Analysis and Interpretation of TIG Brush Fumes using TB-30ND

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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. This presents a severe toxic hazard in the vapour and contact form.

A phosphoric acid complex based solution is typically used with the TIG Brush however these are classified as dangerous goods (DG) and therefore suffer restrictions in transport, handling and even use on sites where non-DG chemicals are required. In early 2009, a new non-DG solution was developed named TB-30ND.
When the TIG Brush is used in its recommended manner on stainless steel TIG welds with any of the recommended solutions, fumes are emitted from the contact area between the conductive brush containing the acid solution and the steel it contacts. This study looks at the fumes emitted by the use of the TIG Brush when using TB-30ND.

Study Aim

As TIG Brush operators are inside arms length distance from the point where these fumes are generated, it is sensible to know what the fumes are comprised of and what risk they present to the operator and the surrounding work area. Once this risk is determined, appropriate personal protective equipment and/or ventilation can be matched.

Study Hypothesis

There are three entities that can contribute to the fumes.

Entity 1: Stainless Steel
Entity 2: TB-30ND
Entity 3: TIG Brush fibres

<u>Entity 1: Stainless Steel.</u>

Stainless steel is commonly defined as a steel alloy with a minimum of 10% chromium content by mass. It is a solid comprised of a combination of elements including iron, chromium, nickel, carbon, manganese, silicon, phosphorus and sulphur. Stainless steel is produced in a variety of grades. The difference between grades is the ratio of elements in the steel. The variations in elemental ratios give the metal varying qualities such as corrosion resistance, temperature resistance, weldability, strength, etc.

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The most common grades of stainless steel are 304 and 316. See below for their percentages of non-ferrous metals.

Stainless Steel Grade	% Cr	%Ni	%C	% Mn	%Si	% P	% S
304	18-20	8-10.5	0.08	2.0	0.75	0.045	0.03
316	16-18	10-14	0.08	2.0	0.75	0.045	0.03

Iron makes up the remainder of each composition.

The knowledge of the elemental composition of the steel is important in this study since chromium can form compounds that are known human health hazards.

Note: 316 stainless steel was used in this study.

Entity 2: TB-30ND Solution.

This solution is a combination of water, phosphorus salts, citric salts and proprietary additives. It contains small quantities of alcohol ethoxylate surfactants.

Entity 3: TIG Brush Fibres.

These are very stable but have the potential to degrade slowly due to the high temperature at the arcing points between the brush tip and the film of solution over the stainless steel. These are not expected to contribute significantly to the fumes due to the very low degradation rate.

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-30ND 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-30ND 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-30ND every 20 seconds.
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.

All filter papers were analysed for inorganic components at the UNSW Analytical Laboratory.

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

Table 1: TIG Brush Fume Inorganic Analysis

TIG Brush fume over two minutes		Derived From
Aluminium	0.30 µg	TB-30ND
Boron	<0.01 µg	Not significant
Barium	<0.01 µg	Not significant
Calcium	15.5 µg	TB-30ND
Cadmium	<0.01 µg	Not significant
Chromium	0.57 µg	Stainless steel
Copper	<0.01 µg	Not significant
Iron	9.40 µg	Stainless steel
Magnesium	1.56 µg	TB-30ND
Manganese	0.24 µg	Stainless Steel
Sodium	61.8µg	TB-30ND
Potassium	0.63 µg	Not significant
Nickel	0.46 µg	Stainless steel
Lead	<0.01 µg	Not significant
Zinc	<0.01 µg	Not significant
Chloride	<0.01 µg	Not significant
Fluoride	<0.01 µg	Not significant
Nitrate	20.0 µg	TB-30ND
Sulphate	5.5 µg	Not significant
Phosphate	164 µg	TB-30ND

Interpretation of Results

The interpretation of the fumes in this report is threefold

1. Determine what entities are present in the fumes
2. Determine what amounts are present in the two-minute fume generation period. This analysis gives a confident indication of what a user would to be exposed to if they had total contact with the fumes for two minutes.
3. By consultation with the Australian Federal Government Hazardous Substances Information System, assess the risk to worker safety. This is the foremost authority on workplace chemical hazard limits. This interpretation is in relation to the short-term exposure limits (STEL) as set by the HSIS and also referring to the Exposure standard time weighted average (TWA). STEL is referring to a short term (15 min. exposure limit) and TWA is based on an 8Hr day

(Note that whilst not analysed for in this study, the fumes are mostly comprised of water vapour from the heat placed on the TB-30ND). Of the approximately 2 mL of TB-30ND for each brush load, almost all of the water, (approximately 1mL) will be converted to steam and be the major component in the fumes.

In the analysis table, noted in this report as Table 1, the results are dominated by phosphates derived from the boiling of the phosphate salts in theTB-30ND.

Calcium and manganese are from the water component in the TB-30ND.

The next most prominent entities are those derived from the stainless steel.
The presence of chromium, nickel, iron and manganese in the fumes indicate that the TIG Brush (together with the TB-30ND) activity is dislodging these elements from the metal surface. The ratio of these elements present in the fumes is quiet closely aligned with the ratios in the steel.

The relatively high iron content in the fumes is in fact a confirmation of the theory that the TIG Brush removes the iron oxide that makes up the dark staining after TIG welding.

Sodium levels were relatively high due to the monosodium phosphate in the TB30-ND.

All other entities are in extremely low concentrations and will not present a hazard to an operator whilst at these low levels. Further recommendations with respect to these elements will not be provided in this report.

Interestingly, the phosphate levels developed in TB30-ND fumes were significantly lower than the levels detected in the TB-25 study.
Chloride levels detected in this study were significantly lower than those found in the study of TB-25.
The workplace hazards from the TIG Brush fumes will therefore be due to the following:

1. phosphate
2. chromium
3. aluminium
4. sodium
5. nitrate

1. Phosphate

The phosphate determined in the analyses is an expression of detected phosphorus. This will be derived from the breakdown of the phosphorus salts. Phosphorus will be present in the fumes 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^3 of workplace atmosphere. The 164ug (0.164mg) measured in this study was in a column of air estimated to be approximately 200L in the two-minute period. That represents a 0.833 mg/m^3 concentration of phosphorus pentoxide which is far below the EU limit.

2. Chromium

The chromium detected in the fumes 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 Cr_2O_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 mg/m^3. If the entire chromium level detected was trivalent, we would have 0.57ug /approx 200L in this study which equates to 0.0028mg/m^3. This is far below the HSIS recommendations.

The trivalent form of chromium can further ionise to the hexavalent form $HCrO_4$. The HSIS exposure limit of 0.05mg/m^3 illustrates the higher toxicity of the hexavalent form compared to the trivalent form. The 0.0028mg total chromium/m3 air, is again far below the HSIS exposure limit.

3. Aluminium

Aluminium can be toxic at relatively high levels with HSIS exposure limit being 2mg/m^3 for the most toxic forms. The 0.00195mg/m^3 aluminium detected in this study is far below the limit.

4. Sodium

There are no HSIS limits for sodium exposure via inhalation. There is also no known health effects of inhaling sodium at the levels found in the TB-30ND fumes. Sodium from TB-30ND poses no known health effects.

5. Nitrate

There are no HSIS limits for nitrate exposure via inhalation. There are also no known health effects of inhaling nitrates at the levels found in the TB-30ND fumes. Nitrates from TB-30ND poses no known health effects.

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Conclusion

This study shows that a range of toxic entities is created which poses a hazard to the operator.
In all cases, the levels of these toxic entities were below the HSIS exposure limits. In particular, whilst there is no HSIS limit for phosphorus pentoxide, the levels of this substance were lower than the EU maximum threshold.

Note that this study measured the components in the entire stream of the fumes as it was emitted from its source. This is the most concentrated fume area and therefore all areas around the fume stream will contain less toxic levels as found in this study.

The HSIS limits and guidelines do not take into consideration people who have specific sensitivities to chemicals. If those specific sensitivities exist with any person, appropriate PPE needs to be used.

Whilst the immediate hazard to the operator is relatively low as determined by the Australian Federal Government HSIS, the effects of chronic exposure is not covered in this study, although no hazard is found based on HSIS TWA exposure limits
If an operator is a long-term TIG Brush user, good practice to ensure safety includes excellent exit flow ventilation, appropriate respiratory protection for acid and inorganic gases and fumes and avoiding breathing the fumes when possible.

Examples of appropriate respirators for use with the TIG Brush are:

3M fullface 6000 series
3M half face 6000 and 7500 series
Both of these should be used with the 3M 6057B filter cartridges with a P2 particle filter eg. 3M 5925.

Workers using the TIG Brush in confined spaces must wear appropriate PPE including respirators such as listed immediately above.

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