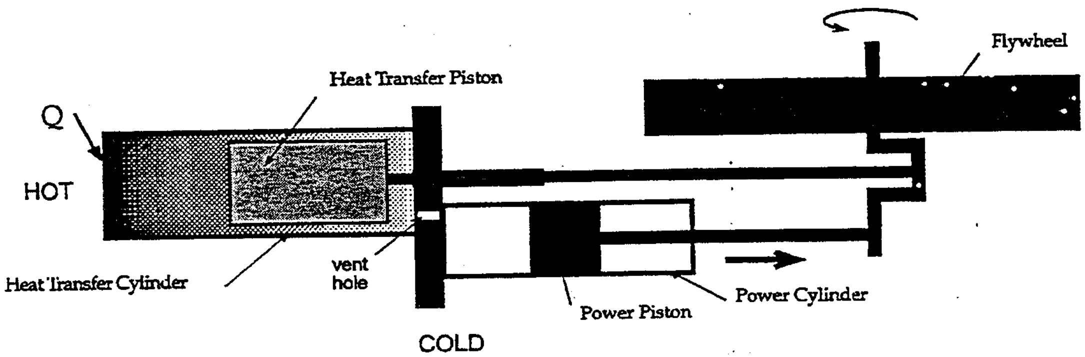
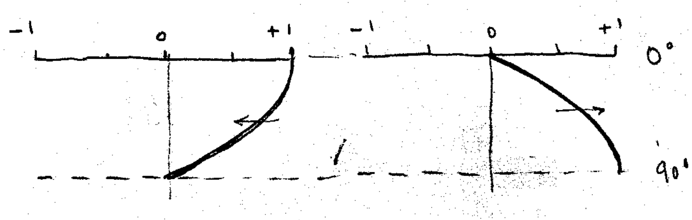
THE FOUR STEPS OF THE STIRLING ENGINE CYCLE

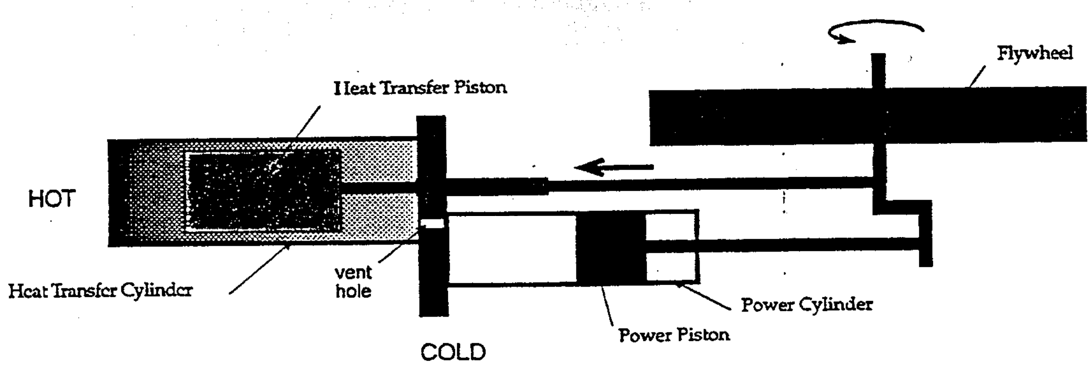
I. *Expansion*
II. *Transfer of air from HOT to COLD side*
III. *Contraction*
IV. *Transfer of air from COLD to HOT side*

I



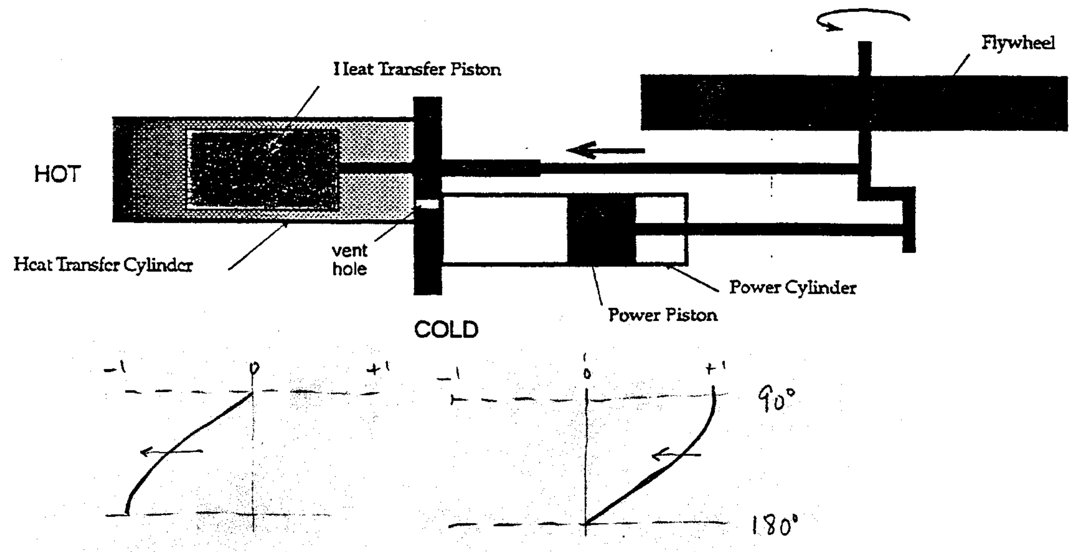


II

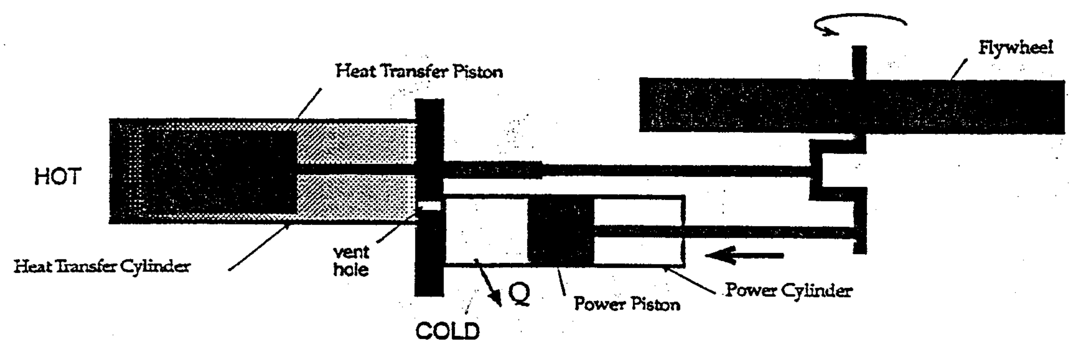


I. ***Expansion*** **-** The air is heated by the flame and expands, pushing the power piston outward and turning the flywheel.

II

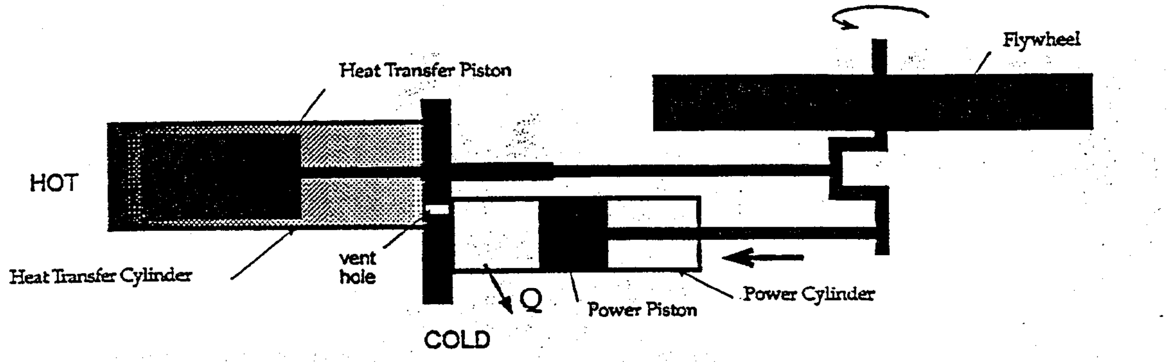


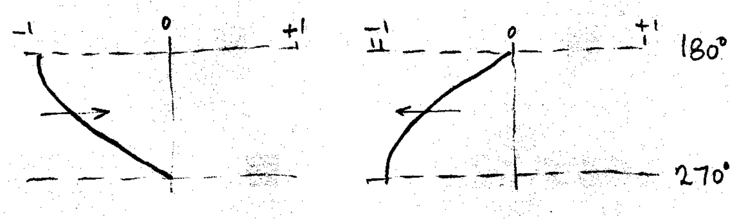
III



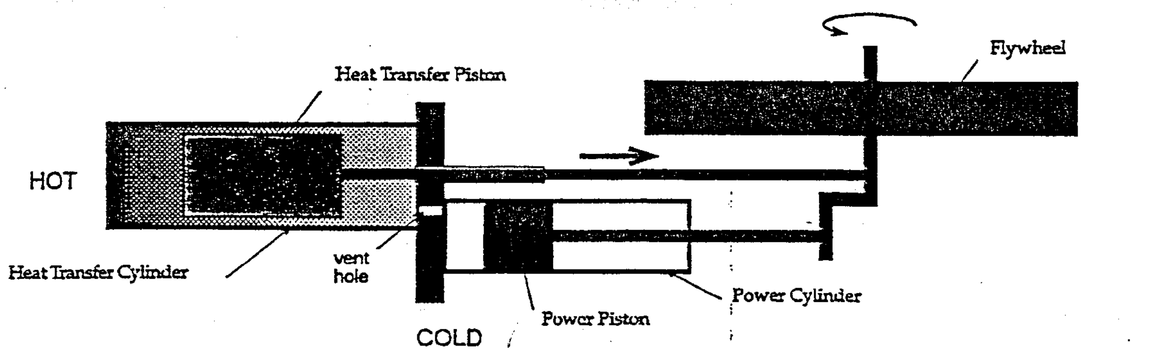
II. ***Transfer of Air from HOT to COLD Side*** **-** The hot air is pushed to the cold side of the engine by the displacer piston. Some of the heat of the air is absorbed by the displacer piston as the air moves by it.

III

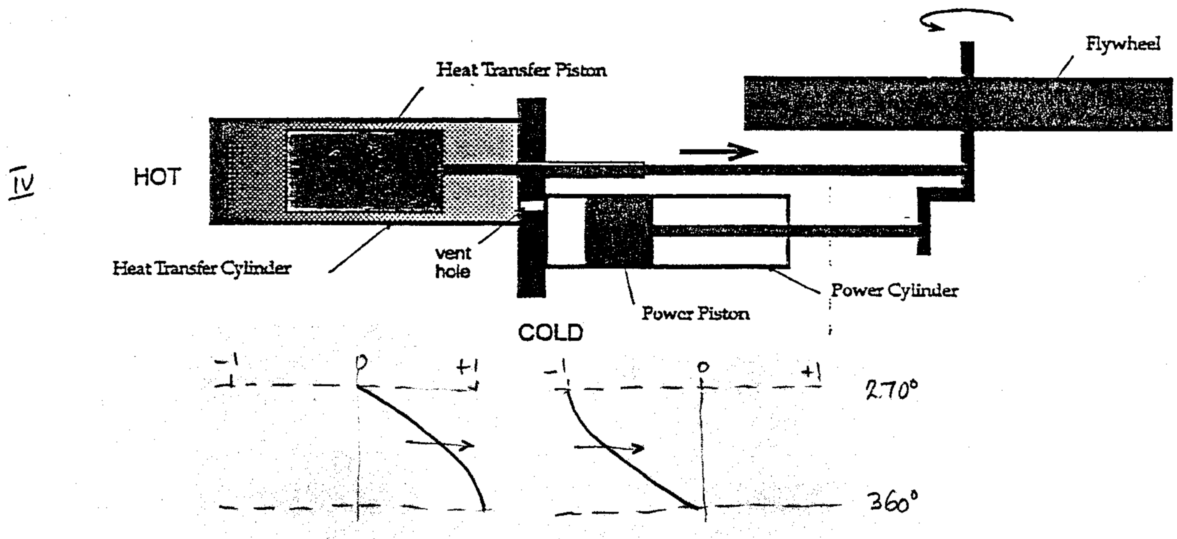


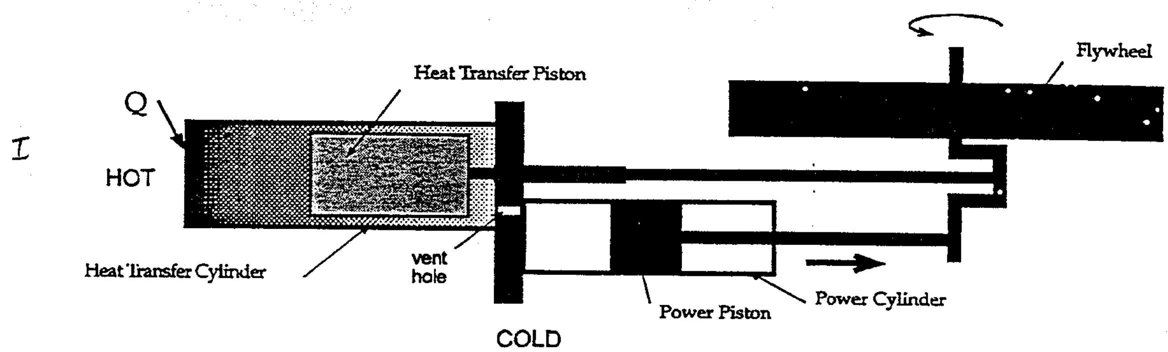


IV

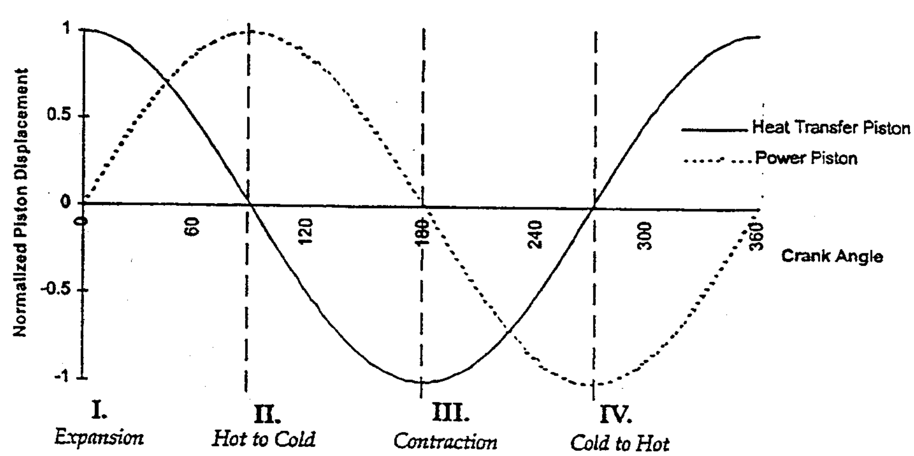


III. ***Contraction -*** The air cools and contracts, pulling the power piston inward and turning the flywheel.





IV. ***Transfer of Air from COLD to HOT Side*** - The cold air is pushed back to the hot side of the engine by the displacer piston, completing the cycle. The displacer piston releases some of its stored heat and warms the air, as it moves to the hot side.



Now that we have a good idea as to how the Stirling engine works, let us now attempt to represent this cycle in terms of an equivalent simple piston-cylinder engine model.

Our piston-cylinder engine model will consist of one cylinder instead of the two cylinders of the Stirling engine (the heat transfer/displacer cylinder and the power cylinder).

Furthermore, the mass of the air in the piston-cylinder model will be constant as apposed to the shuffling back and forth of air mass between the two cylinders of the Stirling engine.

Step I.

Stirling engine: Expansion – the air is heated by the flame and expands, pushing the power piston outward and turning the flywheel.

Piston-cylinder model: Isothermal expansion – the air expands in the piston at constant temperature. Work is done by the system on the surroundings.

You might think that rapid expansion of a gas in a piston should result in cooling of the gas. Recall that in the Stirling cycle, as the power piston moves out to the cold side and the displacer piston moves to the hot side, some hot air mass is transferred into the power cylinder heating the gas there and in this way compensating for the expected drop in temperature. We thus model this overall complex expansion process as occurring at constant temperature in a single piston-cylinder arrangement. As the volume expands, the pressure falls with the relation between pressure and volume given by the ideal gas law: $pv = RT = constant$. As the volume expands, the piston moves out and does work on the surroundings.

Step II.

Stirling engine: Transfer of air from the hot to the cold side – The hot air is pushed to the cold side of the engine by the displacer piston. Some of the heat of the air is absorbed by the displacer piston as the air moves by it.

Piston-cylinder model: Cooling constant volume – the air in the piston is cooled at constant volume. Heat rejection from the system to the surroundings.

In the Stirling engine cycle, both pistons move towards the hot end, with the effect of transporting hot air towards a cool region. This transport of the air is modeled as a cooling of the air at constant volume in the piston-cylinder model. Since this is modeled at constant volume, the piston remains stationary and no work is done. Heat is transferred from the air to the surroundings.

Step III.

Stirling engine: Contraction – The air cools and contracts, pulling the power piston inward and turning the flywheel.

Piston-cylinder model: Isothermal compression – the air in the piston is compressed at constant temperature. Work is done by the surroundings on the system.

In the Stirling engine both the displacer and power piston cylinders move toward each other with the effect of a reduced volume (contraction) between the cylinders. The pull of the power cylinder inward can also be viewed alternatively as the atmospheric air pushing the power piston inward, hence a compression process. During this compression or contraction some of the air is moved past the displacer piston over to the hot side. This contraction is modeled as compression at constant temperature (isothermal compression) in the piston-cylinder model. As the volume decreases at constant temperature, the pressure increases following the ideal gas law: law: $pv = RT = constant$. The increase in pressure during the compression is a result of work being done on the piston-cylinder system by the surroundings.

Step IV.

Stirling engine: Transfer of air from the cold to the hot side – The cold air is pushed to the hot side of the engine by the displacer piston, and thus completing the cycle. The displacer piston releases some of its stored heat and warms the air as it moves to the hot side.

Piston-cylinder model: Constant volume heating – the air in the piston is heated at constant volume. Heat is transferred to the system from the surrounding.

In the Stirling engine cycle, both pistons move towards the cold end, with the effect of transporting cool air towards a hot region where the air can be heated. This transport of the air is modeled as a heating of the air at constant volume in the piston-cylinder model. Since this is modeled at constant volume, the piston remains stationary and no work is done. Heat is transferred to the air from the surroundings.

Let us now represent the Stirling cycle on a pressure-volume (p – v) diagram and a temperature-volume (T – v) diagram:

The four processes are:

I. 1 – 2, Isothermal expansion
II. 2 – 3, Cooling at constant volume
III. 3 – 4, Isothermal compression
IV. 4 –1, Heating at constant volume