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

Joe H. Swindler, CEM, CEA
Wei Guo, PhD, PE

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.

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

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

Model number	Rated compressed air demand (cfm)
1	7.0
2	10.5
3	14.0
4	15.8
5	16.8
6	18.6
7	20.3

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.

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

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.

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

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.

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

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.

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

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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AUTHOR BIOGRAPHIES

Joe H. Swindler, CEM, CEA, is the corporate energy manager for Honda of America Manufacturing, where he is responsible for helping Honda plants reduce their energy usage. Mr. Swindler began his energy engineering career with Honda Company Facilities in 2012. Mr. Swindler has been responsible for achieving Energy Star certification for the East Liberty Plant, Marysville Auto Plant, and Honda Manufacturing of Indiana from 2014 through 2019. Other plants that have achieved Energy Star certifications under Mr. Swindler's leadership include Honda Transmission Manufacturing, Anna Engine Plant, Honda Manufacturing Canada, including its engine plant and Honda Manufacturing Alabama, including its engine plant. Mr. Swindler played a key role in engaging Honda of America Manufacturing in the U.S. Department of Energy Better Plants program that challenges organizations to reduce energy intensity by 25% over a 10-year period. Mr. Swindler's first assignment at Honda was as a facilities engineering coordinator at the East Liberty Plant (ELP) in September of 2007, where he was responsible for the compressed air, chilled water, and HVAC systems at the East Liberty Plant.

Mr. Swindler is a graduate of North Carolina State University with a B.S. in mechanical engineering. He is a member of American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), Association of Energy Engineers (AEE), and the U.S. Chess Federation. Mr. Swindler is a Certified Energy Manager and a Certified Energy Auditor. Mr. Swindler may be contacted at Joe_Swindler@ham.honda.com.

Wei Guo, PhD, PE, CEM works in the Energy Efficiency Research and Analysis Group at Oak Ridge National Laboratory (ORNL). His research area is mainly focused on improving energy and material efficiency for general and special manufacturing equipment and processes. He has been working on smart manufacturing and data analytics, combined heat and power, industrial water management, and recycling and waste management projects for the recent years. Dr. Wei Guo is a senior member of Association of Energy Engineers. He is a Certified Energy Manager and registered Professional Engineer. He received his PhD in mechanical engineering from the University of Arkansas. Dr. Wei Guo may be contacted at guow@ornl.gov.