CNG 7 Consolidated Nail Gun

Christopher Daniel DeSantis

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In

Architecture

Hans Rott
Mario Cortes
William Green

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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
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.

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:
Chris DeSantis
609 North Main St. Apt. #3
Blacksburg, VA 24060
chrisd10@vt.edu
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

- No hoses, air compressor, or electric required
  - Pneumatic Nail Guns require an air hose, compressor, and electric

- 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

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

END CAP (01) SECTION

SPRING (02) SECTION
FIRING PIN (03) SECTION

HANDLE (04) SECTION
BARREL (07) SECTION

WAD (08) SECTION
NAIL (09) SECTION

2.947"

.067"

.374"

.295"

.08"

2.563"

.148"

.227"
**Tool Operation**

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

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

4. Pull Handle back and put in Safe position.

5. Insert top of Barrel into bottom of Casing.
*Warning: Keep Handle in Safe Position.
6. Press loaded Nail Gun into material, Nail first.

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

8. Release Handle with thumb while continuing to hold Nail Gun firmly against material.
9. Take Nail Gun off of material and remove Barrel from Casing.

10. Remove empty Cartridge from Barrel.
**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.
2. Remove End Cap and Spring.

3. Unscrew Handle from Firing Pin by turning counterclockwise.
4. Turn Casing up and let Firing Pin slide out.
Original Design

- COMPRESSED AIR IS STORED IN RESERVOIR TANK

- NAIL GUN IS PUMPED BY OPENING AND CLOSING HAND

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

- HAND CLOSES
- 2ND VALVE CLOSES
- 1ST VALVE OPENS
- TANK FILLS WITH COMPRESSED AIR
- PRESSURE SEALS GASKET ABOVE NAIL
- GASKET IS OPENED
- COMPRESSED AIR IS RELEASED
- NAIL IS DRIVEN THROUGH WOOD
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

- Handle is pulled back with hand
- Handle is released
- Firing pin strikes cartridge
- Powder ignites
- Explosion propels nail through wood
Stress Calculations

**RIGHT SECTION**

- $t = 0.208''$
- $0.64''$
- $0.225''$

**TOP SECTION**

- $0.64''$ Dia.
- $0.225''$ Dia.

\[
A = \text{Area} = \frac{\pi}{4} \text{Dia.}^2
\]

\[
A = \frac{\pi}{4} \cdot 0.225''^2
\]

\[
A = 0.0398''^2
\]
Thick-Walled Pressure Vessel

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

\[
\frac{(0.225''/2)}{0.208''} = 0.541
\]

\[
0.541 \leq 10
\]

Velocity

\( V = \frac{\Delta x}{\Delta time} \)

\( *V = \text{Velocity (Yellow Cartridge)} \)

\( V = 6900 \text{ in/sec} \)

\( 6900 \text{ in/sec} = \frac{2.84''}{\Delta time} \)

\( \Delta time = 4.116 \times 10^{-4} \text{ sec} \)
A = \frac{\Delta velocity}{\Delta time} \quad *A = \text{Acceleration}

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

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

F = M \times A \quad *F = \text{Force(lb)}
* M = \text{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}} \quad *P = \text{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) \quad *P = \text{Pressure( psi)}
*Ri = \text{Inner Radius(in)}
*Ro = \text{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

Yield Strength 4140 steel > F.S. × Hoop Stress
60500psi > 1.6 × 36365psi

60500psi > 58184psi

• **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
PARAMETERS

- Spring dimensions are defined by Casing/End Cap

  • Solid Length ≤ 1.887”
    .95” ≤ 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)

1.887”          2.740”
SPRING BUCKLING

No buckling if:

Free Length < 5 × Mean Diameter
4” < 5 × 1.129”
4” < 5.645”

*Mean Diameter = \( \frac{OD + ID}{2} \)
1.129 = \( \frac{(1.225+1.033)}{2} \)

SPRING FORCE

Force required for Cartridge to discharge:

\( \delta = \text{Total Deflection(in)} \)
\( \delta = \text{Free Length(in)} - \text{Minimum Working Length(in)} \)
\( \delta = 4” - 1.27” \)
\( \delta = 2.73” \)

Firing Pin Force ≈ 17 to 28lbs
\( \delta \times \text{Spring Rate(lbs/in)} > 28lbs \)
2.73” × 11 = 30.03lbs > 28lbs

Firing Pin will cause Cartridge to discharge
*For static load:
Min. Working Length = Initial Working Length
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.”

\[ n_{Active} = \# \text{ of Active Coils} \]

\[ n_{Active} = n_{Total} - 2 \quad *\text{For Closed, Ground Ends} \]

\[ n_{Active} = 9.88 - 2 \]

\[ n_{Active} = 7.88 \]

\[ p = \text{Pitch} = \frac{\text{FreeLength}}{n_{Active}} \]

\[ p = \frac{4”}{7.88} \]

\[ p = .508” \]

\[ d = \text{Wire Diameter} \]
\[ d = .096” \]

\[ D = \text{Mean Diameter} \]
\[ D = 1.129 \quad *\text{Calculated on p. 28} \]
\[ \Delta \text{Dia.} = \text{Change in Diameter} \]

\[ \Delta \text{Dia.} = \frac{0.05(p^2 - d^2)}{D} \]

\[ \Delta \text{Dia.} = \frac{0.05(0.508^2 - 0.096^2)}{1.129} \]

\[ \Delta \text{Dia.} = 0.011" \]

* The Spring OD becomes .011” larger when compressed

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

Compressed Spring OD = .011” + 1.225”

Compressed Spring OD = 1.236”

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

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<tr>
<td>b. CNG7 Between Studs 1</td>
<td>Bishop-Favrao Hall Wood Shop, Blacksburg, VA</td>
</tr>
<tr>
<td>c. CNG7 Between Studs 2</td>
<td>Bishop-Favrao Hall Wood Shop, Blacksburg, VA</td>
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<tr>
<td>d. CNG7 Between Studs 3</td>
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<td>ggg. Overall CNG7 2</td>
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<td>hhh. Exploded CNG7</td>
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### Website Images

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<td>AutoCAD 2015</td>
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**DIGITAL IMAGES**

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<td>v. Barrel/Wad</td>
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<td>ii. Nail/Material 3</td>
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<td>jj. Nail/Material 4</td>
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### DIGITAL IMAGES

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<td>rrr. Cap Closed</td>
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