a shock absorber to prevent the marbles from breaking the end of the tube.

(d) Insert the marbles in the tube (try four marbles to start with). Ensure that your marbles are round by test-rolling them on a flat surface beforehand.

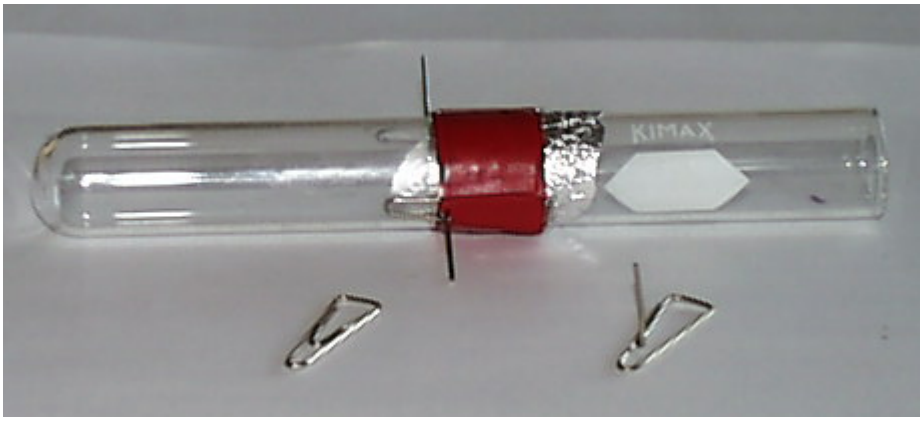

Figure 2.2. Paper clips before (left) and after (right) modification. Attachment of paperclips to the test-tube (background).

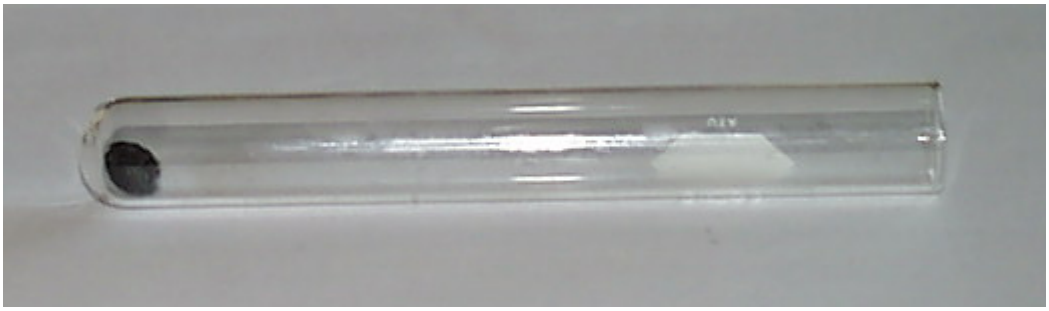

Figure 2.3. Steel wool in the end of the test-tube.

2.3. Diaphragm-piston subassembly

(a) Fit the balloon over the narrow end of the orange bung (the larger of the two bungs), leaving about 20mm of the balloon protruding to form a diaphragm-piston as shown in Figure 2.4.

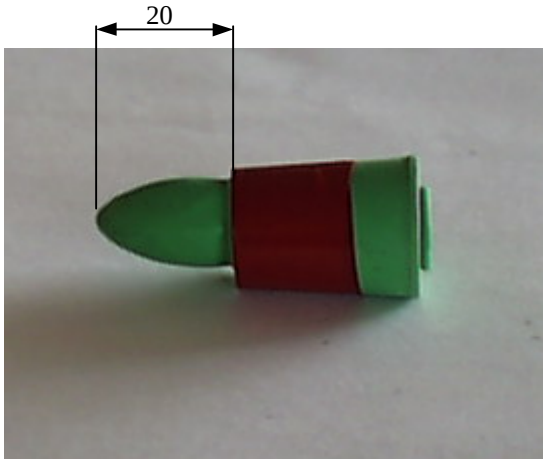

Figure 2.4. Bung with balloon fitted to form diaphragm-piston. Note the insulation tape wrapped around the narrow end of the bung to prevent radial expansion of the balloon.

(b) Wrap insulation tape around the balloon at the narrow end of the bung (this minimizes non-useful radial expansion of the diaphragm-piston).

(c) Fit the bungs to the ends of the copper U-tube. The diaphragm-piston bung goes on the long leg of the U-tube, and the pink (smaller) bung goes on the short leg. The U-tube should protrude nearly all the way through the bung leaving only about 5mm clearance at the end.

2.4. Engine Rocker

(a) Depress the balloon with your finger (to expel <u>all</u> the air) and fit the diaphragm-piston subassembly to the tube subassembly. **WARNING – use only gentle force to insert the bung in the test-tube. Excessive force will break the glass and probably cut your hand.**

(b) Fit the trunnion shafts of the engine rocker into the trunnion vees of the engine stator, so that the diaphragm-piston presses on the non-seam side of the trunnion forks (the seam side is unsuitable as it may flex).

3. COMMISSIONING THE ENGINE

3.1. Set the stroke to 5mm, i.e. slide the test-tube in the trunnion assembly so that when the test-tube is level there is about 5mm clearance between the end of the diaphragm-piston bung and the engine stator, as shown in Figure 3.1.

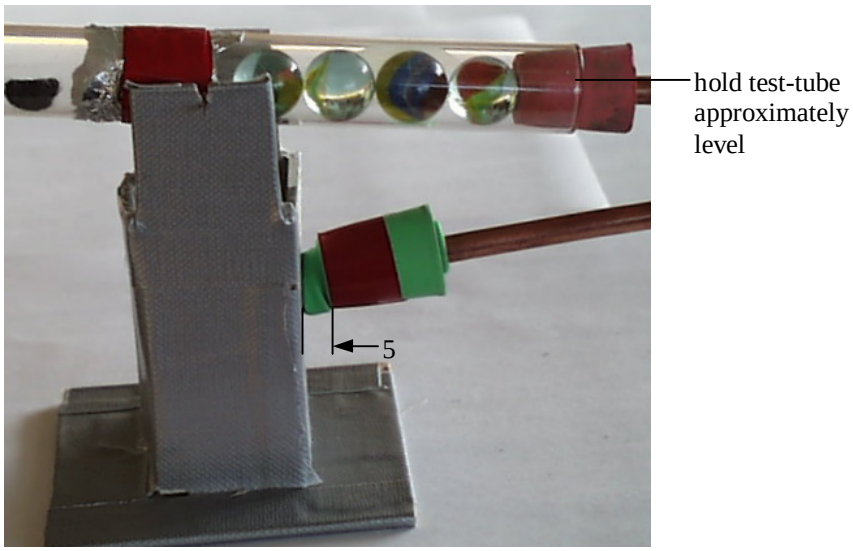

Figure 3.1. Setting the stroke on the engine.

3.2. Adjust the rocker for correct balance, i.e. attach plasticine to the bend in the copper U-tube so that when the marbles are in the end of the test-tube, the rocker will <u>just</u> tip and return the marbles to the piston end of the tube (thus compressing the diaphragm-piston)

3.3. Apply heat to the engine, i.e. place the burner under the end of the test-tube (get your tutor to prime your burner first).
3.4. As the engine warms up, you will probably find that you have to lengthen the stroke and/or increase the balance mass to keep it running.

Note: do not leave the marbles resting for more than a few seconds in the hot end of the test-tube or they will crack.

4. HINTS ON DEBUGGING

Most problems can be solved by adjusting the stroke or the balance:
4.1. If the marbles remain at the cold end of the test tube on start-up then the stroke is set too long or the balance mass (plasticine) is too heavy.
4.2. If the marbles move to the hot-end of the test-tube on start-up and stay there, then the balance mass is too low.
4.3. If the marbles stick or roll erratically, then they are not round. Disassemble and replace with round marbles.
4.4. If the diaphragm-piston doesn't deflate when the marbles are at the hot end of the test-tube then you may have a leak or you may have forgotten to empty the diaphragm-piston on assembly. Check for leaks and reassemble Engine Rocker subassembly (with the marbles at the hot end of the test-tube) as in Section 2.4.
4.5. Poorly-constructed machines (with high friction) will only produce a very small amount of work, and may only operate with 2 or 3 marbles (i.e. they won't work at all with 4). Try reassembling your machine with less marbles.
4.6. Ask your tutor for help – they know what they're doing.

5. WHEN IT WORKS

5.1. Make sure your tutor inspects your machine as there are marks assigned for the successful engine build and run.
5.2. Try running the engine with different numbers of marbles in the test-tube, and see if you can improve performance.