A Case Study of Replacing Pneumatic Tools With Battery-powered Ones At an Automobile Assembly Plant

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ABSTRACT

Compressed air is ubiquitous in manufacturing facilities and vital for the proper operation of numerous types of manufacturing equipment and processes, but compressed air systems are highly inefficient. One way of reducing compressed air usage and the associated electricity consumption is to replace pneumatic tools with battery-powered ones. This article studied the energy cost savings and return on investment (ROI) of replacing pneumatic torque wrenches with battery-powered ones at a typical automobile assembly plant. With a total triggered time of 400.6 hours and an assumed electricity rate of $0.10/kWh, the annual energy cost savings was estimated to be $104/year per tool. The simple payback period and ROI were 5.8 years and 17.3%, respectively.

INTRODUCTION

Compressed air is widely used in manufacturing facilities and vital for the proper operation of numerous types of manufacturing equipment and processes [1]. Compressed air systems account for approximately 10% of the electricity consumed in a typical manufacturing plant, and 30% or more in some plants [2]. Unfortunately, compressed air systems are highly inefficient: approximately 8 hp of electric power is needed to operate a 1-hp air motor [2]. However, many technical resources and training opportunities [3,4] are available for facility managers to improve compressed air system efficiency.

One way of reducing compressed air usage and the associated electricity consumption is to replace pneumatic tools with battery-powered
ones. Battery-powered tools are also typically lighter and allow users to move about more freely without the hindrance of compressed air lines. However, because of the high initial cost of battery-powered tools, plant managers always wonder about the return on investment (ROI) of doing so. This article presents some findings about the energy cost savings and ROI of replacing pneumatic torque wrenches with battery-powered ones at a typical automobile assembly plant.

THE COMPRESSED AIR SYSTEM AND PNEUMATIC TOOLS

The compressed air system in this study comprised centrifugal compressors, refrigerated and desiccant air dryers, and after-coolers. The annual average energy efficiency for the whole compressed air system was estimated to be 4.33 cfm/kW. A blended electricity rate of $0.10/kWh was assumed in the following analysis.

For a typical operating month, using 15-minute interval trend data, the average compressed air usage for all shifts, including weekends, was estimated to 968 cfm. The annual compressed air usage was estimated to be 508,780,800 ft$^3$ using Equation 1.

\[(968 \text{ cfm}) \times (8760 \text{ h/yr}) \times (60 \text{ min/hr}) = 508,780,800 \text{ ft}^3/\text{yr} \quad (1)\]

The plant studied had about 1440 active pneumatic torque wrenches. Table 1 shows their rated air demands.

Table 1. Rated air demands of active pneumatic torque wrenches

<table>
<thead>
<tr>
<th>Model number</th>
<th>Rated compressed air demand (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.0</td>
</tr>
<tr>
<td>2</td>
<td>10.5</td>
</tr>
<tr>
<td>3</td>
<td>14.0</td>
</tr>
<tr>
<td>4</td>
<td>15.8</td>
</tr>
<tr>
<td>5</td>
<td>16.8</td>
</tr>
<tr>
<td>6</td>
<td>18.6</td>
</tr>
<tr>
<td>7</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Because the quantity of each torque wrench model was approximately the same, the average air demand of the torque wrenches was estimated to be 14.7 cfm. To simplify the analysis, a hypothetical pneumatic wrench with an average rated compressed air demand of 14.7 cfm was used in the following analysis.

These pneumatic tools are triggered for an average of only 1 to 2 seconds per use. The average annual total triggered time per tool was estimated to be 400.6 hours using Equation 2.

\[
\frac{508,780,800 \text{ ft}^3/\text{yr}}{(1440 \text{ tools})} \times (14.7 \text{ ft}^3/\text{min-tool}) \times (60 \text{ min/h}) = 400.6 \text{ h/yr (2)}
\]

PROPOSED BATTERY-POWERED TOOLS

Although battery-powered tools are cordless and highly portable, the ratio of pneumatic to electric tools was set at 1:1 to avoid worker physical fatigue and maintain outstanding safety standards.

According to Zolkowski [5], the compressed air demand for a 0.5-hp pneumatic tool averages 20.7 cfm. Therefore, the equivalent electric motor for a pneumatic tool with a 14.7 cfm air demand was estimated to be 0.355 hp, using Equation 3.

\[
\frac{[0.5 \text{ hp}]/(20.7 \text{ cfm})] \times (14.7 \text{ cfm}) = 0.355 \text{ hp (3)}
\]

A 0.5-hp battery-powered tool was selected for power redundancy, but 0.355 hp was used in the following savings analysis.

The energy efficiency of the tool’s electric motor was assumed to be 81.8%, the minimum efficiency for a 0.5-hp electric motor required by the US Department of Energy [6]. The nonactive energy ratio for the battery charger was assumed to be 1.5, the average value of an EnergyStar certified 18-V tool [7], which is equivalent to 40%.

ENERGY COST SAVINGS ANALYSIS

The annual energy cost percentage savings was calculated to be 76% using Equation 4.
From Equation 4, it can be observed that the annual energy cost percentage savings results mainly from the energy efficiency difference between the battery-powered and pneumatic tools.

The annual energy cost savings can be estimated using Equation 5.

\[
\left[ 14.7 \text{ cfm} + \left( \frac{4.33 \text{ cfm}}{\text{kW}} \right) - 0.355 \text{ hp} \times \frac{0.7457 \text{ kW}}{\text{hp}} \right] \times \frac{81.8\% + 40\%}{14.7 \text{ cfm} + \left( \frac{4.33 \text{ cfm}}{\text{kW}} \right)} \quad (4)
\]

\[
\left[ \frac{14.7 \text{ cfm}}{\frac{4.33 \text{ cfm}}{\text{kW}}} - \frac{0.355 \text{ hp} \times 0.7457 \text{ kW}}{81.8\% + 40\%} \right] \times \text{Total Triggered Time} \times \text{Elec. Rate} \quad (5)
\]

With an average annual total triggered time per tool of 400.6 hours and an electricity rate of $0.10/kWh, the annual energy cost savings was estimated to be $104/year per tool.

**FINANCIAL RETURN ANALYSIS**

Vendors quoted an average price of approximately $600 for an industrial grade 18-V, 0.5-hp battery-powered tool, including the battery and charger. The simple payback period and ROI were calculated to be 5.8 years and 17.3%.

**CONCLUSIONS**

For the compressed air system in this study, the energy cost percentage savings for a battery-powered tool was about 76%, which was due mainly to the energy efficiency difference between the battery-powered and pneumatic tools. With a total triggered time of 400.6 hours and an assumed electricity rate of $0.10/kWh, the annual energy cost savings was estimated to be $104/year per tool. The simple payback period and ROI were 5.8 years and 17.3%, respectively.

The annual energy cost savings and ROI are greatly impacted by the annual total triggered time and electricity rate. Longer annual triggered time and higher electricity rates would increase the financial advantage of replacing pneumatic tools with battery-powered tools.
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References


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