Automated Barrel Cleaner

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Introduction – Issue at Hand

- Barrels in industry are reused or unethically dumped
- Effective cleaning methods are costly
- If under-cleaned barrels are re-used
  – “under-cleaning” is hazardous to employees
  – Potential chemical contamination
• AG Industrial (AGI - Oglesby, IL) works with detergents and similar industrial chemicals
  – Current barrel-cleaning process (right)
  – One example of an industry quick-fix
• Barrels are maneuvered around human-operated, rigidly mounted pressure washer head
  – Minimal barrel cleaning coverage
  – Potential hazard to operator
Introduction – Cause/Effect at AGI

• Stationary washer head offers insufficient cleaning capabilities
  – Combatted with “soaking” 15-25min
  – Washer: 2.5GPM Volumetric flow rate
  – Can sometimes be up to 75 Gal of Water
• Washer is ground-level, directed upward
  – Operator must stand nearby to maneuver the barrel before/after soaking process
  – 3000psi at pressure washer’s fanned tip
  – Impact to face at 5 feet is very hazardous
Design Specifications – Goals

• Increase barrel-cleaning capability
• Remove company liability due to human error
• Decrease cycle time via eliminating “soaking”
• Improve employee work environment
• Capability to clean open and closed faced barrels
Design Specifications – Cleaning

• Increase barrel-cleaning capability
  – “Soaking” uses splashes and drips to reach otherwise unreachable areas
  – Design a head to clean more effectively than the soaking process
Design Specifications – Liability

• Makeshift systems introduce safety issues
  – Automate the cleaning process to remove human error
  – Less employee time spent around a moderately dangerous cleaning force
Design Specifications – Cycle Time

• Cycle time is largely dependent on soaking
  – Optimize cleaning time and effectiveness of new process

• Cycle time is directly related to cleaning cost
  – Reduce overall cycle time to reduce cost of cleaning
Design Specifications – Workplace

• Makeshift methods provide an unhealthy work environment for employees causing them to:
  – Fear their work, provoking more danger through lack of confidence
  – Suffer exposure to barrel contents and cleaning materials
  – Undergo rigorous barrel-maneuvering cleaning methods

• Automation of pressure washer head eliminates these issues
## Design Process – Timeline Summary

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Task</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
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<tbody>
<tr>
<td>Design Prototype</td>
<td>Brian</td>
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<td>Build Prototype</td>
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<td>Design Controller</td>
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<td>Test and Troubleshoot Prototype</td>
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<td>Validate and Optimize System</td>
<td>Brian</td>
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</table>
• Gamajet DB is the most widely used alternative and is not cheap (~$1250)
  – Costly vacuum pump is required in addition to the Gamajet to drain water from upright barrel for effective cleaning

• Other competitors are designed for high volume industries and cost upwards of $10,000
  – Impractical cost for smaller businesses
Design Process – Prototype Sectors

- Rotary head
- Control System
- Mechanical apparatus
- Pulley/Actuator system
Design Process – Rotary Head 0

- Main source of risk mitigation and automation
  - Pressured stream is forced through high pressure fittings
  - Parallel nature of the two streams forces rotation without complex control method or additional power source
  - 282 RPM theoretically

- Top nozzle angled at 45 degrees to ensure full coverage of barrel
  - Weight distribution is thrown off

\[ \alpha = \frac{T_{\text{radial}}}{I} \]
• 1/8 inch washer heads used in iteration 1
• Bottom pressure head rotated

Design Tradeoffs Considered:
– Configuration 0 experiences trouble fitting into the bung and poses potential rotational unbalance
– Iteration 1 solves these issues
  • Balancing weight distribution causes loss of impact force
  • Rotation at 209 RPM theoretically
Design Process – Mech. Apparatus 0

• Initial Apparatus design
  – Frame Able to Support well over 200 LB
    • $53.65 \text{ ksi} < \text{UTS} = 79.80 \text{ ksi}$
  – Actuator brings functionality to a pulley system
  – Pressure head is raised by 50lb actuator over 30” stroke at 1.2” per second max
  – Cable tension exaggerated to illustrate retracted actuator state (initial position)

• Actuator mount becomes stress concentrated

\[ \sigma = \frac{Mc}{I} \]

F=100lbf
C=0.5171 in
M=900 in-lb
I=0.00866
Length of Beam = 48 in
Design Process – Apparatus Iteration 1

• Revised actuator mount location (◯)
  – Pulley system modification (◯) required

  Design Tradeoffs Considered:
  – Configuration 0 comes with stress concentrations and cumbersome feel
  – Iteration 1 solves these issues
    • Poses more potential pulley friction
Design Process – Control System Goals

• AGI was content with a less intensive man-operated system
  – Automated control system is to be designed to maximize efficiency and exceed expectations within price point

• Must translate rotary head vertically in a heavily repeatable manner

• Must be considerably splash resistant
A motor was to be used to torque the pulley system
  – A high-torque, splash resistant motor proved to be costly

To combat cost, a lower torque motor and gearbox layout was examined
  – Optical encoder required in event of motor slip
  – Minimal cost reduction including encoder
Design Process – Revised Control System 1

Components:
- Linear Actuator
- H-Bridge
- 12 VDC Power Supply
- Arduino Uno

Design Tradeoffs Considered:
- Configuration 0 is costly and much less splash resistant
- Iteration 1 improves these issues with no considerable setbacks
Prototype Evaluation – Early Testing

• Were design specifications met?

• Tested without barrel or pressure through rotary head
  – Actuator translates rotary head as desired
  – No visible issues raising or lowering

• Set to full speed with dirty barrel
  – First gauge of potential runtime ~40sec

Before/After Cleaning Process
Max translation speed: 40sec clean
Prototype Eval. – Cleaning Capability

• Recall: AGI reported 10-25min cleaning time via “soaking” process
  – Material volume consumed directly related to runtime

• Contrarian comparison: Give AGI’s method the benefit of the doubt
  Assume: AGI is as efficient as ever with their old method, and that this system is at its lowest speed
  – Time saved using this system instead: 8 minutes per barrel
  – Volume of water saved: 20 gallons per barrel

<table>
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<tr>
<th>Cycle Speed Setting</th>
<th>Cycle Time (Minutes)</th>
<th>Volume of Water Used (Gallons)</th>
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<tbody>
<tr>
<td>Max</td>
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<tr>
<td>75%</td>
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<tr>
<td>50%</td>
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<tr>
<td>Min</td>
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<td>5.05</td>
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Prototype Eval. – Was AGI Satisfied?

• The system was left in the hands of AGI for 3 days
  – Estimated 10-20 barrels cleaned per day

• **Operator feedback:**
  – “It’s much easier to use than those wooden blocks” (pictured below)
  – “I can’t believe how good it cleans”

• **Conclusion:**
  This barrel-cleaning system offers a positive impact on the environment, the operator, and the consumer with no considerable setbacks.
Production cost was governed by a budget of $350. Additional investments from the team merged with existing manufacturing skillset allowed for a $425 total cost for the prototype.

Labor costs for a manufacturing scenario are estimated at $125, placing total cost at $550 to produce a single unit.
Economics – Quantity Manufacturing

• Compared to the Gamajet DB ($1250) this system offers similar functionality with decreased labor costs and repeatable results via automation
  – This design shows great potential and the team is confident in a $1200 price point to compete with the current industry leader

<table>
<thead>
<tr>
<th>Build Quantity</th>
<th>Cost to Manufacture</th>
<th>Profit</th>
<th>Profit Extended</th>
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Economics – Cost of Cleaning

• The system offers a vast reduction in the cost to clean barrels regardless of barrel quantity

• Cost to clean without this system is largely influenced by water volume and labor
  – Both decrease heavily if implementing the system

Cost = NumberBarrels[(Labor * CycleTime) + (CostH2O * \( \dot{V} \) * CycleTime)]
Economics – Market Analysis

• 136,568 educational institutes in the US
• 325,000 parks in the US
• 346,000 industrial facilities in the US

• Utilizing a value of 20% market break-in we see that we’ll make a profit of over $131M
Patentability – Utilized Search Terms

- Barrel Cleaner
- Barrel Washer
- Drum Cleaner
- Drum Washer
- 55 Gallon Barrel Cleaner
- 55 Gallon Barrel Washer
- 55 Gallon Drum Cleaner
- 55 Gallon Drum Washer
Patentability – Points of Interest

• Patent # US2889566 (1955 – now lifted)
  – “This invention relates to apparatus for cleaning barrels, drums and the like. More particularly, this invention relates to a machine for automatically cleaning the exterior surfaces of steel drums or barrels.”

• While the patent is lifted due to timeframe, it would not have effected our patentability in any case
  – Intended to clean a steel barrel’s exterior
Patentability – Four Requirements

1. The invention must be statutory.
   – Statutory model that fits into the “design” category in patent law

2. The invention must be new.
   – Gamajet DB underperforms and does not offer an “automated barrel cleaner” or a similar rotary head design

3. The invention must be useful.
   – The automated barrel cleaner speaks for itself

4. The invention must be non-obvious.
   – Several subsystems such as the unique rotary head, self-draining apparatus layout, and control system
Prototype Run
The team would like to thank Dr. Sciammarella and Mr. Springer for their assistance and input into the project. We would also like to thank David Ziliak Jr. and John Curran in their assistance with control system design. We’d like to thank AG Industrial for the use of their facility and willingness to work with us. The team also thanks our friends and family who have been by our side from the beginning to the end of our education and project and Northern Illinois University for the facilities and wealth of knowledge that has been provided to us over our educational careers here.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Source</th>
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