

CNG 7 Consolidated Nail Gun

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in partial fulfillment of the requirements for the degree of

Master of Architecture
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William Green

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CNG7 Consolidated Nail Gun

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ABSTRACT

The purpose of my study is to create a compact, portable nail gun. The nail gun is to be used in tight spaces where hammers, pneumatic nail guns, and portable nail guns will not fit. The intended market is for homeowners renovating their houses. The short length and lightweight, compact frame make the CNG7 ideal for this market. The CNG7 is designed with minimum material waste and fewer parts than other nail guns.

CNG7 User Guide

7" Consolidated Nail Gun



a

Introduction

The CNG7 is a lightweight, compact, and portable nail gun. Consolidated nail guns are engineered for indoor renovations operated by homeowners with little or no building experience. Its short 7" overall length is ideal for renovations, retrofits, or any tight spaces.



b



c



d

The CNG7 fits in spaces where Pneumatic Nail Guns can not.



e



f



g

Warning:

Read entire User Guide before operating this tool. Always wear safety glasses and ear protection when operating this tool.

For questions concerning the CNG7, contact:

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CNG7 Advantages

- Great for renovations

- Fits in tight spaces

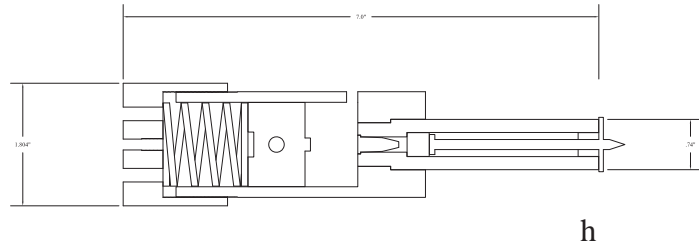
- **CNG7 = 7" long**

- Pneumatic Nail Guns = 10" long

- Portable Nail Guns = 12" long

- Powder-Actuated Nail Guns = 14" long + 8" for hammer

- Powder-Actuated Nail Guns (trigger) = 15" long



- Less bulky and easier to maneuver than Pneumatic, Portable, and Powder-Actuated Nail Guns

- No hammer necessary

- Powder-Actuated Nail Guns (without triggers) require a hammer



i

- No hoses, air compressor, or electric required

- Pneumatic Nail Guns require an air hose, compressor, and electric



j

- No batteries or fuel cell

- Portable Nail Guns require rechargeable batteries and a separate fuel cell

- Made of hardened 4140 steel

- Portable Nail Guns are plastic

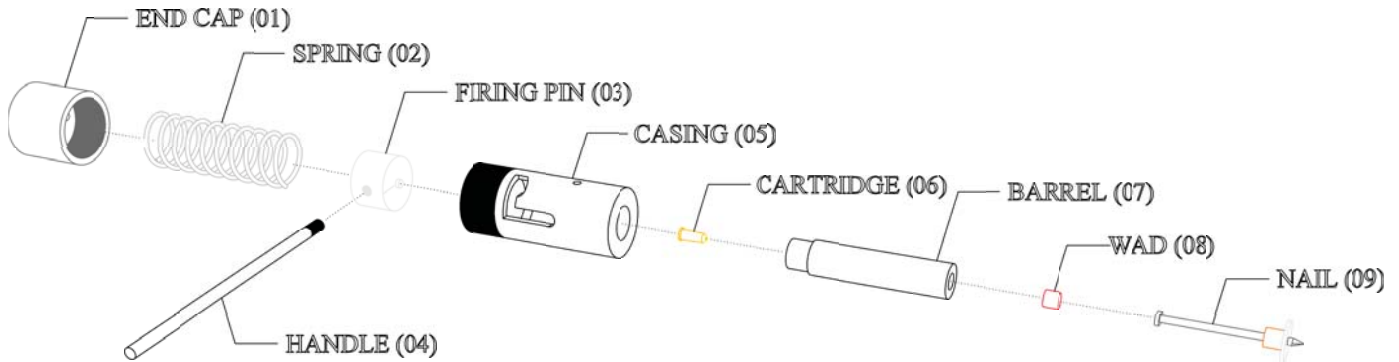


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CNG7 Consolidated Nail Gun



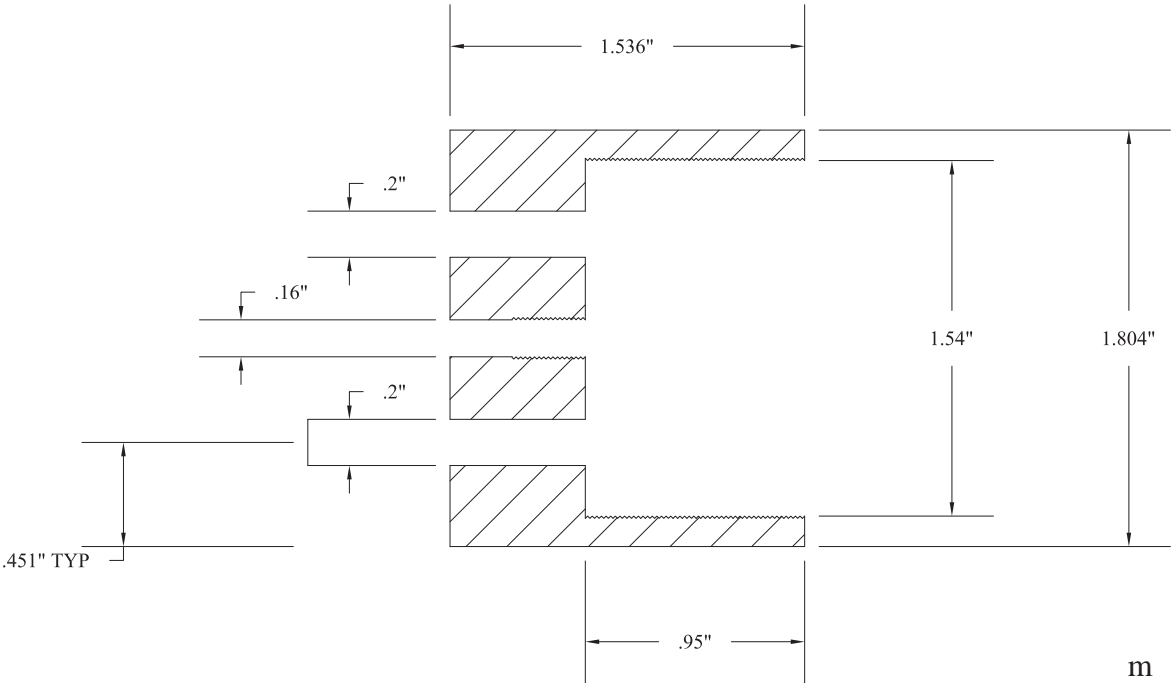
h-a

Parts List

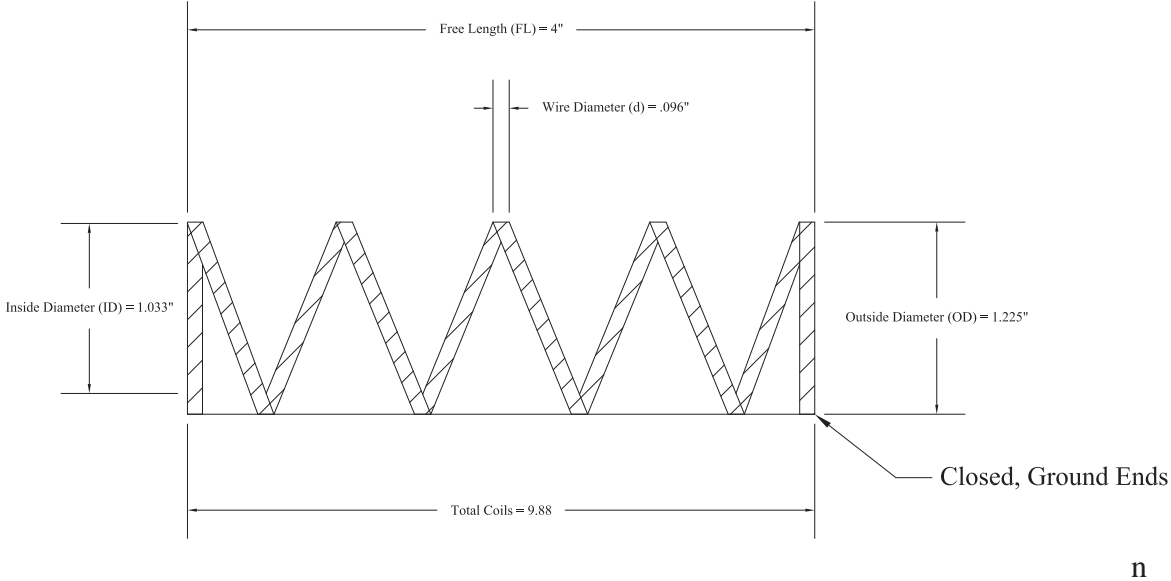
Part #	Part Name	Description	Dimensions	Material
01	END CAP	Threaded Cap Screws on to Casing and adjusts Spring tension	1.804" dia. x 1.536" length	4140 Steel (hardened)
02	SPRING	Propels Firing Pin toward Cartridge	1.225" O.D. x 4" free length	Music Wire
03	FIRING PIN	Strikes Cartridge	1.252" dia. x .92" length	4140 Steel (hardened)
04	HANDLE	Retracts Firing Pin, compresses Spring, acts as Trigger	.253" dia. x 6.45" length	4140 Steel (hardened)
05	CASING	Houses Firing Pin, Spring, and top of Barrel	1.555" dia. x 3.671" length	4140 Steel (hardened)
06	CARTRIDGE	Discharges to propel Wad/Nail	.271" dia. x .603" length	Metal Alloy
07	BARREL	Houses Cartridge, Wad, and Nail. Directs Cartridge explosion	.75" dia. x 3.545" length	4140 Steel (hardened)
08	WAD	Seals area in Barrel between bottom of Cartridge and top of Nail	.355" dia. x .326" length	Nylon Resin
09	NAIL	Propels into wood to join materials	.295" dia. (head) x 2.947" length	Carbon Steel

Detailed Part Dimensions

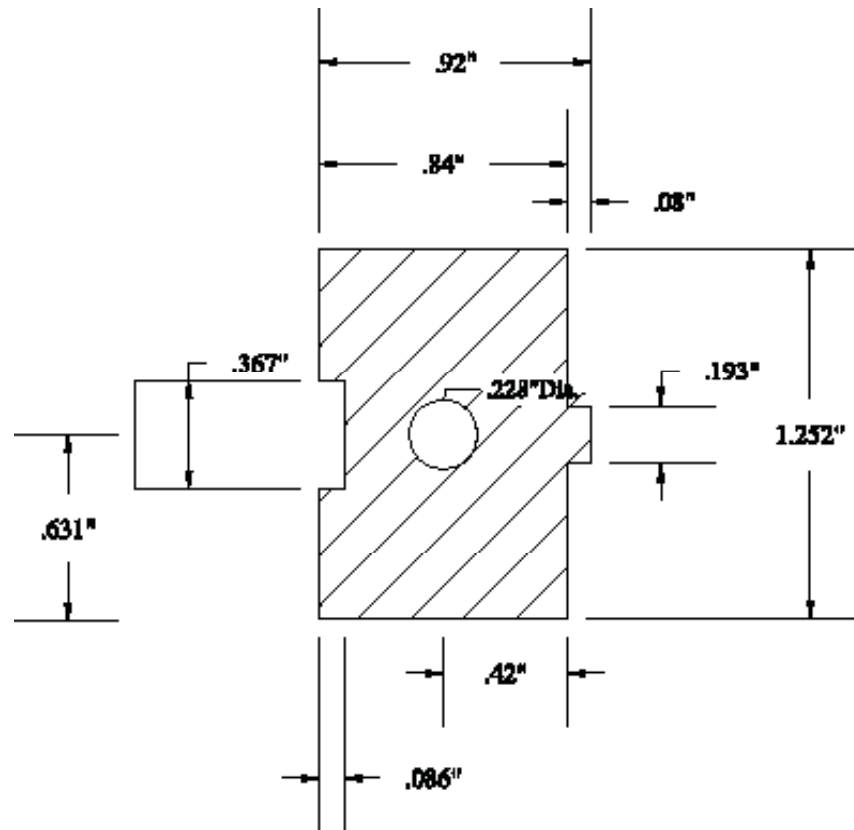
END CAP (01) SECTION



SPRING (02) SECTION

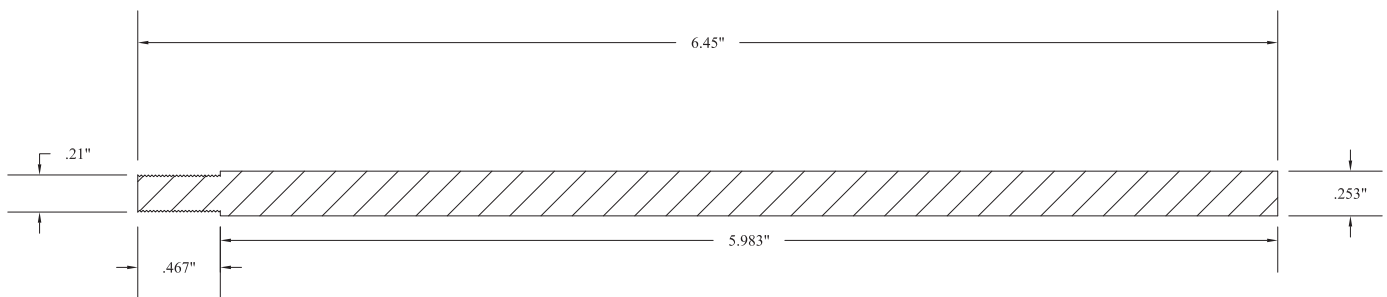


FIRING PIN (03) SECTION



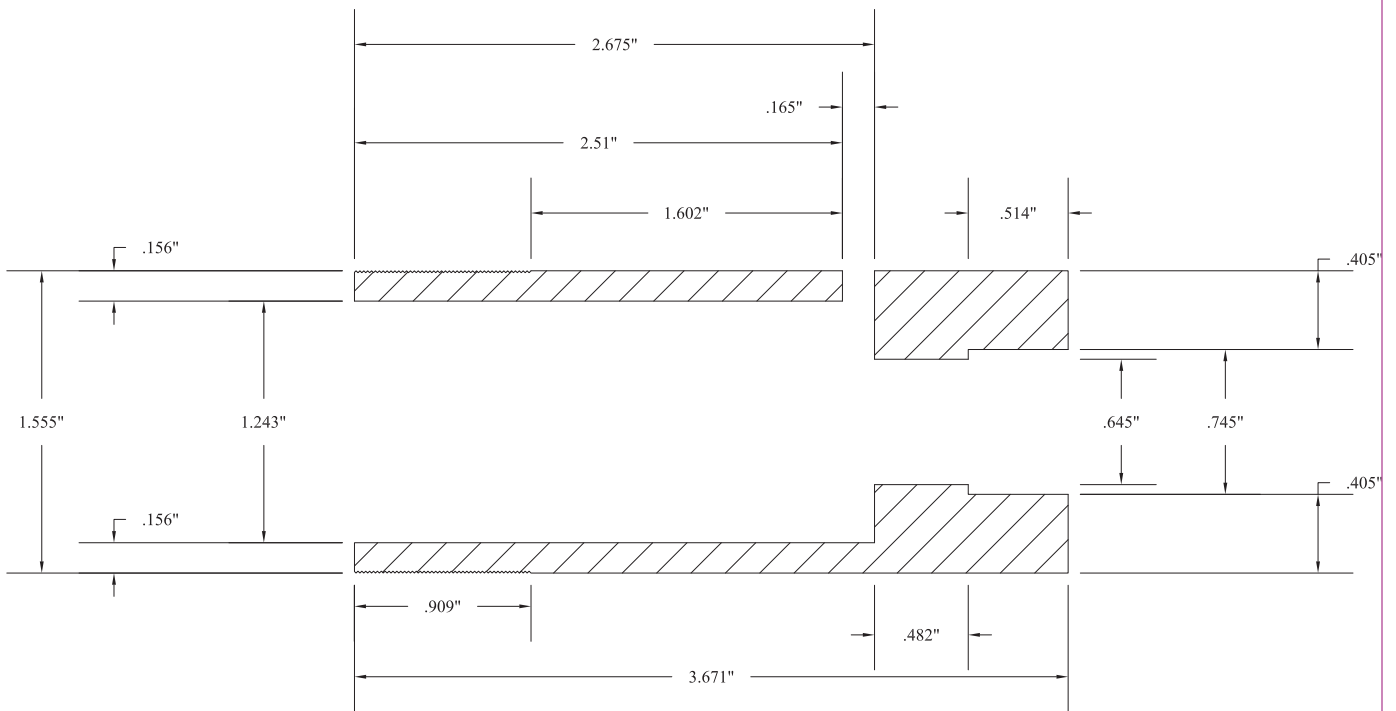
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HANDLE (04) SECTION



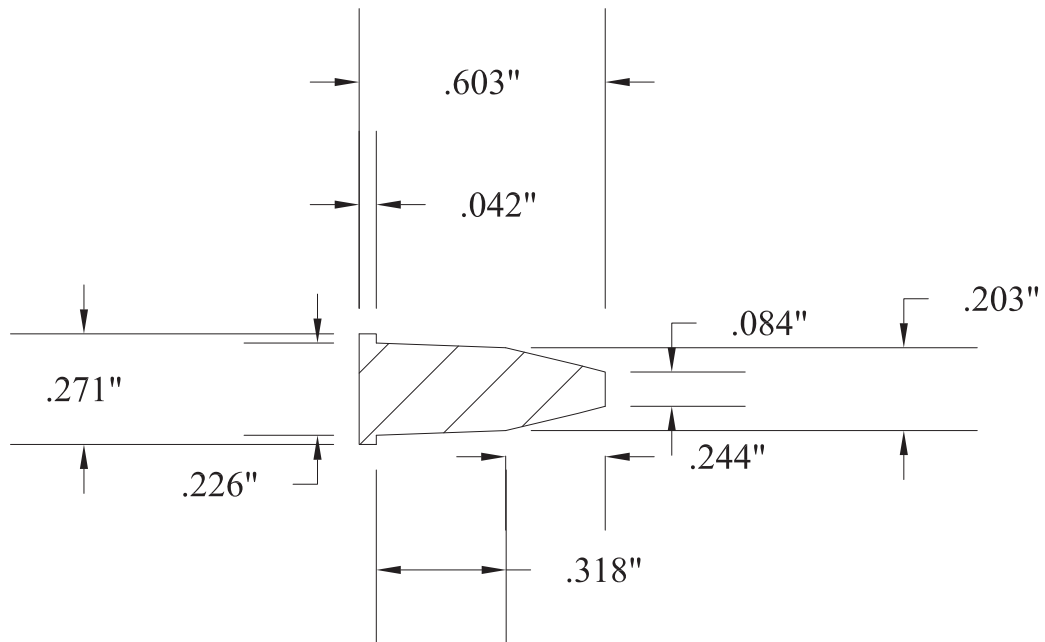
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CASING (05) SECTION



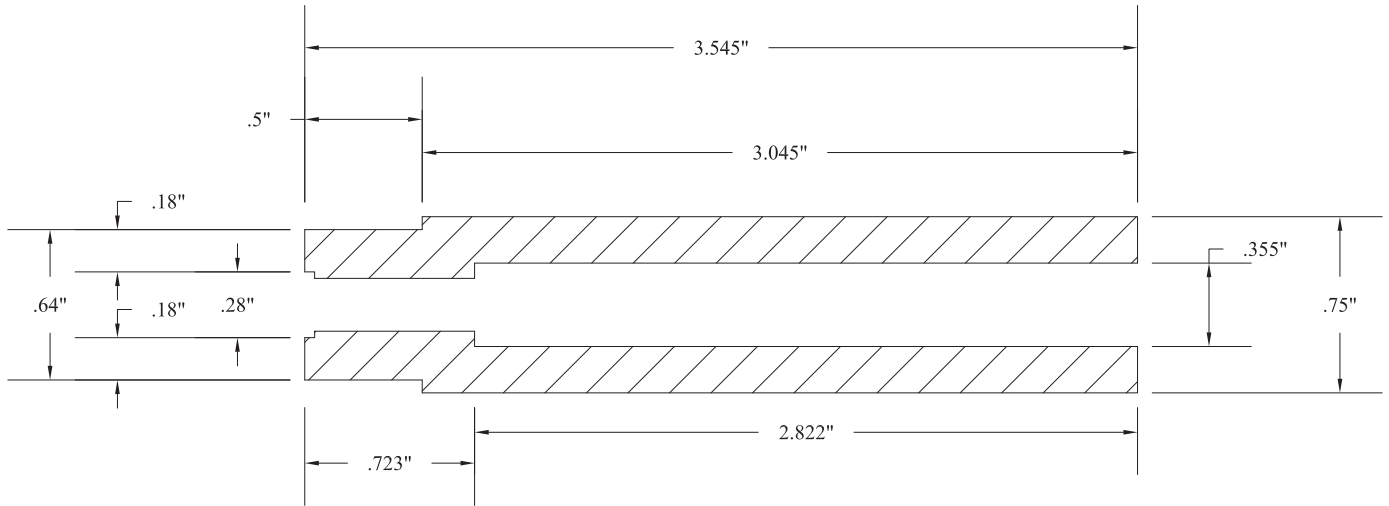
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CARTRIDGE (06) SECTION



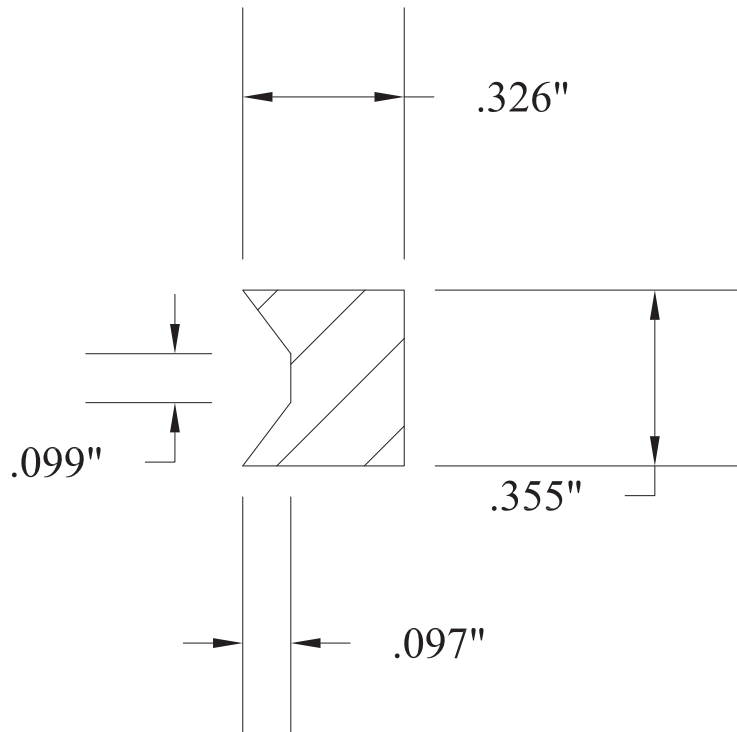
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BARREL (07) SECTION



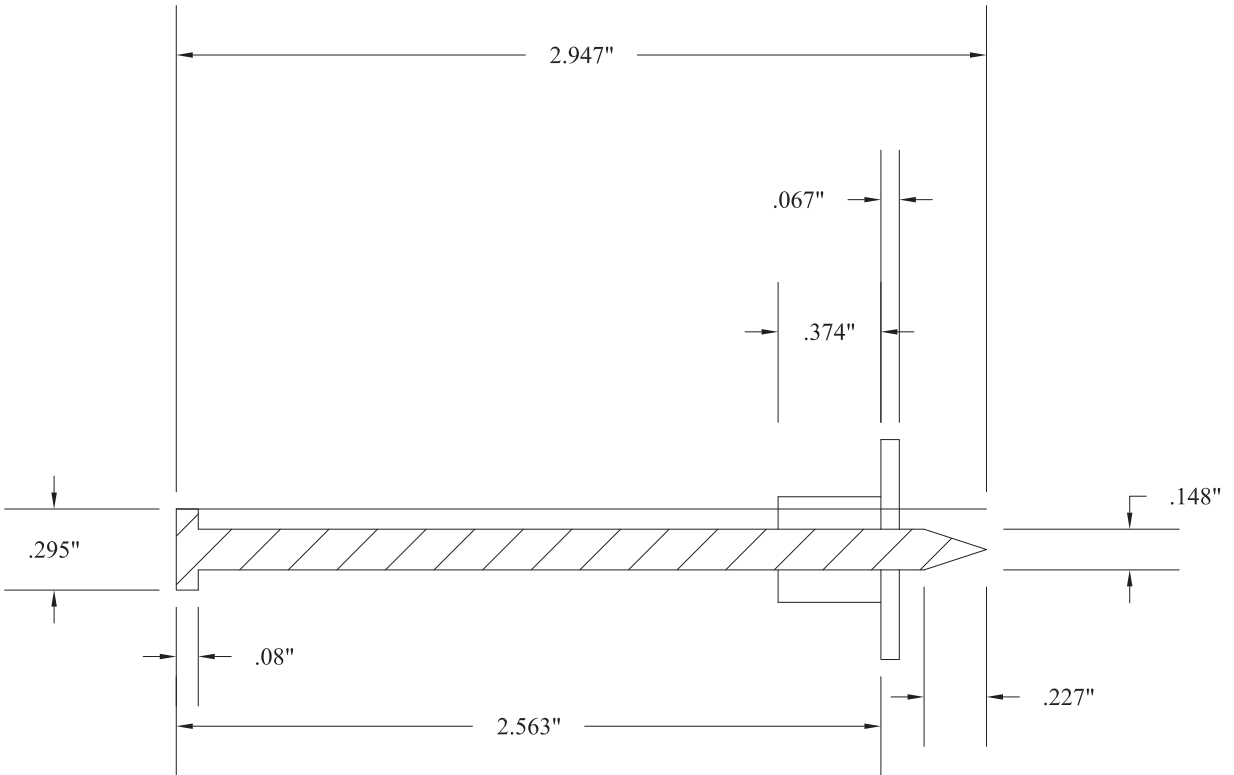
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WAD (08) SECTION



t

NAIL (09) SECTION



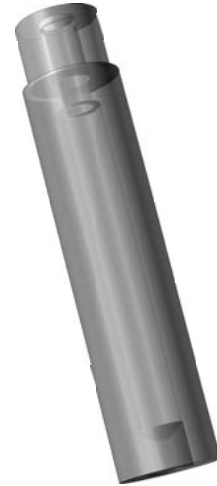
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Tool Operation

1. Insert Wad (hole-side up) into bottom of Barrel.



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w

2. Insert Nail Head into bottom of Barrel, pushing Wad until Nail Washer is flush with bottom of Barrel.



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y

3. Load Cartridge into top of Barrel.

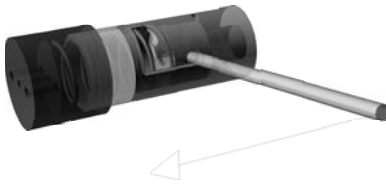


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aa

4. Pull Handle back and put in Safe position.



bb



cc



dd

5. Insert top of Barrel into bottom of Casing.

*Warning: Keep Handle in Safe Position.

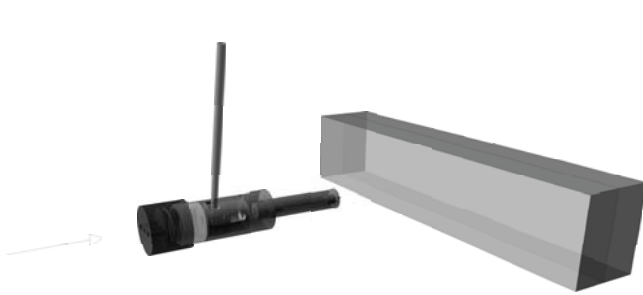


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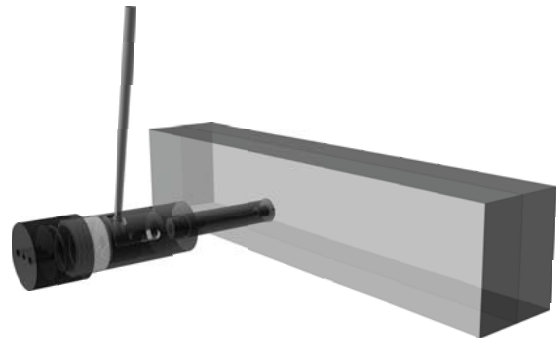


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6. Press loaded Nail Gun into material, Nail first.

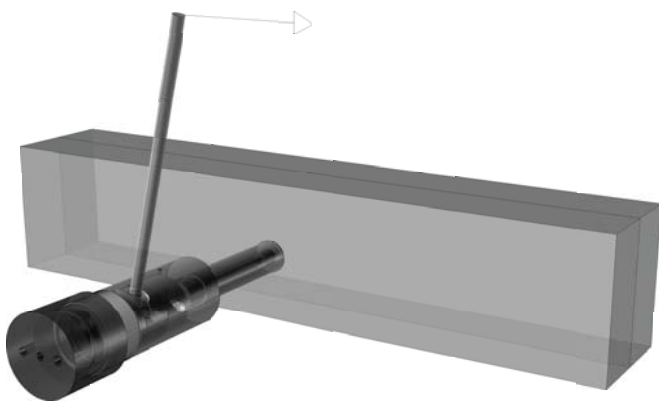


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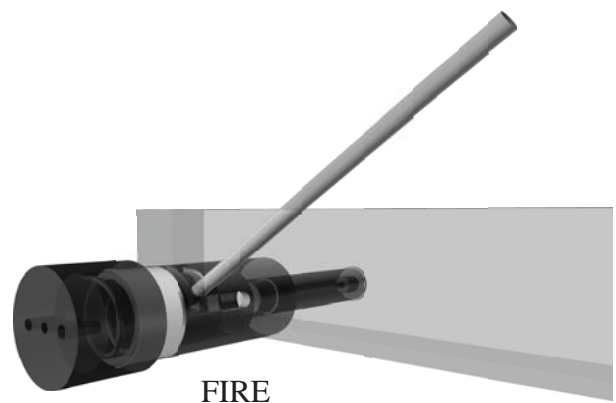


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7. While holding Nail Gun against material, put handle in Fire Position.



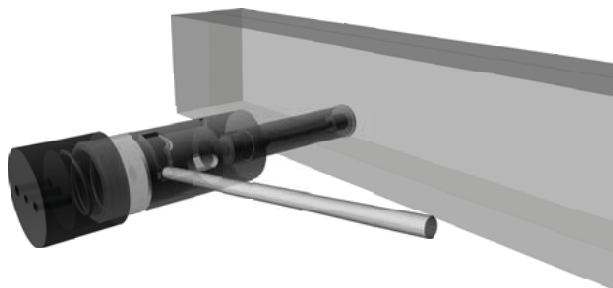
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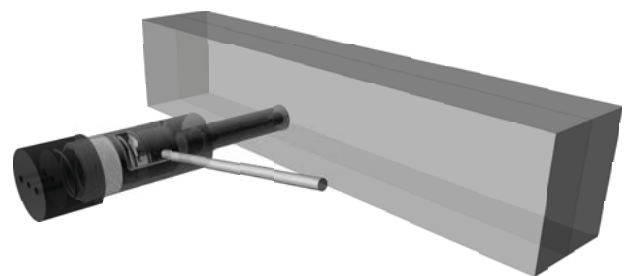
FIRE
POSITION

jj

8. Release Handle with thumb while continuing to hold Nail Gun firmly against material.

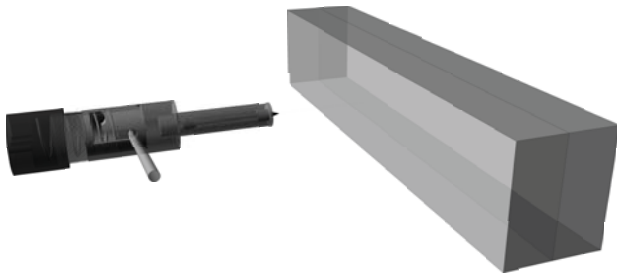


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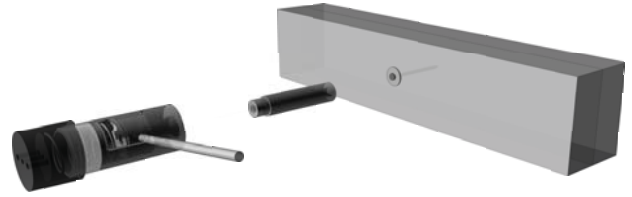


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9. Take Nail Gun off of material and remove Barrel from Casing.



mm



nn

10. Remove empty Cartridge from Barrel.



oo



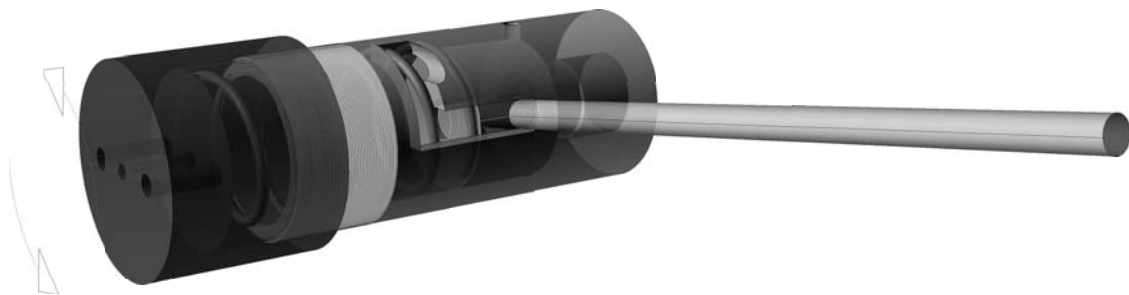
pp

Maintenance

The CNG7 must be kept dry to avoid rust and corrosion. The inside of the Casing must be oiled periodically. This will protect the Casing from rust and corrosion, as well as reduce friction between the Casing and Firing Pin. Keep all threads free from debris. Instructions to disassemble the CNG7 are listed below.

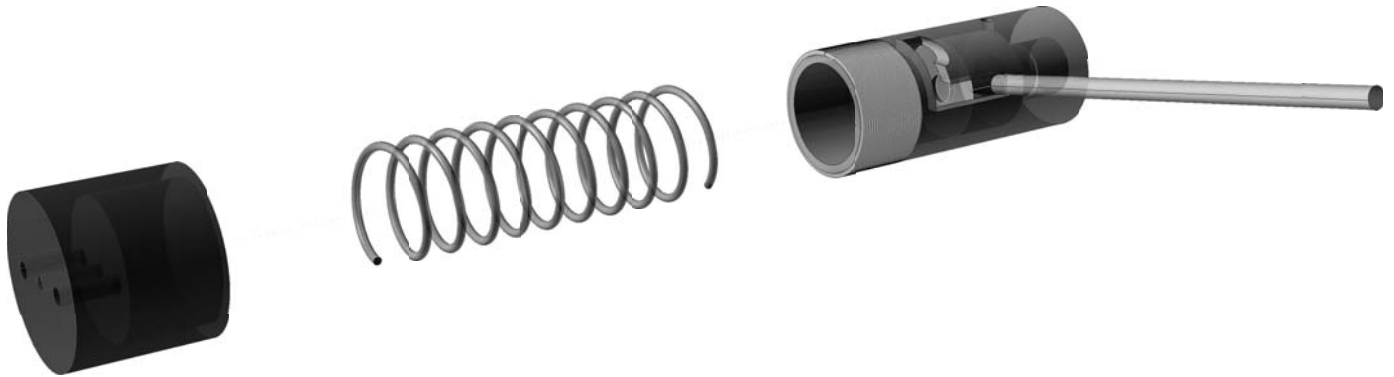
Disassembly

1. Unscrew End Cap by turning counterclockwise. Apply pressure on Cap end to keep Spring compressed.



99

2. Remove End Cap and Spring.



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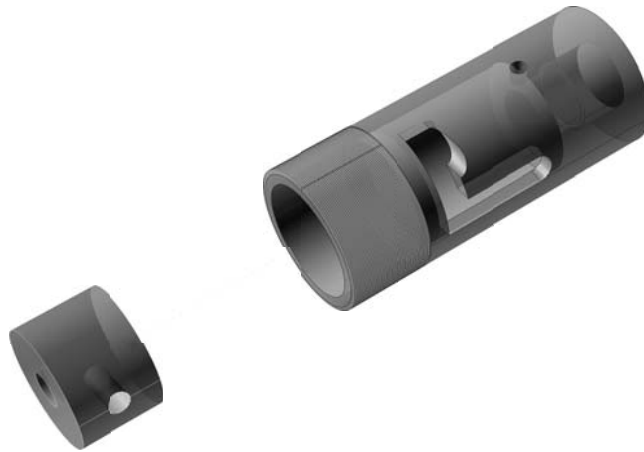
3. Unscrew Handle from Firing Pin by turning counterclockwise.



ss

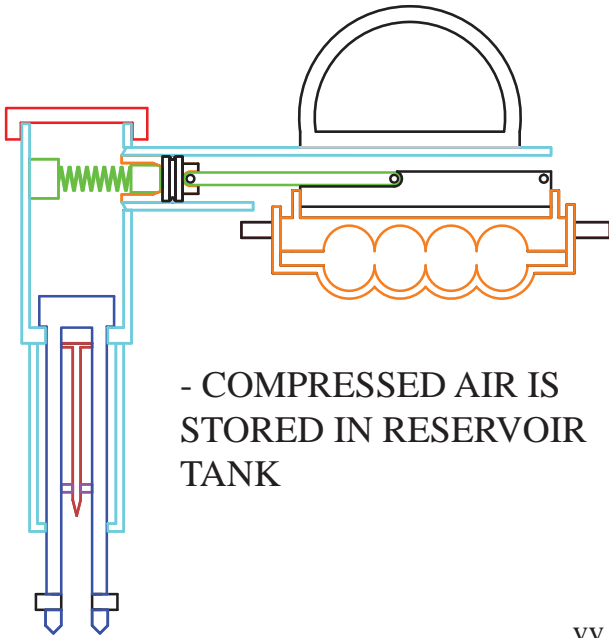
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4. Turn Casing up and let Firing Pin slide out.



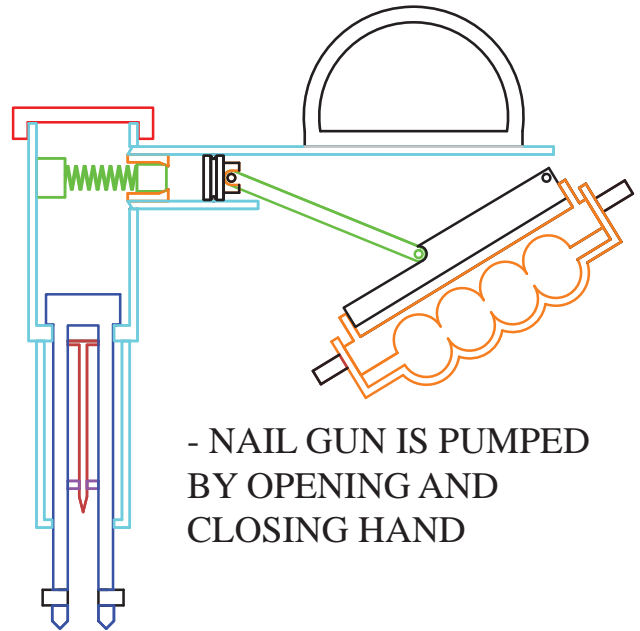
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Original Design



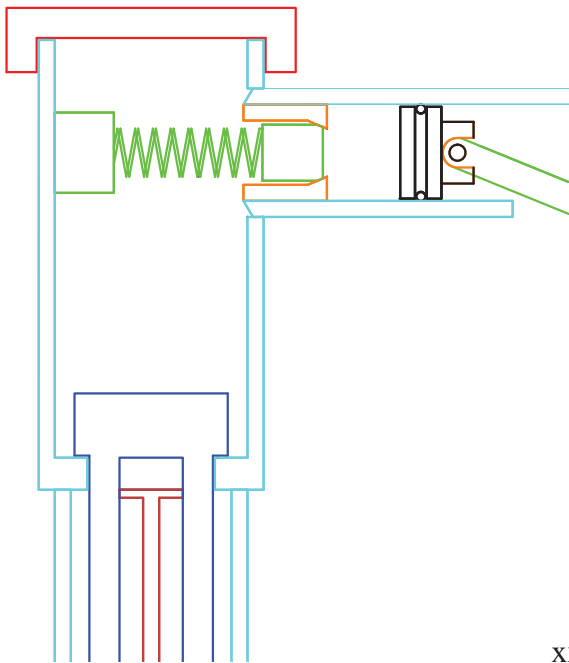
- COMPRESSED AIR IS STORED IN RESERVOIR TANK

vv



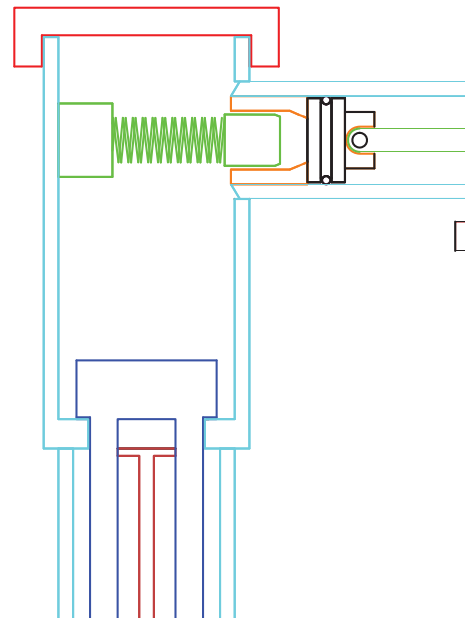
- NAIL GUN IS PUMPED BY OPENING AND CLOSING HAND

ww



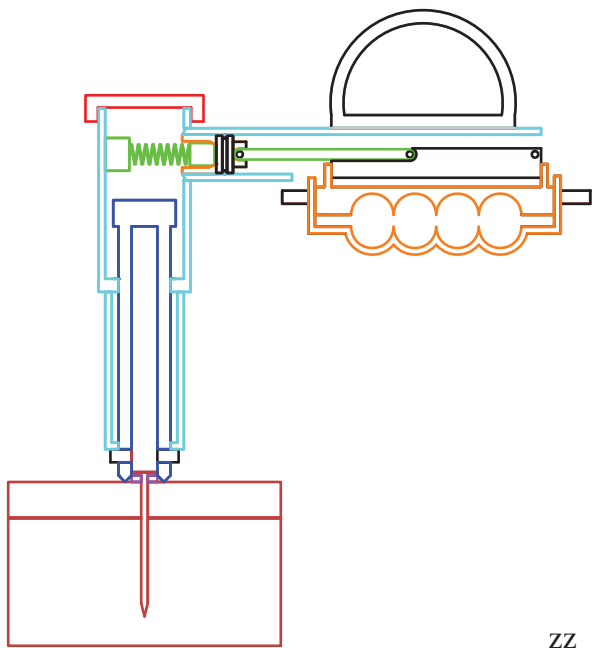
- HAND IS OPENED
- VALVE IS CLOSED
- TANK IS SEALED
- AIR IS INTRODUCED THROUGH 2ND VALVE (NOT SHOWN)

xx



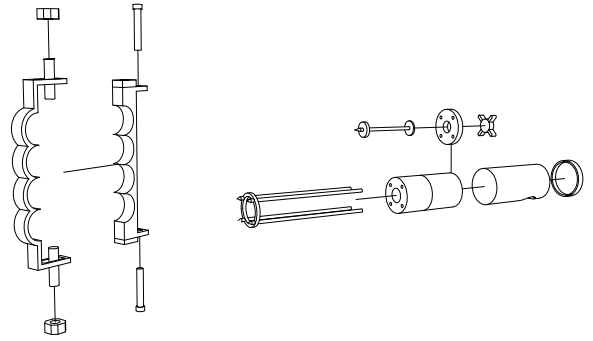
- HAND CLOSES
- 2ND VALVE CLOSES
- 1ST VALVE OPENS
- TANK FILLS WITH COMPRESSED AIR
- PRESSURE SEALS GASKET ABOVE NAIL

yy



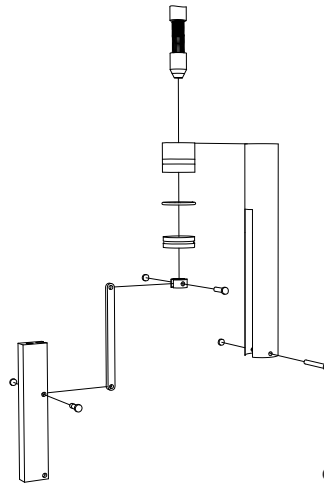
- GASKET IS OPENED
- COMPRESSED AIR IS RELEASED
- NAIL IS DRIVEN THROUGH WOOD

ZZ

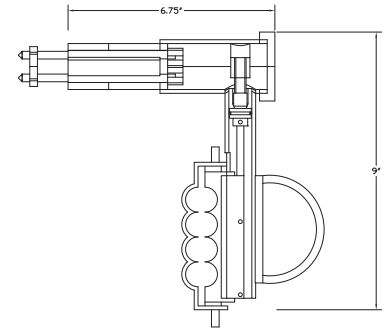


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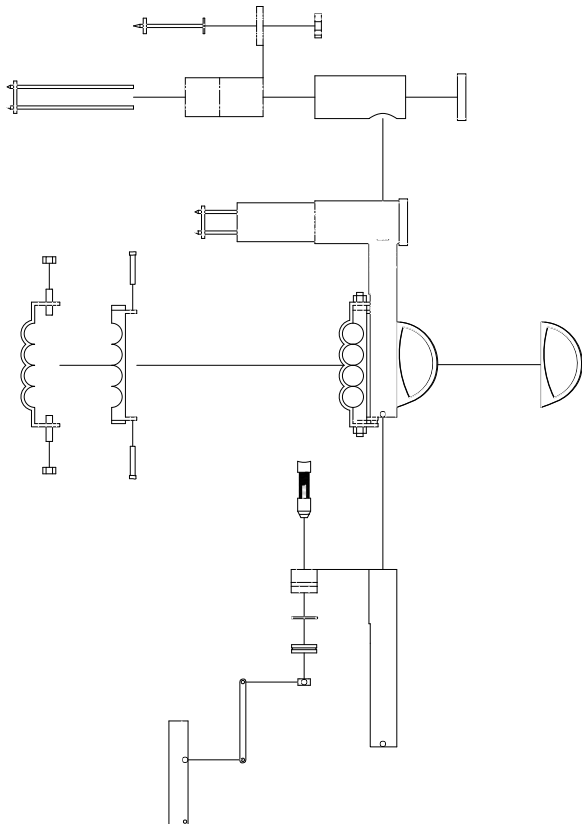
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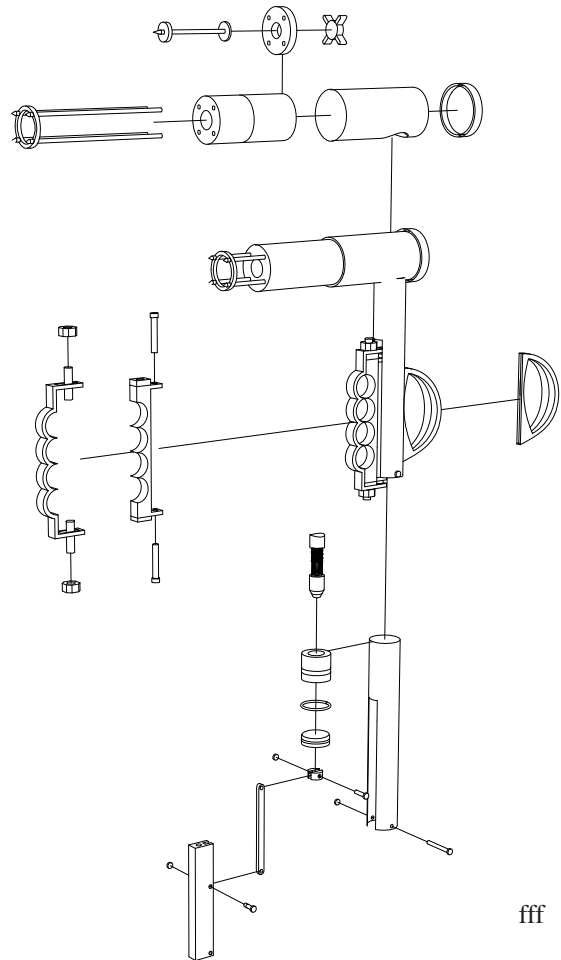
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fff

Problems with Original Design

- Too many pumps to fill tank with the required volume of air
- Too many parts (maintenance)
- Friction between gasket and inside of pipe (requires excessive force)
- Friction of air was not accounted for
- Inside of barrel must be machined smooth (added cost and manufacturing)
- Fatigue stress was not calculated for gasket or spring
- Gasket must be custom-made to withstand tank pressure
- Heat caused by friction will significantly change diameters of gasket and pipe
- Nails must be loaded singly and pumped for each nail
- Recoil causes moment that exceeds wrist strength
- Handle can pinch hand

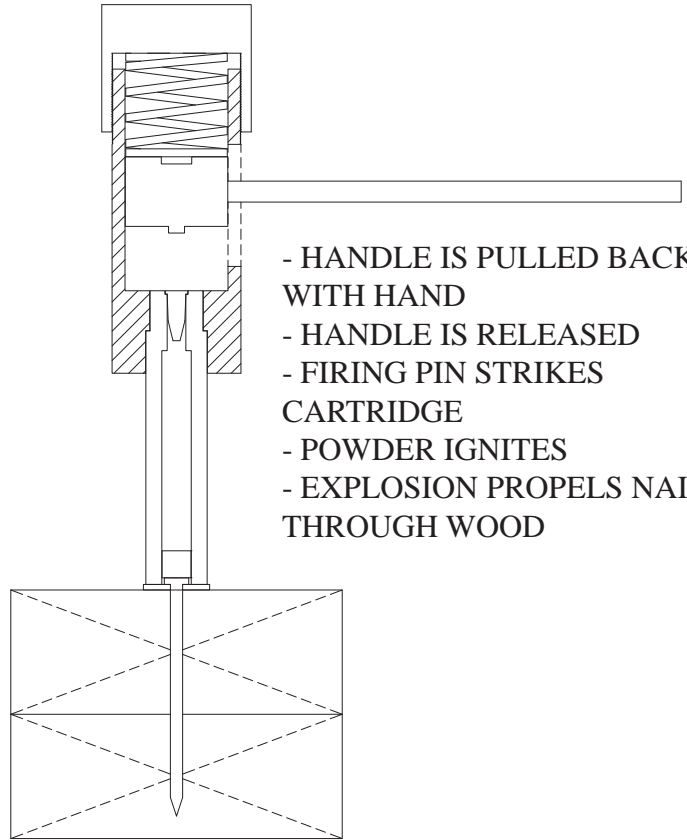
Final Design



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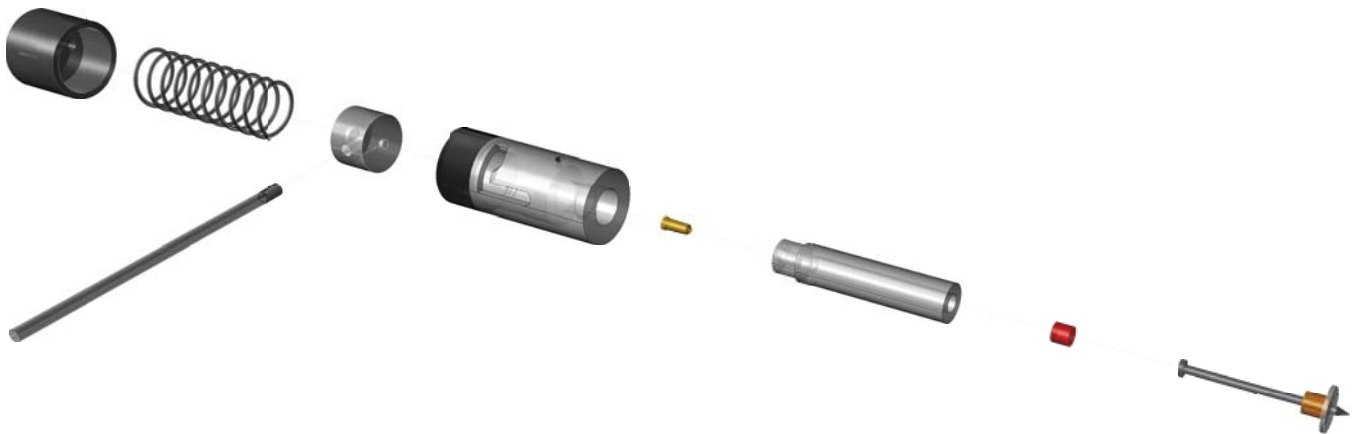


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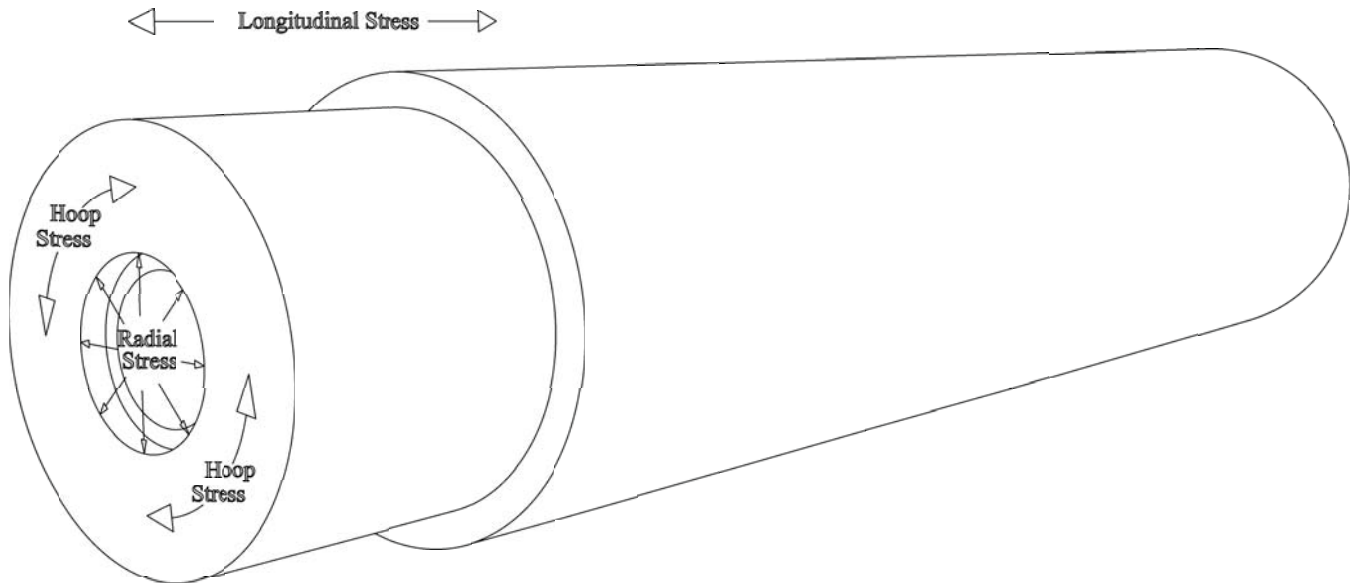
- HANDLE IS PULLED BACK WITH HAND
- HANDLE IS RELEASED
- FIRING PIN STRIKES CARTRIDGE
- POWDER IGNITES
- EXPLOSION PROPELS NAIL THROUGH WOOD

iii



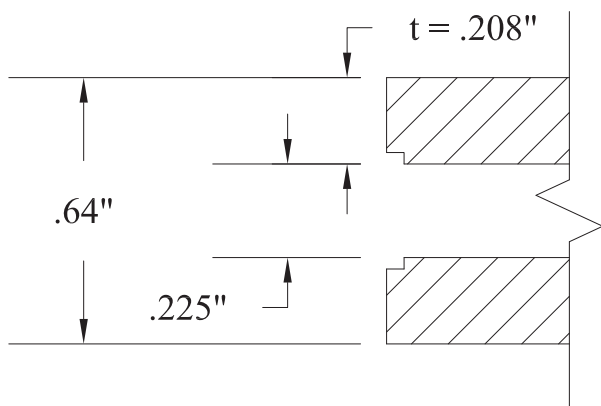
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Stress Calculations



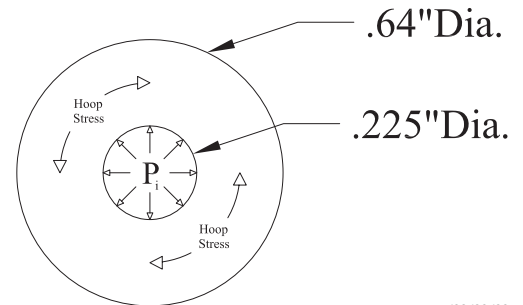
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RIGHT SECTION



lll

TOP SECTION



mmm

$$A = \text{Area} = (\pi/4)\text{Dia.}^2$$

$$A = (\pi/4).225\text{in.}^2$$

$$A = .0398\text{in.}^2$$

Thick-Walled Pressure Vessel

•Thick-Walled if: $\frac{radius}{thickness} \leq 10$



$$\frac{(.225"/2)}{.208"} = .541$$

mm

$$.541 \leq 10$$

Velocity

*V = Velocity (Yellow Cartridge)

$$V = 6900 \text{ in/sec}$$



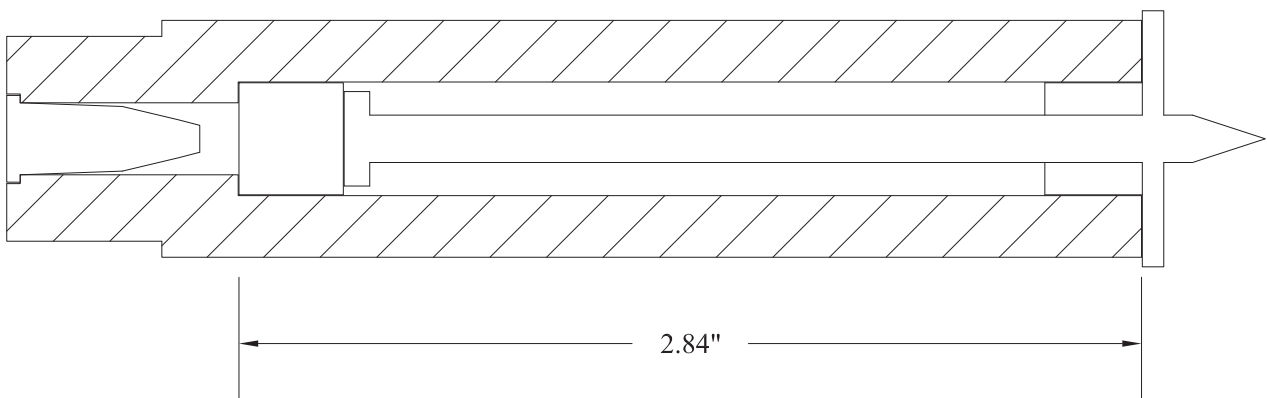
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$$V = \frac{\Delta x}{\Delta time}$$

*Δx = Displacement

$$6900 \text{ in/sec} = \frac{2.84"}{\Delta time}$$

$$\Delta time = 4.116 \times 10^{-4} \text{ sec}$$



PPP

$$A = \frac{\Delta velocity}{\Delta time}$$

*A = Acceleration

$$A = \frac{6900}{4.116 \times 10^{-4}}$$

$$A = 1.676 \times 10^7 \text{ in/sec}^2$$

$$F = M \times A$$

*F = Force(lb)

*M = Mass(nail)

$$F = (6.734 \times 10^{-5}) \times (1.676 \times 10^7)$$

$$F = 1128.927 \text{ lb}$$

$$P = \frac{\text{force}}{\text{area}}$$

*P = Pressure

$$P = \frac{1128.927}{.0398}$$

$$P = 28365 \text{ psi}$$

$$\text{Hoop Stress} = \frac{P(Ri^2)}{(Ro^2 - Ri^2)} \left(1 + \frac{Ro^2}{Ri^2}\right)$$

*P = Pressure(psi)

*Ri = Inner Radius(in)

*Ro = Outer Radius(in)

$$\text{Hoop Stress} = \frac{28365(.1125^2)}{.32^2 - .1125^2} \left(1 + \frac{.32^2}{.1125^2}\right)$$

$$\text{Hoop Stress} = 36365 \text{ psi}$$

- The yield strength of the barrel's steel must exceed the hoop stress of the barrel multiplied by a factor of safety

$$\begin{aligned} \text{Yield Strength 4140 steel} &> \text{F.S.} \times \text{Hoop Stress} \\ 60500\text{psi} &> 1.6 \times 36365\text{psi} \end{aligned}$$

$$60500\text{psi} > 58184\text{psi}$$

∴ **Barrel will withstand cartridge explosion**

*Hoop Stress controls over Radial Stress(28365psi) and Shear Stress(32365psi)

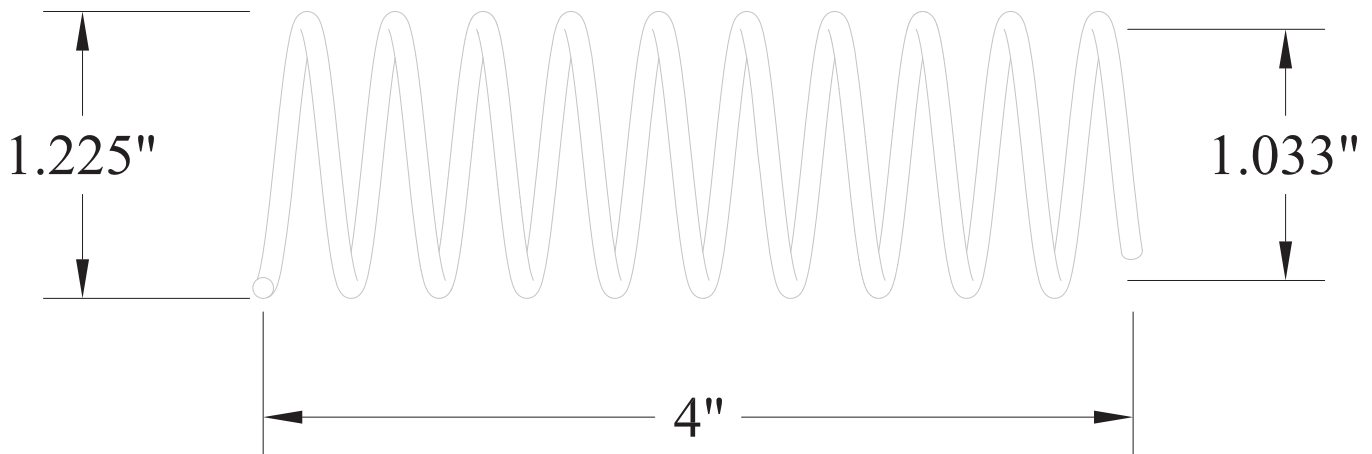
**Longitudinal Stress is negligible because barrel is open-ended

Spring Calculations

*Spring purchased from Century Spring Corporation

Spring chosen for Final Design:

CSC Stock #	72648
Free Length(in)	4
Rate(lbs/in)	11
Outside Diameter(in)	1.225
Inside Diameter(in)	1.033
Max Deflection(in)	3.1
Max Load(lb)	33
Solid Length(in)	0.95
Wire Diameter(in)	0.096
Total Coils	9.88
Material	Music Wire
Ends	Closed Ground
Finish	None



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PARAMETERS

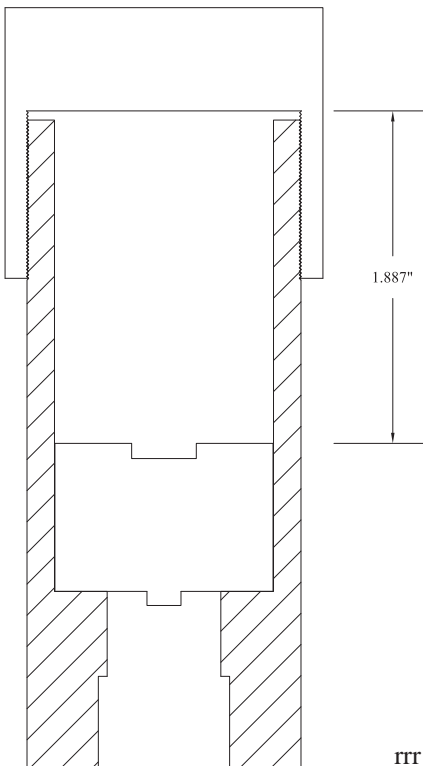
- Spring dimensions are defined by Casing/End Cap

•Solid Length $\leq 1.887''$
 $.95'' \leq 1.887''$

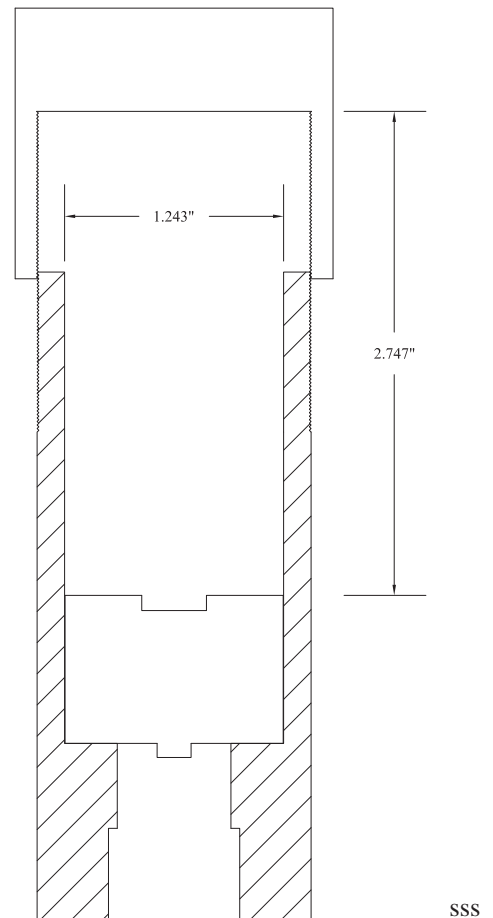
•Free Length $> 2.747''$
 $4.0'' > 2.747''$

•Outside Diameter $< 1.243''$
 $1.225'' < 1.243''$

Cap Closed
(Maxed Out)



Cap Open
(Maxed Out)



SPRING BUCKLING

No buckling if:

Free Length $< 5 \times$ Mean Diameter

$$4'' < 5 \times 1.129''$$

$$4'' < 5.645''$$

$$*\text{Mean Diameter} = \frac{(OD + ID)}{2}$$

$$1.129 = \frac{(1.225 + 1.033)}{2}$$

SPRING FORCE

Force required for Cartridge to discharge:

δ = Total Deflection(in)

δ = Free Length(in) – Minimum Working Length(in)

$$\delta = 4'' - 1.27''$$

$$\delta = 2.73''$$

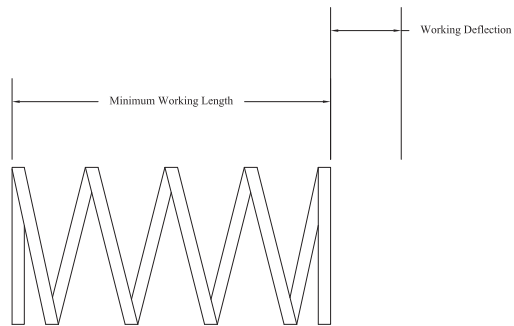
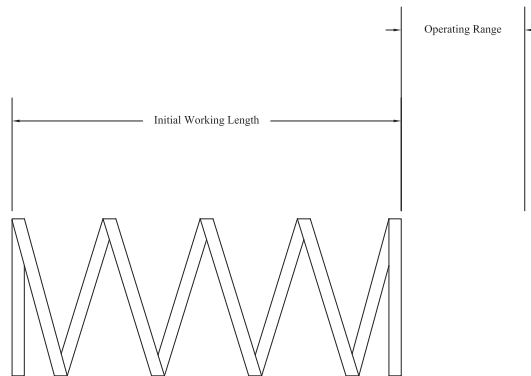
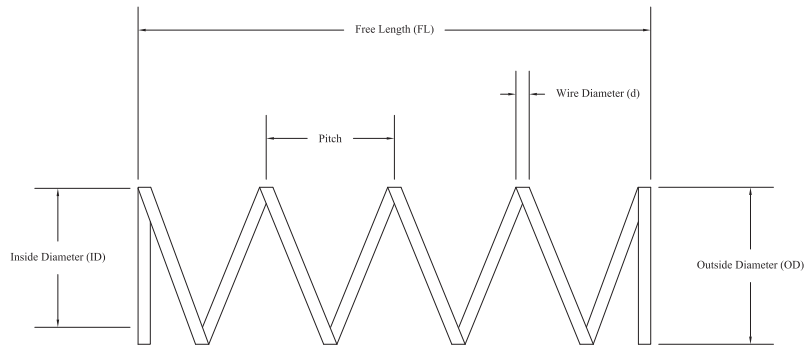
Firing Pin Force \approx 17 to 28lbs

* $\delta \times$ Spring Rate(lbs/in) $>$ 28lbs

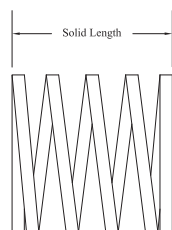
$$2.73'' \times 11 = 30.03\text{lbs} > 28\text{lbs}$$

* Firing Pin will cause Cartridge to discharge

GENERAL SPRING CONDITIONS

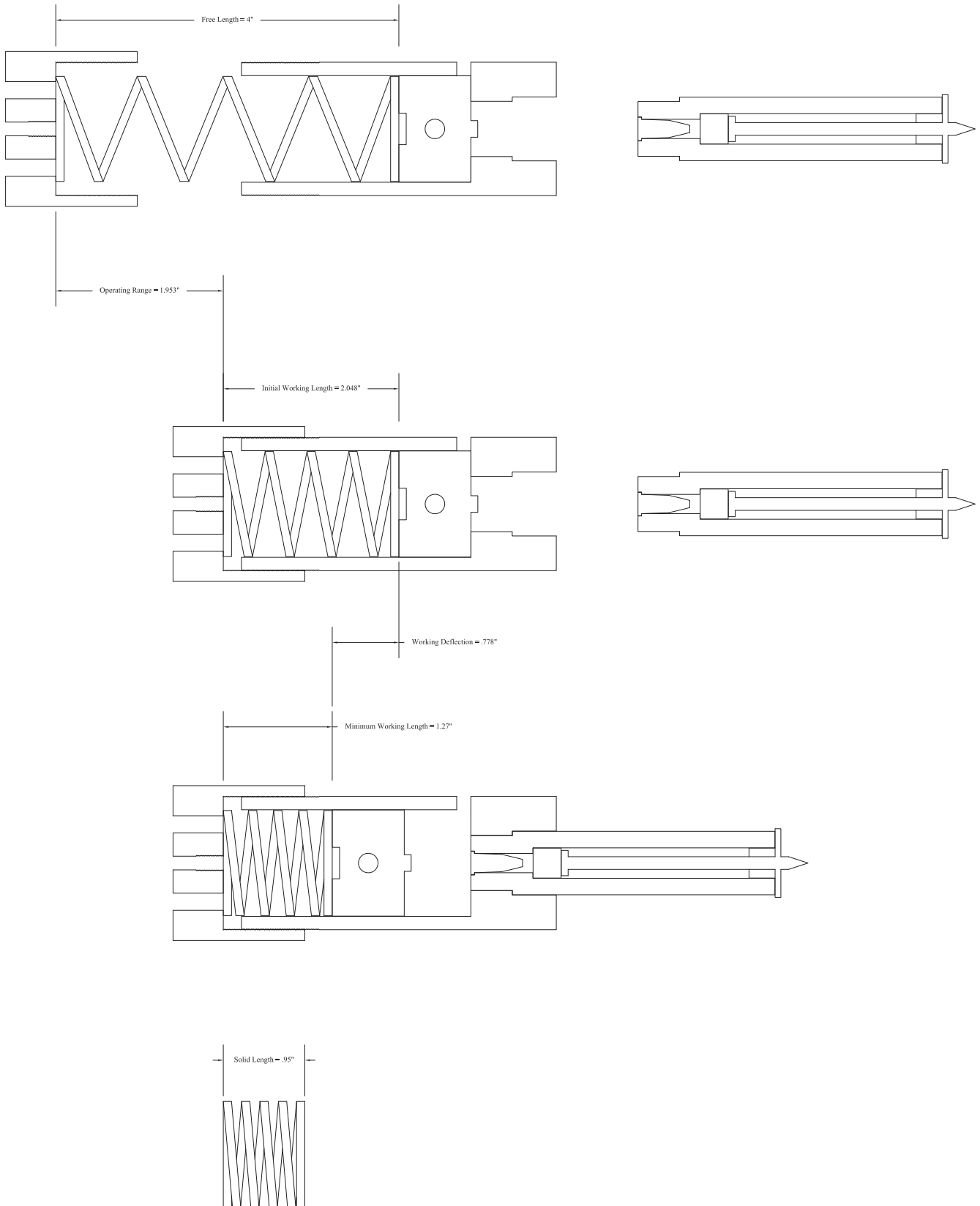


***For static load:**
Min. Working Length = Initial Working Length



tft

CHOSEN SPRING CONDITIONS



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SPRING DIAMETER

- The Spring OD becomes larger as the Spring compresses. The compressed Spring OD must fit inside of the Casing. The given Spring OD = 1.225” and the Casing ID = 1.243.”

n_{Active} = # of Active Coils

$n_{Active} = n_{Total} - 2$ *For Closed, Ground Ends

$n_{Active} = 9.88 - 2$

$n_{Active} = 7.88$

$p = \text{Pitch} = \frac{\text{FreeLength}}{n_{Active}}$

$p = \frac{4''}{7.88}$

$p = .508''$

$d = \text{Wire Diameter}$

$d = .096''$

$D = \text{Mean Diameter}$

$D = 1.129$ *Calculated on p. 28

$\Delta\text{Dia.}$ = Change in Diameter

$$\Delta\text{Dia.} = \frac{.05(p^2 - d^2)}{D}$$

$$\Delta\text{Dia.} = \frac{.05(.508^2 - .096^2)}{1.129}$$

$$\Delta\text{Dia.} = .011''$$

∗ The Spring OD becomes .011'' larger when compressed

$$\text{Compressed Spring OD} = \Delta\text{Dia.} + \text{Spring OD}$$

$$\text{Compressed Spring OD} = .011'' + 1.225''$$

$$\text{Compressed Spring OD} = 1.236''$$

$$\text{Compressed Spring OD} < 1.243''$$

$$1.236'' < 1.243''$$

∗ The Spring will fit inside Casing when compressed

Problems with Final Design

- Thick-Walled Pressure Vessel is inefficient in this case. Calculations for Thin-Walled Pressure Vessels are more precise and faster to calculate
- Connection between Barrel and Trigger Casing is weak. Barrel needs to expand from heat but must stay loose to remove.
- Nail/Wad friction down entire length of Barrel is ignored
- Nail Gun is not self-contained (Powder Cartridge must be introduced)
- Nail, Cartridge, and Wad must be loaded by hand each time
- Empty Cartridge must be removed each time
- Empty Cartridge is hard to remove after expanding
- Steel barrel will rust/corrode
- Fatigue stress was not calculated
- Nail Gun is illegal in US (must have a piston between cartridge and nail/wad)
- Brittleness was not calculated for Barrel or Firing Pin
- Wad needs to be manufactured
- Spring and Firing Pin are inefficient due to the weight of the pin and spring rate

Appendix A

PHOTOGRAPHS

<i>PHOTOGRAPH</i>	<i>LOCATION</i>
a. Overall CNG7 1	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
b. CNG7 Between Studs 1	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
c. CNG7 Between Studs 2	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
d. CNG7 Between Studs 3	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
e. DeWalt Between Studs 1	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
f. DeWalt Between Studs 2	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
g. DeWalt Between Studs 3	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
ggg. Overall CNG7 2	Bishop-Favrao Hall Wood Shop, Blacksburg, VA
hhh. Exploded CNG7	Bishop-Favrao Hall Wood Shop, Blacksburg, VA

WEBSITE IMAGES

<i>IMAGE</i>	<i>Source</i>
i.	Lowe's. DEWALT 3.5-in x .131in Roundhead Framing Pneumatic Nail Gun. Digital Image. Lowe's, n.d. Web. 05 Dec. 2014.
j.	Lowe's. Paslode 7.2-Volt Cordless Nail Gun. Digital Image. Lowe's, n.d. Web. 05 Dec. 2014.
k.	Home Depot. Hammer Shot 0.22 Caliber Single Shot Tool. Digital Image. Home Depot, n.d. Web. 05 Dec. 2014.
ooo.	Home Depot. 0.22 Caliber Yellow Single Shot Powder Loads. Digital Image. Home Depot, n.d. Web. 05 Dec. 2014

DIGITAL IMAGES

<i>IMAGE</i>	<i>SOURCE</i>
h. Overall Section with Dimensions	AutoCAD 2015
h-a. Exploded View with Descriptions	Rhinoceros 4.0
m. End Cap Section	AutoCAD 2015
n. Spring Section 1	AutoCAD 2015
o. Firing Pin Section	AutoCAD 2015
p. Handle Section	AutoCAD 2015
q. Casing Section	AutoCAD 2015
r. Cartridge Section	AutoCAD 2015
s. Barrel Section 1	AutoCAD 2015
t. Wad Section	AutoCAD 2015
u. Nail Section	AutoCAD 2015

Appendix B

DIGITAL IMAGES

<i>IMAGE</i>	<i>SOURCE</i>
v. Barrel/Wad	Rhinoceros 4.0
w. Barrel	Rhinoceros 4.0
x. Barrel/Nail Outside	Rhinoceros 4.0
y. Barrel/Nail Inside	Rhinoceros 4.0
z. Barrel/Cartridge Outside	Rhinoceros 4.0
aa. Barrel/Cartridge Inside	Rhinoceros 4.0
bb. Casing/Handle 1	Rhinoceros 4.0
cc. Casing/Handle 2	Rhinoceros 4.0
dd. Casing/Handle Safe Position	Rhinoceros 4.0
ee. Casing/Barrel Outside	Rhinoceros 4.0
ff. Casing/Barrel Inside	Rhinoceros 4.0
gg. Nail/Material 1	Rhinoceros 4.0
hh. Nail/Material 2	Rhinoceros 4.0
ii. Nail/Material 3	Rhinoceros 4.0
jj. Nail/Material 4	Rhinoceros 4.0
kk. Nail/Material 5	Rhinoceros 4.0
ll. Nail/Material 6	Rhinoceros 4.0
mm. Nail/Material 7	Rhinoceros 4.0
nn. Nail/Material 8	Rhinoceros 4.0
oo. Cartridge Inside Barrel	Rhinoceros 4.0
pp. Cartridge Outside Barrel	Rhinoceros 4.0
qq. End Cap CCW	Rhinoceros 4.0
rr. End Cap/Spring	Rhinoceros 4.0
ss. Handle Unscrew	Rhinoceros 4.0
tt. Handle Outside Casing	Rhinoceros 4.0
uu. Casing/Firing Pin	Rhinoceros 4.0
vv. Original Design 1	AutoCAD 2015
ww. Original Design 2	AutoCAD 2015
xx. Original Design 3	AutoCAD 2015
yy. Original Design 4	AutoCAD 2015
zz. Original Design 5	AutoCAD 2015
aaa. Original Grip	Rhinoceros 4.0
bbb. Original Barrel	Rhinoceros 4.0
ccc. Original Handle	Rhinoceros 4.0
ddd. Original Overall with Dimensions	Rhinoceros 4.0
eee. Original Exploded	Rhinoceros 4.0
fff. Original Exploded Perspective	Rhinoceros 4.0
iii. Overall Section with Wood	AutoCAD 2015
jjj. Exploded Perspective	Rhinoceros 4.0
kkk. Barrel with Stress	Rhinoceros 4.0
lll. Right Section	AutoCAD 2015
mmm. Top Section	AutoCAD 2015
nnn. Barrel Perspective	Rhinoceros 4.0

Appendix C

DIGITAL IMAGES

IMAGE

ppp. Barrel Section 2
qqq. Spring Section 2
rrr. Cap Closed
sss. Cap Open
ttt. General Spring Conditions
uuu. Chosen Spring Conditions

SOURCE

AutoCAD 2015
AutoCAD 2015
AutoCAD 2015
AutoCAD 2015
AutoCAD 2015
AutoCAD 2015