

Duane Bookshar
Chief Engineer
Stanley Assembly Technologies

FASTENING TECHNOLOGY

**ENERGY CONSUMPTION OF
PNEUMATIC AND DC ELECTRIC
ASSEMBLY TOOLS**



Assembly Technologies

May 2001

Energy consumption of pneumatic and electric assembly tools

Many factors affect the Life Cycle Costs (LCC) of power assembly tools for threaded fasteners. These include the procurement costs, the installation costs, the operating costs, and the maintenance costs. Each particular assembly application will have unique factors affecting the LCC of the assembly tool used.

When choosing between pneumatic and electric powered tools, it is seldom an "apples-to-apples" decision. Most of today's electric tools provide dynamic torque monitoring and networking capabilities as part of the standard fastening system, whereas most pneumatic tools can be purchased without instrumentation. One must also consider the differences between replacing existing assembly tooling in a plant where the utilities are already in place, versus a new plant installation, where the power source choices may offer cost avoidance opportunities.

Here we look at only the energy consumption necessary to operate each type of tool for a typical threaded fastener assembly application in an auto final assembly plant. The energy cost comparison method shown here can be used to estimate the energy consumption costs of any other assembly application and it can be extended to estimate plant-wide energy consumption for an entire population of assembly tools.

Typical tool application in an automobile final assembly plant:

In order to illustrate the method, we will define a typical fastening application as follows:

- 4 second tightening cycle, consisting of:
 - 2.5 seconds free run at 10% of the final torque
 - 1.5 seconds torque cycle - increasing from 10% to 100% of final torque
- 2 fasteners per vehicle
- 60 vehicles per hour
- 16 hours per day
- 5 days per week
- 50 weeks per year

We will illustrate the method used to calculate the energy required for both pneumatic and electric assembly systems for this typical application, and then compare the results. Our calculations will be based on the annual costs and will include the latent energy consumed when the tool is not operating.

Pneumatic tool energy consumption:

For pneumatic tools, energy consumption is calculated in terms of standard cubic feet of compressed air consumed during the work cycle. There are three levels of consumption: 1) with the tool in its free-run condition while advancing the fastener threads to a snug torque level, 2) with the tool in its torque cycle while clamping the joint together, and 3) at standby, with the tool not operating.

For simplicity, we will assume the tool is non-instrumented, and therefore there is no electronic equipment associated with the operation of the tool. We also assume the total air leak associated with the tool (supply hose, filter, regulator, lubricator, and all fittings)

is a constant 0.45 SCFM (standard cubic feet per minute), and it is continuous for 24 hours per day. To put this leak rate into perspective, this is equivalent to a 1/64" (0.4 mm) diameter hole.

Actual air consumption of the tool during the fastening cycle depends on the power level of the particular tool in use. Pneumatic tools consume more compressed air at low torque load conditions (free speed), and less at high torque load conditions. For this typical application, we select a pneumatic tool with 30 SCFM consumption during its free run condition, and an average of 15 SCFM consumption during its torque cycle.

We calculate the compressed air consumption during the 2.5 seconds free-run condition while advancing the fastener threads to a snug torque level as follows:

$$2.5 \text{ sec.} \div 60 = .0417 \text{ min.} \times 30 \text{ SCFM} = 1.25 \text{ cubic feet per fastener.}$$

We calculate the compressed air consumption during the 1.5 seconds torque cycle while clamping the joint together as follows:

$$1.5 \text{ sec.} \div 60 = .025 \text{ min.} \times 15 \text{ SCFM} = .375 \text{ cubic feet per fastener.}$$

The total annual compressed air consumption for the fastening cycle of our typical assembly tool application can be calculated as follows:

$$\begin{aligned} 1.25 + .375 &= 1.625 \text{ cubic feet per fastener} \times 2 \text{ fasteners/vehicle} \times 60 \\ &\text{vehicles/hour} \times 16 \text{ hours/day} \times 5 \text{ days/week} \times 50 \text{ weeks/year} \\ &= 780,000 \text{ cubic feet per year} \end{aligned}$$

In addition, the compressed air consumption of the leaks associated with this pneumatic assembly tool system can be calculated as follows:

$$\begin{aligned} 0.45 \text{ SCFM} \times 60 \text{ min./hour} \times 24 \text{ hours/day} \times 365 \text{ hours/year} \\ = 236,520 \text{ cubic feet per year} \end{aligned}$$

So, the total annual compressed air consumption for our example pneumatic assembly tool will be:

$$780,000 + 236,520 = \mathbf{1,016,520 \text{ cubic feet per year}}$$

Now we can calculate the **amount of electric energy required** to produce this amount of compressed air. The actual cost of compressed air will depend of the size and type of compressor, and the efficiency of the electric motor driving that compressor. Typical figures given are usually in the range of 3 to 4 kilowatt-hours per 1000 cubic feet of compressed air at 90 PSIG. Note that this is a very inefficient process. To continuously operate a one horsepower air motor, seven to eight horsepower of electric power is required to drive the air compressor. The overall efficiency of a typical compressed air system can be as low as 10-15%.

For our example, we will use an average figure of 3.5 kilowatt-hours per 1000 cubic feet, and we can calculate the energy required to compress the cubic feet of air needed to operate our example pneumatic tool for one year as follows:

$$1,016,520 \text{ cubic feet} \div 1000 \times 3.5 \text{ kilowatt-hours per 1000 cubic feet} \\ = \mathbf{3558 \text{ kilowatt-hours}}$$

The cost of electric power varies depending on local rates, but a typical cost is \$.06 per kilowatt-hour. So finally, we can calculate **the annual cost of the electric energy to operate this pneumatic tool** as follows:

$$3558 \text{ kilowatt-hours} \times \$.06/\text{kilowatt-hour} \\ = \mathbf{\$213.48 \text{ per year}}$$

Electric tool energy consumption:

For electric tools, the energy consumption is calculated in terms of watts over a period of time, or kilowatt-hours. There are three levels of consumption: 1) with the tool in its free-run condition while advancing the fastener threads to a snug torque level, 2) with the tool in its torque cycle while clamping the joint together, and 3) at standby, with the tool not operating.

Power consumption depends on exactly what tool model is used, and to what percent of its maximum capacity it is used. Electric tools consume low energy at low torque load conditions (free speed), and high energy at high torque load conditions. For this typical application, we select an electric tool with an energy consumption of 3500 watts at the rated torque level. This means the tool will use 350 watts (10% of the maximum) during the free-run portion of the fastening cycle and an average of 1750 watts during the torque cycle.

We will also assume the assembly system includes a torque controller that remains constantly "ON" for 24 hours per day, and the stand-by power consumption is 100 watts.

For our typical assembly tool example, we calculate the watt-hours used during the 2.5 seconds free-run condition while advancing the fastener threads to a snug torque level as follows:

$$2.5 \text{ sec.} \div 60 = .0417 \text{ min.} \div 60 = .0007 \text{ hours} \times 350 \text{ watts} \\ = .243 \text{ watt-hours}$$

We can calculate the watt-hours used during the 1.5 seconds torque cycle as follows:

$$1.5 \text{ sec.} \div 60 = .025 \text{ min.} \div 60 = .0004 \text{ hours} \times 1750 \text{ watts} \\ = .729 \text{ watt-hours}$$

The total annual watt-hour consumption for the fastening cycle of our typical assembly tool application can be calculated as follows:

$$.243 + .729 = .972 \text{ watt-hours} \times 2 \text{ fasteners/vehicle} \times 60 \text{ vehicles/hour} \times 16 \\ \text{hours/day} \times 5 \text{ days/week} \times 50 \text{ weeks/year} \\ = 466,667 \text{ watt-hours} \div 1000 = 467 \text{ kilowatt-hours per year}$$

In addition, the stand-by energy consumption for this electric assembly tool system can be calculated as follows:

$$\begin{aligned} & 100 \text{ watts} \times 24 \text{ hours/day} \times 365 \text{ days/year} \\ & = 876,000 \text{ watt-hours} \div 1000 = 876 \text{ kilowatt-hours per year} \end{aligned}$$

So, **the total annual energy consumption for our example electric assembly tool** will be:

$$467 + 876 = \mathbf{1343 \text{ kilowatt-hours per year}}$$

We can now calculate **the annual cost of operating this electric tool** using the same estimated cost of electric energy as we used for the pneumatic tool:

$$\begin{aligned} & 1343 \text{ kilowatt-hours} \times \$0.06/\text{kilowatt-hour} \\ & = \mathbf{\$80.58 \text{ per year}} \end{aligned}$$

Annual savings with electric assembly tools:

There are many factors to consider when deciding which type of assembly tool to use for each application, and many factors affect the total Life Cycle Costs of both pneumatic and electric tools. The example given above demonstrates the potential annual energy savings by using electric tools in place of pneumatic tools. For this one typical assembly application, **the annual savings** can be calculated as:

$$\$213.48 - \$80.58 = \mathbf{\$132.90 \text{ potential annual savings by selecting the electric tool}}$$

The plant-wide savings can be extrapolated by multiplying this single application, by the number of fastening tools used throughout the assembly plant. If, for example, **1000 tools** can be converted from pneumatic to electric, the potential annual savings for the energy to operate these tools will be:

$$\begin{aligned} & \$132.90 \times 1000 \\ & = \mathbf{\$132,900.00 \text{ per year}} \end{aligned}$$

Environmental impact:

Given the context of recent international agreements (the Kyoto protocol), the reduction of CO₂ emissions has become a public policy priority. Reducing the energy consumption of the power tools used to assemble threaded fasteners in an assembly plant will result in a global reduction in CO₂ emissions.

The CO₂ production from a power plant depends on the primary fuel employed and on the energy conversion efficiency. Given the large differences in the specific emissions among fuel types, the reduction in CO₂ emissions will vary between countries. US figures for 1997 indicate that 72.5% of the total US electricity production is from fossil fuels, and the average CO₂ emissions related to the total electricity production is given as 681 grams per kilowatt-hour. From this overall average figure, we can estimate the

reduction in CO₂ emissions that can be attributed to the potential plant-wide energy savings from converting pneumatic assembly tools to electric.

From our previous calculations, we saw that our example pneumatic tool would use 3558 kilowatt-hours annually. Our example electric tool would use 1343 kilowatt-hours for the same application. So our **potential annual savings for a population of 1000 tools** would be:

$$3558 - 1343 = 2215 \text{ kilowatt-hours} \times 1000 \text{ tools} \\ = \mathbf{2,215,000 \text{ kilowatt-hours savings per year}}$$

We can calculate the **potential annual CO₂ emissions reduction for the plant-wide use of 1000 tools** as follows:

$$2,215,000 \text{ kilowatt-hours} \times 681 \text{ grams of CO}_2/\text{kilowatt-hour} \\ \times .002205 \text{ pounds/gram} \div 2000 \text{ pounds/ton} \\ = \mathbf{1663 \text{ tons of CO}_2 \text{ reduction per year}}$$

These figures can vary widely for different countries and will depend on the local source of electricity at a given assembly plant. But it is clear that electric assembly tool systems can provide a source for significant energy savings and, at a higher level, a source for the reduction of CO₂ emissions into our environment.

Stanley Assembly Technologies
Tel: (440) 461-5500
www.stanleyassembly.com

5335 Avion Park Drive, Cleveland, OH 44143
Fax: (440) 461-2710

© The Stanley Works, All Rights Reserved