Hidro+ analysis

Website:

www.hidroonline.com

Patents:

WO 2008/037004 A1 (attached)

WO 2009/076727 A1 (attached)

Assumptions:

Ideal gas law holds.

Isothermal, reversible compression and expansion (with efficiencies stated separately).

Drag force ignored (this will have a big effect on power (rate of energy production), but can be theoretically neglected for cycle net work calculations by assuming the container moves infinitely slow).

Description:

Consider a rigid container with a diaphragm dividing it into two chambers submerged in a column or body of liquid attached to two air cylinders via hoses. The container is capable of moving vertically up and down as the net force resulting from gravitational and buoyancy forces work on it.

Consider the following 4-step cycle:

Step 1:

The container is at the bottom of its vertical path and filled with water. High-pressure air is compressed into the bottom section created by the diaphragm in the container to push the water out of the container.

Step 2:

The container is released and moves upwards due to the net upwards buoyancy force acting on it. It does work on a pulley or other suitable system.

Step 3:

The container is at the top of its vertical path. The high-pressure air is released through a turbine, reclaiming some of the compression work done in step 1. Water fills the container and the net force is now downwards.

Step 4:

The container is released and moves downwards, again doing work on a pulley or similar system.

Energy calculations:

Variables

ρ_{fluid}	Density of the fluid (kg/m^3)
$\rho_{container}$	Density of the container construction material (kg/m^3)
P_{top}	Pressure at the top of the liquid column (Pa)
h	Height of the vertical path of the container (m)
T	Temperature of gas (K) – cancels out
η_{comp}	Compressor efficiency
η_{turb}	Turbine efficiency
η_{conv}	Efficiency of converting vertical displacement forces into energy form considered useful (usually electricity)
$V_{container}$	The volume of the container that can be occupied by gas or liquid (m^3)
$m_{container}$	Mass of the empty container (kg)
g	Gravitational acceleration (m/s^2)

Step 1:

This is a simple reversible isothermal compression.

$$W_{comp} = -\int P\,dV$$

Using the ideal gas law, this reduces to

$$W_{comp} = nRT \ln\left(\frac{P_{top}}{P_{top} + \rho_{fluid}gh}\right)$$

However,

$$n = \frac{(P_{top} + \rho_{fluid}gh)V_{container}}{RT}$$

Therefore

$$W_{comp} = (P_{top} + \rho_{fluid}gh)V_{container} \ln\left(\frac{P_{top}}{P_{top} + \rho_{fluid}gh}\right) \{J\}$$

Actual compression work required

$$W_{in} = \frac{W_{comp}}{\eta_{comp}}$$

Step 2:

$$W = Fd$$

$$F = \rho_{fluid}\left(V_{container} + \frac{m_{container}}{\rho_{container}}\right)g - m_{container}g$$

$$F = g\left(\rho_{fluid}\left(V_{container} + \frac{m_{container}}{\rho_{container}}\right) - m_{container}\right)$$

$$W_{up} = gh\left(\rho_{fluid}\left(V_{container} + \frac{m_{container}}{\rho_{container}}\right) - m_{container}\right) \{J\}$$

Step 3:

Assuming reversible processes with efficiencies taken into account:

$$W_{out} = -W_{comp}\eta_{turb}$$

Step 4:

$$F = \left[-\rho_{fluid}\left(V_{container} + \frac{m_{container}}{\rho_{container}}\right) + \left(m_{container} + \rho_{fluid}V_{container}\right)\right]g$$

$$F = g\left[m_{container}\left(1 - \frac{\rho_{fluid}}{\rho_{container}}\right)\right]$$

$$W_{down} = gh\left[m_{container}\left(1 - \frac{\rho_{fluid}}{\rho_{container}}\right)\right]$$

Net work:

$$W_{net} = W_{comp}\left(\frac{1}{\eta_{comp}} - \eta_{turb}\right) + \left(W_{up} + W_{down}\right)\eta_{conv}$$

This result is positive (in the sense of net work being output) up to a maximum value of h for each combination of P_{top}, η_{comp}, η_{turb}, and η_{conv}. There is an ideal h for each combination that maximises W_{net}.

The only effect of variations in $m_{container}$ and $\rho_{container}$ is to alter the ratio between W_{up} and W_{down}.