Rocketcam Air Cannon

Thermodynamics Investigation Build/Video Project

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Mechanical Engineering Technology (MET) Undergraduate

MET 220 Thermodynamics Heat and Power, Fall 2019

Professor Damon Sisk, PE

PURDUE UNIVERSITY | Polytechnic Institute

Instructions

1. **INVESTIGATE** the system approved by Professor Sisk and build an operating prototype.
2. **APPLY** appropriate equations/data to predict the performance of the system.
3. **COMPARE** actual operation to the theoretically predicted performance.
4. **EXPLAIN** the theory as well as the results, and discuss your calculated results for comparison to the operation of the prototype.

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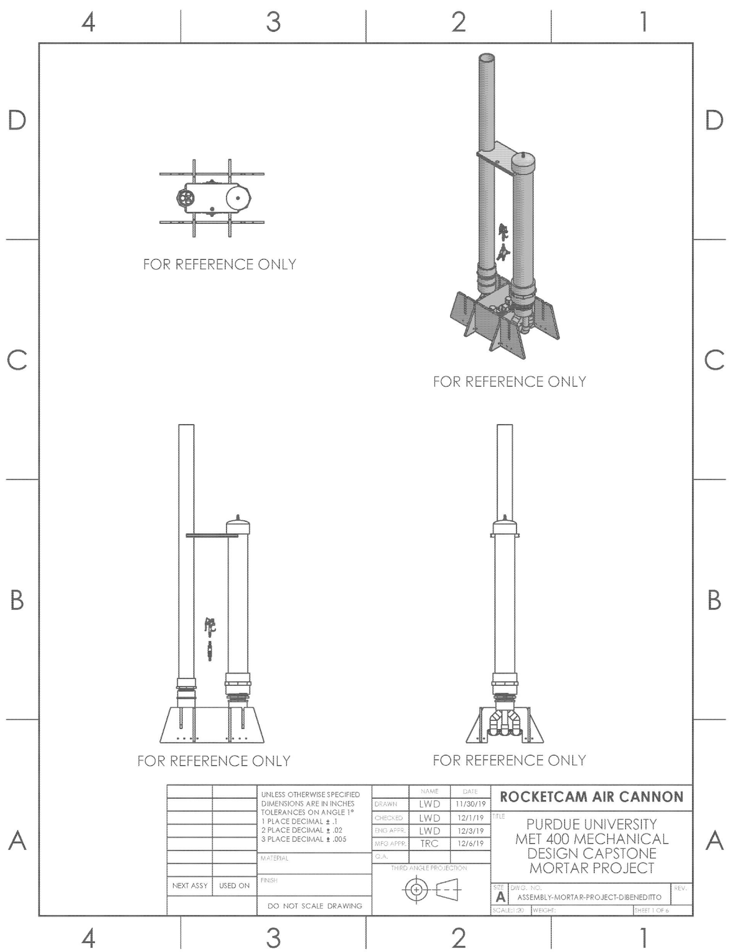

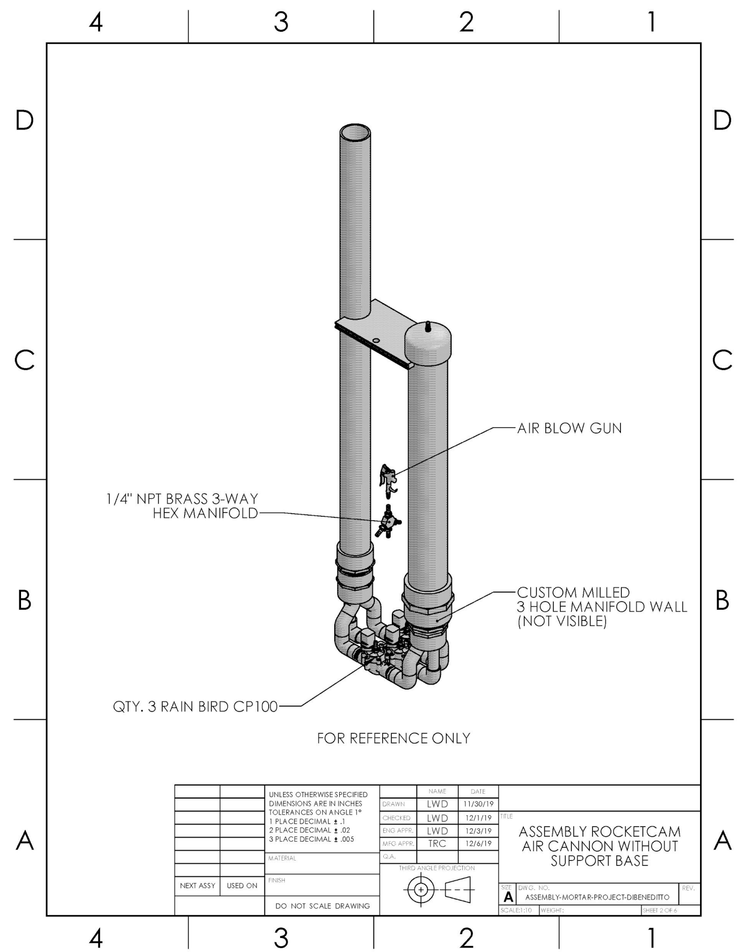

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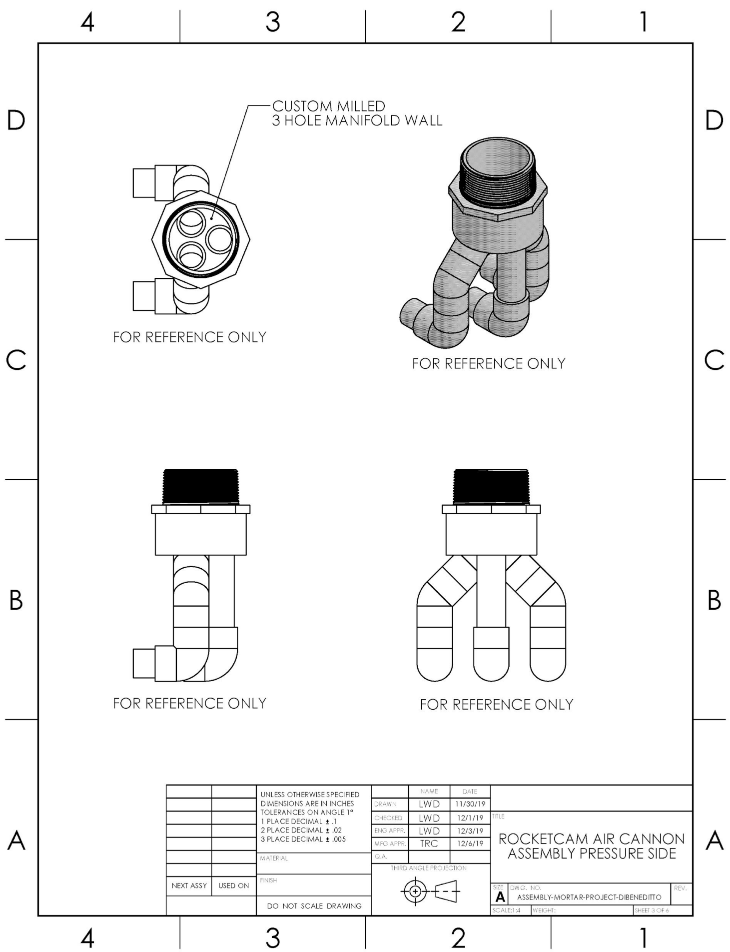

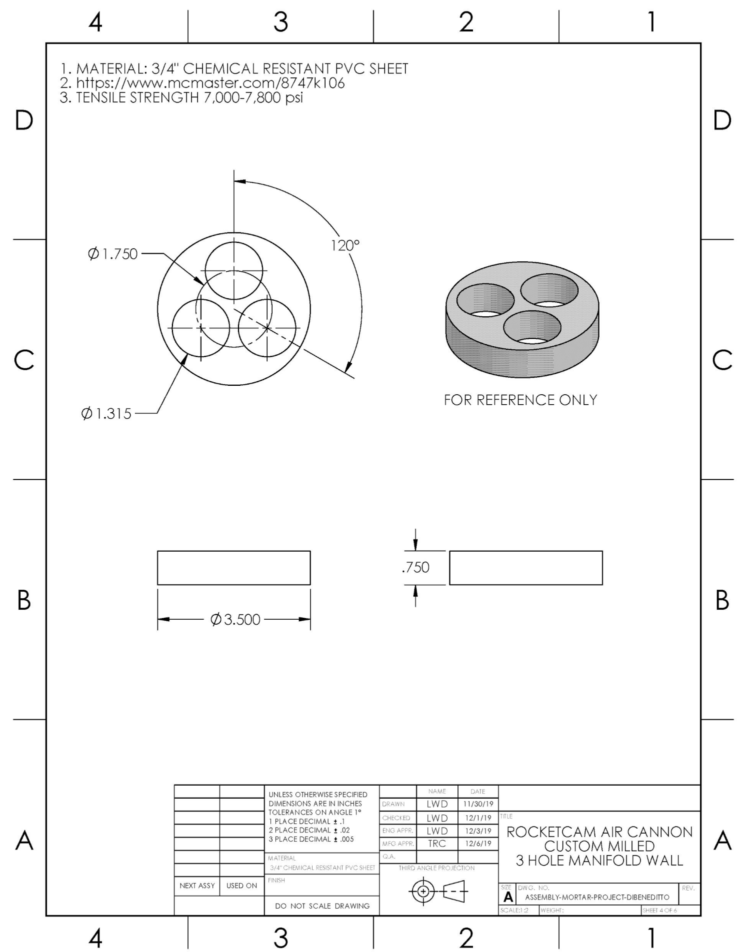

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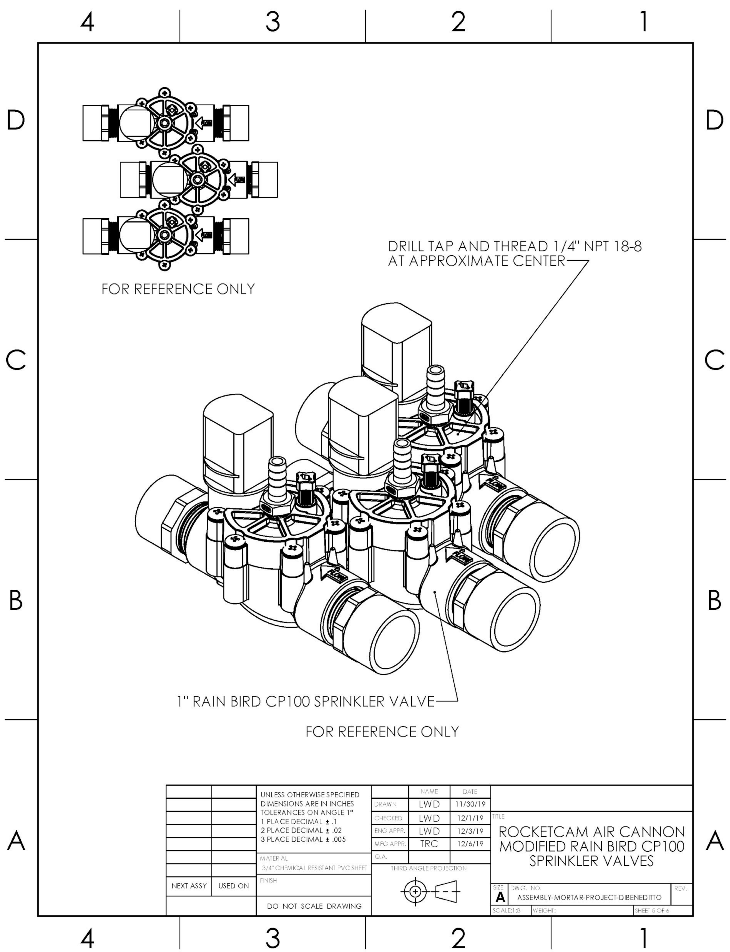

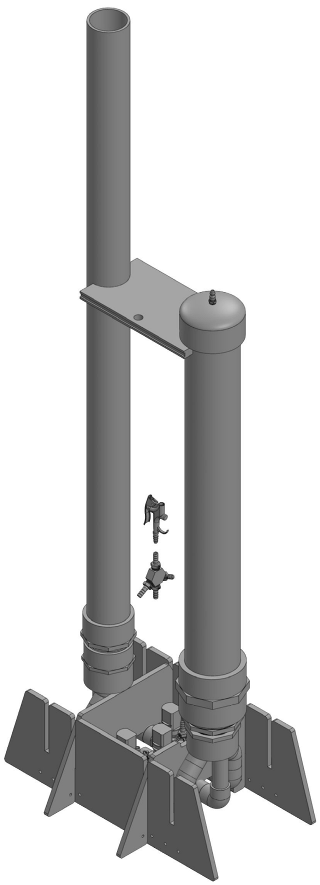

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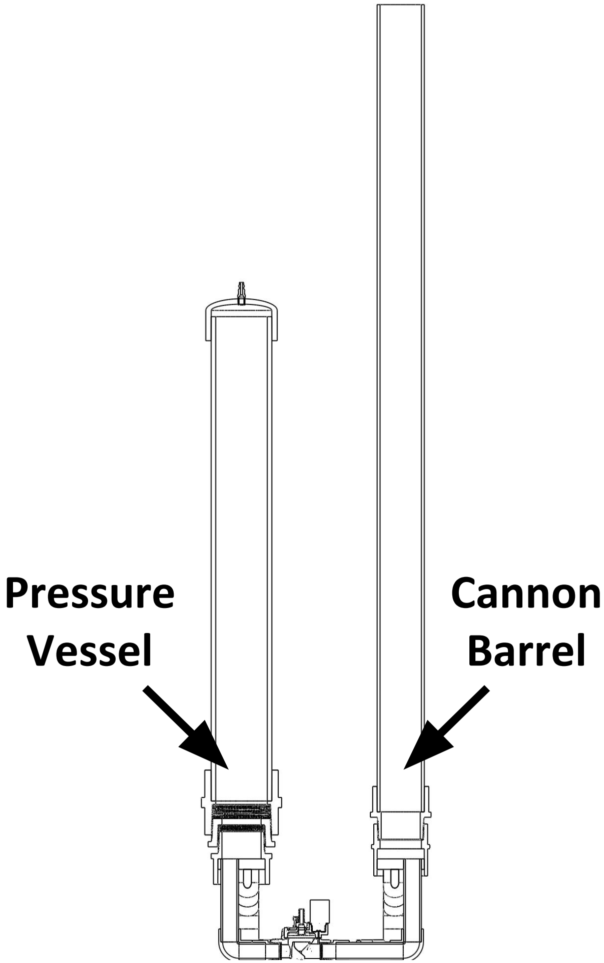

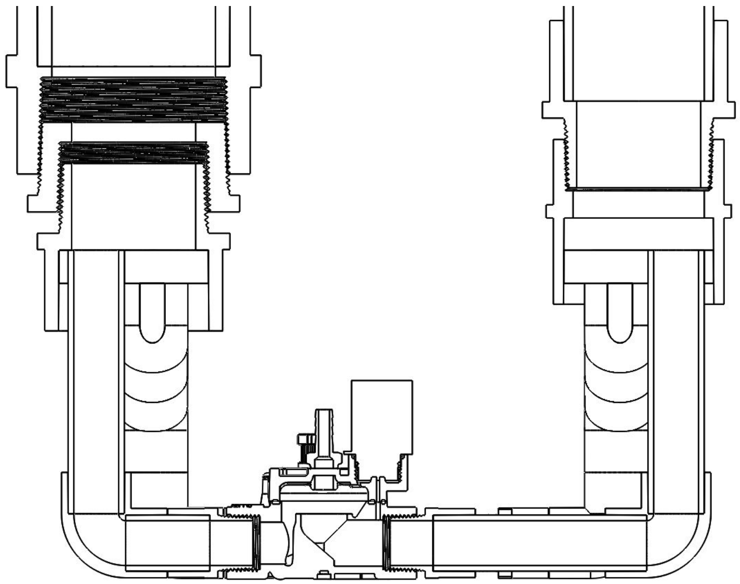

Unpressurized system.

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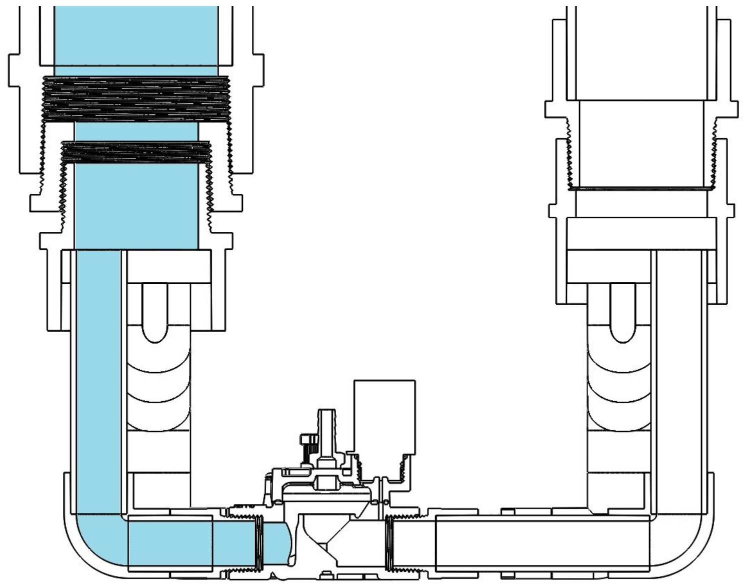
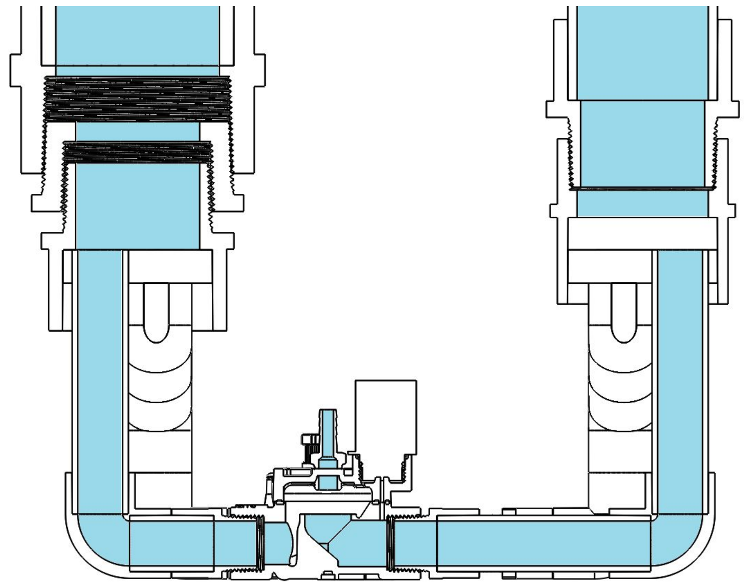


Pressurized system with air before firing.



Pressurized system with air while firing.

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

Givens (English Units)	**Givens (Metric Units) Calculations are Easier**
Pressure Vessel Pressure P_1 = 95 psia	Pressure Vessel Pressure **P_1 = 655 kPa**
Pressure Vessel Volume V_1 = 405.28 in^3	Pressure Vessel Volume **V_1 = 6.641 mm^3**
Cannon Barrel Volume V_2 = 443.56 in^3	Cannon Barrel Volume **V_2 = 7.269 mm^3**
Mass of Rocket Projectile m = 0.5 lb	Mass of Rocket Projectile **m = 0.2268 kg**
Velocity of Rocket Projectile out of Cannon ν = 179.377 ft/s	Velocity of Rocket Projectile out of Cannon **ν = 54.674 m/s**
Time of Flight t = 11.108 s	Time of Flight **t = 11.108 s**
Angle of Launch $\measuredangle$ = 85°	Angle of Launch **$\measuredangle$ = 85°**

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

Assumptions (Not Reality)

- Piston cylinder type device
- Zero Clearance - No escaping of gas as it flows from the pressure vessel to cylinder.
- Frictionless
- Mass-less piston
- Temperature remains constant.
- Pressure remains constant.
- No energy loss outside boundary work.
- Mass in system does not change.
- Volume in pressure vessel does not change.
- Air flows from pressure vessel to rocket (piston cylinder device) raising piston cylinder.
- Neglect friction losses in pipes.
- Neglect volume in small pipes and valve.

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

Assumptions (Not Reality)

- We assume constant pressure due to weight of rocket (piston cylinder) and the atmosphere work required to raise the rocket (piston cylinder).
- Boundary work in constant pressure process.
- The mass is just flowing from the pressure vessel side to the cannon barrel side.
- There is no change in volume in the pressure vessel side but there is on the cannon barrel side.
- There is a change in volume on the cannon barrel side because the valve makes the same pressure on the pressure vessel side as there is on the cannon barrel side.
- Since there is very little resistance on the cannon barrel side (no top on the cannon barrel, as it vents to atmosphere), the rocket is propelled out of the cannon barrel.

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

Finding the **Kinetic Energy** immediately after the rocket has left the barrel, or immediately after state 2.

Initial velocity 54.6724 m/s

Angle of launch 85 deg

Initial height 0 ft

Time of flight 11.108 sec

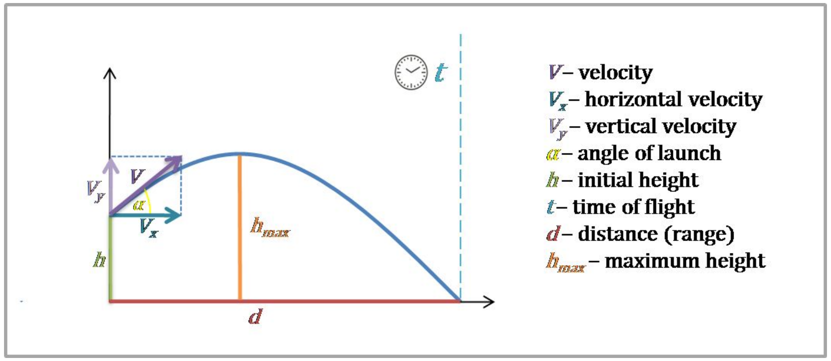
Distance 52.9 m

Maximum height 151.3 m

KE = (1/2)mv^2

KE ≅ (1/2)(0.2268 kg)(54.6724 m/s)^2

KE ≅ 0.3390 kJ



[pmc]

Projectile motion equations

Initial Height h = 0

Horizontal velocity: Vx = V * cos(α)

Vertical velocity: Vy = V * sin(α)

Time of flight: t = 2 * Vy / g

Range of the projectile: R = 2 * Vx * Vy / g

Maximum height: hmax = Vy^2 / (2 * g)

[pmc]

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

$E_{in} - E_{out} = \Delta E_{system}$

Energy in minus the Energy out is equal to the change in total Energy of the system.

$Q_{in} - W_{out} = \Delta U + PE + KE$

Total Heat Transfer minus Work out is equal to change in internal energy plus potential energy plus kinetic energy.

$Q_{in} - W_{out} = 0$

$Q_{in} = W_{out}$

$P_1V_1 = P_2V_2$

$P_2 = P_1V_1/V_2$

$P_2 \cong (655\ \text{kPa})(6.641\ \text{mm}^3)/(7.269\ \text{mm}^3)$

$\mathbf{P_2 \cong 598.41\ kPa}$

2. APPLY

APPLY appropriate equations/data to predict the performance of the system.

$P_2 \cong 598.41$ kPa

$$W_{out} = \int_{V_1}^{V_2} P_2 \, dV$$

$W_{out} = P_2 (V_2 - V_1)$

$W_{out} \cong 598.41 \text{ kPa} (7.269 \text{ mm}^3 - 6.641 \text{ mm}^3)$

$W_b = W_{out} \cong 0.3758$ kJ

3. COMPARE

COMPARE theoretically predicted to the actual operation performance.

Theoretically Predicted (Not Reality)	Actual Performance from Projectile Motion
$W_b = W_{out} \cong 0.3758$ kJ	$KE \cong 0.3390$ kJ
Piston cylinder type device	Pneumatic cannon
Zero Clearance - No escaping of gas as it flows from the pressure vessel to cylinder.	Air escapes through the trigger mechanism, and around the rocket as it is pushed out of the cannon barrel.
Frictionless.	Viscosity (resistance of a air to a change in shape), friction loss of fluid in pipe (skin friction), friction in rocket moving against tube surface
Mass-less piston.	Rocket has mass.
Temperature remains constant.	Temperature changes.
Pressure remains constant.	Pressure losses.
No energy loss outside boundary work.	Energy loss due to friction (see above), inertia (see above), mechanical vibration (sound and movement), unknown energy losses.

4. EXPLAIN

EXPLAIN the theory as well as the results, and discuss your calculated results for comparison to the operation of the prototype.

- We are only interested in what happens between steady states. Steady state where pressure vessel is in thermal equilibrium with pressure at max. Then steady state right before the rocket leaves the cannon barrel.
- We are interested in heat transfer as an energy analysis, which means we are interested in an energy flow.
- Energy enters the system in the form of heat.
- Compressed air does not really have potential energy.
- The energy of the air depends only on the temperature of that gas.
- Since the temperature of the air which is a gas remains constant, then the energy flowing out of the system can be analyzed as boundary work.
- The boundary work of the rocket (piston cylinder) pushes the atmosphere out of the way to make space for the air released from the pressure vessel to expand.
- Theoretical is not the same as actual but is fairly close.

4. EXPLAIN

EXPLAIN the theory as well as the results, and discuss your calculated results for comparison to the operation of the prototype.

$W_b = W_{out} \cong 0.3758$ kJ
KE $\cong 0.3390$ kJ

Percent loss of performance = 1 - (0.3390/0.3758) * 100 ≅ 9.79% due to energy transferred out of the system:

- Air escapes through the trigger mechanism, and around the rocket as it is pushed out of the cannon barrel.
- Viscosity (resistance of a air to a change in shape), friction loss of fluid in pipe (skin friction), friction in rocket moving against tube surface
- Rocket has mass.
- Temperature changes.
- Pressure losses.
- Energy loss due to friction (see above), inertia (see above), mechanical vibration (sound and movement), unknown energy losses.

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- NOTE: Some 3D models in the Drawing Package were obtained from mcmaster.com and grabcad.com and do not represent the work of the authors other than their use in the assembly for reference only.

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