



# Comparison of TIG Brush Fumes with TIG Welding Fumes with Respect to Operator Health Hazard.

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## Background

The TIG Brush is a device which produces a low voltage, high current electrical output through a conductive brush which when used in conjunction with specific conductive liquids, removes iron based oxides from stainless steel TIG welds. The TIG Brush has safety and performance advantages over the traditional method of wiping the iron oxide stains with a pickling paste. Pickling paste is inherently hazardous to the operator and those surrounding due to its components hydrofluoric acid and nitric acid. These acids presents a severe toxic hazard in the vapour and skin contact form.

The conductive liquid for the TIG Brush technique that provides excellent oxide removal and leaves the metal surface with the most desirable appearance and profile is based on orthophosphoric acid. The developers and suppliers of the TIG Brush, Ensitech Pty Ltd., produce their own orthophosphoric acid solutions named TB-20 and TB-25.

When the TIG Brush is used in its recommended manner on stainless steel TIG welds with either TB-20 or TB-25, fumes are emitted from the contact area between the conductive brush containing the acid solution and the steel it contacts. It is known that the heating of orthophosphoric acid produces phosphorus pentoxides, which are respiratory irritants and toxic at very high levels.

For welding stainless steel, a TIG welder uses an electrical arc to create high temperatures, melting the surfaces of the stainless steel they intend to join. This melting of the pieces is combined with a filler metal in the electrode that combines with the metals in the work pieces to create a strong bond when cooled.

TIG welding of stainless steel is known to produce a serious health effect on welders known as Metal Fume Fever. This is a disease contracted through inhalation of welding fumes, which contain zinc oxides mostly, but iron and manganese oxides are also found to contribute and in some cases lead to Metal Fume Fever on their own. This disease manifests itself with an operator (usually a welder) suffering flu-like fever and headache with listlessness and dizziness. Even if the immediate air environment is within workplace guidelines, long-term inhalation of zinc oxide fumes will result in Metal Fume Fever. Long term in this instance is classed as regular minutes per day or multiple hours of exposure leading to the inhalation of high levels of metal oxides. Continued daily inhalation exposure is also known to result in Metal Fume Fever.

The most plausible mechanism accounting for the symptoms involves an immune reaction, which occurs when the inhaled metal oxide fumes injure the cells lining the airways. This is thought to modify proteins in the lung. The modified proteins are then absorbed into the bloodstream, where they act as allergens.

Metal Fume Fever is a common disease in the welding workplace that requires appropriate respiration protection via personal respirators and adequate ventilation. Whilst adequate ventilation is sometimes present in the industrial environment, the wearing of personal respiration protection is still greatly lacking.

## Study Aim

TIG Brush and TIG Welder operators are inside arms length distance from the point where these fumes are generated. The aim of this study is to compare the relative hazards of the fumes from the TIG Brush and the TIG welding process.

## Study Method

A 316 stainless steel plate with a 10cm long TIG welded strip showed extensive iron based oxidation immediately on the weld as well as a 5mm strip on both sides of the weld strip. The iron based oxidation manifests as a brown, red to black mark.

The TIG Brush can be set to a range of power settings designed for various grades of stainless steel. There is also a high power setting for electropolishing. The settings of 3B was used in this study since it is the setting recommended by Ensitech for this grade of stainless steel, and in testing worked effectively to remove the post- weld oxide marks.

The TIG Brush technique involves dipping the TIG Brush brush into the TB-20 and then immediately drawing the tip of the brush over the dark marks on and around the weld strip. The electrical current creates a high temperature area on the surface of the stainless steel that accelerates the deoxidising action of the TB-20 solution. The iron oxides are dissolved, releasing free ferric and ferrous ions and oxygen. It is through this process that fumes are created.

To simulate the typical use of the TIG Brush, a weld was cleaned for two minutes with dips into fresh TB-20 every 20 seconds. A total of two minutes of fume generation occurred. Placing an RO water moistened 11cm diameter No. 41 Whatman Ashless filter paper directly in the path of the fumes being emitted captured the fumes. The filter paper was placed 30cm from the metal surface to simulate an approximate minimum distance to an operator's face. At the end of two minutes, the filter paper was sealed in a new polyethylene bag.

This process was repeated with a fresh filter paper.

Two separate filter papers the same as those used to capture fumes were individually sealed in plastic bags. These provided the analysis a set of blanks from which any contaminants could be subtracted from the test results.

The TIG welding fumes were captured in the same way as with the TIG Brush fumes. Two minutes of fumes were generated per filter paper. Filter paper from the same batch was used for both TIG Brush and TIG welding fume capture. The TIG welding fumes were generated by welding a plate of 316 stainless steel with a TIG welder using BOC Type 316 LSI welding wire. This wire contains approximately 60% iron, 20% chromium, 12% nickel, 2% manganese and 2% molybdenum. An experienced welder was used to generate the fumes in this section of the study. This setup is regarded as typical for stainless steel welding in light manufacturing.

All filter papers were analysed for inorganic components at the UNSW Analytical Laboratory by the department's head chemist Terry Flynn. The inorganic components of the fumes were analysed as the chemistry of the steel and all other components were predominantly inorganic and any hazard will come from inorganic sources.

Note: the volume of air through which the two minutes of fumes were created was estimated as 200L.

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 Below are the results of the analysis expressed as an average between the results of the two test filter papers:

**Table 1: Fume Inorganic Analysis**

	<b>TIG Welding Fumes over 2 minutes (µg)</b>	<b>TIG Brush Fumes over 2 minutes (µg)</b>	<b>% difference in TIG Brush Fumes</b>
<i>Aluminium</i>	0.43	0.39	9.3 Lower
<i>Boron</i>	1.25	<0.01	99.0 Lower
<i>Barium</i>	0.15	<0.01	93.0 Lower
<i>Calcium</i>	49.8	9.7	80.5 Lower
<i>Cadmium</i>	<0.01	<0.01	No Change
<i>Chromium</i>	0.56	0.54	No Significant Change
<i>Copper</i>	1.30	0.60	53.8 Lower
<i>Iron</i>	90.7	3.60	96.0 Lower
<i>Magnesium</i>	11.2	<0.01	99.9 Lower
<i>Manganese</i>	1.72	0.03	98.3 Lower
<i>Sodium</i>	<0.01	<0.01	No Change
<i>Potassium</i>	<0.01	<0.01	No Change
<i>Nickel</i>	0.15	0.05	66.6 Lower
<i>Lead</i>	0.02	<0.01	50.0 Lower
<i>Zinc</i>	8.85	<0.01	99.9 Lower
<i>Chloride</i>	<0.01	100	100 Higher
<i>Fluoride</i>	3.16	<0.01	99.7 Lower
<i>Nitrate</i>	40.0	<0.01	99.9 Lower
<i>Sulphate</i>	30.0	<0.01	99.9 Lower
<i>Phosphate</i>	1.65	433.0	99.6 Higher

## Interpretation of Results

The TIG welding fume results displayed in this study were typical of welding fumes found in stainless steel welding, ie. Elements found in stainless steel and the welding wire.

The TIG Brush fume results also displayed expected chemistry of a high heat action on orthophosphoric acid and a process that is non-destructive to the stainless steel.

This study is interested in the relative hazards between TIG Brush fumes and TIG welding fumes. After consultation with HSIS Guidelines and the document Welding Fumes and Gases (National Occupational Health and Safety Commission), the workplace hazards from the TIG Brush fumes and TIG welding fumes will be due to the presence and concentration of the following elements:

1. Zinc
2. Chromium
3. Copper
4. Chloride
5. Iron
6. Phosphate
7. Manganese
8. Nickel
9. Molybdenum

## 1. Zinc

The TIG welding fumes contained 99.9% more zinc than TIG Brush fumes. Whilst the HSIS upper limit for zinc oxide in workplace air is  $5\text{mg}/\text{m}^3$ , which is well above the  $8.85\text{ug}/200\text{L}$  detected in TIG welding fumes, the long-term exposure of operators to zinc oxide fumes will lead to Metal Fume Fever.

No zinc could be detected in the TIG Brush fumes.

## 2. Chromium

The chromium detected in the fumes of both the TIG Brush and TIG welder will be in three forms. The first and lowest amount will be metallic spatter that occurs when the chromium metal is placed under the heat of the TIG Brush. The heat will tend to ionise most of the chromium atoms thereby creating chromium oxides in the air.

The metallic form represents a relatively minimal hazard.

The next form is the trivalent chromium oxide  $\text{Cr}_2\text{O}_3$ . This is a state that ionised chromium forms easily and readily in the heat of the TIG Brush environment.

The exposure limit as per HSIS is  $0.5\text{ mg}/\text{m}^3$ . If the entire chromium level detected was trivalent, we would have  $0.54\text{ug}/\text{approx } 200\text{L}$  in this study which equates to  $0.0027\text{mg}/\text{m}^3$ . This is far below the HSIS recommendations.

The trivalent form of chromium can further ionise to the hexavalent form  $\text{HCrO}_4$ . The HSIS exposure limit of  $0.05\text{mg}/\text{m}^3$  illustrates the higher toxicity of the hexavalent form compared to the trivalent form. The  $0.0027\text{mg}/\text{m}^3$  total chromium/ $\text{m}^3$  air, is again far below the HSIS exposure limit.

Both the TIG welder and the TIG brush processes produced virtually the same amount of chromium in the fumes. In both cases, the chromium levels were lower than HSIS exposure limits.

## 3. Copper

Copper in a fumed form can be toxic at relatively high levels with HSIS exposure limit being  $0.2\text{mg}/\text{m}^3$ . The  $0.003\text{mg}/\text{m}^3$  copper detected in this study is far below the limit.

The TIG Brush fumes contained 53.8% lower copper than the TIG welding fumes.

## 4. Chloride

The most toxic form of chloride is phosgene that is created when chlorides are reacted with carbon monoxide. This does not happen in the TIG Brush process. The most likely form of chloride is iron chloride that poses no hazard to the operator. Chlorides are of no significant hazard via either TIG welding or TIG Brush operation.

## 5. Iron

The TIG Brush fumes contained 96.0% less iron than TIG welding fumes. Whilst the HSIS limit for iron oxide is  $5\text{mg}/\text{m}^3$ , which is above the  $90.7\text{ug}/200\text{L}$  detected in TIG welding fumes, the long-term exposure of operators to iron oxide fumes is reported as a contributor to Metal Fume Fever.

## 6. Phosphate

The phosphate determined in the analyses is an expression of detected phosphorus. This will be derived from the breakdown of the phosphoric acid. Phosphorus will be present as mostly as the compound phosphorus pentoxide. All other forms will be extremely low and not approach the level of hazard of the pentoxide form.

The Australian HSIS does not have an exposure limit for this compound but the European Union has a "maximum workplace concentration" limit for it.

The EU specifies that the maximum workplace concentration for phosphorus pentoxide as an inhalable fraction is 2 mg/m<sup>3</sup> of workplace atmosphere. The 433ug (0.433mg) measured in this study was in a column of air estimated to be approximately 200L in the two-minute period. That represents a 2.2-mg/m<sup>3</sup> concentration of phosphorus pentoxide, which slightly exceeds the EU limit.

The TIG Welding fumes contained negligible phosphate.

## 7. Manganese

Manganese oxides are known to be chronic toxins with central nervous system effects. It presents as a slow deterioration of muscle control including walking and facial expression problems. Manganese oxide toxicity typically becomes apparent after long-term exposure to the fumes. In this study, TIG welding fumes were 98.3% higher than TIG Brush fumes.

## 8. Nickel

Nickel oxide is a known skin irritant and is classified as a potential human lung carcinogen. It is also noted as a potential nasal carcinogen.

Nickel was found in both fumes at low levels with the TIG Brush fumes containing 66.6% less nickel than TIG welding fumes. Both fumes are not rated as toxic at the concentrations found in this study. HSIS has no exposure limits, although long-term exposure can present health problems.

## 9. Molybdenum

Molybdenum is a minor component of stainless steel, and is of low toxicity, so was not considered in this study

## Conclusion

This study showed that the TIG welding process produced the typical range of “Metal Fume Fever” metals. The TIG Brush fumes contain far less of the Metal Fume Fever metals than TIG welding fumes. Significantly, the main contributor to Metal Fume Fever, zinc, was absent in TIG Brush fumes in this study, whereas TIG welding fumes contained a significant amount.

The TIG welding fumes also contained significantly higher amounts of the hazardous components, nickel, manganese, copper and iron, than TIG Brush fumes. TIG Brush fumes contained significantly higher amounts of phosphorus oxides, which are respiratory irritants and long-term exposure can damage the respiratory tract.

**The overall assessment of this study’s findings is that the chemistry in the TIG welding fumes and the TIG Brush pose similar immediate irritation potential to operators if not suitably protected with respirators and/or ventilation.**

**However, the much higher level of Metal Fume Fever metals, especially Zinc, and the higher levels of potentially toxic metal oxides, (nickel, iron, copper and manganese) in TIG welding fumes presents a significantly greater hazard than the TIG Brush fumes if the operator is exposed long term ie. Continual minutes/ day regularly, hours/day or multiple days.**

## References:

HSIS Guidelines, 2009: Worksafe Australia

European Union Workplace Safety Guidelines, 2009

Technical Note 7: Health and Safety, Welding Technology Institute of Australia

Materials Safety Data Sheet for Welding Materials and Related Products, BOC, 2004.

Metal Fume Fever: An Uncommon Consequence of Inhalation Injury, Kurzbaum et.al., Israel Journal of Emergency Medicine, 2007.

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