



# Advantages of Brushless vs Brushed Motor Technology

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## Introduction

It was Michael Faraday's understanding of the interactions between magnet fields and producing them with coils of wire that lead to the electric motor. Over a century-and-a-half later many details have not changed and the purpose of this article is to discuss the differences between brushed and brushless motors and highlight the key benefits of brushless hand dryers.

## Brushed Motors

Brushed motors are the most common motors manufactured. Their simplicity and established production techniques means they are the cheapest form of motor. The stationary part (or body) is the stator and the rotational part the armature. So that it rotates continuously, the current through the armature coils or windings has to be switched, such that the magnetic field from the stator interacts with that from the armature in giving a force so that the armature rotates continuously.

The commutator (rotary electrical switch), is solidly attached to the armature shaft which is supported between bearings, so that the relative position of the copper segments keep the same spatial relationship with the armature windings. The commutator enables electrical current to be carried from stationary wiring to the rotating armature. Respective springs maintain a pressure on the brushes which are free to move vertically, they maintain contact of the brushes on the commutator and allow for brush wear. Commutator motors are inexpensive to produce and they have significant limitations and their usefulness is determined by brush and commutator wear.

Hand dryers with brushed motors have:

- Shorter life (less than one-tenth)
- Greater noise
- Lower efficiency and therefore use more power
- The air blown from the hand dryer passes through the motor creating greater pollution and dust particles
- The brushes and commutator creates significant pollution
  - carbon and copper dust
  - ozone from the electric arcing which increases with brush wear

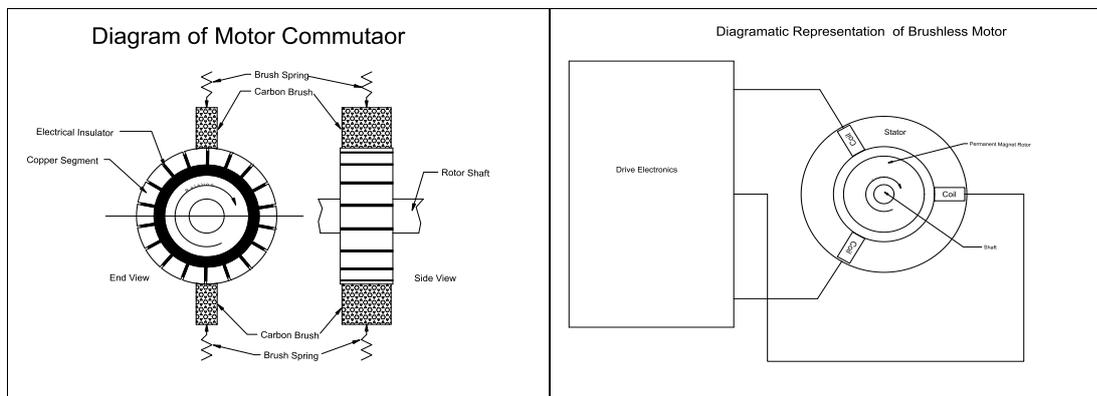
## Brushless Motors

The brushless motor does not have a commutator or windings on the rotor, which is a multi-pole permanent magnet, therefore does not have the problems detailed above with the brush motor. Only the stator has windings which are switched by suitable electronics in a sequence that depends upon the direction of rotation. The magnets and electronics mean that these motors may be more expensive but benefit from a 10x fold operating life.

## Advantages of Brushless vs Brushed Motor Technology

Hand dryers with brushless motors offer:

- Longer life (more than 10x)
- Greater efficiency, less energy
- Greater cost savings on operation and cost of product life
- Significantly Quieter
- Environmentally efficient with lower carbon footprint



## Particulate Emissions from Brushed Motor Hand Dryers

**Particulates** alternatively referred to as **particulate matter (PM)** or **fine particles**, are tiny particles of solid or liquid suspended in a gas or liquid. In contrast, **aerosol** refers to particles and the gas together – definition source Wikipedia)

When a through flow blower powered by a brushed motor is used in a hand dryer the commutator (rotary electrical switch) produces significant pollution in the air exiting the hand dryer.

- Dust particles are produced by the wear of the brushes and copper segments on the commutator.
- These are tiny particles less than 2.5 microns across that are **easily ingested into the respiratory system of anyone** using or are nearby a hand dryer. They are predominately produced by two mechanisms, mechanical wear and the ablation caused by electric arcing.

The Environmental Protection Agency in the United States set a limit for outside air of 15 microgrammes long term and short term 35 microgrammes a cubic metre.

SAVORTEX has conducted a number of measurements on brushed motor hand dryers and our testing concludes that they:

- Produced a total of 75 microgrammes a cubic metre
- This is over **twice the short term level considered safe for outdoor air**
- The air force hand dryer is said to have one-third the life, so its level will be nearly 6.5 times higher.

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- **Along with the Ozone, oxides of nitrogen and nitric acid vapour the pollution from a brushed motor cannot be ignored. A one page summary of the formula and how this conclusion was drawn is available on a separate page.**

### Ozone Emissions from brushed motor hand dryers

Ozone is a form of oxygen; its name comes from the Greek verb *ozien* meaning "to smell" which it does, like bleach. For most people they associate the smell with photo-copiers and laser printers that do produce Ozone.

- Everyday oxygen is diatomic, that is, it hangs around in pairs of atoms hence it is written as O<sub>2</sub>.
- Ozone is triatomic and exists in molecules of three atoms thus written as O<sub>3</sub>. When liquid it is a striking blue and in high concentrations in the atmosphere it gives a blue tinge.
- Oxygen is chemically active Ozone, to the extent that it is used as a biocide to treat water where it has the advantage of quickly reverting to oxygen and doesn't taint the water like chlorine.
- It degrades plastics, fabrics and rubber as well as other materials, when rubber is said to be perished it is usually ozone that has caused it.
- Since oxygen can exist in different forms it is called an 'allotrope', a good example of this is carbon which in graphite form is useful for pencil leads or diamond.
- High in the atmosphere it is a benefit, maintained by the sun's radiation - it prevents harmful ultraviolet light reaching the surface of the planet. Lower down it is a mixed blessing.

### The effects of Ozone on people have been studied for a long time:

- It is accepted that people can smell ozone at a concentration of 100 ppb (parts per billion), which is the maximum level that is considered safe for 8 hours exposure. This is the level that most monitoring systems will start ringing alarm bells.
- More alarming is there is increasing evidence that lower levels can and do cause problems in a significant number of people. 30ppb is the concentration quoted.
- The sparking caused by brushed motors generates Ozone; it increases as the brushes wear.
- The electric arcs also produce oxides of nitrogen and in the damp confines of a washroom produces nitric acid.
- This irritates and inflames the upper respiratory tract, which triggers asthma attacks in those susceptible.
- In buildings that are air conditioned it contributes to what is often called "sick building syndrome" due to a high proportion of the air being re-circulated to save energy.
- As Ozone is so chemically active it reacts with other chemicals present to produce a soup of dubious benefit especially where fragrances are present.

This is alarming and of deep concern which SA Vortex is keen to highlight and open a debate on these very important issues.

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Without doubt more needs to be done and there needs to be less 'smoke and mirrors' and clarity and transparency from other hand dryer manufacturers. We don't know what levels of Ozone are emitted by brushed motor hand dryers, namely the Excel Xcelerator and World Dryer Air Force, as all of the Ozone generated will be expelled because all of the air ingested flows through the motor.

***We welcome transparent open testing and evaluation.***

### **Summary Sheet on the estimates and evaluation of brushed motor hand dryers**

The Environmental Protection Agency in the United States set a limit for outside air of 15 microgrammes long term and short term 35 microgrammes a cubic metre.

Although the following estimate here assumes that the wear over time is constant in reality, it accelerates as wear takes place, mainly due to increased electrical arcing.

An estimate of the particulate content per cubic metre of air given in microgrammes a cubic metre an internationally agreed measure and these estimates, will indicate how the wear dust burden in the expelled air compares with this benchmark.

- If we take the size of the carbon brushes on a motor to be 12 by 4 mm and they wear 10 mm over their life this gives a volume worn:
  - $2 \times 12 \times 4 \times 10 = 960$  cubic millimetres
- To estimate the volume of each particle that results from this wear we take the Excel's Xcelerator hand dryer with a known motor life of 1500 hours. This will mean the volume produced a second will be:
  - $960 / (1500 \times 3600) = 0.0001778$  cubic millimetres a second
- A commutator has 18 segments and the motor is rotating at 350 times a second. For our analysis we can say that one particle is generated as each segment edge passes each brush.
  - The volume of each particle will be:  $0.0001778 / (2 \times 18 \times 350) = 0.00000014109$  cubic millimetres
- If we say that each particle is a sphere then the diameter will be: 2.998 Microns (thousandth of a millimetre).
  - This means that it is smaller than 10 micron making it a particle which has shown to be ingested deep into the respiratory system.
- The density of the brush material is 2.5 grammes a cubic centimetre so the total weight of the dust produced is:  $0.96 \times 2.5 = 2.4$ g
- The air flow through the hand dryer is 25,000cc a second so with even wear over time the dust burden in expelled air due to brush wear will be:
  - $2.4 / (1500 \times 3600 \times 0.025) = 17.778$  microgrammes a cubic metre.

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- If we say the commutator is 36mm in diameter, with a 12mm wide wear area and over the 1500 hour life wears 0.3mm, the volume of copper worn away assuming a solid copper ring: $12\text{PI}(182-17.32)=931.55$  cubic millimetres
- With a density of copper of 8.3 grammes a cubic centimetre the dust burden due to copper wear will be:
  - $.93155*8.3/(1500*3600*.025)=57.273$  microgrammes a cubic metre.

### Summary:

- This gives a total of 75 microgrammes a cubic metre.
- This is over twice the short term level considered safe for out door air. The air force hand dryer is said to have one third the life so its level will be nearly 6.5 times higher. Along with the Ozone, oxides of nitrogen and nitric acid vapour the pollution from a brushed motor cannot be ignored.

### Brushed vs Brushless Electric Motors

The Vortex Hand Dryers use the new brushless technology – one of only few commercial hand dryers to implement this newer, more environmentally-friendly motor

### For hand dryers the brushless motors have:

#### Bullet Points

- ◆ longer life (10x more operating life) than brush motors
- ◆ Significantly quieter than brush motors
- ◆ Greater efficiency, thus using less power than a brush motor
- ◆ By using digital brushless technology we safeguard the user

### Ozone Emissions from Brushed Motor Hand Dryers;

#### Bullet Points

- ◆ Brushed motors with through flow blowers eject ozone
- ◆ Brushed motors give off harmful carbon ozone's into the atmosphere
- ◆ Ozone at a third of the concentration detectable by smell can trigger asthma attacks
- ◆ Asthma attacks can be delayed and the sufferer doesn't realise it was a hand dryer that triggered it

### Particulate Emissions from Brushed Motor Hand Dryers;

#### Bullet Points

- ◆ There is not a standard for particulate level of air in buildings
- ◆ In a brushed motor the brushes and commutator (rotary electrical switch) creates significant pollution, carbon and copper dust, plus ozone, from the electric arcing which increases with brush wear
- ◆ 15 microgrammes a cubic metre is the standard for outside air
- ◆ The Excel Xcelerator produces by calculation an estimated 75 microgrammes a cubic metre.
- ◆ The World Dryer Air Force is potentially three times the Xcelerator, due to shorter motor life and higher speed of rotation

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### References:

**SAVORTEX Monograph: SAVMON7/1004/A4/30.2.sep09.pw**  
Particulate Emissions from Brushed Motor Hand Dryers

**SAVORTEX Monograph: SAVMON5/1004/A4/30.2.sep09.pw**  
Brushed and Brushless Electric Motors

**SAVORTEX Monograph: SAVMON6/1004/A4/30.2.sep09.pw**  
Ozone Emissions from Brushed Motor Hand Dryers

### About the Author

Peter is one of the UK's leading mechanical and electrical engineers, who also specialises in energy efficient technology and airflow dynamics. As well as developing the Vortex Hand Dryer with a unique patented technology set to revolutionise the drying arena, Peter has developed many other unique technologies and has also assisted high-profile clients such as BAE and the US Military.

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### Footnote;

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