Pneumatic Skyhook Launcher

by Terry G Glagowski, PhD / W1TR
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- Goal: Learn about pneumatic systems, what works, what doesn't and… find a suitable replacement for my 66 pound compound bow
- What is a "SkyHook"?
- What are Common Skyhook Hunting Methods?
- Why **Pneumatic**?
- Basics of a Pneumatic Skyhook Launcher
  - Pressure Tank
  - Trigger Mechanism
  - Barrel
  - Projectile
  - Retrieval Mechanism
- Theory
- Tests
- Summary
- Reference: search on: **Pneumatic Antenna Launcher Images**
  https://www.google.com/search?q=pneumatic+antenna+launcher+pvc+bullet&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwir6Zjrv_7aAhVCs1kKHRmfAvMQ7AkINA

What is a “SkyHook”?

- Wikipedia has a number of definitions:
  - Names of Books, Movies, Bands, Companies, Aircraft, Balloons
  - Technology: Climbing Hooks, Space Elevator
  - Mechanism for Flying Aircraft to Snag Payloads from the Ground
- My Definition:
  - I simply ***made up this name*** for a means of **hanging a rope over a tree limb**!
- Typical Use Scenario (SkyHook Hunting):
  - Launch projectile connected to fishing line / reel over support (tree limb)
  - Use fishing line to pull up twine or small rope
  - Use twine to pull up larger rope
  - Use rope to pull up antenna wire
- Connecting to Tree:
  - Over Small High Limbs (springy)
  - Spring Between Skyhook and Antenna, Keeps Tension
  - Pulley Between Skyhook and Antenna, Weight to Keep Tension

160 meter I-Beam

Rope Over Tree

Common Skyhook Hunting Methods

1) Armstrong Method – Throw Projectile Over Support (Tree Limb)
2) Slingshot – Shoot Projectile Over Support
3) Casting Rod – Cast Projectile Over Support
4) **Bow and Arrow – Shoot Projectile Over Support**
5) Crossbow – Shoot Projectile Over Support
6) Explosive Charge Gun – Shoot Projectile Over Support
7) Drone Air Drop – Drop Projectile Over Support
8) **Pneumatic Air Cannon – Shoot Projectile Over Support**

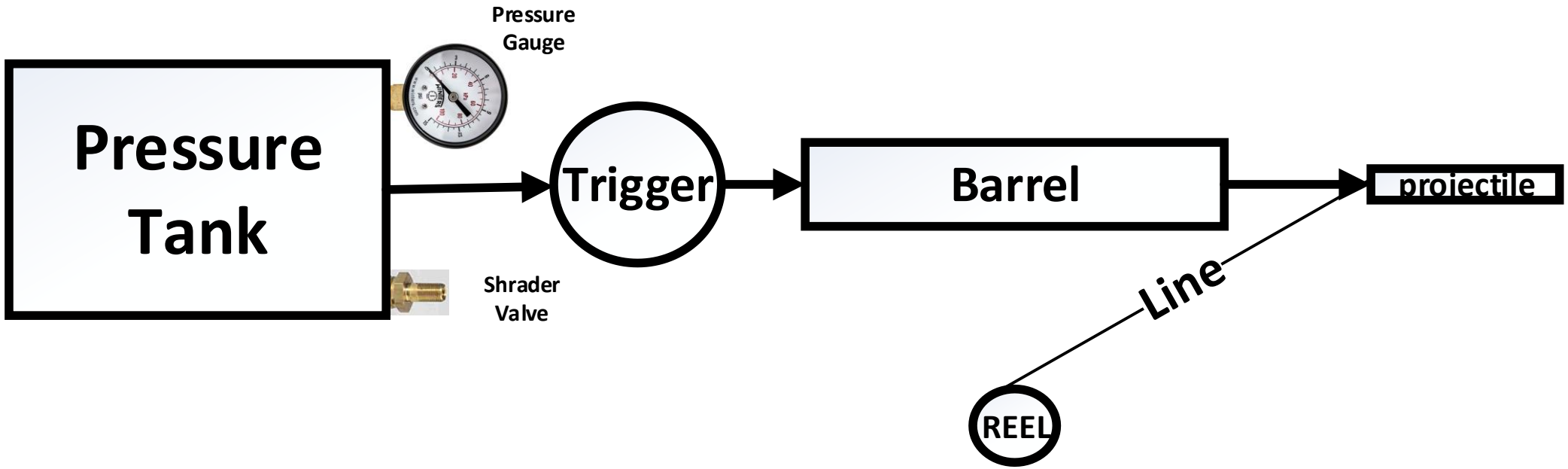
Why Pneumatic?

1) Armstrong Method – Very Simple
   but: requires a strong throwing arm (not me, I was not much of a baseball player)
2) Casting Rod – OK Idea
   but: needs a skilled fisherman (not me, I was never a fisherman)
3) Slingshot – Good Idea
   but: considered a **weapon** in some jurisdictions now (in Mass at the time)
   I considered this, but the bow and arrow seemed a better choice
4) Bow and Arrow – Excellent Idea
   immediate reuse of arrow
   but: requires strength to pull back bow (I'm getting too old for this)
   considered a **weapon** in some jurisdictions now
   I got mine in Dracut, MA (1986), walked right in, bought 66 pound compound hunting bow and arrows
5) Crossbow – Very Good Idea
   immediate reuse of arrow
   crossbow is "cocked" instead of pulling on string, strength not needed
   but: considered a **weapon** in some jurisdictions
6) Explosive Charge Gun – Good Idea
   but: complex, requires explosive charges, may be difficult to come by
   need to **reload** after each use, definitely considered a **weapon**
7) Drone Air Drop – Excellent Idea
   but: complex, requires **expensive** drone apparatus
8) Pneumatic Air Gun – Very Good Idea
   no strength required
   but: need to **reload** after each use
   limited vendor source, or make your own

Basics of a Pneumatic Air Cannon

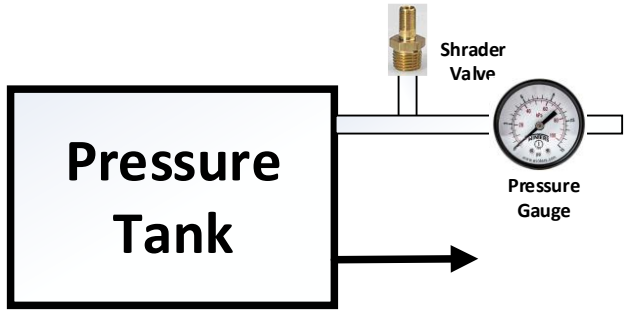
1) Goal:
   1) Experiment with Different Tanks, Triggers, Barrels, Projectiles
   2) Learn the issues of working with PVC and Brass Fittings for Pneumatic Applications
   3) Create a replacement for the compound hunting bow
2) Pressure Tank
   1) Pressure Gauge
   2) Relief Valve for Excessive Pressure
   3) Inlet Valve
   4) Size = Diameter (2r), Length L, Volume $= \pi r^2$L
3) Trigger
   1) PVC Ball Valve
   2) Brass Ball Valve
   3) Pneumatic Thumb Lever Air Gun
   4) Electric Sprinkler Valve
4) Projectile
   1) Tennis Ball
   2) PVC Bullet
   3) Arrow
5) Barrel
   1) Size to Match Projectile
6) Retrieval Mechanism
   1) Reel – cheap fishing reel $25
   2) Line – 20-50 pound

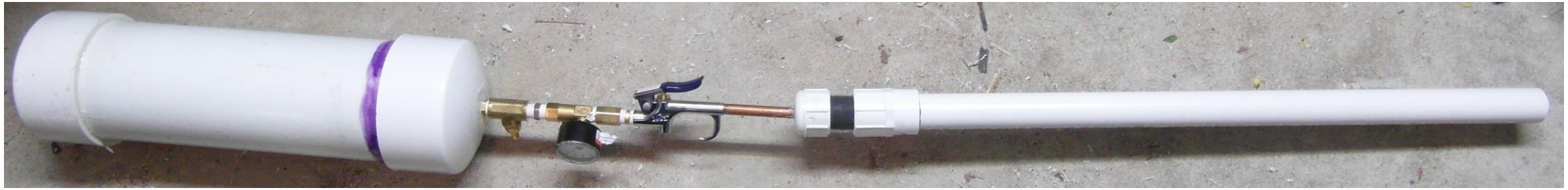
Basics of a Pneumatic Skyhook Launcher

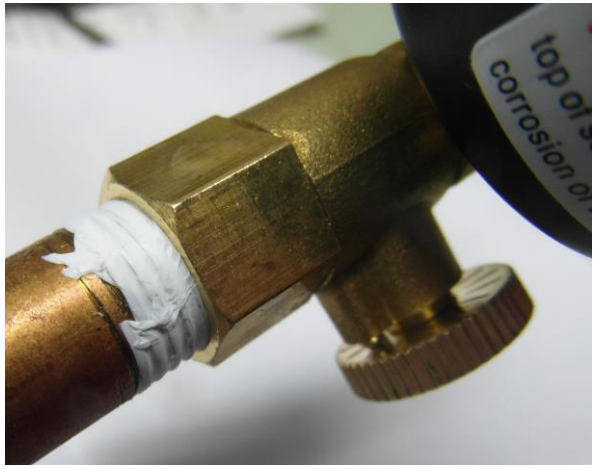


Such items are available on the WEB and at HamFests…
But…I love to experiment and homebrew

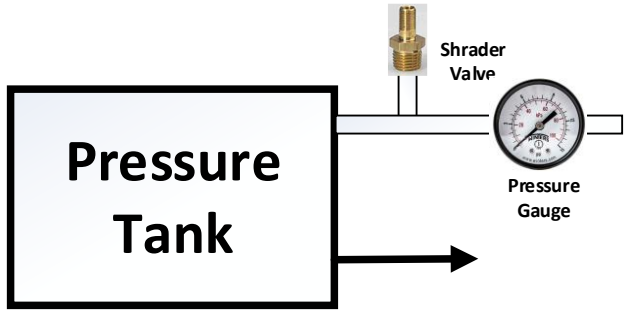
Pressure Tank #1 – Brass Fittings







Pressure Tank #1 – Brass Fittings - Issues

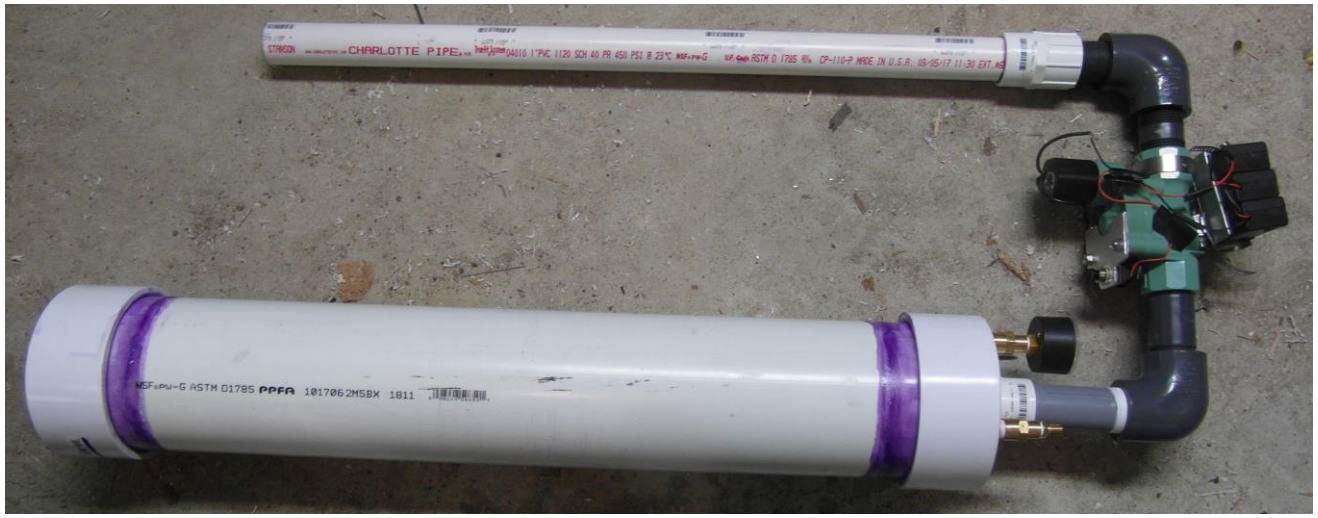


1) Goal: to make tanks interchangeable, also triggers and barrels
2) Solution: use brass subassembly for inlet valve and pressure tank
3) Benefit: pipe tape works OK with brass fittings – cheap $1.00
4) Benefit: combination pressure gauge / relief valves exist - $20.00
5) Benefit: interchangeability preserved:
    1) Pressure Tanks
    2) Trigger Mechanisms
    3) Barrels
    4) Projectiles
6) Problem: Inadequate Air Flow!

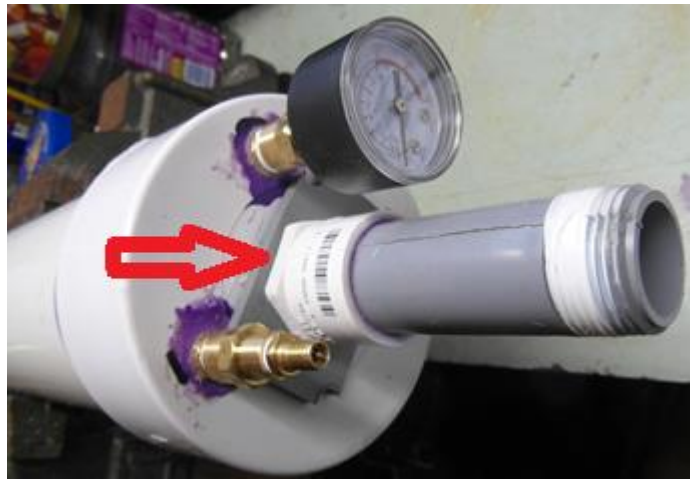
    Eventual Test Showed that it took 15 Seconds to Empty 80 Pounds of Air (Not Good Enough)

    Brass fittings and pipe are too small, airflow too restricted for this application !

Pressure Tank #2 – ALL PVC

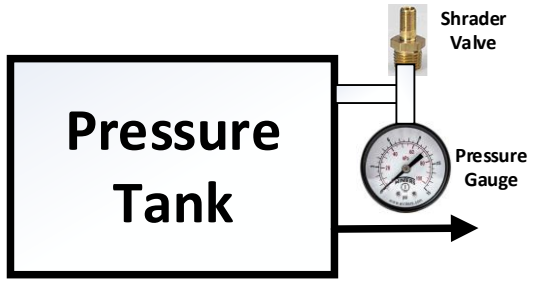


Pressure Tank #2 – ALL PVC - Issues

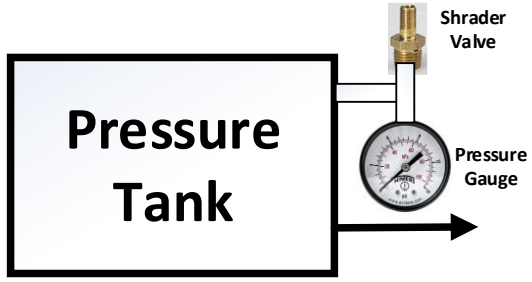


1) Goal: to make tanks interchangeable, also trigger and barrel
2) Solution: use screw in ¼ NPT nipples for pressure guage and Shrader valve
3) Use $^{7}/_{16}$ drill to cut holes for ¼ NPT brass nipple ($2)
    1) Tap hole in PVC using ¼ NPT tap – ½ outer diameter (OD)
    2) ¼ NPT dual male nipple (½ OD) – be sure there is a hex handle for wrench
    3) TEE section – triple female ¼ NPT
    4) Pressure gauge ($5-15)
    5) Shrader (tire inlet) valve ($3)
4) Issue: you **must glue** these parts **carefully** or they will leak
5) Transition from 4 inch to 1 inch pipe tapered to promote lamenter flow rather than turbulent.
6) Pressure Tank 2 had leaks where exit pipe joined cap

Pressure Tank #3 – PVC + Brass Ball Valve



Pressure Tank #3 – ALL PVC - Issues



1) Solution:
   1) Reuse Pressure Tank #2, new cap, discharge pipe, gauge, Shrader valve
   2) Use single subassembly (TEE section) for inlet valve and pressure gauge
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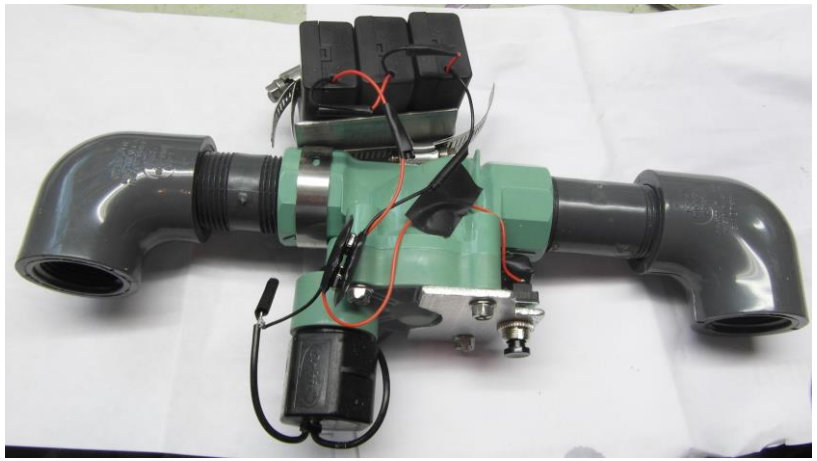
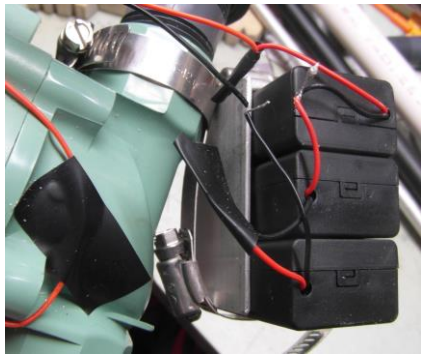
Triggers

1) Ball Valve
   1) PVC Cheap $1-5
   2) Brass Expensive $22
   3) Easy to Install in PVC Only Systems
   4) PVC - Sloppy imprecise, valve sticky
   5) Brass – Smooth precise, use WD-40
   6) Fast Air Flow, very successful

2) Pneumatic Thumb Lever Air Gun
   1) Cheap $5-10
   2) Easy to Install in Brass Fitting Systems
   3) Reasonably precise triggering
   4) ¼ NPT inch brass pipe input
   5) 1/8 NPT inch brass pipe output
   6) Limited Air Flow, insufficient pressure to launch



3) Electric Sprinkler Valve
   1) Complicated, not KISS
   2) More Expensive $20-30
   3) Easy to install in PVC Systems
   4) Precise triggering
   5) Requires 3 x 9 volt batteries and push button
   6) Did not hold pressure (defective?) further investigation warranted



Projectiles

1) Tennis Ball

1) Readily Available
2) Soft – Not as harmful as hard projectile
3) Large Cross Section
   May bounce off branches and trees
4) Need to Add Weight
5) Need to Attach Retrieval Line

2) PVC / Wooden Bullet

1) Need to Construct
2) Hard – could be harmful
3) Medium Cross Section
4) Easy to Add Weight
5) Easy to Attach Retrieval Line

3) Arrow

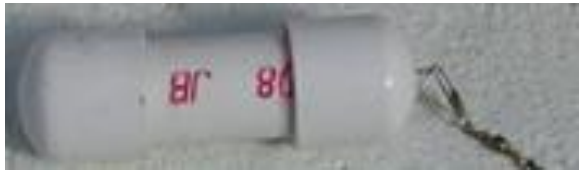
1) Readily Available, Walmart
2) Hard / Sharp – could be harmful
3) Small Cross Section
   shoot through branches
4) Need to Add Weight
5) Easy to Attach Retrieval Line
6) Attach **Cork** or Bottle Stopper

Projectiles – Adding Weight

1) Weight Requirements: 1-5 ounces total (3 nominal)

2) Tennis Ball
    1) Fill with metal hardware or stones

3) PVC / Wooden Bullet
    1) Attach metal bolt (wood)
    2) Fill with sand / stones (PVC)
    3) Fill with metal bolt (PVC)



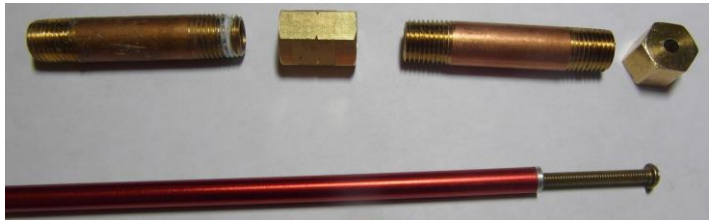
Projectiles – Adding Weight - Arrows

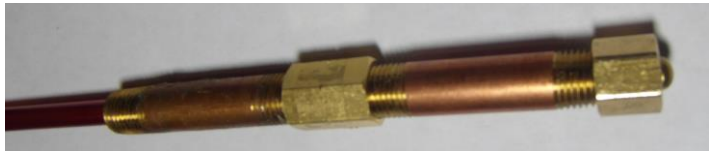
1) Weight Requirements: 1-5 ounces including arrow (3 nominal)
   1) Weight improves downward travel through branches and leaves
   2) Weight decreases acceleration to avoid breaking fishing line

2) Arrow
   1) Outer Diameter varies: 3/8, 5/16
   2) Wrap dummy tip with solder / tape
      1) Use Large Gauge, even Acid Core
      2) Wrap with electrical tape to secure
      3) Used with original arrow / compound bow
   3) Attach brass fittings to tip #8 – 32 tpi thread
      1) Arrow: 1 oz.
      2) Machine Screw: 1/8 oz.
      3) ¼ NPT Cap (drilled): ½ oz.
      4) ¼ NPT 2 ½ Pipe Section – Outside Thread: 1 1/8 oz.
      5) ¼ NPT Female Coupling – Inside Thread: 5/8 oz.
      6) Modify NPT pipe by cutting to size, weight <= 1 1/8
      7) Possible Weights (including arrow):
         1) 1 oz. – arrow alone
         2) 1 1/8 oz. – arrow with machine screw
         3) 1 5/8 oz. – arrow, screw, cap
         4) **2 7/8 oz. – arrow, screw, cap, extender**
         5) 3 5/8 oz. – arrow, screw, cap, extender, coupling
         6) 4 7/8 oz. – arrow, screw, cap, 2x extender, coupling
   4) Attach metal fragment (rod) to arrow
      1) Use Brass or Aluminum Rod (easy to drill and tap)
      2) Extends length of arrow








Projectiles – Attaching to Line

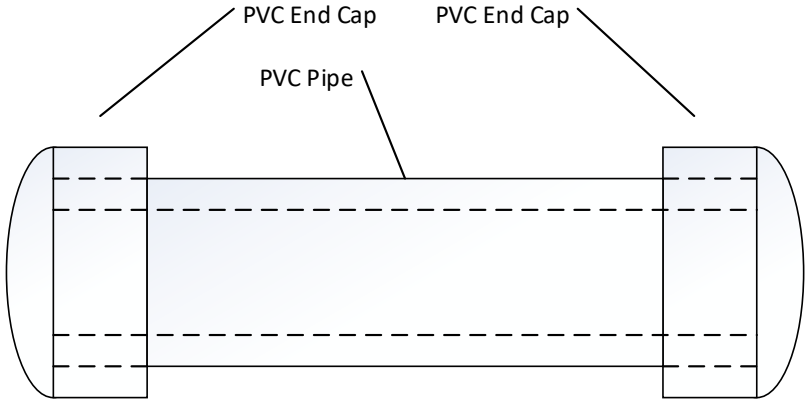
1) Tennis Ball
    1) Stitch Through Outer Cover

2) PVC / Wooden Bullet
    1) Eyehook

3) Arrow
    1) Drill Hole in Tail

Barrel

1) PVC Pipe Sizes - are specified by the Inside Diameter – SCH 40/80
    1) 0.50” – OD = 0.840”
    2) 0.75” – OD = 1.050”
    3) 1.00” – OD = 1.315”
    4) 1.25” – OD = 1.660”
    5) 1.50” – OD = 1.990”
    6) 2.00” – OD = 1.375”
    7) 2.50” – OD = 2.875”
    8) 3.00” – OD = 3.500”
    9) 4.00” – OD = 4.500”
2) Projectile must fit inside the barrel
    1) For PVC Bullets OD of Bullet Cap must be ID of Barrel
    2) W1VD uses ¾ inch PVC Pipe and Caps for bullet, 1 ¼ PVC Pipe for Barrel

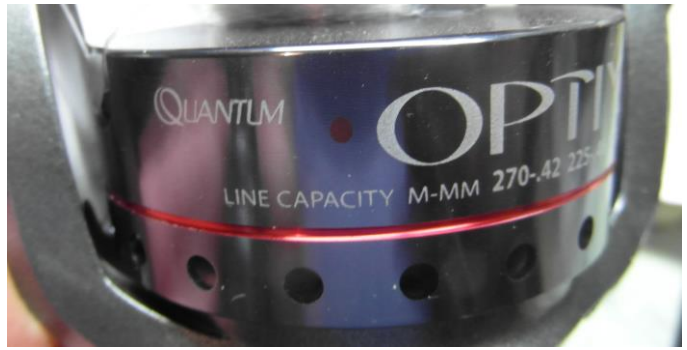


PVC Bullet

Barrel

Retrieval Mechanism

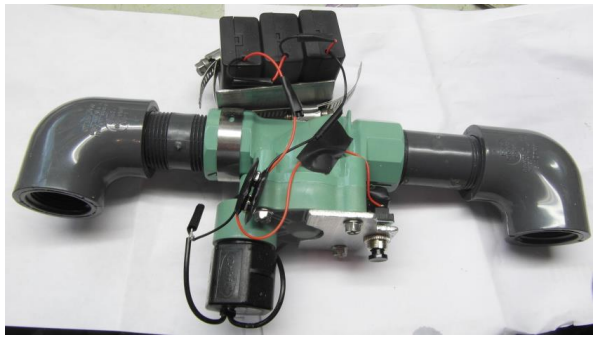
1) Line in ZigZag pattern on ground perpendicular to trajectory
    1) Line will not get tangled
    2) Good for larger size lines such as twine or rope
2) Fishing Line on Reel
    1) Use 20-50 pound line (typically 30)
    2) Tradeoff on size versus length that will fit on reel
    3) Use moderate quality reel (Walmart $20-40)
    4) Important Specification: length of line versus strength of line (size)
    5) Mount Reel on Barrel
    6) Mount Reel on Ground Anchor



Pressure Tests

1) First Test: Tank #1, Brass Fittings
   Result: Insufficient Air Flow to Launch Projectile
   Thumb Valve Trigger took 10 seconds to discharge air (80 pounds)

2) Second Test: Tank #2, Leaking
   Needed Swimming Pool to View Leak Bubbles, large tank
   Wednesday Afternoon: It Was Raining (no work outdoors)
   Thursday Afternoon: Discovered Pipe Not Glued
   Applied Glue to Pipe Connected to Pressure Tank
   Leaking persisted at joint between pipe and tank



3) Third Test: Tank #3, Leaking
   New Tapered Transition from 4 inch to 1 inch in sections
   Pressure test AOK at 50 pounds with cap
   Pressure test NG with Electric Sprinkler Valve (defective?)

4) Fourth Test: Tank #3, Success
   Replaced Electric Sprinkler Valve with Brass Ball Valve
   Pressure test AOK
   very slow leak at Pressure Gauge Fitting (fixable): 1 PSI/minute or less

Initial Ballistic Test

- Initial Test with 40 PSI
  - Original arrow with rubber stopper
  - Elevation angle 60°
  - 90 feet height
  - 120 feet down range
  - Drill 3/8 inch hole in rubber cork
  - Split one side of cork
  - Use electrical tape to fasten cork together
  - Use electrical tape to prevent cork from sliding on arrow when propelling arrow
  - Much better performance: two real corks, slightly smaller diameter in front #8, larger in back #10

Theory – Pressure vs Height

Conservation of Energy

Before Launch, Kinetic Energy, E_k and Potential Energy, $E_{p,}$ are Zero

Launch Pressure adds Kinetic Energy, E_k, to Arrow

At Apogee of Trajectory, Vertical Kinetic Energy, E_k, is Zero, potential energy, $E_{p,}$ is maximum

Potential Energy, $E_{p,}$ at Apogee is Height × Weight of Arrow lb

Kinetic Energy, E_k, after Launch is Pressure PSI × Area sq-in × Barrel Length ft

$E_k = E_p$ Conservation of Energy, less barrel friction and air resistance losses

Weight of Arrow = 4 ounces = ¼ lb

Length of Barrel = 2 ft

Diameter of Cork = 1 inch, ¾ sq-in $({}^{1}/_{2}{}^{2}$ x 3.14)

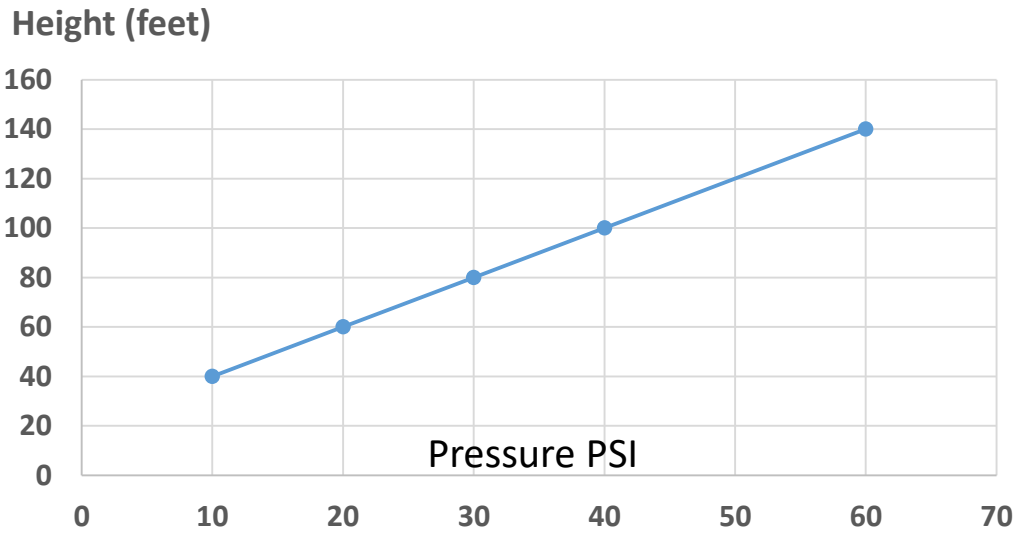
Height ft = (Pressure psi x Area sq-in x Barrel Lth ft) / Weight lb

Height = (60 x 0.75 x 2) / (1/4) = 6 ft/psi x 60 psi = 360 ft

Height = 360 ft

Ballistic Tests

PSI	Height	Range	Angle
10	40	80	70
20	60	70	60
30	80	100	70
40	100	120	70
60	140	100	80



Empirical Ballistics Formula:

Height (ft) = 2 x PSI + 20 … *simplify to Height = 2 x PSI*

PSI = (Height (ft) – 20) / 2 … *simplify to PSI = Height / 2*

Note: this cannot be true at low pressures since 0 PSI = 20 feet height… no way !

Measurements were ***estimates*** based on visual observation, comparison with 70 ft HF tower

Theoretical Ballistics Formula:

Height (ft) = 6 x PSI

PSI = Height (ft) / 6

Summary – Lessons Learned

- PVC Fittings Require Careful Glue Application with Primer
- Tapered Straight Transition Pressure Tank to Exhaust Pipe Reduces Turbulence
- Brass Ball Valve works Smoothly with Rapid Air Flow
- Brass Thumb Trigger Valve and Small Brass Pipe has Insufficient Flow
- Sprinkler Trigger Valve Leaks (is it defective?)
- Attaching Fishing Line to Arrow Has Little or No Effect on Ballistics
- 20 Pound Fishing Line Sometimes Breaks need 30 or 40 pound depending on pressure
- RYOBI Portable Compressor Pressurizes to 70+ PSI, Can be Carried in Tool Bag to Woods
- Best Arrow Performance:
  Two corks not **rubber stoppers** 1 inch OD at tail #10 taper, 5/8 inch OD mid-arrow #8 taper
  Rubber stoppers create too much friction, leave residue inside barrel
- Empirical Ballistics Formula:
  Height (ft) = 2 x PSI + 20 … *simplify to Height = 2 x PSI*
  PSI = (Height (ft) – 20) / 2 … *simplify to PSI = Height / 2*
  Note: this cannot be true at low pressures since 0 PSI = 20 feet height… no way !
  Measurements were ***estimates*** based on visual observation, comparison with 70 ft HF tower
- **Conclusion:**
  2/3 of launch kinetic energy lost in barrel friction, air flow resistance, and other factors