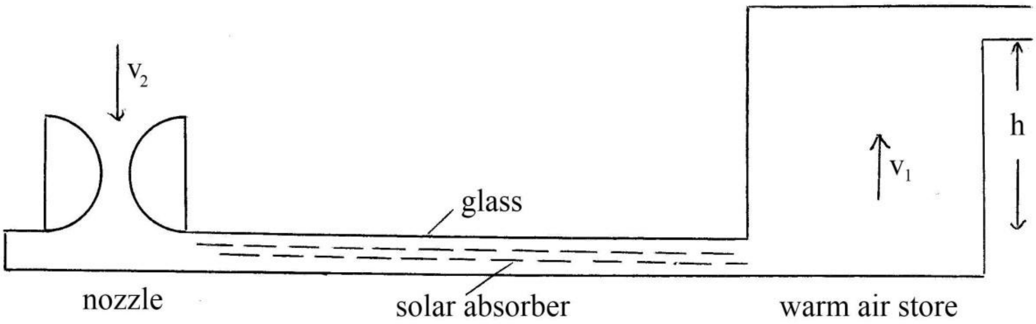
Solar Convection Engines : essential features



(1) Solar energy taken up by the absorber creates flow of air through the warm air store drawing incoming air through the nozzle.

(2) Warm air store height h, area A_1, contains air at $T + \Delta T$ gives air flow velocity v_1 where

$$v_1^2 = \frac{2\,\Delta T\,gh}{T} \qquad \text{(i)}$$

(3) Incoming air flows through a convergent-divergent nozzle with cross sectional area throat of nozzle A_2, and velocity throat of nozzle v_2. Constant mass flow requires

$$A_1v_1 = A_2v_2 \qquad \text{(ii)}$$

(4) As A_2 is reduced, v_2 is increased. In the limiting case kinetic energy air flow through the throat of the nozzle equals the solar energy absorbed. If area solar absorber is A_3

$$\tfrac{1}{2}\rho A_2 v_2^3 = IA_3$$

where I is insolation and ρ the density of air . (iii)

(5) Also with these optimal dimensions, the gain in kinetic energy as air flow accelerates through the nozzle equals the heat flow through the warm air store

$$\tfrac{1}{2}v_2^2 = C_p\Delta T$$

where C_p is the heat capacity of air. (iv)

From equations (i) to (iv) the values of g T ρ I C_p are all known. If three of the variables v_1 v_2 ΔT A_1 A_2 A_3 h are defined, the other four can be calculated.

It is then a simple matter of inserting an air turbine/wind turbine in the throat of the nozzle. The energy exported by the turbine will need to be compensated by having larger h. For example if the turbine is 50% efficient, h will need to be doubled.

For air flow through a ducted turbine, the Betz limit does not apply and an efficiency of 80% should be achievable. In that case a warm air store of height 5h will be needed.